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SINUMERIK

SINUMERIK 840D sl / 828D Fundamentals

Programming Manual

Valid for

Control system
SINUMERIK 840D sl / 840DE sl
SINUMERIK 828D

Software	Version
CNC-Software	4.4

09/2011
6FC5398-1BP40-2BA0

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℗ 01.2011

Preface

SINUMERIK documentation

The SINUMERIK documentation is organized in the following categories:

- General documentation
- User documentation
- Manufacturer/service documentation

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Target group

This publication is intended for:

- Programmers
- Project engineers

Benefits

With the programming manual, the target group can develop, write, test, and debug programs and software user interfaces.

Standard scope

This Programming Guide describes the functionality afforded by standard functions. Extensions or changes made by the machine tool manufacturer are documented by the machine tool manufacturer.

Other functions not described in this documentation might be executable in the control. This does not, however, represent an obligation to supply such functions with a new control or when servicing.

Further, for the sake of simplicity, this documentation does not contain all detailed information about all types of the product and cannot cover every conceivable case of installation, operation or maintenance.

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Information on structure and contents

"Fundamentals" and "Advanced" Programming Manual

The description of the NC programming is divided into two manuals:

1. Fundamentals

   This "Fundamentals" Programming Manual is intended for use by skilled machine operators with the appropriate expertise in drilling, milling and turning operations. Simple programming examples are used to explain the commands and statements which are also defined according to DIN 66025.

2. Job planning

   The Programming Manual "Advanced" is intended for use by technicians with in-depth, comprehensive programming knowledge. By virtue of a special programming language, the SINUMERIK control enables the user to program complex workpiece programs (e.g. for free-form surfaces, channel coordination, ...) and makes programming of complicated operations easy for technologists.

Availability of the described NC language elements

All NC language elements described in the manual are available for the SINUMERIK 840D sl. The availability regarding SINUMERIK 828D can be found in table"Operations: Availability for SINUMERIK 828D [Page 489]".

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Fundamental Geometrical Principles 1

1.1 Workpiece positions

1.1.1 Workpiece coordinate systems

In order that the machine or the control can work with the positions specified in the NC program, these specifications have to be made in a reference system that can be transferred to the directions of motion of the machine axes. A coordinate system with the axes X, Y and Z is used for this purpose.

DIN 66217 stipulates that machine tools must use clockwise, right-angled (Cartesian) coordinate systems.

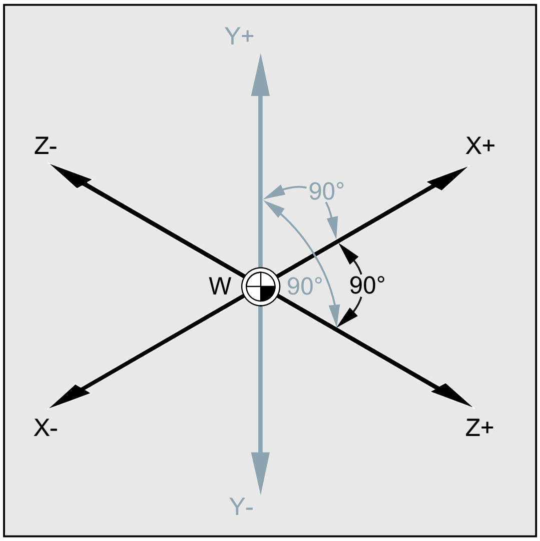


Figure 1-1 Workpiece coordinate system for turning

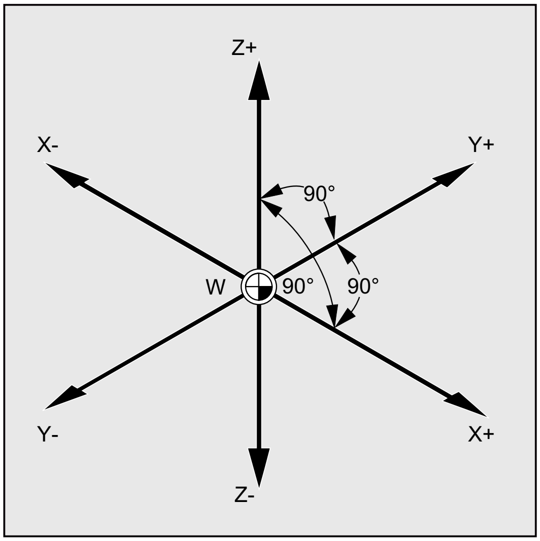


Figure 1-2 Workpiece coordinate system for milling

The workpiece zero (W) is the origin of the workpiece coordinate system.

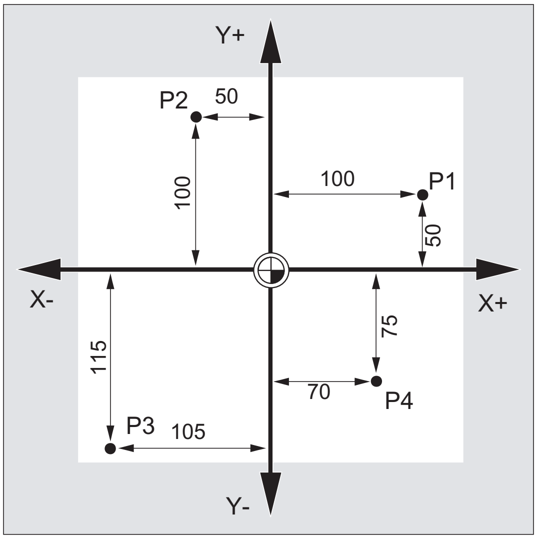
Sometimes it is advisable or even necessary to work with negative position specifications. For this reason, positions that are to the left of the zero point are assigned a negative sign ("-").

1.1.2 Cartesian coordinates

The axes in the coordinate system are assigned dimensions. In this way, it is possible to clearly describe every point in the coordinate system and therefore every workpiece position through the direction (X, Y and Z) and three numerical values The workpiece zero always has the coordinates X0, Y0, and Z0.

Position specifications in the form of Cartesian coordinates

To simplify things, we will only consider one plane of the coordinate system in the following example, the X/Y plane:

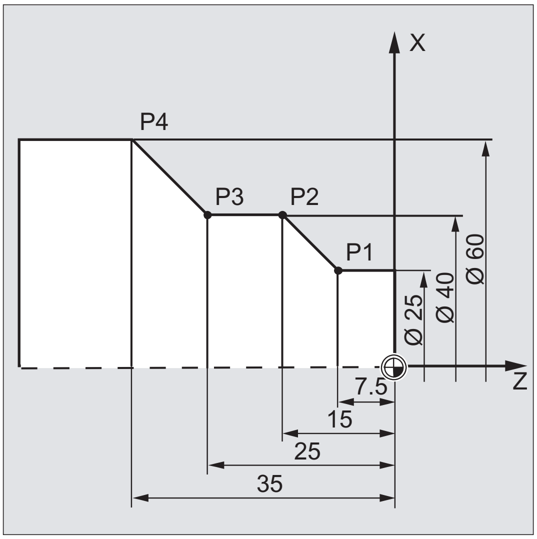


Points P1 to P4 have the following coordinates:

Position	Coordinates
P1	X100 Y50
P2	X-50 Y100
P3	X-105 Y-115
P4	X70 Y-75

Example: Workpiece positions for turning

With lathes, one plane is sufficient to describe the contour:

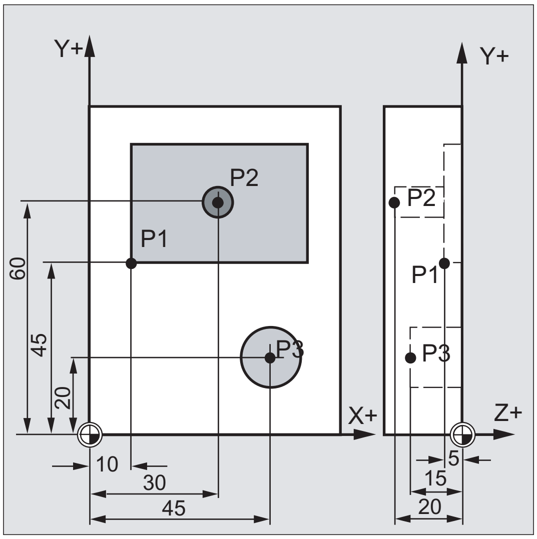


Points P1 to P4 have the following coordinates:

Position	Coordinates
P1	X25 Z-7.5
P2	X40 Z-15
P3	X40 Z-25
P4	X60 Z-35

Example: Workpiece positions for milling

For milling, the feed depth must also be described, i.e. the third coordinate (in this case Z) must also be assigned a numerical value.



Points P1 to P3 have the following coordinates:

Position	Coordinates
P1	X10 Y45 Z-5
P2	X30 Y60 Z-20
P3	X45 Y20 Z-15

1.1.3 Polar coordinates

Polar coordinates can be used instead of Cartesian coordinates to describe workpiece positions. This is useful when a workpiece or part of a workpiece has been dimensioned with radius and angle. The point from which the dimensioning starts is called the "pole".

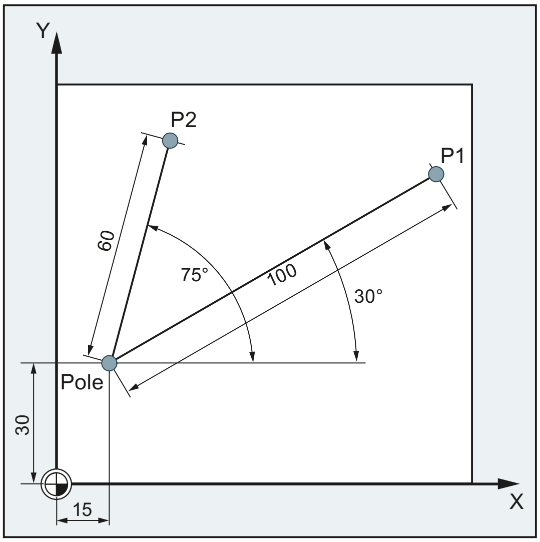
Position specifications in the form of polar coordinates

Polar coordinates are made up of the **polar radius** and the **polar angle.**

The polar radius is the distance between the pole and the position.

The polar angle is the angle between the polar radius and the horizontal axis of the working plane. Negative polar angles are in the clockwise direction, positive polar angles in the counterclockwise direction.

Example



Points P1 and P2 can then be described – with reference to the pole – as follows:

Position	Polar coordinates
P1	RP=100 AP=30
P2	RP=60 AP=75
RP: Polar radius AP: Polar angle	

1.1.4 Absolute dimensions

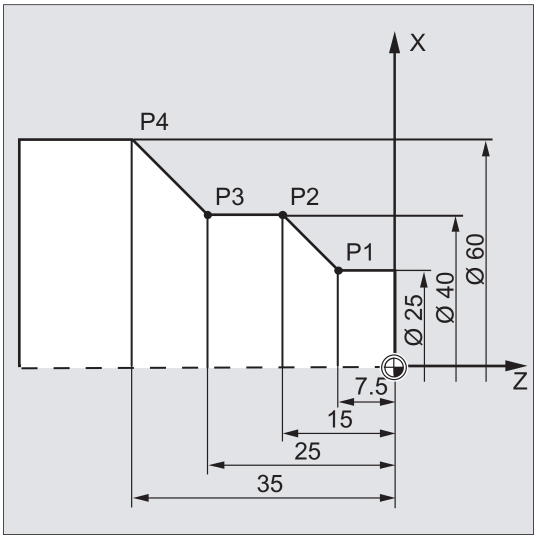
Position specifications in absolute dimensions

With absolute dimensions, all the position specifications refer to the currently valid zero point.

Applied to tool movement this means:

the position, to which the tool is to travel.

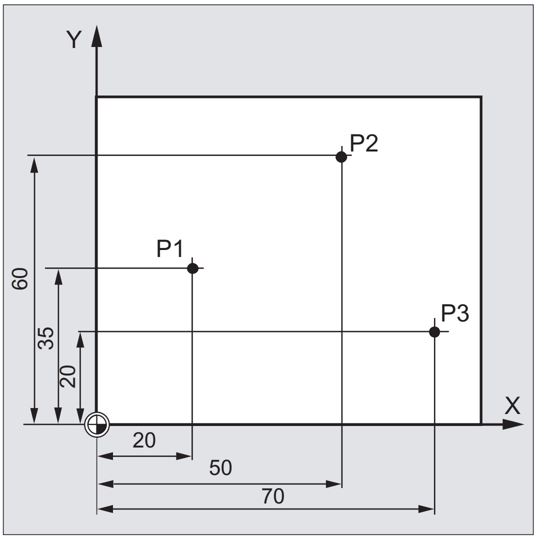
Example: Turning



In absolute dimensions, the following position specifications result for points P1 to P4:

Position	Position specification in absolute dimensions
P1	X25 Z-7.5
P2	X40 Z-15
P3	X40 Z-25
P4	X60 Z-35

Example: Milling



In absolute dimensions, the following position specifications result for points P1 to P3:

Position	Position specification in absolute dimensions
P1	X20 Y35
P2	X50 Y60
P3	X70 Y20

1.1.5 Incremental dimension

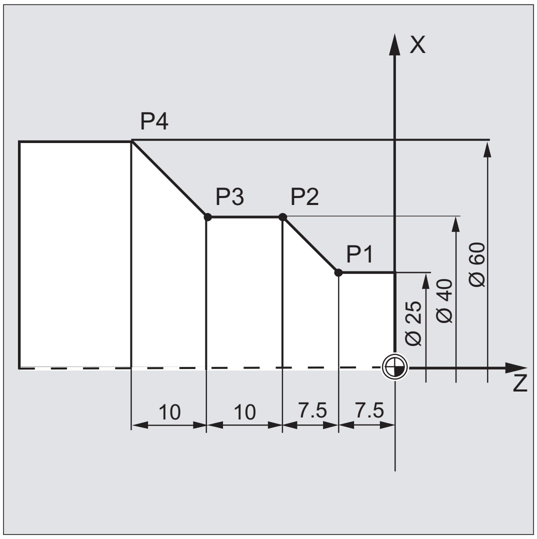
Position specifications in incremental dimensions

In production drawings, the dimensions often do not refer to a zero point, but to another workpiece point. So that these dimensions do not have to be converted, they can be specified in incremental dimensions. In this method of dimensional notation, a position specification refers to the previous point.

Applied to tool movement this means:

The incremental dimensions describe the distance the tool is to travel.

Example: Turning



In incremental dimensions, the following position specifications result for points P2 to P4:

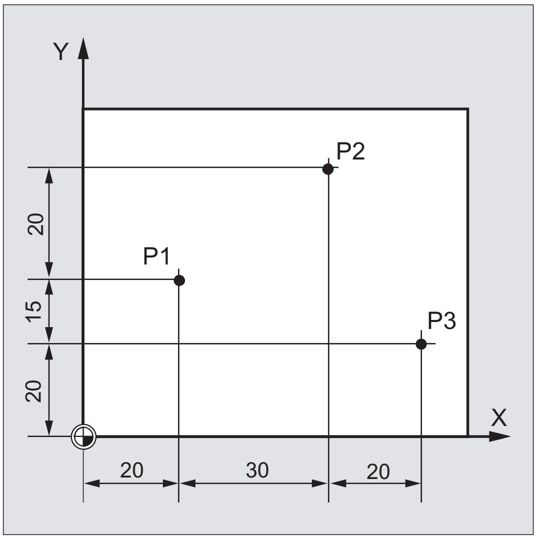
Position	Position specification in incremental dimensions	The specification refers to:
P2	X15 Z-7.5	P1
P3	Z-10	P2
P4	X20 Z-10	P3

Note

With `DIAMOF` or `DIAM90` active, the set distance in incremental dimensions (`G91`) is programmed as a radius dimension.

Example: Milling

The position specifications for points P1 to P3 in incremental dimensions are:



In incremental dimensions, the following position specifications result for points P1 to P3:

Position	Position specification in incremental dimensions	The specification refers to:
P1	X20 Y35	Zero point
P2	X30 Y20	P1
P3	X20 Y -35	P2

1.2 Working planes

An NC program must contain information about the plane in which the work is to be performed. Only then can the control unit calculate the correct tool offsets during the execution of the NC program. The specification of the working plane is also relevant for certain types of circular-path programming and polar coordinates.

Two coordinate axes define a working plane. The third coordinate axis is perpendicular to this plane and determines the infeed direction of the tool (e.g. for 2D machining).

Working planes for turning/milling

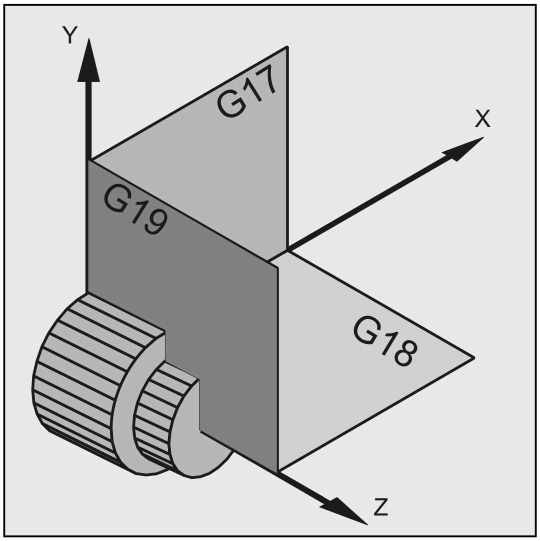


Figure 1-3 Working planes for turning

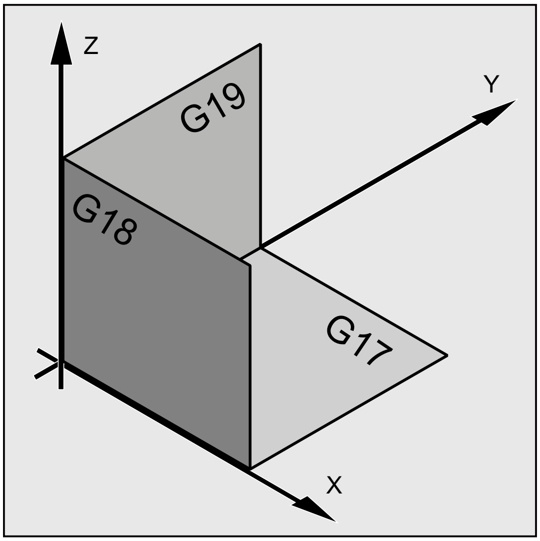


Figure 1-4 Working planes for milling

Programming of the working planes

The working planes are defined in the NC program with the G commands `G17`, `G18` and `G19` as follows:

G command	Working plane	Infeed direction	Abscissa	Ordinate	Applicate
`G17`	X/Y	Z	X	Y	Z
`G18`	Z/X	Y	Z	X	Y
`G19`	Y/Z	X	Y	Z	X

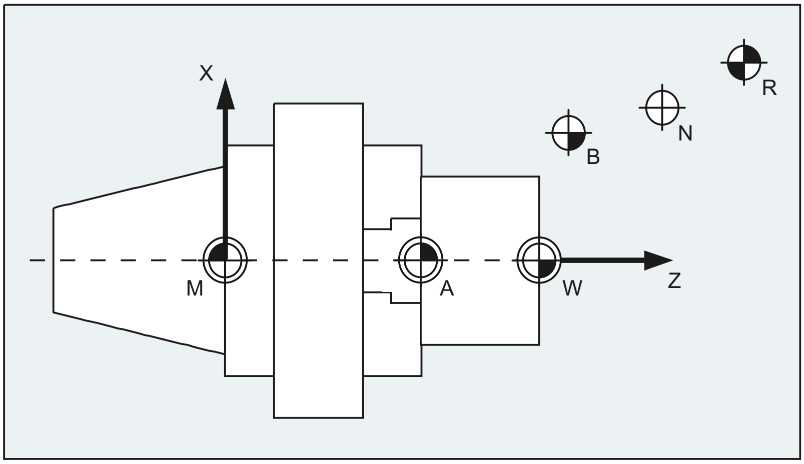
1.3 Zero points and reference points

Various zero points and reference points are defined on an NC machine:

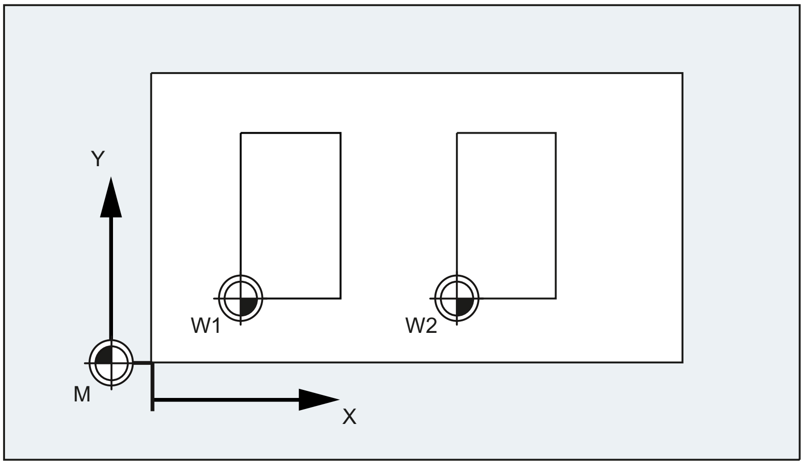
Zero points		
⊕	M	Machine zero The machine zero defines the machine coordinate system (MCS). All other reference points refer to the machine zero.
⊕	W	Workpiece zero = program zero The workpiece zero defines the workpiece coordinate system in relation to the machine zero.
⊕	A	Blocking point Can be the same as the workpiece zero (only for lathes).

Reference points		
⊕	R	Reference point Position defined by output cam and measuring system. The distance to the machine zero M must be known so that the axis position at this point can be set exactly to this value.
⊕	B	Starting point Can be defined by the program. The first machining tool starts here.
⊕	T	Toolholder reference point Is on the toolholder. By entering the tool lengths, the control calculates the distance between the tool tip and the toolholder reference point.
⊕	N	Tool change point

Zero points and reference points for turning



Zero points for milling



1.4 Coordinate systems

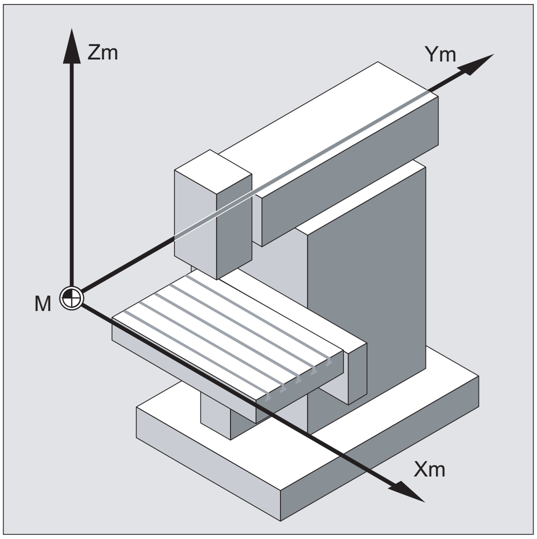
A distinction is made between the following coordinate systems:

- Machine coordinate system (MCS) [Page 25] with the machine zero M
- Basic coordinate system (BCS) [Page 28]
- Basic zero system (BZS) [Page 30]
- Settable zero system (SZS) [Page 31]
- Workpiece coordinate system (WCS) [Page 32] with the workpiece zero W

1.4.1 Machine coordinate system (MCS)

The machine coordinate system comprises all the physically existing machine axes.

Reference points and tool and pallet changing points (fixed machine points) are defined in the machine coordinate system.



If programming is performed directly in the machine coordinate system (possible with some G functions), the physical axes of the machine respond directly. Any workpiece clamping that is present is not taken into account.

Note

If there are various machine coordinate systems (e.g. 5-axis transformation), then an internal transformation is used to map the machine kinematics on the coordinate system in which the programming is performed.

Three-finger rule

The orientation of the coordinate system relative to the machine depends on the machine type. The axis directions follow the so-called "three-finger rule" of the **right** hand (according to DIN 66217).

Seen from in front of the machine, the middle finger of the right hand points in the opposite direction to the infeed of the main spindle. Therefore:

- the thumb points in the +X direction
- the index finger points in the +Y direction
- the middle finger points in the +Z direction

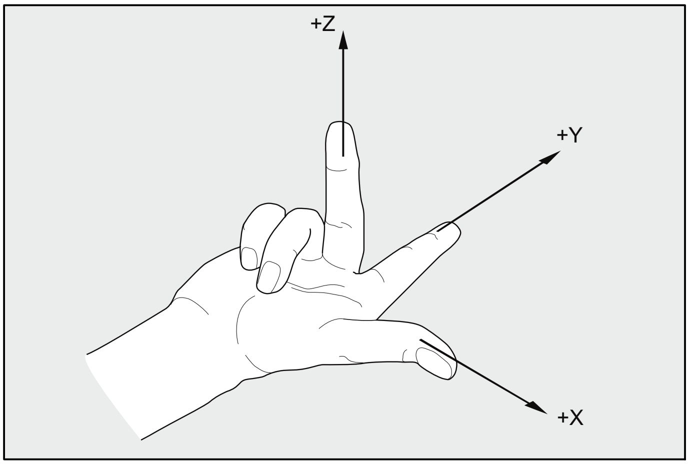
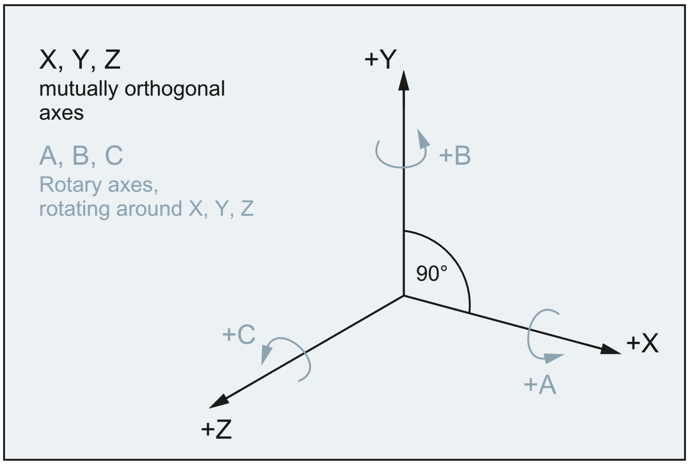


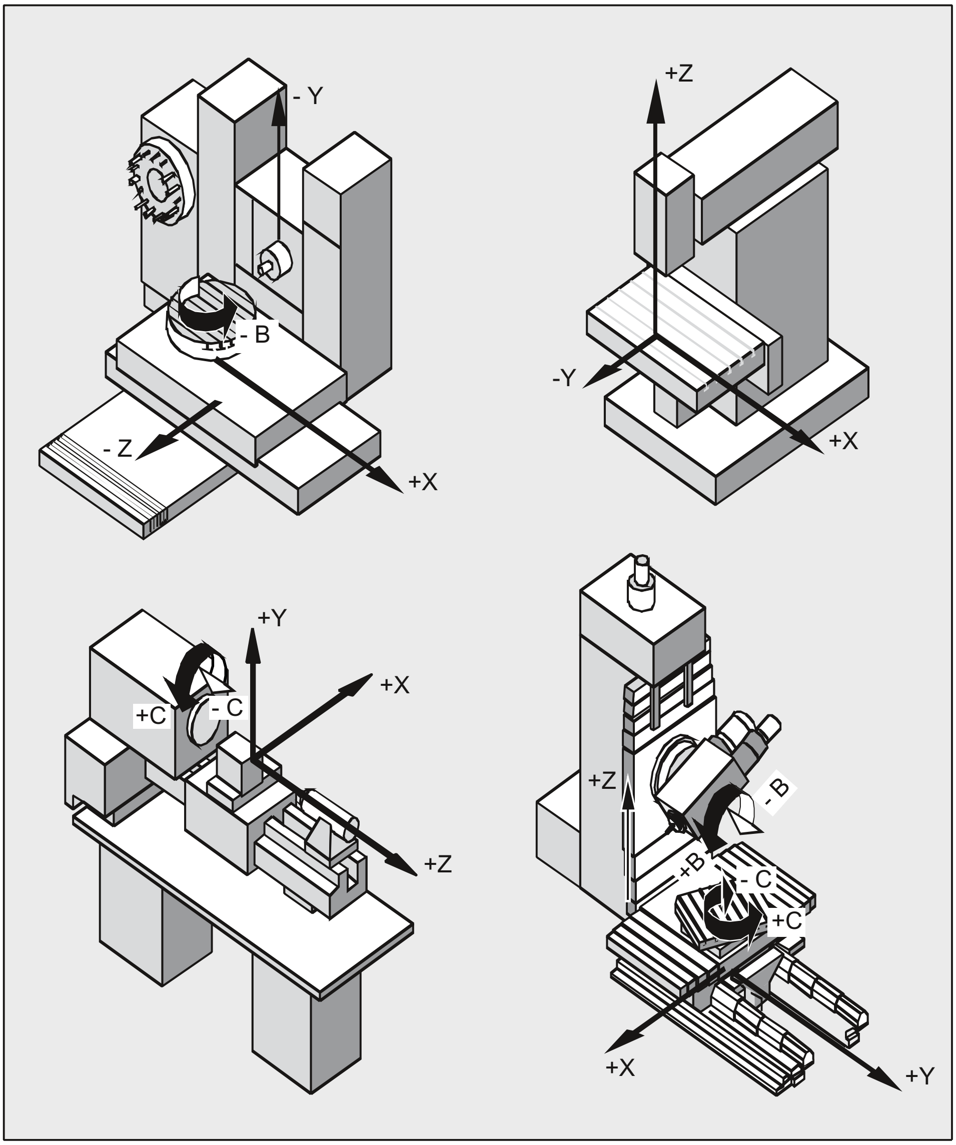
Figure 1-5 "Three-finger rule"

Rotary motions around the coordinate axes X, Y and Z are designated A, B and C. If the rotary motion is in a clockwise direction when looking in the positive direction of the coordinate axis, the direction of rotation is positive:



Position of the coordinate system in different machine types

The position of the coordinate system resulting from the "three-finger rule" can have a different orientation for different machine types. Here are a few examples:



1.4.2 Basic coordinate system (BCS)

The basic coordinate system (BCS) consists of three mutually perpendicular axes (geometry axes) as well as other special axes, which are not interrelated geometrically.

Machine tools without kinematic transformation

BCS and MCS always coincide when the BCS can be mapped onto the MCS without kinematic transformation (e.g. 5-axis transformation, TRANSMIT/TRACYL/TRAANG).

On such machines, machine axes and geometry axes can have the same names.

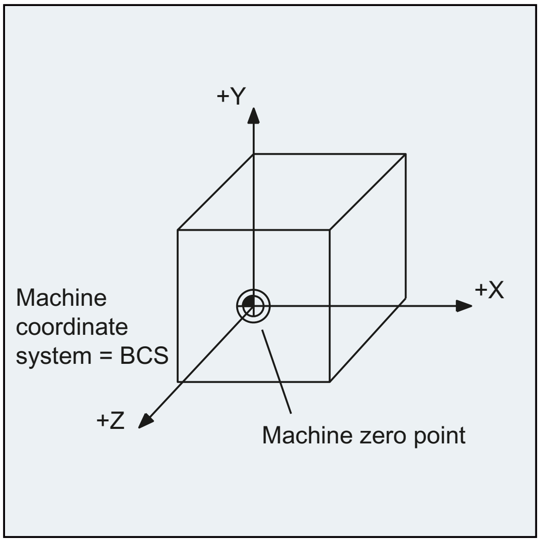


Figure 1-6 MCS = BCS without kinematic transformation

Machine tools with kinematic transformation

BCS and MCS do not coincide when the BCS is mapped onto the MCS with kinematic transformation (e.g. 5-axis transformation, TRANSMIT/TRACYL/TRAANG).

On such machines the machine axes and geometry axes must have different names.

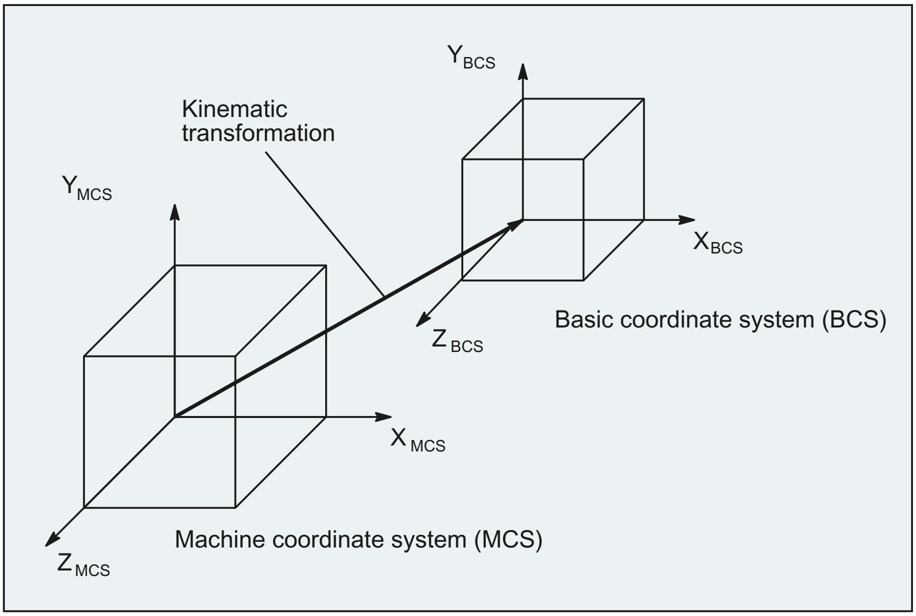


Figure 1-7 Kinematic transformation between the MCS and BCS

Machine kinematics

The workpiece is always programmed in a two or three dimensional, right-angled coordinate system (WCS). However, such workpieces are being programmed ever more frequently on machine tools with rotary axes or linear axes not perpendicular to one another. Kinematic transformation is used to represent coordinates programmed in the workpiece coordinate system (rectangular) in real machine movements.

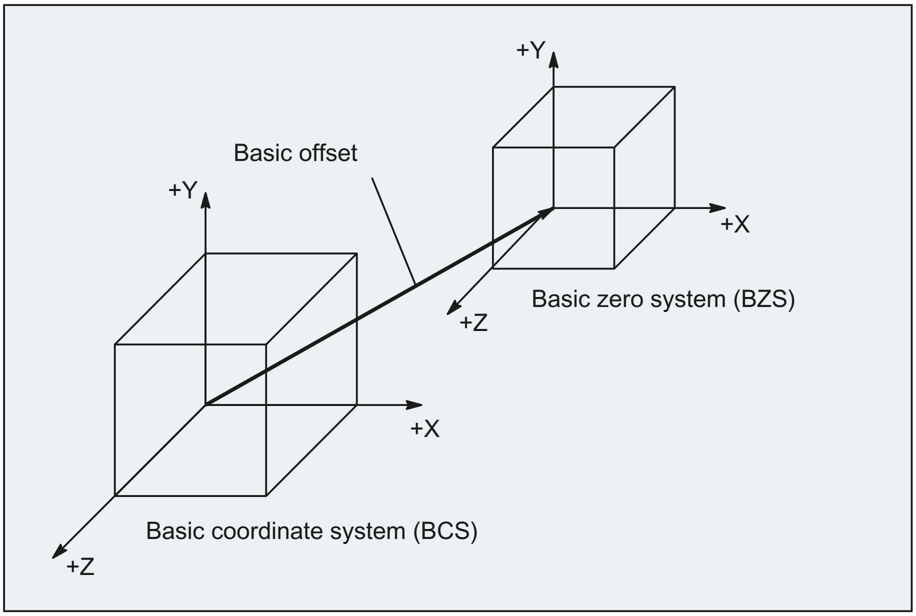
References

Function Manual Expansion Functions; M1: Kinematic transformation

Function Manual, Special Functions; F2: Multi-axis transformations

1.4.3 Basic zero system (BZS)

The basic zero system (BZS) is the basic coordinate system with a basic offset.



Basic offset

The basic offset describes the coordinate transformation between BCS and BZS. It can be used, for example, to define the palette window zero.

The basic offset comprises:

- Zero offset external
- DRF offset
- Overlaid movement
- Chained system frames
- Chained basic frames

References

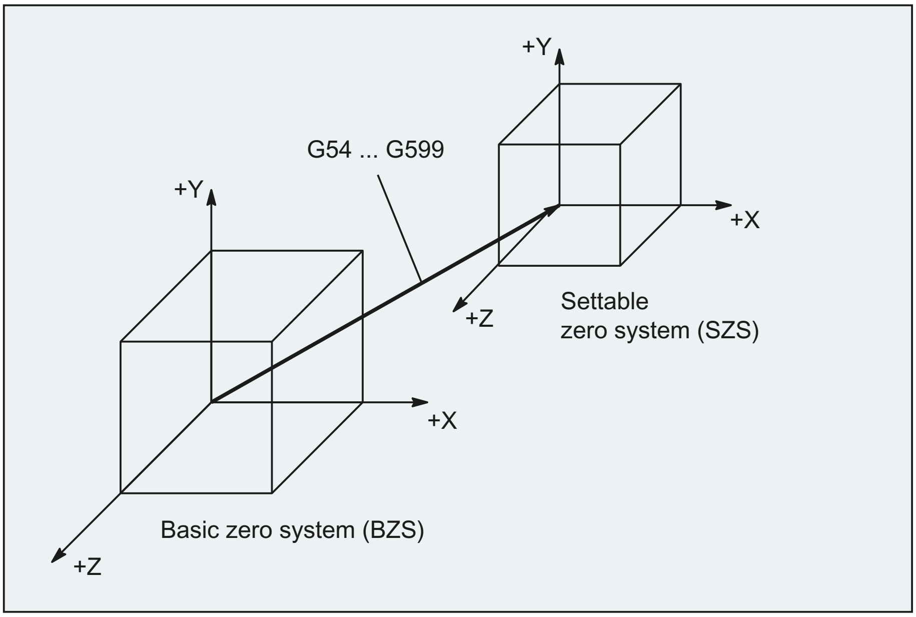
Function Manual, Basic Functions; Axes, Coordinate Systems, Frames (K2)

1.4.4 Settable zero system (SZS)

Settable zero offset

The "settable zero system" (SZS) results from the basic zero system (BZS) through the settable zero offset.

Settable zero offsets are activated in the NC program with the G commands `G54`...`G57` and `G505`...`G599` as follows:



If no programmable coordinate transformations (frames) are active, then the "settable zero system" is the workpiece coordinate system (WCS).

Programmable coordinate transformations (frames)

Sometimes it is useful or necessary within an NC program, to move the originally selected workpiece coordinate system (or the "settable zero system") to another position and, if required, to rotate it, mirror it and/or scale it. This is performed using programmable coordinate transformations (frames).

See Section: "Coordinate transformations (frames)"

Note

Programmable coordinate transformations (frames) always refer to the "settable zero system".

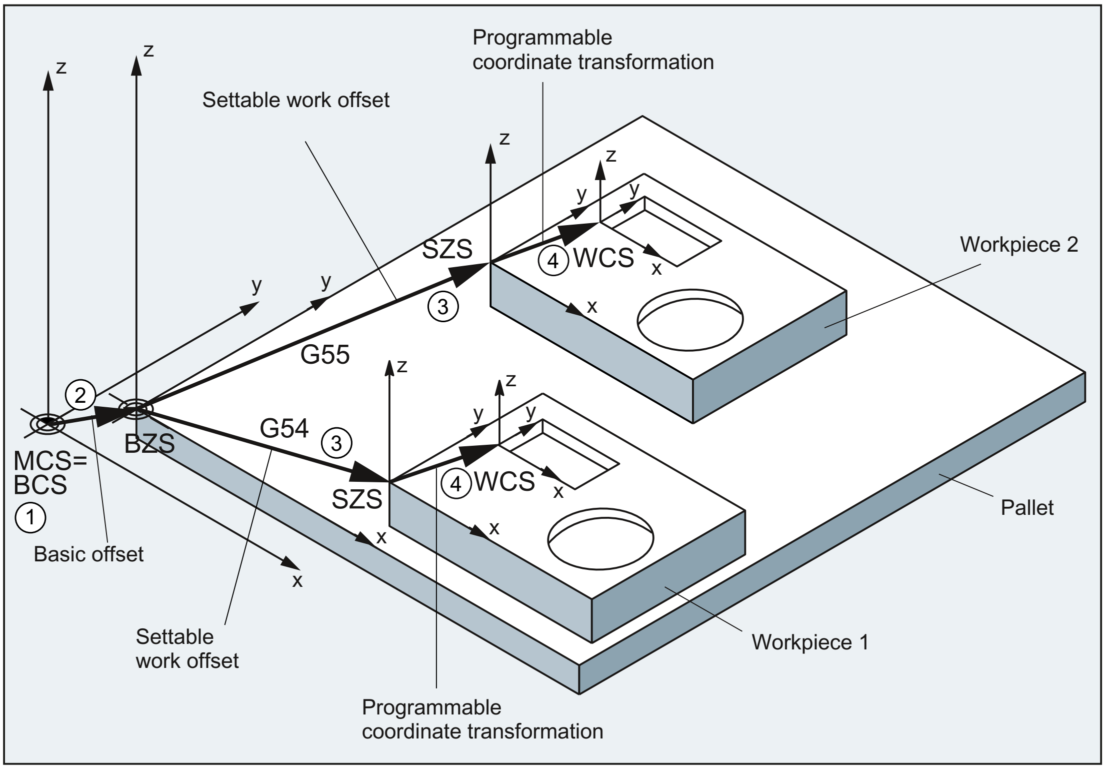
1.4.5 Workpiece coordinate system (WCS)

The geometry of a workpiece is described in the workpiece coordinate system (WCS). In other words, the data in the NC program refer to the workpiece coordinate system.

The workpiece coordinate system is always a Cartesian coordinate system and assigned to a specific workpiece.

1.4.6 What is the relationship between the various coordinate systems?

The example in the following figure should help clarify the relationships between the various coordinate systems:



① A kinematic transformation is not active, i.e. the machine coordinate system and the basic coordinate system coincide.

② The basic zero system (BZS) with the pallet zero result from the basic offset.

③ The "settable zero system" (SZS) for Workpiece 1 or Workpiece 2 is specified by the settable zero offset `G54` or `G55`.

④ The workpiece coordinate system (WCS) results from programmable coordinate transformation.

Fundamental Principles of NC Programming 2

Note

DIN 66025 is the guideline for NC programming.

2.1 Name of an NC program

Rules for program names

Each NC program has a different name; the name can be chosen freely during program creation, taking the following conditions into account:

- The name should not have more than 24 characters as only the first 24 characters of a program name are displayed on the NC.
- Permissible characters are:
  - Letters: A...Z, a...z
  - Numbers: 0...9
  - Underscores: _
- The first two characters should be:
  - Two letters

    or
  - An underscore and a letter

  If this condition is satisfied, then an NC program can be called as subroutine from another program just by specifying the program name. However, if the program name starts with a number then the subroutine call is only possible via the `CALL` statement.

Examples:

_MPF100

SHAFT

SHAFT_2

Files in punch tape format

Externally created program files that are read into the NC via the V.24 interface must be present in punch tape format.

The following additional rules apply for the name of a file in punch tape format:

- The program name must begin with "%":

  %<Name>
- The program name must have a 3-character identifier:

  %<Name>_xxx

Examples:

- %_N_SHAFT123_MPF
- %Flange3_MPF

Note

The name of a file stored internally in the NC memory starts with "_N_".

References

For further information on transferring, creating and storing part programs, please refer to the Operating Manual for your user interface.

2.2 Structure and contents of an NC program

2.2.1 Blocks and block components

Blocks

An NC program consists of a sequence of NC blocks. Each block contains the data for the execution of a step in the workpiece machining.

Block components

NC blocks consist of the following components:

- Commands (statements) according to DIN 66025
- Elements of the NC high-level language

Commands according to DIN 66025

The commands according to DIN 66025 consist of an address character and a digit or sequence of digits representing an arithmetic value.

Address character (address)

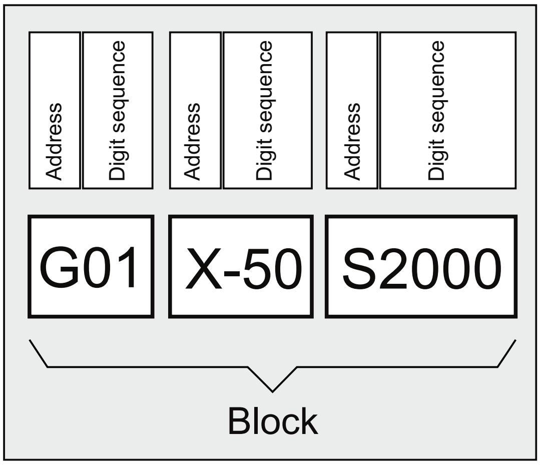
The address character (generally a letter) defines the meaning of the command.

Examples:

Address character	Significance
G	G function (preparatory function)
X	Position data for the X axis
S	Spindle speed

Digit sequence

The digit sequence is the value assigned to the address character. The sequence of digits can contain a sign and decimal point. The sign always appears between the address letter and the sequence of digits. Positive signs (+) and leading zeroes (0) do not have to be specified.



Elements of the NC high-level language

As the command set according to DIN 66025 is no longer adequate for the programming of complex machining sequences in modern machine tools, it has been extended by the elements of the NC high-level language.

These include, for example:

- Commands of the NC high-level language

  In contrast to the commands according to DIN 66025, the commands of the NC high-level language consist of several address letters, e.g.

  - `OVR` for speed override
  - `SPOS` for spindle positioning

- Identifiers (defined names) for:

  - System variables
  - User-defined variables
  - Subroutines
  - Keywords
  - Jump markers
  - Macros

NOTICE
An identifier must be unique and cannot be used for different objects.

- Relational operators
- Logic operators
- Arithmetic functions
- Control structures

References:
Programming Manual, Job Planning; Section: "Flexible NC programming"

Effectiveness of commands

Commands are either modal or non-modal:

- Modal

  Modal commands retain their validity with the programmed value (in all following blocks) until:

  - A new value is programmed under the same command
  - A command is programmed that revokes the effect of the previously valid command

- Non-modal

  Non-modal commands only apply for the block in which they were programmed.

End of program

The last block in the execution sequence contains a special word for the end of program: `M2`, `M17` or `M30`.

2.2.2 Block rules

Start of block

NC blocks can be identified at the start of the block by block numbers. These consist of the character "N" and a positive integer, e.g.

```
N40 ...
```

The order of the block numbers is arbitrary, however, block numbers in rising order are recommended.

Note

Block numbers must be unique within a program in order to achieve an unambiguous result when searching.

End of block

A block ends with the character LF (LINE FEED = new line).

Note

The LF character does not have to be written. It is generated automatically by the line change.

Block length

A block can contain a maximum of **512 characters** (including the comment and end-of-block character LF).

Note

Three blocks of up to 66 characters each are normally displayed in the current block display on the screen. Comments are also displayed. Messages are displayed in a separate message window.

Order of the statements

In order to keep the block structure as clear as possible, the statements in a block should be arranged in the following order:

```
N… G… X… Y… Z… F… S… T… D… M… H…
```

Address	Significance
`N`	Address of block number
`G`	Preparatory function
`X,Y,Z`	Positional data
`F`	Feed
`S`	Spindle speed
`T`	Tool
`D`	Tool offset number
`M`	Additional function
`H`	Auxiliary function

Note

Certain addresses can be used repeatedly within a block, e.g.

`G…, M…, H…`

2.2.3 Value assignments

Values can be assigned to the addresses. The following rules apply:

- An "=" sign must be inserted between the address and the value if:
  - The address comprises more than one letter
  - The value includes more than one constant.

  The "="-sign can be omitted if the address is a single letter and the value consists of only one constant.
- Signs are permitted.
- Separators are permitted after the address letter.

Examples:

`X10`	Value assignment (10) to address X, "=" not required
`X1=10`	Value assignment (10) to address (X) with numeric extension (1), "=" required
`X=10*(5+SIN(37.5))`	Value assignment by means of a numeric expression, "=" required

Note

A numeric extension must always be followed by one of the special characters "=", "(", "[", ")", "]", ",", or an operator, in order to distinguish an address with numeric extension from an address letter with a value.

2.2.4 Comments

To make an NC program easier to understand, comments can be added to the NC blocks.

A comment is at the end of a block and is separated from the program section of the NC block by a semicolon (";").

Example 1:

Program code	**Comments**
`N10 G1 F100 X10 Y20`	`; Comment to explain the NC block`

Example 2:

Program code	**Comment**
`N10`	`; Company G&S, order no. 12A71`
`N20`	`; Program written by H. Smith, Dept. TV 4 ;on November 21, 1994`
`N50`	`; Section no. 12, housing for submersible pump type TP23A`

Note

Comments are stored and appear in the current block display when the program is running.

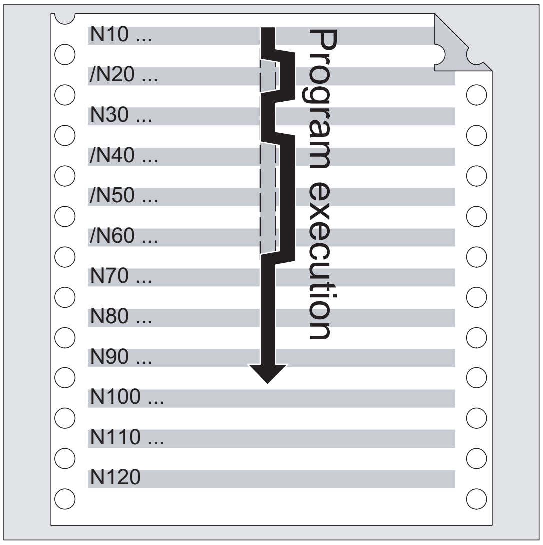
2.2.5 Skipping blocks

NC blocks, which are not to be executed in every program pass (e.g. execute a trial program run), can be skipped.

Programming

Blocks, which are to be skipped are marked with an oblique "/" in front of the block number. Several consecutive blocks can also be skipped. The statements in the skipped blocks are not executed; the program continues with the next block, which is not skipped.

Example:



Program code	Comment
N10	; Is executed
/N20 …	; Skipped
N30 …	; Is executed
/N40 …	; Skipped
N70 …	; Is executed

Skip levels

Blocks can be assigned to skip levels (max. 10), which can be activated via the user interface.

Programming is performed by assigning a forward slash, followed by the number of the skip level. Only one skip level can be specified for each block.

Example:

Program code	**Comment**
`/ ...`	`; Block is skipped (1st skip level)`
`/0 ...`	`; Block is skipped (1st skip level)`
`/1 N010...`	`; Block is skipped (2nd skip level)`
`/2 N020...`	`; Block is skipped (3rd skip level)`
`...`	
`/7 N100...`	`; Block is skipped (8th skip level)`
`/8 N080...`	`; Block is skipped (9th skip level)`
`/9 N090...`	`; Block is skipped (10th skip level)`

Note

The number of skip levels that can be used depends on a display machine data item.

Note

System and user variables can also be used in conditional jumps in order to control program execution.

Creating an NC program 3

3.1 Basic procedure

The programming of the individual operation steps in the NC language generally represents only a small proportion of the work in the development of an NC program.

Programming of the actual instructions should be preceded by the planning and preparation of the operation steps. The more accurately you plan in advance how the NC program is to be structured and organized, the faster and easier it will be to produce a complete program, which is clear and free of errors. Clearly structured programs are especially advantageous when changes have to be made later.

As every part is not identical, it does not make sense to create every program in the same way. However, the following procedure has shown itself to be suitable in the most cases.

Procedure

1. **Prepare the workpiece drawing**
   - Define the workpiece zero
   - Draw the coordinate system
   - Calculate any missing coordinates
2. **Define the machining sequence**
   - Which tools are used when and for the machining of which contours?
   - In which order will the individual elements of the workpiece be machined?
   - Which individual elements are repeated (possibly also rotated) and should be stored in a subroutine?
   - Are there contour sections in other part programs or subroutines that could be used for the current workpiece?
   - Where are zero offsets, rotating, mirroring and scaling useful or necessary (frame concept)?

3. **Create a machining plan**

   Define all machining operations step-by-step, e.g.

   - Rapid traverse movements for positioning
   - Tool change
   - Define the machining plane
   - Retraction for checking
   - Switch spindle, coolant on/off
   - Call up tool data
   - Feed
   - Path correction
   - Approaching the contour
   - Retraction from the contour
   - etc.

4. **Compile machining steps in the programming language**

   - Write each individual step as an NC block (or NC blocks).

5. **Combine the individual steps into a program**

3.2 Available characters

The following characters are available for writing NC programs:

- Upper-case characters:

  A, B, C, D, E, F, G, H, I, J, K, L, M, N,(O),P, Q, R, S, T, U, V, W, X, Y, Z

- Lower-case characters:

  a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z

- Numbers:

  0, 1, 2, 3, 4, 5, 6, 7, 8, 9

- Special characters:

  See the table below.

Special characters	Meaning
%	Program start character (used only for writing programs on an external PC)
(	For bracketing parameters or expressions
)	For bracketing parameters or expressions
[	For bracketing addresses or indexes
]	For bracketing addresses or indexes
<	Less than
>	Greater than
:	Main block, end of label, chain operator
=	Assignment, part of equation
/	Division, block suppression
*	Multiplication
+	Addition
-	Subtraction, minus sign
"	Double quotation marks, identifier for character string
'	Single quotation marks, identifier for special numerical values: hexadecimal, binary
$	System variable identifiers
_	Underscore, belonging to letters
?	Reserved
!	Reserved
.	Decimal point
,	Comma, parameter separator
;	Comment start
&	Format character, same effect as space character
LF	End of block
Tab character	Separator
Space character	Separator (blank)

NOTICE
Take care to differentiate between the letter "O" and the digit "0".

Note

No distinction is made between upper and lower-case characters (exception: tool call).

Note

Non-printable special characters are treated like blanks.

3.3 Program header

The NC blocks that are placed in front of the actual motion blocks for the machining of the workpiece contour, are called the program header.

The program header contains information/statements regarding:

- Tool change
- Tool offsets
- Spindle motion
- Feed control
- Geometry settings (zero offset, selection of the working plane)

Program header for turning

The following example shows the typical structure of an NC program header for turning:

Program code	**Comment**
`N10 G0 G153 X200 Z500 T0 D0`	`; Retract toolholder before tool turret is rotated.`
`N20 T5`	`; Swing in tool 5.`
`N30 D1`	`; Activate cutting edge data record of the tool.`
`N40 G96 S300 LIMS=3000 M4 M8`	`; Constant cutting rate (Vc) = 300 m/min, speed limitation = 3000 rpm, direction of rotation counterclockwise, cooling on.`
`N50 DIAMON`	`; X axis will be programmed in diameter.`
`N60 G54 G18 G0 X82 Z0.2`	`; Call zero offset and working plane, approach starting position.`
`...`	

Program header for milling

The following example shows the typical structure of an NC program header for milling:

Program code	**Comment**
`N10 T="SF12"`	`; Alternative: T123`
`N20 M6`	`; Trigger tool change`
`N30 D1`	`; Activate cutting edge data record of the tool`
`N40 G54 G17`	`; Zero offset and working plane`
`N50 G0 X0 Y0 Z2 S2000 M3 M8`	`; Approach to the workpiece, spindle and coolant on`
`...`	

If tool orientation / coordinate transformation is being used, any transformations still active should be deleted at the start of the program:

Program code	Comment
N10 CYCLE800()	; Resetting of the swiveled plane
N20 TRAFOOF	; Resetting of TRAORI, TRANSMIT, TRACYL, ...
...	

3.4 Program examples

3.4.1 Example 1: First programming steps

Program example 1 is to be used to perform and test the first programming steps on the NC.

Procedure

1. Create a new part program (name)
2. Edit the part program
3. Select the part program
4. Activate single block
5. Start the part program

References:
Operating Manual for the existing user interface

Note

In order that the program can run on the machine, the machine data must have been set appropriately (→ machine manufacturer!).

Note

Alarms can occur during program verification. These alarms have to be reset first.

Program example 1

Program code	Comment
`N10  MSG("THIS IS MY NC PROGRAM")`	`; Message "THIS IS MY NC PROGRAM" displayed in the alarm line`
`N20 F200 S900 T1 D2 M3`	`; Feedrate, spindle, tool, tool offset, spindle clockwise`
`N30 G0 X100 Y100`	`; Approach position in rapid traverse`
`N40 G1 X150`	`; Rectangle with feedrate, straight line in X`
`N50 Y120`	`; Straight line in Y`
`N60 X100`	`; Straight line in X`
`N70 Y100`	`; Straight line in Y`
`N80 G0 X0 Y0`	`; Retraction in rapid traverse`
`N100 M30`	`; End of block`

3.4.2 Example 2: NC program for turning

Program example 2 is intended for the machining of a workpiece on a lathe. It contains radius programming and tool radius compensation.

Note

In order that the program can run on the machine, the machine data must have been set appropriately (→ machine manufacturer!).

Dimension drawing of the workpiece

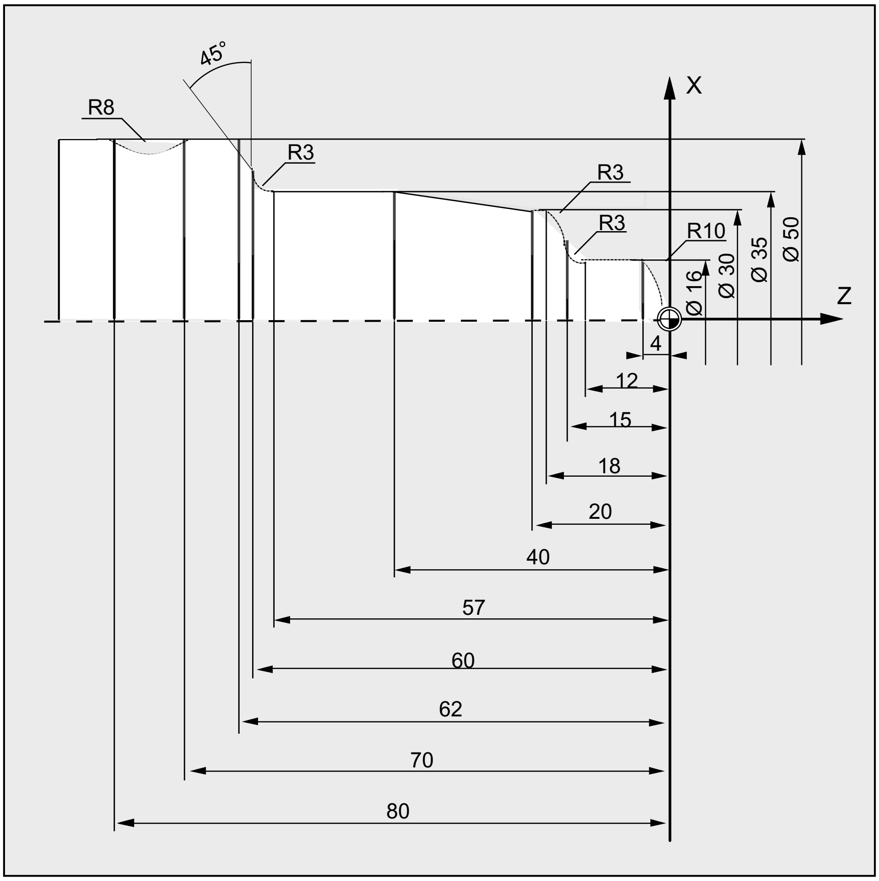


Figure 3-1 Top view

Program example 2

Program code	Comment
N5 G0 G53 X280 Z380 D0	; Starting point
N10 TRANS X0 Z250	; Zero offset
N15 LIMS=4000	; Speed limitation (G96)
N20 G96 S250 M3	; Select constant cutting rate
N25 G90 T1 D1 M8	; Select tool selection and offset
N30 G0 G42 X-1.5 Z1	; Set tool with tool radius compensation
N35 G1 X0 Z0 F0.25	
N40 G3 X16 Z-4 I0 K-10	; Turn radius 10
N45 G1 Z-12	
N50 G2 X22 Z-15 CR=3	; Turn radius 3
N55 G1 X24	
N60 G3 X30 Z-18 I0 K-3	; Turn radius 3
N65 G1 Z-20	
N70 X35 Z-40	
N75 Z-57	
N80 G2 X41 Z-60 CR=3	; Turn radius 3
N85 G1 X46	
N90 X52 Z-63	
N95 G0 G40 G97 X100 Z50 M9	; Deselect tool radius compensation and approach tool change location
N100 T2 D2	; Call tool and select offset
N105 G96 S210 M3	; Select constant cutting rate
N110 G0 G42 X50 Z-60 M8	; Set tool with tool radius compensation
N115 G1 Z-70 F0.12	; Turn diameter 50
N120 G2 X50 Z-80 I6.245 K-5	; Turn radius 8
N125 G0 G40 X100 Z50 M9	; Retract tool and deselect tool radius compensation
N130 G0 G53 X280 Z380 D0 M5	; Approach tool change location
N135 M30	; End of program

3.4.3 Example 3: NC program for milling

Program example 3 is intended for the machining of a workpiece on a vertical milling machine. It contains surface and side milling as well as drilling.

Note

In order that the program can run on the machine, the machine data must have been set appropriately (→ machine manufacturer!).

Dimension drawing of the workpiece

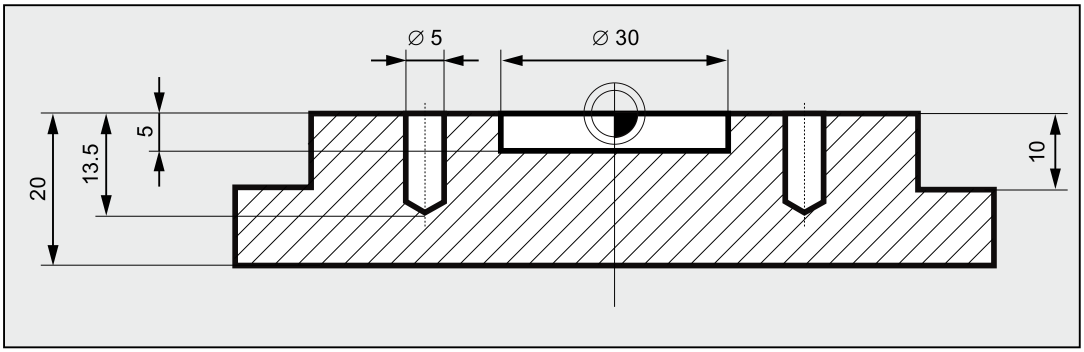


Figure 3-2 Side view

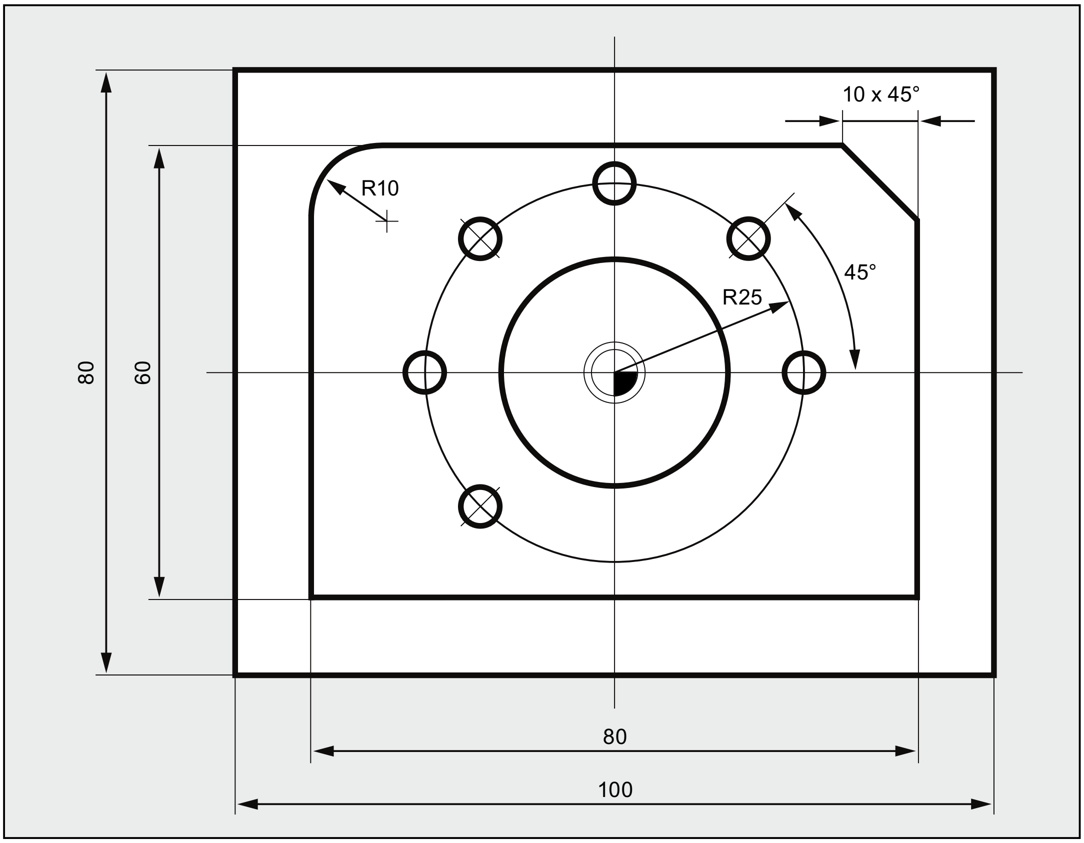


Figure 3-3 Top view

Program example 3

Program code	Comment
N10 T="PF60"	; Preselection of the tool with name PF60.
N20 M6	; Load the tool into the spindle.
N30 S2000 M3 M8	; Speed, direction of rotation, cooling on.
N40 G90 G64 G54 G17 G0 X-72 Y-72	; Basic settings of the geometry and approach starting point.
N50 G0 Z2	; Z axis at safety clearance.
N60 G450 CFTCP	; Behavior with active G41/G42.
N70 G1 Z-10 F3000	; Milling tool at working depth with feedrate = 3000 mm/min.
N80 G1 G41 X-40	; Activation of the milling tool radius compensation.
N90 G1 X-40 Y30 RND=10 F1200	; Travel to the contour with feedrate = 1200 mm/min.
N100 G1 X40 Y30 CHR=10	
N110 G1 X40 Y-30	
N120 G1 X-41 Y-30	
N130 G1 G40 Y-72 F3000	; Deselection of the milling tool radius compensation.
N140 G0 Z200 M5 M9	; Retraction of the milling tool, spindle + cooling off.
N150 T="SF10"	; Preselection of the tool with name SF10.
N160 M6	; Load the tool into the spindle.
N170 S2800 M3 M8	; Speed, direction of rotation, cooling on.
N180 G90 G64 G54 G17 G0 X0 Y0	; Basic settings of the geometry and approach starting point.
N190 G0 Z2	
N200 POCKET4(2,0,1,-5,15,0,0,0,0,0,800,1300,0,21,5,,,2,0.5)	; Call of the pocket milling cycle.
N210 G0 Z200 M5 M9	; Retraction of the milling tool, spindle + cooling off.
N220 T="ZB6"	; Call center drill 6 mm.
N230 M6	
N240 S5000 M3 M8	
N250 G90 G60 G54 G17 X25 Y0	; Exact stop G60 for exact positioning.
N260 G0 Z2	
N270 MCALL CYCLE82(2,0,1,-2.6,,0)	; Modal call of the drilling cycle.

Program code	Comment
N280 POSITION:	; Jump mark for repetition.
N290 HOLES2(0,0,25,0,45,6)	; Position pattern for drilling.
N300 ENDLABEL:	; End identifier for repetition.
N310 MCALL	; Resetting of the modal call.
N320 G0 Z200 M5 M9	
N330 T="SPB5"	; Call twist drill D 5 mm.
N340 M6	
N350 S2600 M3 M8	
N360 G90 G60 G54 G17 X25 Y0	
N370 MCALL CYCLE82(2,0,1,-13.5,,0)	; Modal call of the drilling cycle.
N380 REPEAT POSITION	; Repetition of the position description from centering.
N390 MCALL	; Resetting of the drilling cycle
N400 G0 Z200 M5 M9	
N410 M30	; End of program.

Tool change

4

Tool change method

In chain, rotary-plate and box magazines, a tool change normally takes place in two stages:

1. The tool is sought in the magazine with the T command.
2. The tool is then loaded into the spindle with the M command.

In circular magazines on turning machines, the T command carries out the entire tool change, that is, locates and inserts the tool.

Note

The tool change method is set via a machine data (→ machine manufacturer).

Conditions

Together with the tool change:

- The tool offset values stored under a D number have to be activated.
- The appropriate working plane has to be programmed (basic setting: G18). This ensures that the tool length compensation is assigned to the correct axis.

Tool management (option)

The programming of the tool change is performed differently for machines with active tool management (option) than for machines without active tool management. The two options are therefore described separately.

4.1 Tool change without tool management

4.1.1 Tool change with T command

Function

There is a direct tool change when the T command is programmed.

Application

For turning machines with circular magazine.

Syntax

Tool selection:

```
T<number>
T=<number>
T<n>=<number>
```

Tool deselection:

```
T0
T0=<number>
```

Meaning

`T`: Command for tool selection including tool change and activation of the tool offset

`<n>`: Spindle number as address extension

Note:
The possibility of programming a spindle number as address extension depends on the configuration of the machine;
→ see machine manufacturer's specifications)

`<number>`: Number of the tool

Range of values: 0 - 32000

`T0`: Command for deselection of the active tool

Example

Program code	**Comment**
`N10 T1 D1`	`; Loading of tool T1 and activation of the tool offset D1.`
`...`	
`N70 T0`	`; Deselect tool T1.`
`...`	

4.1.2 Tool change with M6

Function

The tool is selected when the `T` command is programmed. The tool only becomes active with `M6` (including tool offset).

Application

For milling machines with chain, rotary-plate or box magazines.

Syntax

Tool selection:

```
T<number>
T=<number>
T<n>=<number>
```

Tool change:

```
M6
```

Tool deselection:

```
T0
T0=<number>
```

Significance

`T`:	Command for the tool selection
`<n>`:	Spindle number as address extension **Note:** The possibility of programming a spindle number as address extension depends on the configuration of the machine; → see machine manufacturer's specifications.
`<number>`:	Number of the tool Range of values: 0 - 32000
`M6`:	M function for the tool change (according to DIN 66025) `M6` activates the selected tool (`T…`) and the tool offset (`D...`).
`T0`:	Command for deselection of the active tool

Example

Program code	**Comment**
`N10 T1 M6`	`; Loading of tool T1.`
`N20 D1`	`; Selection of tool length compensation.`
`N30 G1 X10 ...`	`; Machining with T1.`
`...`	
`N70 T5`	`; Preselection of tool T5.`
`N80 ...`	`; Machining with T1.`
`...`	
`N100 M6`	`; Loading of tool T5.`
`N110 D1 G1 X10 ...`	`; Machining with tool T5`
`...`	

4.2 Tool change with tool management (option)

Tool management

The optional "Tool management" function ensures that at any given time the correct tool is in the correct location and that the data assigned to the tool are up to date. It also allows fast tool changes and avoids both scrap by monitoring the tool service life and machine downtimes by using spare tools.

Tool name

On a machine tool with active tool management, the tools must be assigned a name and number for clear identification (e.g. "Drill", "3").

The tool call can then be via the tool name, e.g.
```
T="Drill"
```

NOTICE
The tool name may not contain any special characters.

4.2.1 Tool change with T command with active tool management (option)

Function

There is a direct tool change when the T command is programmed.

Application

For turning machines with circular magazine.

Syntax

Tool selection:
```
T=<location>
T=<name>
T<n>=<location>
T<n>=<name>
```

Tool deselection:
```
T0
```

Significance

`T=`: Command for tool change and activation of the tool offset
The following specifications are possible:

`<location>`: Number of the magazine location

`<name>`: Name of tool
Note:
The correct notation (upper/lower case) must be observed when programming a tool name.

`<n>`: Spindle number as address extension
Note:
The possibility of programming a spindle number as address extension depends on the configuration of the machine; → see machine manufacturer's specifications)

`T0`: Command for the tool deselection (magazine location not occupied)

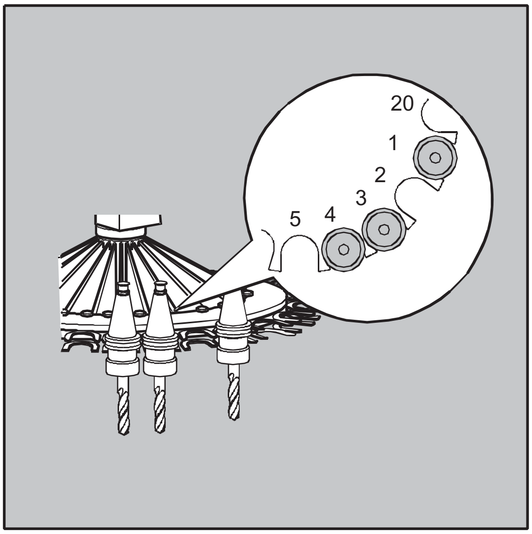
Note

If the selected magazine location is not occupied in a tool magazine, the command acts as for `T0`. The selection of the next occupied magazine location can be used to position the empty location.

Example

A circular magazine has locations 1 to 20 with the following tool assignment:

Location	Tool	Tool group	State
1	Drill, duplo no. = 1	T15	Blocked
2	Not occupied		
3	Drill, duplo no. = 2	T10	Enabled
4	Drill, duplo no. = 3	T1	Active
5 ... 20	Not occupied		



The following tool call is programmed in the NC program:

```
N10 T=1
```

The call is processed as follows:

1. Magazine location 1 is considered and the tool identifier determined.
2. The tool management recognizes that this tool is blocked and therefore cannot be used.
3. A tool search for T="drill" is initiated in accordance with the search method set:

   "Find the active tool; or else, select the one with the next highest duplo number."
4. The following usable tool is then found:

   "Drill", duplo no. 3 (at magazine location 4)

   This completes the tool selection process and the tool change is initiated.

   Note

   If the "Select the first available tool from the group" search method is employed, the sequence must first be defined within the tool group being loaded. In this case group T10 is loaded, as T15 is blocked.

   When the strategy "Take the first tool with "active" status from the group" is applied, T1 is loaded.

4.2.2 Tool change with M6 with active tool management (option)

Function

The tool is selected when the `T` command is programmed. The tool only becomes active with `M6` (including tool offset).

Application

For milling machines with chain, rotary-plate or box magazines.

Syntax

Tool selection:

```
T=<location>
T=<name>
T<n>=<location>
T<n>=<name>
```

Tool change:

```
M6
```

Tool deselection:

```
T0
```

Significance

`T=`: Command for the tool selection
The following specifications are possible:

- `<location>`: Number of the magazine location
- `<name>`: Name of tool
  Note:
  The correct notation (upper/lower case) must be used when programming a tool name.

`<n>`: Spindle number as address extension
Note:
The possibility of programming a spindle number as an address extension depends on the configuration of the machine; → see machine manufacturer's specifications.

`M6`: M function for the tool change (according to DIN 66025)
`M6` activates the selected tool (`T…`) and the tool offset (`D...`).

`T0`: Command for tool deselection (magazine location not occupied)

Note

If the selected magazine location is not occupied in a tool magazine, the command acts as for `T0`. The selection of the next occupied magazine location can be used to position the empty location.

Example

Program code	Comment
`N10 T=1 M6`	`; Loading of the tool from magazine location 1.`
`N20 D1`	`; Selection of tool length compensation.`
`N30 G1 X10 ...`	`; Machining with tool T=1.`
`...`	
`N70 T="Drill"`	`; Preselection of the tool with name "Drill".`
`N80 ...`	`; Machining with tool T=1.`
`...`	
`N100 M6`	`; Loading of the drill.`
`N140 D1 G1 X10 ...`	`; Machining with drill.`
`...`	

4.3 Behavior with faulty T programming

The behavior with faulty T programming depends on the configuration of the machine:

MD22562 TOOL_CHANGE_ERROR_MODE		
Bit	Value	Meaning
7	0	Basic setting! With the T programming, a check is made immediately as to whether the NCK recognizes the T number. If not, an alarm is triggered.
	1	The programmed T number will only be checked following D selection. If the NCK does not recognize the tool number, an alarm is issued during D selection. This response is desirable if, for example, tool programming is also intended to achieve positioning and the tool data is not necessarily available (circular magazine).

Tool offsets 5

5.1 General information about the tool offsets

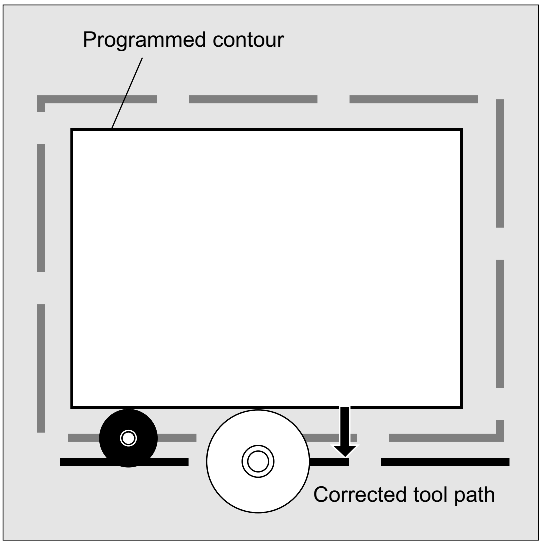
Workpiece dimensions are programmed directly (e.g. according to the production drawing). Therefore, tool data such as milling tool diameter, cutting edge position of the turning tool (counterclockwise/clockwise turning tool) and tool length does not have to be taken into consideration when creating the program.

The control corrects the travel path

When machining a workpiece, the tool paths are controlled according to the tool geometry such that the programmed contour can be machined using any tool.

In order that the control can calculate the tool paths, the tool data must be entered in the tool compensation memory of the control. Only the required tool (`T...`) and the required offset data record (`D...`) are called via the NC program.

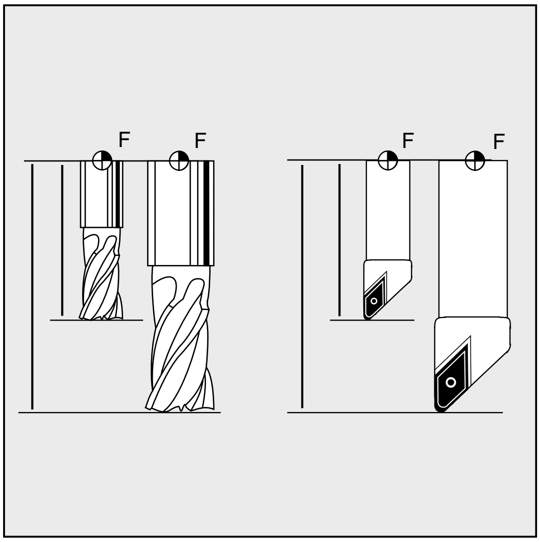
While the program is being processed, the control fetches the offset data it requires from the tool compensation memory and corrects the tool path individually for different tools:



5.2 Tool length compensation

The tool length compensation compensates for the differences in length between the tools used.

The tool length is the distance between the toolholder reference point and the tool tip:



This length is measured and entered in the tool compensation memory of the control together with definable wear values. From this data, the control calculates the traversing movements in the infeed direction.

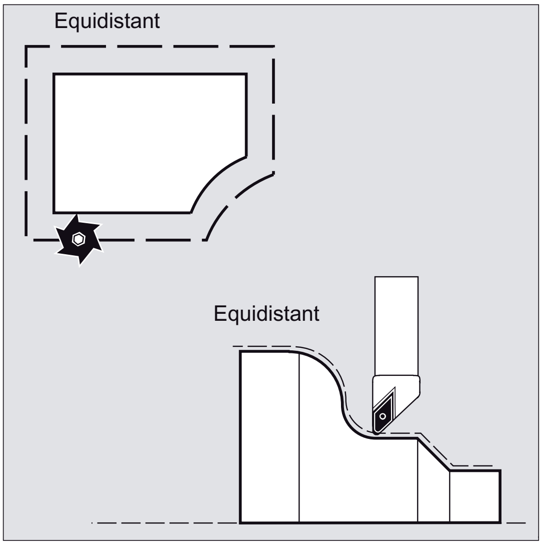
Note

The offset value for the tool length is dependent upon the spatial orientation of the tool.

5.3 Tool radius compensation

The contour and tool path are not identical. The milling tool or cutting edge center must travel along a path that is equidistant from the contour. To do this, the control requires data about the tool form (radius) from the tool compensation memory.

Depending on the radius and the machining direction, the programmed tool center point path is offset during the program processing in such a way that the tool edge travels exactly along the programmed contour:



NOTICE
Tool radius compensation is applied according to the default CUT2D or CUT2DF (see "2D tool compensation (CUT2D, CUT2DF) [Page 317]").

References

The various options for the tool radius compensation are described in detail in Section "Tool radius compensations".

5.4 Tool compensation memory

The following data must be available in the tool compensation memory of the control for each tool edge:

- Tool type
- Cutting edge position
- Tool geometry variables (length, radius)

This data is entered as tool parameters (max. 25). Which parameters are required for a tool depends on the tool type. Any tool parameters that are not required must be set to "zero" (corresponds to the default setting of the system).

NOTICE
Values that have been entered once in the compensation memory are included in the processing at each tool call.

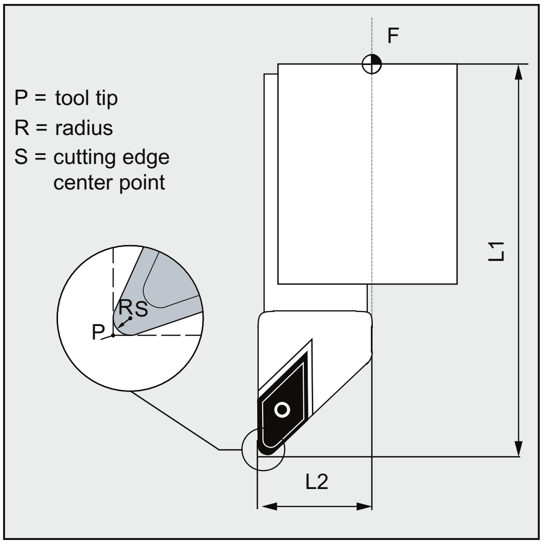
Tool type

The tool type (drill, milling or turning tool) determines which geometry data is necessary and how this is taken into account.

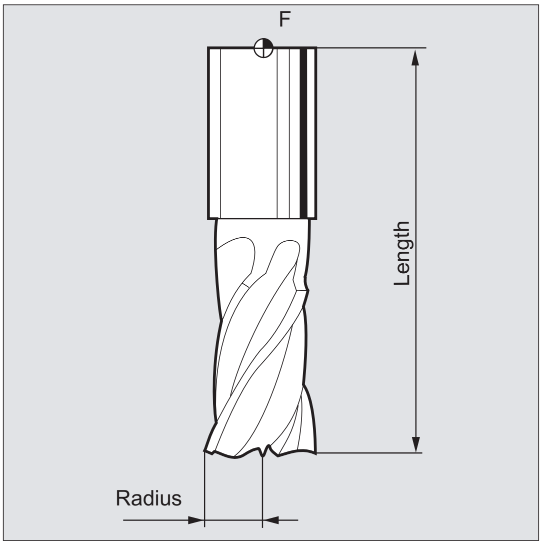
Cutting edge position

The cutting edge position describes the position of the tool tip P in relation to the cutting edge center point S.

The cutting edge position is required together with the cutting edge radius for the calculation of the tool radius compensation for turning tools (tool type 5xx).



Tool geometry variables (length, radius)



The tool geometry variables consist of several components (geometry, wear). The control computes the components to a certain dimension (e.g. overall length 1, total radius). The respective overall dimension becomes effective when the compensation memory is activated.

How these values are calculated in the axes is determined by the tool type and the current plane (`G17`/`G18`/`G19`).

References

Function Manual, Basic Functions; Tool Offsets (W1); Section "Tool edge"

5.5 Tool types

5.5.1 General information about the tool types

Tools are divided into tool types. Each tool type is assigned a 3-digit number. The first digit assigns the tool type to one of the following groups depending on the technology used:

Tool type	Tool group
1xy	Milling tools
2xy	Drills
3xy	Reserved
4xy	Grinding tools
5xy	Turning tools
6xy	Reserved
7xy	Special tools such as a slotting saw

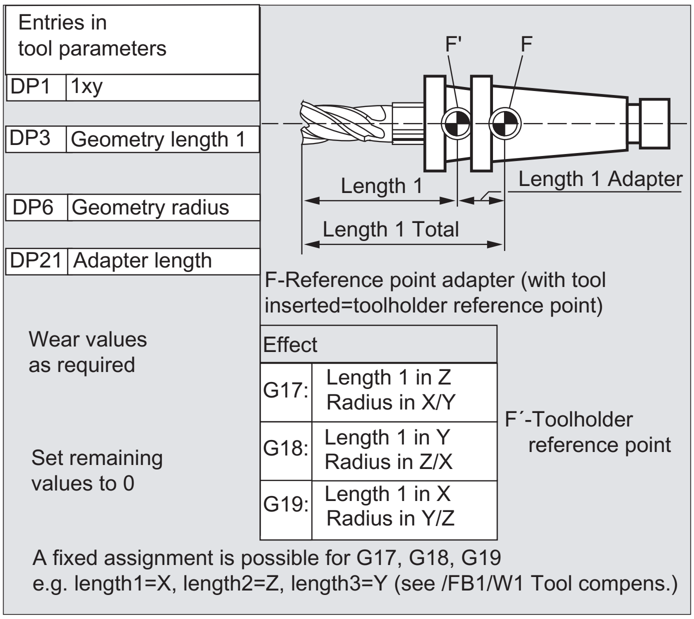
5.5.2 Milling tools

The following tool types are available in the "Milling tools" group:

100	Milling tool according to CLDATA (Cutter Location Data)
110	Ballhead cutter (cylindrical die milling tool)
111	Ballhead cutter (tapered die milling tool)
120	End mill (without corner rounding)
121	End mill (with corner rounding)
130	Angle head cutter (without corner rounding)
131	Angle head cutter (with corner rounding)
140	Facing tool
145	Thread cutter
150	Side mill
151	Saw
155	Bevel cutter (without corner rounding)
156	Bevel cutter (with corner rounding)
157	Tapered die milling tool
160	Drill and thread milling cutter

Tool parameters

The following figures provide an overview of which tool parameters (DP...) for milling tools are entered in the compensation memory:



Entries in tool parameters	
DP1	1xy
DP3	Geometry length 1
DP6	Geometry radius
DP21	Adapter length

Wear values as required

Set remaining values to 0

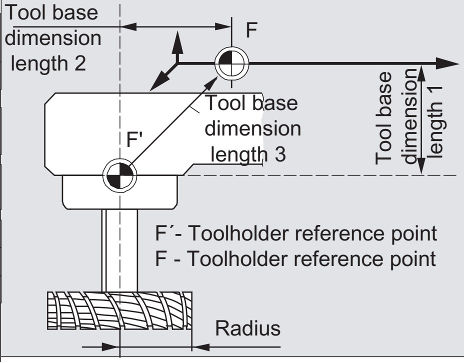
F-Reference point adapter (with tool inserted=toolholder reference point)

Effect	
G17:	Length 1 in Z Radius in X/Y
G18:	Length 1 in Y Radius in Z/X
G19:	Length 1 in X Radius in Y/Z

F´-Toolholder reference point

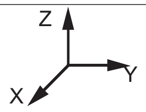
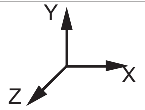
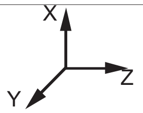
A fixed assignment is possible for G17, G18, G19
e.g. length1=X, length2=Z, length3=Y (see /FB1/W1 Tool compens.)

Entries in tool parameters	
DP1	1xy
DP3	Geometry length 1
DP6	Geometry radius
DP21	Base length 1
DP22	Base length 2
DP23	Base length 3


Tool base dimension length 2
F
Tool base dimension length 3
F'
Tool base dimension length 1
F´- Toolholder reference point
F - Toolholder reference point
Radius

Wear values acc. to requirements

Set remaining values to 0

Effect		
G17:	Length 1 in Z Length 2 in Y Length 3 in X Radius/TRC in X/Y	
G18:	Length 1 in Y Length 2 in X Length 3 in Z Radius/TRC in Z/X	
G19:	Length 1 in X Length 2 in Z Length 3 in Y Radius/TRC in Y/Z	

A fixed assignment is possible for G17, G18, G19
e.g. length 1=X, length 2=Y, length 3=Z (see /FB1/W1 Tool compensation)

Note

Brief description of the tool parameters can be found on the user interface.

For further information, see:
References:
Function Manual, Basic Functions; Tool Offset (W1)

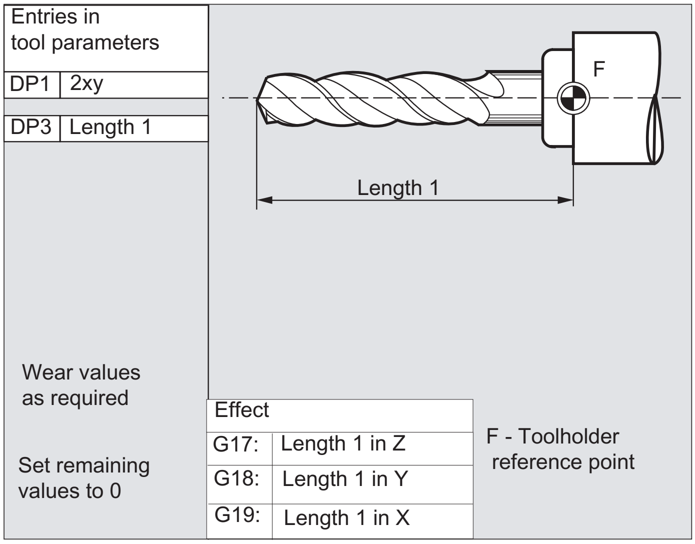
5.5.3 Drills

The following tool types are available in the "Drills" group:

200	Twist drill
205	Drill
210	Boring bar
220	Center drill
230	Countersink
231	Counterbore
240	Tap regular thread
241	Tap fine thread
242	Tap Whitworth thread
250	Reamer

Tool parameters

The following figure provides an overview of which tool parameters (DP...) for drills are entered in the compensation memory:



Entries in tool parameters	
DP1	2xy
DP3	Length 1

Wear values as required

Set remaining values to 0

Effect	
G17:	Length 1 in Z
G18:	Length 1 in Y
G19:	Length 1 in X

Note

Brief description of the tool parameters can be found on the user interface.

For further information, see:
References:
Function Manual, Basic Functions; Tool Offset (W1)

5.5.4 Grinding tools

The following tool types are available in the "Grinding tools" group:

400	Surface grinding wheel
401	Surface grinding wheel with monitoring
402	Surface grinding wheel without monitoring without base dimension (TOOLMAN)
403	Surface grinding wheel with monitoring without base dimension for grinding wheel peripheral speed GWPS
410	Facing wheel
411	Facing wheel (TOOLMAN) with monitoring
412	Facing wheel (TOOLMAN) without monitoring
413	Facing wheel with monitoring without base dimension for grinding wheel peripheral speed GWPS
490	Dresser

Tool parameters

The following figure provides an overview of which tool parameters (DP...) for grinding tools are entered in the compensation memory:

Entries in the tool parameters	
DP1	403
DP2	Position *
DP3	Length 1
DP4	Length 2
DP6	Radius

* Tool nose position

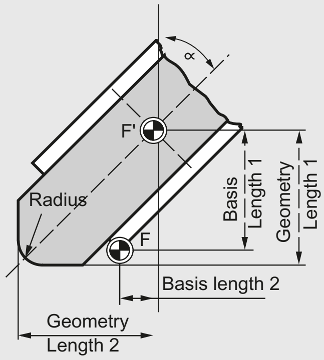
Wear values correspond to the requirement

Other values should be set to 0

Effect	
G17:	Length 1 in Y Length 2 in X Radius in X/Y
G18:	Length 1 in X Length 2 in Z Radius in Z/X
G19:	Length 1 in Z Length 2 in Y Radius in Y/Z

TPG1	Spindle number
TPG2	Chaining rule
TPG3	Minimum wheel radius
TPG4	Min. wheel width
TPG5	Actual wheel width
TPG6	Maximum speed
TPG7	Max. peripheral speed
TPG8	Angle of the inclined wheel
TPG9	Parameter No. for radius calculation

F: Tool carrier reference point



Note

Brief description of the tool parameters can be found on the user interface.

For further information, see:
References:
Function Manual, Basic Functions; Tool Offset (W1)

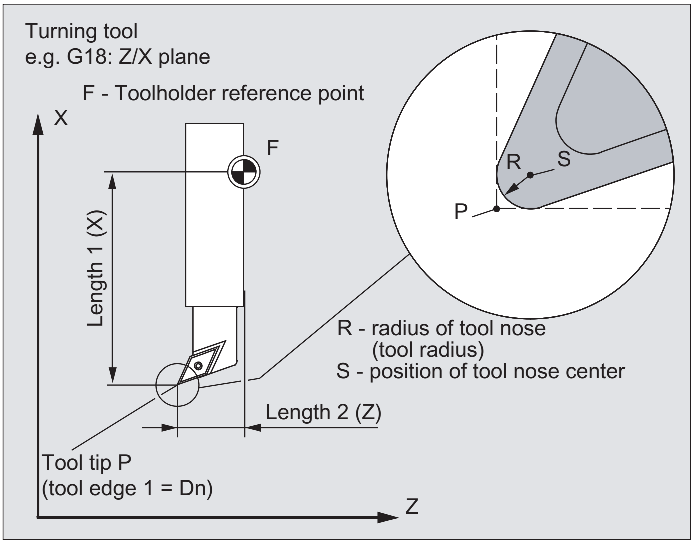
5.5.5 Turning tools

The following tool types are available in the "Turning tools" group:

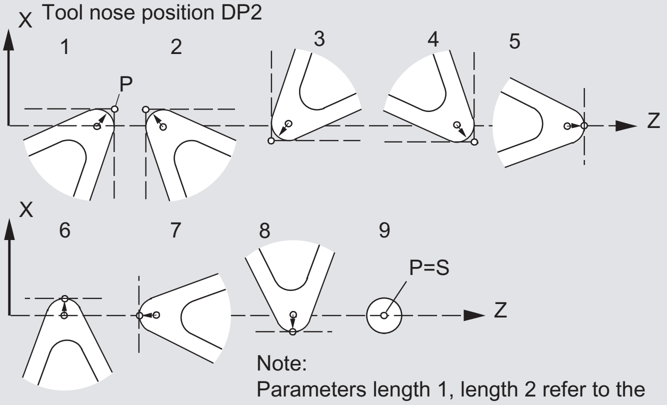
500	Roughing tool
510	Finishing tool
520	Plunge cutter
530	Parting tool
540	Threading tool
550	Button tool / forming tool (TOOLMAN)
560	Rotary drill (ECOCUT)
580	Probe with cutting edge position parameters

Tool parameters

The following figures provide an overview of which tool parameters (DP...) for turning tools are entered in the compensation memory:



The tool parameter DP2 specifies the length of the tool nose.
Position value 1 to 9 possible.



Note:
Parameters length 1, length 2 refer to the point with tool nose position 1-8; but to S (S=P) with 9

Entries in tool parameters	
DP1	5xy
DP2	1...9
DP3	Length 1
DP4	Length 2
DP6	Radius

Wear values as required

Set remaining values to 0

Effect	
G17:	Length 1 in Y Length 2 in X
G18:	Length 1 in X Length 2 in Z
G19:	Length 1 in Z Length 2 in Y

Note

Brief description of the tool parameters can be found on the user interface.

For further information, see:
References:
Function Manual, Basic Functions; Tool Offset (W1)

5.5.6 Special tools

The following tool types are available in the "Special tools" group:

700	Slotting saw
710	3D probe
711	Edge probe
730	Stop

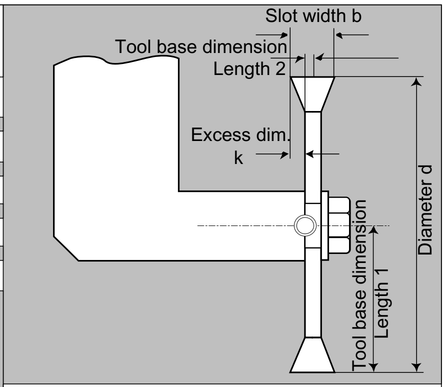
Tool parameters

The following figure provides an overview of which tool parameters (DP...) for "Slotting saw" tool type are entered in the compensation memory:

Entries in tool parameters	
DP3	Base length 1
DP4	Base length 2
DP6	Geometry diameter
DP7	Geometry zero width
DP8	Geometry overshoot

Wear values as required

Set remaining values to 0



Effect		
G17:	Half diameter (L1) in X Excess dim. in (L2) Y Saw blade in (R) X/Y	Plane selection 1st-2nd axis (X-Y)
G18:	Half diameter (L1) in Y Excess dim. in (L2) X Saw blade in (R) Z/X	Plane selection 1st-2nd axis (X-Z)
G19:	Half diameter (L1) in Z Excess dim. in (L2) Z Saw blade in (R) Y/Z	Plane selection 1st-2nd axis (Y-Z)

Note

Brief description of the tool parameters can be found on the user interface.

For further information, see:
References:
Function Manual, Basic Functions; Tool Offset (W1)

5.5.7 Chaining rule

The geometry tool length compensations, wear and base dimension can be chained for both the left and the right tool nose radius compensation, i.e. if the tool length compensations are changed for the left cutting edge, then the values are also automatically entered for the right cutting edge and vice versa.

References

Function Manual, Extended Functions; Grinding (W4)

5.6 Tool offset call (D)

Function

Cutting edges 1 to 8 (with active TOOLMAN 12) of a tool can be assigned different tool offset data records (e.g. different offset values for the left and right cutting edge of a grooving tool).

Activation of the offset data (including the data for the tool length compensation) of a special cutting edge is performed by calling the D number. When `D0` is programmed, offsets for the tool have no effect.

A tool radius compensation must also be activated via `G41`/`G42`.

Note

Tool length offsets take immediate effect when the D number is programmed. If no D number is programmed, the default setting defined via the machine data is active for a tool change (→ see machine manufacturer's specifications).

Syntax

Activation of a tool offset data record:

```
D<number>
```

Activate the tool radius compensation:

```
G41 ...
G42 ...
```

Deactivation of the tool offsets:

```
D0
G40
```

Significance

`D`: Command for the activation of an offset data record for the active tool

The tool length compensation is applied with the first programmed traverse of the associated length compensation axis.

Notice:
A tool length compensation can also take effect without D programming, when the automatic activation of a tool edge has been configured for the tool change (→ see machine manufacturer's specifications).

`<number>`: The tool offset data record to be activated is specified via the <number> parameter.

The type of D programming depends on the configuration of the machine (see paragraph "Type of D programming").

Range of values: 0 - 32,000

`D0`: Command for the deactivation of the offset data record for the active tool

`G41`:	Command for the activation of the tool radius compensation with machining direction **left** of the contour
`G42`:	Command for the activation of the tool radius compensation with machining direction **right** of the contour
`G40`:	Command for the deactivation of the tool radius compensation

Note

The tool radius compensation is described in detail in the section "Tool radius compensation" section.

Type of D programming

The type of D programming is defined via machine data.

This can be done as follows:

- D number = cutting edge number

  D numbers ranging from 1 to max. 12 are available for every tool T<number> or T="Name" (with TOOLMAN). These D numbers are assigned directly to the tool cutting edges.
  A compensation data record ($TC_DPx[t,d]) belongs to each D number (= cutting edge number).

- Free selection of D numbers

  The D numbers can be freely assigned to the cutting edge numbers of a tool. The upper limit for the D numbers that can be used is limited by a machine data.

- Absolute D number without reference to the T number

  Independence between D number and T number can be selected in systems without tool management. The reference of T number, cutting edge and offset by the D number is defined by the user. The range of D numbers is between 1 and 32000.

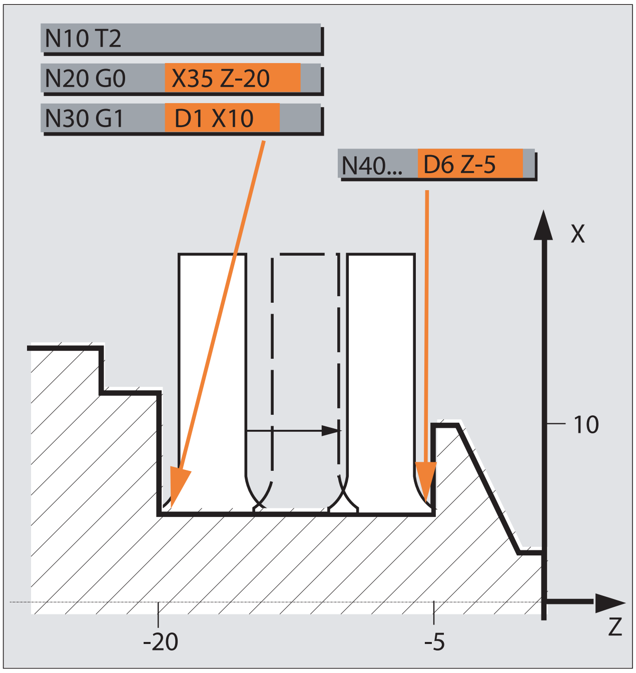
References:
Function Manual, Basic Functions; Tool Offset (W1),
Function Manual, Tool Management, Chapter: "Variants of D-number assignments"

Examples

Example 1: Tool change with T command (turning)

Program code	Comment
`N10 T1 D1`	`; Load tool T1 and activate tool offset data record D1 of T1.`
`N11 G0 X... Z...`	`; The tool length compensations are applied.`
`N50 T4 D2`	`; Load tool T4 and activate tool offset data record D2 of T4.`
`...`	
`N70 G0 Z... D1`	`; Activate other cutting edge D1 for tool T4.`

Example 2: Different offset values for the left and right cutting edge of a grooving tool



5.7 Change in the tool offset data

Effectiveness

A change in the tool offset data takes effect the next time the T or D number is programmed.

Set tool offset data to be active immediately

The following machine data can be used to specify that entered tool offset data takes effect immediately:

MD9440 $MM_ACTIVATE_SEL_USER

⚠ DANGER

If MD9440 is set, tool offsets resulting from changes in tool offset data **during the part program stop**, are applied when the part program is continued.

5.8 Programmable tool offset (TOFFL, TOFF, TOFFR)

Function

The user can use the commands `TOFFL`/`TOFF` and `TOFFR` to modify the effective tool length or the effective tool radius in the NC program, without changing the tool offset data stored in the compensation memory.

These programmed offsets are deleted again at the end of the program.

Tool length offset

Depending on the type of programming, programmed tool length offsets are assigned either to the tool length components L1, L2 and L3 (`TOFFL`) stored in the compensation memory or to the geometry axes (`TOFF`). The programmed offsets are treated accordingly for a plane change (`G17`/`G18`/`G19` ↔ `G17`/`G18`/`G19`):

- If the offset values are assigned to the tool length components, the directions in which the programmed offsets apply, are replaced accordingly.
- If the offset values are assigned to the geometry axes, a plane change does not effect the assignment in relation to the coordinate axes.

Tool radius offset

The command `TOFFR` is available for the programming of a tool radius offset.

Syntax

Tool length offset:

```
TOFFL=<value>
TOFFL[1]=<value>
TOFFL[2]=<value>
TOFFL[3]=<value>
TOFF[<geometry axis>]=<value>
```

Tool radius offset:

```
TOFFR=<value>
```

Significance

`TOFFL`:

Command for the compensation of the effective tool length

`TOFFL` can be programmed with or without index:

- Without index: `TOFFL=`

  The programmed offset value is applied in the same direction as the tool length component **L1** stored in the compensation memory.

- With index: `TOFFL[1]=`, `TOFFL[2]=` or `TOFFL[3]=`

  The programmed offset value is applied in the same direction as the tool length component **L1, L2** or **L3** stored in the offset memory.

The commands `TOFFL` and `TOFFL[1]` have an identical effect.

Note:
How these tool length offset values are calculated in the axes is determined by the tool type and the current working plane (`G17`/`G18`/`G19`).

`TOFF`:

Command for the compensation of the tool length in the component parallel to the specified geometry axis

`TOFF` is applied in the direction of the tool length component, which is effective with non-rotated tool (orientable toolholder or orientation transformation) parallel to the `<geometry axis>` specified in the index.

Note:
A frame does not influence the assignment of the programmed values to the tool length components, i.e. the workpiece coordinate system (WCS) is not used for the assignment of the tool length components to the geometry axes, but the tool in the basic tool position.

`<geometry axis>`

Identifier of the geometry axis

`TOFFR`:

Command for the compensation of the effective tool radius

`TOFFR` changes the effective tool radius **with active tool radius compensation** by the programmed offset value.

`<value>`:

Offset value for the tool length or radius

Type: REAL

Note

The `TOFFR` command has almost the same effect as the `OFFN` command (see "Tool radius compensation (G40, G41, G42, OFFN) [Page 277]"). There is only a difference with active peripheral curve transformation (TRACYL) and active slot side compensation. In this case, the tool radius is affected by `OFFN` with a negative sign, but by `TOFFR` with a positive sign.

`OFFN` and `TOFFR` can be effective simultaneously. They then generally have an additive effect (except for slot side compensation).

Further syntax rules

- The tool length can be changed simultaneously in all three components. However, commands of the `TOFFL`/`TOFFL[1..3]` group and commands of the `TOFF[<geometry axis>]` may not be used simultaneously in one block.

  `TOFFL` and `TOFFL[1]` may also not be written simultaneously in one block.
- If all three tool length components are not programmed in a block, the components not programmed remain unchanged. In this way, it is possible to build up offsets for several components block-by-block. However, this only applies as long as the tool components have been modified either only with `TOFFL` or only with `TOFF`. Changing the programming type from `TOFFL` to `TOFF` or vice versa deletes any previously programmed tool length offsets (see example 3).

Supplementary conditions

- Evaluation of setting data

  The following setting data is evaluated when assigning the programmed offset values to the tool length components:

  SD42940 $SC_TOOL_LENGTH_CONST (change of tool length components on change of planes).

  SD42950 $SC_TOOL_LENGTH_TYPE (assignment of the tool length compensation independent of tool type)

  If this setting data has valid values not equal to 0, then these take preference over the contents of G code group 6 (plane selection `G17` - `G19`) or the tool type ($TC_DP1[<T no.>, <D no.>]) contained in the tool data, i.e. this setting data influences the evaluation of the offsets in the same way as the tool length components L1 to L3.
- Tool change

  All offset values are retained during a tool change (cutting edge change), e.g. they are also effective for the new tool (new cutting edge).

Examples

Example 1: Positive tool length offset

The active tool is a drill with length L1 = 100 mm.

The active plane is `G17`, i.e. the drill points in the Z direction.

The effective drill length is to be increased by 1 mm. The following variants are available for the programming of this tool length offset:

```
TOFFL=1
```

or

```
TOFFL[1]=1
```

or

```
TOFF[Z]=1
```

Example 2: Negative tool length offset

The active tool is a drill with length L1 = 100 mm.

The active plane is `G18`, i.e. the drill points in the Y direction.

The effective drill length is to be decreased by 1 mm. The following variants are available for the programming of this tool length offset:
`TOFFL=-1`

or
`TOFFL[1]=-1`

or
`TOFF[Y]=1`

Example 3: Changing the programming type from TOFFL to TOFF

The active tool is a milling tool. The active plane is `G17`.

Program code	Comment
N10 TOFFL[1]=3 TOFFL[3]=5	; Effective offsets: L1=3, L2=0, L3=5
N20 TOFFL[2]=4	; Effective offsets: L1=3, L2=4, L3=5
N30 TOFF[Z]=1.3	; Effective offsets: L1=0, L2=0, L3=1.3

Example 4: Plane change

Program code	Comment
N10 $TC_DP1[1,1]=120	
N20 $TC_DP3[1,1]= 100	; Tool change L1=100mm
N30 T1 D1 G17	
N40 TOFF[Z]=1.0	; Offset in Z direction (corresponds to L1 for G17).
N50 G0 X0 Y0 Z0	; Machine axis position X0 Y0 Z101
N60 G18 G0 X0 Y0 Z0	; Machine axis position X0 Y100 Z1
N70 G17	
N80 TOFFL=1.0	; Offset in L1 direction (corresponds to Z for G17).
N90 G0 X0 Y0 Z0	; Machine axis position X0 Y0 Z101.
N100 G18 G0 X0 Y0 Z0	; Machine axis position X0 Y101 Z0.

In this example, the offset of 1 mm in the Z axis is retained when changing to `G18` in block `N60`; the effective tool length in the Y axis is the unchanged tool length of 100 mm.

However, in block `N100`, the offset is effective in the Y axis when changing to `G18` as it was assigned to tool length L1 in the programming and this length component is effective in the Y axis with `G18`.

Further information

Applications

The "Programmable tool offset" function is especially interesting for ball mills and milling tools with corner radii as these are often calculated in the CAM system to the ball center instead of the ball tip. However, generally the tool tip is measured when measuring the tool and stored as tool length in the compensation memory.

System variables for reading the current offset values

The currently effective offsets can be read with the following system variables:

System variables		Meaning
$P_TOFFL [<n>]	with 0 ≤ n ≤ 3	Reads the current offset value of `TOFFL` (for n = 0) or `TOFFL[1...3]` (for n = 1, 2, 3) in the preprocessing context.
$P_TOFF [<geometry axis>]		Reads the current offset value of `TOFF[<geometry axis>]` in the preprocessing context.
$P_TOFFR		Reads the current offset value of `TOFFR` in the preprocessing context.
$AC_TOFFL[<n>]	with 0 ≤ n ≤ 3	Reads the current offset value of `TOFFL` (for n = 0) or `TOFFL[1...3]` (for n = 1, 2, 3) in the main run context (synchronized actions).
$AC_TOFF[<geometry axis>]		Reads the current offset value of `TOFF[<geometry axis>]` in the main run context (synchronized actions).
$AC_TOFFR		Reads the current offset value of `TOFFR` in the main run context (synchronized actions).

Note

The system variables $AC_TOFFL, $AC_TOFF and AC_TOFFR trigger an automatic preprocessing stop when reading from the preprocessing context (NC program).

Spindle motion 6

6.1 Spindle speed (S), direction of spindle rotation (M3, M4, M5)

Function

The spindle speed and direction of rotation values set the spindle in rotary motion and provide the conditions for chip removal.

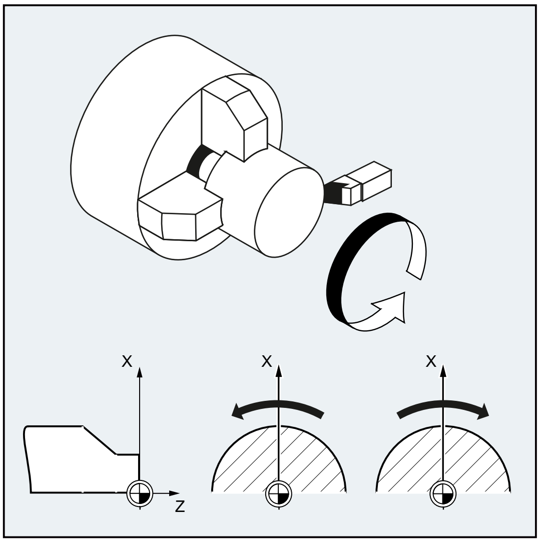


Figure 6-1 Spindle motion during turning

Other spindles may be available in addition to the main spindle (e.g. the counterspindle or an actuated tool on turning machines). As a rule, the main spindle is declared the master spindle in the machine data. This assignment can be changed using an NC command.

Syntax

```
S... / S<n>=...
M3 / M<n>=3
M4 / M<n>=4
M5 / M<n>=5
```

```
SETMS(<n>)
...
SETMS
```

Significance

S… : Spindle speed in rpm for the master spindle

S<n>=... : Spindle speed in rpm for spindle <n>

Note:
The speed specified with S0=… applies to the master spindle.

M3: Direction of spindle rotation clockwise for master spindle

M<n>=3: Spindle direction of rotation CW for spindle <n>

M4: Direction of spindle rotation counterclockwise for master spindle

M<n>=4: Spindle direction of rotation CCW for spindle <n>

M5: Spindle stop for master spindle

M<n>=5: Spindle stop for spindle <n>

SETMS(<n>): Set spindle <n> as master spindle

SETMS: If SETMS is programmed without a spindle name, the configured master spindle is used instead.

Note

Up to three S-values can be programmed per NC block, e.g.:

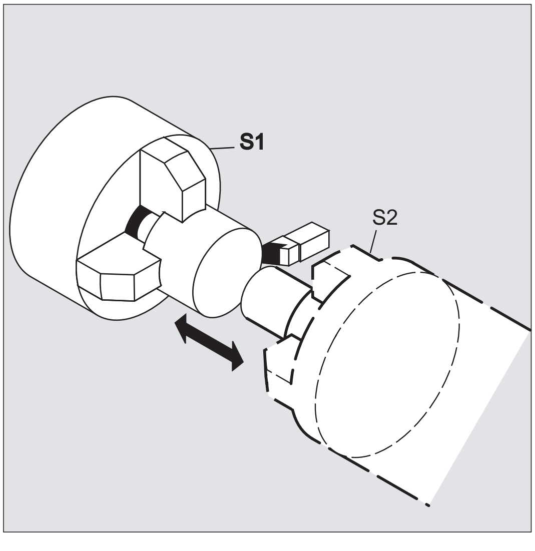
```
S... S2=... S3=...
```

Note

SETMS must be in a separate block.

Example

S1 is the master spindle, S2 is the second spindle. The part is to be machined from two sides. To do this, it is necessary to divide the operations into steps. After the cut-off point, the synchronizing device (S2) takes over machining of the workpiece after the cut off. To do this, this spindle S2 is defined as the master spindle to which G95 then applies.



Program code	Comment
`N10 S300 M3`	`; Speed and direction of rotation for drive spindle = preset master spindle`
`...`	`; Machining of the right-hand workpiece side`
`N100 SETMS(2)`	`; S2 is now the master spindle`
`N110 S400 G95 F…`	`; Speed for new master spindle`
`...`	`; Machining of the left-hand workpiece side`
`N160 SETMS`	`; Switching back to master spindle S1`

Further information

Interpretation of the S-value for the master spindle

If function G331 or G332 is active in G function group 1 (modally valid motion commands), the programmed S-value will always be interpreted as the speed in rpm. Otherwise, the interpretation of the S-value will depend upon G function group 15 (feedrate type): If G96, G961 or G962 is active, the S-value is interpreted as a constant cutting rate in m/min; otherwise, it is interpreted as a speed in rpm.

Changing from G96/G961/G962 to G331/G332 sets the value of the constant cutting rate to zero; changing from G331/G332 to a function within the G function group other than G331/G332 sets the speed value to zero. The corresponding S-values have to be reprogrammed if required.

Preset M commands M3, M4, M5

In a block with axis commands, functions M3, M4, M5 are activated **before** the axis movements commence (basic setting on the control).

Example:

Program code	Comment
`N10 G1 F500 X70 Y20 S270 M3`	`; The spindle ramps up to 270 rpm, then the movements are executed in X and Y.`
`N100 G0 Z150 M5`	`; Spindle stop before the retraction movement in Z.`

Note

Machine data can be used to set when axis movements should be executed; either once the spindle has powered up to the setpoint speed, or immediately after the programmed switching operations have been traversed.

Working with multiple spindles

5 spindles (master spindle plus 4 additional spindles) can be available in one channel at the same time.

One of the spindles is defined in machine data as the **master spindle**. Special functions such as thread cutting, tapping, revolutional feedrate, and dwell time apply to this spindle. For the remaining spindles (e.g. a second spindle and an actuated tool) the numbers corresponding to the speed and the direction of rotation/spindle stop must be specified.

Example:

Program code	**Comment**

`N10 S300 M3 S2=780 M2=4`	`; Master spindle: 300 rpm, CW rotation`
	`  2nd spindle: 780 rpm, CCW rotation`

Programmable switchover of master spindle

The `SETMS(<n>)` command can be used in the NC program to define any spindle as the master spindle. `SETMS` must be in a separate block.

Example:

Program code	**Comment**
`N10 SETMS (2)`	`; Spindle 2 is now the master spindle.`

Note

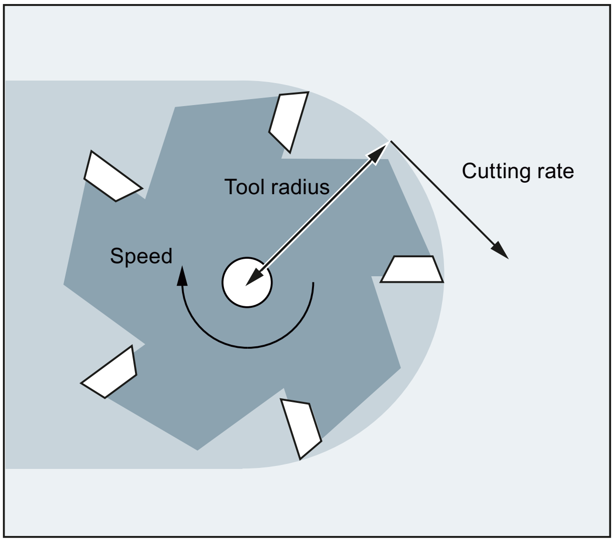
The speed specified with `S...`, along with the functions programmed with `M3`, `M4`, `M5`, now apply to the newly declared master spindle.

If `SETMS` is programmed without a spindle name, the master spindle programmed in the machine data is used instead.

6.2 Cutting rate (SVC)

Function

As an alternative to the spindle speed, the tool cutting rate, which is more commonly used in practice, can be programmed for milling operations.



The control uses the radius of the active tool to calculate the effective spindle speed from the programmed tool cutting rate:

$S = (SVC * 1000) / (R_T * 2\pi)$

where:	S:	Spindle speed in rpm
	SVC:	Cutting rate in m/min or feet/min
	R_T:	Radius of the active tool in mm

The tool type ($TC_DP1) of the active tool is not taken into account.

The programmed cutting rate is independent of the path feedrate `F` and G function group 15. The direction of rotation and the spindle start are programmed using `M3` and `M4` respectively and the spindle stop using `M5`.

A change to the tool radius data in the offset memory will be applied the next time a tool offset is selected or the next time the active offset data is updated.

Changing the tool or selecting/deselecting a tool offset data record generates a recalculation of the effective spindle speed.

Conditions

The programming of the cutting speed requires:

- The geometric ratios of a rotating tool (milling cutter or drilling tool)
- An active tool offset data record

Syntax

```
SVC[<n>]=<value>
```

Note

In the block with `SVC`, the tool radius must be known; in other words, a corresponding tool including a tool offset data record must be active or selected in the block. There is no fixed sequence for `SVC` and `T`/`D` selection during programming in the same block.

Significance

`SVC`: Cutting rate

`[<n>]`: Number of spindle

This address extension specifies which spindle the programmed cutting rate is to be applied for. In the absence of an address extension, the rate is always applied to the master spindle.

Note:
A separate cutting rate can be preset for each spindle.

Note:
Programming `SVC` without an address extension requires that the master spindle has the active tool. If the master spindle changes, the user will need to select a tool accordingly.

Unit: m/min or ft/min (dependent upon G700/G710)

Note

Changing between SVC and S

Changing between `SVC` and `S` programming is possible at will, even while the spindle is turning. In each case, the value that is not active is deleted.

Note

Maximum tool speed

System variable $TC_TP_MAX_VELO[<tool number>] can be used to preset a maximum tool speed (spindle speed).
If no speed limit has been defined, there will be no monitoring.

Note

`SVC` programming is not possible if the following are active:

- `G96/G961/G962`
- `GWPS`
- `SPOS/SPOSA/M19`
- `M70`

Conversely, programming one of these commands will lead to the deselection of `SVC`.

Note

The tool paths of "standard tools" generated e.g. using CAD systems which already take the tool radius into account and only contain the deviation from the standard tool in the tool nose radius are not supported in conjunction with `SVC` programming.

Examples

The following shall apply to all examples: Toolholder = spindle (for standard milling)

Example 1: Milling cutter 6 mm radius

Program code	Comment
N10 G0 X10 T1 D1	; Selection of milling cutter with e.g. $TC_DP6[1,1] = 6 (tool radius = 6 mm)
N20 SVC=100 M3	; Cutting rate = 100 m/min ? Resulting spindle speed: S = (100 m/min * 1,000) / (6.0 mm * 2 * 3.14) = 2653.93 rpm
N30 G1 X50 G95 FZ=0.03	; SVC and tooth feedrate
...	

Example 2: Tool selection and SVC in the same block

Program code	Comment
N10 G0 X20	
N20 T1 D1 SVC=100	; Tool and offset data record selection together with SVC in block (no specific sequence)
N30 X30 M3	; Spindle start with CW direction of rotation, cutting rate 100 m/min
N40 G1 X20 F0.3 G95	; SVC and revolutional feedrate

Example 3: Defining cutting rates for two spindles

Program code	Comment
N10 SVC[3]=100 M6 T1 D1	
N20 SVC[5]=200	; The tool radius of the active tool offset is the same for both spindles. The effective speed is different for spindle 3 and spindle 5.

Example 4:

Assumptions:

Master or tool change is determined by the toolholder.

MD20124 $MC_TOOL_MANAGEMENT_TOOLHOLDER > 1

In the event of a tool change the old tool offset is retained. A tool offset for the new tool is only activated when `D` is programmed:

MD20270 $MC_CUTTING_EDGE_DEFAULT = - 2

```
Program code                              Comment
N10 $TC_MPP1[9998,1]=2                    ; Magazine location is toolholder
N11 $TC_MPP5[9998,1]=1                    ; Magazine location is toolholder 1
N12 $TC_MPP_SP[9998,1]=3                  ; Toolholder 1 is assigned to spindle 3

N20 $TC_MPP1[9998,2]=2                    ; Magazine location is toolholder
N21 $TC_MPP5[9998,2]=4                    ; Magazine location is toolholder 4
N22 $TC_MPP_SP[9998,2]=6                  ; Toolholder 4 is assigned to spindle 6

N30 $TC_TP2[2]="WZ2"
N31 $TC_DP6[2,1]=5.0                      ; Radius = 5.0 mm of T2, offset D1

N40 $TC_TP2[8]="WZ8"
N41 $TC_DP6[8,1]=9.0                      ; Radius = 9.0 mm of T8, offset D1
N42 $TC_DP6[8,4]=7.0                      ; Radius = 7.0 mm of T8, offset D4
...
N100 SETMTH(1)                            ; Set master toolholder number
N110 T="WZ2" M6 D1                        ; Tool T2 is loaded and offset D1 is activated.
N120 G1 G94 F1000 M3=3 SVC=100            ; S3 = (100 m/min * 1,000) / (5.0 mm * 2 * 3.14) = 3184.71 rpm
N130 SETMTH(4)                            ; Set master toolholder number
N140 T="WZ8"                              ; Corresponds to T8="WZ8"
N150 M6                                   ; Corresponds to M4=6
                                            Tool "WZ8" is in the master toolholder, but because
                                            MD20270=-2, the old tool offset remains active.
N160 SVC=50                               ; S3 = (50 m/min * 1,000) / (5.0 mm * 2 * 3.14) = 1592.36 rpm
                                            The offset applied to toolholder 1 is still active and
                                            toolholder 1 is assigned to spindle 3.
N170 D4                                     Offset D4 of the new tool "WZ8" becomes active (in
                                            toolholder 4).
N180 SVC=300                              ; S6 = (300 m/min * 1,000) / (7.0 mm * 2 * 3.14) = 6824.39 rpm
                                            Spindle 6 is assigned to toolholder 4.
```

Example 5:

Assumptions:

Spindles are toolholders at the same time:

MD20124 $MC_TOOL_MANAGEMENT_TOOLHOLDER = 0

In the event of a tool change tool offset data record D4 is selected automatically.

MD20270 $MC_CUTTING_EDGE_DEFAULT = 4

Program code	Comment
`N10 $TC_MPP1[9998,1]=2`	`; Magazine location is toolholder`
`N11 $TC_MPP5[9998,1]=1`	`; Magazine location is toolholder 1 = spindle 1`
`N20 $TC_MPP1[9998,2]=2`	`; Magazine location is toolholder`
`N21 $TC_MPP5[9998,2]=3`	`; Magazine location is toolholder 3 = spindle 3`
`N30 $TC_TP2[2]="WZ2"`	
`N31 $TC_DP6[2,1]=5.0`	`; Radius = 5.0 mm of T2, offset D1`
`N40 $TC_TP2[8]="WZ8"`	
`N41 $TC_DP6[8,1]=9.0`	`; Radius = 9.0 mm of T8, offset D1`
`N42 $TC_DP6[8,4]=7.0`	`; Radius = 7.0 mm of T8, offset D4`
`...`	
`N100 SETMS(1)`	`; Spindle 1 = master spindle`
`N110 T="WZ2" M6 D1`	`; Tool T2 is loaded and offset D1 is activated.`
`N120 G1 G94 F1000 M3 SVC=100`	`; S1 = (100 m/min * 1,000) / (5.0 mm * 2 * 3.14) = 3184.71 rpm`
`N200 SETMS(3)`	`; Spindle 3 = master spindle`

`N210 M4 SVC=150`	`; S3 = (150 m/min * 1,000) / (5.0 mm * 2 * 3.14) = 4777.07 rpm`
	`Refers to tool offset D1 of T="WZ2", S1 continues to turn at previous speed.`

`N220 T="WZ8"`	`; Corresponds to T8="WZ8"`

`N230 M4 SVC=200`	`; S3 = (200 m/min * 1,000) / (5.0 mm * 2 * 3.14) = 6369.43 rpm`
	`Refers to tool offset D1 of T="WZ2".`

`N240 M6`	`; Corresponds to M3=6`
	`Tool "WZ8" is in the master spindle, tool offset D4 of the new tool becomes active.`

`N250 SVC=50`	`; S3 = (50 m/min * 1,000) / (7.0 mm * 2 * 3.14) = 1137.40 rpm`
	`Offset D4 on master spindle is active.`

`N260 D1`	`; Offset D1 of new tool "WZ8" active.`

`N270 SVC[1]=300`	`; S1 = (300 m/min * 1,000) / (9.0 mm * 2 * 3.14) = 5307.86 rpm`
	`S3 = (50 m/min * 1,000) / (9.0 mm * 2 * 3.14) = 884.64 rpm`

`...`	

Further information

Tool radius

The following tool offset data (associated with the active tool) affect the tool radius when:

- $TC_DP6 (radius - geometry)
- $TC_DP15 (radius - wear)
- $TC_SCPx6 (offset for $TC_DP6)
- $TC_ECPx6 (offset for $TC_DP6)

The following are not taken into account:

- Online radius compensation
- Allowance on the programmed contour (`OFFN`)

Tool radius compensation (G41/G42)

Although tool radius compensation (`G41`/`G42`) and `SVC` both refer to the tool radius, with regard to function, they are not linked and are independent of one another.

Tapping without compensating chuck (G331, G332)

`SVC` programming is also possible in conjunction with `G331` or `G332`.

Synchronized actions

`SVC` cannot be programmed from synchronized actions.

Reading the cutting rate and the spindle speed programming variant

The cutting rate of a spindle and the speed programming variant (spindle speed `S` or cutting rate `SVC`) can be read using system variables:

- With preprocessing stop in the part program via system variables:

$AC_SVC[<n>] Cutting rate applied when the current main run record for spindle number <n> was preprocessed.

$AC_S_TYPE[<n>] Spindle speed programming variant applied when the current main run record for spindle number <n> was preprocessed.

Value:	Significance:
1	Spindle speed S in rpm
2	Cutting rate SVC in m/min or ft/min

- Without preprocessing stop in the part program via system variables:

$P_SVC[<n>] Programmed cutting rate for spindle <n>

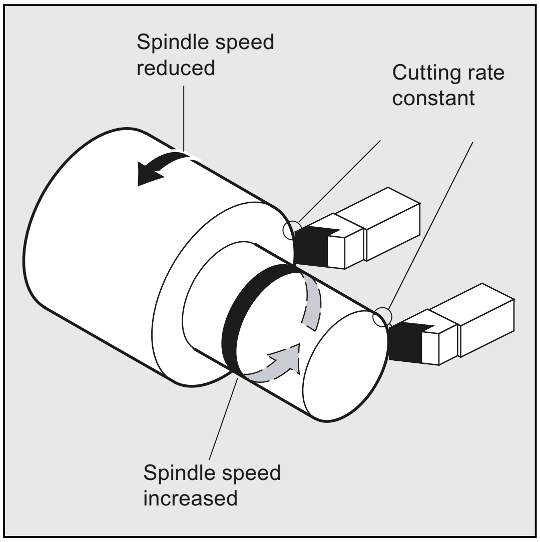
$P_S_TYPE[<n>] Programmed spindle speed programming variant for spindle <n>

Value:	Significance:
1	Spindle speed S in rpm
2	Cutting rate SVC in m/min or ft/min

6.3 Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC)

Function

When the "Constant cutting rate" function is active, the spindle speed is modified as a function of the respective workpiece diameter so that the cutting rate S in m/min or ft/min remains constant at the tool edge.



This results in the following advantages:

- Uniformity and consequently improved surface quality of turned parts
- Machining process is kinder to tools

Syntax

Activating/Deactivating constant cutting rate for the master spindle:

```
G96/G961/G962 S...
...
G97/G971/G972/G973
```

Speed limitation for the master spindle:

```
LIMS=<value>
LIMS[<spindle>]=<value>
```

Other reference axis for G96/G961/G962:

```
SCC[<axis>]
```

Note

`SCC[<axis>]` can be programmed together with `G96`/`G961`/`G962` or in isolation.

Significance

`G96`: Constant cutting rate with feedrate type G95: ON

G95 is activated automatically with G96. If G95 has not been activated previously, a new feedrate value `F...` will have to be specified when G96 is called.

`G961`: Constant cutting rate with feedrate type G94: ON

`G962`: Constant cutting rate with feedrate type G94 or G95: ON

Note:
See " Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]" for information about G94 and G95.

`S...`: In conjunction with `G96`, `G961` or `G962`, `S...` is not interpreted as a spindle speed but as a cutting rate. The cutting rate is always applied to the master spindle.

Unit: m/min (for G71/G710) or feet/min (for G70/G700)

Range of values: 0.1 m/min to 9999 9999.9 m/min

`G97`: Deactivate constant cutting rate with feedrate type G95

After `G97` (or `G971`), `S...` is again interpreted as a spindle speed in rpm. In the absence of a new spindle speed being specified, the last speed set with `G96` (or `G961`) is retained.

`G971`: Deactivate constant cutting rate with feedrate type G94

`G972`: Deactivate constant cutting rate with feedrate type G94 or G95

`G973`: Deactivate constant cutting rate without activating spindle speed limitation

`LIMS`: Speed limitation for the master spindle (only applied if G96/G961/G97 active)

On machines with selectable master spindles, limitations of differing values can be programmed for up to four spindles within one block.

`<spindle>`: Number of spindle

`<value>`: Spindle speed upper limit in rpm

`SCC`: If any of the G96/G961/G962 functions are active, `SCC[<axis>]` can be used to assign any geometry axis as a reference axis.

Note

When `G96`/`G961`/`G962` is selected for the first time, a constant cutting rate `S...` must be entered; when `G96`/`G961`/`G962` is selected again, the entry is optional.

Note

The speed limitation programmed with `LIMS` must not exceed the speed limit programmed with `G26` or defined in the setting data.

Note

The reference axis for `G96/G961/G962` must be a geometry axis assigned to the channel at the time when `SCC[<axis>]` is programmed. `SCC[<axis>]` can also be programmed when any of the `G96/G961/G962` functions are active.

Examples

Example 1: Activating the constant cutting rate with speed limitation

Program code	**Comment**
`N10 SETMS (3)`	
`N20 G96 S100 LIMS=2500`	`; Constant cutting rate = 100 m/min, max. speed 2,500 rpm`
`...`	
`N60 G96 G90 X0 Z10 F8 S100 LIMS=444`	`; Max. speed = 444 rpm`

Example 2: Defining speed limitation for 4 spindles

Speed limitations are defined for spindle 1 (master spindle) and spindles 2, 3, and 4:

Program code
`N10 LIMS=300 LIMS[2]=450 LIMS[3]=800 LIMS[4]=1500`
`...`

Example 3: Y-axis assignment for face cutting with X axis

Program code	**Comment**
`N10 G18 LIMS=3000 T1 D1`	`; Speed limitation to 3,000 rpm`
`N20 G0 X100 Z200`	
`N30 Z100`	
`N40 G96 S20 M3`	`; Constant cutting rate = 20 m/min, is dependent upon X axis.`
`N50 G0 X80`	
`N60 G1 F1.2 X34`	`; Face cutting in X at 1.2 mm/revolution.`
`N70 G0 G94 X100`	
`N80 Z80`	
`N100 T2 D1`	
`N110 G96 S40 SCC[Y]`	`; Y axis is assigned to G96 and G96 is activated (can be achieved in a single block). Constant cutting rate = 40 m/min, is dependent upon X axis.`
`...`	
`N140 Y30`	
`N150 G01 F1.2 Y=27`	`; Grooving in Y, feedrate F = 1.2 mm/revolution.`
`N160 G97`	`; Constant cutting rate off.`
`N170 G0 Y100`	

Further information

Calculation of the spindle speed

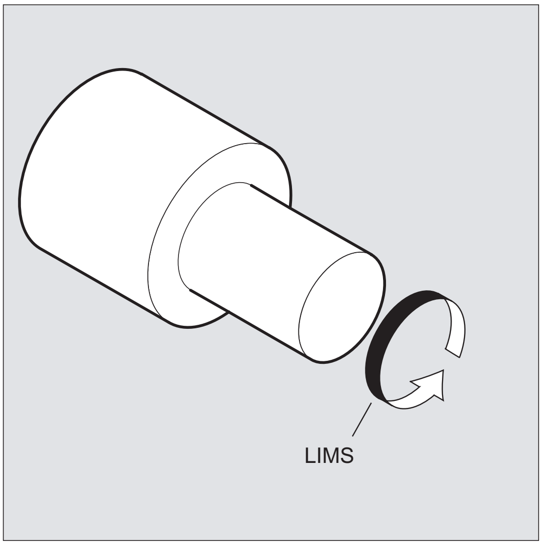
The ENS position of the face axis (radius) is the basis for calculating the spindle speed from the programmed cutting rate.

Note

Frames between WCS and SZS (e.g. programmable frames such as SCALE, TRANS or ROT) are taken into account in the calculation of the spindle speed and can bring about a change in speed (for example, if there is a change in the effective diameter in the case of SCALE).

Speed limitation LIMS

If a workpiece that varies greatly in diameter needs to be machined, it is advisable to specify a speed limit for the spindle with `LIMS` (maximum spindle speed). This prevents excessively high speeds with small diameters. `LIMS` is only applied when `G96`, `G961`, and `G97` are active. `LIMS` is not applied when `G971`is selected.



Note

On loading the block into the main run, all programmed values are transferred into the setting data.

Deactivating the constant cutting rate (G97/G971/G973)

After `G97/G971`, the control interprets an S value as a spindle speed in rpm again. If you do not specify a new spindle speed, the last speed set with `G96/G961` is retained.

The `G96/G961` function can also be deactivated with `G94` or `G95`. In this case, the last speed programmed `S...` is used for subsequent machining operations.

`G97` can be programmed without `G96` beforehand. The function then has the same effect as `G95`; `LIMS` can also be programmed.

Using `G973`, the constant cutting rate can be deactivated without activating a spindle speed limitation.

Note

The transverse axis must be defined in machine data.

Rapid traverse G0

With rapid traverse `G0`, there is no change in speed.

Exception:

If the contour is approached in rapid traverse and the next NC block contains a `G1`/`G2`/`G3`/etc. path command, the speed is adjusted in the `G0`approach block for the next path command.

Other reference axis for G96/G961/G962

If any of the G96/G961/G962 functions are active, `SCC[<axis>]` can be used to assign any geometry axis as a reference axis. If the reference axis changes, which will in turn affect the TCP (tool center point) reference position for the constant cutting rate, the resulting spindle speed will be reached via the set braking or acceleration ramp.

Axis replacement of the assigned channel axis

The reference axis property for G96/G961/G962 is always assigned to a geometry axis. In the event of an axis exchange involving the assigned channel axis, the reference axis property for G96/G961/G962 is retained in the old channel.

A geometry axis exchange will not affect how the geometry axis is assigned to the constant cutting rate. If the TCP reference position for G96/G961/G962 is affected by a geometry axis exchange, the spindle will reach the new speed via a ramp.

If no new channel axis is assigned as a result of a geometry axis exchange (e.g. `GEOAX(0,X)`), the spindle speed will be frozen in accordance with `G97`.

Examples for geometry axis exchange with assignments of the reference axis:

Program code	Comment
N05 G95 F0.1	
N10 GEOAX(1, X1)	; Channel axis X1 becomes first geometry axis.
N20 SCC[X]	; First geometry axis (X) becomes reference axis for G96/G961/ G962.
N30 GEOAX(1, X2)	; Channel axis X2 becomes first geometry axis.
N40 G96 M3 S20	; Reference axis for G96 is channel axis X2.

Program code	Comment
N05 G95 F0.1	
N10 GEOAX(1, X1)	; Channel axis X1 becomes first geometry axis.
N20 SCC[X1]	; X1 and implicitly the first geometry axis (X) becomes the reference axis for G96/G961/G962.
N30 GEOAX(1, X2)	; Channel axis X2 becomes first geometry axis.
N40 G96 M3 S20	; Reference axis for G96 is X2 or X, no alarm.

Program code	Comment
N05 G95 F0.1	
N10 GEOAX(1, X2)	; Channel axis X2 becomes first geometry axis.
N20 SCC[X1]	; X1 is not a geometry axis, alarm.

Program code	Comment
N05 G0 Z50	
N10 X35 Y30	
N15 SCC[X]	; Reference axis for G96/G961/G962 is X.
N20 G96 M3 S20	; Constant cutting rate ON at 10 mm/min.
N25 G1 F1.5 X20	; Face cutting in X at 1.5 mm/revolution.
N30 G0 Z51	
N35 SCC[Y]	; Reference axis for G96 is Y, reduction in spindle speed (Y30).
N40 G1 F1.2 Y25	; Face cutting in Y at 1.2 mm/revolution.

References:

Function Manual, Basic Functions; Transverse Axes (P1) and Feedrates (V1)

6.4 Constant grinding wheel peripheral speed (GWPSON, GWPSOF)

Function

The "Constant grinding wheel peripheral speed (GWPS)" function is used to set the grinding wheel speed so that, taking account of the current radius, the grinding wheel peripheral speed remains constant.

Syntax

```
GWPSON(<t no.>)
GWPSOF(<t no.>)
S.../S<n>=...
```

Significance

`GWPSON`: Select constant grinding wheel peripheral speed

`GWPSOF`: Deselect constant grinding wheel peripheral speed

`<t no.>`: It is only necessary to specify the T number if the tool with this T number is not active.

`S…`: Peripheral speed in m/s or ft/s for the master spindle

`S<n>=…` : Peripheral speed in m/s or ft/s for spindle <n>
Note:
The peripheral speed specified with `S0=…` applies to the master spindle.

Note

A grinding wheel peripheral speed can only be programmed for grinding tools (types 400 to 499).

Example

A constant grinding wheel peripheral speed is to be used for grinding tools T1 and T5.

T1 is the active tool.

Program code	**Comment**
`N20 T1 D1`	`; Select T1 and D1.`
`N25 S1=1000 M1=3`	`; 1000 rpm for spindle 1`
`N30 S2=1500 M2=3`	`; 1500 rpm for spindle 2`
…	
`N40 GWPSON`	`; Selection of GWPS for active tool.`
`N45 S1=60`	`; Set GWPS to 60 m/s for active tool.`
…	
`N50 GWPSON(5)`	`; GWPS selection for tool 5 (spindle 2).`
`N55 S2=40`	`; Set GWPS to 40 m/s for spindle 2.`
…	

Program code	Comment
`N60 GWPSOF`	`; Deactivate GWPS for active tool.`
`N65 GWPSOF(5)`	`; Deactivate GWPS for tool 5 (spindle 2).`

Further information

Tool-specific parameters

In order to activate the function "Constant peripheral speed", the tool-specific grinding data $TC_TPG1, $TC_TPG8 and $TC_TPG9 must be set accordingly. When the GWPS function is active, even online offset values (= wear parameters; cf. "Grinding-specific tool monitoring in the parts program TMON, TMOF" or PUTFTOC, PUTFTOCF) must be taken into account when changing speed.

Select GWPS: GWPSON, programming GWPS

After selecting the GWPS with GWPSON, each subsequent S value for this spindle is interpreted as a grinding wheel peripheral speed.

Selection of grinding wheel peripheral speed with GWPSON does not cause the automatic activation of tool length compensation or tool monitoring.

The GWPS can be active for several spindles on a channel with different tool numbers.

If GWPS is to be selected for a new tool on a spindle where GWPS is already active, the active GWPS must first be deselected with GWPSOF.

Deactivate GWPS: GWPSOF

When GWPS is deselected with GWPSOF, the last speed to be calculated remains valid as the setpoint.

GWPS programming is reset at the end of the parts program or on RESET.

Query active GWPS: $P_GWPS[<spindle no.>]

This system variable can be used to query from the parts program whether the GWPS is active for a specific spindle.

TRUE: GWPS is active.

FALSE: GWPS is inactive.

6.5 Programmable spindle speed limitation (G25, G26)

Function

The minimum and maximum spindle speeds defined in the machine and setting data can be modified by means of a part program command.

Programmed spindle speed limitations are possible for all spindles of the channel.

> ⚠ CAUTION
>
> A spindle speed limitation programmed with `G25` or `G26` overwrites the speed limits in the setting data and, therefore, remains stored even after the end of the program.

Syntax

```
G25 S… S1=… S2=…
G26 S… S1=… S2=…
```

Significance

`G25`: **Lower** spindle speed limit

`G26`: **Upper** spindle speed limit

`S... S1=… S2=…` : Minimum or maximum spindle speed(s)
Note:
A maximum of three spindle speed limits can be programmed for each block.

Range of values: 0.1 to 9999 9999.9 rpm

Example

Program code	**Comment**
`N10 G26 S1400 S2=350 S3=600`	`; Upper speed limit for master spindle, spindle 2 and spindle 3.`

Feed control 7

7.1 Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF)

Function

These commands are used in the NC program to set the feedrates for all axes involved in the machining sequence.

Syntax

```
G93/G94/G95
F...
FGROUP(<axis1>,<axis2>, etc.)
FGREF[<rotary axis>]=<reference radius>
FL[<axis>]=<value>
```

Significance

`G93`: Inverse-time feedrate (in rpm)

`G94`: Linear feedrate (in mm/min, inch/min or °/min)

`G95`: Revolutional feedrate (in mm/revolution or inch/revolution)
`G95` refers to the revolutions of the master spindle (usually the cutting spindle or the main spindle on the turning machine)

`F...`: Feedrate of the geometry axes involved in the movement
The unit set with `G93`/`G94`/`G95` applies.

`FGROUP`: The feedrate programmed under `F` is valid for all axes specified under `FGROUP` (geometry axes/rotary axes).

`FGREF`: `FGREF` is used to program the effective radius (`<reference radius>`) for each of the rotary axes specified under `FGROUP`.

`FL`: Limit velocity for synchronized/path axes
The unit set with `G94` applies.
One `FL` value can be programmed per axis (channel axes, geometry axis or orientation axis).

`<axis>`: The axis identifiers of the basic coordinate system should be used (channel axes, geometry axes).

Examples

Example 1: Mode of operation of FGROUP

The following example is intended to demonstrate the effect of `FGROUP` on the path and path feedrate. The variable `$AC_TIME` contains the time of the block start in seconds. It can only be used in synchronized actions.

```
Program code                Comment
N100 G0 X0 A0
N110 FGROUP(X,A)
N120 G91 G1 G710 F100       ; Feedrate = 100 mm/min or 100 degrees/min
N130 DO $R1=$AC_TIME
N140 X10                    ; Feedrate = 100 mm/min, path = 10 mm, R1 = approx. 6 s
N150 DO $R2=$AC_TIME
N160 X10 A10                ; Feedrate = 100 mm/min, path = 14.14 mm, R2 = approx. 8 s
N170 DO $R3=$AC_TIME
N180 A10                    ; Feedrate = 100 degrees/min, path = 10 degrees, R3
                              = approx. 6 s
N190 DO $R4=$AC_TIME
N200 X0.001 A10             ; Feedrate = 100 mm/min, path = 10 mm, R4 = approx. 6 s
N210 G700 F100              ; Feedrate = 2540 mm/min or 100 degrees/min
N220 DO $R5=$AC_TIME
N230 X10                    ; Feedrate = 2540 mm/min, path = 254 mm, R5 = approx. 6 s
N240 DO $R6=$AC_TIME
N250 X10 A10                ; Feedrate = 2540 mm/min, path = 254.2 mm, R6 = approx. 6
                              s
N260 DO $R7=$AC_TIME
N270 A10                    ; Feedrate = 100 degrees/min, path = 10 degrees, R7
                              = approx. 6 s
N280 DO $R8=$AC_TIME
N290 X0.001 A10             ; Feedrate = 2540 mm/min, path = 10 mm, R8 = approx.
                              0.288 s
N300 FGREF[A]=360/(2*$PI)   ; Set 1 degree = 1 inch via the effective radius.
N310 DO $R9=$AC_TIME
N320 X0.001 A10             ; Feedrate = 2540 mm/min, path = 254 mm, R9 = approx. 6 s
N330 M30
```

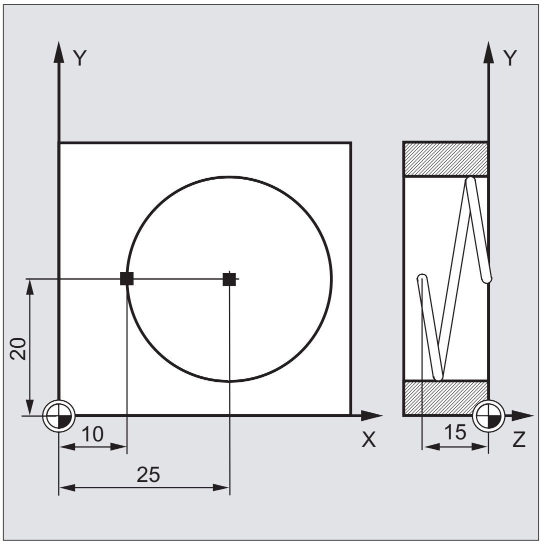
Example 2: Traverse synchronized axes with limit velocity FL

The path velocity of the path axes is reduced if the synchronized axis Z reaches the limit velocity.

```
Program code
N10 G0 X0 Y0
N20 FGROUP(X)
N30 G1 X1000 Y1000 G94 F1000 FL[Y]=500
N40 Z-50
```

Example 3: Helical interpolation

Path axes X and Y traverse with the programmed feedrate, the infeed axis Z is a synchronized axis.

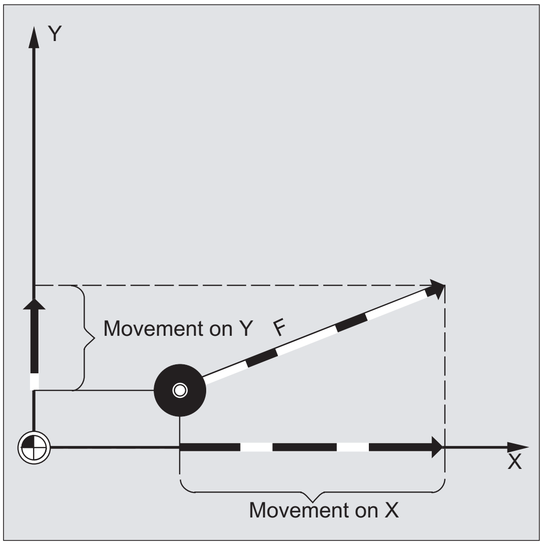


Program code	Comment
N10 G17 G94 G1 Z0 F500	; Feed of the tool.
N20 X10 Y20	; Approach of the starting position
N25 FGROUP(X,Y)	; Axes X/Y are path axes, Z is a synchronized axis.
N30 G2 X10 Y20 Z-15 I15 J0 F1000 FL[Z]=200	; On the circular path, the feedrate is 1,000 mm/min, traversing in the Z direction is synchronized.
...	
N100 FL[Z]=$MA_AX_VELO_LIMIT[0,Z]	; The limit speed is deselected by reading the speed from the MD. Read the value from the MD:
N110 M30	; End of program.

Further information

Feedrate for path axes (F)

The path feedrate is generally composed of the individual speed components of all geometry axes participating in the movement and refers to the center point of the cutter or the tip of the turning tool.



The feedrate is specified under address `F`. Depending on the default setting in the machine data, the units of measurement specified with the G commands are either in mm or inch.

One `F` value can be programmed per NC block. The feedrate unit is defined using one of the G commands `G93`/`G94`/`G95`. The feedrate `F` acts only on path axes and remains active until a new feedrate is programmed. Separators are permitted after the address `F`.

Examples:

`F100` or `F 100`

`F.5`

`F=2*FEED`

Feedrate type (G93/G94/G95)

The G commands `G93`, `G94` and `G95` are modal. In the event of switching between `G93`, `G94` and `G95`, the path feedrate value has to be reprogrammed. When machining with rotary axes, the feedrate can also be specified in degrees/min.

Inverse-time feedrate (G93)

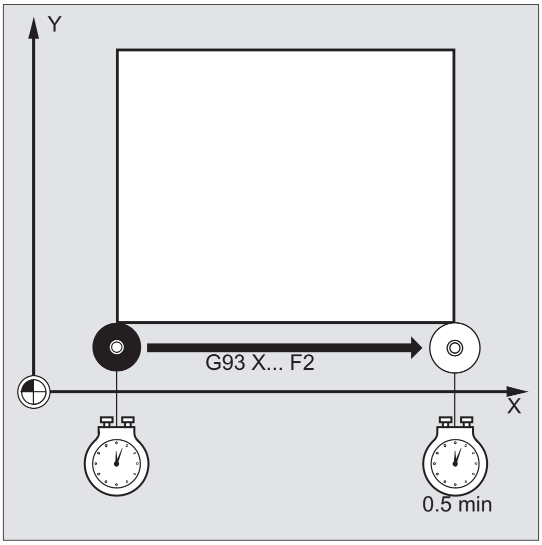
The inverse-time feedrate specifies the time required to execute the motion commands in a block.

Unit: rpm

Example:

```
N10 G93 G01 X100 F2
```

Significance: the programmed path is traversed in 0.5 min.



Note

If the path lengths vary greatly from block to block, a new `F` value should be specified in each block with `G93`. When machining with rotary axes, the feedrate can also be specified in degrees/min.

Feedrate for synchronized axes

The feedrate programmed under address `F` applies to all the path axes programmed in a block but not to the synchronized axes. The synchronized axes are controlled such that they require the same time for their path as the path axes, and all axes reach their end point at the same time.

Limit velocity for synchronized axes (FL)

The `FL` command can be used to program a limit velocity for synchronized axes. In the absence of a programmed `FL`, the rapid traverse velocity applies. `FL` is deselected by assignment to MD (MD36200 $MA_AX_VELO_LIMIT).

Traverse path axis as synchronized axis (FGROUP)

`FGROUP` is used to define whether a path axis should be traversed with path feedrate or as a synchronized axis. In helical interpolation, for example, it is possible to define that only two geometry axes, X and Y, are to be traversed at the programmed feedrate. The infeed axis Z is the synchronized axis in this case.

Example: `FGROUP(X,Y)`

Change FGROUP

The setting made with `FGROUP` can be changed:

1. By reprogramming `FGROUP`: e.g. `FGROUP(X,Y,Z)`
2. By programming `FGROUP` without a specific axis: `FGROUP()`

   In accordance with `FGROUP()`, the initial setting in the machine data applies: Geometry axes are now once again traversed in the path axis grouping.

Note

With `FGROUP`, axis identifiers must be the names of channel axes.

Units of measurement for feedrate F

In addition to the geometrical settings `G700` and `G710`, the G commands are also used to define the measuring system for the feedrates `F`. In other words:

- For `G700`: [inch/min]
- For `G710`: [mm/min]

Note

`G70`/`G71` have **no** effect on feedrate settings.

Unit of measurement for synchronized axes with limit speed FL

The unit set for `F` using G command `G700`/`G710` is also valid for `FL`.

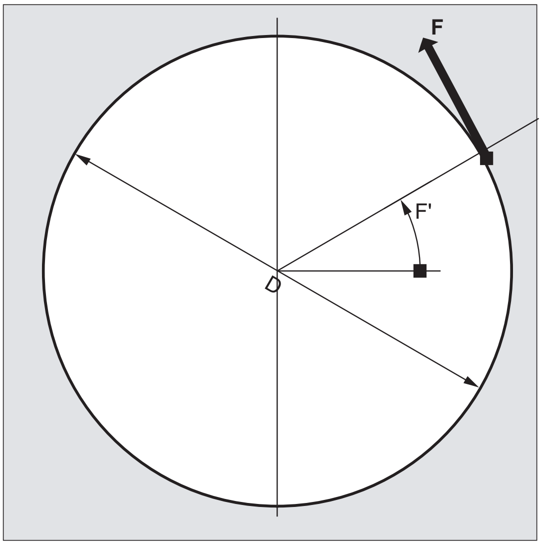
Unit for rotary and linear axes

For linear and rotary axes which are combined with `FGROUP` and traverse a path together, the feedrate is interpreted in the unit of the linear axes (depending on the default with `G94`/`G95`, in mm/min or inch/min and mm/rev or inch/rev).

The tangential velocity of the rotary axis in mm/min or inch/min is calculated according to the following formula:

F[mm/min] = F'[degrees/min] * π * D[mm]/360[degrees]

where:	F:	Tangential velocity
	F':	Angular velocity
	π:	Circle constant
	D:	Diameter



Traverse rotary axes with path velocity F (FGREF)

For machining operations, in which the tool or the workpiece or both are moved by a rotary axis, the effective machining feedrate is to be interpreted as a path feed in the usual way by reference to the F value. This requires the specification of an effective radius (reference radius) for each of the rotary axes involved.

The unit of the reference radius depends on the `G70`/`G71`/`G700`/`G710` setting.

All axes involved must be included in the `FGROUP` command to be taken into account in the calculation of the path feedrate.

In order to ensure compatibility with the behavior with no `FGREF` programming, the factor 1 degree = 1 mm is activated on system power up and RESET. This corresponds to a reference radius of FGREF= 360 mm/(2π) = 57.296 mm.

Note

This default is independent of the active basic system (MD10240 $MN_SCALING_SYSTEM_IS_METRIC) and the currently active `G70`/`G71`/`G700`/`G710` setting.

Special situations:

Program code

```
N100 FGROUP(X,Y,Z,A)
N110 G1 G91 A10 F100
N120 G1 G91 A10 X0.0001 F100
```

With this type of programming, the F value programmed in `N110` is evaluated as the rotary axis feedrate in degrees/min, while the feedrate evaluation in `N120` is either 100 inch/min or 100 mm/min, dependent upon the currently active `G70`/`G71`/`G700`/`G710` setting.

CAUTION

`FGREF` evaluation also works if only rotary axes are programmed in the block. The normal `F` value interpretation as degree/min applies in this case only if the radius reference corresponds to the `FGREF` default:

- For `G71`/`G710`: `FGREF[A]=57.296`
- For `G70`/`G700`: `FGREF[A]=57.296/25.4`

Read reference radius

The value of the reference radius of a rotary axis can be read using system variables:

- In synchronized actions or with preprocessing stop in the part program via system variable:

  $AA_FGREF[<axis>]   Current main run value

- Without preprocessing stop in the part program via system variable:

  $PA_FGREF[<axis>]   Programmed value

If no values are programmed, the default 360 mm/(2π) = 57.296 mm (corresponding to 1 mm per degree) will be read in both variables.

For linear axes, the value in both variables is always 1 mm.

Read path axes affecting velocity

The axes involved in path interpolation can be read using system variables:

- In synchronized actions or with preprocessing stop in the part program via system variables:

$AA_FGROUP[<axis>]	Returns the value "1" if the specified axis affects the path velocity in the current main run record by means of the basic setting or through `FGROUP` programming. Otherwise, the variable returns the value "0".
$AC_FGROUP_MASK	Returns a bit key of the channel axes programmed with `FGROUP` which are to affect the path velocity.

- Without preprocessing stop in the part program via system variables:

$PA_FGROUP[<axis>]	Returns the value "1" if the specified axis affects the path velocity by means of the basic setting or through `FGROUP` programming. Otherwise, the variable returns the value "0".
$P_FGROUP_MASK	Returns a bit key of the channel axes programmed with `FGROUP` which are to affect the path velocity.

Path reference factors for orientation axes with FGREF

With orientation axes the mode of operation of the `FGREF[]` factors is dependent upon whether the change in the orientation of the tool is implemented by means of rotary axis or vector interpolation.

In the case of **rotary axis interpolation**, as is the case with rotary axes, the relevant `FGREF` factors of the orientation axes are calculated individually as reference radius for the axis paths.

In the case of **vector interpolation**, an effective `FGREF` factor, which is calculated as the geometric mean value of the individual `FGREF` factors, is applied.

FGREF[effective] = nth root of [(FGREF[A] * FGREF[B]...)]

where:	A:	Axis identifier of 1st orientation axis
	B:	Axis identifier of 2nd orientation axis
	C:	Axis identifier of 3rd orientation axis
	n:	Number of orientation axes

Example:

Since there are two orientation axes for a standard 5-axis transformation, the effective factor is, therefore, the root of the product of the two axial factors:

FGREF[effective] = square root of [(FGREF[A] * FGREF[B])]

Note

It is, therefore, possible to use the effective factor for orientation axes `FGREF` to define a reference point on the tool to which the programmed path feedrate refers.

7.2 Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC)

Function

Positioning axes are traversed independently of the path axes at a separate, axis-specific feedrate. There are no interpolation commands. The `POS`/`POSA`/`POSP` commands are used to traverse the positioning axes and coordinate the motion sequences at the same time.

The following are typical examples of positioning axes:

- Pallet feed equipment
- Gauging stations

`WAITP` can be used to identify a position in the NC program where the program is to wait until an axis programmed with `POSA` in a previous NC block reaches its end position.

`WAITMC` loads the next NC block immediately when the specified wait marker is received.

Syntax

```
POS[<axis>]=<position>
POSA[<axis>]=<position>
POSP[<axis>]=(<end position>,<partial length>,<mode>)
FA[<axis>]=<value>
WAITP(<axis>) ; Programming in a separate NC block.
WAITMC(<wait marker>)
```

Significance

`POS`/`POSA`: Move positioning axis to specified position

`POS` and `POSA` have the same functionality but differ in their block change behavior:

- `POS` delays the enabling of the NC block until the position has been reached.
- `POSA` enables the NC block even if the position has not been reached.

`<axis>`: Name of the axis to be traversed (channel or geometry axis identifier)

`<position>`: Axis position to be approached

Type: REAL

`POSP`: Move positioning axis to specified end position in sections

`<end position>`: Axis end position to be approached

`<partial length>`: Length of a section

`<mode>`: Approach mode

= `0`: For the last two sections, the path remaining until the end position is split into two residual sections of equal size (preset).

= `1`: The partial length is adjusted so that the total of all calculated partial lengths corresponds exactly to the path up to the end position.

Note:
`POSP` is used specifically to program oscillating motion.

References:
Programming Manual, Job Planning; Chapter "Oscillation"

`FA`: Feedrate for the specified positioning axis

`<axis>`: Name of the axis to be traversed (channel or geometry axis identifier)

`<value>`: Feedrate

Unit: mm/min or inch/min or deg/min

Note:
Up to 5 `FA` values can be programmed for each NC block.

`WAITP`: Wait for a positioning axis to be traversed

The subsequent blocks are not processed until the specified positioning axis programmed in a previous NC block with `POSA` has reached its end position (with exact stop fine).

`<axis>`: Name of the axis (channel or geometry axis identifier) for which the `WAITP` command is to be applied

Note:
With `WAITP`, an axis can be made available as an oscillating axis or for traversing as a concurrent positioning axis (via PLC).

`WAITMC`: Wait for the specified wait marker to be received

When the wait marker is received, the next NC block is loaded immediately.

`<wait marker>`: Number of the wait marker

CAUTION

Travel with POSA

If a command, which implicitly causes a preprocessing stop, is read in a following block, this block is not executed until all other blocks, which are already preprocessed and stored have been executed. The previous block is stopped in exact stop (as `G9`).

Examples

Example 1: Travel with POSA and access to machine status data

The control generates an internal preprocessing stop on access to machine status data ($A...). Machining is stoppeduntil all preprocessed and saved blocks have been executed in full.

Program code	**Comment**
`N40 POSA[X]=100`	
`N50 IF $AA_IM[X]==R100 GOTOF LABEL1`	`; Access to machine status data.`
`N60 G0 Y100`	
`N70 WAITP(X)`	
`N80 LABEL1:`	
`N...`	

Example 2: Wait for end of travel with WAITP

Pallet feed equipment

Axis U:	Pallet store Transport of workpiece pallet to working area
Axis V:	Transfer line to a gauging station where spot checks are carried out to assist the process

Program code	**Comment**
`N10 FA[U]=100 FA[V]=100`	`; Axis-specific feedrate specifications for the individual positioning axes U and V`
`N20 POSA[V]=90 POSA[U]=100 G0 X50 Y70`	`; Traverse positioning and path axes`
`N50 WAITP(U)`	`; Program execution does not resume until axis U reaches the end point programmed in N20.`
…	

Further information

Travel with POSA

Block step enable or program execution is not affected by `POSA`. The movement to the end position can be performed during execution of subsequent NC blocks.

Travel with POS

The next block is not executed until all axes programmed under `POS` reach their end positions.

Wait for end of travel with WAITP

After a `WAITP`, assignment of the axis to the NC program is no longer valid; this applies until the axis is programmed again. This axis can then be operated as a positioning axis through the PLC, or as a reciprocating axis from the NC program/PLC or HMI.

Block change in the braking ramp with IPOBRKA and WAITMC

An axis is only decelerated if the wait marker has not yet been reached or if another end-of-block criterion is preventing the block change. After a `WAITMC`, the axis starts immediately if no other end-of-block criterion is preventing the block change.

7.3 Position-controlled spindle operation (SPCON, SPCOF)

Function

Position-controlled spindle mode may be advisable in some cases, e.g. in conjunction with large-pitch thread cutting with `G33`, where better quality can be achieved.
The `SPCON` NC command is used to switch over to position-controlled spindle mode.

Note

`SPCON` requires a maximum of 3 interpolation cycles.

Syntax

```
SPCON/SPCON(<n>)/SPCON(<n>,<m>, etc.)
...
SPCOF/SPCOF(<n>)/SPCOF(<n>,<m>, etc.)
```

Significance

`SPCON`: Activate position-controlled mode
The specified spindle is switched over from speed control to position control.
`SPCON` s modal and is retained until `SPCOF`.

`SPCOF`: Deactivate position-controlled mode
The specified spindle is switched over from position control to speed control.

`<n>`:	Number of the spindle to be switched over. If a spindle number is not specified, `SPCON`/`SPCOF` will be applied to the master spindle.
`<n>,<m>, etc.`:	`SPCON` or `SPCOF` can even be used to switch over multiple spindles in one block.

Note

The speed is specified with `S`....

`M3`, `M4` and `M5` apply in respect of the directions of rotation and spindle stop.

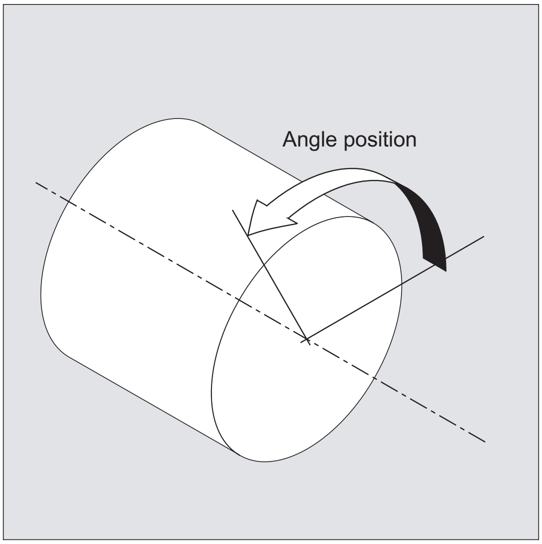
Note

With synchronized spindle setpoint value linkage, the master spindle must be operated in position-control mode.

7.4 Positioning spindles (SPOS, SPOSA, M19, M70, WAITS)

Function

SPOS, SPOSA or M19 can be used to set spindles to specific angular positions, e.g. during tool change.



SPOS, SPOSA and M19 induce a temporary switchover to position-controlled mode until the next M3/M4/M5/M41 to M45.

Positioning in axis mode

The spindle can also be operated as a path axis, synchronized axis or positioning axis at the address defined in the machine data. When the axis identifier is specified, the spindle is in axis mode. M70 switches the spindle directly to axis mode.

End of positioning

The end-of-motion criterion when positioning the spindle can be programmed using FINEA, CORSEA, IPOENDA or IPOBRKA.

The program advances to the next block if the end of motion criteria for all spindles or axes programmed in the current block plus the block change criterion for path interpolation are fulfilled.

Synchronization

In order to synchronize spindle movements, WAITS can be used to wait until the spindle position is reached.

Conditions

The spindle to be positioned must be capable of operation in position-controlled mode.

Syntax

Position spindle:

`SPOS=<value>`/`SPOS[<n>]=<value>`

`SPOSA=<value>`/`SPOSA[<n>]=<value>`

`M19`/`M<n>=19`

Switch spindle over to axis mode:

`M70`/`M<n>=70`

Define end-of-motion criterion:

`FINEA`/`FINEA[S<n>]`

`COARSEA`/`COARSEA[S<n>]`

`IPOENDA`/`IPOENDA[S<n>]`

`IPOBRKA`/`IPOBRKA(<axis>[,<instant in time>])` ; Programming in a separate NC block.

Synchronize spindle movements:

`WAITS`/`WAITS(<n>,<m>)` ; Programming in a separate NC block.

Significance

`SPOS`/`SPOSA`: Set spindle to specified angle

`SPOS` and `SPOSA` have the same functionality but differ in their block change behavior:

- `SPOS` delays the enabling of the NC block until the position has been reached.
- `SPOSA` enables the NC block even if the position has not been reached.

`<n>`: Number of the spindle to be positioned.

If a spindle number is not specified or if the spindle number is set to "0", `SPOS` or `SPOSA` will be applied to the master spindle.

`<value>`: Angular position to which the spindle is to be set.

Unit:	degrees
Type:	REAL

The following options are available about programming the position approach mode:

`=AC(<value>)`:	Absolute dimensions Range of values: 0 … 359,9999
`=IC(<value>)`:	Incremental dimensions Range of values: 0 … ±99 999,999
`=DC(<value>)`:	Approach absolute value directly
`=ACN(<value>)`:	Absolute dimension, approach in negative direction
`=ACP(<value>)`:	Absolute dimension, approach in positive direction
`=<value>`:	as `DC(<value>)`

M<n>=19: Set the master spindle (M19 or M0=19) or spindle number <n> (M<n>=19) to the angular position preset with SD43240 $SA_M19_SPOS with the position approach mode preset in SD43250 $SA_M19_SPOSMODE.

The NC block is not enabled until the position has been reached.

M<n>=70: Switch the master spindle (M70 or M0=70) or spindle number <n> (M<n>=70) over to axis mode.

No defined position is approached. The NC block is enabled after the switchover has been performed.

FINEA: Motion end when "Exact stop fine" reached

COARSEA: Motion end when "Exact stop coarse" reached

IPOENDA: End of motion on reaching "interpolator stop"

S<n>: Spindle for which the programmed end-of-motion criterion is to be effective

<n>: Spindle number

If a spindle is not specified in [S<n>] or a spindle number of "0" is specified, the programmed end-of-motion criterion will be applied to the master spindle.

IPOBRKA: A block change is possible in the braking ramp.

<axis>: Channel axis identifier

<instant in time>: Instant in time of the block change with reference to the braking ramp

Unit:	Percent
Range of values:	100 (application point of the braking ramp) to 0 (end of the braking ramp)

If a value is not assigned to the <instant in time> parameter, the current value of the setting data is applied:

SD43600 $SA_IPOBRAKE_BLOCK_EXCHANGE

Note:

IBOBRKA with an instant in time of "0" is identical to IPOENDA.

`WAITS`: Synchronization command for the specified spindle(s)

The subsequent blocks are not processed until the specified spindle(s) programmed in a previous NC block with `SPOSA` has (have) reached its (their) end position(s) (with exact stop fine).

`WAITS` after `M5`: Wait for the specified spindle(s) to come to a standstill.

`WAITS` after `M3`/`M4`: Wait for the specified spindle(s) to reach their setpoint speed.

`<n>,<m>`: Numbers of the spindles to which the synchronization command is to be applied.

If a spindle number is not specified or if the spindle number is set to "0", `WAITS` will be applied to the master spindle.

Note

Three spindle positions are possible for each NC block.

Note

With incremental dimensions `IC(<value>)`, spindle positioning can take place over several revolutions.

Note

If position control was activated with `SPCON` prior to `SPOS`, this remains active until `SPCOF` is issued.

Note

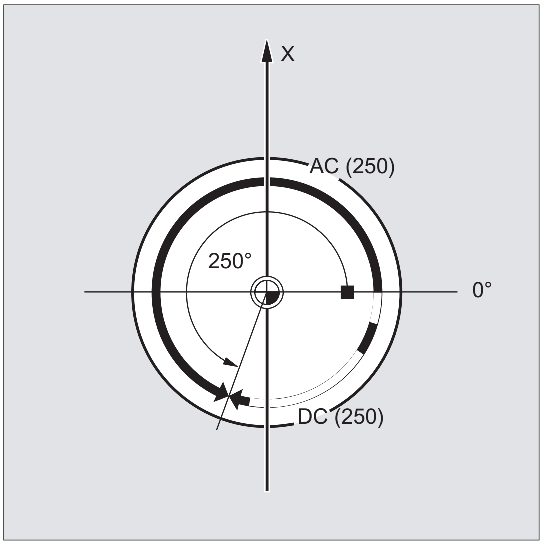
The control detects the transition to axis mode automatically from the program sequence. Explicit programming of M70 in the part program is, therefore, essentially no longer necessary. However, M70 can continue to be programmed, e.g to increase the legibility of the part program.

Examples

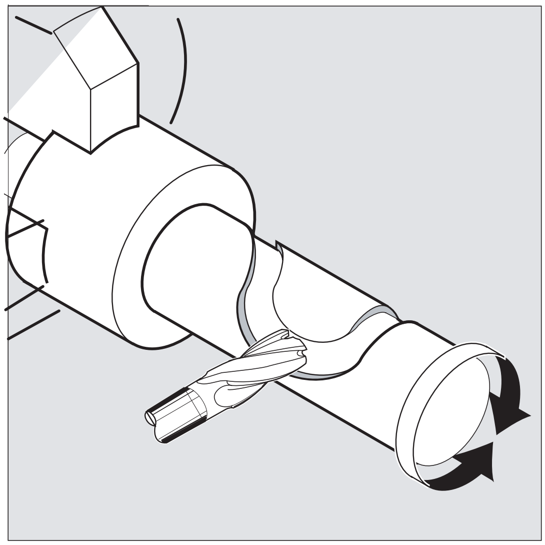
Example 1: Position spindle with negative direction of rotation

Spindle 2 is to be positioned at 250° with negative direction of rotation:

Program code	Comment
`N10 SPOSA[2]=ACN(250)`	`; The spindle is decelerated if necessary and accelerated in the opposite direction to that of the positioning movement.`



Example 2: Spindle positioning in axis mode



Program variant 1:

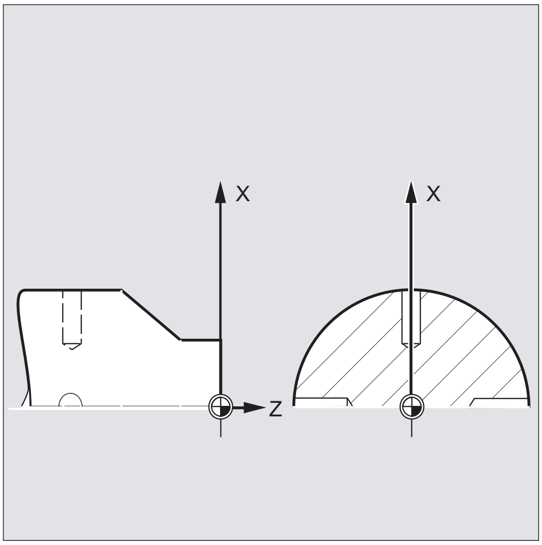
Program code	Comment
...	
N10 M3 S500	
...	
N90 SPOS[2]=0	; Position control on, spindle 2 positioned to 0, axis mode can be used in the next block.
N100 X50 C180	; Spindle 2 (C axis) is traversed with linear interpolation synchronized with X.
N110 Z20 SPOS[2]=90	; Spindle 2 is positioned to 90 degrees.

Program variant 2:

Program code	Comment
...	
N10 M3 S500	
...	
N90 M2=70	; Spindle 2 switches to axis mode.
N100 X50 C180	; Spindle 2 (C axis) is traversed with linear interpolation synchronous to X.
N110 Z20 SPOS[2]=90	; Spindle 2 is positioned to 90 degrees.

Example 3: Drill cross holes in turned part

Cross holes are to be drilled in this turned part. The running drive spindle (master spindle) is stopped at zero degrees and then successively turned through 90°, stopped and so on.



Program code	Comment
`....`	
`N110 S2=1000 M2=3`	`; Switch on cross drilling attachment.`
`N120 SPOSA=DC(0)`	`; Set main spindle to 0° immediately, the program will advance to the next block straight away.`
`N125 G0 X34 Z-35`	`; Switch on the drill while the spindle is taking up position.`
`N130 WAITS`	`; Wait for the main spindle to reach its position.`
`N135 G1 G94 X10 F250`	`; Feedrate in mm/min (G96 is suitable only for the multi-edge turning tool and synchronous spindle, but not for power tools on the cross slide.)`
`N140G0 X34`	
`N145 SPOS=IC(90)`	`; The spindle is positioned through 90° with read halt in a positive direction.`
`N150 G1 X10`	
`N155 G0 X34`	
`N160 SPOS=AC(180)`	`; The spindle is positioned at 180° relative to the spindle zero point.`
`N165 G1 X10`	
`N170 G0 X34`	
`N175 SPOS=IC(90)`	`; The spindle turns in a positive direction through 90° from the absolute 180° position, ending up in the absolute 270° position.`
`N180 G1 X10`	
`N185 G0 X50`	
`...`	

Further information

Positioning with SPOSA

The block step enable or program execution is not affected by SPOSA. The spindle positioning can be performed during execution of subsequent NC blocks. The program moves onto the next block if all the functions (except for spindle) programmed in the current block have reached their block end criterion. The spindle positioning operation may be programmed over several blocks (see WAITS).

NOTICE

If a command, which implicitly causes a preprocessing stop, is read in a following block, execution of this block is delayed until all positioning spindles are stationary.

Positioning with SPOS/M19

The block step enabling condition is met when all functions programmed in the block reach their end-of-block criterion (e.g. all auxiliary functions acknowledged by the PLC, all axes at their end point) and the spindle reaches the programmed position.

Velocity of the movements:

The velocity and the delay response for positioning are stored in the machine data. The configured values can be modified by programming or by synchronized actions, see:

- Feedrate for positioning axes/spindles (FA, FPR, FPRAON, FPRAOF) [Page 133]
- Programmable acceleration override (ACC) (option) [Page 139]

Specification of spindle positions:

As the `G90`/`G91` commands are not effective here, the corresponding dimensions apply explicitly, e.g. `AC`, `IC`, `DC`, `ACN`, `ACP`. If no specifications are made, traversing automatically takes place as for `DC`.

Synchronize spindle movements with WAITS

`WAITS` can be used to identify a point at which the NC program waits until one or more spindles programmed with `SPOSA` in a previous NC block reach their positions.

Example:

Program code	Comment
`N10 SPOSA[2]=180 SPOSA[3]=0`	
`...`	
`N40 WAITS(2,3)`	`; The block waits until spindles 2 and 3 have reached the positions specified in block N10.`

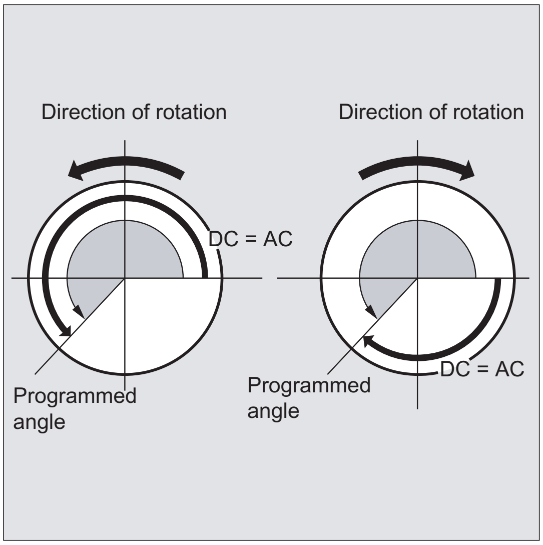
`WAITS` can be used after `M5` to wait until the spindle(s) has (have) stopped. `WAITS` can be used after `M3`/`M4` to wait until the spindle(s) has (have) reached the specified speed/direction of rotation.

Note

If the spindle has not yet been synchronized with synchronization marks, the positive direction of rotation is taken from the machine data (state on delivery).

Position spindle from rotation (M3/M4)

When M3 or M4 is active, the spindle comes to a standstill at the programmed value.



There is no difference between DC and AC dimensioning. In both cases, rotation continues in the direction selected by M3/M4 until the absolute end position is reached. With ACN and ACP, deceleration takes place if necessary, and the appropriate approach direction is taken. With IC, the spindle rotates additionally to the specified value starting at the current spindle position.

Position a spindle from standstill (M5)

The exact programmed distance is traversed from standstill (M5).

7.5 Feedrate for positioning axes/spindles (FA, FPR, FPRAON, FPRAOF)

Function

Positioning axes such as workpiece transport systems, tool turrets and end supports are traversed independently of path and synchronized axes. A separate feedrate is therefore defined for each positioning axis.

A separate axial feedrate can also be programmed for spindles.

It is also possible to derive the revolutional feedrate for path and synchronized axes or for individual positioning axes/spindles from another rotary axis or spindle.

Syntax

Feedrate for positioning axis:

```
FA[<axis>]=…
```

Axis feedrate for spindle:

```
FA[SPI(<n>)]=…
FA[S<n>]=…
```

Derive revolutional feedrate for path/synchronized axes:

```
FPR (<rotary axis>)

FPR(SPI(<n>))

FPR(S<n>)
```

Derive rotational feedrate for positioning axes/spindles:

```
FPRAON(<axis>,<rotary axis>)

FPRAON(<axis>,SPI(<n>))

FPRAON(<axis>,S<n>)

FPRAON(SPI(<n>),<rotary axis>)

FPRAON(S<n>,<rotary axis>)

FPRAON(SPI(<n>),SPI(<n>))

FPRAON(S<n>,S<n>)

FPRAOF(<axis>,SPI(<n>), etc.)

FPRAOF(<axis>,S<n>, etc.)
```

Significance

`FA[...]=...`: Feedrate for the specified positioning axis or positioning speed (axial feedrate) for the specified spindle

Unit: mm/min or inch/min or deg/min

Range of values: … 999 999.999 mm/min, deg/min
… 39 999.9999 inch/min

`FPR(...)`: `FPR` is used to identify the rotary axis (`<rotary axis>`) or spindle (`SPI(<n>)`/`S<n>`) from which the revolutional feedrate for the revolutional feedrate of the path and synchronized axes programmed under `G95` is to be derived.

`FPRAON(...)`: Derive rotational feedrate for positioning axes and spindles

The first parameter (`<axis>`/`SPI(<n>)`/`S<n>`) identifies the positioning axis/spindle to be traversed with revolutional feedrate.

The second parameter (`<rotary axis>`/`SPI(<n>)`/`S<n>`) identifies the rotary axis/spindle from which the revolutional feedrate is to be derived.

Note:
The second parameter can be omitted, in which case the feedrate will be derived from the master spindle.

`FPRAOF(...)`: `FPRAOF` is used to deselect the derived revolutional feedrate for the specified axes or spindles.

`<axis>`: Axis identifier (positioning or geometry axis)

`SPI(<n>)`/`S<n>`: Spindle identifier

`SPI(<n>)` and `S<n>` are identical in terms of function.

`<n>`: Spindle number

Note:
`SPI` converts spindle numbers into axis identifiers. The transfer parameter `(<n>)` must contain a valid spindle number.

Note

The programmed feedrate FA[...] is modal.

Up to five feedrates for positioning axes or spindles can be programmed in each NC block.

Note

The derived feedrate is calculated according to the following formula:

Derived feedrate = programmed feedrate * absolute master feedrate

---

Examples

Example 1: Synchronous spindle coupling

With synchronous spindle coupling, the positioning speed of the following spindle can be programmed independently of the master spindle, e.g. for positioning operations.

Program code	**Comment**
`...`	
`FA[S2]=100`	`; Positioning speed of the following spindle (spindle 2) = 100 deg/min`
`...`	

Example 2: Derived revolutional feedrate for path axes

Path axes X, Y must be traversed at the revolutional feedrate derived from rotary axis A:

Program code
`...`
`N40 FPR(A)`
`N50 G95 X50 Y50 F500`
`...`

Example 3: Derive revolutional feedrate for master spindle

Program code	**Comment**
`N30 FPRAON(S1,S2)`	`; The revolutional feedrate for the master spindle (S1) must be derived from spindle 2.`
`N40 SPOS=150`	`; Position master spindle.`
`N50 FPRAOF(S1)`	`; Deselect revolutional feedrate for the master spindle.`

Example 4: Derive revolutional feedrate for positioning axis

Program code	**Comment**
`N30 FPRAON(X)`	`; The revolutional feedrate for positioning axis X must be derived from the master spindle.`
`N40 POS[X]=50 FA[X]=500`	`; The positioning axis is traversing at 500 mm/ revolution of the master spindle.`
`N50 FPRAOF(X)`	

Further information

FA[…]

The feedrate type is always `G94`. When `G70`/`G71` is active, the unit is metric/inches according to the default setting in the machine data. `G700`/`G710` can be used to modify the unit in the program.

NOTICE
If no `FA` is programmed, the value defined in the machine data applies.

FPR(…)

As an extension of the `G95`command (revolutional feedrate referring to the master spindle), `FPR` allows the revolutional feedrate to be derived from any chosen spindle or rotary axis. `G95 FPR(…)` is valid for path and synchronized axes.

If the rotary axis/spindle specified in the FPR command is operating on position control, then the setpoint linkage is active. Otherwise the actual-value linkage is effective.

FPRAON(…)

`FPRAON` is used to derive the revolutional feedrate for positioning axes and spindles from the current feedrate of another rotary axis or spindle.

FPRAOF(…)

The revolutional feedrate can be deactivated for one or a number of axes/spindles simultaneously with the `FPRAOF` command.

7.6 Programmable feedrate override (OVR, OVRRAP, OVRA)

Function

The velocity of path/positioning axes and spindles can be modified in the NC program.

Syntax

```
OVR=<value>
OVRRAP=<value>
OVRA[<axis>]=<value>
OVRA[SPI(<n>)]=<value>
OVRA[S<n>]=<value>
```

Significance

`OVR`: Feedrate modification for path feedrate F

`OVRRAP`: Feedrate modification for rapid traverse velocity

`OVRA`: Feedrate modification for positioning feedrate `FA` or for spindle speed `S`

`<axis>`: Axis identifier (positioning or geometry axis)

`SPI(<n>)`/`S<n>`: Spindle identifier

`SPI(<n>)` and `S<n>` are identical in terms of function.

`<n>`: Spindle number

Note:
`SPI` converts spindle numbers into axis identifiers. The transfer parameter `(<n>)` must contain a valid spindle number.

`<value>`: Feedrate modification in percent

The value refers to or is combined with the feedrate override set on the machine control panel.

Range of values: … 200%, integers

Note:
With path and rapid traverse override, the maximum velocities set in the machine data are not overshot.

Examples

Example 1:

Set feedrate override: 80%

Program code	Comment
`N10 ... F1000`	
`N20 OVR=50`	`; The programmed path feedrate F1000 is changed in F400 (1000 * 0.8 * 0.5).`
`...`	

Example 2:

Program code	Comment
`N10 OVRRAP=5`	`; The rapid traverse velocity is reduced to 5%.`
`...`	
`N100 OVRRAP=100`	`; The rapid traverse velocity is reset to 100% (= default setting).`

Example 3:

Program code	Comment
`N... OVR=25 OVRA[A1]=70`	`; The path feedrate is reduced to 25% and the positioning feedrate for positioning axis A1 is reduced to 70%.`

Example 4:

Program code	Comment
`N.. OVRA[SPI(1)]=35`	`; The speed for spindle 1 is reduced to 35%.`

or

Program code	Comment
`N.. OVRA[S1]=35`	`; The speed for spindle 1 is reduced to 35%.`

7.7 Programmable acceleration override (ACC) (option)

Function

In critical program sections, it may be necessary to limit the acceleration to below the maximum values, e.g. to prevent mechanical vibrations from occurring.

The programmable acceleration override can be used to modify the acceleration for each path axis or spindle via a command in the NC program. The limit is effective for all types of interpolation. The values defined in the machine data apply as 100% acceleration.

Syntax

```
ACC[<axis>]=<value>
ACC[SPI(<n>)]=<value>
ACC(S<n>)=<value>
```

Deactivate:

```
ACC[...]=100
```

Syntax

ACC: Acceleration change for the specified path axis or speed change for the specified spindle.

<axis>: Channel axis name of path axis

SPI(<n>)/S<n>: Spindle identifier

SPI(<n>) and S<n> are identical in terms of function.

<n>: Spindle number

Note:
SPI converts spindle numbers into axis identifiers. The transfer parameter (<n>) must contain a valid spindle number.

<value>: Acceleration change in percent

The value refers to or is combined with the feedrate override set on the machine control panel.

Range of values: 1 to 200%, integers

NOTICE
With a greater acceleration rate, the values permitted by the manufacturer may be exceeded.

Example

Program code	Comment
N50 ACC[X]=80	; The axis slide in the X direction should only be traversed with 80% acceleration.
N60 ACC[SPI(1)]=50	; Spindle 1 should only accelerate or brake with 50% of the acceleration capacity.

Further information

Acceleration override programmed with ACC

The acceleration override programmed with `ACC[...]` is always taken into consideration on output as in system variable $AA_ACC. Readout in the parts program and in synchronized actions takes place at different times in the NC processing run.

In the part program

The value written in the part program is then only taken into consideration in system variable $AA_ACC as written in the part program if `ACC` has not been changed in the meantime by a synchronized action.

In synchronized actions

The following thus applies: The value written to a synchronized action is then only considered in system variable $AA_ACC as written to the synchronized action if `ACC` has not been changed in the meantime by a part program.

The preset acceleration can also be changed via synchronized actions (see Function Manual, Synchronized Actions).

Example:

Program code
...
N100 EVERY $A_IN[1] DO POS[X]=50 FA[X]=2000 ACC[X]=140

The current acceleration value can be called with system variable $AA_ACC[<axis>]. Machine data can be used to define whether the last `ACC` value set should apply on RESET/ part program end or whether 100% should apply.

7.8 Feedrate with handwheel override (FD, FDA)

Function

The `FD` and `FDA` commands can be used to traverse axes with handwheels during execution of the part program. The programmed settings for traversing the axes are then overlaid with the handwheel pulses evaluated as path or velocity defaults.

Path axes
In the case of path axes, the programmed path feedrate can be overlaid. The handwheel is evaluated as the first geometry axis of the channel. The handwheel pulses evaluated per interpolation cycle dependent on the direction of rotation correspond to the path velocity to be overlaid. The path velocity limit values which can be achieved by means of handwheel override are:

- Minimum: 0
- Maximum: Machine data limit values of the path axes involved in traversing

Note

Path feedrate

The path feedrate F and the handwheel feedrate FD cannot be programmed in the same NC block.

Positioning axes
In the case of positioning axes, the travel path or velocity can be overlaid as an axial value. The handwheel assigned to the axis is evaluated.

- Path override
  The handwheel pulses evaluated dependent on the direction of rotation correspond to the axis path to be traveled. Only handwheel pulses in the direction of the programmed position are evaluated.
- Velocity override
  The handwheel pulses evaluated per interpolation cycle dependent on the direction of rotation correspond to the axial velocity to be overlaid. The path velocity limit values which can be achieved by means of handwheel override are:
  - Minimum: 0
  - Maximum: Machine data limit values of the positioning axis

A detailed description of how to set handwheel parameters appears in:

References:
/FB2/ Function Manual, Extended Functions; Manual Travel and Handwheel Travel (H1)

Syntax

```
FD=<velocity>
FDA[<axis>]=<velocity>
```

Significance

`FD=<velocity>`: Path feedrate and enabling of velocity override with handwheel

<velocity>:

- Value = 0: Not allowed!
- Value ≠ 0: Path velocity

`FDA[<axis>]=<velocity>`: Axial feedrate

<velocity>:

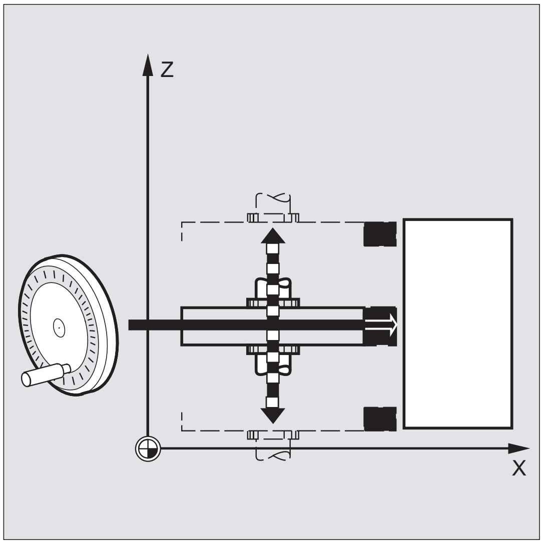
- Value = 0: Path default with handwheel
- Value ≠ 0: Axial velocity

`<axis>`: Axis identifier of positioning axis

Note

`FD` and `FDA` are non-modal.

Example



Path definition: The grinding wheel oscillating in the Z direction is traversed to the workpiece in the X direction with the handwheel.

The operator can continue to feed manually until the sparks are flying uniformly. Activating "Delete distance-to-go" switches to the next NC block and machining continues in AUTOMATIC mode.

Further information

Traverse path axes with velocity override (FD=<velocity>)

The following conditions must be met for the part program block in which path velocity override is programmed:

- Path command `G1`, `G2` or `G3` active
- Exact stop `G60` active
- Linear feedrate `G94` active

Feedrate override

The feedrate override only affects the programmed path velocity and not the velocity component generated with the handwheel (exception: (except if feed override = 0).

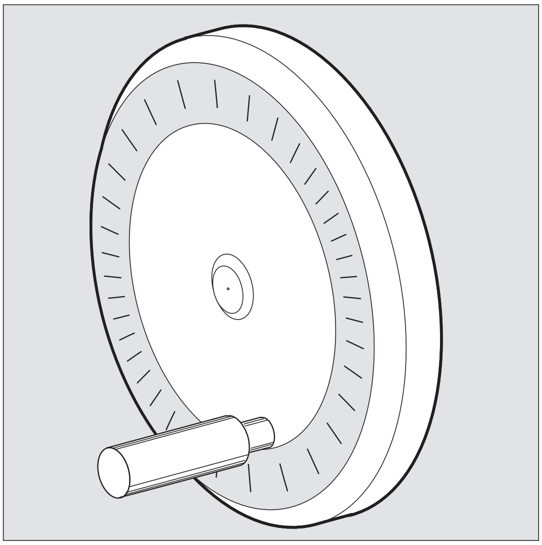
Example:

Program code	Description
`N10 X… Y… F500`	`; Feedrate = 500 mm/min`

`N20 X… Y… FD=700`	`; Feedrate = 700 mm/min and velocity override with handwheel.`
	`; Acceleration from 500 to 700 mm/min in N20. The handwheel`
	`; can be used to vary the speed dependent on the direction of rotation between 0`
	`; and the maximum value (machine data).`

Traverse positioning axes with path default (FDA[<axis>]=0)

In the NC block with programmed `FDA[<axis>]=0` the feed is set to zero so that the program cannot generate any travel movement. The programmed travel movement to the target position is now controlled exclusively by the operator rotating the handwheel.



Example:

Program code	Description
`...`	

`N20 POS[V]=90 FDA[V]=0`	`; Target position = 90 mm, axial feedrate = 0 mm/min and`
	`; path override with handwheel.`
	`; Velocity of axis V at start of block = 0 mm/min.`
	`; Path and speed defaults are set using handwheel pulses`

Direction of movement, travel velocity

The axes follow the path set by the handwheel in the direction of the sign. Forward and backwards travel is possible dependent on the direction of rotation. The faster the handwheel rotates, the higher the traversing speed.

Traversing range:

The traversing range is limited by the starting position and the programmed end point.

Traverse positioning axis with velocity override (FDA[<axis>]=<velocity>)

In NC blocks with programmed `FDA[…]=…`, the feedrate from the last programmed `FA` value is accelerated or decelerated to the value programmed under `FDA`. Starting from the current feedrate `FDA`, the handwheel can be turned to accelerate the programmed movement to the target position or decelerate it to zero. The values set as parameters in the machine data serve as the maximum velocity.

Example:

Program code	**Description**
`N10 POS[V]=… FA[V]=100`	`; Axial feedrate = 100 mm/min`

`N20 POS[V]=100 FAD[V]=200`	`; Axial target position = 100, axial feedrate = 200 mm/min`
	`; and velocity override with handwheel.`
	`; Acceleration from 100 to 200 mm/min in N20. The`
	`; handwheel can be used to vary the velocity dependent on the`
	`; direction of rotation`
	`; between 0 and the maximum value (machine data).`

Traversing range:
The traversing range is limited by the starting position and the programmed end point.

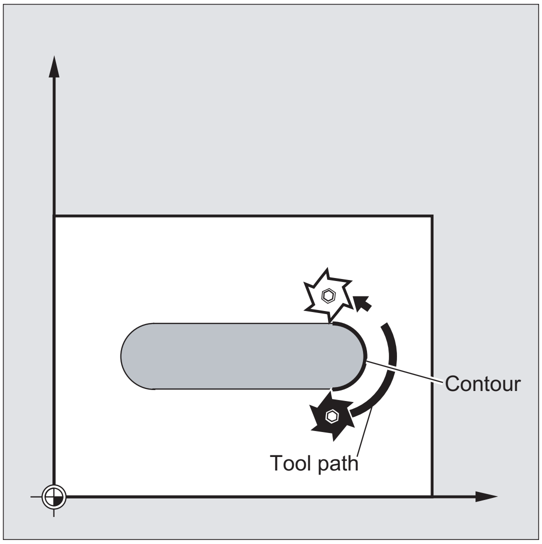
7.9 Feedrate optimization for curved path sections (CFTCP, CFC, CFIN)

Function

With activated offset mode G41/G42, the programmed feedrate for the milling cutter radius initially refers to the milling cutter center path (see the chapter titled "Coordinate transformations (frames)").

When you mill a circle (the same applies to polynomial and spline interpolation) the extent to which the feedrate varies at the cutter edge is so significant under certain circumstances that it can impair the quality of the machined part.

Example: Milling a small outside radius with a large tool. The path that the outside of the milling tool must travel is considerably longer than the path along the contour.



Because of this, machining at the contour takes place with a very low feedrate. To prevent adverse effects, the feedrate needs to be controlled accordingly for curved contours.

Syntax

```
CFTCP
CFC
CFIN
```

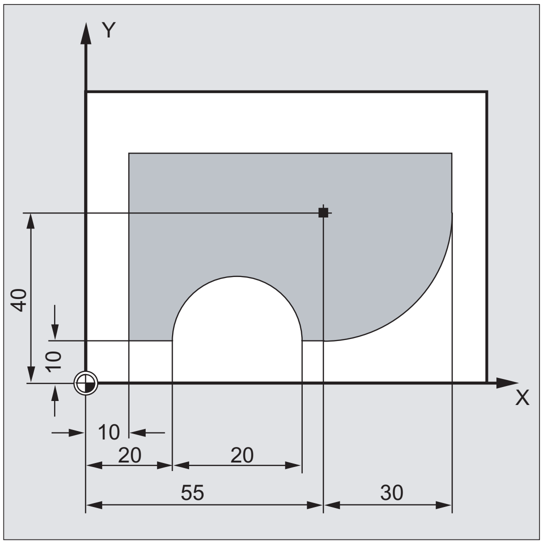
Significance

`CFTCP`: Constant feedrate on the milling cutter center path
The control keeps the feedrate constant and feedrate offsets are deactivated.

`CFC`: Constant feedrate at the contour (tool cutting edge).
This function is preset per default.

`CFIN`: Constant feedrate at the tool cutting edge only at concave contours, otherwise on the milling cutter center path.
The feedrate is reduced for inside radii.

Example

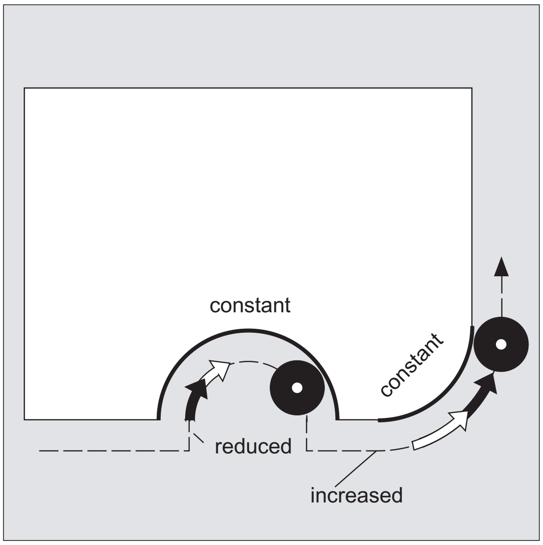


In this example, the contour is first produced with `CFC`-corrected feedrate. During finishing, the cutting base is also machined with `CFIN`. This prevents the cutting base being damaged at the outside radii by a feedrate that is too high.

Program code	Comment
`N10 G17 G54 G64 T1 M6`	
`N20 S3000 M3 CFC F500 G41`	
`N30 G0 X-10`	
`N40 Y0 Z-10`	`; Feed to first cutting depth`
`N50 CONTOUR1`	`; Subroutine call`
`N40 CFIN Z-25`	`; Feed to second cutting depth`
`N50 CONTOUR1`	`; Subroutine call`
`N60 Y120`	
`N70 X200 M30`	

Further information

Constant feedrate on contour with CFC



The feedrate is reduced for inside radii and increased for outside radii. This ensures a constant speed at the tool edge and thus at the contour.

7.10 Several feedrate values in one block (F, ST, SR, FMA, STA, SRA)

Function

The "Multiple feedrates in one block" function can be used to activate different feedrate values for an NC block, a dwell time or a retraction motion-synchronously, dependent on external digital and/or analog inputs.

The HW input signals are combined in one input byte.

Syntax

```
F2=... to F7=...
ST=...
SR=...
```

```
FMA[2,<axis>]=... to FMA[7,<axis>]=...
STA[<axis>]=...
SRA[<axis>]=...
```

Significance

`F2=... to F7=...`:

The path feedrate is programmed under the address `F` and remains valid during the absence of an input signal.

In addition to the path feedrate, up to 6 further feedrates can be programmed in the block. The numerical expansion indicates the bit number of the input that activates the feedrate when changed:

Effective: non-modal

`ST=...`:

Dwell time in s (for grinding technology: sparking-out time)

Input bit: 1

Effective: non-modal

`SR=...`:

Retraction path

The unit for the retraction path refers to the current valid unit of measurement (mm or inch).

Input bit: 0

Effective: non-modal

`FMA[2,<axis>]=... to`
`FMA[7,<axis>]=...:`

The axial feedrate is programmed under the address `FA` and remains valid during the absence of an input signal.

In addition to the axial feedrate `FA` up to 6 further feedrates per axis can be programmed in the block with `FMA`. The first parameter indicates the bit number of the input and the second the axis for which the feedrate is to apply.

Effective:	non-modal

`STA[<axis>]=...:`

Axial dwell time in s (for grinding technology: sparking-out time)

Input bit:	1
Effective:	non-modal

`SRA[<axis>]=...:`

Axial retraction path

Input bit:	0
Effective:	non-modal

Note

If input bit 1 is activated for the dwell time or bit 0 for the return path, the distance to go for the path axes or the relevant single axes is deleted and the dwell time or return started.

Note

The axial feedrate (`FA` or `FMA` value) or path feedrate (`F` value) corresponds to 100% feedrate. The "Multiple feedrate values in one block" function can be used to achieve feedrates smaller than or equal to the axial feedrate or path feedrate.

Note

If feedrates, dwell time or return path are programmed for an axis on account of an external input, this axis must not be programmed as POSA axis (positioning axis over multiple blocks) in this block.

Note

Look Ahead is also active for multiple feedrates in one block. In this way, the current feedrate is restricted by the Look Ahead value.

Examples

Example 1: Path motion

Program code	Comment
F7=1000	; 7 corresponds to input bit 7
F2=20	; 2 corresponds to input bit 2
ST=1	; Dwell time (s) input bit 1
SR=0.5	; Return path (mm) input bit 0

Example 2: Axial motion

Program code	Comment
FMA[3,x]=1000	; Axial feedrate with the value 1,000 for X axis, 3 corresponds to input bit 3.

Example 3: Multiple operations in one block

Program code	Comment
N20 T1 D1 F500 G0 X100	; Initial setting
N25 G1 X105 F=20 F7=5 F3=2.5 F2=0.5 ST=1.5 SR=0.5	; Normal feedrate with F, roughing with F7, finishing with F3, smooth-finishing with F2, dwell time 1.5 s, return path 0.5 mm
...	

7.11 Non-modal feedrate (FB)

Function

The "Non-modal feedrate" function can be used to define a separate feedrate for a single block. After this block, the previous modal feedrate is active again.

Syntax

```
FB=<value>
```

Significance

`FB`: Feedrate for current block only

`<VALUE>`: The programmed value must be greater than zero.
Values are interpreted based on the active feedrate type:

- G94: feedrate in mm/min or degrees/min
- G95: feedrate in mm/rev or inch/rev
- G96: Constant cutting rate

Note

If no traversing motion is programmed in the block (e.g. computation block), the `FB` has no effect.

If no explicit feedrate for chamfering/rounding is programmed, then the value of `FB` also applies for any chamfering/rounding contour element in this block.

Feedrate interpolations `FLIN`, `FCUB`, etc. are also possible without restriction.

Simultaneous programming of `FB` and `FD` (handwheel travel with feedrate override) or `F` (modal path feedrate) is **not** possible.

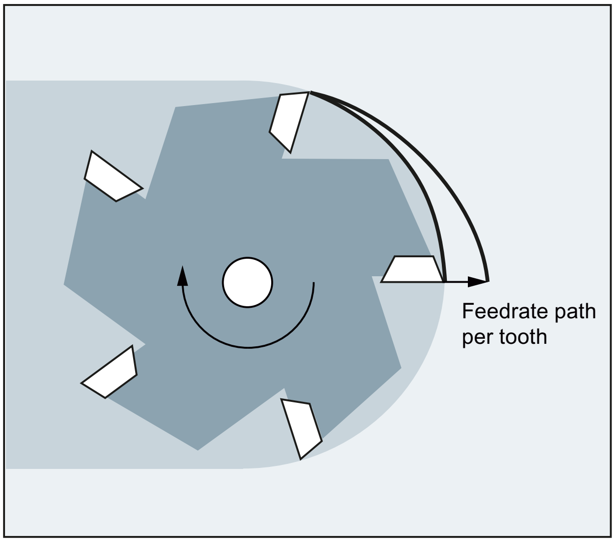
Example

Program code	**Comment**
`N10 G0 X0 Y0 G17 F100 G94`	`; Initial setting`
`N20 G1 X10`	`; Feedrate 100 mm/min`
`N30 X20 FB=80`	`; Feedrate 80 mm/min`
`N40 X30`	`; Feedrate is 100 mm/min again.`
`...`	

7.12 Tooth feedrate (G95 FZ)

Function

Primarily for milling operations, the tooth feedrate, which is more commonly used in practice, can be programmed instead of the revolutional feedrate:



The control uses the $TC_DPNT (number of teeth) tool parameter associated with the active tool offset data record to calculate the effective revolutional feedrate for each traversing block from the programmed tooth feedrate.

F = FZ * $TC_DPNT

where:	F:	Revolutional feedrate in mm/rev or inch/rev
	FZ:	Tooth feedrate in mm/tooth or inch/tooth
	$TC_DPNT:	Tool parameter: Number of teeth/rev

The tool type ($TC_DP1) of the active tool is not taken into account.

The programmed tooth feedrate is independent of the tool change and the selection/ deselection of a tool offset data record; it is retained in modal format.

A change to the $TC_DPNT tool parameter associated with the active tool cutting edge will be applied the next time a tool offset is selected or the next time the active offset data is updated.

Changing the tool or selecting/deselecting a tool offset data set generates a recalculation of the effective revolutional feedrate.

Note

The tooth feedrate refers only to the path (axis-specific programming is not possible).

Syntax

```
G95 FZ...
```

Note

In the block, G95 and FZ can be programmed together or in isolation.
There is no fixed programmed sequence.

Significance

G95:	Type of feedrate: Revolutional feedrate in mm/rev or inch/rev (dependent upon G700/G710) For G95 see "Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]"
FZ:	Tooth feedrate
	Activation: with G95
	Effective: modal
	Unit: mm/tooth or inch/tooth (dependent upon G700/G710)

Note

Switchover between G95 F... and G95 FZ...

Switching over between G95 F... (revolutional feedrate) and G95 FZ... (tooth feedrate) will delete the non-active feedrate value in each case.

Note

Derive feedrate with FPR

As is the case with the revolutional feedrate, FPR can also be used to derive the tooth feedrate of any rotary axis or spindle (see "Feedrate for positioning axes/spindles (FA, FPR, FPRAON, FPRAOF) [Page 133]").

CAUTION

Tool change/Changing the master spindle

A subsequent tool change or changing the master spindle must be taken into account by the user by means of corresponding programming, e.g. reprogramming FZ.

CAUTION

Technological concerns such as climb milling or conventional milling, front face milling or peripheral face milling, etc., along with the path geometry (straight line, circle, etc.), are not taken into account automatically. Therefore, these factors have to be given consideration when programming the tooth feedrate.

Examples

Example 1: Milling cutter with 5 teeth ($TC_DPNE = 5)

Program code	Comment
N10 G0 X100 Y50	
N20 G1 G95 FZ=0.02	; Tooth feedrate 0.02 mm/tooth
N30 T3 D1	; Load tool and activate tool offset data record.
M40 M3 S200	; Spindle speed 200 rpm

N50 X20	; Milling with:
	FZ = 0.02 mm/tooth
	? effective revolutional feedrate:
	F = 0.02 mm/tooth * 5 teeth/rev = 0.1 mm/rev
	or:
	F = 0.1 mm/rev * 200 rpm = 20 mm/min

…	

Example 2: Switchover between G95 F... and G95 FZ...

Program code	Comment
N10 G0 X100 Y50	
N20 G1 G95 F0.1	; Revolutional feedrate 0.1 mm/rev
N30 T1 M6	
N35 M3 S100 D1	
N40 X20	
N50 G0 X100 M5	
N60 M6 T3 D1	; Load tool with e.g. 5 teeth ($TC_DPNT = 5).
N70 X22 M3 S300	
N80 G1 X3 G95 FZ=0.02	; Change G95 F… to G95 FZ…, tooth feedrate active with 0.02 mm/tooth.
…	

Example 3: Derive tooth feedrate of a spindle (FBR)

Program code	Comment
…	
N41 FPR(S4)	; Tool in spindle 4 (not the master spindle).
N51 G95 X51 FZ=0.5	; Tooth feedrate 0.5 mm/tooth dependent upon spindle S4.
…	

Example 4: Subsequent tool change

Program code	Comment
`N10 G0 X50 Y5`	
`N20 G1 G95 FZ=0.03`	`; Tooth feedrate 0.03 mm/tooth`
`N30 M6 T11 D1`	`; Load tool with e.g. 7 teeth ($TC_DPNT = 7).`
`N30 M3 S100`	
`N40 X30`	`; Effective revolutional feedrate 0.21 mm/rev`
`N50 G0 X100 M5`	
`N60 M6 T33 D1`	`; Load tool with e.g. 5 teeth ($TC_DPNT = 5).`
`N70 X22 M3 S300`	

`N80 G1 X3`	`; Tooth feedrate modal 0.03 mm/tooth`
	`? effective revolutional feedrate: 0.15 mm/rev`

…	

Example 5: Changing the master spindle

Program code	Comment
`N10 SETMS (1)`	`; Spindle 1 is the master spindle.`
`N20 T3 D3 M6`	`; Tool 3 is changed to spindle 1.`
`N30 S400 M3`	`; Speed S400 of spindle 1 (and, therefore, T3).`
`N40 G95 G1 FZ0.03`	`; Tooth feedrate 0.03 mm/tooth`

`N50 X50`	`; Path motion, the effective feedrate is dependent upon:`
	`- The tooth feedrate FZ`
	`- The speed of spindle 1`
	`- The number of teeth of the active tool T3`

`N60 G0 X60`	
`...`	
`N100 SETMS(2)`	`; Spindle 2 becomes the master spindle.`
`N110 T1 D1 M6`	`; Tool 1 is changed to spindle 2.`
`N120 S500 M3`	`; Speed S500 of spindle 2 (and, therefore, T1).`

`N130 G95 G1 FZ0.03 X20`	`; Path motion, the effective feedrate is dependent upon:`
	`- The tooth feedrate FZ`
	`- The speed of spindle 2`
	`- The number of teeth of the active tool T1`

Note

Following the change in master spindle (`N100`) the user also has to select an offset affecting the tool actuated by spindle 2.

Further information

Changing between G93, G94 and G95

FZ can also be programmed when G95 is not active, although it will have no effect and is deleted when G95 is selected. In other words, when changing between G93, G94, and G95, in the same way as with F, the FZ value is also deleted.

Reselection of G95

Reselecting G95 when G95 is already active has no effect (unless a change between F and FZ has been programmed).

Non-modal feedrate (FB)

When G95 FZ... (modal) is active, a non-modal feedrate FB... is interpreted as a tooth feedrate.

SAVE mechanism

In subprograms with the SAVE attribute FZ is written to the value prior to the subprogram starting (in the same way as F).

Multiple feedrate values in one block

The "Multiple feedrate values in one block" function is not possible with tooth feedrate.

Synchronized actions

FZ cannot be programmed from synchronized actions.

Read tooth feedrate and path feedrate type

The tooth feedrate and the path feedrate type can be read using system variables.

- With preprocessing stop in the part program via system variables:

$AC_FZ Tooth feedrate effective when the current main run record was preprocessed.

$AC_F_TYPE Path feedrate type effective when the current main run record was preprocessed.

Value:	Significance:
0	mm/min
1	mm/rev
2	inch/min
3	inch/rev
11	mm/tooth
31	inch/tooth

- Without preprocessing stop in the part program via system variables:

$P_FZ Programmed tooth feedrate

$P_F_TYPE Programmed path feedrate type

Value:	Significance:
0	mm/min
1	mm/rev
2	inch/min
3	inch/rev
11	mm/tooth
31	inch/tooth

Note

If `G95` is not active, the $P_FZ and $AC_FZ variables will always return a value of zero.

Geometry settings 8

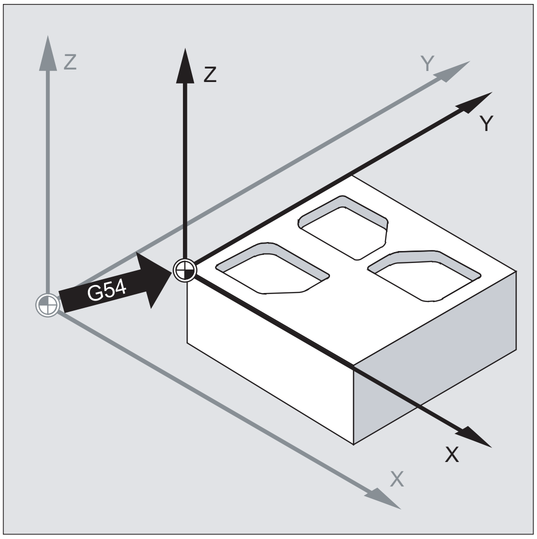
8.1 Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153)

Function

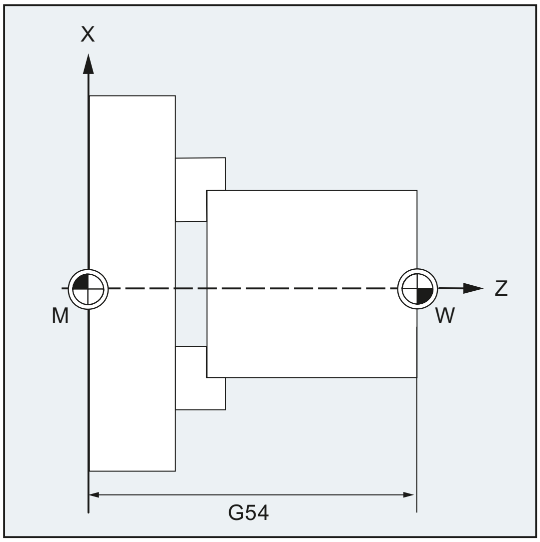
The workpiece zero in relation to the zero point of the basic coordinate system is set up by the settable zero offset (`G54` to `G57` and `G505` to `G599`) in all axes.

In this way it is possible to call zero points program-wide per G command (e.g. for different devices).

Milling:



Turning:



Note

During turning, for example, the offset value for returning of the chuck is entered in G54.

Syntax

Activating settable zero offset:

```
G54
...
G57
G505
...
G599
```

Deactivating settable zero offset:

```
G500
G53
G153
SUPA
```

Significance

`G54` to `G57`: Call of the 1st to 4th settable zero offset (ZO)

`G505` to `G599`: Call of the 5th to 99th settable zero offset

`G500`: Deactivation of the current settable zero offset

`G500`=zero frame: Deactivation of the settable zero offset until the next call, activation of the entire basic frame ($P_ACTBFRAME).

(default setting; contains no offset, rotation, mirroring or scaling)

`G500` not equal to 0: Activation of the first settable zero offset ($P_UIFR[0]) and activation of the entire basic frame ($P_ACTBFRAME) or possibly a modified basic frame is activated.

`G53`: `G53` suppresses the settable work offset and the programmable work offset non-modally.

`G153`: `G153` has the same effect as `G53` and also suppresses the entire basic frame.

`SUPA`: `SUPA` has the same effect as `G153` and also suppresses:

- Handwheel offsets (DRF)
- Overlaid movements
- External zero offset
- PRESET offset

References:
For programmable work offset, see Chapter "Coordinate transformations (frames) [Page 337]".

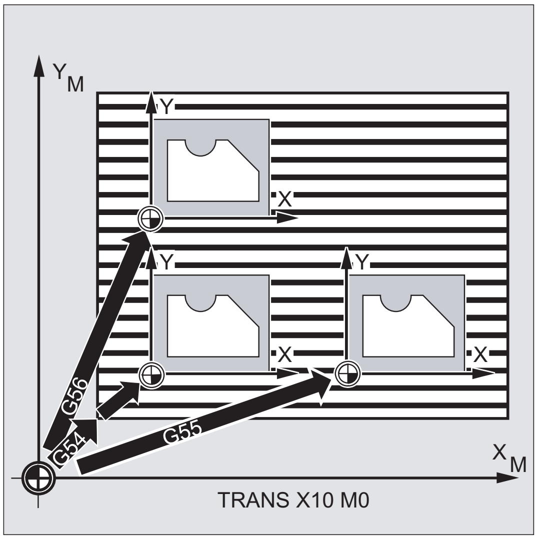
Note

The basic setting at the start of the program, e.g. `G54` or `G500`, can be set via machine data.

Note

For SINUMERIK 828D, the 5th/6th adjustable work offset is not called with `G505` or `G506`, but with `G58` or `G59`. The commands `G505` and `G506` are therefore not available for SINUMERIK 828D.

Example



3 workpieces that are arranged on a pallet in accordance with the zero offset values `G54` to `G56` are to be machined in succession. The machining sequence is programmed in subroutine L47.

Program code	Comment
N10 G0 G90 X10 Y10 F500 T1	; Approach
N20 G54 S1000 M3	; Call of the first ZO, spindle clockwise
N30 L47	; Program pass as subroutine
N40 G55 G0 Z200	; Call of the second ZO, Z via obstruction
N50 L47	; Program pass as subroutine
N60 G56	; Call of the third ZO
N70 L47	; Program pass as subroutine
N80 G53 X200 Y300 M30	; Suppress zero offset, end of program

See also

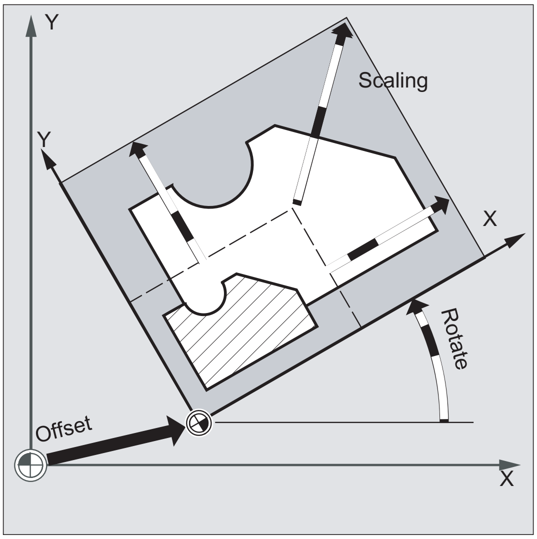
Axial zero offset (G58, G59) [Page 347]

Further information

Setting offset values

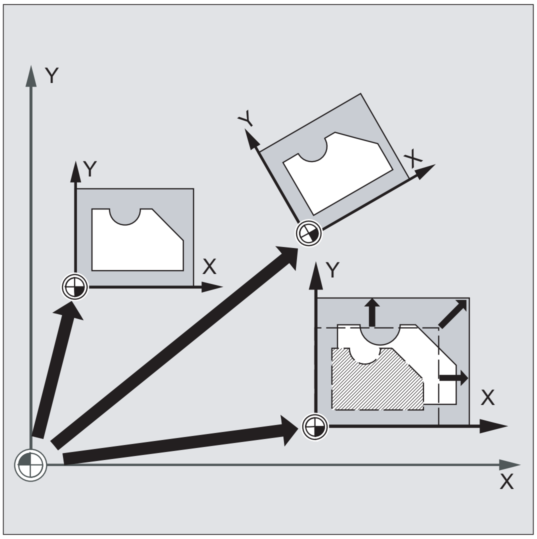
On the operator panel or universal interface, enter the following values in the internal control zero offset table:

- Coordinates for the offset
- Angle for rotated clamping
- Scaling factors (if required)



Zero offset G54 to G57

The call of one of the four commands `G54` to `G57` in the NC program moves the zero point from the basic coordinate system to the workpiece coordinate system.



In the next NC block with a programmed movement, all of the positional parameters and thus the tool movements refer to the workpiece zero, which is now valid.

Note

With the four available zero offsets, it is possible (e.g. for multiple machining) to simultaneously describe four workpiece clampings and call them in the program.

Further settable zero offsets: G505 to G599

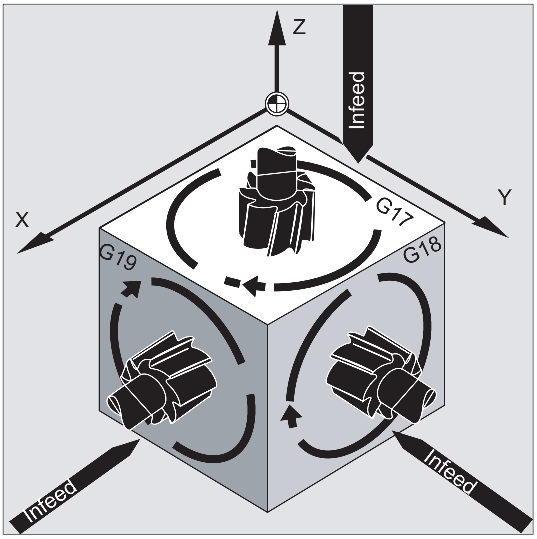
The command numbers `G505` to `G599` are available for further settable zero offsets. Therefore, a total of 100 settable zero offsets can be created in the zero point memory via machine data including the four preset zero offsets `G54` to `G57`.

8.2 Selection of the working plane (G17/G18/G19)

Function

The specification of the working plane, in which the desired contour is to be machined also defines the following functions:

- The plane for tool radius compensation
- The infeed direction for tool length compensation depending on the tool type
- The plane for circular interpolation



Syntax

```
G17
G18
G19
```

Meaning

`G17`:	Working plane X/Y Infeed direction Z, plane selection 1st - 2nd geometry axis
`G18`:	Working plane Z/X Infeed direction Y, plane selection 3rd - 1st geometry axis
`G19`:	Working plane Y/Z Infeed direction X, plane selection 2nd - 3rd geometry axis

Note

In the default setting, G17 (X/Y plane) is defined for milling and G18 (Z/X plane) is defined for turning.

When calling the tool path correction G41/G42 (see Chapter "Tool radius compensation [Page 277]"), the working plane must be defined so that the controller can correct the tool length and radius.

Example

The "conventional" approach for milling is:

1. Define working plane (`G17` default setting for milling).
2. Select tool type (`T`) and tool offset values (`D`).
3. Switch on path correction (`G41`).
4. Program traversing movements.

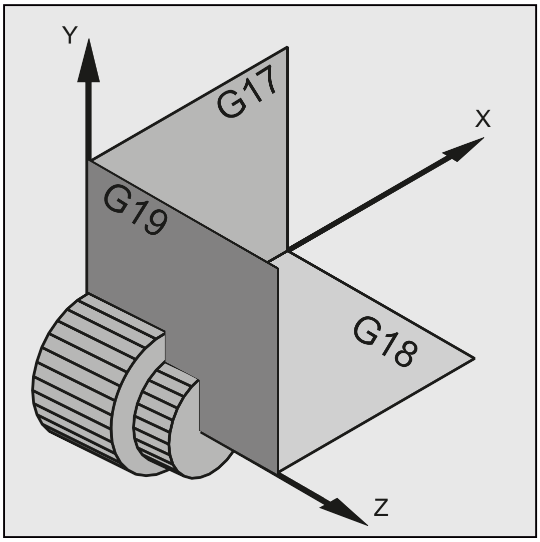
Program code	**Comment**
`N10 G17 T5 D8`	`; Selection of working plane X/Y, call tool. Tool length compensation is performed in the Z direction.`
`N20 G1 G41 X10 Y30 Z-5 F500`	`; Radius compensation is performed in the X/Y plane.`
`N30 G2 X22.5 Y40 I50 J40`	`; Circular interpolation/tool radius compensation in the X/Y plane.`

Further information

General

It is recommended that the working plane G17 to G19 be selected at the start of the program. In the default setting, the Z/X plane is preset for turning G18.

Turning:



The control requires the specification of the working plane for the calculation of the direction of rotation (see circular interpolation G2/G3).

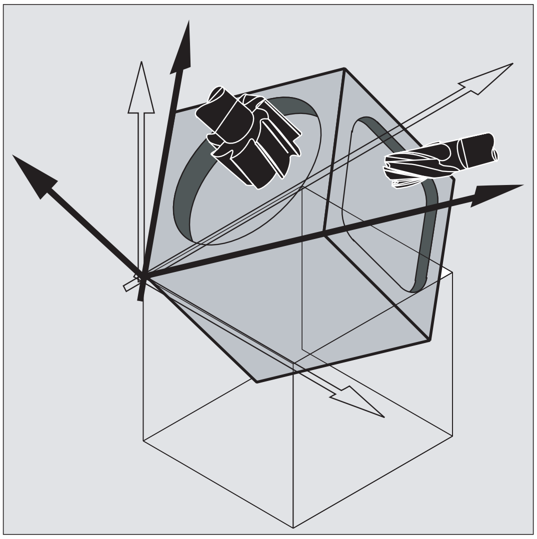
Machining on inclined planes

Rotate the coordinate system with `ROT` (see Section "Coordinate system offset") to position the coordinate axes on the inclined surface. The working planes rotate accordingly.

Tool length compensation on inclined planes

As a general rule, the tool length compensation always refers to the fixed, non-rotated working plane.

Milling:



Note

The tool length components can be calculated according to the rotated working planes with the functions for "Tool length compensation for orientable tools".

The compensation plane is selected with CUT2D, CUT2DF. For further information on this and for the description of the available calculation methods,see Chapter "Tool radius compensation [Page 277]".

The control provides convenient coordinate transformation functions for the spatial definition of the working plane. Please see Chapter "Coordinate transformations (frames) [Page 337]" for more information.

8.3 Dimensions

The basis of most NC programs is a workpiece drawing with specific dimensions.

These dimensions can be:

- In absolute dimensions or in incremental dimensions
- In millimeters or inches
- In radius or diameter (for turning)

Specific programming commands are available for the various dimension options so that the data from a dimension drawing can be transferred directly (without conversion) to the NC program.

8.3.1 Absolute dimensions (G90, AC)

Function

With absolute dimensions, the position specifications always refer to the zero point of the currently valid coordinate system, i.e. the absolute position is programmed, on which the tool is to traverse.

Modal absolute dimensions

Modal absolute dimensions are activated with the `G90` command. Generally it applies to all axes programmed in subsequent NC blocks.

Non-modal absolute dimensions

With preset incremental dimensions (`G91`), the `AC` command can be used to set non-modal absolute dimensions for individual axes.

Note

Non-modal absolute dimensions (`AC`) are also possible for spindle positioning (`SPOS`, `SPOSA`) and interpolation parameters (`I`, `J`, `K`).

Syntax

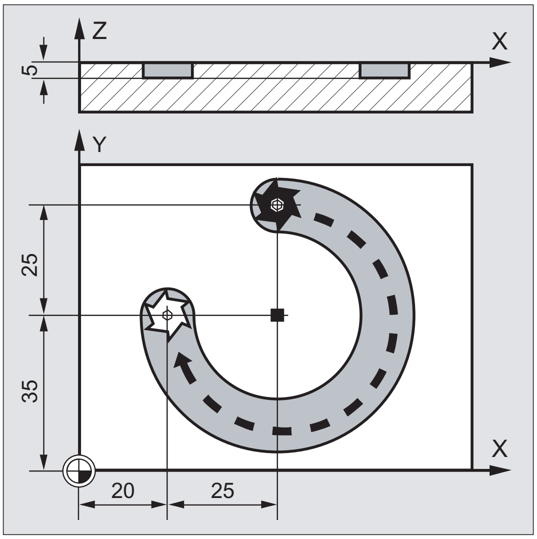
```
G90
<axis>=AC(<value>)
```

Significance

`G90`:	Command for the activation of modal absolute dimensions
`AC`:	Command for the activation of non-modal absolute dimensions
`<axis>`:	Axis identifier of the axis to be traversed
`<value>`:	Position setpoint of the axis to be traversed in absolute dimensions

Examples

Example 1: Milling

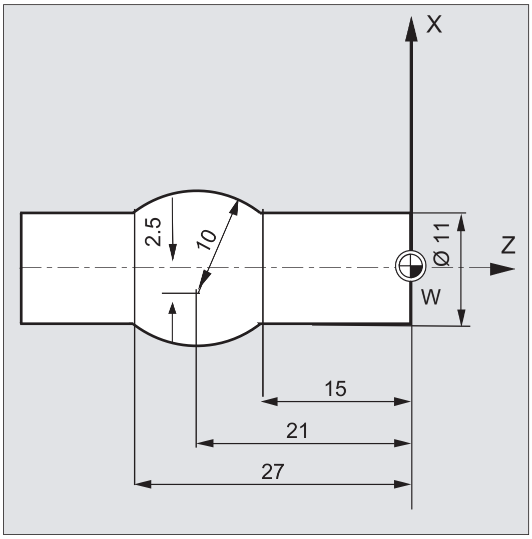


Program code	Comment
N10 G90 G0 X45 Y60 Z2 T1 S2000 M3	; Absolute dimension input, in rapid traverse to position XYZ, tool selection, spindle on with clockwise direction of rotation.
N20 G1 Z-5 F500	; Linear interpolation, feed of the tool.
N30 G2 X20 Y35 I=AC(45) J=AC(35)	; Clockwise circular interpolation, circle end point and circle center point in absolute dimensions.
N40 G0 Z2	; Traverse
N50 M30	; End of block

Note

For information on the input of the circle center point coordinates I and J, see Section "Circular interpolation".

Example 2: Turning



Program code	Comment
`N5 T1 D1 S2000 M3`	; Loading of tool T1, spindle on with clockwise direction of rotation.
`N10 G0 G90 X11 Z1`	; Absolute dimension input, in rapid traverse to position XZ.
`N20 G1 Z-15 F0.2`	; Linear interpolation, feed of the tool.
`N30 G3 X11 Z-27 I=AC(-5) K=AC(-21)`	; Counterclockwise circular interpolation, circle end point and circle center point in absolute dimensions.
`N40 G1 Z-40`	; Traverse
`N50 M30`	; End of block

Note

For information on the input of the circle center point coordinates I and J, see Section "Circular interpolation".

See also

Absolute and incremental dimensions for turning and milling (G90/G91) [Page 174]

8.3.2 Incremental dimensions (G91, IC)

Function

With incremental dimensions, the position specification refers to the last point approached, i.e. the programming in incremental dimensions describes by how much the tool is to be traversed.

Modal incremental dimensions

Modal incremental dimensions are activated with the `G91` command. Generally it applies to all axes programmed in subsequent NC blocks.

Non-modal incremental dimensions

With preset absolute dimensions (`G90`), the `IC` command can be used to set non-modal incremental dimensions for individual axes.

Note

Non-modal incremental dimensions (`IC`) are also possible for spindle positioning (`SPOS`, `SPOSA`) and interpolation parameters (`I`, `J`, `K`).

Syntax

```
G91
<axis>=IC(<value>)
```

Significance

`G91`:	Command for the activation of modal incremental dimensions
`IC`:	Command for the activation of non-modal incremental dimensions
`<axis>`:	Axis identifier of the axis to be traversed
`<value>`:	Position setpoint of the axis to be traversed in incremental dimensions

G91 extension

For certain applications, such as scratching, it is necessary that only the programmed distance is traversed in incremental dimensions. The active zero offset or tool length compensation is not traversed.

This behavior can be set separately for the active zero offset and tool length compensation via the following setting data:

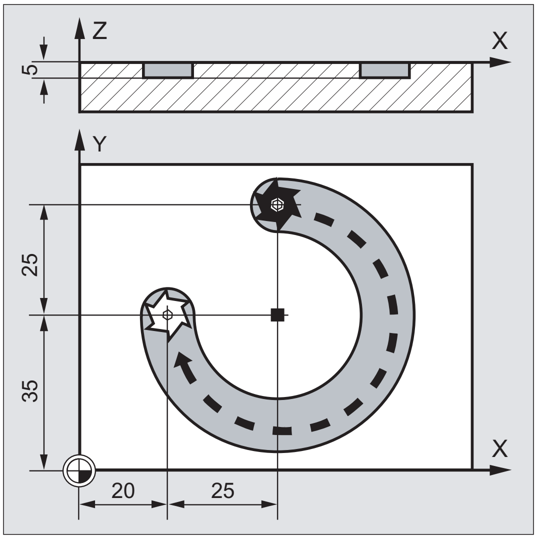
SD42440 $SC_FRAME_OFFSET_INCR_PROG (zero offsets in frames)

SD42442 $SC_TOOL_OFFSET_INCR_PROG (tool length compensations)

Value	Meaning
0	With incremental programming (incremental dimensions) of an axis, the zero offset or the tool length compensation is **not** traversed.
1	With incremental programming (incremental dimensions) of an axis, the zero offset or the tool length compensation is traversed.

Examples

Example 1: Milling

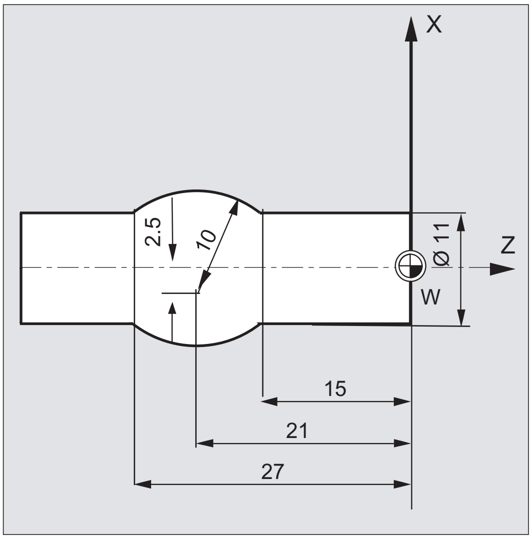


Program code	Comment
`N10 G90 G0 X45 Y60 Z2 T1 S2000 M3`	`; Absolute dimension input, in rapid traverse to position XYZ, tool selection, spindle on with clockwise direction of rotation`
`N20 G1 Z-5 F500`	`; Linear interpolation, feed of the tool.`
`N30 G2 X20 Y35 I0 J-25`	`; Clockwise circular interpolation, circle end point in absolute dimensions, circle center point in incremental dimensions.`
`N40 G0 Z2`	`; Traverse`
`N50 M30`	`; End of block`

Note

For information on the input of the circle center point coordinates I and J, see Section "Circular interpolation".

Example 2: Turning



Program code	Comment
`N5 T1 D1 S2000 M3`	`; Loading of tool T1, spindle on with clockwise direction of rotation.`
`N10 G0 G90 X11 Z1`	`; Absolute dimension input, in rapid traverse to position XZ.`
`N20 G1 Z-15 F0.2`	`; Linear interpolation, feed of the tool.`
`N30 G3 X11 Z-27 I-8 K-6`	`; Counterclockwise circular interpolation, circle end point in absolute dimensions, circle center point in incremental dimensions.`
`N40 G1 Z-40`	`; Traverse`
`N50 M30`	`; End of block`

Note

For information on the input of the circle center point coordinates I and J, see Section "Circular interpolation".

Example 3: Incremental dimensions without traversing of the active zero offset

Settings:

- G54 contains an offset in X of 25
- SD42440 $SC_FRAME_OFFSET_INCR_PROG = 0

Program code	Comment
`N10 G90 G0 G54 X100`	
`N20 G1 G91 X10`	`; Incremental dimensions active, traversing in X of 10 mm (the zero offset is not traversed).`
`N30 G90 X50`	`; Absolute dimensions active, traverse to position X75 (the zero offset is traversed).`

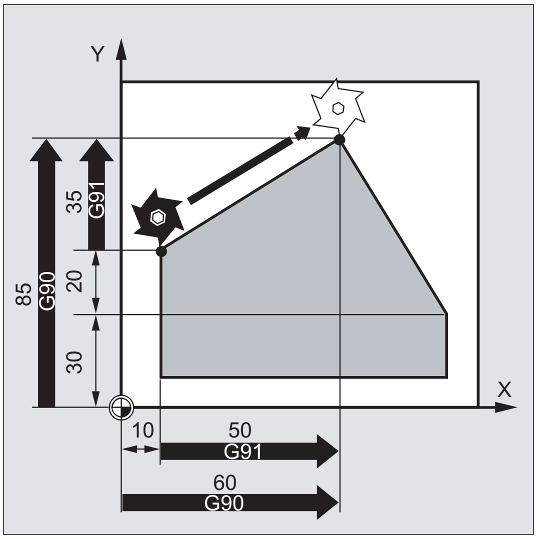
See also

Absolute and incremental dimensions for turning and milling (G90/G91) [Page 174]

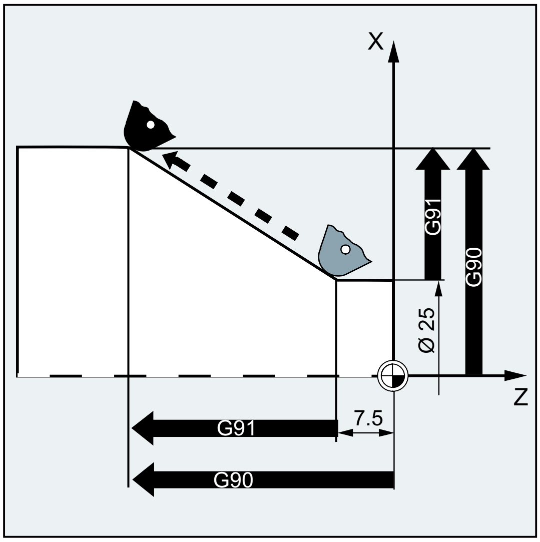
8.3.3 Absolute and incremental dimensions for turning and milling (G90/G91)

The two following figures illustrate the programming with absolute dimensions (`G90`) or incremental dimensions (`G91`) using turning and milling technology examples.

Milling:



Turning:



Note

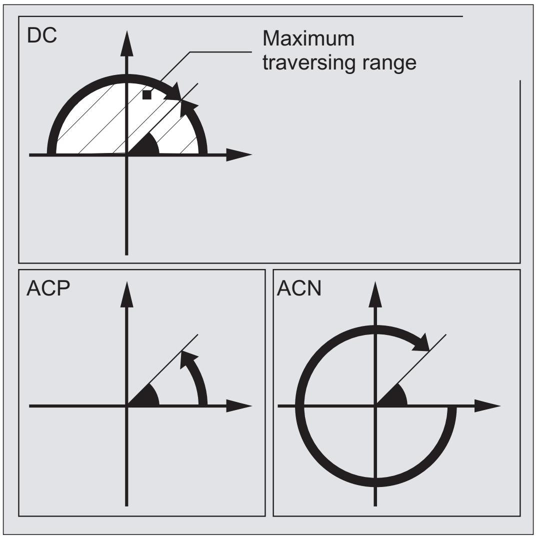
On conventional turning machines, it is usual to consider incremental traversing blocks in the transverse axis as radius values, while diameter specifications apply for the reference dimensions. This conversion for `G90` is performed using the commands `DIAMON`, `DIAMOF` or `DIAM90`.

8.3.4 Absolute dimension for rotary axes (DC, ACP, ACN)

Function

The non-modal and G90/G91-independent commands DC, ACP and ACN are available for the positioning of rotary axes in absolute dimensions.

DC, ACP and ACN differ in the basic approach strategy:



Syntax

```
<rotary axis>=DC(<value>)
<rotary axis>=ACP(<value>)
<rotary axis>=ACN(<value>)
```

Significance

<rotary axis>: Identifier of the rotary axis that is to be traversed (e.g. A, B or C)

DC: Command for the **direct** approach to the position

The rotary axis approaches the programmed position directly on the shortest path. The rotary axis traverses a maximum range of 180°.

ACP: Command to approach the position in a **positive** direction

The rotary axis traverses to the programmed position in the positive direction of axis rotation (counterclockwise).

ACN: Command to approach the position in a **negative** direction

The rotary axis traverses to the programmed position in the negative direction of axis rotation (clockwise).

<value>: Rotary axis position to be approached in absolute dimensions

Range of values: 0 - 360 degrees

Note

The positive direction of rotation (clockwise or counterclockwise) is set in the machine data.

Note

The traversing range between 0° and 360° must be set in the machine data (modulo behavior) for positioning with direction specification (`ACP`, `ACN`). `G91` or `IC` must be programmed to traverse modulo rotary axes more than 360° in a block.

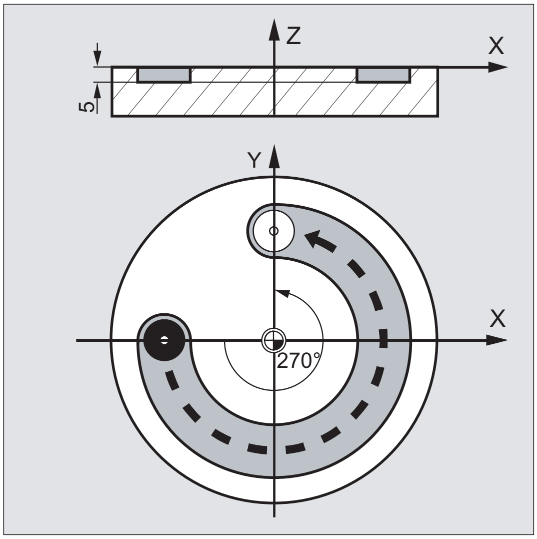
Note

The commands `DC`, `ACP` and `ACN` can also be used for spindle positioning (`SPOS`, `SPOSA`) from standstill.

Example: `SPOS=DC(45)`

Example

Milling on a rotary table



The tool is stationary, the table turns to 270° **in a clockwise direction** to produce a circular groove.

Program code	Comment
`N10 SPOS=0`	`; Spindle in position control`
`N20 G90 G0 X-20 Y0 Z2 T1`	`; Absolute dimensions, feed tool T1 in rapid traverse.`
`N30 G1 Z-5 F500`	`; Lower tool during feed`
`N40 C=ACP(270)`	`; Table turns clockwise to 270 degrees (positive), the tool mills a circular groove.`
`N50 G0 Z2 M30`	`; Retraction, end of program`

References

Function Manual, Extended Functions; Rotary Axes (R2)

8.3.5 Inch or metric dimensions (G70/G700, G71/G710)

Function

The following G functions can be used to switch between the metric measuring system and the inch measuring system.

Syntax

```
G70/G71
G700/G710
```

Significance

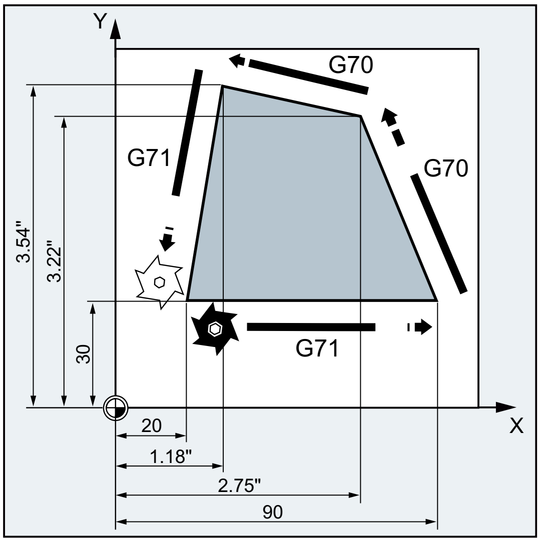
`G70`:	Activation of the inch measuring system The inch measuring system is used to read and write geometric data in units of length. Technological data in units of length, e.g. feedrates, tool offsets or settable work offsets, as well as machine data and system variables, are read and written using the parameterized basic system (MD10240 $MN_SCALING_SYSTEM_IS_METRIC).
`G71`:	Activation of the metric measuring system The metric measuring system is used to read and write geometric data in units of length. Technological data in units of length, e.g. feedrates, tool offsets or settable work offsets, as well as machine data and system variables, are read and written using the parameterized basic system (MD10240 $MN_SCALING_SYSTEM_IS_METRIC).
`G700`:	Activation of the inch measuring system All geometrical and technological data in units of length (see above) is read and written using the inch measuring system.
`G710`:	Activation of the metric measuring system All geometrical and technological data in units of length (see above) is read and written using the metric measuring system.

Example

Changeover between inch system and metric system

The parameterized basic system is metric:

MD10240 $MN_SCALING_SYSTEM_IS_METRIC = TRUE



Program code	Comment
N10 G0 G90 X20 Y30 Z2 S2000 M3 T1	; X=20 mm, Y=30 mm, Z=2 mm, F=rapid traverse mm/min
N20 G1 Z-5 F500	; Z=-5 mm, F=500 mm/min
N30 X90	; X=90 mm
N40 G70 X2.75 Y3.22	; Prog. meas. system: inch X=2.75 inch, Y=3.22 inch, F=500 mm/min
N50 X1.18 Y3.54	; X=1.18 inch, Y=3.54 inch, F=500 mm/min
N60 G71 X20 Y30	; Prog. meas. system: metric X=20 mm, Y=30 mm, F=500 mm/min
N70 G0 Z2	; Z=2 mm, F=rapid traverse mm/min
N80 M30	; End of program

Further information

G70/G71

With G70/G71 active, only the following geometric data is interpreted in the relevant measuring system:

- Position data (X, Y, Z, ...)
- Circular-path programming:
  - Interpolation point coordinates (I1, J1, K1)
  - Interpolation parameters (I, J, K)
  - Circle radius (CR)
- Pitch (G34, G35)
- Programmable zero offset (TRANS)
- Polar radius (RP)

Synchronized actions

If, in a synchronized action (condition component and/or action component) no explicit measuring system is programmed (G70/G71/G700/G710), the measuring system which was active in the channel at the point of execution will be applied to the synchronized action (condition component and/or action component).

NOTICE
Read position data in synchronized actions
If a measuring system has not been explicitly programmed in the synchronized action (condition component and/or action component) **position data specified in units of length** in the synchronized action are always read in the **parameterized basic system.**

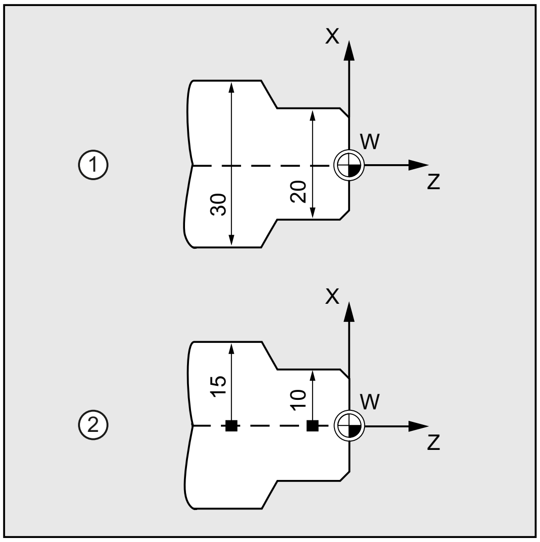
References

- Function Manual, Basic Functions; Speeds, Setpoint/Actual-Value System, Closed-Loop Control (G2), Section "Metric/inch dimension system"
- Programming Manual, Job Planning; Section "Motion-synchronous actions"
- Function Manual, Synchronized Actions

8.3.6 Channel-specific diameter/radius programming (DIAMON, DIAM90, DIAMOF, DIAMCYCOF)

Function

During turning, the dimensions **for the transverse axis** can be specified in the diameter (①) or in the radius (②):



So that the dimensions from a technical drawing can be transferred directly (without conversion) to the NC program, channel-specific diameter or radius programming is activated using the modal commands `DIAMON`, `DIAM90`, `DIAMOF`, and `DIAMCYCOF`.

Note

The channel-specific diameter/radius programming refers to the geometry axis defined as transverse axis via MD20100 $MC_DIAMETER_AX_DEF (→ see machine manufacturer's specifications).

Only one transverse axis per channel can be defined via MD20100.

Syntax

```
DIAMON
DIAM90
DIAMOF
```

Significance

DIAMON: Command for the activation of the **independent** channel-specific diameter programming

The effect of DIAMON is independent of the programmed dimensions mode (absolute dimensions G90 or incremental dimensions G91):

- for G90: Dimensions in the diameter
- for G91: Dimensions in the diameter

DIAM90: Command for the activation of the **dependent** channel-specific diameter programming

The effect of DIAM90 depends on the programmed dimensions mode:

- for G90: Dimensions in the diameter
- for G91: Dimensions in the radius

DIAMOF: Command for the deactivation of the channel-specific diameter programming

Channel-specific radius programming takes effect when diameter programming is deactivated. The effect of DIAMOF is independent of the programmed dimensions mode:

- for G90: Dimensions in the radius
- for G91: Dimensions in the radius

DIAMCYCOF: Command for the deactivation of channel-specific diameter programming during cycle processing.

In this way, computations in the cycle can always be made in the radius. The last G function active in this group remains active for the position indicator and the basic block indicator.

Note

With DIAMON or DIAM90, the transverse-axis actual values will always be displayed as a diameter. This also applies to reading of actual values in the workpiece coordinate system with MEAS, MEAW, $P_EP[x] and $AA_IW[x].

Example

Program code	Comment
`N10 G0 X0 Z0`	`; Approach starting point.`
`N20 DIAMOF`	`; Diameter programming off.`
`N30 G1 X30 S2000 M03 F0.7`	`; X axis = transverse axis, radius programming active; traverse to radius position X30.`
`N40 DIAMON`	`; The diameter programming is active for the transverse axis.`
`N50 G1 X70 Z-20`	`; Traverse to diameter position X70 and Z-20.`
`N60 Z-30`	
`N70 DIAM90`	`; Diameter programming for absolute dimensions and radius programming for incremental dimensions.`
`N80 G91 X10 Z-20`	`; Incremental dimensions active.`
`N90 G90 X10`	`; Absolute dimensions active.`
`N100 M30`	`; End of program.`

Further information

Diameter values (DIAMON/DIAM90)

The diameter values apply for the following data:

- Actual value display of the transverse axis in the workpiece coordinate system
- JOG mode: Increments for incremental dimensions and handwheel travel
- Programming of end positions:

  Interpolation parameters `I`, `J`, `K` for `G2`/`G3`, if these have been programmed absolutely with `AC`.

  If `I`, `J`, `K` are programmed incrementally (`IC`), the radius is always calculated.
- Reading actual values in the workpiece coordinate system for:

  `MEAS`, `MEAW`, `$P_EP[X]`, `$AA_IW[X]`

8.3.7 Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC)

Function

In addition to channel-specific diameter programming, the axis-specific diameter programming function enables the modal or non-modal dimensions and display in the diameter for one or more axes.

Note

The axis-specific diameter programming is only possible for axes that are permitted as further transverse axes for the axis-specific diameter programming via MD30460 $MA_BASE_FUNCTION_MASK (→ see machine manufacturer's specifications).

Syntax

Modal axis-specific diameter programming for several transverse axes in the channel:

```
DIAMONA[<axis>]
DIAM90A[<axis>]
DIAMOFA[<axis>]
DIACYCOFA[<axis>]
```

Acceptance of the channel-specific diameter/radius programming:

```
DIAMCHANA[<axis>]
DIAMCHAN
```

Non-modal axis-specific diameter/radius programming:

```
<axis>=DAC(<value>)
<axis>=DIC(<value>)
<axis>=RAC(<value>)
<axis>=RIC(<value>)
```

Meaning

Modal axis-specific diameter programming

`DIAMONA`: Command for the activation of the **independent** axis-specific diameter programming

The effect of `DIAMONA` is independent of the programmed dimensions mode (`G90`/`G91` or `AC`/`IC`):

- for G90, AC: Dimensions in the diameter
- for G91, IC: Dimensions in the diameter

`DIAM90A`: Command for the activation of the **dependent** axis-specific diameter programming

The effect of `DIAM90A` depends on the programmed dimensions mode:

- for G90, AC: Dimensions in the diameter
- for G91, IC: Dimensions in the radius

`DIAMOFA`: Command for the deactivation of the axis-specific diameter programming

Axis-specific radius programming takes effect when diameter programming is deactivated. The effect of `DIAMOFA` is independent of the programmed dimensions mode:

- for G90, AC: Dimensions in the radius
- for G91, IC: Dimensions in the radius

`DIACYCOFA`: Command for the deactivation of axis-specific diameter programming during cycle processing.

In this way, computations in the cycle can always be made in the radius. The last G function active in this group remains active for the position indicator and the basic block indicator.

`<axis>`: Axis identifier of the axis for which the axis-specific diameter programming is to be activated

Permitted axis identifiers are as follows:

- Geometry/channel axis name

  or

- Machine axis name

Range of values: The axis specified must be a known axis in the channel.

Other conditions:

- The axis must be permitted for the axis-specific diameter programming via MD30460 $MA_BASE_FUNCTION_MASK.
- Rotary axes are not permitted to serve as transverse axes.

Acceptance of the channel-specific diameter/radius programming

`DIAMCHANA`: With the `DIAMCHANA[<axis>]` command, the **specified axis** accepts the channel status of the diameter/radius programming and is then assigned to the channel-specific diameter/radius programming.

`DIAMCHAN`: With the `DIAMCHAN` command, **all** axes permitted for the axis-specific diameter programming accept the channel status of the diameter/radius programming and are then assigned to the channel-specific diameter/radius programming.

Non-modal axis-specific diameter/radius programming

The non-modal axis-specific diameter/radius programming specifies the dimension type as a diameter or radius value in the part program and synchronized actions. The modal status of diameter/radius programming remains unchanged.

`DAC`: The `DAC` command sets the following dimensions to non-modal for the specified axis:
Diameter in absolute dimensions

`DIC`: The `DIC` command sets the following dimensions to non-modal for the specified axis:
Diameter in incremental dimensions

`RAC`: The `RAC` command sets the following dimensions to non-modal for the specified axis:
Radius in absolute dimensions

`RIC`: The `RIC` command sets the following dimensions to non-modal for the specified axis:
Radius in incremental dimensions

Note

With `DIAMONA[<axis>]` or `DIAM90A[<axis>]`, the transverse-axis actual values are always displayed as a diameter. This also applies to reading of actual values in the workpiece coordinate system with `MEAS`, `MEAW`, `$P_EP[x]` and `$AA_IW[x]`.

Note

During the replacement of an additional transverse axis because of a `GET` request, the status of the diameter/radius programming in the other channel is accepted with `RELEASE[<axis>]`.

Examples

Example 1: Modal axis-specific diameter/radius programming

X is the transverse axis in the channel, axis-specific diameter programming is permitted for Y.

Program code	Comment
`N10 G0 X0 Z0 DIAMON`	`; Channel-specific diameter programming active for X.`
`N15 DIAMOF`	`; Channel-specific diameter programming off.`
`N20 DIAMONA[Y]`	`; Modal axis-specific diameter programming active for Y.`
`N25 X200 Y100`	`; Radius programming active for X.`
`N30 DIAMCHANA[Y]`	`; Y accepts the status of the channel-specific diameter/ radius programming and is assigned to this.`
`N35 X50 Y100`	`; Radius programming active for X and Y.`
`N40 DIAMON`	`; Channel-specific diameter programming on.`
`N45 X50 Y100`	`; Diameter programming active for X and Y.`

Example 2: Non-modal axis-specific diameter/radius programming

X is the transverse axis in the channel, axis-specific diameter programming is permitted for Y.

Program code	Comment
`N10 DIAMON`	`; Channel-specific diameter programming on.`
`N15 G0 G90 X20 Y40 DIAMONA[Y]`	`; Modal axis-specific diameter programming active for Y.`
`N20 G01 X=RIC(5)`	`; Dimensions effective in this block for X: Radius in incremental dimensions.`
`N25 X=RAC(80)`	`; Dimensions effective in this block for X: Radius in absolute dimensions.`

`N30 WHEN $SAA_IM[Y]> 50 DO POS[X]=RIC(1)`	`; X is command axis.`
	`Dimensions effective in this block for X: Radius in incremental dimensions.`

`N40 WHEN $SAA_IM[Y]> 60 DO POS[X]=DAC(10)`	`; X is command axis.`
	`Dimensions effective in this block for X: Radius in absolute dimensions.`

`N50 G4 F3`	

Further information

Diameter values (DIAMONA/DIAM90A)

The diameter values apply for the following data:

- Actual value display of the transverse axis in the workpiece coordinate system
- JOG mode: Increments for incremental dimensions and handwheel travel
- Programming of end positions:

  Interpolation parameters `I`, `J`, `K` for `G2`/`G3`, if these have been programmed absolutely with `AC`.

  If `I`, `J`, `K` are programmed incrementally (`IC`), the radius is always calculated.
- Reading actual values in the workpiece coordinate system for:

  `MEAS`, `MEAW`, `$P_EP[X]`, `$AA_IW[X]`

Non-modal axis-specific diameter programming (DAC, DIC, RAC, RIC)

The statements `DAC`, `DIC`, `RAC`, `RIC` are permissible for any commands for which channel-specific diameter programming is relevant:

- Axis position: `X...`, `POS`, `POSA`
- Oscillating: `OSP1`, `OSP2`, `OSS`, `OSE`, `POSP`
- Interpolation parameters: `I`, `J`, `K`
- Contour definition: Straight line with specified angle
- Rapid retraction: `POLF[AX]`
- Movement in tool direction: `MOVT`
- Smooth approach and retraction:

  `G140` to `G143`, `G147`, G148, `G247`, `G248`, `G347`, `G348`, `G340`, `G341`

8.4 Position of workpiece for turning

Axis identifiers

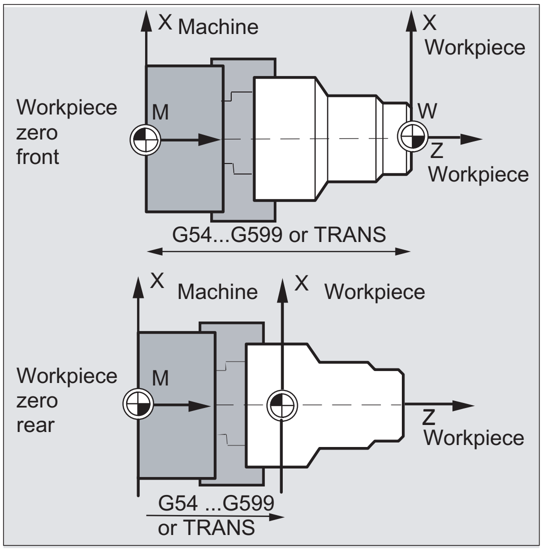
The two geometry axes perpendicular to one another are usually called:

Longitudinal axis	= Z axis (abscissa)
Transverse axis	= X axis (ordinate)

Workpiece zero

Whereas the machine zero is permanently defined, the workpiece zero can be freely selected on the longitudinal axis. Generally the workpiece zero is on the front or rear side of the workpiece.

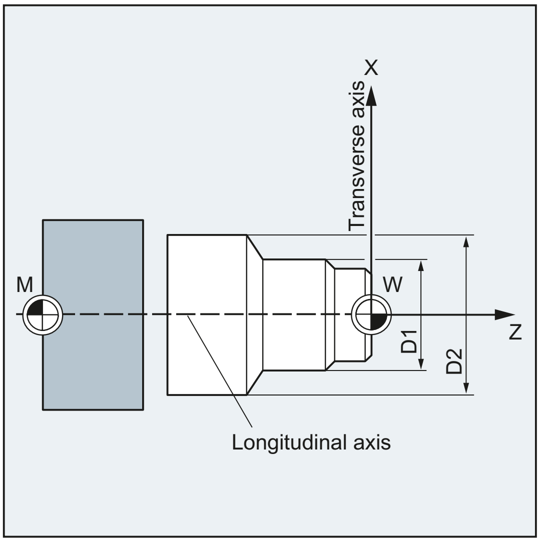
Both the machine and the workpiece zero are on the turning center. The settable offset on the X axis is therefore zero.



M	Machine zero
W	Workpiece zero
`Z`	Longitudinal axis
`X`	Transverse axis
`G54` to `G599` or `TRANS`	Call for the position of the workpiece zero

Transverse axis

Generally the dimensions for the transverse axis are diameter specifications (double path dimension compared to other axes):



The geometry axis that is to serve as transverse axis is defined in the machine data (→ machine manufacturer).

Motion commands 9

9.1 General information about the travel commands

Contour elements

The programmed workpiece contour can be made up of the following contour elements:

- Straight lines
- Circular arcs
- Helical curves (through overlaying of straight lines and circular arcs)

Travel commands

The following travel commands are available for the creation of these contour elements:

- Rapid traverse motion (`G0`)
- Linear interpolation (`G1`)
- Circular interpolation clockwise (`G2`)
- Circular interpolation counterclockwise (`G3`)

The travel commands are modal.

Target positions

A motion block contains the target positions for the axes to be traversed (path axes, synchronized axes, positioning axes).

The target positions can be programmed in Cartesian coordinates or in polar coordinates.

CAUTION
The axis address may only be programmed once per block.

Starting point - target point

The traversing motion is always for the last point reached to the programmed target position. This target position is then the starting position for the next travel command.

Workpiece contour

The motion blocks produce the workpiece contour when performed in succession:

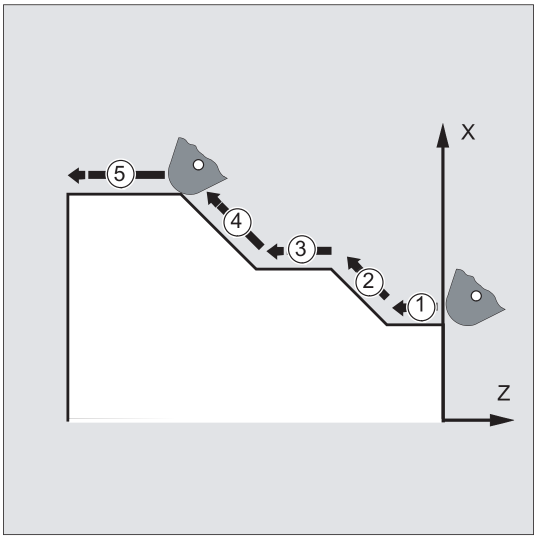


Figure 9-1 Motion blocks for turning

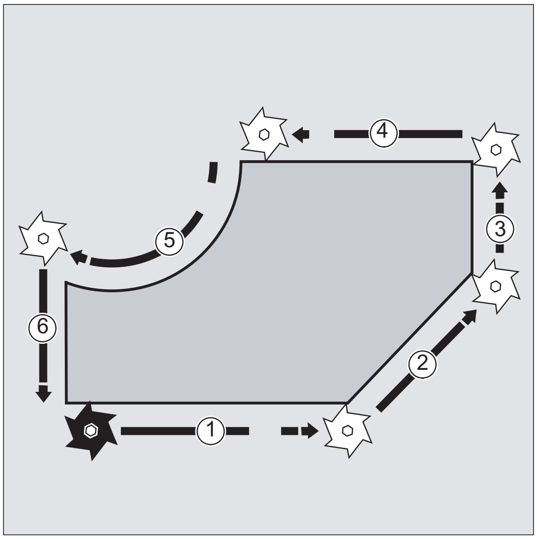


Figure 9-2 Motion blocks for milling

NOTICE
Before machining, the workpiece must be positioned in such a way that the tool or workpiece cannot be damaged.

9.2 Travel commands with Cartesian coordinates (G0, G1, G2, G3, X..., Y..., Z...)

Function

The position specified in the NC block with Cartesian coordinates can be approached with rapid traverse motion G0, linear interpolation G1 or circular interpolation G2 /G3.

Syntax

```
G0 X... Y... Z...
G1 X... Y... Z...
G2 X... Y... Z... ...
G3 X... Y... Z... ...
```

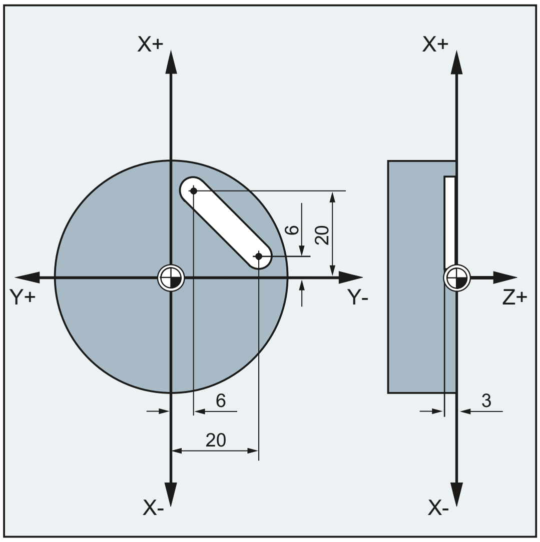
Significance

G0:	Command for the activation of the rapid traverse motion
G1:	Command for the activation of the linear interpolation
G2:	Command for the activation of the clockwise circular interpolation
G3:	Command for the activation of the counterclockwise circular interpolation
X...:	Cartesian coordinate of the target position in the X direction
Y...:	Cartesian coordinate of the target position in the Y direction
Z...:	Cartesian coordinate of the target position in the Z direction

Note

In addition to the coordinates of the target position X..., Y..., Z..., the circular interpolation G2 / G3 also requires further data (e.g. the circle center point coordinates; see "Circular interpolation types (G2/G3, ...) [Page 209]").

Example



Program code	Comment
`N10 G17 S400 M3`	; Selection of the working plane, spindle clockwise
`N20 G0 X40 Y-6 Z2`	; Approach of the starting position specified with Cartesian coordinates in rapid traverse
`N30 G1 Z-3 F40`	; Activation of the linear interpolation, feed of the tool
`N40 X12 Y-20`	; Travel on an inclined line to an end position specified with Cartesian coordinates
`N50 G0 Z100 M30`	; Retraction in rapid traverse for tool change

9.3 Travel commands with polar coordinates

9.3.1 Reference point of the polar coordinates (G110, G111, G112)

Function

The point from which the dimensioning starts is called the pole.

The pole can be specified in Cartesian or polar coordinates.

The reference point for the pole coordinates is clearly defined with the `G110` to `G112` commands. Absolute or incremental dimension inputs therefore have no effect.

Syntax

```
G110/G111/G112 X… Y… Z…
G110/G111/G112 AP=… RP=…
```

Significance

`G110 ...`: With the command `G110`, the following pole coordinates refer to **the last position reached.**

`G111 ...`: With the command `G111`, the following pole coordinates refer to **the zero point of the current workpiece coordinate system**.

`G112 ...`: With the command `G112`, the following pole coordinates refer to **the last valid pole**.

Note:
The commands `G110`...`G112` must be programmed in a separate NC block.

`X… Y… Z…`: Specification of the pole in Cartesian coordinates

`AP=… RP=…`: Specification of the pole in polar coordinates

- `AP=…`: Polar angle

  Angle between the polar radius and the horizontal axis of the working plane (e.g. X axis for `G17`). The positive direction of rotation runs counterclockwise.

  Range of values: ± 0…360°

- `RP=…`: Polar radius

  The specification is **always in absolute positive values** in [mm] or [inch].

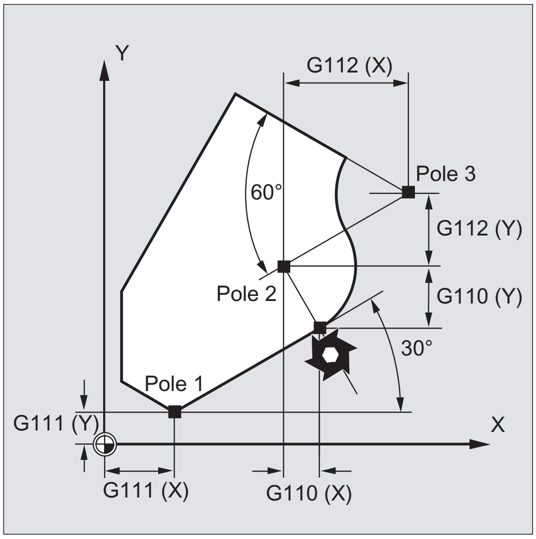
Note

It is possible to switch block-by-block in the NC program between polar and Cartesian dimensions. It is possible to return directly to the Cartesian system by using Cartesian coordinate identifiers (X..., Y..., Z...). The defined pole is moreover retained up to program end.

Note

If no pole has been specified, the zero point of the current workpiece coordinate system applies.

Example



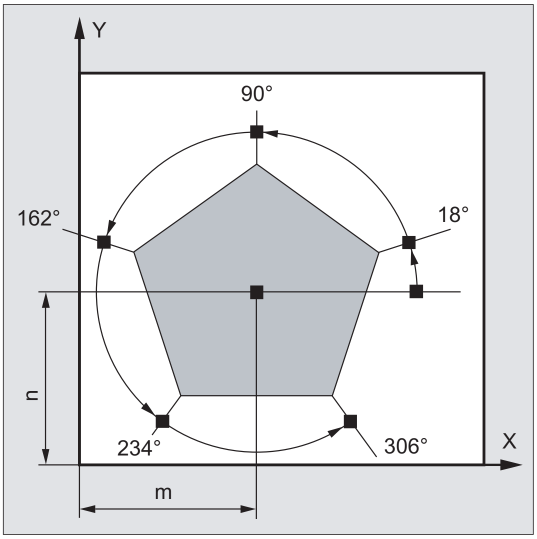
Poles 1 to 3 are defined as follows:

- Pole 1 with `G111 X… Y…`
- Pole 2 with `G110 X… Y…`
- Pole 3 with `G112 X… Y…`

9.3.2 Travel commands with polar coordinates (G0, G1, G2, G3, AP, RP)

Function

Travel commands with polar coordinates are useful when the dimensions of a workpiece or part of the workpiece are measured from a central point and the dimensions are specified in angles and radii (e.g. for drilling patterns).



Syntax

```
G0/G1/G2/G3 AP=… RP=…
```

Meaning

`G0`:	Command for the activation of rapid traverse motion
`G1`:	Command for the activation of linear interpolation
`G2`:	Command for the activation of clockwise circular interpolation
`G3`:	Command for the activation of counter-clockwise circular interpolation

`AP`: Polar angle

Angle between the polar radius and the horizontal axis of the working plane (e.g. X axis for `G17`). The positive direction of rotation runs counter-clockwise.

Range of values: ± 0…360°

The angle can be specified either incremental or absolute:

`AP=AC(...)`: Absolute dimension input

`AP=IC(...)`: Incremental dimension input

With incremental dimension input, the last programmed angle applies as reference.

The polar angle remains stored until a new pole is defined or the working plane is changed.

`RP`: Polar radius

The specification is **always in absolute positive values** in [mm] or [inch].

The polar radius remains stored until a new value is entered.

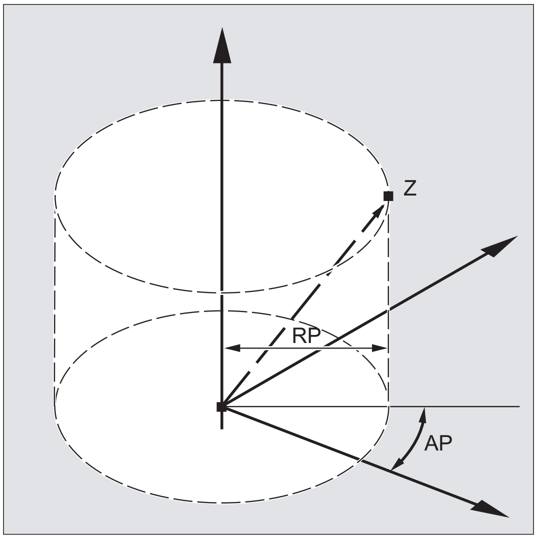
Note

The polar coordinates refer to the pole specified with `G110` ... `G112` and apply in the working plane selected with `G17` to `G19`.

Note

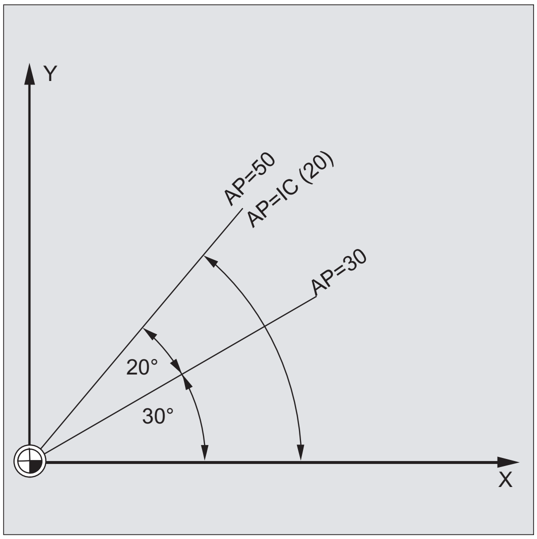
The 3rd geometry axis, which lies perpendicular to the working plane, can also be specified in Cartesian coordinates (see the following diagram). This enables spatial parameters to be programmed in cylindrical coordinates.

Example: `G17 G0 AP… RP… Z…`



General conditions

- No Cartesian coordinates such as interpolation parameters, axis addresses, etc. may be programmed for the selected working plane in NC blocks with polar end point coordinates.
- If a pole has not been defined with `G110` ... `G112`, then the zero point of the current workpiece coordinate system is automatically considered as the pole:



- Polar radius RP = 0

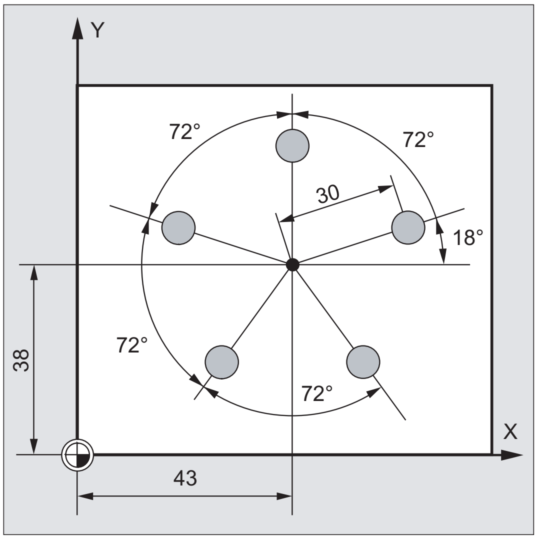
  The polar radius is calculated from the distance between the starting point vector in the pole plane and the active pole vector. The calculated polar radius is then saved as modal.

  This applies irrespective of the selected pole definition (`G110` ... `G112`). If both points have been programmed identically, this radius = 0 and alarm 14095 is generated.
- Only polar angle AP has been programmed

  If no polar radius RP has been programmed in the current block, but a polar angle AP, then when there is a difference between the current position and pole in the workpiece coordinates, this difference is used as polar radius and saved as modal. If the difference = 0, then the pole coordinates are specified again and the modal polar radius remains at zero.

Example

Creation of a drilling pattern



The positions of the holes are specified in polar coordinates.

Each hole is machined with the same production sequence:

Rough-drilling, drilling as dimensioned, reaming …

The machining sequence is stored in the subroutine.

Program code	**Comment**
`N10 G17 G54`	`; Working plane X/Y, workpiece zero.`
`N20 G111 X43 Y38`	`; Specification of the pole.`
`N30 G0 RP=30 AP=18 Z5G0`	`; Approach starting point, specification in cylindrical coordinates.`
`N40 L10`	`; Subprogram call.`
`N50 G91 AP=72`	`; Approach next position in rapid traverse, polar angle in incremental dimensions, polar radius from block N30 remains saved and does not have to be specified.`
`N60 L10`	`; Subprogram call.`
`N70 AP=IC(72)`	.
`N80 L10`	…
`N90 AP=IC(72)`	
`N100 L10`	…
`N110 AP=IC(72)`	
`N120 L10`	…
`N130 G0 X300 Y200 Z100 M30`	`; Retract tool, end of program.`
`N90 AP=IC(72)`	
`N100 L10`	…

See also

Circular interpolation types (G2/G3, ...) [Page 209]

9.4 Rapid traverse movement (G0, RTLION, RTLIOF)

Function

Rapid traverse motion is used:

- For rapid positioning of the tool
- To travel around the workpiece
- To approach tool change points
- To retract the tool

Non-linear interpolation is activated with the part program command `RTLIOF`, linear interpolation is activated with the part program command `RTLION`.

Note

The function is not suitable for workpiece machining!

Syntax

```
G0 X… Y… Z…
G0 AP=…
G0 RP=…
RTLIOF
RTLION
```

Significance

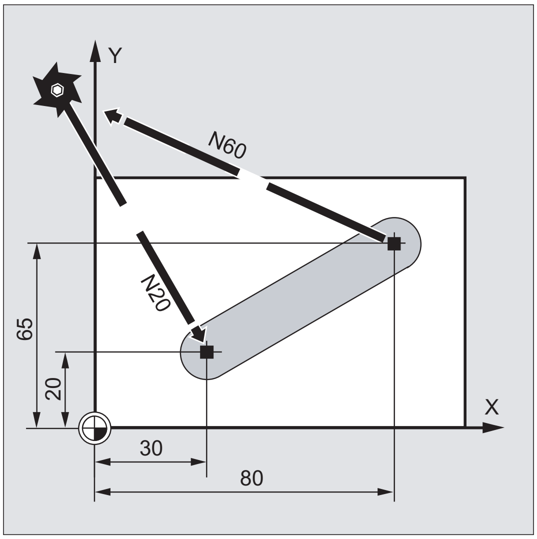
`G0`:	Command for the activation of the rapid traverse motion Active: modal
`X... Y... Z...`:	End point in Cartesian coordinates
`AP=...`:	End point in polar coordinates, in this case polar angle
`RP=...`:	End point in polar coordinates, in this case polar radius
`RTLIOF`:	Nonlinear interpolation (each path axis interpolates as a single axis)
`RTLION`:	Linear interpolation (path axes are interpolated together)

Note

`G0` cannot be replaced by G.

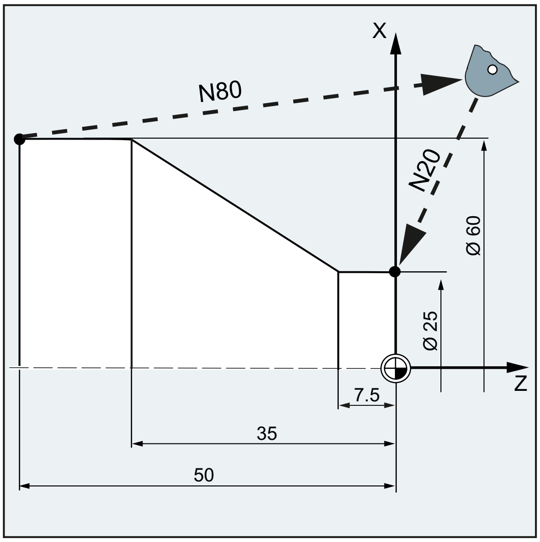
Examples

Example 1: Milling



Program code	Comment
`N10 G90 S400 M3`	`; Absolute dimension input, spindle clockwise`
`N20 G0 X30 Y20 Z2`	`; Approach of the starting position`
`N30 G1 Z-5 F1000G1`	`; Feed of the tool`
`N40 X80 Y65`	`; Travel on a straight line`
`N50 G0 Z2`	
`N60 G0 X-20 Y100 Z100 M30`	`; Retract tool, end of program`

Example 2: Turning

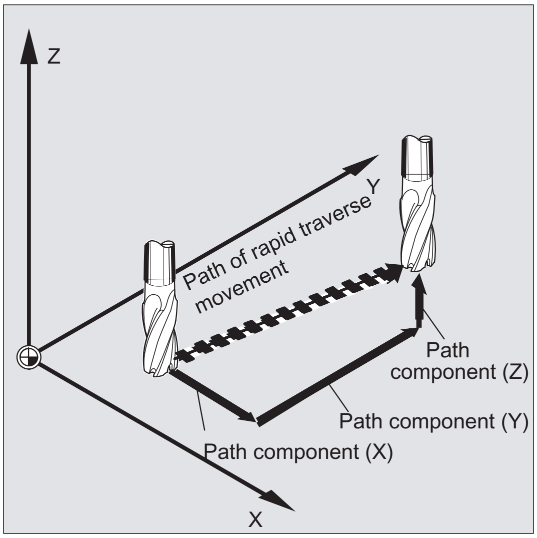


Program code	Comment
`N10 G90 S400 M3`	`; Absolute dimension input, spindle clockwise`
`N20 G0 X25 Z5`	`; Approach of the starting position`
`N30 G1 G94 Z0 F1000G1`	`; Feed of the tool`
`N40 G95 Z-7.5 F0.2`	
`N50 X60 Z-35`	`; Travel on a straight line`
`N60 Z-50`	
`N70 G0 X62`	
`N80 G0 X80 Z20 M30`	`; Retract tool, end of program`

Further information

Rapid traverse velocity

The tool movement programmed with `G0` is executed at the highest traversing speed (rapid traverse). The rapid traverse speed is defined separately for each axis in machine data. If the rapid traverse movement is executed simultaneously on several axes, the rapid traverse speed is determined by the axis, which requires the most time for its section of the path.



Traverse path axes as positioning axes with G0

Path axes can travel in one of two different modes to execute movements in rapid traverse:

- **Linear interpolation** (previous behavior):

  The path axes are interpolated together.

- **Non-linear interpolation**:

  Each path axis interpolates as a single axis (positioning axis) independently of the other axes of the rapid traverse motion.

With non-linear interpolation, the setting for the appropriate positioning axis (`BRISKA`, `SOFTA`, `DRIVEA`) applies with reference to the axial jerk.

NOTICE
Since a different contour can be traversed in nonlinear interpolation mode, synchronized actions that refer to coordinates of the original path are not operative in some cases!

Linear interpolation applies in the following cases:

- For a G-code combination with `G0` that does not permit positioning axis motion (e.g. `G40`/ `G41`/`G42`)
- For a combination of `G0` with `G64`
- When the compressor is active
- When a transformation is active

Example:

Program code
`G0 X0 Y10`
`G0 G40 X20 Y20`
`G0 G95 X100 Z100 M3 S100`

Path POS[X]=0 POS[Y]=10 is traversed in path mode. No revolutional feedrate is active if path POS[X]=100 POS[Z]=100 is traversed.

Settable block change time with G0

For single-axis interpolation, a new end-of-motion criterion `FINEA` or `COARSEA` or `IPOENDA` can be set for block change even within the braking ramp.

Consecutive axes are handled in G0 like positioning axes.

With the combination of

- "Block change settable in the braking ramp of the single axis interpolation" and
- "Traversing path axes in rapid traverse movement as positioning axes with G0"

all axes can travel to their end point independently of one another. In this way, two sequentially programmed X and Z axes are treated like positioning axes in conjunction with G0.

The block change to axis Z can be initiated by axis X as a function of the braking ramp time setting (100-0%). Axis Z starts to move while axis X is still in motion. Both axes approach their end point independently of one another.

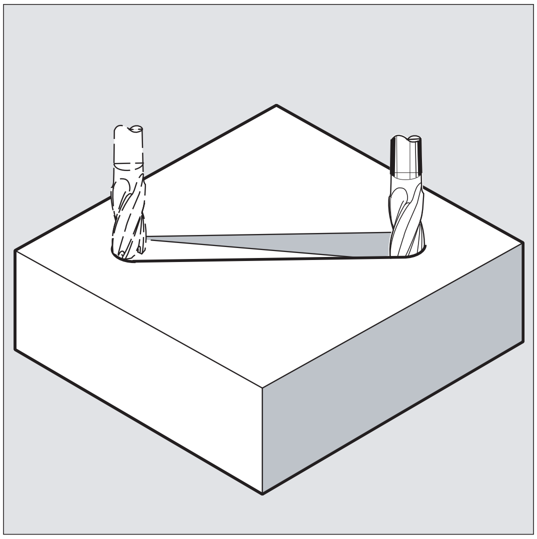
For further information, please refer to "Feed control and spindle motion".

9.5 Linear interpolation (G1)

Function

With `G1` the tool travels on paraxial, inclined or straight lines arbitrarily positioned in space. Linear interpolation permits machining of 3D surfaces, grooves, etc.

Milling:



Syntax

```
G1 X… Y… Z … F…
G1 AP=… RP=… F…
```

Significance

`G1:`	Linear interpolation with feedrate (linear interpolation)
`X... Y... Z...:`	End point in Cartesian coordinates
`AP=...:`	End point in polar coordinates, in this case polar angle
`RP=...:`	End point in polar coordinates, in this case polar radius
`F...:`	Feedrate in mm/min. The tool travels at feedrate F along a straight line from the current starting point to the programmed destination point. You can enter the destination point in Cartesian or polar coordinates. The workpiece is machined along this path. Example: `G1 G94 X100 Y20 Z30 A40 F100` The end point on X, Y, Z is approached at a feedrate of 100 mm/min; the rotary axis A is traversed as a synchronized axis, ensuring that all four movements are completed at the same time.

Note

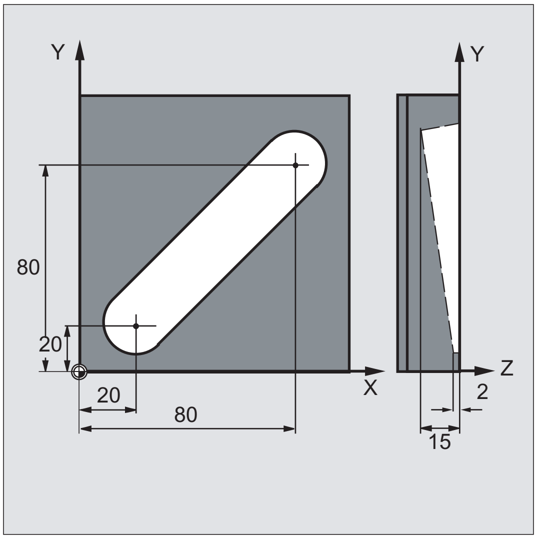
G1 is modal.

Spindle speed S and spindle direction M3/M4 must be specified for the machining.

Axis groups, for which path feedrate F applies, can be defined with FGROUP. You will find more information in the "Path behavior" section.

Examples

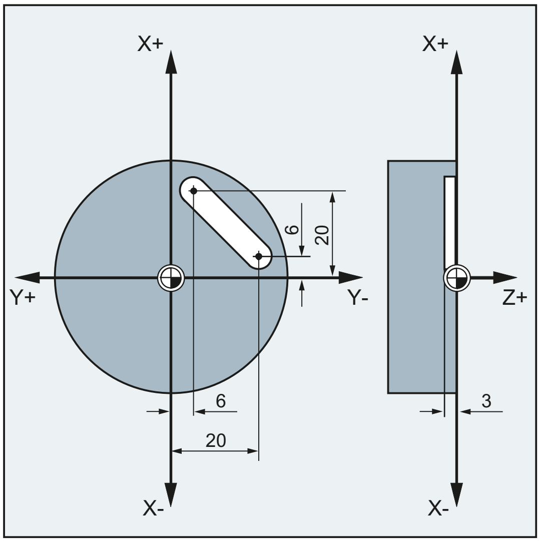
Example 1: Machining of a groove (milling)



The tool travels from the starting point to the end point in the X/Y direction. Infeed takes place simultaneously in the Z direction.

Program code	Comment
N10 G17 S400 M3	; Selection of the working plane, spindle clockwise
N20 G0 X20 Y20 Z2	; Approach of the starting position
N30 G1 Z-2 F40	; Feed of the tool
N40 X80 Y80 Z-15	; Travel on an inclined line
N50 G0 Z100 M30	; Retraction for tool change

Example 2: Machining of a groove (turning)



Program code	Comment
N10 G17 S400 M3	; Selection of the working plane, spindle clockwise
N20 G0 X40 Y-6 Z2	; Approach of the starting position
N30 G1 Z-3 F40	; Feed of the tool
N40 X12 Y-20	; Travel on an inclined line
N50 G0 Z100 M30	; Retraction for tool change

9.6 Circular interpolation

9.6.1 Circular interpolation types (G2/G3, ...)

Possibilities of programming circular movements

The control provides a range of different ways to program circular movements. This allows you to implement almost any type of drawing dimension directly. The circular movement is described by the:

- Center point and end point in the absolute or incremental dimension (default)
- Radius and end point in Cartesian coordinates
- Opening angle and end point in Cartesian coordinates or center point under the addresses
- Polar coordinates with the polar angle AP= and the polar radius RP=
- Intermediate and end point
- End point and tangent direction at the start point.

Syntax

`G2/G3 X… Y… Z…`
`I=AC(…) J=AC(…) K=AC(…) ;`
	Absolute center point and end point with reference to the workpiece zero

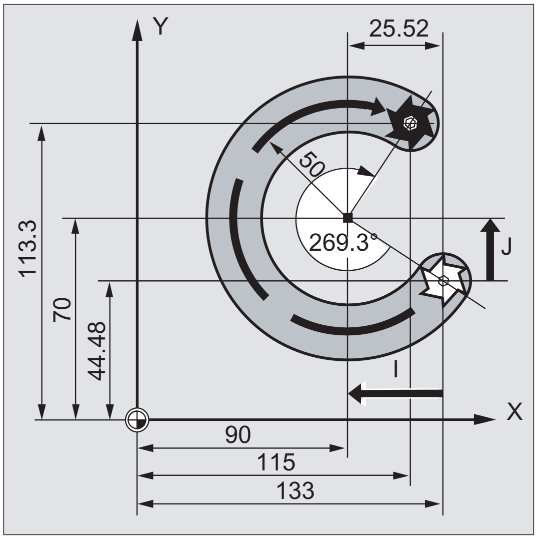
`G2/G3 X… Y… Z… I… J… K… ;`	Center point in incremental dimensions with reference to the circle starting point
`G2/G3 X… Y… Z… CR=… ;`	Circle radius CR= and circle end position in Cartesian coordinates X..., Y..., Z...
`G2/G3 X… Y… Z… AR=… ;`	Opening angle AR= end point in Cartesian coordinates X..., Y..., Z...
`G2/G3 I… J… K… AR=… ;`	Opening angle AR= center point at addresses I..., J..., K...
`G2/G3 AP=… RP=… ;`	Polar coordinates with the polar angle AP= and the polar radius RP=
`CIP X… Y… Z… I1=AC(…) J1=AC(…) K1=(AC…) ;`	The intermediate point at addresses I1=, J1=, K1=
`CT X… Y… Z… ;`	Circle through starting and end point and tangent direction at starting point

Significance

`G2`:	Circular interpolation, clockwise
`G3`:	Circular interpolation, counterclockwise
`CIP`:	Circular interpolation through intermediate point
`CT`:	Circle with tangential transition defines the circle
`X Y Z`:	End point in Cartesian coordinates
`I J K`:	Circle center point in Cartesian coordinates in X, Y, Z direction
`CR=`:	Circle radius
`AR=`:	Opening angle
`AP=`:	End point in polar coordinates, in this case polar angle
`RP=`:	End point in polar coordinates, in this case polar radius corresponding to circle radius
`I1= J1= K1=`:	Intermediate points in Cartesian coordinates in X, Y, Z direction

Examples

Example 1: Milling

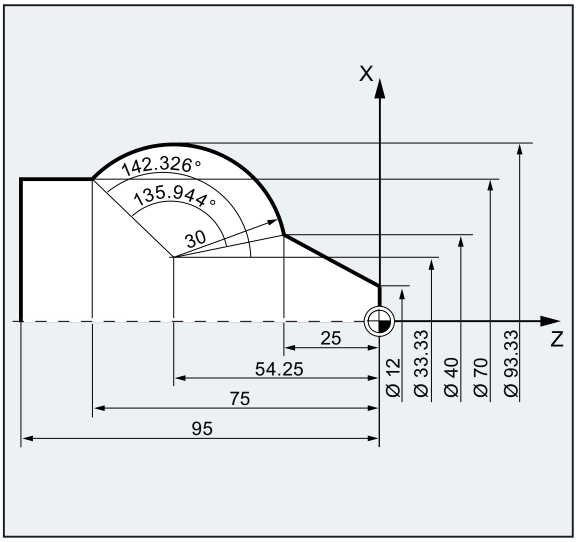


The following program lines contain an example for each circular-path programming possibility. The necessary dimensions are shown in the production drawing on the right.

Program code	Comment
`N10 G0 G90 X133 Y44.48 S800 M3`	`; Approach starting point`
`N20 G17 G1 Z-5 F1000`	`; Feed of the tool`
`N30 G2 X115 Y113.3 I-43 J25.52`	`; Circle end point, center point in incremental dimensions`
`N30 G2 X115 Y113.3 I=AC(90) J=AC(70)`	`; Circle end point, center point in absolute dimensions`
`N30 G2 X115 Y113.3 CR=-50`	`; Circle end point, circle radius`
`N30 G2 AR=269.31 I-43 J25.52`	`; Opening angle, center point in incremental dimensions`

```
Program code                              Comment
N30 G2 AR=269.31 X115 Y113.3              ; Opening angle, circle end point
N30 N30 CIP X80 Y120 Z-10                 ; Circle end point and intermediate point
 I1=IC(-85.35) J1=IC(-35.35) K1=-6        ; Coordinates for all three geometry axes
N40 M30                                   ; End of program
```

Example 2: Turning

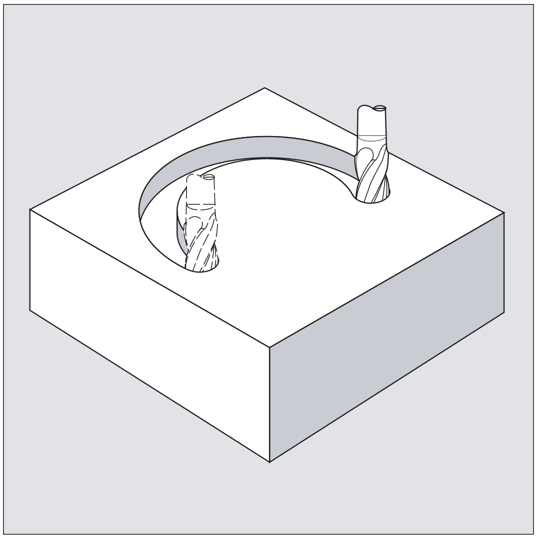


```
Program code                                       Comment
N.. ...
N120 G0 X12 Z0
N125 G1 X40 Z-25 F0.2
N130 G3 X70 Y-75 I-3.335 K-29.25                   ; Circle end point, center point
                                                     in incremental dimensions
N130 G3 X70 Y-75 I=AC(33.33) K=AC(-54.25)          ; Circle end point, center point
                                                     in absolute dimensions
N130 G3 X70 Z-75 CR=30                             ; Circle end point, circle
                                                     radius
N130 G3 X70 Z-75 AR=135.944                        ; Opening angle, circle end
                                                     point
N130 G3 I-3.335 K-29.25 AR=135.944                 ; Opening angle, center point in
                                                     incremental dimensions
N130 G3 I=AC(33.33) K=AC(-54.25) AR=135.944        ; Opening angle, center point in
                                                     absolute dimensions
N130 G111 X33.33 Z-54.25                           ; Polar coordinates
N135 G3 RP=30 AP=142.326                           ; Polar coordinates
N130 CIP X70 Z-75 I1=93.33 K1=-54.25               ; Circular arc with intermediate
                                                     point and end point
N140G1 Z-95
N.. ...
N40 M30                                            ; End of program
```

9.6.2 Circular interpolation with center point and end point (G2/G3, X... Y... Z..., I... J... K...)

Function

Circular interpolation enables machining of full circles or arcs.



The circular movement is described by:

- The end point in Cartesian coordinates X, Y, Z and
- The circle center point at addresses I, J, K.

If the circle is programmed with a center point but no end point, the result is a full circle.

Syntax

```
G2/G3 X… Y… Z… I… J… K…
G2/G3 X… Y… Z… I=AC(…) J=AC(…) K=(AC…)
```

Significance

`G2`:	Circular interpolation clockwise
`G3`:	Circular interpolation counter-clockwise
`X Y Z`:	End point in Cartesian coordinates
`I`:	Coordinates of the circle center point in the X direction
`J`:	Coordinates of the circle center point in the Y direction
`K`:	Coordinates of the circle center point in the Z direction
`=AC(…)`:	Absolute dimensions (non-modal)

Note

`G2` and `G3` are modal.

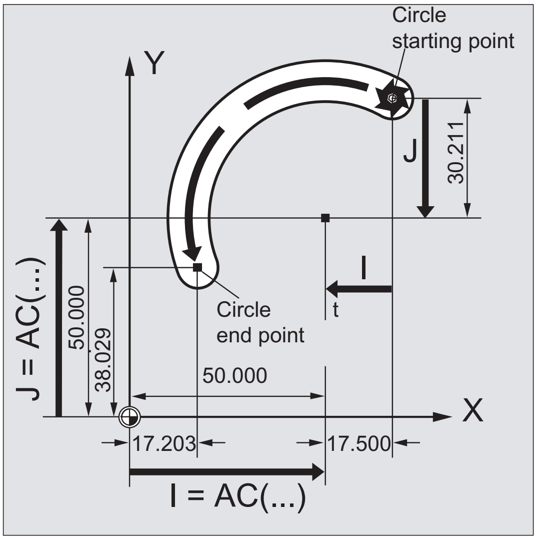
The default settings `G90`/`G91` absolute and incremental dimensions are only valid for the circle end point.

Per default, the center point coordinates `I`, `J`, `K` are entered in incremental dimensions in relation to the circle starting point.

You can program the absolute center point dimensions in relation to the workpiece zero block-by-block with: `I=AC(…)`, `J=AC(…)`, `K=AC(…)`. One interpolation parameter `I`, `J`, `K` with value 0 can be omitted, but the associated second parameter must always be specified.

Examples

Example 1: Milling



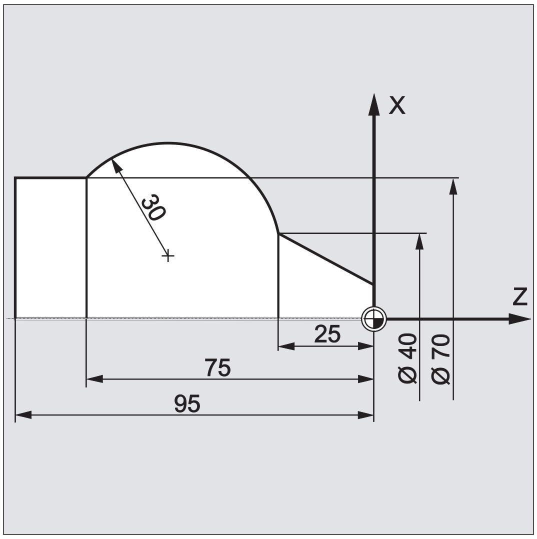
Center point data using incremental dimensions

```
N10 G0 X67.5 Y80.211
N20 G3 X17.203 Y38.029 I-17.5 J–30.211 F500
```

Center point data using absolute dimensions

```
N10 G0 X67.5 Y80.211
N20 G3 X17.203 Y38.029 I=AC(50) J=AC(50)
```

Example 2: Turning



Center point data using incremental dimensions

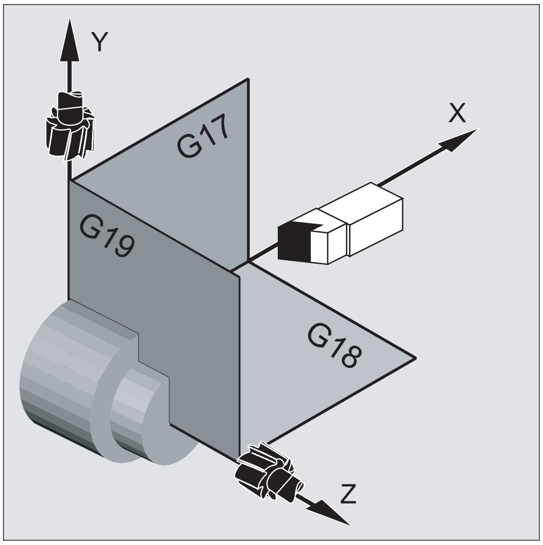
```
N120 G0 X12 Z0
N125 G1 X40 Z-25 F0.2
N130 G3 X70 Z-75 I-3.335 K-29.25
N135 G1 Z-95
```

Center point data using absolute dimensions

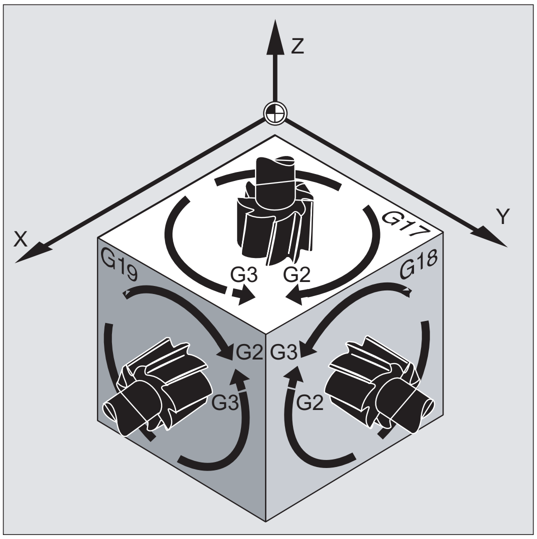
```
N120 G0 X12 Z0
N125 G1 X40 Z-25 F0.2
N130 G3 X70 Z-75 I=AC(33.33) K=AC(-54.25)
N135 G1 Z-95
```

Further information

Indication of working plane



The control needs the working plane parameter (`G17` to `G19`) to calculate the direction of rotation for the circle (`G2` is clockwise or `G3` is counter-clockwise).



It is advisable to specify the working plane generally.

Exception:

You can also machine circles outside the selected working plane (not with arc angle and helix parameters). In this case, the axis addresses that you specify as an end point determine the circle plane.

Programmed feedrate

`FGROUP` can be used to specify which axes are to be traversed with a programmed feedrate. For more information please refer to the Path behavior section.

9.6.3 Circular interpolation with radius and end point (G2/G3, X... Y... Z.../ I... J... K..., CR)

Function

The circular motion is described by the:

- Circle radius `CR=`**and**
- End point in Cartesian coordinates `X`, `Y`, `Z`.

In addition to the circle radius, you must also specify the leading sign +/– to indicate whether the traversing angle is to be greater than or less than 180°. A positive leading sign can be omitted.

> **Note**
>
> There is no practical limitation on the maximum size of the programmable radius.

Syntax

```
G2/G3 X… Y… Z… CR=
G2/G3 I… J… K… CR=
```

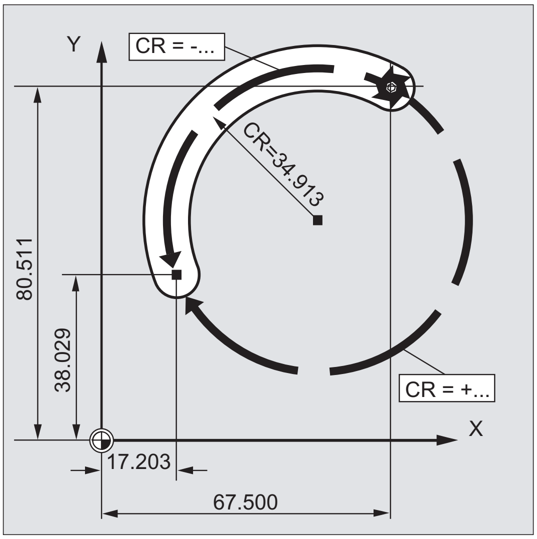
Significance

`G2`:	Circular interpolation clockwise
`G3`:	Circular interpolation counter-clockwise
`X Y Z`:	End point in Cartesian coordinates. These specifications depend on the travel commands G90/G91 or ...=AC(...)/...=IC(..)
`I J K`:	Circle center point in Cartesian coordinates (in X, Y, Z direction) The identifiers have the following meanings: I: Coordinate of the circle center point in the X direction J: Coordinate of the circle center point in the Y direction K: Coordinate of the circle center point in the Z direction
`CR=`:	Circle radius The identifiers have the following meanings: CR=+…: Angle less than or equal to 180° CR=–…: Angle more than 180°

> **Note**
>
> You don't need to specify the center point with this procedure. Full circles (traversing angle 360°) are not programmed with `CR=`, but via the circle end position and interpolation parameters.

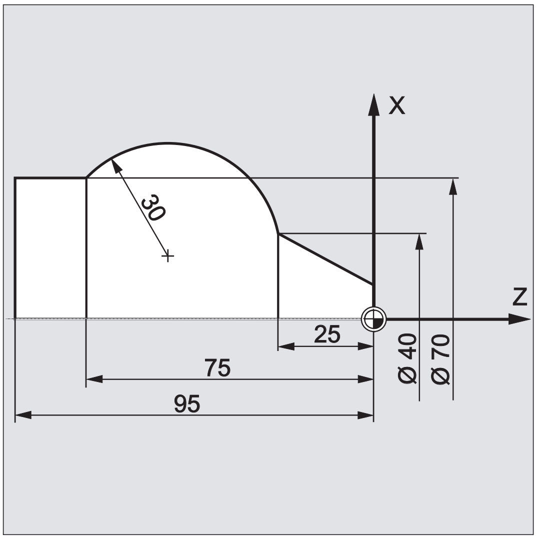
Examples

Example 1: Milling



```
Program code
N10 G0 X67.5 Y80.511
N20 G3 X17.203 Y38.029 CR=34.913 F500
...
```

Example 2: Turning



```
Program code
...
N125 G1 X40 Z-25 F0.2
N130 G3 X70 Z-75 CR=30
N135 G1 Z-95
...
```

9.6.4 Circular interpolation with opening angle and center point (G2/G3, X... Y... Z.../ I... J... K..., AR)

Function

The circular movement is described by:

- The opening angle AR = **and**
- The end point in Cartesian coordinates X, Y, Z **or**
- The circle center at addresses I, J, K

Syntax

```
G2/G3 X… Y… Z… AR=
G2/G3 I… J… K… AR=
```

Significance

`G2`:	Circular interpolation clockwise
`G3`:	Circular interpolation counter-clockwise
`X Y Z`:	End point in Cartesian coordinates
`I J K`:	Circle center point in Cartesian coordinates (in X, Y, Z direction) The identifiers have the following meanings: I: Coordinate of the circle center point in the X direction J: Coordinate of the circle center point in the Y direction K: Coordinate of the circle center point in the Z direction
`AR=`:	Opening angle, range of values 0° to 360°
`=AC(…)`:	Absolute dimensions (non-modal)

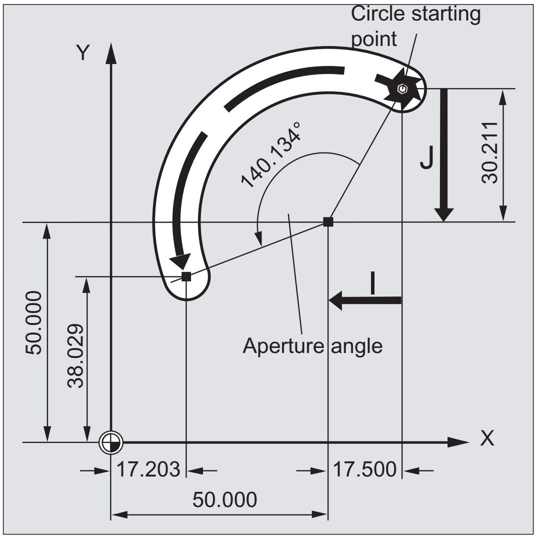
Note

Full circles (traversing angle 360°) cannot be programmed with AR=, but must be programmed using the circle end position and interpolation parameters. The center point coordinates I, J, K are normally entered in incremental dimensions with reference to the circle starting point.

You can program the absolute center point dimensions in relation to the workpiece zero block-by-block with: I=AC(…), J=AC(…), K=AC(…). One interpolation parameter I, J, K with value 0 can be omitted, but the associated second parameter must always be specified.

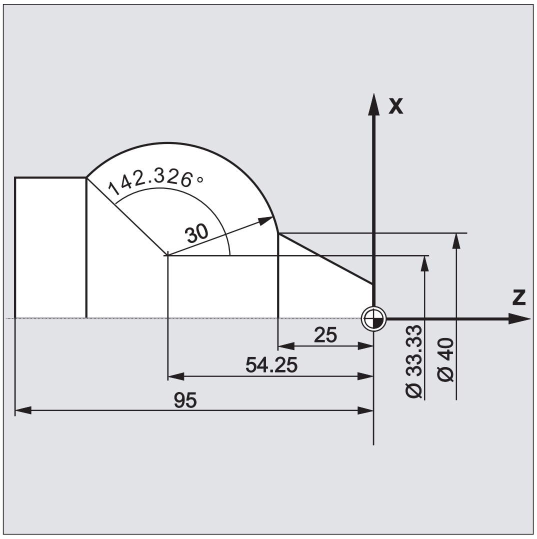
Examples

Example 1: Milling



Program code
N10 G0 X67.5 Y80.211
N20 G3 X17.203 Y38.029 AR=140.134 F500
N20 G3 I–17.5 J–30.211 AR=140.134 F500

Example 2: Turning



Program code
N125 G1 X40 Z-25 F0.2
N130 G3 X70 Z-75 AR=135.944
N130 G3 I-3.335 K-29.25 AR=135.944
N130 G3 I=AC(33.33) K=AC(-54.25) AR=135.944
N135 G1 Z-95

9.6.5 Circular interpolation with polar coordinates (G2/G3, AP, RP)

Function

The circular movement is described by:

- The polar angle AP=...
- The polar radius RP=...

The following rule applies:

- The pole lies at the circle center.
- The polar radius corresponds to the circle radius.

Syntax

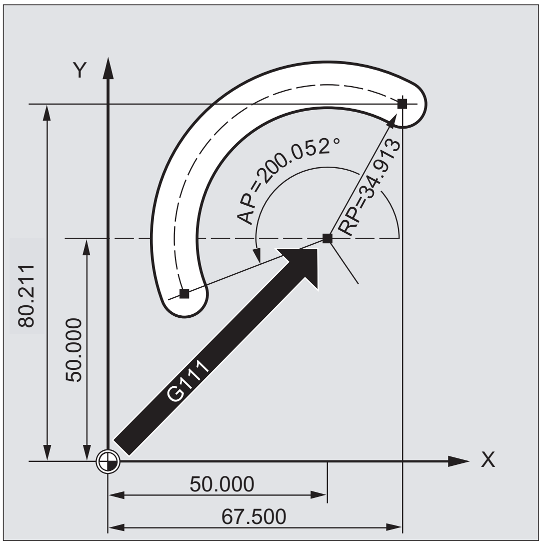
```
G2/G3 AP= RP=
```

Significance

`G2`:	Circular interpolation clockwise
`G3`:	Circular interpolation counter-clockwise
`X Y Z` :	End point in Cartesian coordinates
`AP=` :	End point in polar coordinates, in this case polar angle
`RP=` :	End point in polar coordinates, in this case polar radius corresponds to circle radius

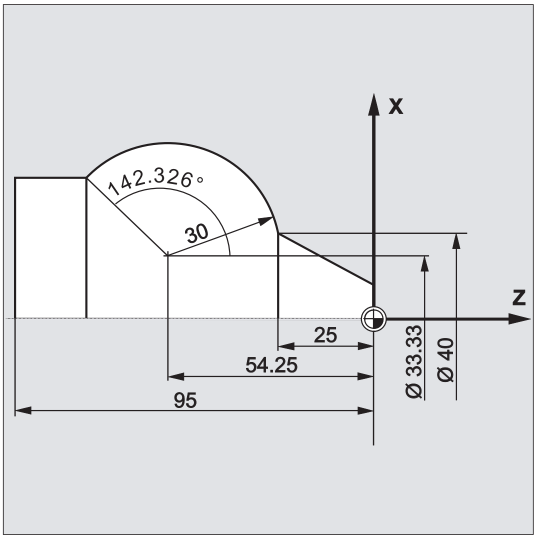
Examples

Example 1: Milling



Program code
N10 G0 X67.5 Y80.211
N20 G111 X50 Y50
N30 G3 RP=34.913 AP=200.052 F500

Example 2: Turning



Program code
N125 G1 X40 Z-25 F0.2
N130 G111 X33.33 Z-54.25
N135 G3 RP=30 AP=142.326
N140 G1 Z-95

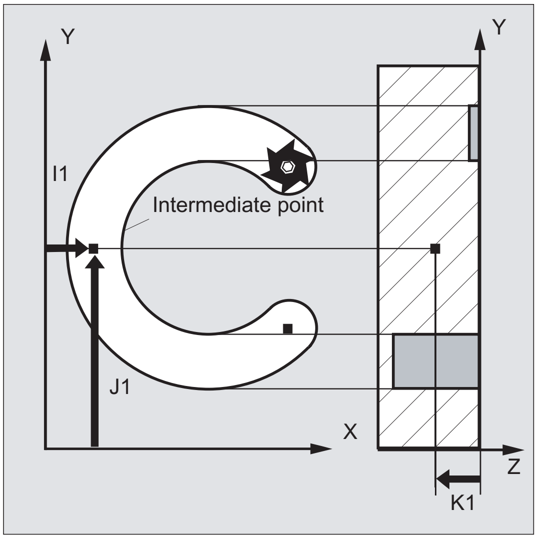
9.6.6 Circular interpolation with intermediate point and end point (CIP, X... Y... Z..., I1... J1... K1...)

Function

`CIP` can be used to program arcs. These arcs can also be inclined in space. In this case, you describe the intermediate and end points with three coordinates.

The circular movement is described by:

- The intermediate point at addresses I1=, J1=, K1= and
- The end point in Cartesian coordinates X, Y, Z.



The traversing direction is determined by the order of the starting point, intermediate point and end point.

Syntax

```
CIP X… Y… Z… I1=AC(…) J1=AC(…) K1=(AC…)
```

Meaning

`CIP`:	Circular interpolation through intermediate point
`X Y Z`:	End point in Cartesian coordinates. These specifications depend on the travel commands G90/G91 or ...=AC(...)/...=IC(..)
`I1= J1= K1=`:	Circle center point in Cartesian coordinates (in X, Y, Z direction) The identifiers have the following meanings: `I1`: Coordinate of the circle center point in the X direction `J1`: Coordinates of the circle center point in the Y direction `K1`: Coordinates of the circle center point in the Z direction
`=AC(…)`:	Absolute dimensions (non-modal)
`=IC(…)`:	Incremental dimensions (non-modal)

Note

`CIP` is modal.

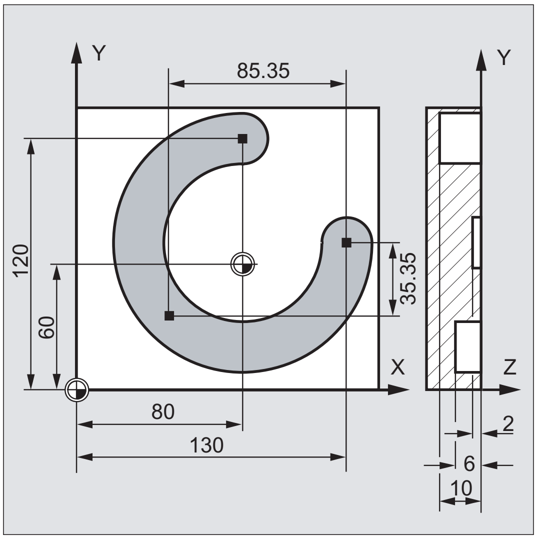
Input in absolute and incremental dimensions

The G90/G91 defaults for absolute or incremental dimensions are valid for the intermediate and circle end points.

With G91, the circle starting point is used as the reference for the intermediate point and end point.

Examples

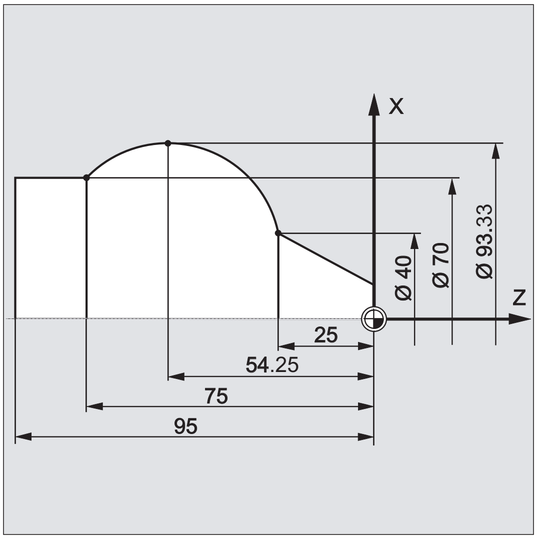
Example 1: Milling



In order to machine an inclined circular groove, a circle is described by specifying the intermediate point with three interpolation parameters, and the end point with 3 coordinates.

Program code	Comment
`N10 G0 G90 X130 Y60 S800 M3`	`; Approach starting point.`
`N20 G17 G1 Z-2  F100`	`; Feed of the tool.`
`N30 CIP X80 Y120 Z-10`	`; Circle end point and intermediate point.`
` I1= IC(-85.35)J1=IC(-35.35) K1=-6`	`; Coordinates for all 3 geometry axes.`
`N40 M30`	`; End of program.`

Example 2: Turning



Program code
`N125 G1 X40 Z-25 F0.2`
`N130 CIP X70 Z-75 I1=IC(26.665) K1=IC(-29.25)`
`N130 CIP X70 Z-75 I1=93.33 K1=-54.25`
`N135 G1 Z-95`

9.6.7 Circular interpolation with tangential transition (CT, X... Y... Z...)

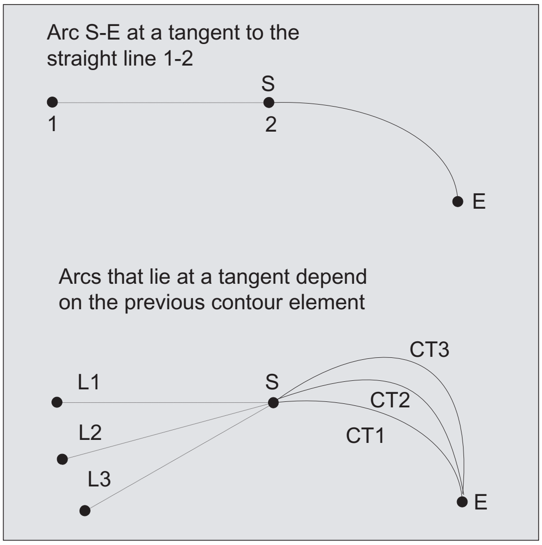
Function

The Tangential transition function is an expansion of the circle programming.

The circle is defined by:

- The start and end point and
- The tangent direction at the start point.

The G code `CT` produces an arc that lies at a tangent to the contour element programmed previously.


Arc S-E at a tangent to the straight line 1-2
S
1
2
E
Arcs that lie at a tangent depend on the previous contour element
CT3
L1
S
CT2
L2
CT1
L3
E

Determination of the tangent direction

The tangent direction in the starting point of a CT block is determined from the end tangent of the programmed contour of the last block with a traversing motion.

There can be any number of blocks without traversing information between this block and the current block.

Syntax

```
CT X… Y… Z…
```

Significance

`CT`:	Circle with tangential transition
`X... Y... Z...`:	End point in Cartesian coordinates

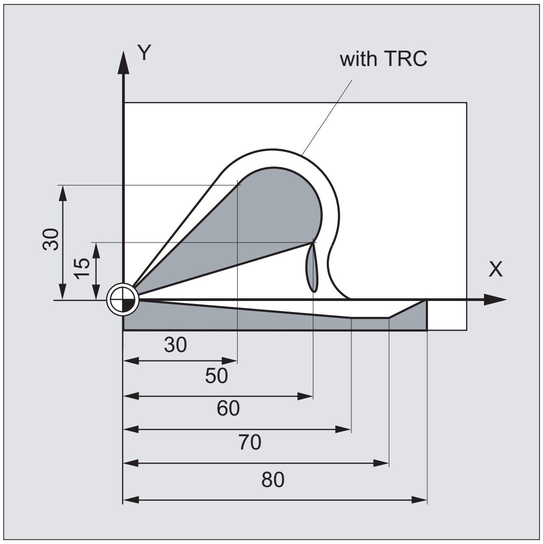
Note

`CT` is modal.

As a rule, the circle is clearly defined by the tangent direction as well as the starting point and end point.

Examples

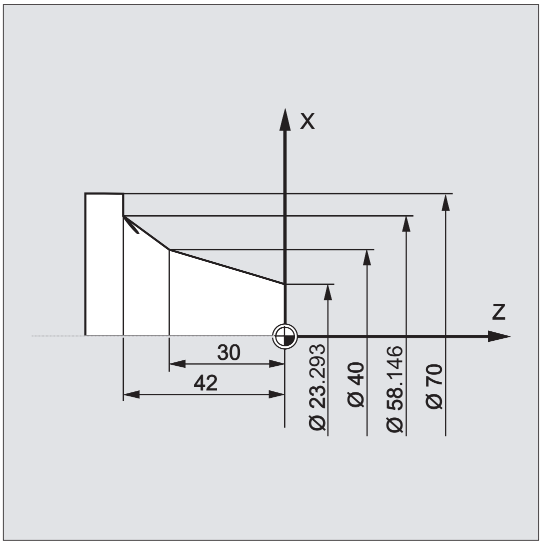
Example 1: Milling



Milling a circular arc with CT directly after the straight part.

Program code	**Comment**
`N10 G0 X0 Y0 Z0 G90 T1 D1`	
`N20 G41 X30 Y30 G1 F1000`	`; Activation of TRC.`
`N30 CT X50 Y15`	`; Circular-path programming with tangential transition.`
`N40 X60 Y-5`	
`N50 G1 X70`	
`N60 G0 G40 X80 Y0 Z20`	
`N70 M30`	

Example 2: Turning



Program code	Comment
`N110 G1 X23.293 Z0 F10`	
`N115 X40 Z-30 F0.2`	
`N120 CT X58.146 Z-42`	`; Circular-path programming with tangential transition.`
`N125 G1 X70`	

Further information

Splines

In the case of splines, the tangential direction is defined by the straight line through the last two points. In the case of A and C splines with active ENAT or EAUTO, this direction is generally not the same as the direction at the end point of the spline.

The transition of B splines is always tangential, the tangent direction is defined as for A or C splines and active ETAN.

Frame change

If a frame change takes place between the block defining the tangent and the CT block, the tangent is also subjected to this change.

Limit case

If the extension of the start tangent runs through the end point, a straight line is produced instead of a circle (limit case: circle with infinite radius). In this special case, TURN must either not be programmed or the value must be TURN=0.

Note

When the values tend towards this limit case, circles with an unlimited radius are produced and machining with TURN unequal 0 is generally aborted with an alarm due to violation of the software limits.

Position of the circle plane

The position of the circle plane depends on the active plane (G17-G19).

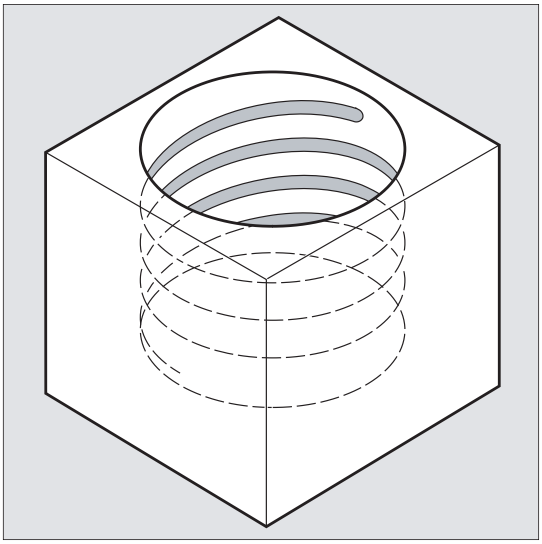
If the tangent of the previous block does not lie in the active plane, its projection in the active plane is used.

If the start and end points do not have the same position components perpendicular to the active plane, a helix is produced instead of a circle.

9.7 Helical interpolation (G2/G3, TURN)

Function

The helical interpolation enables, for example, the production of threads or oil grooves.



With helical interpolation, two motions are superimposed and executed in parallel:

- A plane circular motion on which
- A vertical linear motion is superimposed.

Syntax

```
G2/G3 X… Y… Z… I… J… K… TURN=
G2/G3 X… Y… Z… I… J… K… TURN=
G2/G3 AR=… I… J… K… TURN=
G2/G3 AR=… X… Y… Z… TURN=
G2/G3 AP… RP=… TURN=
```

Significance

`G2`:	Travel on a circular path in clockwise direction
`G3`:	Travel on a circular path in counterclockwise direction
`X Y Z`:	End point in Cartesian coordinates
`I J K`:	Circle center point in Cartesian coordinates
`AR`:	Opening angle
`TURN=`:	Number of additional circular passes in the range from 0 to 999

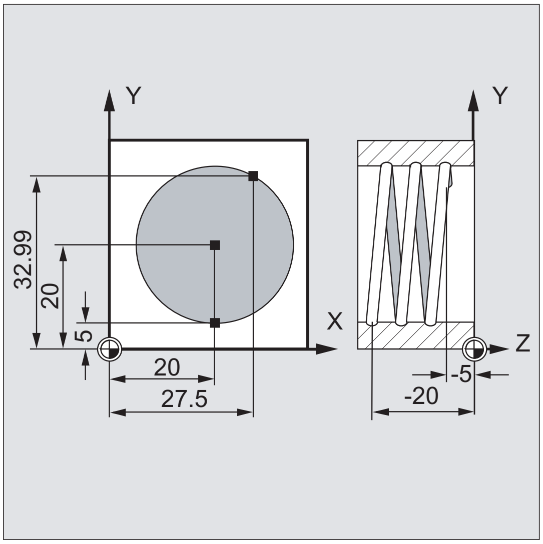
`AP=`:	Polar angle
`RP=`:	Polar radius

Note

`G2` and `G3` are modal.

The circular motion is performed in those axes that are defined by the specification of the working plane.

Example



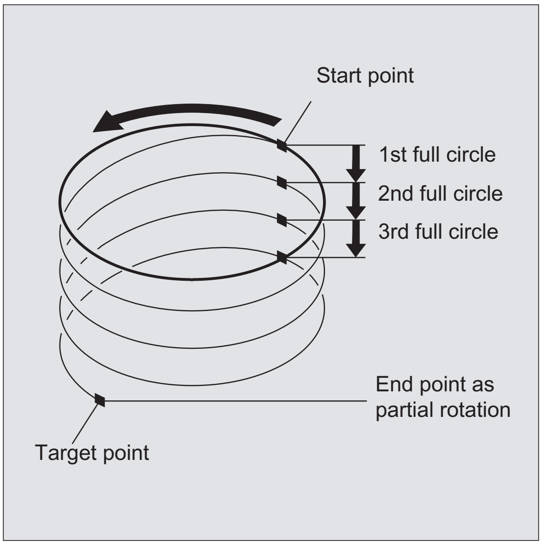
Program code	**Comment**
`N10 G17 G0 X27.5 Y32.99 Z3`	`; Approach of the starting position.`
`N20 G1 Z-5 F50`	`; Feed of the tool.`
`N30 G3 X20 Y5 Z-20 I=AC(20) J=AC(20) TURN=2`	`; Helix with the specifications: Execute 2 full circles after the starting position, then travel to end point.`
`N40 M30`	`; End of program.`

Further information

Sequence of motions

1. Approach starting point
2. Execute the full circles programmed with `TURN=`.
3. Approach circle end position, e.g. as part rotation.
4. Execute steps 2 and 3 across the infeed depth.

The pitch, with which the helix is to be machined is calculated from the number of full circles plus the programmed circle end position (executed across the infeed depth).



Programming the end point for helical interpolation

Please refer to circular interpolation for a detailed description of the interpolation parameters.

Programmed feedrate

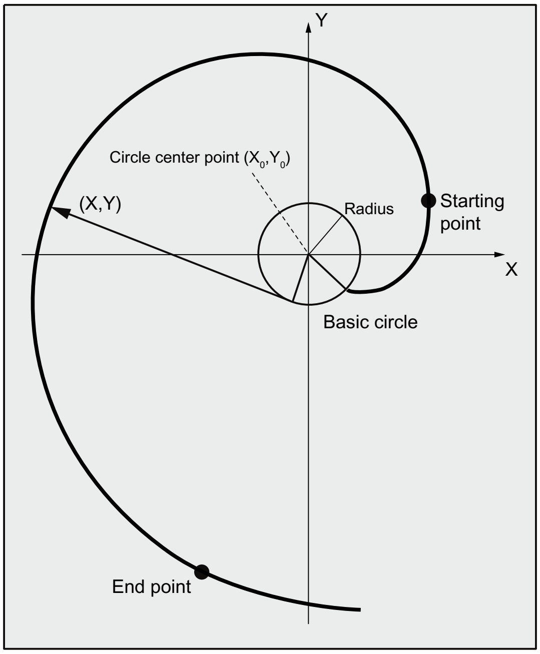
For helical interpolation, it is advisable to specify a programmed feedrate override (`CFC`). `FGROUP` can be used to specify which axes are to be traversed with a programmed feedrate. For more information please refer to the Path behavior section.

9.8 Involute interpolation (INVCW, INVCCW)

Function

The involute of the circle is a curve traced out from the end point on a "piece of string" unwinding from the curve.

Involute interpolation allows trajectories along an involute. It is executed in the plane in which the basic circle is defined and runs from the programmed starting point to the programmed end point.



The end point can be programmed in two ways:

1. Directly via Cartesian coordinates
2. Indirectly by specifying an opening angle (also refer to the programming of the opening angle for the circular-path programming)

If the starting point and the end point are in the plane of the basic circle, then, analogous to the helical interpolation for circles, there is a superimposition to a curve in space.

With additional specification of paths perpendicular to the active plane, an involute can be traversed in space (comparable to the helical interpolation for circles).

Syntax

```
INVCW X... Y... Z... I... J... K... CR=...
INVCCW X... Y... Z... I... J... K... CR=...
INVCW I... J... K... CR=... AR=...
INVCCW I... J... K... CR=... AR=...
```

Meaning

`INVCW`: Command to travel on an involute in clockwise direction

`INVCCW`: Command to travel on an involute in counterclockwise direction

`X... Y... Z...`: Direct programming of the end point in Cartesian coordinates

`I... J... K...`: Interpolation parameters for the description of the center point of the basic circle in Cartesian coordinates

Note:
The coordinate specifications refer to the starting point of the involute.

`CR=...`: Radius of the basic circle

`AR=...`: Indirect programming of the end point through specification of an opening angle (angle of rotation)

The origin of the opening angle is the line from the circle center point to the starting point.

- `AR` > 0: The path of the involute moves **away from the basic circle.**
- `AR` < 0: The path of the involute moves **towards the basic circle.**

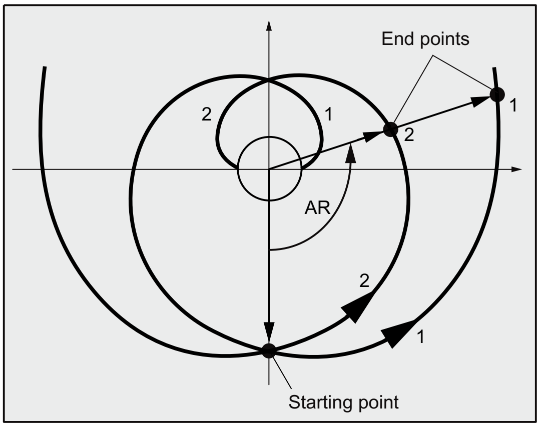
  For AR < 0, the maximum angle of rotation is restricted by the fact that the end point must always be outside the basic circle.

Indirect programming of the end point through specification of an opening angle

NOTICE

With the indirect programming of the end point through specification of an opening angle `AR`, the sign of the angle must be taken into account, as a sign change would result in another involute and therefore another path.

This is demonstrated in the following example:

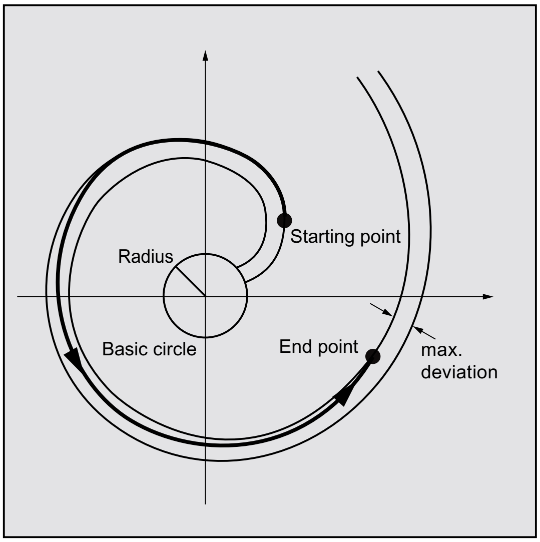


The specifications of the radius and center point of the basic circle as well as the starting point and direction of rotation (`INVCW`/`INVCCW`) are the same for involutes 1 and 2. The only difference is in the sign of the opening angle:

- With AR > 0, the path is on involute 1 and end point 1 is approached.
- With AR < 0, the path is on involute 2 and end point 2 is approached.

Supplementary conditions

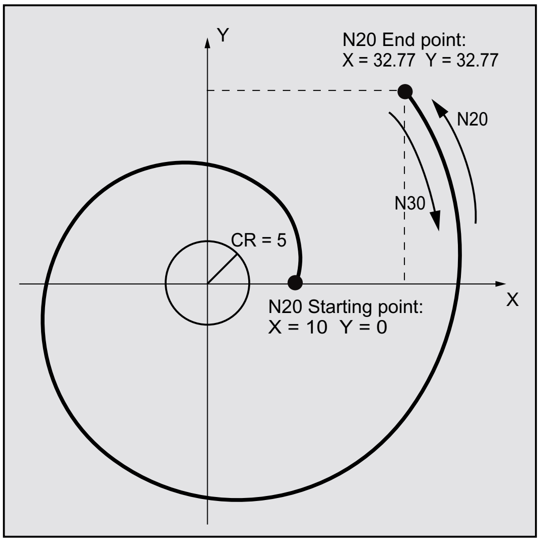
- Both the starting point and the end point must be outside the area of the basic circle of the involute (circle with radius CR around the center point specified by I, J, K). If this condition is not satisfied, an alarm is generated and the program processing is aborted.
- The two options for the programming of the end point (directly via Cartesian coordinates or indirectly via the specification of an opening angle) are mutually exclusive. Consequently, only one of the two programming options may be used in a block.
- If the programmed end point does not lie exactly on the involute defined by the starting point and basic circle, interpolation takes place between the two involutes defined by the starting and end points (see following figure).



The maximum deviation of the end point is determined by a machine data (→ machine manufacturer). If the deviation of the programmed end point in the radial direction is greater than that by the MD, then an alarm is generated and the program processing aborted.

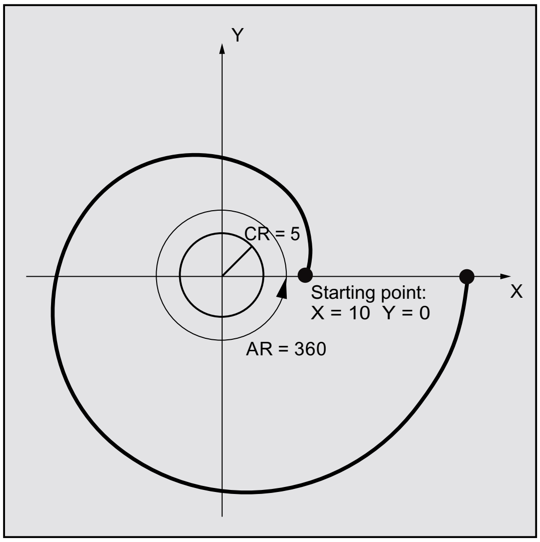
Examples

Example 1: Counterclockwise involute from the starting point to the programmed end point and back again as clockwise involute



Program code	Comment
N10 G1 X10 Y0 F5000	; Approach of the starting position.
N15 G17	; Selection of the X/Y plane as working plane.
N20 INVCCW X32.77 Y32.77 CR=5 I-10 J0	; Counterclockwise involute, end point in Cartesian coordinates.
N30 INVCW X10 Y0 CR=5 I-32.77 J-32.77	; Clockwise involute, starting point is end point from N20, new end point is starting point from N20, new circle center point refers to a new starting point and is the same as the old circle center point.
...	

Example 2: Counterclockwise involute with indirect programming of the end point through specification of an opening angle



Program code	Comment
`N10 G1 X10 Y0 F5000`	`; Approach of the starting position.`
`N15 G17`	`; Selection of the X/Y plane as working plane.`
`N20 INVCCW CR=5 I-10 J0 AR=360`	`; Counterclockwise involute and away from the basic circle (as positive angle specification) with one full revolution (360 degrees).`
`...`	

References

For more information about machine data and supplementary conditions that are relevant to involute interpolation, see:

Function Manual, Basic Functions; Various NC/PLC interface signals and functions (A2), Chapter: "Settings for involute interpolation"

9.9 Contour definitions

9.9.1 General information about contour definitions

Function

The contour definition programming is used for the quick input of simple contours.

Programmable are contour definitions with one, two, three or more points with the transition elements chamfer or rounding, through specification of Cartesian coordinates and/or angles.

Arbitrary further NC addresses can be used, e.g. address letters for further axes (single axes or axis perpendicular to the machining plane), auxiliary function specifications, G codes, velocities, etc. in the blocks that describe contour definitions.

Note

Contour calculator

The contour definitions can be programmed easily with the aid of the contour calculator. This is a user interface tool that enables the programming and graphic display of simple and complex workpiece contours. The contours programmed via the contour calculator are transferred to the part program.

References:
Operating Manual

Assigning parameters

The identifiers for angle, radius and chamfer are defined via machine data:

MD10652 $MN_CONTOUR_DEF_ANGLE_NAME (name of the angle for contour definitions)

MD10654 $MN_RADIUS_NAME (name of the radius for contour definitions)

MD10656 $MN_CHAMFER_NAME (name of the chamfer for contour definitions)

Note

See machine manufacturer's specifications.

9.9.2 Contour definitions: One straight line (ANG)

Note

In the following description it is assumed that

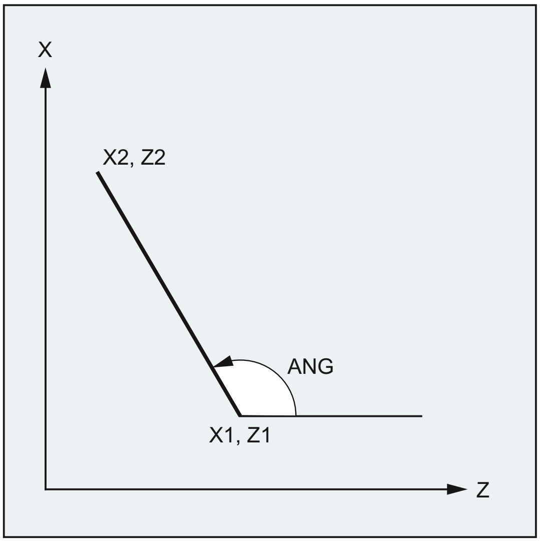
- G18 is active (⇒ active working plane is the Z/X plane).

  (However, the programming of contour definitions is also possible without restrictions with G17 or G19.)
- The following identifiers have been defined for angle, radius and chamfer:
  - ANG (angle)
  - RND (radius)
  - CHR (chamfer)

Function

The end point of the straight line is defined by the following specifications:

- Angle ANG
- **One** Cartesian end point coordinate (X2 or Z2)



ANG:	Angle of the straight line
X1, Z1:	Start coordinates
X2, Z2:	End point coordinates of the straight line

Syntax

```
X… ANG=…
Z… ANG=…
```

Significance

`X...`: End point coordinate in the X direction

`Z...`: End point coordinate in the Z direction

`ANG`: Identifier for the angle programming

The specified value (angle) refers to the abscissa of the active working plane (Z axis with `G18`).

Example

Program code	Comment
`N10 X5 Z70 F1000 G18`	`; Approach of the starting position.`
`N20 X88.8 ANG=110`	`; Straight line with angle specification.`
`N30 ...`	

or

Program code	Comment
`N10 X5 Z70 F1000 G18`	`; Approach of the starting position.`
`N20 Z39.5 ANG=110`	`; Straight line with angle specification.`
`N30 ...`	

9.9.3 Contour definitions: Two straight lines (ANG)

Note

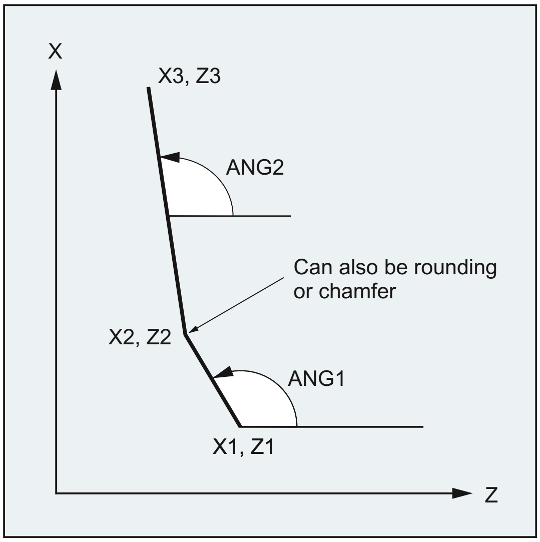
In the following description it is assumed that:

- G18 is active (⇒ active working plane is the Z/X plane).

  (However, the programming of contour definitions is also possible without restrictions with G17 or G19.)
- The following identifiers have been defined for angle, radius and chamfer:
  – ANG (angle)
  – RND (radius)
  – CHR (chamfer)

Function

The end point of the first straight line can be programmed by specifying the Cartesian coordinates or by specifying the angle of the two straight lines. The end point of the second straight line must always be programmed with Cartesian coordinates. The intersection of the two straight lines can be designed as a corner, curve or chamfer.



ANG1: Angle of the first straight line

ANG2: Angle of the second straight line

X1, Z1: Start coordinates of the first straight line

X2, Z2: End point coordinates of the first straight line or start coordinates of the second straight line

X3, Z3: End point coordinates of the second straight line

Syntax

1. Programming of the end point of the first straight line by specifying the angle

- Corner as transition between the straight lines:

```
ANG=…
X… Z… ANG=…
```

- Rounding as transition between the straight lines:

```
ANG=… RND=...
X… Z… ANG=…
```

- Chamfer as transition between the straight lines:

```
ANG=… CHR=...
X… Z… ANG=…
```

2. Programming of the end point of the first straight line by specifying the coordinates

- Corner as transition between the straight lines:

```
X… Z…
X… Z…
```

- Rounding as transition between the straight lines:

```
X… Z… RND=...
X… Z…
```

- Chamfer as transition between the straight lines:

```
X… Z… CHR=...
X… Z…
```

Significance

`ANG=...`: Identifier for angle programming

The specified value (angle) refers to the abscissa of the active working plane (Z axis with `G18`).

`RND=...`: Identifier for the programming of a rounding

The specified value corresponds to the radius of the rounding:

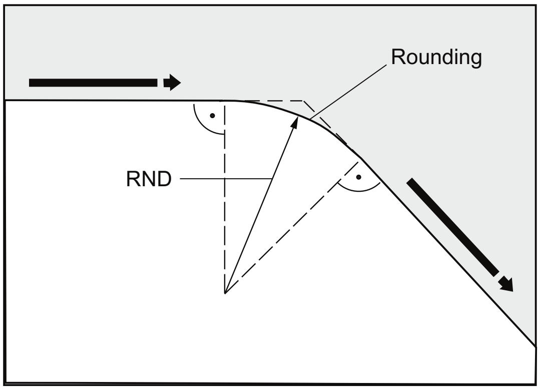


Figure 9-3

`CHR=...`: Identifier for the programming of a chamfer

The specified value corresponds to the width of the chamfer in the direction of motion:

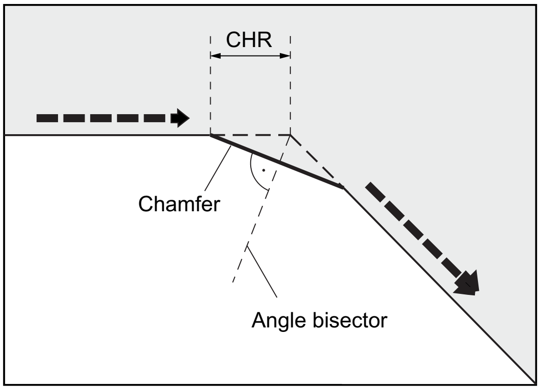


Figure 9-4

`X...`: Coordinates in the X direction

`Z...`: Coordinates in the Z direction

Note

For further information on the programming of a chamfer or rounding, see "Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]".

Example

Program code	Comment
N10 X10 Z80 F1000 G18	; Approach of the starting position.
N20 ANG=148.65 CHR=5.5	; Straight line with angle and chamfer specification.
N30 X85 Z40 ANG=100	; Straight line with angle and end point specification.
N40 ...	

9.9.4 Contour definitions: Three straight line (ANG)

Note

In the following description it is assumed that:

- G18 is active (⇒ active working plane is the Z/X plane).

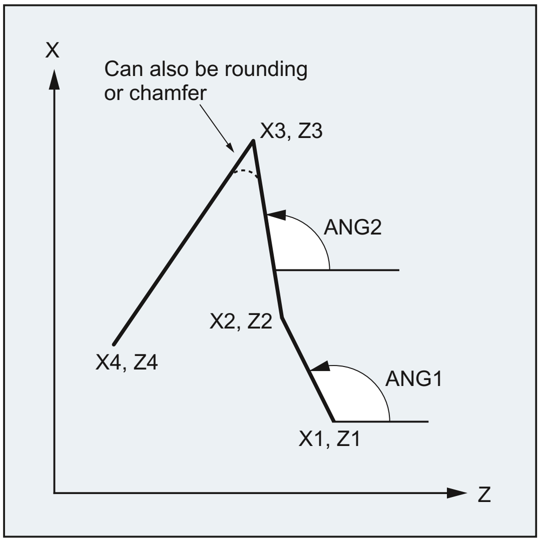
  (However, the programming of contour definitions is also possible without restrictions with G17 or G19.)
- The following identifiers have been defined for angle, radius and chamfer:
  - ANG (angle)
  - RND (radius)
  - CHR (chamfer)

Function

The end point of the first straight line can be programmed by specifying the Cartesian coordinates or by specifying the angle of the two straight lines. The end point of the second and third straight lines must always be programmed with Cartesian coordinates. The intersection of the straight lines can be designed as a corner, a curve, or a chamfer.

Note

The programming described here for a three point contour definition can be expanded arbitrarily for contour definitions with more than three points.



ANG1:	Angle of the first straight line
ANG2:	Angle of the second straight line
X1, Z1:	Start coordinates of the first straight line
X2, Z2:	End point coordinates of the first straight line or start coordinates of the second straight line
X3, Z3:	End point coordinates of the second straight line or start coordinates of the third straight line
X4, Z4:	End point coordinates of the third straight line

Syntax

1. Programming of the end point of the first straight line by specifying the angle

- Corner as transition between the straight lines:

```
ANG=…
X… Z… ANG=…
X… Z…
```

- Rounding as transition between the straight lines:

```
ANG=… RND=...
X… Z… ANG=… RND=...
X… Z…
```

- Chamfer as transition between the straight lines:

```
ANG=… CHR=...
X… Z… ANG=… CHR=...
X… Z…
```

2. Programming of the end point of the first straight line by specifying the coordinates

- Corner as transition between the straight lines:

```
X… Z…
X… Z…
X… Z…
```

- Rounding as transition between the straight lines:

```
X… Z… RND=...
X… Z… RND=...
X… Z…
```

- Chamfer as transition between the straight lines:

```
X… Z… CHR=...
X… Z… CHR=...
X… Z…
```

Significance

`ANG=...`: Identifier for angle programming

The specified value (angle) refers to the abscissa of the active working plane (Z axis with `G18`).

`RND=...`: Identifier for programming a rounding

The specified value corresponds to the radius of the rounding:

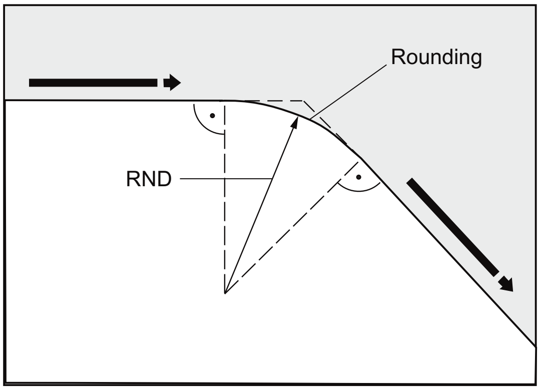


Figure 9-5

`CHR=...`: Identifier for programming a chamfer

The specified value corresponds to the width of the chamfer in the direction of motion:

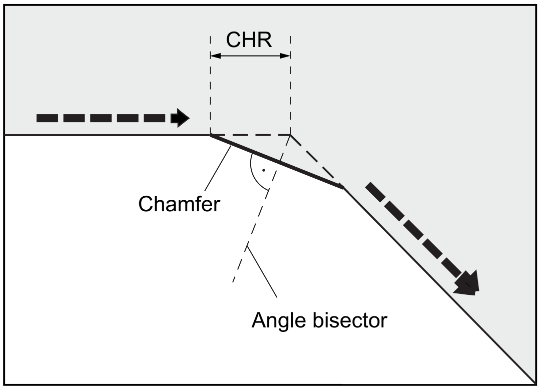


Figure 9-6

`X...`: Coordinates in the X direction

`Z...`: Coordinates in the Z direction

Note

For further information on the programming of a chamfer or rounding, see "Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM)".

Example

Program code	Comment
`N10 X10 Z100 F1000 G18`	`; Approach of the starting position.`
`N20 ANG=140 CHR=7.5`	`; Straight line with angle and chamfer specification.`
`N30 X80 Z70 ANG=95.824 RND=10`	`; Straight line to intermediate point with angle and chamfer specification.`
`N40 X70 Z50`	`; Straight line to end point.`

9.9.5 Contour definitions: End point programming with angle

Function

If the address letter A appears in an NC block, either none, one or both of the axes in the active plane may also be programmed.

Number of programmed axes

- If no axis of the active plane has been programmed, then this is either the first or second block of a contour definition consisting of two blocks.

  If it is the second block of such a contour definition, then this means that the starting point and end point in the active plane are identical. The contour definition is then at best a motion perpendicular to the active plane.
- If exactly one axis of the active plane has been programmed, then this is either a single straight line whose end point can be clearly defined via the angle and programmed Cartesian coordinate or the second block of a contour definition consisting of two blocks. In the second case, the missing coordinate is set to the same as the last (modal) position reached.
- If two axes of the active plane have been programmed, then this is the second block of a contour definition consisting of two blocks. If the current block has not been preceded by a block with angle programming without programmed axes of the active plane, then this block is not permitted.

Angle A may only be programmed for linear or spline interpolation.

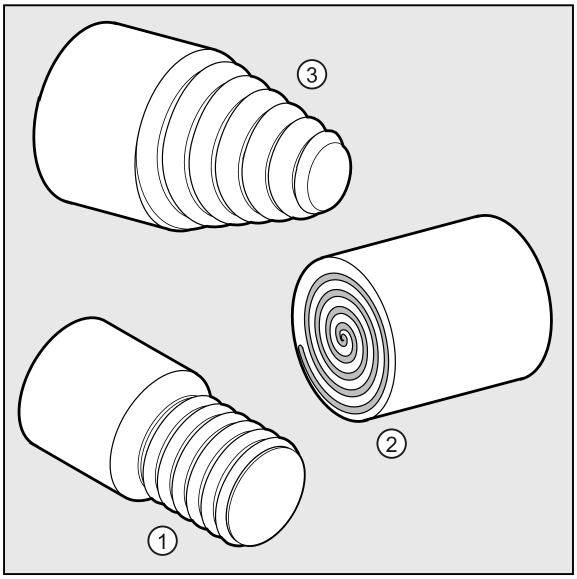
9.10 Thread cutting with constant lead (G33)

9.10.1 Thread cutting with constant lead (G33, SF)

Function

Threads with constant lead can be machined with `G33`:

- Cylinder thread ③
- Face thread ②
- Tapered thread ①

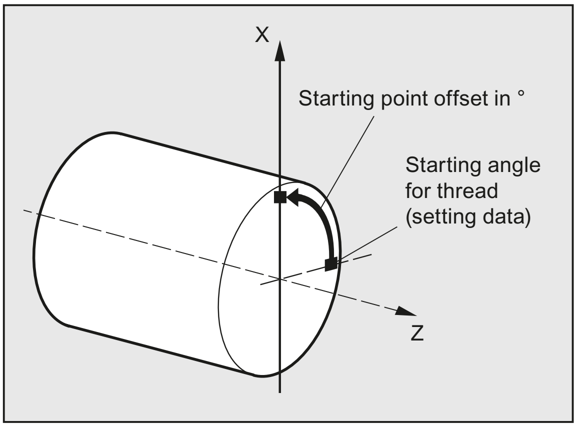


Note

Technical requirement for thread cutting with `G33` is a variable-speed spindle with position measuring system.

Multiple thread

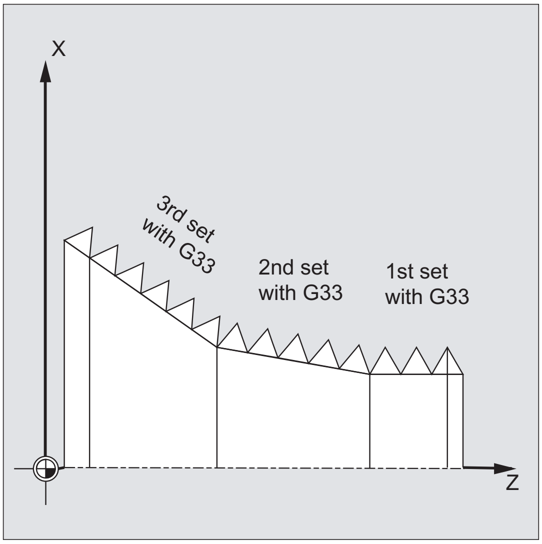
Multiple thread (thread with offset cuts) can be machined by specifying a starting point offset. The programming is performed in the `G33` block at address `SF`.


X
Starting point offset in °
Starting angle for thread (setting data)
Z

> **Note**
>
> If no starting point offset is specified, the "starting angle for thread" defined in the setting data is used.

Thread chain

A thread chain can be machined with several `G33` blocks programmed in succession:



> **Note**
>
> With continuous-path mode `G64`, the blocks are linked by the look-ahead velocity control in such a way that there are no velocity jumps.

Direction of rotation of the thread

The direction of rotation of the thread is determined by the direction of rotation of the spindle:

- Clockwise with `M3` produces a right-hand thread
- Counterclockwise with `M4` produces a left-hand thread

Syntax

Cylinder thread:

```
G33 Z… K…
G33 Z… K… SF=…
```

Face thread:

```
G33 X… I…
G33 X… I… SF=…
```

Tapered thread:

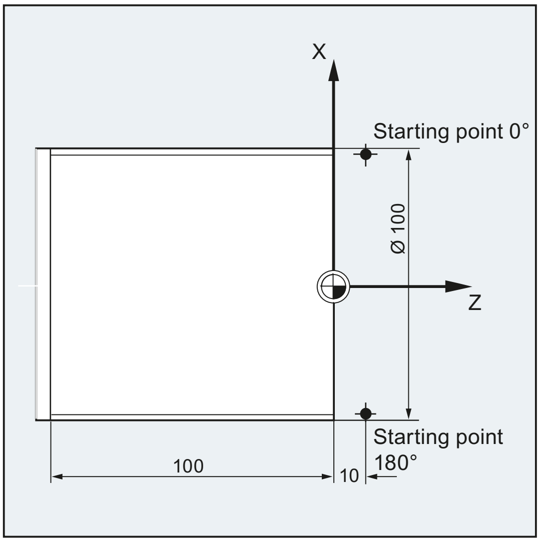
```
G33 X… Z… K…
G33 X… Z… K… SF=…
G33 X… Z… I…
G33 X… Z… I… SF=…
```

Significance

`G33`:	Command for thread cutting with constant lead
`X... Y... Z...`:	End point(s) in Cartesian coordinates
`I...`:	Thread lead in X direction
`J...`:	Thread lead in Y direction
`K...`:	Thread lead in Z direction
`Z`:	Longitudinal axis
`X`:	Transverse axis
`Z... K...`:	Thread length and lead for cylinder threads
`X... I...`:	Thread diameter and thread lead for face threads
`I...` or `K...`:	Thread lead for tapered threads The specification (`I...` or `K...`) refers to the taper angle: < 45°: The thread lead is specified with `K...` (thread lead in longitudinal direction). > 45°: The thread lead is specified with `I..` (thread lead in transverse direction). = 45°: The thread lead can be specified with `I...` or `K...`.
`SF=...`:	Starting point offset (only required for multiple threads) The starting point offset is specified as an absolute angle position. Value range: 0.0000 to 359.999 degrees

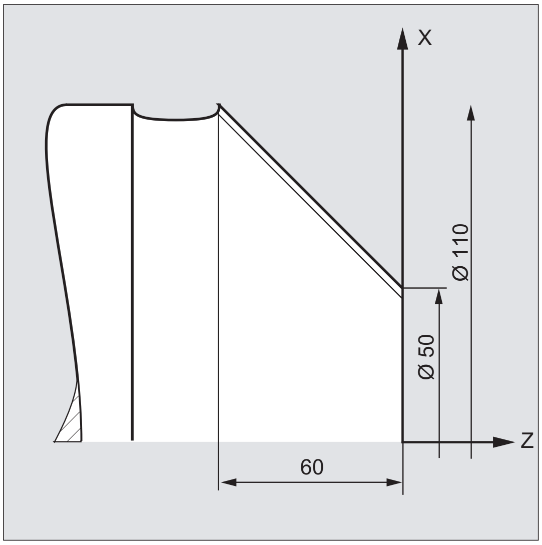
Examples

Example 1: Double cylinder thread with 180° starting point offset



Program code	Comment
`N10 G1 G54 X99 Z10 S500 F100 M3`	`; Work offset, approach starting point, activate spindle.`
`N20 G33 Z-100 K4`	`; Cylinder thread: end point in Z`
`N30 G0 X102`	`; Retraction to starting position.`
`N40 G0 Z10`	
`N50 G1 X99`	
`N60 G33 Z-100 K4 SF=180`	`; 2. 2nd cut: Starting point offset 180°`
`N70 G0 X110`	`; Retract tool.`
`N80 G0 Z10`	
`N90 M30`	`; End of program.`

Example 2: Tapered thread with angle less than 45°

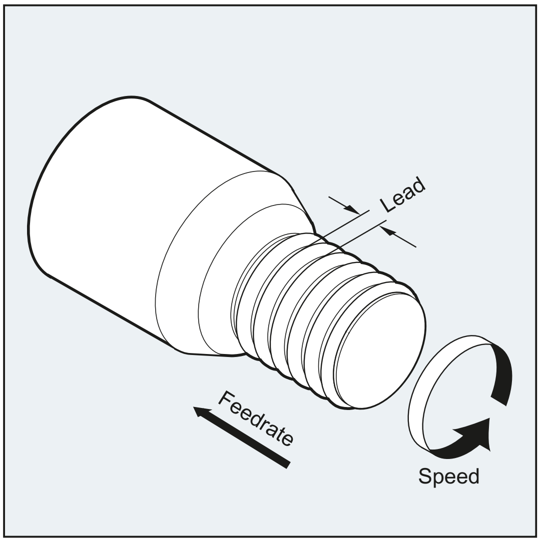


Program code	**Comment**
`N10 G1 X50 Z0 S500 F100 M3`	`; Approach starting point, activate spindle.`
`N20 G33 X110 Z-60 K4`	`; Tapered thread: End point in X and Z, specification of thread lead with K... in Z direction (since angle < 45°).`
`N30 G0 Z0 M30`	`; Retraction, end of program.`

Further information

Feedrate for thread cutting with G33

From the programmed spindle speed and the thread lead, the control calculates the required feedrate with which the turning tool is traversed over the thread length in the longitudinal and/ or transverse direction. The feedrate `F` is not taken into account for `G33`, the limitation to maximum axis velocity (rapid traverse) is monitored by the control.



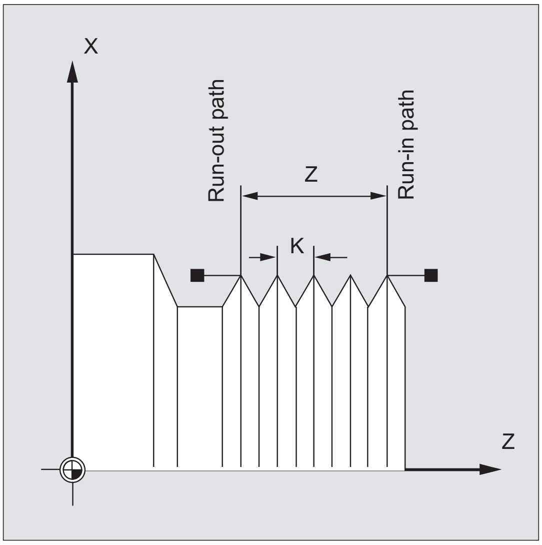
Cylinder thread

The cylinder thread is described by:

- Thread length
- Thread lead

The thread length is entered with one of the Cartesian coordinates X, Y or Z in absolute or incremental dimensions (for turning machines preferably in the Z direction). Allowance must also be made for the run-in and run-out paths, across which the feed is accelerated or decelerated.

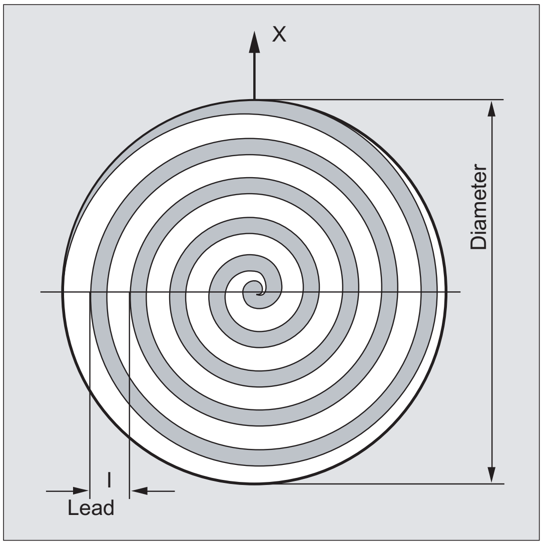
The thread lead is entered at addresses I, J, K (K is preferable for turning machines).



Face thread

The face thread is described by:

- Thread diameter (preferably in the X direction)
- Thread lead (preferably with `I`)



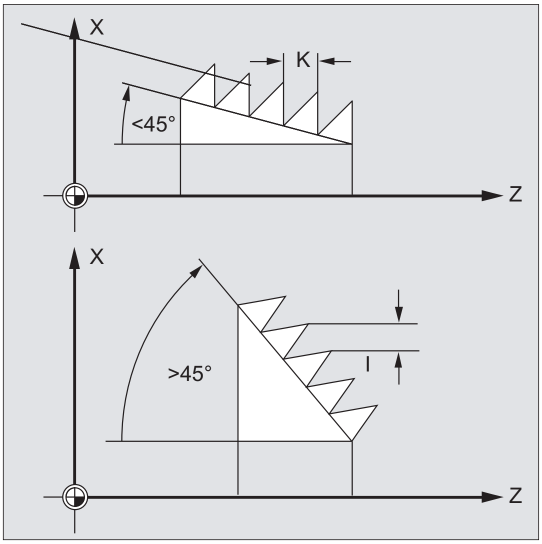
Tapered thread

The tapered thread is described by:

- End point in the longitudinal and transverse direction (taper contour)
- Thread lead

The taper contour is entered in Cartesian coordinates X, Y, Z in absolute or incremental dimensions - preferentially in the X and Z direction for machining on turning machines. Allowance must also be made for the run-in and run-out paths, across which the feed is accelerated or decelerated.

The specification of the lead depends on the taper angle (angle between the longitudinal axis and the outside of the taper):



9.10.2 Programmable run-in and run-out paths (DITS, DITE)

Function

The `DITS` and `DITE` commands can be used to program the path ramp for acceleration and braking, providing a means of adapting the feedrate accordingly if the tool run-in/run-out is too short:

- Run-in path too short

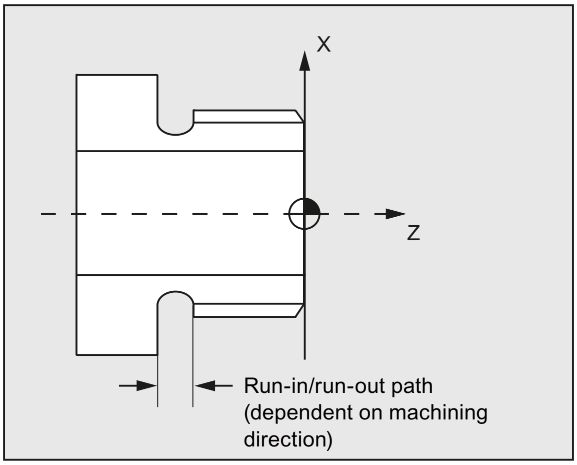
  Because of the shoulder at the thread run-in, there is not much room for the tool starting ramp - this must then be specified shorter using `DITS`.

- Run-out path too short

  Because of the shoulder at the thread run-out, there is not much room for the tool braking ramp, introducing a **risk of collision** between the workpiece and the tool cutting edge.

  The tool braking ramp can be specified shorter using `DITE`. However, there is still a risk of collision.

  Run-out: Program a shorter thread, reduce the spindle speed.



Syntax

```
DITS=<value>
DITE=<value>
```

Significance

`DITS`:	Define thread run-in path
`DITE`:	Define thread run-out path
`<value>`:	Value specification for the run-in/run-out path Range of values: -1, 0, ... n

Note

Only paths, and not positions, are programmed with `DITS` and `DITE`.

Note

The DITS and DITE commands relate to setting data SD42010 $SC_THREAD_RAMP_DISP[0,1], in which the programmed paths are written. If no run-in/deceleration path is programmed before or in the first thread block, the corresponding value is determined by the current value of SD42010.

References:
Function Manual, Basic Functions; Feedrates (V1)

Example

Program code	Comment
...	
N40 G90 G0 Z100 X10 SOFT M3 S500	
N50 G33 Z50 K5 SF=180 DITS=1 DITE=3	; Start of smoothing with Z=53.
N60 G0 X20	

Further information

If the run-in and/or run-out path is very short, the acceleration of the thread axis is higher than the configured value. This causes an acceleration overload on the axis.

Alarm 22280 ("Programmed run-in path too short") is then issued for the thread run-in (with the appropriate configuration in MD11411 $MN_ENABLE_ALARM_MASK). The alarm is purely for information and has no effect on part program execution.

MD10710 $MN_PROG_SD_RESET_SAVE_TAB can be used to specify that the value written by the part program is written to the corresponding setting data during RESET. The values are, therefore, retained following power off/on.

Note

DITE acts at the end of the thread as a rounding clearance. This achieves a smooth change in the axis movement.

When a block with the DITS and/or DITE command is loaded to the interpolator, the path programmed under DITS is written to SD42010 $SC_THREAD_RAMP_DISP[0] and the path programmed under DITE is written to SD42010 $SC_THREAD_RAMP_DISP[1].

The current dimensions setting (inch/metric) is applied to the programmed run-in/run-out path.

9.11 Thread cutting with increasing or decreasing lead (G34, G35)

Function

With the commands `G34` and `G35`, the `G33` functionality has been extended with the option of programming a change in the thread lead at address `F`. With `G34`, this results in a linear increase and with `G35` to a linear decrease of the thread lead. The commands `G34` and `G35` can therefore be used for the machining of self-tapping threads.

Syntax

Cylinder thread with increasing lead:
```
G34 Z… K… F...
```

Cylinder thread with decreasing lead:
```
G35 Z… K… F...
```

Face thread with increasing lead:
```
G34 X… I… F...
```

Face thread with decreasing lead:
```
G35 X… I… F...
```

Taper thread with increasing lead:
```
G34 X… Z… K… F...
G34 X… Z… I… F...
```

Taper thread with decreasing lead:
```
G35 X… Z… K… F...
G35 X… Z… I… F...
```

Significance

`G34`:	Command for thread cutting with linear **in**creasing lead
`G35`:	Command for thread cutting with linear **de**creasing lead
`X... Y... Z...`:	End point(s) in Cartesian coordinates
`I...`:	Thread lead in X direction
`J...`:	Thread lead in Y direction

`K...:` Thread lead in Z direction

`F...:` Thread lead change

If you already know the starting and final lead of a thread, you can calculate the thread lead change to be programmed according to the following equation:

$$\boxed{F = \frac{k_e^2 - k_a^2}{2 * l_G} \text{ [mm/rev}^2\text{]}}$$

The identifiers have the following meanings:

k_a: Thread lead (thread lead of axis target point coordinate) [mm/rev]

k_G: Starting thread lead (programmed under I, J, or K) [mm/rev]

l_G: Thread length [mm]

Example

Program code	**Comment**
`N1608 M3 S10`	`; Spindle on.`
`N1609 G0 G64 Z40 X216`	`; Approach starting point.`

`N1610 G33 Z0 K100 SF=R14`	`; Thread cutting with constant lead`
	`(100 mm/rev)`

`N1611 G35 Z-200 K100 F17.045455`	`; Lead decrease: 17.0454 mm/rev2`
	`Lead at end of block: 50mm/rev`

`N1612 G33 Z-240 K50`	`; Traverse thread block without jerk.`
`N1613 G0 X218`	
`N1614 G0 Z40`	
`N1615 M17`	

References

Function Manual, Basic Functions; Feedrates (V1), Section "Linear increasing/decreasing thread lead change with G34 and G35"

9.12 Tapping without compensating chuck (G331, G332)

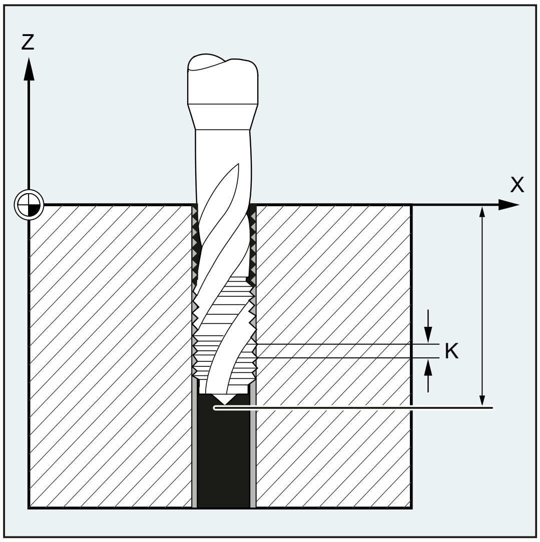
Precondition

With regard to technology, tapping without compensating chuck requires a position-controlled spindle with position measuring system.

Function

Tapping without compensating chuck is programmed using the G331 and G332 commands. The spindle prepared for tapping can make the following movements in position-controlled operation with distance measuring system:

- G331: Tapping with thread lead in tapping direction up to end point
- G332: Retraction movement with the same lead as G331



Right-hand or left-hand threads are defined by the sign of the lead:

- Positive lead → clockwise (as M3)
- Negative lead → counter-clockwise (as M4)

The desired speed is also programmed at address S.

Syntax

```
SPOS=<value>
G331 S...
G331 X… Y… Z… I… J… K…
G332 X… Y… Z… I… J… K…
```

- SPOS (or M70) only has to be programmed prior to tapping:
  - For threads requiring multiple machining operations for their production
  - For production processes requiring a defined thread starting position

  Conversely, when machining multiple threads one after the other, SPOS (or M70) does not have to be programmed (advantage: saves time).
- The spindle speed has to be in a dedicated G331 block without axis motion before tapping (G331 X… Y… Z… I… J… K…).

Meaning

G331: Command: Tapping
The hole is defined by the drilling depth and the thread lead.
Effective: modal

G332: Command: Tapping retraction
This movement is described with the same lead as the G331 movement. The direction of rotation of the spindle is reversed automatically.
Effective: modal

X... Y... Z...: Drilling depth (end point of the thread in Cartesian coordinates)

I...: Thread lead in X direction

J...: Thread lead in Y direction

K...: Thread lead in Z direction
Value range of lead: ±0.001 to 2000.00 mm/rev

Note

After G332 (retraction), the next thread can be tapped with G331.

Note

Second gear-stage data record

To achieve effective adaptation of spindle speed and motor torque and be able to accelerate faster, a second gear-stage data record for two further configurable switching thresholds (maximum speed and minimum speed) can be preset in axis-specific machine data deviating from the first gear step data record and also independent of these speed switching thresholds. Please see the machine manufacturer’s specifications for further details.

References:
Function Manual, Basic Functions; Spindles (S1), Chapter: "Configurable gear adaptations".

Examples

Example 1: G331 and G332

Program code	**Comment**
`N10 SPOS[n]=0`	`; Prepare tapping.`
`N20 G0 X0 Y0 Z2`	`; Approach starting point.`
`N30 G331 Z-50 K-4 S200`	`; Tapping, drilling depth 50, lead K negative = counterclockwise spindle rotation.`
`N40 G332 Z3 K-4`	`; Retraction, automatic reversal of direction.`
`N50 G1 F1000 X100 Y100 Z100 S300 M3`	`; Spindle operates in spindle mode again.`
`N60 M30`	`; End of program.`

Example 2: Output the programmed drilling speed in the current gear stage

Program code	**Comment**
`N05 M40 S500`	`; Gear stage 1 is engaged since the programmed spindle speed of 500 rpm is in the range between 20 and 1,028 rpm.`
`...`	
`N55 SPOS=0`	`; Align spindle.`
`N60 G331 Z-10 K5 S800`	`; Machine thread, spindle speed is 800 rpm in gear stage 1.`

The appropriate gear stage for the programmed spindle speed `S500` with `M40` is determined on the basis of the first gear-stage data record. The programmed drilling speed `S800` is output in the current gear stage and, if necessary, is limited to the maximum speed of the gear stage. No automatic gear-stage change is possible following an `SPOS` operation. In order for an automatic change in gear stage to be performed, the spindle must be in speed-control mode.

Note

If gear stage 2 is selected at a spindle speed of 800 rpm, then the switching thresholds for the maximum and minimum speed must be configured in the relevant machine data of the second gear-stage data record (see the examples below).

Example 3: Application of the second gear-stage data record

The switching thresholds of the second gear-stage data record for the maximum and minimum speed are evaluated for G331/G332 and when programming an S value for the active master spindle. Automatic M40 gear-stage change must be active. The gear stage as determined in the manner described above is compared with the active gear stage. If they are found to be different, a gear-stage change is performed.

Program code	Comment
N05 M40 S500	; Gear stage 1 is selected.
...	
N50 G331 S800	; Master spindle with second gear-stage data record: Gear stage 2 is selected.
N55 SPOS=0	; Align spindle.
N60 G331 Z-10 K5	; Tapping, spindle acceleration from second gear-stage data record.

Example 4: No speed programming → monitoring of the gear stage

If no speed is programmed when using the second gear-stage data record with G331, then the last speed programmed will be used to produce the thread. The gear stage does not change. However, monitoring is performed in this case to check that the last speed programmed is within the preset speed range (defined by the maximum and minimum speed thresholds) for the active gear stage. If it is not, alarm 16748 is signaled.

Program code	Comment
N05 M40 S800	; Gear stage 1 is selected, the first gear-stage data record is active.
...	
N55 SPOS=0	
N60 G331 Z-10 K5	; Monitoring of spindle speed 800 rpm with gear-stage data record 2: Gear stage 2 should be active, alarm 16748 is signaled.

Example 5: Gear stage cannot be changed → monitoring of gear stage

If the spindle speed is programmed in addition to the geometry in the `G331` block when using the second gear-stage data record, if the speed is not within the preset speed range (defined by the maximum and minimum speed thresholds) of the active gear stage, it will not be possible to change gear stages, because the path motion of the spindle and the infeed axis (axes) would not be retained.

As in the example above, the speed and gear stage are monitored in the `G331` block and alarm 16748 is signaled if necessary.

Program code	**Comment**
`N05 M40 S500`	`; Gear stage 1 is selected.`
`...`	
`N55 SPOS=0`	
`N60 G331 Z-10 K5 S800`	`; Gear stage cannot be changed, monitoring of spindle speed 800 rpm with gear-stage data record 2: Gear stage 2 should be active, alarm 16748 is signaled.`

Example 6: Programming without SPOS

Program code	**Comment**
`N05 M40 S500`	`; Gear stage 1 is selected.`
`...`	
`N50 G331 S800`	`; Master spindle with second gear-stage data record: Gear stage 2 is selected.`
`N60 G331 Z-10 K5`	`; Machine thread, spindle acceleration from second gear-stage data record.`

Thread interpolation for the spindle starts from the current position, which is determined by the previously processed section of the part program, e.g. if the gear stage was changed. Therefore, it might not be possible to remachine the thread.

Note

Please note that when machining with multiple spindles, the drill spindle also has to be the master spindle. `SETMS(<spindle number>)` can be programmed to set the drill spindle as the master spindle.

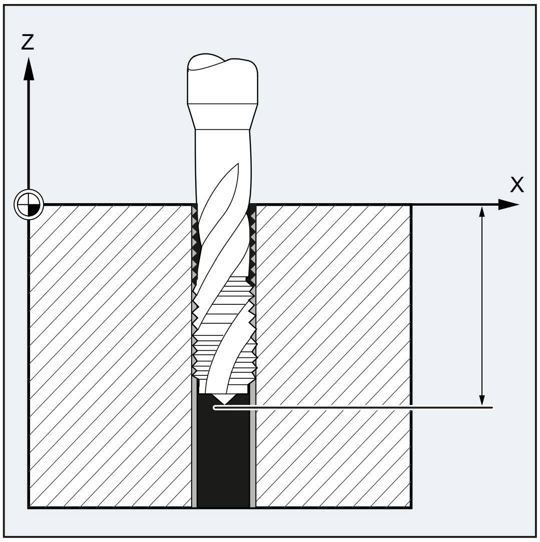
9.13 Tapping with compensating chuck (G63)

Function

With `G63` you can tap a compensating chuck. The following are programmed:

- Drilling depth in Cartesian coordinates
- Spindle speed and direction
- Feedrate

The chuck compensates for any deviations occurring in the path.



Retraction movement

Programming also with `G63`, but with spindle rotation in the opposite direction.

Syntax

```
G63 X… Y… Z…
```

Meaning

`G63`:	Tapping with compensating chuck
`X... Y... Z...`:	Drilling depth (end point) in Cartesian coordinates

Note

`G63` is non-modal.

After a block with programmed `G63`, the last interpolation command programmed (`G0`, `G1`, `G2`, etc.) is reactivated.

Feedrate

Note

The programmed feed must match the ratio of the speed to the thread lead of the tap.

Thumb rule:

Feedrate F in mm/min = spindle speed S in rpm * thread lead in mm/rev

Not only the feedrate, but also the spindle speed override switch are set to 100% with `G63`.

Example

In this example, an M5 thread is to be drilled. The lead of an M5 thread is 0.8 (according to the table).

With a selected speed of 200 rpm, the feed F = 160 mm/min.

Program code	**Comment**
`N10 G1 X0 Y0 Z2 S200 F1000 M3`	`; Approach starting point, activate spindle.`
`N20 G63 Z-50 F160`	`; Tapping, drilling depth 50.`
`N30 G63 Z3 M4`	`; Retraction, programmed reversal of direction.`
`N40 M30`	`; End of program.`

9.14 Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN)

Function

The "Fast retraction for thread cutting (G33)" function can be used to interrupt thread cutting without causing irreparable damage in the following circumstances:

- NC Stop/NC RESET
- Switching of a rapid input (see "Fast retraction from the contour" in the Programming Manual, Job Planning)

Retraction movement to a specific retraction position can be programmed by:

- Specifying the length of the retraction path and the retraction distance

  or

- Specifying an absolute retraction position

Fast retraction **cannot** be used in the context of tapping (`G331`/`G332`).

Syntax

Fast retraction for thread cutting with specification of the length of the retraction path and the retraction direction:

```
G33 ... LFON DILF=<value> LFTXT/LFWP ALF=<value>
```

Fast retraction for thread cutting with specification of an absolute retraction position:

```
POLF[<geometry axis name>/<machine axis name>]=<value> LFPOS
POLFMASK/POLFMLIN(<axis 1 name>,<axis 2 name>, etc.)
G33 ... LFON
```

Disable fast retraction for thread cutting:

```
LFOF
```

Significance

`LFON`:	Enable fast retraction for thread cutting (`G33`)
`LFOF`:	Disable fast retraction for thread cutting (`G33`)
`DILF=` :	Define length of retraction path The value preset during MD configuration (MD21200 $MC_LIFTFAST_DIST) can be modified in the part program by programming `DILF`. **Note:** The configured MD value is always active following NC-RESET.

`LFTXT`
`LFWP`: The retraction direction is controlled in conjunction with `ALF` with G functions `LFTXT` and `LFWP`.

`LFTXT`: The plane in which the retraction movement is executed is calculated from the path tangent and the tool direction (default setting).

`LFWP`: The plane in which the retraction movement is executed is the active working plane.

`ALF=` : The direction is programmed in discrete degree increments with `ALF` in the plane of the retraction movement.

With `LFTXT`, retraction in the tool direction is defined for `ALF=1`.

With `LFWP`, the direction in the working/machining plane has the following assignment:

- `G17` (X/Y plane)

  `ALF=1` ; Retraction in the X direction

  `ALF=3` ; Retraction in the Y direction

- `G18` (Z/X plane)

  `ALF=1` ; Retraction in the Z direction

  `ALF=3` ; Retraction in the X direction

- `G19` (Y/Z plane)

  `ALF=1` ; Retraction in the Y direction

`ALF=3` ; Retraction in the Z direction

References:
Programming options with `ALF` are also described in "Traverse direction for fast retraction from the contour" in the Programming Manual, Job Planning.

`LFPOS`: Retraction of the axis declared using `POLFMASK` or `POLFMLIN` to the absolute axis position programmed with `POLF`.

`POLFMASK`: Release of axes `(<axis 1 name>,<axis 1 name>, etc.)` for independent retraction to absolute position

`POLFMLIN`: Release of axes for retraction to absolute position in linear relation

Note:
Depending on the dynamic response of all the axes involved, the linear relation cannot always be established before the lift position is reached.

`POLF[]`: Define absolute retraction position for the geometry axis or machine axis in the index

Effective: modal

`=<value>`: In the case of geometry axes, the assigned value is interpreted as a position in the workpiece coordinate system. In the case of machine axes, it is interpreted as a position in the machine coordinate system.

The values assigned can also be programmed as incremental dimensions:
`=IC<value>`

Note

`LFON` or `LFOF` can always be programmed, but the evaluation is performed exclusively during thread cutting (`G33`).

Note

`POLF` with `POLFMASK`/`POLFMLIN` are not restricted to thread cutting applications.

Examples

Example 1: Enable fast retraction for thread cutting

Program code	Comment
`N55 M3 S500 G90 G18`	`; Active machining plane`
`...`	`; Approach of the starting position`
`N65 MSG ("thread cutting")`	`; Feed of the tool`
`MM_THREAD:`	
`N67 $AC_LIFTFAST=0`	`; Reset before starting the thread.`
`N68 G0 Z5`	
`N68 X10`	

`N70 G33 Z30 K5 LFON DILF=10 LFWP ALF=7`	`; Enable fast retraction for thread cutting.`
	`Retraction path = 10 mm`
	`Retraction plane: Z/X (because of G18)`
	`Retraction direction: -X`
	`(with ALF=3: Retraction direction +X)`

`N71 G33 Z55 X15`	
`N72 G1`	`; Deselect thread cutting.`
`N69 IF $AC_LIFTFAST GOTOB MM_THREAD`	`; If thread cutting has been interrupted.`
`N90 MSG ("")`	
`...`	
`N70 M30`	

Example 2: Deactivate fast retraction before tapping

Program code	Comment
`N55 M3 S500 G90 G0 X0 Z0`	
`...`	
`N87 MSG ("tapping")`	
`N88 LFOF`	`; Deactivate fast retraction before tapping.`
`N89 CYCLE...`	`; Tapping cycle with G33.`
`N90 MSG ("")`	
`...`	
`N99 M30`	

Example 3: Fast retraction to absolute retraction position

Path interpolation of X is suppressed in the event of a stop and a motion executed to position POLF[X] at maximum velocity instead. The motion of the other axes continues to be determined by the programmed contour or the thread lead and the spindle speed.

Program code	Comment
`N10 G0 G90 X200 Z0 S200 M3`	
`N20 G0 G90 X170`	
`N22 POLF[X]=210 LFPOS`	
`N23 POLFMASK(X)`	`; Activate (enable) fast retraction from axis X.`
`N25 G33 X100 I10 LFON`	
`N30 X135 Z-45 K10`	
`N40 X155 Z-128 K10`	
`N50 X145 Z-168 K10`	
`N55 X210 I10`	
`N60 G0 Z0 LFOF`	
`N70 POLFMASK()`	`; Disable lift for all axes.`
`M30`	

9.15 Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM)

Function

Contour corners within the active working plane can be executed as roundings or chamfers.

For optimum surface quality, a separate feedrate can be programmed for chamfering/ rounding. If a feedrate is not programmed, the standard path feedrate F will be applied.

The "Modal rounding" function can be used to round multiple contour corners in the same way one after the other.

Syntax

Chamfer the contour corner:

```
G... X... Z... CHR/CHF=<value> FRC/FRCM=<value>
G... X... Z...
```

Round the contour corner:

```
G... X... Z... RND=<value> FRC=<value>
G... X... Z...
```

Modal rounding:

```
G... X... Z... RNDM=<value> FRCM=<value>
...
RNDM=0
```

Note

The technology (feedrate, feedrate type, M commands, etc.) for chamfering/rounding is derived from either the previous or the next block dependent on the setting of bit 0 in machine data MD20201 $MC_CHFRND_MODE_MASK (chamfer/rounding behavior). The recommended setting is the derivation from the previous block (bit 0 = 1).

Significance

`CHF=...` : Chamfer the contour corner

`<value>`: Length of the chamfer (unit corresponding to G70/G71)

`CHR=...` : Chamfer the contour corner

`<value>`: Width of the chamfer in the original direction of motion (unit corresponding to G70/G71)

`RND=...` : Round the contour corner

`<value>`: Radius of the rounding (unit corresponding to G70/G71)

`RNDM=...` : Modal rounding (rounding multiple contour corners in the same way one after the other)

`<value>`: Radius of the roundings (unit corresponding to G70/G71)

Modal rounding is deactivated with `RNDM=0`.

`FRC=...` : Non-modal feedrate for chamfering/rounding

`<value>`: Feedrate in mm/min (with active G94) or mm/rev (with active G95)

`FRCM=...` : Modal feedrate for chamfering/rounding

`<value>`: Feedrate in mm/min (with active G94) or mm/rev (with active G95)

`FRCM=0` deactivates modal feedrate for chamfering/rounding and activates the feedrate programmed under F.

Note

Chamfering/Rounding

If the values programmed for chamfering (CHF/CHR) or rounding (RND/RNDM) are too high for the contour elements involved, chamfering or rounding will automatically be reduced to an appropriate value.

No chamfering/rounding is performed if:

- No straight or circular contour is available in the plane
- A movement takes place outside the plane
- The plane is changed
- A number of blocks specified in the machine data not to contain any information about traversing (e.g., only command outputs) is exceeded

---

Note

FRC/FRCM

FRC/FRCM has no effect if a chamfer is traversed with G0; the command can be programmed according to the F value without error message.

FRC is only effective if a chamfer/rounding is programmed in the block or if RNDM has been activated.

FRC overwrites the F or FRCM value in the current block.

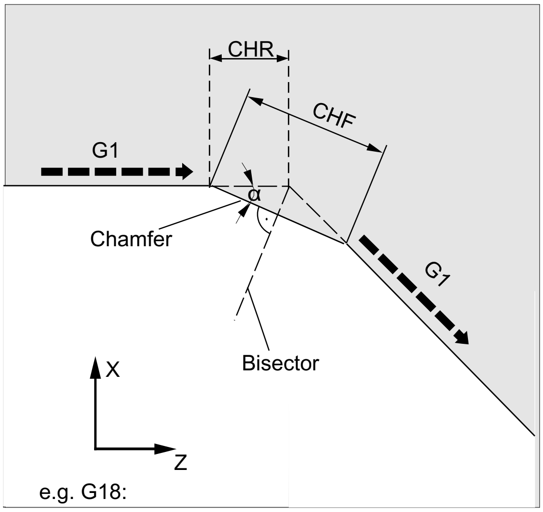
The feedrate programmed under FRC must be greater than zero.

FRCM=0 activates the feedrate programmed under F for chamfering/rounding.

If FRCM is programmed, the FRCM value will need to be reprogrammed like F on change G94 ↔ G95, etc. If only F is reprogrammed and if the feedrate type FRCM > 0 before the change, an error message will be output.

Examples

Example 1: Chamfering between two straight lines



- MD20201 Bit 0 = 1 (derived from previous block)
- G71 is active.
- The width of the chamfer in the direction of motion (CHR) should be 2 mm and the feedrate for chamfering 100 mm/min.

Programming can be performed in two ways:

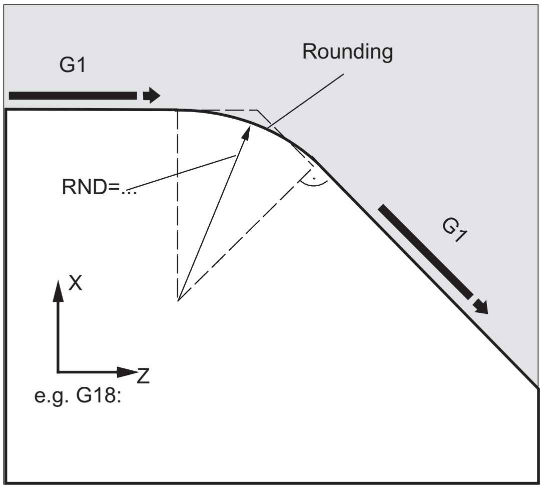
- Programming with CHR

Program code
...
N30 G1 Z… CHR=2 FRC=100
N40 G1 X…
...

- Programming with CHF

Program code
...
N30 G1 Z… CHF=2(cosα*2) FRC=100
N40 G1 X…
...

Example 2: Rounding between two straight lines

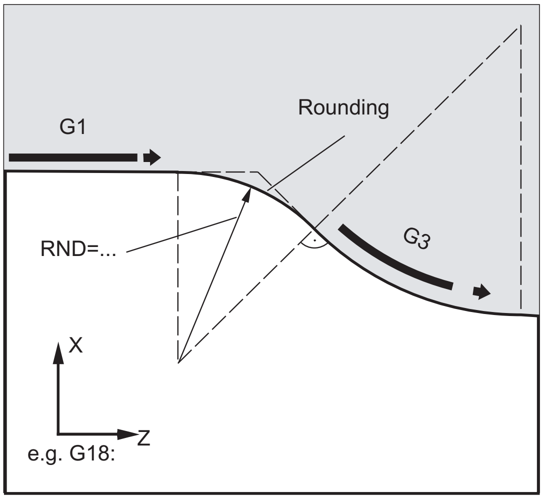


- MD20201 Bit 0 = 1 (derived from previous block)
- G71 is active.
- The radius of the rounding should be 2 mm and the feedrate for rounding 50 mm/min.

```
Program code
...
N30 G1 Z… RND=2 FRC=50
N40 G1 X…
...
```

Example 3: Rounding between straight line and circle

The RND function can be used to insert a circle contour element with tangential connection between the linear and circle contours in any combination.



- MD20201 Bit 0 = 1 (derived from previous block)
- G71 is active.
- The radius of the rounding should be 2 mm and the feedrate for rounding 50 mm/min.

```
Program code
...
N30 G1 Z… RND=2 FRC=50
N40 G3 X… Z… I… K…
...
```

Example 4: Modal rounding to deburr sharp workpiece edges

Program code	Comment
`...`	

`N30 G1 X… Z… RNDM=2 FRCM=50`	`; Activate modal rounding.`
	`Radius of rounding: 2 mm`
	`Feedrate for rounding: 50 mm/min`

`N40...`	
`N120 RNDM=0`	`; Deactivate modal rounding.`
`...`	

Example 5: Apply technology from following block or previous block

- MD20201 Bit 0 = 0: Derived from following block (default setting!)

Program code	Comment
`N10 G0 X0 Y0 G17 F100 G94`	
`N20 G1 X10 CHF=2`	`; Chamfer N20-N30 with F=100 mm/min`
`N30 Y10 CHF=4`	`; Chamfer N30-N40 with FRC=200 mm/min`
`N40 X20 CHF=3 FRC=200`	`; Chamfer N40-N60 with FRCM=50 mm/min`
`N50 RNDM=2 FRCM=50`	
`N60 Y20`	`; Modal rounding N60-N70 with FRCM=50 mm/min`
`N70 X30`	`; Modal rounding N70-N80 with FRCM=50 mm/min`
`N80 Y30 CHF=3 FRC=100`	`; Chamfer N80-N90 with FRC=100 mm/min`

`N90 X40`	`; Modal rounding N90-N100 with F=100 mm/min`
	`(deselection of FRCM)`

`N100 Y40 FRCM=0`	`; Modal rounding N100-N120 with G95 FRC=1 mm/rev`
`N110 S1000 M3`	
`N120 X50 G95 F3 FRC=1`	
`...`	
`M02`	

- MD20201 Bit 0 = 1: Derived from previous block (recommended setting!)

Program code	Comment
`N10 G0 X0 Y0 G17 F100 G94`	
`N20 G1 X10 CHF=2`	`; Chamfer N20-N30 with F=100 mm/min`
`N30 Y10 CHF=4 FRC=120`	`; Chamfer N30-N40 with FRC=120 mm/min`
`N40 X20 CHF=3 FRC=200`	`; Chamfer N40-N60 with FRC=200 mm/min`
`N50 RNDM=2 FRCM=50`	
`N60 Y20`	`; Modal rounding N60-N70 with FRCM=50 mm/min`
`N70 X30`	`; Modal rounding N70-N80 with FRCM=50 mm/min`
`N80 Y30 CHF=3 FRC=100`	`; Chamfer N80-N90 with FRC=100 mm/min`
`N90 X40`	`; Modal rounding N90-N100 with FRCM=50 mm/min`
`N100 Y40 FRCM=0`	`; Modal rounding N100-N120 with F=100 mm/min`
`N110 S1000 M3`	
`N120 X50 CHF=4 G95 F3 FRC=1`	`; Chamfer N120-N130 with G95 FRC=1 mm/rev`

Program code	Comment
N130 Y50	; Modal rounding N130-N140 with F=3 mm/rev
N140 X60	
...	
M02	

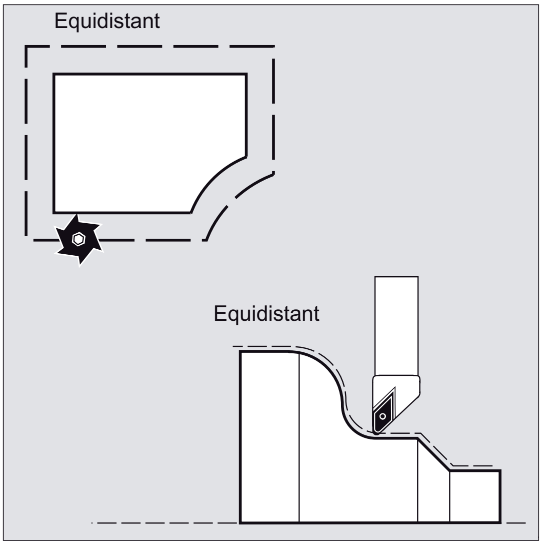
Tool radius compensation

10

10.1 Tool radius compensation (G40, G41, G42, OFFN)

Function

When tool radius compensation (TRC) is active, the control automatically calculates the equidistant tool paths for various tools.



Syntax

```
G0/G1 X... Y… Z... G41/G42 [OFFN=<value>]
...
G40 X... Y… Z...
```

Significance

`G41`: Activate TRC with machining direction **left** of the contour.

`G42`: Activate TRC with machining direction **right** of the contour.

`OFFN=<value>`: Allowance on the programmed contour (normal contour offset) (optional),
e.g. to generate equidistant paths for rough finishing.

`G40`: Deactivate TRC.

Note

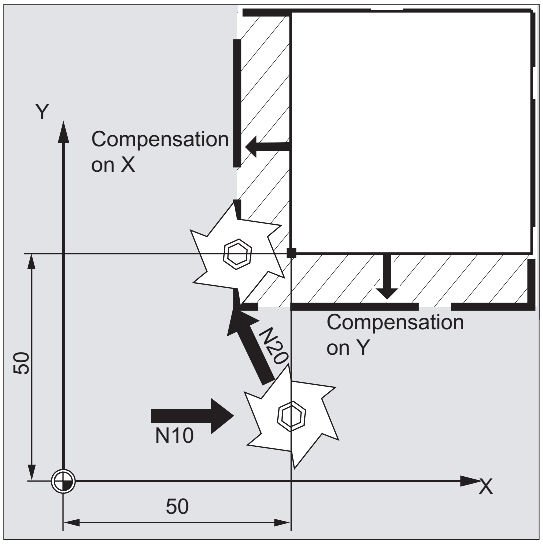
In the NC block with `G40`/`G41`/`G42`, `G0` or `G1` has to be active and at least one axis has to be specified on the selected working plane.

If only one axis is specified on activation, the last position on the second axis is added automatically and traversed with **both** axes.

The two axes must be active as geometry axes in the channel. This can be achieved by means of `GEOAX` programming.

Examples

Example 1: Milling

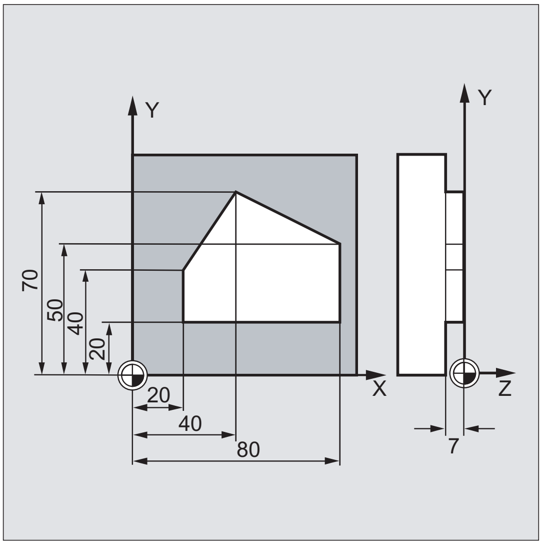


Program code	Comment
`N10 G0 X50 T1 D1`	`; Only tool length compensation is activated. X50 is approached without compensation.`
`N20 G1 G41 Y50 F200`	`; Radius compensation is activated, point X50/Y50 is approached with compensation.`
`N30 Y100`	
…	

Example 2: "Conventional" procedure based on the example of milling

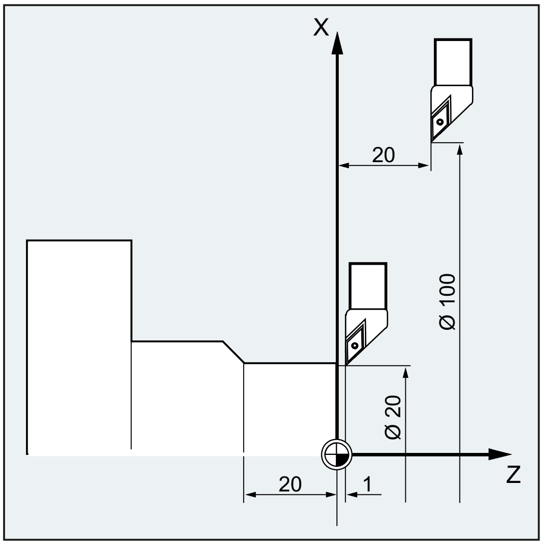
"Conventional" procedure:

1. Tool call
2. Change tool.
3. Activate working plane and tool radius compensation.



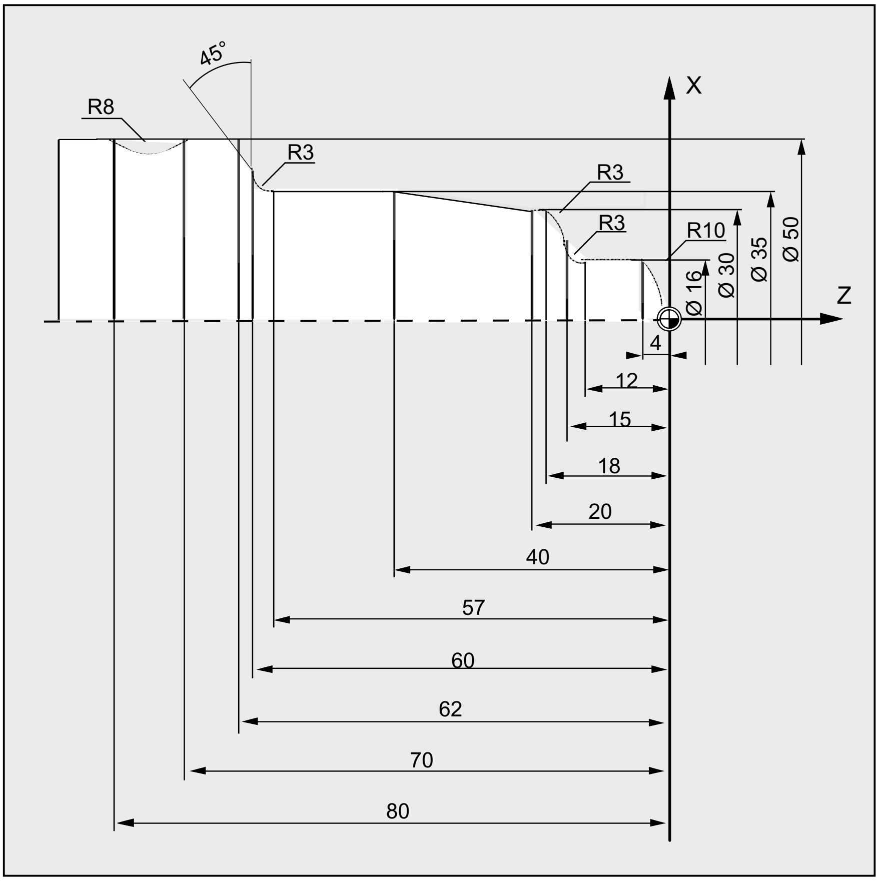
Program code	Comment
N10 G0 Z100	; Retraction for tool change.
N20 G17 T1 M6	; Tool change
N30 G0 X0 Y0 Z1 M3 S300 D1	; Call tool offset values, select length compensation.
N40 Z-7 F500	; Feed in tool.
N50 G41 X20 Y20	; Activate tool radius compensation, tool machines to the left of the contour.
N60 Y40	; Mill contour.
N70 X40 Y70	
N80 X80 Y50	
N90 Y20	
N100 X20	
N110 G40 G0 Z100 M30	; Retract tool, end of program.

Example 3: Turning



Program code	**Comment**
…	
`N20 T1 D1`	`; Only tool length compensation is activated.`
`N30 G0 X100 Z20`	`; X100 Z20 is approached without compensation.`
`N40 G42 X20 Z1`	`; Radius compensation is activated, point X20/Z1 is approached with compensation.`
`N50 G1 Z-20 F0.2`	
…	

Example 4: Turning



Program code	Comment
`N5 G0 G53 X280 Z380 D0`	`; Starting point`
`N10 TRANS X0 Z250`	`; Zero offset`
`N15 LIMS=4000`	`; Speed limitation (G96)`
`N20 G96 S250 M3`	`; Select constant feedrate`
`N25 G90 T1 D1 M8`	`; Select tool selection and offset`
`N30 G0 G42 X-1.5 Z1`	`; Set tool with tool radius compensation`
`N35 G1 X0 Z0 F0.25`	
`N40 G3 X16 Z-4 I0 K-10`	`; Turn radius 10`
`N45 G1 Z-12`	
`N50 G2 X22 Z-15 CR=3`	`; Turn radius 3`
`N55 G1 X24`	
`N60 G3 X30 Z-18 I0 K-3`	`; Turn radius 3`
`N65 G1 Z-20`	
`N70 X35 Z-40`	
`N75 Z-57`	
`N80 G2 X41 Z-60 CR=3`	`; Turn radius 3`
`N85 G1 X46`	
`N90 X52 Z-63`	

Program code	**Comment**
`N95 G0 G40 G97 X100 Z50 M9`	`; Deselect tool radius compensation and approach tool change location`
`N100 T2 D2`	`; Call tool and select offset`
`N105 G96 S210 M3`	`; Select constant cutting rate`
`N110 G0 G42 X50 Z-60 M8`	`; Set tool with tool radius compensation`
`N115 G1 Z-70 F0.12`	`; Turn diameter 50`
`N120 G2 X50 Z-80 I6.245 K-5`	`; Turn radius 8`
`N125 G0 G40 X100 Z50 M9`	`; Retract tool and deselect tool radius compensation`
`N130 G0 G53 X280 Z380 D0 M5`	`; Approach tool change location`
`N135 M30`	`; End of program`

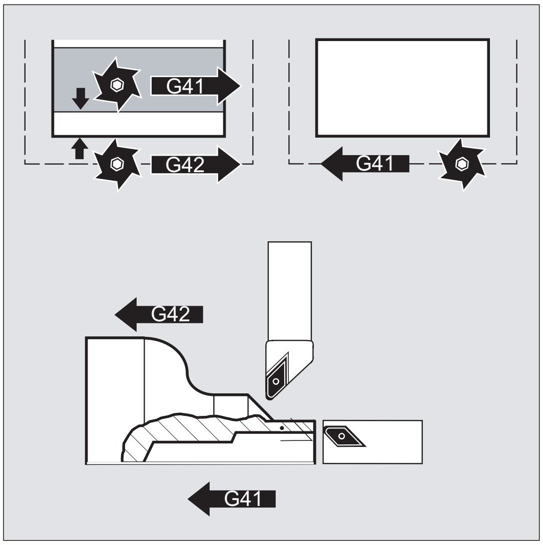
Further information

The control requires the following information in order to calculate the tool paths:

- Tool no. (T...), cutting edge no. (D...)
- Machining direction (G41/G42)
- Working plane (G17/G18/G19)

Tool no. (T...), cutting edge no. (D...)

The distance between tool path and workpiece contour is calculated from the milling cutter radii or cutting edge radii and the tool point direction parameters.



With a flat D number structure, only the D number has to be programmed.

Machining direction (G41/G42)

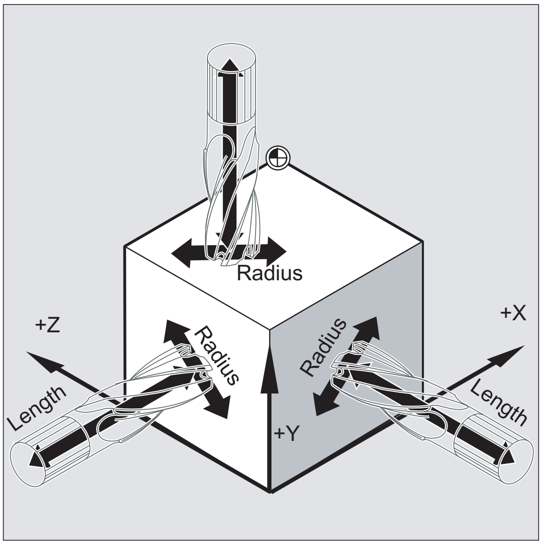
From this information, the control detects the direction, in which the tool path is to be displaced.

Note

A negative offset value has the same significance as a change of offset side (`G41 ↔ G42`).

Working plane (G17/G18/G19)

From this information, the control detects the plane and therefore the axis directions for compensation.



Example: Milling cutter

Program code	Comment
...	
N10 G17 G41 …	; The tool radius compensation is performed in the X/Y plane, the tool length compensation is performed in the Z direction.
...	

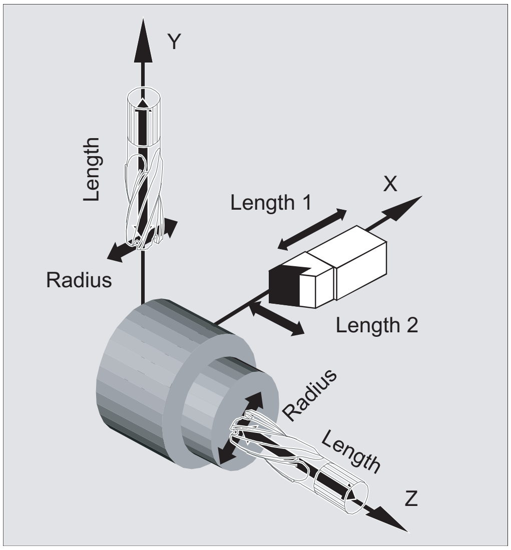
Note

On 2-axis machines, tool radius compensation is only possible in "real" planes, usually with `G18`.

Tool length compensation

The wear parameter assigned to the diameter axis on tool selection can be defined as the diameter value using an MD. This assignment is not automatically altered when the plane is subsequently changed. To do this, the tool must be selected again after the plane has been changed.

Turning:



`NORM` and `KONT` can be used to define the tool path on activation and deactivation of compensation mode (see "Contour approach and retraction (NORM, KONT, KONTC, KONTT) [Page 287]").

Point of intersection

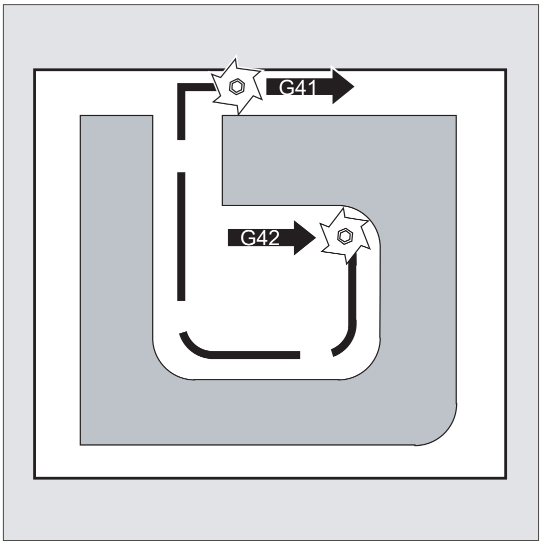
The intersection point is selected in the setting data:

SD42496 $SC_CUTCOM_CLSD_CONT (response of tool radius compensation with closed contour)

Value	Significance
FALSE	If two intersections appear on the inside when offsetting an (virtually) closed contour, which consists of two circle blocks following on from one another, or from one circle block and one linear block, the intersection positioned closest to the end of block on the first partial contour is selected, in accordance with standard procedure. A contour is deemed to be (virtually) closed if the distance between the starting point of the first block and the end point of the second block is less than 10% of the effective compensation radius, but not more than 1,000 path increments (corresponds to 1 mm with 3 decimal places).
TRUE	In the same situation as described above, the intersection positioned on the first partial contour closer to the block start is selected.

Change in compensation direction (G41 ↔ G42)

A change in compensation direction (`G41 ↔ G42`) can be programmed without an intermediate `G40`.



Changing the working plane

The working plane (`G17`/`G18`/`G19`) **cannot** be changed if `G41`/`G42` is active.

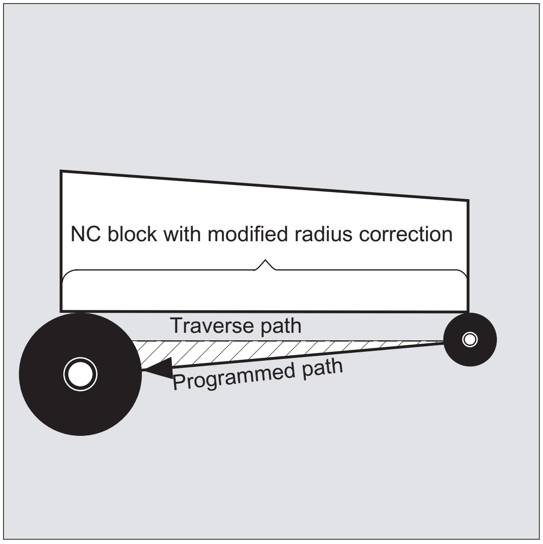
Change in tool offset data record (D…)

The tool offset data record can be changed in compensation mode.

A modified tool radius is active with effect from the block, in which the new D number is programmed.

CAUTION
The radius change or compensation movement is performed across the entire block and only reaches the new equidistance at the programmed end point.

In the case of linear movements, the tool travels along an inclined path between the starting point and end point:



Circular interpolation produces spiral movements.

Changing the tool radius

The change can be made e.g. using system variables. The sequence is the same as when changing the tool offset data record (`D…`).

CAUTION
The modified values only take effect the next time `T` or `D` is programmed. The change only applies with effect from the next block.

Compensation mode

Compensation mode may only be interrupted by a certain number of consecutive blocks or M functions which do not contain drive commands or positional data in the compensation plane.

Note

The number of consecutive blocks or M commands can be set in a machine data item (see machine manufacturer's specifications).

Note

A block with a path distance of zero also counts as an interruption!

10.2 Contour approach and retraction (NORM, KONT, KONTC, KONTT)

Function

If tool radius compensation is active (G41/G42), the NORM, KONT, KONTC or KONTT command can be used to adapt the tool's approach and retract paths to the required contour profile or blank form.

KONTC or KONTT ensure observance of the continuity conditions in all three axes. It is, therefore, permissible to program a path component perpendicular to the offset plane simultaneously.

Condition

The KONTC and KONTT commands will only be available if the "Polynomial interpolation" option has been enabled in the control.

Syntax

```
G41/G42 NORM/KONT/KONTC/KONTT X... Y... Z...
...
G40 X... Y... Z...
```

Significance

NORM:	Activate direct approach/retraction to/from a straight line. The tool is oriented perpendicular to the contour point.
KONT:	Activate approach/retraction with travel around the starting/end point according to the programmed corner behavior G450 or G451.
KONTC:	Activate approach/retraction with constant curvature.
KONTT:	Activate approach/retraction with constant tangent.

Note

Only G1 blocks are permissible as original approach/retraction blocks for KONTC and KONTT. The control replaces these with polynomials for the appropriate approach/retract path.

General conditions

KONTT and KONTC are not available in 3D variants of tool radius compensation (CUT3DC, CUT3DCC, CUT3DF). If they are programmed, the control switches internally to NORM without an error message.

Example

KONTC

The full circle is approached beginning at the circle center point. The direction and curvature radius at the block end point of the approach block are identical to the values of the next circle. Infeed takes place in the Z direction in both approach/retraction blocks simultaneously. The figure below shows the perpendicular projection of the tool path.

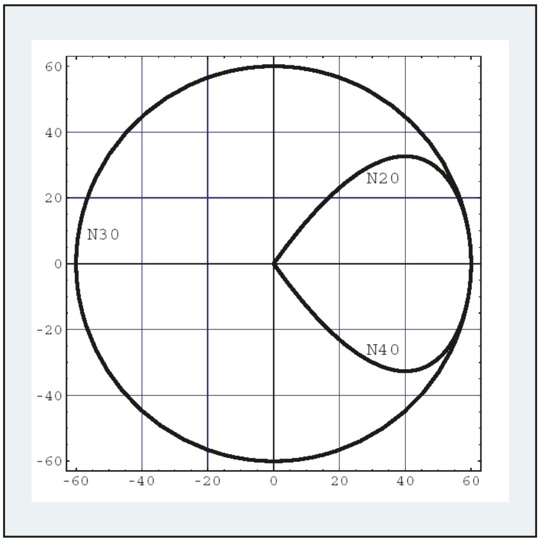


Figure 10-1 Perpendicular projection

The associated NC program segment is as follows:

Program code	Comment
$TC_DP1[1,1]=121	; Milling tool
$TC_DP6[1,1]=10	; Radius 10 mm
N10 G1 X0 Y0 Z60 G64 T1 D1 F10000	
N20 G41 KONTC X70 Y0 Z0	; Approach
N30 G2 I-70	; Full circle
N40 G40 G1 X0 Y0 Z60	; Retract
N50 M30	

At the same time as the curvature is being adapted to the circular path of the full circle, traversing is performed from Z60 to the plane of the circle Z0:

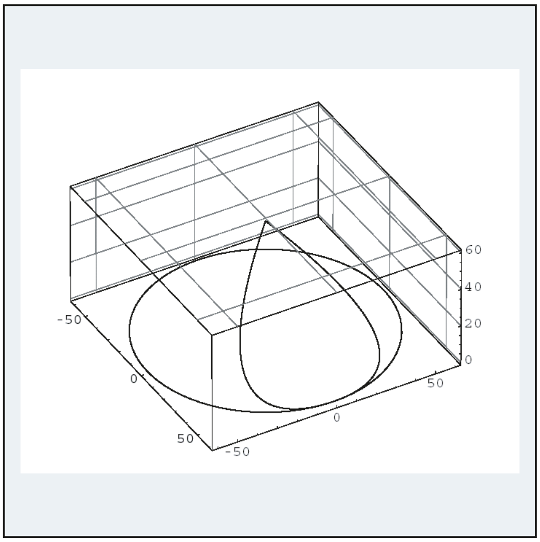


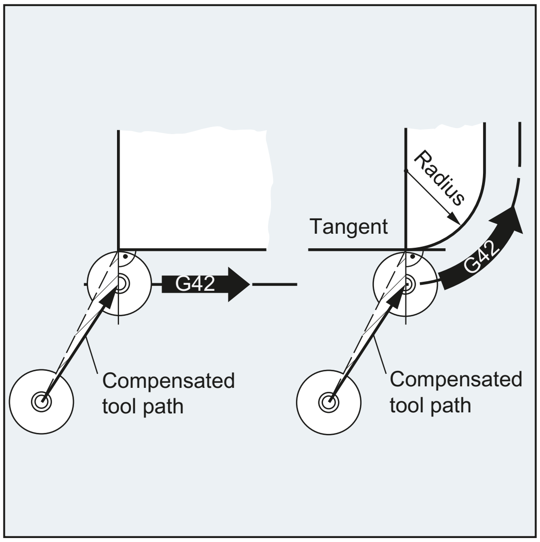
Figure 10-2 3D representation.

Further information

Approach/Retraction with NORM

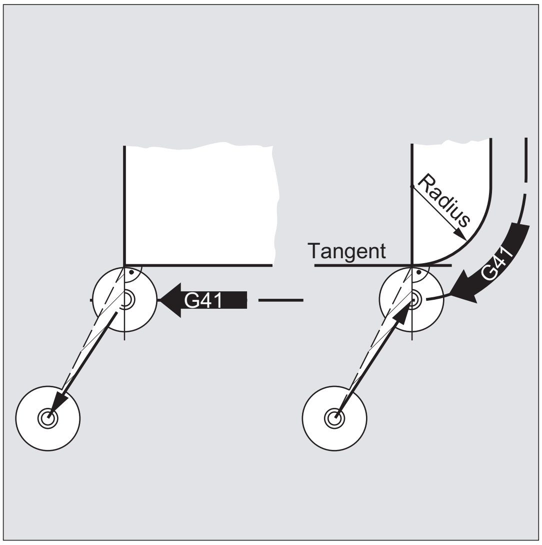
1. Approach:

   If `NORM` is activated, the tool will move directly to the compensated start position along a straight line (irrespective of the preset approach angle programmed for the travel movement) and is positioned perpendicular to the path tangent at the starting point.

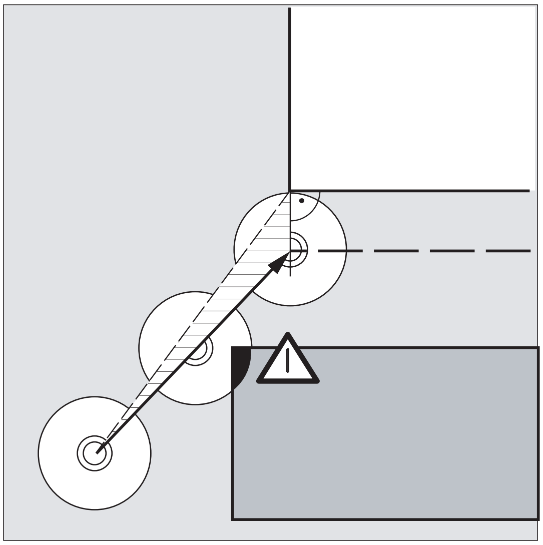


2. Retract:

   The tool is perpendicular to the last compensated path end point and then moves (irrespective of the preset approach angle programmed for the travel movement) directly in a straight line to the next uncompensated position, e.g. to the tool change point.



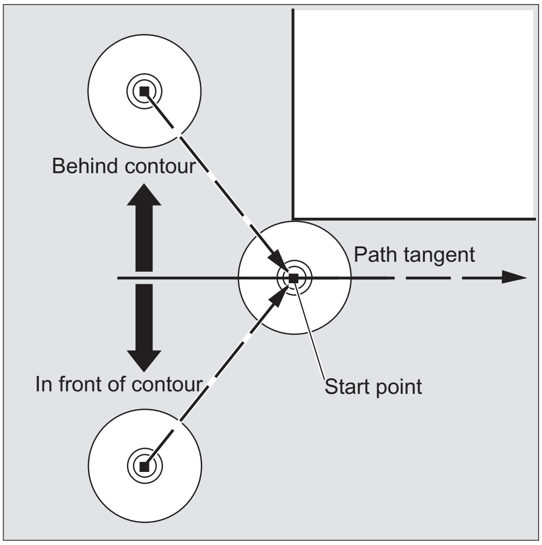
Modifying approach/retract angles introduces a collision risk:



CAUTION
Modified approach/retract angles must be taken into account during programming in order that potential collisions can be avoided.

Approach/Retraction with KONT

Prior to the approach the tool can be located **in front of** or **behind** the contour. The path tangent at the starting point serves as a separation line:



Accordingly, two scenarios need to be distinguished where approach/retraction with `KONT` is concerned:

1. The tool is located in front of the contour.

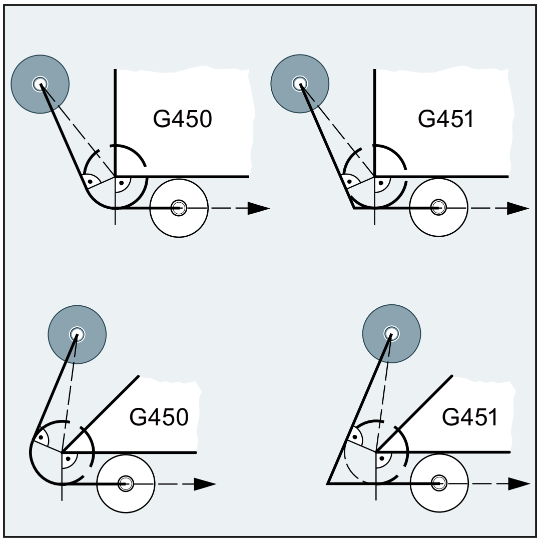
   → The approach/retract strategy is the same as with NORM.

2. The tool is located behind the contour.

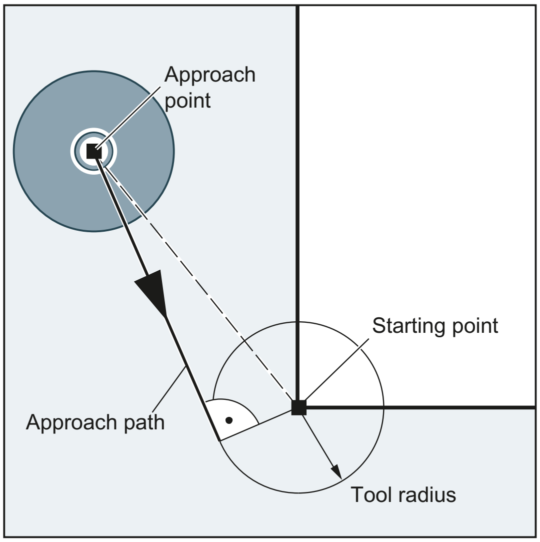
   - Approach:

     The tool travels around the starting point either along a circular path or over the intersection of the equidistant paths depending on the programmed corner behavior (`G450`/`G451`).

     The commands `G450`/`G451` apply to the transition from the current block to the next block:



In both cases (`G450`/`G451`), the following approach path is generated:



A straight line is drawn from the uncompensated approach point. This line is a tangent to a circle with circle radius = tool radius. The center point of the circle is on the starting point.

- Retract:

  The same applies to retraction as to approach, but in the reverse order.

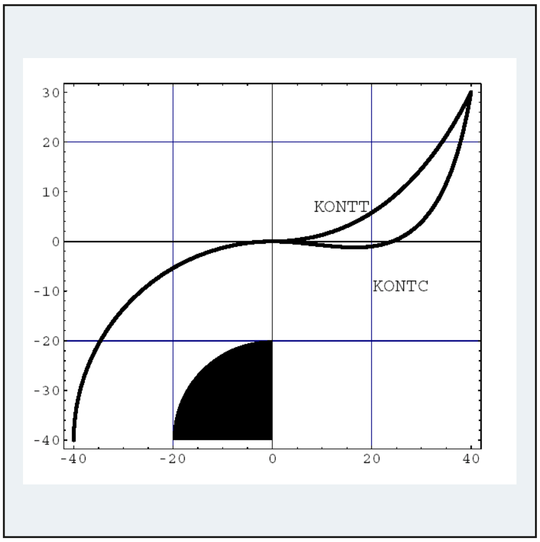
Approach/Retraction with KONTC

The contour point is approached/exited with constant curvature. There is no jump in acceleration at the contour point. The path from the start point to the contour point is interpolated as a polynomial.

Approach/Retraction with KONTC

The contour point is approached/exited with constant tangent. A jump in the acceleration can occur at the contour point. The path from the start point to the contour point is interpolated as a polynomial.

Differences between KONTC and KONTT



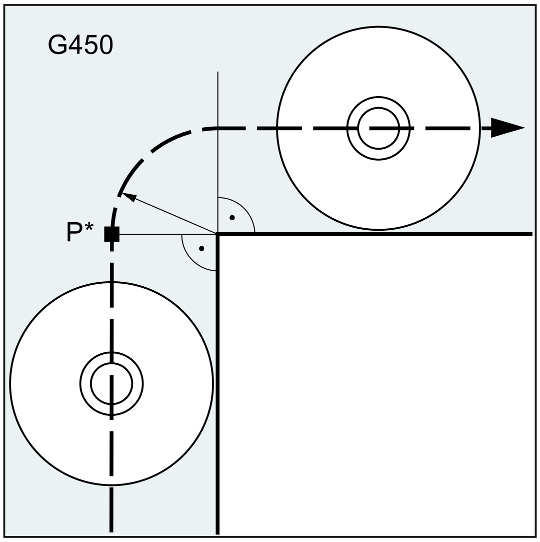
The figure below shows the differences in approach/retraction behavior between KONTT and KONTC. A circle with a radius of 20 mm about the center point at X0 Y-40 is compensated with a tool with an external radius of 20 mm. The tool center point therefore moves along a circular path with radius 40 mm. The end point of the approach blocks is at X40 Y30. The transition between the circular block and the retraction block is at the zero point. Due to the extended continuity of curvature associated with KONTC, the retraction block first executes a movement with a negative Y component. This will often be undesired. This response does not occur with the KONTT retraction block. However, with this block, an acceleration step change occurs at the block transition.

If the KONTT or KONTC block is the approach block rather than the retraction block, the contour is exactly the same, but it is machined in the opposite direction.

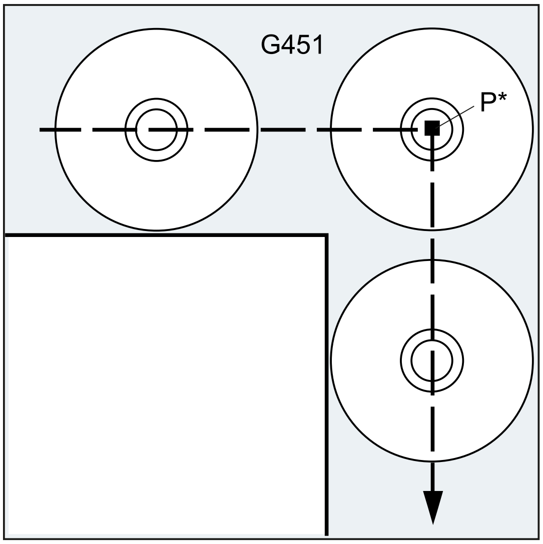
10.3 Compensation at the outside corners (G450, G451, DISC)

Function

With tool radius compensation activated (`G41`/`G42`), command `G450` or `G451` can be used to define the course of the compensated tool path when traveling around outside corners:



With `G450` the tool center point travels around the workpiece corner across an arc with tool radius.



With G451 the tool center point approaches the intersection of the two equidistants, which lie in the distance between the tool radius and the programmed contour. G451 applies only to circles and straight lines.

Note

`G450`/`G451` is also used to define the approach path with `KONT` active and approach point behind the contour (see "Contour approach and retraction (NORM, KONT, KONTC, KONTT) [Page 287]").

The `DISC` command can be used to distort the transition circles with `G450`, thereby producing sharper contour corners.

Syntax

```
G450 [DISC=<value>]
```

```
G451
```

Significance

`G450`: `G450` is used to travel around workpiece corners on a circular path.

`DISC`: Flexible programming of the circular path with G450 (optional)

`<value>`: Type: INT

Range of values: 0, 1, 2 to 100

Significance:

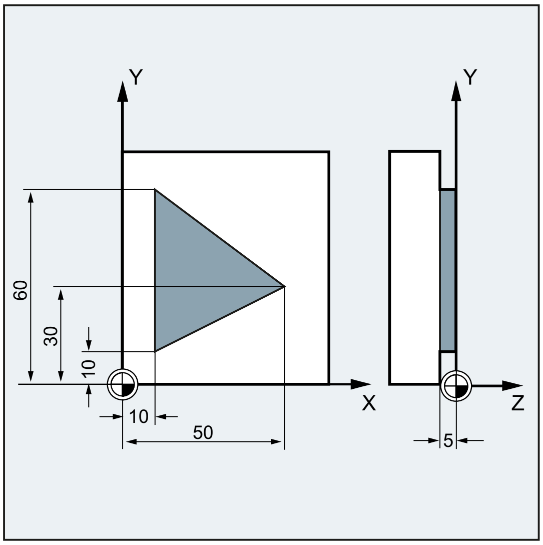
0	Transition circle
100	Intersection of the equidistant paths (theoretical value)

`G451`: G`451` is used to approach the intersection point of the two equidistant paths in the case of workpiece corners. The tool backs off from the workpiece corner.

Note

`DISC` only applies with call of `G450`, but can be programmed in a previous block without `G450`. Both commands are modal.

Example



In this example, a transition radius is programmed for all outside corners (corresponding to the programming of the corner behavior in block N30). This prevents the tool stopping and backing off at the change of direction.

Program code	Comment
`N10 G17 T1 G0 X35 Y0 Z0 F500`	`; Starting conditions`
`N20 G1 Z-5`	`; Feed in tool.`
`N30 G41 KONT` G450 `X10 Y10`	`;` Activate `TRC with KONT approach/retract mode and` corner behavior G450.
`N40 Y60`	`; Mill the contour.`
`N50 X50 Y30`	
`N60 X10 Y10`	
`N80 G40 X-20 Y50`	`; Deactivate compensation mode, retraction on transition circle.`

Program code	Comment
N90 G0 Y100	
N100 X200 M30	

Further information

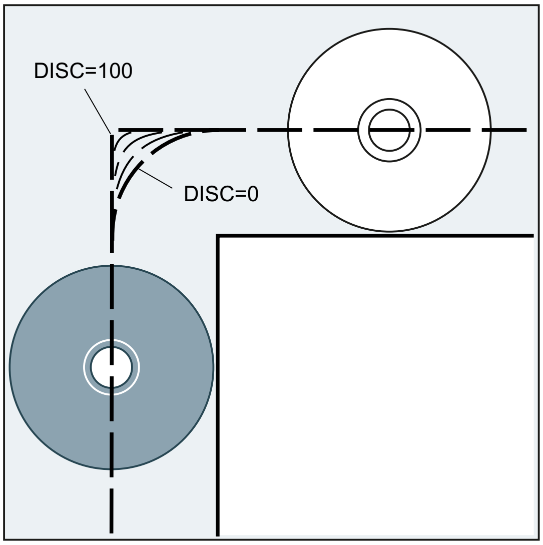
G450/G451

At intermediate point P*, the control executes operations such as infeed movements or switching functions. These operations are programmed in blocks inserted between the two blocks forming the corner.

With G450 the transition circle belongs to the next travel command with respect to the data.

DISC

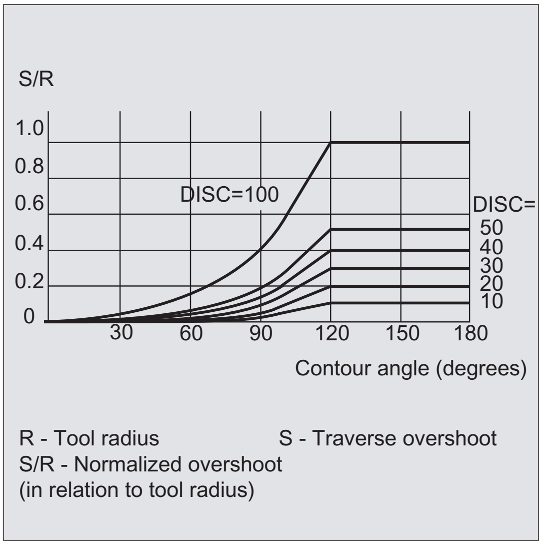
When DISC values greater than 0 are specified, intermediate circles are shown with a magnified height – the result is transition ellipses or parabolas or hyperbolas:



An upper limit can be defined in machine data – generally DISC=50.

Traversing behavior

When `G450` is activated and with acute contour angles and high `DISC` values, the tool is lifted off the contour at the corners. In the case of contour angles equal to or greater than 120°, there is uniform travel around the contour:



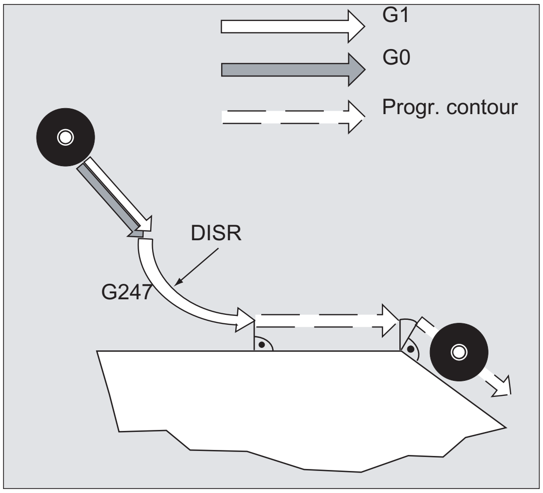
When `G451` is activated and with acute contour angles, superfluous non-cutting tool paths can result from lift-off movements. A parameter can be used in the machine data to define automatic switchover to transition circle in such cases.

10.4 Smooth approach and retraction

10.4.1 Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR)

Function

The SAR (Smooth Approach and Retraction) function is used to achieve a tangential approach to the start point of a contour, regardless of the position of the start point.



This function is used preferably in conjunction with the tool radius compensation, but this is not mandatory.

The approach and retraction movement consists of a maximum of four sub-movements:

- Start point of the movement P_0
- Intermediate points P_1, P_2 and P_3
- End point P_4

Points P_0, P_3 and P_4 are always defined. Intermediate points P_1 and P_2 can be omitted, according to the parameters defined and the geometrical conditions.

Syntax

```
G140
G141 to G143
G147, G148
G247, G248
G347, G348
G340, G341
DISR=..., DISCL=..., FAD=...
```

Significance

G140: Approach and retraction direction dependent on the current compensation side (basic setting)

G141: Approach from the left or retraction to the left

G142: Approach from the right or retraction to the right

G143: Approach and retraction direction dependent on the relative position of the start or end point to the tangent direction

G147: Approach with a straight line

G148: Retraction with a straight line

G247: Approach with a quadrant

G248: Retraction with a quadrant

G347: Approach with a semicircle

G348: Retraction with a semicircle

G340: Approach and retraction in space (basic setting)

G341: Approach and retraction in the plane

DISR: **Approach and retraction with straight lines (G147/G148)**
Distance of the milling tool edge to the starting point of the contour

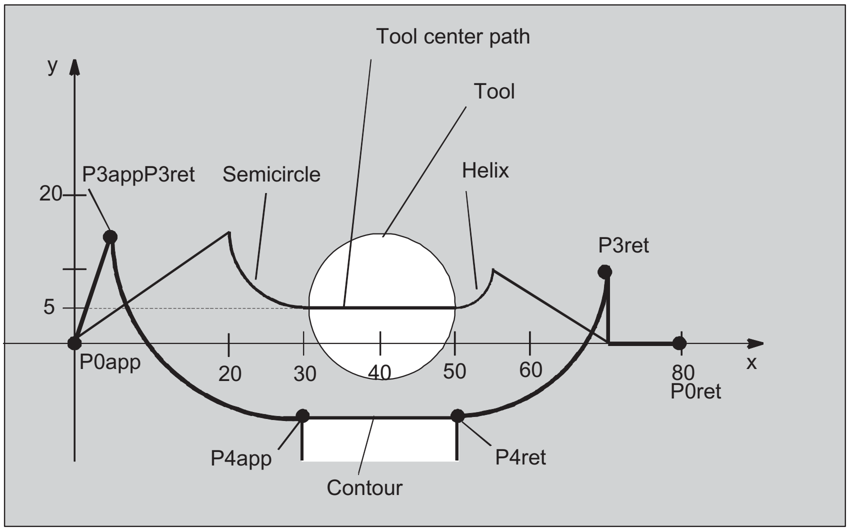
Approach and retraction along circles (G247, G347/G248, G348)
Radius of the tool center path
Notice: For REPOS with a semicircle, DISR is the circle diameter

DISCL: DISCL=... distance of the end point of the
fast feed movement to the machining plane
DISCL=AC(...) specification of the absolute position of the end point of the fast feed movement

FAD: Speed of the slow feed movement

FAD=... the programmed value is applied corresponding to
the G code of group 15 (feedrate; G93, G94, etc.)
FAD=PM(...) the programmed value is interpreted irrespective of the active G code, group 15 as linear feedrate (as G94)
FAD=PR(...) the programmed value is interpreted irrespective of the active G code, group 15 as revolutional feedrate (as G95).

Example



- Smooth approach (block N20 activated)
- Approach with quadrant (G247)
- Approach direction not programmed, G140 applies, i.e. TRC is active (G41)
- Contour offset OFFN=5 (N10)
- Current tool radius=10, and so the effective compensation radius for TRC=15, the radius of the SAR contour =25, with the result that the radius of the tool center path is equal to DISR=10
- The end point of the circle is obtained from N30, since only the Z position is programmed in N20
- Infeed movement
  - From Z20 to Z7 (DISCL=AC(7)) with rapid traverse.
  - Then to Z0 with FAD=200.
  - Approach circle in X-Y-plane and following blocks with F1500 (for this velocity to take effect in the following blocks, the active G0 in N30 must be overwritten with G1, otherwise the contour would be machined further with G0).
- Smooth retraction (block N60 activated)
- Retraction with quadrant (G248) and helix (G340)
- FAD not programmed, since irrelevant for G340
- Z=2 in the starting point; Z=8 in the end point, since DISCL=6
- When DISR=5, the radius of the SAR contour=20, the radius of the tool center point path=5
- Retraction movements from Z8 to Z20 and the movement parallel to the X-Y plane to X70 Y0.

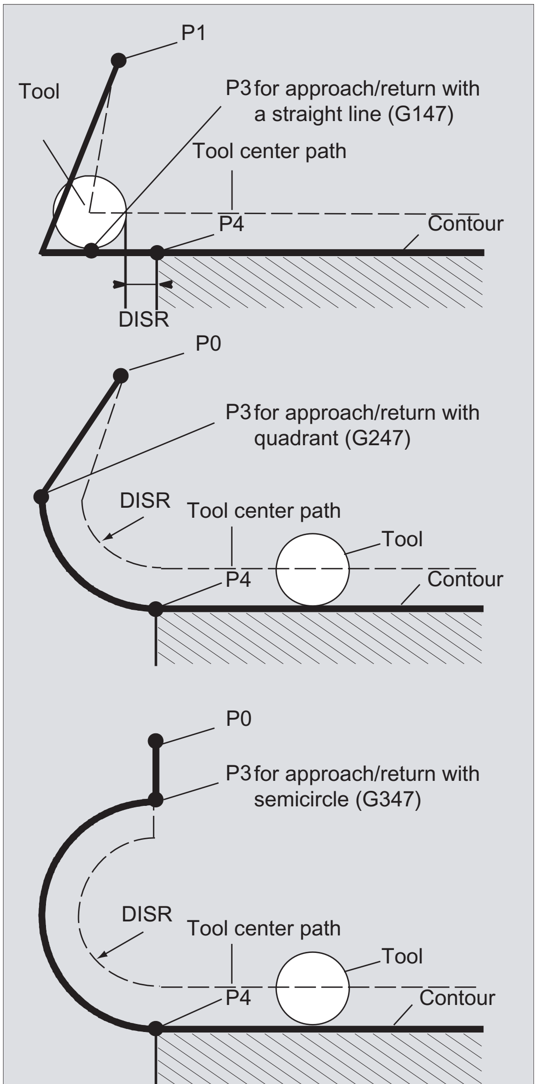
Program code	Comment
`$TC_DP1[1,1]=120`	`; Tool definition T1/D1`
`$TC_DP6[1,1]=10`	`; Radius`
`N10 G0 X0 Y0 Z20 G64 D1 T1 OFFN=5`	`; (P0app)`
`N20 G41 G247 G341 Z0 DISCL=AC(7) DISR=10 F1500 FAD=200`	`; Approach (P3app)`
`N30 G1 X30 Y-10`	`; (P4app)`
`N40 X40 Z2`	
`N50 X50`	`; (P4ret)`
`N60 G248 G340 X70 Y0 Z20 DISCL=6 DISR=5 G40 F10000`	`; Retraction (P3ret)`
`N70 X80 Y0`	`; (P0ret)`
`N80 M30`	

Further information

Selecting the approach and retraction contour

The appropriate G command can be used:

- to approach or retract with a straight line (G147, G148),
- a quadrant (G247, G248) or
- a semicircle (G347, G348).


P1
Tool
P3 for approach/return with a straight line (G147)
Tool center path
P4
Contour
DISR
P0
P3 for approach/return with quadrant (G247)
DISR
Tool center path
Tool
P4
Contour
P0
P3 for approach/return with semicircle (G347)
DISR
Tool center path
Tool
P4
Contour

Approach and retraction, shown with intermediate point P4 (with simultaneous activation of tool radius compensation)

Selecting the approach and retraction direction

Use the tool radius compensation (G140, basic setting) to determine the approach and retraction direction with positive tool radius:

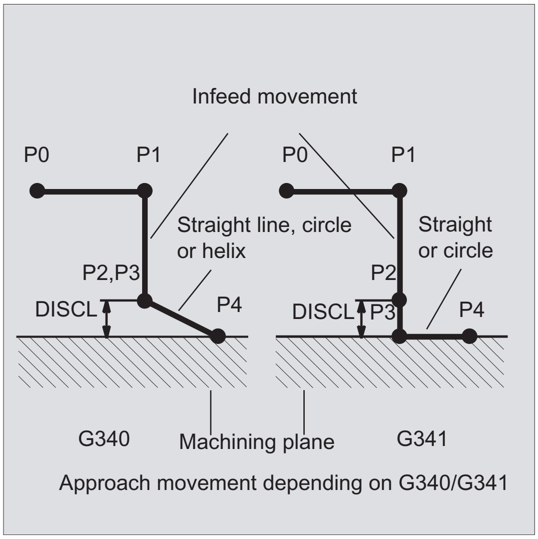
- G41 active → approach from left
- G42 active → approach from right

G141, G142 and G143 provide further approach options.

The G codes are only significant when the approach contour is a quadrant or a semicircle.

Motion steps between start point and end point (G340 and G341).

The approach characteristic from P_0 to P_4 is shown in the figure below:



In cases which include the position of the active plane G17 to G19 (circular plane, helical axis, infeed motion perpendicular to the active plane), any active rotating FRAME is taken into account.

Length of the approach straight line or radius for approach circles (DISR) (see figure "Selecting approach/retraction contour")

- Approach/retract with straight lines

  DISR specifies the distance of the cutter edge from the starting point of the contour, i.e. the length of the straight line when TRC is active is the sum of the tool radius and the programmed value of DISR. The tool radius is only taken into account if it is positive. The resultant line length must be positive, i.e. negative values for DISR are allowed provided that the absolute value of DISR is less than the tool radius.

- Approach/retract with circles

  DISR specifies the radius of the tool center point path. If TRC is activated, a circle is produced with a radius that results in the tool center point path with the programmed radius.

Distance of the point from the machining plane (DISCL) (see figure when selecting approach/ retraction contour)

If the position of point P_2 is to be specified by an absolute reference on the axis perpendicular to the circle plane, the value must be programmed in the form DISCL=AC(...).

The following applies for DISCL=0:

- With G340: The whole of the approach motion now only consists of two blocks (P_1, P_2 and P_3 are combined). The approach contour is formed by P_1 to P_4.
- With G341: The whole approach contour consists of three blocks (P_2 and P_3 are combined). If P_0 and P_4 are on the same plane, only two blocks result (infeed movement from P_1 to P_3 is omitted).
- The point defined by DISCL is monitored to ensure that it is located between P_1 and P_3, i.e. the sign must be identical for the component perpendicular to the machining plane in all motions that possess such a component.
- On detection of a direction reversal, a tolerance defined by the machine data SAR_CLEARANCE_TOLERANCE is permitted.

Programming the end point P4 for approach or P0 for retraction

The end point is generally programmed with X... Y... Z...

- **Programming during approach**
  - P_4 in SAR block.
  - P_4 is defined by means of the end point of the next traversing block.

    More blocks can be inserted between an SAR block and the next traversing block without moving the geometry axes.

Example:

Program code	Comment
`$TC_DP1[1,1]=120`	`; Milling tool T1/D1`
`$TC_DP6[1,1]=7`	`; Tool with 7 mm radius`
`N10 G90 G0 X0 Y0 Z30 D1 T1`	
`N20 X10`	
`N30 G41 G147 DISCL=3 DISR=13 Z=0 F1000`	
`N40 G1 X40 Y-10`	
`N50 G1 X50`	
`...`	

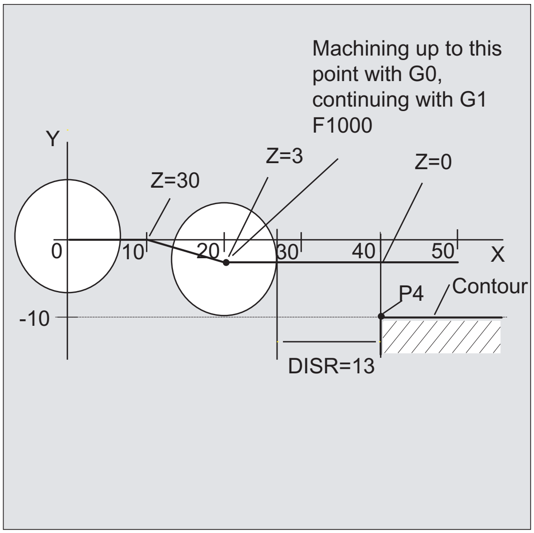
N30/N40 can be replaced by:

1.

Program code	Comment
`N30 G41 G147 DISCL=3 DISR=13 X40 Y-10 Z0 F1000`	

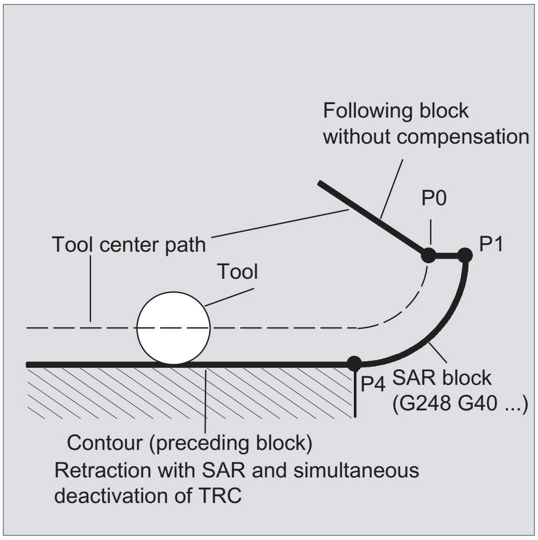
2.

Program code	Comment
`N30 G41 G147 DISCL=3 DISR=13 F1000`	
`N40 G1 X40 Y-10 Z0`	


Machining up to this point with G0, continuing with G1 F1000
Y
Z=3
Z=0
Z=30
0
10
20
30
40
50
X
P4
Contour
-10
DISR=13

- Programming during retraction
  - For an SAR block without programmed geometry axis, the contour ends in P_2. The position in the axes that form the machining plane are obtained from the retraction contour. The axis component perpendicular to this is defined by DISCL. If DISCL=0, movement runs fully in the plane.
  - If in the SAR block only the axis perpendicular to the machining plane is programmed, the contour will end at P_1. The positions of the remaining axes will result, as described above. If the SAR block is also the TRC disable block, an additional path from P_1 to P_0 is inserted such that no motion results at the end of the contour when disabling the TRC.
  - If only one axis on the machining plane is programmed, the missing second axis is modally added from its last position in the previous block.
  - For an SAR block without programmed geometry axis, the contour ends in P_2. The position in the axes that form the machining plane are obtained from the retraction contour. The axis component perpendicular to this is defined by DISCL. If DISCL=0, movement runs fully in the plane.

- If in the SAR block only the axis perpendicular to the machining plane is programmed, the contour will end at P_1. The positions of the remaining axes will result, as described above. If the SAR block is also the TRC disable block, an additional path from P_1 to P_0 is inserted such that no motion results at the end of the contour when disabling the TRC.
- If only one axis on the machining plane is programmed, the missing second axis is modally added from its last position in the previous block.



Retraction with SAR and simultaneous deactivation of TRC

Approach and retraction velocities

- Velocity of the previous block (G0):

  All motions from P_0 up to P_2 are executed at this velocity, i.e. the motion parallel to the machining plane and the part of the infeed motion up to the safety clearance.
- Programming with FAD:

  Specification of the feedrate for

  - G341: infeed movement perpendicular to the machining plane from P_2 to P_3
  - G340: from point P_2 or P_3 to P_4
    If FAD is not programmed, this part of the contour is also traversed at the modally active speed of the previous block, if no F word is programmed in the SAR block.
- Programmed feedrate F:

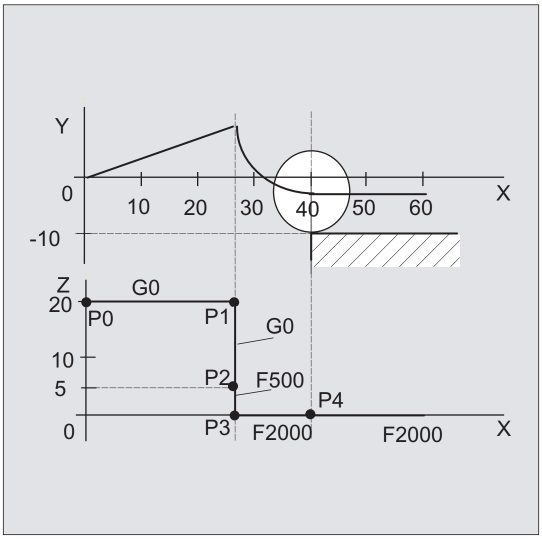
  This feedrate value is effective as of P_3 or P_2 if FAD is not programmed. If no F word is programmed in the SAR block, the speed of the previous block is active.

Example:

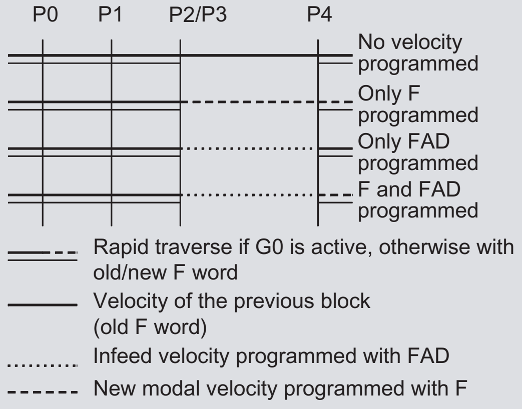
Program code	Comment
`$TC_DP1[1,1]=120`	`; Milling tool T1/D1`
`$TC_DP6[1,1]=7`	`; Tool with 7 mm radius`
`N10 G90 G0 X0 Y0 Z20 D1 T1`	

`N20 G41 G341 G247 DISCL=AC(5) DISR=13`
`FAD 500 X40 Y-10 Z=0 F200`	

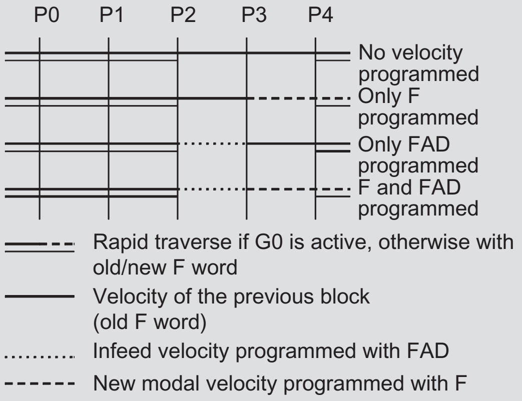
`N30 X50`	
`N40 X60`	
`...`	



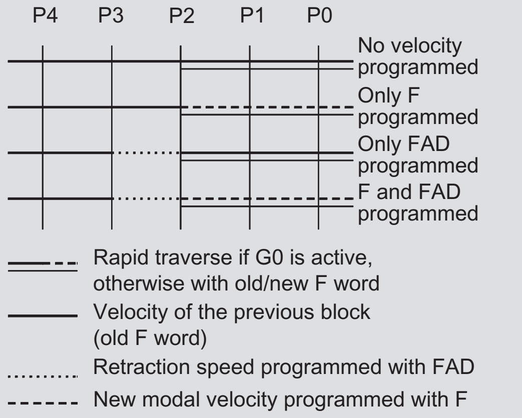
During retraction, the roles of the modally active feedrate from the previous block and the programmed feedrate value in the SAR block are reversed, i.e. the actual retraction contour is traversed with the old feedrate and a new speed programmed with the F word applies from P_2 up to P_0.


P0
P1
P2/P3
P4
No velocity programmed
Only F programmed
Only FAD programmed
F and FAD programmed
Rapid traverse if G0 is active, otherwise with old/new F word
Velocity of the previous block (old F word)
Infeed velocity programmed with FAD
New modal velocity programmed with F

Velocities in the SAR subblocks on retraction with G340


P0
P1
P2
P3
P4
No velocity programmed
Only F programmed
Only FAD programmed
F and FAD programmed
Rapid traverse if G0 is active, otherwise with old/new F word
Velocity of the previous block (old F word)
Infeed velocity programmed with FAD
New modal velocity programmed with F

Velocities in the SAR subblocks on retraction with G341


P4
P3
P2
P1
P0
No velocity programmed
Only F programmed
Only FAD programmed
F and FAD programmed
Rapid traverse if G0 is active, otherwise with old/new F word
Velocity of the previous block (old F word)
Retraction speed programmed with FAD
New modal velocity programmed with F

Velocities in the SAR subblocks on retraction

Reading positions

Points P_3 and P_4 can be read in the WCS as a system variable during approach.

- $P_APR: reading P_3 (initial point)
- $P_AEP: reading P_4 (contour starting point)
- $P_APDV: read whether $P_APR and $P_AEP contain valid data

10.4.2 Approach and retraction with enhanced retraction strategies (G460, G461, G462)

Function

In certain special geometrical situations, special extended approach and retraction strategies, compared with the previous implementation with activated collision detection for the approach and retraction block, are required in order to activate or deactivate tool radius compensation. A collision detection can result, for example, in a section of the contour not being completely machined, see following figure:

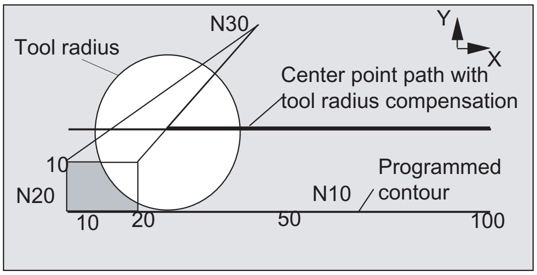


Figure 10-3 Retraction behavior with G460

Syntax

```
G460
G461
G462
```

Significance

`G460`: As previously (activation of the collision detection for the approach and retraction block)

`G461`: Insertion of a circle in the TRC block, if it is not possible to have an intersection whose center point is in the end point of the uncorrected block, and whose radius is the same as the tool radius.

Up to the intersection, machining is performed with an **auxiliary circle** around the contour end point (i.e. up to the end of the contour).

`G462`: Insertion of a circle in the TRC block, if it is not possible to have an intersection; the block is extended by its end tangent (default setting).

Machining is performed up to the **extension** of the last contour element (i.e. until shortly before the end of the contour).

Note

The approach behavior is symmetrical to the retraction behavior.

The approach/retraction behavior is determined by the state of the G command in the approach/retraction block. The approach behavior can therefore be set independently of the retraction behavior.

Examples

Example 1: Retraction behavior with G460

The following example describes only the situation for deactivation of tool radius compensation: The behavior for approach is exactly the same.

Program code	Comment
`G42 D1 T1`	`; Tool radius 20 mm`
`...`	
`G1 X110 Y0`	
`N10 X0`	
`N20 Y10`	
`N30 G40 X50 Y50`	

Example 2: Approach with G461

Program code	Comment
`N10 $TC_DP1[1,1]=120`	`; Milling tool type`
`N20 $TC_DP6[1,1]=10`	`; Tool radius`
`N30 X0 Y0 F10000 T1 D1`	
`N40 Y20`	
`N50 G42 X50 Y5 G461`	
`N60 Y0 F600`	
`N70 X30`	
`N80 X20 Y-5`	
`N90 X0 Y0 G40`	
`N100 M30`	

Further information

G461

If no intersection is possible between the last TRC block and a preceding block, the offset curve of this block is extended with a circle whose center point lies at the end point of the uncorrected block and whose radius is equal to the tool radius.

The control attempts to cut this circle with one of the preceding blocks.

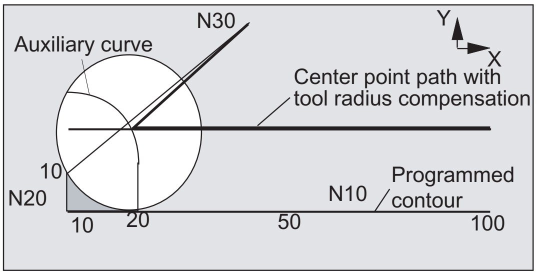


Figure 10-4 Retraction behavior with G461

Collision monitoring CDON, CDOF

If CDOF is active (see section Collision monitoring, CDON, CDOF), the search is aborted when an intersection is found, i.e., the system does not check whether further intersections with previous blocks exist.

If CDON is active, the search continues for further intersections after the first intersection is found.

An intersection point, which is found in this way, is the new end point of a preceding block and the start point of the deactivation block. The inserted circle is used exclusively to calculate the intersection and does not produce a traversing movement.

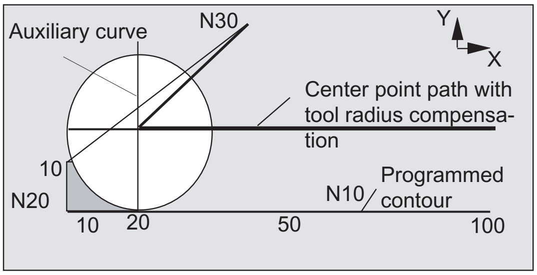
Note

If no intersection is found, alarm 10751 (collision danger) is output.

G462

If no intersection is possible between the last TRC block and a preceding block, a straight line is inserted, on retraction with G462 (initial setting), at the end point of the last block with tool radius compensation (the block is extended by its end tangent).

The search for the intersection is then identical to the procedure for G461.



Retraction behavior with G462 (see example)

With G462, the corner generated by N10 and N20 in the example program is not machined to the full extent actually possible with the tool used. However, this behavior may be necessary if the part contour (as distinct from the programmed contour), to the left of N20 in the example, is not permitted to be violated even with y values greater than 10 mm.

Corner behavior with KONT

If KONT is active (travel round contour at start or end point), the behavior differs according to whether the end point is in front of or behind the contour.

- **End point in front of contour**

  If the end point is in front of the contour, the retraction behavior is the same as with NORM. This property does not change even if the last contour block for G451 is extended with a straight line or a circle. Additional circumnavigation strategies to avoid a contour violation in the vicinity of the contour end point are therefore not required.

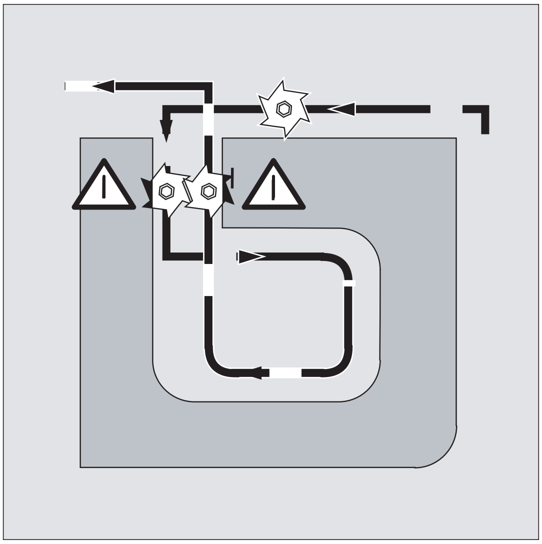
- **End point behind contour**

  If the end point is behind the contour, a circle or straight line is always inserted depending on G450/G451. In this case, G460-462 has no effect. If the last traversing block in this situation has no intersection with a preceding block, an intersection with the inserted contour element or with the straight line of the end point of the bypass circle to the programmed endpoint can result.
  If the inserted contour element is a circle (G450), and this forms an interface with the preceding block, this is equal to the interface that would occur with NORM and G461. In general, however, a remaining section of the circle still has to be traversed. For the linear part of the retraction block, no further calculation of intersection is required.
  In the second case, if no interface of the inserted contour element with the preceding blocks is found, the intersection between the retraction straight line and a preceding block is traversed.
  Therefore, a behavior that deviates from G460 can only occur with active G461 or G462 either if NORM is active or the behavior with KONT is geometrically identical to that with NORM.

10.5 Collision monitoring (CDON, CDOF, CDOF2)

Function

With the collision detection and active tool radius compensation, the tool paths are monitored through look-ahead contour calculation. This Look Ahead function allows possible collisions to be detected in advance and permits the control to actively avoid them.



Collision detection can be activated or deactivated in the NC program.

Syntax

```
CDON
CDOF
CDOF2
```

Significance

`CDON`: Command for the **activation** of the collision detection.

`CDOF`: Command for the **deactivation** of the collision detection.

With deactivated collision detection, a search is made in the **previous** traversing block (at inside corners) for a common intersection for the current block; if necessary the search is extended to even earlier blocks .

Note:

`CDOF` can be used to avoid the faulty detection of bottlenecks, resulting, for example, from missing information that is not available in the NC program.

`CDOF2`: Command for the **deactivation** of the collision detection **during 3D circumferential milling.**

The tool offset direction is determined from adjacent block parts with `CDOF2`.

`CDOF2` is only effective for 3D circumferential milling and has the same significance as `CDOF` for all other types of machining (e.g. 3D face milling).

> **Note**
>
> The number of NC blocks that are included in the collision detection, can be set via machine data.

Example

Milling on the center point path with standard tool

The NC program describes the center point path of a standard tool. The contour for a tool that is actually used results in undersize, which is shown unrealistically large to demonstrate the geometric relationships in the following figure. The control also only has an overview of three blocks in the example.

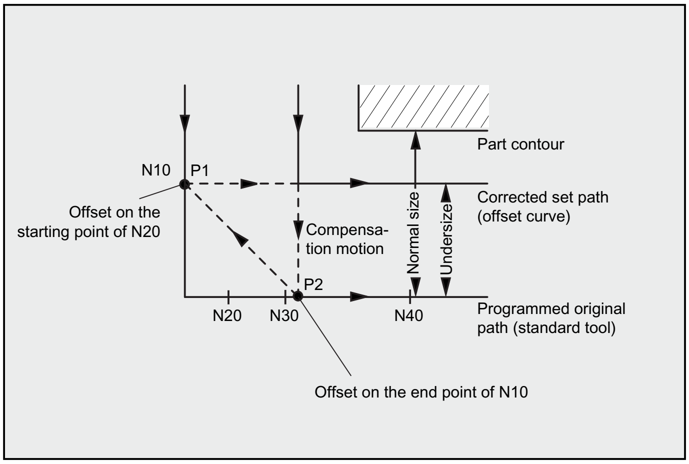

Part contour
N10
P1
Corrected set path (offset curve)
Offset on the starting point of N20
Compensa-tion motion
Normal size
Undersize
P2
N20
N30
N40
Programmed original path (standard tool)
Offset on the end point of N10

Figure 10-5 Compensation motion for missing intersection

Since an intersection exists only between the offset curves of the two blocks N10 and N40, the two blocks N20 and N30 would have to be omitted. In the example, the control does not know in block N40 if N10 has to be completely processed. Only a single block can therefore be omitted.

With active `CDOF2`, the compensation motion shown in the figure is executed and not stopped. In this situation, an active `CDOF` or `CDON` would result in an alarm.

Further information

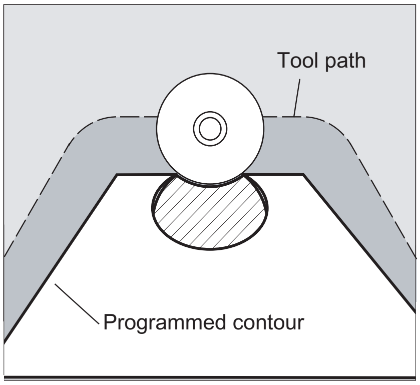
Program test

To avoid program stops, the tool with the largest radius from the range of used tools should always be used during the program test.

Examples of compensation motions for critical machining situations

The following examples show critical machining situations that are detected by the control and compensated through modified tool paths. In all examples, a tool with too large a radius has been used for the machining of the contour.

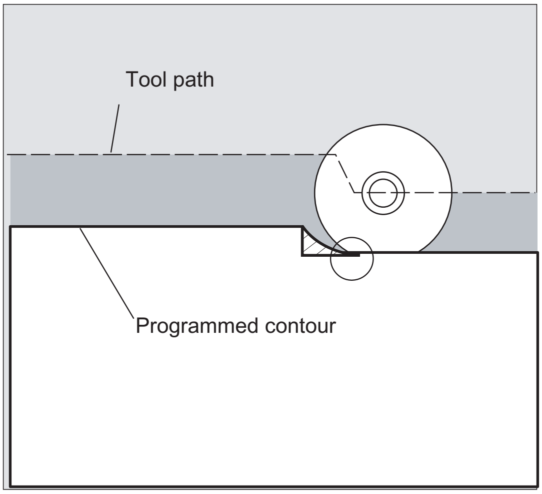
Example 1: Bottleneck detection



As the tool radius selected for the machining of this inside contour is too large, the "bottleneck" is bypassed.

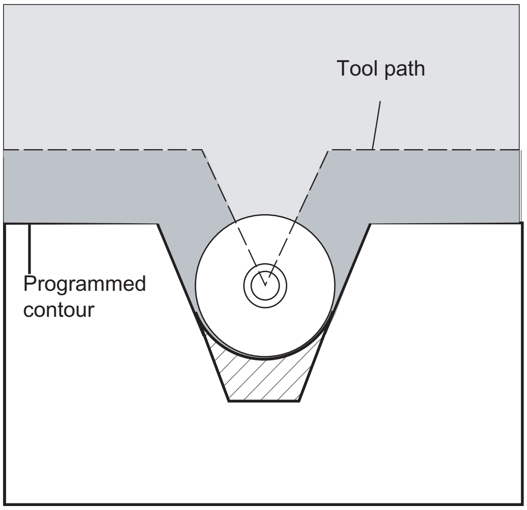
An alarm is output.

Example 2: Contour path shorter than tool radius



The tool bypasses the workpiece corner on a transition circle, then continues on the programmed path.

Example 3: Tool radius too large for internal machining



In such cases, the contours are machined only as much as is possible without causing a contour violation.

References

Function Manual, Basic Functions; Tool Offset (W1), Chapter: "Collision detection and bottleneck detection"

10.6 2D tool compensation (CUT2D, CUT2DF)

Function

With CUT2D or CUT2DF you define how the tool radius compensation is to act or to be interpreted when machining in inclined planes.

Tool length compensation

The tool length compensation generally always refers to the fixed, non-rotated working plane.

2D tool radius compensation with contour tools

The tool radius compensation for contour tools is used for automatic cutting-edge selection in the case of non-axially symmetrical tools that can be used for piece-by-piece machining of individual contour segments.

Syntax

```
CUT2D
```

```
CUT2DF
```

2D tool radius compensation for contour tools is activated if either of the two machining directions G41 or G42 is programmed with `CUT2D` or `CUT2DF`.

Note

If tool radius compensation is not activated, a contour tool will behave like a standard tool with only the first cutting edge.

Significance

`CUT2D`:	Activate 2 1/2 D radius compensation (default)
`CUT2DF`:	Activate 2 1/2 D radius compensation, tool radius compensation relative to the current frame or to inclined planes

CUT2D is used when the orientation of the tool cannot be changed and the workpiece is rotated for machining on inclined surfaces.

CUT2D is generally the standard setting and does not, therefore, have to be specified explicitly.

Cutting-edge selection with contour tools

Up to a maximum of 12 cutting edges can be assigned to each contour tool in any order.

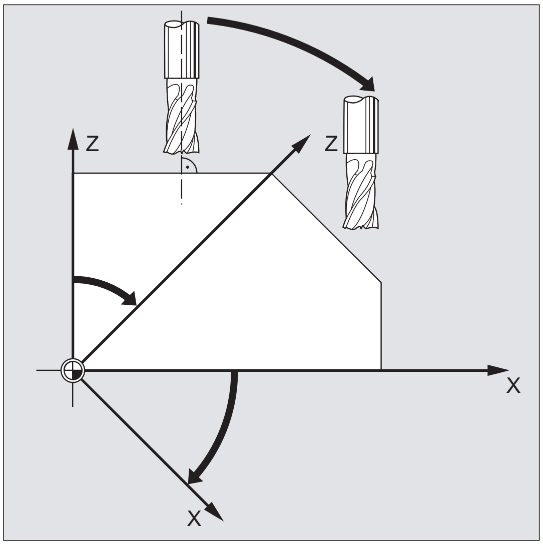
Machine manufacturer

The valid tool types for non-axially symmetrical tools and the maximum number of cutting edges (Dn = D1 to D12) are defined by the machine manufacturer via machine data. Please contact the machine manufacturer if not all of the 12 cutting edges are available.

Further information

Tool radius compensation, CUT2D

As for many applications, tool length compensation and tool radius compensation are calculated in the **fixed** working plane specified with G17 to G19.



Example of G17 (X/Y plane):

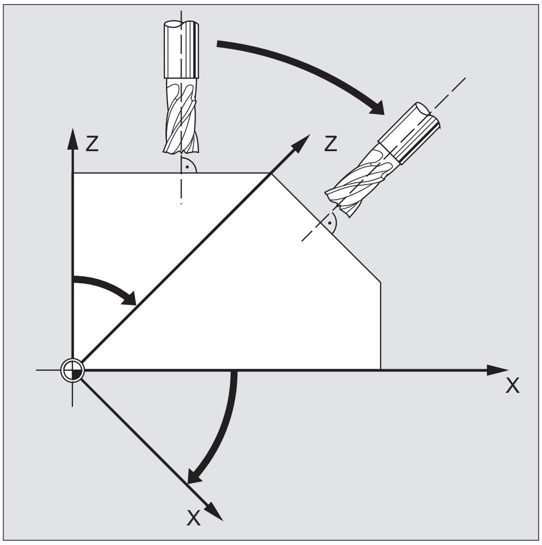
Tool radius compensation is active in the non-rotated X/Y plane, tool length compensation in the Z direction.

Tool offset values

For machining on inclined surfaces, the tool compensation values have to be defined accordingly, or be calculated using the functions for "Tool length compensation for orientable tools". For more information on this calculation method, see chapter "Tool orientation and tool length compensation".

Tool radius compensation, CUT2DF

In this case, it is possible to arrange the tool orientation perpendicular to the inclined working plane on the machine.



If a frame containing a rotation is programmed, the compensation plane is also rotated with CUT2DF. The tool radius compensation is calculated in the rotated machining plane.

Note

The tool length compensation continues to be active relative to the non-rotated working plane.

Definition of contour tools, CUT2D, CUT2DF

A contour tool is defined by the number of cutting edges (on the basis of D nos) associated with a T no. The first cutting edge of a contour tool is the cutting edge that is selected when the tool is activated. If, for example, D5 is activated on T3 D5, then it is this cutting edge and the subsequent cutting edges that define the contour tool either partially or as a whole. The previous cutting edges will be ignored.

References

Function Manual, Basic Functions; Tool Offset (W1)

10.7 Keep tool radius compensation constant (CUTCONON, CUTCONOF)

Function

The "Keep tool radius compensation constant" function is used to suppress tool radius compensation for a number of blocks, whereby a difference between the programmed and the actual tool center path traveled set up by tool radius compensation in the previous blocks is retained as the compensation. It can be an advantage to use this method when several traversing blocks are required during line milling in the reversal points, but the contours produced by the tool radius compensation (follow strategies) are not wanted. It can be used independently of the type of tool radius compensation ($2^{1}/_{2}$D, 3D face milling, 3D circumferential milling).

Syntax

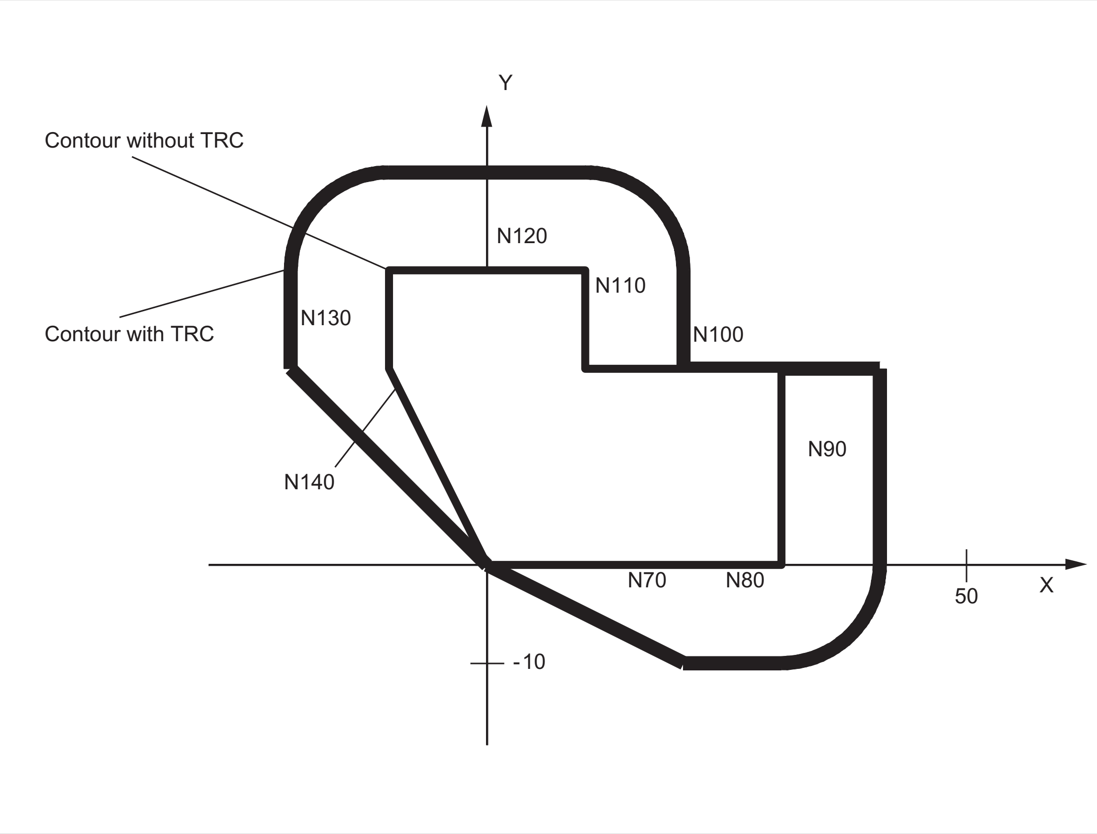
```
CUTCONON
CUTCONOF
```

Significance

`CUTCONON`: Command to activate the "Keep tool radius compensation constant" function

`CUTCONOF`: Command to deactivate the "Keep tool radius compensation constant" function

Example



Program code	Comment
N10	; Definition of tool d1.
N20 $TC_DP1[1,1] = 110	; Type
N30 $TC_DP6[1,1]= 10.	; Radius
N40	
N50 X0 Y0 Z0 G1 G17 T1 D1 F10000	
N60	
N70 X20 G42 NORM	
N80 X30	
N90 Y20	
N100 X10 CUTCONON	; Activation of the compensation suppression.
N110 Y30 KONT	; If required, insert bypass circle when deactivating the compensation suppression.
N120 X-10 CUTCONOF	
N130 Y20 NORM	; No bypass circle when deactivating the TRC.
N140 X0 Y0 G40	
N150 M30	

Further information

Tool radius compensation is normally active before the compensation suppression and is still active when the compensation suppression is deactivated again. In the last traversing block before `CUTCONON`, the offset point in the block end point is approached. All following blocks in which offset suppression is active are traversed without offset. However, they are offset by the vector from the end point of the last offset block to its offset point. These blocks can have any type of interpolation (linear, circular, polynomial).

The deactivation block of the compensation suppression, i.e. the block that contains `CUTCONOF`, is compensated normally. It starts in the offset point of the starting point. One linear block is inserted between the end point of the previous block, i.e. the last programmed traversing block with active `CUTCONON`, and this point.

Circular blocks, for which the circle plane is perpendicular to the compensation plane (vertical circles), are treated as though they had `CUTCONON` programmed. This implicit activation of the offset suppression is automatically canceled in the first traversing block that contains a traversing motion in the offset plane and is not such a circle. Vertical circle in this sense can only occur during circumferential milling.

10.8 Tools with a relevant cutting edge position

In the case of tools with a relevant tool point direction (turning and grinding tools – tool types 400–599; see chapter "Sign evaluation wear"), a change from G40 to G41/G42 or vice-versa is treated as a tool change. If a transformation is active (e.g., TRANSMIT), this leads to a preprocessing stop (decoding stop) and hence possibly to deviations from the intended part contour.

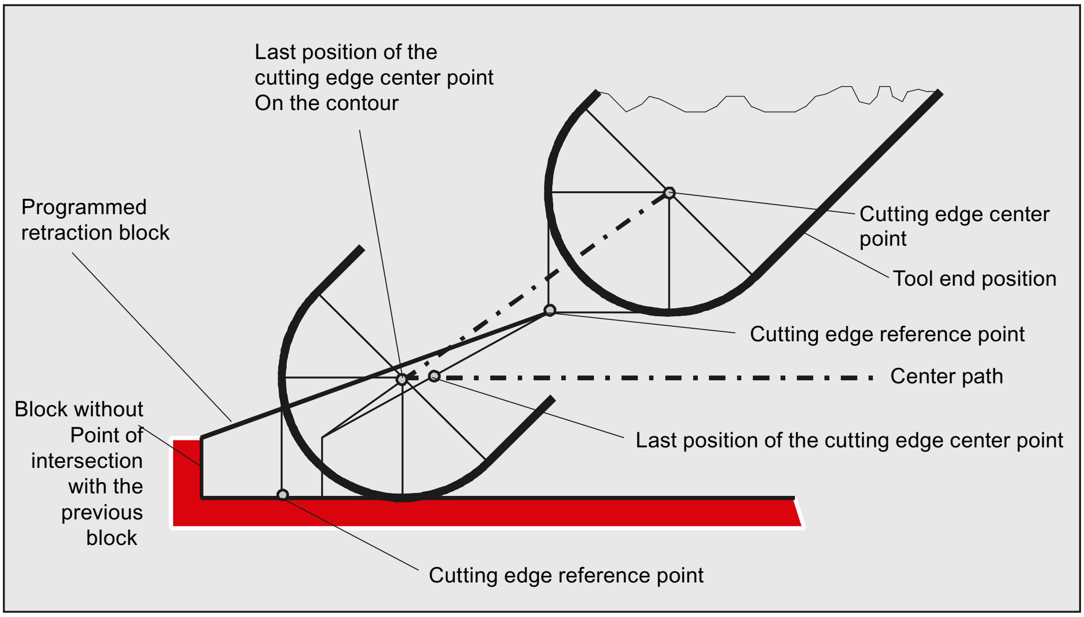
This original functionality changes with regard to:

1. Preprocessing stop on TRANSMIT
2. Calculation of intersection points at approach and retraction with KONT
3. Tool change with active tool radius compensation
4. Tool radius compensation with variable tool orientation at transformation

Further information

The original functionality has been modified as follows:

- A change from G40 to G41/G42 and vice-versa is no longer treated as a tool change. Therefore, a preprocessing stop no longer occurs with TRANSMIT.
- The straight line between the tool edge center points at the block start and block end is used to calculate intersection points with the approach and retraction block. The difference between the tool edge reference point and the tool edge center point is superimposed on this movement.
  On approach and retraction with KONT (tool circumnavigates the contour point, see above subsection "Contour approach and retraction"), superimposition takes place in the linear part block of the approach or retraction motion. The geometric conditions are therefore identical for tools with and without a relevant tool point direction. Deviations from the previous behavior occur only in relatively rare cases where the approach or retraction block does not intersect with an adjacent traversing block, see the following figure:


Last position of the cutting edge center point On the contour
Programmed retraction block
Cutting edge center point
Tool end position
Cutting edge reference point
Center path
Block without Point of intersection with the previous block
Last position of the cutting edge center point
Cutting edge reference point

- In circle blocks and in motion blocks containing rational polynomials with a denominator degree > 4, it is not permitted to change a tool with active tool radius compensation in cases where the distance between the tool edge center point and the tool edge reference point changes. With other types of interpolation, it is now possible to change when a transformation is active (e.g., TRANSMIT).
- For tool radius compensation with variable tool orientation, the transformation from the tool edge reference point to the tool edge center point can no longer be performed by means of a simple zero offset. Tools with a relevant tool point direction are therefore not permitted for 3D peripheral milling (an alarm is output).

Note

The subject is irrelevant with respect to face milling as only defined tool types without relevant tool point direction are permitted for this operation anyway. (A tool with a type, which has not been explicitly approved, is treated as a ball end mill with the specified radius. A tool point direction parameter is ignored).

Path action 11

11.1 Exact stop (G60, G9, G601, G602, G603)

Function

In exact stop traversing mode, all path axes and special axes involved in the traversing motion that are not traversed modally, are decelerated at the end of each block until they come to a standstill.

Exact stop is used when sharp outside corners have to be machined or inside corners finished to exact dimensions.

The exact stop specifies how exactly the corner point has to be approached and when the transition is made to the next block:

- "Exact stop fine"

  The block change is performed as soon as the axis-specific tolerance limits for "Exact stop fine" are reached for all axes involved in the traversing motion.

- "Exact stop coarse"

  The block change is performed as soon as the axis-specific tolerance limits for "Exact stop coarse" are reached for all axes involved in the traversing motion.

- "Interpolator end"

  The block change is performed as soon as the control has calculated a set velocity of zero for all axes involved in the traversing motion. The actual position or the following error of the axes involved are not taken into account

---

Note

The tolerance limits for "Exact stop fine" and "Exact stop coarse" can be set for each axis via the machine data.

Syntax

```
G60 ...
G9 ...
G601/G602/G603, etc.
```

Significance

`G60`:	Command for activation of the **modal** exact stop
`G9`:	Command for activation of the **non-modal** exact stop
`G601`:	Command for activation of the exact stop criterion "**Exact stop fine**"
`G602`:	Command for activation of the exact stop criterion "**Exact stop coarse**"
`G603`:	Command for activation of the exact stop criterion "**Interpolator end**"

Note

The commands for activating the exact stop criteria (`G601`/`G602`/`G603`) are only effective if `G60` or `G9` is active.

Example

Program code	Comment
N5 G602	; Criterion "Exact stop coarse" selected.
N10 G0 G60 Z...	; Exact stop modal active.
N20 X... Z...	; G60 continues to act.
...	
N50 G1 G601	; Criterion "Exact stop fine" selected.
N80 G64 Z...	; Switchover to continuous-path mode.
...	
N100 G0 G9	; Exact stop acts only in this block.
N110 ...	; Continuous-path mode active again.

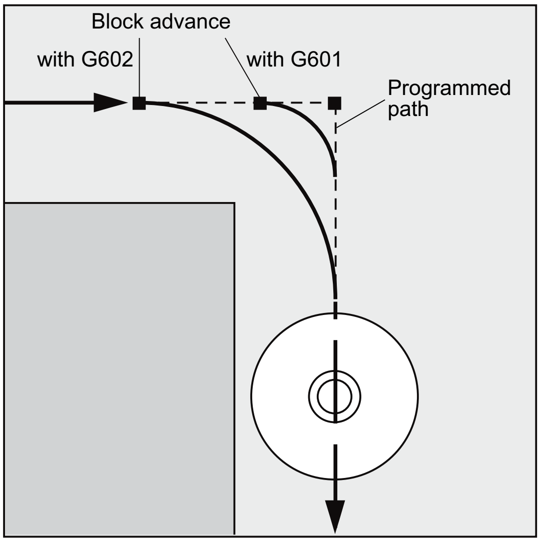
Further information

G60, G9

`G9` generates the exact stop in the current block, `G60` in the current block and in all following blocks.

Continuous-path-mode commands `G64` or `G641` - `G645` are used to deactivate `G60`.

G601, G602



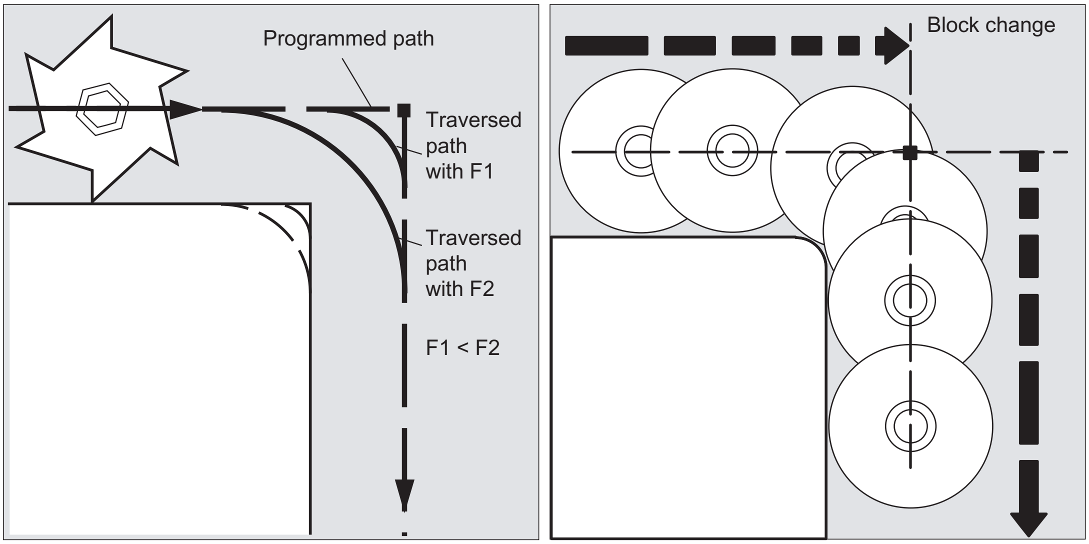
The movement is decelerated and stopped briefly at the corner point.

Note

Do not set the limits for the exact stop criteria any tighter than necessary. The tighter the limits, the longer it takes to position and approach the target position.

G603

The block change is initiated when the control has calculated a set velocity of zero for the axes involved. At this point, the actual value lags behind by a proportionate factor depending on the dynamic response of the axes and the path velocity. The workpiece corners can now be rounded.



Configured exact stop criterion

A channel-specific setting can be made for `G0` and the other commands in the first G function group indicating that contrary to the programmed exact stop criterion a preset criterion should be used automatically (see machine manufacturer's specifications).

References

Function Manual, Basic Functions, Continuous-path Mode, Exact Stop, Look Ahead (B1)

11.2 Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS)

Function

In continuous-path mode, the path velocity at the end of the block (for the block change) is not decelerated to a level which would permit the fulfillment of an exact stop criterion. The objective of this mode is, in fact, to avoid rapid deceleration of the path axes at the block-change point so that the axis velocity remains as constant as possible when the program moves to the next block. To achieve this objective, the "LookAhead" function is also activated when continuous-path mode is selected.

Continuous-path mode with smoothing facilitates the tangential shaping and/or smoothing of angular block transitions caused by local changes in the programmed contour.

Continuous-path operation:

- Rounds the contour
- Reduces machining times by eliminating braking and acceleration processes that are required to fulfill the exact-stop criterion
- Improves cutting conditions because of the more constant velocity

Continuous-path mode is suitable if:

- A contour needs to be traversed as quickly as possible (e.g. with rapid traverse)
- The exact contour may deviate from the programmed contour within a specific tolerance for the purpose of obtaining a continuous contour

Continuous-path mode is not suitable if:

- A contour needs to be traversed precisely
- An absolutely constant velocity is required

Note

Continuous-path mode is interrupted by blocks which trigger a preprocessing stop implicitly, e.g. due to:

- Access to specific machine status data ($A...)
- Auxiliary function outputs

Syntax

```
G64...
G641 ADIS=…
G641 ADISPOS=…
G642...
G643...
G644...
G645...
```

Meaning

`G64`: Continuous-path mode with reduced velocity as per the overload factor

`G641`: Continuous-path mode with smoothing as per distance criterion

`ADIS=...`: Distance criterion with `G641` for path functions `G1`, `G2`, `G3`, etc.

`ADISPOS=...`: Distance criterion with `G641` for rapid traverse `G0`

The distance criterion (= rounding clearance) `ADIS` or `ADISPOS` describes the maximum distance the rounding block may cover before the end of the block, or the distance after the end of block within which the rounding block must be terminated respectively.

Note:
If `ADIS/ADISPOS` is not programmed, a value of "zero" applies and the traversing behavior therefore corresponds to `G64`. The rounding clearance is automatically reduced (by up to 36%) for short traversing distances.

`G642`: Continuous-path mode with smoothing within the defined tolerances

In this mode, under normal circumstances smoothing takes place within the maximum permissible path deviation. However, instead of these axis-specific tolerances, observation of the maximum contour deviation (contour tolerance) or the maximum angular deviation of the tool orientation (orientation tolerance) can be configured.

Note:
Expansion to include contour and orientation tolerance is only supported on systems featuring the "Polynomial interpolation" option.

`G643`: Continuous-path mode with smoothing within the defined tolerances (block-internal)

`G643` differs from `G642` in that is not used to generate a separate rounding block; instead, axis-specific block-internal rounding movements are inserted. The rounding clearance can be different for each axis.

`G644`: Continuous-path mode with smoothing with maximum possible dynamic response

Note:
`G644` is not available with an active kinematic transformation. The system switches internally to `G642`.

`G645`: Continuous-path mode with smoothing and tangential block transitions within the defined tolerances

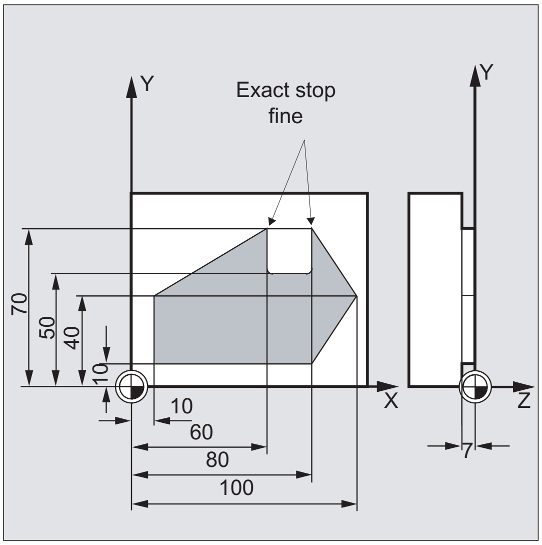
`G645` has the same effect on corners as `G642`. With `G645`, rounding blocks are also only generated on tangential block transitions if the curvature of the original contour exhibits a jump in at least one axis.

Note

Rounding cannot be used as a substitute for smoothing (`RND`). The user should not make any assumptions with respect to the appearance of the contour within the rounding area. The type of rounding can depend on dynamic conditions, e.g. on the tool path velocity. Rounding on the contour is therefore only practical with small `ADIS` values. `RND` must be used if a defined contour is to be traversed at the corner.

NOTICE
If a rounding movement initiated by `G641`, `G642`, `G643`, `G644` or `G645` is interrupted, the starting or end point of the original traversing block (as appropriate for REPOS mode) will be used for subsequent repositioning (REPOS), rather than the interruption point.

Example



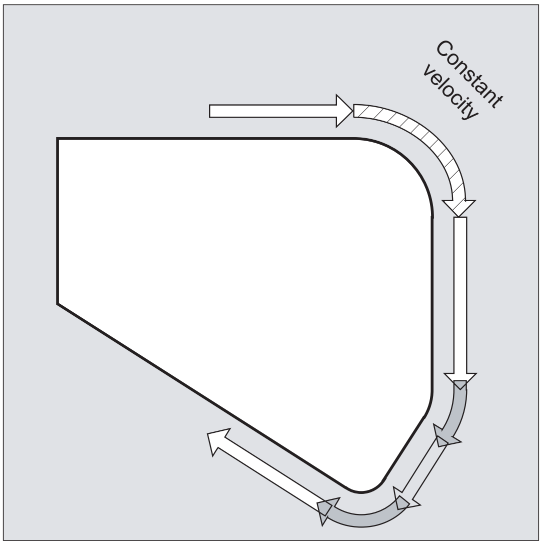
The two outside corners on the groove are to be approached exactly. Otherwise machining should be performed in continuous-path mode.

Program code	Comment
N05DIAMOF	; Radius as dimension.
N10 G17 T1 G41 G0 X10 Y10 Z2 S300 M3	; Approach starting position, activate spindle, path compensation.
N20 G1 Z-7 F8000	; Tool infeed.
N30 G641 ADIS=0.5	; Contour transitions are smoothed.
N40 Y40	
N50 X60 Y70 G60 G601	; Approach position exactly with exact stop fine.
N60 Y50	
N70 X80	
N80 Y70	
N90 G641 ADIS=0.5 X100 Y40	; Contour transitions are smoothed.
N100 X80 Y10	
N110 X10	
N120 G40 G0 X-20	; Deactivate path compensation.
N130 Z10 M30	; Retract tool, end of program.

Further information

Continuous-path mode G64

In continuous-path mode, the tool travels across tangential contour transitions with as constant a path velocity as possible (no deceleration at block boundaries). LookAhead deceleration is applied before corners and blocks with exact stop.



Corners are also traversed at a constant velocity. In order to minimize the contour error, the velocity is reduced according to an acceleration limit and an overload factor.

Note

The extent of smoothing of the contour transitions depends on the feedrate and the overload factor. The overload factor can be set in MD32310 $MA_MAX_ACCEL_OVL_FACTOR.

Setting MD20490 $MC_IGNORE_OVL_FACTOR_FOR_ADIS means that block transitions will always be rounded irrespective of the set overload factor.

The following points should be noted in order to prevent an undesired stop in path motion (relief cutting):

- Auxiliary functions, which are enabled after the end of the movement or before the next movement interrupt continuous-path mode (Exception: High-speed auxiliary functions).
- Positioning axes always traverse according to the exact stop principle, positioning window fine (as for `G601`). If an NC block has to wait for positioning axes, continuous-path mode is interrupted on the path axes.

However, intermediate blocks containing only comments, calculation blocks or subprogram calls do not affect continuous-path mode.

Note

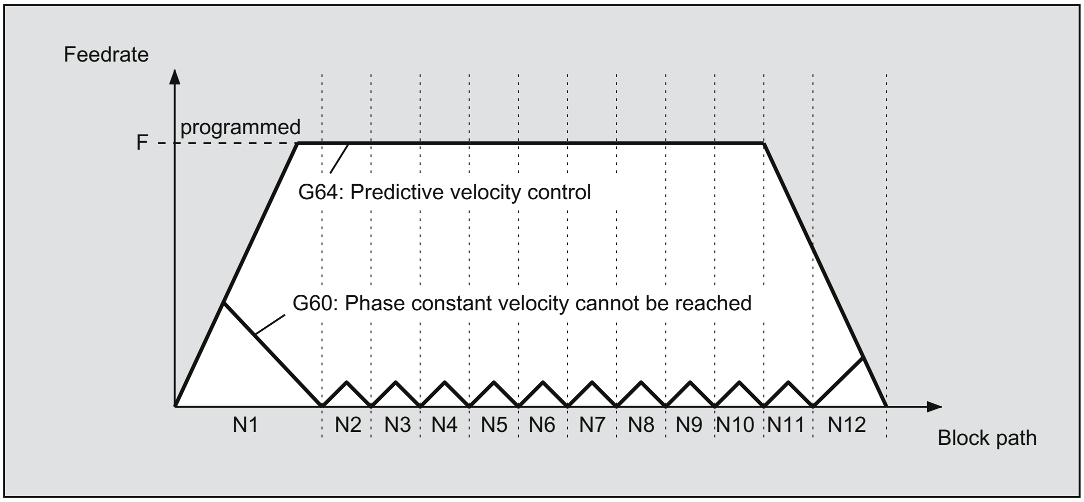
If `FGROUP` does not contain all the path axes, there is often a step change in the velocity at block transitions for those axes excluded from FGROUP; the control limits this change in velocity to the permissible values set in MD32300 $MA_MAX_AX_ACCEL and MD32310 $MA_MAX_ACCEL_OVL_FACTOR. This braking operation can be avoided through the application of a rounding function, which "smoothes" the specific positional interrelationship between the path axes.

LookAhead predictive velocity control

In continuous-path mode the control automatically determines the velocity control for several NC blocks in advance. This enables acceleration and deceleration across multiple blocks with almost tangential transitions.

Look Ahead is particularly suitable for the machining of movement sequences comprising short traverse paths with high path feedrates.

The number of NC blocks included in the Look Ahead calculation can be defined in machine data.



Continuous-path mode with smoothing as per distance criterion (G641)

With `G641`, the control inserts transition elements at contour transitions. The rounding clearance `ADIS` (or `ADISPOS` for `G0`) specifies the maximum extent to which the corners can be rounded. Within this rounding clearance, the control is free to ignore the path construct and replace it with a dynamically optimized distance.

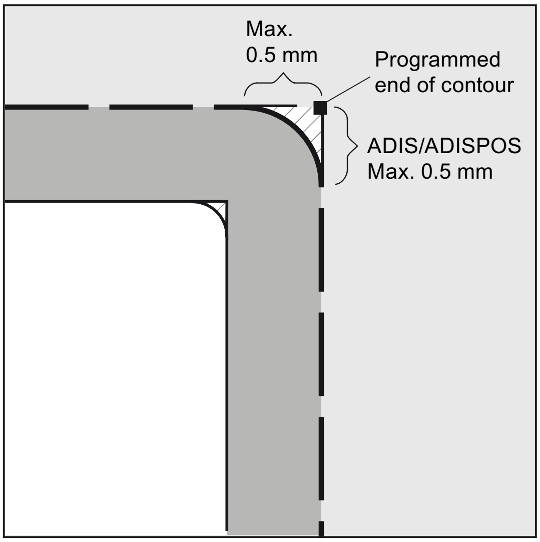
Disadvantage: Only one `ADIS` value is available for all axes.

The effect of `G641` is similar to `RNDM`; however, it is not restricted to the axes of the working plane.

Like `G64`, `G641` works with LookAhead predictive velocity control. Corner rounding blocks with a high degree of curvature are approached at reduced velocity.

Example:

Program code	Comment
`N10 G641 ADIS=0.5 G1 X... Y...`	`; The rounding block must begin no more than 0.5 mm before the programmed end of the block and must finish 0.5 mm after the end of the block. This setting remains modal.`



Note

Smoothing cannot and should not replace the functions for defined smoothing (`RND`, `RNDM`, `ASPLINE`, `BSPLINE`, `CSPLINE`).

Smoothing with axial precision with G642

With G642, smoothing does not take place within a defined `ADIS` range, but the axial tolerances defined with MD33100 $MA_COMPRESS_POS_TOL are complied with. The rounding clearance is determined based on the shortest rounding clearance of all axes. This value is taken into account when generating a rounding block.

Block-internal smoothing with G643

The maximum deviations from the precise contour in the case of smoothing with `G643` are defined for each axis using machine data MD33100 $MA_COMPRESS_POS_TOL.

`G643` is not used to generate a separate rounding block, but axis-specific block-internal rounding movements are inserted. In the case of `G643`, the rounding clearance of each axis can be different.

Smoothing with contour and orientation tolerance with G642/G643

MD20480 $MC_SMOOTHING_MODE can be used to configure rounding with `G642` and `G643` so that instead of the axis-specific tolerances, a contour tolerance and an orientation tolerance can be applied.

The contour tolerance and orientation tolerance are set in the channel-specific setting data:

SD42465 $SC_SMOOTH_CONTUR_TOL (maximum contour deviation)

SD42466 $SC_SMOOTH_ORI_TOL (maximum angular deviation of the tool orientation)

The setting data can be programmed in the NC program; this means that it can be specified differently for each block transition. Very different specifications for the contour tolerance and the tolerance of the tool orientation can only take effect with `G643`.

Note

Expansion to include contour and orientation tolerance is only supported on systems featuring the "Polynomial interpolation" option.

Note

An orientation transformation must be active for smoothing within the orientation tolerance.

Corner rounding with greatest possible dynamic response in G644

Smoothing with maximum possible dynamic response is configured in the thousands place with MD20480 $MC_SMOOTHING_MODE.

Value	Meaning
0	Specification of maximum axial deviations with: MD33100 $MA_COMPRESS_POS_TOL
1	Specification of maximum rounding clearance by programming: `ADIS=...` or `ADISPOS=...`
2	Specification of the maximum possible frequencies of each axis occurring in the rounding area with: MD32440 $MA_LOOKAH_FREQUENCY The rounding area is defined such that no frequencies in excess of the specified maximum can occur while the rounding motion is in progress.
3	When rounding with `G644`, neither the tolerance nor the rounding distance are monitored. Each axis traverses around a corner with the maximum possible dynamic response. With `SOFT`, both the maximum acceleration and the maximum jerk of each axis is maintained. With the `BRISK` command, the jerk is not limited; instead, each axis travels at the maximum possible acceleration.

Smoothing of tangential block transitions with G645

With G645, the smoothing movement is defined so that the acceleration of all axes involved remains smooth (no jumps) and the parameterized maximum deviations from the original contour (MD33120 $MA_PATH_TRANS_POS_TOL) are not exceeded.

In the case of angular non-tangential block transitions, the smoothing behavior is the same as with G642.

No intermediate rounding blocks

An intermediate rounding block is not inserted in the following cases:

- The axis stops between the two blocks.

  This occurs when:

  - The following block contains an auxiliary function output before the movement.
  - The following block does not contain a path movement.
  - An axis is traversed for the first time as a path axis for the following block when it was previously a positioning axis.
  - An axis is traversed for the first time as a positioning axis for the following block when it was previously a path axis.
  - The previous block traverses geometry axes and the following block does not.
  - The following block traverses geometry axes and the previous block does not.
  - Before tapping, the following block uses G33 as preparatory function and the previous block does not.
  - A change is made between BRISK and SOFT.
  - Axes involved in the transformation are not completely assigned to the path motion (e.g. for oscillation, positioning axes).
- The rounding block would slow down the part program execution.

  This occurs:

  - Between two very short blocks.

    Since each block requires at least one interpolation cycle, the added intermediate block would double the machining time.
  - If a block transition G64 (continuous-path mode without smoothing) can be traversed without a reduction in velocity.

    Corner rounding would increase the machining time. This means that the value of the permitted overload factor (MD32310 $MA_MAX_ACCEL_OVL_FACTOR) affects whether a block transition is rounded or not. The overload factor is only taken into account for corner rounding with G641/G642. The overload factor has no effect in the case of smoothing with G643 (this behavior can also be set for G641 and G642 by setting MD20490 $MC_IGNORE_OVL_FACTOR_FOR_ADIS to TRUE).

- Rounding is not parameterized.

  This occurs when:

  - For `G641` in `G0` blocks `ADISPOS = 0` (default!)
  - For `G641` in non-`G0` blocks `ADIS = 0` (default!)
  - For `G641` on transition from `G0` and non-`G0` or non-`G0` and `G0` respectively, the smaller value from `ADISPOS` and `ADIS` applies.
  - For`G642/G643`, all axis-specific tolerances are zero.

- The block does not contain traversing motion (zero block).

  This occurs when:

  - Synchronized actions are active.

    Normally, the interpreter eliminates zero blocks. However, if synchronous actions are active, this zero block is included and also executed. In so doing, an exact stop is initiated corresponding to the active programming. This allows the synchronous action to also switch.

  - Zero blocks are generated by program jumps.

Continuous-path mode in rapid traverse G0

One of the specified functions `G60`/`G9` or `G64`, or `G641` - `G645`, also has to be specified for rapid traverse motion. Otherwise, the default in the machine data is used.

References

For further information about continuous-path mode see:
Function Manual, Basic Functions; Continuous-Path Mode, Exact Stop, LookAhead (B1).

Coordinate transformations (frames) 12

12.1 Frames

Frame

The frame is a self-contained arithmetic rule that transforms one Cartesian coordinate system into another Cartesian coordinate system.

Basic frame (basic offset)

The basic frame describes coordinate transformation from the basic coordinate system (BCS) to the basic zero system (BZS) and has the same effect as settable frames.

See Basic coordinate system (BCS) [Page 28].

Settable frames

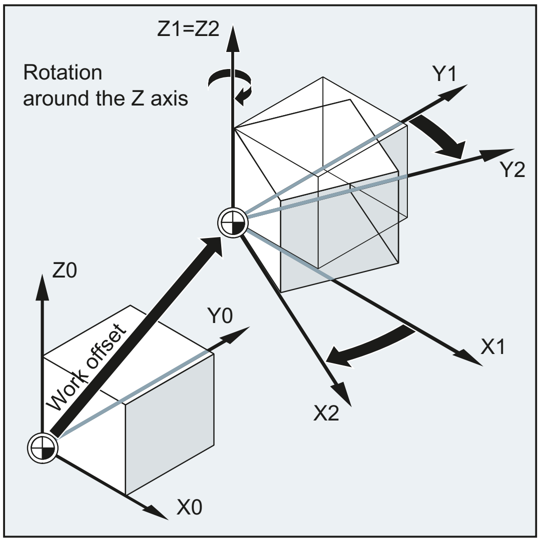
Settable frames are the configurable work offsets which can be called from within any NC program with the `G54` to `G57` and `G505` to `G599` commands. The offset values are predefined by the user and stored in the zero offset memory on the control. They are used to define the settable zero system (SZS).

See:

- Settable zero system (SZS) [Page 31]
- Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]

Programmable frames

Sometimes it is useful or necessary to move the originally selected workpiece coordinate system (or the "settable zero system") to another position within an NC program and, if required, to rotate it, mirror it and/or scale it. This can be achieved using programmable frames.



See Frame instructions [Page 339].

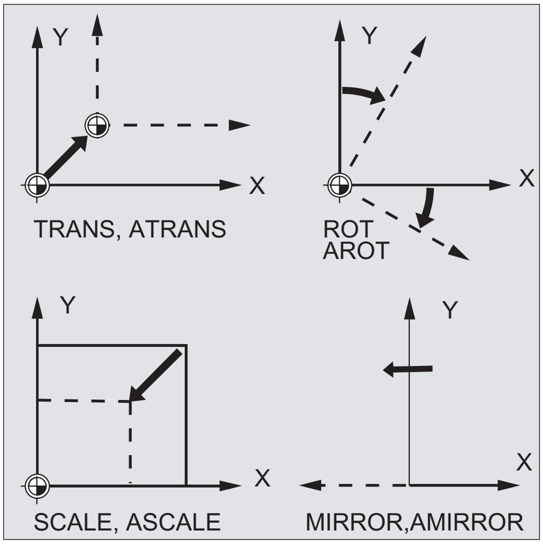
12.2 Frame instructions

Function

The operations for programmable frames apply in the current NC program. They function as either additive or substitute elements:

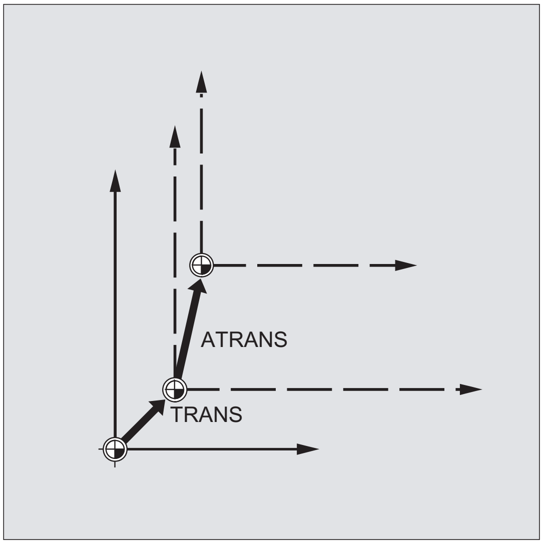
- Substitute operation

  Deletes all previously programmed frame operations. The reference is provided by the last settable work offset called (G54 to G57, G505 to G599).



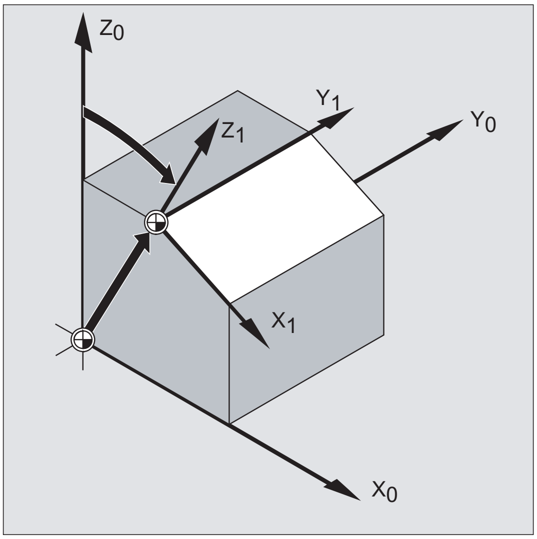
- Additive operation

  Appended to existing frames. The reference is provided by the currently set workpiece zero or the last workpiece zero programmed with a frame operation.



Applications

- Offset the zero point to any position on the workpiece.
- Align the coordinate axes by rotating parallel to the desired working plane.



Advantages

In one setting:

- Inclined surfaces can be machined
- Drill holes with various angles can be produced
- Multi-face machining can be performed

Note

Depending on the machine kinematics, the conventions for working plane and tool offsets must be taken into account for the machining in inclined working planes

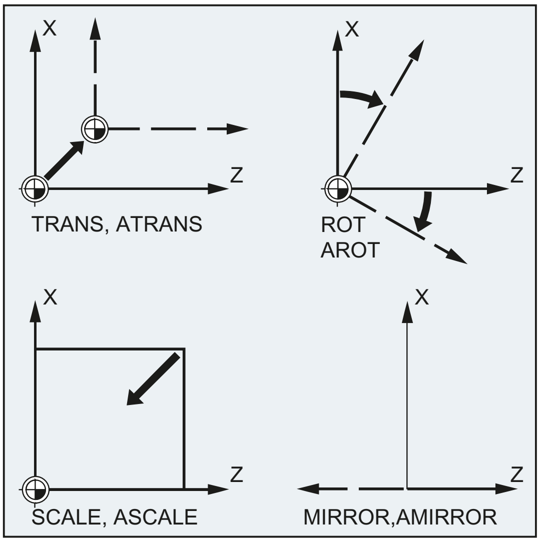
Syntax

Substitute operations:	Additive operations:
`TRANS X… Y… Z…`	`ATRANS X… Y… Z…`
`ROT X… Y… Z…`	`AROT X… Y… Z…`
`ROT RPL=…`	`AROT RPL=…`
`ROTS/CROTS X... Y...`	`AROTS X... Y...`
`SCALE X… Y… Z…`	`ASCALE X… Y… Z…`
`MIRROR X0/Y0/Z0`	`AMIRROR X0/Y0/Z0`

Note

Each frame operation is programmed in a separate NC block.

Meaning



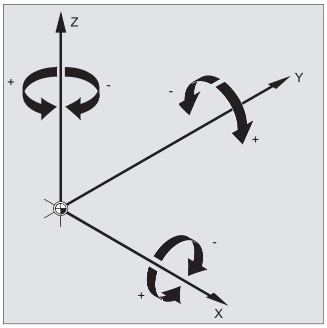
`TRANS/ATRANS`: Workpiece coordinate system offset in the direction of the specified geometry axis or axes

`ROT/AROT`: Workpiece coordinate system rotation:

- By linking individual rotations around the specified geometry axis or axes

  or
- Around the angle `RPL=...` in the current working plane (`G17`/`G18`/`G19`)

Direction of rotation:



Rotation sequence:	With RPY notation: Z, Y', X'' With Euler angle: Z, X', Z''
Range of values:	The angles of rotation are only defined unambiguously in the following ranges:

With RPY notation:	-180	≤	x	≤	180
	-90	<	y	<	90
	-180	≤	z	≤	180
With Euler angle:	0	≤	x	<	180
	-180	≤	y	≤	180
	-180	≤	z	≤	180

`ROTS/AROTS`: Workpiece coordinate system rotation by means of the specification of solid angles

The orientation of a plane in space is defined unambiguously by specifying two solid angles. Therefore, up to 2 solid angles may be programmed:

```
ROTS/AROTS X... Y... / Z... X... / Y... Z...
```

`CROTS`: `CROTS` works in the same way as `ROTS` but refers to the valid frame in the database.

`SCALE/ASCALE`: Scaling in the direction of the specified geometry axis or axes to increase/reduce the size of a contour

`MIRROR/AMIRROR`: Workpiece coordinate system mirroring by means of mirroring (direction change) the specified geometry axis

Value: freely selectable (in this case: "0")

Note

Frame operations can be used individually or combined at will.

CAUTION

Frame operations are executed in the programmed sequence.

Note

Additive statements are frequently used in subroutines. The basic functions defined in the main program are not lost after the end of the subroutine if the subroutine has been programmed with the SAVE attribute.

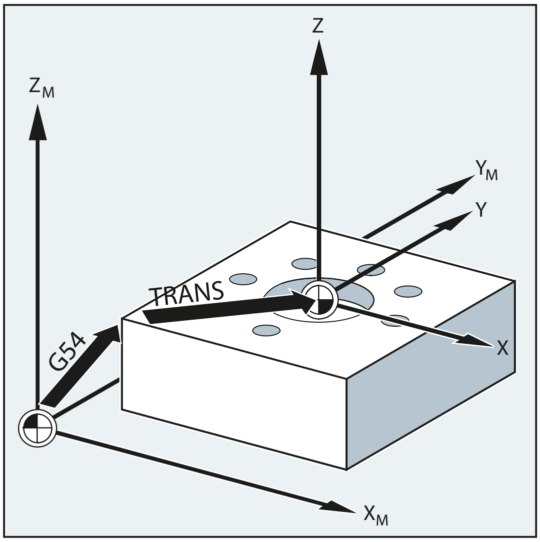
12.3 Programmable zero offset

12.3.1 Zero offset (TRANS, ATRANS)

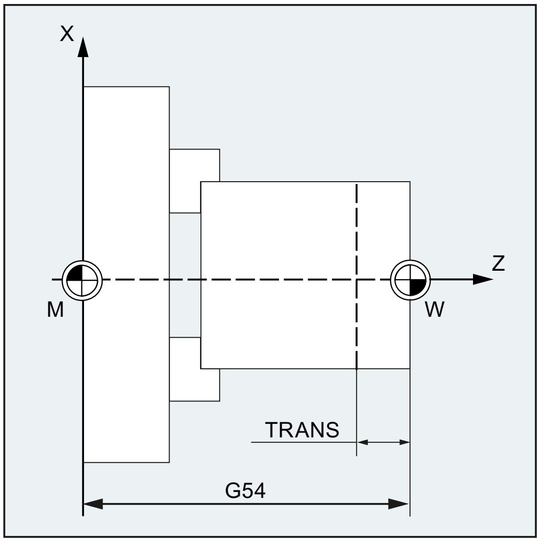
Function

TRANS/ATRANS can be used to program work offsets for all path and positioning axes in the direction of the axis specified in each case. This means that it is possible to work with changing zero points, e.g. during repetitive machining operations at different workpiece positions.

Milling:



Turning:



Syntax

```
TRANS X… Y… Z…
ATRANS X… Y… Z…
```

Note

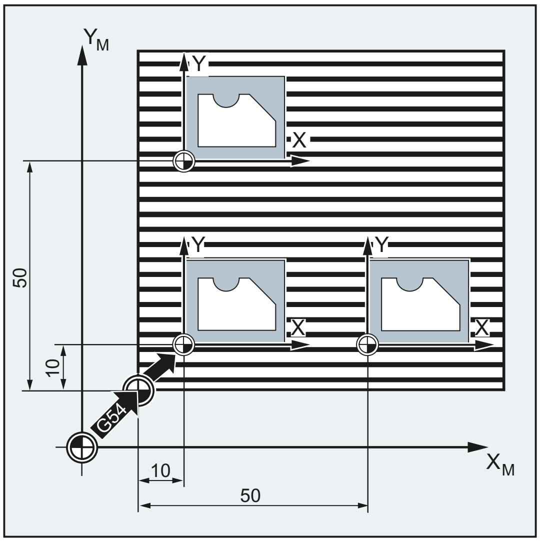
Each frame operation is programmed in a separate NC block.

Significance

TRANS:	Absolute work offset, with reference to the currently valid workpiece zero set with G54 to G57, G505 to G599.
ATRANS:	As TRANS, but with additive work offset
X... Y... Z...:	Offset values in the direction of the specified geometry axes

Examples

Example 1: Milling



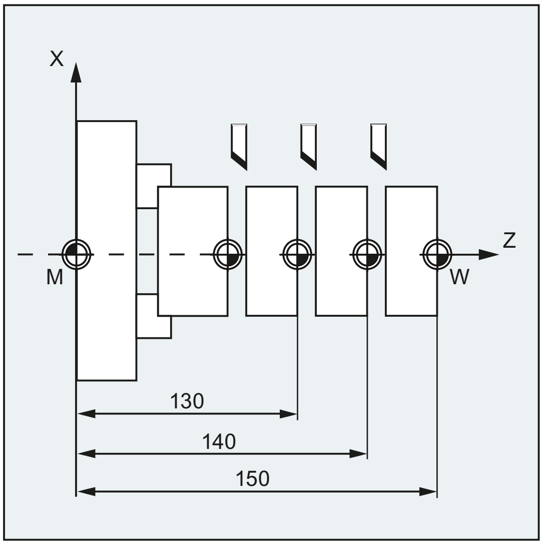
With this workpiece, the illustrated shapes recur several times in the same program.

The machining sequence for this shape is stored in a subroutine.

Work offset is used to set the workpiece zeros required in each case and then call the subprogram.

Program code	**Comment**
`N10 G1 G54`	`; Working plane X/Y, workpiece zero`
`N20 G0 X0 Y0 Z2`	`; Approach starting point`
`N30 TRANS X10 Y10`	`; Absolute offset`
`N40 L10`	`; Subroutine call`
`N50 TRANS X50 Y10`	`; Absolute offset`
`N60 L10`	`; Subroutine call`
`N70 M30`	`; End of program`

Example 2: Turning



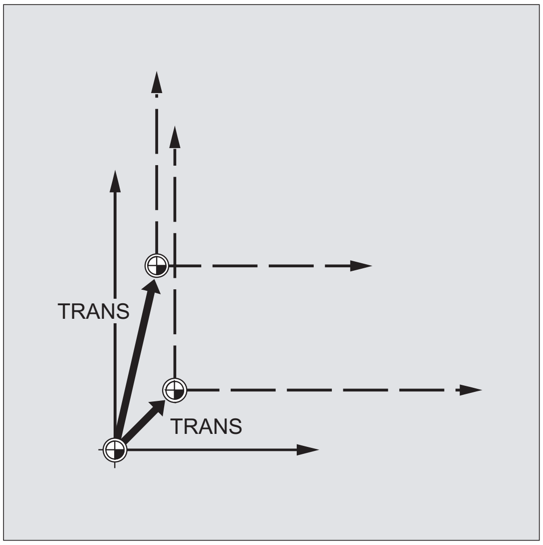
```
Program code                           Comment
N.. ...
N10 TRANS X0 Z150                      ; Absolute offset
N15 L20                                ; Subroutine call
N20 TRANS X0 Z140 (or ATRANS Z-10)     ; Absolute offset
N25 L20                                ; Subroutine call
N30 TRANS X0 Z130 (or ATRANS Z-10)     ; Absolute offset
N35 L20                                ; Subroutine call
N.. ...
```

Further information

TRANS X... Y... Z...

Translation through the offset values programmed in the specified axis directions (path, synchronized axes and positioning axes). The reference is provided by the last settable work offset called (G54 to G57, G505 to G599).

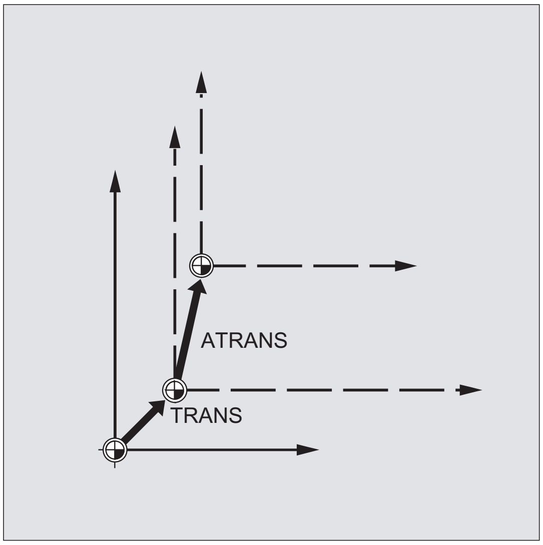
NOTICE
The `TRANS` command resets all frame components of the previously activated programmable frame.



> **Note**
>
> `ATRANS` can be used to program an offset to be added to existing frames.

ATRANS X... Y... Z...

Translation through the offset values programmed in the specified axis directions. The currently set or last programmed zero point is used as the reference.



12.3.2 Axial zero offset (G58, G59)

Note

For SINUMERIK 828D the commands `G58`/`G59` have a different function than for SINUMERIK 840D sl:

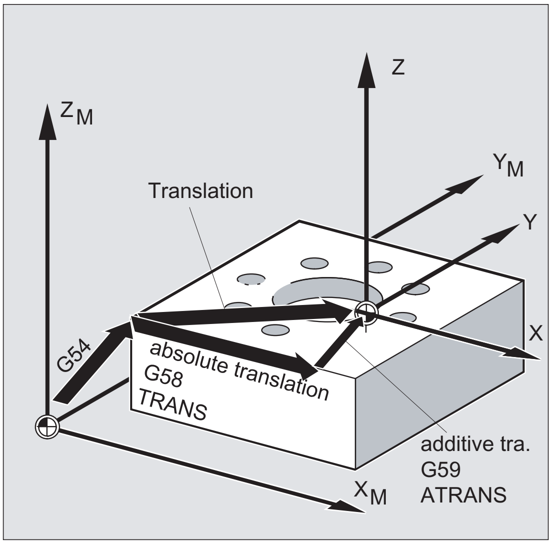
- `G58`: Calls the 5th adjustable work offset (this corresponds to command `G505` for SINUMERIK 840D sl)
- `G59`: Calls the 6th adjustable work offset (this corresponds to command `G506` for SINUMERIK 840D sl)

Therefore, the following description of `G58`/`G59` is only valid for SINUMERIK 840D sl.

Function

The G58 and G59 functions can be used to substitute translation components of the programmable work offset with specific axes:

- G58 is used for the absolute translation component (coarse offset)
- G59 is used for the additive translation component (fine offset)



Conditions

The G58 and G59 functions can only be used if fine offset has been configured (MD24000 $MC_FRAME_ADD_COMPONENTS = 1).

Syntax

```
G58 X… Y… Z… A…
G59 X… Y… Z… A…
```

Note

Each of the substitute operations `G58` and `G59` has to be programmed in a separate NC block.

Significance

`G58`: `G58` replaces the absolute translation component of the programmable work offset for the specified axis, but the programmed additive offset remains valid The reference is provided by the last settable work offset called (G54 to G57, G505 to G599).

`G59`: `G59` replaces the additive translation component of the programmable work offset for the specified axis, but the programmed absolute offset remains valid

`X… Y… Z…`: Offset values in the direction of the specified geometry axes

Example

```
Program code               Comment
...
N50 TRANS X10 Y10 Z10      ; Absolute translation component X10 Y10 Z10
N60 ATRANS X5 Y5           ; Additive translation component X5 Y5
                             → total offset: X15 Y15 Z10
N70 G58 X20                ; Absolute translation component X20
                             + additive translation component X5 Y5
                             → total offset X25 Y15 Z10
N80 G59 X10 Y10            ; Additive translation component X10 Y10
                             + absolute translation component X20 Y10
                             → total offset X30 Y20 Z10
...
```

Further information

The absolute translation component is modified by the following commands:

- TRANS
- G58
- CTRANS
- CFINE
- $P_PFRAME[X,TR]

The additive translation component is modified by the following commands:

- ATRANS
- G59
- CTRANS
- CFINE
- $P_PFRAME[X,FI]

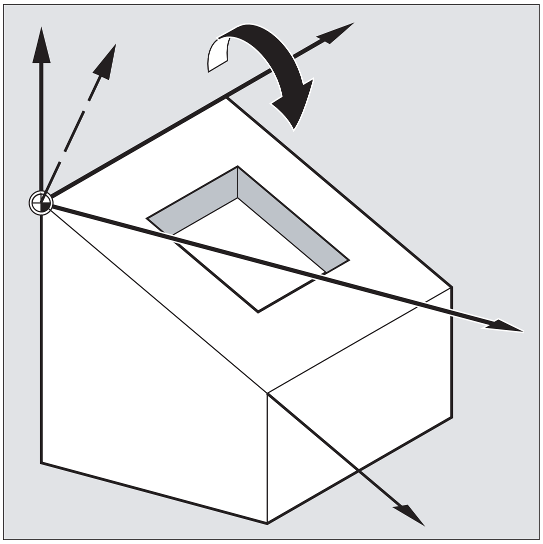
The table below describes the effect of various program commands on the absolute and additive offsets.

command	Coarse or absolute offset	Fine or additive offset	Comment
`TRANS X10`	10	unchanged	Absolute offset for X
`G58 X10`	10	unchanged	Overwrites absolute offset for X
`$P_PFRAME[X,TR]=10`	10	unchanged	Progr. offset in X
`ATRANS X10`	unchanged	Fine (old) + 10	Additive offset for X
`G59 X10`	unchanged	10	Overwriting additive offset for X
`$P_PFRAME[X,FI]=10`	unchanged	10	Progr. fine offset in X
`CTRANS(X,10)`	10	0	Offset for X
`CTRANS()`	0	0	Deselection of offset (including fine offset component)
`CFINE(X,10)`	0	10	Fine offset in X

12.4 Programmable rotation (ROT, AROT, RPL)

Function

`ROT`/`AROT` can be used to rotate the workpiece coordinate system around each of the three geometry axes X, Y, Z or through an angle RPL in the selected working plane G17 to G19 (or around the perpendicular infeed axis). This allows inclined surfaces or multiple workpiece faces to be machined in one setting.



Syntax

```
ROT X… Y… Z…
ROT RPL=…
AROT X… Y… Z…
AROT RPL=…
```

Note

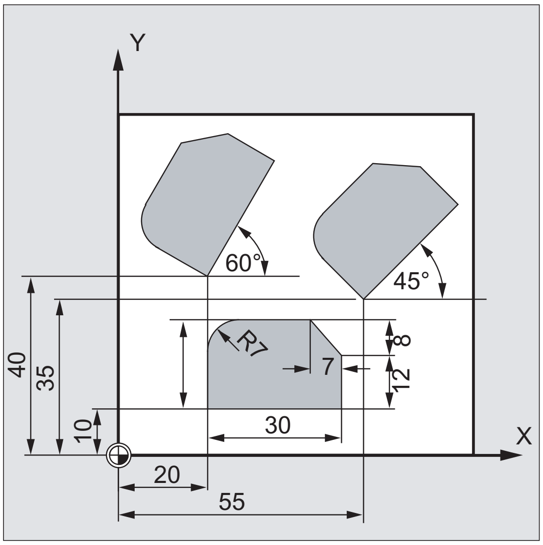
Each frame operation is programmed in a separate NC block.

Significance

`ROT`:	Absolute rotation, with reference to the currently valid workpiece zero set with G54 to G57, G505 to G599.
`RPL`:	Rotation in the plane: Angle through which the coordinate system is rotated (plane set with G17 to G19) The sequence in which the rotation is to be performed can be specified via the machine data. The default setting is RPY notation (= Roll, Pitch, Yaw) with Z, Y, X.
`AROT`:	Additive rotation in relation to the currently valid set or programmed zero point
`X... Y... Z...`:	Rotation in space: Geometry axes around which the rotation is performed

Examples

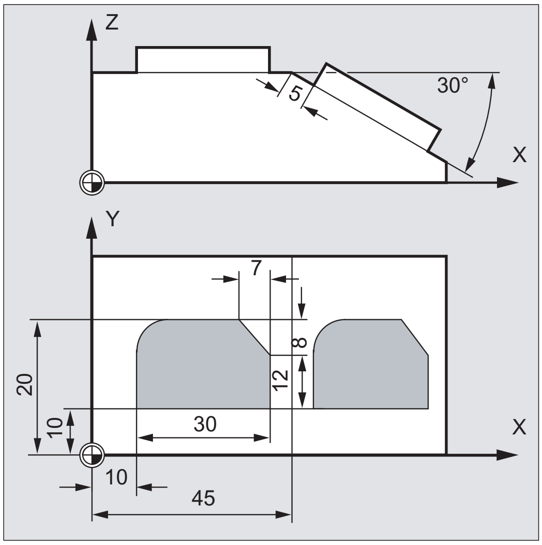
Example 1: Rotation in the plane



With this workpiece, the shapes shown recur in a program. In addition to the zero offset, rotations have to be performed, as the shapes are not arranged paraxially.

Program code	Comment
`N10 G17 G54`	`; Working plane X/Y, workpiece zero`
`N20 TRANS X20 Y10`	`; Absolute offset`
`N30 L10`	`; Subroutine call`
`N40 TRANS X55 Y35`	`; Absolute offset`
`N50 AROT RPL=45`	`; Rotation of the coordinate system through 45°`
`N60 L10`	`; Subroutine call`
`N70 TRANS X20 Y40`	`; Absolute offset (resets all previous offsets)`
`N80 AROT RPL=60`	`; Additive rotation through 60°`
`N90 L10`	`; Subroutine call`
`N100 G0 X100 Y100`	`; Retraction`
`N110 M30`	`; End of program`

Example 2: Spatial rotation

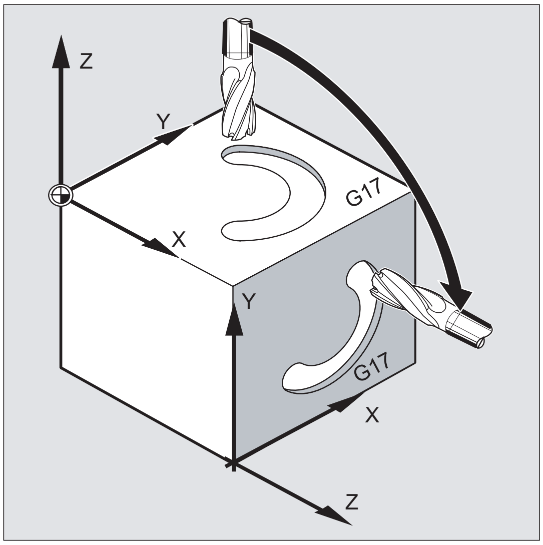


In this example, paraxial and inclined workpiece surfaces are to be machined in a clamping.

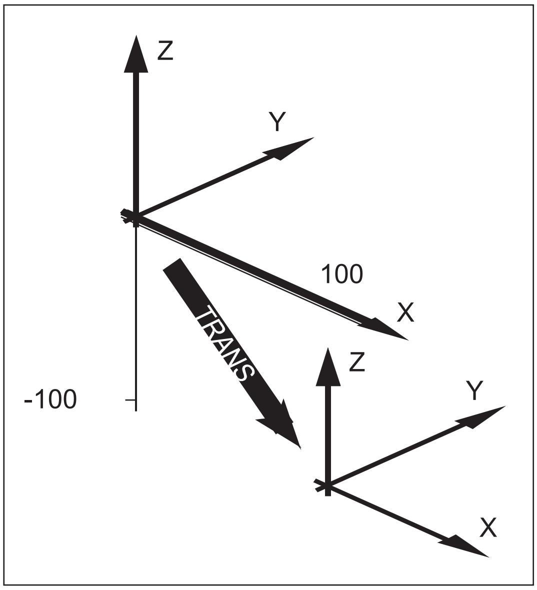
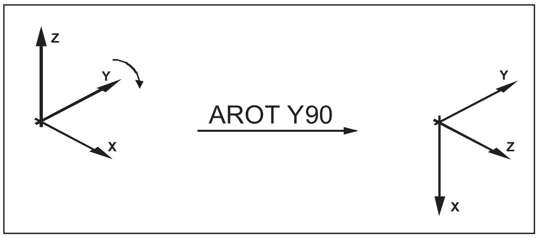
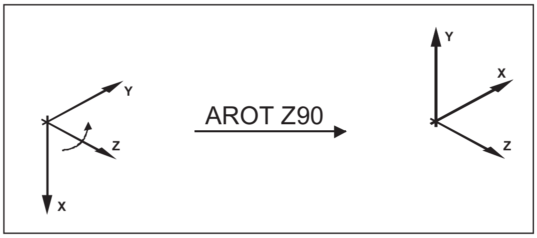
Condition:
The tool must be aligned perpendicular to the inclined surface in the rotated Z direction.

Program code	Comment
N10 G17 G54	; Working plane X/Y, workpiece zero
N20 TRANS X10 Y10	; Absolute offset
N30 L10	; Subroutine call
N40 ATRANS X35	; Additive offset
N50 AROT Y30	; Rotation around the Y axis
N60 ATRANS X5	; Additive offset
N70 L10	; Subroutine call
N80 G0 X300 Y100 M30	; Retraction, end of program

Example 3: Multi-face machining



In this example, identical shapes are machined in two workpiece surfaces perpendicular to one another via subroutines. In the new coordinate system on the right-hand workpiece surface, infeed direction, working plane and the zero point have been set up as on the top surface. Therefore, the conditions required for the subroutine execution still apply: working plane G17, coordinate plane X/Y, infeed direction Z.

Program code	Comment
N10 G17 G54	; Working plane X/Y, workpiece zero
N20 L10	; Subroutine call
N30 TRANS X100 Z-100	; Absolute offset
	
N40 AROT Y90	; Rotation of the coordinate system around Y
	
N50 AROT Z90	; Rotation of the coordinate system around Z
	
N60 L10	; Subroutine call
N70 G0 X300 Y100 M30	; Retraction, end of program

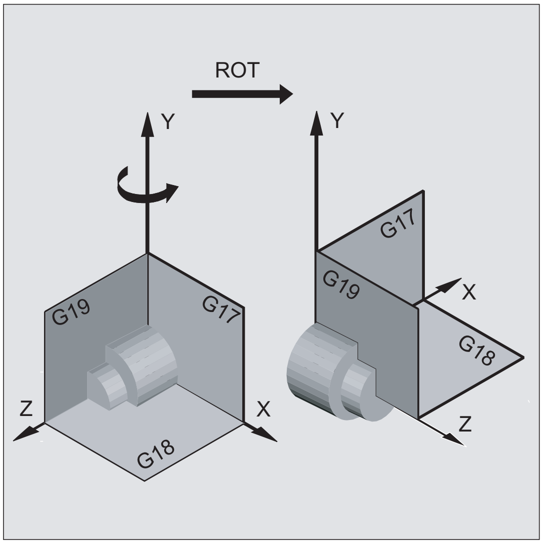
Further information

Rotation in the plane

The coordinate system is rotated:

- in the plane selected with G17 to G19.

  Substitute operation `ROT RPL=...` or additive operation `AROT RPL=...`
- in the current plane around the angle of rotation programmed with `RPL=....`



Note

See "Rotation in space" for more information.

Plane change

⚠ WARNING
If you program a change of plane (G17 to G19) after a rotation, the angles of rotation programmed for the relevant axes are retained and continue to apply in the new working plane. It is, therefore, advisable to deactivate rotation before a change of plane.

Deactivate rotation

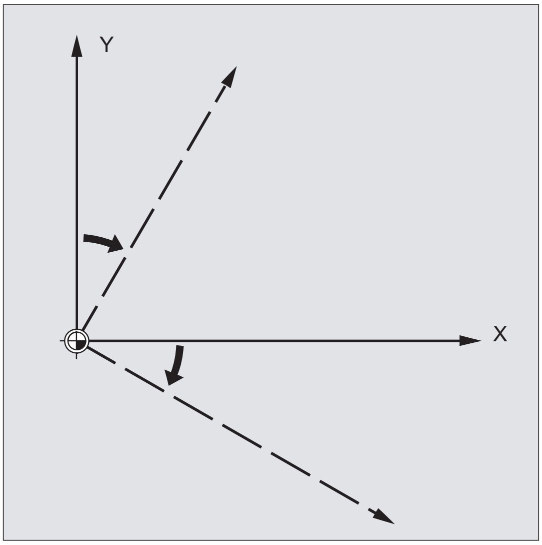
For all axes: `ROT` (without axis parameter)

CAUTION
All frame components of the previously programmed frame are reset.

ROT X... Y... Z...

The coordinate system is rotated through the programmed angle around the specified axes. The center of rotation is provided by the last settable work offset specified (G54 to G57, G505 to G599).

NOTICE
The `ROT` command resets all frame components of the previously activated programmable frame.

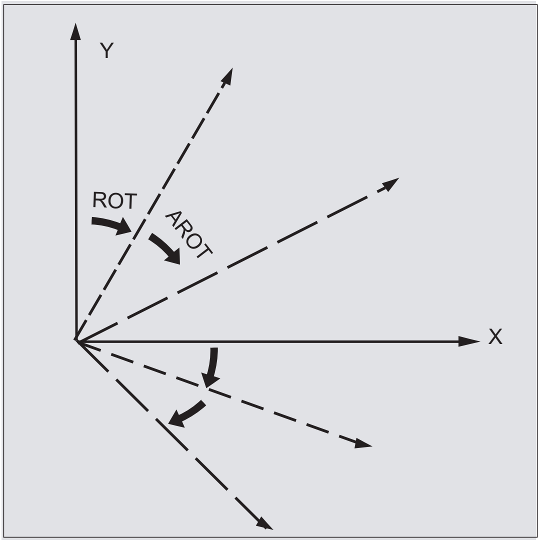


Note

`AROT` can be used to program a new rotation to be added to existing frames.

AROT X... Y... Z...

Rotation through the angle values programmed in the axis direction parameters. The center of rotation is the currently set or last programmed zero point.

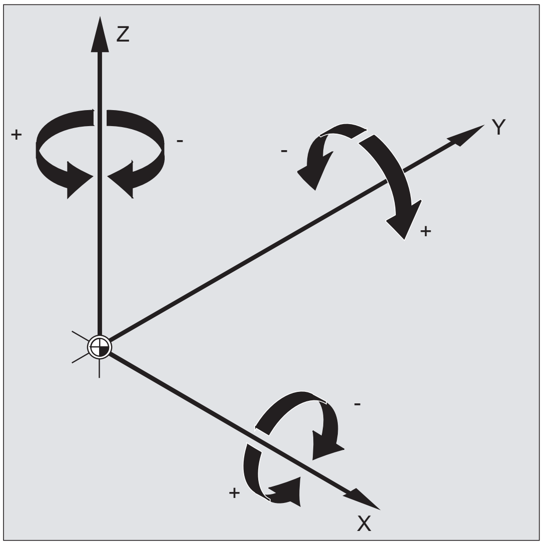


Note

In the case of both operations, please bear in mind the sequence and direction in which the rotations are being executed!

Direction of rotation

The following is defined as the positive direction of rotation: The view in the direction of the positive coordinate axis and clockwise rotation.



Order of rotation

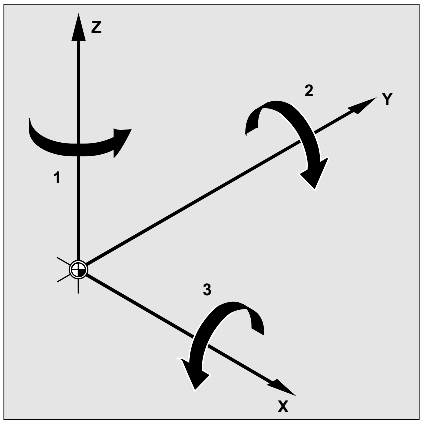
Up to 3 geometry axes can be rotated simultaneously in one NC block.

The sequence in which the rotations are executed is defined using machine data (MD10600 $MN_FRAME_ANGLE_INPUT_MODE):

- RPY notation: Z, Y', X''
- Euler angles: Z, X', Z''

RPY notation (the default setting) results in the following sequence:

1. Rotation around the 3rd geometry axis (Z)
2. Rotation around the 2nd geometry axis (Y)
3. Rotation around the 1st geometry axis (X)



This order applies if the geometry axes are programmed in a **single** block. It also applies irrespective of the input sequence. If only two axes are to be rotated, the parameter for the 3rd axis (value zero) can be omitted.

Value range with RPY angle

The angles are defined uniquely **only** within the following value ranges:

Rotation around 1st geometry axis: -180° ≤ X ≤ +180°

Rotation around 2nd geometry axis: -90° ≤ Y ≤ +90°

Rotation around 3rd geometry axis: -180° ≤ Z ≤ +180°

All possible rotations can be represented with this value range. Values outside the range are normalized by the control into the above range during writing and reading. This value range applies to all frame variables.

Examples of reading back in RPY

$P_UIFR[1] = CROT(X, 10, Y, 90, Z, 40)
returns on reading back:
$P_UIFR[1] = CROT(X, 0, Y, 90, Z, 30)

$P_UIFR[1] = CROT(X, 190, Y, 0, Z, -200)
returns on reading back
$P_UIFR[1] = CROT(X, -170, Y, 0, Z, 160)

When frame rotation components are read and written, the value range limits must be observed to ensure that the same results are obtained for read or write, or repeat write operations.

Value range with Euler angle

The angles are defined uniquely **only** within the following value ranges:

Rotation around 1st geometry axis: 0° ≤ X ≤ +180°

Rotation around 2nd geometry axis: -180° ≤ Y ≤ +180°

Rotation around 3rd geometry axis: -180° ≤ Z ≤ +180°

All possible rotations can be represented with this value range. Values outside the range are normalized by the control into the above range. This value range applies to all frame variables.

⚠ CAUTION

To ensure the angles written are read back unambiguously, it is absolutely essential to observe the defined value ranges.

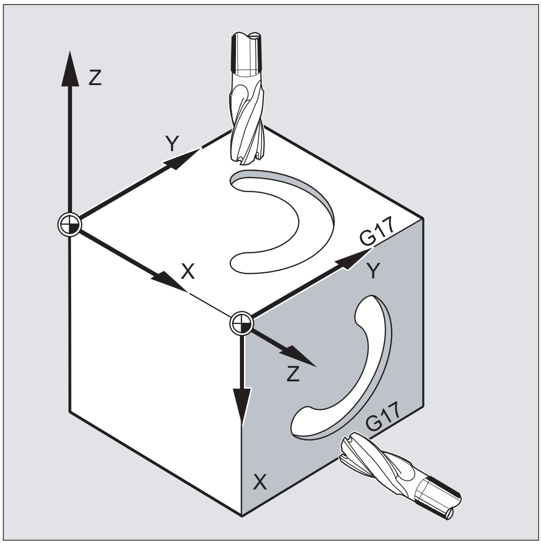
Note

If you want to define the order of the rotations individually, program the desired rotation successively for each axis with `AROT`.

The working plane also rotates

The working plane defined with G17, G18 or G19 rotates with the spatial rotation.

Example: Working plane G17 X/Y, the workpiece coordinate system is positioned on the top surface of the workpiece. Translation and rotation is used to move the coordinate system to one of the side faces. Working plane G17 also rotates. This feature can be used to program plane destination positions in X/Y coordinates and the infeed in the Z direction.



Condition:
The tool must be positioned perpendicular to the working plane. The positive direction of the infeed axis points in the direction of the toolholder. Specifying `CUT2DF` activates the tool radius compensation in the rotated plane.

12.5 Programmable frame rotations with solid angles (ROTS, AROTS, CROTS)

Function

Orientations in space can be defined by programming frame rotations with solid angles. The `ROTS`, `AROTS` and `CROTS` commands are available for this purpose. `ROTS` and `AROTS` behave in the same way as`ROT` and `AROT`.

Syntax

The orientation of a plane in space is defined unambiguously by specifying two solid angles. Therefore, up to 2 solid angles may be programmed:

- When programming the solid angles X and Y, the new X axis lies in the old Z/X plane.

  ```
  ROTS X... Y...
  AROTS X... Y...
  CROTS X... Y...
  ```

- When programming the solid angles Z and X, the new Z axis lies in the old Y/Z plane.

  ```
  ROTS Z... X...
  AROTS Z... X...
  CROTS Z... X...
  ```

- When programming the solid angles Y and Z, the new Y axis lies in the old X/Y plane.

  ```
  ROTS Y... Z...
  AROTS Y... Z...
  CROTS Y... Z...
  ```

Note

Each frame operation is programmed in a separate NC block.

Significance

`ROTS`: Absolute frame rotations with solid angles, with reference to the currently valid workpiece zero set with G54 to G57, G505 to G599.

`AROTS`: Additive frame rotations with solid angles with reference to the currently valid set or programmed zero point

`CROTS`: Frame rotations with solid angles, with reference to the valid frame in the database with rotations in the specified axes

`X… Y…/Z… X…/Y… Z…:` Specification of solid angles

Note

`ROTS`/`AROTS`/`CROTS` can also be programmed together with `RPL` to generate a rotation in the plane set with `G17` to `G19`:

```
ROTS/AROTS/CROTSRPL=...
```

12.6 Programmable scale factor (SCALE, ASCALE)

Function

`SCALE`/`ASCALE` can be used to program up or down scale factors for all path, synchronized, and positioning axes in the direction of the axes specified in each case. This makes it possible, therefore, to take geometrically similar shapes or different shrinkage allowances into account in the programming.

Syntax

```
SCALE X… Y… Z…
ASCALE X… Y… Z…
```

Note

Each frame operation is programmed in a separate NC block.

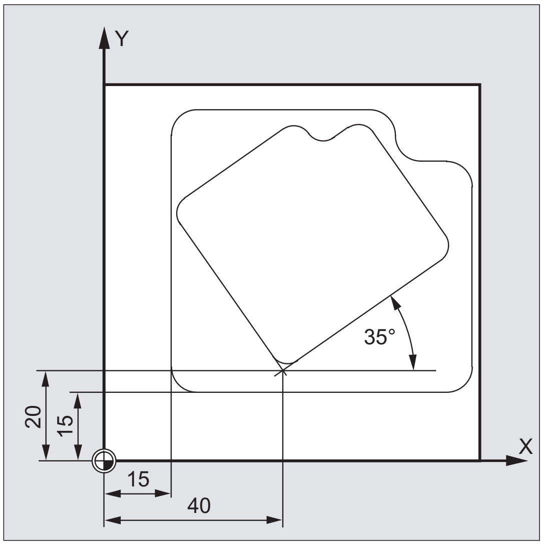
Significance

`SCALE`: Scale up/down absolute in relation to the currently valid coordinate system set with G54 to G57, G505 to G599.

`ASCALE`: Scale up/down additive in relation to the currently valid set or programmed coordinate system

`X… Y… Z…`: Scale factors in the direction of the specified geometry axes

Example



The pocket occurs twice on this workpiece, but with different sizes and rotated in relation to one another. The machining sequence is stored in the subroutine.

The required workpiece zeroes are set with work offset and rotation, the contour is scaled down with scaling and the subprogram is then called again.

Program code	**Comment**
`N10 G17 G54`	`; Working plane X/Y, workpiece zero`
`N20 TRANS X15 Y15`	`; Absolute offset`
`N30 L10`	`; Machine large pocket`
`N40 TRANS X40 Y20`	`; Absolute offset`
`N50 AROT RPL=35`	`; Rotation in the plane through 35°`
`N60 ASCALE X0.7 Y0.7`	`; Scaling factor for the small pocket`
`N70 L10`	`; Machine small pocket`
`N80G0 X300 Y100 M30`	`; Retraction, end of program`

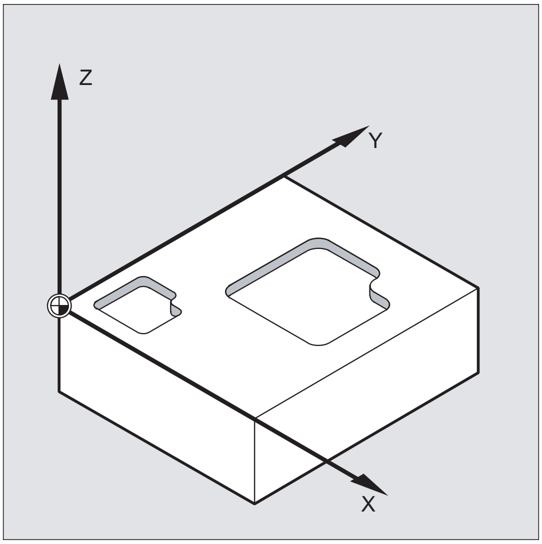
Further information

SCALE X... Y... Z...

You can specify an individual scale factor for each axis, by which the shape is to be reduced or enlarged. The scale refers to the workpiece coordinate system set with G54 to G57, G505 to G599.

CAUTION

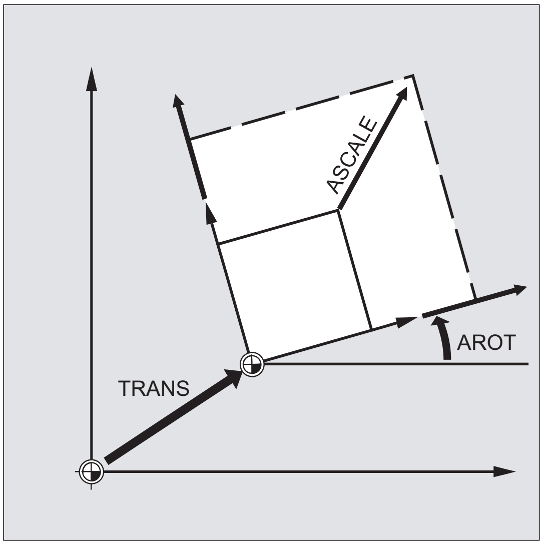
The `SCALE` command resets all frame components of the previously activated programmable frame.



ASCALE X... Y... Z...

The `ASCALE` command is used to program scale changes to be added to existing frames. In this case, the last valid scale factor is multiplied by the new one.

The currently set or last programmed coordinate system is used as the reference for the scale change.



Scaling and offset

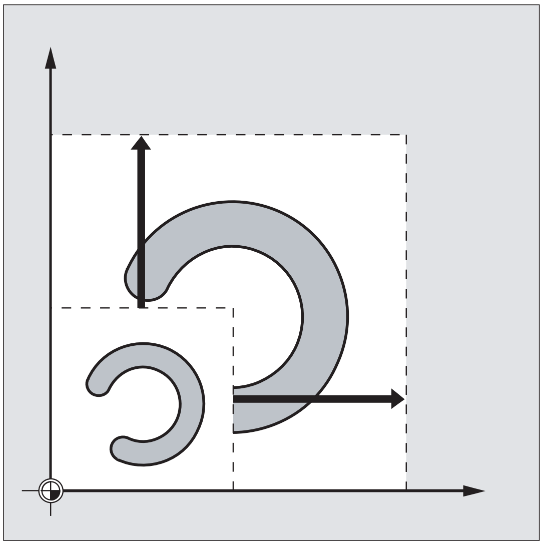
Note

If an offset is programmed with `ATRANS` after `SCALE`, the offset values will also be scaled.

Different scale factors

CAUTION

Please take great care when using different scale factors! Circular interpolations can, for example, only be scaled using identical factors.



Note

However, different scale factors can be used specifically to program distorted circles.

12.7 Programmable mirroring (MIRROR, AMIRROR)

Function

MIRROR/AMIRROR can be used to mirror workpiece shapes on coordinate axes. All traversing movements programmed after the mirror call (e.g. in the subprogram) are executed with mirroring.

Syntax

```
MIRROR X... Y... Z...
AMIRROR X... Y... Z...
```

Note

Each frame operation is programmed in a separate NC block.

Significance

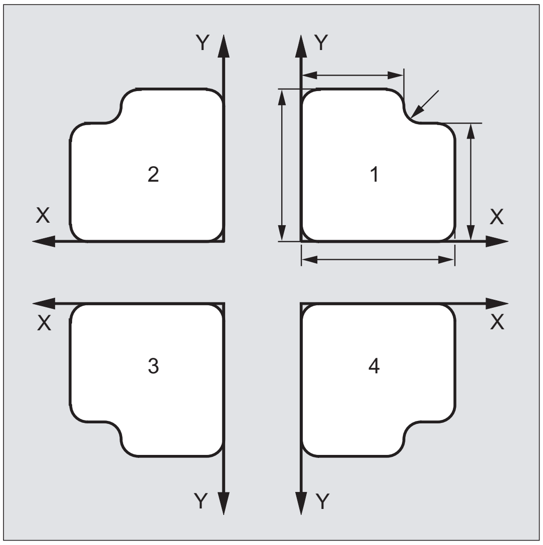
MIRROR: Mirror absolute in relation to the currently valid coordinate system set with G54 to G57, G505 to G599.

AMIRROR: Additive mirror image with reference to the currently valid set or programmed coordinate system

X... Y... Z...: Geometry axis whose direction is to be changed. The value specified here can be chosen freely, e.g. X0 Y0 Z0.

Examples

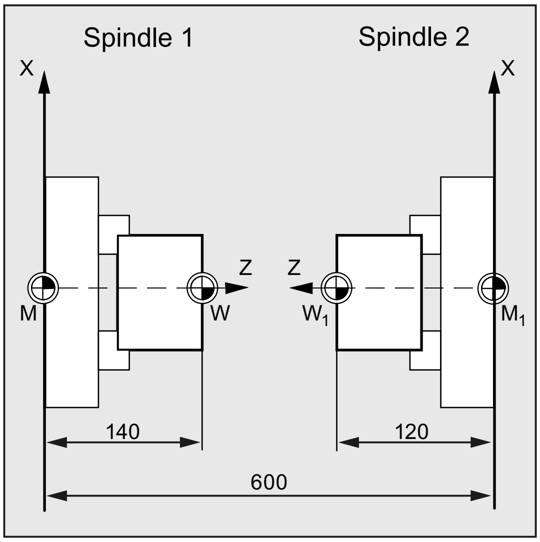
Example 1: Milling



The contour shown here is programmed once as a subprogram. The 3 other contours are generated using mirroring. The workpiece zero is located at the center of the contours.

Program code	Comment
N10 G17 G54	; Working plane X/Y, workpiece zero
N20 L10	; Machine first contour at top right
N30 MIRROR X0	; Mirror X axis (the direction is changed in X)
N40 L10	; Machine second contour at top left
N50 AMIRROR Y0	; Mirror Y axis (the direction is changed in Y)
N60 L10	; Machine third contour at bottom left
N70 MIRROR Y0	; MIRROR resets previous frames. Mirror Y axis (the direction is changed in Y)
N80 L10	; Machine fourth contour at bottom right
N90 MIRROR	; Deactivate mirroring
N100 G0 X300 Y100 M30	; Retraction, end of program

Example 2: Turning



The actual machining is stored as a subprogram and execution at the respective spindle is implemented by means of mirroring and offsets.

Program code	Comment
N10 TRANS X0 Z140	; Zero offset to W
...	; Machining of the first side with spindle 1
N30 TRANS X0 Z600	; Zero offset to spindle 2
N40 AMIRROR Z0	; Mirroring of the Z axis
N50 ATRANS Z120	; Zero offset to W1
...	; Machining of the second side with spindle 2

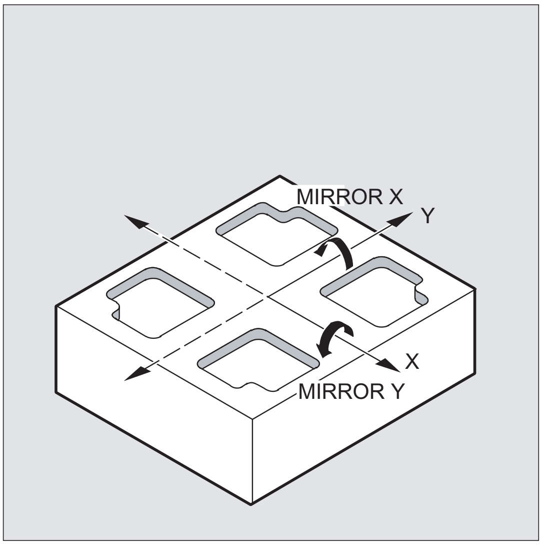
Further information

MIRROR X... Y... Z...

The mirror is programmed by means of an axial change of direction in the selected working plane.

Example: Working plane G17 X/Y

The mirror (on the Y axis) requires a direction change in X and, accordingly, is programmed with `MIRROR X0`. The contour is then mirrored on the opposite side of the mirror axis Y.

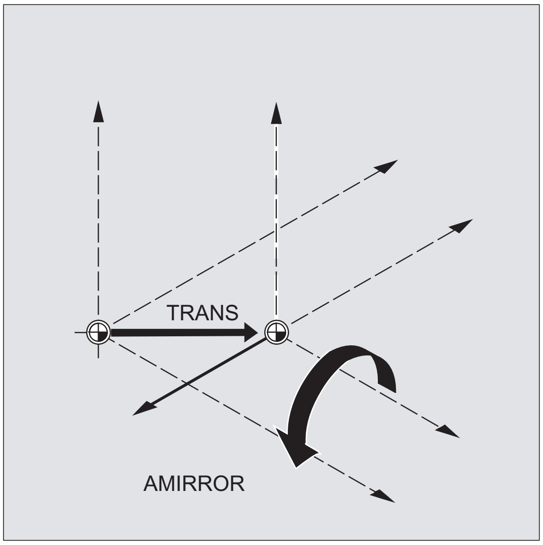


Mirroring is implemented in relation to the currently valid coordinate system set with G54 to G57, G505 to G599.

CAUTION
The `MIRROR` command resets all frame components of the previously activated programmable frame.

AMIRROR X... Y... Z...

A mirror image, which is to be added to an existing transformation, is programmed with `AMIRROR`. The currently set or last programmed coordinate system is used as the reference.



Deactivate mirroring

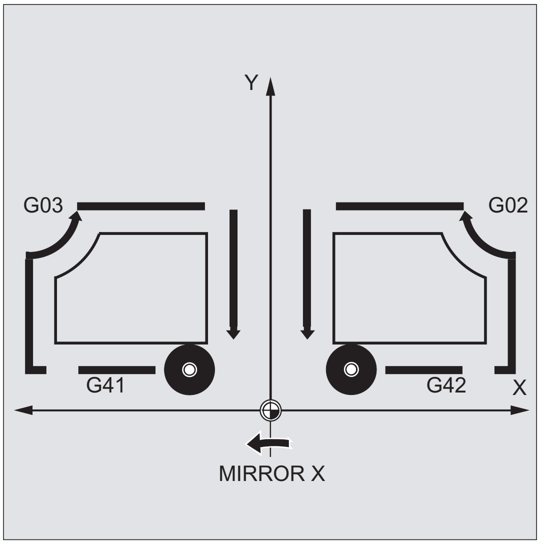
For all axes: `MIRROR` (without axis parameter)

All frame components of the previously programmed frame are reset.

Tool radius compensation

Note

The mirror command causes the control to automatically change the path compensation commands (`G41`/`G42` or `G42`/`G41`) according to the new machining direction.



The same applies to the direction of circle rotation (G2/G3 or G3/G2).

Note

If you program an additive rotation with `AROT` after `MIRROR`, you may have to work with reversed directions of rotation (positive/negative or negative/positive). Mirrors on the geometry axes are converted automatically by the control into rotations and, where appropriate, mirrors on the mirror axis specified in the machine data. This also applies to settable zero offsets.

Mirror axis

The axis to be mirrored can be set in machine data:

MD10610 $MN_MIRROR_REF_AX = <value>

Value	Significance
0	Mirroring is performed around the programmed axis (negation of values).
1	The reference axis is the X axis.
2	The reference axis is the Y axis.
3	The reference axis is the Z axis.

Interpreting the programmed values

Machine data is used to specify how the programmed values are to be interpreted:

MD10612 $MN_MIRROR_TOGGLE = <value>

Value	Significance
0	Programmed axis values are not evaluated.
1	Programmed axis values are evaluated: • For programmed axis values ≠ 0 the axis is mirrored if it has not yet been mirrored. • For a programmed axis value = 0 mirroring is deactivated.

12.8 Frame generation according to tool orientation (TOFRAME, TOROT, PAROT)

Function

TOFRAME generates a rectangular frame whose Z axis coincides with the current tool orientation. This means that the user can retract the tool in the Z direction without risk of collision (e.g. after a tool break in a 5-axis program).

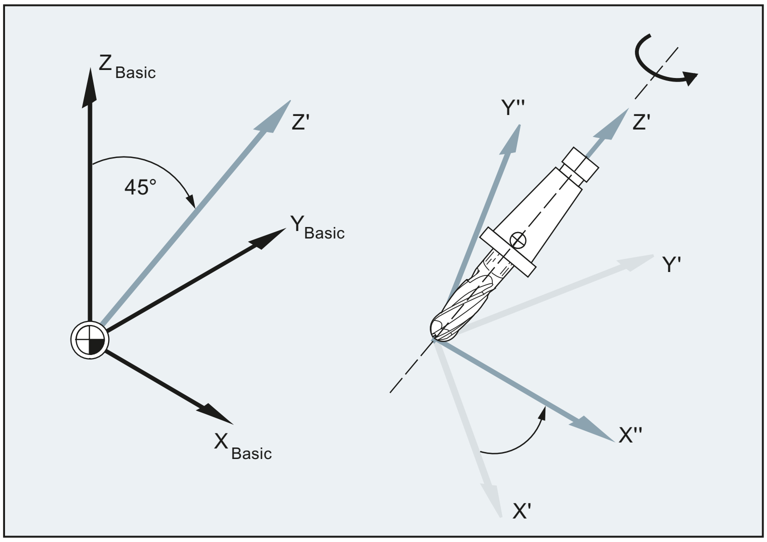
The position of the X and Y axes is determined by the setting in machine data MD21110 $MC_X_AXES_IN_OLD_X_Z_PLANE (coordinate system with automatic frame definition). The new coordinate system is either left as generated from the machine kinematics or is turned around the new Z axis additionally so that the new X axis lies in the old Z/X plane (see machine manufacturer's specifications).

The resulting frame describing the orientation is written in the system variable for the programmable frame ($P_PFRAME).

TOROT only overwrites the rotation component in the programmed frame. All other components remain unchanged.

TOFRAME and TOROT are designed for milling operations in which G17 (working plane X/Y) is typically active. In the case of turning operations or generally when G18 or G19 is active, however, frames are needed where the X or Y axis matches the orientation of the tool. These frames are programmed with the TOFRAMEX/TOROTX or TOFRAMEY/TOROTY commands.

PAROT aligns the workpiece coordinate system on the workpiece.



Syntax

```
TOFRAME/TOFRAMEZ/TOFRAMEY/TOFRAMEX
...
TOROTOF
```

```
TOROT/TOROTZ/TOROTY/TOROTX
...
TOROTOF
```

```
PAROT
...
PAROTOF
```

Significance

`TOFRAME`: Align the Z axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame

`TOFRAMEZ`: As `TOFRAME`

`TOFRAMEY`: Align the Y axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame

`TOFRAMEX`: Align the X axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame

`TOROT`: Align the Z axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame

The rotation defined with `TOROT` is the same as that defined with `TOFRAME`.

`TOROTZ`: As `TOROT`

`TOROTY`: Align the Y axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame

`TOROTX`: Align the X axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame

`TOROTOF`: Deactivate orientation parallel to tool orientation

`PAROT`: Rotate frame to align workpiece coordinate system on workpiece

Translations, scaling and mirroring in the active frame remain valid.

`PAROTOF`: The workpiece-specific frame rotation activated with `PAROT` is deactivated with `PAROTOF`.

Note

The `TOROT` command ensures consistent programming with active orientable toolholders for each kinematic type.

Just as in the situation for rotatable toolholders, `PAROT` can be used to activate a rotation of the work table. This defines a frame which changes the position of the workpiece coordinate system in such a way that no compensatory movement is performed on the machine. Language command `PAROT` is not rejected if no toolholder with orientation capability is active.

Example

```
Program code                   Comment
N100 G0 G53 X100 Z100 D0
N120 TOFRAME
N140 G91 Z20                   ; TOFRAME is included in the calculation, all
                                 programmed geometry axis movements
                                 refer to the new coordinate system.
N160 X50
...
```

Further information

Assigning axis direction

If one of the `TOFRAMEX`, `TOFRAMEY`, `TOROTX`, `TOROTY` commands is programmed instead of `TOFRAME`/`TOFRAMEZ` or `TOROT`/`TOROTZ`, the axis direction commands listed in this table will apply:

Command	Tool direction (applicate)	Secondary axis (abscissa)	Secondary axis (ordinate)
`TOFRAME`/`TOFRAMEZ`/ `TOROT`/`TOROTZ`	Z	X	Y
`TOFRAMEY`/`TOROTY`	Y	Z	X
`TOFRAMEX`/`TOROTX`	X	Y	Z

Separate system frame for TOFRAME or TOROT

The frames resulting from `TOFRAME` or `TOROT` can be written in a separate system frame $P_TOOLFRAME. For this purpose, bit 3 must be enabled in machine data MD28082 $MC_MM_SYSTEM_FRAME_MASK. The programmable frame remains unchanged. Differences occur when the programmable frame is processed further elsewhere.

References

For further information about machines with orientable toolholder, see:

- Programming Manual, Job Planning; Chapter: "Tool orientation"
- Function Manual, Basic Functions; Tool Offset (W1),
  Chapter: "Toolholder with orientation capability"

12.9 Deselect frame (G53, G153, SUPA, G500)

Function

When executing certain processes, such as approaching the tool change point, various frame components have to be defined and suppressed at different times.

Settable frames can either be deactivated modally or suppressed non-modally.

Programmable frames can be suppressed or deleted non-modally.

Syntax

Non-modal suppression:
```
G53/G153/SUPA
```

Modal deactivation:
```
G500
```

Delete:
```
TRANS/ROT/SCALE/MIRROR
```

Meaning

`G53`: Non-modal suppression of all programmable and settable frames

`G153`: `G153` has the same effect as `G53` and also suppresses the entire basic frame ($P_ACTBFRAME).

`SUPA`: `SUPA` has the same effect as `G153` and also suppresses:

- Handwheel offsets (DRF)
- Overlaid movements
- External work offset
- PRESET offset

`G500`: Modal deactivation of all settable frames (G54 to G57, G505 to G599) if G500 does not contain a value.

`TRANS/ROT/SCALE/MIRROR`: `TRANS/ROT/SCALE/MIRROR` without an axis parameter will delete the programmable frames.

12.10 Deselecting overlaid movements (DRFOF, CORROF)

Function

The additive work offsets set by means of handwheel traversal (DRF offsets) and the position offsets programmed using system variable $AA_OFF[<axis>] can be deselected using the part program commands DRFOF and CORROF.

Deselection triggers a preprocessing stop and the position component of the deselected overlaid movement (DRF offset or position offset) is written to the position in the basic coordinate system (in other words, no axes are traversed). The value of system variable $AA_IM[<axis>] (current machine coordinate system setpoint of an axis) does not change; the value of system variable $AA_IW[<axis>] (current workpiece coordinate system setpoint of an axis) does change, because it now contains the deselected component from the overlaid movement.

Syntax

```
DRFOF
CORROF(<axis>,"<character string>"[,<axis>,"<character string>"])
```

Significance

DRFOF: Command for the deactivation (deselection) of DRF handwheel offsets for all active axes in the channel

Active: modal

CORROF: Command for the deactivation (deselection) of the DRF offset/position offset ($AA_OFF) for individual axes

Effective: modal

<axis>: Axis identifier (channel, geometry or machine axis identifier)

"<character string>":

== "DRF":	DRF offset of axis is deselected
== "AA_OFF":	$AA_OFF position offset of axis is deselected

Note

CORROF is only possible from the part program, not via synchronized actions.

Examples

Example 1: Axial deselection of a DRF offset (1)

A DRF offset is generated in the X axis by DRF handwheel traversal. No DRF offsets are operative for any other axes in the channel.

Program code	Comment
`N10 CORROF(X,"DRF")`	`; CORROF has the same effect as DRFOF here.`
`...`	

Example 2: Axial deselection of a DRF offset (2)

A DRF offset is generated in the X and Y axes by DRF handwheel traversal. No DRF offsets are operative for any other axes in the channel.

Program code	Comment
`N10 CORROF(X,"DRF")`	`; Only the DRF offset of the X axis is deselected; the DRF offset of the Y axis is retained (in the case of DRFOF both offsets would have been deselected).`
`...`	

Example 3: Axial deselection of a $AA_OFF position offset

Program code	Comment
`N10 WHEN TRUE DO $AA_OFF[X]=10 G4 F5`	`; A position offset == 10 is interpolated for the X axis.`
`...`	

`N80 CORROF(X,"AA_OFF")`	`; The position offset of the X axis is deselected with: $AA_OFF[X]=0`
	`The X axis is not traversed.`
	`The position offset is added to the current position of the X axis.`

`…`	

Example 4: Axial deselection of a DRF offset and a $AA_OFF position offset (1)

A DRF offset is generated in the X axis by DRF handwheel traversal. No DRF offsets are operative for any other axes in the channel.

Program code	Comment
`N10 WHEN TRUE DO $AA_OFF[X]=10 G4 F5`	`; A position offset == 10 is interpolated for the X axis.`
`...`	
`N70 CORROF(X,"DRF",X,"AA_OFF")`	`; Only the DRF offset and the position offset of the X axis are deselected; the DRF offset of the Y axis is retained.`
`...`	

Example 5: Axial deselection of a DRF offset and a $AA_OFF position offset (2)

A DRF offset is generated in the X and Y axes by DRF handwheel traversal. No DRF offsets are operative for any other axes in the channel.

Program code	**Comment**
`N10 WHEN TRUE DO $AA_OFF[X]=10 G4 F5`	`; A position offset == 10 is interpolated for the X axis.`
`...`	
`N70 CORROF(Y,"DRF",X,"AA_OFF")`	`; The DRF offset of the Y axis and the position offset of the X axis are deselected; the DRF offset of the X axis is retained.`
`...`	

Further information

$AA_OFF_VAL

Once the position offset has been deselected by means of $AA_OFF, system variable $AA_OFF_VAL (integrated distance of axis override) for the corresponding axis will equal zero.

$AA_OFF in JOG mode

In JOG mode too, if $AA_OFF changes, the position offset will be interpolated as an overlaid movement if this function has been enabled via machine data MD 36750 $MA_AA_OFF_MODE.

$AA_OFF in synchronized action

If a synchronized action which immediately resets $AA_OFF (`DO $AA_OFF[<axis>]=<value>`) is active when the position offset is deselected using the `CORROF(<axis>,"AA_OFF")` part program command, then $AA_OFF will be deselected and not reset, and alarm 21660 will be signaled. However, if the synchronized action becomes active later, e.g. in the block after `CORROF`, $AA_OFF will remain set and a position offset will be interpolated.

Automatic channel axis exchange

If an axis for which `CORROF` has been programmed is active in another channel, it will be pulled into the channel when the axis changes (condition: MD30552 $MA_AUTO_GET_TYPE > 0) and then the position offset and/or the DRF offset will be deselected.

Auxiliary function outputs 13

Function

The auxiliary function output sends information to the PLC indicating when the NC program needs the PLC to perform specific switching operations on the machine tool. The auxiliary functions are output, together with their parameters, to the PLC interface. The values and signals must be processed by the PLC user program.

Auxiliary functions

The following auxiliary functions can be transferred to the PLC:

Auxiliary Function	Address
Tool selection	`T`
Tool offset	`D`, `DL`
Feedrate	`F`/`FA`
Spindle speed	`S`
M functions	`M`
H functions	`H`

For each function group or single function, machine data is used to define whether the output is triggered **before**, **with** or **after** the traversing motion.

The PLC can be programmed to acknowledge auxiliary function outputs in various ways.

Properties

Important properties of the auxiliary function are shown in the following overview table:

Function	Address extension		Value			Explanations	Maximum number per block
	Meaning	Range	Range	Type	Meaning		
`M`	-	0 (implicit)	0 ... 99	INT	Function	The address extension is 0 for the range between 0 and 99. Mandatory without address extension: `M0`, `M1`, `M2`, `M17`, `M30`	5
	Spindle no.	1 - 12	1 ... 99	INT	Function	`M3`, `M4`, `M5`, `M19`, `M70` with address extension spindle no. (e.g. `M2=5`; spindle stop for spindle `2)`. Without spindle number, the function applies for the master spindle.	
	Any	0 - 99	100 ... 2147483647	INT	Function	User M function*	
`S`	Spindle no.	1 - 12	0 ... ± 1,8*10^{308}	REAL	Spindle speed	Without spindle number, the function applies for the master spindle.	3
`H`	Any	0 - 99	0 ... ± 2147483647 ± 1,8*10^{308}	INT REAL	Any	Functions have no effect in the NCK; only to be implemented on the PLC.*	3
`T`	Spindle no. (for active tool management)	1 - 12	0 - 32000 (or tool names with active tool management)	INT	Tool selection	Tool names are not passed to the PLC interface.	1
`D`	-	-	0 - 12	INT	Tool offset selection	`D0`: Deselection Default setting: `D1`	1
`DL`	Location-dependent offset	1 - 6	0 ... ± 1,8*10^{308}	REAL	Tool fine offset selection	Refers to previously selected D number.	1
`F`	-	-	0.001 - 999 999,999	REAL	Path feedrate		6
`FA`	Axis No.	1 - 31	0.001 - 999 999,999	REAL	Axial feedrate		
* The meaning of the functions is defined by the machine manufacturer (**see machine manufacturer's specifications**).							

Further information

Number of function outputs per NC block

Up to 10 function outputs can be programmed in one NC block. Auxiliary functions can also be output from the action component of **synchronized actions**.

References:
Function Manual, Synchronized Actions

Grouping

The functions described can be grouped together. Group assignment is predefined for some M commands. The acknowledgment behavior can be defined by the grouping.

High-speed function outputs (QU)

Functions, which have not been programmed as high-speed outputs, can be defined as high-speed outputs for individual outputs with the keyword `QU`. Program execution continues without waiting for the acknowledgment of the miscellaneous function (the program waits for the transport acknowledgment). This helps avoid unnecessary hold points and interruptions to traversing movements.

Note

The appropriate machine data must be set for the "High-speed function outputs" function (→ **machine manufacturer**).

Function outputs for travel commands

The transfer of information as well as waiting for the appropriate response takes time and therefore influences the traversing movements.

High-speed acknowledgment without block change delay

Block change behavior can be influenced by machine data. When the "without block change delay" setting is selected, the system response with respect to high-speed auxiliary functions is as follows:

Auxiliary function output	Response
Before the movement	The block transition between blocks with high-speed auxiliary functions occurs **without** interruption and **without** a reduction in velocity. The auxiliary function output takes place in the first interpolation cycle of the block. The following block is executed with no acknowledgment delay.
During the movement	The block transition between blocks with high-speed auxiliary functions occurs **without** interruption and **without** a reduction in velocity. The auxiliary function output takes place during the block. The following block is executed with no acknowledgment delay.
After the movement	The movement stops at the end of the block. The auxiliary function output takes place at the end of the block. The following block is executed with no acknowledgment delay.

⚠ CAUTION

Function outputs in continuous-path mode

Function outputs **before** the traversing movements interrupt the continuous-path mode (`G64`/ `G641`) and generate an exact stop for the previous block.

Function outputs **after** the traversing movements interrupt the continuous-path mode (`G64`/ `G641`) and generate an exact stop for the current block.

Important: A wait for an outstanding acknowledgment signal from the PLC can also interrupt the continuous-path mode, e.g. for M command sequences in blocks with extremely short path lengths.

13.1 M functions

Function

The M functions initiate switching operations, such as "Coolant ON/OFF" and other functions on the machine.

Syntax

```
M<value>
M[<address extension>] = <value>
```

Significance

`M`:	Address for the programming of the M functions.
`<address extension>`:	The extended address notation applies for some M functions (e.g. specification of the spindle number for spindle functions).
`<value>`:	Assignment is made to a certain machine function through the value assignment (M function number). Type: INT Range of values: 0 ... 2147483647 (max. INT value)

Predefined M functions

Certain important M functions for program execution are supplied as standard with the control:

M function	Meaning
`M0*`	Programmed stop
`M1*`	Optional stop
`M2*`	End of main program with return to beginning of program
`M3`	Spindle clockwise
`M4`	Spindle counterclockwise
`M5`	Spindle stop
`M6`	Tool change (default setting)
`M17*`	End of subroutine
`M19`	Position the spindle
`M30*`	End of program (as `M2`)
`M40`	Automatic gear change
`M41`	Gear stage 1
`M42`	Gear stage 2
`M43`	Gear stage 3
`M44`	Gear stage 4

M function	Meaning
`M45`	Gear stage 5
`M70`	Spindle is switched to axis mode

NOTICE

Extended address notation cannot be used for the functions marked with *.

The commands `M0`, `M1`, `M2`, `M17` and `M30` are always issued **after** the traversing movement.

M functions defined by the machine manufacturer

All free M function numbers can be used by the machine manufacturer, e.g. for switching functions to control the clamping devices or for the activation/deactivation of further machine functions.

NOTICE

The functions assigned to the free M function numbers are machine-specific. A certain M function can therefore have a different functionality on another machine.

Refer to the machine manufacturer's specifications for the M functions available on a machine and their functions.

Examples

Example 1: Maximum number of M functions in a block

Program code	**Comment**
`N10 S...`	
`N20 X... M3`	`; M function in the block with axis movement, spindle accelerates before the X axis movement`
`N180 M789 M1767 M100 M102 M376`	`; Maximum of five M functions in the block`

Example 2: M function as high-speed output

Program code	**Comment**
`N10 H=QU(735)`	`; Fast output for H735.`
`N10 G1 F300 X10 Y20 G64`	`;`
`N20 X8 Y90 M=QU(7)`	`; Fast output for M7.`

`M7` has been programmed as high-speed output so that the continuous-path mode (`G64`) is not interrupted.

Note

Only use this function in special cases as, for example, the chronological alignment is changed in combination with other function outputs.

Further information about the predefined M commands

Programmed stop: M0

The machining is stopped in the NC block with M0. You can now remove chips, remeasure, etc.

Programmed stop 1 - optional stop: M1

M1 can be set via:

- HMI / dialog box "Program Control"

  or

- NC/PLC interface

The program execution of the NC is stopped by the programmed blocks.

Programmed stop 2 - an auxiliary function associated with M1 with stop in the program execution

Programmed stop 2 can be set via the HMI / dialog box "Program Control" and allows the technological sequences to be interrupted at any time at the end of the part to be machined. In this way, the operator can interrupt the production, e.g. to remove chip flows.

End of program: M2, M17, M30

A program is terminated with M2, M17 or M30 and reset to the start of the program. If the main program is called from another program (as subroutine), M2/M30 has the same effect as M17 and vice versa, i.e. M17 has the same effect in the main program as M2/M30.

Spindle functions: M3, M4, M5, M19, M70

The extended address notation with specification of the spindle number applies for all spindles.

Example:

Program code	Comment
M2=3	; Clockwise spindle rotation for the second spindle

If an address extension has not been programmed, the function applies for the master spindle.

Supplementary commands 14

14.1 Messages (MSG)

Function

Using the `MSG()` command, any character string from the part program can be output as message to the operator.

Syntax

```
MSG("<Message text>"[,<Execution>])
...
MSG ()
```

Significance

`MSG`: Keyword for programming a message text

`<message text>`: Any character string to be displayed as message

Type:	STRING
Maximum length:	124 characters; the display takes up two lines (2*62 characters)

By using the link operator "<<", variables can also be output in the message text.

`<Execution>`: Optional parameters to define the instant in time when the message is written.

Value	Significance
0 (default)	To write the message, a dedicated main run block is not generated. This is realized in the next NC block that can be executed. Active continuous-path mode is not interrupted.
1	To write the message, a dedicated main run block is generated. Active continuous-path mode is interrupted.

`MSG()`: The actual message can be deleted by programming `MSG()` without message text.

Note

If the message is to be output in the language active at the user interface, then the user requires information about the language that is currently set at the HMI. This information can be interrogated in the part program and in the synchronized actions using system variable $AN_LANGUAGE_ON_HMI (see "Currently set language in the HMI [Page 557]").

Examples

Example 1: Output/delete message

Program code	Comment
N10 G91 G64 F100	; Continuous-path mode
N20 X1 Y1	
N... X... Y...	
N20 MSG ("Machining part 1")	; The message is first output with N30. ; Continuous-path mode is kept.
N30 X... Y...	
N... X... Y...	
N400 X1 Y1	
N410 MSG ("Machining part 2",1)	; The message is output with N410. ; Continuous-path mode is interrupted.
N420 X1 Y1	
N... X... Y...	
N900 MSG ()	; Delete message.

Example 2: Message text with variable

Program code	Comment
N10 R12=$AA_IW [X]	; Current position of the X axis in R12.
N20 MSG ("Check position of X axis"<<R12<<)	; Output message with variable R12.
...	
N90 MSG ()	; Delete message from N20.

14.2 Writing string in OPI variable (WRTPR)

Function

Using the `WRTPR()` function, you can write any character string from the part program into the OPI variable progProtText.

Syntax

```
WRTPR(<character string>[,<execution>])
```

Meaning

`WRTPR`: Function to output a character string.

`<character string>`: Any character string, which is written to the OPI variable progProtText.

Type:	STRING
Maximum length:	128 characters

`<Execution>`: Optional parameters to define the instant in time when the string is written.

Value range:	0, 1
Default value:	0

Value	Meaning
0	To write the string, a dedicated main run block is not generated. This is realized in the next NC block that can be executed. Active continuous-path mode is not interrupted.
1	To write the string, a dedicated main run block is generated. Active continuous-path mode is interrupted.

Examples

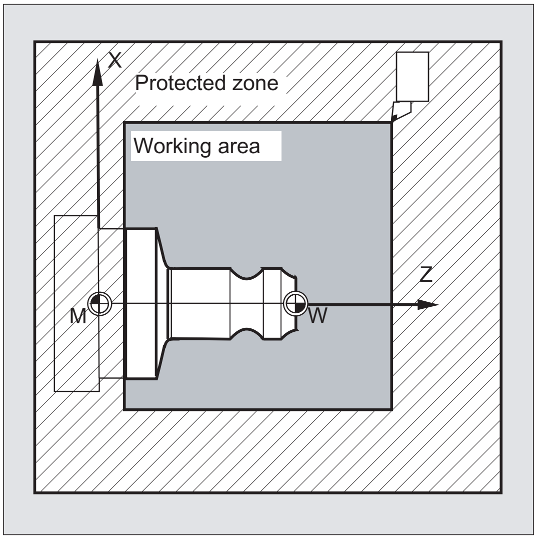
Program code	Comments
N10 G91 G64 F100	; Continuous-path mode
N20 X1 Y1	
N30 WRTPR("N30")	; String "N30" is first written to N40. ; Continuous-path mode is kept.
N40 X1 Y1	
N50 WRTPR("N50",1)	; String "N50" is written to N50. ; Continuous-path mode is interrupted.
N60 X1 Y1	

14.3 Working area limitation

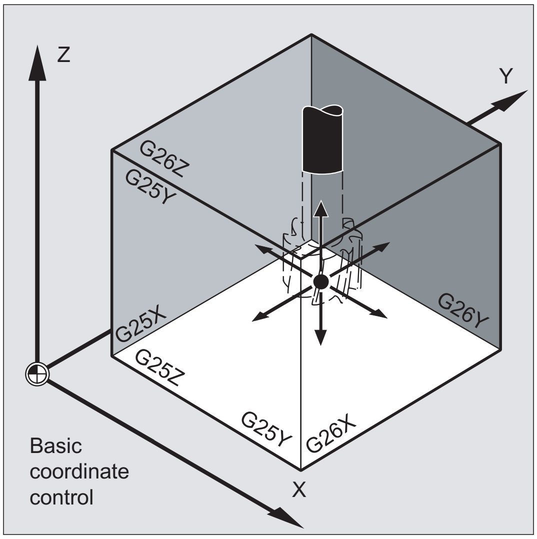
14.3.1 Working area limitation in BCS (G25/G26, WALIMON, WALIMOF)

Function

G25/G26 limits the working area (working field, working space) in which the tool can traverse. The areas outside the working area limitations defined with G25/G26 are inhibited for any tool motion.



The coordinates for the individual axes apply in the basic coordinate system:



The working area limitation for all validated axes must be programmed with the WALIMON command. The WALIMOF command deactivates the working area limitation. WALIMON is the default setting. Therefore, it only has to be programmed if the working area limitation has been disabled beforehand.

Syntax

```
G25 X…Y…Z…
G26 X…Y…Z…
WALIMON
WALIMOF
```

Meaning

G25:	**Lower** working area limitation Assignment of values in channel axes in the basic coordinate system
G26:	**Upper** working area limitation Assignment of values in channel axes in the basic coordinate system
X… Y… Z…:	Lower or upper working area limits for individual channel axes The limits specified refer to the basic coordinate system.
WALIMON:	Switch working area limitation **on** for all axes
WALIMOF:	Switch working area limitation **off** for all axes

In addition to programming values using G25/G26, values can also be entered using axis-specific setting data:

SD43420 $SA_WORKAREA_LIMIT_PLUS (Working area limitation plus)

SD43430 $SA_WORKAREA_LIMIT_MINUS (Working area limitation minus)

Activating and de-activating the working area limitation, parameterized using SD43420 and SD43430, are carried-out for a specific direction using the axis-specific setting data that becomes immediately effective:

SD43400 $SA_WORKAREA_PLUS_ENABLE (Working area limitation active in the positive direction)

SD43410 $SA_WORKAREA_MINUS_ENABLE (Working area limitation active in the negative direction)

Using the direction-specific activation/de-activation, it is possible to limit the working range for an axis in just one direction.

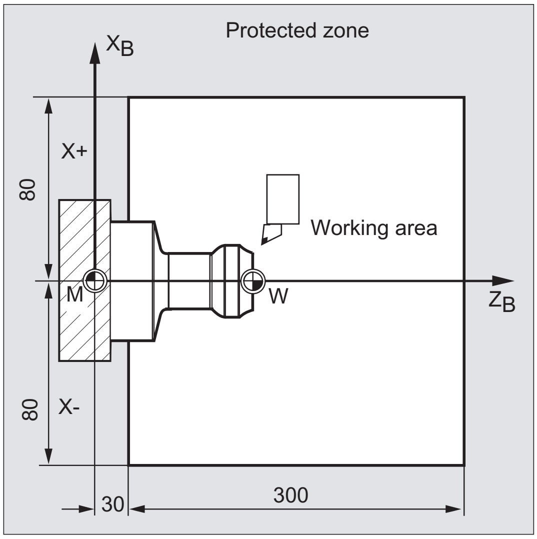
Note

The programmed working area limitation, programmed with G25/G26, has priority and overwrites the values entered in SD43420 and SD43430.

Note

G25/G26 can also be used to program limits for spindle speeds at the address S. For more information see " Programmable spindle speed limitation (G25, G26) [Page 108] ".

Example



Using the working area limitation G25/26, the working area of a lathe is limited so that the surrounding devices and equipment - such as revolver, measuring station, etc. - are protected against damage.

Default setting: WALIMON

Program code	**Comment**
N10 G0 G90 F0.5 T1	
N20 G25 X-80 Z30	; Define the lower limit for the individual coordinate axes
N30 G26 X80 Z330	; Define the upper limit
N40 L22	; Cutting program
N50 G0 G90 Z102 T2	; To tool change point
N60 X0	
N70 WALIMOF	; Deactivate working area limitation
N80 G1 Z-2 F0.5	; Drilling
N90 G0 Z200	; Back
N100 WALIMON	; Activate working area limitation
N110 X70 M30	; End of program

Further information

Reference point at the tool

When tool length compensation is active, the tip of the tool is monitored as reference point, otherwise it is the toolholder reference point.

Consideration of the tool radius must be activated separately. This is done using channel-specific machine data:

MD21020 $MC_WORKAREA_WITH_TOOL_RADIUS

If the tool reference point lies outside the working area defined by the working area limitation or if this area is left, the program sequence is stopped.

Note

If transformations are active, then tool data are taken into consideration (tool length and tool radius) can deviate from the described behavior.

References:
Function Manual, Basic Functions; Axis Monitoring, Protection Zones (A3),
Chapter: "Monitoring the working area limitation"

Programmable working area limitation, G25/G26

An upper (`G26`) and a lower (`G25`) working area limitation can be defined for each axis. These values are effective immediately and remain effective for the corresponding MD setting (→ MD10710 $MN_PROG_SD_RESET_SAVE_TAB) after RESET and after being powered-up again.

Note

The CALCPOSI subroutine is described in the Job Planning Programming Manual Using this subroutine before any traversing motion is made, it can be checked as to whether the predicted path is moved through taking into account the working area limits and/or the protection zones.

14.3.2 Working area limitation in WCS/SZS (WALCS0 ... WALCS10)

Function

In addition to the working area limitation with WALIMON (see "Working area limitation in BCS (G25/G26, WALIMON, WALIMOF) [Page 388]") there is an additional working area limitation that is activated using the G commands WALCS1 to WALCS10. Contrary to the working area limitation with WALIMON, the working area here is not in the basic coordinate system, but is limited **coordinate system-specific** in the workpiece coordinate system (WCS) or in the settable zero system (SZS).

Using the G commands WALCS1 - WALCS10, a data set (working area limitation group) is selected under the up to ten channel-specific data sets for the coordinate system-specific working area limitations. A data set contains the limit values for all axes in the channel. The limitations are defined by channel-specific system variables.

Application

The working area limitation with WALCS1 - WALCS10 ("Working area limitation in the WCS/SZS") is mainly used for working area limitations for conventional lathes. They allow the programmer to use the defined "end stops" - when moving the axis "manually" to define a working area limitation referred to the workpiece.

Syntax

The "working area limitation in the "WCS/SZS" is activated by selecting a working area limitation group. G commands are used to make the selection:

`WALCS1`	Activating working area limitation group No. 1
...	
`WALCS10`	Activating working area limitation group No. 10

The de-activation of the "working area limitation in the WCS/SZS" is realized using G commands:

`WALCS0`	De-activating the active working area limitation group

Meaning

The working area limitations of the individual axes are set and the reference frame (WCS or SZS), in which the working area limits are to be effective, activated with `WALCS1` - `WALCS10`, by writing to channel-specific system variables:

System variable	Meaning	
Setting the working area limits		
$P_WORKAREA_CS_PLUS_ENABLE [<GN>, <AN>]	Validity of the working area limitation in the positive axis direction.	
$P_WORKAREA_CS_LIMIT_PLUS [<GN>, <AN>]	Working area limitation in the positive axis direction. Only effective, if: $P_WORKAREA_CS_PLUS_ENABLE [<GN>,<AN>] = TRUE	
$P_WORKAREA_CS_MINUS_ENABLE [<GN>, <AN>]	Validity of the working area limitation in the negative axis direction.	
$P_WORKAREA_CS_LIMIT_MINUS [<GN>, <AN>]	Working area limitation in the negative axis direction. Only effective, if: $P_WORKAREA_CS_MINUS_ENABLE [<GN>,<AN>] = TRUE	
Selecting the reference frame		
$P_WORKAREA_CS_COORD_SYSTEM [<GN>]	Coordinate system to which the working area limitation group is referred:	
	Value	**Meaning**
	1	Workpiece coordinate system (WCS)
	3	Settable zero system (SZS)

<GN>:	Number of the working area limitation group
<AN>:	Channel axis name

Example

Three axes are defined in the channel: X, Y and Z

A working area limitation group No. 2 is to be defined and then activated in which the axes are to be limited in the WCS acc. to the following specifications:

- X axis in the plus direction: 10 mm
- X axis in the minus direction: No limitation
- Y axis in the plus direction: 34 mm
- Y axis in the minus direction: -25 mm
- Z axis in the plus direction: No limitation
- Z axis in the minus direction: -600 mm

Program code	Comment
...	
N51 $P_WORKAREA_CS_COORD_SYSTEM[2]=1	; The working area limitation of working area limitation group 2 applies in the WCS.
N60 $P_WORKAREA_CS_PLUS_ENABLE[2,X]=TRUE	
N61 $P_WORKAREA_CS_LIMIT_PLUS[2,X]=10	
N62 $P_WORKAREA_CS_MINUS_ENABLE[2,X]=FALSE	
N70 $P_WORKAREA_CS_PLUS_ENABLE[2,Y]=TRUE	
N73 $P_WORKAREA_CS_LIMIT_PLUS[2,Y]=34	
N72 $P_WORKAREA_CS_MINUS_ENABLE[2,Y]=TRUE	
N73 $P_WORKAREA_CS_LIMIT_MINUS[2,Y]=-25	
N80 $P_WORKAREA_CS_PLUS_ENABLE[2,Z]=FALSE	
N82 $P_WORKAREA_CS_MINUS_ENABLE[2,Z]=TRUE	
N83 $P_WORKAREA_CS_LIMIT_PLUS[2,Z]=-600	
...	
N90 WALCS2	; Activating working area limitation group No. 2.
...	

Further information

Effectivity

The working area limitation with WALCS1 - WALCS10 acts independently of the working area limitation with WALIMON. If both functions are active, that limit becomes effective which the axis motion first reaches.

Reference point at the tool

Taking into account the tool data (tool length and tool radius) and therefore the reference point at the tool when monitoring the working area limitation corresponds to the behavior for the working area limitation with WALIMON.

14.4 Reference point approach (G74)

Function

When the machine has been powered up (where incremental position measuring systems are used), all of the axis slides must approach their reference mark. Only then can traversing movements be programmed.

The reference point can be approached in the NC program with G74.

Syntax

`G74 X1=0 Y1=0 Z1=0 A1=0 …` ; Programmed in a separate NC block

Significance

`G74`: Search for reference

`X1=0 Y1=0 Z1=0 …`: Specified machine axis address X1, Y1, Z1… Search for reference for linear axes

`A1=0 B1=0 C1=0 …`: Specified machine axis address A1, B1, C1… Search for reference for rotary axes.

Note

A transformation must not be programmed for an axis which is to approach the reference point with G74.

The transformation is deactivated with command TRAFOOF.

Example

When the measurement system is changed, the reference point is approached and the workpiece zero point is initialized.

Program code	**Comment**
`N10 SPOS=0`	`; Spindle in position control`
`N20 G74 X1=0 Y1=0 Z1=0 C1=0`	`; Reference point approach for linear axes and rotary axes`
`N30 G54`	`; Zero offset`
`N40 L47`	`; Cutting program`
`N50 M30`	`; End of program`

14.5 Fixed-point approach (G75, G751)

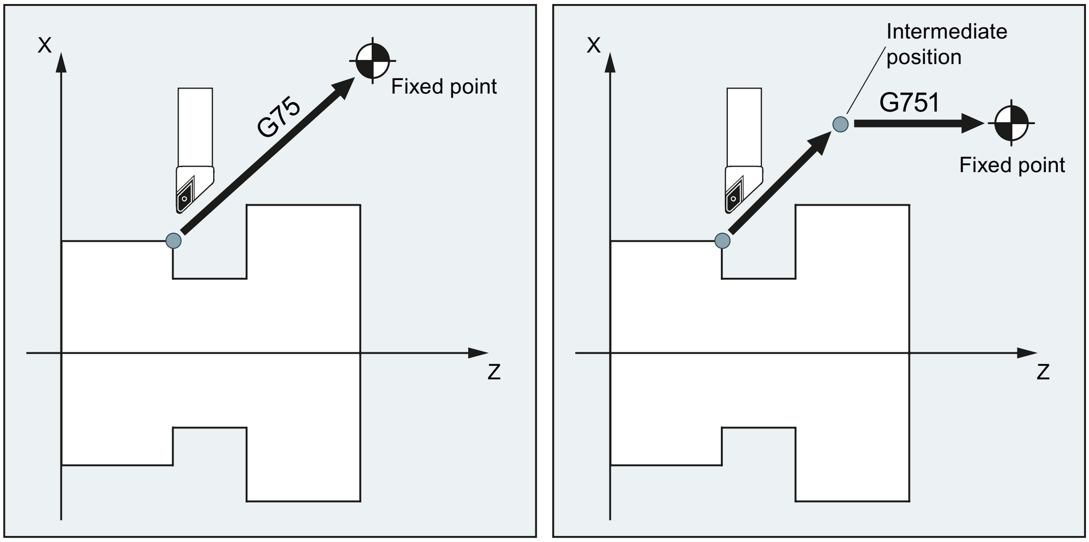
Function

The non-modal command `G75`/`G751` can be used to move axes individually and independently of one another to fixed points in the machine space, e.g. to tool change points, loading points, pallet change points, etc.

The fixed points are positions in the machine coordinate system which are stored in the machine data (MD30600 $MA_FIX_POINT_POS[n]). A maximum of four fixed points can be defined for each axis.

The fixed points can be approached from every NC program irrespective of the current tool or workpiece positions. An internal preprocessing stop is executed prior to moving the axes.

The approach can be made directly (`G75`) or via an intermediate point (`G751`):



Conditions

The following conditions must be satisfied to approach fixed points with `G75`/`G751`:

- The fixed-point coordinates must have been calculated exactly and written to machine data.
- The fixed points must be located within the valid traversing range (→ note the software limit switch limits!)
- The axes to be traversed must be referenced.
- No tool radius compensation must be active.
- A kinematic transformation may not be active.
- None of the axes to be traversed must be involved in active transformation.
- None of the axes to be traversed must be a following axis in an active coupling.
- None of the axes to be traversed must be an axis in a gantry grouping.
- Compile cycles must not activate motion components.

Syntax

```
G75/G751 <axis name><axis position> ... FP=<n>
```

Significance

`G75`:	Approach fixed point directly
`G751`:	Approach fixed point via intermediate point
`<axis name>`:	Name of the machine axis to be traversed to the fixed point All axis identifiers are permitted.
`<axis position>`:	In the case of `G75` the specified position value is irrelevant. A value of "0" is, therefore, usually specified. Things are different for `G751`, where the position of the intermediate point to be approached has to be specified as the value.
`FP=`:	Fixed point that is to be approached `<n>`: Fixed point number Range of values: 1, 2, 3, 4 **Note:** In the absence of `FP=<n>` or a fixed point number, or if `FP=0` has been programmed, this is interpreted as `FP=1` and fixed point 1 is approached.

Note

Multiple axes can be programmed in one `G75`/`751` block. The axes are then traversed simultaneously to the specified fixed point.

Note

The following applies for `G751`: Axes which are to only approach the fixed point without first moving to an intermediate point cannot be programmed.

Note

The value of the address `FP` must not be greater than the number of fixed points specified for each programmed axis (MD30610 $MA_NUM_FIX_POINT_POS).

Examples

Example 1: G75

For a tool change, axes X (= AX1) and Z (= AX3) need to move to the fixed machine axis position 1 where X = 151.6 and Z = -17.3.

Machine data:

- MD30600 $MA_FIX_POINT_POS[AX1,0] = 151.6
- MD30600 $MA_FIX_POINT[AX3,0] = 17.3

NC program:

Program code	Comment
…	
N100 G55	; Activate adjustable work offset.
N110 X10 Y30 Z40	; Approach positions in workpiece coordinate system.
N120 G75 X0 Z0 FP=1 M0	; The X axis moves to 151.6 and the Z axis moves to 17.3 (in the machine coordinate system). Each axis travels at the maximum velocity it is capable of reaching. No additional movements are permitted to be active in this block. To continue to prevent any additional movements once the end positions have been reached, a stop is inserted here.
N130 X10 Y30 Z40	; The position of N110 is approached again. The work offset is reactivated.
…	

Note

If the "Tool management with magazines" function is active, the auxiliary function `T…` or `M...` (typically `M6`) will not be sufficient to trigger a block change inhibit at the end of `G75` motion.

Reason: With "Tool management with magazines is active", auxiliary functions for tool change are not output to the PLC.

Example 2: G751

Position X20 Z30 is to be approached first, followed by the fixed machine axis position 2.

Program code	Comment
…	
N40 G751 X20 Z30 FP=2	; Position X20 Z30 is approached first in rapid traverse as a path. Then the distance from X20 Z30 to the second fixed point in the X and Y axis is traversed, as with G75.
…	

Further information

G75

The axes are traversed as machine axes in rapid traverse. The motion is mapped internally using the "SUPA" (suppress all frames) and "G0 RTLIOF" (rapid traverse motion with single-axis interpolation) functions.

If the conditions for "RTLIOF" (single-axis interpolation) are not met, the fixed point is approached as a path.

When the fixed point is reached, the axes come to a standstill within the "Exact stop fine" tolerance window.

G751

The intermediate position is approached with rapid traverse and active offset (tool offset, frames, etc.), and the axes move with interpolation. The next fixed-point approach is executed as with `G75`. Once the fixed point has been reached the offsets are reactivated (as with `G75`).

Additional axis movements

The following additional axis movements are taken into account at the point at which the `G75`/`G751` block is interpolated:

- External work offset
- DRF
- Synchronization offset ($AA_OFF)

After this, the additional axis movements are not permitted to change until the end of traversing is reached by the `G75`/`G751` block.

Additional movements following interpretation of the `G75`/`G751` block will offset the approach to the fixed point accordingly.

The following additional movements are not taken into account, irrespective of the point at which interpolation takes place, and will offset the target position accordingly.

- Online tool offset
- Additional movements from compile cycles in the BCS and machine coordinate system

Active frames

All active frames are ignored. Traversing is performed in the machine coordinate system.

Working area limitation in the workpiece coordinate system/SZS

Coordinate-system-specific working area limitation (`WALCS0` ... `WALCS10`) is not effective in the block with `G75`/`G751`. The destination point is monitored as the starting point of the following block.

Axis/Spindle movements with POSA/SPOSA

If programmed axes/spindles were previously traversed with `POSA` or `SPOSA`, these movements will be completed first before the fixed point is approached.

Spindle functions in the G75/G751 block

If the spindle is excluded from "Fixed-point approach", then additional spindle functions (e.g. positioning with `SPOS`/`SPOSA`) can be programmed in the `G75`/`G751` block.

Modulo axes

In the case of modulo axes, the fixed point is approached along the shortest distance.

References

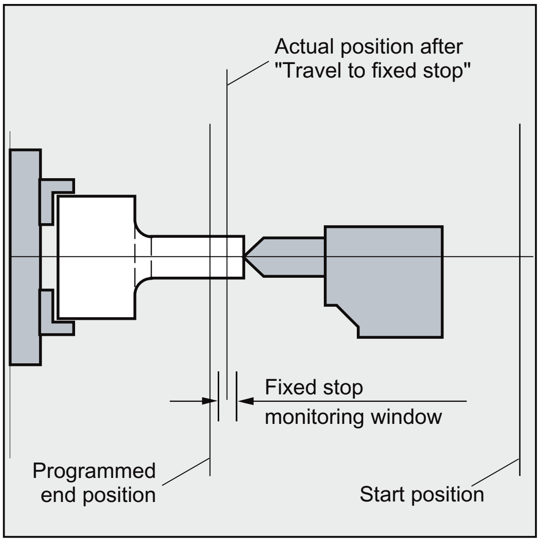
For further information about "Fixed-point approach", see:

Function Manual, Extended Functions; Manual and Handwheel Travel (H1), Chapter: "Fixed-point approach in JOG"

14.6 Travel to fixed stop (FXS, FXST, FXSW)

Function

The "Travel to fixed stop" function can be used to establish defined forces for clamping workpieces, such as those required for tailstocks, quills and grippers. The function can also be used for the approach of mechanical reference points.



With sufficiently reduced torque, it is also possible to perform simple measurement operations without connecting a probe. The "travel to fixed stop" function can be implemented for axes as well as for spindles with axis-traversing capability.

Syntax

```
FXS[<axis>]=…
FXST[<axis>]=…
FXSW[<axis>]=…
FXS[<axis>]=… FXST[<axis>]=…
FXS[<axis>]=… FXST[<axis>]=… FXSW[<axis>]=…
```

Significance

`FXS`: Command for activation and deactivation of the "Travel to fixed stop" function

`FXS[<axis>]=1`: Activate function

`FXS=[<axis>]=0`: Deactivate function

`FXST`: Optional command for setting the clamping torque
Specified as % of the maximum drive torque

`FXSW`: Optional command for setting the window width for the fixed stop monitoring
Specified in mm, inches or degrees

`<axis>`: Machine axis name
Machine axes (X1, Y1, Z1, etc.) are programmed

Note

The commands `FXS`, `FXST` and `FXSW` are modal.

The programming of `FXST` and `FXSW` is optional: If no parameter is specified, the last programmed value or the value set in the relevant machine data applies.

Activate travel to fixed stop: FXS[<axis>] = 1

The movement to the destination point can be described as a path or positioning axis movement. With positioning axes, the function can be performed across block boundaries.

Travel to fixed stop can be performed simultaneously for several axes and parallel to the movement of other axes. The fixed stop must be located between the start and end positions.

Example:

```
Program code                                          Comment
X250 Y100 F100 FXS[X1]=1 FXST[X1]=12.3 FXSW[X1]=2     ; Axis X1 travels with
                                                        feed F100 (parameter
                                                        optional) to
                                                        destination position
                                                        X=250 mm.
                                                        The clamping torque is
                                                        12.3% of the maximum
                                                        drive torque,
                                                        monitoring is
                                                        performed in a 2 mm
                                                        wide window.
...
```

CAUTION

It is not permissible to program a new position for an axis if the "Travel to fixed stop" function has already been activated for an axis/spindle.

Spindles must be switched to position-controlled mode before the function is selected.

Deactivate travel to fixed stop: FXS[<axis>] = 0

Deselection of the function triggers a preprocessing stop.

The block with `FXS[<axis>]=0` may and should contain traversing movements.

Example:

Program code	Comment
`X200 Y400 G01 G94 F2000 FXS[X1]=0`	`; Axis X1 is retracted from the fixed stop to position X = 200 mm. All other parameters are optional.`
`...`	

CAUTION

The traversing movement to the retraction position must move away from the fixed stop, otherwise damage to the stop or to the machine may result.

The block change takes place when the retraction position has been reached. If no retraction position is specified, the block change takes place immediately the torque limit has been deactivated.

Clamping torque (FXST) and monitoring window (FXSW)

Any programmed torque limiting `FXST` is effective from the block start, i.e. the fixed stop is also approached at a reduced torque. `FXST` and `FXSW` can be programmed and changed in the part program at any time. The changes take effect before traversing movements in the same block.

Programming of a new fixed stop monitoring window causes a change not only in the window width, but also in the reference point for the center of the window if the axis has moved prior to reprogramming. The actual position of the machine axis when the window is changed is the new window center point.

CAUTION

The window must be selected such that only a breakaway from the fixed stop causes the fixed stop monitoring to respond.

Further information

Rise ramp

A rate of rise ramp for the new torque limit can be defined in MD to prevent any abrupt changes to the torque limit setting (e.g. insertion of a quill).

Alarm suppression

The fixed stop alarm can be suppressed for applications by the part program by masking the alarm in a machine data item and activating the new MD setting with NEW_CONF.

Activating

The commands for travel to fixed stop can be called from synchronized actions or technology cycles. They can be activated without initiation of a motion, the torque is limited instantaneously. As soon as the axis is moved via a setpoint, the limit stop monitor is activated.

Activation from synchronized actions

Example:

If the expected event ($R1) occurs and travel to fixed stop is not yet running, `FXS` should be activated for axis Y. The torque must correspond to 10% of the rated torque value. The width of the monitoring window is set to the default.

Program code

```
N10 IDS=1 WHENEVER (($R1=1) AND ($AA_FXS[Y]==0)) DO $R1=0 FXS[Y]=1 FXST[Y]=10
```

The normal part program must ensure that $R1 is set at the desired point in time.

Deactivation from synchronized actions

Example:

If an anticipated event ($R3) has occurred and the status "Limit stop contacted" (system variable $AA_FXS) is reached, then FXS must be deselected.

Program code

```
IDS=4 WHENEVER (($R3==1) AND ($AA_FXS[Y]==1)) DO FXS[Y]=0 FA[Y]=1000 POS[Y]=0
```

Fixed stop reached

When the fixed stop has been reached:

- The distance-to-go is deleted and the position setpoint is corrected.
- The drive torque increases to the programmed limit value `FXSW` and then remains constant.
- Fixed stop monitoring is activated within the specified window width.

Supplementary conditions

- Measurement with deletion of distance-to-go

  "Measure with deletion of distance-to-go" (`MEAS` command) and "Travel to fixed stop" cannot be programmed at the same time in one block.

  Exception:

  One function acts on a path axis and the other on a positioning axis or both act on positioning axes.

- Contour monitoring

  Contour monitoring is not performed while "Travel to fixed stop" is active.

- Positioning axes

  For "Travel to fixed stop" with positioning axes, the block change is performed irrespective of the fixed stop movement.

- Link and container axes

  Travel to fixed stop is also permitted for link and container axes.

  The status of the assigned machine axis is maintained beyond the container rotation. This also applies for modal torque limiting with FOCON.

  References:

  - Function Manual, Extended Functions; Several Control Panels on Multiple NCUs, Distributed Systems (B3)
  - Programming Manual, Job Planning; Subject: "Travel to fixed stop (FXS and FOCON/ FOCOF)"

- Travel to fixed stop is not possible:

  - With gantry axes
  - For concurrent positioning axes that are controlled exclusively from the PLC (`FXS` must be selected from the NC program).

- If the torque limit is reduced too far, the axis will not be able to follow the specified setpoint; the position controller then goes to the limit and the contour deviation increases. In this operating state, an increase in the torque limit may result in sudden, jerky movements. To ensure that the axis can follow the setpoint, check the contour deviation to make sure it is not greater than the deviation with an unlimited torque.

14.7 Acceleration behavior

14.7.1 Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA)

Function

The following part program commands are available for programming the current acceleration mode:

- `BRISK`, `BRISKA`

  The single axes or the path axes traverse with maximum acceleration until the programmed feedrate is reached (**acceleration without jerk limitation**).

- `SOFT`, `SOFTA`

  The single axes or the path axes traverse with constant acceleration until the programmed feedrate is reached (**acceleration with jerk limitation**).

- `DRIVE`, `DRIVEA`

  The single axes or the path axes traverse with maximum acceleration up to a programmed velocity limit (MD setting!). The acceleration rate is then reduced (MD setting) until the programmed feedrate is reached.

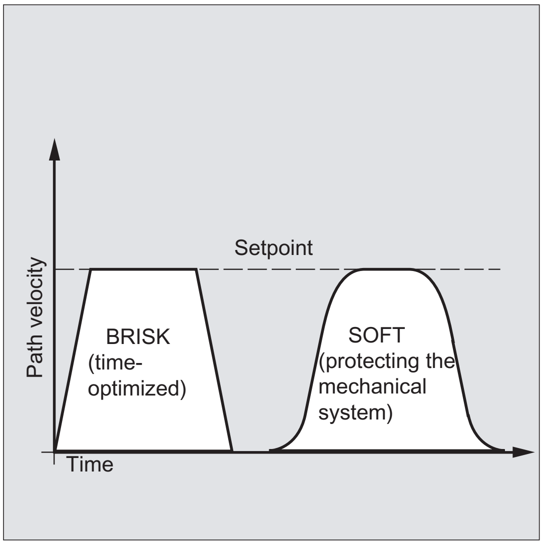


Figure 14-1 Path velocity curve with BRISK and SOFT

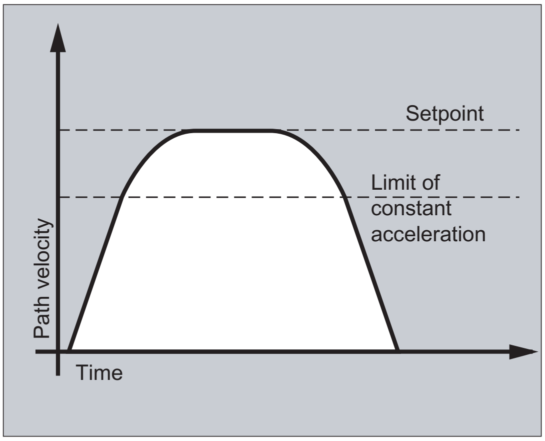


Figure 14-2 Path velocity curve with DRIVE

Syntax

```
BRISK
BRISKA(<axis1>,<axis2>,…)
SOFT
SOFTA(<axis1>,<axis2>,…)
DRIVE
DRIVEA(<axis1>,<axis2>,…)
```

Significance

`BRISK`: Command for activating the "acceleration without jerk limitation" for the path axes.

`BRISKA`: Command for activating the "acceleration without jerk limitation" for single axis movements (JOG, JOG/INC, positioning axis, oscillating axis, etc.).

`SOFT`: Command for activating the "acceleration with jerk limitation" for the path axes.

`SOFTA`: Command for activating the "acceleration with jerk limitation" for single axis movements (JOG, JOG/INC, positioning axis, oscillating axis, etc.).

`DRIVE`: Command for activating the reduced acceleration above a configured velocity limit
(MD35220 $MA_ACCEL_REDUCTION_SPEED_POINT)
for the path axes.

`DRIVEA`: Command for activating the reduced acceleration above a configured velocity limit
(MD35220 $MA_ACCEL_REDUCTION_SPEED_POINT)
for single axis movements (JOG, JOG/INC, positioning axis, oscillating axis, etc.).

`(<axis1>,<axis2>, etc.)`: Single axes for which the called acceleration mode is to apply.

Supplementary conditions

Changing acceleration mode during machining

If the acceleration mode is changed in a part program during machining (BRISK ↔ SOFT), then there is a block change with exact stop at the end of the block during the transition even with continuous-path mode.

Examples

Example 1: SOFT and BRISKA

Program code
N10 G1 X… Y… F900 SOFT
N20 BRISKA(AX5,AX6)
...

Example 2: DRIVE and DRIVEA

Program code
N05 DRIVE
N10 G1 X… Y… F1000
N20 DRIVEA (AX4, AX6)
...

References

Function Manual, Basic Functions; Acceleration (B2)

14.7.2 Influence of acceleration on following axes (VELOLIMA, ACCLIMA, JERKLIMA)

Function

In the case of axis couplings (tangential correction, coupled motion, master value coupling, electronic gear; → see Programming Manual, Job Planning) following axes/spindles are traversed dependent on one or more master axes/spindles.

The dynamics limits of the following axes/spindles can be manipulated using the VELOLIMA, ACCLIMA, and JERKLIMA functions from the part program or from synchronized actions, even if the axis coupling is already active.

Note

The JERKLIMA function is not available for all types of coupling.

References:

- Function Manual, Special Functions; Axis Couplings (M3)
- Function Manual, Extended Functions; Synchronous Spindle (S3)

Note

Availability for SINUMERIK 828D

The VELOLIMA, ACCLIMA and JERKLIMA functions can only be used with SINUMERIK 828D in conjunction with the "coupled motion" function!

Syntax

```
VELOLIMA(<axis>)=<value>
ACCLIMA(<axis>)=<value>
JERKLIMA(<axis>)=<value>
```

Significance

`VELOLIMA`:	Command to correct the parameterized maximum **velocity**
`ACCLIMA`:	Command to correct the parameterized maximum **acceleration**
`JERKLIMA`:	Command to correct the parameterized maximum **jerk**
`<axis>`:	Following axis whose dynamics limits need to be corrected
`<value>`:	Percentage offset value

Examples

Example 1: Correction of the dynamics limits for a following axis (AX4)

Program code	Comment
`...`	
`VELOLIMA[AX4]=75`	`; Limits correction to 75% of the maximum axial velocity stored in the machine data`
`ACCLIMA[AX4]=50`	`; Limits correction to 50% of the maximum axial acceleration stored in the machine data`
`JERKLIMA[AX4]=50`	`; Limits correction to 50% of the maximum axial jerk stored in the machine data`
`...`	

Example 2: Electronic gear

Axis 4 is coupled to axis X via an "electronic gear" coupling. The acceleration capacity of the following axis is limited to 70% of the maximum acceleration. The maximum permissible velocity is limited to 50% of the maximum velocity. Once the coupling has been activated successfully, the maximum permissible velocity is restored to 100%.

Program code	Comment
`...`	
`N120 ACCLIMA[AX4]=70`	`; Reduced maximum acceleration`
`N130 VELOLIMA[AX4]=50`	`; Reduced maximum velocity`
`...`	
`N150 EGON(AX4,"FINE",X,1,2)`	`; Activation of the EG coupling`
`...`	
`N200 VELOLIMA[AX4]=100`	`; Full maximum velocity`
`...`	

Example 3: Influencing master value coupling by static synchronized action

Axis 4 is coupled to X by master value coupling. The acceleration response is limited to position 80% by static synchronized action 2 from position 100.

Program code	Comment
`...`	
`N120 IDS=2 WHENEVER $AA_IM[AX4] > 100 DO ACCLIMA[AX4]=80`	`; Synchronized action`
`N130 LEADON(AX4, X, 2)`	`; Master value coupling on`
`...`	

14.7.3 Activation of technology-specific dynamic values (DYNNORM, DYNPOS, DYNROUGH, DYNSEMIFIN, DYNFINISH)

Function

Using the "Technology" G group, the appropriate dynamic response can be activated for five varying technological machining steps.

Dynamic values and G commands can be configured and are, therefore, dependent on machine data settings (→ machine manufacturer).

References:
Function Manual, Basic Functions; Continuous-Path Mode, Exact Stop, Look Ahead (B1)

Syntax

Activate dynamic values:

```
DYNNORM
DYNPOS
DYNROUGH
DYNSEMIFIN
DYNFINISH
```

Note

The dynamic values are already active in the block in which the associated G command is programmed. Machining is not stopped.

Read or write a specific field element:

```
R<m>=$MA...[n,X]
$MA...[n,X]=<value>
```

Significance

`DYNNORM`:	G command for activating **normal dynamic response**
`DYNPOS`:	G command for activating the dynamic response for **positioning mode**, **tapping**
`DYNROUGH`:	G command for activating the dynamic response for **roughing**
`DYNSEMIFIN`:	G command for activating the dynamic response for **finishing**
`DYNFINISH`:	G command for activating the dynamic response for **smooth-finishing**

`R<m>`:	R-parameter with number `<m>`
`$MA...[n,X]`:	Machine data with field element affecting dynamic response

`<n>`: Array index

Range of values: 0 ... 4

0	Normal dynamic response (`DYNNORM`)
1	Dynamic response for positioning mode (`DYNPOS`)
2	Dynamic response for roughing (`DYNROUGH`)
3	Dynamic response for finishing (`DYNSEMIFIN`)
4	Dynamic response for smooth-finishing (`DYNFINISH`)

`<X>` : Axis address

`<value>`: Dynamic value

Examples

Example 1: Activate dynamic values

Program code	**Comment**
`DYNNORM G1 X10`	`; Basic position`
`DYNPOS G1 X10 Y20 Z30 F…`	`; Positioning mode, tapping`
`DYNROUGH G1 X10 Y20 Z30 F10000`	`; Roughing`
`DYNSEMIFIN G1 X10 Y20 Z30 F2000`	`; Finishing`
`DYNFINISH G1 X10 Y20 Z30 F1000`	`; Smooth finishing`

Example 2: Read or write a specific field element

Maximum acceleration for roughing, axis X

Program code	**Comment**
`R1=$MA_MAX_AX_ACCEL[2,X]`	`; Read`
`$MA_MAX_AX_ACCEL[2,X]=5`	`; Write`

14.8 Traversing with feedforward control, FFWON, FFWOF

Function

The feedforward control reduces the velocity-dependent overtravel when contouring towards zero. Traversing with feedforward control permits higher path accuracy and thus improved machining results.

Syntax

```
FFWON
FFWOF
```

Significance

`FFWON`:	Command to **activate** the feedforward control
`FFWOF`:	Command to **deactivate** the feedforward control

Note

The type of feedforward control and which path axes are to be traversed with feedforward control is specified via machine data.

Default: Velocity-dependent feedforward control

Option: Acceleration-dependent feedforward control

Example

Program code
`N10 FFWON`
`N20 G1 X… Y… F900 SOFT`

14.9 Contour accuracy, CPRECON, CPRECOF

Function

In machining operations without feedforward control (`FFWON`), errors may occur on curved contours as a result of velocity-related differences between setpoint and actual positions.

The programmable contour accuracy function `CPRECON` makes it possible to store a maximum permissible contour violation in the NC program which must never be overshot. The magnitude of the contour violation is specified with setting data $SC_CONTPREC.

The Look Ahead function allows the entire path to be traversed with the programmed contour accuracy.

Syntax

```
CPRECON
CPRECOF
```

Significance

`CPRECON`:	Activate programmable contour accuracy
`CPRECOF`:	Deactivate programmable contour accuracy

Note

A minimum velocity can be defined via the setting data item $SC_MINFEED, which is not undershot, and the same value can also be written directly out from the part program via the system variable $SC_CONTPREC.

On the basis of the value of the contour violation $SC_CONTPREC and the servo gain factor (velocity/following error ratio) of the geometry axes concerned, the control calculates the maximum path velocity at which the contour violation produced by the overtravel does not exceed the minimum value stored in the setting data.

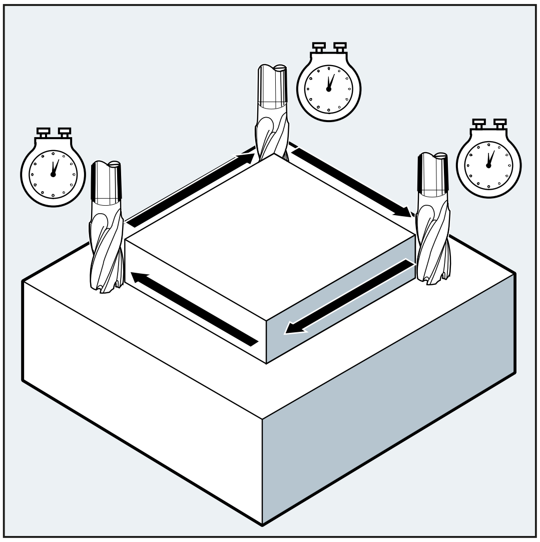
Example

Program code	**Comment**
`N10 X0 Y0 G0`	
`N20 CPRECON`	`; Activate contour accuracy`
`N30 F10000 G1 G64 X100`	`; Machining at 10 m/min in continuous-path mode`
`N40 G3 Y20 J10`	`; Automatic feed limitation in circular block`
`N50 X0`	`; Feedrate without limitation 10 m/min`

14.10 Dwell time (G4)

Function

`G4` can be used to program a "dwell time" between two NC blocks during which workpiece machining is interrupted.



Note

`G4` interrupts continuous-path mode.

Application

For example, for relief cutting.

Syntax

```
G4 F…/S<n>=...
```

Note

`G4` must be programmed in a separate NC block.

Significance

`G4`:	Activate dwell time
`F…`:	The dwell time is programmed in seconds at address `F`.
`S<n>=…`:	The dwell time is programmed in spindle revolutions at address `S`.
	`<n>`: The numeric extension indicates the number of the spindle to which the dwell time is to be applied. In the absence of a numeric extension (`S...`) the dwell time will be applied to the master spindle.

Note

Addresses F and S are only used for time parameters in the G4 block. The feedrate F... and the spindle speed S... programmed upstream of the G4 block are retained.

Example

Program code	Comment
N10 G1 F200 Z-5 S300 M3	; Feedrate F, spindle speed S
N20 G4 F3	; Dwell time: 3 s
N30 X40 Y10	
N40 G4 S30	; Dwelling 30 revolutions of the spindle (at S=300 rpm and 100% speed override, corresponds to t = 0.1 min).
N50 X...	; The feedrate and spindle speed programmed in N10 continue to apply.

14.11 Internal preprocessing stop

Function

The control generates an internal preprocessing stop on access to machine status data ($A...). The following block is not executed until all preprocessed and saved blocks have been executed in full. The previous block is stopped in exact stop (as `G9`).

Example

```
Program code                         Comments
...
N40 POSA[X]=100
N50 IF $AA_IM[X]==R100 GOTOF MARKE1  ; Access to machine status data ($A...),
                                       the control generates an internal
                                       preprocessing stop.
N60 G0 Y100
N70 WAITP(X)
N80 LABEL1:
...
```

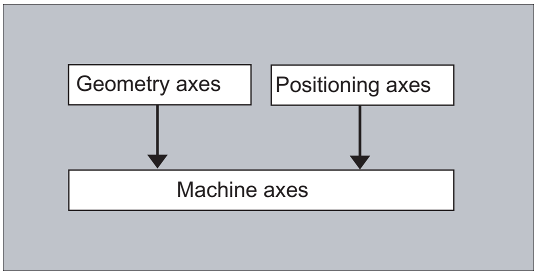
Other information 15

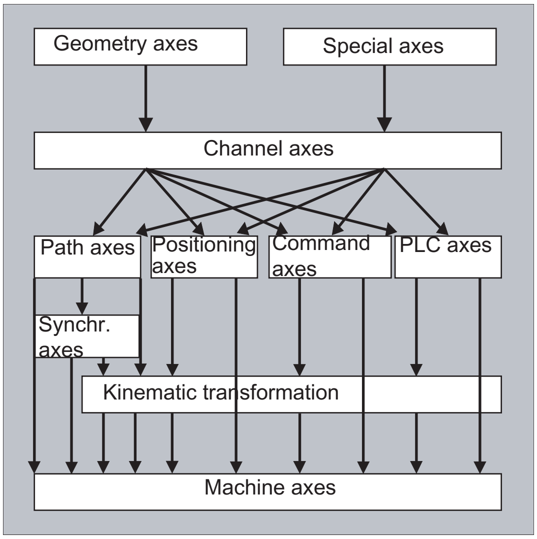
15.1 Axes

Axis types

A distinction is made between the following types of axes when programming:

- Machine axes
- Channel axes
- Geometry axes
- Special axes
- Path axes
- Synchronized axes
- Positioning axes
- Command axes (motion-synchronous actions)
- PLC axes
- Link axes
- Lead link axes





Behavior of programmed axis types

Geometry, synchronized and positioning axes are programmed.

- Path axes traverse with feedrate F in accordance with the programmed travel commands.
- Synchronized axes traverse synchronously to path axes and take the same time to traverse as all path axes.
- Positioning axes traverse asynchronously to all other axes. These traversing movements take place independently of path and synchronized movements.
- Command axes traverse asynchronously to all other axes. These traversing movements take place independently of path and synchronized movements.
- PLC axes are controlled by the PLC and can traverse asynchronously to all other axes. The traversing movements take place independently of path and synchronized movements.

15.1.1 Main axes/Geometry axes

The main axes define a right-angled, right-handed coordinate system. Tool movements are programmed in this coordinate system.

In NC technology, the main axes are called geometry axes. This term is also used in this Programming Guide.

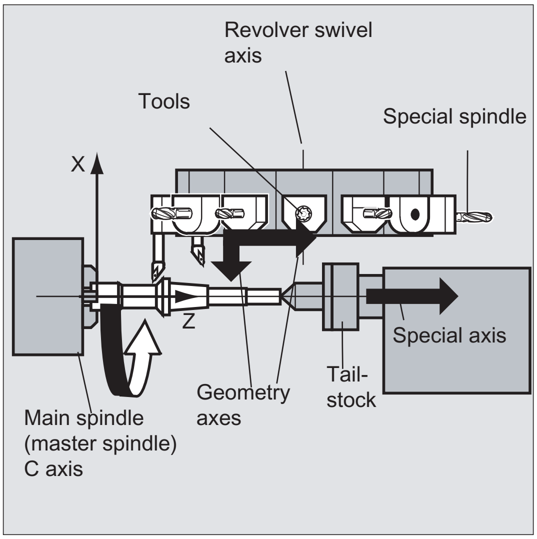
Replaceable geometry axes

The "Replaceable geometry axes" function (see Function Manual, Job Planning) can be used to alter the geometry axes grouping configured using machine data from the part program. Here any geometry axis can be replaced by a channel axis defined as a synchronous special axis.

Axis identifier

For turning machines:

Geometry axes X and Z are used, and sometimes Y.



For milling machines:

Geometry axes X, Y and Z are used.

Further information

A maximum of three geometry axes are used for programming frames and the workpiece geometry (contour).

The identifiers for geometry and channel axes may be the same, provided a reference is possible.

Geometry axis and channel axis names can be the same in any channel so that the same programs can be executed.

15.1.2 Special axes

In contrast to the geometry axes, no geometrical relationship is defined between the special axes.

Typical special axes are:

- Tool revolver axes
- Swivel table axes
- Swivel head axes
- Loader axes

Axis identifier

On a turning machine with circular magazine, for example:

- Revolver position U
- Tailstock V

Programming example

Program code	Comment
`N10 G1 X100 Y20 Z30 A40 F300`	`; Path axis movements`
`N20 POS[U]=10POS[X]=20 FA[U]=200 FA[X]=350`	`; Positioning axis movements`
`N30 G1 X500 Y80 POS[U]=150FA[U]=300 F550`	`; Path and positioning axis`
`N40 G74 X1=0 Z1=0`	`; Approach home position`

15.1.3 Main spindle, master spindle

The machine kinematics determine, which spindle is the main spindle. This spindle is usually declared as the master spindle in the machine data.

This assignment can be changed with the `SETMS(<spindle number>)` program command. `SETMS` can be used without specifying a spindle number to switch back to the master spindle defined in the machine data.

Special functions such as thread cutting are supported by the master spindle.

Spindle identifier

S or S0

15.1.4 Machine axes

Machine axes are the axes physically existing on a machine.

The movements of axes can still be assigned by transformations (TRANSMIT, TRACYL, or TRAORI) to the machine axes. If transformations are intended for the machine, different axis names must be specified during the commissioning (**machine manufacturer**).

The machine axis names are only programmed in special circumstances (e.g. for reference point or fixed point approach).

Axis identifier

The axis identifiers can be set in the machine data.

Standard identifiers:

X1, Y1, Z1, A1, B1, C1, U1, V1

There are also standard axis identifiers that can always be used:

AX1, AX2, …, AX<n>

15.1.5 Channel axes

Channel axes are all axes, which traverse in a channel.

Axis identifier

X, Y, Z, A, B, C, U, V

15.1.6 Path axes

Path axes define the path and therefore the movement of the tool in space.

The programmed feed is active for this path. The axes involved in this path reach their position at the same time. As a rule, these are the geometry axes.

However, default settings define, which axes are the path axes, and therefore determine the velocity.

Path axes can be specified in the NC program with `FGROUP`.

For more information about `FGROUP`, see "Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]".

15.1.7 Positioning axes

Positioning axes are interpolated separately; in other words, each positioning axis has its own axis interpolator and its own feedrate. Positioning axes do not interpolate with the path axes.

Positioning axes are traversed by the NC program or the PLC. If an axis is to be traversed simultaneously by the NC program and the PLC, an error message appears.

Typical positioning axes are:

- Loaders for moving workpieces to machine
- Loaders for moving workpieces away from machine
- Tool magazine/turret

Types

A distinction is made between positioning axes with synchronization at the block end or over several blocks.

POS axes

Block change occurs at the end of the block when all the path and positioning axes programmed in this block have reached their programmed end point.

POSA axes

The movement of these positioning axes can extend over several blocks.

POSP axes

The movement of these positioning axes for approaching the end position takes place in sections.

Note

Positioning axes become synchronized axes if they are traversed without the special POS/POSA identifier.

Continuous-path mode (G64) for path axes is only possible if the positioning axes (POS) reach their final position before the path axes.

Path axes programmed with `POS`/`POSA` are removed from the path axis grouping for the duration of this block.

For more information about `POS`, `POSA`, and `POSP`, see "Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC) [Page 118]".

15.1.8 Synchronized axes

Synchronized axes traverse synchronously to the path from the start position to the programmed end position.

The feedrate programmed in `F` applies to all the path axes programmed in the block, but does not apply to synchronized axes. Synchronized axes take the same time as the path axes to traverse.

A synchronized axis can be a rotary axis, which is traversed synchronously to the path interpolation.

15.1.9 Command axes

Command axes are started from synchronized actions in response to an event (command). They can be positioned, started, and stopped fully asynchronous to the parts program. An axis cannot be moved from the part program and from synchronized actions simultaneously.

Command axes are interpolated separately; in other words, each command axis has its own axis interpolator and its own feedrate.

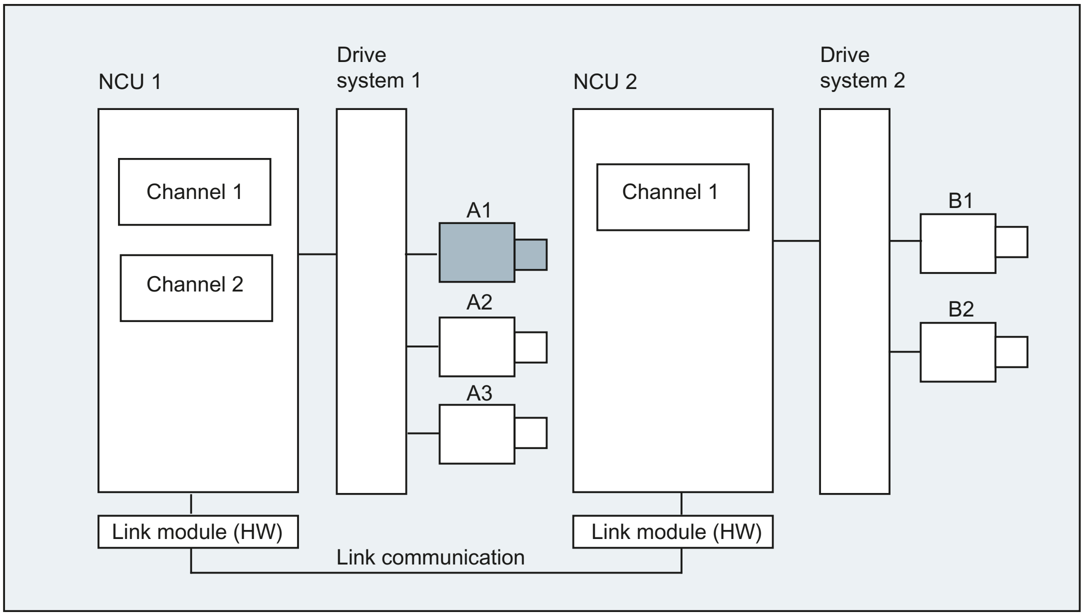
References:
Function Manual, Synchronized Actions

15.1.10 PLC axes

PLC axes are traversed by the PLC via special function blocks in the basic program; their movements can be asynchronous to all other axes. Traversing movements take place independently of path and synchronized movements.

15.1.11 Link axes

Link axes are axes, which are physically connected to another NCU and whose position is controlled from this NCU. Link axes can be assigned dynamically to channels of another NCU. Link axes are non-local axes from the perspective of a specific NCU.



The axis container concept is used for the dynamic modification of the assignment to an NCU. Axis exchange with `GET` and `RELEASE` from the part program is not available for link axes.

Further information

Prerequisites

- The participating NCUs, NCU1 and NCU2, must be connected by means of high-speed communication via the link module.
  References:
  Configuration Manual, NCU
- The axis must be configured appropriately by machine data.
- The "Link axis" option must be installed.

Description

The position control is implemented on the NCU on which the axis is physically connected to the drive. This NCU also contains the associated axis VDI interface. The position setpoints for link axes are generated on another NCU and communicated via the NCU link.

The link communication must provide the means of interaction between the interpolators and the position controller or PLC interface. The setpoints calculated by the interpolators must be transported to the position control loop on the home NCU and, vice versa, the actual values must be returned from there back to the interpolators.

References:
For more detailed information about link axes see:
Function Manual, Advanced Functions; Multiple Operator Panels and NCUs (B3)

Axis container

An axis container is a circular buffer data structure, in which local axes and/or link axes are assigned to channels. The entries in the circular buffer can be **shifted cyclically**.

In addition to the direct reference to local axes or link axes, the link axis configuration in the logical machine axis image also allows references to axis containers. This type of reference consists of:

- A container number **and**
- a slot (circular buffer location within the container)

The entry in a circular buffer location contains:

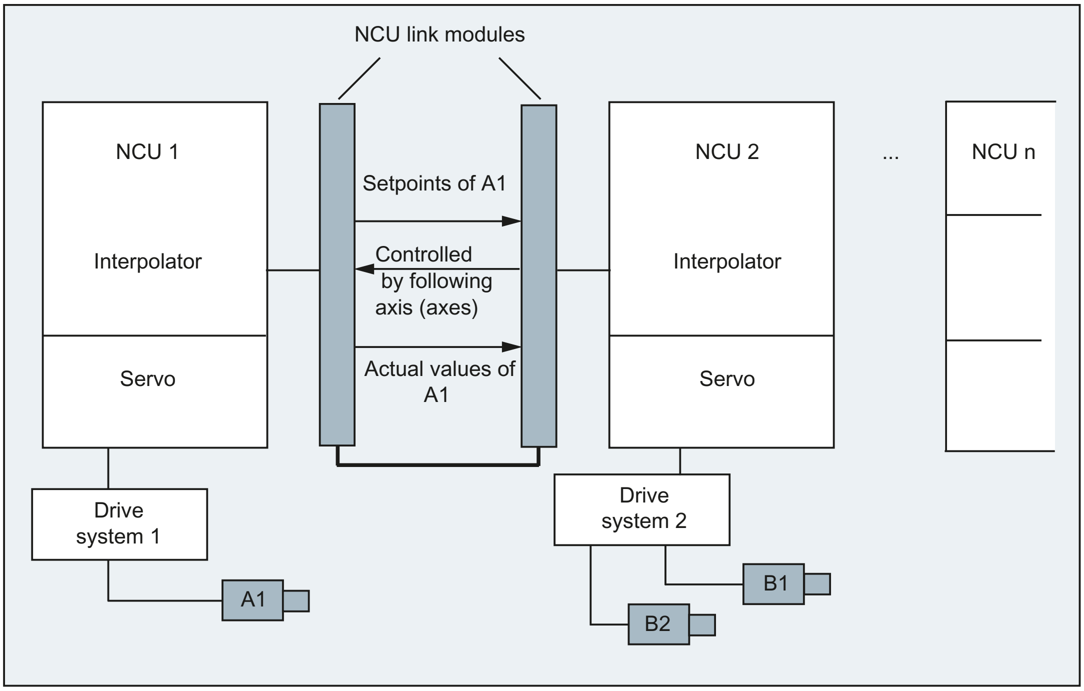
- a local axis **or**
- a link axis

Axis container entries contain local machine axes or link axes from the perspective of an individual NCU. The entries in the logical machine axis image
(MD10002 $MN_AXCONF_LOGIC_MACHAX_TAB) of an individual NCU are fixed.

References:
The axis container function is described in:
Function Manual, Advanced Functions; Multiple Operator Panels and NCUs (B3)

15.1.12 Lead link axes

A leading link axis is one that is interpolated by one NCU and utilized by one or several other NCUs as the master axis for controlling slave axes.



An axial position controller alarm is sent to all other NCUs, which are connected to the affected axis via a leading link axis.

NCUs that are dependent on the leading link axis can utilize the following coupling relationships with it:

- Master value (setpoint, actual master value, simulated master value)
- Coupled motion
- Tangential correction
- Electronic gear (ELG)
- Synchronous spindle

Programming

Master NCU:

Only the NCU, which is physically assigned to the master value axis can program travel motions for this axis. The travel program must not contain any special functions or operations.

NCUs of slave axes:

The travel program on the NCUs of the slave axes must not contain any travel commands for the leading link axis (master value axis). Any violation of this rule triggers an alarm.

The leading link axis is addressed in the usual way via channel axis identifiers. The states of the leading link axis can be accessed by means of selected system variables.

Further information

Conditions

- The dependent NCUs, i.e., NCU1 to NCU<n> (n equals max. of 8), must be interconnected via the link module for high-speed communication.
  References:
  Configuration Manual, NCU
- The axis must be configured appropriately via machine data.
- The "Link axis" option must be installed.
- The same interpolation cycle must be configured for all NCUs connected to the leading link axis.

Restrictions

- A master axis which is a leading link axis cannot be a link axis, i.e. it cannot be traversed by NCUs other than its home NCU.
- A master axis which is a leading link axis cannot be a container axis, i.e. it cannot be addressed alternately by different NCUs.
- A leading link axis cannot be the programmed leading axis in a gantry grouping.
- Couplings with leading link axes cannot be cascaded.
- Axis replacement can only be implemented within the home NCU of the leading link axis.

System variables

The following system variables can be used in conjunction with the channel axis identifier of the leading link axis:

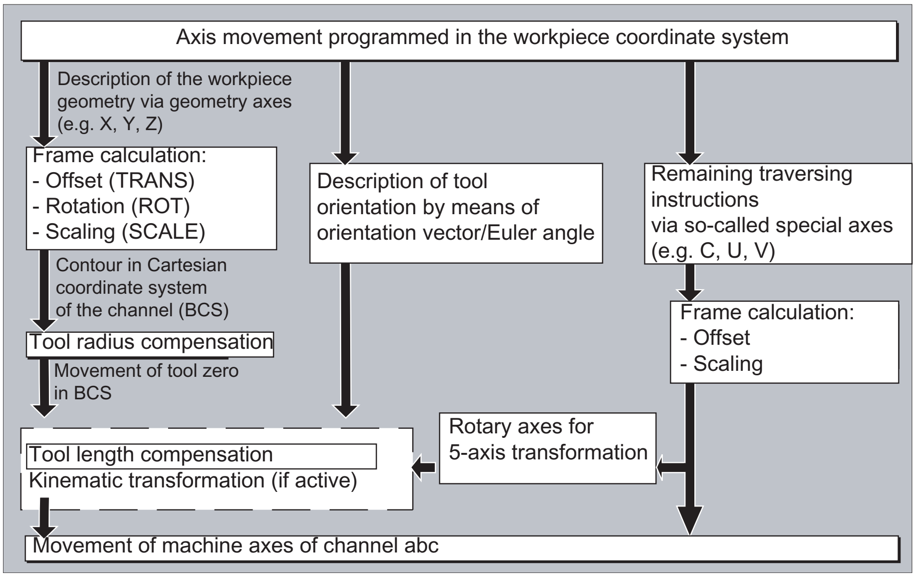
System variables	Significance
$AA_LEAD_SP	Simulated master value - position
$AA_LEAD_SV	Simulated master value - velocity

If these system variables are updated by the home NCU of the master axis, the new values are also transferred to any other NCUs, which wish to control slave axes as a function of this master axis.

References:
Function Manual, Extended Functions; Multiple Operator Panels and NCUs (B3)

15.2 From travel command to machine movement

The relationship between the programmed axis movements (travel commands) and the resulting machine movements is illustrated in the following figure:

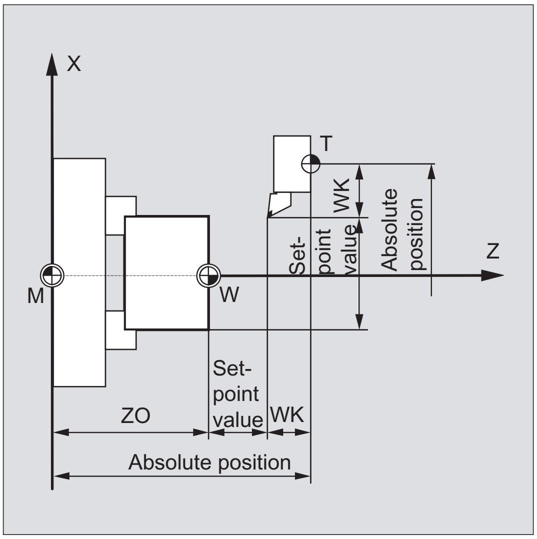

Axis movement programmed in the workpiece coordinate system
Description of the workpiece geometry via geometry axes (e.g. X, Y, Z)
Frame calculation:
- Offset (TRANS)
- Rotation (ROT)
- Scaling (SCALE)
Description of tool orientation by means of orientation vector/Euler angle
Remaining traversing instructions via so-called special axes (e.g. C, U, V)
Contour in Cartesian coordinate system of the channel (BCS)
Frame calculation:
- Offset
- Scaling
Tool radius compensation
Movement of tool zero in BCS
Rotary axes for 5-axis transformation
Tool length compensation
Kinematic transformation (if active)
Movement of machine axes of channel abc

15.3 Path calculation

The path calculation determines the distance to be traversed in a block, taking into account all offsets and compensations.

In general:

Distance = setpoint - actual value + zero offset (ZO) + tool offset (TO)



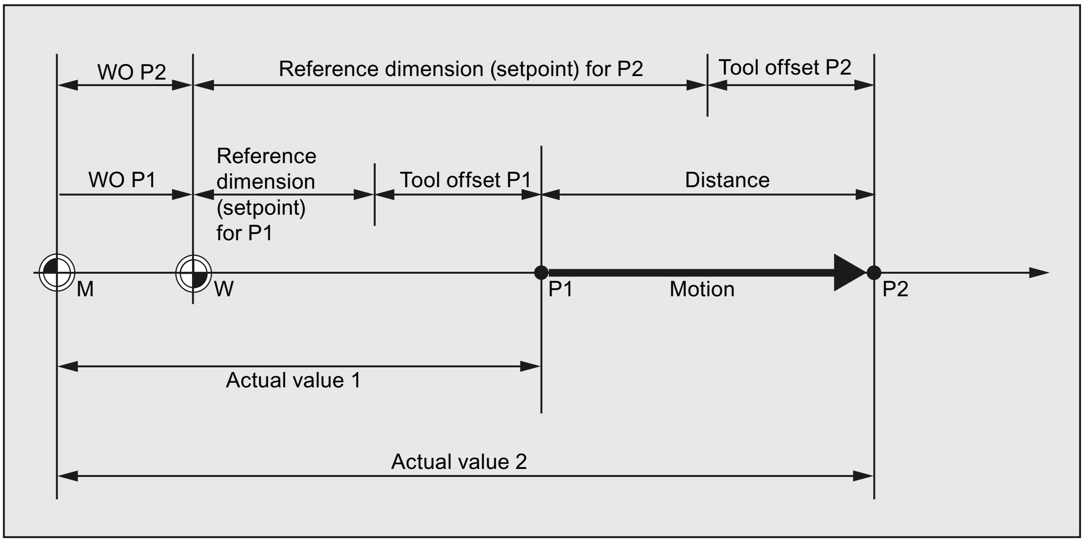
If a new zero offset and a new tool offset are programmed in a new program block, the following applies:

- With absolute dimensioning:

  Distance = (absolute dimension P2 - absolute dimension P1) + (WO P2 - WO P1) + (TO P2 - TO P1).

- With incremental dimensioning:

  Distance = incremental dimension + (WO P2 - WO P1) + (TO P2 - TO P1).



15.4 Addresses

Fixed and settable addresses

Addresses can be divided into two groups:

- Fixed addresses

  These addresses are permanently set, i.e. the address characters cannot be changed.

- Settable addresses

  The machine manufacturer may assign another name to these addresses via machine data.

Some important addresses are listed in the following table. The last column indicates whether it is a fixed or a settable address.

Address	Meaning (default setting)	Name

A=DC(...)
A=ACP(...)
A=ACN(...)
	Rotary axis	Settable

ADIS	Rounding clearance for path functions	Fixed

B=DC(...)
B=ACP(...)
B=ACN(...)
	Rotary axis	Settable

C=DC(...)
C=ACP(...)
C=ACN(...)
	Rotary axis	Settable

CHR=...	Chamfer the contour corner	Fixed
D...	Cutting edge number	Fixed
F...	Feedrate	Fixed

FA[axis]=... or
FA[spindle]=... or
[SPI(spindle)]=...
	Axial feedrate
	(only if spindle no. defined by variable)
		Fixed

G...	Preparatory function	Fixed
H... H=QU(...)	Auxiliary function Auxiliary function without read stop	Fixed
I...	Interpolation parameter	Settable
J...	Interpolation parameter	Settable
K...	Interpolation parameter	Settable
L...	Subroutine call	Fixed
M... M=QU	Additional function Additional function without read stop	Fixed
N...	Subblock	Fixed
OVR	Path override	Fixed
P...	Number of program passes	Fixed
POS[Axis]=...	Positioning axis	Fixed
POSA[Axis]=...	Positioning axis across block boundary	Fixed

SPOS=...
SPOS[n]=...
	Spindle position	Fixed

SPOSA=... SPOSA[n	Spindle position across block boundary	Fixed
Q...	Axis	Settable
R0=... to Rn=... R...	- R parameter, n can be set via MD (standard 0 - 99) - Axis	Fixed Settable
RND	Round the contour corner	Fixed
RNDM	Round contour corner (modal)	Fixed
S...	Spindle speed	Fixed
T...	Tool number	Fixed
U...	Axis	Settable
V...	Axis	Settable
W...	Axis	Settable

X...
X=AC(...)
X=IC
	Axis
	" absolute
	" incremental
		Settable

Y...
Y=AC(...)
Y=IC
	Axis	Settable

Z...
Z=AC(...)
Z=IC
	Axis	Settable

AR+=...	Opening angle	Settable
AP=...	Polar angle	Settable
CR=...	Circle radius	Settable
RP=...	Polar radius	Settable

Note

Settable addresses

Settable addresses must be unique within the control, i.e. the same address name may not be used for different address types.

A distinction is made between the following address types:

- Axis values and end points
- Interpolation parameters
- Feedrates
- Corner rounding criteria
- Measurement
- Axis, spindle behavior

Modal/non-modal addresses

Modal addresses remain valid with the programmed value (in all subsequent blocks) until a new value is programmed at the same address.

Non-modal addresses only apply in the block, in which they were programmed.

Example:

Program code	Comment
`N10 G01 F500 X10`	`;`
`N20 X10`	`; Feedrate F from N10 remains active until a new feedrate is entered.`

Addresses with axial extension

In addresses with axial extension, an axis name is inserted in square brackets after the address. The axis name assigns the axis.

Example:

Program code	Comment
`FA[U]=400`	`; Axis-specific feedrate for U axis.`

Fixed addresses with axial extension:

Address	Meaning (default setting)
AX	Axis value (variable axis programming)
ACC	Axial acceleration
FA	Axial feedrate
FDA	Axis feedrate for handwheel override
FL	Axial feedrate limitation
IP	Interpolation parameter (variable axis programming)
OVRA	Axial override
PO	Polynomial coefficient
POS	Positioning axis
POSA	Positioning axis across block boundary

Extended address notation

Extended address notation enables a larger number of axes and spindles to be organized in a system.

An extended address consists of a numeric extension and an arithmetic expression assigned with an "=" character. The numeric extension has one or two digits and is always positive.

The extended address notation is only permitted for the following direct addresses:

Address	Meaning
X, Y, Z, …	Axis addresses
I, J, K	Interpolation parameters
S	Spindle speed
SPOS, SPOSA	Spindle position
M	Special functions
H	Auxiliary functions
T	Tool number
F	Feedrate

Examples:

```
Program code        Comment
X7                  ; No "=" required, 7 is a value, but the "=" character can also be
                      used here
X4=20               ; Axis X4; "=" is required
CR=7.3              ; Two letters; "=" is required
S1=470              ; Speed for first spindle: 470 RPM
M3=5                ; Spindle stop for third spindle
```

The numeric extension can be replaced by a variable for addresses M, H, S and for SPOS and SPOSA. The variable identifier is enclosed in square brackets.

Examples:

```
Program code                                              Comment
S[SPINU]=470                                              ; Speed for the spindle, whose
                                                            number is stored in the SPINU
                                                            variable.
M[SPINU]=3                                                ; Clockwise rotation for the
                                                            spindle, whose number is stored
                                                            in the SPINU variable.
T[SPINU]=7                                                ; Selection of the tool for the
                                                            spindle, whose number is stored
                                                            in the SPINU variable.
```

15.5 Identifiers

The commands according to DIN 66025 are supplemented with so-called identifiers by the NC high-level language.

Identifiers can stand for:

- System variables
- User-defined variables
- Subroutines
- Keywords
- Jump markers
- Macros

Note

Identifiers must be unique. It is not permissible to use the same identifier for different objects.

Rules for names

The following rules apply when assigning identifier names:

- Maximum number of characters:
  - For program names: 24
  - Axis identifiers: 8
  - Variable identifiers: 31
- Permissible characters are:
  - Letters
  - Numbers
  - Underscores
- The first two characters must be letters or underscores.
- Separators are not permitted between the individual characters.

Note

Reserved keywords must not be used as identifiers.

Reserved character combinations

The following reservations must be noted when assigning cycle identifiers in order to avoid name collisions:

- All identifiers beginning with "CYCLE" or "CUST_" or "GROUP_" or "_" or "S_" are reserved for SIEMENS cycles.
- All identifiers beginning with "CCS" are reserved for SIEMENS compile cycles.
- User compile cycles begin with "CC”.

Note

Users should select identifiers that start with "U" (User), as these identifiers are not used by the system, compile cycles or SIEMENS cycles.

Further reservations are:

- The identifier "RL" is reserved for conventional turning machines.
- All identifiers beginning with "E_ " or "F_" are reserved for EASY-STEP programming.

Variable identifiers

In variables used by the system, the first letter is replaced by the "$" character.

Examples:

System variable	Significance
$P_IFRAME	Active settable frame
$P_F	Programmed path feedrate

Note

The "$" character may not be used for user-defined variables.

15.6 Constants

Integer constants

An integer constant is an integer value with or without sign, e.g. a value assignment to an address.

Examples:

`X10.25`	Assignment of the value +10.25 to address X
`X-10.25`	Assignment of the value -10.25 to address X
`X0.25`	Assignment of the value +0.25 to address X
`X.25`	Assignment of the value +0.25 to address X without leading "0"
`X=-.1EX-3`	Assignment of the value $-0.1*10^{-3}$ to address X
`X0`	Assignment of the value 0 to address X (X0 cannot be replaced by X)

Note

If, in an address, which permits decimal point input, more decimal places are specified than actually provided for the address, then they are rounded to fit the number of places provided.

Hexadecimal constants

Constants can also be interpreted in hexadecimal format. The letters "A" to "F" stand for the digits 10 to 15.

Hexadecimal constants are enclosed in single quotation marks and start with the letter "H", followed by the value in hexadecimal notation. Separators are allowed between the letters and digits.

Example:

Program code	**Comment**
`$MC_TOOL_MANAGEMENT_MASK='H3C7F'`	`; Assignment of hexadecimal constants to machine data: MD18080 $MN_MM_TOOL_MANAGEMENT_MASK`

Note

The maximum number of characters is limited by the value range of the integer data type.

Binary constants

Constants can also be interpreted in binary format. In this case, only the digits "0" and "1" are used.

Binary constants are enclosed in single quotation marks and start with the letter "B", followed by the binary value. Separators are allowed between the digits.

Example:

Program code	**Comment**
`$MN_AUXFU_GROUP_SPEC='B10000001'`	`; The assignment of binary constants sets Bit0 and Bit7 in the machine data.`

Note

The maximum number of characters is limited by the value range of the integer data type.

Tables 16

16.1 Operations

Legend:

1) Effectiveness of the operation:

m	modal
s	non-modal

2) Reference to the document containing the detailed description of the operation:

PGsl	Programming Manual, Fundamentals
PGAsl	Programming Manual, Job Planning
BNMsl	Programming Manual Measuring Cycles
BHDsl	Operating Manual, Turning
BHFsl	Operating Manual, Milling
FB1 ( )	Function Manual, Basic Functions (with the alphanumeric abbreviation of the corresponding function description in brackets)
FB2 ( )	Function Manual, Extended Functions (with the alphanumeric abbreviation of the corresponding function description in brackets)
FB3 ( )	Function Manual, Special Functions (with the alphanumeric abbreviation of the corresponding function description in brackets)
FBSIsl	Function Manual, Safety Integrated
FBSY	Function Manual, Synchronized Actions
FBW	Function Manual, Tool Management

3) Default setting at beginning of program (factory settings of the control, if nothing else programmed).

Operation	Meaning	W [1]	Description see [2]
:	NC main block number, jump label termination, concatenation operator		*PGAsl*
*	Operator for multiplication		*PGAsl*
+	Operator for addition		*PGAsl*
-	Operator for subtraction		*PGAsl*
<	Comparison operator, less than		*PGAsl*
<<	Concatenation operator for strings		*PGAsl*
<=	Comparison operator, less than or equal to		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
=	Assignment operator		*PGAsl*
>=	Comparison operator, greater than or equal to		*PGAsl*
/	Operator for division		*PGAsl*
/0 … … /7	Block is skipped (1st skip level) Block is skipped (8th skip level)		*PGsl* Skipping blocks [Page 40]
A	Axis name	m/s	*PGAsl*
A2	Tool orientation: RPY or Euler angle	s	*PGAsl*
A3	Tool orientation: Direction/surface normal vector component	s	*PGAsl*
A4	Tool orientation: Surface normal vector for beginning of block	s	*PGAsl*
A5	Tool orientation: Surface normal vector for end of block	s	*PGAsl*
ABS	Absolute value (amount)		*PGAsl*
AC	Absolute dimensions of coordinates/ positions	s	*PGsl* Absolute dimensions (G90, AC) [Page 168]
ACC	Effect of current axial acceleration	m	*PGsl* Programmable acceleration override (ACC) (option) [Page 139]
ACCLIMA	Effect of current maximum axial acceleration	m	*PGsl* Influence of acceleration on following axes (VELOLIMA, ACCLIMA, JERKLIMA) [Page 409]
ACN	Absolute dimensions for rotary axes, approach position in negative direction	s	*PGsl* Absolute dimension for rotary axes (DC, ACP, ACN) [Page 175]
ACOS	Arc cosine (trigon. function)		*PGAsl*
ACP	Absolute dimensions for rotary axes, approach position in positive direction	s	*PGsl* Absolute dimension for rotary axes (DC, ACP, ACN) [Page 175]
ACTBLOCNO	Output of current block number of an alarm block, even if "current block display suppressed" (DISPLOF) is active.		*PGAsl*
ADDFRAME	Inclusion and possible activation of a measured frame		*PGAsl, FB1(K2)*

Operation	Meaning	W 1)	Description see 2)
ADIS	Rounding clearance for path functions G1, G2, G3, ...	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
ADISPOS	Rounding clearance for rapid traverse G0	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
ADISPOSA	Size of the tolerance window for IPOBRKA	m	*PGAs/*
ALF	LIFTFAST angle	m	*PGAs/*
AMIRROR	Programmable mirroring	s	*PGs/* Programmable mirroring (MIRROR, AMIRROR) [Page 365]
AND	Logical AND		*PGAs/*
ANG	Contour angle	s	*PGs/* Contour definitions: One straight line (ANG) [Page 238]
AP	Polar angle	m/s	*PGs/* Travel commands with polar coordinates (G0, G1, G2, G3, AP, RP) [Page 197]
APR	Read/show access protection		*PGAs/*
APRB	Read access right, OPI		*PGAs/*
APRP	Read access right, part program		*PGAs/*
APW	Write access protection		*PGAs/*
APWB	Write access right, OPI		*PGAs/*
APWP	Write access right, part program		*PGAs/*
APX	Definition of the access right for executing the specified language element		*PGAs/*
AR	Opening angle	m/s	*PGs/* Circular interpolation with opening angle and center point (G2/G3, X... Y... Z.../ I... J... K..., AR) [Page 218]
AROT	Programmable rotation	s	*PGs/* Programmable rotation (ROT, AROT, RPL) [Page 350]
AROTS	Programmable frame rotations with solid angles	s	*PGs/* Programmable frame rotations with solid angles (ROTS, AROTS, CROTS) [Page 360]

Operation	Meaning	W [1)]	Description see [2)]
AS	Macro definition		*/PGAs/*
ASCALE	Programmable scaling	s	*/PGs/* Programmable scale factor (SCALE, ASCALE) [Page 362]
ASIN	Arithmetic function, arc sine		*/PGAs/*
ASPLINE	Akima spline	m	*/PGAs/*
ATAN2	Arc tangent 2		*/PGAs/*
ATOL	Axis-specific tolerance for compressor functions, orientation smoothing and smoothing types		*/PGAs/*
ATRANS	Additive programmable translation	s	*/PGs/* Zero offset (TRANS, ATRANS) [Page 343]
AX	Variable axis identifier	m/s	*/PGAs/*
AXCTSWE	Rotate axis container		*/PGAs/*
AXCTSWEC	Canceling enable for axis container rotation.		*/PGAs/*
AXCTSWED	Rotating axis container (command variant for commissioning!)		*/PGAs/*
AXIS	Axis identifier, axis address		*/PGAs/*
AXNAME	Converts input string into axis identifier		*/PGAs/*
AXSTRING	Converts string spindle number		*/PGAs/*
AXTOCHAN	Request axis for a specific channel. Possible from NC program and synchronized action.		*/PGAs/*
AXTOSPI	Converts axis identifier into a spindle index		*/PGAs/*
B	Axis name	m/s	*/PGAs/*
B2	Tool orientation: RPY or Euler angle	s	*/PGAs/*
B3	Tool orientation: Direction/surface normal vector component	s	*/PGAs/*
B4	Tool orientation: Surface normal vector for beginning of block	s	*/PGAs/*

Operation	Meaning	W 1)	Description see 2)
B5	Tool orientation: Surface normal vector for end of block	s	*PGAsl*
B_AND	Bit AND		*PGAsl*
B_OR	Bit OR		*PGAsl*
B_NOT	Bit negation		*PGAsl*
B_XOR	Bit exclusive OR		*PGAsl*
BAUTO	Definition of the first spline section by means of the next 3 points	m	*PGAsl*
BLOCK	Together with the keyword TO defines the program part to be processed in an indirect subprogram call		*PGAsl*
BLSYNC	Processing of interrupt routine is only to start with the next block change		*PGAsl*
BNAT 3)	Natural transition to first spline block	m	*PGAsl*
BOOL	Data type: Boolean value TRUE/FALSE or 1/0		*PGAsl*
BOUND	Tests whether the value falls within the defined value range. If the values are equal, the test value is returned.		*PGAsl*
BRISK 3)	Fast non-smoothed path acceleration	m	*PGsl* Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA) [Page 406]
BRISKA	Switch on brisk path acceleration for the programmed axes		*PGsl* Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA) [Page 406]
BSPLINE	B-spline	m	*PGAsl*
BTAN	Tangential transition to first spline block	m	*PGAsl*
C	Axis name	m/s	*PGAsl*
C2	Tool orientation: RPY or Euler angle	s	*PGAsl*
C3	Tool orientation: Direction/surface normal vector component	s	*PGAsl*
C4	Tool orientation: Surface normal vector for beginning of block	s	*PGAsl*
C5	Tool orientation: Surface normal vector for end of block	s	*PGAsl*

Operation	Meaning	W 1)	Description see 2)
CAC	Absolute position approach		*PGAsl*
CACN	Absolute approach of the value listed in the table in negative direction		*PGAsl*
CACP	Absolute approach of the value listed in the table in positive direction		*PGAsl*
CALCDAT	Calculates radius and center point of circle from 3 or 4 points		*PGAsl*
CALCPOSI	Checking for protection zone violation, working area limitation and software limits		*PGAsl*
CALL	Indirect subroutine call		*PGAsl*
CALLPATH	Programmable search path for subroutine calls		*PGAsl*
CANCEL	Cancel modal synchronized action		*PGAsl*
CASE	Conditional program branch		*PGAsl*
CDC	Direct approach of a position		*PGAsl*
CDOF 3)	Collision detection OFF	m	*PGsl* Collision monitoring (CDON, CDOF, CDOF2) [Page 313]
CDOF2	Collision detection OFF, for 3D circumferential milling	m	*PGsl* Collision monitoring (CDON, CDOF, CDOF2) [Page 313]
CDON	Collision detection ON	m	*PGsl* Collision monitoring (CDON, CDOF, CDOF2) [Page 313]
CFC 3)	Constant feedrate on contour	m	*PGsl* Feedrate optimization for curved path sections (CFTCP, CFC, CFIN) [Page 145]
CFIN	Constant feedrate for internal radius only, not for external radius	m	*PGsl* Feedrate optimization for curved path sections (CFTCP, CFC, CFIN) [Page 145]
CFINE	Assignment of fine offset to a FRAME variable		*PGAsl*
CFTCP	Constant feedrate in tool center point (center point path)	m	*PGsl* Feedrate optimization for curved path sections (CFTCP, CFC, CFIN) [Page 145]
CHAN	Specify validity range for data		*PGAsl*

Operation	Meaning	W [1]	Description see [2]
CHANDATA	Set channel number for channel data access		*PGAsl*
CHAR	Data type: ASCII character		*PGAsl*
CHECKSUM	Forms the checksum over an array as a fixed-length STRING		*PGAsl*

CHF	Chamfer;
	value = length of chamfer
		s	*PGsl*
			Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]

CHKDM	Uniqueness check within a magazine		*FBW*
CHKDNO	Check for unique D numbers		*PGAsl*
CHR	Chamfer; value = length of chamfer in direction of movement		*PGsl* Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]
CIC	Approach position by increments		*PGAsl*
CIP	Circular interpolation through intermediate point	m	*PGsl* Circular interpolation with intermediate point and end point (CIP, X... Y... Z..., I1... J1... K1...) [Page 222]
CLEARM	Reset one/several markers for channel coordination		*PGAsl*
CLRINT	Deselect interrupt:		*PGAsl*
CMIRROR	Mirror on a coordinate axis		*PGAsl*
COARSEA	Motion end when "Exact stop coarse" reached	m	*PGAsl*
COMPCAD	Compressor ON: Optimum surface quality for CAD programs	m	*PGAsl*
COMPCURV	Compressor ON: Polynomials with constant curvature	m	*PGAsl*
COMPLETE	Control instruction for reading and writing data		PGAsl
COMPOF [3]	Compressor OFF	m	*PGAsl*
COMPON	Compressor ON		*PGAsl*
CONTDCON	Tabular contour decoding ON		*PGAsl*
CONTPRON	Activate reference preprocessing		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
CORROF	All active overlaid movements are deselected		*PGs/* Deselecting overlaid movements (DRFOF, CORROF) [Page 374]
COS	Cosine (trigon. function)		*PGAs/*
COUPDEF	Definition ELG group/synchronous spindle group		*PGAs/*
COUPDEL	Delete ELG group		*PGAs/*
COUPOF	ELG group/synchronous spindle pair ON		*PGAs/*
COUPOFS	Deactivate ELG group/synchronous spindle pair with stop of following spindle		*PGAs/*
COUPON	ELG group/synchronous spindle pair ON		*PGAs/*
COUPONC	Transfer activation of ELG group/ synchronous spindle pair with previous programming		*PGAs/*
COUPRES	Reset ELG group		*PGAs/*
CP	Path motion	m	*PGAs/*
CPRECOF 3)	Programmable contour accuracy OFF	m	*PGs/* Contour accuracy, CPRECON, CPRECOF [Page 414]
CPRECON	Programmable contour accuracy ON	m	*PGs/* Contour accuracy, CPRECON, CPRECOF [Page 414]
CPROT	Channel-specific protection zone ON/ OFF		*PGAs/*
CPROTDEF	Definition of a channel-specific protection zone		*PGAs/*
CR	Circle radius	s	*PGs/* Circular interpolation with radius and end point (G2/ G3, X... Y... Z.../ I... J... K..., CR) [Page 216]
CROT	Rotation of the current coordinate system.		*PGAs/*
CROTS	Programmable frame rotations with solid angles (rotation in the specified axes)	s	*PGs/* Programmable frame rotations with solid angles (ROTS, AROTS, CROTS) [Page 360]
CRPL	Frame rotation in any plane		*FB1(K2)*
CSCALE	Scale factor for multiple axes		*PGAs/*
CSPLINE	Cubic spline	m	*PGAs/*

Operation	Meaning	W 1)	Description see 2)
CT	Circle with tangential transition	m	*PGs/* Circular interpolation with tangential transition (CT, X... Y... Z...) [Page 225]
CTAB	Define following axis position according to leading axis position from curve table		*PGAs/*
CTABDEF	Table definition ON		*PGAs/*
CTABDEL	Clear curve table		*PGAs/*
CTABEND	Table definition OFF		*PGAs/*
CTABEXISTS	Checks the curve table with number n		*PGAs/*
CTABFNO	Number of curve tables still possible in the memory		*PGAs/*
CTABFPOL	Number of polynomials still possible in the memory		*PGAs/*
CTABFSEG	Number of curve segments still possible in the memory		*PGAs/*
CTABID	Returns table number of the nth curve table		*PGAs/*
CTABINV	Define leading axis position according to following axis position from curve table		*PGAs/*
CTABISLOCK	Returns the lock state of the curve table with number n		*PGAs/*
CTABLOCK	Delete and overwrite, lock		*PGAs/*
CTABMEMTYP	Returns the memory in which curve table number n is created		*PGAs/*
CTABMPOL	Max. number of polynomials still possible in the memory		*PGAs/*
CTABMSEG	Max. number of curve segments still possible in the memory		*PGAs/*
CTABNO	Number of defined curve tables in SRAM or DRAM		*FB3(M3)*
CTABNOMEM	Number of defined curve tables in SRAM or DRAM		*PGAs/*
CTABPERIOD	Returns the table periodicity of curve table number n		*PGAs/*
CTABPOL	Number of polynomials already used in the memory		*PGAs/*
CTABPOLID	Number of the curve polynomials used by the curve table with number n		*PGAs/*

Operation	Meaning	W [1]	Description see [2]
CTABSEG	Number of curve segments already used in the memory		*PGAsl*
CTABSEGID	Number of the curve segments used by the curve table with number n		*PGAsl*
CTABSEV	Returns the final value of the following axis of a segment of the curve table		*PGAsl*
CTABSSV	Returns the initial value of the following axis of a segment of the curve table		*PGAsl*
CTABTEP	Returns the value of the leading axis at curve table end		*PGAsl*
CTABTEV	Returns the value of the the following axis at curve table end		*PGAsl*
CTABTMAX	Returns the maximum value of the following axis of the curve table		*PGAsl*
CTABTMIN	Returns the minimum value of the following axis of the curve table		*PGAsl*
CTABTSP	Returns the value of the leading axis at curve table start		*PGAsl*
CTABTSV	Returns the value of the following axis at curve table start		*PGAsl*
CTABUNLOCK	Revoke delete and overwrite lock		*PGAsl*
CTOL	Contour tolerance for compressor functions, orientation smoothing and smoothing types		*PGAsl*
CTRANS	Zero offset for multiple axes		*PGAsl*
CUT2D [3]	2D tool offset	m	*PGsl* 2D tool compensation (CUT2D, CUT2DF) [Page 317]
CUT2DF	2D tool offset The tool offset is applied relative to the current frame (inclined plane).	m	*PGsl* 2D tool compensation (CUT2D, CUT2DF) [Page 317]
CUT3DC	3D tool offset circumferential milling	m	*PGAsl*
CUT3DCC	3D tool offset circumferential milling with limitation surfaces	m	*PGAsl*
CUT3DCCD	3D tool offset circumferential milling with limitation surfaces with differential tool	m	*PGAsl*
CUT3DF	3D tool offset face milling	m	*PGAsl*
CUT3DFF	3D tool offset face milling with constant tool orientation dependent on active frame	m	*PGAsl*

Operation	Meaning	W 1)	Description see 2)
CUT3DFS	3D tool offset face milling with constant tool orientation independent of active frame	m	*PGAsl*
CUTCONOF 3)	Constant radius compensation OFF	m	*PGsl* Keep tool radius compensation constant (CUTCONON, CUTCONOF) [Page 320]
CUTCONON	Constant radius compensation ON	m	*PGsl* Keep tool radius compensation constant (CUTCONON, CUTCONOF) [Page 320]
CUTMOD	Activate "Modification of the offset data for rotatable tools"		*PGAsl*
CYCLE60	Technological cycle: engraving cycle		*PGAsl*
CYCLE61	Technological cycle: face milling		*PGAsl*
CYCLE62	Technological cycle: contour call		*PGAsl*
CYCLE63	Technological cycle: milling contour pocket		*PGAsl*
CYCLE64	Technological cycle: rough-drilling of contour pocket		*PGAsl*
CYCLE70	Technological cycle: thread milling		*PGAsl*
CYCLE72	Technological cycle: path milling		*PGAsl*
CYCLE76	Technological cycle: milling rectangular spigot		*PGAsl*
CYCLE77	Technological cycle: milling circular spigot		*PGAsl*
CYCLE78	Technological cycle: drill thread milling		*PGAsl*
CYCLE79	Technological cycle: multi-edge milling		*PGAsl*
CYCLE81	Technological cycle: drilling, centering		*PGAsl*
CYCLE82	Technological cycle: drilling, counterboring		*PGAsl*
CYCLE83	Technological cycle: deep-hole drilling		*PGAsl*
CYCLE84	Technological cycle: rigid tapping		*PGAsl*
CYCLE85	Technological cycle: reaming		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
CYCLE86	Technological cycle: boring		*PGAsl*
CYCLE92	Technological cycle: tapping		*PGAsl*
CYCLE98	Technological cycle: thread chain		*PGAsl*
CYCLE99	Technological cycle: thread turning		*PGAsl*
CYCLE800	Technological cycle: swiveling		*PGAsl*
CYCLE801	Technological cycle: grid or frame		*PGAsl*
CYCLE802	Technological cycle: any positions		*PGAsl*
CYCLE832	Technological cycle: high-speed settings		*PGAsl*
CYCLE840	Technological cycle: tapping with compensating chuck		*PGAsl*
CYCLE899	Technological cycle: milling open groove		*PGAsl*
CYCLE930	Technological cycle: groove		*PGAsl*
CYCLE940	Technological cycle: undercut forming		*PGAsl*
CYCLE951	Technological cycle: stock removal		*PGAsl*
CYCLE952	Technological cycle: contour-grooving		*PGAsl*
CYCLE_HSC	Technological cycle: high-speed cutting		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
D	Tool offset number		*PGsl* Tool offset call (D) [Page 79]
D0	With D0, offsets for the tool are ineffective.		*PGsl* Tool offset call (D) [Page 79]
DAC	Absolute non-modal axis-specific diameter programming	s	*PGsl* Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]

Operation	Meaning	W 1)	Description see 2)
DC	Absolute dimensions for rotary axes, approach position directly	s	*PGs/* Absolute dimension for rotary axes (DC, ACP, ACN) [Page 175]
DEF	Variable definition		*PGAs/*
DEFINE	Keyword for macro definitions		*PGAs/*
DEFAULT	Branch in CASE branch		*PGAs/*
DELAYFSTON	Define the start of a stop delay section	m	*PGAs/*
DELAYFSTOF	Define the end of a stop delay section	m	*PGAs/*
DELDL	Delete additive offsets		*PGAs/*
DELDTG	Deletion of distance-to-go		*PGAs/*
DELETE	Delete the specified file. The file name can be specified with path and file identifier.		*PGAs/*
DELTOOLENV	Delete data records describing tool environments		*FB1(W1)*
DIACYCOFA	Axis-specific modal diameter programming: OFF in cycles	m	*FB1(P1)*
DIAM90	Diameter programming for G90, radius programming for G91	m	*PGAs/* Channel-specific diameter/radius programming (DIAMON, DIAM90, DIAMOF, DIAMCYCOF) [Page 180]
DIAM90A	Axis-specific modal diameter programming for G90 and AC, radius programming for G91 and IC	m	*PGs/* Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
DIAMCHAN	Transfer of all axes from MD axis functions to diameter programming channel status		*PGs/* Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
DIAMCHANA	Transfer of the diameter programming channel status		*PGs/* Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
DIAMCYCOF	Channel-specific diameter programming: OFF in cycles	m	*FB1(P1)*

Operation	Meaning	W 1)	Description see 2)
DIAMOF 3)	Diameter programming: OFF Normal position, see machine manufacturer	m	*PGs*/ Channel-specific diameter/radius programming (DIAMON, DIAM90, DIAMOF, DIAMCYCOF) [Page 180]
DIAMOFA	Axis-specific modal diameter programming: OFF Normal position, see machine manufacturer	m	*PGs*/ Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
DIAMON	Diameter programming: ON	m	*PGs*/ Channel-specific diameter/radius programming (DIAMON, DIAM90, DIAMOF, DIAMCYCOF) [Page 180]
DIAMONA	Axis-specific modal diameter programming: ON Activation, see machine manufacturer	m	*PGs*/ Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
DIC	Relative non-modal axis-specific diameter programming	s	*PGs*/ Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
DILF	Retraction path (length)	m	*PGs*/ Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
DISABLE	Interrupt OFF		*PGAs*/
DISC	Transition circle overshoot tool radius compensation	m	*PGs*/ Compensation at the outside corners (G450, G451, DISC) [Page 294]
DISCL	Clearance between the end point of the fast infeed motion and the machining plane		*PGs*/ Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
DISPLOF	Suppress current block display		*PGAs*/
DISPLON	Revoke suppression of the current block display		*PGAs*/
DISPR	Path differential for repositioning	s	*PGAs*/
DISR	Distance for repositioning	s	*PGAs*/
DITE	Thread run-out path	m	*PGs*/ Programmable run-in and run-out paths (DITS, DITE) [Page 256]

Operation	Meaning	W [1]	Description see [2]
DITS	Thread run-in path	m	*PGsl* Programmable run-in and run-out paths (DITS, DITE) [Page 256]
DIV	Integer division		*PGAsl*
DL	Select location-dependent additive tool offset (DL, total set-up offset)	m	*PGAsl*
DO	Keyword for synchronized action, triggers action when condition is fulfilled		*PGAsl*
DRFOF	Deactivation of handwheel offsets (DRF)	m	*PGsl* Deselecting overlaid movements (DRFOF, CORROF) [Page 374]
DRIVE	Velocity-dependent path acceleration	m	*PGsl* Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA) [Page 406]
DRIVEA	Activate bent acceleration characteristic curve for the programmed axes		*PGsl* Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA) [Page 406]
DYNFINISH	Dynamic response for smooth finishing	m	*PGsl* Activation of technology-specific dynamic values (DYNNORM, DYNPOS, DYNROUGH, DYNSEMIFIN, DYNFINISH) [Page 411]
DYNNORM	Standard dynamic response	m	*PGsl* Activation of technology-specific dynamic values (DYNNORM, DYNPOS, DYNROUGH, DYNSEMIFIN, DYNFINISH) [Page 411]
DYNPOS	Dynamic response for positioning mode, tapping	m	*PGsl* Activation of technology-specific dynamic values (DYNNORM, DYNPOS, DYNROUGH, DYNSEMIFIN, DYNFINISH) [Page 411]
DYNROUGH	Dynamic response for roughing	m	*PGsl* Activation of technology-specific dynamic values (DYNNORM, DYNPOS, DYNROUGH, DYNSEMIFIN, DYNFINISH) [Page 411]
DYNSEMIFIN	Dynamic response for finishing	m	*PGsl* Activation of technology-specific dynamic values (DYNNORM, DYNPOS, DYNROUGH, DYNSEMIFIN, DYNFINISH) [Page 411]
DZERO	Marks all D numbers of the TO unit as invalid		*PGAsl*
EAUTO	Definition of the last spline section by means of the last 3 points	m	*PGAsl*
EGDEF	Definition of an electronic gear		*PGAsl*
EGDEL	Delete coupling definition for the following axis		*PGAsl*

Operation	Meaning	W [1]	Description see [2]
EGOFC	Turn off electronic gear continuously		*PGAsl*
EGOFS	Turn off electronic gear selectively		*PGAsl*
EGON	Turn on electronic gear		*PGAsl*
EGONSYN	Turn on electronic gear		*PGAsl*
EGONSYNE	Turn on electronic gear, with specification of approach mode		*PGAsl*
ELSE	Program branch, if IF condition not fulfilled		*PGAsl*
ENABLE	Interrupt ON		*PGAsl*
ENAT [3]	Natural transition to next traversing block	m	*PGAsl*
ENDFOR	End line of FOR counter loop		*PGAsl*
ENDIF	End line of IF branch		*PGAsl*
ENDLABEL	End label for part program repetitions with REPEAT		*PGAsl, FB1(K1)*
ENDLOOP	End line of endless program loop LOOP		*PGAsl*
ENDPROC	End line of program with start line PROC		
ENDWHILE	End line of WHILE loop		*PGAsl*
ESRR	Parameterizing drive-autonomous ESR retraction in the drive		*PGAsl*
ESRS	Parameterizing drive-autonomous ESR shutdown in the drive		*PGAsl*
ETAN	Tangential transition to next traversing block at spline begin	m	*PGAsl*
EVERY	Execute synchronized action on transition of condition from FALSE to TRUE		*PGAsl*
EX	Keyword for value assignment in exponential notation		*PGAsl*
EXECSTRING	Transfer of a string variable with the executing part program line		*PGAsl*
EXECTAB	Execute an element from a motion table		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
EXECUTE	Program execution ON		*PGAsl*
EXP	Exponential function ex		*PGAsl*
EXTCALL	Execute external subprogram		*PGAsl*
EXTCLOSE	Closing external device / file that was opened for writing		*PGAsl*
EXTERNAL	Declaration of a subprogram with parameter transfer		*PGAsl*
EXTOPEN	Opening external device / file for the channel for writing		*PGAsl*
F	Feedrate value (in conjunction with G4 the dwell time is also programmed with F)		*PGsl* Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
FA	Axial feedrate	m	*PGsl* Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC) [Page 118]
FAD	Infeed rate for soft approach and retraction		*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
FALSE	Logical constant: Incorrect		*PGAsl*
FB	Non-modal feedrate		*PGsl* Non-modal feedrate (FB) [Page 151]
FCTDEF	Define polynomial function		*PGAsl*
FCUB	Feedrate variable according to cubic spline	m	*PGAsl*
FD	Path feedrate for handwheel override	s	*PGsl* Feedrate with handwheel override (FD, FDA) [Page 141]
FDA	Axis feedrate for handwheel override	s	*PGsl* Feedrate with handwheel override (FD, FDA) [Page 141]
FENDNORM	Corner deceleration OFF	m	*PGAsl*
FFWOF 3)	Feedforward control OFF	m	*PGsl* Traversing with feedforward control, FFWON, FFWOF [Page 413]
FFWON	Feedforward control ON	m	*PGsl* Traversing with feedforward control, FFWON, FFWOF [Page 413]

Operation	Meaning	W [1]	Description see [2]
FGREF	Reference radius for rotary axes or path reference factors for orientation axes (vector interpolation)	m	*PGs/* Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
FGROUP	Definition of axis/axes with path feedrate		*PGs/* Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
FI	Parameter for access to frame data: Fine offset		*PGAs/*
FIFOCTRL	Control of preprocessing buffer	m	*PGAs/*
FILEDATE	Returns date of most recent write access to file		*PGAs/*
FILEINFO	Returns summary information listing FILEDATE, FILESIZE, FILESTAT, and FILETIME		*PGAs/*
FILESIZE	Returns current file size		*PGAs/*
FILESTAT	Returns file status of rights for read, write, execute, display, delete (rwxsd)		*PGAs/*
FILETIME	Returns time of most recent write access to file		*PGAs/*
FINEA	End of motion when "Exact stop fine" reached	m	*PGAs/*
FL	Limit velocity for synchronized axis	m	*PGs/* Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
FLIN	Feed linear variable	m	*PGAs/*
FMA	Multiple feedrates axial	m	*PGs/* Several feedrate values in one block (F, ST, SR, FMA, STA, SRA) [Page 148]
FNORM [3]	Feedrate normal to DIN 66025	m	*PGAs/*
FOCOF	Deactivate travel with limited torque/ force	m	*PGAs/*
FOCON	Activate travel with limited torque/force	m	*PGAs/*
FOR	Counter loop with fixed number of passes		*PGAs/*
FP	Fixed point: Number of fixed point to be approached	s	*PGs/* Fixed-point approach (G75, G751) [Page 396]
FPO	Feedrate characteristic programmed via a polynomial		*PGAs/*

Operation	Meaning	W 1)	Description see 2)
FPR	Rotary axis identifier		*PGs/* Feedrate for positioning axes/spindles (FA, FPR, FPRAON, FPRAOF) [Page 133]
FPRAOF	Deactivate revolutional feedrate		*PGs/* Feedrate for positioning axes/spindles (FA, FPR, FPRAON, FPRAOF) [Page 133]
FPRAON	Activate revolutional feedrate		*PGs/* Feedrate for positioning axes/spindles (FA, FPR, FPRAON, FPRAOF) [Page 133]
FRAME	Data type for the definition of coordinate systems		*PGAs/*
FRC	Feedrate for radius and chamfer	s	*PGs/* Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]
FRCM	Feedrate for radius and chamfer, modal	m	*PGs/* Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]
FROM	The action is executed if the condition is fulfilled once and as long as the synchronized action is active		*PGAs/*
FTOC	Change fine tool offset		*PGAs/*
FTOCOF 3)	Online fine tool offset OFF	m	*PGAs/*
FTOCON	Online fine tool offset ON	m	*PGAs/*
FXS	Travel to fixed stop ON	m	*PGs/* Travel to fixed stop (FXS, FXST, FXSW) [Page 401]
FXST	Torque limit for travel to fixed stop	m	*PGs/* Travel to fixed stop (FXS, FXST, FXSW) [Page 401]
FXSW	Monitoring window for travel to fixed stop		*PGs/* Travel to fixed stop (FXS, FXST, FXSW) [Page 401]
FZ	Tooth feedrate	m	*PGs/* Tooth feedrate (G95 FZ) [Page 152]

Operation	Meaning	W 1)	Description see 2)
G0	Linear interpolation with rapid traverse (rapid traverse motion)	m	*PGs/* Rapid traverse movement (G0, RTLION, RTLIOF) [Page 201]
G1 3)	Linear interpolation with feedrate (linear interpolation)	m	*PGs/* Linear interpolation (G1) [Page 206]
G2	Circular interpolation clockwise	m	*PGs/* Circular interpolation types (G2/G3, ...) [Page 209]

Operation	Meaning	W [1]	Description see [2]
G3	Circular interpolation counter-clockwise	m	*PGs/* Circular interpolation types (G2/G3, ...) [Page 209]
G4	Dwell time, preset	s	*PGs/* Dwell time (G4) [Page 415]
G5	Oblique plunge-cut grinding	s	*PGAs/*
G7	Compensatory motion during oblique plunge-cut grinding	s	*PGAs/*
G9	Exact stop - deceleration	s	*PGs/* Exact stop (G60, G9, G601, G602, G603) [Page 325]
G17 [3]	Selection of working plane X/Y	m	*PGs/* Selection of the working plane (G17/G18/G19) [Page 165]
G18	Selection of working plane Z/X	m	*PGs/* Selection of the working plane (G17/G18/G19) [Page 165]
G19	Selection of working plane Y/Z	m	*PGs/* Selection of the working plane (G17/G18/G19) [Page 165]
G25	Lower working area limitation	s	*PGs/* Programmable spindle speed limitation (G25, G26) [Page 108]
G26	Upper working area limitation	s	*PGs/* Programmable spindle speed limitation (G25, G26) [Page 108]
G33	Thread cutting with constant lead	m	*PGs/* Thread cutting with constant lead (G33) [Page 248]
G34	Thread cutting with linear increasing lead	m	*PGs/* Thread cutting with increasing or decreasing lead (G34, G35) [Page 258]
G35	Thread cutting with linear decreasing lead	m	*PGs/* Thread cutting with increasing or decreasing lead (G34, G35) [Page 258]
G40 [3]	Tool radius compensation OFF	m	*PGs/* Tool radius compensation (G40, G41, G42, OFFN) [Page 277]
G41	Tool radius compensation left of contour	m	*PGs/* Tool radius compensation (G40, G41, G42, OFFN) [Page 277]
G42	Tool radius compensation right of contour	m	*PGs/* Tool radius compensation (G40, G41, G42, OFFN) [Page 277]
G53	Suppression of current work offset (non-modal)	s	*PGs/* Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]

Operation	Meaning	W [1]	Description see [2]
G54	1st adjustable work offset	m	*PGs*/ Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G55	2nd adjustable work offset	m	*PGs*/ Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G56	3rd adjustable work offset	m	*PGs*/ Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G57	4th adjustable work offset	m	*PGs*/ Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G58 (840D sl)	Axial programmable work offset, absolute, coarse offset	s	*PGs*/ Axial zero offset (G58, G59) [Page 347]
G58 (828D)	5th adjustable work offset	m	*PGs*/ Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G59 (840D sl)	Axial programmable work offset, additive, fine offset	s	*PGs*/ Axial zero offset (G58, G59) [Page 347]
G59 (828D)	6th adjustable work offset	m	*PGs*/ Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G60 [3]	Exact stop - deceleration	m	*PGs*/ Exact stop (G60, G9, G601, G602, G603) [Page 325]
G62	Corner deceleration at inside corners when tool radius offset is active (G41, G42)	m	*PGAs*/
G63	Tapping with compensating chuck	s	*PGs*/ Tapping with compensating chuck (G63) [Page 265]
G64	Continuous-path mode	m	*PGs*/ Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
G70	Inch dimensions for geometric specifications (lengths)	m	*PGs*/ Inch or metric dimensions (G70/G700, G71/G710) [Page 177]
G71 [3]	Metric dimensions for geometric specifications (lengths)	m	*PGs*/ Inch or metric dimensions (G70/G700, G71/G710) [Page 177]
G74	Search for reference	s	*PGs*/ Reference point approach (G74) [Page 395]
G75	Fixed point approach	s	*PGs*/ Fixed-point approach (G75, G751) [Page 396]
G90 [3]	Absolute dimensions	m/s	*PGs*/ Absolute dimensions (G90, AC) [Page 168]

Operation	Meaning	W [1]	Description see [2]
G91	Incremental dimensions	m/s	*PGs*/ Incremental dimensions (G91, IC) [Page 171]
G93	Inverse-time feedrate rpm	m	*PGs*/ Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
G94 [3]	Linear feedrate F in mm/min or inch/min and degree/min	m	*PGs*/ Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
G95	Revolutional feedrate F in mm/rev or inch/rev	m	*PGs*/ Feedrate (G93, G94, G95, F, FGROUP, FL, FGREF) [Page 109]
G96	Constant cutting rate (as for G95) ON	m	*PGs*/ Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
G97	Constant cutting rate (as for G95) OFF	m	*PGs*/ Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
G110	Pole programming relative to the last programmed setpoint position	s	*PGs*/ Reference point of the polar coordinates (G110, G111, G112) [Page 195]
G111	Pole programming relative to zero of current workpiece coordinate system	s	*PGs*/ Reference point of the polar coordinates (G110, G111, G112) [Page 195]
G112	Pole programming relative to the last valid pole	s	*PGs*/ Reference point of the polar coordinates (G110, G111, G112) [Page 195]
G140 [3]	SAR approach direction defined by G41/G42	m	*PGs*/ Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G141	SAR approach direction to left of contour	m	*PGs*/ Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G142	SAR approach direction to right of contour	m	*PGs*/ Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G143	SAR approach direction tangent-dependent	m	*PGs*/ Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G147	Soft approach with straight line	s	*PGs*/ Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]

Operation	Meaning	W [1)]	Description see [2)]
G148	Soft retraction with straight line	s	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G153	Suppression of current frames including basic frame	s	*PGsl* Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G247	Soft approach with quadrant	s	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G248	Soft retraction with quadrant	s	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G290	Switch over to SINUMERIK mode ON	m	*FBW*
G291	Switch over to ISO2/3 mode ON	m	*FBW*
G331	Rigid tapping, positive lead, clockwise	m	*PGsl* Tapping without compensating chuck (G331, G332) [Page 260]
G332	Rigid tapping, negative lead, counter-clockwise	m	*PGsl* Tapping without compensating chuck (G331, G332) [Page 260]
G340 [3)]	Spatial approach block (depth and in plane at the same time (helix))	m	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G341	Initial infeed on perpendicular axis (z), then approach in plane	m	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G347	Soft approach with semicircle	s	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G348	Soft retraction with semicircle	s	*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
G450 [3)]	Transition circle	m	*PGsl* Compensation at the outside corners (G450, G451, DISC) [Page 294]
G451	Intersection of equidistances	m	*PGsl* Compensation at the outside corners (G450, G451, DISC) [Page 294]

Operation	Meaning	W[1]	Description see[2]
G460[3]	Activation of collision detection for the approach and retraction block	m	*PGs/* Approach and retraction with enhanced retraction strategies (G460, G461, G462) [Page 309]
G461	Insertion of a circle into the TRC block	m	*PGs/* Approach and retraction with enhanced retraction strategies (G460, G461, G462) [Page 309]
G462	Insertion of a straight line into the TRC block	m	*PGs/* Approach and retraction with enhanced retraction strategies (G460, G461, G462) [Page 309]
G500[3]	Deactivation of all adjustable frames, basic frames are active	m	*PGs/* Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G505 to G599	5 ... 99th adjustable work offset	m	*PGs/* Settable work offset (G54 to G57, G505 to G599, G53, G500, SUPA, G153) [Page 159]
G601[3]	Block change on exact stop fine	m	*PGs/* Exact stop (G60, G9, G601, G602, G603) [Page 325]
G602	Block change on exact stop coarse	m	*PGs/* Exact stop (G60, G9, G601, G602, G603) [Page 325]
G603	Block change at IPO block end	m	*PGs/* Exact stop (G60, G9, G601, G602, G603) [Page 325]
G621	Corner deceleration at all corners	m	*PGAs/*
G641	Continuous-path mode with smoothing as per distance criterion (= programmable rounding clearance)	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
G642	Continuous-path mode with smoothing within the defined tolerances	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
G643	Continuous-path mode with smoothing within the defined tolerances (block-internal)	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
G644	Continuous-path mode with smoothing with maximum possible dynamic response	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
G645	Continuous-path mode with smoothing and tangential block transitions within the defined tolerances	m	*PGs/* Continuous-path mode (G64, G641, G642, G643, G644, G645, ADIS, ADISPOS) [Page 328]
G700	Inch dimensions for geometric and technological specifications (lengths, feedrate)	m	*PGs/* Inch or metric dimensions (G70/G700, G71/G710) [Page 177]
G710[3]	Metric dimensions for geometric and technological specifications (lengths, feedrate)	m	*PGs/* Inch or metric dimensions (G70/G700, G71/G710) [Page 177]

Operation	Meaning	W [1]	Description see [2]
G751	Approach fixed point via intermediate point	s	PGsl Fixed-point approach (G75, G751) [Page 396]
G810 [3], ..., G819	G group reserved for the OEM user		*PGAsl*
G820 [3], ..., G829	G group reserved for the OEM user		*PGAsl*
G931	Feedrate specified by traversing time	m	
G942	Freeze linear feedrate and constant cutting rate or spindle speed	m	
G952	Freeze revolutional feedrate and constant cutting rate or spindle speed	m	
G961	Constant cutting rate and linear feedrate	m	*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
G962	Linear or revolutional feedrate and constant cutting rate	m	*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
G971	Freeze spindle speed and linear feedrate	m	*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
G972	Freeze linear or revolutional feedrate and constant spindle speed	m	*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
G973	Revolutional feedrate without spindle speed limitation	m	*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
GEOAX	Assign new channel axes to geometry axes 1 - 3		*PGAsl*
GET	Replace enabled axis between channels		*PGAsl*
GETACTT	Gets active tool from a group of tools with the same name		*FBW*
GETACTTD	Gets the T number associated with an absolute D number		*PGAsl*
GETD	Replace axis directly between channels		*PGAsl*
GETDNO	Returns the D number of a cutting edge (CE) of a tool (T)		*PGAsl*
GETEXET	Reading of the loaded T number		*FBW*
GETFREELOC	Find a free space in the magazine for a given tool		*FBW*
GETSELT	Return selected T number		*FBW*
GETT	Get T number for tool name		*FBW*

Operation	Meaning	W [1)]	Description see [2)]
GETTCOR	Read out tool lengths and/or tool length components		*FB1(W1)*
GETTENV	Read T, D and DL numbers		*FB1(W1)*
GOTO	Jump operation first forward then backward (direction initially to end of program and then to beginning of program)		*PGAsl*
GOTOB	Jump backward (toward the beginning of the program)		*PGAsl*
GOTOC	As GOTO, but suppress alarm 14080 "Jump destination not found"		*PGAsl*
GOTOF	Jump forward (toward the end of the program)		*PGAsl*
GOTOS	Jump back to beginning of program		*PGAsl*
GP	Keyword for the indirect programming of position attributes		*PGAsl*
GWPSOF	Deselect constant grinding wheel peripheral speed (GWPS)	s	*PGsl* Constant grinding wheel peripheral speed (GWPSON, GWPSOF) [Page 106]
GWPSON	Select constant grinding wheel peripheral speed (GWPS)	s	*PGsl* Constant grinding wheel peripheral speed (GWPSON, GWPSOF) [Page 106]
H...	Auxiliary function output to the PLC		*PGsl/FB1(H2)* Auxiliary function outputs [Page 377]
HOLES1	Technological cycle: line of holes		*PGAsl*
HOLES2	Technological cycle: hole circle		*PGAsl*
I	Interpolation parameters	s	*PGsl* Circular interpolation with center point and end point (G2/G3, X... Y... Z..., I... J... K...) [Page 212]
I1	Intermediate point coordinate	s	*PGsl* Circular interpolation with opening angle and center point (G2/G3, X... Y... Z.../ I... J... K..., AR) [Page 218]
IC	Incremental dimensions	s	*PGsl* Incremental dimensions (G91, IC) [Page 171]
ICYCOF	All blocks of a technology cycle are processed in one interpolation cycle following ICYCOF		*PGAsl*
ICYCON	Each block of a technology cycle is processed in a separate interpolation cycle following ICYCON		*PGAsl*
ID	Identifier for modal synchronized actions	m	*PGAsl*

Operation	Meaning	W 1)	Description see 2)
IDS	Identifier for modal static synchronized actions		*PGAsl*
IF	Introduction of a conditional jump in the part program/technology cycle		*PGAsl*
INDEX	Define index of character in input string		*PGAsl*
INIPO	Initialization of variables at POWER ON		*PGAsl*
INIRE	Initialization of variables at reset		*PGAsl*
INICF	Initialization of variables at NewConfig		*PGAsl*
INIT	Selection of a particular NC program for execution in a particular channel		*PGAsl*
INITIAL	Generation of an INI file across all areas		*PGAsl*
INT	Data type: Integer with sign		*PGAsl*
INTERSEC	Calculate intersection between two contour elements		*PGAsl*
INVCCW	Trace involute, counter-clockwise	m	*PGsl* Involute interpolation (INVCW, INVCCW) [Page 232]
INVCW	Trace involute, clockwise	m	*PGsl* Involute interpolation (INVCW, INVCCW) [Page 232]
INVFRAME	Calculate the inverse frame from a frame		*FB1(K2)*
IP	Variable interpolation parameter		*PGAsl*
IPOBRKA	Motion criterion from braking ramp activation	m	*PGAsl*
IPOENDA	End of motion when “IPO stop” reached	m	*PGAsl*
IPTRLOCK	Freeze start of the untraceable program section at next machine function block	m	*PGAsl*
IPTRUNLOCK	Set end of untraceable program section at current block at time of interruption	m	*PGAsl*
ISAXIS	Check if geometry axis 1 specified as parameter		*PGAsl*
ISD	Insertion depth	m	*PGAsl*
ISFILE	Check whether the file exists in the NCK application memory		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
ISNUMBER	Check whether the input string can be converted to a number		*PGAs*/
ISOCALL	Indirect call of a program programmed in an ISO language		*PGAs*/
ISVAR	Check whether the transfer parameter contains a variable declared in the NC		*PGAs*/
J	Interpolation parameters	s	*PGs*/ Circular interpolation with center point and end point (G2/G3, X... Y... Z..., I... J... K...) [Page 212]
J1	Intermediate point coordinate	s	*PGs*/ Circular interpolation with intermediate point and end point (CIP, X... Y... Z..., I1... J1... K1...) [Page 222]
JERKA	Activate acceleration response set via MD for programmed axes		
JERKLIM	Reduction or overshoot of maximum axial jerk	m	*PGAs*/
JERKLIMA	Reduction or overshoot of maximum axial jerk	m	*PGs*/ Influence of acceleration on following axes (VELOLIMA, ACCLIMA, JERKLIMA) [Page 409]
K	Interpolation parameters	s	*PGs*/ Circular interpolation with center point and end point (G2/G3, X... Y... Z..., I... J... K...) [Page 212]
K1	Intermediate point coordinate	s	*PGs*/ Circular interpolation with intermediate point and end point (CIP, X... Y... Z..., I1... J1... K1...) [Page 222]
KONT	Travel around contour on tool offset	m	*PGs*/ Contour approach and retraction (NORM, KONT, KONTC, KONTT) [Page 287]
KONTC	Approach/retract with continuous-curvature polynomial	m	*PGs*/ Contour approach and retraction (NORM, KONT, KONTC, KONTT) [Page 287]
KONTT	Approach/retract with continuous-tangent polynomial	m	*PGs*/ Contour approach and retraction (NORM, KONT, KONTC, KONTT) [Page 287]
L	Subprogram number	s	*PGAs*/
LEAD	Lead angle 1. Tool orientation 2. Orientation polynomial	m	*PGAs*/
LEADOF	Master value coupling OFF		*PGAs*/
LEADON	Master value coupling ON		*PGAs*/

Operation	Meaning	W 1)	Description see 2)
LENTOAX	Provides information about the assignment of tool lengths L1, L2, and L3 of the active tool to the abscissa, ordinate and applicate		*FB1(W1)*
LFOF 3)	Fast retraction for thread cutting OFF	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
LFON	Fast retraction for thread cutting ON	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
LFPOS	Retraction of the axis declared with POLFMASK or POLFMLIN to the absolute axis position programmed with POLF	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
LFTXT	The plane of the retraction movement for fast retraction is determined from the path tangent and the current tool direction	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
LFWP	The plane of the retraction movement for fast retraction is determined by the current working plane (G17/G18/G19)	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
LIFTFAST	Fast retraction		*PGsl*
LIMS	Speed limitation for G96/G961 and G97	m	*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/ G972, G973, LIMS, SCC) [Page 100]
LLI	Lower limit value of variables		*PGAsl*
LN	Natural logarithm		*PGAsl*
LOCK	Disable synchronized action with ID (stop technology cycle)		*PGAsl*
LONGHOLE	Technological cycle: elongated hole		*PGAsl*
LOOP	Introduction of an endless loop		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
M0	Programmed stop		*PGsl* M functions [Page 381]
M1	Optional stop		*PGsl* M functions [Page 381]

Operation	Meaning	W 1)	Description see 2)
M2	End of main program with return to beginning of program		*PGsl* M functions [Page 381]
M3	CW spindle rotation		*PGsl* M functions [Page 381]
M4	CCW spindle rotation		*PGsl* M functions [Page 381]
M5	Spindle stop		*PGsl* M functions [Page 381]
M6	Tool change		*PGsl* M functions [Page 381]
M17	End of subprogram		*PGsl* M functions [Page 381]
M19	Spindle positioning to the position entered in SD43240		*PGsl* M functions [Page 381]
M30	End of program, same effect as M2		*PGsl* M functions [Page 381]
M40	Automatic gear change		*PGsl* M functions [Page 381]
M41 ... M45	Gear stage 1 ... 5		*PGsl* M functions [Page 381]
M70	Transition to axis mode		*PGsl* M functions [Page 381]
MASLDEF	Define master/slave axis grouping		*PGAsl*
MASLDEL	Uncouple master/slave axis grouping and clear grouping definition		*PGAsl*
MASLOF	Deactivation of a temporary coupling		*PGAsl*
MASLOFS	Deactivation of a temporary coupling with automatic slave axis stop		*PGAsl*
MASLON	Activation of a temporary coupling		*PGAsl*
MATCH	Search for string in string		*PGAsl*
MAXVAL	Larger value of two variables (arithm. function)		*PGAsl*
MCALL	Modal subprogram call		*PGAsl*
MEAC	Continuous measurement without deletion of distance-to-go	s	*PGAsl*
MEAFRAME	Frame calculation from measuring points		*PGAsl*

Operation	Meaning	W [1)]	Description see [2)]
MEAS	Measurement with touch-trigger probe	s	*PGAsl*
MEASA	Measurement with deletion of distance-to-go	s	*PGAsl*
MEASURE	Calculation method for workpiece and tool measurement		*FB2(M5)*
MEAW	Measurement with touch-trigger probe without deletion of distance-to-go	s	*PGAsl*
MEAWA	Measurement without deletion of distance-to-go	s	*PGAsl*
MI	Access to frame data: Mirroring		*PGAsl*
MINDEX	Define index of character in input string		*PGAsl*
MINVAL	Smaller value of two variables (arithm. function)		*PGAsl*
MIRROR	Programmable mirroring	s	*PGAsl* Programmable mirroring (MIRROR, AMIRROR) [Page 365]
MMC	Call the dialog window interactively from the part program on the HMI		*PGAsl*
MOD	Modulo division		*PGAsl*
MODAXVAL	Determine modulo position of a modulo rotary axis		*PGAsl*
MOV	Start positioning axis		*PGAsl*
MSG	Programmable messages	m	*PGsl* Messages (MSG) [Page 385]
MVTOOL	Language command to move tool		*FBW*
N	NC auxiliary block number		*PGsl* Block rules [Page 37]
NCK	Specify validity range for data		*PGAsl*
NEWCONF	Apply modified machine data (corresponds to "Activate machine data")		*PGAsl*
NEWT	Create new tool		*PGAsl*
NORM [3)]	Standard setting in starting point and end point with tool offset	m	*PGsl* Contour approach and retraction (NORM, KONT, KONTC, KONTT) [Page 287]

Operation	Meaning	W 1)	Description see 2)
NOT	Logic NOT (negation)		*PGAsl*
NPROT	Machine-specific protection zone ON/ OFF		*PGAsl*
NPROTDEF	Definition of a machine-specific protection zone		*PGAsl*
NUMBER	Convert input string to number		*PGAsl*
OEMIPO1	OEM interpolation 1	m	*PGAsl*
OEMIPO2	OEM interpolation 2	m	*PGAsl*
OF	Keyword in CASE branch		*PGAsl*
OFFN	Allowance on the programmed contour	m	*PGsl* Tool radius compensation (G40, G41, G42, OFFN) [Page 277]
OMA1	OEM address 1	m	
OMA2	OEM address 2	m	
OMA3	OEM address 3	m	
OMA4	OEM address 4	m	
OMA5	OEM address 5	m	
OR	Logic operator, OR operation		*PGAsl*
ORIAXES	Linear interpolation of machine axes or orientation axes	m	*PGAsl*
ORIAXPOS	Orientation angle via virtual orientation axes with rotary axis positions	m	
ORIC 3)	Orientation changes at outside corners are overlaid on the circle block to be inserted	m	*PGAsl*
ORICONCCW	Interpolation on a circular peripheral surface in CCW direction	m	*PGAsl/FB3(F3)*
ORICONCW	Interpolation on a circular peripheral surface in CW direction	m	*PGAsl/FB3(F4)*
ORICONIO	Interpolation on a circular peripheral surface with intermediate orientation setting	m	*PGAsl/FB3(F4)*
ORICONTO	Interpolation on circular peripheral surface in tangential transition (final orientation)	m	*PGAsl/FB3(F5)*
ORICURVE	Interpolation of orientation with specification of motion of two contact points of tool	m	*PGAsl/FB3(F6)*

Operation	Meaning	W [1]	Description see [2]
ORID	Orientation changes are performed before the circle block	m	*PGAsl*
ORIEULER	Orientation angle via Euler angle	m	*PGAsl*
ORIMKS	Tool orientation in the machine coordinate system	m	*PGAsl*
ORIPATH	Tool orientation in relation to path	m	*PGAsl*
ORIPATHS	Tool orientation in relation to path, blips in the orientation characteristic are smoothed	m	*PGAsl*
ORIPLANE	Interpolation in a plane (corresponds to ORIVECT), large-radius circular interpolation	m	*PGAsl*
ORIRESET	Initial tool orientation with up to 3 orientation axes		*PGAsl*
ORIROTA	Angle of rotation to an absolute direction of rotation	m	*PGAsl*
ORIROTC	Tangential rotational vector in relation to path tangent	m	*PGAsl*
ORIROTR	Angle of rotation relative to the plane between the start and end orientation	m	*PGAsl*
ORIROTT	Angle of rotation relative to the change in the orientation vector	m	*PGAsl*
ORIRPY	Orientation angle via RPY angle (XYZ)	m	*PGAsl*
ORIRPY2	Orientation angle via RPY angle (ZYX)	m	*PGAsl*
ORIS	Change in orientation	m	*PGAsl*
ORISOF [3]	Smoothing of the orientation characteristic OFF	m	*PGAsl*
ORISON	Smoothing of the orientation characteristic ON	m	*PGAsl*
ORIVECT	Large-radius circular interpolation (identical to ORIPLANE)	m	*PGAsl*
ORIVIRT1	Orientation angle via virtual orientation axes (definition 1)	m	*PGAsl*
ORIVIRT2	Orientation angle via virtual orientation axes (definition 1)	m	*PGAsl*
ORIWKS [3]	Tool orientation in the workpiece coordinate system	m	*PGAsl*

Operation	Meaning	W [1]	Description see [2]
OS	Oscillation on/off		*PGAsl*
OSB	Oscillating: Starting point	m	*FB2(P5)*
OSC	Continuous tool orientation smoothing	m	*PGAsl*
OSCILL	Axis: 1 - 3 infeed axes	m	*PGAsl*
OSCTRL	Oscillation options	m	*PGAsl*
OSD	Smoothing of tool orientation by specifying smoothing distance with SD	m	*PGAsl*
OSE	Oscillation end position	m	*PGAsl*
OSNSC	Oscillating: Number of spark-out cycles	m	*PGAsl*
OSOF [3]	Tool orientation smoothing OFF	m	*PGAsl*
OSP1	Oscillating: Left reversal point	m	*PGAsl*
OSP2	Oscillation right reversal point	m	*PGAsl*
OSS	Tool orientation smoothing at end of block	m	*PGAsl*
OSSE	Tool orientation smoothing at start and end of block	m	*PGAsl*
OST	Smoothing of tool orientation by specifying angular tolerance in degrees with SD (maximum deviation from programmed orientation characteristic)	m	*PGAsl*
OST1	Oscillating: Stopping point in left reversal point	m	*PGAsl*
OST2	Oscillating: Stopping point in right reversal point	m	*PGAsl*
OTOL	Orientation tolerance for compressor functions, orientation smoothing and smoothing types		*PGAsl*
OVR	Speed offset	m	*PGAsl* Programmable feedrate override (OVR, OVRRAP, OVRA) [Page 137]
OVRA	Axial speed offset	m	*PGAsl* Programmable feedrate override (OVR, OVRRAP, OVRA) [Page 137]

Operation	Meaning	W [1)]	Description see [2)]
OVRRAP	Rapid traverse override	m	*PGAsl* Programmable feedrate override (OVR, OVRRAP, OVRA) [Page 137]
P	Number of subprogram cycles		*PGAsl*
PAROT	Align workpiece coordinate system on workpiece	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
PAROTOF	Deactivate frame rotation in relation to workpiece	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
PCALL	Call subprograms with absolute path and parameter transfer		*PGAsl*
PDELAYOF	Punching with delay OFF	m	*PGAsl*
PDELAYON [3)]	Punching with delay ON	m	*PGAsl*
PHU	Physical unit of a variable		*PGAsl*
PL	1. B spline: Node clearance 2. Polynomial interpolation: Length of the parameter interval for polynomial interpolation	s	*PGAsl* 1. 2.
PM	Per minute		*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
PO	Polynomial coefficient for polynomial interpolation	s	*PGAsl*
POCKET3	Technological cycle: milling rectangular pocket		*PGAsl*
POCKET4	Technological cycle: milling circular pocket		*PGAsl*
POLF	LIFTFAST retraction position	m	*PGsl/PGAsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
POLFA	Start retraction position of single axes with $AA_ESR_TRIGGER	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
POLFMASK	Enable axes for retraction without a connection between the axes	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]

Operation	Meaning	W [1)]	Description see [2)]
POLFMLIN	Enable axes for retraction with a linear connection between the axes	m	*PGsl* Fast retraction for thread cutting (LFON, LFOF, DILF, ALF, LFTXT, LFWP, LFPOS, POLF, POLFMASK, POLFMLIN) [Page 267]
POLY	Polynomial interpolation	m	*PGAsl*
POLYPATH	Polynomial interpolation can be selected for the AXIS or VECT axis groups	m	*PGAsl*
PON	Punching ON	m	*PGAsl*
PONS	Punching ON in interpolation cycle	m	*PGAsl*
POS	Position axis		*PGsl* Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC) [Page 118]
POSA	Position axis across block boundary		*PGsl* Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC) [Page 118]
POSM	Position magazine		*FBW*
POSP	Positioning in sections (oscillating)		*PGsl* Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC) [Page 118]
POSRANGE	Determine whether the currently interpolated position setpoint of an axis is located in a window at a predefined reference position		*PGAsl*
POT	Square (arithmetic function)		*PGAsl*
PR	Per revolution		*PGsl* Approach and retraction (G140 to G143, G147, G148, G247, G248, G347, G348, G340, G341, DISR, DISCL, FAD, PM, PR) [Page 298]
PREPRO	Identify subprograms with preparation		*PGAsl*
PRESETON	Set actual values for programmed axes		*PGAsl*
PRIO	Keyword for setting the priority for interrupt processing		*PGAsl*
PROC	First operation in a program		*PGAsl*
PTP	Point-to-point motion	m	*PGAsl*
PTPG0	Point-to-point motion only with G0, otherwise CP	m	*PGAsl*

Operation	Meaning	W 1)	Description see 2)
PUNCHACC	Travel-dependent acceleration for nibbling		*PGAsl*
PUTFTOC	Tool fine offset for parallel dressing		*PGAsl*
PUTFTOCF	Tool fine offset dependent on a function for parallel dressing defined with FCTDEF		*PGAsl*
PW	B spline, point weight	s	*PGAsl*
QECLRNOF	Quadrant error compensation learning OFF		*PGAsl*
QECLRNON	Quadrant error compensation learning ON		*PGAsl*
QU	Fast additional (auxiliary) function output		*PGsl* Auxiliary function outputs [Page 377]
R...	Arithmetic parameter also as settable address identifier and with numerical extension		*PGAsl*
RAC	Absolute non-modal axis-specific radius programming	s	*PGsl* Axis-specific diameter/radius programming (DIAMONA, DIAM90A, DIAMOFA, DIACYCOFA, DIAMCHANA, DIAMCHAN, DAC, DIC, RAC, RIC) [Page 183]
RDISABLE	Read-in disable		*PGAsl*
READ	Reads one or more lines in the specified file and stores the information read in the array		*PGAsl*
REAL	Data type: Floating-point variable with sign (real numbers)		*PGAsl*
REDEF	Setting for machine data, NC language elements and system variables, specifying the user groups they are displayed for		*PGAsl*
RELEASE	Release machine axes for axis exchange		*PGAsl*
REP	Keyword for initialization of all elements of an array with the same value		*PGAsl*
REPEAT	Repetition of a program loop		*PGAsl*
REPEATB	Repetition of a program line		*PGAsl*
REPOSA	Linear repositioning with all axes	s	*PGAsl*
REPOSH	Repositioning with semicircle	s	*PGAsl*

Operation	Meaning	W 1)	Description see 2)
REPOSHA	Repositioning with all axes; geometry axes in semicircle	s	*PGAsl*
REPOSL	Linear repositioning	s	*PGAsl*
REPOSQ	Repositioning in a quadrant	s	*PGAsl*
REPOSQA	Linear repositioning with all axes, geometry axes in quadrant	s	*PGAsl*
RESET	Reset technology cycle		*PGAsl*
RESETMON	Language command for setpoint activation		*FBW*
RET	End of subprogram		*PGAsl*
RIC	Relative non-modal axis-specific radius programming	s	*PGsl*
RINDEX	Define index of character in input string		*PGAsl*
RMB	Repositioning to start of block	m	*PGAsl*
RME	Repositioning to end of block	m	*PGAsl*
RMI 3)	Repositioning to interrupt point	m	*PGAsl*
RMN	Repositioning to the nearest path point	m	*PGAsl*
RND	Round the contour corner	s	*PGsl* Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]
RNDM	Modal rounding	m	*PGsl* Chamfer, rounding (CHF, CHR, RND, RNDM, FRC, FRCM) [Page 271]
ROT	Programmable rotation	s	*PGsl* Programmable rotation (ROT, AROT, RPL) [Page 350]
ROTS	Programmable frame rotations with solid angles	s	*PGsl* Programmable frame rotations with solid angles (ROTS, AROTS, CROTS) [Page 360]
ROUND	Rounding of decimal places		*PGAsl*
ROUNDUP	Rounding up of an input value		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
RP	Polar radius	m/s	*PGsl* Travel commands with polar coordinates (G0, G1, G2, G3, AP, RP) [Page 197]
RPL	Rotation in the plane	s	*PGsl* Programmable frame rotations with solid angles (ROTS, AROTS, CROTS) [Page 360]
RT	Parameter for access to frame data: Rotation		*PGAsl*
RTLIOF	G0 without linear interpolation (single-axis interpolation)	m	*PGsl* Rapid traverse movement (G0, RTLION, RTLIOF) [Page 201]
RTLION	G0 with linear interpolation	m	*PGsl* Rapid traverse movement (G0, RTLION, RTLIOF) [Page 201]

Operation	Meaning	W 1)	Description see 2)
S	Spindle speed (with G4, G96/G961 different significance)	m/s	*PGsl* Spindle speed (S), direction of spindle rotation (M3, M4, M5) [Page 89]
SAVE	Attribute for saving information when subprograms are called		*PGAsl*
SBLOF	Suppress single block		*PGAsl*
SBLON	Revoke suppression of single block		*PGAsl*
SC	Parameter for access to frame data: Scaling		*PGAsl*
SCALE	Programmable scaling	s	*PGsl* Programmable scale factor (SCALE, ASCALE) [Page 362]
SCC	Selective assignment of transverse axis to G96/G961/G962. Axis identifiers may take the form of geometry, channel or machine axes		*PGsl* Constant cutting rate (G96/G961/G962, G97/G971/G972, G973, LIMS, SCC) [Page 100]
SCPARA	Program servo parameter set		*PGAsl*
SD	Spline degree	s	*PGAsl*
SEFORM	Structuring operation in the Step editor to generate the step view for HMI Advanced		*PGAsl*
SET	Keyword for initialization of all elements of an array with listed values		*PGAsl*
SETAL	Set alarm		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
SETDNO	Assign the D number of a cutting edge (CE) of a tool (T)		*PGAsl*
SETINT	Define which interrupt routine is to be activated when an NCK input is present		*PGAsl*
SETM	Setting of markers in dedicated channel		PGAsl
SETMS	Reset to the master spindle defined in machine data		Spindle speed (S), direction of spindle rotation (M3, M4, M5) [Page 89]
SETMS(n)	Set spindle n as master spindle		*PGsl* Spindle speed (S), direction of spindle rotation (M3, M4, M5) [Page 89]
SETMTH	Set master toolholder number		*FBW*
SETPIECE	Set piece number for all tools assigned to the spindle		*FBW*
SETTA	Activate tool from wear group		*FBW*
SETTCOR	Modification of tool components taking all general conditions into account		*FB1(W1)*
SETTIA	Deactivate tool from wear group		*FBW*
SF	Starting point offset for thread cutting	m	*PGsl* Thread cutting with constant lead (G33, SF) [Page 248]
SIN	Sine (trigon. function)		*PGAsl*
SIRELAY	Activate the safety functions parameterized with SIRELIN, SIRELOUT, and SIRELTIME		*FBSIsl*
SIRELIN	Initialize input variables of function block		*FBSIsl*
SIRELOUT	Initialize output variables of function block		*FBSIsl*
SIRELTIME	Initialize timers of function block		*FBSIsl*
SLOT1	Technological cycle: longitudinal groove		*PGAsl*
SLOT2	Technological cycle: circumferential groove		*PGAsl*
SOFT	Soft path acceleration	m	*PGsl* Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA) [Page 406]
SOFTA	Activate soft axis acceleration for the programmed axes		*PGsl* Acceleration mode (BRISK, BRISKA, SOFT, SOFTA, DRIVE, DRIVEA) [Page 406]
SON	Nibbling ON	m	*PGAsl*
SONS	Nibbling ON in interpolation cycle	m	*PGAsl*

Operation	Meaning	W [1]	Description see [2]
SPATH [3]	Path reference for FGROUP axes is arc length	m	*PGAsl*
SPCOF	Switch master spindle or spindle(s) from position control to speed control	m	*PGsl* Position-controlled spindle operation (SPCON, SPCOF) [Page 122]
SPCON	Switch master spindle or spindle(s) from speed control to position control	m	*PGAsl* Position-controlled spindle operation (SPCON, SPCOF) [Page 122]
SPI	Converts spindle number into axis identifier		*PGAsl*
SPIF1 [3]	Fast NCK inputs/outputs for punching/ nibbling byte 1	m	*FB2(N4)*
SPIF2	Fast NCK inputs/outputs for punching/ nibbling byte 2	m	*FB2(N4)*
SPLINEPATH	Define spline grouping		*PGAsl*
SPN	Number of path sections per block	s	*PGAsl*
SPOF [3]	Stroke OFF, nibbling, punching OFF	m	*PGAsl*
SPOS	Spindle position	m	*PGsl* Positioning spindles (SPOS, SPOSA, M19, M70, WAITS) [Page 123]
SPOSA	Spindle position across block boundaries	m	*PGsl* Positioning spindles (SPOS, SPOSA, M19, M70, WAITS) [Page 123]
SPP	Length of a path section	m	*PGAsl*
SPRINT	Returns an input string formatted		*PGAsl*
SQRT	Square root (arithmetic function)		*PGAsl*
SR	Oscillation retraction path for synchronized action	s	*PGsl* Several feedrate values in one block (F, ST, SR, FMA, STA, SRA) [Page 148]
SRA	Oscillation retraction path with external input axial for synchronized action	m	*PGsl* Several feedrate values in one block (F, ST, SR, FMA, STA, SRA) [Page 148]
ST	Oscillation sparking-out time for synchronized action	s	*PGsl* Several feedrate values in one block (F, ST, SR, FMA, STA, SRA) [Page 148]

Operation	Meaning	W 1)	Description see 2)
STA	Oscillation sparking-out time axial for synchronized action	m	*PGsl* Several feedrate values in one block (F, ST, SR, FMA, STA, SRA) [Page 148]
START	Start selected programs simultaneously in several channels from current program		*PGAsl*
STARTFIFO 3)	Execute; fill preprocessing memory simultaneously	m	*PGAsl*
STAT	Position of joints	s	*PGAsl*
STOLF	G0 tolerance factor	m	*PGAsl*
STOPFIFO	Stop machining; fill preprocessing memory until STARTFIFO is detected, preprocessing memory is full or end of program	m	*PGAsl*
STOPRE	Preprocessing stop until all prepared blocks in main run are executed		*PGAsl*
STOPREOF	Revoke preprocessing stop		*PGAsl*
STRING	Data type: Character string		*PGAsl*
STRINGFELD	Selection of a single character from the progr. string field		*PGAsl*
STRINGIS	Checks the present scope of NC language and the NC cycle names, user variables, macros, and label names belonging specifically to this command to establish whether these exist, are valid, defined or active		*PGAsl*
STRINGVAR	Selection of a single character from the progr. string		*PGAsl*
STRLEN	Define string length		*PGAsl*
SUBSTR	Define index of character in input string		*PGAsl*
SUPA	Suppression of current work offset, including programmed offsets, system frames, handwheel offsets (DRF), external work offset, and overlaid movement	s	*PGsl* Deselect frame (G53, G153, SUPA, G500) [Page 373]
SVC	Tool cutting rate	m	*PGsl* Cutting rate (SVC) [Page 93]
SYNFCT	Evaluation of a polynomial as a function of a condition in the motion-synchronous action		*PGAsl*

Operation	Meaning	W [1]	Description see [2]
SYNR	The variable is read synchronously, i.e. at the time of execution		*PGAsl*
SYNRW	The variable is read and written synchronously, i.e. at the time of execution		*PGAsl*
SYNW	The variable is written synchronously, i.e. at the time of execution		*PGAsl*
T	Call tool (only change if specified in machine data; otherwise M6 command necessary)		*PGsl* Tool change with T command [Page 56]
TAN	Tangent (trigon. function)		*PGAsl*
TANG	Definition of axis grouping tangential correction		*PGAsl*
TANGDEL	Deletion of definition of axis grouping tangential correction		*PGAsl*
TANGOF	Tangential correction OFF		*PGAsl*
TANGON	Tangential correction ON		*PGAsl*
TCA (828D: _TCA)	Tool selection/tool change irrespective of tool status		*FBW*
TCARR	Request toolholder (number "m")		*PGAsl*
TCI	Load tool from buffer into magazine		*FBW*
TCOABS[3]	Determine tool length components from the orientation of the current toolholder	m	*PGAsl*
TCOFR	Determine tool length components from the orientation of the active frame	m	*PGAsl*
TCOFRX	Determine tool orientation of an active frame on selection of tool, tool points in X direction	m	*PGAsl*
TCOFRY	Determine tool orientation of an active frame on selection of tool, tool points in Y direction	m	*PGAsl*
TCOFRZ	Determine tool orientation of an active frame on selection of tool, tool points in Z direction	m	*PGAsl*
THETA	Angle of rotation	s	*PGAsl*
TILT	Tilt angle	m	*PGAsl*
TLIFT	In tangential control insert intermediate block at contour corners		*PGAsl*

Operation	Meaning	W 1)	Description see 2)
TMOF	Deselect tool monitoring		*PGAsl*
TMON	Activate tool monitoring		*PGAsl*
TO	Designates the end value in a FOR counter loop		*PGAsl*
TOFF	Tool length offset in the direction of the tool length component that is effective parallel to the geometry axis specified in the index	m	*PGsl* Programmable tool offset (TOFFL, TOFF, TOFFR) [Page 83]
TOFFL	Tool length offset in the direction of the tool length component L1, L2 or L3	m	*PGsl* Programmable tool offset (TOFFL, TOFF, TOFFR) [Page 83]
TOFFOF	Deactivate online tool offset		*PGAsl*
TOFFON	Activate online tool length offset		*PGAsl*
TOFFR	Tool radius offset	m	*PGsl* Programmable tool offset (TOFFL, TOFF, TOFFR) [Page 83]
TOFRAME	Align the Z axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOFRAMEX	Align the X axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOFRAMEY	Align the Y axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOFRAMEZ	As TOFRAME	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOLOWER	Convert the letters of a string into lowercase		*PGAsl*
TOOLENV	Save current states which are of significance to the evaluation of the tool data stored in the memory		*FB1(W1)*
TOROT	Align the Z axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOROTOF	Frame rotations in tool direction OFF	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]

Operation	Meaning	W [1]	Description see [2]
TOROTX	Align the X axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOROTY	Align the Y axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOROTZ	As TOROT	m	*PGsl* Frame generation according to tool orientation (TOFRAME, TOROT, PAROT) [Page 370]
TOUPPER	Convert the letters of a string into uppercase		*PGAsl*
TOWBCS	Wear values in basic coordinate system (BCS)	m	*PGAsl*
TOWKCS	Wear values in the coordinate system of the tool head for kinetic transformation (differs from machine coordinate system through tool rotation)	m	*PGAsl*
TOWMCS	Wear values in machine coordinate system	m	*PGAsl*
TOWSTD	Initial setting value for offsets in tool length	m	*PGAsl*
TOWTCS	Wear values in the tool coordinate system (toolholder ref. point T at the tool holder)	m	*PGAsl*
TOWWCS	Wear values in workpiece coordinate system	m	*PGAsl*
TR	Offset component of a frame variable		*PGAsl*
TRAANG	Transformation inclined axis		*PGAsl*
TRACON	Cascaded transformation		*PGAsl*
TRACYL	Cylinder: Peripheral surface transformation		*PGAsl*
TRAFOOF	Deactivate active transformations in the channel		*PGAsl*
TRAILOF	Asynchronous coupled motion OFF		*PGAsl*
TRAILON	Asynchronous coupled motion ON		*PGAsl*
TRANS	Programmable offset	s	*PGsl* Zero offset (TRANS, ATRANS) [Page 343]

Operation	Meaning	W $^{1)}$	Description see $^{2)}$
TRANSMIT	Pole transformation (face machining)		*PGAsl*
TRAORI	4-axis, 5-axis transformation, generic transformation		*PGAsl*
TRUE	Logical constant: True		*PGAsl*
TRUNC	Truncation of decimal places		*PGAsl*
TU	Axis angle	s	*PGAsl*
TURN	Number of turns for helix	s	*PGsl* Helical interpolation (G2/G3, TURN) [Page 229]
ULI	Upper limit value of variables		*PGAsl*
UNLOCK	Enable synchronized action with ID (continue technology cycle)		*PGAsl*
UNTIL	Condition for end of REPEAT loop		*PGAsl*
UPATH	Path reference for FGROUP axes is curve parameter	m	*PGAsl*
VAR	Keyword: Type of parameter transfer		*PGAsl*
VELOLIM	Reduction of the maximum axial velocity	m	*PGAsl*
VELOLIMA	Reduction or increase of the maximum axial velocity of the following axis	m	*PGsl* Influence of acceleration on following axes (VELOLIMA, ACCLIMA, JERKLIMA) [Page 409]
WAITC	Wait for the coupling block change criterion to be fulfilled for the axes/ spindles		*PGAsl*
WAITE	Wait for end of program in another channel		*PGAsl*
WAITENC	Wait for synchronized or restored axis positions		*PGAsl*
WAITM	Wait for marker in specified channel; terminate previous block with exact stop		*PGAsl*
WAITMC	Wait for marker in specified channel; exact stop only if the other channels have not yet reached the marker.		*PGAsl*
WAITP	Wait for end of travel of the positioning axis		*PGsl* Traversing positioning axes (POS, POSA, POSP, FA, WAITP, WAITMC) [Page 118]

Operation	Meaning	W [1]	Description see [2]
WAITS	Wait for spindle position to be reached		*PGs*/ Positioning spindles (SPOS, SPOSA, M19, M70, WAITS) [Page 123]
WALCS0	Workpiece coordinate system working area limitation deselected	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS1	Workpiece coordinate system working area limitation group 1 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS2	Workpiece coordinate system working area limitation group 2 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS3	Workpiece coordinate system working area limitation group 3 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS4	Workpiece coordinate system working area limitation group 4 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS5	Workpiece coordinate system working area limitation group 5 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS6	Workpiece coordinate system working area limitation group 6 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS7	Workpiece coordinate system working area limitation group 7 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS8	Workpiece coordinate system working area limitation group 8 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS9	Workpiece coordinate system working area limitation group 9 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALCS10	Workpiece coordinate system working area limitation group 10 active	m	*PGs*/ Working area limitation in WCS/SZS (WALCS0 ... WALCS10) [Page 392]
WALIMOF	BCS working area limitation OFF	m	*PGs*/ Working area limitation in BCS (G25/G26, WALIMON, WALIMOF) [Page 388]
WALIMON [3]	BCS working area limitation ON	m	*PGs*/ Working area limitation in BCS (G25/G26, WALIMON, WALIMOF) [Page 388]
WHEN	The action is executed cyclically when the condition is fulfilled.		*PGAs*/
WHENEVER	The action is executed once whenever the condition is fulfilled.		*PGAs*/

Operation	Meaning	W [1)]	Description see [2)]
WHILE	Start of WHILE program loop		*/PGAs/*
WRITE	Write text to file system Appends a block to the end of the specified file.		*/PGAs/*
WRTPR	Delays the machining job without interrupting continuous-path mode		*/PGAs/* Writing string in OPI variable (WRTPR) [Page 387]
X	Axis name	m/s	*/PGs/* Travel commands with Cartesian coordinates (G0, G1, G2, G3, X..., Y..., Z...) [Page 193]
XOR	Logic exclusive OR		*/PGAs/*
Y	Axis name	m/s	*/PGs/* Travel commands with Cartesian coordinates (G0, G1, G2, G3, X..., Y..., Z...) [Page 193]
Z	Axis name	m/s	*/PGs/* Travel commands with Cartesian coordinates (G0, G1, G2, G3, X..., Y..., Z...) [Page 193]

16.2 Operations: Availability for SINUMERIK 828D

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
:	●	●	●	●	●	●
*	●	●	●	●	●	●
+	●	●	●	●	●	●
-	●	●	●	●	●	●
<	●	●	●	●	●	●
<<	●	●	●	●	●	●
<=	●	●	●	●	●	●
=	●	●	●	●	●	●
>=	●	●	●	●	●	●
/	●	●	●	●	●	●
/0 … … /7	● ○	● ○	● ○	● ○	● ○	● ○
A	●	●	●	●	●	●
A2	-	-	-	-	-	-
A3	-	-	-	-	-	-
A4	-	-	-	-	-	-
A5	-	-	-	-	-	-
ABS	●	●	●	●	●	●
AC	●	●	●	●	●	●
ACC	●	●	●	●	●	●
ACCLIMA	●	●	●	●	●	●
ACN	●	●	●	●	●	●
ACOS	●	●	●	●	●	●
ACP	●	●	●	●	●	●
ACTBLOCNO	●	●	●	●	●	●
ADDFRAME	●	●	●	●	●	●
ADIS	●	●	●	●	●	●
ADISPOS	●	●	●	●	●	●
ADISPOSA	●	●	●	●	●	●
ALF	●	●	●	●	●	●
AMIRROR	●	●	●	●	●	●
AND	●	●	●	●	●	●
ANG	●	●	●	●	●	●
AP	●	●	●	●	●	●
APR	●	●	●	●	●	●
APRB	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
APRP	●	●	●	●	●	●
APW	●	●	●	●	●	●
APWB	●	●	●	●	●	●
APWP	●	●	●	●	●	●
APX	●	●	●	●	●	●
AR	●	●	●	●	●	●
AROT	●	●	●	●	●	●
AROTS	●	●	●	●	●	●
AS	●	●	●	●	●	●
ASCALE	●	●	●	●	●	●
ASIN	●	●	●	●	●	●
ASPLINE	-	○	-	○	-	○
ATAN2	●	●	●	●	●	●
ATOL	-	●	-	●	-	●
ATRANS	●	●	●	●	●	●
AX	●	●	●	●	●	●
AXCTSWE	-	-	-	-	-	-
AXCTSWEC	-	-	-	-	-	-
AXCTSWED	-	-	-	-	-	-
AXIS	●	●	●	●	●	●
AXNAME	●	●	●	●	●	●
AXSTRING	●	●	●	●	●	●
AXTOCHAN	●	●	●	●	●	●
AXTOSPI	●	●	●	●	●	●
B	●	●	●	●	●	●
B2	-	-	-	-	-	-
B3	-	-	-	-	-	-
B4	-	-	-	-	-	-
B5	-	-	-	-	-	-
B_AND	●	●	●	●	●	●
B_OR	●	●	●	●	●	●
B_NOT	●	●	●	●	●	●
B_XOR	●	●	●	●	●	●
BAUTO	-	○	-	○	-	○
BLOCK	●	●	●	●	●	●
BLSYNC	●	●	●	●	●	●
BNAT	-	○	-	○	-	○
BOOL	●	●	●	●	●	●
BOUND	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
BRISK	●	●	●	●	●	●
BRISKA	●	●	●	●	●	●
BSPLINE	-	○	-	○	-	○
BTAN	-	○	-	○	-	○
C	●	●	●	●	●	●
C2	-	-	-	-	-	-
C3	-	-	-	-	-	-
C4	-	-	-	-	-	-
C5	-	-	-	-	-	-
CAC	●	●	●	●	●	●
CACN	●	●	●	●	●	●
CACP	●	●	●	●	●	●
CALCDAT	●	●	●	●	●	●
CALCPOSI	●	●	●	●	●	●
CALL	●	●	●	●	●	●
CALLPATH	●	●	●	●	●	●
CANCEL	●	●	●	●	●	●
CASE	●	●	●	●	●	●
CDC	●	●	●	●	●	●
CDOF	●	●	●	●	●	●
CDOF2	●	●	●	●	●	●
CDON	●	●	●	●	●	●
CFC	●	●	●	●	●	●
CFIN	●	●	●	●	●	●
CFINE	●	●	●	●	●	●
CFTCP	●	●	●	●	●	●
CHAN	●	●	●	●	●	●
CHANDATA	●	●	●	●	●	●
CHAR	●	●	●	●	●	●
CHECKSUM	●	●	●	●	●	●
CHF	●	●	●	●	●	●
CHKDM	●	●	●	●	●	●
CHKDNO	●	●	●	●	●	●
CHR	●	●	●	●	●	●
CIC	●	●	●	●	●	●
CIP	●	●	●	●	●	●
CLEARM	-	-	-	-	-	-
CLRINT	●	●	●	●	●	●
CMIRROR	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
COARSEA	●	●	●	●	●	●
COMPCAD	-	○	-	○	-	○
COMPCURV	-	○	-	○	-	○
COMPLETE	●	●	●	●	●	●
COMPOF	-	○	-	○	-	○
COMPON	-	○	-	○	-	○
CONTDCON	●	●	●	●	●	●
CONTPRON	●	●	●	●	●	●
CORROF	●	●	●	●	●	●
COS	●	●	●	●	●	●
COUPDEF	○	-	○	-	○	-
COUPDEL	○	-	○	-	○	-
COUPOF	○	-	○	-	○	-
COUPOFS	○	-	○	-	○	-
COUPON	○	-	○	-	○	-
COUPONC	○	-	○	-	○	-
COUPRES	○	-	○	-	○	-
CP	●	●	●	●	●	●
CPRECOF	●	●	●	●	●	●
CPRECON	●	●	●	●	●	●
CPROT	●	●	●	●	●	●
CPROTDEF	●	●	●	●	●	●
CR	●	●	●	●	●	●
CROT	●	●	●	●	●	●
CROTS	●	●	●	●	●	●
CRPL	●	●	●	●	●	●
CSCALE	●	●	●	●	●	●
CSPLINE	-	○	-	○	-	○
CT	●	●	●	●	●	●
CTAB	-	-	-	-	-	-
CTABDEF	-	-	-	-	-	-
CTABDEL	-	-	-	-	-	-
CTABEND	-	-	-	-	-	-
CTABEXISTS	-	-	-	-	-	-
CTABFNO	-	-	-	-	-	-
CTABFPOL	-	-	-	-	-	-
CTABFSEG	-	-	-	-	-	-
CTABID	-	-	-	-	-	-
CTABINV	-	-	-	-	-	-

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
CTABISLOCK	-	-	-	-	-	-
CTABLOCK	-	-	-	-	-	-
CTABMEMTYP	-	-	-	-	-	-
CTABMPOL	-	-	-	-	-	-
CTABMSEG	-	-	-	-	-	-
CTABNO	-	-	-	-	-	-
CTABNOMEM	-	-	-	-	-	-
CTABPERIOD	-	-	-	-	-	-
CTABPOL	-	-	-	-	-	-
CTABPOLID	-	-	-	-	-	-
CTABSEG	-	-	-	-	-	-
CTABSEGID	-	-	-	-	-	-
CTABSEV	-	-	-	-	-	-
CTABSSV	-	-	-	-	-	-
CTABTEP	-	-	-	-	-	-
CTABTEV	-	-	-	-	-	-
CTABTMAX	-	-	-	-	-	-
CTABTMIN	-	-	-	-	-	-
CTABTSP	-	-	-	-	-	-
CTABTSV	-	-	-	-	-	-
CTABUNLOCK	-	-	-	-	-	-
CTOL	-	○	-	○	-	○
CTRANS	●	●	●	●	●	●
CUT2D	●	●	●	●	●	●
CUT2DF	●	●	●	●	●	●
CUT3DC	-	-	-	-	-	-
CUT3DCC	-	-	-	-	-	-
CUT3DCCD	-	-	-	-	-	-
CUT3DF	-	-	-	-	-	-
CUT3DFF	-	-	-	-	-	-
CUT3DFS	-	-	-	-	-	-
CUTCONOF	●	●	●	●	●	●
CUTCONON	●	●	●	●	●	●
CUTMOD	●	●	●	●	●	●
CYCLE...	●	●	●	●	●	●
D	●	●	●	●	●	●
D0	●	●	●	●	●	●
DAC	●	●	●	●	●	●
DC	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
DEF	●	●	●	●	●	●
DEFINE	●	●	●	●	●	●
DEFAULT	●	●	●	●	●	●
DELAYFSTON	●	●	●	●	●	●
DELAYFSTOF	●	●	●	●	●	●
DELDL	●	●	●	●	●	●
DELDTG	●	●	●	●	●	●
DELETE	●	●	●	●	●	●
DELTOOLENV	●	●	●	●	●	●
DIACYCOFA	●	●	●	●	●	●
DIAM90	●	●	●	●	●	●
DIAM90A	●	●	●	●	●	●
DIAMCHAN	●	●	●	●	●	●
DIAMCHANA	●	●	●	●	●	●
DIAMCYCOF	●	●	●	●	●	●
DIAMOF	●	●	●	●	●	●
DIAMOFA	●	●	●	●	●	●
DIAMON	●	●	●	●	●	●
DIAMONA	●	●	●	●	●	●
DIC	●	●	●	●	●	●
DILF	●	●	●	●	●	●
DISABLE	●	●	●	●	●	●
DISC	●	●	●	●	●	●
DISCL	●	●	●	●	●	●
DISPLOF	●	●	●	●	●	●
DISPLON	●	●	●	●	●	●
DISPR	●	●	●	●	●	●
DISR	●	●	●	●	●	●
DITE	●	●	●	●	●	●
DITS	●	●	●	●	●	●
DIV	●	●	●	●	●	●
DL	-	-	-	-	-	-
DO	●	●	●	●	●	●
DRFOF	●	●	●	●	●	●
DRIVE	●	●	●	●	●	●
DRIVEA	●	●	●	●	●	●
DYNFINISH	●	●	●	●	●	●
DYNNORM	●	●	●	●	●	●
DYNPOS	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
DYNROUGH	●	●	●	●	●	●
DYNSEMIFIN	●	●	●	●	●	●
DZERO	●	●	●	●	●	●
EAUTO	-	○	-	○	-	○
EGDEF	-	-	-	-	-	-
EGDEL	-	-	-	-	-	-
EGOFC	-	-	-	-	-	-
EGOFS	-	-	-	-	-	-
EGON	-	-	-	-	-	-
EGONSYN	-	-	-	-	-	-
EGONSYNE	-	-	-	-	-	-
ELSE	●	●	●	●	●	●
ENABLE	●	●	●	●	●	●
ENAT	-	○	-	○	-	○
ENDFOR	●	●	●	●	●	●
ENDIF	●	●	●	●	●	●
ENDLABEL	●	●	●	●	●	●
ENDLOOP	●	●	●	●	●	●
ENDPROC	●	●	●	●	●	●
ENDWHILE	●	●	●	●	●	●
ESRR	●	●	●	●	●	●
ESRS	●	●	●	●	●	●
ETAN	-	○	-	○	-	○
EVERY	●	●	●	●	●	●
EX	●	●	●	●	●	●
EXECSTRING	●	●	●	●	●	●
EXECTAB	●	●	●	●	●	●
EXECUTE	●	●	●	●	●	●
EXP	●	●	●	●	●	●
EXTCALL	●	●	●	●	●	●
EXTCLOSE	●	●	●	●	●	●
EXTERN	●	●	●	●	●	●
EXTOPEN	●	●	●	●	●	●
F	●	●	●	●	●	●
FA	●	●	●	●	●	●
FAD	●	●	●	●	●	●
FALSE	●	●	●	●	●	●
FB	●	●	●	●	●	●
FCTDEF	-	-	-	-	-	-

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
FCUB	●	●	●	●	●	●
FD	●	●	●	●	●	●
FDA	●	●	●	●	●	●
FENDNORM	●	●	●	●	●	●
FFWOF	●	●	●	●	●	●
FFWON	●	●	●	●	●	●
FGREF	●	●	●	●	●	●
FGROUP	●	●	●	●	●	●
FI	●	●	●	●	●	●
FIFOCTRL	●	●	●	●	●	●
FILEDATE	●	●	●	●	●	●
FILEINFO	●	●	●	●	●	●
FILESIZE	●	●	●	●	●	●
FILESTAT	●	●	●	●	●	●
FILETIME	●	●	●	●	●	●
FINEA	●	●	●	●	●	●
FL	●	●	●	●	●	●
FLIN	●	●	●	●	●	●
FMA	-	-	-	-	-	-
FNORM	●	●	●	●	●	●
FOCOF	○	-	○	-	○	-
FOCON	○	-	○	-	○	-
FOR	●	●	●	●	●	●
FP	●	●	●	●	●	●
FPO	-	-	-	-	-	-
FPR	●	●	●	●	●	●
FPRAOF	●	●	●	●	●	●
FPRAON	●	●	●	●	●	●
FRAME	●	●	●	●	●	●
FRC	●	●	●	●	●	●
FRCM	●	●	●	●	●	●
FROM	●	●	●	●	●	●
FTOC	●	●	●	●	●	●
FTOCOF	●	●	●	●	●	●
FTOCON	●	●	●	●	●	●
FXS	●	●	●	●	●	●
FXST	●	●	●	●	●	●
FXSW	●	●	●	●	●	●
FZ	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
G0	●	●	●	●	●	●
G1	●	●	●	●	●	●
G2	●	●	●	●	●	●
G3	●	●	●	●	●	●
G4	●	●	●	●	●	●
G5	●	●	●	●	●	●
G7	●	●	●	●	●	●
G9	●	●	●	●	●	●
G17	●	●	●	●	●	●
G18	●	●	●	●	●	●
G19	●	●	●	●	●	●
G25	●	●	●	●	●	●
G26	●	●	●	●	●	●
G33	●	●	●	●	●	●
G34	●	●	●	●	●	●
G35	●	●	●	●	●	●
G40	●	●	●	●	●	●
G41	●	●	●	●	●	●
G42	●	●	●	●	●	●
G53	●	●	●	●	●	●
G54	●	●	●	●	●	●
G55	●	●	●	●	●	●
G56	●	●	●	●	●	●
G57	●	●	●	●	●	●
G58	●	●	●	●	●	●
G59	●	●	●	●	●	●
G60	●	●	●	●	●	●
G62	●	●	●	●	●	●
G63	●	●	●	●	●	●
G64	●	●	●	●	●	●
G70	●	●	●	●	●	●
G71	●	●	●	●	●	●
G74	●	●	●	●	●	●
G75	●	●	●	●	●	●
G90	●	●	●	●	●	●
G91	●	●	●	●	●	●
G93	●	●	●	●	●	●
G94	●	●	●	●	●	●
G95	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
G96	●	●	●	●	●	●
G97	●	●	●	●	●	●
G110	●	●	●	●	●	●
G111	●	●	●	●	●	●
G112	●	●	●	●	●	●
G140	●	●	●	●	●	●
G141	●	●	●	●	●	●
G142	●	●	●	●	●	●
G143	●	●	●	●	●	●
G147	●	●	●	●	●	●
G148	●	●	●	●	●	●
G153	●	●	●	●	●	●
G247	●	●	●	●	●	●
G248	●	●	●	●	●	●
G290	●	●	●	●	●	●
G291	●	●	●	●	●	●
G331	●	●	●	●	●	●
G332	●	●	●	●	●	●
G340	●	●	●	●	●	●
G341	●	●	●	●	●	●
G347	●	●	●	●	●	●
G348	●	●	●	●	●	●
G450	●	●	●	●	●	●
G451	●	●	●	●	●	●
G460	●	●	●	●	●	●
G461	●	●	●	●	●	●
G462	●	●	●	●	●	●
G500	●	●	●	●	●	●
G505 ... G599	●	●	●	●	●	●
G601	●	●	●	●	●	●
G602	●	●	●	●	●	●
G603	●	●	●	●	●	●
G621	●	●	●	●	●	●
G641	●	●	●	●	●	●
G642	●	●	●	●	●	●
G643	●	●	●	●	●	●
G644	●	●	●	●	●	●
G645	●	●	●	●	●	●
G700	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
G710	●	●	●	●	●	●
G751	●	●	●	●	●	●
G810 ... G819	-	-	-	-	-	-
G820 ... G829	-	-	-	-	-	-
G931	●	●	●	●	●	●
G942	●	●	●	●	●	●
G952	●	●	●	●	●	●
G961	●	●	●	●	●	●
G962	●	●	●	●	●	●
G971	●	●	●	●	●	●
G972	●	●	●	●	●	●
G973	●	●	●	●	●	●
GEOAX	●	●	●	●	●	●
GET	●	●	●	●	●	●
GETACTT	●	●	●	●	●	●
GETACTTD	●	●	●	●	●	●
GETD	●	●	●	●	●	●
GETDNO	●	●	●	●	●	●
GETEXET	●	●	●	●	●	●
GETFREELOC	●	●	●	●	●	●
GETSELT	●	●	●	●	●	●
GETT	●	●	●	●	●	●
GETTCOR	●	●	●	●	●	●
GETTENV	●	●	●	●	●	●
GOTO	●	●	●	●	●	●
GOTOB	●	●	●	●	●	●
GOTOC	●	●	●	●	●	●
GOTOF	●	●	●	●	●	●
GOTOS	●	●	●	●	●	●
GP	●	●	●	●	●	●
GWPSOF	●	●	●	●	●	●
GWPSON	●	●	●	●	●	●
H...	●	●	●	●	●	●
HOLES1	●	●	●	●	●	●
HOLES2	●	●	●	●	●	●
I	●	●	●	●	●	●
I1	●	●	●	●	●	●
IC	●	●	●	●	●	●
ICYCOF	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
ICYCON	●	●	●	●	●	●
ID	●	●	●	●	●	●
IDS	●	●	●	●	●	●
IF	●	●	●	●	●	●
INDEX	●	●	●	●	●	●
INIPO	●	●	●	●	●	●
INIRE	●	●	●	●	●	●
INICF	●	●	●	●	●	●
INIT	-	-	-	-	-	-
INITIAL	●	●	●	●	●	●
INT	●	●	●	●	●	●
INTERSEC	●	●	●	●	●	●
INVCCW	-	-	-	-	-	-
INVCW	-	-	-	-	-	-
INVFRAME	●	●	●	●	●	●
IP	●	●	●	●	●	●
IPOBRKA	●	●	●	●	●	●
IPOENDA	●	●	●	●	●	●
IPTRLOCK	●	●	●	●	●	●
IPTRUNLOCK	●	●	●	●	●	●
ISAXIS	●	●	●	●	●	●
ISD	-	-	-	-	-	-
ISFILE	●	●	●	●	●	●
ISNUMBER	●	●	●	●	●	●
ISOCALL	●	●	●	●	●	●
ISVAR	●	●	●	●	●	●
J	●	●	●	●	●	●
J1	●	●	●	●	●	●
JERKA	●	●	●	●	●	●
JERKLIM	●	●	●	●	●	●
JERKLIMA	●	●	●	●	●	●
K	●	●	●	●	●	●
K1	●	●	●	●	●	●
KONT	●	●	●	●	●	●
KONTC	●	●	●	●	●	●
KONTT	●	●	●	●	●	●
L	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
LEAD Tool orientation Orientation polynomial	- -	- -	- -	- -	- -	- -
LEADOF	-	-	-	-	-	-
LEADON	-	-	-	-	-	-
LENTOAX	●	●	●	●	●	●
LFOF	●	●	●	●	●	●
LFON	●	●	●	●	●	●
LFPOS	●	●	●	●	●	●
LFTXT	●	●	●	●	●	●
LFWP	●	●	●	●	●	●
LIFTFAST	●	●	●	●	●	●
LIMS	●	●	●	●	●	●
LLI	●	●	●	●	●	●
LN	●	●	●	●	●	●
LOCK	●	●	●	●	●	●
LONGHOLE	-	-	-	-	-	-
LOOP	●	●	●	●	●	●
M0	●	●	●	●	●	●
M1	●	●	●	●	●	●
M2	●	●	●	●	●	●
M3	●	●	●	●	●	●
M4	●	●	●	●	●	●
M5	●	●	●	●	●	●
M6	●	●	●	●	●	●
M17	●	●	●	●	●	●
M19	●	●	●	●	●	●
M30	●	●	●	●	●	●
M40	●	●	●	●	●	●
M41 ... M45	●	●	●	●	●	●
M70	●	●	●	●	●	●
MASLDEF	●	●	●	●	●	●
MASLDEL	●	●	●	●	●	●
MASLOF	●	●	●	●	●	●
MASLOFS	●	●	●	●	●	●
MASLON	●	●	●	●	●	●
MATCH	●	●	●	●	●	●
MAXVAL	●	●	●	●	●	●
MCALL	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
MEAC	-	-	-	-	-	-
MEAFRAME	●	●	●	●	●	●
MEAS	●	●	●	●	●	●
MEASA	-	-	-	-	-	-
MEASURE	●	●	●	●	●	●
MEAW	●	●	●	●	●	●
MEAWA	-	-	-	-	-	-
MI	●	●	●	●	●	●
MINDEX	●	●	●	●	●	●
MINVAL	●	●	●	●	●	●
MIRROR	●	●	●	●	●	●
MMC	●	●	●	●	●	●
MOD	●	●	●	●	●	●
MODAXVAL	●	●	●	●	●	●
MOV	●	●	●	●	●	●
MSG	●	●	●	●	●	●
MVTOOL	●	●	●	●	●	●
N	●	●	●	●	●	●
NCK	●	●	●	●	●	●
NEWCONF	●	●	●	●	●	●
NEWT	●	●	●	●	●	●
NORM	●	●	●	●	●	●
NOT	●	●	●	●	●	●
NPROT	●	●	●	●	●	●
NPROTDEF	●	●	●	●	●	●
NUMBER	●	●	●	●	●	●
OEMIPO1	-	-	-	-	-	-
OEMIPO2	-	-	-	-	-	-
OF	●	●	●	●	●	●
OFFN	●	●	●	●	●	●
OMA1	-	-	-	-	-	-
OMA2	-	-	-	-	-	-
OMA3	-	-	-	-	-	-
OMA4	-	-	-	-	-	-
OMA5	-	-	-	-	-	-
OR	●	●	●	●	●	●
ORIAXES	-	-	-	-	-	-
ORIAXPOS	-	-	-	-	-	-
ORIC	-	-	-	-	-	-

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
ORICONCCW	-	-	-	-	-	-
ORICONCW	-	-	-	-	-	-
ORICONIO	-	-	-	-	-	-
ORICONTO	-	-	-	-	-	-
ORICURVE	-	-	-	-	-	-
ORID	-	-	-	-	-	-
ORIEULER	-	-	-	-	-	-
ORIMKS	-	-	-	-	-	-
ORIPATH	-	-	-	-	-	-
ORIPATHS	-	-	-	-	-	-
ORIPLANE	-	-	-	-	-	-
ORIRESET	-	-	-	-	-	-
ORIROTA	-	-	-	-	-	-
ORIROTC	-	-	-	-	-	-
ORIROTR	-	-	-	-	-	-
ORIROTT	-	-	-	-	-	-
ORIRPY	-	-	-	-	-	-
ORIRPY2	-	-	-	-	-	-
ORIS	-	-	-	-	-	-
ORISOF	-	-	-	-	-	-
ORISON	-	-	-	-	-	-
ORIVECT	-	-	-	-	-	-
ORIVIRT1	-	-	-	-	-	-
ORIVIRT2	-	-	-	-	-	-
ORIWKS	-	-	-	-	-	-
OS	-	-	-	-	-	-
OSB	-	-	-	-	-	-
OSC	-	-	-	-	-	-
OSCILL	-	-	-	-	-	-
OSCTRL	-	-	-	-	-	-
OSD	-	-	-	-	-	-
OSE	-	-	-	-	-	-
OSNSC	-	-	-	-	-	-
OSOF	-	-	-	-	-	-
OSP1	-	-	-	-	-	-
OSP2	-	-	-	-	-	-
OSS	-	-	-	-	-	-
OSSE	-	-	-	-	-	-
OST	-	-	-	-	-	-

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
OST1	-	-	-	-	-	-
OST2	-	-	-	-	-	-
OTOL	-	●	-	●	-	●
OVR	●	●	●	●	●	●
OVRA	●	●	●	●	●	●
OVRRAP	●	●	●	●	●	●
P	●	●	●	●	●	●
PAROT	●	●	●	●	●	●
PAROTOF	●	●	●	●	●	●
PCALL	●	●	●	●	●	●
PDELAYOF	-	-	-	-	-	-
PDELAYON	-	-	-	-	-	-
PHU	●	●	●	●	●	●
PL	- -	○ -	- -	○ -	- -	○ -
PM	●	●	●	●	●	●
PO	-	-	-	-	-	-
POCKET3	●	●	●	●	●	●
POCKET4	●	●	●	●	●	●
POLF	●	●	●	●	●	●
POLFA	●	●	●	●	●	●
POLFMASK	●	●	●	●	●	●
POLFMLIN	●	●	●	●	●	●
POLY	-	-	-	-	-	-
POLYPATH	-	-	-	-	-	-
PON	-	-	-	-	-	-
PONS	-	-	-	-	-	-
POS	●	●	●	●	●	●
POSA	●	●	●	●	●	●
POSM	●	●	●	●	●	●
POSP	●	●	●	●	●	●
POSRANGE	●	●	●	●	●	●
POT	●	●	●	●	●	●
PR	●	●	●	●	●	●
PREPRO	●	●	●	●	●	●
PRESETON	●	●	●	●	●	●
PRIO	●	●	●	●	●	●
PROC	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
PTP	●	●	●	●	●	●
PTPG0	●	●	●	●	●	●
PUNCHACC	-	-	-	-	-	-
PUTFTOC	●	●	●	●	●	●
PUTFTOCF	●	●	●	●	●	●
PW	-	○	-	○	-	○
QECLRNOF	●	●	●	●	●	●
QECLRNON	●	●	●	●	●	●
QU	●	●	●	●	●	●
R...	●	●	●	●	●	●
RAC	●	●	●	●	●	●
RDISABLE	●	●	●	●	●	●
READ	●	●	●	●	●	●
REAL	●	●	●	●	●	●
REDEF	●	●	●	●	●	●
RELEASE	●	●	●	●	●	●
REP	●	●	●	●	●	●
REPEAT	●	●	●	●	●	●
REPEATB	●	●	●	●	●	●
REPOSA	●	●	●	●	●	●
REPOSH	●	●	●	●	●	●
REPOSHA	●	●	●	●	●	●
REPOSL	●	●	●	●	●	●
REPOSQ	●	●	●	●	●	●
REPOSQA	●	●	●	●	●	●
RESET	●	●	●	●	●	●
RESETMON	●	●	●	●	●	●
RET	●	●	●	●	●	●
RIC	●	●	●	●	●	●
RINDEX	●	●	●	●	●	●
RMB	●	●	●	●	●	●
RME	●	●	●	●	●	●
RMI	●	●	●	●	●	●
RMN	●	●	●	●	●	●
RND	●	●	●	●	●	●
RNDM	●	●	●	●	●	●
ROT	●	●	●	●	●	●
ROTS	●	●	●	●	●	●
ROUND	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
ROUNDUP	●	●	●	●	●	●
RP	●	●	●	●	●	●
RPL	●	●	●	●	●	●
RT	●	●	●	●	●	●
RTLIOF	●	●	●	●	●	●
RTLION	●	●	●	●	●	●
S	●	●	●	●	●	●
SAVE	●	●	●	●	●	●
SBLOF	●	●	●	●	●	●
SBLON	●	●	●	●	●	●
SC	●	●	●	●	●	●
SCALE	●	●	●	●	●	●
SCC	●	●	●	●	●	●
SCPARA	●	●	●	●	●	●
SD	-	○	-	○	-	○
SEFORM	●	●	●	●	●	●
SET	●	●	●	●	●	●
SETAL	●	●	●	●	●	●
SETDNO	●	●	●	●	●	●
SETINT	●	●	●	●	●	●
SETM	-	-	-	-	-	-
SETMS	●	●	●	●	●	●
SETMS(n)	●	●	●	●	●	●
SETMTH	●	●	●	●	●	●
SETPIECE	●	●	●	●	●	●
SETTA	●	●	●	●	●	●
SETTCOR	●	●	●	●	●	●
SETTIA	●	●	●	●	●	●
SF	●	●	●	●	●	●
SIN	●	●	●	●	●	●
SIRELAY	-	-	-	-	-	-
SIRELIN	-	-	-	-	-	-
SIRELOUT	-	-	-	-	-	-
SIRELTIME	-	-	-	-	-	-
SLOT1	●	●	●	●	●	●
SLOT2	●	●	●	●	●	●
SOFT	●	●	●	●	●	●
SOFTA	●	●	●	●	●	●
SON	-	-	-	-	-	-

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
SONS	-	-	-	-	-	-
SPATH	●	●	●	●	●	●
SPCOF	●	●	●	●	●	●
SPCON	●	●	●	●	●	●
SPI	●	●	●	●	●	●
SPIF1	-	-	-	-	-	-
SPIF2	-	-	-	-	-	-
SPLINEPATH	-	○	-	○	-	○
SPN	-	-	-	-	-	-
SPOF	-	-	-	-	-	-
SPOS	●	●	●	●	●	●
SPOSA	●	●	●	●	●	●
SPP	-	-	-	-	-	-
SPRINT	●	●	●	●	●	●
SQRT	●	●	●	●	●	●
SR	-	-	-	-	-	-
SRA	-	-	-	-	-	-
ST	-	-	-	-	-	-
STA	-	-	-	-	-	-
START	-	-	-	-	-	-
STARTFIFO	●	●	●	●	●	●
STAT	●	●	●	●	●	●
STOLF	-	-	-	-	-	-
STOPFIFO	●	●	●	●	●	●
STOPRE	●	●	●	●	●	●
STOPREOF	●	●	●	●	●	●
STRING	●	●	●	●	●	●
STRINGFELD	●	●	●	●	●	●
STRINGIS	●	●	●	●	●	●
STRINGVAR	-	-	-	-	-	-
STRLEN	●	●	●	●	●	●
SUBSTR	●	●	●	●	●	●
SUPA	●	●	●	●	●	●
SVC	●	●	●	●	●	●
SYNFCT	●	●	●	●	●	●
SYNR	●	●	●	●	●	●
SYNRW	●	●	●	●	●	●
SYNW	●	●	●	●	●	●
T	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
TAN	●	●	●	●	●	●
TANG	-	-	-	-	-	-
TANGDEL	-	-	-	-	-	-
TANGOF	-	-	-	-	-	-
TANGON	-	-	-	-	-	-
TCA (828D: _TCA)	●	●	●	●	●	●
TCARR	-	●	-	●	-	●
TCI	●	●	●	●	●	●
TCOABS	-	●	-	●	-	●
TCOFR	-	●	-	●	-	●
TCOFRX	-	●	-	●	-	●
TCOFRY	-	●	-	●	-	●
TCOFRZ	-	●	-	●	-	●
THETA	-	-	-	-	-	-
TILT	-	-	-	-	-	-
TLIFT	-	-	-	-	-	-
TMOF	●	●	●	●	●	●
TMON	●	●	●	●	●	●
TO	●	●	●	●	●	●
TOFF	●	●	●	●	●	●
TOFFL	●	●	●	●	●	●
TOFFOF	●	●	●	●	●	●
TOFFON	●	●	●	●	●	●
TOFFR	●	●	●	●	●	●
TOFRAME	●	●	●	●	●	●
TOFRAMEX	●	●	●	●	●	●
TOFRAMEY	●	●	●	●	●	●
TOFRAMEZ	●	●	●	●	●	●
TOLOWER	●	●	●	●	●	●
TOOLENV	●	●	●	●	●	●
TOROT	●	●	●	●	●	●
TOROTOF	●	●	●	●	●	●
TOROTX	●	●	●	●	●	●
TOROTY	●	●	●	●	●	●
TOROTZ	●	●	●	●	●	●
TOUPPER	●	●	●	●	●	●
TOWBCS	-	●	-	●	-	●
TOWKCS	-	●	-	●	-	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
TOWMCS	-	●	-	●	-	●
TOWSTD	-	●	-	●	-	●
TOWTCS	-	●	-	●	-	●
TOWWCS	-	●	-	●	-	●
TR	●	●	●	●	●	●
TRAANG	-	-	-	-	○	-
TRACON	-	-	-	-	○	-
TRACYL	○	○	○	○	○	○
TRAFOOF	●	●	●	●	●	●
TRAILOF	●	●	●	●	●	●
TRAILON	●	●	●	●	●	●
TRANS	●	●	●	●	●	●
TRANSMIT	○	○	○	○	○	○
TRAORI	-	●	-	●	-	●
TRUE	●	●	●	●	●	●
TRUNC	●	●	●	●	●	●
TU	●	●	●	●	●	●
TURN	●	●	●	●	●	●
ULI	●	●	●	●	●	●
UNLOCK	●	●	●	●	●	●
UNTIL	●	●	●	●	●	●
UPATH	●	●	●	●	●	●
VAR	●	●	●	●	●	●
VELOLIM	●	●	●	●	●	●
VELOLIMA	●	●	●	●	●	●
WAITC	-	-	-	-	○	-
WAITE	-	-	-	-	-	-
WAITENC	-	-	-	-	-	-
WAITM	-	-	-	-	-	-
WAITMC	-	-	-	-	-	-
WAITP	●	●	●	●	●	●
WAITS	●	●	●	●	●	●
WALCS0	●	●	●	●	●	●
WALCS1	●	●	●	●	●	●
WALCS2	●	●	●	●	●	●
WALCS3	●	●	●	●	●	●
WALCS4	●	●	●	●	●	●
WALCS5	●	●	●	●	●	●
WALCS6	●	●	●	●	●	●

Operation	828D control version					
	PPU240.2 / 241.2		PPU260.2 / 261.2		PPU280.2 / 281.2	
	basic T	basic M	Turning	Milling	Turning	Milling
WALCS7	●	●	●	●	●	●
WALCS8	●	●	●	●	●	●
WALCS9	●	●	●	●	●	●
WALCS10	●	●	●	●	●	●
WALIMOF	●	●	●	●	●	●
WALIMON	●	●	●	●	●	●
WHEN	●	●	●	●	●	●
WHENEVER	●	●	●	●	●	●
WHILE	●	●	●	●	●	●
WRITE	●	●	●	●	●	●
WRTPR	●	●	●	●	●	●
X	●	●	●	●	●	●
XOR	●	●	●	●	●	●
Y	●	●	●	●	●	●
Z	●	●	●	●	●	●

●	Standard
○	Option
-	Not available

16.3 Addresses

List of addresses

The list of addresses consists of:

- Address letters
- Fixed addresses
- Fixed addresses with axis expansion
- Settable addresses

Address letters

The following address letters are available:

Letter	Meaning	Numeric extension
A	Settable address identifier	x
B	Settable address identifier	x
C	Settable address identifier	x
D	Selection/deselection of tool length compensation, tool cutting edge	
E	Settable address identifier	
F	Feedrate dwell time in seconds	x
G	G function	
H	H function	x
I	Settable address identifier	x
J	Settable address identifier	x
K	Settable address identifier	x
L	Subroutines, subroutine call	
M	M function	x
N	Subblock number	
O	Unassigned	
P	Number of program runs	
Q	Settable address identifier	x
R	Variable identifier (arithmetic parameter) / settable address identifier without numerical extension	x
S	Spindle value dwell time in spindle revolutions	x x
T	Tool number	x
V	Settable address identifier	x
V	Settable address identifier	x
W	Settable address identifier	x
X	Settable address identifier	x

Letter	Meaning	Numeric extension
Y	Settable address identifier	x
Z	Settable address identifier	x
%	Start character and separator for file transfer	
:	Main block number	
/	Skip identifier	

Available fixed addresses

Axis identifier	Address type	Modal/non-modal	G70/G71	G700/G710	G90/G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Data type
L	Subroutine no.	s									Integer without sign
P	Number of subroutine passes	s									Integer without sign
N	Block number	s									Integer without sign
G	G function	See list of G functions									Integer without sign
F	Feed, dwell time	m, s	x							x	Real without sign
OVR	Override	m									Real without sign
S	Spindle, dwell time	m, s								x	Real without sign
SPOS	Spindle position	m	x	x	x						Real
SPOSA	Spindle position beyond block limits	m	x	x	x						Real
T	Tool number	m								x	Integer without sign
D	Offset number	m								x	Integer without sign
M, H,	Auxiliary functions	s								x	M: Integer without sign H: Real

Fixed addresses with axis expansion

Axis identifier	Address type	Modal /non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Data type
AX: Axis	Variable axis identifier	*)	x	x	x	x	x	x			Real
IP: Interpolation parameter	Variable interpolation parameter	s	x	x	x	x	x				Real
POS: Positioning axis	Positioning axis	m	x	x	x	x	x	x	x		Real
POSA: Positioning axis above end of block	Positioning axis across block boundaries	m	x	x	x	x	x	x	x		Real
POSP: Positioning axis in parts	Positioning axis in parts (oscillation)	m	x	x	x	x	x	x			Real: End position / Real: Partial length Integer: Option
PO: Polynomial	Polynomial coefficient	s	x	x							Real without sign
FA: Feed axial	Axial feedrate	m	x							x	Real without sign
FL: Feed limit	Axial feed limit	m	x								Real without sign
OVRA: Override	Axial override	m	x								Real without sign
ACC: Axial acceleration	Axial acceleration	m									Real without sign
FMA: Feedrate multiple axial	Synchronous feedrate axial	m	x								Real without sign
STW: Sparking-out time axial	Sparking out time axial	m									Real without sign
SRA: Sparking-out retract	Retraction path on external input axial	m	x	x							Real without sign
OS: Oscillating ON/OFF	Oscillation ON/OFF	m									Integer without sign

Axis identifier	Address type	Modal /non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Data type
OST1: Oscillating time 1	Stopping time at left reversal point (oscillation)	m									Real
OST2: Oscillating time 2	Stopping time at right reversal point (oscillation)	m									Real
OSP1: Oscillating position 1	Left reversal point (oscillation)	m	x	x	x	x	x	x			Real
OSP2: Oscillating position 2	Right reversal point (oscillation)	m	x	x	x	x	x	x			Real
OSB: Oscillating start	Oscillation start position	m	x	x	x	x	x	x			Real
OSE: Oscillating end position	Oscillation end position	m	x	x	x	x	x	x			Real
OSNSC: Oscillating: number spark-out cycles	Number of spark-out cycles (oscillation)	m									Integer without sign
OSCTRL: Oscillating control	Oscillation control options	m									Integer without sign: set options, integer without sign: reset options
OSCILL: Oscillating	Axis assignment for oscillation activate oscillation	m									Axis: 1 - 3 infeed axes
FDA: Feedrate DRF axial	Axis feedrate for handwheel override	s	x								Real without sign
FGREF	Reference radius	m	x	x							Real without sign
POLF	LIFTFAST position	m	x	x							Real without sign
FXS: Fixed stop	Travel to fixed stop ON	m									Integer without sign

Axis identifier	Address type	Modal /non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Data type
FXST: Fixed stop torque	Torque limit for travel to fixed stop	m									Real
FXSW: Fixed stop window	Monitoring window for travel to fixed stop	m									Real

In these addresses, an axis or an expression of axis type is specified in square brackets. The data type in the above column shows the type of value assigned.
*) Absolute end points: modal, incremental end points: non-modal, otherwise modal/non-modal depending on syntax of G function.

Settable addresses

Axis identifier	Address type	Modal/ non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Max. num-ber	Data type
Axis values and end points												
X, Y, Z, A, B, C	Axis	*)	x	x	x	x	x	x		8		Real
AP: Angle polar	Polar angle	m/s*	x	x	x					1		Real
RP: Polar radius	Polar radius	m/s*	x	x	x	x	x			1		Real without sign
Tool orientation												
A2, B2, C2 [1])	Euler angle or RPY angle	s								3		Real
A3, B3, C3	Direction vector component	s								3		Real
A4, B4, C4 for start of block	Normal vector component	s								3		Real
A5, B5, C5 for end of block	Normal vector component	s								3		Real
A6, B6, C6 standardized vector	Direction vector component	s								3		Real

Axis identifier	Address type	Modal/ non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Max. number	Data type
A7, B7, C7 standardized vector	Intermediate orientation component	s								3		Real
LEAD: Lead angle	Lead angle	m								1		Real
THETA: Third degree of freedom tool orientation	Angle of rotation, rotation around the tool direction	s			x	x	x			1		Real
TILT: Tilt angle	Tilt angle	m								1		Real
ORIS: Orientation smoothing factor	Orientation change (referring to the path)	m								1		Real
Interpolation parameters												
I, J, K** I1, J1, K1	Interpolation parameter Intermediate point coordinate	s s	x x	x x	 x	x** x	x** x			3		Real Real
RPL: Rotation plane	Rotation in the plane	s								1		Real
CR: Circle radius	Circle radius	s	x	x						1		Real without sign
AR: Angle circular	Opening angle									1		Real without sign
TURN	Number of turns for helix	s								1		Integer without sign
PL: Parameter interval length	Parameter interval length	s								1		Real without sign
PW: Point	Point weight	s								1		Real without sign
SD: Spline degree	Spline degree	s								1		Integer without sign
TU: Turn	Turn	m										Int without sign

Axis identifier	Address type	Modal/ non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Max. number	Data type
STAT: State	State	m										Integer without sign
SF: Spindle offset	Starting point offset for thread cutting	m								1		Real
DISR: Distance for repositioning	Distance for repositioning	s	x	x						1		Real without sign
DISPR: Distance path for repositioning	Repos path difference	s	x	x						1		Real without sign
ALF: Angle lift fast	Fast retraction angle	m								1		Integer without sign
DILF: Distance lift fast	Fast retraction length	m	x	x						1		Real
FP	Fixed point: Number of fixed point to approach	s								1		Integer without sign
RNDM: Round modal	Modal rounding	m	x	x						1		Real without sign
RND: Round	Non-modal rounding	s	x	x						1		Real without sign
CHF: Chamfer	Chamfer non-modal	s	x	x						1		Real without sign
CHR: Chamfer	Chamfer in initial direction of motion	s	x	x						1		Real without sign
ANG: Angle	Contour angle	s								1		Real
ISD: Insertion depth	Insertion depth	m	x	x						1		Real
DISC: Distance	Transition circle overshoot tool offset	m	x	x						1		Real without sign
OFFN	Offset contour - normal	m	x	x						1		Real

Axis identifier	Address type	Modal/ non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Max. number	Data type
DITS	Thread run-in path	m	x	x						1		Real
DITE	Thread run-out path	m	x	x						1		Real
Nibbling/punching												
SPN: Stroke/ punch number 1)	Number of path sections per block	s								1		INT
SPP: Stroke/punch path 1)	Length of a path section	m								1		Real
Grinding												
ST: Sparking-out time	Sparking-out time	s								1		Real without sign
SR: Sparking-out retract path	Return path	s	x	x						1		Real without sign
Approximate positioning criteria												
ADIS	Rounding clearance	m	x	x						1		Real without sign
ADISPOS	Rounding clearance for rapid traverse	m	x	x						1		Real without sign
Measurement												
MEAS: Measure	Measure with touch-trigger probe	s								1		Integer without sign
MEAW: Measure without deleting distance-to-go	Measure without deleting distance-to-go	s								1		Integer without sign
Axis, spindle behavior												
LIMS: Limit spindle speed	Spindle speed limitation	m								1		Real without sign
Feedrates												
FAD	Speed of the slow infeed motion	s		x						1		Real without sign

Axis identifier	Address type	Modal/ non-modal	G70/ G71	G700/ G710	G90/ G91	IC	AC	DC, ACN, ACP	CIC, CAC, CDC, CACN, CACP	Qu	Max. num-ber	Data type
FD: Feed DRF	Path feed for hand-wheel override	s		x						1		Real without sign
FRC	Feed for radius and chamfer	s		x								Real without sign
FRCM	Feed for radius and chamfer, modal	m		x								Real without sign
OEM addresses												
OMA1: OEM address 1 [1]	OEM address 1	m				x	x	x		1		Real
OMA2: OEM address 2 [1]	OEM address 2	m				x	x	x		1		Real
OMA3: OEM address 3 [1]	OEM address 3	m				x	x	x		1		Real
OMA4: OEM address 4 [1]	OEM address 4	m				x	x	x		1		Real
OMA5: OEM address 5 [1]	OEM address 5	m				x	x	x		1		Real

*) Absolute end points: modal, incremental end points: non-modal, otherwise modal/non-modal depending on syntax of G function.

**)As circle center points, IPO parameters act incrementally. They can be programmed in absolute mode with AC. The address modification is ignored when the parameters have other meanings (e.g. thread lead).

[1] The keyword is not valid for NCU571.

16.4 G function groups

The G functions are divided into function groups. Only one G function of a group can be programmed in a block. A G function can be either modal (until it is canceled by another function of the same group) or only effective for the block in which it is programmed (non-modal)

Key:

[1] Internal number (e.g. for PLC interface)

[2] Configurability of the G function as a delete setting for the function group on power up, reset or end of part program with MD20150 $MC_GCODE_RESET_VALUES:

+ Configurable

- Not configurable

[3] Effectiveness of the G function:

m modal

n non-modal

[4] Default setting
If no function from the group is programmed with modal G functions, the default setting, which can be changed in the machine data
(MD20150 $MN_$MC_GCODE_RESET_VALUES), applies:

SAG Default setting **S**iemens **AG**

MM Default setting **M**achine **M**anufacturer (see machine manufacturer's specifications)

[5] The G function is not valid for NCU571.

Group 1: Modally valid motion commands						
G function	No. [1]	Meaning	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G0	1.	Rapid traverse	+	m		
G1	2.	Linear interpolation (linear interpolation)	+	m	x	
G2	3.	Circular interpolation clockwise	+	m		
G3	4.	Circular interpolation counterclockwise	+	m		
CIP	5.	Circular interpolation through intermediate point	+	m		
ASPLINE	6.	Akima spline	+	m		
BSPLINE	7.	B-spline	+	m		
CSPLINE	8.	Cubic spline	+	m		
POLY	9.	Polynomial interpolation	+	m		
G33	10.	Thread cutting with constant lead	+	m		
G331	11.	Tapping	+	m		
G332	12.	Retraction (tapping)	+	m		
OEMIPO1 [5]	13.	Reserved	+	m		
OEMIPO2 [5]	14.	Reserved	+	m		
CT	15.	Circle with tangential transition	+	m		
G34	16.	Thread cutting with linear increasing lead	+	m		

G35	17.	Thread cutting with linear decreasing lead	+	m		
INVCW	18.	Involute interpolation clockwise	+	m		
INVCCW	19.	Involute interpolation counter-clockwise	+	m		
If no function from the group is programmed with modal G functions, the default setting, which can be changed in the machine data (MD20150 $MN_$MC_GCODE_RESET_VALUES), applies:						

Group 2: Non-modally valid motions, dwell time						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G4	1.	Dwell time preset	-	n		
G63	2.	Tapping without synchronization	-	n		
G74	3.	Reference point approach with synchronization	-	n		
G75	4.	Fixed-point approach	-	n		
REPOSL	5.	Linear repositioning	-	n		
REPOSQ	6.	Repositioning in a quadrant	-	n		
REPOSH	7.	Repositioning in semicircle	-	n		
REPOSA	8.	Linear repositioning with all axes	-	n		
REPOSQA	9.	Linear repositioning with all axes, geometry axes in quadrant	-	n		
REPOSHA	10.	Repositioning with all axes; geometry axes in semicircle	-	n		
G147	11.	Approach contour with straight line	-	n		
G247	12.	Approach contour with quadrant	-	n		
G347	13.	Approach contour with semicircle	-	n		
G148	14.	Leave contour with straight line	-	n		
G248	15.	Leave contour with quadrant	-	n		
G348	16.	Leave contour with semicircle	-	n		
G5	17.	Oblique plunge-cut grinding	-	n		
G7	18.	Compensatory motion during oblique plunge-cut grinding	-	n		

Group 3: Programmable frame, working area limitation and pole programming						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
TRANS	1.	TRANSLATION: Programmable offset	-	n		
ROT	2.	ROTATION: Programmable rotation	-	n		
SCALE	3.	SCALE: Programmable scaling	-	n		
MIRROR	4.	MIRROR: Programmable mirroring	-	n		
ATRANS	5.	Additive TRANSLATION: Additive programmable offset	-	n		
AROT	6.	Additive ROTATION: Programmable rotation	-	n		
ASCALE	7.	Additive SCALE: Programmable scaling	-	n		
AMIRROR	8.	Additive MIRROR: Programmable mirroring	-	n		
	9.	Unassigned				

G25	10.	Minimum working area limitation/spindle speed limitation	-	n		
G26	11.	Maximum working area limitation/spindle speed limitation	-	n		
G110	12.	Pole programming relative to the last programmed setpoint position	-	n		
G111	13.	Polar programming relative to origin of current workpiece coordinate system	-	n		
G112	14.	Pole programming relative to the last valid pole	-	n		
G58	15.	Programmable offset, absolute axial substitution	-	n		
G59	16.	Programmable offset, additive axial substitution	-	n		
ROTS	17.	Rotation with solid angle	-	n		
AROTS	18.	Additive rotation with solid angle	-	n		

Group 4: FIFO						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
STARTFIFO	1.	Start FIFO Execute and simultaneously fill preprocessing memory	+	m	x	
STOPFIFO	2.	STOP FIFO, stop machining; fill preprocessing memory until STARTFIFO is detected, FIFO is full or end of program	+	m		
FIFOCTRL	3.	Activation of automatic preprocessing memory control	+	m		

Group 6: Plane selection						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G17	1.	Plane selection 1st - 2nd geometry axis	+	m	x	
G18	2.	Plane selection 3rd - 1st geometry axis	+	m		
G19	3.	Plane selection 2nd - 3rd geometry axis	+	m		

Group 7: Tool radius compensation						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G40	1.	No tool radius compensation	+	m	x	
G41	2.	Tool radius compensation left of contour	-	m		
G42	3.	Tool radius compensation right of contour	-	m		

Group 8: Settable zero offset						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G500	1.	Deactivation of adjustable work offset (G54 to G57, G505 to G599)	+	m	x	
G54	2.	1st Settable zero offset	+	m		

G55	3.	2nd adjustable work offset	+	m		
G56	4.	3rd adjustable work offset	+	m		
G57	5.	4th adjustable work offset	+	m		
G505	6.	5th adjustable work offset	+	m		
...	...	...	+	m		
G599	100.	99th adjustable work offset	+	m		
Each of the G functions in this group is used to activate an adjustable user frame $P_UIFR[ ]. G54 corresponds to frame $P_UIFR[1], G505 corresponds to frame $P_UIFR[5]. The number of adjustable user frames and, therefore, the number of G functions in this group, can be parameterized using machine data MD28080 $MC_MM_NUM_USER_FRAMES.						

Group 9: Frame suppression						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G53	1.	Suppression of current frames: Programmable frame including system frame for TOROT and TOFRAME and active adjustable frame (G54 to G57, G505 to G599).	-	n		
SUPA	2.	As for G153 including suppression of system frames for actual-value setting, scratching, ext. work offset, PAROT including handwheel offsets (DRF), [external work offset], overlaid movement	-	n		
G153	3.	As for G53 including suppression of all channel-specific and/or NCU-global basic frames	-	n		

Group 10: Exact stop - continuous-path mode						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G60	1.	Exact stop	+	m	x	
G64	2.	Continuous-path mode	+	m		
G641	3.	Continuous-path mode with smoothing as per distance criterion (= programmable rounding clearance)	+	m		
G642	4.	Continuous-path mode with smoothing within the defined tolerances	+	m		
G643	5.	Continuous-path mode with smoothing within the defined tolerances (block-internal)	+	m		
G644	6.	Continuous-path mode with smoothing with maximum possible dynamic response	+	m		
G645	7.	Continuous-path mode with smoothing and tangential block transitions within the defined tolerances	+	m		

Group 11: Exact stop, non-modal						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G9	1.	Exact stop	-	n		

Group 12: Block change criteria at exact stop (G60/G9)						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G601	1.	Block change at exact stop fine	+	m	x	
G602	2.	Block change at exact stop coarse	+	m		
G603	3.	Block change at IPO - end of block	+	m		

Group 13: Workpiece measuring inch/metric						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G70	1.	Input system inches (length)	+	m		
G71	2.	Input system metric mm (lengths)	+	m	x	
G700	3.	Input system inch, inch/min (lengths + velocity + system variable)	+	m		
G710	4.	Input system metric mm, mm/min (lengths + velocity + system variable)	+	m		

Group 14: Workpiece measuring absolute/incremental						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G90	1.	Absolute dimension	+	m	x	
G91	2.	Incremental dimension input	+	m		

Group 15: Feed type						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
G93	1.	Inverse-time feedrate 1/rpm	+	m		
G94	2.	Linear feedrate in mm/min, inch/min	+	m	x	
G95	3.	Revolutional feedrate in mm/rev, inch/rev	+	m		
G96	4.	Constant cutting rate and type of feedrate as for G95 ON	+	m		
G97	5.	Constant cutting rate and type of feedrate as for G95 OFF	+	m		
G931	6.	Feedrate specification by means of traversing time, deactivate constant path velocity	+	m		
G961	7.	Constant cutting rate and type of feedrate as for G94 ON	+	m		
G971	8.	Constant cutting rate and type of feedrate as for G94 OFF	+	m		
G942	9.	Freeze linear feedrate and constant cutting rate or spindle speed	+	m		
G952	10.	Freeze revolutional feedrate and constant cutting rate or spindle speed	+	m		
G962	11.	Linear feedrate or revolutional feedrate and constant cutting rate	+	m		

G972	12.	Freeze linear feedrate or revolutional feedrate and constant cutting rate	+	m		
G973	13	Revolutional feedrate without spindle speed limitation (G97 without LIMS for ISO mode)	+	m		

Group 16: Feedrate override on inside and outside curvature

G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
CFC	1.	Constant feedrate at contour effective for internal and external radius	+	m	x	
CFTCP	2.	Constant feedrate in tool center point (center point path)	+	m		
CFIN	3.	Constant feedrate for internal radius only, acceleration for external radius	+	m		

Group 17: Approach and retraction response, tool offset

G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
NORM	1.	Normal position at starting and end points	+	m	x	
KONT	2.	Travel around contour at starting and end points	+	m		
KONTT	3.	Approach/retraction with constant tangent	+	m		
KONTC	4.	Approach/retraction with constant curvature	+	m		

Group 18: Corner behavior, tool offset

G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G450	1.	Transition circle (tool travels around workpiece corners on a circular path)	+	m	x	
G451	2.	Intersection of equidistant paths (tool backs off from the workpiece corner)	+	m		

Group 19: Curve transition at beginning of spline

G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
BNAT	1.	Natural transition to first spline block	+	m	x	
BTAN	2.	Tangential transition to first spline block	+	m		
BAUTO	3.	Definition of the first spline section by means of the next 3 points	+	m		

Group 20: Curve transition at end of spline						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
ENAT	1.	Natural transition to next traversing block	+	m	x	
ETAN	2.	Tangential transition to next traversing block	+	m		
EAUTO	3.	Definition of the last spline section by means of the last 3 points	+	m		

Group 21: Acceleration profile						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
BRISK	1.	Fast non-smoothed path acceleration	+	m	x	
SOFT	2.	Soft smoothed path acceleration	+	m		
DRIVE	3.	Velocity-dependent path acceleration	+	m		

Group 22: Tool offset type						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
CUT2D	1.	2½D tool offset determined by G17-G19	+	m	x	
CUT2DF	2.	2½D tool offset determined by frame The tool offset is effective in relation to the current frame (inclined plane).	+	m		
CUT3DC [5]	3.	3D tool offset circumferential milling	+	m		
CUT3DF [5]	4.	3D tool offset face milling with non-constant tool orientation	+	m		
CUT3DFS [5]	5.	3D tool offset face milling with constant tool orientation independent of active frame	+	m		
CUT3DFF [5]	6.	3D tool offset face milling with fixed tool orientation dependent on active frame	+	m		
CUT3DCC [5]	7.	3D tool offset circumferential milling with limitation surfaces	+	m		
CUT3DCCD [5]	8.	3D tool offset circumferential milling with limitation surfaces and differential tool	+	m		

Group 23: Collision monitoring at inside contours						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
CDOF	1.	Collision detection OFF	+	m	x	
CDON	2.	Collision detection ON	+	m		
CDOF2	3.	Collision detection OFF (currently only for CUT3DC)	+	m		

Group 24: Feedforward control						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
FFWOF	1.	Feedforward control OFF	+	m	x	
FFWON	2.	Feedforward control ON	+	m		

Group 25: Tool orientation reference						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
ORIWKS 5)	1.	Tool orientation in workpiece coordinate system (WCS)	+	m	x	
ORIMKS 5)	2.	Tool orientation in machine coordinate system (MCS)	+	m		

Group 26: Repositioning point for REPOS						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
RMB	1.	Reapproach to start of block position	+	m		
RMI	2.	Reapproach to interruption point	+	m	x	
RME	3.	Repositioning to end-of-block position	+	m		
RMN	4.	Reapproach to nearest path point	+	m		

Group 27: Tool offset for change in orientation at outside corners						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
ORIC 5)	1.	Orientation changes at outside corners are superimposed on the circle block to be inserted	+	m	x	
ORID 5)	2.	Orientation changes are performed before the circle block	+	m		

Group 28: Working area limitation						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
WALIMON	1.	Working area limitation ON	+	m	x	
WALIMOF	2.	Working area limitation OFF	+	m		

Group 29: Radius/diameter programming						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
DIAMOF	1.	Modal channel-specific diameter programming OFF Deactivation activates channel-specific radius programming.	+	m	x	
DIAMON	2.	Modal independent channel-specific diameter programming ON The effect is independent of the programmed dimensions mode (G90/G91).	+	m		

DIAM90	3.	Modal dependent channel-specific diameter programming ON The effect is dependent on the programmed dimensions mode (G90/G91).	+	m		
DIAMCYCOF	4.	Modal channel-specific diameter programming during cycle processing OFF	+	m		

Group 30: NC block compression						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
COMPOF [5]	1.	NC block compression OFF	+	m	x	
COMPON [5]	2.	Compressor function COMPON ON	+	m		
COMPCURV [5]	3.	Compressor function COMPCURV ON	+	m		
COMPCAD [5]	4.	Compressor function COMPCAD ON	+	m		

Group 31: OEM G function group						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G810 [5]	1.	OEM G function	-	m		
G811 [5]	2.	OEM G function	-	m		
G812 [5]	3.	OEM G function	-	m		
G813 [5]	4.	OEM G function	-	m		
G814 [5]	5.	OEM G function	-	m		
G815 [5]	6.	OEM G function	-	m		
G816 [5]	7.	OEM G function	-	m		
G817 [5]	8.	OEM G function	-	m		
G818 [5]	9.	OEM G function	-	m		
G819 [5]	10.	OEM G function	-	m		
Two G function groups are reserved for the OEM user. This enables the OEM to program functions that can be customized.						

Group 32: OEM G function group						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G820 [5]	1.	OEM - G function	-	m		
G821 [5]	2.	OEM G function	-	m		
G822 [5]	3.	OEM G function	-	m		
G823 [5]	4.	OEM G function	-	m		
G824 [5]	5.	OEM G function	-	m		
G825 [5]	6.	OEM G function	-	m		
G826 [5]	7.	OEM G function	-	m		
G827 [5]	8.	OEM G function	-	m		

G828[5]	9.	OEM G function	-	m		
G829[5]	10.	OEM G function	-	m		
Two G function groups are reserved for the OEM user. This enables the OEM to program functions that can be customized.						

Group 33: Settable fine tool offset						
G function	No.[1]	Significance	MD20150[2]	W[3]	STD[4]	
					SAG	MM
FTOCOF[5]	1.	Online fine tool offset OFF	+	m	x	
FTOCON[5]	2.	Online fine tool offset ON	-	m		

Group 34: Tool orientation smoothing						
G function	No.[1]	Significance	MD20150[2]	W[3]	STD[4]	
					SAG	MM
OSOF[5]	1.	Tool orientation smoothing OFF	+	m	x	
OSC[5]	2.	Continuous tool orientation smoothing	+	m		
OSS[5]	3.	Tool orientation smoothing at end of block	+	m		
OSSE[5]	4.	Tool orientation smoothing at start and end of block	+	m		
OSD[5]	5	Block-internal smoothing with specification of path length	+	m		
OST[5]	6	Block-internal smoothing with specification of angular tolerance	+	m		

Group 35: Punching and nibbling						
G function	No.[1]	Significance	MD20150[2]	W[3]	STD[4]	
					SAG	MM
SPOF[5]	1.	Stroke OFF, nibbling and punching OFF	+	m	x	
SON[5]	2.	Nibbling ON	+	m		
PON[5]	3.	Punching ON	+	m		
SONS[5]	4.	Nibbling ON in interpolation cycle	-	m		
PONS[5]	5.	Punching ON in interpolation cycle	-	m		

Group 36: Punching with delay						
G function	No.[1]	Significance	MD20150[2]	W[3]	STD[4]	
					SAG	MM
PDELAYON[5]	1.	Punching with delay ON	+	m	x	
PDELAYOF[5]	2.	Punching with delay OFF	+	m		

Group 37: Feed profile						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
FNORM [5]	1.	Feed normal (as per DIN 66025)	+	m	x	
FLIN [5]	2.	Feed linear variable	+	m		
FCUB [5]	3.	Feedrate variable according to cubic spline	+	m		

Group 38: Assignment of fast inputs/outputs for punching/nibbling						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
SPIF1 [5]	1.	Fast NCK inputs/outputs for punching/nibbling byte 1	+	m	x	
SPIF2 [5]	2.	Fast NCK inputs/outputs for punching/nibbling byte 2	+	m		

Group 39: Programmable contour accuracy						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
CPRECOF	1.	Programmable contour precision OFF	+	m	x	
CPRECON	2.	Programmable contour precision ON	+	m		

Group 40: Tool radius compensation constant						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
CUTCONOF	1.	Constant tool radius compensation OFF	+	m	x	
CUTCONON	2.	Constant tool radius compensation ON	+	m		

Group 41: Interruptible thread cutting						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
LFOF	1.	Interruptible thread cutting OFF	+	m	x	
LFON	2.	Interruptible thread cutting ON	+	m		

Group 42: Toolholder						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
TCOABS	1.	Determine tool length components from the current tool orientation	+	m	x	
TCOFR	2.	Determine tool length components from the orientation of the active frame	+	m		
TCOFRZ	3.	Determine tool orientation of an active frame on selection of tool, tool points in Z direction	+	m		
TCOFRY	4.	Determine tool orientation of an active frame on selection of tool, tool points in Y direction	+	m		
TCOFRX	5.	Determine tool orientation of an active frame on selection of tool, tool points in X direction		m		

Group 43: SAR approach direction						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G140	1.	SAR approach direction defined by G41/G42	+	m	x	
G141	2.	SAR approach direction to left of contour	+	m		
G142	3.	SAR approach direction to right of contour	+	m		
G143	4.	SAR approach direction tangent-dependent	+	m		

Group 44: SAR path segmentation						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G340	1.	Spatial approach block; in other words, infeed depth and approach in plane in one block	+	m	x	
G341	2.	Start with infeed on perpendicular axis (Z), then approach in plane	+	m		

Group 45: Path reference for FGROUP axes						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
SPATH	1.	Path reference for FGROUP axes is arc length	+	m	x	
UPATH	2.	Path reference for FGROUP axes is curve parameter	+	m		

Group 46: Plane selection for fast retraction						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
LFTXT	1.	The plane is determined from the path tangent and the current tool orientation	+	m	x	
LFWP	2.	The plane is determined by the current working plane (G17/G18/G19)	+	m		
LFPOS	3.	Axial retraction to a position	+	m		

Group 47: Mode switchover for external NC code						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
G290	1.	Activate SINUMERIK language mode	+	m	x	
G291	2.	Activate ISO language mode	+	m		

Group 48: Approach and retraction response with tool radius compensation						
G function	No. [1)]	Significance	MD20150 [2)]	W [3)]	STD [4)]	
					SAG	MM
G460	1.	Collision detection for approach and retraction block ON	+	m	x	
G461	2.	Extend border block with arc if no intersection in TRC block	+	m		
G462	3.	Extend border block with straight line if no intersection in TRC block	+	m		

Group 49: Point-to-point motion						
G function	No. [1)]	Significance	MD20150 [2)]	W [3)]	STD [4)]	
					SAG	MM
CP	1.	Path motion	+	m	x	
PTP	2.	Point-to-point motion (synchronized axis motion)	+	m		
PTPG0	3.	Point-to-point motion only with G0, otherwise path motion CP	+	m		

Group 50: Orientation programming						
G function	No. [1)]	Significance	MD20150 [2)]	W [3)]	STD [4)]	
					SAG	MM
ORIEULER	1.	Orientation angle via Euler angle	+	m	x	
ORIRPY	2.	Orientation angle via RPY angle (rotation sequence XYZ)	+	m		
ORIVIRT1	3.	Orientation angle via virtual orientation axes (definition 1)	+	m		
ORIVIRT2	4.	Orientation angle via virtual orientation axes (definition 2)	+	m		
ORIAXPOS	5.	Orientation angle via virtual orientation axes with rotary axis positions	+	m		
ORIRPY2	6.	Orientation angle via RPY angle (rotation sequence ZYX)	+	m		

Group 51: Interpolation type for orientation programming						
G function	No. [1)]	Significance	MD20150 [2)]	W [3)]	STD [4)]	
					SAG	MM
ORIVECT	1.	Large-radius circular interpolation (identical to ORIPLANE)	+	m	x	
ORIAXES	2.	Linear interpolation of machine axes or orientation axes	+	m		
ORIPATH	3.	Tool orientation trajectory referred to path	+	m		
ORIPLANE	4.	Interpolation in plane (identical to ORIVECT)	+	m		
ORICONCW	5.	Interpolation on a peripheral surface of the cone in clockwise direction	+	m		
ORICONCCW	6.	Interpolation on the peripheral surface of a taper in the counter-clockwise direction	+	m		

ORICONIO	7.	Interpolation on a conical peripheral surface with intermediate orientation setting	+	m		
ORICONTO	8.	Interpolation on a peripheral surface of the cone with tangential transition	+	m		
ORICURVE	9.	Interpolation with additional space curve for orientation	+	m		
ORIPATHS	10.	Tool orientation in relation to path, blips in the orientation characteristic are smoothed	+	m		

Group 52: Frame rotation in relation to workpiece						
G function	No.[1]	Significance	MD20150[2]	W[3]	STD[4]	
					SAG	MM
PAROTOF	1.	Frame rotation in relation to workpiece OFF	+	m	x	
PAROT	2.	Frame rotation in relation to workpiece ON The workpiece coordinate system is aligned on the workpiece.	+	m		

Group 53: Frame rotation in relation to tool						
G function	No.[1]	Significance	MD20150[2]	W[3]	STD[4]	
					SAG	MM
TOROTOF	1.	Frame rotation in relation to tool OFF	+	m	x	
TOROT	2.	Align the Z axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	+	m		
TOROTZ	3.	As TOROT	+	m		
TOROTY	4.	Align the Y axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	+	m		
TOROTX	5.	Align the X axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	+	m		
TOFRAME	6.	Align the Z axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	+	m		
TOFRAMEZ	7.	As TOFRAME	+	m		
TOFRAMEY	8.	Align the Y axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	+	m		
TOFRAMEX	9.	Align the X axis of the workpiece coordinate system parallel to the workpiece orientation by rotating the frame	+	m		

Group 54: Vector rotation for polynomial programming						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
ORIROTA	1.	Vector rotation absolute	+	m	x	
ORIROTR	2.	Vector rotation relative	+	m		
ORIROTT	3.	Vector rotation tangential	+	m		
ORIROTC	4.	Tangential rotational vector in relation to path tangent	+	m		

Group 55: Rapid traverse with/without linear interpolation						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
RTLION	1.	Rapid traverse motion with linear interpolation ON	+	m	x	
RTLIOF	2.	Rapid traverse motion with linear interpolation OFF Rapid traverse motion is achieved with single-axis interpolation.	+	m		

Group 56: Inclusion of tool wear						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
TOWSTD	1.	Initial setting value for offsets in tool length	+	m	x	
TOWMCS	2.	Wear values in the machine coordinate system	+	m		
TOWWCS	3.	Wear values in the workpiece coordinate system	+	m		
TOWBCS	4.	Wear values in the basic coordinate system (BCS)	+	m		
TOWTCS	5.	Wear values in the tool coordinate system (toolholder ref. point T at the tool holder)	+	m		
TOWKCS	6.	Wear values in the coordinate system of the tool head for kinetic transformation (differs from machine coordinate system through tool rotation)	+	m		

Group 57: Corner deceleration						
G function	No. [1]	Significance	MD20150 [2]	W [3]	STD [4]	
					SAG	MM
FENDNORM	1.	Corner deceleration OFF	+	m	x	
G62	2.	Corner deceleration at inside corners when tool radius compensation is active (G41/G42)	+	m		
G621	3.	Corner deceleration at all corners	+	m		

Group 59: Dynamic response mode for path interpolation						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
DYNNORM	1.	Standard dynamic, as previously	+	m	x	
DYNPOS	2.	Positioning mode, tapping	+	m		
DYNROUGH	3.	Roughing	+	m		
DYNSEMIFIN	4.	Finishing	+	m		
DYNFINISH	5.	Smooth-finishing	+	m		

Group 60: Working area limitation						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
WALCS0	1.	Workpiece coordinate system working area limitation OFF	+	m	x	
WALCS1	2.	WCS working area limitation group 1 active	+	m		
WALCS2	3.	WCS working area limitation group 2 active	+	m		
WALCS3	4	WCS working area limitation group 3 active	+	m		
WALCS4	5	WCS working area limitation group 4 active	+	m		
WALCS5	6	WCS working area limitation group 5 active	+	m		
WALCS6	7	WCS working area limitation group 6 active	+	m		
WALCS7	8	WCS working area limitation group 7 active	+	m		
WALCS8	9	WCS working area limitation group 8 active	+	m		
WALCS9	10	WCS working area limitation group 9 active	+	m		
WALCS10	11	WCS working area limitation group 10 active	+	m		

Group 61: Tool orientation smoothing						
G function	No. 1)	Significance	MD20150 2)	W 3)	STD 4)	
					SAG	MM
ORISOF	1.	Tool orientation smoothing OFF	+	m	x	
ORISON	2.	Tool orientation smoothing ON	+	m		

16.5 Predefined subroutine calls

1. Coordinate system					
Keyword / subroutine identifier	**1st parameter**	**2nd parameter**	**3rd-15th parameter**	**4th-16th parameter**	**Explanation**
PRESETON	AXIS*: Axis identifier Machine axis	REAL: Preset offset G700/G7100 context	3rd-15th parameter as 1 ...	4th-16th parameter as 2 ...	Sets the actual value for programmed axes. One axis identifier is programmed at a time, with its respective value in the next parameter. PRESETON can be used to program preset offsets for up to 8 axes.
DRFOF					Deletes the DRF offset for all axes assigned to the channel.

*) As a general rule, geometry or special axis identifiers can also be used instead of the machine axis identifier, as long as the reference is unambiguous.

2. Axis groupings			
Keyword / subroutine identifier	**1st-8th parameter**	**Explanation**	
FGROUP	Channel axis identifiers	Variable F value reference: defines the axes to which the path feed refers. Maximum axis number: 8 The default setting for the F value reference is activated with FGROUP ( ) without parameters.	
	1st-8th parameter	**2nd-9th parameter**	**Explanation**
SPLINEPATH	INT: Spline group (must be 1)	AXIS: Geometry or special axis identifier	Definition of the spline group Maximum number of axes: 8
BRISKA	AXIS		Switch on brisk axis acceleration for the programmed axes
SOFTA	AXIS		Switch on jerk limited axis acceleration for programmed axes
JERKA	AXIS		The acceleration behavior set in machine data $MA_AX_JERK_ENABLE is active for the programmed axes.

3. Coupled motion							
Keyword / subroutine identifier	1st parameter	2nd param.	3rd param.	4th param.	5th param.	6th param.	Explanation
TANG	AXIS: Axis name following axis	AXIS: Leading axis 1	AXIS: Leading axis 2	REAL: Coupling factor	CHAR: Option: "B": follow-up in basic coordinate system "W": follow-up in work-piece coord. system	CHAR Optimization: "S" default "P" autom. with rounding travel, angle tolerance	Preparatory statement for the definition of a tangential follow-up: The tangent for the follow-up is determined by the two master axes specified. The coupling factor specifies the relationship between a change in the angle of tangent and the following axis. It is usually 1. Optimization: See PGA
TANGON	AXIS: Axis name following axis	REAL: Offset Angle	REAL: Rounding travel	REAL: Angle tolerance			Tangential follow-up mode ON: par. 3, 4 with TANG Par. 6 = "P"
TANGOF	AXIS: Axis name following axis						Tangential follow-up mode OFF
TLIFT	AXIS: Following axis	REAL: Lift-off path	REAL: Factor				Tangential lift: tangential follow-up mode, stop at contour end rotary axis lift-off possible
TRAILON	AXIS: Following axis	AXIS: Leading axis	REAL: Coupling factor				Trailing ON: Asynchronous coupled motion ON
TRAILOF	AXIS: Following axis	AXIS: Leading axis					Trailing OFF: Asynchronous coupled motion OFF

6. Revolutional feedrate			
Keyword / subroutine identifier	1st parameter	2nd parameter	Explanation
FPRAON	AXIS: Axis, for which revolutional feedrate is activated	AXIS: Axis/spindle, from which revolutional feedrate is derived. If no axis has been programmed, the revolutional feedrate is derived from the master spindle.	Feedrate per revolution axial ON: Axial revolutional feedrate ON.
FPRAOF	AXIS: Axis for which revolutional feedrate is deactivated		Feedrate per revolution axial OFF: Axial revolutional feedrate OFF. The revolutional feedrate can be deactivated for several axes at once. You can program as many axes as are permitted in a block.
FPR	AXIS: Axis/spindle, from which revolutional feedrate is derived. If no axis has been programmed, the revolutional feedrate is derived from the master spindle.		Feedrate per revolution: Selection of a rotary axis or spindle from which the revolutional feedrate of the path is derived if G95 is programmed. If no axis/spindle has been programmed, the revolutional feedrate is derived from the master spindle. The setting made with FPR is modal.

It is also possible to program a spindle instead of an axis: FPR(S1) or FPR(SPI(1))

7. Transformations			
Keyword / subroutine identifier	1st parameter	2nd parameter	Explanation
TRACYL	REAL: Working diameter	INT: Number of the trans-formation	Cylinder: Peripheral surface transformation Several transformations can be set per channel. The transformation number specifies which transformation is to be activated. If the second parameter is omitted, the transformation group defined in the MD is activated.
TRANSMIT	INT: Number of the trans-for-mation		Transmit: Polar transformation Several transformations can be set per channel. The transformation number specifies which transformation is to be activated. If the parameter is omitted, the transformation group defined in the MD is activated.
TRAANG	REAL: Angle	INT: Number of the trans-formation	Transformation inclined axis: Several transformations can be set per channel. The transformation number specifies which transformation is to be activated. If the second parameter is omitted, the transformation group defined in the MD is activated. If no angle programmed: TRAANG (,2) or TRAANG, the last angle applies modally.
TRAORI	INT: Number of the trans-formation		Transformation oriented: 4, 5-axis transformation Several transformations can be set per channel. The transformation number specifies which transformation is to be activated.

TRACON	INT: Number of the transformation	REAL: Further parameters, MD-dependent	Transformation concentrated: Cascaded transformation; the meaning of the parameters depends on the type of cascading.
TRAFOOF			Deactivate transformation

For each transformation type, there is one command for one transformation per channel. If there are several transformations of the same transformation type per channel, the transformation can be selected with the corresponding command and parameters. It is possible to deselect the transformation by a transformation change or an explicit deselection.

8. Spindles			
Keyword / subroutine identifier	**1st parameter**	**2nd parameter and others**	**Explanation**
SPCON	INT: Spindle number	INT: Spindle number	Spindle position control ON: Switch to position-controlled spindle operation.
SPCOF	INT: Spindle number	INT: Spindle number	Spindle position control OFF: Switch to speed-controlled spindle operation.
SETMS	INT: Spindle number		Set master spindle: Declaration of spindle as master spindle for current channel. With SETMS( ), the machine-data default applies automatically without any need for parameterization.

9. Grinding		
Keyword / subroutine identifier	**1st parameter**	**Explanation**
GWPSON	INT: Spindle number	Grinding wheel peripheral speed ON: Constant grinding wheel peripheral speed ON. If the spindle number is not programmed, then grinding wheel peripheral speed is selected for the spindle of the active tool.
GWPSOF	INT: Spindle number	Grinding wheel peripheral speed OFF. Constant grinding wheel peripheral speed OFF. If the spindle number is not programmed, grinding wheel peripheral speed is deselected for the spindle of the active tool.
TMON	INT: Spindle number	Tool monitoring ON: If no T number is programmed, monitoring is activated for the active tool.
TMOF	INT: T number	Tool monitoring OFF: If no T number is programmed, monitoring is deactivated for the active tool.

10. Stock removal					
Keyword / subroutine identifier	**1st parameter**	**2nd parameter**	**3rd parameter**	**4th parameter**	**Explanation**
CONTPRON	REAL [, 11]: Contour table	CHAR: Stock removal method "L": Longitudinal turning: External mach. "P": Face turning: External mach. "N": Face turning: Internal machining "G": Longitudinal turning: Internal machining	INT: Number of relief cuts	INT: Status of calcu-lation: 0: unchanged 1: Calculation forwards **and** backwards	Contour preparation on: Activate reference-point editing. The contour programs or NC blocks which are called in the following steps are divided into individual movements and stored in the contour table. The number of relief cuts is returned.
CONTDCON	REAL [, 6]: Contour table	INT: 0: In programmed direction			Contour decoding The blocks for a contour are stored in a named table with one table line per block and coded to save memory.
EXECUTE	INT: Error status				EXECUTE: Activate program execution. This switches back to normal program execution from reference-point-editing mode or after setting up a protection zone.

11. Execute table		
Keyword / subroutine identifier	**1st parameter**	**Explanation**
EXECTAB	REAL [11]: Element from motion table	Execute table: Execute an element from a motion table.

12. Protection zones						
Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter	4th parameter	5th parameter	Explanation
CPROTDEF	INT: Number of the protection zone	BOOL: TRUE: Tool-oriented protection zone	INT: 0: 4th and 5th parameters not evaluated 1: 4th parameter evaluated 2: 5th parameter evaluated 3: 4th and 5th parameters evaluated	REAL: Limit in plus direction	REAL: Limit in minus direction	Channel-specific protection zone definition: Definition of a channel-specific protection zone
NPROTDEF	INT: Number of the protection zone	BOOL: TRUE: Tool-oriented protection zone	INT: 0: 4th and 5th parameters not evaluated 1: 4th parameter evaluated 2: 5th parameter evaluated 3: 4th and 5th parameters evaluated	REAL: Limit in plus direction	REAL: Limit in minus direction	NCK-specific protection zone definition: Definition of a machine-specific protection zone
CPROT	INT: Number of the protection zone	INT: Option 0: Protection zone OFF 1: Preactivate protection zone 2: Protection zone ON 3: Preactivate protection zone with conditional stop, only with protection zones active	REAL: Offset of protection zone in 1st geometry axis	REAL: Offset of protection zone in 2nd geometry axis	REAL: Offset of protection zone in 3rd geometry axis	Channel-specific protection zone ON/ OFF

NPROT	INT: Number of the protection zone	INT: Option 0: Protection zone OFF 1: Preactivate protection zone 2: Protection zone ON 3: Preactivate protection zone with conditional stop, only with protection zones active	REAL: Offset of protection zone in 1st geometry axis	REAL: Offset of protection zone in 2nd geometry axis	REAL: Offset of protection zone in 3rd geometry axis	Machine-specific protection zone ON/ OFF
EXECUTE	VAR INT: Error status	EXECUTE: Activate program execution. This switches back to normal program execution from reference point editing mode or after setting up a protection zone.				

13. Preprocessing/single block		
STOPRE		Stop processing: Preprocessing stop until all prepared blocks are executed in main run

14. Interrupts		
Keyword / subroutine identifier	1st parameter	Explanation
ENABLE	INT: Number of the interrupt input	Activate interrupt: Activates the interrupt routine assigned to the hardware input with the specified number. An interrupt is enabled after the SETINT statement.
DISABLE	INT: Number of the interrupt input	Deactivate interrupt: Deactivates the interrupt routine assigned to the hardware input with the specified number. Fast retraction is not executed. The assignment between the hardware input and the interrupt routine made with SETINT remains valid and can be reactivated with ENABLE.
CLRINT	INT: Number of the interrupt input	Select interrupt: Cancel the assignment of interrupt routines and attributes to an interrupt input. The interrupt routine is deactivated and no reaction occurs when the interrupt is generated.

15. Motion synchronization		
Keyword / subroutine identifier	1st parameter	Explanation
CANCEL	INT: Number of synchronized action	Aborts the modal motion-synchronous action with the specified ID

16. Function definition					
Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter	4th-7th parameter	Explanation
FCTDEF	INT: Function number	REAL: Lower limit value	REAL: Upper limit value	REAL: Coefficients a0 – a3	Define polynomial. This is evaluated in SYFCT or PUTFTOCF.

17. Communication			
Keyword / subroutine identifier	1st parameter	2nd parameter	Explanation
MMC	STRING: Command	CHAR: Acknowledgement mode** "N": Without acknowledgment "S": Synchronous acknowledgment "A": Asynchronous acknowledgment	MMC command: Command to MMC command interpreter for the configuration of windows via NC program **Reference:** Commissioning Manual Base Software and HMI sl

**** Acknowledgement mode:**
Commands are acknowledged on request from the executing component (channel, NC, etc.).
Without acknowledgement: Program execution is continued when the command has been transmitted. The sender is not informed if the command cannot be executed successfully.

18. Program coordination							
Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter	4th parameter	5th para-meter	6th-8th para-meter	Explanation
INIT #	INT: Channel numbers 1 - 10 **or** STRING: Channel name $MC_CHAN_NAME	STRING: path	CHAR: Acknowledgement mode**				Selection of a module for execution in a channel. 1 : 1st channel; 2 : 2nd. channel. As an alternative to the channel number, the channel name defined in $MC_CHAN_NAME can also be used.
START #	INT: Channel numbers 1 - 10 **or** STRING: Channel name $MC_CHAN_NAME						Starts selected programs simultaneously on multiple channels from running program. The command has no effect on the existing channel. 1 : 1st channel; 2 : 2nd channel or channel name defined in $MC_CHAN_NAME.
WAITE #	INT: **or** channel numbers 1 - 10	STRING: Channel name $MC_CHAN_NAME					Wait for end of program: Waits until end of program in another channel (number or name).
WAITM #	INT: Marker numbers 0-9	INT: Channel numbers 1 - 10 **or** STRING: Channel name $MC_CHAN_NAME					Wait: Wait for a marker to be reached in other channels. The program waits until the WAITM with the relevant marker has been reached in the other channel. The number of the own channel can also be specified.

WAITMC #	INT: Marker numbers 0-9	INT: Channel numbers 1 - 10 **or** STRING: Channel name $MC_CHAN_NAME					Wait: Waits conditionally for a marker to be reached in other channels. The program waits until the WAITMC with the relevant marker has been reached in the other channel. Exact stop only if the other channels have not yet reached the marker.
WAITP	AXIS: Axis identifier	AXIS: Axis identifier	AXIS: Axis identifier	AXIS: Axis identifier	AXIS: Axis identifier	AXIS: Axis identifier	Wait for positioning axis: Wait for positioning axes to reach their programmed end point.
WAITS	INT: Spindle number	INT: Spindle number	INT: Spindle number	INT: Spindle number	INT: Spindle number		Wait for positioning spindle: Wait until programmed spindles previously programmed with SPOSA reach their programmed end point.
RET							End of subroutine with no function output to the PLC.
GET #	AXIS	AXIS	AXIS	AXIS	AXIS	AXIS	Assign machine axis
GETD#	AXIS	AXIS	AXIS	AXIS	AXIS	AXIS	Assign machine axis directly
RELEASE #	AXIS	AXIS	AXIS	AXIS	AXIS	AXIS	Release machine axis
PUTFTOC #	REAL: Offset value	INT: Parameter number	INT: Channel number **or** STRING: Channel name $MC_CHAN_NAME	INT: Spindle number			Put fine tool correction: Fine tool compensation
PUTFTOCF #	INT: No. of function The number used here must be specified in FCTDEF.	VAR REAL: Reference value *)	INT: Parameter number	INT: Channel numbers 1 - 10 **or** STRING: Channel name $MC_CHAN_NAME	INT: Spindle number		Put fine tool correction function dependent: Change online tool compensation according to a function defined with FCTDEF (max. 3rd degree polynomial).

The SPI function can also be used to program a spindle instead of an axis: GET(SPI(1))

#) The keyword is not valid for NCU571.

**** Acknowledgement mode:**

Commands are acknowledged on request from the executing component (channel, NC, etc.).

Without acknowledgement: Program execution is continued when the command has been transmitted. The executing component is not informed if the command cannot be executed successfully. Acknowledgment mode "N" or "n".
Synchronous acknowledgement: The program execution is paused until the receiving component acknowledges the command. If the acknowledgement is positive, the next command is executed.

If the **acknowledgement is negative** an error is output.
Acknowledgement "S", "s" or to be omitted.

For some commands, the acknowledgement response is predefined, for others it is programmable.
The acknowledgement response for program-coordination commands is always synchronous.
If the acknowledgement mode is not specified, synchronous acknowledgement is the default response.

19. Data access		
Keyword / subroutine identifier	**1st parameter**	**Explanation**
CHANDATA	INT: Channel number	Set channel number for channel data access (only permitted in initialization block); the subsequent accesses refer to the channel set with CHANDATA.

20. Messages			
Keyword / subroutine identifier	**1st parameter**	**2nd parameter**	**Explanation**
MSG	STRING: STRING: signal	INT: Continuous-path-mode call parameter	Message modal: The message is active until the next message is queued. If the 2nd parameter = 1 is programmed, e.g. MSG(Text, 1), the message will even be output as an executable block in continuous-path mode.

22. Alarms			
Keyword / subroutine identifier	**1st parameter**	**2nd parameter**	**Explanation**
SETAL	INT: Alarm number (cycle alarms)	STRING: Character string	Set alarm: Sets alarm. A character string with up to four parameters can be specified in addition to the alarm number. The following predefined parameters are available: %1 = channel number %2 = block number, label %3 = text index for cycle alarms %4 = additional alarm parameters

23. Compensation			
Keyword / subroutine identifier	**1st parameter- 4th parameter**		**Explanation**
QECLRNON	AXIS: Axis number		Quadrant error compensation learning ON: Quadrant error compensation learning ON
QECLRNOF			Quadrant error compensation learning OFF: Quadrant error compensation learning OFF

24. Tool management					
Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter		Explanation
DELT	STRING[32]: Tool designation	INT: Duplo number			Delete tool. Duplo number can be omitted.
GETSELT	VAR INT: T number (return value)	INT: Spindle number			Get selected T number. If no spindle number is specified, the command for the master spindle applies.
SETPIECE	INT: Count	INT: Spindle number			Takes account of set piece number for all tools assigned to the spindle. If no spindle number is specified, the command for the master spindle applies.
SETDNO	INT: Tool number T	INT: Tool edge no.	INT: D no.		Set D no. of tool (T) and its tool edge to new.
DZERO					Set D numbers of all tools of the TO unit assigned to the channel to invalid
DELDL	INT: Tool number T	INT: D no.			Delete all additive offsets of the tool edge (or of a tool if D is not specified).
SETMTH	INT: Tool-holder no.				Set toolholder no.
POSM	INT: Location no. for positioning	INT: No. of the magazine to be moved	INT: Location number of the internal magazine	INT: Magazine number of the internal magazine	Position magazine
SETTIA	VAR INT: Status = result of the operation (return value)	INT: Magazine number	INT: Wear group no.		Deactivate tool from wear group
SETTA	VAR INT: Status = result of the operation (return value)	INT: Magazine number	INT: Wear group no.		Activate tool from wear group
RESETMON	VAR INT: Status = result of the operation (return value)	INT: Internal T no.	INT: D no. of tool		Set actual value of tool to setpoint

25. Synchronous spindle							
Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter	4th parameter	5th parameter Block change behavior	6th parameter	Explanation
COUPDEF	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)	REAL: Numerator transformation ratio (FA) or (FS)	REAL: Denominator transformation ratio (LA) or (LS)	STRING[8]: Block change behavior: "NOC": No block change control, block change is enabled immediately, "FINE": Block change on "synchronism fine", "COARSE": Block change on synchronism coarse and "IPOSTOP": block change in setpoint-dependent termination of overlaid movement. If the block change behavior is not specified, the set behavior is applicable and there is no change.	STRING[2]: "DV": Setpoint coupling "AV": Actual-value coupling	Couple definition: Definition of synchronized spindle grouping.
COUPDEL	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)					Couple delete: Delete synchronized spindle grouping.
COUPOF	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)			The block change is enabled immediately.		Fastest possible deactivation of synchronous operation.
COUPOF	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)	REAL: POS_{FS}		Block change is not enabled until this position has been crossed.		Deselection of synchronous operation after deactivation position POS_{FS} has been crossed.
COUPOF	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)	REAL: POS_{FS}	REAL: POS_{LS}	Block change is not enabled until both programmed positions have been crossed. Range of POS_{FS}, POS_{LS}: 0 ... 359.999 degrees.		Deselection of synchronous operation after the two deactivation positions. POS_{FS} and POS_{LS} have been crossed.

COUPOFS	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)			Block change performed as quickly as possible with immediate block change.		Deactivation of couple with following-spindle stop.
COUPOFS	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)	REAL: POS_{FS}		After the programmed deactivation position that refers to the machine coordinate system has been crossed, the block change is not enabled until the deactivation positions POS_{FS} have been crossed. Value range 0 ... 359.999 degrees.		Only deactivated after programmed following-axis deactivation position has been crossed.
COUPON	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)			The block change is enabled immediately.		Fastest possible activation of synchronous operation with any angular reference between the leading and following spindles.
COUPON	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)	REAL:POS_{FS}		The block change is enabled according to the defined setting. Range of POS_{FS}: 0 ... 359.999 degrees.		Activation with a defined angular offset POS_{FS} between the following and leading spindles. This offset is referred to the zero degrees position of the leading spindle in a positive direction of rotation.

COUPONC	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)	An offset position cannot be programmed.				Acceptance of activation with previously programmed M3 S.. or M4 S... Immediate acceptance of rotational speed difference.
COUPRES	AXIS: Following axis or following spindle (FS)	AXIS: Leading axis or leading spindle (LS)					Couple reset: Reset synchronous spindle group. The programmed values become invalid. The machine data values are valid.

For synchronous spindles, the axis parameters are programmed with SPI(1) or S1.

26. Structure statements in the STEP editor (editor-based program support)					
Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter		Explanation
SEFORM	STRING[128]: section name	INT: level	STRING[128]: icon		Current section name for STEP editor

Keyword / subroutine identifier	1st parameter	2nd parameter	3rd parameter	4th parameter	Explanation
COUPON	AXIS: Following axis	AXIS: Leading axis	REAL: Activation position of following axis		Couple on: Activate ELG group/synchronous spindle pair. If no activation positions are specified, the couple is activated as quickly as possible (ramp). If an activation position is specified for the following axis and spindle, this refers absolutely or incrementally to the master axis or spindle. Parameters 4 and 5 only have to be programmed if the 3rd parameter is specified.
COUPOF	AXIS: Following axis	AXIS: Leading axis	REAL: Deactivation position of following axis (absolute)	REAL: Deactivation position of master axis (absolute)	Couple OFF: Deactivate ELG group/synchronous spindle pair. The couple parameters are retained. If positions are specified, the couple is only canceled when all the specified positions have been overtraveled. The following spindle continues to revolve at the last speed programmed before deactivation of the couple.
WAITC	AXIS: Axis/ spindle	STRING[8]: Block change criterion	AXIS: Axis/ spindle	STRING[8]: Block change criterion	Wait for couple condition: Wait until couple block change criterion for the axes/spindles is fulfilled. Up to two axes/spindles can be programmed. Block change criterion: "NOC": No block change control, block change is enabled immediately, "FINE": Block change on "synchronism fine", "COARSE": Block change on synchronism coarse and "IPOSTOP": Block change in setpoint-dependent termination of overlaid movement. If the block change behavior is not specified, the set behavior is applicable and there is no change.
AXCTSWE	AXIS: Axis/ spindle				Advance container axis.

16.6 Predefined subroutine calls in motion-synchronous actions

27. Synchronous procedures				
Keyword/ function identifier	1st parameter	2nd parameter	3rd parameter to 5th parameter	Explanation
STOPREOF				Stop preparation OFF: A synchronized action with a STOPREOF command causes a preprocessing stop after the next output block (= block for the main run). The preprocessing stop is canceled with the end of the output block or when the STOPREOF condition is fulfilled. All synchronized action statements with the STOPREOF command are therefore interpreted as having been executed.
RDISABLE				Read-in disable Read-in disable
DELDTG	AXIS: Axis for axial delete distance-to-go (optional). If the axis is omitted, delete distance-to-go is triggered for the path distance			Delete distance-to-go: A synchronized action with the DELDTG command causes a preprocessing stop after the next output block (= block for the main run). The preprocessing stop is canceled with the end of the output block or when the first DELDTG condition is fulfilled. The axial distance to the destination point on an axial delete distance-to-go is stored in $AA_DELT[axis]; the distance-to-go is stored in $AC_DELT.
SYNFCT	INT: Number of polynomial function defined with FCTDEF.	VAR REAL: Result variable*)	VAR REAL: Input variable **)	If the condition in the motion synchronous action is fulfilled, the polynomial determined by the first expression is evaluated at the input variable. The upper and lower range of the value is limited and the input variable is assigned.
FTOC	INT: Number of polynomial function defined with FCTDEF	VAR REAL: Input variable **)	INT: Length 1, 2, 3 INT: Channel number INT: Spindle number	Modify tool fine compensation according to a function defined with FCTDEF (polynomial no higher than 3rd degree). The number used here must be specified in FCTDEF.

*) Only special system variables are permissible as result variables. These are described in the Programming Guide Advanced in the section on "Write main run variable".

**) Only special system variables are permissible as input variables. These variables are described in the Programming Guide Advanced in the list of system variables.

16.7 Predefined functions

Predefined functions

Predefined functions are invoked by means of a function call. Function calls return a value. They can be included as an operand in an expression.

1. Coordinate system						
Keyword/ function identifier	**Result**	**1st parameter**	**2nd parameter**			**Explanation**
CTRANS	FRAME	AXIS	REAL: Offset	3rd - 15th parameter as 1 ...	4th - 16th parameter as 2 ...	Translation: Zero offset for multiple axes. One axis identifier is programmed at a time, with its respective value in the next parameter. CTRANS can be used to program offset for up to 8 axes.
CROT	FRAME	AXIS	REAL: Rotation	3rd/5th parameter as 1 ...	4th/6th parameter as 2 ...	Rotation: Rotation of the current coordinate system. Maximum number of parameters: 6 (one axis identifier and one value per geometry axis)
CSCALE	FRAME	AXIS	REAL: Scale factor	3rd - 15th parameter as 1 ...	4th - 16th parameter as 2 ...	Scale: Scale factor for multiple axes. Maximum number of parameters is 2* maximum number of axes (axis identifier and value). One axis identifier is programmed at a time, with its respective value in the next parameter. CSCALE can be used to program scale factors for up to 8 axes.
CMIRROR	FRAME	AXIS	2nd - 8th parameter as 1 ...			Mirror: Mirror on a coordinate axis
MEAFRAME	FRAME	2-dim. REAL array	2-dim. REAL array	3rd parameter: REAL variables		Frame calculation from 3 measuring points in space

Frame functions CTRANS, CSCALE, CROT and CMIRROR are used to generate frame expressions.

2. Geometry functions					
Keyword/ function identifier	**Result**	**1st parameter**	**2nd parameter**	**3rd parameter**	**Explanation**
CALCDAT	BOOL: Error status	VAR REAL [,2]: Table with input points (abscissa and ordinate for points 1, 2, 3, etc.)	INT: Number of input points for calculation (3 or 4)	VAR REAL [3]: Result: Abscissa, ordinate and radius of calculated circle center point	CALCDAT: Calculate circle data Calculates radius and center point of a circle from 3 or 4 points (according to parameter 1), which must lie on a circle. The points must be different.

Names	Result	1st parameter	2nd parameter	3rd parameter	4th parameter	5th parameter	6th parameter
CALCPOSI	INT: Status 0 OK -1 DLIMIT neg. -2 Trans. n.def. 1 SW limit 2 Working area 3 Prot. zone See PGA for more	REAL: Starting position in WCS [0] Abscissa [1] Ordinate [2] Applicate	REAL: Increment: Path definition [0] Abscissa [1] Ordinate [2] Applicate referred to starting position	REAL: Minimum clearances of limits to be observed [0] Abscissa [1] Ordinate [2] Applicate [3] Lin. machine Axis [4] Rot. Axis	REAL: **Return value** possible incr. path if path from parameter 3 cannot be fully traversed without violating limit	BOOL: 0: Evaluation G code group 13 (inch/metr.) 1: Reference to basic control system, independent of active G codes group 13	bin encoded to be monitored 1 SW limits 2 working area 4 active protection zone 8 preactive protection zone
	Explanation: **CALCPOSI**	CALCPOSI is for checking whether, starting from a defined starting point, the geometry axes can traverse a defined path without violating the axis limits (software limits), working area limitations, or protection zones. If the defined path cannot be traversed without violating limits, the maximum permissible value is returned.					

INTERSEC	BOOL: Error status	VAR REAL [11]: First contour element	VAR REAL [11]: Second contour element	VAR REAL [2]: Result vector: Intersection coordinate, abscissa and ordinate	Intersection: Calculation of intersection The intersection between two contour elements is calculated. The intersection coordinates are return values. The error status indicates whether an intersection was found.

3. Axis functions				
	Result	1st parameter	2nd parameter	Explanation
AXNAME	AXIS: Axis identifier	STRING [ ]: Input string		AXNAME: Get axis identifier Converts the input string to an axis identifier. An alarm is generated if the input string does not contain a valid axis identifier.
AXTOSPI	INT: Spindle number	AXIS: Axis identifier		AXTOSPI: Convert axis to spindle Converts an axis identifier into a spindle number. An alarm is set if the transfer parameter does not contain a valid axis identifier.
SPI	AXIS: Axis identifier	INT: Spindle number		SPI: Convert spindle to axis Converts a spindle number to an axis identifier. An alarm is generated if the passed parameter does not contain a valid spindle number.
ISAXIS	BOOL TRUE: Axis exists: Otherwise: FALSE	INT: Number of the geometry axis (1 to 3)		Check whether the geometry axis 1 to 3 specified as parameter exists in accordance with $MC_AXCONF_GEOAX_ASSIGN_TAB.
AXSTRING	STRING	AXIS		Convert axis identifier into string.

4. Tool management				
	Result	1st parameter	2nd parameter	Explanation
NEWT	INT: T number	STRING [32]: Tool name	INT: Duplo number	Create new tool (prepare tool data). The duplo number can be omitted.
GETT	INT: T number	STRING [32]: Tool name	INT: Duplo number	Get T number for tool identifier.
GETACTT	INT: Status	INT: T number	STRING[32]: Tool name	Get active tool from a group of tools with the same name.
TOOLENV	INT: Status	STRING: Name		Save a tool environment in SRAM with the specified name.
DELTOOLENV	INT: Status	STRING: Name		Delete a tool environment in SRAM with the specified name. All tool environments if no name specified.

GETTENV	INT:
	Status
		STRING:
		Name
			INT:
			Number = [0]
			Number = [1]
			Number = [2]
				Reading:
				T number,
				D number,
				DL number
				from a tool environment with the specified name

	Result	1st par.	2nd par.	3rd par.	4th par.	5th par.	6th par.	Explanation
GETTCOR	INT: Status	REAL: Length [11]	STRING: Components: Coordinate system	STRING: Tool environment/ " "	INT: Int. T number	INT: D number	INT: DL number	Read tool lengths and tool length components from tool environment or current environment Details: See /FB1/ Function Manual Basic Functions; (W1)

	Result	1st par.	2nd par.	3rd par.	4th par.	5th par.	6th par.	7th par.	8th par.	9th par.
SETTCOR	INT: Status	REAL: Offset vector [0-3]	STRING: Component(s)	INT: Component(s) to be offset	INT: Type of write operation	INT: Index of geo. axis	STRING: Name of tool environment	INT: Int. T number	INT: D number	INT: DL number
Explanation	Changing tool components whilst observing all marginal conditions that are included in the evaluation of the individual components. Details: See Function Manual Basic Functions; (W1)									

	Result	1st parameter	2nd parameter	3rd parameter	Explanation
LENTOAX	INT: Status	INT: Axis index [0-2]	REAL: L1, L2, L3 for abscissa, ordinate, applicate [3], [3] Matrix	STRING: Coordinate system for the assignment	The function provides information about the assignment of the tool lengths L1, L2, L3 of the active tools to abscissa, ordinate, applicate. The assignment to the geometry axes is affected by frames and the active plane (G17 - 19). Details: See Function Manual Basic Functions; (W1)

5. Arithmetic					
	Result	1st parameter	2nd parameter	Explanation	
SIN	REAL	REAL		Sine	
ASIN	REAL	REAL		Arcsine	
COS	REAL	REAL		Cosine	
ACOS	REAL	REAL		Arccosine	
TAN	REAL	REAL		Tangent	
ATAN2	REAL	REAL	REAL	Arctangent 2	
SQRT	REAL	REAL		Square root	
ABS	REAL	REAL		Generate absolute value	
POT	REAL	REAL		Square	
TRUNC	REAL	REAL		Truncate decimal places	
ROUND	REAL	REAL		Round decimal places	
LN	REAL	REAL		Natural logarithm	
EXP	REAL	REAL		Exponential function ex	
MINVAL	REAL	REAL	REAL	Determines the smaller value of two variables	
MAXVAL	REAL	REAL	REAL	Determines the larger value of two variables	
	Result	1st parameter	2nd parameter	3rd parameter	Explanation
BOUND	REAL: Check status	REAL: Minimum	REAL: Maximum	REAL: Check variable	Checks whether the variable value lies within the defined min/ max value range
Explanation	The arithmetic functions can also be programmed in synchronized actions. Arithmetic functions are calculated and evaluated in the main run. Synchronized action parameter $AC_PARAM[n] can also be used for calculations and as buffer memory.				

6. String functions				
	Result	1st parameter	2nd parameter to 3rd parameter	Explanation
ISNUMBER	BOOL	STRING		Check whether the input string can be converted to a number. Result is TRUE if conversion is possible.
ISVAR	BOOL	STRING		Check whether the transfer parameter contains a variable known in the NC. (Machine data, setting data, system variable, general variables such as GUDs) Result is TRUE if all the following checks produce positive results according to the (STRING) transfer parameter: – The identifier exists – It is a one or two-dimensional array – An array index is allowed. For axial variables, the axis names are accepted as an index but not checked.
NUMBER	REAL	STRING		Convert the input string into a number.
TOUPPER	STRING	STRING		Convert all alphabetic characters in the input string to upper case.
TOLOWER	STRING	STRING		Convert all alphabetic characters in the input string to lower case.
STRLEN	INT	STRING		The result is the length of the input string up to the end of the string (0).
INDEX	INT	STRING	CHAR	Find the character (2nd parameter) in the input string (1st parameter). The reply gives the place, at which the character was first found. The search is from left to right. The 1st character in the string has the index 0.
RINDEX	INT	STRING	CHAR	Find the character (2nd parameter) in the input string (1st parameter). The reply gives the place, at which the character was first found. The search is from right to left. The 1st character in the string has the index 0.
MINDEX	INT	STRING	STRING	Find one of the characters specified in the 2nd parameter in the input string (1st parameter). The place where one of the characters was first found is output. The search is from left to right. The 1st character in the string has the index 0.
SUBSTR	STRING	STRING	INT	Returns the substring of the input string (1st parameter), defined by the start character (2nd parameter) and number of characters (3rd parameter). Example: SUBSTR("ACKNOWLEDGEMENT:10 to 99", 10, 2) returns substring "10".
SPRINT	STRING	STRING		Returns the input string (1st parameter).

16.8 Currently set language in the HMI

The table below lists all of the languages available at the user interface.

The currently set language can be queried in the part program and in the synchronized actions using the following system variable:

$AN_LANGUAGE_ON_HMI = <value>

<value>	Language	Language code
1	German (Germany)	GER
2	French	FRA
3	English (Great Britain)	ENG
4	Spanish	ESP
6	Italian	ITA
7	Dutch	NLD
8	Simplified Chinese	CHS
9	Swedish	SVE
18	Hungarian	HUN
19	Finnish	FIN
28	Czech	CSY
50	Portuguese (Brazil)	PTB
53	Polish	PLK
55	Danish	DAN
57	Russian	RUS
68	Slovakian	SKY
72	Rumanian	ROM
80	Traditional Chinese	CHT
85	Korean	KOR
87	Japanese	JPN
89	Turkish	TRK

Note

$AN_LANGUAGE_ON_HMI is updated:

- after the system boots.
- after NCK and/or PLC reset.
- after switching over to another NCK within the scope of M2N.
- after changing over the language on the HMI.

Appendix A

A.1 List of abbreviations

A	Output
AS	Automation system
ASCII	American Standard Code for Information Interchange
ASIC	Application Specific Integrated Circuit: User switching circuit
ASUB	Asynchronous subprogram
AuxF	Auxiliary function
AV	Job planning
BA	Operating mode
BB	Ready to run
BCD	Binary Coded Decimals: Decimal numbers encoded In binary code
BCS	Basic Coordinate System
BIN	Binary files (**Bin**ary Files)
BIOS	Basic Input Output System
BP	Basic program
C Bus	Communication bus
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CNC	Computerized Numerical Control: Computerized numerical control
COM	Communication
COR	Coordinate rotation
CP	Communications Processor
CPU	Central Processing Unit: Central processing unit
CR	Carriage Return
CRC	Cutter radius compensation
CRT	Cathode Ray Tube picture tube
CSB	Central Service Board: PLC module
CSF	Function plan (PLC programming method)
CTS	Clear To Send: Signal from serial data interfaces
CUTCOM	Cutter radius compensation: Tool radius compensation
DAC	Digital-to-Analog Converter
DB	Data block in the PLC
DBB	Data block byte in the PLC
DBW	Data block word in the PLC
DBX	Data block bit in the PLC
DC	Direct Control: Movement of the rotary axis via the shortest path to the absolute position within one revolution
DCD	Data Carrier Detect

DDE	Dynamic Data Exchange
DIN	Deutsche Industrie Norm (German Industry Standard)
DIO	Data Input/Output: Data transfer display
DIR	Directory: Directory
DLL	Dynamic Link Library
DOE	Data transmission equipment
DOS	Disk Operating System
DPM	Dual-Port Memory
DPR	Dual-Port RAM
DRAM	Dynamic Random Access Memory
DRF	Differential Resolver Function: Differential resolver function (DRF)
DRY	Dry Run: Dry run feedrate
DSB	Decoding Single Block: Decoding single block
DTE	Data Terminal Equipment
DW	Data word
E	Input
EIA code	Special punched tape code, number of holes per character always odd
ENC	Encoder: Actual value encoder
EPROM	Erasable Programmable Read Only Memory
Error	Error from printer
FB	Function block
FBS	Slimline screen
FC	Function Call: Function block in the PLC
FDB	Product database
FDD	Floppy Disk Drive
FDD	Feed Drive
FEPROM	Flash-EPROM: Read and write memory
FIFO	First In First Out: Memory that works without address specification and whose data are read in the same order in which they were stored.
FIPO	Fine InterPOlator
FM	Function Module
FPU	Floating Point Unit Floating Point Unit
FRA	Frame block
FRAME	Data record (frame)
FST	Feed Stop: Feed stop
GUD	Global User Data: Global user data
HD	Hard Disk Hard disk
HEX	Abbreviation for hexadecimal number
HHU	Handheld unit
HMI	Human Machine Interface
HMI	Human Machine Interface: Operator functionality of SINUMERIK for operation, programming and simulation.

HMS	High-resolution Measuring System
HW	Hardware
I/O	Input/Output
IBN	Startup
IF	Drive module pulse enable
IK (GD)	Implicit communication (global data)
IKA	Interpolative Compensation: Interpolatory compensation
IM	Interface Module Interconnection module
IMR	Interface Module Receive: Interconnection module for receiving data
IMS	Interface Module Send: Interconnection module for sending data
INC	Increment: Increment
INI	Initializing Data: Initializing data
IPO	Interpolator
IS	Interface signal
ISA	Industry Standard Architecture
ISO	International Standardization Organization
ISO code	Special punched tape code, number of holes per character always even
JOG	Jogging: Setup mode
K1 .. K4	Channel 1 to channel 4
K_{UE}	Speed ratio
K_v	Servo gain factor
LAD	Ladder diagram (PLC programming method)
LCD	Liquid Crystal Display: Liquid crystal display
LEC	Leadscrew error compensation
LED	Light-Emitting Diode: Light emitting diode
LF	Line Feed
LR	Position controller
LUD	Local User Data
MB	Megabyte
MC	Measuring circuit
MCP	Machine control panel
MCS	Machine coordinate system
MD	Machine data
MDI	Manual Data Automatic: Manual input
MLFB	Machine-readable product designation
Mode group	Mode group
MPF	Main Program File: NC part program (main program)
MPI	Multiport Interface Multiport Interface
MS	Microsoft (software manufacturer)
MSD	Main Spindle Drive
NC	Numerical Control: Numerical Control
NCK	Numerical Control Kernel: NC kernel with block preparation, traversing range, etc.

NCU	Numerical Control Unit: Hardware unit of the NCK
NRK	Name for the operating system of the NCK
NURBS	Non-Uniform Rational B-Spline
OB	Organization block in the PLC
OEM	Original Equipment Manufacturer
OP	Operator Panel
OP	Operator Panel: Operating setup
OPI	Operator Panel Interface
OPI	Operator Panel Interface: Interface for connection to the operator panel
OPT	Options: Options
OSI	Open Systems Interconnection: Standard for computer communications
P bus	Peripheral Bus
PC	Personal Computer
PCIN	Name of the SW for data exchange with the control
PCMCIA	Personal Computer Memory Card International Association: Standard for plug-in memory cards
PCU	PC Unit: PC box (computer unit)
PG	Programming device
PLC	Programmable Logic Control: Interface control
PLC	Programmable Logic Controller
PMS	Position measuring system
POS	Positioning
RAM	Random Access Memory: Program memory that can be read and written to
REF	Reference point approach function
REPOS	Reposition function
RISC	Reduced Instruction Set Computer: Type of processor with small instruction set and ability to process instructions at high speed
ROV	Rapid override: Input correction
RPA	R-Parameter Active: Memory area on the NCK for R parameter numbers
RPY	Roll Pitch Yaw: Rotation type of a coordinate system
RTS	Request To Send: RTS, control signal of serial data interfaces
SBL	Single Block: Single block
SD	Setting Data
SDB	System Data Block
SEA	Setting Data Active: Identifier (file type) for setting data
SFB	System Function Block
SFC	System Function Call
SK	Softkey
SKP	SKiP: Skip block
SM	Stepper Motor
SPF	Sub Routine File: Subprogram
SR	Subprogram

SRAM	Static RAM (non-volatile)
SSI	Serial Synchronous Interface: Synchronous serial interface
STL	Statement list
SW	Software
SYF	System Files System files
T	Tool
TC	Tool change
TEA	Testing Data Active: Identifier for machine data
TLC	Tool length compensation
TNRC	Tool Nose Radius Compensation
TO	Tool Offset: Tool offset
TO	Tool offset
TOA	Tool Offset Active: Identifier (file type) for tool offsets
TRANSMIT	TRANSform Milling Into Turning: Coordinate conversion on turning machine for milling operations
TRC	Tool Radius Compensation
UFR	User Frame: Zero offset
UI	User interface
V.24	Serial interface (definition of the exchange lines between DTE and DCE)
WOP	Workshop-oriented Programming
Work	Workpiece coordinate system
WPD	Workpiece Directory: Workpiece directory
ZO	Zero offset
ZOA	Zero Offset Active: Identifier (file type) for zero offset data
µC	Micro Controller

A.2 Documentation overview

SINUMERIK 840D sl Documentation Overview

General Documentation

SINUMERIK
840D sl

Sales Brochure

SINUMERIK
840D sl
840Di sl
802D sl

Catalog NC 61

SINAMICS
S120

PM 21 Catalog SIMOTION,
SINAMICS S120 and Motors
for Production Machines

User Documentation

SINUMERIK
840D sl

Operating Instructions
– Universal
– Turning
– Milling
– HMI Advanced

SINUMERIK
840D sl
828D

Operating Manual
– Turning
– Milling

SINUMERIK
840D sl
828D

Programming Manual
– Fundamentals
– Job planning
– Measuring cycles

SINUMERIK
840D sl
840Di sl
828D
802D sl

Programming Manual
– ISO Turning
– ISO Milling

SINUMERIK
840D sl
S120

Diagnostics Manual

Manufacturer/service documentation

SINUMERIK
840D sl

Manual
– NCU
– Operator components
and networking

SINUMERIK
840D sl
S120

System Manual
Guidelines for machine
configuration

SINUMERIK
840D sl
828D

System Manual
Ctrl Energy

SINUMERIK
840D sl

Commissioning Manual
– CNC: NCK, PLC,
Drive
– Basic Software and
Operating Software
– Basic Software and
HMI Advanced

SINUMERIK
840D sl
S120

Parameter Manual
– Part 1
– Part 2
– Detailed
Machine Data
Description
– System variables

Manufacturer/service documentation

SINUMERIK
840D sl
828D

Function Manual
– Basic Functions
– Extension Functions
– Special functions
– Synchronized actions
– Tool management

SINUMERIK
840D sl
840Di sl
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Function Manual
ISO dialects

SINAMICS
S120

Function Manual
Drive functions

SINUMERIK
840D sl

Function Manual
Safety Integrated

SINUMERIK

Configuration Manual
EMC Design Guidelines

Information / Training

SINUMERIK

Beginner´s Manual
Milling and Turning

SINUMERIK

Training documents
– Milling made easier
with ShopMill
– Turning made easier
with ShopTurn

SINUMERIK

Manuals
Tool and
mold making

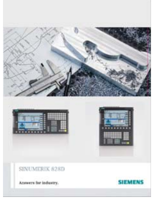
Electronic documentation

DOConCD
DOConWEB

My Documentation
Manager

Documentation overview, SINUMERIK 828D

General documentation



Sales brochure

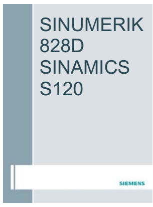
EMC directives

User documentation

Operating Manual
- Turning
- Milling

Programming Manual
- Basic information
- Production planning
- Easy Screen

Programming Manual
- ISO turning
- ISO milling



Diagnostics Manual

Manufacturer/service documentation

Manual
Commissioning Manual
Service Manual

Function Manual
- Basic functions
- Extended functions

Function Manual
ISO dialects

List Manual
- Machine data and interface signals
- Detailed Parameter description

Electronic documentation

DOConCD
DOConWEB

Industry Mall

Glossary

Absolute dimensions

A destination for an axis movement is defined by a dimension that refers to the origin of the currently active coordinate system. See → Incremental dimension

Acceleration with jerk limitation

In order to optimize the acceleration response of the machine whilst simultaneously protecting the mechanical components, it is possible to switch over in the machining program between abrupt acceleration and continuous (jerk-free) acceleration.

Address

An address is the identifier for a certain operand or operand range, e.g. input, output etc.

Alarms

All → messages and alarms are displayed on the operator panel in plain text with date and time and the corresponding symbol for the cancel criterion. Alarms and messages are displayed separately.

1. Alarms and messages in the part program:

   Alarms and messages can be displayed in plain text directly from the part program.

2. Alarms and messages from PLC

   Alarms and messages for the machine can be displayed in plain text from the PLC program. No additional function block packages are required for this purpose.

Archive

Reading out of files and/or directories on an **external** memory device.

Asynchronous subroutine

Part program that can be started asynchronously to (independently of) the current program status using an interrupt signal (e.g. "Rapid NC input" signal).

Automatic

Operating mode of the control (block sequence operation according to DIN): Operating mode for NC systems in which a → subprogram is selected and executed continuously.

Auxiliary functions

Auxiliary functions enable → part programs to transfer → parameters to the → PLC, which then trigger reactions defined by the machine manufacturer.

Axes

In accordance with their functional scope, the CNC axes are subdivided into:

- Axes: interpolating path axes
- Auxiliary axes: non-interpolating feed and positioning axes with an axis-specific feed rate. Auxiliary axes are not involved in actual machining, e.g. tool feeder, tool magazine.

Axis address

See → Axis identifier

Axis identifier

Axes are identifed using X, Y, and Z as defined in DIN 66217 for a dextrorotatory, right-angled → coordinate system.

Rotary axes rotating around X, Y, and Z are identified using A, B, and C. Additional axes situated parallel to the specified axes can be designated using other letters.

Axis name

See → Axis identifier

Backlash compensation

Compensation for a mechanical machine backlash, e.g. backlash on reversal for ball screws. Backlash compensation can be entered separately for each axis.

Backup battery

The backup battery ensures that the → user program in the → CPU is stored so that it is safe from power failure and so that specified data areas and bit memory, timers and counters are stored retentively.

Base axis

Axis whose setpoint or actual value position forms the basis of the calculation of a compensation value.

Basic Coordinate System

Cartesian coordinate system which is mapped by transformation onto the machine coordinate system.

The programmer uses axis names of the basic coordinate system in the → part program. The basic coordinate system exists parallel to the → machine coordinate system if no → transformation is active. The difference between the two coordinate systems lies in the → axis identifiers.

Baud rate

Rate of data transfer (Bit/s).

Blank

Workpiece as it is before it is machined.

Block

"Block" is the term given to any files required for creating and processing programs.

Block search

For debugging purposes or following a program abort, the "Block search" function can be used to select any location in the part program at which the program is to be started or resumed.

Booting

Loading the system program after power ON.

C axis

Axis around which the tool spindle describes a controlled rotational and positioning movement.

Channel

A channel is characterized by the fact that it can process a → part program independently of other channels. A channel exclusively controls the axes and spindles assigned to it. Part program runs of different channels can be coordinated through → synchronization.

Circular interpolation

The → tool moves on a circle between specified points on the contour at a given feed rate, and the workpiece is thereby machined.

CNC

See → NC

COM

Component of the NC for the implementation and coordination of communication.

Compensation axis

Axis with a setpoint or actual value modified by the compensation value

Compensation memory

Data range in the control, in which the tool offset data are stored.

Compensation table

Table containing interpolation points. It provides the compensation values of the compensation axis for selected positions on the basic axis.

Compensation value

Difference between the axis position measured by the encoder and the desired, programmed axis position.

Connecting cables

Connecting cables are pre-assembled or user-assembled 2-wire cables with a connector at each end. This connecting cable connects the → CPU to a → programming device or to other CPUs by means of a → multi-point interface (MPI).

Continuous-path mode

The objective of continuous-path mode is to avoid substantial deceleration of the → path axes at the part program block boundaries and to change to the next block at as close to the same path velocity as possible.

Contour

Contour of the → workpiece

Contour monitoring

The following error is monitored within a definable tolerance band as a measure of contour accuracy. An unacceptably high following error can cause the drive to become overloaded, for example. In such cases, an alarm is output and the axes are stopped.

Coordinate system

See → Machine coordinate system, → Workpiece coordinate system

CPU

Central processing unit, see → PLC

C-Spline

The C-Spline is the most well-known and widely used spline. The transitions at the interpolation points are continuous, both tangentially and in terms of curvature. 3rd order polynomials are used.

Curvature

The curvature k of a contour is the inverse of radius r of the nestling circle in a contour point (k = 1/r).

Cycles

Protected subroutines for execution of repetitive machining operations on the → workpiece.

Data Block

1. Data unit of the → PLC that → HIGHSTEP programs can access.
2. Data unit of the → NC: Data modules contain data definitions for global user data. These data can be initialized directly when they are defined.

Data word

Two-byte data unit within a → data block.

Diagnosis

1. Operating area of the control.
2. The control has both a self-diagnostics program as well as test functions for servicing purposes: status, alarm, and service displays

Dimensions specification, metric and inches

Position and lead values can be programmed in inches in the machining program. Irrespective of the programmable dimensions (`G70`/`G71`), the controller is set to a basic system.

DRF

Differential Resolver Function: NC function which generates an incremental zero offset in Automatic mode in conjunction with an electronic handwheel.

Drive

The drive is the unit of the CNC that performs the speed and torque control based on the settings of the NC.

Dynamic feedforward control

Inaccuracies in the → contour due to following errors can be practically eliminated using dynamic, acceleration-dependent feedforward control. This results in excellent machining accuracy even at high → path velocities. Feedforward control can be selected and deselected on an axis-specific basis via the → part program.

Editor

The editor makes it possible to create, edit, extend, join, and import programs/texts/program blocks.

Exact stop

When an exact stop statement is programmed, the position specified in a block is approached exactly and, if necessary, very slowly. To reduce the approach time, → exact stop limits are defined for rapid traverse and feed.

Exact stop limit

When all path axes reach their exact stop limits, the control responds as if it had reached its precise destination point. A block advance of the → part program occurs.

External zero offset

Zero offset specified by the → PLC.

Fast retraction from contour

When an interrupt occurs, a motion can be initiated via the CNC machining program, enabling the tool to be quickly retracted from the workpiece contour that is currently being machined. The retraction angle and the distance retracted can also be parameterized. After fast retraction, an interrupt routine can also be executed (SINUMERIK 840D).

Feed override

The programmed velocity is overriden by the current velocity setting made via the → machine control panel or from the → PLC (0 to 200%). The feedrate can also be corrected by a programmable percentage factor (1-200%) in the machining program.

Finished-part contour

Contour of the finished workpiece. See → Raw part.

Fixed machine point

Point that is uniquely defined by the machine tool, e.g. machine reference point.

Fixed-point approach

Machine tools can approach fixed points such as a tool change point, loading point, pallet change point, etc. in a defined way. The coordinates of these points are stored in the control. The control moves the relevant axes in → rapid traverse, whenever possible.

Frame

A frame is an arithmetic rule that transforms one Cartesian coordinate system into another Cartesian coordinate system. A frame contains the following components: → zero offset, → rotation, → scaling, → mirroring.

Geometry

Description of a → workpiece in the → workpiece coordinate system.

Geometry axis

Geometry axes are used to describe a 2- or 3-dimensional area in the workpiece coordinate system.

Ground

Ground is taken as the total of all linked inactive parts of a device which will not become live with a dangerous contact voltage even in the event of a malfunction.

Helical interpolation

The helical interpolation function is ideal for machining internal and external threads using form milling cutters and for milling lubrication grooves.

The helix comprises two movements:

- Circular movement in one plane
- A linear movement perpendicular to this plane

High-level CNC language

The high-level language offers: → user-defined variables, → system variables, → macro techniques.

High-speed digital inputs/outputs

The digital inputs can be used for example to start fast CNC program routines (interrupt routines). The digital CNC outputs can be used to trigger fast, program-controlled switching functions (SINUMERIK 840D).

HIGHSTEP

Summary of programming options for → PLCs of the AS300/AS400 system.

Identifier

In accordance with DIN 66025, words are supplemented using identifiers (names) for variables (arithmetic variables, system variables, user variables), subroutines, key words, and words with multiple address letters. These supplements have the same meaning as the words with respect to block format. Identifiers must be unique. It is not permissible to use the same identifier for different objects.

Inch measuring system

Measuring system, which defines distances in inches and fractions of inches.

Inclined surface machining

Drilling and milling operations on workpiece surfaces that do not lie in the coordinate planes of the machine can be performed easily using the function "inclined-surface machining".

Increment

Travel path length specification based on number of increments. The number of increments can be stored as → setting data or be selected by means of a suitably labeled key (i.e. 10, 100, 1000, 10000).

Incremental dimension

Also incremental dimension: A destination for axis traversal is defined by a distance to be covered and a direction referenced to a point already reached. See → Absolute dimension.

Intermediate blocks

Motions with selected → tool offset (G41/G42) may be interrupted by a limited number of intermediate blocks (blocks without axis motions in the offset plane), whereby the tool offset can still be correctly compensated for. The permissible number of intermediate blocks which the control reads ahead can be set in system parameters.

Interpolator

Logic unit of the → NCK that defines intermediate values for the motions to be carried out in individual axes based on information on the end positions specified in the part program.

Interpolatory compensation

Interpolatory compensation is a tool that enables manufacturing-related leadscrew error and measuring system error compensations (SSFK, MSFK).

Interrupt routine

Interrupt routines are special → subroutines that can be started by events (external signals) in the machining process. A part program block which is currently being worked through is interrupted and the position of the axes at the point of interruption is automatically saved.

Inverse-time feedrate

With SINUMERIK 840D, the time required for the path of a block to be traversed can be programmed for the axis motion instead of the feed velocity (G93).

JOG

Control operating mode (setup mode): In JOG mode, the machine can be set up. Individual axes and spindles can be traversed in JOG mode by means of the direction keys. Additional functions in JOG mode include: → Reference point approach, → Repos, and → Preset (set actual value).

Key switch

The key switch on the → machine control panel has four positions that are assigned functions by the operating system of the control. The key switch has three different colored keys that can be removed in the specified positions.

Keywords

Words with specified notation that have a defined meaning in the programming language for → part programs.

KV

Servo gain factor, a control variable in a control loop.

Leading axis

The leading axis is the → gantry axis that exists from the point of view of the operator and programmer and, thus, can be influenced like a standard NC axis.

Leadscrew error compensation

Compensation for the mechanical inaccuracies of a leadscrew participating in the feed. The control uses stored deviation values for the compensation.

Limit speed

Maximum/minimum (spindle) speed: The maximum speed of a spindle can be limited by specifying machine data, the → PLC or → setting data.

Linear axis

In contrast to a rotary axis, a linear axis describes a straight line.

Linear interpolation

The tool travels along a straight line to the destination point while machining the workpiece.

Load memory

The load memory is the same as → RAM for the CPU 314 of the → PLC.

Look Ahead

The Look Ahead function is used to achieve an optimal machining speed by looking ahead over an assignable number of traversing blocks.

Machine axes

Physically existent axes on the machine tool.

Machine control panel

An operator panel on a machine tool with operating elements such as keys, rotary switches, etc., and simple indicators such as LEDs. It is used to directly influence the machine tool via the PLC.

Machine coordinate system

A coordinate system, which is related to the axes of the machine tool.

Machine zero

Fixed point of the machine tool to which all (derived) measuring systems can be traced back.

Machining channel

A channel structure can be used to shorten idle times by means of parallel motion sequences, e.g. moving a loading gantry simultaneously with machining. Here, a CNC channel must be regarded as a separate CNC control system with decoding, block preparation and interpolation.

Macro techniques

Grouping of a set of statements under a single identifier. The identifier represents the set of consolidated statements in the program.

Main block

A block prefixed by ":" introductory block, containing all the parameters required to start execution of a -> part program.

Main program

The term "main program" has its origins during the time when part programs were split strictly into main and → subprograms. This strict division no longer exists with today's SINUMERIK NC language. In principle, any part program in the channel can be selected and started. It then runs through in → program level 0 (main program level). Further part programs or → cycles as subprograms can be called up in the main program.

MDA

Control operating mode: Manual Data Automatic. In the MDA mode, individual program blocks or block sequences with no reference to a main program or subroutine can be input and executed immediately afterwards through actuation of the NC start key.

Messages

All messages programmed in the part program and → alarms detected by the system are displayed on the operator panel in plain text with date and time and the corresponding symbol for the cancel criterion. Alarms and messages are displayed separately.

Metric measuring system

Standardized system of units: For length, e.g. mm (millimeters), m (meters).

Mirroring

Mirroring reverses the signs of the coordinate values of a contour, with respect to an axis. It is possible to mirror with respect to more than one axis at a time.

Mode group

Axes and spindles that are technologically related can be combined into one mode group. Axes/spindles of a BAG can be controlled by one or more → channels. The same → mode type is always assigned to the channels of the mode group.

Mode of operation

An operating concept on a SINUMERIK control. The following modes are defined: → Jog, → MDA, → Automatic.

NC

Numerical Control: Numerical control (NC) includes all components of machine tool control: → NCK, → PLC, HMI, → COM.

Note

A more correct term for SINUMERIK 840D controls would be: Computerized Numerical Control

NCK

Numerical Control Kernel: Component of NC that executes the → part programs and basically coordinates the motion operations for the machine tool.

Network

A network is the connection of multiple S7-300 and other end devices, e.g. a programming device via a → connecting cable. A data exchange takes place over the network between the connected devices.

NRK

Numeric robotic kernel (operating system of → NCK)

NURBS

The motion control and path interpolation that occurs within the control is performed based on NURBS (**N**on **U**niform **R**ational **B**-**S**plines). As a result, a uniform process is available within the control for all interpolations for SINUMERIK 840D.

OEM

The scope for implementing individual solutions (OEM applications) for the SINUMERIK 840D has been provided for machine manufacturers, who wish to create their own operator interface or integrate process-oriented functions in the control.

Operator Interface

The user interface (UI) is the display medium for a CNC in the form of a screen. It features horizontal and vertical softkeys.

Oriented spindle stop

Stops the workpiece spindle in a specified angular position, e.g. in order to perform additional machining at a particular location.

Oriented tool retraction

`RETTOOL`: If machining is interrupted (e.g. when a tool breaks), a program command can be used to retract the tool in a user-specified orientation by a defined distance.

Overall reset

In the event of an overall reset, the following memories of the → CPU are deleted:

- → Work memory
- Read/write area of → load memory
- → System memory
- → Backup memory

Override

Manual or programmable control feature, which enables the user to override programmed feedrates or speeds in order to adapt them to a specific workpiece or material.

Part program block

Part of a → part program that is demarcated by a line feed. There are two types: → main blocks and → subblocks.

Part program management

Part program management can be organized by → workpieces. The size of the user memory determines the number of programs and the amount of data that can be managed. Each file (programs and data) can be given a name consisting of a maximum of 24 alphanumeric characters.

Path axis

Path axes include all machining axes of the → channel that are controlled by the → interpolator in such a way that they start, accelerate, stop, and reach their end point simultaneously.

Path feedrate

Path feed affects → path axes. It represents the geometric sum of the feed rates of the → geometry axes involved.

Path velocity

The maximum programmable path velocity depends on the input resolution. For example, with a resolution of 0.1 mm the maximum programmable path velocity is 1000 m/min.

PCIN data transfer program

PCIN is an auxiliary program for sending and receiving CNC user data (e.g. part programs, tool offsets, etc.) via a serial interface. The PCIN program can run in MS-DOS on standard industrial PCs.

Peripheral module

I/O modules represent the link between the CPU and the process.

I/O modules are:

- → Digital input/output modules
- → Analog input/output modules
- → Simulator modules

PLC

Programmable Logic Control: → Programmable logic controller. Component of → NC: Programmable controller for processing the control logic of the machine tool.

PLC program memory

SINUMERIK 840D: The PLC user program, the user data and the basic PLC program are stored together in the PLC user memory.

PLC Programming

The PLC is programmed using the STEP 7 software. The STEP 7 programming software is based on the WINDOWS standard operating system and contains the STEP 5 programming functions with innovative enhancements.

Polar coordinates

A coordinate system, which defines the position of a point on a plane in terms of its distance from the origin and the angle formed by the radius vector with a defined axis.

Polynomial interpolation

Polynomial interpolation enables a wide variety of curve characteristics to be generated, such as **straight line, parabolic, exponential functions** (SINUMERIK 840D).

Positioning axis

Axis that performs an auxiliary movement on a machine tool (e.g. tool magazine, pallet transport). Positioning axes are axes that do not interpolate with → path axes.

Pre-coincidence

Block change occurs already when the path distance approaches an amount equal to a specifiable delta of the end position.

Program block

Program blocks contain the main program and subroutines of → part programs.

Program level

A part program started in the channel runs as a → main program on program level 0 (main program level). Any part program called up in the main program runs as a → subprogram on a program level 1 ... n of its own.

Programmable frames

Programmable → frames enable dynamic definition of new coordinate system output points while the part program is being executed. A distinction is made between absolute definition using a new frame and additive definition with reference to an existing starting point.

Programmable Logic Control

Programmable logic controllers (PLC) are electronic controls, the function of which is stored as a program in the control unit. This means that the layout and wiring of the device do not depend on the function of the control. The programmable logic controller has the same structure as a computer; it consists of a CPU (central module) with memory, input/output modules and an internal bus system. The peripherals and the programming language are matched to the requirements of the control technology.

Programmable working area limitation

Limitation of the motion space of the tool to a space defined by programmed limitations.

Programming key

Character and character strings that have a defined meaning in the programming language for → part programs.

Protection zone

Three-dimensional zone within the → working area into which the tool tip must not pass.

Quadrant error compensation

Contour errors at quadrant transitions, which arise as a result of changing friction conditions on the guideways, can be virtually entirely eliminated with the quadrant error compensation. Parameterization of the quadrant error compensation is performed by means of a circuit test.

R parameters

Arithmetic parameter that can be set or queried by the programmer of the → part program for any purpose in the program.

Rapid traverse

The highest traverse rate of an axis. For example, rapid traverse is used when the tool approaches the → workpiece contour from a resting position or when the tool is retracted from the workpiece contour. The rapid traverse velocity is set on a machine-specific basis using a machine data element.

Reference point

Machine tool position that the measuring system of the → machine axes references.

Rotary axis

Rotary axes apply a workpiece or tool rotation to a defined angular position.

Rotation

Component of a → frame that defines a rotation of the coordinate system around a particular angle.

Rounding axis

Rounding axes rotate a workpiece or tool to an angular position corresponding to an indexing grid. When a grid index is reached, the rounding axis is "in position".

Safety Functions

The control is equipped with permanently active montoring functions that detect faults in the → CNC, the → PLC, and the machine in a timely manner so that damage to the workpiece, tool, or machine is largely prevented. In the event of a fault, the machining operation is interrupted and the drives stopped. The cause of the malfunction is logged and output as an alarm. At the same time, the PLC is notified that a CNC alarm has been triggered.

Scaling

Component of a → frame that implements axis-specific scale modifications.

Selecting

Series of statements to the NC that act in concert to produce a particular → workpiece. Likewise, this term applies to execution of a particular machining operation on a given → raw part.

Serial RS-232-C interface

For data input/output, the PCU 20 has one serial V.24 interface (RS232) while the PCU 50/70 has two V.24 interfaces. Machining programs and manufacturer and user data can be loaded and saved via these interfaces.

Setting data

Data, which communicates the properties of the machine tool to the NC, as defined by the system software.

Softkey

A key, whose name appears on an area of the screen. The choice of soft keys displayed is dynamically adapted to the operating situation. The freely assignable function keys (soft keys) are assigned defined functions in the software.

Software limit switch

Software limit switches limit the traversing range of an axis and prevent an abrupt stop of the slide at the hardware limit switch. Two value pairs can be specified for each axis and activated separately by means of the → PLC.

Spline interpolation

With spline interpolation, the controller can generate a smooth curve characteristic from only a few specified interpolation points of a set contour.

SRT

Transformation ratio

Standard cycles

Standard cycles are provided for machining operations, which are frequently repeated:

- Cycles for drilling/milling applications
- for turning technology

The available cycles are listed in the "Cycle support" menu in the "Program" operating area. Once the desired machining cycle has been selected, the parameters required for assigning values are displayed in plain text.

Subblock

Block preceded by "N" containing information for a sequence, e.g. positional data.

Subroutine

The term "subprogram" has its origins during the time when part programs were split strictly into → main and subprograms. This strict division no longer exists with today's SINUMERIK NC language. In principle, any part program or any → cycle can be called up as a subprogram within another part program. It then runs through in the next → program level (x+1) (subprogram level (x+1)).

Synchronization

Statements in → part programs for coordination of sequences in different → channels at certain machining points.

Synchronized Actions

1. Auxiliary function output

   During workpiece machining, technological functions (→ auxiliary functions) can be output from the CNC program to the PLC. For example, these auxiliary functions are used to control additional equipment for the machine tool, such as quills, grabbers, clamping chucks, etc.

2. Fast auxiliary function output

   For time-critical switching functions, the acknowledgement times for the → auxiliary functions can be minimized and unnecessary hold points in the machining process can be avoided.

Synchronized axes

Synchronized axes take the same time to traverse their path as the geometry axes take for their path.

Synchronized axis

A synchronized axis is the → gantry axis whose set position is continuously derived from the motion of the → leading axis and is, thus, moved synchronously with the leading axis. From the point of view of the programmer and operator, the synchronized axis "does not exist".

System memory

The system memory is a memory in the CPU in which the following data is stored:

- Data required by the operating system
- The operands times, counters, markers

System variables

A variable that exists without any input from the programmer of a → part program. It is defined by a data type and the variable name preceded by the character **$**. See → User-defined variable.

Tapping without compensating chuck

This function allows threads to be tapped without a compensating chuck. By using the interpolating method of the spindle as a rotary axis and the drilling axis, threads can be cut to a precise final drilling depth, e.g. for blind hole threads (requirement: spindles in axis operation).

Text editor

See → Editor

TOA area

The TOA area includes all tool and magazine data. By default, this area coincides with the → channel area with regard to the reach of the data. However, machine data can be used to specify that multiple channels share one → TOA unit so that common tool management data is then available to these channels.

TOA unit

Each → TOA area can have more than one TOA unit. The number of possible TOA units is limited by the maximum number of active → channels. A TOA unit includes exactly one tool data block and one magazine data block. In addition, a TOA unit can also contain a toolholder data block (optional).

Tool

Active part on the machine tool that implements machining (e.g. turning tool, milling tool, drill, LASER beam, etc.).

Tool nose radius compensation

Contour programming assumes that the tool is pointed. Because this is not actually the case in practice, the curvature radius of the tool used must be communicated to the control which then takes it into account. The curvature center is maintained equidistantly around the contour, offset by the curvature radius.

Tool offset

Consideration of the tool dimensions in calculating the path.

Tool radius compensation

To directly program a desired → workpiece contour, the control must traverse an equistant path to the programmed contour taking into account the radius of the tool that is being used (`G41`/`G42`).

Transformation

Additive or absolute zero offset of an axis.

Traversing range

The maximum permissible travel range for linear axes is ± 9 decades. The absolute value depends on the selected input and position control resolution and the unit of measurement (inch or metric).

User memory

All programs and data, such as part programs, subroutines, comments, tool offsets, and zero offsets/frames, as well as channel and program user data, can be stored in the shared CNC user memory.

User Program

User programs for the S7-300 automation systems are created using the programming language STEP 7. The user program has a modular layout and consists of individual blocks.

The basic block types are:

- Code blocks

  These blocks contain the STEP 7 commands.

- Data blocks

  These blocks contain constants and variables for the STEP 7 program.

User-defined variable

Users can declare their own variables for any purpose in the → part program or data block (global user data). A definition contains a data type specification and the variable name. See → System variable.

Variable definition

A variable definition includes the specification of a data type and a variable name. The variable names can be used to access the value of the variables.

Velocity control

In order to achieve an acceptable traverse rate in the case of very slight motions per block, an anticipatory evaluation over several blocks (→ Look Ahead) can be specified.

WinSCP

WinSCP is a freely available open source program for Windows for the transfer of files.

Working area

Three-dimensional zone into which the tool tip can be moved on account of the physical design of the machine tool. See → Protection zone.

Working area limitation

With the aid of the working area limitation, the traversing range of the axes can be further restricted in addition to the limit switches. One value pair per axis may be used to describe the protected working area.

Working memory

RAM is a work memory in the → CPU that the processor accesses when processing the application program.

Workpiece

Part to be made/machined by the machine tool.

Workpiece contour

Set contour of the → workpiece to be created or machined.

Workpiece coordinate system

The workpiece coordinate system has its starting point in the → workpiece zero-point. In machining operations programmed in the workpiece coordinate system, the dimensions and directions refer to this system.

Workpiece zero

The workpiece zero is the starting point for the → workpiece coordinate system. It is defined in terms of distances to the → machine zero.

Zero offset

Specifies a new reference point for a coordinate system through reference to an existing zero point and a → frame.

1. Settable

   SINUMERIK 840D: A configurable number of settable zero offsets are available for each CNC axis. The offsets - which are selected by means of G functions - take effect alternately.

2. External

   In addition to all the offsets which define the position of the workpiece zero, an external zero offset can be overridden by means of the handwheel (DRF offset) or from the PLC.

3. Programmable

   Zero offsets can be programmed for all path and positioning axes using the `TRANS` statement.

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