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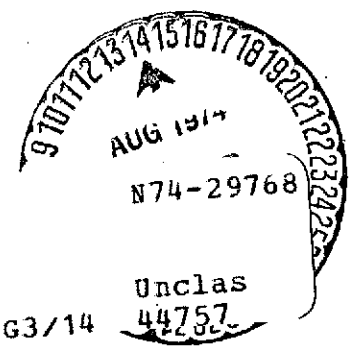
# SOFTWARE AND MODIFICATIONS FOR AUTOMATED MICROWAVE SPECTRAL MEASUREMENTS ON THE HEWLETT PACKARD 8460 SPECTROMETER

By William F. White

July 1, 1974

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16. Abstract

**A Hewlett-Packard 8460A MRR spectrometer has been adapted for automatic spectral searches and measurements under computer control. Software consists of a BASIC language control program and assembly language equipment drivers. Complete software listings are given including cross reference tables. In addition, there are discussions of each equipment driver program and wiring diagrams for the additions required for computer control.**

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# SOFTWARE AND MODIFICATIONS FOR AUTOMATED MICROWAVE SPECTRAL MEASUREMENTS ON THE HEWLETT-PACKARD 8460A SPECTROMETER

By William F. White

## SUMMARY

A BASIC language program for making automated spectral searches and measurements of line frequencies, intensities, and widths has been developed. The program is written to operate a Hewlett-Packard 8460A spectrometer controlled by a 2116B computer with 16,384 words of core storage, Direct Memory Access, and disc memory. Complete listings and cross reference tables are provided for the BASIC control program as well as the assembly language equipment driver subroutines. A discussion of each of the latter routines is included which contains the purpose, use, restrictions, and hardware requirements for each. Suggestions are given for reducing the length of the program if necessary to adapt it to other systems with less storage or different peripheral equipment.

## INTRODUCTION

An automated microwave spectrometer was first put into operation at the Langley Research Center in 1968. The following year, modifications were made to the microwave source that resulted in the present hardware configuration, which is essentially a Hewlett Packard 8460A MRR spectrometer with computer control and readout. One of the major goals to be achieved

with this system has always been to provide large quantities of accurate spectral data for analytical reference purposes. Several years of operating experience were required to develop the programs and to debug both software and hardware. For more than a year the system has been producing spectral data on a routine basis with only minor changes to either hardware or programming. It has proven capable of handling almost all situations which arose including the following: intensity variations of more than three orders of magnitude, linewidth variations of one order of magnitude, exceptionally sensitive Stark effects, interference from Stark lobes of strong adjacent lines, and unusual line shapes and overlap situations caused by unresolved or partially resolved splittings of the spectral lines. The only operating restriction is an arbitrarily chosen upper limit for linewidth of about 3/4 MHz. If lines wider than this are encountered, the widths are not measured.

Overall system block diagrams and a description of the basic program algorithms used appeared in reference 1, but the actual program listings and wiring details were not included. The purpose of this paper is to provide system documentation of software and the wiring diagrams for additions and modifications to the 8460A spectrometer when used for automated spectral data cataloging.

## COMPUTER SUBSYSTEM CONFIGURATION

The program as listed runs on a Hewlett Packard 2116B computer with 16,384 words of core storage, 2 channel Direct Memory Access, 2770A Disc Memory, 2151A Input/Output Extender, 2160A Auxiliary Power Supply, and a large-screen CRT display device. Figures 1 - 3 are block diagrams of the

system. However, the program could easily be modified to run on only the basic computer with 12,288 words of core storage by eliminating some of the features such as the CRT display and data storage on the disc. The Extender and auxiliary power supply are needed because of the number of Input/Output slots used, but many of these are not required for the cataloging program itself. The Input/Output cards used and slot locations may be found on page 5 of the Assembler listing, under the heading of Equipment Channel Numbers.

The operating environment is a modified Disc Operating System using the Hewlett Packard 25379A/25503A Basic Compiler Phases 1 and 2, and 25380A/25504A Basic Compiler Phase 3. The modifications consist of the necessary changes to move the compiler phase swapping routine from low core to a location adjacent to the user driver routines, so that memory locations below $55_8$ are freed for programmer use. The changes are on pages 4 and 5 of the Assembler output listing.

## ASSEMBLY LANGUAGE EQUIPMENT DRIVER ROUTINES

Each interface card associated with an input or output device must have an assembly language routine written to operate it. These routines are called by the BASIC language control program. Appendix A contains descriptions of each routine, a symbol table, the Assembly language program listing and corresponding machine code, and a cross reference table.

Subroutine descriptions.- Each description includes information on the hardware and storage required, calling sequence to use, and a brief description of the purpose of the routine and how it works. Restrictions on the use of the routine and information on any external routines called are also given.

A writeup is included for the disc data swapping routine even though it is part of the BASIC compiler, since the routine is called several times by the control program. Since the routine is part of the compiler, it is not included in the Assembler listing.

Two routines are not written up since they are not callable by the BASIC program. One of these is BTBCD, which converts binary integers into 1-2-4-8 BCD format. The other is SCHK, which tests the value of variables to be certain they are within the 0-255 allowable limits for the Digital/ Analog converters. If not, the variables are set to either 0 or 255 as appropriate.

Assembler listing.- The symbol table makes up the first 3 pages of the listing, followed by 17 pages of the Assembly language source program and binary machine code.

The parameter linkage addresses and most of the constants used are stored on the base page to allow the use of driver routine sets long enough to cross a page boundary without any problems in addressing. All but one of these constants are part of the BASIC compiler.

The compiler parameter linking routine is located at $7105_8$ and stores the addresses of parameters in locations beginning at $7230_8$. In order that a routine have access to the parameters, it is necessary that control first be transferred to the linkage routine by a JSB ENTER, I instruction. This must be immediately followed by a code giving the number and type of variables in the subroutine. The most general code is an octal 7 for each parameter. ENTER checks the code against the CALL statement, and if the parameter number and types agree, it stores the addresses of the parameters in the locations beginning at $7230_8$. Control is then returned to the routine

at the statement following the octal code. Parameters are accessed by the routine through indirect addressing, using the addresses labelled PAR1, PAR2, etc., on the base page. Two locations are required for each parameter since all BASIC variables are handled as floating point quantities.

Page 6 of the Assembler listing has the user subroutine table. Each entry consists of two words. The first gives the (octal) call number of the routine in bits 0-7 and the number of parameters in bits 8-10. Thus the code $1021_8$ indicates a subroutine with 2 parameters (bit 9 = 1) and BASIC call number 17 ($21_8$). The second word gives the core address of the routine entry point. Immediately following the subroutine table is the compiler phase swapping routine. This routine allows reduced core requirements for the compiler by overlaying the execution portion (Phase 3) onto part of the Phases 1 and 2 in core when a RUN command is given. After the program has executed or upon an interrupt from the teleprinter, the routine reloads Phases 1 and 2. Linkages between this routine and the compiler are in locations $55_8$ and $56_8$.

Cross reference table.- A standard cross reference table is included to facilitate any changes which may be desired in the program. IHOUR, IMIN, ISEC, and ITNTH show no references since the timed interrupt capability of the software clock routine was not used here.

## BASIC LANGUAGE CONTROL PROGRAM

Program listing.- Appendix B contains a complete listing of the automatic cataloging control program. A detailed description of the logic flow is beyond the scope of this paper. However, a discussion of the basic algorithms is given in reference 1. In addition, comments have been inserted

throughout the listing by the use of REM statements. These facts should allow a sufficient understanding of the program to allow modifications when desired.

Some modifications which are necessary to use this program on a different spectrometer involve lines 2800 to 2894. This routine converts the signal readout into a value of absorption coefficient (not corrected for guide wavelength). The spectrometer calibration factor and crystal characteristics must be determined experimentally for each instrument. If the listed routine were to be used on a different spectrometer without modification, the likely results would be inaccurate, and possibly unrepeatable, intensity measurements. Other such calibration factors include the cell temperature function defined in statement 70, and the pressure calibration in statements 2700 and 2710. The latter is based on a 100 millivolt full scale output from the pressure gage.

Cross reference tables.- Three types of tables have been provided. The first lists all the variables with a list of statements in which they appear. The second lists subroutine numbers with the statement numbers in which the subroutines are called. The third table lists each statement number which is referred to in a GO TO, GOSUB, or IF...THEN... statement, and the referring statements.

Sample output.- Appendix C contains a sample page of data output from the program, taken during spectral runs on a sample of pyrrole.

## SYSTEM WIRING

Figures 4 to 6 are diagrams of the relay register wiring for measurement and control functions, along with the additional equipment or circuitry which was added to the basic 8460A spectrometer. The wiring of the Stark fault interrupt circuit has not been shown, since it consists simply of a transistor switch which provides a 0 output level when a voltage is applied to the Stark FAULT lamp on the 8428 control unit. This switch output is applied to the flag input of a 12620A breadboard interface card to cause an interrupt.

The 355E and 355F gain control attenuators are connected between the preamp and synchronous detector, and the latter is operated on the -80 dBm range at all times. A 50 ohm termination must be supplied for the attenuators, or the high input impedance of the synchronous detector will cause erratic attenuation values.

## REDUCTION OF STORAGE REQUIREMENTS

If it becomes necessary to reduce the core storage used, or if some piece of peripheral equipment is not available, there are a number of routines which may be deleted from the program without destroying its overall usefulness. The following suggestions will result in the greatest reduction of core requirement with the least effect on program utility.

Elimination of Disc Data Storage.- This routine is used to accumulate a quantity of data which is then dumped to magnetic tape and sent to the data processing center for printing and punching of cards. The routine rounds off intensity and/or frequency data as necessary to suit the measurement

conditions, and produces a line type code which is stored with the data. Elimination of the entire BASIC routine saves 655 words ($1217_8$) in program length and a further 76 words ($114_8$) in reduced variable storage requirements during execution. There is no change in the driver subroutines.

To remove this routine from the program, delete statements 42 to 52, 3712 to 3944, and 9310 to 9982. Eliminate any other references to the variables DØ, D1, D2, D3, N9, and Q3, the array Z, and subroutine 3. Make certain to modify any statements which used a deleted statement number as a destination.

Elimination of CRT Display.- This routine is used to display on a large screen CRT a continuously updated plot of the signal array during scanning across a line. It allows observation of line shapes and signal to noise ratio and is very useful in troubleshooting if a situation is encountered which was not anticipated in the program logic. However, deleting it from the programs saves 363 words ($553_8$) in program length and an additional 64 words ($100_8$) in reduced variable storage requirements during execution.

To remove this routine from the BASIC program, delete all references to variable YØ, array A, and subroutines 15 and 17. In the Assembly language program, delete routines SETP2, PLPT2, and REF and remove their entries from the subroutine table.

Shortening of print control routines.- A significant saving may be realized by reducing the amount of editing done. Part of these routines are devoted to keeping track of the number of lines printed, turning pages through form feed commands, and printing headings on each page. One routine has the sole purpose of defeating the compiler formatter by allowing an "S" to be printed adjacent to the Stark field for sensitive Stark effects, while

not causing a carriage return before the pressure is printed. Elimination of the routine saves 257 words ($401_8$). To do so, delete statements 3102 through 3342 and add X to the print command in line 3400.

A further savings may be achieved by eliminating the page editing routine. A savings of up to 302 words ($456_8$) is possible in program length and 2 more words during execution if no headings are printed. Delete statements 8000 to 8120, all statements referring to LØ, and all GOSUB 8000 statements.

Comments on required storage.- Other program features may be eliminated to save space, but most of the remaining ones will individually result in a decrease of the order of 100 words or less. The programs as listed occupy 9134 words ($21656_8$) of core and require 644 more ($1204_8$) words for storage of arrays and variables during execution. This leaves approximately 900 words of available core with no comment statements. Thus, to allow this program to execute in an identical environment but with only 12,288 words of core, a reduction in program length of about 3200 words is required. The changes just described will account for about 1700 words, but it is unlikely that the other 1500 words can be deleted without significantly changing the capabilities of the program. One way to achieve this would be by the deletion of the signal smoothing routine in lines 1400 to 1790. This saves 1551 words of program length and 122 words of storage through the elimination of the array P and the variable U7. However, the cost of this would be greatly increased measurement time in order to achieve the same signal to noise ratio.

A more profitable way to adapt the program to a smaller core size might be to consider modification of the BASIC compiler or use of a shorter

version. The compiler used includes matrix handling routines which are not needed for the cataloging program. The only matrix statements used are to zero out a matrix, and this can easily be done with a loop. Elimination of the matrix package would go a long way toward achieving the necessary core reduction.

A second possible approach, if a disc or magnetic tape system is used, is to divide the program into shorter portions which could be considered subroutines to be called in sequence. In this way the entire program can be used, and even added to, with computers of 12,288 or even 8,192 word core size.

## CONCLUDING REMARKS

Since there are so many possible combinations of variables which may be encountered when running the spectra of various types of molecules, it is doubtful that a program of this type could ever be considered to be completely developed. The program listed is believed to be free of errors and has been able to handle most situations encountered in the past year. Only a few minor changes have been necessary, and most of these have been made to decrease the amount of operator attention required or to improve measurement accuracy.

A major goal of this paper is to provide information which will aid the operator in making any necessary changes to the program, either to eliminate a bug or to adapt its operation to changing future operational requirements. The information may also be used to adapt this software to a different computer system. With the BASIC language system, such changes are simple if two principles are followed strictly: (1) use the cross reference tables

whenever any factor in a program is modified, to make certain that all other affected parts of the program are also modified accordingly, and (2) immediately change the cross reference table to conform to the new version of the program so that a current table is always available. Unfortunately there is no software available to create the three types of cross references for BASIC programs, so it is vital that the table be kept up to date by the programmer. If a series of changes is made to a program as complicated as this one without observing these two principles, the likely result is that sooner or later difficulties will be encountered which may eventually be resolved only by going back to the original version and starting all over with the modification process.

## REFERENCES


1. White, W. F.: The Microwave Spectra of Sulfur and Nitrogen Compounds. NASA TND-7450, 1974.

2. White, W. F.; and Easley, W. C.: Interpretation of Intensity Measurements on Partially Saturated Microwave Spectral Lines. NASA TND-5726, 1970.


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## APPENDIX A

## DISCUSSION AND LISTING OF ASSEMBLY LANGUAGE ROUTINES

This appendix begins with discussions of each of the driver subroutines which is callable from the BASIC language control program. This section is followed by the Assembler symbol table, listing each symbol used in the programs and the core address of the symbol.

The Assembly program listing is a standard software output, with the columns having the following significance: statement sequence number, octal memory address, contents of the memory address, and Assembly source program listing. This is followed by a cross reference table.

SUBROUTINE: RWDSC

PURPOSE: To read data from the disc or write data on the disc.

HARDWARE REQUIRED: Disc memory and interfaces, Direct Memory Access.

STORAGE REQUIRED: This routine is included as part of the Disc Operating System Basic Compiler.

USE: CALL (3,Z(J),I,N)

This routine transfers 1 sector (32 floating point words) of data between the disc and an array, beginning with location Z(J). The parameter I is set to 0 to read from the disc, and 1 to write on the disc. N is the data sector address on the disc.

RESTRICTIONS: The value of J must be such that J + 31 does not exceed the dimensions of Z, or information in core locations above the array Z will be destroyed during read operations.

The parameter I must be either 0 or 1, and N must have a positive non-zero value not greater than the number of available data sectors. An invalid value for either I or N causes the computer to halt.

SUBROUTINE: SETCL

PURPOSE: To set, start, and stop a software clock; and to provide interrupts for user programs at intervals from 0.1 second to 1 hour.

HARDWARE REQUIRED: 12539A time base generator card.

STORAGE REQUIRED: 76 words ($114_8$). Includes interrupt routine to operate clock.

USE: CALL (13,H,M,S)

H, M, and S are respectively the hour (on a 24 hour system), minute, and second at which the routine is executed, if time of day information is desired. To measure elapsed time, all three parameters should be zero. Whenever this routine is called with zero or positive values for H, the clock begins running with the initial time set by the values of H, M, and S. The clock may be stopped by calling the routine with a negative value for H.

Routine CLOCK is included in the storage allocation for SETCL. CLOCK is the interrupt routine which increments the values of H, M, and S. Interrupts are generated each 0.1 second, and provisions are included for branching to user routines at intervals of 0.1 second, 1 second, 1 minute, and 1 hour. The user routine must contain an initiator section which places a JSB instruction in location ITNTH, ISEC, IMIN, or IHOUR as desired. The routine will then be executed repeatedly at the appropriate times until the JSB is replaced by a NOP instruction. A chain of routines may be executed by having the user routine change the JSB destination.

RESTRICTIONS: The accuracy of the clock is dependent on continuous operation of the interrupt system. Thus no programs should be run which turn off the priority interrupt system for an appreciable period if the clock is in use. An example of this is the SIO magnetic tape driver routine which turns off

the interrupt system while the tape deck is in use. Placing the time base generator card in a low priority slot could also affect the clock accuracy if the interrupt system is in frequent use.

A JMP instruction should never be used in the branching locations, since the time will not be incremented for that period unless control is returned to CLOCK before the next interrupt. When using the clock routine to provide timed interrupts, care must be taken that the user routine is finished executing before the selected interval is over. For example, if a JSB is placed in ITNTH, the called routine must complete operation in less than 100 milliseconds or it will still be executing when the next interrupt causes it to start over. Allowances must be made for any time lost to the servicing of other interrupts or to operation of the DMA in determining routine execution time.

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SUBROUTINE: DAYTM

PURPOSE: To read current time from the software clock.

HARDWARE REQUIRED: None.

STORAGE REQUIRED: 25 words ($31_8$).

USE: CALL (14,H,M,S)

The current hour, minute, and second are returned in H, M, and S when this routine is executed. The values may be actual time of day on a 24 hour system, or elapsed time, depending on the initialization of the clock.

RESTRICTIONS: The software clock must be set and started by subroutine SETCL before this routine can be used. In order to provide access to the stored parameters, this routine must be loaded on the same page with SETCL.

SUBROUTINE: SETP2

PURPOSE: To turn on and off a 60 point CRT display.

HARDWARE REQUIRED: Direct Memory Access, 12555A dual D/A converter, and oscilloscope or other XY display compatible with the 12555A interface.

STORAGE REQUIRED: 61 words ($75_8$), including the scope display refresher routine.

USE: CALL (15,A(1),N)

Calling this routine with a non-zero value of N sets up a data array for a scope display of 60 points in the form of a horizontal line with Y = 0, plus two points at the upper and lower left corners to allow adjustment of the CRT gain settings. The 60 points may be moved vertically to any Y position by routine PLPT2, but the number of points may not be changed.

Calling the routine with N = 0 clears the display and disables the display refresher timer.

RESTRICTIONS: The calling program must declare dimensions of 31 for the array A. The interrupt system must be in operation in order to refresh the display every 20 milliseconds.

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SUBROUTINE: PLPT2

PURPOSE: To vertically move the points in the display generated by routine SETP2.

HARDWARE REQUIRED: None.

STORAGE REQUIRED: 19 words ($23_8$)

USE: CALL (17,X,Y)

This routine moves the point specified by its X value to a new location Y. The point previously at X and the old Y vlaue is erased. The result is a continuous display in which any desired point may be given a new Y value without erasing the display and restarting.

RESTRICTIONS: The range of Y is 0 to 255 for full scale deflection with the oscilloscope gain set for 0 to 10 volt input. Negative values for Y are set to 0, and values greater than 255 are set to 255. The same applies to X, but the maximum value should not exceed 60 in order to keep the points on scale.

EXTERNALS: Routine SCHK is used to determine that X and Y are within range. Routine SETP2 must be called prior to PLPT2 to start the display.

SUBROUTINE: FREQ

PURPOSE: To control the frequency of the microwave source

HARDWARE REQUIRED: 11629A 44-bit output card

STORAGE REQUIRED: 44 words ($54_8$)

USE: CALL (20, F1,F2,F3)

Parameters F1 and F2 program the 8456 Sweep Control unit to obtain the proper reference frequency. F1 is a word containing the four most significant digits of the desired microwave frequency, and F2 contains the four least significant digits.

F3 is an integer from 0 to 999 which programs the BWO helix voltage to provide the approximate frequency desired. The final tuning voltage is supplied by the phase synchronizer. F3 is a linear function of frequency unless the power is leveled, in which case it is necessary to make up a calibration table for F3.

The routine provides for calibration as follows: upon entry, switch 15 is tested. If it is 1, the value of F3 is read from the switch register and the routine loops until switch 15 if set to 0. The switches may be toggled until the phase error is as near zero as possible. When switch 15 is set to zero, control returns to the calling program and the value of F3 is available if the calling program has treated it as a variable. To make a calibration table, the initial frequency should be at the bottom of the band and F3 should be 0. Subsequent steps should be small enough that the phase lock is not lost, so that there is no chance of relocking on the wrong harmonic.

If the power is not to be controlled by the computer or leveled, the 8456 may be allowed to control the helix voltage and thr routine FREQ

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can be shortened by about 40 percent by eliminating references to PAR3 and the calibration routine.

RESTRICTIONS: A waiting loop has been included between the data outputs to the interface card and the final CLC command. The time required is a function of frequency, but the value used in this routine has been found sufficient up to 40,000 MHz. The frequency can still be stepped faster than the fastest manual mode, and control problems could be experienced if other routines such as signal measurement do not take enough time between frequency steps. There is a 20 millisecond uncertainty when the frequency will actually be changed after the execute command is issued to the 8456.

All switches on the front panel of the 8456 must be set for the fastest sweep time (full left positions).

EXTERNALS: Subroutine BTBCD is used to convert all parameters to BCD format before outputting them to the interface card.

SUBROUTINE: PWATT

PURPOSE: To control cell power by adjusting the cell input power attenuator.

HARDWARE REQUIRED: DC power supply and geared motor with rubber tired drive wheel, DPDT relay, 2 contacts on a 12551B-01 relay register card

STORAGE REQUIRED: 20 words ($24_8$)

USE: CALL (22,I)

The cell input power attenuator is driven by a geared DC motor with an output speed of 2.25 rpm when operated at 6 volts. Drive is accomplished by a rubber-tired wheel of about 1.5" diameter in contact with the attenuator. The direction is controlled by a polarity reversing relay. The schematic of this arrangement is shown in figure 1.

Calling the routine with a positive value of I starts driving the attenuator in a direction such that the cell power is increased. A negative value for I causes a decrease in cell power. I = 0 stops the motor.

RESTRICTIONS: There is no provision for sensing the position of the attenuator; therefore, the proper setting must be determined by measurement of crystal current or power level. However, no physical damage occurs if the attenuator is driven to the stops since the wheel friction is adjusted to slip if any resistance is encountered.

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SUBROUTINE: SATT

PURPOSE: To control the range setting of the 3410 synchronous detector and set the integration period for the V to F converter used for signal measurement.

HARDWARE REQUIRED: 3410 modified for remote control, 0452-4001 special V-F converter interface card, 12539A time base generator, 1 contact on 12551B-01 relay register card (optional).

STORAGE REQUIRED: 72 words ($110_8$)

USE: CALL (25, G, N, D)

The 3410 range is set to the value specified by G, which may be any multiple of 10 from 0 to 130. These values correspond to the ranges REMOTE through -100 dBm on the front panel. G = 0 is the setting required for manual operation. A value of G outside the given range results in an error message being printed, and control is returned to the calling program with no action taken on the range setting.

N and D determine the integration period to be used. D is the decade code for the time base generator (values from 0 for 0.1 milliseconds to 7 for 1,000 seconds). N is a positive non-zero integer which determines the number of intervals used for the integration. Thus to measure for ½ second, use N = 5 and D = 3. If an invalid value of D or N is input, the message *TBG is printed and control is returned to the calling program with no further action.

The routine closes a relay contact whenever the value of G is greater than 0, and lights an indicator lamp to show that the computer has control of the range setting.

RESTRICTIONS: The 3410 must be set to the remote range position during computer control. Operation of the front panel control when the computer has set a range other than G = 0 will result in large errors in range setting.

The V to F converter must be set to the 1 volt range and the dividers on the interface card must be bypassed so that the full scale pulse rate is 100 kHz.

The calling program must provide the logic to avoid setting the range to a value which will overload the amplifiers or V to F converter. Further, the integration time must not be long enough for the total count number to exceed 32,767, or the computer input register will overflow and give meaningless answers. On the other hand, the range and integration time should not be such that resolution and accuracy suffer from a low number of counts.

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**SUBROUTINE:** DAC

**PURPOSE:** To control the Stark modulator outputs and provide for modulator shutdown in case of malfunction.

**HARDWARE REQUIRED:** 12555A dual D/A converter, 12602A breadboard interface card with interrupt circuitry (optional), 2 contacts on 12551B-01 relay register card (one contact optional).

**STORAGE REQUIRED:** 93 words ($135_8$)

**USE:** CALL (26, V1, V2)

V1 is an integer with permissible values from 0 to 255 which controls the Stark ground to base (DC bias) voltage. Direct application of the 10 volt D/A converter output allows control of the ground to base voltage over its enitre range. However, it has been found much more useful to place a 175:1 voltage divider on this output so that the base voltage is controlled over a small range in very small increments. If the modulators are adjusted to have a slight negative DC output with V1 = 0, subsequent variation of V1 allows precise adjustment of the ground to base voltage, which is critical for spectral lines with very sensitive Stark effects.

V2 is the desired Stark square wave modulation voltage. The range is 0 to 2,000 volts in 255 steps. Any voltage within the range is a legitimate input, but the value will be rounded to approximately the nearest 8 volt increment. Calling the routine with a zero or positive V2 switches the modulators to the AUTO mode through a contact closure on the relay card. A second contact operates an indicator lamp to show that the front panel controls have been disabled. A negative value of V2 returns the modulators to manual control.

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If the requested value of V2 is too large, the modulators will be set to maximum output but there is no error message.

Any malfunction which applies voltage to the FAULT lamp circuit operates a transistor switch across the lamp, which in turn activates the interrupt circuitry on the breadboard interface card. The routine sets the outputs to 0, rings the teleprinter bell and prints an error message, then halts the computer. If the fault is corrected operation may be resumed by pressing RUN.

**RESTRICTIONS:** The interrupt system must be on for the malfunction routine to work. The modulator control switch must be in either the STARK or BOTH positions or the computer will halt due to inability to obtain the programmed voltage.

**EXTERNALS:** SCHK is used to check the values of V1 and V2.

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SUBROUTINE: ATTEN

PURPOSE: To control gain by operation of attenuators located between the preamp and synchronous detector

HARDWARE REQUIRED: 355E and 355F VHF attenuators, DC power supply, 9 contacts on 12551B-01 relay register card

STORAGE REQUIRED: 88 words ($130_8$)

USE: CALL(27,A)

A is the desired attenuation in decibels, and may be any value from 0 to 129. In that case the routine turns on the DC power supply and sets the attenuators to a value of A dB. If A is negative, the attenuators are set to 0 and the power supply is turned off. A value of A too large causes an error message but no action. Figure 2 is a wiring diagram showing the method of attenuator control.

RESTRICTIONS: The only restrictions are physical ones. If current limiting resistors and diodes are not used as shown in the diagram, switching transients up to 400 volts may occur and burn the contacts on the relay register card. This problem may be severe enough to cause the relay points to stick in the closed position.

28<

**SUBROUTINE:** INT

**PURPOSE:** To initiate a signal measurement by the V to F converter and store the result at the completion of the measurement

**HARDWARE REQUIRED:** 12539A time base generator, 2212A V to F converter and 0452-4001 special interface card

**STORAGE REQUIRED:** 52 words ($64_8$)

**USE:** CALL (30,S)

This routine initiates a measurement by the V to F converter of the 3410 signal output. It then returns control to the calling program. The result of the measurement is not returned by this routine since it uses the interrupt system, and it would be necessary to save a large number of addresses, temporary variable values, and register contents when using the FLOAT routine in the BASIC compiler. Thus, the conversion to floating point and subsequent return of the signal to the calling program is handled by a separate routine which does not use the interrupt system. However, the value of S may be tested by the calling program to determine when the measurement is complete, since it is set to -32768 when the measurement is initiated and is changed only after the interrupt causes the V to F counter to be read out and the result stored.

**RESTRICTIONS:** Subroutine SATT must be called prior to the first use of INT to set the integration period. The interrupt system must be on. Subroutine GOFLT must be called after each use to retrieve the result. If INT is called again before GOFLT, the original measurement will be lost.

**EXTERNALS:** INT must be loaded on the same page with SATT in order to have access to date stored within SATT.

SUBROUTINE: GOFLT

PURPOSE: To retrieve the signal reading made by INT, convert it to floating point form, and return it to the calling program.

HARDWARE REQUIRED: None

STORAGE REQUIRED: 8 words ($10_8$)

USE: CALL (31, S)

This routine retrieves the integer number of counts from the V to F converter, converts it to floating point form, and stores it in the location reserved by the BASIC compiler for the variable S. To convert the result to voltage, it is necessary to know the full scale range setting of the converter, the integration time, and the connection of the decade dividers on the V to F converter interface card. It is current practice to bypass the dividers so that full scale input to the converter results in an output pulse rate of 100,000 kHz.

RESTRICTIONS: Subroutine INT must be called before GOFLT, since the latter do does not make any measurements but merely retrieves the result of the measurement made by INT.

SUBROUTINE: CNVTR

PURPOSE: To initiate a voltage measurement by an A/D converter and return the results

HARDWARE REQUIRED: 15 words ($17_8$)

USE: CALL (32, V)

V is the measured voltage value returned to the calling program and is in the range of -10 to +10 volts. When used to monitor the UNLOCKED SIGNAL OUTPUT jack on the 8709 synchronizer, the normal reading with proper phase lock is about -0.2V. When lock is lost, the voltage goes to about +3½ volts.

RESTRICTIONS: The input jumper on the interface card must be set for the 10 volt range. When this routine is used to monitor the phase loop, allowance must be made for finite time constants in the electronic circuits and for the 20 millisecond uncertainty in execution of the frequency step command, since the measurement aperture time is less than 20 microseconds.

SUBROUTINE: METER

PURPOSE: To provide measurements of operating parameters.

HARDWARE REQUIRED: 2212A V to F converter with 0452-4001 special interface card, 12539A time base generator, 7 contacts on 12551B-01 relay register card

STORAGE REQUIRED: 51 words ($63_8$)

USE: CALL (35, I, D, C)

This routine allows measurements of 7 different parameters. The armatures of 7 of the relays are connected to the input of a V to F converter, and 7 measurement devices are connected to the other 7 contacts. The integer I selects the device for measurement. An invalid value of I does not result in an error message but the result of the measurement is returned as -32768. The valid codes for I are as follows:

1 Stark modulator no. 1 ground to base monitor

2 Stark modulator no. 2 ground to base monitor

3 8709 phase error voltage (from SERVO output)

4 Source power meter

5 Crystal current

6 Detector power meter

7 Sample pressure gage

D is the decade code for the time base generator. There is no provision for looping to provide measurement times other than those selected by D.

C is the number of V to F converter counts which is returned to the calling program. Individual device calibrations are not done by this routine but must be handled by the calling program.

Figure 3 is a wiring diagram for the RLY1 card showing the metering and control functions of that card.

RESTRICTIONS: The interrupt system must be in operation. See the discussion of SATT for precautions to avoid overflow of the computer registers. The V to F converters must be on the 1 volt range, and the dividers on the interface card must be bypassed to provide a full scale pulse rate of 100 kHz.

33<

SUBROUTINE: THERM

PURPOSE: To make cell temperature measurements

HARDWARE REQUIRED: Same as METER, plus 3 more contacts on 12551B-01 relay register card and thermistor type temperature gage with two probes

STORAGE REQUIRED: 29 words ($35_8$)

USE: CALL (36, P, D, C)

This routine is used in conjunction with METER to select one of the thermistor probes and connect the readout device to the V to F converter. P selects the probe and must have a value of either 1 or 2. D and C have the same meaning as in METER, since the latter routine actually makes the measurement. C is returned as counts, and the calling program must convert it to temperature.

RESTRICTIONS: This routine should be called before turning on the thermistor gage to avoid pegging the meter. This happens because the relays are preset open by the computer at turn on, and there is no probe connected to the bridge. The other restrictions for METER apply here also.

EXTERNALS: Subroutine METER is given control after the measurement device is set up, and it actually makes the measurement and returns the result to the calling program.

```
0001                    ASMB,A,T,L
.1          000134
.10         000144
.12         000145
.2          000135
.24         012337
.3          000136
.30         000154
.31         000155
.4          000137
.58         000172
.6          000140
.60         012340
.7          000141
.8          000142
AD1         012676
AD2         012677
ADC         000040
BUF         013373
CCR         012675
CRT         000014
DAC         012140
FDV         000377
FMP         000376
FRS         000030
INF         000220
INT         012552
L1          012663
LEN         013372
M10         000234
M13         012544
M24         012342
M25         000241
M60         012343
M62         013323
M7          000231
MIN         012345
MPY         001231
OFF         013321
PWR         013026
REF         013347
SEC         012346
SVA         013375
WD2         012135
WD3         012136
.10.        012550
.10V        013101
ADCOD       013207
ADR1        012700
ADR2        012716
ADSTK       012264
ATERR       013224
ATMSG       013230
ATOFF       013174
ATTEN       013103
B12K        012274
B1777       012137
B4000       000211
```

| | |
|---|---|
| BASE | 013376 |
| BEGIN | 012047 |
| BSPGI | 000030 |
| BTBCD | 012646 |
| CALIB | 012126 |
| CLCIF | 012270 |
| CLKAD | 012350 |
| CLKOF | 012335 |
| CLOCK | 012352 |
| CLVTF | 013025 |
| CNTI0 | 012351 |
| CNTLW | 000100 |
| CNVTR | 013064 |
| COREZ | 000060 |
| DACEX | 012225 |
| DAYTM | 012411 |
| DCMND | 000017 |
| DDACI | 000031 |
| DDATA | 000016 |
| DECAD | 012547 |
| DISKZ | 000061 |
| DMA1 | 000006 |
| DMA2 | 000007 |
| ENTER | 000041 |
| ENTFR | 012076 |
| ERATT | 012517 |
| ERTBG | 012532 |
| EXEC | 012042 |
| FINIS | 013377 |
| FLOAT | 000077 |
| FREQ | 012064 |
| GAIN | 012545 |
| GOFLT | 012734 |
| HIMSK | 000262 |
| HOUR | 012344 |
| IFIX | 001477 |
| IFLAG | 000023 |
| INOUR | 012401 |
| IMIN | 012372 |
| INADR | 012634 |
| INIT1 | 000002 |
| INIT2 | 000003 |
| ISEC | 012363 |
| ITNTH | 012354 |
| JMPCL | 012347 |
| JSBIN | 012633 |
| JSBL | 013370 |
| JSTKR | 012271 |
| KEEP | 012546 |
| LINK1 | 000024 |
| LINK2 | 000025 |
| LINK3 | 000026 |
| LINK4 | 000027 |
| LSBTB | 012034 |
| M256 | 000254 |
| M370 | 000051 |
| MAXSN | 000256 |
| METER | 012744 |

```
MNEG    000221
MSK0    000257
MSK11   013256
MSKPR   013063
MTRER   013056
NLOOP   012605
NTIME   012632
ONES    013205
PAR1    000042
PAR2    000044
PAR3    000046
PASE1   000063
PASE3   000064
PHS1C   000057
PLPT2   013324
PNTR    013374
PRR1    000050
PWATT   013233
PWOFF   013254
PWOP    013247
RDVTF   012616
REFAD   013371
RLY1    000034
RLY2    000035
SATT    012442
SCHK    012636
SETBS   013276
SETCL   012275
SETP2   013257
SIGAT   012523
SIGTM   012536
START   012034
STKER   012230
STMAN   012170
STMSG   012256
STMSK   012273
SVAC    012341
SVAST   012265
SVAT    012635
SVBST   012266
SVEST   012267
TBG1    000012
TBG2    000013
TDAC    012272
TENS    013206
THENT   012761
THERM   013027
UNNRM   000267
VSET    012201
VTF1    000032
VTF2    000033
VTIMR   012213
WCNT    000062
XLOC    012630
**  NO ERRORS*
```

```
0001  00012                ORG 12B  SHORT DRIVER SET 7H, 11/1/73
0002                       REP 10  INITIALIZE INTERRUPT LOCATIONS
0003  00012 000000         NOP
0003  00013 000000         NOP
0003  00014 000000         NOP
0003  00015 000000         NOP
0003  00016 000000         NOP
0003  00017 000000         NOP
0003  00020 000000         NOP
0003  00021 000000         NOP
0003  00022 000000         NOP
0003  00023 000000         NOP
0004  00024 000000  LINK1  NOP
0005  00025 000000  LINK2  NOP
0006  00026 000000  LINK3  NOP
0007  00027 000000  LINK4  NOP
0008  00030 000000  BSPG1  NOP
0009*
0010*  ADDRESSES FOR INDIRECT LINKAGES
0011*
0012  00041                ORG 41B
0013  00041 007105  ENTER  OCT 7105  PARAMETER LINKING SUBROUTINE
0014  00042 107230  PAR1   OCT 107230,107231    AND LINK LOCATIONS
      00043 107231
0015  00044 107232  PAR2   OCT 107232,107233
      00045 107233
0016  00046 107234  PAR3   OCT 107234,107235
      00047 107235
0017  00050 007230  PRR1   OCT 7230
0018  00051 177410  M37B   OCT 177410
0019*
0020*  LINKAGE TO DISC ROUTINES FOR COMPILER PHASE SWAPPING
0021*
0022  00055                ORG 55B
0023  00055 012034         DEF START
0024  00056 012042         DEF EXEC
0025  00076                ORG 76B
0026  00076 124055         JMP 55B,I
0027*
0028  00110                ORG 110B  LAST WORD ADDRESS OF DRIVERS
0029  00110 013377         DEF FINIS
0030  00122                ORG 122B  END OF SUBROUTINE TABLE
0031  00122 012034         DEF LSBTB
0032*
0033* MODIFICATIONS TO COMPILER SWAPPING LINKAGES
0034*
0035  00332                ORG 332B
0036  00332 100056         OCT 100056
0037  00337                ORG 337B
0038  00337 100055         OCT 100055
0039  02154                ORG 2154B
0040  02154 124055         JMP 55B,I
0041  06462                ORG 6462B
0042  06515                ORG 6515B
0043  06515 060165         LDA 165B
0044  06516 124055         JMP 55B,I
0045  07272                ORG 7272B
0046  07272 124055         JMP 55B,I
```

```
0047  07302                 ORG 7302B
0048  07302 124055          JMP 55B,I
0049  07335                 ORG 7335B
0050  07335 124055          JMP 55B,I
0051*
0052*  LINKAGE TO MATH ROUTINES
0053*
0054  00377          FDV    EQU 377B
0055  00077          FLOAT  EQU 77B
0056  00376          FMP    EQU 376B
0057  01477          IFIX   EQU 1477B
0058  01231          MPY    EQU 1231B
0059*
0060*  EQUIPMENT CHANNEL NUMBERS
0061*
0062  00002          INIT1  EQU 2B    DMA CHANNELS 1 AND 2
0063  00003          INIT2  EQU 3B
0064  00006          DMA1   EQU 6B
0065  00007          DMA2   EQU 7B
0066  00012          TBG1   EQU 12B   TIME BASE GENERATORS
0067  00013          TBG2   EQU 13B
0068  00014          CRT    EQU 14B   DUAL D/A FOR CRT DISPLAY
0069  00016          DDATA  EQU 16B   DISC DATA AND COMMAND
0070  00017          DCMND  EQU 17B
0071  00023          IFLAG  EQU 23B   STARK FAULT INTERRUPT
0072  00030          FRS    EQU 30B   44 BIT FREQ CONTROL
0073  00031          DDAC1  EQU 31B   DUAL D/A STARK CONTROL
0074  00032          VTF1   EQU 32B   VOLTAGE/FREQ CONVERTERS
0075  00033          VTF2   EQU 33B
0076  00034          RLY1   EQU 34B   RELAY OUTPUT REGISTERS
0077  00035          RLY2   EQU 35B
0078  00040          ADC    EQU 40B   A/D PHASE LOCK MONITOR
0079*
0080*  BASE PAGE BASIC COMPILER CONSTANTS USED
0081*
0082  00134          .1     EQU 134B  DECIMAL 1
0083  00135          .2     EQU 135B  DECIMAL 2
0084  00136          .3     EQU 136B  DECIMAL 3
0085  00137          .4     EQU 137B  DECIMAL 4
0086  00140          .6     EQU 140B  DECIMAL 6
0087  00141          .7     EQU 141B  DECIMAL 7
0088  00142          .8     EQU 142B  DECIMAL 8
0089  00144          .10    EQU 144B  DECIMAL 10
0090  00145          .12    EQU 145B  DECIMAL 12
0091  00154          .30    EQU 154B  DECIMAL 30
0092  00172          .58    EQU 172B  DECIMAL 58
0093  00211          B4000  EQU 211B  OCT 4000
0094  00262          HIMSK  EQU 262B  OCT 174000
0095  00220          INF    EQU 220B  OCT 77777
0096  00221          MNEG   EQU 221B  OCTAL 100000
0097  00231          M7     EQU 231B  DECIMAL -7
0098  00234          M10    EQU 234B  DECIMAL -10
0099  00241          M25    EQU 241B  DECIMAL -25
0100  00254          M256   EQU 254B  DECIMAL -256
0101  00256          MAXSN  EQU 256B  DECIMAL -10000
0102  00257          MSK0   EQU 257B  OCTAL 377
0103  00267          UNNRM  EQU 267B  OCT 140000
0104*
```

```
0105*  CONSTANTS FOR DISC SWAPPING ROUTINE
0106*
0107  00155          .31    EQU 155B
0108  00057          PHSIC  EQU 57B
0109  00100          CNTLW  EQU 100B
0110  00060          COREZ  EQU 60B
0111  00061          DISKZ  EQU 61B
0112  00062          WCNT   EQU 62B
0113  00063          PASE1  EQU 63B
0114  00064          PASE3  EQU 64B
0115*
0116*  START OF USER SUBROUTINE TABLE
0117*
0118  12000                 ORG 12000B
0119  12000 000436          OCT 436
0120  12001 012552          DEF INT
0121  12002 000437          OCT 437
0122  12003 012734          DEF GOFLT
0123  12004 001424          OCT 1424
0124  12005 012064          DEF FREQ
0125  12006 000440          OCT 440
0126  12007 013064          DEF CNVTR
0127  12010 001021          OCT 1021
0128  12011 013324          DEF PLPT2
0129  12012 001443          OCT 1443
0130  12013 012744          DEF METER
0131  12014 000426          OCT 426
0132  12015 013233          DEF PWAIT
0133  12016 001416          OCT 1416
0134  12017 012411          DEF DAYTM
0135  12020 001431          OCT 1431
0136  12021 012442          DEF SATT
0137  12022 000433          OCT 433
0138  12023 013103          DEF ATTEN
0139  12024 001032          OCT 1032
0140  12025 012140          DEF DAC
0141  12026 001444          OCT 1444
0142  12027 013027          DEF THERM
0143  12030 001415          OCT 1415
0144  12031 012275          DEF SETCL
0145  12032 001017          OCT 1017
0146  12033 013257          DEF SETP2
0147  12034           LSBTB EQU *  END OF SUBROUTINE TABLE
0148*
0149* END OF LINKS AND CONSTANTS
0150*
0151* ROUTINE FOR DISK SWAPPING OF BASIC COMPILER PHASES
0152*
0153  12034 060100  START LDA CNTLW
0154  12035 102606        OTA DMA1
0155  12036 060057        LDA PHSIC
0156  12037 064155        LDB .31
0157  12040 000040        CLE
0158  12041 026047        JMP BEGIN
0159  12042 060100  EXEC  LDA CNTLW
0160  12043 102606        OTA DMA1
0161  12044 060060        LDA COREZ
0162  12045 064061        LDB DISKZ
```

```
0163   12046 002300          CCE
0164   12047 106702  BEGIN CLC INIT1
0165   12050 102602          OTA INIT1
0166   12051 102702          STC INIT1
0167   12052 060062          LDA WCNT
0168   12053 102602          OTA INIT1
0169   12054 106617          OTB DCMND
0170   12055 103706          STC DMA1,C
0171   12056 102716          STC DDATA
0172   12057 102306          SFS DMA1
0173   12060 026057          JMP *-1
0174   12061 002040          SEZ
0175   12062 124064          JMP PASE3,I
0176   12063 124063          JMP PASE1,I
0177*
0178*  BEGINNING OF DRIVER SUBROUTINES
0179*
0180*  FREQUENCY CONTROL ROUTINE
0181*
0182   12064 000000  FREQ   NOP
0183   12065 114041          JSB ENTER,I
0184   12066 000777          OCT 777
0185   12067 102501          LIA 1
0186   12070 002020          SSA
0187   12071 026126          JMP CALIB
0188   12072 160046          LDA PAR3,I
0189   12073 164047          LDB PAR3+1,I
0190   12074 015477          JSB IFIX
0191   12075 012137          AND B1777
0192   12076 016646  ENTFR JSB BTBCD
0193   12077 072136          STA WD3
0194   12100 160044          LDA PAR2,I
0195   12101 164045          LDB PAR2+1,I
0196   12102 015477          JSB IFIX
0197   12103 016646          JSB BTBCD
0198   12104 072135          STA WD2
0199   12105 160042          LDA PAR1,I
0200   12106 164043          LDB PAR1+1,I
0201   12107 015477          JSB IFIX
0202   12110 016646          JSB BTBCD
0203   12111 106730          CLC FRS
0204   12112 102630          OTA FRS
0205   12113 062135          LDA WD2
0206   12114 102630          OTA FRS
0207   12115 062136          LDA WD3
0208   12116 102630          OTA FRS
0209   12117 060262          LDA HIMSK
0210   12120 002006          INA,SZA
0211   12121 026120          JMP *-1
0212   12122 106730          CLC FRS
0213   12123 102501          LIA 1
0214   12124 002021          SSA,RSS
0215   12125 126064          JMP FREQ,I
0216   12126 012137  CALIB AND B1777
0217   12127 072136          STA WD3
0218   12130 114077          JSB FLOAT,I
0219   12131 170046          STA PAR3,I
0220   12132 174047          STB PAR3+1,I
```

```
0221   12133 062136          LDA WD3
0222   12134 026076          JMP ENTFR
0223*
0224   12135 000000   WD2    NOP
0225   12136 000000   WD3    NOP
0226   12137 001777   B1777  OCT 1777
0227*
0228*   STARK VOLTAGE CONTROL ROUTINE
0229*
0230*
0231   12140 000000   DAC    NOP
0232   12141 114041          JSB ENTER,I
0233   12142 000077          OCT 77
0234   12143 062264          LDA ADSTK
0235   12144 070027          STA LINK4
0236   12145 160042          LDA PAR1,I
0237   12146 164043          LDB PAR1+1,I
0238   12147 015477          JSB IFIX
0239   12150 016636          JSB SCHK
0240   12151 001727          ALF,ALF
0241   12152 072272          STA TDAC
0242   12153 160044          LDA PAR2,I
0243   12154 164045          LDB PAR2+1,I
0244   12155 015477          JSB IFIX
0245   12156 002020          SSA
0246   12157 026170          JMP STMAN
0247   12160 040137          ADA .4
0248   12161 001121          ARS,ARS
0249   12162 001100          ARS
0250   12163 016636          JSB SCHK
0251   12164 032272          IOR TDAC
0252   12165 072272          STA TDAC
0253   12166 016201          JSB VSET
0254   12167 126140          JMP DAC,I
0255   12170 102534   STMAN  LIA RLY1
0256   12171 012273          AND STMSK
0257   12172 006400          CLB
0258   12173 106631          OTB DDAC1
0259   12174 066270          LDB CLCIF
0260   12175 074023          STB IFLAG
0261   12176 102634          OTA RLY1
0262   12177 106723          CLC IFLAG
0263   12200 126140          JMP DAC,I
0264*
0265   12201 000000   VSET   NOP
0266   12202 066272          LDB TDAC
0267   12203 102534          LIA RLY1
0268   12204 012273          AND STMSK
0269   12205 032274          IOR B12K
0270   12206 102634          OTA RLY1
0271   12207 106631          OTB DDAC1
0272   12210 062270          LDA CLCIF
0273   12211 070023          STA IFLAG
0274   12212 064241          LDB M25
0275   12213 060256   VTIMR  LDA MAXSN
0276   12214 002006          INA,SZA
0277   12215 026214          JMP *-1
0278   12216 006006          INB,SZB
```

```
0279  12217 026213         JMP VTIMR
0280  12220 103723         STC IFLAG,C
0281  12221 102323         SFS IFLAG
0282  12222 026225         JMP DACEX
0283  12223 016230         JSB STKER
0284  12224 026143         JMP DAC+3
0285  12225 062271  DACEX LDA JSTKR
0286  12226 070023         STA IFLAG
0287  12227 126201         JMP VSET,I
0288*
0289  12230 000000  STKER NOP
0290  12231 103100         CLF 0
0291  12232 106723         CLC IFLAG
0292  12233 072265         STA SVAST
0293  12234 002400         CLA
0294  12235 102631         OTA DDAC1
0295  12236 102100         STF 0
0296  12237 002040         SEZ
0297  12240 002004         INA
0298  12241 072267         STA SVEST
0299  12242 060144         LDA .10
0300  12243 076266         STB SVBST
0301  12244 066256         LDB STMSG
0302  12245 114102         JSB 102B,I
0303  12246 102023         HLT 23B
0304  12247 016201         JSB VSET
0305  12250 062267         LDA SVEST
0306  12251 002102         CLE,SZA
0307  12252 002200         CME
0308  12253 062265         LDA SVAST
0309  12254 066266         LDB SVBST
0310  12255 126230         JMP STKER,I
0311*
0312  12256 012257  STMSG DEF *+1
0313  12257 003407         OCT 3407,6412
      12260 006412
0314  12261 025123         ASC 2,*STK
      12262 052113
0315  12263 006412         OCT 6412
0316*
0317  12264 012230  ADSTK DEF STKER
0318  12265 000000  SVAST NOP
0319  12266 000000  SVBST NOP
0320  12267 000000  SVEST NOP
0321  12270 106723  CLCIF CLC IFLAG
0322  12271 114027  JSTKR JSB LINK4,I
0323  12272 000000  TDAC  NOP
0324  12273 165777  STMSK OCT 165777
0325  12274 012000  B12K  OCT 12000
0326*
0327*
0328*  CLOCK SETTING AND READOUT ROUTINES
0329*
0330  12275 000000  SETCL NOP
0331  12276 114041         JSB ENTER,I
0332  12277 000777         OCT 777
0333  12300 160042         LDA PAR1,I
0334  12301 164043         LDB PAR1+1,I
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0335   12302 015477          JSB IFIX
0336   12303 002020          SSA
0337   12304 026335          JMP CLKOF
0338   12305 042342          ADA M24
0339   12306 072344          STA HOUR
0340   12307 160044          LDA PAR2,I
0341   12310 164045          LDB PAR2+1,I
0342   12311 015477          JSB IFIX
0343   12312 042343          ADA M60
0344   12313 072345          STA MIN
0345   12314 160046          LDA PAR3,I
0346   12315 164047          LDB PAR3+1,I
0347   12316 015477          JSB IFIX
0348   12317 042343          ADA M60
0349   12320 072346          STA SEC
0350   12321 062347          LDA JMPCL
0351   12322 070012          STA TBG1
0352   12323 062350          LDA CLKAD
0353   12324 070024          STA LINK1
0354   12325 002400          CLA
0355   12326 070013          STA TBG2
0356   12327 060136          LDA .3
0357   12330 102612          OTA TBG1
0358   12331 103712          STC TBG1,C
0359   12332 060234          LDA M10
0360   12333 072351          STA CNT10
0361   12334 126275          JMP SETCL,I
0362   12335 106712  CLKOF    CLC TBG1
0363   12336 126275          JMP SETCL,I
0364*
0365   12337 000030  .24      DEC 24
0366   12340 000074  .60      DEC 60
0367   12341 000000  SVAC     NOP
0368   12342 177750  M24      DEC -24
0369   12343 177704  M60      DEC -60
0370   12344 000000  HOUR     NOP
0371   12345 000000  MIN      NOP
0372   12346 000000  SEC      NOP
0373   12347 114024  JMPCL    JSB LINK1,I
0374   12350 012352  CLKAD    DEF CLOCK
0375   12351 000000  CNT10    NOP
0376*
0377   12352 000000  CLOCK    NOP
0378   12353 103712           STC TBG1,C
0379   12354 000000  ITNTH    NOP
0380   12355 036351           ISZ CNT10
0381   12356 126352           JMP CLOCK,I
0382   12357 072341           STA SVAC
0383   12360 060234           LDA M10
0384   12361 072351           STA CNT10
0385   12362 062341           LDA SVAC
0386   12363 000000  ISEC     NOP
0387   12364 036346           ISZ SEC
0388   12365 126352           JMP CLOCK,I
0389   12366 072341           STA SVAC
0390   12367 062343           LDA M60
0391   12370 072346           STA SEC
0392   12371 062341           LDA SVAC
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0393   12372 000000  IMIN   NOP
0394   12373 036345         ISZ MIN
0395   12374 126352         JMP CLOCK,I
0396   12375 072341         STA SVAC
0397   12376 062343         LDA M60
0398   12377 072345         STA MIN
0399   12400 062341         LDA SVAC
0400   12401 000000  IHOUR  NOP
0401   12402 036344         ISZ HOUR
0402   12403 126352         JMP CLOCK,I
0403   12404 072341         STA SVAC
0404   12405 062342         LDA M24
0405   12406 072344         STA HOUR
0406   12407 062341         LDA SVAC
0407   12410 126352         JMP CLOCK,I
0408*
0409   12411 000000  DAYTM  NOP
0410   12412 114041         JSB ENTER,I
0411   12413 000777         OCT 777
0412   12414 103100         CLF 0
0413   12415 062344         LDA HOUR
0414   12416 170042         STA PAR1,I
0415   12417 062345         LDA MIN
0416   12420 066346         LDB SEC
0417   12421 102100         STF 0
0418   12422 042340         ADA .60
0419   12423 046340         ADB .60
0420   12424 174046         STB PAR3,I
0421   12425 114077         JSB FLOAT,I
0422   12426 170044         STA PAR2,I
0423   12427 174045         STB PAR2+1,I
0424   12430 160042         LDA PAR1,I
0425   12431 042337         ADA .24
0426   12432 114077         JSB FLOAT,I
0427   12433 170042         STA PAR1,I
0428   12434 174043         STB PAR1+1,I
0429   12435 160046         LDA PAR3,I
0430   12436 114077         JSB FLOAT,I
0431   12437 170046         STA PAR3,I
0432   12440 174047         STB PAR3+1,I
0433   12441 126411         JMP DAYTM,I
0434*
0435*  GAIN AND PERIOD CONTROL ROUTINE
0436*
0437   12442 000000  SATT   NOP
0438   12443 114041         JSB ENTER,I
0439   12444 000777         OCT 777
0440   12445 160042         LDA PAR1,I
0441   12446 164043         LDB PAR1+1,I
0442   12447 114377         JSB FDV,I
0443   12450 012550         DEF .10.
0444   12451 015477         JSB IFIX
0445   12452 002021         SSA,RSS
0446   12453 026455         JMP *+2
0447   12454 026517         JMP ERATT
0448   12455 064000         LDB 0
0449   12456 046544         ADB M13
0450   12457 006020         SSB
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0451   12460 026462          JMP *+2
0452   12461 026517          JMP ERATT
0453   12462 044140          ADB .6
0454   12463 006021          SSB,RSS
0455   12464 040135          ADA .2
0456   12465 072545          STA GAIN
0457   12466 102632          OTA VTF1
0458   12467 102534          LIA RLY1
0459   12470 010220          AND INF
0460   12471 066545          LDB GAIN
0461   12472 006002          SZB
0462   12473 030221          IOR MNEG
0463   12474 102634          OTA RLY1
0464   12475 160044          LDA PAR2,I
0465   12476 164045          LDB PAR2+1,I
0466   12477 015477          JSB IFIX
0467   12500 003004          CMA,INA
0468   12501 002021          SSA,RSS
0469   12502 026532          JMP ERTBG
0470   12503 072546          STA KEEP
0471   12504 160046          LDA PAR3,I
0472   12505 164047          LDB PAR3+1,I
0473   12506 015477          JSB IFIX
0474   12507 002020          SSA
0475   12510 026532          JMP ERTBG
0476   12511 064000          LDB 0
0477   12512 044231          ADB M7
0478   12513 006021          SSB,RSS
0479   12514 026532          JMP ERTBG
0480   12515 072547          STA DECAD
0481   12516 126442          JMP SATT,I
0482   12517 060145  ERATT   LDA .12
0483   12520 066523          LDB SIGAT
0484   12521 114102          JSB 102B,I
0485   12522 126442          JMP SATT,I
0486   12523 012524  SIGAT   DEF *+1
0487   12524 003407          OCT 3407,6412
       12525 006412
0488   12526 025107          ASC 3,*GAIN*
       12527 040511
       12530 047052
0489   12531 006412          OCT 6412
0490*
0491   12532 060144  ERTBG   LDA .10
0492   12533 066536          LDB SIGTM
0493   12534 114102          JSB 102B,I
0494   12535 126442          JMP SATT,I
0495   12536 012537  SIGTM   DEF *+1
0496   12537 003407          OCT 3407,6412
       12540 006412
0497   12541 025124          ASC 2,*TBG
       12542 041107
0498   12543 006412          OCT 6412
0499*
0500   12544 177763  M13     DEC -13
0501   12545 000000  GAIN    NOP
0502   12546 000001  KEEP    OCT 1
0503   12547 000003  DECAD   OCT 3
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0504   12550 050000  .10.   DEC 10.
       12551 000010
0505*
0506*  SIGNAL MEASUREMENT ROUTINE
0507*
0508   12552 000000  INT    NOP
0509   12553 114041         JSB ENTER,I
0510   12554 000007         OCT 7
0511   12555 160050         LDA PRR1,I
0512   12556 072630         STA XLOC
0513   12557 002004         INA
0514   12560 072631         STA XLOC+1
0515   12561 060221         LDA MNEG
0516   12562 170042         STA PAR1,I
0517   12563 060154         LDA .30
0518   12564 170043         STA PAR1+1,I
0519   12565 062546         LDA KEEP
0520   12566 072632         STA NTIME
0521   12567 062545         LDA GAIN
0522   12570 102632         OTA VTF1
0523   12571 060013         LDA TBG2
0524   12572 002002         SZA
0525   12573 026571         JMP *-2
0526   12574 062547         LDA DECAD
0527   12575 102613         OTA TBG2
0528   12576 062633         LDA JSBIN
0529   12577 070013         STA TBG2
0530   12600 062634         LDA INADR
0531   12601 070026         STA LINK3
0532   12602 103713         STC TBG2,C
0533   12603 103732         STC VTF1,C
0534   12604 126552         JMP INT,I
0535   12605 000000  NLOOP  NOP
0536   12606 106732         CLC VTF1
0537   12607 036632         ISZ NTIME
0538   12610 026613         JMP *+3
0539   12611 107713         CLC TBG2,C
0540   12612 026616         JMP RDVTF
0541   12613 103713         STC TBG2,C
0542   12614 103732         STC VTF1,C
0543   12615 126605         JMP NLOOP,I
0544   12616 072635  RDVTF  STA SVAT
0545   12617 002400         CLA
0546   12620 070013         STA TBG2
0547   12621 102532         LIA VTF1
0548   12622 003000         CMA
0549   12623 172630         STA XLOC,I
0550   12624 002400         CLA
0551   12625 172631         STA XLOC+1,I
0552   12626 062635         LDA SVAT
0553   12627 126605         JMP NLOOP,I
0554*
0555   12630 000000  XLOC   BSS 2
0556   12632 000000  NTIME  NOP
0557   12633 114026  JSBIN  JSB LINK3,I
0558   12634 012605  INADR  DEF NLOOP
0559   12635 000000  SVAT   NOP
0560*
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0561*  SIGN AND MAGNITUDE ERROR TEST ROUTINE
0562   12636 000000  SCHK   NOP
0563   12637 064000         LDB 0
0564   12640 002020         SSA
0565   12641 002400         CLA
0566   12642 044254         ADB M256
0567   12643 006021         SSB,RSS
0568   12644 060257         LDA MSK0
0569   12645 126636         JMP SCHK,I
0570*
0571*  BINARY TO BCD CONVERSION ROUTINE
0572*
0573   12646 000000  BTBCD  NOP
0574   12647 066700         LDB ADR1
0575   12650 076676         STB AD1
0576   12651 066716         LDB ADR2
0577   12652 076677         STB AD2
0578   12653 066544         LDB M13
0579   12654 076675         STB CCR
0580   12655 006400         CLB
0581   12656 142676         ADA AD1,I
0582   12657 002020         SSA
0583   12660 026663         JMP L1
0584   12661 006004         INB
0585   12662 026664         JMP *+2
0586   12663 142677  L1     ADA AD2,I
0587   12664 005200         RBL
0588   12665 036676         ISZ AD1
0589   12666 036677         ISZ AD2
0590   12667 036675         ISZ CCR
0591   12670 026656         JMP *-10
0592   12671 005222         RBL,RBL
0593   12672 005200         RBL
0594   12673 040001         ADA 1
0595   12674 126646         JMP BTBCD,I
0596   12675 000000  CCR    NOP
0597   12676 000000  AD1    NOP
0598   12677 000000  AD2    NOP
0599   12700 012701  ADR1   DEF *+1
0600   12701 154360         DEC -10000
0601   12702 160300         DEC -8000,-4000,-2000,-1000
       12703 170140
       12704 174060
       12705 176030
0602   12706 176340         DEC -800,-400,-200,-100
       12707 177160
       12710 177470
       12711 177634
0603   12712 177660         DEC -80,-40,-20,-10
       12713 177730
       12714 177754
       12715 177766
0604   12716 012717  ADR2   DEF *+1
0605   12717 023420         DEC 10000
0606   12720 017500         DEC 8000,4000,2000,1000
       12721 007640
       12722 003720
       12723 001750
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0607  12724 001440          DEC 800,400,200,100
      12725 000620
      12726 000310
      12727 000144
0608  12730 000120          DEC 80,40,20,10
      12731 000050
      12732 000024
      12733 000012
0609*
0610*  FLOATING POINT CONVERSION ROUTINE FOR SIGNAL MEASUREMENT
0611*
0612  12734 000000  GOFLT NOP
0613  12735 114041        JSB ENTER,I
0614  12736 000007        OCT 7
0615  12737 162630        LDA XLOC,I
0616  12740 114077        JSB FLOAT,I
0617  12741 172630        STA XLOC,I
0618  12742 176631        STB XLOC+1,I
0619  12743 126734        JMP GOFLT,I
0620*
0621* V/F MEASUREMENT ROUTINE FOR STATUS CHECKING
0622*
0623  12744 000000  METER NOP
0624  12745 114041        JSB ENTER,I
0625  12746 000777        OCT 777
0626  12747 160042        LDA PAR1,I
0627  12750 164043        LDB PAR1+1,I
0628  12751 015477        JSB IFIX
0629  12752 002020        SSA
0630  12753 027056        JMP MTRER
0631  12754 064000        LDB 0
0632  12755 007004        CMB,INB
0633  12756 044141        ADB .7
0634  12757 006020        SSB
0635  12760 027056        JMP MTRER
0636  12761 003004  THENT CMA,INA
0637  12762 064221        LDB MNEG
0638  12763 005200        RBL
0639  12764 002006        INA,SZA
0640  12765 026763        JMP *-2
0641  12766 102534        LIA RLY1
0642  12767 010051        AND M370
0643  12770 030001        IOR 1
0644  12771 102634        OTA RLY1
0645  12772 160044        LDA PAR2,I
0646  12773 164045        LDB PAR2+1,I
0647  12774 015477        JSB IFIX
0648  12775 064013        LDB TBG2
0649  12776 006002        SZB
0650  12777 026775        JMP *-2
0651  13000 102613        OTA TBG2
0652  13001 063026        LDA PWR
0653  13002 102633        OTA VTF2
0654  13003 063025        LDA CLVTF
0655  13004 070013        STA TBG2
0656  13005 060256        LDA MAXSN
0657  13006 002006        INA,SZA
0658  13007 027006        JMP *-1
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0659  13010 103713          STC TBG2,C
0660  13011 102733          STC VTF2
0661  13012 102313          SFS TBG2
0662  13013 027012          JMP *-1
0663  13014 107713          CLC TBG2,C
0664  13015 102533          LIA VTF2
0665  13016 006400          CLB
0666  13017 074013          STB TBG2
0667  13020 003004          CMA,INA
0668  13021 114077          JSB FLOAT,I
0669  13022 170046          STA PAR3,I
0670  13023 174047          STB PAR3+1,I
0671  13024 126744          JMP METER,I
0672*
0673  13025 106733  CLVTF CLC VTF2
0674  13026 000000  PWR    NOP
0675*
0676*  V/F MEASUREMENT ROUTINE FOR CELL TEMPERATURES
0677*
0678  13027 000000  THERM NOP
0679  13030 114041          JSB ENTER,I
0680  13031 000777          OCT 777
0681  13032 063027          LDA THERM
0682  13033 072744          STA METER
0683  13034 160042          LDA PAR1,I
0684  13035 164043          LDB PAR1+1,I
0685  13036 015477          JSB IFIX
0686  13037 050134          CPA .1
0687  13040 027044          JMP *+4
0688  13041 050135          CPA .2
0689  13042 027044          JMP *+2
0690  13043 027056          JMP MTRER
0691  13044 070001          STA 1
0692  13045 005727          BLF,BLF
0693  13046 102534          LIA RLY1
0694  13047 013063          AND MSKPR
0695  13050 030001          IOR 1
0696  13051 102634          OTA RLY1
0697  13052 063027          LDA THERM
0698  13053 072744          STA METER
0699  13054 060142          LDA .8
0700  13055 026761          JMP THENT
0701  13056 060221  MTRER LDA MNEG
0702  13057 170046          STA PAR3,I
0703  13060 060154          LDA .30
0704  13061 170047          STA PAR3+1,I
0705  13062 126744          JMP METER,I
0706*
0707  13063 176377  MSKPR OCT 176377
0708*
0709*  A/D CONVERTER MEASUREMENT ROUTINE
0710*
0711  13064 000000  CNVTR NOP
0712  13065 114041          JSB ENTER,I
0713  13066 000007          OCT 7
0714  13067 103140          CLF ADC
0715  13070 102340          SFS ADC
0716  13071 027070          JMP *-1
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0717   13072 102540          LIA ADC
0718   13073 114077          JSB FLOAT,I
0719   13074 114376          JSB FMP,I
0720   13075 013101          DEF .10V
0721   13076 170042          STA PAR1,I
0722   13077 174043          STB PAR1+1,I
0723   13100 127064          JMP CNVTR,I
0724*
0725   13101 047776  .10V     DEC .01953
       13102 130367
0726*
0727   13103 000000  ATTEN   NOP
0728   13104 114041          JSB ENTER,I
0729   13105 000007          OCT 7
0730   13106 160042          LDA PAR1,I
0731   13107 164043          LDB PAR1+1,I
0732   13110 015477          JSB IFIX
0733   13111 002020          SSA
0734   13112 027174          JMP ATOFF
0735   13113 106534          LIB RLY1
0736   13114 005200          RBL
0737   13115 006020          SSB
0738   13116 027132          JMP *+12
0739   13117 044221          ADB MNEG
0740   13120 005300          RBR
0741   13121 106634          OTB RLY1
0742   13122 064000          LDB 0
0743   13123 102535          LIA RLY2
0744   13124 010257          AND MSK0
0745   13125 102635          OTA RLY2
0746   13126 060001          LDA 1
0747   13127 064267          LDB UNNRM
0748   13130 006006          INB,SZB
0749   13131 027130          JMP *-1
0750   13132 073205          STA ONES
0751   13133 160042          LDA PAR1,I
0752   13134 164043          LDB PAR1+1,I
0753   13135 114377          JSB FDV,I
0754   13136 012550          DEF .10.
0755   13137 015477          JSB IFIX
0756   13140 073206          STA TENS
0757   13141 070001          STA 1
0758   13142 046544          ADB M13
0759   13143 006021          SSB,RSS
0760   13144 027224          JMP ATERR
0761   13145 015231          JSB MPY
0762   13146 000144          DEF .10
0763   13147 003004          CMA,INA
0764   13150 043205          ADA ONES
0765   13151 073205          STA ONES
0766   13152 063206          LDA TENS
0767   13153 043207          ADA ADCOD
0768   13154 164000          LDB 0,I
0769   13155 005700          BLF
0770   13156 077206          STB TENS
0771   13157 063205          LDA ONES
0772   13160 043207          ADA ADCOD
0773   13161 164000          LDB 0,I
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0774   13162 047206          ADB TENS
0775   13163 102535          LIA RLY2
0776   13164 010257          AND MSK0
0777   13165 005727          BLF,BLF
0778   13166 030001          IOR 1
0779   13167 102635          OTA RLY2
0780   13170 064267          LDB UNNRM
0781   13171 006006          INB,SZB
0782   13172 027171          JMP *-1
0783   13173 127103          JMP ATTEN,I
0784   13174 102535  ATOFF   LIA RLY2
0785   13175 010257          AND MSK0
0786   13176 102635          OTA RLY2
0787   13177 102534          LIA RLY1
0788   13200 001200          RAL
0789   13201 010220          AND INF
0790   13202 001300          RAR
0791   13203 102634          OTA RLY1
0792   13204 127103          JMP ATTEN,I
0793*
0794*
0795   13205 000000  ONES    NOP
0796   13206 000000  TENS    NOP
0797   13207 013210  ADCOD   DEF *+1
0798   13210 000000          OCT 0,1,2,4,5,6,10
       13211 000001
       13212 000002
       13213 000004
       13214 000005
       13215 000006
       13216 000010
0799   13217 000011          OCT 11,12,14,15,16
       13220 000012
       13221 000014
       13222 000015
       13223 000016
0800*
0801   13224 060140  ATERR   LDA .6
0802   13225 067230          LDB ATMSG
0803   13226 114102          JSB 102B,I
0804   13227 127103          JMP ATTEN,I
0805*
0806   13230 013231  ATMSG   DEF *+1
0807   13231 025101          ASC 2,*ATT
       13232 052124
0808*
0809* POWER ATTEN CONTROL ROUTINE
0810*
0811   13233 000000  PWATT   NOP
0812   13234 114041          JSB ENTER,I
0813   13235 000007          OCT 7
0814   13236 160042          LDA PAR1,I
0815   13237 164043          LDB PAR1+1,I
0816   13240 015477          JSB IFIX
0817   13241 002003          SZA,RSS
0818   13242 027254          JMP PWOFF
0819   13243 006400          CLB
0820   13244 002020          SSA
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0821   13245 064142          LDB .8
0822   13246 044211          ADB B4000
0823   13247 102534  PWOP    LIA RLY1
0824   13250 013256          AND MSK11
0825   13251 030001          IOR 1
0826   13252 102634          OTA RLY1
0827   13253 127233          JMP PWATT,I
0828   13254 006400  PWOFF   CLB
0829   13255 027247          JMP PWOP
0830   13256 173767  MSK11   OCT 173767
0831*
0832   13257 000000  SETP2   NOP
0833   13260 114041          JSB ENTER,I
0834   13261 000077          OCT 77
0835   13262 160050          LDA PRR1,I
0836   13263 073373          STA BUF
0837   13264 006400          CLB
0838   13265 174000          STB 0,I
0839   13266 002004          INA
0840   13267 064254          LDB M256
0841   13270 174000          STB 0,I
0842   13271 002004          INA
0843   13272 073374          STA PNTR
0844   13273 060134          LDA .1
0845   13274 001727          ALF,ALF
0846   13275 067323          LDB M62
0847   13276 173374  SETBS   STA PNTR,I
0848   13277 002004          INA
0849   13300 037374          ISZ PNTR
0850   13301 006006          INB,SZB
0851   13302 027276          JMP SETBS
0852   13303 073372          STA LEN
0853   13304 160044          LDA PAR2,I
0854   13305 164045          LDB PAR2+1,I
0855   13306 015477          JSB IFIX
0856   13307 002003          SZA,RSS
0857   13310 027321          JMP OFF
0858   13311 063371          LDA REFAD
0859   13312 070025          STA LINK2
0860   13313 063370          LDA JSBL
0861   13314 070014          STA CRT
0862   13315 060145          LDA .12
0863   13316 070030          STA BSPG1
0864   13317 103714          STC CRT,C
0865   13320 127257          JMP SETP2,I
0866   13321 106714  OFF     CLC CRT
0867   13322 127257          JMP SETP2,I
0868   13323 177702  M62     DEC -62
0869*
0870   13324 000000  PLPT2   NOP
0871   13325 114041          JSB ENTER,I
0872   13326 000077          OCT 77
0873   13327 160042          LDA PAR1,I
0874   13330 164043          LDB PAR1+1,I
0875   13331 015477          JSB IFIX
0876   13332 016636          JSB SCHK
0877   13333 073376          STA BASE
0878   13334 160044          LDA PAR2,I
```

```
0879  13335 164045          LDB PAR2+1,I
0880  13336 015477          JSB IFIX
0881  13337 016636          JSB SCHK
0882  13340 001727          ALF,ALF
0883  13341 043376          ADA BASE
0884  13342 067373          LDB BUF
0885  13343 044135          ADB .2
0886  13344 047376          ADB BASE
0887  13345 170001          STA 1,I
0888  13346 127324          JMP PLPT2,I
0889*
0890  13347 000000  REF     NOP
0891  13350 106714          CLC CRT
0892  13351 073375          STA SVA
0893  13352 060030          LDA BSPGI
0894  13353 102607          OTA DMA2
0895  13354 106703          CLC INIT2
0896  13355 063373          LDA BUF
0897  13356 102603          OTA INIT2
0898  13357 063374          LDA PNTR
0899  13360 003004          CMA,INA
0900  13361 102703          STC INIT2
0901  13362 043373          ADA BUF
0902  13363 102603          OTA INIT2
0903  13364 103714          STC CRT,C
0904  13365 103707          STC DMA2,C
0905  13366 063375          LDA SVA
0906  13367 127347          JMP REF,I
0907*
0908*
0909*     DATA
0910*
0911  13370 114025  JSBL    JSB LINK2,I
0912  13371 013347  REFAD   DEF REF
0913  13372 000000  LEN     NOP
0914  13373 000000  BUF     NOP
0915  13374 000000  PNTR    NOP
0916  13375 000000  SVA     NOP
0917  13376 000000  BASE    NOP
0918*
0919  13377         FINIS   EQU *
0920                        END
**   NO ERRORS*
```

CROSS REFERENCE TABLE

CROSS REFERENCE TABLE

## CROSS REFERENCE TABLE

CROSS REFERENCE TABLE

## CROSS REFERENCE TABLE

CROSS REFERENCE TABLE



60<

CROSS REFERENCE TABLE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VSET | 0265 | 0253 | 0287 | 0304 | | | |
| VTF1 | 0074 | 0457 | 0522 | 0533 | 0536 | 0542 | 0547 |
| VTF2 | 0075 | 0653 | 0660 | 0664 | 0673 | | |
| VTIMR | 0275 | 0279 | | | | | |
| WCNT | 0112 | 0167 | | | | | |
| WD2 | 0224 | 0198 | 0205 | | | | |
| WD3 | 0225 | 0193 | 0207 | 0217 | 0221 | | |
| XLOC | 0555 0618 | 0512 | 0514 | 0549 | 0551 | 0615 | 0617 |

## APPENDIX B

### BASIC LANGUAGE CONTROL PROGRAM LISTING

This appendix contains the BASIC language source program listing for automated spectral measurements. It is followed by three cross reference tables: one for variables, one for subroutines, and one for statement numbers which are referred to in other statements as destinations for a jump or branch.

62<

```
1   REM ** BASIC 20DB AUTOMATED CATALOGING PROGRAM, 11/1/73 **
3   REM ** SET POWER ATTENUATOR TO MAX TO ALLOW CHECK OF CRYSTAL
4   REM ** CURRENT AND POWER METER ZERO READINGS **
6   PRINT "ATTEN AT MAX";
7   INPUT I
8   CALL (35,5,4,I)
9   LET I1=-1.00000E-03*I
10   DIM P[60],Z[32],A[31],E[6]
11   CALL (25,0,1,3)
12   CALL (27,0)
14   CALL (36,1,3,A1)
16   CALL (35,6,3,A1)
18   CALL (15,A[1],62)
19   REM ** INPUT HOUR, MINUTE, SECOND ON 24 HOUR SYSTEM **
20   PRINT "TIME";
30   INPUT C1,C2,C3
35   CALL (13,C1,C2,C3)
40   LET C5=100*C1+C2+1.00000E-02*C3
41   REM ** INPUT DESIRED STARTING ADDRESS FOR DISC DATA STORAGE **
42   PRINT "DISC SECTOR AND WORD";
44   INPUT D0,D2
46   LET D1=D0
48   MAT Z=ZER
50   IF D2=1 THEN 54
52   CALL (3,Z[1],0,D1)
54   CALL (20,2650,0,0)
56   MAT E=ZER
60   LET L0=100
70   DEF FNT(X0)=.1*INT(10*(293+4.28600E-02*(1140-X0)))
73   REM ** LINE 75 SETS INITIAL STEP SIZE IN MULTIPLES OF 50 KHZ **
75   LET F5=350
80   LET W0=W4=F5
83   REM ** LINE 85 SETS CRYSTAL CURRENT TO BE USED, 100*MICROAMPS **
85   LET A0=900
88   REM ** INPUT NBS MOLECULE IDENTIFICATION NUMBER **
90   PRINT "ID #";
92   INPUT G0
94   LET Z[32]=G0
98   REM ** INPUT RANGE SETTING TO BE USED DURING SEARCH **
100   PRINT "RANGE";
102   INPUT G0
110   DEF FNI(X0)=1.00000E-02*INT(100*(S1-4.34294*(LOG(X0)-LOG(P))))
120   LET G=G0=30-G0
128   REM ** LINE 130 SETS STARK VOLTAGE TO USE DURING SEARCH **
130   LET V0=1000
150   LET V=V0
198   REM ** SPECIFY FREQUENCY RANGE TO BE COVERED, STARTING AT LOW END *
200   PRINT "START FREQ";
210   INPUT F
220   PRINT "END FREQ";
225   LET L0=L0+2
230   INPUT F9
238   REM ** LINE 240 GIVES DETECTOR TIME CONSTANT IN MILLISECONDS **
240   LET T0=30
242   LET F0=N9=F3=0
244   LET T=400+5*T0
245   REM ** BEGIN OPERATION **
```

```
246  GOSUB 5200
270  LET F1=INT(.1*F)
280  LET F2=INT(1000*(F-10*F1)+.1)
290  CALL (20,F1,F2,INT(.74*(F1-2650)+.5))
300  CALL (27,110-G)
305  CALL (25,110,1,2)
310  WAIT (2*T)
320  GOSUB 8000
330  LET F=INT(.1*F9)
670  LET F3=INT(.74*(F1-2650)+.5)
672  LET I4=F3
674  GOSUB 4400
680  IF F3<1000 THEN 700
690  LET F3=I4=999
700  LET F4=INT(1.33*F5+.5)
710  CALL (20,F1,F2,F3)
715  GOSUB 7000
720  LET F3=INT(.74*(F1-2650)+.5)
725  IF F3<1000 THEN 740
730  LET F3=999
738  REM ** CRYSTAL CURRENT IS CHECKED EACH 13.5 MHZ IN R BAND **
740  IF I4=F3 THEN 750
742  LET I4=F3
744  GOSUB 4400
746  GOTO 760
750  WAIT (15)
760  GOSUB 6000
790  IF ABS(S)<350 THEN 9000
791  REM ** SIGNAL DETECTED, LOOK FOR PEAK **
792  LET F4=-F4
794  GOSUB 7000
800  LET F4=F5
801  LET E4=-1
802  IF S<0 THEN 810
804  GOSUB 6000
806  IF S>350 THEN 850
808  GOTO 4310
810  IF S<-1000 THEN 840
811  REM ** SIGNAL IS A STARK LOBE, KEEP MOVING **
812  GOSUB 7000
814  CALL (20,F1,F2,F3)
816  WAIT (5*T0)
818  GOSUB 6000
820  IF S<-400 THEN 810
822  IF S>350 THEN 851
824  IF G >= G0 THEN 4310
826  LET G=G+10
828  GOTO 842
840  LET G=G-10
842  CALL (27,110-G)
844  WAIT (T)
846  GOTO 812
850  CALL (27,110-G)
851  CALL (25,110,1,3)
853  WAIT (T)
855  IF F4<F5 THEN 858
856  GOSUB 6000
```

```
857  GOTO 860
858  GOSUB 5000
860  IF S<8500 THEN 880
862  LET G=G-10
864  GOTO 850
880  LET S1=S
890  GOSUB 7000
900  CALL (20,F1,F2,F3)
902  WAIT (T)
904  IF F4<F5 THEN 910
906  GOSUB 6000
908  GOTO 912
910  GOSUB 5000
912  IF S>0 THEN 920
916  GOTO 842
920  IF S>S1 THEN 860
930  LET F4=INT(-.5*F4+.5)
940  GOSUB 7000
945  CALL (20,F1,F2,F3)
947  WAIT (T)
950  IF ABS(F4)>9.00000E-02*F5 THEN 858
952  GOSUB 7000
953  REM ** VERIFY THIS LINE HAS NOT ALREADY BEEN MEASURED **
954  IF 10*F1+1.00000E-03*F2+.5*F5>F0 THEN 958
956  GOTO 4030
958  CALL (20,F1,F2,F3)
960  IF S1>3450 THEN 986
962  IF G<G0 THEN 970
966  GOTO 4300
970  LET G=G+10
980  CALL (27,110-G)
982  WAIT (T)
984  LET S1=3.17*S1
986  IF 10*F1+1.00000E-03*F2-1.00000E-03*F5+5.00000E-02>F0 THEN 990
988  GOTO 4000
990  CALL (20,F1,F2,F3)
995  GOSUB 4400
998  REM ** CHECK STARK SENSITIVITY AND FIND BEST VOLTAGE **
1000  WAIT (T)
1002  GOSUB 5220
1004  LET V1=V0
1010  GOSUB 5000
1012  LET S1=S+.1*E3
1014  LET V=V-200
1016  GOSUB 5220
1018  GOSUB 5000
1020  LET S=S+.1*E3
1022  LET V=V+200
1024  IF S>1.005*S1 THEN 1030
1026  IF S<.995*S1 THEN 1038
1028  GOTO 1080
1030  LET V1=V-200
1032  GOTO 1036
1034  LET V1=V
1036  LET S1=S
1038  LET V=V+200
1040  GOSUB 5220
```

```
1042  GOSUB 5000
1044  LET S=S+.1*E3
1046  IF S>1.005*S1 THEN 1060
1048  IF S<.995*S1 THEN 1070
1050  IF V <= V0+200 THEN 1034
1052  IF V1 >= V-200 THEN 1100
1060  IF V<1800 THEN 1034
1062  GOTO 1100
1070  IF V<1800 THEN 1038
1080  LET V=V1
1082  GOSUB 5220
1098  REM ** SET GAIN FOR FULL SCALE OUTPUT ON 3410 **
1100  IF S1>10000 THEN 1120
1102  IF G >= G0 THEN 1120
1104  LET Y=INT(8.686*LOG(10000/S1)+.1)
1106  LET G=G+Y
1107  REM ** MAXIMUM GAIN USED IS EQUIVALENT TO -65 RANGE **
1108  IF G <= 95 THEN 1114
1110  LET G=95
1112  LET Y=Y-G+95
1114  LET S1=S1*8.686*LOG(.5*Y)
1116  CALL (27,110-G)
1120  GOSUB 5213
1125  WAIT (T)
1130  CALL (25,110,2,2)
1140  LET F4=-INT(2.9*F5+.1)
1150  GOSUB 7000
1160  CALL (20,F1,F2,F3)
1165  LET F6=F1
1170  LET F7=F2
1185  LET F4=INT(.1*F5+.1)
1194  REM ** CALCULATE NUMBER OF SCANS NEEDED **
1195  LET N=4+INT(2.00000E-02*(G-40)↑2+.1)
1198  IF T0=10 THEN 1210
1200  LET N=2*INT(.7*N*SQR(10/T0)+.1)
1210  LET J1=1
1212  LET J2=60
1214  LET J3=1
1215  REM ** SET SCALE FACTOR FOR CRT DISPLAY **
1216  LET Y0=1000/S1
1220  DIM S[60],N[60]
1230  MAT S=ZER
1232  MAT N=ZER
1234  LET N0=7
1235  REM ** AVERAGE SIGNAL DURING REPEATED SCANS BACK AND FORTH **
1236  FOR I=1 TO N
1238  FOR J=J1 TO J2 STEP J3
1239  CALL (20,F1,F2,F3)
1240  GOSUB 7000
1241  WAIT (1.4*T0)
1243  LET S0=N[J]*S[J]
1244  LET N[J]=N[J]+1
1245  LET X=1/N[J]
1246  LET S0=S0*X
1247  GOSUB 6000
1248  LET S[J]=S0+X*S
1249  CALL (17,J-1,240-Y0*S[J])
```

```
1250  NEXT J
1252  IF J3>0 THEN 1278
1254  LET J1=J1-N0
1256  IF J1<38 THEN 1270
1258  LET J2=J2+N0
1260  LET F4=-F4*N0
1262  GOSUB 7000
1264  LET F4=F4/N0
1267  LET N0=N0-1
1268  GOTO 1280
1270  LET J1=60
1272  LET J2=1
1273  LET N0=7
1274  LET F1=F6
1276  LET F2=F7+F4
1278  LET F4=-F4
1280  GOSUB 7000
1281  CALL (20,F1,F2,F3)
1282  LET J3=-J3
1283  WAIT (T)
1284  LET J=J1
1286  LET J1=J2
1288  LET J2=J
1290  NEXT I
1291  REM ** CHECK TIME, PRESSURE, TEMPERATURE **
1292  CALL (14,C1,C2,C3)
1293  CALL (35,7,4,P)
1294  LET F1=F6
1295  LET F2=F7
1296  CALL (20,F1,F2,F3)
1300  CALL (36,1,3,Y)
1302  LET Y=FNT(Y)
1304  LET D3=INT(Y+.5)
1309  REM ** ADJUST SIGNAL FOR STARK PICKUP CORRECTION **
1310  LET X=2.00000E-02*E3
1312  FOR J=1 TO 60
1314  LET S[J]=S[J]+X
1316  NEXT J
1318  LET U7=-1
1399  REM ** SMOOTH SIGNAL ARRAY WITH 11 POINT CUBIC FIT **
1400  LET X=678*S[1]+288*S[2]+48*(S[3]+S[8]+S[10])-72*(S[4]+S[6]+S[11])
1410  LET P[1]=(X-102*S[5]-12*S[7]+78*S[9])/858
1411  CALL (17,0,240-Y0*P[1])
1420  LET X=288*S[1]+246*S[2]+192*S[3]+132*S[4]+72*S[5]+18*(S[6]-S[10])
1430  LET P[2]=(X-24*S[7]-48*(S[8]+S[9]-S[11]))/858
1431  CALL (17,1,240-Y0*P[2])
1440  LET X=48*(S[1]-S[10])+192*S[2]+246*S[3]+232*S[4]+172*S[5]
1450  LET P[3]=(X+88*(S[6]-S[9])+2*S[7]-64*S[8]+78*S[11])/858
1451  CALL (17,2,240-Y0*P[3])
1460  LET X=-72*S[1]+132*S[2]+232*S[3]+251*S[4]+212*S[5]+138*S[6]
1470  LET P[4]=(X+52*S[7]-23*S[8]-64*S[9]-48*(S[10]-S[11]))/858
1471  CALL (17,3,240-Y0*P[4])
1480  LET X=-102*S[1]+72*S[2]+172*S[3]+212*S[4]+206*S[5]+138*S[6]
1490  LET P[5]=(X+112*S[7]+52*S[8]+2*S[9]-24*S[10]-12*S[11])/858
1491  CALL (17,4,240-Y0*P[5])
1500  FOR J=6 TO 55
1510  LET X=-36*(S[J+5]+S[J-5])+9*(S[J+4]+S[J-4])+44*(S[J+3]+S[J-3])
```

```
1520  LET P[J]=(X+69*(S[J+2]+S[J-2])+84*(S[J+1]+S[J-1])+89*S[J])/429
1521  CALL (17,J-1,240-Y0*P[J])
1530  NEXT J
1540  LET X=-12*S[50]-24*S[51]+2*S[52]+52*S[53]+112*S[54]
1550  LET X=X+168*S[55]+206*S[56]+212*S[57]+172*S[58]+72*S[59]
1560  LET P[56]=(X-102*S[60])/858
1561  CALL (17,55,240-Y0*P[56])
1570  LET X=48*(S[50]-S[51])-64*S[52]-23*S[53]+52*S[54]
1580  LET X=X+138*S[55]+212*S[56]+251*S[57]+232*S[59]+132*S[59]
1590  LET P[57]=(X-72*S[60])/858
1591  CALL (17,56,240-Y0*P[57])
1600  LET X=78*S[50]-48*(S[51]-S[60])-88*S[52]-64*S[53]
1610  LET X=X+2*S[54]+88*S[55]+172*S[56]+232*S[57]+246*S[58]
1620  LET P[58]=(X+192*S[59])/858
1621  CALL (17,57,240-Y0*P[58])
1630  LET X=48*(S[50]-S[52]-S[53])-18*(S[51]-S[55])-24*S[54]
1640  LET X=X+72*S[56]+132*S[57]+192*S[58]+246*S[59]+288*S[60]
1650  LET P[59]=X/858
1651  CALL (17,58,240-Y0*P[59])
1660  LET X=-72*(S[50]+S[55]+S[57])+48*(S[51]+S[53]+S[58])
1670  LET X=X+78*S[52]-12*S[54]-102*S[56]+288*S[59]+678*S[60]
1680  LET P[60]=X/858
1681  CALL (17,59,240-Y0*P[60])
1690  IF U7 >= 0 THEN 2000
1699  REM ** FIND RMS RESIDUAL OF FIT **
1700  LET U0=0
1710  FOR J=5 TO 56
1720  LET U0=U0+(P[J]-S[J])↑2
1730  NEXT J
1732  LET U7=0
1738  LET X=0
1740  LET U7=X=0
1749  REM ** LOOK FOR BAD POINTS AND DISCARD **
1750  LET U0=.25*INT(10*SQR(U0/52)+.5)
1760  FOR J=5 TO 56
1765  IF ABS(P[J]-S[J])<U0 THEN 1780
1770  LET X=1
1775  LET S[J]=.5*(S[J-1]+S[J+1])
1780  NEXT J
1789  REM ** IF ANY POINTS DISCARDED, REPEAT SMOOTHING **
1790  IF X#0 THEN 1400
2000  LET U0=0
2001  REM ** LOCATE MAXIMUM SIGNAL POINT IN ARRAY **
2004  FOR J=20 TO 41
2006  IF P[J]>P[J-1] THEN 2012
2008  IF U0=0 THEN 2014
2010  GOTO 2020
2012  LET U0=1
2014  NEXT J
2016  GOTO 2042
2020  LET X=J
2022  LET U0=0
2023  REM ** REPEAT IN OPPOSITE DIRECTION, VERIFY SINGLE PEAK **
2024  FOR J=41 TO 20 STEP -1
2026  IF P[J]>P[J+1] THEN 2032
2028  IF U0=0 THEN 2034
2030  GOTO 2036
```

```
2032  LET U0=1
2034  NEXT J
2035  GOTO 2042
2036  IF ABS(J-X)>3 THEN 2080
2037  LET J=INT(.5*(J+X)+.5)
2038  GOTO 2049
2042  PRINT "NO MAX AT"10*F6+1.00000E-03*(F7+25*F4)
2044  LET L0=L0+1
2046  GOSUB 8000
2047  GOTO 4000
2049  IF J>27 THEN 2070
2050  LET F4=.1*F5*(J-30)
2060  GOSUB 7000
2062  GOTO 1160
2070  IF J<33 THEN 2090
2072  GOTO 2050
2080  LET S0=F7+X*F4
2082  IF 10*F6+1.00000E-03*S0-1.00000E-03*F5+5.00000E-02>F0 THEN 2049
2084  LET J=X
2086  GOTO 2049
2090  LET S0=.5*P[J]
2199  REM ** FIND LOWER HALF MAXIMUM INTENSITY POINT **
2200  FOR K=4 TO J
2210  IF P[K]<S0 THEN 2230
2220  GOTO 2240
2230  NEXT K
2232  LET W1=0
2238  GOTO 2250
2240  IF K=4 THEN 2232
2244  LET W1=F7+(K-2)*F4+F4*(S0-P[K-1])/(P[K]-P[K-1])
2249  REM ** FIND UPPER HALF MAXIMUM INTENSITY POINT **
2250  FOR K=J TO 56
2260  IF P[K]>S0 THEN 2280
2270  GOTO 2290
2280  NEXT K
2282  LET W2=0
2284  GOTO 2300
2290  LET W2=F7+(K-2)*F4+F4*(P[K-1]-S0)/(P[K-1]-P[K])
2299  REM ** CHECK TO SEE IF FREQUENCY STEP SIZE APPROPRIATE **
2300  IF W1=0 THEN 2350
2310  IF W2=0 THEN 2400
2315  IF F5=50 THEN 2500
2330  IF (W2-W1)<4.5*(F5-50) THEN 2356
2340  GOTO 2500
2350  IF W2#0 THEN 2370
2352  IF 10*F6+1.00000E-03*F7-F0<2.50000E-03*F5 THEN 2500
2356  GOSUB 4500
2360  IF F5#X0 THEN 1150
2366  LET F4=INT(.1*F5+.1)
2368  GOTO 2500
2370  IF 2.2*F5>W2-F7-(J-1)*F4 THEN 2500
2375  IF 10*F6+1.00000E-03*F7-F0<1.00000E-03*F5 THEN 2500
2380  GOSUB 4500
2390  GOTO 2360
2400  IF 2.2*F5>F7-W1+(J-1)*F4 THEN 2500
2405  IF 10*F6+1.00000E-03*F7-F0<1.00000E-03*W4 THEN 2500
2410  GOSUB 4500
```

```
2430  GOTO 2360
2499  REM ** INTERPOLATE FOR DERIVATIVE = 0 TO FIND FREQUENCY **
2500  LET X=J-2
2510  LET Y1=.5*(P[X]-P[X-2])/F4
2520  IF Y1<0 THEN 2550
2530  LET X=X+1
2540  GOTO 2510
2550  LET Y2=.5*(P[X-1]-P[X-3])/F4
2560  LET Y=Y2/(Y2-Y1)
2570  LET J=X-1
2600  LET F2=INT(F7+(J-2+Y)*F4+.5)
2610  IF F2<10000 THEN 2650
2620  LET F1=F6=F6+1
2630  LET F2=INT(F2-9999.9)
2650  CALL (20,F1,F2,F3)
2652  LET F0=10*F1+1.00000E-03*F2
2654  REM ** SAVE STRONGEST SIGNAL TO FIND GAMMA **
2655  LET S0=P[J-1]
2657  REM ** CALCULATE LOWER AND UPPER HALF WIDTHS **
2658  IF W1=0 THEN 2678
2660  LET W1=INT(F2-W1+.1)
2662  IF W1>0 THEN 2670
2664  LET W1=INT(W1+10000.1)
2666  GOTO 2678
2670  IF W1<10000 THEN 2678
2672  LET W1=INT(W1-9999.9)
2678  IF W2=0 THEN 2700
2680  LET W2=INT(W2-F2+.1)
2682  IF W2 >= 0 THEN 2690
2684  LET W2=INT(W2+10000.1)
2686  GOTO 2700
2690  IF W2<10000 THEN 2700
2692  LET W2=INT(W2-9999.9)
2699  REM ** USE X=.1 MULTIPLIER FOR PRESSURE RANGE 10 MILLITORR **
2700  LET X=.1
2705  LET C4=100*C1+C2+1.00000E-02*C3
2710  LET P=1.00000E-02*X*P
2711  REM ** MEASURE POWER AND CRYSTAL CURRENT **
2715  CALL (35,6,3,X)
2720  CALL (35,5,4,I0)
2722  IF I0>0 THEN 2720
2729  REM ** CHECK METER ZEROES IF NOT DONE IN PAST 20 MINUTES **
2730  IF C4-C5 <= 20 THEN 2760
2732  LET I5=.1*I0
2734  CALL (22,-1)
2736  LET C5=C4
2738  WAIT (5000)
2740  CALL (35,5,3,I2)
2742  IF I2 <= I5 THEN 2748
2744  LET I5=I2
2746  GOTO 2738
2748  CALL (22,0)
2750  WAIT (50)
2752  CALL (35,5,3,I1)
2754  CALL (35,6,3,A1)
2756  LET I1=-1.00000E-02*I1
2758  CALL (22,1)
```

```
2760  LET I0=-1.00000E-03*I0-I1
2799  REM ** CORRECT SIGNAL FOR GAIN AND CRYSTAL CHARACTERISTICS **
2800  LET S0=7.41490E-06*S0*10↑(5.00000E-02*(20-G))
2810  IF I0 >= 5 THEN 2840
2820  LET S1=-.149297+.746211*I0+1.60785E-02*I0↑2-4.14767E-04*I0↑3
2824  LET S0=S0/S1
2830  GOTO 2900
2840  IF I0>10 THEN 2870
2850  LET S1=.110741+.616477*I0+3.61183E-02*I0↑2-1.31368E-03*I0↑3
2860  GOTO 2824
2870  IF I0>25 THEN 2890
2875  LET S1=-.442058+.863511*I0+3.04523E-03*I0↑2+7.61275E-05*I0↑3
2880  GOTO 2824
2890  PRINT "CALIB ONLY TO 25 MICROAMPS, I ="I0
2892  LET L0=L0+1
2894  GOTO 2875
2899  REM ** CALCULATE -10 LOG GAMMA AND POWER IN DBM **
2900  LET S1=-2.17147*LOG(1-(6.557/(1.00000E-03*F0))↑2)
2910  LET S1=S1-4.34294*LOG(S0)
2914  REM ** LINE 2915 ADJUSTS FOR SENSITIVITY DRIFT OR AGING **
2915  LET S1=S1-.1
2920  LET Y=4.34294*LOG(1.00000E-04*(X-A1))-10
2930  CALL (20,F1,F2,F3)
2940  LET S1=1.00000E-02*INT(100*S1+.5)
2949  REM ** LINE 2950 ADJUSTS FOR SLIGHT REFERENCE FREQUENCY ERRORS **
2950  LET Y1=F4
2960  LET F4=5
2970  GOSUB 7000
2999  REM ** PRINT RESULTS OF MEASUREMENTS AND CALCULATIONS **
3000  PRINT C4;TAB(12);F1;TAB(21);F2;TAB(30);
3010  PRINT S1;TAB(42);W1;TAB(48);W2;TAB(54);
3100  LET X=1.00000E-02*INT(.2135*V+.5)
3102  IF E5=0 THEN 3110
3104  PRINT "S";
3106  GOTO 3112
3110  PRINT " ";
3112  LET N=INT(X)
3120  GOSUB 3250
3150  PRINT ".";
3160  LET N=INT(10*X-10*N)
3170  GOSUB 3250
3180  LET N=INT(10*X)
3190  LET N=INT(100*X-10*N)
3200  GOSUB 3250
3210  GOTO 3400
3250  IF N#1 THEN 3260
3252  PRINT "1";
3254  RETURN
3260  IF N#2 THEN 3270
3262  PRINT "2";
3264  RETURN
3270  IF N#3 THEN 3280
3272  PRINT "3";
3274  RETURN
3280  IF N#4 THEN 3290
3282  PRINT "4";
3284  RETURN
```

```
3290  IF N#5 THEN 3300
3292  PRINT "5";
3294  RETURN
3300  IF N#6 THEN 3310
3302  PRINT "6";
3304  RETURN
3310  IF N#7 THEN 3320
3312  PRINT "7";
3314  RETURN
3320  IF N#8 THEN 3330
3322  PRINT "8";
3324  RETURN
3330  IF N#9 THEN 3340
3332  PRINT "9";
3334  RETURN
3340  PRINT "0";
3342  RETURN
3400  PRINT TAB(62);.1*INT(10*P)
3402  IF W1#0 THEN 3408
3404  IF W2#0 THEN 3408
3405  LET X=Q4=0
3406  GOTO 3426
3408  PRINT "LOG INT/MIC =";
3410  IF W1=0 THEN 3414
3411  LET Q4=FNI(W1)
3412  PRINT Q4;
3413  IF W2=0 THEN 3425
3414  LET Q4=FNI(W2)
3415  PRINT Q4;
3416  IF W1=0 THEN 3425
3417  LET X=.5*(W1+W2)
3418  LET Q4=FNI(X)
3419  PRINT Q4;
3420  PRINT "DELTA ="X;
3425  PRINT
3426  PRINT "DBM =".1*INT(10*Y);"GAIN ="30-G;"STEPS ="Y1;"ACCURACY =";
3499  REM ** CALCULATE FREQUENCY MEASUREMENT UNCERTAINTY **
3500  IF W1=0 THEN 3510
3504  IF W2=0 THEN 3516
3506  LET E4=E4*X+4.00000E-02*F5+.2*ABS(W1-W2)
3508  GOTO 3518
3510  IF W2#0 THEN 3516
3512  LET E4=F5*(.2+.15*E4)
3514  GOTO 3518
3516  LET E4=(E4+.25)*ABS(W1-W2)
3518  IF S1 <= 60 THEN 3530
3520  LET E4=E4+2.00000E-02*(S1-50)↑2
3530  IF E4>10 THEN 3560
3540  LET E4=10
3550  GOTO 3680
3560  IF E4>20 THEN 3590
3570  LET E4=20
3580  GOTO 3680
3590  IF E4>50 THEN 3620
3600  LET E4=50
3610  GOTO 3680
3620  IF E4>100 THEN 3650
```

```
3630  LET E4=100
3640  GOTO 3680
3650  LET E4=200
3680  PRINT E4;"KHZ"
3700  PRINT "-20 LOG CAP GAMMA ="1.00000E-02*INT(100*(2*S1-Y))
3710  LET L0=L0+4
3712  LET Q3=0
3719  REM ** DETERMINE LINE TYPE CODE **
3720  IF X#0 THEN 3730
3722  LET Q3=1
3724  GOTO 3760
3730  IF W1#0 THEN 3740
3732  LET Q3=2
3734  GOTO 3760
3740  IF W2#0 THEN 3750
3742  LET Q3=3
3744  GOTO 3760
3750  IF ABS(W1-W2)/X<5.00000E-02 THEN 3760
3752  LET Q3=4
3760  GOSUB 8000
3770  IF X=0 THEN 3800
3772  IF W2=0 THEN 3780
3774  LET W4=W2
3776  GOTO 3800
3780  LET W4=X
3799  REM ** ROUND DATA IF NECESSARY AND STORE ON DISC **
3800  LET Z[D2]=F1
3802  LET Z[D2+1]=F2
3804  LET Z[D2+2]=1.00000E-03*E4
3810  IF Q3>0 THEN 3840
3812  IF S1 <= 60.5 THEN 3822
3814  LET Q3=5
3816  GOTO 3840
3822  IF E5=0 THEN 3834
3824  LET Q3=6
3834  LET Z[D2+3]=.1*INT(10*S1+.5)
3836  LET Z[D2+4]=.1*INT(10*Q4+.5)
3838  GOTO 3850
3840  LET Z[D2+3]=INT(S1+.5)
3842  LET Z[D2+4]=INT(Q4+.5)
3850  LET Z[D2+5]=1.00000E-03*INT(2.135*V+.5)
3852  IF E5=0 THEN 3856
3854  LET Z[D2+5]=-Z[D2+5]
3856  LET Z[D2+6]=INT(Y+.5)
3858  LET Z[D2+7]=D3
3860  LET Z[D2+8]=INT(P+.5)
3862  LET Z[D2+9]=Q3
3870  LET D2=D2+10
3875  LET N9=N9+1
3880  CALL (3,Z[1],1,D1)
3890  IF D2<29 THEN 3950
3900  LET D1=D1+1
3902  LET D2=Z[32]
3910  MAT Z=ZER
3912  LET Z[32]=D2
3920  LET D2=1
3930  CALL (3,Z[1],1,D1)
```

```
3935  PRINT
3940  PRINT "SECTOR"D1-1;"FULL"
3942  PRINT
3944  LET L0=L0+3
3946  GOSUB 8000
3950  PRINT
3960  LET L0=L0+1
3970  LET F4=-F4
3980  GOSUB 7000
3990  GOSUB 4400
4000  CALL (25,110,1,3)
4002  LET G=10*INT(.1*G+.3)
4008  IF V=V0 THEN 4015
4010  LET V=V0
4012  GOSUB 5200
4015  CALL (27,110-G)
4018  LET E4=1
4020  LET S0=32767
4022  LET W0=(2*W0+F5)/3
4024  LET X=2.3*W0
4026  GOSUB 4610
4030  LET F4=INT(.5*F5+.1)
4035  GOSUB 7000
4040  CALL (20,F1,F2,F3)
4050  WAIT (T)
4100  GOSUB 5000
4120  IF S>3500 THEN 4200
4130  IF G >= G0 THEN 4300
4132  IF F4 >= 1.33*F5 THEN 4140
4134  LET F4=F4+50
4140  LET G=G+10
4142  IF G <= G0 THEN 4150
4144  LET G=G0
4146  GOTO 4300
4150  CALL (27,110-G)
4160  WAIT (T)
4170  LET S0=3.17*S0
4180  LET S=3.17*S
4200  IF S<1.02*S0 THEN 4260
4210  CALL (25,110,1,2)
4229  REM ** ANOTHER LINE HERE, RETURN TO PEAK FINDING MODE **
4230  GOTO 800
4260  GOSUB 7000
4270  LET S0=S
4280  GOTO 4040
4300  CALL (25,110,1,2)
4310  LET F4=INT(1.33*F5+.5)
4319  REM ** SIGNAL BELOW THRESHHOLD, RETURN TO SEARCH MODE **
4320  GOTO 9000
4399  REM ** SUBROUTINE TO ADJUST CRYSTAL CURRENT **
4400  CALL (35,5,3,Y1)
4410  LET Y1=INT(2.00000E-02*(Y1+A0))
4420  CALL (22,SGN(Y1))
4430  IF Y1#0 THEN 4400
4440  RETURN
4499  REM ** SUBROUTINE TO CHOOSE PROPER STEP SIZE **
4500  IF ABS(P[5]-P[56])/(P[5]+P[56])<.15 THEN 4506
```

```
4501  IF P[5]<P[56] THEN 4504
4502  LET S1=P[56]
4503  GOTO 4507
4504  LET S1=P[5]
4505  GOTO 4507
4506  LET S1=.5*(P[5]+P[56])
4507  LET X0=F5
4508  LET F5=(2.5*F5)↑2
4510  LET Y=.5*S1/S0
4520  FOR X=90 TO 990 STEP 20
4530  IF Y-X↑2/(F5+X↑2)<0 THEN 4560
4540  NEXT X
4542  LET F5=SQR(F5)/2.5
4544  IF W1>0 THEN 4610
4546  IF W2>0 THEN 4610
4550  PRINT "*W"
4555  RETURN
4560  LET F5=SQR(F5)/2.5
4610  IF X>110 THEN 4650
4615  IF F5=50 THEN 4640
4620  LET F4=F4*(J-30)+3*(F5-50)
4630  LET F5=50
4640  RETURN
4650  IF X>230 THEN 4690
4655  IF F5=100 THEN 4680
4660  LET F4=F4*(J-30)+3*(F5-100)
4670  LET F5=100
4680  RETURN
4690  IF X>350 THEN 4730
4695  IF F5=150 THEN 4720
4700  LET F4=F4*(J-30)+3*(F5-150)
4710  LET F5=150
4720  RETURN
4730  IF X>470 THEN 4770
4735  IF F5=200 THEN 4760
4740  LET F4=F4*(J-30)+3*(F5-200)
4750  LET F5=200
4760  RETURN
4770  IF X>590 THEN 4810
4775  IF F5=250 THEN 4800
4780  LET F4=F4*(J-30)+3*(F5-250)
4790  LET F5=250
4800  RETURN
4810  IF X>710 THEN 4850
4815  IF F5=300 THEN 4840
4820  LET F4=F4*(J-30)+3*(F5-300)
4830  LET F5=300
4840  RETURN
4850  IF F5=350 THEN 4870
4855  LET F4=F4*(J-30)+3*(F5-350)
4860  LET F5=350
4870  RETURN
4999  REM ** SUBROUTINE TO DO TIME INTEGRATION OF SIGNAL **
5000  LET N=INT(2.00000E-02*(G-30)↑2+.2)+2
5030  LET Y=0
5040  FOR J=1 TO N
5050  GOSUB 6000
```

```
5060  LET Y=Y+S
5070  NEXT J
5080  LET S=Y/N
5090  RETURN
5199  REM ** SUBROUTINE TO SET STARK BASELINE AND MODULATION VOLTAGES **
5200  LET E0=100
5210  CALL (26,E0,V)
5212  WAIT (T)
5213  LET E3=.25*V
5214  IF G<80 THEN 5216
5215  LET E3=E3+1.00000E-02*(G-70)*V
5216  RETURN
5220  GOSUB 5200
5221  IF E4=0 THEN 5238
5222  IF E4=-1 THEN 5226
5223  IF E[V/200-3]=0 THEN 5242
5224  LET E0=E[V/200-3]
5225  GOTO 5236
5226  GOSUB 5000
5227  LET X=S
5228  CALL (26,E0+25,V)
5229  WAIT (T)
5230  GOSUB 5000
5232  IF S<.99*X THEN 5240
5234  LET E4=E5=0
5236  GOSUB 5210
5238  RETURN
5240  LET E5=1
5241  LET E4=.1*SQR(50*ABS(X-S)/X)
5242  LET E0=E0+1.50000E-02*V-9
5244  GOSUB 5210
5246  GOSUB 5000
5248  LET X=S
5250  LET E0=E0-3
5252  GOSUB 5210
5254  GOSUB 5000
5256  IF S<.997*X THEN 5262
5258  LET X=S
5260  GOTO 5250
5262  LET E0=E0+5
5264  GOSUB 5210
5266  LET E[V/200-3]=E0
5268  RETURN
5999  REM ** SUBROUTINE TO CHECK PHASE LOCK AND MEASURE SIGNAL **
6000  CALL (30,S)
6010  CALL (32,L)
6020  IF L<-.15 THEN 6100
6030  CALL (14,T1,T2,T3)
6035  CALL (32,L)
6040  IF L >= -.15 THEN 6046
6042  WAIT (T)
6044  GOTO 6000
6046  CALL (14,T4,T5,T6)
6050  IF T4-T1+(T5-T2)/60+(T6-T3)/3600>5.00000E-04 THEN 6060
6055  GOTO 6035
6059  REM ** RING BELL, NOTIFY OPERATOR OF LOSS OF LOCK **
6060  PRINT ""100*T1+T2+1.00000E-02*T3;"*LOCK"
```

```
6070  LET L0=L0+2
6080  PRINT "GO";
6085  INPUT S
6090  GOTO 6000
6100  IF S=-32768. THEN 6010
6110  CALL (31,S)
6120  RETURN
6999  REM ** SUBROUTINE TO INCREMENT FREQUENCY VARIABLES **
7000  LET F2=INT(F2+F4)
7010  IF F2>9999 THEN 7050
7020  IF F2<0 THEN 7100
7030  RETURN
7050  LET F2=INT(F2-10000+.1)
7060  LET F1=F1+1
7070  RETURN
7100  LET F2=INT(10000+F2+.1)
7110  LET F1=F1-1
7120  RETURN
7999  REM ** SUBROUTINE TO TURN PAGES AND PRINT HEADINGS **
8000  IF L0>55 THEN 8015
8010  RETURN
8015  IF L0>90 THEN 8100
8018  REM ** PUT A FORM FEED COMMAND IN LINE 8018 **
8020  LET L0=7
8022  CALL (36,1,3,X)
8024  CALL (14,T1,T2,T3)
8026  PRINT "  TEMP ="INT(FNT(X)+.5);"DEG K AT"100*T1+T2+1.00000E-02*T3
8028  PRINT
8030  LET L0=L0+2
8050  PRINT "  TIME"TAB(14)"F1"TAB(22)"F2"TAB(31);
8060  PRINT "INT"TAB(42)"LO W"TAB(49)"HI W";
8070  PRINT TAB(55)"KV/CM"TAB(62)"MTORR"
8080  PRINT
8090  RETURN
8100  REM ** PUT A VERTICAL TAB COMMAND IN LINE 8100 **
8110  LET L0=15
8120  GOTO 8022
8999  REM ** END OF FREQUENCY STEPPING LOOP FOR SEARCH MODE **
9000  IF F1<F THEN 710
9100  IF 10*F1+1.00000E-03*F2 <= F9+1.00000E-03*F4 THEN 710
9310  PRINT
9320  PRINT N9;"LINES ON SECTORS";
9330  PRINT D0;"TO"D1;"WORD";D2-1
9980  PRINT
9981  PRINT
9982  LET L0=L0+4
9983  REM ** REQUEST NEW FREQUENCY RANGE TO COVER **
9984  GOTO 200
9988  REM ** TO END RUN AFTER INITIAL FREQUENCY RANGE IS COVERED,
9989  REM ** DELETE 9984.  FOLLOWING RETURNS SYSTEM TO MANUAL MODE **
9990  CALL (25,0,1,3)
9991  CALL (15,A[1],0)
9992  CALL (26,0,-1)
9993  CALL (22,0)
9994  CALL (27,-1)
9995  CALL (20,2650,0,0)
9998  CALL (13,-1,-1,-1)
9999  END
```

BASIC PROGRAM 20DB CROSS REFERENCE

VARIABLES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A(31) | 0010 | 0018 | 9991 | | | | |
| AØ | 0085 | 4410 | | | | | |
| A1 | 0014 | 0016 | 2754 | 2920 | | | |
| A3 | 0180 | 3755 | 3765 | 3785 | | | |
| C1 | 0030 | 0035 | 0040 | 1292 | 2705 | | |
| C2 | 0030 | 0035 | 0040 | 1292 | 2705 | | |
| C3 | 0030 | 0035 | 0040 | 1292 | 2705 | | |
| C4 | 2705 | 2730 | 2736 | 3000 | | | |
| C5 | 0040 | 2730 | 2736 | | | | |
| DØ | 0044 | 0046 | 9330 | | | | |
| D1 | 0046 | 0052 | 3880 | 3900 | 3930 | 3940 | 9330 |
| D2 | 0044 | 0050 | 3800 | 3802 | 3804 | 3834 | 3836 |
| | 3840 | 3842 | 3850 | 3854 | 3856 | 3858 | 3860 |
| | 3862 | 3870 | 3890 | 3902 | 3912 | 3920 | 9330 |
| D3 | 1304 | 3858 | | | | | |
| E(6) | 0010 | 0056 | 5223 | 5224 | 5266 | | |
| EØ | 5200 | 5210 | 5224 | 5228 | 5242 | 5250 | 5262 |
| | 5266 | | | | | | |
| E3 | 1012 | 1020 | 1044 | 1310 | 5213 | 5215 | |
| E4 | 0801 | 3506 | 3512 | 3516 | 3520 | 3530 | 3540 |
| | 3560 | 3570 | 3590 | 3600 | 3620 | 3630 | 3650 |
| | 3680 | 3804 | 4018 | 5221 | 5222 | 5234 | 5241 |
| E5 | 3102 | 3822 | 3852 | 5234 | 5240 | | |
| F | 0210 | 0270 | 0280 | 0330 | 9000 | | |
| FØ | 0242 | 0954 | 0986 | 2082 | 2352 | 2375 | 2405 |
| | 2652 | 2900 | | | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

VARIABLES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F1 | 0270 | 0280 | 0290 | 0670 | 0710 | 0720 | 0814 |
| | 0900 | 0945 | 0954 | 0958 | 0986 | 0990 | 1160 |
| | 1165 | 1239 | 1274 | 1281 | 1294 | 1296 | 2620 |
| | 2650 | 2652 | 2930 | 3000 | 3800 | 4040 | 7060 |
| | 7110 | 9000 | 9100 | | | | |
| F2 | 0280 | 0290 | 0710 | 0814 | 0900 | 0945 | 0954 |
| | 0958 | 0986 | 0990 | 1160 | 1170 | 1239 | 1276 |
| | 1281 | 1295 | 1296 | 2600 | 2610 | 2630 | 2650 |
| | 2652 | 2660 | 2680 | 2930 | 3000 | 3802 | 4040 |
| | 7000 | 7010 | 7020 | 7050 | 7100 | 9100 | |
| F3 | 0242 | 0670 | 0672 | 0680 | 0690 | 0710 | 0720 |
| | 0725 | 0730 | 0740 | 0742 | 0814 | 0900 | 0945 |
| | 0958 | 0990 | 1160 | 1239 | 1281 | 1296 | 2650 |
| | 2930 | 4040 | | | | | |
| F4 | 0700 | 0792 | 0800 | 0855 | 0904 | 0930 | 0950 |
| | 1140 | 1185 | 1260 | 1264 | 1276 | 1278 | 2042 |
| | 2050 | 2080 | 2244 | 2290 | 2366 | 2370 | 2400 |
| | 2510 | 2550 | 2600 | 2950 | 2960 | 3970 | 4030 |
| | 4132 | 4134 | 4310 | 4620 | 4660 | 4700 | 4740 |
| | 4780 | 4820 | 4855 | | | | |
| F5 | 0075 | 0080 | 0700 | 0800 | 0855 | 0904 | 0950 |
| | 0954 | 0986 | 1140 | 1185 | 2050 | 2082 | 2315 |
| | 2330 | 2352 | 2360 | 2366 | 2370 | 2375 | 2400 |
| | 3506 | 3512 | 4022 | 4030 | 4132 | 4310 | 4507 |
| | 4508 | 4530 | 4542 | 4560 | 4615 | 4620 | 4630 |
| | 4655 | 4660 | 4670 | 4695 | 4700 | 4710 | 4735 |
| | 4740 | 4750 | 4775 | 4780 | 4790 | 4815 | 4820 |
| | 4830 | 4850 | 4855 | 4860 | | | |
| F6 | 1165 | 1274 | 1294 | 2042 | 2082 | 2352 | 2375 |
| | 2405 | 2620 | | | | | |
| F7 | 1170 | 1276 | 1295 | 2042 | 2080 | 2244 | 2290 |
| | 2352 | 2370 | 2375 | 2400 | 2405 | 2600 | |
| F9 | 0230 | 0330 | 9100 | | | | |
| G | 0120 | 0300 | 0824 | 0826 | 0840 | 0842 | 0850 |
| | 0862 | 0962 | 0970 | 0980 | 1102 | 1106 | 1108 |
| | 1110 | 1112 | 1116 | 1195 | 2800 | 3426 | 4002 |
| | 4015 | 4130 | 4140 | 4142 | 4144 | 4150 | 5000 |
| | 5214 | 5215 | | | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

VARIABLES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| GØ | 0092 | 0094 | 0102 | 0120 | 0824 | 0962 | 1102 |
| | 4130 | 4142 | 4144 | | | | |
| I | 0007 | 0008 | 0009 | 1236 | 1290 | | |
| IØ | 2720 | 2722 | 2732 | 2760 | 2810 | 2820 | 2840 |
| | 2850 | 2870 | 2875 | 2890 | | | |
| I1 | 0009 | 2752 | 2756 | 2760 | 2772 | | |
| I2 | 2740 | 2742 | 2744 | | | | |
| I4 | 0672 | 0690 | 0740 | 0742 | | | |
| I5 | 2732 | 2742 | 2744 | | | | |
| J | 1238 | 1243 | 1244 | 1245 | 1249 | 1250 | 1284 |
| | 1288 | 1312 | 1314 | 1316 | 1500 | 1510 | 1520 |
| | 1521 | 1530 | 1710 | 1720 | 1730 | 1760 | 1765 |
| | 1775 | 1780 | 2004 | 2006 | 2014 | 2020 | 2024 |
| | 2026 | 2034 | 2036 | 2037 | 2049 | 2050 | 2070 |
| | 2084 | 2090 | 2200 | 2250 | 2370 | 2400 | 2500 |
| | 2570 | 2600 | 2655 | 4620 | 4660 | 4700 | 4740 |
| | 4780 | 4820 | 4855 | 5040 | 5070 | | |
| J1 | 1210 | 1238 | 1254 | 1256 | 1270 | 1284 | 1286 |
| J2 | 1212 | 1238 | 1258 | 1272 | 1286 | 1288 | |
| J3 | 1214 | 1238 | 1252 | 1282 | | | |
| K | 2200 | 2210 | 2230 | 2240 | 2244 | 2250 | 2260 |
| | 2280 | 2290 | | | | | |
| L | 6010 | 6020 | 6035 | 6040 | | | |
| LØ | 0060 | 0225 | 2044 | 2892 | 3710 | 3944 | 3960 |
| | 6070 | 8000 | 8015 | 8020 | 8030 | 8110 | 9982 |
| N | 1195 | 1200 | 1236 | 3112 | 3160 | 3180 | 3190 |
| | 3250 | 3260 | 3270 | 3280 | 3290 | 3300 | 3310 |
| | 3320 | 3330 | 5000 | 5040 | 5080 | | |
| N(60) | 1220 | 1232 | 1243 | 1244 | 1245 | | |
| NØ | 1234 | 1254 | 1258 | 1260 | 1264 | 1267 | 1273 |

BASIC PROGRAM 20DB CROSS REFERENCE

VARIABLES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| N9 | 0242 | 3875 | 9320 | | | | |
| P | 0110 | 1293 | 2710 | 3400 | 3860 | | |
| P(60) | 0010 | 1410 | 1411 | 1430 | 1431 | 1450 | 1451 |
| | 1470 | 1471 | 1490 | 1491 | 1520 | 1521 | 1560 |
| | 1561 | 1590 | 1591 | 1620 | 1621 | 1650 | 1651 |
| | 1680 | 1681 | 1720 | 1765 | 2006 | 2026 | 2090 |
| | 2210 | 2244 | 2260 | 2290 | 2510 | 2550 | 2655 |
| | 4500 | 4501 | 4502 | 4504 | 4506 | | |
| Q3 | 3712 | 3722 | 3732 | 3742 | 3752 | 3810 | 3814 |
| | 3824 | 3862 | | | | | |
| Q4 | 3405 | 3441 | 3412 | 3414 | 3415 | 3418 | 3419 |
| | 3836 | 3842 | | | | | |
| S | 0790 | 0802 | 0806 | 0810 | 0820 | 0822 | 0860 |
| | 0880 | 0912 | 0920 | 1012 | 1020 | 1024 | 1026 |
| | 1036 | 1044 | 1046 | 1048 | 1248 | 4120 | 4180 |
| | 4200 | 4270 | 5060 | 5080 | 5227 | 5232 | 5241 |
| | 5248 | 5256 | 5258 | 6000 | 6085 | 6100 | 6110 |
| S(60) | 1220 | 1230 | 1243 | 1248 | 1249 | 1314 | 1400 |
| | 1410 | 1420 | 1430 | 1440 | 1450 | 1460 | 1470 |
| | 1480 | 1490 | 1510 | 1520 | 1540 | 1550 | 1560 |
| | 1570 | 1580 | 1590 | 1600 | 1610 | 1620 | 1630 |
| | 1640 | 1660 | 1670 | 1720 | 1765 | 1775 | |
| SØ | 1243 | 1246 | 1248 | 2080 | 2090 | 2210 | 2244 |
| | 2260 | 2290 | 2655 | 2800 | 2824 | 2910 | 4020 |
| | 4170 | 4200 | 4270 | 4510 | | | |
| S1 | 0110 | 0880 | 0920 | 0960 | 0984 | 1012 | 1024 |
| | 1026 | 1036 | 1046 | 1048 | 1100 | 1104 | 1114 |
| | 1216 | 2820 | 2824 | 2850 | 2875 | 2900 | 2910 |
| | 2915 | 2940 | 3010 | 3518 | 3520 | 3700 | 3812 |
| | 3834 | 3840 | 4502 | 4504 | 4506 | 4510 | |
| T | 0244 | 0310 | 0844 | 0853 | 0902 | 0947 | 0982 |
| | 1000 | 1125 | 1283 | 4050 | 4160 | 5212 | 5229 |
| | 6042 | | | | | | |
| TØ | 0240 | 0244 | 0816 | 1198 | 1200 | 1241 | |
| T1 | 6030 | 6050 | 6060 | 8024 | 8026 | | |

BASIC PROGRAM 20DB CROSS REFERENCE

VARIABLES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| T2 | 6030 | 6050 | 6060 | 8024 | 8026 | | |
| T3 | 6030 | 6050 | 6060 | 8024 | 8026 | | |
| T4 | 6046 | 6050 | | | | | |
| T5 | 6046 | 6050 | | | | | |
| T6 | 6046 | 6050 | | | | | |
| UØ | 1700 | 1720 | 1750 | 1765 | 2000 | 2008 | 2021 |
| | 2022 | 2028 | 2032 | | | | |
| U7 | 1318 | 1690 | 1732 | 1740 | | | |
| V | 0150 | 1014 | 1022 | 1030 | 1034 | 1038 | 1050 |
| | 1052 | 1060 | 1070 | 1080 | 3100 | 3850 | 4008 |
| | 4010 | 5210 | 5213 | 5215 | 5223 | 5224 | 5228 |
| | 5242 | 5266 | | | | | |
| VØ | 0130 | 0150 | 1004 | 1050 | 4008 | 4010 | |
| V1 | 1004 | 1030 | 1034 | 1052 | 1080 | | |
| WØ | 0080 | 4022 | 4024 | | | | |
| W1 | 2232 | 2244 | 2300 | 2330 | 2400 | 2658 | 2660 |
| | 2662 | 2664 | 2670 | 2672 | 3010 | 3402 | 3410 |
| | 3411 | 3416 | 3417 | 3500 | 3506 | 3516 | 3730 |
| | 3750 | 4544 | | | | | |
| W2 | 2282 | 2290 | 2310 | 2330 | 2350 | 2370 | 2678 |
| | 2680 | 2682 | 2684 | 2690 | 2692 | 3010 | 3404 |
| | 3413 | 3414 | 3417 | 3504 | 3506 | 3510 | 3516 |
| | 3740 | 3750 | 3772 | 3774 | 4546 | | |
| W4 | 0080 | 3405 | 3774 | 3780 | | | |
| X | 1245 | 1246 | 1248 | 1310 | 1314 | 1400 | 1410 |
| | 1420 | 1430 | 1440 | 1450 | 1460 | 1470 | 1480 |
| | 1490 | 1510 | 1520 | 1540 | 1550 | 1560 | 1570 |
| | 1580 | 1590 | 1600 | 1610 | 1620 | 1630 | 1640 |
| | 1650 | 1660 | 1670 | 1680 | 1740 | 1770 | 1790 |
| | 2020 | 2036 | 2037 | 2080 | 2084 | 2500 | 2510 |
| | 2530 | 2550 | 2570 | 2700 | 2710 | 2715 | 2920 |
| | 3100 | 3112 | 3160 | 3180 | 3190 | 3405 | 3417 |

BASIC PROGRAM 20DB CROSS REFERENCE

VARIABLES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3418 | 3425 | 3506 | 3720 | 3750 | 3770 | 3780 |
| | 4024 | 4520 | 4530 | 4540 | 4610 | 4650 | 4690 |
| | 4730 | 4770 | 4810 | 5227 | 5232 | 5241 | 5248 |
| | 5256 | 5258 | 8022 | 8026 | | | |
| XØ | 0070 | 0110 | 2360 | 4507 | | | |
| Y | 1104 | 1106 | 1112 | 1112 | 1300 | 1302 | 1304 |
| | 2560 | 2600 | 2920 | 3426 | 3700 | 3856 | 4510 |
| | 4530 | 5030 | 5060 | 5080 | | | |
| YØ | 1216 | 1249 | 1411 | 1431 | 1451 | 1471 | 1491 |
| | 1521 | 1561 | 1591 | 1621 | 1651 | 1681 | |
| Y1 | 2510 | 2525 | 2560 | 2950 | 3426 | 4400 | 4410 |
| | 4420 | 4430 | | | | | |
| Y2 | 2550 | 2560 | | | | | |
| Z(32) | 0010 | 0048 | 0052 | 0094 | 3800 | 3802 | 3804 |
| | 3834 | 3836 | 3840 | 3842 | 3850 | 3854 | 3856 |
| | 3858 | 3860 | 3862 | 3880 | 3902 | 3910 | 3912 |
| | 3930 | | | | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

SUBROUTINES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 03 | 0052 | 3880 | 3930 | | | | |
| 13 | 0035 | 9998 | | | | | |
| 14 | 1292 | 6030 | 6046 | 8024 | | | |
| 15 | 0018 | 9991 | | | | | |
| 17 | 1249 | 1411 | 1431 | 1451 | 1471 | 1491 | 1521 |
| | 1561 | 1591 | 1621 | 1651 | 1681 | | |
| 20 | 0054 | 0290 | 0710 | 0814 | 0900 | 0945 | 0958 |
| | 0990 | 1160 | 1239 | 1281 | 1296 | 2650 | 2930 |
| | 4040 | 9995 | | | | | |
| 22 | 2734 | 2748 | 2758 | 4420 | 9993 | | |
| 25 | 0011 | 0305 | 0851 | 1130 | 4000 | 4210 | 4300 |
| | 9990 | | | | | | |
| 27 | 0012 | 0300 | 0842 | 0850 | 0980 | 1116 | 4015 |
| | 4150 | 9994 | | | | | |
| 30 | 6000 | | | | | | |
| 31 | 6110 | | | | | | |
| 32 | 6010 | 6035 | | | | | |
| 35 | 0008 | 0016 | 1293 | 2715 | 2720 | 2740 | 2752 |
| | 2754 | 4400 | | | | | |
| 36 | 0014 | 1300 | 8022 | | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | |
|---|---|---|
| 0054 | 0050 | |
| 0200 | 9984 | |
| 0700 | 0680 | |
| 0710 | 9000 | 9100 |
| 0740 | 0725 | |
| 0750 | 0740 | |
| 0760 | 0746 | |
| 0800 | 4230 | |
| 0810 | 0802 | 0820 |
| 0812 | 0846 | |
| 0840 | 0810 | |
| 0842 | 0828 | 0916 |
| 0850 | 0806 | 0864 |
| 0851 | 0822 | |
| 0858 | 0855 | 0950 |
| 0860 | 0857 | 0920 |
| 0880 | 0860 | |
| 0910 | 0904 | |
| 0912 | 0908 | |
| 0920 | 0912 | |
| 0958 | 0954 | |
| 0970 | 0962 | |
| 0986 | 0960 | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | |
|---|---|---|
| 0990 | 0986 | |
| 1030 | 1024 | |
| 1034 | 1050 | 1060 |
| 1036 | 1032 | |
| 1038 | 1026 | 1070 |
| 1060 | 1046 | |
| 1070 | 1048 | |
| 1080 | 1028 | |
| 1100 | 1052 | 1062 |
| 1114 | 1108 | |
| 1120 | 1100 | 1102 |
| 1150 | 2360 | |
| 1160 | 2062 | |
| 1210 | 1198 | |
| 1270 | 1256 | |
| 1278 | 1252 | |
| 1280 | 1268 | |
| 1400 | 1790 | |
| 1780 | 1765 | |
| 2000 | 1690 | |
| 2012 | 2006 | |
| 2014 | 2008 | |
| 2020 | 2010 | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2032 | 2026 | | | | | | |
| 2034 | 2028 | | | | | | |
| 2036 | 2030 | | | | | | |
| 2042 | 2016 | 2035 | | | | | |
| 2049 | 2038 | 2082 | 2086 | | | | |
| 2050 | 2072 | | | | | | |
| 2070 | 2049 | | | | | | |
| 2080 | 2036 | | | | | | |
| 2090 | 2070 | | | | | | |
| 2230 | 2310 | | | | | | |
| 2232 | 2240 | | | | | | |
| 2240 | 2220 | | | | | | |
| 2250 | 2238 | | | | | | |
| 2280 | 2260 | | | | | | |
| 2290 | 2270 | | | | | | |
| 2300 | 2284 | | | | | | |
| 2350 | 2300 | | | | | | |
| 2356 | 2330 | | | | | | |
| 2360 | 2390 | 2430 | | | | | |
| 2370 | 2350 | | | | | | |
| 2400 | 2310 | | | | | | |
| 2500 | 2315 2405 | 2340 | 2352 | 2368 | 2370 | 2375 | 2400 |
| 2510 | 2405 | | | | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | | |
|---|---|---|---|
| 2550 | 2520 | | |
| 2650 | 2610 | | |
| 2670 | 2662 | | |
| 2678 | 2658 | 2666 | 2670 |
| 2690 | 2682 | | |
| 2700 | 2678 | 2686 | 2690 |
| 2720 | 2722 | | |
| 2738 | 2746 | | |
| 2748 | 2742 | | |
| 2760 | 2730 | | |
| 2824 | 2860 | 2880 | |
| 2840 | 2810 | | |
| 2870 | 2840 | | |
| 2875 | 2894 | | |
| 2890 | 2870 | | |
| 2900 | 2830 | | |
| 3110 | 3102 | | |
| 3112 | 3106 | | |
| 3250 | 3120 | 3170 | 3200 |
| 3260 | 3250 | | |
| 3270 | 3260 | | |
| 3280 | 3270 | | |
| 3290 | 3280 | | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | | | |
|---|---|---|---|---|
| 3300 | 3290 | | | |
| 3310 | 3300 | | | |
| 3320 | 3310 | | | |
| 3330 | 3320 | | | |
| 3340 | 3330 | | | |
| 3400 | 3210 | | | |
| 3408 | 3402 | 3404 | | |
| 3414 | 3410 | | | |
| 3425 | 3413 | 3416 | | |
| 3426 | 3406 | | | |
| 3510 | 3500 | | | |
| 3516 | 3504 | 3510 | | |
| 3518 | 3508 | 3514 | | |
| 3560 | 3530 | | | |
| 3590 | 3560 | | | |
| 3620 | 3590 | | | |
| 3650 | 3620 | | | |
| 3680 | 3550 | 3580 | 3610 | 3640 |
| 3730 | 3720 | | | |
| 3740 | 3730 | | | |
| 3750 | 3740 | | | |
| 3760 | 3724 | 3734 | 3744 | 3750 |
| 3780 | 3772 | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | | | | |
|---|---|---|---|---|---|
| 3800 | 3770 | 3776 | | | |
| 3822 | 3812 | | | | |
| 3840 | 3810 | 3816 | | | |
| 3850 | 3838 | | | | |
| 3856 | 3852 | | | | |
| 3950 | 3890 | | | | |
| 4000 | 0988 | 2047 | | | |
| 4015 | 4008 | | | | |
| 4030 | 0956 | | | | |
| 4040 | 4280 | | | | |
| 4140 | 4132 | | | | |
| 4150 | 4142 | | | | |
| 4200 | 4120 | | | | |
| 4260 | 4200 | | | | |
| 4300 | 0966 | 4130 | 4146 | | |
| 4310 | 0808 | 0824 | | | |
| 4400 | 0674 | 0744 | 0995 | 3990 | 4430 |
| 4500 | 2356 | 2380 | 2410 | | |
| 4504 | 4501 | | | | |
| 4506 | 4500 | | | | |
| 4507 | 4503 | 4505 | | | |
| 4560 | 4530 | | | | |
| 4610 | 4026 | 4544 | 4546 | | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBER

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4640 | 4615 | | | | | | |
| 4650 | 4610 | | | | | | |
| 4680 | 4655 | | | | | | |
| 4690 | 4650 | | | | | | |
| 4720 | 4695 | | | | | | |
| 4730 | 4690 | | | | | | |
| 4760 | 4735 | | | | | | |
| 4770 | 4730 | | | | | | |
| 4800 | 4775 | | | | | | |
| 4810 | 4770 | | | | | | |
| 4840 | 4815 | | | | | | |
| 4850 | 4810 | | | | | | |
| 4870 | 4850 | | | | | | |
| 5000 | 0858 | 0910 | 1010 | 1018 | 1042 | 4100 | 5226 |
| | 5230 | 5246 | 5254 | | | | |
| 5200 | 0246 | 4012 | 5220 | | | | |
| 5210 | 5236 | 5244 | 5252 | 5264 | | | |
| 5213 | 1120 | | | | | | |
| 5216 | 5214 | | | | | | |
| 5220 | 1002 | 1016 | 1040 | 1082 | | | |
| 5226 | 5222 | | | | | | |
| 5236 | 5225 | | | | | | |
| 5238 | 5221 | | | | | | |
| 5240 | 5232 | | | | | | |

BASIC PROGRAM 20DB CROSS REFERENCE

STATEMENT NUMBERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5242 | 5223 | | | | | | |
| 5250 | 5260 | | | | | | |
| 5262 | 5256 | | | | | | |
| 6000 | 0760 | 0804 | 0818 | 0856 | 0906 | 1247 | 5050 |
| | 6044 | 6090 | | | | | |
| 6010 | 6100 | | | | | | |
| 6035 | 6055 | | | | | | |
| 6046 | 6040 | | | | | | |
| 6060 | 6050 | | | | | | |
| 6100 | 6020 | | | | | | |
| 7000 | 0715 | 0794 | 0812 | 0890 | 0940 | 0952 | 1150 |
| | 1240 | 1262 | 1280 | 2060 | 2970 | 3980 | 4035 |
| | 4260 | | | | | | |
| 7050 | 7010 | | | | | | |
| 7100 | 7020 | | | | | | |
| 8000 | 0320 | 2046 | 3760 | 3946 | | | |
| 8015 | 8000 | | | | | | |
| 8022 | 8120 | | | | | | |
| 8100 | 8015 | | | | | | |
| 9000 | 0790 | 4320 | | | | | |

## APPENDIX C

## SAMPLE DATA OUTPUT

This appendix contains a page from part of the spectrum run on pyrrole. The program start up procedure at the top of the page is explained by comments inserted in the program listing.

The data output is interpreted as follows: as an example, consider the first measurement on section 32. At approximately 11:59 a line was measured at 33 351.222 MHz. The intensity, in the form -10 log$\gamma$, was 56.98. The lower halfwidth was 273 kHz and the upper halfwidth was 266 kHz, giving an average of 269.5 kHz for the linewidth. The measurement was made at a Stark field of 2.14 kV/cm and a sample pressure of 9.9 millitorr. The integrated intensity per unit pressure, in the form -10 log$\gamma\Delta$/P, was 42.58, 42.7, and 42.64 for the lower, upper, and average values of halfwidth, respectively. The power level at the detector was -16.8 dBm, the range setting -50, and 15 kHz steps were used during the measurement. The measurement uncertainty is 10 kHz. Finally, -20 log$\Gamma$ was 130.74 (see reference 2 for a discussion of this quantity).

For lines with a sensitive Stark effect, an "S" appears immediately before the Stark field value.

```
ATTEN AT MAX?1
TIME?11,20,0
DISC SECTOR AND WORD?31,11
ID #?764
RANGE?-60
START FREQ?32962
END FREQ?34000


  TEMP = 298  DEG K AT 1128.44

  TIME        F1       F2        INT         LO W   HI W  KV/CM  MTORR

 1133.96     3296     3197      52.23         244   245   2.99     10
LOG INT/MIC = 38.37        38.36        38.36       DELTA = 244.5
DBM =-17.1        GAIN =-40    STEPS = 15   ACCURACY = 10   KHZ
-20 LOG CAP GAMMA = 121.49

 1146.4      3330      747      53.65         267   268   2.14     9.9
LOG INT/MIC = 39.36        39.35        39.36       DELTA = 267.5
DBM =-17.1        GAIN =-40    STEPS = 15   ACCURACY = 10   KHZ
-20 LOG CAP GAMMA = 124.39

SECTOR 31   FULL

 1158.52     3335     1222      56.98         273   266   2.14     9.9
LOG INT/MIC = 42.58        42.7         42.64       DELTA = 269.5
DBM =-16.8        GAIN =-50    STEPS = 15   ACCURACY = 10   KHZ
-20 LOG CAP GAMMA = 130.74

 1211.76     3337     1937      64.35         251   243   2.14     10
LOG INT/MIC = 50.38        50.52        50.45       DELTA = 247
DBM =-17.1        GAIN =-60    STEPS = 15   ACCURACY = 20   KHZ
-20 LOG CAP GAMMA = 145.75

 1230.12     3362     1667      64.82         269   261   2.99     10
LOG INT/MIC = 50.56        50.69        50.62       DELTA = 265
DBM =-17.5        GAIN =-60    STEPS = 15   ACCURACY = 20   KHZ
-20 LOG CAP GAMMA = 147.09

SECTOR 32   FULL

 1240.08     3388     7997      51.92         276   259   2.14     10
LOG INT/MIC = 37.53        37.8         37.66       DELTA = 267.5
DBM =-17.7        GAIN =-40    STEPS = 15   ACCURACY = 10   KHZ
-20 LOG CAP GAMMA = 121.52

 1257.12     3395     8693      64.6          265   0     2.56     10
LOG INT/MIC = 50.39
DBM =-17.8        GAIN =-60    STEPS = 15   ACCURACY = 100  KHZ
-20 LOG CAP GAMMA = 146.97
```

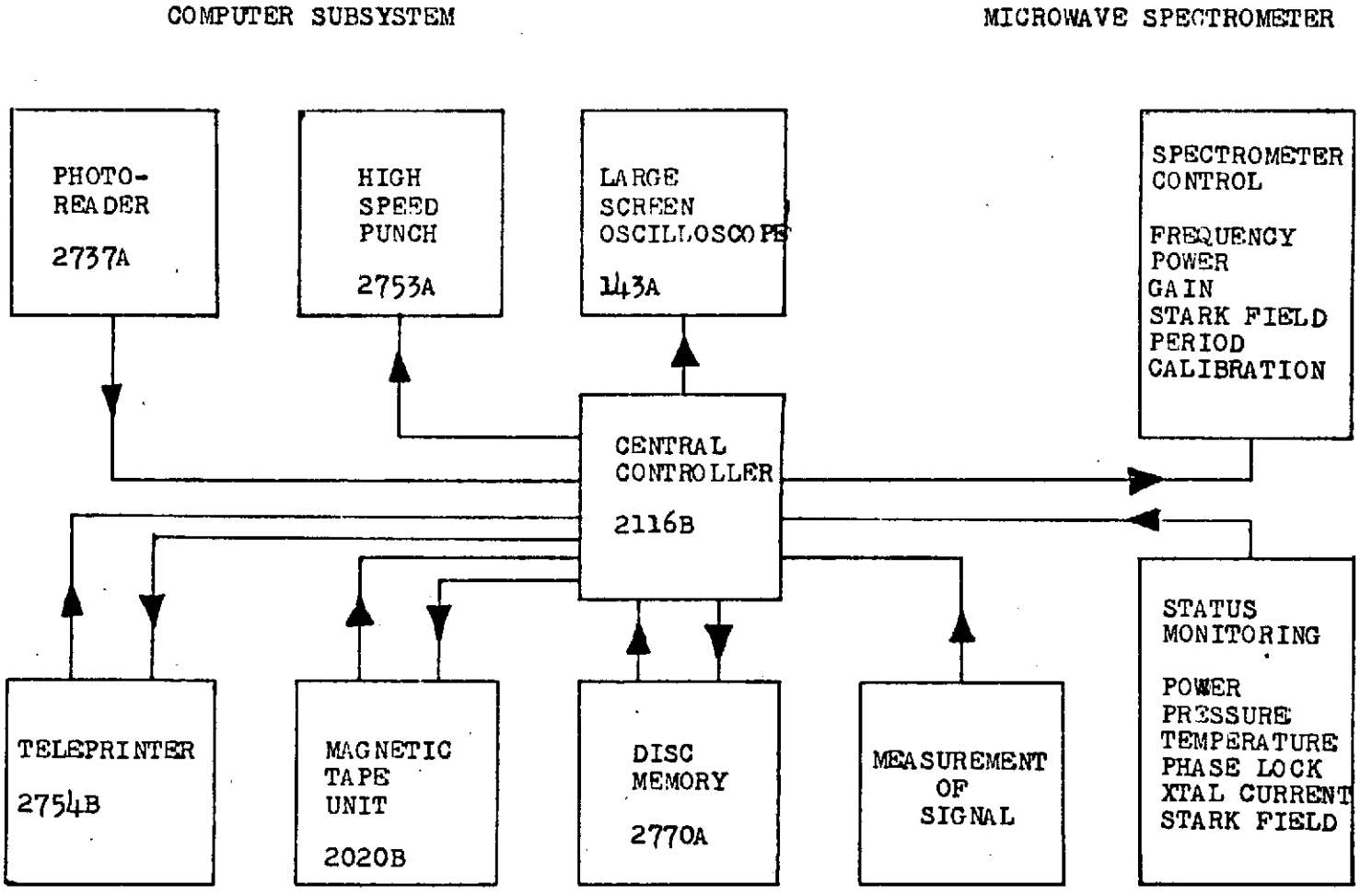


Figure 1. Overall block diagram of automated spectrometer system.

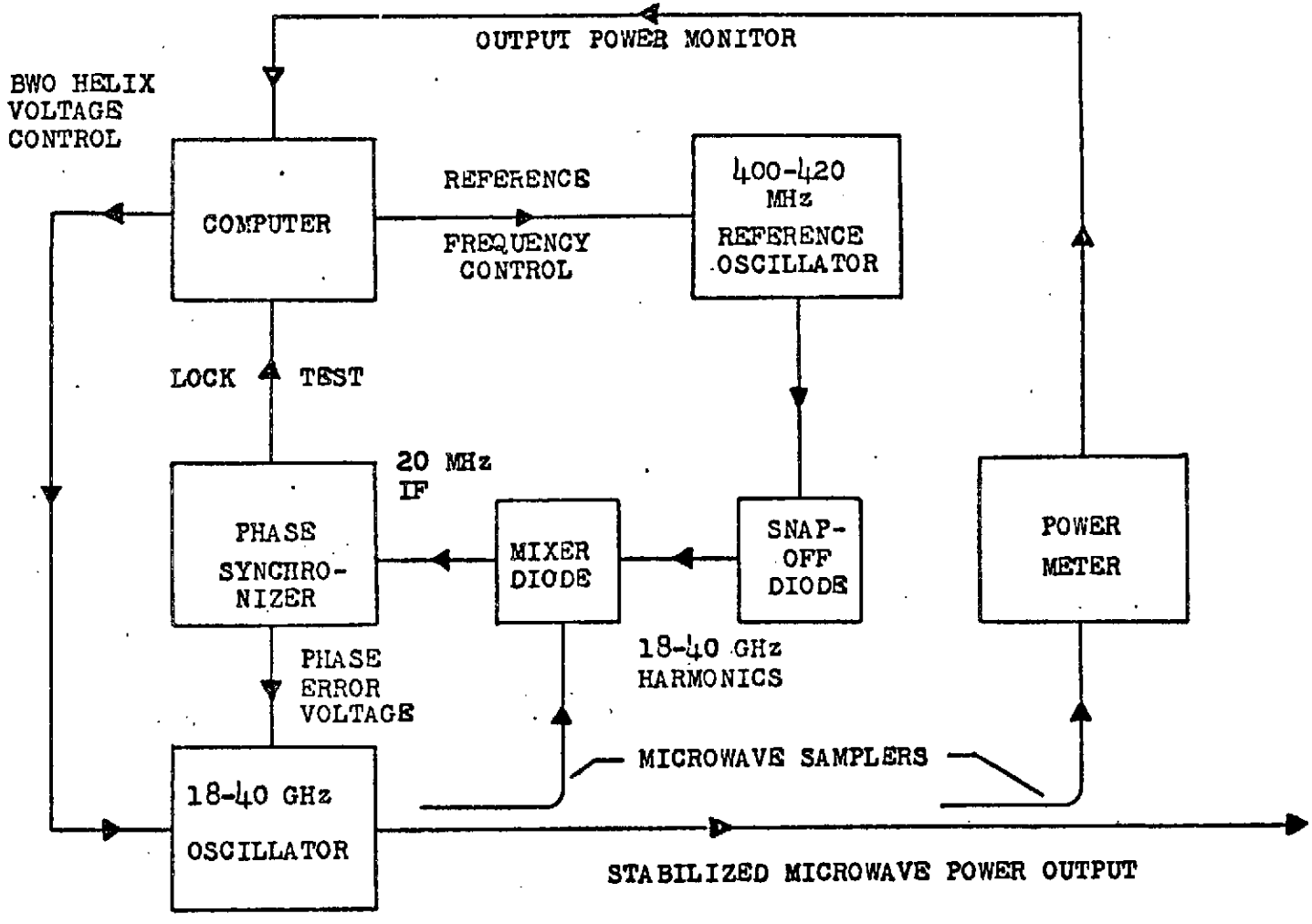


Figure 2.- Stabilized digital microwave source.

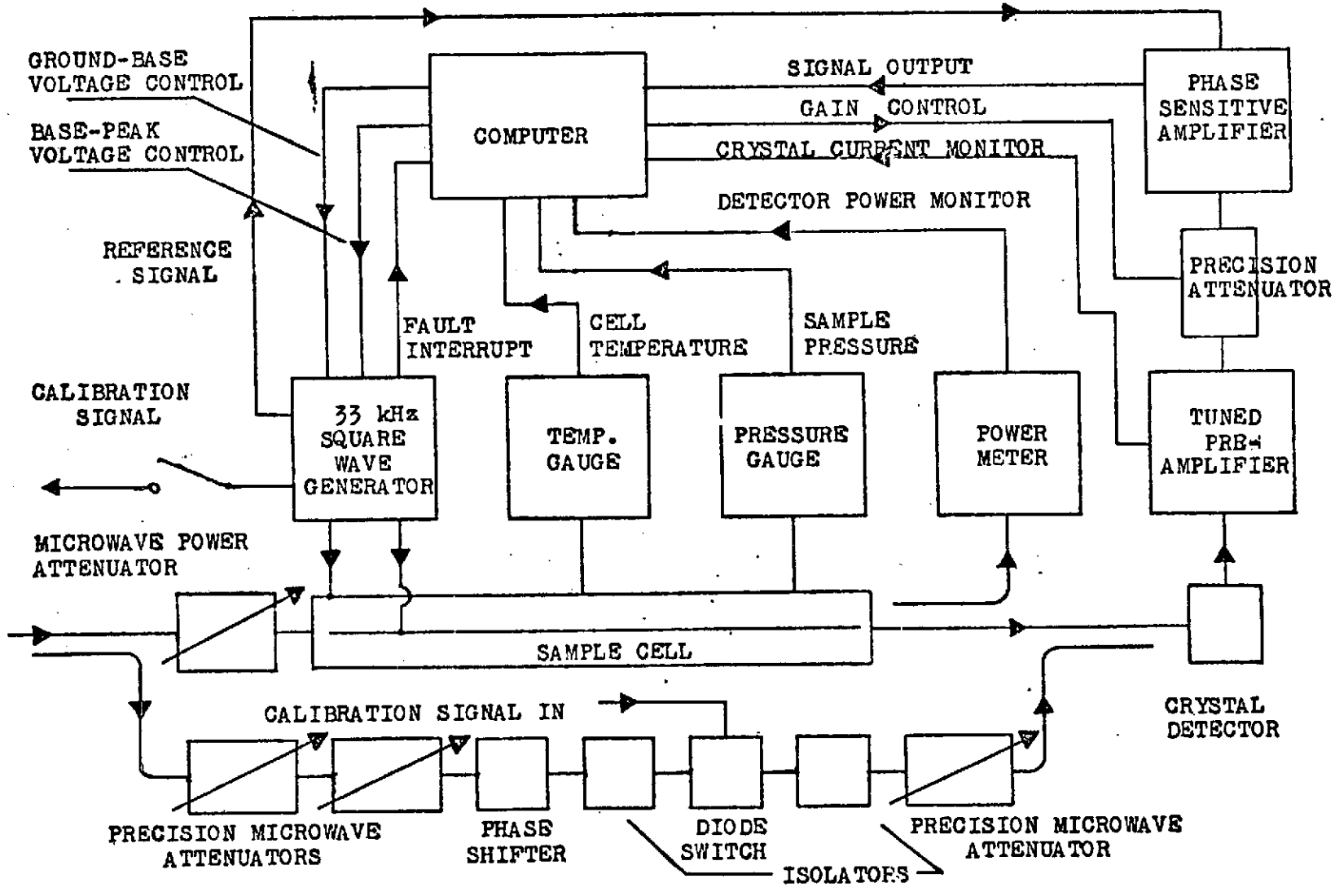


Figure 3.-Detedtion, calibration, and status monitoring system.

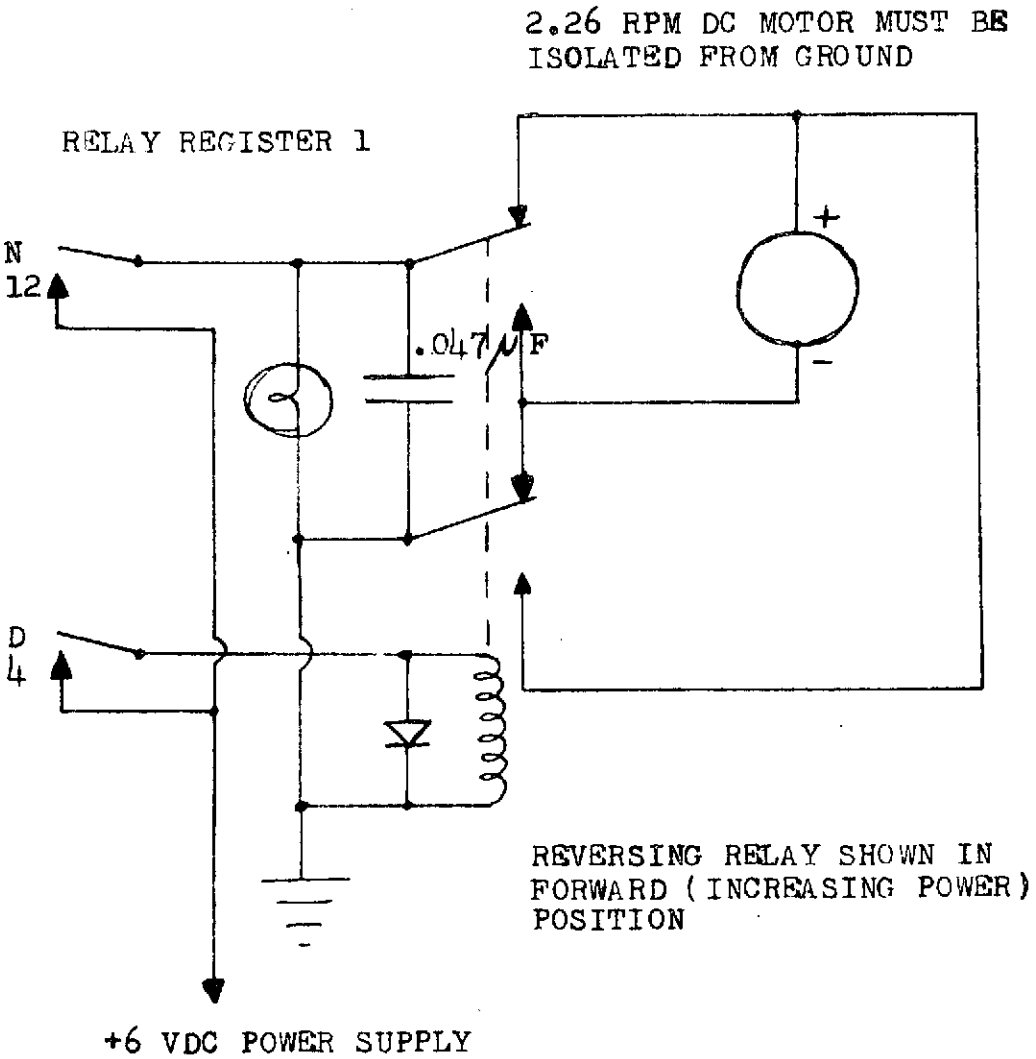


Figure 4. Power attenuator control wiring diagram.

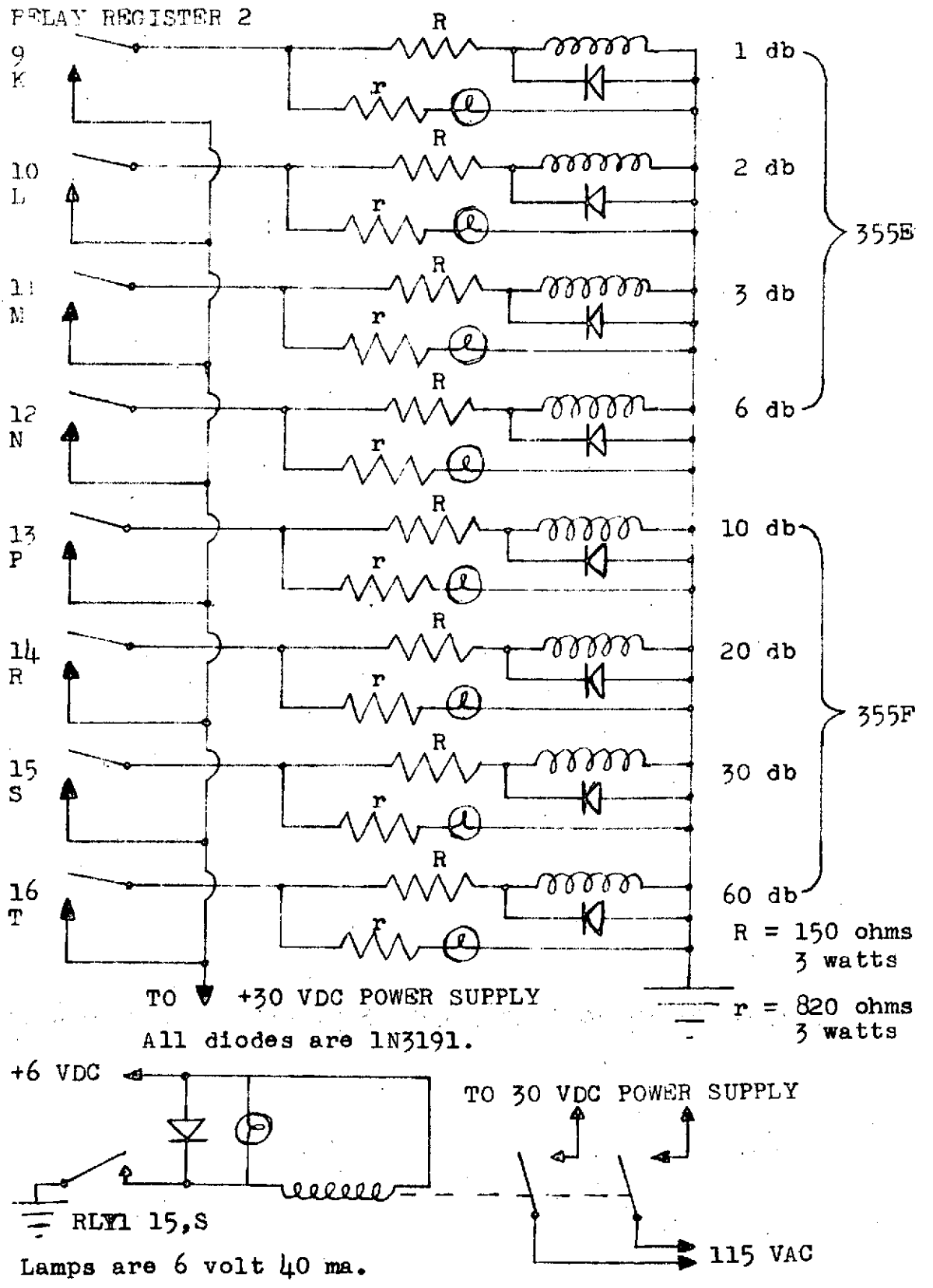


Figure 5. Gain attenuator control wiring diagram.

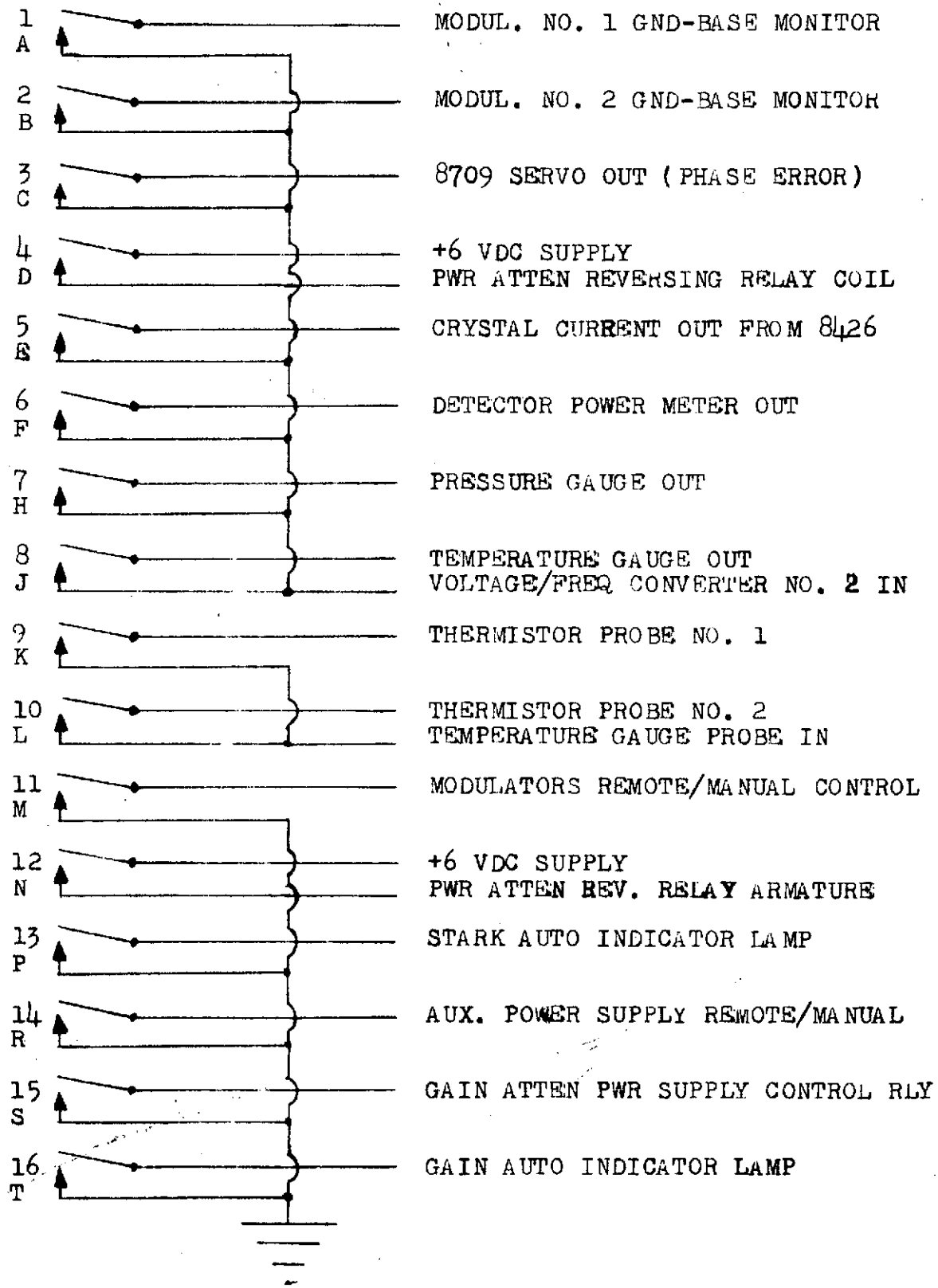


Figure 6. Relay register 1 connection diagram.