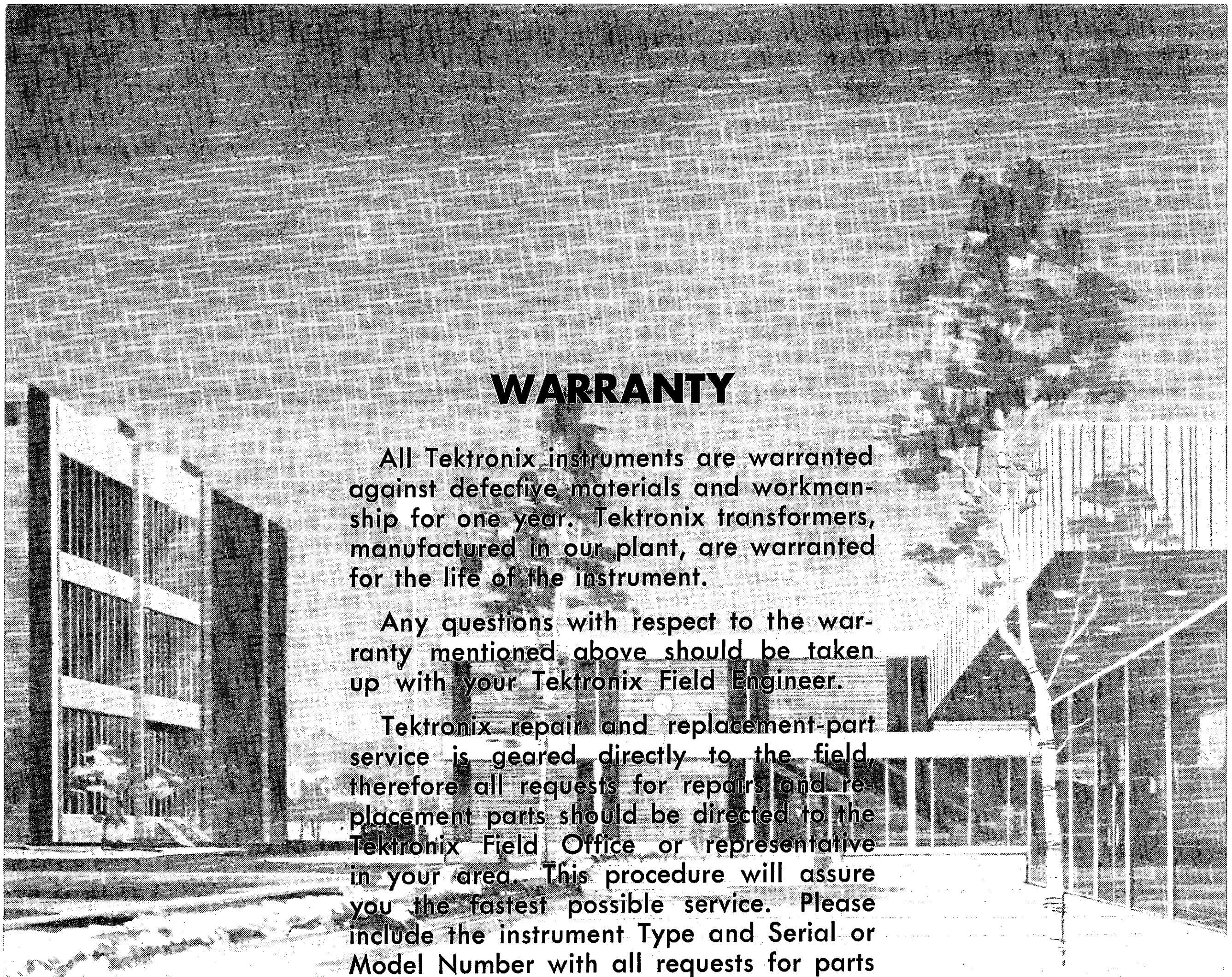
INSTRUCTION MANUAL

Serial Number ______________

ENGINE ANALYZER SYSTEM

Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon 97005 ● Phone 644-0161 ● Cables: Tektronix

070-0890-00 968



WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial or Model Number with all requests for parts or service.

Specifications and price change privileges reserved.

CONTENTS

Abbreviations and symbols used in this manual are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this manual.

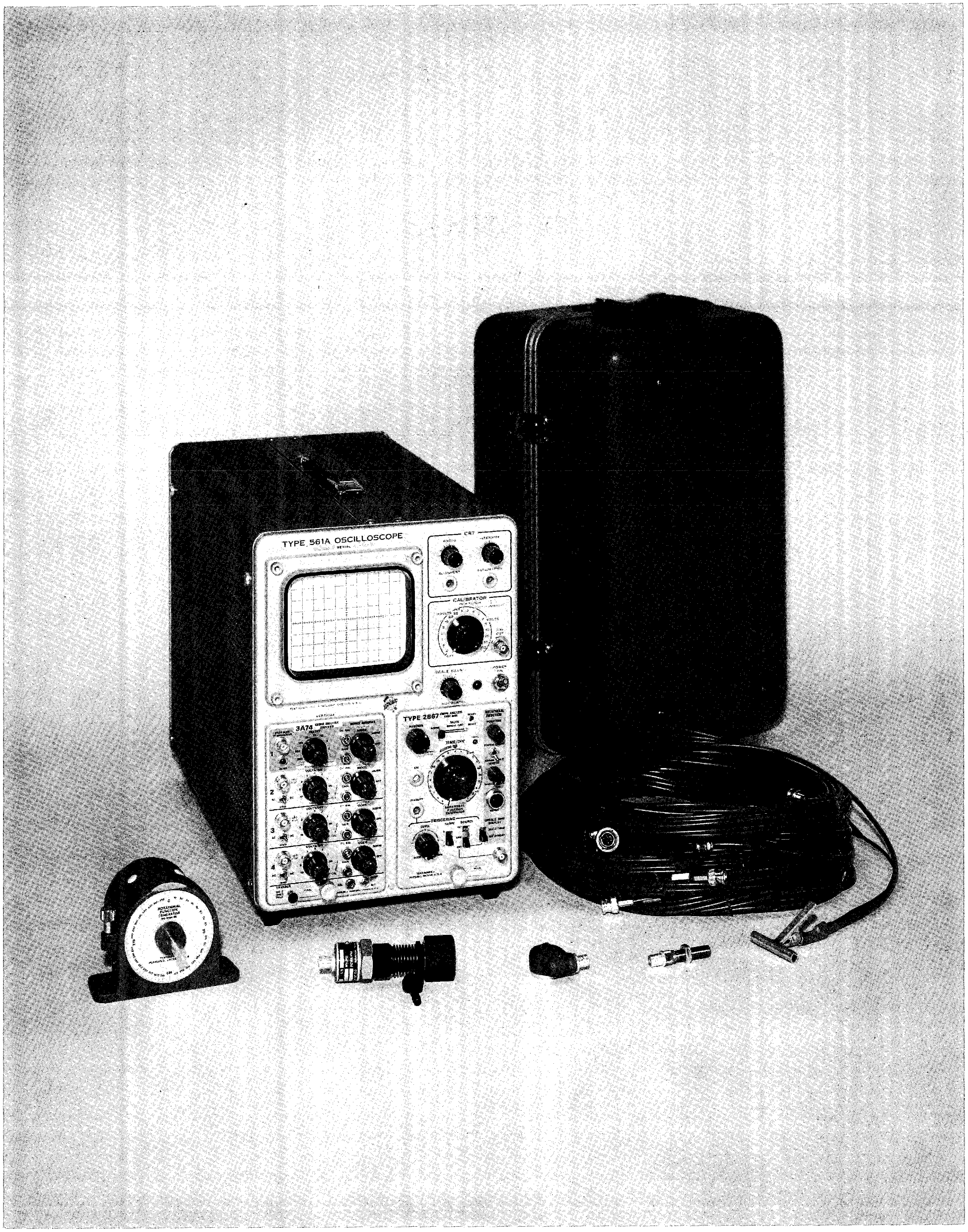


Fig. 1-1. Engine Analyzer System.

SECTION 1
ENGINE ANALYZER SYSTEM SPECIFICATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The Engine Analyzer System is an oscilloscope system designed to evaluate the performance of reciprocating engines, compressors and pumps. Functions such as pressure, ignition and vibration can be compared against the crankshaft angular position or the cylinder volume to permit analysis of operating efficiency. The functions can also be compared against real time.

The Engine Analyzer System can improve operating efficiency by detecting malfunctions such as improper timing, valve leakage, piston or bearing damage and ignition problems. Since the system permits comparison of operation against previous operating parameters, any appreciable degradation of performance can be noticed. Repairs can often be scheduled on a routine basis and effected before breakdowns actually occur.

The system employs a Tektronix 561[1] or 564-Series Oscilloscope (or Rackmount equivalent) equipped with a 3A74 (Mod 730A) Engine Analyzer (Vertical) Amplifier, a 2B67 (Mod 730A) Engine Analyzer (Horizontal) Time Base, and a Rotational Function Generator. A pressure transducer, ignition pickoff, vibration transducer and a magnetic top-dead-center sensor provide the signals to the vertical amplifier. The horizontal amplifier receives its crankshaft position signals from the Rotational Function Generator. The operation of the system is fully explained in Section 2.

The operating capabilities and environmental characteristics of the system and its individual components are listed in detail in the following tables.

TABLE 1-1
ELECTRICAL SPECIFICATION

Characteristic	Performance Requirement
TYPE 3A74 ENGINE ANALYZER AMPLIFIER	
Channel 1 CHARGE AMPLIFIER	
Deflection Factor Calibrated Range	1 PSI/div to 500 PSI/div in a 1-2-5 sequence.
Accuracy	Within 3% throughout calibrated range.
GAIN (front panel)	Adjustable to match transducers with 100 to 300 pC/PSI outputs.
Frequency Response Bandwidth LONG RESTORE TIME	0.05 Hz or less to at least 10 kHz.
SHORT RESTORE TIME	0.5 Hz or less to at least 10 kHz.
Maximum Dynamic Charge Signal	0.6 μC at 10 kHz increasing to 2 μC at 2.75 kHz.
RESTORE TIME LONG	At least 3 s RC Time Constant.
SHORT	At least 0.3 s RC Time Constant.
Noise (RMS referred to Input)	Noise is 0.15 pC/1000 pF of source capacitance or less with 1 PSI/div and gain set to 100 pC/PSI.
Attenuation Due to Shunt Input Capacitance	1% or less with 0.03 μF at 1 PSI/div and gain set to 100 pC/PSI. Not to exceed 0.09 μF.
Channels 2, 3, 4 Vertical Amplifier	
Deflection Factor Calibrated Range	0.02 V/div to 10 V/div in a 1, 2, 5 sequence.
Accuracy	Within 3% throughout calibrated range.
Uncalibrated (Variable) Range	Continuously variable between calibrated deflection factor settings. Extends the deflection factor range to at least 25 V/div.
Frequency Response Bandwidth DC-Coupled (Variable at CAL)	DC to 2 MHz.
AC (Capacitive) Coupled	2 Hz to 2 MHz.
Step Response Risetime	0.17 μs or less.
Maximum Input Voltage DC (Direct) Coupled	600 V (DC + peak AC)
Input R and C Resistance	1 MΩ within 1%.
Capacitance	47 pF within 3%.
Chopped Mode Repetition Rate	≈250 kHz for two channels. ≈167 kHz for three channels. ≈125 kHz for four channels.
Channel Time Segment	Nominally 2 μs.
TYPE 2B67 ENGINE ANALYZER TIME BASE	
Time Base Sweep TIME/DIV Calibrated Range	1 μs/div to 5 s/div; 21 steps in a 1-2-5 sequence. X5 magnifier extends displayed sweep time/div to 0.2 μs/div.

[1] **561-Series Oscilloscopes below Serial No. 579 must be modified with kit 040-0267-00 before they can be used with the system.**

Characteristic	Performance Requirement
Accuracy Unmagnified	Within 3% over center 8 graticule divisions.
Magnified	Within 5% over center 8 graticule divisions.
VARIABLE TIME/DIV	At least 2.5:1.
Trigger Sensitivity Internal Source AC coupled only	0.4 divisions of 1 kHz square-wave display.
External Source AC Coupled Only	0.5 V at 5 Hz increasing to 2 V at 2 MHz.
Function Amplifier Deflection Factor	10 mV/div or less to at least 100 mV/div; determined by WIDTH control setting.
Bandwidth 100 mV/Div	DC to at least 75 kHz.
10 mV/Div	DC to at least 25 kHz.
Standby Trace Duration	Off whenever the Function Generator is operating above 25 RPM.
Length	Nominally 2 divisions with Function Generator connected and not rotating.
Degree Markers 0/360° Pedestal Tilt (AC-coupled)	Trailing edge of pedestal drops not more than 60% (with respect to leading edge) at 25 RPM (130 ms wide 0/360° pedestal); Tilt not discernible above 500 RPM.

ROTATIONAL FUNCTION GENERATOR

Output Signal Amplitude Sine wave	Between 200 and 500 mV P-P.
Sawtooth	Between 200 and 500 mV P-P.
Degree Markers	At least 30 mV as measured at tallest marker (delivered to a high impedance circuit).
Output DC Level Sine wave and Sawtooth	—2.25 V ± 0.4 V.
Degree Markers	—5 V ± 1 V.
Source Impedance Sine wave and Sawtooth	1.5 kΩ ± 5%.
Degree Markers	2.1 kΩ ±20%.
Voltage Requirement	—11 V to —13 V with Standard Accessory 20-foot Function Generator Cable.
Maximum RPM	20,000.
Maximum Cable Length	300 Ft.
Degree Marker Angular Accuracy	Within 1°.
Shaft Load, Axial and Radial	10 lbs maximum.

Characteristic	Performance Requirement
TRANSDUCERS	
Pressure Transducer	
Maximum Acoustic Reponse (+3 dB) Transducer Alone	1000 Hz
Transducer with Cooling Adapter Attached	250 Hz
Transducer with Cooling Adapter and 5 inches of Additional Pipe	200 Hz
Transducer with Cooling Adapter and 10 inches of Additional Pipe	160 Hz
Maximum Recommended Combustion Engine RPM Transducer Alone	6000 RPM
Transducer with Cooling Adapter Attached	1500 RPM
Transducer with Cooling Adapter and 5 inches of Additional Pipe	1200 RPM
Transducer with Cooling Adapter and 10 inches of Additional Pipe	1000 RPM
Voltage Sensitivity	Nominally 25 mV/PSI. Value listed on the individual units.
Charge Sensitivity	Within 100 to 300 pC/PSI. Value listed on individual units.
Accuracy	Within 5% of reading, excluding temperature coefficient.
Temperature Coefficient	Value listed in chart supplied with unit.
Pressure Range	0 to 3000 PSI.
Maximum Overpressure	300%.
Linearity	Within 1%.
First Resonance	At least 30 kHz.
Vibration Sensitivity	0.1 PSI/g or less.
Operating Temperature Range	—40°C to +150°C (Standard Accessory Cooling Adapter required to maintain transducer temperature within range).
Maximum Temperature	+200°C.
Vibration Transducer (See Fig. 1-2)	
Voltage Sensitivity	Nominally 6 mV/g. Value listed on the calibration chart supplied with the unit.
Charge Sensitivity	Nominally 20 pC/g. Value listed on the calibration chart supplied with the unit.
Capacitance	Nominally 3300 pF. Value listed on the calibration chart supplied with the unit.

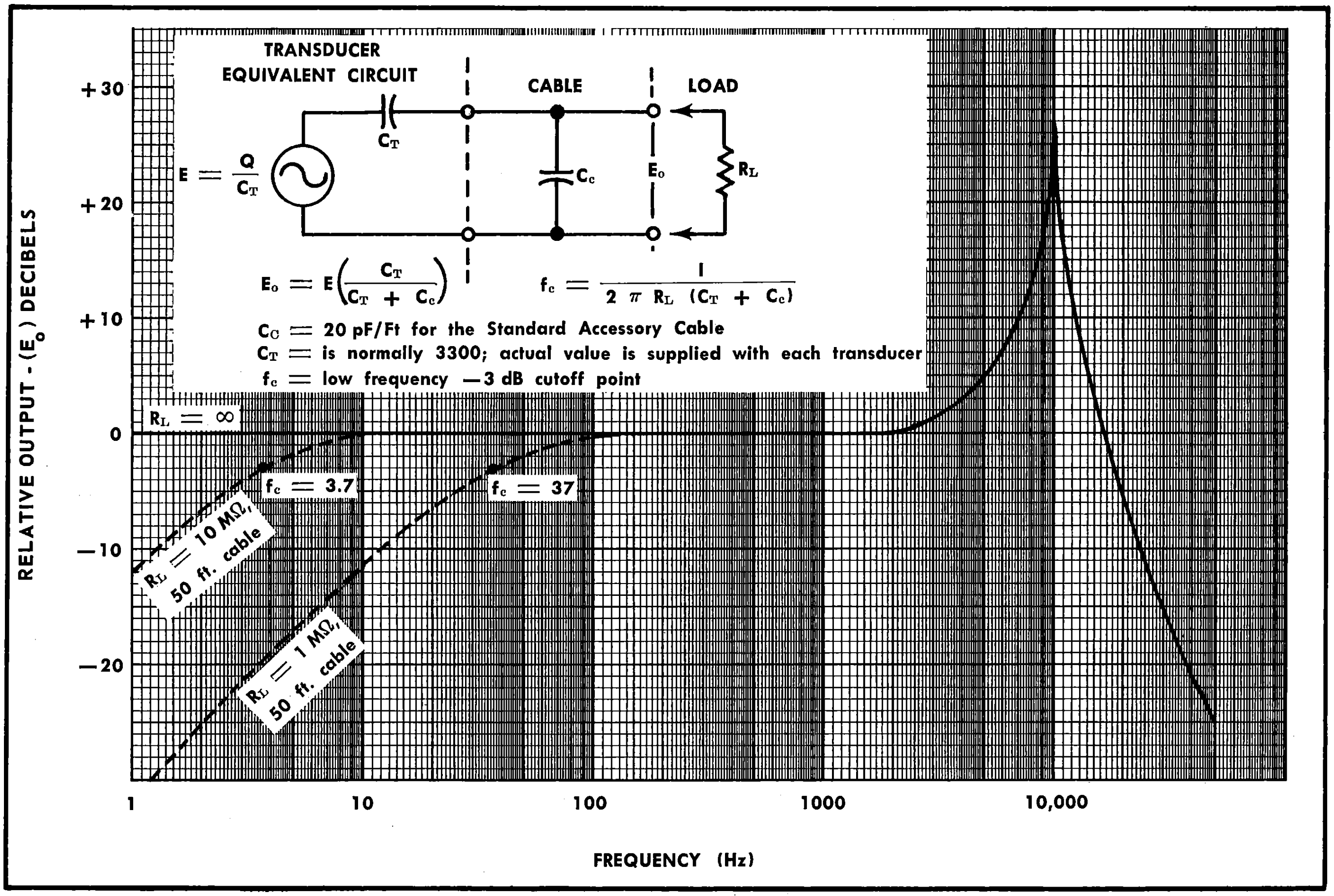


Fig. 1-2. Graph of Vibration Transducer output versus frequency.

Characteristic	Performance Requirement
Cross Axis Sensitivity	Within 3%.
First Resonance	At least 10 kHz.
Linearity	Within 1%.
Maximum Acceleration	1000 g's.
Temperature Range	—40°C to +150°C.
Magnetic Pickup	
Output Voltage	At least 15 V P-P at 1000 inch/second and 0.005 inch clearance.
Coil Resistance	Within 90 Ω to 110 Ω.
Coil Inductance	Within 26 mH to 40 mH.
Temperature Range	—54°C to +107°C.
Ignition Pickoff	
Attenuation	Nominally 1000×. Determined by the capacitance at the pickoff point.
RC Time Constant	At least 6.5 ms.

SYSTEM CHARACTERISTICS

Characteristic	Performance Requirement
Vertical Display	
Pressure Transducer/ Charge Amplifier Range	0 to 3000 PSI, not to exceed 0.6 μC at 10 kHz up to 2 μC at 2.75 kHz.
Deflection	1 PSI/div to 500 PSI/div in a 1-2-5 sequence.
Accuracy	Within 5% throughout calibrated range.
Maximum Overpressure	300%.
Frequency Response	
Long Restore Time	0.05 Hz or less to at least 10 kHz.
Short Restore Time	0.5 Hz or less to at least 10 kHz.
Restore Time	
Long	At least 3 s RC Time Constant.
Short	At least 0.3 s RC Time Constant.
Noise (RMS Referred to Input)	Not discernible with the 50 ft, 20 pF/ft cable supplied; 6 pC RMS or less (0.3 div of display) at a deflection factor of 1 PSI/div, 2000 ft of 20 pF/ft cable and gain set to 100 pC/PSI.
Attenuation Due to Shunt Input Capacity (cable capacity)	1% or less with .03 μF at 1 PSI/div and gain set to 100 pC/PSI (Shunt input capacitance not to exceed .09 μF).

Characteristic	Performance Requirement
Vibration Transducer into 3A74 Voltage Amplifier	
Transducer Sensitivity	
Transducer with Cable	Nominally 4.5 mV/g with the 50 ft, 20 pF cable included in the system. Value can be determined from the calibration chart supplied with the transducer.
Transducer Alone	Nominally 6 mV/g. Value listed on the calibration chart supplied with the unit.
Frequency Response	See graph, Fig. 1-2.
Magnetic Pickup (TDC Sensor) into 3A74 Voltage Amplifier	
Output Voltage	At least 15 V P-P at a surface speed of 1000 inches/second, clearance gap of 0.005 inch, and using a 20 pitch, 30 tooth ferrous metal gear. (Output voltage is approximately proportional to surface speed and inversely proportional to the clearance gap.)
Ignition Pickoff into 3A74 Voltage Amplifier	
Attenuation	Nominally 1000× with the 50 ft, 20 pF/ft cable supplied with the system. Attenuation determined by the capacitance between the pickoff clamp and the high-voltage lead under test. Longer cable increases the attenuation approximately 10% per 40 ft; (Pickoff calibrated using the 40 V or 100 V output from the Oscilloscope Calibrator into a sample of the ignition cable. See Operator's Adjustment Procedure in Section 2.)
RC Time Constant	At least 6.5 ms with the cable supplied.
Markers into 3A74 Voltage Amplifier (Internally coupled to Channel 2)	
Amplitude	At least 1 division of display of 0/360° marker above trace base line.
Horizontal Display	
WIDTH Control Range	5 divisions or less to at least 20 divisions.
CRANK (ANGLE)	Sawtooth, 350° of usable display (less than 10° used during retrace).
Incremental Accuracy	Within 3% of full scale display.
PISTON (VOLUME)	Sine wave plus ≈ 6% second harmonics, simulating crank radius-to-connecting rod-ratio of 1:4.
Incremental Accuracy	Within 3% of full scale display.
Phase Shift	0.5 degrees or less at 20,000 RPM with the Standard Accessory 20-foot cable; 2 degrees or less with a 200 ft 20 pF/ft cable.

TABLE 1-2
ENVIRONMENTAL SPECIFICATION
TYPES 3A74 AND 2B67

Characteristic	Performance Requirement
Temperature	
Non-operating	—40°C to +65°C
Operating	0° to +50°C
Altitude	
Non-operating	To 50,000 feet
Operating	To 15,000 feet
Vibration	
Operating	15 minutes along each axis at 0.015 inch. Vary the frequency from 10 to 50 to 10 c/s in 1-minute cycles. Three minutes at any resonant point or at 50 c/s.
Shock	
Non-operating	30 g's, ½ sine, 11 ms duration, 2 shocks per axis. Total of 6 shocks.
Transportation	Qualifies under National Safe Transit Committee Procedure 1A, Category IV (48 inch drop).

ROTATIONAL FUNCTION GENERATOR

Characteristic	Performance Requirement
Temperature	
Non-operating	—55° to +75°C
Operating	—15°C to +75°C
Altitude	
Non-operating	To 50,000 feet
Operating	To 15,000 feet
Vibration	
Operating	15 minutes along each axis at 0.015 inch. Vary the frequency from 10 to 55 to 10 c/s in 1-minute cycles. Three minutes at any resonant point or at 55 c/s.
Shock	
Non-operating	250 g's, ½ sine, 12 ms duration, 2 shocks per axis. Total of 6 shocks.
Transportation	Qualifies under National Safe Transit Committee Test Procedure 1A, Category IV (48 inch drop).

TRANSDUCERS

Characteristic	Performance Requirement
Pressure Transducer	
Vibration Sensitivity	0.1 PSI/g or less.
Temperature Range	—40°C to +150°C.
Temperature Coefficient	—0.035%/°C from +21°C to +150°C.
Maximum Temperature	+200°C.
Vibration Transducer	
Maximum Acceleration	1000 g's.
Temperature Range	—40° C to +150° C.
Magnetic Pickup	
Temperature Range	—54°C to +107°C.

SECTION 2
OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The following information is contained in this section, in the order in which it is listed:

Block Diagram Description

System Components and Standard Accessories

First Time Operation of Oscilloscope, 3A74, 2B67 and Rotational Function Generator

Operators Adjustment Procedure

Installing the Standard Accessories

System Operating Procedure

BLOCK DIAGRAM DESCRIPTION

The interconnection of components and data flow during system operation is explained here. An understanding of it is essential for obtaining optimum results.

The Oscilloscope and its plug-in units make up the indicating section of the system. The 3A74 Engine Analyzer Amplifier (hereafter called 3A74) processes signals which result in vertical deflection of the oscilloscope electron beam. The 2B67 Engine Analyzer Time Base (hereafter called 2B67) processes signals which provide horizontal deflection of the beam. The combination of the two-coordinate deflection causes the beam to be positioned to a specific point on the face of the cathode-ray tube (CRT). As the signals change, so does the positioning point. Continuously changing signals result in a constantly moving dot on the CRT face. The CRT phosphorescence causes the constantly moving dot to appear as a line, or trace, providing a continuous comparison of the signals present in the vertical versus horizontal plug-in units. The vertical circuit (3A74) is capable of switching from one signal channel to another, thereby permitting simultaneous display of several vertical signals on separate traces. These displays are normally placed at different vertical positions on the CRT to provide convenient viewing and identification.

Refer to Fig. 2-1. The Rotational Function Generator (hereafter called Function Generator) controls trace horizontal deflection when ROTATIONAL FUNCTION GENERATOR operation is selected by the 2B67 TIME/DIV switch. The Function Generator shaft is directly (1:1 ratio) coupled to the equipment crank shaft through an Extension Shaft and a Friction Drive Adapter (standard accessories), or by way of any other arrangement which provides a 1:1 rotation ratio without slippage. The Function Generator should be mounted on a tripod (optional accessory) or other stable base. Alignment between the Function Generator, shaft, and equipment under test must be as accurate as practical to insure optimum operation.

The Function Generator is connected to the Oscilloscope horizontal plug-in unit (2B67) by a four conductor cable. One of the leads supplies —12.2 V to lamps in the Function Generator, which provides light-excitation for photo-transistors. The light to the transistors is controlled by a function generator disc which is rotated by the drive shaft. The body of the Function Generator can be rotated to align the photo-transistors to the crankshaft, permitting their outputs to be indicative of crankshaft position.

The generator disc causes the following outputs to be generated: thirty-six 10-degree markers, with distinctive markers appearing at 60 and 360 degree intervals; a sine wave indicative of piston position (cylinder volume), with the maximum positive excursion of the waveform coincident with the top-dead-center (TDC) position of the piston to which the Function Generator is aligned; a sawtooth waveform indicative of crankshaft angle, with the beginning of the ramp coincident with the down position of the piston to which the Function Generator is aligned. A ROTATION DIRECTION switch (located on the Function Generator) permits selection of a positive-going ramp voltage so that the trace moves from left to right on the Oscilloscope, regardless of the direction of rotation.

The markers can be either rejected or accepted by a MARKERS PULL switch on the 2B67. When accepted, they are internally connected to Channel 2 of the 3A74. They are then displayed on the Channel 2 trace at any time the Channel 2 MODE switch is not turned off.

Either the sine wave (PISTON) or the sawtooth wave (CRANK) can be used to cause horizontal deflection when the 2B67 TIME/DIV switch is at ROTATIONAL FUNCTION Generator position. The PISTON-CRANK switch at the 2B67 controls the selection. If the sine wave is used, the CRT beam will be deflected to the left when the maximum positive potential is reached (piston up), and to the right when the maximum negative potential is reached (piston down). If the sawtooth is selected, the trace will start at the left at the beginning of the ramp (piston down) and progress to the right as the ramp voltage increases. When the piston again reaches bottom, the ramp voltage collapses, the beam rapidly returns to the left of the CRT and a new sweep begins. The beam returns to the left so quickly that only a very dim return trace is created by the few electrons striking the face of the CRT.

When the 2B67 TIME/DIV switch is in any position except ROTATIONAL FUNCTION GENERATOR, a sawtooth voltage can be generated within the 2B67 to provide trace horizontal deflection. Accurately timed sweeps can be made to start in coincidence with signals being processed by the 3A74

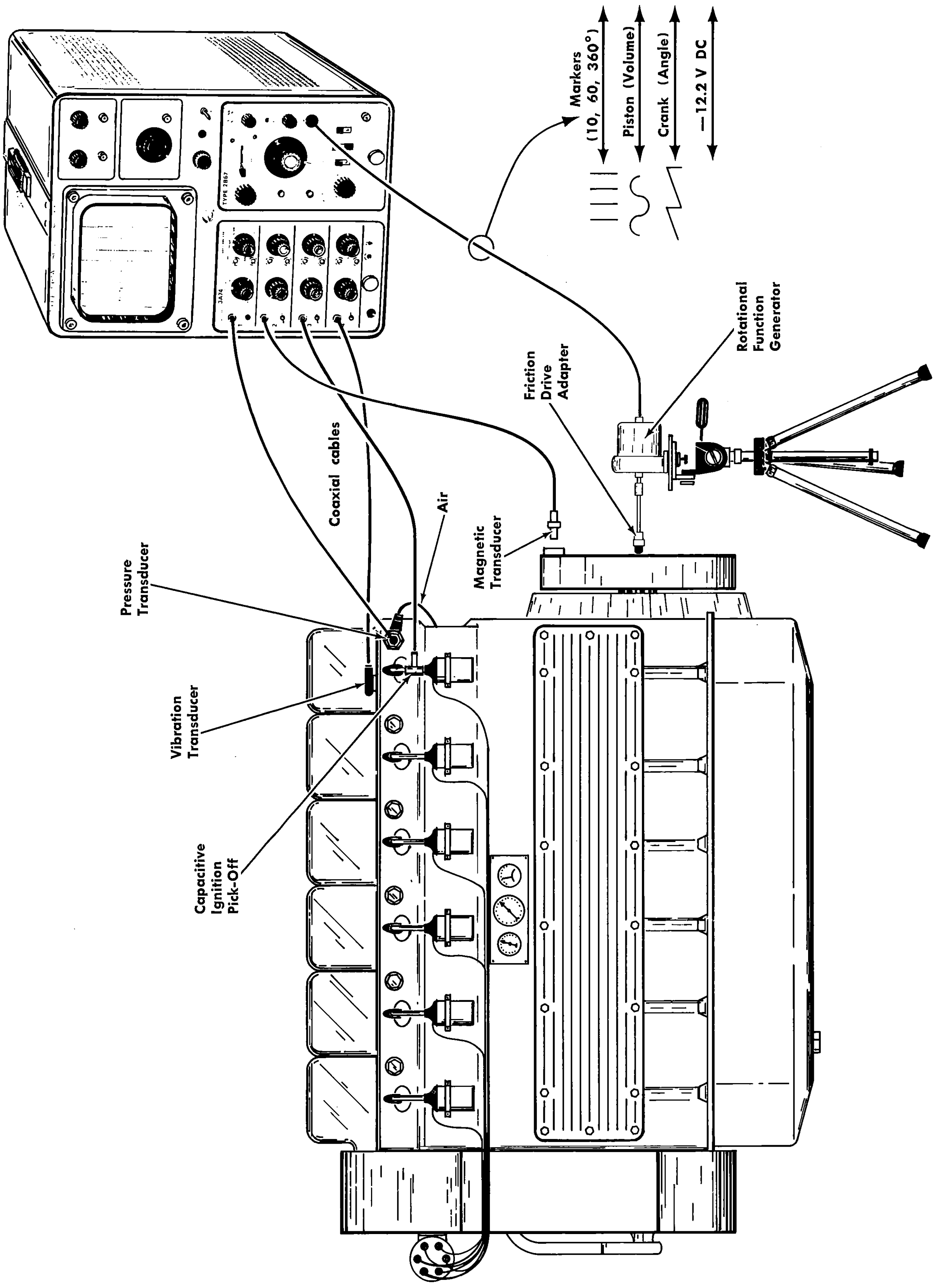
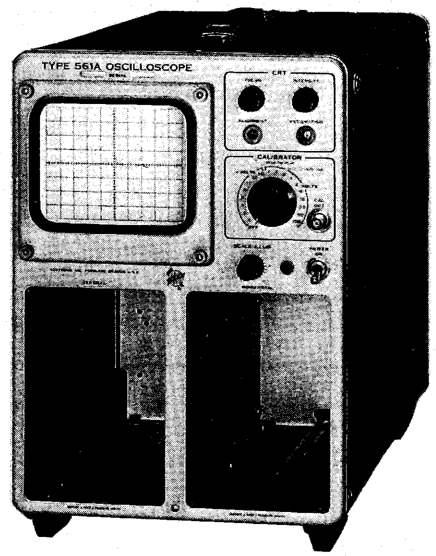
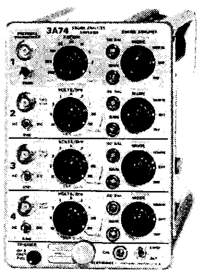


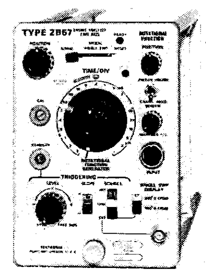
Fig. 2-1. Engine Analyzer System data flow.



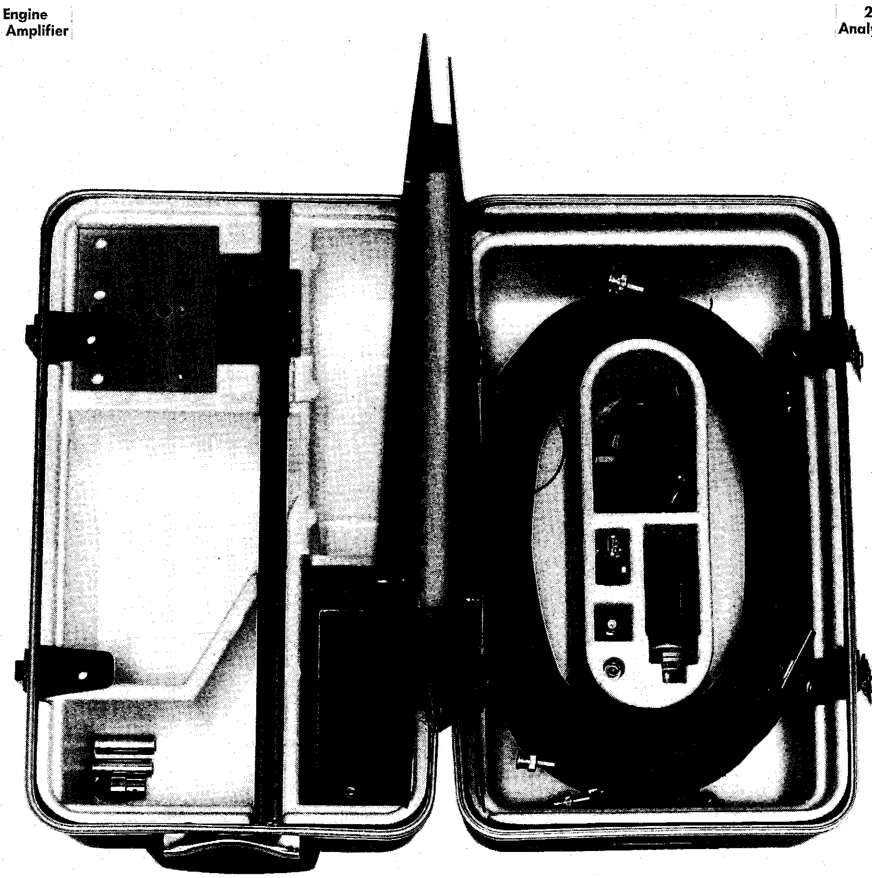
561 or 564-Series
Oscilloscope



3A74 Engine
Analyzer Amplifier



2B67 Engine
Analyzer/Time Base



Carrying Case with
Standard Accessories

Fig. 2-2. Major assemblies of the Engine Analyzer System.

vertical plug-in unit. Engine rotation speed can then be measured by determining the time required to complete one cycle of operation.

Engine pressure indication is obtained by inserting a Pressure Transducer (standard accessory) into the pressure chamber, and coupling its output to channel 1 of the vertical amplifier unit (3A74) through a low-noise 50 foot coaxial cable. The piezoelectric effect of the transducer supplies a signal in response to pressure changes. The signal is processed by the vertical amplifier and causes a Channel 1 vertical display on the CRT whenever the Channel 1 MODE switch is not in its OFF position. The trace provided by the combined effects of rotation (horizontal) and pressure (vertical) permit evaluation of combustion chamber operation. A cooling adapter is attached to the transducer to lower its operating temperature.

The Magnetic Transducer (standard accessory) can be mounted adjacent to the edge of the flywheel or other rotational reference device. A 20 foot coaxial cable is provided to couple its output to the 3A74.

The Magnetic Transducer provides an output in response to any change of ferrous material in its immediate vicinity. The flywheel grooves indicating TDC and associated timing reference marks will therefore create impulses which can be used to compare against the markers from the Function Generator. The Function Generator can thus be reliably referenced to the crankshaft.

Although the Magnetic Transducer output can be accepted by Channel 2, 3 or 4, it is recommended that it be coupled into Channel 2, where it can be superimposed on the Function Generator signals. When the Generator body is rotated so that its 0/360 degree marker is aligned with the TDC mark from the Magnetic Transducer, the system is aligned to the piston referenced by the TDC mark.

The Capacitive Ignition Pickoff (standard accessory) is a permanently attached termination on a 50 foot coaxial cable. It generates an output voltage when a voltage pulse occurs in the cable to which it is clamped. Its output can be accepted by Channels 2, 3 or 4 of the 3A74, but it is recommended that Channel 3 be used consistently with it to standardize operation. Engine ignition pulses are displayed for comparison and evaluation whenever the appropriate channel (Channel 3) MODE switch is not in its OFF position. Ignition voltage pulse amplitudes can be accurately determined as explained in the Operator's Adjustment Procedure.

Vibrations which accompany engine operation can be detected through use of the Vibration Transducer (standard accessory). Its permanent magnet permits attachment to any ferrous surface. For example, when it is attached in the immediate vicinity of valves, the vibrations which accompany their opening and closing will create an electrical output which can be coupled to the 3A74 through a 50 foot coaxial cable. Its output can also be accepted by Channels 2, 3 or 4, but it is again recommended that operation be standardized by always applying it to channel 4. When the appropriate MODE switch (Channel 4) is in other than the OFF position, the vibrations will be displayed with the other presentations, aiding the overall evaluation of the engine.

SYSTEM COMPONENTS AND STANDARD ACCESSORIES

The following major assemblies make up the Engine Analyzer System. They are illustrated in Fig. 2-2, and their operation is explained in detail in this section. In addition, a separate manual is provided with the Oscilloscope.

561 or 564-Series Oscilloscope

3A74 Engine Analyzer Amplifier

2B67 Engine Analyzer Time Base

Carrying Case with Standard Accessories

In addition to the above, the following optional accessories are recommended for use with the system. They can be purchased through Tektronix Field Representatives.

Tripod, Tektronix Part No. 016-0253-00 (Includes Adapter Plate, Tektronix Part No. 386-1453-00).

C-12 Camera

Projected Graticule (for use with C-12 Camera)

Scopemobile Model 201-1.

Oscilloscope

The Oscilloscope controls, connectors and indicators (exclusive of the 3A74 MOD 730A and 2B67 MOD 730A plug-in units) are explained in the Oscilloscope manual. The operator should read those explanations in addition to the material in this operating section before using the Engine Analyzer System. Failure to understand proper operating procedure may result in damage to the Engine Analyzer System equipment.

Camera

Complete information regarding the Camera and waveform photography can be found in the manual which accompanies the camera.

3A74 Engine Analyzer Amplifier (see Fig. 2-3)

Channel 1	Pressure Transducer Input	BNC connector. Circuit is designed to accept charge signals. Coupling between the connector and the pressure transducer is accomplished through a 50 foot coaxial cable which is supplied as a standard accessory.
	ZERO	Push-button which resets the channel's amplifier to 0, placing trace at its reference position.
	PSI/DIV	Vertical deflection factor selector. Graduated in 1, 2, 5 sequence from 1 PSI/DIV to 500 PSI/DIV.
	RESTORE TIME	2 position switch. Enables selection of time required to recover from input signals after the signal has expired or is removed.

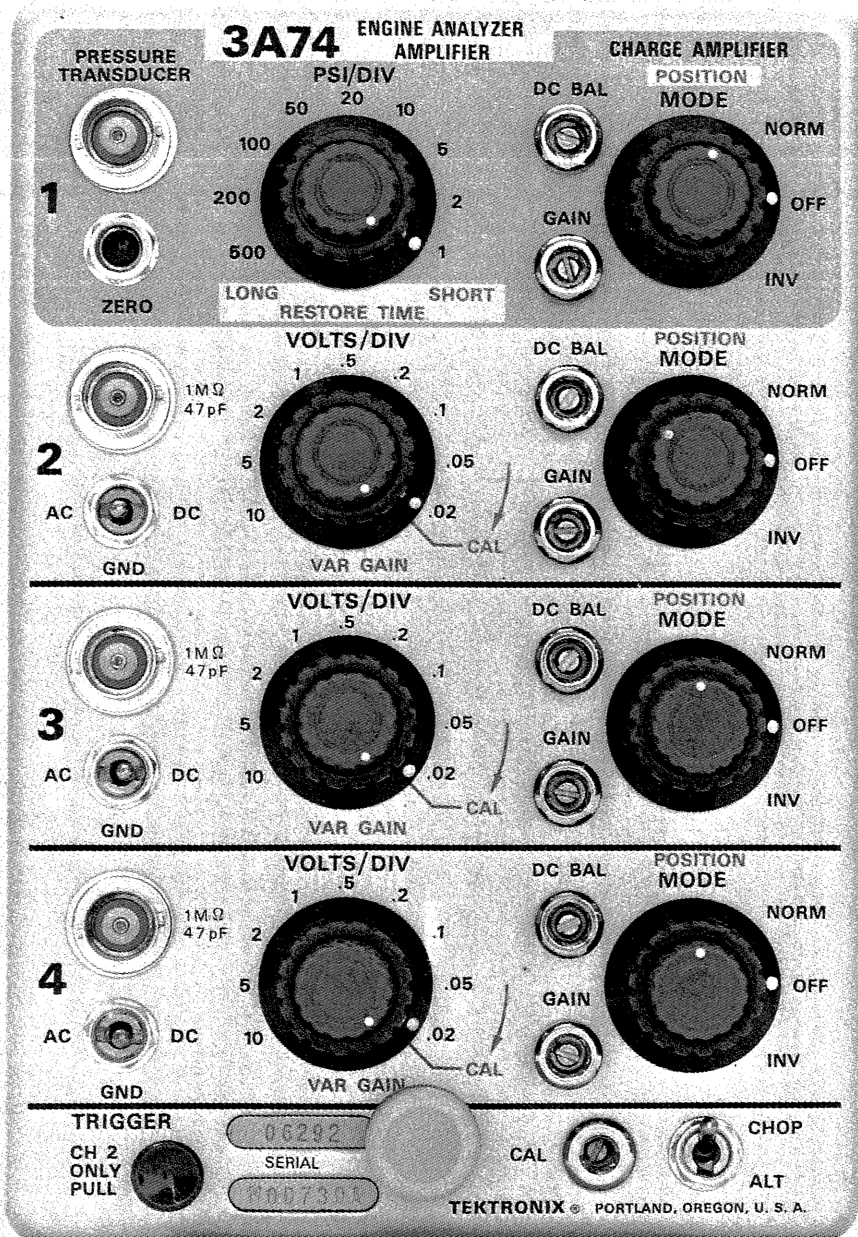


Fig. 2-3. 3A74 Engine Analyzer Amplifier.

		LONG should be selected for low RPM applications (approximately 600 RPM and below) where critical pressure measurement is required.
	DC BAL	Screwdriver adjustment. Permits the operator to adjust for a minimum amount of trace shift accompanying PSI/DIV switching when no signal is present and channel has been "zeroed".
	GAIN ADJ	Screwdriver adjustment. Use in conjunction with Charge Amplifier Calibrator (standard accessory) and Oscilloscope CALIBRATOR signal to set PSI/DIV factor in accordance with rated output of Pressure Transducer being used. See Operator's Adjustment Procedure in this section.
	MODE	Three position switch. Enables or disables presentation of Channel 1 normal (NORM) or inverted (INV) display.
	POSITION	Controls the vertical position of Channel 1 display. Has no effect upon CRT presentation when Channel 1 MODE switch is OFF.
Channels 2, 3 & 4	Input Connector	BNC connector designed to accept voltage signals. Channel 2 Input should be connected through a 20 or 50 foot cable to the Magnetic Transducer which signals the crankshaft top-dead-center position; Channels 3 and 4 should be connected to the Capacitive Ignition Pickoff and the Vibration Transducer respectively through 50 foot coaxial cable.
	AC-GND-DC	Three position toggle switch. AC connects AC component of signal to the amplifier channel through a 0.1 μF capacitor. GND grounds the input to the applicable channel. DC connects all signal components directly to the amplifier channel.
	VOLTS/DIV	Vertical deflection factor selector. Graduated in 1, 2, 5 sequence from .02 through 10 V/division.
	VAR GAIN	Variable gain selector. When fully CCW it increases the deflection factor to at least 2.5 times that indicated by the VOLTS/DIV switch, enabling selection of any deflection factor from .02 V/division to more than 25 V/division. When set to CAL position it provides calibrated deflection factors as indicated by the VOLTS/DIV switch.
	DC BAL	Screwdriver adjustment. Permits the operator to adjust for a minimum amount of trace shift accompanying rotation of the VAR GAIN control when no signal is present. See Operator's Adjustment Procedure in this section.
	GAIN ADJ	Screwdriver adjustment. Permits the operator to obtain calibrated deflection factors for individual channels. Adjust at .02 VOLTS/DIV with VAR GAIN at CAL. See Operator's Adjustment Procedure in this section.
	MODE	Three position switch. Enables or disables presentation of normal (NORM) or inverted (INV) display of applicable channel.
	POSITION	Controls the vertical position of the applicable channel's presentation. Has no effect upon CRT presentation when applicable MODE switch is OFF.
TRIGGER		Plunger-type switch. When pulled out, horizontal sweeps are initiated in response to the signal present in Channel 2 only, regardless of the position of Channel 2 MODE switch.
CAL		Screwdriver adjustment. Synchronously adjusts the gain of all 4 amplifier channels. Permits compensating for CRT deflection sensitivity differences when the 3A74 is moved from one oscilloscope to another.
CHOP-ALT		Toggle switch. Selects method of switching between traces. In CHOP position, small segments of the traces selected by the MODE switches are sequentially presented. Switching frequency is sufficiently high for the composite of each channel's segments to appear as a continuous trace at sweep rates of approximately 0.2 ms / division and slower (higher time/div ratio) during 4 channel operation. The CHOP position should be selected during multi-channel operation of the Engine Analyzer System. In ALT posi-

	tion, sequential switching to the next "on" channel occurs at the end of each sweep. During four channel operation, the display appears to be four simultaneously occurring traces at sweep rates of 2 ms/division and faster (lower time/division ratio).
Securing Knob	Fastens unit in place in Oscilloscope compartment. Unscrew to counterclockwise limit before removal or insertion; tighten after insertion to provide reliable plug connections.

2B67 Engine Analyzer Time Base (See Fig. 2-4)

Control	ROTATIONAL FUNCTION GENERATOR Operation	Sweep Operation
POSITION (left)	No effect	Controls the horizontal position of the display.
MODE	NORM provides a continuously unblanked CRT display; traces caused by successive rotational functions are superimposed. SINGLE SWP position permits unblanking of the CRT for display of functions occurring during 360 or 720 degrees of rotation, as selected by the SINGLE SWP DISPLAY switch. RESET position "arms" the circuit, permitting it to unblank the CRT upon receipt of the next negative-going triggering signal from the Rotational Function Generator; RESET position is spring-loaded to return the switch to SINGLE SWP position when released; READY lamp is on whenever circuit is armed.	NORM permits the CRT to be unblanked as each sweep is generated, with blanking occurring during retrace. SINGLE SWP permits generation of one sweep after READY lamp has been lighted. RESET position arms the circuit and lights the READY lamp. Switch is spring loaded to return to SINGLE SWP position from RESET.
READY	Indicates that the circuit is ready to display 360 or 720 degrees of rotational functions upon receipt of the next triggering signal. Light goes out following completion of indicated rotation.	Indicates that the circuit is ready to display a single sweep upon receipt of the next triggering signal. Light goes out after completion of sweep.
TIME/DIV	ROTATIONAL FUNCTION GENERATOR position accepts inputs from the Rotational Function Generator through the front panel INPUT connector.	Numbered positions provide indicated horizontal sweep rates for conventional oscilloscope operation. (VARIABLE at CAL position).
VARIABLE	No effect	Potentiometer. Permits the TIME/DIV factor to be increased by at least 2.5 times the indicated value, providing continuous horizontal deflection factors of from 0.2 μs/division (with 5X MAG) to more than 12.5 seconds/division.
UNCAL	No effect	Lights when the VARIABLE control is not in CAL position.
5X MAG	No effect	Plunger actuated switch connected to VARIABLE shaft. Expands the center two divisions of unmagnified presentation. Effectively divides the indicated sweep rate by 5.
CAL	No effect	Screwdriver adjustment. Permits operator calibration of the TIME/DIV feature of conventional oscilloscope operation. Compensates for difference in CRT deflection sensitivity when plug-in is used with different oscilloscopes. See Operator's Adjustment Procedure in this section.
STABILITY	Screwdriver adjustment. Adjusts for proper sensitivity to triggering signals during all except FREE RUN Triggering operation. See Operator's Adjustment Procedure in this section.	Same as ROTATIONAL FUNCTION GENERATOR operation.
TRIGGERING LEVEL	Set at AUTO during 2B67 NORM operation; set at 0 or at desired triggering point during SINGLE SWP operation.	Combination of switches and potentiometer. AUTO position provides triggers at a 50 Hz rate to initiate horizontal sweeps; either internal or external signals of higher frequency will override

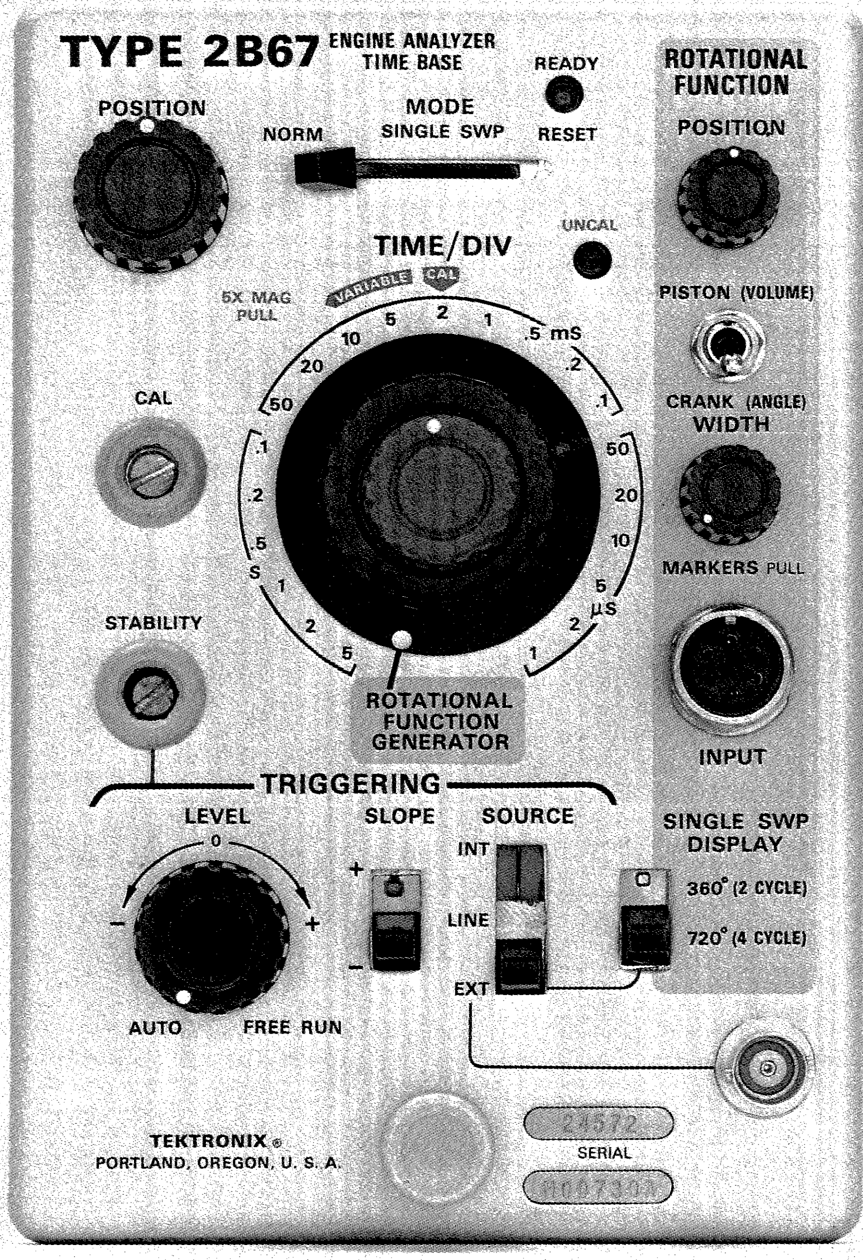


Fig. 2-4. 2B67 Engine Analyzer Time Base.

Control	ROTATIONAL FUNCTION GENERATOR Operation	Sweep Operation
		AUTO operation. FREE RUN permits continuous generation of sweeps, independent of triggers; FREE RUN does not permit presentation of a stable triggered display, but provides a relatively constant brightness baseline independent of sweep rate. The area between AUTO and FREE RUN permits manual triggering level selection; in conjunction with SLOPE it permits trigger action to occur at various points on the triggering waveform. If repetitive signals of different amplitude are present, manual triggering can be used to trigger from only the larger signals to provide a stable, triggered display.
SLOPE	Two position slide switch. Determines whether the positive-going (+) or negative-going (—) slope of the triggering waveform will cause CRT unblanking to occur. (—) SLOPE should be used during SINGLE SWP operation when the CRANK signal is selected. Either position can be used in NORM operation with no apparent difference.	Determines whether the positive-going or negative-going slope of the triggering waveform will initiate the horizontal sweep, thereby determining which slope will be displayed immediately after the sweep starts. In conjunction with LEVEL, it permits triggering action to occur at various points on the triggering waveforms.
SOURCE	Three position slide switch which selects source of signal to be used to generate triggers. EXT position recommended for ROTATIONAL FUNCTION GENERATOR operation. It internally couples the PISTON or CRANK signal from the Function Generator to the triggering circuit.	INT selects a triggering signal from the vertical amplifier circuit; LINE selects the AC supply waveform; EXT permits triggering from the PISTON or CRANK waveform if the Rotational Function Generator is connected, and permits triggering from signals applied to the EXT Input connector.
EXT Input Connector	BNC connector through which external triggering signals can be accepted any time the (TRIGGERING) SOURCE switch is at EXT.	Same as Rotational FUNCTION GENERATOR operation.
ROTATIONAL FUNCTION POSITION	Potentiometer which controls horizontal position of display.	No effect
PISTON (VOLUME)-CRANK (ANGLE)	Two-position toggle switch. Selects type of Rotational Function Generator waveform for horizontal deflection. PISTON accepts an approximate sine wave (for pressure versus volume display) and CRANK accepts a linear sawtooth ramp (for pressure versus crank angle display).	Selects PISTON or CRANK signal for internal application to EXT (TRIGGERING) line whenever ROTATIONAL FUNCTION GENERATOR is connected to 2B67.
WIDTH	Potentiometer. Permits adjustment of horizontal size of display. Display expands and contracts around graticule center vertical line.	Controls amplitude of PISTON or CRANK signal being applied to EXT (TRIGGERING) line.
MARKERS PULL	Push-pull switch connected to WIDTH knob shaft. Internally couples angle markers from the (ROTATIONAL FUNCTION) INPUT connector into the vertical amplifier. 3A74 Channel 2 MODE switch must be at NORM or INVERT to permit display of markers.	Same as ROTATIONAL FUNCTION GENERATOR operation.
INPUT	Six-connector jack which supplies power to and accepts signals from the Rotational Function Generator. Signals can also be accepted directly into terminal A or B (depending upon PISTON-CRANK switch position) to provide horizontal deflection while the TIME/DIV switch is in ROTATIONAL FUNCTION GENERATOR position.	Same as ROTATIONAL FUNCTION GENERATOR operation.

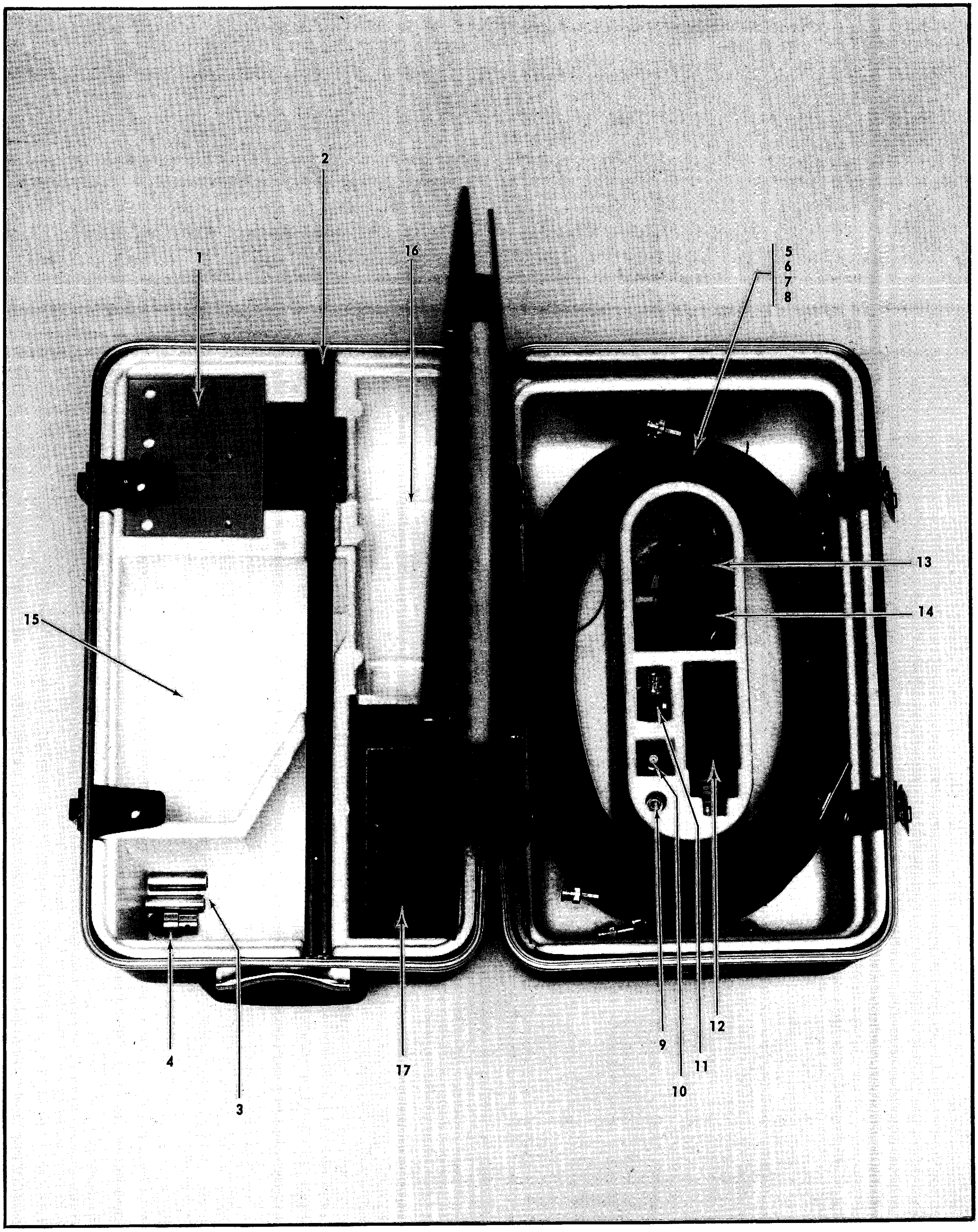


Fig. 2-5. Carrying Case and Standard Accessories.

Control	ROTATIONAL FUNCTION GENERATOR Operation	Sweep Operation
SINGLE SWP DISPLAY	Two-position slide switch. Effective when MODE switch is at SINGLE SWP. Selects amount of rotation during which a display is presented. Normally, 360 degrees for compressors and two-cycle engines and 720 degrees for four-cycle engines.	No effect
Securing Knob	Fastens unit in place in Oscilloscope Compartment. Unscrew to counterclockwise limit before removal or insertion; tighten after insertion to provide reliable plug connections.	

Carrying Case and Standard Accessories

The Carrying Case is shown in Fig. 2-5. Spaces 1 through 14 in the case are designed to hold the following standard Accessories:

1. Rotational Function Generator (with or without the Adapter Plate which is a standard accessory)
2. Extension Shaft (2 ea) (part of extension shaft kit)
3. Shaft Coupling (2 ea) (part of extension shaft kit)
4. Friction Drive Adapter (part of extension shaft kit)
5. Cable, 50 foot, BNC-BNC (3 ea)
6. Cable, 20 foot, BNC-BNC
7. Cable, 20 foot, equipped with two 6-terminal connectors for use with Rotational Function Generator
8. Magnetic Transducer
9. Charge Amplifier Calibrator
10. Vibration Transducer
11. Pressure Transducer; equipped with cooling adapter
12. Snap-on Clips; for identifying cable ends
13. Cable, 18 inch, BNC-BNC

Spaces 15, 16 and 17 are designed to hold a timing light, planimeter and Polaroid® film packs, respectively.

Most of the Standard Accessories were discussed in the block diagram description. Additional information regarding them is contained on the following pages. Pictures of the Standard Accessories can be found in the Accessories information near the rear of this manual.

Rotational Function Generator. The following features are found on the exterior of the Rotational Function Generator. Their locations are indicated in Fig. 2-6.

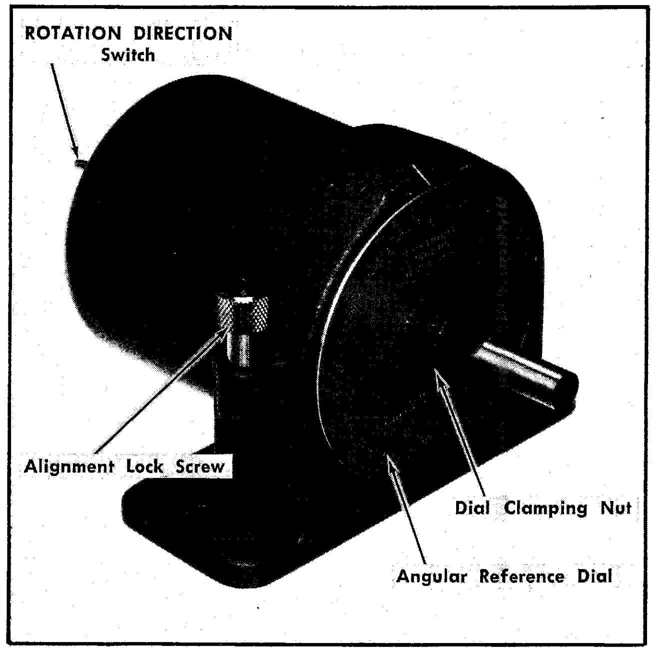


Fig. 2-6. Rotational Function Generator.

ROTATION DIRECTION	Electrically inverts the slope of the sawtooth output from the Function Generator. When set to agree with direction of engine rotation, it provides a positive-going ramp, permitting the CRT display to progress from left to right.
Alignment Lock Screw	Located on the base assembly. Clamps the body to the base. Loosening it permits the body to be rotated for aligning the Function Generator with the crankshaft reference position. See Operator's Adjustment Procedure in this section.
Angular Reference Dial	360 degree dial, graduated in degrees. Indicates zero position of rotational functions with respect to a preset reference. Dial can be rotated independently when Dial Clamping Nut is loose; dial rotates with Generator body when Dial Clamping Nut is tight. See Operator's Adjustment Procedure in this section.
Dial Clamping Nut	Releases Angular Reference Dial for aligning purposes. See Operator's Adjustment Procedure in this section.

Extension Shaft, Coupling and Friction Drive Pad. These components enable the operator to couple the Rotational Function Generator to the crankshaft of the equipment under test. It can be coupled directly if the drive shaft is equipped with a 3/8-inch take-off shaft, or it can be coupled by applying the Friction Drive Adapter against a detent in the center of the drive shaft. The extension shafts permit locating the Rotational Function Generator at any of three distances from the take-off point.

Cables. Three 50 foot low-noise cables and one 20 foot low-noise cable are provided, equipped with BNC connectors on both ends. These cables are interchangeable and any three can be used at a given time to couple signals from the three transducers to the 3A74.

The cables are apt to become tangled, twisted and mixed up because of their length and the number of cables involved. This is inconvenient and can cause damage to the cables. Observing the following will minimize this problem.

Snap matching colored clips (standard accessories) to opposite ends of each cable to facilitate identification.

"Fake" the cables when coiling them to avoid introducing twists which are usually associated with coiling. See Fig. 2-7 for an explanation of "faking."

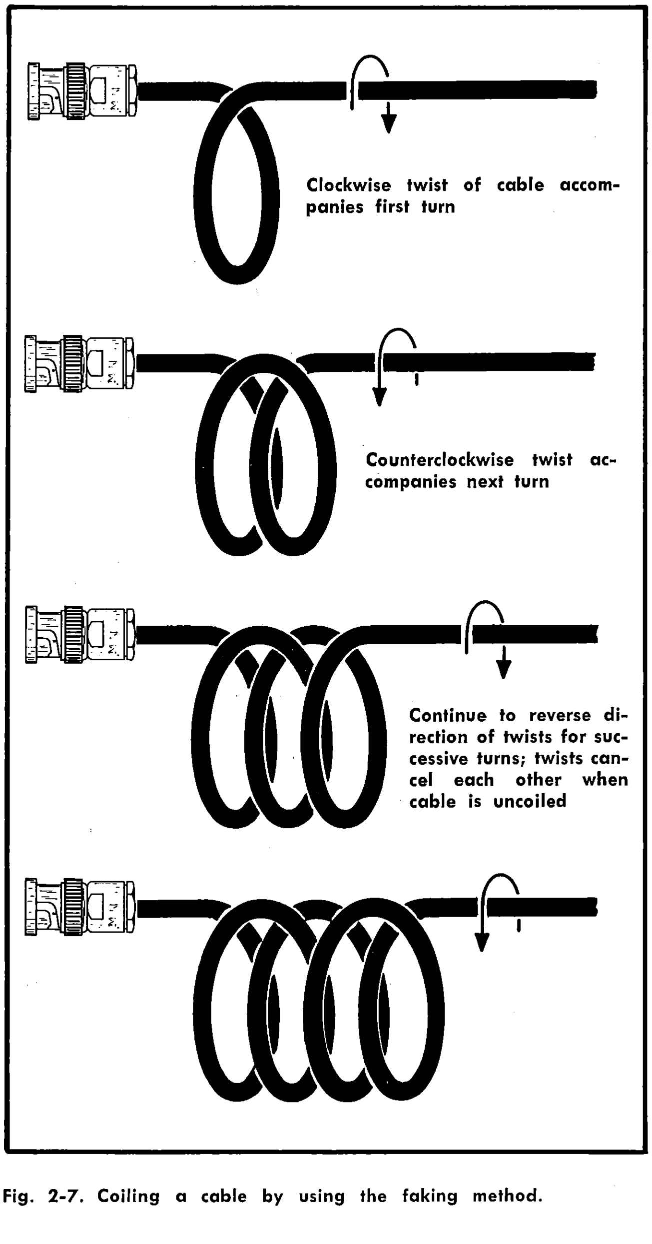


Fig. 2-7. Coiling a cable by using the faking method.

Fasten the coiled cable at two or three places (preferably near the end connectors) before laying it down.

If repairs must be made to the cables, consult the Maintenance section for pertinent information.

Transducers. These units are ruggedly built and simple to operate. However, they should not be dropped or otherwise exposed to unnecessary shocks. The pressure transducer contains a piezoelectric crystal which could be damaged by excessive heat. It is equipped with a cooling adapter. A stream of pressurized air should be applied to the cooling adapter whenever the transducer is attached to an operating engine. Approximately 30 to 50 PSI available at the input of a 1/4-inch hose should provide adequate cooling. The vibration transducer also contains a piezoelectric crystal but is not equipped with any cooling devices. It is not expected that it will be attached to surfaces which will raise its temperature above 300° F.

NOTE

The pressure transducer is screwed into the cooling adapter, and a gasket is installed between them. If they are separated for any reason, make certain that the gasket is installed properly on the transducer's flanged surface before fastening them together. A pressure leak may otherwise occur.

Charge Amplifier Calibrator. This permits gain calibration of the Charge Amplifier (3A74 Channel 1). It is connected between the Calibrator on the Oscilloscope and the Channel 1 PRESSURE TRANSDUCER Input connector, using an 18 inch BNC-BNC cable (standard accessory). The Charge Amplifier Calibrator is not required for calibrating Channels 2, 3 and 4. See the Operator's Adjustment Procedure later in this section for complete details.

FIRST TIME OPERATION OF OSCILLOSCOPE, 3A74, 2B67 AND ROTATIONAL FUNCTION GENERATOR

Power Source

The oscilloscopes which can be used with the Engine Analyzer System operate from power supplies of 50 to 400 Hz whose voltages are either between 105 and 125 volts (117 V nominal) or between 210 and 250 volts (234 V nominal), depending upon the transformer wiring and fuse size. Unless otherwise requested, they are wired at the factory for 117 V operation. They must be rewired as shown in the applicable oscilloscope manual if they are to be used with 234-volt supplies.

Oscilloscope and Plug-In Setup

Insert the 3A74 Engine Analyzer (hereafter called 3A74) into the left compartment (viewer's left) of the Oscilloscope, and the 2B67 Engine Analyzer Time Base (hereafter called 2B67) into the right compartment of the Oscilloscope. Rotate the plug-in securing knobs counterclockwise, fully insert the units, and then turn the securing knobs clockwise until they are moderately tight.

Set the Oscilloscope and Plug-In controls as follows:

Oscilloscope

FOCUS	Midrange
INTENSITY	Fully CCW
CALIBRATOR	OFF
CRT CATHODE SELECTOR (Rear of Oscilloscope)	CHOPPED BLANKING (DUAL TRACE, if so named)
DISPLAY (564-Series Oscilloscopes)	NON-STORE

3A74

Channel 1	PSI/DIV	10
	RESTORE TIME	SHORT
	MODE	OFF
	POSITION	Midrange
Channels 2, 3 and 4	AC-GND-DC	GND
	VOLTS/DIV	.2
	VAR GAIN	Detented at CAL
	MODE	OFF
	POSITION	Midrange
TRIGGER		Pushed in
CHOP-ALT		CHOP

2B67

POSITION	Midrange
MODE	NORM
TIME/DIV	5 ms if the oscilloscope has a line frequency CALIBRATOR signal. (.2 ms if the oscilloscope has a 1 kHz CALIBRATOR signal.)
VARIABLE	CALIBRATED (Fully CW)
5× MAG	IN
TRIGGERING	
LEVEL	AUTO
SLOPE	+
SOURCE	INT
ROTATIONAL FUNCTION	
POSITION	Midrange
PISTON-CRANK	CRANK
WIDTH	Fully CCW
MARKERS	In
SINGLE SWP DISPLAY	360°

Connect the Oscilloscope power cord to an appropriate power source and turn the Oscilloscope POWER switch ON. Permit the equipment to warm up while the remaining equipment is being set up. (The Oscilloscope and plug-in units are ready for routine operation approximately 30 seconds after turn-on. The system will operate within its specified accuracy limits after 20 minutes of warmup.)

Operating the CRT Controls

Turn the INTENSITY control clockwise until a horizontal trace is visible on the CRT. If none appears, recheck the control setup.

Adjust the FOCUS control to obtain the sharpest appearing trace.

Turn the SCALE ILLUM knob fully clockwise and note the brightness of the graticule lines. Turn the knob counterclockwise until the desired graticule line brightness is obtained.

Operating the 3A74 Controls

Channel 2, 3 and 4 Operation. Rotate the Channel 2 POSITION control and note that it has no effect upon trace position. Move the Channel 2 MODE switch to NORM and note that the Channel 2 POSITION control now affects the trace position. A channel's MODE switch must be at either NORM or INV before its POSITION control can affect trace position.

Connect the 18 inch coaxial cable (standard accessory) between the Oscilloscope CAL OUT jack and the Channel 2 Input connector. Set the CALIBRATOR to .2 VOLTS (.4 V on oscilloscopes equipped with 1 kHz CALIBRATOR signals).

Switch the Channel 2 AC-GND-DC switch to DC and note that a square-wave display appears. If the Oscilloscope is equipped with an ASTIGMATISM knob, rotate the knob while noting the sharpness of the square wave vertical lines. Alternately adjust the ASTIGMATISM control for optimum sharpness of the vertical lines, and the FOCUS control for optimum sharpness of the horizontal lines, until the best overall focusing is obtained.

Measure (in divisions) the display amplitude. Multiply by the VOLTS/DIV switch setting to determine the signal amplitude represented by the display. (0.2 or 0.4 V) Note that the DC level of the square wave is being displayed at all times. The calibrator is referenced to 0 (the trace position with the AC-GND-DC switch at GND), and deflects in a positive direction by an amount determined by the Oscilloscope Calibrator setting.

Switch the AC-GND-DC control to AC. The DC component of the signal is now blocked and the display will shift until the average level of the AC signal straddles the trace reference position. Only the signal's AC component now can be measured. Return the AC-GND-DC control to DC.

Rotate the VOLTS/DIV knob clockwise one position and note that the display amplitude increases. Rotate the VAR GAIN knob counterclockwise out of its detent and note that the display amplitude decreases. Continue rotating the knob counterclockwise until the knob is again detented and the display returns to its calibrated amplitude. The VAR GAIN control can reduce the display amplitude to 40% or less of its calibrated amplitude, thus providing uncalibrated deflection factors of as much as $2\frac{1}{2}$ times the value indicated by the VOLTS/DIV switch.

Switch the Channel 2 MODE switch to INV and note that no change appears to occur in the polarity of the symmetrical display. This is because the positive-going edge of the signal occurring at the CRT deflection plate is being sent to the 2B67 triggering circuitry to initiate sweeps, even though the display is now deflecting upward in response to negative-going input signals.

Place the 3A74 TRIGGER—CH 2 ONLY switch in its out position. Note that the display now starts with a negative-going signal. (The triggering circuit is now receiving its signal from the input to the Channel 2 circuit, before it is inverted. The 2B67 triggering circuitry starts a sweep during a positive-going portion of the input signal. Channel 2 inverts the signal and presents it as a negative-going signal at the beginning of the sweep.) Leave the TRIGGERING switch in its out position.

Switch the Channel 2 MODE switch to NORM, and note that the signal now is going positive at the beginning of the sweep, since no inversion is being applied to the displayed signal.

Disconnect the 18 inch cable from the Channel 2 Input connector. Connect a patch cord (Oscilloscope standard accessory) between the Channel 2 and 3 Input connectors. Connect the 18 inch cable to the patch cord at the Channel 2 Input connector.

Switch the Channel 3 MODE switch to NORM, and adjust the Channel 2 and 3 POSITION controls to set the traces apart.

Place the Channel 2 AC-GND-DC switch at DC. Note that a square wave appears on the Channel 3 trace. Push the 3A74 TRIGGER knob in and note that the displays become unstable. This occurs because of interference from the channel-switching transients which exist in multiple-channel CHOP operation.

Switch the CHOP-ALT control to ALT and note that the displays stabilize. Return the CHOP-ALT control to CHOP.

Place the 3A74 TRIGGER knob in its out position. Note that the display again stabilizes. This occurs because the CH 2 ONLY trigger signal is picked off at the input to the Channel 2 amplifier, before the switching transients are introduced.

Switch the Channel 2 AC-GND-DC control to GND and note that the Channel 2 square wave disappears, although the trace remains. Also note that the Channel 3 display becomes unstable. This occurs because the Channel 2 signal has been removed from the 2B67 triggering circuitry, and CH 2 ONLY triggering is still being selected at the 3A74.

Return the Channel 2 AC-GND-DC control to DC, then switch the Channel 2 MODE switch OFF. Note that the Channel 2 square wave and trace disappear from the CRT, but also note that the Channel 3 display remains stable. Although the Channel 2 signal has been blocked from the CRT, it is still present in the Channel 2 amplifier circuit and is being applied to the 2B67 triggering circuitry.

Switch the Channel 2 MODE switch to NORM, and the Channel 3 MODE switch to OFF. Switch the Channel 3 AC-GND-DC switch to GND position.

Channel 4 operation is identical to that of Channel 3.

Channel 1 Operation. Attach the Charge Amplifier Calibrator (standard accessory) to the Channel 1 PRESSURE TRANSDUCER Input connector. Remove the patch cord from the Channel 3 Input connector and attach it to the Charge Amplifier Calibrator which is connected to the Channel 1 Input connector.

NOTE

Do not connect the Oscilloscope CAL OUT signal directly to the Channel 1 Input connector. The circuit requires a capacitive input and the Oscilloscope CALIBRATOR output is essentially resistive.

Switch the Channel 1 MODE switch to NORM and note that its display appears on the CRT. Adjust the Channel 1 and 2 POSITION controls to separate the displays.

Switch the Channel 1 PSI/DIV knob to 20 and note that the display amplitude decreases. Switch to 5 and note that the display amplitude increases. The PSI/DIV switch performs the same function as the Channel 2, 3 and 4 VOLTS/DIV switches, increasing circuit sensitivity (lower PSI/DIV) as the knob is switched clockwise, and decreasing circuit sensitivity (higher (PSI/DIV) as the knob is switched counterclockwise.

Push the Channel 1 ZERO button and note that the display disappears, and that the trace moves to its quiescent reference position. Release the button and note that the square wave instantly appears either above or below the quiescent trace position. (The direction is dependent upon the signal polarity which exists at the instant the button is released.) The square wave then rapidly shifts until it straddles the quiescent trace position.

Switch the RESTORE TIME knob to LONG. Again push and release the ZERO button, noting that a considerably longer time is required (10 times as long) for the square wave to settle after the button is released. This rate of shift reflects the amplifier's ability to follow average signal values. LONG operation is recommended during operation with engines of 600 RPM and below where pressure measurement accuracy is critical.

Operating the 2B67 Controls

Rotate the left POSITION control and note that the display can be shifted so that either end can be placed at the center vertical graticule line.

Measure (in divisions) the horizontal spread of 1 cycle of the displayed square wave. Multiply the number of divisions by the TIME/DIV setting to determine the time required (period) for 1 cycle. Find the reciprocal of the time to determine the frequency of the applied CALIBRATOR signal. (Either line frequency or 1 kHz, depending upon the type of oscilloscope.)

Rotate the TIME/DIV control clockwise and note that the horizontal spread of each cycle increases. Switch the TIME/DIV control to 5 μs and note that the chopped segments of each trace are visible. (Readjust the CRT intensity control as necessary. It may also be necessary to adjust the LEVEL control to synchronize to the segments so that they can be seen.)

At the 3A74, switch the CHOP-ALT control to ALT. Note that the displays seem to be presented simultaneously. (Readjust the INTENSITY and LEVEL controls if necessary.)

Switch the 2B67 TIME/DIV control to 20 ms. Return the LEVEL control to AUTO, if its position has been disturbed. Note that the trace alternates between channels. Switch the 3A74 CHOP-ALT switch to CHOP and note that the displays again seem to be presented simultaneously.

If the Oscilloscope has a 1 kHz calibrator, switch the TIME/DIV control to 1 ms. Rotate the (TIME/DIV) VARIABLE control counterclockwise, noting that the UNCAL lamp comes on and that the horizontal spread of each square wave decreases. With the VARIABLE control fully counterclockwise, the horizontal spread will decrease to 40% or less of its previous amount. This indicates a VARIABLE range of at least 2.5 times the calibrated sweep rate selected by the TIME/DIV control.

Return the VARIABLE control to CAL and note that the UNCAL lamp goes out. Using the 2B67 left POSITION control, place the left edge of the display exactly at the center vertical graticule line. Note the amount of horizontal spread of the first square wave. Now pull out on the TIME/DIV) VARIABLE knob, closing the 5X MAG switch. Note that the left edge of the display remains near graticule center, but the horizontal spread of the square wave increases to five times its previous value. Compute the period and frequency. This is done in the same manner as before, except that the TIME/DIV indicated by the TIME/DIV control must be divided by 5 to compensate for the effect of the 5X MAG switch. The results should be the same as before. (Either line frequency or 1 kHz, depending upon the type of oscilloscope in use.)

Push the (TIME/DIV) VARIABLE knob in, and position the trace to start at the first graticule line at the left side of the CRT. Switch the TIME/DIV control back it its original position (5 ms or .2 ms, depending upon the oscilloscope in use).

Rotate the (TRIGGERING) LEVEL knob slowly clockwise noting that the display first disappears, and then reappears as the knob moves through certain positions. The setting of the knob will determine the voltage level of the waveform at which triggering will occur. When the knob reaches the FREE RUN detent, an unstable display will appear, since the sweep will no longer be triggered by the displayed signals.

Move the (TRIGGERING) SLOPE switch to the — position, and slowly return the LEVEL control from FREE RUN to AUTO. Note that the LEVEL Control again selects the signal voltage level at which triggering occurs, but that this time it selects the voltage level on the negative slope, as indicated by the SLOPE control. Return the SLOPE switch to +.

An illustration of various triggering setups and their effects is given in Fig. 2-8. A sine wave signal from an AC power source was used so that the changing triggering levels could be shown.

Move the (TRIGGERING) SOURCE switch to EXT and note that the trace becomes unstable. Remove the patch cord from the Charge Amplifier Calibrator at Channel 1, and attach it to the 2B67 (TRIGGERING) EXT Input connector.

The Channel 2 display will again stabilize. If the Rotational Function Generator is connected to the 2B67, either the CRANK (sawtooth) or PISTON (sine wave) signal is internally applied to the EXT TRIG circuit whenever the Generator shaft is rotating.

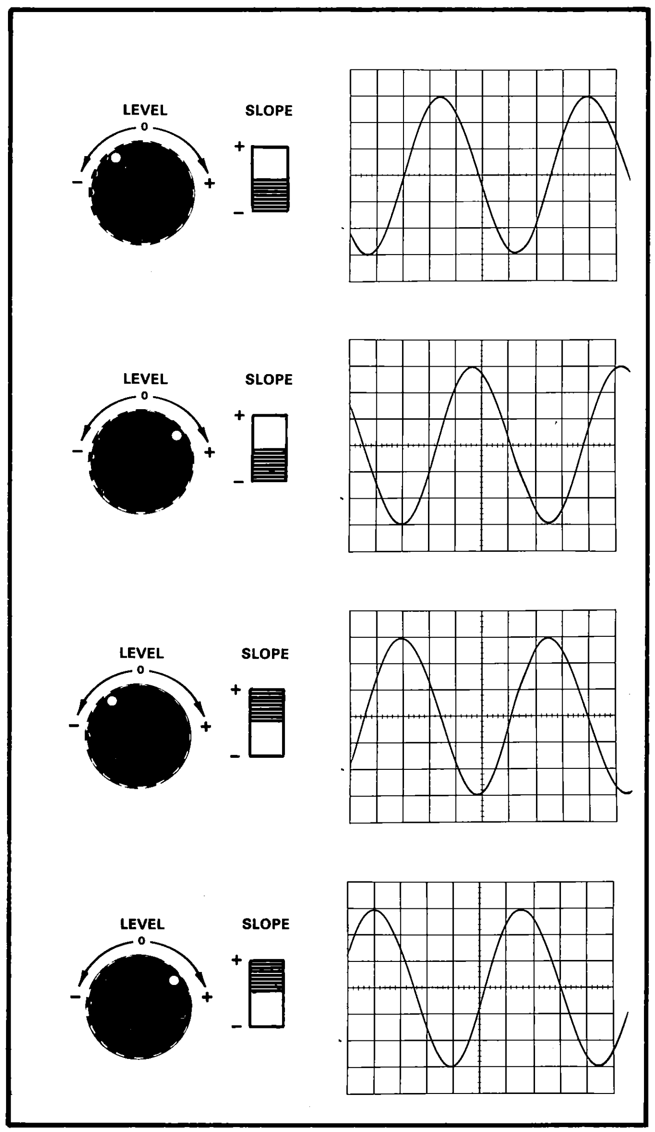


Fig. 2-8. Effect of the LEVEL control and SLOPE switch.

Return the (TRIGGERING) SOURCE switch to INT and move the patch cord back to the Calibration Adapter at Channel 1.

Single Sweep Operation. Move the LEVEL control away from AUTO position and select a triggering level that provides a stable display.

Move the MODE switch to SINGLE SWP and note that the trace disappears. Now move the MODE switch to RESET. The beam will sweep across the CRT one time as the switch is returned to the SINGLE SWP position.

Move the 3A74 CHOP-ALT switch to ALT and again place the SINGLE SWP control at RESET. Note that only one channel's trace is presented as the switch is returned to the SINGLE SWP position. Reset the sweep several times and note that the channel traces are alternately presented. If three or four channel MODE switches are on during ALT operation, the single sweep displays will progress through all of the selected channels and then repeat. CHOP operation is therefore more practical for multi-channel SINGLE SWP operation at all except the highest sweep rates.

Return the CHOP-ALT switch to CHOP. Turn the Oscilloscope CALIBRATOR switch off. Momentarily place the 2B67 MODE switch at RESET and allow it to return to SINGLE SWP. Note that no trace is generated and that the READY light remains on. Return the Oscilloscope CALIBRATOR control to its previous setting, and notice that a single sweep is generated when the output of the CALIBRATOR reaches a level high enough to cause triggering action.

Return the 2B67 MODE switch to NORM and the LEVEL control to AUTO.

Operation with TIME/DIV Switch at ROTATIONAL FUNCTION GENERATOR Position. Up to this point, an internally generated sweep voltage was used to obtain a horizontal base line on which to display the vertical signal(s). When the TIME/DIV switch is placed at the ROTATIONAL FUNCTION GENERATOR position, all of the above information remains applicable except as follows: the 2B67 left POSITION control, the (TIME/DIV) VARIABLE control and the 5× MAG control are disabled; internal sweep voltages are no longer generated to provide a horizontal base line; a signal can be inserted through the ROTATIONAL FUNCTION INPUT connector to provide a horizontal base line on the CRT.

Turn the Oscilloscope CALIBRATOR off, and disconnect the 18 inch coaxial cable and the patch cord from the equipment.

Connect the Rotational Function Generator to the 2B67 (ROTATIONAL FUNCTION) INPUT connector, using the 50 foot cable which is supplied as a standard accessory. (The Function Generator need not be connected to a prime mover to perform this part of the First Time Operation.)

Switch the TIME/DIV switch to ROTATIONAL FUNCTION GENERATOR position. Note that the ten-division traces are replaced by two-division traces, caused by the standby trace signal. These traces will respond to the 3A74 POSITION controls, just as they did during timed sweep operation.

CAUTION

When performing the following step, do not allow focused stationary dots to exist on the CRT for more than a few seconds. They can cause burn spots on the CRT phosphor in very short periods of time. The CRT INTENSITY should be turned to minimum (CCW) prior to removing the Rotational Function Generator cable whenever the TIME/DIV switch is at the ROTATIONAL FUNCTION GENERATOR position.

Turn the CRT FOCUS control fully clockwise.

Momentarily disconnect the Rotational Function Generator cable from the 2B67 INPUT connector. Note that the standby traces are replaced by dots. Immediately replace the cable, since the dots can damage the CRT phosphor if allowed to remain in one place very long. Re-focus the display.

Switch the 3A74 Channel 1, 3 and 4 MODE switches OFF. Readjust the INTENSITY control if necessary.

Rotate the shaft of the Rotational Function Generator by hand. Note that while the shaft is rotating (and the WIDTH control is fully counterclockwise) a trace of between 2 and 5 horizontal divisions exists. It moves relatively slowly across the CRT in one direction and returns rapidly to the starting point.

Switch the ROTATION DIRECTION switch (back of Rotational Function Generator) to its opposite position. Again rotate the shaft in the same direction as before and note that the direction of slow movement has been reversed. During actual operation, the switch is normally set so that the trace's slow movement is from left to right as viewed by the observer, regardless of the direction of engine rotation.

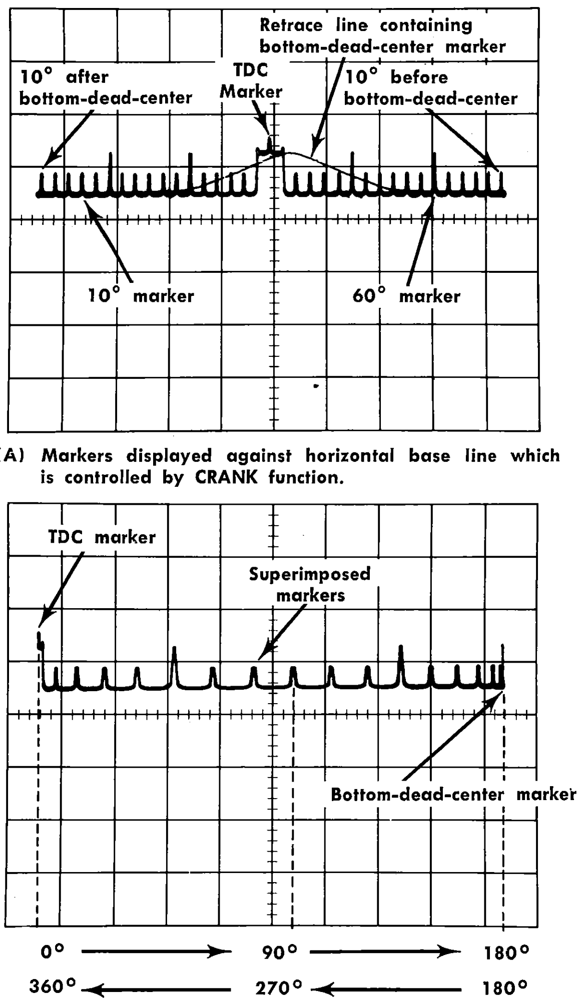
Adjust the 2B67 right POSITION knob while rotating the Function Generator shaft until the display is centered on the CRT. Note that when the Function Generator shaft stops rotating, the standby trace may appear at various places on the CRT. The location is dependent upon the shaft position after it stops rotating.

Rotate the WIDTH control fully clockwise. Note that now when the shaft is stopped, its position may cause the standby trace to be out of the viewing area.

Return the WIDTH control to its fully counterclockwise position. Then pull out out on the WIDTH knob, connecting the marker signals from the Function Generator to the 3A74 Channel 2 circuitry.

Again rotate the Function Generator shaft and note that marker signals appear while the shaft is rotating. The amplitude of these markers can be changed by the Channel 2 VAR GAIN control, but is not affected by the VOLTS/DIV control.

Turn the WIDTH control clockwise while rotating the Function Generator shaft. Notice that the trace expands in both directions away from the center. Set the width control so that approximately 10 divisions of trace appear. The markers can then be seen clearly enough to notice the three types. Thirty-six markers exist, with the 10, 60 and 360 degree markers being distinctive. (Thirty-five of the markers appear on the trace and one appears on the retrace line.) See Fig. 2-9(A).



(A) Markers displayed against horizontal base line which is controlled by CRANK function.

(B) Markers displayed against horizontal base line which is controlled by Piston function.

Fig. 2-9. Marker signals.

When the Function Generator is being driven by a prime mover, the center of the wide pedestal indicates the point on the trace at which the reference function occurs (normally top-dead-center of the reference piston). The 10 and 60 degree markers permit determination of the point on the waveform at which related functions occur (ignition, valve action, top-dead-center of pistons other than the one being referenced to, etc.).

Note that the signal causing the horizontal deflection is indicative of the shaft's angular position, and that it displays the angular position as a linear function. This is possible because the Function Generator CRANK output is a linear sawtooth whose amplitude is proportional to shaft position. The spacings between the 10 degree markers are therefore equal. It may also be noticed that approximately 10 degrees of rotation are required to cause the beam to retrace from one side of the CRT to the other. The beam is positioned in the middle of the CRT when the piston to which the Function Generator is aligned is at its top-dead-center position. This is illustrated in Fig. 2-9A.

Switch the 2B67 PISTON-CRANK switch to PISTON. Again rotate the Function Generator shaft. This time notice that the left-right and right-left motion of the beam occurs at rates equal to each other, providing that the speeds of rotation are equal. Also note that the trace movement is more rapid near the center of the trace than near the ends. This point is emphasized by the difference in marker spacings. See Fig. 2-9(B). These actions occur because of Function Generator PISTON output is an approximate sine wave whose angular value is dependent upon the Function Generator shaft position. When the center of the broad marker is aligned with the top-dead-center of a piston, the extreme left side of the waveform represents top-dead-center. Piston bottoming is then coincident with the beam being at the right of the CRT.

Set the 2B67 MODE switch to SINGLE SWP, the (TRIGGERING) SOURCE switch to EXT, and set the (TRIGGERING) LEVEL control to 0. Check that the SINGLE SWP DISPLAY switch is at 360°. Start rotating the Function Generator shaft slowly. Keep it rotating for the rest of this procedure, simulating engine drive. Place the MODE switch to RESET and hold it there. The trace should disappear and the ready light should go on. Permit the MODE switch to return to SINGLE SWP. If the LEVEL control is in a position to permit triggering, the trace will go back and forth across the CRT one time and then blank out. If no trace appears, slowly move the (TRIGGERING) LEVEL control until the sweep occurs. Leave the level control in this position. Again reset the MODE switch and notice that the trace occurs as the MODE switch is returning to the SINGLE SWP position.

Move the 360°-720° switch to 720°. Reset the single sweep circuit and notice that the trace make two trips back and forth across the CRT when the Mode switch is permitted to return to the SINGLE SWP position. Two complete revolutions of the FUNCTION GENERATOR shaft occur during the time the trace is unblanked.

Switch the PISTON-CRANK switch to CRANK, permitting the sawtooth from the Function Generator to control the horizontal deflection and unblanking. Set the Rotation Position switch (rear of Function Generator) to the direction of shaft rotation. Reset the single sweep circuit and notice that the CRT unblanks as the trace moves from left to right across the CRT. Switch the (TRIGGERING) SLOPE control to negative (—) and again reset the single sweep circuit. Note that now the CRT unblanks during the rapid right-to-left movement of the trace. (Reset the LEVEL control, if necessary.) The negative SLOPE is preferred for triggering whenever the CRANK signal has been selected during SINGLE SWP ROTATIONAL FUNCTION GENERATOR operation.

It may be noted that the (TRIGGERING) SLOPE and SOURCE knobs affect the display during timed sweep operation and during the single sweep phase of ROTATIONAL FUNCTION GENERATOR operation. During the NORM MODE of ROTATIONAL FUNCTION GENERATOR operation they have no effect once the trace has initially been unblanked.

TABLE 2-1

Engine Analyzer System Control Setup Summary

Operating Mode	ROTATIONAL FUNCTION GENERATOR		Timed Sweep	
Operating Sub-Mode	NORM	SINGLE SWP	NORM	SINGLE SWP
3A74 Ch 1 PSI/DIV	Set for desired vertical display amplitude of pressure signal			
RESTORE TIME	Above 600 RPM—SHORT; Below 600 RPM—LONG			
MODE	NORM for upward display of positive-going signals; INV for downward display of positive-going signals; OFF to remove trace from CRT.			
POSITION	Set for desired vertical position of display			
Input Connector	Connect to pressure transducer			
Ch 2 AC-GND-DC	Set at DC to accept signals from connector; Set at AC to accept only AC or transient components of signal from Input connector; Does not affect RFG marker signals, which are applied internally.			
VOLTS/DIV	Set for desired amplitude of signal accepted from Input connector after VAR GAIN has been set; Does not affect displayed amplitude of RFG marker signals.			
VAR GAIN	Set for desired vertical display amplitude of RFG marker signals; Set at CAL to obtain calibrated VOLTS/DIV display amplitude of signals accepted from Input connector.			
MODE	Same as Ch 1			
POSITION	Same as Ch 1			
Input Connector	Can be connected to any desired signal voltage source; Normally connected to the Magnetic Transducer (TDC sensor)			
Ch 3, 4 AC-GND-DC	Set at DC to accept signals from Input connector; Set at AC to accept only AC or transient components of signal from Input connector.			
VOLTS/DIV	Set for desired amplitude of signal accepted from Input connector			
VAR GAIN	Set at CAL for calibrated VOLTS/DIV display; Set at any position to obtain desired amplitude of uncalibrated VOLTS/DIV display			
MODE	Same as Ch 1			
POSITION	Same as Ch 1			
Input Connector	Can be connected to any desired signal voltage source; Normally connected to the Ignition Pick-up and Vibration Transducer, respectively			
TRIGGER	Not applicable		Out for multi-trace operation	Out
CHOP-ALT	CHOP	CHOP	CHOP for slow and intermediate sweep speeds; ALT for fast	CHOP
2B67 POSITION (left side)	Not applicable		Start trace at left edge of graticule during ×1 mag operation; Set point of interest to graticule center prior to pulling 5× MAG out	
MODE	NORM	SINGLE SWP	NORM	SINGLE SWP
TIME/DIV	ROTATIONAL FUNCTION GENERATOR		Numbered position which displays area(s) of interest of vertical signals	
VARIABLE	Not applicable		Cal for calibrated TIME/DIV sweep rates; Any position for sweep rates slower than those indicated by the TIME/DIV switch	
5× MAG	Not applicable		Causes 5× expansion of center two divisions of ×1 horizontal trace	
TRIGGERING LEVEL	AUTO	Set at 0; Slightly modify setting as necessary to trigger single sweep; Do not select AUTO or FREE RUN	AUTO; Can be set to any other position to cause triggering to occur at selected point of displayed waveform or EXT signal (including signal selected by PISTON-CRANK)	
SLOPE	Not applicable	Negative (—)	Set to slope which is desired to appear at left edge of trace	
SOURCE	Not applicable	EXT	EXT to trigger from RFG sine wave or sawtooth signal, or from signals connected to EXT (TRIGGERING) connector; INT to trigger on displayed signal; LINE to trigger from AC power supply sine wave	

TABLE 2-1 *(cont)*

ROTATIONAL FUNCTION POSITION	Set for desired horizontal position of display	Not applicable
PISTON-CRANK	PISTON for horizontal display indicative of cylinder volume; CRANK for display indicative of crank angle	Set to Function Generator signal desired for EXT triggering
WIDTH	Set for desired horizontal display amplitude	Set to Function Generator signal amplitude desired for EXT triggering
MARKERS	Pull out to display markers on Channel 2 trace; Ch 2 MODE switch must be at NORM or INV.	
SINGLE SWP DISPLAY	Not applicable 360° for 2-cycle operation; 720° for 4-cycle	Not applicable
ROTATIONAL FUNCTION GENERATOR		
ROTATIONAL DIRECTION	Set for left-to-right CRANK sweep; Not applicable with PISTON-CRANK at PISTON	Selects polarity of RFG crank signal applied to EXT triggering line

OPERATOR'S ADJUSTMENT PROCEDURE

This procedure consists of adjusting the externally accessible screwdriver adjustments on the Type 3A74 and the 2B67 as necessary to obtain operation within the limits specified in the Specification section of this manual.

Initial Setup

3A74 Engine Analyzer Amplifier

Channel 1	PSI/DIV	5
	RESTORE TIME	SHORT
	MODE	OFF
	POSITION	Midrange
Channels 2, 3, 4	AC-GND-DC	GND
	VOLTS/DIV	.02
	VARIABLE	CAL
	MODE	OFF
	POSITION	Midrange
TRIGGER		In

2B67 Engine Analyzer Time Base

POSITION	Midrange
MODE	NORM
TIME/DIV	5 ms (.2 ms on oscilloscopes having a 1 kHz CALIBRATOR signal)
VARIABLE	CAL
TRIGGERING	
LEVEL	AUTO
SLOPE	+
SOURCE	INT
ROTATIONAL FUNCTION	
POSITION	Midrange
PISTON-CRANK	CRANK
WIDTH	CCW
MARKERS	Out

Turn the Oscilloscope on. Adjust the INTENSITY and FOCUS controls until a sharp trace of desired intensity is obtained.

3A74 DC BAL Adjustment

These adjustments must be performed prior to the GAIN adjustments. When properly adjusted, the DC CAL control prevents any change in trace reference position from accompanying rotation of the VAR GAIN controls.

Channel 1 DC BAL Adjustment

1. Set the Channel 1 MODE switch at NORM.
2. Using the Channel 1 POSITION control, set the trace to graticule center.
3. Move the Channel 1 PSI/DIV control to 10 and check the trace position. If it has shifted less than 0.1 division, no adjustment is necessary. If it shifted more than 0.1 division, continue with the adjustment procedure.
4. Adjust the Channel 1 DC BAL as necessary to return the trace to graticule center.
5. Switch the PSI/DIV control back to 5. Check that less than 0.1 division of trace shift occurs.
6. Repeat steps 2 through 5 until no further adjustment is necessary. Then turn the Channel 1 MODE switch OFF.

Channel 2, 3 and 4 DC BAL Adjustments

Perform the following procedure on each of the three channels.

1. Place a channel MODE switch at NORM.
2. With the POSITION control near midrange, check that the trace is in view. If not, adjust the DC BAL control until the trace is at the middle of the CRT.

3. Rotate the channel VAR GAIN control clockwise out of its detent, simultaneously checking for trace shift. If less than 0.1 division of trace shift occurs, return the control to CAL and start with step 1 at the next channel.

4. If trace shift occurs, make note of the shifted position and then return the VAR GAIN control to its detent.

5. Using the DC BAL control, move the trace to the shifted position.

6. Repeat steps 3 through 5 until less than 0.1 division of trace shift accompanies rotation of the VAR GAIN control. Then return the VAR GAIN control to its detented position and the MODE switch to OFF.

7. Repeat steps 1 through 6 until Channels 2, 3 and 4 are adjusted.

3A74 Gain Adjustment

NOTE

If the 3A74 is moved from one oscilloscope to a different one, check the gain of Channels 2, 3 and 4 before adjusting the gain of any one channel. If the gain is off by an equal amount in all channels, adjust the CAL potentiometer at the bottom of the unit.

General. The gain of the 3A74 is initially set at the factory against an accurate Amplitude Calibrator. However, this gain is partially dependent upon the deflection factor associated with the vertical deflection plates of the CRT. This factor varies slightly between different oscilloscopes. The gain of Channels 2, 3 and 4 should be checked each time the unit is used with a different oscilloscope.

If the three channels are in error by equal amounts, adjust only the CAL potentiometer at the bottom of the front panel. This will simultaneously adjust the gain of all four channels. The gain of Channel 1 should then be checked and adjusted if necessary. If only one or two channels are in error, adjust only the GAIN control of each of those channels. If the setting of all of the GAIN controls has been indiscriminately disturbed, the CAL control should be set to midrange, then the GAIN control of all four channels should be set according to the following procedure.

Channel 2, 3 and 4 Gain Adjustments

Adjustment accuracy consideration. In this procedure, the vertical amplifier channels of the 3A74 are adjusted at the .02 VOLTS/DIV setting, using a signal from the Oscilloscope's built-in calibrator. The worst-case amplitude error in any switch position will not exceed the sum of the specified maximum percentages of deviation of the calibrator and the amplifier.

For example, assume that the calibrator is accurate to within 3% and each channel's gain is accurate in all positions to within 3% of the value to which the .02 VOLTS/DIV position is adjusted. The worst-case accuracy of the channel in all other switch positions will be within 6% of the value selected by the deflection factor switch (VOLTS/DIV).

This is considered sufficiently accurate for Engine Analyzer System operation. If higher accuracy is desired, the applicable channel can be adjusted at the setting to be used, limiting the worst-case percent of error to the accuracy limitation of the calibrating signal source. However, if this method is used to calibrate any but the .02 VOLTS/DIV position, the remaining positions may be less accurate.

Channels 2, 3 and 4 GAIN Adjustment Procedure

1. Set up the equipment according to the Operator's Adjustment Procedure Initial Setup.

2. Using a patch cord, connect the CALIBRATOR output to the Channel 2 Input connector.

3. Set the CALIBRATOR switch to .1 V (.04 V on an oscilloscope having a 1 kHz calibrator).

4. Set the Channel 2 AC-GND-DC control to DC and the Channel 2 MODE switch to NORM.

5. Check for exactly 5 divisions of display amplitude (2 divisions on oscilloscopes equipped with a 1 kHz Calibrator).

6. Return the MODE switch to OFF and the AC-GND-DC switch to GND.

7. Repeat steps 2 through 6 at Channels 3 and 4.

8. If all three channels are equally in error, adjust the CAL control for the proper display amplitude on one of the channels. Measure from trace center to trace center to avoid the effect of trace width.

9. If the three channels are in error by different amounts, set the CAL control to midrange and adjust the GAIN control at each channel until proper signal amplitudes are obtained.

Ignition Voltage Measurement. The Capacitive Ignition Pickup is dependent upon capacitive action. The amount of voltage sensed is dependent upon the amount of source voltage, the mating of the clamp and cable, and the amount and type of insulating material between the conductor and the pickup clamp. The calibrated deflection factors indicated on the VOLTS/DIV switch apply to voltage signals which are applied directly to the Channel Input connector. When a voltage depends upon capacitive coupling to reach the input connector, a conversion factor must be applied to the indicated signal value before the actual signal voltage can be determined. The following procedure will permit the operator to determine the value of this conversion factor.

1. Obtain a clean piece of cable of the same type used in the ignition system to be monitored. The piece should be at least 18 inches long. Strip off 3/4 inch of insulation. If carbon-core wire is involved, cut a 2 inch piece of copper wire and insert about 1 1/4 inch of the wire into the carbon conductor.

2. Set up the equipment according to the Operator's Adjustment Procedure Initial Setup.

3. Connect the center conductor of the ignition cable to the center conductor of the Oscilloscope CALIBRATOR Output connector. (A Tektronix BNC-to-Binding Post Adapter, Part No. 103-0033-00 can be used for this purpose.) Support the wire as necessary to hold it in this position.

4. Clamp the Capacitive Ignition Pickup approximately 8 inches from one end of the wire. Keep the clamp clear of other wires or surrounding metal. Connect the BNC con-

nector (other end of the Capacitive Ignition Pickup cable) to the 3A74 Channel 3 Input connector.

WARNING

Do not touch the ignition wire conductor while voltage is applied during the remainder of this procedure. Also, avoid contact with the cable or the exposed metal part of the Capacitive Ignition pickup. In addition to the electric shock hazard, measurement accuracy may be affected.

5. Set the Channel 3 AC-GND-DC control to DC and its MODE switch to NORM. Check that the (VOLTS/DIV) VAR GAIN control is at CAL.

6. Set the 2B67 TIME/DIV control to 5 ms.

7. Set the Oscilloscope CALIBRATOR control to 100 V.

8. Adjust the 3A74 Channel 3 VOLTS/DIV as necessary to obtain a display of between 3 and 6 divisions. Measure the peak-to-peak display amplitude and convert it to volts by multiplying the number of divisions by the VOLTS/DIV setting.

9. Divide 100 by the voltage from step 8. The quotient is the conversion factor by which observed ignition voltage measurements must be multiplied to determine actual ignition voltages. The conversion factor applies only to the type of cable from which it was determined.

Channel 1 Gain Adjustment

Background Information. Channel 1 receives its drive signal from transducers rated in picocoulombs per pound per square inch of applied pressure (pC/PSI). A known electron source must be available to calibrate the Channel 1 gain. Assume that a 100 pC/PSI transducer is to be used with the Engine Analyzer System. To develop an equivalent electron source, a 1 V square wave from the Oscilloscope Calibrator is applied through a 4000 pF capacitor to the Channel 1 PRESSURE TRANSDUCER Input connector.

According to the formula $Q = EC$, 4000 pC of electrons will flow through the circuit each time the square wave switches from one half cycle to the other. ($Q = 1\ V \times 4000 \times 10^{-12} = 4000 \times 10^{-12}$ coulombs). This 4000 pC is equivalent to the current resulting from applying 40 PSI to the assumed 100 pC/PSI transducer.

If the Channel 1 PSI/DIV knob is at the 5 PSI/DIV position, an 8 division signal should should result. If 8 divisions are not obtained, the Channel 1 GAIN control must be adjusted to obtain 8 divisions. The display will be at least as accurate as the combination of the rated accuracy of the calibrator signal plus the percent of accuracy of the 4000 pF capacitor which is contained in the Charge Amplifier Calibrator.

Transducers characteristically have individual pC/PSI ratings which vary considerably between transducers. It would be uneconomical to attempt to standardize them, and unrealistic to permanently calibrate the charge amplifier to a specific one. It may be desirable or necessary to use several transducers with the same charge amplifier. The Charge Amplifier in Channel 1 of the 3A74 can be quickly calibrated prior to use with each one of them, once Table 2-2 has been completed for each transducer.

Instructions For Completing Table 2-2. Determine the pC/PSI rating of the transducer to be used. It is normally printed on the transducer or on its accompanying literature. Record the value and identification in Table 2-2.

TABLE 2-2

Charge Amplifier Gain Calibration Data

Transducer		Oscillo-scope Calibrator Signal	3A74 PSI/DIV Setting	Calibrated Vertical Deflection (Divisions)
Identification (Serial Number)	pC/PSI Rating			
Example 1	270	1 V	2	7.4
Example 2	270	4 V	10	5.9

Enter the left margin of the graph in Fig. 2-10 with this value. (Consult the Tektronix Field Representative for information regarding use of transducers whose pC/PSI ratings fall outside the values listed in Fig. 2-10.) Move horizontally to the right, intercepting a diagonal line which lists a voltage present on the Oscilloscope Calibrator.

Place a mark at the selected intercept, and record the selected Calibrator voltage in Table 2-2. Then drop vertically from the intercept to the bottom of the graph and determine the divisions of deflection and the PSI/DIV value represented there. Record those numbers in the two right columns of Table 2-2.

Channel 1 GAIN Adjustment Procedure. As previously explained, a line in Table 2-2 must be completed for the transducer in use before this adjustment can be performed. If this has been done, proceed as follows:

1. Set up the equipment according to the Operator's Adjustment Procedure Initial Setup.

2. Set the Oscilloscope Calibrator and the 3A74 PSI/DIV switch to the values recorded in Table 2-2.

3. Connect the Charge Amplifier Calibrator to the Channel 1 PRESSURE TRANSDUCER Input connector.

4. Connect the 18 inch coaxial cable from the Calibrator output to the Charge Amplifier Calibrator.

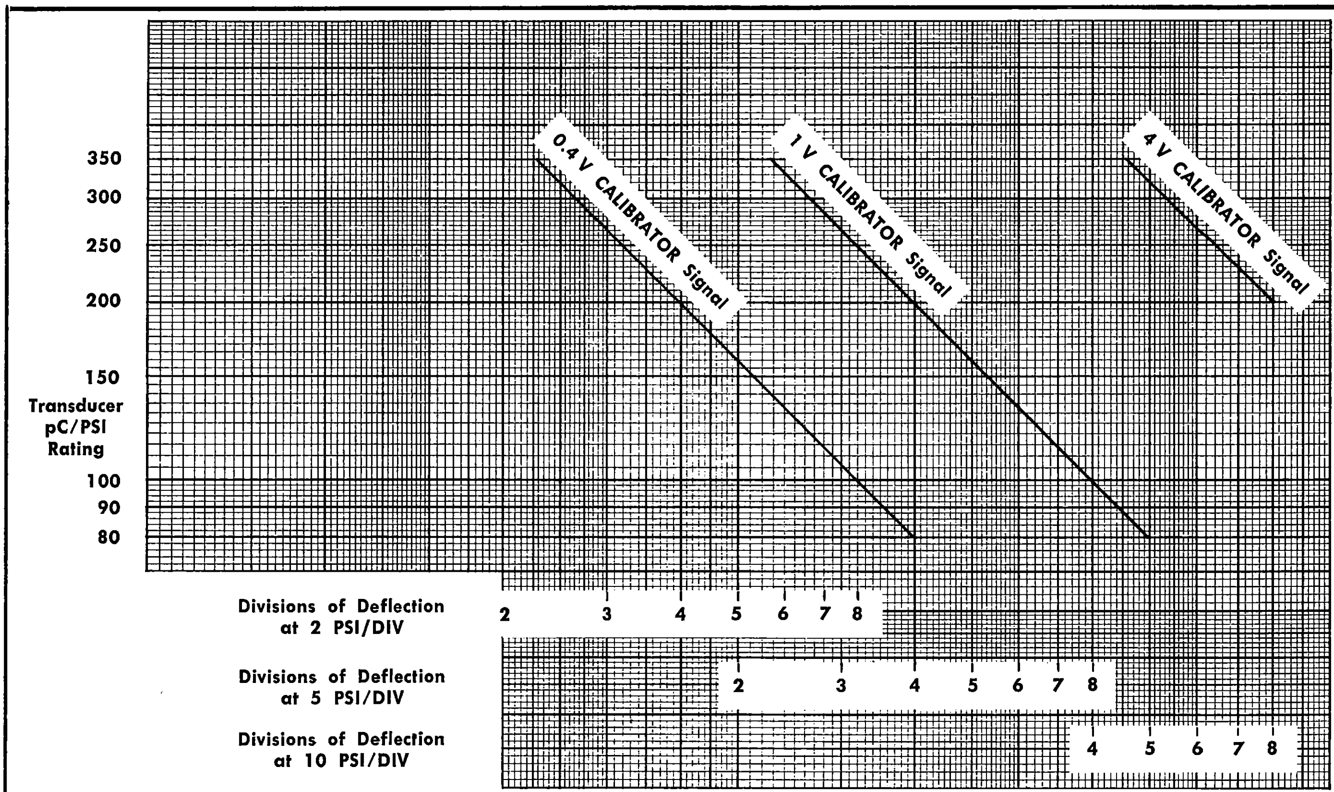
5. Adjust the Channel 1 GAIN control to obtain the calibrated vertical deflection indicated in Table 2-2.

6. Disconnect the patch cord from the Charge Amplifier Calibrator, remove the Charge Amplifier Calibrator from the Channel 1 Input Connector, and switch the Channel 1 MODE control OFF.

2B67 CAL Adjustment

This adjustment affects the speed of the timed horizontal traces. It is partially dependent upon the sensitivity of the horizontal deflection plates of individual oscilloscopes and should be performed whenever the 2B67 is used with an oscilloscope other than the one with which it was calibrated.

This adjustment can be performed by using the relatively accurate frequency of the Oscilloscope Calibrator. If greater



Instructions: Enter with the Transducer pC/PSI Rating. Intercept the Calibrator Signal line applicable to the Oscilloscope. Move straight down to the bottom and read the Divisions of Deflection and the PSI/DIV value.

Fig. 2-10. Gain calibration chart for calibrating the 3A74 Channel 1 Charge Amplifier, using the 4000 pF Charge Amplifier Calibrator.

accuracy is required, the adjustment listed in the 2B67 Calibration Procedure should be used in place of the following.

1. Set the equipment up according to the Operator's Adjustment Procedure Initial Setup.

2. Check that the trace is parallel to the graticule horizontal lines. If not, adjust the Oscilloscope (TRACE) ALIGNMENT as necessary to set the trace parallel to the graticule horizontal lines.

3. If the Oscilloscope has a line-frequency Calibrator, set the 2B67 TIME/DIV control to the setting which corresponds to the available line frequency (column 3, Table 2-3). If the local line frequency is other than one of the values given in Table 2-3, data concerning it should be computed and entered in one of the available line spaces. If the Oscilloscope has a 1 kHz Calibrator, check that the 2B67 TIME/DIV control is set to .2 ms.

4. Connect a patch cord from the Oscilloscope Calibrator output jack to the 3A74 Channel 2 Input connector.

5. Set the CALIBRATOR control as follows: 50 mV for line-frequency calibrators; 40 mV for 1 kHz calibrators.

6. Place the Channel 2 MODE switch at NORM and the AC-GND-DC control at DC.

TABLE 2-3

2B67 CAL Adjustment

Line Frequency (Hz)	Period (1/f)	TIME/DIV Setting	Horizontal Display
50	20 ms	5 ms	4 divisions per cycle
60	16-2/3 ms	5 ms	3 cycles per 10 divisions
400	2.5 ms	.5 ms	5 divisions per cycle

7. Check that the 2B67 (TIME/DIV) VARIABLE control is at its CAL position (UNCAL lamp out) and then measure the number of divisions per cycle. Adjust the 3A74 and 2B67 POSITION controls as necessary for convenient measurement, as in Fig. 2-11. Five divisions per cycle should exist if the Oscilloscope has a 1 kHz Calibrator. The number of divisions per cycle for a line-frequency Calibrator can be found in Table 2-3.

8. Adjust the 2B67 CAL potentiometer (accessible through front panel) as necessary to obtain the specified number of divisions per cycle.

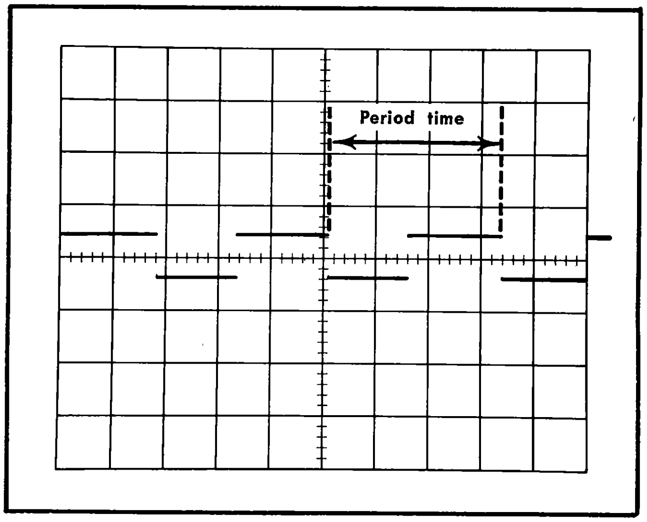


Fig. 2-11. 2B67 CAL adjustment waveform.

2B67 (TRIGGERING) STABILITY Adjustment

1. Set up the equipment according to the Operator's Adjustment Procedure Initial Setup.

2. Set the TIME/DIV switch to .1 ms, and check that the (TRIGGERING) LEVEL control is at AUTO.

3. Set the STABILITY control fully clockwise and then adjust the INTENSITY control to obtain a moderately bright trace.

4. Adjust the STABILITY control counterclockwise, noting that the trace first dims, and then disappears as the control is rotated.

5. Set the STABILITY control to the position midway between where the trace dims and where it disappears.

This concludes the Operator's Adjustment Procedure.

Rotational Function Generator 0/360° Marker Alignment

Each time the Rotational Function Generator is connected to a crankshaft, it will be necessary to align the 0/360° Marker (center marker on tall marker pedestal) with the piston top-dead-center mark which is received through the Magnetic Transducer. To perform the adjustment, loosen the Alignment Lock Screw on the Rotational Function Generator. Then rotate the body of the Rotational Function Generator until the piston top-dead-center mark and the 0/360° marker are aligned. Then re-tighten the Alignment Lock Screw. A waveform showing this alignment appears later in this section.

Rotational Function Generator Angular Reference Dial Alignment

After the Rotational Function Generator 0/360° marker has been aligned to the piston top-dead-center mark, loosen the Dial Clamping Nut on the front of the Rotational Function Generator. Rotate the dial until 0° (or the desired angular value) appears opposite the scribe mark. Then re-tighten the Dial Clamping Nut.

INSTALLING THE STANDARD ACCESSORIES

General. After the equipment has been initially set up to accept the Engine Analyzer System components, they can be safely installed or removed from equipment without interrupting operation. However, due regard must be given to the danger associated with working in the immediate vicinity of machinery while it is operating.

Rotational Function Generator Installation

Connect the Rotational Function Generator (hereafter called Function Generator) to the crankshaft or other 1:1 drive take-off point, using an appropriate coupling method. Several suggested methods are listed here, and are illustrated in Fig. 2-12.

WARNING

Avoid touching rotating components. Loose clothing (such as ties) can become entangled in the machinery and cause injury to the wearer.

Direct Take-off Using Friction Drive. The take-off point must have a V-shaped depression on the shaft rotational axis. Connect the Friction Drive Adapter to the Function Generator drive shaft. Use extension shafts and additional coupling sleeves as necessary. Mount the Function Generator immediately in front of or behind the drive shaft, inserting the Friction Drive Adapter into the V-shaped depression in the drive shaft. A thrust pressure not exceeding 10 pounds should be applied for adequate drive coupling. This pressure can be applied through use of a spring or a dead-weight arranged to hold the function Generator shaft against the drive shaft.

Insure that optimum alignment is obtained to avoid slippage and undue wear. A permanent mounting for the Function Generator may be installed, or a tripod (optional accessory) or other mounting pedestal or stand can be utilized. A special mounting plate for use with a tripod or other mounting stand is provided as a standard accessory.

Direct Take-off Using Positive Drive. The take-off point must have a 3/8 inch diameter shaft or coupling which will permit connecting the Function Generator drive shaft directly to the take-off point. This method is essentially the same as the one just described, except that the friction drive adapter is not used. The Function Generator shaft or extension is rigidly coupled to the take-off point.

Offset Drive Take-off. The drive shaft must provide a 1:1 drive to an offset shaft, using a chain or gear drive arrangement. A pulley drive can also be used, if slippage can be eliminated. Coupling to the offset shaft can be done by either of the previously described methods. Or the driven sprocket, gear, or pulley can be mounted directly on the Function Generator shaft.

After the Function Generator has been mounted, set the ROTATION DIRECTION toggle switch so that it points in the direction that the Function Generator shaft is turning. Con-

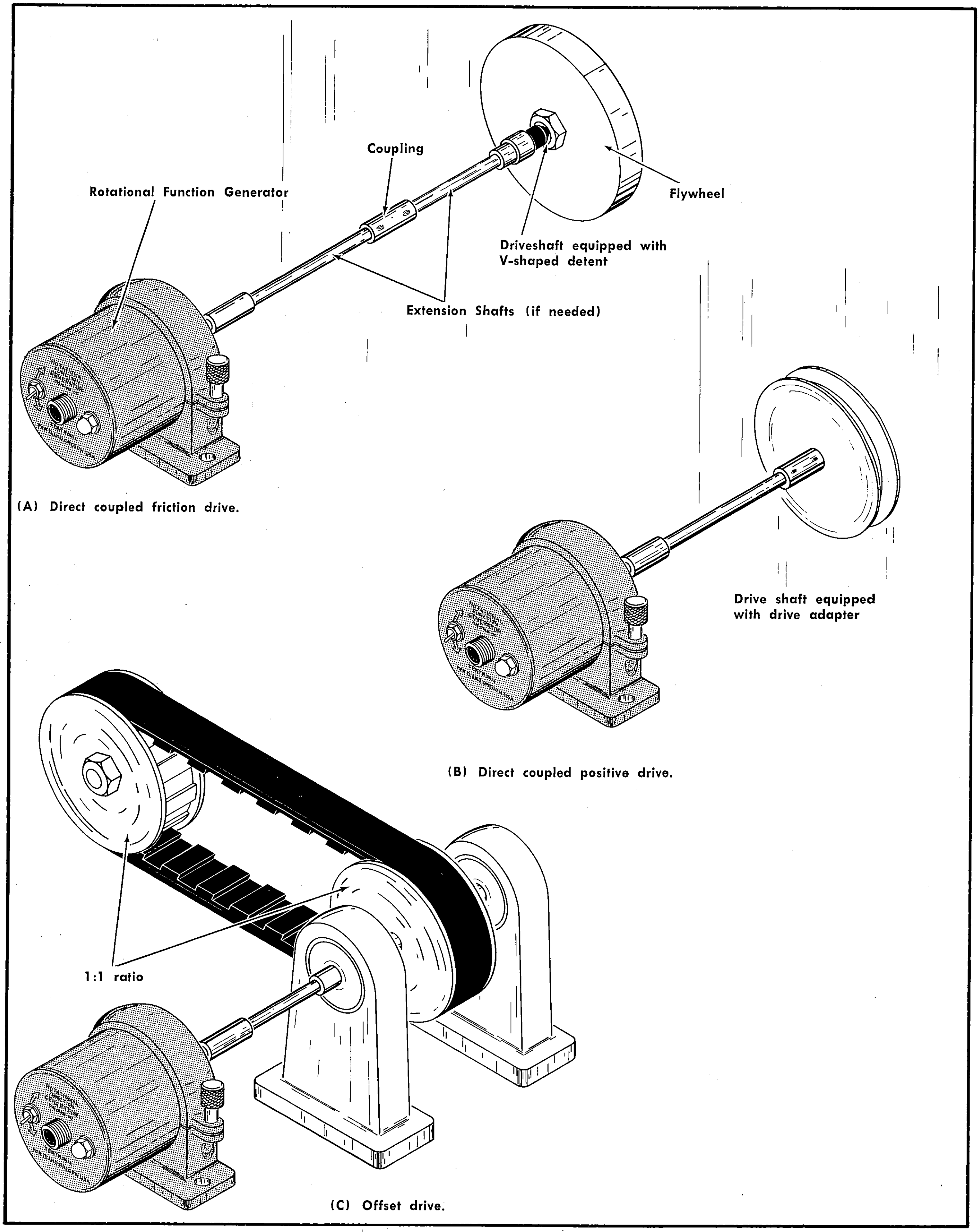


Fig. 2-12. Three methods for driving the Rotational Function Generator.

nect the multiple-conductor cable to the connectors on the Function Generator and the 2B67.

Magnetic Transducer Installation

Install the Magnetic Transducer in the vicinity of the flywheel or some other rotating member. Installation must be done so that a change in mass of a ferrous metal occurs immediately opposite the pick-off end of the transducer as the crankshaft rotates. A suggested method follows:

Build a metal bracket of suitable configuration to mount the Magnetic Transducer immediately adjacent to the surface of the rotating reference point. It can be placed either tangential to the circumference, or at right angles to the plane of rotation, and can be installed permanently in place. See Fig. 2-13. (If it is located at right angles to the plane of rotation, the amplitude of the transducer output signal will vary directly with the distance between it and the center of rotation at any given speed of rotation.) Drill and tap a 3/8 inch—24 UNF threaded hole in the bracket at the point where the transducer is to be installed. Rotate the crankshaft 360°, and note that no obstructions pass the point at which the pickoff is to be installed. Also check for concentricity of the rotating member if the transducer is to be mounted tangentially. Or check for wobble if the transducer is to be mounted at right angles to the plane of rotation. Screw the transducer nut all the way on the transducer. Screw the transducer into the bracket and fasten it in position by locking the transducer nut against the bracket.

CAUTION

Use moderate torque when tightening the nut. 16 inch-pounds of torque should not be exceeded.

Insure that the transducer is sufficiently far from the rotating surface to clear it through the entire 360° of rotation. The reference point on the rotating member should be aligned with the transducer tip and be between 1/16 and 1/8 inch from it.

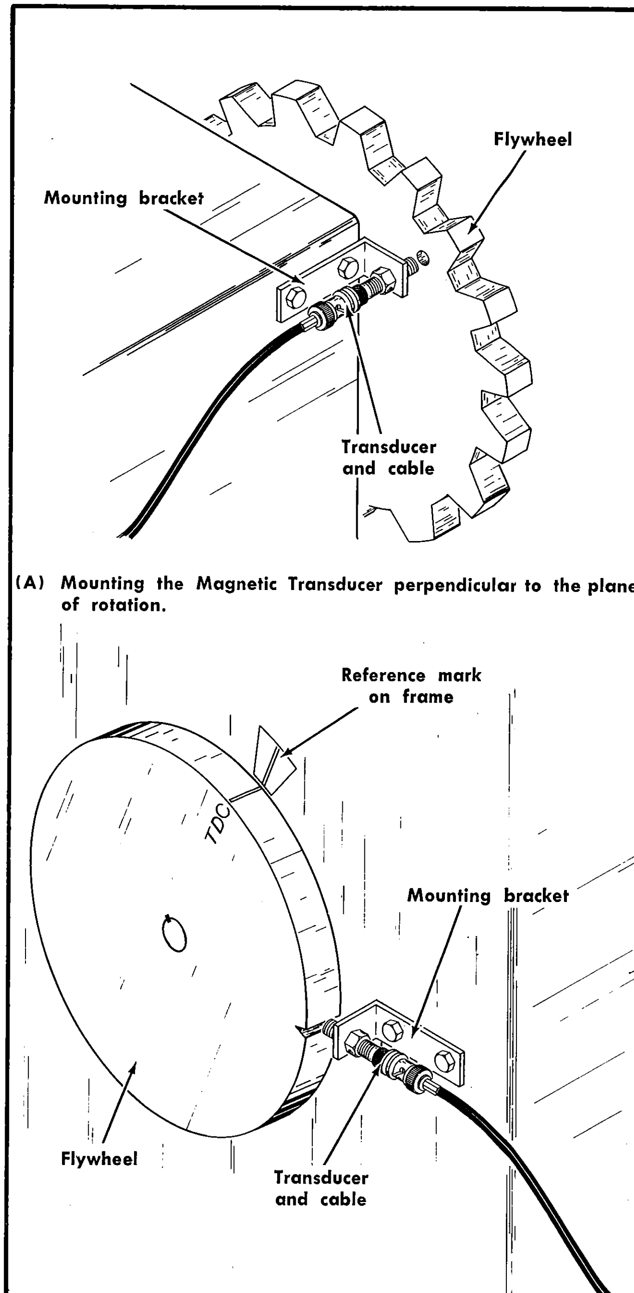
NOTE

A 3/8 inch hole can be drilled and 2 nuts used to hold the transducer in place in the bracket, although the threaded hole method is preferred.

If the transducer can be mounted exactly at the top-dead-center reference point on the frame or mounting, no additional considerations must be given to alignment, providing that the flywheel is made of ferrous metal and is equipped with either an abrupt notch or tang at its top-dead-center reference point. If it is not, other provisions must be made. Some possibilities are:

If the flywheel is made of ferrous metal, file a notch at a point on the perimeter and mount the transducer tangentially. Or drill a hole in either the perimeter or the rotating plane and mount the transducer so that the hole will pass the end of the transducer.

Weld or otherwise securely attach a small rectangular or square piece of 1/8 inch thick ferrous metal so that it will



(A) Mounting the Magnetic Transducer perpendicular to the plane of rotation.

(B) Mounting the Magnetic Transducer tangential to the rotating surface.

Fig. 2-13. Installation of the Magnetic Transducer.

pass the tip of the transducer and be within 1/8 inch of the transducer end.

Drill and tap the rotating surface at the reference point, and insert a ferrous screw or bolt into it.

WARNING

Any attachments to a rotating surface must be fastened securely to avoid being thrown off during operation.

If the transducer is to be installed at any point other than at a top-dead center reference on the frame or mounting, additional alignment consideration must be made. Proceed as follows: Align the rotating top-dead-center reference point with the chassis or frame top dead center reference point. Install the transducer in the desired location. Provide a transducer reference on the rotating surface so that it is aligned with the end of the transducer. The piston top-dead-center mark and reference will then be in alignment at the same time as the transducer and its reference as shown in Fig. 2-13 (B). A signal will be generated each time the piston passes through the top-dead-center position. Use caution so that neither the transducer or rotating reference material strike (or are struck by) other protuberances.

One more consideration must be given to the Magnetic Pickoff. If identical reference detents or appendages exist on the flywheel (such as top-dead-center marks for other pistons), they will provide identical marker signals to the Engine Analyzer System. At least one of the references, (preferably the master reference) must be sufficiently different to provide a distinctive signal. The other signals can then be related to their respective pistons through knowledge of their operating sequence. A reference detent or appendage can be modified slightly to make it distinctive. See Fig. 2-14 for waveforms resulting from various reference marks.

Connect the 20 foot coaxial cable between the Magnetic Transducer and the Channel 2 Input connector of the 3A74. (Any of the 50-foot BNC-BNC cables can be used if 20 feet is not long enough.)

Pressure Transducer Installation

Install the Pressure Transducer in the cylinder to be monitored and connect an air line to the transducer's cooling adapter. The air line should have an inner diameter of at least $1/4$ inch, and should be connected to a compressed air supply of 30 PSI (minimum) whenever the engine is operating.

The pressure transducer supplied as a standard accessory is connected to a cooling adapter (standard accessory). The cooling adapter is designed to fit a cylinder pressure-output port which has a standard Bacharach pressure fitting. Other adapters can be manufactured or purchased to match the transducer to different sized apertures. In addition, various types of pressure transducers are available to suit specific needs. For example, spark plugs with built-in pressure transducers are commercially available. See the Tektronix Field Representative for assistance in specific problems.

Once the Pressure Transducer is installed, connect a 50 foot BNC-BNC cable between the transducer and the PRESSURE TRANSDUCER (Channel 1) Input of the 3A74. Turn the air supply on.

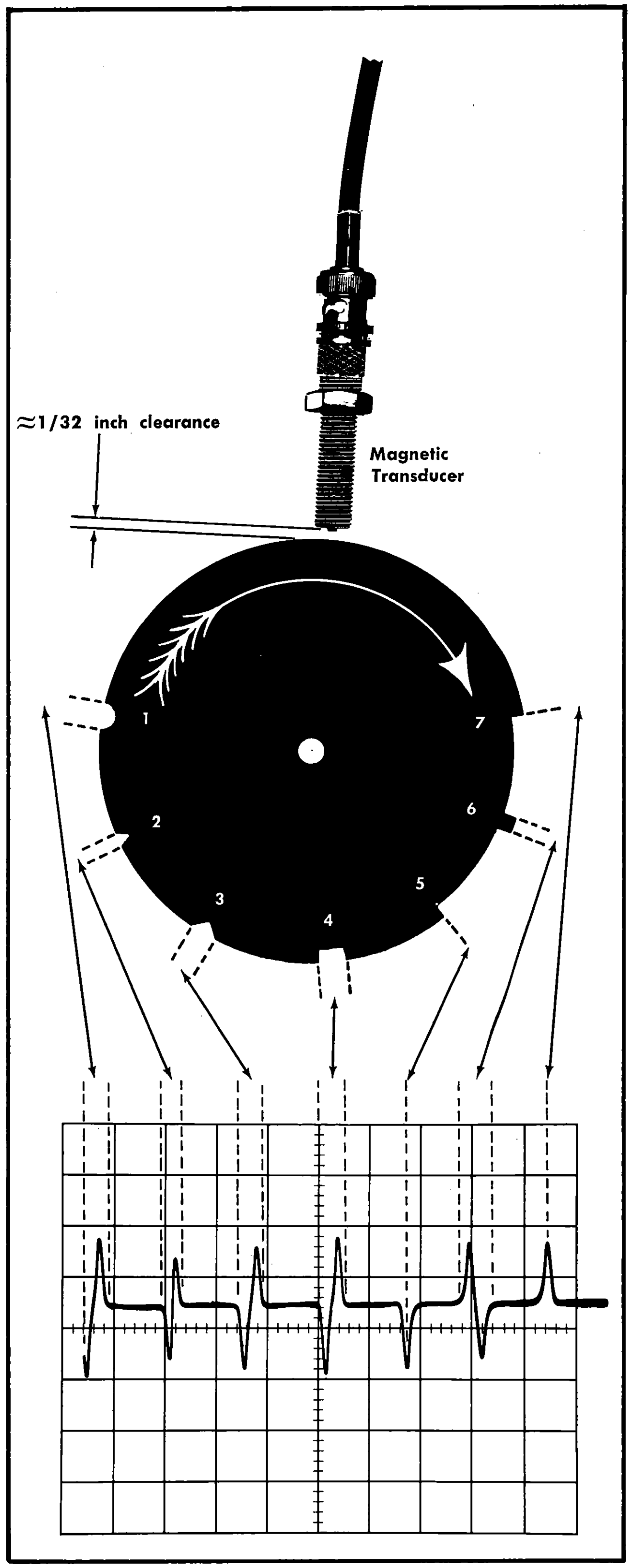


Fig. 2-14. Magnetic transducer signal reaction, using a sample rotor. Rotor is mild steel, $1/4$ inch thick, 4 inches in diameter, traveling at approximately 350 RPM. Metal recessed $1/8$ inch in each instance. Note that decrease of distance between rotor and metal causes opposite reaction to that of increase of distance (5 and 7), and that the width of recess determines width of signal (2 and 3).

Vibration Transducer Installation

Connect a BNC-BNC coaxial cable to the Vibration Transducer. Attach the Vibration Transducer to the selected vibration pick-off point by placing it against a flat and clean ferrous metal surface. Its built-in permanent magnet is adequate to hold it in place in most instances. When properly located, the Transducer should not rock if pushed in any direction.

CAUTION

Although the Vibration Transducer will hold itself in place in most situations, the possibility of its vibrating away from its installed position always exists. The cable (or an additional safety line) should be attached to an adjacent fixture to insure that the transducer cannot vibrate into any working machinery.

Connect the Vibration Transducer cable to the Channel 4 input connector at the 3A74. If the engine or compressor was stopped while the equipment was being connected, recheck all equipment and cables for safe positioning before starting the prime mover.

ENGINE ANALYZER SYSTEM OPERATING PROCEDURE

It is assumed that the operator has made himself aware of the operating procedure and the Standard Accessories information which appears in the preceding part of this section.

Initial Setup

Connect the Engine Analyzer System Standard Accessories to the engine or compressor as previously explained. Place the Oscilloscope assembly near the Rotational Function Generator. (This will enable the Oscilloscope operator to adjust the Function Generator rather than have a second person do it.) Connect the cables between the accessories and the Oscilloscope assembly as follows:

Pressure Transducer	3A74 Channel 1
Magnetic Transducer (TDC sensor)	3A74 Channel 2
Ignition Pickup (Engine only)	3A74 Channel 3
Vibration Transducer	3A74 Channel 4
Rotational Function Generator	2B67 INPUT

Set the Oscilloscope and Plug-in controls as follows:

3A74	
Channel 1	
PSI/DIV	500
RESTORE TIME (Settings not critical unless accurate pressure measurements are required)	LONG for less than 600 RPM. SHORT OR LONG for more than 600 RPM.
MODE	OFF
POSITION	Midrange
Channel 2, 3, 4	
AC-GND-DC	GND
VOLTS/DIV	10
VAR GAIN	CAL
MODE	OFF
POSITION	Midrange
TRIGGER	OUT
CHOP-ALT	CHOP
2B67	
POSITION	Midrange
MODE	NORM
TIME/DIV	ROTATIONAL FUNCTION GENERATOR
VARIABLE	CAL
5X MAG	In
TRIGGERING	
LEVEL	AUTO
SLOPE	—
SOURCE	EXT
ROTATIONAL FUNCTION	
POSITION	Midrange
PISTON-CRANK	CRANK
WIDTH	CCW
MARKERS	Pushed In
SINGLE SWP DISPLAY	720°

Turn the Oscilloscope on and wait about 5 minutes for it to warm up. Then adjust the INTENSITY and FOCUS controls for optimum presentation of the 2 division (approximate) horizontal trace. See Fig. 2-15(A).

If the engine or compressor was stopped during hook-up, check that all cables and equipment are clear of the engine or compressor moving parts, and check that the outer end of the ROTATIONAL DIRECTION toggle switch (rear of Function Generator) is pointing in the direction that the Function Generator shaft will be turning. Then start the engine or compressor. Note that the 2 division trace is replaced by a trace between 2 and 5 divisions long. See Fig. 2-15(B).

ROTATIONAL FUNCTION GENERATOR Mode of Operation

Turn the 3A74 Channel 2 MODE switch to NORM, and adjust the Channel 2 POSITION control as necessary to center the trace in the second division below graticule center.

Pull the 2B67 WIDTH control out, closing the MARKERS switch. Note that markers from the Rotational Function Generator appear on the trace. Rotate the 3A74 Channel 2 VAR GAIN control as necessary to make the larger marker between ½ and 1 division high. See Fig. 2-15(C).

Adjust the 2B67 WIDTH CONTROL and notice that the display can be expanded in both directions from center. Set the control for a 10 division horizontal display.

Switch the Channel 2 AC-GND-DC control to DC. Reduce the Channel 2 VOLTS/DIV setting until the TDC marker from the Magnetic Transducer is clearly visible.

At the Rotational Function Generator, loosen the Alignment Lock screw. Rotate the body of the Function Generator until the TDC marker is superimposed on the center of the large marker signal. See Fig. 2-15 (D). Then tighten the Alignment Lock Screw.

At the Function Generator, loosen the Dial Clamping Nut and rotate the Angular Reference Dial until its 0 mark is aligned with the scribe mark on the Function Generator frame.

Switch the 3A74 Channel 1 MODE switch to NORM, and note that the pressure waveform appears. Adjust the PSI/DIV and the POSITION controls as necessary to obtain approximately 3 divisions of display amplitude, located in the upper half of the viewing area. See Fig. 2-15 (E).

Switch the 3A74 Channel 3 AC-GND-DC control to DC and the MODE switch to NORM. Set the VOLTS/DIV and POSITION controls so that approximately 1 division of ignition signal appears below the channel 2 trace.

Switch the 3A74 Channel 4 AC-GND-DC control to DC and the MODE switch to NORM. Set the VOLTS/DIV and POSITION controls so that approximately 1 division of vibration signal appears below the Channel 3 trace. See Fig. 2-15 (F).

The four-trace display which has just been established is a linear horizontal representation of phenomena occurring during crankshaft rotation. It can be used for analysis as it appears. Or the trace sequence can be rearranged, traces removed, vertical and/or horizontal amplitudes increased or decreased as required by the evaluation being performed.

Single Sweep Operation

During 2B67 NORM operation, each successive revolution of the compressor or engine superimposes a trace on the existing display. Any deviation of signal input causes a lack of exact superimposition. The primary purpose of the single sweep feature is to provide a sharp single display of the selected signal(s) to permit photographing one evolution of engine or compressor operation.

Switch the 2B67 MODE switch to SINGLE SWP. Set the (TRIGGERING) LEVEL control near 0. Hold the MODE switch at RESET and note that the READY lamp goes on. Permit the MODE switch to return to SINGLE SWP and note that a trace appears momentarily, and that the READY lamp goes out. If the READY lamp remains on, slightly readjust the LEVEL control until triggering occurs. The trace has a duration equal to the time required to complete two engine revolutions when the (ROTATIONAL FUNCTION) SINGLE SWP DISPLAY switch is at 720°. This permits display of a complete evolution of 4-cycle engine operation.

When the (ROTATIONAL FUNCTION) SINGLE SWP DISPLAY switch is at 360°, it permits display of functions occurring during only one revolution, since this is all that is required to observe one complete evolution of compressor or 2-cycle engine operation.

Display of Cylinder Pressure Versus Cylinder Volume

Place the 2B67 MODE switch at NORM and the (TRIGGERING) LEVEL control at AUTO. Check that the Channel 2 Magnetic Transducer (TDC sensor) signal is centered on the large marker signal. Then switch the (ROTATIONAL FUNCTION) PISTON-CRANK switch to PISTON.

Note that the maximum upward deflection caused by the Channel 1 pressure signal now occurs near the left of the display. Also note that the top-dead-center marker has moved to the left edge of the display. The sine wave which represents cylinder volume is now deflecting the beam to the left side of the CRT when the piston is at top-dead-center, and to the right side of the CRT when the piston is at the extreme bottom of its travel.

Turn the 3A74 Channel 3 and 4 MODE switches off. Set the Channel 2 display near the bottom of the graticule. Change the Channel 1 PSI/DIV switch to a more sensitive position, providing between 4 and 8 divisions of vertical display amplitude. Keep the display within the graticule limits. This PV display (pressure versus volume) can be used to determine cylinder horsepower as follows:

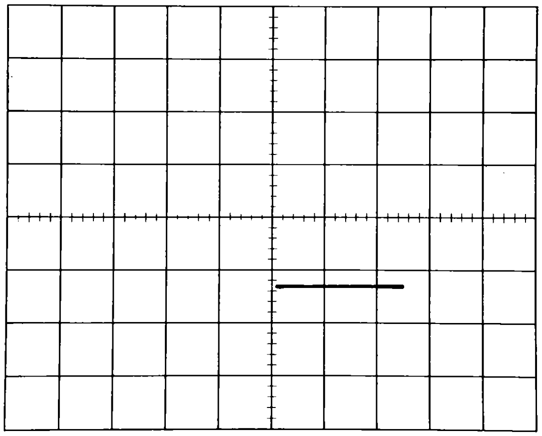
Measuring Cylinder Horsepower. Using the SINGLE SWP operating mode, select 720° for 4-cycle engine operation, or 360° for compressor or 2-cycle engine operation. Obtain a photograph of the PV display. (Or a fairly exact tracing of the display may be made instead.)

1. Measure the number of divisions per inch of the waveform photograph. See Fig. 2-16(A). (If a tracing is being used, this value will automatically be 2.54, since each division is equal to 1 cm.)

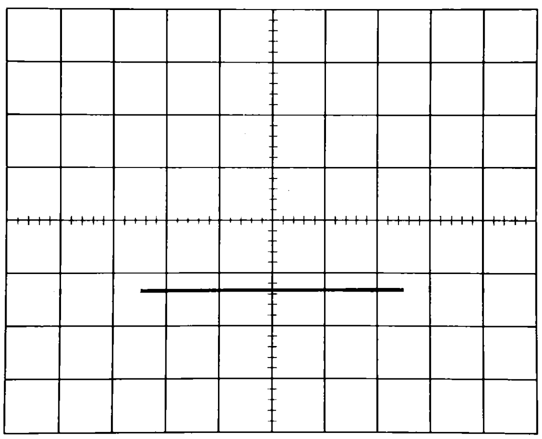
2. Multiply the divisions per inch from Step 1 by the PSI/DIV setting that existed at the time the waveform was observed. The result becomes the PSI/inch value represented by the waveform reproduction.

3. Using a planimeter which reads directly in square inches (such as a Keuffel and Esser Co. No. 62 0000 Compensating Polar Planimeter), measure the area included within the confines of the waveform. Make at least three measurements and determine their average. (A second, but cumbersome, method of determining the area consists of superimposing the waveform on a graph containing small inch-related squares. The area in square inches can then be determined by counting the number of small squares which occur within the limits of the waveform and converting to square inches.)

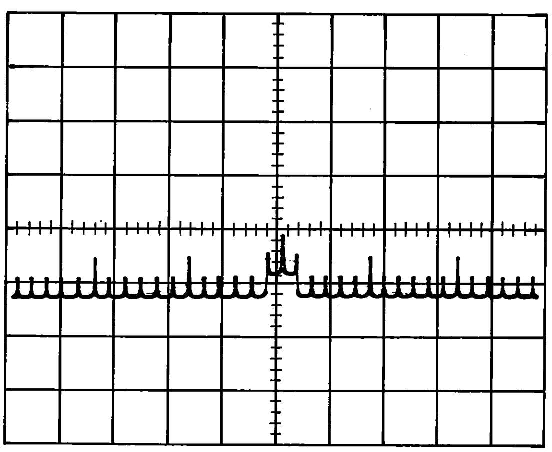
If the PV diagram is of a compressor or a 2-cycle engine, only one confine (and therefore only one value) need be considered. If the diagram is of a 4-cycle engine, the area of two confines must be measured. The area of the lower enclosure must then be substracted from the area of the upper one to determine the area required in this procedure. See Fig. 2-16(B).



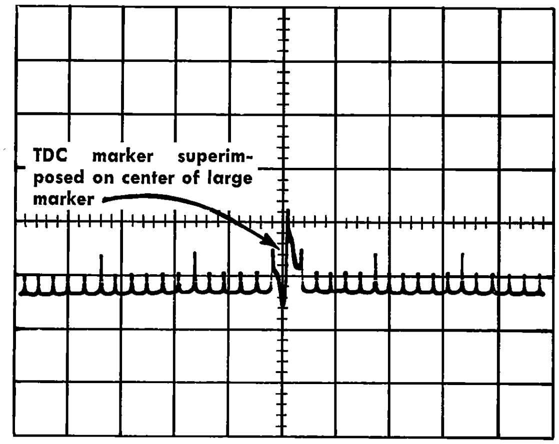
(A) Standby trace; Rotational Function Generator connected to 2B67, but not rotating.



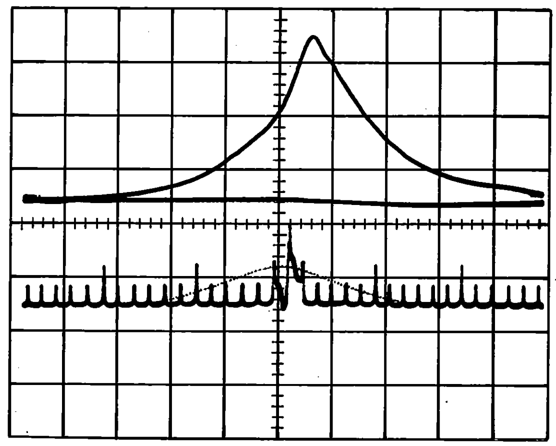
(B) Rotational Function Generator trace.



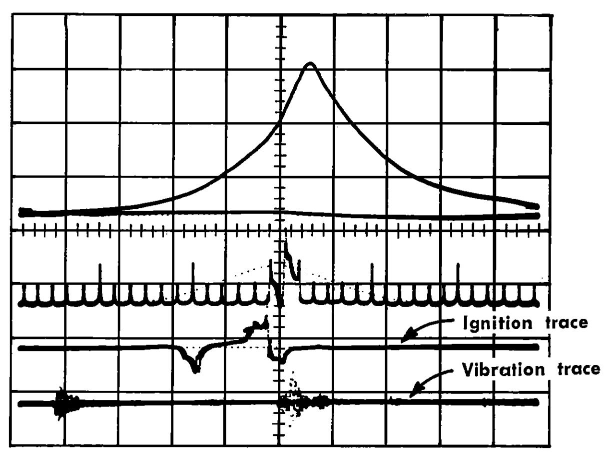
(C) 10° markers displayed on 10 division Rotational Function Generator CRANK base line.



(D) TDC signal superimposed on the 0/360° pedestal.

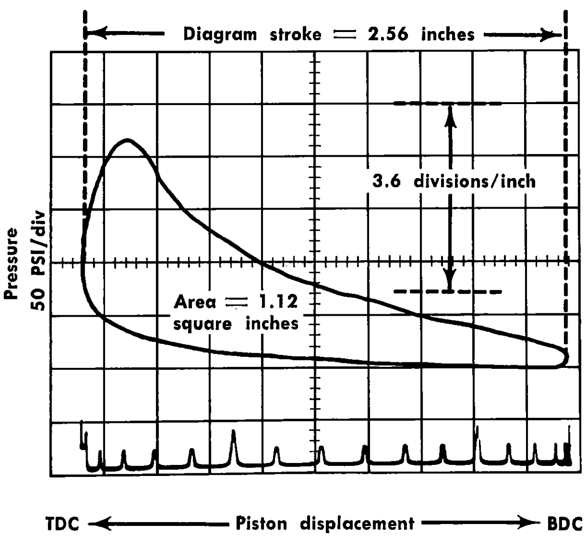


(E) Pressure waveform and markers being displayed.



(F) Ignition and vibration signals added to (E).

Fig. 2-15. Creating a four trace display.



3.6 div/inch × 50 PSI/div = 180 PSI/inch

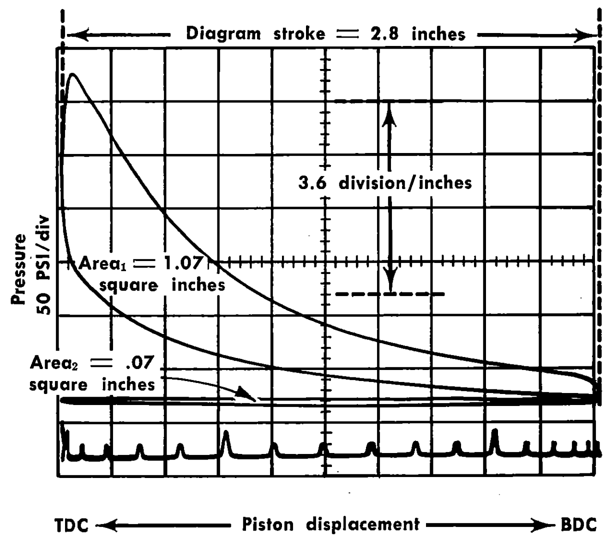
180 PSI/inch ÷ 2.56" diagram stroke = 70.3 PSI/inch²

70.3 PSI/inch² × 1.12 inch² area = 78.7 PSI MEP

IHP = PLAN/33,000

IHP = 78.7 × 1 × 78.5 × 600 ÷ 33,000 = 112.3 HP

(A) Example 1. PV diagram of a 2-cycle engine operating at 600 RPM, with accompanying horsepower calculation; piston stroke = 1 foot; cylinder cross sectional area = 78.5 sq. in.



3.6 div/inch × 50 PSI/div = 180 PSI/inch

180 PSI/inch ÷ 2.8 inches diagram stroke = 64.3 PSI/inch²

1.07 inch² ($Area_1$) — .07 inch² ($Area_2$) = 1.0 inch²

64.3 PSI/inch² × 1.0 inch² ($Area_1$ — $Area_2$) = 64.3 PSI MEP

IHP = PLAN/33,000

IHP = 64.3 × 1 × 78.5 × 600/2 ÷ 33,000 = 45.9 HP

(B) Example 2. PV diagram of a 4-cycle engine operating at 600 RPM, with accompanying horsepower calculation; piston stroke = 1 foot; cylinder cross-section area = 78.5 sq. in.

Fig. 2-16. PV diagrams and horsepower calculations. Waveform pictures are 7/10 actual graticule size. Additional Explanation is contained in the text.

4. Measure (in inches) the horizontal stroke of the PV diagram. See Fig. 2-16(A) and (B).

5. Divide the PSI/inch value (from step 2) by the stroke of the diagram (from step 4) to obtain the PSI/inch² value.

6. Multiply PSI/inch² from step 5 by the area of the diagram (from step 3). This provides the Mean Effective Pressure (MEP) in pounds per square inch that is being delivered by the cylinder.

7. Convert the Mean Effective Pressure to indicated horsepower (IHP) by completing the following equation:

IHP = PLAN/33,000

where IHP is indicated cylinder horsepower

P is Mean Effective Pressure in PSI (from step 6)

L is Physical Length of the piston stroke in feet

A is Cross-sectional area of the cylinder in square inches

N relates to speed of rotation existing at the time the waveform was taken. It is equal to RPM ÷ 2 in 4-cycle engines. In compressors or 2-cycle engines it is equal to RPM.

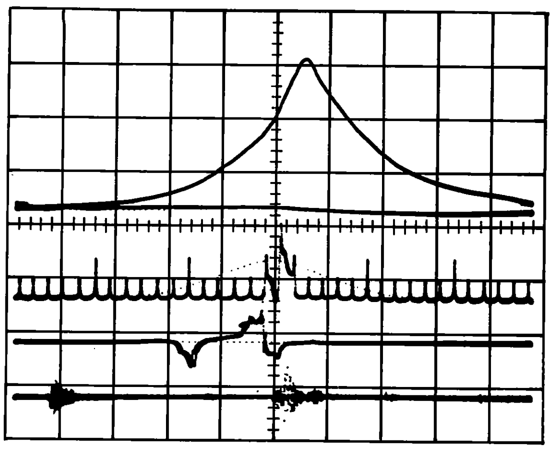
The total indicated horsepower of an engine or total indicated power being used by a compressor can be determined by adding together the indicated horsepower of all the cylinders involved.

The mechanical efficiency of devices can be determined by comparing indicated horsepower to output or delivered horsepower (BHP).

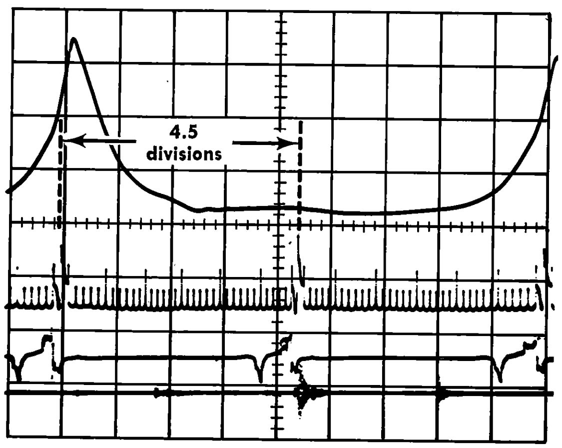
Mechanical Efficiency = BHP ÷ IHP

For example, assume that a gasoline engine is driving a compressor. After determining the Indicated Horsepower of each device, the engine indicated horsepower can be divided into the compressor indicated horsepower to determine the combined mechanical efficiency of the engine and driven components.

One additional note regarding horsepower calculations. Any measurement unit (such as metric) can be used throughout the procedure. However, the 33,000 constant must be modified accordingly.

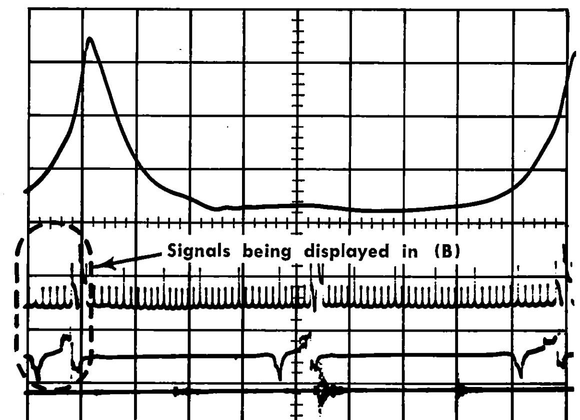


(A) Engine function signals (vertical) versus crankshaft angular position (horizontal). Same as Fig. 2-15 (F).

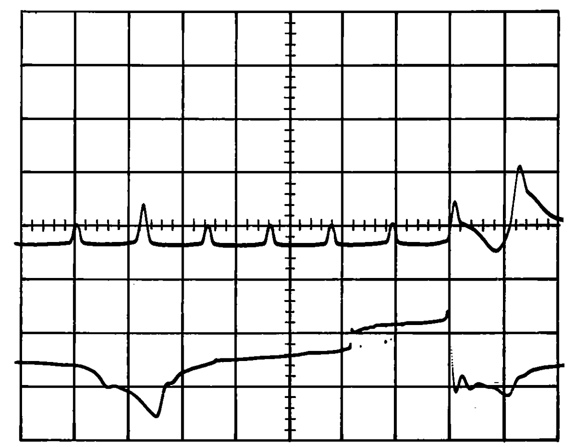


(B) Same engine function signals (vertical) versus 10 ms/division timed horizontal sweep. Period time for 1 revolution equals 45 ms (4.5 divisions x 10 ms/division). Frequency equals approximately 22.2 cycles per second or 1332 RPM.

Fig. 2-17. RPM measurement.



(A) Engine function signals (vertical) versus 10 ms/division horizontal baseline. Same as Fig. 2-17 (B).



(B) 2B67 TIME/DIV changed to 1 ms/division to horizontally expand area of interest on channel 3 trace (spark signal). Channels 1 and 4 traces have been removed; channel 3 sensitivity has been increased to aid in signal evaluation.

Fig. 2-18. Magnifying a signal horizontally by increasing the sweep rate. Display was externally triggered by + slope of CRANK signal from Rotational Function Generator.

Operation Employing Timed Horizontal Deflection

In the preceding operation, the horizontal deflection signal was generated by the Rotational Function Generator, and was therefore a function of engine or compressor rotation. When the TIME/DIV control is not at the ROTATIONAL FUNCTION GENERATOR position, a timed sweep which is generated within the 2B67 controls the horizontal deflection. This mode of operation permits timed measurement of any functions whose signals are applied to the vertical input connectors.

It is recommended that AUTO (TRIGGERING) not be employed when the timed sweep is being used for engine analysis. Use the PISTON-CRANK switch to select the EXT triggering signal, and the SLOPE and LEVEL controls to select the triggering point.

Measuring RPM. Measure the time required to complete one revolution. This can be measured by selecting a sweep speed which allows functions to appear during more than one revolution. Then measure the number of divisions between two top-dead-center marks. Multiply this value by the TIME/DIV switch settings (seconds). This obtains the period time (seconds) for one revolution. Find the reciprocal of the time required for one revolution. Multiply the results by 60 to convert to RPM. An example is provided in Fig. 2-17.

Horizontal Magnification of Signals During Timed Horizontal Deflection. Timed sweep operation can also be used to horizontally expand any desired vertical signal by a considerable amount. An example is shown in Fig. 2-18 and explained here. With the TIME/DIV switch at a numbered position, place the signal of interest at the extreme left edge of the trace by combined adjustment of the (TRIGGERING) LEVEL and SLOPE controls. If the SOURCE switch is at EXT and the Rotational Function Generator is in use, the PISTON-CRANK switch can be used to select the signal being applied to the triggering circuit.)

Switch the TIME/DIV control clockwise to a faster sweep rate until the desired expansion has been achieved. If the selected sweep rate is so high that the switching segments show, the 3A74 CHOP-ALT switch can be placed at ALT to provide a continuous trace. (Readjust the INTENSITY control if necessary.) If further expansion of the signal is desired, use the left POSITION control to set the point of interest to the center vertical graticule line. Pull out on the 5× MAG control, and the center two divisions of ×1 display will appear as a 10 division magnified display.

Single Sweep Operation During Timed Horizontal Deflection. This operation is effectively the same as it was during ROTATIONAL FUNCTION GENERATOR operation. The two exceptions are: (1) one timed sweep is presented each time the circuit is reset, regardless of the number (or partial amount) of rotations represented on the sweep; and (2) the SINGLE SWP DISPLAY switch has no effect.

External Horizontal Operation

The electron beam can be deflected horizontally by external signals other than those generated by the Rotational Function Generator. This is described as "external horizontal operation". Operation in this mode is essentially the same as ROTATIONAL FUNCTION GENERATOR operation, except that neither the Function Generator nor its cable are attached to the 2B67 INPUT connector. The external signal which is to provide deflection should be injected directly into terminal A or B, depending upon the position of the PISTON-CRANK switch. Whenever the TIME/DIV switch is in ROTATIONAL FUNCTION GENERATOR position, the horizontal deflection of the beam is in response to the signal thus applied. The position and amount of horizontal display is then controlled by the 2B67 ROTATION FUNCTION controls. The maximum signal applied directly to terminal A or B should be limited to ± 10 V (DC + peak AC).

CAUTION

Do not permit a focused spot to remain stationary on the CRT for more than a few seconds. Phosphor damage may otherwise occur. Either defocus the spot or turn the INTENSITY to minimum when the 2B67 is in ROTATIONAL FUNCTION GENERATOR position and no horizontal signal is applied.

SECTION 3
CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of the manual.

General. This section contains detailed circuit descriptions of the major units which make up the Engine Analyzer System. The oscilloscope indicator description is not included, since it is adequately explained in its respective manual. The accessories are explained in the Operating Instructions section.

The explanations contained here are referenced to the block diagrams and schematics contained near the rear of this manual. Numbers which are contained in diamond-shaped outlines appear in conjunction with the schematic names. These numbers are used extensively on the schematics for cross-referencing. Additional diagrams appear with the text as necessary to facilitate explanations.

Refer to Fig. 3-1, which illustrates the basic inter-relation between major units of the Engine Analyzer System. The Oscilloscope (or Indicator Unit) provides power for all of the units concerned. The 3A74 Engine Analyzer Amplifier plug-in unit processes signals which are then applied to the Oscilloscope CRT to provide vertical deflection. The Rotational Function Generator develops signal voltages in response to rotation. These signal voltages are amplified by the 2B67 Engine Analyzer Time Base plug-in unit and applied to the Oscilloscope CRT to provide horizontal deflection. The 2B67 is also capable of generating horizontal deflection signals independent of the Rotational Function Generator. Additional inter-relations between the units are covered in detail in the respective circuit descriptions.

3A74 ENGINE ANALYZER AMPLIFIER

General. The 3A74 Engine Analyzer Amplifier (hereafter called 3A74) is the amplifying unit for signals which provide vertical deflection for the CRT electron beam. The 3A74 permits one, two, three or four separate trace displays. They are presented on a time-sharing basis by automatic switching between traces at a high repetition rate (CHOP), or by automatic switching between traces at the end of each sweep (ALT). The ALT mode is disabled while ROTATIONAL FUNCTION GENERATOR is selected by the TIME/DIV switch. CHOP mode must then be selected.

3A74 Block Diagram Description

Refer to the 3A74 block diagram in the Schematics section of this manual. A signal into the Channel 1 PRESSURE TRANSDUCER Input connector is applied to the Charge Amplifier, where it is amplified by an amount determined by the setting of the PSI/DIV switch. It is then applied to the Channel 1 Switched Amplifier where it is converted to a differential signal and applied to contacts of the Channel 1 MODE switch. With the switch in either NORM or INV position, the signal is applied to the Channel 1 Diode Switches. The signal is cancelled out if the MODE switch is OFF.

The Channel 2, 3, and 4 circuitry is similar to that of Channel 1 except for the following:

The signals into the channels are controlled by AC-GND-DC switches.

Attenuator sections and VOLTS/DIV switches are used in place of the Charge Amplifier and PSI/DIV switch.

The Switched Amplifiers are equipped with VAR GAIN controls to provide the operator with deflection factor capabilities other than those indicated on the VOLTS/DIV switch.

The Channel 1 MODE switch connections are interchanged with respect to Channels 2, 3 and 4 to permit proper deflection polarity.

Channel 2 amplifies markers and applies them to its MODE switch whenever they are being sent from the horizontal plug-in unit to the 3A74, regardless of the position of the Channel 2 AC-GND-DC switch.

When accepted by the MODE switches, the signals being processed by each channel are applied to their respective Diode Switches. A gating pulse from the Gating Diodes circuit enables (turns on) one channel switch at a time, permitting that channel's signal to be applied to the Output Amplifier and thus to the CRT vertical deflection plates. During CHOP operation, a Blocking Oscillator (associated with the Ring Counter circuit) causes rapid switching from one channel to another. A small increment of a channel's trace is presented and then the Ring Counter switches to the next channel. When the Ring Counter returns to a specific channel, it presents another segment alongside that channel's previous segment. The overall effect of a number of such segments in one channel is that they appear as a continuous trace during 4-channel operation at sweep rates of 0.2 ms/division and slower.

Whenever a channel MODE switch is OFF, that channel is ignored by the Ring Counter. The rate at which the remaining diode switches are enabled increases with a decrease in the number of channels whose MODE switches are on. When only one MODE switch is on, that channel's display is presented continuously.

The Sync Pulse and Blanking Pulse Regenerator creates a pulse in response to Blocking Oscillator operation. The Blanking Pulse is applied to the CRT cathode to prevent switching transients from being seen. The Sync Pulse output is not used in the Engine Analyzer System.

During ALT operation, the Blocking Oscillator is prevented from free-running but goes through one cycle of operation each time a signal is received from the Sync Pulse Input Emit-

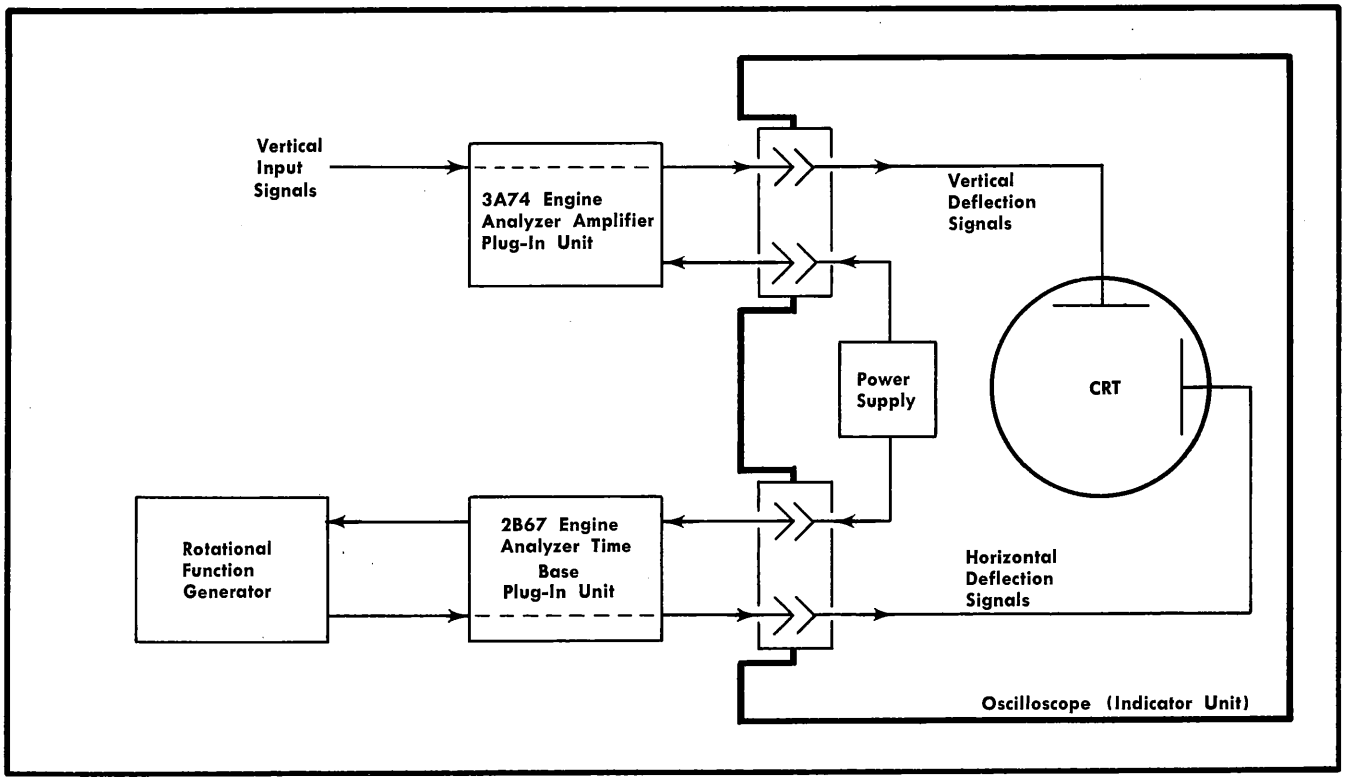


Fig. 3-1. Basic inter-relation of major units of the Engine Analyzer System.

ter Follower. The Ring Counter then advances to the next channel. ALT operation should not be used during 2B67 Rotational Function Generator operation, since the desired signals are not available from the 2B67 in that mode. Either CHOP or ALT (depending on sweep rate) can satisfactorily be used during TIME/DIV sweep operation.

A trigger signal selection circuit is also available in the 3A74. This is of no concern during ROTATIONAL FUNCTION GENERATOR operation, since external triggering is used. However, during TIME/DIV sweep operation it permits the displaying of traces which are either individually triggered (Channel 2 TRIGGER knob "in" during ALT operation) or time-related (TRIGGER knob out during ALT or CHOP operation). When the TRIGGER knob is in, the signal from the Output Amplifier makes all displayed signals available to the 2B67 triggering circuit. When the TRIGGER knob is out, only those signals being processed in Channel 2 are provided to the 2B67 triggering circuitry. (See the 2B67 Trigger Generator and the Sweep and Unblanking Pulse Generator circuit descriptions if additional triggering information is desired.)

Channel 1 Input Amplifier ⟨1⟩

General. The Charge Amplifier contained in Channel 1 is a modified integrating amplifier whose feedback capacitor can be selected in accordance with the desired gain. The higher the PSI/DIV setting, the larger the feedback capacitor. In a true integrating amplifier, when an input signal causes the amplifier to change its output, the output will theoretically remain at that value until another input signal is received. In this integrating amplifier, the feedback capacitor is shunted with a large resistor to permit the amplifier to return to a preset output condition after a given time (restore time) has elapsed. A RESTORE TIME switch permits selection of a LONG (3 second) or a SHORT (0.3 second) RC time constant.

Charge Amplifier Operation. Refer to the Charge Amplifier circuitry. The transducer which supplies the signal to the amplifier is rated in pC/PSI (pico coulombs/pounds per square inch). Assume that the transducer in use delivers 100 pC/PSI, and one PSI is applied to the transducer. Electrons flow through the PRESSURE TRANSDUCER Input and collect on C246, impressing a voltage on it. The amount of voltage follows the formula $E = Q/C$, where E is the voltage,Q is the charge in coulombs, and C is the capacitance infarads.

With 1 PSI/DIV selected, the voltage developed across C246 is equal to 100 pC divided by .004 μF, which is 25 mV. As the left plate of C246 attempts to go negative, a signal is felt at the gate of Q204. This causes the inverting amplifier to generate a positive voltage which is applied to the right plate of C246. The open loop gain of the amplifier is approximately 2000. The output, therefore, goes positive 25 mV by the time the input reaches —12.5 μV. C246 becomes charged to 25 mV with no appreciable change in the voltage at the gate of Q204. This reaction to input current is instantaneous, permitting the output to follow the continuously changing input signal.

The gain of the integrating amplifier is designed to produce a greater signal than that required by each PSI/DIV setting. The amount of signal needed for calibrated PSI/DIV operation is then selected by adjusting the front panel GAIN control, R270.

When a higher PSI/DIV setting is selected, a larger feedback capacitor is inserted. This results in a smaller voltage being developed across the feedback capacitor for a given amount of electron flow input. The amplifier output is reduced accordingly. Selecting the 100 PSI/DIV position inserts a 0.4 μF capacitor (C248) into the feedback path. When subjected to 100 pC of electrons resulting from 1 PSI change at the transducer, it charges to 0.25 mV (100 pC divided by 0.4 μF). The amplifier open-loop gain of 2000 now requires only 0.125 μV at the gate of Q204 to produce the 0.25 mV output to charge C248.

Charge Amplifier Circuit Description. Q204 is a metal-oxide semiconductor field effect transistor (MOSFET) whose operation can be compared to that of a PNP transistor, except that no significant signal current flows through the gate junction. Therefore, the only signal current that flows is that which charges the feedback capacitor. D202 is a dual diode which protects Q204 against overdrive signals, and both diodes are slightly back-basied by voltage dividers to insure against any signal current flowing through them during normal conditions.

Q204-Q214 form a comparator circuit which permits adjusting the amplifier output voltage. When R215 and R216 are properly adjusted, the output voltage is equal to 0 when no input signal is present. Since no DC current path exists in the input cicuit, this 0 V potential also exists at the gate of Q204.

When electrons flow into the amplifier from the transducer, the left side of the feedback capacitor attempts to go negative. This negative signal at the Q204 gate increases the source-drain current. As the current though R213 attempts to increase, the Q214 source voltage goes slightly negative. This causes a decrease in Q214 conduction, effectively decreasing the current through it by an amount equal to the increase through Q204.

As the current through Q214 decreases, the voltage across R219 decreases, causing a negative signal at the base and emitter of Q223. The negative signal at the emitter of Q223 is applied to Q224 where it decreases Q224 collector current. The resulting positive signal at the Q224 collector is felt through the base-emitter junctions of Q233 and Q243, and through those of Q253 and Q263 to determine the output voltage of the integrating amplifier.

The output voltage is applied across voltage divider R270 and R271, where a sufficient amount is selected by the R270 wiper to provide calibrated deflection values in the 1, 10 and 100 PSI/DIV switch positions. These values are further reduced in other positions of the PSI/DIV switch by the R273-R274-R275 voltage divider. R265, C265, L265 and C266 form a filter circuit designed to dampen high frequency oscillations (from the transducer crystal).

The ZERO switch (which is spring-loaded in the open position) enables the operator to short-circuit the integrating amplifier feedback circuit. When the switch is depressed (closed), the trace immediately returns to its reference position. The feedback capacitor discharges at the same time, permitting the amplifier to respond to the signal existing at the time the ZERO switch is opened, without having to overcome a previous charge.

Channel 1 Switched Amplifier Operation. This amplifier consists of Input Cathode Follower V423, Paraphase Amplifier Q424-Q434, MODE switch SW430, Diode Switches D440 through D443, INT DC BAL Cathode Follower V433, and associated components. Input signals pass through the Input Cathode Follower, creating push-pull signal current outputs from the Q424-Q434 Paraphase Amplifier. The signals are applied to contacts of the MODE switch. With the switch in either NORM or INV position, the signal currents are passed to the output amplifier whenever the channel Diode Switches are gated on.

Channel 1 Switched Amplifier Circuit Description. The voltage present at the grid of V423 determines the base voltages of Q424. V433 establishes the base voltage of Q434, with C428 providing an AC ground reference. With 0 V at the grid of V423 and the INT DC BAL control properly set, the current through Q424 is equal to that through Q434 and equal voltages appear on both sides of the R436-R437 combination . No trace shift then accompanies rotation of GAIN RANGE (R436) because no current is flowing through it; no trace shift occurs when the MODE switch is changed from NORM to INV because the currents through the two paths of the MODE switch are equal.

The emitter of Q434 is held at a given voltage by its base-biasing components. A relatively fixed current (approximately 2.5 mA) flows through R435 regardless of signal input conditions. When a signal is present at the grid of V423, the base and emitter of Q424 follow the signal voltage. The emitter of Q434 is held at a constant value by the voltage at its base. This unbalance of voltage between the emitters of Q424 and Q434 causes signal current to flow through R424 where it adds to or subtracts from the R425 current which flows through Q424. If the input signal is positive, the increase of electrons flowing up through R424 is obtained from R435. The electron flow through Q434 must then decrease because of the constant-current characteristics of R435. This push-pull signal current from the two transistors is felt in the output circuitry when the Channel 1 switching diodes (D440 and D443) are enabled and the MODE switch is at NORM or INV. Signal current (and therefore circuit gain) varies inversely with the amount of R436 resistance inserted into the Q424 circuit.

If the MODE switch is at NORM or INV and D441 and D442 are enabled by the Ring Counter circuit, the current for Q424 and Q434 operation is obtained through these diodes. The push-pull currents then cancel each other at the junctions of D441 and D442. Under this condition, D440 and D443 are gated off by the potential at the anodes of D441 and D422. (A complete explanation of the Diode Switches and the Ring Counter circuit is given in the Channel Switching Circuit explanation.)

If the MODE switch is in the OFF position, the current for Q424 and Q434 is still derived from the Ring Counter circuit through D441 and D442, but the push-pull signal effect is cancelled out by a jumper across the OFF position of the MODE switch.

The output currents can be modified through use of the front-panel POSITION control, which increases one current while it decreases the other. The POSITION control modifies the current on the output side of the MODE switch, and therefore permits the Channel 1 trace to maintain the same reference position with the MODE switch in either NORM or INV position.

Channel 2, 3 and 4 Input Amplifiers ⟨2⟩

General. These amplifiers are essentially the same as the Channel 1 Switched Amplifier just described, with exceptions as follows:

Deflection sensitivity is rated in VOLTS/DIV;

The input signal can be selected or rejected by the AC-GND-DC Input Coupling switch.

Signals are coupled directly to the amplifiers in the .02 VOLTS/DIV switch position, or through attenuators in all other positions of the switch.

The DC BAL and GAIN controls are front-panel screwdriver adjustments rather than internal adjustments, and have names which are different than those in the Channel 1 Switched Amplifier.

A VAR GAIN control is provided to permit selection of deflection factors other than those indicated by the VOLTS/DIV switch. When the knob is at the CAL detent, the potentiometer is shunted and the deflection factor is as indicated by the VOLTS/DIV switch. As the knob is rotated counterclockwise, the deflection factor increases. At the extreme counterclockwise position the deflection factor is at least 2.5 times that indicated by the VOLTS/DIV control.

Additional exceptions exist in the Channel 2 Amplifier circuit. The MARKERS switch in the 2B67 internally connects Rotational Function Generator degree marker signals into the Channel 2 Amplifier. Signals are routed from the Channel 2 circuit to the Int Trig Amplifier circuit to permit selection of CH 2 ONLY triggering.

AC-GND-DC Switch. The AC position couples AC signals to the amplifier through DC blocking capacitor C401. The GND position open-circuits the signal path and grounds the amplifier input, thus providing it with a zero DC reference. The DC position enables both AC and DC signal components to affect trace positioning.

Attenuators. Attenuators are selected either individually or in pairs. When selected in pairs they are series-connected and the attenuator factor in effect is the product of the two. The attenuators are RC voltage dividers, with the resistors doing the division of DC inputs, and the combination of resistors and capacitors dividing the AC signals. R416 and C416 establish the ×1 (.02 VOLTS/DIV) input impedance of the amplifiers. When the attenuators are used, either singly or in pairs, the channel input impedance remains the same as it is when no attenuators are in use (.02 VOLTS/DIV position). A further analysis of the attenuator circuitry is provided in Fig. 3-2.

DC BAL and GAIN Controls. Although these controls are assigned different names and are located on the front panel, their function remains the same as that described for the INT DC BAL and GAIN RANGE controls in Channel 1. GAIN is adjusted to provide calibrated VOLTS/DIV deflection factors when the VAR GAIN control is at CAL position.

VAR GAIN. When this knob is rotated away from its CAL position, R426 inserts resistance into the emitter path of Q424. Since the gain of the amplifier is a function of the load resistance divided by the emitter resistance, gain decreases as the value of R426 increases. When the full resistance of R426 is inserted into the emitter circuit, gain is decreased to 40% or less of CAL gain, increasing the deflection factor at least 2.5 times that indicated by the VOLTS/DIV switch.

Protection Circuits. B419 protects V423 from excessively large negative input signals. B419 conducts to limit V423 Grid voltage to approximately —60 V. Positive signals are limited by the action of D423 and the resulting cathode-to-grid conduction of V423. The circuit is protected from excessive overdrive current by R417. C417 shunts R417 to avoid a decrease in high-frequency response.

D424 protects Q424 from emitter-base reverse breakdown by limiting reverse voltages across the junction to about 0.6 V.

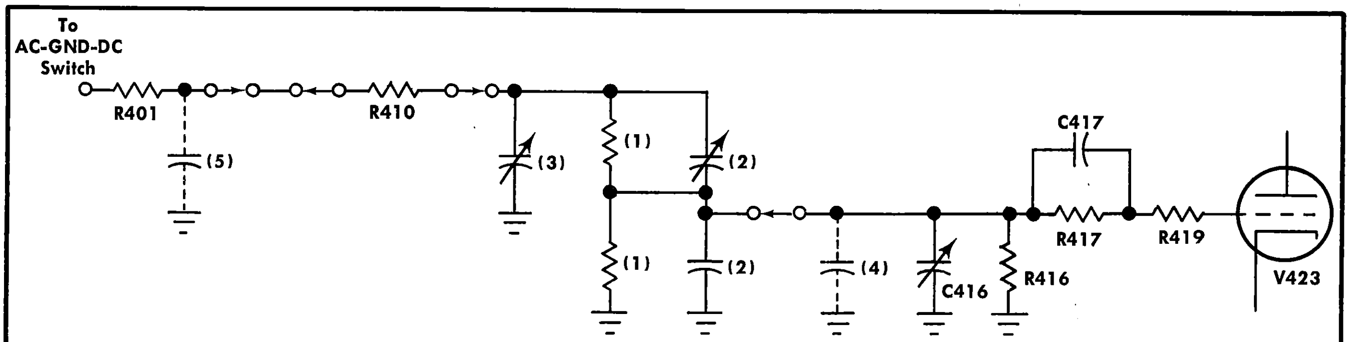
Channel 2 Exceptions. Signals being processed through the Channel 2 INPUT connector are taken from the cathode of V423 and sent to Q503 in the Trigger Amplifier circuit for use in the trigger selection circuitry. Marker signals can be injected into the Channel 2 Switched Amplifier at the grid of V433. They are then taken from the cathode circuit of V433 and routed to D512 in the Trigger Amplifier circuit, where they are also used in the trigger selection circuitry.

Output Amplifier ⟨3⟩

General. Refer to the Output Amplifier schematic. The Output Amplifier consists of First Amplifier stage Q444-Q454, Emitter Follower stage Q463-Q473, Second Amplifier stage V464-V474, and associated circuitry. The components make up a balanced amplifier which receives differential (push-pull) current signals from any one of the Switched Amplifiers and develops differential deflection signals for the CRT deflection plates. The gain of the First Amplifier stage (in conjunction with the Switched Amplifier) is equal to approximately 50, and the gain of the Second Amplifier stage is equal to about 20. Since the upper and lower halves of the Output Amplifier are identical, only the upper half is explained here.

Output Amplifier Circuit Description. The base of Q444 is held at —12.2 V by the power supply, and therefore sets the emitter at approximately —12.5 V. The fixed potential causes a constant flow of about 7.1 mA through the series-parallel combination of R447, R448 and one-half of R449. Approximately 3.8 mA is required to supply the switched amplifier circuitry. (Approximately 1.3 mA for POSITION control while at midrange, and 2.5 mA for Q424 under no-signal conditions.) The remaining 3.3 mA flows through Q444 and its collector impedances, then combines with the electron flow from Q454 and R459. The total electron flow then splits, passing through R446 and R456. The push-pull signal current permits a constant current through R446 and R456, and the inductors have relatively no impedance at low frequencies; therefore, the DC and low-frequency load for Q444 consists of R444. When the Input Amplifier is balanced and no signal is present, the 3.3 mA combines with the R459-R446-R456 voltage divider to set the Q444 collector voltage at approximately 9 V. It is interesting to note that when all MODE switches are off, the 3.8 mA which normally goes to a Switched Amplifier flows through Q444. Its collector voltage then drops to about —2 V.

The POSITION RANGE permits balancing of the outputs of the two sides of the Output Amplifier during balanced input conditions.



R416	Amplifier input resistance.
C416	Amplifier input capacitance; combines with (4) to establish 47 pF input capacitance.
(1)	Attenuator resistive voltage divider; combines with R416 to reduce the DC voltage at the grid of V423, while maintaining 1 MΩ of resistance at the input connector.
(2)	Attenuator capacitive voltage divider; combines with (4) and C416 to reduce the AC voltage at the grid of V423.
(3)	Attenuator input capacitance; combines with (2), (4), (5) and C416 to maintain 47 pF of capacitance at the input connector.
(4)	Stray capacitance associated with the input to V423.
(5)	Stray capacitance associated with the input circuitry.
R401, R410, R419	Oscillation suppressors.
R417	Overload current limiter.
C417	High frequency response bypass capacitor.

Fig. 3-2. Analysis of attenuator circuitry.

The electron flow demanded by the Switched Amplifier changes under signal conditions. It also changes in response to the Switched Amplifier's POSITION control setting. Any change in electron flow demanded by the Switched Amplifier must be accompanied by an opposite change through Q444, since it shares a common electron source with the Switched Amplifier. The resultant change in voltage across R444 provides a voltage signal to Emitter Follower Q463.

Emitter Follower Q463 establishes the control grid voltage for V464, referencing it to the voltage at the Q444 collector. If excesively large positive voltages appear at the collector of Q444, D461 conducts to protect the Q463 base-emitter junction from reverse breakdown.

The voltage at the control grid of V464 determines the cathode potential, and therefore the electron flow through R466. Under balanced conditions no electrons flow through the R467-R468-R477 circuit, and the plate of V464 is at about +170 V. When a signal is received by V464, an opposite-polarity signal is also received by V474. The resulting imbalance of voltage across the R467-R468-R477-R466-R476 voltage divider causes some of the electrons to divert from one side and flow through the other. The smaller the effective resistance of this network, the more the electron flow for a given signal, and the greater the voltage swing across the load resistors. R477 permits adjustment of this electron flow in response to signals, to permit simultaneous changing of gain in all four channels in response to one adjustment. This permits rapid gain calibration of the unit when it is moved between oscilloscopes which have slightly different deflection factors associated with their vertical deflection plates.

D468 and D469 (cathode circuit components) do not conduct during center screen display conditions. They go into conduction and decrease the effective cathode resistance as signal amplitude increases. This insures a relatively linear gain factor, independent of signal size. The inductors associated with the various circuits improve high frequency response of the unit.

Trigger Selection Circuit. Signals for internal triggering of the sweep and unblanking circuits in the 2B67 can be selected at the 3A74 front panel. When the TRIGGER switch is in the Composite position, both the DC and AC outputs from the plate of V474 are connected through the R535-C535 combination, and through the TRIGGER switch contacts to the grid of V533A. This tube is used as a cathode follower to provide a low impedance triggering signal to the horizontal unit without loading down the deflection plate from which the signal is derived. R530 is part of a voltage divider (R535, R536) which permits adjustment of the DC level of the triggering signal output to insure compatibility with the 2B67 trigger circuit.

When the TRIGGER switch is in the CH 2 ONLY position, triggering signals are taken from the Internal Trigger Amplifier circuit which consists of Q503, Q504, Q514, Q524 and the associated components. The operating level of the circuit is initially established by the cathode potentials of V423 and V433 in the Channel 2 Switched Amplifier. They operate at about +1.5 V under no-signal conditions. This V423 cathode potential is applied to the base of emitter-follower Q503, where it causes the Q503 emitter and the Q504 base to operate at approximately +1.7 V. Similarly, the V433

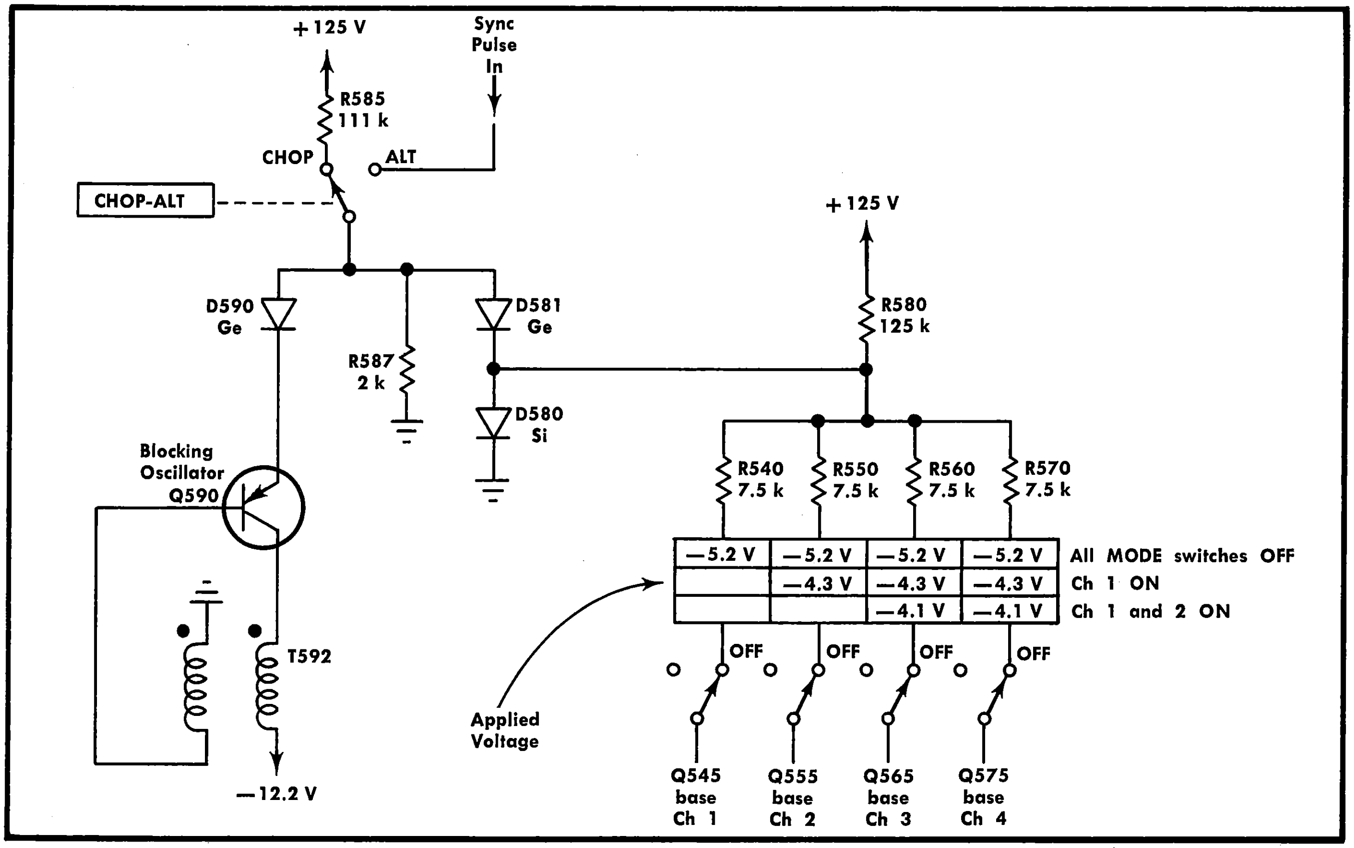


Fig. 3-3. Oscillator Control Circuit.

cathode voltage is applied to D512, which sets the Q514 base near +1.7 V. Q504 and Q514 form an emitter-coupled amplifier which has two relatively constant current paths, through R508 and R518. If a negative signal arrives at the base of Q514, it is coupled to the emitter, where it increases the voltage across R518. The large size of R518 prevents much change of electron flow through it. However, the voltage increase causes an unbalance to occur across R510. The small value of R510 permits an appreciable amount of electron flow through it. Electron flow through Q504 then decreases by an amount comparable to the increase through Q514, causing a negative signal to be developed across R504. This negative signal is further amplified by Q524, and applied through voltage divider R528-R529 to the grid of cathode follower V533A.

A negative signal arriving at the base of Q504 causes essentially the same circuit action to occur, except that it is accompanied by an increase of electron flow through Q504 and a positive signal output.

The amplifier provides both AC and DC voltages to the triggering circuit. R521 (CH 2 INT TRIG DC LEVEL) permits adjustment of the DC output of the amplifier to insure a zero-volt output from V533A in response to 0 V at the input connector. L525 and C529 improve the high frequency response of the amplifier.

Power Supply Voltages. Most of the power supply inputs are equipped with decoupling components within the 3A74. These are shown on the Output Amplifier schematic. In addition, some of the supplies are used to develop other regulated supplies within the unit. Zener diode D494 uses the +125 V supply to delevop a 51 V output, which is filtered by C494. Q487 and Zener diode D487 combine to provide regulated +12 V and +11.2 V supplies. The Zener action provides the 12 V and sets the reference for Q487, which then functions as a series regulator to provide the +11.2 V output.

Channel Switching Circuit ⟨4⟩

General. The Channel Switching Circuit consists of a Blocking Oscillator, a Sync Pulse Emitter Follower, a Ring Counter, Gating Diodes, and a Sync Pulse and Blanking Pulse Regenerator. It is recommended that the reader return to the beginning of the 3A74 circuit description and re-read the section of the Block Diagram Description which involves these components. It will aid in the understanding of the following circuit description.

Blocking Oscillator and Sync Pulse Emitter Follower. Refer to the simplified version of the Oscillator Control Circuit shown in Fig. 3-3. The Blocking Oscillator is similar to an Armstrong, with the collector of the transistor connected through the primary winding to —12.2 V, its base connected through a secondary winding to ground, and its emitter connected through diode D590 to a voltage divider network. The voltage divider network includes R585, R587, D581, R580, R540, R550, R560, R570 and the base biasing networks of Q545, Q555, Q565 and Q575. Q590 conducts whenever the voltage at the anode of D590 becomes suf-

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ficiently positive to turn on D590 and the base-emitter junction of Q590 (about +0.4 V). The Q590 collector current flows through the primary of T592 and induces a voltage into the secondary winding. This causes the Q590 base to go negative, carrying the emitter and D590 with it. When the rate of change of electron flow through the primary decreases, the voltage induced into the secondary becomes less, decreasing the drive to Q590. This causes Q590 to decrease conduction, causing the current through T592 to decrease. This induces a positive voltage into the base of Q590, cutting it off.

The oscillator is thus controlled by the D590 anode voltage, which is determined by the previously-mentioned voltage divider. When CHOP is selected and all the MODE switches are OFF, electrons cannot pass from all four MODE switches through R580 without reverse-biasing D580 and lowering the D580-D581 junction enough for D581 to turn on. Some of the electrons from the MODE switches then flow through D581 and the R585-R587 combination, holding the voltage at the anode of D590 below that required for conduction. With one MODE switch on, one current path is interrupted and less electrons flow through D581. The junction of R585 and R587 attempts to go toward approximately +2 V, but the current through R580 is still enough to keep D581 in conduction. This limits the voltage at the D590 anode to slightly less than +0.4 V. This is still not sufficient for operating the oscillator. When two MODE switches are on, electron flow decreases to a point where almost all of it is handled by R580. D581 conducts only a very small amount and the anode of D590 is permitted to go positive enough to allow Q590 to oscillate at a high frequency. Q590 continues to operate if three or four MODE switches are on, and D580 conducts to hold the D581 cathode at approximately +0.5 V.

The Oscillator Control Circuit functions in a similar manner during ALT operation, with the exception that turning on two or more channel MODE switches only brings the oscillator to the threshold of operation. The ALT position of the CHOP-ALT switch removes R585 from the circuit to accomplish this. When multi-channel operation back-biases D581, no current flows through R587 and the anode of D590 is at 0 V. When a positive sync signal is applied from the horizontal plug-in unit through the CHOP-ALT switch, it puts Q590 into conduction, initiating a single cycle of Q590 operation.

Refer to the schematic of the Channel Switching Circuit. The Sync Pulse from the horizontal plug-in unit is coupled into the oscillator through Sync Pulse Input Emitter Follower Q583. This transistor is normally not conducting (since its base and emitter are both at —12.2 V). When retrace is initiated in the horizontal plug-in unit the positive-going edge of a square wave is applied to C582 and differentiated across R582. Q583 conducts while the positive spike is present, developing a spike in its emitter circuit. This spike is coupled through C583 to the ALT contact of the CHOP-ALT switch. If ALT operation has been selected, each spike will initiate a single cycle of blocking oscillator operation.

Ring Counter Circuit. Refer to the simplified diagram of the Ring Counter circuit which is shown in Fig. 3-4. Assume that Q545 is conducting and that the MODE switches in all four channels are in NORM position. (In the actual circuit, each collector is connected through resistors to the bases of the other three transistors. These interconnections are not shown here, so that the sketch can be kept simple.) With Q545 conducting, its collector circuit is at a less negative potential than when it is not conducting. This effect is felt at the base of each of the other three transistors, holding them in a non-conducting state. Under this condition, the voltage out to the Channel 1 Diode Switch is approximately —11.8 V, and that to the Diode Switches in the other three channels is approximately —13.1 V. These values are sufficient to permit the signal which is applied to the Channel 1 Input connector to reach the Output Amplifier, while the signals in the other channels are blocked.

When a negative pulse is received from Q590, it is applied simultaneously to all four emitters. It has no effect on Q555, Q565 or Q575, since these three transistors are not conducting. But it lowers the emitter volage of Q545 enough to cut it off. When Q545 cuts off, its collector voltage goes more negative. This causes a negative spike to be coupled through C547 and the Channel 2 MODE switch to the base of Q555. The base-emitter junction of Q555 becomes forward biased, and Q555 goes into conduction. Its collector become less negative. The collector voltage change is felt at the bases of the other three transistors, holding them cut off. The Channel 2 Switched Amplifier output is now coupled to the Output Amplifier, while the outputs from channels 1, 3 and 4 are blocked.

In this manner the channels are sequentially gated on in response to successive negative pulses from Q590, and the 1-2-3-4-1-2-3-4 sequence continues as long as pulses are received and all four MODE switches are on. Two complete cycles of 4-channel operation are indicated in the waveforms shown in Fig. 3-4.

If any one of the MODE switches is in the OFF position, the negative-going collector signal bypasses that channel and is routed to the next channel where the MODE switch also either rejects or accepts it. If only one MODE switch is on, the Blocking Oscillator is disabled. The voltage at the collectors of the three non-conducting transistors holds the base of the conducting transistor negative, maintaining a collector voltage which permits the selected Switched Amplifier signal to reach the Output Amplifier.

Gating Diodes and Diode Switches. The Gating Diodes are enabled or disabled by the actions of the transistors in the Ring Counter, which have just been discussed. The Diode Switches, in conjunction with these Gating Diodes, permit the Output Amplifier to display the signals in the four Switched Amplifiers on a time-sharing basis.

Refer to Fig. 3-5. Each transistor in the Ring Counter is associated with a specific Switched Amplifier. When that transistor is turned on, its Switched Amplifier is coupled to the Output Amplifier by the following situation:

Approximately —6 V occurs at the transistor's base because of the voltage dividers from the other three transistors in the Ring Counter.

The —5.7 V at the emitter of the transistor demands approximately 12 mA through the emitter resistance to ground.

11.7 mA drops enough voltage across R548 to cause D548 to conduct. This clamps the anode of D548 to about —11.8 V, and the additional 0.3 mA required by R586 and R588 flows through D548. D547 is back biased and cannot conduct.

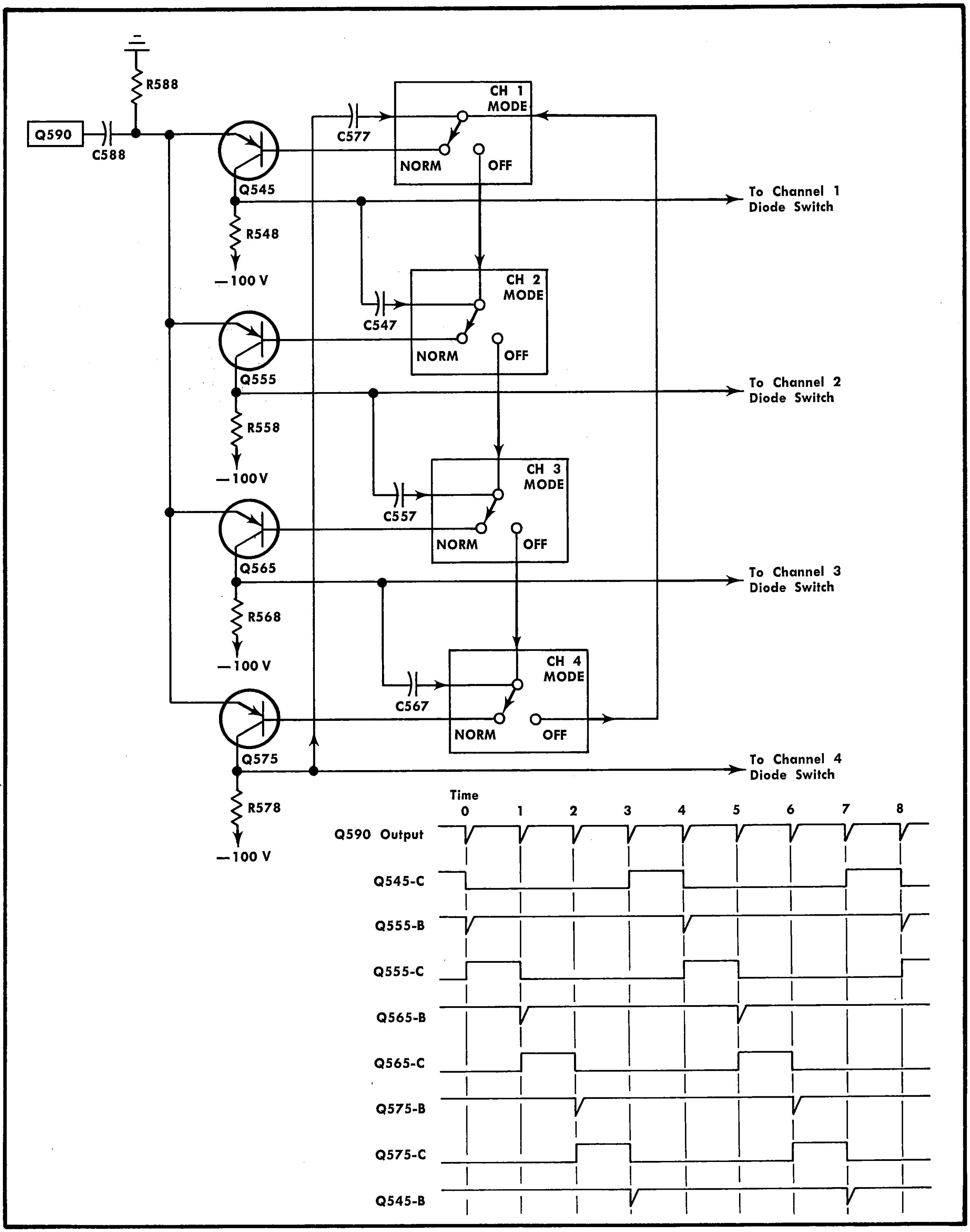


Fig. 3-4. Channel Switching Circuit; simplified diagram and idealized waveforms portraying operation with all four switches in NORM position.

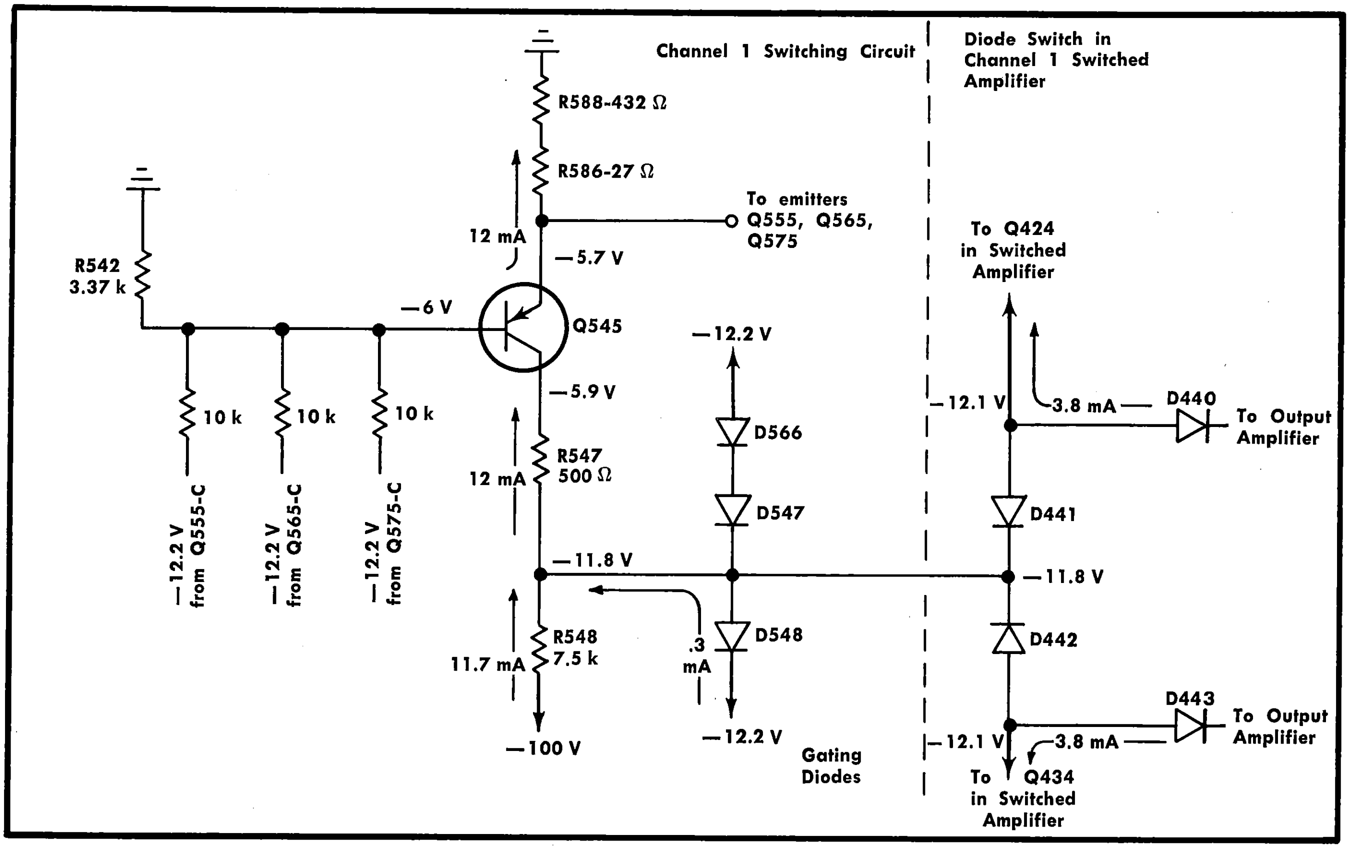


Fig. 3-5. Electron flow and voltage existing in the Channel 1 Switching Circuit when Channel 1 is gated on by the Ring Counter.

The Switched Amplifier requires approximately 3.8 mA to satisfy circuit requirements. D440 and D443 are referenced to a fixed voltage point and become enabled when the Switched Amplifier voltage pulls their anodes up to approximately —12.1 V. The output from the Switched Amplifier is thereby applied to the Output Amplifier.

D441 and D442 have —11.8 V at their cathodes and —12.1 V at their anodes and are therefore back-biased.

Now consider the simplified circuit shown in Fig. 3-6. Electrons from one of the other transistors in the Ring Counter flow through R586 and R588, holding the transistor emitter at about —5.7 V. Electron flow in the base network sets the base at about —5.2 V. The transistor base-emitter junction is reverse-biased, holding the transistor cut off. The signal from the Switched Amplifier associated with that transistor is prevented from reaching the Output Amplifier by the following conditions:

No electrons flow in the collector circuit of the transistor.

The —100 V pulls down on the D547-D548 junction until D547 conducts. The voltage across D547 and D566 subtracts from the —12.2 V power supply, setting the D547-D548 junction at about —13.1 V.

The —13.1 V appears at the junction of D441-D442, causing them to conduct. This supplies the electrons demanded by the Switched Amplifier, simultaneously clamping the anodes of D440 and D443 at approximately —12.8 V. D440 and D443 have —12.4 V at their cathodes, and are therefore back biased.

Summary of Blocking Oscillator, Ring Counter, and Gating Diode Operation. The operation of these circuits was explained with reference to simplified drawings. It is recommended that the descriptions now be re-read while referring to the Channel Switching Circuit schematic diagram.

Blanking Pulse and Sync Pulse Regenerator. Refer to the Channel Switching Circuit schematic diagram. V533B is normally cut off, since its grid is at —12.2 V and its cathode is set at about —0.6 V by the R595-D595 voltage divider. Whenever Q590 goes into conduction, the electron flow through the T592 primary winding causes a positive signal to be induced into the grid circuit of V533B, and the tube conducts. The T595 primary winding in the cathode circuit induces a regenerative positive voltage into the grid circuit, snapping the tube into heavy conduction. The positive pulse which develops in the cathode circuit is then routed through the interconnecting plug to the CRT cathode to decrease the CRT intensity while channel switching occurs. Although a negative-going sync pulse is generated in the secondary of T593, it is not used in the Engine Analyzer System.

ROTATIONAL FUNCTION GENERATOR ⟨5⟩

General. The Rotational Function Generator is the source of the sine wave, sawtooth wave, and markers which are indicative of the rotational position of the engine to which the Function Generator is connected.

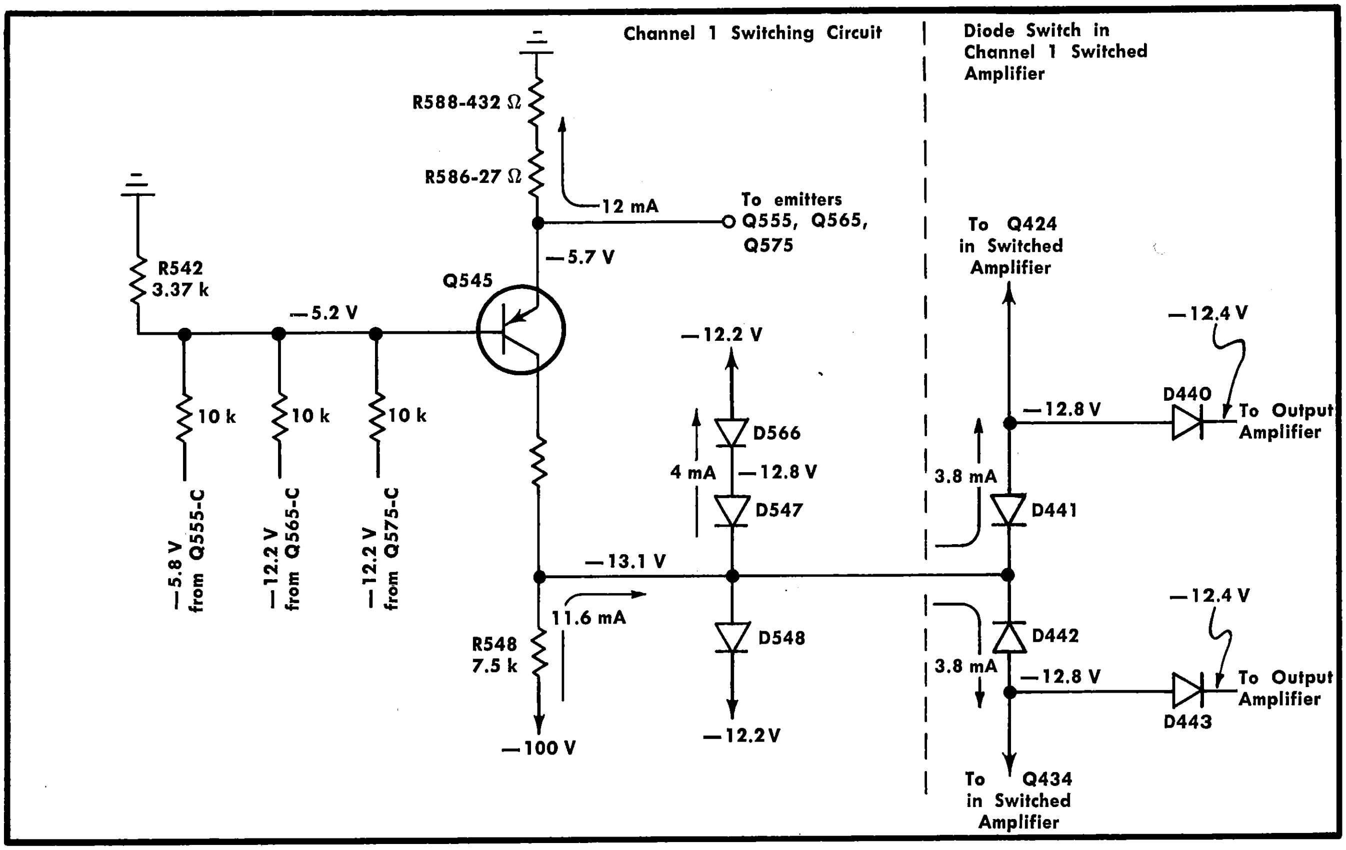


Fig. 3-6. Electron flow and voltage existing in the Channel 1 Switching Circuit when Channel 1 is gated off by the Ring Counter.

Circuit Description

Refer to the schematic diagram of the Rotational Function Generator. The Function Generator Disc (which is driven by the engine) contains three concentric light-conducting paths. A light source and diffusing window are located adjacent to the disc, opposite three phototransistor apertures. As the disc rotates, the amount of light striking each phototransistor varies in accordance with the disc program with which it is aligned. This causes proportional changes in transistor emitter currents. These changing currents are applied to amplifiers, after which the output signals are routed to the 2B67.

Sawtooth Generator. This circuit consists of phototransistor Q53, paraphase amplifier Q54 (dual transistor) and associated components. Voltage divider R56-R57-R58 and the voltage drop across D56 set the voltage at the base of Q54B at about —5.5 V, which then determines the voltage at the emitters of Q53. Voltage divider R51-R52 sets the voltage at the base of Q53 to about —5 V, which set the Q53 emitter voltage at about —5.5 V. With the bases of Q54A and B at approximately equal potentials, each passes about half of the 2 mA which flows through R54. The resultant voltage drops across D59, R50 and R59 set the Q54 collectors at about —2.2 V. This potential is available at the contacts of ROTATION DIRECTION switch SW60.

As the Function Generator Disc rotates, a constantly changing amount of light strikes phototransistor Q53, causing its collector current to change. An increase in light causes an increase in current, which increases the drive to Q54A. Q54A increases conduction, lowering the voltage at its collector. The common-emitter configuraion of Q54A and B causes a decrease in conduction through Q54B, causing its collector voltage to increase. The increase of current through Q53 causes an increase of voltage drop across R56, which sends a negative signal to the base of Q54B. This assists the common emitter in decreasing the Q54B conduction. Reverse effects occur for a decrease in the amount of light striking Q53.

Either collector signal can be selected by SW60, permitting a left-to-right CRT sweep regardless of the direction of engine rotation. The SAWTOOTH DC BAL control (R57) permits balancing of the two outputs under operating conditions to avoid changes in trace position from occurring when the ROTATION DIRECTION switch position is changed.

Sine Wave Generator. This circuit is electrically the same as the Sawtooth Generator, except that no output selection is available. The SINE DC BAL control (R77) is adjusted to provide a PISTON horizontal trace display which occupies the same area as the display which exists during CRANK operation.

Marker Generator. This circuit contains phototransistor Q93, inverting amplifier Q94, and associated components. The voltage developed across D92 in the base circuit of Q93 forward biases the emitter-base junction enough for current flow to occur. This provides drive current to Q94, which conducts about 1 mA of collector current. The Q94 current through R95 is degenerative to Q93, stabilizing the circuit at desired conduction levels. When light pulses strike phototransistor Q93, it increases conduction, increasing the drive to Q94. This causes positive pulses at the Q94 collector, which are routed through R96 to output connector J370.

Power Supply, Illumination and Mechanical Alignment. —12.2 volts from 2B67 provides operating power for the three illuminating lamps. The —12.2 V is also applied to Zener diode D99 to develop the —9 V which powers the transistor circuits. The signal outputs from the Function Generator vary directly with the intensity of the light striking the phototransistors. The spacing between the phototransistors and the lamps is adjustable to allow compensation for differences in phototransistor sensitivity. Failure of the center lamp will affect signal amplitude. Failure of either of the end lamps will effect both signal amplitude and linearity. In addition, the linearity of the signals is partially dependent upon the mechanical alignment of the phototransistor block. Lamp replacement is discussed in the Maintenance Section, and mechanical alignment is explained in the Calibration Procedure.

2B67 ENGINE ANALYZER TIME BASE

General. The 2B67 Engine Analyzer Time Base (hereafter called 2B67) performs the following functions: provides an unblanking voltage to the CRT to permit displays; receives position signals from the Rotational Function Generator (hereafter called Function Generator) and amplifies them to provide horizontal positioning signals to the CRT electron beam; receives marker signals from the Function Generator, amplifies them and routes them through the oscilloscope chassis to the vertical plug-in unit. In addition, the 2B67 can develop internal sweep votlages independent of the Function Generator. These sweep voltages can provide either calibrated or uncalibrated horizontal deflection of the electron beam to form a time base against which the vertical presentations can be observed.

Block Diagram Description

Refer to the 2B67 Simplified Block Diagram in Fig. 3-7. The Trigger Generator accepts signals selected by the SOURCE switch and develops a trigger pulse output in response to the signals. The trigger pulse is sent to the Sweep and Blanking Voltage Generator. The Trigger Generator can also be set up to automaticaly develop trigger pulses, independent of input signals.

The Sweep and Blanking Voltage Generator circuit is capable of developing three outputs—a Blanking Voltage to control CRT electron beam blanking, a Sync Pulse to control Vertical Plug-In Unit channel switching, and a Sawtooth voltage to control horizontal deflection of the CRT electron beam. Only the Blanking Voltage output is used while the TIME/DIV switch is in the ROTATIONAL FUNCTION GENERATOR position. During this time, the sync pulse is normally interrupted in the Vertical Plug-In Unit, and the sawtooth is not generated. When the TIME/DIV switch is at a numbered position, the sawtooth voltage can be generated to cause CRT electron beam horizontal deflection. The blanking voltage then prevents horizontal retrace from being seen, and the sync pulse can be used in the Vertical Plug-In Unit to cause channel switching to coincide with sweep horizontal retrace.

The Horizontal Amplifier provides the ,CRT with horizontal deflection plate voltages. When the TIME/DIV switch is at the ROTATIONAL FUNCTION GENERATOR position, the deflection plate voltage is controlled by the signal from the Function Generator. In the event that no signal is being received from the Function Generator, a Standby Trace is applied to the Output Amplifier to provide approximately two divisions of horizontal deflection. This avoids having a stationary dot on the CRT, which could damage the phosphor. Whenever the TIME/DIV switch is in a numbered position, the sawtooth from the Sweep and Blanking Pulse Generator is used. Regardless of the position of the TIME/DIV switch, the signal from the Function Generator is always processed by the Rotational Function Amplifier and routed to the EXT triggering signal line.

The cable which brings the sine wave and sawtooth from the Function Generator also contains a lead which carries degree marker signals. Whenever markers are present, they are amplified and applied to the MARKERS PULL switch. The markers are also coupled into the Standby Trace Generator. Whenever present, they prevent the standby trace from being applied to the Output Amplifier. When the MARKERS PULL switch is closed, the markers are routed through the oscilloscope connector to the Vertical Plug-In Unit.

Trigger Generator ⟨6⟩

Block Diagram Description. Refer to the block diagram contained on the Trigger Generator schematic. The principal components of the Trigger Generator circuit are the Trigger Input Amplifier and the Trigger Multivibrator. The Amplifier accepts AC or transient signals from the SOURCE switch and converts them to the polarity, amplitude and DC level required by the Multivibrator.

The Multivibrator develops a square wave output with fast leading and trailing edges. This square wave can be generated in response to signals from the Amplifier, or it can be generated independent of the Amplifier when the LEVEL control is at the AUTO position. When AUTO operation is selected and no signal is present, the Multivibrator operates at approximately 50 Hz. This AUTO mode can be over-ridden by signals from the amplifier which are of a higher frequency and of sufficient amplitude.

When the LEVEL control is not at the AUTO position, the Trigger Multivibrator becomes a Schmitt Trigger circuit, switching states whenever its DC input voltage crosses through certain levels. The switching action still produces the rapid positive and negative-going transients which are characteristic of the circuit.

The negative-going transient from the Trigger Multivibrator is used by the Sweep and Blanking Pulse Generator to cause switching action. The multivibrator requires a negative signal from the Trigger Output Amplifier to create this negative transient. The Trigger Input Amplifier is equipped with a SLOPE control, which permits a negative output from the Amplifier in response to either a positive-going or negative-going input signal.

Detailed Description. Refer to the Trigger Generator Schematic Diagram. Under quiescent conditions, the LEVEL control determines the conduction status of both halves of V24. If the LEVEL control is set at 0, both grids of V24 will

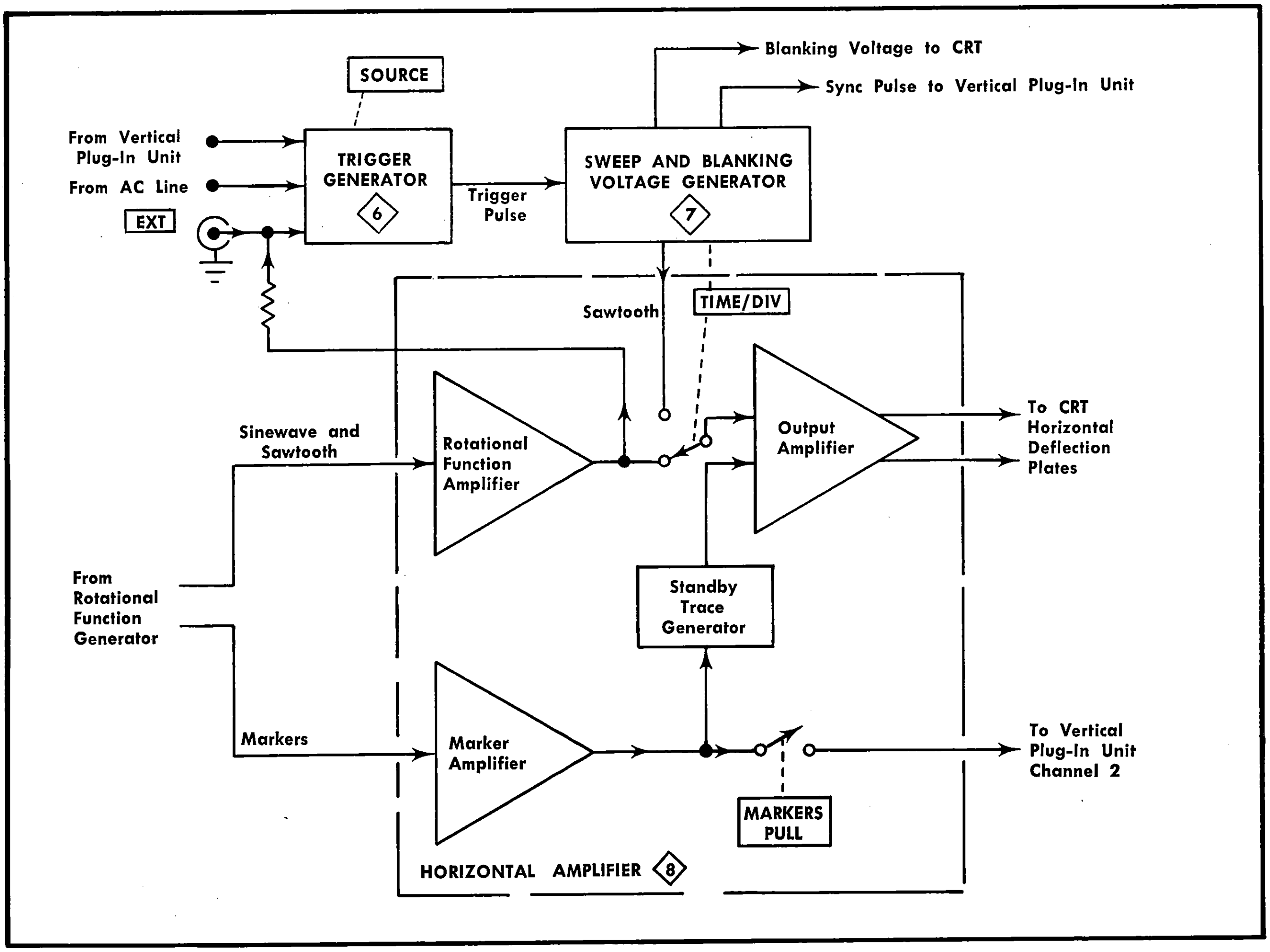


Fig. 3-7. 2B67 simplified block diagram.

be at 0 volts and the two halves will have an approximately equal amount of electron flow through them. The plates will be at about +112 V. This value is not positive enough to cause V45A to conduct, and is not negative enough to cut V45A off, so V45A can be in either state.

Assume that the LEVEL control is at 0, V45A is conducting, V45B is cut off, and that the SLOPE switch is at —. When a negative-going signal is coupled through the SOURCE switch and C14, it causes the grid of V24A to decrease the conduction through that side. The common-cathode action of V24 causes an increase of electron flow through V24B, lowering its plate voltage. When the V24B plate voltage decreases through approximately +111 V, V45A decreases conduction. The increase in V45A plate voltage is coupled through C37 and R37 to put V45B into conduction. The combination of common-cathode and plate-feedbock causes V45A to rapidly cut off and V45B to conduct. The fast negative-going plate voltage is then applied to the Sweep and Blanking Pulse Generator. When a positive signal into V24A causes the V24B plate voltage to increase through about +113 V, V45A will again conduct and reset the multivibrator.

The voltage required to cut off V45A is referred to as the multivibrator "lower hysteresis level" and that required to turn V45A back on is called the "upper hysteresis level". The voltage difference between the two limits is the "hysteresis width".

If the LEVEL control is set to some negative voltage, V24B will decrease conduction and its plate voltage will rise, putting V45A into conduction. Incoming signals will have to drive the grid of V24A more negative than the value selected by the LEVEL control before the common cathode action will permit the V24B plate voltage to go down through the lower hysteresis level of V45A, generating a negative-going trigger pulse output.

If a positive value is selected by the LEVEL control, V24B will conduct more than V24A and V45A will be cut off. V24A will have to receive a signal voltage more positive than that at the grid of V24B before V45A can conduct and reset the Trigger Multivibrator. Then when the signal into the grid of V24A decreases to a value below that on the V24B grid, the V24B plate voltage will again decrease through the lower hysteresis level of V45A to create another negative-going trigger pulse output.

The just-decribed action permits triggers to be generated at different voltage levels of the triggering signal, as determinated by the LEVEL control setting. R21 is placed in parallel with R20 during ROTATIONAL FUNCTION GENERATOR operation to decrease the maximum + and — voltage delivered to the Trigger Input Amplifier. This provides less critical (TRIGGERING) LEVEL control than would otherwise be available.

Note that the SLOPE switch was in the — position for the above discussion, and that the signal in to V24A had to be negative-going to generate a negative trigger pulse out, regardless of whether the LEVEL control was at 0, —, or + If the SLOPE switch is placed in its + position, the signal input and POSITION voltage will reverse their grid connections. The same circuit response will occur, except that the signal into the multivibrator will change in a direction opposite to the incoming signal, generating a negative trigger pulse output only in response to a positive-going input signal.

Auto Operation. When the LEVEL control is placed in its AUTO position, the DC circuit between the V24B plate and the V45A grid is interrupted. Additional resistance is inserted into the V45A plate circuit and the LEVEL control voltage output is short circuited to ground. With 0 volts on both grids of V24A, both plates and the left plate of C31 are quiescently at approxmately +112 V.

Assume that C31 initially has no charge on it and that its right plate is also at +112 V, setting the V45A grid at +112 V and its cathode potential at about +117 V. About 4.25 mA is demanded through R46 and flows through R34 and R35, setting the V45A plate at about +285 V. The R37-R38 voltage divider causes about +105 V to appear on the grid of V45B. With +117 V on its cathode and +105 V on its grid, V45B is virtually cut off.

The +105 V at the R37-R38 junction places a 7 volt potential across R40, R31 and C31 (whose left plate is at +112 V). As C31 charges, its right plate goes in a negative direction. The grid of V45A follows, causing the cathode voltage to also decrease. This voltage is coupled to the cathode of V45B. When it becomes low enough, V45B sarts conducting. Some of the electrons from R46 flow through V45B, decreasing current flow through V45A. The decreased current through R34 and R35 raises the V45A plate voltage. The grid voltage of V45B follows. The combination of cathode coupling and plate feedback causes V45A to rapidly cut off and causes V45B to go into full conduction, creating a negative trigger pulse output.

With the plate of V45A at almost +300 V, the voltage divider causes about +112 V to occur at the V45B grid. C31 now discharges until the grid of V45A rises enough to permit V45A to conduct. The cycle then repeats itself.

Signals arriving from V24B combine with the potential at the grid of V45A, and can either cause it to prematurely conduct or cut off, depending upon polarity and amplitude. AUTO operation can be completely over-ridden by any signals from V24B whose peak-to-peak value exceeds the approximately 0.5 V hysteresis width of the multivibrator.

Sweep and Blanking Voltage Generator ⟨7⟩

General. When the TIME/DIV switch is in the ROTATIONAL FUNCTION GENERATOR position, this circuit provides a continuous unblanking voltage to the CRT while the MODE switch is at NORM. If the MODE switch is in the SINGLE SWP position, the circuit must provide the CRT with unblanking voltage only long enough to permit one or two sweeps, as selected by the (ROTATIONAL FUNCTION) SINGLE SWP DISPLAY switch. The circuit must then be manually reset before another display can be presented.

When the TIME/DIV switch is in a numbered position, the Sweep and Blanking Voltage Generator develops a linear sawtooth sweep voltage and provides unblanking to the CRT during the time the sawtooth is being applied to the Horizontal Amplifier. When the sawtooth voltage collapses, the circuit blanks the CRT, and sends a sync pulse to the Vertical Plug-In Unit. If the MODE switch is at SINGLE SWP, the circuit must be manually reset after each sweep before another sweep can be displayed.

Operation With TIME/DIV at ROTATIONAL FUNCTION GENERATOR Position

Block Diagram Description. Refer to the Block Diagram contained on the Sweep and Blanking Voltage Generator schematic. When the TIME/DIV switch is placed in the ROTATIONAL FUNCTION GENERATOR position, V135A is conducting and V145A is cut off. This provides a blanking voltage to the CRT, and a back-biasing voltage through R140 and R142 to D132. When a negative-going trigger pulse arrives from the Trigger Generator, it passes through C130 and causes the Gating Multivibrator to switch states. This raises the voltage on the Blanking Voltage line to +125 V, unblanking the CRT. The back-biasing voltage is also removed from D132. If the MODE switch is at NORM, the circuit remains in this condition until manually switched to another mode of operation.

If the MODE switch is at SINGLE SWP, and the SINGLE SWP DISPLAY switch is at 360° (2 CYCLE), the next negative-going pulse from the Trigger Generator passes through C133, D132 and through the 2 Cycle/4 Cycle Multivibrator. This pulse is amplified and inverted by the Pulse/Sweep Amplifier, sending a positive-going signal through the Hold-off Enabling Diode. (This diode is used when the TIME/DIV switch is at a numbered position, and has no effect when the TIME/DIV switch is at the ROTATIONAL FUNCTION GENERATOR position.) The positive pulse passes through the Feedback Cathode Follower and is applied to the Gating Multivibrator, which it resets.

During SINGLE SWP operation the Single Sweep Lockout circuit causes D124 to conduct when the 2 Cycle/4 Cycle circuit resets the Gating Multivibrator. Its conduction prevents the Gating Multivibrator from accepting any more negative-going signals. When the MODE switch is momentarily placed in the RESET position, D124 stops conducting and the READY lamp goes on. The circuit is then ready to go through another unblanking cycle.

If the SINGLE SWP DISPLAY switch is at the 720° (4 CYCLE) position, circuit response is similar, except that the 2 Cycle/4 Cycle Multivibrator requires 2 negative pulses to develop a negative-going pulse. This means that three negative-going pulses are required from the Trigger Generator to first unblank and then blank the CRT. Since the Trigger Generator develops a Trigger Pulse once each cycle of input signal, the CRT remains unblanked for 2 cycles of Rotational Function Generator operation.

It should be noted here that the 360° (2 CYCLE)/720° (4 CYCLE) nomenclature refers to engine operation. The flywheel and the Rotational Function Generator go through one complete revolution as a 2 cycle engine goes through its two cycles of operation, or as a 4 cycle engine goes through two of its four cycles.

Circuit Description. Refer to the schematic diagram. Assume that the TIME/DIV switch is at ROTATIONAL FUNCTION GENERATOR position, the MODE switch is at NORM and the LEVEL control is not at FREE RUN. Before the first negative trigger pulse arrives, the circuit is set up as follows: R111, R112 and R113 apply approximately —51 V to the cathode of V145A and the grid of V135A. This establishes the V135A cathode voltage at about —50 V. The current required by this voltage flows through R144, V135A, R135 and R134, establishing the voltage at the grid and cathode of V135B. The voltage at the cathode of V135B must be in the vicinity of +125 V to unblank the CRT. With V135A conducting, this voltage is at about +20 V, and the CRT is blanked. The R141-R143 voltage divider causes about —60 V to be felt at the control grid of V145A. With —50 V on its cathode and —60 V on its control grid, V145A is cut off.

With V145A cut off, its plate attempts to go to 0 V. V152A conducts, delivering about 2.2 mA from the R174-R176-R178 voltage divider. This current through R147 thus causes the V145A plate to be about —3.3 V.

About —70 V appears at the wiper of R176, causing V152C to turn on, contributing a very small amount of the V152A electron flow. This causes the V152C cathode and the V145B grid to be near —70 V. With —70 V on its grid and —51 V on its cathode, V145B is cut off.

V161A is passing maximum current because its cathode is connected to ground and its control grid is referenced to ground through R182. This causes its plate to be at about +5 V. The B167-R167 voltage divider connects between the V161A plate and —100 V, and sets the grid of V161B at about —50 V. With its grid at —50 V and its cathode near —4 V, V161B is near cut off.

Some consideration must be given to other components in the grid circuit of V135A before discussing what occurs when a trigger is received. D132 is provided with voltage dividers at its cathode and anode. R132 and R133 set its cathode at about +123 V. With the MODE switch at NORM, R128, R140 and R142 form a voltage divider which sets the D132 anode at about +0.1 V while V135A is conducting. D132 is therefore cut off.

When a negative pulse arrives from the trigger generator, it passes through C130, develops across R130-D130, and is applied to the grid of V135A. V135A decreases conduction, simultaneously causing its cathode to go negative and its plate to go positive. The positive-going plate voltage signal is coupled through V135B to the grid of V145A. The combination of decreasing cathode voltage and increasing grid voltage turns V145A on hard, raising its cathode voltage sufficiently to hold V135A cut off after the negative input signal disappears. The plate of V135B goes to about +123 V, and its cathode goes to +125 V. The +125 V is applied to the blanking voltage line to unblank the CRT.

With +125 V at the cathode of V125B, the voltage at the anode of D132 rises to about +0.5 V, but the diode remains back biased and still cannot permit incoming signals to pass through it.

The CRT has been unblanked in response to a negative going input signal, and remains unblanked until the 2B67 is manually switched to another operating mode.

Assume now that the MODE switch has been momentarily placed in the RESET position, and then placed at SINGLE SWP. Circuit operation from that point is as previously described, with the following exceptions:

The ground connection is removed from the base of Q124, and its emitter is connected to ground. The R126-R127 voltage divider places about +0.9 V at the base of Q124 and the anode of D126. Q124 is cut off, and D126 cannot conduct until its cathode falls below about +0.3 V. The R121-R123-R124 voltage divider causes B123 to turn on and sets the collector of Q124 at about 80 V. That potential is applied to the anode of D124, holding it cut off.

If the SINGLE SWP DISPLAY switch is in the 360° (2 CYCLE) position, it lowers the base circuit resistance of Q195 below that of Q185. This holds the 2 Cycle/4 Cycle Multivibrator in a monostable state with Q185 cut off.

Disconnecting R128 from ground places the anode of D132 at the same potential as the cathode of V135B. Thus it is at about +20 V while V135A is conducting. This back-biases it against input signals while the CRT is blanked.

When a negative trigger pulse cuts off V135A, the +125 V at the cathode of V135B places +125 V at the anode of D132, turning it on. The next negative trigger pulse to arrive passes through C133, D132, C199, D198, C182 and a contact of the TIME/DIV switch. The pulse is felt at the grid of V161A, causing the plate current to decrease. The positive spike developed in the V161A plate circuit is felt at the cathode of V161B, the cathode of V152C, the cathode of V145B, and the grid of V135A. V135A conducts heavily, resetting the V135A-V145A multivibrator. This removes the unblanking voltage from the blanking voltage line, and the CRT becomes blanked.

When the feedback pulse turns V135A on, it causes the plate of V135A to drop below —1.2 V, turning on D126 and Q124. The Q124 collector voltage goes positive to almost 0 volts, which turns D124 on. This moves the V135A grid voltage in a positive direction, saturating V135A. Incoming trigger signals are not large enough to over-ride this saturation voltage. With V135A saturated, approximately 8 V appears at the cathode of V135B. This voltage is also felt at the anode of D132. With +123 V on its cathode, D132 is back biased.

The circuit remains in this status until the MODE switch is moved. When it is placed at RESET, the Q124 cathode circuit is opened, and the anode of D125 is grounded. Q124 stops conducting and its collector voltage goes toward —100 V. The D124 cathode voltage follows until it arrives at about —50 V (the value set by the R111, R112, R113 voltage divider). D124 then becomes back biased and stops conducting. With a lowered grid voltage, V135A conducts less current. When the MODE switch is allowed to return from the RESET to the SINGLE SWP position, the V135A plate voltage rises to about +11 V. D126 is again back biased, and Q124 remains in a non-conducting state. The voltage across Q124 rises and B124 turns on, indicating that the circuit is again ready to accept incoming trigger pulses.

The preceding SINGLE SWP explanation assumed that the (ROTATIONAL FUNCTION) SINGLE SWP DISPLAY switch was in the 360° (2 CYCLE) position. Circuit operation is essentially the same when the switch is in the 720° (4 CYCLE) position except as follows:

The base circuit resistance of Q185 and Q195 are equal, and the multivibrator is bistable.

Putting the MODE switch at reset turns Q185 on, which turns Q195 off. The multivibrator remains in this condition until the first negative trigger pulse arrives after the CRT has been unblanked. That pulse passes through C133, D132, C199, D188 and C194, back biasing D187. Q185 cuts off, turning Q195 on. The positive-going Q185 collector voltage forward biases D198, but has no effect upon saturated V161A.

The next negative-going trigger pulse to arrive passes through C133, D132, C199, D198 and C182. Q195 turns off and puts Q185 back into conduction. The negative-going signal voltage is differentiated across R182 and is applied to the control grid of V161A. It then causes circuit reaction identical to that previously described.

Operation with TIME/DIV At A Numbered Position

Block Diagram Description. Refer to the block diagram contained on the Sweep and Blanking Voltage Generator schematic. Assume that the TIME/DIV switch is in a numbered position, the MODE switch is at NORM, and the (TRIGGERING) LEVEL control is not at FREE RUN. When a negative--going pulse arrives from the Trigger Generator, it passes through C130 to cause the Gating Multivibrator to change states. An unblanking voltage is sent to the CRT, and the Disconnect Diodes become back-biased.

When the Disconnect Diodes stop conducting, the Timing RC Circuit starts charging, developing a linear positive-going sawtooth ramp voltage at the output of the Pulse/Sweep Amplifier. This ramp is sent to the Horizontal Amplifier to develop the CRT horizontal deflection plate voltages. A portion of the ramp is coupled through the Holdoff Enabling Diode, where it charges the Holdoff Capacitor, and is also applied to the grid of the Feedback Cathode Follower.

When the ramp voltage gets sufficiently positive to develop about 10½ divisions of horizontal deflection, the Feedback Cathode Follower output becomes positive enough to reset the Gating Multivibrator. The CRT unblanking voltage is then removed from the blanking voltage line, a positive-going voltage is applied to the Sync Pulse line and the Disconnect Diodes go into conduction. Trigger pulses cannot affect the Gating Multivibrator until the output voltage from the Feedback Cathode Follower returns to its quiescent value.

When the Disconnect Diodes are turned on, the Timing RC Circuit discharges rapidly, causing the Pulse/Sweep Amplifier ramp voltage to collapse. The voltage at the R176 wiper follows, and the Holdoff Enabling Diode turns off. The Holdoff Capacitor discharges slowly, keeping the Feedback Cathode Follower turned on while the horizontal sweep circuitry stabilizes. When the Holdoff Capacitor becomes sufficiently discharged, the Feedback Cathode Follower decreases its output, finally cutting off. The Gating Multivibrator is then able to change states in response to the next negative-going trigger pulse, repeating the cycle.

During SINGLE SWP operation, circuit response is similar to that which has just been explained, with the following exceptions: When the Feedback Cathode Follower resets the Gating Multivibrator, it also causes the Single Sweep Lockout circuit to enable D124. This holds V135A in saturation, preventing input trigger pulses from affecting the Gating Multivibrator. When the MODE switch is mommentarily placed at RESET, it turns D124 off. Then when the MODE switch is permitted to return to SINGLE SWP, D124 remains off, and the READY lamp lights, indicating that the circuit is ready to produce another single sweep.

When the (TRIGGERING) LEVEL control is placed in the FREE RUN position, the Sweep and Unblanking Pulse Generator operates as previously described, except that operation is independent of trigger pulses. After a sweep is completed and retrace occurs, the V135A bias returns to a value sufficient to flip the multivibrator, immediately initiating another sweep.

Circuit Description. Refer to the schematic diagram. Assume that the TIME/DIV switch is in a numbered position, the MODE switch is at NORM, the (TRIGGERING) LEVEL control is not at FREE RUN and the circuit is ready to accept a trigger pulse. When a negative-going trigger pulse arrives, it passes through C130, is developed across R130, and turns V135A off. V135 and V145A then react just as they do during ROTATIONAL FUNCTION GENERATOR operation. The cathode of V135B goes to +125 V, unblanking the CRT and turning V145A on. The plate of V145A goes to about —9 V and Disconnect Diodes V152A and V152B turn off. Electrons from the —100 V supply pass through R160 and collect on the lower plate of C160, applying a negative-going voltage to the control grid of V161A.

V161A has a gain of about 150, and develops a positive-going ramp at its plate in response to the negative-going voltage at the grid. This voltage is coupled through B167, R168 and C167 to the grid of V161B. The V161B cathode follows, applying the voltage to the top of C160. The voltage at the top plate of C160 rises almost as fast as the charge accumulates on the bottom, with their difference being the small amount of signal drive required by V161A. The voltage across R160 remains relatively constant, developing a linear sawtooth ramp voltage.

The positive-going ramp at the V161B cathode is applied to the Horizontal Amplifier to develop paraphase drive voltages for application to the CRT horizontal deflection plates. Part of the ramp voltage is picked off by the wiper of R176 and is coupled through V152C to C160 and the grid of V145B. As the ramp voltage rises, the voltage on C160 follows and V145B turns on. The ramp voltage continues to rise, carrying the V145B cathode voltage with it. When the ramp reaches a voltage which is predetermined by the setting of R176, the cathode voltage of V145B is sufficiently high to cause V135A to conduct. V135A goes into saturation and the V135B cathode voltage decreases, blanking the CRT. V145A stops conducting. As the V145A plate voltage goes toward ground potential, V152B conducts. The voltage at the V161A control grid goes toward 0, and the plate voltage decreases. The grid and cathode of V161B follow the V161A plate voltage down until V152A conducts. Part of the R174-R176-R178 current then flows through V152A and R147, holding the V161A grid at about —2.4 V. The rapid collapse of

V161B cathode voltage causes the Horizontal Amplifier output voltages to "retrace" (return to their quiescent value). The beam retrace cannot be seen because the CRT has been blanked by V135B.

As long as V145B conducts, V135A is held in saturation and incoming trigger pulses have no effect. During the time that the output voltage was rising, C160 followed the voltage at the wiper of R176. When the ramp voltage collapsed, V152C cut off, and C160 started charging to —100 V through the large resistance offered by R181. As C160 charges toward —100 V, the grid and cathode of V145B follow, causing the V135A grid voltage to go in a negative direction. When the C160 voltage becomes sufficiently negative, V145B cuts off. The V135A grid voltage is then at its quiescent value and the circuit can again accept incoming trigger pulses.

Now consider what happens when the MODE switch is at SINGLE SWP and the rising ramp voltage causes V135A to go into conduction. The voltage at the cathode of V145B is high enough to put V135A into saturation, and its plate voltage goes sufficiently negative for D126 to conduct and supply drive current to the base-emitter junction of Q124. Q124 goes into conduction and the READY lamp goes out. The current through R124 raises the D124 anode voltage enough to put D124 into conduction and hold V135A in saturation. V135A is then unable to accept incoming trigger pulses until the MODE switch has been momentarily placed at RESET and then allowed to return to SINGLE SWP. When at RESET, the MODE switch grounds the V135A plate and opens the Q124 emitter circuit, turning Q124 off. Its collector goes toward —100 V and D124 turns off, permitting the V135A grid voltage to return to the values set by R111. When the MODE switch is returned to SINGLE SWP, the V135A plate voltage goes slightly positive, and Q124 is held cut off, permitting V135A to respond to the next incoming negative-going trigger pulse.

When the (TRIGGERING) LEVEL control is placed in the FREE RUN position, R111 is bypassed, creating a bias voltage which is sufficiently negative to cut V135A off. A ramp voltage is developed. When the ramp becomes large enough to develop a full sweep, feedback through V152C and V145B raises the V135A grid voltage enough for V135A to conduct. The ramp voltage then collapses. V152C cuts off and C160 starts charging toward —100 V. If the MODE switch is at NORM, the cathode of V145B follows the charge on C160 until it is sufficiently negative to turn off V135A. The cycle then repeats itself. If the MODE switch is in SINGLE SWP position, a sweep voltage will be developed immediately after the circuit is reset, independent of incoming trigger pulses.

Sync Pulse Circuitry

A sync pulse is generated and sent to the vertical plug-in unit each time V135A goes into conduction. The pulse is generated in different manners for different serial-numbered instruments as follows:

In instruments serial number B040250 and up, while a sweep is being generated the V135B cathode is held at about +125 volts by the voltage on its grid. The R151-R153 voltage divider attempts to place the Q150 base at +35 V, putting D151 into conduction and limiting the base voltage to about +0.6 V. This holds Q150 cut off, and interconnecting pin 4 is held at –12.2 V by the potential applied through interconnecting pin 16. When V135A conducts, V135B stops conducting, causing the V135B cathode voltage to change from +125 V to +20 V. The R151-R153 voltage divider attempts to apply –28 V to the base of Q150. Q150 conducts saturation current, holding its base voltage to about –0.6 volts and its collector to about –0.2 volt. The positive-going change at the collector is sent out terminal 4 as a Sync Pulse for the vertical unit.

In instruments serial number B030200 to B030249 when V135A conducts to end a sweep, V145A stops conducting and its screen grid current supply is interrupted. The screen voltage rises, applying a positive voltage to the Q145 base. The emitter follower action applies a positive voltage to C148, which causes C148 to apply a positive-going pulse to interconnecting plug terminal 4.

In instruments below serial number B030200, when V135A conducts V145A stops conducting and interrupts its screen grid current. The positive transition is applied to interconnecting plug terminal 4 as a sync pulse.

Miscellaneous Components

D126 disconnects the base of Q124 from the plate of V135A during the time that sweeps are being generated. This protects Q124 from base-emitter reverse breakdown. R123 and R125 form a voltage divider (with R124) which limits the voltage across B124 and the emitter-base junction of Q124 during NORM operation. This insures that B124 remains off and that the voltage across the base-emitter junction of Q124 remains below breakdown. D130 provides a low impedance shunt through C113 for positive pulses from the Trigger Generator. This prevents the positive pulses from interfering with the operation of V135A. C142 decouples incoming trigger pulses before they can affect the unblanking circuit or the grid of V145A. In addition, during ROTATIONAL FUNCTION GENERATOR SINGLE SWP operation, C142 delays D132 turn-on, so that the signal which unblanks the CRT cannot affect the 2 Cycle/4 Cycle multivibrator. C134, C137 and C141 speed up the action of the Gating Multivibrator. C165 and C167 aid the high-frequency response of the Pulse/Sweep Amplifier. B161 limits the V161B grid-cathode voltage to about 65 V, preventing breakdown. Different values of C160 are used at different sweep rates to decrease holdoff time as sweep rate increases. This provides a relatively constant brightness trace.

Horizontal Amplifier ⟨9⟩

Block Diagram Description. Refer to the block diagram contained on the Horizontal Amplifier schematic. The Output Amplifier can accept signals from either of two sources. One of these sources is the Sweep and Blanking Voltage Generator circuit which was just explained. The other source is the Rotational Function Generator.

When the Rotational Function Generator is being driven by a rotating device (and its electrical cable is connected to the 2B67), a sine wave and a sawtooth wave are applied to contacts of the (ROTATIONAL FUNCTION) PISTON-CRANK selector switch. The selected signal is amplified by the Rotational Function Amplifier and applied to contacts of the TIME/DIV switch. With this switch at ROTATIONAL FUNCTION GENERATOR position, the signal is applied to the Output Amplifier, where it is amplified and converted to push-pull signal voltages for application to the CRT horizontal deflection plates. The amount of horizontal deflection can be controlled by the setting of the (ROTATIONAL FUNCTION) WIDTH knob. The (ROTATIONAL FUNCTION) POSITION control affects the sweep's horizontal position.

The output from the Rotational Function Amplifier is routed to the Trigger Generator circuit to provide unblanking during ROTATIONAL FUNCTION GENERATOR SINGLE SWP operation.

When the TIME/DIV switch is placed at a numbered position, the output of the Sweep Cathode Follower is applied to the Output Amplifier. If sweep voltage ramps are being generated by the Sweep and Unblanking Pulse Generator, they are amplified and applied to the CRT horizontal deflection plates. The R323 POSITION control is then the only operator control affecting the horizontal position occupied by the sweep.

The output from the Rotational Function Amplifier continues to be sent to the Trigger Generator while the TIME/DIV switch is at a numbered position. It can be used to initiate sweep ramp voltages to obtain stable displays of engine functions against calibrated (or uncalibrated) time bases.

Markers from the Rotational Function Generator are amplified and sent internally to the MARKERS PULL switch and to the Standby Trace Generator. When the MARKERS PULL switch is closed, the markers are routed to the vertical plug-in unit, regardless of the position of the TIME/DIV switch.

The Standby Trace Generator is designed to protect the CRT phosphor whenever the Function Generator is connected to the 2B67 and the TIME/DIV switch is in the ROTATIONAL FUNCTION GENERATOR position. If the Function Generator stops rotating, signals are no longer received by the Marker Amplifier. When the marker signals stop arriving at the Standby Trace Generator, a standby trace signal is applied to the Output Amplifier Reference Cathode Follower. The signal causes approximately 2 divisions of trace deflection to protect the CRT phosphor while giving visual evidence of trace location. The Standby Trace Generator is disabled whenever the TIME/DIV switch is in a numbered position.

Circuit Description—TIME/DIV Switch At ROTATIONAL FUNCTION GENERATOR Position. Refer to the schematic diagram. The Rotational Function Amplifier consists of U380 and its associated circuitry.

U380 is an encapsulated integrated circuit designed for use as an operational amplifier. When considered with respect to a signal arriving at terminal 3, the amplifier feedback resistance (R_2) consists of R386 and R388. The input resistance (R_1) for the inverting input is determined by the series-parallel network of R381, R382, R383, R384 and R385. Gain of the Amplifier for signals arriving at terminal 3 is approximately equal to ($R_2 + R_1$) divided by R_1, and can vary between approximately 7 and 102, depending upon the position of the (ROTATIONAL FUNCTION) WIDTH control. This gain range provides a horizontal deflection range of from less than 5 to greater than 20 divisions in response to a normal sine wave or sawtooth signal from the Rotational Function Generator.

Terminal 3 of U380 uses terminal 2 as its reference, and the difference between the voltage at the two points determines the output at terminal 6. This difference is always small, since the minimum open loop gain of U380 (gain with feedback resistors disconnected) is at least 15,000, with 45,000 being a typical value.

When a signal is applied to terminal 3, it is amplified and an in-phase signal appears at terminal 6. This causes signal current to flow in the feedback circuit, driving the voltage at terminal 2 toward that at terminal 3. The circuit stabilizes when the difference between the signal voltages at terminals 2 and 3 is approximately equal to the output signal voltage divided by the open loop gain.

When the setting of the (ROTATIONAL FUNCTION) POSITION control is changed, it attempts to change the voltage at terminal 2. The current change which must accompany the voltage change across R385 attempts to flow in the low resistance path of R383 and R381. This causes a change in voltage at terminal 2. An amplified but opposite change occurs at terminal 6. Current flows through feedback resistors R386 and R388, supplying most of the current change required by R385. Once again, the circuit stabilizes when the voltage difference between terminals 2 and 3 is approximately equal to the output voltage divided by the U380 open loop gain.

It should be noted that the less the gain (WIDTH), the less the change in horizontal position that can result from a given change of the (ROTATIONAL FUNCTION) POSITION setting.

The output from U380 pin 6 is applied through the TIME/DIV switch to the grid of V374A. V374A and V374B share the R375 common current source. When a change in voltage at the grid of V374A causes a change in plate current, an equal but opposite change must occur in V374B plate current. The oppositely-changing currents cause push-pull voltage outputs to develop at the two plates. The resistances of R373 and R377 are slightly different, compensating for the fact that the grid of only one of the two halves is being driven by an input signal. The output signals are routed through the interconnecting plug to the CRT horizontal deflection plates.

V353B provides a reference voltage for the grid of V374B. This voltage is initially established by the R355-R356 voltage divider and can be modified by the setting of the R325 ROTATION FUNCTION REGIS control. When R325 is properly set, the WIDTH control will cause the display to expand and contract around the CRT graticule center vertical line. The comparison of the V374B grid voltage to the no-signal voltage on the brid of V374A determines the quiescent beam voltage.

Circuit Description—TIME/DIV Switch At a Numbered Position. When the TIME/DIV switch is at a numbered position, the cathode of V353A becomes the signal source for V374A. An operational amplifier with a gain of about $2\frac{1}{2}$ is formed by the two vacuum tubes, with R348 being the feedback resistor (R_f) and R341-R342 being the input resistance (R_i). The resistors are shunted by capacitors to permit calibrated gain at high sweep rates.

When a sweep ramp voltage is received from V161B, it is applied across the RC divider consisting of R320, R321, C320 and C321, where a portion of it is applied to the grid of Input Cathode Follower V333A. (C321 permits adjustment of the capacitive portion of the divider.) The proper amount of signal required to produce a calibrated 5× MAG sweep is selected by the wiper of R334 and applied to Second Cathode Follower V333B. (C334 improves circuit response during fast sweeps.) The signal is then applied to the input of the operational amplifier. R341 is adjusted with SW341 open (5X MAG "in") to provide the proper amount of gain for calibrated unmagnified sweeps.

V374A, in addition to being part of the operational amplifier, remains part of the paraphase amplifier which was described previously. It should be noted that the voltage at the grid of V374B is controlled solely by the R355-R356 voltage divider and the V353 grid-cathode circuit when the TIME/DIV knob is at a numbered position.

When the 5× MAG knob is pulled out, SW341 short-circuits R341 and R342. The operational amplifier takes on a different configuration and its gain is determined principally by the ratio of (R348 + R338) divided by R338. Two divisions of the unmagnified sweep presentation can then be displayed as a 10 division presentation.

When a ramp is being processed, a point occurs in time at which the voltage across R341-R342 drops to 0. No current then flows through the resistors, and they can be inserted or removed from the circuit with no apparent effect on the beam position. The unmagnified and magnified sweeps are said to "register" upon each other at this point. R346 is adjusted to set the voltage at the V353A grid so that registration occurs at the middle of the CRT graticule. Closing the 5X MAG switch will then cause the two unmagnified divisions which straddled the graticule center line to be displayed as a 10 division trace.

The R323 POSITION control is capable of modifying the operating level of the incoming voltage ramp so that any two divisions of unmagnified sweep can be presented as a 10-division magnified display.

Marker Amplifier. The Marker Amplifier circuitry is contained on the Horizontal Amplifier schematic and is made up of C301, R301, R302, R303 and Q304. The voltage divider in the base circuit of Q304 holds the transistor in conduction. Positive-going marker signals from the Function Generator are AC-coupled through C301, amplified and inverted by Q304, and applied to the MARKERS switch. When this switch is closed, the marker signals are internally routed through the oscilloscope interconnecting plugs to the vertical plug-in unit.

Standby Trace Generator. The Standby Trace Generator is dependent upon the Marker Amplifier and the AC filament supply line for its operation. When the TIME/DIV switch is in the ROTATIONAL FUNCTION GENERATOR position and markers are not being received, Q308 is conducting and D307-D308 are back-biased. The —100 V being applied to R310 pulls down on the cathode of D313 and puts it into conduction. The AC-signal (which is coupled in from the AC filament supply line through R311 and C311) passes through D313 and is supplied through C317 to the grid of V353B. It is then applied to the grid of V374B, where the resulting paraphase amplification causes a two-division horizontal signal to be applied to the CRT.

When the Function Generator is rotating, each marker signal causes Q308 to cut off. The +125 V applied through R308 pulls up on the anode of D307, which goes into conduction and charges C308 positive. The positive charge on C308 is limited to approximately +12.6 V by D308, whose cathode is connected to +12 V. This raises the cathode voltage of D313, cutting it off. The AC signal is thus blocked by D313 whenever marker signals are being received. The CRT electron beam then responds to only CRANK or PISTON signals. The average charge on C308 keeps D313 cut off in the interval between marker pulses, and holds D313 cut off for approximately 1 second after the last marker pulse has been received.

If the Function Generator cable is removed from the 2B67 INPUT connector, the —12.2 V supply for Q308 is interrupted, and the Q308 collector rises. D307 and D308 go into conduction and D313 becomes back biased. The Standby Trace circuit is thus disabled. A dot can then appear on the CRT whenever the TIME/DIV switch is in the ROTATIONAL FUNCTION GENERATOR position. (Note that the Standby Trace circuit will not be disabled as long as the cable is connected to the 2B67, regardless of whether or not the cable is disconnected from the Rotational Function Generator.)

A contact of the TIME/DIV switch prevents the standby trace signal from reaching the Output Amplifier whenever the TIME/DIV switch is at a numbered position.

Miscellaneous Circuitry. D395 and R395 form a voltage divider to provide a +12-V supply which is necessary for U380 operation. R396 and C396 are frequency compensating components for the input circuit, and C395 provides frequency compensation for the output circuit.

SECTION 4
MAINTENANCE

Change information, if any, affecting this section will be found at the rear of the manual.

The following information appears in this section in the order listed:

Preventive Maintenance
- Cleaning
- Visual Inspection
- Lubrication
- Transistor Checks
- Recalibration

Troubleshooting
- Test Equipment
- General Techniques
- Troubleshooting Basic Components
- Troubleshooting Chart

Corrective Maintenance
- Parts Procurement
- Soldering Equipment and Techniques
- Cable Maintenance

3A74 Maintenance

2B67 Maintenance

Rotational Function Generator Maintenance

PREVENTIVE MAINTENANCE

General Information

The Engine Analyzer equipment should be cleaned, lubricated, inspected and recalibrated at regular intervals. A recommended schedule for average operating conditions is every 6 months or every 500 hours of operation, whichever occurs first.

Cleaning

Keeping the equipment clean can help to maintain peak performance and lengthen its operating life. Dirt on components (including cables) can result in short circuits. A dry, soft cloth and a soft-bristled brush are recommended for removing loose dirt from the outside of the instrument. Dirt on the inside should be loosened with a soft-bristled brush and removed by using a vacuum cleaner or a stream of low-pressure air. High-pressure air can damage the equipment and should not be used.

WARNING

Use an eye-shield when cleaning with pressurized air.

Hardened dirt should be removed by using a mild detergent and water solution on a cotton-tipped swab or a soft cloth. Disconnect the equipment from power sources before using the solution. Avoid excessive use of water. Do not allow water to penetrate any parts. Dry the instrument thoroughly before energizing it. Avoid the use of abrasives and chemical cleaning agents. Protect the equipment from dirt and damage by keeping it covered when not in use.

Visual Inspection

After cleaning, the equipment should be carefully inspected for defects such as poor connections, damaged parts and improperly seated tubes and transistors. Damaged parts require that the cause of the damage be eliminated before operation is resumed.

Lubrication

Keep all metallic moving parts properly lubricated. Use a cleaning-type lubricant on shaft bushings and switch contacts. Lubricate switch detents and screw threads with a slight amount of grease. Do not lubricate plastic parts. Do not lubricate the sealed bearings on the Rotational Function Generator. They are permanently lubricated prior to installation. **Do not overlubricate.** Proper lubricants and lubricating instructions are contained in Tektronix Lubrication Kit, part no. 003-0342-00. Contact the Tektronix Field Representative if additional information regarding lubricants or lubrication is required.

Transistor Checks

Checking transistors as a preventive maintenance function is not recommended. Circuit performance is thoroughly checked during calibration; unacceptable transistors will be detected at that time.

Recalibration

The calibration status of an instrument should be determined as a part of preventive maintenance for several reasons: (1) the performance of an instrument changes slightly with age, use and operating conditions; (2) performance may be affected by the cleaning process; and (3) checking the calibration status may reveal troubles which are not obvious during regular operation.

The calibration status can be determined rapidly by accomplishing the Performance Check portions of the procedure contained in section 5.

TROUBLESHOOTING

Test Equipment

The test equipment listed here should suffice for most troubleshooting jobs on the Engine Analyzer System.

High Impedance Voltmeter; 10,000 Ω/V DC or greater

Ohmmeter; 1½-V source supplying less than 2 mA of current on the X 1 k scale.

Test oscilloscope; 2 MHz bandwidth (10 MHz bandwidth for troubleshooting Vertical Amplifier high frequency problems).

Tube Tester and Transistor Curve Tracer or Transistor Tester

General Techniques

Proper troubleshooting logic is the most important tool in equipment repair. The following guide provides a logical sequence for analyzing equipment failures:

1. Check all external control settings.

2. Determine that operating procedure is correct.

3. Determine all of the trouble symptoms. Analyze the trouble, keeping in mind the symptom inter-relationship.

4. Perform a visual inspection, concentrating on the area indicated by the trouble analysis.

5. Troubleshoot the circuitry; repair as necessary.

6. Check the calibration status; recalibrate as necessary.

Control Settings and Operating Procedure. Refer to the Operating Instructions section of this manual to verify external control settings and operating procedure.

Trouble Symptoms. After it is confirmed that trouble exists, the response to all exterior controls should be observed. The first-time operation listed in Section 2 or the Troubleshooting Chart in this section can be used for this purpose. All trouble symptoms should be evaluated and compared against each other. Epuipment trouble will often create a combination of symptoms that will pin-point the trouble. A good example of this is power supply trouble, which causes symptoms to occur in otherwise unrelated circuits.

Visual Inspection. In visually examining the Engine Analyzer System, take special note of the area localized by evaluation of symptoms. Look for loose or broken connections, improperly seated tubes or transistors, and burned or otherwise damaged components. Repair all obviously defective parts. Investigate the cause of heat damage to components.

Detailed Troubleshooting. If the trouble has not been disclosed and corrected through the procedure outlined, a detailed troubleshooting analysis must be performed. The Circuit Description section, the Schematic Diagrams, the Calibration Procedure, and the troubleshooting aids contained in this section are designed to expedite troubleshooting.

The Circuit Description section provides a fundamental understanding of circuit operation and is referenced to the Schematic Diagrams. The Schematic Diagrams contain voltage and resistance values and signal waveforms. All specified operating conditions should be duplicated before making voltage or waveform comparisons. In cases where the black numbers and blue numbers on the schematics give conflicting voltage values, the blue numbers should be used.

NOTE

Voltages and waveforms may vary slightly between individual instruments and are also dependent upon the characteristics of the test equipment used to obtain them. Voltages and waveforms given on the schematics should be checked against each instrument while it is operating properly. Deviations should be noted on the schematics for later reference.

Calibration. Although the calibration procedure is intended primarily for instrument calibration, it can serve as an efficient troubleshooting aid. Since each step is based upon satisfactory performance of the preceding steps, the problem circuit will be encountered before circuits which are dependent upon it.

Troubleshooting Basic Components

The quantity of semiconductor devices in the Engine Analyzer System requires that anyone working on it have a general knowledge of semiconductor operation. Some information is presented here to aid in this respect.

Direct Replacement. Once a casualty has been isolated to a specific circuit, the ease of replacing tubes and transistors often makes substitution the fastest means of repair. Adhere to the following instructions if the replacement method is used:

Determine that the circuit is safe for the substitute component.

Use only known-good substitutes.

Have only one tube or transistor out of the instrument at a time to avoid inserting them in the wrong socket.

Insert components properly, using Fig. 4-6 and 4-7 as a guide for inserting transistors.

Check operation after each component is replaced, and be sure to return good components to their original sockets.

Check calibration after a bad component has been replaced.

WARNING

Voltage, either positive or negative, is often present on the cases of metal-cased transistors when the equipment is energized.

Transistor Troubleshooting. Transistor defects usually take the form of the transistor opening, shorting, or developing excessive leakage. The best means of checking a transistor for these and other defects is by using a transistor curve display instrument such as a Tektronix Type 575. If a transistor checker is not readily available, a defective transistor can be found by signal tracing, by making in-circuit voltage checks, by measuring the transistor resistances, or by the substitution method previously described.

When troubleshooting with a voltmeter, measure the emitter-to-base and emitter-to-collector voltages to determine if the voltages are consistent with normal circuit voltage. Voltages across a transistor vary with the type of device and its circuit function. Some of these voltages are predictable. The base-emitter voltage of a conducting germanium transistor will normally be 0.3 V and a silicon transistor's will normally be 0.6 to 0.7 V. The collector-emitter voltage of saturated transistors is approximately 0.2 V. Because these values are small, the best way to check them is by connecting the voltmeter across the junction and using a sensitive voltmeter setting, rather than by comparing two voltages taken with respect to ground. **Both leads of the voltmeter must be isolated from ground if this method is used.**

If values less than these are obtained, either the device is shorted or no current is flowing in the circuit. If values are in excess of the base-emitter values given, the junction is back-biased or the device is defective (open). Values in excess of those given for emitter-collector could indicate either a non-saturated device operating normally, or a defective (open) transistor. If the device is conducting, voltage will be developed across resistances in series with it; if it is open, no voltage will be developed across resistances in series with it unless current is being supplied by a parallel path.

An ohmmeter can be used to check a transistor if the ohmmeter voltage source and current are kept within safe limits. 1½ volts and 2 mA are generally acceptable. Selecting the × 1 k scale on most ohmmeters will automatically provide safe voltages and currents. If the voltage and maximum output current of a specific ohmmeter is in doubt, it should be checked before using it on transistors by connecting the test leads to another multimeter.

CAUTION

A transistor's specifications should be checked to determine maximum allowable ratings before subjecting it or associated circuits to voltage or current higher than that recommented here.

Table 4-1 contains the normal values of resistance to expect when making an ohmmeter check on an otherwise unconnected transistor. Fig. 4-6 and 4-7 illustrate transistors and sockets for pin location purposes.

Field Effect Transistor Checks. The field effect transistors contained in the Charge Amplifier circuit are relatively delicate components which require special care. Refer to the precautions contained in the 3A74 Maintenance part of this section before handling or servicing them.

Diode Troubleshooting. Checks on diodes (other than Zeners) can be performed in much the same manner as on transistor base-emitter junctions. Germanium diodes should have approximately 0.3 V and silicon diodes should have about 0.6 V across the junction when conducting. Higher readings indicate that they are either back biased or defective, depending on polarity. The ohmmeter precautions pertaining to transistors should also be observed when checking diodes.

TABLE 4-1

Transistor Resistance Checks

Ohmmeter Connections[1]	Resistance Reading That Can Be Expected When Using the R × 1 k Range (1.5 V ohmmeter operating voltage)
Emitter-Collector	High readings both ways (100 kΩ to 500 kΩ, approximately)
Emitter-Base	High reading one way (200 kΩ or more) Low reading the other way (400 Ω to 3.5 kΩ, approximately)
Base-Collector	High reading one way (200 kΩ or more) Low reading the other way (400 Ω to 3.5 kΩ, approximately)

[1]**Reverse the test lead connections to make the second reading. Reversal of the applied voltage polarity causes the junction to shift between being reverse and forward biased, as indicated by the difference in resistance.**

Some diodes used in the equipment are color coded to identify the diode type. A blue or pink first band indicates that the next three colors translate to the last three digits of its part number. Diode polarity can be determined by color code position. See Fig. 4-1.

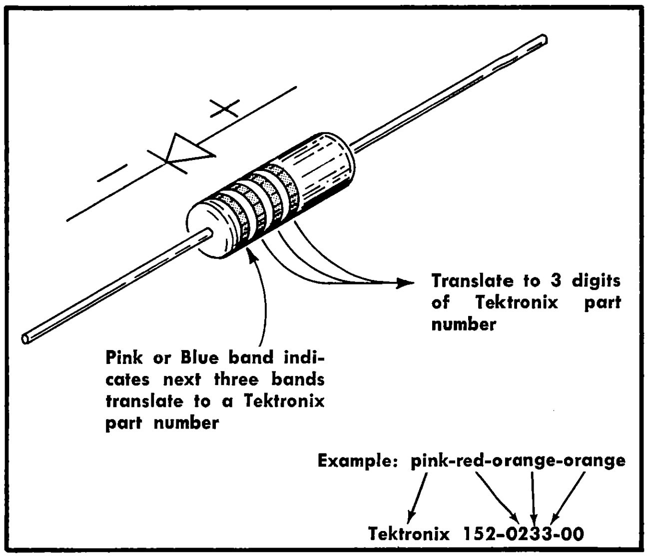


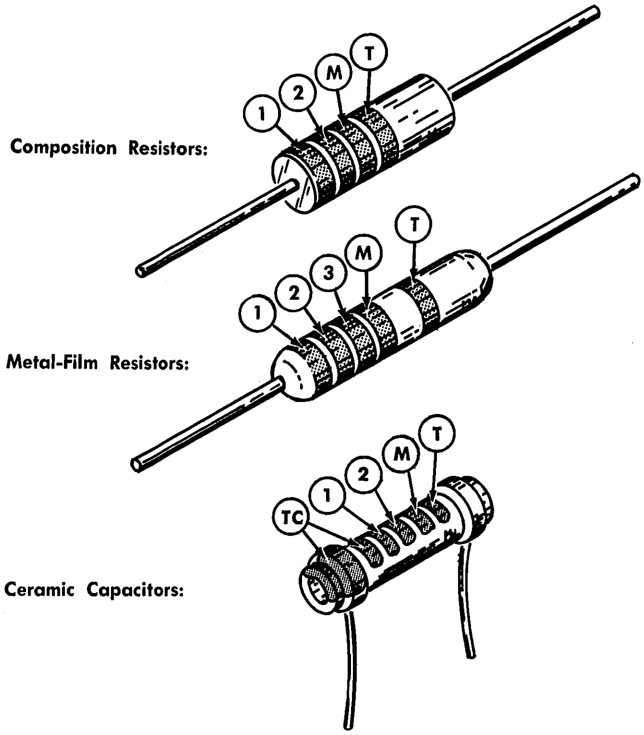
Fig. 4-1. Diode color code related to Tektronix part number and conducting polarity.

NOTE

The positive side of an ohmmeter voltage source is often connected to the meter common test lead.

Integrated Circuit Testing. The integrated circuit used in the Horizontal Amplifier section of the 2B67 should be tested in accordance with the information contained in the 2B67 Maintenance part of this section.

Resistors. The same ohmmeter voltage and current precautions observed in transistor troubleshooting also apply when making in-circuit resistance checks of circuits containing semiconductors. Resistors must be isolated from the semiconductors before reliable resistance checks can be made.



Resistor and Capacitor Color Code

Color	Significant Figures	Multiplier		Tolerance	
		Resistors	Capacitors	Resistors	Capacitors
Silver	---	10^{-2}	---	±10%	---
Gold	---	10^{-1}	---	±5%	---
Black	0	1	1	---	±20% or 2 pF*
Brown	1	10	10	±1%	±1% or 0.1 pF*
Red	2	10^2	10^2	±2%	±2%
Orange	3	10^3	10^3	±3%	±3%
Yellow	4	10^4	10^4	±4%	+100% −0%
Green	5	10^5	10^5	±0.5%	±5% or 0.5 pF*
Blue	6	10^6	10^6	---	---
Violet	7	---	---	---	---
Gray	8	---	10^{-2}	---	+80% −20% or 0.25 pF*
White	9	---	10^{-1}	---	±10% or 1 pF*
(none)	---	---	---	±20%	±10% or 1 pF*

*For capacitance of 10 pF or less.

NOTE: T and/or TC color code for capacitors depends upon manufacturer and capacitor type. May not be present in some cases.

Fig. 4-2. Color code for resistors and ceramic capacitors.

The types of resistors found in this equipment vary in accordance with the circuit needs. Composition, metal film and wire-wound resistors are used. Replacement resistors should be of the same type and must be at least as accurate as those originally contained in the circuit to maintain the performance standards. The size, location and lead length are often critical because of frequency considerations. Resistor values are indicated by one of three methods in the Engine Analyzer System equipment.

4 color bands (digit, digit, multiplier—tolerance)

5 color bands (digit, digit, digit, multiplier—tolerance)

Numbers printed on wire wound and metal film resistors

The first two methods translate to the IEEE color-code equivalent and are illustrated in Fig. 4-2.

Wire Information. All insulated wires and cables used in the Engine Analyzer System are color-coded to facilitate circuit tracing. Signal-carrying leads are identified with one or two colored stripes. Voltage supply leads are identified with three stripes to indicate the approximate voltage, using the IEEE resistor color code. A white background color indicates a positive voltage and a tan background indicates a negative voltage. The widest color stripe identifies the first color of the code. Table 4-2 gives the wire color-code for the power-supply voltages. Wire connections should be recorded before removal to facilitate replacement.

TABLE 4-2

Power Supply Wiring Color Code

Supply	Background color	1st Stripe	2nd Stripe	3rd Stripe
+125 V	wht	brn	red	brn
+150 V	wht	brn	grn	brn
+300 V	wht	orn	blk	brn
−12.2 V	tan	brn	red	blk
−100 V	tan	brn	blk	brn

Capacitors. The capacitance values of common disc capacitors and small electrolytics are marked in microfarads on the side of the component body. The white ceramic capacitors are color coded in picofarads using a modified IEEE code. See Fig. 4-2.

Switches. Rotary switch wafers are coded with a number and a letter on the schematic diagrams. The number indicates the wafer position in the switch assembly, counting from the front (mounting end). The letters "F" and "R" indicate whether the front or rear of the wafer performs the switching action. For example, a switch section designated 2R is contained on the rear of the second wafer as viewed from the front of the switch.

Individual switch wafers or mechanical parts of rotary switches are normally not replaced. If a switch is defective, replace the entire assembly. Wired and unwired replacement switches are available; refer to the Parts List for part numbers. When a switch is removed, make careful notation of the lead connections for installation reference.

Troubleshooting Chart

The Master Troubleshooting Chart contained in Fig. 4-3 can be used without disassembling the equipment. It will indicate the circuit or circuits most likely to contain the source of the trouble which is being investigated.

To use the chart, start at the top, working down and to the right. If a check provides a "yes" answer, proceed down along the solid line. If the answer to a check is "no", follow the broken line to the right. Exceptions to the direction of flow are indicated by arrows where they occur.

When checking the probable casualty area, associated leads, switches and other components should not be ignored. A transistor might be inoperative because of a defective resistor in series with it.

The chart is designed on the basis of single defects. Multiple problems may disrupt the logic, but it should still be effective in determining the problems, one at a time.

CORRECTIVE MAINTENANCE

General. Many electrical components are mounted in a particular way to reduce or control stray capacitance and inductance. Dressing of leads and orientation of parts should duplicate the original installation.

WARNING

Disconnect all power from the equipment before removing or replacing components.

A thorough cleaning should accompany any repairs, and a satisfactory Performance Check or Calibration Procedure should be performed after the repairs have been completed.

Parts Procurement

All parts used in this equipment can be purchased through Tektronix Field Offices or representatives. However, replacements for standard electronic items can be readily obtained from local electronic parts stores.

When selecting replacement parts, it is important to remember that the physical size and shape of a component may affect its performance at high frequencies. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance. Before purchasing, consult the Electrical Parts List in this manual to determine the required specifications.

Special Parts. Some electrical parts are specially reworked, quality checked, or manufactured to fulfill a particular requirement. Most mechanical parts are common to the specific equipment. All electrical parts whose part numbers are preceded by an asterisk, and most mechanical parts, can therefore be obtained only through the Tektronix Field Office or representative. Ordering information precedes the Electrical Parts List.

Soldering Equipment and Techniques

Soldering Equipment. Solder containing 3% silver should be used on ceramic terminal strips. Ordinary electrical solder should be used for all other circuit repairs. The soldering iron should be selected in accordance with the work being done, as follows:

Soldering on circuit boards — 15 to 40 watt iron with a 1/16 or 1/8 inch tip.

Soldering to ceramic terminal strips and metal terminals such as on switches and potentiometers — 40 to 75 watt iron with 1/8 inch tip.

Soldering to heavy metal such as the chassis or binding posts — 40 to 75 watt iron with 1/4 inch tip.

Component size and density demands the use of needle-nose pliers and needle-nose end nipper pliers when replacing components. Tweezers are also helpful. Heat sinks (such as small alligator clips) are invaluable for protecting components from heat damage, leaving both hands free for soldering. A hold-down aid can be made from a wooden dowel, 6 to 8 inches long and 1/4 to 3/8 inch in diameter. Shape one end like a pencil tip and the other end similar to a screwdriver tip. Note that the wood will absorb only a minimum of heat from the iron but will not guard against heat transfer to the parts being soldered. Flux remover solvent and cotton-tipped swabs are needed to remove flux from soldered connections.

A vacuum type solder removing device is extremely useful in removing solder from connections, expediting component removal and replacement. Other soldering aids should be made or purchased to suit specific needs.

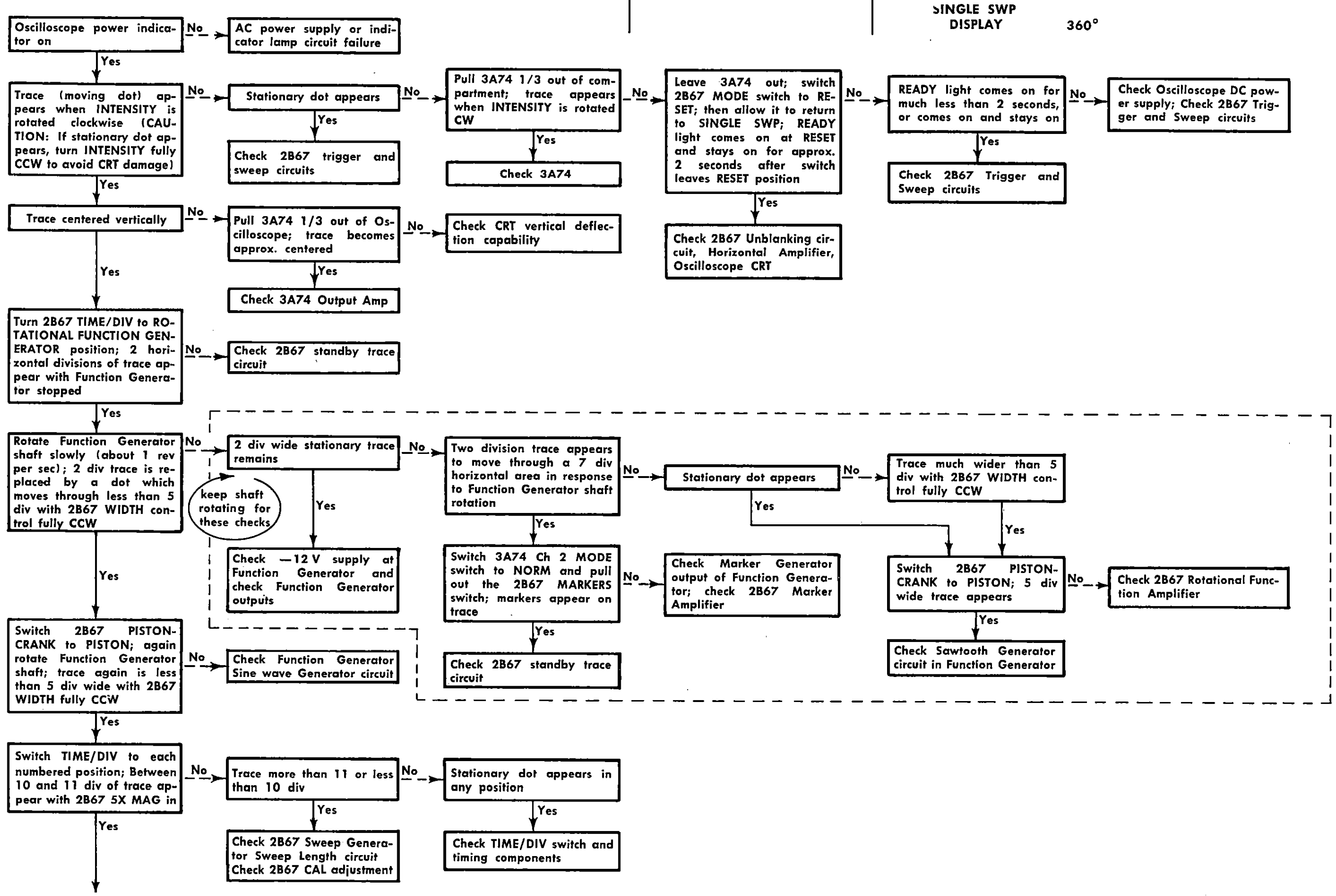
General Soldering Techniques. Keep the soldering iron well tinned and wiped clean. To avoid excessive heating of the general area around the connection, the iron sould be completely heated before being applied. When removing components, apply heat only long enough to allow the part to be removed easily. (Applying a small amount of solder between the tip and the joint will usually aid in heat transfer on difficult connections. This will decrease heating of the general area.) Use the extreme tip of needle-nosed pliers to avoid drawing off too much heat. When connecting components, heat the solder sufficiently to allow free flow. Apply the solder to the wire being joined, not to the soldering iron. This will insure proper bonding. Applying a small amount of solder between the iron and the wire will again aid in initial heat transfer. Once solder flows between the tip and the wire, the solder should be applied to the opposite side of the wire to complete the process. Do not use more solder than is necessary to make a neat and effective bond.

Use heat sinks between the body of components and the joint being soldered whenever small components and/or short leads are involved. After soldering has been completed, clip off excess wire, deflecting wire ends with a gloved finger or other device to avoid damage to fingers, eyes, or

ENGINE ANALYZER MASTER TROUBLESHOOTING CHART

Initial Setup:

Oscilloscope		3A74		2B67	
FOCUS	Midrange	Ch 1		POSITION	Midrange
INTENSITY	CCW	PSI/DIV	1	MODE	NORM
POWER	ON	MODE	OFF	TIME/DIV	.2 s
Rotational Function Generator		CH 2, 3, 4		VARIABLE	CAL
Connected to 2B67 INPUT connector		AC-GND-DC	GND	TRIGGERING	
		MODE	OFF	LEVEL	AUTO
		VOLTS/DIV	.02	SLOPE	+
		TRIGGER	In	SOURCE	INT
		CHOP-ALT	CHOP	ROTATIONAL FUNCTION	
				POSITION	Midrange
				PISTON-CRANK	CRANK
				WIDTH	CCW
				SINGLE SWP DISPLAY	360°



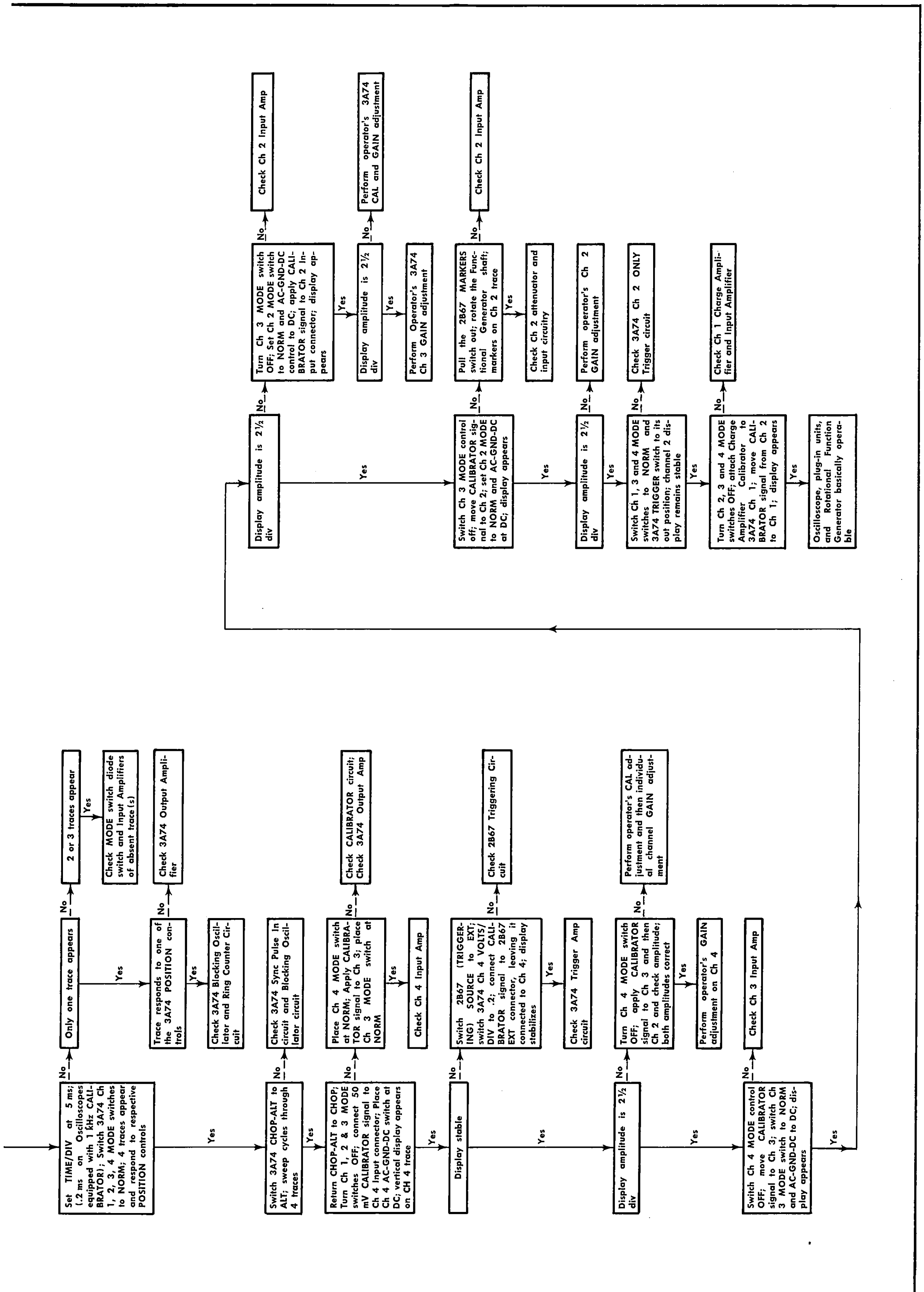


Fig. 4-3. Master troubleshooting chart.

circuit components. Remove clipped leads from the chassis. Clean the newly soldered area with a cotton-tipped swab and flux remover solvent.

Be careful when soldering wafer-type switch terminals. Excessive heat or solder flowing around and beyond the rivet will destroy the contact spring tension. Excessive heat will damage plastic parts of switches.

Ceramic Terminal Strips. Solder used on the ceramic termial strips should contain about 3% silver. Use a 40- to 75-watt soldering iron with a 1/8-inch wide wedge-shaped tip. Ordinary solder can be used occasionally without damage to the ceramic terminal strips. However, if ordinary solder is used repeatedly or if excessive heat is applied, the solder-to-ceramic bond may be broken.

A sample roll of solder containing about 3% silver is provided with the Plug-In Units. Additional solder of the same type should be available locally, or it can be purchased from Tektronix, Inc., in one-pound rolls; order by Part No. 251-0514-00.

Observe the following precautions when soldering to ceramic terminal strips.

1. Use a hot iron for a short time. Apply only enough heat to make the solder flow freely.

2. Maintain a clean, properly tinned tip.

3. Avoid putting pressure on the ceramic terminal strip.

4. Do not attempt to fill the terminal-strip notch with solder; use only enough solder to cover the wires adequately.

5. Clean the flux from the terminal strip with a flux remover solvent.

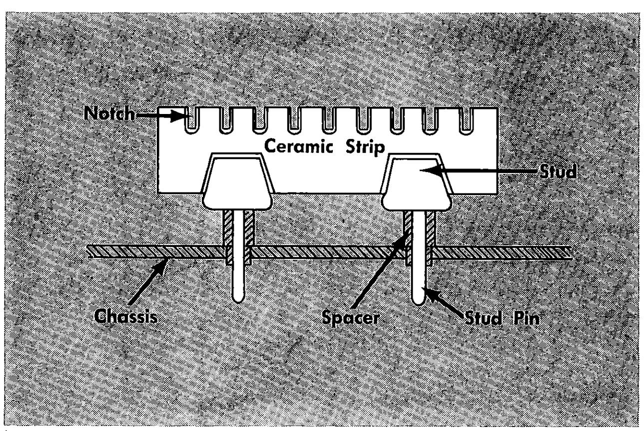


Fig. 4-4. Ceramic terminal strip assembly.

Ceramic Terminal Strip Replacement. A complete ceramic terminal strip assembly is shown in Fig. 4-4. Replacement strips (including studs) and spacers are supplied under separate part numbers. However, the old spacers may be re-used if they are not damaged. The applicable Tektronix Part Numbers for the ceramic strips and spacers used in this instrument are given in the Mechanical Part List.

To replace a ceramic terminal strip, use the following procedure.

REMOVAL:

1. Unsolder all components and connections on the strip. To aid in replacing the strip, it may be advisable to mark each lead or draw a sketch to show location of the components and connections.

2. Pry or pull the damaged strip from the chassis.

3. If the spacers come out with the strip, remove them from the stud pins for use on the strip (spacers should be replaced if they are damaged).

REPLACEMENT:

1. Place the spacers in the chassis holes.

2. Carefully press the studs of the strip into the spacers until they are completely seated. If necessary, use a soft mallet and tap lightly, directly over the stud to seat the strip completely.

3. If the stud extends through the spacers, cut off the excess.

4. Replace all components and connections. Observe the soldering precautions given under Soldering Techniques in this section.

Circuit Board Soldering Techniques. Use a 15- to 40-watt iron with a 1/8-inch tip. Keep the tip well tinned and clean. Do not overheat components or circuit board. Do not put excessive pressure on the board.

To remove a component, grip a lead with the tip of a pair of needle-nosed pliers. Touch the tip of the soldering iron to the connection. When the solder melts, gently pull the lead from the board. If a clean hole is not left in the board, reheat it and remove the solder with a solder removing device, or bore it out gently with a tooth-pick or similar non-abrasive device.

Defective multiple-lead components that cannot be removed by the above process should first be removed by cutting the leads. Then remove the leads one at a time and clean the holes as necessary. If the leads are not accessible, remove the solder from each contact point with a solder removing device, then work the component out, applying heat alternately to the connections involved.

To replace components, first bend the leads to the proper shape. Cut the leads to proper size if the extra lead length interferes with installation or cannot be reached for cutting after installation. Insert the leads in holes and set the component to the position of the original part. Reheat holes if necessary for proper insertion of the part. Apply heat sinks to component leads as necessary. The tips of needle-nosed pliers serve as excellent heat sinks if only the component being installed needs protection. Apply the iron and a small amount of solder to the connection. Do not remove the iron until the solder flows freely. After removing the iron, hold the component steady until the solder is firm. Clip any excess lead wire. Clean the solder area with a cotton-tipped swab and flux remover.

CAUTION

Ink used for circuit-board lettering will dissolve when contacted by certain types of solvents.

Cable Maintenance

The cables provided with the Engine Analyzer System are relatively rugged and should provide long operating life under normal use. Avoid abusing the cables and do not permit an excessive film of dirt to accumulate on them. Although the material used in cable construction is impervious to most materials, certain types of solvents can affect it. Cleaning should be done with a mild soap or detergent.

Note that the Capacitive Ignition Pickup cable has a .0068 μF capacitor installed beneath protective insulation in the vicinity of the pickup clamp. It is able to withstand considerable mechanical shock, but should not be abused.

Do not drop the cable ends against hard surfaces. Damage to the connectors can result. If any of the low-noise cables must be repaired, consideration must be given to the special semiconductor polyethylene which exists between the braided shield and the clear polyethylene insulation. See Fig. 4-5. This semiconductor material must be stripped back approximately $^3/_{16}$ inch from the end of the clear insulation when end-dressing the cable, to avoid a partial short-circuit between the conductor and the sheild.

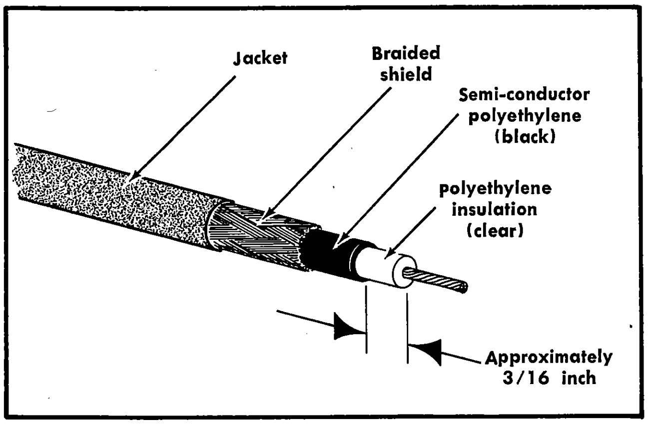


Fig. 4-5. Low-noise coaxial cable.

3A74 MAINTENANCE

General. Maintenance data pertaining specifically to the 3A74 is contained here. It is to be used in conjunction with the general maintenance information which is presented in the beginning of this section.

Component Locations

The major sections of the 3A74 are indicated in Fig. 4-8, which shows the terminal strip side of the unit. The components can be located by tracing them from associated vacuum tubes, transistors, switches or potentiometers identified on the chassis. Some of the less obvious components are identified as an aid for troubleshooting.

Components on the Charge Amplifier circuit board are identified in Fig. 4-9. The location of adjustable components in the channel 2, 3 and 4 attenuators is shown on the bottom cover plate of the Channel 4 VOLTS/DIV switch assembly.

Specific Component Information

Charge Amplifier Feedback Resistors. These components are hermetically sealed in glass cases to maintain minimum leakage around them. Do not touch the glass cases. Handle them by their leads rather than by the glass case. Do not bump them with tools or apply excessive heat to them. When bending their leads, use caution so that the ends of the glass envelope do not chip. Prebend the leads so that no continuous strain exists on the glass ends after they are installed.

Front Panel Controls. The switches and connectors are held in place by hexagonal nuts fastened on either the outside or inside of the panel. The potentiometers associated with the screwdriver adjustments are held in place by threaded bosses which are recessed to accept allen wrenches.

Channel 2, 3 and 4 Input Coupling Capacitors. These capacitors are mounted in insulated clamps to prevent loss of input signals. Care must be exercised to insure that adequate clearance exists between the capacitors and surrounding metal whenever work is performed in that area of the unit.

Transistors and Nuvistors. Base terminals for these components are identified in Fig. 4-6. It should be noted that heat dissipators are installed over Q444 and Q454. They must be in place whenever the unit is operating.

IMPORTANT

The high input impedance of Q204 and Q214 makes them subject to damage from excessive static charges when out of their circuits. Therefore, they require special handling considerations. The following precautions should be observed to avoid damaging them.

If replacements are obtained, keep them wrapped in their shipping material until they are ready to be inserted into the circuit.

Pick them up by the can; do not touch the terminal wires.

Always neutralize static charges before installing or removing them. This can be done by holding on to the equipment prior tc and during installation or removal.

Do not insert Q204 or Q214 into or remove them from the circuit or transistor tester while the circuit or tester socket is energized.

In circuit testing with a voltmeter having a high DC Ω/V sensitivity is the recommended troubleshooting procedure.

Troubleshooting by replacement is recommended only if circuit components are within limits and applied voltages are correct.

The case and collector of Q487 are connected together, and are insulated from ground by a micro insulator and a bakelite socket. Silicone grease is applied to both sides of the insulator to provide maximum heat dissipation. The insulators and silicone grease must be in place whenever the transistor is replaced.

Disassembly/Assembly Information

Q487 Mounting Plate Removal. Remove the nut from the front of the Channel 2 AC-GND-DC switch. Unsolder

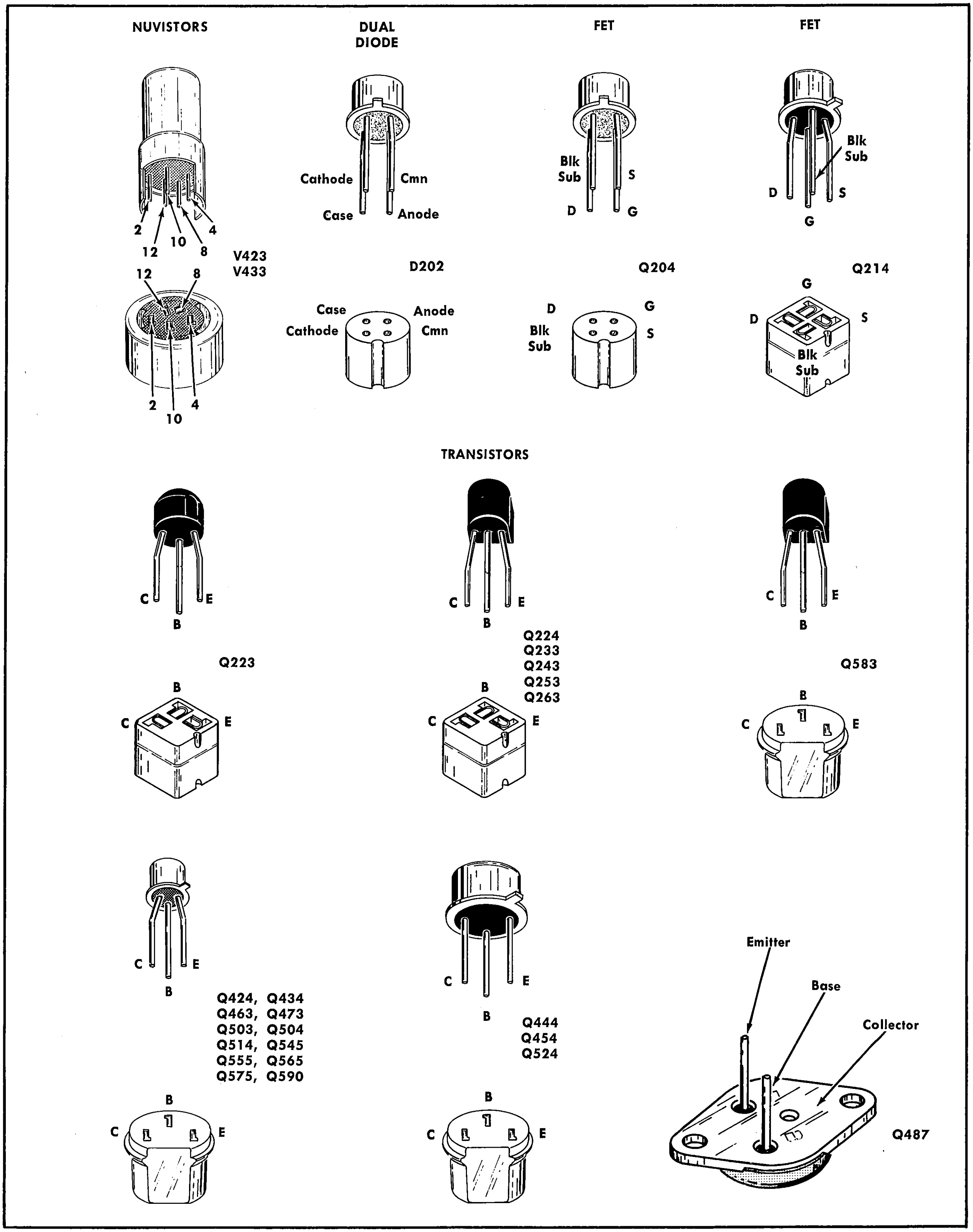


Fig. 4-6. 3A74 semiconductor and Nuvistor data.

the signal lead and shield wire from the Channel 2 input connector and its ground lug. Remove the two nuts from the lower edge of the plate. Lift the plate off the mounting screws. Pull the plate back and out, simultaneously extracting the Channel 2 AC-GND-DC switch from its mounting. Replace by reversing the procedure. Insure that the components on the rear of the plate do not touch or interfere with the operation of the Channel 1 switch assembly.

Channel 1 PSI/DIV Switch Removal. Unsolder two leads from the rear of the switch and two leads from the accessible area of wafer 1. (The third lead on wafer 1 can be unsoldered after the switch is out of its mounting.) Remove the knobs, using a $^{1}/_{16}$ inch allen wrench. Move the switch up, back and out. Reverse the procedure for replacement.

Channel 2 VOLTS/DIV switch and Attenuator Assembly Removal/Replacement. Unsolder the two leads from the potentiometer at the rear end of the assembly. Unsolder the purple-striped lead (rear of the attenuator housing) from the terminal located between V423 and V433 in Channel 2. Unsolder the yellow-striped lead (front of the attenuator housing) from the upper-center terminal of the AC-GND-DC switch. Remove the knobs from the Channel 2 VOLTS/DIV switch shaft. Remove the Charge Amplifier circuit board from the top of the Channel 2 attenuator assembly housing, after disconnecting the connecting pins and removing the four mounting screws. Remove four screws from the Channel 2 attenuator housing upper cover, and remove the cover. Insert a small phillips-head screwdriver into the attenuator assembly housing and remove the screw and nut which fasten the bottom of the assembly to the U-bracket between the Channel 2 and 4 assemblies. Remove the screw from the mounting post which connects the Channel 2 and 4 assemblies. Remove two screws from the mounting bracket at the front of the Channel 2 attenuator housing. Lift the assembly back, up and out. (Remove V433 if additional room is required.) Reverse the procedure to replace the assembly.

Channel 3 VOLTS/DIV switch and Attenuator Assembly Removal/Replacement. The Channel 4 assembly must be removed before the Channel 3 assembly can be removed. Once that has been done, proceed as follows:

Remove the Q487 mounting panel as previously explained. Remove the knobs and mounting nut from the Channel 3 VOLTS/DIV switch shaft. Unsolder the coaxial lead from the terminal between V423 and V433 in Channel 3. Remove the sheet metal screw from the V433 socket, releasing the shield soldering lug. Remove the machine screw and nut from the capacitor holding clamp on the bottom cover of the Channel 3 Attenuator housing. Loosen (do not remove) the two screws which hold the bracket in place at the front of the Channel 2 attenuator housing. Move the Channel 3 attenuator housing down and back, holding the Channel 2 attenuator housing up out of the way. Unsolder the red and white lead from the AC-GND-DC switch to enable complete removal of the assembly.

Channel 4 VOLTS/DIV Switch and Attenuator Assembly Removal/Replacement. Remove the knob from the front of the switch shaft. Unsolder two leads from the potentiometer at the rear of the assembly. Unsolder the purple-striped lead (rear of attenuator housing) from the terminal between V423 and V433 in Channel 4. Unsolder the yellow striped lead (front of attenuator housing) from the upper middle contact of the AC-GND-DC switch. Remove the lower cover plate from the assembly. Insert a small phillips-head screwdriver through the enclosure and remove the machine screw and nut from the U-bracket at the upper side of the assembly. At the Channel 2 attenuator assembly, remove the machine screw which connects to the post installed between the Channel 2 and 4 assemblies. Remove the two machine screws from the bracket at the front of the attenuator housing. Move the attenuator and switch housing back, up and out. Reverse the procedure for replacement.

2B67 MAINTENANCE

General. The simple construction of this unit permits component replacement with a minimum of disassembly. Individual components can be located by referencing them to associated tubes, switches and potentiometers, identified on the chassis or front panel.

The vacuum tube side of the unit is shown in Fig. 4-10, which also indicates the location and layout of the two circuit boards. Transistor and integrated circuit installation information is provided in Fig. 4-7.

The integrated circuit in the 2B67 (U380 on the Rotational Function Amplifier board) can be checked by comparing voltages against those given on the schematics. U380 should be replaced if improper outputs are obtained when applied voltages are correct and external components are within limits.

ROTATIONAL FUNCTION GENERATOR MAINTENANCE

General. Specific maintenance information for the Function Generator is contained here, and is to be used in conjunction with the general maintenance information which is contained in the beginning of this section. Fig. 4-11 should be referred to for component orientation.

CAUTION

The function generator disc and phototransistor window determine the signal outputs of the generator. Use care not to scratch or otherwise damage these parts. Do not rub the Function Generator Disc. Static charges may result. Refer to the Function Generator Disc topic for details.

Circuit Board and Transistors. Circuit board component layout is shown in Fig. 4-11, which also provides wiring information.

Disassembly/Assembly

Cover Removal. The hexagonal nut around the ROTATION DIRECTION switch and an acorn nut hold the cover in place. Most of the components are accessible once the cover is removed. Note that a spacer is mounted on the threaded stud to provide proper spacing between the cover and the main mounting bracket.

Removing the Function Generator From Its Base. The knurled thumb screw (Alignment Lock Screw) must be loosened and the allen screw (Thrust Detent Screw) which is located immediately below it must be partially removed to

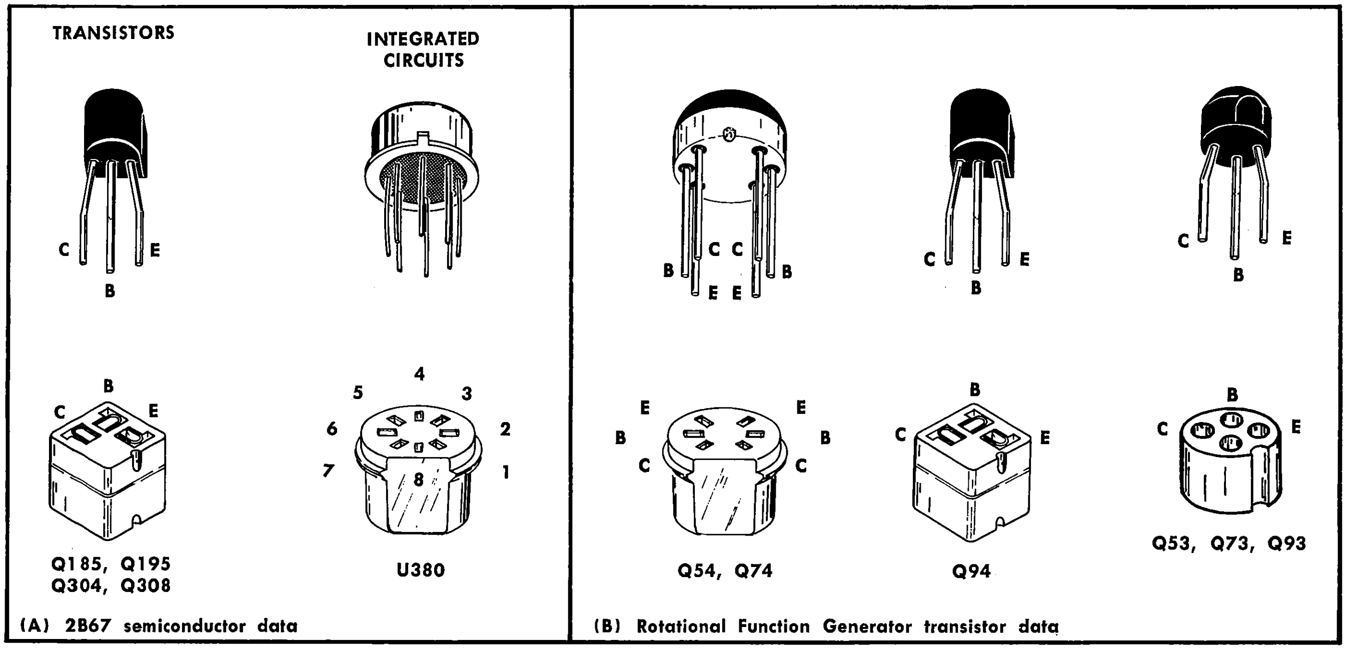


Fig. 4-7. Semiconductor installation.

permit the Function Generator to be withdrawn from the base. It can then be removed in either direction.

Main Mounting Bracket. The Generator must be removed from the base before the main mounting bracket can be removed. Note that a spring ground contact is installed beneath a rear mounting screw.

Phototransistor Mounting Bracket. The accuracy of the signals from the Generator is partially dependent upon the positioning of the phototransistor block. This is controlled by the screws which hold the phototransistor mounting bracket to the main mounting bracket. The block should be aligned as explained in the Calibration Procedure after any maintenance which requires loosening or removal of these screws.

Phototransistor and Light Window. The light window is glued in place and should not be removed. Care should be used to avoid scratching or otherwise damaging the window, since it will affect the signal output. The phototransistors can be replaced by loosening set screws at the side of the phototransistor block and withdrawing both the base and transistor from the mounting hole. Carefully pull on the transistor base leads with an even pressure to remove the base and transistor from the mounting block. The base and transistor must be re-inserted to a depth determined by the transistor sensitivity. Perform the signal amplitude adjustment in the Rotational Function Generator Calibration Procedure whenever the transistors are replaced, or when transistor location is disturbed.

Bearings and Function Generator Disc. The shaft bearings are permanently lubricated and should require no additional attenuation. The Function Generator is treated with an anti-static substance to prevent build-up of static charges. These charges could distort the output of the phototransistors. Avoid rubbing the Generator Disc. If re-treatment is necessary, clean the disc and coat it with ANASTAC "M", Tektronix Part No. 006-0503-00. The Function Generator Disc is held in place against the forward bearing by an elastic stop-nut, which should be tight enough to prevent slippage, but not so tight as to damage or warp the generator disc. The lamp excitation wires must be kept clear of the disc. A wrench slot is provided on the shaft to hold it in the event the elastic stop-nut must be adjusted.

Lamp Replacement. The lamps have an extremely long life and seldom require replacement. However, a decrease in signal output or a lack of signal accuracy can be indicative of an inoperative lamp. The phototransistor excitation lamps are accesible through the front of the Rotational Function Generator. Remove the dial clamping nut on the dial, exposing the lamp and bearing ground-return plate. Remove the two screws. The outer end of the plate will then spring up and it can then be removed. Lamps can then be replaced individually. Insure that the spring is removed from the old lamp and attach to the new one prior to installation. It is required to insure adequate base contact. Check that each lamp and spring move freely in their mountings by depressing the base of the lamp and noting that it springs out when pressure is removed. Clean all contact points prior to reassembly. When replacing the ground return plate, insert the ear in its detent first. Then push down on the outer end and hold it in place while replacing the screws. Check that the ear is making contact with the bearing. Install the spring ground clip so that the convex surface will touch the Angular Reference Dial. After assembly, check that the lamp excitation wires will not interfere with the function generator disc.

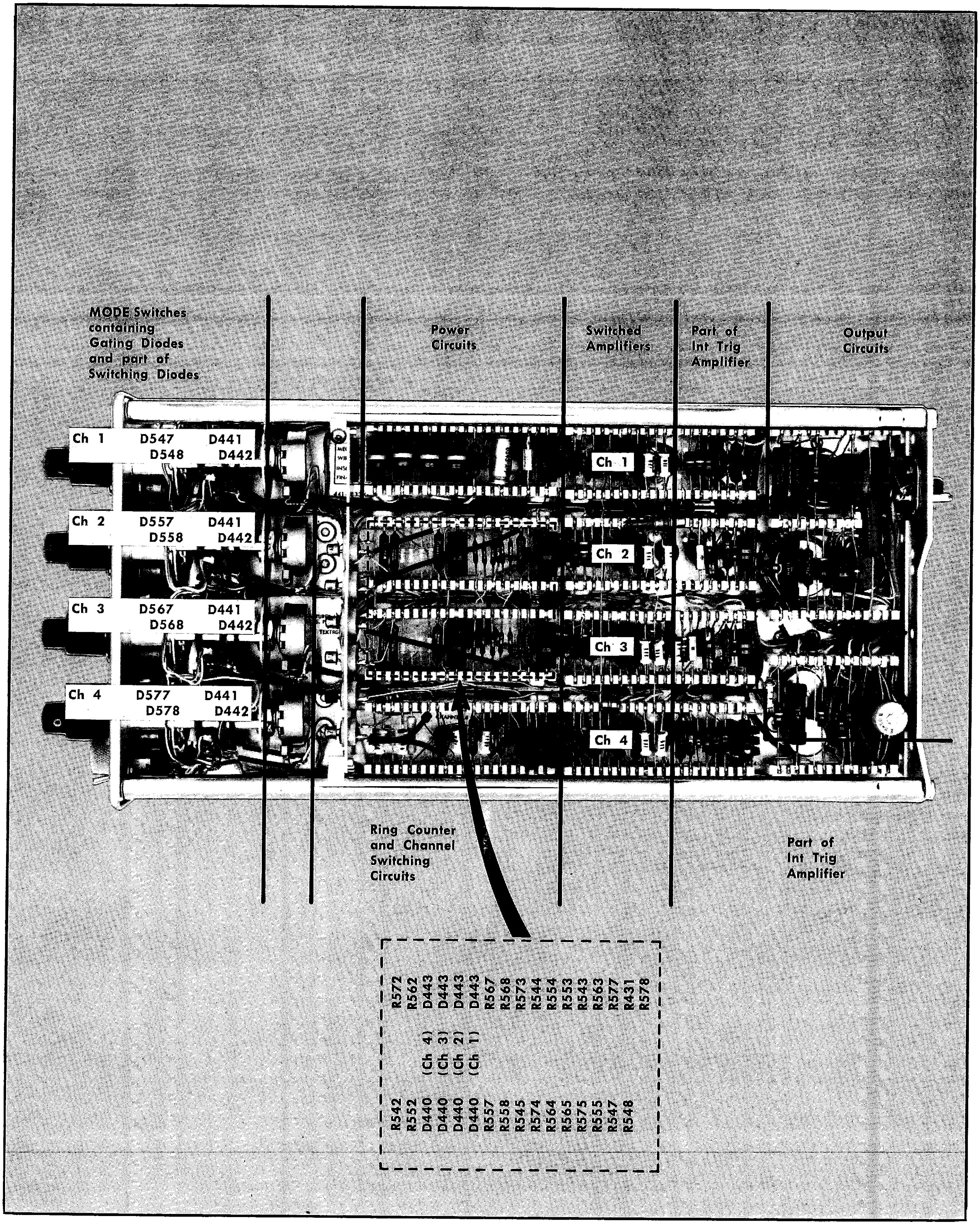


Fig. 4-8. Terminal strip side of 3A74. General location of circuits and identification of less-obvious components.

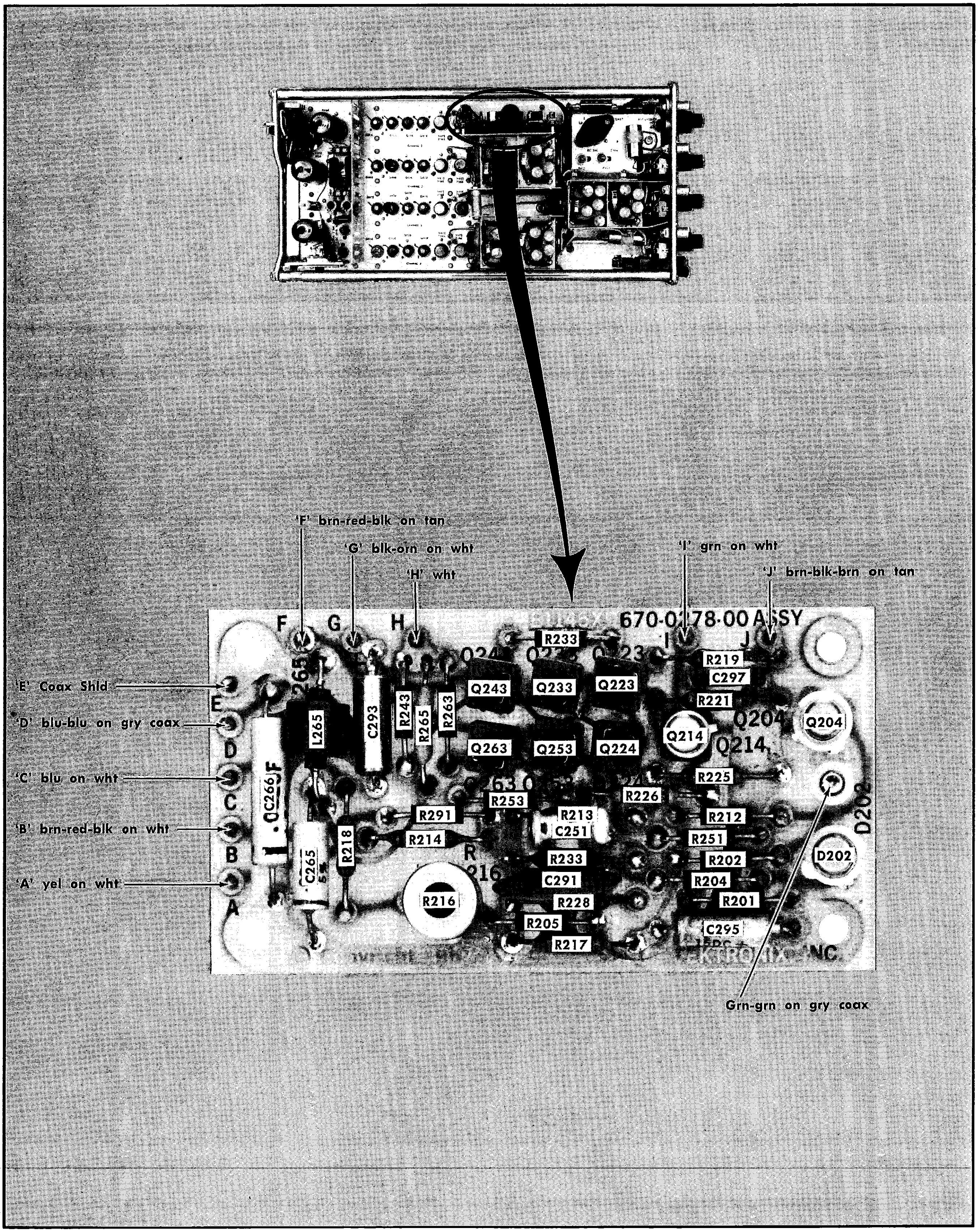


Fig. 4-9. 3A74 Charge Amplifier circuit board.

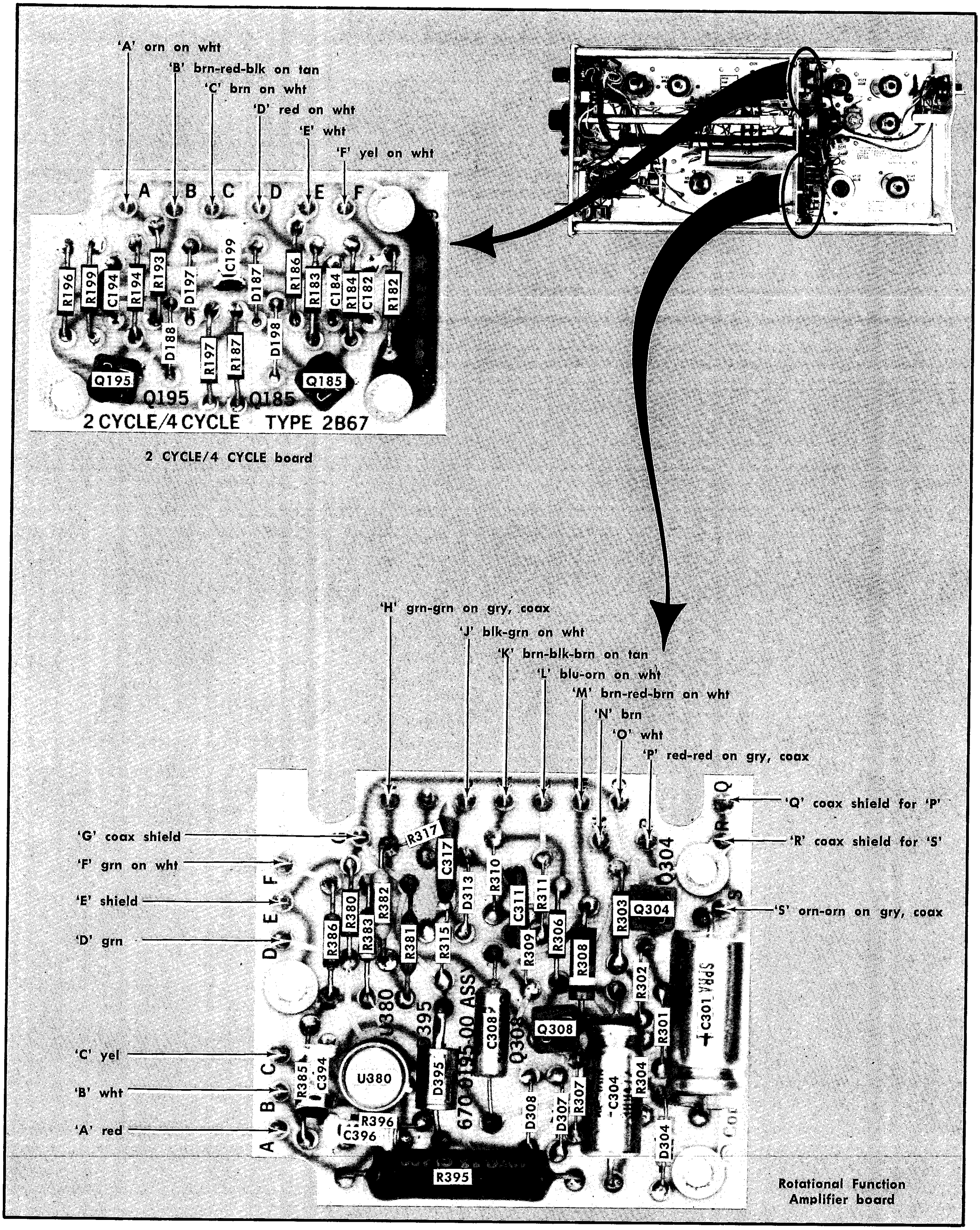


Fig. 4-10. 2B67 circuit boards.

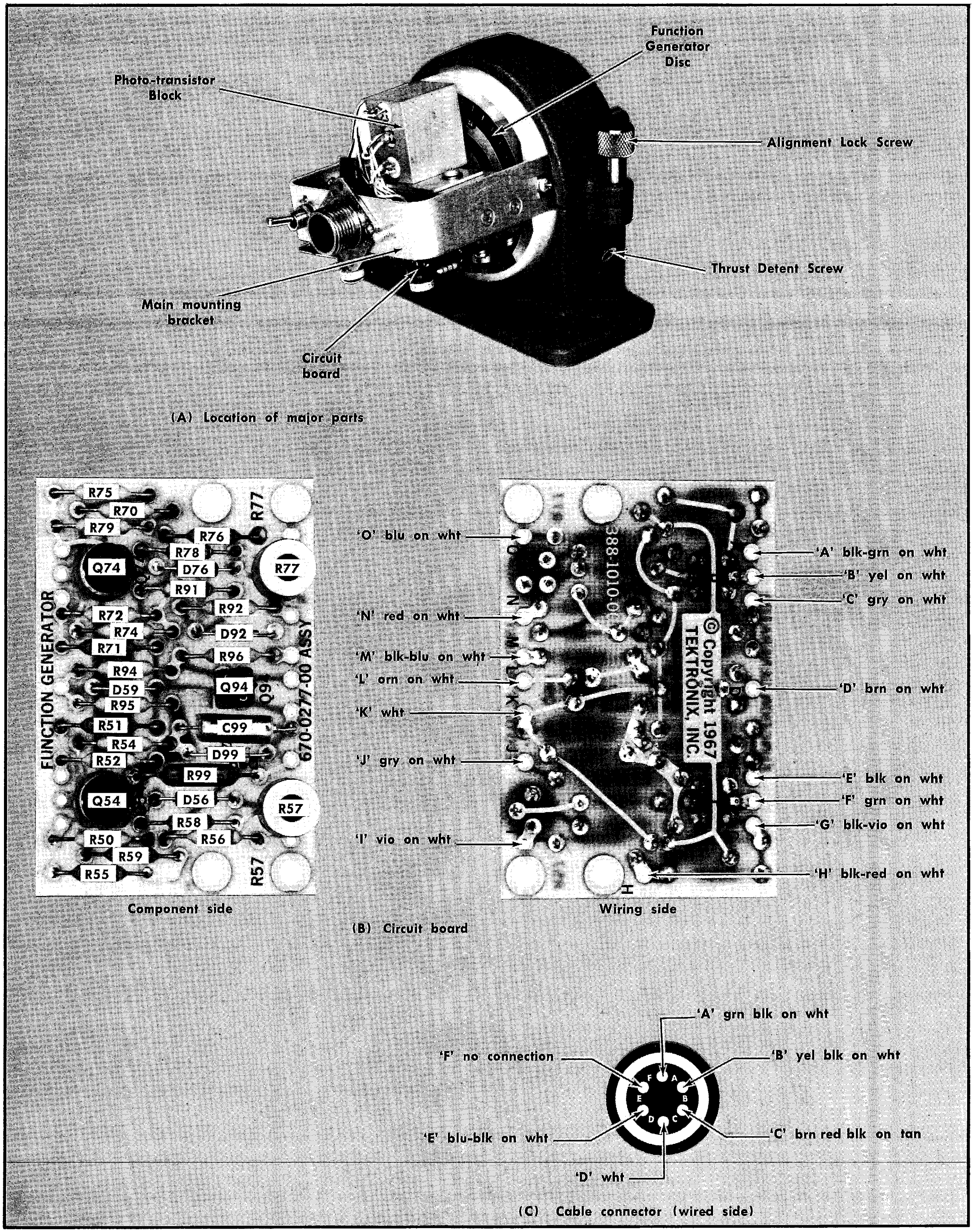


Fig. 4-11. Rotational Function Generator.

SECTION 5
PERFORMANCE CHECK/CALIBRATION PROCEDURE

Change information, if any, affecting this section will be found at the rear of the manual.

General

The Engine Analyzer System components should be Performance Checked and calibrated as necessary every 6 months or 500 operating hours, whichever occurs first.

This section contains Performance Checks and Calibration Procedures in combined form, and either can be performed by following the application directions. The Performance Checks permit comparison of equipment operation against specifications given in Section 1, without removing the equipment covers. The Calibration Procedures contain these same checks and include directions for calibrating the equipment to the limits specified in Section 1.

Procedures for the 3A74, 2B67, and for the Rotational Function Generator appear here. They can be performed in the given sequence, or can be done individually. A list of equipment required for each procedure is contained in Table 5-1.

A short form procedure for the three instruments is contained immediately preceding the 3A74 procedure. It can be used as an index or as a short form Performance Check/Calibration Procedure for experienced calibrators. It is also useful as a check-off list which can be retained as a permanent record of calibration. If it is used in the latter manner, it is recommended that duplicate copies be made.

If a complete procedure is being done, the steps of each procedure should be performed in the sequence given, since many of the steps are dependent upon preceding steps. Each adjustment should be made as accurately as possible.

INTERACTION comments should be ignored if a complete Performance Check or Calibration Procedure is being done. However, if an adjustment is made during a partial procedure, any steps listed under INTERACTION should be checked.

The term "division" used throughout the procedure refers to the 10 major horizontal graticule divisions and the 8 major vertical divisions.

Equipment Required

The equipment listed in Table 5-1 is required for performing the three calibration procedures which make up the Engine Analyzer System Performance Check/Calibration Procedure. Equipment required for each of the three procedures is indicated in the appropriate column. An "X" indicates that the equipment is required for the Calibration Procedure. A "P" indicates that it is required for the Performance Check. The equipment and accessories are illustrated in Fig. 5-1 and 5-2.

TABLE 5-1

Equipment Required

Item		3A74	2B67	Rotational Function Generator
	Equipment (Fig. 5-1)			
1	Oscilloscope, Tektronix 561-Series or 564-Series	XP	XP	XP
2	3A74 (Mod 730A) Engine Analyzer Amplifier	XP	XP	XP
3	2B67 (Mod 730A) Engine Analyzer Time Base	XP	XP	XP
4	Rotational Function Generator and Cable Assembly		XP Optional	XP
5	Test Oscilloscope, Bandwidth DC to 10 MHz; minimum deflection factor 50 mV/division or less; Tektronix Type 422 Oscilloscope recommended	X	XP	X
6	DC Voltmeter, 10,000 Ω/V or more DC sensitivity	X	Optional; Test Oscilloscope can be substituted if it has DC measurement capabilities	X
7	Standard Amplitude Calibrator having 1 kHz square wave output with $\leq$ 0.25% amplitude error; Tektronix Standard Amplitude Calibrator, Part No. 067-0502-00, recommended.	XP		

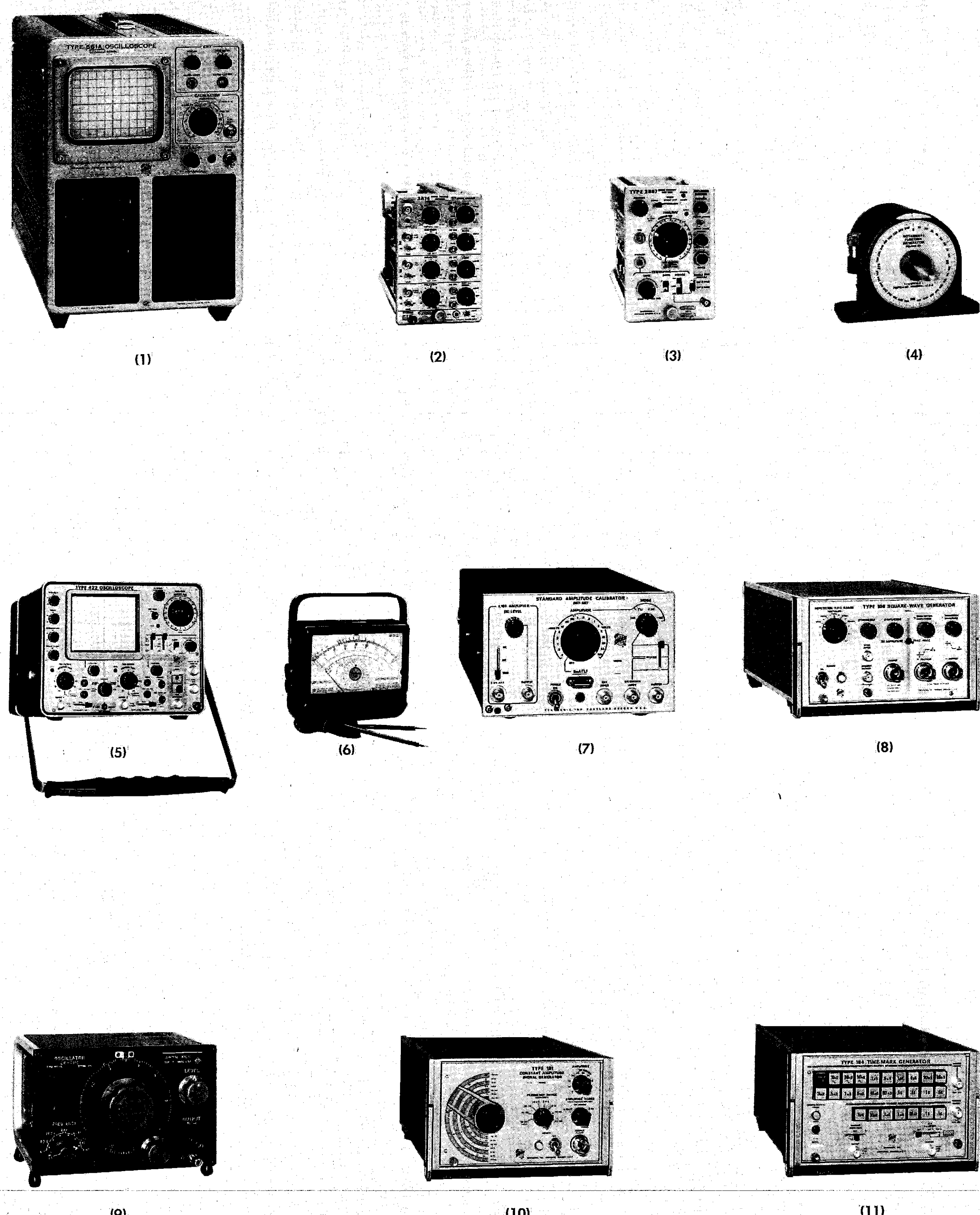


Fig. 5-1. Equipment required for calibrating the Engine Analyzer System.

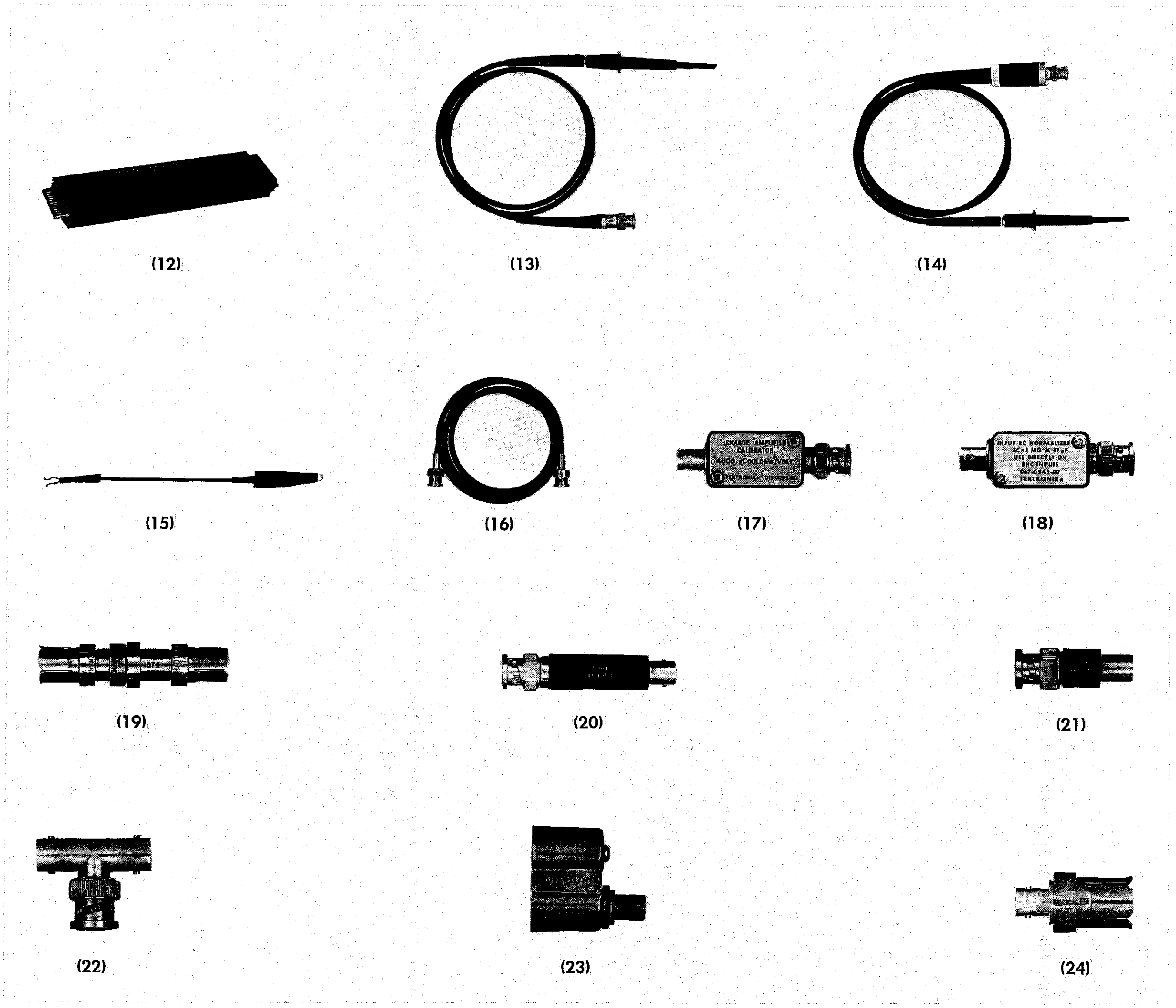


Fig. 5-2. Accessories required for calibrating the Engine Analyzer System.

8	Square Wave Generator with following capabilities: 0.5 V at 1 kHz, 200 mV at 5 kHz, 80 mV at 10 kHz, 100 mV at 100 kHz; risetime 50 ns or faster; Tektronix Type 106 Square Wave Generator recommended	XP	XP	
9	Low Frequency Sine Wave Generator with following capabilities: 0.5 V at 5 Hz, 50 mV at 1 kHz, 0.5 V at 75 kHz, 2 V at 2 MHz; General Radio Oscillator Type 1310A used in the accompanying procedure.	X Optional see note in step 23	XP	
10	Constant Amplitude Sine-Wave Generator with 50 kHz and 2 MHz capabilities; Tektronix Type 191 Constant Amplitude Signal Generator recommended	XP Optional see note in step 23		
11	Time Mark Generator having markers at 1 μs through 5 s intervals in 1-5-1-5 sequence; accuracy within 0.1%; Tektronix Type 184 Time Mark Generator recommended		XP	
	Accessories (Fig. 5-2)			
12	Extension, Plug-in; Tektronix Part No. 013-0034-00	X	X	

13	Probe, 1×; Tektronix P6011 recommended		XP	XP
14	Probe, 10×; Tektronix P6012 recommended	X		
15	Probe Ground Lead, 5-inch, equipped with Alligator Clip; Tektronix Part No. 175-0124-00 and 344-0046-00	X		
16	Coaxial Cable, 42-inch; two required; Tektronix Part No. 012-0057-01; (18-inch cable, Tektronix Part No. 012-0076-00 can be substituted for either one)	XP	XP	
17	Charge Amplifier Calibrator; Tektronix Part No. 011-0095-00; standard accessory	XP		
18	Input RC Normalizer, 47 pF; Tektronix Part No. 067-0541-00	XP		
19	5:1 GR Attenuator; Tektronix Part No. 017-0079-00	XP		
20	5:1 BNC Attenuator; Tektronix Part No. 011-0060-00		X	
21	Termination, 50 Ω, BNC; Tektronix Part No. 011-0049-00	XP	XP	
22	Adapter (BNC-Tee), 1 BNC Male to 2 BNC Female; Tektronix Part No. 103-0030-00	XP	XP	
23	Adapter, Dual Banana Plug to BNC; Tektronix Part No. 013-0094-00	XP Optional; used with Low-Frequency Sine Wave Generator; see note in step 23	XP	
24	Adapter, GR to BNC Female; Tektronix Part No. 017-0063-00	XP	XP	
25	Resistor, 2 kΩ, 5%, ¼ W		XP	XP
26	Capacitor, .033 μF, ±10%	XP		
	Tools (Not shown)			
27	Screwdriver, ⅛ inch Standard Tip	XP	X	X
28	Screwdriver, No. 1 Phillips Head Tip			X
29	Screwdriver, Alignment, Plastic with Metal Tip; Tektronix Part No. 003-0000-00		X	XP
30	Rod, Alignment, 0.1 inch Hexagonal; for powdered iron slugs; Tektronix Part Number 003-0003-00	X	X	
31	Rod, Alignment, 0.1 inch Hexagonal; for powdered iron slugs; Tektronix Part No. 003-0301-00	X		
32	Wrench, 5/16 inch; box, open end or spintite			X
33	Allen Wrench, .050			X

NOTES

TABLE 5-2

Adjustment Index

3A74		2B67	
Adjustment	Step	Adjustment	Step
C403B		C160A	
C403C		C160B	11
C405B		C321	
C405C		C341	
C407B	15	R111	2
C407C		R176	7
C409B		R325	17
C409C		R334	4
C416		R341	5
C435	18	R346	6
C597	13		
L464 L474	20	**Rotational Function Generator**	
R216	2	R57	2
R270	10	R77	5
R427 (Ch. 1)	2		
R427 (Ch. 2, 3, 4)	3		
R436 (Ch. 1)	8		
R436 (Ch. 2, 3, 4)	11		
R449	4		
R477	7		
R521	17		
R530	16		

SHORT FORM PROCEDURE

3A74 Mod 730A Engine Analyzer Amplifier

☐ 1. Check Regulated Voltages (Page 5-8)

+50 V ±5 V at D494-R494 junction; +12 V ±1 V at R487-D487 junction; +11.2 V ±1 V at Charge Amplifier Board terminal G.

☐ 2. Check/Adjust DC Balance, Channel 1 (Page 5-9) (COARSE DC BAL R216, DC BAL R215, INT DC BAL R427)

0.1 div or less trace shift accompanies PSI/DIV switching—adjust R216 COARSE DC BAL and R215 DC BAL; minimum trace shift accompanies R436 GAIN RANGE rotation—adjust R427 INT DC BAL.

☐ 3. Check/Adjust DC Balance, Channel 2, 3, 4 (Page 5-10) (DC BAL—R427)

0.1 div or less trace shift accompanies VAR GAIN rotation—adjust DC BAL; repeat at all channels.

☐ 4. Check/Adjust POSITION RANGE—R449 (Page 5-10)

All four traces within 1 division of CRT electrical center with POSITION knobs at midrange.

☐ 5. Check Channel 1, 2, 3 and 4 Input Amplifier Output Current Balance (Page 5-11)

Trace shift within 2.5 divisions when switching MODE between NORM and INV.

☐ 6. Check Grid Current and Microphonics (Page 5-11)

Trace shift within 0.1 division when switching Channel 2, 3 or 4 between GND and DC; Noise (ringing) within 1 division in response to tapping on front panel, Channels 1, 2, 3 and 4.

☐ 7. Check/Adjust Output Amplifier Gain (CAL—R477) (Page 5-12)

40 V peak-to-peak at V464 plate with 2 V peak-to-peak at emitter of Q463; calibrator square wave applied to a channel input connector.

☐ 8. Check/Adjust Channel 1 Gain Range (GAIN RANGE—R436) (Page 5-14)

0.2 V square wave applied to Charge Amplifier Calibrator at Channel 1 Input connector; Channel 1 GAIN 15° from full clockwise position; 8 divisions ±0.2 division deflection—adjust R436 GAIN RANGE

☐ 9. Check Channel 1 Attenuation and Noise Due to Shunt Input Capacitance (Page 5-14)

Within 0.1 division of attenuation of 8 division signal results from shunting .033 μF capacitor from Channel 1 input connector to ground; trace thickness 0.3 division with .033 μF capacitor between input connector and ground, no signal applied.

☐ 10. Check/Adjust Channel 1 Gain (GAIN—R270); Check Attenuation Ratio Accuracy (Page 5-15)

Adjust GAIN for 8 divisions at 1 PSI/DIV with .2 V applied through Charge Amplifier Calibrator; check gain with Table 5-3; then readjust GAIN in accordance with Table 2-2.

☐ 11. Check/Adjust Channel 2, 3 and 4 Gain (GAIN—R436); Check Channel 2, 3 and 4 Variable Gain (VAR GAIN); Check Attenuation Ratio Accuracy. (Page 5-15)

Adjust GAIN for 5 divisions at 20 mV/DIV with .1 V applied; check for 2 div or less with VAR GAIN fully inserted; check gain attenuation with Table 5-4.

☐ 12. Check CHOP Mode of Operation (Page 5-16)

1, 2, 3 or 4 traces available in CHOP mode with MODE switches at NORM or INV; CHOP period time of 2 μs ±0.6 μs.

☐ 13. Check Chopped Blanking; Check/Adjust Chopped Blanking Pulse Amplitude (C597) (Page 5-17)

Chopped Blanking switch obscures chopped blanking transients; 35 V peak to peak ±2 V chopped blanking pulse at Chopped Blanking switch terminal—adjust C597; trace segments "on" for at least 6/10 of CHOP period time; each channel trace thickness within 0.1 division during FREE RUN.

☐ 14. Check Alternate Mode Operation (Page 5-18)

In ALT mode, trace alternates through four channels in all numbered positions of 2B67 TIME/DIV switch.

☐ 15. Check/Adjust Channel 2, 3 and 4 Input Capacitance and Attenuator Compensation (C416, C403B, C403C, C405B, C405C, C407B, C407C, C409B, C409C) (Page 5-18)

5 division square wave applied through 47 pF Normalizer—adjust C416 for square corner on Channels

2, 3 and 4; check/adjust for square corners according to Table 5-5, Channel 2, 3 and 4.

☐ 15 Alternate. Same as 15, except for using 10× probe and 1 calibrated channel in place of 47 pF Normalizer. (Page 5-20)

☐ 16. Check/Adjust Composite Internal Trigger DC Level (COMPOSITE INT TRIG DC LEVEL—R530) (Page 5-20)

0 V ±0.5 V Composite internal trigger DC level at 2B67 interconnecting plug terminal 12 with one trace on and centered, TRIGGER knob pushed in.

☐ 17. Check/Adjust Channel 2 Internal Triggering DC Level (CHAN 2 INT TRIG DC LEVEL—R521) (Page 5-21)

0 V ±0.5 V Channel 2 internal triggering DC level with Channel 2 on and centered, TRIGGER knob out.

☐ 18. Check/Adjust Channel 2 Trigger Signal Noise (C435); Check Channel 2 Trigger Amplitude and Risetime (Page 5-21)

All Channels on, CHOP mode, TRIGGER switch out, no signal applied; trigger noise at terminal 12 of 2B67 interconnecting plug within 0.5 V peak to peak—adjust C435; $\geq$10 V signal at terminal 12 with 4 division square wave signal displayed on Channel 2, and other channels off; risetime $\leq$0.7 μs.

☐ 19. Check Composite Internal Triggering Signal Amplitude (Page 5-22)

TRIGGER switch pushed in; 9.5 V signal at terminal 12 of 2B67 interconnecting plug with 4-division square wave displayed on channel 2.

☐ 20. Check/Adjust High Frequency Response (Page 5-22)

Optimum square corner of 5 division square wave.

☐ 21. Check Vertical Compression and Expansion (Page 5-23)

Compression/expansion at CRT top and bottom within ±0.1 division of 2 division display.

☐ 22. Check Channel 1 Bandwidth (Page 5-23)

Risetime within 35 ns with square wave applied through Charge Amplifier Calibrator.

☐ 23. Check Channel 2, 3 and 4 Bandwidth (Page 5-25)

Attenuation within 3 dB at 2 MHz.

2B67 Engine Analyzer Time Base

☐ 1. Check Single Sweep Operation (Page 5-27)

☐ 2. Adjust Triggering Stability (STABILITY—R111) (Page 5-27)

Set midway between AUTO "on" trace and bright trace; TIME/DIV at .1 ms.

☐ 3. Check Triggering Sensitivity, Slope, Level (Page 5-27)

EXT triggering from 0.5 V at 5 Hz to 2 V at 2 MHz; INT triggering from 0.4 division of 1 kHz square wave; Triggers from various points of both slopes of larger signals.

☐ 4. Check/Adjust Basic Magnified Sweep Timing (CAL—R334) (Page 5-28)

Timing accurate within 5% at .2 ms/division (1 ms/div and 5× MAG).

☐ 5. Check/Adjust Basic Unmagnified Sweep timing (SWP GAIN—R341) (Page 5-28)

Timing accurate within 3% over 8 divisions at 1 ms/div.

☐ 6. Check/Adjust Magnified Sweep Registration (SWP MAG REGIS—R346) (Page 5-29)

Registration within 0.2 division (TIME/DIV at 1 ms).

☐ 7. Check/Adjust Sweep Length (SWP LENGTH—R176) (Page 5-29)

At least 10 divisions; normally 10.5.

☐ 8. Check Variable Time/Division Range (TIME/DIV VARIABLE) (Page 5-30)

Range of 2.5:1

☐ 9. Check Horizontal Positioning Range (POSITION) (Page 5-30)

Either side of trace can be set to graticule center.

☐ 10. Check Slow Sweep Rate Accuracy (Page 5-30)

Check according to Table 5-6.

☐ 11. Check/Adjust Fast Sweep Rate Accuracy and Linearity (C160A, C160C, C321, C341). (Page 5-31)

10 μs/division (50 μs/DIV and 5× MAG) accurate within 5% with POSITION near midrange—adjust C160C; 2 μs/division (10 μs/DIV and 5× MAG) accurate within 5% with POSITION clockwise—adjust C321; 1 μs/division (5 μs/DIV and 5× MAG) accurate within 5% with POSITION near midrange—adjust C160A; 1 μs/div (MAG off) accurate within 3% at first 3 division—adjust C341; check unmagnified fast sweep rate accuracy according to Table 5-7.

☐ 12. Check Rotational Function Single Sweep Display Operation (Page 5-32)

2 triggers per on-off cycle at 360°; 3 triggers per on-off cycle at 720°.

☐ 13. Check Rotational Function Marker Amplifier Operation (Page 5-34)

Approximately 1.5 division display with 50 mV square wave (or 1.3 division display with 40 mV square wave) applied through 2 kΩ resistor to INPUT terminal E.

☐ 14. Check Rotational Function Amplifier Maximum and Minimum Deflection Factors (Page 5-34)

At least 100 mV/division with WIDTH counterclockwise; 10 mV/division or less with WIDTH clockwise.

☐ 15. Check Rotational Function Amplifier Upper Frequency Response (Page 5-35)

Attenuation within 3 dB at 100 mV/division with 75 kHz input; attenuation within 3 dB at 10 mV/division with 25 kHz input.

☐ 16. Check Standby Trace Operation (Page 5-36)

Standby trace present with TIME/DIV at ROTATIONAL FUNCTION GENERATOR, Function Generator attached, shaft stopped; Standby trace disabled above 25 RPM shaft rotation.

☐ 17. Check/Adjust Rotational Function (Page 5-36)
WIDTH Registration (ROTATIONAL FUNCTION REGIS—R325)

Stop to stop WIDTH rotation accompanied by not more than 0.4 division center display movement.

☐ 18. Check Rotational Function Positioning (Page 5-37)
Range

(ROTATIONAL FUNCTION) POSITION capable of placing either end of trace to graticule center with WIDTH control at either extreme.

Rotational Function Generator

Preliminary Procedure. Inspect the phototransistor block for parallelism with the function generator disc.

☐ 1. Check 9-V Zener Supply (Page 5-39)

9 V at D99-R99 junction.

☐ 2. Check/Adjust Sawtooth Signal DC (Page 5-39)
Balance (SAWTOOTH DC BAL—R57)

Same trace position with ROTATIONAL DIRECTION switch in either position.

☐ 3. Check/Adjust Signal Linearity (Page 5-39)

Equal spacing of degree markers; center marker on tall pedestal within 0.24 division of center with 10 division centered display—adjust photo-transistor block up-down position.

☐ 4. Check/Adjust Sawtooth Signal Amplitude (Page 5-41)

Between 200 and 500 mV—adjust photo-transistor depth.

☐ 5. Check/Adjust Sine Wave Signal DC (Page 5-41)
Balance and Sine Wave Signal Amplitude (SINE DC BAL—R77)

PISTON trace same position and amplitude as CRANK trace—adjust SINE DC BAL and photo-transistor depth respectively.

☐ 6. Check/Adjust Signal Phasing (Page 5-43)

Superimposed markers on PISTON display—adjust photo-transistor block left-right position.

☐ 7. Check Amplitude of Marker Signals (Page 5-43)

30 mV or more amplitude of center mark on tall pedestal above signal baseline.

☐ 8. Recheck/Readjust SAWTOOTH DC BAL (Page 5-44)
and SINE DC BAL

With Function Generator cover on, adjust SAWTOOTH DC bal for minimum CRANK display shift accompanying ROTATION DIRECTION switching; adjust SINE DC BAL for minimum display shift accompanying PISTON-CRANK switching.

☐ 9. Alternate Performance Check/ (Page 5-44)
Calibration Procedure

3A74 PERFORMANCE CHECK/CALIBRATION PROCEDURE

Preliminary Procedure

Install the 3A74 and the 2B67 into the left and right compartments of the 561-series or 564-series Oscilloscope.

If a Calibration Procedure is being done, remove the side covers from the Oscilloscope.

NOTE

During the following procedure it is important that the Channel 2, 3 and 4 VAR GAIN controls remain at CAL position except when noted otherwise. In addition, all measurements should be made from trace center to trace center to avoid including trace width in the measurements.

NOTES

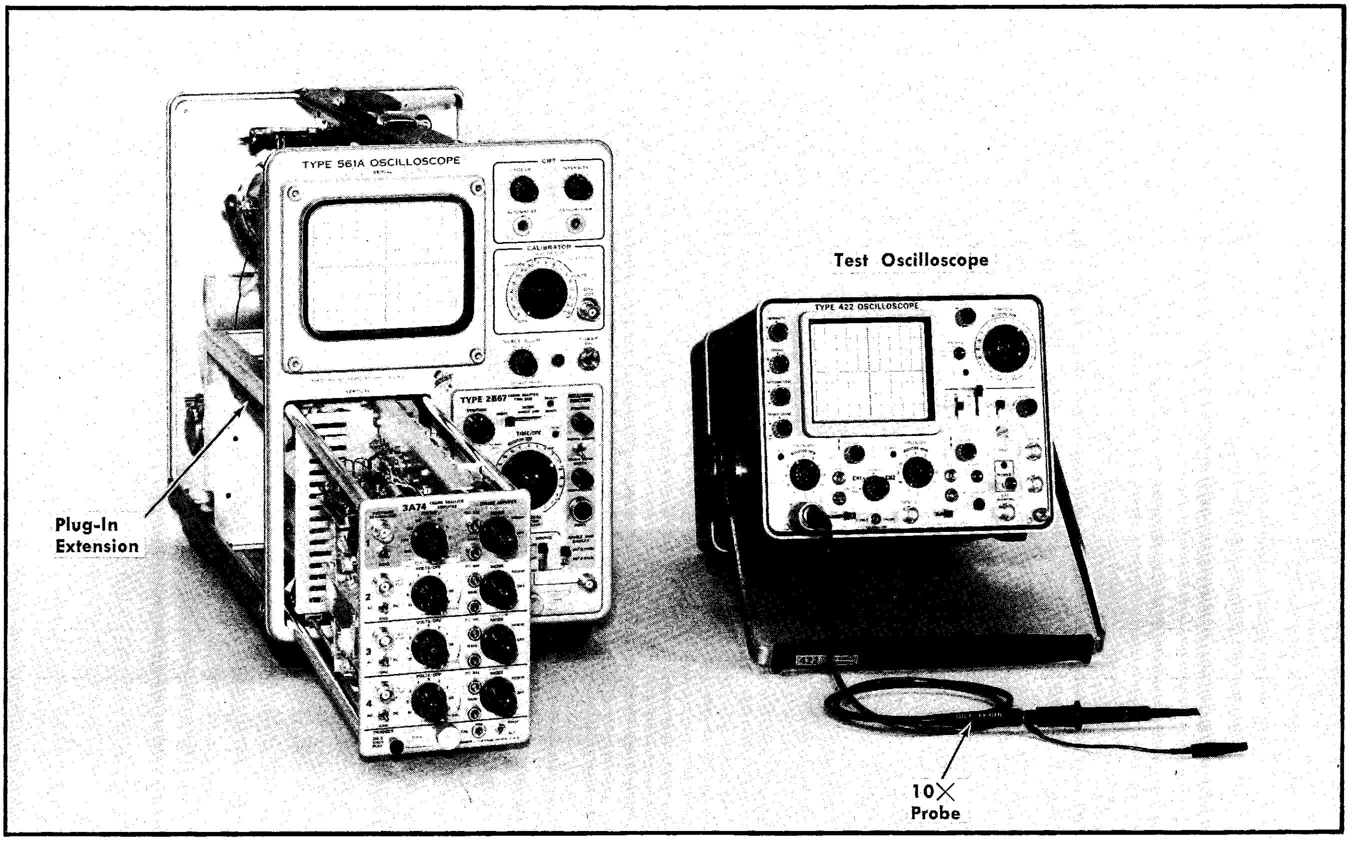


Fig. 5-3. Equipment arrangement for step 1.

Preliminary Setup

Set the equipment controls as follows:

3A74

Channel 1	
PSI/DIV	10
RESTORE TIME	SHORT
MODE	OFF
POSITION	Midrange
Channel 2, 3, 4	
AC-GND-DC	GND
VOLTS/DIV	.02
MODE	OFF
POSITION	Midrange
TRIGGER	In
CHOP-ALT	CHOP

2B67

POSITION	Midrange
MODE	NORM
TIME/DIV	.1 ms
VARIABLE	CAL
TRIGGERING	
LEVEL	FREE RUN
SLOPE	—
SOURCE	INT
ROTATIONAL FUNCTION	
POSITION	Midrange
PISTON-CRANK	CRANK
WIDTH	Fully CCW
MARKERS	In

1. Check Regulated Voltages

a. Omit step 1 if a Performance Check is being made, and proceed with step 2. If a Calibration Procedure is being done, continue with step 1-b.

b. The preliminary control setup applies. The equipment arrangement is shown in Fig. 5-3.

c. Remove the 3A74 from the assembly and install a plug-in extension (item 12) into the Oscilloscope. Connect the 3A74 to the extender. Connect all equipment to appropriate power sources. Energize the Oscilloscope and test equipment to be used and permit 5 minutes warmup time before continuing. Adjust the Oscilloscope INTENSITY and FOCUS controls as necessary to obtain a sharp trace having an intensity consistent with good viewing.

NOTE

The Test Oscilloscope is referred to by that name throughout the procedure. The Oscilloscope being used with the 3A74 is referred to as Oscilloscope or as 561-Series or 564-Series Oscilloscope.

d. Connect the Test Oscilloscope (item 5), or DC Voltmeter (item 6), negative lead to ground. Connect the signal probe to the D494-R494 junction. See Fig. 5-4.

e. CHECK— +50 V ±5 V.

f. Move the signal probe to the R487-D487 junction (Fig. 5-4).

g. CHECK— +12 V ±1 V.

h. Move the signal probe to terminal G on the Charge Amplifier circuit board (Fig. 5-4).

i. CHECK— +11.2 V ±1 V.

j. Disconnect the Signal probe from the 3A74.

k. De-energize the Oscilloscope and disconnect the 3A74 from the plug-in extender. Remove the extender from the Oscilloscope and install the 3A74 in the plug-in compartment. Turn the Oscilloscope on.

2. Check/Adjust DC Balance, Channel 1

a. The preliminary control setup applies. The equipment arrangement appears in Fig. 5-5.

b. Switch the Channel 1 MODE switch to NORM. Check that the Channel 1 POSITION control is at midrange.

c. Calibration Procedure Only.

(1) If the trace is not present on the face of the CRT, set R427, INT DC BAL (Fig. 5-6) and R215, DC BAL (front panel) to midrange.

(2) If the trace still is not present, hold the Channel 1 ZERO button depressed and adjust R216, COARSE DC BAL (Fig. 5-6) as necessary to bring the trace within the graticule viewing area.

(3) ADJUST—COARSE DC BAL (R216, Fig. 5-6) until less than 0.5 division of trace shift accompanies switching the PSI/DIV control between the 5 and 10 PSI/DIV positions.

(4) ADJUST—DC BAL (R215, front panel) until minimum trace shift (less than 0.1 division) accompanies switching between the 5 and 10 PSI/DIV positions.

d. Performance Check Only.

(1) If the trace is not present on the face of the CRT, hold the Channel 1 ZERO button depressed and adjust the Channel 1 DC BAL control (front panel) as necessary to bring the trace to graticule center.

(2) CHECK—DC Balance. Rotate the PSI/DIV switch to 5 and check that the accompanying trace shift does not exceed 0.1 division.

(3) ADJUST—Channel 1 DC BAL (front panel) until minimum trace shift (not exceeding 0.1 division) accompanies switching between the 5 and 10 PSI/DIV positions.

e. If a Performance Check is being made, omit steps 2-f through 2-h and proceed with step 3.

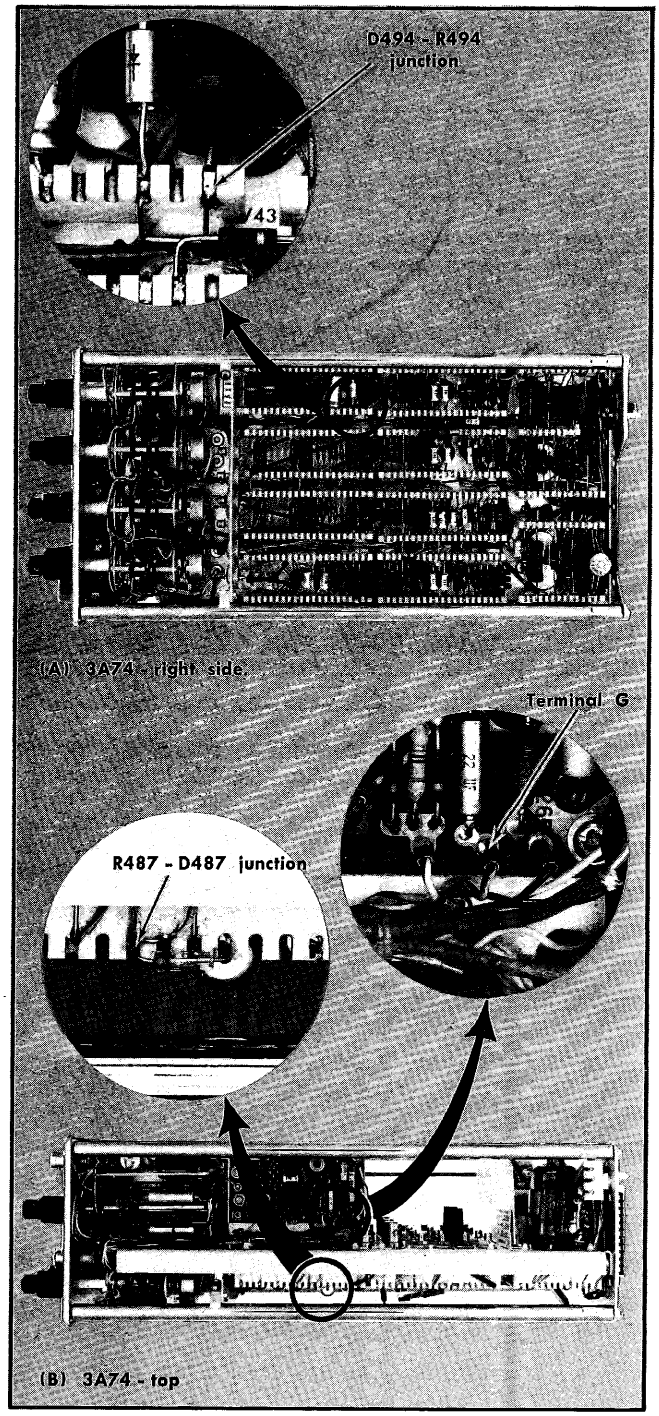


Fig. 5-4. Test point locations for step 1.

f. Set the PSI/DIV switch at 5.

g. CHECK—INT DC BAL. Rotate GAIN RANGE - R436 (Fig. 5-6), and check that the accompanying trace shift does not exceed 0.1 division.

h. ADJUST—INT DC BAL - R427 (Fig. 5-6) until minimum trace shift (not exceeding 0.1 division) accompanies rotation of the GAIN RANGE potentiometer.

i. INTERACTION—Step 8.

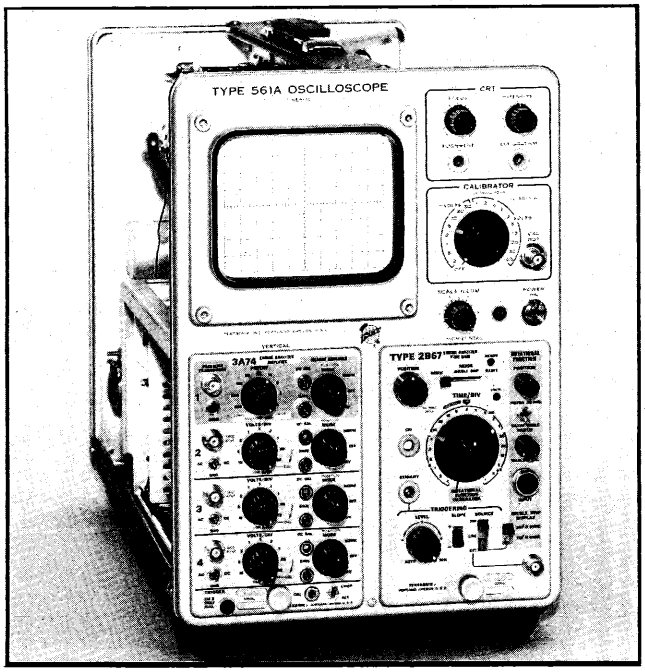


Fig. 5-5. Equipment arrangement for steps 2 through 6.

3. Check/Adjust DC Balance, Channels 2, 3 and 4 (DC BAL—R427)

a. The preliminary control setup applies.

b. Set the Channel 1 MODE switch OFF, and the Channel 2 MODE switch at NORM.

c. CHECK—DC balance. Rotate the Channel 2 VAR GAIN control (front panel) clockwise out of its detent and check that not more than 0.1 division trace shift accompanies the rotation.

d. ADJUST—Channel 2 DC BAL (front panel) until minimum trace shift (not exceeding 0.1 division) occurs as the Channel 2 VAR GAIN control is rotated clockwise out of its detent.

e. CHECK/ADJUST—Channel 3 DC BAL. Set the Channel 2 MODE switch OFF and the Channel 3 MODE switch at NORM. Apply steps c and d to Channel 3.

f. CHECK/ADJUST—Channel 4 DC BAL. Set the Channel 3 MODE switch OFF and the Channel 4 MODE switch at NORM. Apply steps c and d to Channel 4.

NOTE

DC BAL adjustment failure may be caused by DC imbalance between the applicable V423 and V433.

g. Return all VAR GAIN controls to CAL.

4. Check/Adjust POSITION RANGE—R449

a. If a Performance Check is being made, omit step 4 and proceed with step 5. If a Calibration Procedure is being done, continue with step 4-b.

b. The preliminary control setup applies.

c. Turn off the Oscilloscope and connect a short jumper wire between the plates of V464 and V474. See Fig. 5-6 for plate contact locations. Then turn the Oscilloscope on.

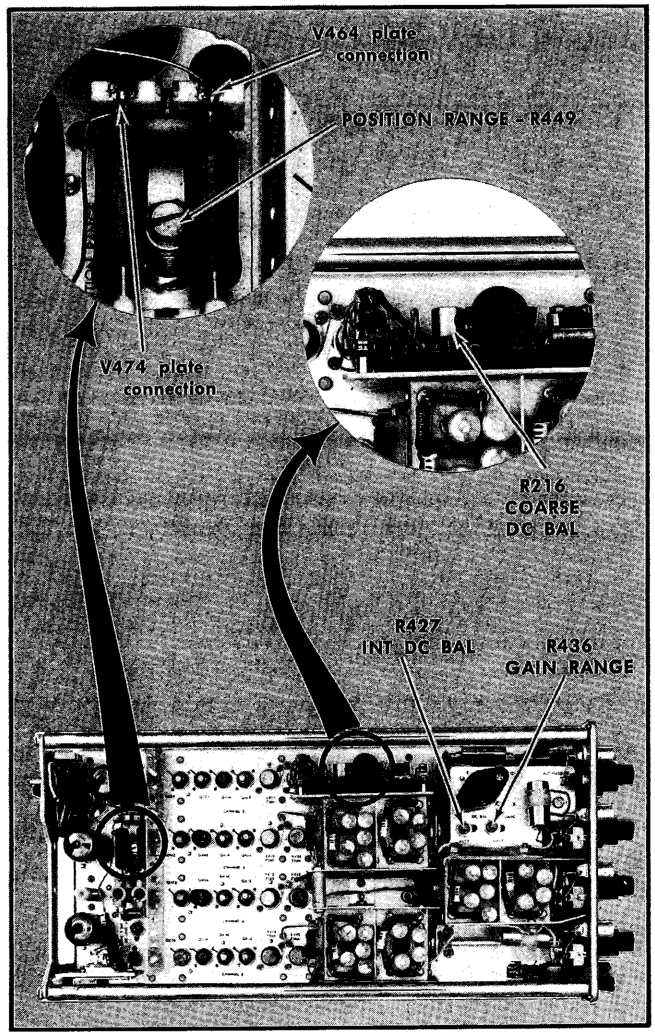


Fig. 5-6. Test point and adjustment locations for steps 2 and 4; 3A74 - left side.

WARNING

Approximately +170 V exists at the plates of V464 and V474. Avoid touching or grounding the contacts while the circuit is energized.

d. Wait until the trace stabilizes and then note the exact position (vertical electrical center) of the CRT trace. (A grease pencil can be used to mark the position on the CRT.)

e. Turn the Oscilloscope off. Remove the jumper wire and then re-energize the Oscilloscope.

f. Set all four channel MODE switches to NORM and all four channel POSITION controls to exact midrange. All four traces should appear within 2 divisions of each other.

NOTE

Failure of the traces to be within two divisions of each other may be caused by a misadjusted DC BAL control or by a defective Q424, Q434, D440, D441, D442 or D443. Exchanging Q424 and Q434 with each other will often correct the situation.

g. CHECK—POSITION RANGE. Check that all four traces are within ±1 division of CRT vertical electrical center.

h. ADJUST—POSITION RANGE - R449 (Fig. 5-6) as necessary to cause the group of traces to be centered around CRT vertical electrical center, with all traces within ±1 division of it.

5. Check Channel 1, 2, 3 and 4 Input Amplifier Output Current Balance

a. The preliminary control setup applies. The DC Balance of each channel (steps 2 and 3) must be within limits before reliable results can be obtained from this step.

b. Turn off all except one channel MODE switch.

c. Using the "on" channel POSITION control, set the trace to graticule center.

d. CHECK—Input Amplifier output current balance. Switch the channel MODE switch to INV and note the trace position. The trace should be within 2.5 divisions of the previous position. Do not permit the channel POSITION control to rotate while the MODE control is being switched.

e. CHECK—Input Amplifier output current balance for the remaining 3 channels. Repeat steps b, c and d for the remaining three channels.

NOTE

Check Q424 and Q434 in the appropriate channel if any channel does not meet the specified limit.

6. Check Grid Current and Microphonics

a. The preliminary control setup applies.

b. Set the Channel 1 MODE switch to NORM, and turn the Channel 2, 3 and 4 MODE switches OFF.

c. Adjust the Channel 1 POSITION control as necessary to position the trace to graticule center.

d. CHECK—Channel 1 microphonics. Tap lightly on the front panel while observing the trace. Deflection (ringing) resulting from the tapping should be within 1 division peak to peak.

e. Switch the Channel 1 MODE control OFF and the Channel 2 MODE control to NORM. Adjust the Channel 2 POSITION control to set the trace to graticule center.

f. CHECK—Channel 2 Input grid current. Switch the Channel 2 AC-GND-DC control to DC while observing the trace position. Trace shift should be within 0.1 division.

g. CHECK—Channel 2 microphonics. Tap lightly on the front panel while observing the trace. Deflection (ringing) resulting from the tapping should be within 1 division peak to peak.

h. CHECK—Channel 3 and 4 grid current and microphonics. Apply the procedure from steps e, f and g to Channels 3 and 4.

NOTES

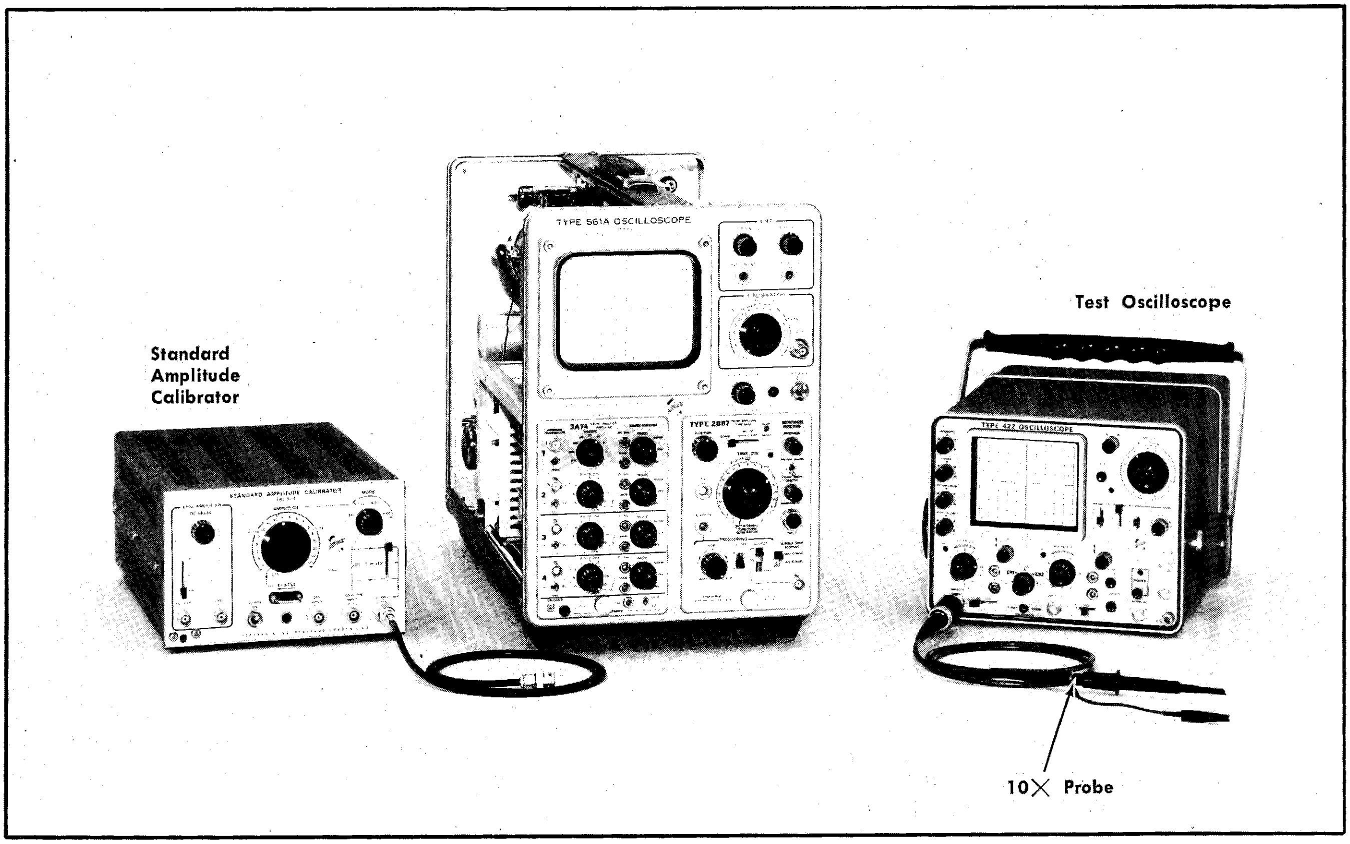


Fig. 5-7. Equipment arrangement for step 7.

7. Check/Adjust Output Amplifier Gain (CAL—R477)

a. The preliminary control setup applies. The equipment arrangement appears in Fig. 5-7.

b. Turn the Channel 2 AC-GND-DC switch to DC. Place its MODE switch at NORM and turn the other channel MODE switches off. Check that the Channel 2 VOLTS/DIV switch it at .02 V and that the VAR GAIN control is at CAL.

c. Connect a coaxial cable (item 16) from the right OUTPUT jack of the Standard Amplitude Calibrator (item 7) to the Channel 2 input connector.

d. Set the Standard Amplitude Calibrator to .1 V.

e. If a Calibration Procedure is being done, omit steps 7-f through 7-j and proceed with step 7-k. If a Performance Check is being made, continue with step 7-f.

f. Adjust the Channel 2 POSITION control as necessary to center the two traces. Record the number of divisions of display amplitude between the upper and lower traces.

g. Repeat steps c, d and f at Channels 3 and 4. Do not attempt to perform these steps at Channel 1.

h. CHECK—Output Amplifier gain. If the display amplitudes of the three channels are equal and of proper amplitude, the CAL adjustment is properly set.

i. ADJUST—Output Amplifier gain. If the display amplitudes of the three channels are in error by approximately equal amounts, adjust CAL (front panel) until proper display amplitude is obtained. If the display amplitudes of the three channels are in error by differing amounts, set the CAL adjustment to midrange.

j. Proceed with step 9. Steps 10 and 11 must also be performed if any error in display amplitude is found in this step.

k. The remainder of step 7 pertains only to the Calibration Procedure. Set the Channel 2 GAIN adjustment (front panel) fully clockwise.

l. Set the Test Oscilloscope Input coupling switch to AC, its Volts/Div control to .05 V, and its Time/Div control to .2 ms.

m. Connect the Test Oscilloscope 10× probe (item 14) to the emitter of Q463 (Fig. 5-8) and adjust the Channel 2 VAR GAIN (front panel) as necessary to obtain a 4 division (2 V) peak-to-peak signal on the Test Oscilloscope.

n. Set the Test Oscilloscope VOLTS/DIV to 1 V. Then move the Test Osciloscope probe from the emitter of Q463 to the plate of V464 (Fig. 5-8).

o. CHECK—4 divisions (40 V) peak to peak should be present on the plate of V464.

p. ADJUST—CAL (front panel) as necessary to obtain 40 V peak to peak at the plate of V464.

q. Move the Test Oscilloscope probe from the plate of V464 to the plate of V474 (Fig. 5-8).

r. CHECK—Signal amplitude should equal 40 V peak to peak, ±2 V.

s. Disconnect the probe from the plate of V474.

t. Return the Channel 2 VAR GAIN control to CAL.

u. INTERACTION—This adjustment controls the gain of Channels 1, 2, 3 and 4, and adjusts for changes in CRT deflection plate sensitivity. See steps 10 and 11 for individual channel gain adjustments.

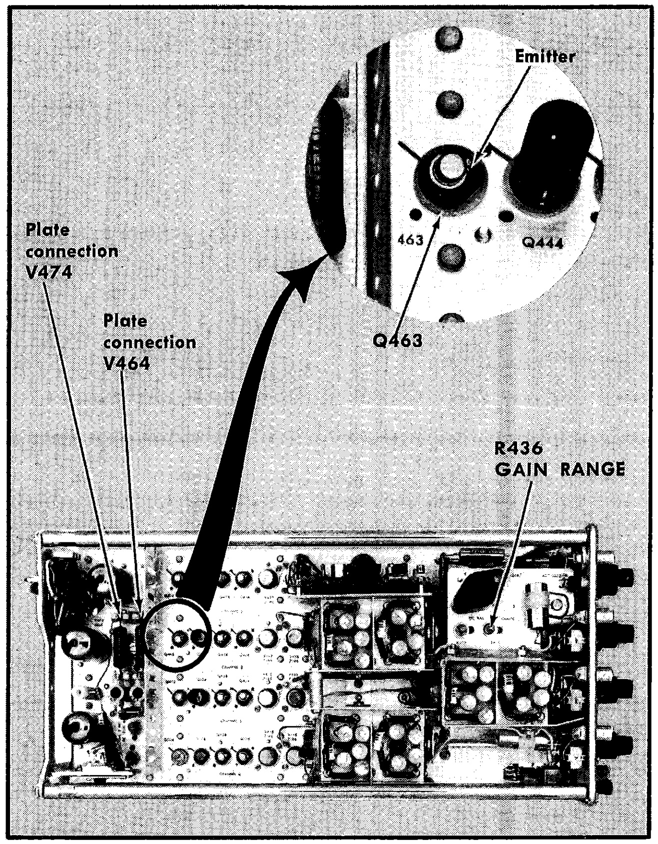


Fig. 5-8. Test point locations for step 7; 3A74 - left side.

NOTES

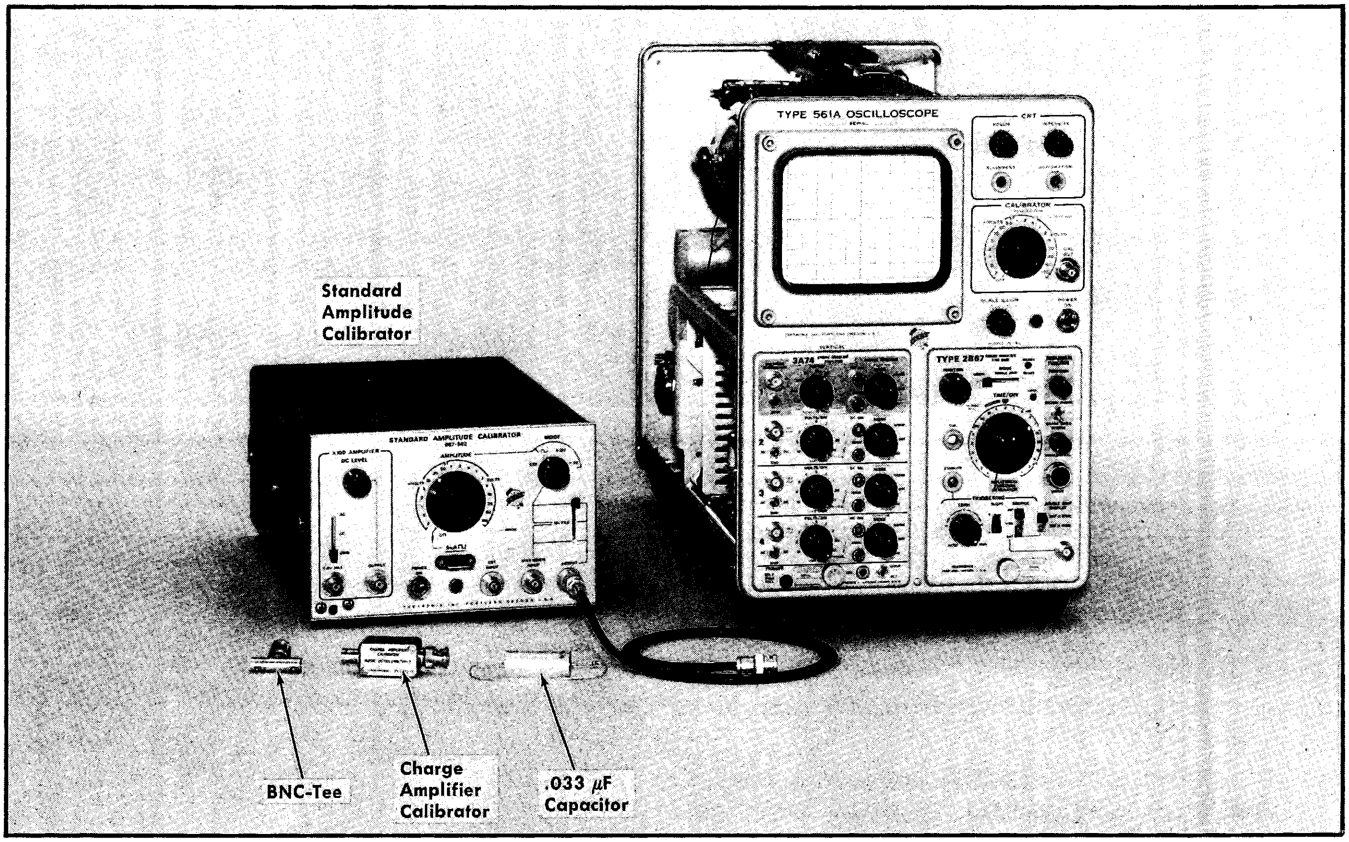


Fig. 5-9. Equipment arrangement for steps 8 through 11.

8. Check/Adjust Channel 1 Gain Range (GAIN RANGE—R436)

a. If a Performance Check is being made, omit step 8 and proceed with step 9. If a Calibration Procedure is being done, continue with step 8-b.

b. The preliminary control setup applies. The equipment arrangement appears in Fig. 5-9.

c. Turn the Channel 2 MODE switch OFF and the Channel 1 MODE switch to NORM. Set the PSI/DIV switch to 1 and adjust the Channel 1 POSITION control for a centered trace.

d. Connect a BNC Tee (item 22) to the Channel 1 Input connector. (The Tee will be used in a later step.) Then connect the Charge Amplifier Calibrator (item 17) to the BNC Tee.

e. Connect the coaxial cable from the Charge Amplifier Calibrator at Channel 1 to the right output connector of the Standard Amplitude Calibrator.

f. Turn the Channel 1 GAIN control (front panel) fully clockwise, and then move it approximately 15 degrees counterclockwise.

g. Set the Standard Amplitude Calibrator to .2 V.

h. CHECK—8 divisions ±0.2 division display amplitude exists between the bright flat section of the upper and lower traces; ignore any "hash" which may appear.

i. ADJUST—GAIN RANGE - R436 (Fig. 5-8), to obtain 8 divisions display amplitude between the bright flat section of the upper and lower traces.

j. INTERACTION—Step 10.

9. Check Channel 1 Attenuation and Noise Due to Shunt Input Capacitance

a. The preliminary control setup applies, except that the Channel 1 MODE switch is at NORM. If the procedure is being continued from step 8, omit steps 9-b through 9-f and proceed with step 9-g. Otherwise, continue with step 9-b.

b. Connect a BNC Tee (item 22) to the Channel 1 Input connector. Then connect the Charge Amplifier Calibrator (item 17) to the BNC Tee.

c. Check that the PSI/DIV switch is at 1.

d. Set the Standard Amplitude Calibrator to .2 V.

e. Using a coaxial cable, connect the Standard Amplitude Calibrator signal to the Charge Amplifier Calibrator which is connected to the Channel 1 Input connector.

f. Adjust the Channel 1 GAIN control as necessary to obtain exactly 8 divisions of vertical separation between the two traces.

g. Connect one lead of a .033 μF capacitor (item 26) directly to the female contact at the third connector on the BNC Tee. One-half inch or less lead length should be exposed between the capacitor and the connector.

h. Connect the capacitor's second lead to Oscilloscope ground.

i. CHECK—Attenuation due to shunt capacitance. Display amplitude should remain within 0.1 division of the previously established 8 divisions of display.

j. Disconnect the Charge Amplifier Calibrator from the BNC Tee. (The .033 μF capacitor should remain connected to the Tee.)

k. CHECK—Channel 1 noise due to shunt capacitance. Trace thickness should not exceed 0.3 divisions.

l. Disconnect the .033 μF capacitor and the BNC Tee from the Channel 1 Input connector .

10. Check/Adjust Channel 1 Gain (GAIN—R270); Check Attenuation Ratio Accuracy

a. The preliminary control setup applies except that the Channel 1 MODE switch is at NORM.

b. Connect the Charge Amplifier Calibrator to the Channel 1 Input connector.

c. Set the Standard Amplitude Calibrator to .2 V.

d. Check that the PSI/DIV switch is at 1.

e. Connect the coaxial cable between the Standard Amplitude Calibrator and the Charge Amplifier Calibrator at the Channel 1 Input connector.

f. Check for exactly 8 divisions of display amplitude. Adjust the Channel 1 GAIN control (front panel) if necessary to obtain exactly 8 divisions.

g. CHECK—PSI/DIV gain accuracy. Set the Standard Amplitude Calibrator and the 3A74 Channel 1 PSI/DIV controls as indicated in Table 5-3. Check that the specified vertical display amplitude is obtained.

h. Refer to Table 2-2 in the Operating Instructions section and obtain the gain calibration data for the pressure transducer which is to be used with the 3A74. Set the CALIBRATOR and PSI/DIV controls accordingly. (If the data is unknown, leave the gain as is. The channel is set for use with a 100pC/PSI pressure transducer.)

i. ADJUST—GAIN, R270 (front panel), as necessary to obtain the deflection indicated in Table 2-2.

j. Disconnect the cable from the Charge Amplifier Calibrator and remove the Charge Amplifier Calibrator from the Channel 1 Input connector.

TABLE 5-3

PSI/DIV Accuracy Check

3A74 PSI/DIV	Standard Amplitude Calibrator	Display Amplitude (divisions)
1	.2 V	Calibrated for 8
2	.2 V	4 ±0.12
5	1 V	8 ±0.24
10	2 V	8 ±0.24
20	2 V	4 ±0.12
50	10 V	8 ±0.24
100	20 V	8 ±0.24
200	20 V	4 ±0.12
500	50 V	4 ±0.12

11. Check/Adjust Channel 2, 3 and 4 Gain (GAIN—R436); Check Channel 2, 3 and 4 Variable Gain (VAR GAIN—R426); Check Attenuation Ratio Accuracy

a. The preliminary control setup applies.

b. Set the Standard Amplitude Calibrator for a 0.1 V signal output.

c. Connect the Standard Amplitude Calibrator signal cable to the Channel 2 Input connector.

d. Turn the Channel 1 MODE switch OFF and the Channel 2 MODE switch to NORM. Set the Channel 2 AC-GND-DC switch to DC.

e. CHECK—Gain. With the channel VOLTS/DIV switch at .02, check for 5 divisions display amplitude.

f. ADJUST—Gain. With the Channel VOLTS/DIV switch at 0.2, adjust GAIN (front panel) for exactly 5 divisions vertical displacement between the two traces.

g. CHECK—Variable gain. Rotate the Channel VAR GAIN control (front panel) counterclockwise out of its detent and check for a smooth decrease of signal amplitude as the control is rotated. Check for a display amplitude of 2 divisions or less at the minimum amplitude setting of the VAR GAIN control, indicating a gain control range of at least 2.5:1.

h. Return the VAR GAIN control to CAL.

i. CHECK/ADJUST—Channel 3 and 4 gain. Apply steps c through h to Channel 3 and then to Channel 4.

j. CHECK—Channel 4 VOLTS/DIV attenuation ratio accuracy. With the Standard Amplitude Calibrator signal applied to the Channel 4 Input connector, check the gain accuracy of each position of the VOLTS/DIV switch as indicated by Table 5-4.

TABLE 5-4
Channel 2, 3 and 4 Attenuator Ratio Check

3A74 VOLTS/DIV Switch Setting	Standard Amplitude Calibrator AMPLITUDE	Vertical Display Amplitude (Div.)[1]
.05	.2 V	4 ±0.12
.1	.5 V	5 ±0.15
.2	1 V	5 ±0.15
.5	2 V	4 ±0.12
1	5 V	5 ±0.15
2	10 V	5 ±0.15
5	20 V	4 ±0.12
10	50 V	5 ±0.15

[1]These tolerances apply only when the specified Standard Amplitude Calibrator (0.25% tolerance) is used, and the applicable channel has been calibrated at the .02 V position. Increase the tolerance by an appropriate amount whenever a less accurate calibrator is in use.

k. CHECK—Channel 3 and 2 VOLTS/DIV attenuation accuracy, again using Table 5-4. Do not attempt to perform this check on Channel 1.

l. Turn the Standard Amplitude Calibrator off and disconnect the signal cable from the 3A74.

12. Check CHOP Mode of Operation

a. The preliminary control setup applies.

b. Check that the 3A74 CHOP-ALT switch is at CHOP position.

c. Place the Channel 1 and 2 MODE switches at NORM and check that the Channel 3 and 4 MODE switches are OFF.

d. CHECK—2-channel CHOP operation. Two traces should appear on the CRT or should be available simultaneously by adjusting the appropriate channel POSITION controls.

e. CHECK—3-channel CHOP operation. Switch the Channel 3 MODE switch to NORM and check that three traces can be simultaneously displayed.

f. CHECK—4-channel CHOP operation. Switch the Channel 4 MODE switch to NORM and check that four traces can be simultaneously displayed.

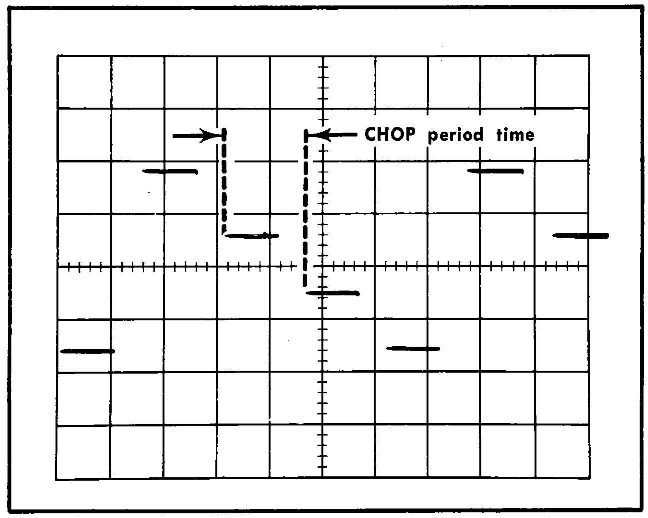


Fig. 5-10. Four-channel chopped trace segments; sweep rate 1 μs/div.

g. Switch each channel MODE switch to INV.

h. CHECK—INV 4-channel CHOP operation. 4 traces should remain.

i. Switch the 2B67 (TRIGGERING) LEVEL to AUTO and the TIME/DIV switch to 1 μs. Note that the traces are replaced by chopped segments, as in Fig. 5-10. (If an uncalibrated 2B67 is being used, it is possible that the segments may not appear. In this event, adjust the 2B67 (TRIGGERING) LEVEL control as necessary to obtain a display as in Fig. 5-10.)

j. (Calibration Procedure only.) If a calibrated 2B67 is being used, ignore step j. If an uncalibrated 2B67 is being used, connect the Test Oscilloscope 10× probe to the plate of V464 (Fig. 5-6) and perform the step k measurement at the Test Oscilloscope. Disconnect the Test Oscilloscope probe after step k has been performed.

k. CHECK—CHOP period duration. Measure the period existing between the end of one segment and the end of the next segment. See Fig. 5-10. Period duration should be 2 μs ±0.6 μs. If the equipment fails to pass this step, check the blocking oscillator in the channel switching circuit.

NOTES

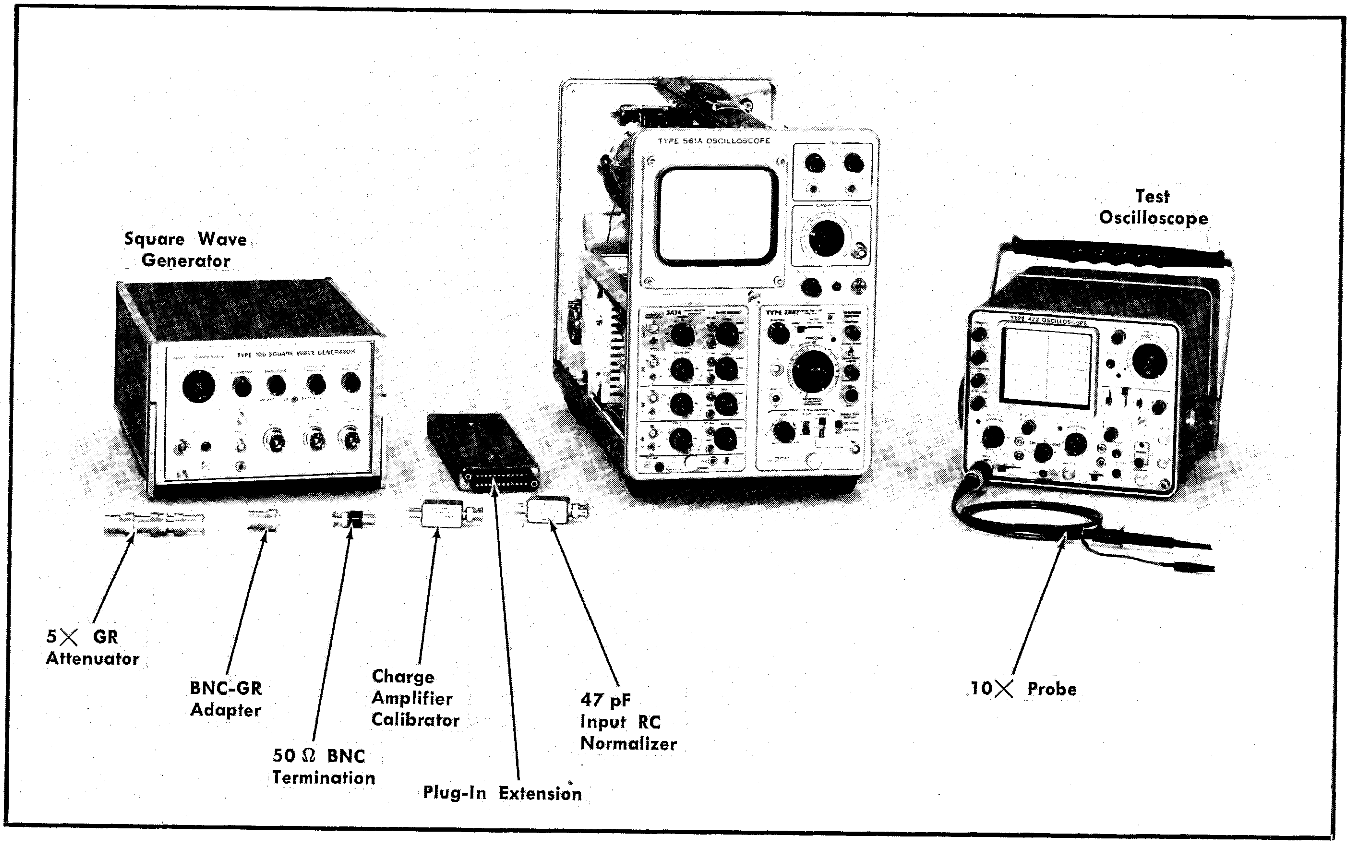


Fig. 5-11. Equipment arrangement for steps 13 through 22.

13. Check Chopped Blanking; Check/Adjust Chopped Blanking Pulse Amplitude (C597)

a. The preliminary control setup applies, except that all four channel MODE switches are at INV, the 2B67 TIME/DIV switch is at 1 μs and the (TRIGGERING LEVEL control is at AUTO. The equipment arrangement appears in Fig. 5-11.

b. Set the CRT CATHODE SELECTOR switch (rear of Oscilloscope) away from the CHOPPED BLANKING (or DUAL TRACE) position.

c. Set the Oscilloscope INTENSITY control for normal viewing intensity. NOTE that channel segments are connected between traces by switching transients.

d. Measure and record the number of divisions of separation between the switching transients as in Fig. 5-12 (A).

e. CHECK—Chopped Blanking. Switch the CRT CATHODE SELECTOR switch back to CHOPPED BLANKING (or DUAL TRACE) position and note that the transients are no longer visible as in Fig. 5-12 (B).

f. If a Performance Check is being made, omit steps 13-g through 13-k and proceed with step 13-l. If a Calibration Procedure is being performed, continue with step 13-g.

g. Set the Test Oscilloscope for a sweep rate of 1 μs/division and set its volts/division control to 1. Connect a 10X probe from the Test Oscilloscope to the Chopped Transient terminal on the Oscilloscope CRT CATHODE SELECTOR switch. (The terminal can be found on the inside of the Oscilloscope rear panel.) Connect a grounding lead (item 15) from the probe to the Oscilloscope chassis ground. Failure to connect this lead will result in an incorrect display.

h. CHECK—Amplitude of Chopped Blanking pulse as displayed on the Test Oscilloscope. It should be 3.5 divisions (35 V) peak to peak, ±0.2 divisions (2 V). See Fig. 5-12 (C).

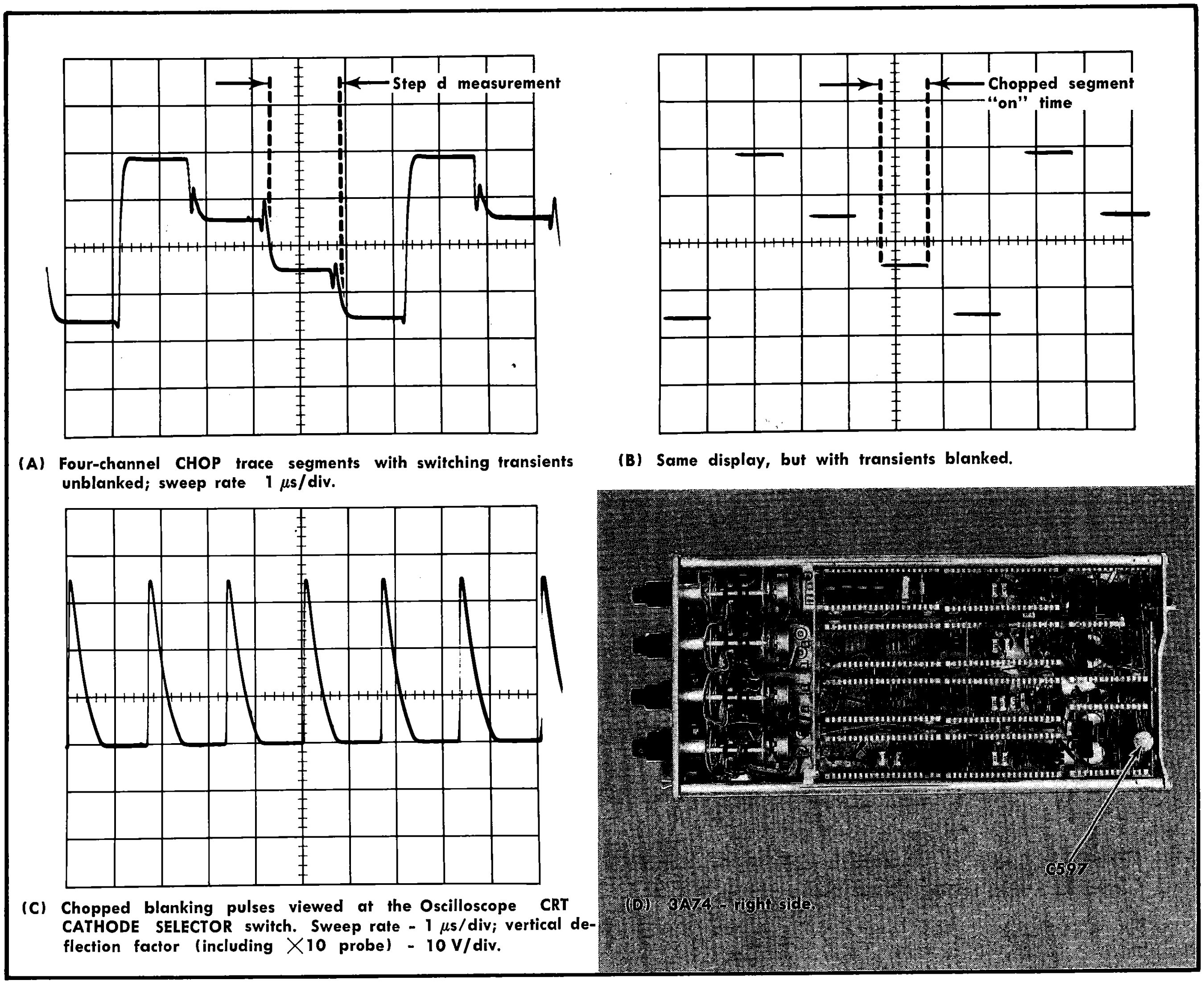
i. ADJUST—Chopped Blanking pulse amplitude. Remove the 3A74 from the Oscilloscope and adjust C597 approximately ¼ turn. See Fig. 5-12 (D). Return the 3A74 to the Oscilloscope compartment and recheck the chopped blanking pulse amplitude. Repeat the C597 adjustment until 35 V peak-to-peak amplitude is obtained.

IMPORTANT

The chopped blanking pulse amplitude must be checked with the 3A74 inserted fully into the Oscilloscope. Unreliable results will be obtained if a plug-in extender is used.

j. Remove the Test Oscilloscope probe from the test point.

k. With the Oscilloscope INTENSITY set for normal viewing brightness, measure and record the number of divisions displayed by each of four adjacent segments as displayed on the 561- or 564-Series Oscilloscope. A measurement of one segment is shown in Fig. 5-12 (B).



(A) Four-channel CHOP trace segments with switching transients unblanked; sweep rate 1 μs/div.

(B) Same display, but with transients blanked.

(C) Chopped blanking pulses viewed at the Oscilloscope CRT CATHODE SELECTOR switch. Sweep rate - 1 μs/div; vertical deflection factor (including ×10 probe) - 10 V/div.

Fig. 5-12. Waveforms and adjustment locations for step 13.

l. CHECK—CHOP segment "on" time. Segment width should be at least 6/10 of the divisions recorded in step d.

m. Switch the 2B67 (TRIGGERING) LEVEL control to FREE RUN.

n. CHECK—CHOP trace thickness. At normal viewing intensity, trace thickness of each of the 4 traces should not exceed 0.1 division.

NOTE

If either step 1 or n fail, check the appropriate gating diodes in the ring counter and the appropriate channel switching diodes.

o. INTERACTION—Step 18.

14. Check Alternate Mode Operation

a. The preliminary control setup applies, except that all four MODE switches are at INV. During this step, adjust the CRT INTENSITY as necessary to maintain a moderately bright presentation. Avoid excessive brightness, since it may shorten the life of the phosphor.

b. Set the 2B67 (TRIGGERING) LEVEL control to FREE RUN.

c. Set the 3A74 CHOP-ALT switch to ALT. Set the CRT INTENSITY for normal display brightness.

d. CHECK—ALT operation. Switch through the entire range of numbered positions of the 2B67 TIME/DIV switch. Note that four traces are present, or that the trace alternates between channels in all switch positions.

e. Switch all four Channel MODE switches off.

15. Check/Adjust Channel 2, 3 and 4 Input Capacitance and Attenuator Compensation (C416, C403B, C403C, C405B, C405C, C407B, C407C, C409B, C409C)

NOTE

Do not move the vertical input signal transporting leads or components associated with a calibrated attenuator. They affect the input capacitance.

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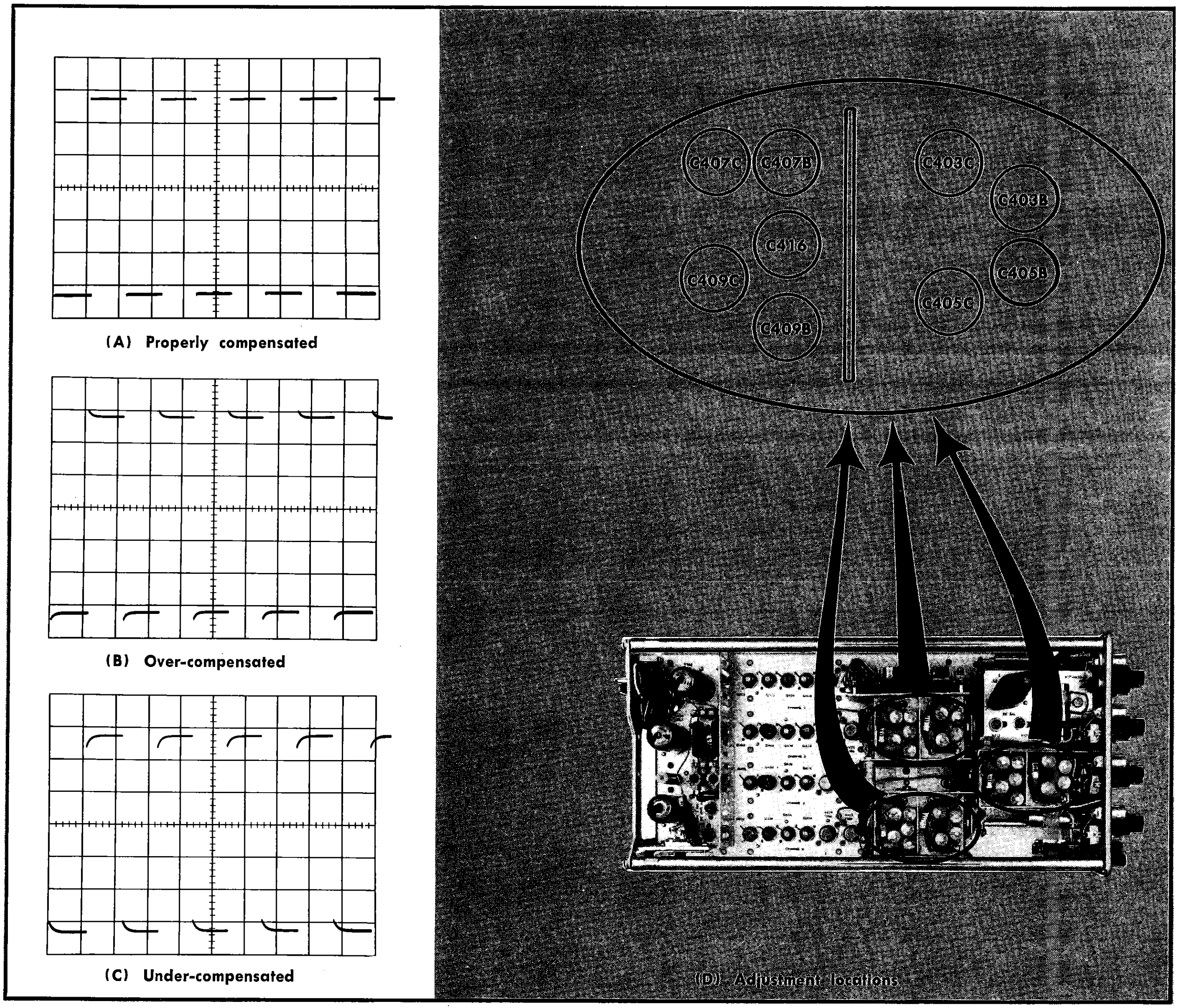


Fig. 5-13. Input capacitance and attenuator compensation waveform pictures and adjustment locations.

a. Two procedures are included here. Step 15 is the standard procedure and should be used whenever a 47 pF Input RC Normalizer is available. Step 15 Alternate can be used to adjust the input capacitance for non-critical use if an input RC Normalizer is not available and at least one channel attenuator is in calibrated condition.

b. The preliminary control setup applies.

c. Set the 3A74 Channel 4 controls as follows: VOLTS/DIV switch to .02, AC-GND-DC switch to DC, MODE switch to NORM. Check that the VAR GAIN control is at CAL.

d. Set the 2B67 TIME/DIV switch to .5 ms and the (TRIGGERING) LEVEL to AUTO. Check that the (TRIGGERING) SLOPE control is at —.

e. Set the Type 106 Square Wave Generator (item 8) for a 1 kHz output, set its HI AMPLITUDE-FAST RISE switch to HI AMPLITUDE, and set its AMPLITUDE control to minimum.

f. Connect the following components to the 3A74 Channel 4 Input connector in the sequence given:

47 pF Input RC Normalizer (item 18)

50 Ω BNC Termination (item 21)

Coaxial cable

GR-BNC Female Adapter (item 24)

5X GR Attenuator (item 19)

g. Connect the 5X attenuator to the HI AMPLITUDE OUTPUT connector of the Square Wave Generator, and adjust the Square Wave Generator AMPLITUDE control as necessary to obtain a five-division square wave display. If an uncalibrated 2B67 is in use, it is possible that a display may not appear. In that event, adjust the 2B67 (TRIGGERING) LEVEL control as necessary to obtain a stable display as in Fig. 5-13.

h. CHECK—Channel 4 Input Capacitance. The top of the square wave should be flat, as in Fig. 5-13 (A). Examples of misadjusted input capacitance are given in Fig. 5-13 (B) and (C).

i. (Calibration Procedure only.) ADJUST—Channel 4 input capacitance. Adjust C416 in Channel 4 as necessary to obtain flatness, using Fig. 5-13 (A) as a guide. Use a metal tipped plastic screwdriver.

j. CHECK/ADJUST—Channel 4 Attenuator compensation. The equipment setup is given in Table 5-5. Check that the top of the square wave is flat in all switch positions. Maintain approximately 5 divisions of display amplitude throughout the procedure. If a calibration procedure is being done, perform the indicated adjustment as necessary before making the next check. The location of adjustments is shown in Fig. 5-13 (D).

TABLE 5-5

Attenuator Compensation Adjustments

VOLTS/DIV Switch Setting	Adjust
.05	C407B, C407C
.1	C409B, C409C
Remove 5X attenuator from signal path	
.2	C403B, C403C
Remove 50 Ω termination from signal path	
2	C405B, C405C

k. Move the 47 pF Input RC Normalizer and cable assembly to Channels 3 and then 2, applying steps g through j at each channel. The MODE switch of the channel being checked/adjusted should be at NORM. All other MODE switches should be OFF.

l. Disconnect the Input RC Normalizer from the 3A74.

m. INTERACTION—Step 20.

15 (Alternate). Check/Adjust Channel 2, 3 and 4 Input Capacitance and Attenuator Compensation, using Tektronix 10X probe rather than Input RC Normalizer

a. If a 47 pF Input RC Normalizer is not available, the input capacitance and attenuator compensation check/adjustment can be made by using a Tektronix 10X probe which can be adjusted for use with vertical circuits having 47 pF input capacitance. One prerequisite is that the components, wiring and adjustments in at least one channel (channel 2, 3 or 4) have not been tampered with since the last time the Input Capacitance and Attenuation Compensation adjustments were performed or satisfactorily checked. Proceed as follows:

b. Attach the BNC connector end of a Tektronix 10X probe to the Input connector of the calibrated channel. Set that channel VOLTS/DIV switch to .02.

c. Connect the probe tip to a 5X attenuator whose other end is attached to the output of a 1 kHz square wave generator.

d. Set the Square Wave Generator AMPLITUDE as necessary to obtain approximately 5 divisions of vertical deflection.

e. Adjust the Probe Compensation as necessary to obtain optimum squareness and flatness at the top left corners of the square waves.

f. Turn the calibrated channel MODE switch off. Move the probe BNC connector to the Input connector of the channel to be adjusted, and then perform steps 15-g through 15-1, removing the 5X attenuator as necessary to obtain sufficient amplitude (typically 5 divisions, but at least 3 divisions).

g. INTERACTION—Step 20.

16. Check/Adjust Composite Internal Trigger DC Level (COMPOSITE INT TRIG DC LEVEL —R530)

a. Steps 16 through 19 apply to Performance Checks only. If a Calibration Procedure is being done, proceed with step 20.

b. The preliminary control setup applies.

c. Turn the Channel 2 MODE switch to NORM and check that the other three channel MODE switches are OFF.

d. Using the Channel 2 POSITION control, set the trace to graticule vertical center.

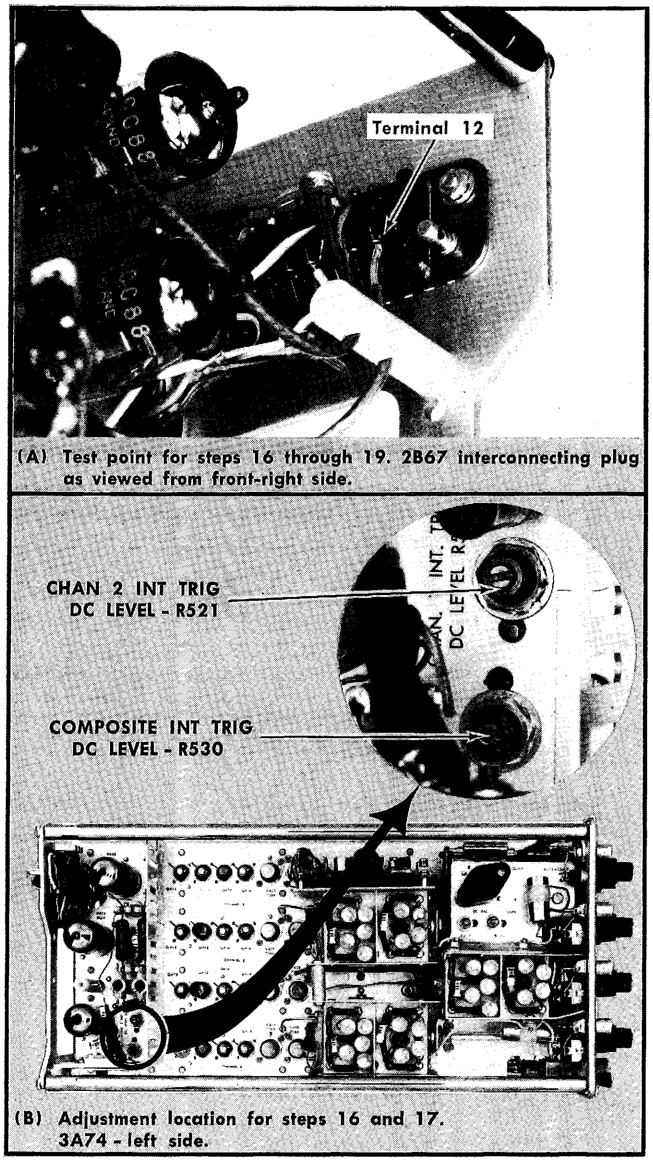
e. Connect the Test Oscilloscope to the COMPOSITE INT TRIG DC LEVEL line, which is accessible at terminal 12 of the 2B67 interconnecting plug. See Fig. 5-14 (A).

WARNING

All equipment should be de-energized when connecting and disconnecting the test equipment to avoid electrical shock and equipment damage.

f. CHECK—Composite internal Trigger DC level for 0 V ± 0.5 V.

g. ADJUST—COMPOSITE INT TRIG DC LEVEL —R530 (Fig. 5-14B), for 0 V. Adjust so that any drift is centered around 0.



(A) Test point for steps 16 through 19. 2B67 interconnecting plug as viewed from front-right side.

(B) Adjustment location for steps 16 and 17. 3A74 - left side.

Fig. 5-14. Test point and adjustment locations.

17. Check/Adjust Channel 2 Internal Triggering DC Level (CHAN 2 INT TRIG DC LEVEL —R521)

a. Omit this step if only a Performance Check is being made. The preliminary control setup applies, except that the Channel 2 MODE switch is at NORM, the trace is exactly at the vertical center of the graticule, and the Test Oscilloscope is connected to terminal 12 of the 2B67 interconnecting plug.

b. Pull the 3A74 TRIGGER switch out to the CH 2 ONLY position.

c. CHECK—Channel 2 Internal Trigger DC Level for 0 V ± 0.5 V.

d. ADJUST—CHAN 2 INT TRIG DC LEVEL —R521 (Fig. 5-14B) as necessary to obtain 0 V. Adjust so that any drift is centered around 0.

18. Check/Adjust Channel 2 Trigger Signal Noise (C435): Check Channel 2 Trigger Amplitude and Risetime

a. Omit step 18 if only a Performance Check is being made. The preliminary control setup applies, except that the 3A74 TRIGGER control is at the CH 2 ONLY position, and the Test Oscilloscope is connected to terminal 12 of the 2B67 interconnecting plug.

b. Turn all four channel MODE switches to NORM and the CHOP-ALT switch to CHOP. Set the individual POSITION controls as necessary to place each trace near graticule center.

c. Set the Test Oscilloscope input coupling switch to AC, its Time/Div to 1 μs and its Volts/Div to 50 mV. Adjust the Test Oscilloscope as necessary to obtain a stable display.

d. CHECK—Channel 2 trigger signal noise. Noise displayed on the Test Oscilloscope should not exceed 1 division (500 mV) peak to peak. See Fig. 5-15 (A).

e. ADJUST—Channel 2 trigger signal noise as follows:

(1) Turn the Oscilloscope off and remove the 3A74 from the Oscilloscope. Reconnect the 3A74 to the Oscilloscope through the plug-in extension.

(2) Turn the Oscilloscope on. After the Test Oscilloscope display has stabilized, adjust C435 (Fig. 5-15B) as necessary to obtain minimum peak-to-peak amplitude of Test Oscilloscope display. (Amplitude may still be in excess of 500 mV because of the plug-in extension.)

(3) Turn the Oscilloscope off. Remove the extension from between the 3A74 and the Oscilloscope. Reconnect the 3A74 to the Oscilloscope and turn the Oscilloscope on.

(4) CHECK—Peak-to-peak noise amplitude should not exceed 500 mV. If it does, recheck the chopped blanking pulse amplitude as outlined in step 13.

f. Set the Test Oscilloscope Time/Div control to 5 μs and its Volts/Div to .2 volts.

g. Switch the Channel 1, 3 and 4 MODE switches OFF and the Channel 2 AC-GND-DC switch to DC. Set the Channel 2 VOLTS/DIV switch to .02.

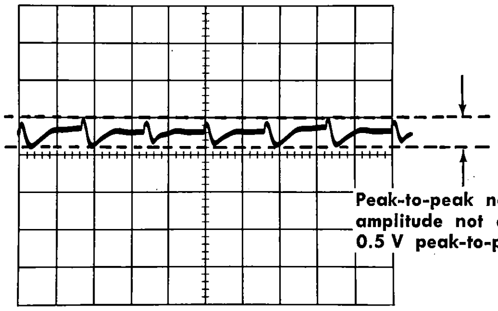
h. Set the Type 106 Square Wave Generator for a 100 kHz output and set its + TRANSITION AMPLITUDE control fully counterclockwise. Switch the HI AMPLITUDE-FAST RISE switch to FAST RISE.

i. Connect the following components to the 3A74 Channel 2 Input connector in the sequence given:

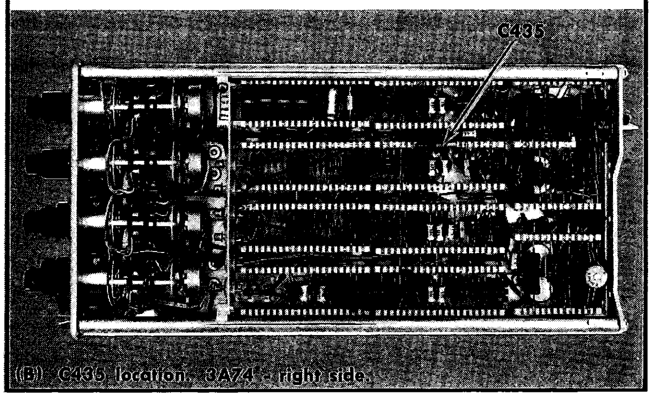
50 Ω BNC Termination

Coaxial Cable

GR-BNC Female Adapter



(A) Channel 2 trigger signal noise waveform. Time/div - 1 µs; volts/div - 0.5 V.



(B) C435 location, 3A74 - right side.

Fig. 5-15. Waveform and adjustment location for steps 18 and 19.

j. Connect the other end of the GR-BNC adapter to the FAST RISE + OUTPUT connector of the Type 106 Square Wave Generator. Adjust the Square Wave Generator as necessary to obtain 4 divisions of separation between the two traces on the 561 or 564-Series Oscilloscope.

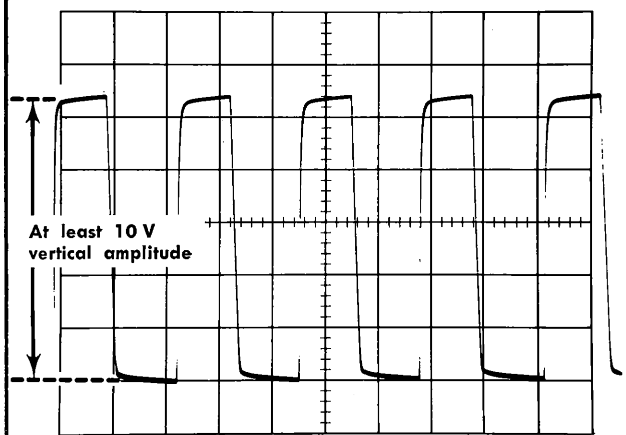
k. CHECK—Channel 2 trigger signal amplitude. The display on the Test Oscilloscope should have 10 V or greater vertical amplitude, as in Fig. 5-16 (A).

l. Set the Test Oscilloscope Volts/Div and Variable Gain controls as necessary to obtain exactly 5 divisions of vertical display. Then set its Time/Div control to 0.5 µs/Div. Adjust the Test Oscilloscope triggering and position controls as necessary to position the display for convenient risetime measurement as in Fig. 5-16 (B).

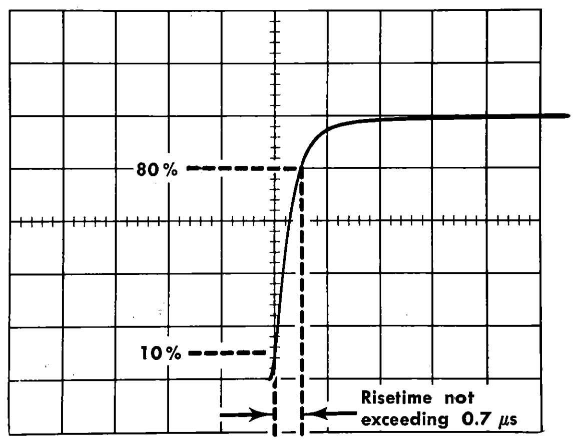
m. CHECK—Channel 2 Triggering Signal risetime. The time required for the trace to rise between the 10% and 80% amplitude points (with respect to the pulse base line) should not exceed 0.7 µs, as illustrated in Fig. 5-16 (B).

19. Check Composite Internal Triggering Signal Amplitude

a. Omit step 19 if only a Performance Check is being made. The preliminary control setup applies, except that the 3A74 Channel 2 MODE switch is at NORM and its AC-GND-DC switch is at DC. All other channel MODE switches are OFF. The Square Wave Generator FAST RISE OUTPUT signal is connected through a 50 Ω coaxial cable and a 50 Ω termination to the 3A74 Channel 2 Input connector.



(A) Channel 2 trigger signal. Sweep rate - 5 µs/div; vertical deflection (including 10X probe) - 2 V/div.



(B) Channel 2 Trigger signal risetime measurement. Sweep rate - 0.5 µs/div.

Fig. 5-16. Channel 2 trigger waveforms for step 18.

The 10X probe is connected between terminal 12 of the 2B67 interconnecting plug and the Test Oscilloscope.

b. Push the 3A74 TRIGGER knob in.

c. Set the Square Wave Generator frequency to 10 kHz and adjust its + TRANSITION AMPLITUDE as necessary to obtain 4 divisions of display amplitude on the 561- or 564-Series Oscilloscope.

d. CHECK—Composite internal triggering signal amplitude. Set the Test Oscilloscope Time/Div to 50 µs and check its display for at least 9.5 V amplitude, as illustrated in Fig. 5-17. (Check that the Test Oscilloscope Variable Gain is at its calibrated position before making the measurement.)

e. Disconnect the 10X probe from the 2B67.

20. Check/Adjust High Frequency Response (L464-L474)

a. The preliminary control setup applies except that Channel 2 of the 3A74 has its AC-GND-DC switch at DC, its

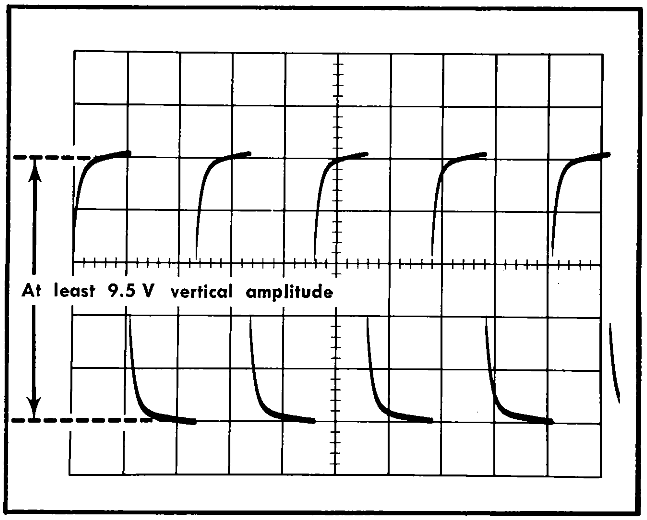


Fig. 5-17. Composite internal triggering signal amplitude waveform for step 19. Sweep rate —50 μs/div.

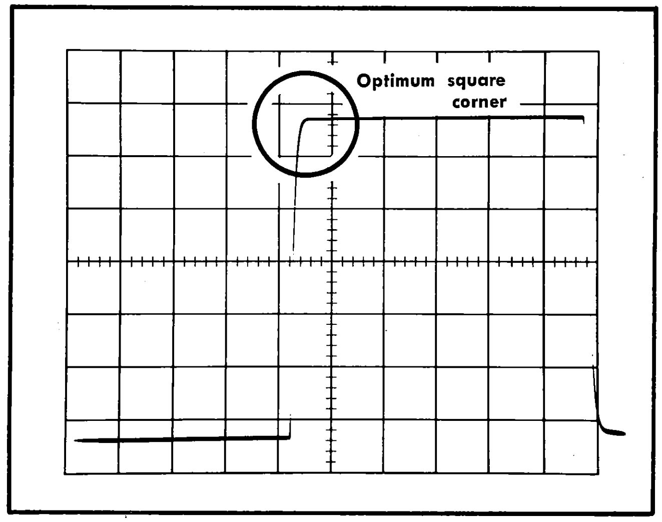


Fig. 5-18. High frequency response waveform for step 20. Sweep rate - 1 μs/div; vertical sensitivity - .02 v/div.

MODE switch at NORM, and the following components are connected to the Channel 2 Input connector:

50 Ω BNC Termination

Coaxial Cable

BNC-GR Adapter

Square Wave Generator FAST RISE OUTPUT connector

b. Set the Square Wave Generator frequency to 100 kHz.

c. Adjust the Square Wave Generator + TRANSITION AMPLITUDE as necessary to obtain 5 divisions of separation between the two traces displayed on the Oscilloscope.

d. Set the 2B67 TIME/DIV control to 1 μs/div.

e. Adjust the 2B67 (TRIGGERING) LEVEL control as necessary to obtain a display similar to that shown in Fig. 5-18.

f. CHECK—High Frequency Response. Upper left corner of the waveform should be square, with a minimum of rounding or overshoot.

g. (Calibration Procedure only.) ADJUST—High frequency response. Using the hexagonal alignment rod (item 31), adjust L464 and L474 in equal increments as necessary to obtain optimum squareness at the upper left corner of the square wave. Use Fig. 5-18 as a reference. Note that two slugs are contained in each core. Do not tighten them against each other so hard that they bind or break.

h. Switch the Channel 2 MODE switch OFF. Switch the Channel 3 TIME/DIV switch to .02, its MODE switch to NORM, and its AC-GND-DC switch to DC.

i. Move the 50 Ω termination and cable assembly to the Channel 3 Input connector and position the display vertically on the CRT.

j. CHECK—Channel 3 high frequency response. Then switch the channel 3 MODE switch OFF and check Channel 4 response in the same manner as for Channel 3.

k. INTERACTION—Steps 22 and 23.

21. Check Vertical Compression and Expansion

a. The preliminary control setup applies, except that the Channel 4 MODE switch is on, its AC-GND-DC switch is at DC, and the following components are connected to its Input connector.

50 Ω BNC Termination

50 Ω Coaxial Cable

GR-BNC Adapter

Square Wave Generator FAST RISE + OUTPUT

b. Switch the 2B67 (TRIGGERING) LEVEL control to FREE RUN and adjust the Square Wave Generator + TRANSITION AMPLITUDE as necessary to obtain 2 divisions of vertical separation between the two traces displayed on the CRT. Use the Channel 4 POSITION control as necessary to center the display. Adjust the Channel 4 VAR GAIN control if necessary to reduce the display to two divisions.

c. CHECK—Compression and expansion. Using the Channel 4 POSITION control, set the top of the display to the top horizontal line and check for 2 divisions ± 0.1 division. Move the bottom of the display to the bottom graticule line and repeat the check.

d. Disconnect the 50 Ω BNC termination from the Channel 4 Input connector and turn the Channel 4 MODE switch OFF.

22. Check Channel 1 Bandwidth

NOTE

There is a direct relationship between bandwith and risetime, expressed as

$$BW \approx 0.35/T_r$$

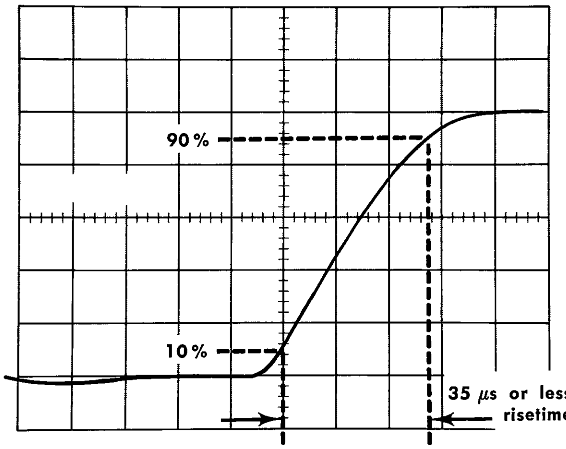


Fig. 5-19. Risetime waveform for step 22. Sweep rate - 10 μs/div; vertical sensitivity - 1 PSI/DIV.

Bandwidth is measured as a function of risetime in this step.

a. If an uncalibrated 2B67 is being used, step 22 should be omitted. It can be accomplished after the 2B67 has been calibrated.

b. The preliminary control setup applies.

c. Set the Channel 1 PSI/DIV switch to 1 and its MODE switch to NORM.

d. Connect the following components to the Channel 1 Input connector in the sequence listed:

Charge Amplifier Calibrator

50 Ω BNC Termination

50 Ω Coaxial Cable

BNC-GR Adapter

Square Wave Generator (+ TRANSITION AMPLITUDE) OUTPUT

e. Set the Square Wave Generator frequency to approximately 5 kHz and adjust the + TRANSITION AMPLITUDE control as necessary to obtain 5 divisions of vertical separation between the two traces displayed on the CRT.

f. Set the 2B67 TIME/DIV control to 10 μs and its (TRIGGERING) SLOPE control to —. Adjust its POSITION and (TRIGGERING) LEVEL controls as necessary to obtain a display as shown in Fig. 5-19.

g. CHECK—Risetime. The time required for the display to travel between the 10% and 90% points(as indicated in Fig. 4-19) should not exceed 35 μs, indicating 3 dB or less attenuation at 10 kHz. ($0.35 \div 35 \times 10^{-6} = 10$ kHz)

h. Turn the Channel 1 MODE switch OFF and disconnect the Charge Amplifier Calibrator from the Input connector.

i. Set the 2B67 (TRIGGERING) LEVEL control to FREE RUN.

NOTES

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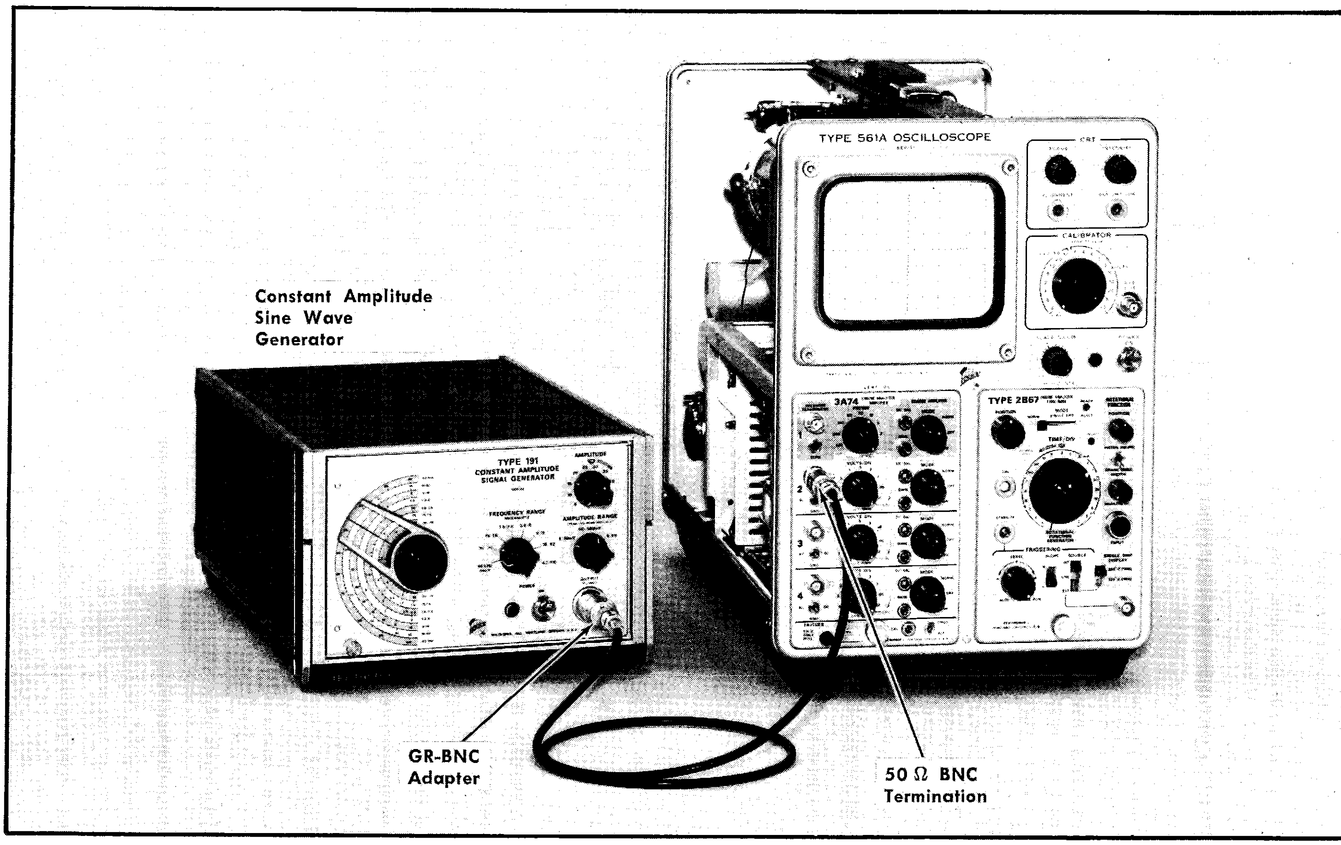

Fig. 5-20. Equipment arrangement for step 23.

23. Check Channel 2, 3 and 4 Bandwidth

a. The preliminary control setup applies. The equipment arrangement is shown in Fig. 5-20.

b. Connect the following components to the Channel 2 Input connector in the sequence listed:

50 Ω BNC Termination

50 Ω Coaxial Cable

GR-BNC Adapter

c. Turn the Channel 2 MODE switch to NORM and its AC-GND-DC control to DC.

d. Connect the GR-BNC adapter and cable assembly to the OUTPUT connector of the Type 191 Constant Amplitude Signal Generator.

NOTE

Any 2 MHz sine wave generator may be used, provided that its output is monitored by a 10 MHz test oscilloscope. The sine wave generator must provide exactly 80 mV peak to peak throughout the step. Step e does not have to be performed if a test oscilloscope is used.

e. Set the Signal Generator for a 50 kHz ONLY output and adjust its amplitude controls as necessary to obtain exactly 4 divisions of vertical display amplitude.

f. CHECK—Bandwidth. Switch the Signal Generator frequency to 2 MHz and check that at least 2.8 divisions of vertical display remain, indicating 3 dB or less attenuation at 2 MHz.

g. Switch the Channel 2 MODE switch OFF. Switch the Channel 3 MODE switch to NORM and its AC-GND-DC switch to DC.

h. CHECK—Channel 3 bandwidth. Move the 50 Ω BNC termination and cable assembly to the Channel 3 Input connector and repeat steps e and f.

i. Switch the Channel 3 MODE switch OFF. Switch the Channel 4 MODE switch to NORM and its AC-GND-DC control to DC.

j. CHECK—Channel 4 bandwidth. Move the 50 Ω termination and cable assembly to the Channel 4 Input connector and again repeat steps e and f.

k. This concludes the 3A74 Performance Check/Calibration Procedure. Disconnect the 50 Ω termination and cable assembly from Channel 4.

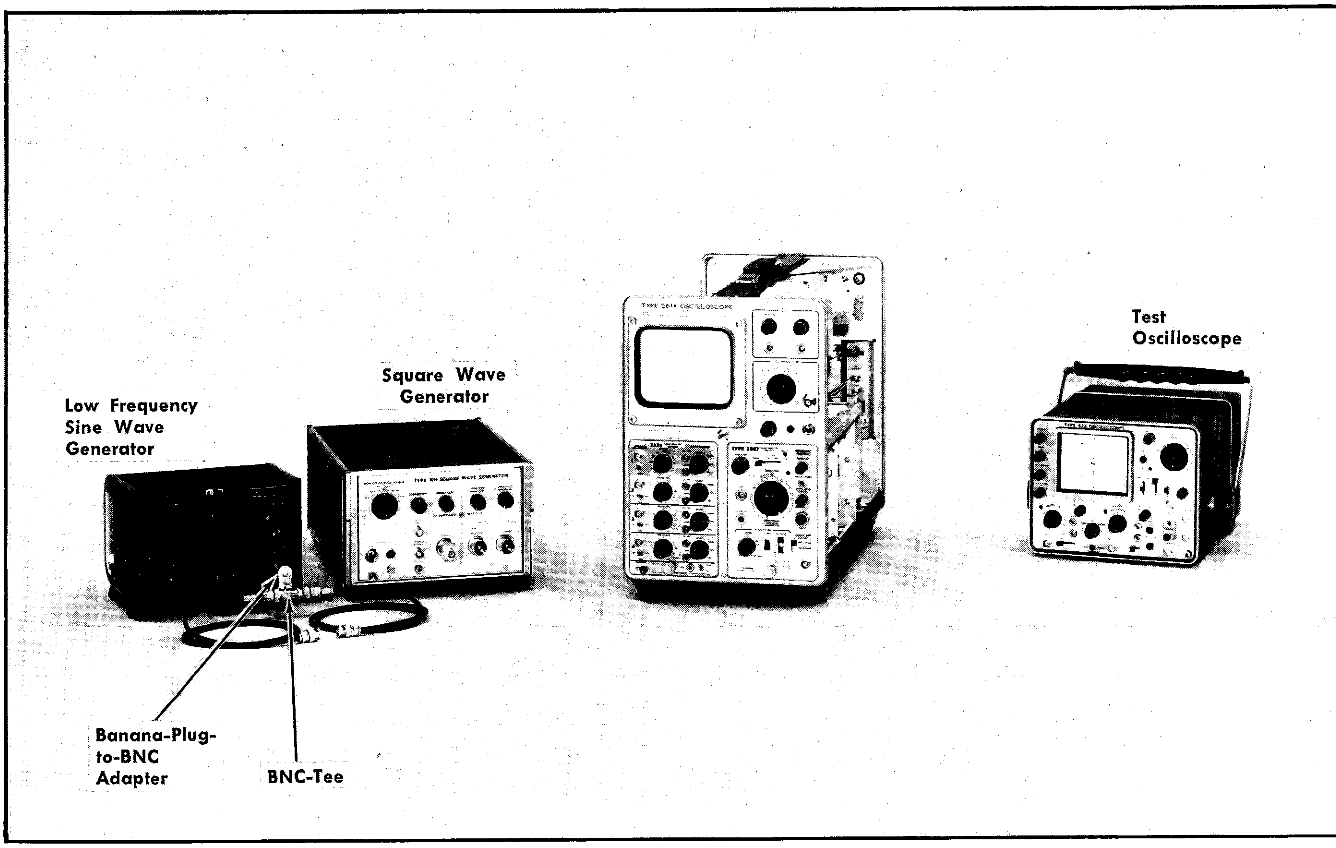

Fig. 5-21. Equipment arrangement for steps 1, 2 and 3.

2B67 PERFORMANCE CHECK/CALIBRATION PROCEDURE

Equipment Required

The equipment required for performing the 2B67 Calibration Procedure is listed at the beginning of this section. The 3A74 (Mod 730A) Engine Analyzer Amplifier must be operable, but does not have to be in calibrated condition. A Rotational Function Generator is required for part of the procedure; however, that part of the procedure can be omitted if a Rotational Function Generator is not available.

Preliminary Procedure

a. Set the equipment controls as follows:

Oscilloscope

CRT FOCUS	Midrange
INTENSITY	Fully CCW
CALIBRATOR	OFF

3A74

Channel 1, 2, 3 and 4	
MODE switches	OFF
Channel 2	
AC-GND-DC	DC
VOLTS/DIV	.1

2B67

POSITION	Midrange
MODE	NORM
TIME/DIV	5 ms
VARIABLE	CAL
5× MAG	Pushed In
TRIGGERING	
LEVEL	FREE RUN
SLOPE	+
SOURCE	EXT
ROTATIONAL FUNCTION	
POSITION	Midrange
PISTON-CRANK	CRANK
WIDTH	Fully CCW
MARKERS	Pushed In
SINGLE SWP DISPLAY	360°

b. Connect the Oscilloscope to an appropriate voltage source. Turn the POWER switch ON and allow 5 minutes warmup time before continuing.

c. Turn the CRT INTENSITY control clockwise until a trace is visible. If no trace appears, recheck the setup.

d. Adjust the FOCUS and INTENSITY controls as necessary to obtain a sharp trace with intensity consistent with good viewing. (If the Oscilloscope is equipped with an ASTIGMATISM control, it should be adjusted in conjunction with the FOCUS control to obtain optimum trace sharpness.)

1. Check Single Sweep Operation

a. The equipment arrangement is shown in Fig. 5-21. The preliminary control setup applies.

b. Set the MODE switch to RESET and hold it there. Note that the READY lamp lights.

c. Permit the MODE switch to return to SINGLE SWP. Note that one sweep occurs and the READY lamp goes out.

d. Place the MODE switch to NORM.

2. Adjust Triggering Stability (STABILITY—R111)

a. The equipment arrangement is shown in Fig. 5-21. The preliminary control setup applies.

b. Switch the 2B67 TIME/DIV control to .1 ms and its (TRIGGERING) LEVEL control to AUTO.

c. Using a small-bladed screwdriver, rotate the (TRIGGERING) Stability control (located on 2B67 front panel) fully counterclockwise.

d. Slowly rotate the STABILITY control clockwise and note the position at which the trace first appears.

e. Continue rotating the STABILITY control clockwise and note the position at which the trace brightens noticeably.

f. Set the STABILITY control at the point midway between the positions noted in steps d and e.

g. INTERACTION—Check step 3.

3. Check Triggering Sensitivity, Slope and Level

a. The equipment arrangement is shown in Fig. 5-21. The peliminary control setup applies.

b. Connect the dual banana plug to BNC adapter (item 23) to the Low-Frequency Sine Wave Generator (item 9). Connect a BNC Tee (item 22) to the adapter.

c. Connect a coaxial cable (item 16) from the BNC Tee to the 2B67 (TRIGGERING) EXT connector. Check that the 2B67 (TRIGGERING) SOURCE switch is at EXT.

d. Connect a second coaxial cable to the third connection of the BNC Tee. Connect the other end of the cable to the Test Oscilloscope (item 5) vertical input connector.

e. Set the Test Oscilloscope Volts/Div to 0.5 V and its Time/Div to 2 ms.

f. Set the Sine Wave Generator frequency to 2 MHz and adjust its amplitude as necessary to obtain 4 divisions (2 V) display on the Test Oscilloscope. Verify the frequency against the Test Oscilloscope time base.

g. Move the coaxial cable from the Test Oscilloscope to the 3A74 Channel 2 Input connector.

h. Set the 3A74 Channel 2 AC-GND-DC switch to DC, its VOLTS/DIV to .5, and its MODE switch to NORM.

i. Set the 2B67 TIME/DIV control to 1 μs.

j. CHECK—High-frequency external triggering response. A stable sine wave display should be obtainable through proper adjustment of the (TRIGGERING) LEVEL control. If the results of this check are not satisfactory, recheck the STABILITY adjustment, step 2, and then repeat step 3.

k. Move the coaxial cable from Channel 2 back to the Test Oscilloscope vertical input connector. Set the Test Oscilloscope Input coupling switch to DC, its Volts/Div to 0.1 and its Time/Div to 50 ms.

l. Change the Sine Wave Generator frequency to 5 Hz and adjust its amplitude as necessary to obtain 5 divisions (0.5 V) of display amplitude on the Test Oscilloscope. Verify the frequency against the Test Oscilloscope time base.

m. Move the coaxial cable from the Test Oscilloscope to the Channel 2 Input connector and set the Channel 2 VOLTS/DIV control to .1 V.

n. Switch the 2B67 TIME/DIV to 50 ms.

o. CHECK—Low-frequency external triggering response. A stable display should be obtainable through proper adjustment of the (TRIGGERING) LEVEL control.

p. Disconnect the cables from the Sine Wave Generator and the Oscilloscope.

q. Set the 2B67 TIME/DIV control to .2 ms, its LEVEL control to FREE RUN and its SOURCE switch to INT.

NOTE

If the Oscilloscope (or Test Oscilloscope) has a 1 kHz calibrator, it can be used in place of the Type 106 Square Wave Generator in the following steps.

r. Connect the Type 106 Square Wave Generator (item 8) FAST RISE + OUTPUT connector to the 3A74 Channel 2 Input connector, using a GR-BNC adapter (item 24) and a coaxial cable.

s. Set the Square Wave Generator frequency to 1 kHz. Set its + TRANSITION AMPLITUDE control and the 3A74 VOLTS/DIV control as necessary to obtain 0.4 division separation between the centers of the 2 horizontal traces.

t. CHECK—Internal triggering response. A stable square wave display should be obtained through proper positioning of the 2B67 LEVEL control.

NOTE

If a stable display cannot be obtained, adjust the (TRIGGERING) STABILITY control clockwise 1 or 2 degrees and again attempt to obtain a stable display with the LEVEL control. Repeat as necessary. However, if the STABILITY control must be readjusted, repeat step 3 from the beginning.

u. Disconnect the cable from the 3A74.

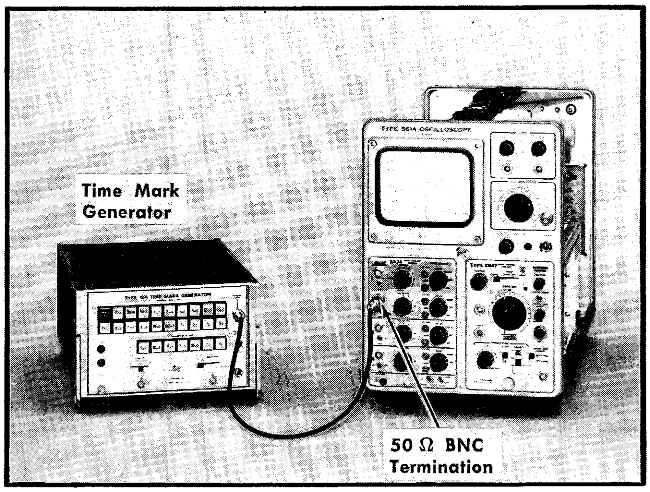

Fig. 5-22. Equipment arrangement for steps 4 through 12.

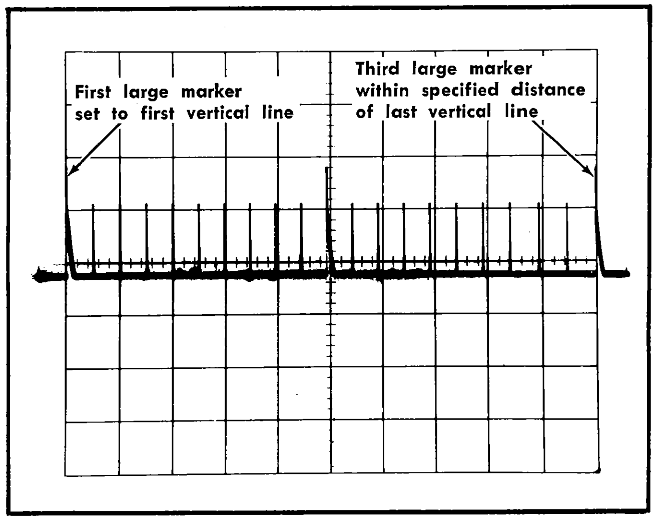

Fig. 5-23. Sweep timing waveform for step 4. Sweep rate —0.2 ms/div (1 ms/div and 5× magnification); vertical sensitivity - 1 volt/div.

NOTE

The 2B67 (TIME/DIV) VARIABLE control must remain at CAL (UNCAL LAMP OUT) during performance of steps 4 through 12.

4. Check/Adjust Basic Magnified Sweep Timing (Cal—R334)

a. The initial control setup applies except that the 3A74 Channel 2 AC-GND-DC control is at DC and its MODE switch is at NORM.

b. Set the 3A74 Channel 2 VOLTS/DIV control to 1 and its VAR GAIN to CAL.

c. Switch the 2B67 TIME/DIV control to 1 ms and pull the 5× MAG knob out. Check that the (TIME/DIV) VARIABLE is at CAL.

d. Connect the 50 Ω BNC termination (item 21) to the 3A74 Channel 2 Input connector. Then connect a 50 Ω coaxial cable between the termination and the MARKER OUTPUT connector of the Type 184 Time Mark Generator (item 11).

e. Select .1 ms and 1 ms markers at the Time Mark Generator by simultaneously depressing those buttons.

f. Adjust the 2B67 (TRIGGERING) LEVEL control as necessary to obtain a triggered display which has large markers positioned approximately 5 divisions apart. Adjust the CRT INTENSITY as necessary for convenient viewing. See Fig. 5-23.

g. Adjust the 2B67 POSITION control as necessary to set one large marker exactly at the first vertical line at the left edge of the graticule, as in Fig. 5-23.

h. CHECK—Basic magnified sweep timing accuracy. The third visible large marker should appear on the last vertical line at the right of the graticule, as in Fig. 5-23.

i. ADJUST—Basic magnified sweep timing. Adjust CAL, R334 (located on 2B67 front panel) as necessary to set the sweep timing so that the first and third visible large markers coincidentally appear exactly on the first and last vertical graticule lines as in Fig. 5-23.

j. Return the 2B67 5× MAG to its "in" position.

k. INTERACTION—This step affects steps 5, 6, 10 and 11 by synchronously adjusting them to compensate for different Oscilloscope CRT sensitivity.

5. Check/Adjust Basic Unmagnified Sweep Timing (SWP GAIN—R341)

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that the 2B67 TIME/DIV control is at 1 ms, the (TRIGGERING) SLOPE is at +, SOURCE is at INT, and the LEVEL control is set for a triggered display. 1 ms and .1 ms markers from the Time Mark Generator are displayed on the 3A74 Channel 3 trace.

b. Remove the .1 ms marker, and readjust the (TRIGGERING) LEVEL control as necessary to display the 1 ms markers.

c. Check that the 2B67 TIME/DIV VARIABLE control is at CAL and then adjust the POSITION control as necessary to display the second marker from the left exactly on the second vertical graticule line from the left. See Fig. 5-24 (A).

d. CHECK—Basic Unmagnified timing accuracy. The 10th marker should be displayed within ±0.24 division of the 10th vertical graticule line, as illustrated in Fig. 5-24 (A).

e. (Calibration Procedure only) ADJUST—Basic unmagnified timing accuracy. Adjust SWP GAIN, R341 (Fig. 5-25) as necessary to have the 10th marker fall exactly on the 10th vertical graticule line when the second marker is exactly on the second vertical graticule line. Use Fig. 5-24 (A) as a guide.

f. INTERACTION—Check steps 6, 10 and 11.

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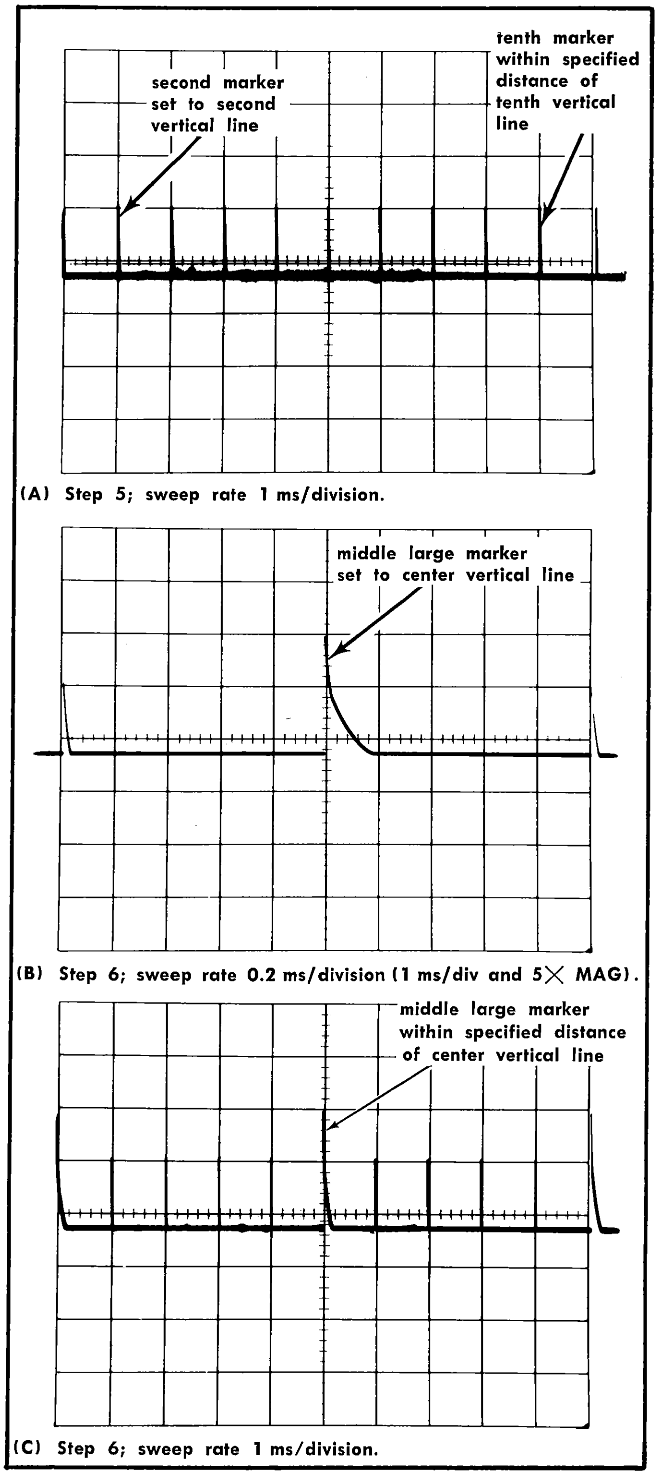


(A) Step 5; sweep rate 1 ms/division.

(B) Step 6; sweep rate 0.2 ms/division (1 ms/div and 5× MAG).

(C) Step 6; sweep rate 1 ms/division.

Fig. 5-24. Sweep timing waveform. Vertical sensitivity - 1 volt/division.

6. Check/Adjust Magnified Sweep Registration (SWP MAG REGIS—R346)

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that the 2B67 TIME/DIV is at 1 ms and the triggering controls are set for a triggered display. 1 ms markers from the Time Mark Generator are displayed on the Channel 2 trace.

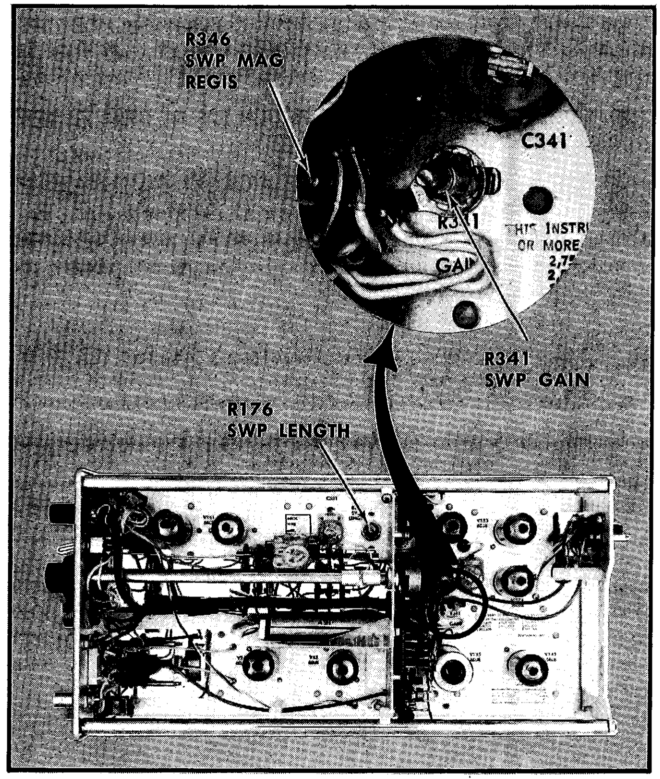


Fig. 5-25. Adjustment locations for steps 5, 6 and 7; 2B67 - right side.

b. Simultaneously apply 1 ms and 5 ms markers from the Time Mark Generator to the Channel 2 trace. Readjust the 2B67 Triggering controls as necessary to obtain a stable display as in Fig. 5-24 (C).

c. Pull the 2B67 5× MAG out, and check that the (TIME/DIV) VARIABLE is at CAL. Using the POSITION control, set the middle large marker exactly to the center vertical line, as in Fig. 5-24 (B).

d. Push the 5× MAG control in and check that the VARIABLE control remains at CAL.

e. CHECK—Magnified sweep registration. The middle large marker should be within ±0.2 division of the center vertical line as in Fig. 5-24 (C).

f. (Calibration Procedure only.) ADJUST—Magnified sweep registration. Adjust SWP MAG REGIS, R346 (Fig. 5-25), as necessary to set the center large marker exactly to the graticule center vertical line as in Fig. 5-24 (C).

g. REPEAT—Steps c through f until step e requirements are met.

7. Check/Adjust Sweep Length (SWP LENGTH —R176)

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that the 2B67 TIME/DIV is at 1 ms. A triggered marker display remains from the preceding step, but is not essential to this check/adjustment.

b. Check that the 2B67 5X MAG knob is in. Then adjust the POSITION control as necessary to set the trace to start exactly at the first vertical line at the left of the graticule.

c. CHECK—Sweep length. It should be at least 10 divisions.

d. (Calibration Procedure only). ADJUST—SWP LENGTH, R176 (Fig. 5-25), as necessary to obtain approximately 10.5 divisions of trace length. (This adjustment is not critical, and is considered satisfactory if the trace length adjustment results in at least 10 divisions.)

8. Check Variable Time/Division Range (TIME/DIV VARIABLE—R160Y)

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that the 2B67 TIME/DIV is at 1 ms and the Triggering controls are set for a triggered display. 1 and 5 ms markers from the Time Mark Generator are displayed on the Channel 2 trace.

b. CHECK—(TIME/DIV) VARIABLE range. Rotate the (TIME/DIV) VARIABLE control counterclockwise and note that the number of markers being displayed increases (sweep rate decreases). Note that with the VARIABLE control fully counterclockwise, at least 5 large markers are being displayed, indicating a variable time/division range of at least 2.5:1.

c. CHECK—UNCAL lamp. It should be on whenever the (TIME/DIV) VARIABLE control is not at CAL.

d. Return the VARIABLE control to CAL.

9. Check Horizontal Positioning Range (POSITION—R323)

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that the 2B67 TIME/DIV switch is at 1 ms. A triggered display of 1 and 5 ms markers from the Time Mark Generator appears on the Channel 2 trace.

b. CHECK—Horizontal positioning range. Using the 2B67 POSITION control, check that the left end of the trace can be positioned to graticule center. Then check that the large marker which appears at the right side of the trace can be positioned to graticule center.

c. Reposition the left end of the trace to the first vertical graticule line at the left side of the CRT.

10. Check Slow Sweep Rate Accuracy

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that a triggered display of 1 and 5 ms markers is being displayed on the Channel 2 trace.

b. Set the Channel 2 VOLTS/DIV switch to .5.

c. Using the Channel 2 POSITION control, set the marker baseline below the visible portion of the CRT to avoid damage to the CRT during the following procedure.

d. CHECK—Slow sweep rate accuracy. Use the following procedure in conjunction with Table 5-6. Keep the TIME/DIV VARIABLE control at CAL throughout the check.

(1) Set the Time Mark Generator according to Table 5-6.

(2) Set the 2B67 TIME/DIV according to Table 5-6.

(3) Adjust the 2B67 Triggering controls as necessary to obtain a stable display.

(4) Adjust the 2B67 POSITION control so that the specified marker coincides with the second vertical line from the left of the graticule, as shown in Fig. 5-24(A).

TABLE 5-6

Time Mark Generator Output	2B67 TIME/DIV	Marker Set To 2nd Vertical Graticule Line	Markers Per Division	Displacement Tolerance At 10th Vertical Line
.1 ms	.1 ms	2	1	±0.24 divisions
.1 ms	.2 ms	3	2	
.5 ms	.5 ms	2	1	
1 ms	1 ms	2	1	
1 ms	2 ms	3	2	
5 ms	5 ms	2	1	
10 ms	10 ms	2	1	
10 ms	20 ms	3	2	
50 ms	50 ms	2	1	
.1 s	.1 s	2	1	
.1 s	.2 s[2]	3	2	
.5 s	.5 s[2]	2	1	
1 s	1 s[2]	2	1	
1 s	2 s[2]	3	2	
5 s	5 s[2]	2	1	

[2]Use 2B67 SINGLE SWP Mode to check these positions. The MODE switch can be repeatedly reset while adjusting the specified marker to the second vertical graticule line, thus saving considerable time.

(5) Adjust the 3A74 Channel 2 POSITION control as necessary to keep the markers in view, while keeping the baseline below the viewing area of the CRT.

(6) Check that the specified number of markers per division appears, with the marker displacement at the 10th vertical line being within the tolerance given in Table 5-6. See Fig. 5-24(A).

e. Switch the 2B67 MODE control back to NORM.

11. Check/Adjust Fast Sweep Rate Accuracy and Linearity (C160A, C160C, C321, C341)

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies, except that the MARKER OUTPUT of the Time Mark Generator is connected through a coaxial cable and a 50 Ω termination to the 3A74 Channel 2 Input connector. The 3A74 Channel 2 AC-GND-DC control is at DC and the Channel 2 MODE switch is at NORM.

b. Set the Time Mark Generator for 10 μs and 50 μs markers.

c. Set the 2B67 TIME/DIV control to 50 μs and pull the 5× MAG knob out. Adjust the Triggering controls as necessary to obtain a stable display as in Fig. 5-26 (A).

d. With the 2B67 POSITION control near midrange, set a marker exactly on the 2nd vertical graticule line as in Fig. 5-26 (A).

e. CHECK—10 μs/div (magnified) accuracy. One marker per division should be displayed. The marker associated with the 10th vertical line should be within ±0.4 division of it, as in Fig. 5-26 (A).

f. (Calibration Procedure only.) ADJUST—10 μs/div (magnified) accuracy. Adjust C160C (Fig. 5-27) as necessary to obtain one marker per division when the POSITION control is near midrange. Adjust for exactly 8 divisions separation between markers set to the 2nd and 10th vertical lines, using Fig. 5-26 (A) as a guide.

g. Select 1 μs markers from the Time Mark Generator.

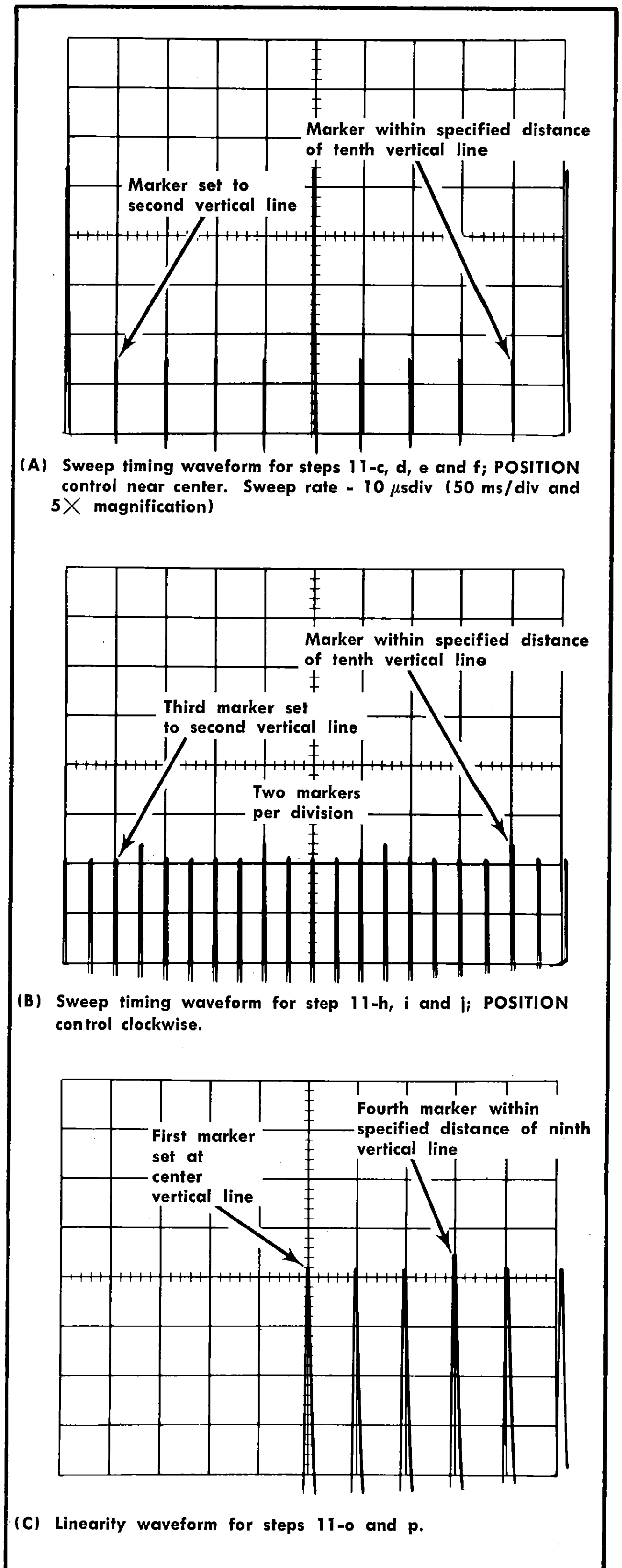
h. Switch the 2B67 TIME/DIV control to 10 μs and adjust the 2B67 Triggering controls as necessary for a stable display. Adjust the POSITION control clockwise as necessary to place the third marker (left side of trace) to the second vertical graticule line, as in Fig. 5-26 (B).

i. CHECK—2 μs/div (magnified) accuracy. Two markers per division should exist. The marker associated with the 10th vertical graticule line should be within 0.4 divisions of it as illustrated in Fig. 5-26 (B).

j. (Calibration Procedure only.) ADJUST—2 μs/div magnified accuracy. Adjust C321 (Fig. 5-27) as necessary to obtain two markers per division when the beginning of the trace is set to the left edge of the graticule. Adjust for exactly 8 divisions separation between markers set to the 2nd and 10th vertical lines using Fig. 5-26(B) as a guide.

k. Switch the TIME/DIV control to 5 μs and adjust the 2B67 Triggering controls as necessary for a stable display.

l. With the POSITION control near midrange, set a marker exactly to the 2nd vertical graticule line.



(A) Sweep timing waveform for steps 11-c, d, e and f; POSITION control near center. Sweep rate - 10 μsdiv (50 ms/div and 5× magnification)

(B) Sweep timing waveform for step 11-h, i and j; POSITION control clockwise.

(C) Linearity waveform for steps 11-o and p.

Fig. 5-26. Waveform for step 11.

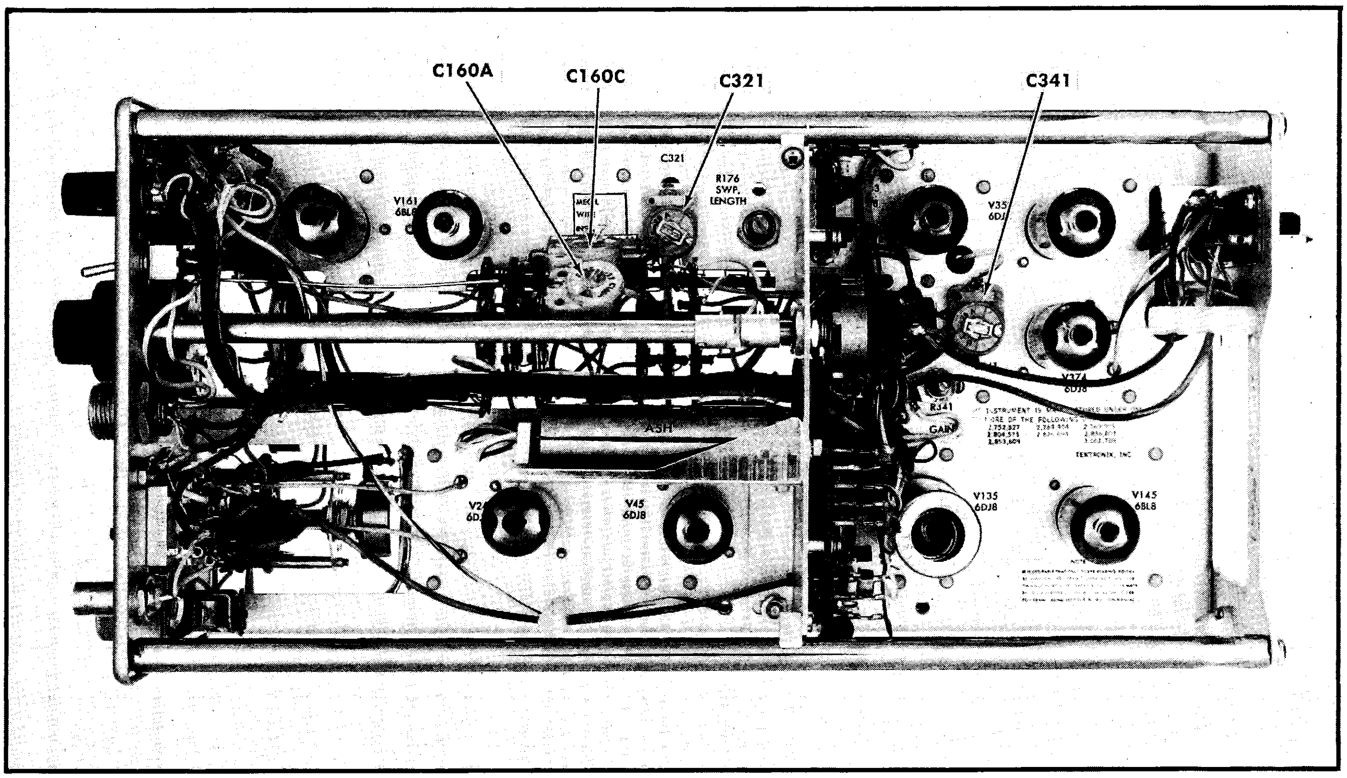


Fig. 5-27. Adjustment locations for step 11.

m. CHECK—1 μs/div (magnified) accuracy. One marker per division should exist. The marker associated with the 10th vertical line should be within 0.4 division of it, similar to that illustrated in Fig. 5-26(A).

n. (Calibration Procedure only.) ADJUST—1 μs/div (magnified) accuracy. Adjust C160A (Fig. 5-27) as necessary to obtain one marker per division with the POSITION control near midrange. Adjust for exactly 8 divisions separation between markers set to the 2nd and 10th vertical lines, using Fig. 5-26(A) as a reference.

o. Switch the TIME/DIV control to 1 μs and turn the 5× MAG off. Using the POSITION control, set the first marker (left of trace) to start at graticule center as in Fig. 5-26(C).

p. CHECK—1 μs linearity. One marker per division should be displayed, with the marker associated with the 9th vertical graticule line being within .09 division of it as in Fig. 5-26(C).

q. (Calibration Procedure only.) ADJUST—1 μs/div linearity. With the display starting at graticule vertical center, adjust C341 (Fig. 5-27) as necessary to obtain 1 division separation between each of the first four markers. Compromise as necessary for best linearity, keeping the 4th marker within .09 division of its vertical line.

r. Using the 2B67 POSITION control, set the display to start at the first graticule line.

s. CHECK—Unmagnified fast sweep rate accuracy. Use the following procedure in conjunction with Table 5-7:

(1) Set the Time Mark Generator according to column 1.

(2) Set the 2B67 TIME/DIV according to column 2.

(3) Adjust the triggering controls as necessary to obtain a stable display.

(4) Set the POSITION control as necessary to set the marker specified in colmn 3 to the 2nd vertical graticule line.

(5) Check for the specified number of markers, with marker displacement at the 10th vertical line within the tolerance given in Table 5-7. Fig. 5-26 (A) can be used as a reference.

t. Disconnect the 50 Ω termination and cable assembly from the 3A74, Switch the 3A74 Channel 2 MODE switch OFF.

12. Check Rotational Function Single Sweep Display Operation

a. The equipment arrangement is shown in Fig. 5-22. The preliminary control setup applies.

b. Set the 2B67 controls as follows:

TIME/DIV	.1 s
SOURCE	EXT
SINGLE SWP DISPLAY	360°
SLOPE	+

TABLE 5-7

Marker Generator Output	2B67 TIME/DIV	Marker Set To 2nd Vertical Graticule Line	Markers Per Division	Displacement Tolerance At 10th Vertical Line
1 μs	1 μs	2	1	±0.24 divisions
2 μs	1 μs	3	2	
5 μs	5 μs	2	1	
10 μs	10 μs	2	1	
20 μs	10 μs	3	2	
50 μs	50 μs	2	1	

c. Connect the coaxial cable from the Time Mark Generator to the 2B67 (TRIGGERING) EXT connector.

d. Select 1 s markers at the Time Mark Generator.

e. Set the 2B67 (TRIGGERING) LEVEL control to a point which provides a trace. Do not use the AUTO or FREE RUN position.

f. Rotate the FOCUS control fully clockwise.

g. Switch the TIME/DIV control to ROTATIONAL FUNCTION GENERATOR. If a defocused spot appears, set the INTENSITY control so that the minimum intensity required for easy viewing is obtained.

h. Adjust the 2B67 Rotational Function POSITION control as necessary to set the defocused spot near graticule center. Reduce its intensity until the minimum brightness required for good viewing is obtained.

i. CHECK—Rotational Function 360° (2 CYCLE) single sweep operation. Place the 2B67 MODE switch to RESET and then permit it to return to SINGLE SWP. Note that a display appears within 1 second, and then disappears after 1 second. (If the spot does not reappear, a slight adjustment of the (TRIGGERING) LEVEL control may be necessary.

j. Switch the 2B67 (ROTATIONAL FUNCTION) SINGLE SWP DISPLAY switch to 720° (4 CYCLE).

k. CHECK—Rotational Function 720° (4 CYCLE) single sweep operation. Place the 2B67 MODE switch at RESET and then permit it to return to SINGLE SWP. Note that the defocused spot appears within 1 second, but this time remains for 2 seconds before disappearing.

l. Remove the coaxial cable from the 2B67. Switch the single sweep MODE switch to NORM, the (TRIGGERING) LEVEL control to AUTO and the SOURCE control to INT.

NOTES

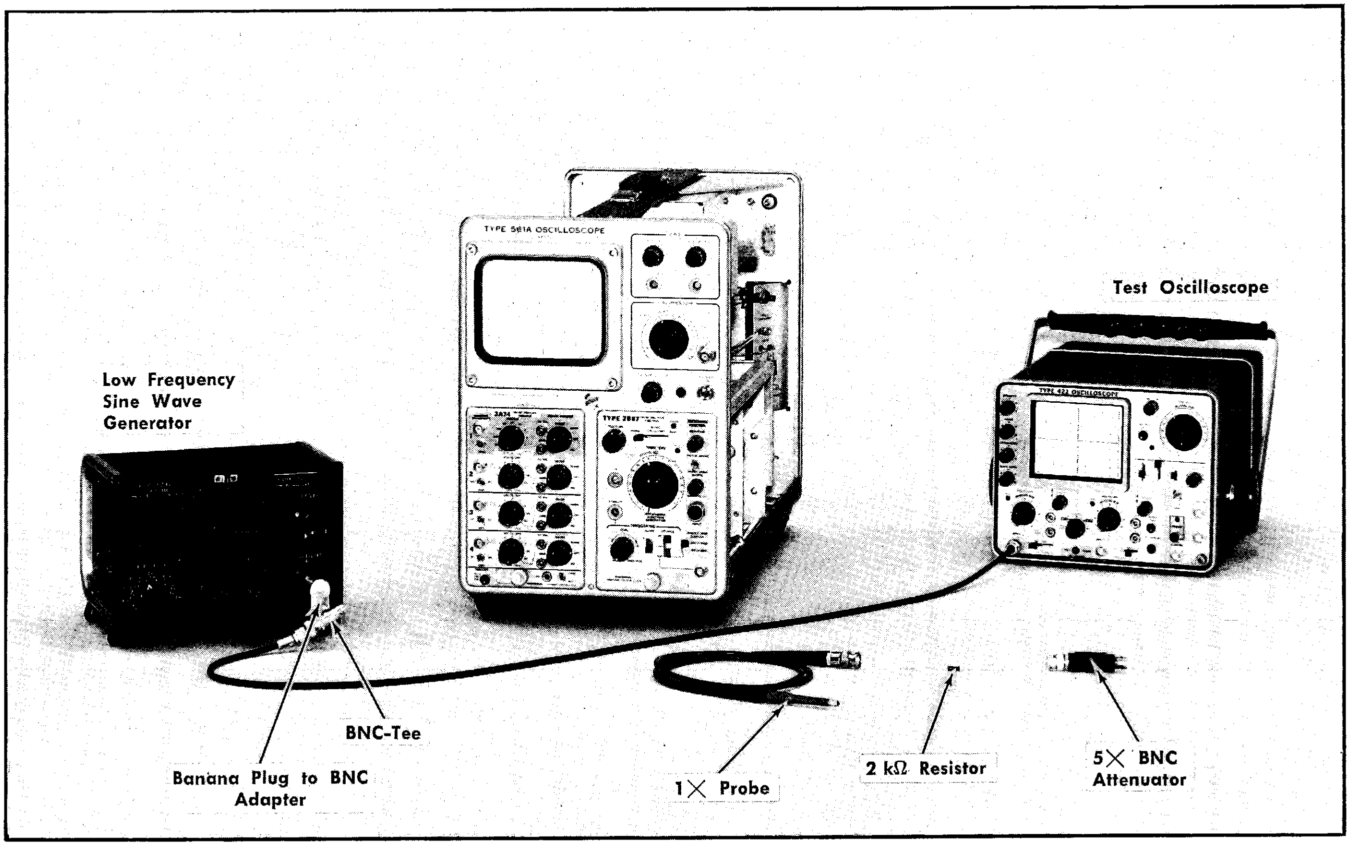


Fig. 5-28. Equipment arrangement for steps 13, 14 and 15.

13. Check Rotational Function Marker Amplifier Operation

a. The equipment arrangement is shown in Fig. 5-28. The preliminary control setup applies, except that the 2B67 (TRIGGERING) LEVEL control is at AUTO.

b. Switch the 2B67 TIME/DIV control to 5 ms (.5 ms if the Oscilloscope has a 1 kHz calibrator) and focus the trace.

c. Turn the 3A74 Channel 2 MODE switch to NORM and adjust its POSITION control as necessary to center the trace.

d. Connect the 1× Probe (item 13) BNC connector (or a patch cord) to the Oscilloscope CALIBRATOR Output jack.

e. Switch the CALIBRATOR to 50 mV (40 mV on 1 kHz calibrators).

f. Insert one end of a 2 kΩ resistor (item 25) into terminal E of the 2B67 Function Amplifier INPUT connector.

g. Touch the 1× probe tip (or patch cord) to the other end of the resistor, completing a circuit to the 2B67 Marker Amplifier.

h. CHECK—Marker Amplifier operation. Pull the 2B67 Rotational Function MARKERS switch out and note that a vertical display of approximately 1.5 divisions (1.3 with 1 kHz calibrators) appears on the CRT.

i. Disconnect the probe (or patch cord) and resistor from the INPUT connector.

14. Check Rotational Function Amplifier Maximum and Minimum Deflection Factors

a. The equipment arrangement is shown in Fig. 5-28. The preliminary control setup applies, except that the 1× probe (or patch cord) is connected to the Oscilloscope CALIBRATOR.

b. Turn the Oscilloscope FOCUS control fully clockwise and set the CALIBRATOR to .5 V (.4 V for 1 kHz calibrators).

c. Check that the 2B67 Rotational Function PISTON-CRANK switch is at CRANK and the WIDTH control is fully counterclockwise.

d. Switch the 2B67 TIME/DIV control to ROTATIONAL FUNCTION GENERATOR, and adjust the Rotational Function POSITION control as necessary to set the defocused spot approximately 4 divisions to the left of graticule center.

e. Check—Maximum deflection factor. Connect the tip of the 1× probe to terminal B of the Rotational Function INPUT connector and check that 5 divisions or less horizontal separation exists between the centers of the defocused spots. (Four divisions or less for 1 kHz calibrators). This indicates a maximum deflection factor (minimum sensitivity) of 100 mV/division or greater.

f. Disconnect the probe from the Rotational Function INPUT connector.

g. Switch the Oscilloscope CALIBRATOR to 50 mV (40 mV for 1 kHz calibrators) and the 2B67 WIDTH control fully clockwise. Readjust the 2B67 Rotational Function POSITION control as necessary to position the defocused spot 4 divisions to the left of graticule center.

h. CHECK—Minimum deflection factor. Connect the probe tip to terminal B of the 2B67 INPUT connector and check that 5 divisions or more (4 divisions or more for 1 kHz calibrator) horizontal separation exists between the centers of the defocused spots. This indicates a minimum deflection factor (maximum sensitivity) of 10 mV/division or less. Readjust the POSITION control as necessary for viewing the defocused spots.

i. Disconnect the probe from terminal B and from the Oscilloscope calibrator.

15. Check Rotational Function Amplifier Upper Frequency Response

a. The equipment arrangement is shown in Fig. 5-28. The preliminary control setup applies except that the TIME/DIV control is at ROTATIONAL FUNCTION GENERATOR position and the FOCUS control is fully clockwise.

b. Connect the banana plug-to-BNC adapter to the output of the Low Frequency Sine Wave Generator, and connect a BNC Tee to the adapter. Connect a coaxial cable from the BNC Tee to the input of the Test Oscilloscope (item 5).

c. Set the Sine Wave Generator frequency to 1 kHz and adjust its amplitude as necessary to obtain a 0.5 V vertical display on the Test Oscilloscope.

d. Connect a 1× probe (or patch cord) to the BNC Tee at the Sine Wave Generator.

e. Check that the 2B67 Rotational Function PISTON-CRANK switch is at CRANK. Then connect the probe tip to terminal B of the 2B67 Rotational Function INPUT connector.

CAUTION

During the rest of step 15, do not remove the signal from pin B without first defocusing the display or turning the INTENSITY control fully counterclockwise to avoid a phosphor burn on the CRT.

f. Set the 2B67 Rotational Function WIDTH and POSITION controls as necessary to obtain a centered display of exactly 5 horizontal divisions. Adjust the FOCUS control for optimum trace sharpness.

g. Change the Sine Wave Generator frequency to 75 kHz. Readjust the Sine Wave Generator as necessary to maintain 0.5 V display on the Test Oscilloscope.

h. CHECK—Rotational Function Amplifier 100 mV/division upper frequency limit. Check that the horizontal display is at least 3.5 divisions, indicating not more than 3 dB attenuation at 75 kHz.

i. Reset the Sine Wave Generator to 1 kHz and adjust its amplitude as necessary to obtain 50 mV display amplitude on the Test Oscilloscope. (Insert a 5× BNC attenuator, item 19, in the signal path if necessary to reduce the output to 50 mV.)

j. Turn the 2B67 Rotational Function WIDTH and POSITION controls as necessary to obtain exactly 5 divisions display amplitude.

k. Change the Sine Wave Generator frequency to 25 kHz, and readjust the Sine Wave Generator amplitude if necessary to maintain 50 mV display amplitude on the Test Oscilloscope.

l. CHECK—Rotational Function Amplifier 10 mV/division upper frequency limit. Check that the 561 or 564-Series Oscilloscope horizontal display is at least 3.5 divisions, indicating not more than 3 dB attenuation at 25 kHz.

m. Rotate the FOCUS control fully clockwise and remove the probe from the 2B67. Use of the Sine Wave Generator, 1× probe, and Test Oscilloscope has been completed.

n. If an operable Rotational Function Generator is available, continue with step 16. If one is not available, omit steps 16 through 18-c and proceed with step 18-d.

NOTES

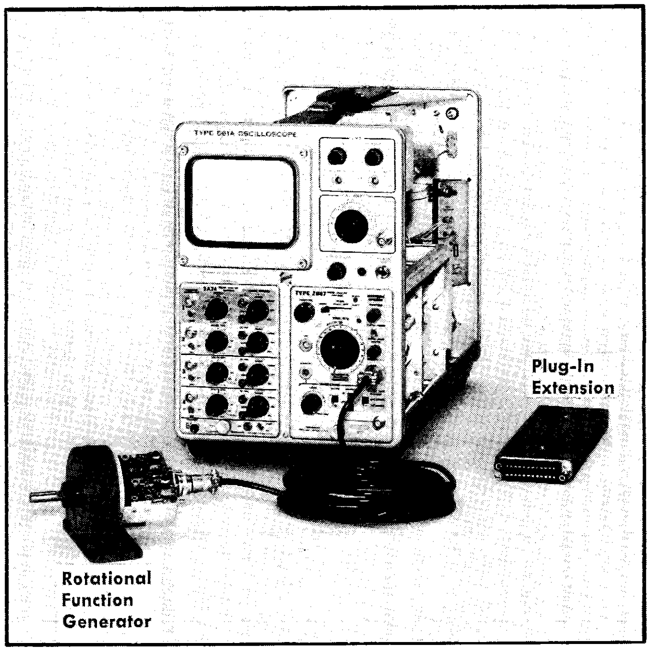


Fig. 5-29. Equipment arrangement for steps 16, 17 and 18.

16. Check Standby Trace Operation

a. This step can be performed only if an operable Rotational Function Generator is available.

b. The equipment arrangement is shown in Fig. 5-29. The preliminary control setup applies, except that the FOCUS control is fully cockwise and the TIME/DIV control is at ROTATIONAL FUNCTION GENERATOR position.

c. Connect the Rotational Function Generator to the 2B67 Rotational Function INPUT connector, using the 20 ft Function Generator Cable (item 4).

d. Set the 2B67 WIDTH control fully counterclockwise.

e. CHECK—Standby trace operation. Using the 2B67 Rotational Function POSITION control, set the display to graticule center. A horizontal display of approximately 2 divisions should be present with the Function Generator shaft stopped. Adjust the CRT FOCUS and INTENSITY controls as necessary for optimum viewing.

f. CHECK—Standby Trace disabling circuitry. Rotate the Rotational Function Generator shaft slowly (about ½ revolution per second) and note that the standby trace is replaced by a moving dot. Stop rotating the shaft and note that the dot is replaced within approximately 1 second by the standby trace.

17. Check/Adjust Rotational Function WIDTH Registration (ROTATION FUNCTION REGIS —R325)

a. This step can be performed only if an operable Rotational Function Generator is available.

b. The equipment arrangement is shown in Fig. 5-29. The preliminary control setup applies, except that the Rotational Function Generator is connected to the 2B67 and the 2B67 TIME/DIV switch is at ROTATIONAL FUNCTION GENERATOR position. The 3A74 Channel 2 MODE switch is at NORM.

c. Check that the 2B67 PISTON-CRANK switch is at CRANK. Note the position of the horizontal display while rotating the Function Generator shaft. Switch the ROTATION DIRECTION switch (back of Rotational Function Generator) to its opposite position and again note the position of horizontal display. If the position is within ±2 divisions of the previous display position, continue with step d. If this requirement cannot be met, remove the R57 SAWTOOTH DC BAL access cover (Fig. 5-32C) from the Function Generator and adjust R57 as necessary to minimize the change of trace position which accompanies ROTATION DIRECTION switching.

d. Pull the 2B67 MARKERS switch out and check that the 3A74 Channel 2 MODE switch is at NORM.

e. Rotate the Rotational Function Generator shaft and adjust the 2B67 Rotational Function WIDTH control to obtain 10 divisions of display.

f. While rotating the shaft, adjust the 2B67 POSITION control as necessary to set the tall pedestal's center marker exactly to the center vertical graticule line as in Fig. 5-30(A).

g. CHECK—Rotational Function WIDTH registration. Rotate the 2B67 WIDTH control fully clockwise and note that the center marker on the tall pedestal remains within 2 divisions of graticule center. See Fig. 5-30 (B).

h. If a Performance Check is being made, omit step i through n and proceed with step 18. If a Calibration Procedure is being performed, continue with step i.

NOTE

If a Calibration Procedure is being performed and the result of step g is satisfactory, steps j through n may be omitted.

i. Turn the Oscilloscope off and remove the 2B67 from its compartment. Install a plug-in extension (item 12) in the Oscilloscope and connect the 2B67 to it. Then turn the Oscilloscope on. After approximately 5 minutes, continue with the procedure.

WARNING

Use caution when working in the vicinity of the plug-in while it is on the plug-in extender. Dangerous voltages exist on the exposed circuitry.

j. Check that the 2B67 WIDTH control is fully clockwise. Then rotate the Rotational Function Generator shaft and adjust the Rotational Function POSITION control as necessary to set the tall pedestal's center marker exactly to graticule center.

k. Turn the 2B67 WIDTH control fully counterclockwise.

l. ADJUST—Rotational Function WIDTH registration. While rotating the Function Generator shaft, adjust ROTATION FUNCTION REGIS, R325 (Fig. 5-30C), as necessary to return the pedestal center marker to graticule center.

m. Repeat steps g, j, k and l until the requirements of step g are met.

n. Turn the Oscilloscope off. Remove the plug-in extender. Plug the 2B67 into the Oscilloscope and turn the Oscilloscope on.

18. Check Rotational Function Positioning Range

a. This step is dependent upon satisfactory performance of step 17. The equipment arrangement is shown in Fig. 5-29. The preliminary setup applies, except that the TIME/DIV switch is at ROTATIONAL FUNCTION GENERATOR position an an operable Rotational Function Generator is connected to the 2B67.

b. Set the 2B67 WIDTH control fully counterclockwise.

c. CHECK—Rotational Function POSITION range. Check that the Rotational Function POSITION control can place each end of the display to graticule vertical center. Then turn the WIDTH control fully clockwise and repeat the check.

d. This completes the 2B67 Performance Check/Calibration Procedure. Perform step 22 in the 3A74 Performance Check/Calibration Procedure if it was not done during the 3A74 Calibration Procedure.

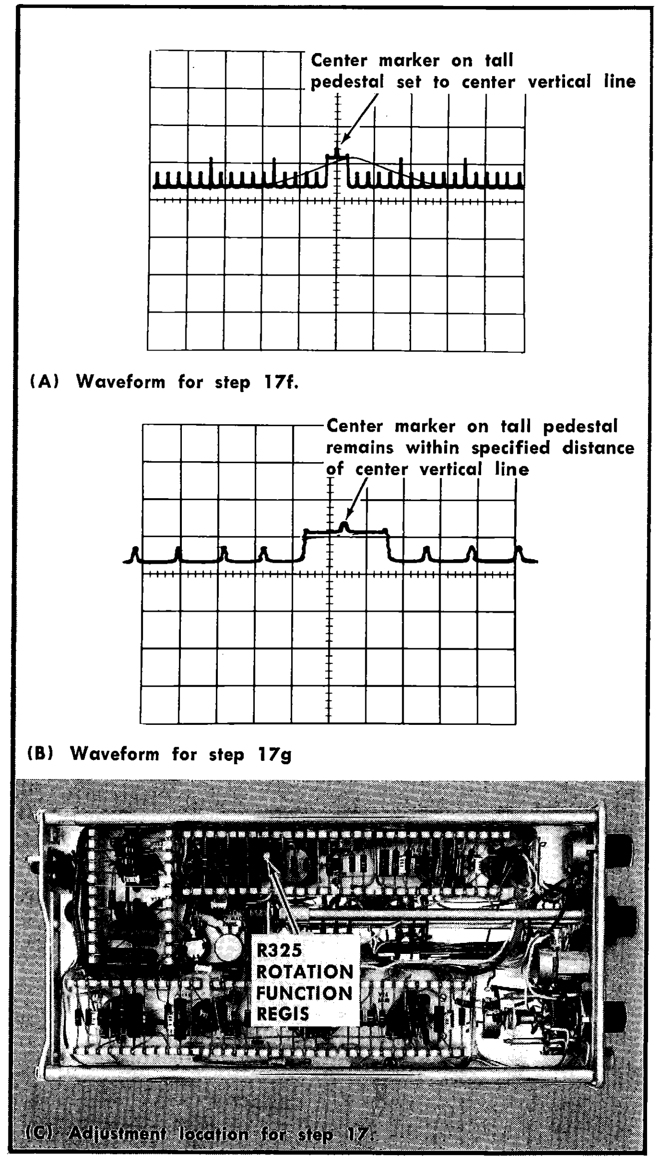


Fig. 5-30. Waveforms and adjustment location for step 17.

NOTES

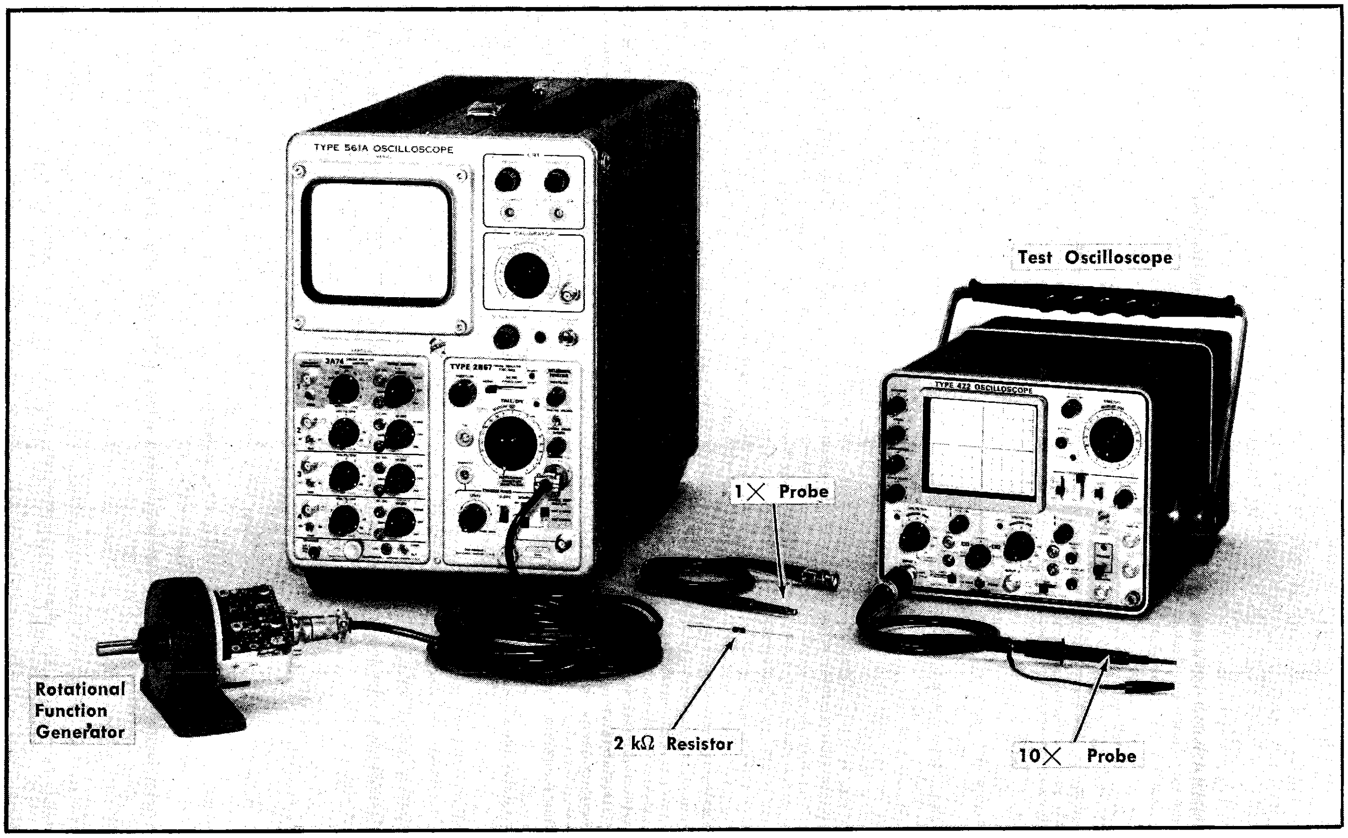


Fig. 5-31. Equipment arrangement for calibrating the Rotational Function Generator.

ROTATIONAL FUNCTION GENERATOR PERFORMANCE CHECK/CALIBRATION PROCEDURE

General. This procedure is designed to be used with a 3A74 (Mod 730A) and a 2B67 (Mod 730A) installed in a 561 or 564-Series Oscilloscope. The calibration status of the 3A74 and the 2B67 is of no concern to this procedure, as long as the instruments are operating. An alternate procedure for calibrating the Rotational Function Generator (hereafter called Function Generator) without a 3A74 or 2B67 is included as step 9 of this procedure. It permits calibrating the unit by using a separate DC source voltage and a test oscilloscope.

Equipment Preliminary Setup

Oscilloscope

CRT FOCUS	Midrange
INTENSITY	Fully CCW
CALIBRATOR	OFF

3A74

Channel 1, 2 3 and 4 MODE Switches	OFF

2B67

POSITION	Midrange
MODE	NORM
TIME/DIV	ROTATIONAL FUNCTION GENERATOR
VARIABLE	CAL
5X MAG	Pushed in
TRIGGERING	
LEVEL	AUTO
SLOPE	—
SOURCE	EXT
ROTATIONAL FUNCTION	
POSITION	Midrange
PISTON-CRANK	CRANK
WIDTH	Fully CCW
MARKERS	Pushed In

Ⓐ

Preliminary Procedure

a. Install the 3A74 (Mod 730A) and the 2B67 (Mod 730A) into the 561- or 564-Series Oscilloscope and set the equipment controls according to the setup which accompanies Fig. 5-31.

b. Perform step b only if a Calibration Procedure is being performed.

(1) Remove the cover from the Function Generator after removing the acorn nut and the hex nut from the rear. Remove the spacer washer which is installed on the machine screw.

CAUTION

Do not touch the function generator disc or permit any tools or components to rub against it at any time during the following procedure. Damage to the disc may occur, or the anti-static coating on the disc (see Maintenance Section) might be rubbed off. Either situation can cause distortion in the signals which are dependent upon the disc. Push the Function Generator shaft in to take up end play before performing any mechanical alignment. This will avoid the disc's being pushed against the photo-transistor block when the Function Generator is connected to an engine and end-thrust is applied.

(2) Inspect the photo-transistor block for parallelism with the function generator disc when viewed from the side and top. See Fig. 5-32 (A) and (B). If they are obviously not parallel when viewed from the side, loosen the saddle-bracket mounting screws (Fig. 5-32A) until the bracket is slip-tight. Tilt the bracket front or back to obtain parallelism and then tighten the screws. Do not move the block any more than is necessary, and do not place it closer than approximately $\frac{1}{32}$ inch from the function generator disc. If the block is obviously not parallel when viewed from the top, loosen the photo-transistor base-plate mounting screws (Fig. 5-32B) and adjust it as necessary to make it parallel. Then tighten the screws.

c. Connect the Function Generator to the 2B67, using the 20-foot Function Generator cable.

d. Connect the Function Generator to a prime mover. A fan motor with the blade removed serves ideally for this purpose. If no prime mover is available, this procedure can be performed while manually rotating the Function Generator shaft. The Function Generator shaft must be rotating during all checks and adjustments in this procedure unless otherwise noted.

e. Turn the equipment on and allow 5 minutes for warm-up.

CAUTION

Do not permit a focused stationary dot to remain on the CRT for any period of time. Phosphor damage may occur. The equipment is provided with a safeguard against it while the Function Generator is connected to the 2B67. However, this safeguard does not exist when the TIME/DIV switch is at ROTATIONAL FUNCTION GENERATOR position and the Function Generator and cable are disconnected from the 2B67.

1. (Calibration Procedure only) Check —9 V Zener Supply

a. Set the Test Oscilloscope (or DC voltmeter) to measure —9 VDC.

b. Provide a common ground for the Test Oscilloscope (or meter). Then connect the test probe to the D99-R99 junction on the Function Generator circuit board. See Fig. 5-32 (C).

c. CHECK— —9 V ± 0.5 V should exist at the D99-R99 junction.

d. Disconnect the probe from the circuit board.

2. Check/Adjust Sawtooth Signal DC Balance (SAWTOOTH DC BAL—R57)

a. Increase the CRT INTENSITY and check that a horizontal trace appears on the CRT. If it does not, recheck the setup. If it still does not appear, adjust R57, SAWTOOTH DC BAL (Fig. 5-32C) to midrange and again check for trace appearance.

b. CHECK—Sawtooth signal DC balance. Switch the ROTATION DIRECTION switch (back of Function Generator) back and forth while observing trace position. Trace should be within 2 divisions of occupying the same horizontal position in both positions of the switch.

c. ADJUST—Sawtooth signal DC balance. Adjust R57, SAWTOOTH DC BAL (Fig. 5-32C) as necessary to have minimum difference in horizontal display area in the two positions of the ROTATION DIRECTION switch.

d. (Performance Check only.) Replace the access cover.

3. Check/Adjust Signal Linearity

a. Using the 2B67 POSITION control, center the trace. Then rotate the WIDTH control clockwise and note that a display remains on the CRT. It should be slightly dimmer when the WIDTH control is fully clockwise. If the trace disappears or becomes noticeably brighter on one end, the 2B67 Rotational Function WIDTH Registration adjustments (step 17 in the 2B67 Calibration Procedure) will have to be performed before continuing.

b. Turn the 3A74 Channel 2 MODE switch to NORM and check that its VAR GAIN control is at CAL. Adjust the 3A74 POSITION control as necessary to center the trace.

c. Pull out on the MARKERS switch at the 2B67. Markers should appear on the trace.

d. Adjust the 2B67 WIDTH and POSITION controls as necessary to have the first and last marker start at the second and tenth vertical line as in Fig. 5-33 (A).

e. CHECK—CRANK display linearity. Approximately equal spacings should exist between the markers. The 0/360° marker (center of tall pedestal) should be within 0.24 divisions of graticule center. See Fig. 5-33 (A).

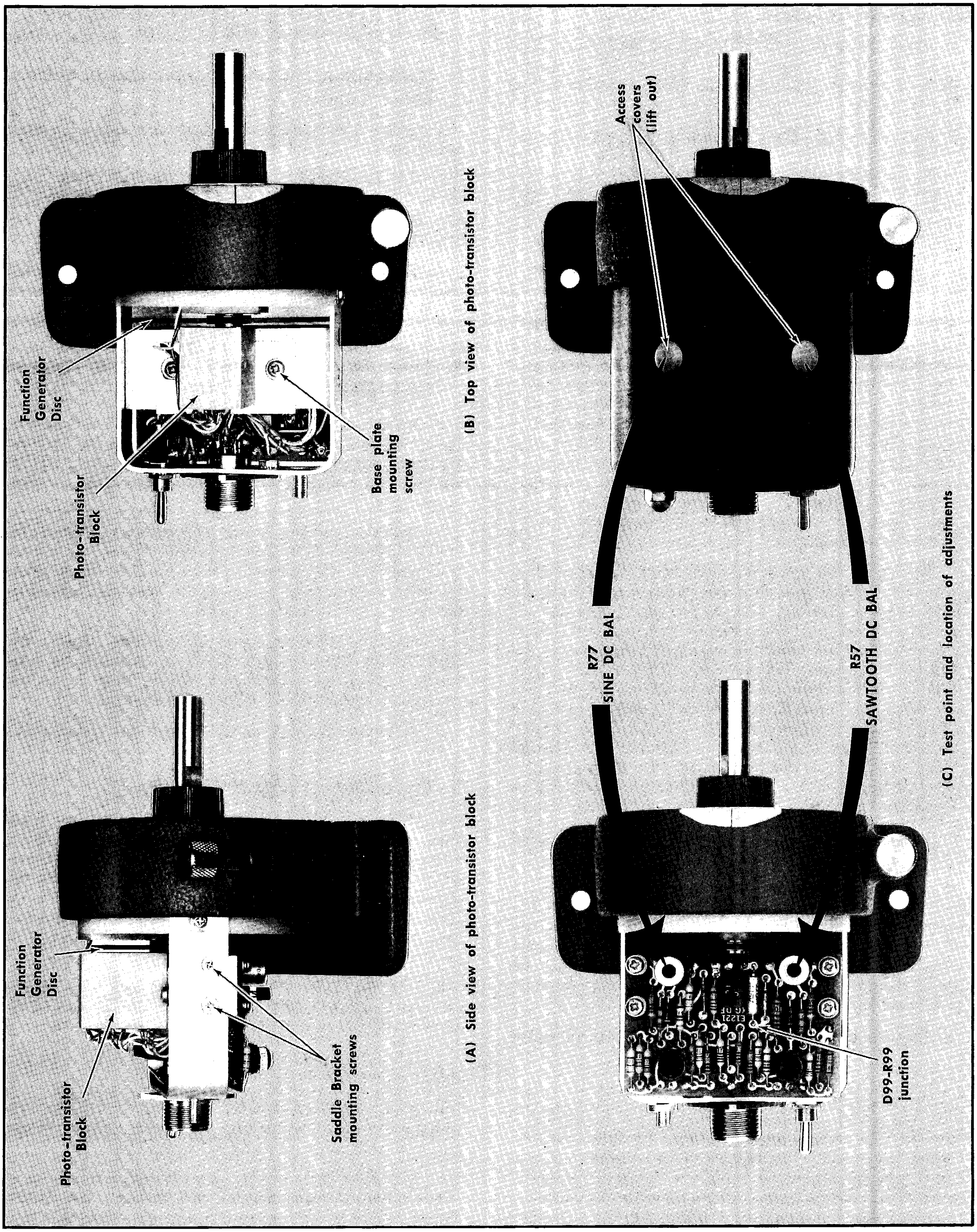


Fig. 5-32. Rotational Function Generator.

f. (Calibration Procedure only.) ADJUST—CRANK display linearity. If random compression or expansion is noted, it may be due to a static charge and the disc will have to be treated in accordance with the information in the Maintenance Section before continuing. (It is also possible that an electrostatic field in the vicinity of the Rotational Function Generator is causing the trouble.) If the markers are obviously compressed on one end, it is an indication that the photo-transistor block is too high or low and the following procedure should then be carried out.

(1) Turn the CRT INTENSITY to minimum and remove the cable from the Function Generator.

(2) Note the depth to which the sawtooth photo-transistor (center transistor) is inserted into the photo-transistor block. See Fig. 5-33 (B). Then loosen the setscrew which holds the transistor assembly in place. Unscrew the setscrew four turns. Grasp the leads at the base and gently pull the photo-transistor assembly out of the block. Do not exert much force. If the assembly is not loose in the block, loosen the setscrew another two turns. If it does not release, use a small screwdriver or an awl to work the assembly loose. Once removed, move it aside so that the mounting hole can be sighted through.

(3) Place the Function Generator under a bright light and sight through the sawtooth photo-transistor mounting hole. Rotate the Function Generator shaft until the retrace portion of the sawtooth window can be seen through the hole as illustrated in Fig. 5-33 (C) and (D). The retrace portion should be centered in front of the hole, with equal spacings visible above and below the window. If is it not, loosen the saddle-bracket mounting screws (Fig. 5-32-A) until the saddle bracket is slip tight. Adjust the saddle bracket either up or down as necessary to obtain the centered display. Then check the position of the photo-transistor block. The front surface of the block (when viewed from the side) must be parallel to the function generator disc, and at least $1/32$ inch from it. Check that the shaft has been pushed back to take up end play before checking the spacing. Tighten the saddle-bracket mounting screws after the block has been properly positioned.

(4) Re-insert the transistor assembly to its original depth and tighten the setscrew by the number of turns that it was unscrewed.

(5) Reconnect the Function Generator cable and increase the CRT INTENSITY.

(6) Repeat steps 3-d and 3-e.

(7) Repeat step 2.

g. INTERACTION—Steps 4 and 6.

4. Check/Adjust Sawtooth Signal Amplitude

a. Turn the Oscilloscope FOCUS control fully clockwise. Push the 2B67 MARKERS switch in. Then disconnect the cable from the 2B67 INPUT connector and set the POSITION control so that the defocused spot appears near the left edge of the graticule.

b. Set the Oscilloscope Calibrator to .5 V (.4 V for 1 kHz calibrators).

c. Connect the 1X probe's BNC connector (item 13) to the Calibrator Output connector and insert the probe tip into terminal B of the 2B67 INPUT connector. A patch cord or a short piece of wire can be used if a 1X probe is not available.

d. Set the 2B67 POSITION and WIDTH controls as necessary to obtain exactly 10 divisions separation between the defocused spots. (8 divisions for 1 kHz calibrators.) Do not move the WIDTH control during the remainder of this step.

e. Remove the probe (or patch cord) and re-connect the Function Generator cable to the 2B67.

f. Re-focus the display and readjust the POSITION control if necessary to observe the display.

g. CHECK—Not less than 4 nor more than 10 divisions of horizontal display should appear, indicating a sawtooth signal amplitude of between 200 and 500 mV.

h. (Calibration Procedure only.) ADJUST—Sawtooth photo-transistor position as necessary to obtain between 4 and 10 divisions of display. Use the following procedure:

(1) Loosen the sawtooth transistor assembly setscrew (middle one) four turns. See Fig. 5-33(B).

(2) Push the transistor assembly in to increase the signal amplitude, or pull it out to decrease the signal amplitude. Apply very little force to the base leads. If the assembly is not loose, unscrew the setscrew two more turns and try again. If it still is not loose, work it loose with an awl or a small screwdriver tip.

(3) After the amplitude is between 4 and 10 divisions, retighten the setscrew by not more than the amount by which it was loosened. Make sure that the base is not in or out so far that the setscrew will miss it.

(4) Repeat step 2.

NOTE

Amplitude problems can be caused by the photo-transistors, the amplifier circuit, or by the illuminating lamps (although the latter should be the last to fail).

i. Interaction—Check step 5.

5. Check/Adjust Sine Wave Signal DC Balance and Sine Wave Signal Amplitude (SINE DC BAL — R772)

a. Set the WIDTH and POSITION controls to obtain an 8-division display, starting at the 3rd graticule line from the left.

b. Switch the PISTON-CRANK switch to PISTON.

c. CHECK—Sine wave signal DC balance. The display should start within 2 divisions of the 3rd graticule line.

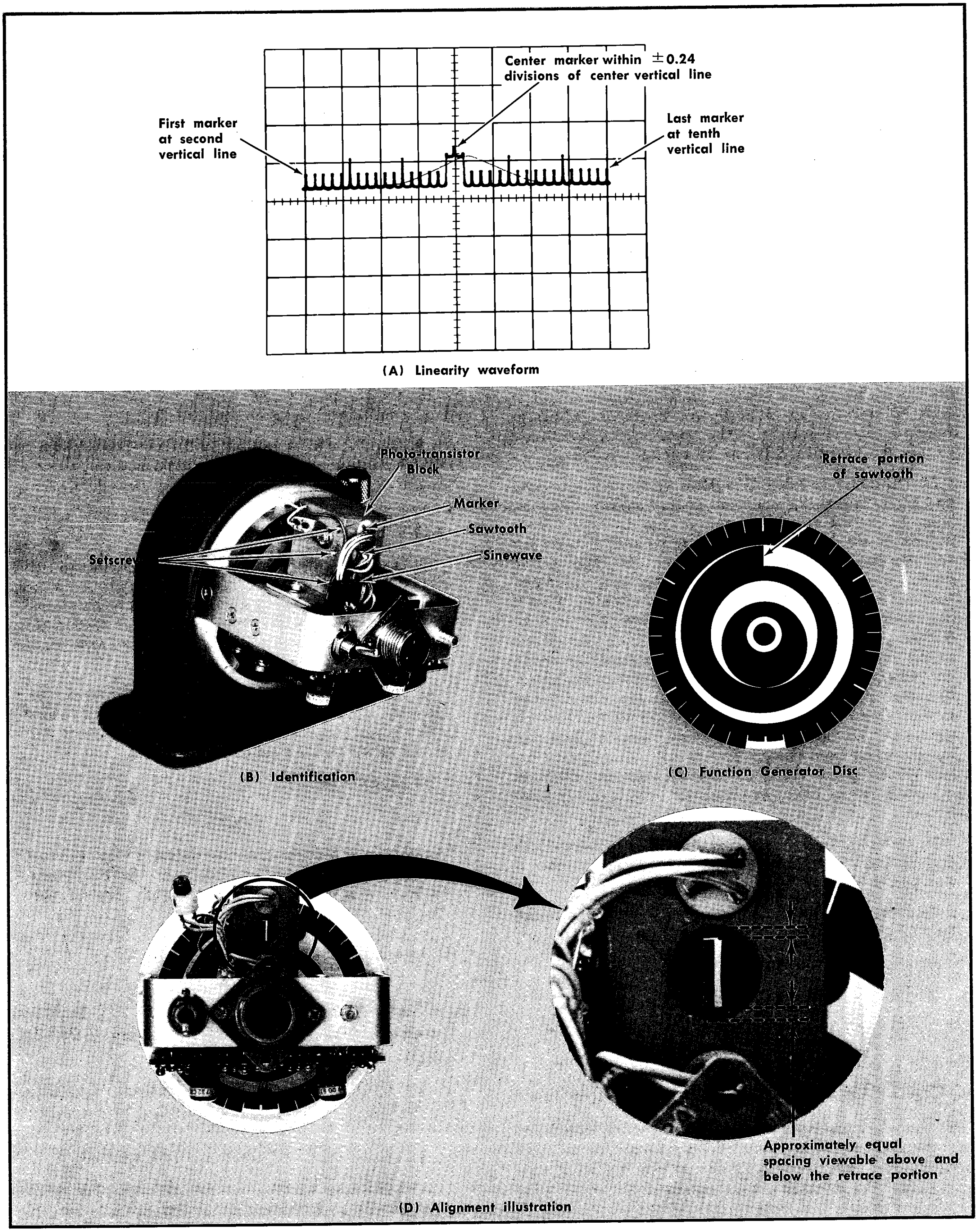


Fig. 5-33. Photo-transistor alignment information.

d. ADJUST—Sine wave signal DC balance. Remove the R77, SINE DC BAL, access cover (Fig. 5-32) and adjust R77 as necessary to center the trace horizontally.

e. Replace the access cover.

f. CHECK—Sine wave amplitude. Trace length should be 8 divisions ±1 division. (Readjust the POSITION Control to make the measurement, if necessary.)

g. (Calibration Procedure only.) ADJUST—Sine wave signal amplitude. Adjust the sine wave photo-transistor position in the same manner as described for the sawtooth photo-transistor in step 4-h, except that it should be adjusted for 8 divisions of horizontal trace. See Fig. 5-33(B) for the transistor location. Then repeat step 5.

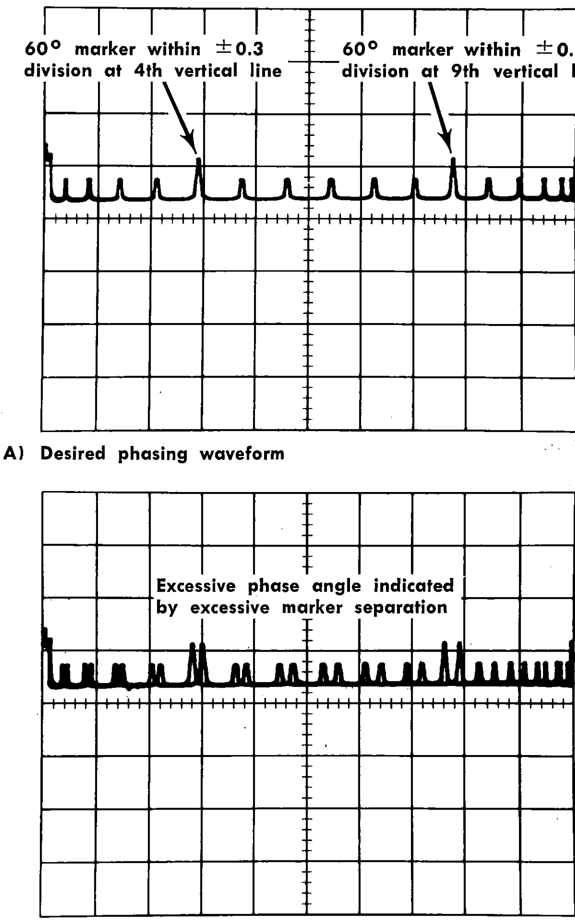
6. Check/Adjust Signal Phasing

a. Switch the 2B67 PISTON-CRANK switch to PISTON and adjust the WIDTH and POSITION controls as necessary to obtain a 10 division trace, starting at the first vertical graticule line.

b. Pull out on the markers switch and note that markers appear on the trace.

c. CHECK—Marker phasing with respect to the sine wave deflected baseline. Markers which are generated during left-to-right trace movement should be within ±0.2 division of being superimposed on those which are generated during right-to-left trace movement. See Fig. 5-34. If linearity and phasing are both correct, 60° markers should exist within ±0.3 division of the fourth and ninth vertical graticule lines from the left, as shown in Fig. 5-34(A). A waveform indicating improper phasing is provided in Fig. 5-34(B) for comparison.

d. (Calibration Procedure only.) ADJUST—Marker phasing. Loosen the photo-transistor block base plate screws and move the block either left or right as necessary to superimpose the left-to-right and right-to-left markers. Keep the front of the block parallel to and at least 1/32 inch from the generator disc. After the adjustment has been completed, the 60° markers should be within ±0.3 division of the fourth and ninth vertical graticule lines from the left, as illustrated in Fig. 5-34(A).



(A) Desired phasing waveform

(B) Improper phasing waveform

Fig. 5-34. Signal phasing waveforms for step 6.

7. Check Amplitude of Marker Signals

a. With the Channel 2 MODE switch at NORM, adjust its POSITION control as necessary to center the trace vertically.

b. Check that the 2B67 VOLTS/DIV VAR GAIN is at CAL and that the MARKERS knob is pulled out. Set the 2B67 PISTON-CRANK switch to CRANK.

c. Switch the 2B67 TIME/DIV control to 5 ms.

d. Disconnect the cable from the 2B67 INPUT connector.

e. Insert one end of a 2 kΩ 5% resistor (item 25) into terminal E of the 2B67 INPUT connector.

f. Set the Oscilloscope calibrator to 50 mV (40 mV for 1 kHz calibrators).

g. Connect the 1× probe BNC connector (or a patch cord) to the Calibrator output jack. Connect the other end to the exposed end of the 2 kΩ resistor.

h. Set the Channel 2 VAR GAIN control as necessary to obtain 1 division (0.8 division for 1 kHz calibrators) of peak-to-peak vertical display amplitude.

i. Remove the resistor and probe (or patch cord). Reconnect the Function Generator cable to the 2B67.

j. Switch the TIME/DIV switch to ROTATIONAL FUNCTION GENERATOR.

k. CHECK—Amplitude of Marker signals. 0.6 division or more vertical display amplitude should appear from the trace baseline to the top of the center marker on the tall pedestal. This indicates 30 mV or more signal amplitude at the signal source.

l. (Calibration Procedure only.) ADJUST—Marker signal amplitude. Adjust the marker photo-transistor position in the same manner as described for the sawtooth photo-transistor in step 4h, except that it should be adjusted for at least 0.6 division between the baseline and the top of the center marker. See Fig. 5-33(B) for the transistor location.

8. (Calibration Procedure only.) Recheck/Re-adjust Sawtooth and Sine wave DC Balance (R57—SAWTOOTH DC BAL, R77—SINE DC BAL)

NOTE

These adjustments must be re-adjusted because of minor differences which may exist between the covered and uncovered status of a Function Generator.

a. Replace the cover on the Rotational Function Generator.

b. Switch the 2B67 PISTON-CRANK switch to CRANK. Push the MARKERS switch in and wait approximately 5 minutes for the temperature within the Rotational Function Generator to stabilize.

c. ADJUST—Sawtooth signal DC balance. Remove the R57, SAWTOOTH DC BAL, access cover Fig. 5-32(C) and adjust R57 until minimum trace shift accompanies ROTATION DIRECTION switching.

d. Replace the access cover.

e. Set the 2B67 WIDTH and POSITION controls as necessary to obtain a centered 8 division display.

f. Switch the 2B67 PISTON-CRANK switch to PISTON.

g. ADJUST—Sine wave signal DC balance. Remove the R77, SINE DC BAL, access cover Fig. 5-32(C) and adjust R77 until the trace is centered.

h. Replace the access cover.

9. Alternate Performance Check/Calibration Procedure

a. This step may be performed in the absence of the equipment required for the preceding 8 steps. However, it is not recommended as a substitute for those steps if optimum Engine Analyzer System performance is desired.

b. (Calibration Procedure only.) Check the Function Generator mechanical alignment given in the Preliminary Procedure.

c. Connect a lead between a common ground connection and terminal D of the Function Generator connector.

d. Connect terminal C to a DC voltage supply of between —11 and —13 V.

e. Using the Test Oscilloscope and DC input coupling (or a DC voltmeter), check the following terminals of the connector for indicated voltages. Rotate the Function Generator shaft during the checks and perform the indicated adjustments as necessary.

Terminal B —2.25 V ±0.4 V

Adjust R57, SAWTOOTH DC BAL (Fig. 5-32(C) as necessary to obtain equal values with the ROTATION DIRECTION switch (back of FUNCTION GENERATOR) in either position. Note the value.

Terminal A Voltage equal to that at terminal B

Adjust R77, SINE DC BAL (Fig. 5-32(C) as necessary to make the voltage equal to that at terminal B.

Terminal E —7 V ±1 V

f. Using the Test Oscilloscope and AC input coupling, check the following terminals of the connector plug for the indicated signals while the Function Generator shaft is rotating. Externally trigger the Test Oscilloscope from terminal A of the connector.

Terminal B Sawtooth waveform; between 200 and 500 mV peak to peak

Adjust photo-transistor block to correct for flatness at either end of the sawtooth; see step 3f. Adjust photo-transistor depth to change signal amplitude; see step 4h.

Terminal B with ROTATION DIRECTION switch reversed	Sawtooth waveform, equal to but inverse of that in preceding check; note the value.
Terminal A	Sine wave; peak-to-peak amplitude equal to sawtooth amplitude at terminal B
Terminal E	Marker signals; amplitude of tallest marker at least 30 mV above trace baseline when delivered to 1 MHz Oscilloscope input impedance; at least 15 mV if delivered to a 2 kΩ impedance

g. This concludes the procedure.

PARTS LIST ABBREVIATIONS

BHB	binding head brass
BHS	binding head steel
cap.	capacitor
cer	ceramic
comp	composition
conn	connector
CRT	cathode-ray tube
csk	countersunk
DE	double end
dia	diameter
div	division
elect.	electrolytic
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ext	external
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
h	height or high
hex.	hexagonal
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
ID	inside diameter
inc	incandescent
int	internal
lg	length or long
met.	metal
mtg hdw	mounting hardware
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
P/O	part of
PHB	pan head brass
PHS	pan head steel
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
RHB	round head brass
RHS	round head steel
SE	single end
SN or S/N	serial number
S or SW	switch
TC	temperature compensated
THB	truss head brass
thk	thick
THS	truss head steel
tub.	tubular
var	variable
w	wide or width
WW	wire-wound

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

SPECIAL NOTES AND SYMBOLS

×000	Part first added at this serial number
00×	Part removed after this serial number
*000-0000-00	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components.
Use 000-0000-00	Part number indicated is direct replacement.

SECTION 6
ELECTRICAL PARTS LIST

TYPE 3A74

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description				
				Bulb				
B419	150-0030-00			Neon	NE 2 V			(Ch. 1, 2, 3, 4)
				Capacitors				
Tolerance ±20% unless otherwise indicated.								
C215	290-0367-00			70 μf	Elect.	6 V		(Ch. 1)
C246	*295-0112-00			0.004 μF	Timing Capacitor Assembly			(Ch. 1)
C247	*295-0112-00			0.04 μF	Timing Capacitor Assembly			(Ch. 1)
C248	*295-0112-00			0.4 μF	Timing Capacitor Assembly			(Ch. 1)
C251	281-0525-00			470 pF	Cer	500 V		(Ch. 1)
C265	285-0643-00			0.0047 μF	PTM	100 V	5%	(Ch. 1)
C266	285-0683-00			0.022 μF	PTM	100 V	5%	(Ch. 1)
C291	283-0092-00			0.03 μF	Cer	200 V		(Ch. 1)
C293	290-0134-00			22 μF	Elect.	15 V		(Ch. 1)
C295	290-0134-00			22 μF	Elect.	15 V		(Ch. 1)
C297	283-0003-00			0.01 μF	Cer	150 V		(Ch. 1)
C401	*285-0609-00			0.1 μF	MT	600 V	10%	(Ch. 3)
C401	*285-0610-00			0.1 μF	MT	600 V	10%	(Ch. 2, 4)
C403A	281-0504-00			10 pF	Cer	500 V	10%	(Ch. 2, 3, 4)
C403B	281-0061-00	B010100	B049999	5.5-18 pF, Var	Cer			(Ch. 2, 3, 4)
C403B	281-0063-00	B050000		9-35 pF, Var	Cer			(Ch. 1, 2, 3, 4)
C403C	281-0060-00			2-8 pF, Var	Cer			(Ch. 2, 3, 4)
C403E	281-0512-00			27 pF	Cer	500 V	10%	(Ch. 2, 3, 4)
C405A	281-0504-00			10 pF	Cer	500 V	10%	(Ch. 2, 3, 4)
C405B	281-0061-00	B010100	B049999	5.5-18 pF, Var	Cer			(Ch. 2, 3, 4)
C405B	281-0063-00	B050000		9-35 pF, Var	Cer			(Ch. 2, 3, 4)
C405C	281-0060-00			2-8 pF, Var	Cer			(Ch. 2, 3, 4)
C405E	283-0541-00			500 pF	Mica	500 V	10%	(Ch. 2, 3, 4)
C407B	281-0061-00			5.5-18 pF, Var	Cer			(Ch. 2, 3, 4)
C407C	281-0061-00			5.5-18 pF, Var	Cer			(Ch. 2, 3, 4)
C409B	281-0061-00	B010100	B049999	5.5-18 pF, Var	Cer			(Ch. 2, 3, 4)
C409B	281-0063-00	B050000		9-35 pF, Var	Cer			(Ch. 2, 3, 4)
C409C	281-0060-00			2-8 pF, Var	Cer			(Ch. 2, 3, 4)
C409E	281-0504-00			10 pF	Cer	500 V	10%	(Ch. 2, 3, 4)
C416	281-0061-00			5.5-18 pF, Var	Cer			(Ch. 2, 3, 4)
C417	283-0068-00			0.01 μF	Cer	500 V		(Ch. 2, 3, 4)
C424	281-0536-00			1000 pF	Cer	500 V	10%	(Ch. 1, 2, 3, 4)
C428	283-0023-00	B010100	B049999	0.1 μF	Cer	10 V		(Ch. 1, 3, 4)
C428	281-0081-00	B040000	B059999	0.1 μF	Cer	25 V	+80%—20%	(Ch. 1, 3, 4)
C428	283-0024-00	B060000	B099999	0.1 μF	Cer	30 V		(Ch. 1, 3, 4)
C428	283-0167-00	B100000		0.1 μF	Cer	100 V	10%	(Ch. 1, 3, 4)

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Capacitors (cont)			
C431	283-0001-00			0.005 μF	Cer	500 V	(Ch. 2)
C432	283-0059-00			1 μF	Cer	25 V	(Ch. 2)
C433	281-0557-00			1.8 pF	Cer	500 V	(Ch. 1, 2, 3, 4)
C434	281-0536-00			1000 pF	Cer	500 V	10% (Ch. 1, 2, 3, 4)
C435	281-0027-00			0.7-3 pF, Var	Tub.		(Ch. 2)
C460	281-0572-00			6.8 pF	Cer	500 V	±0.5 pF
C470	281-0572-00			6.8 pF	Cer	500 V	±0.5 pF
C478	283-0057-00			0.1 μF	Cer	200 V	+80%—20%
C490	283-0057-00			0.1 μF	Cer	200 V	+80%—20%
C491	283-0006-00			0.02 μF	Cer	500 V	
C493	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C494	290-0145-00			10 μF	Elect.	50 V	
C499	283-0057-00			0.1 μF	Cer	200 V	+80%—20%
C529	281-0551-00			390 pF	Cer	500 V	10%
C533	283-0002-00			0.01 μF	Cer	500 V	
C534	283-0002-00			0.01 μF	Cer	500 V	
C535	281-0544-00			5.6 pF	Cer	500 V	10%
C547	281-0524-00			150 pF	Cer	500 V	(Ch. 1)
C557	281-0524-00			150 pF	Cer	500 V	(Ch. 2)
C567	281-0524-00			150 pF	Cer	500 V	(Ch. 3)
C577	281-0524-00			150 pF	Cer	500 V	(Ch. 4)
C578	283-0006-00			0.02 μF	Cer	500 V	
C580	283-0006-00			0.02 μF	Cer	500 V	
C582	281-0523-00			100 pF	Cer	350 V	
C583	281-0525-00			470 pF	Cer	500 V	
C585	281-0605-00			200 pF	Cer	500 V	
C587	281-0543-00			270 pF	Cer	500 V	10%
C588	281-0523-00	B010100	B039999	100 pF	Cer	350 V	
C588	281-0605-00	B040000		200 pF	Cer	500 V	
C589	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C593	283-0002-00			0.01 μF	Cer	500 V	
C594	283-0059-00			1 μF	Cer	25 V	+80%—20%
C595	281-0518-00	B010100	B039999	47 pF	Cer	500 V	
C595	281-0564-00	B040000		24 pF	Cer	500 V	5%
C596	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C597	281-0022-00			8-50 pF, Var	Cer		
				Semiconductor Device, Diodes			
D202	*152-0321-00			Silicon	Dual, Tek Spec		(Ch. 1)
D423	*152-0185-00			Silicon	Replaceable by 1N4152		(Ch. 1, 2, 3, 4)
D424	*152-0185-00			Silicon	Replaceable by 1N4152		(Ch. 1, 2, 3, 4)
D440	152-0079-00	B010100	B039999	Germanium	HD 1841		(Ch. 1, 2, 3, 4)
D440	*152-0185-00	B040000		Silicon	Replaceable by 1N4152		(Ch. 1, 2, 3, 4)
D441	152-0079-00	B010100	B039999	Germanium	HD 1841		(Ch. 1, 2, 3, 4)
D441	*152-0185-00	B040000		Silicon	Replaceable by 1N4152		(Ch. 1, 2, 3, 4)

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				Semiconductor Device, Diodes (cont)		
D442	152-0079-00	B010100	B039999	Germanium	HD 1841	(Ch. 1, 2, 3, 4)
D442	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 1, 2, 3, 4)
D443	152-0079-00	B010100	B039999	Germanium	HD 1841	(Ch. 1, 2, 3, 4)
D443	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 1, 2, 3, 4)
D461	*152-0185-00			Silicon	Replaceable by 1N4152	
D468	*152-0061-00			Silicon	Tek Spec	
D469	*152-0061-00			Silicon	Tek Spec	
D471	*152-0185-00			Silicon	Replaceable by 1N4152	
D487	152-0168-00			Zener	1N963A 12 V, 0.4 W, 5%	
D494	152-0150-00			Zener	1N3037B 51 V, 1 W, 5%	
D502	152-0008-00			Germanium		
D512	*152-0075-00			Germanium	Tek Spec	
D547	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 1)
D547	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 1)
D548	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 1)
D548	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 1)
D557	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 2)
D557	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 2)
D558	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 2)
D558	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 2)
D566	*152-0061-00	B010100	B039999	Silicon	Tek Spec	
D566	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	
D567	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 3)
D567	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 3)
D568	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 3)
D568	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 3)
D577	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 4)
D577	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 4)
D578	*152-0075-00	B010100	B039999	Germanium	Tek Spec	(Ch. 4)
D578	*152-0185-00	B040000		Silicon	Replaceable by 1N4152	(Ch. 4)
D580	*152-0061-00			Silicon	Tek Spec	
D581	152-0079-00			Germanium	HD 1841	
D582	*152-0185-00	XB040000		Silicon	Replaceable by 1N4152	
D590	152-0079-00			Germanium	HD 1841	
D595	*152-0061-00			Silicon	Tek Spec	
				Connectors		
J201	131-0106-00			BNC		(Ch. 1)
J401	131-0183-00			BNC		(Ch. 2, 3, 4)
P11	131-0149-00			Receptacle 24 pin, male		

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				Inductors		
L265	*108-0324-00			10 mH		(Ch. 1)
L444	*108-0016-00			29 μH		
L445[1]	*108-0251-00			12 μH wound on a 30 Ω resistor		
L454	*108-0016-00			29 μH		
L455[2]	*108-0251-00			12 μH wound on a 30 Ω resistor		
L464	*114-0150-00			55-100 μH, Var Core 276-0540-00		
L474	*114-0150-00			55-100 μH, Var Core 276-0540-00		
L525	108-0254-00			600 μH		
L584	276-0507-00			Core, Ferramic Suppressor		
L588	276-0507-00			Core, Ferramic Suppressor		
L590	276-0507-00			Core, Ferramic Suppressor		
				Transistors		
Q204	151-1024-00			Silicon	FET	(Ch. 1)
Q214	151-1024-00			Silicon	FET	(Ch. 1)
Q223	151-0220-00			Silicon	2N4122	(Ch. 1)
Q224	*151-0192-00			Silicon	Replaceable by MPS-6521	(Ch. 1)
Q233	*151-0216-00			Silicon	Replaceable by MPS-6523	(Ch. 1)
Q243	*151-0192-00			Silicon	Replaceable by MPS-6521	(Ch. 1)
Q253	*151-0192-00			Silicon	Replaceable by MPS-6521	(Ch. 1)
Q263	*151-0216-00			Silicon	Replaceable by MPS-6523	(Ch. 1)
Q424	151-0135-00			Germanium	2N2635	(Ch. 1, 2, 3, 4)
Q434	151-0135-00			Germanium	2N2635	(Ch. 1, 2, 3, 4)
Q444	*151-0062-00	B010100	B089999	Germanium	Tek Spec	
Q444	151-0103-00	B090000		Silicon	2N2219	
Q454	*151-0062-00	B010100	B089999	Germanium	Tek Spec	
Q454	151-0103-00	B090000		Silicon	2N2219	
Q463	151-0135-00			Germanium	2N2635	(Ch. 2)
Q473	151-0135-00			Germanium	2N2635	(Ch. 3)
Q487	*151-0210-00			Silicon	Tek Spec	
Q503	151-0135-00			Germanium	2N2635	(Ch. 1)
Q504	151-0135-00			Germanium	2N2635	(Ch. 4)
Q514	151-0135-00			Germanium	2N2635	(Ch. 1)
Q524	151-0084-00			Germanium	2N1225	
Q545	151-0135-00	B010100	B039999	Germanium	2N2635	(Ch. 1)
Q545	151-0188-00	B040000		Silicon	2N3906	(Ch. 1)
Q555	151-0135-00	B010100	B039999	Germanium	2N2635	(Ch. 1)
Q555	151-0188-00	B040000		Silicon	2N3906	(Ch. 1)
Q565	151-0135-00	B010100	B039999	Germanium	2N2635	(Ch. 1)
Q565	151-0188-00	B040000		Silicon	2N3906	(Ch. 1)
Q575	151-0135-00	B010100	B039999	Germanium	2N2635	(Ch. 1)
Q575	151-0188-00	B040000		Silicon	2N3906	(Ch. 1)
Q583	151-0190-00			Silicon	2N3904	
Q590	151-0135-00			Germanium	2N2635	(Ch. 1)

[1]Furnished as a unit with R445.
[2]Furnished as a unit with R455.

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
R201	315-0240-00			24 Ω	¼ W		5% (Ch. 1)
R202	315-0103-00			10 kΩ	¼ W		5% (Ch. 1)
R204	315-0103-00			10 kΩ	¼ W		5% (Ch. 1)
R205	315-0240-00			24 Ω	¼ W		5% (Ch. 1)
R212	315-0101-00			100 Ω	¼ W		5% (Ch. 1)
R213	321-0402-00			150 kΩ	⅛ W	Prec	1% (Ch. 1)
R214	321-0394-00			124 kΩ	⅛ W	Prec	1% (Ch. 1)
R215	311-0449-00			1.5 kΩ, Var			(Ch. 1)
R216	311-0704-00	B010100	B079999	500 Ω, Var			(Ch. 1)
R216	311-1261-00	B080000		500 Ω, Var			(Ch. 1)
R217	321-0197-00			1.1 kΩ	⅛ W	Prec	1% (Ch. 1)
R218	321-0193-00			1 kΩ	⅛ W	Prec	1% (Ch. 1)
R219	321-0411-00			187 kΩ	⅛ W	Prec	1% (Ch. 1)
R221	321-0353-00			46.4 kΩ	⅛ W	Prec	1% (Ch. 1)
R223	321-0424-00			255 kΩ	⅛ W	Prec	1% (Ch. 1)
R225	321-0193-00			1 kΩ	⅛ W	Prec	1% (Ch. 1)
R226	321-0201-00			1.21 kΩ	⅛ W	Prec	1% (Ch. 1)
R228	321-0394-00			124 kΩ	⅛ W	Prec	1% (Ch. 1)
R233	315-0103-00			10 kΩ	¼ W		5% (Ch. 1)
R243	315-0200-00			20 Ω	¼ W		5% (Ch. 1)
R246	314-0010-00			1000 MΩ	0.001 W		(Ch. 1)
R247	314-0009-00			100 MΩ	0.01 W		(Ch. 1)
R248	309-0095-00			10 MΩ	½ W	Prec	1% (Ch. 1)
R249	323-0481-00			1 MΩ	½ W	Prec	1% (Ch. 1)
R251	315-0391-00			390 Ω	¼ W		5% (Ch. 1)
R253	315-0103-00			10 kΩ	¼ W		5% (Ch. 1)
R263	315-0200-00			20 Ω	¼ W		5% (Ch. 1)
R265	321-0180-00			732 Ω	⅛ W	Prec	1% (Ch. 1)
R270	311-0487-00			30 kΩ, Var			(Ch. 1)
R271	315-0822-00			8.2 kΩ	¼ W		5% (Ch. 1)
R273	321-0692-00			49.9 kΩ	⅛ W	Prec	½% (Ch. 1)
R274	321-0685-00			30 kΩ	⅛ W	Prec	½% (Ch. 1)
R275	321-0744-02			20.25 kΩ	⅛ W	Prec	½% (Ch. 1)
R291	315-0270-00			27 Ω	¼ W		5% (Ch. 1)
R401	316-0100-00			10 Ω	¼ W		(Ch. 2, 3, 4)
R403C	322-0621-01			900 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R403E	322-1389-01			111 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R405C	322-0624-01			990 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R405E	322-1289-01			10.1 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R407C	322-0643-01			600 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R407E	322-0644-01			666.6 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R409C	322-0620-01			800 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R409E	322-0614-01			250 kΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R410	316-0100-00			10 Ω	¼ W		(Ch. 2, 3, 4)
R416	322-0481-01			1 MΩ	¼ W	Prec	½% (Ch. 2, 3, 4)
R417	302-0105-00			1 MΩ	½ W		(Ch. 2, 3, 4)
R419	316-0101-00			100 Ω	¼ W		(Ch. 1, 2, 3, 4)

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R423	301-0103-00			10 kΩ	½ W		5% (Ch. 1, 2, 3, 4)
R424	301-0272-00			2.7 kΩ	½ W		5% (Ch. 1, 2, 3, 4)
R425	309-0090-00			50 kΩ	½ W	Prec	1% (Ch. 1, 2, 3, 4)
R426	*311-0304-00			185 Ω, Var			(Ch. 3)
R426	*311-0309-00			185 Ω, Var			(Ch. 2, 4)
R427	311-0157-00	B010100	B079999	100 kΩ, Var			(Ch. 1, 2, 3, 4)
R427	311-1146-00	B080000		100 kΩ, Var			(Ch. 1, 2, 3, 4)
R428	301-0685-00			6.8 MΩ	½ W		5% (Ch. 1, 2, 3, 4)
R429	301-0474-00			470 kΩ	½ W		5% (Ch. 1, 2, 3, 4)
R430	316-0101-00			100 Ω	¼ W		(Ch. 1, 2, 3, 4)
R431	315-0272-00			2.7 kΩ	¼ W		5% (Ch. 2)
R432	315-0101-00			100 Ω	¼ W		5% (Ch. 2)
R433	301-0103-00			10 kΩ	½ W		5% (Ch. 1, 2, 3, 4)
R434	301-0272-00			2.7 kΩ	½ W		5% (Ch. 1, 2, 3, 4)
R435	309-0090-00			50 kΩ	½ W	Prec	1% (Ch. 1, 2, 3, 4)
R436	311-0461-00			250 Ω, Var			(Ch. 1)
R436	311-0258-00			100 Ω, Var			(Ch. 2, 3, 4)
R437	316-0270-00			27 Ω	¼ W		(Ch. 1, 2, 3, 4)
R438	311-0305-00			50 kΩ, Var			(Ch. 1, 2, 3, 4)
R439	305-0114-00			110 kΩ	2 W		5% (Ch. 1, 2, 3, 4)
R444	309-0182-00			3 kΩ	½ W	Prec	1%
R445[3]				30 Ω			
R446	310-0132-00			19.6 kΩ	1 W	Prec	1%
R447	310-0115-00			15 kΩ	1 W	Prec	1%
R448	301-0473-00			47 kΩ	½ W		5%
R449	311-0305-00			50 kΩ, Var			
R454	309-0182-00			3 kΩ	½ W	Prec	1%
R455[4]				30 Ω			
R456	310-0132-00			19.6 kΩ	1 W	Prec	1%
R457	310-0115-00			15 kΩ	1 W	Prec	1%
R458	301-0473-00			47 kΩ	½ W		5%
R459	309-0105-00			4.21 kΩ	½ W	Prec	1%
R460	301-0914-00			910 kΩ	½ W		5%
R461	303-0223-00			22 kΩ	1 W		5%
R462	315-0302-00			3 kΩ	¼ W		5%
R464	308-0228-00			4 kΩ	7 W	WW	5%
R465	308-0067-00			750 Ω	5 W	WW	5%
R466	305-0751-00			750 Ω	2 W		5%
R467	302-0330-00			33 Ω	½ W		
R468	301-0470-00			47 Ω	½ W		5%
R470	301-0914-00			910 kΩ	½ W		5%
R471	303-0223-00			22 kΩ	1 W		5%
R472	315-0302-00			3 kΩ	¼ W		5%
R474	308-0228-00			4 kΩ	7 W	WW	5%
R476	305-0751-00			750 Ω	2 W		5%

[3]Furnished as a unit with L445.

[4]Furnished as a unit with L455.

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R477	311-0097-00			200 Ω, Var			
R478	302-0270-00			27 Ω	½ W		
R487	308-0212-00			10 kΩ	3 W	WW	5%
R491	308-0106-00			1 kΩ	5 W	WW	5%
R493	302-0270-00			27 Ω	½ W		
R494	305-0622-00			6.2 kΩ	2 W		5%
R496	301-0100-00			10 Ω	½ W		5% (Ch. 1, 2, 3, 4)
R498	316-0100-00			10 Ω	¼ W		
R499	302-0270-00			27 Ω	½ W		
R501	302-0102-00			1 kΩ	½ W		
R502	301-0164-00			160 kΩ	½ W		5%
R503	301-0183-00			18 kΩ	½ W		5%
R504	309-0191-00			4.535 kΩ	½ W	Prec	1%
R506	309-0159-00	B010100	B069999	5 kΩ	½ W	Prec	1%
R506	322-0677-00	B070000		5 kΩ	¼ W	Prec	1%
R508	309-0042-00			68 kΩ	½ W	Prec	1%
R510	315-0820-00			82 Ω	¼ W		5%
R512	301-0154-00			150 kΩ	½ W		5%
R513	302-0183-00			18 kΩ	½ W		
R518	309-0042-00			68 kΩ	½ W	Prec	1%
R521	311-0068-00			500 kΩ, Var			(Ch. 2)
R522	316-0124-00			120 kΩ	¼ W		
R524	301-0561-00			560 Ω	½ W		5%
R525	301-0123-00			12 kΩ	½ W		5%
R526	301-0163-00			16 kΩ	½ W		5%
R528	301-0684-00			680 kΩ	½ W		5%
R529	301-0223-00			22 kΩ	½ W		5%
R530	311-0157-00	B010100	B09999	100 kΩ, Var			
R530	311-1146-00	B080000		100 kΩ, Var			
R532	315-0470-00			47 Ω	¼ W		5%
R533	316-0103-00			10 kΩ	¼ W		
R534	302-0473-00			47 kΩ	½ W		
R535	301-0514-00			510 kΩ	½ W		5%
R536	301-0204-00			200 kΩ	½ W		5%
R540	315-0752-00			7.5 kΩ	¼ W		5% (Ch. 1)
R542	309-0320-00			3.37 kΩ	½ W	Prec	1%
R543	318-0084-00			10 kΩ	⅛ W	Prec	1%
R544	318-0084-00			10 kΩ	⅛ W	Prec	1%
R545	318-0084-00			10 kΩ	⅛ W	Prec	1%
R547	309-0250-00			500 Ω	½ W	Prec	1%
R548	305-0752-00			7.5 kΩ	2 W		5%
R549	316-0221-00			220 Ω	¼ W		(Ch. 1)

TYPE 3A74 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R550	315-0752-00			7.5 kΩ	¼ W		5% (Ch. 2)
R552	309-0320-00			3.37 kΩ	½ W	Prec	1%
R553	318-0084-00			10 kΩ	⅛ W	Prec	1%
R554	318-0084-00			10 kΩ	⅛ W	Prec	1%
R555	318-0084-00			10 kΩ	⅛ W	Prec	1%
R557	309-0250-00			500 Ω	½ W	Prec	1%
R558	305-0752-00			7.5 kΩ	2 W		5%
R560	315-0752-00			7.5 kΩ	¼ W		5% (Ch. 3)
R562	309-0320-00			3.37 kΩ	½ W	Prec	1%
R563	318-0084-00			10 kΩ	⅛ W	Prec	1%
R564	318-0084-00			10 kΩ	⅛ W	Prec	1%
R565	318-0084-00			10 kΩ	⅛ W	Prec	1%
R567	309-0250-00			500 Ω	½ W	Prec	1%
R568	305-0752-00			7.5 kΩ	2 W		5%
R570	315-0752-00			7.5 kΩ	¼ W		5% (Ch. 4)
R572	309-0320-00			3.37 kΩ	½ W	Prec	1%
R573	318-0084-00			10 kΩ	⅛ W	Prec	1%
R574	318-0084-00			10 kΩ	⅛ W	Prec	1%
R575	318-0084-00			10 kΩ	⅛ W	Prec	1%
R577	309-0250-00			500 Ω	½ W	Prec	1%
R578	305-0752-00			7.5 kΩ	2 W		5%
R580	309-0376-00	B010100	B039999	125 kΩ	½ W	Prec	1%
R580	309-0279-00	B040000		180 kΩ	½ W	Prec	1%
R582	302-0473-00			47 kΩ	½ W		
R583	316-0392-00			3.9 kΩ	¼ W		
R584	316-0331-00			330 Ω	¼ W		
R585	309-0046-00	B010100	B039999	111 kΩ	½ W	Prec	1%
R585	309-0260-00	B040000		100 kΩ	½ W	Prec	1%
R586	316-0270-00			27 Ω	¼ W		
R587	309-0098-00			2 kΩ	½ W	Prec	1%
R588	323-0158-00			432 Ω	½ W	Prec	1%
R589	302-0270-00			27 Ω	½ W		
R593	302-0103-00			10 kΩ	½ W		
R595	301-0302-00			3 kΩ	½ W		5%
R596	302-0270-00			27 Ω	½ W		
R597	316-0821-00			820 Ω	¼ W		

Switches

Ckt. No.	Unwired or Wired		Description		
SW240[5]			Rotary	RESTORE TIME	(Ch. 1)
SW245		260-0247-00	Push	ZERO	(Ch. 1)
SW270	Wired	*262-0843-00	Rotary	PS1/DIV	(Ch. 1)
SW270		260-0996-00	Rotary	PS1/DIV	(Ch. 1)
SW401		260-0446-00	Toggle	AC-DC-GND	(Ch. 2, 3, 4)

[5]Furnished as a unit with SW270.

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TYPE 3A74 (cont)

Ckt. No.		Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
					Switches (cont)		
SW410B[6]	Wired	*262-0545-00			Rotary	VOLTS/DIV	(Ch. 2)
SW410B		260-0513-00			Rotary	VOLTS/DIV	(Ch. 2)
SW410C[6]	Wired	*262-0546-00			Rotary	VOLTS/DIV	(Ch. 3)
SW410C		260-0512-00			Rotary	VOLTS/DIV	(Ch. 3)
SW410D[6]	Wired	*262-0547-00			Rotary	VOLTS/DIV	(Ch. 4)
SW410D		260-0513-00			Rotary	VOLTS/DIV	(Ch. 4)
SW430[7]	Wired	*262-0841-00	B010100	B039999	Rotary	MODE	(Ch. 1)
SW430[7]	Wired	*262-0841-01	B040000		Rotary	MODE	(Ch. 1)
SW430		260-0445-00			Rotary	MODE	(Ch. 1)
SW430[7]	Wired	*262-0649-00	B010100	B039999	Rotary	MODE	(Ch. 2, 3, 4)
SW430[7]	Wired	*262-0649-01	B040000		Rotary	MODE	(Ch. 2, 3, 4)
SW430		260-0445-00			Rotary	MODE	(Ch. 2, 3, 4)
SW530		260-0447-00			Slide	TRIGGER	
SW580		260-0613-00			Toggle	CHOP-ALT	
					Transformers		
T592		*120-0462-00			Toroid trifilar		
T593		*120-0284-00			Toroid 2 turn bifilar		
T595		*120-0273-00			Toroid 2 turn bifilar		
					Electron Tubes		
V423		154-0306-00			7586		(Ch. 1, 2, 3, 4)
V433		154-0306-00			7586		(Ch. 1, 2, 3, 4)
V464		*157-0006-00			6CL6, Checked		
V474		*157-0006-00			6CL6, Checked		
V533		154-0187-00			6DJ8		

[6]Furnished as a unit with R426.

[7]Furnished as a unit with R438.

TYPE 2B67

Values are fixed unless marked Variable.

Bulbs

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
B124	150-0030-00			Neon	NE2V		
B160W	150-0030-00			Neon	NE2V		
B161	150-0027-00			Neon	NE23		
B167	150-0027-00			Neon	NE23		

Capacitors

Tolerance ±20% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C14	283-0057-00			0.1 μF	Cer	200 V	+80%—20%
C15	283-0000-00			0.001 μF	Cer	500 V	
C20	283-0003-00			0.01 μF	Cer	150 V	
C24	281-0546-00			330 pF	Cer	500 V	10%
C31	283-0001-00			0.005 μF	Cer	500 V	
C37	281-0511-00			22 pF	Cer	500 V	10%
C113	283-0000-00			0.001 μF	Cer	500 V	
C130	281-0518-00			47 pF	Cer	500 V	
C133	281-0546-00			330 pF	Cer	500 V	10%
C134	281-0504-00			10 pF	Cer	500 V	10%
C137	281-0549-00			68 pF	Cer	500 V	10%
C141	281-0544-00			5.6 pF	Cer	500 V	10%
C142	283-0001-00			0.005 μF	Cer	500 V	
C147	281-0525-00			470 pF	Cer	500 V	
C148	283-0003-00	XB030000	B039999X	0.01 μF	Cer	150 V	
C151	281-0544-00	XB070000		5.6 pF	Cer	500 V	10%
C156	283-0111-00	XB040000		0.1 μF	Cer	50 V	
C160A	281-0007-00			3-12 pF, Var	Cer		
C160B	281-0574-00			82 pF	Cer	500 V	10%
C160C	281-0010-00			4.5-25 pF, Var	Cer		
C160D	*295-0109-01			0.001 μF	Timing Capacitor Assembly (matched to within 1%)		
C160E				0.01 μF			
C160F				0.1 μF			
C160G				1 μF			
C165	281-0523-00	B010100	B059999	100 pF	Cer	350 V	
C165	281-0580-00	B060000		470 pF	Cer	500 V	10%
C167	283-0000-00			0.001 μF	Cer	500 V	
C182	283-0067-00			0.001 μF	Cer	200 V	10%
C184	283-0067-00			0.001 μF	Cer	200 V	10%
C194	283-0067-00			0.001 μF	Cer	200 V	10%
C199	281-0580-00			470 pF	Cer	500 V	10%
C301	290-0201-00			100 μF	Elect.	15 V	

TYPE 2B67 (cont)

Capacitors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C304	290-0290-00			10 μF	Elect.	25 V	
C308	290-0261-00			6.8 μF	Elect.	35 V	
C311	283-0059-00			1 μF	Cer	25 V	+80%—20%
C317	283-0010-00			0.05 μF	Cer	50 V	
C320	281-0509-00			15 pF	Cer	500 V	10%
C321	281-0010-00			4.5-25 pF, Var	Cer		
C334	281-0510-00			22 pF	Cer	500 V	
C341	281-0010-00			4.5-25 pF, Var	Cer		
C348	281-0534-00			3.3 pF	Cer	500 V	±0.25 pF
C356	283-0003-00			0.01 μF	Cer	150 V	
C395	281-0558-00			18 pF	Cer	500 V	
C396	281-0623-00			650 pF	Cer	500 V	5%
C397	283-0008-00			0.1 μF	Cer	500 V	

Semiconductor Device, Diodes

Ckt. No.	Tektronix Part No.	Eff	Disc	Description	
D124	*152-0061-00			Silicon	Tek Spec
D126	*152-0061-00			Silicon	Tek Spec
D130	152-0008-00			Germanium	
D132	152-0242-00			Rectifier	650 mA, 240 V
D151	*152-0185-00	XB040000		Silicon	Replaceable by 1N4152
D152	152-0246-00			Silicon	Low Leakage 0.25 W, 40 V
D187	152-0141-02			Silicon	1N4152
D188	152-0141-02			Silicon	1N4152
D197	152-0141-02			Silicon	1N4152
D198	152-0141-02			Silicon	1N4152
D304	152-0005-00			Germanium	T13G
D307	152-0141-02			Silicon	1N4152
D308	152-0141-02			Silicon	1N4152
D313	152-0141-02			Silicon	1N4152
D394	152-0141-02			Silicon	1N4152
D395	152-0059-00			Zener	1 W, 12.6 V, 5%

Connectors

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
J370	131-0609-01			6 contact, female
P21	131-0149-00			24 contact, male

TYPE 2B67 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Transistors			
Q124	151-0093-00			Germanium	2N2043		
Q145	151-0250-00	XB030000	B039999X	Silicon	2N5184		
Q150	151-0220-00	XB040000		Silicon	2N4122		
Q185	*151-0192-00			Silicon	Replaceable by MPS-6521		
Q195	*151-0192-00			Silicon	Replaceable by MPS-6521		
Q304	*151-0216-00			Silicon	Replaceable by MPS-6523		
Q308	151-0190-00			Silicon	2N3904		

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
R4	302-0104-00			100 kΩ	½ W		
R14	302-0105-00			1 MΩ	½ W		
R15	302-0474-00			470 kΩ	½ W		
R16	301-0303-00			30 kΩ	½ W		5%
R17	311-0206-00			250 kΩ, Var			
R19	301-0105-00			1 MΩ	½ W		5%
R20	301-0304-00			300 kΩ	½ W		5%
R21	301-0203-00			20 kΩ	½ W		5%
R22	302-0151-00			150 Ω	½ W		
R23	302-0151-00			150 Ω	½ W		
R24	301-0512-00			5.1 kΩ	½ W		5%
R25	301-0512-00			5.1 kΩ	½ W		5%
R28	303-0223-00			22 kΩ	1 W		5%
R30	302-0224-00			220 kΩ	½ W		
R31	302-0224-00			220 kΩ	½ W		
R32	302-0101-00			100 Ω	½ W		
R34	301-0621-00			620 Ω	½ W		5%
R35	301-0332-00			3.3 kΩ	½ W		5%
R37	309-0139-00	B010100	B059999	333 kΩ	½ W	Prec	1%
R37	309-0053-00	B060000		333 kΩ	½ W	Prec	1%
R38	309-0056-00			390 kΩ	½ W	Prec	1%
R40	302-0225-00			2.2 MΩ	½ W		
R41	302-0101-00			100 Ω	½ W		
R43	302-0472-00			4.7 kΩ	½ W		
R46	304-0273-00			27 kΩ	1 W		
R111	311-0112-00			15 kΩ, Var			
R112	301-0123-00			12 kΩ	½ W		5%
R113	301-0183-00			18 kΩ	½ W		5%
R121	302-0563-00			56 kΩ	½ W		
R123	301-0274-00			270 kΩ	½ W		5%
R124	301-0273-00			27 kΩ	½ W		5%

TYPE 2B67 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R125	316-0334-00			330 kΩ	¼ W		
R126	302-0684-00	B010100	B029999	680 kΩ	½ W		
R126	302-0564-00	B030000		560 kΩ	½ W		
R127	316-0472-00			4.7 kΩ	¼ W		
R128	302-0102-00			1 kΩ	½ W		
R130	302-0472-00			4.7 kΩ	½ W		
R131	302-0101-00			100 Ω	½ W		
R132	301-0513-00			51 kΩ	½ W		5%
R133	301-0335-00			3.3 MΩ	½ W		5%
R134	309-0263-00			13.5 kΩ	½ W	Prec	1%
R135	309-0263-00			13.5 kΩ	½ W	Prec	1%
R137	302-0224-00			220 kΩ	½ W		
R138	302-0272-00			2.7 kΩ	½ W		
R140	316-0124-00			120 kΩ	¼ W		
R141	310-0070-00			33 kΩ	1 W	Prec	1%
R142	316-0124-00			120 kΩ	¼ W		
R143	309-0231-00			16.69 kΩ	½ W	Prec	1%
R144	324-0296-00			11.8 kΩ	1 W	Prec	1%
R145	316-0561-00	XB030000	B039999X	560 Ω	¼ W		
R146	302-0101-00			100 Ω	½ W		
R147	302-0152-00			1.5 kΩ	½ W		
R148	302-0393-00	XB030000	B039999X	39 kΩ	½ W		
R149	302-0822-00			8.2 kΩ	½ W		
R150	315-0274-00	XB060000		270 kΩ	¼ W		5%
R151	301-0124-00	XB040000		120 kΩ	½ W		5%
R152	316-0226-00	XB040000		180 kΩ	½ W		
R153	301-0184-00	XB040000		1.8 kΩ	½ W		5%
R154	301-0182-00	XB040000		100 Ω	½ W		5%
R155	301-0101-00			22 MΩ	¼ W		5%
R160A	309-0007-00			666.6 kΩ	½ W	Prec	1%
R160B	309-0007-00			666.6 kΩ	½ W	Prec	1%
R160C	309-0023-00	B010100	B089999	2 MΩ	½ W	Prec	1%
R160C	323-0510-00	B090000		2 MΩ	½ W	Prec	1%
R160D	309-0351-00			6.67 MΩ	½ W	Prec	1%
R160F	309-0351-00			6.67 MΩ	½ W	Prec	1%
R160H	310-0583-00			20 MΩ	2 W	Prec	1%
R160W	316-0104-00			100 kΩ	¼ W		
R160X	302-0103-00			10 kΩ	½ W		
R160Y[8]	311-0567-00			20 kΩ, Var			
R161	302-0101-00			100 Ω	½ W		
R165	302-0683-00			68 kΩ	½ W		
R166	302-0683-00			68 kΩ	½ W		

[8]Furnished as a unit with SW341.

TYPE 2B67 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R167	302-0105-00			1 MΩ	½ W		
R168	302-0473-00			47 kΩ	½ W		
R169	323-0418-00			221 kΩ	½ W	Prec	1%
R174	303-0273-00			27 kΩ	1 W		5%
R176	311-0117-00			5 kΩ, Var			
R178	301-0113-00			11 kΩ	½ W		5%
R181	302-0475-00			4.7 MΩ	½ W		
R182	315-0104-00			100 kΩ	¼ W		5%
R183	315-0563-00			56 kΩ	¼ W		5%
R184	315-0154-00			150 kΩ	¼ W		5%
R186	315-0103-00			10 kΩ	¼ W		5%
R187	315-0243-00			24 kΩ	¼ W		5%
R193	315-0243-00			24 kΩ	¼ W		5%
R194	315-0154-00			150 kΩ	¼ W		5%
R196	315-0103-00			10 kΩ	¼ W		5%
R197	315-0243-00			24 kΩ	¼ W		5%
R199	315-0224-00			220 kΩ	¼ W		5%
R301	317-0224-00			220 kΩ	⅛ W		5%
R302	317-0473-00			47 kΩ	⅛ W		5%
R303	315-0152-00			1.5 kΩ	¼ W		5%
R304	317-0102-00			1 kΩ	⅛ W		5%
R306	315-0155-00			1.5 MΩ	¼ W		5%
R307	317-0104-00			100 kΩ	⅛ W		5%
R308	301-0393-00			39 kΩ	½ W		5%
R309	317-0203-00			20 kΩ	⅛ W		5%
R310	317-0105-00			1 MΩ	⅛ W		5%
R311	317-0243-00			24 kΩ	⅛ W		5%
R315	317-0203-00			20 kΩ	⅛ W		5%
R317	317-0474-00			470 kΩ	⅛ W		5%
R320	309-0019-00			1.75 MΩ	½ W	Prec	1%
R321	309-0016-00			1.23 MΩ	½ W	Prec	1%
R323	311-0224-00			50 kΩ, Var			
R324	303-0183-00			18 kΩ	1 W		5%
R325	311-0106-00			200 Ω, Var			
R326	301-0305-00			3 MΩ	½ W		5%
R327	301-0754-00			750 kΩ	½ W		5%
R330	302-0101-00			100 Ω	½ W		
R332	304-0183-00			18 kΩ	1 W		
R333	301-0103-00			10 kΩ	½ W		5%
R334	311-0326-00			10 kΩ, Var			

TYPE 2B67 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R336	302-0101-00			100 Ω	½ W		
R338	302-0393-00			39 kΩ	½ W		
R341	311-0173-00			100 kΩ, Var			
R342	309-0043-00			82 kΩ	½ W	Prec	1%
R344	309-0279-00			180 kΩ	½ W	Prec	1%
R345	302-0473-00			47 kΩ	½ W		
R346	311-0125-00			50 kΩ, Var			
R348	309-0126-00			400 kΩ	½ W	Prec	1%
R350	302-0101-00			100 Ω	½ W		
R352	302-0393-00			39 kΩ	½ W		
R355	301-0155-00			1.5 MΩ	½ W		5%
R356	301-0124-00			120 kΩ	½ W		5%
R357	302-0101-00			100 Ω	½ W		
R359	302-0393-00			39 kΩ	½ W		
R370	302-0101-00			100 Ω	½ W		
R371	302-0101-00			100 Ω	½ W		
R373	308-0105-00			30 kΩ	8 W	WW	5%
R375	305-0153-00			15 kΩ	2 W		5%
R377	308-0191-00			35 kΩ	8 W	WW	5%
R380	315-0104-00			100 kΩ	¼ W		5%
R381	321-0103-00			115 Ω	⅛ W	Prec	1%
R382	321-0165-00			511 Ω	⅛ W	Prec	1%
R383	321-0189-00			909 Ω	⅛ W	Prec	1%
R384	311-0170-00			20 kΩ, Var			
R385	321-0327-00			24.9 kΩ	⅛ W	Prec	1%
R386	321-0268-00			6.04 kΩ	⅛ W	Prec	1%
R387	315-0184-00	B010100	B039999X	180 kΩ	¼ W		5%
R388[9]	311-0311-00	B010100	B039999	200 kΩ, Var			
R388[9]	311-0969-00	B040000		100 kΩ, Var			
R390	301-0151-00			150 Ω	½ W		5%
R391	301-0151-00			150 Ω	½ W		5%
R394	315-0154-00			150 kΩ	¼ W		5%
R395	308-0054-00			10 kΩ	5 W	WW	5%
R396	315-0152-00			1.5 kΩ	¼ W		5%
R397	302-0470-00			47 Ω	½ W		

Switches

	Unwired or Wired			
SW5		260-0450-00	Slide	SOURCE
SW17	Wired	*262-0844-00	Rotary	LEVEL
SW17		260-0353-00	Rotary	LEVEL
SW20		260-0447-00	Slide	SLOPE
SW124		260-0990-00	Lever	MODE

[9]Furnished as a unit with SW375.

TYPE 2B67 (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Switches (cont)	
SW160	Wired *262-0840-00			Rotary	TIME/DIV
SW160	260-0989-00			Rotary	TIME/DIV
SW185	260-0447-00			Slide	SINGLE SWP DISPLAY
SW341[10]	311-0567-00			Pull	5 X MAG
SW370	260-0613-00			Toggle	PISTON (VOLUME)
SW375[11]	311-0311-00	B010100	B039999	Pull	MARKERS
SW375[11]	311-0969-00	B040000		Pull	MARKERS
				Integrated Circuit	
U380	156-0015-00			Oper. Ampl. TO-99	
				Electron Tubes	
V24	154-0187-00	B010100	B049999	6DJ8	
V24	*157-0125-00	B050000		6DJ8, checked	
V45	154-0187-00	B010100	B049999	6DJ8	
V45	*157-0125-00	B050000		6DJ8, checked	
V135	154-0187-00			6DJ8	
V145	154-0278-00			6BL8	
V152	154-0453-00			6BJ7	
V161	154-0278-00			6BL8	
V333	154-0187-00			6DJ8	
V353	154-0187-00			6DJ8	
V374	154-0187-00			6DJ8	

ROTATIONAL FUNCTION GENERATOR

Values are fixed unless marked Variable.

Bulbs

B53	150-0078-00	B010100	B039999	Incandescent 382 clear
B53	150-0122-00	B040000		Incandescent #2306, 6 V, 200 mA
B73	150-0078-00	B010100	B039999	Incandescent 382 clear
B73	150-0122-00	B040000		Incandescent #2306, 6 V, 200 mA
B93	150-0078-00	B010100	B039999	Incandescent 382 clear
B93	150-0122-00	B040000		Incandescent #2306, 6 V, 200 mA

Capacitors

Tolerance ±20% unless otherwise indicated.

C99	290-0134-00	22 μF	Elect.	15 V	
C370	283-0059-00	1 μF	Cer	25 V	+80%—20%

[10]Furnished as a unit with R160Y.

[11]Furnished as a unit with R388.

ROTATIONAL FUNCTION GENERATOR (cont)

Diodes

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
D56	152-0246-00			Silicon	Low Leakage, 0.25 W, 40 V
D59	152-0141-02			Silicon	1N4152
D76	152-0246-00			Silicon	Low Leakage, 0.25 W, 40 V
D92	152-0141-02			Silicon	1N4152
D99	152-0212-00			Zener	1N936, 500 mW, 9 V, ±5%

Connector

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description
J370	131-0617-01			6 contact, female

Transistors

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
Q53[12]	*153-0569-00			Silicon	Photo FPT-100 (Fairchild)
Q54A, B	151-0249-00	B010100	B029999	Silicon	Dual NPN
Q54A, B	151-0232-00	B030000		Silicon	Dual NPN
Q73[12]	*153-0569-00			Silicon	Photo FPT-100 (Fairchild)
Q74A, B	151-0249-00	B010100	B029999	Silicon	Dual NPN
Q74A, B	151-0232-00	B030000		Silicon	Dual NPN
Q93	151-0252-00			Silicon	Photo FPT-100 (Fairchild)
Q94	*151-0216-00			Silicon	Replaceable by MOT MPS-6523

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R50	321-0210-00			1.5 kΩ	1/8 W	Prec	1%
R51	321-0385-00			100 kΩ	1/8 W	Prec	1%
R52	321-0376-00			80.6 kΩ	1/8 W	Prec	1%
R54	321-0210-00			1.5 kΩ	1/8 W	Prec	1%
R55	321-0309-00			16.2 kΩ	1/8 W	Prec	1%
R56	321-0258-00			4.75 kΩ	1/8 W	Prec	1%
R57	311-0704-00	B010100	B039999	500 Ω, Var			
R57	311-1261-00	B040000		500 Ω, Var			
R58	321-0248-00			3.74 kΩ	1/8 W	Prec	1%
R59	321-0212-00			1.58 kΩ	1/8 W	Prec	1%
R70	321-0210-00			1.5 kΩ	1/8 W	Prec	1%
R71	321-0365-00			61.9 kΩ	1/8 W	Prec	1%
R72	321-0402-00			150 kΩ	1/8 W	Prec	1%
R74	321-0235-00			2.74 kΩ	1/8 W	Prec	1%
R75	321-0331-00			27.4 kΩ	1/8 W	Prec	1%
R76	321-0229-00			2.37 kΩ	1/8 W	Prec	1%

[12] **Q53 and Q73 furnished as a matched pair.**

ROTATIONAL FUNCTION GENERATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R77	311-0704-00	B010100	B039999	500 Ω, Var			
R77	311-1261-00	B040000		500 Ω, Var			
R78	321-0269-00			6.19 kΩ	1/8 W	Prec	1%
R79	321-0210-00			1.5 kΩ	1/8 W	Prec	1%
R91	321-0250-00			3.92 kΩ	1/8 W	Prec	1%
R92	321-0340-00			34 kΩ	1/8 W	Prec	1%
R94	321-0222-00			2 kΩ	1/8 W	Prec	1%
R95	321-0097-00			100 Ω	1/8 W	Prec	1%
R96	321-0218-00			1.82 kΩ	1/8 W	Prec	1%
R99	322-0102-00			113 Ω	1/4 W	Prec	1%
				Switch			
SW60	260-0613-00			Toggle	ROTATION DIRECTION		

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear on the pullout pages immediately following the Diagrams section of this instruction manual.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the Description column.

Assembly and/or Component
  Detail Part of Assembly and/or Component
  mounting hardware for Detail Part
    Parts of Detail Part
    mounting hardware for Parts of Detail Part
mounting hardware for Assembly and/or Component

Mounting hardware always appears in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation.

Mounting hardware must be purchased separately, unless otherwise specified.

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

ABBREVIATIONS AND SYMBOLS

For an explanation of the abbreviations and symbols used in this section, please refer to the page immediately preceding the Electrical Parts List in this instruction manual.

INDEX OF MECHANICAL PARTS LIST ILLUSTRATIONS

(Located behind diagrams)

SECTION 7
MECHANICAL PARTS LIST

FIG. 1 EXPLODED TYPE 2B67

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-1	366-0113-00			1	KNOB, charcoal--POSITION
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-2	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch
-3	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-4	366-0215-01			1	KNOB, lever, gray--MODE
-5	260-0990-00			1	SWITCH, lever--MODE
	- - - - - -			-	mounting hardware: (not included w/switch)
-6	220-0413-00			2	NUT, hex., 4-40 x 3/16 x 0.562 inch long
-7	366-0153-00			1	KNOB, charcoal--POSITION (ROTATIONAL FUNCTION)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-8	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-9	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-10	366-0113-00			1	KNOB, charcoal--LEVEL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-11	262-0844-00			1	SWITCH, wired--LEVEL
	- - - - - -			-	switch includes:
	260-0353-00			1	SWITCH, unwired
-12	376-0014-00			1	COUPLING
-13	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-14	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-15	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-16	366-0236-00			1	KNOB, charcoal--WIDTH MARKERS
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-17	366-0038-00			1	KNOB, red--CAL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-18	366-0144-00			1	KNOB, charcoal--TIME/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS

FIG. 1 EXPLODED, TYPE 2B67 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-	262-0840-00			1	SWITCH, wired--TIME/DIVISION
	- - - - - -			-	switch includes:
-19	260-0989-00			1	SWITCH, unwired
-20	384-0226-00			1	ROD, extension, 8 7/16 inches long
-21	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-22	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-23	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-24	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
-25	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-26	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-27	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-28	376-0052-00			1	ASSEMBLY, coupling
	- - - - - -			-	assembly includes:
	354-0251-00			1	RING, coupling, 0.251 inch long
	354-0261-00			1	RING, coupling, 0.437 inch long
	376-0049-00			1	COUPLING, plastic
	213-0022-00			2	SCREW, set, 4-40 x 3/16 inch, HSS
	213-0075-00			2	SCREW, set, 4-40 x 3/32 inch, HSS
	213-0115-00			1	SCREW, set, 4-40 x 5/16 inch, HSS
-29	376-0060-00			1	ASSEMBLY, coupling
	- - - - - -			-	coupling includes:
	213-0075-00			4	SCREW, set, 4-40 x 3/32 inch, HSS
	354-0261-00			2	RING, coupling
	376-0049-00			1	COUPLING, plastic
-30	348-0031-00			1	GROMMET, plastic, 5/32 inch diameter
-31	348-0050-00			1	GROMMET, plastic, 3/4 inch diameter
-32	210-0202-00			2	LUG, solder, SE #6
	- - - - - -			-	mounting hardware for each: (not included w/lug)
	210-0449-00			1	NUT, hex., 5-40 x 1/4 inch
	- - - - - -			1	ASSEMBLY, capacitor
	- - - - - -			-	assembly includes:
-33	407-0277-00			1	BRACKET
-34	179-0508-01			1	CABLE HARNESS
-35	124-0208-01			1	STRIP, ceramic, 7/16 inch h, w/6 notches
	- - - - - -			-	strip includes:
	- - - - - -			2	STUD, plastic

FIG. 1 EXPLODED, TYPE 2B67 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-36	124-0208-03			1	STRIP, ceramic, 7/16 inch h, w/6 notches w/silver
	- - - - - -			-	band strip includes:
	355-0046-00			2	STUD, plastic
	361-0007-00			4	SPACER, plastic, 5/32 inch long (not shown)
	- - - - - -			-	mounting hardware: (not included w/assembly)
	210-0803-00			2	WASHER, flat, 0.150 ID x 3/8 inch OD
-37	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
-38	407-0453-00			1	BRACKET
	- - - - - -			-	bracket includes:
-39	211-0094-00			2	SCREW, 4-40 x 1/2 inch, THS
	- - - - - -			-	mounting hardware: (not included w/switch)
-40	210-0457-00			4	NUT, keps, 6-32 x 5/16 inch
-41	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
	210-0803-00			4	WASHER, flat, 0.150 ID x 3/8 inch OD
-42	260-0447-00			1	SWITCH, slide--SLOPE
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-43	260-0450-00			1	SWITCH, slide--SOURCE
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-44	260-0447-00			1	SWITCH, slide--SINGLE SWP DISPLAY
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-45	260-0613-00			1	SWITCH, toggle--PISTON (VOLUME)
	- - - - - -			-	mounting hardware: (not included w/switch)
-46	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-47	210-0562-00			1	NUT, hex., 1/4-40 x 5/16 inch
-48	131-0609-01			1	CONNECTOR, 6 pin, female
	- - - - - -			-	mounting hardware: (not included w/connector)
	210-0959-00			1	WASHER, flat, 0.562 ID x 0.750 inch OD
-49	220-0504-00			1	NUT, hex., 9/16-24 x 11/16 inch
-50	366-0109-00			1	KNOB, plug-in securing
	- - - - - -			-	knob includes:
	213-0005-00			1	SCREW, set, 8-32 x 1/8 inch, HSS
-51	214-0052-00			1	FASTENER, pawl right w/stop
	- - - - - -			-	mounting hardware: (not included w/fastener)
-52	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch

FIG. 1 EXPLODED, TYPE 2B67 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-53	131-0106-00			1	CONNECTOR, coaxial, 1 contact, BNC w/hardware
	- - - - - -			-	mounting hardware: (not included w/connector)
-54	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-55	210-0202-00			1	LUG, solder, SE #6
	- - - - - -			-	mounting hardware: (not included w/lug)
	211-0541-00			1	SCREW, 6-32 x 1/4 inch, 100° csk, FHS
	210-0457-00			1	NUT, keps, 6-32 x 5/16 inch
-56	384-0446-00			1	ROD, extension, 6.938 inches long
-57	384-0215-00			1	ROD, extension, 6.625 inches long
-58	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-59	358-0010-00			1	BUSHING, resistor mounting
-60	358-0216-00			1	BUSHING, front panel
-61	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-62	210-0494-00			1	NUT, hex., 3/8-32 x 1/2 x 11/16 inch long
	210-0255-00			1	LUG, solder, 3/8 inch diameter
-63	358-0010-00			1	BUSHING
-64	378-0541-00			2	FILTER, lens, neon
-65	352-0067-00			2	HOLDER, neon, single
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-66	211-0109-00			1	SCREW, 4-40 x 7/8 inch, 100° csk, FHS
-67	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-68	670-0195-00			1	ASSEMBLY, circuit board--FUNCTION AMPLIFIER
	- - - - - -			-	assembly includes:
	388-1023-00			1	BOARD, circuit
-69	136-0220-00			2	SOCKET, transistor, 3 pin
-70	136-0237-00			1	SOCKET, transistor, 6 pin
-71	131-0633-00			19	TERMINAL PIN
	- - - - - -			-	mounting hardware: (not included w/assembly)
-72	211-0116-00			3	SCREW, sems, 4-40 x 5/16 inch, PHS
-73	670-0196-00			1	ASSEMBLY, circuit board--2 CYCLE/4 CYCLE
	- - - - - -			-	assembly includes:
	388-1024-00			1	BOARD, circuit
-74	136-0220-00			2	SOCKET, transistor, 3 pin
-75	131-0633-00			6	TERMINAL PIN
	- - - - - -			-	mounting hardware: (not included w/assembly)
-76	211-0116-00			3	SCREW, sems, 4-40 x 5/16 inch, PHB

FIG. 1 EXPLODED, TYPE 2B67 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-77	441-0332-02			1	CHASSIS
	------			-	mounting hardware: (not included w/chassis)
-78	211-0504-00			3	SCREW, 6-32 x 1/4 inch, PHS
-79	348-0031-00			5	GROMMET, plastic, 5/32 inch diameter
-80	348-0055-00			3	GROMMET, rubber, 1/4 inch diameter
-81	348-0063-00			1	GROMMET, rubber, 1/2 inch diameter
-82	136-0015-00			8	SOCKET, tube, 9 pin w/ground lugs
	------			-	mounting hardware for each: (not included w/socket)
	213-0044-00			2	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-83	136-0022-00			1	SOCKET, tube, 9 pin
	------			-	mounting hardware: (not included w/socket)
	213-0044-00			2	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-84	337-0008-00			1	SHIELD, tube
-85	------			2	CAPACITOR
	------			-	mounting hardware for each: (not included w/capacitor)
-86	214-0153-00			1	FASTENER, snap, plastic
-87	------			1	RESISTOR, variable
	------			-	mounting hardware: (not included w/resistor)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-88	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-89	------			1	RESISTOR, variable
	------			-	mounting hardware: (not included w/resistor)
	210-0940-00			1	LOCKWASHER, internal, 1/4 ID x 3/8 inch OD
-90	210-0583-00			1	NUT, hex., 1/4-32 x 5/16
-91	------			1	RESISTOR, variable
	------			-	mounting hardware: (not included w/resistor)
	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-92	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-93	333-1069-01			1	PANEL, front
-94	386-1405-00			1	SUB-PANEL, front
-95	384-0615-00			4	ROD, spacer
	------			-	mounting hardware for each: (not included w/rod)
-96	212-0023-00			1	SCREW, 8-32 x 5/16 inch, PHS

FIG. 1 EXPLODED, TYPE 2B67 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-97	385-0129-00			1	ROD, plastic, 1 5/8 inches long
	- - - - - -			-	mounting hardware: (not included w/rod)
	211-0507-00			1	SCREW, 6-32 x 5/16 inch, PHS
-98	385-0113-00			1	ROD, plastic, 1 1/8 inches long
	- - - - - -			-	mounting hardware: (not included w/rod)
	211-0507-00			1	SCREW, 6-32 x 5/16 inch, PHS
-99	351-0037-00			1	GUIDE, plug-in
	- - - - - -			-	mounting hardware: (not included w/guide)
	211-0013-00			1	SCREW, 4-40 x 3/8 inch, PHS
	210-0004-00			1	LOCKWASHER, internal, #4
-100	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-101	131-0149-00			1	CONNECTOR, 24 pin, male
	- - - - - -			-	mounting hardware: (not included w/connector)
-102	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-103	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
-104	387-0581-00			1	PLATE, rear
-105	179-1257-00			1	CABLE HARNESS, chassis
-106	179-1258-00			1	CABLE HARNESS, function amplifier
	- - - - - -			-	cable harness includes:
	131-0371-00			25	CONNECTOR, single contact
-107	343-0043-00			2	CLAMP, neon bulb
-108	124-0088-00			2	STRIP, ceramic, 3/4 inch h, w/4 notches
	- - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, 13/32 inch long
-109	124-0091-00			12	STRIP, ceramic, 3/4 inch h, w/11 notches
	- - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, 13/32 inch long

FIG. 2 FRONT, TYPE 3A74

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-1	366-0140-00	B010100	B029999	1	KNOB, red--RESTORE TIME (CH. 1)
	366-0189-00	B030000		1	KNOB, red--RESTORE TIME (CH. 1)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set 6-32 x 3/16 inch, HSS
-2	366-0250-00	B010100	B029999	1	KNOB, charcoal--PS1/DIV (CH. 1)
	366-0322-00	B030000		1	KNOB, charcoal--PS1/DIV (CH. 1)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, 6-32 x 3/16 inch, HSS
-3	262-0843-00			1	SWITCH, wired--PS1/DIV (CH. 1)
	- - - - - -			-	switch includes:
	260-0996-00			1	SWITCH, unwired
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-4	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-5	366-0140-00	B010100	B029999	1	KNOB, red--POSITION (CH. 1)
	366-0189-00	B030000		1	KNOB, red--POSITION (CH. 1)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-6	366-0250-00	B010100	B029999	1	KNOB, charcoal--MODE (CH. 1)
	366-0322-00	B030000		1	KNOB, charcoal--MODE (CH. 1)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-7	262-0841-00	B010100	B039999	1	SWITCH, wired--MODE (CH. 1)
	262-0841-01	B040000		1	SWITCH, wired--MODE (CH. 1)
	- - - - - -			-	switch includes:
	260-0445-00			1	SWITCH, unwired
-8	384-0250-00			1	ROD, extension
-9	376-0014-00			1	COUPLING
-10	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-11	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	- - - - - -			-	mounting hardware: (not included w/switch)
-12	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-13	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-14	366-0140-00	B010100	B029999	1	KNOB, red--VAR GAIN (CH. 2)
	366-0189-00	B030000		1	KNOB, red--VAR GAIN (CH. 2)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-15	366-0250-00	B010100	B029999	1	KNOB, charcoal--VOLTS/DIV (CH. 2)
	366-0322-00	B030000		1	KNOB, charcoal--VOLTS/DIV (CH. 2)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-16	366-0140-00	B010100	B029999	1	KNOB, red--POSITION (CH. 2)
	366-0189-00	B030000		1	KNOB, red--POSITION (CH. 2)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-17	366-0250-00	B010100	B029999	1	KNOB, charcoal--MODE (CH. 2)
	366-0322-00	B030000		1	KNOB, charcoal--MODE (CH. 2)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS

FIG. 2 FRONT, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
2-18	262-0649-00	B010100	B039999	1	SWITCH, wired--MODE (CH. 2)
	262-0649-01	B040000		1	SWITCH, wired--MODE (CH. 2)
	- - - - - -			-	switch includes:
	260-0445-00			1	SWITCH, unwired
-19	384-0250-00			1	ROD, extension
-20	376-0014-00			1	COUPLING
-21	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-22	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
q	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	- - - - - -			-	mounting hardware: (not included w/switch)
-23	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 1/2 inch OD
-24	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-25	366-0140-00	B010100	B029999	1	KNOB, red--VAR GAIN (CH. 3)
	366-0189-00	B030000		1	KNOB, red--VAR GAIN (CH. 3)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-26	366-0250-00	B010100	B029999	1	KNOB, charcoal--VOLTS/DIV (CH. 3)
	366-0332-00	B030000		1	KNOB, charcoal--VOLTS/DIV (CH. 3)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-27	366-0140-00	B010100	B029999	1	KNOB, red--POSITION (CH. 3)
	366-0189-00	B030000		1	KNOB, red--POSITION (CH. 3)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-28	366-0250-00	B010100	B029999	1	KNOB, charcoal--MODE (CH. 3)
	366-0322-00	B030000		1	KNOB, charcoal--MODE (CH. 3)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-29	262-0649-00			1	SWITCH, wired--MODE (CH. 3)
	- - - - - -			-	switch includes:
	260-0445-00			1	SWITCH, unwired
-30	384-0250-00			1	ROD, extension
-31	376-0014-00			1	COUPLING
-32	- - - - - -			-	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-33	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	- - - - - -			-	mounting hardware: (not included w/switch)
-34	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 1/2 inch OD
-35	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch

FIG. 2 FRONT, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-36	366-0140-00	B010100	B029999	1	KNOB, red--VAR GAIN (CH. 4)
	366-0189-00	B030000		1	KNOB, red--VAR GAIN (CH. 4)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-37	366-0250-00	B010100	B029999	1	KNOB, charcoal--VOLTS/DIV (CH. 4)
	366-0322-00	B030000		1	KNOB, charcoal--VOLTS/DIV (CH. 4)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-38	366-0140-00	B010100	B029999	1	KNOB, red--POSITION (CH. 4)
	366-0189-00	B030000		1	KNOB, red--POSITION (CH. 4)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-39	366-0250-00	B010100	B0299999	1	KNOB, charcoal--MODE (CH. 4)
	366-0322-00	B030000		1	KNOB, charcoal--MODE (CH. 4)
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-40	262-0649-00			1	SWITCH, wired--MODE (CH. 4)
	- - - - - -			-	switch includes:
	260-0445-00			1	SWITCH, unwired
-41	384-0250-00			1	ROD, extension
-42	376-0014-00			1	COUPLING
-43	- - - - - -			-	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-44	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	- - - - - -			-	mounting hardware: (not included w/switch)
-45	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 1/2 inch OD
-46	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-47	260-0247-00			1	SWITCH, push w/hardware--ZERO (CH. 1)
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
	210-0562-00			1	NUT, hex., 1/4-40 x 5/16 inch
-48	260-0446-00			1	SWITCH, toggle--AC GND DC (CH. 2)
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-49	210-0562-00			1	NUT: hex., 1/4-40 x 5/16 inch
-50	260-0446-00			1	SWITCH, toggle--AC GND DC (CH. 3)
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-51	210-0562-00			1	NUT, hex., 1/4-40 x 5/16 inch
-52	260-0446-00			1	SWITCH, toggle--AC GND DC (CH. 4)
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-53	210-0562-00			1	NUT, hex., 1/4-40 x 5/16 inch

FIG. 2 FRONT, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-54	260-0613-00			1	SWITCH, toggle--CHOP ALT
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-55	210-0562-00			1	NUT, hex., 1/4-40 x 5/16 inch
-56	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-57	210-0471-00			1	NUT, hex., 1/4-32 x 5/16 x 19/32 inch long
-58	210-0046-00			2	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
-59	358-0054-00			1	BUSHING, resistor mounting
-60	- - - - - -			7	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-61	358-0075-00			1	BUSHING, resistor mounting
-62	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-63	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-64	358-0075-00			1	BUSHING, resistor mounting
-65	384-0304-00			1	ROD, extension w/knob--TRIGGER
-66	366-0109-00			1	KNOB, plug-in securing
	- - - - - -			-	knob includes:
	213-0005-00			1	SCREW, set, 8-32 x 1/8 inch, HSS
-67	214-0052-00			1	FASTENER, pawl right, w/stop
	- - - - - -			-	mounting hardware: (not included w/fastener)
	210-0004-00			2	LOCKWASHER, internal, #4
-68	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-69	131-0106-00			4	CONNECTOR, coaxial, 1 contact, BNC w/hardware
	- - - - - -			-	mounting hardware for each: (not included w/connector)
-70	210-0255-00			1	LUG, solder, 3/8 inch diameter
-71	333-1070-01			1	PANEL, front
-72	387-0646-00			1	PLATE, sub-panel

FIG. 3 VOLTS/DIV SWITCHES, TYPE 3A74

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-1	262-0545-00			1	SWITCH, wired--VOLTS/DIV (CH. 2)
	- - - - - -			-	switch includes:
	260-0513-00			1	SWITCH, unwired
-2	406-0806-00			1	BRACKET, attenuator
	- - - - - -			-	mounting hardware: (not included w/bracket)
-3	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-4	337-0498-00			1	SHIELD, attenuator bracket
-5	348-0031-00			1	GROMMET, plastic, 1/4 inch diameter
-6	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-7	384-0248-00			1	ROD, extension, 7 inches long
	213-0022-00			1	SCREW, set, 4-40 x 3/16 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/resistor)
-8	210-0004-00			2	LOCKWASHER, internal, #4
-9	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
	- - - - - -			-	mounting hardware: (not included w/switch)
-10	210-0012-00			3	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-11	210-0413-00			2	NUT, hex., 3/8-32 x 1/2 inch
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	358-0029-00			1	BUSHING, hex., 3/8-32 x 1/2 inch long
-12	262-0546-00			1	SWITCH, wired--VOLTS/DIV (CH. 3)
	- - - - - -			-	switch includes:
	260-0512-00			1	SWITCH, unwired
-13	406-0806-00			1	BRACKET, attenuator
	- - - - - -			-	mounting hardware: (not included w/bracket)
-14	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-15	337-0511-00			1	SHIELD, attenuator bracket
-16	348-0031-00			1	GROMMET, plastic, 1/4 inch diameter
-17	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-18	384-0247-00			1	ROD, extension, 4 3/8 inches long
	213-0022-00			1	SCREW, 4-40 x 3/16 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/resistor)
-19	210-0004-00			2	LOCKWASHER, internal, #4
-20	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
	- - - - - -			-	mounting hardware: (not included w/switch)
-21	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 1/2 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch

FIG. 3 VOLTS/DIV SWITCHES, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
3-22	262-0547-00			1	SWITCH, wired--VOLTS/DIV (CH. 4)
	- - - - - -			-	switch includes:
	260-0513-00			1	SWITCH, unwired
-23	406-0806-00			1	BRACKET, attenuator
	- - - - - -			-	mounting hardware: (not included w/bracket)
-24	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-25	337-0499-00			1	SHIELD, attenuator bracket
-26	348-0031-00			1	GROMMET, plastic, 1/4 inch diameter
-27	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-28	384-0248-00			1	ROD, extension, 7 inches long
	213-0022-00			1	SCREW, set, 4-40 x 3/16 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/resistor)
-29	210-0004-00			2	LOCKWASHER, internal, #4
-30	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
	- - - - - -			-	mounting hardware: (not included w/switch)
-31	210-0012-00			2	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-32	210-0413-00			2	NUT, hex., 4-40 x 3/16 inch
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	358-0029-00			1	BUSHING, hex., 3/8-32 x 1/2 inch long
-33	406-0804-00			2	BRACKET, switch mounting
	- - - - - -			-	mounting hardware: (not included w/bracket)
-34	211-0504-00			2	SCREW, 6-32 x 1/4 inch, PHS
-35	337-0512-00			2	SHIELD, attenuator
	- - - - - -			-	mounting hardware for each: (not included w/shield)
-36	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-37	337-0504-00			1	SHIELD, attenuator
	- - - - - -			-	mounting hardware: (not included w/shield)
-38	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-39	337-1022-00			1	SHIELD, channel separator
	- - - - - -			-	mounting hardware: (not included w/shield)
-40	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-41	337-0501-00			1	SHIELD, channel separator
	- - - - - -			-	mounting hardware: (not included w/shield)
-42	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS

FIG. 3 VOLTS/DIV SWITCHES, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-43	343-0072-00			2	CLAMP, cable, 1/2 inch plastic
	- - - - - -			-	mounting hardware for each: (not included w/clamp)
	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
	210-0801-00			1	WASHER, flat, 0.140 ID x 0.281 inch OD
-44	210-0586-00			1	NUT, keps, 4-40 x 1/4 inch
-45	407-0452-00			1	BRACKET, angle
	- - - - - -			-	mounting hardware: (not included w/bracket)
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
-46	343-0072-00			1	CLAMP, cable, 1/2 inch plastic
	- - - - - -			-	mounting hardware: (not included w/clamp)
-47	211-0510-00			1	SCREW, 6-32 x 3/8 inch, PHS
	210-0863-00			1	WASHER, D shape, 0.191 ID x 33/64 W x 33/64 inch long
-48	210-0457-00			1	NUT, keps, 6-32 x 5/16 inch
-49	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-50	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-51	136-0270-00			1	SOCKET, transistor, 2 pin
	- - - - - -			-	mounting hardware: (not included w/socket)
-52	213-0088-00			2	SCREW, thread forming, #4 x 1/4 inch, PHS
-53	- - - - - -			1	TRANSISTOR
	- - - - - -			-	mounting hardware: (not included w/transistor)
-54	213-0183-00			1	SCREW, thread forming, #6 x 1/2 inch, PHS
-55	200-0669-00			1	COVER, transistor
	213-0104-00			1	SCREW, thread forming, #6 x 3/8 inch, THS
-56	286-0143-00			1	PLATE, insulator
-57	441-0786-00			1	CHASSIS, circuit board mounting
	- - - - - -			-	mounting hardware: (not included w/chassis)
-58	213-0055-00			4	SCREW, thread forming, 2-32 x 3/16 inch, PHS

FIG. 3 VOLTS/DIV SWITCHES, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
3-59	670-0278-00			1	ASSEMBLY, circuit board--CHARGE AMP
	- - - - - -			-	assembly includes:
	388-1011-00			1	BOARD, circuit
-60	136-0219-00			1	SOCKET, transistor, 4 pin
-61	136-0220-00			6	SOCKET, transistor, 3 pin
-62	136-0257-00			2	SOCKET, transistor, 4 pin
-63	131-0663-00			12	CONNECTOR, receptacle
-64	131-0180-00			1	CONNECTOR, terminal stand-off
	358-0135-00			1	BUSHING, plastic (not shown)
	- - - - - -			-	mounting hardware: (not included w/assembly)
-65	211-0116-00			4	SCREW, sems, 4-40 x 5/16 inch, PHB
-66	407-0456-00			1	BRACKET, support
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0008-00			1	SCREW, 4-40 x 1/4 inch, PHS
	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
	210-0801-00			1	WASHER, flat, 0.140 ID x 0.281 inch OD
	210-0994-00			4	Washer, flat, 0.125 ID x 0.250 inch OD
	211-0097-00			2	SCREW, 4-40 x 5/16 inch, PHS

FIG. 4 CHASSIS & REAR, TYPE 3A74

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
4-1	441-0433-03			1	CHASSIS
	- - - - - -			-	mounting hardware: (not included w/chassis)
-2	211-0504-00			3	SCREW, 6-32 x 1/4 inch, PHS
	211-0538-00			2	SCREW, 6-32 x 5/16 inch, FHS
-3	210-0204-00			1	LUG, solder, DE #6
	- - - - - -			-	mounting hardware: (not included w/lug)
-4	213-0044-00			1	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-5	210-0201-00			7	LUG, solder, SE #4
	- - - - - -			-	mounting hardware for each: (not included w/lug)
-6	213-0044-00			1	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-7	210-0259-00			14	LUG, solder, SE #2
	- - - - - -			-	mounting hardware for each: (not included w/lug)
-8	213-0055-00			1	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-9	348-0067-00			1	GROMMET, rubber, 5/16 inch
-10	348-0031-00			4	GROMMET, plastic, 5/32 inch diameter
-11	348-0055-00			2	GROMMET, plastic, 1/4 inch diameter
-12	385-0061-00			1	ROD, plastic, 5/16 x 1 3/4 inches long
	- - - - - -			-	mounting hardware: (not included w/rod)
	211-0507-00			1	SCREW, 6-32 x 5/16 inch, PHS
-13	- - - - - -			2	COIL
	- - - - - -			-	mounting hardware for each: (not included w/coil)
-14	213-0054-00			1	SCREW, thread cutting, 6-32 x 5/16 inch, PHS
-15	131-0183-00			4	CONNECTOR, terminal feed thru
	- - - - - -			-	mounting hardware for each: (not included w/connector)
	358-0136-00			1	BUSHING, plastic
-16	337-0502-00			1	SHIELD, output
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0007-00			2	SCREW, 4-40 x 3/16 inch, PHS
-17	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-18	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-19	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0223-00			1	LUG, solder
	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-20	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch

FIG. 4 CHASSIS & REAR, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
4-21	343-0072-00			1	CLAMP, cable, 1/2 inch plastic
	- - - - - -			-	mounting hardware: (not included w/clamp)
	210-0801-00			1	WASHER, flat, 0.140 ID x 9/32 inch OD
	210-0586-00			1	NUT, keps, 4-40 x 1/4 inch
-22	179-1255-00			1	CABLE HARNESS, circuit board
-23	179-1339-00			1	CABLE HARNESS, switch & chassis
-24	179-1254-00			1	CABLE HARNESS, chassis #1
-25	179-1340-00			1	CABLE HARNESS, chassis #2
-26	179-0649-00			1	CABLE HARNESS, mode switch
-27	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-28	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
	210-0590-00	XB040340		1	NUT, hex., 3/8-32 x 7/16 inch
	210-0012-00	XB040340		1	LOCKWASHER, internal
-29	406-0801-02			1	BRACKET, transistor mounting
	- - - - - -			-	bracket includes:
-30	211-0094-00			1	SCREW, 4-40 x 1/2 inch, THS
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0007-00			4	SCREW, 4-40 x 3/16 inch, PHS
-31	136-0181-00			22	SOCKET, transistor, 3 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-32	354-0234-00			1	RING, socket mounting
-33	136-0101-00			8	SOCKET, nuvistor, 5 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-34	213-0055-00			2	SCREW, thread forming, 2-56 x 3/16 inch, PHS
-35	214-0269-00			2	HEAT SINK, 5/16 x 3/4 inch long
-36	136-0015-00			1	SOCKET, tube, 9 pin, w/ground lugs
	- - - - - -			-	mounting hardware: (not included w/socket)
-37	213-0044-00			2	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-38	136-0072-00			2	SOCKET, tube, 9 pin miniature
	- - - - - -			-	mounting hardware for each: (not included w/socket)
	213-0044-00			2	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-39	260-0447-00			1	SWITCH, slide--TRIGGER
-40	406-0918-00			1	BRACKET, switch actuating
-41	406-0949-00			1	BRACKET, switch
	- - - - - -			-	mounting hardware: (not included w/bracket)
-42	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch

FIG. 4 CHASSIS & REAR, TYPE 3A74 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
4-43	406-0800-00			1	BRACKET, switch mounting
	- - - - - -			-	mounting hardware: (not included w/bracket)
-44	211-0504-00			2	SCREW, 6-32 x 1/4 inch, PHS
-45	210-0201-00			1	LUG, solder, SE #4
	- - - - - -			-	mounting hardware: (not included w/lug)
-46	211-0029-00			1	SCREW, 5-40 x 3/16 inch, PHS
-47	351-0037-00			1	GUIDE, plug-in
	- - - - - -			-	mounting hardware: (not included w/guide)
-48	211-0013-00			1	SCREW, 4-40 x 3/16 inch, RHS
-49	210-0004-00			1	LOCKWASHER, internal, #4
-50	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-51	384-0615-00			4	ROD, frame spacing
	- - - - - -			-	mounting hardware for each: (not included w/rod)
-52	212-0023-00			1	SCREW, 8-32 x 3/8 inch, RHS
-53	131-0149-00			1	CONNECTOR, 24 contact
	- - - - - -			-	mounting hardware: (not included w/connector)
-54	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-55	210-0201-00			2	LUG, solder, SE #4
-56	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-57	387-0647-00			1	PLATE, rear panel
-58	124-0092-00			1	STRIP, ceramic, 7/16 inch h, w/3 notches
	- - - - - -			-	each strip includes:
	355-0046-00			1	STUD, plastic
	- - - - - -			-	mounting hardware: (not included w/strip)
	361-0007-00			1	SPACER, plastic, 0.188 inch long
-59	124-0092-00			2	STRIP, ceramic, 7/16 inch h, w/3 notches
	- - - - - -			-	each strip includes:
	355-0046-00			1	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0008-00			1	SPACER, plastic, 0.281 inch long
-60	124-0145-00			16	STRIP, ceramic, 7/16 inch h, w/20 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0009-00			2	SPACER, plastic, 0.406 inch long

FIG. 4 CHASSIS & REAR, TYPE 3A74 (CONT)

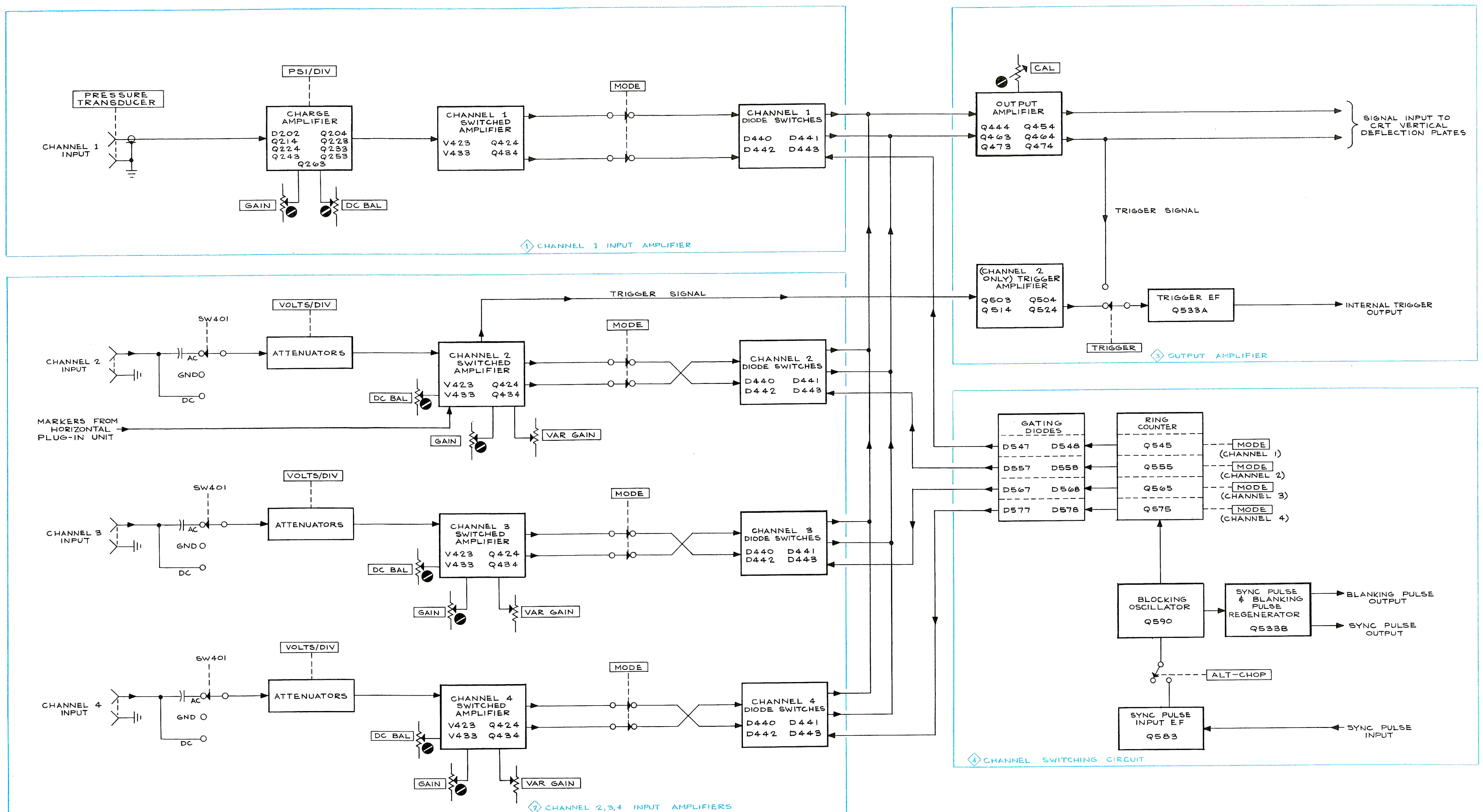
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
4-61	124-0148-00			1	STRIP, ceramic, 7/16 inch h, w/9 notches
	- - - - - -			-	strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware: (not included w/strip)
	361-0009-00			2	SPACER, plastic, 0.406 inch long
-62	124-0147-00			4	STRIP, ceramic, 7/16 inch h, w/13 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0009-00			2	SPACER, plastic, 0.406 inch long

FIG. 5 ROTATIONAL FUNCTION GENERATOR, 015-0108-00

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
5-	015-0108-00			1	GENERATOR, ROTATIONAL FUNCTION
	- - - - - -			-	generator includes:
-1	220-0505-00			1	NUT, plain, cap, 3/4-32 x 0.466 inch h, x 1.032 inch OD
-2	006-1177-00			1	COVER, plastic
-3	426-0426-01			1	FRAME, casting
-4	214-0195-00			1	SCREW, thumb 10-24 x 1.250 inches
-5	212-0588-01			1	SCREW, cap, 10-32 x 0.375 inch, HSS
-6	331-0216-00			1	SCALE
-7	384-0698-00			1	SHAFT, drive
-8	401-0018-00			2	BEARING
-9	361-0189-00			1	SPACER, sleeve
-10	361-0190-00			2	SPACER, stepped
-11	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-12	220-0506-00			1	NUT, self locking, hex., 1/4-28 x 0.375 inch
-13	331-0214-00			1	FILM DISK
-14	- - - - - -			3	BULB
	- - - - - -			-	mounting hardware: (not included w/bulb)
-15	214-1041-00			3	SPRING, helical compression
-16	386-1435-00			1	PLATE, bulb contact, outer
-17	386-1434-00			1	PLATE, bulb contact, tip
-18	131-0613-00			1	CONTACT, electrical
-19	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-20	380-0140-00			1	HOUSING
-21	378-0588-00			1	LENS, light diffusion
	- - - - - -			-	mounting hardware: (not included w/lens)
-22	211-0101-00			2	SCREW, 4-40 x 1/4 inch, 100° csk. FHS
-23	331-0215-00		6952	1	FILM
-24	352-0143-00		6952	1	HOLDER, phototransistor
	352-0143-01	7001		1	HOLDER, phototransistor, w/film
	- - - - - -			-	mounting hardware: (not included w/holder)
-25	211-0105-00			2	SCREW, 4-40 x 3/16 inch, 100° csk, FHS
-26	136-0257-00			3	SOCKET, transistor, 4 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-27	213-0205-00			1	SCREW, set, 4-40 x 3/16 inch, HSS, w/plastic tip
-28	343-0119-00			1	CLAMP, cable, plastic
	- - - - - -			-	mounting hardware: (not included w/clamp)
	211-0116-00			1	SCREW, sems, 4-40 x 5/16 inch, DHB

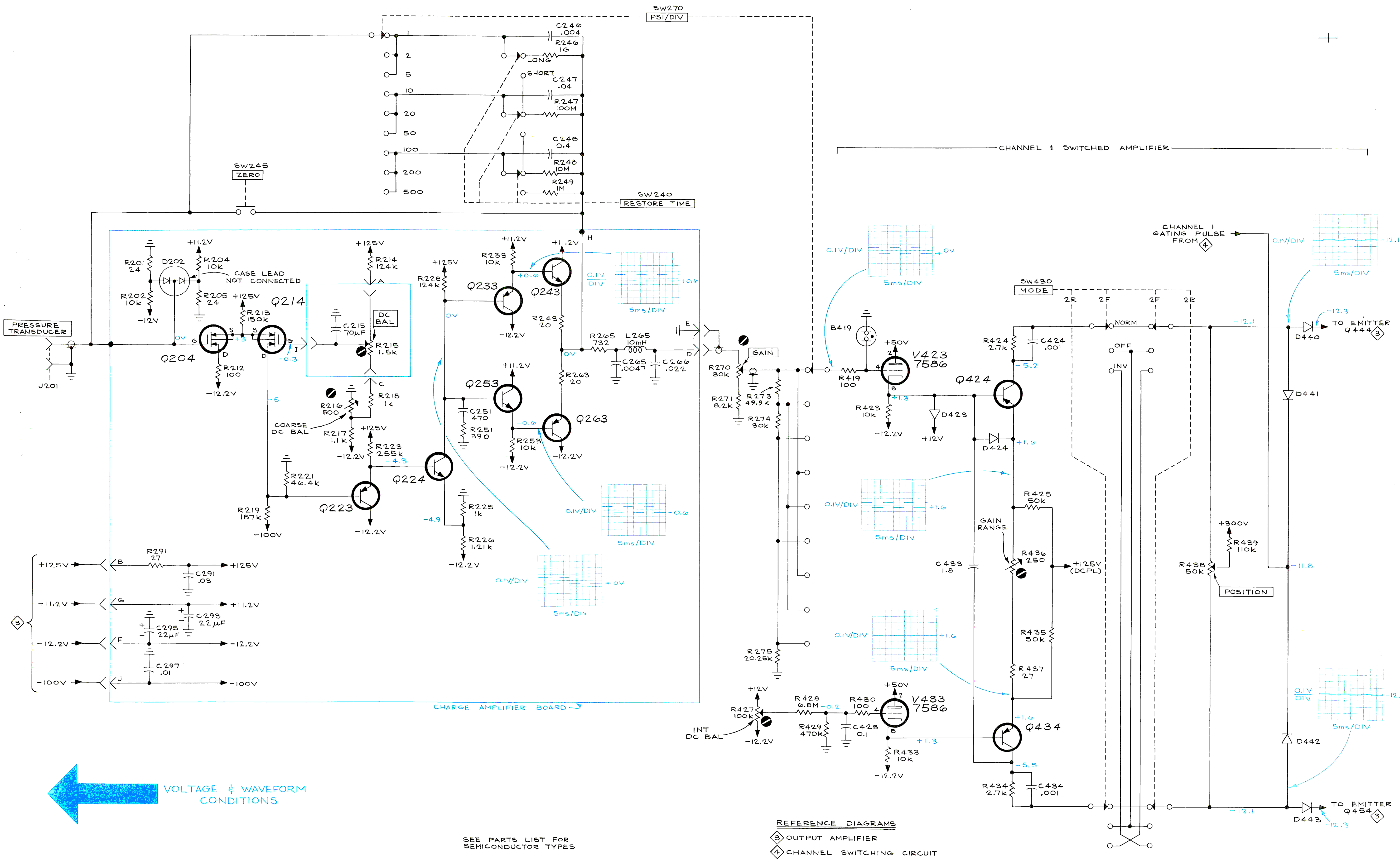
FIG. 5 ROTATIONAL FUNCTION GENERATOR, 015-0108-00 (CONT)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
5-30	386-1468-00			1	PLATE, holder mounting
	- - - - - -			-	mounting hardware: (not included w/plate)
	210-0994-00			2	WASHER, flat, 0.125 ID x 0.250 inch OD
-31	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-32	407-0471-00			1	BRACKET, double angle
	- - - - - -			-	mounting hardware: (not included w/bracket)
-33	211-0038-00			4	SCREW, 4-40 x 5/16 inch, 100° csk, FHS
-34	220-0503-00			2	NUT, block
-35	670-0277-00			1	ASSEMBLY, circuit board--FUNCTION GENERATOR
	- - - - - -			-	assembly includes:
	388-1010-00			1	BOARD, circuit
-36	136-0220-00			1	SOCKET, transistor, 3 pin
-37	136-0235-00			2	SOCKET, transistor, 6 pin
	- - - - - -			-	mounting hardware: (not included w/assembly)
-38	211-0116-00			4	SCREW, sems, 4-40 x 5/16 inch, PHB
-39	407-0470-00			1	BRACKET, connector
	- - - - - -			-	mounting hardware: (not included w/bracket)
-40	211-0101-00			3	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-41	131-0613-00			1	CONTACT, electrical
-42	211-0007-00			1	SCREW, 4-40 x3/16 inch, PHS
-43	260-0613-00			1	SWITCH, toggle w/hardware--ROTATION DIRECTION
-44	131-0617-01			1	CONNECTOR, 6 contact, female
	- - - - - -			-	mounting hardware: (not included w/connector)
-45	211-0038-00			2	SCREW, 4-40 x 5/16 inch, 100° csk, FHS
	210-0201-00			1	LUG, solder, SE #4
-46	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
-47	200-0874-00			1	COVER
	- - - - - -			-	mounting hardware: (not included w/cover)
-48	210-0852-00			1	WASHER, flat, 3/16 ID x 3/8 inch OD
-49	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
-50	210-0804-00			1	WASHER, flat, 0.170 ID x 3/8 inch OD
-51	210-0402-00			1	NUT, hex., cap, 8-32 x 5/16 inch
-52	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-53	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-54	214-0271-00			2	BUTTON, plastic
-55	179-1316-00			1	CABLE HARNESS



768

3A74 AMPLIFIER BLOCK DIAGRAM

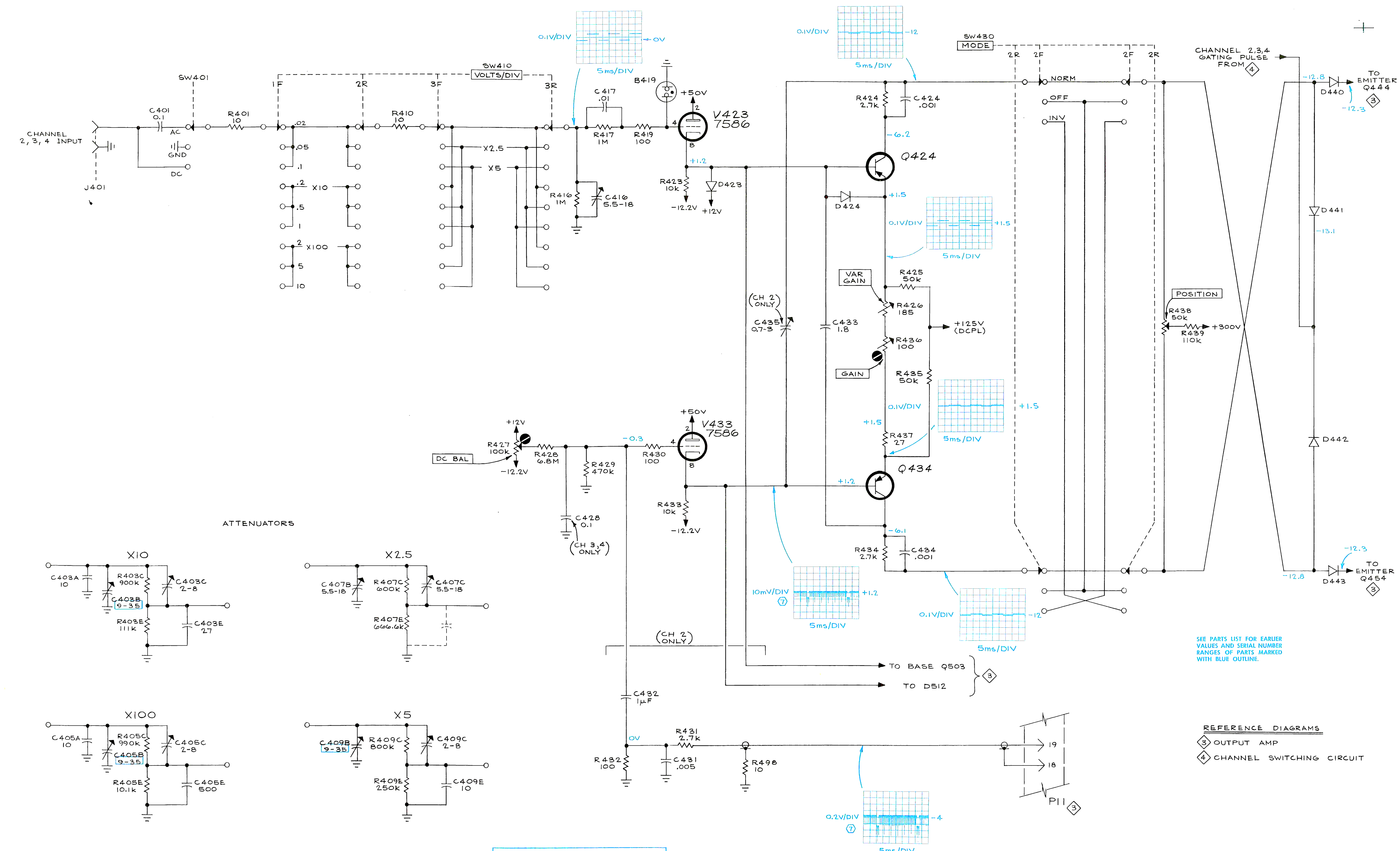


ENGINE ANALYZER SYSTEM

A4

968

(3A74 AMPLIFIER) CHANNEL 1 INPUT AMPLIFIER 1



VOLTAGES and WAVEFORMS obtained under conditions listed on Diagram 1. Noted exceptions follow:

7 Rotational Function Generator connected to 2B67; shaft rotating. 2B67 MARKERS switch pulled out. 3A74 Channel 2 AC-GND-DC switch set to GND.

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

1270

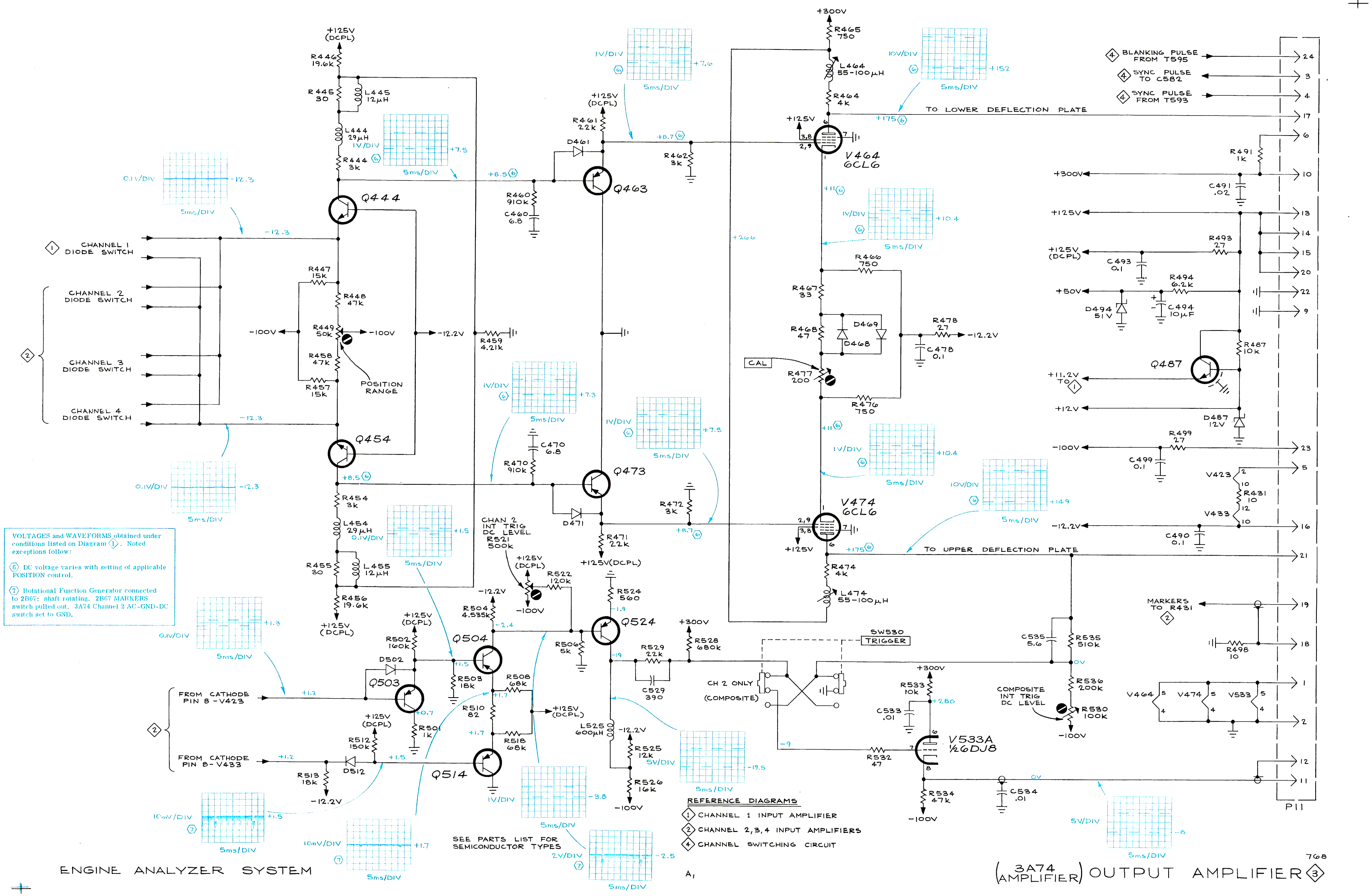
ENGINE ANALYZER SYSTEM

B

(3A74 AMPLIFIER) CHANNEL 2,3,4 INPUT AMPLIFIERS 2

3A74 CH 2, 3, 4 INPUT AMPS

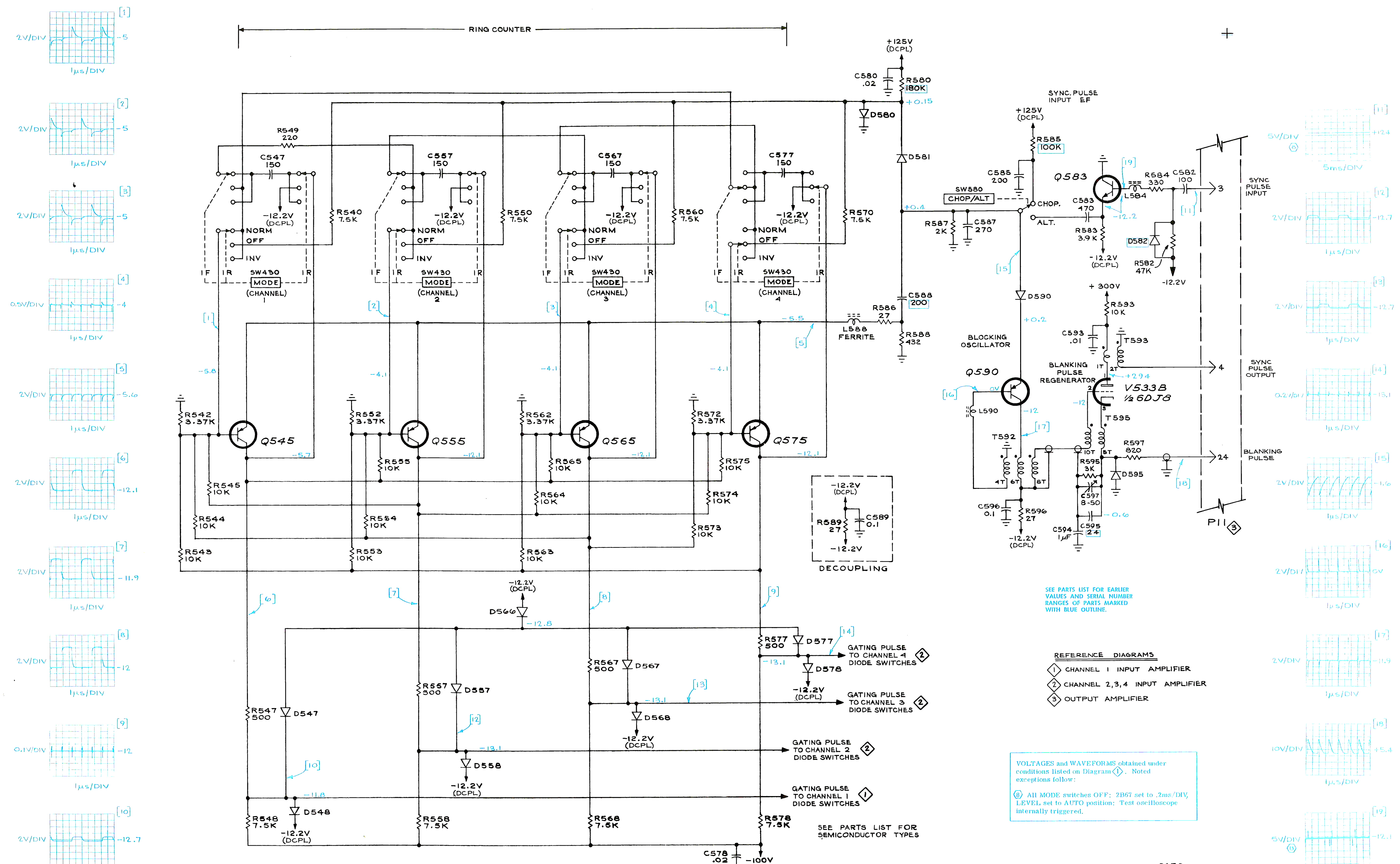
2



ENGINE ANALYZER SYSTEM

(3A74 AMPLIFIER) OUTPUT AMPLIFIER 3

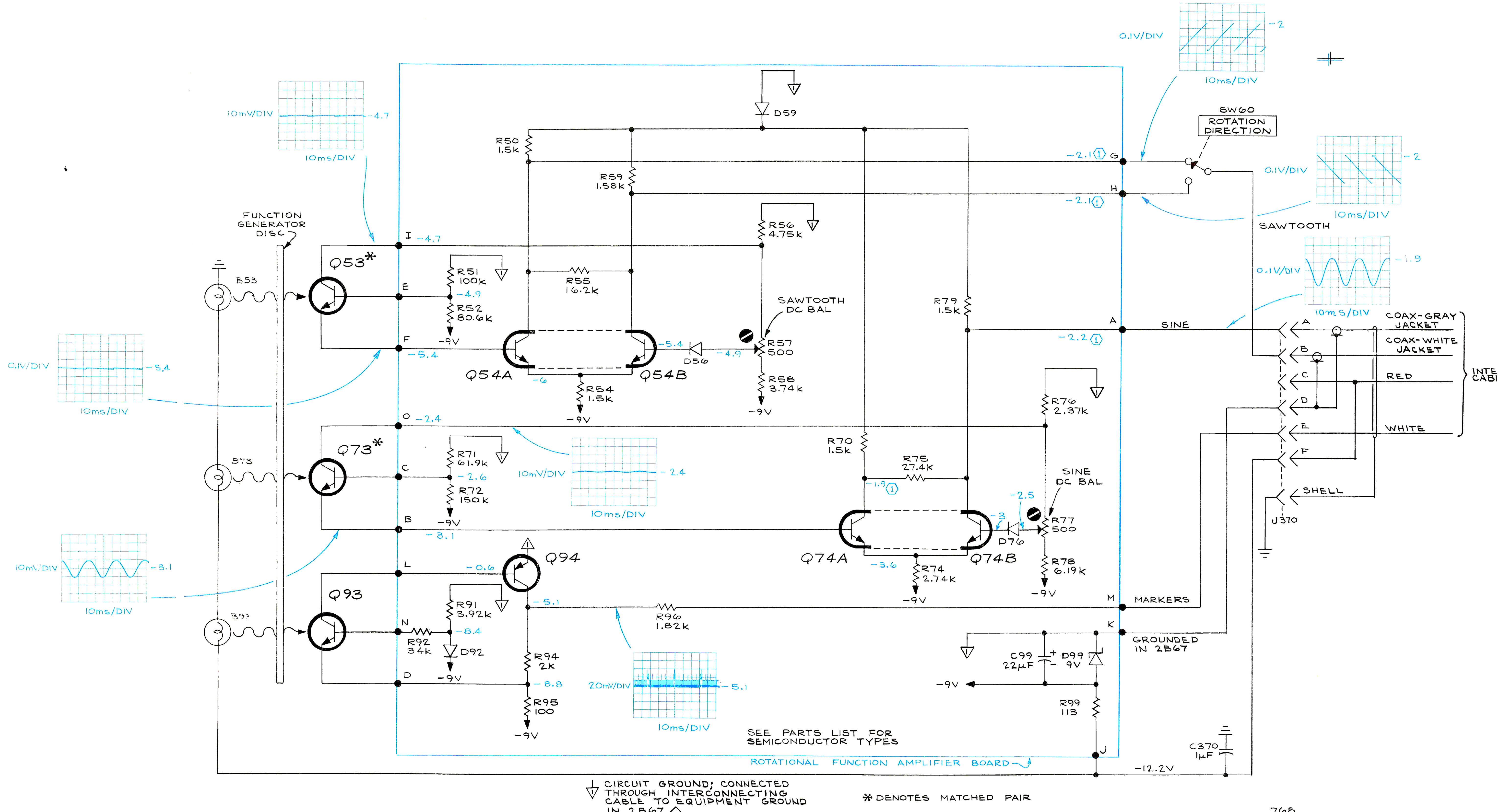
3A74 OUTPUT AMP 3



ENGINE ANALYZER SYSTEM

(3A74 AMPLIFIER) CHANNEL SWITCHING CIRCUIT 4

0670



ENGINE ANALYZER SYSTEM

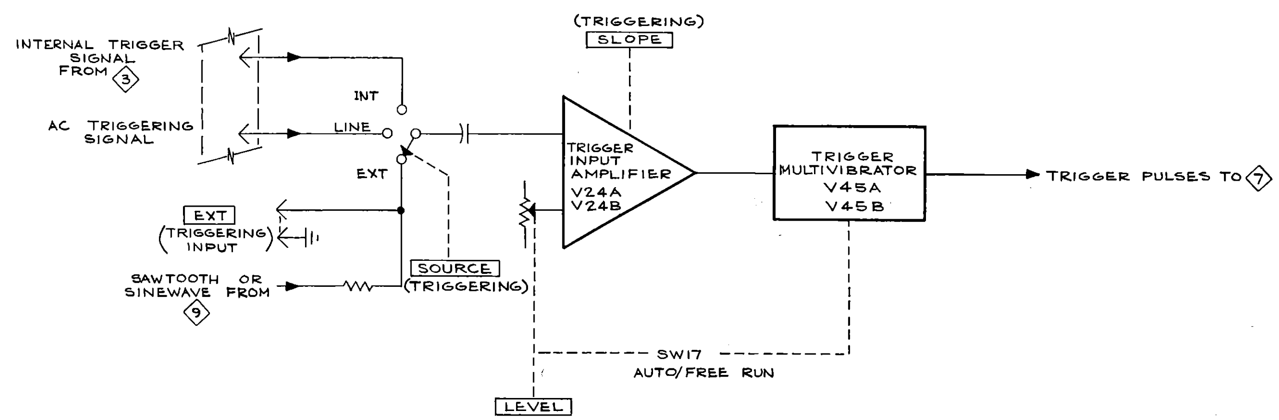
A4

768

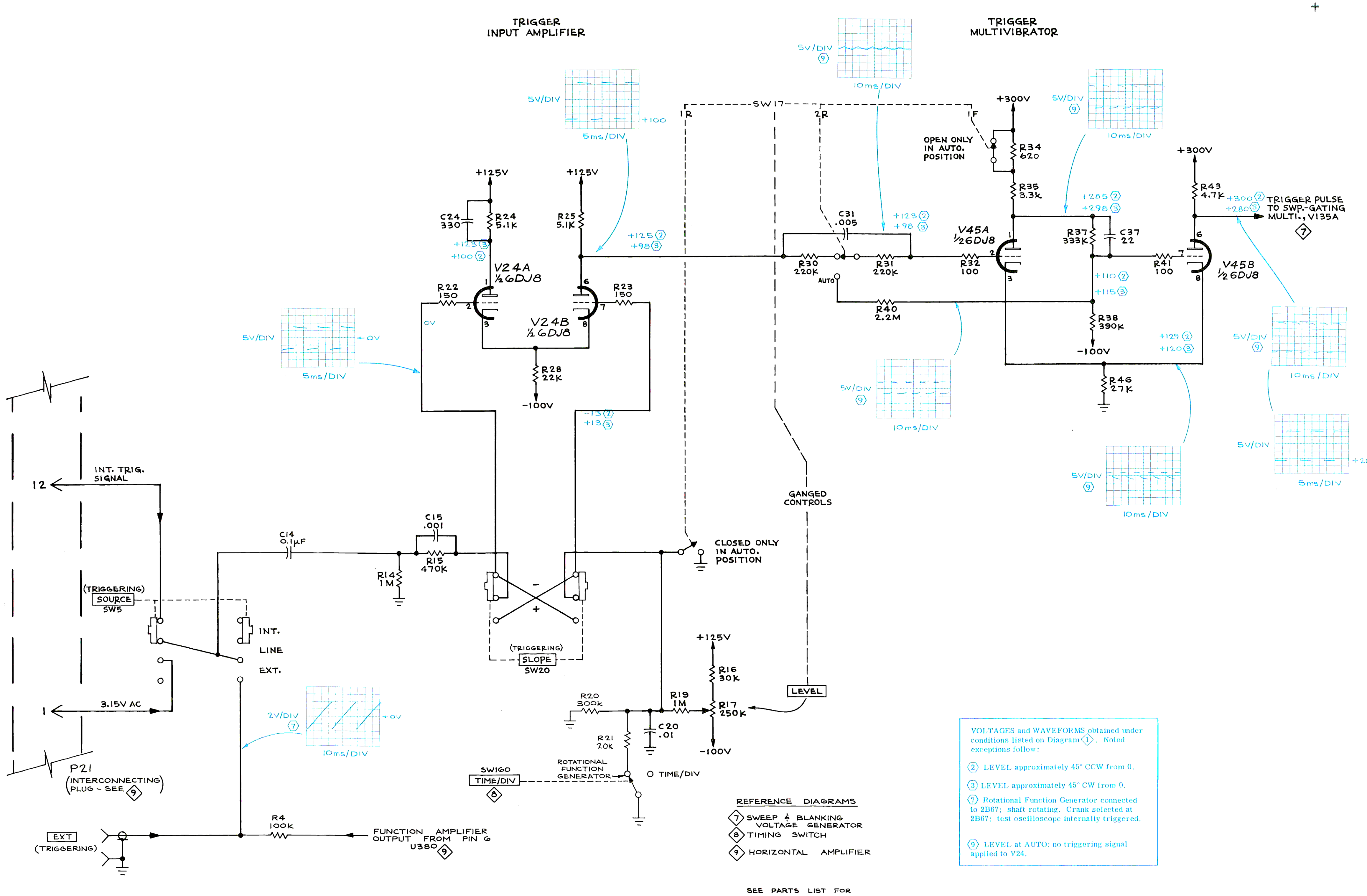
ROTATIONAL FUNCTION GENERATOR 5

VOLTAGES and WAVEFORMS obtained under conditions listed on Diagram 1. Noted exceptions follow:

1 Varies ≈ ±0.5V with position of shaft.



TRIGGER GENERATOR
BLOCK DIAGRAM



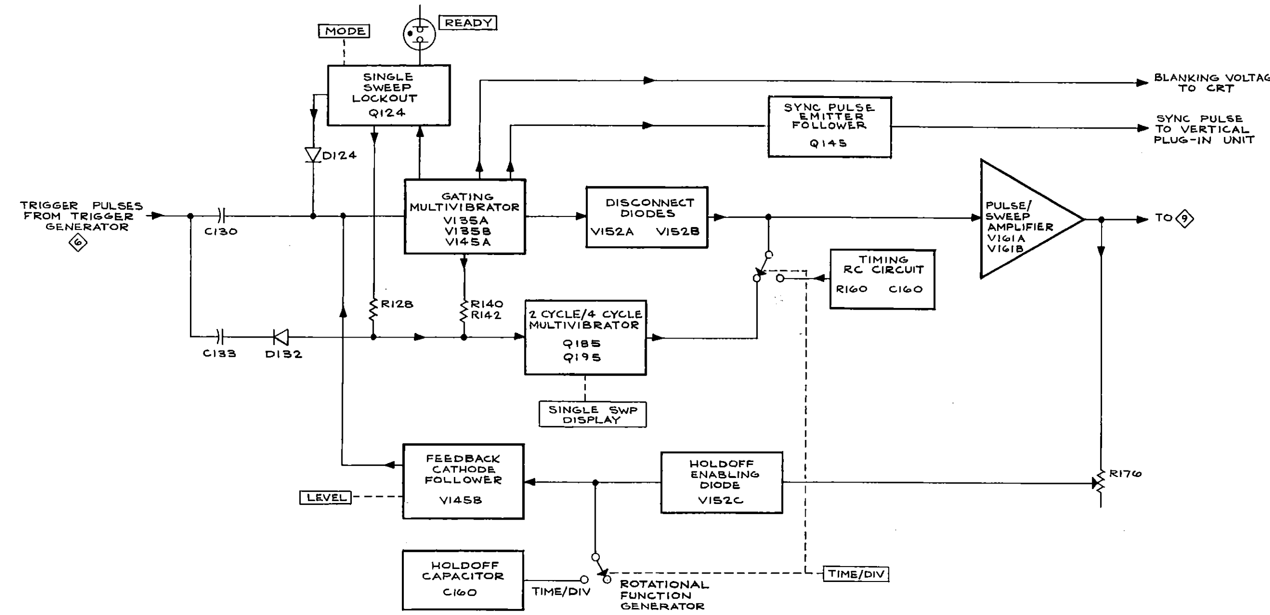
A1

ENGINE ANALYZER SYSTEM

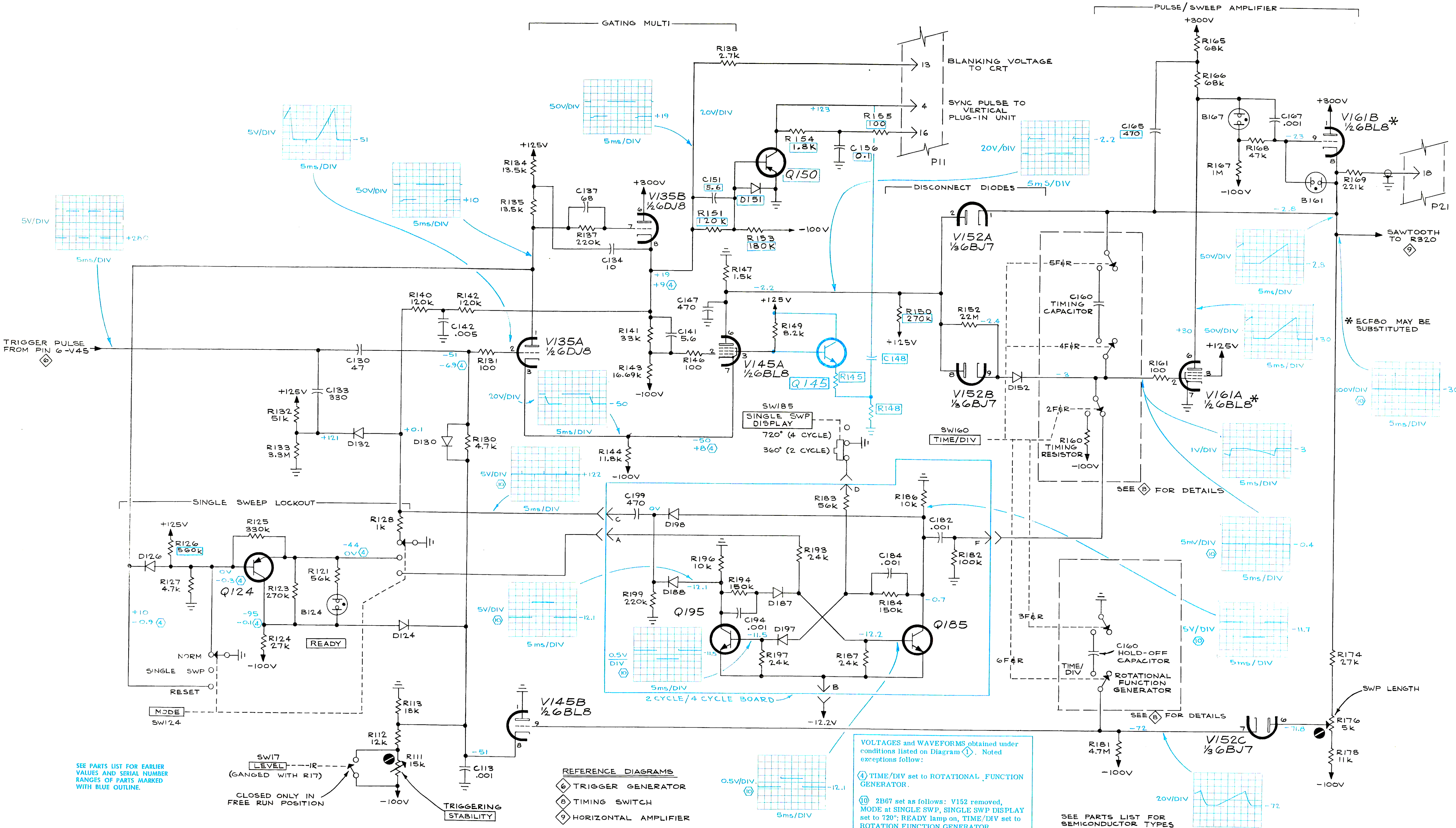
(2B67 TIME-BASE) TRIGGER GENERATOR 6

768

2B67 TRIGGER GEN 6



SWEEP & BLANKING VOLTAGE GENERATOR
BLOCK DIAGRAM

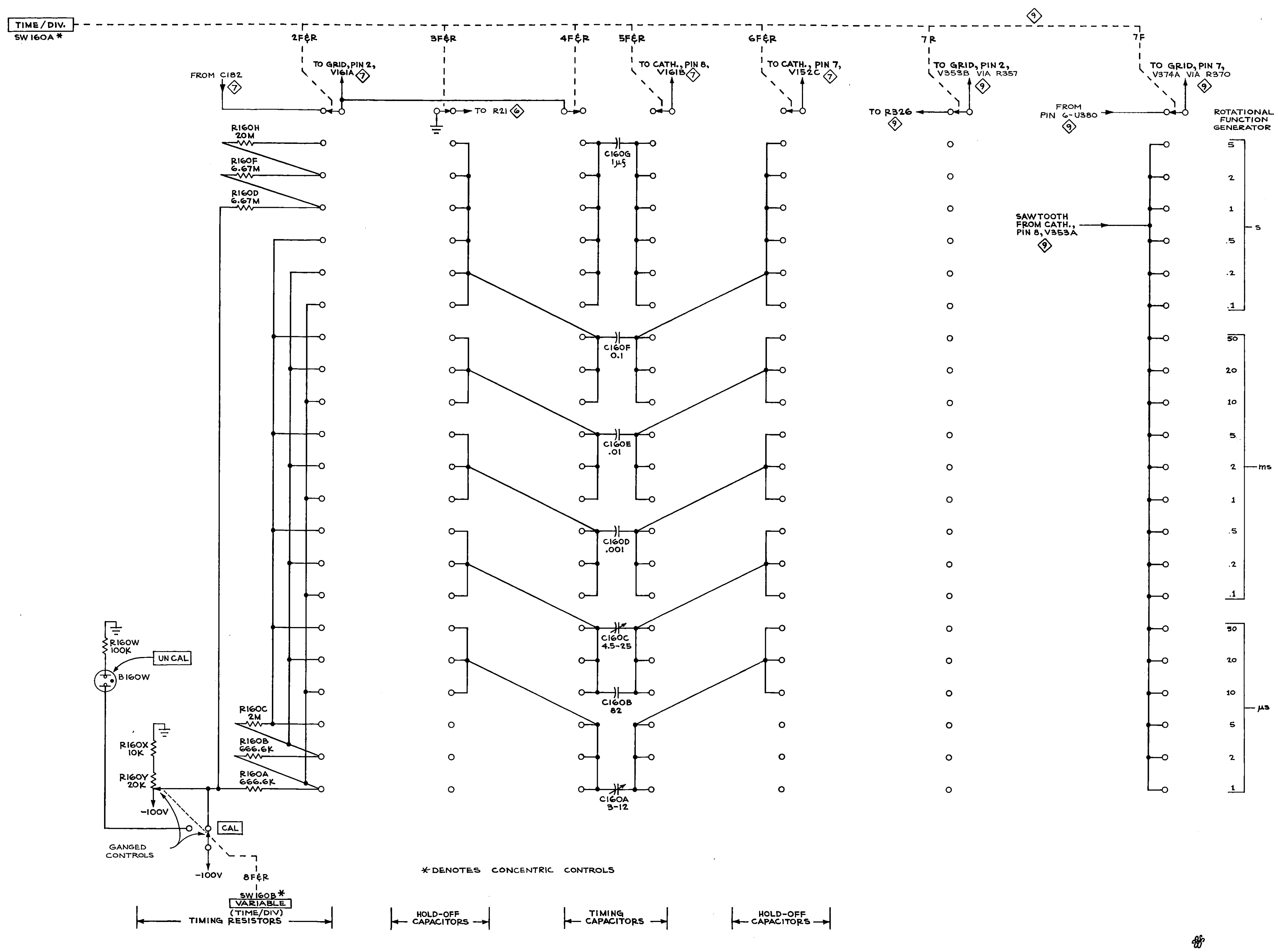


ENGINE ANALYZER SYSTEM

(2B67 TIME-BASE) SWEEP & BLANKING VOLTAGE GENERATOR 7

2B67 SWEEP & BLANKING VOLTAGE GEN

7



TIME/DIV.
SW160A *
2F&R
3F&R
4F&R
5F&R
6F&R
7R
7F
FROM C182 7
TO GRID, PIN 2, V161A 7
TO R21 6
TO CATH., PIN 8, V161B 7
TO CATH., PIN 7, V152C 7
TO GRID, PIN 2, V353B VIA R357 9
TO R326 9
TO GRID, PIN 7, V374A VIA R370 9
FROM PIN 6-U380 9
ROTATIONAL FUNCTION GENERATOR
R160H 20M
R160F 6.67M
R160D 6.67M
C160G 1µf
C160F 0.1
C160E .01
C160D .001
C160C 4.5-25
C160B 82
C160A 3-12
SAWTOOTH FROM CATH., PIN 8, V353A 9
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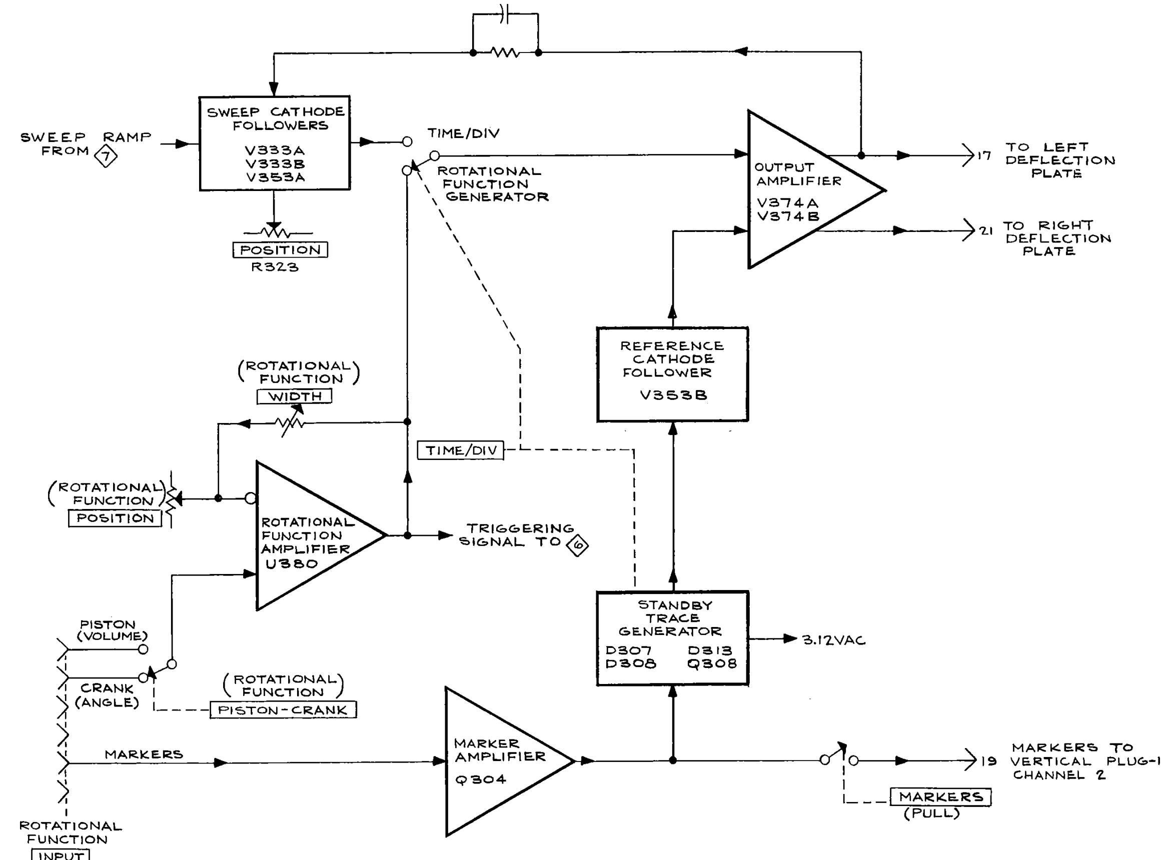
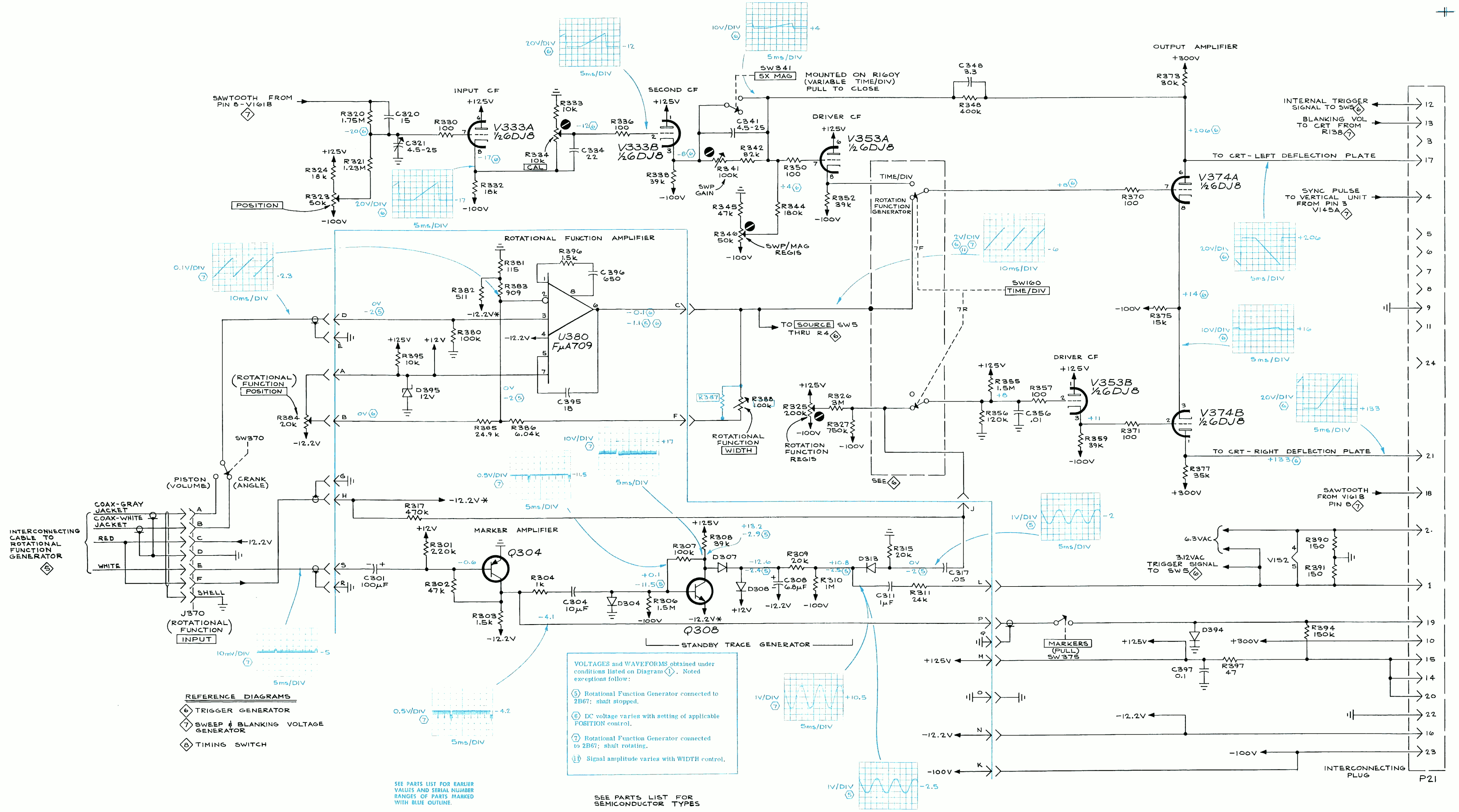
.5
.2
.1
s
50
20
10
5
2
1
.5
.2
.1
ms
50
20
10
5
2
1
µs
R160W 100K
UNCAL
B160W
R160C 2M
R160B 666.6K
R160A 666.6K
R160X 10K
R160Y 20K
-100V
CAL
GANGED CONTROLS
-100V
8F&R
SW160B *
VARIABLE
(TIME/DIV)
*DENOTES CONCENTRIC CONTROLS
TIMING RESISTORS
HOLD-OFF CAPACITORS
TIMING CAPACITORS
HOLD-OFF CAPACITORS
768



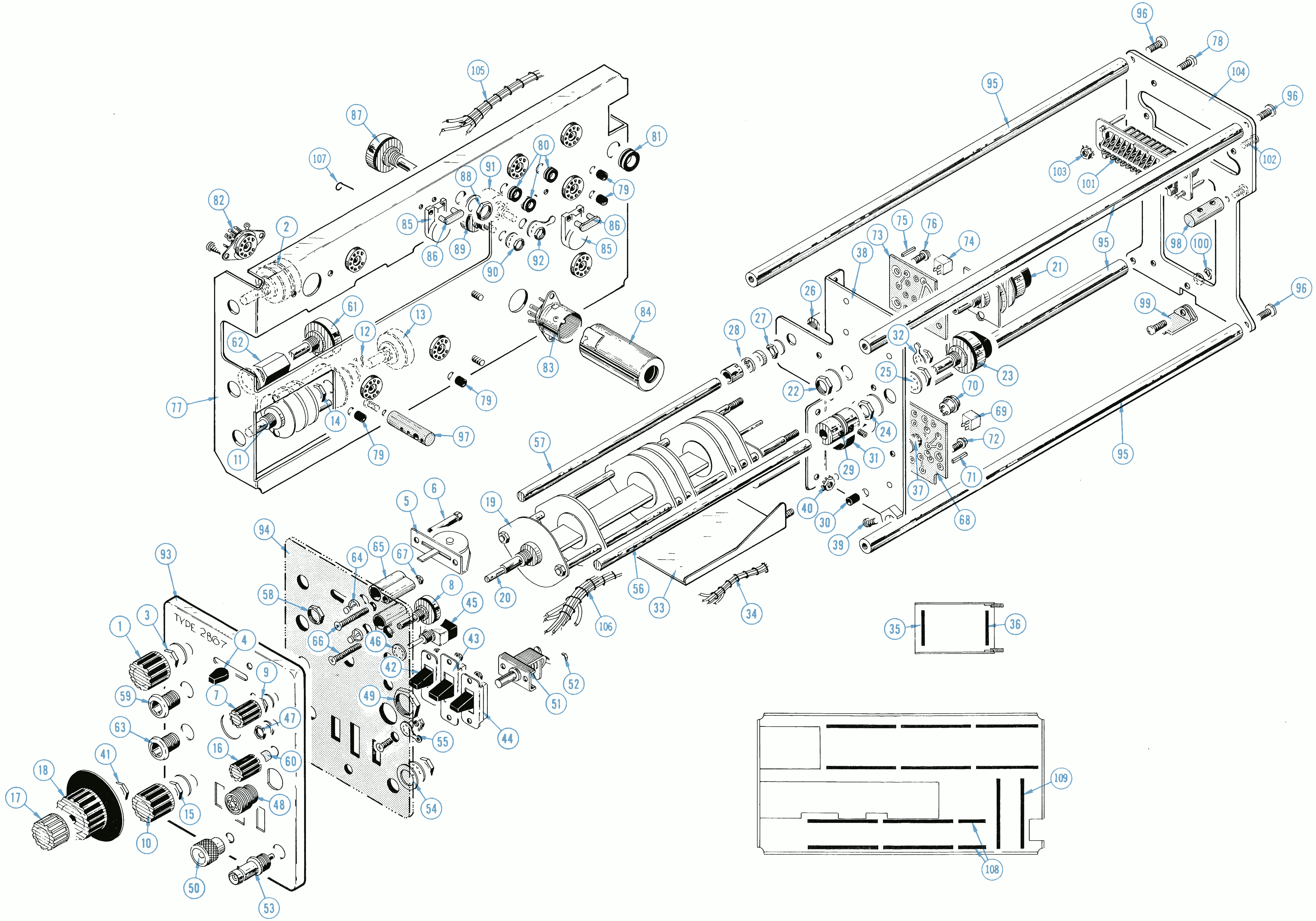
HORIZONTAL AMPLIFIER
BLOCK DIAGRAM



969

ENGINE ANALYZER SYSTEM B (2B67 TIME-BASE) HORIZONTAL AMPLIFIER 9

FIG. 1 EXPLODED, TYPE 2B67



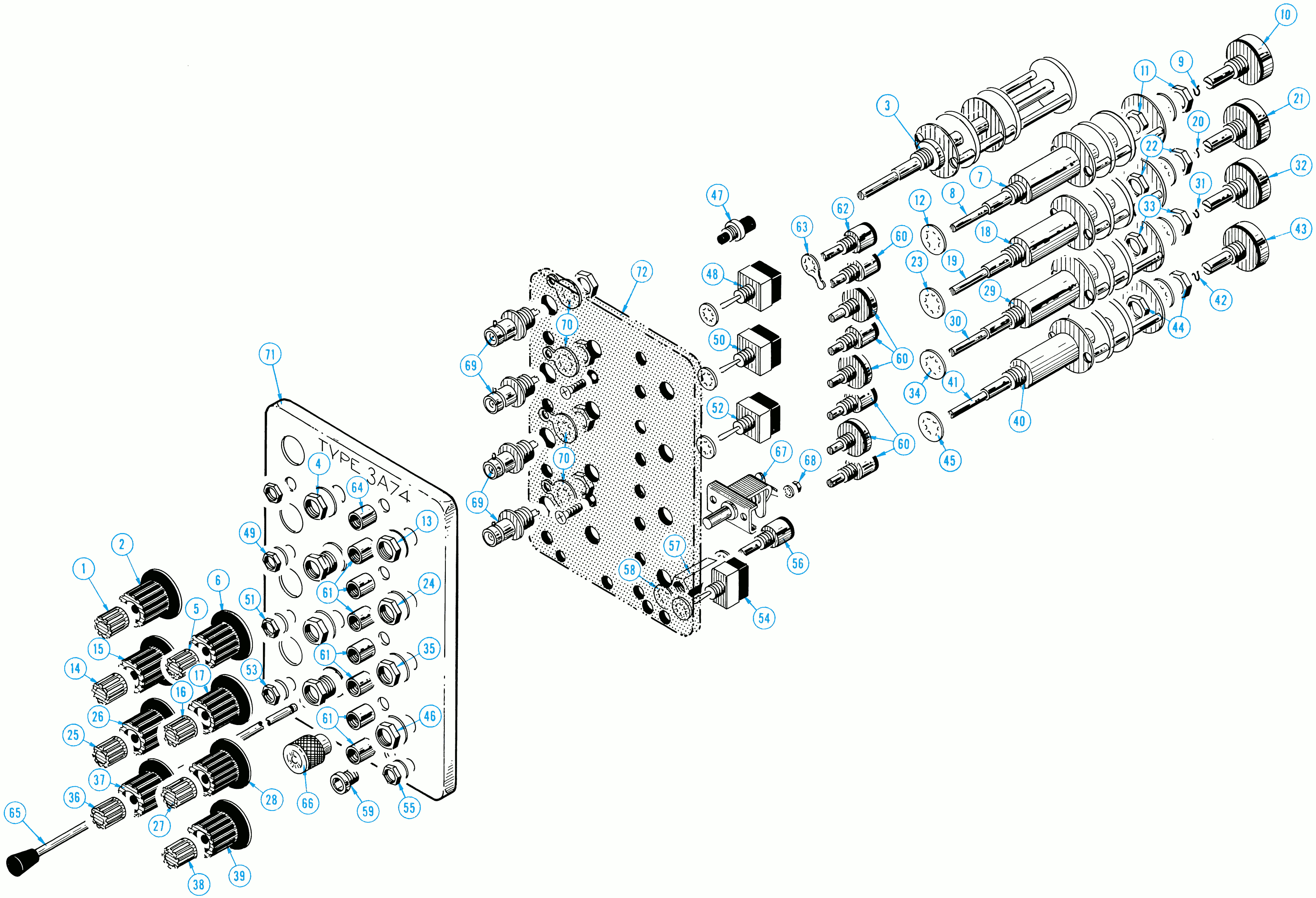

TYPE 3A74

FIG. 3 VOLTS/DIV SWITCHES, TYPE 3A74

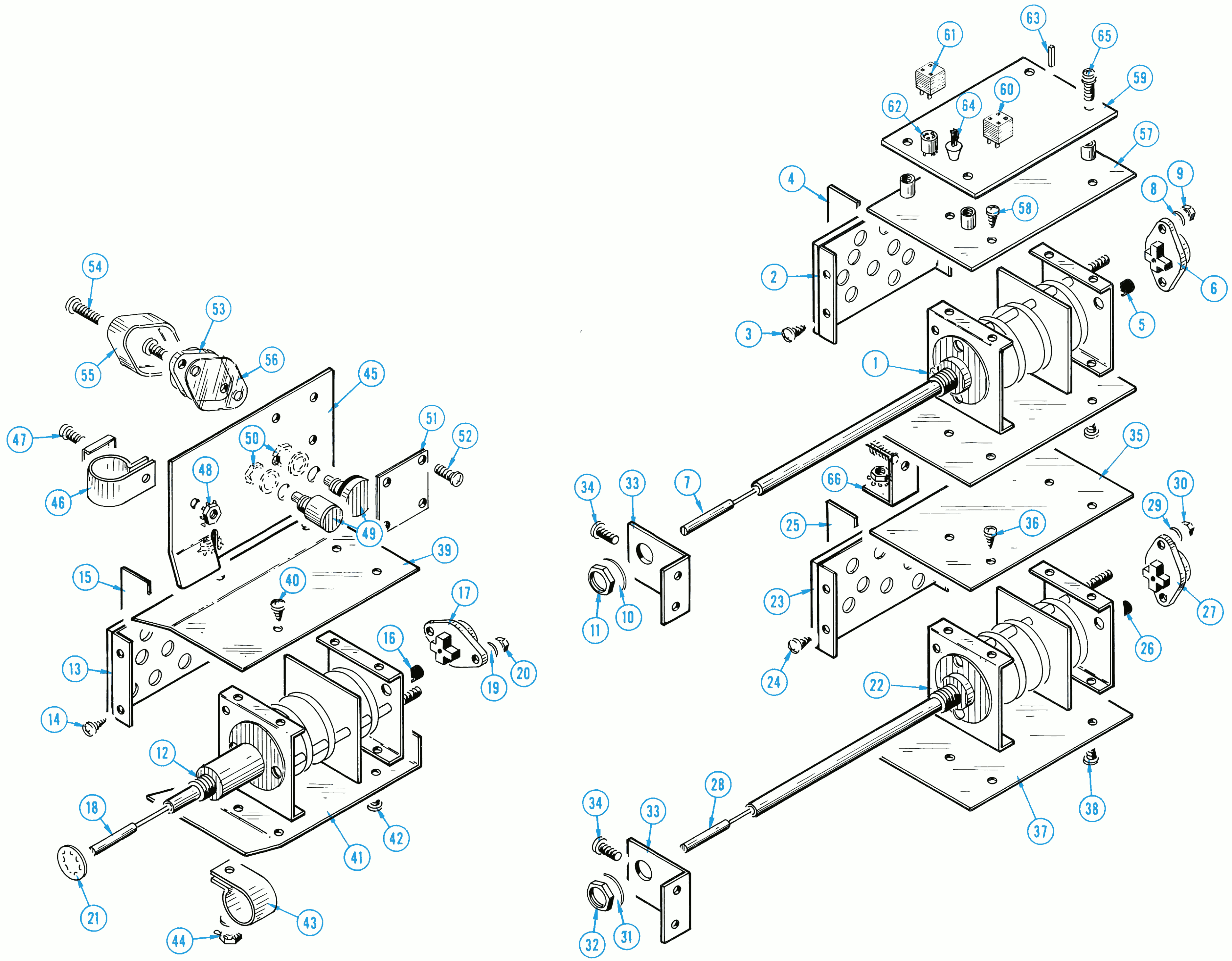


FIG. 3

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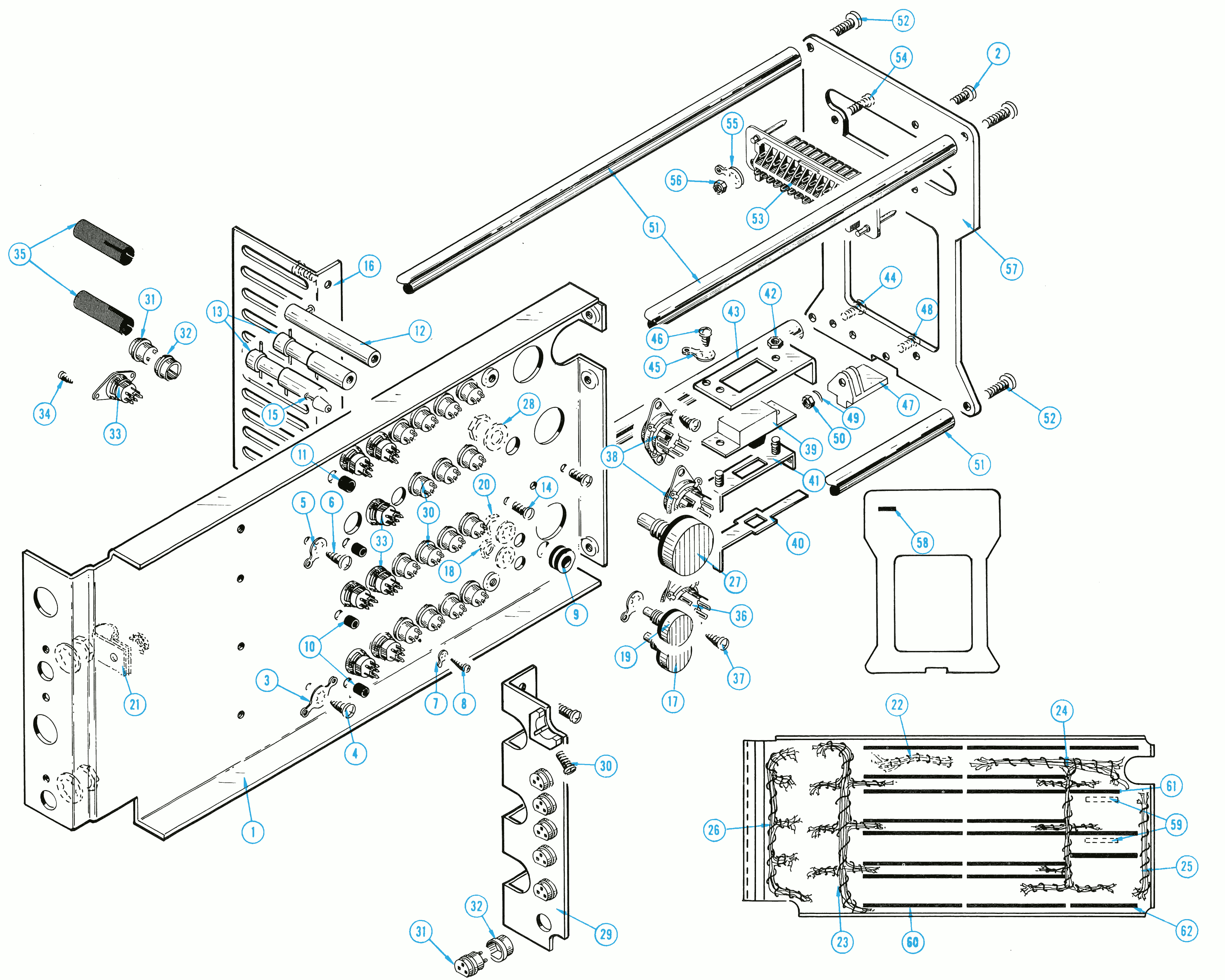
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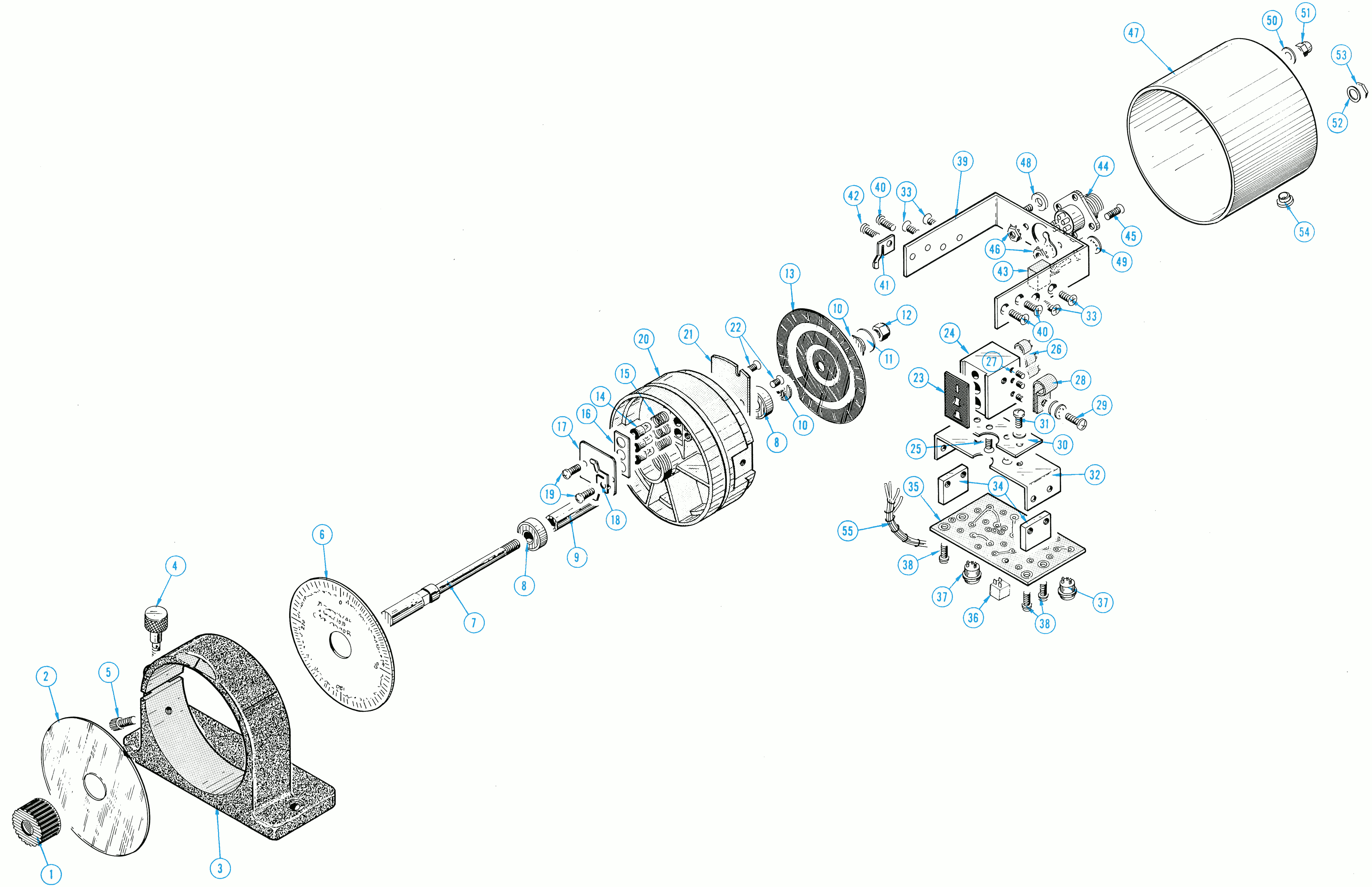
FIG. 5 ROTATIONAL FUNCTION GENERATOR



C

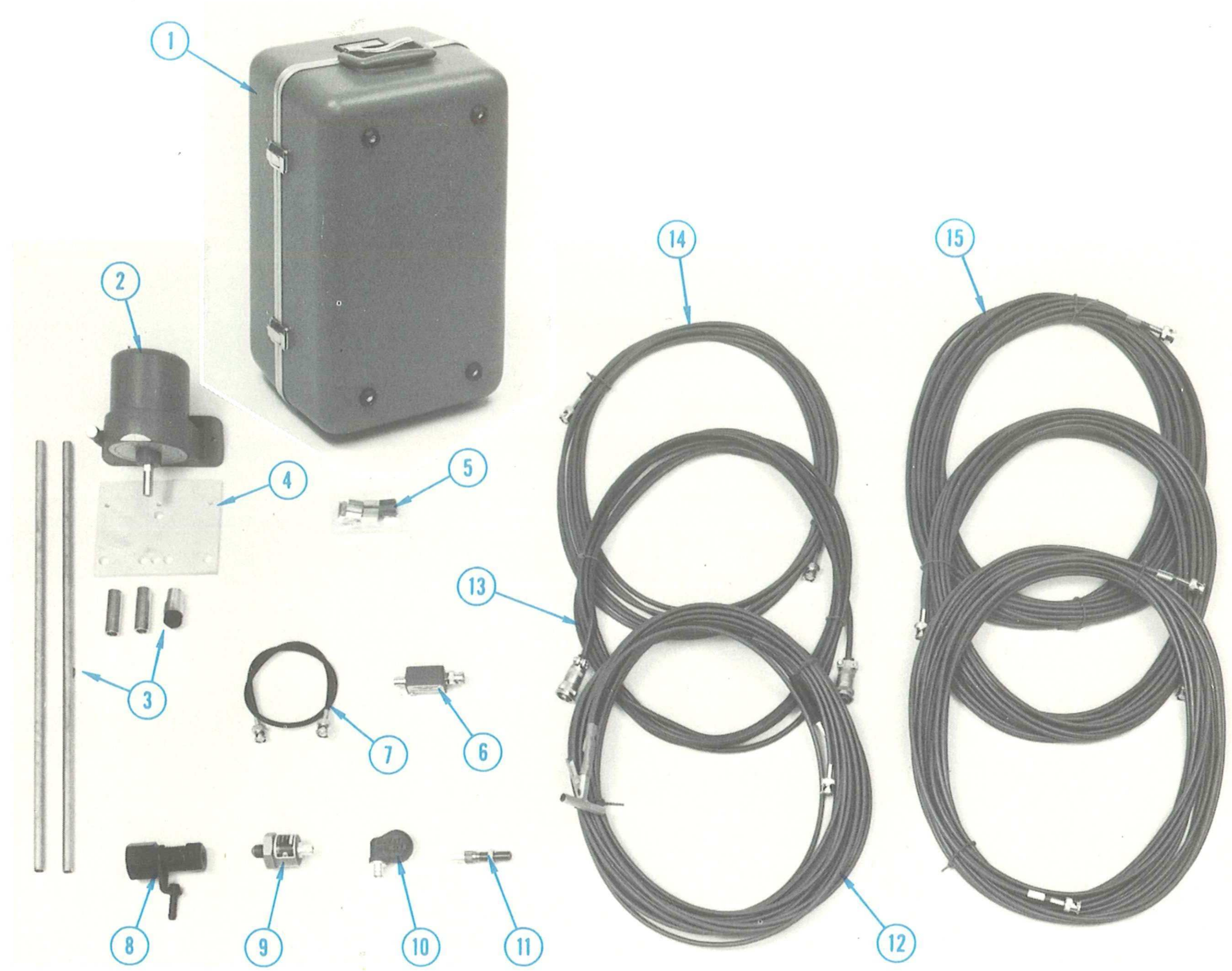


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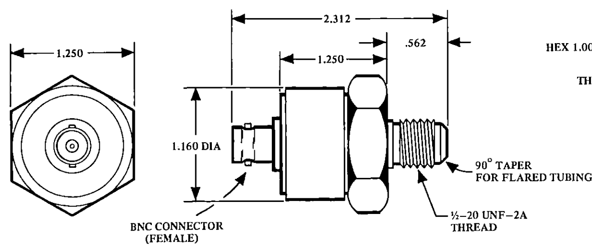
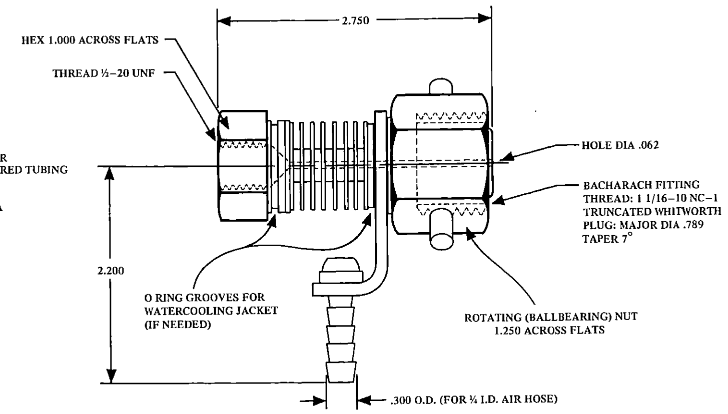
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
6-	015-0126-00			1	PACKAGE, engine analyzer
	- - - - - -			-	package includes:
-1	202-0170-01			1	CASE, carrying
-2	015-0108-00			1	ROTATIONAL FUNCTION GENERATOR
-3	015-0124-00			1	KIT, extension shaft
-4	386-1453-00			1	PLATE, adapter
-5	016-0127-00			1	KIT, cable marker clip
-6	011-0095-00			1	ADAPTER, calibration
-7	012-0076-00			1	CABLE, coaxial, 18 inches long
-8	015-0118-00			1	ADAPTER, cooling transducer
-9	015-0117-00			1	TRANSDUCER, pressure
-10	015-0116-00			1	ACCELEROMETER, piezoelectric
-11	015-0119-00			1	ELECTROMAGNETIC PICKUP
-12	012-0139-00			1	CABLE ASSEMBLY, ignition pick-off
-13	012-0140-00			1	CABLE ASSEMBLY, function generator, 20 feet long
-14	012-0136-00			1	CABLE ASSEMBLY, coaxial, low-noise, 20 feet long
-15	012-0137-00			3	CABLE ASSEMBLY, coaxial, low-noise, 50 feet long
	070-0890-00			1	MANUAL, instruction (not shown)

DIMENSIONS OF ACCESSORIES

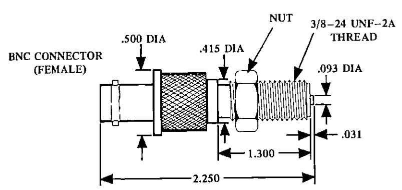
PRESSURE TRANSDUCER
Part No. 015-0117-00
WEIGHT: 5.9 OZ
CASE: STAINLESS STEEL



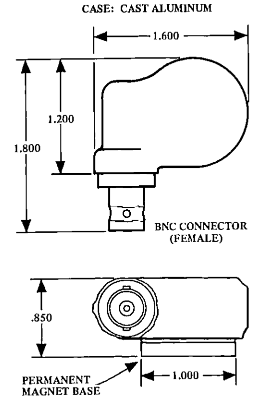
COOLING ADAPTER
Part No. 015-0118-00
WEIGHT: 11 OZ
MAT: BRASS & STAINLESS STEEL



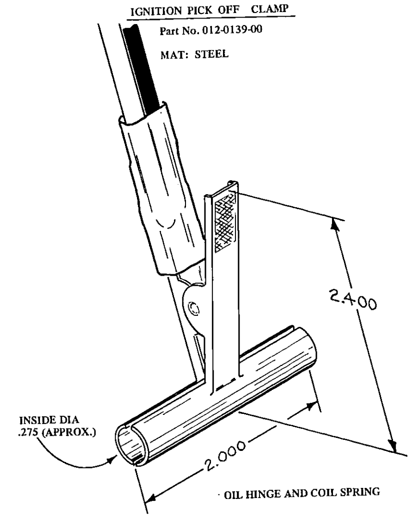
MAGNETIC PICK-UP
Part No. 015-0119-00
WEIGHT: 0.6 OZ
CASE: STAINLESS STEEL



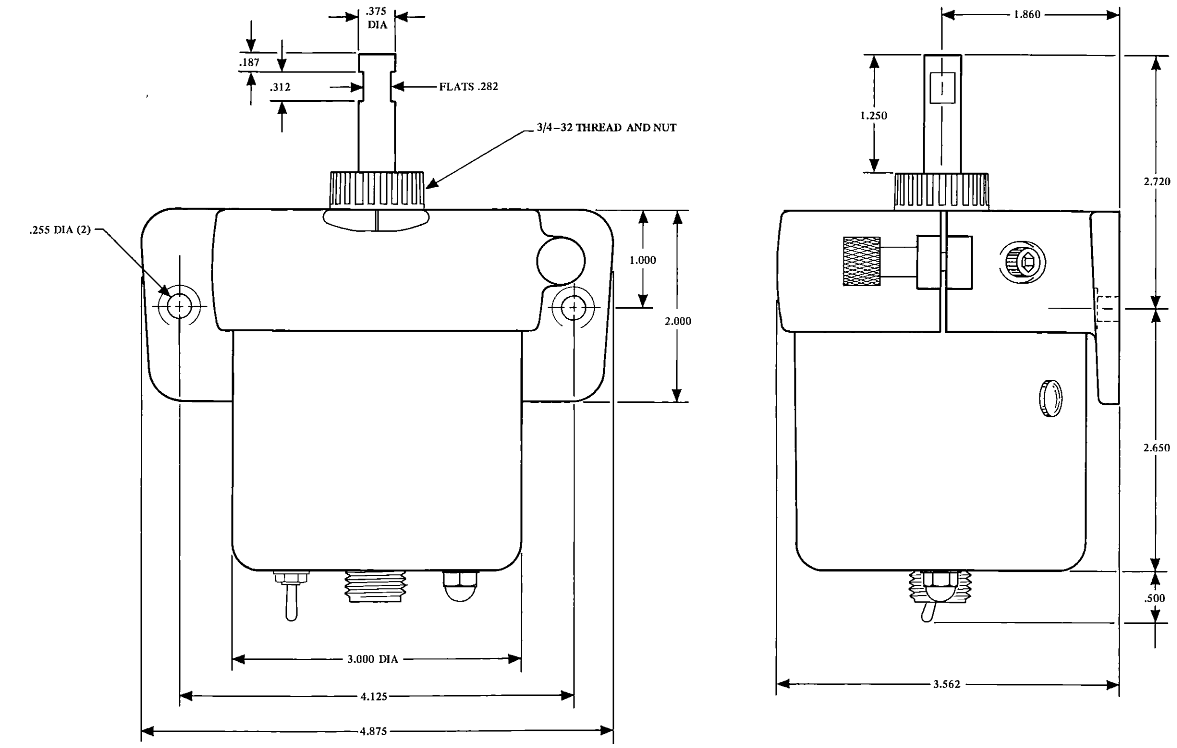
ACCELEROMETER
Part No. 015-0116-00
WEIGHT: 2.4 OZ
CASE: CAST ALUMINUM



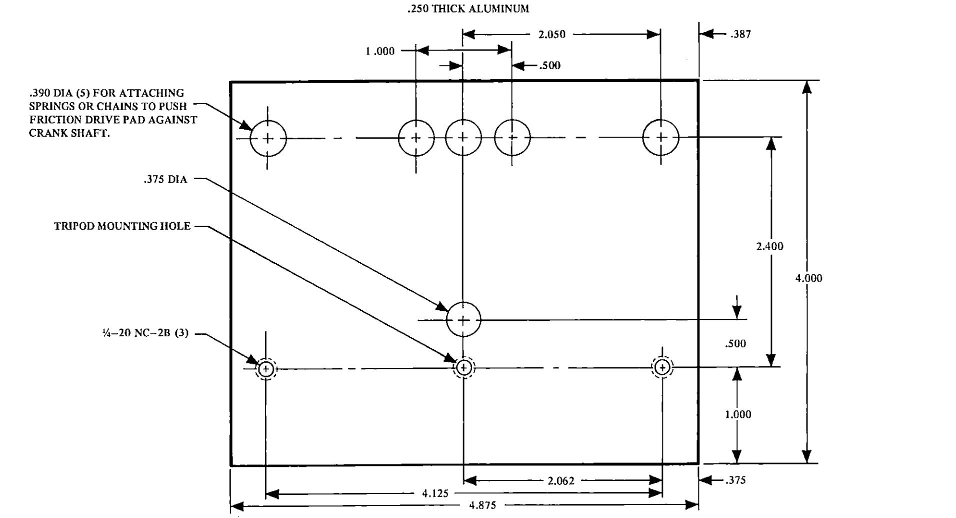
IGNITION PICK OFF CLAMP
Part No. 012-0139-00
MAT: STEEL



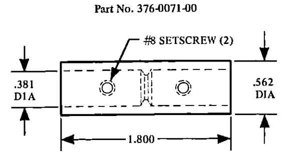
ROTATIONAL FUNCTION GENERATOR
Part No. 015-0108-00
WEIGHT: 21 OZ



TRIFOD ADAPTER PLATE
Part No. 386-1453-00
.250 THICK ALUMINUM

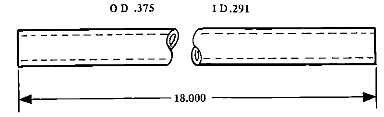


COUPLER
Part No. 376-0071-00

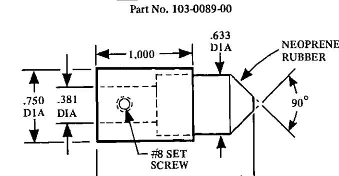


EXTENSION SHAFT KIT
Part No. 015-0124-00

SHAFT
Part No. 384-0437-00
STAINLESS STEEL TUBING
O D .375 I D .291



FRICTION DRIVE PAD
Part No. 103-0089-00



ALL DIMENSIONS ARE NOMINAL

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DIMENSIONAL DATA

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.

ELECTRICAL PARTS LIST CORRECTION

CHANGE TO:

B53	150-0122-00	Incandescent 6 V
B73	150-0122-00	Incandescent 6 V
B93	150-0122-00	Incandescent 6 V

MECHANICAL PARTS LIST CORRECTION

CHANGE TO:

Page 7-19 & 7-20

Fig. 5-	015-0108-01	1	GENERATOR, ROTATIONAL FUNCTION
5-6	331-0216-02	1	SCALE
5-24	352-0143-00	1	HOLDER, phtotransistor

REMOVE:

Fig. 5-15	214-1041-00	3	SPRING, helical compression
5-16	386-1435-00	1	PLATE, bulb contact, outer
5-17	386-1434-00	1	PLATE, bulb contact, tip
5-18	131-0613-00	1	CONTACT, electrical
5-49	210-0046-00	1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
5-50	210-0804-00	1	WASHER, flat, 0.170 ID x 3/8 inch OD

ADD:

	136-0252-04	6	SOCKET, pin
	210-0008-00	1	LOCKWASHER, internal #8
	388-2412-00	1	ETCHED CIRCUIT BOARD

ELECTRICAL PARTS LIST AND SCHEMATIC CORRECTION

ADD:

C492	283-0057-00	0.1 μF	Cer	200 V	+80% -20%