ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

MAINTENANCE MANUAL
VOLUME I
TR-48 ANALOG COMPUTER
MODEL 45.034

Reprinted October 1963

PRINTED IN U.S.A.

NOTICE

In order to enable us to process your requests for spare parts and replacement items quickly and efficiently, we request your conformance with the following procedure:

1. Please specify the type number and serial number of the basic unit as well as the identification of the part when inquiring about replacement items as potentiometer assemblies or cups, relays, transformers, precision resistors, etc.

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MANUAL REVISION NOTICE*

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PAGE	ITEM / PARA	REVISION
12	7b.	Described below is an alternate method of using the 51.114 Service Shelf to test the 6.514 Dual DC Amplifier. The 51.114 Service Shelf may be used for testing or servicing a 6.514 Dual DC Amplifier without having the pre-patch panel in place, avoiding the necessity of removing the amplifier's patch block from the panel. This is accomplished by removing the amplifier module, and the pot set relay (K1) from its socket on the 12.730 Resistor Network Card. Refer to Figure 2.1.1. The computer may be left in the pot set mode (to avoid overloading any of the other amplifiers), and the amplifier under test installed (on the service shelf) in its patch bay position. The amplifier now functions as if in the operate mode, allowing the use of standard input and feedback patching. When testing is completed, be sure to replace the relay before installing the amplifier.

DATE 10/25/63

MANUAL TITLE TR-48 ANALOG COMPUTER MAINTENANCE MANUAL, VOLUME I

REVISION NOTICE NO. 63-16
SH. 1 **OF** 1 **SH.**

*** THIS MANUAL REVISION NOTICE IS ISSUED TO INCORPORATE IMPROVEMENTS OR CHANGES OF ROUTINE OR MINOR NATURE IN THE SUBJECT MANUAL.**

MANUAL REVISION NOTICE*

ELECTRONIC ASSOCIATES INC.
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PAGE	ITEM / PARA	REVISION
		To assure specified performance of the Model 40.404 Comparator, the computer ±15 volt power supply levels must be adjusted to within 0.1 volt of the nominal 15-volt value. This may be readily accomplished by connecting the output of the supply to be adjusted to the top of an attenuator, setting the attenuator dial for a coefficient of 0.667, and monitoring the wiper with the DVM. Set the output level control of the supply for a reading of 10.00 volts at the wiper.

DATE 10 /14/63

MANUAL TITLE TR-48 MAINTENANCE MANUAL

REVISION NOTICE
NO. 63-6
SH. 1 OF 1 SH.

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Does not apply see page 66 Fig. 4.4-1

NOTICE

Figure 4.4-1 PATCH PANEL READOUT MODULE WIRING:

The information shown below replaces the external Scope and Plotter/Recorder information shown on Figure 4.4-1

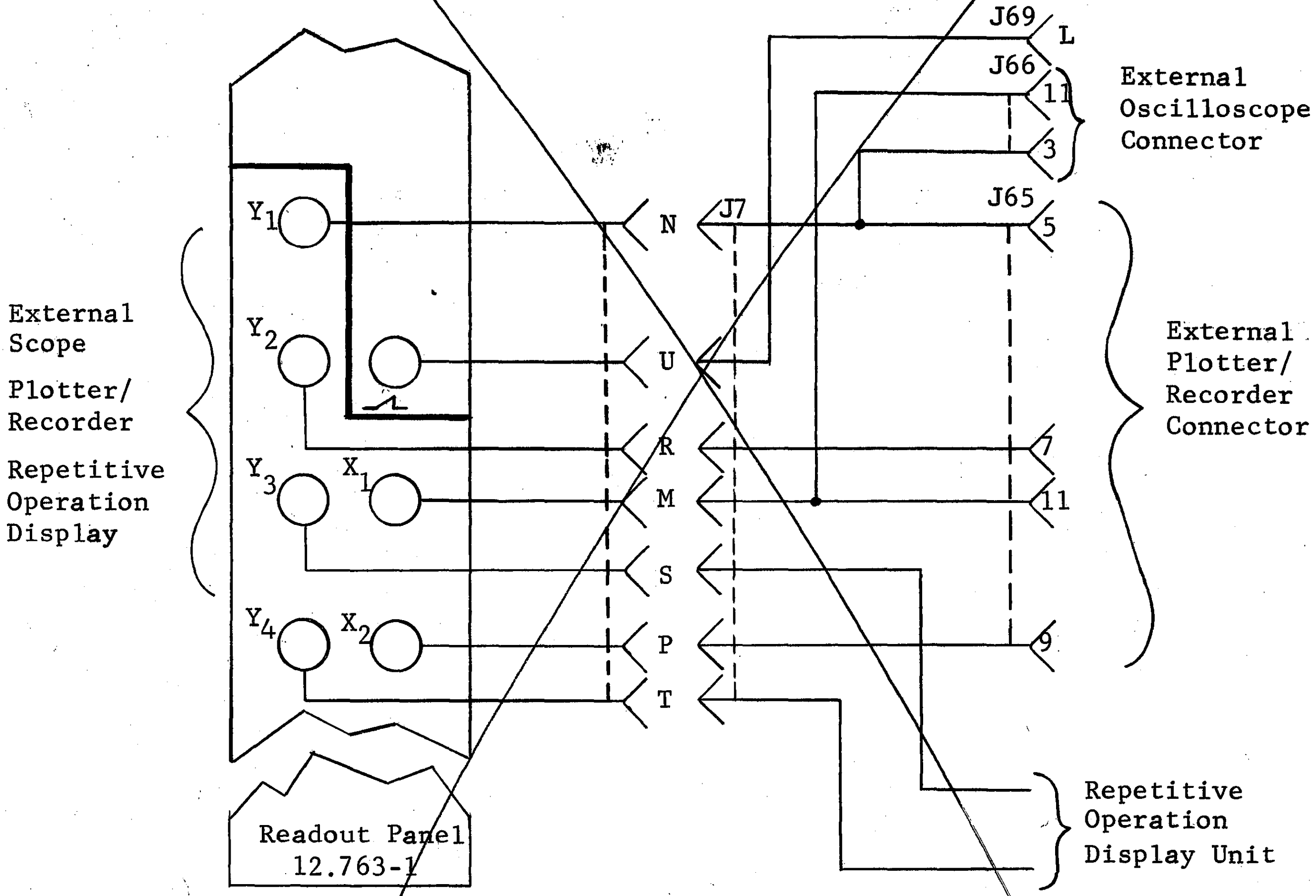


Figure 4.4-1

NOTICE

✓ Page v (List of Contents), Section IV, Paragraph 4	Change title as follows: PATCH PANEL READOUT MODULE 12.763-1
Page 6, Paragraph 5c.	Change first sentence as follows: This connector provides terminations for slaving two or more computers together for common mode-control (except for Pot-Set PS mode) from one computer.
Page 10, Paragraph 5d., SL (Slave) Section	Change description as follows: ... on the slaved computer. The slaved computer then responds to the selected modes (except Pot-Set which can not be slaved) of the master computer.
Page 10, Paragraph 5e., PS (Pot-Set) Section	Change description as follows: (The summing junctions of the integrator networks are connected to ±ground by means of relay contacts.)
Page 64, Section IV, Paragraph 4 - Change paragraph title to:	PATCH PANEL READOUT MODULE 12.763-1
	Add following information to last sentence of second paragraph: ... connected to J65, two Repetitive Operation Display unit inputs (Y_3 and Y_4) and ten trunk ...
Page 12, Paragraph 7b.	Change first sentence as follows: ...TR-48 is a Model 51.114 Service Shelf.

NOTE

SLAVING TR-48 COMPUTERS

1. SLAVING TWO TR-48 COMPUTERS

When slaving two TR-48 computers connect the 19.261 cable between the J61 plug connectors on the rear of each computer (Figure 1.5-1). Determine the computer to be slaved and depress the SL Mode Control button. On the slaved computer reference units (behind Attenuator Panel) remove the patch cord from the INT REF termination and place it in the EXT REF termination (patch cord now between EXT REF and REF IN terminations); this slaves the two computer reference supplies in addition to the computer modes.

2. SLAVE THREE OR MORE TR-48 COMPUTERS

The procedure is similar to the above except the slave cables from J61 of each computer terminate in the 47.040 Junction Box. (See Page 6) As described above, the slaved computer SL Mode Control buttons are depressed and the EXT REF to REF IN connection is made in each of the slaved computers. Note, that the master computer 19.261 slave cable must be terminated in the connector labeled MASTER (Position 1) on the 47.040 Junction Box. The slaved computers' 19.261 cables may be connected to any of the remaining connectors.

10/14/63

NOTICE

Page AI-26 **Add Item 21** **R9 Resistor, Fixed, Composition:**
100 ohms ±10%, 1W; Allen-Bradley GB
(EAI 627 101 1) A Category

NOTICE

1. Prior to setting up any D.F.G. (including the V.D.F.G.), the computer plus and minus reference supplies must be carefully balanced.
2. The D.C. Error Test Setup waveform for the Quarter-Square multiplier shown in Figure 2.3-5b shows the optimum error curve after DFG adjustment. Note, however, that a maximum allowable error deviation from +80 MV to -80 MV still maintains the unit within the allowable accuracy limits.
3. When following the typical VDFG Setup Procedure described on Page 46, the X inputs of +1, +2, +3, etc. should be obtained from the output of an amplifier rather than directly from the wiper of a potentiometer. The amplifier permits the setting of the potentiometer under load in the computer Pot Set mode and provides a constant wiper load (the impedance of the VDFG changes with input magnitude).

ERRATA

Page 14 Paragraph 1a Technical Data, after sub-title Noise and Ripple: add "(peak-to-peak)" and after sub-title Offset Voltage change parenthetical notation to read "(amplifier balanced, R_f = 10K)"

Page 17 Equation 2.1-2 should be $e_o = - \frac{Z_f}{Z_{in}} e_{in}$

last equation on page should be $e_o = - \frac{10K}{100K} e_{in} = - 0.1 \ e_{in}$

Page 33 The second sentence of Paragraph (1)(d) should read "This waveform should not exceed 160 millivolts peak-to-peak."

Figure 2.4-4 Potentiometer #1 (X^2 DFG Test Setup) should be set for 0.050 not 0.500 as indicated.

Page 41 Delete the second, third, and fourth paragraphs under the Paragraph heading "a. Operation Considerations" and replace with the following paragraphs. "Note that the maximum output of the 16.276 Log X Unit occurs when the absolute value of X is 10 volts. The output is therefore 5 Log_{10} 10 10 = 10 volts, plus or minus depending on the generator used. The 1/2 Log X Unit, with an output equal to 1/2 of the Log X generator has a maximum absolute value output of 5 volts.

In Figure 2.5-2, the upper portion illustrates the patching for a plus X input Log DFG and the lower portion shows the patching for a minus X input DFG."

Figure 2.6-2 Title should read Figure 2.6-2 VDFG "MODEL" 16.274 Components.

Figure 3.2-1 -8 volt 1.5 Amp fuse on panel face should be "2 AMP"

Page 49 Paragraph 7b First Paragraph, Third sentence should read "When the computer is switched to the Pot-Set mode relay voltage is applied to P1-R; if K2 is energized, K1 energizes and connects the four grounded to the +10 volt reference bus."

Page 52 Paragraph (c), Last sentence should read "Typical switching time for a normal comparator is 3.5 milliseconds."

Paragraph (e), Last sentence should read "Typical value of 0.5 millivolts."

ERRATA cont'd

Page 56 and Figure 3.3-2	Paragraph 3a Change the designation of the cabinet connectors for Reference Amplifier and Reference Regulator to J67 and J68 respectively. Also, on Figure 3.3-2, Pin T of J68 (J69 on drawing) is wired to J61-1 for reference slaving.
Page 62	Paragraph 3a Change designation of cabinet connector for Rep Op Timing Unit to J69.

NOTICE

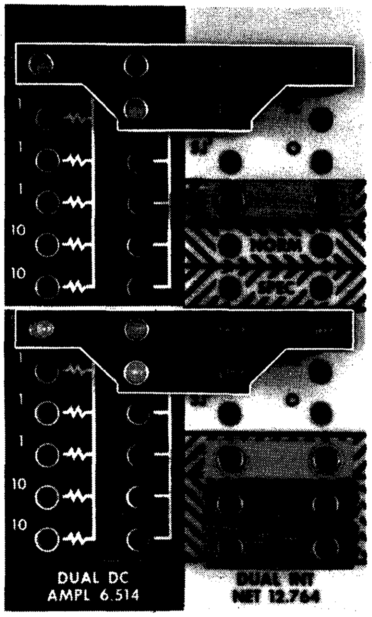
In later models of the TR-48 Computer, the Variable DFG's, Models 16.154 and 16.156, have been moved from the left-hand to the right-hand side of the TR-48 rack. To accommodate this change, the DFG's have been inverted to allow access to the variable-resistor screwdriver adjustments. The 16.154-2 and 16.156-2 variations incorporate this change and are identical with the 16.154-1 and 16.156-1 variations respectively, except for the use of a new card to permit wiring to the rear connector and the use of a different cover and connector block. Note that Figure 2.6-1 shows the VDFG's mounted on the left-hand side of the TR-48 rack. The relative position and the numerical sequence of the VDFG's in relation to the pre-patch panel is shown in Figure 1.

	+	−	+	−	+	−	+	−	+	−
Pre-Patch Panel Side	VDFG	VDFG	VDFG	VDFG	VDFG	VDFG	VDFG	VDFG	VDFG	VDFG
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

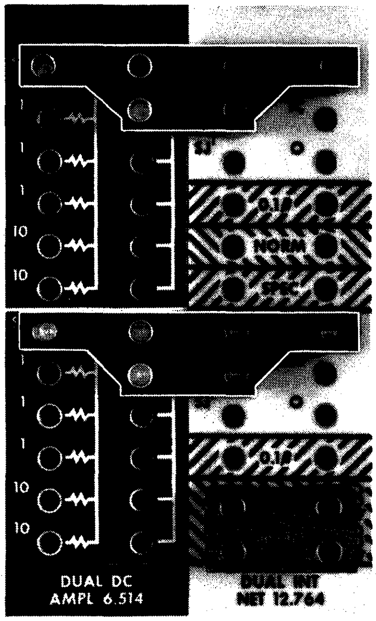
Figure 1. VDFG Location

SUMMARY OF PATCHING FOR TR-48 INTEGRATORS

1. NON-REPETITIVE OPERATION

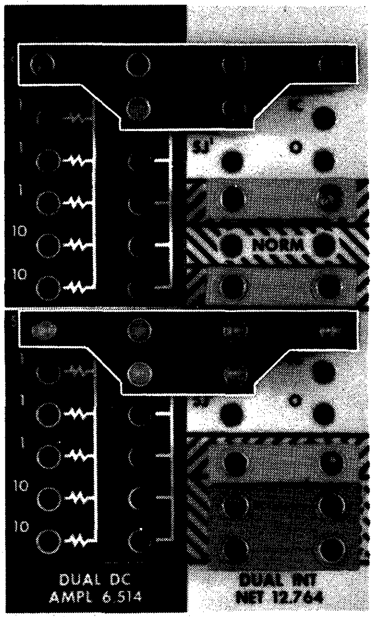


Time Scale: Normal
Feedback Capacitor = 10 MFD

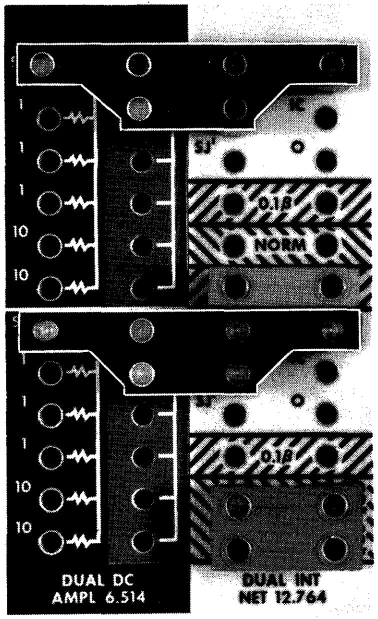


Time Scale: 0.1β
Feedback Capacitor = 1 MFD

2. REPETITIVE OPERATION



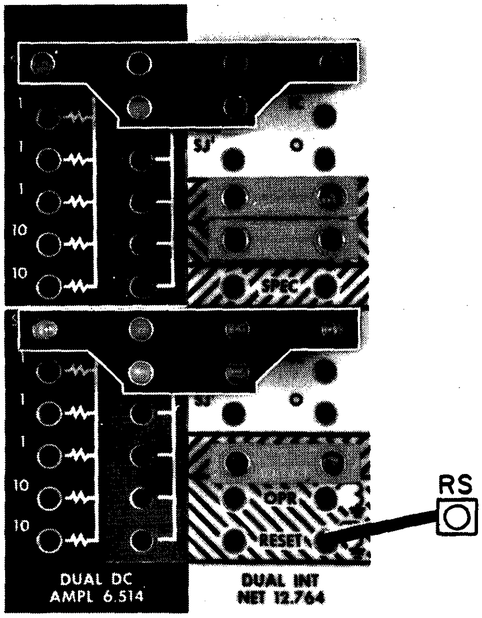
Rep Op Time Scale: Normal
Feedback Capacitor = 0.02 MFD



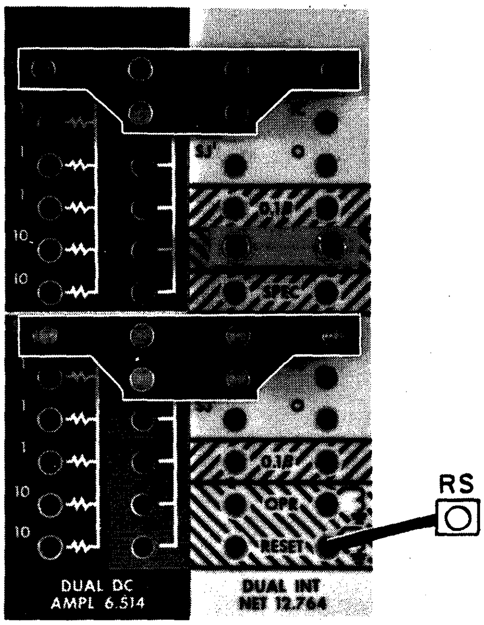
Rep Op Time Scale: 0.1β
Feedback Capacitor = 0.002 MFD

3. SPECIAL OPERATION

a. Patching for an integrator that stays in the operate mode while other integrators are in Repetitive Operation:



Time Scale: Normal
Feedback Capacitor = 10 MFD



Time Scale: 0.1β
Feedback Capacitor = 1 MFD

Patch the reset relay termination to the RS termination on the Readout Panel 12.763. The integrator is in the operate mode as long as the computer is in repetitive operation. The integrator is placed in the reset mode by placing the computer in the reset mode.

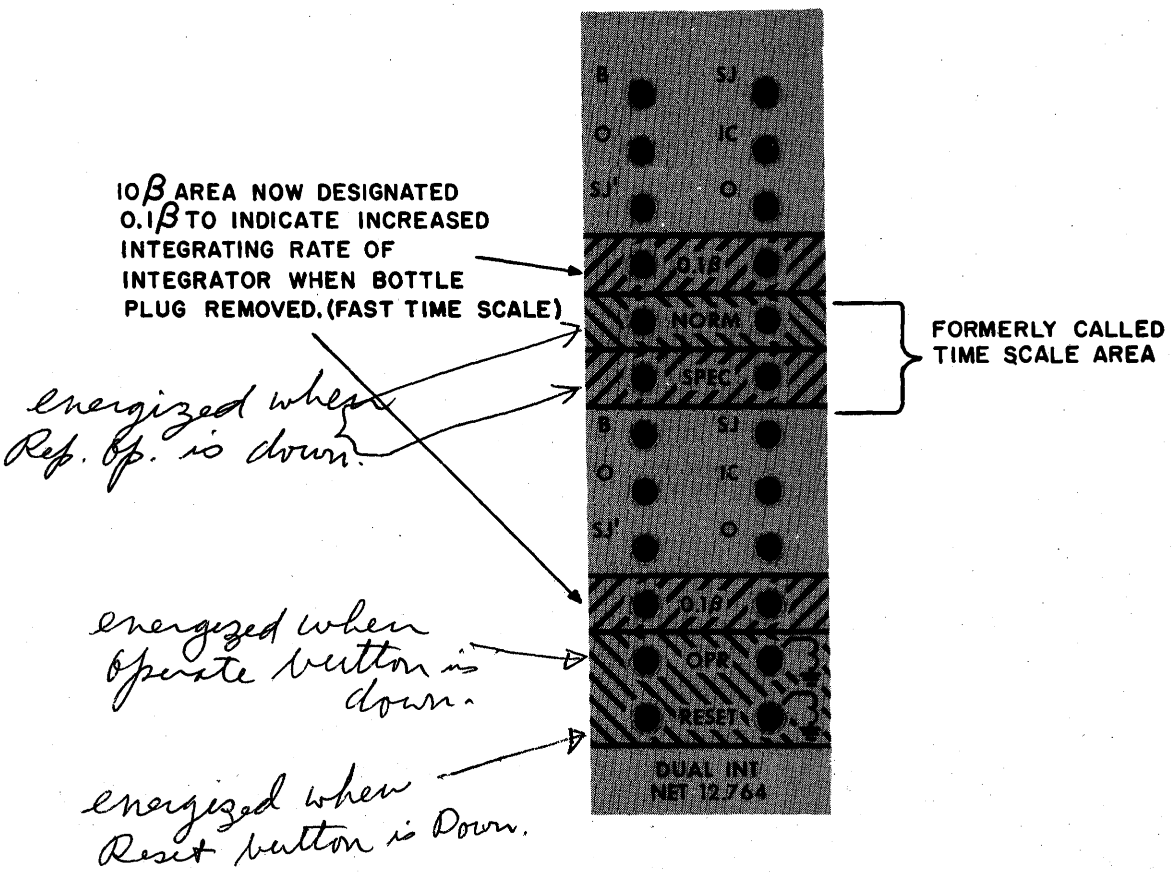
b. Patching for an integrator that is in the reset mode when the computer is in the operate mode and when the computer is in reset, the integrator is in operate:

1. Cross patch the OPR-RESET terminations.
2. All other patching is as shown under NON-REPETITIVE and REPETITIVE OPERATION.

NOTE

Integrator Patching Block Change

The Dual Integrator Network 12.764 patching block configuration has been modified to further simplify the TR-48 Integrator patching. The old time scale area (TS) of the patching block (**see below**) has been sub-divided into two areas designated NORM and SPEC. For normal repetitive operation a two connector bottle plug is placed in the SPEC area; the word NORM remains exposed thus indicating normal operation. Placing a two connector bottle plug in the NORM area, exposing SPEC (indicating special), the integrator is placed in the operate mode when the Rep-Op button is depressed and remains in that mode until the computer mode is changed.



10β AREA NOW DESIGNATED 0.1β TO INDICATE INCREASED INTEGRATING RATE OF INTEGRATOR WHEN BOTTLE PLUG REMOVED. (FAST TIME SCALE)

FORMERLY CALLED TIME SCALE AREA

energized when Rep. Op. is down.

energized when Operate button is down.

energized when Reset button is Down.

NOTICE

Page 30	Restriction (2) for division should read: "The divisor must be positive."
Page 34	The second sentence of the first footnote (*) should read: "As an example---card 1 conducts; if both are negative only card 3 conducts."
Figure 2.3-7 d and e.	The connections from the output of the amplifier (connected to the TDVM) to termination B should go from the output of the amplifier to termination +U.
Figure 3.2-1	Regulated Power Supply 10.203. Change the -8V Fuse rating shown on the front panel to read 3 AMPS.
Page 56, Paragraph 2.	a. Change the Max Load Current for the -8V dc supply to read 3.0 AMPS.
Page AI-15	Add following description: Resistor, Fixed, Wirewound: 1 ohm ±10%, 2W; International Resistance Co. Type BW-2 (EAI 636 127 0).
Page AI-22	Item 3, delete Ref. Desig. R5 and R42. Add new description for R5 and R42 as follows: Resistor, Variable, Wirewound: 1K ohms ±20%; CTC Type 115 (EAI A642 569 0).
Page AI-23	Item 17, change description of R19, R22 as follows: Resistor, Variable, Wirewound: 100 ohms ±20%, CTC Type 115 (EAI A642 577 0).
Page AI-24	Item 24, Item 3, delete Ref. Desig. R5 and R42. Add new description for R5 and R42 as follows: Resistor, Variable, Wirewound: 2K ohms ±20%; CTC Type 115 (EAI A642 580 0).
Page AI-25	Item 17, change description of R19, R22 as follows: Resistor, Variable, Wirewound: 500 ohms ±20%; CTC Type 115 (EAI 642 579 0).
Page AI-29	Item 5, change description of DS1 as follows: Lamp, Incandescent: Hudson Lamp Co. 2307 (EAI A578 047 1).
Page AI-32	Change descriptions of Items 6 and 7 as follows: Item 6 R1. Resistor, Fixed, Wirewound, Precision: 82,000 ohms ±1%; Resistance Products Co. PB Type (EAI A638 541 0). Item 7 R2. Resistor, Fixed, Wirewound, Precision: 100,000 ohms ±1%; Resistance Products Co. PB Type (EAI A638 483 3).

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ILLUSTRATIONS (Cont)

ILLUSTRATIONS (Cont)

INTRODUCTION

TR-48 Manuals

Operation, programming instructions, and maintenance data for the TR-48 Analog Computer, designed and manufactured by EAI, are contained in two separate publications provided with each computer. This handbook is intended to serve as a maintenance manual for the instrument, and is arranged in accordance with that use. The manual includes technical and physical descriptions of the computer and its plug-in components, circuit theory and analysis of all components, and recommended test and adjustment procedures. In addition, this handbook contains parts lists and schematic and wiring diagrams for the TR-48. Sufficient operational data and patching instructions are given to permit the maintenance technician to set up and operate the instrument in accordance with the recommended test and adjustment procedures. Complete operating, patching, and programming instructions, in addition to fundamental analog applications, are contained in a separate Operator's Manual. (The Operator's Manual is also useful as an introduction to analog computation and simulation.)

The maintenance handbook is divided into four SECTIONS as follows:

SECTION I	Contains the technical and physical description of the computer and plug-in components, describes installation and preliminary check procedures, lists and describes all operational controls and indicators, and outlines (in general terms) maintenance data, required test equipment, and a maintenance program for the TR-48.
SECTION II	Covers all computing components and accessories. For each component this section describes operational specifications, patching and setup instructions, circuit analysis, and a test and adjustment procedure designed to quickly verify component performance.
SECTIONS III and IV	Provide generally the same data as above for POWER AND REFERENCE circuits, and the CONTROL AND MONITORING circuits, respectively.

The TR-48 replaceable parts lists are contained in Appendix I bound in the rear of this handbook. Electrical drawings are contained in Volume II.

SECTION I

TR-48 ANALOG COMPUTER

1. GENERAL DESCRIPTION

The PACE® TR-48 (Figure 1.1-1) is a solid-state, general-purpose, analog computer housed in a single cabinet suitable for installation on a laboratory cart or tabletop. The cabinet is composed of three sections, and houses all computing components, power supplies, and control and monitoring circuits necessary for relatively large-scale problem solving capabilities.

The TR-48 contains space for 48 operational amplifiers (24 dual units), 60 manually operated, coefficient-setting attenuators, and non-linear components such as diode function generators and electronic multipliers. (See Paragraph 3 of this section for a complete component list.)

Computing components in the TR-48 are housed in the center section of the cabinet. (The component front panels form the computer patch bay.) Each TR-48 is factory-wired to accept the full complement of computing components. Thus expansion to a larger system simply involves plugging in additional components into the center area.

The left-hand section of the computer contains the control and monitoring circuits of the TR-48. These include a 4-place electronic digital voltmeter, a multi-range voltmeter, and push-button selection systems for readout and computer mode control.

The right-hand panel of the TR-48 contains the coefficient-setting attenuators, and function switches. Behind this panel are mounted the computer reference voltage components, and operational power supplies.

The component front panels are normally covered by the pre-patch panel, a 1350-hole board that permits <u>pre-patching</u> to be performed away from the computer. The patch bay and associated pre-patch board provide a central terminal point to permit connecting the TR-48 computing components into any desired configuration.

The rear panel of the computer contains connectors for remote control, recorder terminations, slaved operation, and AC power input.

2. TECHNICAL AND PHYSICAL DATA

Computer Type	D-C Analog
Number of Components	Cabinet contains 60 wired cradles (See SECTION I, Paragraph 3)
System Reference	±10 volts (internally generated)
Primary Power Requirements	115 or 230 volts, 50 to 60 cycles. Fully expanded computer requires 150 watts.

Operational Voltage Levels (Internally Generated)

Computing Components	Digital Voltmeter	Relays
±15V d-c	±15V d-c	—
+30V d-c	+30V d-c	—
—	+2V d-c	—
—	-8V d-c	—
6.3V a-c	6.3V a-c	—
—	—	20V d-c (nominal value)

Computer Physical Dimensions

Width......................	46-1/2 inches
Height.....................	24 inches
Depth......................	20 inches
Weight (Fully Expanded).....	320 pounds

3. EQUIPMENT COMPLEMENT

As previously indicated, each TR-48 Computer is factory-wired for a full complement of computing components. With this arrangement, expansion to a larger system can be accomplished by plugging in additional components.

Figure 1.3-1 illustrates the computer component cradles and those components that each cradle is wired to accept. It should be noted that this illustration shows the standard arrangement for the TR-48. In accordance with individual system requirements, the cabinet may be wired for other component arrangements. In these cases, a supplemental layout wiring diagram is provided with the computer to indicate the particular cradle configuration.

For a complete list of TR-48 components, refer to Table 1.3-1 and Figure 1.3-1.

TR 48
45

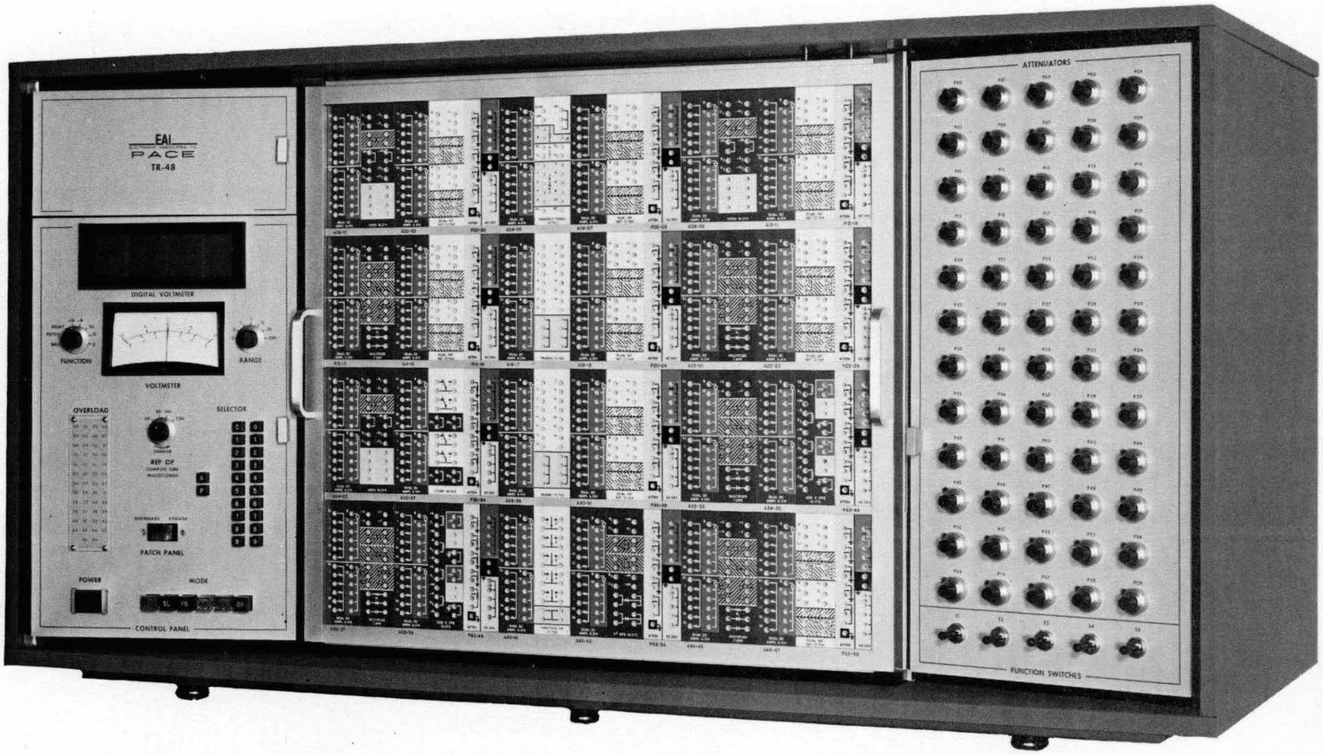
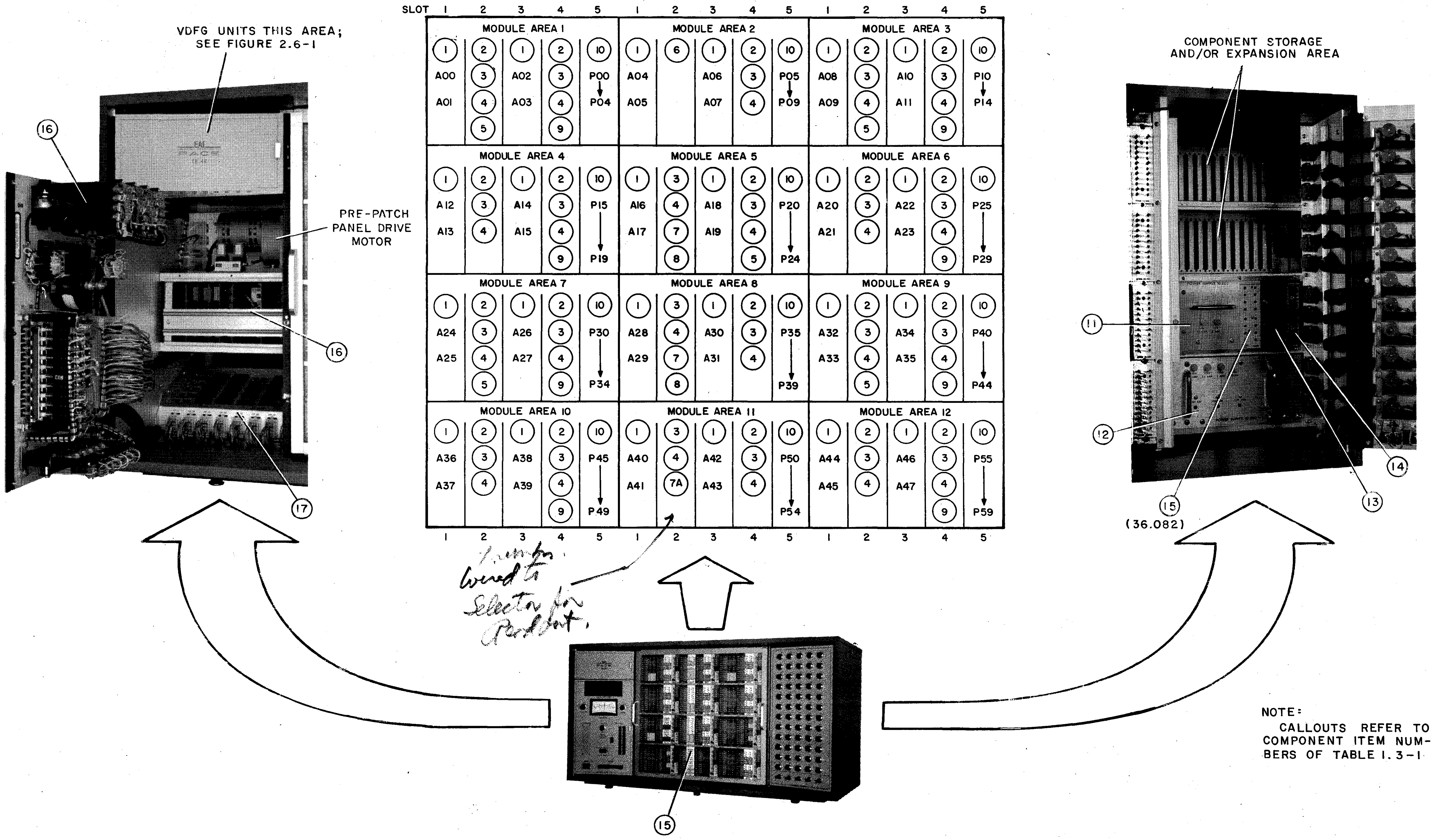


FIGURE 1.1-1 TYPICAL TR-48, FRONT VIEW

A 4711

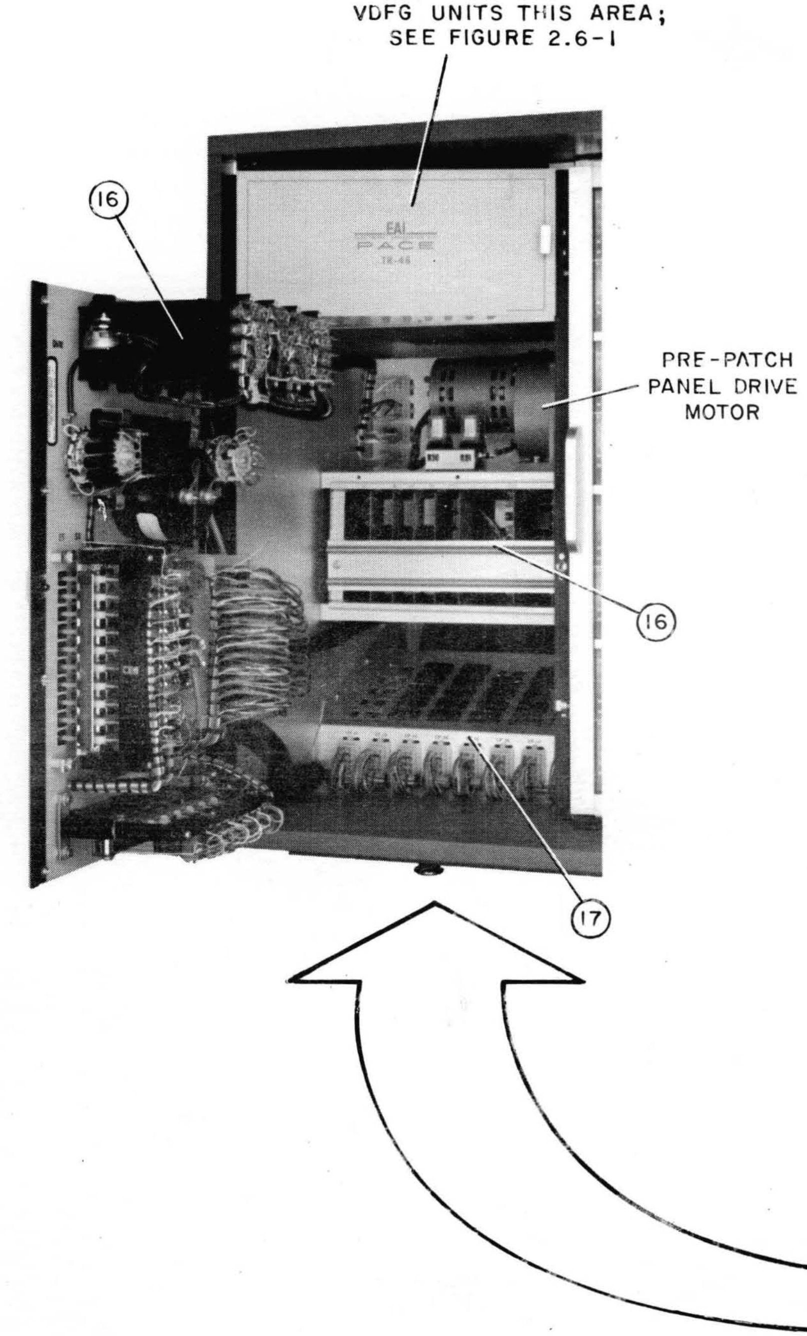


SLOT	1	2	3	4	5
MODULE AREA 1	① A00 A01	② ③ ④ ⑤	① A02 A03	② ③ ④ ⑨	⑩ P00 ↓ P04
MODULE AREA 2	① A04 A05	⑥	① A06 A07	② ③ ④	⑩ P05 ↓ P09
MODULE AREA 3	① A08 A09	② ③ ④ ⑤	① A10 A11	② ③ ④ ⑨	⑩ P10 ↓ P14
MODULE AREA 4	① A12 A13	② ③ ④	① A14 A15	② ③ ④ ⑨	⑩ P15 ↓ P19
MODULE AREA 5	① A16 A17	③ ④ ⑦ ⑧	① A18 A19	② ③ ④ ⑤	⑩ P20 ↓ P24
MODULE AREA 6	① A20 A21	② ③ ④	① A22 A23	② ③ ④ ⑨	⑩ P25 ↓ P29
MODULE AREA 7	① A24 A25	② ③ ④ ⑤	① A26 A27	② ③ ④ ⑨	⑩ P30 ↓ P34
MODULE AREA 8	① A28 A29	③ ④ ⑦ ⑧	① A30 A31	② ③ ④	⑩ P35 ↓ P39
MODULE AREA 9	① A32 A33	② ③ ④ ⑤	① A34 A35	② ③ ④ ⑨	⑩ P40 ↓ P44
MODULE AREA 10	① A36 A37	② ③ ④	① A38 A39	② ③ ④ ⑨	⑩ P45 ↓ P49
MODULE AREA 11	① A40 A41	③ ④ (7A)	① A42 A43	② ③ ④	⑩ P50 ↓ P54
MODULE AREA 12	① A44 A45	② ③ ④	① A46 A47	② ③ ④ ⑨	⑩ P55 ↓ P59

Limiters wired to Selector for Readout.

NOTE:
CALLOUTS REFER TO COMPONENT ITEM NUMBERS OF TABLE 1.3-1

FIGURE 1.3-1
TR-48 COMPUTER (PANELS AND COVERS OPEN TO SHOW COMPONENT LOCATIONS)



SLOT 1	2	3	4	5	1	2
MODULE AREA 1					MODU	
① A00 A01	② ③ ④ ⑤	① A02 A03	② ③ ④ ⑨	⑩ P00 ↓ P04	① A04 A05	⑥
MODULE AREA 4					MODU	
① A12 A13	② ③ ④	① A14 A15	② ③ ④ ⑨	⑩ P15 ↓ P19	① A16 A17	③ ④ ⑦ ⑧
MODULE AREA 7					MODU	
① A24 A25	② ③ ④ ⑤	① A26 A27	② ③ ④ ⑨	⑩ P30 ↓ P34	① A28 A29	③ ④ ⑦ ⑧
MODULE AREA 10					MODU	
① A36 A37	② ③ ④	① A38 A39	② ③ ④ ⑨	⑩ P45 ↓ P49	① A40 A41	③ ④ (7A)
1	2	3	4	5	1	2

Trunks.
Wired to
Selector for
Readout.

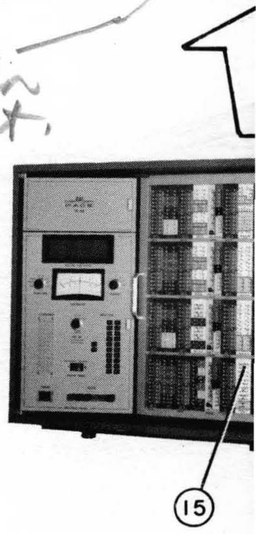


TABLE 1.3-1

Component	Model No.
TR-48 COMPUTING COMPONENTS	
1. Dual D-C Amplifier	6.514
2. Dual Integrator Network	12.764
3. Quarter-Square Multiplier (Standard) or Quarter-Square Multiplier (High Accuracy)	7.099 7.096
4. X^2 Diode Function Generator, Log X Diode Function Generator, or 1/2 Log X Diode Function Generator	16.275 16.276 16.281
5. Variable Diode Function Generator	16.274
6. Readout Patching Module	12.763
7. Trunk Patching Module (7A In Trunks)	12.762
8. Function Switch Group	12.766
9. Signal Comparator	40.404
10. Coefficient Setting Attenuator Group	42.283
TR-48 POWER AND REFERENCE SUPPLIES	
11. TDVM Power Supply	10.203
12. Regulated Power Supply	10.200
13. Reference Regulator	43.104
14. Dual D-C Amplifier	6.282
TR-48 CONTROL AND MONITORING COMPONENTS	
15. Repetitive Operation Group	2.424
16. Digital Voltmeter (TDVM)	26.183
17. Relay Panel	11.148
18. Null Potentiometer*	20.285
TR-48 OPERATING AND MAINTENANCE ACCESSORIES	
19. Pre-Patch Panel	5.183
20. Patching Kit (Bottle Plugs, and Patch Cords)	5.171
21. Service Shelf	51.114
22. A.C. Power Cable	510.040

*Used only when computer has no Digital Voltmeter (TR-48-0)

4. INSTALLATION AND PRELIMINARY CHECKS

The TR-48 Computer is completely solid-state; thus, it requires very little primary power and no cooling other than that provided by normal working environments. The computer may be operated in any area that is not subjected to excessive dust or dirt or temperature extremes, and is relatively free from vibration.

After the computer is unpacked from its shipping container, a visual inspection should be made to ensure that no damage has occurred during shipment. Check all plug-in components for proper seating.

The computer is designed for operation from a 50 to 60 cycle a-c supply. The a-c circuits are factory-wired for 115 volt or 230 volt operation as specified in the purchase order for the computer. (Figure 1.4-1 and Drawing C002 476 0A contain wiring requirements for operating from the 230 volt power source.) A 3-wire power cable is furnished with the TR-48 for connecting a-c power to AC1 (the lowest connector on the plug mounting-plate on the rear of the computer). The other end of the a-c power cable is terminated in a 3-prong plug for connection to a standard grounded and polarized receptacle. If the primary power line to which the computer is to be connected is not equipped with a three-terminal receptacle, a three-pole adapter must be used. In this case two precautions must be observed: (1) The power cable must be connected so that the neutral side of the a-c line is connected to the a-c common side of the primary power wiring in the computer; and (2) The ground wire on the adaptor must be connected to an earth ground. Failure to connect the a-c circuits in this manner will result in a safety hazard if the hot side of the computer primary power circuits should ever be inadvertently shorted to the computer cabinet. Also, the d-c amplifiers will have an excessively high noise level if the computer frame is not grounded.

After power is connected, the computer should be turned on, switched to the pot set mode (see SECTION I, Paragraph 6 for description of controls), and allowed to warm up for 15 minutes or so.

It should be noted that each TR-48 is completely checked and adjusted prior to shipment, and the computer should be ready for operation upon receipt. However, it is suggested that certain initial checks be performed when the computer is received; these checks should be performed periodically thereafter (once a week or so, depending on use) as a form of routine maintenance.

When the computer is first turned on and warmed up, all amplifiers should balance with the mode selector in PS (pot set). This balance condition is indicated by the fact that no overload lamps are lit. The power supply outputs should then be checked and levels adjusted if required. The computer voltmeter may be used for this purpose. Next the digital voltmeter should be zero-set (refer to the TDVM manual for adjustment procedures for this instrument). At this point the TR-48 is ready for normal operation as outlined in the following text. (SECTION I, Paragraph 6.)

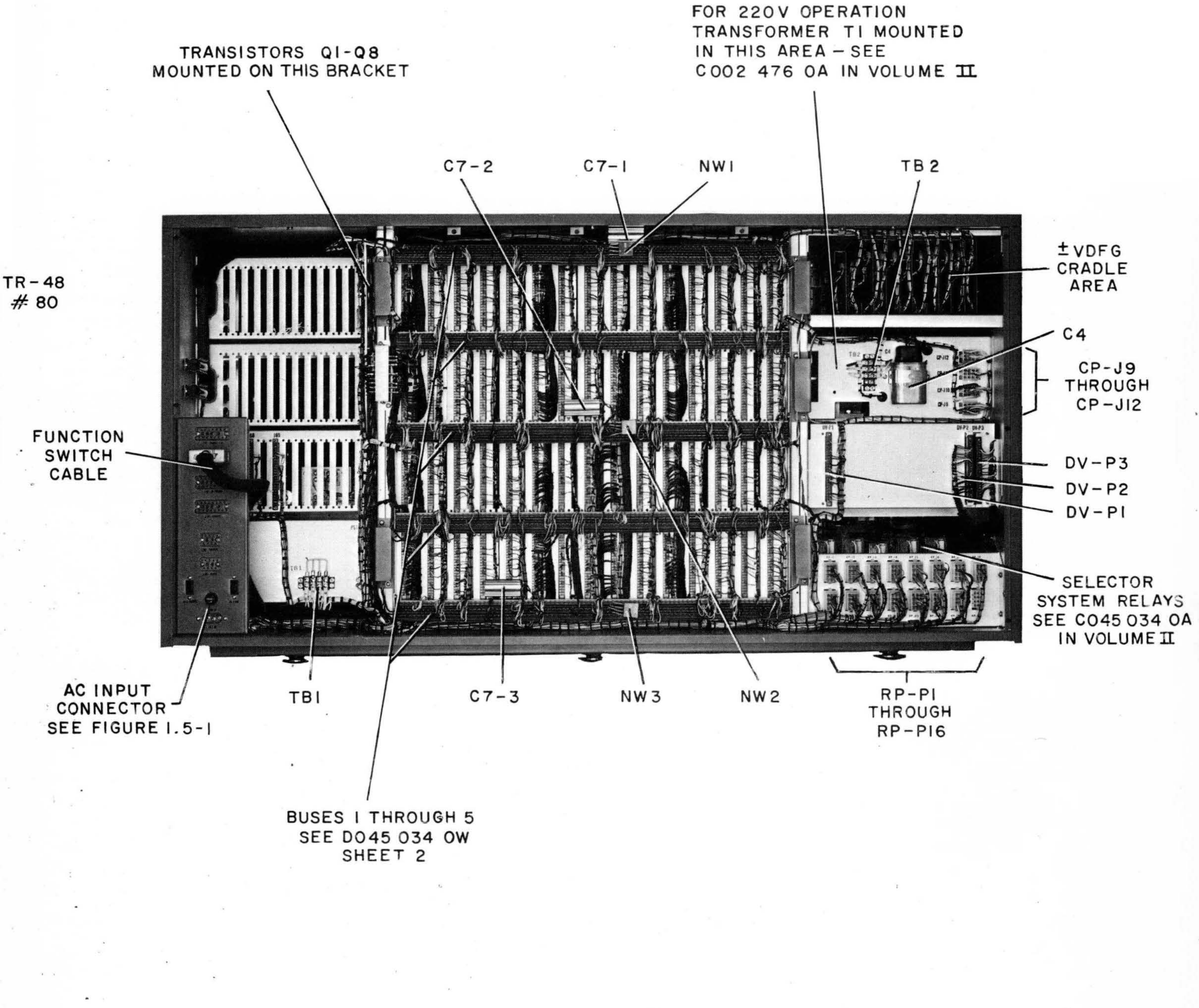


FIGURE 1.4-1. TR-48 REAR VIEW, COVER PLATES REMOVED

5. EXTERNAL CONNECTIONS

a. General

All external equipment terminations and wiring required for operation of the TR-48 is brought into the computer cabinet through a group of connectors mounted on a plate on the rear of the cabinet. Included here are connectors for primary a-c power, external trunks, slaved operation (for common mode-control between two or more computers), and facilities for connecting external monitoring equipment such as oscilloscopes, plotters, and recorders to the TR-48.

Figure 1.5-1 shows the location and function of each connector, and the following sub-paragraphs describe the connector wiring and terminations within the computer.

b. A.C. Connectors (AC1, AC2, AC3)

AC1 is the primary power input connector for the TR-48. This is a 3-terminal connector that mates with EAI Power Cable 510.040-1 to provide one hot lead, one neutral lead, and one ground lead. Refer to Paragraph 1-4 for details on connecting the computer to a primary power source.

AC2 and AC3 are convenience outlets for powering maintenance equipment such as an oscilloscope or VTVM. Both connectors are protected by F60 (1.5 amperes), the primary power fuse. AC2 is unswitched and is thus energized whenever the computer is connected to the power line. AC3 is controlled through the primary power switch on the computer control panel.

c. Slave and Trunk Connector (J61)

x Revision except for Pot set mode.

This connector provides terminations for slaving two or more computers together for common mode-control from one computer. Cable 19.261 is provided to connect the computers together for slaved operation. If two computers are to be slaved, the 19.261 cable should be installed between the J61 connectors on each TR-48. If more than two computers are to be slaved, a Model 47.040 Junction box is supplied and the 19.261 cable from each computer is connected to the junction box, which simply parallels the mode control lines of all computers.

from one Computer.

When desiring to operate previously slaved computers separately, the slave cable(s) must be removed.

In addition to the slave circuits, the J61 connector carries the ten trunks that appear on the 12.763 Patch Panel Readout Module. Refer to Sheet 41 of the computer Wiring Diagram (B045 034 OW) for details on specific connections terminated at J61.

d. Trunk-Function Switch Connectors (J62, J63, and J64)

This group of connectors is wired to the three component cradles that accept a trunk or function switch module. (See Figure 1.3-1.) The wiring is arranged such that J62 is wired to module 5, slot 2 (cradle 22), J63 to module 8, slot 2 (cradle 37), and J64 to module 11, slot 2 (cradle 52). EAI Cable 19.262 is designed for

Picture back 3 pages.

use with these connectors.

The function switches are located on the attenuator panel; the wiring from these switches terminates in a plug connector. By mating this plug with J62 or J63 the function switches are connected to the associated module slot (J62 connects the function switches to module 5, slot 2 and J63 to module 11, slot 2). The Function Switch 12.766 Unit inserted in either of the two slots provides the patching terminations at the Pre-Patch Panel.

Certain leads connected to J64 are also routed to the control panel to permit readout via the selector system. Selector addresses A50 through A64 select these leads. Figure 1.5-2 shows the trunk patching block and the corresponding address for each trunk in this area. The trunks in this area are normally used as <u>in-trunks</u>; this permits the operator to readout and check the incoming signal levels.

For complete details on the wiring to connectors J62, J63, and J64, see Sheets 41 and 42 of B045 034 OW.

e. Recorder/Plotter Connector (J65)

This connector is wired to the Readout Module 12.763 area (Module 2, slot 2) to make the input circuits of an external recorder or plotter accessible at the Pre-Patch Panel. Cable 19.323 is provided for connecting the EAI Series 1110 VARIPLOTTER® to the TR-48 readout module. See Pg. 64 for Readout Panel.

In addition to the four signal terminations (X_1, X_2, Y_1, Y_2), J65 also includes three leads for control of the plotter pen-lift circuit. This wiring is compatible with the control circuits of the 1110 Series of VARIPLOTTERS, and is arranged so that the pen circuits are energized only when the computer is in the <u>operate</u> mode. All connections to J65 are listed on Sheet 43 of B045 034 OW; the pen control circuits are shown on Drawing D045 034 OS (Sheet 2).

f. Oscilloscope Connector (J66)

This connector provides inputs for an external oscilloscope to be terminated at the Patch Panel Readout Module. Cable 19.322 provides the signal leads between the oscilloscope and the computer. Sheet 43 of B045 034 OW lists the connections to J66.

6. OPERATION

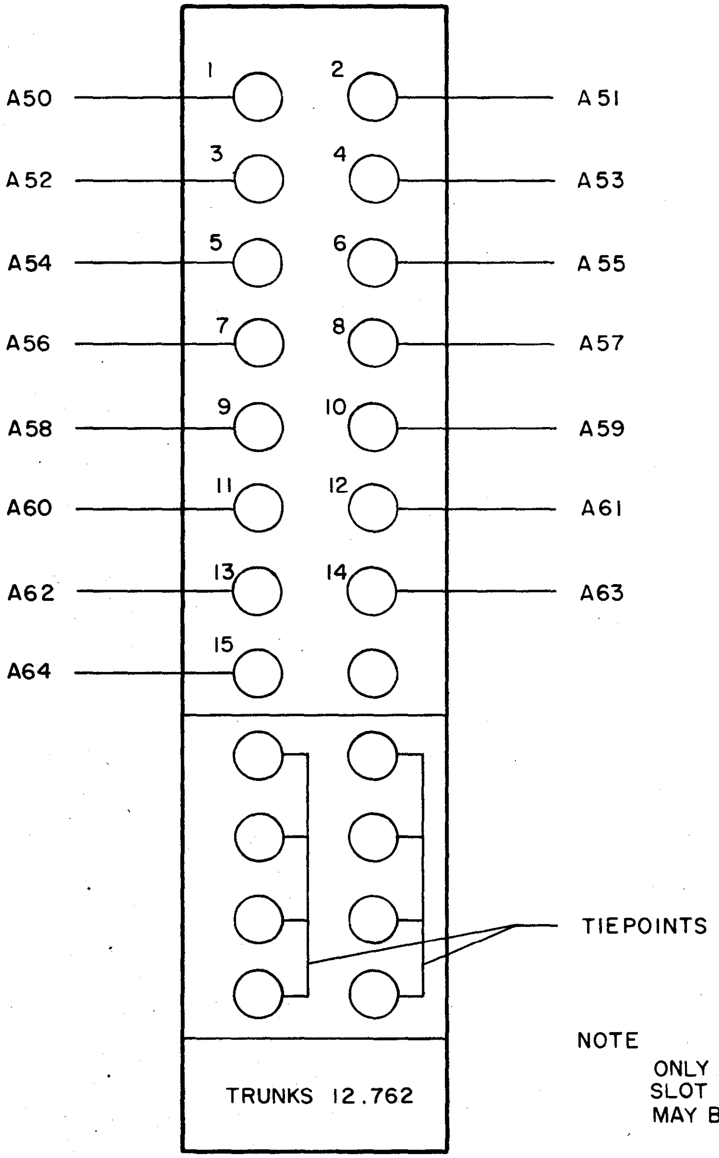
A detailed description of the operating procedures (including problem programming) for the TR-48 is given in the Operator's Handbook. This paragraph therefore, is limited to a brief description of the TR-48 operating controls.

All of the computer operating controls are located on the left-hand control panel of the insturment (Figure 1.6-1).

TR48
#68

FIGURE 1.5-1 PLUG PLATE, REAR TR-48

A4712



NOTE
ONLY TRUNK UNIT IN MODULE 11
SLOT 2 OF PRE-PATCH PANEL
MAY BE READ OUT

FIGURE 1.5-2 READOUT ADDRESS FOR 12.762 TRUNK MODULE

TR 48
48

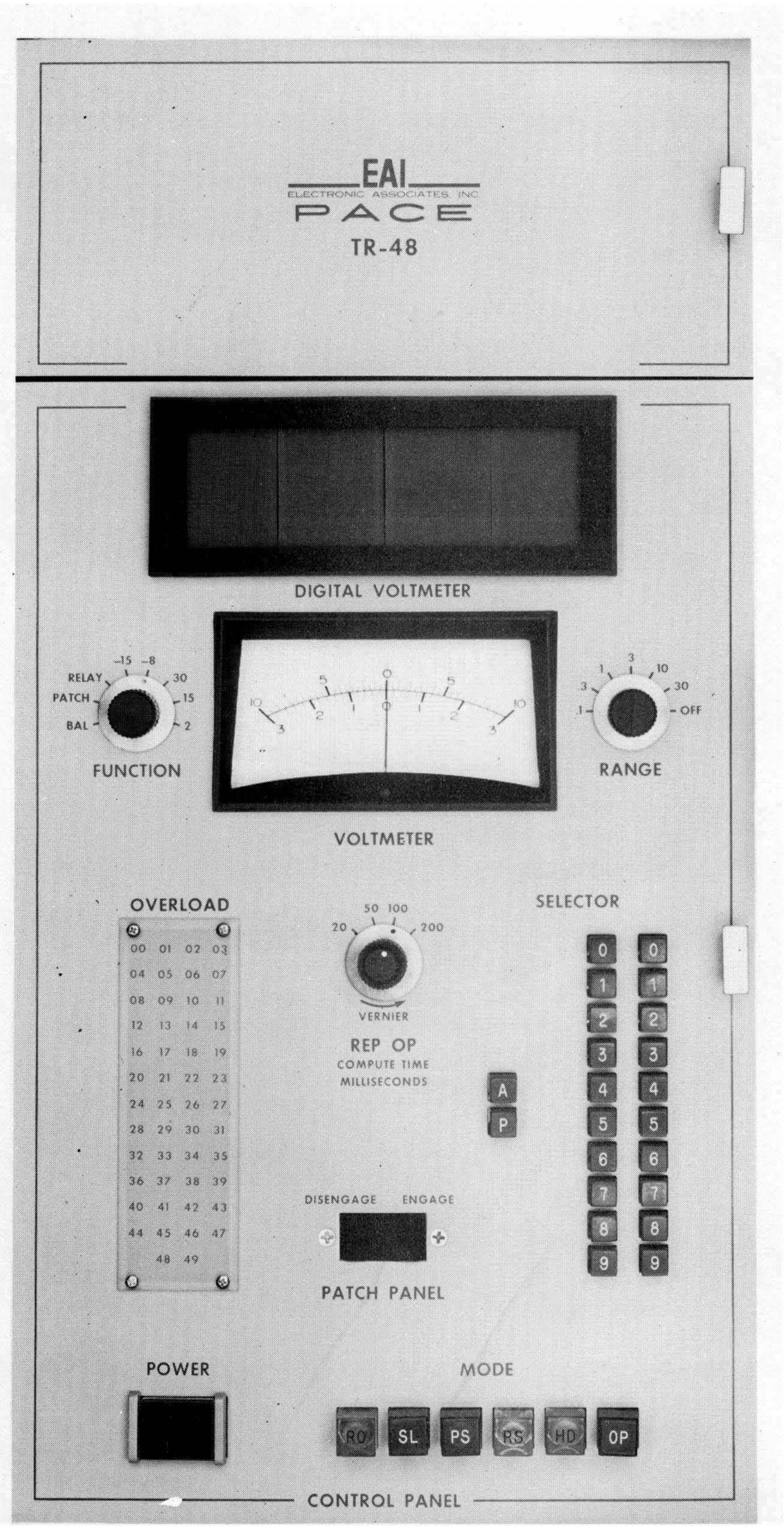


FIGURE 1.6-1 TR-48 CONTROL PANEL

A 4697

a. POWER Switch

This switch controls the application of primary power to the TR-48. It is a push-button switch that is depressed to turn the unit on and again depressed to turn the unit off. When power is applied to the TR-48 the switch face is illuminated.

b. Multi-range Voltmeter Controls

The following is a list of the voltmeter FUNCTION switch positions with a brief description of each.

Position	Description
BAL	The stabilizer output of the amplifier addressed by the Selector System is applied to the voltmeter to facilitate checking and/or adjusting the amplifier balance. (The meter RANGE switch may by at any position except OFF when monitoring stabilizer outputs.)
PATCH	Connects the meter, via the RANGE switch, to the VM Pre-Patch Panel termination (on 12.763 Readout Patch-Block).
RELAY	Connects meter to the relay power supply (nominally -20 volts).
-15, -8, 30 15, and 2	Connects meter to output of corresponding power supply; the proper scaling resistor is automatically selected.

The RANGE switch permits the operator to select full-scale deflection range of the voltmeter when the FUNCTION switch is in the PATCH position. This switch in general has no effect on the meter when the FUNCTION switch is in any position other than PATCH. Note, however, the RANGE switch must not be in the OFF position when monitoring amplifier stabilizers (BAL).

The OFF position of the RANGE switch is used to connect the attenuator wipers to the null pot (via the meter) for TR-48 computers that are not equipped with a DVM (TR-48-0).

c. Signal Selectors

The signal SELECTOR permits the readout of various circuits of the TR-48 Computer. A detailed explanation of these circuits is given in Section IV of this manual. The following is a list of signals available for readout with a standard selector system.

Address	Signal Source
A00 through A47	Addresses the outputs of the 48 d-c operational amplifiers. The address corresponds to the Pre-Patch Panel designation. Also addresses the stabilizers of these amplifiers for readout via the multi-range voltmeter when the FUNCTION switch is in the BAL position.
A48 and A49	Addresses the positive and negative reference amplifier outputs for readout (A48 positive and A49 negative reference amplifier).
A50 through A64	Addresses the 15 IN-TRUNKS, located in Module 8, slot 2 (cradle 37) of the Pre-Patch Panel, for monitoring. (See Figure 1.5-2.) These trunks terminate at J63 on the rear of the TR-48. (See Figure 1.5-1.)
A65 through A99	Unassigned.
P00 through P59	Addresses the wipers (under load) of the attenuators for monitoring and adjustment. The attenuators are designated and labeled P00 through P59 on the attenuator panel at the right-hand side of the computer.
P60 through P99	Unassigned.

To have the addressed signals displayed by the DVM or multi-range voltmeter (VM) a patch connection must be made between the SEL and DVM and/or VM terminations on the Pre-Patch Panel 12.763 Readout Patching Block. The VM FUNCTION switch must be placed in the PATCH position to connect this instrument to the VM patching termination. Note, however, that the multi-range voltmeter should not be used to monitor attenuators because of the relatively low input impedance of the meter circuit. To prevent this situation a relay disconnects the VM from the selector system when the computer is placed in the PS mode.

d. Mode Control Pushbuttons

These controls determine the operating mode of the computer. Following is a list of the pushbuttons and a brief description of their functions.

Mode Pushbutton	Description
OP (Operate)	When this button is depressed, all integrators are simultaneously released (operate bus energized) to respond to input signal voltages.

Mode Pushbutton	Description
	The integrator outputs change in potential as dictated by the inputs; a time varying behavior is produced. This generates the voltage solution of the programmed problem.
HD (Hold)	Depressing the HD pushbutton permits the problem solution to be stopped and all the voltages held at the potential attained up to the instant of depressing the button. After making the desired observations (or adjustments), the problem may be continued from this point by depressing the OP button or re-set to the starting point by depressing the RS button.
RS (Reset)	In the Reset mode, RS, all circuits except the integrators function normally. The integrator outputs are held at their respective initial conditions (IC) as dictated by the IC input voltage. (The integrator output is zero if no IC voltage is applied.)
PS (Pot Set) Revision Summing Junction connected to ± Grd. by relay contacts.	In the Pot Set Mode, PS, relay contacts close, connecting the output of all the high-gain amplifiers to their inputs. This essentially provides the amplifiers with a zero feedback impedance (preventing them from overloading) and also holds the amplifier summing junction at virtual ground. This permits setting the attenuators under load conditions. (The summing junctions of the integrator networks are physically connected to ± ground.)
SL (Slave)	When a TR-48 Computer is to be slaved to another TR-48, this button is depressed on the slaved computer. The slaved computer then responds to the selected modes of the master computer. Revision except Pot Set mode.
RO (Rep-Op)	The RO button places the computer in the repetitive operation mode. The computer automatically switches between the operate, and reset modes at a pre-determined rate. (See Paragraph 7 of this section.)

e. Repetitive-Operation Timing Selector

This control, actually a dual control, determines the operate duration of the computer integrators when the TR-48 is in the Rep-Op mode. The control consists of a four position outer switch and an inner vernier control that will expand each of the four ranges by two and one-half times.

f. Overload Indicators

The overload indicators provide a visual alarm when an overload occurs in any of the operational amplifiers, i.e., when the summing junction error exceeds a tolerable limit. An operational overload may be due to improper scaling or improper patching; in some cases a temporary overload (lamp flashes on and then goes out) may not cause appreciable error and the operator, after consideration, may choose to neglect the indication.

When the computer is initially turned on all the indicator lamps light; however, in a few seconds, as the amplifiers settle, all the lamps should go out. Should a lamp remain lit it generally indicates a patching error (such as the failure to provide un-used amplifiers with feedback). Prolonged overloads will not damage an amplifier.

g. Patch Panel Engage/Disengage Switch

This switch controls the operation of the Pre-Patch Panel drive motor. For a description of the operation see the Pre-Patch Panel insertion and removal instructions in the Operators Handbook.

7. TR-48 MAINTENANCE

a. General Information

The TR-48 is constructed of the best commercial grade components and hardware and is designed for long periods of trouble-free operation. Before shipment from the factory, each instrument is subjected to extensive quality control checks and adjustments.

In order to maintain the computer in peak operating condition, a definite plan for regular maintenance checks is recommended. It is not desirable to allow the computer to operate continuously until some malfunction occurs. If this course is followed there is no assurance of accuracy and optimum performance at any given time.

A maintenance program for equipment such as the TR-48 should be accomplished in three phases. First to be considered is the operational maintenance which occurs during periodic checks of such things as amplifier balance, power supply and reference levels, and diode function generator settings. Due to the frequency of these checks most malfunctions are discovered during this operational maintenance phase.

The second phase of a maintenance program would involve troubleshooting defective units discovered during the operational checks. This is most conveniently accomplished on the computer by operating the defective component on a test shelf as shown in Figure 1.7-1. This permits the defective unit to operate in its normal environment, and at the same time exposes all components and wiring to facilitate troubleshooting.

The third phase of the maintenance program should consist of periodic testing of all components in a system. This is generally referred to as preventive maintenance. Tests should be designed to detect units that, while presently useful, may fail in the near future, or units whose performance may have gradually deteriorated. This type of maintenance is predicated on the availability of unit spares. Having unit spares on hand is highly recommended to permit using the computer while components are being periodically checked. Also, a malfunctioning component can be replaced immediately if a working spare is on hand.

To assist TR-48 maintenance personnel, this handbook includes in SECTION II, a complete circuit description for each unit in the computer, and a recommended test and adjustment procedure for that unit. Also included in this manual are replaceable parts lists (APPENDIX I) and Schematic and Wiring Diagrams for the computer and all plug-in components (VOLUME II).

b. Maintenance Accessories and Equipment

Revision
See pink sheet 6 3-16

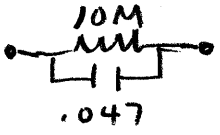
51.114

Included with the accessories provided with each TR-48 is a Model ~~51.116~~ Service Shelf. This unit fits into the component cradles of the computer and mates with the cradle connectors. The other end is terminated with a mating connector for the component under test.

As shown in Figure 1.7-1, by removing the component patching block at the same time the faulty component is removed from the computer, the service shelf may be inserted through the Patch Panel opening into the vacated module slot. To facilitate patching into the component on the service shelf the spring contacts on the front of the unit must be removed. These contacts may be readily removed by simply pulling them out with a pair of long-nose pliers; reasonable care should be exercised to prevent damaging the contacts.

When replacing the spring contacts they should be seated with the insertion tool provided. Only those component-block holes with small dots to their immediate left require contacts. To assure the contacts are at the proper angle when replaced, cover this dot with the contact projection that rests flush against the component front block.

It should be noted that the TR-48 itself contains many of the facilities required for component maintenance. The digital voltmeter (if it is not affected by the particular malfunction) permits reading d-c voltages to four-place accuracy. The control panel voltmeter is also available for monitoring operational and computing voltages. The lowest voltmeter range permits reading potentials as low as 10 millivolts with reasonable accuracy. The sensitivity of the voltmeter may be increased by using a d-c amplifier as a meter pre-amplifier. For this purpose a special feedback network consisting of a 10 megohm (±1%) resistor shunted by a .047 mfd capacitor should be made up with standard banana plugs. By connecting this network across an amplifier and using a gain-of-10 input, voltages to be observed may be multiplied by a factor of 1000 before application to the meter circuit. Thus, by using the 0.1-volt scale, potentials as low as 10 microvolts can be read with sufficient accuracy for maintenance purposes.



In addition to the facilities offered by the TR-48, maintenance personnel should have two other items of test equipment available for performing the test and adjustment procedures outlined in this manual: a d-c oscilloscope (Dumont, Model 403 or equivalent), and a vacuum tube voltmeter, or a high-impedance multimeter (Triplett, Model 630-A or equivalent).

_c_. Applicable Drawings

The following diagrams are contained in Volume II of this handbook.

Drawing Number	Type	Description
B019 261 0A	Assembly	Trunk Cable
B019 262 0A	Assembly	Slave Cable
B019 322 0A	Assembly	Scope Cable
B019 323 0A	Assembly	1110 VARIPLOTTER Cable
B019 330 0A	Assembly	1100E VARIPLOTTER Cable
C045 034 0A (Sheet 3)	Assembly	11.148 Relay Panel Layout
D045 034 0S (Sheets 1 through 3)	Schematic	Schematic diagrams of selector system, relay, panel, meter circuit, Patch Panel motor and Mode Control switches.
B045 034 0W (Sheets 2 through 56)	Wiring	Wiring run sheets (plus key sheet) of computer rack wiring.
A047 040 0W	Wiring	Slave cable junction box (for slaving three or more computers).

A5280

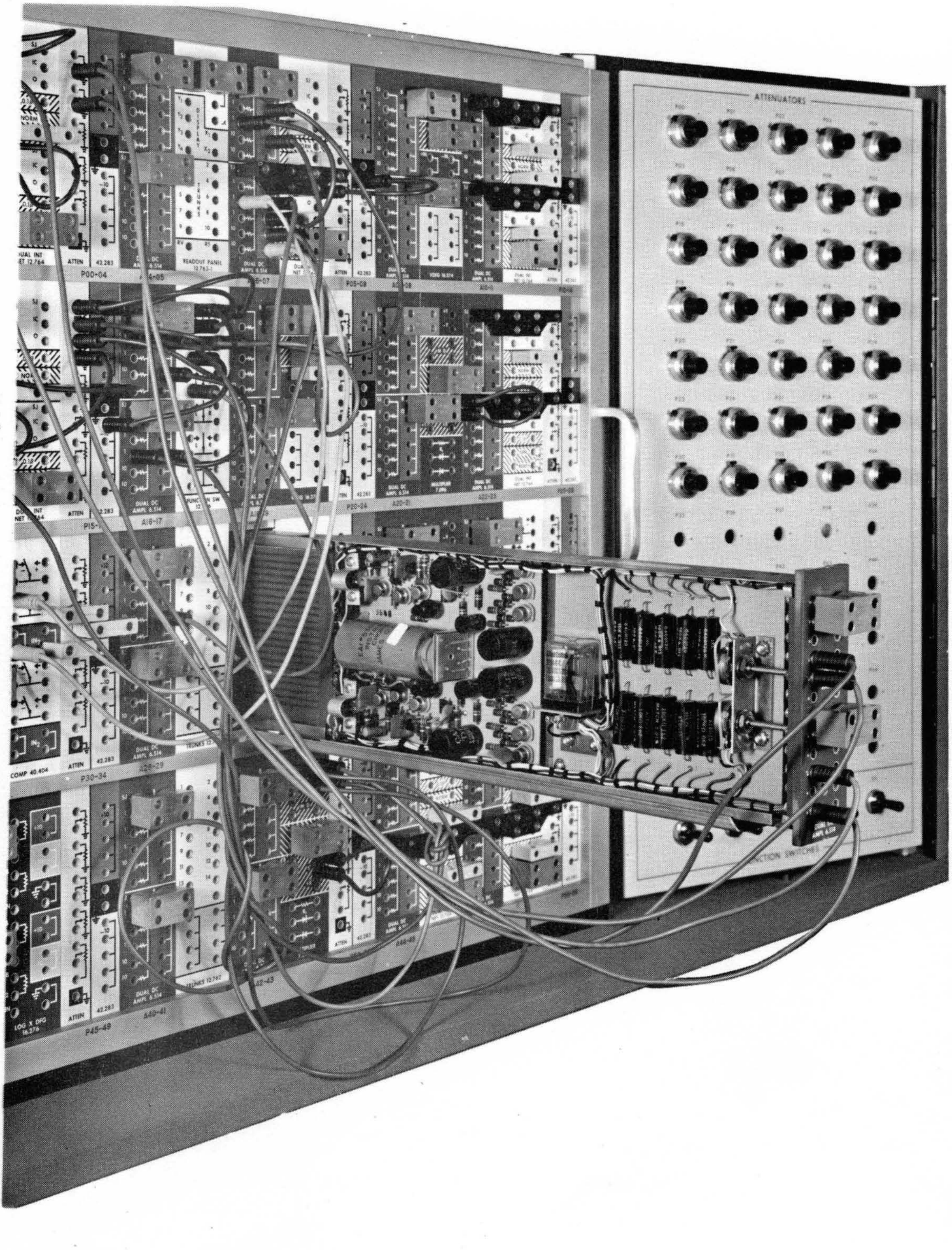


FIGURE 1.7-1 TEST SHELF IN USE.

SECTION II

COMPUTING COMPONENTS AND ACCESSORIES

1. DUAL D.C. AMPLIFIER 6.514

The TR-48 Dual D.C. Amplifier 6.514 consists of two independent high-gain d-c amplifiers and two independent resistor networks (Figure 2.1-1). The amplifiers are transistorized and designed for optimum stability and frequency response. Chopper stabilization virtually eliminates amplifier drift. In addition the amplifiers feature high open-loop gain, low noise and offset, and a short-circuit-protected output stage. Conservatively rated components ensure long-term reliability.

Patched as an operational amplifier these units become the basic computing unit in an analog computer. Used with appropriate input and feedback networks each amplifier can perform such linear functions as inversion, summation, integration, and multiplication by a constant. Accessory components enable the amplifier to multiply two variables, divide variables, simulate transfer functions, limit, simulate deadtime, and generate analytic or arbitrary functions.

a. Technical Data

Output Voltage Range:
0 to ±10 volts minimum

Output Current Range:
at ±10 volts d-c............20 milliamperes minimum

Noise and Ripple:
400 microvolts maximum (200 microvolts typical)

Offset Voltage (amplifier balanced)
20 microvolts maximum (5 microvolts typical)

b. Operating Considerations

The data in this sub-paragraph is general operating information with which maintenance personnel should be familiar in order to rapidly isolate amplifier troubles and eliminate causes of apparent faults which may be due to improper amplifier usage.

(1) Amplifier Balancing. The amplifiers should be periodically balanced to assure computer accuracy. The amplifier balance should be checked as a matter of routine maintenance, although, under normal operating conditions, balancing is only required after a period of several months. An amplifier requiring frequent balancing is indicative of eventual failure.

NOTE

> Initially, due to component aging, more frequent balancing of amplifiers may be required. Movement of the computer to different areas with extreme changes in ambient conditions (or extreme changes at the same location) may also necessitate amplifier balancing.

(2) Amplifier Patching. The input and output terminations of the dual high-gain amplifiers and the dual resistor networks are terminated at the Pre-Patch Panel and arranged for patching ease. The non-linear components are also located in close proximity to the amplifiers for ease of patching and short patch cord runs.

Patching, when using an amplifier(s) in conjunction with an integrator network or one of the non-linear components, is covered in the paragraphs covering these units. This section is therefore limited to the description of an amplifier used in conjunction with a resistor network.

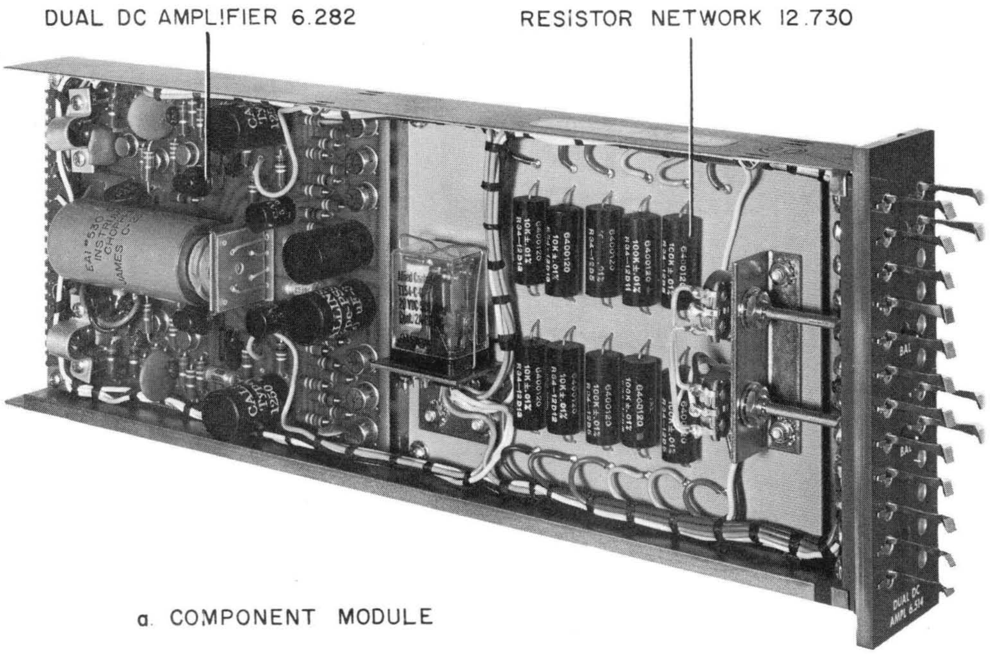
Figure 2.1-2a illustrates two of the more common amplifier patching arrangements. The upper amplifier makes use of the standard 4-connector bottle plug, shown by the shaded area, and provides a summing circuit as shown schematically in Figure 2.1-2b. This configuration has two gain-of-one and two gain-of-ten inputs for summing, inversion, or multiplication.

The lower amplifier of Figure 2.1-2a provides one gain-of-one and three gain-of-one tenth inputs by using two, 2-connector bottle plugs shown by the shaded area. The simplified schematic of the configuration is shown in Figure 2.1-2c.

As previously indicated, these are only two of many possible amplifier configurations. An important point to note is that all amplifiers whether used (assigned) or unused (unassigned) for a particular problem solution, must be provided with feedback. Failure to provide a feedback circuit for an amplifier will cause that amplifier to overload as soon as the computer is switched to any mode other than pot-set.

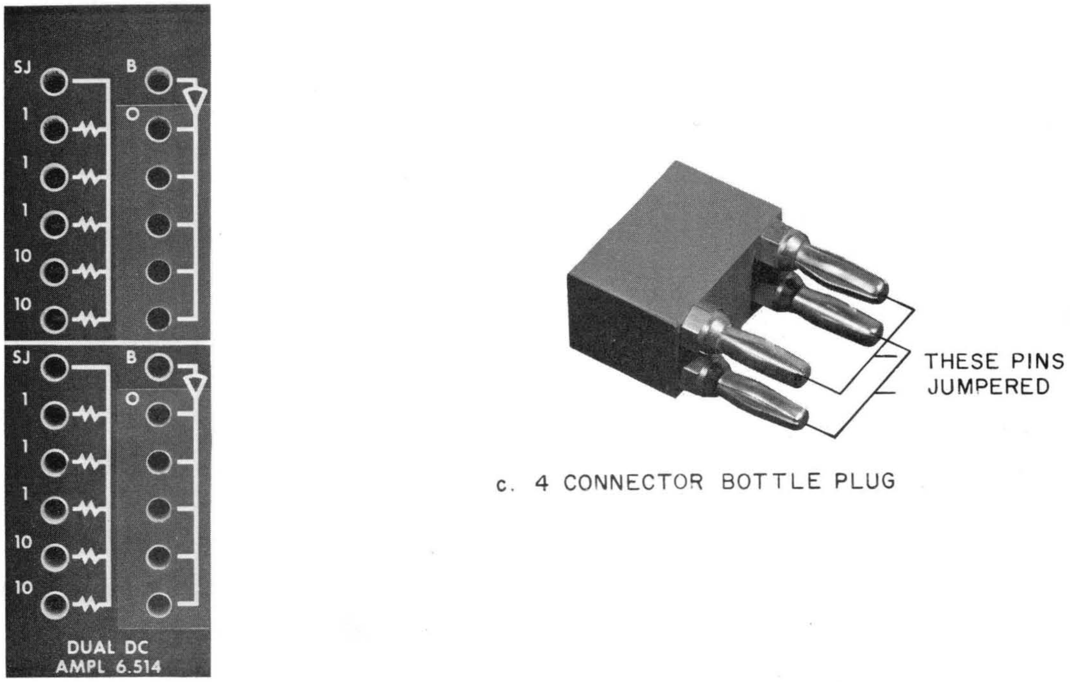
The d-c operational amplifiers are rated for normal operational outputs of ±10 volts maximum. Thus the amplifier patching arrangements, regardless of the application, should be such that the output level does not exceed either plus or minus 10 volts. (The amplifiers are capable of slightly higher outputs to allow minor scaling discrepancies.)

(3) Amplifier Overload. The overload system provides a visual indication to the operator when an amplifier summing junction error exceeds a tolerable limit. The overloading of an assigned amplifier indicates that an error is induced in the problem solution at the instant of overload. An overload may be due to improper scaling or patching; in some cases a momentary overload may not induce appreciable error and the operator may choose to neglect the indication. Prolonged overloads will not damage the amplifier unless caused by excessively high voltages other than those normally obtainable from the computer itself.



TR-48
38,53,
70

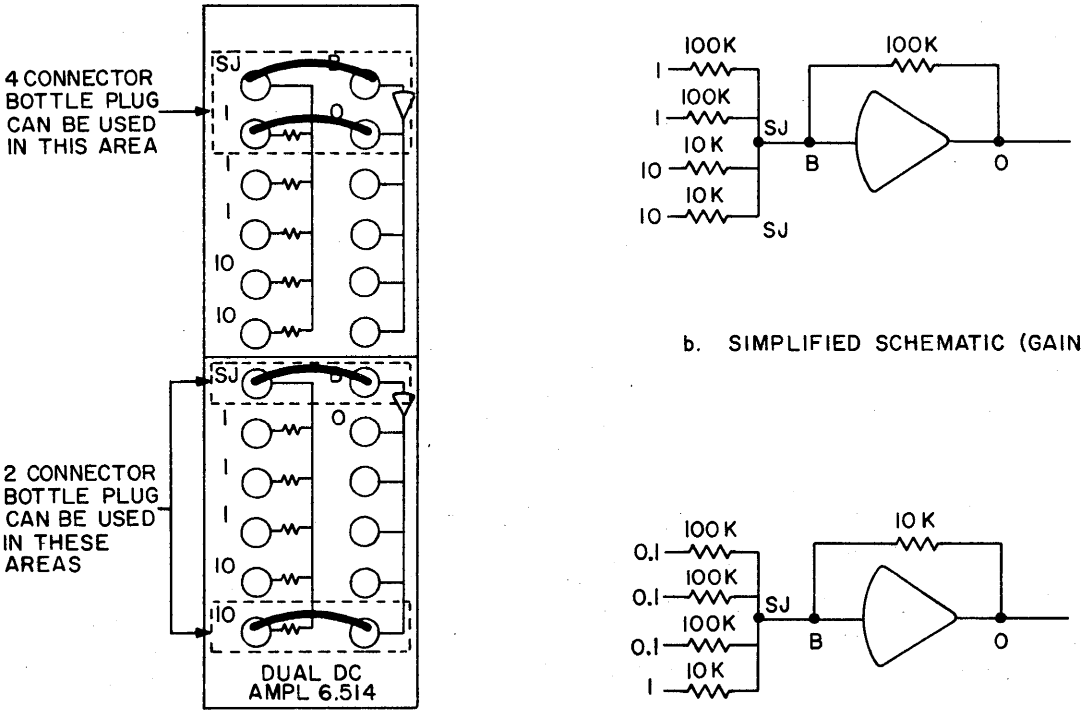
a. COMPONENT MODULE



c. 4 CONNECTOR BOTTLE PLUG

b. PATCHING BLOCK

FIGURE 2.1-1 DUAL DC AMPLIFIER, MODEL 6.514



b. SIMPLIFIED SCHEMATIC (GAINS OF I AND 10)

a. PRE-PATCH PANEL CONFIGURATIONS

c. SIMPLIFIED SCHEMATIC (GAINS OF 0.I AND I)

FIGURE 2.1-2 AMPLIFIER PATCHING, TYPICAL CONFIGURATIONS

Overload of an unassigned amplifier will neither damage the amplifier or affect the problem solution. The fact that one or more unassigned amplifier overload-lamps are lit, however, may cause the operator to overlook an overload of an assigned amplifier. This will cause an erroneous problem solution, thus defeating the purpose of the overload alarm system.

When power is initially applied to the computer, all of the overload lamps light; after a few seconds all of the lamps should extinguish. The lamps may also momentarily flicker when switching from pot-set to some other computer mode.

c. Theory of Operation

When a high-gain d-c amplifier is used in conjunction with input and feedback networks to perform mathematical operations, the resulting system is generally referred to as an operational amplifier. The operational amplifier is the basic and most versatile unit in the analog computer. It can be used for inversion, summation, multiplication by a constant, integration, and used in conjunction with special networks for squaring, extracting square root, generating logarithmic functions, etc.

To understand the basic concept of the operational amplifier, consider the simplified block diagram of Figure 2.1-3 where a high-gain amplifier (gain of -A) has a feedback impedance Z_f and an input impedance Z_{in}. The amplifier is designed so that it has three basic and essential characteristics.

1. The amplifier output (e_o) is related to the summing junction voltage (e_b) by the gain of the amplifier: $\underline{e_o = -Ae_b}$
2. The input stage of the amplifier draws negligible current: $\underline{i_b = 0}$
3. The open loop gain of the amplifier is extremely high: $\underline{A >> 1}$ (on the order of 3×10^7 at d-c).

Using Kirchhoff's laws, the nodal current equation at the summing junction (Sj) is:

$$i_{in} = i_f + i_b$$

or

$$\frac{e_{in} - e_b}{Z_{in}} = \frac{e_b - e_o}{Z_f} + i_b$$

Since $e_b = \frac{-e_o}{A}$ and since $i_b = o$ from characteristics (1) and (2), respectively

then $$\frac{e_{in}}{Z_{in}} + \frac{e_o}{AZ_f} = -\frac{e_o}{AZ_f} - \frac{e_o}{Z_f}$$

Solving for e_o:

$$e_o = \frac{-\dfrac{Z_f}{Z_{in}} \quad e_{in}}{1 + \frac{1}{A}\left(\dfrac{Z_f}{Z_{in}} + 1\right)} \qquad \text{(EQ 2.1-1)}$$

In most applications the ratio of Z_f to Z_{in} is less than 30 and since $\frac{1}{A}$ approaches zero, equation 2.1-1 becomes:

$$e_o = \frac{Z_f}{Z_{in}} \; e_{in} \qquad \text{(EQ 2.1-2)}$$

Equation 2.1-2 illustrates one of the most important considerations of the operational amplifier: the input-output relationship of the operational amplifier is solely dependent on the ratio of the feedback to the input impedance.

Using equation 2.1-2 as the basis of discussion, the following sub-paragraphs describe the various uses of the operational amplifier.

(1) Inversion. When the same value resistor is used for both the feedback and the input impedance, the amplifier output voltage has the same amplitude as the input voltage but is opposite in polarity.

$$e_o = -\frac{R_f}{R_{in}} \; e_{in}$$

In the TR-48 the value of R_f and R_{in} used for the inverter is normally 100,000 ohms, (100K); therefore

$$e_o = -\frac{100K}{100K} \; e_{in} = -e_{in}$$

Thus a +10 volt input results in a -10 volt output, and the amplifier is said to have a gain of minus one. The accuracy of the output to input 1:1 ratio depends only on the comparative equality of R_{in} to R_f.

(2) Multiplication by a Constant. A change in the ratio of the resistors results in multiplication by a constant. With R_f equal to 100K and R_{in} equal to 10K, for example, the amplifier output is:

$$e_o = -\frac{100K}{10K} \; e_{in} = -10e_{in}$$

An input of plus one volt results in an output of minus ten volts. This operational amplifier has a gain of ten. The multiplying constant can be made smaller than one by using a 10K feedback resistor with a 100K input resistor.

$$e_o = \frac{10K}{100K} \; e_{in} = -0.1e_{in}$$

An input of minus ten volts produces an output of plus one volt.

(3) Summation. When multiple input resistors are used with a feedback resistor R_f, the basic relationship is extended to:

$$e_o = -\left(\frac{R_f}{R_1} e_1 + \frac{R_f}{R_2} e_2 + \ldots + \frac{R_f}{R_n} e_n\right)$$

The circuit can be used to algebraically sum an indefinite number of inputs; furthermore, each input may be multiplied by an arbritrary constant.

(4) Integration With Respect to Time. When the feedback element Z_f is a capacitor rather than a resistor, the summing junction current equation is:

$$\frac{e_1}{R_1} + \frac{e_2}{R_2} + \ldots + \frac{e_n}{R_n} = -c \frac{d_{eo}}{dt}$$

Integrating this equation and assuming an initial charge on the feedback capacitor of V_o:

$$e_o = -\frac{1}{c} \int_o^t \left(\frac{e_1}{R_1} + \frac{e_2}{R_2} + \ldots + \frac{e_n}{R_n}\right) dt + V_o$$

Alternately, if Z_f is a capacitor having an operational impedance 1/pc and Z_{in} is a resistor, the basic operational amplifier relationship (equation 2.5-2) becomes:

$$e_o = -\frac{e_{in}}{pRC} = -\frac{1}{RC} \int_o^t e_{in}\, dt$$

With this arrangement, the operational amplifier will integrate (with respect to time) any input voltage. In addition to integrating, the amplifier also inverts the input voltage. An indefinite number of inputs may be applied to produce the time-integral of the sum of the input voltages.

(5) Other Mathematical Operations. As previously indicated the operational amplifier has uses other than those indicated in sub-paragraph a through d. Complicated transfer functions can be simulated by using series and parallel RC networks for the feedback and input impedance. The circuit performance is still governed by the basic relationship of equation 2.5-2. For the general case where three-terminal networks are used, the short-circuit transfer impedance of Z_f and Z_{in} must be used. (The short circuit transfer impedance of a network is the ratio of input voltage to short-circuit output current.) The input and feedback elements need not be linear; therefore, almost any non-linear characteristics can be approximated. The amplifier can also be used in conjunction with diodes and resistors to simulate the non-linear operations of limiting, dead-zone generation, absolute value derivation, X^2, Log X, etc.

A problem encountered in a d-c amplifier that is not prevalent in an a-c amplifier is drift or offset. That is, the output does not remain constant with a constant input and in particular does not remain at zero with a zero input. This is an undesirable feature, especially when using a d-c amplifier for integration since drift can lead to serious computational errors. To compensate for possible drift and to stabilize the d-c amplifier, the TR-48 units contains an a-c amplifier or stabilization circuit.

Figure 2.1-4 is a simplified block diagram of the TR-48 high-gain amplifier. A d-c signal is changed to a-c by a electro-mechanical chopper and amplified by the stabilizer amplifier. The stabilizer output is rectified by the same electro-mechanical chopper and further amplified by the d-c amplifier circuit. Any a-c component on the d-c input by-passes the stabilizer (via the capacitor). Thus a-c components are amplified by the d-c section only, while d-c components are amplified by the cascaded stabilizer d-c amplifier combination.

To visualize the stabilizer circuit operation, assume the operational amplifier of Figure 2.1-4 is provided with a feedback element from the output of the d-c section to the input of the stabilizer section (Figure 2.1-3). Assume also that an input is applied via an input resistor and the amplifier output attains a level, as dictated by the feedback-input ratio, so that the summing junction (d-c input of Figure 2.1-4) is at virtual ground. If the amplifier now begins to drift, the drift voltage (or offset) at the output causes an unbalance between the feedback and input currents, or an offset at the amplifier summing junction. The stabilizer "sees" this offset as an input, amplifies it, and applies it in opposite polarity to the d-c amplifier where it cancels the original drift voltage. The cancellation is not complete but the effect is to reduce the drift <u>by a factor equal to the gain of the stabilizer circuit</u>. This permits the amplifier to be used for several months before there is a need to balance the amplifier manually to assure that the output is zero with a zero input.

Each 6.514 Amplifier Unit contains two identical but independent operational amplifiers. Figure 2.1-5 is the schematic diagram of one of the two amplifiers. (Compared to D006 282 0S, Figure 2.1-5 is the schematic of the amplifier on the upper half of the drawing; it is, however, typical of both amplifier circuits.)

Transistors Q6, Q7, and Q8, with associated circuitry, comprise the stabilization amplifier. Contacts 2 and 3 of electro-mechanical chopper D1 change the d-c input to a-c for amplification by the stabilizer, and contacts 1 and 2 restore the stabilizer output to d-c for application to the d-c amplifier section.

Transistors Q17, Q1, Q2, Q3, Q4, and Q5 comprise the d-c amplifier portion of the unit. The output stage of the d-c amplifier consists of Q4 and Q5, a complementary symmetry (or totem pole) circuit which provides the advantages of push-pull operation with single-ended input and output. The circuit is similar to a balanced bridge. With a zero input, equal current flows through Q4, I1, I2, and Q5 from the -15 volt to +15 volt supply; thus, the output is zero. An input signal causes one stage to conduct more heavily than the other, i.e., the bridge becomes unbalanced and current flows to the external circuit.

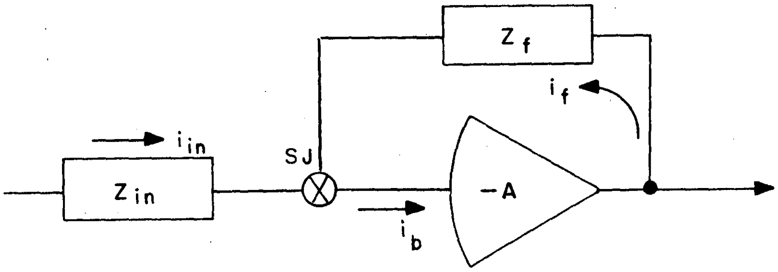


FIGURE 2.1−3. OPERATIONAL AMPLIFIER, BLOCK DIAGRAM

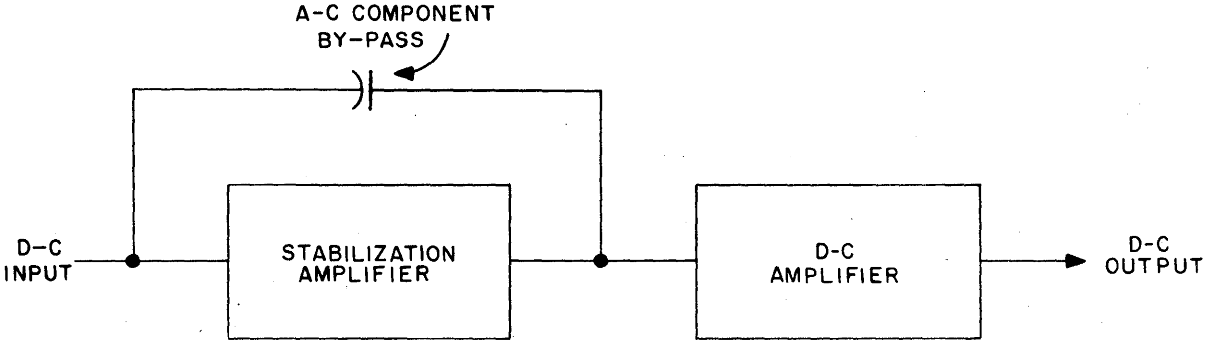
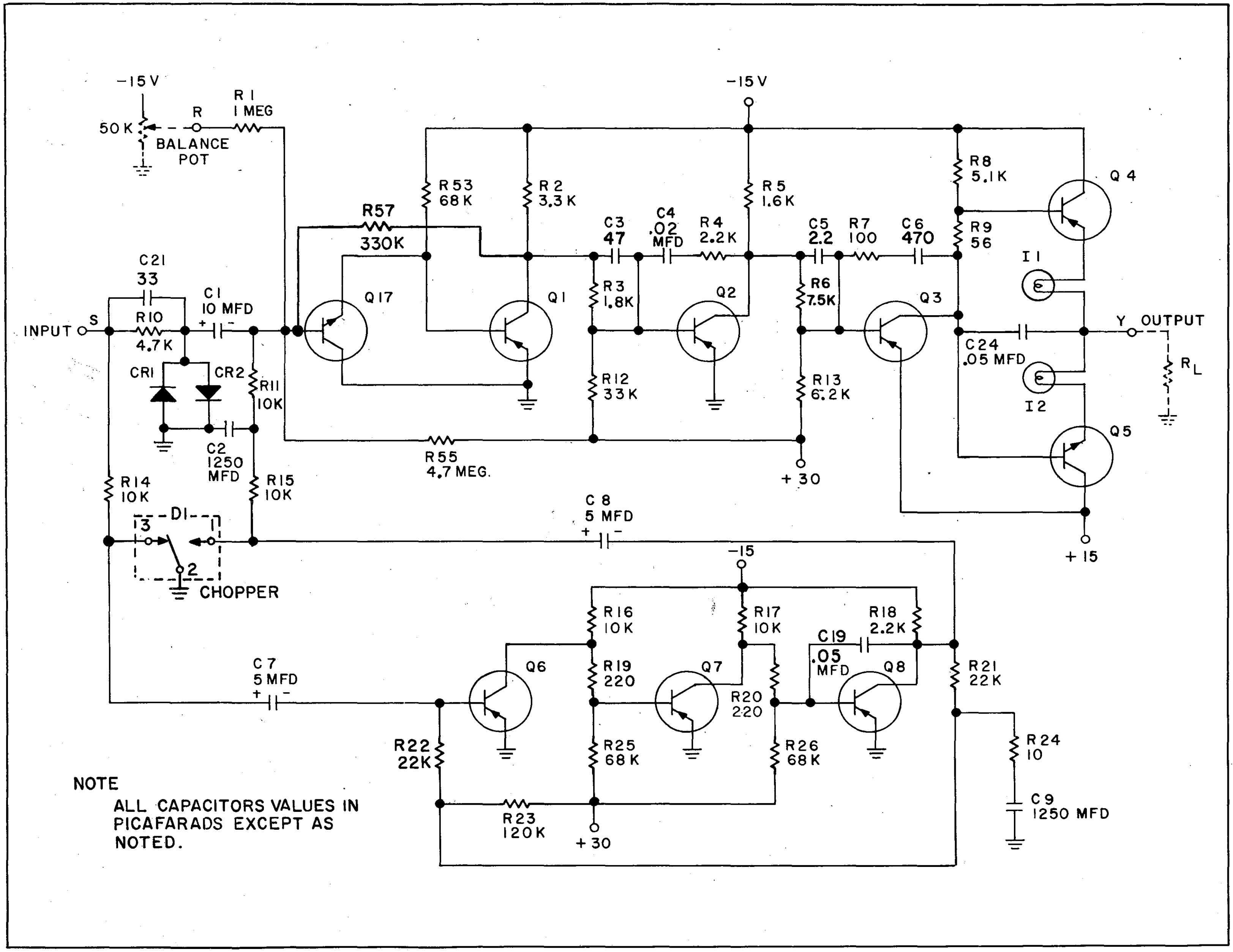


FIGURE 2.1-4. HIGH GAIN D-C AMPLIFIER, SIMPLIFIED BLOCK DIAGRAM



NOTE

ALL CAPACITORS VALUES IN PICAFARADS EXCEPT AS NOTED.

FIGURE 2.1-5. HIGH GAIN AMPLIFIER, SIMPLIFIED SCHEMATIC

Incandescent lamps (I1 and I2) are connected in series with the emitter of each output transistor to stabilize and protect these components. As current through a stage increases, the lamp impedance also increases, thus acting as a current limiting device. The diode current limiting network (CR1 and CR2) in the input circuit permits quick overload recovery.

Transistor Q17 uses the base-to-emitter voltage of Q1 as its operating potential and the base-to-emitter impedance of Q1 as its load; with this configuration, the amplifier input impedance becomes relatively high.

Figure 2.1-6 is a simplified schematic of one of the dual amplifiers and one of the dual resistor networks interconnected with a four-connector bottle plug. As shown in the figure, the 12.730 Network not only contains the input and feedback resistor of the amplifier, but also the balance potentiometer and the pot set relay. The pot set relay is energized when the computer is placed in the pot set mode; the relay contacts short the amplifier output to the input. Since the amplifier summing junction is tied to the output, the amplifier gain is zero; thus, any current flow at the output of the amplifier is due to drift in the d-c section. The balance pot may then be adjusted for a potential equal in magnitude and opposite in polarity to that of the drift. The pot set relay also prevents the amplifiers from overloading when the Pre-Patch Panel is removed (thus disconnecting any patched feedback circuits) to expose the balance controls. When switching from pot-set to any other computer mode, the pot-set relay de-energizes, and the amplifier re-gains its patched feedback circuit (the 100K resistor of Figure 2.1-6, for example). During the switching time of the relay an amplifier may momentarily go into overload before settling.

d. Maintenance and Test Procedures

As previously indicated the amplifier balance adjustment should be checked at periodic intervals to assure computer accuracy. The balance procedure [outlined in Sub-Paragraph b(1)] is also indicative of subsequent amplifier failure if frequent balance is required. Inability to balance an amplifier is a positive indication of component malfunction. Two tests are given in this sub-paragraph for checking a suspected amplifier and for checking repaired units to assure that a malfunction has been adequately rectified. Prior to attempting any maintenance procedure the amplifier must be balanced.

(1) Amplifier Output Current Check. Set up the test circuit shown in Figure 2.1-7 and select the amplifier under test for readout on the DVM. Apply positive and then negative reference to the amplifier input, observing the output voltage level in each case. A DVM reading of less than 10 volts magnitude in either case indicates the amplifier is not capable of supplying 20 milliamperes of current (the minimum allowable for reliable amplifier operation).

500
load

(2) Amplifier Dynamic Error Check. Set up the test circuit shown in Figure 2.1-8a. Note that the amplifier under test is used as an inverter while the second amplifier is used as a summer (gain-of-ten for both inputs). In patching the amplifier under test it is suggested that two 2-connector bottle plugs are used instead of the normal 4-connector plug, since the input and feedback resistors may

have to be interchanged.

2 v/cm.

Set the scope horizontal (X) gain for approximately full scale deflection with the 6.3V a-c input. Calibrate the vertical gain for 10 millivolts/centimeter. Set R2 for minimum resistance.

Potentiometer R1 is used to trim input resistor R5 to the exact value of R6, thus assuring the amplifier under test has an exact gain-of-one. Therefore, any error indication will be that of the amplifier tested and not of the input and feedback resistor ratio. This trimming is accomplished by adjusting R1 so that connections at C and D may be interchanged (i.e., C connected to D and C' to D'; Figure 2.1-8b) without affecting the scope diagonal pattern. It may be necessary to interchange R5 with R6 (thus R6 will be in series with R1) should the impedance of R5 be greater than that of R6; this may easily be accomplished if two 2-connector bottle plugs are used to patch the amplifier under test.

Potentiometer R2 is used to trim R4 to the exact value of R3, thus assuring amplifier 2 has an equal factor for both inputs. This trimming is accomplished by adjusting R2 so that connections at A and B may be interchanged (i.e., A connected to B and A' to B', Figure 2.1-8c) without affecting the scope pattern.

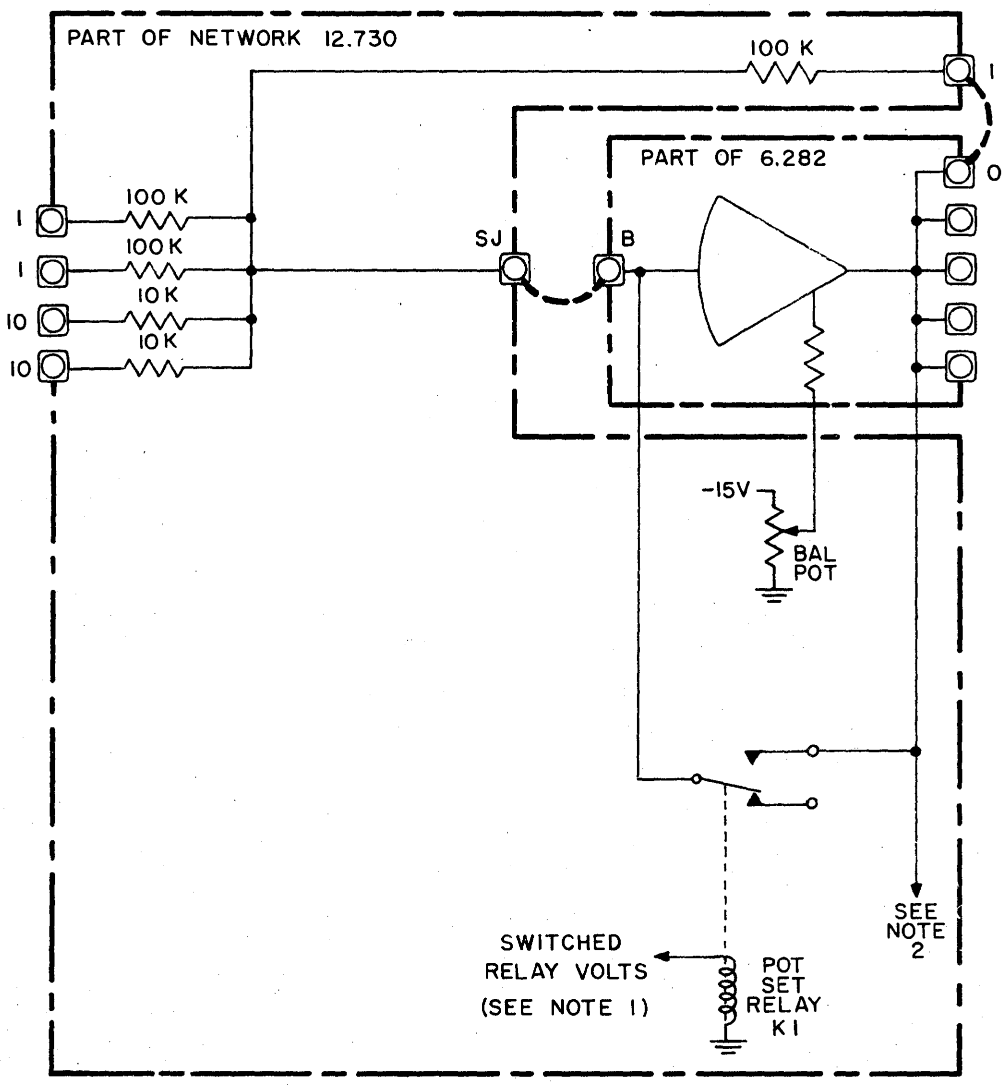
With both R1 and R2 adjusted, the scope pattern indicates the amplifier dynamic error multiplied by a factor of 10, i.e., the extent that the line (peak-to-peak) deviates from the horizontal is 10 times the amplifier dynamic error at 10 millivolts/centimeter of deflection peak-to-peak. A typical amplifier will cause approximately 2.5 centimeters, or 25 millivolts of vertical deflection; this is actually 2.5 millivolts error. The maximum permissible scope deflection is 6 centimeters (60 millivolts).

(3) Trouble Analysis. The amplifier is used with different types of networks depending on the operation it is to perform; thus unsatisfactory performance may actually be due to a malfunction in the network rather than the amplifier. The malfunction can usually be isolated to a particular chassis by interconnecting suspected components with those known to be good. Unlike most types of electronic equipment, a faulty amplifier usually identifies itself immediately; if a component within the amplifier fails, the output voltage of the amplifier characteristically flops to its plus or minus limit (up to ±13 volts, depending on the load).

The most common indication of unsatisfactory amplifier operation is failure to balance properly. If an amplifier cannot be balanced, the malfunction can be localized to either the d-c or stabilizer section by the following procedure.

(1) Place the amplifier on service shelf and patch a feedback resistor around the amplifier; remove all inputs.

(2) Disable the stabilizer by grounding the stabilizer output line. (This line is terminated at Pin P of the rear connector or pin 1 of the chopper for the upper amplifier, and pin L of the rear connector or pin 9 of the chopper for the lower amplifier; see Drawing D006 282 OS.)



SYMBOL KEY:

▢ INDICATES PRE-PATCH PANEL PATCHING TERMINATION

◡ INDICATES PATCH CORD OR BOTTLE PLUG CONNECTION

NOTES:

1. SWITCHED RELAY VOLTS (NOM. -20V) IS ONLY PRESENT WHEN THE COMPUTER IS IN THE POT SET MODE.
2. THE AMPLIFIER OUTPUT IS ALSO WIRED TO THE SELECTOR SYSTEM FOR READOUT.
3. RELAY K1 SHOWN DE-ENERGIZED

FIGURE 2.1-6 AMPLIFIER 6.514, SIMPLIFIED SCHEMATIC

A4672

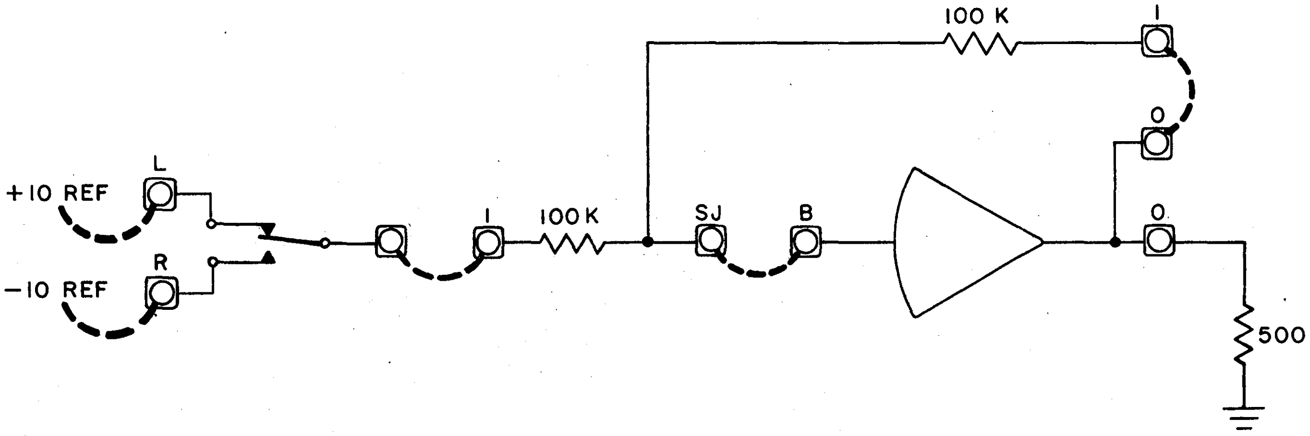
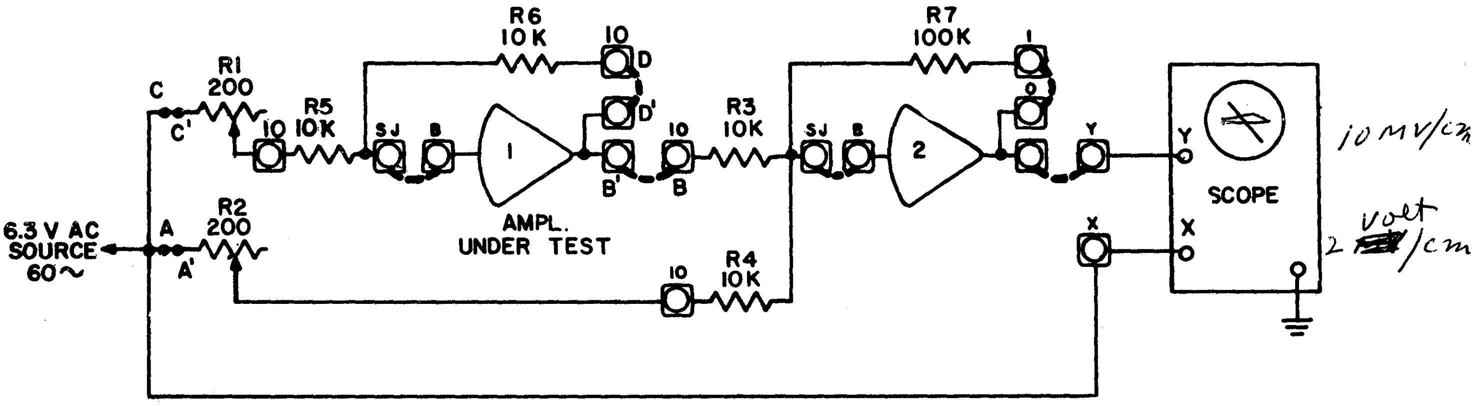
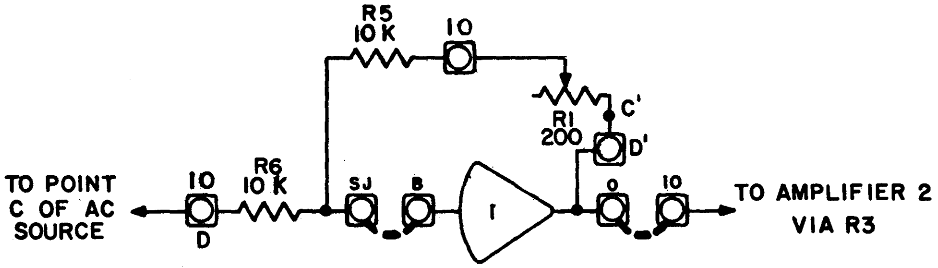


FIGURE 2.1-7 OUTPUT CURRENT TEST CIRCUIT

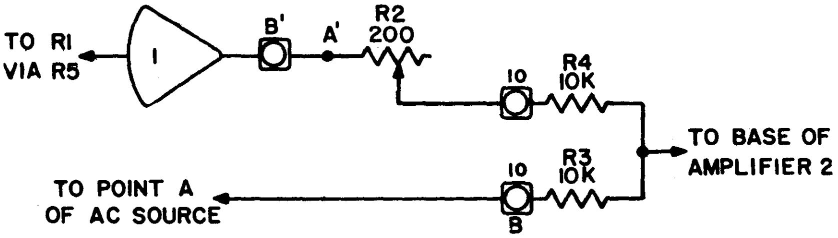
A 4673



a. INITIAL TEST SET UP



b. C AND D LEAD INTERCHANGE



c. A AND B LEAD INTERCHANGE

FIGURE 2.1-8 AMPLIFIER DYNAMIC ERROR TEST SETUP

(3) Monitor the output voltage of the amplifier with an oscilloscope or voltmeter and slowly rotate the balance potentiometer.

(4) The amplifier output should flop between its plus and minus limits (about ±13 volts) as the balance control is turned from one end to the other. A slight delay in response is normal. If the amplifier fails to do this, the malfunction is probably in the d-c section of the amplifier.

(5) Remove the ground from the BAL terminal. Connect an oscilloscope to the BAL terminal and observe the stabilizer output as the balance potentiometer is slowly rotated.

(6) The square wave output should change polarity, from negative-going to positive-going, as the balance control is turned from one end to the other. Failure to do so indicates that the malfunction is probably in the stabilizer section.

The d-c section of the amplifier may be checked by again disabling the stabilizer section and proceeding as outlined in the following procedure.

(1) Remove the feedback resistor and all inputs to the amplifier.

(2) Observe the output swing of each stage in turn as the balance control is rotated between its limits.

Troubles in the stabilizer section can frequently be isolated to a particular stage by the following procedure.

(1) Patch the amplifier as shown in Figure 2.1-9. The gain-of-ten input should cause the amplifier to overload.

(2) Circuit wave forms for a properly functioning stabilizer are shown in Figure 2.1-10. With an oscilloscope, compare these waveforms with the suspected stabilizer.

The following table lists some of the more common amplifier trouble symptoms and some suggested remedies. Note that the components listed in the remedy column are not <u>always</u> the source of the indicated symptoms. The components listed are for the upper amplifier only, see Diagram D006 282 OS for the corresponding items in the lower amplifier.

Symptom	Suggested Remedy
Excessive High-Frequency Noise	Replace Q1 or Q17 or both
Excessive Low-Frequency Noise	Replace Q6
Poor Frequency Response	Replace Q1; Check interstage coupling networks
Amplifier oscillates with negative output, positive output satisfactory	Replace Q4

Symptom	Suggested Remedy
Amplifier oscillates with positive output, negative output satisfactory	Replace Q3 or Q5 or both
Excessive Offset	Replace C1 or C7 or both
Extremely High Offset	Replace Q1
Negative Output Only	Replace I1
Positive Output Only	Replace I2

(4) Applicable Drawings. The following drawings are contained in Volume II of this handbook:

Drawing Number	Type	Description
C006 514 OS	Schematic	Schematically shows all components of the 12.730 network and inter-connection to 6.282 amplifier. Also shows connections to rear connector (P1) of the 6.514 module.
D006 282 OS	Schematic	Schematic diagram of d-c amplifier card only.
B045 034 OW	Wiring	Contains run sheets listing wiring from 6.514 rear mating connector to other points in computer cabinet.

(5) Parts Lists. Appendix I contains the replaceable parts lists for the 6.514 amplifier. See Index of Appendix I.

2. DUAL INTEGRATOR NETWORK 12.764

The 12.764 Dual Integrator Network permits the conversion of either or both of the high gain amplifiers into integrating amplifiers merely by the insertion of T-shaped bottle plugs (Figure 2.2-1). The integrator networks are designed to provide maximum flexibility, and permit the computer to be used for real time, interative, or high speed repetitive operation (Rep-Op) problem solutions.

The design of the networks, and the access to circuits provided at the patching area permit the operator to determine the operating mode and time scale of each integrator individually.

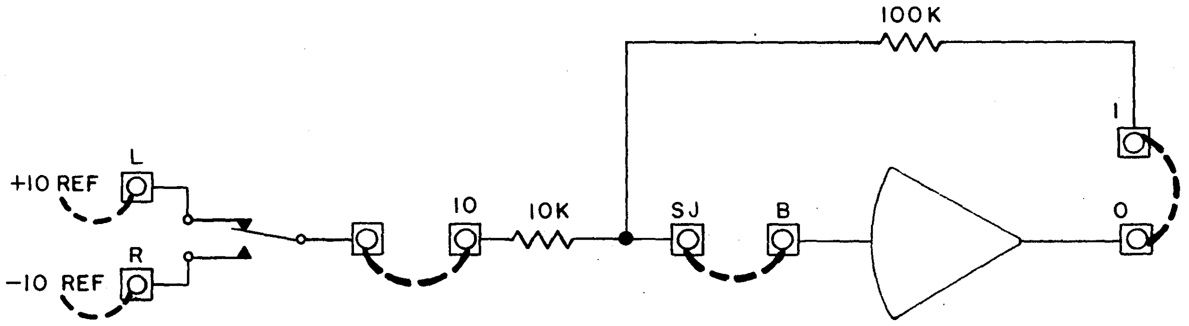
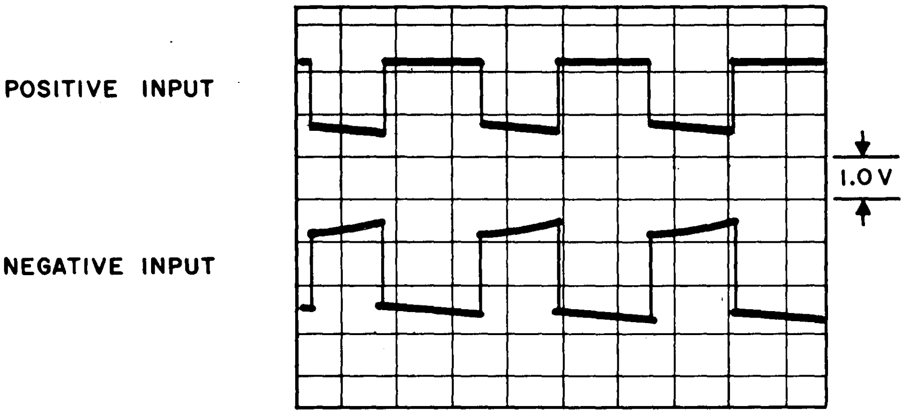
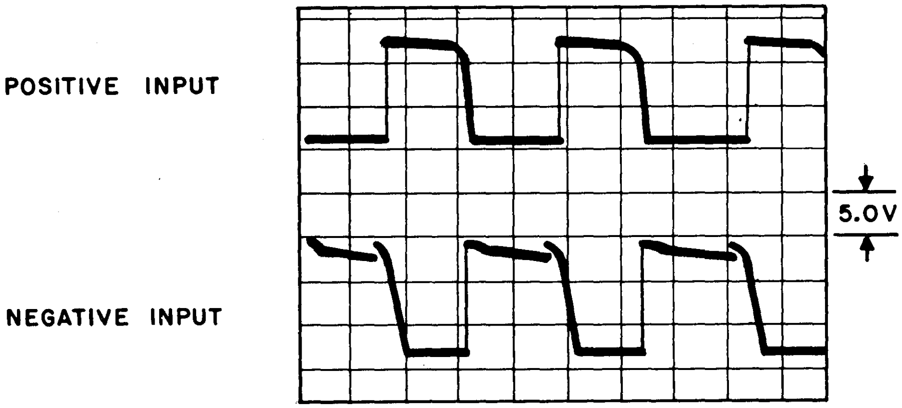


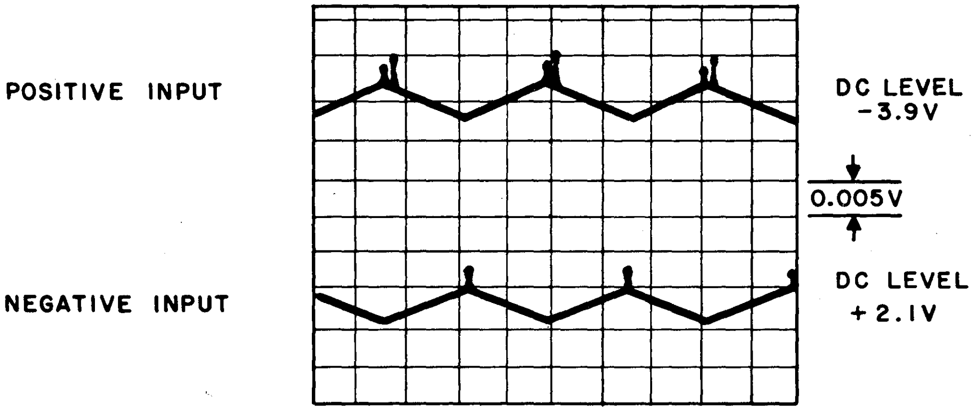
FIGURE 2.1-9. AMPLIFIER STABILIZER TEST SETUP



a. BASE OF Q6 (OR Q14)

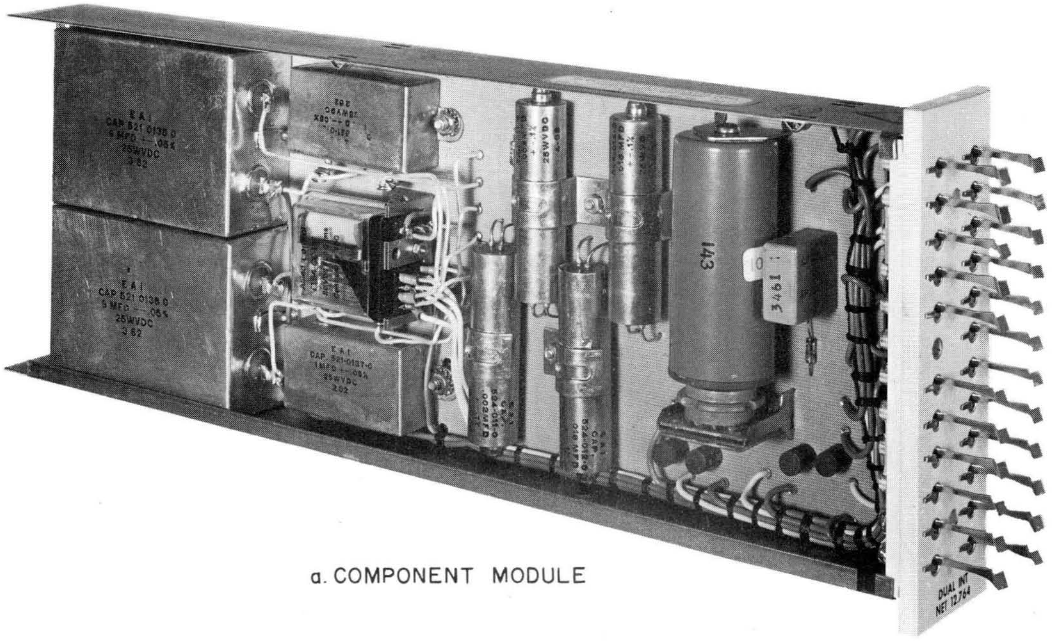


b. COLLECTOR OF Q8 (OR Q16)



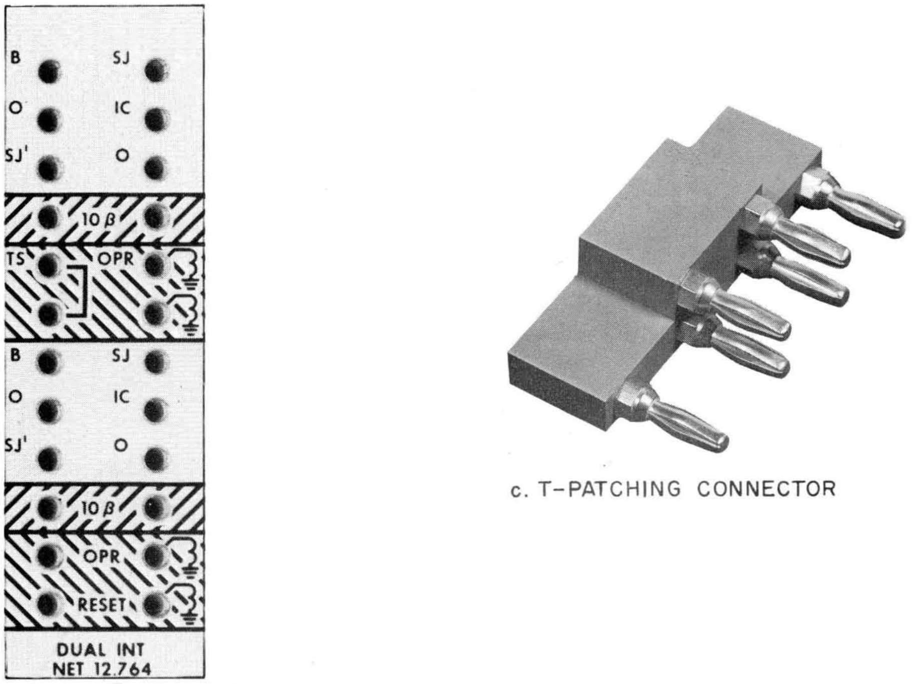
c. JUNCTION OF R11-R15
(OR R34-R39)

FIGURE 2.1-10 PROPERLY FUNCTIONING OVERLOADED STABLIZER WAVESHAPES



a. COMPONENT MODULE

TR 48
#71,46A,
39



c. T-PATCHING CONNECTOR

b. PATCHING BLOCK

FIGURE 2.2-1 DUAL INTEGRATOR NETWORK, MODEL 12.764

A4709

a. Operating Considerations

The flexibility of the integrating amplifiers of the TR-48 is indicated by the Pre-Patch Panel terminations available to the operator. There are essentially six separate areas within the integrator network patching block; four of these areas (two each) function with respect to the individual integrator sections while the remaining two function with respect to both sections. This sub-paragraph describes some of the more common patching configurations.

There are two all-white areas on the integrator patching block of the Pre-Patch Panel. Each area is associated with one of the dual networks; they are conveniently located for patching to the dual d-c amplifiers, normally located to the immediate left, with the T-shaped bottle plugs. The bottle plug completes the following jumper connections: B of the amplifier to B of the integrator, SJ of the amplifier to SJ of the integrator, and O of the amplifier to O of the integrator (Figure 2.2-2). These three jumper connections must be made in order for the integrator to function.

The IC termination in the white area is for the insertion of the initial condition ✓ voltage (V_o). The IC input should be equal in magnitude but opposite in polarity to the desired IC, i.e., if an IC of -10 volts is desired (the output of the integrator to equal -10 volts at the instant integration starts) then a +10 volt potential must be applied to the IC termination.

The SJ' termination is connected to the integrator summing junction when the unit is in the reset mode. If desired, the amplifier may be used to multiply the actual input IC voltage by a constant by connecting an input resistor to the SJ' termination of appropriate value.

Directly below each of the two all-white patching areas are a pair of terminations (in a cross hatched area) labeled 10β. For normal time scale integrator operation, these two terminations must be jumpered together. The removal of the 10β jumper changes the integrator time scale by a factor of 10 (faster integration rate).

The 10β jumper also affects the integration rate when the computer is in repetitive operation. With the 10β jumper in place the Rep-Op rate is 500 times faster than real time; when the jumper is removed the Rep-Op rate is increased by a factor of 10, or 5000 times faster than the normal time rate. Since each integrator section of the dual unit has a 10β jumper, the time scale of each integrator may be controlled independently.

Note that failure to insert the 10β jumper when desiring to operate an integrator at normal time results in integrator gains of 10 and 100 instead of 1 and 10 respectively and will probably cause the amplifier to overload during problem solution.

For additional flexibility, the operate and reset buses as well as the operate and reset relay coils are also terminated at the Pre-Patch Panel. These circuits terminate in the cross-hatched area at the bottom of the integrator patching block. For normal integrator operation, a four-connector bottle plug is placed in this area (the terminations are therefore jumpered horizontally). Terminating these circuits at the Pre-Patch Panel permits interchanging leads (such as connecting the operate relay to the reset bus and the reset relay to the operate bus); this facilitates the setup of a form of track (or sample) and hold.

The time scale bus (TS) for repetitive operation terminates in the cross hatched area just below the upper 10β area. When desiring to operate in the normal repetitive operation mode, a two-connector jumper is placed between the lower two horizontal terminations of this cross hatched area.

By placing the two-connector jumper between the TS and OPR terminations in the upper half of the cross-hatched area (with jumper in lower half removed) the dual integrator may be made to operate in real time when the computer is placed in the Rep-Op mode. This facilitates the usage of the integrators for iterative computation.

b. Theory of Operation

The integrating network essentially provides the high-gain amplifiers with a capacitive feedback element in place of the resistive feedback component. In addition, relays are provided for time scaling, permitting the insertion of an IC voltage, and controlling the integrator operation (Figure 2.2-2).

Taking the algebraic sum of the input currents, if forced to pass through a feedback capacitor rather than a resistor, the current equation at the summing junction becomes:

$$c \frac{de_o}{dt} = - \left[\frac{e_1}{R_1} + \frac{e_2}{R_2} + \frac{e_3}{R_3} + \ldots \right] \qquad \text{(EQ. 2.2-1)}$$

where c = capacitance in farads
e_o = amplifier output voltage
e_1, e_2, e_3, etc. = input voltages
R_1, R_2, R_3, etc. = input resistor values in ohms

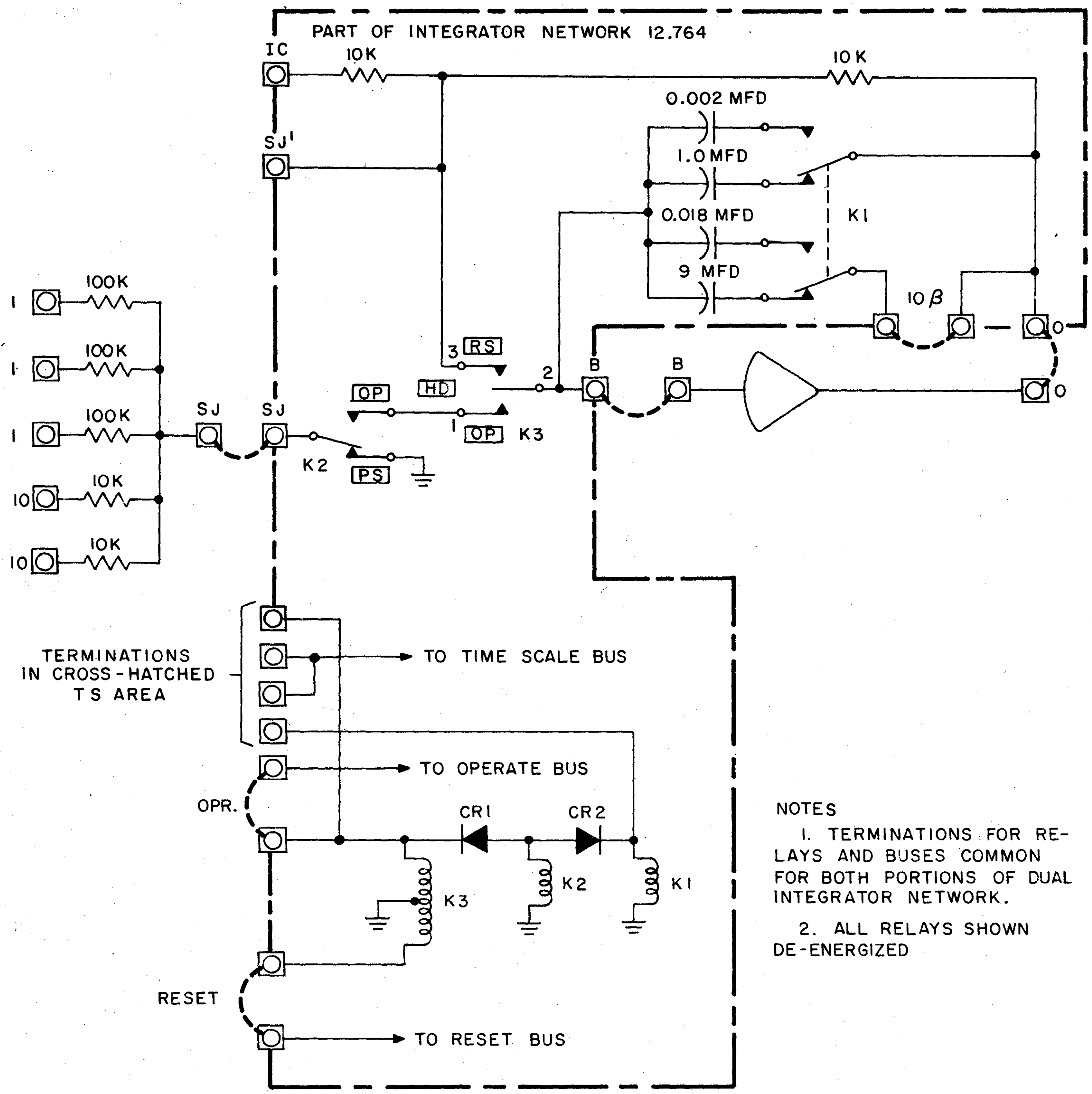
The relationships in equation 2.2-1 depend on the fact that when current passes through a capacitor, the voltage across the capacitor changes at a rate proportional to the current. By integrating and assuming an initial condition (IC) voltage, (V_o) across the capacitor, equation 2.2-1 becomes:

$$e_o = - \frac{1}{c} \int_o^t \left[\frac{e_1}{R_1} + \frac{e_2}{R_2} + \frac{e_3}{R_3} + \ldots \right] dt + V_o \qquad \text{(EQ. 2.2-2)}$$

If c has a value of 10 microfarads and all of the input resistors have a value of 100,000 ohms the RC time constant is one second. Equation 2.2-2 therefore reduces to:

$$e_o = - \int_o^t [e_1 + e_2 + e_3 + \ldots] \, dt + V_o \qquad \text{(EQ. 2.2-3)}$$

where t is in seconds.



NOTES

1. TERMINATIONS FOR RELAYS AND BUSES COMMON FOR BOTH PORTIONS OF DUAL INTEGRATOR NETWORK.

2. ALL RELAYS SHOWN DE-ENERGIZED

FIGURE 2. 2-2. INTEGRATOR, SIMPLIFIED SCHEMATIC

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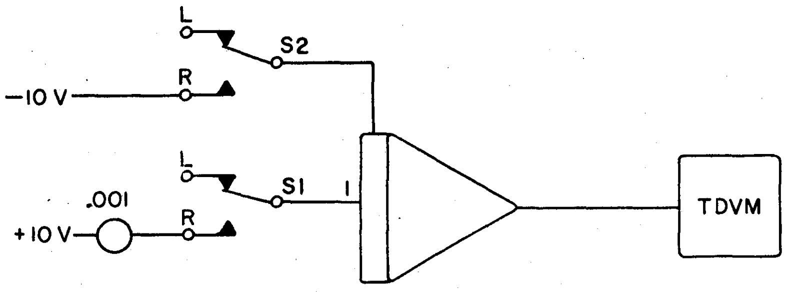


FIGURE 2.2-3 INTEGRATOR OPERATIONAL TEST SETUP

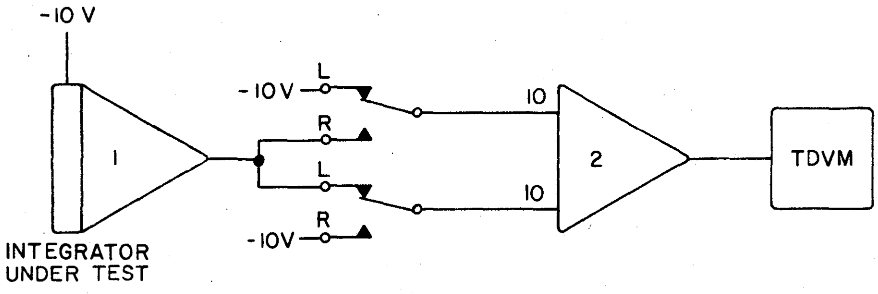


FIGURE 2.2-4 IC RESISTOR-RATIO CHECK CIRCUIT

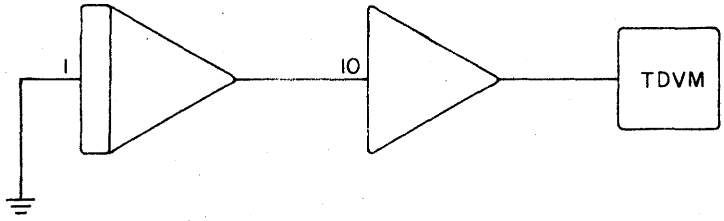


FIGURE 2.2-5 INTEGRATOR DRIFT-RATE TEST SETUP

If one of the input resistors is changed to some value other than 100K (X ohms), then the corresponding input voltage must be multiplied by a factor of 100K/X before the summation and integration indicated by equation 2.2-3. As an example, assume the input resistor for e_3 is 10K ohms; equation 2.2-3 becomes:

$$e_o = - \int_o^t [e_1 + e_2 + 10e_3 + . . .] \quad dt + V_o \qquad \text{(EQ. 2.2-4)}$$

Similarily, should the capacitance of c change to a value of Y microfarads, then <u>all</u> of the inputs must be multiplied by a factor of 10/Y (where Y is in microfarads) before summation and integration. As an example, when the TR-48 is placed in repetitive operation (with the 10β plug in place) the feedback capacitor beomes 0.02 microfarads. Each input must therefore be multiplied by a factor of 10/0.02 or 500. Should c be changed to 0.02 microfarads and the input resistor changed from 100K to 10K, that particular input is multiplied by 10/0.02 times 100K/10K or 5000.

It can be seen, therefore, that the integrator rate-of-integration may be changed for individual inputs by changing the value of the input resistor, or the rate may by changed for all of the inputs by changing the value of the feedback capacitor.

A normal-time rate integrator of the TR-48 produces an output voltage rate of change of 1 volt-per-second per-volt input via a 100K resistor, and a output change of 10 volts-per-second per-volt input when the input is applied via a 10K resistor (gain-of-one and gain-of-ten inputs of the dual d-c amplifier, respectively). With the 10β plug removed, the gain-of-one and ten inputs provide a 10 volt-per-second per-volt and a 100 volt-per-second per-volt rate-of-change respectively.

The integrator, unlike most computational components, produces a varying output with a fixed input; therefore, if the integrators are controlled by the computer mode switches the overall operation of the computer is actually being controlled. The relays, K1, K2, and K3, of Figure 2.2-2 control the integrator operation in response to the computer mode switches. The following sub-paragraphs describe the relay positions for each of the computer modes and the integrator operation in each of these modes.

(1) <u>Pot-Set Mode</u>. In the pot-set mode all three of the relays are de-energized and attain the positions shown in Figure 2.2-2. Relay K2 grounds the resistor summing junction thus permitting the adjustment of any potentiometers connected to the integrator input under actual load.

(2) <u>Reset Mode</u>. Relay K3 is energized via the reset bus (contacts 2 and 3 make) and the capacitors are charged to the potential applied to the IC termination. Relays K1 and K2 remain de-energized.

(3) <u>Operate Mode</u>. Relay K3 is energized via the operate bus (contacts 1 and 2 make). Relay K2 is also energized by the operate bus via diode CR1. The inputs applied to the resistor network are applied to the amplifier and integrated.

(4) Hold Mode. This mode de-energizes all the relays; thus, integration is stopped and the unit is essentially in the pot-set condition. The main difference is that the pot set relay of the dual d-c amplifier is not energized; thus the amplifier output remains at the level determined by the charge on the feedback capacitor.

(5) Rep-Op Mode. This mode energizes the TS bus which in turn pulls in K1 and K2 (via CR2) and maintains them in the energized state as long as the computer is in repetitive operation. Relay K3 remains free to respond to the reset and operate bus voltages.

c. Maintenance

Since the high-gain amplifier and integrator-networks are contained in separate modules it is relatively simple to localize malfunctioning units. Integrator malfunctions are not normally due to the integrator network because the network contains so few components and these components are conservatively rated. Most integrators with unacceptable characteristics probably are caused by a high-gain amplifier that has high offset; consequently all tests should be performed with an amplifier of known satisfactory characteristics.

(1) Test Procedures

(a) Operational Check. The following simple operational check indicates the qualitive performance of the integrator.

(1) Patch the test circuit shown in Figure 2.2-3. Place the computer in the reset mode.

(2) Close S1; the TDVM should read zero.

(3) Close S2; the TDVM should read +10 volts.

(4) Place the computer in hold. The TDVM reading should remain at +10 volts.

(5) Place the computer in operate. The integrator output should change linearly from +10 volts at a rate of minus one volt per second. (A stop watch will normally be of sufficient accuracy for maintenance purposes for this test. If accurate measurement is required a more elaborate time-measuring procedure is required.)

(6) After exactly 20 seconds of operation place the computer in hold; the TDVM should read -10 volts.

(7) Place the computer in reset; the TDVM should read +10 volts.

(2) Initial Condition Resistor Ratio Check

(a) Set up the test circuit shown in Figure 2.2-4. Place the computer in the reset mode.

(b) Place both function switches in the left (L) position; record the TDVM reading.

(c) Place both function switches in the right (R) position; record the TDVM reading.

(d) The algebraic average of the readings in (b) and (c), divided by 10, should be less than 20 millivolts. (The algebraic average is the algebraic sum divided by two.)

(e) If the results of this test are unsatisfactory, the initial condition resistors are probably out of tolerance.

(3) Integrator Drift Rate

(a) Set up the test circuit shown in Figure 2.2-5. Place the computer in the reset mode.

(b) Place the computer in operate; after 100 seconds record the TDVM reading.

(c) The meter reading should be less than 0.05 volts; 0.05 volts corresponds to a drift rate of 50 microvolts per second.

d. Trouble Analysis

A point-to-point resistance check is the quickest way to troubleshoot a malfunctioning integrator network. Comparison of readings with a properly functioning unit will frequently aid in isolating faulty components. The following table lists symptoms and probable causes for some malfunctions; this table assumes the high-gain amplifier is functioning properly. The table is not complete for all possible symptoms and causes; however, it should serve as a guide in troubleshooting.

Mode	Symptom of Malfunction	Probable Cause
Reset	Amplifier output is zero for all initial condition inputs.	1. Open IC input resistor. 2. Reset relay not operating. 3. Shorted feedback capacitor.
	Amplifier goes into overload if inputs are connected.	Operate Relay is energized.

Mode	Symptom of Malfunction	Probable Cause
Reset (cont.)	Amplifier goes into overload when IC input is applied. The amplifier holds the voltage reached while in operation with no IC input	Open IC feedback resistor.
	The amplifier output is not equal in magnitude to the initial condition input.	Ratio of IC Resistors is not unity.
Hold	Amplifier will not hold voltage reached during operation but resets to the IC input.	Reset relay energized.
	Amplifier will not hold voltage reached during operation nor will it hold the IC input level.	Leaky or open feedback capacitor.
Operate	Integrator does not have the proper integration rate.	Check circuit time constants. Wrong value of input resistor or feedback capacitor used (check 10β plugs).

(1) Applicable Drawings. The following drawings are contained in Volume II of this handbook.

Drawing Number	Type	Description
C012 764 OS	Schematic	Schematic Diagram of Dual D.C. Integrator Model 12.764.
B045 034 OW	Wiring	Contains sheets listing wiring from the 12.764 rear mating connector to other points within the computer.

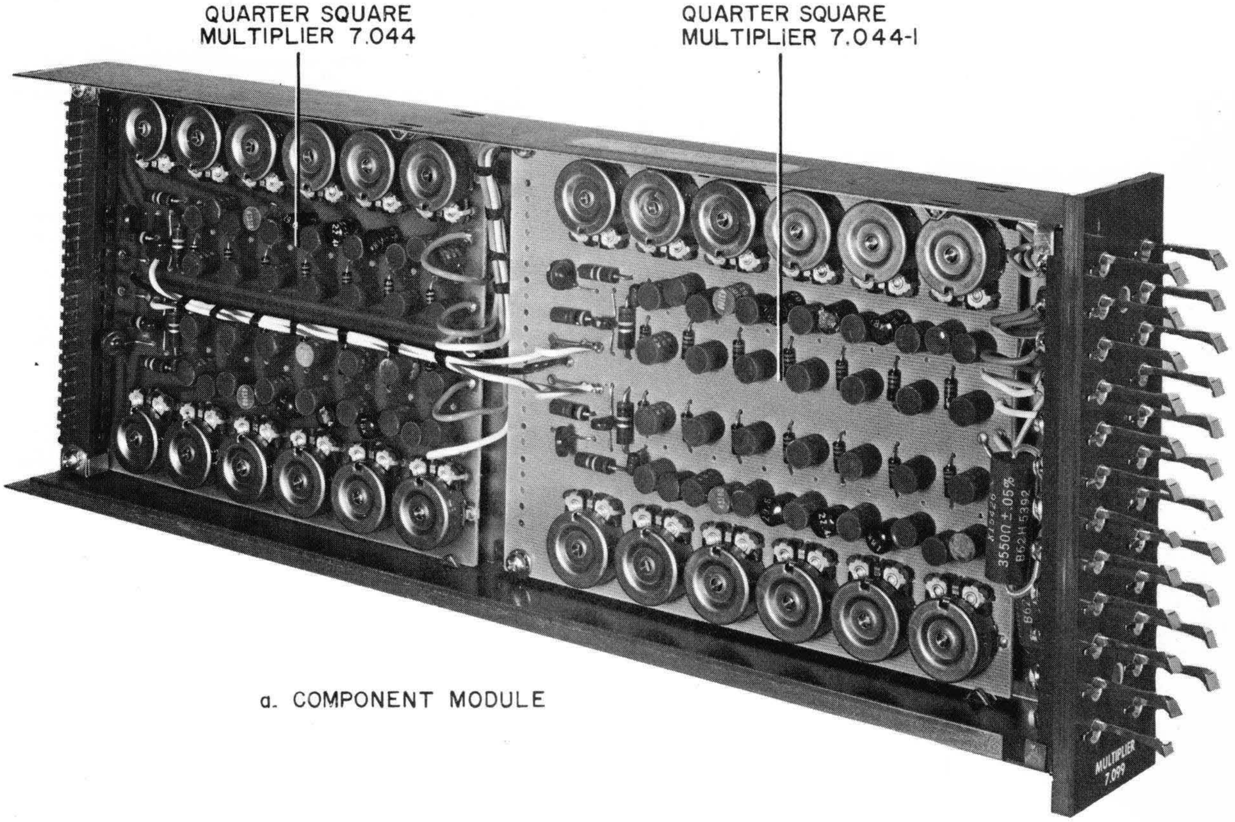
(2) Parts Lists. Appendix I contains the replaceable parts lists for the 12.764 Integrating Network. See Index of Appendix I.

3. QUARTER-SQUARE MULTIPLIER 7.099

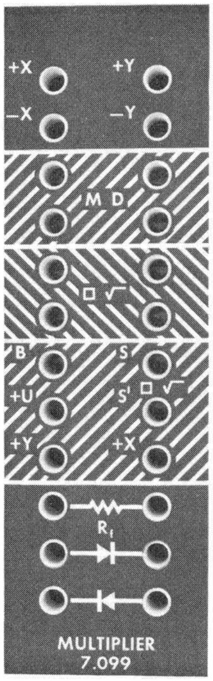
The Model 7.099 Quarter-Square Multiplier as the input impedance of an external high-gain amplifier permits the multiplication of two variables (Figure 2.3-1). This unit utilizes the quarter-square multiplication technique to produce the product of two variables (X and Y) as illustrated by equation 2.3-1.

$$XY = \frac{1}{4} [(X + Y)^2 - (X - Y)^2] \qquad \text{(EQ. 2.3-1)}$$

TR-48
#72,57



a. COMPONENT MODULE



b. PATCHING BLOCK

NOTE

THE 7.044 AND 7.044-I ARE PHYSICALLY AND ELECTRICALLY IDENTICAL EXCEPT THE 7.044-I DOES NOT HAVE A PLUG CONNECTOR

FIGURE 2.3-I QUARTER SQUARE MULTIPLIER, MODEL 7.099

The TR-48 quarter-square multiplier is basically a biased-diode circuit application of this technique. The design and Pre-Patch Panel termination configuration is such that the multipliers are also capable of division, squaring*, and obtaining the square root of an input variable.

a. Operating Considerations

As previously indicated, the quarter-square multiplier is capable of performing four primary functions. The patching procedures for the multiplier divides these four functions into two separate groups: the multiplication-division group and the square-square root group. The two upper cross hatched areas of the patching block are marked with a capital MD and a small square and square root sign respectively. A four-connector bottle plug connected in one or the other of these areas determines which functions the multiplier can perform.

Placing the four-connector plug in the square-square root area, leaving the MD exposed, prepares the multiplier for multiplication or division. Placing the four connector plug in the MD area, leaving the small square and square root sign exposed, prepares the multiplier for squaring and/or obtaining the square root of an input variable. Note in each case that the function to be performed is exposed, while the bottle plug covers the other cross hatched area. This feature permits the operator to glance at a multiplier and tell whether its being used for multiplication-division or square-square root operation.

Figure 2.3-2 is a simplified patching diagram of the quarter-square multiplier. During multiplication both the positive and negative X and Y inputs are required even if neither of these inputs change sign during the problem solution. (The X and Y inputs are applied as shown in the figure regardless of the actual polarity of these variables.)

The multiplier is used as the input impedance for the operational amplifier when multiplying two variables. For division the multiplier is used as a <u>feedback element</u> for the operational amplifier. See the Operator's Handbook for the patching procedure for division, squaring, or square root operation.

When using the multiplier for division the following restrictions must be observed:

(1) The absolute value of the divisor must always be greater than or equal to the absolute value of the dividend.

(2) The divisor must not change sign. The divisor may be either positive or negative but it must not change in sign during a problem run.

(3) The divisor must never equal zero.

b. Theory of Operation

As previously stated the 7.099 multiplier utilizes the quarter-square multiplication technique illustrated by equation 2.3-1.

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*The unit actually produces the product of X times the absolute value of X; thus, the "X^2" output will change sign with a sign change of X.

The TR-48 quarter-square multipliers employ diode function generators which in one case sums the two input variables and squares this sum. The output current of this DFG is in proportion to the quantity $1/4\ (X + Y)^2$. A second DFG takes the difference of the two inputs and squares this difference; the output in this case is negative and in proportion to $-1/4\ (X - Y)^2$. If these two currents are summed by an operational amplifier with an appropriate value feedback resistor, equation 2.3-1 is satisfied as follows:

$$1/4\ (X + Y)^2 + [-1/4\ (X - Y)^2] = 1/4\ [(X + Y)^2\ -\ (X - Y)^2] = XY \qquad \text{(EQ. 2.3-2)}$$

The two DFG outputs are scaled by a factor of one tenth; thus, the summing amplifier output is actually 1/10 of the product XY. This permits both inputs, X and Y, to reach a magnitude of 10 volts and not overload the amplifier. In addition, the amplifier inverts the input polarity; therefore, the amplifier output is actually -XY/10.

Figure 2.3-3 is a simplified schematic of the $(X + Y)^2$ DFG portion of the quarter-square multiplier. Each diode is back-biased at a different negative potential; thus, as the sum of X and Y increases, more diodes conduct (or reach their break points). As each diode conducts, the ratio of the feedback to input impedance of the amplifier changes in a pre-determined manner such that the amplifier output approximates the $(X + Y)^2$ curve. The input resistor and bias potential are selected so that the current through the diodes is equivalent to one tenth the square of X plus Y. By providing a second DFG to produce an output current equivalent to minus one-tenth the square of the difference between X and Y and connecting it to the input of the amplifier for summation with the $(X + Y)^2$ current, equation 2.3-2 is satisfied.

To permit the multipliers to accept positive and negative values of either or both X and Y inputs and to allow both to vary in magnitude such that either may be larger, a combination of DFG units is required.

Figure 2.3-4 is a simplified schematic of a quarter-square multiplier patched for multiplication. In the multiplier there are actually four DFG units similar to the one shown in Figure 2.3-3. In Figure 2.3-4, however, each DFG unit is simplified and shown as a composite with one diode, bias resistor, etc. At any one time only two of the four cards will conduct and produce the product of X and Y at the amplifier output.

Considering that either or both X and Y can be negative and that either may be the larger, there are eight combinations of polarity and magnitude relationships of X and Y that may be applied to the multiplier. All eight of these combinations are listed in Table 2.3-1; the DFG card designation (1, 2, 3, or 4) corresponds to the notations of Figure 2.3-4.

Note that on Figure 2.3-4 as well as on the actual Pre-Patch Panel of the TR-48 the X and Y input terminations are designated as +X, +Y, -X, and -Y. The sign designations of these terminations do not necessarily indicate the actual polarity

TR48
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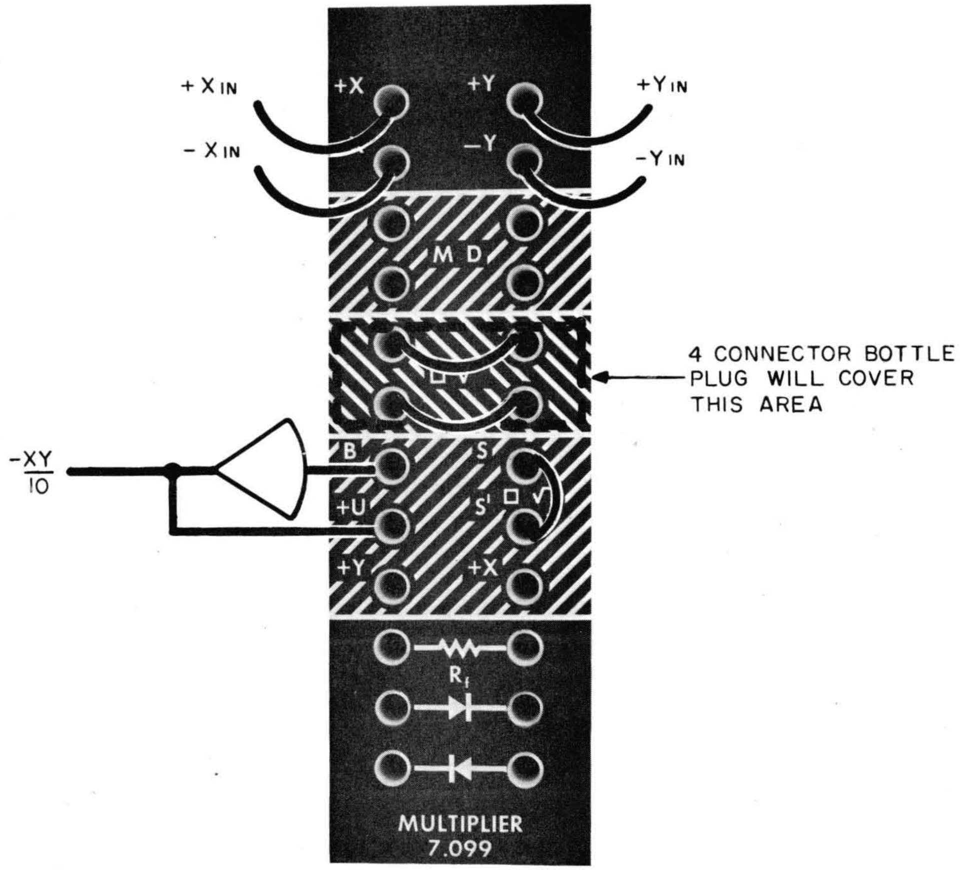

FIGURE 2.3-2 MULTIPLICATION PATCHING

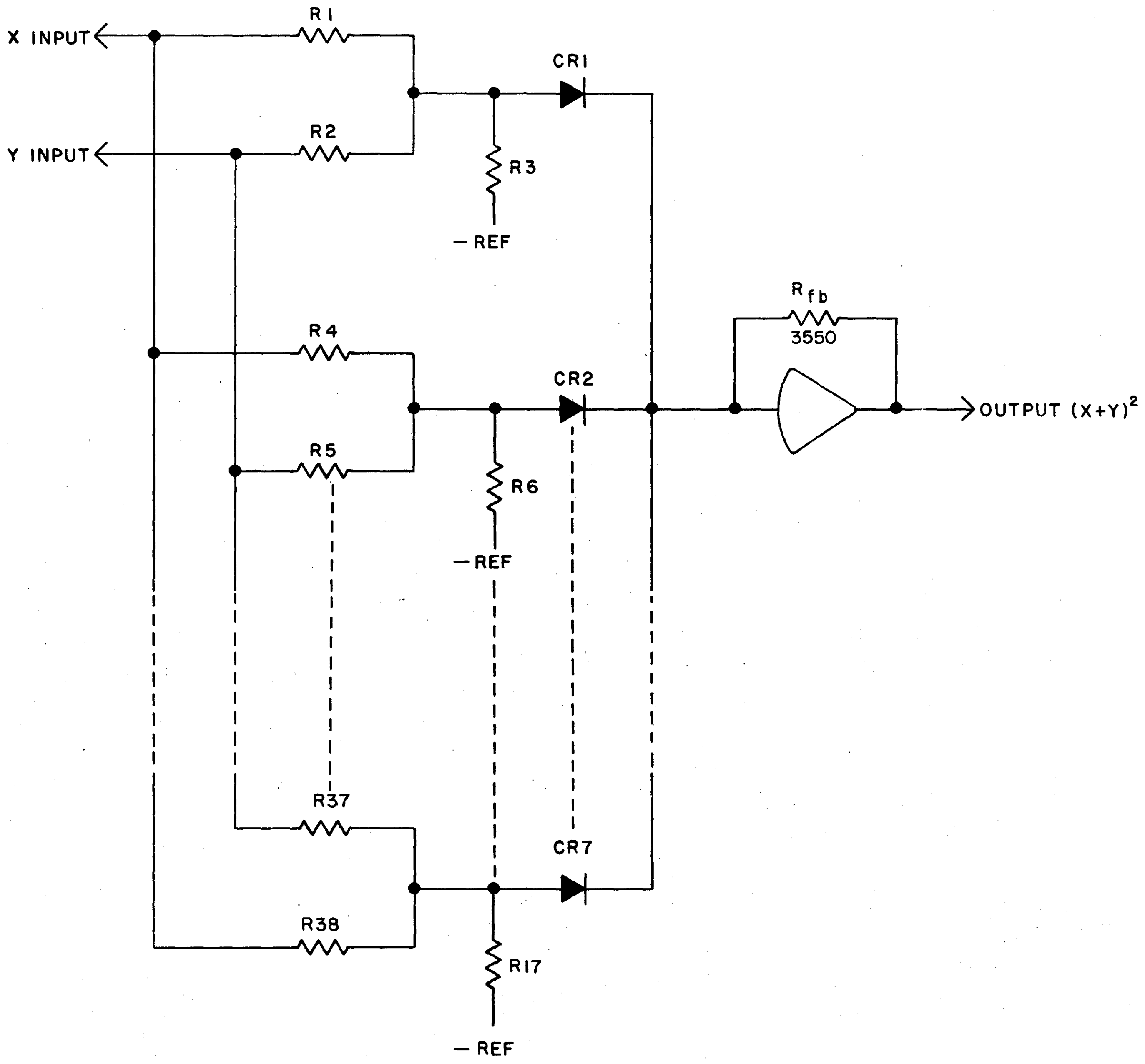

FIGURE 2.3–3. SIMPLIFIED PARTIAL–SCHEMATIC OF ONE SQUARING CIRCUIT

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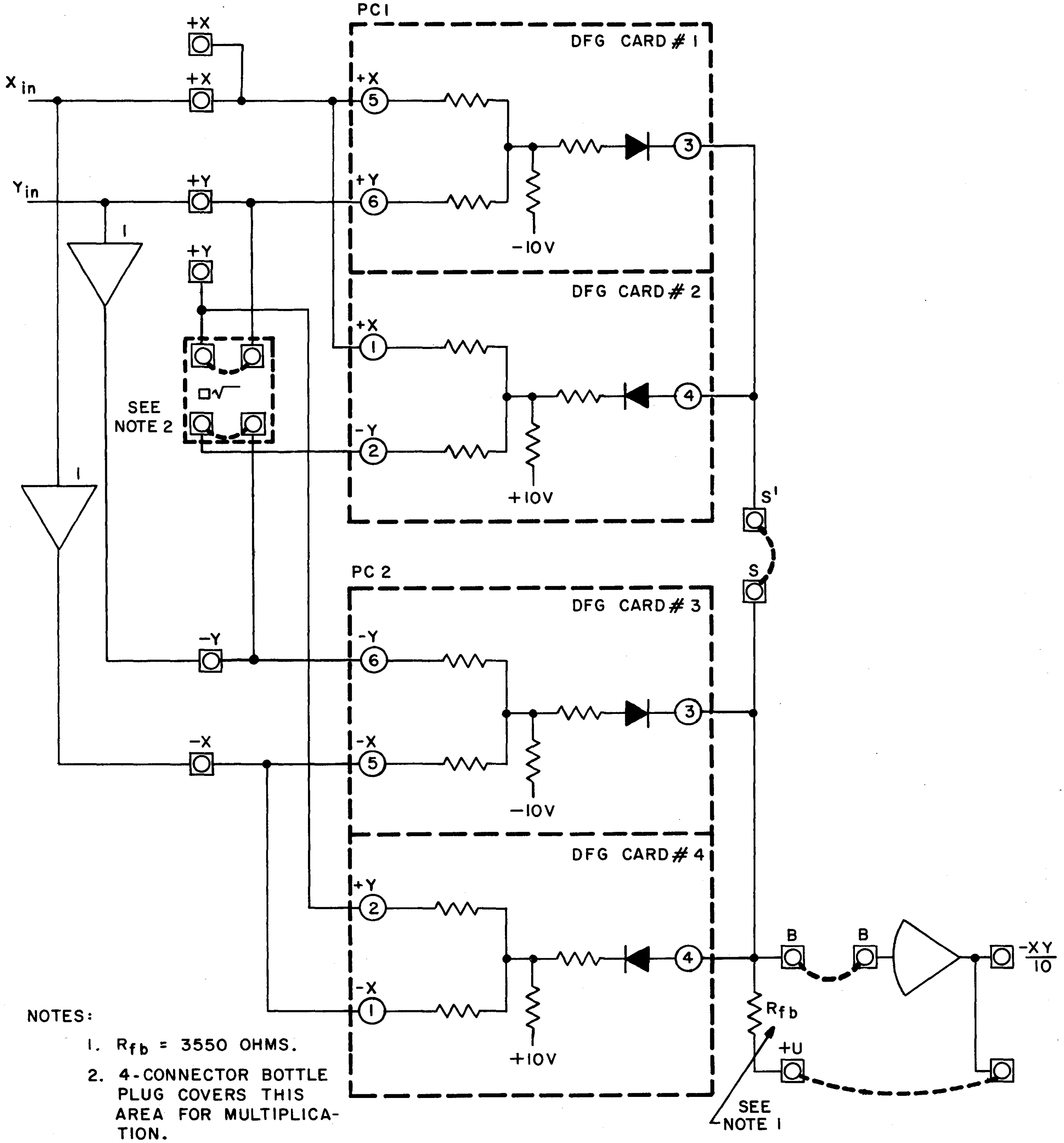


NOTES:

1. R_{fb} = 3550 OHMS.
2. 4-CONNECTOR BOTTLE PLUG COVERS THIS AREA FOR MULTIPLICATION.

FIGURE 2.3-4. MULTIPLICATION PATCHING AND SIMPLIFIED SCHEMATIC.

of either X or Y. The X and Y variables as they are multiplied for the problem solution are applied to +X and +Y respectively, regardless of their actual polarity. The inversion of these signals are applied to -X and -Y. Thus, even if the problem variable X is always negative, it is still patched to +X and the inverted problem variable X is patched to -X.

The first column of Table 2.3-1 gives the eight possible input combinations of X and Y. The second column indicates the DFG unit considered in the remaining columns. The third column indicates the actual polarity of X and Y applied to the cards with respect to the conditions of column 1. The fourth column indicates the polarity of the resultant summation of X and Y and the fifth column indicates the bias potential applied to the card diodes. For a card to conduct and provide an output, columns four and five must be of opposite polarity, otherwise the X and Y summation adds to the back bias of the diodes.

The last column (card output) indicates whether or not a card is conducting and if the current is proportional to the sum of X and Y or the difference (indicated as $(X + Y)^2$ and $(X - Y)^2$ respectively). These designations do not indicate the polarity of the signals and are not intended to indicate that a voltage may be read out at the amplifier summing junction (the amplifier summing junction is normally at virtual ground potential).

As an example of the quarter-square multiplier operation consider the first input combination of Table 2.3-1. X is positive, Y is positive and X is always larger than Y. DFG cards 2 and 3 do not conduct because in each case the summation of X and Y is additive to the reverse bias of the card diodes (as long as the three conditions as stated above hold true).

Card 1 will conduct because the summation of X and Y is positive and will overcome the negative reverse bias of the card. The number of diodes that conduct is dependent on the magnitude of this summation. Card 1 will produce a current output that is proportional to one-tenth of $1/4\ (X + Y)^2$ thus satisfying half of equation 2.3-1.

Card 4 will also conduct because the summation of X and Y is negative in polarity and the diodes are reverse biased by a positive potential. (The inverted polarity of the variable X is applied to this card and because X is larger than Y the resultant summation must be negative.) Since X and Y are opposite in polarity the resultant current output satisfies the $(X - Y)^2$ portion of the equation. In addition, because X is larger and negative, this current is equivalent to minus one-tenth of $1/4\ (X - Y)^2$. Thus, equation 2.3-1 is satisfied as follows:

$$\frac{1/4\ (X + Y)^2}{10} - \frac{1/4\ (X - Y)^2}{10} = \frac{1/4\ [(X + Y)^2 - (X - Y)^2]}{10} = \frac{XY}{10} \qquad \text{(EQ. 2.3-3)}$$

The XY product of the quarter-square multiplier is actually negative, however, due to the inversion by the amplifier.

Note that the cards supplying the $(X + Y)^2$ current and $(X - Y)^2$ current of the first two and last two input combinations of Table 2.3-1 are opposite to that of the middle four combinations, i.e., $(X + Y)^2$ is due to a positive X and Y summation in one case, and due to a negative X and Y summation in the other. This indicates the middle four combinations will produce a product opposite in polarity to the other four combinations; this should be the case since the middle four combinations consist of X and Y inputs of opposite sign.

c. Maintenance and Test Procedures

The Quarter-Square Multiplier is factory calibrated prior to shipment; re-calibration should not be attempted unless definitely indicated after throughly checking the unit. The multiplier requires the use of external high-gain amplifiers; ascertain that these components are functioning properly before attempting to troubleshoot the multiplier.

(1) D.C. Error Check

(a) Set up the test circuit shown in Figure 2.3-5. The input/feedback resistors of the amplifiers should be matched to ±0.02% or better.

(b) Set the oscillator for a frequency of 5 cycles/second at 20 volts peak-to-peak amplitude.

(c) Set the oscilloscope Y sensitivity to 10 millivolts/centimeter D.C. with zero reference in the center. Set the X sensitivity for 2 volts/centimeter.

(d) With both function switches in the position shown, observe the scope trace; Figure 2.3-5b. This waveform should not exceed 100 millivolts peak-to-peak. (This set up checks the two squaring circuits on PC1.)

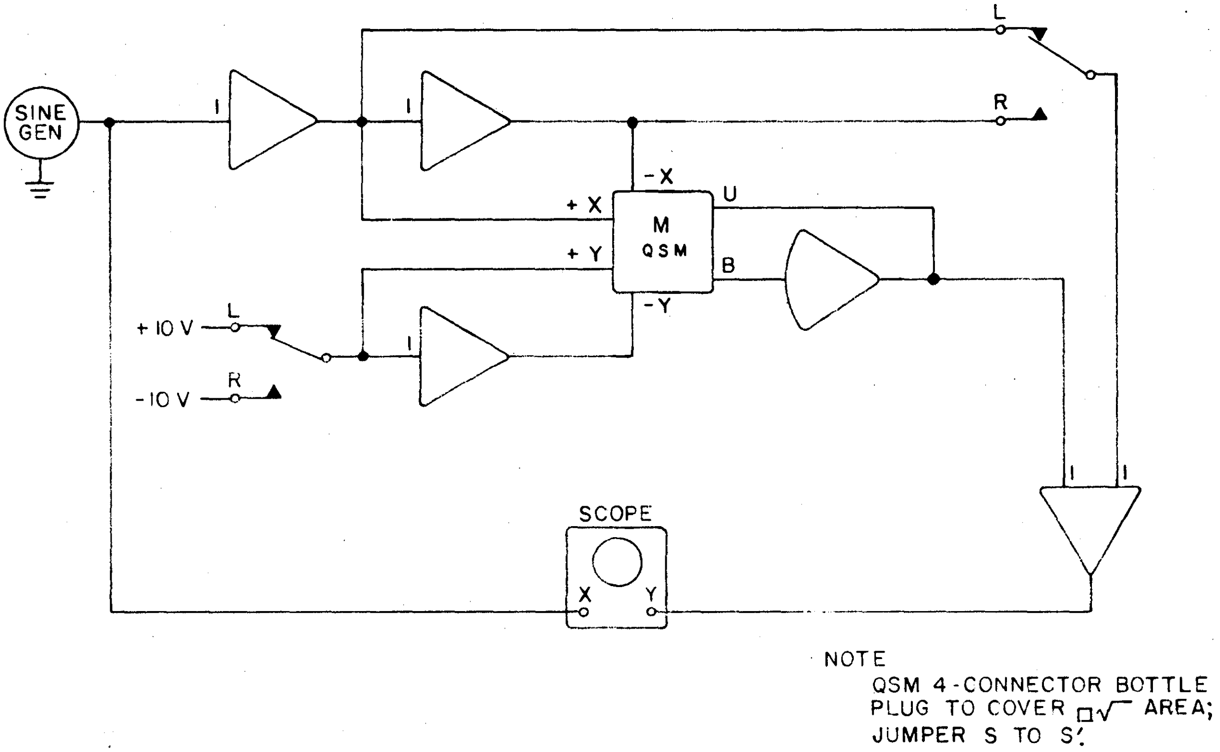
(e) Place both function switches in the R position; observe the scope trace. (This setup checks the two squaring circuits on PC2.)

(2) Phase Shift and Gain Error Check

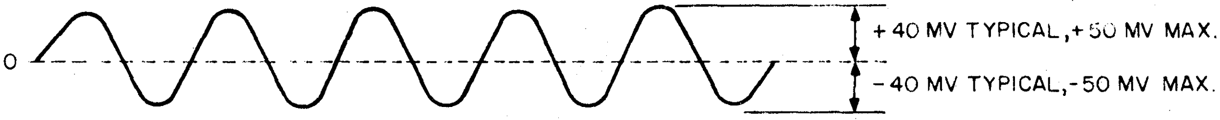
(a) Retain the test setup of Figure 2.3-5. Increase the oscillator frequency to 1 KC at 20 volts peak-to-peak.

(b) With both function switches as shown on Figure 2.3-5, observe the scope trace and compare to Figure 2.3-6. The distance from A to B represents the phase shift error in millivolts (90 millivolts peak-to-peak maximum or 0.26 degrees). The distance from C to D represents the gain error in millivolts (160 millivolts peak-to-peak maximum). (This checks PC1.)

(c) Repeat step (b) with both function switches in the R position to check PC2.



a. TEST SETUP



b. 5.c.p.s. WAVEFORM

FIGURE 2.3-5 MULTIPLIER DC ERROR TEST SETUP AND TYPICAL WAVEFORM

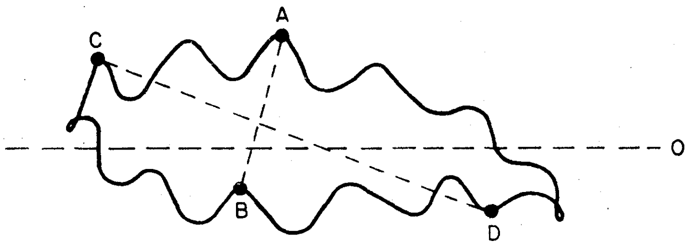


FIGURE 2.3-6 1 KC WAVEFORM

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TABLE 2.3-1 Multiplier Input Combination and Card Conduction Sequence*

X and Y Polarity & Magnitude Relationship	DFG Card Designation	Actual Card Input Polarity	Polarity of X & Y Summation	Card Bias Polarity	Card** Output
X positive (+) Y positive (+) X>Y	1	X (+), Y (+)	(+)	(-)	$(X + Y)^2$
	2	X (+), Y (-)	(+)	(+)	None
	3	X (-), Y (-)	(-)	(-)	None
	4	X (-), Y (+)	(-)	(+)	$(X - Y)^2$
X positive (+) Y positive (+) X<Y	1	X (+), Y (+)	(+)	(-)	$(X + Y)^2$
	2	X (+), Y (-)	(-)	(+)	$(X - Y)^2$
	3	X (-), Y (-)	(-)	(-)	None
	4	X (-), Y (+)	(+)	(+)	None
X positive (+) Y negative (-) X>Y	1	X (+), Y (-)	(+)	(-)	$(X - Y)^2$
	2	X (+), Y (+)	(+)	(+)	None
	3	X (-), Y (+)	(-)	(-)	None
	4	X (-), Y (-)	(-)	(+)	$(X + Y)^2$
X positive (+) Y negative (-) X<Y	1	X (+), Y (-)	(-)	(-)	None
	2	X (+), Y (+)	(+)	(+)	None
	3	X (-), Y (+)	(+)	(-)	$(X - Y)^2$
	4	X (-), Y (-)	(-)	(+)	$(X + Y)^2$
X negative (-) Y positive (+) X>Y	1	X (-), Y (+)	(-)	(-)	None
	2	X (-), Y (-)	(-)	(+)	$(X + Y)^2$
	3	X (+), Y (-)	(+)	(-)	$(X - Y)^2$
	4	X (+), Y (+)	(+)	(+)	None
X negative (-) Y positive (+) X<Y	1	X (-), Y (+)	(+)	(-)	$(X - Y)^2$
	2	X (-), Y (-)	(-)	(+)	$(X + Y)^2$
	3	X (+), Y (-)	(-)	(-)	None
	4	X (+), Y (+)	(+)	(+)	None
X negative (-) Y negative (-) X>Y	1	X (-), Y (-)	(-)	(-)	None
	2	X (-), Y (+)	(-)	(+)	$(X - Y)^2$
	3	X (+), Y (+)	(+)	(-)	$(X + Y)^2$
	4	X (+), Y (-)	(+)	(+)	None
X negative (-) Y negative (-) X<Y	1	X (-), Y (-)	(-)	(-)	None
	2	X (-), Y (+)	(+)	(+)	None
	3	X (+), Y (+)	(+)	(-)	$(X + Y)^2$
	4	X (+), Y (-)	(-)	(+)	$(X - Y)^2$

* When $X \doteq Y$ in magnitude, either the X + Y or X - Y term equals zero; thus only one card will actually conduct. As an example, when X = Y and both are positive in polarity only card 1 conducts; if both are negative only card 4 conducts.

** See Text

(3) Diode Break-Point Check and Adjustment. The following procedure permits checking of the multiplier diode break-point settings. Before attempting to change any of the break-point potentiometer adjustments, double check the test set-up; be certain that the associated amplifiers are functioning properly, and be sure the proper potentiometer is being adjusted.

(a) Patch the multipliers as shown in Figure 2.3-7b.

(b) Apply the positive inputs listed in Table 2.3-2 (in sequence starting at 2.5V) for Figure 2.3-7b. The TDVM should read out the potential listed in the output column in each case. (Note that the output may be ±0.01 volt.)

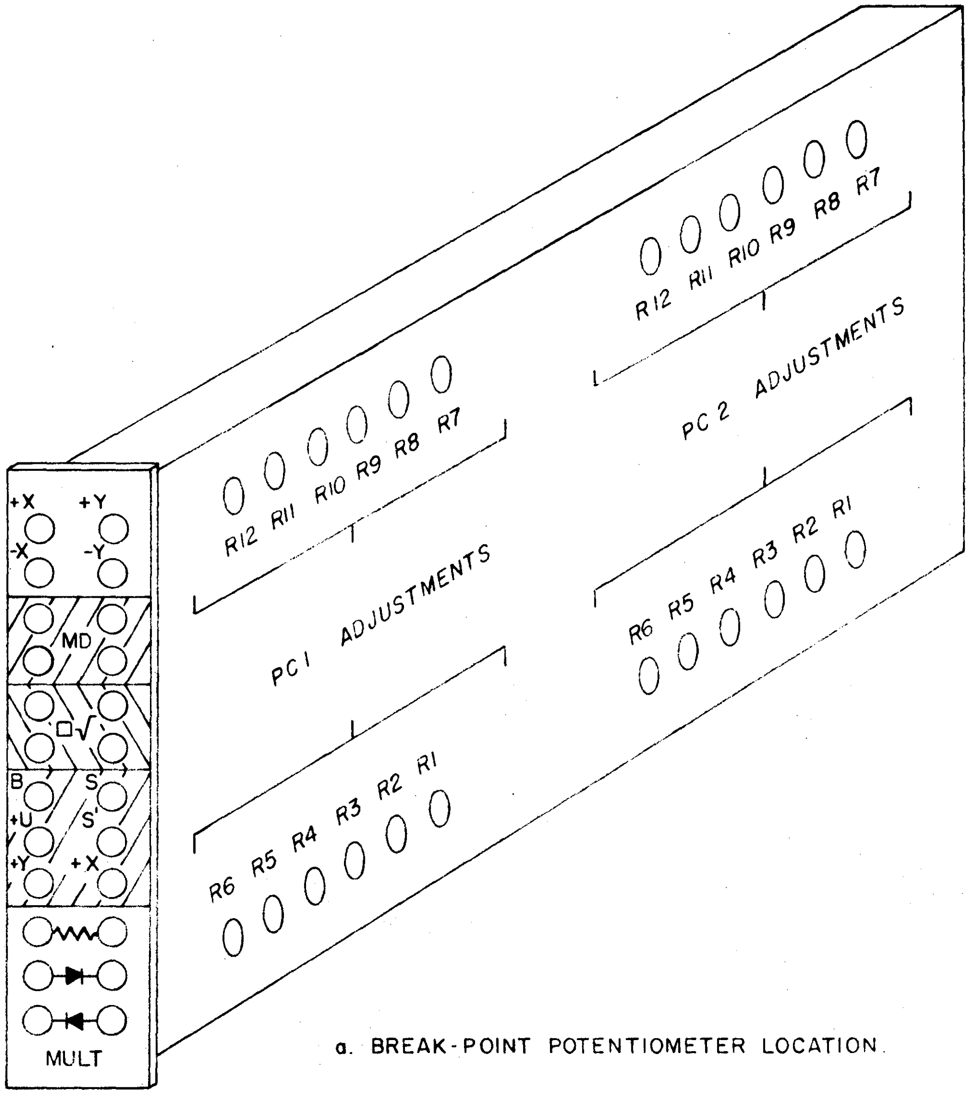
(c) If any output reading indicates adjustment is necessary, adjust the potentiometer listed in the potentiometer column.

(d) Repeat steps (b) and (c) as necessary; interaction of the DFG break-point settings necessitates this procedure for optimum accruacy.

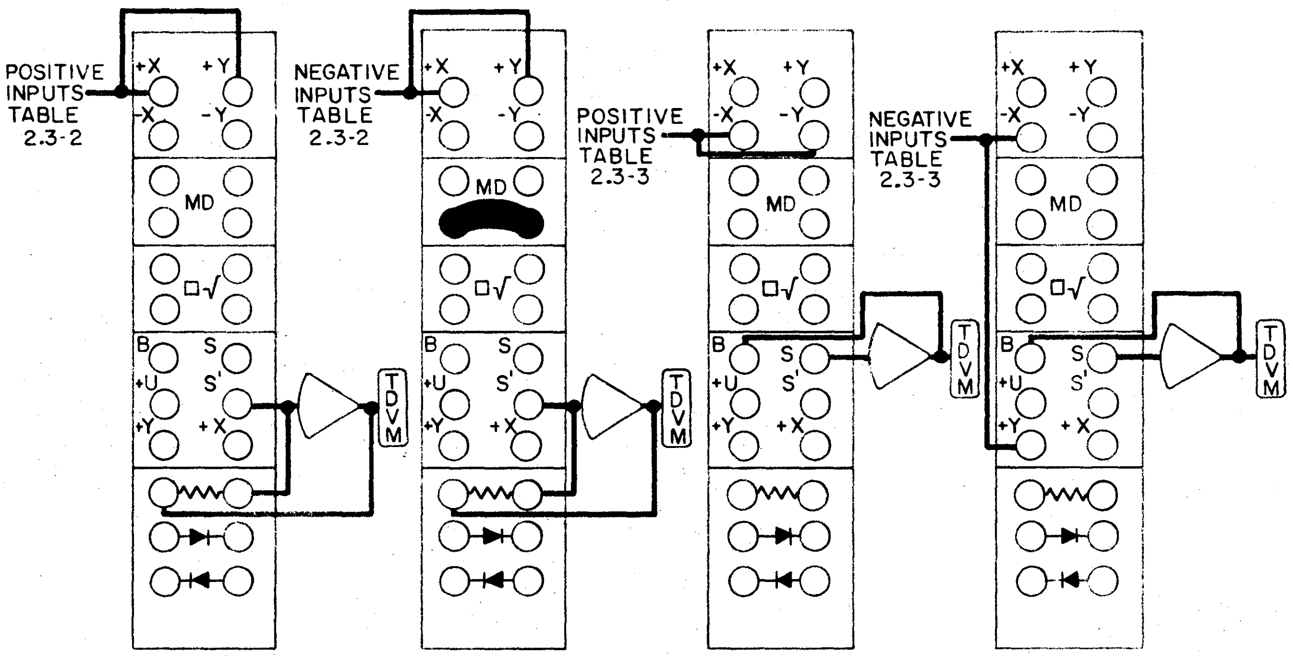
(e) Patch the multiplier as shown in Figure 2.3-7c. (Note the patch connection in the lower portion of the MD area; note also that the +Y termination at the top of the patching block must be used.)

TABLE 2.3-2 Multiplier Adjustment Data; PC1

Figure Reference	Input Voltage	Potentiometer	Output
Figure 2.3-7b	+2.5V	PC1-R1	-0.64V ±.01
	+3.9V	PC1-R2	-1.54V ±.01
	+5.3V	PC1-R3	-2.82V ±.01
	+6.7V	PC1-R4	-4.50V ±.01
	+8.1V	PC1-R5	-6.58V ±.01
	+9.5V	PC1-R6	-9.04V ±.01
Figure 2.3-7c	-2.5V	PC1-R7	+0.64V ±.01
	-3.9V	PC1-R8	+1.54V ±.01
	-5.3V	PC1-R9	+2.82V ±.01
	-6.7V	PC1-R10	+4.50V ±.01
	-8.1V	PC1-R11	+6.58V ±.01
	-9.5V	PC1-R12	+9.04V ±.01



a. BREAK-POINT POTENTIOMETER LOCATION



b. PC1; R1-R6

c. PC1; R7-R12

d. PC2; R1-R6

e. PC2; R7-R12

FIGURE 2.3-7 MULTIPLIER ADJUSTMENT LOCATION AND TEST SETUP PATCHING

A4681

(f) Repeat steps (b) through (d) but apply the inputs listed in table 2.3-2 for Figure 2.3-7c.

(g) Patch the multiplier as shown in Figure 2.3-7d.

(h) Repeat steps (b) through (d) but apply the inputs listed in table 2.3-3 for Figure 2.3-7d.

(i) Patch the multiplier as shown in Figure 2.3-7e. Note that the +Y input toward the bottom of the patching block must be used.

(j) Repeat steps (b) through (d) but apply the inputs listed in table 2.3-3 for Figure 2.3-7e.

TABLE 2.3-3 Multiplier Adjustment Data; PC2

Figure Reference	Input Voltage	Potentiometer	Output
Figure 2.3-7d	+2.5V	PC2-R1	-0.64V ±.01
	+3.9V	PC2-R2	-1.54V ±.01
	+5.3V	PC2-R3	-2.82V ±.01
	+6.7V	PC2-R4	-4.50V ±.01
	+8.1V	PC2-R5	-6.58V ±.01
	+9.5V	PC2-R6	-9.04V ±.01
Figure 2.3-7e	-2.5V	PC2-R7	+0.64V ±.01
	-3.9V	PC2-R8	+1.54V ±.01
	-5.3V	PC2-R9	+2.82V ±.01
	-6.7V	PC2-R10	+4.50V ±.01
	-8.1V	PC2-R11	+6.58V ±.01
	-9.5V	PC2-R12	+9.04V ±.01

(4) Applicable Drawings. The following diagrams are contained in Appendix II of this handbook.

Drawing Number	Type	Description
C007 099 0A	Assembly	Assembly diagram of 7.099 Multiplier.

Drawing Number	Type	Description
B007 099 OS	Schematic	Schematically shows connections between patching block and printed circuit card and between the cards and the rear module connector.
C007 044 OS	Schematic	Schematic diagram of 7.096 multiplier printed circuit cards.
B045 034 OW	Wiring	Contains run sheets listing wiring from the multiplier rear mating connectors to other points within the computer.

(5) Parts Lists. Appendix I contains the replaceable parts lists for the 7.099 quarter-square multiplier. See Index of Appendix I.

4. X^2 DIODE FUNCTION GENERATOR 16.275

The X^2 Diode Function Generator (Figure 2.4-1) is capable of producing $+X^2$ or $-X^2$ for limited or bi-polar inputs, as well as extracting the square-root of an input. These functions are generated by using the DFG as the input (X^2) or feedback ($\sqrt{X}$) elements of a high-gain d-c amplifier.

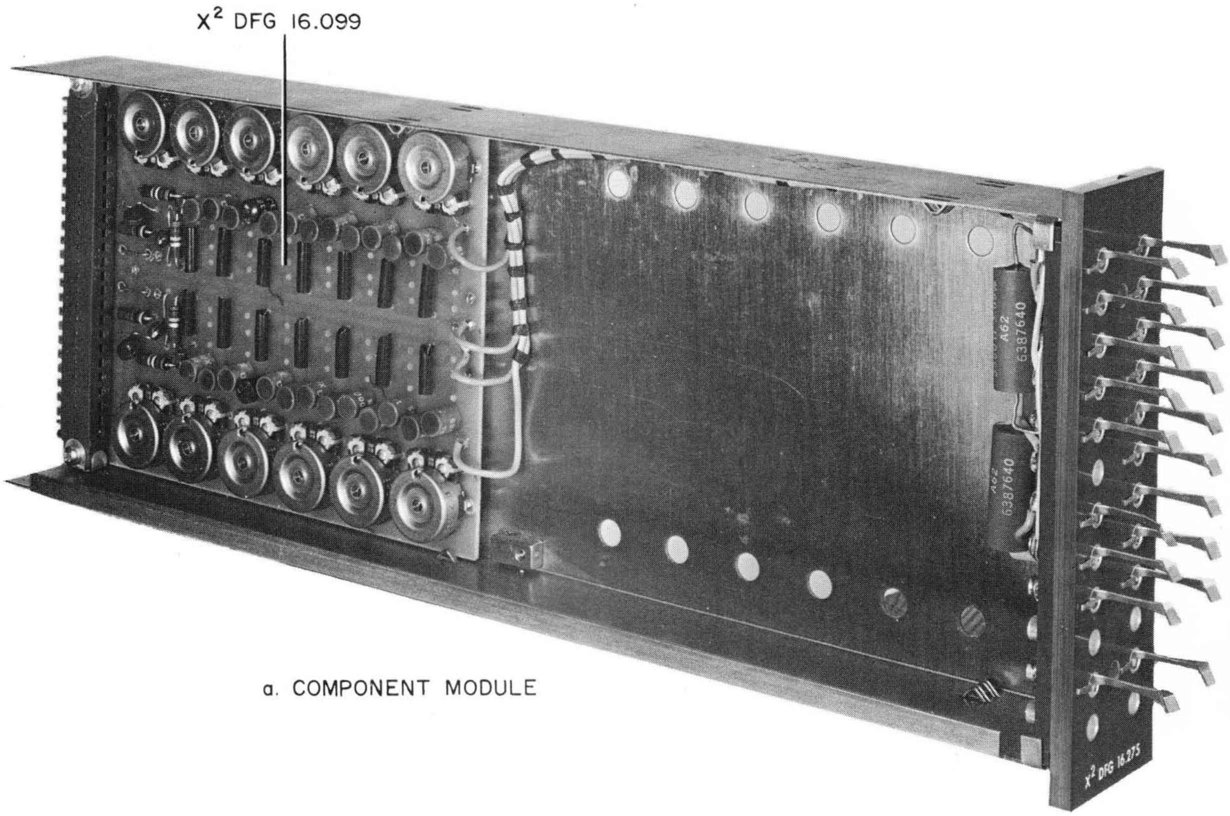
The output functions are approximated by a series of straight line-segments of various slopes. The slopes of the line segments are attained by a series of paralleled resistors each with a diode gate in series. The diode gates are reverse biased such that the input magnitude must attain certain levels to cause succeeding diodes to conduct. As a diode conducts (or the diode breakpoint is reached) the gain of the operational amplifier used in conjunction with the generator changes so the line segment slope approximates that of the function curve. The breakpoint of each diode gate is selected so that the amplifier output produces a very accurate approximation of the X^2 function.

a. Operating Considerations

The X^2 DFG actually consists of two independent X^2 DFG's: one which produces an X^2 output for input of $X \leq 0$ and one which produces an X^2 output for inputs of $X \geq 0$. These two individual DFG units may be combined to produce X^2 for inputs of $-10 \leq X \leq +10$.

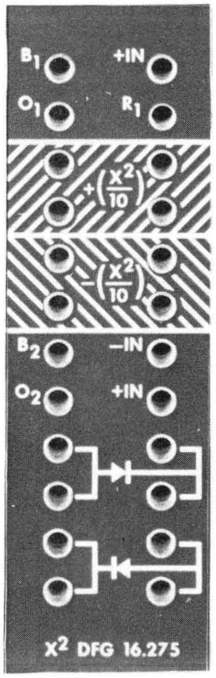
This paragraph only describes the patching procedures required to operate the DFG as separate units. This will enable the technician to check out each circuit individually. The patching procedures for operating the DFG in other configurations are given in the TR-48 Operator's Manual (Appendix IV).

Figure 2.4-2 shows the patching configuration for operating the two DFG's of the 16.275 unit individually; the diagram also gives the input signal limits.



TR-48
#73,69A

a. COMPONENT MODULE



b. PATCHING BLOCK

FIGURE 2.4-1 X^2 DFG, MODEL 16.275

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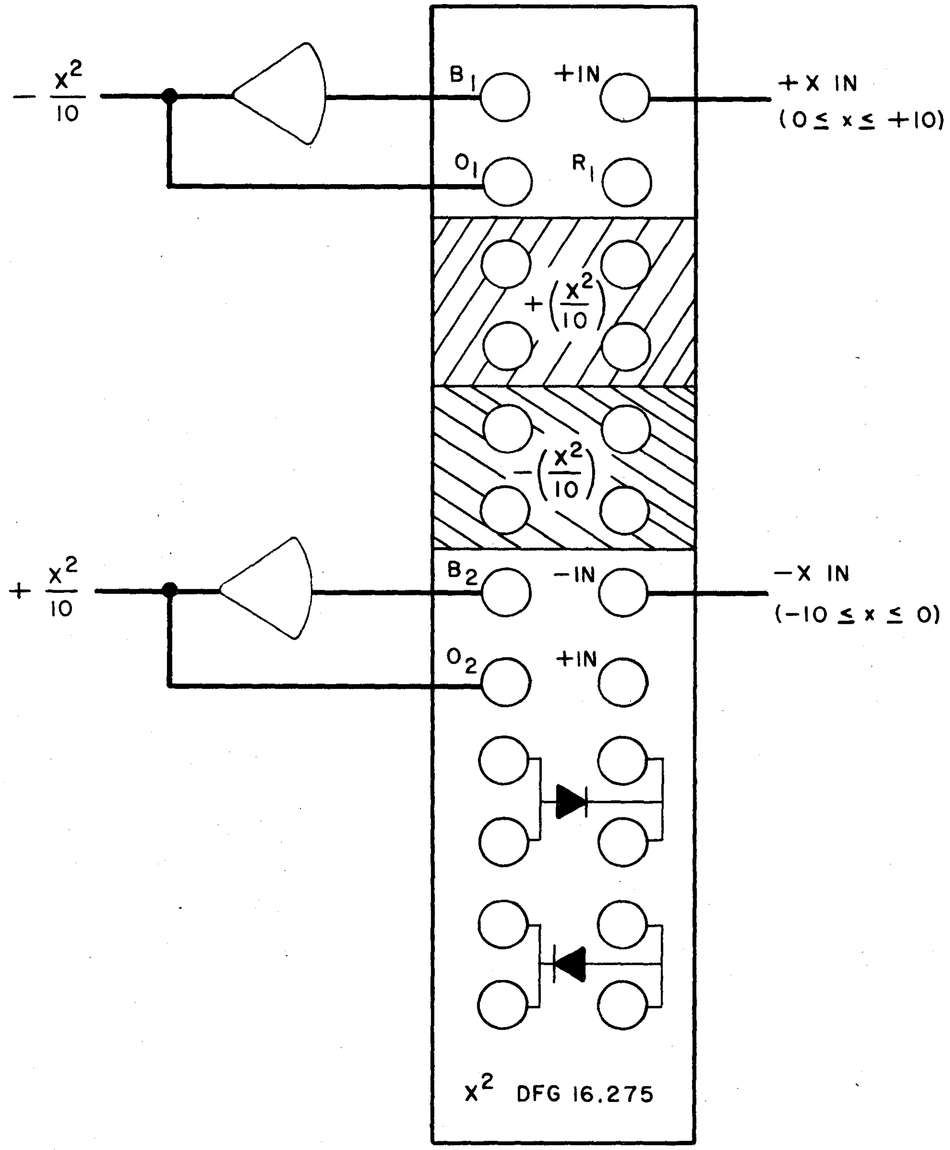


FIGURE 2.4-2. $-\frac{x^2}{10}$ AND $+\frac{x^2}{10}$ PATCHING CONFIGURATION

b. Theory of Operation

As previously stated the X^2 DFG actually consists of two separate function generators; one accepts only positive inputs, and the other accepts only negative inputs. The two units are essentially identical with respect to theory of operation and differ mainly in diode orientation and polarity of bias voltage. This description will, therefore, cover only the circuit which accepts negative input values of X.

Drawing C016 275 OS is the schematic diagram of the entire X^2 unit; Figure 2.4-3 is a simplified schematic of the negative input portion (right-hand portion of C016 275 OS). (The temperature compensation thermistors and certain bias resistors, as well as some of the gated resistor networks are eliminated for clarity.)

The diodes, CR8, CR9 ....CR13, and CR14 are back biased at different potentials so that as the input signal reaches various levels more and more of the diodes conduct. As each diode conducts, the slope of the amplifier output is changed and corrects the straight line approximation of the X^2 curve.

The X^2 DFG can also be used to produce $\sqrt{X}$ by using the unit as a feedback element for the amplifier, i.e., the diode-resistor networks replace R3, and R3 becomes a fixed input resistor. The patching configuration for this function as well as others, are given in the Operator's Manual. If the DFG's function properly when patched as shown in Figure 2.4-2 the X^2 DFG may be assumed to be in proper working order. Should the DFG then indicate a fault when patched in another operational mode the error is generally external to the DFG (improper patching, faulty external component, etc.).

c. Maintenance and Test Procedures

The X^2 DFG is designated with high-quality, conservatively rated components and will provide long-term trouble-free operation. The unit is factory calibrated prior to shipment; re-adjustment should only be attempted when definitely indicated by thorough checkout.

(1) X^2 DFG Test Procedure

(a) Set up the test circuit shown in Figure 2.4-4.

(b) Set potentiometers 1, 2, and 3 for the values indicated on the diagram. Potentiometer 5 is to be set so the comparator switches when IN reaches -10 volts.

(c) Set function switch F_1 to +10 volts (L) and F_2 to the output of Integrator 1 (L).

(d) Place the computer in reset and than in operate. When the comparator switches (at -10 volts, thus placing both integrators essentially in the hold mode) adjust potentiometer 4 for a -10 volt output from amplifier (measure with TDVM).

(e) Place the computer in reset; address amplifier 5 for readout on the TDVM. Set the computer in operate and note TDVM variations. The max-reading should not exceed 0.4 volts (0.4% or 40 millivolts into a gain-of-ten amplifier). Typical error is 0.2% or 0.2 volts on TDVM.

(f) The above procedure checks the X^2 unit for a negative input. If desired to obtain an error plot, connect this circuit to the X and Y inputs of a VARIPLOTTER as shown by dotted lines on Figure 2.4-4.

(g) To check the generator for a positive input, place function switches F_1 and F_2 in the R position and repeat step (e).

(2) X^2 DFG Break-Point Adjustment. The following adjustments should only be attempted when definitely indicated as necessary. The amplifiers used in conjunction with the X^2 DFG during this procedure must be functioning properly.

(a) Patch the X^2 DFG as shown in Figure 2.4-5b.

(b) Apply the positive inputs listed in Table 2.4-1 (in sequence starting at 2.5V). The TDVM should read out the potential listed in the output column in each case.

(c) If any readout indicates adjustment is necessary, adjust the potentiometer listed in the middle column.

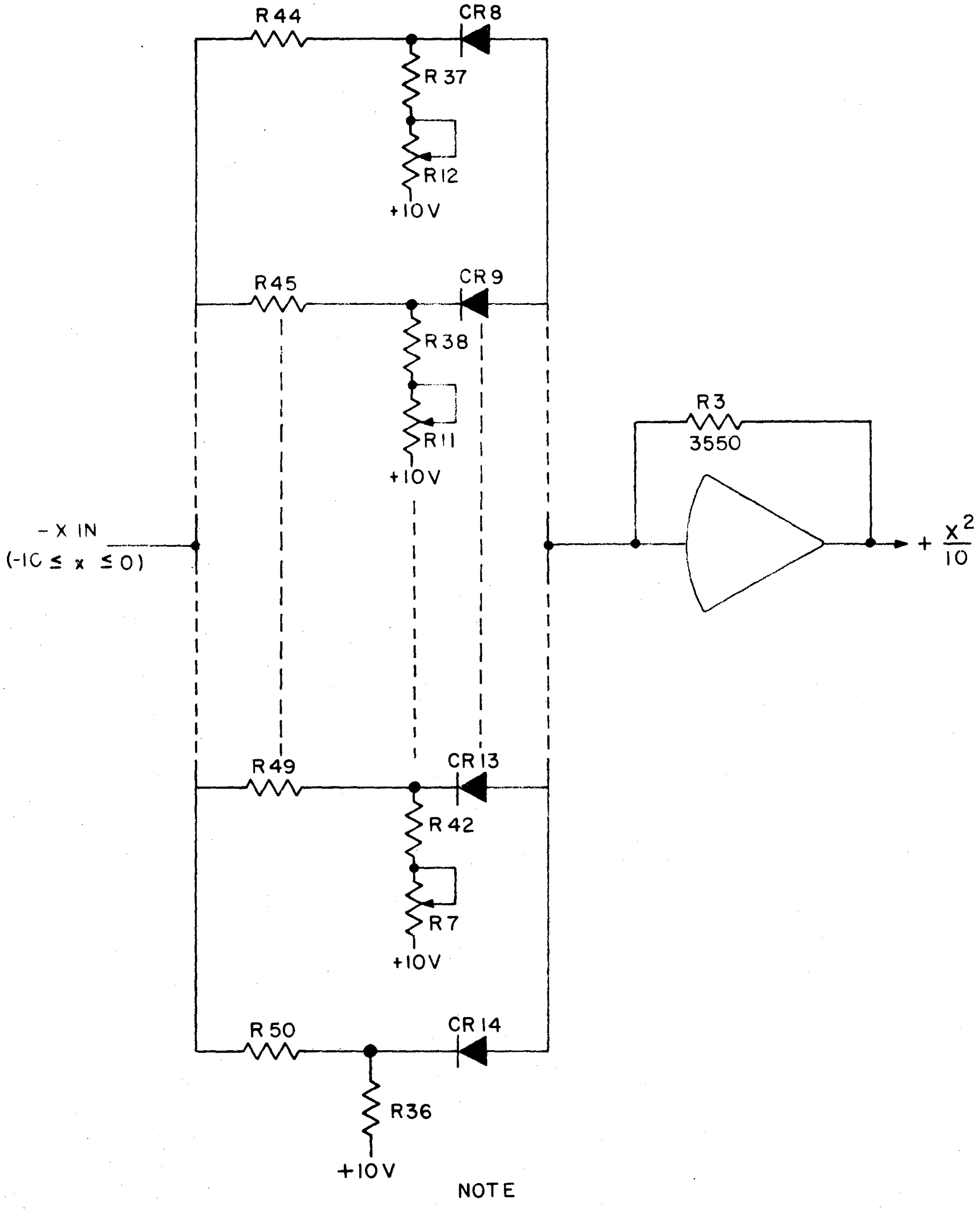
(d) Repeat steps (b) and (c) as necessary; interaction of the DFG break-point settings necessitates this procedure for optimum accuracy.

(e) Patch the X^2 DFG as shown in Figure 2.4-5c.

(f) Repeat steps (b) through (d) but use the data listed in Table 2.4-2.

TABLE 2.4-1

Input Voltage	Potentiometer	Output
+2.5V	R1	-0.64V ±.01V
+3.9V	R2	-1.54V ±.01V
+5.3V	R3	-2.82V ±.01V
+6.7V	R4	-4.50V ±.01V
+8.1V	R5	-6.58V ±.01V
+9.5V	R6	-9.04V ±.01V



NOTE

1. R3 PERMANENTLY WIRED TO PATCHING BLOCK.

FIGURE 2.4-3 NEGATIVE INPUT X^2 DFG, SIMPLIFIED SCHEMATIC

A4683

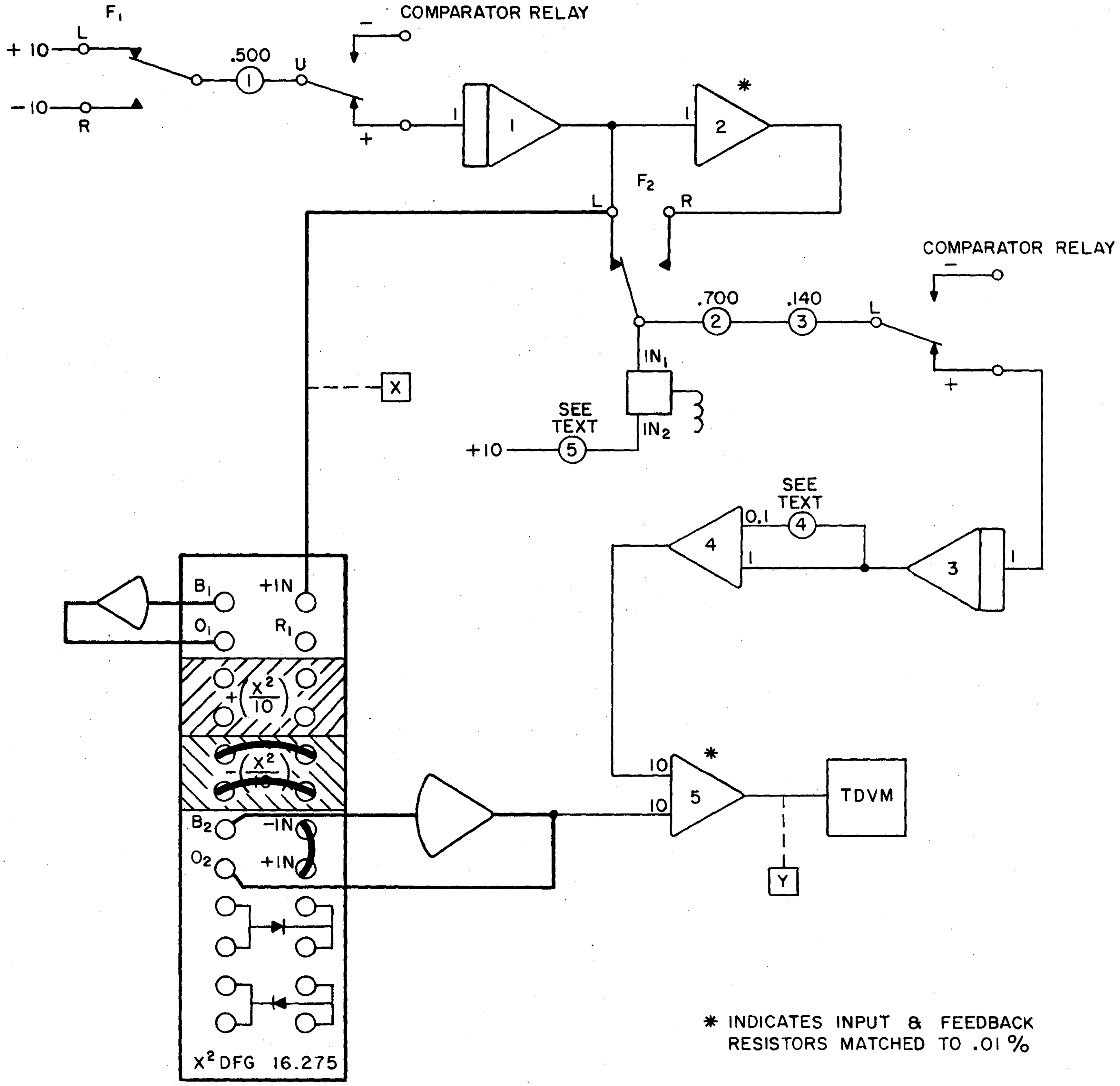
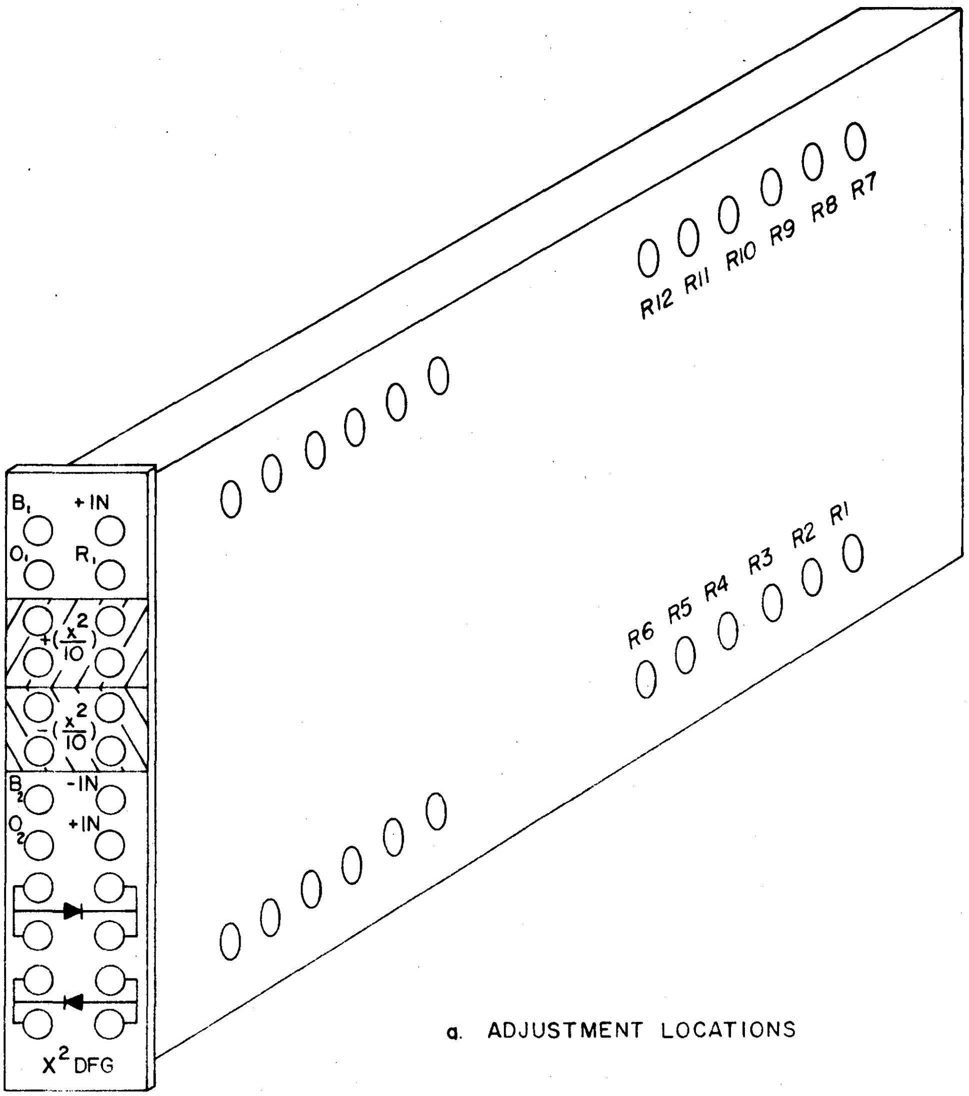
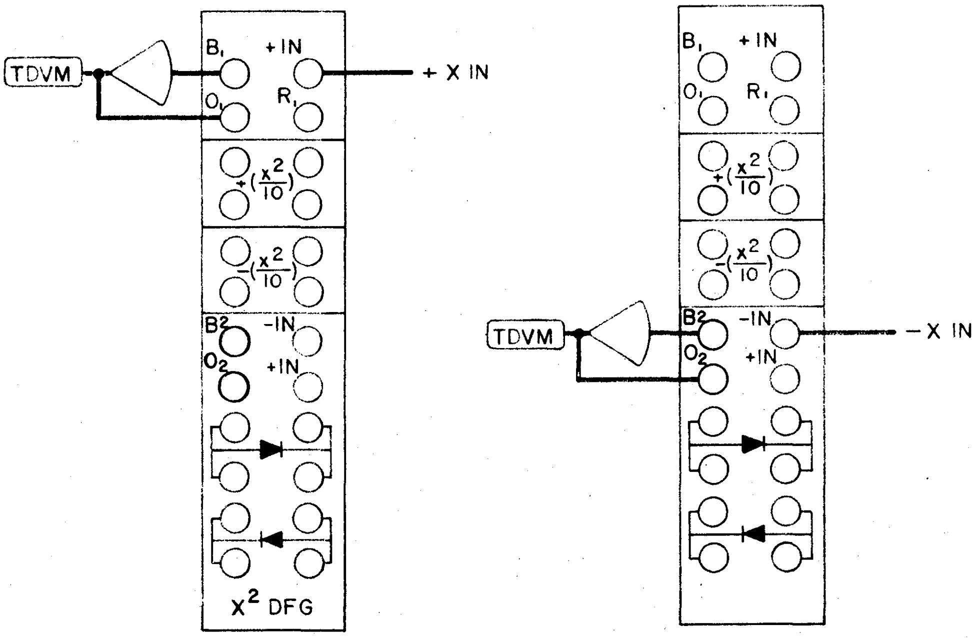


FIGURE 2.4-4 X^2 DFG TEST SETUP

A4684



a. ADJUSTMENT LOCATIONS



b. $-\frac{X^2}{10}$ TEST SETUP

c. $+\frac{X^2}{10}$ TEST SETUP

FIGURE 2.4-5 X^2 DFG ADJUSTMENT LOCATION AND PATCHING

TABLE 2.4-2

Input Voltage	Potentiometer	Output
-2.5V	R7	+0.64V ±.01V
-3.9V	R8	+1.54V ±.01V
-5.3V	R9	+2.82V ±.01V
-6.7V	R10	+4.50V ±.01V
-8.1V	R11	+6.58V ±.01V
-9.5V	R12	+9.04V ±.01V

(3) Applicable Drawings. The following drawings are contained in Volume II of this handbook.

Drawing Number	Type	Description
C016 275 0A	Assembly	Shows components mounted on module block and wiring from block to printed circuit card.
C016 275 0S	Schematic	Schematic diagram of X^2 DFG unit.
B045 034 0W	Wiring	Contains run sheets listing wiring from 16.275 rear mating connectors to other points in the computer console.

(4) Parts Lists. Appendix I contains the replaceable parts lists for the 16.275 amplifier. See Index of Appendix I.

5. LOG X (16.276) AND 1/2 LOG X (16.281) DIODE FUNCTION GENERATORS

The 16.276 Log X DFG and 16.281 1/2 Log X Diode Function Generators (Figure 2.5-1) generate a logarithmic function of an input variable. These units are extremely versatile since they may be used to perform multiplication, division, squaring, obtaining the square-root in addition to the capability of raising an input to an unusual or variable power.

The 16.276 Log X and 16.281 1/2 Log X DFG units are essentially identical in theory and operation; the main difference lies in the output function. The output function of the Log X DFG is scaled at five times the log to the base 10 of ten times the absolute value of X (equation 2.5-1).

$$e_o = -5 \, \mathrm{Log}_{10} \, (10|X|) \qquad \text{(EQ. 2.5-1)}$$

The minus sign of equation 2.5-1 indicates the polarity of the DFG output (e_o) is opposite to that of the input variable X, i.e., if X is positive, e_o is negative.

The output function of the 16.281 1/2 Log X DFG is, as indicated, half of that of equation 2.5-1 or:

$$e_o = -2.5 \text{ Log}_{10} (10|X|) \qquad \text{(EQ. 2.5-2)}$$

Both the Log X and 1/2 Log X DFG contain four separate log function generators: two cards which accept only positive inputs and two cards which accept only negative inputs.

a. Operating Considerations

Figure 2.5-2 illustrates the patching procedure for obtaining the log of +X and -X with the 16.276 Log X DFG. The patching for the 16.281 1/2 Log X DFG is similar; as indicated previously the difference lies in the output function.

Note that the maximum value of the output of the 16.276 unit occurs when X is either plus or minus 10. The output is, therefore, $\pm 5 \log_{10} 10|10| = \pm 10$ volts. The 1/2 log X unit, therefore, with an output equal to 1/2 of the 16.276 unit has a maximum output voltage range of ±5 volts.

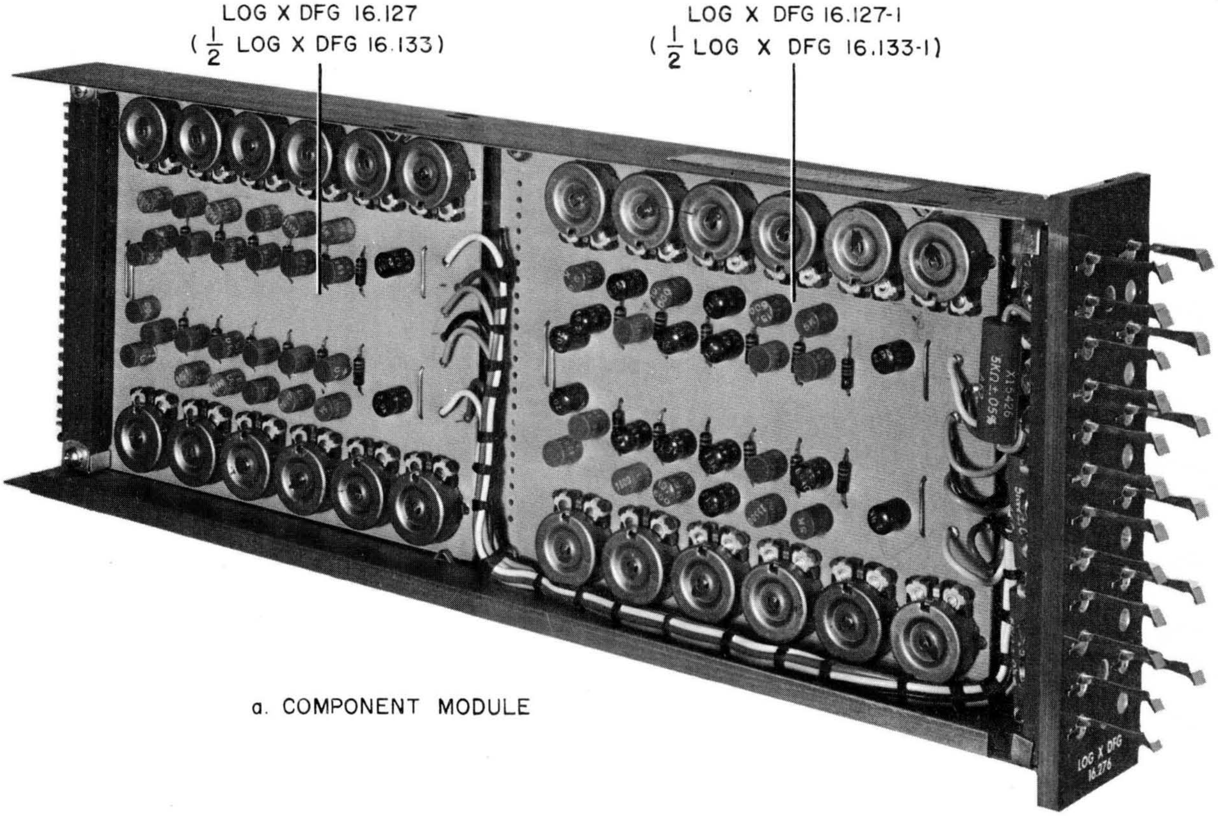
In Figure 2.5-2 the lower two DFG input cards are patched as separate log X DFG units with limited inputs. The top two cards are shown combined permitting an input where $-10 \leq X \leq +10$ volts.

During maintenance checkout procedures, by operating each DFG as a separate limited input unit, a fault may be rapidly isolated to a small portion of the overall circuitry.

b. Theory of Operation

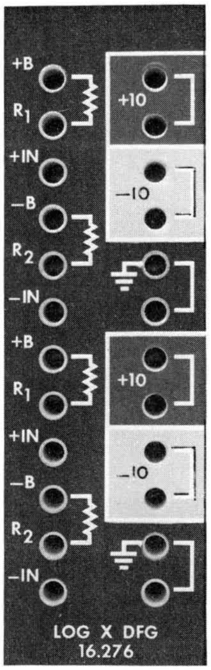
Drawings C016 276 OS and C016 281 OS are the schematic diagrams of the Log X and 1/2 Log X DFG printed circuit cards respectively. Comparing the two schematics reveals that the two are similar and actually only differ in resistor values. The resistor values of the 16.281 unit are approximately twice the magnitude of those of the 16.276 unit with the exception of R1 through R4 (the feedback resistors between the R and B terminations). It can be seen that the outputs of the 1/2 Log X will be one-half the magnitude of the Log X DFG.

Because of this similarity the Log X (16.276) DFG is used as the basis of this description. Note on Schematic C016 276 OS that there are two separate but similar circuits. The circuit on the left-hand side responds only to negative input signals; the circuit on the right-hand side responds only to positive input signals. These two circuits differ only in the orientation of the diodes with respect to the bias voltages and also the polarities of the bias voltages. Again, due to this similarity, only the right-hand circuit (sensitive to positive input signals) is described.



TR-48
75,59

a. COMPONENT MODULE



NOTE

THE 16.127 AND 16.127-1 (ALSO 16.133 AND 16.133-1) ARE PHYSICALLY AND ELECTRICALLY IDENTICAL EXCEPT 16.127-1 AND 16.133-1 DO NOT HAVE PLUG CONNECTORS

b. PATCHING BLOCK

FIGURE 2.5-1 LOG X DFG, MODEL 16.276 ($\frac{1}{2}$ LOG X DFG 16.281 SIMILAR)

A4701

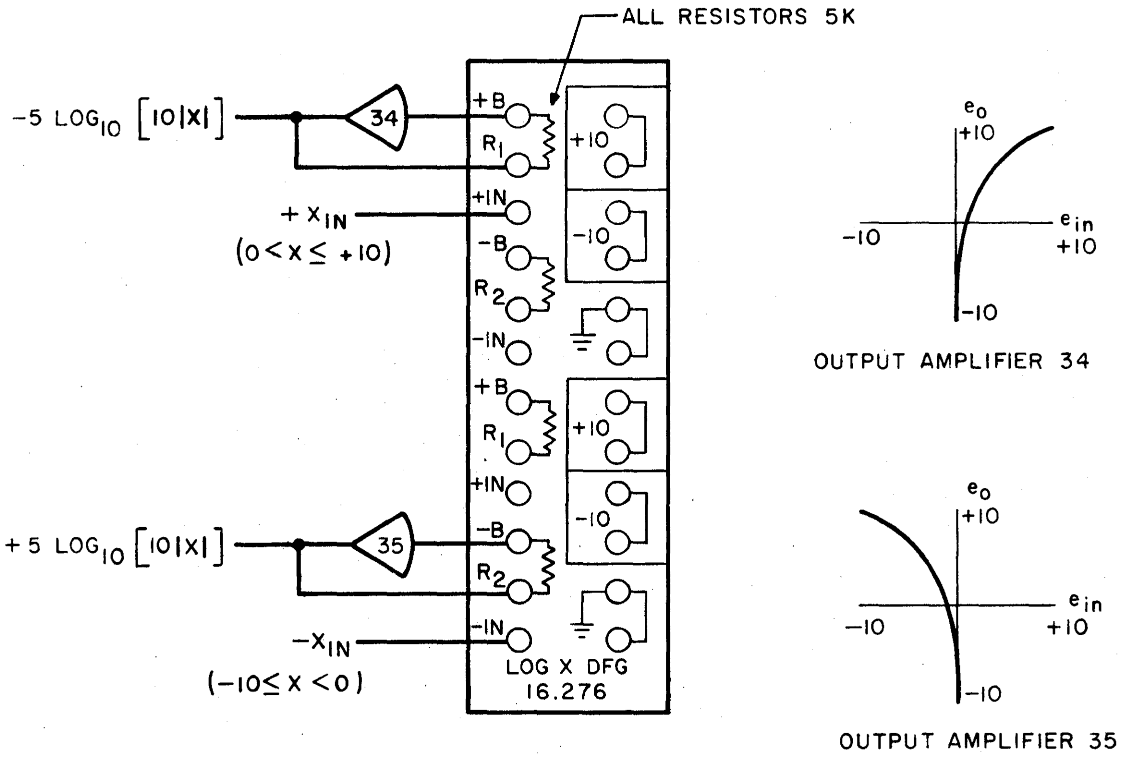


FIGURE 2.5-2 LOG X DFG PATCHING DIAGRAM

$\left(\frac{1}{2}\ \text{LOG X DFG SIMILAR}\right)$

Figure 2.5-3 is a simplified schematic of the positive input circuit of the 16.276 Log X DFG. This circuit functions in a manner similar to all of the DFG units of the TR-48; as the input signal reaches various levels the input-to-feedback impedance ratio is changed, thus changing the gain of the associated amplifier. In the case of the Log X DFG there are six changes in slope of the amplifier output, or six straight-line segments are used to approximate the log curve.

The main difference in the Log X circuit operation as compared to most other TR-48 DFG units is that with a near zero input all of the diodes are forward biased and conducting. Thus, when the input (+IN) of Figure 2.5-3 is close to zero, resistors R25 through R31 are all in parallel and the amplifier has a gain greater than 10.

As the input level increases toward +10 volts the diodes are reverse biased and their corresponding resistors are removed from the parallel group. This process continues until the gain of the amplifier is somewhat less than 0.25 (20.9K input resistor, 5K feedback resistor).

Figure 2.5-4 compares graphically the input-to-output voltages of the Log X positive input circuit. Note that due to the inversion of the amplifier, the output signal is negative, or as previously indicated, $-5 \text{ Log}_{10} 10|X|$. This curve illustrates the initial steep slope of the output curve (requiring a high amplifier gain) and the decrease in slope as X approaches 10 volts (requiring very small amplifier gain).

c. Maintenance and Test Procedures

The Log X and 1/2 Log X DFG's are factory calibrated prior to shipment. Adjustment should not be attempted unless definitely indicated as necessary by the dynamic error check described in the following sub-paragraph.

(1) Dynamic Error Test Procedure Log X DFG. This test can be used to indicate if adjustment of the Log DFG's is required and also to check the DFG output after completion of the adjustment procedure.

(a) Set up the test circuit shown in Figure 2.5-5a. (The setup shown is for the -Log X cards only.) An oscilloscope or voltmeter may be substituted for the VARIPLOTTER. Set the plotter Y input to 0.1 volt/inch sensitivity and the X input to 1.0 volt/inch.

(b) Figure 2.5-5b shows a typical error plot. Note that when checking a -Log X card that the resultant plot starts at the right and runs to the left side of the plotter.

(c) If the error plot does not remain within the ±0.1 volt limits (0.1% error) refer to the static adjustment procedure.

(d) To check a +Log X card, substitute the plus for the minus card of Figure 2.5-5 and change the IC input of the two integrators to +10 volts. Change the +10 input to integrator-2 to -10 volts.

The resultant error curve should be similar to Figure 2.5-5c. Note in this case the plot will run left to right.

(2) Dynamic Error Test Procedure 1/2 Log X DFG

(a) Set up a test circuit similar to that shown in Figure 2.5-5a with this single exception; the output of amplifier-3 should be applied to amplifier-4 through a gain-of-two input.

(b) The remainder of the test procedure and the results are the same as listed for steps (b) through (d) of the Log X cards.

(3) Static Adjustment Procedure; Log X DFG. The setup temperature should be approximately 75°F.

(a) Set up the test circuit shown in Figure 2.5-6b.

(b) Apply the inputs as indicated in Table 2.6-1 in the sequence listed, to the +IN termination.

(c) If an adjustment is made, recheck the previous setting before proceeding to the next adjustment (due to interaction between adjustments).

(d) Repeat Steps (b) through (c) as necessary.

(e) Set up the test circuit for the second +Log X card. Repeat (b) through (d) but adjust the potentiometers on the PC2 unit.

(f) Set up the test circuit shown in Figure 2.5-6c. Apply the inputs listed in Table 2.6-2 to the -IN termination.

(g) Repeat Steps (c) through (e) but for the -Log cards. (See adjustment notations indicated in Table 2.6-2.)

Table 2.6-1. +Log X Adjustment Data

	Adjustment		
+X Input	Number	Potentiometer	TDVM Readout
+0.32V	1	PC1-R22	-2.15V ±0.05 V
+1.16V	2	PC1-R42	-5.23V ±0.05 V
+2.47V	3	PC1-R41	-6.92V ±0.05 V
+4.28V	4	PC1-R40	-8.13V ±0.05 V
+6.51V	5	PC1-R39	-9.05V ±0.05 V
+9.13V	6	PC1-R38	-9.79V ±0.05 V

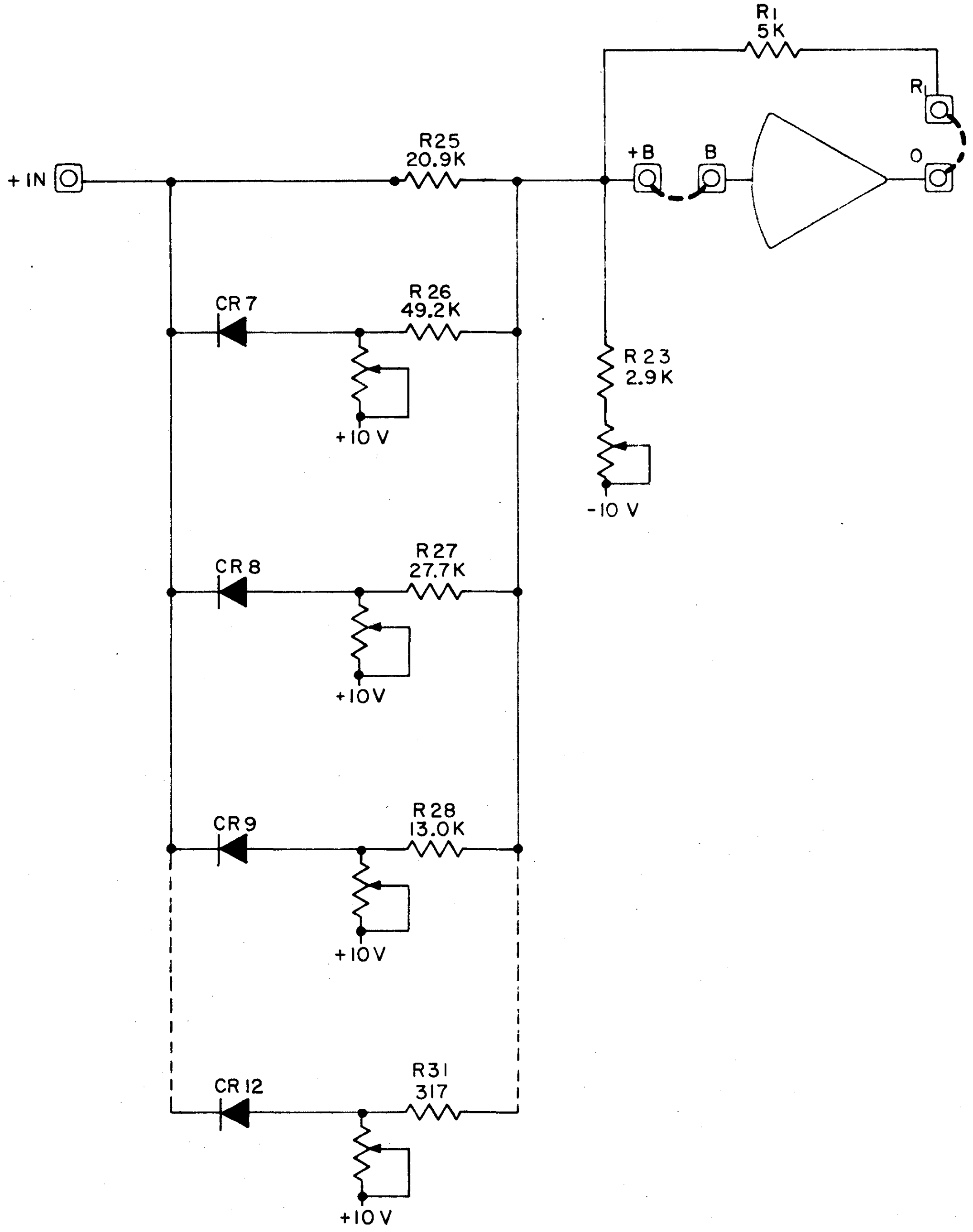


FIGURE 2.5-3 POSITIVE INPUT LOG X DFG CIRCUIT, SIMPLIFIED SCHEMATIC

A 4687

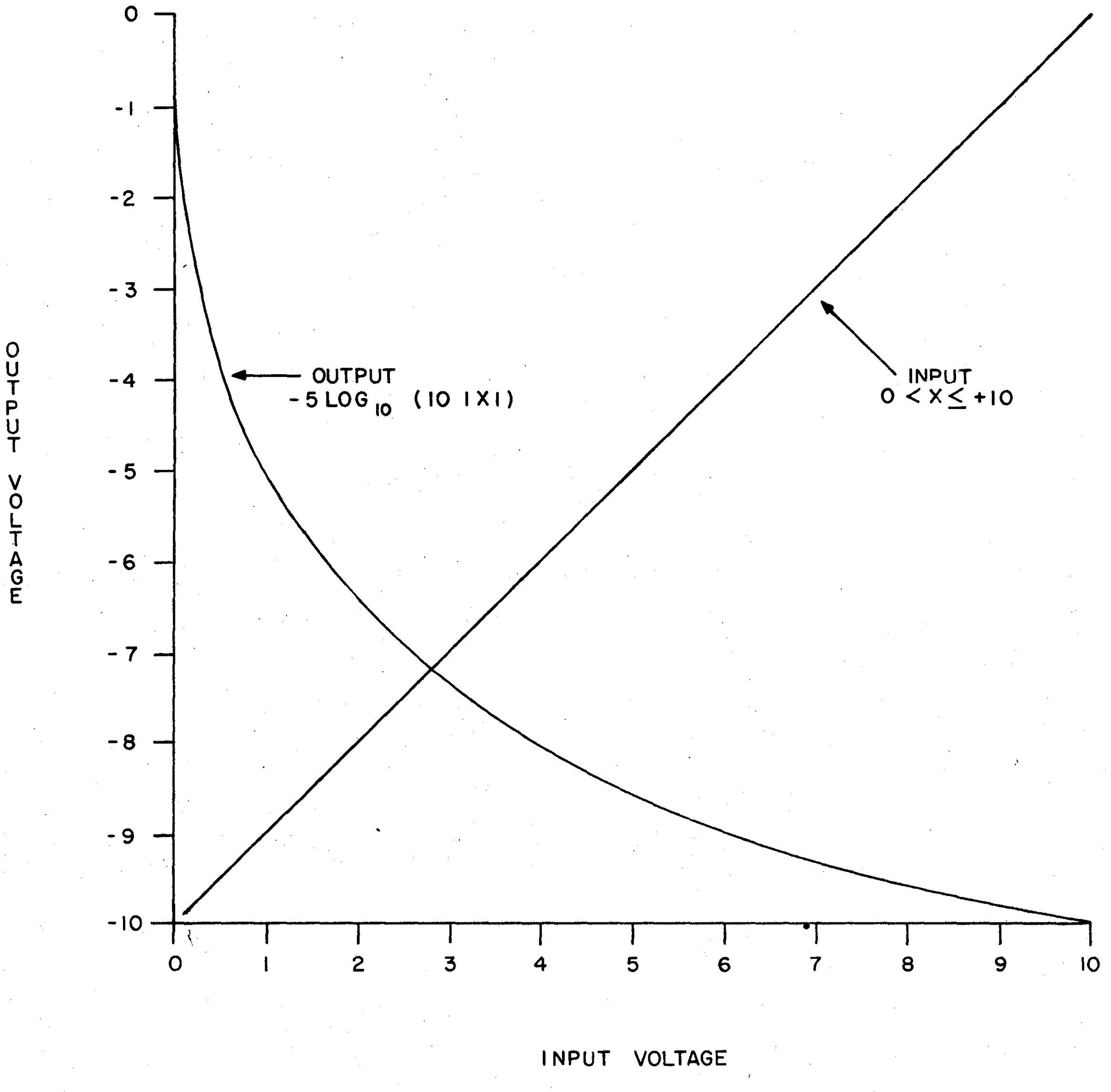
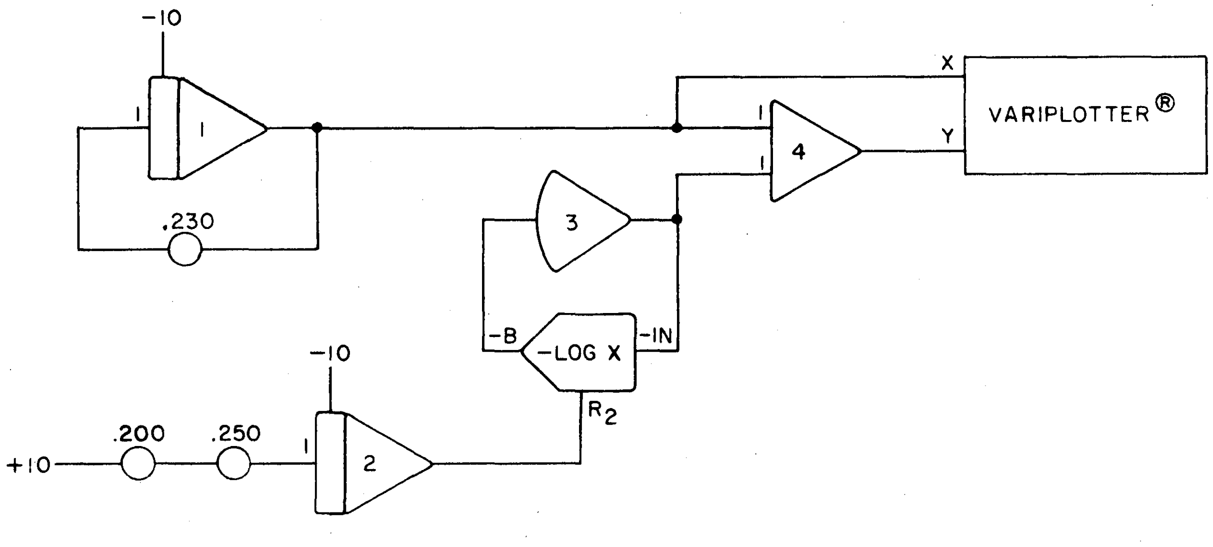
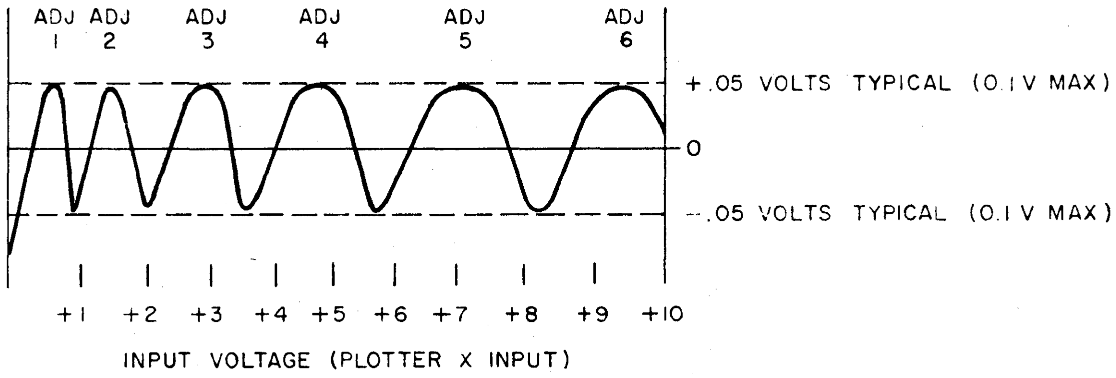


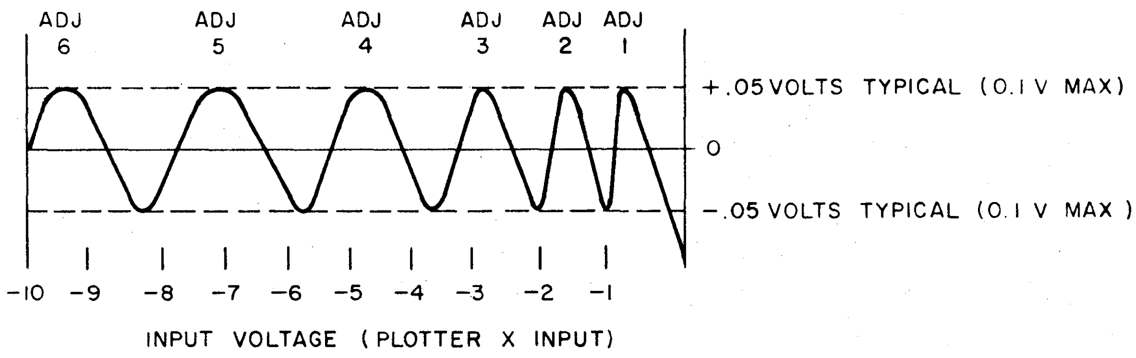
FIGURE 2.5-4 GRAPHICAL INPUT-TO-OUTPUT COMPARISON OF POSITIVE INPUT LOG X DFG



a. TEST CIRCUIT

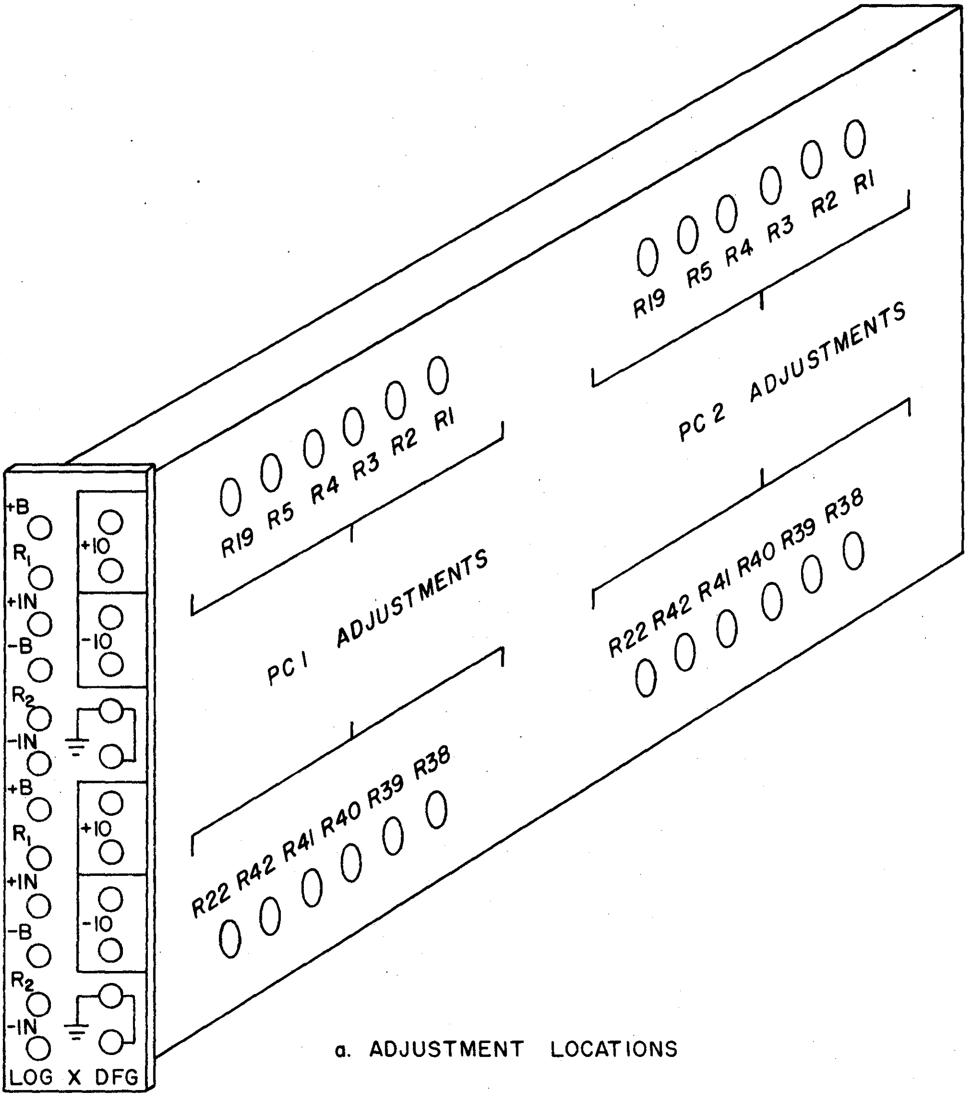


b. TYPICAL DYNAMIC ERROR PLOT; – LOG X DFG

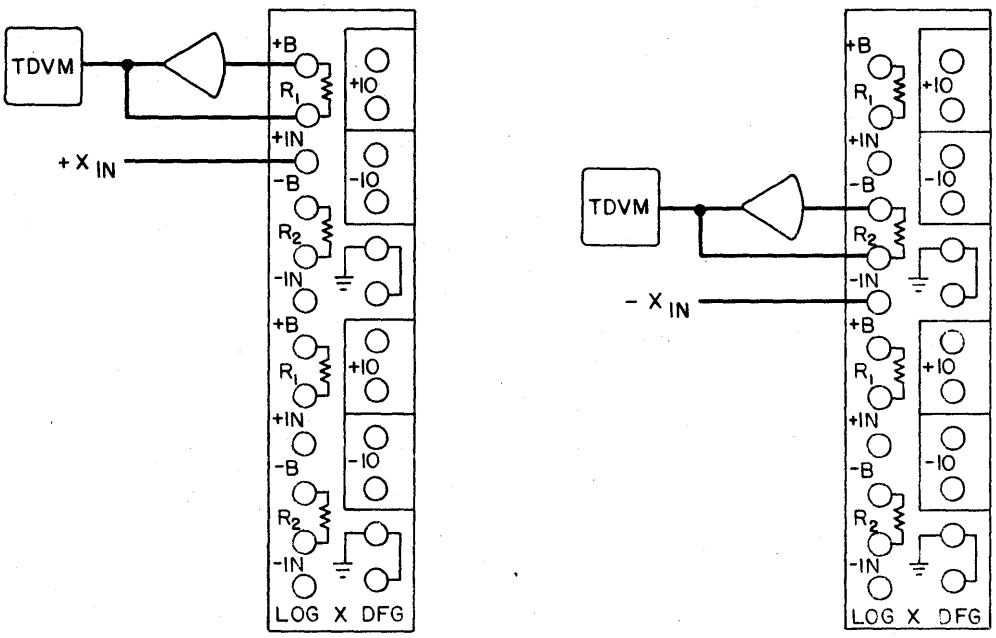


c. TYPICAL DYNAMIC ERROR PLOT; + LOG X DFG

FIGURE 2.5-5 LOG X DFG DYNAMIC ERROR TEST CIRCUIT



a. ADJUSTMENT LOCATIONS



b. +LOG TEST SETUP

c. −LOG TEST SETUP

FIGURE 2.5-6 LOG X ADJUSTMENT LOCATION AND TEST SETUP PATCHING

Table 2.6-2. -Log X Adjustment Data

	Adjustment		
-X Input	Number	Potentiometer	TDVM Readout
-0.32V	1	PC1-R19	+2.15V ±0.05V
-1.16V	2	PC1-R5	+5.23V ±0.05V
-2.47V	3	PC1-R4	+6.92V ±0.05V
-4.28V	4	PC1-R3	+8.13V ±0.05V
-6.51V	5	PC1-R2	+9.05V ±0.05V
-9.13V	6	PC1-R1	+9.79V ±0.05V

(4) Static Adjustment Procedures; 1/2 Log X DFG. The 1/2 Log X DFG is adjusted in a similar manner to the Log X DFG. Using the test setups as shown on Figure 2.5-6 proceed as indicated in Paragraph (3) but use the data of Tables 2.6-3 and 2.6-4.

Table 2.6-3. +1/2 Log X Adjustment Data

	Adjustment		
+X Input	Number	Potentiometer	TDVM Readout
+0.32V	1	PC1-R22	-1.08V ±0.05V
+1.16V	2	PC1-R42	-2.62V ±0.05V
+2.47V	3	PC1-R41	-3.46V ±0.05V
+4.28V	4	PC1-R40	-4.07V ±0.05V
+6.51V	5	PC1-R39	-4.56V ±0.05V
+9.13V	6	PC1-R38	-4.90V ±0.05V

Table 2.6-4. -1/2 Log X Adjustment Data

	Adjustment		
-X Input	Number	Potentiometer	TDVM Readout
-0.32V	1	PC1-R19	+1.08V ±0.05V
-1.16V	2	PC1-R5	+2.62V ±0.05V
-2.47V	3	PC1-R4	+3.46V ±0.05V
-4.28V	4	PC1-R3	+4.07V ±0.05V
-6.51V	5	PC1-R2	+4.56V ±0.05V
-9.13V	6	PC1-R1	+4.90V ±0.05V

(5) Applicable Drawings. The following drawings are contained in Volume II of this handbook.

Drawing Number	Title	Description
C016 276 0A	Assembly	Shows components mounted on module and wiring from block to printed circuit cards.
C016 276 0S	Schematic	Schematic Diagram of 16.276 printed circuit cards.
C016 281 0A	Assembly	Shows components mounted on module and wiring from block to printed circuit cards.
C016 281 0S	Schematic	Schematic diagram of 16.281 printed circuit card.

(6) Parts Lists. Appendix I contains the replaceable parts lists for both the 16.276 and 16.281 units. See Index of Appendix I.

6. VARIABLE DIODE FUNCTION GENERATOR 16.274

The Variable Diode Function Generator (VDFG) permits the operator to generate a function whose complexity makes it extremely difficult, if not impossible, to obtain by other computer components.

The TR-48 VDFG actually consists of two VDFG's: a negative VDFG that responds to inputs between -10 volts and zero, and a positive VDFG that repsonds to inputs between zero and +10 volts. These VDFG's may be used individually (split) or combined to form a ±VDFG that accepts inputs from -10 to +10 volts.

The VDFG units mount on slide-out shelves behind the control panel (Figure 2.6-1). Thus the units are readily accessible for curve setup. The various input and output leads are cabled from the rear of the VDFG components to specific positions behind the Pre-Patch Panel (Figures 2.6-1 and 1.3-1); by inserting a wired-through chassis in the proper module, the input and output terminations are brought to the Pre-Patch Panel patching block. Figure 2.6-2 shows the various components of the 16.274 VDFG in addition to the slide out chassis shown in Figure 2.6-1.

a. Operating Considerations

Figure 2.6-3 shows the VDFG patching area and a simplified schematic of the overall unit; the plus and minus VDFG portions show only single diode-gated resistor circuits for clarity. Figure 2.6-4 shows the patching for the plus and minus VDFG's separately; this figure also contains a simplified schematic of the plus VDFG. The minus VDFG is similar except that the diodes are oriented in the opposite sense and are biased by plus reference.

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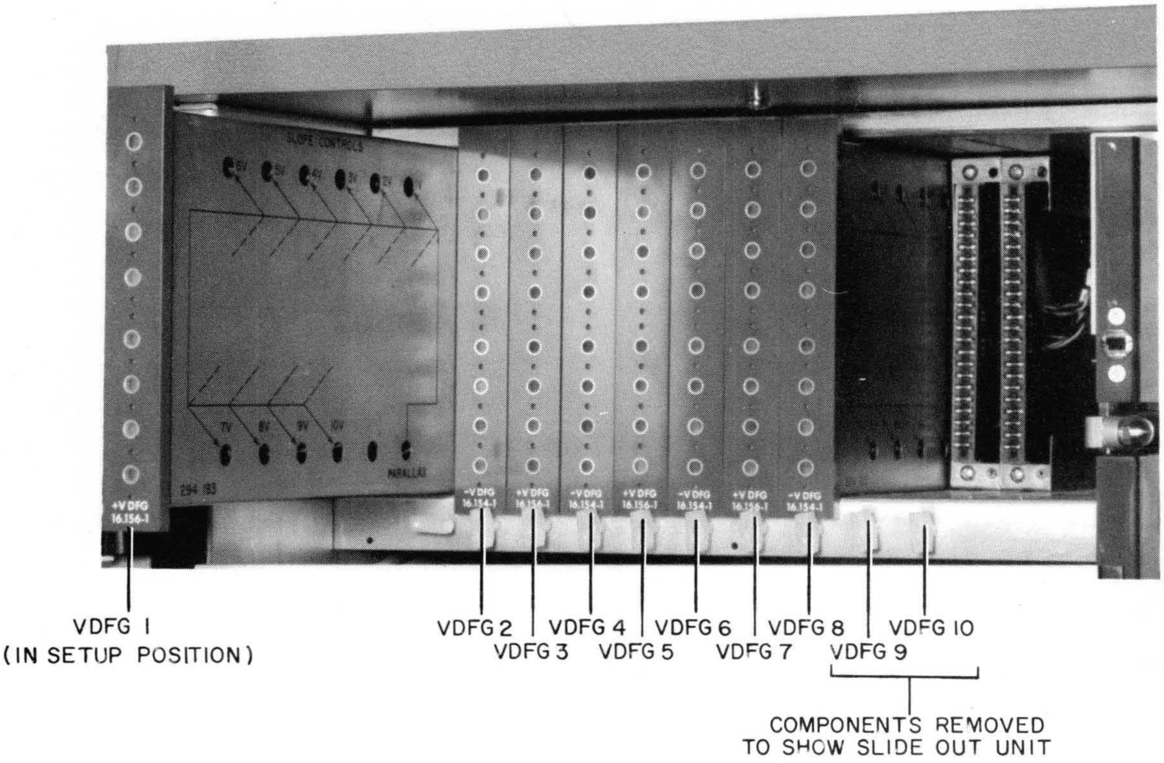
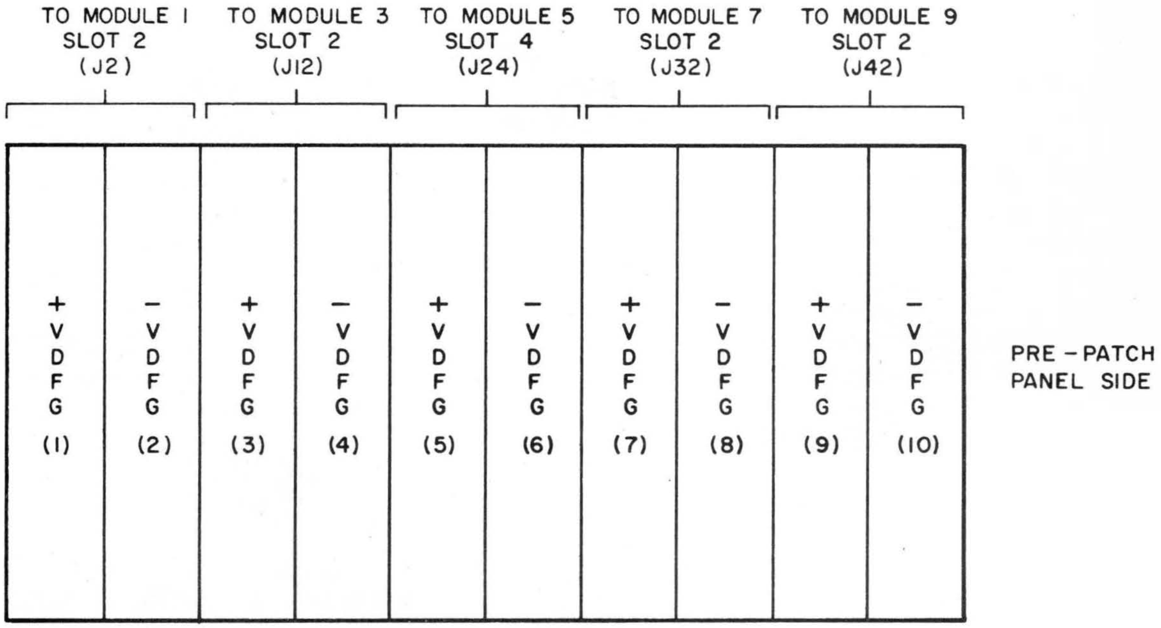


a. VDFG UNIT LOCATION



b. VFDG LOCATIONS AND ASSOCIATED PRE-PATCH PANEL AREAS

FIGURE 2.6-1. ± VDFG UNIT LOCATION AND CHASSIS IN SETUP POSITION

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TR48
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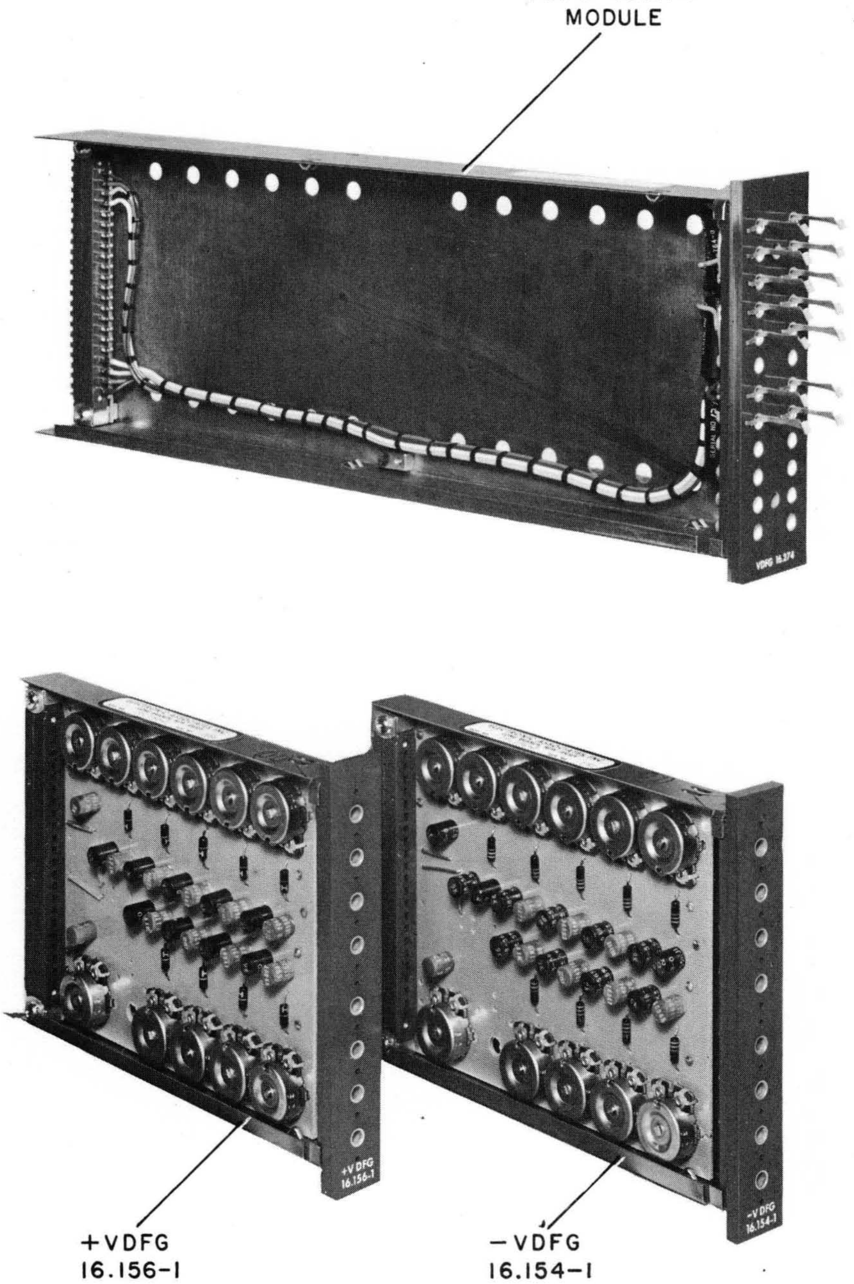


FIGURE 2.6−2. VDFG MODULE 16.274 COMPONENTS

TR-48
50

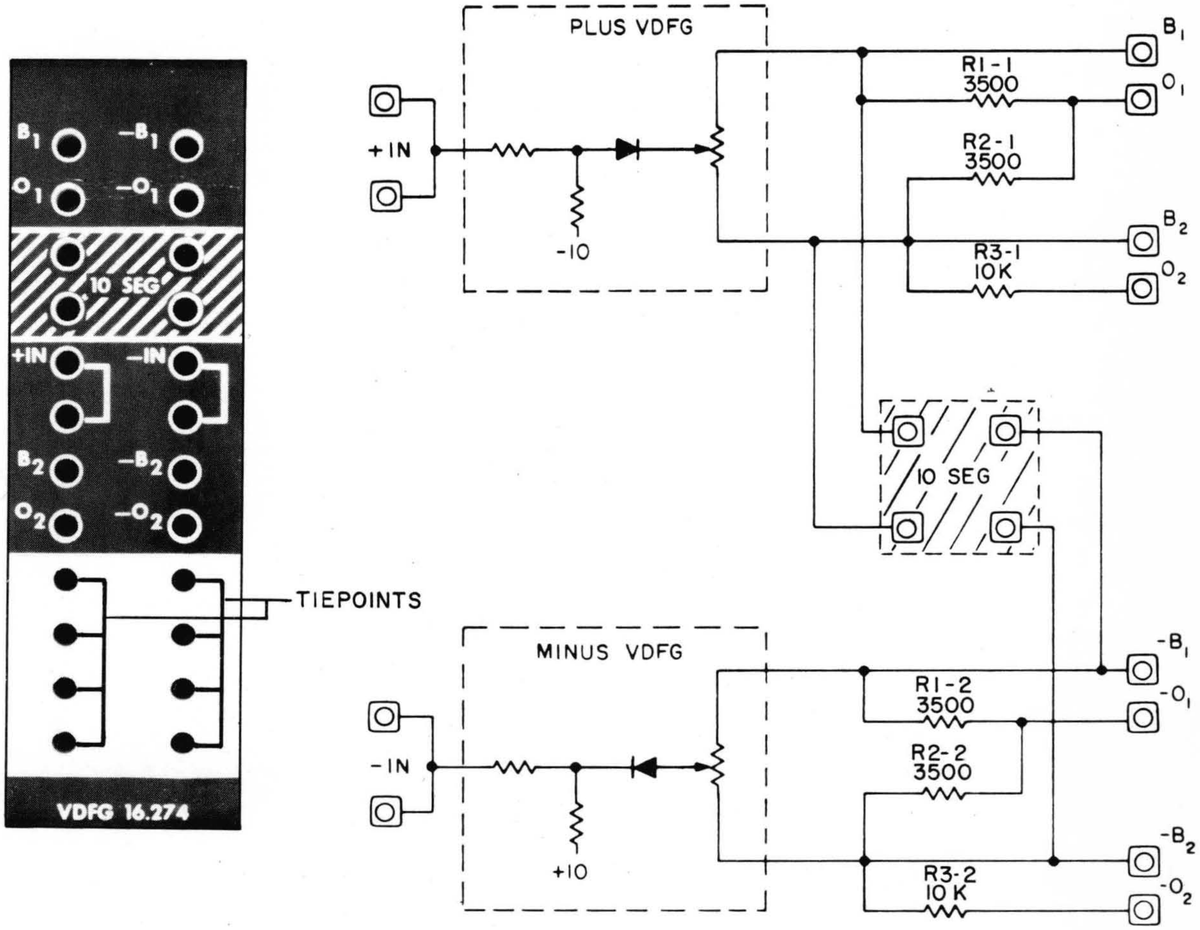
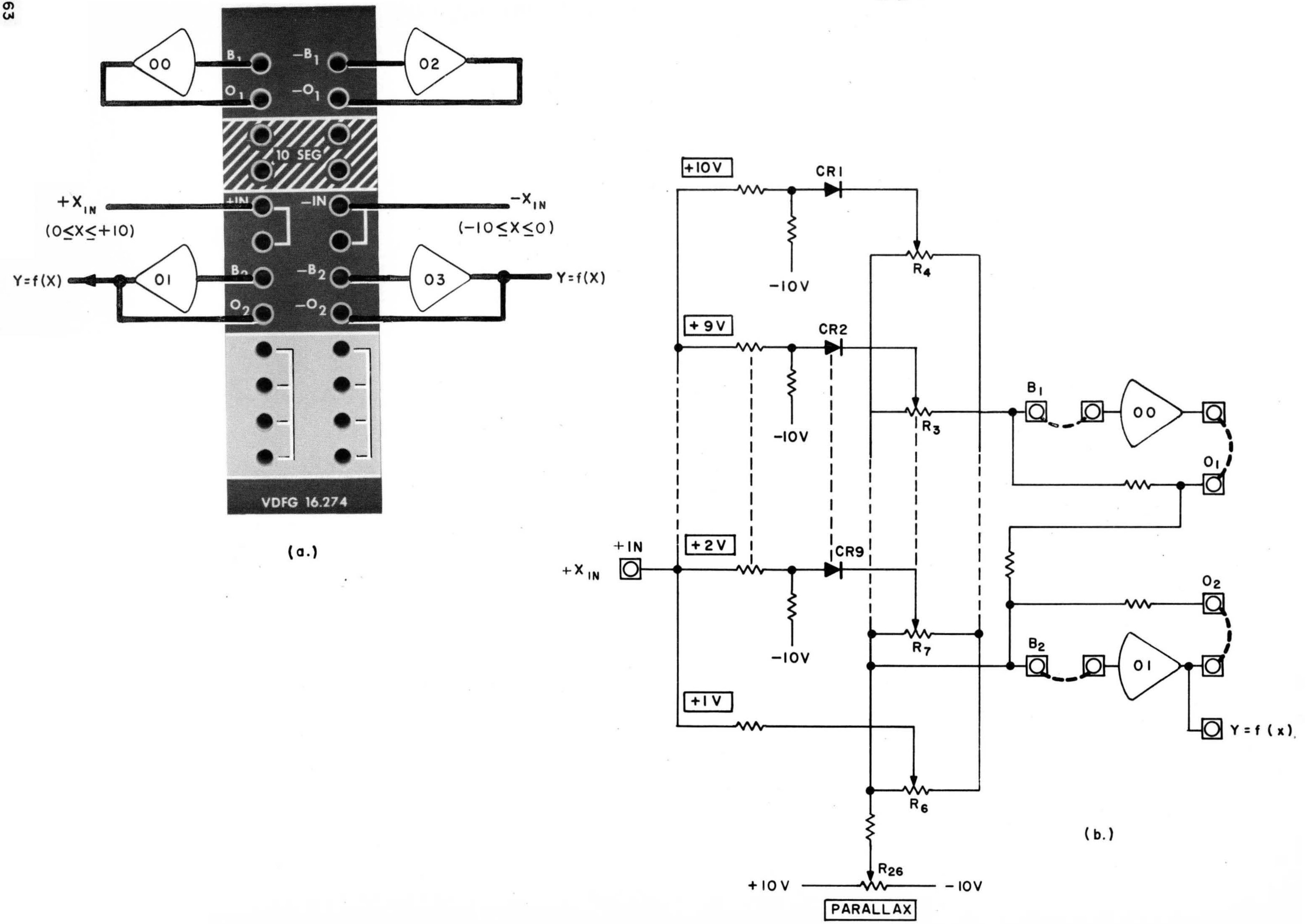


FIGURE 2.6-3 VDFG PATCHING BLOCK AND SIMPLIFIED SCHEMATIC



(a.)

(b.)

FIGURE 2.6-4. +VDFG AND -VDFG PATCHING AND +VDFG SIMPLIFIED SCHEMATIC

Figure 2.6-5 shows the VDFG patching to combine the plus and minus VDFG's for bipolar inputs. Note that a four-connector bottle plug covers the 10 SEG area of the patching block; one of the +IN terminations is jumpered to a -IN termination to combine the input leads.

Each VDFG unit has eleven adjustments; one is a parallax control and the other ten are slope potentiometers to adjust the output curve slope between unitary incremental inputs of X. When used in the ±VDFG combined mode the parallax pots of the -VDFG and +VDFG are interdependent.

The parallax potentiometer permits the operator to set the value of Y (at X = 0) within the range of +10 to -10 volts. The +1 slope adjustment permits the operator to set the initial line segment slope between 0 and 1 volt so that with 1 volt into the DFG, the Y output can be set to a voltage between ±2 volts above or below the X = 0 point (i.e., a slope of 2 volts/volt). The remaining slope potentiometers (2 to 10) permit the operator the change the slope of each preceding segment by a voltage slope of one volt per volt.

Figure 2.6-6 is a sample output curve of a plus VDFG. This curve is used as the basis for the typical VDFG set-up procedure.

The following procedure is for the set-up of a +VDFG patched as shown on Figure 2.6-4. The set-up adjustments of the +VDFG must be started at X = 0 and continued in sequence to X = +10. The procedure for the -VDFG is accomplished in a similar manner, again starting at X = 0 and in sequence X = -10.

When setting up a VDFG for combined plus and minus inputs the operator again starts at X = 0. Once the X = 0 point is set (parallax potentiometer) the operator must proceed in sequence to either +10 or -10 on one VDFG, then starting again at zero, proceed in sequence to the limit of the remaining VDFG.

Typical VDFG Set-Up Procedure

(1) Release the quarter-turn locking device and slide the desired +VDFG forward exposing the set-up controls.

(2) Select the Y = f(X) amplifier output (designated 01 on Figure 2.6-4) for readout on the DVM (or multi-range voltmeter if the DVM is not available).

(3) Ground the +IN termination of the VDFG. Using a small-blade screw driver set the PARALLAX control for a DVM readout of -2 volts.

(4) Apply +1 volt to the +IN termination and adjust the +1 control for a DVM readout of -1.

(5) Apply +2 volts to +IN. Adjust the +2 control for -1.

(6) Continue the procedure applying X = +3, +4, etc., and adjusting the corresponding control for the proper DVM readout as listed in the table.

(7) For optimum accuracy repeat the set-up procedure, starting with Step (3), and making any necessary touch up adjustments.

b. Theory of Operation

Figure 2.6-4 is a simplified schematic of the +VDFG (portions of the diode networks are eliminated for clarity). The VDFG approximates a desired curve with straight line segments in a manner similar to the fixed diode function generators. As the input level increases, the diodes conduct (or reach their breakpoint) one by one and change the input-to-feedback impedance ratio and thus the amplifier output slope, thus changing the VDFG function to a desired curve. Note, however, that the breakpoint of each diode is fixed and cannot be changed. Only the slope of a line segment (or gain of the amplifier) is variable.

The PARALLAX control (R26, Figure 2.6-4) permits the operator to offset the X, Y point at X = 0 to any point along the Y axis between -10 and +10 volts. Potentiometer R6 determines the slope between X = 0 and X = +1; this adjustment permits setting the slope to a maximum of 2 volts per volt input either in a positive or negative direction. Potentiometer R7 determines the change in slope between X = +1 and X = +2 volts with respect to the slope between X = 0 and X = +1 volt. Each potentiometer in turn determines the change in slope of its corresponding line segment over the previous line segment slope.

c. Maintenance and Test Procedures

There are no calibration adjustments for the VDFG units since the slope potentiometers are set in accordance with the required function. The overall condition of the VDFG's can be determined by the following operational tests. These tests are set up for an oscilloscope display of the VDFG output; an XY plotter may be substituted if desired.

(1) Operational Test; -VDFG

(a) Set up the test circuit shown in Figure 2.6-7a. Set the scope X and Y range for 1 volt/centimeter.

(b) Place the computer in Rep-Op at the 20 millisecond rate and adjust the potentiometer input of the integrator for a 0 to -10 volt ramp output per Rep-Op cycle.

(c) With a zero input to the DFG check the PARALLAX control for a full +10 to -10 volt range; set the PARALLAX at Y = 0.

(d) Adjust the 1V control for a slope of zero from X = 0 to X = -1 volt.

(e) Set the 2V, 4V, 6V, 8V and 10V controls fully clockwise.

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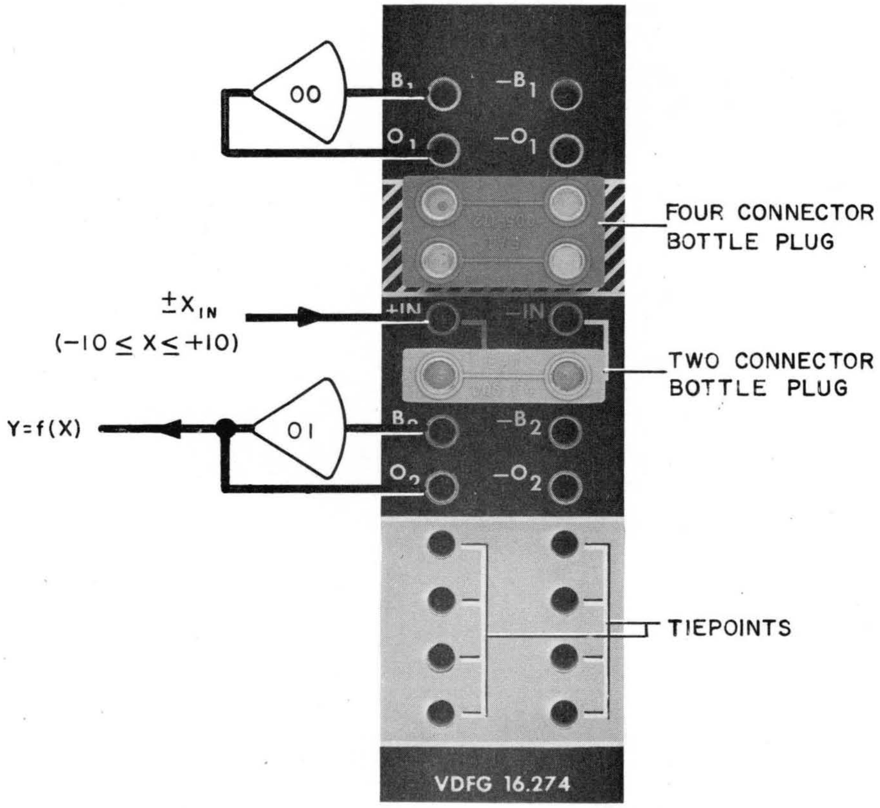
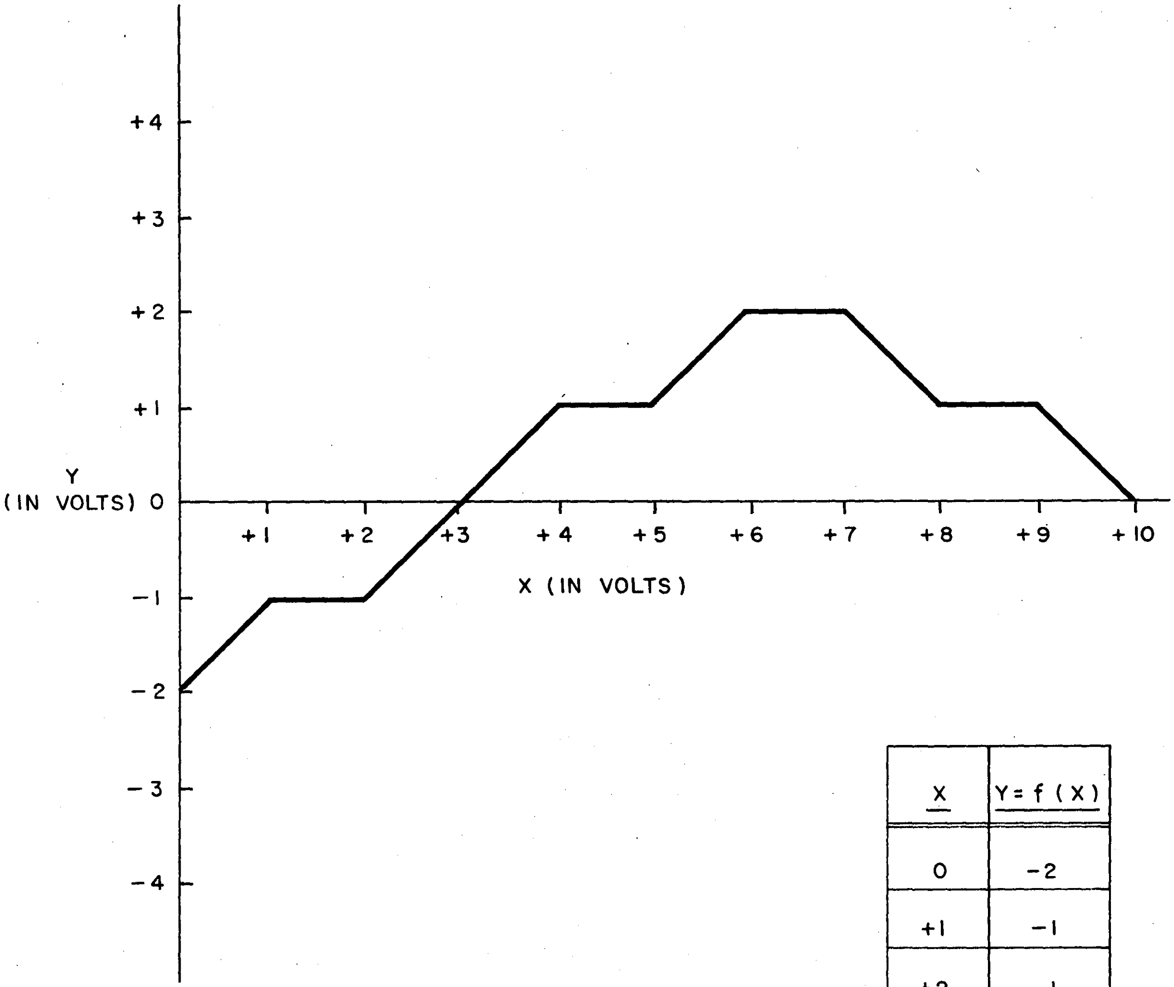


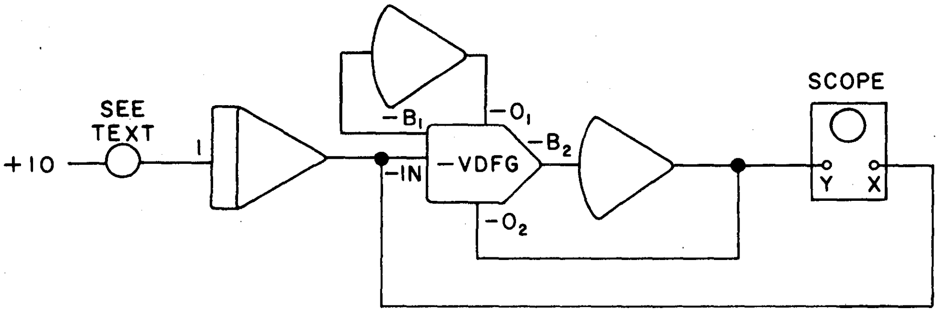
FIGURE 2.6-5. ± VDFG PATCHING

A4638

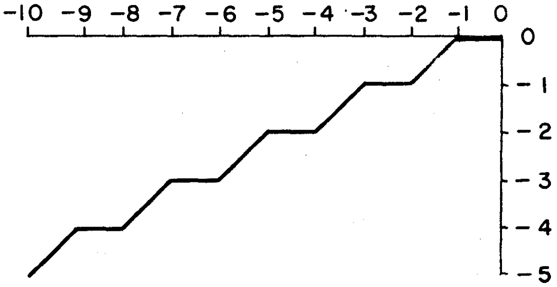


X	Y = f (X)
0	-2
+1	-1
+2	-1
+3	0
+4	+1
+5	+1
+6	+2
+7	+2
+8	+1
+9	+1
+10	+0

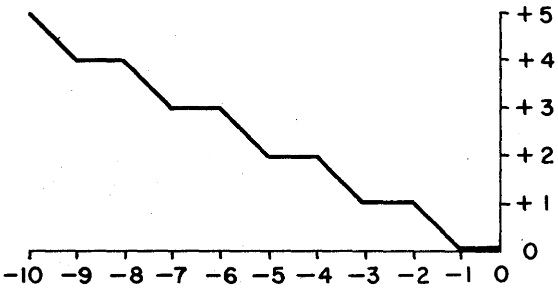
FIGURE 2.6-6. SAMPLE +VDFG OUTPUT CURVE



a. OPERATIONAL TEST CIRCUIT



b. SCOPE TRACE, FIRST TEST



c. SCOPE TRACE, SECOND TEST

FIGURE 2.6-7. −VDFG OPERATIONAL TEST SETUP

A 4691

(f) Set the 3V, 5V, 7V, and 9V controls fully counter-clockwise.

(g) Using the test circuit of Figure 2.6-7a and placing the computer in the Rep-Op mode, check the scope for the trace as shown in Figure 2.6-7b.

(h) Apply a fixed -1 volt input to the DFG (PARALLAX control still at zero) and check range of the 1V adjustment. The output should swing between -2 and +2 volts. Reset the -1 adjustment to zero.

(i) Set the 2V, 4V, 6V, 8V and 10V controls fully counter-clockwise.

(j) Set the 3V, 5V, 7V and 9V controls fully clockwise.

(k) Using the test circuit of Figure 2.6-7a with the computer in Rep-Op, check the scope for the trace as shown in Figure 2.6-7c.

(2) Operational Test; +VDFG

(a) Set up the test circuit shown in Figure 2.6-8a. Set the scope X and Y range for 1 volt/centimeter.

(b) Repeat steps (b) through (k) of the -VDFG procedure substituting positive potential inputs and observing traces b and c of Figure 2.6-8.

(3) Applicable Drawings. The following diagrams are contained in Volume II of this handbook.

Drawing Number	Type	Description
C016 274 0A	Assembly	Shows wiring of module behind Pre-Patch Panel area.
C016 156 0S	Schematic	Schematic diagram of +VDFG unit mounted behind control panel.
C016 154 0S	Schematic	Schematic diagram of -VDFG unit mounted behind control panel.
B045 034 0W	Wiring	Contains wire run sheets for computer wiring including interconnecting wiring between patch-panel area modules and VDFG connectors behind connectors behind control panel.

(4) Parts Lists. Appendix I contains the replaceable parts lists for the 16.274 VDFG units. See Index of Appendix I.

7. COEFFICIENT SETTING ATTENUATOR GROUP 2.440

a. General

The coefficient setting attenuators in the TR-48 are mounted on the right-hand panel of the computer cabinet. The panel can accept a total of 60 attenuators, in addition to 5 function switches.

Each 2.440 Attenuator Group consists of five potentiometers and an associated 42.283 Module that plugs into various cradles behind the patch panel. (See Figure 1.3-1.) In addition to providing patching terminations for the five pots, the 42.283 Module contains two relays to enable any pot to be selected for setting and readout.

The potentiometers are 10-turn, wire-wound units, equipped with calibrated, front-panel dials. The resistance element of each pot is protected by 1/32 ampere fuse in series with the wiper element. The fuse is mounted in a holder on the rear of the pot and can be reached by opening the attenuator panel door.

Four of the five pots in each group have two terminals (wiper and one end of the resistance winding) available at the patch panel. The fifth pot of the group is wired so that the wiper and both ends of the winding are terminated at the patch panel. See Figure 2.7-1.

b. Circuit Description

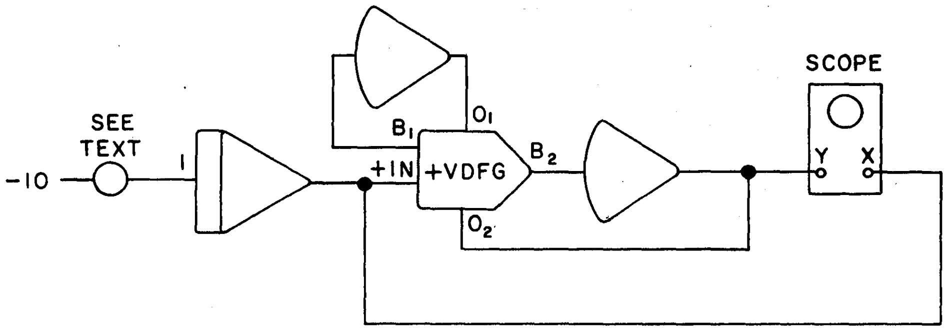
The circuit configuration of the 42.283 Module and the associated pots is shown on Drawing C042 287 OS. The ungrounded end of each pot is connected to the patch panel through normally closed contacts on K1, the Coefficient relay. When the computer is switched to the pot-set mode, K1 is energized, and connects the four grounded pots to the +10 volt reference bus. (Reference must be patched to the ungrounded pot.) Thus, each pot may be set to the required coefficient.

A particular pot is selected for setting and readout by depressing appropriate push-buttons on the control panel signal SELECTOR. The K2 relays of any consecutive pair of five-pot groups (0-9, 10-11, etc.) are energized by depressing first the P button of the SELECTOR hundreds row, and then any one of the top six buttons (0-5) in the tens row. When K2 in each pair of groups is energized, the wipers of all ten pots are connected to the ten switches (0-9) in the SELECTOR units row. From this point the wiper of one pot may be connected to the DVM (via the selector line) by depressing the appropriate units push-button (0-9).

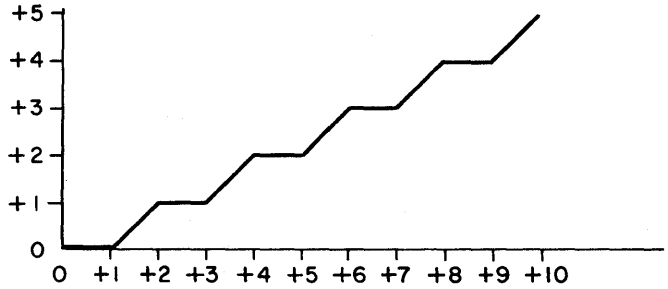
c. Maintenance

(1) Applicable Drawings. The following diagrams are contained in Volume II of this handbook.

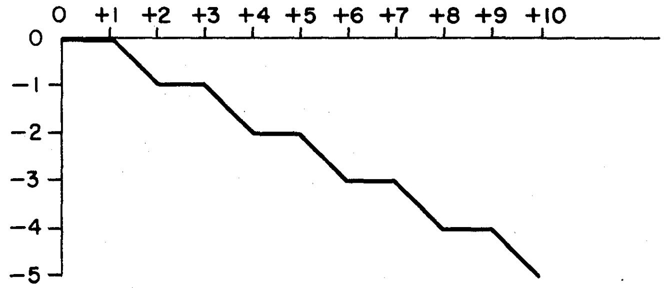
Drawing Number	Type	Description
C042 283 OS	Schematic	Schematic diagram of attenuator module.



a. OPERATIONAL TEST CIRCUIT

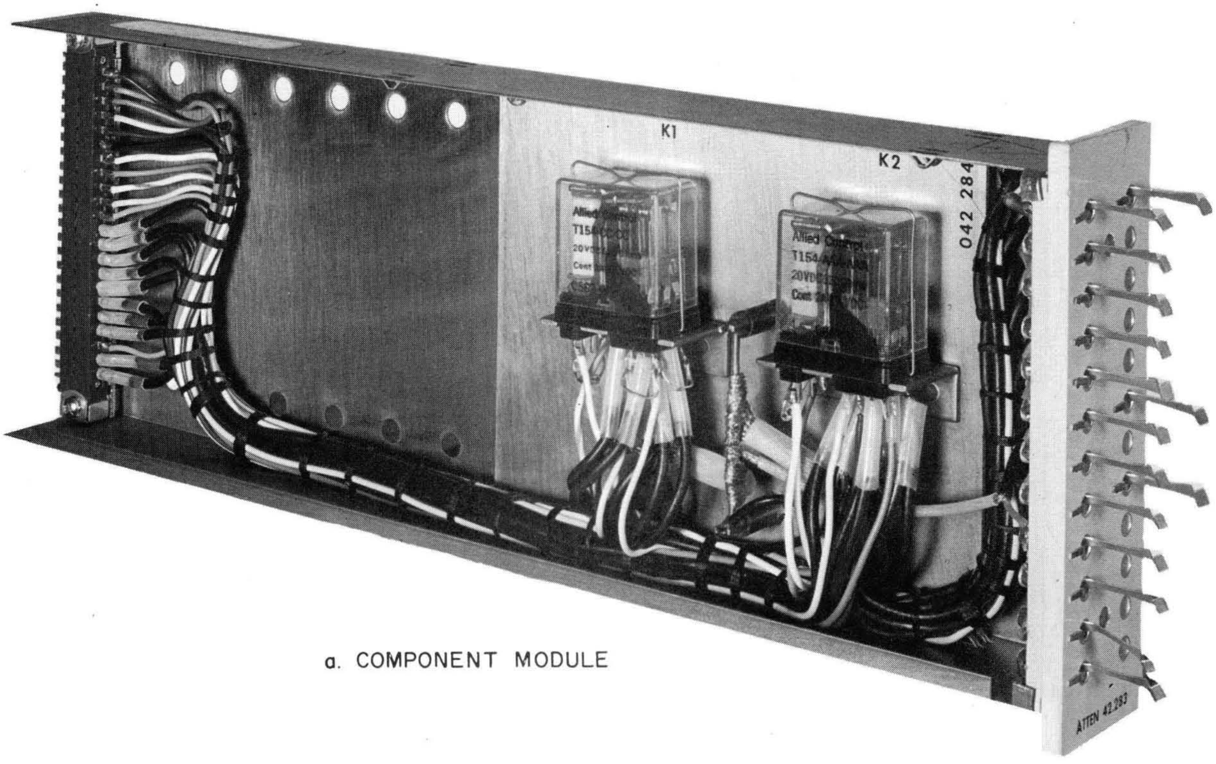


b. SCOPE TRACE, FIRST TEST



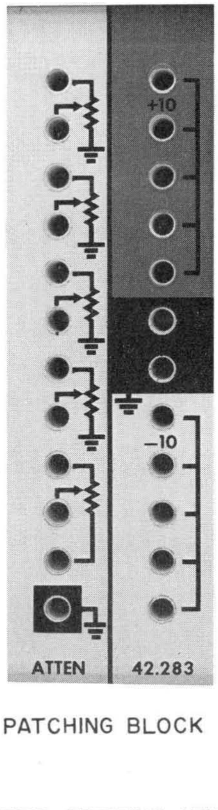
c. SCOPE TRACE, SECOND TEST

FIGURE 2.6-8. +VDFG OPERATIONAL TEST SETUP



TR 48
#76,56

a. COMPONENT MODULE



b. PATCHING BLOCK

FIGURE 2.7-1 COEFFICIENT SETTING ATTENUATOR, MODEL 42.283

A 4708

Drawing Number	Type	Description
B045 034 OW	Wiring	Contains wire run sheets for computer wiring from Pot Panel to Attenuator module connector plugs behind Pre-Patch Panel.

(2) Parts Lists. Appendix I contains the replaceable parts lists for the 42.283 Attenuator Units. See Index of Appendix I.

8. SIGNAL COMPARATOR 40.404

a. General

The 40.404 Comparator (Figure 2.8-1) consists of a sensitive switching amplifier that drives a double-pole, double-throw relay. This component is generally used to perform automatic switching functions when required in a problem setup. The amplifier compares two inputs and controls the associated relay in accordance with the relative signal level of each input.

The 40.404 Comparator is a dual unit, containing two amplifiers and two relays; the two sections are identical.

b. Comparator Patching

The patching area for the dual comparator includes two sets of input terminations and four sets of relay contact terminations. Each set of IN_1 and IN_2 terminations provides inputs for the potentials to be compared. Usually one of these inputs is a bias voltage against which a particular problem voltage is to be compared.

Each amplifier is arranged such that when the sum of the two input voltages is zero or less (negative), the associated relay is energized and the contacts transfer to the normally open side. If the input sum is positive the relay is de-energized.

To set up a comparator for an accurate switching level, use the following procedure. Connect reference of the appropriate polarity to a coefficient setting attenuator, and connect the attenuator wiper to the input of a gain-of-one amplifier. Patch the amplifier output to the IN_1 termination, and set the pot for the desired switching level. Patch the output of the amplifier to the IN_1 input. Connect reference voltage (same polarity as above) across another attenuator; connect the wiper to the IN_2 termination, and then adjust the second attenuator until the really operates. Finally, remove the setup amplifier from the IN_1 terminal, and connect this point to the control voltage source in the problem setup.

With the arrangement described, the normally-closed relay contacts will make when the input sum is positive, and the relay will transfer to the normally open side when the input sum is negative.

c. Circuit Description

The comparator amplifier and relay circuitry is shown on Drawings B006 134 0S, and B040 404 0S. Each input termination is connected through a summing resistor to the base of Q1. As long as the sum of the inputs is positive, Q1 is cut off; Q6 is also cut off and the relay is de-energized.

The conditions in the amplifier at this time are as follows: Q1 is cut off as mentioned above; Q3 is conducting because the base is returned to the -15 volt supply through R3, and the emitter is connected to the +15 volt supply through R9. (Q4 is not conducting, as explained below.) Q5 is cut off by the bias developed across R8. No current flows in the emitter circuit through R10, and Q6 is reverse-biased to cut off through R11.

Any drift due to temperature is reduced through the use of Q2 and Q4. Note that an increase in temperature will increase Ico in the input transistor Q1 and a similar increase will occur in Q2. These changes are applied to the base and emitter of Q3 respectively, thus causing the two increases to cancel.

When the sum of the inputs at the base of Q1 is zero or negative, the transistor conducts due to the slight forward bias applied to the emitter through R5. Collector current in R3 biases Q3 to cutoff and, as a result, Q5 is driven into conduction. Since Q5 is connected as an emitter-follower, Q6 also conducts due to the forward bias developed across R11. Relay K1 in the collector circuit is energized and the relay transfers to the - contacts.

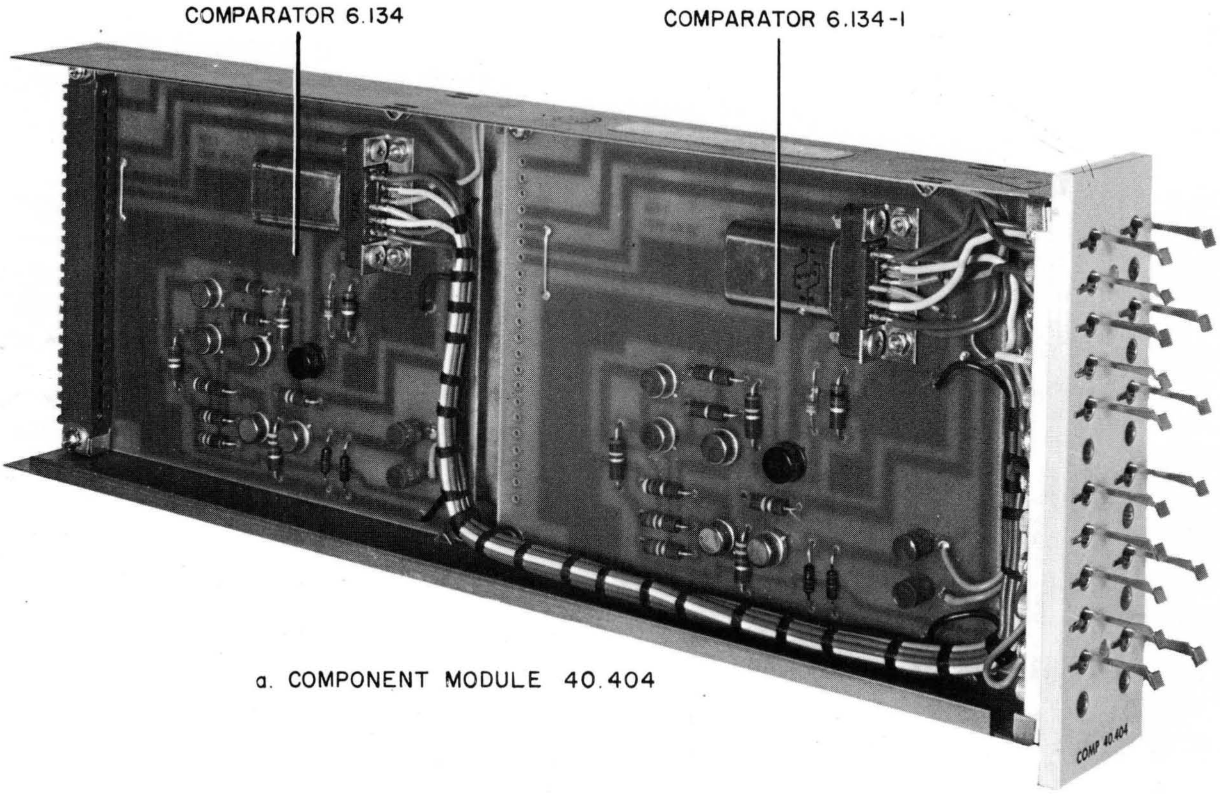
When Q1 conducts, the emitter current through R6 develops cut-off bias for the emitter of Q2. As Q2 is turned off, Q4 conducts, drawing current through R9 which applies reverse bias to the emitter of Q3. Thus the emitter receives a negative signal at the same time the positive signal is applied to the base.

Diodes CR1 and CR2 protect the input transistor by limiting the amount of voltage which can be applied across the base-emitter junction. In the output circuit of Q6, diode CR3 protects the transistor against momentary application of a high-forward bias to the collector caused by the collasping field around the relay coil when the circuit is broken.

d. Maintenance and Test Procedures

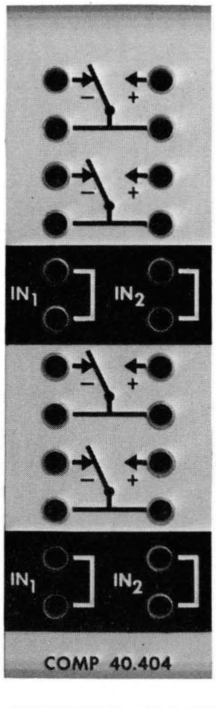
(1) Comparator Check. The most important characteristics of the signal comparator are the switching sensitivity and the switching time. These may be checked readily by using an oscilloscope and the test circuit as shown in Figure 2.8-2. The comparator is driven alternately by positive and negative-going ramp voltages (generated by the integrator). With the arrangement shown, the scope will display a triangular waveform from which the switching time and switching sensitivity may be determined. To perform these checks, proceed as follows:

(a) Patch the circuit shown in Figure 2.8-2; set the scope controls for an internal sweep rate of 2 milliseconds/centimeter and for a sensitivity of 0.1 volts/centimeter.



a. COMPONENT MODULE 40.404

TR-48
#74,52



b. PATCHING BLOCK

NOTE

THE 6.134 AND 6.134-1 ARE PHYSICALLY AND ELECTRICALLY IDENTICAL EXCEPT THE 6.134-1 DOES NOT HAVE A PLUG CONNECTOR

FIGURE 2.8-1 SIGNAL COMPARATOR, MODEL 40.404

A 4699

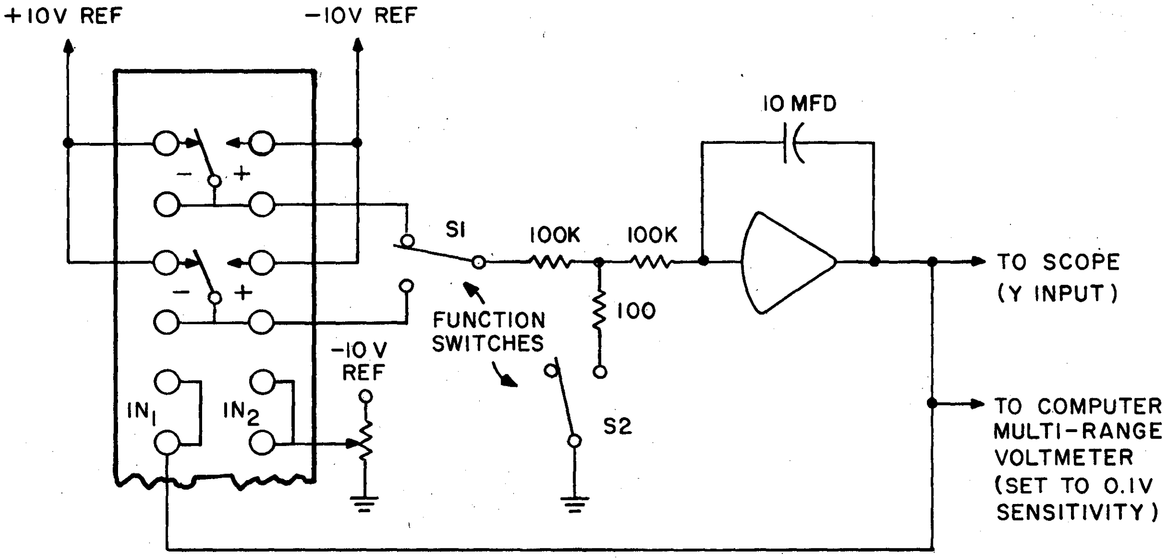


FIGURE 2.8−2 SIGNAL COMPARATOR
TEST SETUP

(b) Set the function switches as shown; switch the computer first to the reset and then to the operate mode. Adjust the attenuator for a reading of zero volts on the voltmeter (meter sensitivity should be 0.1 volt.)

(c) The distance between the top and bottom peaks of the triangular wave form represents twice the switch time (1 centimeter equals two milliseconds). Typical switching time for a normal comparator is 7 milliseconds.

(d) Move function switch S2 to ground the 100 ohm resistor. Set the scope sweep for 50 milliseconds/centimeter, and the sensitivity to 0.5 millivolts/centimeter.

(e) The peak-to-peak voltage of the displayed waveform represents the switching sensitivity. Typical values are 2 to 3 millivolts.

(f) The second set of contacts may be checked for switching time by setting S1 to the lower position.

(2) Applicable Drawings. The following drawings are contained in Volume II of this handbook.

Drawing Number	Type	Description
C040 404 0A	Assembly	Shows printed circuit card location on module and wiring to patching block and rear connector of module.
B040 404 0S	Schematic	Schematic diagram of relay contact connection for TR-48 comparator.
B006 134 0S	Schematic	Schematic diagram of 6.134 Amplifier used in 40.404 Comparator Module.

(3) Parts Lists. Appendix I contains the replaceable parts lists for the 40.404 Comparator Module. See Index of Appendix I.

9. FUNCTION SWITCH GROUP 2.462

A typical TR-48 Computer includes five function switches that are generally used to perform manual switching operations in problem setups.

Each function switch is a double-pole, triple-throw (center off) unit. Associated contacts are jumpered together to increase the current-handling ability; the switch is thus wired as a single-pole, triple-throw unit.

The 2.462 Group consists of the group of five switches, and a 12.766 patch panel module for terminating the switch contacts at the pre-patch panel.

The 12.766 Module may be used in module 5, slot 2, or module 8, slot 2. (See Figure 1.3-1.) Since these cradles are wired to rear-panel connectors J62 and J63, respectively, the plug that terminates the function switch wiring must be connected to the rear-panel connector that is wired to the cradle into which the 12.766 module is mounted. These cradles are all wired in the same fashion.

The replaceable parts for the 2.462 Function Switch Group is contained in Appendix I. See the Index of Appendix I. The following is a list of Applicable Drawings contained in Volume II of this handbook.

Drawing Number	Type	Description
C012 766 0A	Assembly	Shows the wiring of the function switch patching module from the patching block to the module rear connector.
B045 034 0W	Wiring	Contains wire lists giving the wiring from the function switches on the Pot Panel to the connector at the rear of the Patching Module.

SECTION III

POWER AND REFERENCE CIRCUITS

1. REGULATED POWER SUPPLY 10.200

a. General

This unit supplies all operational voltages required for the TR-48 components. The power supply is constructed on a small U-shaped chassis (see Figure 3.1-1) that mounts in a cradle behind the attenuator panel in the right-hand bay of the TR-48 cabinet. The mating cabinet connector is designated PS1.

The power supply chassis contains all components except the regulator transistors. These are fastened on a heavy metal heat sink that is mounted behind the component cradles. (See Figure 1.1-2.)

The 10.200 Power Supply operates directly from commercial 50 to 60 cycle power sources; the transformer primary windings are wired for 115 or 230 volts a-c by jumpers on the PS1 connector in the cabinet. The outputs provided by this unit are listed in the following table.

VOLTAGE	MAX LOAD CURRENT
+30V d-c*	0.5 amp
+15V d-c*	1.5 amps
-15V d-c*	2.0 amps
-20V d-c	2.0 amps
-6V d-c	1.0 amp
6.3V a-c	2.5 amps

*Electronically regulated to 1.0% of the rated level.

b. Circuit Description

The circuit configuration of the 10.200 is shown on Drawing C010 200 OS. As this drawing indicates, the unit actually consists of three regulated 15-volt supplies, a 20-volt filtered supply, an unfiltered 6-volt supply, and a 6.3 volt a-c source.

The three 15-volt supplies are all similar in circuit configuration; each consists of a full-wave rectifier, a filter capacitor, a series regulator (externally mounted) and a regulator amplifier in the form of a plug-in printed circuit card. Each two-stage regulator controls the output level of its associated rectifier-filter by amplifying any deviation from the rated 15-volt level, and applying the amplified difference voltage to the base of the associated series regulator. Thus, by controlling the emitter-to-collector impedance of the regulating transistor, the output is stabilized at the 15-volt level as long as the current-handling capability of the regulating transistor is not exceeded.

The three 15-volt supplies are connected to +15 volt, -15 volt, and +30 volt buses to facilitate distribution of this power to all components. The upper supply on the diagram (CR1-CR2) provides the -15 volt power since its negative terminal is connected to the -15 volt bus and its positive terminal (P1-3, 4) is grounded. The second 15-volt supply (CR3, CR4) provides the +15 volt power since the negative terminal is grounded and the positive terminal is connected to the +15 volt bus. The +30 volt power is provided by the second and third 15-volt supplies (CR3-4, and CR5-6, respectively). This is accomplished by connecting the negative side of the third supply (P1-9, 10) to the +15 volt bus and the positive side (P1-11, 12) to the +30 volt bus. This arrangement connects these two sources in series to provide the +30-volt potential.

c. Routine Maintenance and Adjustments

Level adjustments for each of the 15-volt regulated sources are provided in the form of panel mounted screw driver set potentiometers. The voltage levels should be checked occasionally, using the front panel voltmeter. If the supplies require adjustment, the +15 volt level should be set before adjusting the 30-volt output. This is necessary since the 30-volt supply is comprised of two series-connected 15-volt supplies.

Preventive maintenance of the 10.200 should consist of an occasional check of the ability of each source to maintain regulation under maximum load conditions. This can be accomplished by connecting appropriate values of load resistances across each supply to determine that the supply maintains regulation up to the maximum load current indicated in the table in sub-paragraph a.

It should be noted that regulated supplies of this type are relatively insensitive to any gradual deterioration that may occur in component characteristics, and will often continue to operate satisfactorily if such deterioration occurs. Usually a power supply malfunction results in complete loss of regulation; this is evidenced by overload indications in all amplifiers. In nearly all cases of regulation failure, the trouble can be cured by transistor replacement.

2. TDVM POWER SUPPLY 10.203

a. General

The 10.203 Power Supply (Figure 3.2-1) provides d-c operating potentials of -8 volts and +2 volts for the TR-48 Digital Voltmeter. This power supply plugs into a cradle behind the attenuator panel in the right-hand bay of the computer. The mating cabinet connector is designated PS2.

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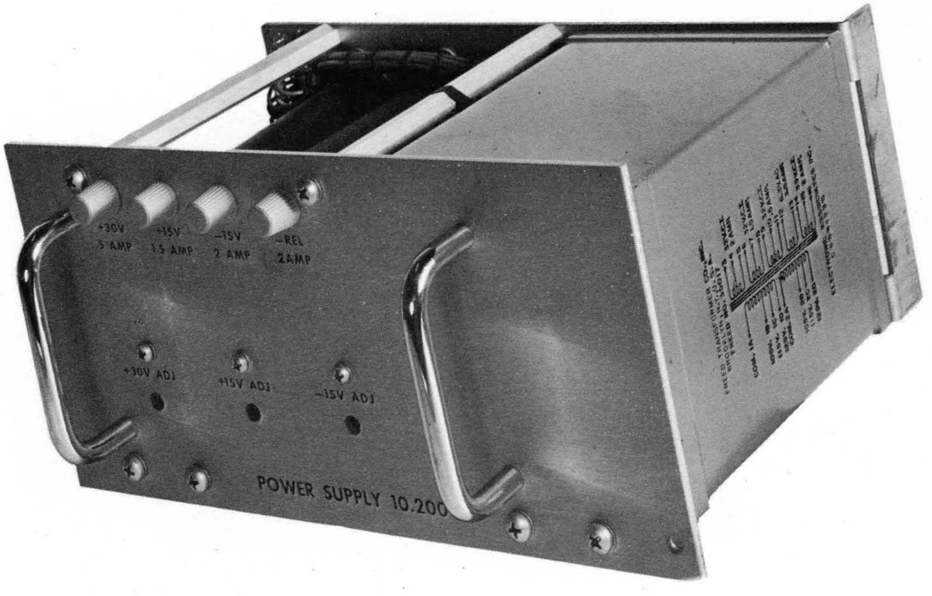

FIGURE 3.1-1. REGULATED POWER SUPPLY 10.200

TR48
#78

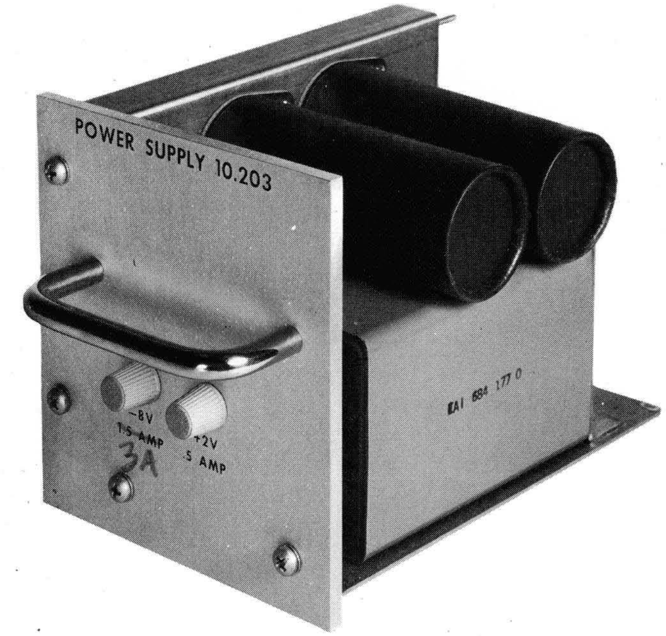

FIGURE 3.2–1. REGULATED POWER SUPPLY 10.203

The 10.203 supply operates directly from commercial 50 to 60 cycle power sources; the transformer primary windings are wired for 115 or 230 volts a-c by jumpers on the PS2 connector in the cabinet. The outputs provided by this unit are listed in the following table.

	VOLTAGE	MAX LOAD CURRENT
-6.5	-8V d-c	3 ~~1.5~~ amps
+1.6	+2V d-c*	0.5 amps
	6.3V a-c	1.0 amp

*Electronically Regulated

b. Circuit Description

The circuitry of the 10.203 Power Supply is shown on Drawing B010 203 OS. This simple unit consists of two full-wave rectifier and filter circuits supplying the 8-volt and +2 volt d-c potentials. Transistor Q1 functions as a series regulator to regulate the +2 volt output. Zener diode CR5 stabilizes the base of Q1.

The transformer includes an additional 6.3 volt winding to supply a-c power to the oven heater of the comparator in the digital voltmeter.

3. REFERENCE REGULATOR 43.104

a. General

The TR-48 uses a system reference level of ±10 volts for computational purposes. These potentials are generated by the 43.104 Reference Regulator, (Figure 3.3-1) and a 6.282 Dual D.C. Amplifier; both of these components are located in cradles behind the attenuator panel in the right-hand bay of the TR-48 cabinet. The mating cabinet connectors for the amplifier and regulator are designated P68 and P69 respectively.

The reference regulator includes a temperature-stabilized zener diode which functions as an internal reference standard. Under normal operating conditions, the regulator-amplifier combination generates ±10 volt potentials that are maintained to within 0.02% of 10 volts, and that are stable up to the maximum output of 250 milliamperes for each reference source.

Provision is made for using an external 10-volt reference source. The external reference line is terminated at Pin T of J69; by connecting the external reference source to this point and changing one patch cord (see sub-paragraph b), the computer reference circuits can be slaved to an external voltage standard.

b. Reference Patching

To connect the TR-48 reference circuits for internal reference, a patch cord is required between the REF IN and INT REF terminations on the reference regulator front panel. If an external 10-volt standard is to be used, the REF IN termination should be patched to EXT REF. To connect the amplifier to the regulator, each of the S terminations on the regulator must be patched to a corresponding S termination on the 6.282 Dual D.C. Amplifier.

c. Circuit Description

The configuration of the TR-48 reference circuits is shown in Figure 3.3-2. (For detailed circuitry of the amplifier and regulator see Drawings D006 282 0S and C043 104 0S respectively.)

The ±10 volt reference potentials are generated by using a zener diode as a voltage standard, and applying the zener-stabilized potential to a pair of cascaded d-c amplifiers with sufficient gain to develop the required reference levels. As shown in Figure 3.3-2, CR1 (the zener diode) and R10 are connected across the -15 volt supply to provide a stable source of approximately -6 volts. Resistors R7, R8, and R9 form the amplifier input resistor; R5 is connected as a 10,000 ohm feedback resistor across the amplifier. The input resistance value is selected and set at the time of manufacture so that the amplifier output is exactly 10 volts. To permit the reference source to deliver more load current than the amplifier itself is capable of delivering, an emitter-follower power stage (transistor Q4, mounted on the heat sink bracket), is driven by the amplifier. With this arrangement, the maximum load current capability of the source is increased to about 250 milliamperes.

The negative reference source consists of a similar arrangement. In this case the closed-loop gain of the amplifier is unity, thus multiplying the +10 volt level by a factor of -1 to develop the -10 volt potential. Potentiometer R1 permits a small gain adjustment (BAL ADJ) so that the plus and minus 10 volt levels may be precisely balanced with respect to each other.

To protect the reference circuits from overload damage, a bank of incandescent lamps is connected into the emitter circuit of each power amplifier. These lamps permit the amplifiers to function normally when delivering load currents of up to about 250 milliamperes. If a reference source is loaded beyond this point, the circuit loses regulation, the output level drops accordingly, and no damage can occur to the reference supply components.

d. Routine Maintenance and Adjustment

Prior to shipment, each reference regulator is adjusted to yield +10 volts ±0.02%; the negative source is balanced against this standard. These reference levels may be checked and re-adjusted at any time, if sufficiently accurate equipment is available. If not, EAI recommends that the regulator be returned to the factory should component replacement or adjustment become necessary.

TR48
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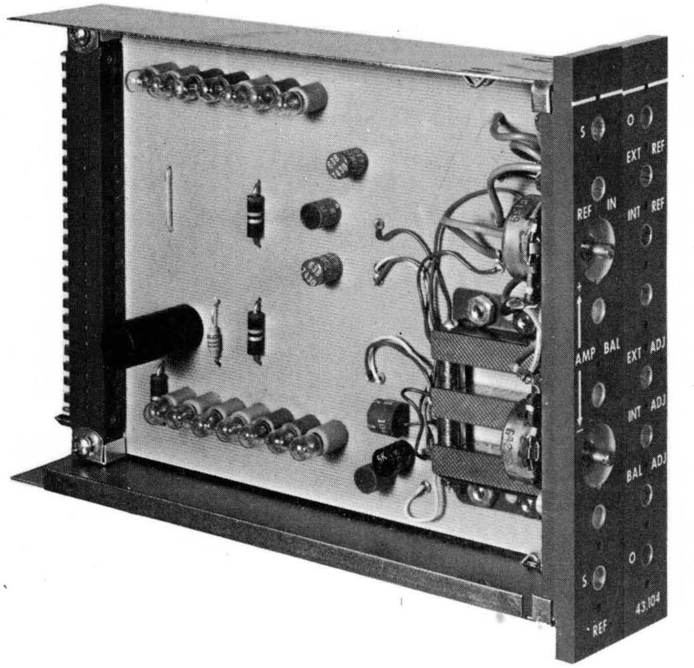
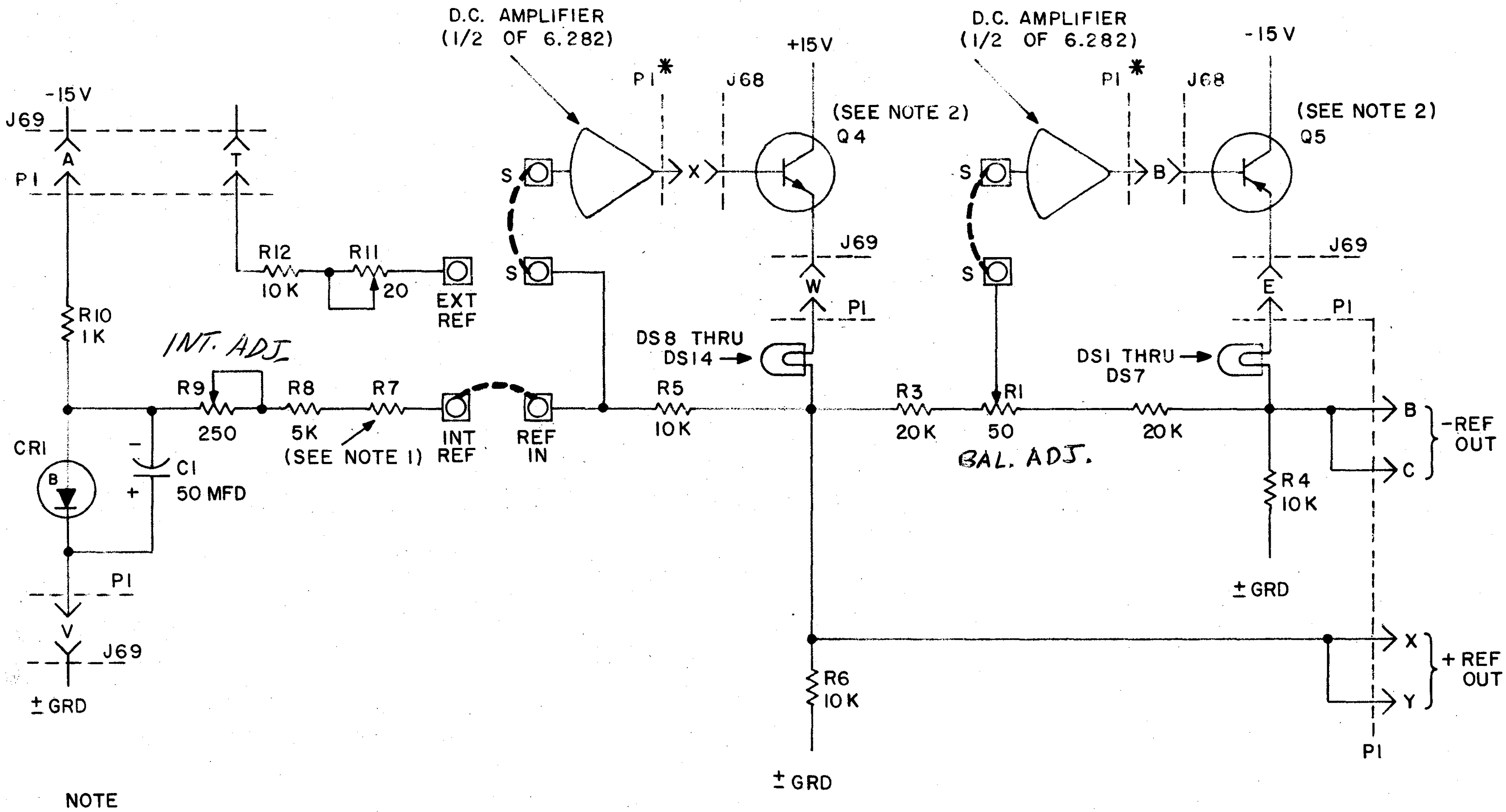


FIGURE 3.3-1. REFERENCE REGULATOR 43.104

A4668



NOTE

1. VALUE OF R7 DETERMINED AT TIME OF MANUFACTURE
2. Q4 AND Q5 ARE LOCATED ON HEAT SINK BEHIND COMPONENT CRADLES
3. * DENOTES AMPLIFIER CONNECTOR
4. (DENOTES PATCH CORD OR BOTTLE PLUG

FIGURE 3.3-2 TR-48 REFERENCE CIRCUITS, SIMPLIFIED SCHEMATIC

When required, the balance control (BAL ADJ) on the reference regulator may be adjusted to within 0.01% by using measuring circuits provided by the TR-48 itself. To set this control, use two gain-of-10 summing amplifier inputs; patch plus reference to one input and minus reference to the other. Observe the amplifier output ← PATCH with the control panel voltmeter on the 0.1 volt scale. Set the BAL ADJ control for a zero reading. Reverse the input polarities and again observe the amplifier output. If a voltage is indicated, set the BAL ADJ control for the mean of the difference. Continue this process until the same voltage (in both polarities) is obtained when switching the reference inputs.

Each amplifier in the 6.282 should be checked occasionally for balance. This is readily accomplished by setting the control panel VOLTMETER FUNCTION switch to the BAL position, and selecting the desired amplifier with the control panel SELECTOR. (The plus reference amplifier is No. 48, and the minus is No. 49.) The associated AMP BAL control should be set for a zero reading.

4. DUAL D.C. AMPLIFIER 6.282

a. General

As previously indicated this unit contains the two operational amplifiers used with the 43.104 Reference Regulator to generate the plus and minus 10 volt reference potentials.

The 6.282 amplifier circuitry is identical with that of the 6.514 Dual D.C. Amplifier described in SECTION 2-1 of this manual. Refer to that section for all details regarding circuit description and maintenance techniques for the 6.282 Amplifier.

SECTION IV

CONTROL AND MONITORING CIRCUITS

1. CONTROL PANEL 20.790 (See Figures 1.3-1 and 1.6-1.)

a. General

The control and monitoring facilities for the TR-48 are consolidated at the 20.790 Control Panel, which forms the left side of the computer front panel. The monitoring circuits of the TR-48 include a multi-range voltmeter with associated RANGE and FUNCTION selector switches, an electronic digital voltmeter*, a push-button select readout system, and a set of amplifier overload lamps.

The control facilities on this panel include power on/off, pre-patch panel engage and disengage, and a push-button switch for controlling the computer mode of operation.

b. Monitoring Circuitry

The TR-48 monitoring circuits are shown in block diagram form in Figure 4.1-1. The four main components of this system are the 3-level push-button signal SELECTOR system, the selector relays (mounted on the 11.148 Relay Unit), the digital voltmeter, and the multi-range voltmeter with associated RANGE and FUNCTION selectors.

In the standard TR-48, the readout system is wired to scan 175 points in the computer. (The maximum capacity of the system is 230 points; thus, some computers may be wired to read out additional points.) These 175 circuits include 50 amplifier output terminals, 50 amplifier stabilizer outputs (for balancing purposes), the wiper of each of the 60 coefficient setting attenuators, and fifteen of the leads connected to J64 (IN TRUNK connector on the rear of the TR-48 cabinet).

As the block diagram shows, the amplifier outputs, the stabilizer lines and the J64 leads are connected to contacts of the selector relays. (See Sheet 2 of Drawing D045 034 OS.) The coils of these relays are controlled by the hundreds (in position A) and tens push-buttons of the signal SELECTOR (shown in the center of Figure 4.1-1).

The switching action of the relays connects selected groups of the monitored points to contacts on the units push-buttons. By depressing one of these buttons, the

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*Computers not equipped with a digital voltmeter have a 10-turn potentiometer and associated reference voltage selector switch for measuring computing voltage levels. These components are mounted on the 20.790 Control Panel in place of the digital voltmeter readout unit.

selected point is connected to the selector line, which is terminated at Pin 5 of switch S8c. (See Sheet 3 of D045 034 OS.)

The coefficient setting attenuators are selected for readout by a similar process. Operating the P push-button (hundreds row) and then one of the tens buttons will energize the output relay of each Attenuator Group in a pair of groups (see Sheet 1 of D045 034 OS and C042 283 OS). This switching action connects the wipers of the ten selected attenuators to the contacts of the units level of the signal SELECTOR; thus, one of these ten attenuators may be selected by operating the appropriate push-button in the units level.

As previously indicated, the output of the signal SELECTOR is connected to pin 5 of switch S8c. This control is the PS (pot set) push-button of the computer MODE control. (See Paragraph 5 of SECTION I, and sub-paragraph c below for details of computer operational modes.) With the computer switched to any mode other than pot set, the selector output line is connected to the SEL terminations of the patch panel readout module. Terminations for the inputs to the DVM and the multi-range voltmeter are adjacent to the SEL terminations, so that bottle plugs may be used to connect either or both of these instruments to the selector line. It should be noted, however, that the voltmeter circuit is a relatively heavy load and should never be used to monitor circuits that cannot tolerate loading; for this reason the selector line is routed through the PS switch. Thus, when the computer is in the PS mode, the selector line is connected directly to the DVM input and will not be affected by voltmeter loading even if the SEL and VM terminations are patched together.

Amplifiers are selected for balance monitoring in the same fashion as for output monitoring. The only difference is that the stabilizer of the selected amplifier is connected to the balance monitoring line, rather than the selector line. The balance monitoring line is connected to the meter through the VOLTMETER RANGE and FUNCTION switches.

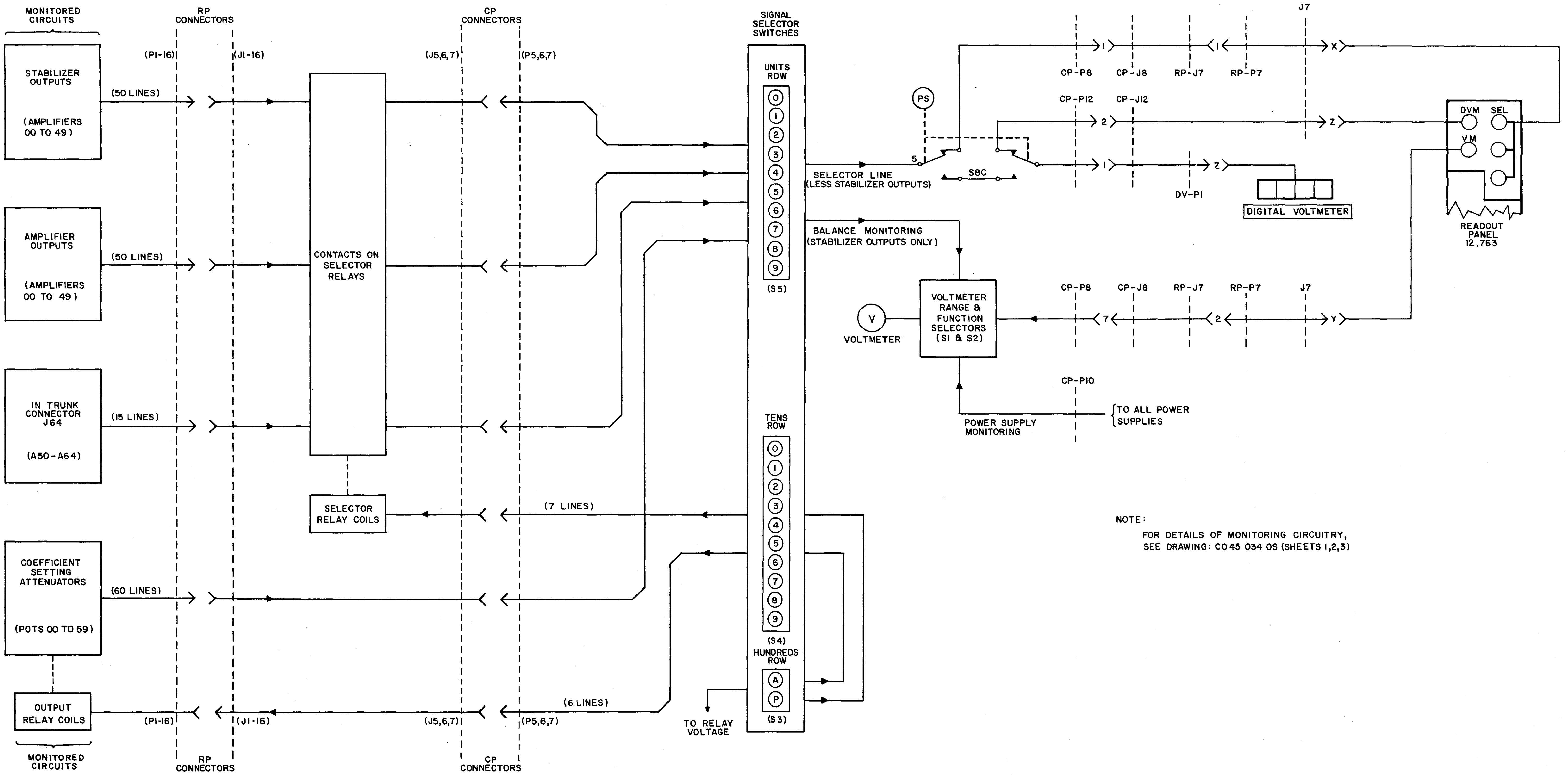
c. Computer Mode Control

The operational modes of the TR-48 are controlled by a 6-position push-button MODE switch on the 20.790 Control Panel. Operating these buttons performs various switching functions depending on the mode selected. The main function is to drive switching transistors which energize or de-energize certain control buses; actual component switching is accomplished by relays which are connected to these buses. (The switching transistors are Q1, Q2, and Q3, mounted on the heat sink bracket on the back of the computer.)

Detailed operational descriptions of mode control appear in the TR-48 Operator's Manual. This paragraph is intended only as an electrical description of the mode circuits to show how the control buses are energized.

The mode control circuits are shown on Sheet 2 of Drawing D045 034 OS. S8 is the MODE selector; this switch is constructed so that only one button can be down at any time. A lamp inside each button indicates the selected mode.

The switching functions performed in each mode are summarized in the following table.



NOTE:

FOR DETAILS OF MONITORING CIRCUITRY, SEE DRAWING: CO45 034 OS (SHEETS 1,2,3)

FIGURE 4.1-1.
TR-48 MONITORING CIRCUITS,
BLOCK DIAGRAM

B3162

MODE	CIRCUIT					
	OPERATE BUS	RESET BUS	TIME SCALE BUS	SW. REL BUS (AMPL. P.S. RELAYS)	DVM INPUT LINE	SIGNAL SELECTOR LINE
HOLD (HD)	De-energized	De-energized	De-energized	De-energized	Connected to Patch Panel. (DVM Terminal on Readout Module.)	Connected to Patch Panel. (SEL Terminal on Readout Module.)
POTSET (PS)	De-energized	De-energized	De-energized	Energized (-20 volts)	Connected directly to selector line. (Disconnected from Patch Panel.)	Connected to DVM Input. (Disconnected from Patch Panel.)
RESET (RS)	De-energized	Energized (-20 volts)	De-energized	De-energized	Same as HOLD	Same as HOLD
OPERATE (OP)	Energized (-20 volts)	De-energized	De-energized	De-energized	Same as HOLD	Same as HOLD
SLAVE (SL)	Disconnected from Mode Control. Controlled from external source (master TR-48) through slave table.		De-energized	De-energized	Same as HOLD	Same as HOLD
REPETITIVE OPER. (RO)	Connected to and controlled by Rep Op Timing Unit		Energized (-20 volts)	De-energized	Same as HOLD	Same as HOLD

2. DIGITAL VOLTMETER 26.183

The 26.183 DVM provides accurate and rapid measurements of d-c voltages. When mounted in the TR-48, the DVM main chassis is housed in a cradle behind the control panel, and the four-place display unit is mounted on the front of the control panel. The main chassis connector designated DV-P1 mates with DV-J1 in the DVM cradle; DV-J2, and DV-J3 serve to connect the DVM display unit to the main chassis.

3. REPETITIVE OPERATION

a. General

Repetitive operation of an analog computer consists of forcing the computer to speed up the time of problem solution, and to continually repeat the problem solution. The rate at which this occurs is usually high enough to permit displaying computing voltages on a conventional oscilloscope.

In the TR-48 the repetitive operation feature is provided by a Model 36.082 Timing Unit (Figure 4.3-1) and a REP OP Control Module on the 20.790 Control Panel. (See Figure 1.6-1.) These circuits permit the computer to be switched rapidly (at a selectable rate) between the operate and reset modes of operation.

The timing unit is mounted in a cradle behind the attenuator panel and mates with J67 in the cabinet. The control module connects to CP-J11.

b. Repetitive Operation Mode

The computer is prepared for repetitive operation by depressing the RO button of the MODE control. This switching action connects operating potentials (±15 volts and -20 volts) to the timing unit circuits, connects the reset and operate buses to the reset and operate control lines in the timing unit, and also energizes the time scale bus. Under these conditions, the computer time scale is changed to permit high-speed runs (in faster than real time), and switching between the reset and operate modes is controlled automatically by the timing unit.

Refer to the TR-48 Operator's Manual for operation of the Rep Op system.

c. Timing Unit and Rep Op Control Module

These components are shown schematically on Drawings C036 082 OS and B002 435 OS. The function of the timing unit is to provide control voltages to energize the reset and operate buses, and to supply sweep voltages for the display oscilloscope. The control module consists of a 4-position COMPUTE TIME switch and a VERNIER potentiometer. These components permit selection of the repetitive operation rate by controlling the operation of the Q1-T1 blocking oscillator in the timing unit. (See Drawing C036 082 OS.) The blocking oscillator drives Q2, which supplies the oscilloscope sweep voltage. (Pin L of the timing unit connector is wired to the terminal adjacent to the pulse symbol on the Patch Panel Readout Module.)

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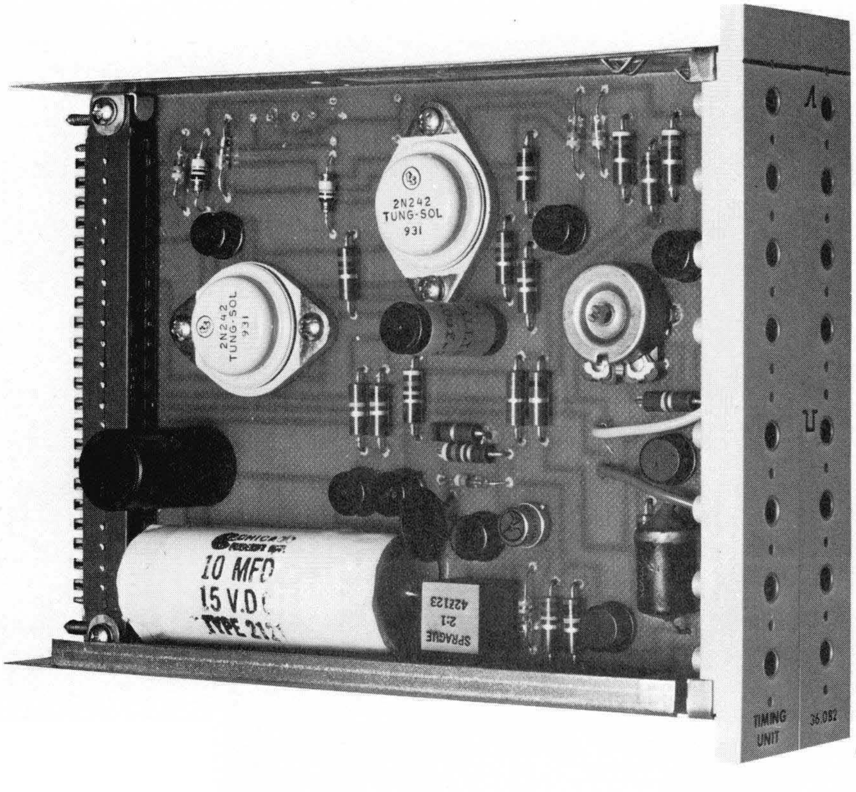


FIGURE 4.3-1. REP-OP TIMING UNIT, MODEL 36.082

A4707

The blocking oscillator also triggers a monostable multivibrator (Q3, Q4) which controls the repetitive operation reset timing. The multivibrator output is taken from Q5 (an isolating stage) and drives the 4-stage switching amplifier consisting of Q8, Q9, Q10, and Q11. The circuitry is arranged such that the sharp negative-going pulse appearing at pin 4 of T1 triggers the multivibrator. The resultant switching action drives the reset bus (connected to pin Y) to -20 volts while the multivibrator is cycling. When the multivibrator switching cycle is completed, the reset bus potential drops back to zero and the operate bus is energized (-20 volts). This action continues at the rate selected by the COMPUTE TIME control. Adjustment of the multivibrator rate is provided by R9 in the base circuit of Q4.

The isolated output of the multivibrator is also brought out to the front panel of the timing unit to provide an oscilloscope sync signal for adjusting the repetitive operation timing circuits. Refer to sub-paragraph d below for complete details.

d. Repetitive Operation Timing Adjustments

Five screwdriver adjust potentiometers are included in the timing circuits to permit calibration of repetitive operation timing. These controls consist of R1, R2, R3, and R4, mounted on the rear of the REP OP COMPUTE TIME switch, and R9 on the timing unit card. The COMPUTE TIME pots control operate timing, and the timing unit pot permits adjustment of reset time. To check and adjust these controls proceed as follows:

(1) Prepare the computer for operation; remove the timing unit from its cradle and mount it on the test shelf.

(2) Patch a real time integrator and connect it to the repetitive operation display scope as shown in Figure 4.3-2.

(3) Set the COMPUTE TIME switch to the 20 millisecond position; rotate the VERNIER control fully counter-clockwise.

(4) Set the oscilloscope controls for a 5 millisecond/centimeter sweep, and for external sync (adjust as necessary).

(5) Switch the computer to the repetitive operation mode. Set the integrator input voltage as high as possible without amplifier overload, then adjust the vertical sensitivity of the scope for sufficient deflection to observe the waveform shown in Figure 4.3-2.

(6) If the displayed waveform is not as shown, adjust R9 on the timing unit until the reset time is 10 milliseconds (±5%).

(7) To set the operate time, adjust R1 on the COMPUTE TIME switch assembly (behind the attenuator panel) for an operate time of 20 milliseconds.

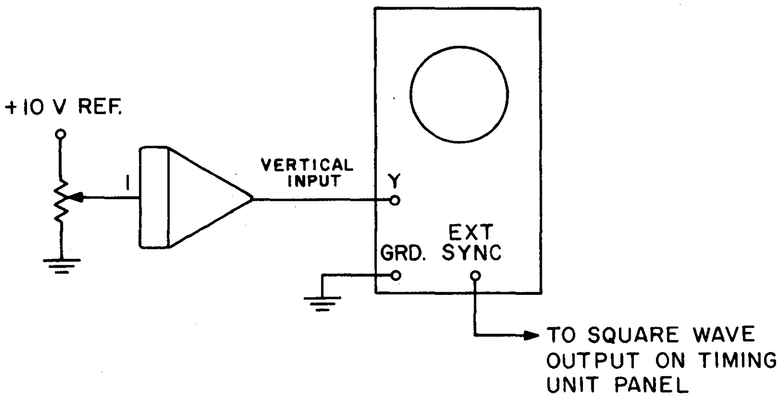
(8) Repeat step (7) for each of the remaining ranges; re-adjust the scope controls accordingly. In each case adjust the appropriate potentiometer for the <u>operate</u> time (±5%) as selected by the switch.

4. PATCH PANEL READOUT MODULE ~~12.762~~ 12-763 Revision 12-763

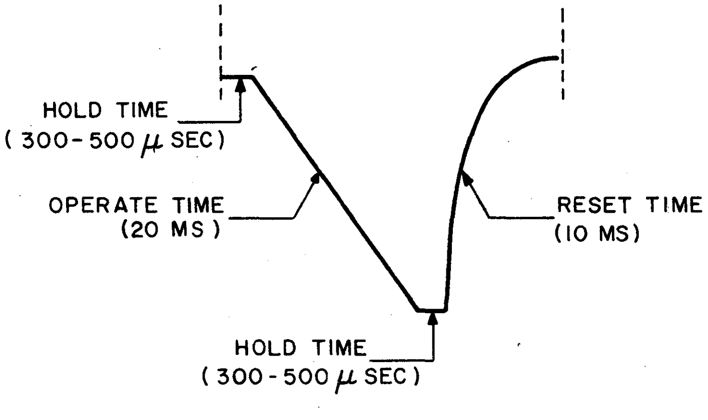
The 12.762 Module provides a consolidated patch panel area in which all TR-48 monitoring circuits (including external equipment cabled to the computer) are terminated. The readout module is normally positioned in module 2, slot 2 (J7) of the computer cabinet, as shown in Figure 1.3-1.

Internal monitoring facilities terminated at the readout module include the signal selector output line and the digital voltmeter and multi-range voltmeter input terminals. External circuits terminated at the readout module include X and Y inputs to an oscilloscope connected to J66 on the rear of the TR-48 cabinet, two sets (X and Y) of plotter/recorder inputs connected to J65, and ten trunk lines that enter the TR-48 at J61. (See Figure 1.3-1 and Paragraph 1-5 for details on the external connector module.)

Figure 4.4-1 is a schematic diagram showing the function and origin of all terminations brought out to the readout module.

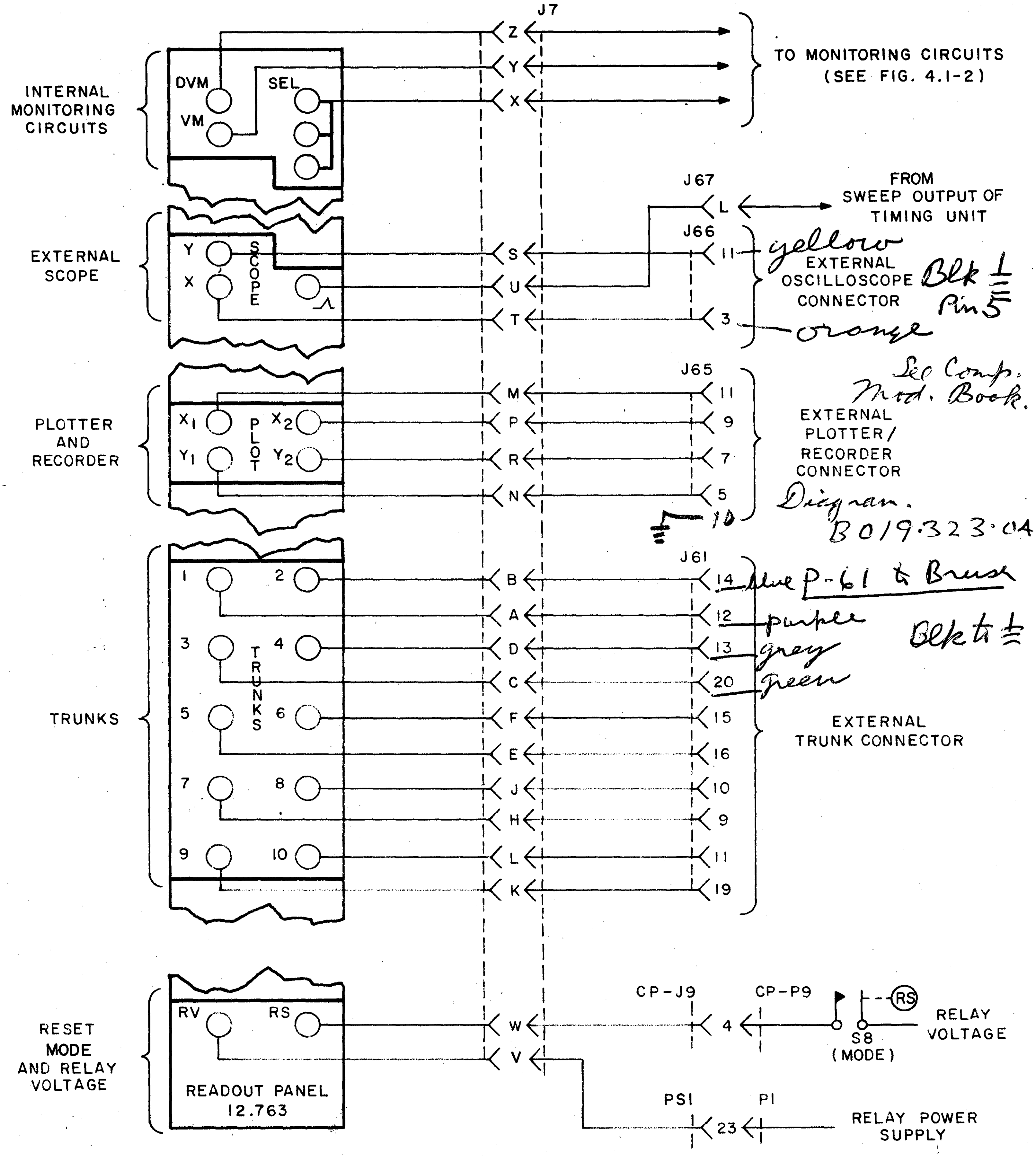


A. TIMING ADJUSTMENT TEST SETUP



B. DESIRED WAVEFORM

FIGURE 4.3-2 REPETITIVE OPERATION TIMING ADJUSTMENTS



yellow

Blk ⏚ Pin 5

orange

See Comp. Mod. Book. Diagram. B019·323·04

10

blue P-61 to Brush

purple

grey

green

Blk to ⏚

Revision on pink sheet does not apply.

FIGURE 4.4-1. PATCH PANEL READOUT MODULE WIRING

For Wiring Drawing. See B045 034 0W Sheet 14

A4695

APPENDIX I

REPLACEABLE PARTS LIST

This appendix lists all replaceable parts in the TR-48 Analog Computer, Model 45.034. In each case a brief description of the part and a manufacturer's number are listed. Where applicable, a reference symbol (schematic designation) is included. To enable a particular sheet to be readily located, an index precedes the individual spare parts lists.

The category column in the parts list indicates the availability of each listed part so that a replacement part can be obtained as quickly as possible. The components in category A are standard electronic items that are usually available from any commercial electronic supplier. In order to expedite obtaining items of this nature, it is suggested that they be purchased from a local source whenever possible. If necessary, these parts may be ordered from EAI.

The components in category B are items that can be obtained from EAI or any of the listed manufacturers. However, in most cases EAI is in a position to offer the most rapid service on items in this category.

The parts in category C are custom-made components and proprietary items that are available only from EAI. When ordering items of this type, please specify the type number and serial number of the basic unit in which the part is located, as well as the part identification.

Where possible, sufficient information is given for category C items to permit an electrically-similar replacement part to be obtained locally. Thus, if desired, a temporary repair may be made while the exact replacement is being obtained from EAI. Note, however, that EAI does not guarantee that the affected unit will operate within specifications when the specified category C part is not used.

PLEASE NOTE THAT EAI RESERVES THE RIGHT TO MAKE PART SUBSTITUTIONS WHEN REQUIRED. IN ALL CASES, EAI GUARANTEES THAT THESE SUBSTITUTIONS ARE ELECTRICALLY AND PHYSICALLY COMPATIBLE WITH THE ORIGINAL COMPONENTS.

PARTS LIST INDEX

TR-48 ANALOG COMPUTER, MODEL 45.034

PARTS LIST INDEX (Cont)

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*The components marked with an asterisk (*) are listed for reference only. The parts lists for these components appear in a separate manual for the respective components.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,2,3	Capacitor, Fixed, Paper (Triple): .01UF +20% -10%, 600V; Sangamo Electric Co. CP54BEF-104V	520 016 0	A
2	C5,6,7	Capacitor, Fixed, Electrolytic: 3000UF +100% -10%, 3V; International Electronic Industries APS Type	516 247 0	C
3	F60	Fuse, Cartridge, Slow Acting Type: 1-1/2 amp 125V; Bussman Type MDL	570 033 0	A
4	K2,3,5,6,8 9,11,12,14-18,20-24, 26-30,50,51	Relay: 18V DC Coil, 6 Form A Contacts; Allied Control Co. T-154-6A-520	618 172 0	B
5	K10	Relay: 18V DC Coil, 4Form C Contacts; Allied Control Co. T-154-4C-520	618 171 0	B
6	Q1,2,3,6,7 8	Transistor, Germanium: PNP; Delco 2N277	686 003 0	B
7	Q4	Transistor, Germanium: PNP; Tung-Sol 2N242	686 018 0	A
8	Q5	Transistor, Germanium: NPN; Sylvania 2N1218	686 025 0	B
9	R1,2,3	Resistor, Fixed, Composition: 10 ohms ±10% 1W; Allen-Bradley GB	627 100 1	A
10	R4,5,6	Resistor, Fixed, Composition: 1K ohms ±10% 1/2W; Allen-Bradley EB	626 102 1	A
11		Motor,Reversible Gearmotor:115V 60CPS; New England Gear Works HD-PSC	594 056 0	C
12		Switch,Sensitive:Momentary Contact,SPST; Micro Switch 11SM1	662 009 0	B

We have. 45-034

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT CAN BE PURCHASED LOCALLY OR FROM EAI.
C - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.
THE PROPER EAI PART SHOULD BE INSTALLED FOR CATEGORY C ITEMS. A COMPLETE DESCRIPTION IS GIVEN TO PROVIDE FOR TEMPORARY REPAIRS; HOWEVER, EAI WILL NOT BE RESPONSIBLE IF UNIT IS NOT WITHIN SPECIFICATIONS UNDER THESE CONDITIONS.

DATE 6 / 19 / 62

UNIT TITLE

TR 48 Computer

MODEL NO.

45.034 Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1	Resistor, Variable, Composition: 20K ohms ±20%, .2W; Bourns Laboratories 276-1-203	642 471 0	B
2	R2	Resistor, Variable, Composition: 50K ohms ±20%, .2W; Bourns Laboratories 276-1-503	642 472 0	B
3	R3	Resistor, Variable, Composition: 100K ohms ±20%, .2W; Bourns Laboratories 276-1-104	642 482 0	B
4	R4	Resistor, Variable, Composition: 200K ohms ±20%, .2W; Bourns Laboratories 276-1-204	642 490 0	B
5	R5	Resistor, Fixed, Wirewound, Precision: 2900 ohms ±1%, .005% Stability; National Resistor Corp. EU-2 Type	A638 439 0	C
6	R6	Resistor, Variable, Composition: 7.5K ohms ±20%, 1W; Reon Resistor Corp. RA75221R2X	A642 486 0	C
7	R7	Resistor, Fixed, Composition: 4.7K ohms ±10% 1W; Allen-Bradley GB	627 472 1	A
8	S6	Switch, Rotary: 2 Sections, 6 Positions; Centralab PA037-085	B658 180 0	C

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT CAN BE PURCHASED LOCALLY OR FROM EAI.
C - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.
THE PROPER EAI PART SHOULD BE INSTALLED FOR CATEGORY C ITEMS. A COMPLETE DESCRIPTION IS GIVEN TO PROVIDE FOR TEMPORARY REPAIRS; HOWEVER, EAI WILL NOT BE RESPONSIBLE IF UNIT IS NOT WITHIN SPECIFICATIONS UNDER THESE CONDITIONS.

DATE 6 / 1 / 62

UNIT TITLE

REPETITIVE OPERATION
SWITCHING UNIT

MODEL NO.
20.534 Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Plastic: 10 UF +0%-5%, 50V	B 521 077 0	C
2	C2	Capacitor, Fixed, Ceramic: 1,000 PF GMF; 600V; Cornell-Dublier BYA6D1	515 005 0	C
3	C3	Capacitor, Fixed, Paper: .05 UF ±20%, 200V; Aerovox P8292ZN9	520 210 0	A
4	C4	Capacitor, Fixed, Electrolytic: 50 UF +100%-10%, 25V; Callins Industries PSS Type	A516 198 0	C
5	C5	Capacitor, Fixed, Electrolytic: 100 UF +150%-10%, 25V; P.R. Mallory Pet-A Type	A516 191 0	C
6	CR1-6	Diode, Germanium: Clevite CTP462 Type	614 043 0	B
7	CR7,8	Rectifier, Silicon: Pacific Semiconductors PSC05 Type	614 035 0	B
8	Q1-7	Transistor, Germanium: PNP; Industro	B686 032 0	C
9	Q8,10	Transistor, Germanium: PNP; General Electric 2N321 Type	686 004 0	A
10	Q9,11	Transistor, Germanium: PNP; Tung-Sol 2N242 Type	686 018 0	A
11	R1,2	Resistor, Fixed, Composition: 47K Ohms ±10%, 1/2W; Allen-Bradley EB	626 473 1	A
12	R3	Resistor, Fixed, Composition: 18K Ohms ±10%, 1/2W; Allen-Bradley EB	626 183 1	A
13	R4	Resistor, Fixed, Composition: 2.2K Ohms ±10%, 1/2W; Allen-Bradley EB	626 222 1	A
14	R5,13,16	Resistor, Fixed, Composition: 10K Ohms ±10%, 1/2W; Allen-Bradley EB	626 103 1	A
15	R6,14	Resistor, Fixed, Composition: 15K Ohms ±10%, 1/2W; Allen-Bradley EB	626 153 1	A
16	R7,18,19, 20	Resistor, Fixed, Composition: 1K Ohms ±10%, 1/2W; Allen-Bradley EB	626 102 1	A
17	R8	Resistor, Fixed, Composition: 220K Ohms ±10%, 1/2W; Allen-Bradley EB	626 224 1	A

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6/1/62

UNIT TITLE

TIMING UNIT

MODEL NO.

36.082 Sht. 1 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
18	R9	Resistor, Variable, Composition: 300K Ohms ±30%, .2W; Chicago Telephone Supply UPE-70 Type	A642 476 0	C
19	R10,11	Resistor, Fixed, Composition: 4.7K Ohms ±10%, 1/2W; Allen-Bradley EB	626 472 1	A
20	R12	Resistor, Fixed, Composition: 22K Ohms ±10%, 1/2W; Allen-Bradley EB	626 223 1	A
21	R15,17	Resistor, Fixed, Composition: 560 Ohms ±10%, 1/2W; Allen-Bradley EB	627 561 1	A
22	T1	Transformer, Pulse: 2:1 TURNS Ratio; Sprague Electric Co. 42Z123 Style 1	B684 125 0	B

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6/1/62

UNIT TITLE
TIMING UNIT

MODEL NO.
36.082

Sht. 2 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,10	Capacitor, Fixed, Electrolytic: 10 μF ±20%; 50V; Sprague Elect. Co., 109D106X0050C2	516 206 0	A
2	C2,9,11,18	Capacitor, Fixed, Electrolytic: 1,250 μF; 3V; Callins Industries PSS Type	A516 184 0	C
3	C3,12	Capacitor, Fixed, Ceramic: 100 PF ±10%; 1,000V; Cornell Dubilier L10T1	515 019 0	A
4	C4,13	Capacitor, Fixed, Ceramic: .015 μF ±20% 500V; Sprague 33C30A	515 140 0	B
5	C5,14	Capacitor, Fixed, Ceramic: 47 PF ±10%; 1000V; Cornell Dubilier L10Q47	515 017 0	A
6	C6,15	Capacitor, Fixed, Ceramic: 1,000 PF ±20%; 75V; Glenco Min-Z-1000-M	515 075 0	B
7	C7, 16	Capacitor, Fixed, Electrolytic: 5μF ±20%-15%; Sprague Elect. Co., 109D505C2050C2	516 186 0	A
8	C8,17	Capacitor, Fixed, Electrolytic: 5μF +100%-10% 25V; Callins Industries PSS Type	B516 056 0	C
9	C19,20	Capacitor, Fixed, Ceramic: .01 μF +60%-40%; 150V; Centralab DDM-103	515 151 0	A
10	C21,22	Capacitor, Fixed, Ceramic: 12PF ±5%; 1000V; Cornell-Dubilier C10Q12C	515 091 0	A
11	C23,24	Capacitor, Fixed, Ceramic: .05 μF +100%-20%; 30V; Centralab DA-503	515 183 0	A
12	C25,26	Capacitor, Fixed, Ceramic: 4700 PF ±10%, 500V; Erie Resistor Corp., 871-000-Z5T0-472K	515 218 0	B
13	CR1-4	Rectifier, Silicon: Hughes Semi-Conductors HR10212	614 034 0	B
14	D1	Chopper: 6.3V 60 cps Coil, DPDT BBM; James Electronics C2335	530 042 0	C
15	I1-4	Lamp, Incandescent: Chicago Miniature Lamp Works 1705 14v at .08 amp.	578 037 0	B
16	Q1-3,9-11	Transistor, Germanium: PNP; General Transistor Corp., GT1236	B686 028 0	B
17	Q4,12	Transistor, Germanium: PNP; General Transistor Corp., GT1361	686 029 0	B

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DATE 6 / 19 / 62

UNIT TITLE
DUAL DC AMPLIFIER

MODEL NO.
6.282 Sh.1 of 3 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
18	Q5,13	Transistor, Germanium: NPN; General Transistor Corp., GT1442	B686 039 0	B
19	Q6-8,14-16	Transistor, Germanium: PNP; Industro	B686 032 0	C
20	Q17,18	Transistor, Germanium: NPN; General Electric 2N169A	686 036 0	A
21	R1,27	Resistor, Fixed, Composition: 1 Megohm ±10%; 1/2W; Allen-Bradley EB	626 105 1	A
22	R2,28	Resistor, Fixed, Composition: 3.3K ohms ±10%; 1/2W; Allen-Bradley EB	626 332 1	A
23	R3,35	Resistor, Fixed, Composition: 1.8K ohms ±10%; 1/2W; Allen-Bradley EB	626 182 1	A
24	R4,18,36,50	Resistor, Fixed, Composition: 2.2K ohms ±10%; 1/2W; Allen-Bradley EB	626 222 1	A
25	R5,29	Resistor, Fixed, Composition: 1.6K ohms ±5%; 1/2W; Allen-Bradley EB	626 162 0	A
26	R6,37	Resistor, Fixed, Composition: 7.5K ohms ±5%; 1/2W; Allen-Bradley EB	626 752 0	A
27	R7,30	Resistor, Fixed, Composition: 100 ohms ±10%; 1/2W; Allen-Bradley EB	626 101 1	A
28	R8,31	Resistor, Fixed, Composition: 5.1K ohms ±5%; 1/2W; Allen-Bradley EB	626 512 0	A
29	R9,32	Resistor, Fixed, Composition: 56 ohms ±10%; 1/2W; Allen-Bradley EB	626 560 1	A
30	R10, 33	Resistor, Fixed, Composition: 4.7K ohms ±10%; 1/2W; Allen-Bradley EB	626 472 1	A
31	R11,14-17, 34,38,39,46 48	Resistor, Fixed, Composition: 10K ohms ±10%; 1/2W; Allen-Bradley EB	626 103 1	A
32	R12,40	Resistor, Fixed, Composition: 33K ohms ±10%; 1/2W; Allen-Bradley EB	626 333 1	A
33	R13,41	Resistor, Fixed, Composition: 6.2K ohms ±5%; 1/2W; Allen-Bradley EB	626 622 0	A
34	R19,20,47, 49	Resistor, Fixed, Composition: 220 ohms ±10%; 1/2W; Allen-Bradley EB	626 221 1	A

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DATE 6 / 19 / 62

UNIT TITLE

DUAL DC AMPLIFIER

MODEL NO.

6.282 Sh. 2 of 3 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
35	R21,22,42,43	Resistor, Fixed, Composition: 22K ohms ±10%; 1/2W; Allen-Bradley EB	626 223 1	A
36	R23,45	Resistor, Fixed, Composition: 120K ohms ±10%; 1/2W; Allen-Bradley EB	626 124 1	A
37	R24,44	Resistor, Fixed, Composition: 10 ohms ±10%; 1/2W; Allen-Bradley EB	626 100 1	A
38	R25,26,51-54	Resistor, Fixed, Composition: 68K ohms ±10%; 1/2W; Allen-Bradley EB	626 683 1	A
39	R55,56	Resistor, Fixed, Composition: 4.7 Megohms ±10%; 1/2W; Allen-Bradley EB	626 475 1	A
40	R57,58	Resistor, Fixed, Composition: 330 ohms ±10%; 1/2W; Allen-Bradley EB	626 331 1	A
41		Diode, Germanium: Clevite CTP462	614 043 0	B

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DATE 6 / 19 / 62

UNIT TITLE

DUAL DC AMPLIFIER

MODEL NO.

6.282 Sh.3 of 3 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1	Diode, Germanium: Clevite CTP462	614 043 0	B
2	K1	Relay: 18V DC Coil, 2 Form C Contacts, Allied Control Co., T-154-2C-520	618 173 0	B
3	R6	Resistor, Variable, Composition: 50K ohms ±30%; .2W; Chicago Telephone Supply Model 70	A642 524 0	C
4		Resistor, Fixed, Wirewound, Precision, (Matched Set): 3 ea, 100,000 ohms, 2 ea. 10,000 ohms matched to ±.01%; Julie Research Labs R34 Type	B640 012 0	C

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6/19/62

UNIT TITLE

RESISTOR NETWORK

MODEL NO.

12.730 SH 1 OF 1 SH

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode, Silicon: Hughes Semiconductors 1N459	B614 007 0	B
2	R1-4	Resistor, Fixed, Wirewound, Precision: 3550 Ohms ±.05%, .005% Stability	B638 764 0	C
		7.044 $(1/4)^2$ MULTIPLIER		
1	CR1-14	Diode, Silicon: General Instrument DR837	A614 042 0	B
2	R1,7	Resistor, Variable, Composition: 15K Ohms ±30%, Chicago Telephone Supply UPE-70 Type	A642 457 0	C
3	R2,3,8,9	Resistor, Variable, Composition: 2.5K Ohms ±30%; Chicago Telephone Supply UPE-70 Type	A642 445 0	C
4	R4,5,6,10, 11,12	Resistor, Variable, Composition: 1K Ohms ±30%; Chicago Telephone Supply UPE-70 Type	A642 444 0	C
5	R13,39	Resistor, Fixed, Composition: 300 Ohms ±5%, 1/2W; Allen-Bradley EB	626 301 0	A
6	R14,40	Thermistor: 88 Ohms ±5% at 37.8°C; Keystone Carbon Co. L3006-88-77-S11	A646 004 0	B
7	R15,41	Resistor, Fixed, Composition: 12K Ohms 1/2W; Allen-Bradley EB	626 123 1	A
8	R16,42	Thermistor: 550 Ohms ±5% at 37.8°C; Keystone Carbon Co. L2006-550-92-S10	A646 003 0	B
9	R17,43	Resistor, Fixed, Composition: 820K Ohms ±10%, 1/2W; Allen-Bradley EB	626 824 1	A
10	R18,44	Resistor, Fixed, Wirewound, Precision: 14,800 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 282 0	C
11	R19,45	Resistor, Fixed, Wirewound, Precision: 18,000 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 283 0	C
12	R20,46	Resistor, Fixed, Wirewound, Precision: 22,400 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 284 0	C

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6/1/62

UNIT TITLE
$(1/4)^2$ MULTIPLIER

MODEL NO.
7.099 Sh 1 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
13	R21,47	Resistor, Fixed, Wirewound, Precision: 29,600 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 285 0	C
14	R22,48	Resistor, Fixed, Wirewound, Precision: 43,300 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 525 0	C
15	R23,49	Resistor, Fixed, Wirewound, Precision: 82,000 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 541 0	C
16	R24,50	Thermistor: 300K Ohms ±5% at 37.8°C; Keystone Carbon Co. L1215-300K-152-S12	A646 002 0	B
17	R25-36, 51-62	Resistor, Fixed, Wirewound, Precision: 25,000 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 305 0	C
18	R37,38,63, 64	Resistor, Fixed, Wirewound, Precision: 27,000 Ohms ±1%, .01% Stability; Resistance Products Co PB Type	A638 306 0	C

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6/1/62

UNIT TITLE

$(1/4)^2$ MULTIPLIER

MODEL NO.

7.099 Sh 2 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,2,4	Capacitor, Fixed, Electrolytic: 2500 UF, 25V; P.R. Mallory 20-20979	516 052 0	B
2	C3	Capacitor, Fixed, Electrolytic: 4500 UF, 25V; P.R. Mallory SPO-20-6312	516 245 0	C
3	CR1-4	Rectifier, Silicon: General Electric 1N1342A	614 124 0	B
4	CR5-12	Rectifier, Silicon: Solitron Devices, Inc. CER-680	614 110 0	B
5	F1,4	Fuse, Cartridge, Fast Acting, Visual Indicating Type: 2 Amps, 125V; Bussman GMW2	570 138 0	A
6	F2	Fuse, Cartridge, Fast Acting, Visual Indicating Type: 1-1/2 Amps, 125V; Bussman GMW 1-1/2	570 137 0	A
7	F3	Fuse, Cartridge, Fast Acting, Visual Indicating Type: 1/2 Amp, 125V; Bussman GMW 1/2	570 135 0	A
8	T1	Transformer, Power: 2ea 105/115/125V 50/60 CPS Primaries, 1ea 33VCT 3ea 32VCT and 1ea 6.3V Secondaries; James Electronics A7271	C684 173 0	C

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6/1/62

UNIT TITLE

REGULATED POWER SUPPLY

MODEL NO.

10.200

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C7	Capacitor, Fixed, Electrolytic: 20 UF 12V; Callins Industries	A516 199 0	C
2	C8,9	Capacitor, Fixed, Electrolytic: 50 UF, 25V; Callins Industries	A516 198 0	C
3	CR3	Diode, Silicon: Zener; Texas Instruments 1N754 Type	614 046 0	B
4	CR6	Diode, Germanium: Clevite CTP 462	614 043 0	B
5	Q5	Transistor, Germanium: PNP; Texas Instrument 2N1377	686 079 0	B
6	Q6	Transistor, Germanium: PNP;Gen. Trans. GT1236	B686 028 0	C
7	R15	Resistor, Fixed, Composition: 10K Ohms ±10%, 1/2W; Allen-Bradley EB	626 103 1	A
8	R16,17	Resistor, Fixed, Composition: 4.7K Ohms ±10%, 1/2W; Allen-Bradley EB	626 472 1	A
9	R18,20	Resistor, Fixed, Composition: 560 Ohms ±10%, 1/2W; Allen-Bradley EB	626 561 1	A
10	R19	Resistor, Fixed, Composition: 1K Ohm ±10%, 1/2W; Allen-Bradley EB	626 102 1	A
11	R21	Resistor, Variable, Composition: 250 Ohms ±10%, .2W; Chicago Telephone Supply Model UPE-70 HA9083	642 443 0	B
12	R24	Resistor, Fixed, Composition: 56 Ohms ±10%, 1/2W; Allen-Bradley EB	626 560 1	A

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6/1/62

UNIT TITLE

POWER SUPPLY REGULATOR

MODEL NO.

43.107

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,2	Capacitor, Fixed, Electrolytic: 4000UF, 15V; Sprague Co. TVL-1173	516 044 0	A
2	F1	Fuse, Cartridge, Fast Acting, Visual Indicating: 1/2 amp, 125V; Bussman Mfg. Corp. GMW1/2	570 135 0	A
3	F2	Fuse, Cartridge, Fast Acting, Visual Indicating: 1-1/2 amp, 125V; Bussman Mfg. Corp. GMW1-1/2	570 137 0	A
4	CR1,2	Rectifier, Silicon: General Electric IN1342A	614 124 0	B
5	CR3-6	Rectifier, Silicon: Solitron Devices, Inc. CER-680	614 110 0	B
6	CR7	Diode, Silicon: Zener; Pacific Semi-Conductor PS6880	A614 079 0	C
7	Q1	Transistor, Germanium: NPN; Sylvania 2N1218	686 025 0	B
8	R1	Resistor, Fixed, Composition: 1.2K ohms ±10% 1/2W; Allen-Bradley EB	626 122 1	A
9	T1	Transformer, Power: 2 ea 105/~~195~~115/125V 50/60 cps Primaries, 1 ea 6.3V, 13V & 4V Secondaries; Freed 35018	C684 177 0	C
	R1	Resistor 1~ 10% 2w ww.		

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DATE 6 / 1 / 62

UNIT TITLE

POWER SUPPLY

MODEL NO.

10.203 Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Plastic: 1 UF ±.05%, 25V	521.137	C
2	C2	Capacitor, Fixed (Adjustable), Plastic: .002 UF ±.1% Adjustable Range	524.011	C
3	C3	Capacitor, Fixed, Plastic: 9 UF ±.05%, 25V	521.138	C
4	C4	Capacitor, Fixed (Adjustable), Plastic: .018 UF ±.1% Adjustable Range	524.012	C
5	CR1,2,3	Diode, Germanium: Clevite CTP462	614 043 0	B
6	K1	Relay: 18V DC Coil, 4 Form C Contacts; Allied Controls T-154-4C-520	618 171 0	B
7	K2	Relay: 12.6V DC Coil, 2 Form C Contacts; C.P. Clare RP7641-G40	618 097 0	B
8	K3	Relay: 940 Ohms CT Coil, 2 Form A Contacts; James Electronic Corp C2213	C618 149 0	C
9	R1,2	Resistor, Fixed, Wirewound, Precision: 10,000 Ohms ±.1%; Resistance Products Co PB Type	A638 245 0	C

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6/1/62

UNIT TITLE

INTEGRATOR NETWORK

MODEL NO.

12.764

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1,2	Resistor, Fixed, Wirewound, Precision: 3,550 ohms ±05%, .005% Stability; Julie Research Labs R34 Type	B638 764 0	C
2	R3	Resistor, Fixed, Wirewound, Precision: 10,000 ohms ±.05%, .005% Stability; Julie Research Labs R34 Type	B638 763 0	C

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DATE 6 / 1 / 62

UNIT TITLE
VARIABLE DIODE
FUNCTION GENERATOR

MODEL NO.
16.274 Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1-9	Rectifier, Silicon:General Instrument DR587	A614 042 0	C
2	R1-4,6-11, 26	Resistor, Variable, Composition: 25K Ohms ±30%, .2W; Chicago Telephone Supply Co. UPE-70 Type	A642 452 0	C
3	R14,16, 18,20,22, 24,27,29, 31	Resistor, Fixed, Wirewound, Precision: 9,000 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 565 0	C
4	R15	Resistor, Fixed, Wirewound, Precision: 11,000 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 556 0	C
5	R17	Resistor, Fixed, Wirewound, Precision: 12,547 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 561 0	C
6	R19	Resistor, Fixed, Wirewound, Precision: 14,347 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 557 0	C
7	R21	Resistor, Fixed, Wirewound, Precision: 16,945 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 562 0	C
8	R23	Resistor, Fixed, Wirewound, Precision: 20,670 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 558 0	C
9	R25	Resistor, Fixed, Wirewound, Precision: 26,493 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 563 0	C
10	R28	Resistor, Fixed, Wirewound, Precision: 36,882 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 559 0	C
11	R30	Resistor, Fixed, Wirewound, Precision: 60,677 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 564 0	C
12	R32	Resistor, Fixed, Wirewound, Precision: 171,000 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 560 0	C

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6/1/62

UNIT TITLE

-VARIABLE DFG

MODEL NO.

16.154-1 Sh 1 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
13	R33	Resistor, Fixed, Wirewound, Precision: 5,000 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 476 0	C
14	R34	Resistor, Fixed, Wirewound, Precision: 10,000 Ohms ±.5%, .01% Stability; Resistance Products Co PB Type	A638 477 0	C

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6/1/62

UNIT TITLE

-VARIABLE DFG

MODEL NO. 16.154-1 Sh 2 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode, Silicon: Hughes Semiconductors 1N459	B614 007 0	B
2	R1-4	Resistor, Fixed, Wirewound, Precision: 3550 Ohms ±.05%, .005% Stability	B638 764 0	C
		<u>16.099 X^2 DFG</u>		
1	CR1-14	Diode, Silicon: General Instrument DR837	A614 042 0	B
2	R1,7	Resistor, Variable, Compsition: 5K Ohms ±30%, Chicago Telephone Supply UPE-70 Type	B642 446 0	C
3	R2,3,8,9	Resistor, Variable, Composition: 2.5K Ohms ±30%; Chicago Telephone Supply UPE-70 Type	A642 445 0	C
4	R4,5,6,10, 11,12	Resistor, Variable, Composition: 1K Ohms ±30%; Chicago Telephone Supply UPE-70 Type	A642 444 0	C
5	R13,32	Resistor, Fixed, Composition: 300 Ohms ±5%, 1/2W; Allen-Bradley EB	626 301 0	A
6	R14,33	Thermister, 88 Ohms ±5% at 37.8°C; Keystone Carbon Co. L3006-88-77-S11	A646 004 0	B
7	R15,34	Resistor, Fixed, Composition: 12K Ohms ±10%, 1/2W; Allen-Bradley EB	626 123 1	A
8	R16,35	Thermistor: 550 Ohms ±5% at 37.8°C; Keystone Carbon Co. L2006-550-92-S10	A646 003 0	B
9	R17,36	Resistor, Fixed, Composition: 820K Ohms ±10%, 1/2W; Allen-Bradley EB	626 824 1	A
10	R18,37	Resistor, Fixed, Wirewound, Precision: 14,800 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 282 0	C
11	R19,38	Resistor, Fixed, Wirewound, Precision: 18,000 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 283 0	C
12	R20,39	Resistor, Fixed, Wirewound, Precision: 22,400 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 284 0	C

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6/1/62

UNIT TITLE
X^2 DFG

MODEL NO.
16.275 Sh 1 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
13	R21,40	Resistor, Fixed, Wirewound, Precision: 29,600 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 285 0	C
14	R22,41	Resistor, Fixed, Wirewound, Precision: 43,300 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 525 0	C
15	R23,42	Resistor, Fixed, Wirewound, Precision: 85,500 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 287 0	C
16	R24,43	Thermistor: 300K Ohms ±5% at 37.8°C; Keystone Carbon Co. L1215-300K-152-S12	A646 002 0	B
17	R25-30, 44-49	Resistor, Fixed, Wirewound, Precision: 12,500 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 280 0	C
18	R31,50	Resistor, Fixed, Wirewound, Precision: 13,500 Ohms ±1%, .2W; Resistance Products Co PB Type	A638 281 0	C

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6/1/62

UNIT TITLE
X^2 DFG

MODEL NO.
16.275 Sh 2 of 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1-4	Resistor, Fixed, Wirewound, Precision: 5000 ohms +.05%, .005% stability; Julie Research Labs R45	B638 765 0	C
		16.127 Log X DFG		
1.	CR1-12	Diode, Silicon: General Instrument DR837	A614 042 0	B
2	R1,2,38,39	Resistor, Variable, Composition: 2K ohms +30%; .3W; Chicago Telephone Supply UPE-70 Model (Modified)	A642 448 0	C
3	R3,4,5✓,40, 41,42✓ see notice	Resistor, Variable, Composition: 1K ohms +30%; .3W; Chicago Telephone Supply UPE-70 Model (Modified)	B642 444 0	C
4	R6,32	Resistor, Fixed, Wirewound, Precision: 9,800 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 609 0	C
5	R7,33	Resistor, Fixed, Wirewound, Precision: 19,600 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 611 0	C
6	R8,34	Resistor, Fixed, Wirewound, Precision: 21,200 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 470 0	C
7	R9,35	Resistor, Fixed, Wirewound, Precision: 15,500 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 610 0	C
8	R10,36	Resistor, Fixed, Wirewound, Precision: 5,000 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 608 0	C
9	R11,37	Resistor, Fixed, Wirewound, Precision: 4,280 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 440 0	C
10	R12,25	Resistor, Fixed, Wirewound, Precision: 20,900 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 447 0	C
11	R13,26	Resistor, Fixed, Wirewound, Precision: 49,200 ohms +1%; .005% stability; National Resistance Corp., EU-2 Type	A638 450 0	C

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UNIT TITLE
LOG X DFG

MODEL NO.
16.276 SH 1 OF 2 SH

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
12	R14,27	Resistor, Fixed, Wirewound, Precision: 27,700 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 449 0	C
13	R15,28	Resistor, Fixed, Wirewound, Precision: 13,000 ohms ±1%; .005% stability; National Resistance Corp., Eu-2 Type	A638 444 0	C
14	R16,29	Resistor, Fixed, Wirewound, Precision: 4,440 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 441 0	C
15	R17,30	Resistor, Fixed, Wirewound, Precision: 694 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 438 0	C
16	R18,31	Resistor, Fixed, Wirewound, Precision: 317 ohms ±1%; .005% stability; National Resistance Corp EU-2 Type	A638 437 0	C
17	R19,22	Resistor, Variable, Composition: ~~200~~ 100 ohms ±~~3~~20%; .3W; Chicago Telephone Supply UPE-70 Model (Modified)	~~A642 449 0~~ See notice	C
18	R20,23	Resistor, Fixed, Wirewound, Precision: 2,900 ohms ±.1%; .005% stability; National Resistance Corp., EU-2 Type	A638 439 0	C

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6/19/62

UNIT TITLE

LOG X DFG

MODEL NO.

16.276 SH 2 OF 2 SH

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1-4	Resistor, Fixed, Wirewound, Precision: 5000 ohms ±.05%; .005% stability; Julie Research Labs R45	B638 765 0	C
		<u>16.134 1/2 Log X DFG</u>		
1	CR1-12	Diode, Silicon: General Instrument DR837	A614 042 0	B
2	R1,2,38,39	Resistor, Variable, Composition: 4K ohms ±30%; .3W; Chicago Telephone Supply UPE-70 Model (Modified)	A642 487 0	C
3	R3,4,5,40, 41,42 See note 2	Resistor, Variable, Composition: 2K ohms ±30%; .3W; Chicago Telephone Supply UPE-70 Model (Modified)	B642 448 0	C
4	R6,32	Resistor, Fixed, Wirewound, Precision: 19,900 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 613 0	C
5	R7,33	Resistor, Fixed, Wirewound, Precision: 39,600 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 615 0	C
6	R8,34	Resistor, Fixed, Wirewound, Precision: 41,100 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 434 0	C
7	R9,35	Resistor, Fixed, Wirewound, Precision: 30,700 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 614 0	C
8	R10,36	Resistor, Fixed, Wirewound, Precision: 11,000 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 612 0	C
9	R11,37	Resistor, Fixed, Wirewound, Precision: 8,450 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 427 0	C
10	R12,25	Resistor, Fixed, Wirewound, Precision: 41,800 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 433 0	C
11	R13,26	Resistor, Fixed, Wirewound, Precision: 101,600 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 436 0	C

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DATE 6 / 19 / 62

UNIT TITLE

1/2 LOG X DFG

MODEL NO.

16.281 Sh. 1 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
12	R14,27	Resistor, Fixed, Wirewound, Precision: 55,400 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 435 0	C
13	R15,28	Resistor, Fixed, Wirewound, Precision: 26,000 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 430 0	C
14	R16,29	Resistor, Fixed, Wirewound, Precision: 8,870 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 428 0	C
15	R17,30	Resistor, Fixed, Wirewound, Precision: 1,480 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 424 0	C
16	R18,31	Resistor, Fixed, Wirewound, Precision: 605 ohms ±1%; .005% stability; National Resistance Corp., EU-2 Type	A638 423 0	C
17	✓ ✓ R19, 22 See notice	Resistor, Variable, Composition: 500 ohms ±30%; .3W; Chicago Telephone Supply UPE-70 Model (Modified)	A642 450 0	C
18	R20,23	Resistor, Fixed, Wirewound, Precision: 5,800 ohms ±.1%; .005% stability; National Resistance Corp., EU-2 Type	A638 425 0	C

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DATE 6 / 19 / 62

UNIT TITLE

1/2 LOG X DFG

MODEL NO.

16.281 Sh.2 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode, Germanium: Clevite CTP462	614 043 0	B
2	DS1-8	Lamp, Incandescent: General Electric 328	578 010 0	A
3	M1	Meter, DC Microammeter: 50-0-50 Microamp Movement with Scale per EAI Dwg A214 027 0; Assembly Products, Inc. 561 Model	590 032 0	C
4	R1	Resistor, Fixed, Composition: 8.2K ohms ±10% 1/2W; Allen-Bradley EB	626 822 1	A
5	R2	Resistor, Fixed, Film: 4000 ohms ±1%, 1/2W; Weston 9852B	634 096 0	B
6	R3	Resistor, Fixed, Film: 18,000 ohms ±1%, 1/2W; Weston 9852B	634 097 0	B
7	R4	Resistor, Fixed, Film: 58,000 ohms ±1%, 1/2W; Weston 9852B	634 098 0	B
8	R5	Resistor, Fixed, Film: 198,000 ohms ±1%, 1/2W Weston 9852B	634 064 0	B
9	R6	Resistor, Fixed, Film: 598,000 ohms ±1%, 1/2W Weston 9852B	634 099 0	B
10	R7	Resistor, Variable, Wirewound: 500 ohms ±10% .25W; Bourns Laboratories 273-1-501	B642 289 0	B
11	R8	Resistor, Fixed, Film: 700 ohms ±1%, 1/2W; Weston 9852B	634 339 0	B
12	S1	Switch, Rotary: 3 Sections, 1 Pole Per Section, 2-12 Positions; Centralab PA-2009	658 011 0	A
13	S2	Switch, Rotary: 1 Section, 2 Poles, 2-12 Positions; Centralab PA-2000 Series	B658 197 0	C
14	S3	Switch, Push: 2 ea 2 Form A Contacts; Capitol Machine Co. SP-202 Model	B656 077 0	C
15	S4	Switch, Push: 10 ea 2 Form A Contacts; Capitol Machine Co. SP-210 Model	C656 078 0	C
16	S5	Switch, Push: 10 ea 2 Form A Contacts; Capitol Machine Co. SP-210 Model	C656 078 1	C
17	S6	Switch, Push, Rocker: DPDT; Cutler-Hammer 8138K1-BK-09	656 080 0	B

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DATE 5 / 22 / 62

UNIT TITLE
Lve Lave
CONTROL PANEL
R0-790

MODEL NO.
20.790 Sh. 1 of Sh. 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
18	S7	Switch, Sensitive: Momentary Contact, DPDT; Micro Switch 2D26	662 014 0	B
19	S8	Switch, Push: 4 ea 2 Form C 1 Form A, 1 ea 2 Form C 2 Form A and 1 ea 3 Form C 1 Form A Contacts; Capitol Machine Co. SP-IA-306	C656 079 0	C
20	XDS7,8	Display Unit: Short Barrier Type, 2 Sockets; Micro Switch 2C1	554 013 0	B
		(REP-OP Compute Time Switch and associated components listed seperate- see REPETITIVE OPERATION SWITCH UNIT 20.534.)		

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5/22/62

UNIT TITLE

CONTROL PANEL

MODEL NO.

20.790 Sh 2 of Sh 2

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Ceramic: .2UF +80%-10%, 10V Centralab UK10-204	515 208 0	A
2	C2	Capacitor, Fixed, Ceramic: .1UF GMV, 3V; Centralab UK-104	515 207 0	A
3	CR1,2,4	Diode, Germanium: Clevite CTP462	614 043 0	B
4	CR3	Switch, Silicon Controlled: Solid State Products, Inc. 3B1080	B648 001 0	C
5	DS1	Lamp, Incandescent: Chicago Miniture Lamp Works 1730 6V at .04amp.	578 044 0	B
6	R1	Resistor, Fixed, Composition: 9.1K ohms ±5% 1/2W; Allen-Bradley EB	626 912 0	A

[illegible] #1730 lamp Burns too dull. get a different #

20-753 in Bolt Beranek Newman Computer.

20-753 in Our TR-48

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DATE 6 / 11 / 62

UNIT TITLE

OVERLOAD INDICATOR

MODEL NO.

20.753

Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Ceramic: .2UF +80%-10%, 10V Centralab UK10-204	515 208 0	A
2	C2	Capacitor, Fixed, Ceramic: .1UF GMV, 3V; Centralab UK-104	515 207 0	A
3	CR1,2,4	Diode, Germanium: Clevite CTP462	614 043 0	B
4	CR3	Switch, Silicon Controlled: Solid State Products, Inc. 3B1080	B648 001 0	C
5	DS1	Lamp, Incandescent: ~~Chicago Miniture Lamp Works 1730~~ Hudson Lamp #2307 blue base 6.3V at 200ma.	~~578 044 0~~ A578-047-1	B
6	R1	Resistor, Fixed, Composition: 9.1K ohms ±5% 1/2W; Allen-Bradley EB	626 912 0	A
7	R2	Resistor, Fixed, Wirewound: 1 ohm ±10%, 1/2W International Resistance Co. BW-1/2	636 092 0	A

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DATE 6 / 11 / 62

UNIT TITLE

OVERLOAD INDICATOR

MODEL NO.

20.791

Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1	Resistor, Fixed, Wirewound: 2K Ohms ±3%, 5W; Helipot AR2KL.1	642 134 0	C
2	S1	Switch, Toggle: DPDT; Cutler-Hammer 7563K4	664 010 0	A

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6/1/62

UNIT TITLE
NULL CONTROL PANEL

MODEL NO.
20.825

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	DS1,2,3	Indicator, In Line Display Unit: Characters 0 thru 9 and Decimal Point; Industrial Electronic Engineers, Inc. 10984-47	B554 016 0	C
2	DS4	Indicator, In Line Display Unit: Characters 1,0, Plus and Minus Signs; Industrial Electronic Engineers, Inc. 10B06-47	B554 022 0	C
3	R1	Resistor, Variable, Composition: 10K ohms ±10%, 2W; Allen-Bradley JAIN056P103UA	642 527 0	A
4		Lamp, Incandescent: Dialco 47	578 003 0	A

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DATE 6 / 1 / 62

UNIT TITLE
DISPLAY UNIT

MODEL NO.
26.195 Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Rectifier, Silicon: Hughes Semi-Conductors HR10212	614 034 0	B
2	CR3	Diode, Germanium: Clevite CTP462 Type	614 043 0	B
3	K1	Relay: 430 Ohms D.C. Coil, 2 Form C Contacts General Electric 3S2791G210-A-29	618 126 0	B
4	Q1-5	Transistor, Germanium: PNP; Industro	B686 032 0	C
5	Q6	Transistor, Germanium: PNP; General Electric 2N321 Type	686 004 0	A
6	R1 ✓ See notice	Resistor, Fixed, Wirewound, Precision: 82000 ~~10,000~~ Ohms ±1%, .2W; Resistance Products Co PB Type	A638 288 0	C
7	R2 ✓ See notice	Resistor, Fixed, Wirewound, Precision: ~~12,000~~ Ohms ±1%, .2W; Resistance Products Co PB Type 100,000 ~	A638 289 0	C
8	R3,4	Resistor, Fixed, Composition: 27K Ohms ±10%, 1/2W; Allen-Bradley EB	626 273 1	A
9	R5	Resistor, Fixed, Composition: 12K Ohms ±10%, 1/2W; Allen-Bradley EB	626 123 1	A
10	R6	Resistor, Fixed, Composition: 330 Ohms ±10%, 1/2W; Allen-Bradley EB	626 331 1	A
11	R7	Resistor, Fixed, Composition: 4.7K Ohms ±10%, 1/2W; Allen-Bradley EB	626 472 1	A
12	R8,11	Resistor, Fixed, Composition: 15K Ohms ±10%, 1/2W; Allen-Bradley EB	626 153 1	A
13	R9	Resistor, Fixed, Compsition: 8.2K Ohms ±10%, 1/2W; Allen-Bradley EB	626 822 1	A
14	R10	Resistor, Fixed, Composition: 2.2K Ohms ±10%, 1/2W; Allen-Bradley EB	626 222 1	A
15	R12	Resistor, Fixed, Composition: 100 Ohms ±10%, 1/2W; Allen-Bradley EB	626 101 1	A

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT CAN BE PURCHASED LOCALLY OR FROM EAI.
C - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.
THE PROPER EAI PART SHOULD BE INSTALLED FOR CATEGORY C ITEMS. A COMPLETE DESCRIPTION IS GIVEN TO PROVIDE FOR TEMPORARY REPAIRS; HOWEVER, EAI WILL NOT BE RESPONSIBLE IF UNIT IS NOT WITHIN SPECIFICATIONS UNDER THESE CONDITIONS.

6/1/62

UNIT TITLE

COMPARATOR

MODEL NO.

40.404

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode, Germanium: Clevite CTP462	614 043 0	B
2	K1	Relay: 18V DC Coil, 4 Form C Contacts; Allied Controls Co. T-154-4C-520	618 171 0	B
3	K2	Relay: 18V DC Coil, 6 Form A Contacts; Allied Controls Co. T-154-6A-520	618 172 0	B
		(Potentiometer listed on POTENTIOMETERS/ FUNCTION SWITCH PANEL 42.287.)		

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DATE 6 / 1 / 62

UNIT TITLE

ATTENUATOR

MODEL NO.

42.283 Sh.1 of Sh.1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	F01-F59	Fuse, Cartridge, Plug in Type Fast Acting: 1/20 amp, 125V; Littelfuse 272000 Type See Below	~~570 139 0~~	B
2	P01-P59	Resistor, Variable, Wirewound: 5K ohms ±5%; Clarostat D-2-02-435	A642 538 0	C
3	S1-5	Switch, Lever: Three Locking Positions, Contacts 1 Form F at sections C1 & C3; General Control Co. MCT1-T1-F-O-F-O	654 009 0	B
1		Limit Res. to replace $\frac{1}{20}$ a fuse $1.15 each.	646.0062-1	

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DATE 6 / 1 / 62

UNIT TITLE
ATTENUATORS/FUNCTION
SWITCH PANEL

MODEL NO.
42.287 Sh. 1 of Sh. 1

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Electrolytic: 50 UF, 25V; International Electronic Industries	A516 122 0	C
2	CR1	Diode, Silicon: Zener; Pacific Semi-Conductor 1N752	614 078 0	B
3	DS1-14	Lamp, Incandescent: General Electric 1705	578 037 0	A
4	R1	Resistor, Variable, Wirewound: 50 Ohms ±10%, .25W; Bourns Laboratories 200L-1-500	642 074 0	B
5	R2,3	Resistor, Fixed, Wirewound, Precision: 20,000 Ohms ±.1%, .005% Stability; Resistance Products Co PB Type	A638 702 0	C
6	R4,6	Resistor, Fixed, Composition: 10K Ohms ±10%, 1/2W; Allen-Bradley EB	626 103 1	A
7	R5,12	Resistor, Fixed, Wirewound, Precision: 10,000 Ohms ±.1%, .005% Stability; Resistance Products Co PB Type	A638 743 0	C
8	R7	Resistor, Fixed, Wirewound, Precision: Value determined at time of manufacture.	———	—
9	R8	Resistor, Fixed, Wirewound, Precision: 5,000 Ohms ±1%, .01% Stability; Resistance Products Co PB type	A638 315 0	C
10	R9	Resistor, Variable, Wirewound: 250 Ohms ±10%, .25W; Bourns Laboratories 271-1-251	642 491 0	B
11	R10	Resistor, Fixed, Composition: 1K Ohms ±10%, 1/2W; Allen-Bradley EB	626 102 1	A
12	R11	Resistor, Variable, Wirewound: 20 Ohms ±10%, .25W; Bourns Laboratories 200L-1-200	642 073 0	B
13	R13,14	Resistor, Variable, Composition: 50K Ohms ±30%, .2W; Chicago Telephone Supply HH1860	642 351 0	B

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6/1/62

UNIT TITLE

REFERENCE REGULATOR

MODEL NO.

43.104