220

surplus manual

Jim Rose

Computer Group Model 231-R

PACE®

PRECISION ANALOG COMPUTING EQUIPMENT

ELECTRONIC ASSOCIATES INCORPORATED

LONG BRANCH, NEW JERSEY

Jim Rose

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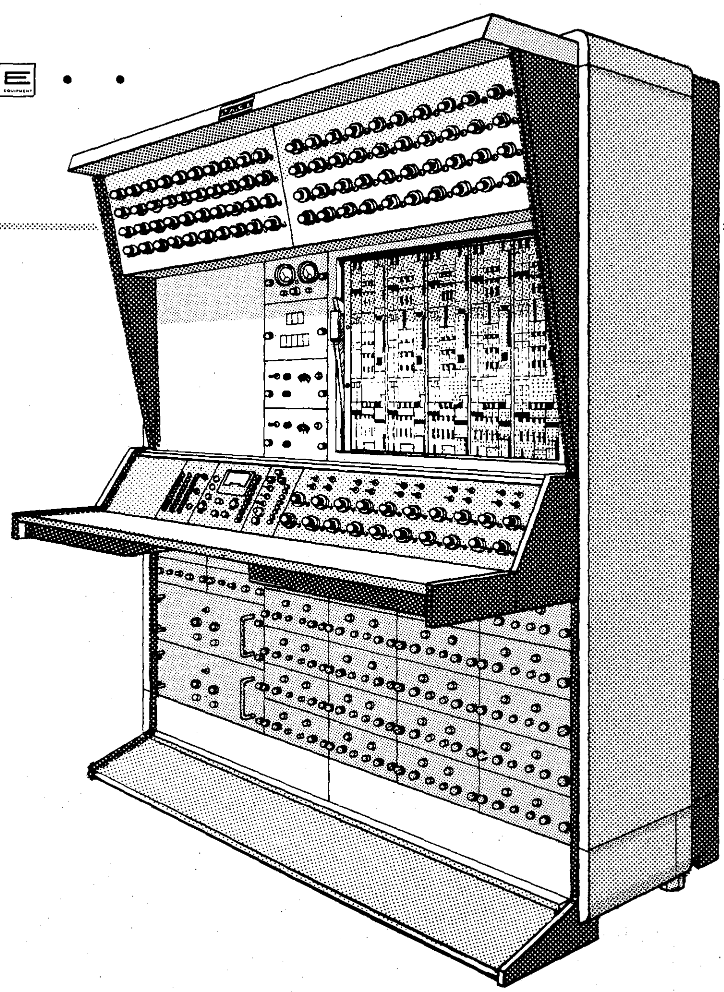
ELECTRONIC ASSOCIATES Incorporated

PACE



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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.

2. When inquiring about items as servo multipliers, resolvers, networks, cables, potentiometer expansions, etc., please specify the serial numbers of the major equipment with which the units are to be used, such as: Console Type 16-31R, serial #000, or Amplifier Group Type 16-31C, serial #000, etc. If at all possible, please include the purchase order or the EAI project number under which the equipment was originally procured.

Your cooperation in supplying the required information will facilitate the processing of your requests and aid in assuring that the correct items are supplied.

It is the policy of Electronic Associates, Inc. to supply equipment patterned as closely as possible to the individual requirements of the individual customer. This is accomplished, without incurring the prohibitive costs of custom design, by substituting new components, modifying old components, etc. wherever necessary to expedite conformance with requirements. As a result, this instruction manual, which has basically been written to cover standard equipment, may not entirely concur in its content with the equipment supplied. It is felt, however, that a technically qualified person will find the manual a fully adequate guide in understanding, operating, and maintaining the equipment actually supplied.

Printed in U.S.A.

2-15-60

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SUPPLEMENT

COMPUTER GROUP 231R

The Set-Up Amplifier for Control Panel 20.143 (located in Combination Rack 4.015) is terminated at the Pre-Patch Panel at position PB-19B (below DVM IN).

The Summing Amplifier Connections Figure 11 (page 20) and Summing Network 12.003, Simplified Schematic Figure 32 (page 48) Drawings shown the feedback resistor connected between S' and F. This circuit has been modified so that the feedback resistor is between G and F.

SUPPLEMENT

SUMMING NETWORK 12.003 AND COMBINATION NETWORK 12.002

In an operational summing amplifier, the cut-off frequency of the grid network must complement the cut-off frequency of the succeeding stages. If the corner frequencies do not match, the amplifier will be unstable under certain conditions such as capacitive load.

The input and feedback resistors that are used with Quadruple D.C. Amplifiers 6.002-3 and 6.002-4 must be capacity-compensated such that the time constant is equal to 6.5 microseconds; this insures that the cut-off frequency of the grid network is matched to the following stages.

The input resistors of these networks are paralleled with appropriate values of capacitance so that the time constant of each is equal to 6.5 microseconds. The feedback resistor is paralleled with a capacitor such that the *total* time constant is 6.5 microseconds. (There is stray capacitance around the amplifier.) These capacitors are shown in *figure 1* and *figure 2*. All of the networks in the computer console are constructed in this manner.

For optimum frequency characteristics, and stability when low value feedback resistors are used, *when an external input or feedback resistor is used, it should be paralleled with an appropriate value of capacitance so that the time constant is*

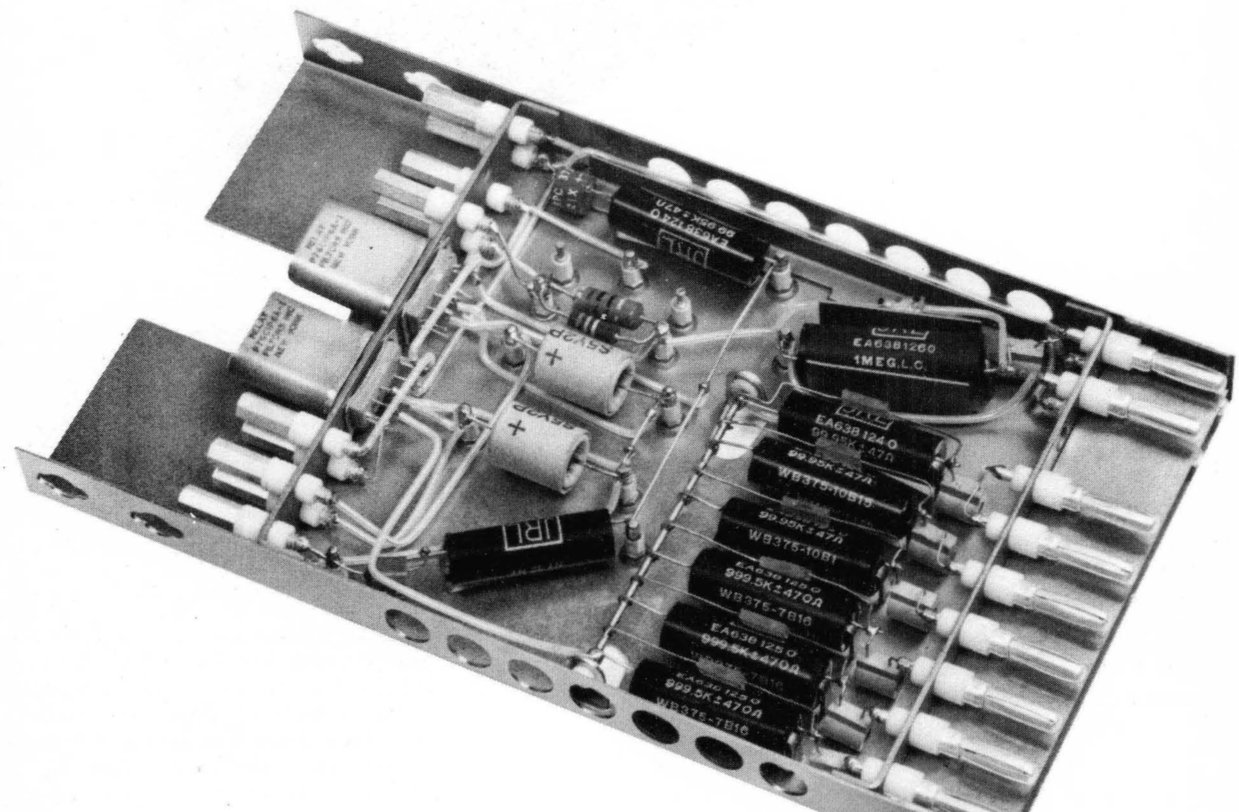


Figure 1. Combination Network 12.002-5

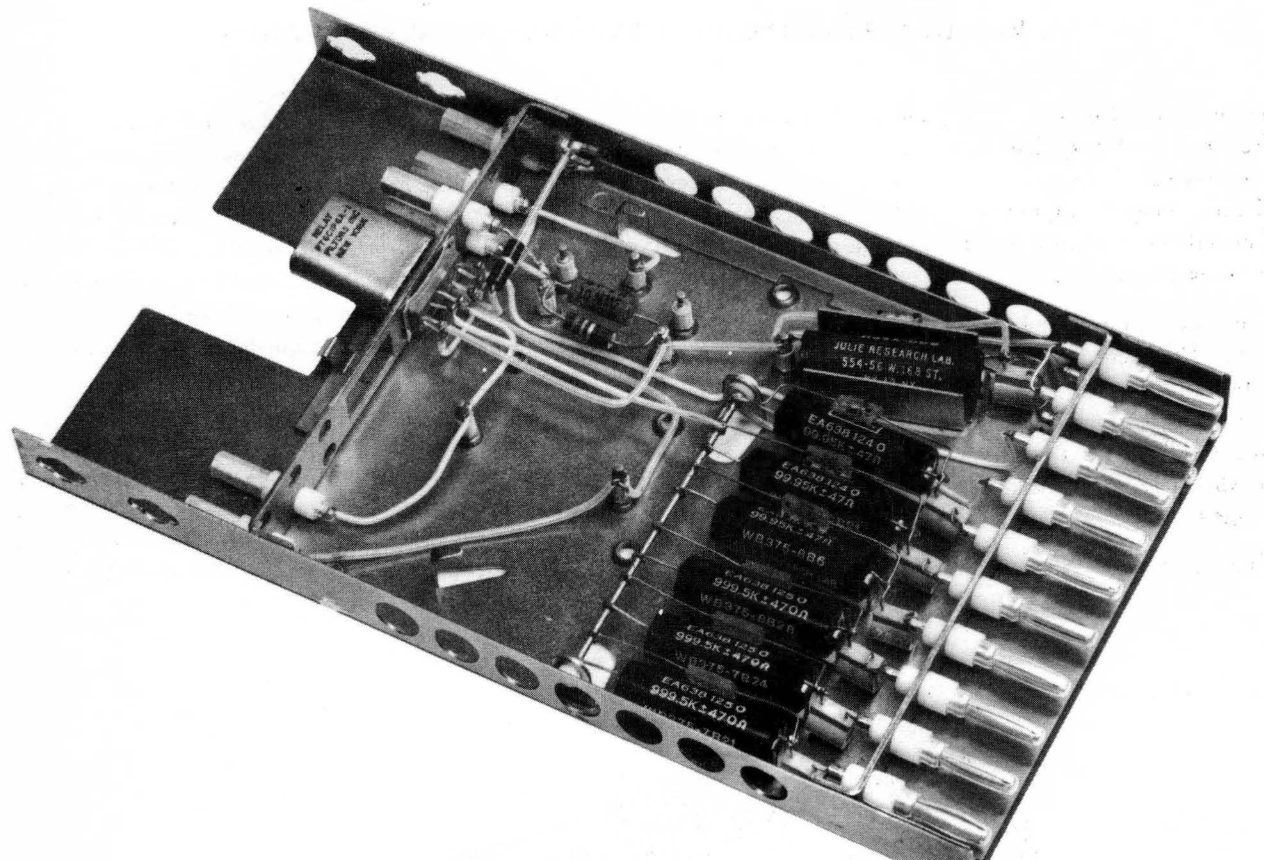


Figure 2. Summing Network 12.003-3

equal to 6.5 microseconds. Example: If a gain of 5 is desired, the feedback resistor (1 megohm) of the standard network would be used and an input resistor of 200,000 ohms. The feedback resistor in the network has a time constant of 6.5 microseconds; however, the input resistor must be paralleled with a capacitor to raise the time constant to 6.5 microseconds.

$$T = RC \quad (1)$$

$$C = \frac{T}{R} \quad (2)$$

$$C = \frac{6.5\,(10^{-6})}{2\,(10^{5})} \quad (3)$$

$$C = 32.5\,(10^{-12}) \quad (4)$$

$$C = 32.5 \text{ mmf} \quad (5)$$

NOTES:

1. In most instances a standard value capacitor that has a value close to the calculated value may be used. However, if the calculated value is small and there is a large percentage differential between the calculated value and the nearest standard value, the amplifier characteristics may vary slightly from the specifications.

2. In equation 2, insert R in megohms and T in microseconds; this will give a value of C in mmf.

1. GENERAL

Computer Model 231R, figures 1 and 2, is a general purpose analog computer containing circuits for summation, integration and multiplication. This unit may be operated independently or in combination with other computer groups. As the control operating point for an expanded computation system, the console provides complete control and monitoring facilities for the expanded system. The operational and control circuits in this equipment are highly flexible to accommodate a wide variety of expansion and auxiliary equipment.

Computational problems are introduced into the equipment at the removable Pre-Patch Panel. This panel is a metal board containing 3450 holes for operational circuit terminations. Shielded color coded patch cords and "bottle" (jumper) plugs are inserted into these holes and, when the panel is inserted into the patch bay, engage gold plated spring contacts individually mounted on special low-loss insulator brushings. The rear terminations of the spring contacts are provided with jacks into which the shielded networks are plugged, making possible low-loss, completely shielded signal circuits. The patch panel layout is designed to conform with the sequence of steps in typical computations, thus reducing the number of long patch cords in a given problem; many connections which formerly required patch cords may now be accomplished with bottle plugs.

The precision resistors are contained in shielded network assemblies in a constant-temperature oven directly behind the patch bay. (The oven temperature is thermostatically controlled.) This oven also contains the polystyrene-dielectric integrating capacitors; both the resistors and capacitors are stabilized and adjusted to an accuracy of ±0.01%.

All operational, control, and monitoring facilities of the system are consolidated on slanting panels directly over the desk of the console. These facilities include the Mode Control, Signal Selector, VTVM, and Overload Indicator Panel. In addition to the VTVM, a Digital Voltmeter and printer are available as optional equipment, for monitoring signal voltages.

The console contains regulated d-c power supplies that furnish plate power to all components. Plus and minus 100 volt reference sources are also available. Balance between the plus and minus reference sources can be monitored with the VTVM.

The basic 231R Computer contains twenty operational amplifiers. Eight of these units are provided with networks for combination (summer-integrator) operation; the position of a bottle plug on the pre-patch panel determines whether the amplifier is connected for summing or integrating. The other twelve amplifiers are used as summers.

The console also features an Overload Indicator providing visual and audible indication of an overloaded amplifier or servo. The alarm system can be set to automatically switch the computer into the Hold mode when an overload occurs.

The attenuator complement of the 231R includes twenty hand-set potentiometers located on the sloping panel to the right of the control panels. This basic complement may be increased by adding hand-set potentiometers mounted on the sloping panels above the operating position of the console. Available as an optional expansion is a Digital Attenuator System (DAS) which provides servo-set attenuators in groups of ten, up to a total of 150, in addition to the hand-set potentiometers.

The 231R Computer contains circuitry for the addition of an Automatic-Digital-Input-Output-System (ADIOS). This system, mounted in a special desk, contains the equipment necessary to perform the various data coding and storage functions required to control computer operating modes, attenuator setting, and automatic readout. One to six 231R type consoles may be controlled by an ADIOS system.

2. DESCRIPTION OF BASIC COMPUTER

The 231R Computer is housed in a three-bay console containing all the required power supplies. A writing shelf is mounted across the front of the console at desk height, with the sloping control panel just above it bearing all the operating controls. Indirect fluorescent lighting illuminates the patch panel, controls, and writing surface.

a. Physical Characteristics.

Console Dimensions

Height .... 74-1/4 inches
Length .... 60 inches
Depth (including writing shelf) .... 40 inches
Required floor space .... 1,920 square inches

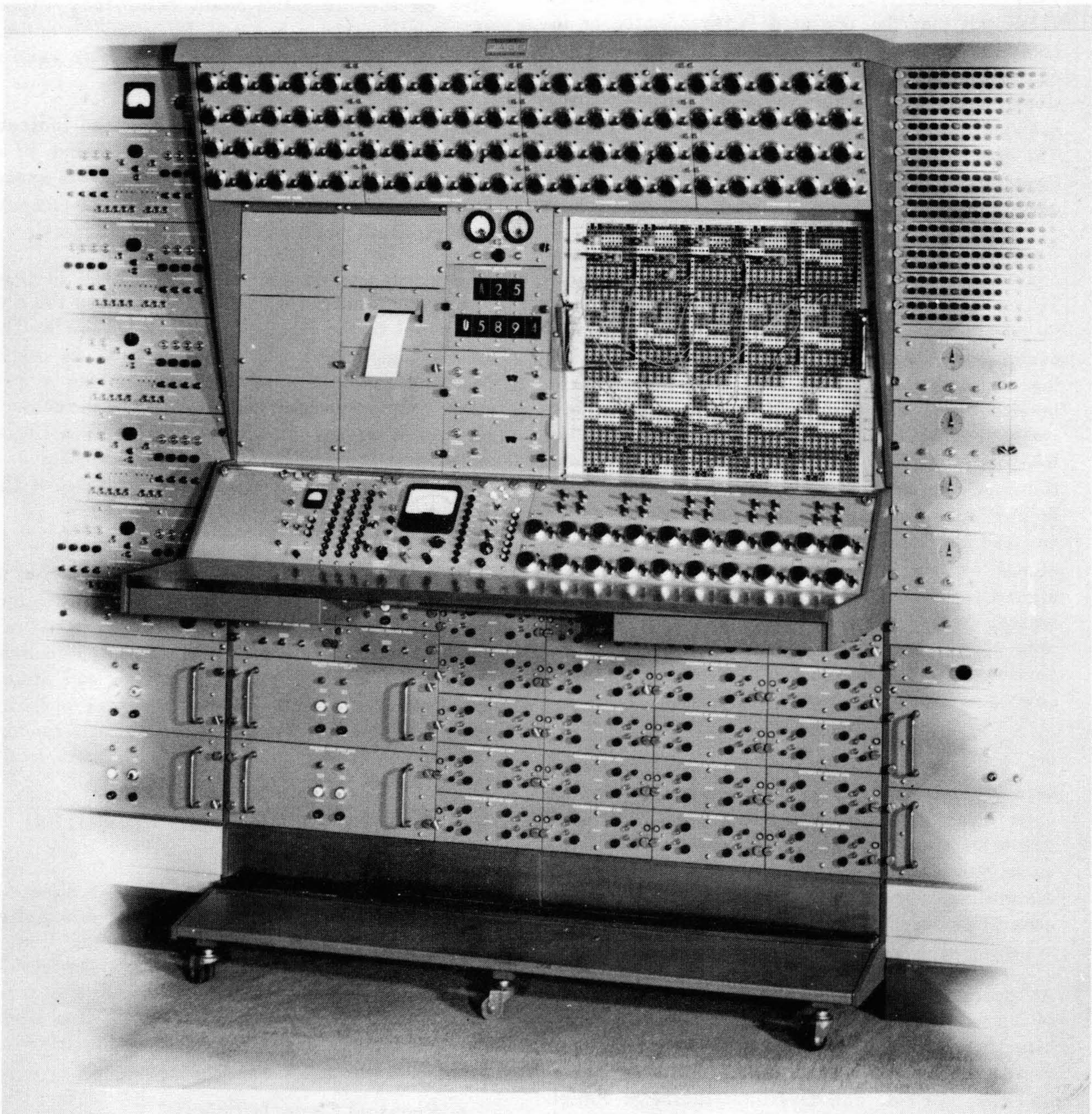


Figure 1. Computer 231R, Front View.

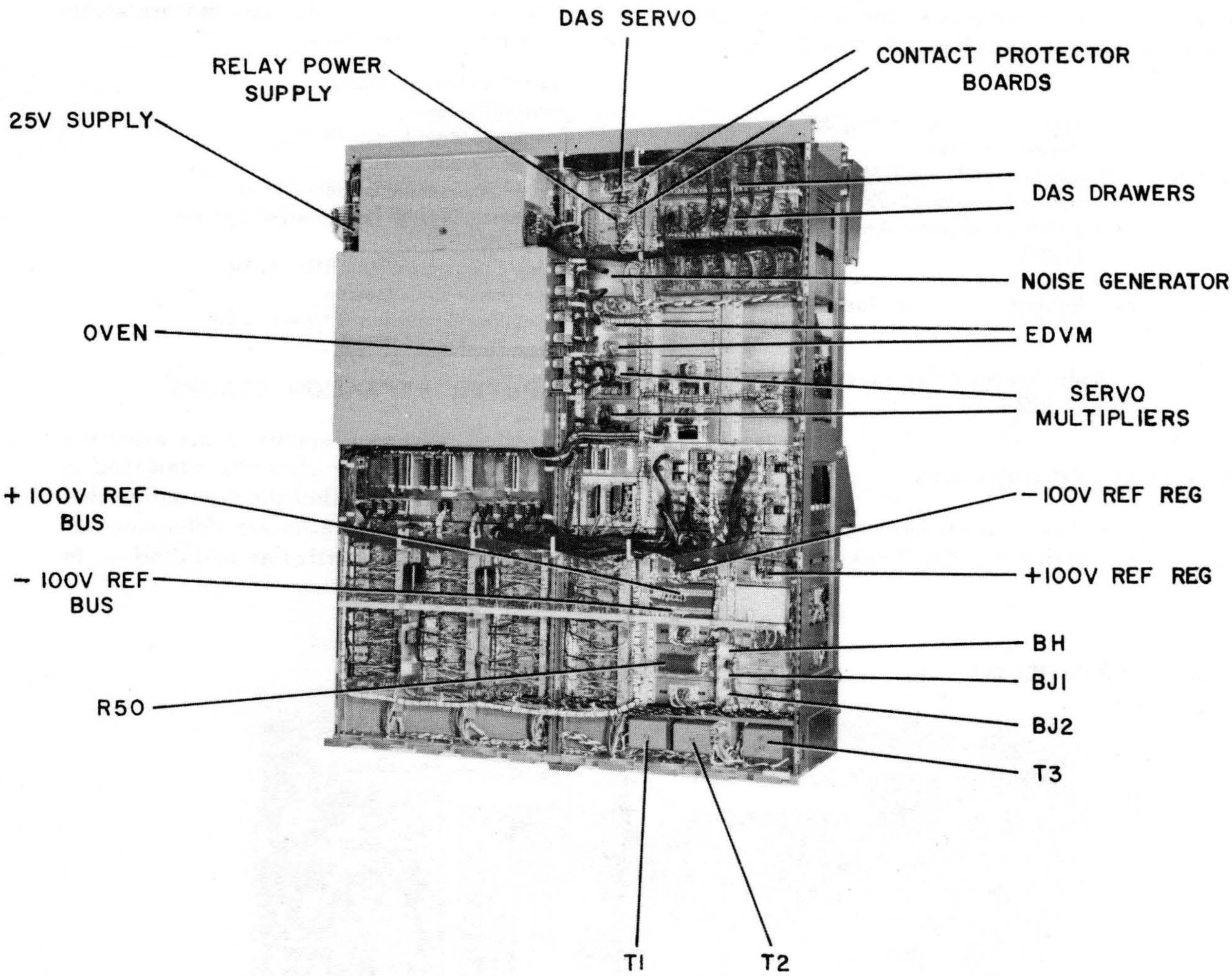


Figure 2. Computer 231R, Rear View.

Console Weight

Crated .... 2,440 pounds
Uncrated .... 2,300 pounds

NOTE: These are approximate weights. The actual weight depends on the equipment complement in the console.

b. Equipment Complement.

(1) Basic Computer. The standard model computer 26-231R contains the following major components:

5 each	Quadruple D.C. Amplifier 6.002
2 each	Regulated Power Supply 10.001
1 each	Regulated Power Supply 10.017
1 each	Vibrator Drive Unit 21.004
1 each	Relay Power Supply 10.002
1 each	25 Volt Power Supply 10.008
1 each	Power Control and Relay 11.001
1 each	Dual Overload Alarm 13.001
1 each	ERO Control System 14.001
1 each	Signal Selector Panel 20.001
1 each	VTVM 20.002
1 each	Mode Control 20.003
1 each	Attenuator and Function Switch Assembly 42.001
1 each	Pre-Patch Panel 5.001
1 each	Overload Indicator 20.024

In addition to the components listed above, the following network assemblies are located in the oven (fig. 3):

1 each	Reference and Check Amplifier Network 12.098
8 each	Combination Network 12.002
12 each	Summing Network 12.003
1 each	Integrator Capacitor Assembly 12.031

Miscellaneous Assembly, not located in the oven:

1 each	Mode Control Relay Assembly 11.008

3. OPTIONAL COMPONENTS

The components listed below have been designed for use with the 231R Computer. These components are not part of the basic computer but are available as optional accessories.

Digital Voltmeter 26.001
Servomultipliers
Reference Regulators 43.003
Printer 39.003
Digital Attenuator System (DAS)
Automatic Digital Input-Output System (ADIOS)
Relay Comparator Amplifier 6.086
Time Scale Modification
Repetitive Operation Console 3.006
Noise Generator Model 201A

4. COMPUTER EXPANSION GROUPS

The following groups of equipment are available to expand the computing elements contained in the basic 231R Console. Both the type and number of components in these racks are determined by the requirements of a particular installation. In

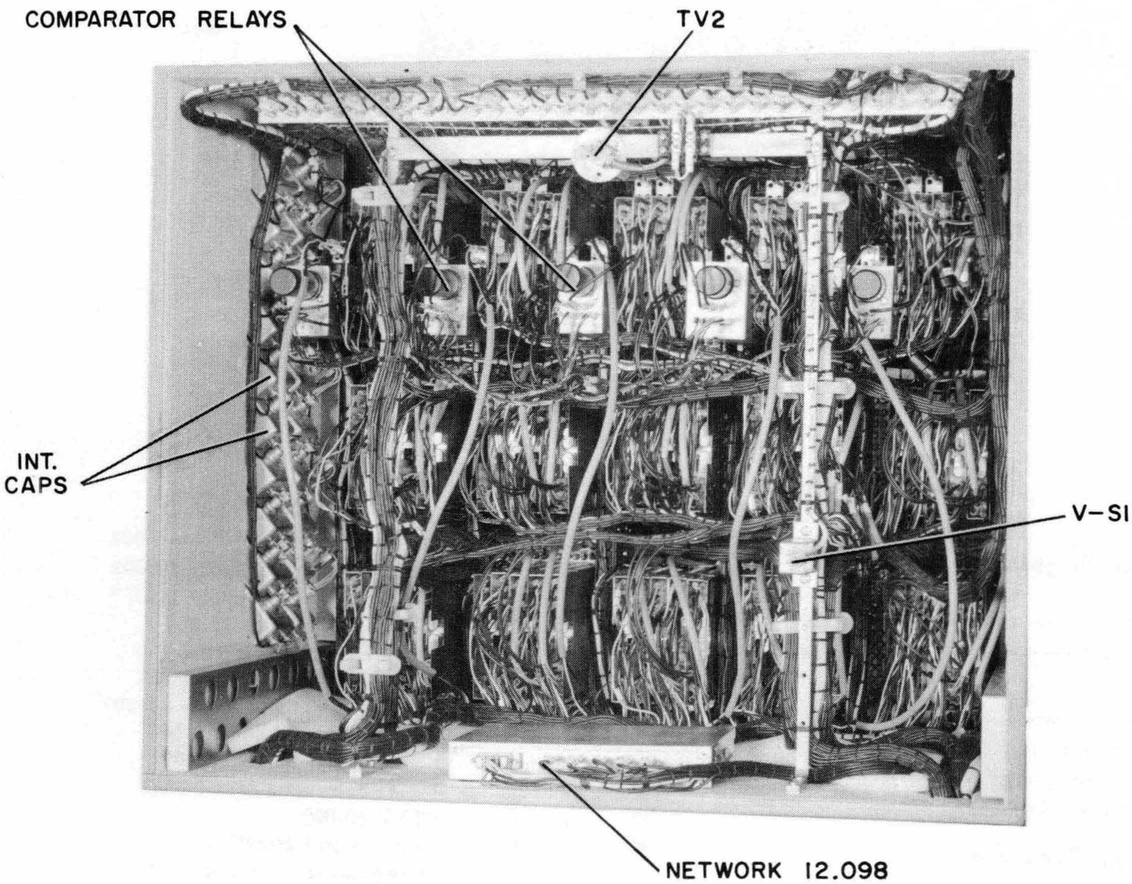


Figure 3. Typical Oven, Cover Removed.

general, these groups provide all additional computing elements designated on the standard patch panel and not included in the console.

Combination Group 14.015
Electronic Multiplier Group 14.010

5. MAINTENANCE ACCESSORIES

To facilitate maintenance and adjustment of component chassis in the computer, service shelves and test cables are provided with the equipment (fig. 4).

The table below lists the service cables provided with the equipment and the components with which each cable is used.

6. A-C POWER

a. Power Requirements and Input Connections. The 231R Computer is designed for operation from commercial 115 volt, 60-cycle a-c power lines. This primary source may be either single phase or three phase. The basic computer requires approximately 20 amperes for line 1, and 13 amperes for line 2.

Primary power is brought into the console at connector BH mounted on a bracket at the rear of the third bay. BH is a three-terminal connector, with terminals A and B connected to line 1 and line 2, respectively, of the a-c distribution circuits in the computer and terminal C connected to the common side. If the a-c source is a three-wire, 115 volt two phase service, the connections shown in figure 5a should be made. Terminal A is connected to phase 1, terminal B is connected to phase 2, and terminal C is connected to the

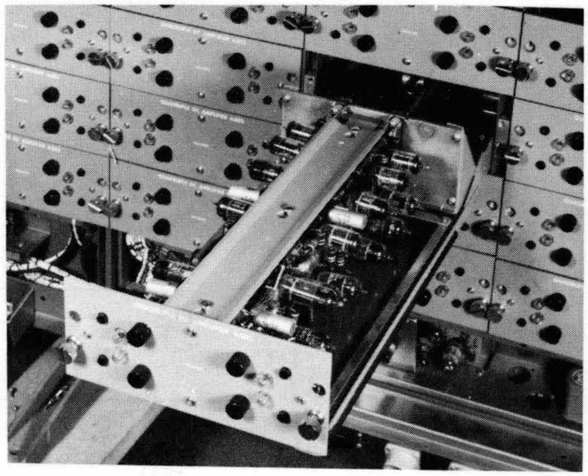


Figure 4. Service Shelf in Use.

Rack Receptacle Number	Cable Number	Used with Component
G1	C3A13F	Vibrator Drive Unit 21.004
PS1	C3A13F	Regulated Power Supply 10.017
PS6	C3A13F	Relay Power Supply 10.002
PS2	C3A13K	+300 Volt Regulated Power Supply
PS3	C3A13K	−300 Volt Regulated Power Supply
DV-B1	C3A13N	Digital Voltmeter
DV-B2	C3A13N	(Indicator Chassis)
N1	C3A13N	Noise Generator Model 201A
DJ1	D3A13T	Digital Printer
DJ2	D3A13T	Digital Printer
DR	D3A13T	D. A. S. Relay Panel
SM0, 1	D3A13U	Servo Multipliers
	B3A13UB	
DV-A1	A019 006 0P	Digital Voltmeter
DV-A2	A019 006 0P	(Amplifier Chassis)
AR0 to AR99	A422 017 0P	Quadruple D-C Amplifier 6.002

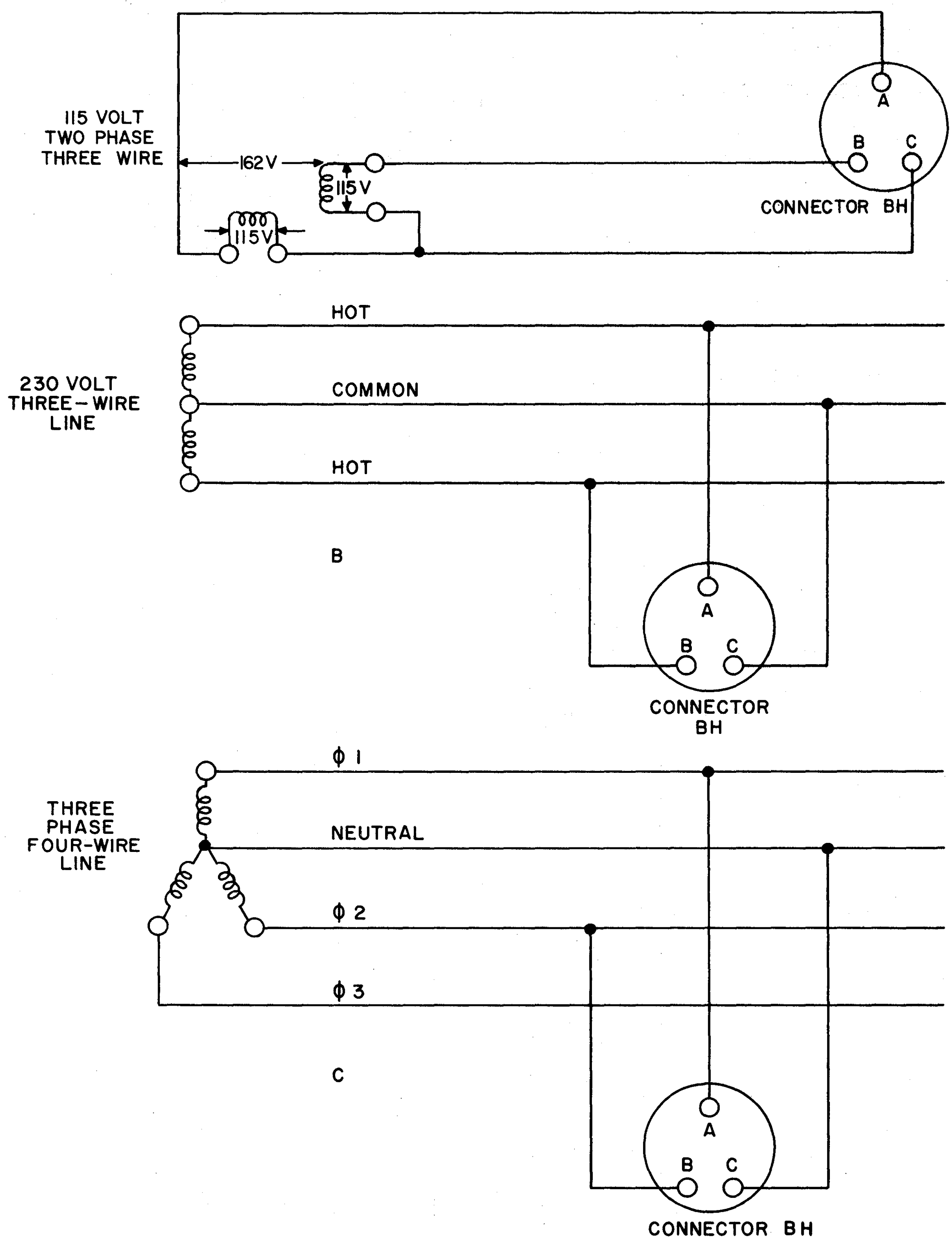


Figure 5. A-C Power Connections to Computer.

common.

Figure 5b shows the computer connected to a three-wire, 230 volt, single-phase service. Terminals A and C are each connected to one of the outside legs of the line, and terminal C is tied to the a-c common.

The computer can also be operated from a three-phase a-c system. Figure 5c illustrates the connections to a three-phase, 4-wire, wye connected line. In this case, terminal A is connected to phase 1, terminal B to phase 2, and terminal C to the neutral. The third phase is unused. If more equipment is to be connected to this line, phase 3 should be utilized to distribute the load as evenly as possible. Other three-phase systems such as a three-phase delta or a three-wire wye should not be used.

b. A-C Power Distribution and Control Circuits. Schematic drawing D003 025 0S (sheet 1) illustrates the a-c control and distribution circuits. Terminals A and B of connector BH are wired to CB1 and CB2. These units are 25-ampere circuit breakers mounted on the 11.001 Power Control and Relay Unit located at the bottom of the third bay of the console. Power for the oven blower motor and heater circuits is tapped off the a-c line directly and is not controlled by the circuit breakers.

CB1 controls the application of power to line 1. This line feeds all filament transformers in the rack and power supplies, and also supplies the rack blower motors and the heater winding of thermal relay TDI. The contacts of this relay are in series with the coil of K1, the plate relay. This arrangement prevents the application of power to the high voltage transformers before the filaments are at the proper operating temperature. TDI pulls in approximately 30 seconds after line 1 has been energized.

Plate relay K1 controls the application of a-c power to line 2. The coil of this relay is in series with the contacts of TD1, contacts 2 and 3 of S5 (PL/REF Switch) on the Mode Control, and the patch bay micro-switch. (The micro-switch is is closed by installing a patch board.) After TD1 pulls in, line 2 is energized by operating CB2 to the ON position. Line 2 supplies power to all plate transformer primaries and to the rack connectors for the servo multipliers, digital voltmeter, noise generator and Digital Attenuator System.

Line 2 power is also applied to the d-c reference voltage control circuits through contacts 5 and 6 of switch S5, the PL/REF switch. When S5 is operated to the ON position, a-c voltage energizes K11, the reference relay, and is also applied to the servo multiplier reference phase connector SRH. This connector provides a-c voltage to the reference phases of servo multipliers located in other racks controlled from this console.

c. A-C Power Control of Expansion Groups. Control of primary a-c power for various equipment groups associated with each 231R console is provided by power control connectors BJ1 and BJ2. These plugs are located on the same bracket containing BH. Cables designated 16-19L are used to connect a group of associated racks together for this purpose.

Terminal C of both BJ1 and BJ2 is tied to the a-c common. Terminal A of each connector is wired to line 1 and is powered when CB1 is operated to the ON position. The voltage on this line may then be used to operate the filament power relays of other racks of equipment that are to be controlled from the console.

A similar arrangement is provided for plate power switching. Terminal B of each power control connector is wired to line 2. When line 2 is energized, the control voltage on terminal B may be used to energize the plate power control relays in associated racks of equipment.

7. REFERENCE VOLTAGE CONTROL AND DISTRIBUTION CIRCUITS

The positive and negative d-c reference voltages required for the operational circuits in the computer are normally furnished by the Reference Regulator 43.003 and associated Reference and Check Amplifier Network 12.098. Two regulators and one network are required for a complete reference source.

Figure 6 is a simplified schematic of the reference control circuits. As this diagram indicates, the input voltage to the regulator stabilizer is applied through contacts on relay K1 in the Reference and Check Amplifier Network 12.098. The relay is controlled by the SL (slave) pushbutton on the the Mode Control. With this pushbutton in the up position, K1 is energized and the 6.5 volt mercury battery is connected to the stabilizer. When the SL button is depressed, K1 drops out and reference voltage from any selected console in the system is applied through the REMOTE MASTER switch to the stabilizer input terminal. This feature permits slaving all reference supplies in a system to one source of voltage.

Distribution of reference voltages to the operational circuits is accomplished through use of four reference buses. The ±100 volt unswitched reference buses are connected directly to the output terminals of the reference supplies. These buses are energized as soon as filament and plate power voltages are switched on. The other two buses supply switched reference. Voltages to these buses are fed through contacts on K11, the Reference Relay. This relay is controlled by the PL/REF switch (S5) on the Mode Control, and is energized when the switch is operated to the ON position. K11 is also interlocked through normally closed contacts on the Pot Set Follower (K10) and Rate Test Follower (K7) relays. If either of these relays is energized, K11 drops out and reference voltages are removed from the switched reference buses.

8. SYSTEM CABLING

a. Expansion Group Connectors. The 231R Computer can be operated independently or in conjunction with other computer groups. When used in an expanded computing system, the 231R Console is the central control and operating point for all racks of equipment.

To enable the computer to be used for system control, the console is equipped with cable connectors mounted on a plate at the rear of the first bay (fig. 7). This plate can accommodate a maximum of thirty-four connectors. The arrangement used is very flexible and the number of connectors and the function of each can be varied to fit the individual system. In general, the connectors on the plate can provide cabling facilities for all computational elements that can be accommodated by the standard pre-patch panel as indicated by the table below.

Connector	Normal Function
J1, J2, J3	Resolvers R0, R1, R2, R3, R4
J4, J5, J6, J7, J9	Unassigned
J8	Inverting Amplifiers (inputs)
J10, J11	Diode Function Generators (and inverter outputs)
J12, J13	Electronic Multipliers
J14, J15, J16, J17	Servo Multipliers
J18, J19, J20, J21, J22, J23	Trunks
J24 through J30	Unassigned
J31, J32, J33, J34	Trunks

b. Variplotter Connections. The 231R Computer has provision for accommodating up to four plotting boards. The connectors for these units are designated PJ0, PJ2, PJ3, and PJ5, and are located on the plug mounting plate (left side) beneath the foot rest. (The foot rest is hinged to provide access to these connectors.) The plate also contains two relay sockets designated K8 and K18. Relay K18 provides pen lift control and is energized by the Indicator and Pen Lift relay (K3) in the Mode Control Relays. Relay K8 provides standby control of the plotter servos and is energized when the computer is switched to the Pot Set Mode.

c. Recorder Connections. The plug mounting plate beneath the footrest on the right side contains connectors for three eight-channel recorders. These connectors are designated RJ0, RJ2, RJ4. This panel also contains connector BT used for slaving the computer to the recorder.

d. Slaving. The 231R Computer contains facilities for slaving up to a maximum of six consoles in one expanded system. When required, a slave cable is provided that mates with slaving connector MC-J1. This connector is located on the rear of the console directly behind the Mode Control Panel.

9. BRIEF DESCRIPTION OF COMPUTER COMPONENTS AND FUNCTIONS

a. Power Supplies and Power Control Units.

(1) Power Control and Relay 11.001. This unit provides control of primary a-c power to the console. The panel contains the a-c circuit breaker-switches, the plate power relay, the time delay relay, and four fuses. The fuses protect the oven heater circuits, filaments transformers T1, T2, and T3, servo reference phase circuits, and cabinet blower motors.

(2) Regulated Power Supply 10.001. The console contains two of these units, each providing 300

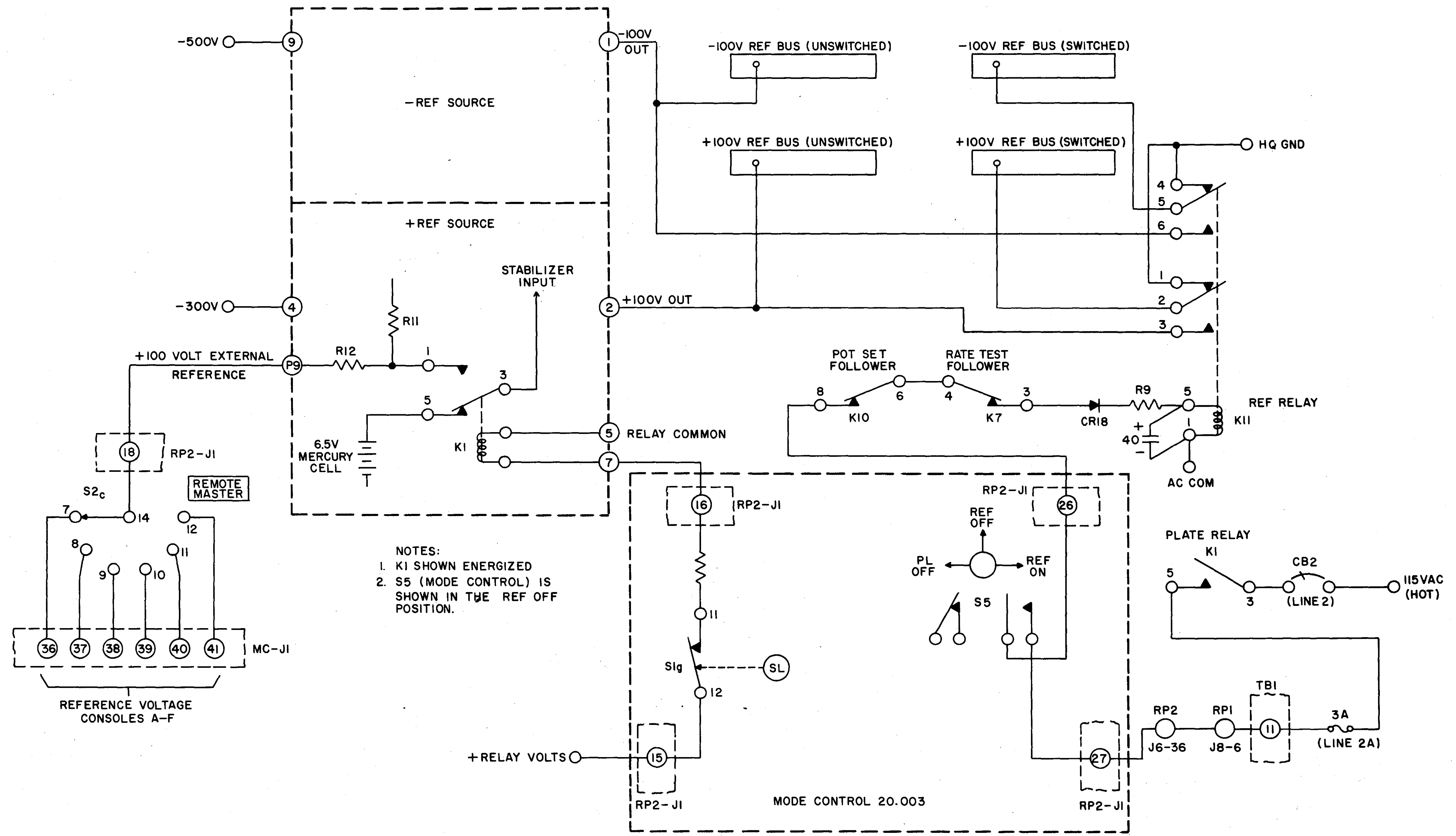


Figure 6. Reference Voltage and Distribution Circuits.

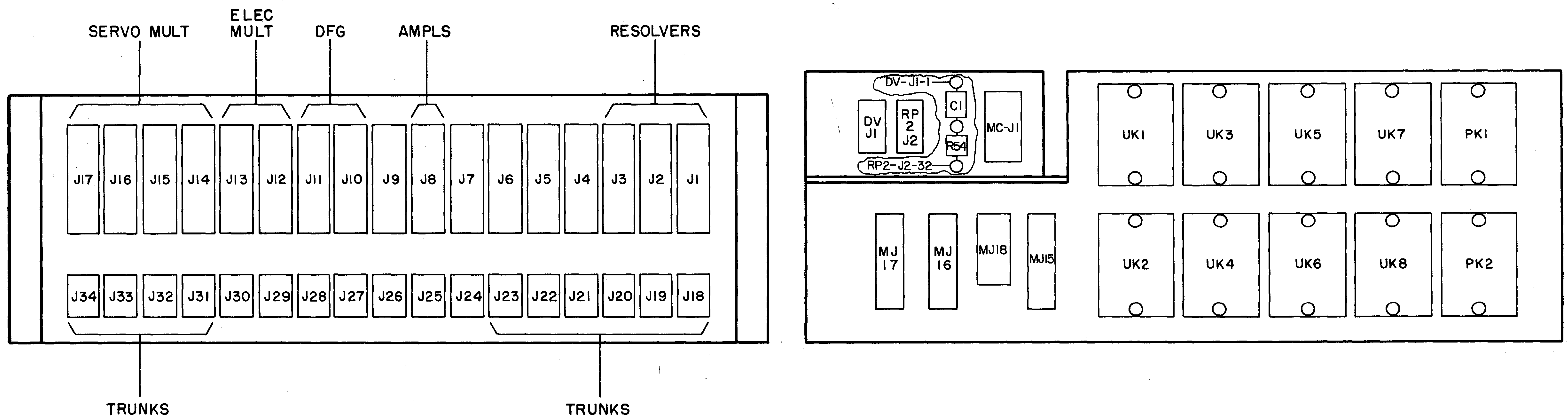


Figure 7. Drawing of Console Showing Plug Mounting Plate.

volts of regulated d-c at 2.0 amperes. Each supply also contains two 6.3 volt, 45-ampere filament transformers. The power supplies are mounted in the left side of the rack below the shelf. The upper unit provides +300 volts and the lower –300 volts.

(3) Regulated Power Supply 10.017. This power supply furnishes regulated outputs of 200 volts at 80 milliamperes, and +110 volts at 500 milliamperes. The 200-volt output of this unit is utilized with the –300-volt supply to provide a bias voltage of –500 volts for the d-c amplifiers.

(4) 25 Volt Supply 10.008. This supply provides a regulated d-c output of 25 volts used for relay holding voltage in the Mode Control relay circuits.

(5) Relay Power Supply 10.002. This unit supplies 90 volts d-c at 4.0 amperes. This power is used for control and network relays in the computer.

(6) Vibrator Drive Unit 21.004. The Vibrator Drive Unit supplies 6 volt a-c power at a nominal frequency of 94 cps to the choppers in the d-c amplifiers.

(7) Filament Transformers T1, T2, T3. These are 6.5-volt, 45-ampere transformers which supply filament power to a-c busses on the rear of the rack.

b. Reference Supply Units.

(1) Reference Regulator 43.003. This unit is a chopper stabilized, d-c amplifier. It is used in conjunction with the Reference and Check Amplifier Network 12.098 to provide reference voltage sources of plus and minus 100 volts.

(2) Reference and Check Amplifier Network 12.098. This network contains the voltage dividers and mercury reference battery used with the Reference Regulator described above. The network also contains the reference balance resistors and feedback resistors for the check amplifier.

c. Computation Elements.

(1) Quadruple D.C. Amplifier 6.002. Each of these units consists of four separate d-c amplifiers that are used for summation, integration, multiplication by a constant coefficient, isolation, and phase inversion. Each amplifier is chopper stabilized to provide automatic balancing, and is capable of stable operation with a wide range of feedback impedances.

(2) Combination Network 12.002. This network provides the combination amplifiers with feedback and input resistors for three gain-of-10 inputs and three gain-of-1 inputs. The network also contains one input and one feedback resistor which are used to establish the initial condition of an integrator. This unit is used in conjunction with the integrating capacitors mounted on Integrating Capacitor Assembly 12.031 for operation of d-c amplifiers as integrating amplifiers. This network contains the Pot-Set Hold relay and the I.C. relay.

(3) Summing Network 12.003. The 12.003 Network contains feedback and input resistors for one summing amplifier and a pot set relay. Three gain-of-10 and three gain-of-1 inputs are provided.

(4) Integrator Capacitor Assembly 12.031. This panel is mounted in the oven and contains up to twenty adjustable 1.0 microfarad capacitors. These capacitors are used to permit operation of d-c amplifiers as integrators.

(5) Attenuators and Function Switches 42.001. This panel is mounted on the front of the console directly below the patch bay, and contains twenty hand-set potentiometers and four function switches. Each potentiometer is a 30,000-ohm, ten-turn unit protected by a 1/32-ampere fuse in series with the wiper. One side and the wiper of each attenuator is brought out to the patch panel and the other end of each is grounded. Associated with each potentiometer is a three-position switch (spring return to center) used for metering purposes. The function switches are three-position lever switches with the connections brought out to the patch panel.

d. Programming.

(1) Pre-Patch Panel 5.001. The Pre-Patch Panel is a metal panel containing 3450 holes. The panel mounts in the patch bay. Patch cords and bottle plugs are inserted into the holes to engage the gold plated contact springs of the patch bay terminations. The panel and bay are so constructed that all leakages are confined to ground, and no leakage may occur between adjacent leads. This panel is the central terminal point for all the computing elements in the system.

(2) Mode Control 20.003. This unit is located at the center of the sloping control panel and contains the switches and indicators that control the various modes of operation of the computer.

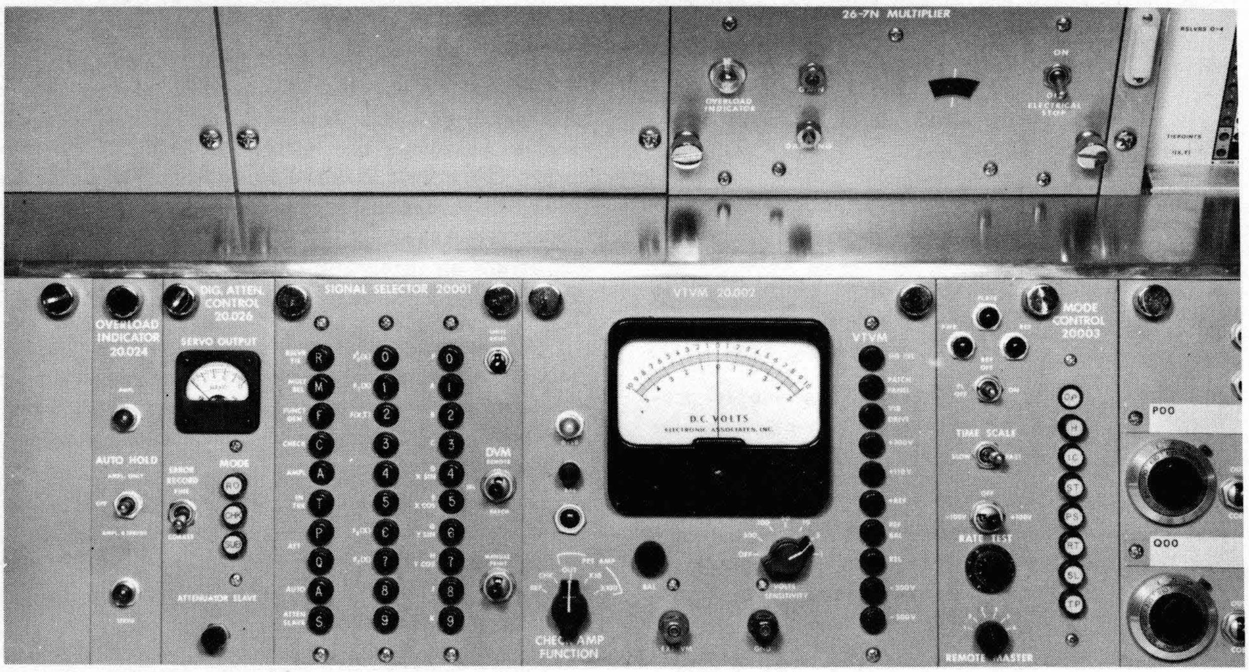


Figure 8. Control Panels.

e. Monitoring. (See fig. 8 and 8a)

(1) ERO Control System. The Extended Read Out Control System provides control circuitry and switching for all readout facilities of the computer. The major components of the system are the master and unit stepper switches that provide a possible total of 540 switch positions for readout of signal voltages. The steppers also provide address signals for a digital voltmeter and a printer when these components are being used for readout.

(2) Signal Selector 20.001. This unit controls the ERO system. It contains three 10-position pushbutton switches that are used to select positions on the stepper switches. Any of these positions may be manually selected, or all points may be scanned automatically.

(3) VTVM 20.002. This panel is located adjacent to the Signal Selector and contains the vacuum tube voltmeter and associated control switches. A ten-position pushbutton switch is provided to enable the meter to monitor the various power voltages in the computer. Controls for the check amplifier are also located on this unit.

(4) Dual Channel Overload Alarm 13.001 and Overload Indicator 20.024. These circuits provide visual and audible warnings when an overload occurs in an amplifier or servo. The warning lamps are located on the Overload Indicator Panel 20.024 together with the AUTO HOLD switch.

(5) EDVM Amplifier 26.040 and EDVM Indicator 26.027. These units compose an electronic digital voltmeter used for readout of all signal voltages in the computer. The readout unit is located in the center of the console adjacent to the patch bay. The EDVM, in addition to displaying the signal voltages on the readout unit, also supplies signal voltages to the printer.

(6) Printer 39.001. The printer and associated control circuitry form part of the readout system of the computer. The printer provides a permanent record of signal voltages read by the EDVM.

NOTE: When the E.D.V.M. and V.T.V.M. are in SELECT and the signal selector is stopped on an open point or any high impedance point, (such as a trunk which is not being used) the meters read approximately three volts. When the meters are both in SEL, the SEL output on the patch panel, which is normally the output of the signal selector, is the output of the unloading amplifier of the E.D.V.M.

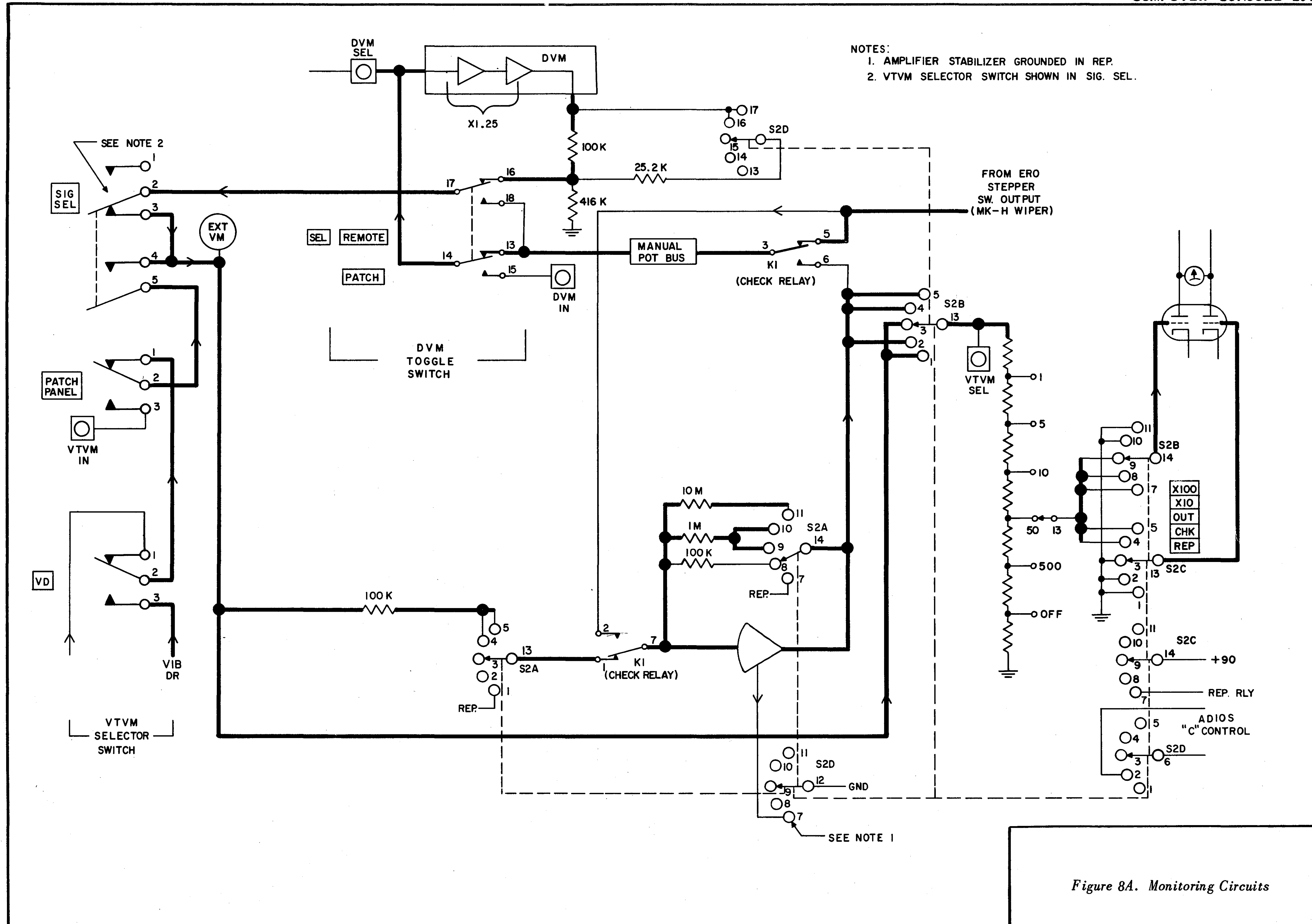


Figure 8A. Monitoring Circuits

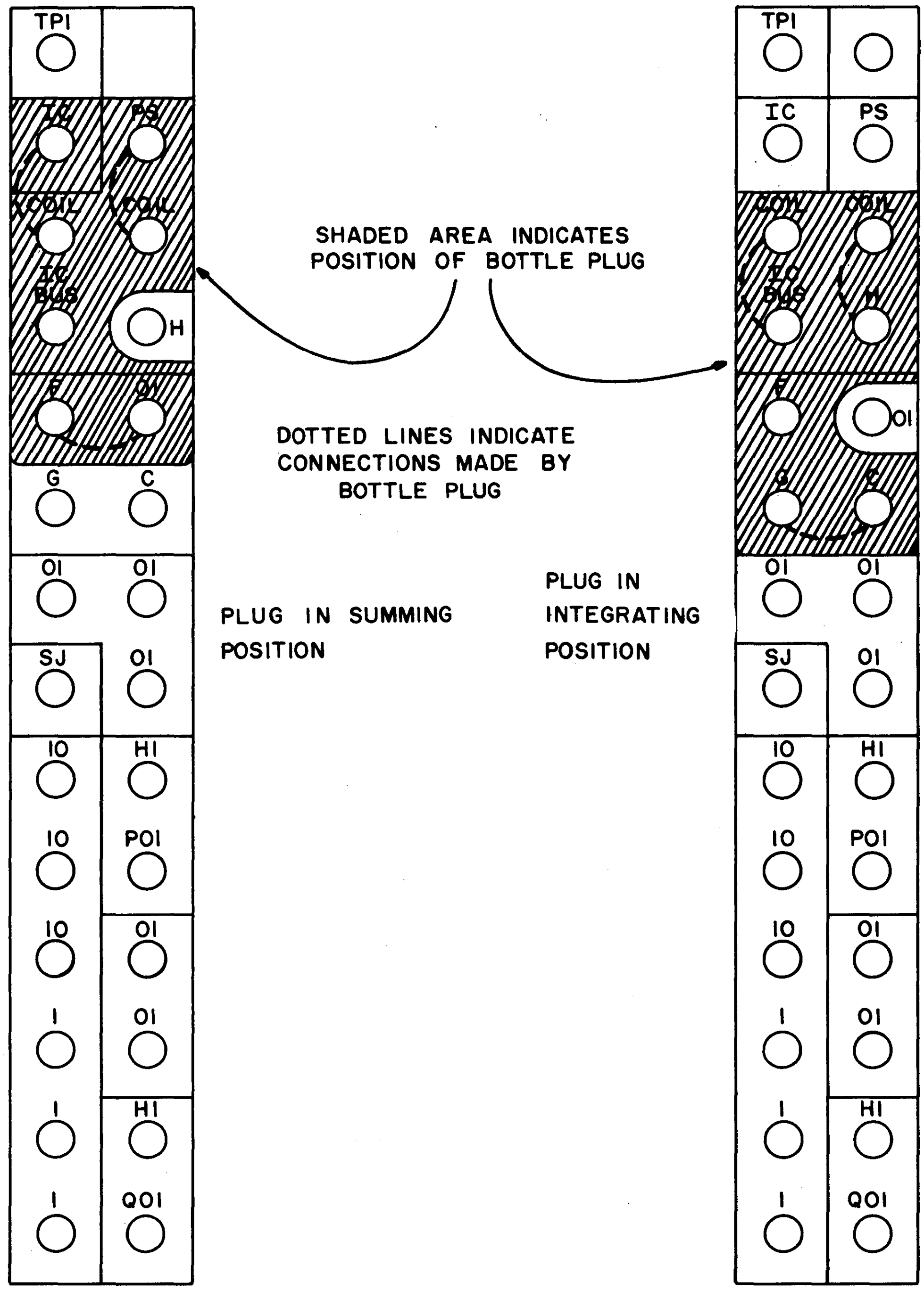


Figure 9. Combination Amplifier Patching.

10. OPERATION

a. Control Functions. All the operating controls for the computer are located on the slanting control panel on the console (see fig. 9). The functions of the controls are described in the order in which they appear on the console from left to right. A detailed circuit description of each unit will be found in paragraph 15.

(1) Overload Indicator 20.024. Two indicators and the AUTO HOLD switch are located on this panel. The indicator at the top (AMPL) glows when an overload occurs in any one of the d-c amplifiers. The one at the bottom (SERVO) glows when a servo multiplier or servo-resolver becomes overloaded.

The AUTO HOLD switch has three positions, and controls the operation of the Automatic Overload Alarm circuits. When this switch is in the upper position (AMPL ONLY) the computer is switched in the Hold mode automatically whenever an operational amplifier is overloaded. A servo overload does not effect the Hold circuits. When the switch is in the down position (AMPL & SERVOS) the computer is switched into the Hold mode whenever an amplifier or a servo overloads. With the switch in the center (OFF) position, the automatic hold feature is not operative.

(2) Signal Selector 20.001. Operation of the computer readout system is consolidated at the Signal Selector panel on the front of the console. This panel contains three ten-position pushbutton switches for signal selection, the UNITS RESET switch, the EDVM control switch, and the MANUAL PRINT control switch.

The Signal Selector pushbutton switches enable the operator to select manually any position on the stepper switches for readout. The voltage at this point may be applied to the VTVM or the EDVM and printer, if the computer is equipped with these monitoring facilities.

Automatic operation of the readout system is also controlled by switches on the Signal Selector. In this mode of readout operation, the stepping switch positions are scanned automatically in a definite sequence and the address and signal voltages at each position monitored by the EDVM and printer.

The function of the MANUAL PRINT switch is to control the printer during manual operation of the readout system. Operating this switch to the down (momentary) position, causes the printer to operate and print the address and voltage of the test point selected by the operator prior to operating the MANUAL PRINT switch. In the up (fixed) position, the readout system is prepared to measure the voltage at the arm of any hand-set attenuator. This voltage and the address may be printed by operating the switch to the right side of the desired attenuator with the MANUAL PRINT switch in the up position.

The DVM switch provide control of the DVM input circuit. In the PATCH position the switch connects the DVM input to the DVM termination on the patch panel, and in the SEL position, the DVM is connected to the signal selector output. The REMOTE position on this switch is used for switching control of the computer to a remote point such as an ADIOS console.

(3) VTVM 20.002. This panel contains the vacuum tube voltmeter, with associated control switches, and operational controls for the check amplifier. The chart found on page 15 of this section describes the function of these controls.

(4) Mode Control 20.003. Three indicators in the upper left corner show when power is applied to the computer circuits: PWR, when lighted indicates primary power circuits are energized–filaments on; PLATE, glows when plate voltage is applied to all units; REF, glows when Patch Panel reference voltage is on.

Below these indicators a three-position switch controls plate power and reference voltage: in the PL OFF position plate and reference voltage are both off; in the REF OFF position plate voltage is applied; in the ON position both plate and reference are turned on.

The TIME SCALE switch has three positions. In the SLOW position, the integration rate of the integrators is halfed; in the center position, the rate is normal; in the FAST position, the integration rate is ten times as fast as in the center position.

The RATE TEST controls include a three position switch and a potentiometer. In the center (OFF) position of the switch, no voltage is connected to the top of the potentiometer. The –100V and the +100V positions connect unswitched reference voltage of the indicated polarity to the top of the potentiometer. The RATE TEST potentiometer adjusts the value of voltage connected to all integrators in the RATE TEST mode.

The REMOTE MASTER selector switch is used when in the SLAVE mode. Its position indicates

Control	Position	Function
CHECK AMP FUNCTION	REP	Connects check amplifier as sweep amplifier for repetitive operation.
	CHK	Prepares amplifier circuitry for CHECK operation by connecting a 100,000 feedback resistor across the amplifier, and connecting the VTVM to the output of the amplifier.
	OUT	Connects VTVM to VTVM pushbutton switch.
	X10	Connects 100,000 ohm input and 1 meg ohm feedback resistors for gain-of-10 input to check amplifier. Connects amplifier outputs to VTVM.
	X100	Changes feedback resistor to 10 meg for gain of −100 input to check amplifier.
VTVM	SIG SEL	Connects VTVM to signal selector if DVM switch is in PATCH PANEL position. If DVM Switch is not in PATCH PANEL position, VTVM is connected to the output of the unloading amplifier in the DVM.
	PATCH PANEL	Connects VTVM input to VTVM termination on patch panel.
	VIB DRIVE	Switches VTVM to output of Vibrator Drive Unit.
	+300V	Connects VTVM to +300 volt bus.
	+110	Connects VTVM to +110 volt bus.
	+REF	Connects VTVM to switched reference source.
	REF BAL	Connects VTVM to junction of reference balance resistors.
	REL	Connects VTVM to output of 90 volt relay supply.
	−300	Connects VTVM to −300 volt bus.
	−500	Connects VTVM to −500 volt bus.
VOLTS SENSI-TIVITY		Selects full scale voltage range of VTVM.
BAL (Below Meter)		Balance control for setting electrical zero of VTVM.
EXT VM/GND		Binding posts for connecting an external voltmeter or oscilloscope in parallel with VTVM.
OVLD		Overload indicator for check amplifier.
BAL (Below OVLD indicator)		Balance control for check amplifier.

Switch Position		Function
TP	Latching	Prepares the computer for ADIOS control.
SL	Latching	Switches computer to Slave mode so that it will operate simultaneously with the console selected as the REMOTE MASTER.
RT	Momentary	Switches computer to rate test mode to enable dynamic test to be performed with the integrators.
PS	Momentary	Removes input signals from amplifiers; switches computer to Pot Set mode. Summing points of networks are removed from grids and grounded, permitting attenuators connected to input networks to be adjusted with normal load. (NOTE: In Pot Set Reference voltages are removed from Patch Panel.)
ST	Momentary	Applies + and – reference to the Static Test bus which is used to test integrators whose I.C. voltage is normally zero.
IC	Momentary	Energizes all I.C. and Hold relays in the amplifier networks and applies initial condition voltage to integrators. All other integrator inputs are removed.
H	Momentary	Allows I.C. relays to drop out; Hold relays remain energized. I.C. voltages are removed from integrating capacitors which remain charged. No inputs are applied to integrators.
OP	Momentary	Starts integration. Hold relays drop out.

the number of the computer console to be used as the master.

The functions of the eight position pushbutton MODE CONTROL SWITCH on the right side of the panel are summarized in the table found on page 16.

(5) Attenuators and Function Switches 42.001. The switches under the hand-set attenuators (P00–P09 and Q00–Q09) are used for readout. Two positions are marked for each switch; COEF and OUT. To read out attenuators on the VTVM, depress the SIG SEL pushbutton of the VTVM switch, and move the attenuator switch to one of its two positions. In the COEF position, the VTVM indicates the coefficient by which any voltage applied to the top of the attenuator is multiplied (80 volts indicates a multiplier of 0.8). In the OUT position of the switch, the meter reads the actual voltage at the arm of the attenuator.

To use the DVM for attenuator readout, set the DVM switch to the SEL position, and operate attenuator switches as before.

If a printer is available, it can be used to make a permanent record of the readings. (The DVM *must* be used if a print-out is required.) Two methods of operating the printer are available. In the first, the attenuator switch is held in one of the readout positions and the MANUAL PRINT switch is pressed down (this is a momentary, spring return position). A single print will be made. If another print is desired, the MANUAL print switch must be allowed to return to its center position and then pressed down again. The second method of operating the printer is to place the MANUAL PRINT switch in the up position. This is a fixed position of the switch. With this setting, any attenuator switch moved to either position causes one print to be made. In this way, a whole series of readings can be recorded quickly by operating the attenuator switches.

Each function switch is a single-pole three-position switch. The patch panel terminations are designated as follows:

L	left contact
C	center contact
A	arm contact
R	right contact

b. Pre-Operating Check of Controls. Before applying a-c power to the computer, the controls should be set as follows:

Control	Setting
FILAMENT switch (circuit breaker switch on Power Control and Relay 11.001, at bottom of console)	OFF
PLATE switch (located next to FILAMENT switch)	OFF
PL/REF switch (on Mode Control 20.003)	PL OFF
VOLTS SENSITIVITY (on VTVM 20.002)	OFF

As soon as the computer is connected to the power source, the oven heaters and blowers start operation. The oven should never be allowed to cool off. Thermostats are set at the time of manufacture for an oven temperature of 100°F. Schematic drawing D003 025 0S sheet 1 shows the connections for the two thermostats (VTH-1 and VTH-2). Thermostat #1 is located at the top of the oven and can be reached by lowering the slanting panel over the pre-patch panel and removing the blank panel or the buffer unit, and inserting a small screw driver through the access hole. Thermostat #2 is located at the rear of the oven.

TH 1 – (top front)	I1 – (right side)
TH 2 – (rear)	I2 – (left)

TH 2 cannot be turned on unless TH 1 is on.

Since the oven thermostats are factory set, the temperature should remain at 100° ±1°. If the thermostats should require re-setting at any time, the following procedure should be followed:

1– Advance TH 1 (turn CCW).

2– Advance TH 2 until I2 (left) goes on.

3– Continue periodic adjustment of TH 2 until oven temperature varies about 100° as the average.

4– Adjust TH 1 for a differential of ±1° in temperature.

c. Starting Procedure. Before starting, install the Pre-Patch Panel. Lower the lever arm at the front of the panel, place the Pre-Patch Panel in position and raise the arm. Plate voltage cannot be turned on until the panel is in place and the lever arm is raised. This process actuates the the microswitch in the plate voltage control circuits.

Insert 8-prong bottle plugs in the Pre-Patch Panel at the combination amplifier positions, and 4-prong bottle plugs at the summing amplifier positions. Combination units are numbered 00, 01, 05, 06, 10, 11, 15, 16. Summer Amplifiers are numbered 02, 03, 04, 07, 08, 09, 12, 13, 14, 17, 18, 19.

Operate the FILAMENT switch to the ON position. The green PWR indicator on the Mode Control should light, as well as those on the high voltage power supplies, and the blower motors should begin operating. After a 30-second delay to permit the thermal relay to close, operate the PLATE switch to the ON position. Plate voltage will not be turned on until the PL/REF switch on the Mode Control is operated to the REF OFF position; at this time the red PLATE indicator will glow. To apply reference voltage to the switched buses, move the switch to the ON position. The red indicator marked REF will glow. (The reference voltage is not applied to the switched reference buses in P.S. and R.T. mode.)

d. Preliminary Adjustments. After a few minutes of warm-up time, adjust the VTVM BAL control so that the meter reads zero. (The VOLTS SENSITIVITY switch should be in the OFF position.)

Make the following power supply voltage checks when the computer is first turned on and occasionally thereafter as a routine operating procedure. Voltages to be measured are selected by depressing buttons on the VTVM switch.

Use an external meter connected to the EXT. VM terminals of the VTVM Panel 20.002 for initial power supply calibration. The VTVM is calibrated and balanced after the power supplies have been properly adjusted. *Do not use VTVM for power supply adjustments.*

Balance all d-c amplifiers by depressing the balance pushbutton and adjusting the potentiometer until the overload indicator is extinguished and remains extinguished for five seconds.

Check	Volts Sensitivity	Adjust
−300	500	VOLTAGE ADJUST control on lower Power Supply 10.001.
+300	500	VOLTAGE ADJUST control on upper Power Supply 10.001.
−500	500	200V ADJ control on Power Supply 10.017.
+110	500	110V ADJ on Power Supply 10.017.
Vibrator Drive	10	AMPLITUDE control on Vibrator Drive Unit 21.004. Adjust for 6 volts.
+REF	100	Balance both Reference Regulators (43.003) by pressing the BAL pushbutton until the overload indicator is extinguished. Adjust AM Control R10 in Network 12.098, located in oven (Reference and Check Amplifier Network) for +100V.
REF BAL	1	Adjust BAL control in above network for zero.
REL	100	None

e. Patching.

CAUTION

If patching is accomplished after the pre-patch panel has been installed care must be exercised to prevent shock to the operator or damage to the equipment. With plate and reference voltage turned on, voltage is present at many terminals on the panel. The patching sequence should be made TO an INPUT and FROM an OUTPUT, in that order. Even with the plate and reference supplies switched OFF, voltages may be present on the TRUNK terminations from other circuits in the system not controlled from this console.

Note that plate and reference voltages cannot be turned on unless the pre-patch panel is in place.

(1) Combination Amplifier. Figure 9 shows the combination amplifier section of the patch panel; the shaded area indicates the position of the six-prong bottle plug. The diagram on the left shows the bottle plug position and connections made in order to use the combination amplifier as a summer. On the right, patching for integrators is shown. The two vertical jumpers at the top of the plug connect the coils of the IC and Pot Set-Hold relays to the proper voltage source. In the summing operation the IC relay coil (K1) is connected to ground through one of the IC resistors so that it does not function when the amplifier is being used as a summer. The Pot Set-Hold relay coil (K2) is connected to the Pot Set bus. The relay therefore, functions as a pot set relay. In the illustration at the right, the IC relay is connected to the IC bus. The coil of K2 is connected to the Hold bus so that it functions as a Hold relay. Figure 20 contains a chart showing the busses energized during each mode.

The horizontal jumper at the bottom of the bottle plug connects the feedback resistor or capacitor across the amplifier depending upon the position of the plug.

Figure 10 shows the wiring behind the patch panel. Most of this circuitry is contained in Combination Network 12.002 (see fig. 30).

(2) Summing Amplifier. Figure 11 shows the wiring associated with the Summing (only) amplifiers. A four-prong bottle plug is inserted in position as indicated by the shaded area. The Pot Set relay is operated from the Summer Only bus.

(3) Servo Multiplier. Figure 12 shows the patch panel terminations of the servo multipliers and the connections to the servo-amplifier. Dotted lines show bottle plugs used to make reference voltage connections to the follow-up potentiometer. Input is patched into terminal SM1.

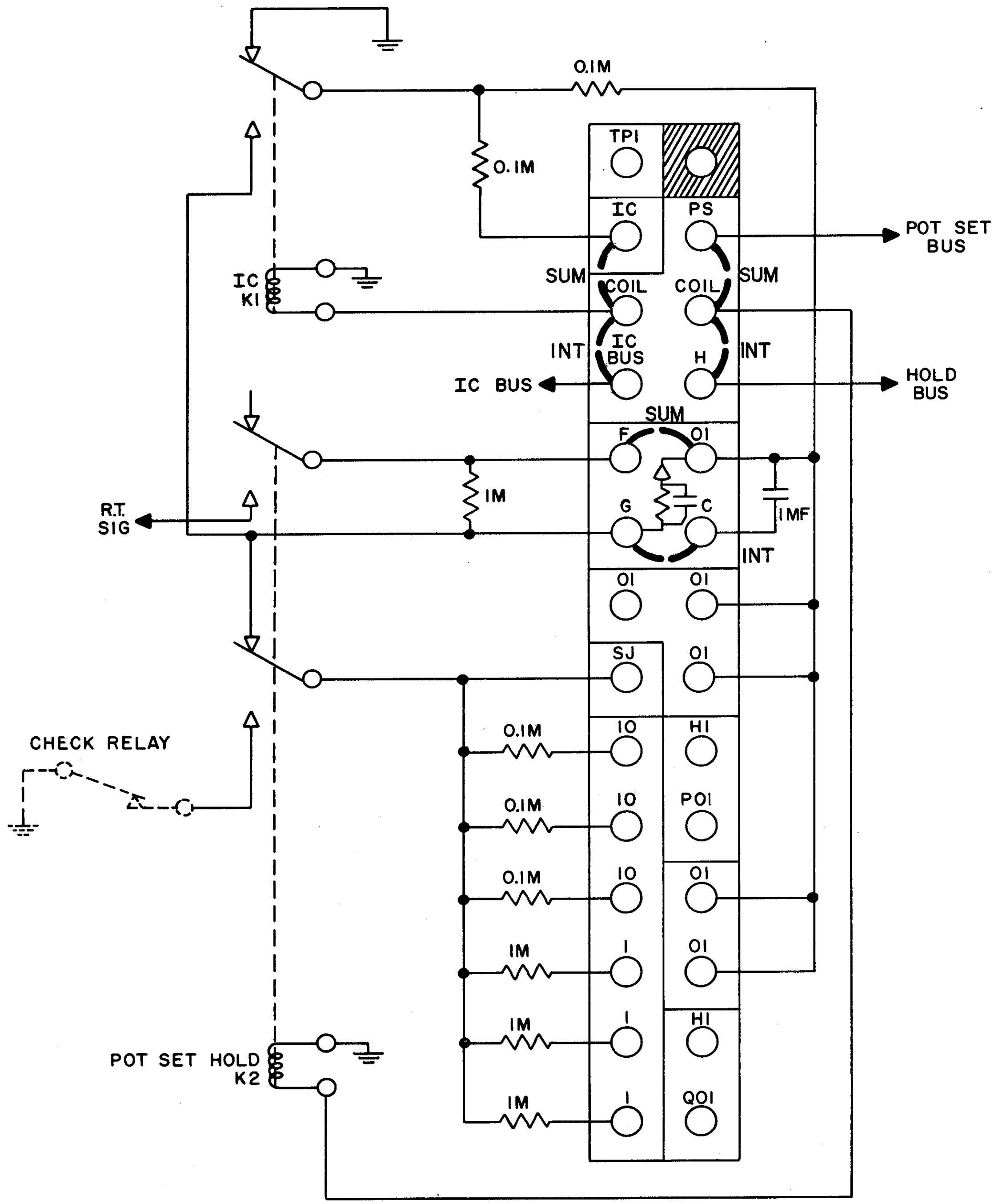


Figure 10. Combination Network Connections.

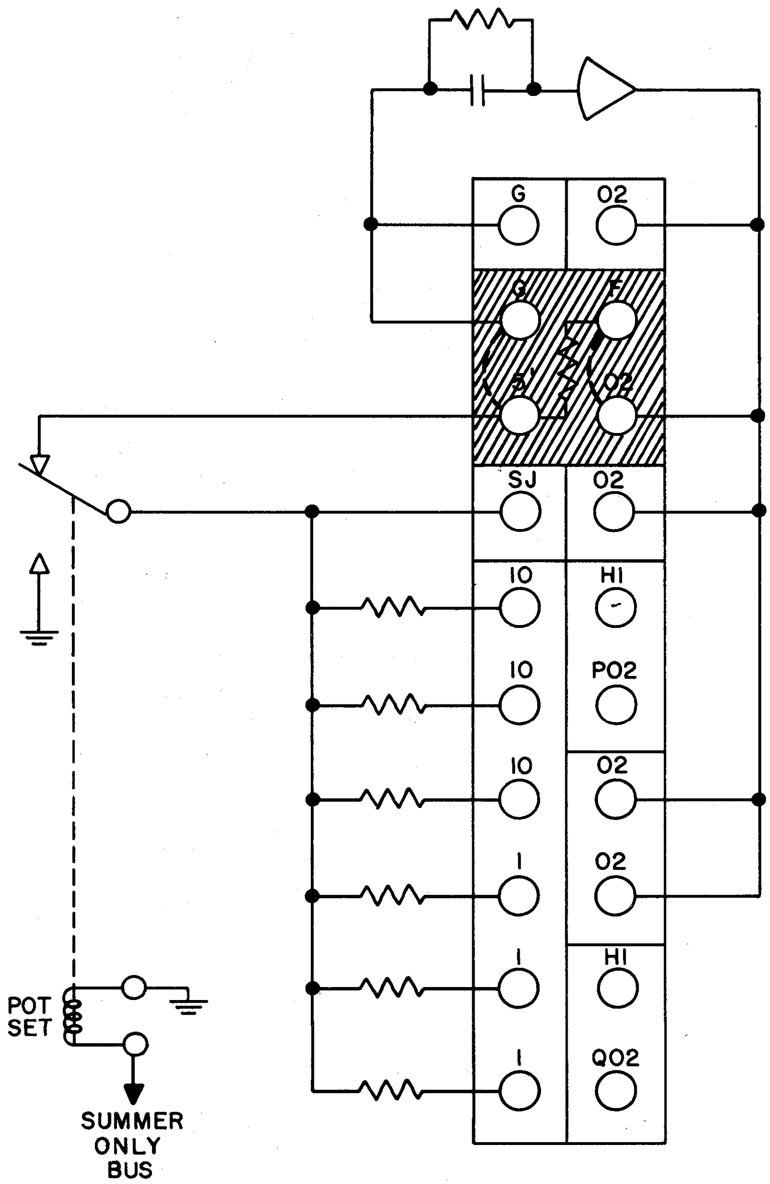


Figure 11. Summing Amplifier Connections.

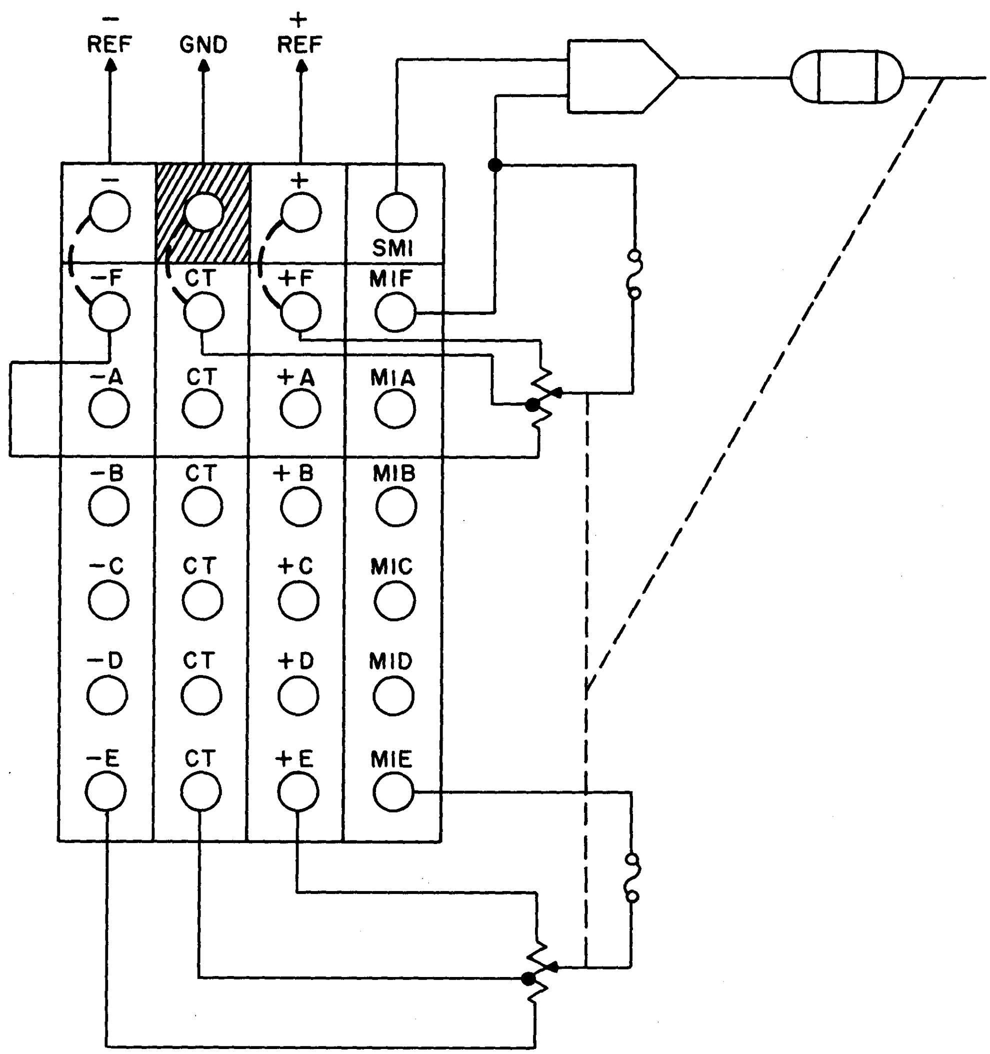


Figure 12. Servomultiplier Connections.

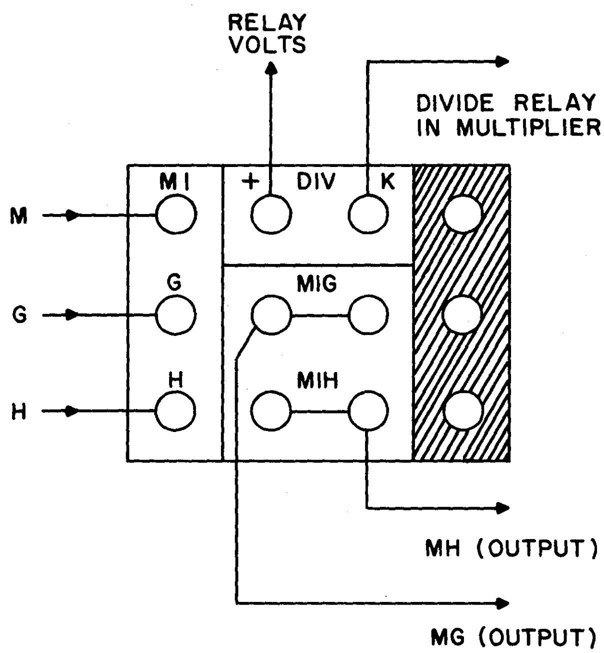


Figure 13. Electronic Multiplier Patching.

(4) Electronic Multipliers. Figure 13 shows inputs patched to M, G, and H, with products -MH/100 and -MG/100 available at the dual output terminals. To use the Electronic Multiplier as a divider, a red bottle plug is inserted into the DIV terminals labelled + and K. This operation energizes the divider relay in the multiplier. One output is produced in this mode of operation equal to -M/100, and is taken from the terminals marked MG.

(5) Diode Function Generators. Figure 14 shows the location of inputs X_1 and X_2 and the output terminals for FX_1 and FX_2. This is the patching configuration for two ten-segment functions. If one twenty-segment function is desired, a green bottle plug is placed in the 20 SEG holes at the right. The two amplifiers (labelled 65 and 66 in figure 14) are made available for inverter service during 20 segment operation, they cannot be used in this manner unless the bottle plug is installed.

Figure 15 shows the connections behind the patch panel. A quadruple d-c amplifier, located in Combination Rack Model 4.015 (para. 4) is associated with each DFG unit. Two of the amplifiers are permanently wired to the DFG; their terminations do not appear on the patch panel. The other two amplifiers are connected to a network (type 12.004) which is plugged into the rear of the patch panel. The input and output terminals of these two amplifiers are brought to the patch panel as shown in figure G.

The relay contacts switching the two amplifiers are part of a relay mounted on the DFG chassis (Junction Panel with Relay 47.010; schematic drawing C047 010 0S). It is this relay which is energized when the bottle plug is inserted in the 20 SEG position. The relay switches the two amplifiers from the DFG to the patch panel network; it is then possible to use them as inverters.

The quadruple d-c amplifier located in the combination rack may be replaced with a "quasi" quadruple d-c amplifier i.e. half a quadruple d-c amplifier. When a quasi d-c amplifier is installed, the D.F.G. must be used as one 20-segment generator.

(6) Resolvers. Figure 16 shows the patch panel arrangement and schematic drawing for rectangular conversion; figure 17 gives the same information for polar conversion. In the patch panel small white lines are used to indicate bottle plug connections. The curved lines are to be followed when patching for polar conversions and the straight lines for rectangular conversions.

It should be noted that two rectangular conversions can be performed simultaneously by one resolver provided the angles θ and θ' are equal. Only one polar conversion is possible, however.

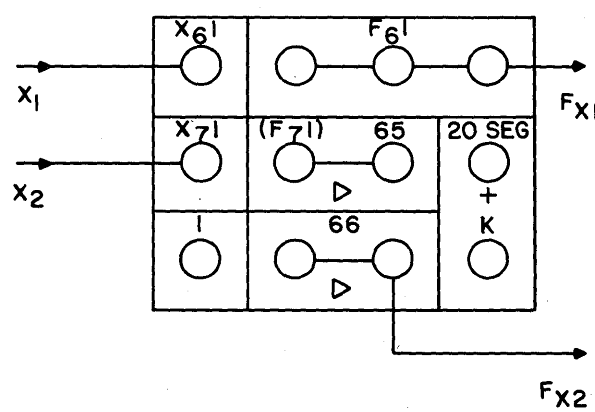


Figure 14. Diode Function Generator Patching.

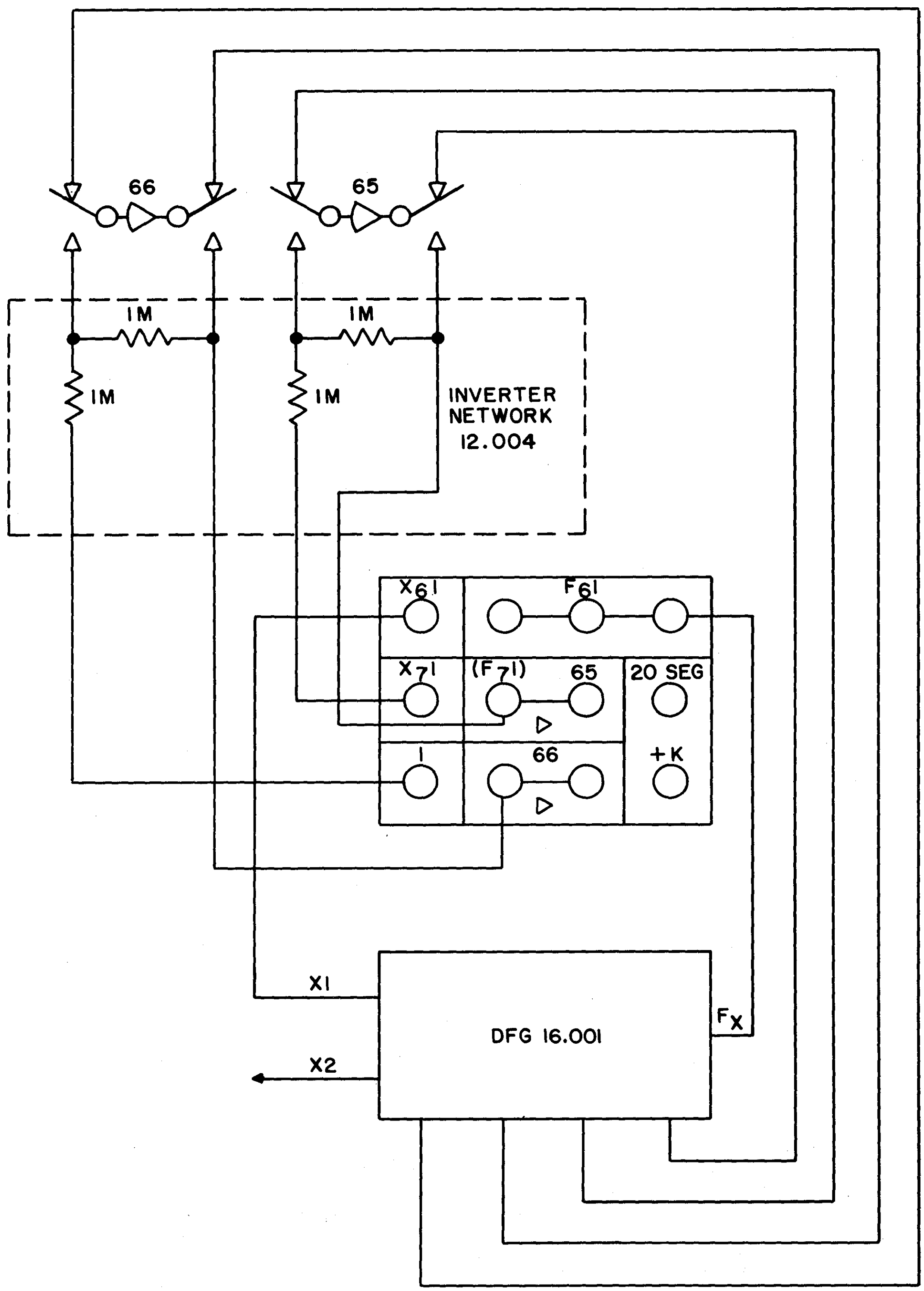


Figure 15. Diode Function Generator Connections.

Four potentiometers are terminated at the patch panel; the one labelled F is used for a follow-up potentiometer during rectangular conversion, and to supply a voltage proportional to the angle θ during polar conversion. The other three potentiometers can be used as servo-multipliers. The d-c amplifiers used are shown on the patch panel as being part of the DFG unit. The diode function generator above the resolver must be patched as a 20 segment D.F.G. (bottle plug inserted in 20 SEG block) to permit use of the inverters for the resolver.

f. Patching to Auxiliary Equipment.

(1) EDVM and VTVM. At the top of the patch panel above summing amplifiers 12 and 13 are two terminals associated with the EDVM, and two with the VTVM. The terminals marked SEL are connected directly to the inputs of the EDVM and VTVM. Voltages to be measured should not be connected to these points because of the danger of having two input voltages simultaneously to one meter. The SEL terminals are provided as convenient means of connecting an external EDVM, VTVM or oscilloscope.

The EDVM terminal marked IN is connected to the EDVM input only when the EDVM switch is moved to the PATCH position. The VTVM terminal marked IN is connected to the meter by depressing the PATCH PANEL button of the VTVM switch.

(2) Variplotters. Across the top of the patch panel are four green areas used for connection to plotting boards. Four terminals in each area are labelled X, Y, –X, –Y. The external cable connections to the Variplotters are located under the foot rest at the bottom of the console. Connectors are labelled PJ-0, PJ-2, PJ-3, PJ-4. The patch panel areas follow this order, the first one on the left is associated with the Variplotter connected at PJ-0.

(3) Recorders. Adjacent to the Variplotter areas are terminals for three eight-channel recorders. External cable connection to the recorders is made in the same manner as the Variplotters at connectors RJ-0, RJ-2, and RJ-4.

g. Readout Procedure–Manual. To monitor signal voltages on the VTVM, set the CHECK AMP. FUNCTION switch to the OUT position, and depress the SIG SEL button on the VTVM. To monitor these voltages on the EDVM, set the EDVM switch on the Signal Selector panel to the SEL position. If it is desired to record a particular signal voltage on the printer. The MANUAL PRINT switch on the Signal Selector panel must be operated to the down (momentary) position. This causes the printer to record the voltage and address at the test point chosen by the Signal Selector switch.

Figure 18 lists the Signal Selector pushbutton switches that must be operated to monitor test points on the stepper switches.

h. Readout Procedure – Automatic. Automatic readout requires that the computer be equipped with a digital voltmeter and a printer. To make a complete cycle of the automatic readout, it is necessary to reset all stepping switches to their respective "home" (zero) positions. This is accomplished by depressing the three pushbuttons at the top of the signal selector which are labeled R, O, O. The UNITS RESET switch is then operated to the down position momentarily, and then holding the switch in the up position for the short time required for the steppers to move to zero. If the computer has a D.A.S. expansion the attenuator steppers must also be zero set. To accomplish this depress the three pushbuttons P, O, O and then depress the three pushbuttons Q, O, O. Return the Signal Selector to its original position – R, O, O.

> *NOTE:* If the computer does not have a resolver expansion the steppers will step continuously when R, O, O are depressed. If this is the case depress the M (hundreds) push button.

The automatic readout circuits are now ready for operation, and depressing the AUTO pushbutton initiates the cycle. No further steps are required for this operation. The readout system monitors each test point, prints a record of the voltage and address of each point, and stops when the final reading is completed. The approximate speed of print out, in all but attenuator readout, is 200 prints per minute; in attenuator readout the print out is slowed to 120 prints per minute.*

i. Problem Test.

(1) Rate Test. Depress the RT pushbutton of the Mode Control. Set the RATE TEST potentiom-

* The speed change is accomplished by contacts 9 and 10 of the P and Q relays K10 and K11 in the ERO Control Unit 14.001.

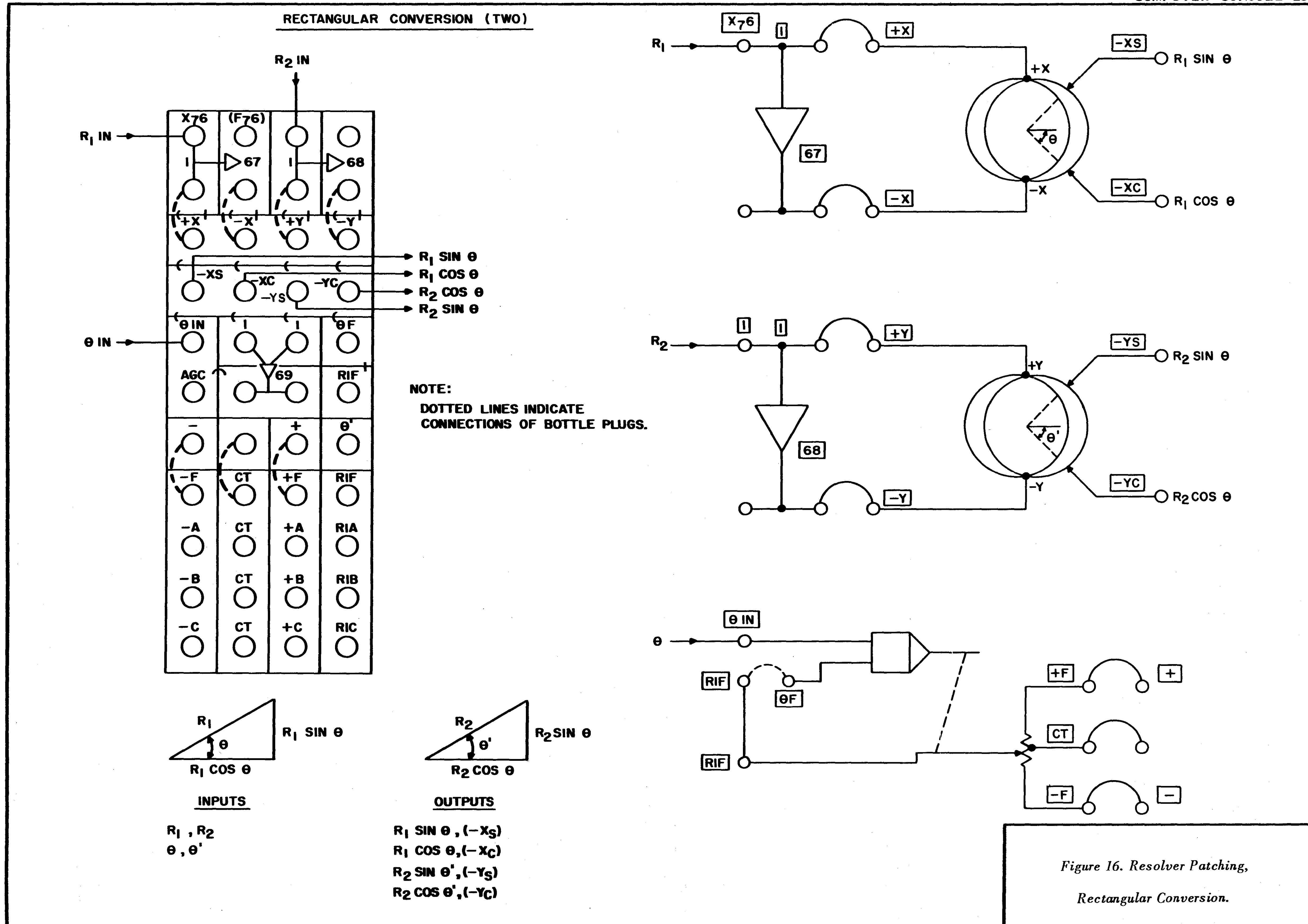


Figure 16. Resolver Patching, Rectangular Conversion.

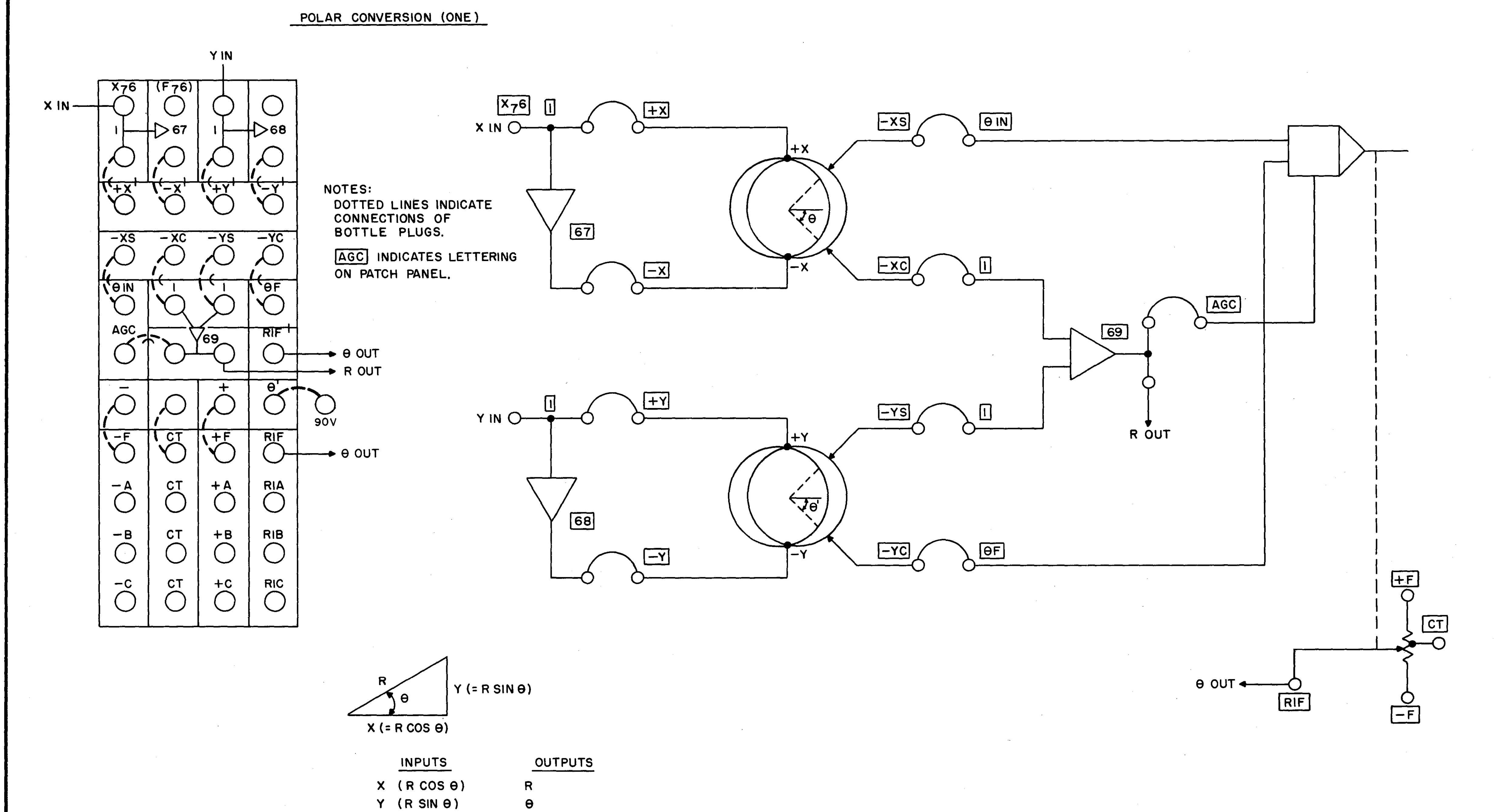


Figure 17. Resolver Patching, Polar Conversion.

DESIRED SIGNAL VOLTAGE	SIGNAL SELECTOR SETTINGS		
	ROW 1	ROW 2	ROW 3
RESOLVERS 0 - 4	RSLVR/TIE	0-4	F, A, B, C, XSIN, XCOS, YSIN, YCOS
TIEPOINTS R0J-R4K	RSLVR/TIE	0-4	J, K
MULTIPLIERS			
SERVO 0-9	MUL/REL	0-9	F, A, B, C, D, E
ELECTRONIC 0-9	MUL/REL	0-9	G, H
RELAYS	MUL/REL	0-9	J, K
FUNCTION GENERATORS 0-9	FUNCT/GEN	6-7	0-9
CHECK	CHECK	0-9	0, 1, 5, 6
AMPLIFIERS	AMPL	0-9	0-9
TRUNKS	IN/TRK	0-9	0-9

Figure 18. Signal Selector Operation Chart.

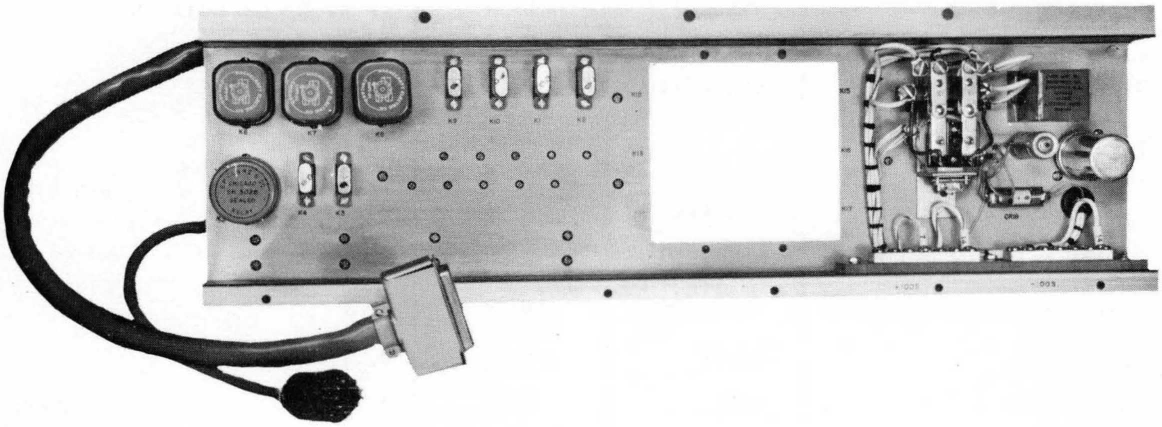
eter to the desired value. Move the RATE TEST switch to −100 or +100 position and monitor the output of one of the integrators. When the output has reached 95 volts, turn the RATE TEST switch to OFF. Read and compare the outputs of all integrators.

(2) Static Test. A large portion of the problem patching may be tested in I.C. The ST mode is used to complete the testing by the automatic insertion of arbitrary initial condition voltages to the integrators which normally would require zero outputs in I.C. Patch from the TEST REF buses to potentiometers and thence to the selected integrators (TP0, TP1, TP5, and TP6 may conveniently be used for tie points for these test signals) and adjust the potentiometers for the desired values under load. Compare the output readings with calculated or previously measured values. The outputs should be equal in value and opposite in polarity to the input. The test may be performed with or without the normal reference voltages on the patch panel. The TEST REF patch panel terminations are automatically reduced to zero volts in modes other than S.T.; there is no danger of affecting the problem.

(3) Check. The check facility is used to complete the readout capabilities for problem test, with respect to integrator inputs, or initial rates. It may be used in ST, IC or HOLD. Readout is available on any of the normal readout indicators or recorders. It is accomplished by depressing the C pushbutton in the hundreds column of the signal selector, and the integrator number in the other two columns. Scale factor is determined by the position of the VTVM function switch. In CHK the indicated scale is in voltage per tenth of a second, with a plus sign indicating positive initial derivative on the integrator output. In OUT the scale is in voltage per second. On systems provided with ADIOS, the address (on the typewriter) hundreds column will be identified by a "C" for the former case, and by a "3" in the latter case.

11. DETAILED CIRCUIT DESCRIPTION

a. Mode Control (refer to schematic diagram D003 025 0S, sheet 2). There are three methods of controlling the computer mode of operation:



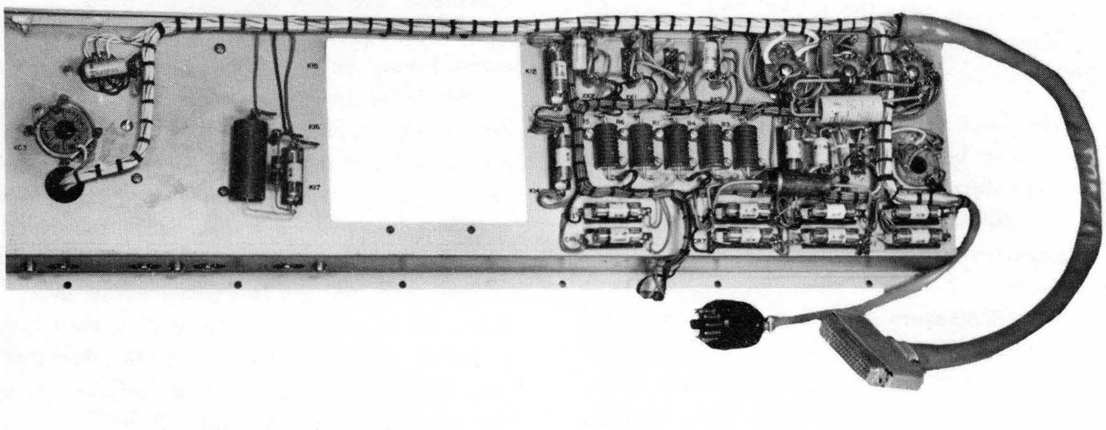


Figure 19. Mode Control Relays.

local control by means of the pushbuttons on the Mode Control panel; slaved control from a remote console selected by the REMOTE MASTER switch; ADIOS control from the ADIOS desk; and limited control from the EAI eight-channel recorder, if one is used. If more than one console is connected in a system of computers, the ADIOS desk must select the console to be operated by energizing the proper Console Select Relay (CSR). ADIOS control is accomplished by transmitting a 50 millisecond pulse to the computer Mode Control circuits. Holding circuits are provided to retain the selected mode after the pulse is removed.

The Mode Control panel (20.003) contains only the pushbutton and other switches, and indicators. The relays and associated circuits are mounted on relay panel RP1 (11.008) which is located behind the Attenuators and Function Switches panel 42.001 (fig. 19). The schematic diagrams D020 003 OS (mode control) and D011 008 OS (mode Control Relays–RP1) are combined in diagram D003 025 0S (231R Control Circuit). For the following explanation, refer to diagram D003 025 0S, (sheet 2).

The pushbuttons for OP, H, IC, ST, PS and RT operate momentary contact switches. In operation they are depressed and immediately released. Holding circuits maintain the proper circuit connections. The SL and TP pushbuttons operate latching type switches; when depressed, they remain down until released by depressing another button.

The Rate Test Follower K7 has three sets of contacts; 9 and 10 form a holding circuit through the ST master and Hold Release Relay to keep K7 energized. Contacts 6 and 7 illuminate the RT indicator; contacts 3 and 4 remain open and the Reference Relay K11 removes ±100 volt reference voltage from all the computation circuits. The Rate Test Signal Relays K15, K16, K17 are also held energized by the RT follower holding circuit. These relays connect the rate test voltage to each of the combination amplifiers.

The Indicator and Pen Lift Relay K3 remains energized after K4 drops out by virtue of the 25 volt holding voltage applied through CR3. Contacts 3 and 5 on this relay illuminate the H indicator lamp; contacts 4 and 6 apply 90 volts to the Variplotter pen lift circuits. The Sum Only bus remains energized by 25 volts through CR8. The Hold bus remains energized by CR3.

At this time the following conditions prevail which are of significance to the computing networks:

Whenever one of the momentary contact pushbuttons is depressed (OP, H, IC, ST, PS, RT), the Hold Release relay K4 is energized for about 20 milliseconds.

This relay is operated through capacitor C1 to provide a short pull-in time so that it will pull in quickly and drop out before the pushbutton is released. The upper set of contacts provide a 90-volt holding voltage for the Static Test master Relay K8 and the Rate Test Follower relay K7. The lower set of contacts provide a 25-volt holding circuit for the Hold, IC, Pot Set Summer Only busses. When a pushbutton is pressed, the holding circuits through this relay are broken; after it is released, only the desired relays remain energized. Silicon rectifiers are used to isolate the 90 volt and 25 volt supplies. For example, the anode of CR3 is connected to +25 volts through K4, contacts 6 and 8. The cathode is connected to the Hold bus which receives 90 volts when K2 is energized. The 90 volts is applied long enough to energize all the Hold relays connected to the Hold bus; when K2 drops out, the 25 volts applied through CR3 maintains the Hold relays energized until K4 pulls in momentarily.

In the following discussion the operation during the Rate Test mode is described in detail. Operation in the other modes uses the same switching logic, and only the functions peculiar to each one are mentioned.

(1) Rate Test (Local Control). The purpose of the Rate Test Mode is to test the accuracy of the integrating capacitors. This is accomplished by applying a rate input to all integrators from a common source (the Rate Test potentiometer), starting them simultaneously, stopping them simultaneously and then reading and comparing the outputs.

When the RT pushbutton is depressed momentarily, the Rate Test Master Relay K5 and the Hold Master Relay K2 are energized. K5 energizes the following:

a– Sum Only Bus

b– Rate Test Follower K7

c– Rate Test Signal Relays K15, K15, K17

K2 energizes the following:

a– Hold bus

b– Hold Release Relay K4

c– Indicator and Pen Lift Relay K3

The Rate Test Follower K7 has three sets of contacts; 9 and 10 form a holding circuit through the ST master and Hold Release Relay to keep K7 energized. Contacts 6 and 7 illuminate the RT indicator; contacts 3 and 4 remain open and the Reference Relay K11 removes ±100 volt reference voltage from all the computation circuits. The Rate Test Signal Relays K15, K16, K17 are are also held energized by the RT follower holding circuit. These relays connect the rate test voltage to each of the combination amplifiers.

The Indicator and Pen Lift Relay K3 remains energized after K4 drops out by virtue of the 25 volt holding voltage applied through CR3. Contacts 3 and 5 on this relay illuminate the H indicator lamp; contacts 4 and 6 apply 90 volts to the Variplotter pen lift circuits. The Sum Only bus remains energized by 25 volts through CR8.

The Hold bus remains energized by CR3.

At this time the following conditions prevail which are of significance to the computing networks.

a– Rate Test Signal Relays K15, K16, and K17 are energized.

b– Sum Only bus is energized.

c– Hold bus is energized.

The Rate Test Signal Relays connect the Rate Test voltage to terminal K of all Combination Networks (12.002). This is shown in figure 29. The Sum Only bus energizes the Pot Set relays in the Summing Networks (12.003) through terminal L at the rear of each network (see fig. 32). This action disconnects the summing junction of each network from the amplifier grid and connects it to ground so that there will be no output from summing amplifiers while the computer is in the Rate Test Mode.

The Hold bus energizes all the Hold relays in the Combination Networks (12.002). In the network (fig. 29) the Hold relay removes the summing junction from the amplifier grid and connects the Rate Test signal to the feedback resistor R1 which is used as the input resistor in this mode.

(2) Rate Test (Slave Control). In the Slave Mode all the sections of the SL switch remain closed because this switch section is the latching type. When the RT pushbutton in the master console is depressed, relay voltage is transmitted through the slave cable to S2b-14 of the REMOTE MASTER switch, through contacts 17 and 18 of the Slave switch to the Rate Test Master Relay K5. After this, circuit operation is the same as during Local Control.

(3) Rate Test (ADIOS Control). For ADIOS control the Tape pushbutton is depressed. This is also a latching type switch. Contacts 6 and 7 permit the ADIOS to energize the Console Select Relay. Contacts 4 and 5 feed relay voltage to the ADIOS desk through the CSR relay. This voltage is switched by the ADIOS Console and returns to the computer in the form of 50-millisecond Mode control pulses. A 50-millisecond pulse through the CSR relay causes the same action as depressing the RT pushbutton.

The Hold Release Relay K4 causes any of the energized operational relays to drop out. K4 drops out after about 20 milliseconds to complete the holding circuits before the 50 millisecond pulse shuts off. This assures that the selected relay does not drop out at the end of the pulse.

When ADIOS controls only one console, the CSR relays are unnecessary.

(4) Static Test (Local Control). The Static Test mode provides a switched reference voltage to the TEST REF sections at the top of the patch panel. This voltage (or some fraction of it taken through an attenuator) can be applied to the IC inputs of integrators which have zero IC in the patched problem. This provides a check on the patching and input resistor of an amplifier whose input is the output of the integrator having zero IC.

The ST pushbutton operates K8, the ST Master relay; two sets of contacts connect the switched reference, and the third set are used for holding the relay closed. The holding contacts (90V) of the Static Test master relay and the Rate Test follower relay are in series. This is possible because these two relays are never energized at the same time. The IC master K1 is energized (through CR10 and C2) momentarily while the button is depressed, long enough to operate the IC Follower relay which remains energized by the holding voltage.

In the Network (12.002) the IC relay is energized (see fig. 29) and the voltage from the TEST REFERENCE bus charges the capacitor. Output of the integrator is equal to the test voltage, but of opposite polarity. The Hold relay is energized (by the Hold bus) to remove the summing junction from the amplifier grid so that other voltages patched into the network will not effect the test.

Operation of the Static Test circuits with Slaved and ADIOS control is similar to that for Rate Test.

(5) Pot Set. The Pot Set mode is used during the setting of attenuators. The Pot Set, Pot Set Hold, Hold, and I.C. relays of the networks are all energized; the summing junction of each network is removed from the amplifier grid and grounded so that attenuators connected to input networks can be adjusted under normal load. As shown in figure 20, all four busses are energized–Hold,

	MODE CONTROL RELAYS										
	MASTER RELAYS										
MODE	HOLD K2	IC K1	ST K8	PS K6	RT K5		IND PEN LIFT K3	IC FOL. K9	PS FOL. K10	RT FOL. K7	REF K11
OPERATE	O	O	O	O	O		O	O	O	O	X
HOLD	⊗	O	O	O	O		X	O	O	O	X
IC	O	⊗	O	O	O		X	X	O	O	X
ST	O	⊗	X	O	O		X	X	O	O	X
PS	O	⊗	O	⊗	O		X	X	X	O	O
RT	⊗	O	O	O	⊗		X	O	O	X	O

O Open, not energized
⊗ Energized momentarily, while button is depressed
X Energized as long as mode is maintained

	COMB. NETWORK 12.002			SUMMING NTWK. 12.003				
	IC K1	POT SET-HOLD K2		POT SET K1				
MODE		INT	SUM		HOLD BUS	IC BUS	SUM ONLY BUS	PS BUS
OPERATE	O	O	O	O	O	O	O	O
HOLD	O	X	O	O	X	O	O	O
IC	X	X	O	O	X	X	O	O
ST	X	X	O	O	X	X	O	O
PS	X	X	X	O	X	X	X	X
RT	O	X	O	X	X	O	X	O

NOTE: Pot Set–Hold relay K2 is energized by the Hold Bus when the combination amplifier is patched as an integrator. When the amplifier is used as a summer, K2 is energized by the Pot Set Bus.

Figure 20, Summary of Mode Control Relay Operation.

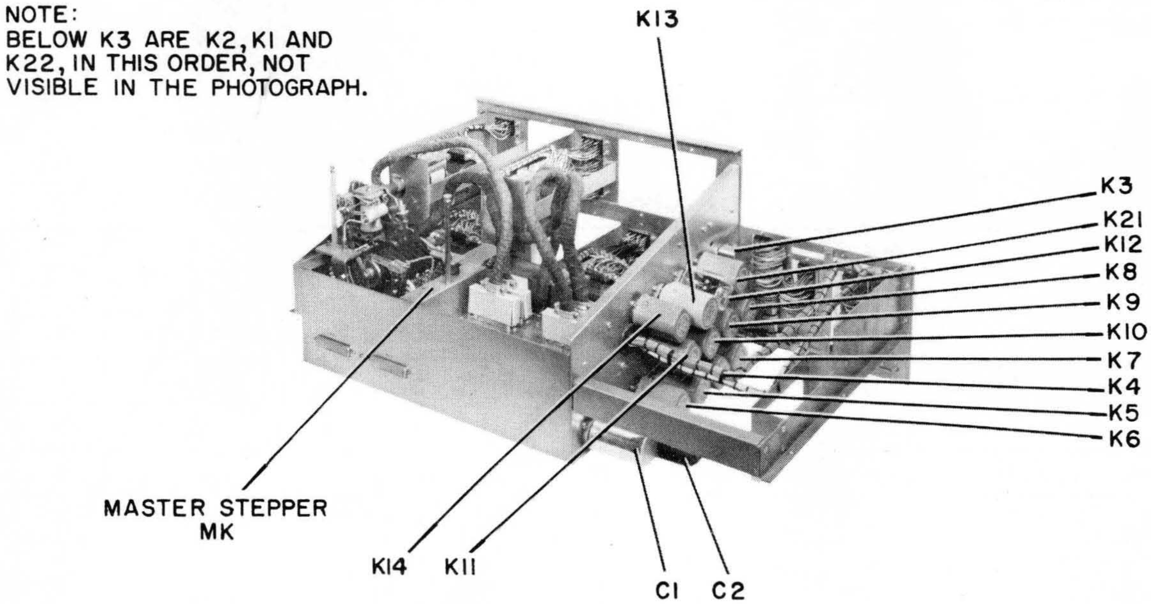


Figure 21. ERO Control Unit.

I.C., Sum Only, and P.S. Circuit operation with Local, Slaved and ADIOS control is similar to that of the Rate Test mode.

A network consisting of rectifier CR19, a 10 MFD Capacitor, and an 82K resistor operates the PS relay K6 when the plate voltage switch is turned on. When the capacitor charging current drops below the minimum required to hold in K6, the relay drops out permitting the selection of another mode. The purpose of this circuit is to switch the computer to the Pot Set mode when plate voltage is applied.

(6) I.C. The I.C. and Hold busses are energized in this mode. (See Table I); this action energizes both I.C. and Hold relays in the combination networks (fig. 20). The junction of R9 and R10 is connected to the amplifier grid and integrating capacitor. The summing junction of the network input resistors is removed from the grid and grounded by the Hold relay.

(7) Hold. In this mode only the Hold Bus is energized (by the Hold Master Relay K2). In the combination networks the I.C. relays drop out and the integrating capacitor remains charged to the I.C. voltage.

(8) Operate. As shown in figure 20, none of the buses are energized in this mode. Only the Reference Relay K11 is energized. The OP pushbutton momentarily operates the Hold Release Relay K4 which breaks the holding circuits for any other buses or relays previously operated. In the combination networks, the Hold relays drop out, connecting the input resistor summing junction to the grid of the amplifier so that integration commences.

(9) Slave. The SL pushbutton switch removes relay voltage from K1 in Reference Amplifier Network 12.001. With K1 de-energized, the reference voltage standard is obtained from a divider circuit in the network, rather than the mercury cell. The divider obtains its input from the +100 volt reference regulator of the console which has been selected as the master. In this way the reference voltage is slaved as well as the mode. The amplitude of this reference can be adjusted by manipulating R19 in network 12.098 .

b. ERO Control Unit 14.001 (fig. 21).

Applicable Schematics:

ERO Control Unit E003 025 0S, sht. 3
Unit Steppers UK4, C014 004 0S

Unit Steppers UK1, UK2, UK3, UK7, UK8, C014 003 0S
Unit Stepper UK5, UK6, C014 002 0S
PK1 Stepper C014 006 0S
PK2 Stepper C014 007 0S

(1) General Description. The ERO (extended readout) Control Unit contains the Master Stepper MK, eight Unit Steppers UK1 through UK8, and two steppers associated with attenuator selections, PK1 and PK2. In addition to these larger units are a number of relays and their associated circuits which control the operation of all the stepping switches. These circuits are controlled from the Signal Selector panel, or the ADIOS desk.

Each stepper switch has a plug at the rear and a cable with a connector on the front (fig. 22). As an example: the unit stepper to be used as UK1 is inserted into the location labelled UK1 at the rear of the ERO unit; plugs at the rear carry all the signal leads from levels of the stepper switch except the wiper lead. The cable at the front of the stepper switch assembly has a plug which mates with MJ1 on the top of the ERO unit. This cable contains all the leads to the Signal Level wiper contacts and all leads to the Position and Address levels.

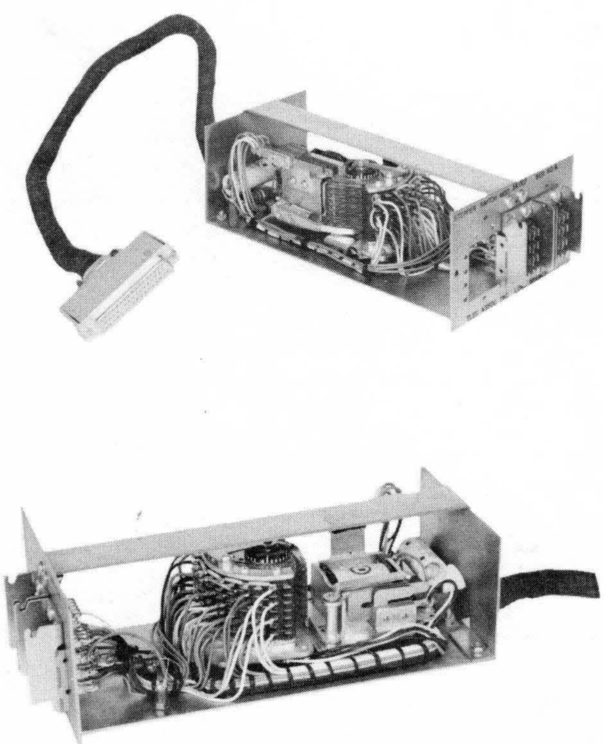


Figure 22. Typical Stepper Switch.

The Master Stepper MK has eight levels, a through h. (See drawing D003 025 0S, sht. 3). The function of each level is given in the following table.

MKa, MKb	Master Position	
MKc, MKg	Units Position	
MKd	Units Code	Address Codes to D.V.M.
MKe	Tens Code	
MKf	Hundreds Code	
MKh	Signal	

The wiper contacts of the signal levels used on each unit stepper (UK1 through UK8) are connected to contacts on MKh. The contacts on the signal levels of the unit steppers are connected to the signals to be monitored. The wiper contact on MKh is the output lead carrying the signal to be measured and goes through the VTVM and Signal Selector panels where it is switched to the vacuum tube voltmeter or the EDVM.

(2) Manual Readout. Manual operation of the ERO system is controlled by pushbutton switches on the Signal Selector Panel. These switches control the positions of both the master and units stepper switches to provide selection of any signal voltage that is connected to the steppers. The selected voltage may be monitored by the VTVM or the EDVM and associated printer if these facilities are available. The table in figure 18 lists all signal voltages available for readout.

The master stepper switch, designated MK on the ERO schematic, has 50 positions and 8 levels or banks of contacts. The 8 wipers are mechanically connected together and rotate in one direction over the banks of contacts arranged in the arc of of a circle. The switch is of the indirect drive type, in which the wipers advance during release of the armature rather than when the armature pulls in. When the coil is energized, the armature pulls in, and a pawl engages the next rachet tooth. At the same time the armature operates two sets of interrupter contacts and compresses a spring. When the coil is de-energized, the force of the compressed spring is applied through the pawl to the ratchet, thus advancing the wipers one step.

The unit stepper switches operate in the same manner as the master stepper. These switches are smaller, however, each containing eight banks of ten contacts each.

Figure 23 is a simplified schematic of the stepper switch control circuitry. The schematic shows that the relay voltage for operating the master stepper is applied through normally closed contacts on K2, the Master Stop Relay. Once the master is energized and begins to step, the operation continues until relay voltage is removed by energizing K2. Voltage for this relay is controlled

is depressed, the RSLVR section of the selector switch opens and the TRK section closes. The MK stop relay drops out as the circuit to the source of relay volts is opened. Relay voltage is now applied to the master stepper relay causing this unit to advance along the bank of contacts. The unit steppers cannot advance, however, as the circuit to relay volts for these coils is open at K2 and level c of the master stepper. When the 20 pushbutton in the Tens row is depressed, the 0 section of the selector switch opens and the 20

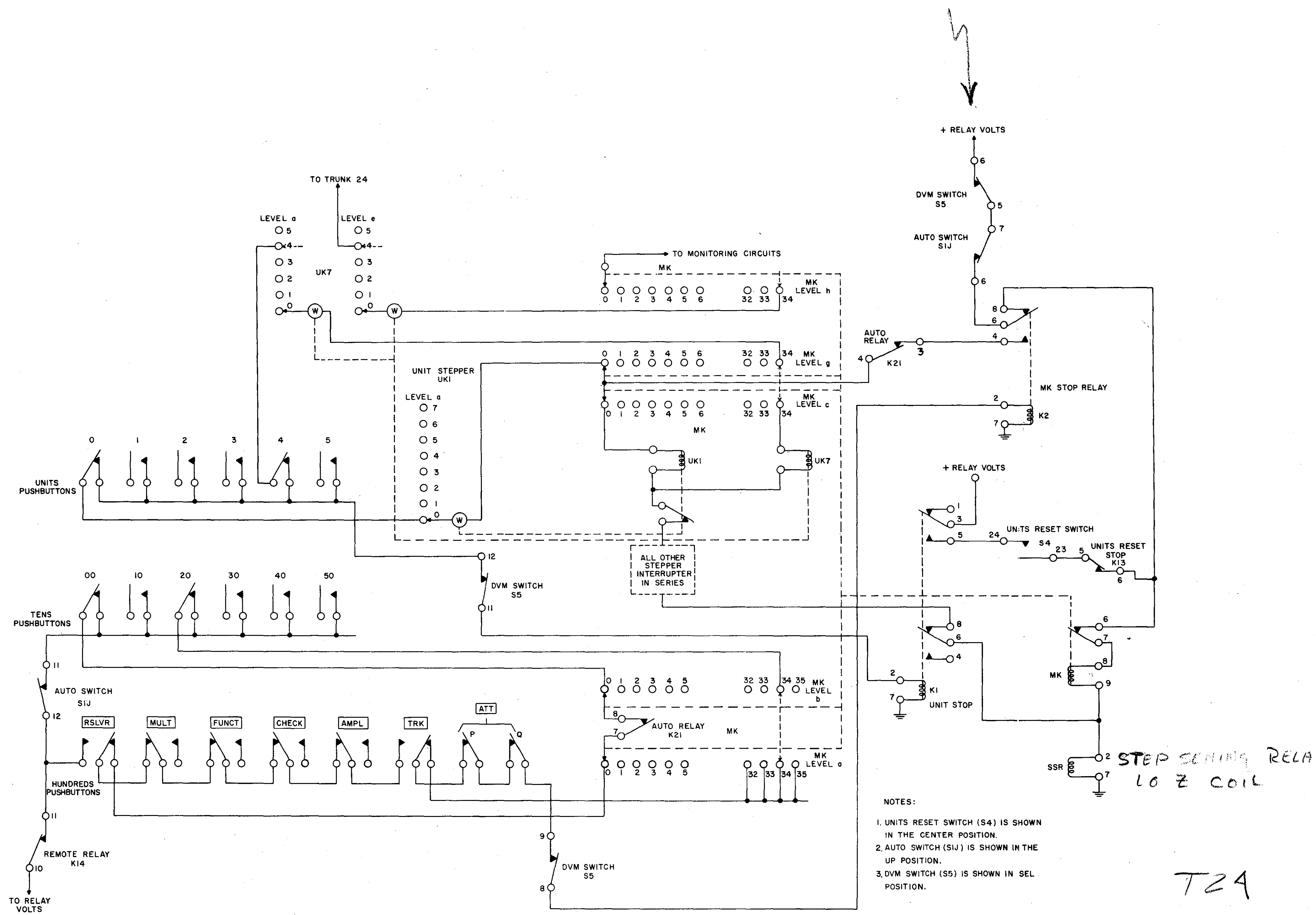


Figure 23. Manual Readout, Simplified Schematic.

In order to understand the operation of the ERO unit during the Units Reset process, assume that Trunk #24 has been selected previously and the pushbuttons are depressed for this selection. Figure 23 illustrates the circuits involved. The switch closures shown in dotted lines are those made for reading trunk #24. Master Stepper MK is in position 34 for this reading, as shown by the dotted lines. When R pushbutton is depressed in the first step of the reset procedure, the TRK switch opens the circuit for the MK Stop relay K2. As a result, the Master Stepper is energized through its interrupter contacts and moves along until a circuit is closed for K2. At position 2 of MK, K2 is energized through the R pushbutton, levels a and b of MK, and Tens pushbutton #2.

When K2 pulls in, contacts 4 and 6 transmit relay voltage to the wiper contacts of MKc and MKg which are tied together. Unit stepper UK1 is connected to MKc-2 and, therefore, it steps to posi-4 where the circuit for the Unit Stop relay K1 is completed through Units Pushbutton #4.

Depressing the 0 pushbutton in the Tens column opens the circuit through pushbutton #2 and MK steps through its cycle to the zero position. At this point K2 is energized through Tens Pushbutton 0; the Master Stepper MK is reset to its zero position. UK1 remains at position 4 until the Units Pushbutton #0 is depressed, then moves to zero. The two final steps in the Units Reset procedure are for the purpose of resetting all the other unit steppers to their zero positions.

During the reset process the master stepper moves along from position 0 to positions 5, 11, 17 etc., stopping at each one to reset the unit stepper associated with that position. (The correlation between the position of the master stepper and the units stepper associated with that position can be seen by referring to schematic drawing E014 001 0S; see MKc, and MKg, the UNITS POSITION Levels.) The same process is repeated for each step: the master stepper moves until its stop relay K2 is energized; then the unit stepper moves to its zero position at which (because the 0 pushbutton is depressed) the Units Stop Relay K1 is energized, stopping the unit stepper and sending a signal to the master stepper which bypasses the master stop relay.

Refer to figure 24. The Units Reset Stop relay K13 is energized whenever MK reaches position 44; it remains so because of its holding contacts (2 and 3) which receive relay voltage through contacts 11 and 12 of the Units Reset Switch. Now the Units Reset switch is momentarily depressed, opening the holding circuit, and K13 drops out. Contacts 5 and 6 of K13 connect the Master Stepper interrupter contact 6 to terminal 23 of the Units Reset Switch. When the Units Reset switch is moved to UP position and held there, contacts 23 and 24 close, connecting relay voltage from the Units Stop Relay (3, 5) through K13 (5, 6) to the Master Stepper Interrupter. As MK takes its first step (to position 1) K2 drops out because its energizing circuit through MKa-0 and MKb-0 is broken. The Unit Stop relay K1 also drops out because its coil is in series with contacts of MK Stop Relay K2. The master steppers moves along until K2 is energized again. At position 5 this circuit is again complete, from MKa-5 through Units Reset switch contacts 21 and 22 to the coil of K2; on the MKb level, position 5 is tied to position 0. This point is connected to the relay voltage through the Tens Pushbutton #0. When K2 pulls in, its contacts 4 and 6 connect relay voltage to the Units Position levels MKc and MKg which causes UK2 to step to position 0. At position 0 the Unit Stop relay (K1) is energized through Tens Pushbutton #0 and MKg-5. Contacts 3 and 5 of K1 connect relay voltage to the Master Stepper through 23 and 24 of the Units Reset Stop relay K13. MK steps along. After the first step, K2 (Master Stop) drops out. At position 11 the circuit for K2 is completed through MKa-11, MKb-11 and 13 and 14 of the Units Reset Switch.

The process continues until position 44 is reached, at which time contacts 2 and 3 of MK (off-normal, close at 44) close, energizing K13, the Units Reset Stop relay. Contacts 5 and 6 open the line to MK-6. MK stops at its zero position.

(4) Automatic Readout. As previously indicated, a maximum of 540 positions are available on the Signal Selector stepper switches for monitoring signal voltages. When automatic operation of the readout circuits is desired, the ERO Control Unit and the control circuits in the printer function to scan each stepper switch position sequentially and to provide a printed record of the signal voltage and address of each point. This automatic scanning cycle continues until the last position is reached, at which point the system is shut down. In general, the order in which the switch positions are scanned corresponds to the captions on the Signal Selector pushbuttons, beginning with Resolver 0 and ending with Trunk 99.

The automatic readout cycle is usually started from the zero position of the steppers by depress-

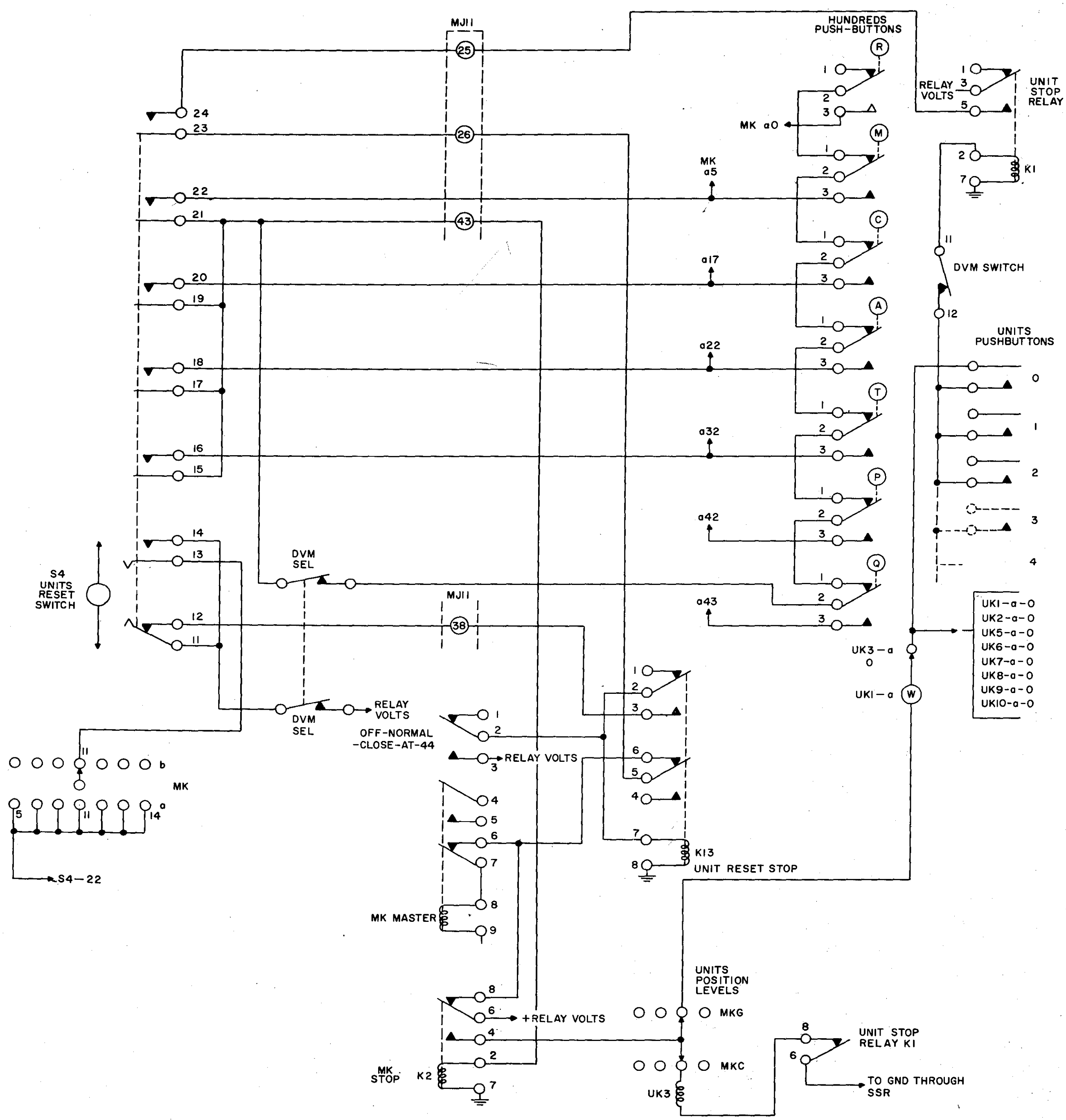


Figure 24. Units Reset Circuits, Simplified Schematic.

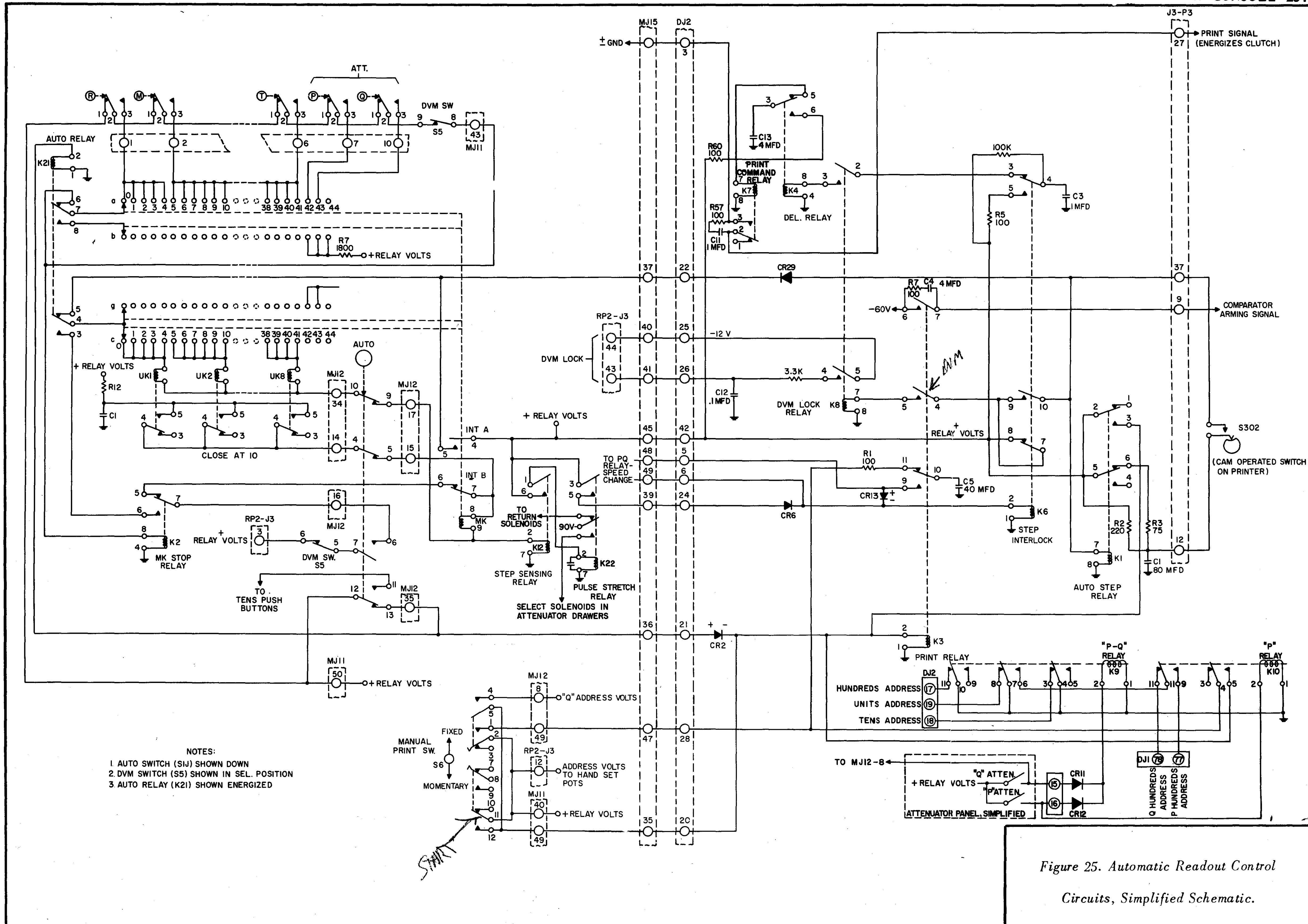


Figure 25. Automatic Readout Control Circuits, Simplified Schematic.

ing the AUTO pushbutton on the Signal Selector after all steppers have been set to their zero positions by operating the UNITS RESET switch. If desired, the cycle may be initiated at any other point on the steppers by depressing the appropriate pushbuttons after the units reset operation has been accomplished.

The control circuits for automatic readout are located on the printer chassis and in the ERO unit. The printer circuits are designed to control the timing of the readout and printing operation. A simplified schematic of these circuits is shown in figure 25. This drawing should be referred to for the following explanation of the control circuits.

When the AUTO pushbutton is depressed to initiate the automatic readout cycle, relay voltage is applied through contacts 12 and 13 of the AUTO switch, to the Print Relay, K3 (Printer). When K3 energizes contacts 4 and 5 energize the DVM Lock Relay K8 (Printer) through contacts 7 and 8 of the STEP INT. LOCK relay K6 (Printer). Contacts 2 and 3 of K8 connect the coil of relay K4 to capacitor C3. K4 is momentarily energized by the discharge current of the capacitor. C13 changes through contacts 3 and 6 of K4. When the charge across C3 drops below the level required to keep K4 energized it de-energizes. K7 is energized by the discharge current of C13 through contacts 3 and 5 of K4. Contacts 2 and 3 of K7 provide the ground return path for the electric clutch on the printer motor and the printer operates to record the voltage and address of the DVM.

During the print cycle, a cam-operated switch (S302) on the printer provides a circuit closure to connect relay voltage to the coil of UK1 through contacts 4 and 5 of the Auto Relay, and level c of the master stepper. This relay voltage cocks stepper UK1* and also energizes K12, the Step Sensing Relay, through contacts 9 and 10 of the Auto switch. K12 energizes K22, the Pulse Stretch Relay, and this unit pulls in K6. K22 is held in 50 milliseconds after the voltage to the stepper is removed, because of the time constant of c and the relay coil. When the print cycle is complete, the printer switch (S302) opens, the UK stepper advances one position, K6 drops out and the switching cycle begins again.

The control circuits continue to advance the UK1 stepper wiper along level c until each of the ten positions have been scanned, and the signal voltages recorded. At position 10, the OFF-NORMAL contacts of UK1 close and apply 90 volts (from C1 in the ERO unit) through contacts 4 and 5 of the AUTO switch to the MK coil.

This energizes the master stepper and closes the Int. A contacts to cock the UK1 stepper. As soon as the charge on C1 drops below the level required to keep the master stepper cocked the MK coil is de-energized, the master steps to Position 2, the interrupter A contacts open, and UK1 steps to position zero. With the Master Stepper on position 2, the wiper of UK2-d is advanced sequentially along level d, and the printer records the voltage at each of the 10 positions as previously explained. When position 10 on this level is reached, the OFF-NORMAL contacts close and advance the Master Stepper to position 3.

The scanning process continues until the master stepper advances to a point beyond the last unit stepper (position 44 on a fully expanded computer console). At this time the step sensing relay is no longer energized due to the absence of a unit stepper; therefore, the pulse stretcher relay is not energized. The pulse stretcher normally energizes K6 which permits C3 to charge, in turn permitting the cycle to repeat. The automatic scanning cycle is stopped due to the lack of a charge on C3.

c. VTVM 20.002.

Applicable Schematics:

C020 002 0S (VTVM Assembly)
B16S26B-3 (Vacuum Tube Voltmeter)
A26S12A (Rectifier Network)
C26S6B (D.C. Amplifier)

(1) General. The VTVM 20.002 is a panel assembly which is part of the main control panel of the computer. Its component parts are:

a– VTVM pushbutton switch for voltage selection.

b– CHECK Amplifier Function switch.

c– D.C. Amplifier 26-6B.

d– Vacuum Tube Voltmeter 16-26B-3.

e– Rectifier Network 26-12A.

* The stepper coil is energized by the 90 volts across the charged capacitor C1 (in the printer). It is held in at a voltage reduced by the drop across R2 (220 ohms).

The unit provides a means of monitoring all supply and reference voltages, and all values selected on the SIGNAL SELECTOR. In addition, the d-c amplifier is used for the CHECK measurements, as an amplifier for the VTVM on the lower ranges, and for repetitive operation. The d-c amplifier in this unit is referred to as the CHECK amplifier.

(a) VTVM Switch S1 (C020 002 0S). This is a ten-pushbutton switch mounted vertically at the right side of the panel. The switch sections are of the latching type so that when one button is depressed, it stays down until another is pushed. With the CHECK AMP FUNCTION switch in OUT position, voltages selected by the VTVM switch are connected to the + grid of the VTVM 16-26B-3. When the REF BAL button is depress- the junction of resistors R15 and R16 in network 12.098 (in the oven) is connected to the + grid. When the VIB DRIVE pushbutton is depressed, input voltage for the VTVM is obtained from RECTIFIER NETWORK 26-12A. When the PATCH PANEL pushbutton is depressed, the VTVM input is connected to a terminal at the top of the patch panel. The SIG SEL button connects the VTVM input to the Signal Selector 20.001 so that any voltage selected by the pushbuttons on that panel can be read on the meter.

(b) Check Amplifier Function Switch. This is a 4-section, 5 position rotary switch which performs several functions. The first three sections (see fig. 26) establish the gain of the amplifier and determine in which circuit it is connected. In position 1 marked REP on the panel, the input and output of the amplifier are connected to terminals 49 and 6, respectively, of RP2-J4 by section 2 of the switch. This allows the amplifier to be used in the Repetitive Operation control circuits as a sweep amplifier. The CHECK position connects a 100K resistor across the amplifier as a feedback resistor. The input is connected to the wiper of the stepper switch MKh by relay contacts 2 and 7 of K1. This relay is energized when the CHECK pushbutton on the SIGNAL SELECTOR panel is depressed. Contacts 3 and 6 connect the amplifier output to the DVM.

In the OUT (output) position of the rotary switch the circuit remains unchanged except that the VTVM input is connected to the VTVM pushbutton switch instead of to the amplifier output. This is accomplished by section 2b. The last two positions of the switch are labelled X10, X100. Section 2a (upper) of the switch connects the 100K resistor R2 to the amplifier as its input resistor. Section 2a (lower) connects the proper feedback resistor across the amplifier; 1 megohm for the gain of 10, and 10 megohm for the gain of 100 position of the switch. Section 2b connects the amplifier output to the VTVM.

Sections 2b and 2c (fig. 27) of the CHECK AMP FUNCTION switch are used as a polarity switch for the VTVM. The arm of section 2b is connected to the + grid and that of section 2c to the – grid. The polarity switch is required when the test amplifiers used in the CHECK, and PRE-AMP positions, because the signal input to the VTVM. is inverted. The polarity switch applies the signal to the – grid and grounds the positive grid.

Section 2c (lower) of the CHECK AMP FUNCTION switches +90 to REP control in the Repetitive Operation Control Unit in the REP position.

Section 2d (upper) changes check code from "C" to 3 indicating a change of scale factor in the ADIOS console.

Section 2d (lower) is used to disable the stabilizer in the Check Amplifier during Repetitive Operation.

(c) Test Amplifier 26-6B (See schematic C26S6B). This unit is a chopper-stabilized d-c amplifier. The circuit may be considered as three parts: (1) Voltage amplifier consisting of V1a and V2. (2) Cathode follower output stage, V3. (3) Stabilizer, D1, V4, V1a.

1– The voltage amplifier consists of V1a, V2a, V2b. The input signal is directly coupled to the grid of V1a. Cathode bias is used in this stage. The plate is coupled to the grid of V2a by the 1 megohm resistor R5, and the plate of V2a is coupled to the grid of V2b by the 2.2 megohm resistor R10. Thus V1a, V2a, and V2b comprise a three stage direct-coupled voltage amplifier. The voltage level at the grid of V2a is held down by the use of the voltage divider R5, R7, and the 1 megohm balance potentiometer. The bottom of this divider is returned to –300V so that the d-c reference level at grid V2a is lower than that at the plate of V1a. The grid of V2b is connected to the junction of R10 and R11 for the same reason. The lower end of R11 is returned to –500 volts. The gain of the voltage amplifier is about 30,000.

2– The plate of V2b is directly coupled to the control grid of V3, the cathode follower output stage. The 100,000-ohm, 2-watt cathode resistor for the test amplifier is located on the external side of the amplifier connector. The lower end of this resistor is connected to the –300 volt supply. Output from the amplifier is

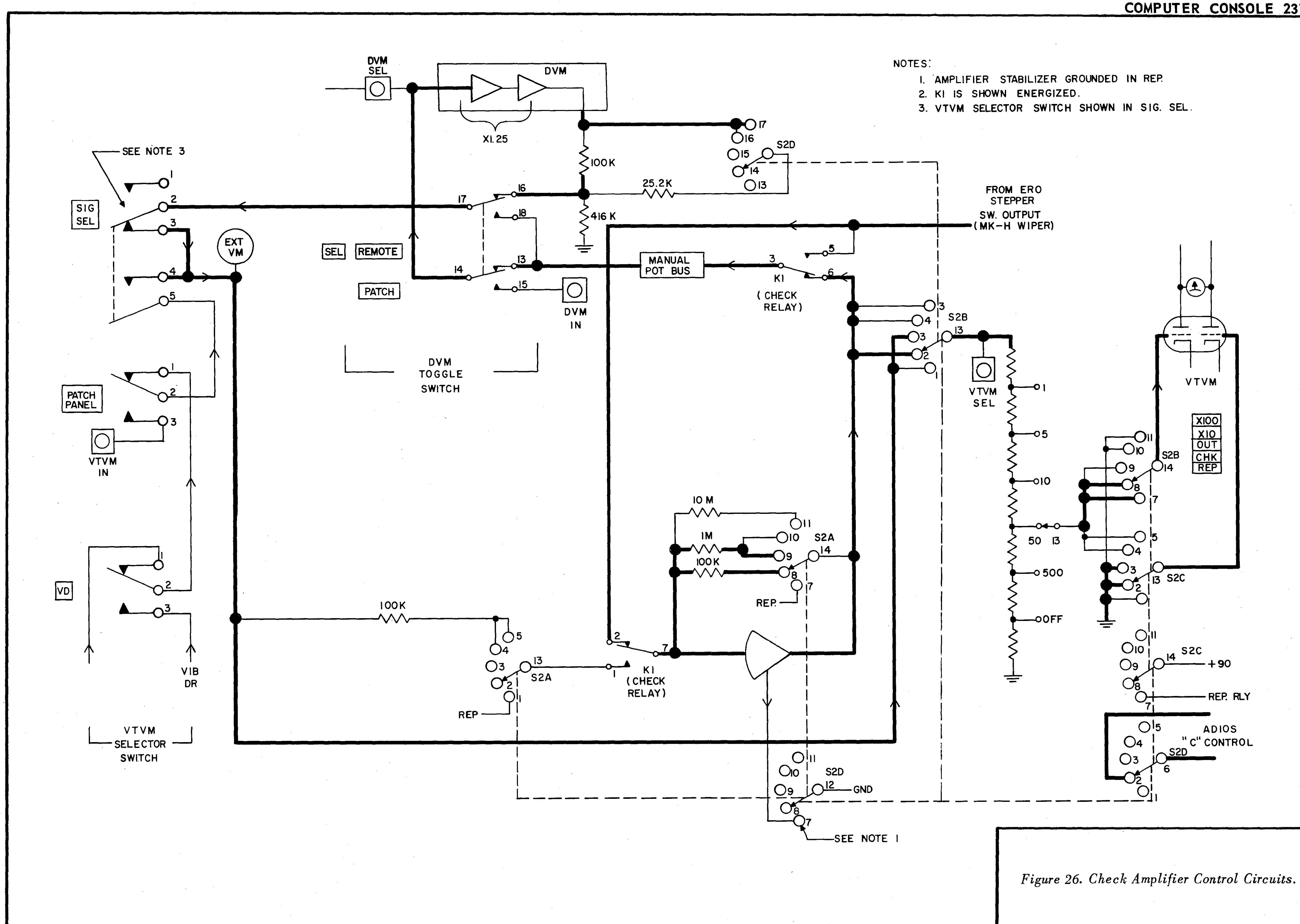


Figure 26. Check Amplifier Control Circuits.

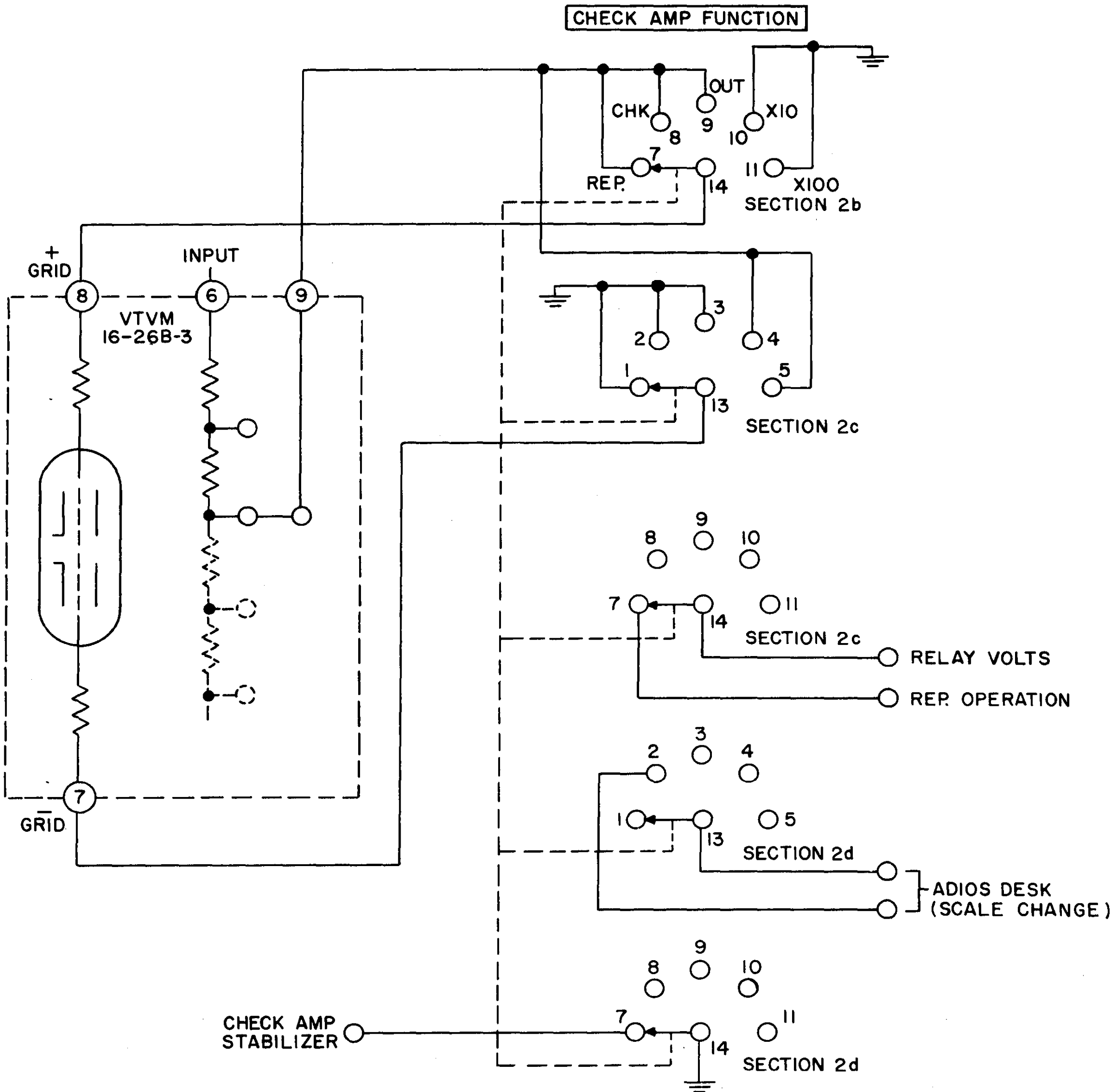


Figure 27. Check Amplifier Function Switch.

taken from the cathode, terminal A on the schematic diagram. R6 and C1 form a high-frequency cut-off network.

3— The stabilizer portion consists of the chopper D1, the two-stage amplifier V4, a low-pass filter, and V1b. In order to understand the operation of the stabilizer, assume that a positive drift voltage appears at the grid of V1a. This voltage is coupled to terminal 1 of chopper D1 through resistor R14. The vibrating reed is grounded so that during a portion of each cycle it connects terminal 1 to ground. As a result, a 60-cycle square wave appears at C2 and is impressed upon the grid of V4a. R23 is a grid limiting resistor. The square wave is amplified by V4a and V4b and appears at the junction of C5 and R21. Junction of R21 and R22 is connected to terminal 6 of the chopper. The operation of D1 is such that when the input (pin 1) is grounded, the output (pin 6) is ungrounded, and vice versa. The purpose of the second chopper connection is to establish the zero reference level—and therefore the polarity—of the output voltage. Instead of the square wave at the plate of V4, a pulsating negative d-c voltage appears at the junction of R21 and R22. This voltage is filtered by R22 and C6 and the d-c component applied to the grid of V1b.

Thus far it has been shown that a positive drift voltage at the amplifier input produces a negative correction voltage at the stabilizer output. When this negative voltage is applied to the grid of V1b, the triode draws less current through its cathode resistor, R2. Since the two sections of the tube have this cathode resistor in common, the cathode bias on the first section (V1a) decreases. This causes a negative voltage at the output of the amplifier which, when fed back through the external feedback-resistor, cancels the positive drift voltage.

A neon bulb overload indicator is connected in series with R20 (56K) between the junction of C5 and R21 and ground. An input to the stabilizer of more than four millivolts causes the lamp to light. The overload indicator is useful in balancing the amplifier. On the left side of the panel (VTVM 20.002) are two controls: the balancing potentiometer labelled BAL, and the pushbutton switch above it. Above the controls is the neon indicator marked OVLD. The pushbutton switch grounds the output of the stabilizer and the grid of V1b, when depressed.

The procedure for balancing the amplifier is as follows. Depress the CHECK button under the indicator and rotate the AMP BAL control until the neon bulb is extinguished. Rotating the control varies the fixed bias on the grid of V2a. When this bias is adjusted until the indicator is extinguished, the grid of V1a is set at zero and there is no input to the stabilizer. Releasing the pushbutton allows the stabilizer to control the grid of V1b once again.

R15 and C3 is a high-frequency cutoff network to prevent any high frequency transients, which might be present due to the chopper operation, from being amplified by the stabilizer and adding to the correction voltage at its output.

(d) Vacuum Tube Voltmeter 16-26B-3 (See schematic B16S26B-3). This unit employs a straightforward circuit with two triodes. The grids are connected to an external polarity switch which applies the input to one, and grounds the other. With the normal connection the grid of V1a receives the input signal and that of V1b is grounded. Both sections of the tubes have identical plate and cathode resistors. Before an input voltage is applied, the BAL control is adjusted until the meter reads zero, which balances the current in the two triodes. In this condition the voltages at the plates are equal.

When a positive voltage is applied to grid V1a, this tube draws more current; the cathode potential becomes more positive and the plate voltage becomes less positive. The rise in cathode voltage causes V1b to draw somewhat less current and its plate voltage rises. With the two plate voltages changing in opposite directions, current flows through the micro-ammeter circuit.

The high resistance (R16, 270K) in the cathode circuit makes the cathode current insensitive to small differences in tube characteristics or supply voltages. The 3300 mmf capacitors between the grids and ground, in conjunction with the 10-megohm series grid resistors filter out any noise or ripple on the input to the VTVM.

The BAL control is located on the front panel. The 50,000-ohm potentiometer R12 is a calibration adjustment behind the panel which is set at the time of manufacture and should not require readjustment unless tubes are changed. It is set using a known d-c input voltage.

(e) Rectifier Network 26-12A. This network is a plug-in unit located on the VTVM 20.002 chassis. Its only function is to rectify the Vibrator Drive voltage so that it can be measured by the Vacuum Tube Voltmeter 16-26B-3. Since the capacitor in the filter increases the output voltage of the rectifier by about 5 volts, the rectifier diode is connected to the tap on the voltage divider composed of R1 and R2. The potentiometer R1 is set at the time of manufacture so that 19 volts d-c appears at terminals 2 and 3 when 19 volts a-c is applied across terminals 1 and 2. R1 is a screwdriver adjustment.

d. Attenuators. Figure 28 illustrates the circuits of the hand-set attenuators P00-P09, and Q00-Q09. The three-position switch below each attenuator is used for readout. The switch can be moved up or down, and is momentary in each direction with a spring return to center. The up position is marked COEF; in this position, the top of the potentiometer is connected to +100 volts and the arm to the monitoring circuits (DVM) for reading the coefficient by which any voltage applied to the top will be multiplied. (The attenuator multiplies by a fixed factor of less than one.) In the center position the top of the potentiometer is connected to the patch panel. The down position, designated OUT, is used to measure the output voltage at the arm of the attenuator after a problem has been patched in. The top of the potentiometer remains connected to the patch panel termination and the arm is connected to the metering circuits.

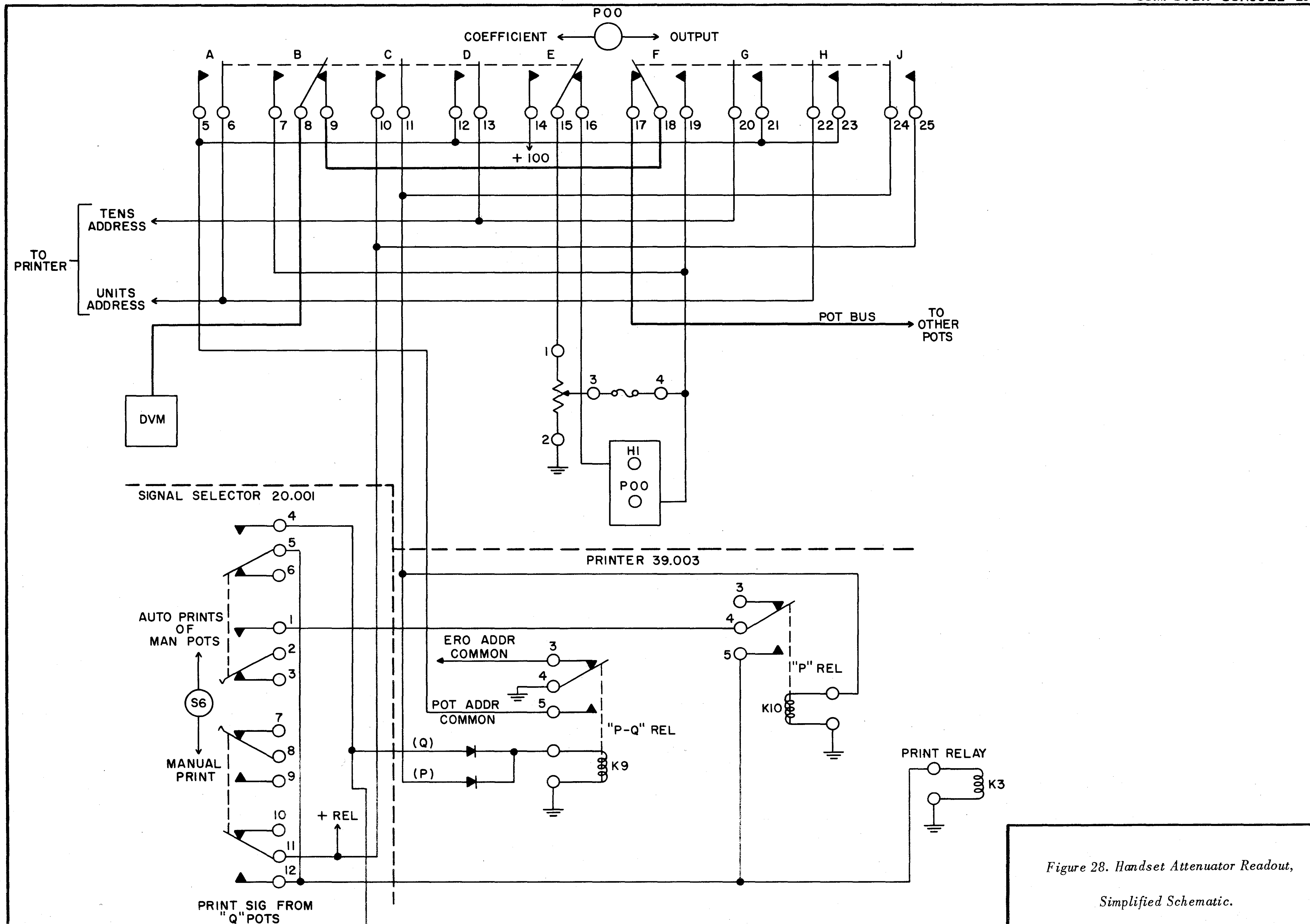


Figure 28. Handset Attenuator Readout, Simplified Schematic.

In figure 28 the "pot bus" is shown in heavy lines. Moving the switch to either COEF or OUT positions opens the pot bus and connects the arm of the potentiometer to the monitoring circuit. Switch sections B, E, and F accomplish this action.

The switch also transmits address information to the printer so that a permanent record can be made of the readings. Switch sections A and H send a signal to the Units Address circuits of the printer; sections D and G actuate the Tens address printer circuits. Sections C and J operate the "P" and "P-Q" relays in the printer.

e. Computation Circuits. The basic 231R Console contains twenty operational amplifiers packaged as five each Quadruple D.C. Amplifier, Model 6.002. This basic complement of amplifiers is arranged as follows:

Quantity	Type	Channel Number
8	Combination	00, 01, 05, 06 10, 11, 15, 16
12	Summer	02, 03, 04, 07, 08, 09 12, 13, 14, 17, 18, 19

(1) Combination Amplifiers. Dual purpose operation of the eight combination amplifiers is made possible through the use of Combination Network 12.002 (fig. 29), and Integrating Capacitor Assembly 12.031. The combination networks contain input and feedback resistors for three gain-of-10 inputs, and three gain-of-1 inputs. The network also contains two resistors to establish the initial condition of the integrator, and two relays to control operation of the network and amplifier.

Figure 30 is a simplified schematic of a combination network connected to its amplifier. The dotted lines on this drawing indicate connections made by the bottle plugs inserted into the prepatch panel holes. The position of the bottle plugs determines whether the amplifier is connected as a summer or an integrator.

Inserting bottle plugs to connect the amplifier as a summer completes the following circuits:

a– Connects the feedback resistor across the amplifier.

b– Connects the coil of the Pot Set-Hold relay to the Pot Set bus.

When the Computer is switched to the Pot Set mode, the Pot Set-Hold relay is energized, grounding the summing junction (through the Check Relay). This permits the setting of any attenuator, patched to the network input, under normal load conditions.

To patch the amplifier as an integrator, the six-prong bottle plug is moved down one row. The bottle plug in this position completes the following circuits:

a– Connects an integrating capacitor across the amplifier.

b– Connects the IC relay to the IC bus.

c– Connects the Hold relay to the Hold bus.

The Hold bus and, consequently, the Pot Set-Hold relays are energized in all computer modes except Operates. The IC bus is energized in the IC, Static Test and Pot Set Modes. In the IC mode, the IC relay is energized and connects the junction of the IC resistors to the amplifier grid. The Hold relay is also energized in this mode, removing the summing junction from the grid.

In the Static Test mode, both relays are again energized. This mode supplies a reference voltage to the Test Ref. busses of the patch panel which

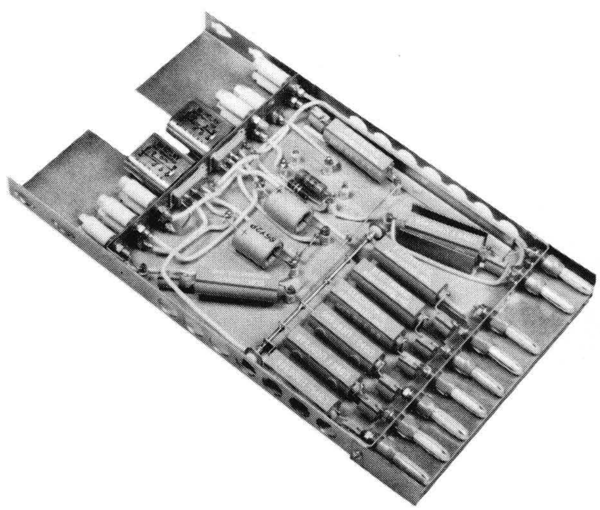


Figure 29. Combination Network 12.002.

may be applied to the IC input of an integrator which has zero IC input in the patched problem. When the computer is switched to the Rate Test mode, the IC relay drops out and the Hold relay remains energized. Contacts on this relay apply the rate test signal (from the Rate Test potentiom-

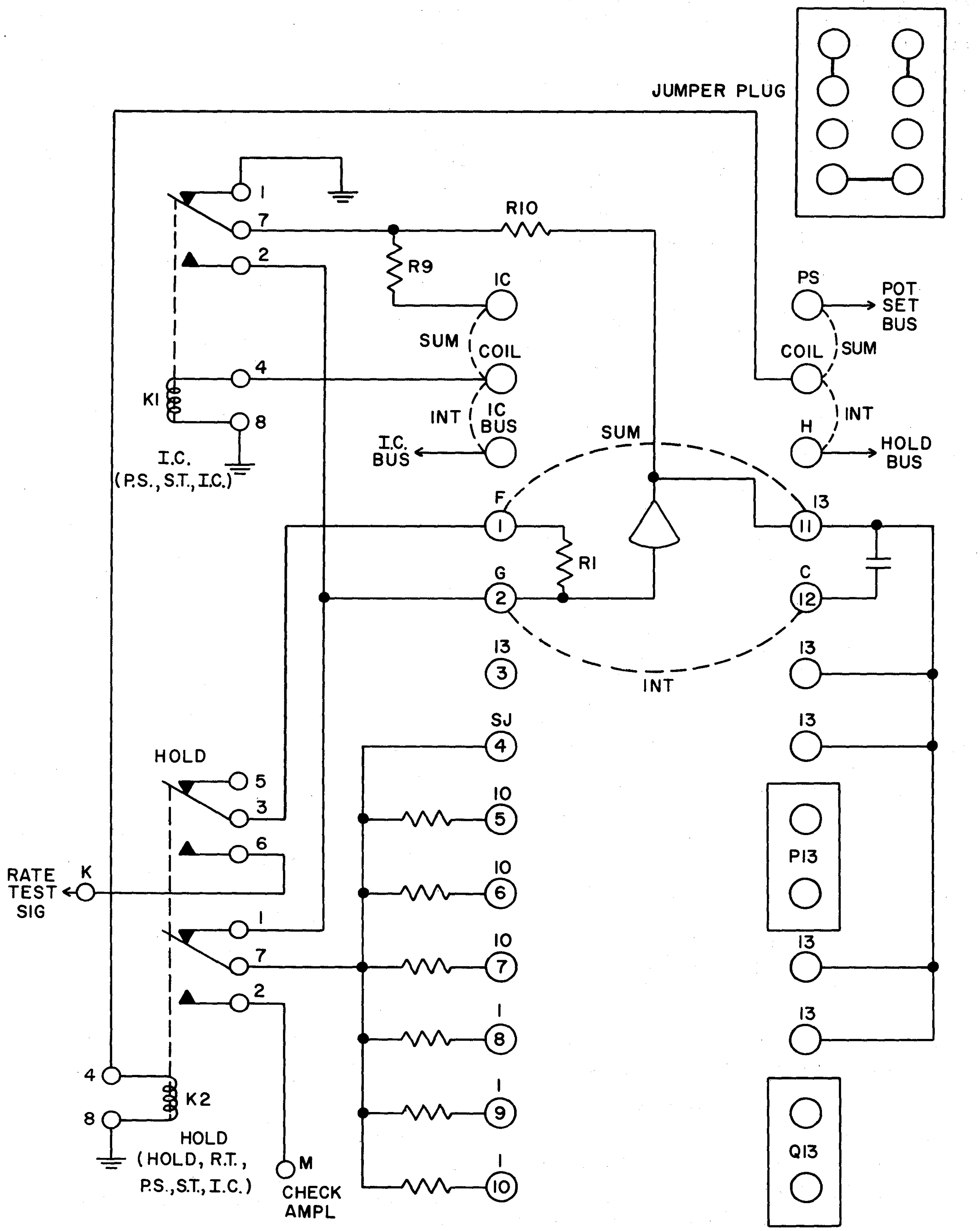


Figure 30. Combination Network 12.002, Simplified Schematic.

eter) through the feedback resistor to the amplifier grid. (Feedback resistor R1 is used as an input resistor in this mode.) All other inputs are removed from the amplifier during this mode to permit an accuracy test on the integrating capacitors.

(2) Summing Amplifiers. A Summing Network 12.003 (fig. 31) is provided for use with each of the twelve summing amplifiers in the console. This network contains input and feedback resistors for three gain-of-10 and three gain-of-1 inputs. The network also contains a relay that is used during the Pot Set mode (see fig. 32).

Inserting a four-prong bottle plug into the amplifier patch panel terminations connects the feedback resistor across the amplifier, and the summing junction to the amplifier grid. The amplifier and network function as a summer in all computer modes except Pot Set and Rate Test. In these modes the network relay is energized by the Summer Only bus and the relay contacts connect the summing junction to signal ground. In Pot Set, this permits attenuators patched to the network inputs to be set with a normal load. The purpose of grounding the summing junction in the Rate Test mode is to prevent the summing amplifier from driving an integrator to which it may be patched.

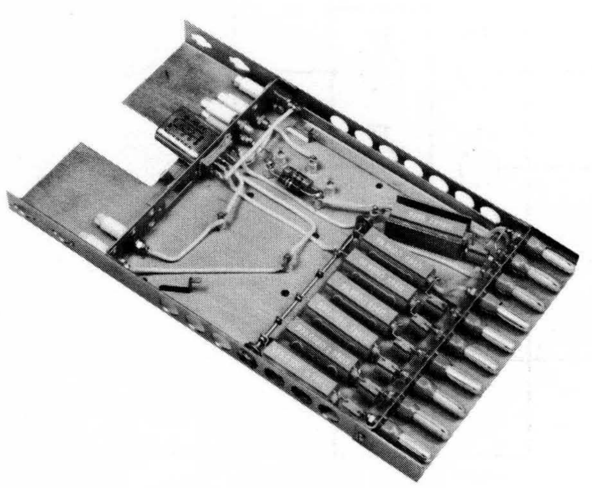


Figure 31. Summing Network 12.003.

f. Problem Test. Three methods of problem testing are available in the computer. The circuits are actuated by two pushbuttons on the Mode Control Panel and one on the Signal Selector:

Type of Test	Pushbutton	Location
Rate Test	RT	Mode Control
Static Test	ST	Mode Control
Check	CHECK	Signal Selector

In Rate Test (see fig. 33) a voltage is taken from the arm of the Rate Test Potentiometer, R1, and applied to terminal K of all combination networks through the Slave switch, and contacts of the Rate Test Signal Relays (K15, K16, K17). When the computer is in the Slave Mode, the rate test signal originates in the remote master console and is connected to the networks via the Remote Master switch and contacts 15 and 16 of the Slave switch. When the console shown is used as the master, the rate test signal is sent to other slaved consoles through terminal 49 on MC-J1.

The Rate Test potentiometer (terminal 1) is connected to +100 volts reference with S3 in the right position, and to −100 volt reference with S3 in the left position. In the center (OFF) position, terminal 1 is grounded.

In the Rate Test Mode the IC bus is not energized. In combination network (fig. 30) the junction of R9 and R10 is grounded, and the integrating capacitor is uncharged. The Summer Only bus is energized so that no voltage will be present at the output of any summing amplifier. Thus it is not necessary to remove patch connections between any summers and integrator inputs. The test is started and stopped by the Rate Test switch.

The Static Test mode is used to test integrators which normally have zero initial condition voltage in the patched problem. A patch cord is connected from the Test Reference section of the pre-patch panel (usually through an attenuator) to the IC input of the integrators in this category. When the ST pushbutton of the Mode Control is depressed, the IC and Pot Set-Hold relays in the combination networks are both energized. The Pot Set-Hold relay removes the input resistor summing junction from the grid so that no signal is received from this source. The IC relay connects the patched IC voltage through resistor R9 to the grid. The output of the amplifier should be equal to that voltage but opposite in polarity.

The CHECK pushbutton of the Signal Selector is used to determine the instantaneous derivative of an integrator resulting from the application of several inputs to the network. This is accomplished by placing the computer in the IC or Hold mode and depressing the CHECK pushbutton.

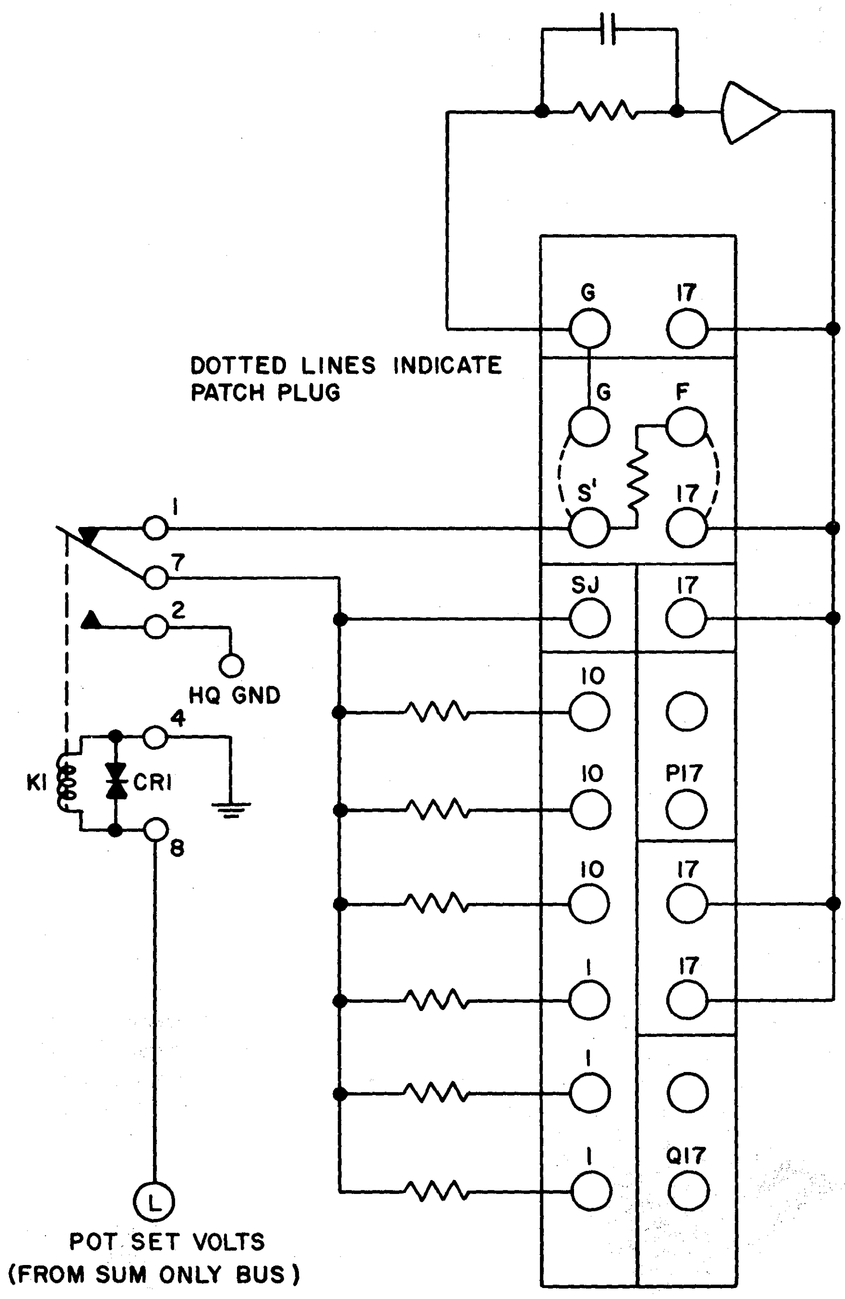


Figure 32. Summing Network 12.003, Simplified Schematic.

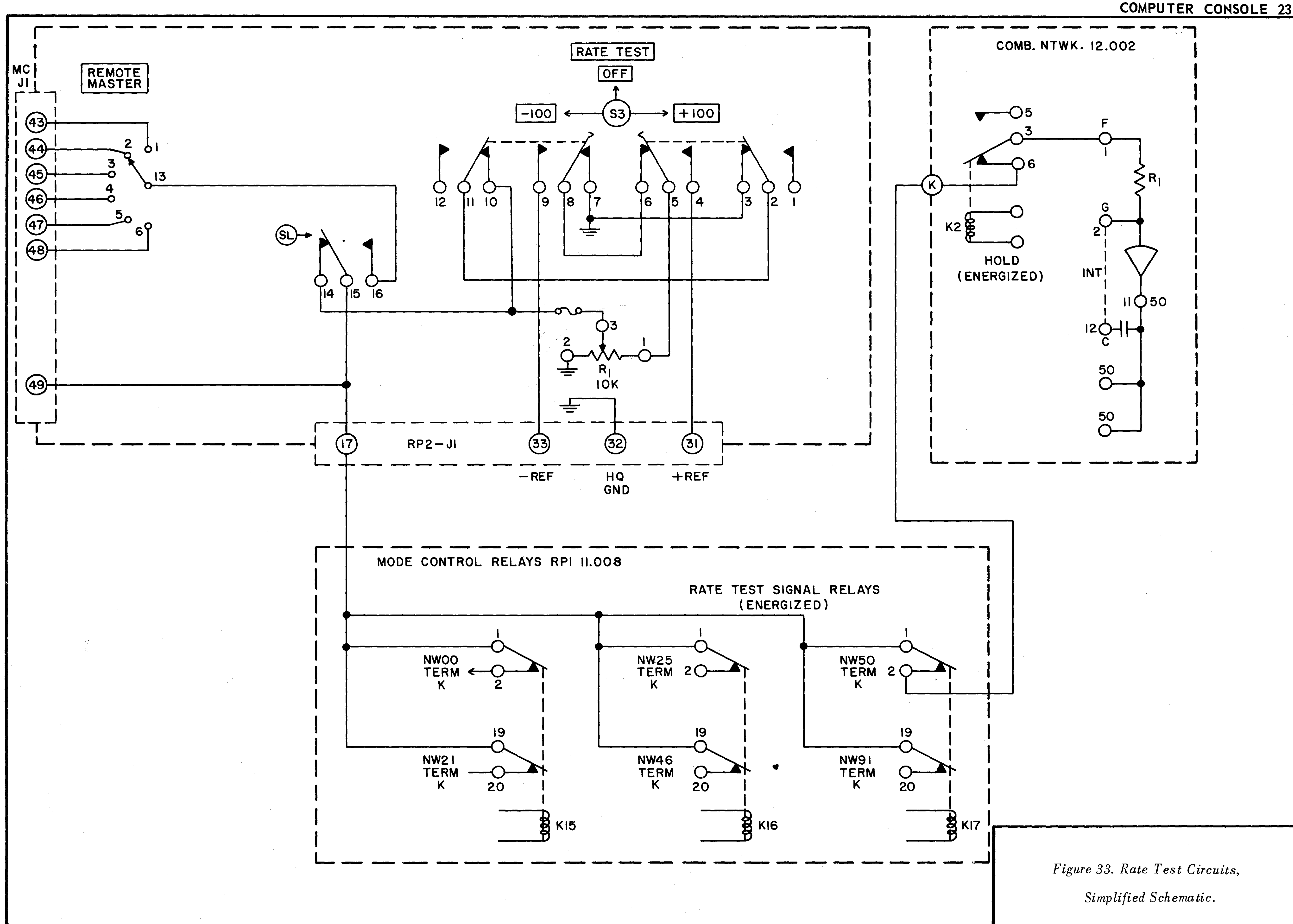


Figure 33. Rate Test Circuits, Simplified Schematic.

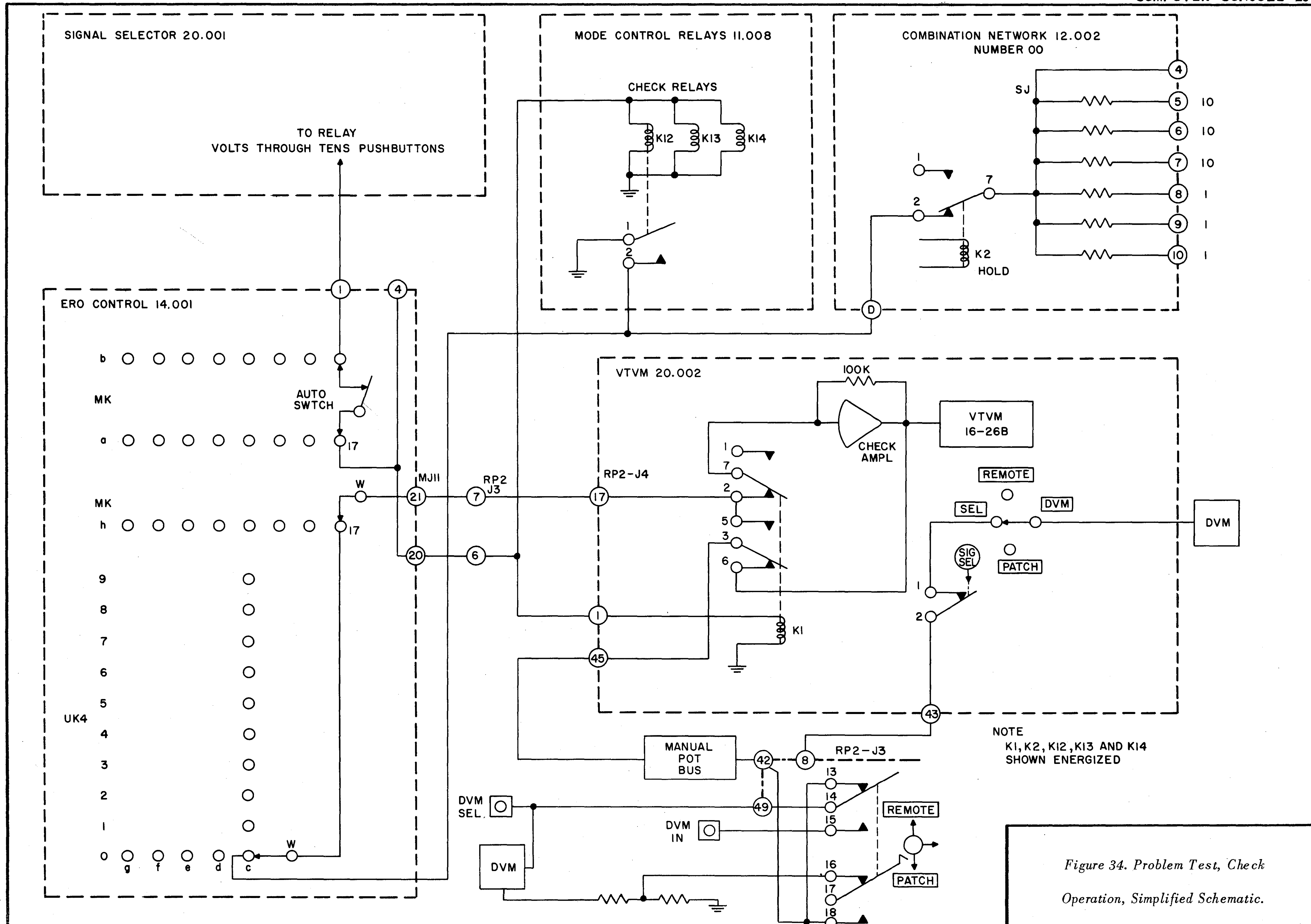


Figure 34. Problem Test, Check Operation, Simplified Schematic.

Refer to figure 34. The summing junction SJ is connected to terminal N of the combination network by the Hold relay. Check relays K12, K13, K14 are energized by the CHECK pushbutton removing all M terminals from ground. Terminal M of network 00 is directly connected to UK4C-0. The master stepper and MK4 are positioned to read out the voltage on this contact by depressing pushbuttons CHECK, 0, 0. The master stepper wiper is connected to the input of the Check amplifier by relay K1 in VTVM 20.002. Relay K1 is also energized when the CHECK pushbutton is depressed. The VTVM is connected to the output of the amplifier by the CHECK AMP FUNCTION switch, and the DVM may be connected simultaneously if the DVM switch is in the SEL position and the SIG SEL pushbutton of the VTVM switch is up. In this way the voltage at the summing junction of Network 00 is indicated.

g. Slaving Circuits. In a system containing more than one computer, the operational steps involved in computation may be coordinated at any one of the consoles through use of the slaving circuits wired into each rack. This feature permits control of up to five computers from a sixth, designated as master. The slaving circuits are arranged such that any desired console in the group may be designated as the master. Slaving of all computer modes of operation is provided, as well as reference slaving.

Each computer contains two slaving controls on the Mode Control Panel. The SL pushbutton on the Mode Control selector switch prepares the Mode Control circuits for slaved operation, and the REMOTE MASTER switch determines which unit in the system is the master or controlling console.

A number of different slaving arrangements is possible with these circuits, depending on the manner in which the slave cable, used to connect all consoles together, is arranged. Figure 35 is a simplified schematic of a system in which four computers are slaved together, with console 3 controlling consoles 1, 2, and 4. (Only the Pot Set control circuits are shown to avoid needless complication of the diagram. Slaving of all other modes is accomplished in the same manner.) To arrange the system slaving as described above, the SL pushbutton on the Mode Control panel of each console except the master, is depressed. The REMOTE SELECTOR on each Mode Control panel is set to the position represented by the master in the system. In this case, console 3 is to be the master, and all REMOTE SELECTOR switches are set to position 3. The slaving cables can be arranged cyclically also in such a manner that the REMOTE SELECTOR setting for each console depends on its relative position to the master.

When the PS pushbutton on the Mode Control panel of console 3 is depressed, relay voltage is applied to the Pot Set Master relay in the mode control circuits and the computer goes into the Pot Set mode. At the same time relay voltage is also applied through pin 21 of the slave cable connector, through the slave cable to pin 17 of the slave cable connectors of all controlled consoles. From this point the relay voltage is routed through the REMOTE MASTER switch (position 3) and the SL section of the Mode Control selector switch, to the Pot Set Master Relay in each console. Note that relay control voltage is only applied momentarily to the slaving circuits. After the initial voltage pulse is applied by operating and releasing the Mode Selector pushbutton, the normal holding circuits in the mode control circuits of each console maintain the consoles in that mode until another pushbutton is operated to switch to a new mode.

12. MAINTENANCE

a. General. The computer is designed to be as trouble-free as possible and should require very little maintenance. General trouble-shooting and repair techniques used on electronic equipment are applicable to maintenance of the individual component chassis in the computer. As an aid to maintenance personnel, schematic diagrams, wiring diagrams, and complete parts lists for all components are included in the manual.

b. Maintenance Accessories and Equipment. To facilitate maintenance and adjustment of the components in the computer, service shelves and test cables are provided with the equipment (see para. 6). Any plug-in component, with the exception of the 10.001 Power Supply can be placed on the service shelf. Because of its weight, the 10.001 Power Supply should be placed on the floor or a sturdy table if this unit must be removed from the rack.

The service shelf is prepared for use by fastening the proper cable to the mounting plate at the rear of the shelf. The shelf is then inserted into the bay, the chassis to be checked placed on the shelf, and the service cable plugged into the chassis connector.

c. Maintenance and Adjustments of Components.

(1) General Maintenance Considerations. The purpose of maintenance is to keep the equipment

in working order and enable it to be used properly. This section describes the various tests which can be carried out on the equipment and suggests, roughly, at what intervals they should be made.

Maintenance procedures are often divided into two broad and frequently overlapping sections—routine maintenance, and preventive maintenance. In the first category are found such simple tests as daily balancing of d-c amplifiers, adjustment of power supplies, etc. In the second are more searching tests designed to indicate any deterioration in the performance of the units when such deterioration is not sufficiently obvious to be detected by routine tests. These tests might indicate that the equipment is satisfactory in operation, but will in a short time require readjustment or repair.

(2) Routine Maintenance.

a— D.C. Amplifiers. One of the basic units of the computer is the d-c amplifier. This unit is highly developed, rugged and reliable. However, it is one of the units which requires relatively frequent checking. For this reason, balance controls are mounted on the front panel of each d-c amplifier to allow any offset to be cancelled before the computer is placed in service at the beginning of a day's operation. The balance pushbutton should be depressed on each d-c amplifier after suitable warm-up time, and correction made with the BALANCE control if necessary. If an amplifier will not balance, some malfunction is indicated in either the amplifier or the balancing circuit. Corrective procedure can vary widely. Ideally, enough spares should be available so that a faulty unit can be replaced by a good one and the operation of the computer will not be interrupted; the faulty unit may be repaired later.

Amplifier troubles are rare; however, when they do occur, experience has shown that 90% have been corrected by tube replacement.

b— Power Supplies. Power supply voltages should be checked daily, before a computer run. After warm-up time (approximately 30 minutes) all supply voltages should be measured using the Test Panel meters and adjusted, if necessary, at the individual units.

(3) Preventive Maintenance. Apart from the routine tests, other tests can be carried out to determine the accuracy of a component. These may include noise tests of d-c amplifiers or servo units, the gain of the d-c portion of an operational amplifier, the gain of the stabilizer section, the alignment of potentiometers on the servo multiplier, etc. These tests are lengthy and may be carried out at regular intervals, a certain number of units being thoroughly tested each week. They require more time, and sometimes additional equipment. They do give extensive and detailed information about the performance of the equipment and should be carried out after a unit has been repaired, or after a gross malfunction.

It is advisable to carry a reasonable number of spare components for the equipment. These are obtainable from Electronic Associates Inc., and a list of parts has been supplied with this computer. The majority of repairs can be accomplished by a competent technician with adequate measuring equipment. Major repairs are best accomplished by removing the unit and returning it to E.A.I. where the Field Service Department is equipped to handle complete overhaul and thorough testing. For most tests, a VTVM or multimeter, an audio signal generator, and a low-speed oscilloscope (preferably with d-c amplifiers) is sufficient. Tests on servo units usually require a six-channel recorder or similar recording device.

a— Quadruple D.C. Amplifier. The more common amplifier troubles are listed in figure 36 together with suggested remedies. When an amplifier malfunction becomes apparent, it is best to consult the chart and apply these remedies if possible, before assuming that the amplifier itself is defective.

b— Output Noise Checks. To check the output noise level of a d-c amplifier, remove the input to its associated network so that no signal is fed to the unit. Connect an oscilloscope (Y input) to the amplifier output with a shielded lead. The oscilloscope lead can be connected to the SEL terminal (of the VTVM or EDVM) on the patch panel and the Signal Selector used to monitor all amplifier outputs sequentially. The other vertical deflection plate is grounded. The oscilloscope is operated at a moderate horizontal sweep rate of about 100 cps. This may be adjusted to examine particular output conditions. The vertical sensitivity of the scope should be 0.1 volts a-c peak-to peak fullscale.

The noise output should not exceed 5 mv. peak-to-peak. Tapping the chassis should result in microphonic noise of not more than twice this figure. The 94 cps spike in the output should not exceed 20 mv. (This spike may not be present.)

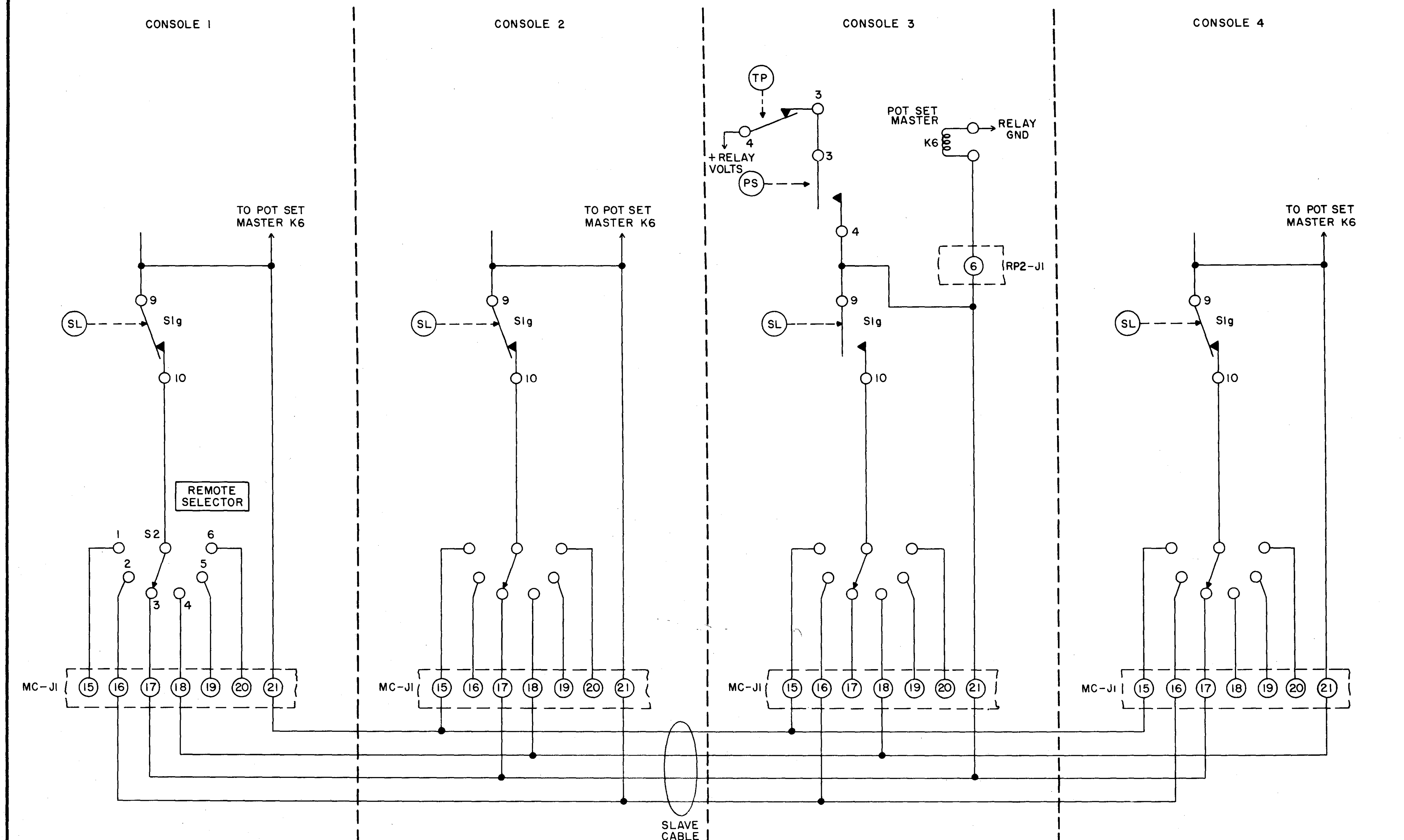


Figure 35. Slaving Circuits, Simplified Schematic.

SYMPTOMS			CAUSE	SUGGESTED REMEDY
OVERLOAD INDICATOR	OUTPUT VOLTAGE	RESPONSE TO BALANCE CONTROL		
With input voltage applied to the amplifier, overload indicator will not null. With no input voltage applied, the indicator will not light.	zero	None	Grounded Output	1) Check connections 2) Remove output leads and re-connect one at a time to isolate trouble.
Overload indicator will not light.	approx. ±200V	Varying the balance control varies the output voltage between ±200V.	Grounded Grid	Check input Connections
With input voltage applied to the amplifier, the overload indicator will not null. With no input, the indicator will not light.	approx. ±200V	A) With input voltage applied, the balance control has no effect B) With no input, the balance control will vary the output ±200V.	No Feedback	1) Check to be sure unit is not dividing by zero. 2) Check pot fuses if dividing circuit is used.
The overload indicator may flicker or glow brightly.	approx. ±100V variable	None	High Frequency Oscillation	Often associated with unusual feedback or output circuits
Overload indicator glows for large inputs, especially for positive inputs.	Limits at less than ±100V	Normal except when limiting	Heavy Load	Lighten load, check output connections.
Overload Indicator will not null.	Greater than ±100V	None	Excessive Input voltage	Check inputs.

Figure 36. Amplifier Troubleshooting Chart.

Some of the more common faults which may occur are:

- Excessive 60 cycle signal in the output (for example, more than 0.05 volts). The usual cause is heater-cathode leakage in a tube near the input of the unit.
- Sudden burst of noise. The usual cause of this is the output tube, type 5881.
- The tubes and the chopper can be sources of microphonic noise.
- Most other cases of high noise level can be corrected by tube replacement. The input stage is the most sensitive.

c– Gain Check of D.C. Section of Amplifier. The open-loop gain of an amplifier at d-c is far too high to be measured conveniently. For this reason, the gain measurement is usually made by observing the decline of the closed-loop gain at higher frequencies. This procedure requires a test jig especially built for this purpose, or an EAI general purpose computer, if one is available. The amplifier under test is connected to a precision resistor network (contained in a temperature-controlled oven) which provides a gain of one. A signal generator is connected to the input resistor, and an oscilloscope to the output of the amplifier. The signal generator is set at the cutoff frequency and the output adjusted on the scope for a convenient amplitude. The output should be 70% of the input amplitude.

d– Gain Check of the D.C. Amplifier Stabilizer Section. This requires a test set-up similar to that mentioned in paragraph (*c*) above. The balance button of the amplifier is depressed while monitoring its output of the amplifier. When the pushbutton is released, the amplifier output should be reduced to 0.4 mv. or less by the action of the stabilizer. Any error greater than 0.4 mv. indicates that the stabilizer is not operating properly, and that tubes and other components should be checked.

e– ERO System. The magnitude of the current controlled by the stepping switches in the Extended Readout System is usually extremely small and often is of the value of microamperes with potentials in the order of millivolts. At times, the stepping switches may introduce malfunctions because of "dry circuit" problems which can exist in these high-sensitivity circuits. (A "dry circuit", in relay and switching circuit terminology, is one in which the current and voltage levels are extremely low. No specific values have been assigned to delineate the areas concerned, however.)

The appearance of a dry circuit malfunction is evidenced by the erratic behavior of the ERO system such as an apparent open circuit which may be cleared by allowing the stepper switches to run, or an open circuit which closes a few seconds after the point has been selected. This occurence may not reappear for hours or even days, apparently depending upon the frequency of operation of the stepping switches and the tendency of the switch contacts to form high-resistance or open circuits.

A usually effective remedy for the erratic operation described above is the application of Nye's Watch Oil to the stepper switch wiper blades followed by the operation of the stepper switches for approximately one minute. (Nye's Watch Oil #165-4 may be obtained from Wm. F. Nye, New Bedford, Mass., or from Wm. Dixon, Newark, N.J.). The period for which the application is effective will depend upon the duty cycle of the equipment. The unit stepper switches can be quickly removed for service if necessary. Detailed information in stepper switch maintenance is contained in the appendix.

f. Air Filters. Air filters are provided under the intake fans at the bottom of the console. They are replaced by raising the foot rest and reaching under the rack *(power should be OFF and fans stopped).* The front of the air filter holder can be pulled down allowing the old filter to slide out. When a new one is installed, the holder can be snapped back into place.

13. PARTS LIST

a. Computer Console.

Reference Symbol	Description
K8, K18	Relay: 4 form "B" contacts, Magnecraft #11HPX40
RS	Switch; Hetherington #W102L5R
R50	Resistor; wirewound, 385 ohms ±3%, 25W, Dale Products Inc. #RH-250

b. Power Control and Relay 11.001.

Reference Symbol	Description
CB1	Circuit breaker: Aircraft, for sq. panel mtg., single pole unit, Heinemann #LAM-12 (25 amp)
CB2	Circuit breaker: Aircraft, for sq. panel mtg., single pole unit, Heinemann #RAM-12 (25 amp)
F1,	Fuse; 5 amp, Littelfuse #313003
F2, F3,	Fuse; 3 amp, Littelfuse #313003
F4	Fuse; 6-¼ amp, Littelfuse #313005
K1	Relay; –115V ac 60cps 2 form C, Wheelock Signals Inc. #130-2C
TD1	Relay: time delay, Elly #115-30-C

c. Filament Transformers.

Reference Symbol	Description
T1, T3	EAI part/dwg. #B3M50B3
T2	EAI part/dwg. #B684 079 0

d. Combination Network 12.002.

Reference Symbol	Description
C1	Capacitor; ceramic, insulated Erie #GP1K 47 ±4.7 mmf
C2	Capacitor; ceramic, insulated Erie #GP1K, 100 ±10 mmf
C3, C4	Capacitor; ceramic, insulated Erie #GP1K, 10±1 mmf
CR1, CR2,	Contact Protector, IRC #S5Y2P "EAI Part No. 614 015 0 (Federal #15A5PS2) may be used"
K1, K2	Relay, micro miniature, plug-in type GE #3S2791G200-A-13
R1, R5, R6, R7	Resistor, precision, 999,000 ±940 ohms stability .005%, EPR type NS-5L
R1p, R5p, R6p, R7p	Resistor, padder (value to raise R1, R5, R6, R7 to 1,000,000 ±25 ohms) EPR type NM-2
R2, R4 R9, R10	Resistor, precision, 99,900 ±94 ohms; stability .005% EPR type NS-5L
R2p, R3p, R4p	Resistor, padder (value to raise R2, R3, R4, R9, and R10 to 100,000 ±2.5 ohms) EPR type NM-2
R8	Resistor, 100K ±10%, 1/2W AB
R11, R12	Resistor, 2.2 megohm ±10%, 1/2W AB
XK1, XK2,	Socket, Relay and Retaining Spring GE #561A374

e. Summing Network 12.003.

Reference Symbol	Description
C1	Capacitor; ceramic, insulated Erie #GP1K 47 ±4.7 mmf
C2	Capacitor; ceramic, insulated Erie #GP1K 100 ±10 mmf
C3, C4	Capacitor; ceramic, insulated Erie #GP1K 10 ±1 mmf
K1	Relay, micro miniature, plug-in type GE #3S2791G200-A-13
R1, R6, R7, R8	Resistor, precision, 999,000 ±940 ohms, stability .005%, EPR type NS-5L
R1p, R6p, R7p, R8p	Resistor, padder, (value to raise R1, R6, R7, R8 to 1,000,000 ±25 ohms) EPR type NM-2
R3, R4, R5	Resistor, precision, 99,900 ±94 ohms; stability .005% EPR type NS-5L
R3p, R4p, R5p	Resistor, padder (value to raise R3, R4, R5 to 100,000 ±2.5 ohms) EPR type NM-2
R2	Resistor, 100K ±10%, 1/2W AB
R9, R10	Resistor, 2.2 megohm ±10%, 1/2 W
XK1, XK2	Socket, Relay and Retaining Spring GE #561A374

f. Integrator Capacitors 12.031.

Reference Symbol	Description
C00, C01, C05, C06, C10, C11, C15, C16	Capacitor, adjustable, 1.0 mfd, 200V dc, Southern Electronic Corp. #PO-1-0-200E (EAI 521 011 0)

g. Reference and Check Amplifier Network 12.098.

Reference Symbol	Description
BT1	Battery; Mallory Mercury Dry Cell #TR-135R
K1	Relay, micro miniature, plug in type; GE #3S2791G200-A-13
R1, R2	Resistor; fixed, wirewound, precision; 200,000 ohms ±1.0%, stability .005%, EPR type NS-5L
R3	Resistor; fixed, wirewound, precision; 100,000 ohms ±1.0%, stability .005%, EPR type NS-5L
R4	Resistor; fixed, wirewound, precision, 300,000 ohms ±1.0%, stability .005%, EPR type NS-5L
R5, R7	Resistor; fixed, wirewound, precision, 100,000 ohms ±0.1%, stability .005%, EPR type NS-5L
R6, R10	Resistor; variable, precision, Bourns Trimpot #130-1-501
R8	Resistor; fixed, wirewound, precision 180,000 ohms ±0.1%, stability .005%, EPR type NS-5L
R9	Resistor; fixed, wirewound, precision; 12,780 ohms ±0.1%, stability .005%, EPR type NS-5L
R11	Resistor; fixed, wirewound, precision; 13,000 ±12 ohms stability .005%, EPR type NS-5L
R11p	Resistor; padder (value to raise R11 to 13,030 ±0.3 ohms) EPR type NM-2
R12	Resistor; fixed, wirewound, precision, 179,820 ±168 ohms stability .005%, EPR type NS-5L
R12p	Resistor, fixed, wirewound, precision, 180,000 ±4.5 ohms) EPR type NM-2
R13, R14	Resistor; 10K ±10%, 1W AB
R15, R16, R17	Resistor; fixed, wirewound, Precision, 99,900 ±94 ohms, stability .005%, EPR type NS-5L
R15p, R16p, R17p	Resistor; padder (value to raise R15, R17 and R16 to 100,000 ±2.5 ohms) EPR type NM-2
R18	Resistor, fixed, wirewound, precision, 999,000 ±940 ohms stability .005%, EPR type NS-5L
R18p	Resistor; padder (value to raise R18 to 1,000,000 ±25 ohms) EPR type NM-2
	Battery holder; Keystone #135

h. ERO Control Unit 14.001.

Reference Symbol	Description
C1	Capacitor, 80-80 mfd, 150V, Tobe #CQ8815
C2	Capacitor, 80 mfd, 450V, Aerovox #AEP16J
C3	Capacitor, 1 mfd, 450V, Aerovox type PRS "Dandee"
C4	Capacitor, 2 mfd, 450V, Sprague #TVA-1701
C5	Capacitor, 100 mfd, 15V, Cornell-Dubilier #BBR-100-15
C6	Capacitor Electrolytic, 4MFD +50% −10% 450V
CR1 through CR13, CR15	Contact Protector; Int. Rect. Corp. #S5Y2P (EAI 614 016 0)
CR16, CR17	Diode, 1N91 (EAI 614 019 0)
K1, K2, K3, K22	Relay; micro miniature plug-in type, GE #3S2791G200-A-13

Reference Symbol	Description
K4 through K11, K14, K21	Relay; Magnecraft #11HPX24
K13	Relay; Clare CP #SK-5028
K12	Relay; Line Electric #MKP1D
MK1	Stepping switch; EAI part/dwg. #C658 001 0
R1, R6, R11	Resistor; 2,400 ±5%, 1W AB
R2, R3, R7, R8, R12, R13	Resistor; 1,800 ±10%, 1W AB
R4	Resistor; 220 ±10%, 2W AB
R5	Resistor; wirewound, 75 ±5%, 10W, Ward Leonard #10F75WL
R9	Resistor; 820 ±10%, 2W AB
R10	Resistor; 1,000 ±10%, 2W AB

(1) Stepping Switch 14.002.

Reference Symbol	Description
C1	Capacitor; 1 mfd, 450V Aerovox type PRS "Dandee"
R1	Resistor; 220 ±10%, 2W AB
UK	Stepping, switch EAI #B3M52A1-1
	Connector receptacle; Cannon #DD-50S

(2) Stepping Switch 14.003.

Reference Symbol	Description
C1	Capacitor; 1 mfd, 450V Aerovox type PRS "Dandee"
R1	Resistor; 220 ±10%, 2W AB
UK	Stepping, switch EAI #B3M52A1-1
	Connector receptacle; Cannon #DD-50S

(3) Stepping Switch 14.004.

Reference Symbol	Description
C1	Capacitor; 1 mfd, 450V Aerovox type PRS "Dandee"
R1	Resistor; 220 ±10%, 2W AB
UK	Stepping, switch EAI #B3M52A2-1
	Connector receptacle; Cannon #DD-50S

(4) Stepping Switch 14.006.

Reference Symbol	Description
C1	Capacitor; 1 mfd, 450V Aerovox type PRS "Dandee"
R1	Resistor; 220 ±10%, 2W AB
UK	Stepping, switch EAI #B3M52A1-1
	Connector receptacle; Cannon #DD-50S

(5) Stepping Switch 14.007.

Reference Symbol	Description
R1	Resistor; 220 ±10%, 2W AB
UK	Stepping, switch EAI #B3M52A1-1
	Connector receptacle; Cannon #DD-50S
C1	Capacitor; 1 MFD, 450V Aerovox Type PRS "Dandee"
C2	Capacitor; 20 MFD, 450V, Cornell Dubilier BR2045
R1	Resistor; 220 ohms ±10% 2W AB
CR1, CR2	Diode; 1N91
R2	Resistor; 680 ohms ±10% 2W AB
R3	Resistor; 10K ±10% 1W AB

i. Signal Selector 20.001

Reference Symbol	Description
	Assembly, screw EAI part/dwg. #B246 001 0A

Reference Symbol	Description
CR1	Diode, #IN294
R1	Resistor; Precision, 100K ±1%, Weston "Vamistor" Model #9851
R2	Resistor; Precision, 416K ±1%, Weston "Vamistor" Model #9851
R3	Resistor; 25.2K ±1%, 1/2W, Aerovox "Carbofilm" CP1
S1	Assembly, Switch EAI 656 003 0
S2	Assembly, Switch EAI 656 002 0
S3	Assembly, Switch EAI 656 001 0
S4	Switch; General Control, #MCT-1 T3, 3A-2A1B-3A-3A
S5	Switch; General Control, EA-35-A5 (MCT-1, T1, 2C-2C-C-C)
S6	Switch; General Control, #MCT-1 T2, C-C-C-C

j. VTVM 20.002.

Reference Symbol	Description
	Assembly, switch, EAI part/dwg #B26F20A4
	Assembly, VTVM, EAI #16-26B-3
	Assembly, D.C. Amplifier, EAI #26-6B
CR	Assembly, rectifier network, EAI #26-12A
I1	Lamp Holder, Dialco #137-7236-937
K1	Relay, micro miniature, plug-in type; GE #3S2791G200-A-13
R1	Resistor; variable, comp., 1 meg ±20%, Chicago Telephone Supply Co. type 65 #X3527
R2	Resistor, 100K ±0.1%, 1/2W Aerovox "Carbofilm" type CP1/2
R3	Resistor, 10 meg ±0.1%, 1W Aerovox "Carbofilm type CP-1
R4, R5	Resistor, 100K ±10%, 1/2W AB
R6	Resistor, 100K ±10%, 2W AB
S2	Switch, rotary selector EAI 658 150 0
	Lamp, Neon #NE-2D
	Knob, pointer, Whitso #K105
S3	Switch, pushbutton, Hetherington #C41006
XK1	Socket, Relay W/Retaining Spring; GE #561 A374

(1) VTVM 16-26B-3.

Reference Symbol	Description
C1, C2	Capacitor, CM30B332K
M1	Meter; micro-ammeter, Marion model 55, 2% zero center, 25-0-25 micro amp. movement calibrated for non-magnetic panel, knife pointer, meter scale to be as per. dwg. #A16M26B3
R1	Resistor; carbofilm 3 meg, Wilkor, type CP1/2
R2	Resistor; carbofilm, 5.6 meg, Wilkor, type CP-1
R3	Resistor; carbofilm 700K, Wilkor type CP1/2
R4	Resistor; carbofilm 560K, Wilkor type CP1/2
R5	Resistor; carbofilm, 70K, Wilkor type CP1/2
R6	Resistor; carbofilm, 56K, Wilkor type CP1/2
R7	Resistor; carbofilm, 14K, Wilkor type CP1/2
R8	Resistor; carbofilm, 10 meg, Wilkor type CP1/2
R9	Resistor; carbofilm, 75K, Wilkor type CP1/2
R10	Resistor; variable comp., AB JU1031

Reference Symbol	Description
R11	Resistor; carbofilm, 75K, Wilkor type CP 1/2
R12	Resistor; variable comp., AB JU5031
R13	Resistor; carbofilm, 12K, Wilkor type CP 1/2
R14	Resistor; carbofilm, 10K, Wilkor type CP 1/2
R15	Resistor; carbofilm, 100K, Wilkor type CP 1/2
R16	Resistor; carbofilm, 270K, Wilkor type CP-1
R17	Resistor; carbofilm, 10K, Wilkor type CP 1/2
R18	Resistor; carbofilm, 10 meg, Wilkor type CP 1/2
S1	Switch; rotary selector, Centralab #PA-2001
V1	Tube; electron, type 12AU7
XV1	Socket; Tube, Noval, Methode #PS-161

(2) Test Amplifier 26-6B.

Reference Symbol	Description
C1	Capacitor, 2700 Cornell Dubilier #K075
C2, C4, C5	Capacitor, 0.02 mfd Cornell Dubilier K085
C3	Capacitor, 27 Cornell Dubilier C027
C6	Capacitor, 1.0 mfd, 200V Hopkins Micro-Miniature type #1P2M
D1	Converter, Airpax #A-175 6.3V AC 60 cps
R1	Resistor; 1.5 meg ±10%, 1/2W AB
R2	Resistor; 10K ±10%, 1/2W AB
R3	Resistor; 91K ±5%, 1/2W AB
R4	Resistor, 47K ±10%, 1/2W AB
R5, R11	Resistor; 1.0 meg ±5%, 1/2W AB
R6, R15, R23	Resistor; 100K ±10%, 1/2W AB
R7	Resistor; 3.0 meg ±5% 1/2W AB
R9	Resistor; 270K ±10%, 1/2W AB
R10	Resistor; 2.2 meg ±5%, 1/2W AB
R12	Resistor; 560K ±10%, 1/2W AB
R14, R17, R19	Resistor; 470K ±10%, 1/2W AB
R16, R18	Resistor; 4.7 meg ±10%, 1/2W AB
R20	Resistor; 56K ±10%, 1/2W AB
R21	Resistor; 1.0 meg ±10%, 1/2W AB
R22	Resistor; 10.0 meg ±10%, 1/2W AB
V1	Electron tube; type 12AT7 or 6201
V2, V4	Electron tube; type 12AX7
V3	Electron tube; type 5763
XV1, XV2 XV3, XV4	Socket; Tube Noval, Methode #P161
XD1	Socket; Tube; 7 pin min Methode #P151

(3) Rectifier Network 26-12A.

Reference Symbol	Description
C1	Capacitor; 0.1 mfd 200V dc, Astron Hy-Met type MLL-2-1
CR1	Rectifier; selenium, Bradley #SE8L2H
R1	Resistor; variable, WW, 4000 Clarostat type 39PX
R2	Resistor; 12K ±10%, 1W AB
R3	Resistor; 1.0 meg ±10%, 1W AB

k. Mode Control 20.003.

Reference Symbol	Description
S1	Assembly, switch, EAI part/dwg #B656 004 0

Reference Symbol	Description
F1	Fuse, 1/32 amp, Littelfuse #361.031
I1, I3	Lampholder, Dialco #101-3830-971
I2	Lampholder, Dialco #101-3830-972
R1	Resistor; variable, precision, Ford Engineering Multipot #10K-L.1A
R2	Resistor; fixed, 2700 ±10%, 1W AB
S2	Switch, rotary selector, Centralab #PA-2027
S3	Switch, General Control #MCT-1, T1-C-C-C-C
S4	Switch, toggle C-H #7563K4
S5	Switch, toggle Carling #2-GG53
	Fuseclip, Littelfuse #387001
	Decadial, Ford Engineering Co. Model B1
	Lamp NE2D

l. Mode Control Relays 11.008

Reference Symbol	Description
C1	Capacitor; 2.0 mfd, 200V dc, Aerovox type P82Z Aerolite
C2	Capacitor; 4 mfd 450V Aerovox type PRS "Dandee"
C3	Capacitor, 40 mfd, 450V Aerovox AEP8J
C4	Capacitor, 10 mfd, 450V dc Cornell Dubilier type BR1045
CR1 through 11, CR19, CR20	Silicon rectifier, Sarkes Tarzian, type 10M
CR12 through 14, CR16, CR17	Contact protector; Federal #8A4PS2
CR18	Silicon rectifier, Sarkes Tarzian, type M-500
K1, K2, K3, K4, K9, K10	Relay; micro miniature, plug-in type GE #3S2791G200-A13
K5	Relay, Clare CP #SK-5028
K6, K7, K8	Relay, Magnecraft #11HPX24
K11	Relay; Wheelock #130-2C
K12, K13, K14	Relay; Magnecraft #22TX119
K15, K16, K17	Relay; Magnecraft #22TX28
R1, R3, R4, R5, R6	Resistor; power Dalohm type B-25, 1250 ohms
R2	Resistor; power WW 5000 WL 5X
R7	Resistor; power WW 2500 WL 5X
R8	Resistor; 10K ohms ±10%, 1W AB
R9	Resistor; power WW 400 WL 25F
R10	Resistor; 82K ±10% 2W
T1	Transformer, filament, EAI #B3M50B2
XC3	Socket, Tube; Octal Eby #9751-3
XCR1 through 11, XCR18,19,20	Socket Silicon Rectifier Littelfuse #099062
XK1, XK2, XK3, XK4, XK9, XK10	Socket, Relay, Viking #VB8/3DV3
	Grommet AN931-6-10
XK5	Socket, Tube; Octal Eby #9751-3
XK6 through 8	Socket, Tube, 11 pin Amphenol #77-MIP-11T

m. Overload Indicator 20.024

Reference Symbol	Description
I1, I2	Lampholder, Dialco 101-3830-976
S1	Switch, toggle CH #7563K4
	Lamp Neon, #NE2D

n. Attenuators and Function Switches 42.001.

Reference Symbol	Description
	Duodial, Helipot type RB
	Fuse, 1/32 amp, Littelfuse #361.031
	Fuse clip, Littelfuse #387001
	Resistor; variable, precision, Helipot #30K AZ
	Switch, General Control #MCT-1, T-3 AC-2AC-AC-2A
	Switch, General Control #MCT-1, T-1 C-0-C-0

DVM Cooling Unit 89.030

Reference Symbol	Description
	Filter EAI 254 008 0
C1	Capacitor; Fixed, Paper, 1 mfd ±10% 600V Sangamo Electric #CP53B1EF105K (EAI 520 005 0)
	Fan, Rotron, Type DF-301R (EAI 242 019 0)

SUPPLEMENT

QUADRUPLE D. C. AMPLIFIER

The 6.002 Quadruple D. C. Amplifier is superseded by an improved model, the 6.002-3. The 6.002-3 is identical with the 6.002 except that D. C. Amplifier 6.017-1 replaces D. C. Amplifier 6.017. The d-c amplifiers are similar. The parts list and schematic describe the difference between the two models.

In an operational summing amplifier, the cut-off frequency of the grid network must complement the cut-off frequency of the succeeding stages. If the corner frequencies do not match, the amplifier will be unstable under certain conditions such as capacitive load.

The input and feedback resistors that are used with Quadruple D. C. Amplifier 6.002-3 must be capacity-compensated such that the time constant is equal to 6.5 microseconds; this insures that the cut-off frequency of the grid network is matched to the following stages.

The input resistors of these networks are paralleled with appropriate value of capacitance so that the time constant is equal to 6.5 microseconds. The feedback resistor is paralleled with a capacitor such that the *total* time constant is 6.5 microseconds. (There is stray capacitance around the amplifier and across the resistors.) All of the networks in the computer console are constructed in this manner.

For optimum frequency characteristics, and stability when low value feedback resistors are used, *when an external input or feedback resistor is used, it should be paralleled with an appropriate value of capacitance so that the time constant is equal to 6.5 microseconds.* Example: If a gain of 5 is desired, the feedback resistor (1 megohm) of the standard network would be used and an input resistor of 200,000 ohms. The feedback resistor in the network has a time constant of 6.5 microseconds; however, the input resistor must be paralleled with a capacitor to raise the time constant to 6.5 microseconds.

$$T = RC \qquad (1)$$

$$C = \frac{T}{R} \qquad (2)$$

$$C = \frac{6.5\,(10^{-6})}{2\,(10^{5})} \qquad (3)$$

$$C = 32.5\,(10^{-12}) \qquad (4)$$

$$C = 32.5 \text{ mmf} \qquad (5)$$

NOTES: 1. In most instances a standard value capacitor that has a value close to the calculated value may be used. However, if the calculated value is small and there is a large percentage differential between the calculated value and the nearest standard value, the amplifier characteristics will vary slightly from the specifications.

2. In equation 2, insert R in megohms and T in microseconds; this will give a value of C in mmf.

The improved amplifier results in the following specifications: (Amplifier located in 231R Computer Console, Unity Gain, $R_f = R_{in} = 1$ Meg, Time Constants = 6.5 microseconds.)

Amplifier Gain

Total D-C Gain .... 1.35×10^{8}, typical
Main Amplifier Gain .... 3×10^{4}, typical
Stabilizer Gain .... 4.5×10^{3}, typical

Power Output

30 ma. at ±100V, typical
25 ma. at ±100V, minimum

Output Capacitance Loading for Stability

Stable for any value *

Summing Point Capacitance Loading for Stability

Stable for any value *

Noise

5 mv p-p within band pass of amplifier
2 mv p-p maximum 0 to 200 cps

Integrator Drift *(R = 1 Meg, C = 1 Mfd.)*

3.6 mv. per minute, maximum
1.6 mv. per minute, typical

Frequency Response

3 db down at 30 KC, typical

** See figure 1 for typical combination performance.*

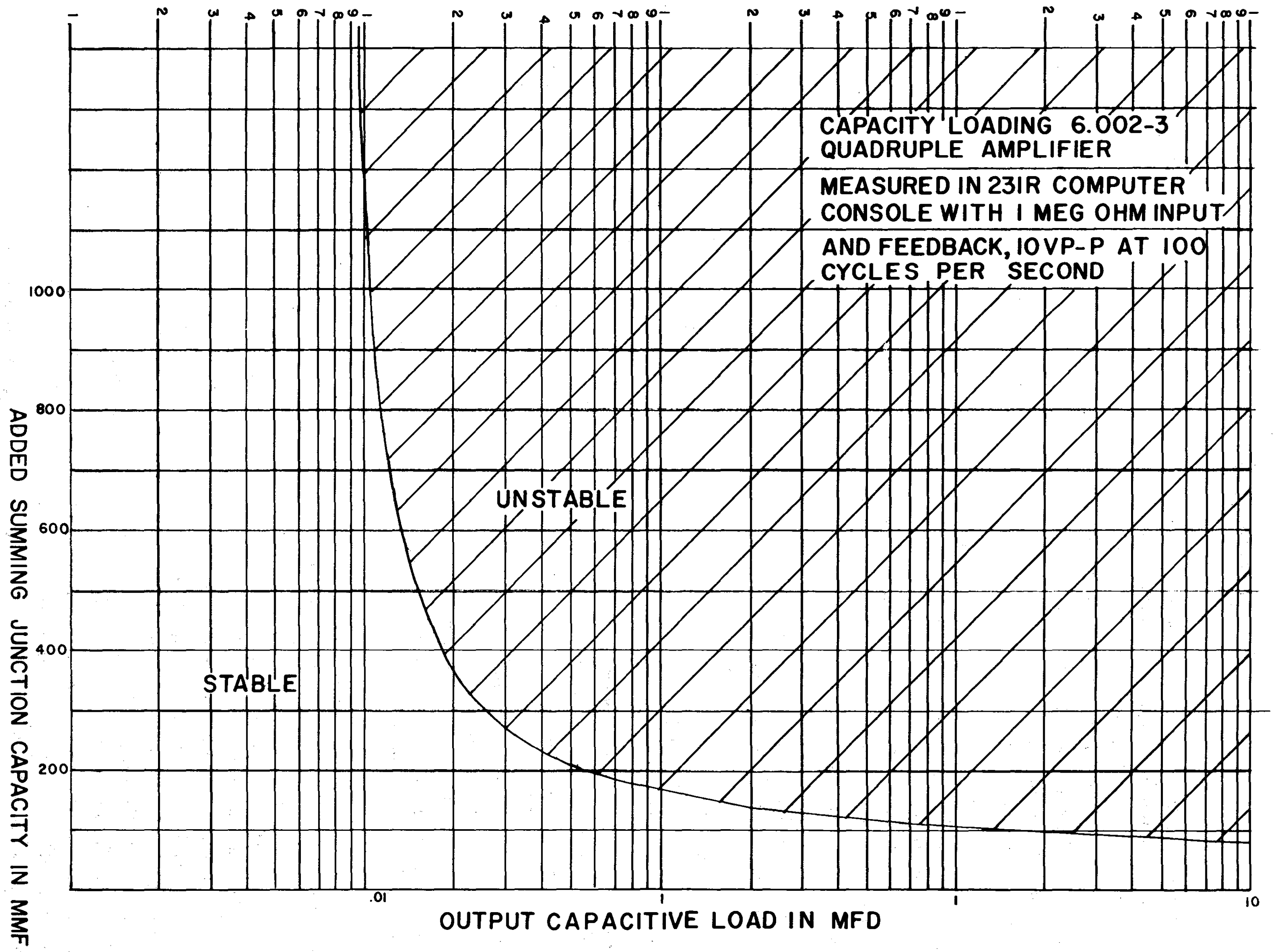


Figure 1. Capacity Loading, Amplifier 6.002-3

Overload Characteristic

200V p-p minimum up to 4000 ohms resistive load

Accuracy at 100 cps

Phase Shift: *0.1 Degree, typical*
0.14 Degree, maximum

Gain Error: *.025%, typical*
.035%, maximum

PARTS LIST

Reference Symbol	Description
C1, C6, C13, C18	Capacitor, fixed, polystyrene: 0.1 mfd ±5%, 200V; EAI B521 027 0
C2	Capacitor, fixed, ceramic, disc: 33 mmf ±5%, 500V; Solar type NP0
C3, C15	Capacitor, fixed, ceramic, disc: 1200 mmf ±5%, 500V; Solar type NP0
C4, C16	Capacitor, fixed, ceramic, disc: 8 mmf ±5%, 500V; Solar type NP0
C5, C17	Capacitor, fixed, ceramic, disc: 100 mmf ±5%, 500V; Solar type NP0
C7, C10 C19, C22	Capacitor, fixed, electrolytic: 50 mfd 6V; Sprague #TE1100
C8, C11, C20, C23	Capacitor, fixed, ceramite: .05 mfd ±20%, .500V; Sprague Ceramite type #36C142A1
C9, C21	Capacitor, fixed, ceramic: 5 ±.5 mmf 500V; Erie #GP1K 5 ±.5
C12, C24	Capacitor, fixed, mylar: 2 mfd ±20%, 200V; EAI B521 028 0
C14	Capacitor, fixed, ceramic, disc: 47 mmf ±5%, 500V; Solar type NP0
C25, C26, C33, C34	Capacitor, fixed, ceramic, disc: .02 mfd GMV, 600V; Cornell-Dubilier #BYB6S2
C27, C28	Capacitor, fixed, ceramic, disc: 2.2 mmf ±5%, 500V; Solar type NP0
C29, C30	Capacitor, fixed, ceramic, disc: 750 mmf ±5%, 500V; Solar type NP0
C35, C36	Capacitor, fixed, ceramic, disc: 5 mmf ±5%, 500V; Solar type NP0
CR1 through CR4	Diode: Hughes type #HD6008
D1	Chopper: James #C1978EA (EAI 530 006 0)
I1, I2	Lamp, Indicator: NE2D
P1	Connector, printed circuit: Amphenol #133-817
R1, R26, R51, R52	Resistor, fixed, composition: 270,000 ohms ±10%, 1/2 watt; Allen-Bradley EB
R2, R16, R27, R41	Resistor, fixed, composition: 2.2 megohms ±10%, 1/2 watt; Allen-Bradley EB
R3, R28	Resistor, fixed, composition: 180,000 ohms ±5%, 1 watt; Allen-Bradley GB
R4, R29	Resistor, fixed, composition: 100,000 ohms ±10%, 2 watt; Allen-Bradley HB
R5, R30	Resistor, fixed, composition: 47,000 ohms ±5%, 1/2 watt; Allen-Bradley EB
R7, R32	Resistor, fixed, composition: 100,000 ohms ±5%, 1/2 watt; Allen-Bradley EB
R8, R33	Resistor, fixed, composition: 560,000 ohms ±5%, 1/2 watt; Allen-Bradley EB
R9, R34	Resistor, fixed, composition: 56,000 ohms ±5%, 2 watt; Allen-Bradley HB

Reference Symbol	Description
R10, R24, R35, R49, R55, R56	Resistor, fixed, composition: 100,000 ohms ±10%, 1/2 watt; Allen-Bradley EB
R11, R36	Resistor, fixed, composition: 1 megohm ±5%, 1/2 watt; Allen-Bradley EB
R12, R37	Resistor, fixed, composition: 470,000 ohms ±5%, 1/2 watt; Allen-Bradley EB
R13, R38	Resistor, fixed, composition: 1.5 megohms ±5%, 1/2 watt; Allen-Bradley EB
R14, R15, R39, R40	Resistor, fixed, composition: 1800 ohms ±5%, 2 watt; Allen-Bradley HB
R17, R21, R42, R46	Resistor, fixed, composition: 220,000 ohms ±10%, 1/2 watt; Allen-Bradley EB
R18, R23, R43, R48	Resistor, fixed, composition: 820 ohms ±10%, 1/2 watt; Allen-Bradley EB
R19, R20, R44, R45	Resistor, fixed, composition: 1 megohm ±10%, 1/2 watt; Allen-Bradley EB
R22, R47	Resistor, fixed, composition: 47,000 ohms ±10%, 2 watt; Allen Bradley HB

Reference Symbol	Description
R25, R50, R51 through R58	Resistor, fixed, composition: 10 megohms ±10%, 1/2 watt; Allen-Bradley EB
R64, R65	Resistor, fixed, composition: 470 ohms ±5%, 1 watt; Allen-Bradley GB
V1, V2, V7	Tube, electron: type 6072
V3, V8	Tube, electron: type 6U8
V4, V5, V9, V10	Tube, electron: Amperex type 7062
V6, V11	Tube, electron: type 6AW8
XD1	Socket, printed circuit, single sided, 9 pin miniature; Methode #PMS-161-B28
XV1, XV7	Socket, printed circuit, single sided, 9 pin miniature; Methode #PMS-161-B17
XV2, XV4, XV5, XV9, XV10	Socket, printed circuit, single sided, 9 pin miniature; Methode #PMS-161-B16
XV3, XV8	Socket, printed circuit, single sided, 9 pin miniature; Methode #PMS-161-B69
XV6, XV11	Socket, printed circuit, single sided, 9 pin miniature; Methode #PMS-161

1. GENERAL

The Quadruple D.C. Amplifier 6.002 (fig. 1) consists of four identical independent d-c amplifiers, each designed for use as a computer system summer, integrator, or constant-coefficient multiplier. Each amplifier has an automatic balancing circuit for reduction of amplifier drift, and may be located remote from the summing or control point (up to 200 feet). Balancing controls and indicators for each amplifier are located on the front panel of the assembly; provisions are made in the amplifier for remote overload indicator. Each amplifier is composed of a d-c portion and a stabilizer (a-c) portion. Two amplifiers are mounted on a printed-circuit board; two such boards make up the complete four-amplifier package.

2. TECHNICAL DATA

Front Panel

Height........ 4 inches
Width........ 9-1/2 inches

Chassis

Height........ 3-1/2 inches
Width........ 8 inches
Depth........ 14-1/2 inches

Weight of Unit

6 pounds

Tube Complement (each amplifier section)

1 each	–	6072
1/2	–	6072
1 each	–	6U8
2 each	–	5965 or 7062
1 each	–	6AW8

Controls and Indicators

BALANCE ....
Potentiometer control for balancing amplifier; used in conjunction with BALANCE pushbutton switch and indicator light.

Amplifier Gain

D-C portion........ 30,000, typical
Stabilizer........ 4,500, typical
Total d-c gain........ 1.35×10^8, typical

Amplifier Error

Gain error at 100 cps: .015%, maximum
Phase error at 100 cps: 0.1°, maximum

Amplifier Phase Shift

Refer to figure 3.

Amplifier Output

±100V d-c at 30 ma., typical
±100V d-c at 25 ma., minimum

Integrator Drift

(R = 1 meg. C = 1 mf.) 3.6 millivolts per minute, maximum

Noise Output

5 millivolts, peak-to-peak, maximum within amplifier pass band (0-25kc)

1 millivolt, peak-to-peak, maximum within computing region (0-200 cps)

Input Power (total for four amplifiers)

+300V	–500V
+110V	6.3V a-c at 8 amperes (gnd)
–300V	6.3V a-c at 1.8 amperes (at –300V)

Unit Terminations

All connections to the unit are made at two connectors; each connector accommodates two amplifiers (Dual D-C Amplifier 6.017) and is designated P_1 on schematic diagram D006 017 0S. The following tabulation indicates the termination for each terminal on P_1.

Terminal Number	Termination
A	Overload indicator
B	Overload warning system (audible)
C	6.3V, 60 cps (at –300V)
D	± Ground
E	Output
F	+300 volts
H	+110 volts
J	6.3V, 60 cps (at ground)
K	6.3V, 60 cps (at ground)
L	–300 volts
M	–500 volts
N	Vibrator Drive
P	Vibrator Drive Return

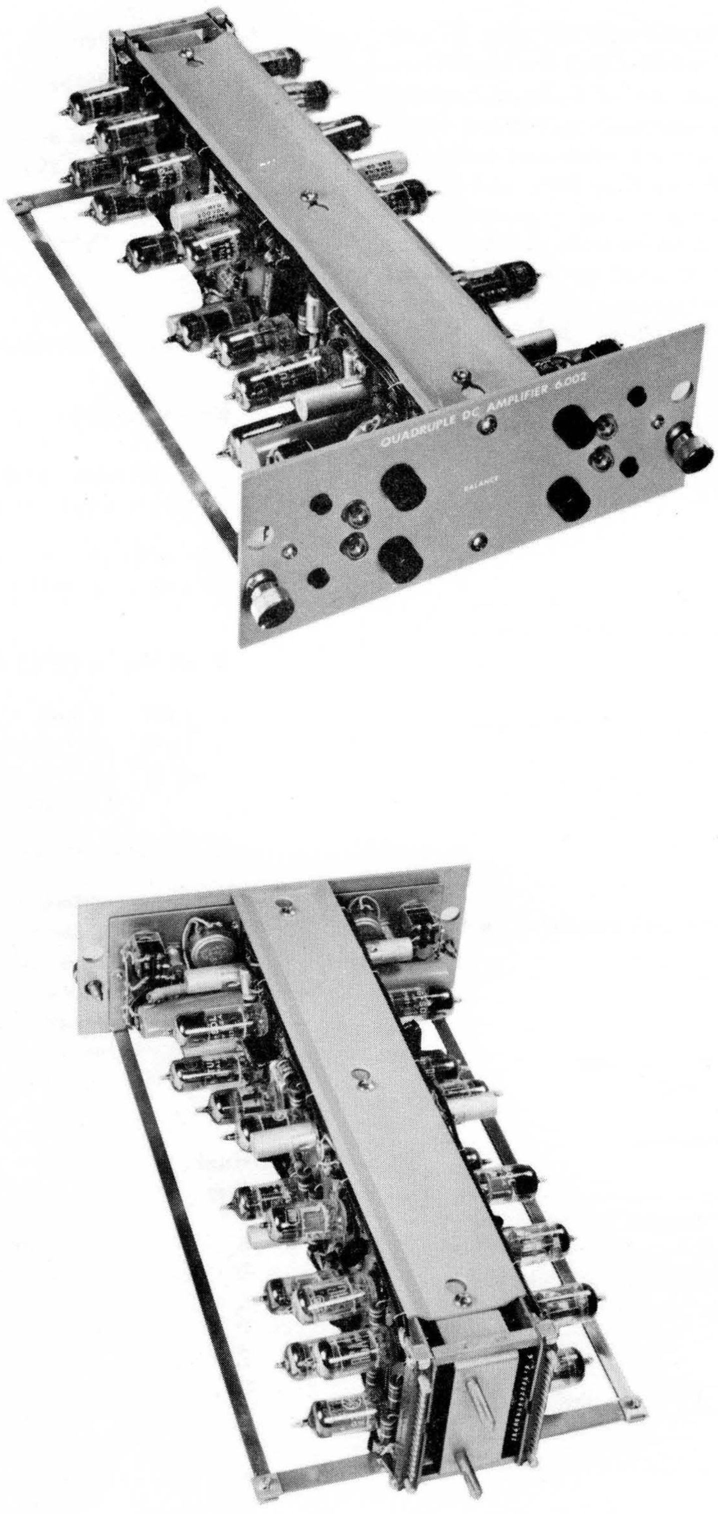


Figure 1. Quadruple D.C. Amplifier 6.002.

(Not available at time of printing.)

Figure 2.. Amplifier Low Frequency Characteristics.

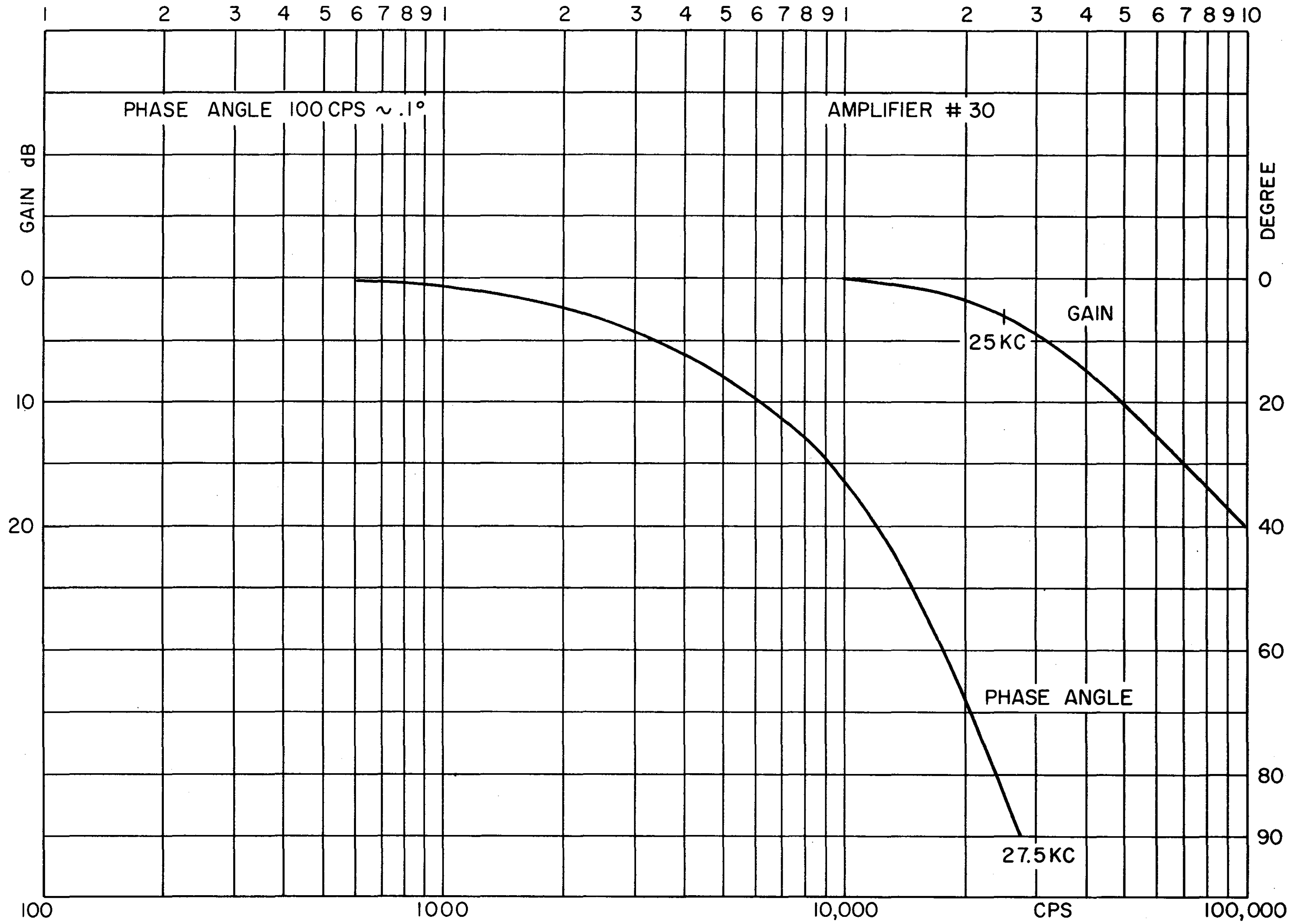


Figure 3. Amplifier High Frequency Characteristics.

Terminal Number	Termination
R	Output
S	6.3V, 60 cps (at −300V)
T	High quality ground
U	Overload indicator

The unmarked coaxial jacks are used for the amplifier inputs.

3. MULTIPLICATION BY A CONSTANT COEFFICIENT

When it is desired to multiply a voltage by a constant coefficient, the network and amplifier shown in figure 4 is used.

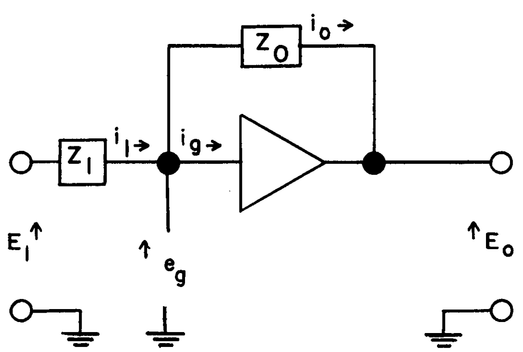


Figure 4. Multiplication by a Constant Coefficient.

The mathematical relationship of this configuration is

$$E_o = -\frac{Z_o}{Z_1} E_1$$

Since this network is the basis for all operational amplifiers, a step-by-step mathematical derivation is given below. The following assumptions are made:

1. Input grid current (i_g) = 0
2. Drift and offset = 0.
3. Amplifier output is 180° out-of-phase with input

On the basis of the first assumption, it is evident that any and all current flowing through Z_1 must flow through Z_o, or

Since $e_g = \frac{E_o}{-A}$ where $-A$ = amplifier gain:

$$i_1 = \frac{E_1 - e_g}{Z_1} \qquad (1)$$

$$i_o = \frac{e_g - E_o}{Z_o} \qquad (2)$$

Since

$i_1 = i_o$:

$$\frac{E_1 - e_g}{Z_1} = \frac{e_g - E_o}{Z_o} \qquad (3)$$

$$\frac{E_1 + E_o/A}{Z_1} = \frac{-E_o/A - E_o}{Z_o} \qquad (4)$$

$$Z_o E_1 + \frac{E_o}{A} Z_o = -E_o Z_1 - \frac{E_o}{A} Z_1 \qquad (5)$$

$$E_o \left[Z_1 + \frac{1}{A}(Z_o + Z_1) \right] = -E_1 Z_o \qquad (6)$$

$$\frac{E_o}{E_1} = \frac{-Z_o}{Z_1 + \frac{1}{A}(Z_o + Z_1)} \qquad (7)$$

$$= \frac{-\frac{Z_o}{Z_1}}{1 + \frac{1}{A}\left[1 + \frac{Z_o}{Z_1}\right]} \qquad (8)$$

Assuming A>>1,

$$\frac{E_o}{E_1} = -\frac{Z_o}{Z_1} \qquad (9)$$

For the specific case where $Z_1 = R_1$ and $Z_o = R_o$, equation (9) becomes:

$$\frac{E_o}{E_1} = -\frac{R_o}{R_1} \qquad (10)$$

or

$$E_o = -\frac{R_o}{R_1} E_1 \qquad (11)$$

The output voltage is seen to be practically independent of amplifier gain. The negative sign indicates that the circuit also acts as a phase inverter.

4. SUMMATION (addition)

When a number of inputs are to be added together, the circuit shown in figure 5 is used.

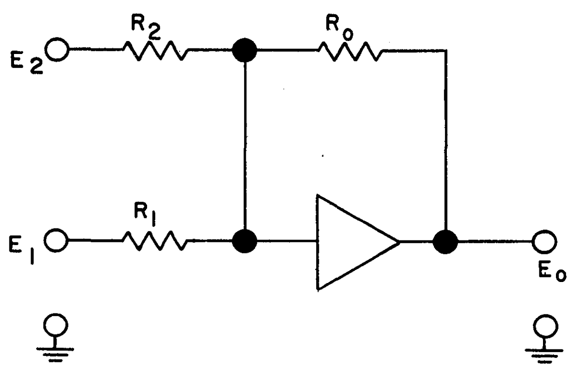


Figure 5. Summation.

The relationship between input and output is

$$E_o = -\frac{R_o}{R_1} E_1 - \frac{R_o}{R_2} E_2 - \dots - \frac{R_o}{R_n} E_n \qquad (12)$$

This equation is essentially an extension of equation (11).

5. INTEGRATION

To integrate a voltage, the circuit shown in figure 6 is used.

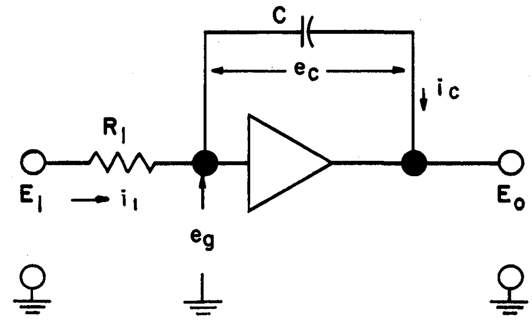


Figure 6. Integration.

The relationship between input and output voltage is derived from the basic equation:

$$e_c = \frac{1}{C} \int_0^t i_c \, dt \qquad (13)$$

From the derivation of paragraph 4:

$$i_c = i_1 \qquad (14)$$

or

$$e_c = \frac{1}{C} \int_0^t \frac{E_1}{R_1} dt \qquad (15)$$

Assuming "e_g" is essentially zero due to the extremely high gain of amplifier:

$$e_c = E_o \qquad (16)$$

or

$$E_o = \frac{1}{CR_1} \int_0^t E_1 \, dt \qquad (17)$$

If Laplace transform $\frac{1}{s}$ is substituted for dt

$$E_o = -\frac{E_1}{R_1 C s} \qquad (18)$$

6. AMPLIFIER CHARACTERISTICS

A series of characteristic curves for Quadruple

D-C Amplifier 6.002 is shown in figures 2 and 3. These curves indicate the capabilities of the amplifier over a range of different frequency requirements.

a. Low-frequency Characteristics. Figure 2 gives the low-frequency characteristics for 1-megohm ideal input and feedback resistors. The percentage of error is defined as

$$\%\ \text{output} \quad \frac{\text{Act. output} - \text{theor. output}}{\text{theor. output}} \times 100\%$$

7. DETAILED CIRCUIT DESCRIPTION.

All four of the d-c amplifiers are identical, therefore only one will be described. The amplifier discussed here appears at the top of schematic diagram D006 017 0S.

a. D.C. Amplifier Section. The input to the d-c amplifier section consists of the two triodes V1a and V2a which are connected in a differential input circuit. Offset and integrator drift are reduced to a minimum in this stage by virtually eliminating input grid current. This is accomplished through the use of the grid-blocking capacitor C1 and a separate grid return resistor R2.* The other grid of the differential input circuit is that of V2a which is direct-coupled to the output of the stabilizer section. V1a and V2a have a common cathode resistor, R4.

The two reverse-connected diodes CR1 and CR2 are connected from the input point to ground so that capacitor C1 cannot be charged to a high value during momentary overload conditions. This allows the amplifier to recover quickly after an overload occurs.

If the d-c level at the input rises, this d-c signal cannot pass directly to the input grid but charges C25 through R1 in the low-pass filter. The d-c signal component is amplified in the stabilizer section and applied to the grid of V2a. A d-c signal is, therefore, amplified by a factor equal to the gain of the d-c section multiplied by that of the stabilizer. A-C signal voltages pass through C1 to the grid of V1a. Stabilization techniques are concentrated in the first stage because any drift originating here is amplified by the following stages.

The input stage is followed by cathode follower V1b, pentode amplifier V3a, and cathode follower V3b. Output from V3b drives a "totem-pole" output circuit** composed of V4 and V5. The operating point of V1b is controlled by the 100,000 ohm potentiometer, R54 in its cathode circuit. (This is the BALANCE control located on the front panel.) To balance, the pushbutton is depressed, disabling the stabilizer, and the BALANCE potentiometer is adjusted, after which the automatic balancing circuit assures control. (Sub-paragraph b below provides further information on adjustment of the BALANCE control.) Output of V1b is taken from a tap on the voltage divider and direct-coupled to the grid of V3a, the pentode portion of a type 6U8 tube. The pentode is direct-coupled to the cathode follower V3b which drives the grids of V4 in parallel. The two output tubes V4 and V5 are connected in series between the +300V and –300V power supplies. The output tubes operate Class B with low quiescent plate current. If the grid voltage at V4 rises, conduction increases and plate voltage decreases. As a result, the grid bias of V5 increases, and the plate-cathode impedance does likewise so that current flows through the external load and V4. A voltage change in the negative direction on the grid of V4 decreases the current through it and causes V5 to conduct. Current through the load is opposite in direction to that described above. R8, C3, and C27 are used in a feedback network which is partly responsible for the broadband characteristics of the amplifier. C2 and C12 in the cathode circuits compensate for the lag introduced by the grid-plate capacitance of the tubes.

b. Stabilizer Circuit. The automatic balancing circuit of the d-c amplifier consists of the synchronous vibrator D1 and the triode-pentode tube V6 (type 6AW8). The purpose of this section is to compensate for drift in the d-c portion, *automatically*. Output of the stabilizer is applied to the second grid (V2a) of the differential input stage of the d-c amplifier. Refer to figure 7 which shows the way the stabilizer is connected. The summing point 0 must be maintained essentially at zero potential by the amplifier. Any variation of the output voltage above or below the required value causes point 0 to become slightly positive or negative. This voltage change is coupled through the low-pass filter to the contact of chopper D1. For the purpose of the following explanation assume that the voltage at the output of the d-c amplifier rises slightly. This is referred to as a positive drift. Point 0 becomes slightly positive and this voltage is chopped at a 94 cps rate by D1 and applied to the input capacitor of the stabilizer section in the form of a square wave. The square wave is amplified by

*Korn and Korn, Electronic Analog Computers, P. 209, 235

**Millman and Taub, Pulse and Digital Circuits, P. 99

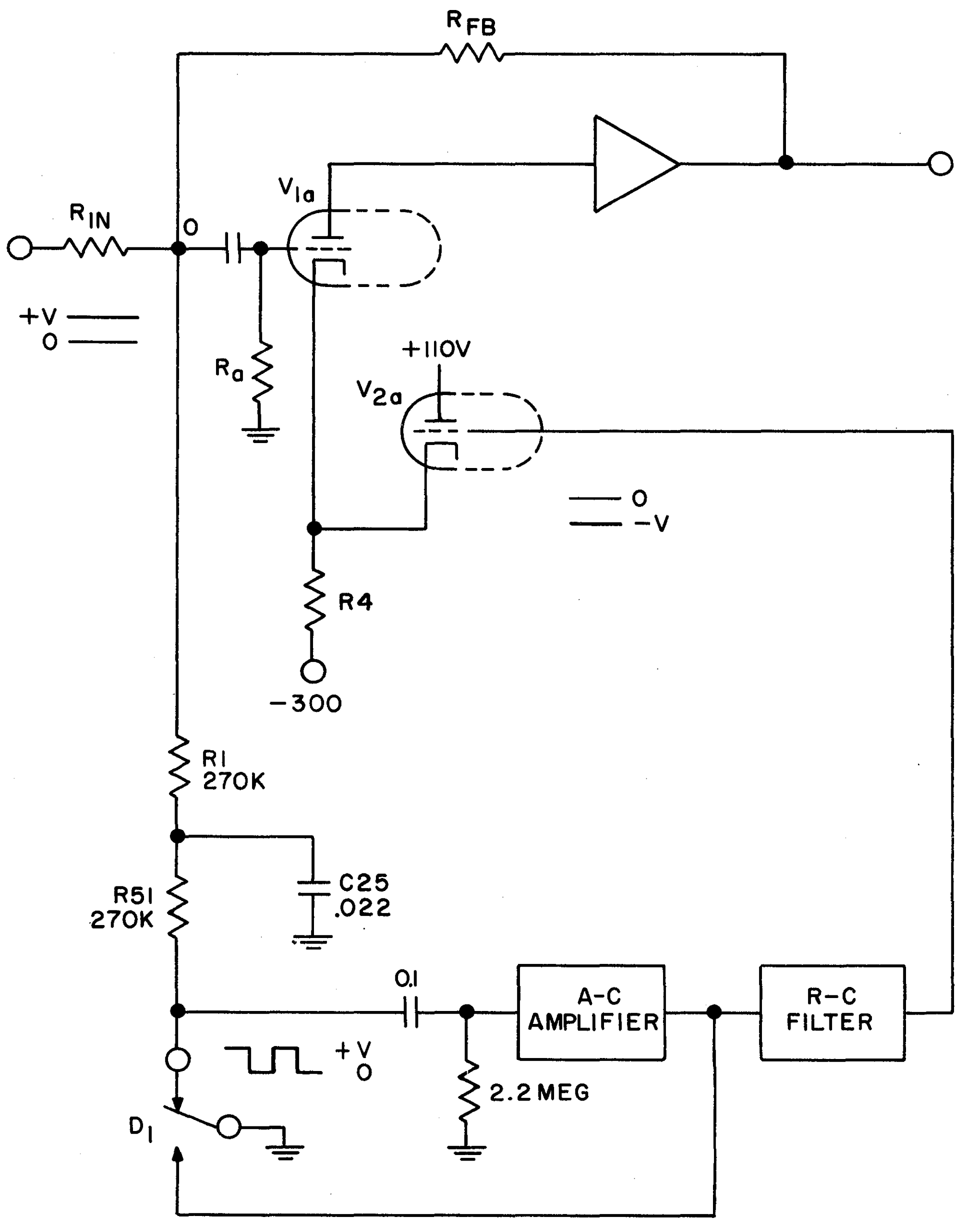


Figure 7. Amplifier Stabilizer Operation.

about 10,000 in the two sections of the 6AW8 tube and appears at the output with the same polarity. The second contact of D1 restores the d-c reference level to the signal. The RC filter composed of R25 and C12 provides d-c output which is then applied to the grid of V2a. The polarity of this signal is negative and this causes V2a to draw less current; its cathode potential drops along with that of V1a. When this effect on V1a is passed along through the d-c amplifier, and the grid of V5 becomes less positive; the tube draws less current through the load and the output voltage drops. In this way, the original positive drift voltages are removed. The amplifier is balanced in the following manner:

(1) Depress the BALANCE pushbutton on the front panel. (This disconnects the stabilizer circuit from the amplifier.)

(2) Rotate the potentiometer until the neon light is extinguished.

(3) Release the pushbutton. (This restores the stabilizer circuit to normal operation.)

8. SPARE PARTS LIST

Reference Symbol	Description
C1, C6, C13, C18	Capacitor; fixed, polystyrene 0.1 mfd ±5% 200V Southern Electronics #SEC 1507
C2, C14	Capacitor; fixed, ceramic 33 ±3.3 mmfd 500V, Erie #GP1K (EAI 515 030 0)
C3, C15	Capacitor; fixed, ceramic 680 ±68 mmfd 500V, Erie #GP2K (EAI 515 048 0)
C4, C16	Capacitor; fixed, ceramic disc 12 mmfd ±10%, 1000V, Cornell Dubilier "Tinymike" #C10Q12C
C5, C17	Capacitor; fixed, ceramic disc 2700 mmfd ±20%, 1000V, Cornell Dubilier, "Tinymike" #L10D27
C7	Capacitor; fixed, electrolytic, 50-50 mfd 6V, Mallory Type "PET"
C8, C11, C20, C23	Capacitor; fixed, ceramic .05 mfd ±20%, 500V Sprague "Type" #36C142A1
C9, C21	Capacitor; fixed, ceramic 5±.5 mmfd 500V, Erie #GP1K

Reference Symbol	Description
C10, C22	Capacitor, Electrolytic, 50 mfd 6V Sprague #TE1100
C12, C24	Capacitor; fixed mylar 2 mfd 200V, Southern Electronics #SEC 1506
C25, C26, C33, C34	Capacitor; fixed, ceramic .02 mfd ±20% 500V Sprague "Type" #36C201A
C27, C28	Capacitor; fixed, ceramic disc 2.2 mmfd 1000V, Cornell Dubilier "Tinymike" #C10 V22C, (EAI 515 048 0)
C29, C30	Capacitor; fixed, ceramic .0018 mfd ±20%, 1000V, Sprague "Type" #19C217A
CR1 through CR4	Diode; Hughes type #HD6008 (EAI 614 007 0)
D1	Chopper: Stevens-Arnold #CH500-94 or James, C1978EA adjusted for operation of 94 cps.
P1	Connector, Printed Circuit Amphenol #133-817
I1, I2	Lamp, Neon #NE2D
XI1, XI2	Lamp, Holder, Dialco #137-7236-937
R1, R26, R51, R52	Resistor; fixed, comp., 270K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 274 1)
R2, R16, R27, R41	Resistor; fixed, comp., 2.2 megohm ±10%, 1/2W Allen-Bradley EB (EAI 626 225 1)
R3, R28	Resistor; fixed, comp., 180K ohms ±10%, 1W Allen-Bradley GB (EAI 627 563 1)
R4, R29	Resistor, fixed, comp., 100K ohms ±10%, 2W Allen-Bradley HB (EAI 628 104 1)
R5, R30, R6, R31	Resistor; fixed, comp., 47K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 473 1)
R7, R10, R24, R32, R35, R49, R55, R56	Resistor; fixed, comp., 100K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 104 1)

Reference Symbol	Description
R8, R33	Resistor; fixed, comp., 560K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 564 1)
R9, R34	Resistor; fixed, comp., 56K ohms ±10%, 2W Allen-Bradley HB (EAI 628 563 1)
R11, R19, R20, R36, R44, R45	Resistor; fixed, comp., 1 megohms ±10%, 1/2W Allen-Bradley EB (EAI 626 104 1)
R12, R37	Resistor; fixed, comp., 470K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 474 1)
R13, R38	Resistor; fixed, comp., 33K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 333 1)
R14, R15, R39, R40	Resistor; fixed, comp., 1.8K ohms ±10%, 2W Allen-Bradley HB (EAI 628 182 1)
R17, R21, R42, R46	Resistor; fixed, comp., 220K ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 224 1)
R18, R23, R43, R48 R62 through 69	Resistor; fixed, comp., 820 ohms ±10%, 1/2W Allen-Bradley EB (EAI 626 821 1)
R22, R47	Resistor; fixed, comp., 47K ohms ±10%, 2W Allen-Bradley HB (EAI 628 473 1)
R25, R50, R58, R59	Resistor; fixed, comp., 10 megohms ±10%, 1/2W Allen-Bradley EB (EAI 626 106 1)
R53, R54	Resistor; variable, comp., 100K ohms ±10%, 2W Allen-Bradley #JU1041-P3056
S1, S2	Switch; pushbutton, Mallory #B-PBZ-2 (EAI 656 010 0)
V1, V2, V7	Tube; electron, type 6072 (EAI 562 046 0)
V3, V8	Tube; electron; type 6U8 (EAI 562 052 0)
V4, V5, V9, V10	Tube; electron, type 5965
V6, V11	Tube; electron, type 6AW8 (EAI 562 051 0)

Figure 1
Schematic D010 001 0S
Wiring D010 001 0W

1. GENERAL

Regulated Power Supply 10.001 provides 300 volts of regulated d-c power at 2 amperes from a 115 volt 60 cycle source. Also included in this unit are two sources of filament power of 6.3 volts at 45 amperes each. The component is considerably lighter than comparable power supplies due to the incorporation of a special type of power transformer and a highly efficient metallic rectifier. The Power Supply is constructed on a U-shaped chassis of the plug-in type to facilitate maintenance and handling.

2. TECHNICAL DATA

Front Panel

Height.......... 7 inches
Width.......... 19 inches

Chassis

Height.......... 7 inches
Width..........19-1/2 inches
Depth.......... 14-7/8 inches

Weight of Unit

90 pounds

Tube Complement

4 each – 6336
1 each – 6U8
1 each – 5651
1 each – 12AX7

Input Power

See figure 2

Unregulated Output Voltage

390 volts d-c

Regulated Output Voltage

290 to 310 volts d-c (Adjustable)

Low-Voltage Outputs

Two separate, identical, 6.3 volt, 45 ampere, centertapped outputs.

Output Impedance

Less than 0.2 ohms at frequencies up to 6 KC.

Controls

VOLTAGE ADJUST located on front panel. RIPPLE ADJUST located on front panel.

Unit Terminations

Input and output terminations are made at two standard connectors. Terminal numbers for each function are listed below.

Terminal Number	Termination
P1-1	115V, 60 cps input to filament transformers
P1-2	Centertap of filament transformer T2 secondary
P1-3	115V, 60 cps input to filament transformers (common)
P1-5	390 volts d-c, unregulated
P1-6, 7	300 volts d-c, regulated output
P1-9, 10	Connection for external stabilizer. Install jumper when stabilizer is not used.
P1-11	Connection for external reference. When external reference is not used, jumper to terminal 12.
P1-12, 13	300 volts d-c, regulated output, common side
P1-A1, A2	6.3V a-c at 45 amperes
P2-1	115 volts, 60 cps, input to plate transformer (hot)
P2-2	Centertap of filament transformer T3 secondary
P2-3	115 volt, 60 cps input to plate transformer (common)
P2-13	Chassis Ground
P2-A1, A2	6.3V a-c at 45 amperes

3. DETAILED CIRCUIT DESCRIPTION

a. As indicated in schematic diagram D010 001 0S, the circuit consists of these parts:

D-C power supply (Sola Electric Co. D.C. Power Supply #28389)

Power Supply Regulator 43.001

Series-type regulator consisting of four type 6336 vacuum tubes

Three filament transformers

The power supply rectifies and filters the output of the high voltage transformer and supplies 390 volts unregulated d-c to terminal 5 of P1. The series regulator, consisting of four type 6336 tubes in parallel, is connected between the un-

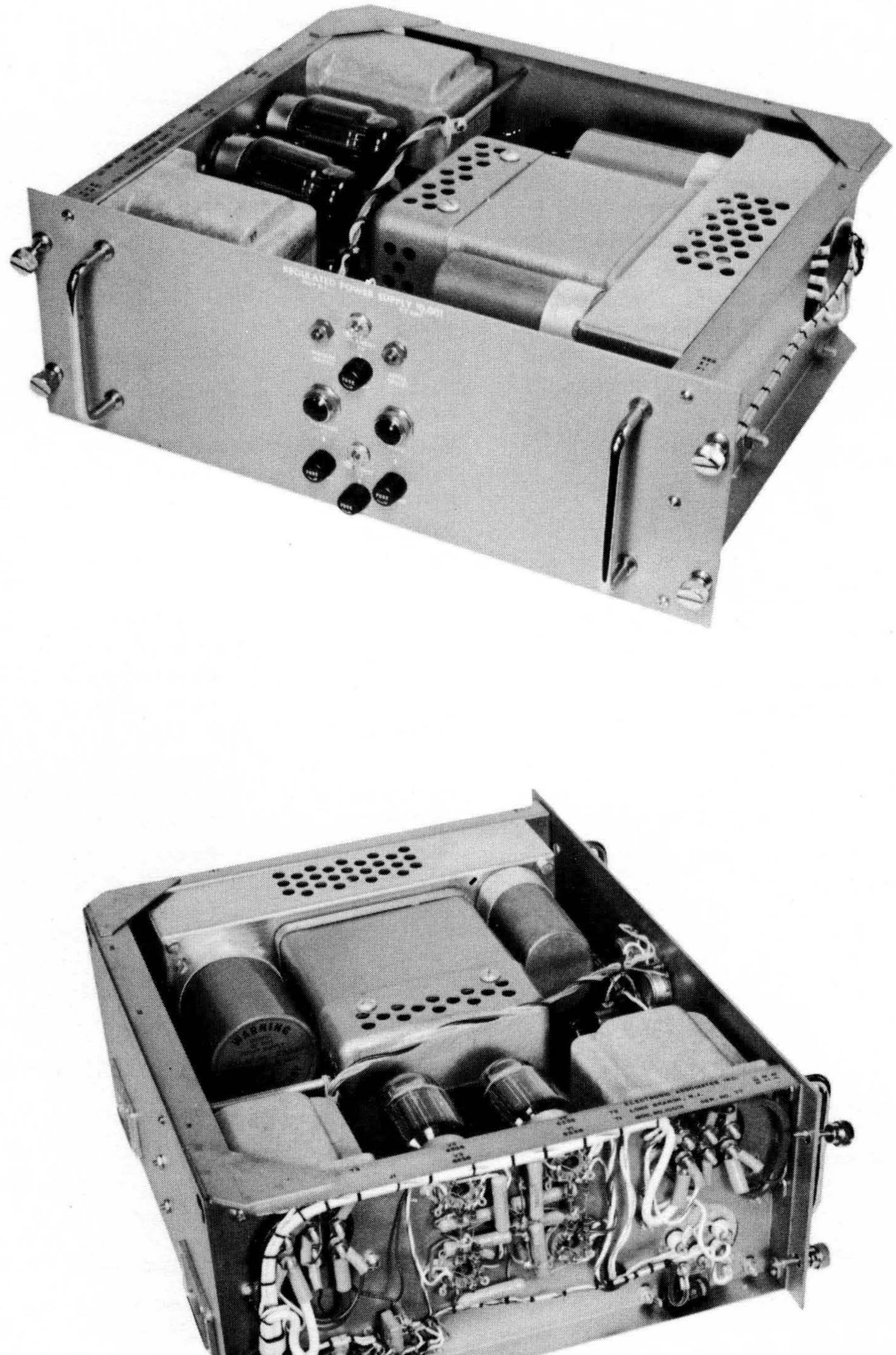


Figure 1. Regulated Power Supply 10.001.

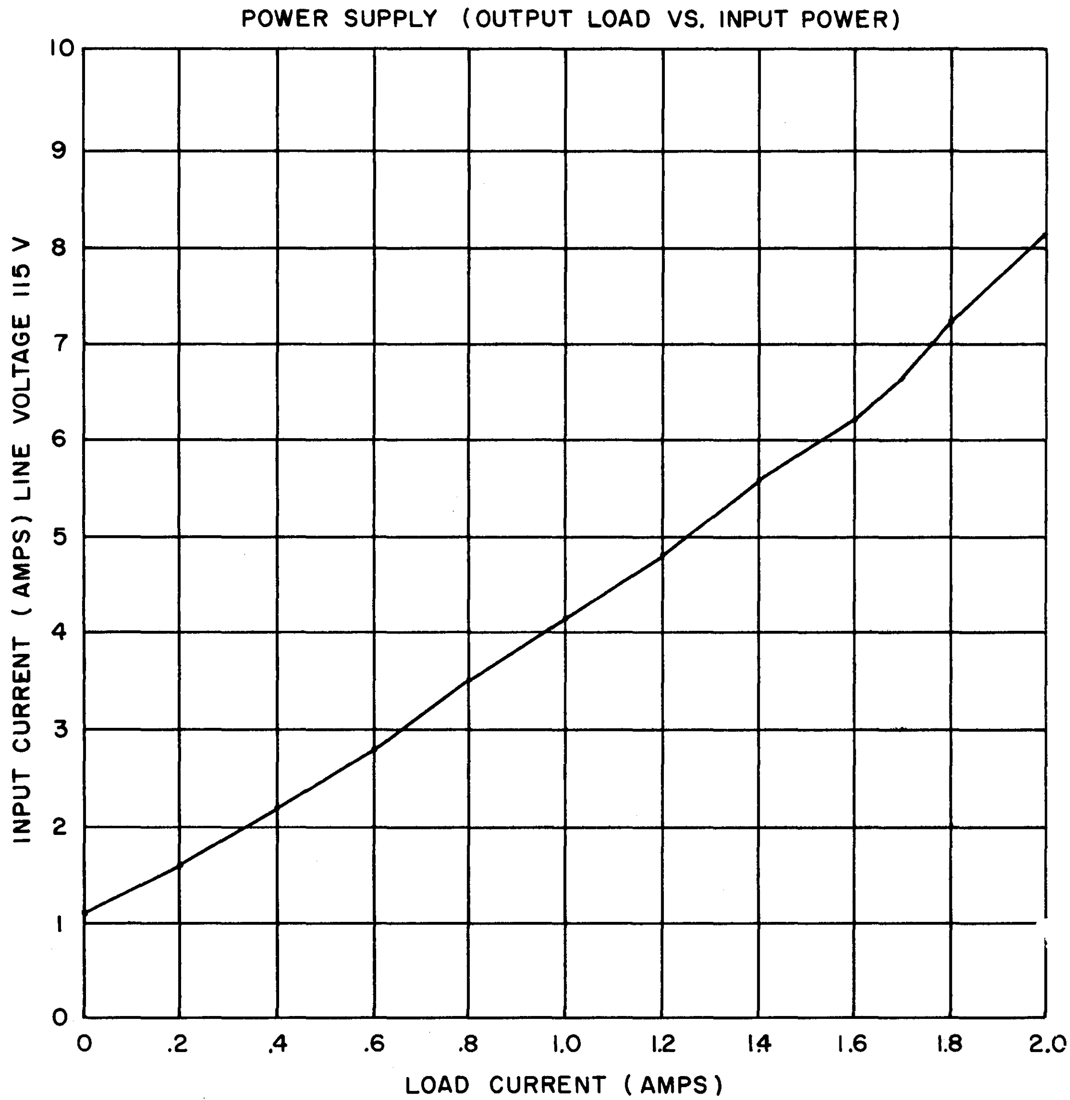


Figure 2. Input Power Requirements.

regulated supply and terminals 6 and 7 of P1. The resistance of these tubes is dependent upon the grid bias which is supplied from the output of the Regulator Amplifier.

The filament transformers supply the heaters of tubes in the power supply and those in external equipment.

b. The Sola Electric Co. D-C Power Supply contains a constant voltage transformer, rectifier, and filter.

The transformer includes three windings: the primary; a resonant winding (the lower secondary winding on the diagram, with two taps); and a compensating winding (the upper secondary on the schematic). When alternating current is impressed across the primary, the magnetic flux induces a voltage in the tuned secondary (tuned by the two 5MFD capacitors). When the flux density of the core increases to the point at which the inductive reactance of the winding equals the capacitive reactance of the two capacitors at the frequency of the exciting voltage, the circuit becomes resonant, and the voltage across it increases rapidly to a stable, predetermined value. This, in effect, increases the flux density of that part of the core on which the resonant winding is wound. Further changes in flux produced by line voltage changes in the primary cause only small variations in voltage across the resonant circuit. The upper secondary shown (compensating winding) is used to compensate for these small variations.

Output is taken from a tap on the resonant winding. The compensating winding is connected in series opposition with the output. This winding is so proportioned that the voltage change induced by a given change in primary voltage is about equal to the change in the output. Therefore, the output voltage remains constant regardless of changes in the primary. Output is constant within ±1% with line voltage variations of ±15%.

The current limiting properties of the constant voltage transformer allow the use of a high capacity filter with the silicon diode bridge rectifier, eliminating the need for a choke. The transformer limits the current supplied to the large filter capacitor and will not allow the capacitor to draw more than the rated output through the rectifiers. When the supply is first energized, the capacitor is charged slowly without a large surge.

c. The Regulator Amplifier 43.001 detects any change in the regulated output voltage, amplifies and inverts the voltage variation in a d-c amplifier, and applies the resulting signal to the grids of the four regulator tubes. Refer to figure 3. The grid of V2b is connected to a voltage divider (R11, R12, R21) across the output of the 300 volt supply. Any change in the output is amplified and inverted in this triode. Capacitor C3 provides a low impedance coupling to the grid for high frequency transient voltages. The signal appearing at the plate of V2b is coupled to the grid of the cathode-follower V1b. Since this tube and V1a have a common cathode resistor, the signal is impressed upon the cathode of V1a and amplified again. Grid no. 1 of V1a is connected to another voltage divider (R3, R4) across the output of the supply. A portion of any change in the output voltage appears at this grid and is amplified in V1a. Both signals have the same effect on the plate voltage of V1a; a rise in output voltage of the supply drives the cathode of V1a down and grid no. 1 more positive; the tube draws more current through the plate load resistor R1. The series regulator grids are directly coupled to this plate through 4,700-ohm resistors. When the grids become less positive, the internal plate-cathode resistance of the regulators increases. The voltage drop across the regulators increases, causing a smaller drop across the load on the output of the supply.

Grid no. 2 of V1a is connected to a voltage divider (R2, R22, R5) between the unregulated (+390V) voltage and ground. Since the screen voltage-plate current characteristic curve for the 6U8 is quite linear over a wide range, this circuit is effective in cancelling any ripple voltage present at the output of the filter. The RIPPLE ADJUST control R22, adjusts the operating point of the screen on the above-mentioned curve. Adjustment is made at the time of manufacture by observing the ripple-content of the supply output on an oscilloscope and adjusting R22 for minimum ripple.

V2a maintains a fixed cathode bias for the operation of V2b. The plate is connected directly to the regulated +300 volt output; the grid is held at 84 volts by the gas filled regulator tube V3 (5651). The tube establishes a cathode potential of +85 volts at the top of R9 (47K). This, together with the position of the tap on R21, determines the operating point of V2b and the "no-signal" voltage at the plate which, when impressed upon the next two stages, determines the plate-to-cathode resistance of the series regulator tubes. It serves, therefore, as the output voltage adjustment because the output is taken from across a portion of the voltage divider consisting of the series regulator tubes, R11, R21, and R12.

Use of another triode (V2a) to establish operating conditions for the input tube V2b is a superior method to circuits using a gas tube in the cathode circuit. The transient noise spikes characteristic of glow discharge tubes can be filtered easily in the grid circuit by the RC filter R8, C1 and C2.

Since the cathodes of V1 and V2 are operated at relatively high potentials, (158 volts and 85 volts respectively), the filament source for these tubes is returned to a 150-volt point. This bias is provided by R13 and R14, connected in series across the 300-volt output of the supply.

V1 – 6U8

Pin No.	Tube Element	Voltage
1	Plate-Triode Section	+310
2	Control Grid-Pentode Section	+170
3	Screen Grid-Pentode Section	+200
4	Filament	+150
5	Filament	+150
6	Plate-Pentode Section	+310
7	Cathode-Pentode Section	+175
8	Cathode-Triode Section	+175
9	Grid-Triode Section	+170

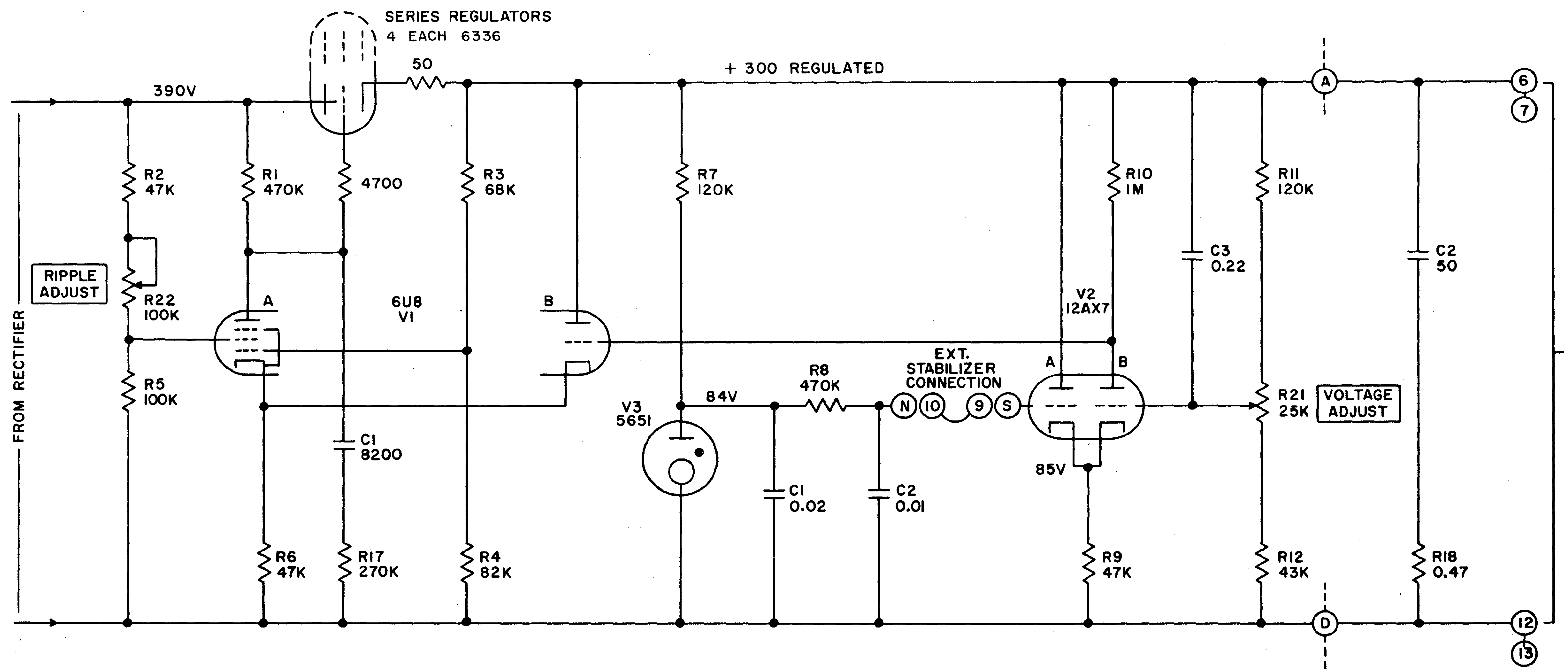


FIGURE 3.
SIMPLIFIED SCHEMATIC OF VOLTAGE
REGULATOR AND REGULATOR AMPLIFIER
CIRCUITS, 10.001 POWER SUPPLY

V2 – 12AX7

Pin No.	Tube Element	Voltage
1	Plate – V2b	+175
2	Grid – V2b	+85*
3	Cathode – V2b	+90
4	Filament V2a, V2b	+150
5	Filament V2a, V2b	+150
6	Plate V2a	+310
7	Grid V2a	+85*
8	Cathode V2a	+90

All voltages are measured with respect to terminal P1-12 with a 20,000 ohms-per-volt meter, except grid potentials of V2.

* These measurements made with VTVM.

External stabilization may be used if desired. Terminals P1-9 and P1-10 are normally jumpered. If an external stabilizer is used, the jumper is removed and the stabilizer connected across these terminals with the output going to P1-9.

d. The series regulator consists of four type 6336 triode tubes in parallel. This high perveance tube was developed especially for regulator service. In the circuit the 6336 operates with about a 78 volt plate-to-cathode voltage and a 12.5 volt drop across the cathode resistor, delivering 250 ma. under full load. The internal plate-cathode resistance of the tube is determined by the bias on the grid which is varied about the 12.5 volt level by the regulator amplifier.

e. The three filament transformers T1, T2, and T3 are rated at 6.3 volts a-c at 45 amperes. T1 supplies the filaments of the power supply regulator amplifier. T2 and T3 are used for supplying filament voltage to external equipment.

4. PARTS LIST

This section lists all replaceable parts in the Model 10.001 Power Supply. In each case the reference symbol (schematic designation) is listed, together with a brief description and manufacturer's part number.

The components in this list that are indicated by an asterisk (*) are standard electronic components that are usually available at any commercial electronic supply house. In order to expedite obtaining these parts, it is suggested that they be purchased from a local source whenever possible. If necessary the items may be ordered from Electronic Associates, Inc.

Certain components in this parts list contain *only* an EAI number. These items are custom-made components or proprietary items that are available only from EAI. When ordering components 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.

Those components in the parts lists that are *not* asterisked, but contain both an EAI and a manufacturer's number, 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 of this nature.

Please note that EAI reserves the right to make part changes and substitutions when required; in all cases EAI guarantees that these substitutions are electrically and physically compatible with the original component.

Reference Symbol	Description
	Assembly, Power Supply Regulator (See Separate List) EAI 43.001
C1*	Capacitor, fixed, mica: 8200 mmfd, ±10% 500V; EAI 519 050 0 (CM35B822K)
C2*	Capacitor, fixed, electrolytic: 50 mfd, ±25%, 450V; Mallory NP-4505 (EAI 516 033 0)
C3*	Capacitor, fixed, paper: .047 mfd, ±20%, 400V; Aerovox P88N (EAI 520 053 0)
F1*	Fuse: 12 ampere, Littelfuse 314012 (EAI 570 122 0)
F2, F3, F4*	Fuse, 3 ampere, Littelfuse 313003 (EAI 570 112 0)
I1, I2*	Lamp, Incandescent: 6T 4-1/2-120 EAI 578 007 0
R1, R4,* R5, R8, R9, R12, R13, R16	Resistor, fixed, composition: 4700 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 472 1)

Reference Symbol	Description
R2, R3,* R6, R7, R10, R11, R14, R15	Resistor, fixed, wirewound: 500 ohms ±5%, 10W; Ward-Leonard 10X50WL (EAI 636 069 0)
R17*	Resistor, fixed, composition: 270,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 274 1)
R18*	Resistor, fixed, wirewound: 0.47 ohms ±10%, 1W; IRC BW-1 (EAI 636 094 0)
R19, R20*	Resistor, fixed, composition: 200 ohms ±10%, 1W; Allen-Bradley HB (EAI 627 201 1)
R21*	Resistor, variable, composition: 25,000 ohms ±10%, 2W; Allen-Bradley JLU2531 SD4040L (EAI 642 014 0)
R22*	Resistor, variable, composition: 100,000 ohms ±10%, 2W; Allen-Bradley JLU1041 SD4040L (EAI 642 017 0)
T1, T2, T3	Transformer, filament: EAI 684 079 0
V1, V2, V3, V4	Tube, Electron: Type 6336; EAI 562 049 0

a. POWER SUPPLY REGULATOR 43.001

Reference Symbol	Description
C1*	Capacitor, fixed, ceramic, disc: .02 mfd, 600V; Centralab DD-203 (EAI 515 001 0)
C2*	Capacitor, fixed, ceramic: .1mfd, 300V; Sprague 3GAB-P1 (EAI 515 067 0)
C3*	Capacitor, fixed, paper: .22 mfd, 600V; Aerovox P151N (EAI 520 063 0)
C4*	Capacitor, fixed, plastic: 0.1 mfd, 400V; Hopkins P14M (EAI 521 054 0)
R1, R8*	Resistor, fixed, composition: 4,700 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 474 1)
R2, R6, R9*	Resistor, fixed, composition: 47,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 473 1)
R3*	Resistor, fixed, composition: 68,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 683 1)
R4*	Resistor, fixed, composition: 82,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 823 1)
R5*	Resistor, fixed, composition: 100,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 104 1)
R7*	Resistor, fixed, composition: 120,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 124 1)
R10*	Resistor, fixed, composition: 1 meg, ±10%, 1/2W; Allen-Bradley EB (EAI 626 105 1)
R11	Resistor, fixed, wirewound, precision: 120,000 ohms ±1.0%, Stability .005%, EPR PC-18; EAI 638 064 0
R12	Resistor, fixed, wirewound, precision: 43,000 ohms ±1.0%, Stability .005%, EPR PC-18; EAI 638 063 0
R13, R14*	Resistor, fixed, composition: 220,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 224 1)
R15*	Resistor, fixed, composition: 27,000 ohms ±10%, 1/2W; Allen-Bradley EB (EAI 626 273 1)
V1*	Tube, Electron: Type 6U8 (EAI 562 052 0)
V2*	Tube, Electron: Type 12AX7 (EAI 562 035 0)
V3*	Tube, Electron: Type 5651 (EAI 562 006 0)

Figure 1
Schematic C010 017 0S
Wiring D010 017 0W

1. GENERAL

Regulated Power Supply 10.017 contains two separate regulated power sources, independent of each other except for a common power transformer. The upper section shown on the schematic delivers 200 volts regulated d-c, at 80 ma, the lower section furnishes 110 volts regulated d-c at 500 ma. In most applications of this supply the 200 volt section is connected to the -300 volt supply in the computer in order to obtain -500 volts. The +110 volt supply is used for plate and screen voltages in the d-c amplifier.

2. TECHNICAL DATA

Front Panel

Height.................................2-15/16 inches
Width.....................................9-7/16 inches

Chassis

Height.................................. 2-3/4 inches
Width..................................7-15/16 inches
Depth................................... 14-3/4 inches

Weight of Unit

7.5 lbs.

Tube Complement

12AX7	–	2 each
5651	–	2 each
6U8	–	2 each
6BX7	–	1 each
6528	–	1 each

Power Input

115 volts 50-60 cps, 1 amp. (approx.)
6.3 volts 60 cps, 2.25 amp.
6.3 volts, 60 cps, 5.75 amp.

Regulated Output Voltages

200 volts d-c, 80 ma.
110 volts d-c, 500 ma.

Low Voltage Outputs

6.3 volts, 60 cps, 2 amp.

Output Impedance

0.025 ohms up to 20KC
Not more than 1 ohm up to 600KC

Controls and Indicators

110V ADJ...
Located on front panel, potentiometer adjustment of 200 volt output.

200V ADJ...
Located on front panel, potentiometer adjustment of 200 volt output.

PLATE...
Red light indicated when plate power is applied.

Unit Terminations

All connections to the unit are made at connector P_1. Refer to figure 1. The function of each terminal of P_1 is indicated below.

Terminal Number	Function
A1	6.3 volts, 60 cps; filament power for V1, V3, V4
A2	6.3 volts, 60 cps; filament power for V1, V3, V4
1	6.3 volts, 60 cps; filament power for V6, V7, V8
2	6.3 volts, 60 cps; filement power for V6, V7, V8
3	110 volt d-c output, positive terminal
4	110 volt d-c output, negative terminal
6	115 volt 60 cps input to transformer primary
7	115 volt 60 cps input to transformer primary
8	6.4 volt 60 cps output, 2 amp.
9	200 volt d-c input to regulator
10	6.4 volt 60 cps output, 2 amp.
11	200 volt output, positive terminal
12	200 volt output, negative terminal
13	Chassis ground

3. DETAILED CIRCUIT DESCRIPTION

Reference to schematic drawing C010 017 0S reveals the upper and lower circuits to be almost identical. Because of this, the upper supply shown is described in detail here. At the end of this description the differences in the lower supply are enumerated.

Each power supply can be divided into three parts for the purpose of explaining its operation. They are:

Transformer and full-wave rectifiers
Regulator (d-c) amplifier
Series Regulator

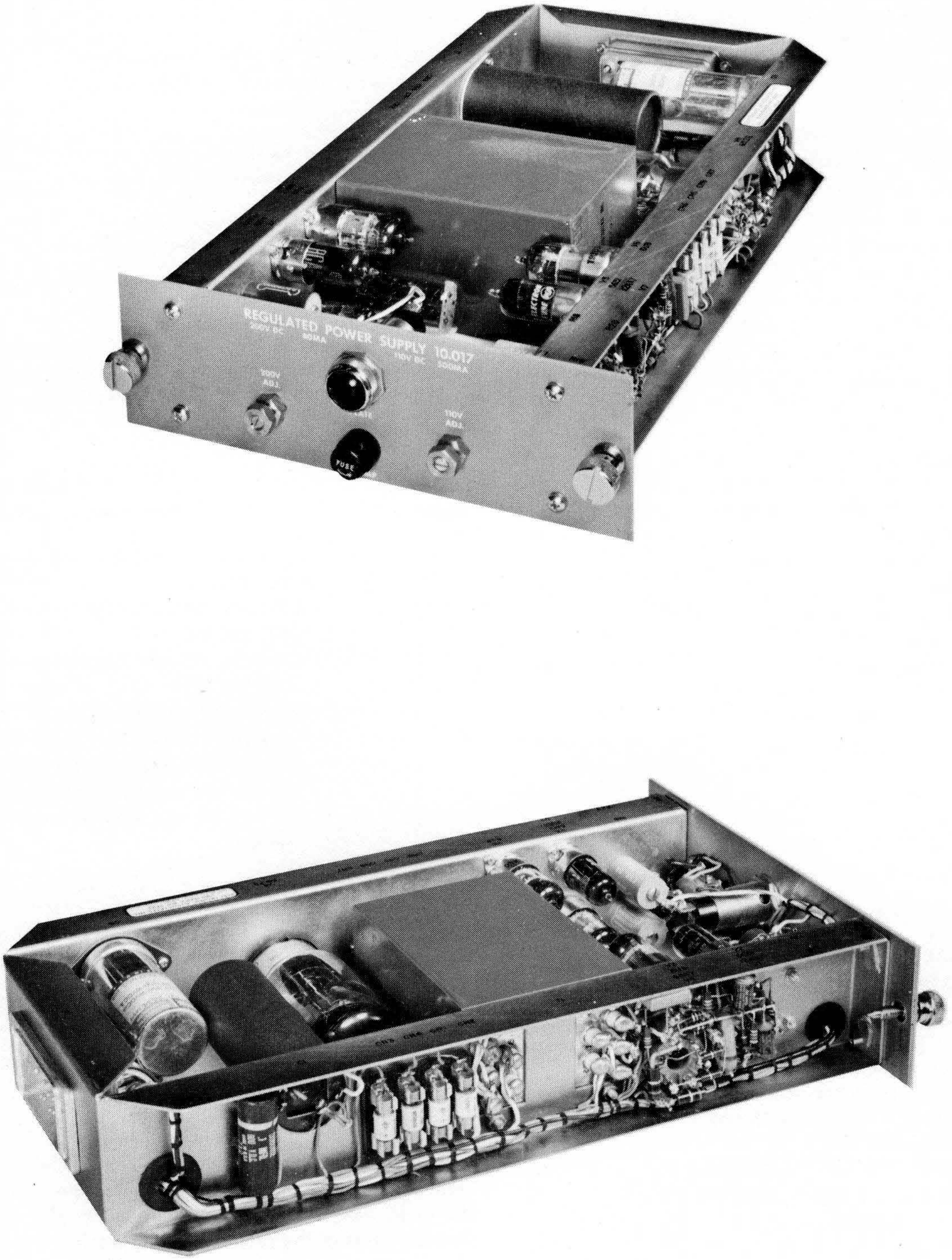


Figure 1. Regulated Power Supply 10.017.

The upper winding of the transformer develops about 285 volts either side of the center tap. This voltage is rectified by the four silicone diodes CR1–C44 in a full wave connection.

The Regulator Amplifier detects any change in the regulated output voltage, amplifies and inverts it in a d-c amplifier, and applies the resulting signal to the grids of the two triode regulators. Refer to the schematic. The grid of V1b is connected to a voltage divider (R15, R16, R17) across the output of the supply. Any change in the output is amplified and inverted in this triode. Capacitor C4 provides a low impedance coupling to the grid for high frequency transient voltages (noise). The signal appearing at the plate of V1b is coupled to the grid of the cathode-follower V3a. Since this tube has its cathode resistor in common with V3b, the signal is impressed upon the cathode of V3b and amplified again. Grid No. 1 of V3b is connected to another voltage divider (R9, R10) across the output of the supply. A portion of any change in the output voltage appears at this grid and is amplified in V3b. Both signals have the same effect on the plate voltage of V3b; a rise in output voltage of the supply drives the cathode of V3b down and its grid No. 1 more positive; the tube draws more current through its plate load resistor R3. The series regulator grids are directly coupled to this plate through a 1,500-ohm resistor. When the grids become less positive, the internal plate-cathode resistance of the regulators increase. The voltage drop across the regulators increases and there is less drop across the load on the output of the supply.

Grid No. 2 of V3b is connected to a voltage divider (R1, R2) between the unregulated voltage and ground. Since the screen voltage-plate current characteristic curve for the 6U8 is quite linear over a wide range, this circuit is effective in cancelling any ripple voltage present at the output of the filter.

V1a maintains a fixed cathode bias for the operation of V1b. The plate is connected directly to the regulated 200 volt output; the grid is held at 84 volts by the gas filled regulator tube V2 (5651). The tube establishes a cathode potential at the top of R14 (47K) which, together with the position of the tap on R16, determines the operating point of V1b and the "no signal" voltage at its plate which, when impressed upon the next two stages, determines the plate-to-cathode resistance of the series regulator tubes. It serves, therefore, as the output voltage adjustment because the output is taken from across a portion of the voltage divider consisting of the series regulator tubes, R15, R17, R16. All the components in the regulator amplifier are designed to serve one purpose, that of controlling the resistance of the regulator tubes.

Use of another triode (V1a) to establish operating conditions for the input tube V1b is a superior method to circuits using a gas tube in the cathode circuit. The transient noise spikes characteristic of glow discharge tubes can be filtered easily in the grid circuit by the RC filter R12, C2, C3.

The series regulator consists of a type 6BX7 dual triode with the two sections in parallel.

The internal plate-cathode resistance of the tube is determined by the bias on the grid which is varied about the 12.5 volt level by the regulator amplifier.

The filament winding is rated at 6.4 volts a-c at 2 amperes and is used for supplying indicator lamp voltage to external equipment.

The lower power supply shown on the schematic delivers 110 volts at 500 ma. The principle differences are found in the No. 2 grid circuit of the 6U8 and that of V7a. A lag network composed of C8 and R31 is connected across the grid No. 2 input to compensate for the lead introduced into the 120 cycle component of input signal by C6. The lag network effectively places the signal at the No. 2 grid in phase with that at the No. 1 grid of the pentode which provides excellent ripple filtering action.

The grid circuit of V7a is modified in such a way that the grid is attached to a point on the voltage divider R25, R26, and R27 which is maintained at about 42 volts through the action of V5.

The relay K1 shown on the schematic is a protective device. If the output voltage increases to +160 volts, the relay will energize and open the load circuit, thereby protecting the quadruple d-c amplifiers.

4. SPARE PARTS LIST

Reference Symbol	Description
C1a, b	Capacitor; fixed, electrolytic, daul 80-40 mfd; Sprague #TVL 2634; 350V
C2, C6, C8	Capacitor, fixed, paper 0.1 mfd 200V; Aerovox P82Z

Reference Symbol	Description
C3, C7	Capacitor; fixed, paper .02 mfd 200V; Aerovox P82Z
C4	Capacitor; fixed, paper .047 mfd 200V; Aerovox P85N
C5a, b	Capacitor; fixed, electrolytic, dual 80-40 mfd; Sprague #TVL 2778; 450V
C9	Capacitor, fixed, paper 0.1 mfd 600V; Aerovox P85N
CR1-8	Rectifier; silicon; Sparkes Tarzian M500
F1	Fuse; 2 amp; Littelfuse #313002
I1	Lamp; incandescent; #6R 4-1/2/120
R1, R2, R11, R22, R38	Resistor; fixed, 100K ±10% 1/2W, EAI 626 104 1
R3, R12, R32	Resistor, fixed, comp., 470K ±10%, 1/2W; EAI 626 474 1
R4, R6	Resistor; fixed, comp., 1500 ohms ±10%, 1/2W; EAI 626 152 1
R5, R7	Resistor, fixed, comp., 27 ohms ±10%, 1W; EAI 627 270 1
R8, R14	Resistor; fixed, comp 47K ±10% 1/2W; EAI 626 473 1
R9, R28	Resistor; fixed, comp., 82K ±10%, 1/2W; EAI 626 823 1
R10, R26, R30	Resistor; fixed, comp., 68K ±10%, 1/2W; EAI 626 683 1
R13, R23	Resistor; fixed, comp., 1.0 meg ±10%, 1/2W; EAI 626 105 1
R15	Resistor; fixed, WW precision 100K ±1% stability .005% EPR #N113E
R16	Resistor; variable, 25K ohms ±10%; Mallory #M25MPK
R17	Resistor; fixed, WW precision 51K ±1% stability .005%; EPR #N113E
R18	Resistor; fixed, WW precision 62K ±1% stability .005% EPR #N113E
R19	Resistor; variable; 10K ohms ±10%, Mallory #M10MP
R20	Resistor; fixed, WW precision 39K ±1% stability .005%; EPR #N113E
R21	Resistor; fixed, WW power 5K ±5% 10W; EAI 636 020 0
R24, R31, R40, R41	Resistor; fixed, comp., 27K ±10%, 1/2W; EAI 626 273 1
R25, R26	Resistor; fixed, comp. 100K ±5%, 1/2W; Allen Bradley EB EAI 626 104 0
R27	Resistor; fixed, comp., 10K ±10%, 1/2W; Allen Bradley EB, EAI 626 103 1
R29	Resistor; fixed, comp., 33K ±10%, 1/2W; Allen Bradley EB, EAI 626 333 1
R33, R34	Resistor; fixed, comp., 10 ohms ±10%, 2 watt; Allen Bradley HB, EAI 628 100 1
R35, R36	Resistor; fixed, comp., 1K ±10% 1/2W; Allen Bradley EB, EAI 626 102 1
R37	Resistor; fixed, comp., 120K ±10%, 1/2W; Allen Bradley EB, EAI 626 124 1
R39	Resistor; fixed, comp., 220 ohms ±10%, 1 watt; Allen Bradley GB, EAI 627 221 1
T1	Transformer; EAI B684 070 0
V1, V7	Tube, electron; type #12AX7
V2, V5	Tube, electron; type #5651
V3, V6	Tube, electron; type #6U8
V4	Tube, electron; type #6BK7
V8	Tube, electron; type #6528 (Catham only)
K1	Relay, GE #3S2791G200-A13 EAI 618 019 0
XV2, XV5	Socket: Tube; 7 Pin Min, Elco #235 BC
XV4, XV8	Socket: Tube; Octal, Eby #9751-3

Reference Symbol	Description	Reference Symbol	Description
XK1	Socket; Viking VB8/3DV3	XI1	Pilot Lamp Assembly; Dialco #721515-111
XCR1 through 4	Fuse Block; Littelfuse #099063	XV1, XV7, XV3, XV6	Socket; Tube; Noval, Elco #169 BC
XF1	Fuse Holder; Bus #HKP		

Figure 1
Schematic C043 003 0S
Wiring D043 003 0W
Reference and Check Amplifier Network 12.098

1. GENERAL

These two units are considered at the same time because they operate together and the circuit operation of one cannot be described without involving the other. Two Reference Regulators and one Reference Network are required for a complete ±100 volt reference supply. Figure 2 is a block diagram of the +100 reference supply showing the components of Network 12.098 and within the dashed lines, the amplifier, stabilizer and BALANCE potentiometer that comprise the Regulator Amplifier. K1, in the position shown, connects 6.5 volt point on the voltage divider R11, R12, to the stabilizer input. The top of the voltage divider is connected to a source of +100 volt reference which is derived from another console in the system. This permits slaving of the Reference Regulators in all consoles. The output voltage may be set by adjusting R19 of network 12.098. With relay K1 energized, the 6.5 volt mercury cell serves as the standard. The stabilizer contains a chopper which samples the output of the cell and compares it with a tap on the divider composed of R8, R9 and R10. If there is any difference between the two voltages, it is amplified in an a-c amplifier (stabilizer section) rectified, filtered, and applied to the amplifier section as a correction voltage.

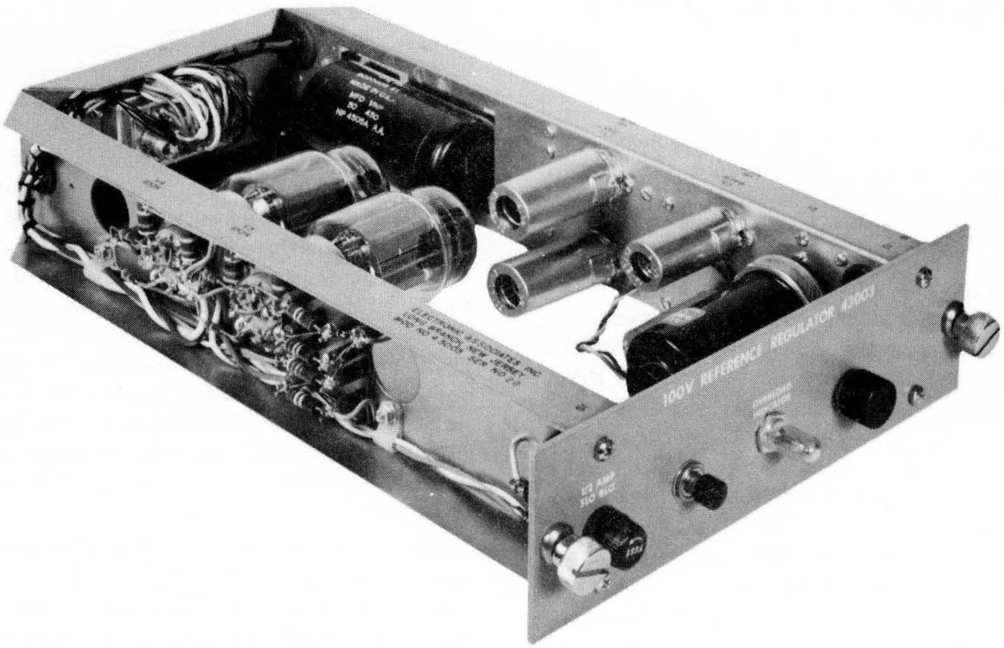
2. AMPLIFIER SECTION

The schematic diagram has been simplified and rearranged in figure 3 showing only the amplifier section of the Reference Regulator, and associated resistors of network 12.098. (See fig. 5.)

Two type #6528 dual triode tubes are connected as series regulators, the four triodes being in parallel with each other, and each in series with the load. The load is represented in the drawing by the resistors shown by dotted lines connected from the cathodes to ground of the 6528's. The grids of the regulators are controlled by the output of a d-c amplifier composed of V1 and V2. The regulator tubes may be considered to act as a series rheostat, the resistance of which is controlled by the grid voltage. Assume, as an example, that a heavy load is connected to the output at A. For an instant the reference voltage drops. The change in voltage is transferred to the grid of V2a by means of the voltage divider R3 (NTWK), R1, and R4 (NTWK), and the 1 megohm resistor R2. As the voltage on the grid drops, the voltage on the plate of V1a rises; this rise is coupled directly to the grid of V2a, the triode section of 6U8. This tube draws more current and the cathode potential increases. The cathode of V2a is directly coupled to that of V2b. Raising the cathode potential of V2b has the same effect as increasing its negative grid bias; the tube conducts less current and the voltage at its plate becomes more positive. This increase in voltage is the control voltage for the regulator tube grids and is coupled to the grids through the 4700 ohm resistors. The increasing positive voltage on the regulator grids causes internal resistance of the tubes to decrease; more current is conducted through them, and through the load resistors connected in series with their cathodes, until the voltage drop across the load is again equal to exactly 100 volts.

Notice that the grid of V2b is also controlled so that a decrease in the output voltage causes this grid to become more negative at the same time that its cathode is rising, as described above. The combined effect of these two simultaneous actions is to decrease the grid bias quickly causing the tube's plate current to drop and its plate voltage to rise. Greater control is achieved by the two methods applied simultaneously then would be possible using only one.

The series resistors in the grid and cathode circuits of the 6528 regulator tubes prevent parasitic oscillations at high frequencies. Without the resistors the tubes behave as tuned-plate, tuned-grid oscillators with the wiring, and lead length in the tubes themselves, supplying the resonant circuit. Capacitor C2 connected in series with R12 to ground from the regulator grids aids further in preventing oscillation by providing a low impedance coupling to the grid of V1a for higher frequencies such as are caused by rapid changes in the output load value. This tends to minimize "noise" in the output also. C10 connected directly across the output to ground helps to prevent any rapid fluctuations in the output voltage. The grid of V1b is used to inject the correction voltage from the stabilizer. The action involved here is described below. Relay K1 is normally energized from the relay power supply when the plate voltage of the computer is turned on. It remains energized for all positions of the MODE switch except the SLAVE. In this mode, the relay drops out and the normally closed contacts select a +100 volt reference from the remote master com-



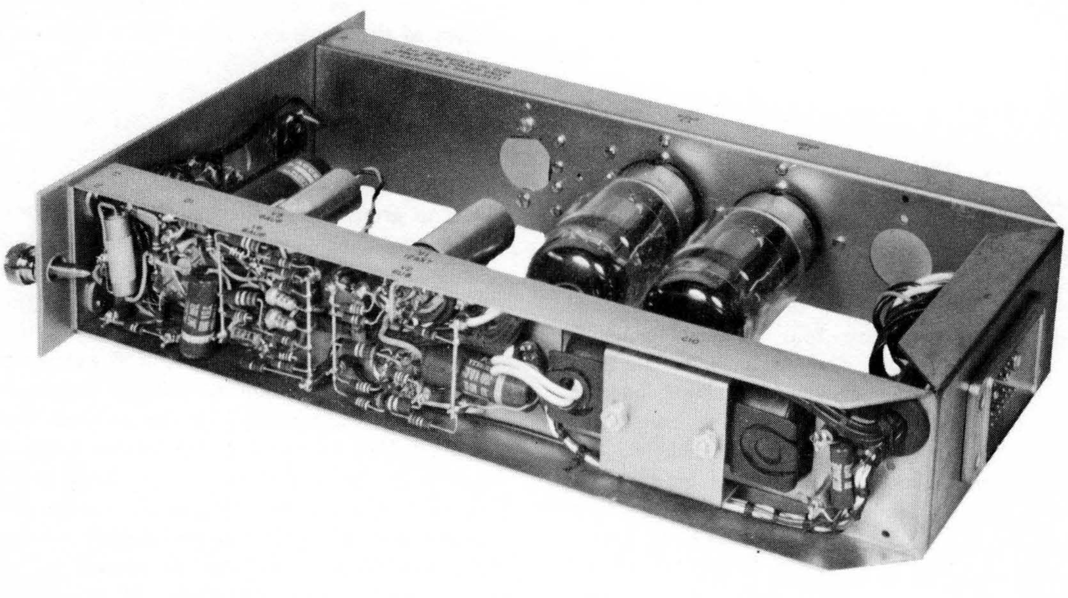


Figure 1. Reference Regulator 43.003.

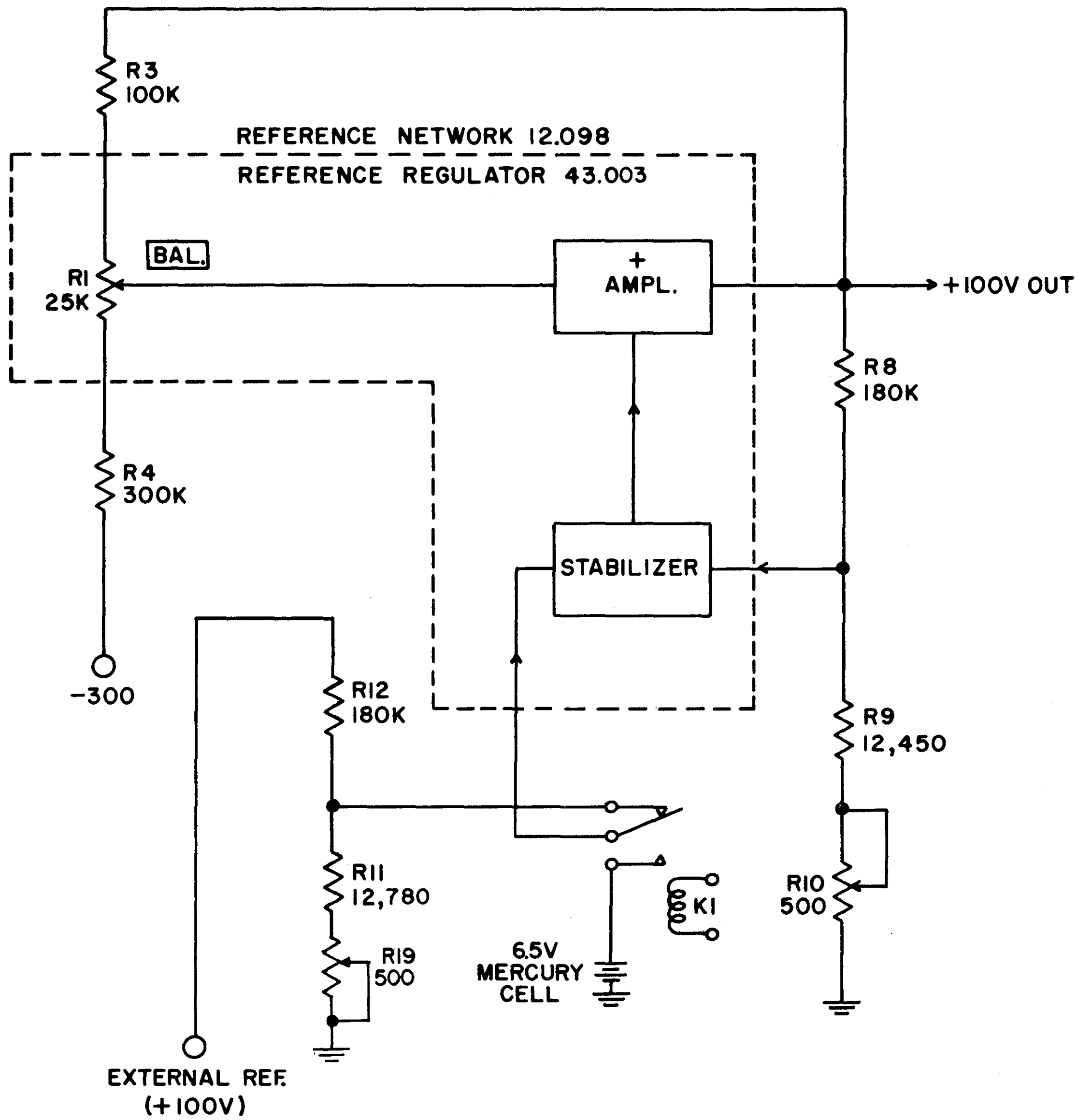


Figure 2. Block Diagram, +100 Volt Reference Source.

puter for the reference standard, instead of the mercury cell.

3. STABILIZER

This circuit consists of two pentode tubes (type 6AU6) V5, and V6 connected as a resistance-coupled amplifier, and a synchronous vibrator operating at a frequency of 60 cycles. The first section of the synchronous vibrator D1 compares the voltage at the divider output with the standard cell voltage and transmits the difference to the grid of V5 (through the coupling capacitor C3) in the form of a square wave. This wave is amplified by V5 and V6, then rectified by the second section of the vibrator, which also establishes the d-c reference level of the stabilizer output. R32 and C9 comprise a filter. The d-c output of the stabilizer is fed to the grid of V1b in the amplifier section. If the stabilizer is called upon to deliver a large voltage, the neon bulb OVERLOAD INDICATOR I1 ignites, and an audible alarm sounds. The audible overload alarm is external to Reference Regulator.

The way in which the stabilizer operates to maintain the Reference Regulator output at a constant value is explained as follows. As shown in figure 2, the voltage divider R8, R9, R10 is

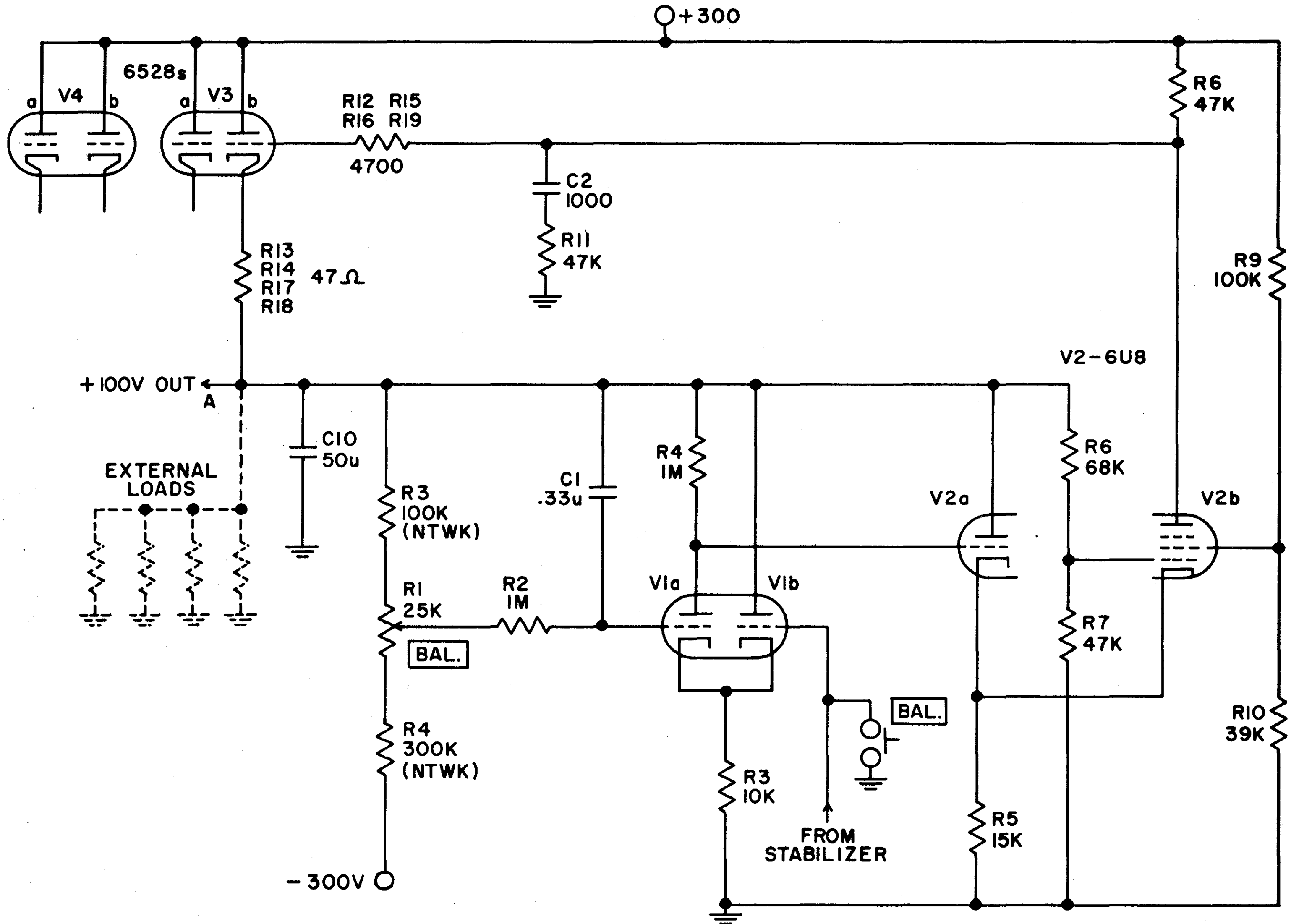


Figure 3. Amplifier Section of Reference Regulator 43.003.

connected from +100 volt output to ground. The voltage at the junction of resistors R8 and R9 is almost exactly 6.5 volts. It is this point which is connected to terminal 18, labelled DIVIDER OUTPUT on schematic C043 003 0S.

Terminal 25 is the 6.5 volt mercury cell connection. As long as terminals 5 and 7 of D1 are both 6.5 volts, there is no input to the amplifier. If the divider output voltage changes, a square wave is developed which is amplified, rectified, and filtered. The chopper restores the d-c level in such a way that a drop in the output voltage of the Reference Regulator causes the stabilizer to produce a positive going d-c signal. This signal, when applied to the grid of V1b changes the bias on V1a because of the common cathode resistor. The cathode voltage is reduced and the effect is to raise the grid voltage on the regulators, which boosts the output voltage.

The OVERLOAD INDICATOR glows whenever there is any appreciable output from the stabilizer. Therefore it can be used as a means of setting the BALANCE CONTROL at the input of the Regulator Amplifier. The BALANCE pushbutton is depressed, shorting the grid of V2b to ground and the BALANCE control is adjusted until the OVERLOAD indicator is extinguished. When the pushbutton is released, the stabilizer again controls the bias on V1a.

4. THE –100 VOLT REFERENCE REGULATOR

The –100 Volt Reference Regulator operates in exactly the same manner as the +100 volt unit. However, it is connected somewhat differently (see fig. 4). Referring to the schematic, C043 003 0S, terminal 14 is returned to –300 volts instead of ground. The grid of the input tube operates

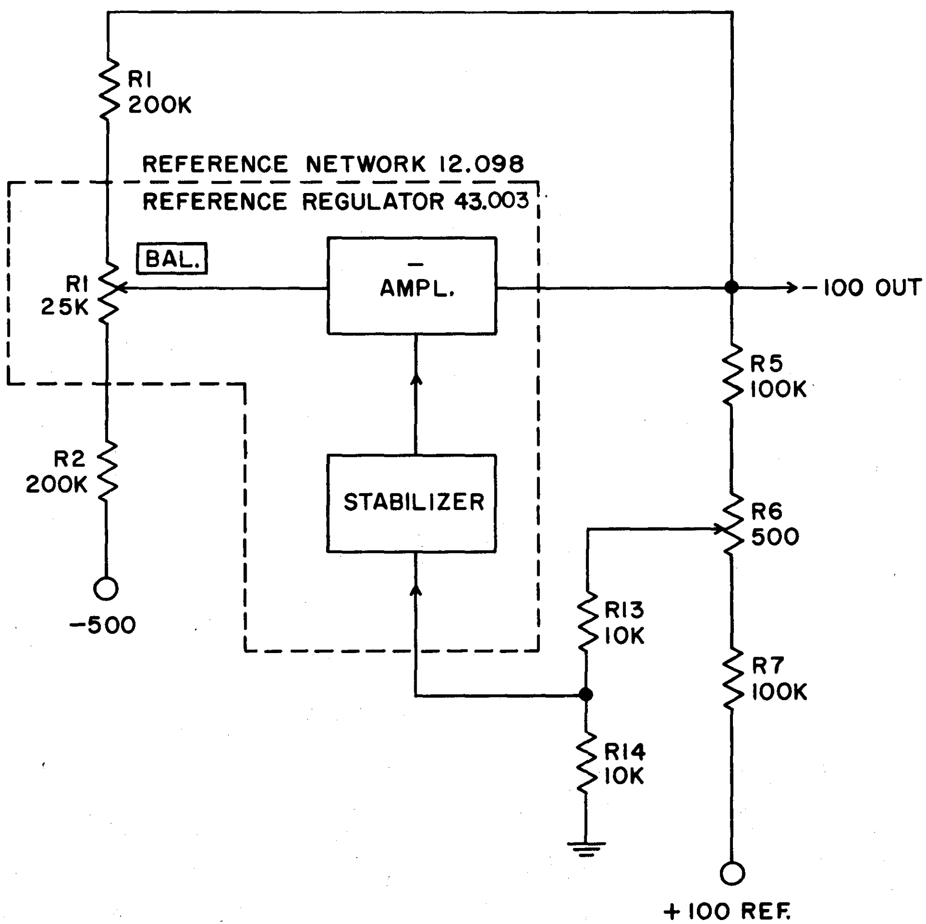


Figure 4. Block Diagram –100 Volt Reference Source.

near the −300 volt level. The plates of V1 and V2 are connected to −100 volts. Input to the stabilizer is obtained from the center of the voltage divider composed of R5, R6, R7 in the network.

5. PARTS LIST

Reference Symbol	Description
C1	Capacitor; 0.33 mfd 200V Aerovox Duranite type P88N
C2	Capacitor; ceramic, insulated, Erie #GP2L 1000 ±100 mmfd
C3	Capacitor; .047 mfd 100V Aerovox Hyvol "W" type P123WGP
C4	Capacitor; ceramic, insulated, Erie GP1L 56 ±5.6 mmfd
C5, C7	Capacitor; 10 mfd 25V Fansteel #PP10B25A2
C6	Capacitor; .022 mfd 400V Aerovox Duranite type P88N
C8	Capacitor; .047 mfd 600V Aerovox Duranite type P88N
C9	Capacitor; .47 mfd 100V Aerovox Hyvol "W" type P123WGP
C10	Capacitor; 50 mfd 450V Mallory type NP4505
C11	Capacitor; ceramic, insulated Erie GP1K 100 ±10 mmfd
C12	Capacitor; 0.01 mfd 400V Aerovox Duranite type P88N
CR1, CR2	Diode; Hughes HD6008
D1	Chopper; Stevens-Arnold #A12-12 W/#252-04 connector
F1	Fuse 1/2 Amp (S60 B60) Littelfuse #313.500
I1	Lamp; Neon #NE-2D
R1	Resistor; variable, WW Mallory #M25MP
R2, R4, R31	Resistor; 1.0 meg ±10%, 1/2W AB
R3	Resistor; 10K ±10%, 1/2W AB
R25, R30	Resistor; 15K ±10%, 1/2W AB
R6	Resistor; 68K ±10%, 1/2W AB
R7, R35, R11, R20	Resistor; 47K ±10%, 1/2W AB
R8	Resistor; 470K ±10%, 1/2W AB
R33, R34	Resistor; 100K ±10%, 1/2W AB
R10	Resistor; 39K ±10%, 1/2W AB
R12, R15, R16, R19	Resistor; 4700 ±10%, 1/2W AB
R13, R14, R17, R18, R41, R44	Resistor; 47 ±10%, 2W, AB
R21, R26	Resistor; 2.2 meg ±10%, 1/2W AB
R22, R27	Resistor; 1500 ±10%, 1/2W AB
R23, R28	Resistor; 470K ±10%, 1/2W AB
R24, R29	Resistor; 180K ±10%, 1W AB
R32	Resistor; 22 meg ±10%, 1/2W AB
R40	Resistor; 10 meg ±10% 1/2W AB
S1	Switch, Push Button, Subminiature, Micro switch, Cat #2PB7
XF1	Fuse Holder Buss #HKP
XI1	Lamp Base; Dialco #137-7236-937
XV1, XV2	Socket; Tube, 9 Pin Min. Eby #9714-21
V1	Electron tube; type 12AX7
V2	Electron tube; type 6U8
V3, V4	Electron tube; type 6528
V5, V6	Electron tube; type 6AU6
XD1, XV3, XV4, XV7	Socket; Tube; Octal Eby #9751-3
XV5, XV6	Socket; Tube, 7 Pin Min. Eby #9735-11

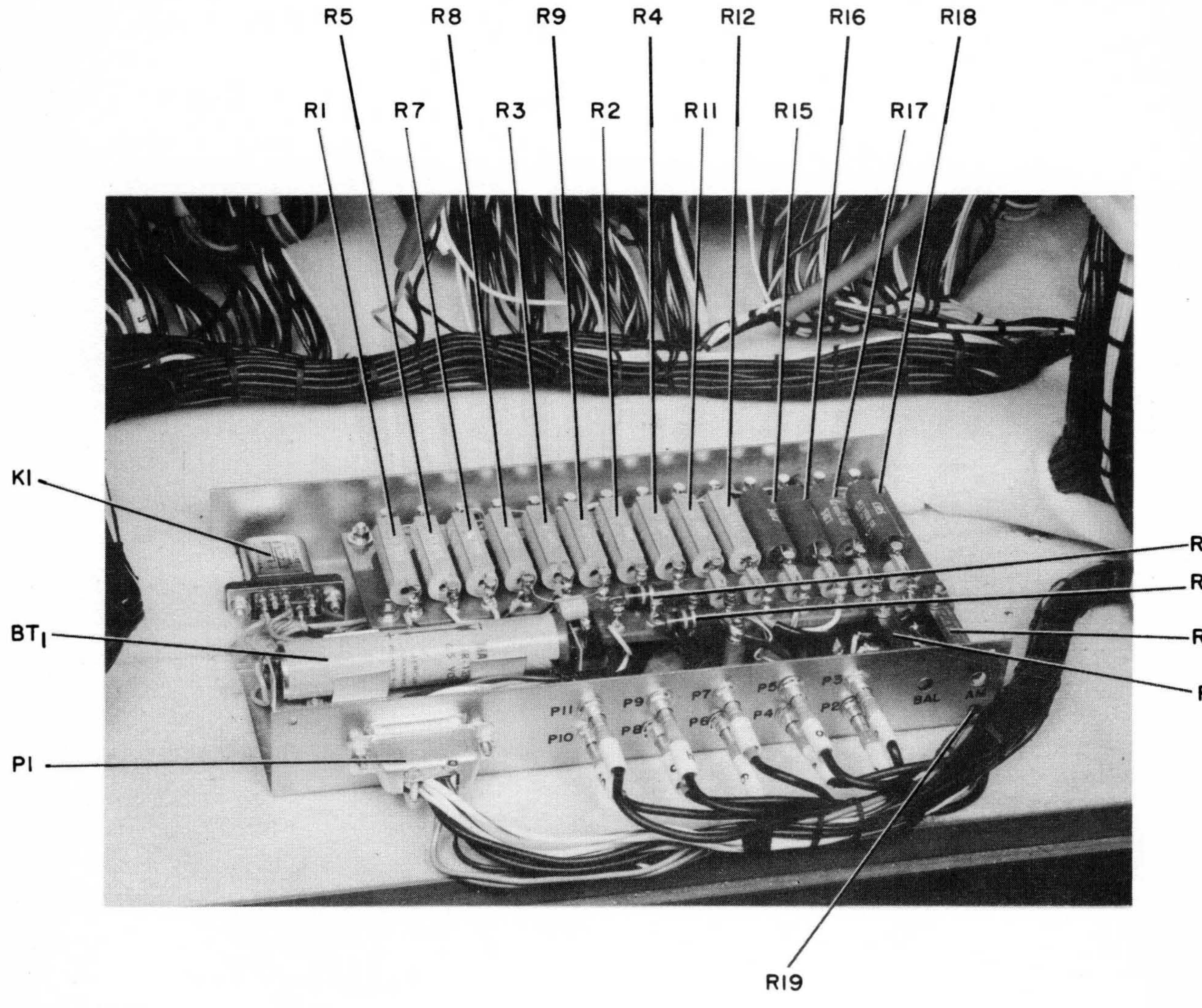


Figure 5. Reference and Check Amplifier Network 12.098.

Schematic B010 002 0S
Figure 1

1. GENERAL

The Power Supply 10.002 (fig. 1) delivers 90 volts d-c at 4 amperes and is used primarily for operating relays in the computer.

2. TECHNICAL DATA

Front Panel

Height..........5 inches
Width..........9-1/2 inches

Chassis

Height..........4-3/4 inches
Width..........7-15/16 inches
Depth..........14-5/8 inches

Weight of Unit

37 pounds

Power Input

115 volts 60 cps; less than 8 amperes maximum.

Power Output

90 volts at 4 amperes maximum

Controls and Indicators

Front panel ON-OFF switch with pilot lamp.

3. CIRCUIT DESCRIPTION

The complete circuit consists of the Sola constant voltage transformer, the full-wave silicon diode rectifier and filter. The transformer contains three windings: The primary; a resonant winding (the lower secondary winding on the diagram with two taps); and a compensating winding (the upper secondary on the schematic). When an alternating current flows in the primary, the magnetic flux induces a voltage in the tuned secondary (tuned by the 6 MF capacitor). When the flux density of the core increases to the point at which the inductive reactance of the winding equals the capacitive reactance of the capacitor—at the frequency of the exciting voltage—the circuit becomes resonant and the voltage across it rises quickly to a stable, predetermined value. This, in effect, increases the flux density of that part of the core on which the resonant winding is wound. Further changes in flux produced by line voltage changes in the primary cause only small variations in voltage across the resonant circuit. The upper secondary shown (compensating winding) is used to compensate for these small variations.

Output is taken from a tap on the resonant winding. The compensating winding is connected in series with the output, and opposed to it. This winding is so proportioned that the voltage change induced in it by a given change in primary voltage is about equal to the change in the output. Therefore, the output voltage remains constant regardless of changes in the primary. Output is constant within ±1% with line voltage variations of ±15%.

The current limiting properties of the constant voltage transformer allow the use of a high capacity filter with the silicon diode bridge rectifier, eliminating the need for a choke. The transformer limits the current supplied to the large filter capacitor and will not allow the capacitor to draw more than the rated output through the rectifiers. When the supply is initially energized, the capacitor is charged slowly without a surge.

4. PARTS LIST

Reference Symbol	Description
	Rectifier Stack, Germanium, full wave GE #4JA211BB1AH3
	Capacitor; fixed, electrolytic, 5000 mfd 100V dc Sola #9890-5
	Resistor; fixed, WW 5000 ohms ±10%, 20 W Ohmite "Brown Devil"
	Transformer; power, constant voltage, with matched 6 mfd 660V ac capacitor, PRI = 100 –130V 60 cps, SEC (output after rect. and filter) = 90V dc 4A, Sola P/O #28734 power supply (special)
	Lamp, indicator, Neon NE 51
	Fuse, 8 amp 32V Littelfuse type 3AG #31108

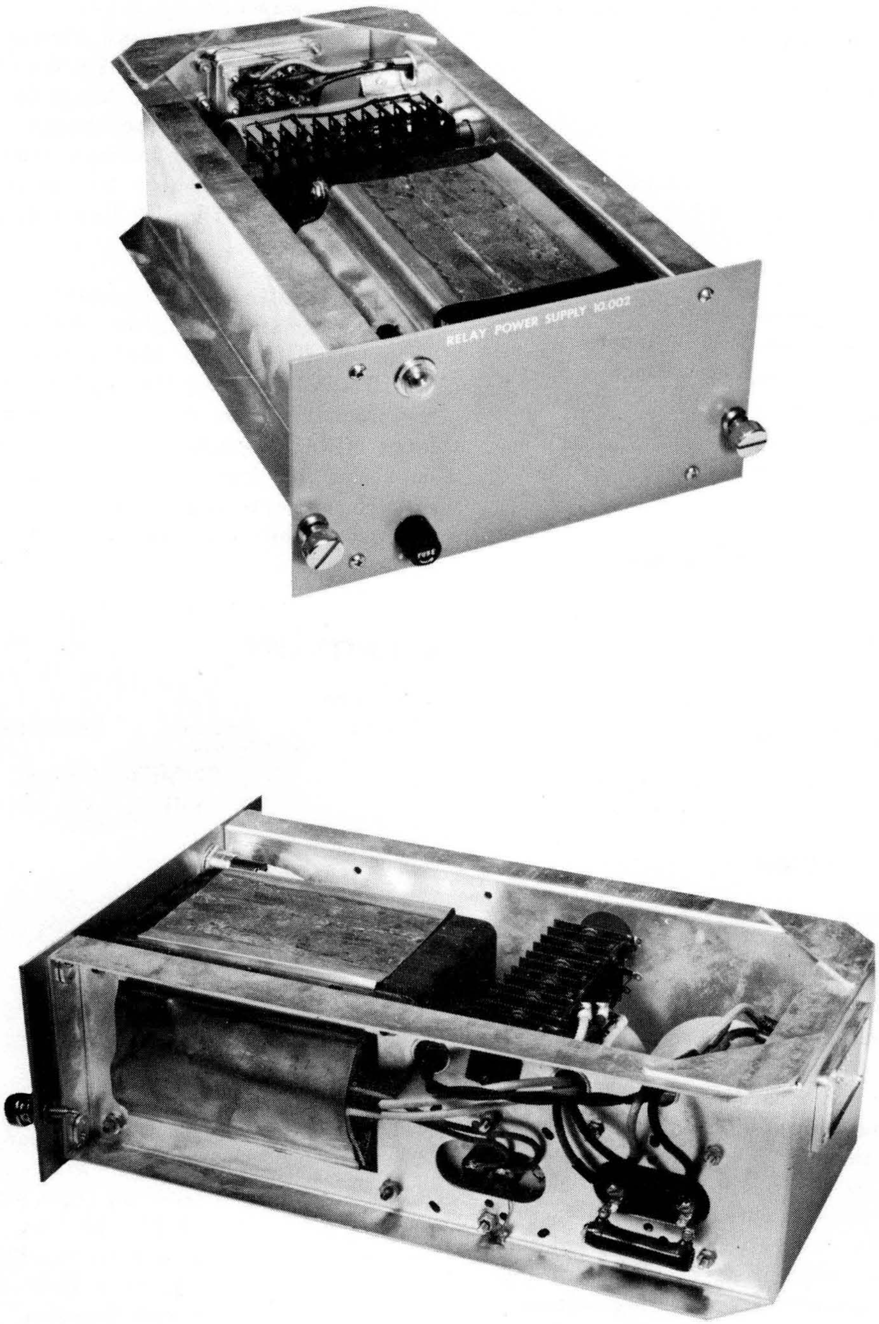


Figure 1. Relay Power Supply 10.002.

Schematic B010 008 0S
Figure 1

1. CIRCUIT DESCRIPTION

In the circuit of figure 2 the grid of V1 is biased by the drop across R1, the collector load resistor. Input is applied between base and emitter; output is taken between collector and emitter. The emitter is the common element making this a "common emitter" circuit.

The emitter is maintained at a constant value of 3 volts positive by the voltage divider R2, R3. Due to the high collector voltage supply (90 volts), the diode is forced to conduct in the reverse direction. The base of Q1 is biased by the potential difference between the arm of R5 and the emitter, and controls the current flow through the transistor. Since Q1 is an NPN type, the more positive the base becomes, the greater will be the collector current. The collector current controls the bias on the grid of V1 because of the drop across R1. Therefore the setting of R5 establishes the normal resistance of V1. This adjustment is used to set the value of load voltage which the regulator is to maintain.

Assume that R5 is adjusted for an output of 25 volts. Then, if the load on the supply is suddenly reduced, the output voltage (instantaneous) will rise; the voltage at the top of R5 rises making the base of Q1 more positive. Collector current increases. This current flows from ground up through the R3 to the emitter, across the emitter and collector barriers (by hole conduction) to the collector, and through R1 to +90 volts. The voltage drop across R1 increases, making the lower end less positive. This less positive voltage applied to the grid of V1 increases the internal resistance of the tube, which is in series with the external load. Thus, the voltage drop across the tube increases and the output voltage of the supply is lowered.

2. PARTS LIST

Reference Symbol	Description
Q1	Transistor, GE, type 2N167
R1	Resistor; fixed, comp., 470K ±10%, 1/2W AB
R6	Resistor, fixed, comp. 8.2K ±10%, 1/2W AB
R4	Resistor; fixed, comp., 82K ±10%, 1/2W AB

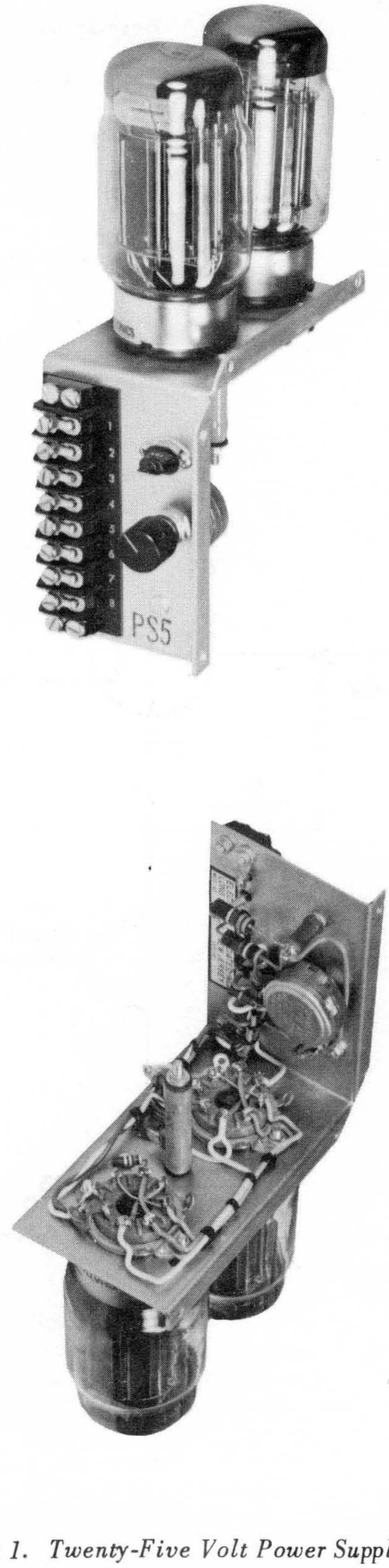


Figure 1. Twenty-Five Volt Power Supply 10.008.

Reference Symbol	Description	Reference Symbol	Description
R2	Resistor; fixed, comp., 300K ±5%, 1W AB	R5	Resistor; variable, comp., AB-JU1031
		V1, V2	Tube; Electron, type 6336
R3	Resistor; fixed, comp., 3300 ±10%, 1W AB	XQ1	Socket, Transistor, (Flat Saddle) Elco #3301
R7	Resistor; fixed, W/W 250 ±5%, 10W WL	XV1, XV2	Socket, Tube Octal, Eby #9751-3

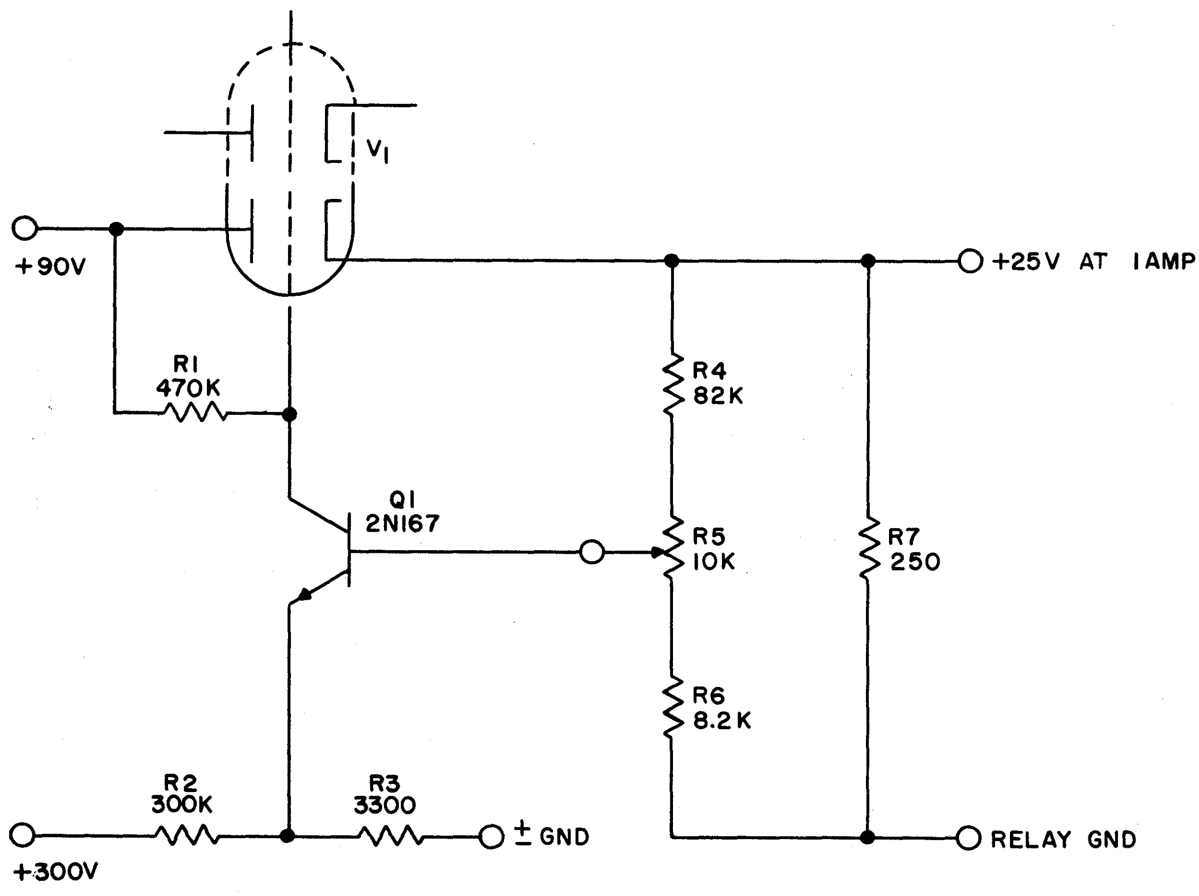


Figure 2. Power Supply 10.008, Simplified Schematic.

1. GENERAL

The Vibrator Drive Unit 21.004 (fig. 1) generates a 94 cycle sinusiodal output voltage used to drive the synchronous converters in the computer. The frequency can be decreased in two one CPS steps, or increased in two steps of one CPS. The unit, mounted on a plug-in U shaped chassis, is designed to function by taking power from either the +300 or −300 volt supply so that power supply loading can be equalized. When a choice is made, power input connections are accomplished according to paragraph 2 below.

In the Electronic Associates Computer Model 231R, the −300 volt supply is used for the principle power source.

2. TECHNICAL DATA

Front Panel

Height .... 2-15/16 inches
Width .... 9-7/16 inches

Chassis

Height .... 2-3/4 inches
Width .... 8 inches
Depth .... 14-5/8 inches

Weight of Unit

9 pounds

Tube Complement

3 each – 12AU7
2 each – 6550

Power Input Connections–

Using +300 Volt Supply

Terminal Number	Function
P1-1	+390V at 200 ma.
P1-2	−300V at 2 ma.
P1-4	±GND
P1-5	6.3V (±gnd) 4.1 Amps
P1-6	No connection
P1-7	6.3V (±gnd) 4.1 Amps.
P1-8	+300V at 40 ma.
P1-9 } P1-11 }	Jumper Externally

Using −300 Volt Supply

Terminal Number	Function
P1-1	+90V at 200 ma.
P1-2	No connection
P1-4	−300V at 40 ma.
P1-5	6.3V (−300V), 4.1 Amps
P1-6	−500V at 2 ma.
P1-7	6.3V (−300V), 4.1 Amps
P1-8	±GND

Output

94 cycles-per-second, center frequency. Two outputs are available: One (high impedance) is variable from zero to about 22 volts for driving Leeds and Northrup Synchronous Converters or similar units; the second output (low impedance) is variable from zero to about 10 volts, normally used to drive converters with 6.3 volt coils.

Power output is 50 watts for either low or high impedance connection; the L and N Converters require about 20 ma. each so the unit will drive 100 or more of these. The 6.3 volt converters require 60 ma. each and about the same number can be operated from the low impedance connection.

Controls

FREQUENCY ....
Selector switch, five positions. Permits adjustment of output frequency in 1 cps step.

AMPLITUDE ....
Permits adjustment of output from zero to 6.3 volts. Should be set at 6 volts vms.

BIAS ....
Screwdriver adjustment on chassis. Allows adjustment of grid bias of push-pull output tubes to −40 volts. (Factory adjusted to this value.)

BALANCE ....
Screwdriver adjustment on chassis. Allows the cathode current of the two output tubes to be equalized. (Factory adjusted for balanced output.)

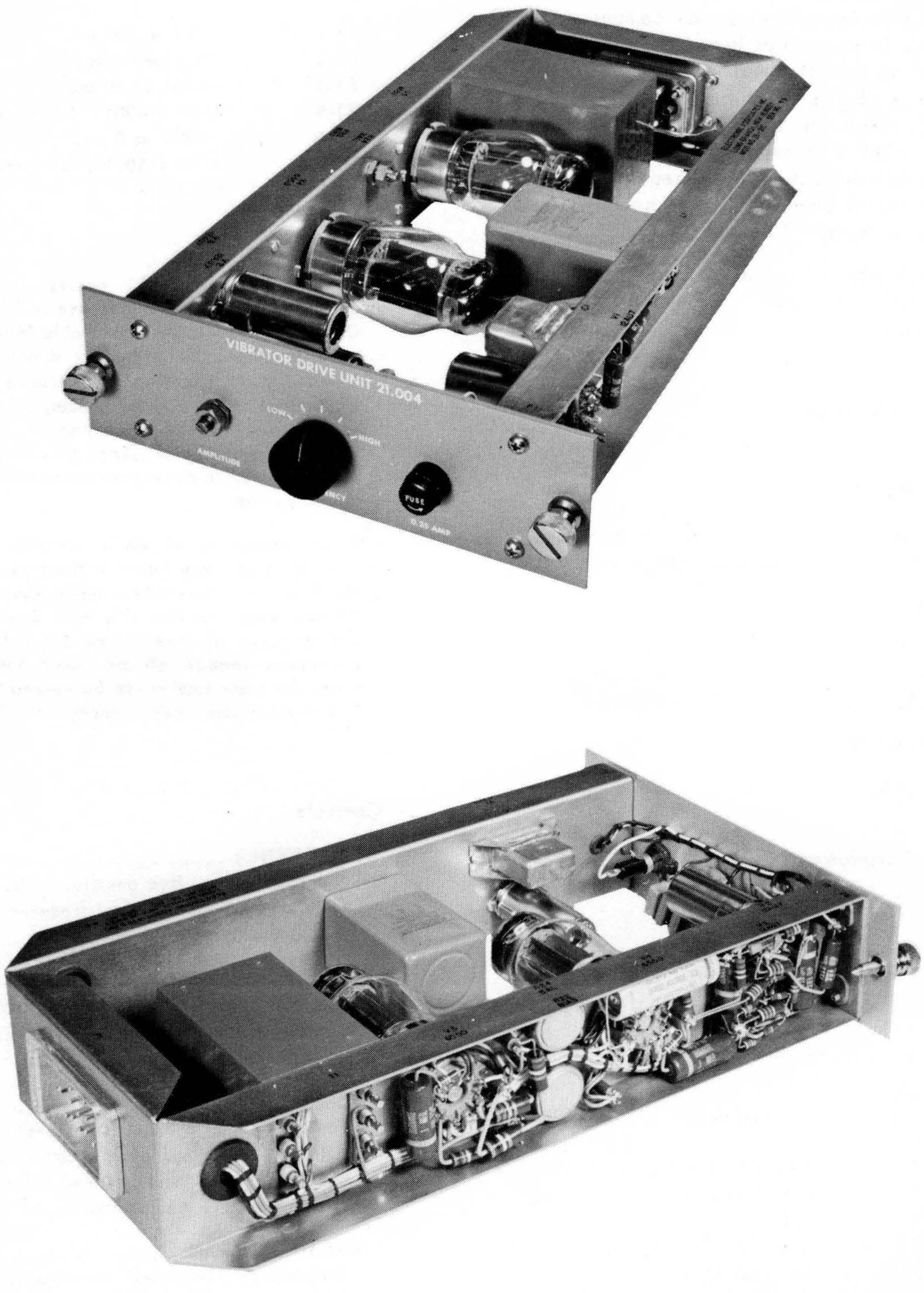


Figure 1. Vibrator Drive Unit 21.004.

Unit Terminations

All connections to the unit are made through plug P1. Connections to the mating jack can be made according to either of two schedules, depending upon whether the output is to be operated at d-c ground potential or at −300 volts. The following table lists the connections for each of the two options. The reason for providing a choice of two methods of connection is to make possible an equitable distribution of load between the plus and minus 300 volt supplies in a large system.

Terminal Number	Output at ± Ground Potential
P1-1	+450 volts at 200 ma.
P1-2	−300 volts at 2 ma.
P1-4	±GND
P1-5	6.3V a-c (± ground)
P1-6	No connection
P1-7	6.3V a-c (± Ground)
P1-8	+300 volts at 40 ma.

Also jumper plus 9 and 11, externally

Terminal Number	Output at −300 Volt Potential
P1-1	+150 volts at 200 ma.
P1-2	No connection
P1-4	−300 volts at 40 ma.
P1-5	6.3 volts a-c (−300V)
P1-6	−500 volts at 2 ma.
P1-7	6.3 volts a-c (−300V)
P1-8	± ground

3. CIRCUIT DESCRIPTION

Refer to drawings D021 004 0S, the schematic diagram of the Vibrator Drive Unit. V1a is connected as a Hartley oscillator with output taken from the grid circuit. The tapped coil L1 is tuned by fixed capacitors C1 and C2, with added capacity connected in parallel when necessary, by the FREQUENCY switch. At the time of manufacture, this switch is placed in the center position (#3) and the value of C2 is selected so that the center frequency is 94 cps ±2 cps. C3, C4, C5, and C6 are so proportioned that the frequency is changed 1 cps for each step of the switch. V2a is a voltage amplifier and V2b is connected as a phase splitter to drive the grids of V3 in push-pull. V4 and V5 operate in push-pull with the primary of T1 as the plate-to-plate load impedance. R24 serves as cathode resistor for both tubes; the tap is adjusted to balance the current through the two tubes. This is the BALANCE control, a screwdriver adjustment on the chassis; it is set at the factory during final test of the equipment. Should it be necessary to check the balance of the output tubes, one of several methods can be employed. An oscilloscope can be used to view the wave forms at the plates; or a VTVM can be connected between the plates, and the a-c scale used to read the voltage while the BALANCE control is adjusted for a null. If the latter method is used caution should be exercised if the VTVM is the type in which the common lead is connected to the case. If it is, the case would be above ground potential by 450 volts d-c.

Negative feedback is used between the secondary of the output transformer and the cathode of V2a. Capacitor C14 is used for the d-c blocking when the output is operated at −300 volt d-c potential. Its reactance at 94 cycles is negligible in this circuit.

4. PARTS LIST

Reference Symbol	Description
XV1, XV2, XV3	Tube Socket; Noval Elco #169BC
XV4, XV5	Tube Socket; Octal Elco #335
R1, R4	Resistor; 1.0 MEG ±10% 1/2W
R3	Resistor; 100K ±10% 1/2W
R5	Resistor; 470 ±10% 1W
R6, R12, R15	Resistor; 47K ±10% 1W
R7, R8	Resistor; 22K ±10% 1W
R9, R10	Resistor; 470K ±10% 1/2W
R11	Resistor; 470 ±10% 1W
R13, R14	Resistor; 220 ±10% 1/2W
R16	Resistor; 5100 ±5% 1W
R21	Resistor; 150K ±5% 2W AB
R22	Resistor; Var Comp. 5000 #JLU5 021 AB
R23	Resistor; 22K ±5% 2W AB
R25, R26	Resistor; 100 ±10% 1W
R19, R20	Resistor; 47K ±10% 1/2W

Reference Symbol	Description
R28	Resistor; 100K ±5% 2W
R27	Resistor; 2.2 Meg 1/2W ±10%
V1, V2, V3	Electron Tube; Type 12AU7
V4, V5	Electron Tube; Type 6550
XF1	Fuse Holder; Buss #HKP
C1	Capacitor; 0.1 mfd CP65B1EF 104K (EAI 520 023 0)
C3	Capacitor; 2200 mmfd CM30B 222K(EAI 519 040 0)
C4	Capacitor; 4700 mmfd CM35B 472K (EAI 519 047 0)
C5	Capacitor; 6800 mmfd CM35B 682K (EAI 519 049 0)
C6, C7, C8, C9	Capacitor; 0.01 mfd, 400V, Aerovox type P88N
C10, C11, C12, C13	Capacitor; 0.1 mfd, 400V, Aerovox type P88N

Reference Symbol	Description
C14	Capacitor; 20 mfd, 450V Sprague #TVA-1709
C16	Capacitor; 1000 mmfd Erie #GP2L-102
F1	Fuse; 1/4 amp Littelfuse #313. 250
L1	Choke; Freed #1860 EAI 610 002 0
P1	Connector; receptacle, Cannon #DPD-A15-34P-1L
R2	Resistor; variable, comp., 500K #JLU5041
R24	Resistor; variable comp., 50 #JLU5001AB
R28	Resistor; 100K ±5%, 2W AB
S1	Switch; Centralab #PA-2002
T1	Transformer; Audio output; EAI part/dwg. #B3M50C1

Figure 1
Schematic D013 001 0S
Wiring D013 001 0W

1. CIRCUIT DESCRIPTION

The Dual Channel Overload Alarm 13.001 (fig. 1) provides visual and audible signals when an overload occurs in any servo or operational amplifier. Two lamps on the Overload Indicator 20.024 supply visual indication; the upper lamp lights when any amplifier overloads, and the bottom lamp warns of a servo overload. A speaker provides the audible warning.

In addition to the overload indicators, circuits are provided that automatically switch the computer control circuits to the Hold mode in the event of an overload.

The Dual Overload Alarm is composed of two channels of voltage amplification and an audio oscillator. The two voltage amplifiers are identical so that a description of one will suffice. Figure 2 is a simplified schematic of one channel, composed of B1 and B3a.

V1a and V1b comprise a two-stage voltage amplifier. The signal applied to the input terminal A is a square wave from the stabilizer of an overloaded amplifier. When the amplitude of this signal exceeds four millivolts, the output of the voltage amplifier is sufficient to drive the grid of V3a positive nearly to zero. K1 and R10 constitute a plate load for V3a of about 13,000 ohms. When the grid reaches –1 volt the tube current pulls in the relay. The grid is returned to a point on voltage divider R8 and R9 which is at a potential of –13 volts. The biased diode CR2 prevents the grid from going below –13 volts, and in combination with R7 and C3, assures an essentially positive d-c voltage added to the –13V bias when a signal is applied. C4 provides negative feedback to the grid circuit so that the tube is stable and the relays do not chatter.

V4 is a modified Hartley oscillator with T1 and C12 as the resonant circuit. A loudspeaker is connected across the secondary of T1. The frequency of oscillation is dependent partly on the time constant in the feedback circuit, C10, R24, and R25. R24 is adjustable and functions as a tone control.

With no fixed bias applied to the grid of V4, this stage oscillates, supplying an audible tone. Normally K1 and K2 are de-energized and apply –300 volts applied through R23 to the junction of R24 and R25 in the oscillator grid circuit. This voltage cuts the tube off, and the oscillation is stopped. When channel A receives an overload signal, K1 drops out, removing the fixed bias from the oscillator, and permitting this stage to generate the alarm tone. If the overload signal is applied to channel two, K2 performs the same function.

Contacts 3 and 4 of K1 and K2 function to apply relay voltage through the AUTO HOLD switch to the Hold circuits in the Mode Control Relays. This provides the automatic hold feature.

Visual indication is provided by the AMPL and SERVO lamps on the Overload Indicator Panel. These lamps are energized by a source of 6.3 volts through contacts 9 and 10 of K1 and K2.

Switch Position	Operation
AMPL ONLY	Any amplifier or servo that overload causes the alarm to sound the lamps to glow. Only an amplifier overload switches the computer to the Hold mode. When the overload is corrected, the alarm stops and the indicators are extinguished. The computer remains in the Hold mode until another button on the Mode Control panel is depressed.
OFF	Audible and visual alarm function without the automatic hold feature.
AMPL & SERVOS	Same as AMPL ONLY position except that overloaded servos as well as amplifiers switch the computer to the Hold mode.

2. PARTS LIST

Reference Symbol	Description
K1, K2	Relay; Magnecraft #11HPX24
LS1	Speaker; Perm Mag Oxford #2CMS
R10, R22	Resistor; fixed, comp., 6800 ±10%, 1W Allen Bradley GB
R24	Resistor; variable comp., 100K Allen Bradley JU1041-SD3040
R27	Resistor; variable WW, 10 ohms Mallory #M10P

Reference Symbol	Description
T1	Transformer, overload alarm EAI #B16M13A3
C1, C2, C5, C6	Capacitor; fixed, paper 0.01 mfd 400V Aerovox P82Z
C3, C7	Capacitor; fixed, ceramic 1000 ±100 mmfd 500V
CR1, CR2	Diode; Germanium type #1N34A
R1, R13	Resistor; 100 ±10% 1/2W Allen Bradley
R2, R5, R14, R17	Resistor; 470K ±10%, 1/2W Allen Bradley
C4, C8	Capacitor; Midget, Tubular Type 68P 600V Sprague #68P36 0.1 MFD
C9	Capacitor; Phenolic-Cased, 0.022 Mfd 600V Cornell Dubilier #BC-6S227
C10, C12	Ceramic, Insulated Erie #GP2M 4700 ± 940MMFD 500V
C11	Capacitor; Electrolytic, 20 MFD 400V Cornell Dubilier "Blue Beaver" Type #BR-2045
R3, R9, R15, R21	Resistor; 2.2 meg ±10%, 1/2W Allen Bradley
R4, R16	Resistor; 2200 ±10%, 1/2W Allen Bradley
R7, R19	Resistor; 1.0 meg ±10%, 1/2W Allen Bradley
R8, R20	Resistor; 100K ±10%, 1/2W Allen Bradley
R11, R12	Resistor; 56K ±10%, 2W Allen Bradley
R23	Resistor; 27K ±10%, 1/2 Allen Bradley
R25	Resistor; 47K ±10%, 1/2W Allen Bradley
R26	Resistor; 1000 ±10%, 2W Allen Bradley
V1, V2	Tube; electron type #12AX7
V3	Tube; electron type #12AT7
V4	Tube; electron type #6CG7
XK1, XK2	Socket; Tube; 11 pin Amphenol #77-MIP-11T
XV1, XV2, XV3, XV4	Socket; Printed Circuit; Single sided 9 pin min; Methode #PS-161

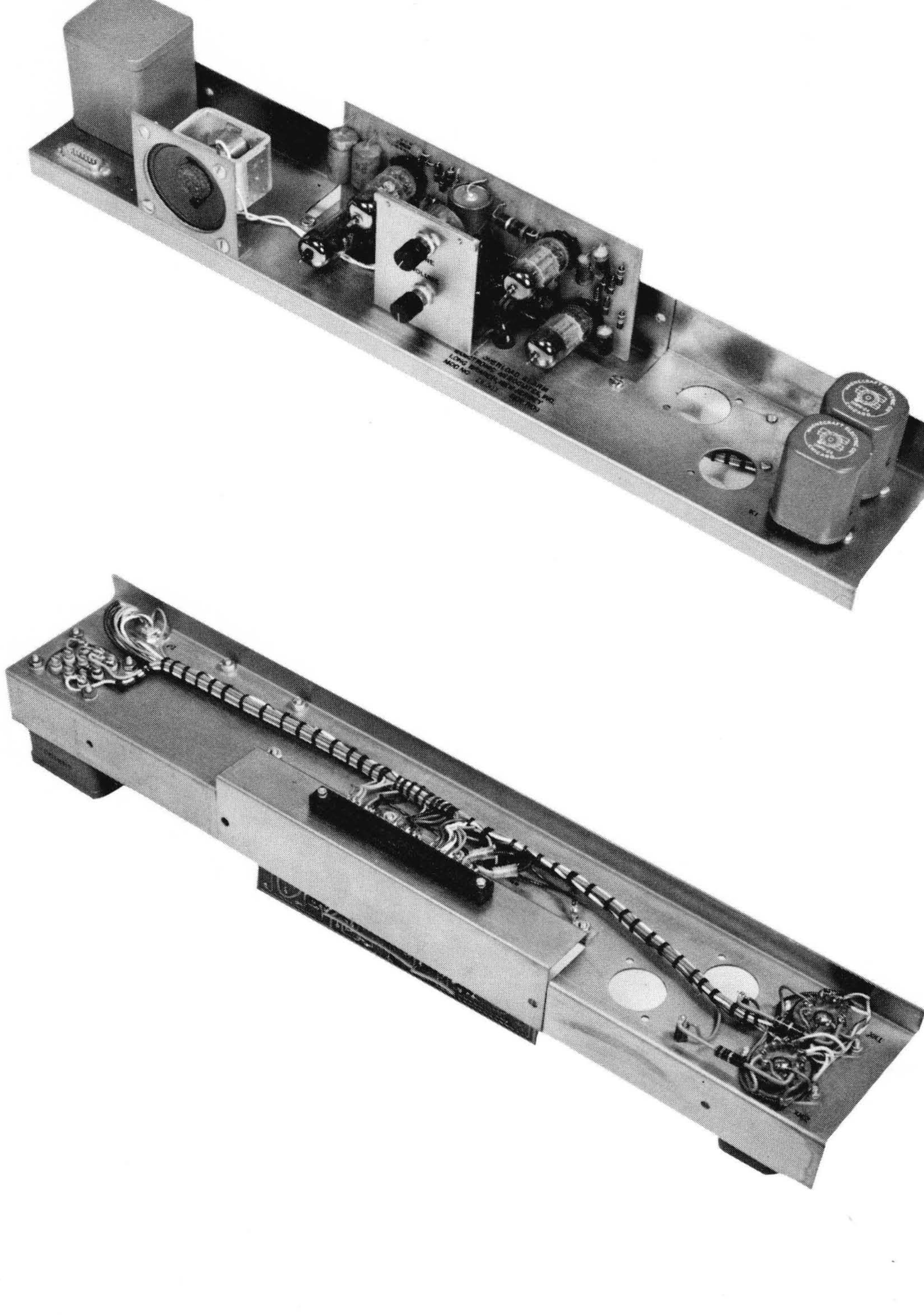


Figure 1. Dual Overload Alarm 13.001.

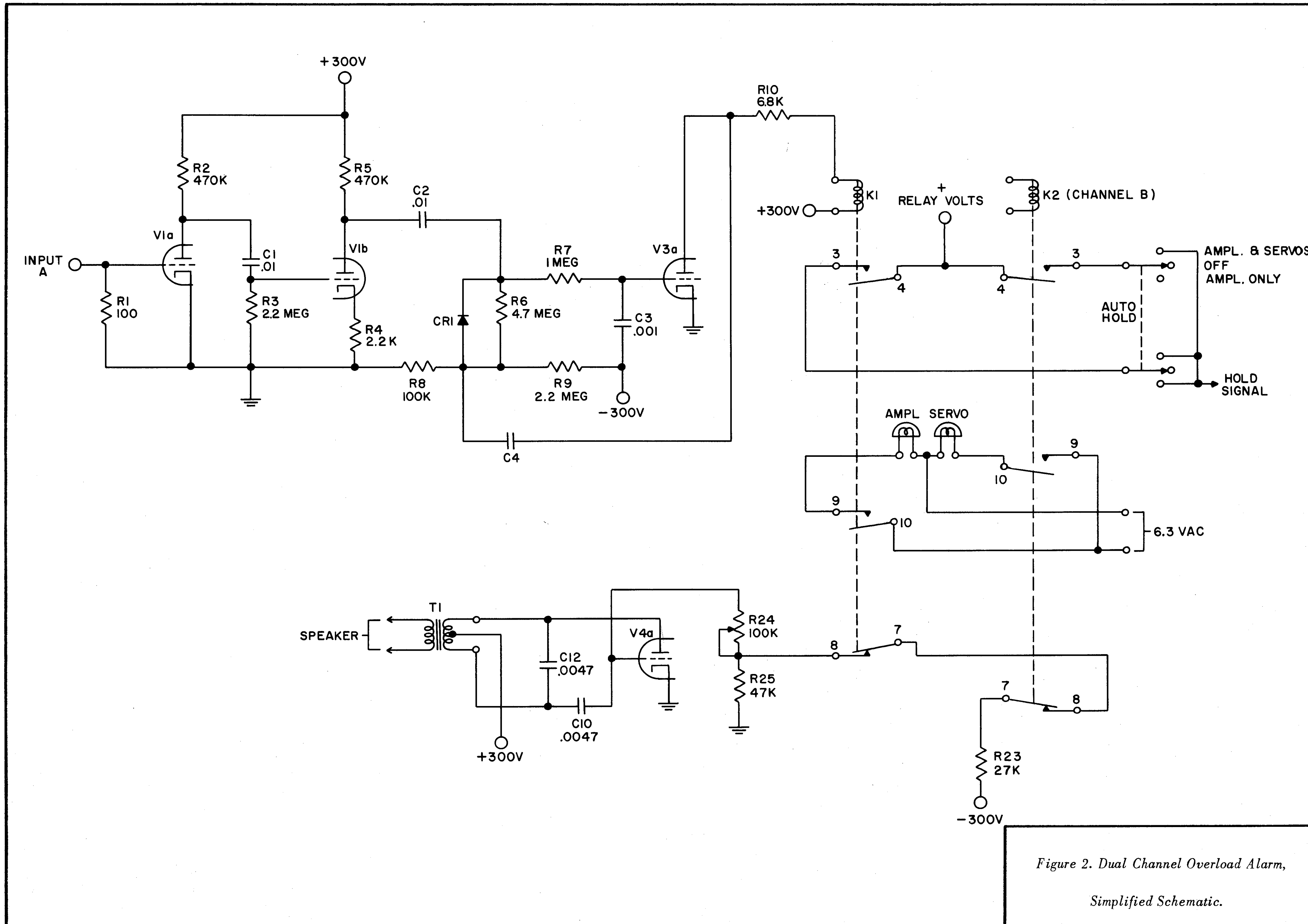


Figure 2. Dual Channel Overload Alarm,

Simplified Schematic.