INDUSTRIAL AND NUCLEAR INSTRUMENTS

ANALOG COMPUTERS

Berkeley *division*

BECKMAN INSTRUMENTS, INC.

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WARNING

Do not attempt to operate this instrument until you have read the Instruction Manual.

EASE Computer

INSTALLATION INSTRUCTIONS

BERKELEY division of
Beckman Instruments Inc.

Richmond 4, California
16 August 1955

Installation

GENERAL

All computer components are rack-mounted in one or more cabinets. The cabinets are fitted with casters which may be removed after the racks have been rolled into position. Cabinets may be arranged in any order provided that the inter-connecting cables have been cut to the proper length. Allow some air space at the rear of the cabinets for ventilation and install them in a room that is generally well-ventilated.

Ordinarily, cable connections between components in the same cabinet will have been completed at the factory. Connections from the power line to the computer and connections between cabinets must be made at the installation site. These connections consist of:

1. A common ground bus between cabinets.

2. Connections from the power line to each cabinet and from the power control unit in the base of the control unit cabinet to similar units in other cabinets.

3. Other connections between cabinets consisting mainly of input and output connections from the control unit to each of the operational components.

GROUND CONNECTIONS

To attach the ground bus, slide the copper ground clamps onto the large bare copper cable. String the cable along the rear of the cabinets and screw a ground clamp to the end of each copper ground strap which protrudes from the rear of the cabinets. Then tighten the clamps on the cable.

LINE POWER CONNECTIONS

To supply line power to the computer connect a source of 115 volt a-c power to the socket at the rear of each cabinet. The cabinet holding the control unit will not draw more than 7 amperes. Each of the other cabinets may draw as much as 20 amperes. The line voltage at the input to each cabinet should not drop below 105 volts nor rise above 125 volts.

A line power control unit occupies the base of each computer cabinet. This unit provides a means of energizing the filament supplies throughout the cabinet independently of the plate supplies. The unit connects 115 volt a-c power to the sockets spaced along the vertical strip inside the cabinet. Line power for filament supplies appears at the sockets labelled "FIL" or "FIL REG". Power for plate supplies appears at the sockets labelled "PLATE". The power control unit also connects line power to a terminal strip at the bottom rear of the cabinet. This strip is used to interconnect the unit in the control unit cabinet with those in the other cabinets.

Figure 1 is a schematic diagram of the power control system in the control unit cabinet. This cabinet contains an automatic time delay switch which prevents power from reaching the plate sockets until the filament power has been applied 30 seconds. Closing the FILAMENT switch starts the time delay motor which closes a switch after 30 seconds. This switch applies the line voltage across the PLATE switch and relay and across the plate relay control terminals on the inter-cabinet connection strip.

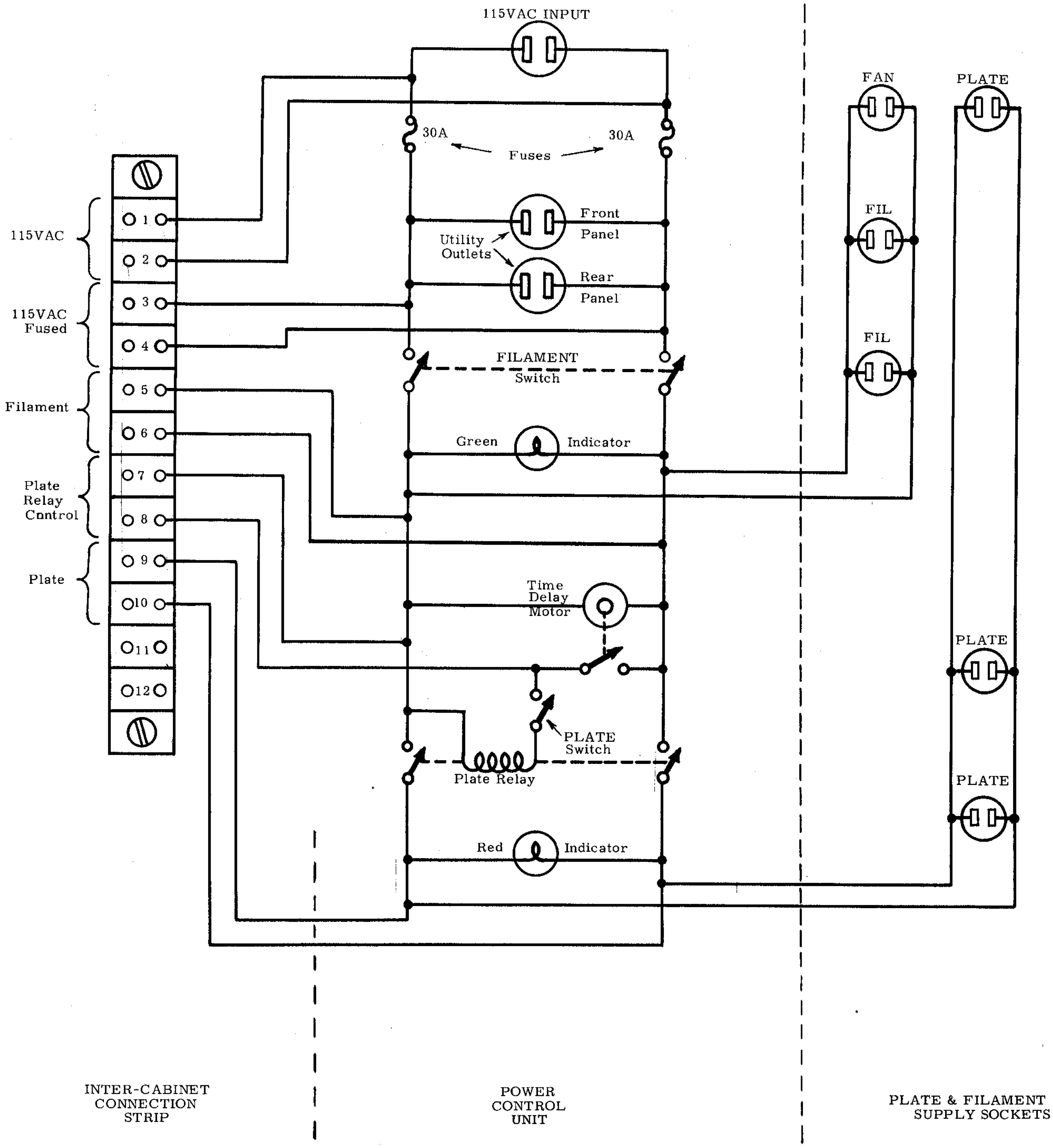


Figure 1 Line Power Control System
Control Unit Cabinet, Model 1187

Figure 2 is a schematic diagram of the power control system in the other cabinets. This system differs from that in the control unit cabinet in that it lacks a time delay switch. 115 volts a-c must be brought to the plate relay control terminals to energize the plate relay. If you wish to supply power to this cabinet independent of the control unit cabinet, simply connect the plate relay terminals to the filament supply terminals; that is, terminal 7 to terminal 5 and terminal 8 to terminal 6. So connected, power reaches the plate sockets as soon as both FILAMENT and PLATE switches are closed. When applying power you must be careful to close the FILAMENT switch first and wait 30 seconds before closing the PLATE switch. On the other a hand, you may take advantage of the automatic time delay in the control unit cabinet by connecting the computing cabinet to that circuit. To do this, connect the plate relay control terminals to the plate terminals in the control unit cabinet -- terminal 7 to terminal 9 and terminal 8 to terminal 10. So connected, the plate relay contacts in the control cabinet are in series with the plate relay coil in the other cabinet, and power cannot reach the PLATE sockets in any cabinet until 30 seconds after the FILAMENT switch on the control unit cabinet has been closed. All the cabinets in the computer installation may be connected to the control cabinet in this way. If you do this, the PLATE switch on the control cabinet becomes the master plate on-off switch for the entire computer and all other PLATE switches may be left permanently closed. When applying power you must be careful to close the FILAMENT switches on the other cabinets before closing the one on the control cabinet.

Cabinets holding one or more Model 1041 Operation Amplifier Units contain a voltage regulating transformer for each unit. These transformers are located in the base of the cabinet near the power control unit. A line from the primary winding of each plugs into a socket carrying unregulated filament power, and a line from a FIL REG socket plugs into a socket on the transformer which is connected to the secondary.

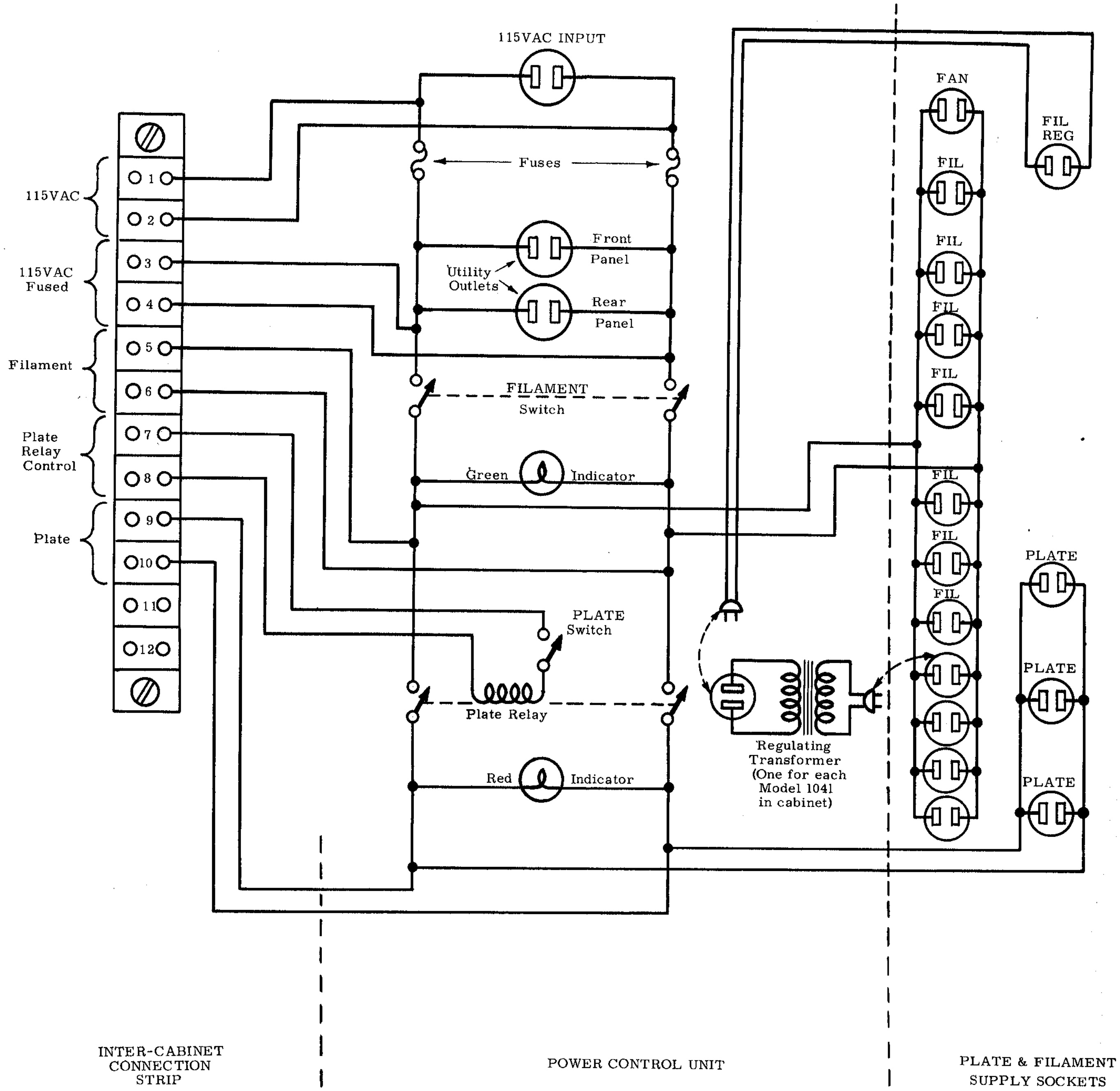


Figure 2 Line Power Control System
Operational Component Cabinet, Model 1185

OTHER CONNECTIONS BETWEEN CABINETS

The text and diagrams on the following pages describe all necessary cable connections to each of the computer components. Most of these connections will be completed when you receive the computer since they link components in the same cabinet. Connections which must be made at the installation site consist mainly of input and output connections from the control unit to the various operational components.

Each power supply will provide d-c voltages for several combinations of operational components. The number of each type of component connected to a specific power supply differs from one installation to another. The best arrangement is that which takes full advantage of the load capacity of the power supply. The instructions for connecting each component specify the power supply to which it must be connected and list the current it draws at each d-c voltage. The output capacities of the power supplies and the d-c requirements of all the operational components are listed together in table on opposite page.

POWER SUPPLY	D-C VOLTAGES GENERATED	LOAD CURRENT CAPACITY	COMPONENTS USING POWER SUPPLY	VOLTAGES REQUIRED	CURRENT DRAIN
Model 1011	+250v	0 to 300 ma	1041 Operational Amplifier unit with ten 1048 Amplifiers	+250	235 ma
	-250v	0 to 150 ma*		-250	90 ma
	-465v	0 to 55 ma		-465	45 ma
			1072 Set-up Unit (for 1071)	+250v	20 ma
				-250v	5 ma
				-465v	5 ma
			1071 Function Generator	+250v	40 ma
				-250v	12 ma
				-465v	9 ma
			1070A Function Generator	+250v	22 ma
				-250v	22 ma
			1032 Control Unit	+250v	15 ma
Model 1010	+400v	125 to 300 ma	1051 Multiplier Panel (excluding multipliers)	+400v	14 ma
	-400v	125 to 300 ma		-400v	17 ma
			1056 Multiplier	+400v	52 ma
				-400v	44 ma
			1070 Function Generator	+400v	22 ma
				-400v	22 ma
Model 1015	+100v	0 to 150 ma	1032 Control Unit	+100v	15 ma
	-100v	0 to 150 ma		-100v	15 ma
			1072 Set-up Unit (for 1071)	+100v	12 ma
				-100v	12 ma
			1071 Function Generator	+100v	10 ma
				-100v	10 ma

* The Model 1011 will supply 200 ma at -250v if no current is drawn from the -465v output. Notice that the Model 1070A does not require a -465 volt supply.

Model 1041 Operational Amplifier Unit

All necessary cable connections to this unit are shown in figure 3. One Model 1011 customarily supplies d-c voltages for one Model 1041 containing ten Model 1048 amplifiers and may, in addition, supply two Model 1070A Function Generators or one Model 1071 Function Generator. Under normal amplifier output loads, a Model 1041 with ten amplifiers will not draw more than 235 ma at +250 volts, 90 ma at -250 volts and 45 ma at -465 volts. The Model 1011 will provide 300 ma at +250 volts, 150 ma at -250 volts and 55 ma at -465 volts.

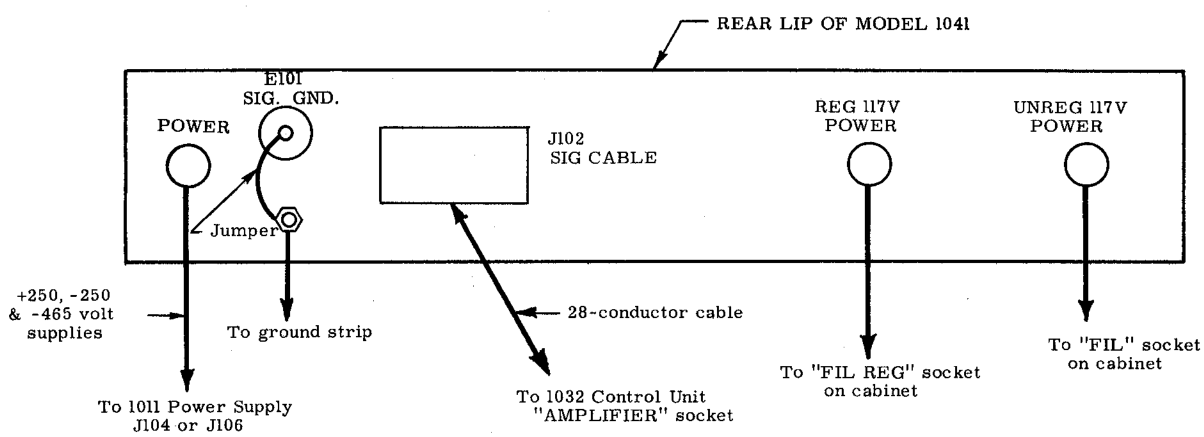


Figure 3

The Model 1051 Mhltiplier Panel.

All necessary cable connections to this unit are shown in figure 4. D-C power at +400 and -400 volts is supplied by a Model 1010 Power Supply. One Model 1010 customarily supplies a panel with four Model 1056 Multipliers and may, in addition, supply as many as three Model 1070 Function Generators. The current drawn by the Model 1051 varies with the number of multipliers it holds.

Number of multipliers in Model 1051 Panel	Current Drain At +400 volts	Current Drain At -400 volts
4	222 ma.	193 ma.
3	170 ma.	149 ma.
2	118 ma.	105 ma.
1	66 ma.	61 ma.

The current drain from each voltage source on the Model 1010 must be at least 125 ma and no more than 300 ma. Notice that if the Model 1051 panel contains fewer than 3 multipliers, some other load must be placed on the power supply.

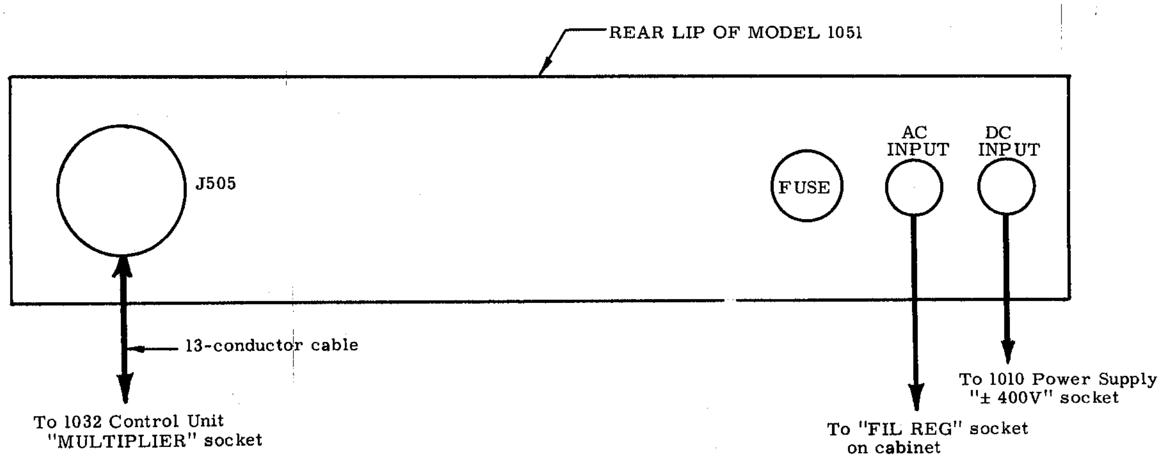
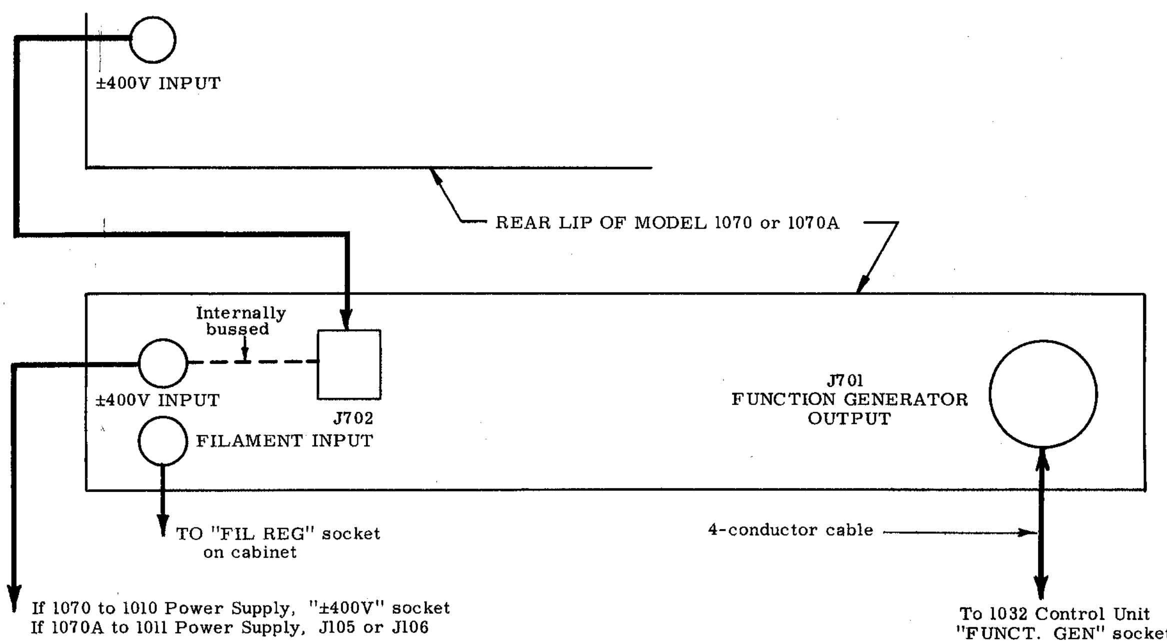


Figure 4

Models 1070 and 1070A Function Generators

All necessary cable connections to either of these units are shown in figure 5. The only difference between the models is that the Model 1070 requires d-c voltages of +400 and -400 volts while the Model 1070A operates on +250 and -250 volts.

Each Model 1070 draws 22 ma at +400 volts and 22 ma at -400 volts from a Model 1010 Power Supply. The current drain on the Model 1010 must be between 300 and 125 ma at each voltage. Therefore, the Model 1010 will supply as many as 13 function generators but no less than 6 function generators unless some other load is also drawing current. Three Model 1070's may be supplied from a Model 1010 which is also supplying a Model 1051 Multiplier Panel containing 4 Multipliers. If necessary, you may procure a dummy load from the factory.



NOTE: The Model 1070 operates on d-c voltages of +400 and -400 volts obtained from the 1010 Power Supply
The Model 1070A operates on d-c voltages of +250 and -250 volts obtained from the 1011 Power Supply.

Figure 5

Each Model 1070A requires 22 ma at +250 volts and 22 ma at -250 volts. These requirements are met by the Model 1011 Power Supply which will deliver 0 to 300 ma at +250 volts and 0 to 200 ma at -250 volts if its -465 volt source is not loaded. Consequently, one Model 1011 will supply 9 function generators or 2 function generators plus a Model 1041 Operational Amplifier Unit containing ten amplifiers.

Model 1071 Function Generator with Model 1072 Set-up Unit.

The Model 1072 Set-up Unit and the Model 1071 Function Generators it serves (as many as 10) form an interconnected system. Figure 6 shows all necessary cable connections to a set-up unit with two function generators. Additional function generators are connected in the same way.

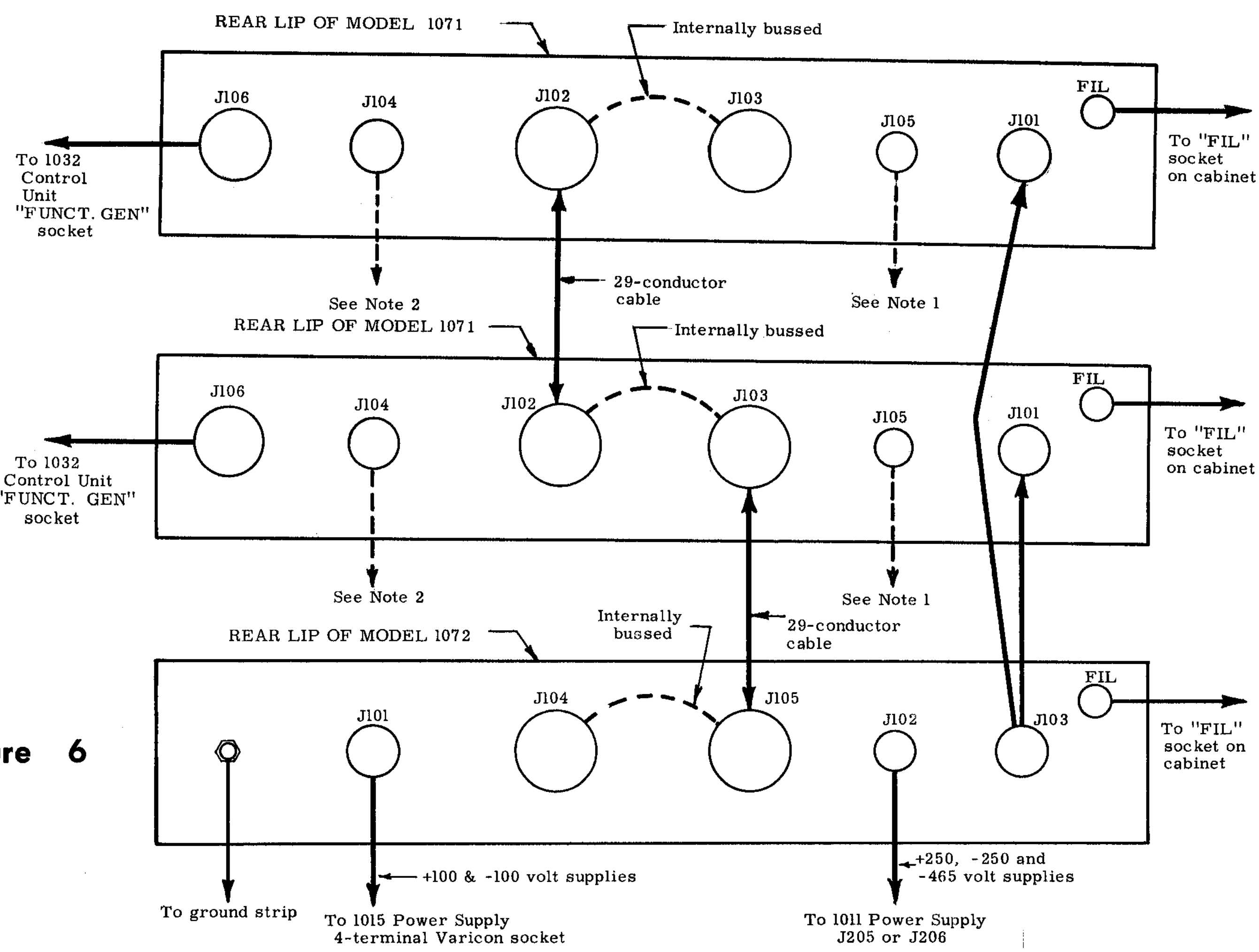


Figure 6

NOTES: 1. D-C voltages from the 1011 Power Supply may be introduced at J102 on the set-up unit or at J105 on any one of the function generators.

2. D-C voltages from the 1015 Power Supply may be introduced at J101 on the set-up unit or at J104 on any one of the function generators.

The system procures d-c voltages of +100 and -100 volts from the Model 1015 Power Supply. The set-up unit draws .12 ma at each of these voltages, and each function generator consumes about 10 ma at each voltage. The Model 1015 will provide from 0 to 150 ma at each voltage. Customarily one Model 1015 supplies a set-up unit and as many as 10 function generators and, in addition, supplies reference voltages for the control unit. The conductors carrying the +100 and -100 volt supply should be large enough to make the voltage drop between the power supply and the system negligible.

The system procures d-c voltages of +250, -250 and -465 volts from the Model 1011 Power Supply. The following table lists the maximum current drawn at each voltage when the function generators are operating into normal output loads.

	Current Drain		
	+250v	-250v	-465v
Set-Up Unit	20 ma	5 ma	5 ma
Each Function Generator	40 ma	12 ma	9 ma

The Model 1011 Power Supply will deliver 300 ma at +250 volts, 150 ma at -250 volts and 55 ma at -465 volts. One Model 1011 will supply a set-up unit and five function generators. One function generator may be supplied by the same Model 1011 which supplies a Model 1041 Operational Amplifier Unit containing ten amplifiers.

Power supplied by one Model 1011 is inserted at the set-up unit or at one of the function generators and carried to other components in the system by the 29-conductor interconnecting cable shown in figure 6. The three d-c voltages appear at pins 6, 7 and 8 of connectors J102 and J103 on the function generators and connectors J104 and J105 on the set-up unit. When one part of the system is supplied by a different Model 1011 than another part, you must take care to keep the power supplies isolated from one another, The cable interconnecting the two parts of the system should have no conductors connected to pins 6, 7 and 8. Connections at these points would parallel the outputs of the power supplies and impair the regulation of both supplies.

Model 1006 Variable D-C Voltage Source.

Figure 7 shows all necessary cable connections to this unit.

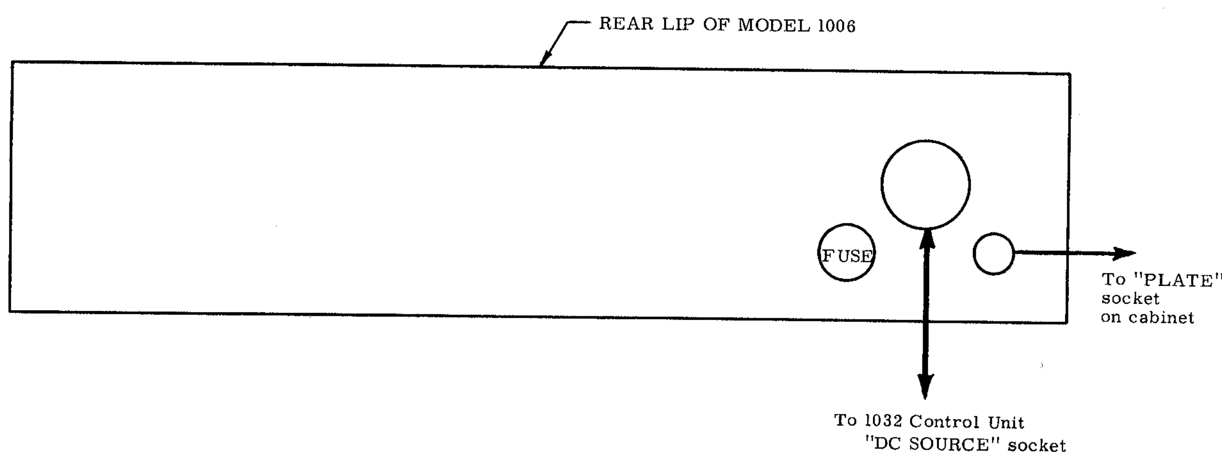


Figure 7

Model 1032 Control Unit

To learn how to connect operational components to this unit see the installation instructions for each component.

The control unit obtains reference voltages of +100 and -100 volts from the Model 1015 Power Supply. The "MODEL 1015 INPUT" jack at the rear of the control unit should be connected to the 6-terminal Varicon connector on the rear lip of Model 1015. Under normal operating conditions the control unit will not draw more than 15 ma at each of these reference voltages. The

Model 1015 will supply 150 ma at each voltage. The conductors carrying the +100 and -100 volt supply should be large enough to cause only a negligible voltage drop between the power supply and the control unit.

The control unit obtains a +250 volt supply from a Model 1011 Power Supply. The 6-pin Varicon connector at the rear labelled "MODEL 1011 INPUT" should be connected to J105 or J106 on a Model 1011. The control unit draws about 15 ma when the computer is in the "REPETITIVE" operating condition. It draws no current in any other condition.

The Power Supplies

The diagrams below show all necessary connections to the power supplies except the output cabling. See the installation instructions on the operational components to learn how they should be connected to the power supplies.

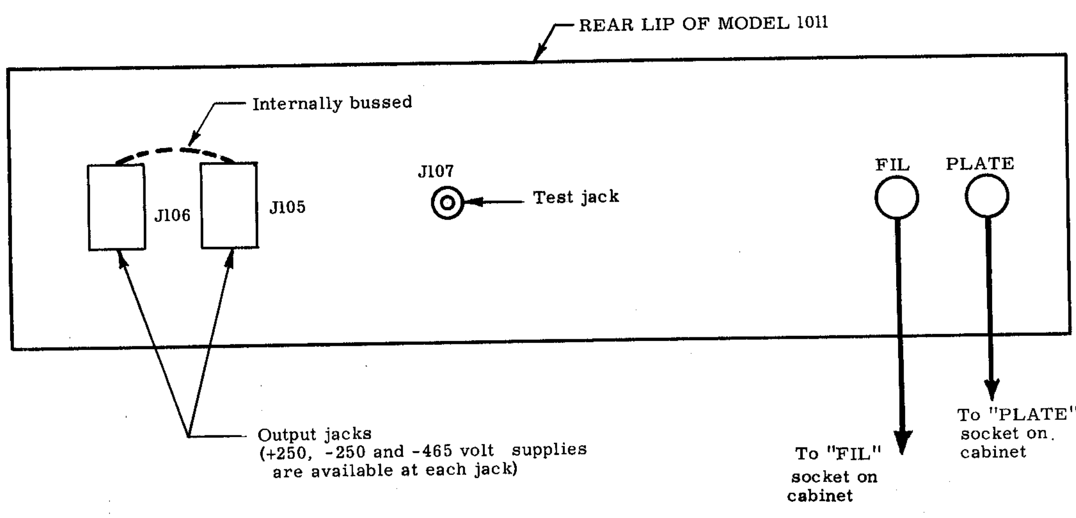


Figure 8 Cable Connections to Model 1011 Power Supply

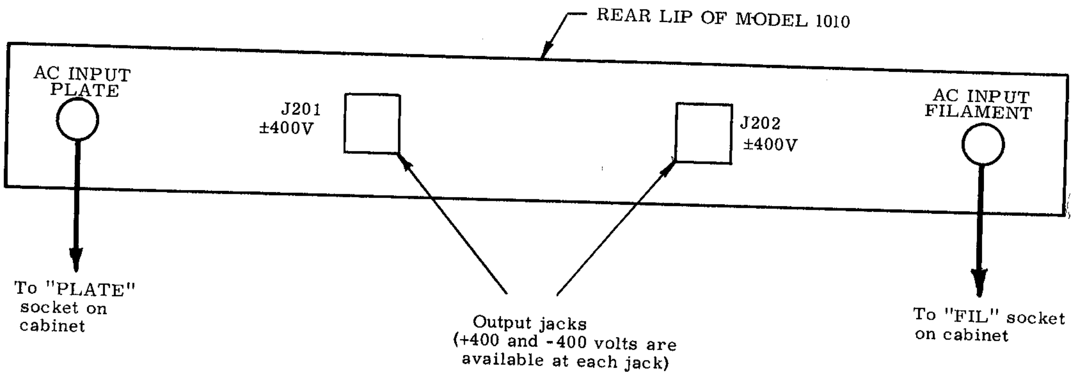


Figure 9 Cable Connections to Model 1010 Power Supply

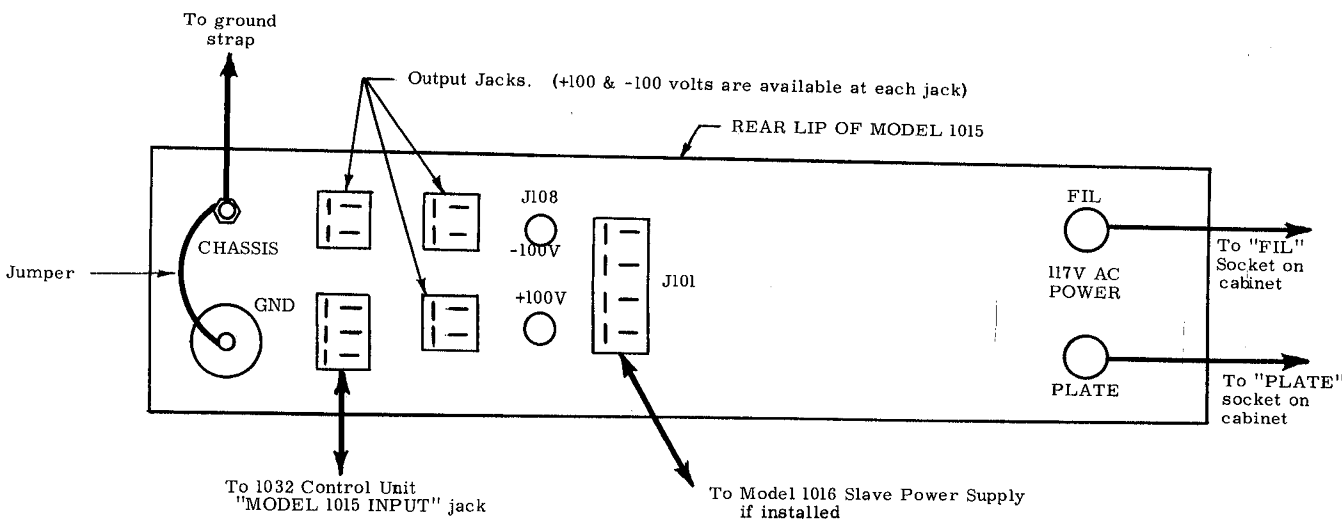


Figure 10 Cable Connections to Model 1015 Power Supply

EASE Computer

OPERATING INSTRUCTIONS

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
15 December 1955

WARRANTY

Every instrument manufactured by the BERKELEY division of Beckman Instruments, Inc. is warranted to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year from date of shipment to the original purchaser prove to be defective after our examination.

Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

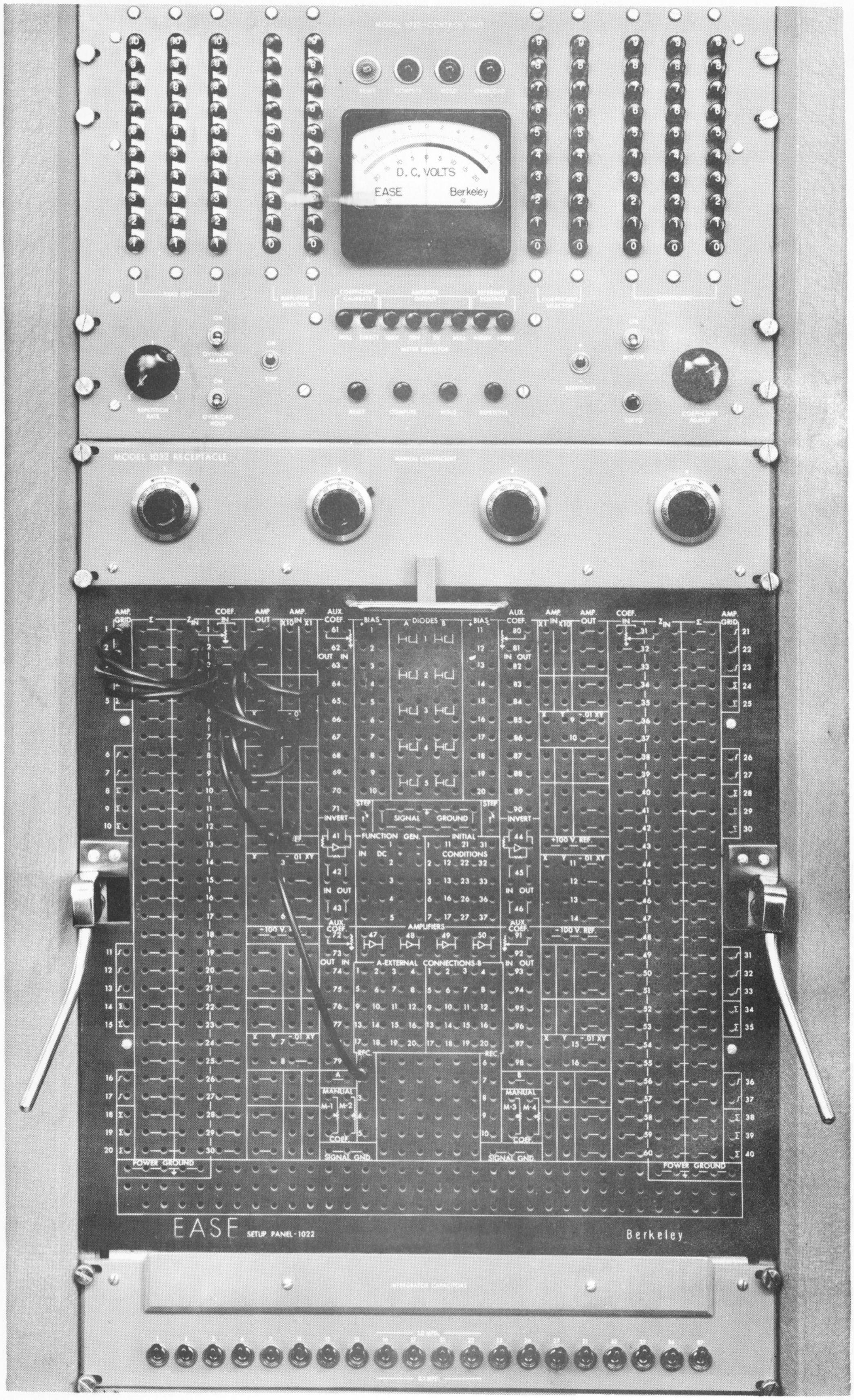
Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

Operation

CONTENTS



Computer Control System

INTRODUCTION

See the "PROBLEM PREPARATION" section of the computer manual to learn how to devise a circuit analogous to a given equation; that is, to prepare a diagram similar toFigure 4 at the rear of this section. This operation section contains instructions for preparing computer components for use in such a circuit, for constructing the circuit with those components and for running a problem and measuring or recording the resultant voltages. Most of the operations are performed on the control system shown opposite. The part of this section headed "The Control Apparatus" tells what is connected to each of the set-up panel terminals and describes the function of the operating controls above and below the panel. This part provides a convenient source of information for an operator who is not sure how to use a particular control or terminal. The part headed "A Sample Problem" describes the construction of a complete problem-solving circuit. The circuit has been designed especially to illustrate the use of nearly all the devices available on the computer. The sample problem is primarily an introduction for someone who has not used the computer before. He may familarize himself with the equipment by actually constructing the circuit step by step as it is described.

APPLYING POWER

The computer is equipped with separate plate and filament 115 VAC supplies. These supplies are controlled by the PLATE and FILAMENT switches at the base of the cabinets. All filaments in a cabinet are energized whenever the FILAMENT switch is on. When applying power close these switches first. Wait at least 30 seconds for the tubes to warm up before applying plate power.

In standard computer installations power reaches the plate circuits in a cabinet only when four conditions are met.

1. The PLATE switch on that cabinet is on.
2. The FILAMENT switch on that cabinet is on.
3. The PLATE switch on the control system cabinet is on.
4. The FILAMENT switch on the control system cabinet has been on at least 30 seconds.

With this arrangement it is convenient to use the PLATE switch on the control cabinet as a master plate on-off switch and to leave all other PLATE switches permanently on. When applying power, first turn on the FILAMENT switches in all cabinets except the control cabinet. The green indicators only will light on these cabinets. (If the red indicators light the installation is not standard and this procedure should not be followed.) Then, turn on the control cabinet FILAMENT and PLATE switches in that order. After an automatic 30-second delay the red indicators will light on all cabinets. When removing power turn the switches off in reverse order. Non-standard installations may be wired so that the plate supply to each cabinet is not affected by the control cabinet switches. See the installation section of the computer manual (pages 2 thru 5) for a description of the power control system and the various ways it may be wired.

INITIAL CHECKS AND ADJUSTMENTS

The operational components mentioned below must be occasionally checked and adjusted to insure continued accuracy. Whenever you have reason to suspect that a computer component may have lost the accuracy desired, make the checks and adjustments described here before inserting it in a problem-solving circuit.

MODEL 1048 OPERATION AMPLIFIER

Allow the amplifier to warm up one-half hour with both filament and plate power applied before making the front panel balance or zero adjustment. This adjustment corrects for amplifier drift and provides an indication of the operating condition of the amplifier. Although daily drift is negligible under normal conditions, daily adjustment is suggested since the procedure is quick and easy and will help the operator detect faulty amplifiers before they are used.

To balance an amplifier place all the lever switches on the Model 1041 panel at ON (up) except the switch for the amplifier to be adjusted. Move this switch to the down (balance) position. Then, if necessary, adjust the screwdriver control above it until the front panel meter reads zero. This indicates that the output voltage is zero (at ground) with the input at ground.

If the meter will not come to zero, the amplifier is defective and should not be used in a problem-solving circuit. If the balance adjustment is insenstive compared to that of other amplifiers, the amplifier may lack enough gain to perform properly.

When a defective amplifier is left in the computer rack and energized along with the rest, make sure that a feedback resistor (100K to 1M) is connected between the amplifier output and the input grid. This will prevent the amplifier from overloading and actuating the alarm circuitry on the control system. All amplifiers used as summers have a feedback resistor connected under all conditions. The other amplifiers may require a resistor patched in on the set-up panel.

CAUTION: Take care not to connect an amplifier output to ground since this will damage the output tube. Do not connect a patch cord from an AMP OUT terminal to an AMP GRID terminal because the AMP GRID terminal is grounded during some computer operations.

MODEL 1056 FUNCTION MULTIPLIER

Properly adjusted this multiplier produces an output voltage within 1 volt of .01XY where X and Y are the input voltages. The output voltage may drift as much as 1 volt during each hour following adjustment.

The multipliers are numbered from 1 to 4 on the Model 1041 panel. Below each number is a switch and four potentiometer controls for adjusting that multiplier. Make all four adjustments on each multiplier while all the other multipliers in the chassis are switched to OPERate. To make a precise adjustment using the meter on the 1051 panel, press the METER SENsitivity button after the pointer has been brought near zero. Use the following procedure to adjust each multiplier:

1. Turn the switch to DC ADJ and rotate the DC ADJ. control until the meter on the 1051 panel reads zero.

   At this position of the switch both X and Y inputs are zero. The adjustment sets the output voltage at zero.

2. Turn the switch to X ADJ. and adjust the X ADJ control for a minimum reading on the meter.

   At this switch position the Y input is zero and the X input is a 60 cycle test signal which peaks at -100 and +100 volts. The adjustment sets the output voltage as near zero as possible over the full range of X values when Y is zero.

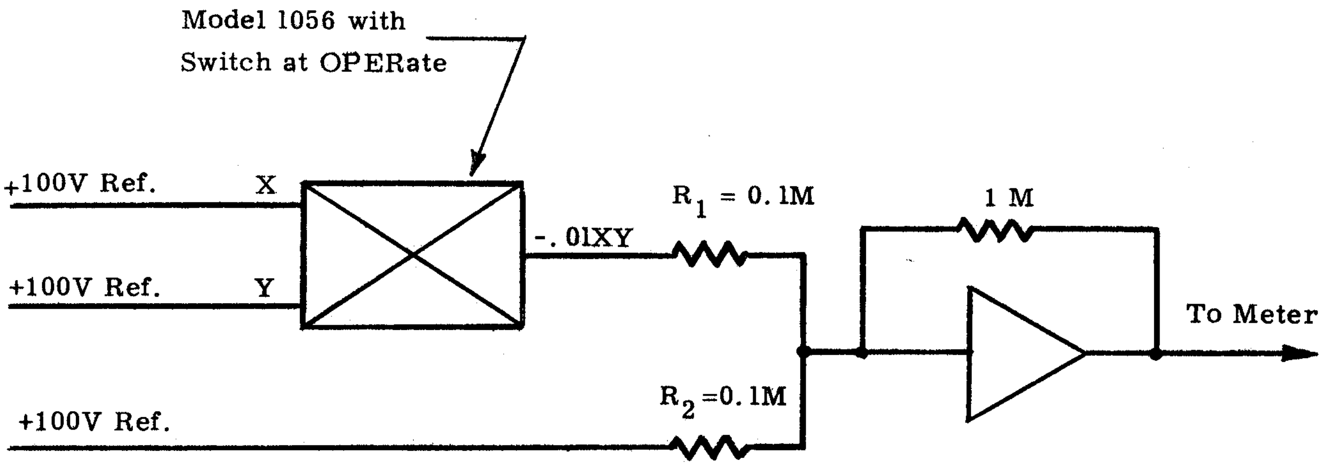
3. Turn the switch to Y ADJ. and adjust the Y ADJ control for a minimum meter reading.

   At this switch position the X input is zero and the Y input is the test signal.

   NOTE: If the operator is preparing the multiplier for use in the sample problem, he may omit adjustment No. 4. To set up the Model 1056 for this adjustment requires considerable knowledge of the control system. The multiplier will function accurately enough in the sample problem circuit without adjustment No. 4.

4. The last adjustment determines the value of K in the output expression KXY. Ideally, the adjustment should be made to achieve a minimum average error for all combinations of X and Y input voltages. If the first three adjustments have been made carefully, the static error may be held within 0.5% by setting K at .01 for only one combination of X

and Y voltages. Apply +100 volts to both X and Y inputs and connect the multiplier and a 100 volt reference source to a summing amplifier as shown in the diagram below.



Turn the switch to OPERate and adjust the OPERate control until the output of the summing amplifier is zero. This indicates that the output of the multiplier is -100 volts which is -.01 XY when X and Y are both +100 volts. The error due to any slight mismatch in the input resistors R_1 and R_2 may be detected and eliminated by reversing the inputs to the summing amplifier. Connect the multiplier output to R_2 and the reference source to R_1. If the output of the summer is still zero, the resistors are well matched. If an output voltage appears, readjust the OPERate potentiometer until the output voltage has the same absolute magnitude with summer inputs reversed as it does when the inputs are connected as diagramed above.

When the above adjustments are made the multiplier is ready to be connected in a problem-solving circuit. Repeat the adjustments before taking any critical data if so much time has passed since the last adjustment that drift might cause too great an error. The output of a multiplier may drift a maximum of 1 volt in a hour.

FUNCTION GENERATORS

See the section of the computer manual on the type function generator installed for directions. If the function generator circuit conatins any Model 1048 amplifiers, make initial adjustments on those as described on "Operation, Page 2".

CONSTRUCTING AND USING A PROBLEM-SOLVING CIRCUIT

GENERAL METHOD

A problem-solving circuit is constructed mainly by making patch board connections and other adjustments on the control system shown opposite Page 1. Input and output terminals of the various operational components which must be connected to form the circuit are gathered together within the system. Connections between different components are made by patching cords from one terminal to another on the set-up panel or patch board. This may be done with the board in the receptacle unit or removed whichever is most convenient. Input and feedback resistors and capacitors are inserted by plugging an external component into the patch board or by making connections to resistors and capacitors in the receptacle unit whose terminals have been brought out to the patch board. Fixed voltages are introduced into the computing circuitry by patching a cord from a terminal connected to a voltage source to an operational components terminal.

After patch board connections are complete the board is placed in the receptacle unit (if it has been removed) and the values of internal resistors, capacitors and fixed voltages sources are set by controls on the control cabinet. Starting from a "reset" condition in which each integrator output is held at some initial condition voltage, the computer is switched to complete the problem-solving circuit and the circuit voltages begin to change with time. The solution to a problem is usually the voltage changes with respect to time a certain points in the circuit. Voltages at these points may be observed on a meter or recorded. The changing voltages a may be halted at any time to inspect values at that point. The control system may be switched so that the solution is automatically repeated and consequently suitable for display on an oscilloscope.

THE CONTROL APPARATUS

SET-UP PANEL TERMINALS

Each hole on the patch board becomes a single terminal jack when the board is in place in the receptacle unit. In some places schematic diagrams printed on the face of the patch board indicate the behind-the-board connections. All bussed terminals are connected by a line from one hole to the other. There are terminals for more operational components than are ordinarily installed in the computer. Identical components are numbered from 1 up and connected to groups of terminals numbered in the same way. Terminals bearing a higher number than the quantity of components installed are not connected to anything.

The following pages contain a list of all the types of terminals on the patch board. Under the name of each type is the identifying patch board label, the location on the board and information on to what each is connected.

Bussed Terminals (Σ & Z_{IN})

The terminals in the columns under the Σ sign and the column nearest the edge of the board under the Z_{IN} sign, are connected to no internal components whatever. These terminals are simply bussed as indicated on the face of the patch board. They are used for two purposes: first, to increase the number of terminals connected to any chosen point in a circuit so that several elements may be connected to that point; second, as simple mounting points for plug-in components which are connected with patch cords to component terminals elsewhere on the board.

Summing Amplifier Terminals (AMP GRID, AMP IN & AMP OUT)

The terminals of each amplifier (summers and integrators) are in a horizontal row opposite the number of the amplifier on the margin of the patch board. The complete behind-the-board connections to amplifier No. 4 are shown in Figure 1. All summers (that is, all amplifiers labelled Σ) are connected in this way.

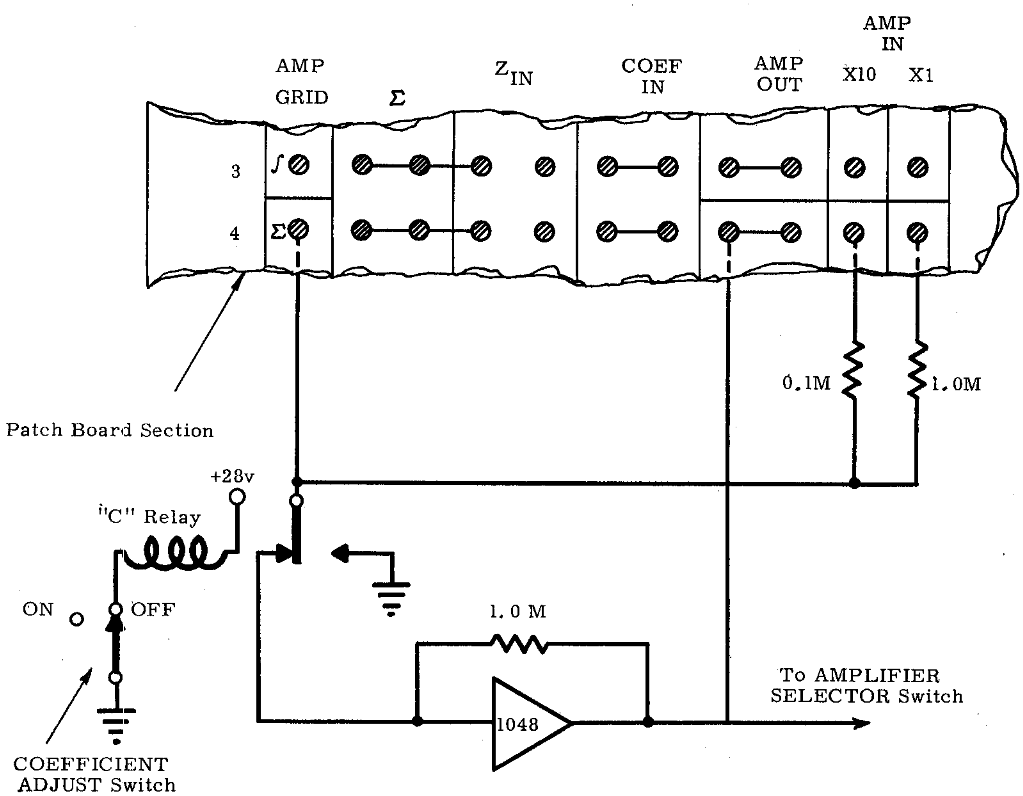


Figure 1

Each amplifier has a fixed feedback resistance (R_o) of 1 megohm. A 1 megohm input resistor is connected from the input grid to the X1 terminal on the patch board. A 0.1 megohm input resistor is connected from the grid to the X10 terminal on the board. You may use these terminals to set up the amplifier as a "unity" or "times ten" inverter without patching in external resistors. The input grid is also connected directly to the GRID terminal on the patch board. External plug-in input resistors may be patched to this terminal. The "C" Relay contact in Figure 1 is positioned as shown except when the COEFFICIENT ADJUST Switch is ON.

Integrator Amplifiers Terminals (AMP GRID, AMP IN, AMP OUT)

The complete behind-the-board connections to integrator amplifier No. 1 are shown in Figure 2. All amplifiers labelled " ∫ " are connected in this way.

1.0 megohm and 0.1 megohm input resistors are connected to the X1 and X0 AMP IN terminals, and the input grid is connected directly to

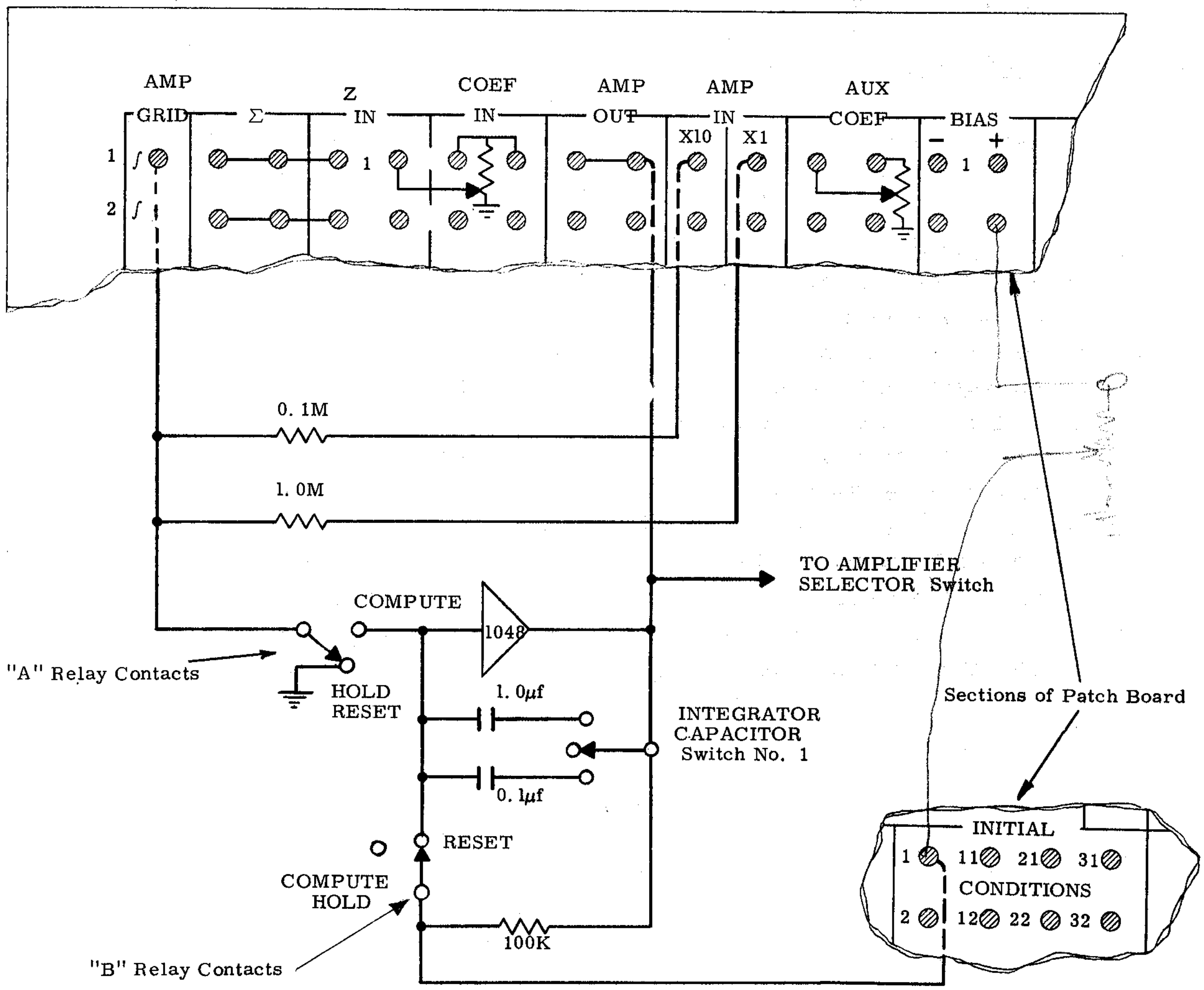


Figure 2

the AMP GRID terminals. A 1.0μf or 0.1μf feedback capacitor is chosen by 3-position switch labelled with the number of the integrator under "INTEGRATOR CAPACITORS" below the patch board.

When the SPECIAL-INTEGRATE switch bearing the number of the integrator is at INTEGRATE, the "A" & "B" relays are positioned according to the operating condition set by the control unit. In the RESET condition the input grid is connected to the INITIAL CONDITION terminal marked by the number of the integrator. In this state the BIAS voltage, patched across the AMP OUT terminal and the INITIAL CONDITION terminals, charges the feedback capacitor.

NOTE: The five SPECIAL-INTEGRATE switches above the control unit panel are each labelled with the numbers of four integrators. Any group of four may be converted to summing amplifiers by the following steps:

1. Place the SPECIAL-INTEGRATE switch at SPECIAL.
2. Place the INTEGRATOR CAPACITORS switches labelled with the same numbers at the center position.
3. Patch a 1 megohm feedback resistor from the AMP GRID to the AMP OUT terminal of each amplifier.

When this is done the amplifier operates exactly like a summing amplifier. The "A" & "B" relays are not influenced by the operating condition of the computer. "A" and "B" relay contacts are positioned as shown in Figure 2 when the COEFFICIENT adjust switch is ON. When this switch is OFF both contacts assume the opposite position.

Unity Inverter Terminals

INVERT

Terminals for six unity inverter amplifiers numbered 41 to 46 are available near the center of the board under the two columns labelled "INVERT". Two input terminals for each are adjacent the number of the amplifier in the column labelled "IN" and two output terminals in the OUT column. The input and feedback resistances of these amplifiers are fixed and are both 1M, so that any voltage introduced at either of the two input terminals appears with an opposite sign at both of the output terminals.

Auxiliary Amplifier Terminals

AMPLIFIERS

Terminals for four extra amplifiers which have no internal input or feedback resistors are available in a row near the center of the patch board labelled "AMPLIFIERS."

Multiplier Terminals

X, Y & .01 XY

Terminals for sixteen multipliers are located in convenient gaps in the AMP IN and AMP. OUT columns labelled X, Y and -.01 XY. The terminals for each multiplier are in the row marked by its number. The voltage appearing at either of the output terminals in the .01XY column is equal to -.01 times the product of the voltage introduced at the input terminal in the X column and that introduced at the input terminal in the Y column.

Function Generator Terminals

FUNCTION GEN.

Terminals for five function generators are located in the center of the patch board under FUNCTION GEN. See the section of this manual on function generators to learn how these terminals are connected.

Silicon Diode Terminals

DIODES

These are at the top center of the patch board under DIODES. They are connected exactly as shown on the face of the board. Since the diodes are ordinarily used in pairs for limiting circuits, etc, they are numbered in pairs from 1 to 5.

Servo Potentiometer Terminals

COEF IN & AUX COEF

The numbers composing the second column in from the margins of the patch board refer to the first sixty precision potentiometers located in the control unit. The terminals adjacent to each number (one under Z_{IN} and two under COEF. IN) are connected to that potentiometer as shown in the schematic diagram which appears on the patch board near numbers 1 and 31. Terminals for the remaining thirty-eight potentiometers in the control unit are in the broken columns labelled "AUX. COEF." These, numbered 61 to 98, are connected as shown on the board near numbers 61, 72 80 and 92. To learn how to set the potentiometers see "Coefficient Potentiometer Servo Adjustments" under "CONTROL SYSTEM CONTROLS".

Manual Potentiometer Terminals

MANUAL COEF.

Terminals for four manually adjusted, auxiliary potentiometers are located near the bottom of the patch panel. These are marked MANUAL COEF. and numbered M-1, M-2, M-3 and M-4. The potentiometers are located on the control unit panel just above the patch board.

Variable DC Voltage Terminals

BIAS

The + and - terminals in the columns marked "BIAS" are connected to the positive and negative sides of 20 adjustable ungrounded d-c voltages sources located in the Model 1006 Variable DC Voltage Source. These sources are used mainly to provide initial conditions voltages for the integrator amplifiers.

Reference Voltage Terminals

+100V REF. & -100V REF

Terminals near the center of the patch board labelled +100V. REF. and -100V. REF carry a fixed reference potential 100 volts positive or negative of ground.

Step Switch Terminals

STEP

Two pairs of these are located near the center of the board under "STEP". The terminals are connected exactly as indicated on the board. Snapping the STEP switch on the control unit to "ON" closes both switches simultaneously.

Amplifier Output Terminals

AMP SW.

Two terminals at the extreme lower right corner of the patch board are connected to the output of the amplifier selected by the AMPLIFIER SELECTOR pushbuttons on the control unit.

Meter Input Terminals

MTR CKT

Two terminals at the exterme lower left corner of the patch board may be connected to the control unit meter. See "CONROL SYSTEM CONTROLS, Meter Readings" for instructions on how to measure voltages introduced at this point.

Slave Unit Connection Terminals

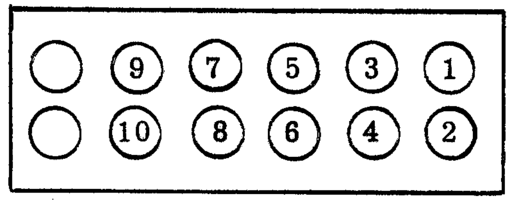
A & B

Two pairs of terminals labelled only A and B are just above the MANUAL COEF. terminals. The potential at these points determines the operating condition (RESET COMPUTE HOLD or REPETITIVE) of the computer. If one of the A terminals is patched into an A terminal on another control unit patch board and a B terminal into a B terminal on the other, this control unit will govern the operation of the other or vice versa. The RESET button on the slave control unit must be depressed.

Recorder Terminals

REC.

At the lower center of the board are ten recorder terminals in two columns under "REC". A pushbutton selector on the control unit will connect any one of these terminals to any one of three recorder input terminals at the rear of the receptacle unit. See "CONTROL SYSTEM CONTROLS Recorder Input Selector". In addition each patch board recorder terminal is permanently connected to a pin on the 10 CHANNEL RECORDER socket at the rear of the receptacle unit. The arrangement of pins in this socket viewed from the side which receives the recorder plug is shown below. The circle representing each pin contains the number of the patch board terminal connected to that pin.

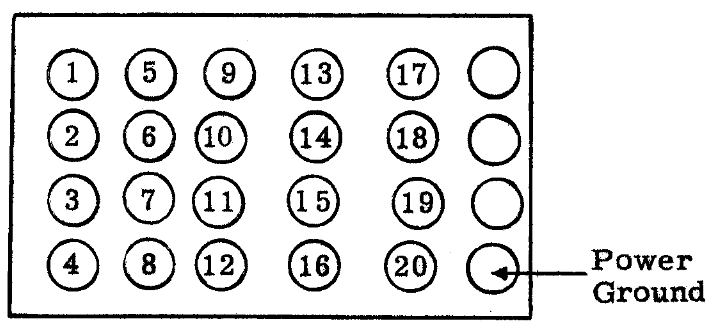


10 CHANNEL RECORDER

External Connection Terminals

EXTERNAL CONNECTIONS

Two groups of twenty terminals, located in the lower center of the patch board under EXTERNAL CONNECTIONS, are connected directly to two INTERCONNECTION sockets on the rear of the receptacle unit. Below is a diagram of an INTERCONNECTION socket viewed from side into which the plug fits. The number of the EXTERNAL CONNECTION patch board terminal to which each pin connects is lettered within the circle representing the pin.



INTERCONNECTION A or B

CONTROL SYSTEM CONTROLS

Controls on the control system perform five primary functions:

1. They establish the over-all operating condition of the computer.
2. They select a precise comparison voltage which is used as a reference to measure or adjust other voltages in the computer.
3. They select the meter input to measure voltages at selected points in a problem-solving circuit.
4. They adjust the coefficient potentiometers
5. They select the points in a problem-solving circuit which are connected to recorder channels.

The Operating Conditions (RESET, COMPUTE, HOLD & REPETITIVE)

With the COEFFICIENT ADJUST switch at OFF the operating condition of the computer is established by depressing one of four pushbuttons low on the face of the control unit.

1. In the COMPUTE condition the computer will "solve" whatever problem has been entered into it. The computer elements are connected in accordance with the problem-solving circuit set up on the patch board.
2. The computer is placed in the RESET condition to set up a problem-solving circuit. It should be in this state when initial conditions voltages are being applied and integrator coefficient potentiometers are being adjusted. At RESET the computing circuitry is connected as it is in the COMPUTE condition with two differences. First, all integrator input resistors are disconnected from the integrator input grids and grounded. Second, any initial condition voltage which has been patched to an integrator is connected across the feedback capacitor.

3. Pressing the HOLD button interrupts the solution of a problem and allows you to inspect the voltages existing in the computing circuitry at the instant of interruption. In this condition the voltages remain fixed at their previous value. The computing circuitry is connected as it is in the COMPUTE condition except that all integrator input resistors are disconnected from the integrator grids and grounded.

4. In the REPETITIVE condition the computer switches repeatedly from COMPUTE to RESET and back. The RESET period is one-tenth of a second. The COMPUTE period may be varied from about 1/3 of a second to 10 seconds by adjusting the REPETITION RATE control. This condition is used to repeat a solution which is in the form of voltages varying with time so that they may be observed on an oscilloscope. When the computer is operated in this way the stability of a solution is immediately apparent.

A problem will not be solved correctly if any of the operational amplifiers is overloaded during the computation. When an overload occurs the blue OVERLOAD indicator lamp will light. If the OVERLOAD ALARM switch is ON, a buzzer will buzz also to call attention to the error. If the OVERLOAD HOLD switch is ON, the computer will automatically switch to the HOLD condition so that the offending amplifier will remain overloaded and may be located. An overload indicator lamp will be lighted on the front panel of the chassis which holds this amplifier.

A simplified diagram of the circuitry which establishes the operating condition appears in Figure 3 of the control system section of the computer manual.

The Comparison Voltage (COEFFICIENT Pushbuttons)

A pushbutton adjusted voltage divider in the control unit produces a precise comparison voltage ranging from 0 to 99.9 volts in tenth-volt steps. This voltage is used as a reference with which other voltages generated in the computer are compared in order to determine their magnitude or to adjust them to a desired value. Its value is set by punching in three digits on the triple row of pushbuttons labelled "COEFFICIENT". For example, if you punch in 8, 3 and 5 from left to right the comparison voltage produced is 83.5 volts.

Meter Readings (METER SELECTOR Pushbuttons)

By pressing the proper pushbutton in the row labelled "METER SELECTOR" you may connect the meter to indicate:

1. A potentiometer setting
2. The output of an amplifier
3. Either of the precise reference voltages
4. The voltage introduced at one of the MTR CKT terminals at the extreme lower left corner of the patch board.

The most accurate voltage measurements are obtained by using one of the NULL buttons. When either of these buttons is depressed the meter indicates the difference betwean the voltage being measured and a comparison voltage selected by the COEFFICIENT pushbuttons. When the meter reads zero the measured voltage equals the punched-in comparison voltage. You may measure a voltage by punching in different values on the COEFFICIENT buttons until the meter comes to zero. You may set a voltage at a desired value by punching in that value on the COEFFICIENT buttons and adjusting the voltage until the meter indicates zero.

1. Potentiometer settings are read by metering the output of a selected potentiometer when its input is connected to a +100 volts reference source. To do this place the COEFFICIENT ADJUST switch at ON and, if the potentiometer is at the input to an integrator, push the RESET button. Then punch in the potentiometer

number on the COEFFICIENT SELECTOR. When the DIRECT button under COEFFICIENT CALIBRATE is depressed the meter indicates the output voltage on the 100 volt scale. When the NULL button is depressed the meter indicates the difference between the potentiometer output voltage and the comparison voltage selected by the COEFFICIENT pushbuttons.

2. To read the output voltage of an amplifier punch in its number on the AMPLIFIER SELECTOR push buttons and set the full scale of the meter with one of the pushbuttons under "AMPLIFIER OUTPUT". For greatest accuracy use the NULL button. When this button is depressed the meter indicates the difference between the amplifier output voltage and the comparison voltage selected by the COEFFICIENT pushbuttons.

3. To read one of the reference voltages depress the pushbutton labelled +100V or -100V in the REFERENCE VOLTAGE section. Both positive and negative voltages deflect the meter to the positive side and both are read on the 0 to 100 volt range.

4. To read any voltage introduced at one of the MTR CKT terminals on the patch board, depress the button labelled "M" on the AMPLIFIER SELECTOR and proceed as though you were measuring the output of an amplifier.

Coefficient Potentiometer Servo Adjustments (COEFFICIENT SELECTOR pushbuttons)

The control unit may contain as many as 98 10-turn potentiometers which can be inserted at various points in the problem solving circuit by patch board connections. Any potentiometer may be set with pushbuttons to produce an output voltage which is a desired fraction of its input voltage.

First, the input of a selected potentiometer is disconnected from the patch board terminal and connected to the +100 volt reference source. Then the comparison voltage is adjusted to that fraction of 100 volts and the servo system varies the potentiometer until its output equals the comparison voltage. The adjustment should be made after the potentiometer has been inserted into the problem-solving circuitry with patch cords. To set a potentiometer proceed as follows:

1. If the potentiometer is at the input to an integrator, press the RESET button.

   This grounds all the integrator input resistors so that if the potentiometer is connected to one it will be adjusted under load.

2. Snap the COEFFICIENT ADJUST switch to ON. This step:
   1. Grounds all summer input resistors
   2. Provides +100 volts to be connected to the potentiometer input.
   3. Energizes the servo amplifier
   4. Permits potentiometer terminals to be disconnected from the patch board.

3. Punch in the number of the potentiometer on the double row of pushbuttons labelled COEFFICIENT SELECTOR

   This disconnects input of the potentiometer from the board and connects it to the +100 volts source. It also connects the output of the potentiometer to the servo mechanism while leaving it connected to the board.

4. Punch in the desired fraction in thousandths on the COEFFICIENT pushbuttons. For example, if the output is to be .473 of the input, depress 4, 7 and 3 from left to right.

5. Press and hold the SERVO motor button until the SERVO NULL light goes out, indicating that the potentiometer is set.

   This adjusts the potentiometer until its output equals the comparison voltage or, in the example given, 47.3 volts which is .473 of the 100 volt input

6. You may check the potentiometer setting by pressing the NULL button under the COEFFICIENT CALIBRATE section of the METER SELECTOR.* The meter will read very near zero if the potentiometer is set accurately. You may adjust the potentiometer until the meter reads exactly zero by rotating the COEFFICIENT ADJUST knob. Ordinarily the servo adjustment is sufficiently accurate and this manual adjustment is unnecessary.
7. Reconnect the potentiometer input to the board terminal by changing the COEFFICIENT SELECTOR setting or turning the COEFFICIENT ADJUST switch off.

Manual Potentiometer Adjustments (MANUAL COEFFICIENT Controls)

Four manually adjusted 10-turn potentiometers are located just above the patch board and connected to correspondingly numbered MANUAL COEF terminals on the board. These potentiometers have a full resistance of 50K and are calibrated from 0 to 1000. Thus, each division on the dial represents 50 ohms. The resistance between the upper patch board terminal and the wiper terminal equals that indicated by the dial ± 50 ohms.

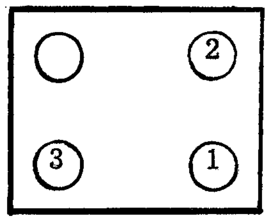
The Recorder Input Selector (READOUT pushbuttons)

The READOUT pushbuttons are used to connect any 3 of 10 possible readout points to a three-channel recorder. For example, depressing button 7 in column 1 connects recorder terminal 7 on the patch board to terminal 1 on the 3 CHANNEL RECORDER socket at the rear of the control unit. The recorder terminals connected to terminals 2 and 3 on the rear socket are chosen similarly by depressing buttons in columns

* If the NULL button is depressed during step 5, the meter will swing to zero as the potentiometer is servo-adjusted.

2 and 3. The socket terminals are numbered as diagramed below viewed from the side into which the recorder plug will fit.

3 CHANNEL RECORDER



Integrator Capacity Selector (INTEGRATOR CAPACITORS Switches)

Each switch in the row beneath the set-up panel selects the feedback capacitance of the integrator whose number is labelled above the switch. Each switch has three positions. In the center position the feedback circuit is open.

A SAMPLE PROBLEM

INTRODUCTION

Figure 4 is a diagram of a sample problem-solving circuit. This circuit is designed to illustrate the use of nearly all the types of operational components. The following pages describe a method of constructing the entire circuit (except the function generator) and extracting information on its performance. As a practice exercise you may actually construct the circuit step-by-step in accorance with the directions. The connactions and adjustments which form the function generator circuit are complex and vary with the type of function generator used. See the section of the computer manual on function generators for instructions. For the sake of simplicity you may replace the function generator by a coefficient potentiometer connected between "In" and "Out" in Figure 4.

References to other pages of the manual appear in brackets. Thus, [Op. 2] refers to page 2 of the operation section. You need not read the references to successfully complete the sample problem. The referenced pages contain further information which will help you see why each step is necessary and how it would be done in a different problem.

INITIAL ADJUSTMENTS

Amplifier No. 4 is used for the summing amplifier in Figure 4, amplifier No. 1 for the integrator, and amplifier No. 47 for the limiting inverter. The multiplier and the function generator may be any of those installed in the computer. Apply power to these components and make initial adjustments as described on pages 1 to 8 of the operation section.

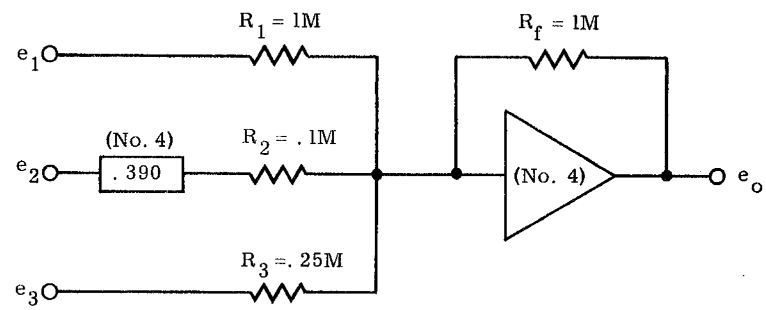
PATCH BOARD CONNECTIONS

The patchboard connections are described first since these may be made before the board is placed in the receptacle unit. Following this is a description of the various control settings which complete the circuit.

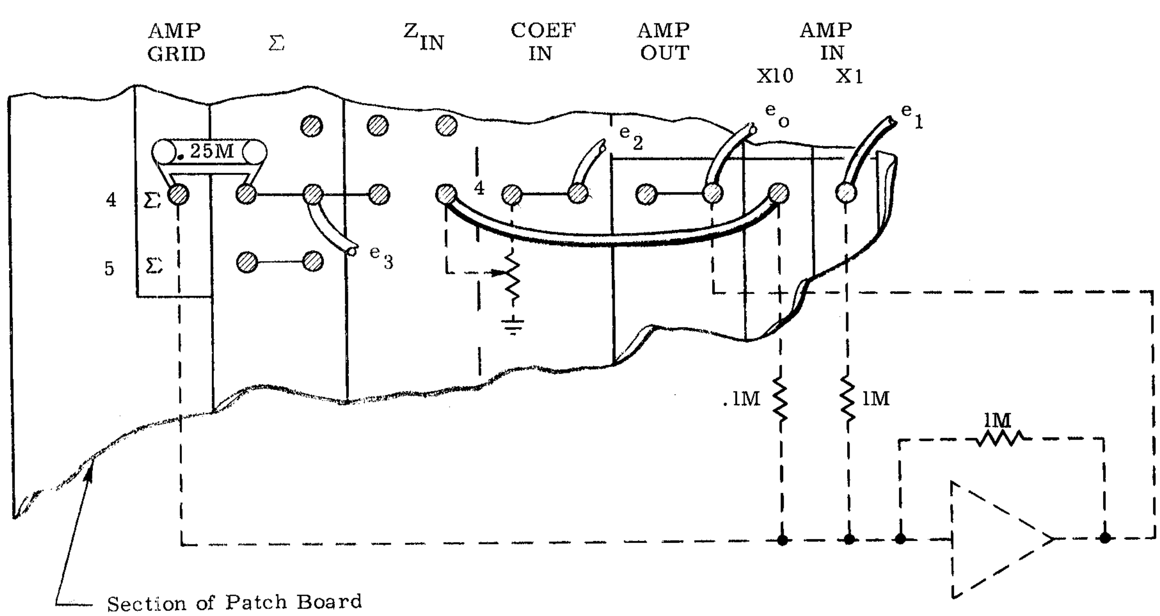
Plug-in resistors are available in three values identified by color: 1 megohm (brown), .1 megohm (grey) and .25 megohms (yellow). The shorting bars look just like the resistors but are colored black. The yellow plug-in components with two black binding posts projecting from one end are not resistors. Each post is connected to the prong beneath it.

Connecting the Summing Amplifier

The diagram below is the part of Figure 4 enclosed in dotted lines on the left hand side. It is a typical summing amplifier circuit. The rectangle represents a potentiometer set to the coefficient marked within it.



Patch board connections which must be made to construct this circuit using amplifier No. 4 are shown below. The rest of the circuit which will be

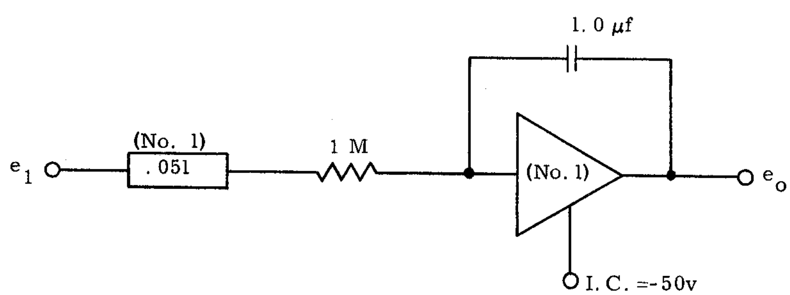


formed when the patch board is in place and the solution is being generated is shown by dotted lines. For a complete description of the behind-the-board connections to a summing amplifier see "Operation-9".

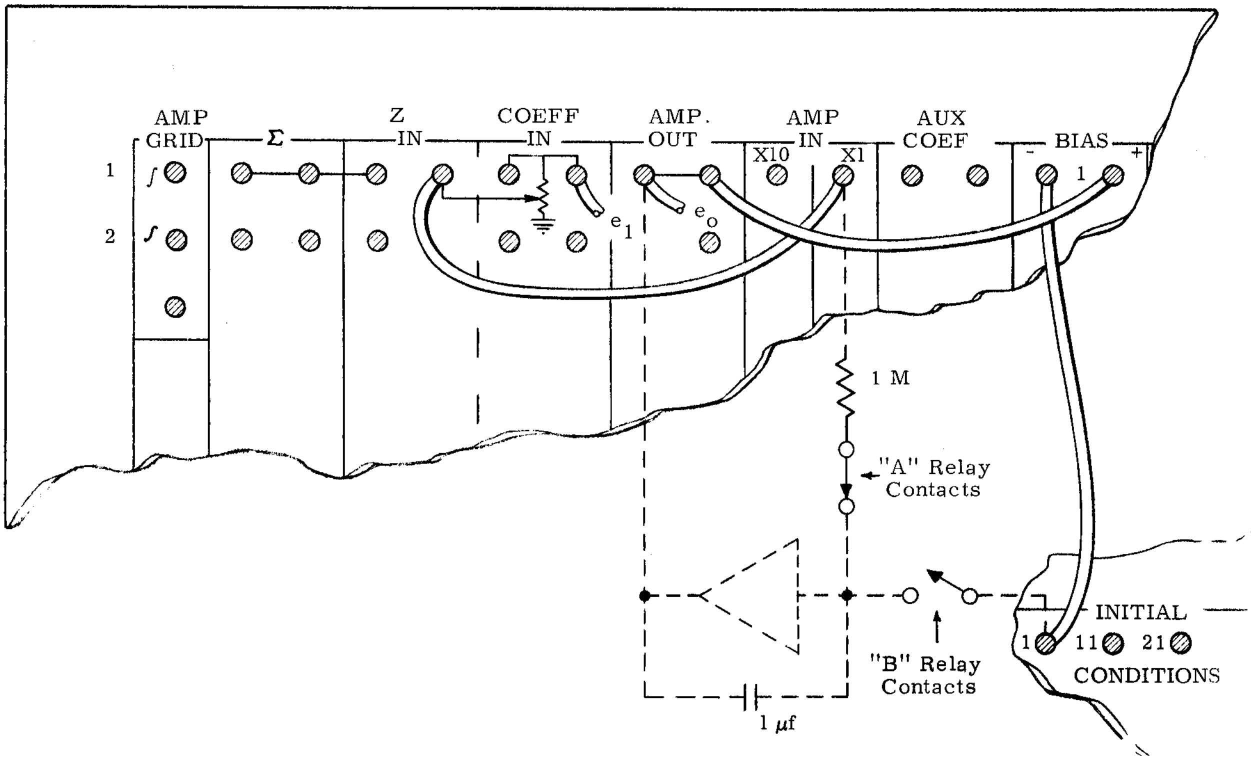
Note that the internal resistors connected to the X1 and X10 terminals have been used for R_1 and R_2. Coefficient potentiometer No. 4 has been used merely because its terminals are near the summing amplifier terminals. Any other potentiometer would work just as well in the circuit. [Op. -13]

Connecting the Integrator

The diagram below is the part of Figure 4 enclosed in dotted lines on the right-hand side. It is an integrator circuit. I.C. is the initial condition voltage.



Patch board connections which must be made to create the circuit diagramed are shown on next page. The dotted lines show the rest of the circuit which will be formed when the patch board is in place. The relay contacts are shown as they are positioned when the equipment is actively computing. When the I.C. voltage is being applied the "A" relay contacts are open and the "B" relay contacts closed, thus placing the BIAS voltage across the feedback capacitor. For a complete description of the behind-the-board connections to the integrator terminals see "Operation-10".



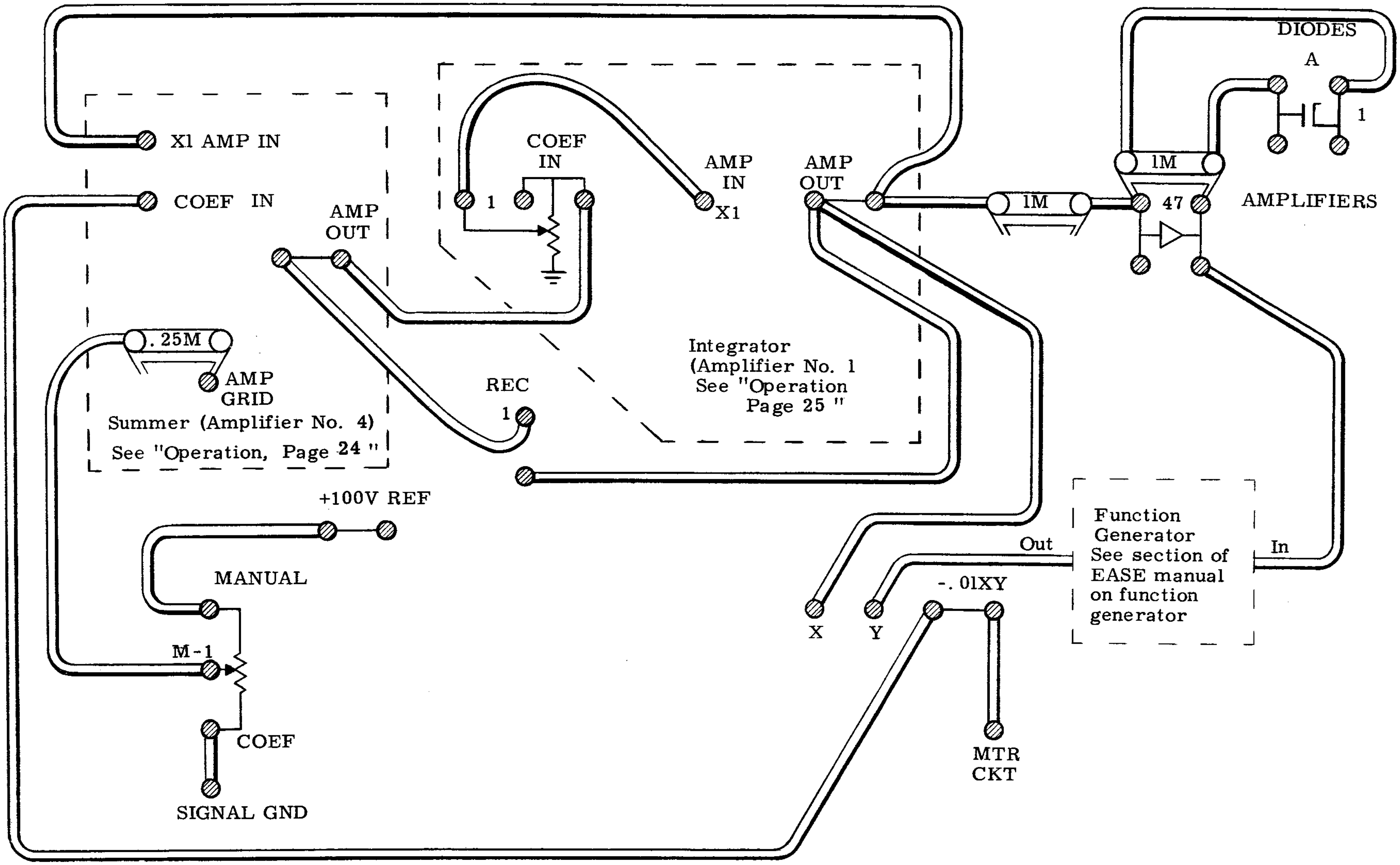
Connecting Other Components

Figure 3 shows all the remaining patch board connections necessary to form the circuit of Figure 4 except those forming the function generator circuit. Directions for constructing that circuit are in the section of the computer manual on function generators. The function generator may be replaced by a direct connection from "In" to "Out" in this practice exercise.

Since no internal input or feedback resistors are connected to amplifier No. 47, plug-in resistors are used for both. Because there is no room to mount the input plug-in resistor at the amplifier grid terminal, it is mounted elsewhere on the board and connected to the input grid with a patch cord.

The multiplier circuit is not influenced by controls on the control system. It is complete once the patchboard connections shown have been made. [Op.-13]

Manual potentiometer M-1 has been used instead of a servo-adjusted potentiometer because it is easier to adjust manually over a wide range. [Op.-14]



The double lines represent patch cords or shorting bars. The circles represent patch board holes identified on the board by the capitalized abreviations and by the simple schematic diagrams drawn between the holes.

Figure 3 Sample Problem Patch Board Wiring

CONTROL SETTINGS

After the patch board connections forthe sample problem are complete, place the set-up panel in the receptacle unit and lock in place. Then make the following adjustments on the face of the control cabinet.

Servo Potentiometer Adjustments

Refer to Figure 4. Note that coefficient potentiometer No. 4 is to be set to .390. Do this as follows:

1. Place the COEFFICIENT ADJUST switch at ON.
2. Punch in 0 4 on the COEFFICIENT SELECTOR pushbuttons.
3. Depress 3 9 0 from left to right on the COEFFICIENT pushbuttons.
4. Press and hold the SERVO button until the SERVO NULL light goes out.
5. Depress the NULL button under the COEFFICIENT CALIBRATE section of the METER SELECTOR. The meter should read near zero.
6. Rotate the COEFFICIENT ADJUST knob until the meter reads exactly zero. (For most purposes this adjustment is unnecessary, since the servo adjustment is sufficiently accurate).

Notice that on Figure 4 potentiometer No. 1 is to be set to .051. Do this as follows.

1. Leave the COEFFICIENT ADJUST switch ON.
2. Depress the RESET button.
3. Punch in 0 1 on the COEFFICIENT SELECTOR and 0 5 1 on the COEFFICIENT pushbuttons.

4, 5 & 6 Follows steps 4 thru 6 listed above for the other potentiometer adjustment.

If a coefficient potentiometer is used in place of the function generator, set it to .100 in the same way that potentiometer No. 4 was adjusted. Then return the COEFFICIENT ADJUST switch to OFF.

Adjusting the Manual Potentiometer [Op. -21]

Manual potentiometer M-1 is to be set so that the output of amplifier No. 4 is +93.6 volts when X = 0. X appears at the output of amplifier No. 1 To set the output of this amplifier at zero depress the RESET button and temporarily unplug one end of the patch cord running from BIAS terminal +1 to the AMP OUT terminal for amplifier 1. Then, proceed as follows to adjust the potentiometer while metering the output of amplifier 4.

1. Punch in 0 4 on the AMPLIFIER SELECTOR pushbuttons
2. Place the REFERENCE toggle switch at "+" and punch in 9 3 6 on the COEFFICIENT pushbuttons
3. Depress the NULL button under the AMPLIFIER OUTPUT section of the METER SELECTOR.
4. Rotate MANUAL COEFFICIENT potentiometer No. 1 until the meter reads zero.
5. Replace the patch cord connecting the BIAS terminal with the AMP OUT terminal.

Control Adjustments for the Integrator Circuit.

Notice on Figure 4 that the integrator is amplifier No. 1. Place the SPECIAL-INTEGRATE level switch which has "1" labelled above it at INTEGRATE (that is, perpendicular to the panel). Note that the integrator feedback capacitor should be 1μf. To put this in the circuit move INTEGRATOR CAPACITORS switch No. 1 up to 1.0 MFD. Note that the initial condition voltage should be +50 volts and that the INITIAL CONDITION terminal for amplifier 1 has been connected to BIAS terminal -1. To set the initial condition voltage proceed as follows:

1. Depress the RESET button.

   This connects the INITIAL CONDITION terminal to the integrator grid.
2. Place the REFERENCE TOGGLE switch at "+" and punch in 5 0 0 from left to right on the COEFFICIENT pushbuttons.

   This places +50 volts on one side of the meter circuit.

3. Punch in 0 1 on the AMPLIFIER SELECTOR pushbuttons.
   This connects the output of amplifier No. 1 to the other side of the meter circuit.
4. Depress the NULL button under the AMPLIFIER OUTPUT section of the METER SELECTOR.
   This completes the meter circuit.
5. Adjust potentiometer No. 1 on the Model 1006 Variable D-C Voltage Source panel until the meter reads zero.
   This places 50 volts across the feedback capacitor.

RUNNING THE PROBLEM [Op-16]

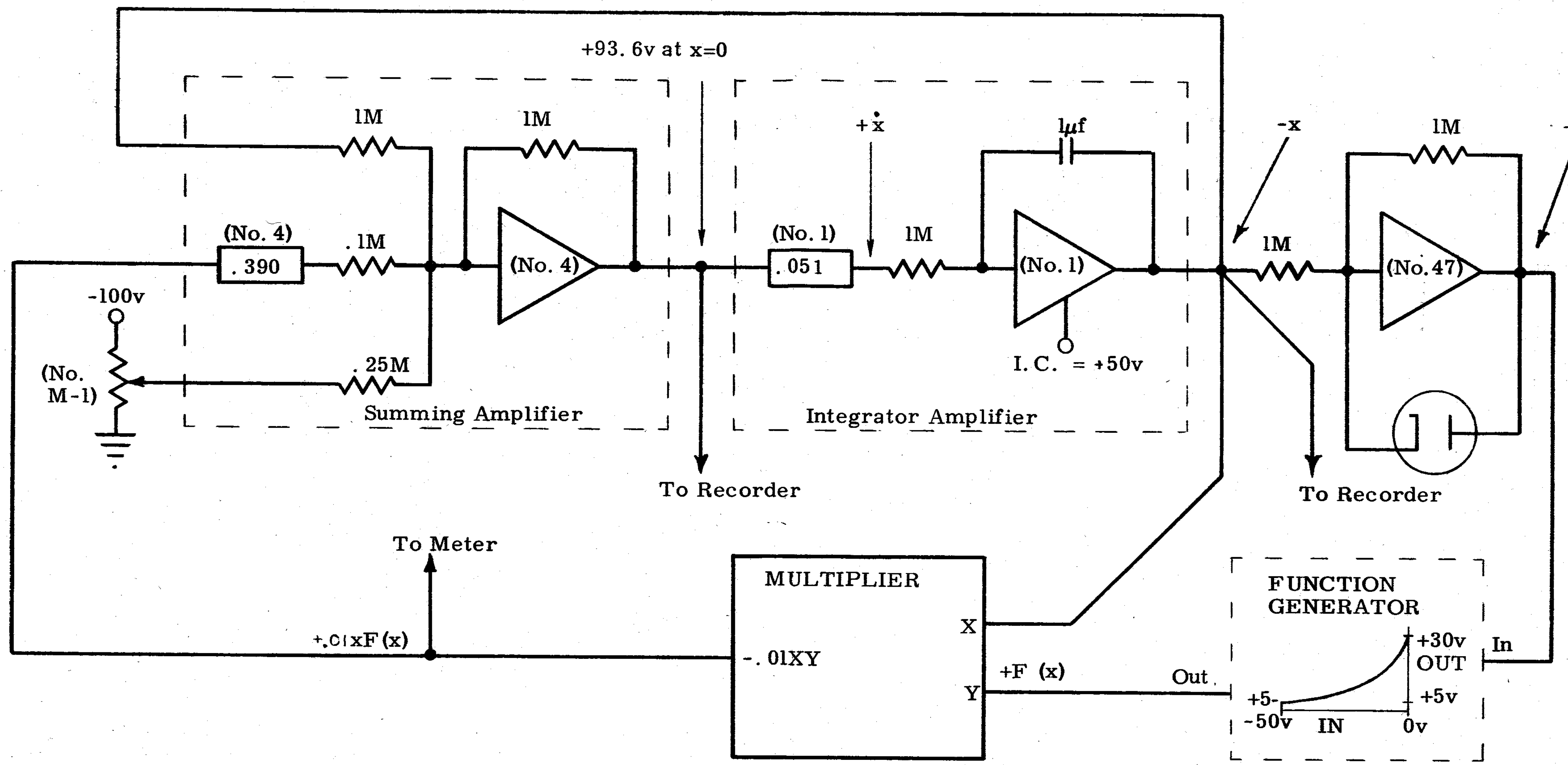
After the patchboard connections and the control adjustments described on the preceeding pages are complete, the circuit diagramed in Figure 4 will be formed whenever the COMPUTE button is depressed. To generate the solution, first press the RESET button. This enters the initial condition voltage at the output of the integrator. Then, press the COMPUTE button. This initiates the voltage changes throughout the problem-solving circuit which constitute the solution. Note whether the OVERLOAD indicator lights at any point in the solution. This indicates that an amplifier is overloaded and that the solution is incorrect if it is an amplifier used in the problem-solving circuit. A lighted indicator on one of the Model 1041 panels will identify the overload amplifier. Auxilliary amplifiers (Nos. 47 thru 50) are likely to overload if they are left without a feedback resistor. Insert a plug-in resistor from the input to the output of all these amplifiers which are not used in the problem-solving circuit.

To meter the output of the multiplier depress the button labelled"M" on the AMPLIFIER SELECTOR and depress one of the buttons in the AMPLIFIER OUTPUT section of the METER SELECTOR [Op. -18]. Press the button labelled with the appropriate full scale range.

Patch board connections have been made from the output of amplifier 4 to recorder terminal No. 1 (REC 1) and from the output of amplifier 1 to recorder terminal No. 2 (REC 2). To record the changing voltages at these points connect recorder channels to Pins 1 and 2 of the 10 CHANNEL RECORDER jack at the rear of the control system cabinet. The location of pins 1 and 2 is shown on "Operation-15".

> NOTE: In more complex problem than this you may wish to record voltages at a greater number of points in the circuit than the number of channels on available recording apparatus. The READ OUT pushbutton switches provide a means of quickly switching a recorder channel from one point in the circuit to another. See "Operation-21" for a description of this device.

To halt the solution at any time press the HOLD button. This fixes circuit voltages at the values existing at the instant the button is pressed. If you place the OVERLOAD HOLD switch at ON, the computer will switch to the "hold" condition automatically when an overload occurs. This gives the operator an opportunity to locate the cause of the overload. To remove and "overload hold" turn the OVERLOAD HOLD switch off momentarily or simply press the RESET button.

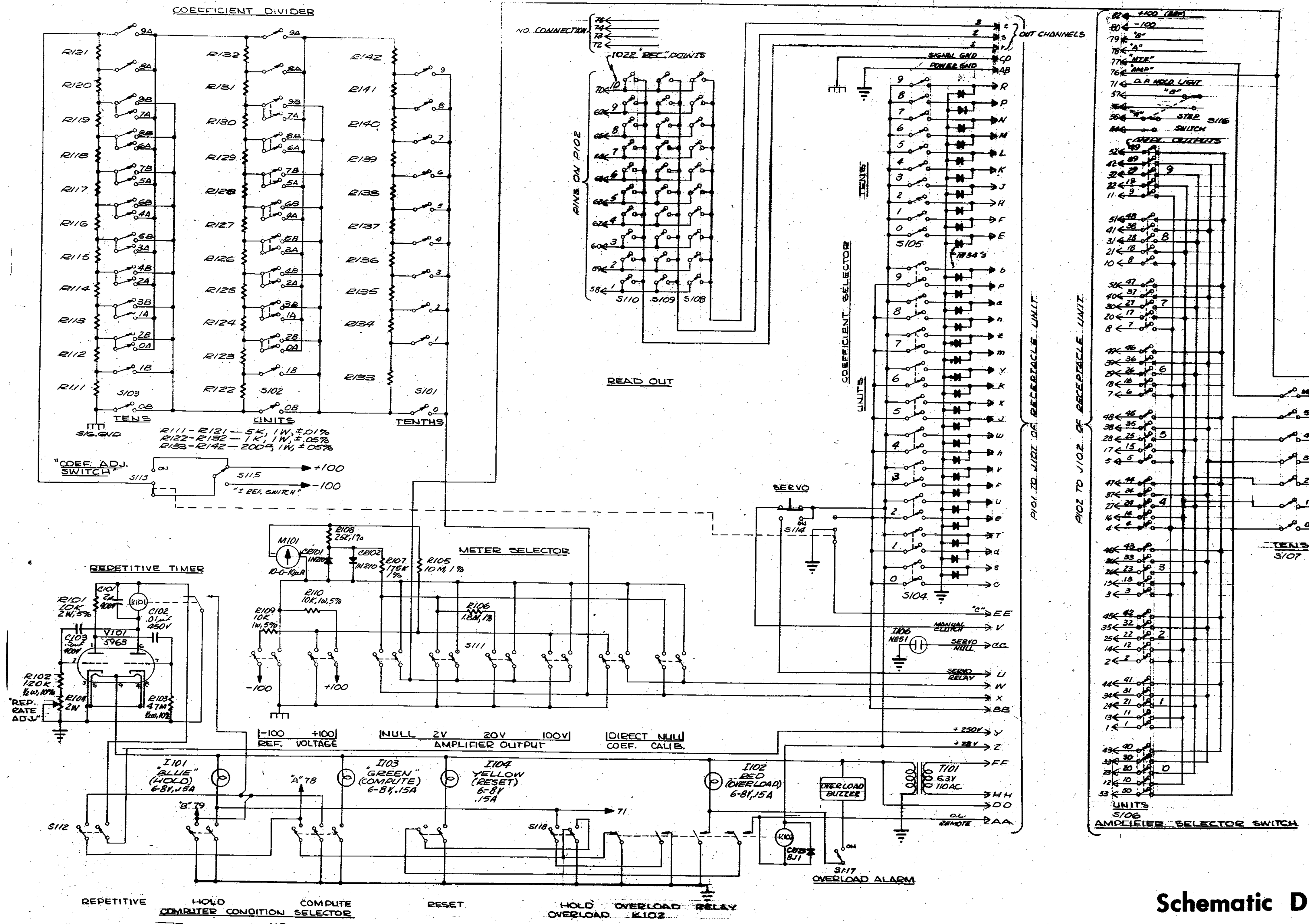


This circuit simulates the equation: $\frac{dx}{dt} = .051x - (.051)^2 (.039)\, x\, F(x) + (93.6)(.051)$

Where x is limited to negative values and at t=0, x =-50

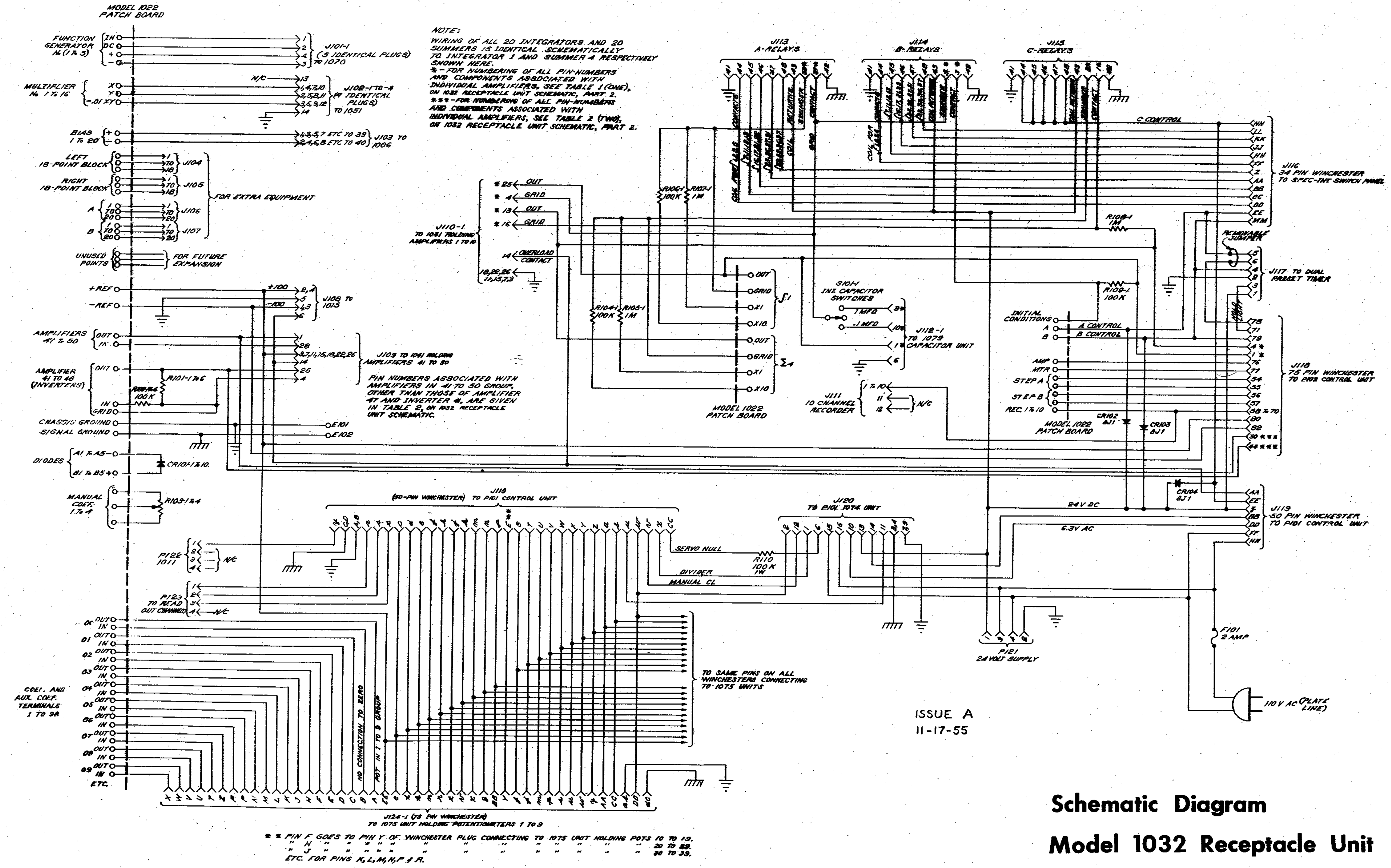
The numbers of computer components used in setting up the sample problem appear in parentheses.

Figure 4 Sample Problem-Solving Circuit



Schematic Diagram

Model 1032 Control Unit



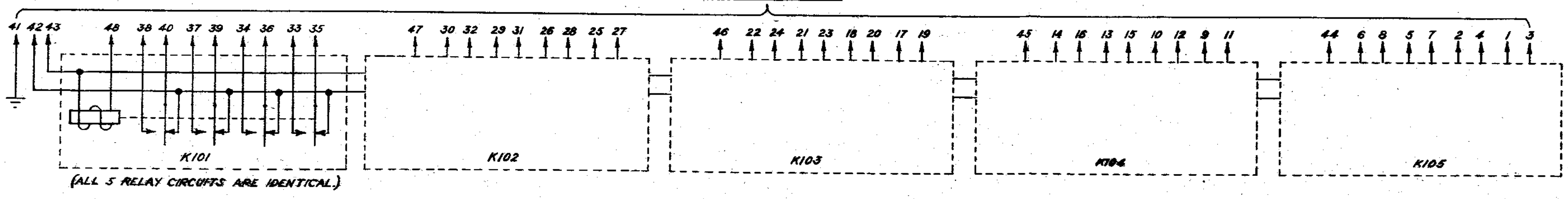
Schematic Diagram

Model 1032 Receptacle Unit

Part 1 of 2

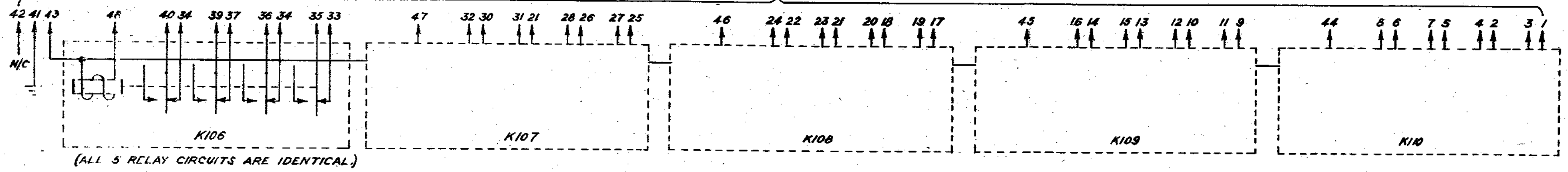
A & C RELAY

P113 (TO J113 OR J115)



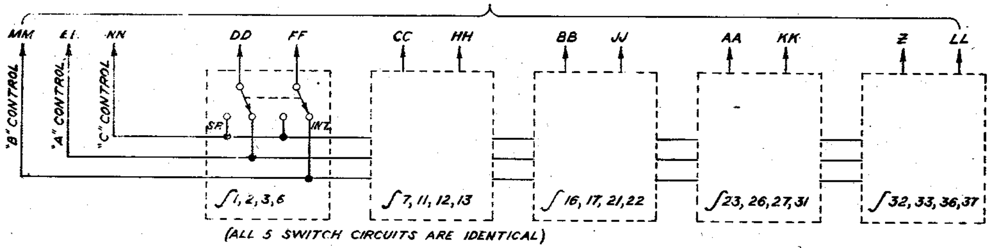
B RELAY

P114 (TO J114)

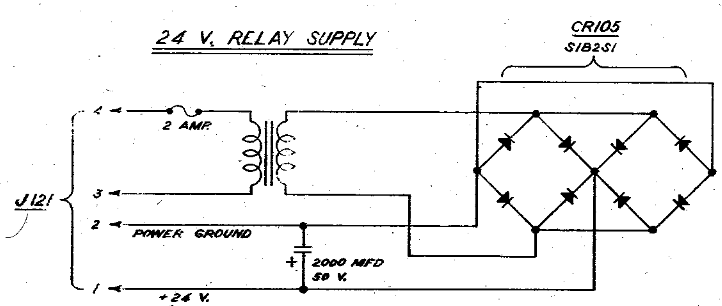


SPEC.-INT. SWITCH PANEL

P116 (TO J116)

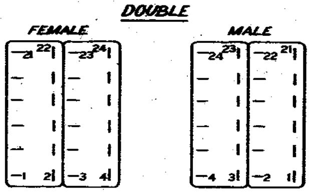


24 V. RELAY SUPPLY



PIN NUMBERING SCHEME FOR VARICON CONNECTORS

DOUBLE



NOTE: THIS SIDE TO WHICH WIRES ARE CONNECTED.

TABLE 2

WIRING OF AMPLIFIERS 41 TO 50

(CONNECTOR PIN NOS.)

INVERTER AMPLIFIERS	J109 PIN NOS. AMPLIFIERS		J118 PIN NOS. CONTROL UNIT
	GRID	OUTPUT	
41	4	25	44
42	8	21	45
43	12	17	46
44	16	13	47
45	20	9	48
46	24	5	49
SIMPLE AMPLIFIERS			
47	28	1	50
48	27	2	51
49	23	6	52
50	19	10	53

WIRING SCHEME FOR AMPLIFIERS 1 TO 40

TABLE 1(a)

INTEGRATOR AMPLIFIERS	J113 PIN NOS. A RELAY		J114 PIN NOS. B RELAY		J118 PIN NOS. CONTROL UNIT	J110 PIN NOS. MODEL 1041			J112 PIN NOS. MODEL 1079			
	CONTACT	SWINGER	CONTACT	SWINGER		GRID	OUTPUT		1.0 μf	0.1 μf	COMMON	
1	37	39	1	3	1	4	25	J110-1	9	10	1	J112-1
2	38	40	2	4	2	8	21		7	8	2	
3	33	35	5	7	3	12	17		13	14	3	
6	34	36	6	8	7	24	5		11	12	4	
7	29	31	9	11	8	28	1		15	16	5	
11	30	32	10	12	13			J110-2				J112-2
12	25	27	13	15	14							
13	26	28	14	16	15							
16	21	23	17	19	18							
17	22	24	18	20	20							
21	17	19	21	23	24			J110-3				J112-3
22	18	20	22	24	25							
23	13	15	25	27	28							
26	14	16	26	28	29							
27	9	11	29	31	30							
31	10	12	30	32	34			J110-4				J112-4
32	5	7	33	35	35							
33	6	8	34	36	36	SAME AS ABOVE			SAME AS ABOVE			
36	1	3	37	39	39							
37	2	4	88	40	40							

TABLE 1(b)

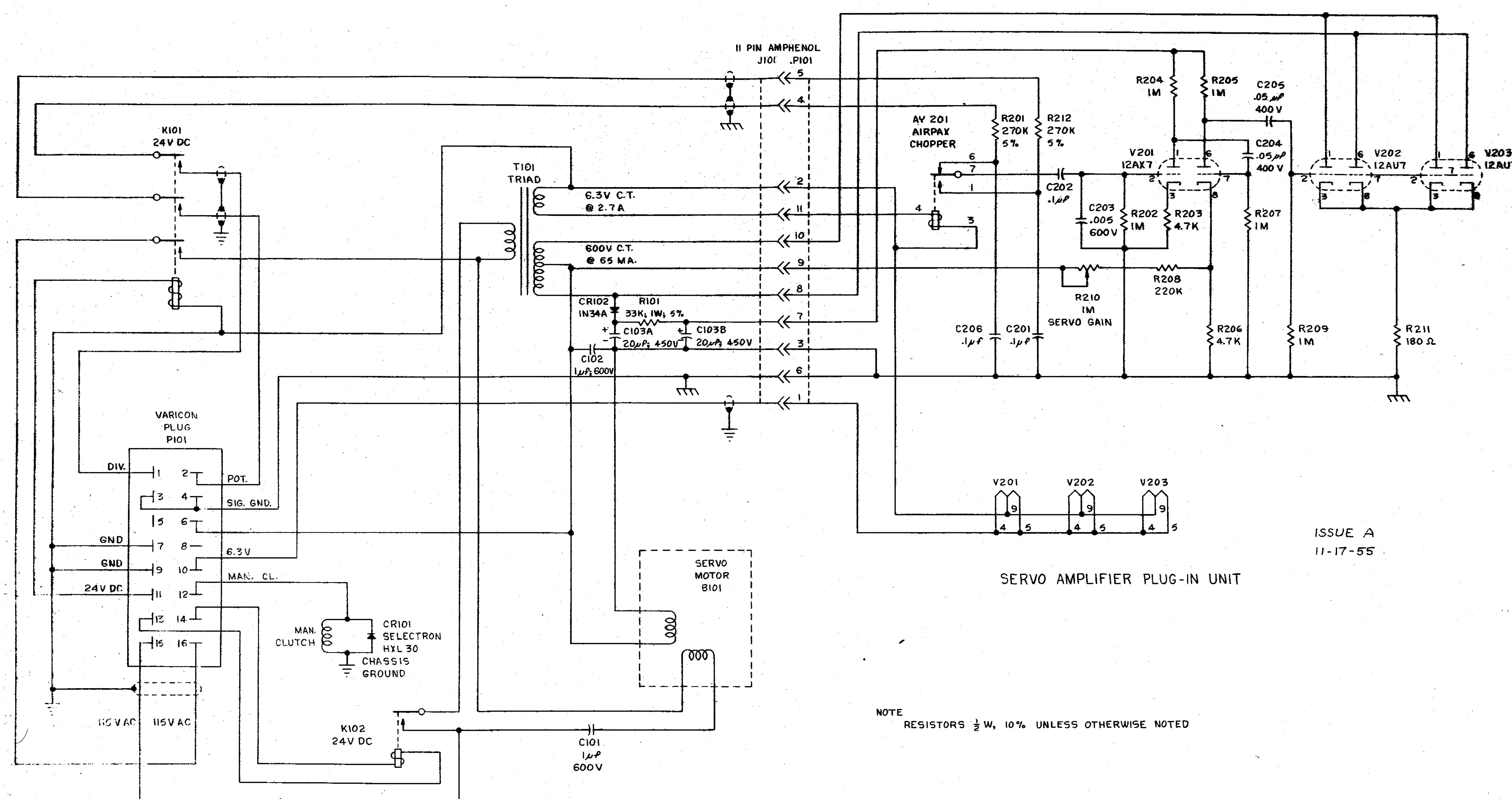
SUMMING AMPLIFIERS	J115 PIN NOS. C RELAY		J118 PIN NOS. CONTROL UNIT	J110-1 TO J110-4 PIN NOS. MODEL 1041		
	CONTACT	SWINGER		GRID	OUTPUT	
4	1	3	4	16	13	J110-1
5	2	4	5	20	9	
8	5	7	10	27	2	
9	6	8	11	23	6	
10	9	11	12	19	10	
14	10	12	16			J110-2
15	13	15	17			
18	14	16	21			
19	17	19	22			
20	18	20	23			
24	21	23	27			J110-3
25	22	24	28			
28	25	27	31			
29	26	28	32			
30	29	31	33			
34	30	32	37			J110-4
35	32	35	38			
38	34	36	41	SAME AS ABOVE		
39	37	39	42			
40	38	40	43			

ISSUE A
11-17-55

Schematic Diagram

Model 1032 Receptacle Unit

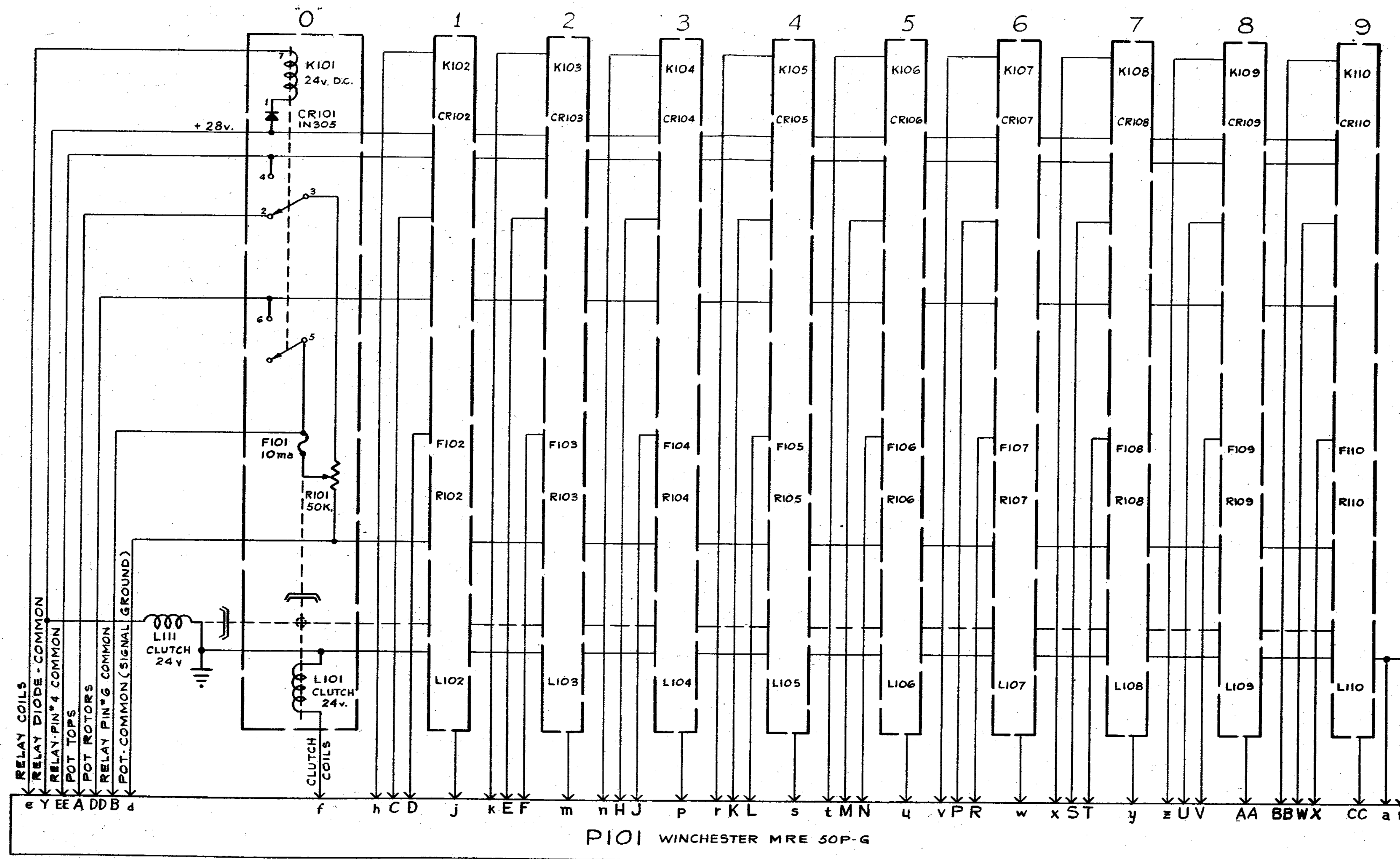
Part 2 of 2



NOTE
RESISTORS ½ W, 10% UNLESS OTHERWISE NOTED

Schematic Diagram

Model 1074 Potentiometer Mounting Unit



11-17-55

NOTE:-
"1" THRU "9" ENCLOSURES ARE IDENTICAL CIRCUITS AS SHOWN IN "0" ENCLOSURE

Schematic Diagram

Model 1075 Potentiometer Unit

INSTRUCTION MANUAL

Model 1048
OPERATION AMPLIFIER

BERKELEY division
Beckman Instruments, Inc.

Richmond 4, California
30 November 1955

WARRANTY

Every instrument manufactured by the BERKELEY division of Beckman Instruments, Inc. is warranted to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year from date of shipment to the original purchaser prove to be defective after our examination.

Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

Model 1048 Amplifier

DESCRIPTION

The Model 1048 Operational Amplifier is a chopper stabilized d-c type offering the foremost in accuracy, quality, flexibility, and convenience. Its extremely high gain and low drift, together with plug-in mounting, make it ideal for analog computer use. Ten Model 1048 amplifiers can be plugged into the Model 1041 Operational Amplifier Panel. The Model 1041 supplies plate and filament voltages and contains circuitry for balancing the amplifiers and indicating overloads.

SPECIFICATIONS

D-C drift after Warm-up (Referred to summing junction	Average per hour: Less than 30 μv
	Average per day: Less than 100 μv
	Average drift of unity integrator is less than 0.1 v per hour at output.

Gain

D-C Amplifier	Above 100,000
Stabilizing Amplifier	1,000 from d-c to .005 cps
Total	Above 10^8 at d-c
Variation with output voltage	Constant at d-c over full operating voltage range.

Frequency Response

When connected as a unity inverter with 1 megohm input and feedback resistances, the amplifier behaves as a second order linear system with a natural frequency of 20 kc, a damping ratio of 1/2 and a phase shift of about 10° at 4 kc.

Summing Junction Error Current	Less than 100 $\mu\mu$ amperes
Noise Level	Less than 5 mv referred to summing junction.
Output	
Type	A voltage 180° out of phase with the input
Voltage Range	± 125v maximum ± 100v normal
Maximum Power	15 ma at 100 volts
Impedance at d-c	Below 0.01 ohms
Power Requirements (Furnished by Model 1041)	
Regulated d-c	+250v, 16 ma plus load current
	-250v, 2 ma plus load current
	-465v, 4.5 ma
Regulated a-c	6.3 volts, 60 cps, 1.3 amps
Non-regulated a-c	6.3 volts, 60 cps, 0.6 amps
Tube Complement	One each: 12AU7, 12AY7, 12AX7, 6U8, 12AT7, 5963, Chopper (Stevens Arnold type D-11)
Dinensions	5 3/8" high, 3 1/8" wide, 6 1/2" deep
Weight	2 lbs.

INSTALLATION

Each Model 1048 amplifier is shipped with a clamp on the chopper mounting to protect the chopper during shipment. The clamp may be removed after installing the computer. If the clamp is retained, it should be kept insulated from the chopper shell. The chopper shell is internally connected to signal ground but the clamp is at power ground. Insulation between the two will avoid connecting signal ground to power ground at this point. See the installation section of the computer manual to learn how to connect a Model 1041 panel in an EASE computer. The amplifiers are throughly checked and adjusted before shipment. After a check of power supply voltages they should be ready for operation.

OPERATION

To place the amplifier in operation apply power to the filaments, wait one-half minute, then apply plate power. Allow the amplifier to warm up half an hour before balancing it or using it in a problem-solving circuit. (If the filaments have been energized for some time, a 15 minute warm-up under plate power is sufficient.) When plate power is applied the overload indicator may light and remain lit for a minute or two while the amplifier stabilizes. This is normal. However, an indicator which remains lit indefinitely indicates a faulty amplifier.

Below the number of each amplifier on the panel is a two-position lever switch. When this switch is in the ON (up) position the input and output terminals of the amplifier are connected to the set-up panel and other control system circuitry, and the amplifier may be inserted in a problem-solving circuit if it is properly balanced.

Front Panel Balance or "Zero" Adjustment

This adjustment corrects for amplifier drift and provides an indication of the operating condition of the amplifier. Although daily drift is negligible under normal conditions, daily adjustment is suggested since the procedure is quick and easy and will enable the operator to detect faulty amplifiers before they are used.

To balance an amplifier place all lever switches at ON (up) except the switch belonging to the amplifier to be adjusted. Move this switch to the down (balance) position. Then, adjust the screwdriver control above it until the front panel meter reads zero. This indicates that the output voltage is zero (at ground) with the input at ground. If the meter will not come to zero the amplifier is defective and should not be used in a problem-solving circuit. If the balance adjustment is insensitive compared to that of other amplifiers, the amplifier may lack enough gain to perform properly. When a defective amplifier is left in the computer rack and energized along with the rest, make sure that a feedback resistor (100K to 1M) is connected between the amplifier output and the input grid. This will prevent the amplifier from overloading and actuating the alarm circuitry on the control system. All amplifiers used as summers have a feedback resistor connected under all conditions. The other amplifiers may require a resistor patched in on the set-up panel.

CAUTION: Take care not to connect the amplifier output to ground, since this will damage the output tube. Do not connect a patch cord from the AMP OUT terminal to the AMP GRID terminal on the Model 1022 patch board because the AMP GRID terminal is grounded during some computer operations.

When the lever switch is in the balance (down) position the input and output of the amplifier are disconnected from the set-up panel and connected as follows:

1. Input to ground thru 1 K resistor.
2. Output to front panel meter
3. Output to input through 1 megohm feedback resistance.

This arrangement yields a summing amplifier with a gain of 1000. Since the input resistor is grounded, the output voltage is 1000 times the drift or offset voltage. The front panel meter is calibrated to indicate the offset voltage referred to the summing junction. The meter has a usable indicating range of $\pm 100 \mu$volts.

METHOD OF STABILIZATION

When the input voltage of a d-c amplifier is kept constant, the output voltage changes with time from the original value to some other. This phenomenon, called drift, is caused mainly by changes in B+ and heater voltages, variations in resistor values, tube aging and grid current changes. In a multistage d-c amplifier drift occurring in an early stage causes a greater change in the output voltage than the same drift in a later stage because the early drift is amplified by the gain all succeeding stages. If drift can be eliminated from the first stage the output drift will be reduced in proportion to the gain of that stage. If the gain of this stage is considerable, the output drift will be reduced to a small fraction of its former value.

The first stage of the Model 1048 is an essentially drift-free amplifier with a gain of 1000. Figure 1 is a simplified diagram of the circuit. The chopper is simply a SPDT switch which switches back and forth at the line frequency of 60 cps. It alternately grounds the input and the output of the a-c amplifier. The resulting amplifier input is a square wave with one peak at ground potential and the other at a positive or negative voltage proportional to the summing junction voltage. The output of this capacitor-coupled amplifier is a greatly amplified square wave. The action of the chopper (which grounds the output during one half of each cycle) places one peak of the amplified square wave at ground.

This wave is then filtered by R_2 and C_2 to produce an average d-c voltage proportional to the d-c input but of the opposite polarity. R_1 and C_1 form a filter which prevents 60 cps noise at the summing junction from reaching the a-c amplifier and producing a change in the d-c output level.

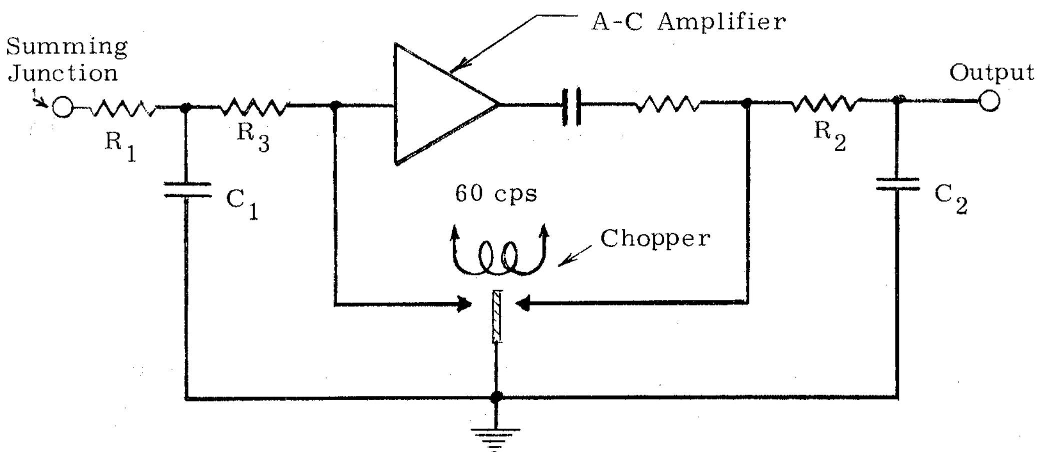


Figure 1 Simplified Diagram of Stabilizing Amplifier

Figure 2 is the frequency response curve of the stabilizing amplifier. Notice that the gain is nearly constant at 1000 from d-c to about .005 cps. At this point the gain begins to decline at 6 db per octave until at 10 cps it is -6 db. Beyond 10 cps the gain declines at 12 db per octave.

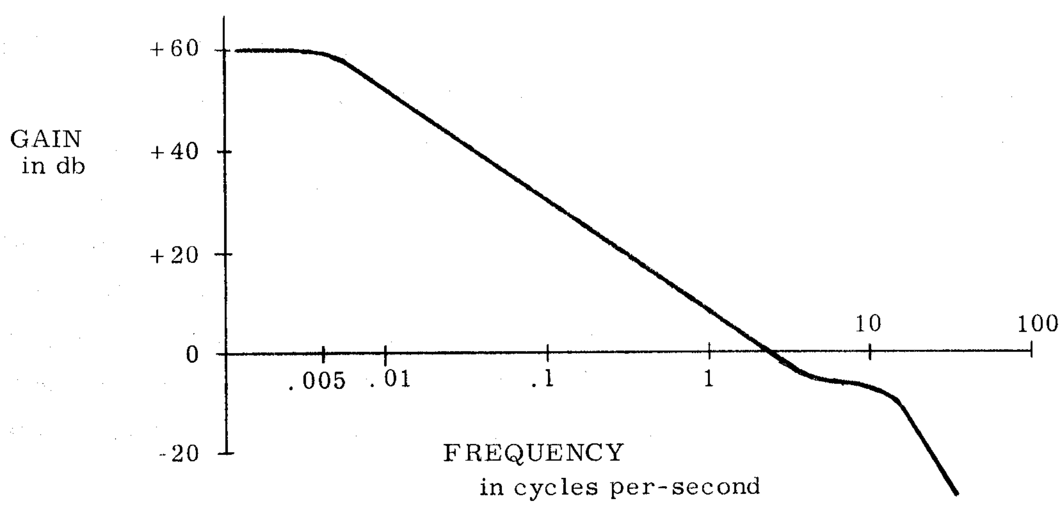


Figure 2 Frequency Response of Stabilizing Amplifier

Figure 3 shows the way the stabilizing amplifier fits into the rest of the Model 1048. The object of this arrangement is to combine the advantages of a drift-free first stage with the broad frequency response of a d-c amplifier. The input signal follows two paths: One directly to the d-c amplifier input, the other through the stabilizing amplifier to the d-c amplifier. The total gain of the Model 1048 is A_2 $(1+A_1)$ where A_2 is the gain of the d-c amplifier (about 100,000) and A_1 is the gain of the stabilizing amplifier. At drift frequencies (from d-c to .005 cps) A_1 is about 1000, and the stabilizing amplifier functions as a first stage. Above .005 cps its gain declines progressively until at higher frequencies this stage is effectively out of the circuit. The dotted lines in Figure 3 shows the way input and feedback resistances are connected when the Model 1048 is used as a summing amplifier.

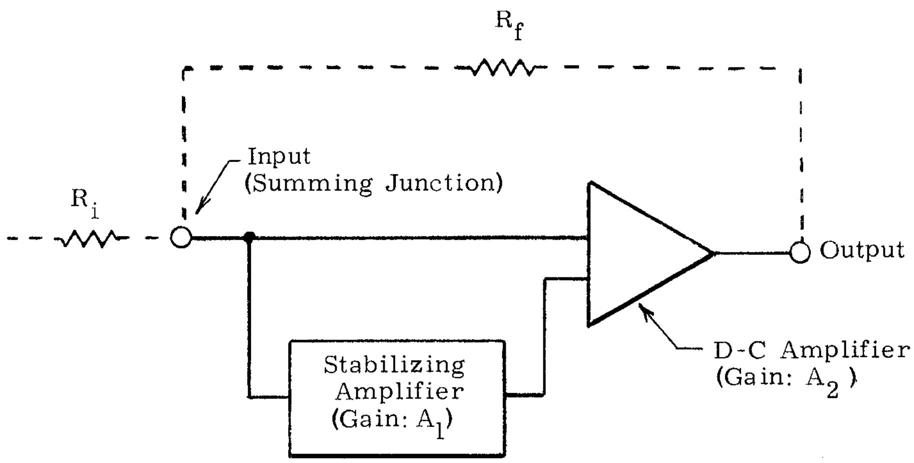


Figure 3 Model 1048 Block Diagram

CIRCUIT DESCRIPTION

The total Model 1048 circuit is shown in the accompanying schematic diagram. V101, the input cathode follower, is operated at very low plate voltage and current in order to keep the grid current less than 100 $\mu\mu$a. C102 couples frequencies above the range of V101 directly to the input of the next stage. The second stage (V102A & B) is an amplifier with positive feedback adjusted to provide "infinite" gain at d-c. This adjustment is described in the maintenance section. The resistor and capacitor (R106 and C102), in series between the plate of V102-A and ground, form a stabilizing network which controls the frequency response and phase shift of this stage. Following the second stage is another stage of amplification (V103-A) which in turn drives the single-ended push-pull output stage (V103-B and V104 A & B). The chief advantage of this type of output circuit is its very low quiescent plate current. This results in a much higher efficiency for a given load than can be obtained with conventional pentode or cathode follower output circuits.

By confining the positive feedback portion of the circuit to the second stage (V102-A, and B) it is possible to keep the gain very high because the unfedback gain is very constant due to the small swing of the plate voltage. As a result, the output linearity of the Model 1048 is about 0.01% for an over-all gain of ten (R_f / R_i = 10) and the output impedance is less than 0.01 ohm below 0.005 cps.

The stabilizing amplifier is the circuit between R118 and C111. The grid of the cathode follower (V105-B) connected to C111 is equivalent to the second input of the d-c amplifier of Figure 3. The output impedance of the cathode follower in series with the coarse and fine zero adjustment potentiometers, all in parallel with the cathode impedance of V102-A, form part of positive feedback network of the infinite gain stage. R108 in series with R109 is the other portion.

The amplitude of the square wave at the output of the a-c amplifier is limited by the capacitor C114 and the selenium diodes CR101 & 2 before it reaches the output filter (R132, R133 and 1 C111). If this were not done the filter capacitor C111 would be over-charged during overload and greatly increase the recovery time of the whole amplifier after the overload was removed. This limiting action reduces the recovery time and, in addition, protects the output chopper contacts from excessive voltages.

The series resistor and capacitor combination (R131 and C110) shunting the filter at the output of the stabilizing amplifier critically damps the response of the system. This minimizes the transient response time of the a-c amplifier and increases its stability.

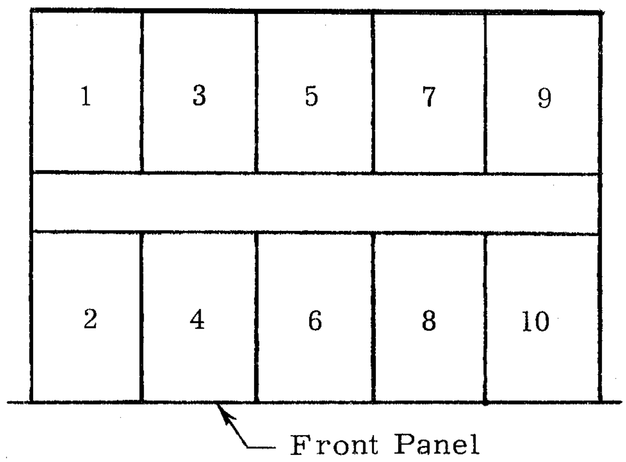
If, due to an overload, summing junction voltage exceeds about 15 millivolts, the amplitude of the square wave at the plate of V106-A becomes very large compared to its amplitude under normal conditions. The diode pumping circuit associated with V106-B responds to this increase in amplitude by increasing the grid bias on V106-B and raising its plate voltage. Referring to the Model 1041 schematic, notice that this increases the voltage across the overload indicator lamp (located on the Model 1041 panel) until it lights. When the summing junction voltage exceeds about 20 millivolts the bias on the 12AU7 (V101 of the 1041) is removed causing it to conduct and energize relay K101. This action in turn can be made to put the computer in a "hold" condition and at the same time operate an audible overload alarm. Since all of the overload indicating lamps have one side connected together, the overload circuit operates when any one of the lamps fires.

The over-all performance of the amplifier when connected as a unity inverter approximates that of a 2nd order system with a damping ratio of about .05 and a natural frequency of about 20KC. Figures 4 and 5 show the relationship between gain and frequency and between phase shift and frequency in the circuits diagramed there.

A .001 μf capacitor (C101) is connected within the amplifier between the summing junction and ground. In case the cable connecting the amplifier to the set-up panel is extraordinarily long, this capacitor may be removed to compensate for the capacity of about 20 feet of cable. The amplifiers are stable even if the summing junction capacity is as high as 0.01 μf, which is the capacity of 200 ft. of cable having a capacitance of 50 $\mu\mu$f per foot.

MAINTENANCE

The diagram below shows how the Model 1048 amplifiers are arranged in the Model 1041 panel. The amplifiers are numbered from 1 to 10. The number of each amplifier appears above the front panel controls associated with it.



TOP VIEW OF MODEL 1041 PANEL

When an amplifier fails to operate properly in a problem-solving circuit, check it first by trying the balance adjustment. If the amplifier balances and shows normal sensitivity, the trouble may be outside the amplifier. The fault may lie in any of three locations:

1. In the amplifier itself.
2. In the circuitry between the amplifier and the set-up panel (relays, connectors, etc)
3. In the patch board connections which have been made. To test the third possibility, patch in an amplifier from some other Model 1041 panel in place of the amplifier which seems to be causing trouble. This substitutes a different amplifier and different connecting circuitry in the problem-circuit. If the trouble persists, the patch board connections are probably wrong. To test the second possibility, remove the suspected amplifier from the Model 1041 panel and replace it with a properly operating Model 1048. If the trouble persists now it is probably due to a defect in the connecting circuitry. If the

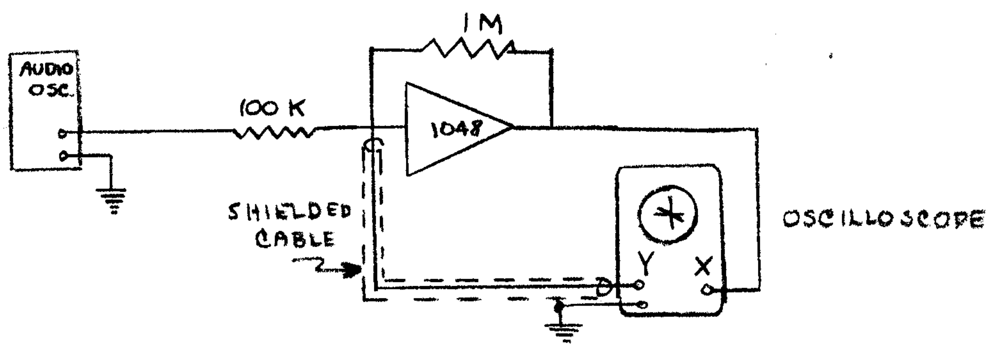
trouble clears, search for a fault in the Model 1048 which was removed. The following adjustment and test procedures will help locate the source of trouble within an amplifier.

Equipment required:

Oscilloscope - 25 mv/in. (e.g. Du Mont 304-A) or 5 mv / cm (e.g. Tektronix 512)
Audio oscillator - 20 cps to 50K cps
Vacuum tube voltmeter - 10 megohms input resistance (e.g. Shasta 201)
Test Cable - Berkeley Model 1048T or equivalent.

Internal Balance and Gain Adjustments

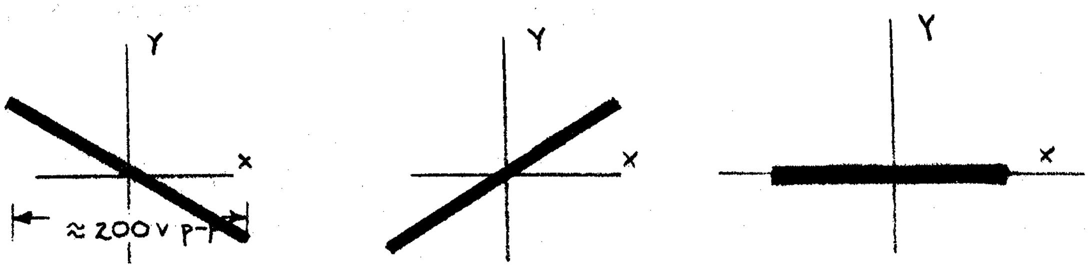
1. Install the amplifier in a 1041 panel and make connections on the set-up panel which form the circuit diagramed below



2. Set oscillator to 45 cps and output to zero voltage.
3. On oscilloscope set Y (vertical) amplifier to minimum gain on a-c and the X (horizontal) amplifier to full deflection at about 200 volts peak-to-peak.
4. Set the front panel balance control halfway between the extremes of rotation. Place the toggle switch beneath this control in the balance (down) position. Adjust the COARSE ZERO control on the top of the Model 1048 chassis until the front panel meter reads within 100 μ volts of zero.
5. Increase output of oscillator until oscilloscope pattern (should be a

horizontal line) extends across tube face.

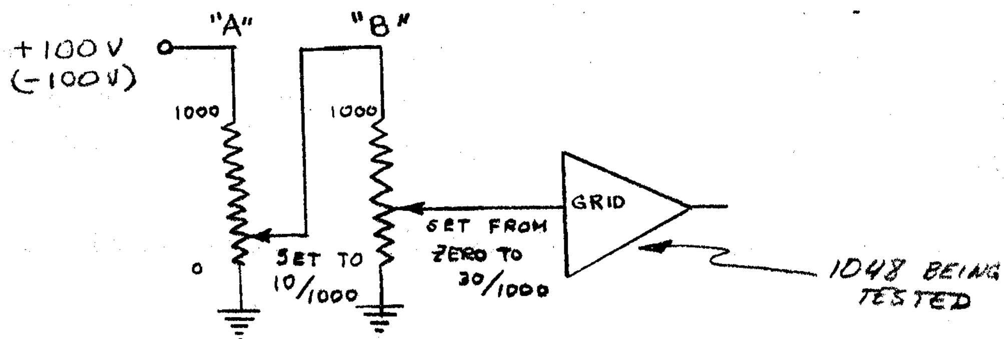
6. Increase gain of Y amplifier to maximum and, adjust the GAIN control on the Model 1048 chassis until the general slope of the pattern is horizontal. The multiple tract pattern is due to 60 cps noise and is normal. It is the general (average) slope that is to be considered. See sketches below:



7. Since the GAIN and COARSE ZERO adjustments interact slightly it may be necessary to repeat each until both show the proper results.

Stabilizing Amplffier Test

1. Remove amplifier from 1041 panel socket and remove V102 (12AX7), V103 (12AT7), V104 (12AU7) and front and side covers.
2. Connect the amplifier to the panel socket with the Model 1048T test cable. This cable merely extends the socket terminals so that the amplifier may be tested in a convenient location. The cable also carries a toggle switch for applying and removing plate voltages and test point jacks connected to the summing junction and amplifier output points. Wait one minute after the amplifier is connected and filaments energized before applying plate voltages with the toggle switch.
3. Connect the amplifier at the computer set-up panel as in the diagram below.



4. Connect the oscilloscope Y input to a point connected to pin 4 of the chopper socket. Set oscilloscope for d-c and an amplitude sensitivity of 25 volts / inch. Synchronize the sweep with the a-c line and adjust it to contain four or five cycles of the line frequency. A square wave should appear on the scope.

5. Vary potentiometer "B" between 0 and 30. This varies the summing junction voltage from zero to 30 millivolts. At 30 millivolts the wave on the scope should reach an amplitude of about 25 volts. Reversing the polarity of the voltage at the input of potentiometer "A" should produce an equal but inverted pattern. C114, CR101 and CR102 limit the amplitude of the square wave. The overload indicator on the 1041 panel should light when the summing junction voltage reaches about 20 mv.

6. Measure the voltage at Pin 8 of V102. This should be about 3 volts when the summing junction voltage is zero and rise smoothly as the summing junction voltage is increased.

Amplifier Load Test

1. Connect a 6,700 ohm resistor (at least 2 watt) from the amplifier output to ground on the set-up panel.

2. With amplifier connected as either a summer or integrator adjust the input voltage to cause output voltage to rise to +100 and -100 volts.

3. The output should reach ±100 volts or more before the amplifier overloads. If the amplifier overloads below 100 volts check V103 and V104.

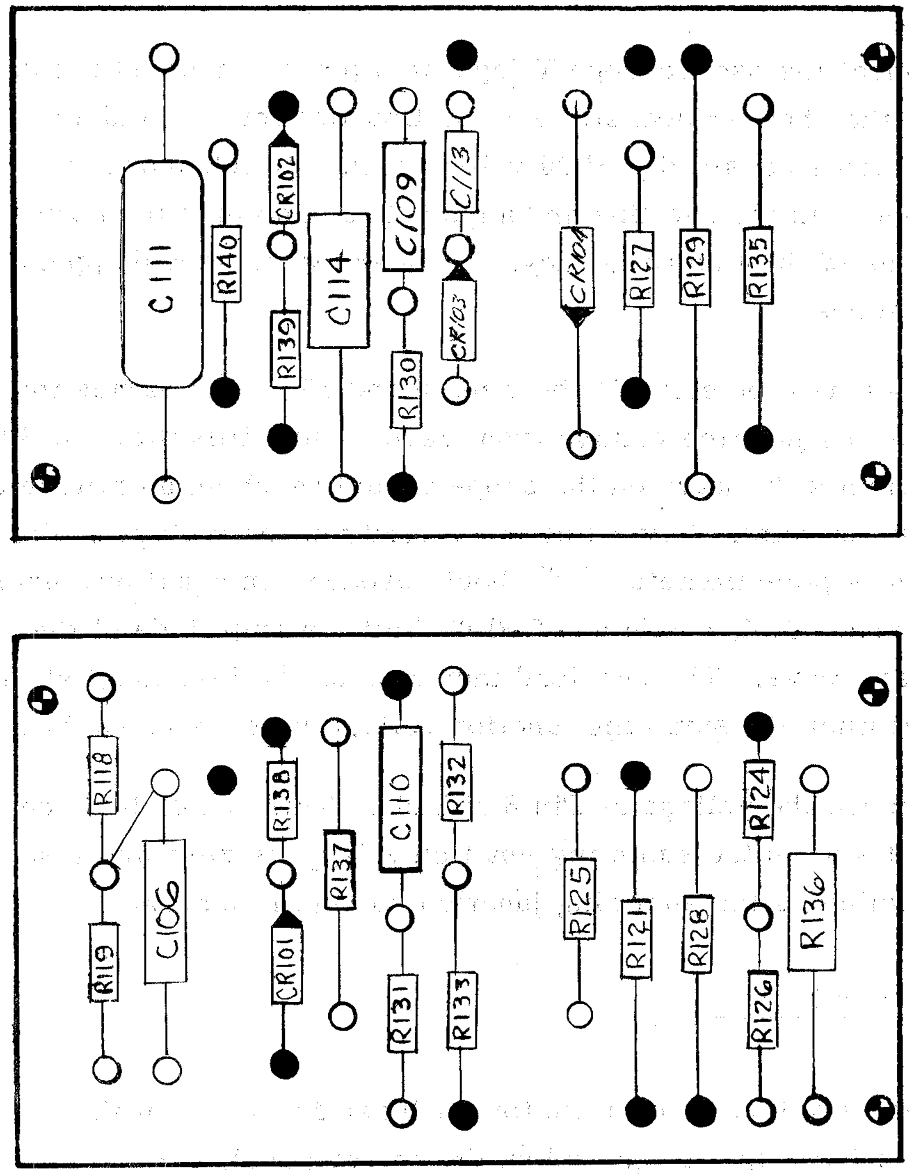


Figure 6 Model 1048 Parts Location Diagram

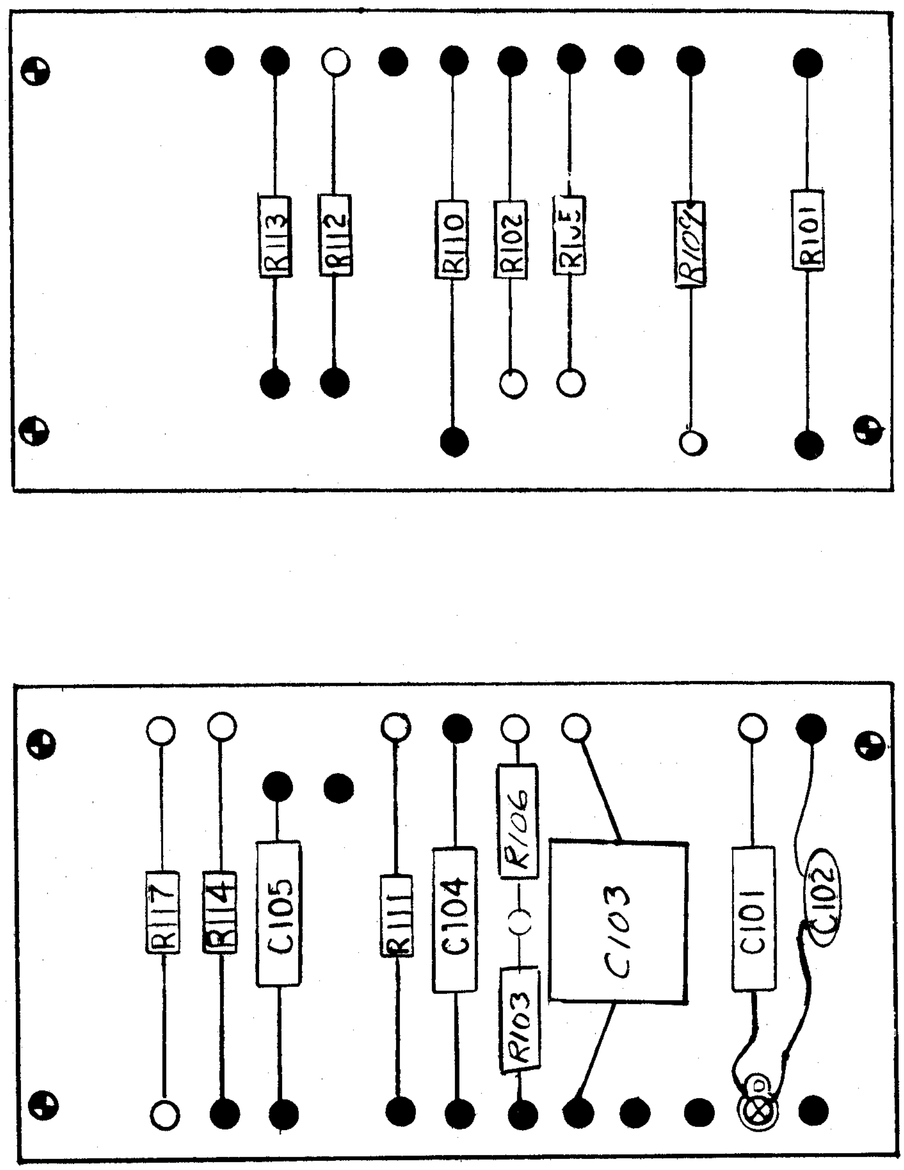


Figure 7 Model 1048 Parts Location Diagram

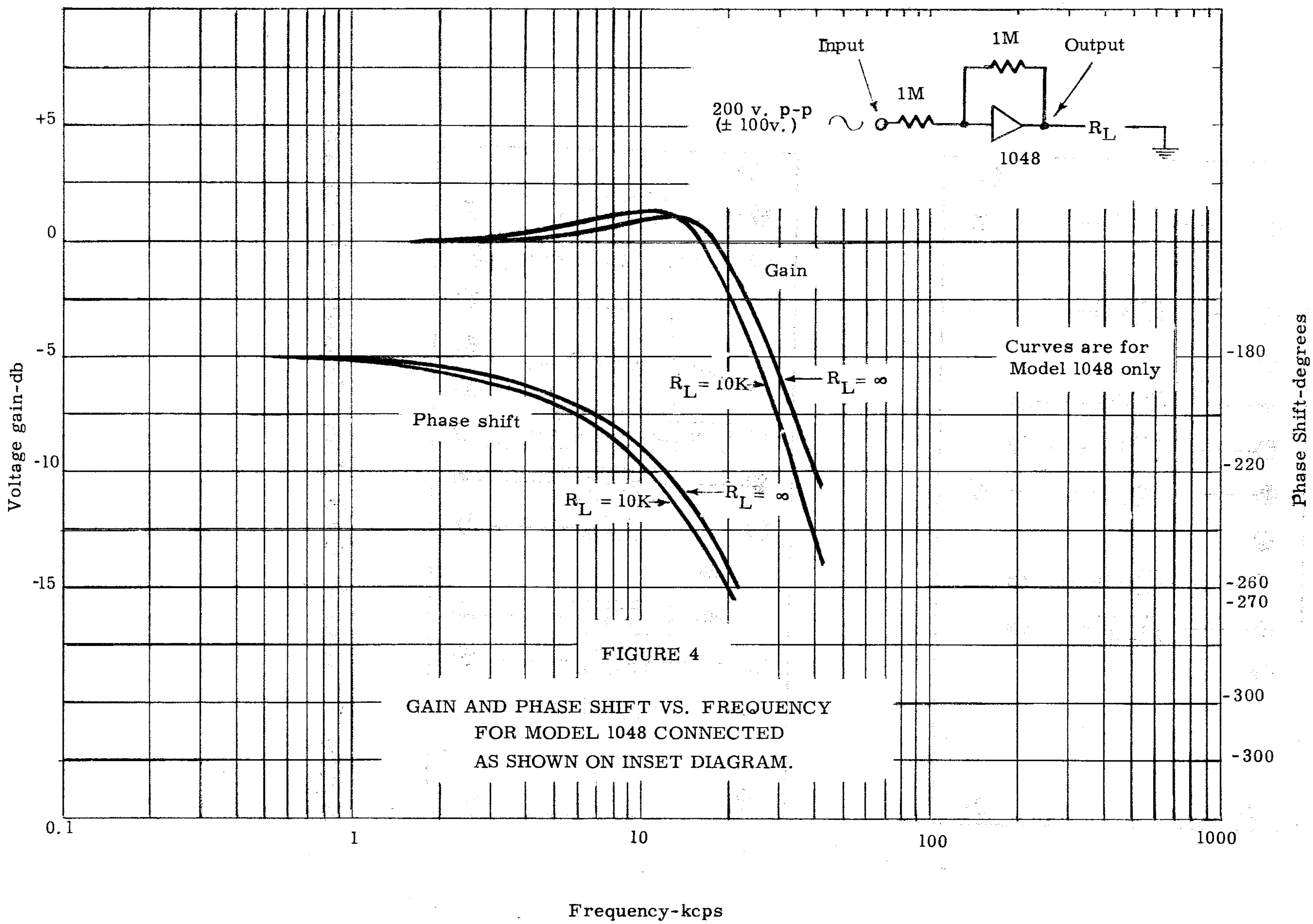


FIGURE 4

GAIN AND PHASE SHIFT VS. FREQUENCY
FOR MODEL 1048 CONNECTED
AS SHOWN ON INSET DIAGRAM.

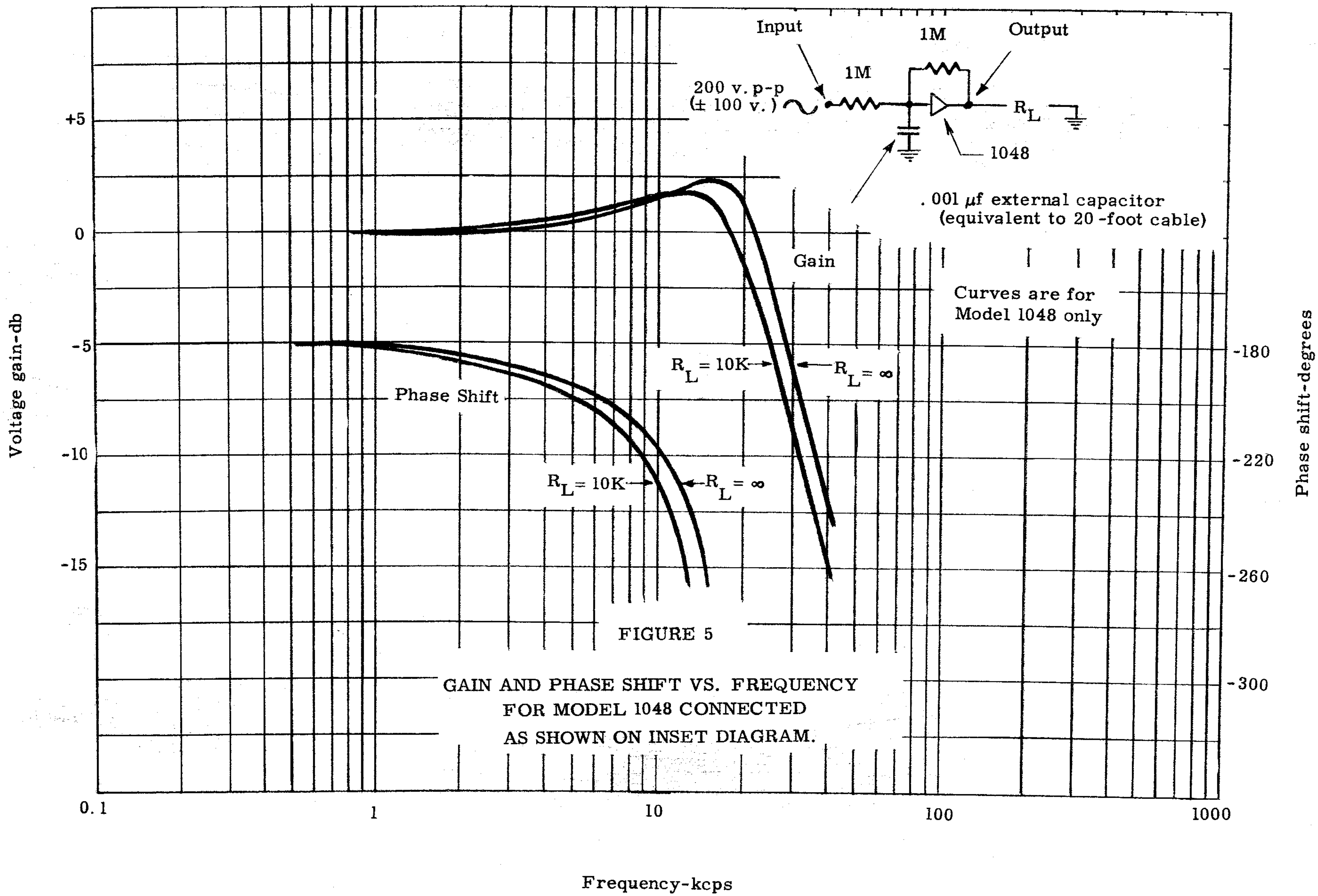


FIGURE 5

GAIN AND PHASE SHIFT VS. FREQUENCY
FOR MODEL 1048 CONNECTED
AS SHOWN ON INSET DIAGRAM.

MODEL 1048 PARTS LIST

TUBES

Type	Quantity	Type	Quantity
5963	1	12AU7	1
12AX7	1	12AY7	1
12AT7	1	6U8	1

Detail No.	Stock No.	Description	Mfr. & No.
		RESISTORS	
R101	1-1178A	4.7 M, 1/2 W, 5%	AB EB 4755
R102	1-1208	180 K, 1/2 W, 5%	AB EB 1845
R103	1-1169A	18 K, 1/2 W, 5%	AB EB 1835
R105	1-0225A	1 M, 1/2 W, 5%	AB EB 1055
R106	1-0209A	1 K, 1/2 W, 5%	AB EB 1025
R108	1-5692	500 K, 2 W, Linear Potentiometer	AB JU 2541-SD 3032
R109	1-0214	47 K, 1/2 W, 5%	AB EB 4735
R110	1-0798A	1.5 M, 1/2 W, 5%	AB EB 1555
R111	1-1182	10 M, 1/2 W, 5%	AB EB 1065
R112	1-0215A	56 K, 1/2 W, 5%	AB EB 5635
R113	1-2751	2.2 M, 1/2 W, 5%	AB EB 2255
R114		Same as R105	
R115, R116	1-2396	6.8 K, 1/2 W, 5%	AB EB 6825
R117	1-0239	47 K, 1 W, 5%	AB GB 4735
R118		Same as R110	
R119		Same as R113	
R120		Same as R111	
R121	1-0220	220 K, 1/2 W, 5%	AB EB 2245

Detail No	Stock No.	Description	Mfr. & No.
R124	1-3609	3.9 K, 1/2 W, 5%	AB EB 3925
R125	1-1856	470 K, 1/2 W, 5%	AB EB 4745
R126		Same as R111	
R127		Same as R105	
R128	1-0376	270 K, 1/2 W, 5%	AB EB 2745
R129		Same as R109	
R130		Same as R105	
R131, R132 R133	1-5768	22 M, 1/2 W, 5%	AB EB 2265
R135	1-0228A	2.7 M, 1/2 W, 5%	AB EB 2755
R136		Same as R121	
R137	1-0223	560 K, 1/2 W, 5%	AB EB 5645
R138, R139	1-0312	22 K, 1/2 W, 10%	AB EB 2235
R140		Same as R137	
R142	1-5065	Potentiometer 5 K, 2 W, WW	Clarostat Series 43
R143	1-0210A	10 K, 1/2 W, 5%	AB EB 1035
		CAPACITORS	
C101	2-1760	.001 μfd, ± 20% Mica	Sangamo K1210
C102	2-2230	.01 μfd, Disc.	Erie #811
C103	2-2915	2500 μμfd, 500 V, 10%	Sangamo C1225
C104		Same as C101	
C105	2-2138	25 μμfd, Mica	Sangamo RR1425
C106, C107	2-4187	.01 μfd,	Gudeman XF-2207-10
C108, C109	2-3899	.01 μfd, 400 V, 10%	Gudeman XF-1819-10
C110		Same as C101	
C111	2-5707	.68 μfd, Tubular Paper, 10%	Gudeman XGS 2118-10 Sprague 78P-68491S3
C112		Same as C102	
C113	2-2137	500 μμfd, Mica	Sangamo RR 1350
C114	2-3086	.1 μfd, 400 V, Tubular Paper 10%	Gudeman XF1816-10
C115	2-2082	10 mmfd, ±1 mmfd 500 V	Sangamo RR 1410
C116	2-0295	10 μfd, 25 V DC	Sangamo MMT-0210

OTHER COMPONENTS

Detail No.	Stock No.	Description	Mfr. & No.
CR101 & CR102, CR103 CR104	8-2986	Selenium Diodes	Inter. Rectifier 1U1
K101	16-5695	Chopper Electro-Mechanical SPDT, M-B-B Action	Stevens-Arnold #D-11
P101	17-5694	Connector 14 Pin Male, Chassis Mtg.	Elco Varicon M11450-3

MODEL 1041 PARTS LIST

TUBES

Type	Quantity
12AU7	1

RESISTORS

Detail No	Stock No.	Description	Mfr. & No.
R101	1-5733	270 K, 1 W, 5 %	AB GB 2745
R102	1-1101	82 K, 1/2 W, 5 %	AB EB 8235
R103		Same as R101	
R104	1-0217	100 K, 1/2 W, 10%	AB EB 1041
R105	1-1174	150 K, 1/2 W, 10%	AB EB 1541
R106	1-0209A	1 K, 1/2 W, 5 %	AB EB 1025
R107	1-5853	100 K, 1 W, 1 %	SW- 1B Allow E Cinema
R108	1-2329	Potentiometer 500 Ω, 2 W Linear	AB JU 5011 SD 3048
R109	1-0225A	1 M, 1/2 W, 5 %	AB EB 1055
R110	1-0011B	10 K, 2 W, 5 %	AB EB 1035

CAPACITORS

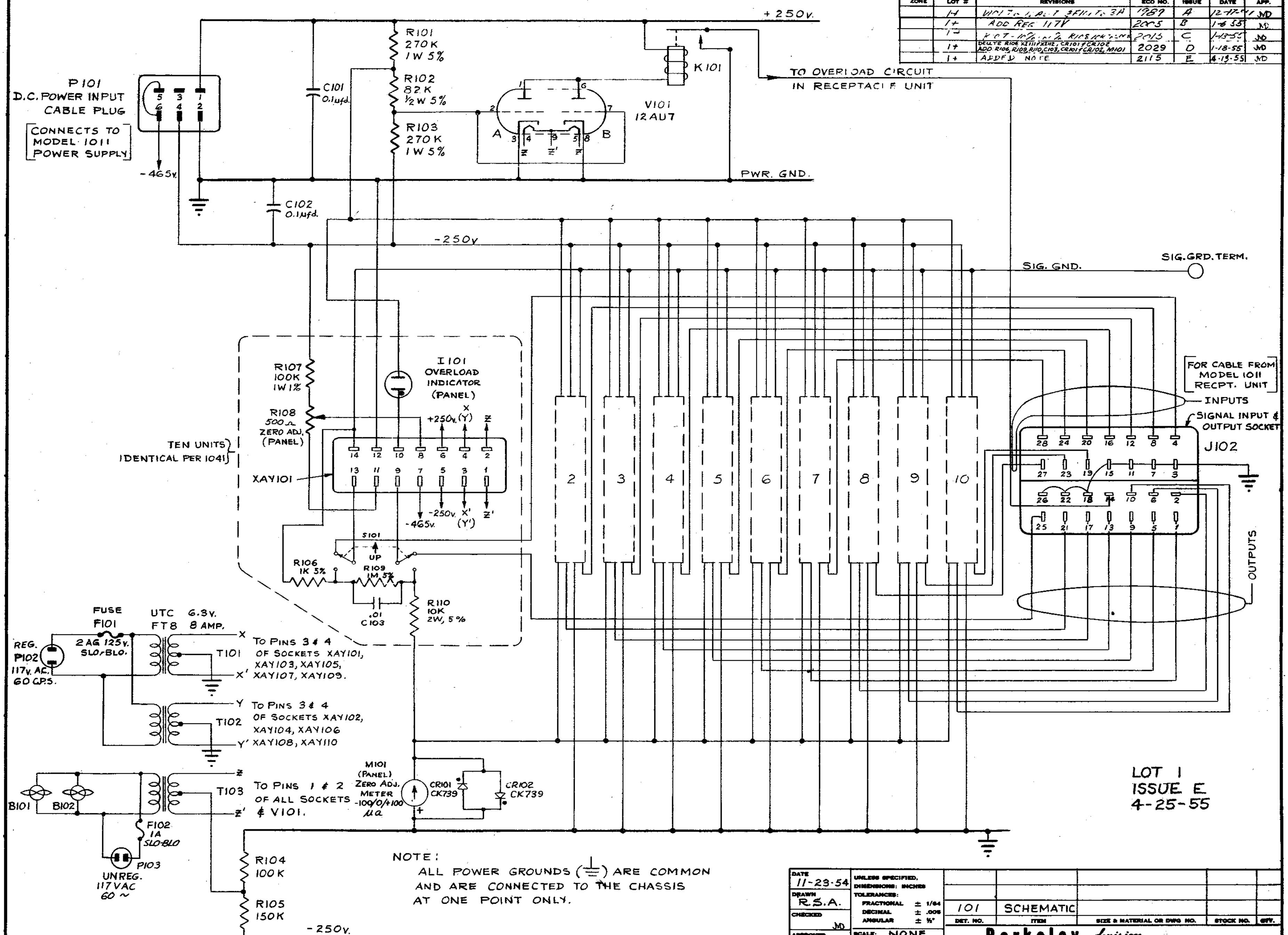
Detail No	Stock No.	Description	Mfr. & No.
C101, C102	2-0763	.1 μfd, 400 V, Molded Paper	Sangamo Type 30, 300401
C103	2-2230	.01 μfd, Disc	Erie Type 811

OTHER COMPONENTS

Detail No	Stock No.	Description	Mfr. & No.
B101, B102	9-3390	Fan Motor	General Industries A5-CW

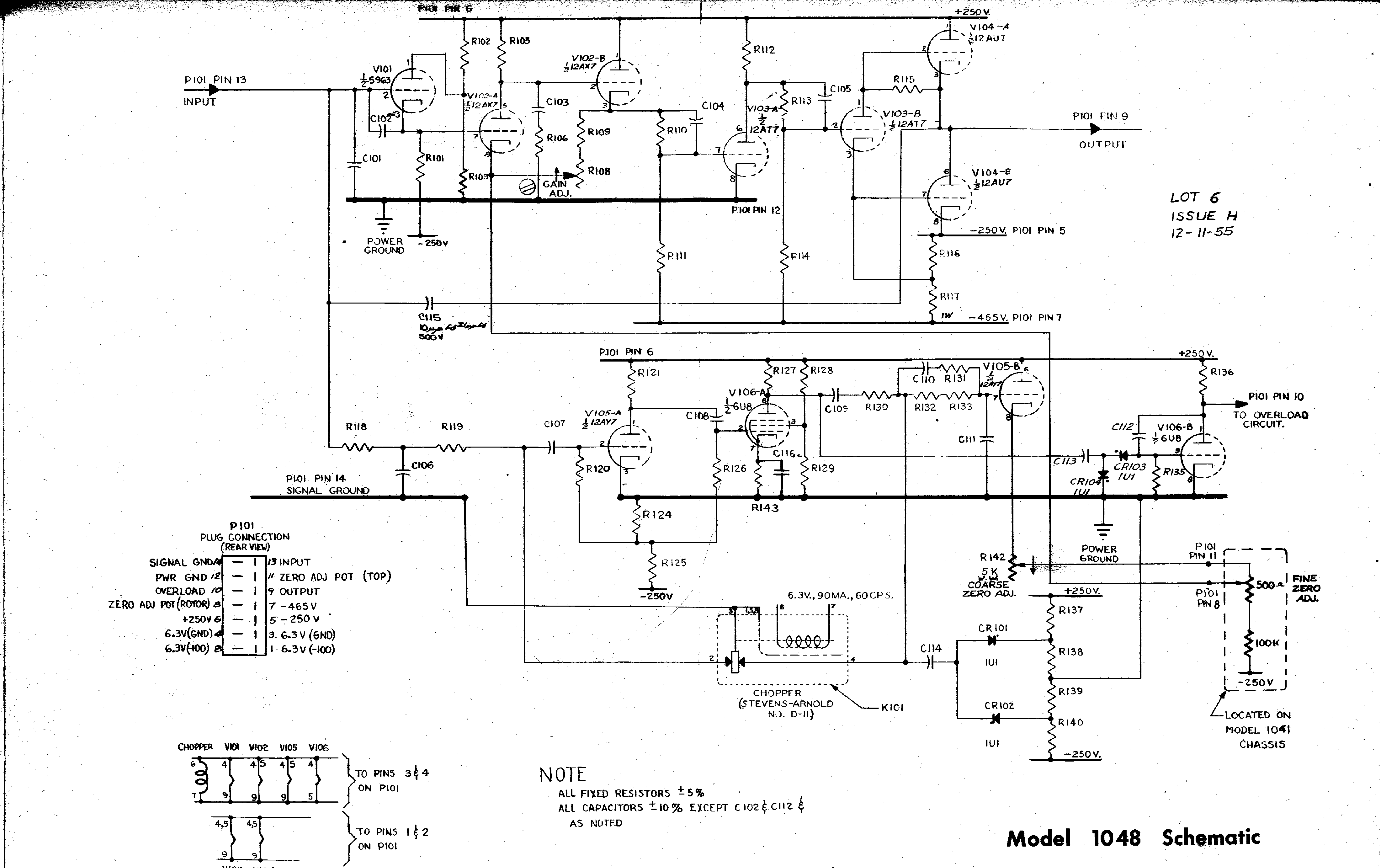
Detail No.	Stock No.	Description	Mfr. & No.
CR101 & CR102	8-5870	Diode Germanium Junction	Raytheon CK 739
F101	7-0504A	Fuse 2 Amp SLO BLO	LittleFuse 313002M
F102	7-5883	Fuse 1 Amp, 125V SLO BLO	LittleFuse 313001
I101	21-1679	Neon Lamp NE51	GE NE 51
J102	17-6403	Connector Ruggedized Female Varicon, 28 Contact Chassis Mtg.	Elco Varicon, RF22850-
K101	16-1865	Relay Plate SPST N.O.	Leach Type 321, Coil 912
M101	15-5871	Meter -100/0/+100 Micro A	Simpson 1027
P101	17-5732	Connector Male Varicon, 6 Contact w/hood	Elco Varicon, M10654
S101	12-5803	Switch	Switchcraft 6S-1245
T101, T102 T103	6-0917	Transformer Filament 6.3V 8 A	UTC FT-8
T104	6-2979	Transformer 120V A Capacity	Sola Type 2, Cat # 30806
XAY101	17-6402	Connector Female Ruggedized Varicon, 14 Contact Chassis Mtg.	Elco Varicon, R F11450-3

ZONE	LOT #	REVISIONS	ECO NO.	ISSUE	DATE	APP.
	1+	[illegible] 3A	1987	A	12-17-54	JMD
	1+	ADD REG 117V	2005	B	1-6-55	JMD
	1+	[illegible]	2013	C	1-13-55	JMD
	1+	DELETE R106 XI111 & XI112, CR101 & CR102 ADD R106, R109, R110, C103, CR101 & CR102, M101	2029	D	1-18-55	JMD
	1+	ADDED NOTE	2115	E	4-15-55	JMD



NOTE: ALL POWER GROUNDS (⏚) ARE COMMON AND ARE CONNECTED TO THE CHASSIS AT ONE POINT ONLY.

DATE 11-23-54	UNLESS SPECIFIED, DIMENSIONS: INCHES	DET. NO. 101	ITEM SCHEMATIC	SIZE & MATERIAL OR DWG NO.	STOCK NO.	QTY.
DRAWN R.S.A.	TOLERANCES: FRACTIONAL ± 1/64, DECIMAL ± .005, ANGULAR ± ½°					
CHECKED JMD	SCALE: NONE	Berkeley division BECKMAN INSTRUMENTS INC.				
APPROVED JMD	PART OF.					
MODEL 1041	TITLE SCHEMATIC	DRAWING NO. 1041 C 1	ISSUE E			



NOTE

ALL FIXED RESISTORS ±5%
ALL CAPACITORS ±10% EXCEPT C102 & C112 & AS NOTED

Model 1048 Schematic

INSTRUCTION MANUAL

Model 1056
FUNCTION MULTIPLIER
with
Model 1051
MULTIPLIER PANEL

BERKELEY division of
Beckman Instruments Inc.

Richmond 4, California
26 October 1955

WARRANTY

Every instrument manufactured by the BERKELEY division of Beckman Instruments, Inc. is warranted to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year from date of shipment to the original purchaser prove to be defective after our examination.

Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

Model 1056 Multipler

GENERAL DESCRIPTION

The Model 1056 is a time division all-electronic multiplier. It produces varying output voltage proportional to the product of two varying input voltages. If the input voltages are X and Y the output is KXY where K is a constant which is adjusted to -.01. Both X and Y may vary in amplitude from -100 to +100 volts and in frequency from d-c to 700 cps. Consequently, the output (-.01XY) may vary from -100 to +100 volts. The static accuracy of the multiplier is better than ± 0.5% of 200 volts, the full scale voltage.

The Model 1051 Function Multiplier Panel houses as many as four multipliers. It provides +150 volt and -105 volt reference voltage, a test signal and a metering circuit used to adjust the multipliers.

SPECIFICATIONS

<u>Model 1056</u>

Input	
Type:	Two voltages, X & Y
Amplitude range:	-100 to +100 volts for X & Y
Input Impedance	250K at X input 130K at Y input
Output	
Type:	Voltage equal to -.01XY
Amplitude range:	-100 to +100 volts
Output Impedance	Less than 300 ohms below 100 cps

Frequency response	In worst case with X = 50 volts and Y ≐ 100 Sin 2 ft, the output amplitude is constant (+1/2db) up to 700 cps. At 1500 cps the output rises 1.5 db. The phase shift is less than 2.5 degrees below 100 cps.
Static accuracy	Output accurate to better than 0.5% of full scale (Full scale is 200 volts)
Drift	Less than .2 volts (0.1% of full scale) over any 2 minute period Less than 1 volt (0.5% of full scale) over any one hour period.
Noise Level	200 millivolts rms at output (0.1% of full scale)
Tube Complement	Two 12AT7's, one 6AU6, two 6CB6's two 6AL5's, two 12AU7's, one 0B2.
Power requirements	52 ma at +400 volts 44 ma at - 400 volts .18 amperes at 117 volts a-c 2 ma at -105 volts d-c stabilized 1.5 ma at +150 volts d-c stabilized Power is ordinarily supplied by the 1051 panel.

Model 1051

Power requirements (When serving 4 Model 1056's)	212 ma at +400 volts d-c 193 ma at -400 volts d-c .22 amperes at 117 volts a-c
Dimensions	8 3/4" high, 19" wide, 14 1/2" deep (Fits into standard relay rack)
Tube complement	Four 5651's two 12AT7's

OPERATION

NOTE: See the installation section of the computer instruction manual to learn how to install the Model 1051.

Apply filament voltages to the multipliers by snapping on the FILAMENT toggle switch at the base of the computer rack in which the units are installed. After a one minute warm up period, snap on the PLATE switch at the bottom of the rack to apply plate voltages throughout. Then wait one half hour before attempting to adjust the multipliers.

The multipliers are numbered from 1 to 4 on the Model 1051 panel. Below each number is a switch and four potentiometer controls for adjusting that multiplier. Make all four adjustments on each multiplier while all the other multipliers in the chassis are switched to OPERate. To make a precise adjustment using the meter on the 1051 panel, press the METER SENsitivity button after the pointer has been brought near zero. Use the following procedure to adjust each multiplier:

1. Turn the switch to DC ADJ and rotate the DC ADJ. control until the meter on the 1051 panel reads zero.

   At this position of the switch both X and Y inputs are zero. The adjustment sets the output voltage at zero.

2. Turn the switch to X ADJ. and adjust the X ADJ control for a minimum reading on the meter.

   At this switch position the Y input is zero and the X input is a 60 cycle test signal which peaks at -100 and +100 volts. The adjustment sets the output voltage as near zero as possible over the full range of X values when Y is zero.

3. Turn the switch to Y ADJ. and adjust the Y ADJ control for a minimum meter reading.

   At this switch position the X input is zero and the Y input is the test signal.

4. The last adjustment determines the value of K in the output expression KXY. Ideally, the adjustment should be made to achieve a minimum average error for all combinations of X and Y input voltages. If the first three adjustments have been made carefully, the static error may be held within 0.5% by setting K at .01 for only one combination of X and Y voltages. Apply +100 volts to both X and Y inputs and connect the multiplier and a +100 volt reference source to a summing amplifier as shown in Figure 1.

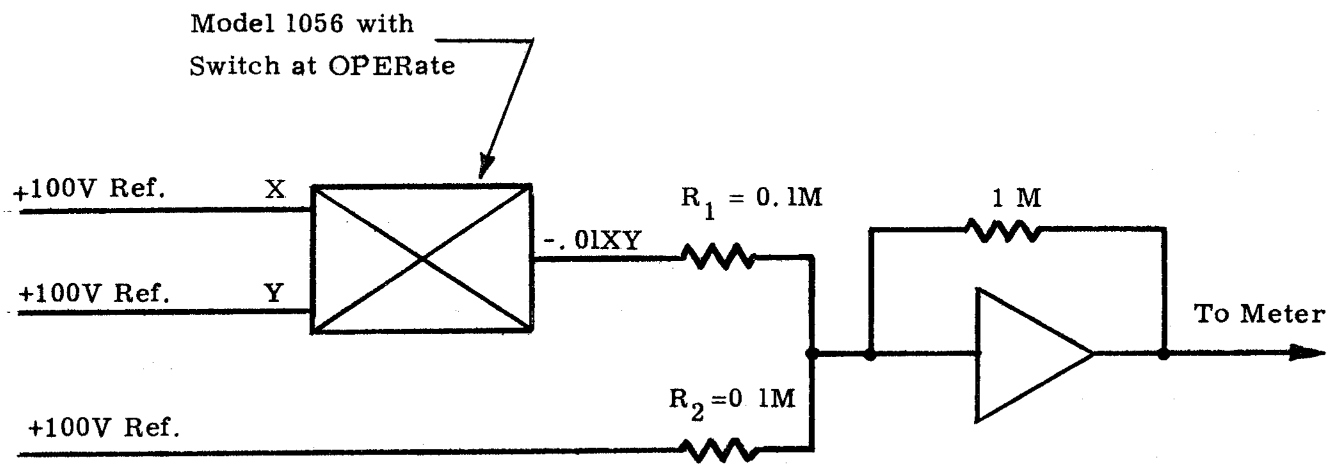


Figure 1

Turn the switch to OPERate and adjust the OPERate control unitl the output of the summing amplifier is zero. This indicates that the output of the multiplier is -100 volts which is -.01 XY when X and Y are both +100 volts. The error due to any slight mismatch in the input resistors R_1 and R_2 may be detected and eliminated by reversing the inputs to the summing amplifier. Connect the multiplier output to R_2 and the reference source to R_1. If the output of the summer is still zero, the resistors are well matched. If an output voltage appears, readjust the OPERate potentiometer until the output voltage has the same absolute magnitude with summer inputs reversed as it does when the inputs are connected as diagramed in Figure 1.

When the above adjustments are made the multiplier is ready to be connected in a problem-solving circuit. Repeat the adjustments before taking any critical data if so much time has passed since the last adjustment that drift might cause too great an error. The output of a multiplier may drift a maximum of 1 volt in a hour.

CIRCUIT DESCRIPTION

If the height of a rectangular pulse is made proportional to one variable and the width or duration of the pulse proportional to another variable, then the area of the pulse will always be proportional to the product of the two variables. The multiplier operates upon a modification of this principle. It generates a series of rectangular pulses similar to those shown in Figure 2.

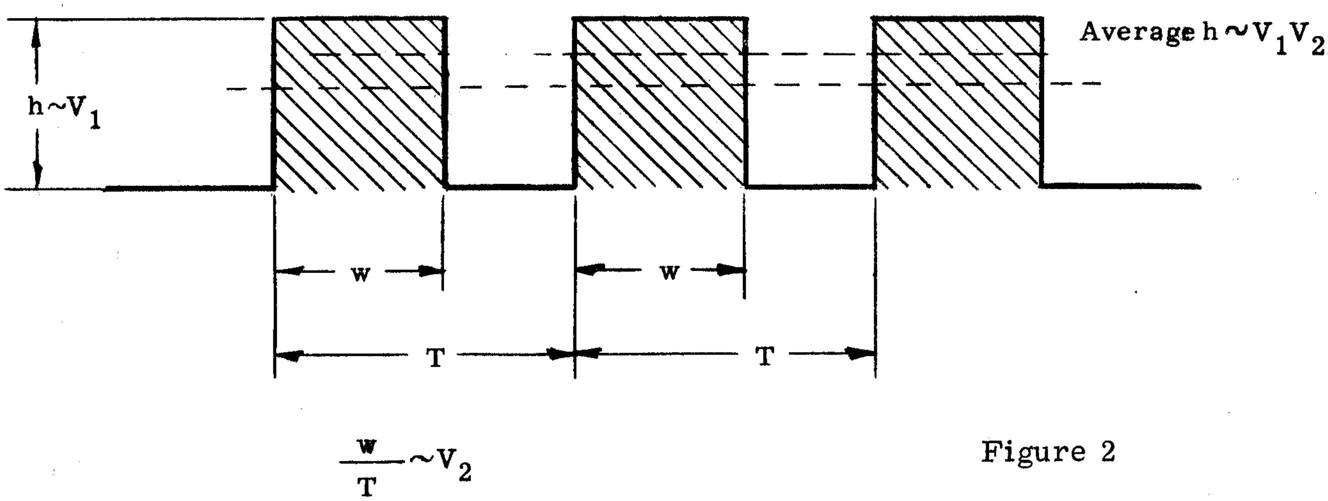


Figure 2

The height (h) is kept proportional to one variable, V_1. The ratio of the width (w) to T is made proportional to the other variable, V_2. As a result, the area of the shaded rectangles in figure 2 ($A_1 + A_2 + A_3$ etc) remains proportional to the product of the two variables, $V_1 V_2$. When the string of pulses is filtered an average height is obtained which is proportional to the area and to V_1V_2.

The two variables multiplied by this method within the unit are not the input voltages X and Y but, for convenience, a quantity proportional to B-X and one pooportional to A-Y where A and B are constants. The product obtained is proportional to (B-X) (A-Y) or AB-AX-BY+XY. The first three terms are subtracted at an output summing amplifier leaving an output voltage proportional to the last term, XY.

Figure 3 shows the basic circuitry of the multiplier. The X summing amplifier creates a voltage proportional to B-X using the -105 volt reference to supply the B constant. The diode switch V607 connects the output of the X summer to the input of the output summing amplifier. The diode switches on and off to create a series of pulses like those shown in Figure 2. In Figure 2, w is the time V607 is ON, T is the ON time plus the OFF Time.

$$\frac{w}{T} = \frac{\text{ON time}}{\text{ON time} + \text{OFF time}}$$

The Y integrator, the switch control and another diode switch (V606) form a closed loop circuit which generates ON and OFF times so that the $\frac{\text{ON time}}{\text{ON time} + \text{OFF time}}$ ratio is proportional to A-Y.

The switch control is a Schmitt trigger circuit. Its action will be discussed in greater detail later. At this point it is sufficient to note that it is a circuit with two stable states. In one state the Schmitt trigger turns V607 and V606 on; in the other state, off. The output voltage of the Y integrator is the triangular wave shown in Figure 4. When the Schmitt Trigger is in the OFF state two currents flow to the input grid of the Y integrator: one created by the -105 volt source and proportional to -A and another created by the Y input voltage and proportional to Y. The output of the integrator is then a rising voltage with a slope proportional to A-Y. This voltage is applied to the Schmitt Trigger input and when it reaches a certain level the Schmitt Trigger suddenly changes to the ON stable state. This action switches V606 on, applying the +150 volt source to the input of the integrator. The added voltage creates a current flowing to the integrator grid proportional to +2A so that the net input currents there are now +A+Y. The output of the integrator begins to fall with a slope proportional to -A-Y. When the output reaches a certain low level the Schmitt Trigger suddenly resumes the OFF state, disconnecting the +150 volt source and causing the cycle to begin again.

When the Y input is zero the slope of the rising voltage is proportional to A and the slope of the falling voltage proportional to -A. In this case the OFF time equals the ON time. When Y is positive the rising slope is flattened and the falling slope made steeper. In this case the

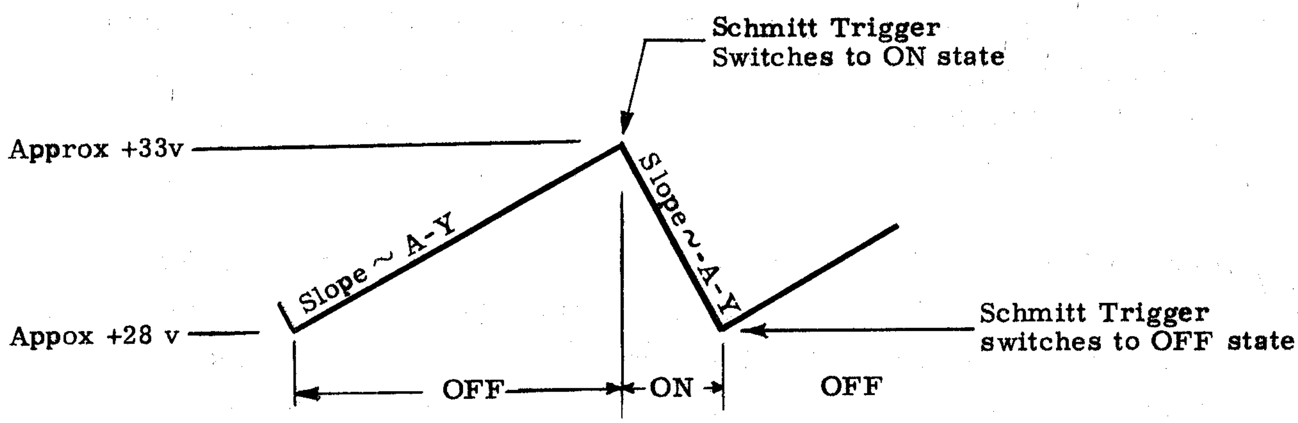


Figure 4

OFF time is greater than the ON time. When Y is negative the rising slope becomes steeper and the falling slope more gradual so that the ON time is greater than the OFF time. These changes in slope cause the

$$\frac{\text{ON time}}{\text{ON time + OFF time}}$$ ratio to be proportional to A-Y.

Four currents flow to the input junction of the output summing amplifier. (See figures 3 & 5). One is the rectangular pulses created by the output voltage of the X summer and the switching action of V607. This current has an average value proportional to (B-X) (A-Y) or AB-AX-BY+XY. The other three currents are adjusted to cancel out the first three terms in this expression. The first is proportional to +AX. It is created by

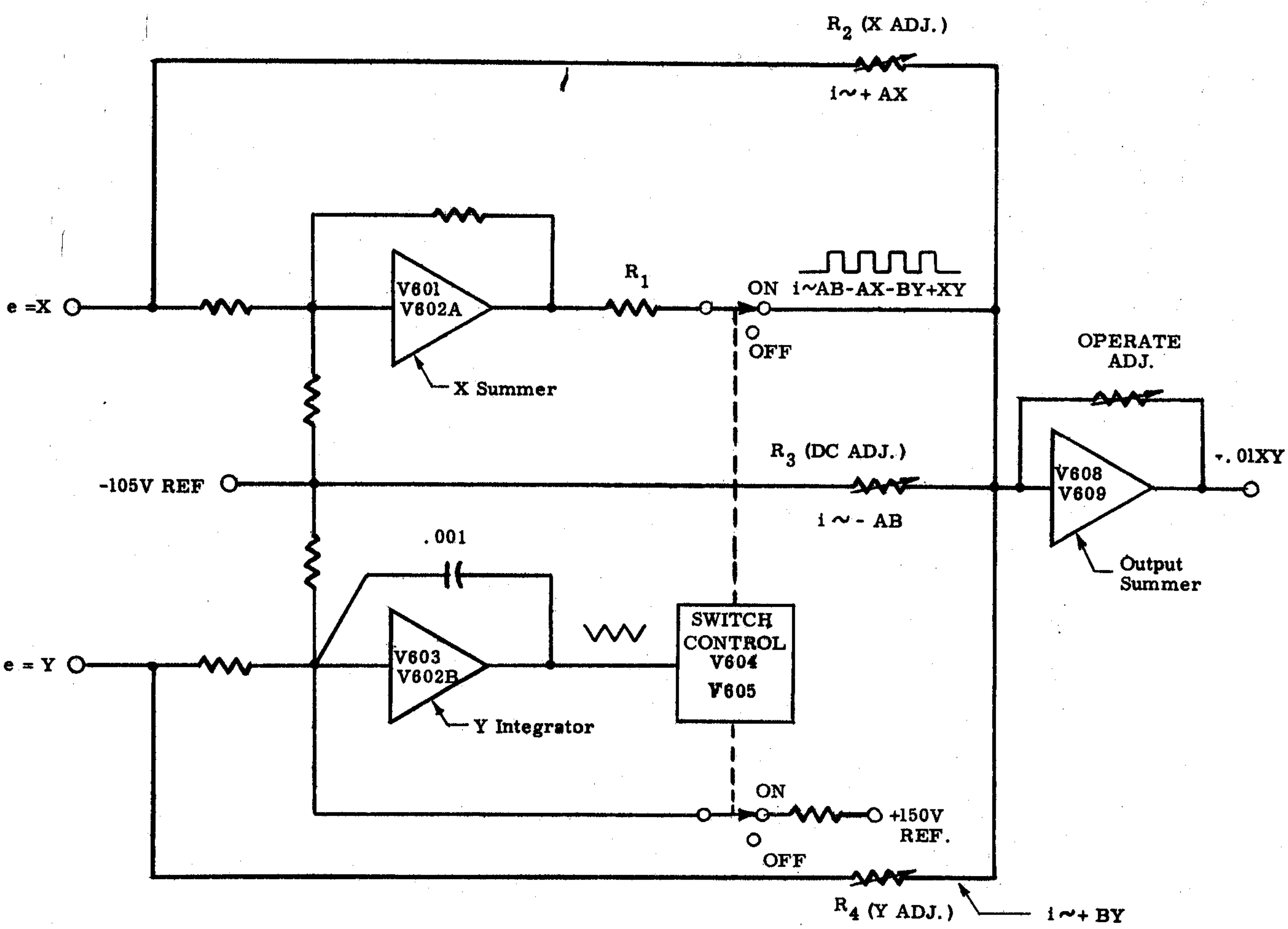


Figure 3 Basic Circuitry of Multiplier

the X voltage and flows through R_2 in Figure 3. This resistance is varied by the X ADJ control so that the current cancels the AX term. The second, is proportional to +AB. It is created by the -105 volt reference source and flows through R_3. This resistance is varied by the DC ADJ. control until the current cancels the +AB term. The last is proportional to +BY. It is created by the Y voltage and flows through R_4. This resistance is varied by the Y ADJ. control until the current cancels the -BY term. When these three terms are removed the output voltage of the output summer is proportional to - XY. When the feedback resistance of the summer is adjusted correctly by the OPERate control the output equals -.01XY.

The Switch Control and the Diode Switches

The switch control is a Schmitt Trigger circuit (V604) followed by a cathode follower (V605). (See the schematic diagram) The Schmitt trigger assumes one of two stable states depending upon the voltage at the left (the input) grid. With a low initial input voltage the circuit is stable with the left half cut off and the right half drawing a steady current. When the input voltage rises above a certain level (about +33 volts with respect to ground) the left half begins to conduct.

As soon as this happens a regenerative coupling from the left plate to the right grid and through the common cathode resistance causes a rapid increase in current through the left half and cuts off the right half. The circuit remains in this stable state until the input voltage falls below another critical level (about +28 volts). When this happens a reverse regenerative action snaps the circuit back to its original condition.

The input to the Schmitt trigger is the triangular voltage wave produced by the Y integrator. Its output is a voltage at the junction of the right plate resistors which switches back and forth from one steady positive value to another. When the input voltage is rising toward +33 volts the right half is conducting and the output voltage is low. This is the OFF state of the circuit. When the input voltage reaches +33 volts, the circuit changes states and the input begins to decline. While the input is dropping

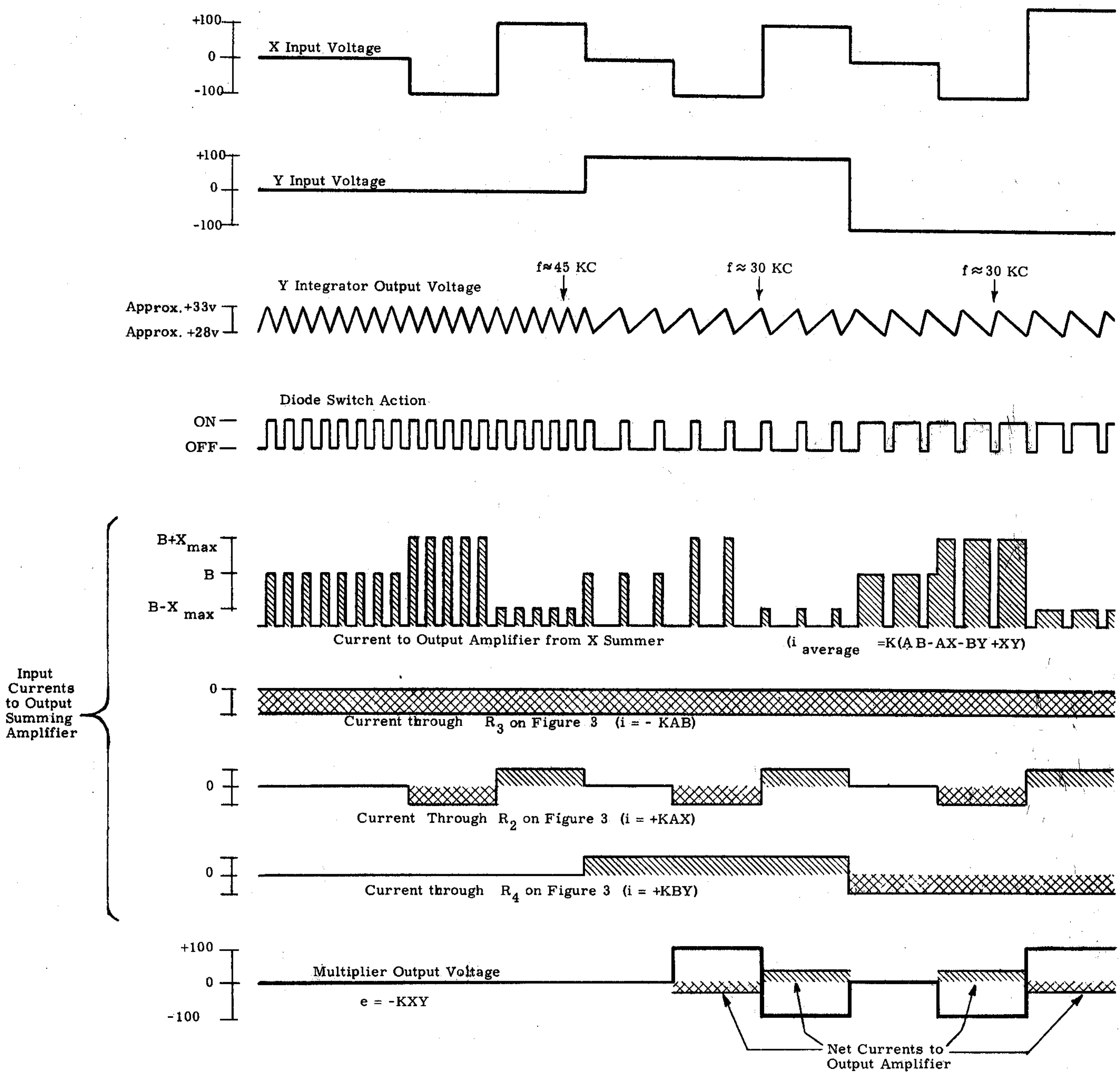


Figure 5 Internal Voltages & Currents at Various X & Y Input Levels

toward +28 volts the right half is cut off and the output voltage is high. This is the ON state of the circuit.

The output of the Schmitt trigger is coupled through a cathode follower (V605) to the left cathodes of the diode switches. The low output voltage of the OFF state brings these cathodes below ground. The high output of the ON state lifts them above ground. In the ON state the left halves of the diodes are cut off. The right half of V607 couples the output of the X summer to the input grid of the output amplifier and the right half of V606 couples the +150 volts source to the input grid of the Y integrator. The diode switches are closed. In the OFF state the left halves of the diodes conduct, lowering the plates below ground. Since the operational amplifier grids attached to the right cathodes are held at ground, the right halves of the diodes cannot conduct in this state. The switches are open.

ROUTINE ADJUSTMENTS

Reference Voltage Adjustments

Two potentiometer controls on the top of the Model 1051 chassis set the value of the reference voltages supplied to the multipliers. Adjust the -102V potentiometer until the voltage on the red -102V test jack at the rear of the chassis is -102v ± 1% with respect to the adjacent GND jack. Adjust the +150 V potentiometer until the +150V jack is +150v ± 1% with respect to the GND jack.

Model 1056 Adjustments

Two dual potentiometers (R655 & R614) on the main terminal board on each multiplier may be adjusted to compensate for changes in tube characteristics which would otherwise make it impossible to adjust the front panel potentiometers successfully. Whenever it is not possible to complete one of the front panel potentiometer adjustments follow the procedure below before searching for trouble elsewhere. Do not attempt to adjust the multiplier by setting the +150v or -102v reference voltages off their proper value.

1. Set all front panel potentiometer controls halfway between the extremes of rotation.
2. Turn the front panel switch to Y ADJ.
3. Adjust the dual potentiometer farthest from the front panel (R655) for a minimum reading onthe front panel meter.
4. Turn the switch to X ADJ. and adjust the dual potentiometer nearest the front panel (R614) for a minimum meter reading.
5. Turn the switch to DC ADJ. and adjust the DC ADJ. potentiometer until the meter reads zero. If the meter will adjust to within ±.2 but not to zero, re-adjust R655 or R614 slightly to extend the range to zero.

6. Re-adjust the other front panel potentiometers as described under "OPERATION".

TROUBLESHOOTING

General Procedure

When a multiplier fails to operate properly, first substitute another multiplier and note whether the trouble persists. If it does, the fault lies in the Model 1051 panel or in the Model 1010 power supply serving the panel. If the trouble clears, the fault is probably in the original Model 1056.

Ordinarily, a defect in the multiplier will make it impossible to complete one or more of three front panel zero adjustments (X ADJ, Y ADJ & DC ADJ.) The particular adjustments which fail offer a clue to the location of the fault. Referring to Figure 3, note that each of these adjustments creates a current which should cancel one of the first three terms in the expression AB-AX-BY+XY. The failure of an adjustment indicates that the term to be canceled is extrodinarily large or small and this, in turn, indicates a defect in the part of the multiplier which produces the coefficients in the term. The X summer produces the B coefficient. The Y integrator and the switch control (Schmitt trigger) circuit produce the A coefficient.

The Y ADJ. should cancel -BY. The most likely causes of an improper value of B are the following defects in the X summer circuit:

1. Changed tube characteristics (V601, V602A or V607). R655 may be adjusted as described under ROUTINE ADJUSTMENTS to compensate for limited changes.
2. An inaccurate -102 volt reference voltage.
3. A faulty resistor (R655, R603, R602, R636, R608 or R606).

The X ADJ should cancel -AX. The most likely causes of an improper value of A are the following defects in the Y integrator and Schmitt trigger circuit:

1. Changed tube characteristics (V603, V602B, V604, V605 or V606). R614 may be adjusted as described under ROUTINE ADJUSTMENTS to compensate for limited changes.
2. Inaccurate +150v or -102v reference voltages.
3. A faulty resistor (R614, R613 or R635)

The DC ADJ. should cancel +AB. The failure of this adjustment may indicate that either of these coefficients is out of range. More commonly, however, this adjustment fails because the control grid of V608 is more negative than the control grid of V603. These voltages are a function of the tube characteristics. Both tubes have been selected at the factory so that the grid of V603 will be more negative. However, if either tube has been replaced since then, V608 may have become more negative. To correct the situation, simply interchange the tubes. If this change does not make the d-c adjustment possible, return the tubes to their original position and investigate the possibleity of a defect in the circuitry producing the A or B coefficient.

Common Faults - Symptoms and Remedies

Symptom: X ADJ control will not move meter from zero, Y ADJ. control will not move meter from zero and meter reads off scale at all settings of DC ADJ control.

Cause: Y integrator or Schmitt trigger not functioning.

Remedy: Follow these steps until symptom disappears:

1. Turn plate power off for 10 seconds, then on again.
2. Replace V604, V606, and V607 one at a time (Turn off plate power while changing each tube.)
3. Replace V602, V603 and V605.

4. Check Schmitt trigger circuit as follows:

   Remove V603 and connect a 1 megohm potentiometer from pin 5 of the tube socket to ground so that the resistance between these points may be varied. Connect a voltmeter (20,000 ohm-per-volt or better) between Pin 3 of V605 and ground. As the potentiometer is varied from one extreme to the other, the voltage at V605 should move above and below ground. (usually between about +1 and -4 volts). If this doesn't occur, search for a faulty component in the circuitry surrounding V602B, V603 and V605. Compare voltages with those found in Table A. Compare other voltages and resistances with those found in a properly functioning multiplier.

Symptom: All or any of the following:

1. Meter off or nearly off scale at all settings of the DC ADJ control.
2. Meter approaches zero but will not come satisfactorily close at any setting of the X ADJ control.
3. Meter approaches zero but will not come satisfactorily close at any setting of the Y ADJ control.

1.	Possible Cause:	Inaccurate reference voltage
	Remedy:	Adjust +150 and -102 volt supply
2.	Possible Cause:	Control grid of V608 more negative than control grid of V603.
	Remedy:	See discussion on page 15.
3.	Possible Cause:	Defective tubes in output summer
	Remedy:	Replace V608, V609 and V610.
4.	Possible Cause:	Defective tube in first stage of X summer or Y integrator.
	Remedy:	Replace V601 and V603.

5. Possible Cause: Other defective components.

Remedy: Locate and replace component. Compare d-c voltages to ground with those listed in Table 1. Compare other voltages and resistances to ground with those found in a properly functioning multiplier.

Symptom: Meter reads off scale at all settings of the X ADJ, Y ADJ and DC ADJ controls.

Cause: Defect in output amplifier.

Remedy: Replace V608, V609 and V610. If symptoms persist search for defective components in output amplifier circuitry. C606 may be shorted.

Table 1

Test Point	D-C Voltage to Ground at X = 0, Y = 0.
V601, Pin 6	+38V ±3 V
V602, Pin 3	+140V ± 5 V
V603, Pin 6	+38 V ± 3 V
Junction R620, R621	+33 V ± 3 V
V608, Pin 6	+38 V ± 3 V
V609, Pin 8	+150 V ± 5 V

MODEL 1056 PARTS LIST

TUBES

Type	Quantity	Type	Quantity
6AU6	3	6AL5	2
12AU7	2	OA2	1
12AT7	2		

Detail No.	Stock No.	Description	Mfr. & No.
		RESISTORS	
R601	1-2837	1 M, 1 W, 1%	Electra
R602	1-3949	830 K, 2 W, 1 % WW	Helipot or Cinema
R603	1-5338	600 K, 1 W, 1 %	Electra
R604	1-2888	200 K, 2 W, 5 %	AB HB 2045
R605	1-1124A	22 K, 1 W, 5 %	AB GB 2235
R606	1-3952	300 Ω, 1 W, 5 %	AB HB 3015
R607	1-1136	1 M, 1 W, 5 %	AB GB 1055
R608	1-2861	1 K, 1 W, 5 %	AB GB 1025
R609	1-1132A	330 K, 1 W, 5 %	AB GB 3345
R610, R611	1-3953	100 K, 2 W, 5 %	AB HB 1045
R612	1-3954	270 K, 1 W, 1 %	Electra
R613	1-3955	130 K, 1 W, 1 %	Electra
R614	1-3956	Potentiometer Screw driver slot 10 K -10K, 2 W WW(dual)	3/8" Shaft Clarastat 3/8" Bushing
R615		Same as R604	
R616		Same as R605	
R617		Same as R606	
R618		Same as R607	
R619		Same as R608	

Detail No.	Stock No.	Description	Mfr. & No.
R620	1-3957	51 K, 2 W, 5 %	AB HB 5135
R621	1-3958	150 K, 2 W, 5 %	AB HB 1545
R623	1-1121B	5.6 K, 2 W, 5 %	AB HB 5625
R624	1-0011B	10 K, 2 W, 5 %	AB HB 1035
R625	1-2899	50 K, 10 W, 10% WW	Model Eng.
R626	1-3959	560 K, 2 W, 5 %	AB HB 5645
R627	1-118B	3.3 K, 2 W, 5 %	AB HB 3325
R628	1-0919A	15 K, 2 W, 5 %	AB HB 1535
R629	1-3960	220 K, 2 W, 5 %	AB HB 2245
R630	1-3961	270 K, 2 W, 5 %	AB HB 2745
R631	1-3962	800 K, 1 W, 1 %	Electra
R632	1-3963	815 K, 1 W, 1 %	Electra
R633	1-0234B	8.2 K, 2 W, 5 %	AB HB 8225
R634	1-2894	30 K, 10 W, 10 % WW	Model Eng.
R635	1-2833	100 K, 1 W, 1 %	Electra
R636	1-3965	100 K, 2 W, 1 % WW type 14	Cinema or Helipot
R637	1-5065	Potentiometer 5 K, 2 W, WW	Clarostat Series 43
R638	1-2835	250 K, 1 W, 1 %	Electra DCF
R639	1-3966	290 K, 1 W, 1 %	Electra
R640	1-5066	Potentiometer 10 K, 2 W, WW	Clarostat Series 43
R641	1-2834	150 K, 1 W, 1 %	Electra DCF
R642		Same as R637	
R643		Same as R604	
R644		Same as R605	
R645		Same as R606	
R647		Same as R608	
R648		Same as R609	
R649	1-3968	470 K, 1 W, 1 %	Electra
R650	1-1340	Potentiometer 100 K, 2 W, 10 %	AB Type J
R651	1-2861	1 K, 1 W, 5 %	AB GB 1025

Detail No.	Stock No.	Description	Mfr. & No.
R652	1-3970	43 K, 1 W, 5 %	AB GB 4335
R653		Same as R634	
R654	1-2765	2.7 K, 1 W, 5 %	AB GB 2735
R655		Same as R614	
R656	1-1026	100 Ohm 1/2 W, 10 %	AB EB 1011

CAPACITORS

C601	2-3106	33 μμfd	Erie NPO
C602	2-5204	.001 μfd, 500 V	Polly Sprague
C603	2-1636	10 μμfd	Sangamo KR1410
C604	2-2915	2500 μμfd	Sangamo Type C1225
C605	2-3540	.05 μfd, 600 V, (Flat grn)	Centralab DF503
C606	2-2230	.01 μfd, 450 V	Erie Type 811
C607	2-3071	.003 μfd, 500 V, 5 %	Sangamo CR 1230
C608	2-1950	.002 μfd, 600 V, 5 %	Sangamo 300622
C609		Same as C606	
C610		Same as C606	
C611	2-3074	50 μμfd, Ceramicon	Erie
C612		Same as C606	
C613		Same as C601	
C614	2-2141	50 μμfd, 500 V	Sangamo RR 1450

OTHER COMPONENTS

L601	3-3971	Choke 80 MH RF	Miller #694
P601	17-2955	Plug Male	Amphenol 26-159-16
T601	6-2953	Transformer 117V, 60 AC	Stancor P4019

MODEL 1051 PARTS LIST

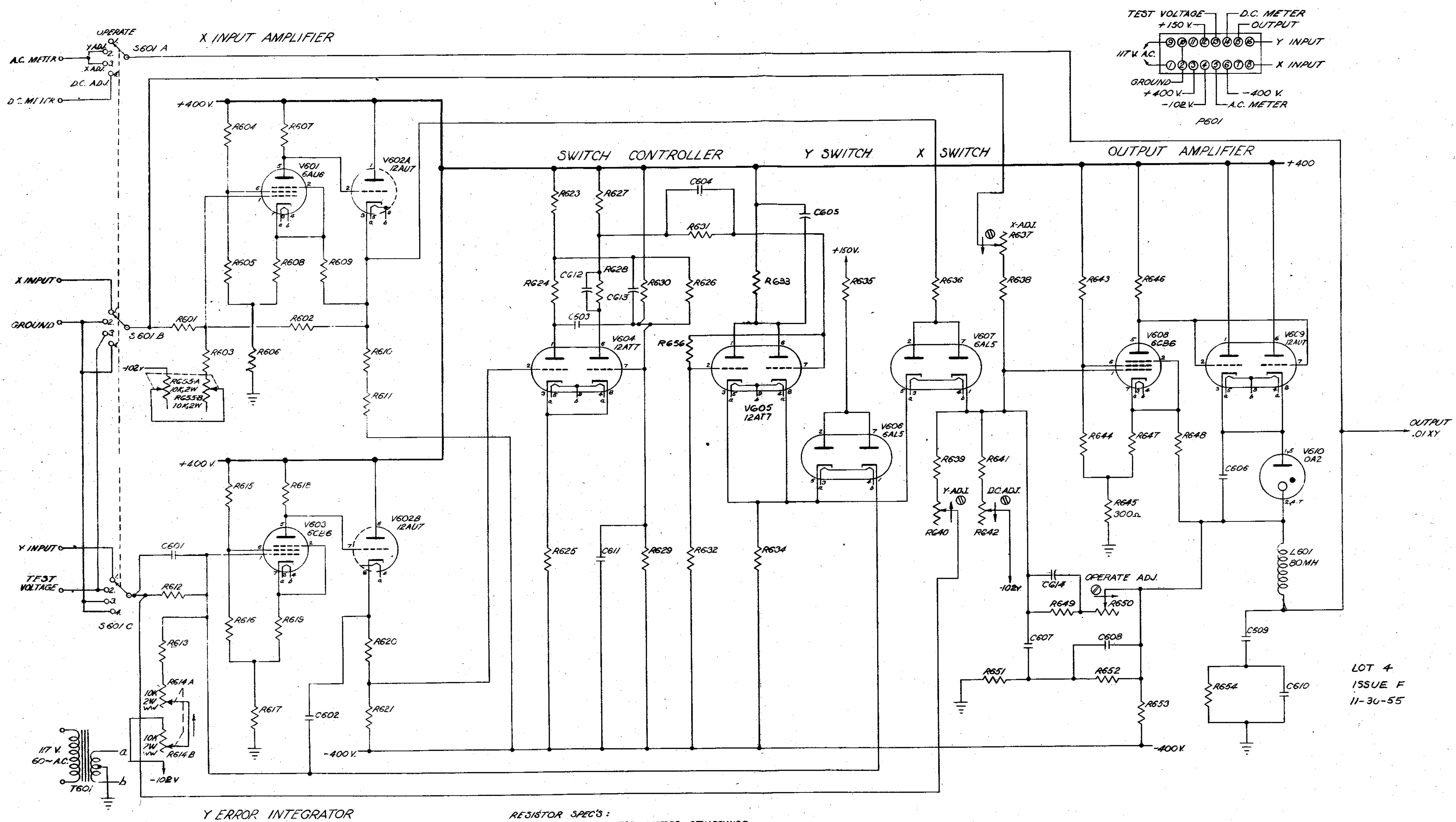
TUBES

Type	Quantity
5651	4
12AT7	2

Detail No.	Stock No.	Description	Mfr. & No.
		RESISTORS	
R501	1-2784	56 K, 2 W, 5 % Carbon	AB HB 5635
R502	1-5154	5.1 K, 1 W, 5 % Carbon	
R503	1-5156	Potentiometer 20 K, 3 W, WW 10 %	
R504	1-5157	91 K, 1 W, 5 % Carbon	
R505	1-2274	18 K, 10 W, 10 % WW	Ohmite
R506	1-5158	62 K, 1 W, 5 % Carbon	
R507		Same as R503	
R508	1-1125A	33 K, 1 W, 5 % Carbon	AB GB 3335
R509	1-2784	56 K, 2 W, 5 % Carbon	AB HB 5635
R510	1-2901	24 K, 10 W, 10 % WW	Tru-Ohm FRL-10
R511	1-2765	2.7 K, 1 W, 5 % Carbon	AB GB 2725
R512	1-0341	27 K, 1 W, 5 % Carbon	AB GB 2735
R513	1-0235A	10 K, 1 W, 5 % Carbon	AB GB 1035
		CAPACITORS	
C501, C502	2-2230	.01 Mfd, Ceramic Disc	Erie #811
C503	2-2150	.05 Mfd, 400 V, Paper	Spargue Type 67P.
C504		Same as C501	
C505	2-2179	1.0 Mfd, 400 V, Paper	Sangamo 300410
C506	2-3943	0.1 Mfd, 200 V, Paper	Cornell Dubilier Type PJ 2P1

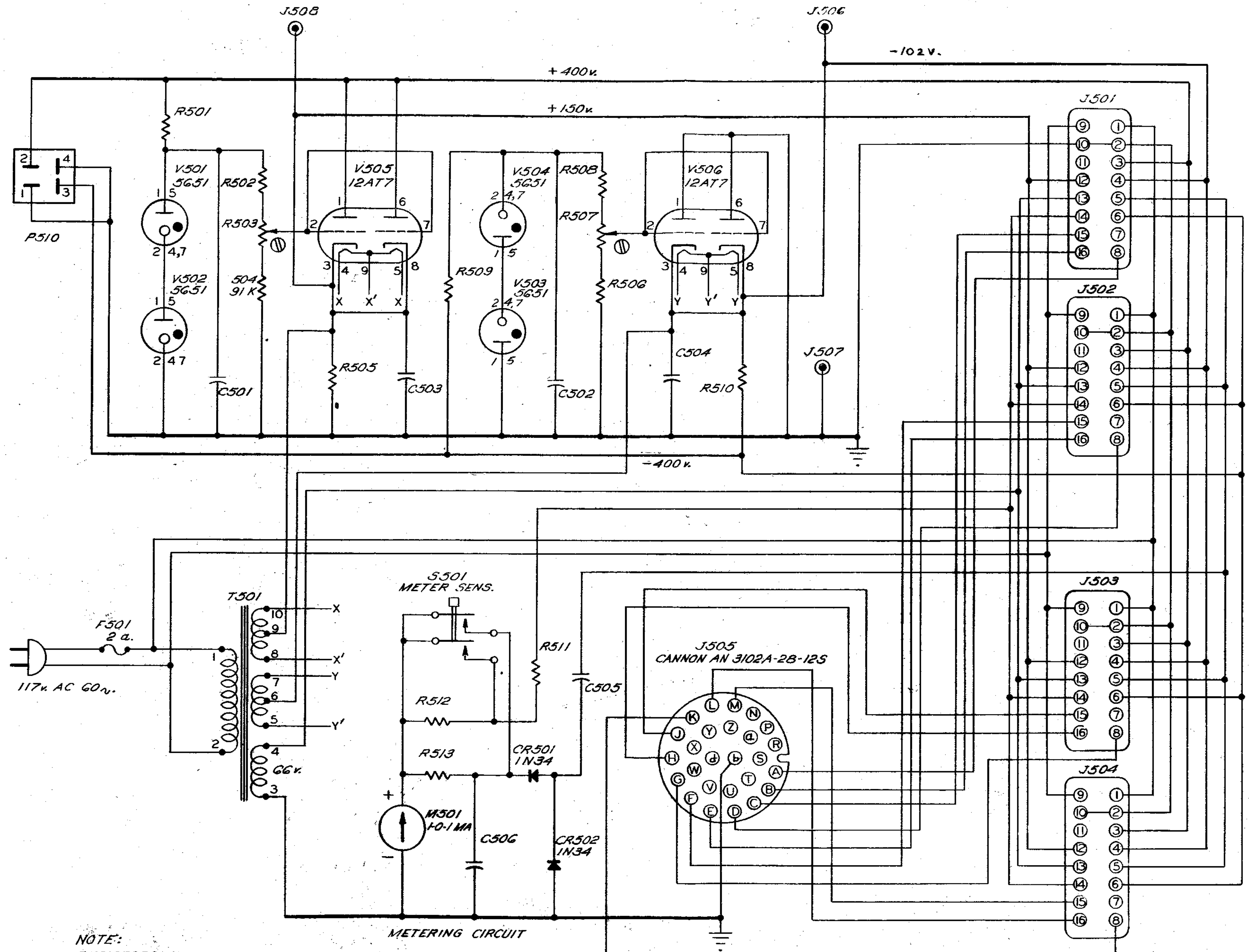
OTHER COMPONENT

Detail No.	Stock No.	Description	Mfr. & No.
CR501 & CR502	8-0668	Germanium Diode 1N34	
F501	7-0504	Fuse 2 a SLO BLO	Littlefuse 312002
J501, J502 J503, J504	17-2954	Connector Blue Ribbon 16 P	
J505	17-2940	Connector Cannon 26P	AN 3102A-28-12S
J506	17-3294	Jack, Pin (Red)	
J507	17-3295	Pin Jack (Black)	
J508		Same as J506	
M501	15-5205	Meter 1-0-1 MA Model 1027	Simpson
P501	11-2855	Plug 4 Pin	Jones
P502	11-3160	Plug	Cannon AN 3108B-28-12P
P503	11-2941	Plug	Cannon AN 3106B-28-12P
S501	12-2600	Switch DPDT (Pushbutton)	Switchcraft FF1006
T501	6-5164	Transformer	Electra E8 541



RESISTOR SPEC'S:
1 W. & 5% UNLESS NOTED OTHERWISE.
CAPACITOR SPEC'S:
VALUES LESS THAN ONE IN μfds.
VALUES MORE THAN ONE IN μμfds.
VOLTAGE RATING: 500V. UNLESS NOTED OTHERWISE.

Model 1056 Schematic



NOTE:
RESISTORS:
WATTAGE—— ½W UNLESS OTHERWISE NOTED.
TOLERANCE—— 10% " " " .
CAPACITORS:
CAPACITY—— IN MFD'S.
VOLTAGE RATING—— 600v. UNLESS OTHERWISE NOTED.

LOT 5
ISSUE A
8-11-55

Model 1051, Function Multiplier Chassis

INSTRUCTION MANUAL

Model 1011
POWER SUPPLY

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
30 Sept. 1955

WARRANTY

Every instrument manufactured by the BERKELEY division of Beckman Instruments, Inc. is warranted to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year from date of shipment to the original purchaser prove to be defective after our examination.

Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

Model 1011 Power Supply

DESCRIPTION

The Model 1011 supplies regulated power at +250 volts, -250 volts, and -465 volts. These voltage sources will supply:

1. One Model 1041 Operational Amplifier Chassis with ten Model 1048 Amplifier and two Model 1070 Function Generators.

or

2. One Model 1041 with ten Model 1048 Amplifiers and one Model 1071 Function Generator

or

3. Five Model 1071's

Both plus and minus 250 volt sources are electronically regulated. An improved transient-filtering system eliminates the need for chokes and substantially reduces the weight and bulk on the unit. The -465 volt source supplies only the output stage of the 1048 Operational Amplifiers. It is regulated satisfactorily by VR tubes. Separate plate and filament transformers are energized by individually fused a-c lines. Indicator lamps on the front panel light to indicate blown fuses. Output voltage and regulation adjustments are also on the front panel.

SPECIFICATIONS

Input	
Filament	115v,50-60 cps, 150 watts
Plate	115v, 50-60 cps, 140 watts.
Output	+250 volts, 300 ma maximum
	-250 volts, 150 ma maximum
	-465 volts, 55 ma maximum

Regulation — Ripple below 10 millivolts on both 250 volt supplies.

INSTALLATION & INITIAL ADJUSTMENTS.

Normally the plate and filament a-c input cords are plugged into the plate and filament a-c lines along the back of the "EASE" * Computer ra k. Adjust the 250 volt sou ces from the front panel. First connect a voltmeter and a high gain oscilloscope to the red -250 volt jack. Adjust the VOLTAGE CONTROL on that side of the panel until the meter reads 250 volts. Then adjust the adjacent REGULATION control until the scope shows minimal ripple. Adjusting one contr l will affect the other slightly so the adjustments will probably have to be repeated. Adjust the +250 volt supply in the same way.

A potentiometer on the top of the chassis labelled " -460 LOAD" adjusts the -465 vol. supply for best regulation. It is calibrated in terms of the number of Model 1048 Amplifiers the unit supplies. To obta n regulation which is ordinarily adequate, simply tur the pointer to the number of Model 1048's served. o obtain the best regulation possible place the operating load on the power supply and plug a milliammeter into J107, a two terminal jack on the chassis rear. Adjust the potentiometer for a reading of 18 ma.

CIRCUIT DESCRIPTION

-465 vo t Supply

This supp y is obtained from one side of the plate transformer secondary which also generates the -250 volt supply. The a-c voltage is applied to a half wave selenium rectifier (CR 102 to 104) and the d-c output is R-C filtered and held constant with respect to the -250 volt source by two VR tubes in series (V116 and V117). The regulated output is available at J104 and Pin 6 of both J105 and J106. The -465 volt source is also used internally in the Model 101 to provide a bottom potential for the negative-feedback d-c amplifier in the -250 volt regulating system. The voltage is independently regulated by another pair of VR tubes (V113 and V114).

* Trademark

A reference voltage for the -250 volt regulating system is obtained by dropping the bottom potential through R139. The resulting voltage is held 86 volts below the -250 volt source by V115, a 5651 VR tube.

The -250 Volt Supply

This supply voltage is obtained from V103, a 5U4G full wave rectifier. The d-c output of the rectifier is series regulated by a negativefeedback system (V109 to V112). The load current passes through two parallel-connected 6080 tubes (V109 & V110). The voltage drop across these tubes is controlled by their grid potential in such a way as to maintain a constant output supply voltage. The control mechanism may be understood by considering V111, V112 and the 6080 tubes as an intergral high-gain amplifier with negative feedback. See Figure 1. The voltages in parenthesis on the figure are those which would exist if the -250 volt bus were grounded instead of the cathodes of the 6080 tubes, that is, considering the -250 volt line as ground potential. The fixed input potential (e_i) maintained by the VR tube is -86 volts. The input resistance (R_i) is R136 plus a part of R135. The feedback resistance (R_o) is R134 plus the other part of R135. The equation describing such an amplifier is

$$e_o = - e_i \frac{R_o}{R_i}$$

Since e_i is constant, e_o remains constant at a value determined by the ratio of R_o to R_i. When R135 (the VOLTAGE CONTROL potentiometer) is adjusted properly the ratio is about 3 to 1 and e_o is stable at +250 volts. The REGULATION potentiometer (R122). adjusts the system for most senstive regulation by setting the positive feedback ratio of V111, thus maximizing the gain of the regulation amplifier.

The +250 volt Supply

This supply is generated and regulated in the same way as the -250 volt supply. However, the input voltage to the regulating amplifier is the output voltage of the -250 volt supply so it depends upon this supply for its accuracy and regulation. (See Figure 2).

MAINTENANCE

In case of trouble check tubes first. Faulty tubes can often be spotted visually. If all the tubes prove to be satisfactory, check the amplitude and regulation of the three supplies. Keep in mind that the +250 volt supply depends upon the -250 volt supply and this in turn on a part of the -465 volt supply. Make the following tests in the order listed:

1. Examine the -465 volt output at J103 and J104. Low or poorly regulated voltage at these points may indicate defective selenium rectifiers (CR 102 to 104) or open filter resistors.
2. Examine the -250 volt output at the red front panel jack. If the voltage is absent or poorly regulated under load, check the components associated with the rectifier (V103) and the 6080 tubes (V109 & V110). If the VOLTAGE CONTROL adjustment has no effect on the output voltage check components associated with V111 and V112.
3. Examine the +250 volt output at the red front panel jack. If the voltage is absent or poorly regulated under load, check the components associated with the two rectifiers (V101 and V102) and the three 6080 tubes (V104 to 106). If the VOLTAGE CONTROL adjustment has no effect on the output voltage check the components associated with V107 and V108. The grids of the 6080 tubes are at the plate potential of the triode half of V107. This plate voltage is supplied by an independent rectifier-filter system including CR101 and R101. Failure of either of these components will remove the positive charge from the grids of the 6080 tubes and cause the output voltage to drop very low.

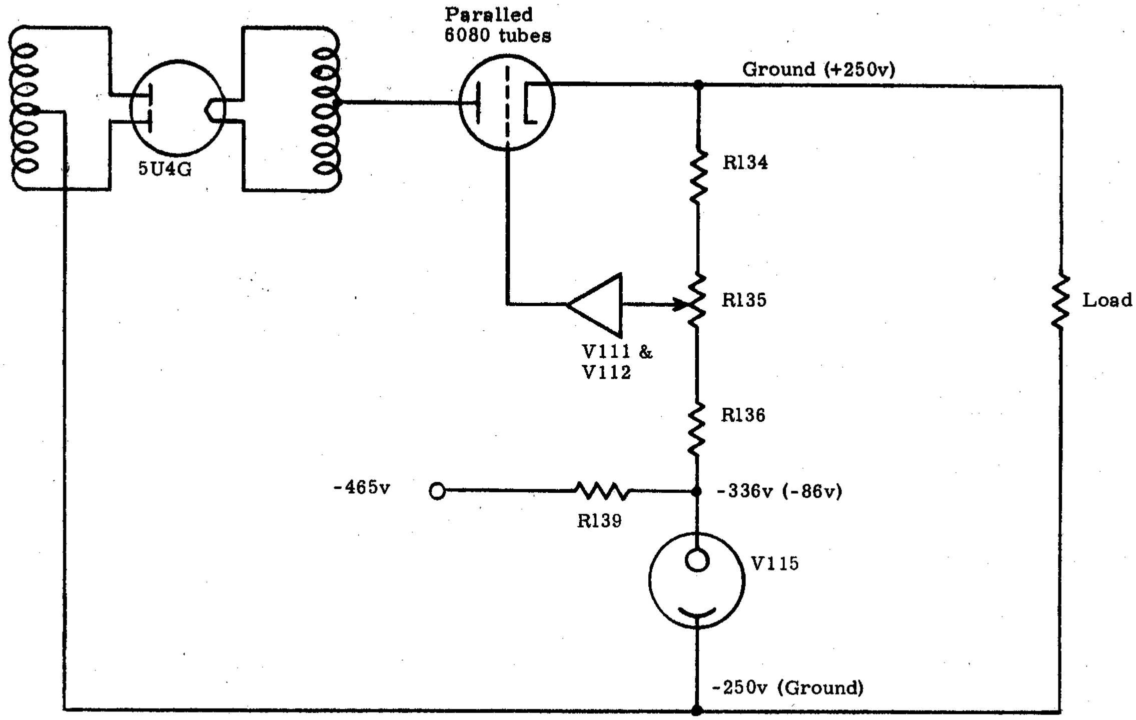


FIGURE 1 -250 VOLT REGULATING SYSTEM
MODEL 1011

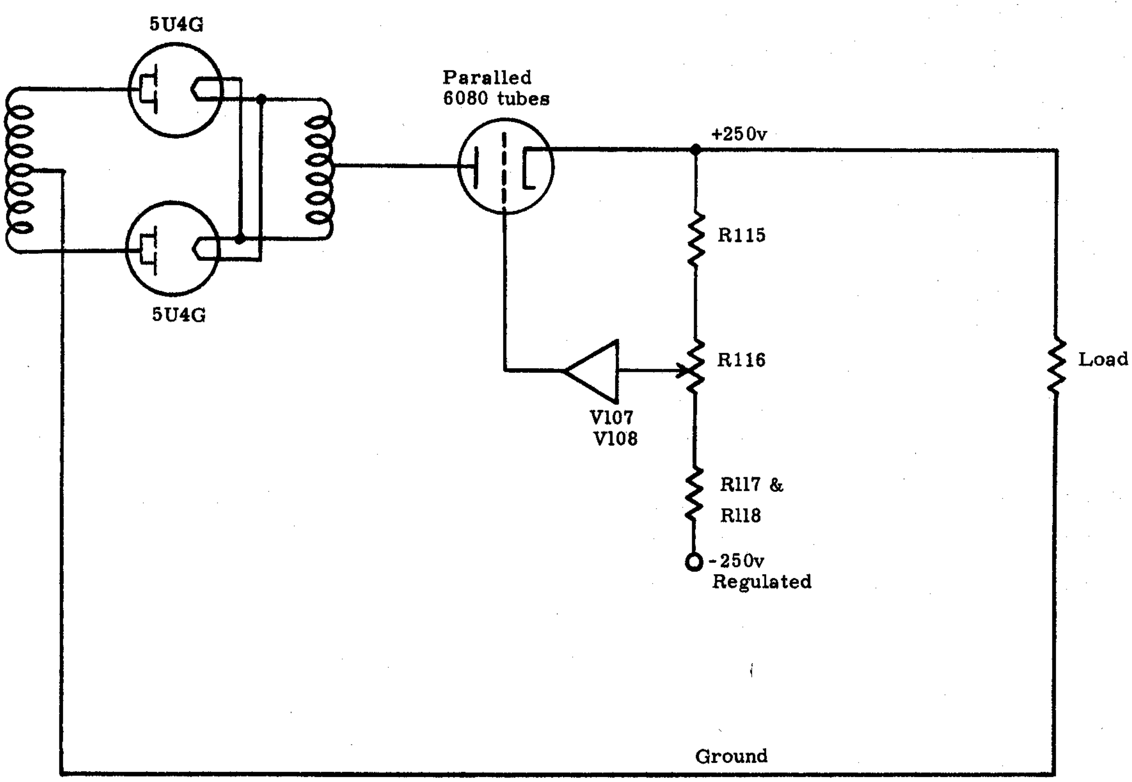


FIGURE 2 +250 VOLT REGULATING SYSTEM
MODEL 1011

PARTS LIST

TUBES

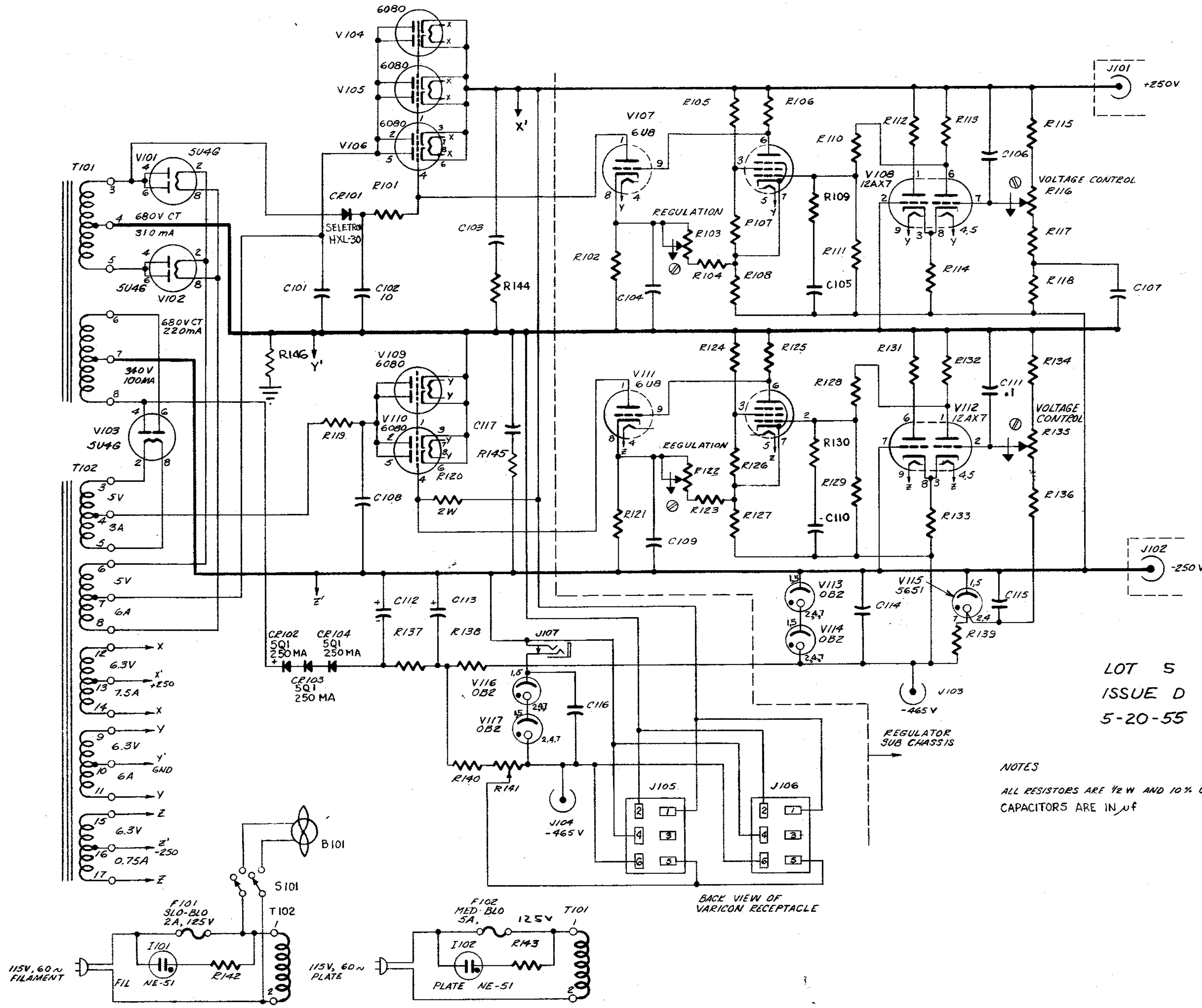
Type	Quantity	Type	Quantity
5U4G	3	12AX7	2
6080	5	OB2	4
6U8	2	5651	1

Detail No.	Stock No.	Description	Mfr. & No.
		RESISTORS	
R101	1-2802	150K, 2 W, 10%	AB HB 1541
R102	1-1120	4.7 K, 1W, 10%	AB GB 4721
R103	1-1340	Potentiometer 100K, 2W Linear	AB JU 1041
R104	1-1124	22K, 1W, 10%	AB GB 2231
R105	1-0248	47K, 2 W, 10%	AB HB 4731
R106	1-1131	220K, 1 W, 10%	AB GB 2241
R107	1-1575B	33K, 2 W, 5%	AB HB 3335
R108	1-0688A	22K, 2 W, 5%	AB HB 2235
R109	1-0208	6.8K, 1/2 W, 10%	AB EB 6821
R110	1-3134	1.8 M, 1/2 W, 5%	AB EB 1855
R111	1-0798A	1.5 M, 1/2 W, 5%	AB EB 1555
R112, R113 & R114	1-1856	470 K, 1/2 W, 5%	AB EB 4745
R115	1-3289	240 K, 1W, 1%	Electra DC-1
R116	1-5708	Potentiometer 25K, WW, 3 W	A: 3/8; B:3/8 no flats Clarostat Type 58-25000
R117	1-5729	90K, 1/2 W, 1%	Electra DC-1/2
R118	1-3361	150 K, 1/2 W, 1%	Electra DC-1/2
R119	1-5855	50 Ohm, 5 W, 10% WW	Tru Ohm
R120	1-5710	220 K, 2 W, 10%	AB HB 2241
R121		Same as R102	
R122	1-2169	Potentiometer 25K, 2 W, Linear	

Detail No.	Stock No.	Description	Mfr. & No.
		RESISTORS	
R123	1-1123	18 K, 1 W, 10%	
R124		Same as R105	
R125		Same as R106	
R126		Same as R107	
R127		Same as R108	
R128		Same as R110	
R129		Same as R111	
R130		Same as R109	
R131, R132 R133		Same as R112	
R134		Same as R115	
R135		Same as R116	
R136	1-5046	75 K, 1/2 W, 1%	Electra DC- 1/2
R137	1-0998	1 K, 10 W, 10% WW	Ohmite
R138	1-1044	5 K, 10W, WW	Model Eng.
R139		Same as R105	
R140	1-5825	1750 Ohm, 20 W, 10% WW	Tru Ohm
R141	1-5711	5 K, 25 W, WW	Ohmite 0162
R142	1-0219	180 K, 1/2 W, 10%	AB EB 1841
R143		Same as R142	
R144	1-3607	10 Ohm, 1/2 W, 10%	AB EB 1001
R145		Same as R144	
R146	1-0210	10 K, 1/2 W, 10%	AB EB 1031
		CAPACITORS	
C101	2-5712	20 Mdf, 600 V, W/Mtg. Brackets	Sangamo 7106-20
C102	2-0703	10 Mfd, 600 V, W/Mtg. Brackets	National CP70B1EF106K
C103	2-2179	1. Mfd, 400 V	Sangamo 30410

Detail No.	Stock No.	Description	Mfr. & No.
		CAPACITORS	
C104	2-1950A	.02 Mfd, 600 V	Sangamo 30612
C105	2-1760	.001 Mfd, 500 V	Sangamo K 1210
C106	2-0763	.1 Mfd, 400 V	Sangamo 300401
C107	2-3835	0.5 Mfd, 400 V	Sangamo Type 30 300405
C108		Same as C101	
C109		Same as C104	
C110		Same as C105	
C111		Same as C106	
C112	2-1675	80 Mfd, 450 V	Sangamo PL 4580
C113		Same as C112	
C114	2-1957	.05 Mfd, 400 V	Sangamo Type 30 300615
C115		Same as C104	
C116		Same as C106	
C117		Same as C103	
		OTHER COMPONENTS	
B101	9-3390	Fan Motor	General Industries A-5-CW
CR101	8-5713	Rectifier	Seletron HXL-30 (only)
CR102	8-1285	Rectifier 250 MA 5Q1	Radio Receptor Co.
CR103		Same as CR102	
CR104		Same as CR102	
F101	7-0504A	Fuse 2A-125V Slo Blo	Littlefuse
F102	7-277A	Fuse 5A-250 V Med Blo	Littlefuse #312005
I101	21-1679	Pilot Lamp	NE-51
I102		Same as I101	

Detail No.	Stock No.	Description	Mfr. & No.
		OTHER COMPONENTS	
T101	6-5719	Transformer Plate 680V CT, at 310 MA, DC, 680V at 220 MA DC, CTat 340 V at 100 MA DC	Electro E 8985
T102	6-5720	Filament Transformer 6. 3V at 6. A 6. 3V at.75A 5V at 3A; 5V at 6A; 6. 3V at 7. 5A	Electro E 8977



LOT 5
ISSUE D
5-20-55

NOTES

ALL RESISTORS ARE ½ W AND 10% UNLESS OTHERWISE NOTED
CAPACITORS ARE IN µf

Model 1011 Schematic

INSTRUCTION MANUAL

Model 1015
POWER SUPPLY

BERKELEY division of
Beckman Instruments Inc.

Richmond 4, California
30 Sept. 1955

WARRANTY

Every instrument manufactured by the BERKELEY division of Beckman Instruments, Inc. is warranted to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year from date of shipment to the original purchaser prove to be defective after our examination.

Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

Model 1015 Power Supply

DESCRIPTION

The Model 1015 Power Supply furnishes extremely accurate and reliable reference voltages of +100 and -100 volts. These voltages are used to insert constants at points in a problem-solving circuit, to set the co-efficient potentiometers in the control unit, to bias diodes in the 1071 Function Generator and to provide a voltage source for other uses in which accuracy is important. The positive and negative sources will each provide 150 milliamperes. When higher currents must be drawn, the Model 1015 may be supplemented by the Model 1016 Reference Slave Supply, which boosts the maximum current to 1.15 amperes from each source.

Each 100 volt supply is regulated by a Model 1048 operational amplifier. The unit generates three other regulated supply voltages (+250 -250 and -465 volts) solely for the purpose of powering the amplifiers. All supply voltages, as well as output and ground currents, may be monitored with a meter on the front panel. When one of the operational amplifiers overloads a neon lamp on the front panel lights, indicating faulty regulation. At the same time relay contacts connected to the control unit close, so that the overload warning appears there too.

The output voltages are available at four Varicon receptacles at the rear of the chassis. Three are 4-terminal connectors which carry +100 volts at two terminals and -100 volts at the other two. The fourth is a 6-terminal receptacle for connecting Model 1032 Control Unit.

SPECIFICATIONS

Input	105 to 125 volts, 60 cps
Output	+100 volts at 150 ma -100 volts at 150 ma
Accuracy of output voltage	Better than ± 0.1 volts.

OPERATION

NOTE: See the installation section of the computer manual to learn how to install the Model 1015.

To energize the power supply turn on the FILAMENT toggle switch at the bottom of the computer rack and allow the tubes to warm up one minute. Then turn on the PLATE switch. The OVERLOAD indicators will light immediately and remain lit for about half a minute. When these lights go out, the 100 volt outputs are accurate to within one teenth of a volt.

The rotary switch on the front panel connects the meter to indicate various supply voltages and currents. At the +100 position of the switch the meter indicates the output of the +100 volts supply on a 150 volt scale. At -100 it indicates the -100 volt supply voltage on the same scale. At the +250 -250 and -465 positions the meter indicates that these supply voltages are adequate if the pointer stops near the red line.

For current readings the meter scale is calibrated in milliamperes. Make these readings after the power supply has been loaded. At the +I position the meter measures the current drawn from the +100 volt supply.

At the -I position it indicates the current drawn from the -100 volt supply. At GND I + and GND I - the meter measures the current in the ground return line common to both 100 volt supplies. This current is the difference between the current drawn from the +100 volt supply and that drawn from the -100 volt supply. It may flow in either direction. If the +100 volt current is the greater the meter will read on scale when the switch is at GND I +. If the -100 volt current is thegreater the meter will read on scale at GND I -.

The 100 volt supply voltages are available at the read jacks on the front panel labelled " -100" and "+100". The OVERLOAD lamp above each jack will light when the Model 1048 amplifier which regulates that supply is overloading. This indicates that that supply is not properly regulated.

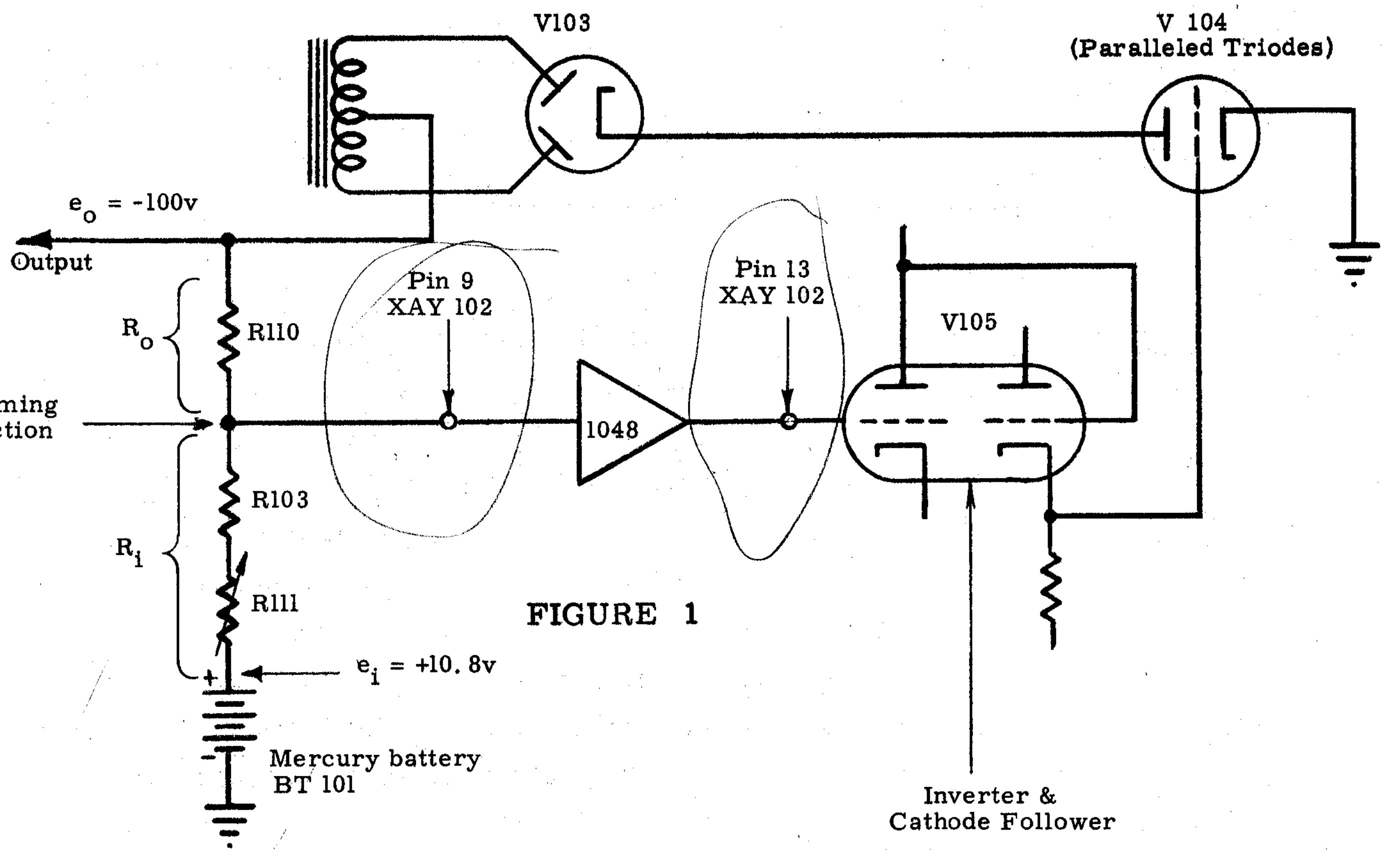


FIGURE 1

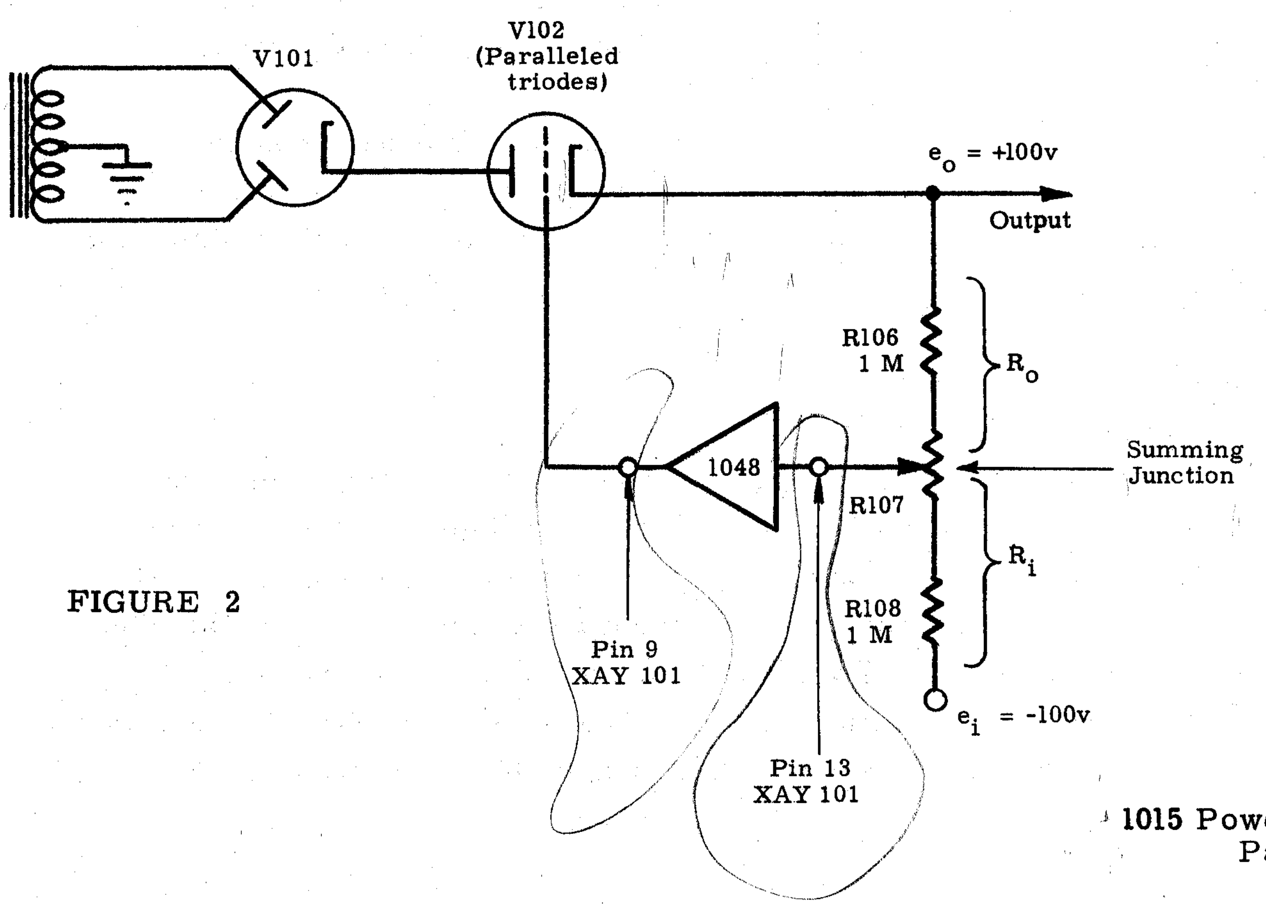


FIGURE 2

Power Supplies for the Model 1048 Regulating Amplifiers

Figure 3 is a simplified diagram of the -250 volt regulating system. The load current passes through the parallel connected triodes(V108). The voltage drop across these triodes is varied by a signal at their grids in such a way as to maintain a constant output supply voltage. The grid signal is supplied by V109 which operates as a voltage comparison tube. Its cathode is held 87 volts positive of the output voltage by the VR tube V113. Its grid picks up a fraction of the output voltage from the junction of R134 and R136. When the output voltage varies, the potential difference between the grid and cathode varies in a direction which creates an output signal at the plate of V109 tending to cancel the variation. Since the gain of V109 is about 2000, the regulation is very good.

Figure 4 is simplified diagram of the +250 volt regulating system. The circuit is like the -100 volt regulating system except that a single high gain tube (V107) takes the place of the Model 1048 amplifier and both e_i and e_o are approximately 250 volts instead of 100 volts.

The -465 volt supply is drawn from the same transformer winding that creates the -250 volt supply. The a-c voltage is half wave rectified by CR 105B and CR 106, filtered by C110 and C111 and regulated for a small current drain by two VR tubes (V111 and V112).

Meter Circuitry

At the +100, -100, +250, -250 and -465 positions the rotary switch on the front panel connects the meter (and appropriate resistors in series with it) between each of the five supply voltages and ground. At the +I position the switch shunts the meter across a 10 ohm resistor in the +100 volt output line. At the -I position it shunts the meter across a similar resistor in the -100 volt output line. At the GND I + and GND I - positions the meter is shunted across a 10 ohm resistor in the ground current

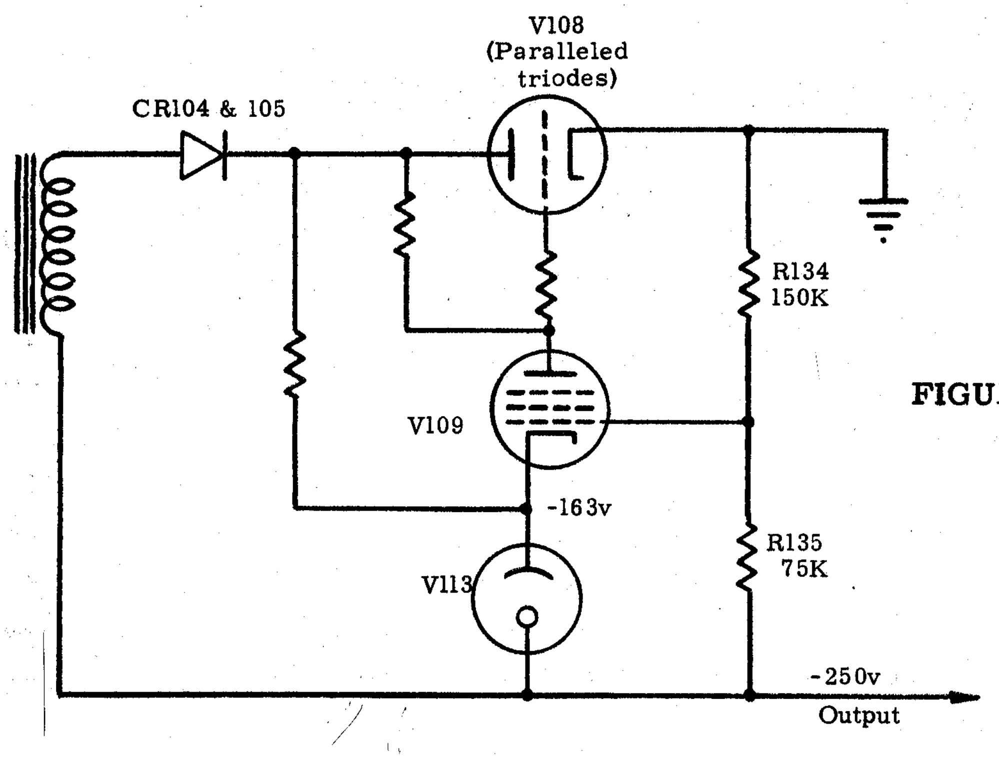


FIGURE 3

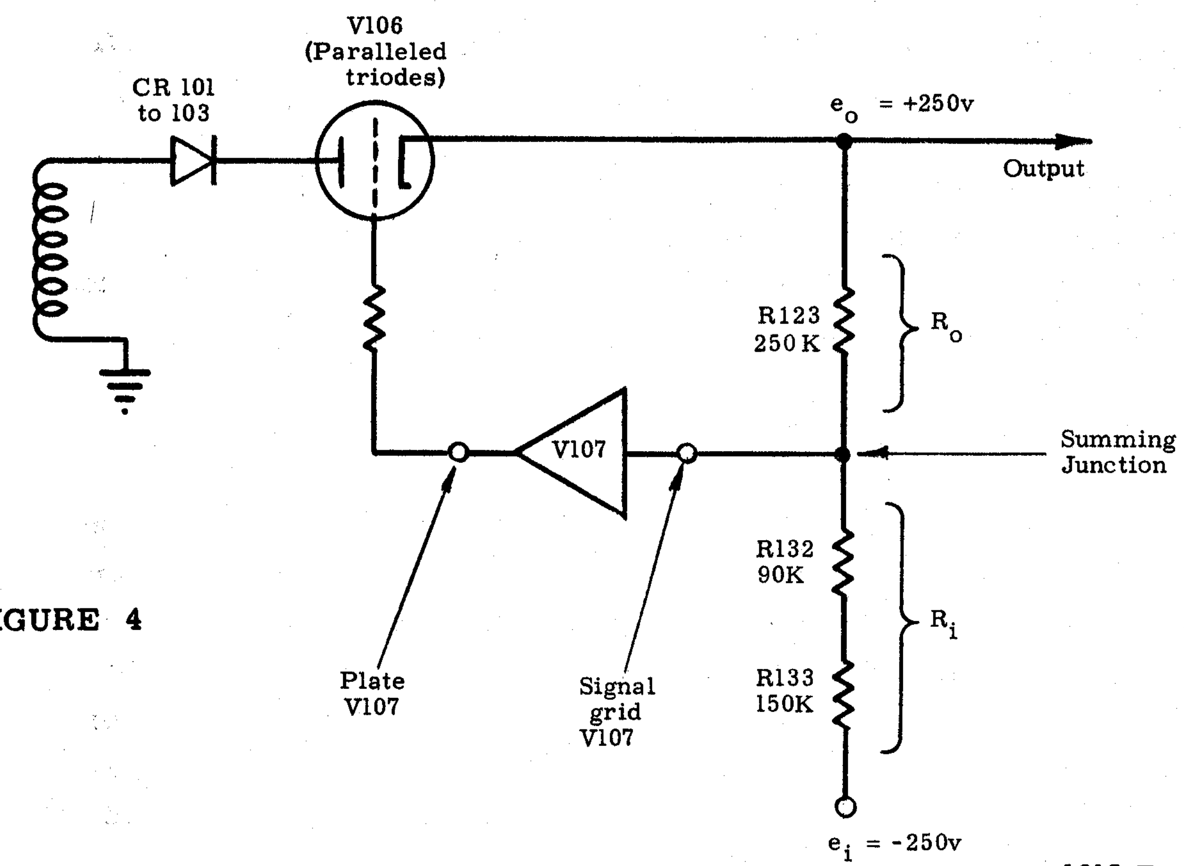


FIGURE 4

return common to both +100 and -100 volt supplies. The current flowing in this resistor is the difference between the currents drawn from the 100 volt supplies and it may flow in either direction. Two positions are provided so that the meter may be connected in the proper polarity.

TUBES

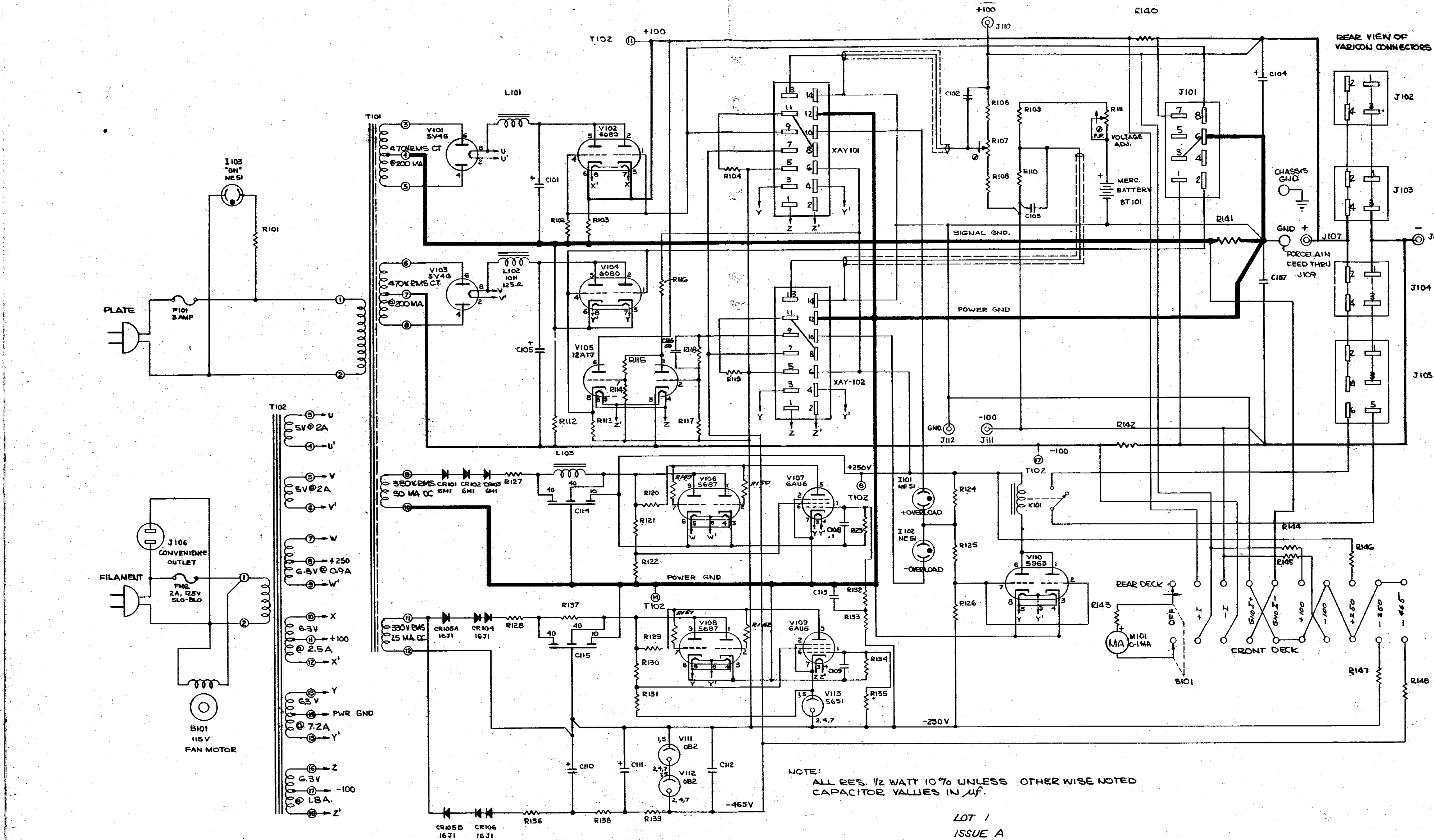
Type	Quantity	Type	Quantity
5V4G	2	6AU6	2
6080	2	5963	1
12AT7	1	OB2	2
5687	2	5651	1

Detail No.	Stock no.	Description	Mfr. & No.
		RESISTORS	
R101	1-0219	180 K, 1/2 W, 10%	AB EB 1841
R102	1-0217	100 K, 1/2 W, 10%	AB EB 1041
R103	1-6267	5 K, 5 W, 10%	Tru Ohm
R104	1-2833	100 K, 1 W, 1% D.C.	Electra DC
R106	1-5886	1 M, 1/2 W, .05% W.W.	Daven Type 1113 Alloy Type V
R107	1-0874	Potentiometer 1 K, 2 W Linear	AB JU 1021 SD 3048
R108		Same as R106	
R109	1-5885	104 K, 1/2W, .1%, WW	Daven Type 1112 Allow Type V
R110		Same as R106	
R111	1-1343	Potentiometer 5K, 2W Linear	AB JU 5021 SD 3048
R112		Same as R103	
R113	1-0248	47 K, 2 W, 10%	AB HB 4731
R114	1-0225A	1 M, 1/2 W, 5%	AB EB 1055
R115	1-1177A	680 K, 1/2 W, 5%	AB EB 6845
R116	1-2802	150 K, 2 W, 10%	AB HB 1541
R117	1-1174A	150 K, 1/2 %, 5%	AB EB 1545
R118	1-0960	100 K, 1/2 W, 5%	AB EB 1045

Detail No.	Stock No.	Description	Mfr. & No.
		RESISTORS	
R119		Same as R104	
R120	1-1177	680 K, 1/2 W, 10%	AB EB 6841
R121	1-0243	270 K, 1 W, 10%	AB GB 2741
R122		Same as R102	
R123	1-5887	250 K, 1 W, 1% D. C.	Electra
R124	1-0376	270 K, 1/2 W, 5%	AB EB 2745
R125	1-1101	82K, 1/2 W, 5%	AB EB 8235
R126		Same as R124	
R127	1-3607	10 Ω, 1/2 W 10%	AB EB 1001
R128	1-1195	330hm 1/2 W, 10%	AB EB 3301
R129		Same as R120	
R130	1-1128	120 K, 1W, 10%	AB GB 1241
R131	1-1172	47 K, 1/2 W, 10%	AB EB 4731
R132	1-5729	90 K, 1/2 W, 1% D. C.	Electra DC 1/2
R133, R134	1-3361	150 K, 1/2 W, 1% D. C.	Electra DC 1/2
R135	1-5046	75 K, 1/2 W, D. C. 1%	Electra DC 1/2
R136		Same as R128	
R137	1-1112A	1 K, 2 W, 10%	AB HB 1021
R138, R139	1-2942	6 K, 10 W, 10%	Tru-Ohm
R140, R141 R142	1-5958	10 Ω 1 W, 1% WW	Brown corp. Ltd. EM-S CAL-OHM
R143	1-5959	1450 Ω, 1/4 W, 1% WW	Cinema 410N
R144, R145	1-5960	149 K, 1/4 W, 1% W. W.	Cinema 411N
R146, R147	1-5956	300 K, 1/2 W, 1% W. W.	Cinema R11N
R148	1-5957	555 K, 1 W, 1% W. W.	Cinema SW-1BN
R149, R150 R151, R152	1-3547	100 Ohm 1/2 W, 5%	ABEB 1015

Detail No.	Stock No.	Description	Mfr. & No.
		CAPACITORS	
C101	2-1965	12 µfd, 450 V DCW, Elect. Paper	Sangamo MT 4512
C102, C103	2-3086	.1 µfd, 400 V	Gudeman XF 1816
C104	2-3135	20 µfd, 250 V	Sangamo MT 2520
C105		Same as C101	
C107	2-3358	12 Mfd 250 V	Sangamo MT 2512
C108, C109	2-0763	.1 µfd, 400V, Molded Paper	Sangamo Type 30 300401
C110, C111	2-1321	40 µfd, 450 V	Sangamo PL 4540
C112	2-2150	.05 µfd, 400 V	Sangamo 300415
C113	2-3835	.5 µfd, 400 V	Sangamo 300405
C114, C115	2-3589	40-40-10 µfd, 450 V	Sangamo PLT 7415
C116	2-2141	50 Mfd 500 V	Sangamo Type RR
		OTHER COMPONENTS	
AY101, AY102	Model 1048	Amplifier	
B101	9-3390	Motor Fan	General Industries A5-CW
BT101	28-5898	Mercury Battery	Mallory Type 302908
CR101, CR102 CR103	8-1699A	Rectifier 6 M1 Selinium	Radio Receptor Co.
CR104, CR105 CR106	8-5892	16J1 Selenium Rectifier	Seletron 16J1
F101	7-5891	Fuse 3 Amp, 125 V, Med-Blo	Littlefuse 312003
F102	7-0504A	Fuse 2 Amp, 125 V, Slo-Blo	Littlefuse 313002
I101, I102 I103	21-1679	Neon Lamp 1/25 W, 105-125 V	GE NE 51
K101	16-1865	Relay Plate SPST N.O.	Leach Type 321, Coil 912.

Detail No.	Stock No.	Description	Mfr. & No.
		OTHER COMPONENTS	
L101, L102	3-6203	Inductor 10 H, 200 MA Filter Choke	Osborne #5701
L103	3-5888	Inductor 10 H, 50 MA, 500 Ω, Filter Choke	Triad C-3X
M101	15-5962	Meter 1 MA, Special Scale	Simpson Model 1027
S101	12-5961	Switch 3/8" Shaft, Miniature Steatite, 2 Gang, 2 Poles Total, 10 Pos., Non-Shorting	Centralab PA-2005 Type
T-101	6-5889	Transformer Plate	Wahlgren #2403
T102	6-5890	Transformer Filament	Wahlgren 2402



NOTE:
ALL RES. ½ WATT 10% UNLESS OTHER WISE NOTED
CAPACITOR VALUES IN μf.

LOT 1
ISSUE A
7-13-55

Model 1015 Schematic

TEMPORARY
INSTRUCTION MANUAL

Model 1070
FUNCTION GENERATOR

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
12 July 1955

WARRANTY

Every instrument manufactured by the BERKELEY division of Beckman Instruments, Inc. is warranted to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year from date of shipment to the original purchaser prove to be defective after our examination.

Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

Model 1070 Function Generator

DESCRIPTION

The Model 1070 Function Generator produces an output voltage (Y) which is some selected function of an input voltage (X). X may vary with time in any way so long as the rapidity of the variations does not exceed the upper frequency limit of the unit which is about 1000 cycles. To set up a function, a curve showing the desired relationship between X and Y is drawn and the unit adjusted to approximate this curve in 22 straight-line segments. The lengths and position of the segments may be varied for the best approximation; that is, several short segments may be clustered where the slope of the curve changes rapidly and fewer and longer segments used where the slope is nearly constant.

The segmented curve is produced by the action of 22 diodes. Each of eleven diodes is adjusted to begin conducting at some positive value of X called a "break-point". The X voltage, rising positively from zero causes these diodes to conduct successively. At each break-point the slope of the curve is changed in accordance with a potentiometer setting. Each of the remaining eleven diodes is set to begin conducting at a negative value of X and these conduct successively as X moves negatively from zero.

SPECIFICATIONS

Input

A voltage (X), constant or varying with time, within the range of -100 to +100 volts.

Output

A voltage (Y) having a desired functional relationship to X. Y varies in 22 straight-line segments which approximate the curve of the function.

Static accuracy

In most cases the desired function may be approximated to within ± 0.5%.

Drift

None except that due to the externally connected amplifiers which form part of the function generator circuit.

Slope change

The maximum change in slope at a break-point is 1/2 R where R is the value of the feedback resistor in the output summing amplifier in megohms.

Input resistance

Varies with X voltage from 48K at X = 0 volts to 16K at X = ±100 volts.

Power requirements

115 volts, 60 cps, 21 watts.
-400 volts d-c, 22 ma
+400 volts d-c, 22 ma

OPERATION

Connecting Output Amplifiers

The Model 1070 must be supplemented by two output amplifiers to make up a complete function generator. Connect two amplifiers to the "+" and "-" FUNCTION GENerator terminals on the patch board as diagramed in figure 1. So connected, the Y voltage appears at the output of the output summer when the X voltage is introduced at the IN terminal on the patch board.

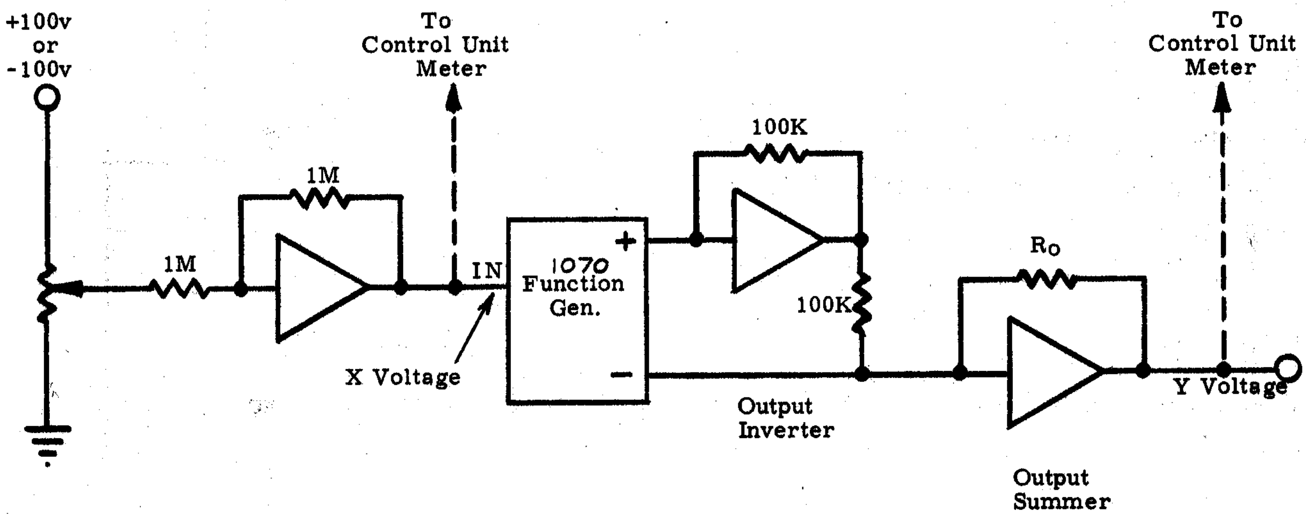


Figure 1

The value of R_0 determines the maximum change in slope at a break-point. It must not be greater than 5 megohms, a value which permits a change in slope of 2.5 volts in Y per 1 volt in X. It may be less than 5 megohms if so great a slope change is not required.

Adjusting the Unit to Produce a Desired Function

1. Draw a graph similar to Figure 2 showing the desired functional relationship. Choose X and Y scale factors so that both variables remain with the range of -100 to +100 volts, and the curve passes through X = 0, Y = 0. Select 10 points on the curve to each side of X = 0 which best approximate the curve when connected by straight lines. These are the break-points and the X values at these points are the break voltages. Make a table of X and Y values at these points.

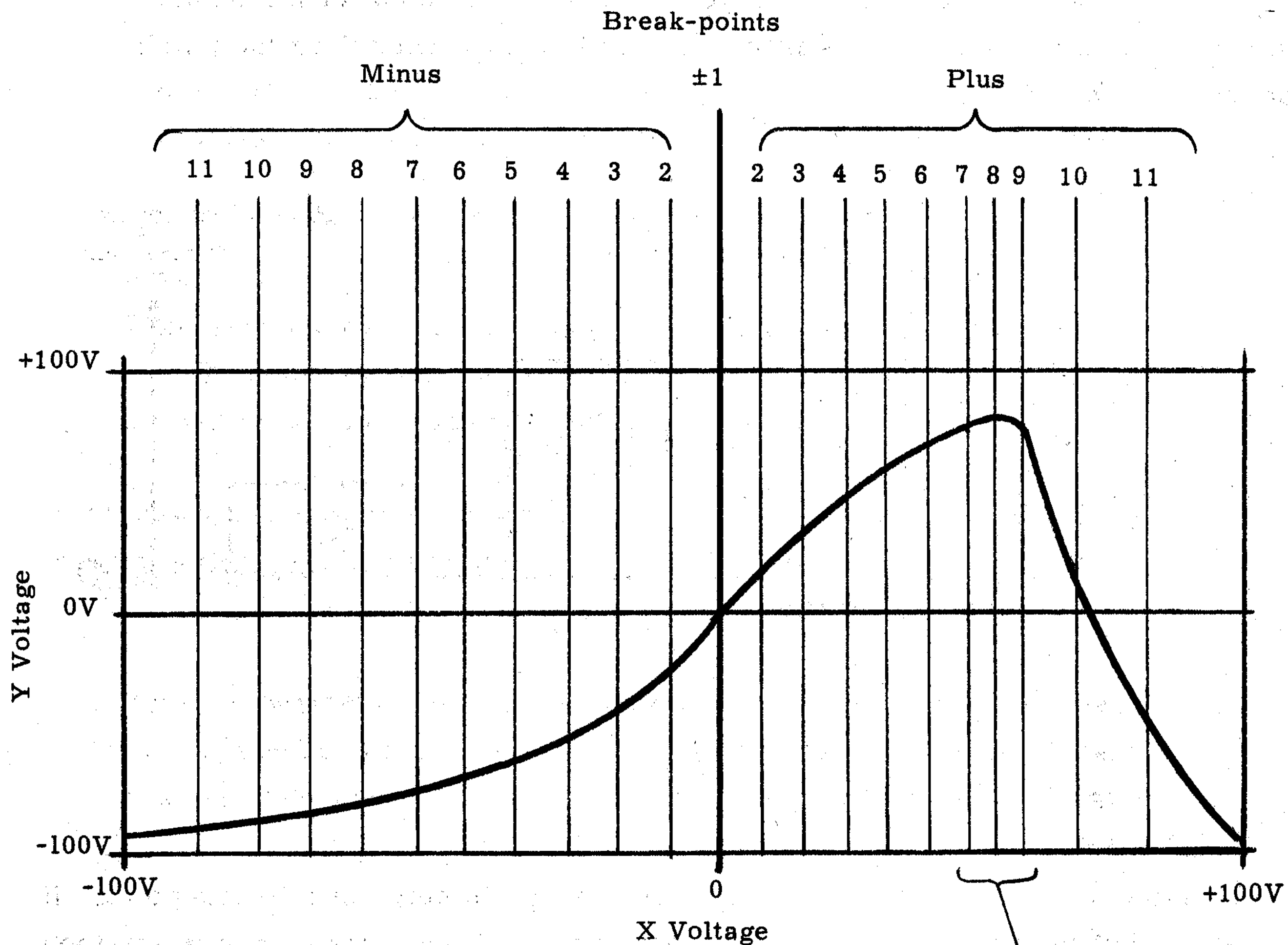


Figure 2

Locate the break-points on the curve in such positions that the change in slope at any break-point does not exceed 1/2 R_o where R_o is the value of the output summer feedback resistor in megohms. R_o must not exceed 5 megohms so the maximum slope change at a break-point is 2.5 volts on the Y axis per

1 volt on the X axis. Where the curve changes slope rapidly locate break-points very close together or, if necessary, at the same point.

2. Connect a variable reference voltage source to the IN terminal as shown in figure 1.

3. Turn all the controls on the front panel of the Model 1070 fully clockwise
   This sets all break voltages except +1 and -1 at +105 or -105 volts and all increment slopes at a maximum.

4. Break-point +1 is permanently fixed at 0 volts. Adjust the slope between break-points +1 and +2 and fix break-point +2 as follows:

   a. Adjust the variable reference voltage to the positive X value at break-point +2.

   b. Turn INCREMENT SLOPE control +1 counter-clockwise until the Y output voltage equals the Y value at break-point +2.
      This adjusts the slope between break-points +1 and +2.

   c. Turn BREAK VOLTAGE control +2 slowly counter-clockwise to precisely the position at which the Y output voltage begins to rise
      This sets break-point +2.

5. Adjust the variable reference voltage to the X value at break-point +3. Adjust INCREMENT SLOPE control +2 to set the slope between break-points +2 and +3 and adjust BREAK VOLTAGE control +3 to set break-point +3.

6. Raise the reference voltage to successively higher positive X values and adjust the other slopes and plus break-points in a similar way. INCREMENT SLOPE control +11 fixes the slope from break-point +11 to +100 volts on the X axis.

7. Adjust slopes and break-points for negative values of X in a similar way. INCREMENT SLOPE control -11 fixes the slope from break-point -11 to -100 volts on the X axis.

CIRCUIT DESCRIPTION

The circuitry shown to the left of the dotted line in figure 3 is one of 11 identical diode networks which form the Model 1070. Each network receives the same input voltage (X) and each has its positive output connected to the "+" terminal and its negative output connected to the "-" terminal. The output voltage (Y) is proportional to the sum of all currents flowing to the "+" terminal minus the sum of all currents flowing to the "-" terminal. The contribution of each diode network to this current sum is the current flowing to its positive output minus theh current flowing to its negative output. If we call this net current i_o, then

$$Y = K(i_{o_1} + i_{o_2} + i_{o_3} \ldots i_{o_n})$$

Consider first the action of the individual diode network shown in figure 3. $+e_b$ and $-e_b$ are plus and minus break voltages. As long as X lies between these values neither diode conducts. Due to the symmetry of the circuit, $e_1 = e_2$ and the current at the positive output equals the current at the negative output. Then, $i_o = 0$ and the network has no effect on Y. When X becomes more positive than $+e_B$, the positive diode conducts. If P_1 is set at the midpoint, the circuit remains symetrical and e_1 still equals e_2. If, however, P_1 is set so that the resistance from the diode to point e_1 is greater than that to point e_2, e_1 will become more positive than e_2 as X rises. In this case the current at the positive output exceeds that at the negative output and i_o is positive. If P_1 is set so that the resistance from the diode to point e_1 is less than that to point e_2, e_1 will become less positive than e_2 as X rises and i_o will be negative. Stated quantitively,

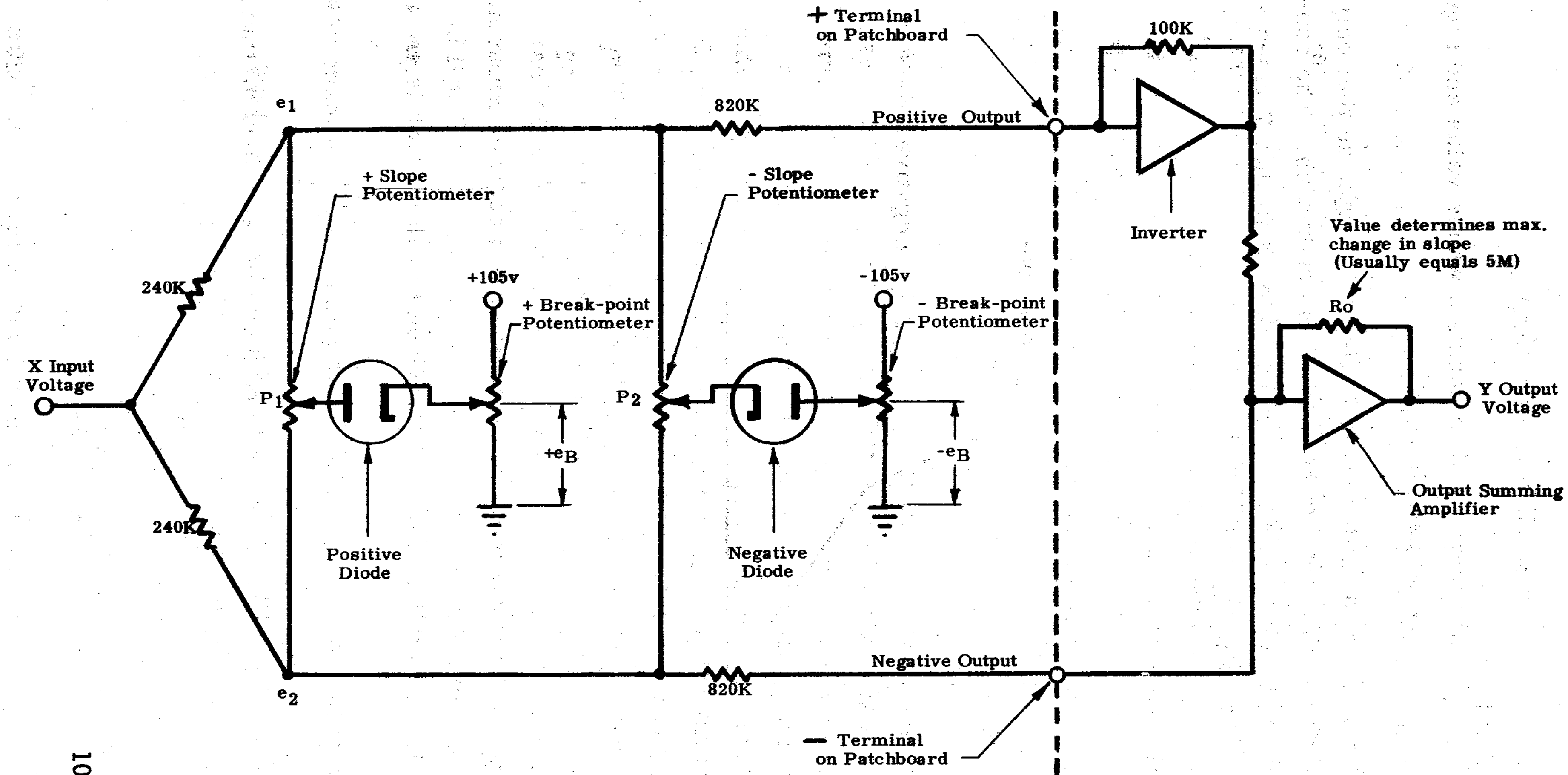
$$e_1 - e_2 = a(X - e_{B-})$$

where a is a positive or negative constant determined by the setting of P_1

and

$$i_o = k(e_1 - e_2)$$

where k is a constant determined by the 820K resistors.



NOTE:

The positive output of all diode pairs is connected to the "+" patchboard terminal.

The negative output of all pairs is connected to the "-" patchboard terminal.

FIGURE 3

Therefore,

$$i_o = ka\ (X - e_B) \text{ or } b\ (X - e_B)$$

where b is still a constant whose value and sign are adjustable by P_1

To see how the action of each diode network affects Y, suppose that only the first positive diode with a break voltage of zero is conducting. The conducting network contributes a current i_{o_1} equal to b_1 X to that Y rises as diagramed in figure 4 up to e_{B_2}.

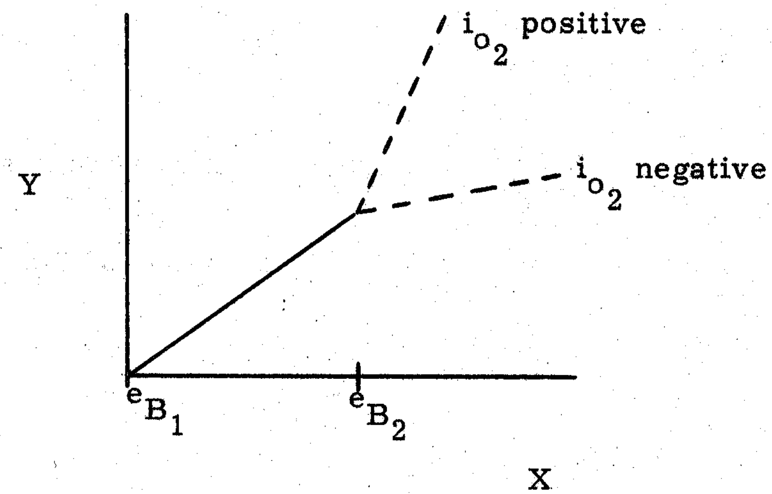


Figure 4

When X reaches e_{B_2} the second positive diode begins to conduct contributing i_{o_2} which also varies linearly with X. If the slope potentiometer is set so that i_{o_2} is positive, the slope of Y increases at this point. If i_{o_2} is made negative, the slope decreases. The effect of the second diode is described mathematically in the following equations:

At all times

$$Y = K(i_{o_1} + i_{o_2} + \text{etc})$$

From e_{B_2} to the next break-point (e_{B_3})

$$Y = K[b_1 X + b_2 (X - e_{B_2})] \quad \text{or}$$

$$Y = K[b_1 X + b_2 X - b_2 e_{B_2}] \quad \text{therefore,}$$

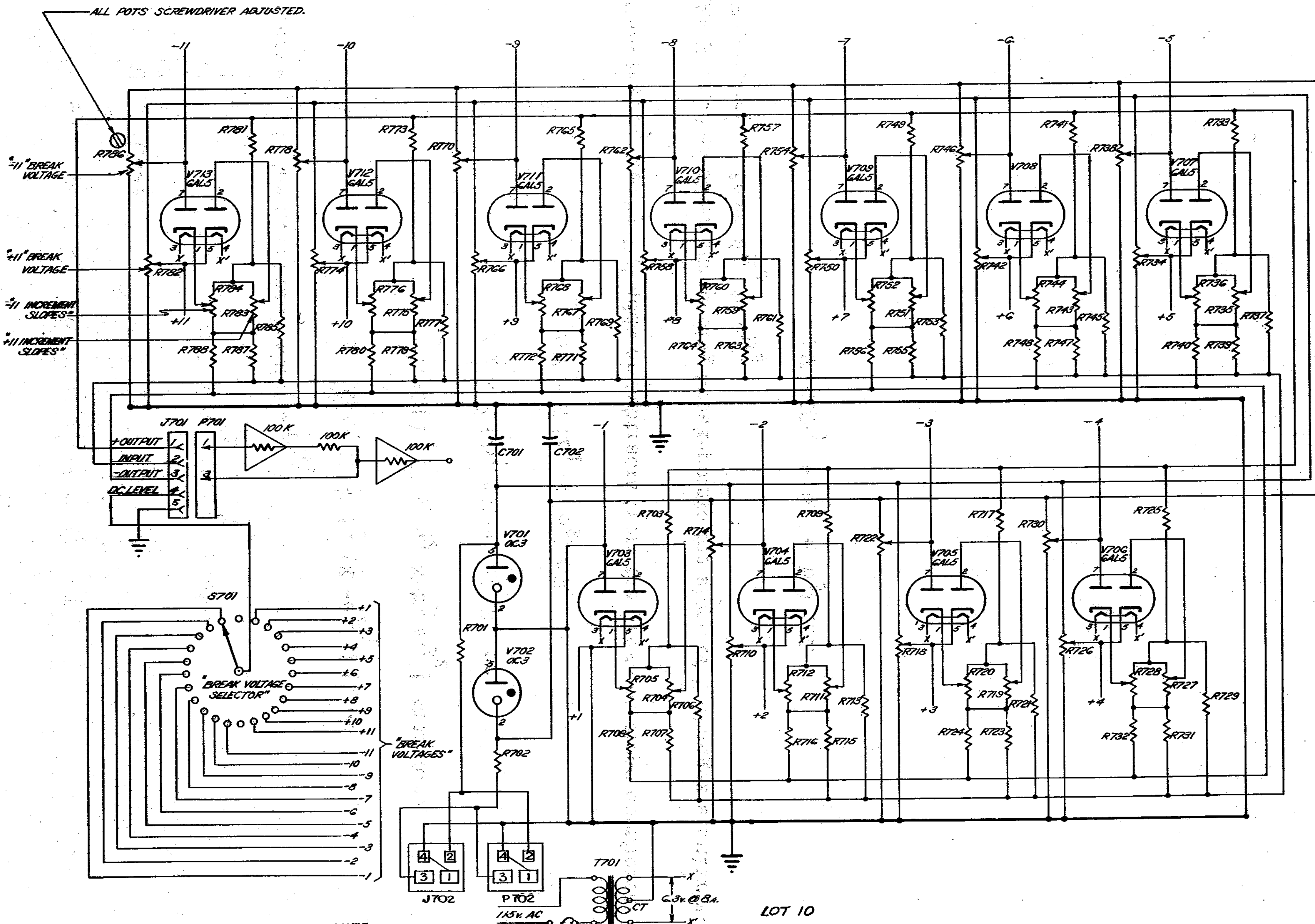
$$\Delta Y = K(b_1 \Delta X + b_2 \Delta X) \quad \text{or}$$

$$\Delta Y = K(b_1 + b_2) \Delta X$$

Note that b_2 (set by P_1) adds or subtracts from the previous slope coefficient b_1.

As X reaches other succeeding break-points the slope of Y changes similarly. For example, from e_{B_3} to e_{B_4}

$$\Delta Y = K(b_1 + b_2 + b_3) \Delta X.$$



NOTE:
1. RESISTORS 1W 10% UNLESS NOTED OTHERWISE.
2. CAPACITORS ARE IN MICROFARADS.

LOT 10
ISSUE E
12-7-55

Model 1070 Schematic

TUBES

Type	Quantity	Type	Quantity
OC3	2	6AL5	11

RESISTORS

Detail No.	Stock No.	Description	Mfr. & No.
R701 & R702	1-2858	15 K, 10W, 10% WW	Tru-Ohm FRL-10
R703	1-3288	820 K, 1 W, 1% Comp.	Electra Type DC-1
R704 & R705	1-0644	pot 250 K, 2W, Carbon	AB J2541
R706 & R707	1-3289	240 K, 1W, 1%	Electra Type DC-1
R708	1-3288	820 K, 1W, 1% Comp.	Electra Type DC-1
R709 R717 R725 R733 R741 R749 R757 R765 R773 R781	1-3288	820 K, 1W, 1% Comp.	Electra Type DC-1
R710 R718 R726 R734 R742 R750 R758 R766 R774 R782	1-1340	Pot. 100K, 2 W, 10%	Type J AB-U1041
R711 R719 R727 R735 R743 R751 R759 R767 R775 R783	1-0644	pot 250K, 2W, Carbon	AB J2541
R712 R720 R728 R736 R744 R752 R760 R768 R776 R784	1-0644	pot 250K, 2W, Carbon	AB J2541
R713 R721 R729 R737 R745 R753 R761 R769 R777 R785	1-3289	240 K, 1W, 1%	Electra Type DC-1
R714 R722 R730 R738 R746 R754 R762 R770 R778 R786	1-1340	pot 100K, 2 W, 10%	Type J AB-U1041
R715 R723 R731 R739 R747 R755 R763 R771 R779 R787	1-3289	240 K, 1 W, 1%	Electra Type DC-1
R716 R724 R732 R740 R748 R756 R764 R772 R780 R788	1-3288	820 K, 1W, 1% Comp.	Electra Type DC-1

OTHER COMPONENTS

Detail No.	Stock No.	Description	Mfr. & No.
C701 & C702	2-2230	Capacitor .01 Mfd, 500 V, Disc.	Erie #811
J701	4-2119	Socket 5 Prong	Amphenol 77 MIP 5
J702	17-2830	Connector	Jones S-304A-B
P703	11-2855	4 Terminal Jones Plug	P304CCT
S701	12-2876	Switch Shaft to be cut 1" beyond Bushing 24 Point non-shorting switch Rotary	Mallory 13124L
T701	6-0917	Transformer 6.3 V, 8 A	Triad FT-8

Model 1003 D-C Voltage Source

The Model 1003 is a source of d-c voltage used mainly for charging feedback capacitors associated with integrators in the computer. The schematic diagram shows the two small power supplies which make up one Model 1003. Ten such units are installed in the Model 1006 Panel which then provides a total of 20 d-c sources.

The voltage between the "+" and "-" terminals may be varied from 0 to 100 volts by rotating a front panel potentiometer control. Neither terminal is grounded. Each source will provide 5 ma full load current. The output voltage varies about 0.5% from no load to full load. Under a same load the output voltage will not vary more than about 0.25% from one time to another.

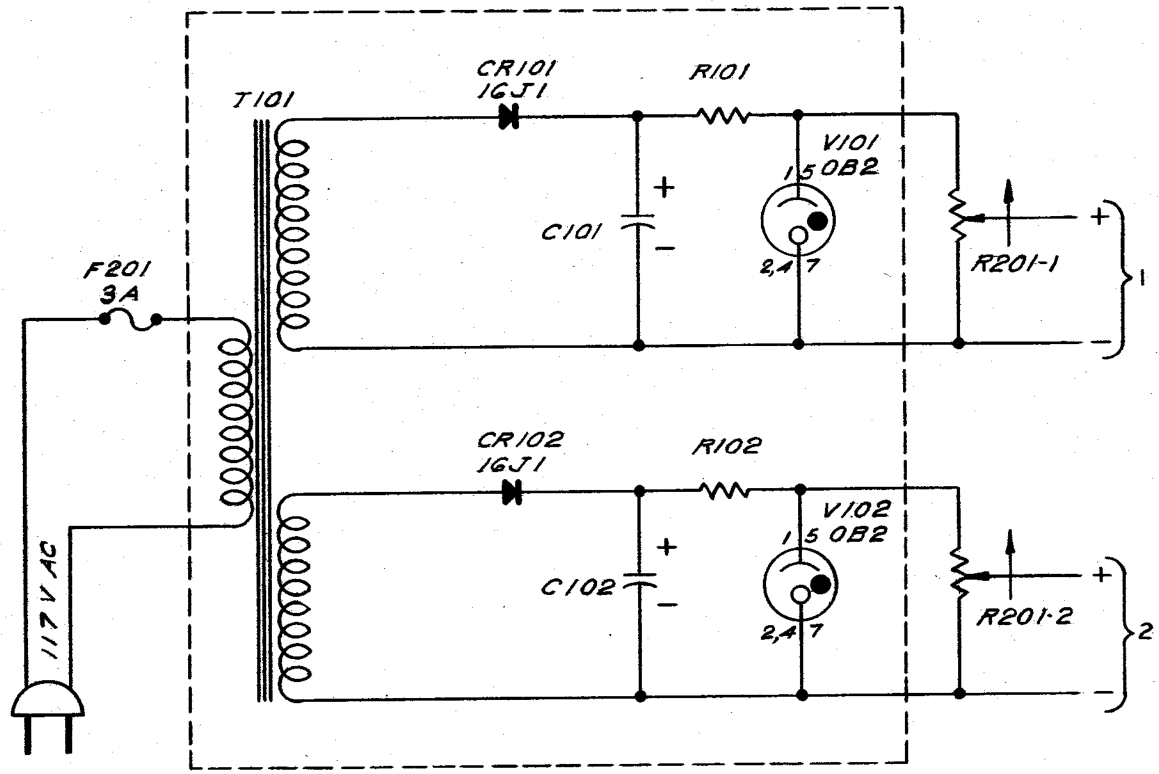
The voltage sources are numbered from 1 to 20. The number of each source appears on the front panel below the potentiometer control which adjusts its output voltage. The number is also labelled on the computer patch board between the output terminals for that source in the section headed "BIAS".

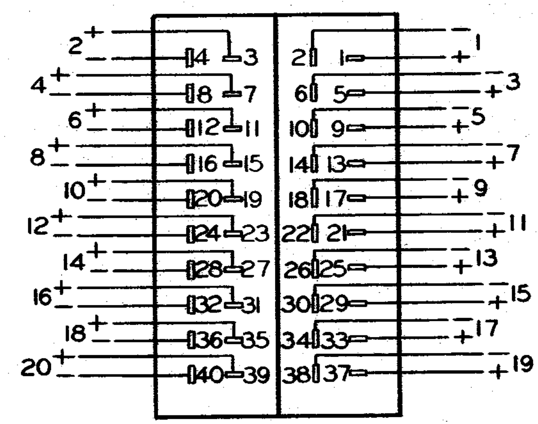
MODEL 1003 PARTS LIST

Detail No.	Stock No.	Description	Mfr. & No.
C101 & C102	2-1321	Capacitor 40 μfd, 450 V, Elec.	Sangamo PL 4540
CR101 & CR102	8-5892	Rectifier Selenium	Radio Receptor 16J1
R101 & R102	1-2942	Resistor 6 K, 10 W, 10% W. W.	Tru-Ohm, FRL-10
T101	6-5796	Transformer 115 V Prim.; 2 Sec: 200 V at 40 MADC (each)	Electro E9051
V101 & V102	5-0531	Tube OB2	

MODEL 1006 PARTS LIST

F201	7-2213	Fuse 3 A, SLO	Littlefuse
P201	17-5843	Connector 40 Pin Female W/Hood & Clamp on Top	Elco #F24054
R201-1 thru R201-20	1-0875	Potentiometer 10 K, 2 W, 10 %	AB U 1031





P201 OF MODEL 1006
FEMALE PLUG AS
VIEWED FROM WIRED SIDE

NOTE:
POWER SUPPLY 1 & 2 INSIDE DOTTED LINE.
SUPPLIES 3 THROUGH 20 IDENTICAL &
CONNECTED TO P201 OF MODEL 1006
AS INDICATED.

LOT 1
ISSUE A
7-8-55

Model 1003 Schematic

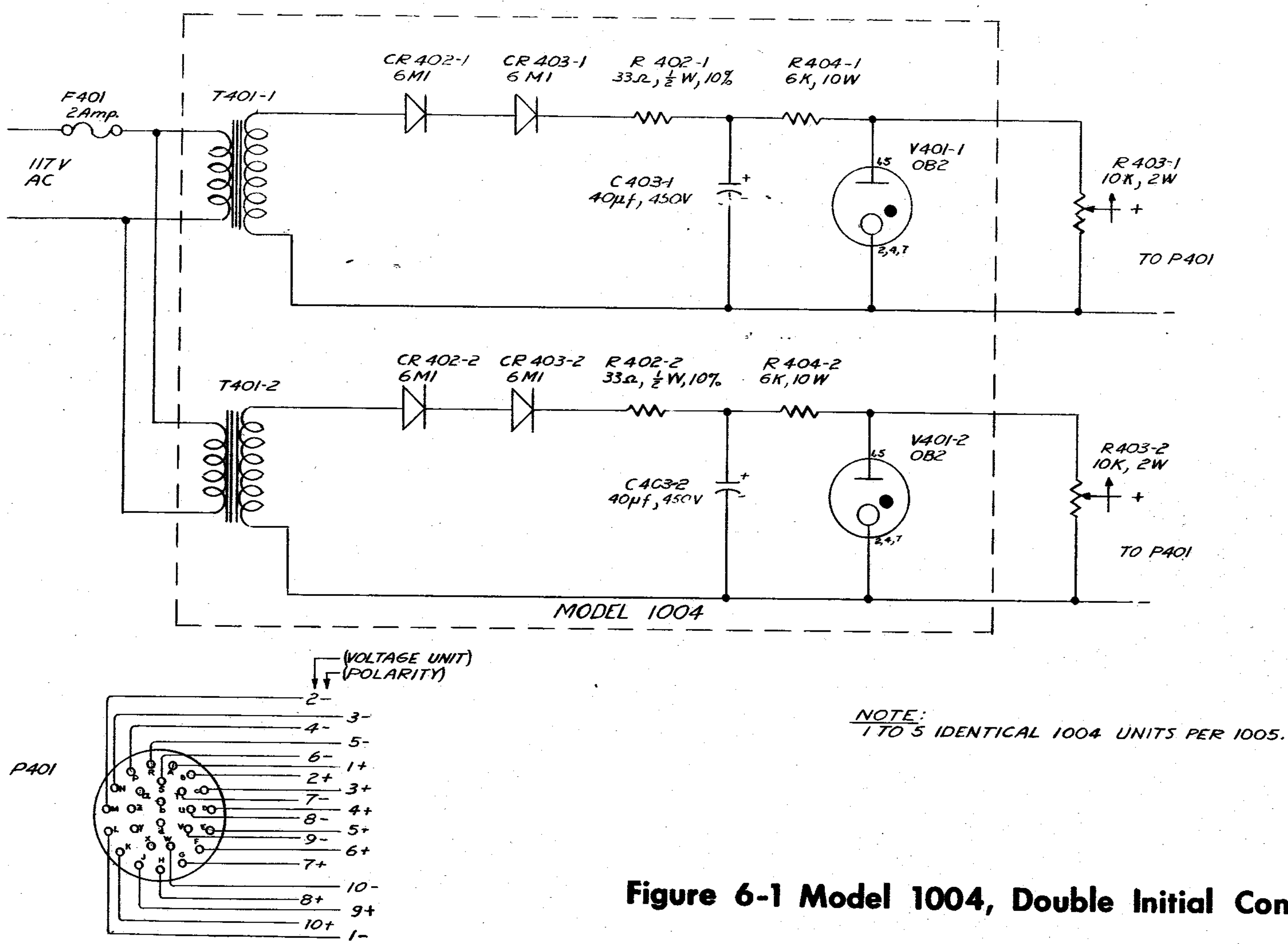


Figure 6-1 Model 1004, Double Initial Condition voltage source

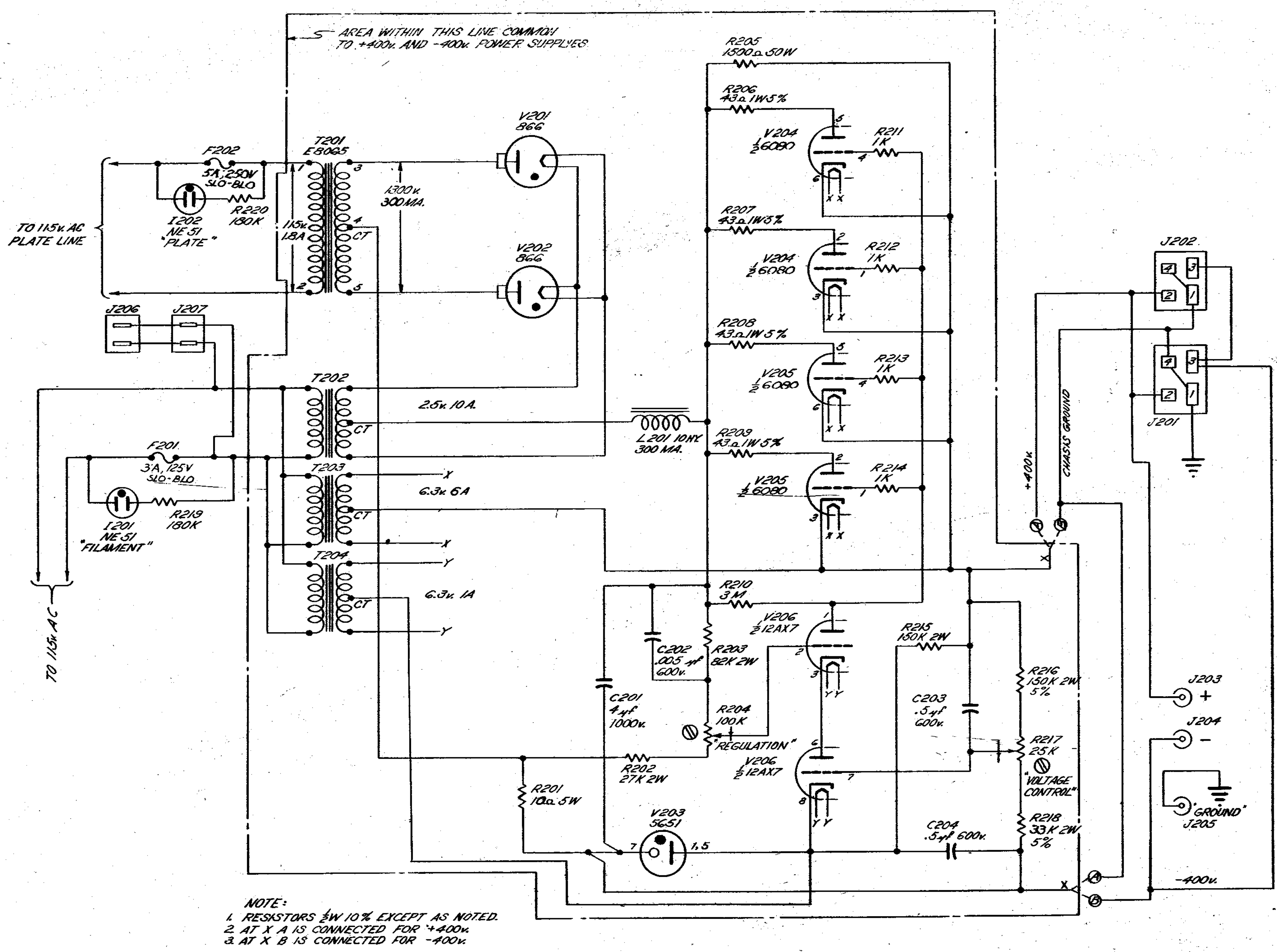


Figure 6-2 Model 1010, Power Supply ±400 volts

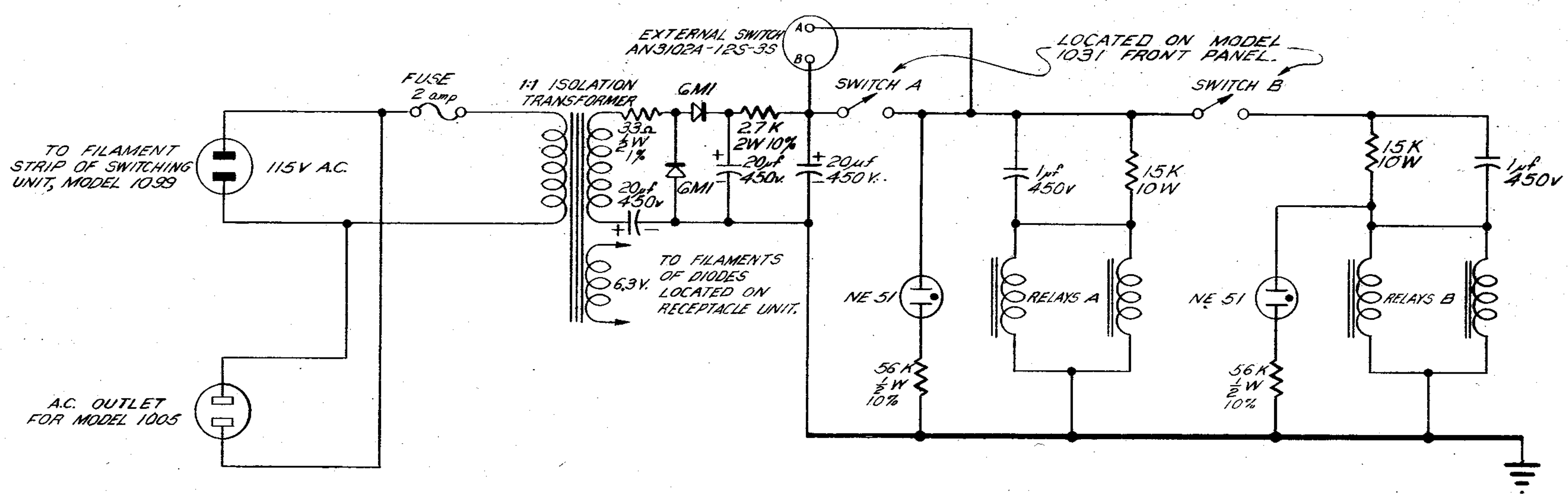


Figure 6-3 Model 1031, D.C. for functional relays A & B

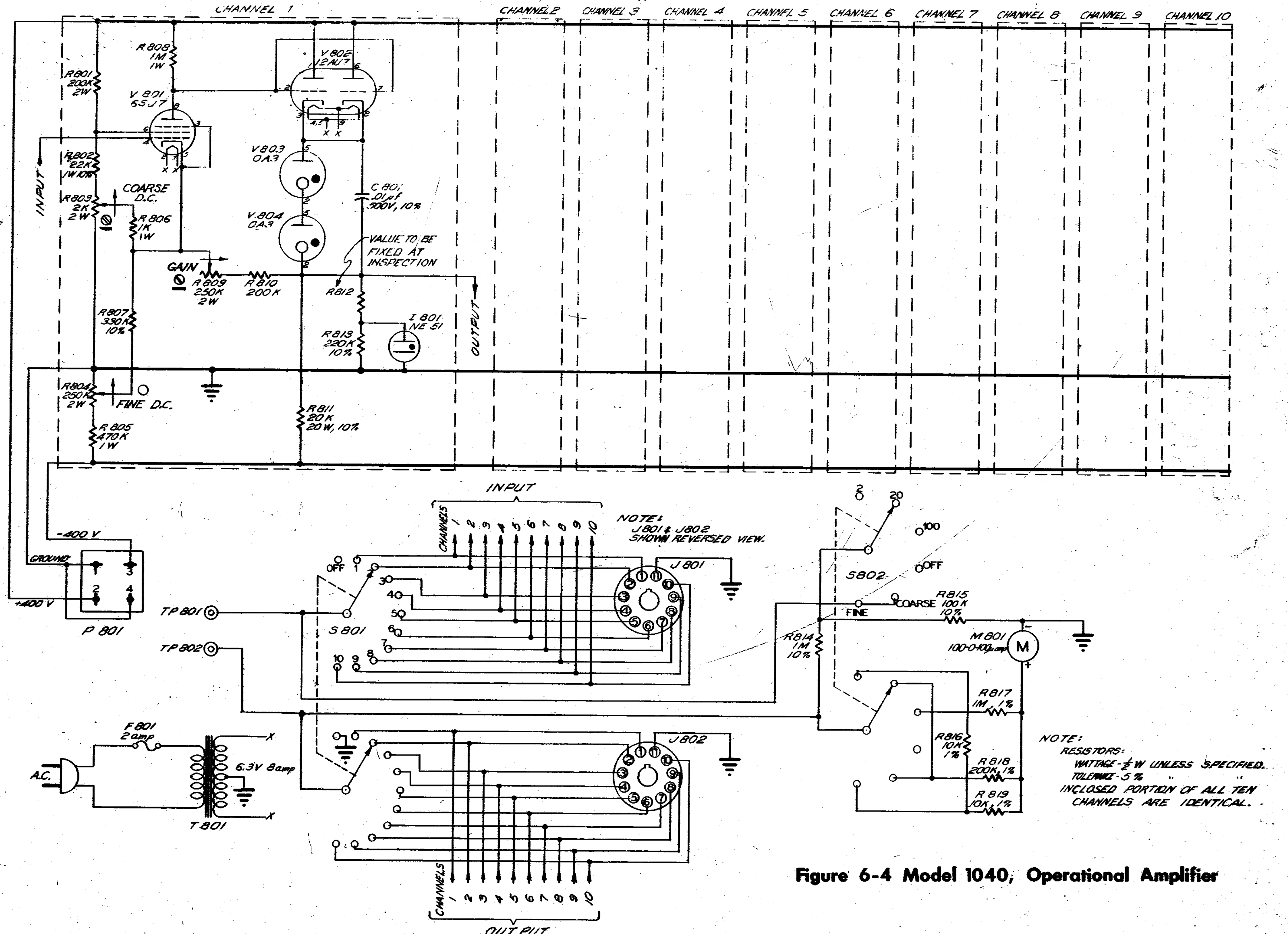
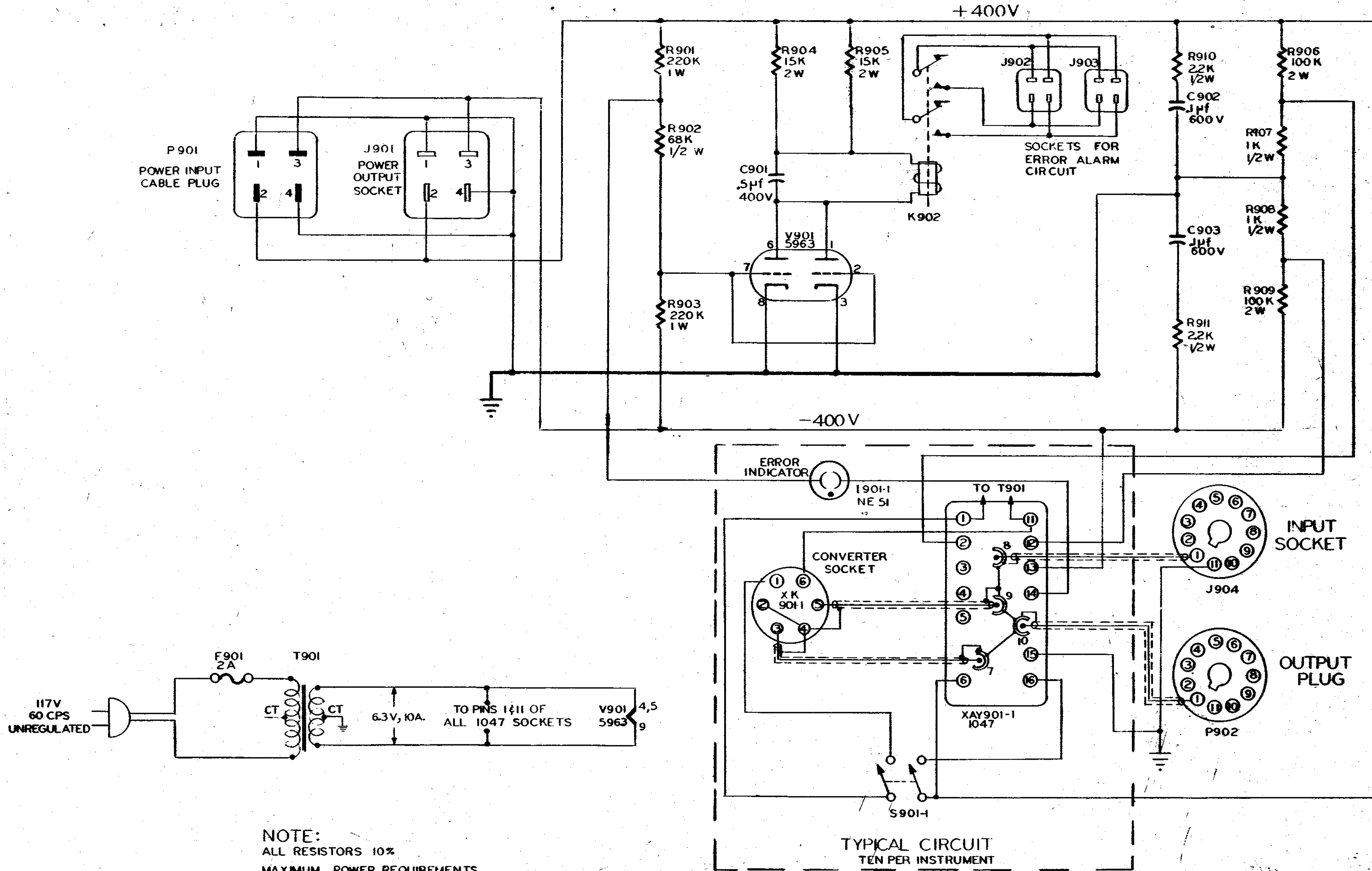
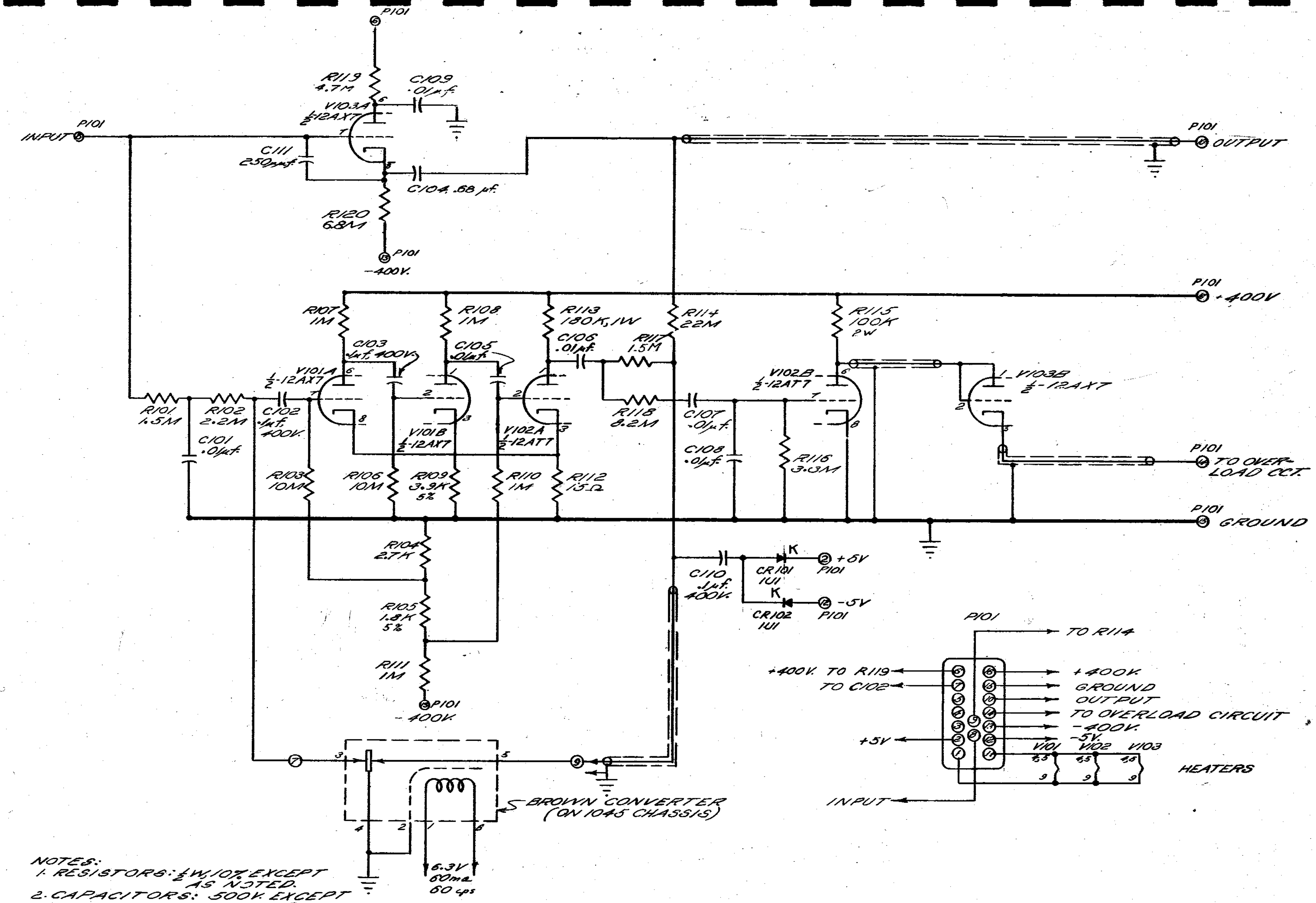


Figure 6-4 Model 1040, Operational Amplifier



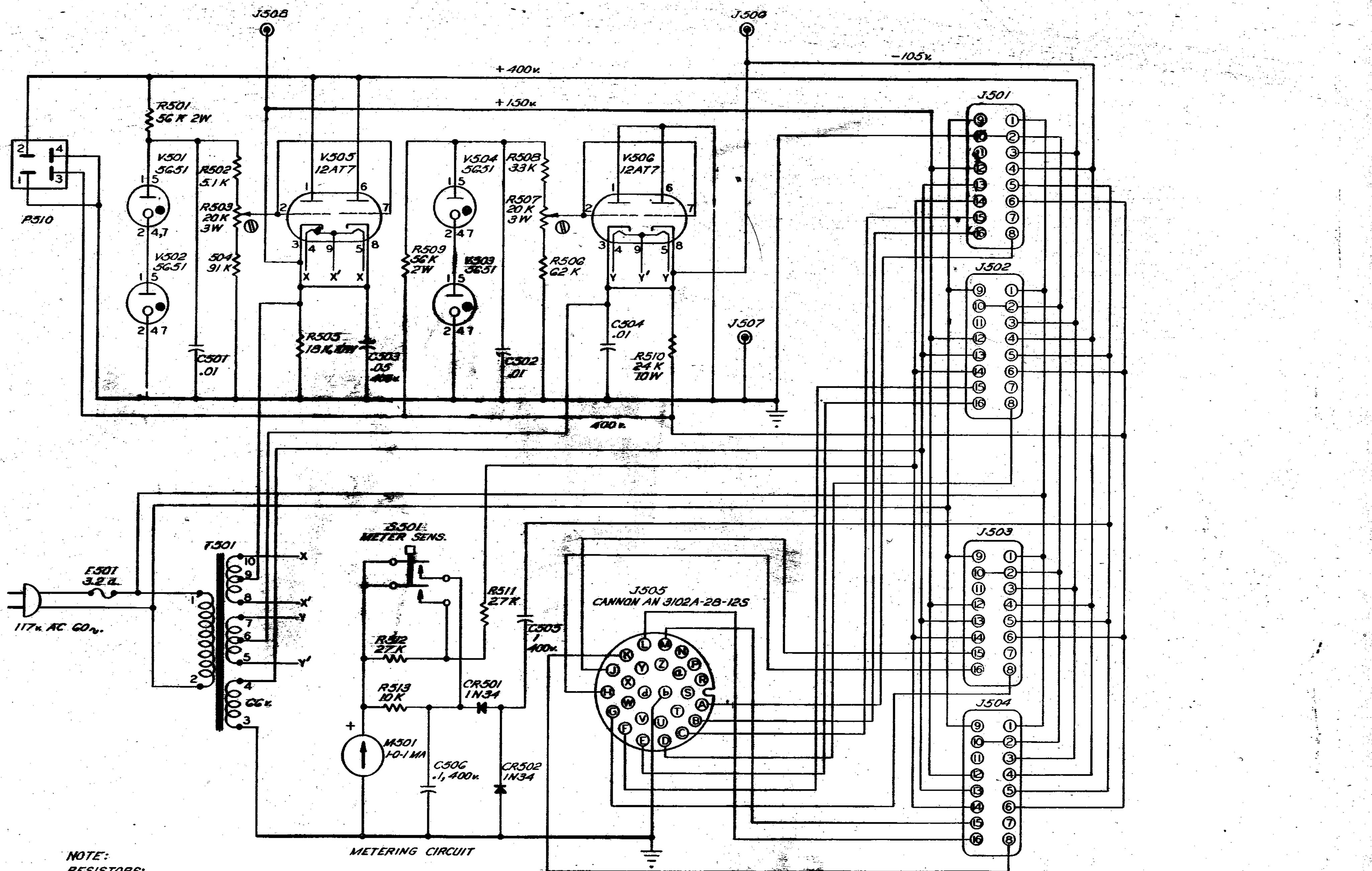
NOTE:
ALL RESISTORS 10%
MAXIMUM POWER REQUIREMENTS
117 V., 60CPS, 0.6A., 65W.
+400V. DC_____62 MA.
-400V. DC_____15 MA

Figure 6-5 Model 1045, Operational Amplifier Stabilizer Chassis



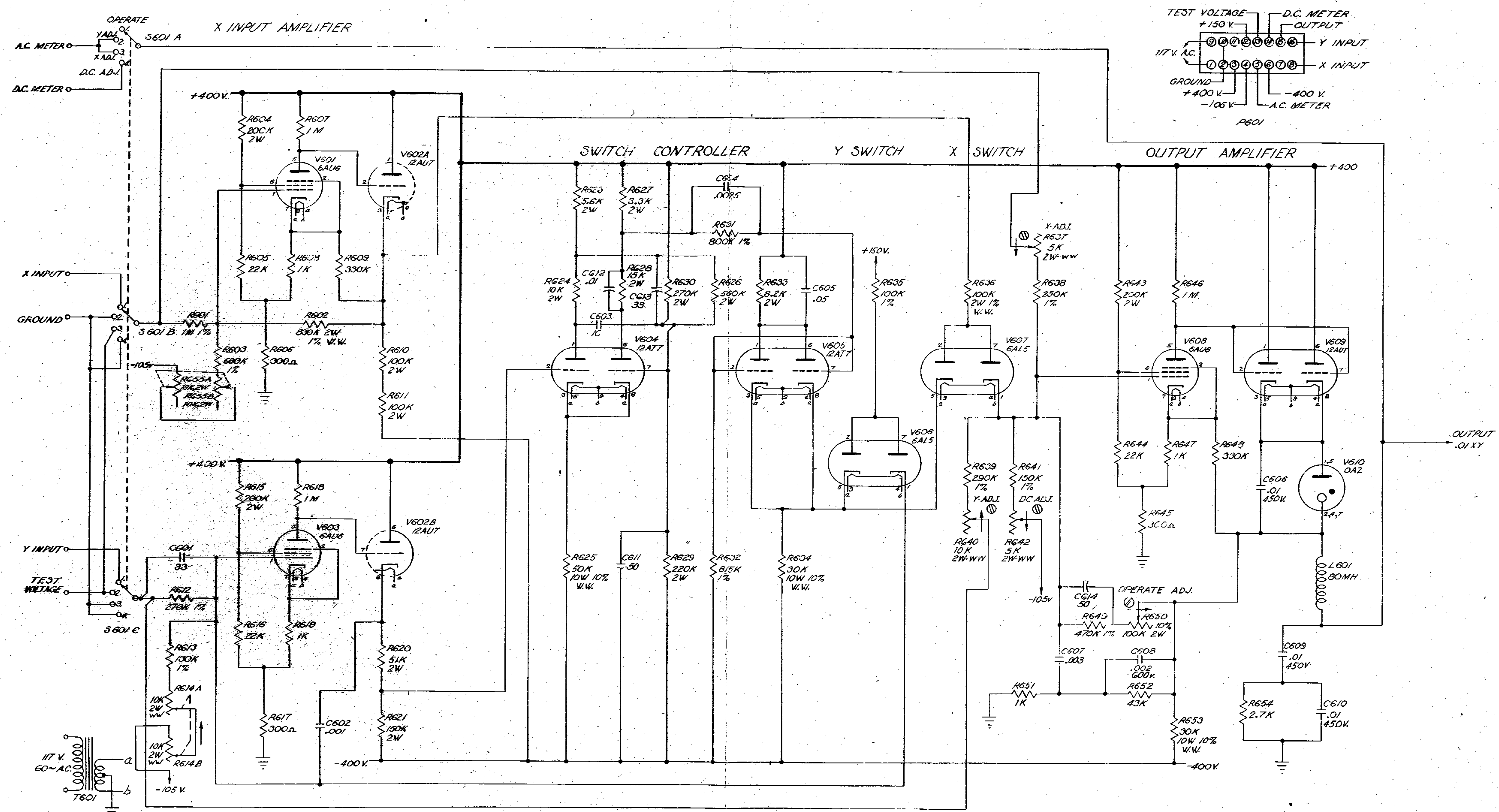
NOTES:
1. RESISTORS: ½W, 10% EXCEPT AS NOTED.
2. CAPACITORS: 500V. EXCEPT AS NOTED.

Figure 6-6 Model 1047, Chopper Amplifier



NOTE:
RESISTORS:
WATTAGE——— ½W UNLESS OTHERWISE NOTED.
TOLERANCE——— 10% " " " .
CAPACITORS:
CAPACITY——— IN MFD'S.
VOLTAGE RATING——— 600v. UNLESS OTHERWISE NOTED.

Figure 6-7 Model 1051, Function Multiplier Chassis



RESISTOR SPEC'S:
1 W. & 5% UNLESS NOTED OTHERWISE.

CAPACITOR SPEC'S:
VALUES LESS THAN ONE IN μfds.
VALUES MORE THAN ONE IN $\mu\mu$fds.
VOLTAGE RATING: 500V. UNLESS NOTED OTHERWISE.

Figure 6-8 Model 1056, Function Multiplier Panel

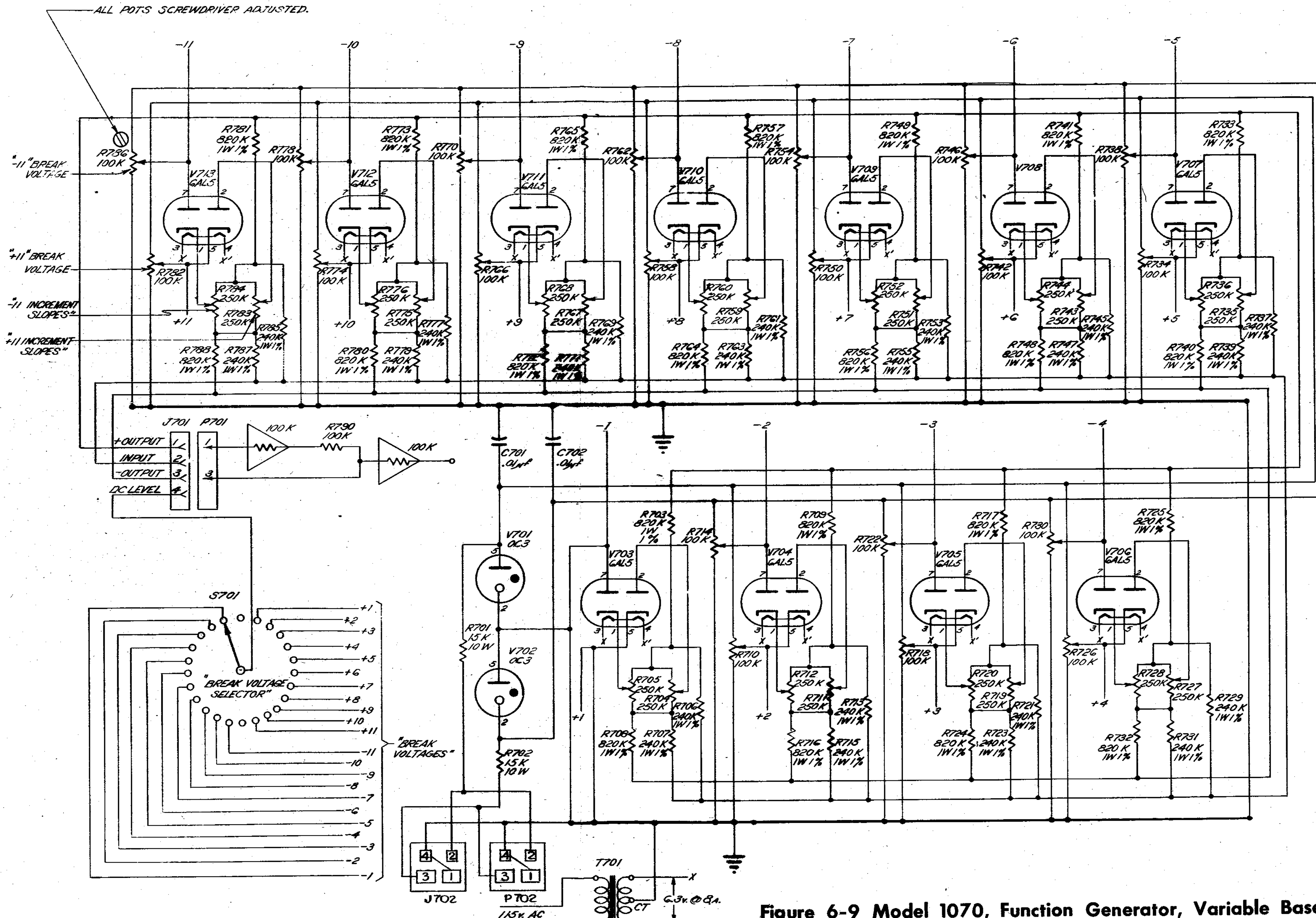


Figure 6-9 Model 1070, Function Generator, Variable Base

NOTE:
1. RESISTORS 1W 10% UNLESS NOTED OTHERWISE.
2. CAPACITORS ARE IN MICROFARADS.