GP-6 ANALOG COMPUTER

OPERATOR'S MANUAL

COMDYNA, Inc.
COMPUTERS FOR DYNAMIC ANALYSIS

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1. GP-6 OPERATING PROCEDURES

1.0 CONNECTION OF EXTERNAL READOUT INSTRUMENTS

The GP-6 functions in the slow time and/or high speed repetitive operation modes. Slow time outputs are normally recorded with an XY plotter; repetitive operation outputs are normally displayed with an oscilloscope having DC horizonatl and vertical inputs. Slow time outputs also may be recorded with a strip chart recorder; repetitive operation outputs also may be displayed with an oscilloscope having a DC vertical input and an internal time base with an external trigger.

It is noted that the GP-6 is furnished with various options that must be considered for connection and calibration of readout instruments.

1. Slow time only (no internal time base.)
2. Slow time only (internal time base provided.)
3. High speed repetitive operation only (internal time base provided.)
4. Slow time and repetitive operation (internal slow and high speed time bases provided.)

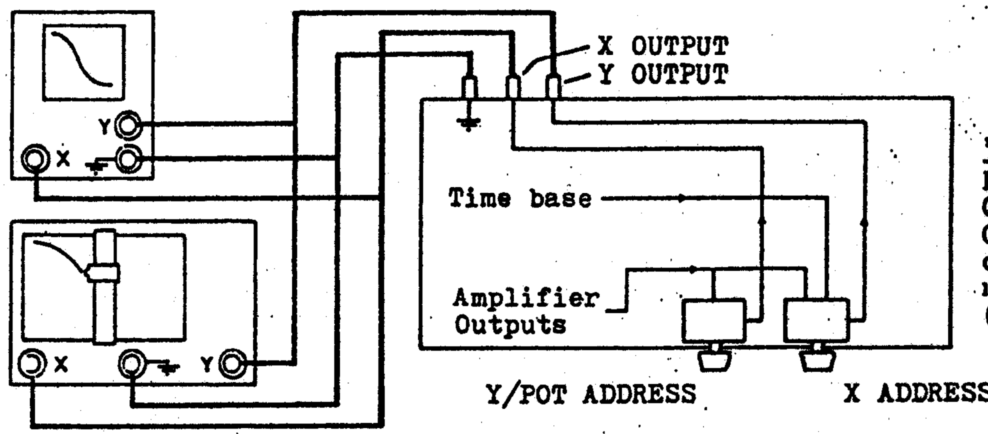


Figure 1-1

***Note:**
Rear terminals OP OUTPUT and OP INPUT must be connected for normal operation. (See para. 2.8)

Rear terminals on the GP-6 offer convenient connections to the X and Y inputs of the plotter and/or oscilloscope. The three connections are shown in Fig. 1-1 and listed below:

1. Common ground.
2. "Y OUTPUT" to the plotter and/or oscilloscope Y (vertical) input.
3. "X OUTPUT" to the plotter and/or oscilloscope X (horizontal) input.

If the oscilloscope's internal time base and external trigger is to be used for display of repetitive solutions, the external trigger input should be connected to the "OP OUTPUT" rear terminal. The OP Output mode control logic is a convenient trigger for repetitive outputs.

1.1 CALIBRATION OF READOUT INSTRUMENTS

The readout plotter or oscilloscope is calibrated so that the full scale horizontal and vertical axes extend between the computer's negative and positive reference (minus to plus ten volts) as shown in Fig. 1-2.

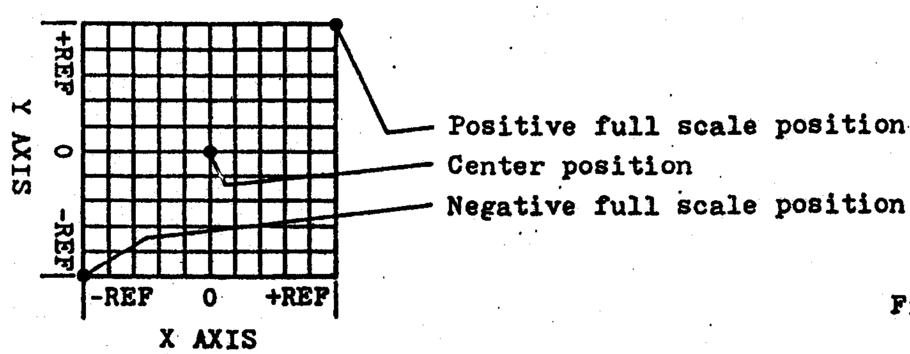


Figure 1-2

The following are procedures for input scaling adjustments:

1. Position the Mode Selector switch to "OPR."
2. Depress the "IC" mode control push button.
3. Position both the "Y/POT ADDRESS" and "X ADDRESS" switches to "GND."
4. Adjust the plotter or oscilloscope Y and X zero controls until the plotter's pen or oscilloscope's dot is in the graph or display center position as shown in Fig. 1-2.
5. Position the "Y/POT ADDRESS" and "X ADDRESS" switches to "-REF."
6. Adjust the plotter or oscilloscope Y and X scale controls until the plotter's pen or oscilloscope's dot is in the graph or display negative full scale position as shown in Fig. 1-2.
7. Position the "Y/POT ADDRESS" and "X ADDRESS" switches to "+REF."
8. Check the pen or dot. It should be in the positive full scale position.
9. Repeat the above procedures if necessary.

The readout instruments are calibrated to present either Y vs Time or Y vs X curves depending on the positions of the Y and X address switches. Amplifier outputs appear as variables that function within their full scale negative and positive operating ranges. The time base is presented so that the negative full scale co-ordinate is a zero time condition and the positive full scale co-ordinate is the compute time period. Time co-ordinates, therefore, depend on the operator's choice of a time period that is adjustable within a range of 10 to 100 computer time scaled seconds.

If the oscilloscope internal time base is to be used for the repetitive display, the high speed time scale ratio of 400:1 must be considered. One computer time scaled second is equal to 2.5 milliseconds of real time.

1.2 SETTING COEFFICIENT POTENTIOMETERS

Coefficients are set in a potentiometer setting mode with the internal readout meter that is either a digital voltmeter or null meter depending on the option that is furnished. Procedures for setting coefficient potentiometers are listed as follows:

1. Coefficients are set after all patching is completed. (It is noted that when used as normal attenuators the bottom ends of potentiometers 7 and 8 must be patched to ground.)
2. Position the "MODE SELECTOR" switch to "POT SET."
3. Position the "Y/POT ADDRESS" switch to the number of the potentiometer to be set.

4a Where the digital voltmeter is employed the coefficient value is displayed. Adjust the potentiometer until the desired setting is observed.

4b Where the null meter is employed the potentiometer must be nulled against a preset potential. Prior to setting the coefficient potentiometer adjust the null potentiometer until the calibrated dial shows the desired coefficient value. Place the adjacent toggle switch in the up position. Adjust the coefficient potentiometer until the null meter needle is in a null (center) position.

1.3 SETTING THE COMPUTE TIME PERIOD

The Compute Time Period is the full scale X axis co-ordinate for response curves produced by the XY plotter or displayed on the oscilloscope when the computer's internal time base is employed.

Procedures for setting the Compute Time Period are as follows: (Note- only units furnished with the internal time base have the Compute Time Period setting feature.)

1. Position the "MODE SELECTOR" switch to "POT SET."
2. Position the "Y/POT ADDRESS" switch to "GND/X."
3. Position the X ADDRESS" switch to "CTP."

4a Where the digital readout is employed, the display shows CTP/100 computer time scaled seconds. Adjust the "COMPUTE TIME" control until the desired Compute Time Period is observed.

4b Where the null meter is employed, first set the null potentiometer to the desired CTP/100 value. Place the adjacent toggle switch into the down position. Adjust the "COMPUTE TIME" control until a null condition is observed.

1.4 STATIC MEASUREMENT OF AMPLIFIER OUTPUTS

The amplifier address and internal readout meter may be used for the static measurement of amplifier outputs.

<u>1.4.1 Measurement of amplifier outputs in the Pot Set mode.</u> (The "MODE SELECTOR" switch is in the "POT SET" position.)

1. Position the "Y/POT ADDRESS" switch to "GND/X."
2. Position the "X ADDRESS" switch to the number of the amplifier output to be measured.

3a Where the digital readout is employed the addressed amplifier output is displayed. Its polarity is automatically indicated.

3b Where the null meter is employed first the toggle switch must be in the position for the correct output polarity. If the amplifier output is positive the toggle switch must be in the up position; if the output is negative the toggle switch must be down. Adjust the null potentiometer until a null condition is observed. The null potentiometer dial reading is the measured amplifier output.

<u>1.4.2 Measurement of amplifier outputs in the Operate mode.</u> (The "MODE SELECTOR" switch is in the "OPR" position.)

1. Patch the rear terminal "Y OUTPUT" to rear terminal "METER INPUT."
2. Position the "Y/POT ADDRESS" switch to the number of the amplifier output to be measured.
3. Follow above procedures 3a or 3b to measure the desired amplifier output.

<u>1.4.3 Measuring the sum of integrator inputs.</u> The sum of integrator inputs, as required in standard program static check procedures, may be measured as follows:

1. Position the "MODE SELECTOR" switch to "OPR."
2. Depress the "IC" mode control push button.
3. Patch the "SJ" jack of the integrator input to be measured to the "SJ" jack of an unused amplifier; the unused amplifier is to have a 1 resistor feedback.
4. Measure the summer amplifier output using the procedures of 1.4.2. The summer output is the inverted sum of the integrator inputs.

1.5 PROBLEM SOLUTION

Problem solution is oriented primarily to the XY graph or display. Following programming, patching, setting of coefficients, program check out and setting the compute time period, the program is ready to be run. Computed variables are ready to be recorded, displayed and evaluated.

The principle graphical readout is the response curve where dependent variables (amplifier outputs) are presented as functions of the independent variable time. To obtain response curves:

1. Position the "Y/POT ADDRESS" switch to the number of the amplifier output that is to be the curve's ordinate.
2. Position the "X ADDRESS" switch to "TIME."

3a For XY plotter readout, depress the "IC" mode control push button. (All integrators are placed into the initial condition mode.)

4a Depress the "OP" push button. (All integrators are simultaneously placed into an operate or run state and the plotter produces the Y vs Time response curve.)

3b For oscilloscope readout, depress the "RO" mode control push button. (The response of all integrators is increased by a factor of 400; all integrators are repeatidly switched from initial condition to operate modes and the complete response curves appear on the oscilloscope display.

If the response curve is to be evaluated in physical units, the amplifier output scale factor (maximum estimated amplitude) is the full scale Y axis co-ordinate and the function operates within the range of zero to plus or minus the scale factor value. The full scale real time co-ordinate is the compute time period divided by the time scale factor.

If the operator determines that the compute time period is either too long or too short for convenient readout, the "COMPUTE TIME" control may be adjusted and a new compute time period established. It is emphasized that adjustment of the "COMPUTE TIME" control does not alter the response function but varies only the period that is observed. (If the full range "COMPUTE TIME" control adjustment does not meet readout requirements, a new time scale factor must be selected and coefficient settings recalculated.)

An alternate graphical readout is the phase-plane curve (a variable plotted against its derivative) or a curve of one variable plotted against another variable. To produce such curves position the "X ADDRESS" switch to the amplifier output that is to be the abscissa and follow above procedures 3a and 4a or 3b.

It is noted that the curves displayed on the oscilloscope are identical to graphs produced by the XY plotter. If the oscilloscope and plotter are used for the simulation analysis it is convenient to connect both readout instruments and leave the plotter in a stand-by condition when not being used. The analysis may then be conducted as follows:

1. Evaluate functions in the repetitive operation mode with the oscilloscope display. A view of the total output curves and the quick response to parameter changes is often valuable to an understanding of problem characteristics. When hard copy is desired the curve may then be plotted.
2. Depress the "IC" mode control push button.
3. Activate the plotter.
4. Depress the "OP" push button and plot the curve that was displayed on the oscilloscope.

In addition to the initial condition and operate modes described in above procedures 3a and 4a, output functions may be placed into a hold condition. At any time during a run computer time may be stopped by depressing the "HD" mode control push button. The hold mode enables the operator to evaluate the static values of variable at desired points in time. From the hold mode the run may either be continued by redepressing the "OP" pushbutton or the function may be returned to the initial condition state by depressing the "IC" push button.

1.6 SLAVING TWO OR MORE COMPUTERS

When problem requirements exceed the capacity of one unit two or more GP-6 computers may be slaved into a single operating system.

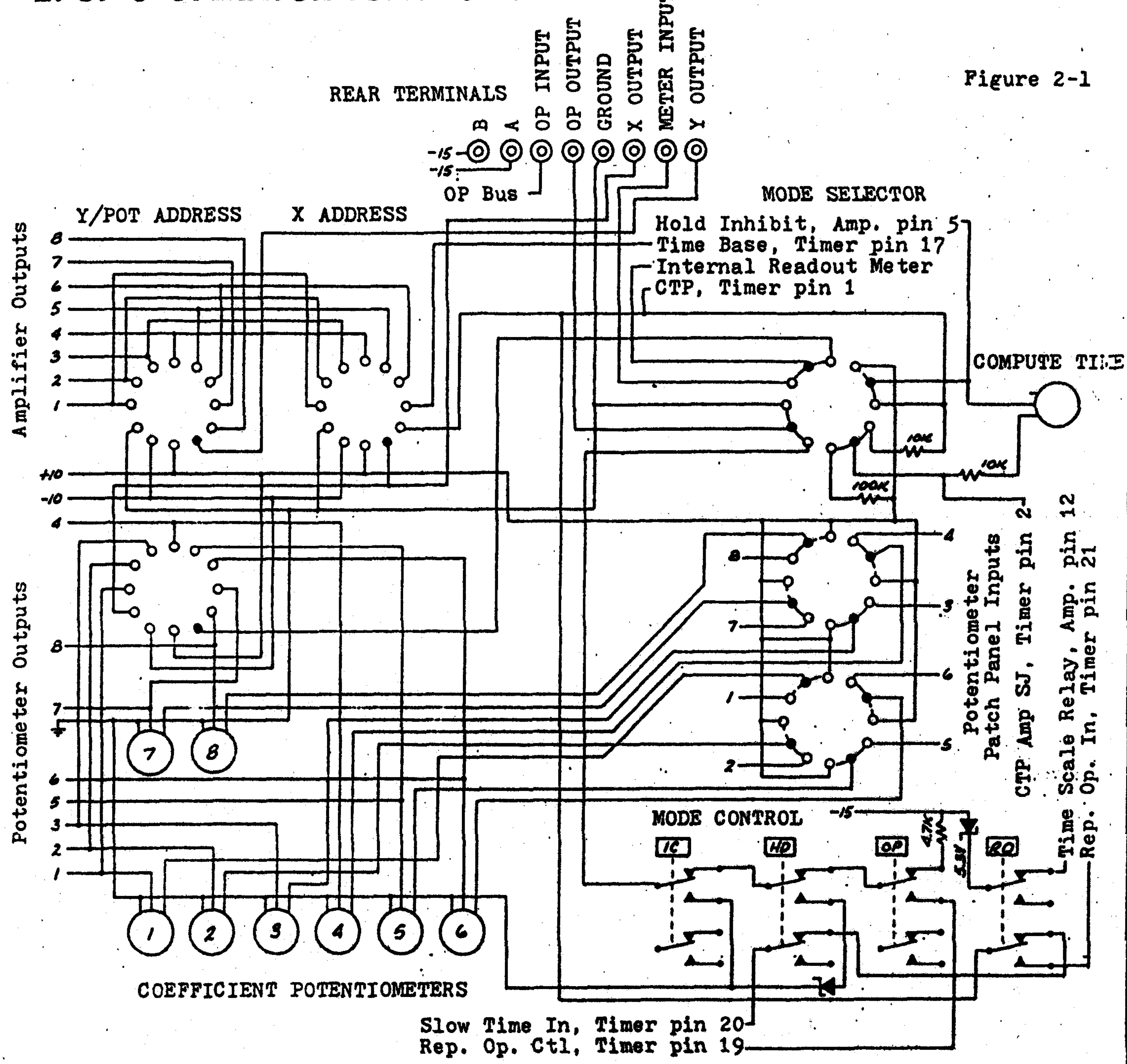
1. Designate a unit to be the master; others shall then be slaves to the master.
2. Connect a common ground between units through rear terminals "GND."
3. Program each unit and then patch interconnections. Patching between panels is identical to patching within a panel.
4. On all slave units remove the shoring wire between rear terminals "OP OUTPUT" and "OP INPUT."
5. Connect the rear terminal "OP OUTPUT" of the master to the "OP INPUT" terminals of all slave units.
6. The modes of all slaved units will then be controlled by operation of the master computer.

1.7 POWER

The 115 volt A.C. power switch is a part of the Compute Time control. To turn power "on" rotate the Compute Time control clockwise from the "OFF" position. The above pilot light indicates a power-on condition.

2. GP-6 OPERATOR FUNCTIONS

Figure 2-1



2.0 GP-6 OPERATOR FUNCTIONS

Figure 2-1 is a schematic of operator functions. Descriptions of individual functions are described in the following.

2.1 Y/POT ADDRESS

The Y/Pot Address switch is an 11 position, 2 pole rotary switch. One section selects amplifier outputs for external readout; the other section selects coefficient potentiometer outputs for setting attenuator constants. The amplifier selector wiper is connected to the rear terminal "Y OUTPUT;" the potentiometer selector is connected to the Mode Selector switch and is the input to the internal readout meter in the Pot Set mode. It is noted that the "GND/X" position of the potentiometer section is connected to the X Address switch wiper so that the internal readout meter may be used to measure the X Address selections in the Pot Set mode.

2.2 X ADDRESS

The X Address switch is an 11 position, 1 pole rotary switch. It selects amplifier outputs, the internal time base and the CTP output for both external and internal readout. The wiper is connected to the rear terminal "X OUTPUT" and the "GND/X" position of the Y/Pot Address switch, potentiometer section.

2.3 MODE SELECTOR

The Mode Selector switch is a 2 position, 12 pole rotary switch. It provides a number of functions that distinguish the computer's Pot Set and Operate modes.

2.3.1 Setting of Coefficient Potentiometers

The top end input to each coefficient potentiometer is connected to one of 8 poles. In the OPR position the poles are switched to the patch panel input; in the POT SET position the poles are switched to positive reference. Thus in the Pot Set mode the inputs to all potentiometers are replaced by positive reference and the potentiometer output values are measurements of voltage divider ratios.

2.3.2 Internal Readout Meter

One pole is connected to the internal readout meter input. In the POT SET position the pole is switched to the X Address switch wiper; in the OPR position the pole is switched to the rear terminal "METER INPUT."

2.3.3 Integrator Mode Control

One pole is connected to the rear terminal "OP OUTPUT." In the Pot Set mode the pole is switched to ground; in the OPR position the pole is switched to the push button mode control selection. Thus in the Pot Set mode all integrators are placed into an initial condition state; in the OPR mode integrators are controlled by the push button mode switches.

2.3.4 CTP Amplifier

Two poles are used to program the CTP amplifier as shown in Figures 2-1 and 2-2. The CTP amplifier is located on the Timer board assembly.

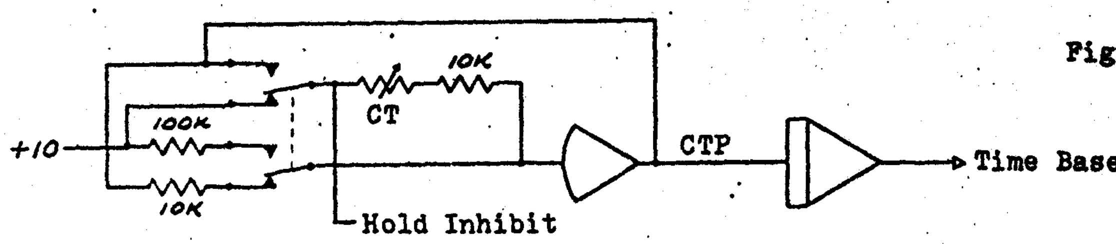


Figure 2-2

In the OPR position, positive reference is applied through the Compute Time control (100K ohms) and a series 10K ohm resistor to the CTP amplifier summing junction. A 10K ohm resistor is the feedback, therefore,

$$CTP = -10/(CT + 10) \times Reference.$$

In the POT SET position, positive reference is applied through a 100K ohm resistor to the CTP amplifier summing junction. The Compute Time control and 10K ohm resistor is the feedback, therefore,

$$CTP = -(CT + 10)/100 \times Reference.$$

The CTP amplifier output in the POT SET position is one tenth the reciprocal of its value in the OPR position. As the CTP output is the input to the time base integrator, its reciprocal is a measurement of the Compute Time Period.

2.3.5 Hold Inhibit

In the normal integrator initial condition mode the hold switch is shut off, thereby isolating the input resistor network. It is necessary, however, to set potentiometers with their resistor loads connected. Therefore, during the pot set mode each integrator hold switch is inhibited; it is held in an "on" condition and the resistor network summing junction is ground potential. A separate hold inhibit logic circuit is found on the quad amplifier assembly. A positive logic input enables the hold switch to operate normally; a negative input inhibits the switch. Such logic levels are found on one pole of the CTP program switch, as shown in Figure 2-2.

2.4 COMPUTE TIME

The Compute Time control is a combination 100K variable resistor and off-on switch. While in the operate mode the variable resistor is the CTP amplifier input. The CTP amplifier is scaled so that the Compute Time control adjusts its output within a range of -10 volts to -1 volt. The time base integrator is scaled so that a -10 volt input produces a compute time period of 10 computer time scaled seconds; a -1 input produces 100 seconds.

The off-on switch is the primary 115 volt A.C. power switch for the computer.

2.5 COEFFICIENT POTENTIOMETERS

The coefficient potentiometers are ten turn, 5k ohm variable resistors. Potentiometers 1 through 6 are arranged as attenuators with their bottom ends grounded; potentiometers 7 and 8 have their bottom ends terminated at the patch panel. Patch panel, readout and setting functions are described in above paragraphs 2.1 and 2.3.1

2.6 OVERLOAD INDICATOR

The "OVLD" lamp is a light alarm that indicates when one or more of the eight patch panel amplifier outputs exceed either positive or negative 10 volts reference.

2.7 INTERNAL READOUT METER

The GP-6 is furnished with one of two meter options. Input functions are described in above paragraph 2.3.2.

2.7.1 Digital Voltmeter

The digital voltmeter has the features of 3 1/2 digits display, 10 volts full scale and autopolarity. Its decimal is positioned so that 10 volts reference appears as unity (1.000) in conformance with normalized scaling programming methods.

2.7.2 Null Meter

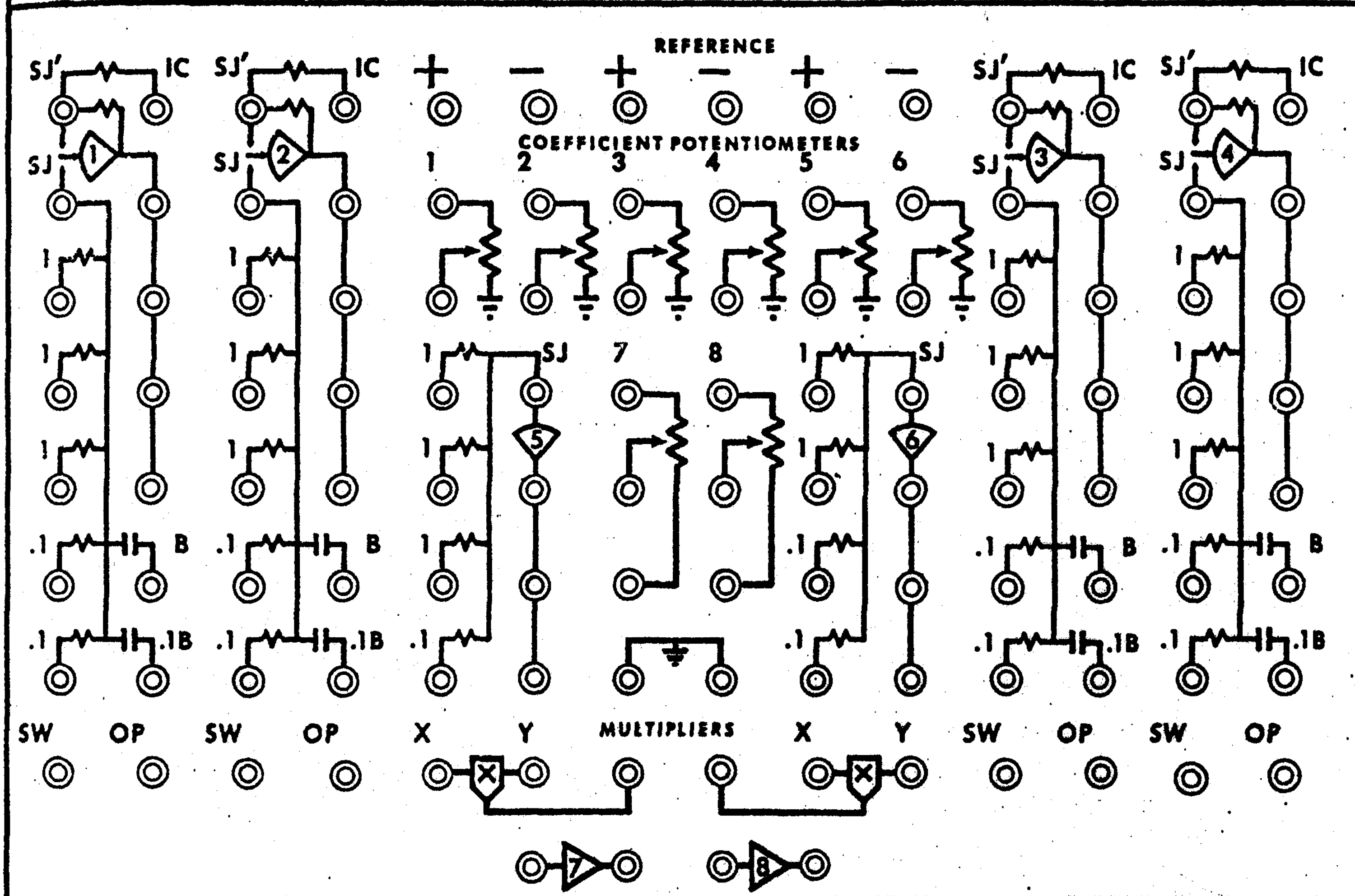
The null system consists of a balance meter, null potentiometer and polarity switch as shown in Figure 2-3. When the input potential equals the null potentiometer wiper potential, the meter is in a null condition and the needle is in its center position. When measuring input voltages the toggle switch must be in a correct position so that the input and null potentiometer are of the same polarity.

2.8 REAR TERMINALS

The following is a descritpion of the rear interface terminals.

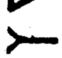
Terminal	Color	Description
0	Red	-15 volts
1	Green	+15 volts
OP OUTPUT	Red	Integrator mode control logic output, see para. 2.3.3.
OP INPUT	Green	Integrator mode control logic input, connected to patch panel "OP" jacks and the time base integrator control. For normal operation a jumper wire connects OP OUTPUT to OP INPUT. For slave operation see para. 1.6.
X OUTPUT	Red	Output of the X Address switch and horizontal input to readout instruments, see para. 2.2.
GND	Black	Signal ground.
Y OUTPUT	Red	Output of the Y Address switch, amplifier output section and vertical input to readout instruments, see para 2.1.
METER INPUT	Green	Input to the internal readout meter during the operate mode, see para. 2.3.2.

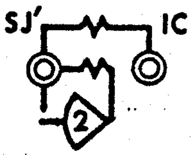
3. GP-6 PATCH PANEL



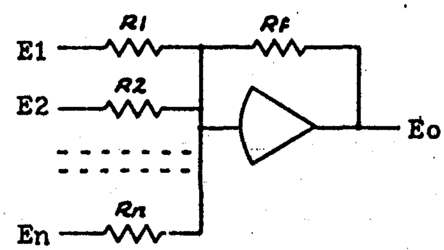
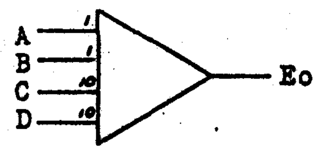
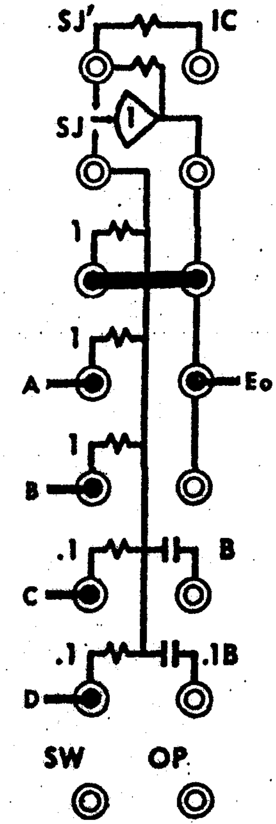
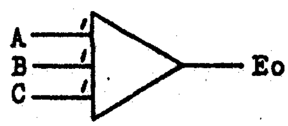
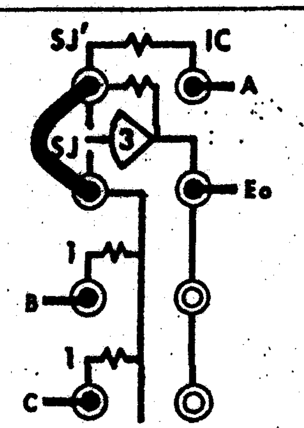
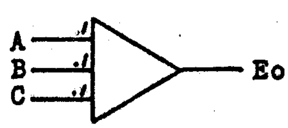
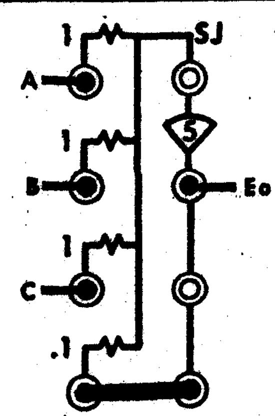
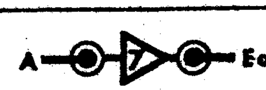
Patch panel graphics represent networks as they are applied in normal analog computer programming. Amplifiers 1 thru 6 may be used as summers or high gain operational amplifiers; amplifiers 1 thru 4 have electronic switch networks and may also be programmed as integrators, track/store amplifiers and single pole, double throw electronic switches. Amplifiers 7 and 8 are inverters. Potentiometers 1 thru 6 are attenuators. Potentiometers 7 and 8 have their bottom ends open and may be used as voltage dividers or attenuators. Multiplier networks have current outputs; with one amplifier each may be used as a multiplier, divider, squarer or square root extractor.

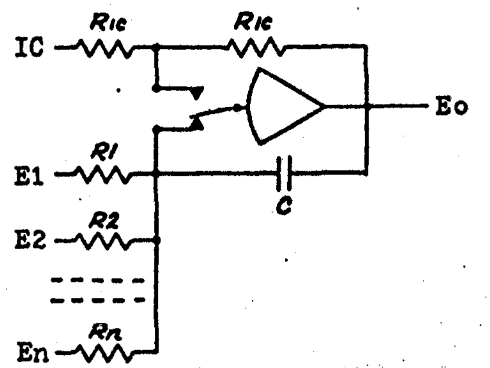
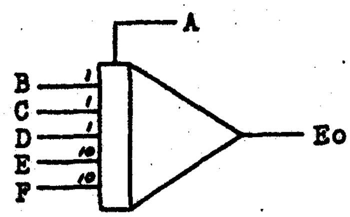
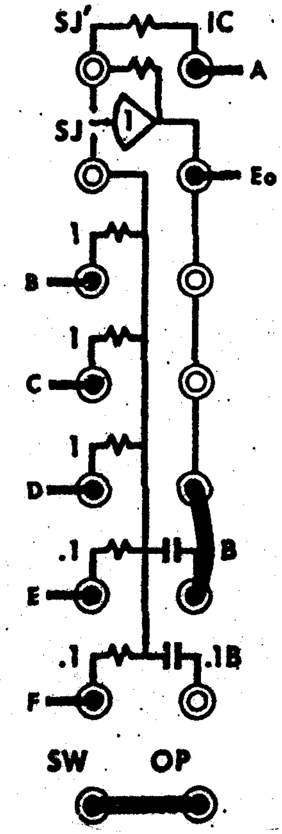
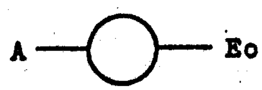
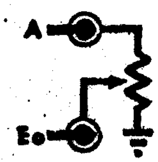
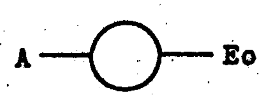
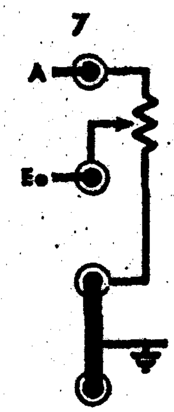
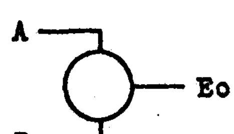
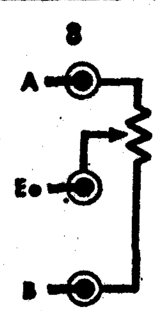
The following is a description of patch panel symbols:

SYMBOL	COLOR CODE	DESCRIPTION
+	Red	Positive reference, considered unity, 1.0, for normalized programming. (Actual amplitude is 10 volts.)
—	Yellow	Negative reference
		High gain operational amplifier.
		High gain operational amplifier with electronic switch.
		Inverter
	Red	Amplifier output.
SJ	Gray	The summing junction for amplifiers 1 thru 6. (Active for amplifiers 1 thru 4 when a logic "1" is applied to the "SW" switch control jack or when there is no switch control patching.)

SYMBOL	COLOR CODE	DESCRIPTION
SJ'	Gray	Alternate summing junction for amplifiers 1 thru 4. (Active when a logic "0" is applied to the "SW" switch control jack.)
	Green	Standard input summing resistor, normalized as a unity value to simplify programming. (Actual value is 50 K ohms.)
	Green	Summing resistor input that has a value one tenth the standard. (Actual value is 5 k ohms.)
	Green	Standard integrating capacitor input, normalized so that the 1 resistor and B capacitor combination produces a one second time constant as referred to programming time scales. (Actual value is 20 ufd in the slow time mode and .05 ufd in the repetitive operation mode.)
	Green	Integrating capacitor input that has a value one tenth the standard. (Actual value is 2 ufd in the slow time mode and .005 ufd in the repetitive operation mode.)
	Green	Resistor input to the SJ' summing junction. Amplifier become an inverter when SJ' is active. Normally used for integrator initial conditions. Input and feedback resistors may be used for summer operation by patching SJ' to SJ. (Actual value of input and feedback resistor is 50 k ohms.)
	Yellow	Attenuator, input and wiper indicated by standard electrical symbol.
	Yellow	Voltage divider; top, bottom and wiper indicated by standard electrical symbol. Bottom must be patched to ground for attenuator operation. (Potentiometer value is 5 k ohms.)
	Black	System ground.
		Multiplier network.
X	Brown	One of two multiplier inputs.
Y	Brown	One of two multiplier inputs.
	Brown	Multiplier output, a current proportional to the product of inputs "X" and "Y"; normalized so that when connected to the summing junction of an operational amplifier with a 1 resistor feedback, and with reference applied to "X" and "Y", the amplifier output equals reference.
SW	White	Electronic switch control input. With a logic "0" (ground or positive voltage) the SJ' summing junction of the above amplifier is active and SJ shuts off. With a logic "1" (-5 thru -15 volts) SJ is active and SJ' shuts off. With "HD" logic (-2 thru -3 volts) SJ' shuts off, the SJ summing junction is active but the summing resistor network is disconnected. "HD" logic is used for normal integrator hold mode operation.
OP	White	The computer's operate bus; provides integrator mode logic (slow time, repetitive operation or slave) as selected by the operator. Normal integrator operation requires that the "OP" bus be patched to the "SW" switch control input.

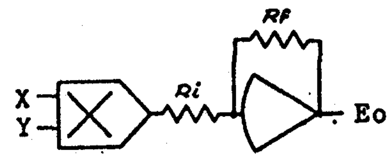
PATCH PANEL OPERATIONS

FUNCTION	OPERATION	PATCHING
Summer (amplifiers 1-4)	Fundamental Summer Operation  Eo = -Rf(E1/R1 + E2/R2 ... + En/Rn)  Eo = -(A + B + 10C + 10D) NO PATCHING TO SWITCH CONTROL "SW"	
Summer (amplifiers 1-4 with IC networks)	 Eo = -(A + B + C) NO PATCHING TO SWITCH CONTROL "SW"	
Summer (amplifiers 5 & 6)	 Eo = -(.1A + .1B + .1C)	
Inverter (amplifiers 7 & 8)	Eo = -A	

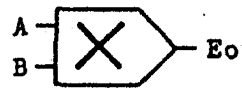
FUNCTION	OPERATION	PATCHING
Integrator (amplifiers 1-4)	Fundamental Integrator Operation  $E_o = -1/C\int(E1/R1 + E2/R2 \ldots + En/Rn)dt - IC$  $E_o = -\int(B + C + D + 10E + 10F)dt - A$	
Attenuator (pots 1 - 6)	 $E_o = K(A)$	
Attenuator (pots 7 & 8)	 $E_o = K(A)$	
Voltage Divider (pots 7 & 8)	 $E_o = K(A - B) + B$	

<table>
<tr><th>FUNCTION</th><th>OPERATION</th><th>PATCHING</th></tr>
<tr><td>Multiplier</td><td>

Fundamental Multiplier Operation

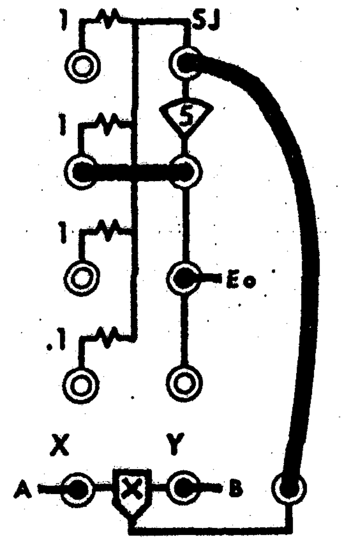


$Eo = -(X \cdot Y)$



$Eo = -(A \cdot B)$

</td><td>



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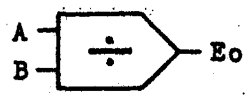
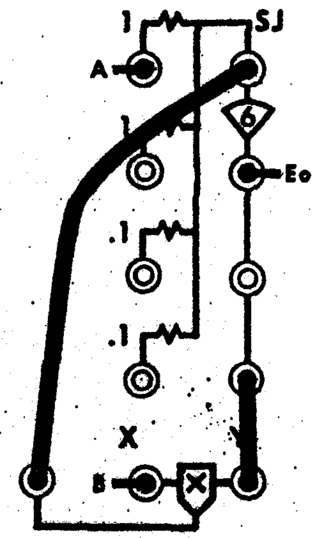
<tr><td>Divider</td><td>



$Eo = -(A/B) \quad A > 0$

</td><td>



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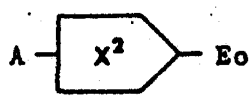
<tr><td>Squarer</td><td>



$Eo = -A^2$

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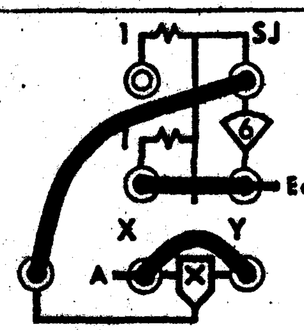
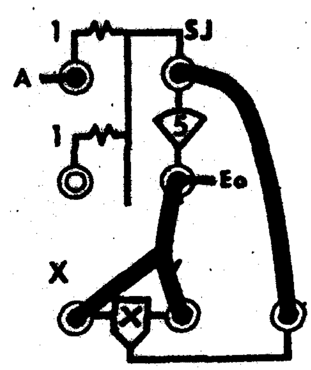


</td></tr>
<tr><td>Square Root</td><td>

$Eo = -\sqrt{A} \quad A < 0$

</td><td>



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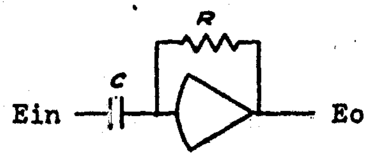
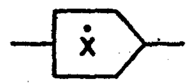
FUNCTION	OPERATION	PATCHING

Differentiator (amplifiers 1-4)

Fundamental Differeniator Operation

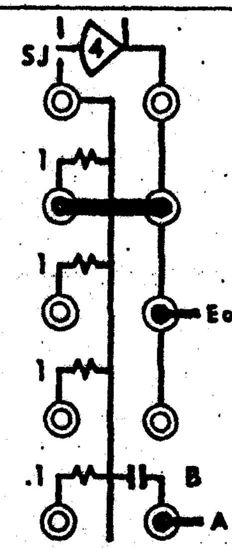


Eo = -RC•dEin/dt-

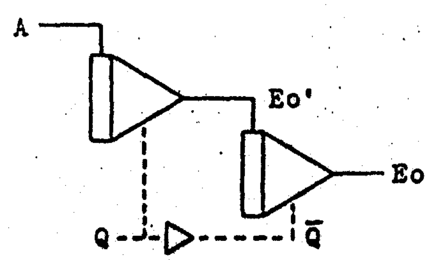


Eo = -dA/dt

NO SWITCH CONTROL PATCHING



Track/Store (amplifiers 1-4)



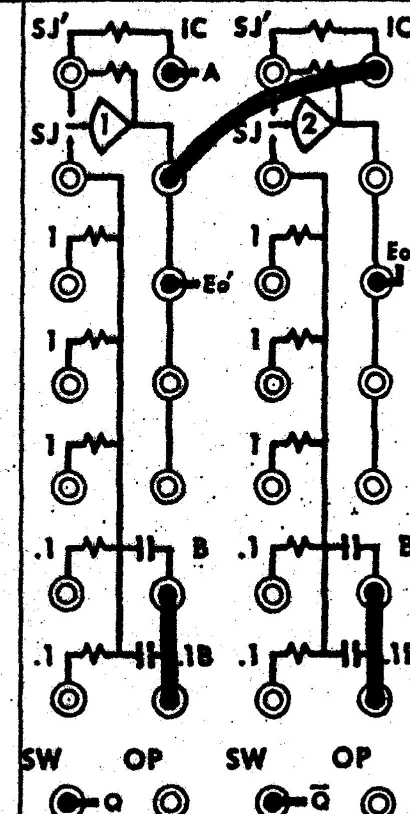
Eo' = -A when Q is a logic 0

Eo' = -A' when Q is a logic 1

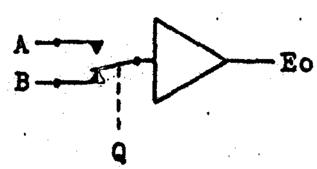
A' is the stored value of A when Q switches from 0 to 1

Eo = A'(n-1)

A'(n-1) is the previous value of A'



SPDT Electronic Switch (amplifiers 1-4)



Eo = -A when Q is a Logic "0"

Eo = -B when Q is a Logic "1"