

**Instruction Manual
Model 180
Digital Nanovoltmeter**

INSTRUCTION MANUAL

MODEL 180

DIGITAL NANOVOLTMETER
(AND MODEL 1802 DIGITAL OUTPUT)

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Cleveland, Ohio, U.S.A.**

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SPECIFICATIONS

RANGE: 10 nanovolts per digit (100.00 μV full scale) to 1-volt full scale in 5 decade ranges. 100% overranging on all ranges.

DISPLAY: 4½ digits from 0000 to 19999; floating decimal and "µV" or "mV" indicator.

POLARITY SELECTION: Automatic.

RANGE SELECTION: Automatic: Range change possible after each A/D conversion. Uprange at 20000, downrange at 0999. Front panel control limits downranging to one of the three most sensitive ranges. Isolated Programming: Range may be programmed by closure to output Lo (< +0.4 volt while sinking 2.1 mA) of a "Remote Enable" line and appropriate 3-line binary range control lines (TTL compatible). Preset; When "Remote Enable" line is released, auto-ranging proceeds from the programmed range. Manual: Front panel switch (uses programming lines).

ACCURACY (90 days): $\pm 0.03\%$ of reading $\pm 0.02\%$ of full scale exclusive of noise and drift. Calibrated at $25^\circ\text{C} \pm 1^\circ\text{C}$.

TEMPERATURE COEFFICIENT: $< \pm 0.01\%$ of reading/ $^\circ\text{C}$.

ZERO DRIFT: $< \pm (30 \text{ nanovolts} + 0.005\% \text{ of full scale})$ per $^\circ\text{C}$ after stabilization.

INPUT NOISE: Less than 30 nanovolts p-p with up to 1 kilohm source resistance on the most sensitive range.

INPUT RESISTANCE: Greater than 30 M Ω on all ranges.

OFFSET CURRENT: Typically less than 100 picoamperes.

NORMAL MODE REJECTION RATIO: Greater than 90 dB at line frequency, 75 dB at twice line frequency.

MAXIMUM NORMAL-MODE OVERLOAD: ± 50 volts instantaneous, 30 volts rms continuous.

COMMON MODE REJECTION RATIO: Greater than 160 dB at dc, line frequency or twice line frequency.

MAXIMUM COMMON-MODE VOLTAGE: 500 volts peak ac + dc, input Lo to output Lo or chassis ground; 100 volts peak ac + dc, output Lo to chassis ground.

ISOLATION: Input Lo to output Lo greater than 10^9 ohms (10^{10} at 25°C , 40% R.H.) shunted by less than 1500 picofarads with Model 1506 input cable attached. Output Lo to chassis ground, greater than 10^8 ohms shunted by 0.1 μF .

SETTLING TIME: Less than 3 seconds to rated accuracy on a fixed range (100 millisecond rise time) except on the bottom range where rise time is 3 seconds.

CONVERSION RATE: Adjustable from ½ to 4 seconds per reading.

ZERO SUPPRESSION: Up to 200 microvolts.

ISOLATED ANALOG OUTPUT: 1 volt at up to 1 milliamperes for full scale.

ISOLATED DIGITAL OUTPUT: Model 1802 accessory provides BCD output and output control functions.

OPERATING ENVIRONMENT: 15°C to 35°C up to 70% relative humidity.

POWER: 105-125 or 210-250 volts (switch selected), 90 watts; specify 50 or 60 Hz.

CONNECTORS: Input (Front: Keithley Model 1485. Analog Output (Rear): Amphenol 80PC2F. Remote Program (Rear): Cannon DA-155. Output Lo, Chassis Ground (Rear): Binding Posts.

DIMENSIONS, WEIGHT: 3½ in. full-rack, overall bench size 4 in. high x 17¼ in. wide x 15½ in. deep (100 x 435 x 390 mm); net weight 17 pounds (7.6 kg).

ACCESSORIES FURNISHED: Model 1506 Low-Thermal Input Cable: 4 ft. (1.2 m) Low-Thermal triaxial cable, copper alligator clips. Mating output and remote control connectors; hardware for standard 3½ in. x 19 in. rack mounting, 15½ in. (390 mm) depth behind front panel.

SECTION 1. GENERAL DESCRIPTION

1-1. **GENERAL.** The Model 180 Digital Nanovoltmeter provides measuring capability from 100 μV to 1 volt full scale with the convenience of automatic ranging. The lighted 4-1/2 digit display automatically indicates polarity, decimal point, and engineering unit. The display also indicates when range changing is occurring to prevent the possibility of recording erroneous data. The Model 180 is uniquely suited to systems applications due to the versatility of the automatic and remote ranging features. The 180 can also be quickly adapted to automatic data acquisition systems through the installation of the optional Model 1802 isolated BCD output. Complete input/output isolation is provided enabling the input to be floated to 500 volts above output low. The input is isolated from output low by greater than $10^9 \Omega$ so that off ground measurements can easily be made. The output can also be floated to 100 volts above chassis. The combination of floating input/floating output means that system grounding is simplified. This built-in isolation feature is an asset when using either the standard analog output or the optional Model 1802 Digital Output.

1-2. FEATURES.

- a. Four Digit Display. The 180 display provides 0.01% of full scale resolution (0 to ± 19999 counts).
- b. Five Ranges. The 180 provides five ranges (100 μV , 1 mV, 10 mV, 100 mV, and 1000 mV full scale) with 100% overranging.
- c. Automatic Ranging. The 180 provides either manual or automatic ranging.
- d. Remote Programming. The 180 has built-in 3-bit binary range lines.
- e. Fully Isolated Input. The 180 has complete input/output isolation enabling the input to be floated to 500 volts with isolation of 10^{10} ohms.
- f. Isolated Analog Output. The 180 has a 1V full scale output as a standard feature.
- g. Optional BCD Outputs. The 180 also can be used with Model 1802 Digital Output.

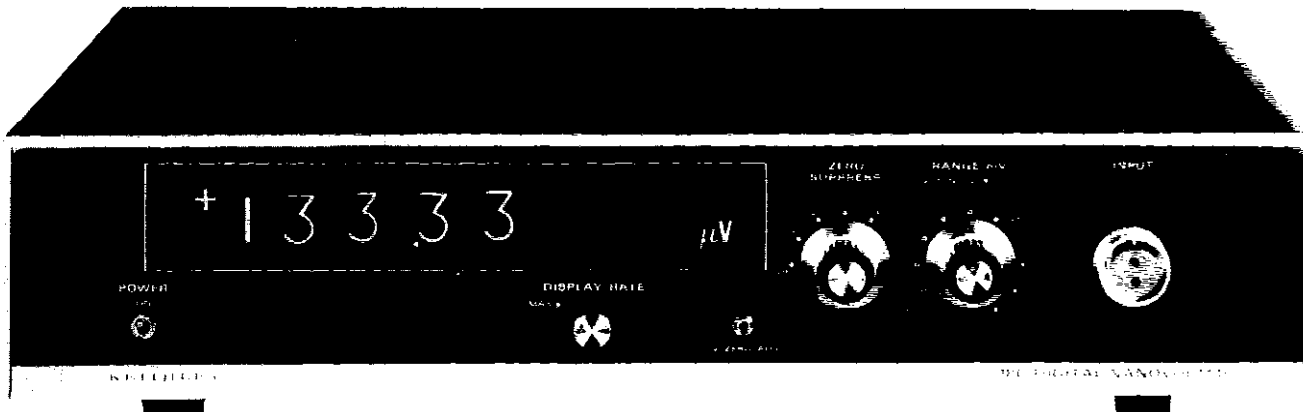


TABLE 1-1.
Front Panel Controls

Control	Functional Description	Paragraph
<u>POWER ON</u>	Turns instrument on	2-3a
<u>RANGE</u>	Sets instrument sensitivity	2-3b
- MANUAL	Adjusts range in decade steps	2-3b1
- LIMIT	Sets autoranging limit	2-3b2
<u>ZERO SUPPRESS</u>	Adjusts input zero suppression	2-3c
- Coarse	Sets zero suppression in 4 steps	2-3c1
Fine	Sets zero suppression (continuous control)	2-3c2
<u>DISPLAY RATE</u>	Sets display rate up to two readings per second	2-3d
<u>1V ZERO ADJ</u>	Adjusts 1V zero	2-5c
<u>INPUT</u>	Shielded low-thermal receptacle	2-2a

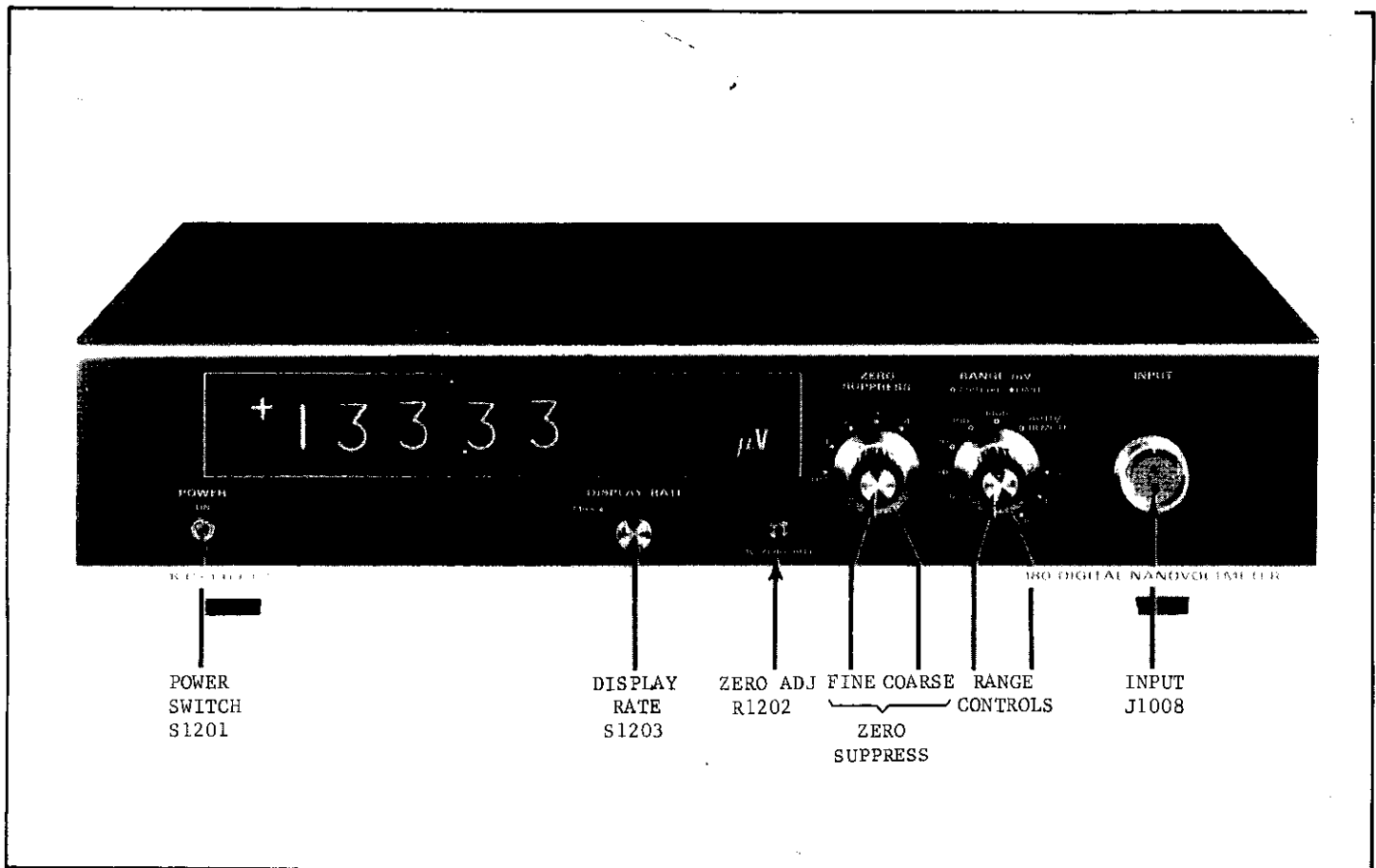


FIGURE 2. Front Panel Controls.

TABLE 1-2.
Rear Panel Controls

Control	Functional Description	Paragraph
LINE Switch	Sets instrument for either 117 or 234 V.	2-3c
LINE Receptacle	Mates with 3-wire line cord.	-
FUSE	117V: 3/4 ampere 234V: 3/8 ampere	- -
LO Terminal	Connection to output low.	-
GND Terminal	Connection to chassis ground.	-
ANALOG OUTPUT	Auxiliary output, 1 V for full range.	2-2b
REMOTE PROGRAM Receptacle	Mates with remote program connector supplied.	2-3b
BCD OUTPUT (Not Shown)	Provides digital outputs with Model 1802 installed	2-2c

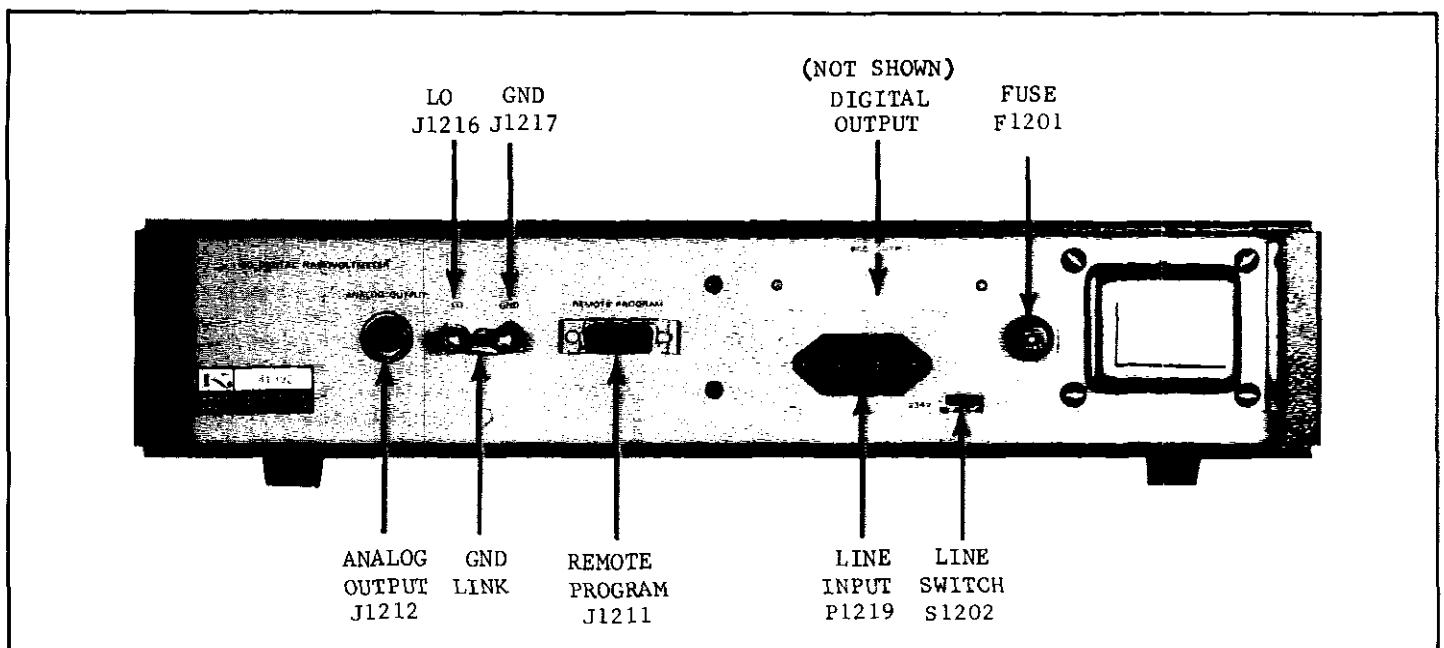


FIGURE 3. Rear Panel.

SECTION 2. OPERATION

2-1. MEASUREMENT CONSIDERATIONS.

a. Noise Considerations. The limit of resolution in voltage and current measurements is determined largely by the noise generated in the source. Stray low-level noise is present in some form in nearly all electrical circuits. The instrument does not distinguish between stray and signal voltages since it measures the net voltage. When using the .1 mV and 1 mV ranges, consider the presence of low-level electrical phenomena such as thermocouples (thermoelectric effect), flexing of coaxial cables (triboelectric effect), apparent residual charges on capacitors (dielectric absorption), and battery action of two terminals (galvanic action).

1. Thermal Noise. A common limitation of micro-voltmeter measurements from high source impedance is the thermal noise (Johnson noise) generated in the source. Thermal noise in an ideal resistance can be theoretically determined from the Johnson noise equation as follows.

$$E_{rms} = \sqrt{4k \cdot T \cdot R \cdot F}$$

Where

E_{rms} = rms voltage noise generated in the resistance.

T = temperature, °K.

R = ideal resistance, ohms.

F = noise bandwidth, Hz.

k = Boltzmann constant (1.38×10^{-10} joules/°K).

The peak-to-peak noise is approximately five times the rms value therefore the equation can be expressed as follows.

$$E_{pp} = 5 \times E_{rms}$$

If the ambient temperature is 300°K (room ambient) then the peak-peak noise can be expressed as follows.

$$E_{pp} = 6.45 \times 10^{-10} / \sqrt{RF}$$

The peak-peak thermal noise generated in an ideal source resistance can be illustrated as follows:

Given: noise bandwidth* = .08 Hz

R = 30kohms

t = 3 sec on 100 μV range.

$$E_{pp} \text{ (typically)} = 6.45 \times 10^{-10} / \sqrt{3 \times 10^4 \times .08}$$

$E_{pp} = 0.03 \mu\text{V}$ peak-peak

*Noise Bandwidth = $1/(4t) = 0.08$ Hz.

2. Thermal EMFs. Thermal emfs (thermoelectric potentials) are generated by thermal differences between two junctions of dissimilar metals. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the instrument. The ZERO SUPPRESS control can be used to buck out a constant thermal offset voltage if necessary. The Keithley accessory Model 1483 Low Thermal Connection Kit contains all necessary materials for making very low thermal copper crimp connections for minimizing thermal effects.

3. AC Electric Fields. The presence of electric fields generated by power lines or other sources can have an effect on instrument operation. AC voltages which are very large with respect to the full-scale range sensitivity could drive the ac amplifier into saturation, thus producing an erroneous dc output.

NOTE

The instrument provides attenuation of line frequency noise superimposed on an input signal. The ac rejection is specified as follows:

NMRR: Greater than 90 dB at line frequency, or 75 dB at twice line frequency. Maximum normal overload is +50 volts instantaneous or 30 volts rms continuous.

CMRR: Greater than 160 dB at dc, line frequency or twice line frequency.

Proper shielding as described in paragraph 2-1, b can minimize noise pick-up when the instrument is in the presence of large ac fields or when very sensitive measurements are being made.

4. Magnetic Fields. The presence of strong magnetic fields can be a potential source of ac noise. Magnetic flux lines which cut a conductor can produce significant noise usually at power line frequencies. The voltage induced due to magnetic flux is proportional to the area enclosed by the circuit as well as the rate of change of magnetic flux. For example, the motion of a 3-inch diameter loop in the earth's magnetic field will induce a signal of several tenths of a microvolt. One way to minimize magnetic pick-up is to arrange all wiring so that the loop area enclosed is as small as possible (such as twisting input leads). All leads should be rigidly mounted to avoid magnetic pickup due to lead vibration.

b. Shielding.

1. Electric Fields. Shielding is usually necessary when the instrument is in the presence of very large ac fields or when very sensitive measurements are being made. The shields of the measurement circuit and leads should be connected together to ground at only one point. This provides a "tree" configuration, which minimizes ground loops.

2. Magnetic Fields. Magnetic shielding is useful where very large magnetic fields are present. Shielding, which is available in the form of plates, foil or cables, can be used to shield the measuring circuit, the lead wires, or the instrument itself.

c. Floating The Model 180 utilizes Input low to Output Low isolation to minimize the effects of system ground loops or source isolation problems. Input low to output low is isolated by greater than 10^9 ohms shunted by less than 1500 pF. The output ground is isolated from chassis by greater than $10^8 \Omega$ shunted by less than 0.1 microfarads. In addition, the source can be floated up 500 volts off chassis or output low. At the same time the output low can be floated at up to 100 volts off chassis.

d. Source Resistance. The Model 180 can be used in measurement circuits with up to 1 megohm source resistance. The Model 180 has an input resistance greater than 30 megohms on all ranges, however the loading effects should be considered when making measurements with source resistance greater than 3 kilohms.

e. Grounding. The special design of the Model 180 eliminates grounding problems in making system connections. Since the input low is isolated from output low by a high impedance the typical current through the system ground (I_G) is small compared to the signal of interest. Thus I_G is a function of the ground loop impedance Z_{ISO} as shown in Figure 4.

NOTE

Any ground loop resulting from system connections is effectively broken by the isolation amplifier in the Model 180.

f. Grounding Shift. If a nanovolt measurement has a fixed ground configuration the effects of grounding shift need not be considered. If an experiment's grounding is changed in the middle of an experiment, the Model 180 or any other nanovoltmeter will have to be rezeroed using the zero suppress due to a change of thermals. There may also be an additional shift due to grounding which can also be suppressed by the zero suppression (on the order of tenths of microvolts). Once the ground shift is suppressed on the 180 no further changes will be noticed. The extreme case for ground shift effect would be the situation going from a completely isolated input to a grounded input. A completely isolated input is defined as greater than 100 k Ω resistance and less than 2000 pf capacitance. A grounded input is defined as less than 1 k Ω resistance and greater than .01 μ f capacitance.

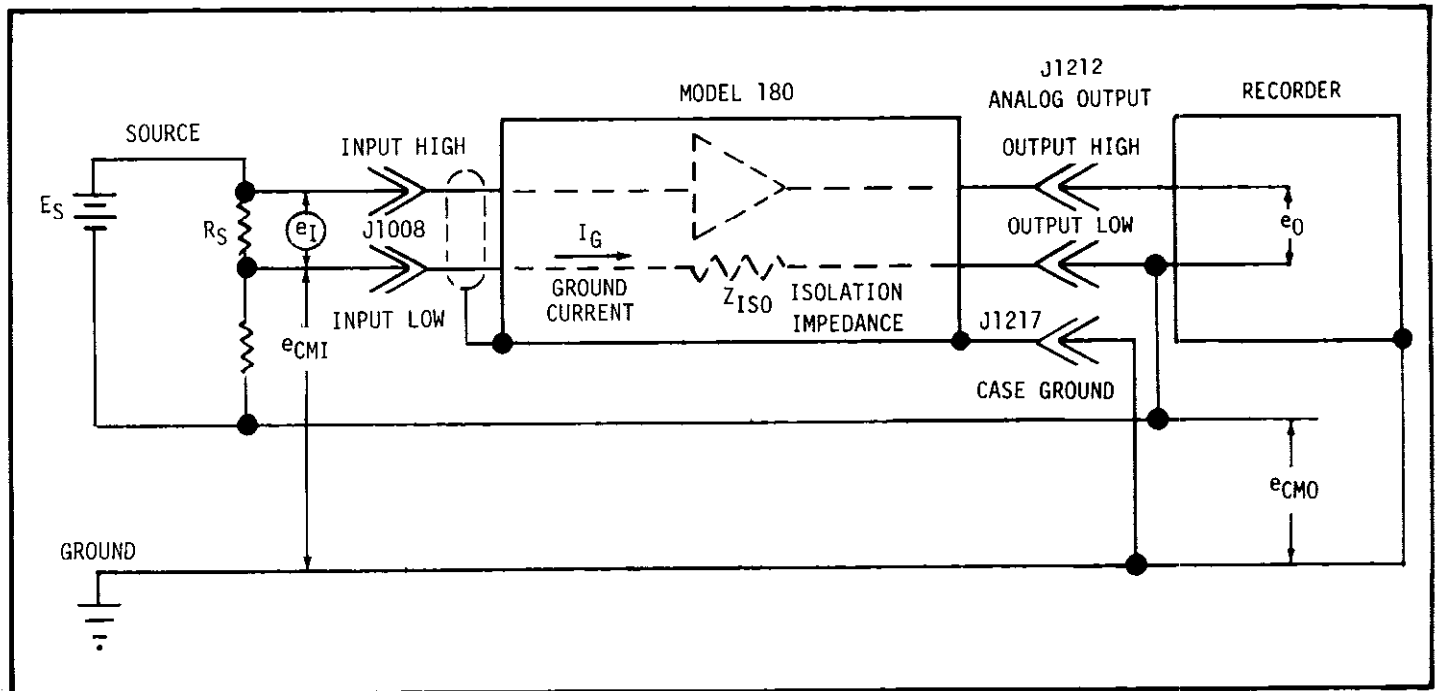


FIGURE 4. Input-Output Connections.

2-2. CONNECTIONS.

a. Input. The input receptacle (J1008) on the front panel is a special Keithley Model 1505. This connector has two pins for input high and low. (The outer shell is at chassis.) The mating cable, Model 1506, (supplied) has four feet of low-thermal triaxial cable terminated with two alligator clips. Refer to Accessories section for other cables available.

b. Analog Output. The output receptacle (J1212) on the rear panel is an Amphenol type 80PC2F (Keithley CS-32). The mating connector (supplied) is an Amphenol type 80MC2M (Keithley CS-33). The Output low is isolated from input low as stated in the Specifications.

c. Digital Output. This output is available only as part of Model 1802 Digital Output Option. The receptacle supplied with the 1802 is a 50-pin Amphenol Micro-Ribbon type (Keithley CS-221). The mating connector is a Keithley CS-220. The pins are identified as in Table 2-6. The digital output common is isolated from input low as stated in the Specifications.

d. Power. After verifying that the proper line voltage is selected and proper fuse is installed (see p. 3) connect the power cord. The 90W power specification is a maximum worst case value at 250 V 50Hz line with all components and the 1802 output pulling max. current. A typical value for normal line voltages and output loads is 40 to 50 watts.

2-3. CONTROLS.

a. "POWER ON" (S1201). This switch controls the line power to the instrument. In the "OFF" position both sides of the line are disconnected.

b. "RANGE mV" (S1204). This switch is a dual-concentric type control.

1. "MANUAL". The outer control sets the range in decade steps from 0.1 to 1000 mV. The extreme clockwise position is the AUTO/REMOTE mode. In this mode the Model 180 is useable as an automatic ranging nanovoltmeter with remote ranging capability.

2. "LIMIT". The inner control sets the lower range for downranging when in the AUTO/REMOTE mode of operation. The three LIMIT positions 0.1, 1, and 10mV designate the most sensitive range to which the Model 180 will autorange with less than 100µV applied signal.

c. "ZERO SUPPRESS" (S1001). This switch is a dual-concentric type control. (200 µV maximum suppression)

1. Coarse. The outer control sets the coarse suppression in four steps. The "OFF" position removes the zero suppression completely.

2. FINE (R1051). The inner control is a continuously variable suppression adjustment.

d. "DISPLAY RATE" (R1201). This control sets the display rate from a half second per reading to four seconds per reading. The "MAX" position switches the display rate to the maximum rate of a half second per reading.

e. Line Voltage (S1202). This rear panel switch sets the instrument for either 117 or 234 volt operation.

TABLE 2-1.
Line Switch Settings

S1202 Setting	Line Volt Range
117V	105 V to 125 V
234V	210 V to 250 V

2-4. OPERATING CONSIDERATIONS.

a. Digital Display. The display is composed of four digits, an overrange "1", a floating decimal, and "µV" or "mV" designations. A typical four digit display is shown in Figure 5.

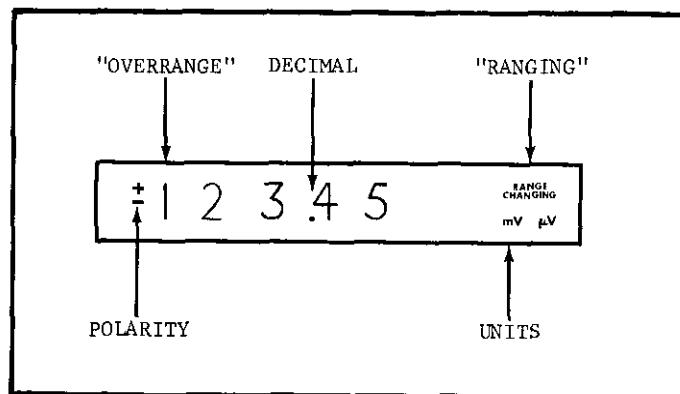


FIGURE 5. Digital Display.

TABLE 2-2.
Full-Range Displays

Display	Full Range Input Voltage	Last Digit
+1000.0 mV	+1 x 10 ⁰ V	100 µV
+100.00 mV	+1 x 10 ⁻¹ V	10 µV
+10.000 mV	+1 x 10 ⁻² V	1 µV
+1.0000 mV	+1 x 10 ⁻³ V	0.1 µV
+100.00 µV	+1 x 10 ⁻⁴ V	0.01 µV

b. Ranging. The Model 180 permits manual or automatic ranging through the use of RANGE Switch S1204.

1. Manual Mode. In this mode the full range is set by the user for any one of five ranges. The display will be blanked (except for overrange "1" and polarity indicators) whenever the input voltage exceeds 1.9999 times full scale. For a more complete discussion of overloads refer to paragraph 2-4 c.

2. Auto/Remote Mode. In this mode the full range is automatically determined by the autoranging circuitry for a given input voltage as shown in Table 2-2. The Model 180 will down range to the range set by the LIMIT Switch.

3. "LIMIT" Operation. The LIMIT switch can be used to select the lowest range which will be displayed with no input signal applied to the instrument. The LIMIT operates when the AUTO/REMOTE position is selected only. This feature is useful for measurements on the 1 or 10 mV ranges since upranging time is minimized.

4. Remote Operation. In the Auto/Remote mode the instrument can be controlled remotely through the use of a coded range inputs as shown in Table 2-3. Remote operation is enabled by grounding pin P_E.

TABLE 2-3.
Remote Ranging Lines

INPUTS *			RANGE
P1	P2	P4	
---	---	LOW	0.1 mV
LOW	LOW	---	1 mV
---	LOW	---	10 mV
LOW	---	---	100 mV
---	---	---	1000 mV

*When P_E is grounded instrument is in Remote mode.

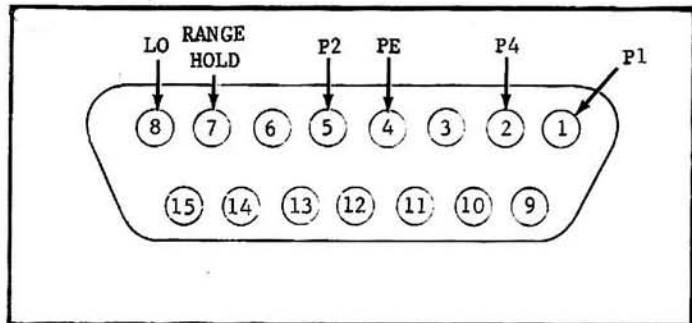


FIGURE 6. Remote Ranging Connector.

5. Ranging Time. The time for range changing depends on the number of range changes required and the display rate set on the front panel. The minimum time for up-ranging on any scale is approximately 1000 ms (two conversion cycles). Each additional range change will require 500 ms with Display Rate set at MAX.

c. Overloads. The maximum voltage which can be applied between input high and input low is 50 volts instantaneous or 30V rms continuous. When the input exceeds 1.9999 times the full range the four digits will blank leaving only the polarity, units, and over-range "1" displayed.

d. Settling Time. The settling time required to obtain a display within rated accuracy depends on the range selected and the source impedance used.

1. 1 mV to 1000 mV Ranges. The rise time on these ranges is 0.1 second. The settling time for these ranges is less than 3 seconds with less than 1 k Ω source impedance.

NOTE

The input of the Model 180 has a filter with a large shunt capacity (see circuit description). Therefore, it is necessary to add 30 ms per k Ω of source impedance to the settling time.

2. .1 mV Range. This range has a 3-second rise time with less than 1 k Ω source impedance. Accurate readings may be obtained in 40 to 60 seconds.

e. Zero Suppression. Thermal emf's in the source and connections to the source may be compensated using the zero suppress controls. In making any low level measurement these controls are to be used to zero the input on the range which is intended to be used or the 100 μ V range. Table 2-4. indicates the maximum suppression voltage for each "coarse" position. The "FINE" control (R1051) can be used to adjust the ZERO SUPPRESS voltage to any value up to the maximum given in Table 2-4.

TABLE 2-4.
Maximum Zero Suppress

Coarse Position	Maximum Suppression
1	$\pm 1 \mu$ V
2	$\pm 6 \mu$ V
3	$\pm 30 \mu$ V
4	$\pm 200 \mu$ V

f. 1V Zero Adjustment (1000mV RANGE). This control is intended to be used to zero the instrument at high levels (1000mV range). Normally adjustment is needed only when the instrument is operated at a temperature significantly different than the calibration temperature.

g. Digital Outputs and Controls (Model 1802 Digital Output Option).

1. General. The Model 1802 Digital Output provides binary coded decimal (BCD) outputs and control functions. This option is available only as a field installable accessory. The Model 1802 includes an output buffer module, a pre-wired 50-pin receptacle, wiring harness, and mating 50-pin connector (not wired).

2. Connector Pin Identification. Refer to Table 2-6. The 50-pin PRINTER/CONTROL receptacle is an Amphenol Microribbon Series 5740-5001 (Keithley Part No. CS-221). The mating connector is an Amphenol 5730-5001 (Keithley Part No. CS-220).

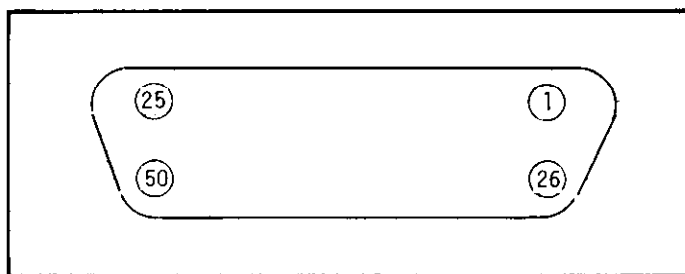


FIGURE 7a. Digital Output Connector.

TABLE 2-5.
Model 1802 Digital Output Specifications

DIGITAL OUTPUT: BCD (1, 2, 4, 8) open collector logic (Motorola MC 858P) represents each of 4 digits (0000 = 0), overrange digit, overload ("1"), polarity (+ = "1"), range changing and 4 decimal positions.

OUTPUT LOGIC LEVEL: Output Logic "1" = open transistor collector to output Lo with less than 100 microamperes leakage. + 6 volts maximum allowable applied voltage. Output Logic "0" = transistor switch closure to output Lo with less than 0.5 volt saturation voltage. +35 mA sink current.

REMOTE CONTROL: Strobe: Open circuit inhibits all output lines from conducting. Closure enables conduction. Hold: Closure retains result of last conversion at both the digital output and display; conversions continue. Hold #2: Closure halts conversions holding reading at both digital output and display. Trigger: Release edge of pulsed closure initiates one conversion when in Hold #2. Signal is averaged for a 200-millisecond period starting 100 milliseconds after release of Hold #2 or Trigger. Flag Reset: Closure sets Flag (Flag) to logic "0" ("1").

TIMING OUTPUT: Clock: Internal clock pulses (100 kHz count rate). Count Interval: Logic "0" appears during count interval (i.e. pulse width is proportional to analog input signal). Flag (Flag): Logic "1" ("0") appears for a 300 millisecond interval out of a conversion time of 500 milliseconds. No change of digital output is made inside this interval.

REQUIRED CONTROL LOGIC LEVEL: Open circuit = either >4 kilohms resistance or a voltage between +2 and +12 volts (except Flag Reset, +5V max.) referenced to output Lo. Closure = Closure to output Lo within 0.5V while sinking 2.5 mA.

CONNECTOR: Output: 50-pin Amphenol Micro-Ribbon type 57-40500.

ACCESSORIES SUPPLIED: Output mating connector.

TABLE 2-6.
Model 1802 Printer/Control Output Pin Identification

J108 Pin No.	Line	Function	J108 Pin No.	Line	Function
1	1 x 10 ⁰	Data #1	26	-	Not used
2	2 x 10 ⁰	Data #1	27	Output Lo	Common
3	4 x 10 ⁰	Data #1	28	-	Not used
4	8 x 10 ⁰	Data #1	29	Clock	100 kHz
5	1 x 10 ¹	Data #2	30	Count Interval	See Table 2-5
6	2 x 10 ¹	Data #2	31	-	Not used
7	4 x 10 ¹	Data #2	32	Flag	See Table 2-5
8	8 x 10 ¹	Data #2	33	Flag	See Table 2-5
9	1 x 10 ²	Data #3	34	Range Changing	Control Output
10	2 x 10 ²	Data #3	35	Function 1	See Table 5-12
11	4 x 10 ²	Data #3	36	Function 2	See Table 5-12
12	8 x 10 ²	Data #3	37	Function 3	See Table 5-12
13	1 x 10 ³	Data #4	38	Overload	Control Output
14	2 x 10 ³	Data #4	39	Polarity	Data
15	4 x 10 ³	Data #4	40	TRIGGER	Control Input
16	8 x 10 ³	Data #4	41	Hold #2	Control Input
17	1 x 10 ⁴	Data Overrange	42	-	Not used
18	-	Not used	43	Strobe Overrange	Control
19	DP1 (1.0000)	Decimal Point	44	Strobe Flag	Control
20	DP2 (10.000)	Decimal Point	45	Strobe Function	Control
21	DP3 (100.00)	Decimal Point	46	Strobe Data #4	Control
22	DP4 (1000.0)	Decimal Point	47	Strobe Data #3	Control
23	HOLD	Control Input	48	Strobe Data #2	Control
24	FLAG RESET	Control Input	49	Strobe Data #1	Control
25	-	Not used	50	Strobe DP	Control

4. Timing Diagrams. The timing diagram shown in Figure 7b illustrates the time sequence of a single overall A-to-D conversion cycle. Figure 7c shows how the conversion cycle is controlled by the Hold and Trigger lines.

a). Integrate Period (34). During this period the analog signal is applied to the integrating amplifier. The slope of the ramp waveform shown in Figure 7b has a sign opposite the polarity of the input signal.

b). Count Period (01). During this period the integrating amplifier is driven to zero by the proper polarity discharge voltage (the analog signal is removed from the integrating amplifier). During this period a p-p pulse is generated which updates the data in the latches.

c). Zero Period (2). During this period the integrator is zeroed and the decade counters are reset prior to a new conversion cycle.

5. Open Collector Output. The buffer output stages of the Model 1802 utilize "Open Collector" outputs. An outstanding feature of open collector outputs is the ability to drive into a variety of digital data processing equipment such as printers and computers. Since the open collector output operates in either a low impedance (saturated) state or a high impedance (open) state it is compatible with a wide variety of logic types including TTL, DTL, and RTL. The Model 1802 operates with any logic level up to +6 volts making it useable with the majority of levels commonly available. In most cases a pull-up resistor is recommended to define the "open" or Logic "1" state. The value will depend on the capacitive coupling among wires in the cable and to other circuitry external to 180/1802. A value from 1k to 5k is usually sufficient. The minimum value is 180 ohms $\pm 10\%$ on the output lines.

a) The Open-Collector configuration can be used to connect multiple outputs to one input of a control system. For example, if the 1802 is interfaced to a 16-bit computer, the 4 BCD digits (Data #1, #2, #3 and #4) may be presented to a 16-bit data register in the computer by setting lines 46 through 49 to Logic "0" at a given time. If the function, DP, overload, polarity and 1×10^4 outputs are wired in parallel with some of the BCD data outputs, the BCD data will be unaffected provided lines 43, 45 and 50 are set to Logic "1". At another time, lines 46 through 49 may be set to Logic "1", lines 43, 45 and 50 to Logic "0". This will present the function, DP, overload, polarity and 1×10^4 outputs to the same 16-bit register.

b) When a particular 180 is being operated, line 44 may be set to Logic "0", enabling FLAG and FLAT. When not in use, line 44 may be set to Logic "1", disabling the Flags, and another device may use the same line for interrupt or polling.

c) Since the data is in 4-bit or smaller groups, all output data from the 1802 may be sequentially connected to a 4-bit buss using the same technique described above. This is useful when interfacing to programmable calculators and logic systems where bit-parallel, character-serial data transmission is used.

6. Timing Outputs and Controls. The Model 1802 provides various output signals and control lines to regulate the data transfer from the Model 180 to the particular digital acquisition system.

a). CLOCK: This output provides 5 μ s pulses at the 100 kHz clock rate. When used in conjunction with the COUNT INTERVAL output the clock serves as a reference frequency for direct binary outputs.

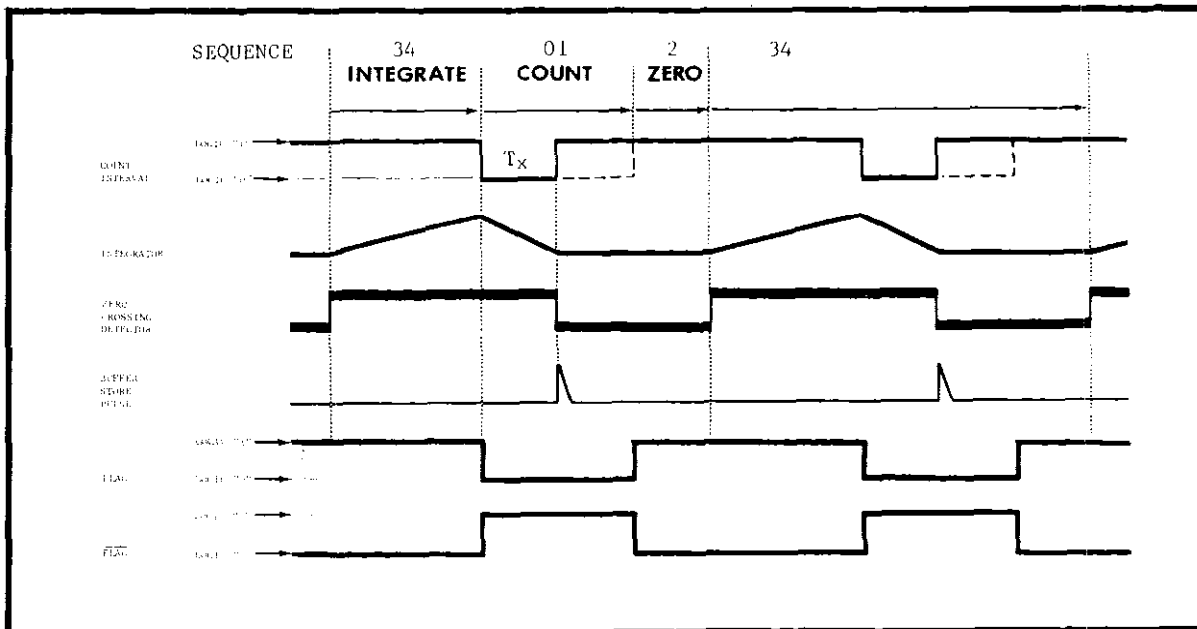


FIGURE 7b. Timing Diagram.

b) COUNT INTERVAL: This line is at Logic "0" for a time (T_x in Fig. 7b) proportional to the input signal; 10 μ s corresponds to 1 digit. The COUNT INTERVAL output may be used with an external binary ripple counter and gate to obtain a reading directly in binary form. The Logic "0" to "1" transition of COUNT INTERVAL occurs prior to the p-p pulse. Therefore it is not intended for use as a flag.

IN DESIGNING CABLING TO THE 1802 OUTPUT, THE COUPLING CAPACITY BETWEEN "COUNT INTERVAL" AND "TRIGGER" LINES SHOULD BE MINIMIZED TO AVOID ERRATIC TRIGGERING. IF COUNT INTERVAL IS USED, A LOW VALUE PULL-UP RESISTOR SHOULD BE USED, NOT LESS THAN 180 OHMS \pm 10%. IF THE "COUNT INTERVAL" OUTPUT IS NOT NEEDED, DO NOT CONNECT A WIRE TO THIS OUTPUT (PIN 30).

c). FLAG, $\overline{\text{FLAG}}$:

1. Internal Triggering (using DISPLAY RATE control): When flag is Logic "1" ($\overline{\text{FLAG}}$ is Logic "0") the data from the most recent conversion is available at the data lines. The flags stay in this state for 300 ms.

2. External Triggering (using TRIGGER and HOLD #2 controls): FLAG remains in the Logic "1" state until 100 ms after the next trigger (see Fig. 7c, Control Timing Diagram). It then goes to Logic "0" for 200 ms, then back to Logic "1" indicating that a new reading is available at the data lines. If it is desired that Flag be in the Logic "1" state only after new data is available, FLAG must be reset prior to the Logic "0" to "1" transition of TRIGGER or HOLD #2.

d). FLAG RESET: FLAG may be reset at any time by setting FLAG RESET to Logic "0" for at least 0.5 μ s. FLAG will remain at Logic "0" while FLAG RESET is at Logic "0". FLAG goes to Logic "1" the first time that new data is available after FLAG RESET returns to Logic "1".

e). STROBE Lines: All data outputs except COUNT INTERVAL, RANGE CHANGING and CLOCK are grouped into 3- or 4-line groups. Each group is controlled by a "STROBE" line. Logic "1" on a STROBE line inhibits the data; the output is an "open collector" of a transistor. A Logic "0" on a STROBE line enables the data to determine the logic state of the output. The groupings are indicated in Table 2-6. The STROBE lines are pins 43 through 50. Section 5 (above) discusses some applications using the open collector outputs.

f). HOLD: If this line is set to Logic "0", the data at the display and output will not be updated as conversions are completed. FLAG will operate normally. When Hold is returned to Logic "1", the display and output will be updated normally. New data will be available beginning with the next Logic "1" state of the FLAG. If it is desired that FLAG be inhibited when HOLD is set to Logic "0", a jumper may be installed on the 1802 PC-275 between point "X" and "Y", see Fig. 35.

g). HOLD #2: When this line is set to Logic "0" the conversion process is stopped. The analog output and CLOCK at output pin 29 operate normally. The sequence counter is stopped at the beginning of the "2" period (zero). Flags remain in the state they are in when HOLD #2 is set to Logic "0". The internal "DISPLAY RATE" control is disabled. Single conversions may be initiated using the TRIGGER control.

h). TRIGGER: This line is used to initiate a single conversion when HOLD #2 is set to Logic "0". A conversion is initiated by a transition of TRIGGER or HOLD #2 from Logic "0" to Logic "1". When TRIGGER is at Logic "0" the internal counters are reset, thus

REGARDLESS OF THE STATE OF HOLD #2, IF TRIGGER IS NOT AT LOGIC "1" THE CONVERSION PROCESS WILL BE INTERRUPTED AND ERRONEOUS READINGS MAY RESULT. IF THE TRIGGER LINE IS IN A NOISY ENVIRONMENT LOW IMPEDANCE DRIVE SHOULD BE USED. IF THE TRIGGER LINE IS NOT USED NO WIRE SHOULD BE CONNECTED TO PIN 40 OF THE OUTPUT CONNECTOR.

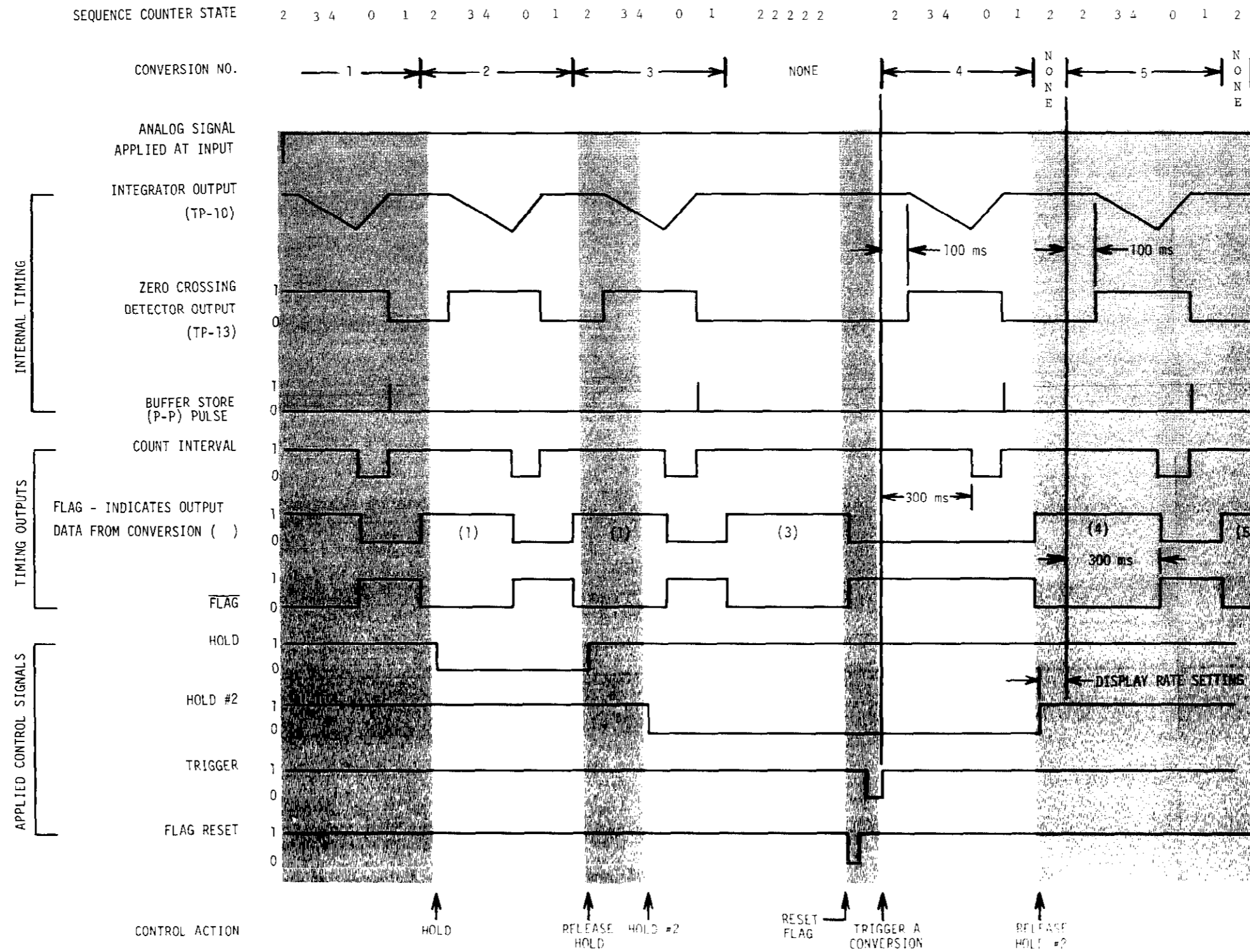
In the Logic "1" state, TRIGGER has no effect on the 180 or 1802 operation. To initiate a conversion, trigger must be at Logic "0" for at least 1 μ s prior to the Logic "0" to "1" transition.

7. Overload and Range Changing (Lines 38 and 34).

a) Overload Logic "1" indicates that a reading in excess of 19999 digits has been obtained. This information is available when Flag = Logic "1". Generally, at least the first conversion after an overload will provide erroneous data at the output and display due to preamplifier and input time constants.

b) Range Changing: When in the auto range mode, Logic "0" indicates that the range is changing, thus the data is erroneous. The Flag is inhibited in this state. If the programming lines are used, range changing will not indicate a change in range setting while P_E is at Logic "0". If P_E changes from Logic "1" to Logic "0" and the programmed range is different, range changing may go to Logic "0" for a few hundred microseconds. Data available at the first conversion after "Range Changing" (Pin logical "0") will be incorrect. It is recommended that this data be ignored by a control system connected to the output.

8. Installation. To gain access to the Model 180 chassis remove the top cover by removing four screws. Insert PC-275 circuit board module in the mating receptacle (J1202) on the chassis. (See Fig. 22). Remove the SPARE connector cover on the rear panel. Feed the cable harness through the rear panel opening so that the receptacle is oriented with the manufacturer's part number facing down. Fasten the 50-pin receptacle (Keithley CS-220) to the chassis using the two screws supplied with the cover plate. Carefully connect each of the mini-plug-in connectors on the pc board module as shown on schematic 24866D.



Convert -
STOP No. CONVERTER 6-116

- 1 Normal conversion at maximum display rate.
- 2 HOLD is activated prior to the CI period. The p-p pulse is inhibited, the output data is not updated, and the data for Conversion 2 is lost.
- 3 HOLD is released. HOLD #2 is activated, which stops the conversion process immediately after the present conversion is complete.
- 4 A logic "0" to "1" transition of TRIGGER initiates one complete conversion, after which the conversion process again stops.
- 5 HOLD #2 is released. After a delay determined by the setting of the display rate control (minimum delay at "max" setting), normal conversion resumes at the rate set by the display rate control.

FIGURE 7c. CONTROL TIMING DIAGRAM: MODELS 180 AND 1802

2-5. OPERATING TECHNIQUE.

a. Power.

1. Check line switch on rear panel for proper line voltage setting, either 117 or 234 V.
2. Check fuse for proper current rating.
3. Connect line cord to line voltage outlet. Use the third ground pin to connect chassis to earth ground. If line socket is not a three-terminal type, use line plug adapter supplied.
4. Set POWER Switch to ON.

b. System Connections.

1. Connect analog output to readout device. Use the Keithley accessory Model 3701 Cable (not supplied) for easy connection to a recorder such as the Model 370.
2. Connect digital output (Model 1802 Option only) as described in paragraph 2-4 g. The Keithley accessory Model 4405 Terminal Box can be used to make quick connections between the 1802 output and digital device.
3. Connect the Remote Ranging output to control device if remote control is desired. The mating connector is a Keithley CS-87 (supplied). The control logic is described in paragraph 2-4 b.
4. Refer to paragraphs 2-1 b and 2-1 c for a discussion of grounding and source impedance considerations.
5. Refer to paragraph 2-1 a for a discussion of thermal emf considerations. For critical measurements the Model 1483 Low Thermal Connection Kit can be used for making low thermal connections.
6. Connect source between Input high and low.

c. Warm-up and Stabilization.

1. Short Term Measurements. The Model 180 may be used for measurements on any range after a few minutes warm-up time (typically 15 to 20 minutes). A slight zero-offset may be seen on the 0.1 millivolt range just after turn-on, but the offset may disappear after complete stabilization occurs.
2. Long Term Measurements. Stabilization of the 180 is required in order to perform meaningful long term measurements on the most sensitive ranges. The 180's solid state chopper input has been designed for minimum thermal sensitivity through the use of extensive heat sinking. However, zero shifts may be apparent due to the thermal time lag of the input FETs. During warm-up the 180 may be subject to a large temperature change especially if the ambient temperature is significantly different from the typical 23° ambient usually found in the typical r & d or measurements laboratory. If a large step change in temperature occurs the 180 may exhibit

high drift in one direction while stabilizing. The offset drift may overshoot (peak excursion) and gradually recover to the nominal zero setting. If the 180 shows a slight zero offset on the 1 volt range after stabilization the front panel 1 V zero adjustment may be used. Thermal emfs introduced by the source connections should be nulled out using the Zero Suppress controls. After stabilization occurs the typical zero drift may be on the order of 100-150 nanovolts per day in a closely controlled ambient environment.

d. Measurement Procedure.

1. Manual Mode.

- a). Set RANGE to proper sensitivity for manual operation.
- b). Set coarse ZERO SUPPRESS to buck out residual voltage offsets due to thermal emfs. Adjust fine control for precise zero suppression.
- c). Set DISPLAY RATE for desired reading rate.

2. Auto/Remote Mode.

- a). Set RANGE to AUTO/REMOTE.
- b). Set coarse ZERO SUPPRESS to buck out residual voltage offsets due to thermal emfs. Adjust fine control for precise zero suppression.
- c). Set DISPLAY RATE.
- d). Set LIMIT Switch for 0.1, 1, or 10 mV.
- e). For remote ranging operation activate (ground) proper control lines P_E, P₁, P₂, P₄ in accordance with paragraph 2-4 b.

f. Accuracy. Accuracy is defined in the specifications as exclusive of noise and drift. Therefore, it may be necessary to rezero the Model 180 due to environmental extremes with the zero suppression. If this is not feasible then it will be necessary to take the zero offset into account when measurements are taken. Also, it is necessary to take into account long or short term drift (depending on the type of measurement taken). The average of the noise should be considered when a reading is taken. The specification of ±0.03% of reading ±0.02% of range indicates that if a 180 is properly calibrated, and the front zero controls are properly set for the 1V and 100mV ranges, no more than 2 digits zero error will be seen on any range, and errors for any reading will be within the envelope defined by the specification.

g. Offset Current. For applications where source impedance may be changing over decade values the offset current should be considered. Typically, the offset current is 100 pA. At environmental extremes it may be possible to see as high as 300 pA offset current. Adjustment procedures are described in Section 7, page 59.

SECTION 3. APPLICATIONS

3-1. GENERAL. The Model 180 Digital Nanovoltmeter can be used in a wide variety of applications requiring nanovolts resolution, automatic ranging, digital display and flexible digital outputs. The following examples describe only a few of the many applications of the Model 180.

3-2. TYPICAL APPLICATIONS.

a. Temperature Measurements. The Model 180 may be used with thermocouples or thermopiles to monitor small temperature changes (typically within 0.001°C). Connections can be made using materials supplied with the accessory Model 1483 Low-Thermal Connection Kit. Although some shielding is recommended, the high ac rejection of the 180 eliminates most of the problems usually caused by nearby ac operated equipment such as heaters, fans, pumps, etc. The rear panel analog output may be used to provide a continuous recording in chart form. When the Model 1802 Digital Output is used, data can be easily transferred to digital printers or computers.

b. Standards Laboratory Work. The Model 180 may be used for comparisons of standard cells without problems related to different ground connections. The isolation of the input low eliminates the possibility of shorting out a cell when output connections are changed. The low offset current of the 180 also eliminates cell polarization. Measurements can be automated through the use of crossbar scanners at the input of the instrument. When the Model 1802 Digital Output is used, data can be easily transferred to digital printers or computers.

1. Inter-comparing standard cells. By far, the greatest concern of people doing this type of work is that the measurement does not present a load to the cells which significantly changes their voltage. Figure 8a shows the equivalent circuit for this measurement. Note that the common terminal of the two cells is connected to the output ground and earth ground on the Model 180. This is to prevent electrostatic pickup due to the high isolation impedance of the input. As seen in Figure 8a, the 180 common-mode and normal-mode impedances determine the current and charge which is required from the standard cells. The common-mode impedance appears across only one cell (V_2); when the 180 is first connected into the circuit, a charge of 10^{-9} coulombs from V_2 is needed to charge C_1 , and a current of 10^{-10} Amps flows through R_1 while the 180 is connected. The normal-mode impedance appears between the two cells, therefore the charge and current required by R_{1n} and C_{1n} is proportional to $(V_1 - V_2)$, which is on the order of mV or less. In the case of "primary" cells, two saturated standard cells are used which are in the same enclosure, and the $(V_1 - V_2)$ is on the order of $100\mu\text{V}$ or less. Thus the charge required from the cells when the 180 is connected is on the order of 5×10^{-10} coulombs, and the current drawn by the 180 after the settling time is 3×10^{-12} A due to the minimum $30\text{M}\Omega$ input resistance. The offset cur-

rent of about 10^{-10} A must be added to this normal mode current. Figure 8c shows that the difference between the input voltage and feedback voltage V_f in the 180 preamplifier is exponentially decreasing in time due to the time constant of the amplifier, shown in Figure 8b. Since the modulator has an input resistance of at least 100k , this is also the form of I_{in} , and the input resistance (V_{in}/I_{in}) has the exponentially increasing form shown in Figure 8d. From these curves it is seen that the peak input current drawn with the $100\mu\text{V}$ cell differential is 10^{-9} A, decreasing with the instrument time constant shown in Figure 8c. The acceptable limits of current and charge drawn from standard cells will be somewhat different between various laboratories and for various levels of comparison. However, the nanoampere and nanocoulomb numbers given above due to these various effects will be low enough to satisfy all but the most extreme requirements. The magnitudes of the normal mode input impedance and capacity during settling time are such that it is not recommended to connect the 180 directly across an individual reference cell to measure the cell voltage. This is a situation which would rarely be useful. Figures 8b, c, d indicates the difference in time constant between the mV range and the other ranges on the Model 180. For most standard cell inter-comparison work, the mV range has sufficient resolution ($0.1\mu\text{V}$) so that the mV range with its slow time constant will not need to be used. Due to the transient input impedances, it is recommended that the resolution be considered before connecting the instrument and the 180 be set manually to the desired range.

2. Other voltage difference measurements. At the Keithley standards facility, the Model 180 has been used for a number of voltage difference measurements in addition to the standard cell intercomparison mentioned above. These include comparisons between resistors and comparisons between electronic supplies, perhaps using ratio dividers to compare against a standard cell as shown in Figure 8e. Our standards people were particularly impressed with the combined speed and sensitivity on the mV range, and the trade-offs between speed and noise which could be made to get better resolution using the most sensitive range. The precautions mentioned above are to be used whenever standard cells are involved in the measurements. When electronic sources are involved, the grounding may be handled differently, since the electronic source usually has a ground back to power line of its own. See Figure 8e. The input lo (black clip lead) in general should be connected to the lowest impedance point with respect to the output low. However, our experience has been that "reversal" error due to interchanging the two input leads is at the worst about $0.1\mu\text{V}$ and typically is within the noise level on the most sensitive range. This "reversal" error, of course, depends upon the magnitude of the output impedances, as can be seen by looking at Figure 8a. There is usually no need to use the instrument in the autoranging

mode for this type of measurement, but if a standard cell is not involved, the instrument may be used in this fashion.

3. Low-resistance "Lindeck" measurements. As in the above situations, the Model 180 has a definite advantage in speed and convenience over potentiometer systems which have traditionally been used to do this type of measurement. The problem with low resistance measurements has been the trade-off between power level and available sensitivity. In a circuit such as Figure 8f, a current of only 100mA may be used with the 180 on the 1mV range, providing .01% resolution. A 1μV DVM would require 1 Amp to provide the same resolution. Potentiometers would provide an equally sensitive measurement of such a low resistance, but not with the speed and convenience of the 180 on the 1mV range. On the .1mV range, the 180 may be used in this circuit to measure resistances of 1 milliohm with .05% accuracy, still using the 100mA from the current source.

c. Resistance Thermometry. The Model 180 may be used for resistance thermometry where small deviations are measured with nanowatt power dissipation. The Keithley Model 225 Current Source may be used to provide constant low-level currents. A typical resolution of 0.0002°C is possible using a 1000 ohm germanium thermometer (at 4.2°K) with only 1 nanowatt power dissipation. The floating input of the 180 eliminates problems usually encountered when floating four terminal measurements are made. The 180 can be used with a wide range of source resistance. When the Model 1802 Digital Output is used, data can be easily transferred to digital printers or computers.

d. Semiconductor Testing. The Model 180 may be used for semiconductor testing on an automated production line basis. Sensitive measurements can be made to determine gain stability, temperature coefficient, etc. without loading errors.

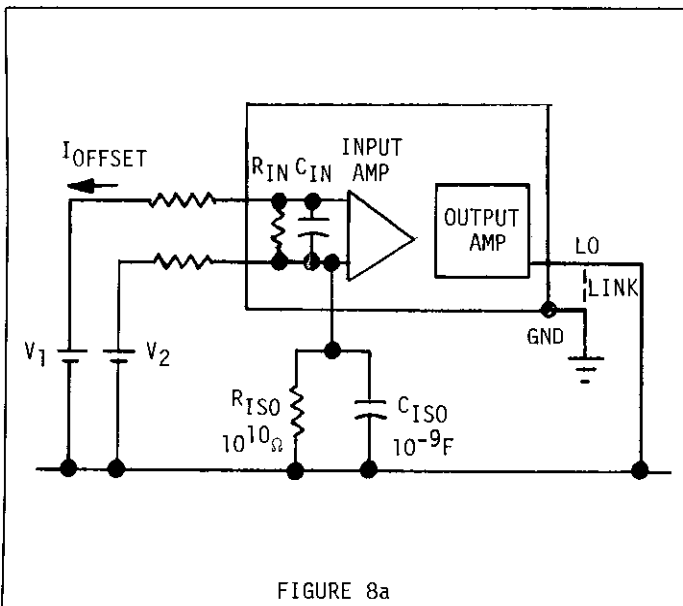


FIGURE 8a

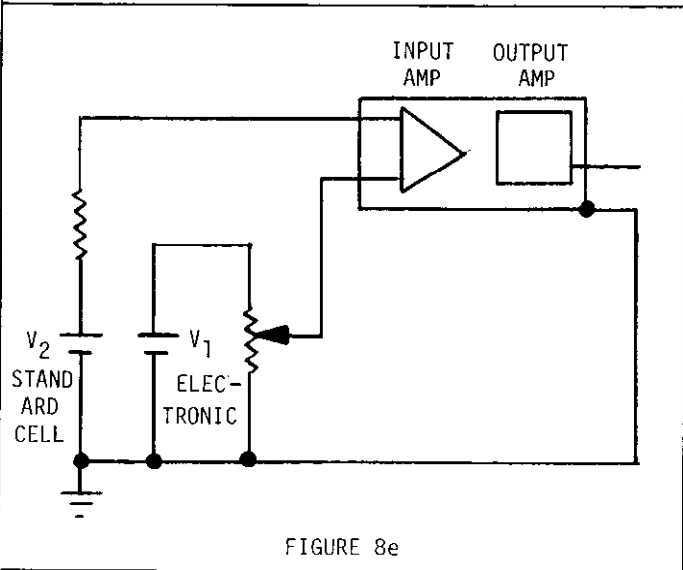


FIGURE 8e

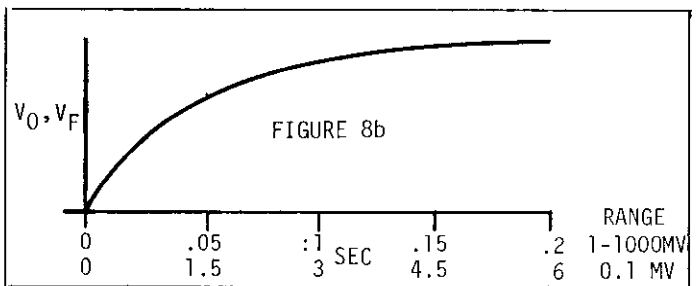


FIGURE 8b

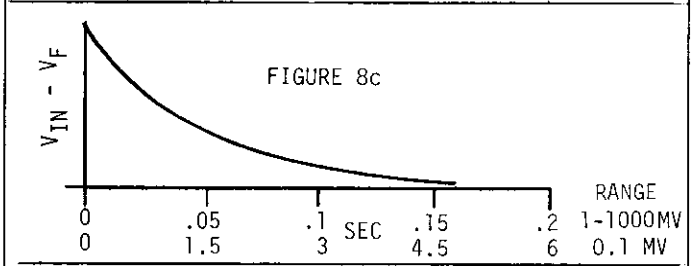


FIGURE 8c

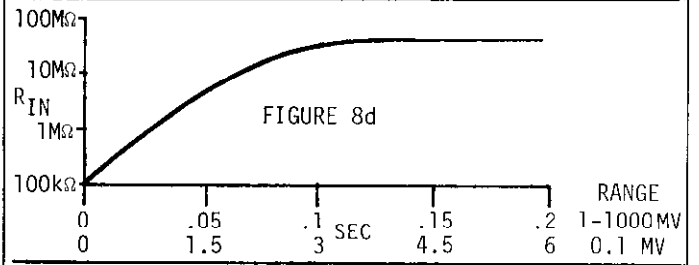


FIGURE 8d

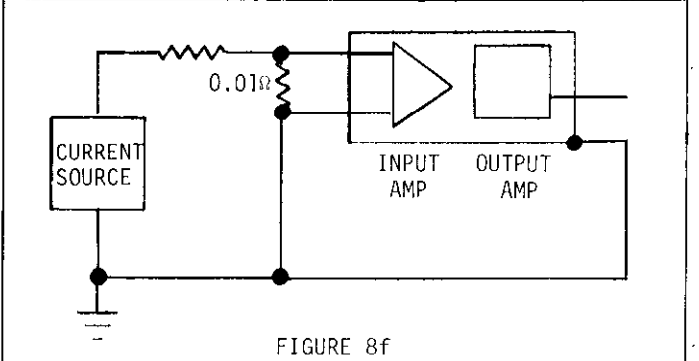


FIGURE 8f

SECTION 4. ACCESSORIES

4-1. GENERAL. The following Keithley accessories can be used with the Model 180 to provide additional convenience and versatility.

4-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 1486 Low-Thermal Connector

Description:

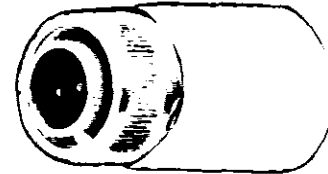
The Model 1486 is a mating connector for this instrument. It can be used to assemble a custom length cable to connect to the particular measurement set-up used. This is the same connector used on Models 1506 and 1507.



Model 1488 Low-Thermal Shorting Plug

Description:

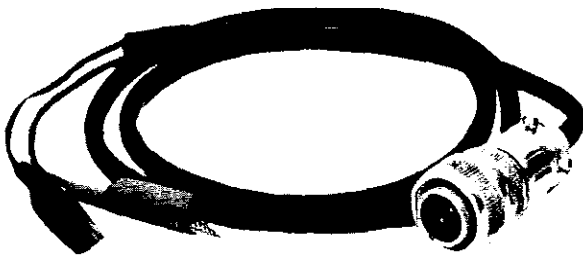
The Model 1488 is a special low-thermal plug which minimizes errors caused by thermal emfs. The 1488 can be used for checking the instrument with the input shorted.



Model 1506 Low-Thermal Input Cable

Description:

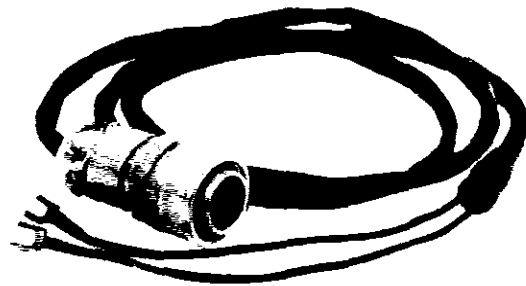
The Model 1506 is a triaxial cable 4' long terminated by two copper alligator clips. The cable mates with the input receptacle. It has been specially designed to provide excellent shielding for sensitive measurements.



Model 1507 Low-Thermal Input Cable

Description:

The Model 1507 is a triaxial cable 4' long terminated by two copper spade lugs. The cable mates with the input receptacle. It has been specially designed to provide excellent shielding for sensitive measurements.



Model 1534 Shielded Triaxial Cable

Description:

The Model 1534 consists of 10' of low-thermal triaxial cable as used in Models 1506 and 1507. This cable can be used with the Model 1486 connector and Model 1483 Connection Kit to assemble a custom cable for sensitive measurements.

Model 1503 Low-Thermal Solder

Description:

This solder can be used to make low-thermal connections. It is a cadmium-tin composition, also included as part of the Model 1483 Connection Kit.

Model 1483 Low-Thermal Connection Kit

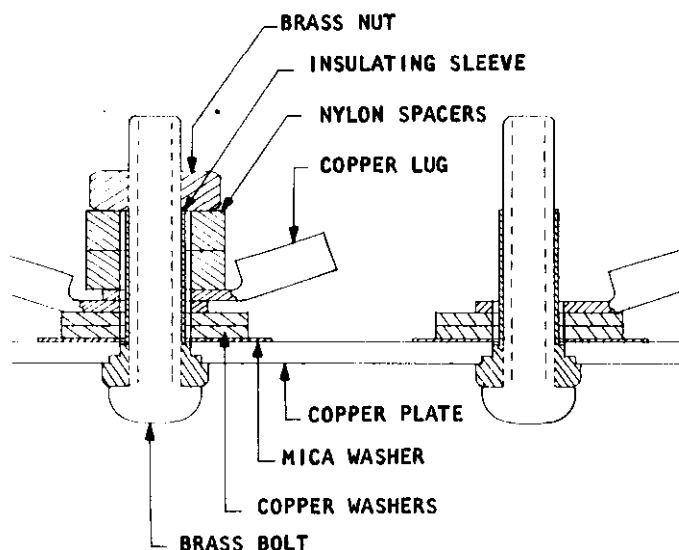
Description:

This kit contains various parts required when making low-thermal connections.

Application:

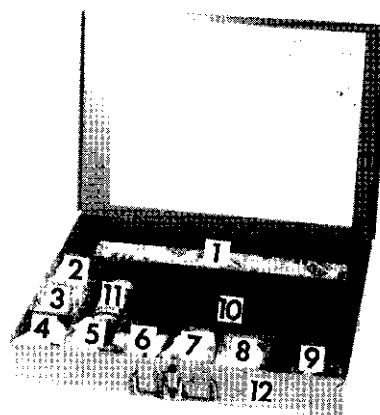
The parts in this kit, when properly used, provides good low-thermal connections for use when making very sensitive measurements. The following diagram illustrates a method useful in many applications. Other methods of making low-thermal connections include:

- 1) Crimp connections using copper lugs and wire.
- 2) Soldered connections using low-thermal solder (70% Cd, 30% Tin).



Parts List:

Item No.	Description	Part No.
1	Crimping Tool	TL-1
2	Hex nuts, nylon	-
3	Screws, nylon	-
4	Hook Lugs, copper	LU-22
5	Splice Tubes, copper	LU-23
6	Spade Lugs, copper	LU-66
7	Lugs, copper	LU-19
8	Alligator Clips, copper	AC-9
9	Solder, cadmium-tin	-
10	Shielded Cable	SC-5
11	Copper Wire, #20	WS-1
12	Storage Box	17329D



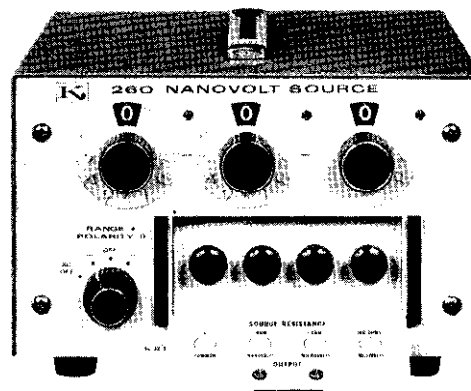
Model 260 Nanovolt Source

Description:

The Model 260 is a secondary standard for use in calibrating microvoltmeters and nanovolts. A choice of grounding is provided for use in floating systems and for elimination of ground loops. The direct reading front panel dials and output terminals set the output voltage, positive or negative, from 1 nanovolt to 1 volt with 3-dial resolution and up to 0.25% accuracy. The rated accuracy includes stability considerations for six months after calibration. Extreme precautions have been taken in the design of the Model 260 to minimize thermal emfs. All critical components, wires and connectors are made of pure copper.

Application:

Besides its function as a calibration source for ultra-sensitive voltmeters, the Model 260 can also be used as an accurate voltage source for zero suppression and potentiometric measurements.



 Model 1802 Digital Output

Description:

The Model 1802 is a buffered BCD module which provides both output and control capability. The 1802 includes an output buffer module pre-wired to a 50-pin receptacle and a mating 50-pin connector (not wired). This option is available only as a field installable accessory. The printed circuit module (PC-275) plugs into a pre-wired connector on the chassis.

Application:

The 1802 utilizes BCD "open collector logic" to represent each of 4 digits, overrange, overload, polarity, 4 decimal points, range changing and functions. The 1802 can be used to provide control as well as BCD output data. When connected to a digital output device such as a digital recorder or computer the Model 180 can be monitored and controlled with great flexibility.

Model 1803 Extender Card Set

Description:

This accessory provides a variety of extender cards for ease in checkout of circuitry. It also provides a calibration cover with access holes to calibration adjustments.

Parts List:

Description:	Part No:
1 - Extender Card, 25-pin	PC-337
2 - Extender Card, 15-pin	PC-339
1 - Extender Card, 22-pin	PC-338
1 - Extender Card, 22-pin	PC-340
1 - Calibration Cover	26072C
1 - Test Shield	26073B

Rack Mounting Kit (Supplied)

Description:

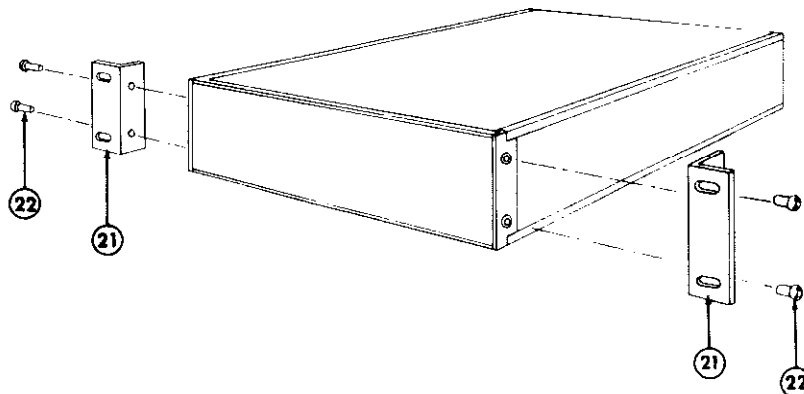
This instrument can be rack mounted in a standard 19" width rack. The rack mounting hardware is supplied with the instrument.

NOTE

Clearance should be provided behind the panel for access to power and monitoring cables. Recommended depth (measured from the front panel) is 14 inches.

Assembly Instructions:

- Remove the two Phillips head screws (Item 24) in two places.
- Attach an "angle bracket" (Item 21) on both corners using longer Phillips screws (Item 22) as shown.
- The plastic feet and tilt bail assemblies may be removed if necessary.



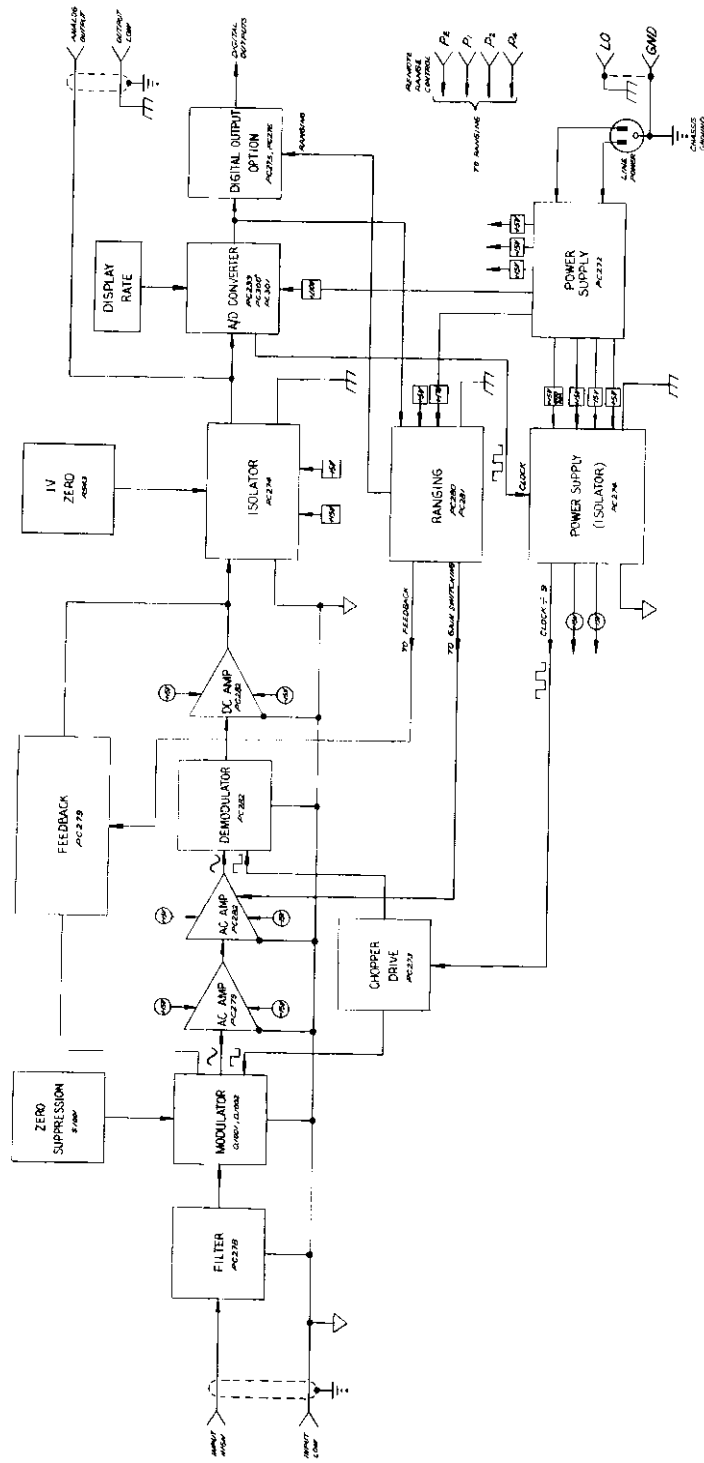


FIGURE 9. Overall Block Diagram.

SECTION 5. CIRCUIT DESCRIPTION

5-1. GENERAL. The Model 180 is a sensitive accurate nanovoltmeter with both analog and digital output capability. The circuit design includes a low-noise semiconductor modulator voltage amplifier, automatic ranging. Complete A-to-D converter and digital display, optional digital output, and isolating amplifier.

5-2. ANALOG SECTION.

a. Theory. The analog section includes a sensitive voltage amplifier, autorange switches, and an isolating output amplifier as shown in Figure 9. The voltage amplifier has a two-volt output corresponding to full-scale inputs of 100 μ V to 1000 mV. The autoranging circuit senses the output of the A/D converter in order to range up or down to the desired full-scale sensitivity. The isolating amplifier provides isolation between input low and output low greater than 10^9 ohms (10^{10} ohms at 25°C, 50% RH) and reduces the effects of transients due to output monitoring equipment (spikes, etc. which would otherwise feed back to the source through common low connections).

b. Circuitry.

1. Voltage Amplifier. The voltage amplifier consists of a line-frequency filter, input modulator, two-stage ac amplifier, demodulator, and output dc amplifier.

a). Line-Frequency Filter (PC-278). This filter provides up to 60 dB filtering of line frequencies. The circuit is a "twin-tee" filter composed of capacitors C1001, C1002, and C1003, resistors R1007, R1008, R1009, R1010. Potentiometer R1009 is an internal line-frequency rejection adjustment.

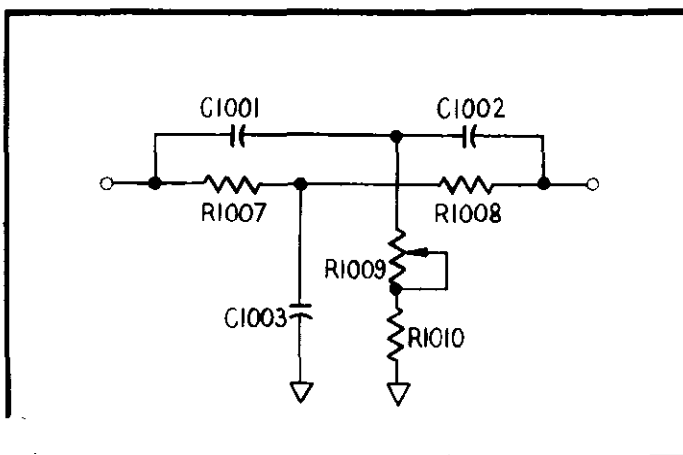


FIGURE 10. Line-frequency Filter.

b). Modulator. The basic modulator circuit consists of FET switches Q1001 and Q1002. Diodes D1001 and D1002 protect the transistors from load signals. Potentiometer R1004 is an internal zero adjustment for nulling input offset current. The chopper drive is provided by circuitry on PC-

c). AC Amplifiers.

1). The first-stage (low-noise) ac amplifier is composed of FET Q1003 and integrated circuit IA1001 (PC-279). The gain for this stage is determined by resistors R1035, R1039, and R1040 as follows.

For all ranges except 100 mV and 1000 mV,

$$G_1 (\text{gain}) = \frac{R1035 + R1040}{R1035}$$

For 100 mV and 1000 mV ranges,

$$G_2 (\text{gain}) = \frac{(R1035 + R1039)}{R1035} \approx \frac{1}{30} \times G_1$$

Resistors R1041 through R1046 and capacitors C1011, C1012, and C1015 form a "twin-tee" tuned circuit set for 1041.6 Hz. Potentiometers R1043 and R1046 are internal frequency tuning adjustments. FET Q1004 acts as a gain setting switch which connects resistor R1039 on the 100 mV and 1000 mV ranges.

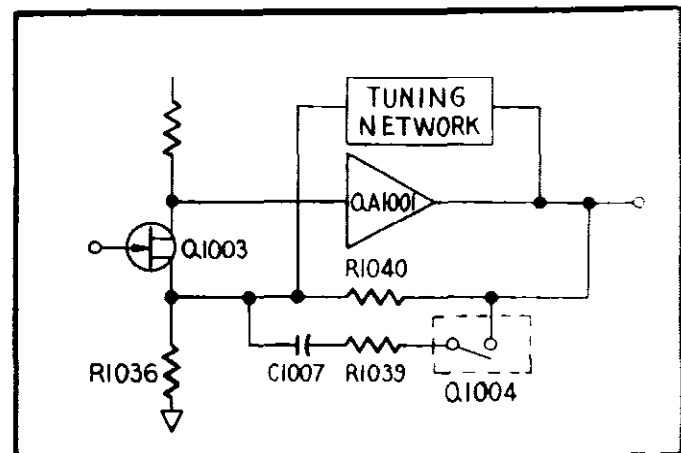


FIGURE 11. AC Amplifier, 1st Stage.

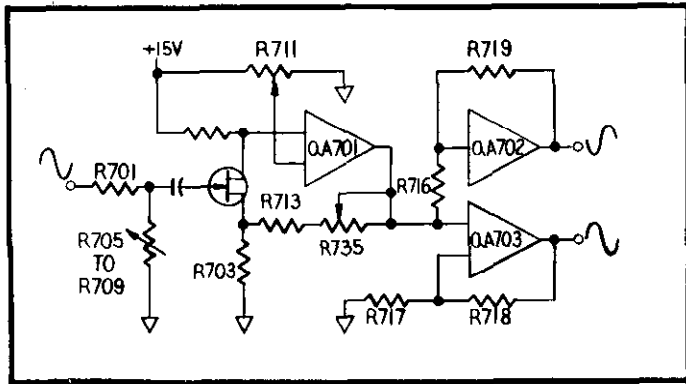


FIGURE 12. AC Amplifier, 2nd Stage.

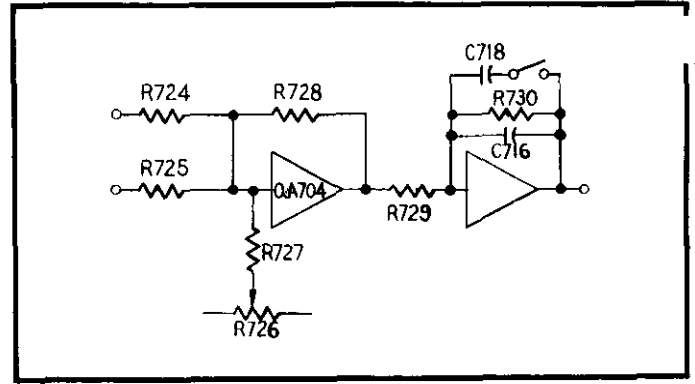


FIGURE 13. DC Amplifier Circuit.

2). The second-stage ac amplifier is composed of FET Q701 and integrated circuit QA701 (PC-282). The gain for this stage is determined by resistors R703 and R713 plus R735 where

$$\text{gain} = \frac{R703 + R713 + R735}{R703}$$

3). The open-loop ac gain is set by a resistor divider for each range. The divider consists of resistor R701 and resistors R705 through R709. Transistors Q702 through Q706 act as switches corresponding to ranges 100 μ V through 1 V respectively. For example, the divider ratio for the 1 V range would be (R709 + R701)/R709. Capacitor C719 is a phase-adjustment internal control.

4). The output of the second-stage is connected to a pair of X2 amplifiers to provide two outputs 180° out-of-phase. A non-inverting stage is composed of integrated circuit QA703 and resistors R717 and R718, where

$$\text{gain} = \frac{R717 + R718}{R717} = 2$$

An inverting stage is composed of integrated circuit QA702 and resistors R716 and R719, where gain = -R719/R716 = -2.

d). **Demodulator.** The demodulator is composed of FET switches Q707 and Q708. The demodulator drive is obtained from PC-273. This synchronously fullwave rectifies the ac from the ac amplifiers by grounding the junction of R721 and R725, allowing the signal from QA702 to be presented to the dc amplifier, or grounding the junction of R720 and R724, allowing the signal from QA703 to be presented.

e). **DC Amplifier.** The first-stage dc amplifier is composed of integrated circuit QA704. Gain is determined by resistors R720, R721, R724, R725, and R728 where,

$$\text{Gain (inv. input)} = \frac{R728}{(R720 + R724)/R725}$$

$$\text{Gain (noninv. input)} = \frac{R728}{(R721 + R725)/R724}$$

The second-stage dc amplifier is composed of integrated circuit QA705 and complementary transistors Q710 and Q711. Gain is determined by resistors R729 and R730 where,

$$\text{Gain} = R730/R729$$

Potentiometer R726 is an input voltage-offset adjustment for the dc amplifier stage. C716 and C718 are integrating capacitors. Transistor Q709 and relay K805 connects C718 on 100 μ V range.

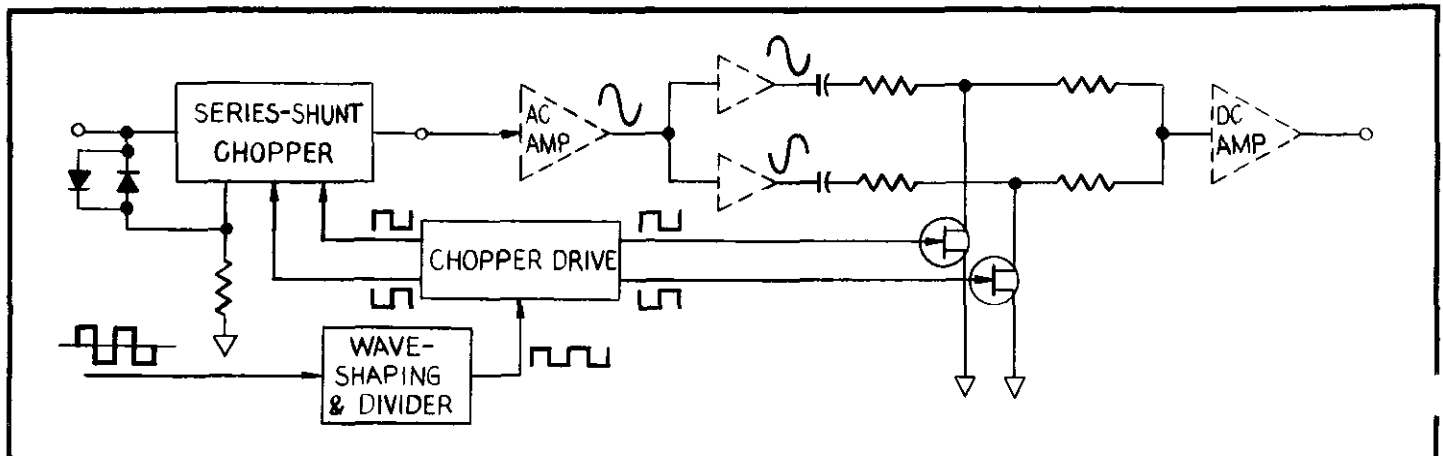


FIGURE 14. Chopper and Switching Circuits.

f). Feedback. Negative feedback is used to provide gain stability. The feedback resistance is connected between the input to the modulator and the dc output using range resistors R1026 through R1034 located on PC-279. Relays K801 through K806 connect the feedback network corresponding to the range selected either manually or by the autoranging circuit. Potentiometers R1024 through R1033 are gain accuracy adjustments for each range.

g). Chopper Drive. A 12.5 kHz signal from the isolator circuitry drives a voltage level translator QA601 to provide square waves referenced to input low. Integrated circuit QA602 is a divider module

($\div 6$). Transistors Q602 through Q605 form a divide by-2 flip-flop to provide 180° out-of-phase chopper drive signals.

2. Isolating Output Amplifier (PC-274). The amplifier input is composed of a series-shunt chopper driven by a 6.25 kHz frequency (FET switches Q509, Q513). Transformer T503 provides greater than 10⁹ ohms isolation between input low and output low. The demodulator is composed of FET switches Q514 and Q515 which are driven by a 6.25 kHz frequency. DC gain is provided by amplifier QA505. Potentiometer R5 is a front panel 1V Zero Control. Potentiometer R557 is an internal dc gain control.

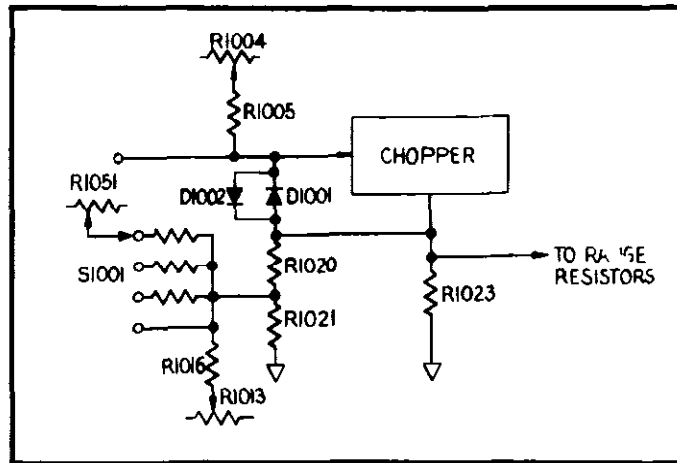


FIGURE 15. Zero Suppression Circuit

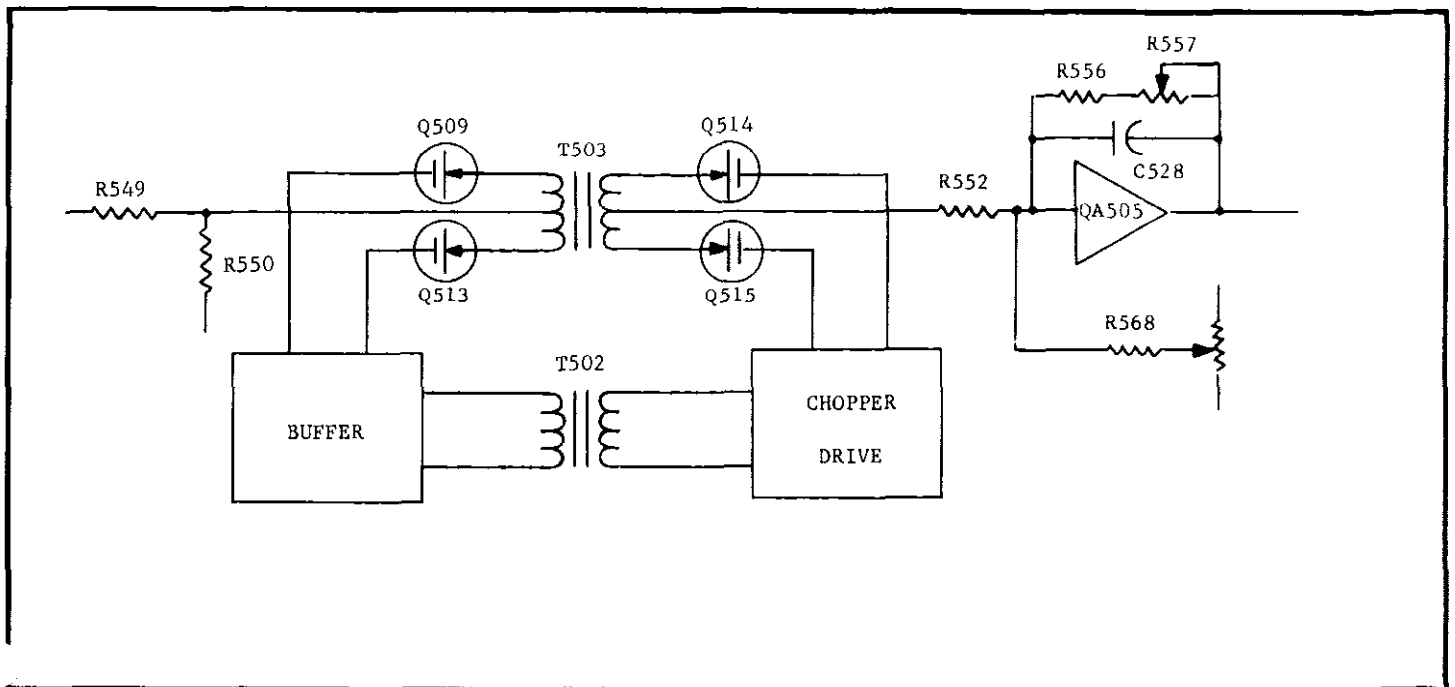


FIGURE 16. Isolator Circuit.

3. Autoranging. The autoranging circuit permits manual, automatic, or auto-remote operation through the use of various logic and control circuits. The overall block diagram of the autoranging circuit is shown in Figure 17.

a). Up-Ranging Logic. This circuit is composed of integrated circuit QA904A (NOR Gate). A truth table for the Up-Ranging Logic is given in Table 5-1.

TABLE 5-1.
Truth Table - Up-Ranging Logic

INPUTS		OUTPUT
OVERLOAD	1000 mV	QA904A (Pin 13)
0	0	1
0	1	0
1	0	0
1	1	0

b). Down-Ranging Logic. This circuit is composed of integrated circuits QA905A (NAND Gate), QA905B (NAND Gate), and QA904B (NOR Gate). A truth table for the Down-Ranging Logic is given in Table 5-2.

TABLE 5-2.
Truth Table - Down-Ranging Logic

OVERLOAD	INPUTS					OUTPUT	
	1x10 ⁴	8x10 ³	4x10 ³	2x10 ³	1x10 ³	QA904B	Pin 1
1	1	1	1	1	1	1	1
All other outputs are logical "0".							

c). Down-Ranging Gate. This gate is composed of integrated circuits QA906B (Inverter) and QA903B (NAND Gate). A truth table for the Down-Ranging Gate is given in Table 5-3.

TABLE 5-3.
Truth Table - Down Ranging Gate

INPUTS		OUTPUT
QA906B Pin 11	QA903B Pin 10	QA903B Pin 8
0	0	1
0	1	0
1	0	1
1	1	1

d). Up-Ranging Gate. This gate is composed of integrated circuit QA903A (NAND Gate). A truth table for this gate is given in Table 5-4.

TABLE 5-4.
Truth Table - Up Ranging Gate

INPUTS		OUTPUT
QA903A Pin 12	QA903A Pin 13	QA903A Pin 11
0	0	1
0	1	1
1	0	1
1	1	0

e). Range Counter. The Range Counter is an "UP/DOWN" Counter which provides a BCD output. This integrated circuit module (QA901) has four inputs designated P_E, P₁, P₂, and P₃ which can be used for remote range selection. A truth table for these inputs are given in Table 2-8. The counter is triggered by either of two inputs when auto-ranging, namely, "UP COUNT" and "DOWN COUNT".

TABLE 5-5.
Truth Table - Range Counter

INPUTS		OUTPUT
UP Pin 5	DOWN Pin 4	
Pulse	No Pulse	Count Up
No Pulse	Pulse	Count Down

f). Range Decoder. The BCD outputs from the Range Counter are decoded by integrated circuit module QA902. A simplified truth table for Range Decoder is shown in Table 5-6.

TABLE 5-6.
Truth Table - Range Decoder

INPUTS			OUTPUT*
(Pin 6)	(Pin 3)	(Pin 7)	Logical Input "1" (high)
1	1	0	100 μV (Pin 9)
0	0	1	1 mV (Pin 13)
0	1	1	10 mV (Pin 14)
1	0	1	100 mV (Pin 11)
1	1	1	1000 mV (Pin 10)

* All other outputs are off.

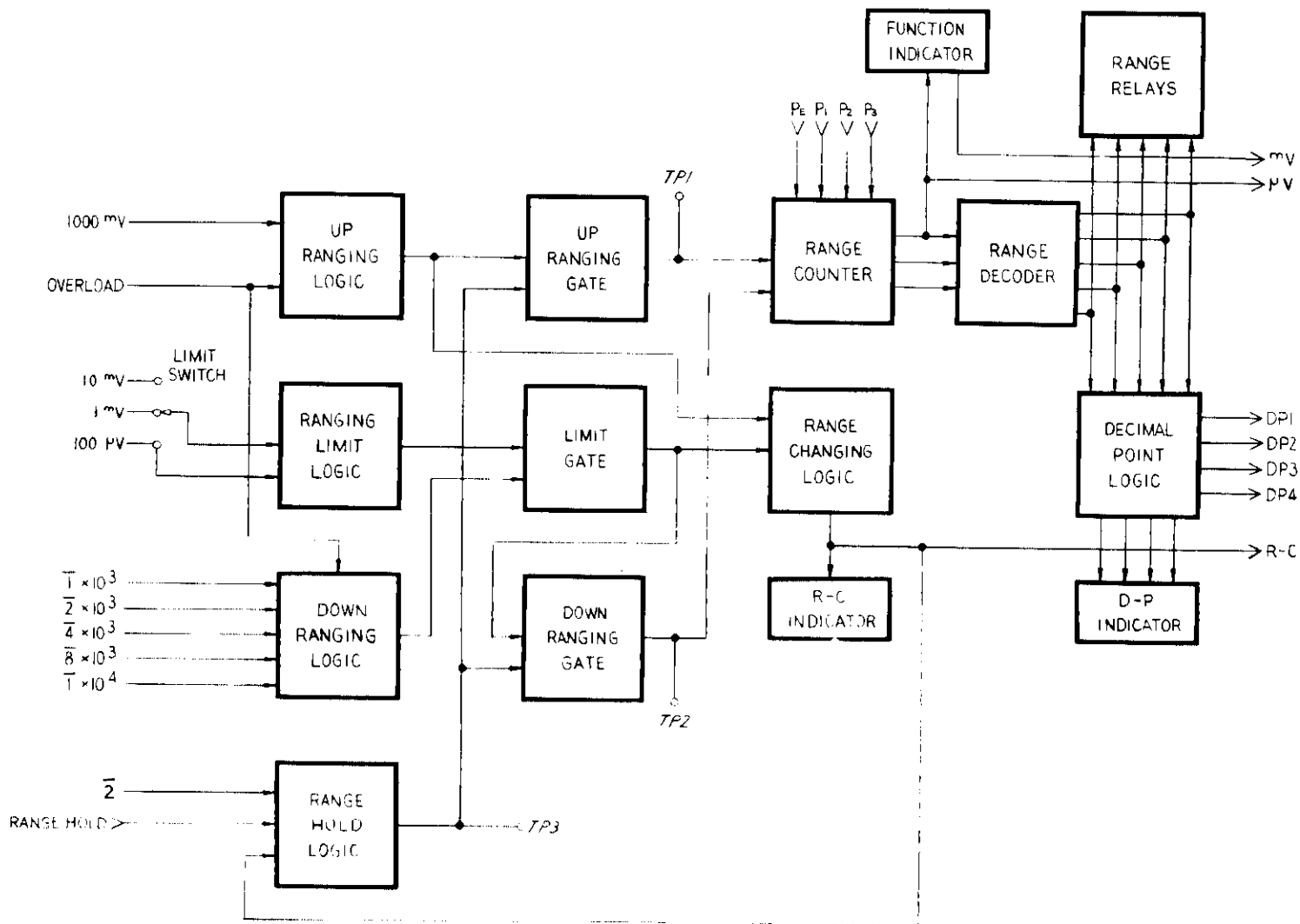


FIGURE 17. Ranging Block Diagram.

g). Ranging Limit Logic. This circuit is composed of integrated circuit QA904C (NOR Gate). A truth table for this gate is given in Table 5-7. The two inputs are derived from the Range Decoder outputs. The LIMIT Switch S1204 can be set to any one of three ranges, namely, 10 mV, 1 mV, and 100 μ V. The effect of the LIMIT logic is to set the lower range when in the AUTO-REMOTE mode.

TABLE 5-7.
Truth Table - Ranging Limit Logic

INPUTS		OUTPUT
Pin 5	Pin 6	Pin 4
0	0	1
0	1	0
1	0	0
1	1	0

h). Limit Gate. This circuit is composed of integrated circuit QA903D (NAND Gate). A truth table for this gate is given in Table 5-8.

TABLE 5-8.
Truth Table - Limit Gate

INPUTS		OUTPUT
Pin 1	Pin 2	Pin 3
0	0	1
0	1	1
1	0	1
1	1	0

i). Range Changing Logic. This circuit is composed of integrated circuits QA906A (Inverter) and QA903C (NAND Gate). A truth table for the Range Changing Logic is given in Table 5-9.

TABLE 5-9.
Truth Table - Range Changing Logic

INPUTS		OUTPUT
QA906A (Pin 12)	QA903C (Pin 4)	QA903C (Pin 6)
0	0	0
0	1	0
1	0	1
1	1	0

j). Decimal Point Logic. This circuit is composed of integrated circuits (all NAND Gates) QA908A, B, C, and D. A truth table for the Decimal Point Logic is given in Table 5-10.

TABLE 5-10.
Truth Table - Decimal Point Logic

INPUTS					OUTPUT*
100 μ V	1mV	10mV	100mV	1000mV	Logical Input "1" (high)
-	0	-	-	-	DP1 (Thous.)
-	-	0	-	-	DP2 (Hund.)
0	-	-	0	-	DP3 (Tens)
-	-	-	-	0	DP4 (Units)

* All other outputs are low.

k). Relays. Each relay has two sets of contacts. One set used to connect the proper feedback resistor. A second set is used to set the open-loop ac gain.

5-3. DIGITAL SECTION.

a. General. The digital section includes the analog-to-digital converter, digital display, and digital output option as shown in Figure 18.

b. Analog-to-Digital Converter. The analog-to-digital converter uses a dual-slope integration technique which has inherent line-frequency noise rejection.

1. Conversion Cycle. The analog signal is applied to the Integrator for a total of 200 milliseconds which is an even multiple of the line frequency. At the end of this interval the analog signal is removed and the integrator voltage is driven to zero. The time interval to reach a "Zero Crossing" is counted to complete the analog-to-digital conversion. The "Discharge" period is 200 milliseconds for a full-scale input as shown in Timing Diagram of Figure 7c. The Integrator is zeroed for a minimum of 100 milliseconds before the sampling is repeated. The total conversion time is 500 milliseconds which corresponds to approximately two conversions per second.

2. Timing Sequence. The operation of the A-to-D Converter can be described by considering a typical conversion cycle.

a). The clock provides pulses at a rate of 100 kHz for 50 or 60 Hz instruments.

b). The BCD Counter serves as a master timing control for the A-to-D conversion cycle. The timing is accomplished by the "1000" counter which has five coded states, namely 0, 1, 2, 3, and 4.

c). The Program/Decoder controls the sequence of commands based on the coded states from the BCD Counter. The "2" command initiates the integrator "ZERO" period which removes any residual charge on the integrator capacitor. The "3,4" command initiates the "INTEGRATE" period during which "analog sampling" occurs. At the end of the "INTEGRATE" period the "0,1" command initiates the "COUNT" period.

d). When the "3,4" command is given, the integrator samples the analog signal for a period of 167 milliseconds.

e). When the "0,1" command is given, the analog signal is removed and the integrator is driven to zero by a discharge current source. The Zero-Crossing Detector senses a zero-crossing of the Integrator output and removes the current source. A "Buffer/Store" pulse is generated to control the Buffer Storage Registers.

f). When the "Buffer/Store" command is given, the Buffer/Storage Register copies the BCD information from the BCD Counter.

g). The conversion cycle is completed after the "2" period (i.e., the Zeroing Period).

3. The A-to-D converter is composed of six major circuits as follows. See Figure 18 for a block diagram.

- a). Clock (located on PC-300)
- b). BCD Counter (located on PC-299)
- c). Program/Decoder (located on PC-299)
- d). Integrator (located on PC-301)
- e). Zero-Crossing Detector (located on PC-301)
- f). Buffer/Storage Register (located on PC-299)

4. Circuitry.

a). Clock. An oscillator composed of integrated circuits QA401A, B, C provides clock pulses at a rate of 100 kHz. A crystal oscillator Y401 determines the frequency of operation.

b). BCD Counter. The Decade Counters designated "1", "10", "100", and "1000" are composed of individual integrated circuit modules QA217, QA214, QA211, and QA208 respectively. All four counters have a capacity of 10-counts each.

c). Program/Decoder. This circuit produces event commands to control the overall sequence for the conversion cycle. The Program/Decoder consists of a 5-state counter (QA207) and logic circuits QA203D, QA205D, E, and F. The event commands are defined as 01, 2, 34.

d). Integrator. The operation of the Integrator is controlled by switches identified as S_A , S_D , S_X , and S_R as shown in Figure 19. Switch S_X (Sampling Switch) is composed of Q302. Switch S_D (Zeroing Switch) is composed of transistors Q305 and Q315. Transistors Q306, Q307 are control circuits arranged to control the proper FET switches depending on the event commands. The integrator amplifier consists of two stages: gain of 20 and gain of 50. They are QA302 and QA303. The integrator capacitor is C312 (.1 μ fd). Switches Q308 and Q310 control the discharge current period. The feedback rezeroing of the Integrator circuit is performed by FET Q315 (Switch S_D). Resistor R351 and capacitor C317 provide filtering in the feedback loop. Diodes D312 and D313 provide fast response for large input offsets (especially due to input overloads).

e). Zero-Crossing Detector. The level detector is composed of QA304. It is biased -3 volts to insure noise immunity. Its output provides two levels which selects the proper reference for discharge period and also produces a zero crossing pulse.

f). Buffer/Storage Register. The "1", "10", "100", and "1000" storage registers are composed of individual integrated circuits QA218, QA215, QA212, and QA209 respectively.

c. Digital Display. The display is composed of four numerical readout tubes plus an overrange indicator. The Decoder/Driver circuits decode the BCD information from the Storage Register into ten-line decimal code. A separate driver circuit controls the "Overrange 1" whenever the full range exceeds 9-9-9-9.

1. Numerical Readouts. The four numerical readouts V204, V203, V202, and V201 are driven by Decoder/Driver modules QA219, QA216, QA213, and QA210 respectively. Blanking of the numerical readouts occurs whenever the display exceeds 1-9-9-9-9. The Blanking circuit is composed of transistors Q204, Q205, and Q206. Transistor Q205 drives the base of Q204 to provide +170 volts for the readout tubes during normal operation. When an overload occurs transistor Q206 is driven "ON" which in turn reduces the +170-volt output, thus blanking the readout tubes.

2. Polarity Indication. This circuit is composed of integrated circuit QA205A, transistors Q202 and Q203, and polarity indicator module DS202. Integrated circuit QA202B is the Polarity Storage Register.

3. Overrange Indication. This circuit is composed of integrated circuits QA201A and QA202A, transistor Q201, and indicator DS201. QA202A is the Overload Storage Register.

4. Display Rate. The Display Rate circuit (located on PC-300) is a variable display-rate circuit (transistors Q401, Q402, integrated circuits QA402A, B, and C, and integrated circuit QA401D). Provision is made for "TRIGGER" and "HOLD 2" external controls when used with the Digital Output Option.

d. Digital Output Option. The digital output includes output buffers for all output information. The buffers utilize "Open Collector" output transistors as shown in Figure 8. The buffer stages have provision for optional "STROBE" control as shown in Figure 18.

1. Buffer Stage. Each buffer is composed of a Motorola type MC858P NAND Gate (four gates per circuit module). The "NAND" logic for this type of circuit is shown in Table 5-11.

TABLE 5-11.
Positive "NAND" Logic

Input 1	Input 2	Output
Low	Low	High
Low	High	High
High	Low	High
High	High	Low

2. "STROBE" Circuit. A typical "STROBE" circuit consists of an inverter stage (Keithley IC-32), a 10 kilohm pull-up resistor (Keithley R76-10), and a blocking diode (Keithley RF-39). The strobe enables the "NAND" gate so that the buffered outputs can be monitored.

3. "HOLD" Circuit. This circuit inhibits the "PP" pulse when the HOLD is grounded. Inverters QA102 A,B are buffer stages. Diode D102 is a protection diode to block voltages higher than +5V.

4. "FLAG" Circuit. The flag period corresponds to the 0,1 period except during range changing. QA103C is a "NOR" gate with inputs corresponding to 0,1 and Range Changing. The FLAG output is obtained by inverting the FLAG (QA106A is the inverter stage). Both FLAG and FLAG buffer stages will conduct when the "FLAG" strobe is grounded.

5. "COUNT" Circuit. Integrated circuit QA103B is a "NOR" gate with "STORE" and "0,1" inputs. The "COUNT" period is logic "0" when both inputs are high.

6. "POLARITY" Circuit. Integrated circuit QA101B is a flip-flop which is triggered by a "PP" pulse. A "high" at pin 10 corresponds to a "+" polarity. Integrated circuit QA104B is the polarity buffer. The polarity output buffer conducts when the "OVERLOAD" strobe is grounded.

7. "OVERLOAD" Circuit. Integrated circuit QA104A is the overload buffer stage which conducts when the "OVERLOAD" strobe is grounded.

8. "TRIGGER LEVEL" Circuit. Not used.

9. "FUNCTION" Circuit. The "FUNCTION" outputs are logical "1" for corresponding inputs as shown in Table 5-12. The function buffer conducts when the "FUNCTION" strobe is grounded.

TABLE 5-12.
Truth Table-Function Outputs

INPUT		OUTPUT			Indication
R ₁	R ₂	F ₁	F ₂	F ₃	
0	1	1	0	0	mV
1	0	0	1	0	μV

10. "DECIMAL POINT" Circuit. This circuit consists of four output buffer stages corresponding to decimal positions DP-1, DP-2, DP-3, and DP-4. Integrated circuits QA111 A,B,C, and D are "NAND" gates which will conduct when the "DECIMAL POINT" strobe is grounded. Inverters QA110, B,C,D, and E are used to invert the decimal point logic from the range circuitry.

11. "DATA" Buffer Circuits. The data output buffers consist of integrated circuits QA112 (A,B,C,D), QA113 (A,B,C,D), QA114 (A,B,C,D), and QA115 (A,B,C,D). Each set of BCD data can be monitored separately or in parallel by grounding the respective strobe designated Data #1, Data #2, Data #3, or Data #4.

12. "OVERRANGE 1" Circuit. Integrated circuit QA104C is a "NAND" gate which conducts when the "OVERLOAD" strobe is grounded.

13. "HOLD #1" Circuit. Not used.

14. "HOLD #2" Circuit. This input is biased "high" through resistor R118. Diode D107 is a protection diode used to block voltages higher than +5V.

15. "RANGE CHANGING" Circuit. Integrated circuit QA105B is a "NAND" gate which conducts whenever the range changing input is high.

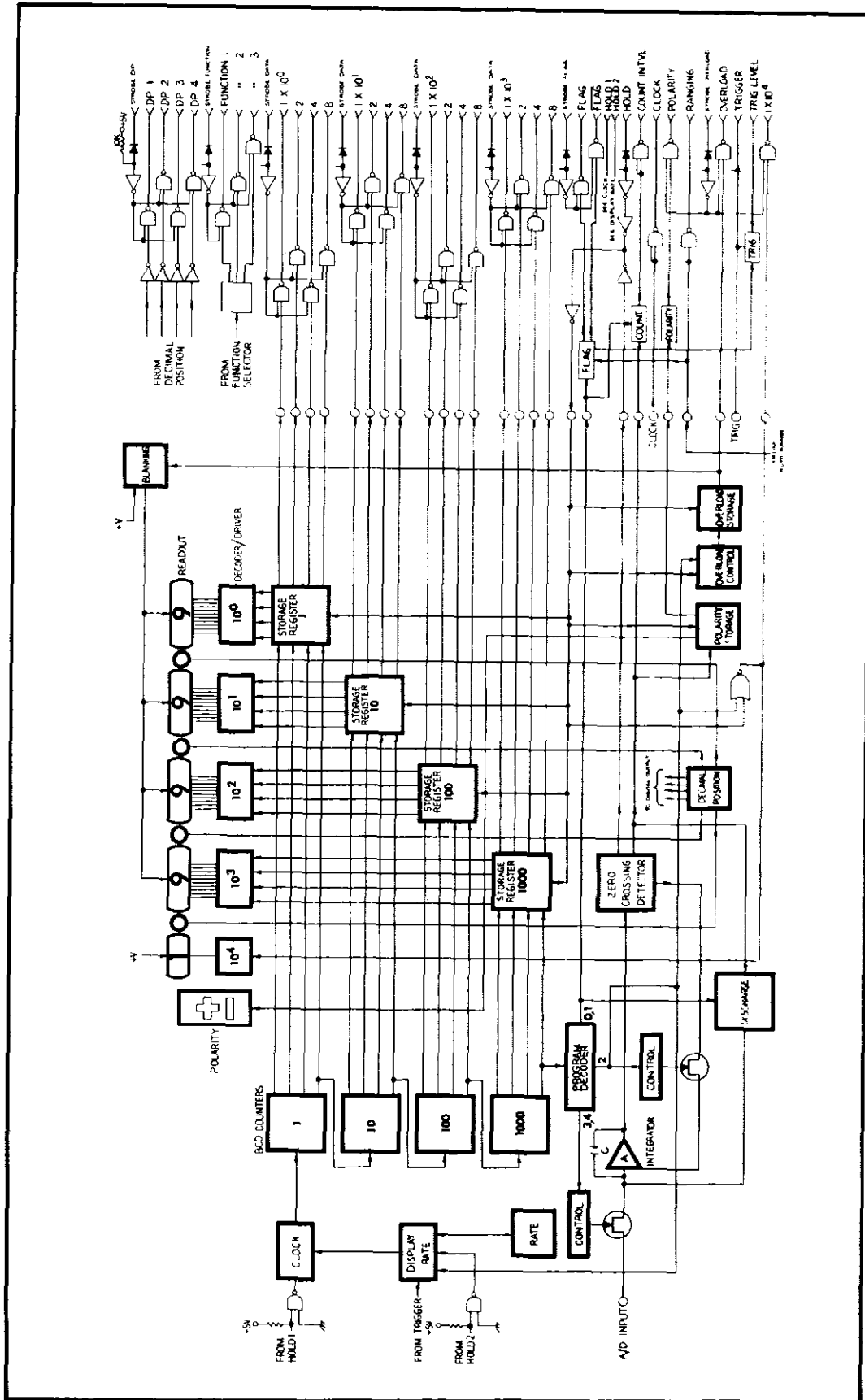


FIGURE 18. A-to-D Converter Block Diagram.

5-4. POWER SUPPLY SECTION. The power supply circuitry consists of supplies referenced to output low and input low (isolated).

a. Non-Isolated Supply (PC-272). This supply provides main power for the instrument. Transformer T1101 provides isolation between output low and chassis greater than 10^6 ohms shunted by less than microfarads.

1. Regulated +5.0V. Diodes D1101 and D1102 provide full-wave rectification from a center-tapped winding (GRN, GRN/YEL, GRN). Integrated circuit QA1102 is a regulator which supplies +5.0 volts at 1 ampere approx.

2. Regulated +15V. Diodes D1103 and D1104 provide full-wave rectification from a center-tapped winding (RED, RED/WHT, RED). Transistor Q1102 is the series pass regulating element. Integrated circuit QA1101 is a regulator. Potentiometer R1110 is an internal voltage adjustment for the +15 volt output only.

3. Regulated -15V. Diodes D1107 and D1108 provide full-wave rectification for the -15V supply. Transistor Q1107 is the series-pass regulating element. Transistors Q1101 and Q1102 form a differential pair which is referenced between resistors R1115 and R1116 (+15 and -15 volt outputs).

4. +15V (@400 mA). Diodes D1111 through D1114 provide full-wave rectification from a single transformer winding (ORN, ORN). Transistor Q1109 provides series regulation for the +15 volts output. This supply provides power for the isolating amplifier circuitry.

5. +17V. Diode D1110 provides a half-wave rectified voltage of approximately +17 volts. This supply provides power for the range relay circuitry.

6. +210V. Diode D1109 provides a half-wave rectified voltage of approximately +210V. This supply provides power for the digital display circuitry.

b. Isolated Supply. The isolated supply provides regulated +15 volts for the voltage amplifier section as well as the square-wave drive for the isolating amplifier chopper.

1. Chopper Drive (12.5 kHz). This drive is obtained by dividing down the "CLOCK" signal from the A-to-D converter section. Integrated circuits QA501 and QA502 divide down the 100 kHz (CLOCK) frequency to 12.5 kHz ($CLOCK \div 8$). Transistors Q501, Q502, Q503, Q505, Q506, and Q507 form the inverter stage. Main power for the inverter stage is provided by the +15V (@400 mA) supply and power switching transistors Q503 and Q507. The square-wave drive for the isolating amplifier is provided by transistors Q502 and Q506. Transformer T501 provides isolation between input low and output low.

2. Transformer T502 provides power for the isolated +15 volt supplies. Diodes D501 and D502 provide full-wave rectification from a center-tapped winding. Transistor Q514 is the series-pass regulating element. Integrated circuit QA503 is a regulator module. Potentiometer R523 is an internal voltage adjustment for the +15 volt output only. Diodes D503 and D504 provide full-wave rectification for the -15 volt supply. Transistor Q508 is the series-pass regulating element. Integrated circuit QA504 is a regulator module. Potentiometer R527 is an internal voltage adjustment for the -15 volt output only. Capacitors C509 and C517 are internal tuning adjustments.

3. Electronic Filter (PC-273). Transistors Q606 through Q609 form an electronic filter for the +15 volt supplies.

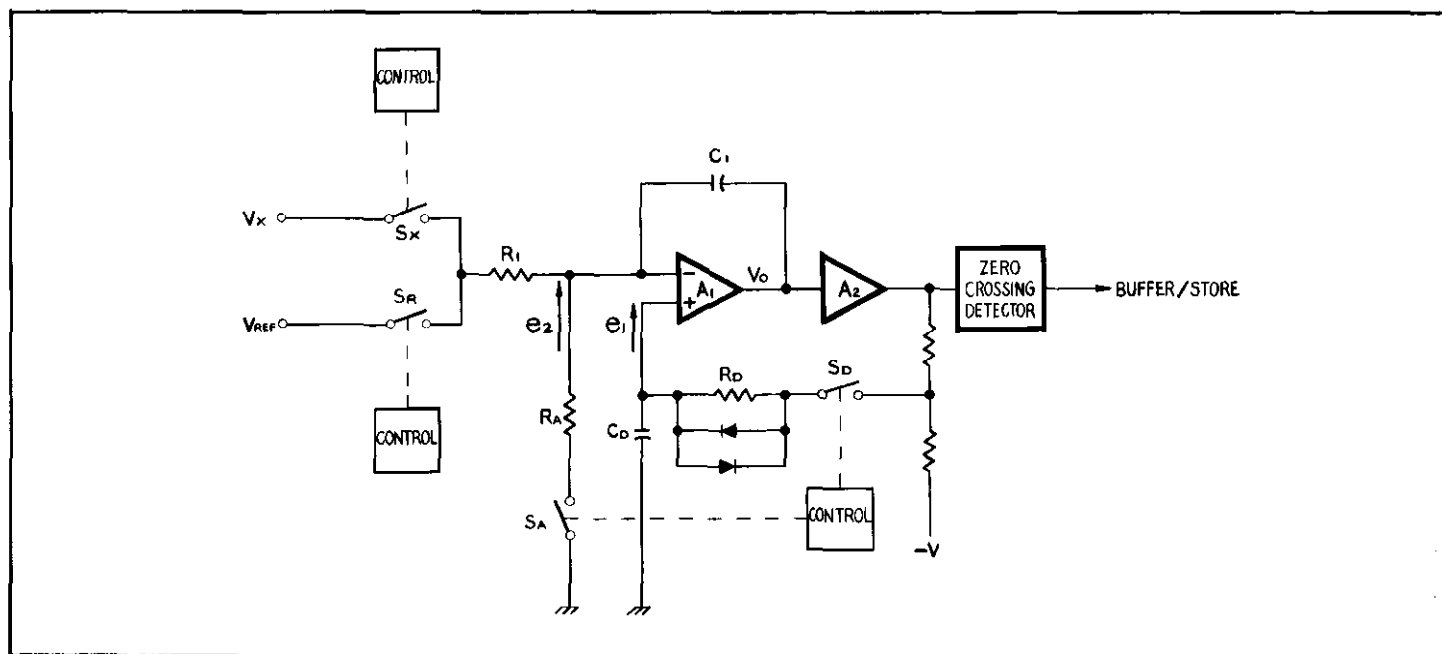


FIGURE 19. Integrator Block Diagram.

SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST: This section contains a list of components used in this instrument for user reference. The Replaceable Parts List described the individual parts giving Circuit Designation, Description, Suggested Manufacturer (Code Number), Manufac-

turer's Part Number, and the Keithley Part Number. Also included is a Figure Reference Number where applicable. The complete name and address of each Manufacturer is listed in the CODE-TO-NAME Listing following the parts list.

TABLE 6-1.
Abbreviations and Symbols

A	ampere	F	farad	Ω	ohm
CbVar	Carbon Variable	Fig	Figure	p	pico (10^{-12})
CerD	Ceramic Disc	Gcb	Glass enclosed Carbon	PC	Printed Circuit
CerTB	Ceramic Tubular	k	kilo (10^3)	Poly	Polystyrene
Cer Trimmer	Ceramic Trimmer	μ	micro (10^{-6})	Ref.	Reference
Comp	Composition	M	Meg (10^6)	TCu	Tinner Copperweld
DCb	Deposited Carbon	Mfr.	Manufacturer	V	volt
Desig.	Designation	MtF	Metal Film	W	watt
EAL	Electrolytic, Aluminum	My	Mylar	WW	Wirewound
ETB	Electrolytic, Tubular	No.	Number	WWVar	Wirewound Variable
ETT	Electrolytic, Tantalum				

6-2. ELECTRICAL SCHEMATICS AND DIAGRAMS. Schematics and diagrams are included to describe the electrical circuits as discussed in Section 5. Table 6-2 identifies all schematic part numbers included.

Sales Service Department, Keithley Instruments, Inc. or your nearest Keithley representative.

6-3. HOW TO USE THE REPLACEABLE PARTS LIST. This Parts List is arranged such that the individual types of components are listed in alphabetical order. Main Chassis parts are listed followed by printed circuit boards and other subassemblies.

b. When ordering parts, include the following information.

1. Instrument Model Number
2. Instrument Serial Number
3. Part Description
4. Schematic Circuit Designation
5. Keithley Part Number

6-4. HOW TO ORDER PARTS.

a. Replaceable parts may be ordered through the

c. All parts listed are maintained in Keithley Spare Parts Stock. Any part not listed can be made available upon request. Parts identified by the Keithley Manufacturing Code Number 80164 should be ordered directly from Keithley Instruments, Inc.

TABLE 6-2.
Schematic Diagrams

Description	Assembly No.	Schematic No.
Mother Board	PC-271	25548E
Power Supply	PC-272	25054D
Filter - AC Amplifier	PC-278, PC-279	24543D
AC Amplifier (2nd)	PC-282	25111D
Chopper Drive	PC-273	25112D
Isolator Board	PC-274	25117D
Ranging Board	PC-280	25024D
Relay Board	PC-281	25100D
Clock Board	PC-300	25098D
Integrator Board	PC-301	25017D
Tube Board	PC-299	24873D
Digital Output (1802)	PC-275	24866D

TABLE 6-3.
Circuit Designation Series

Series	Description	Circuit Designation	Page No.
100	Digital Output	PC-275	30
200	Tube Board	PC-299	32
300	Integrator Board	PC-301	34
400	Clock Board	PC-300	37
500	Isolator Board	PC-274	38
600	Chopper Drive	PC-273	40
700	AC Amplifier (2nd)	PC-282	42
800	Relay Board	PC-281	44
900	Ranging Board	PC-280	45
1000	Filter - AC Amplifier (1st)	PC-278, PC-279	46
1100	Power Supply	PC-272	48
1200	Mother Board	PC-271	50

TABLE 6-4.
Mechanical Parts List

Item No.	Description	Qty. Per Assembly	Keithley Part No.	Figure No.
-	Chassis Assembly	-	-	36
-	Front Panel Assembly	-	-	
1	Front Panel	1	24580D	
2	Screw, Slotted, 6-32 x 3/8	4	-	
3	Front Panel Overlay	1	24387C	
4	Rear Panel	1	24383D	
5	Side Extrusion Left	1	24874C	
6	Side Extrusion Right	1	24874C	
7	Corner Bracket	2	24736B	
8	Screw, Phillips, 6-32 x 1/2	4	-	
9	Screw, Phillips, 6-32 x 1/2	4	-	
10	Clip for Side Dress	2	FA-101	
11	Side Dress Panel	2	24360B	
-	Top Cover Assembly	-	-	
12	Top Cover	1	24381C	
13	Screw, Phillips, 6-32 x 5/16	4	-	
-	Bottom Cover Assembly	-	24379B	37
14	Bottom Cover	1	24382C	
15	Screw, Phillips, 6-32 x 5/16	4	-	
-	Feet Assembly	-	-	
16	Feet	4	24322B	
17	Ball	4	FE-6	
18	Tilt Bail	1	14704B	
19	Screw, Phillips, 6-32	4	-	
20	Kep Nut, 6-32	4	-	
-	Rack Hardware	-	-	
21	Angle Bracket	2	24783A	
22	Screw, Phillips, 6-32 x 5/8	4	-	

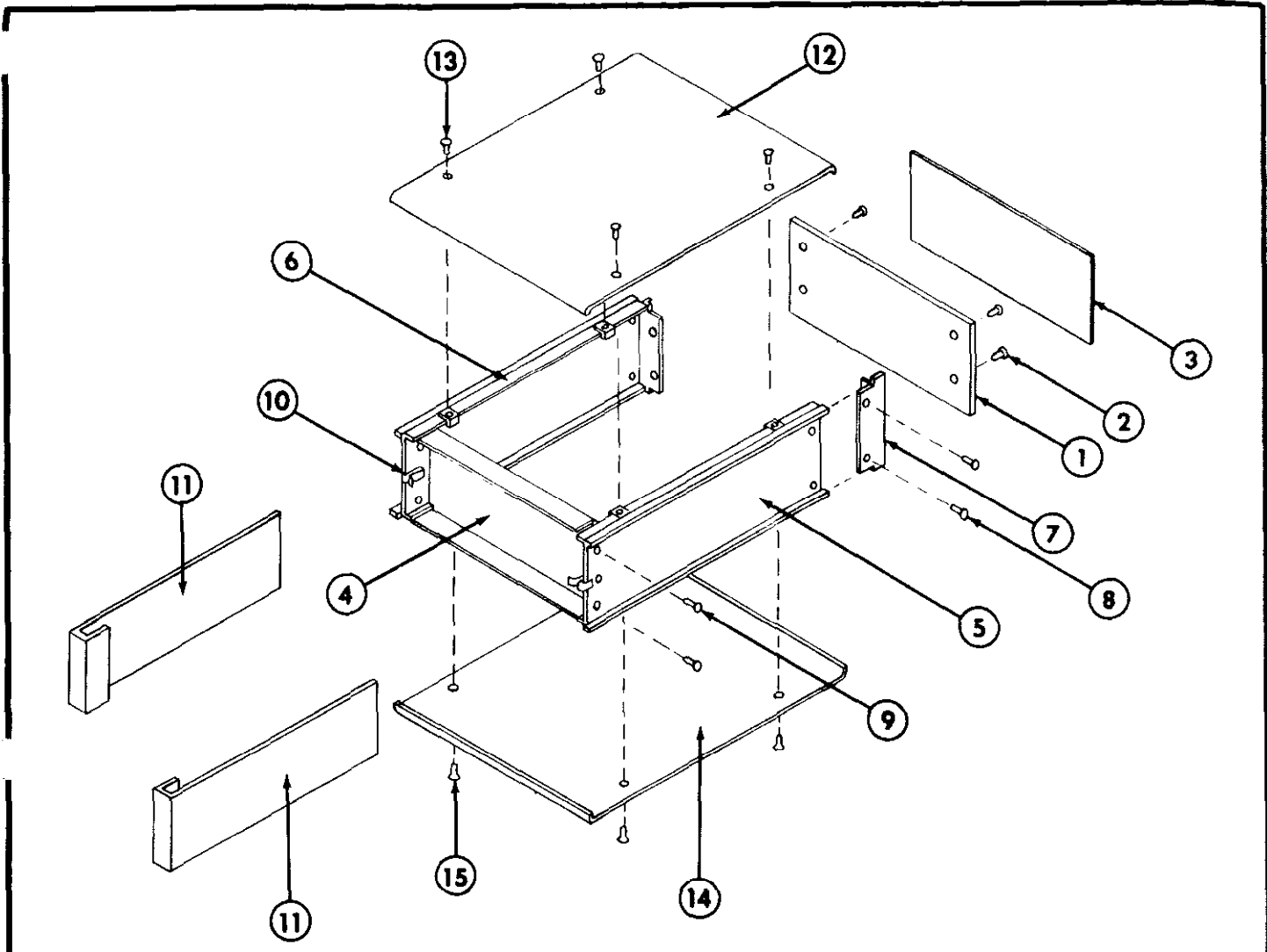


FIGURE 20. Chassis Assembly - Exploded View.

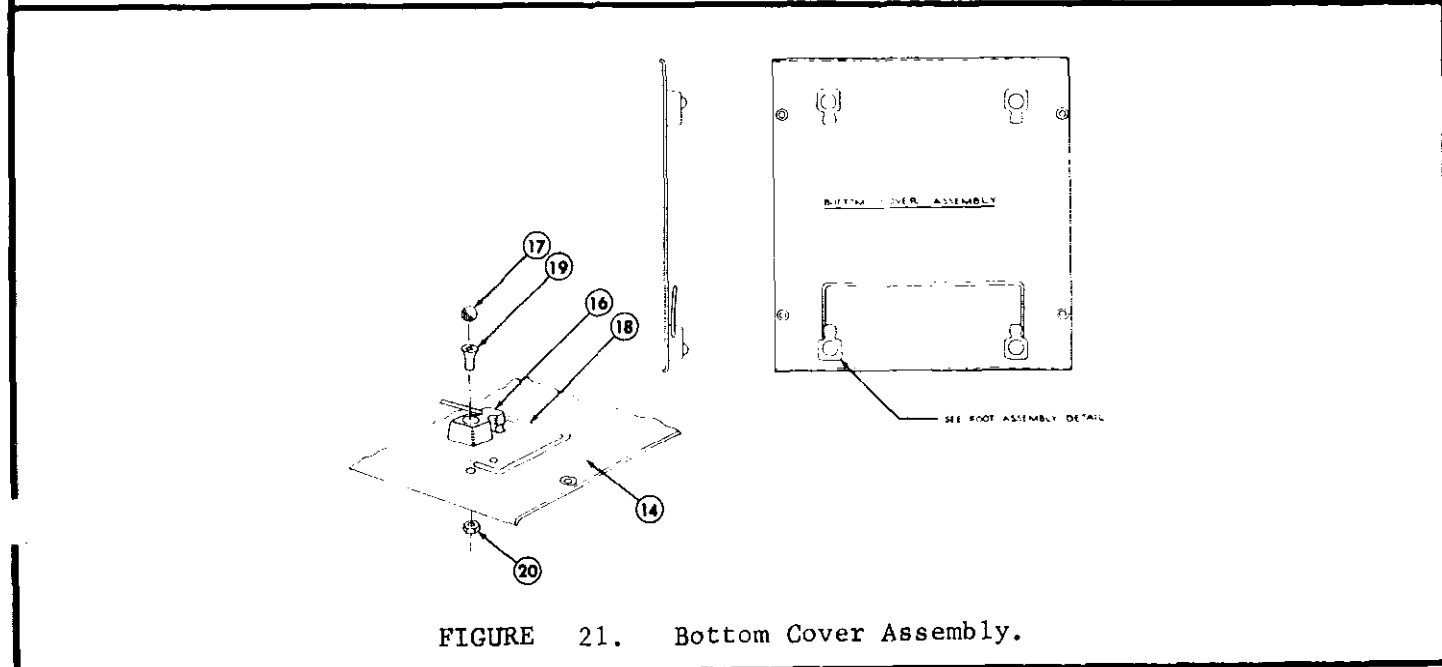


FIGURE 21. Bottom Cover Assembly.

MODEL 1802 DIGITAL OUTPUT "100" SERIES (PC-275)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C101	10 μ F	20 V	ETT	17554	TD2-20-106-20	C179-10M	35
C102	0.01 μ F	600 V	CerD	72982	871-Z5UO-103M	C22-.01M	35

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D101	Germanium	15238	1N3592	RF-39	36
D102	Germanium	15238	1N3592	RF-39	35
D103	Germanium	15238	1N3592	RF-39	36
D104	Germanium	15238	1N3592	RF-39	36
D105	Germanium	15238	1N3592	RF-39	35
D106	Silicon	01295	1N914	RF-28	36
D107	Germanium	15238	1N3592	RF-39	36
D108	Germanium	15238	1N3592	RF-39	35
D109	Germanium	15238	1N3592	RF-39	35
D110	Germanium	15238	1N3592	RF-39	35
D111	Germanium	15238	1N3592	RF-39	35
D112	Silicon	01295	1N914	RF-28	35
D113	Silicon	01295	1N914	RF-28	35
D114	Germanium	15238	1N3592	RF-39	36

INTEGRATED CIRCUITS

QA101	Dual Flip-Flop, 14-pin DIP	01295	SN7474N	IC-31	36
QA102	Hex Inverter DTL, 14-pin DIP	04713	MC835P	IC-81	35
QA103	Positive NOR Gate, 14-pin DIP	01295	SN7402N	IC-32	35
QA104	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	36
QA105	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	36
QA106	Hex Inverter DTL, 14-pin DIP	04713	MC836P	IC-80	36
QA107	Positive NAND Gates, 14-pin DIP	01295	SN7420N	IC-48	36
QA108	Positive NAND Gates, 14-pin DIP	01295	SN7420N	IC-48	36
QA109	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	36
QA110	Hex Inverter DTL, 14-pin DIP	04713	MC838P	IC-80	35
QA111	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	35
QA112	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	35
QA113	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	35
QA114	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	35
QA115	Quad NAND Gate, 14-pin DIP	04713	MC858P	IC-52	35

MISCELLANEOUS

J101	Connector, 10-pin	22526	65039-039	CS-237	36
J102	Connector, 10-pin	22526	65039-039	CS-237	35
J103	Connector, 10-pin	22526	65030-039	CS-237	35
J104	Connector, 10-pin	22526	65039-039	CS-237	35
J105	Not Used	---	-----	---	--
J106	Connector, 10-pin	22526	65039-039	CS-237	36
J107	Connector, 5-pin	22526	65039-040	CS-251	36
J108	Receptacle, 50-pin	02660	5740500	CS-221	--
P108	Connector, 50-pin, Mate of J108	02660	5730500	CS-220	--
--	Connector, Mini, Female, Insert in CS-237 & CS-251	22526	47439	CS-236	--
--	Jumper	ANSLEY-WEST	.100FS2-D-16	J-4	--
Q101	Transistor, Silicon, NPN, Case TO-106	07263	2N5134	TG-65	36
Q102	Transistor, Silicon, NPN, Case TO-106	07263	2N5134	TG-65	36

MODEL 1802 DIGITAL OUTPUT (Cont'd)

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R101	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R102	270 Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-270	36
R103	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R104	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R105	220 Ω	10%, 1/4W	Comp	44655	CB221-10%	R76-220	36
R106	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R107	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R108	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R109	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R110	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R111	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R112	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R113	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R114	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R115	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R116	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R117	2.2 k Ω	10%, 1/4W	Comp	44655	CB222-10%	R76-2.2K	--
R118	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	36
R119	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R120	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R121	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R122	10 k Ω	10%, 1/4W	Comp	44655	CB103-10%	R76-10K	35
R123	4.7 k Ω	10%, 1/4W	Comp	44655	CB472-10%	R76-4.7K	35
R124	220 Ω	10%, 1/4W	Comp	44655	CB221-10%	R76-220	35
R125	2.2 k Ω	10%, 1/4W	Comp	44655	CB222-10%	R76-2.2K	35

TUBE BOARD, "200" SERIES (PC-299)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C201	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C202	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C203	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C204	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C205	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C206	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C207	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C208	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C209	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C210	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C211	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C212	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C213	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C214	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C215	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C216	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C217	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C218	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C219	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	32
C220	.0022 μ F	500 V	CerD	72982	831-Z5UO-222M	C22-.0022M	32
C221	100 pF	1000 V	CerD	71590	DD101-10%	C64-100P	32
C222	10 μ F	20 V	ETT	17554	TD2-20-106-20	C179-10M	32

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D201	Germanium	15238	1N3592	RF-39	32
D202	Germanium	15238	1N3592	RF-39	32
D203	NOT USED				
D204	NOT USED				
D205	Germanium	15238	1N3592	RF-39	32

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA201	Dual Flip-Flop, 14-pin DIP	01295	SN7474N	IC-31	32
QA202	Dual Flip-Flop, 14-pin DIP	01295	SN7474N	IC-31	32
QA203	Positive NOR Gates, 14-pin DIP	01295	SN7402N	IC-32	32
QA204	Positive NAND Gates, 14-pin DIP	01295	SN7400N	IC-38	32
QA205	Hex Inverters TTL, 14-pin DIP	01295	SN7404N	IC-33	32
QA206	Hex Inverters TTL, 14-pin DIP	01295	SN7404N	IC-33	32
QA207	5-Bit Shift Register, 16-pin DIP	01295	SN7496N	IC-39	32
QA208	Decade Counters, 14-pin DIP	01295	SN7490N	IC-37	32
QA209	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	32
QA210	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	32
QA211	Decade Counters, 14-pin DIP	01295	SN7490N	IC-37	32
QA212	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	32
QA213	Decodes/Driver, 16-pin DIP	01295	SN7441AN	IC-35	32
QA214	Decade Counters, 14-pin DIP	01295	SN7490N	IC-37	32

TUBE BOARD (PC-299) (continued)

INTEGRATED CIRCUITS (continued)

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA215	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	32
QA216	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	32
QA217	Decade Counters, 14-pin DIP	01295	SN7490N	IC-37	32
QA218	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	32
QA219	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	32

INDICATORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
V201	Readout Tube	94144	CK1916	EV-841	32
V202	Readout Tube	94144	CK1916	EV-841	32
V203	Readout Tube	94144	CK1916	EV-841	32
V204	Readout Tube	94144	CK1916	EV-841	32
DS201	Readout Tube, Overrange "1", Neon	74276	A261	PL-42	32
DS202	Polarity Indicator Lamps Assembly	91802	2330	PL-48	32

RESISTORS

Circuit Desig.	Value	Rating T	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R201	1 k Ω	10%, 1/4 W	Comp	01121	CB102-10%	R76-1K	32
R202	22 k Ω	10%, 1/4 W	Comp	01121	CB223-10%	R76-22K	32
R203	100 k Ω	10%, 1 W	Comp	01121	CB104-10%	R2-100K	32
R204	3.3 k Ω	10%, 1/4 W	Comp	01121	CB332-10%	R76-3.3K	32
R205	3.3 k Ω	10%, 1/4 W	Comp	01121	CB332-10%	R76-3.3K	32
R206	470 Ω	10%, 1/4 W	Comp	01121	CB471-10%	R76-470	32
R207	10 k Ω	1%, 1/2 W	MtF	07716	CEC-T-0	R94-10K	32
R208	10 k Ω	1%, 1/2 W	MtF	07716	CEC-T-0	R94-10K	32
R209	10 k Ω	1%, 1/2 W	MtF	07716	CEC-T-0	R94-10K	32
R210	10 k Ω	1%, 1/2 W	MtF	07716	CEC-T-0	R94-10K	32
R211	220 Ω	10%, 1/4 W	Comp	01121	CB221-10%	R76-220	32
R212	100 k Ω	10%, 1/2 W	Comp	01121	EB104-10%	R1-100K	32
R213	80.6 k Ω	1%, 1/2 W	MtF	07716	CEC-T-0	R94-80.6K	32
R214	47 k Ω	10%, 1/4 W	Comp	01121	CB473-10%	R76-47K	32
R215	7.87 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-7.87K	32
R216	1 k Ω	10%, 1/4 W	Comp	01121	CB102-10%	R76-1K	32
R217	220 Ω	10%, 1/4 W	Comp	01121	CB221-10%	R76-220	32

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q201	Silicon, NPN, TO-5 Case	86684	2N3439	TG-93	32
Q202	Silicon, NPN, TO-5 Case	86684	2N3439	TG-93	32
Q203	Silicon, NPN, TO-5 Case	86684	2N3439	TG-93	32
Q204	Silicon, NPN, TO-39 Case	04713	MM3003	TG-58	32
Q205	Silicon, NPN, TO-39 Case	04713	MM3003	TG-58	32
Q206	Silicon, NPN, TO-39 Case	04713	MM3003	TG-58	32

INTEGRATOR BOARD, "300" SERIES (PC-301)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C301	.05 μ F	50 V	MPC	14752	625B1A503-J	C201-.05M	34
C302	.015 μ F	50 V	MPC	14752	625B1A153-J	C201-.015M	34
C303	.15 μ F	50 V	MPC	14752	625B1A154-J	C201-.15M	34
C304	Not Used	-----	-----	-----	-----	-----	--
C305	Not Used	-----	-----	-----	-----	-----	--
C306	Not Used	-----	-----	-----	-----	-----	--
C307	.15 μ F	50 V	MPC	14752	625B1A154-J	C201-.15M	34
C308	10 μ F	20 V	ETT	17554	TD2-20-106-20	C179-10M	34
C309	10 μ F	20 V	ETT	17554	TD2-20-106-20	C179-10M	34
C310	.15 μ F	50 V	MPC	14752	625B1A154-J	C201-.15M	34
C311	Not Used	-----	-----	-----	-----	-----	--
C312	.1 μ F	100 V	Poly	97419	PYW-R	C142-.1M	34
C313	47 pF	1000 V	CerD	71590	DD-470	C64-47P	34
C314	.0022 μ F	1000 V	CerD	56289	10SS-D-22	C64-.0022M	34
C315	Not Used	-----	-----	-----	-----	-----	--
C316	33 pF	1000 V	CerD	71590	DD-330	C64-33P	34
C317	1.0 μ F	50 V	MPC	14752	625B1A105-J	C201-M	34
C318	100 μ F	15 V	ETT	17554	TSD5-15-107-A	C205-100M	34
C319	Not Used	-----	-----	-----	-----	-----	--
C320	100 μ F	15 V	ETT	17554	TSD5-15-107-A	C205-100M	34
C321	5 pF	1000 V	CerD	71590	DD-050	C64-5P	34
C322	100 μ F	15 V	ETT	17554	TSD5-15-107-A	C205-100M	34
C323	5 pF	1000 V	CerD	71590	DD-050	C64-5P	34
C324	Not Used	-----	-----	-----	-----	-----	--
C325	10 μ F	20 V	ETT	17554	TD2-20-106-20	C179-10M	34
C326	100 μ F	15 V	ETT	17554	TSD5-15-107-A	C205-100M	34
C327	10 μ F	20 V	ETT	17554	TD2-20-106-20	C179-10M	34
C328	.0022 μ F	1000 V	CerD	56289	10SS-D22	C64-.0022M	34
C329	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	34
C330	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	34
C331	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	34

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D301	Not Used	-----	-----	-----	--
D302	Not Used	-----	-----	-----	--
D303	Silicon, Zener, 9V, 1/2 W	04713	1N938	DZ-6	34
D304	Silicon, Zener, 9V, 1/2 W	04713	1N938	DZ-6	34
D305	Not Used	-----	-----	-----	--
D306	Not Used	-----	-----	-----	--
D307	Silicon	01295	1N914	RF-28	34
D308	Silicon	01295	1N914	RF-28	34
D309	Not Used	-----	-----	-----	--
D310	Silicon	01295	1N914	RF-28	34
D311	Silicon	01295	1N914	RF-28	34
D312	Silicon	01295	1N914	RF-28	34
D313	Silicon	01295	1N914	RF-28	34
D314	Silicon, Zener, 6.2V, 0.4 W	06751	1N823	DZ-36	34

INTEGRATOR BOARD (PC-301) (continued)

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA301	Operational Amplifier, TO-99 Case, 8-pin	12040	SL12916	IC-2	34
QA302	Operational Amplifier, TO-99 Case, 8-pin	12040	SL12916	IC-2	34
QA303	Operational Amplifier, TO-99 Case, 8-pin	12040	SL12916	IC-2	34
QA304	Voltage Comparator, TO-99 Case, 8-pin	12040	LM311	IC-29	34
QA305	Positive NAND Gates, 14-pin DIP	01295	SN7401	IC-47	34
QA306	Positive NOR Gates, 14-pin DIP	01295	SN7402N	IC-32	34
QA307	Hex Inverters, 14-pin DIP	01295	SN7404N	IC-33	34

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R301	10 k Ω	0.6 W	Var	80294	3279W	RP94-10K	34
R302	1 M Ω	1%, 1/8 W	MtF	91637	MFF-1/8	R88-1M	34
R303	1 M Ω	1%, 1/8 W	MtF	91637	MFF-1/8	R88-1M	34
R304	100 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-100	34
R305	392 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-392K	34
R306	15 k Ω	10%, 1/4 W	Comp	01121	CB-153-10%	R76-15K	34
R307	100 k Ω	10%, 1/4 W	Comp	01121	CB-104-10%	R76-100K	34
R308	56 k Ω	10%, 1/4 W	Comp	01121	CB-56-10%	R76-56K	34
R309	100 Ω	10%, 1/4 W	Comp	01121	CB-101-10%	R76-100	34
R310	1 k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-1K	34
R311	820 Ω	10%, 1/4 W	Comp	01121	CB-821-10%	R76-820	34
R312	15 k Ω	10%, 1/4 W	Comp	01121	CB-153-10%	R76-15K	34
R313	4.7 k Ω	10%, 1/4 W	Comp	01121	CB-472-10%	R76-4.7K	34
R314	33 k Ω	10%, 1/4 W	Comp	01121	CB-333-10%	R76-33K	34
R315	1 k Ω	10%, 1/4 W	Comp	01121	CB-102-10%	R76-1K	34
R316	1 k Ω	10%, 1/4 W	Comp	01121	CB-102-10%	R76-1K	34
R317	18 k Ω	10%, 1/4 W	Comp	01121	CB-183-10%	R76-18K	34
R318	22 k Ω	10%, 1/4 W	Comp	01121	CB-223-10%	R76-22K	34
R319	1 k Ω	10%, 1/4 W	Comp	01121	CB-102-10%	R76-1K	34
R320	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	34
R321	715 Ω	1%, 1/2 W	MtF	07716	3279W	R113-175	34
R322	1 k Ω	0.6 W	Var	80294	3279W	RP94-1K	34
R323	301 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-301	34
R324	10 Ω	.25%, 1/2W	MtF	07716	CEC-T-0	R127-10	34
R325	33.3 k Ω	.01%, 1/4W	--	17870	1283	R194-33.3K	34
R326	100 Ω	0.6 W	Var	80294	502-00HS	RP94-100	34
R327	1 k Ω	0.6 W	Var	80294	502-00S-1k	RP94-1K	34
R328	9.1 k Ω	.01%, 1/4W	--	17870	1283	R194-9.1K	34
R329	9.1 k Ω	.01%, 1/4W	--	17870	1283	R194-9.1K	34
R330	1 k Ω	0.6 W	Var	80294	3279W	RP94-1K	34
R331	100 Ω	0.6 W	Var	80294	3279W	RP94-100	34
R332	33.3 k Ω	0.1%, 1/4W	--	17870	1283	R194-33.3K	34
R333	200 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-200	34
R334	200 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-200	34
R335	10 Ω	.25%, 1/2W	MtF	07716	CEC-T-0	R127-10	34
R336	1 k Ω	0.6 W	Var	80294	3279W	RP94-1K	34
R337	301 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-301	34
R338	715 Ω	1%, 1/2 W	MtF	07716	CEC-T-9	R113-175	34
R339	18 k Ω	10%, 1/4 W	Comp	01121	CB-183-10%	R76-18K	34
R340	22 k Ω	10%, 1/4 W	Comp	01121	CB-223-10%	R76-22K	34

INTEGRATOR BOARD (PC-301) (continued)

RESISTORS (continued)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R341	1 k Ω	10%, 1/4 W	Comp	01121	CB-102-10%	R76-1K	34
R342	392 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-392K	34
R343	100 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-100K	34
R344	1 M Ω	1%, 1/8 W	MtF	91637	MFF-1/8	R88-1M	34
R345	301 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-301K	34
R346	301 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-301K	34
R347	47 Ω	10%, 1/4 W	Comp	01121	CB-470-10%	R76-47	34
R348	2.2 k Ω	10%, 1/4 W	Comp	01121	CB-222-10%	R76-2.2K	34
R349	4.7 Ω	10%, 1/4 W	Comp	01121	CB-47R-10%	R76-4.7	34
R350	4.7 Ω	10%, 1/4 W	Comp	01121	CB-47R-10%	R76-4.7	34
R351	1 M Ω	1%, 1/8 W	MtF	91637	MFF-1/8	R88-1M	34
R352	4.7 Ω	10%, 1/4 W	Comp	01121	CB-47R-10%	R76-4.7	34
R353	1 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-1K	34
R354	32.4 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-32.4K	34
R355	634 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-634	34
R356	10 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-10K	34
R357	20 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-20K	34
R358	2.8 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-2.8K	34
R359	2.49 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-2.49K	34
R360	2.8 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-2.8K	34
R361	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	34
R362	Not Used	-----	-----	-----	-----	-----	---
R363	1.8 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-1.8K	34
R364	1 k Ω	10%, 1/4 W	Comp	01121	CB-102-10%	R76-1K	34
R365	4.7 k Ω	10%, 1/4 W	Comp	01121	CB-47R-10%	R76-4.7K	34
*R366	80.6 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-80.6K	34
R367	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	34
R368	4.7 k Ω	10%, 1/4 W	Comp	01121	CB-472-10%	R76-4.7K	34
R369	100 Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-100	34
*R370	232 k Ω	1%, 1/8 W	MtF	07716	CEA-T-0	R88-232K	34

*Nominal value, selected during cal.

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q301	N-Channel JFET, Case R110	32293	ITE4391	TG-76	34
Q302	P-Channel FET, Case TO-72	80164	Selected	25740A	34
Q303	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	34
Q304	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	34
Q305	N-Channel JFET, Case R110	32293	ITE4391	TG-76	34
Q306	Silicon, NPN, Case TO-106	07263	2N5134	TG-65	34
Q307	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	34
Q308	P-Channel FET, Case TO-72	80164	Selected	25740A	34
Q309	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	34
Q310	P-Channel FET, Case TO-72	80164	Selected	25740A	34
Q311	Not Used	-----	-----	-----	---
Q312	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	34
Q313	Dual N-Channel JFET, Case TO-18	32293	2N3956	TG-74	34
Q314	Not Used	-----	-----	-----	---
Q315	N-Channel JFET, Case R110	32293	ITE4391	TG-76	34
Q316	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	34

CLOCK BOARD, "400" SERIES (PC-300)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C401	.068 μ F	50 V	MPC	14752	625B1A683-J	C201-.068M	33
C402	.068 μ F	50 V	MPC	14752	625B1A683-J	C201-.068M	33
C403	.0082 μ F	50 V	MPC	14752	625B1A822-J	C201-.0082M	33
C404	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	33
C405	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	33
C406	10 μ F	20 V	ETT	17554	CCL-020-10610	C80-10M	33
C407	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	33
C408	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	33
C409	.01 μ F	500 V	CerD	56289	5GAS-S10	C22-.01M	33
C410	.47 μ F	50 V	CerF	72982	8131-050-651-474M	C237-.47M	33

DIODES

D401	Silicon	07263	1N4607	RF-41	33
D402	Germanium	15238	1N3592	RF-39	33
D403	Germanium	15238	1N3592	RF-39	33
D404	Silicon	01295	1N645	RF-14	33
D405	Silicon	01295	1N914	RF-28	33
D406	Silicon	01295	1N914	RF-28	33

MISCELLANEOUS

J401	Not Used	.....	.....	.....	.....
J402	Connector, Card-Edge Type, 44-pins (Mates with PC-299).	09922	PSCADD(22)-12	CS-205	33
J403	Connector, Card-Edge Type, 22-pins (Mates with PC-301).	09922	PSC4SS(22)-12	CS-182	33
J404	Not Used	.....	.....	.....	.....
P401	Not Used	.....	.....	.....	.....
P402	Part of PC-299	.....	.....	.....	33
P403	Part of PC-301	.....	.....	.....	33
P404	Not Used	.....	.....	.....	.....
QA401	Positive NOR Gates, 14-pin DIP	01295	SN7402N	IC-32	33
QA402	Positive NOR Gates, 14-pin DIP	01295	SN7402N	IC-32	33
QA403	Decade Counters, 14-pin DIP	01295	SN7490N	IC-37	33
Y401	Crystal Resonator, 200kHz.	00815	NE-6E	CR-3	33
--	Jumper	.....	.....	J-3	33

TRANSISTORS

Q401	Silicon, NPN, Case TO-106	07263	2N5134	TG-65	33
Q402	Silicon, Unijunction, Case TO-72	03508	2N2646	TG-52	33
Q403	Silicon, NPN, Case TO-106	07263	2N5134	TG-65	33

RESISTORS

R401	402 Ω	1%, 1/8 W	MtF	75042	CEA-T-0	R88-402	33
R402*	301 Ω	1%, 1/8 W	MtF	75042	CEA-T-0	R88-301	33
R403	220 Ω	10%, 1/4W	Comp	01121	CB221-10%	R76-220	33
R404	470 Ω	10%, 1/4W	Comp	01121	CB471-10%	R76-470	33
R405	3.9k Ω	10%, 1/4W	Comp	01121	CB392-10%	R76-3.9K	33
R406	3.9k Ω	10%, 1/4W	Comp	01121	CB392-10%	R76-3.9K	33
R407	1.5k Ω	10%, 1/4W	Comp	01121	CB152-10%	R76-1.5K	33
R408	Not Used	-----	-----	-----	-----	-----	---
R409	220 Ω	10%, 1/4W	Comp	01121	CB221-10%	R76-220	33
R410	22 k Ω	10%, 1/4W	Comp	01121	CB223-10%	R76-22K	33
R411	1 k Ω	1%, 1/8 W	MtF	75042	CEA-T-0	R88-1K	33
R412	100 Ω	10%, 1/4W	Comp	01121	CB101-10%	R76-100	33
R413	1.5k Ω	10%, 1/4W	Comp	01121	CB152-10%	R76-1.5K	33
R414	330 Ω	10%, 1/4W	Comp	01121	CB331-10%	R76-330	33
R415	10 k Ω	10%, 1/4W	Comp	01121	CB103-10%	R76-10K	33
R416	68 Ω	10%, 1/4W	Comp	01121	CB680-10%	R76-68	33
R417	4.02k Ω	1%, 1/8 W	MtF	75042	CEA-T-0	R88-4,02K	33
R418	10 k Ω	10%, 1/4W	Comp	01121	CB103-10%	R76-10K	33
R419	Not Used	-----	-----	-----	-----	-----	---
R420*	500 Ω	0.75W	Cermet Variable	BECK	89P-500 Ω	RP-89-500	33

*Alternate construction as shown on Schematic 25098D.

ISOLATOR BOARD, "500" SERIES (PG-274)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C501	0.01 μ F	500 V	CerD	72982	871-Z5U0-103M	C22-0.01M	29
C502	100 μ F	25 V	EAL	29309	JC8100258P	C211-100M	29
C503	100 μ F	25 V	EAL	29309	JC8100258P	C211-100M	29
C504	0.01 μ F	500 V	CerD	72982	871-Z5U0-103M	C22-0.01M	29
C505	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0M	29
C506	0.02 μ F	500 V	CerD	72982	811-Z5U0-203M	C22-0.02M	29
C507	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0M	29
C508	0.02 μ F	500 V	CerD	72982	811-Z5U0-203M	C22-0.02M	29
C509	0.1 μ F	50 V	My	84411	601PE-0.1 μ F	C41-0.1M	29
C510	100 μ F	40 V	EAL	73445	C437AR/G100	C150-100M	29
C511	100 μ F	40 V	EAL	73445	C437AR/G100	C150-100M	29
C512	200 μ F	35 V	EAL	90201	MTV200N35PDN	C177-200M	29
C513	0.01 μ F	500 V	CerD	72982	871-Z5U0-103M	C22-0.01M	29
C514	10 μ F	20 V	ETT	17554	TSD2-20-106	C179-10M	29
C515	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0	29
C516	0.01 μ F	500 V	CerD	72982	871-5U0-103M	C22-0.01M	29
C517	1.2 μ F	20 V	ETT	17554	TSD1-20-125	C179-1.2M	29
C518	100 μ F	40 V	EAL	73445	C437AR/G100	C150-100M	29
C519	200 μ F	35 V	EAL	90201	MTV200N35PDN	C177-200M	29
C520	1.0 μ F	50 V	CerF	72982	8131050651	C237.1.0	29
C521	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0	29
C522	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0	29
C523	1.0 μ F	50 V	MPolyC	14752	636A1A105	C213-1.0M	29
C524	10 μ F	20 V	ETT	17554	TSD1-20-106	C179-10M	29
C525	10 μ F	20 V	ETT	17554	TSD2-20-106	C179-10M	29
C526	330 pF	1000 V	CerD	71590	DD-331-10%	C64-330P	29
C527	0.5 μ F	50 V	MPolyC	14752	625B1A-0.5	C201-0.5M	29
C528	0.22 μ F	50 V	My	84411	601PE-.22 μ F	C41-0.22M	29
C529	0.1 μ F	50 V	My	84411	601PE-.1 μ F	C41-0.1M	29
C530	470 pF	1000 V	Cer D	71590	DD471-10%	C64-470P	29

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D501	Rectifier	07263	1N4607	RF-41	29
D502	Rectifier	07263	1N4607	RF-41	29
D503	Rectifier	07263	1N4607	RF-41	29
D504	Rectifier	07263	1N4607	RF-41	29
D505	Rectifier	07263	1N4607	RF-41	29
D506	Rectifier	07263	1N4607	RF-41	29
D507	Rectifier	07263	1N4607	RF-41	29
D508	Rectifier	07263	1N4607	RF-41	29

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA501	Dual J-K Flip-Flop, 14-pin, DIP	01295	SN7473N	IC-54	29
QA502	Dual J-K Flip-Flop, 14-pin, DIP	01295	SN7473N	IC-54	29
QA503	Voltage Regulator, 14-pin, DIP	07263	U6A7723393	IC-25	29
QA504	Voltage Regulator, 14-pin, DIP	07263	U6A7723393	IC-25	29
QA505	Operational Amplifier, 8-pin, Case TO-99	24355	AD504L	IC-56	29

ISOLATOR BOARD (PC-274) continued

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q501	NPN, Case TO-106	07263	2N5134	TG-65	29
Q502	NPN, Power, Case TO-5	86684	2N2102	TG-87	29
Q503	NPN, Case TO-5	02734	40317	TG-43	29
Q504	NPN, Case TO-106	07263	2N5134	TG-65	29
Q505	NPN, Case TO-106	07263	2N5134	TG-65	29
Q506	NPN, Case TO-106	07263	2N5134	TG-65	29
Q507	NPN, Power, Case TO-5	86684	2N2102	TG-87	29
Q508	PNP, Case TO-106	07263	2N5140	TG-111	29
Q509	P-Channel FET, Case TO-72	--	--	25740A*	29
Q510	PNP, Case TO-106	07263	2N5140	TG-111	29
Q511	PNP, Case TO-106	07263	2N5140	TG-111	29
Q512	PNP, Case TO-106	07263	2N5140	TG-111	29
Q513	P-Channel MOS FET, Case TO-72	--	--	25740A*	29
Q514	P-Channel MOS FET, Case TO-72	73293	HDGP1001	TG-86	29
Q515	P-Channel MOS FET, Case TO-72	73293	HDGP1001	TG-86	29
Q516	NPN, Case TO-106	07263	2N5134	TG-65	29
Q517	PNP, Case TO-5	02734	40319	TG-50	29
Q518	PNP, Case TO-106	07263	2N5139	TG-66	29

*Selected at factory

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R501	4.7k Ω	10%, 1/4 W	Comp	01121	CB-472-10%	R76-4.7k	29
R502	4.7k Ω	10%, 1/4 W	Comp	01121	CB-472-10%	R76-4.7k	29
R503	680 Ω	10%, 1/4 W	Comp	01121	CB-681-10%	R76-680	29
R504	330 Ω	10%, 1/4 W	Comp	01121	CB-331-10%	R76-330	29
R505	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	29
R506	180 Ω	10%, 1/4 W	Comp	01121	CB-181-10%	R76-180	29
R507	470 Ω	Sensitor				RT-3	29
R508	10 Ω	10%, 1/4 W	Comp	01121	CB-100-10%	R76-10	29
R509	10k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-10k	29
R510	10k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-10k	29
R511	47k Ω	10%, 1/4 W	Comp	01121	CB-473-10%	R76-47k	29
R512	2.7 Ω	10%, 1/2 W	Comp	01121	EB-2.7 Ω	R1-2.7	29
R513	3.01k Ω	1%, 1/8 W	MeF	07716	CEA-3.01k Ω	R88-3.01k	29
R514	500 Ω	0.75 W	Cermet V	73138	89P-500.1	RP89-500	29
R515	1.8k Ω	10%, 1/4 W	Comp	01121	CB-182-10%	R76-1.8k	29
R516	3.01k Ω	1%, 1/8 W	MeF	07716	CEA-3.01k Ω	R88-3.01k	29
R517	680 Ω	10%, 1/4 W	Comp	01121	CB-681-10%	R76-680	29
R518	680 Ω	10%, 1/4 W	Comp	01121	CB-681-10%	R76-680	29
R519	680 Ω	10%, 1/4 W	Comp	01121	CB-681-10%	R76-680	29
R520	330 Ω	10%, 1/4 W	Comp	01121	CB-331-10%	R76-330	29
R521	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	29
R522	Not used						29
R523	180 Ω	10%, 1/4 W	Comp	01121	CB-181-10%	R76-180	29
R524	10 Ω	10%, 1/4 W	Comp	01121	CB-100-10%	R76-10	29
R525	28.7k Ω	1%, 1/8 W	MeF	07716	CEA-28.7k Ω	R88-28.7k	29
R526	47k Ω	10%, 1/4 W	Comp	01121	CB-473-10%	R76-47k	29
R527	3.01k Ω	1%, 1/8 W	MeF	07716	CEA-3.01k Ω	R88-3.01k	29
R528	4.02k Ω	1%, 1/8 W	MeF	07716	CEA-4.02k Ω	R88-4.02k	29
R529	2.2k Ω	10%, 1/4 W	Comp	01121	CB-222-10%	R76-2.2k	29
R530	10k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-10k	29

RESISTORS (cont'd.)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R531	1M Ω	10%, 1/4 W	Comp	01121	CB-105-10%	R76-1M	29
R532	10k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	29
R533	1.8k Ω	10%, 1/4 W	Comp	01121	CB-182-10%	R76-1.8k	29
R534	500 Ω	0.75 W	CermetV	73138	89P-500 Ω	RP89-500	29
R535	1.24k Ω	1%, 1/8 W	MtF	07716	CEA-1.24k Ω -1%	R88-1.24k	29
R536	3.01k Ω	1%, 1/8 W	MtF	07716	CEA-3.01k Ω -1%	R88-3.01k	29
R537	2.7 Ω	10%, 1/2 W	Comp	01121	EB-2.7 Ω	R1-2.7	29
R538	2.2k Ω	10%, 1/4 W	Comp	01121	CB-222-10%	R76-2.2k	29
R539	10k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-10k	29
R540	10k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-10k	29
R541	10k Ω	10%, 1/4 W	Comp	01121	CB-103-10%	R76-10k	29
R542	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	29
R543	2.2k Ω	10%, 1/4 W	Comp	01121	CB-222-10%	R76-2.2k	29
R544	1M Ω	10%, 1/4 W	Comp	01121	CB-105-10%	R76-1M	29
R545	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	29
R546	2.2k Ω	10%, 1/4 W	Comp	01121	CB-222-10%	R76-2.2k	29
R547	1M Ω	10%, 1/4 W	Comp	01121	CB-105-10%	R76-1M	29
R548	1M Ω	10%, 1/4 W	Comp	01121	CB-105-10%	R76-1M	29
R549	3k Ω	0.25%, 1/4W	WW	15909	1350-3k Ω	R195-3k	29
R550	700 Ω	0.25%, 1/4W	WW	15909	1350-700 Ω	R195-700	29
R551	20k Ω	1%, 1/8 W	MtF	07716	CEA-20k Ω -1%	R88-20k	29
R552	11.35k Ω	0.25%, 1/4W	WW	15909	1350-11.35k	R195-11.35k	29
R553	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	29
R554	100 Ω	10%, 1/4 W	Comp	01121	CB-101-10%	R76-100	29
R555	470 Ω	10%, 1/4 W	Comp	01121	CB-471-10%	R76-470	29
R556	35.9k Ω	0.25%, 1/4W	WW	15909	1350-35.9k	R195-35.9k	29
R557	2k Ω	0.75 W	CermetV	73138	89P-2k Ω	RP-89-2k	29
R558	10M Ω	1%, 1/2 W	DCb	91637	DCF-1/2-10M Ω	R12-10M	29
R559	* 8.06k Ω	1%, 1/8 W	MtF	07716	CEA-8.06k Ω	R88-8.06k	29
R560	Not Used						
R561	* 14k Ω	1%, 1/8 W	MtF	07716	CEA-14k Ω	R88-14k	29
R562	7.6k Ω	0.25%, 1/4W	WW	15909	1350-7.6k Ω	R195-7.6k	29

*Nominal value

TRANSFORMERS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
T501	Drive for isolator	80164	---	TR-137	29
T502	Isolation for $\pm 15V$ Regulator	80164	---	TR-135	29
T503	Isolation for analog signal	80164	---	TR-151	29

CHOPPER DRIVE, "600" SERIES (PC-273)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C601	.047 μF	400 V	Poly	97419	M2W-F-.047 μF	C197-.047M	28
C602	100 μF	15 V	ETT	06751	TSD-100 μF	C205-100M	28
C603	1.5 μF	50 V	MPC	14752	625B1A-1.5 μF	C201-1.5M	28
C604	.0022 μF	100 V	Poly	13934	E3FR2221C	C152-.0022M	28
C605	.0022 μF	100 V	Poly	13934	E3FR2221C	C152-.0022M	28
C606	1.5 μF	50 V	MPC	14752	625B1A-1.5 μF	C201-1.5M	28
C607	100 μF	15 V	EAL	29309	JC6100158P	C210-100M	28
C608	100 μF	15 V	EAL	29309	JC6100158P	C210-100M	28
C609	100 μF	15 V	EAL	29309	JC6100158P	C210-100M	28
C610	100 μF	15 V	EAL	29309	JC6100158P	C210-100M	28

CHOPPER DRIVE (PC-273) continued

CAPACITORS (Cont'd)

Circuit Desig.	Value	Rate	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C611	400 μ F	35 V	EAL	29309	JC12400358P	C212-400M	28
C612	400 μ F	35 V	EAL	29309	JC12400358P	C212-400M	28
C613	10 μ F	20 V	ETT	17554	TSD1-20-10 μ F	C179-10	28
C614	10 μ F	20 V	ETT	17554	TSD1-20-10 μ F	C179-10	28
C615	.001 μ F	1000 V	CerD	72982	801000X5F0102K	C64-.001M	28
C616	.001 μ F	1000 V	CerD	72982	801000X5F0102K	C64-.001M	28

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA601	Voltage Comparator, 8-pin, TO-99 Case	12040	LM311	IC-29	28
QA602	Decade Counters, 14-pin DIP	01295	SN7490N	IC-37	28
D601	Silicon	01295	1N914	RF-28	28
D602	Silicon	01295	1N914	RF-28	28

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R601	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28
R602	2.8 k Ω	1%, 1/8 W	MtF	07716	CEA-2.8k Ω -1%	R88-2.8k	28
R603	604 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-604 Ω	R12-604	28
R604	370 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-370 Ω	R12-370	28
R605	1 M Ω	10%, 1/4 W	Comp	44655	CB-105-10%	R76-1M	28
R606	1.5 k Ω	1%, 1/8 W	MtF	07716	CEA-1.5k Ω -1%	R88-1.5k	28
R607	15 k Ω	1%, 1/8 W	MtF	07716	CEA-15k Ω -1%	R88-15k	28
R608	47 k Ω	10%, 1/4 W	Comp	44655	CB-473-10%	R76-47k	28
R609	15 k Ω	1%, 1/8 W	MtF	07716	CEA-15k Ω -1%	R88-15k	28
R610	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	28
R611	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	28
R612	15 k Ω	1%, 1/8 W	MtF	07716	CEA-15k Ω -1%	R88-15k	28
R613	47 k Ω	10%, 1/4 W	Comp	44655	CB-473-10%	R76-47k	28
R614	15 k Ω	1%, 1/8 W	MtF	07716	CEA-15k Ω -1%	R88-15k	28
R615	1.5 k Ω	1%, 1/8 W	MtF	07716	CEA-1.5k Ω -1%	R88-1.5k	28
R616	1 M Ω	10%, 1/4 W	Comp	44655	CB-105-10%	R76-1M	28
R617	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	28
R618	100 k Ω	1%, 1/8 W	MtF	07716	CEA-100k Ω -1%	R88-100k	28
R619	100 k Ω	1%, 1/8 W	MtF	07716	CEA-100k Ω -1%	R88-100k	28
R620	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	28
R621	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28
R622	10 Ω	10%, 1/4 W	Comp	44655	CB-100-10%	R76-10	28
R623	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28
R624	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28
R625	10 Ω	10%, 1/4 W	Comp	44655	CB-100-10%	R76-10	28
R626	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28
R627	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28
R628	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	28

TRANSISTORS

Q601	NPN, Case TO-5	02734	40317	TG-43	28
Q602	Silicon, PNP, TO-92 Case	04713	2N5087	TG-61	28
Q603	Silicon, PNP, TO-92 Case	04713	2N5087	TG-61	28
Q604	Silicon, PNP, TO-92 Case	04713	2N5087	TG-61	28
Q605	Silicon, PNP, TO-92 Case	04713	2N5087	TG-61	28
Q606	NPN, TO-92 Case	04713	2N3904	TG-47	28
Q607	Silicon, NPN, TO-92 Case	04713	2N5089	TG-62	28
Q608	PNP, TO-92 Case	04713	2N3905	TG-53	28
Q609	PNP, TO-92 Case	04713	2N3905	TG-53	28

AC AMPLIFIER "700" SERIES (PC-282)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C701	.10 μ F	50 V	My	84411	601PE	C41-.10M	27
C702	Selected*	1000 V	CerD	-	-	C64-*	27
C703	Selected*	1000 V	CerD	-	-	C64-*	27
C704	Selected*	1000 V	CerD	-	-	C64-*	27
C705	Selected*	1000 V	CerD	-	-	C64-*	27
C706	Selected*	1000 V	CerD	-	-	C64-*	27
C707	22 μ F	10 V	ETT	17554	TSD 22 μ F	C180-22M	27
C708	0.05 μ F	50 V	MPC	14752	625B1A-.05 μ F	C201-.05M	27
C709	100 pF	1000 V	CerD	71590	DD-101-10%	C64-100P	27
C710	33 pF	1000 V	CerD	71590	DD-330	C64-33P	27
C711	33 pF	1000 V	CerD	71590	DD-330	C64-33P	27
C712	33 pF	1000 V	CerD	71590	DD-330	C64-33P	27
C713	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0M	27
C714	1.0 μ F	50 V	CerF	72982	8131050651	C237-1.0M	27
C715	33 pF	1000 V	CerD	71590	DD-330	C64-33P	27
C716	5 μ F	50 V	MPC	14752	625B1A-5 μ F	C201-5M	27
C717	33 pF	1000 V	CerD	71590	DD-330	C64-33P	27
C718	125 μ F	10 V	ETT	05079	TES12510C2NK	C217-125M	27
C719	7-25 pF	350 V	Trimmer	72982	53801193R	C89-7/25P	27

* Selected in calibration

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D701	Zener, 5.8V	12954	1N706	DZ-1	27
D702	Zener, 5.8V	12954	1N706	DZ-1	27
D703	Zener, 6V, 400 mW (Selected)**	12954	**1N754A	DZ-50	27
D704	Zener, 6V, 400 mW (Selected)**	12954	**1N754A	DZ-50	27

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
IA701	Operational Amplifier, 8-Pin, DIP	12040	LM301AN	IC-24	27
IA702	Operational Amplifier, 8-Pin, DIP	12040	LM301AN	IC-24	27
IA703	Operational Amplifier, 8-Pin, DIP	12040	LM301AN	IC-24	27
IA704	Operational Amplifier, 8-Pin, DIP		Special	IC-76	27
IA705	Operational Amplifier, 8-Pin, DIP		Special	IC-76	27

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R701	100 k Ω	1%, 1/8 W	MtF	07716	CEA-100K Ω -1%	R88-100k	27
R702	8.87 k Ω	1%, 1/8 W	MtF	07716	CEA-8.87K Ω -1%	R88-8.87k	27
R703	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1K Ω -1%	R88-1k	27
R704	14 k Ω	1%, 1/8 W	MtF	07716	CEA-14K Ω -1%	R88-14k	27
R705	Selected*	1%, 1/8 W	MtF	07716	CEA*	R88-*	27

* Selected in calibration

AC AMPLIFIER (PC-282) continued

RESISTORS (cont'd.)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R706	Selected*	1%, 1/8 W	MtF	07716	CEA-*	R88-*	27
R707	Selected*	1%, 1/8 W	MtF	07716	CEA-*	R88-*	27
R708	Selected*	1%, 1/8 W	MtF	07716	CEA-*	R88-*	27
R709	Selected*	1%, 1/8 W	MtF	07716	CEA-*	R88-*	27
R710	17.4 k Ω	1%, 1/8 W	MtF	07716	CEA-*	R88-17.4k	27
R711	50 k Ω	.75 W	Comp Var	80294	3009P-50K Ω	RP89-50k	27
R712	15 k Ω	1%, 1/8 W	MtF	07716	CEA-15K Ω -1%	R88-15k	27
R713	100 k Ω	1%, 1/8 W	MtF	07716	CEA-100K Ω +1%	R88-100k	27
R714	1 M Ω	1%, 1/8 W	MtF	07716	CEA-1M Ω -1%	R88-1M	27
R715	2.2 M Ω	1%, 1/2 W	DCb	91637	DCF-1/2-2.2Me	R12-2.2M	27
R716	4.99 k Ω	1%, 1/8 W	MtF	07716	CEA-4.99K Ω -1%	R88-4.99k	27
R717	4.99 k Ω	1%, 1/8 W	MtF	07716	CEA-4.99K Ω -1%	R88-4.99k	27
R718	4.99 k Ω	1%, 1/8 W	MtF	07716	CEA-4.99K Ω -1%	R88-4.99k	27
R719	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R720	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R721	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R722	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R723	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R724	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R725	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10K Ω -1%	R88-10k	27
R726	100 k Ω	.75 W	Comp Var	80294	3009P-100K Ω	RP89-100k	27
R727	2.2 M Ω	1%, 1/2 W	DCb	91637	DCF-1/2-2.2M Ω	R12-2.2M	27
R728	49.9 k Ω	1%, 1/8 W	MtF	07716	CEA-49.9K Ω -1%	R88-49.9k	27
R729	40.2 k Ω	1%, 1/8 W	MtF	07716	CEA-40.2K Ω -1%	R88-40.2k	27
R730	10 M Ω	1%, 1/2 W	DCb	91637	DCF-1/2-10M Ω	R12-10M	27
R731	10 k Ω	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	27
R732	330 Ω	10%, 1/4 W	Comp	44655	CB-331-10%	R76-330	27
R733	330 Ω	10%, 1/4 W	Comp	44655	CB-331-10%	R76-330	27
R734	10 k Ω	10%, 1/4 W	Comp	44655	CB-100-10%	R76-10k	27
R735	50 k Ω	.75 W	Comp Var	80294	3009P-50K Ω	RP89-50k	27

* Selected in Calibration

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q701	N-JFET, TO-72 Case	04713	2N4220	TG-42	27
Q702	Silicon, PNP, TO-92 Case	07263	2N404A	TG-99	27
Q703	Silicon, PNP, TO-92 Case	07263	2N404A	TG-99	27
Q704	Silicon, PNP, TO-92 Case	07263	2N404A	TG-99	27
Q705	Silicon, PNP, TO-92 Case	07263	2N404A	TG-99	27
Q706	Silicon, PNP, TO-92 Case	07263	2N404A	TG-99	27
Q707	N-Channel JFET, TO-18 Case	32293	ITE4391	TG-76	27
Q708	N-Channel JFET, TO-18 Case	32293	ITE4391	TG-76	27
Q709	P-Channel, MOS-FET	27832	HGPI1001	TG-86	27
Q710	NPN, TO-5 Case	02734	40317	TG-43	27
Q711	NPN, TO-5 Case	02734	40319	TG-50	27

RELAY BOARD, "800" SERIES (PC-281)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C801	1.2 μ F	20 V	ETT	05397	K1R2J20K	C80-1.2M	31
C802	1.2 μ F	20 V	ETT	05397	K1R2J20K	C80-1.2M	31
C803	1.2 μ F	20 V	ETT	05397	K1R2J20K	C80-1.2M	31
C804	1.2 μ F	20 V	ETT	05397	K1R2J20K	C80-1.2M	31
C805	1.2 μ F	20 V	ETT	05397	K1R2J20K	C80-1.2M	31
C806	1.2 μ F	20 V	ETT	05397	K1R2J20K	C80-1.2M	31

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D801	Silicon	01295	1N914	RF-28	31
D802	Silicon	01295	1N914	RF-28	31
D803	Silicon	01295	1N914	RF-28	31
D804	Silicon	01295	1N914	RF-28	31
D805	Silicon	01295	1N914	RF-28	31
D806	Silicon	01295	1N914	RF-28	31
D807	Silicon	01295	1N914	RF-28	31
D808	Silicon	01295	1N914	RF-28	31

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
K801	Relay, Reed	27682	5300022	RL-37	31
K802	Relay, Reed	27682	5300022	RL-37	31
K803	Relay, Reed	27682	5300022	RL-37	31
K804	Relay, Reed	27682	5300022	RL-37	31
K805	Relay, Reed	27682	5300022	RL-37	31
K806	Relay, Reed	27682	5300022	RL-37	31
QA801	Integrated Circuit, 14-pin DIP	01295	SN7406	IC-62	31

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R801	820 Ω	10%, 1/4 W	Comp	44655	CB-821-10%	R76-820	31
R802	820 Ω	10%, 1/4 W	Comp	44655	CB-821-10%	R76-820	31
R803	820 Ω	10%, 1/4 W	Comp	44655	CB-821-10%	R76-820	31
R804	820 Ω	10%, 1/4 W	Comp	44655	CB-821-10%	R76-820	31
R805	820 Ω	10%, 1/4 W	Comp	44655	CB-821-10%	R76-820	31
R806	820 Ω	10%, 1/4 W	Comp	44655	CB-821-10%	R76-820	31
R807	100 k Ω	10%, 1/4 W	Comp	44655	CB-104-10%	R76-100k	31
R808	220 k Ω	10%, 1/4 W	Comp	44655	CB-221-10%	R76-220k	31
R809	220 k Ω	10%, 1/4 W	Comp	44655	CB-221-10%	R76-220k	31
R810	220 k Ω	10%, 1/4 W	Comp	44655	CB-221-10%	R76-220k	31
R811	220 k Ω	10%, 1/4 W	Comp	44655	CB-221-10%	R76-220k	31
R812	220 k Ω	10%, 1/4 W	Comp	44655	CB-221-10%	R76-220k	31
R813	100 k Ω	10%, 1/4 W	Comp	44655	CB-101-10%	R76-100k	31
R814	8.2 k Ω	10%, 1/4 W	Comp	44655	CB-822-10%	R76-8.2k	31
R815	8.2 k Ω	10%, 1/4 W	Comp	44655	CB-822-10%	R76-8.2k	31
R816	8.2 k Ω	10%, 1/4 W	Comp	44655	CB-822-10%	R76-8.2k	31
R817	8.2 k Ω	10%, 1/4 W	Comp	44655	CB-822-10%	R76-8.2k	31
R818	8.2 k Ω	10%, 1/4 W	Comp	44655	CB-822-10%	R76-8.2k	31

RANGING BOARD, "900" SERIES (PC-280)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C901	10 μ F	20 V	ETT	17554	TSD1-20-10 μ F	C179-10M	30
C902	.0015 μ F	1000 V	CerD	71950	DD-152-10%	C64-.0015M	30
C903	47 pF	1000 V	CerD	71950	DD-470-10%	C64-47P	30
C904	47 pF	1000 V	CerD	71590	DD-470-10%	C64-47P	30
C905	47 pF	1000 V	CerD	71590	DD-470-10%	C64-47P	30
C906	47 pF	1000 V	CerD	71590	DD-470-10%	C64-47P	30

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D901	Germanium	15238	1N3592	RF-39	30
D902	Germanium	15238	1N3592	RF-39	30
D903	Germanium	15238	1N3592	RF-39	30
D904	Germanium	15238	1N3592	RF-39	30

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA901	Up/Down Counter, 16-pin DIP	01295	SN74193N	IC-44	30
QA902	Decoder/Driver, 16-pin DIP	01295	SN7442N	IC-51	30
QA903	Positive NAND Gates, 14-pin DIP	01295	SN7400N	IC-38	30
QA904	Positive NOR Gates, 14-pin DIP	01295	SN7402N	IC-32	30
QA905	Positive NAND Gates, 14-pin DIP	01295	SN7410N	IC-43	30
QA906	Hex Inverters, 14-pin DIP	01295	SN7404N	IC-33	30
QA907	Hex Inverters, 14-pin DIP	01295	SN7404N	IC-33	30
QA908	Positive NAND Gates, 14-pin DIP	01295	SN7400N	IC-38	30

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R901	10 k Ω	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R902	10 k Ω	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R903	10 k Ω	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R904	10 k Ω	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R905	1.5 k Ω	10%, 1/4 W	Comp	44655	CB-102-10%	R76-1.5k	30

RANGING BOARD (PC-280) continued

RESISTORS (cont'd.)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R906	470 Ω	10%, 1/4 W	Comp	44655	CB-471-10%	R76-470	30
R907	220 Ω	10%, 1/4 W	Comp	44655	CB-221-10%	R76-220	30
R908	10 kΩ	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R909	10 kΩ	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R910	10 kΩ	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R911	10 kΩ	10%, 1/4 W	Comp	44655	CB-103-10%	R76-10k	30
R912	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152-10%	R76-1.5k	30
R913	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152-10%	R76-1.5k	30
R914	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152-10%	R76-1.5k	30
R915	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152-10%	R76-1.5k	30
R916	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152-10%	R76-1.5k	30
R917	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152-10%	R76-1.5k	30
R918	82 Ω	10%, 1/2 W	Comp	01121	EB-82Ω-10%	R1-82	30
R919	82 Ω	10%, 1/2 W	Comp	01121	EB-82Ω-10%	R1-82	30
R920	33 Ω	10%, 1/2 W	Comp	01121	EB-33Ω-10%	R1-33	30

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q901	Silicon, NPN, Case TO-104	02735	2N5183	TG-68	30
Q902	Silicon, NPN, Case TO-104	02735	2N5183	TG-68	30
Q903	Silicon, NPN, Case TO-104	02735	2N5183	TG-68	30
Q904	Silicon, NPN, Case TO-92	04713	2N5551	TG-67	30
Q905	Silicon, NPN, Case TO-92	04713	2N5551	TG-67	30
Q906	Silicon, NPN, Case TO-92	04713	2N5551	TG-67	30
Q907	Silicon, NPN, Case TO-92	04713	2N5551	TG-67	30

FILTER - AC AMPLIFIER, "1000" SERIES (PC-278, PC-279)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C1001	2.5 μF	50 V	MPC	14752	636A1A255F	C218-2.5M	25
C1002	2.5 μF	50 V	MPC	14752	636A1A255F	C218-2.5M	25
C1003	5.0 μF	50 V	MPC	14752	636A1A505F	C218-5M	25
C1004	1.5 pF	2000 V	Trim	74970	27311-1.5pF	C184-1.5P	25
C1005	2.0 μF	50 V	MPC	14752	636A1A205	C213-2M	25
C1006	.10 μF	50 V	My	84411	601PE·0.1μF	C41-.1M	26
C1007	10 μF	6 V	ETT	07436	NG106A	C182-10M	26
C1008	33 pF	1000 V	CerD	71590	DD-330-10%	C64-33P	26
C1009	100 μF	15 V	ETT	06751	TSD515107A	C205-100M	26
C1010	.0155 μF	100 V	Poly	84171	PE-153J	C45-.0155M	26
C1011	.0155 μF	100 V	Poly	84171	PE-153J	C45-.0155M	26
C1012	.0155 μF	100 V	Poly	84171	PE-153J	C45-.0155M	26
C1013	33 pF	1000 V	CerD	71590	DD-330-10%	C64-33P	26
C1014	4.7 μF	20 V	ETT	05397	K4R7J20K	C80-4.7M	26
C1015	.0155 μF	100 V	Poly	84171	PE-153J	C45-.0155M	26

FILTER - AC AMPLIFIER (PC-278, PC-279) continued

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D1001	Silicon	01295	1N914	RF-28	25
D1002	Silicon	01295	1N914	RF-28	25
D1003	Silicon	01295	1N914	RF-28	26
D1004	Silicon	01295	1N914	RF-28	26

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA1001	Integrated Circuit, 8-Pin DIP	12040	LM301AN	IC-24	26
QA1002	Integrated Circuit, 8-Pin DIP	12040	LM301AN	IC-24	26
J1001	Terminal, Berg Pin	80164	-	24249A	26
J1002	Terminal, Berg Pin	80164	-	24249A	26
J1003	Terminal, Berg Pin	80164	-	24249A	26
J1004	Terminal, Berg Pin	80164	-	24249A	26
J1005	Terminal, Berg Pin	80164	-	24249A	26
J1006	Terminal, Berg Pin	80164	-	24249A	26
J1007	Not Used	-	-	-	-
S1001	Switch, ZERO SUPPRESS, COARSE	80164	-	SW-346	22a,b
J1008	Connector, Input, Triaxial	80164	-	24613A	22a

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R1001	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	25
R1002	20 k Ω	1%, 1/8 W	MtF	07716	CEA-20k Ω -1%	R88-20k	25
R1003	15 k Ω	1%, 1/8 W	MtF	07716	CEA-15k Ω -1%	R88-15k	25
R1004	1 k Ω	0.6 W	Var	94271	50200S1K	RP94-1k	25
R1005	99 M Ω	1%, 1 W	..	HIMEG	A-60-99M	R-235-99M	25
R1006	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	25
R1007	1060 Ω *	.25%, .33 W	WW	01686	7010-1060 Ω *	R132-1060*	25
R1008	1060 Ω *	.25%, .33 W	WW	01686	7010-1060 Ω *	R132-1060*	25
R1009	200 Ω	.75 W	Comp Var	80294	3009P-200 Ω	RP89-200	25
R1010	499 Ω	1%, 1/8 W	MtF	07716	CEA-499 Ω -1%	R88-499	25
R1011	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	26
R1012	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	26
R1013	10 k Ω	.75 W	Comp Var	80294	3009P-10k Ω	RP89-10k	26
R1014	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	26
R1015	1 k Ω	1%, 1/8 W	MtF	07716	CEA-1k Ω -1%	R88-1k	26
R1016	1 M Ω	1%, 1/8 W	MtF	07716	CEA-1M Ω -1%	R88-1M	26
R1017	9 M Ω	1%, 1/2 W	MtF	91637	HMF-9M Ω	R219-9M	22b
R1018	1.5 M Ω	1%, 1/2 W	MtF	07716	CEC-1.5M Ω -1%	R94-1.5M	22b
R1019	301 k Ω	1%, 1/2 W	MtF	07716	CEC-301k Ω -1%	R94-301K	22b
R1020	150 k Ω	1%, 1/2 W	MtF	07716	CEC-150k Ω -1%	R94-150k	22b
R1021	1 k Ω	1%, 1/2 W	MtF	07716	CEC-1k Ω -1%	R94-1k	22b
R1022	12.1 k Ω	1%, 1/8 W	MtF	07716	CEA-12.1k Ω -1%	R88-12.1k	26
R1023	100 Ω	.01%, .33 W	WW	15909	1283-100 Ω	R196-100	22a
R1024	50 Ω	.75 W	Comp Var	80294	3009P-50 Ω	RP89-50	26
R1025	3 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-5	R12-3	26

*Value for 60 Hz line frequency (1273 Ω for 50 Hz)

FILTER - AC AMPLIFIER (PC-278, PC-279) continued

RESISTORS (cont'd.)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R1026	100 Ω	.01%, 1/4 W	-	15909	1350-100 Ω	R198-100	26
R1027	100 Ω	.75 W	Comp Var	80294	3009P-100 Ω	RP89-100	26
R1028	1900.391 Ω	.01%, 1/4 W	-	15909	1350-1900.391 Ω	R198-1900.391	26
R1029	500 Ω	.75 W	Comp Var	80294	3009P-500 Ω	RP89-500	26
R1030	19903.1 Ω	.01%, 1/4 W	-	15909	1350-19903.1 Ω	R198-19903.1	26
R1031	5 k Ω	.75 W	Comp Var	80294	3009P-5k Ω	RP89-5k	26
R1032	199931 Ω	.01%, 1/4 W	-	15909	1350-199931 Ω	R198-199931	26
R1033	100 k Ω	.75 W	Comp Var	80294	3009P-100k Ω	RP89-100k	26
R1034	2.00021 M Ω	.01%, .4 W	WW	15909	1250-2.00021M Ω	R197-2.0021M	26
R1035	121 Ω	1%, 1/8 W	MtF	07716	CEA-121 Ω -1%	R88-121	26
R1036	6.04 k Ω	1%, 1/8 W	MtF	07716	CEA-6.04k Ω -1%	R88-6.04k	26
R1037	1 M Ω	1%, 1/8 W	MtF	07716	CEA-1M Ω -1%	R88-1M	26
R1038	2.2 M Ω	1%, 1/2 W	DCb	91637	DCF-1/2-2.2M Ω	R12-2.2M	26
R1039	3.01 k Ω	1%, 1/8 W	MtF	07716	CEA-3.01k Ω -1%	R88-3.01k	26
R1040	90.9 k Ω	1%, 1/8 W	MtF	07716	CEA-90.9k Ω -1%	R88-90.9k	26
R1041	4.99 k Ω	1%, 1/8 W	MtF	07716	CEA-4.99k Ω -1%	R88-4.99k	26
R1042	11 k Ω	1%, 1/8 W	MtF	07716	CEA-11k Ω -1%	R88-11k	26
R1043	500 Ω	.75 W	Comp Var	80294	3009P-500 Ω	RP89-500	26
R1044	7.87 k Ω	1%, 1/8 W	MtF	07716	CEA-7.87k Ω -1%	R88-7.87	26
R1045	4.99 k Ω	1%, 1/8 W	MtF	07716	CEA-4.99k -1%	R88-4.99k	26
R1046	500 Ω	.75 W	Comp Var	80294	3009P-500 Ω	RP89-500	26
R1047	32.4 k Ω	1%, 1/8 W	MtF	07716	CEA-32.4k Ω -1%	R88-32.4k	26
R1048	10 k Ω	1%, 1/8 W	MtF	07716	CEA-10k Ω -1%	R88-10k	26
R1049	2 k Ω	1%, 1/8 W	MtF	07716	CEA-2k Ω -1%	R88-2k	26
R1050	2.8 k Ω	1%, 1/8 W	MtF	07716	CEA-2.8k Ω -1%	R88-2.8k	26
R1051	10 k Ω	5% 2 W	WW	12697	62JA-10k Ω	RP42-10k	26
R1052	100 k Ω	1%, 1/8 W	MtF	07716	CEA-100k Ω -1%	R88-100k	26
R1053	9.1 k Ω	.01%, .25W	---	15909	1283-9.1k Ω	R194-9.1k	26
R1054	45.3 k Ω	1%, 1/2 W	MtF	07716	CEC-45.3K Ω	R94-45.3K	22b

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q1001	FET, Case TO-18	94144	RN-1030	TG-51	22376A
Q1002	FET, Case TO-18	94144	RN-1030	TG-51	
Q1003	N-Channel FET, Case TO-72	17856	2N4869A	TG-83	26
Q1004	P-Channel FET, Case TO-72	73293	HDGP1001	TG-86	26

*Order pair from factory using part no. 22376A.

POWER SUPPLY, "1100" SERIES (PC-272)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C1101	2000 μ F	15 V	EAL	29309	JCN2000158P	C210-2000M	24
C1102	100 μ F	15 V	EAL	29309	JC6100158P	C210-100M	24
C1103	200 μ F	35 V	EAL	90201	MTV200N35	C177-200M	24
C1104	200 μ F	35 V	EAL	90201	MTV200N35	C177-200M	24
C1105	200 μ F	35 V	EAL	90201	MTV200N35	C177-200M	24
C1106	200 μ F	35 V	EAL	90201	MTV200N35	C177-200M	24
C1107	10 μ F	350 V	EAL	MATSU	ECE-A350Y10	C-240-10M	24
C1108	400 μ F	35 V	EAL	29309	JC50400358P	C212-400M	24
C1109	2000 μ F	35 V	EAL	29309	JC52000358P	C212-2000M	24
C1110	200 μ F	35 V	EAL	90201	MTV200N35	C177-200M	24

POWER SUPPLY (PC-272) continued

CAPACITORS (cont'd.)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C1111	10 μ F	20 V	ETF	17554	TSD1-20-10 μ F	C179-10M	24
C1112	470 pF	1000 V	CerD	71590	DD-471-10%	C64-470P	24
C1113	100 μ F	25 V	EAL	29309	JC8100258P	C211-100M	24
C1114	100 μ F	25 V	EAL	29309	JC8100258P	C211-100M	24
C1115	390 pF	1000 V	CerD	71590	DD-391-10%	C64-390P	24

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D1101	Silicon	13327	1N4139	RF-34	24
D1102	Silicon	13327	1N4139	RF-34	24
D1103	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1104	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1105	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1106	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1107	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1108	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1109	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1110	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1111	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1112	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1113	Rectifier, 1A, 800V	04713	1N4006	RF-38	24
D1114	Rectifier, 1A, 800V	04713	1N4006	RF-38	24

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA1101	Voltage Regulator, 14-pin, DIP	07263	U6A7723393	1C-25	24
QA1102	5 V Regulator, Case TO-3	12040	LM309K	1C-34	24

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R1101	10 Ω	10%, 1/2 W	Comp	01121	EB-10 Ω -10%	R1-10	24
R1102	1 M Ω	10%, 1/2 W	Comp	01121	EB-1Me-10%	R1-1M	24
R1103	70 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-70 Ω	R12-70	24
R1104	4.7 k Ω	10%, 1/4 W	Comp	44655	CB 472-10%	R76-4.7k	24
R1105	3 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-3 Ω	R12-3	24
R1106	1.8 k Ω	10%, 1/4 W	Comp	44655	CB182-10%	R76-1.8k	24
R1107	4.7 k Ω	10%, 1/4 W	Comp	44655	CB 472-10%	R76-4.7k	24
R1108	3 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-3 Ω	R12-3	24
R1109	3.32 k Ω	1%, 1/8 W	MtF	07716	CEA-3.32K Ω -1%	R88-3.32k	24
R1110	1 k Ω	.75 W	Comp Var	80294	3009P-1K Ω	RP89-1k	24
R1111	3.01 k Ω	1%, 1/8 W	MtF	07716	CEA-3.01K Ω -1%	R88-3.01k	24
R1112	33 k Ω	10%, 1/4 W	Comp	44655	CB 333-10%	R76-33k	24
R1113	15 k Ω	10%, 1/4 W	Comp	44655	CB 153-10%	R76-15k	24
R1114	18 k Ω	10%, 1/4 W	Comp	44655	CB 183-10%	R76-18k	24
R1115	7.5 k Ω	1%, 1/8 W	MtF	07716	CEA-7.5K Ω -1%	R88-7.5k	24
R1116	7.5 k Ω	1%, 1/8 W	MtF	07716	CEA-7.5k Ω -1%	R88-7.5k	24
R1117	330 Ω	3%, 3 W	WW	44655	4400-330 Ω	R92-330	24
R1118	33 k Ω	10%, 1/4 W	Comp	44655	CB 333-10%	R76-33k	24

POWER SUPPLY (PG-272) continued

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q1101	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	24
Q1102	Silicon, Power, NPN, Case TO-5	02734	40317	TG-43	24
Q1103	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	24
Q1104	Silicon, PNP, Case TO-39	04713	MM4003	TG-59	24
Q1105	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	24
Q1106	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	24
Q1107	Silicon, PNP, Case TO-106	07263	2N5139	TG-66	24
Q1201*	Power, Case TO-66	02734	40312	TG-54	22a

*See Schematic 25548E

MAIN CHASSIS, "1200 SERIES"

FRONT PANEL

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.
R1201	Potentiometer, "DISPLAY RATE", 500k Ω , CbVar	71450	GC45-500k	RP75-500k
	Knob assembly, "DISPLAY RATE"	80164	--	24517A
R1202	Potentiometer, "1V ZERO ADJ", 2k Ω , 0.75 W	73138	78LR2K56BW	RP95-2K
S1201	Switch, "POWER ON"	80164	--	SW-271
S1202	Switch, "117-234V" (Located on Rear Panel)	80164	--	SW-318
S1203	Switch, "DISPLAY RATE MAX"	80164	--	SW-346
S1204	Switch, "RANGE", dual concentric	80164	--	SW-333
--	Knob assembly, "LIMIT", inner concentric	80164	--	25066A
--	Knob assembly, "MANUAL", outer concentric	80164	--	25062A
S1001	Switch "ZERO SUPPRESS", outer concentric	80164	--	SW-346
--	Knob assembly, "COARSE", outer concentric	80164	--	25062A
R1051	Potentiometer, "ZERO SUPPRESS", inner concentric	12697	62JA	RP42-10k
--	Knob assembly, "FINE", inner concentric	80164	--	24606A
DS1201	Indicator Lamp	08806	382	PL-55
DS1202	Indicator Lamp	08806	382	PL-55
DS1203	Indicator Lamp	08806	382	PL-55
DS1204	Indicator Lamp	08806	382	PL-55
--	Indicator Module	72619	7111885180	PL-56

REAR PANEL

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.
J1219	Receptacle, Line Voltage	82389	FAC-301	CS-254
P1219	Line Cord, 3-pins	70903	---	CO-7
F1201	Fuse, 3AG, Slo-Blo 117V: 3/4A	71400	MDL-3/4A	FU-19
F1201	Fuse, 3AG, Slo-Blo 234V: 3/8A	71400	MDL-3/8A	FU-18
---	Fuse Holder, Extractor Type	75915	342012	FH-3
T1201	Transformer, Power	80164	---	TR-133
J1211	Connector, 15-pins "REMOTE PROGRAM"	71468	DA-15S	CS-86
P1211	Connector, 15-pins, Mates with J1211	71468	DA-15P	CS-87
---	Cap, Mates with J1211	71468	DA-5920	CAP-11
---	Retainer, Mates with J1211	71468	DA-51220-1	CS-153
J1212	Connector, "ANALOG OUTPUT"	02660	80PC2F	CS-32
P1212	Connector, Mates with J1212	02660	80MC2M	CS-33
J1217	Binding Post, Green, "CASE GND"	58474	DF21GC	BP-11 GRN
J1216	Binding Post, Black, "OUTPUT LO"	58474	DF21BC	BP-11 BLK
---	Shorting Link (for binding posts)	24655	938-L	BP-6
---	Plate, Connector Cover (DIGITAL OUTPUT)	80164	24530A	24530A
S1202	Switch, "117-234V", Slide type	80164	SW-318	SW-318
C1201	Capacitor, 0.01 μ F, 1200V	97419	M2W-R-.01 μ F	C181-.01M
C1202	Capacitor, 1000 pF, 2000 V	ERI	808-25U102M2KV	C-287-1000P
C1203	Capacitor, 1000 pF, 2000 V	ERI	808-25U102M2KV	C-287-1000P

MOTHER BOARD, "1200" SERIES (PC-271)
CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
J1201	Receptacle, Card-Edge Type, 25-pins (Mates with PC-271)	.....	.....	.....	....
J1202	Receptacle, Card-Edge Type, 44-pins (Mates with PC-275)	.....	.....	.....	....
J1203	Receptacle, Card-Edge Type, 44-pins (Mates with PC-300)	.....	.....	.....	....
J1204	Receptacle, Card-Edge Type, 15-pins (Mates with PC-274)	.....	.....	.....	....
J1205	Receptacle, Card-Edge Type, 15-pins (Mates with PC-274)	.....	.....	.....	....
J1206	Receptacle, Card-Edge Type, 44-pins (Mates with PC-280)	.....	.....	.....	....
J1207	Receptacle, Card-Edge Type, 44-pins (Mates with PC-281)	.....	.....	.....	....
J1208	Receptacle, Card-Edge Type, 44-pins (Mates with PC-282)	.....	.....	.....	....
J1209	Receptacle, Card-Edge Type, 44-pins (Mates with PC-279)	.....	.....	.....	....
J1210	Receptacle, Card-Edge Type, 44 pins (Mates with PC-273)	.....	.....	.....	....
J1211	Receptacle, 15-pins, "REMOTE PROGRAM" (Located on Rear Panel)	71468	DA-155	CS-86	3
J1212	Receptacle, 2-pins, "ANALOG OUTPUT" (Located on Rear Panel)	02660	80PC2F	CS-32	3
J1213	Receptacle, 10-pins, Mini-PV (Range Switch Interconnect)	22526	22052	CS-237	22
J1214	Not Used	.....	.....	.....	....
J1215	Not Used	.....	.....	.....	....
J1216	Binding Post, Black, "OUTPUT LO" (Located on Rear Panel)	58474	DF21BC	BP-11BLK	3
J1217	Binding Post, Green, "CASE GND" (Located on Rear Panel)	58474	DF21GC	BP-11GRN	3
J1218	Receptacle, 10-pins, Mini-PV (Remote Program Interconnect)	22526	20052	CS-237	22
J1219	Receptacle for Line Cord (P1219)	82389	FAC-301	CS-254	3
P1201	Part of PC-271	.....	.....	.....	....
P1202	Part of PC-275	.....	.....	.....	....
P1203	Part of PC-300	.....	.....	.....	....
P1204	Part of PC-274	.....	.....	.....	....
P1205	Part of PC-274	.....	.....	.....	....
P1206	Part of PC-280	.....	.....	.....	....
P1207	Part of PC-281	.....	.....	.....	....
P1208	Part of PC-282	.....	.....	.....	....
P1209	Part of PC-279	.....	.....	.....	....
P1210	Part of PC-273	.....	.....	.....	....
P1211	Mating connector for J1211, "REMOTE PROGRAM"	71468	DA-15P	CS-87	3
P1212	Mating connector for J1212, "ANALOG OUTPUT"	02660	80MC2M	CS-33	3
P1213	Mating pins for J1213 (Part of PC-271)	.....	.....	.....	....
P1214	Not Used	.....	.....	.....	....
P1215	Not Used	.....	.....	.....	....
P1216	Not Used	.....	.....	.....	....
P1217	Not Used	.....	.....	.....	....
P1218	Mating pins for J1218 (Part of PC-271)	.....	.....	.....	....
P1219	Line Cord, 3-pins	70903	CO-7	CO-7	3

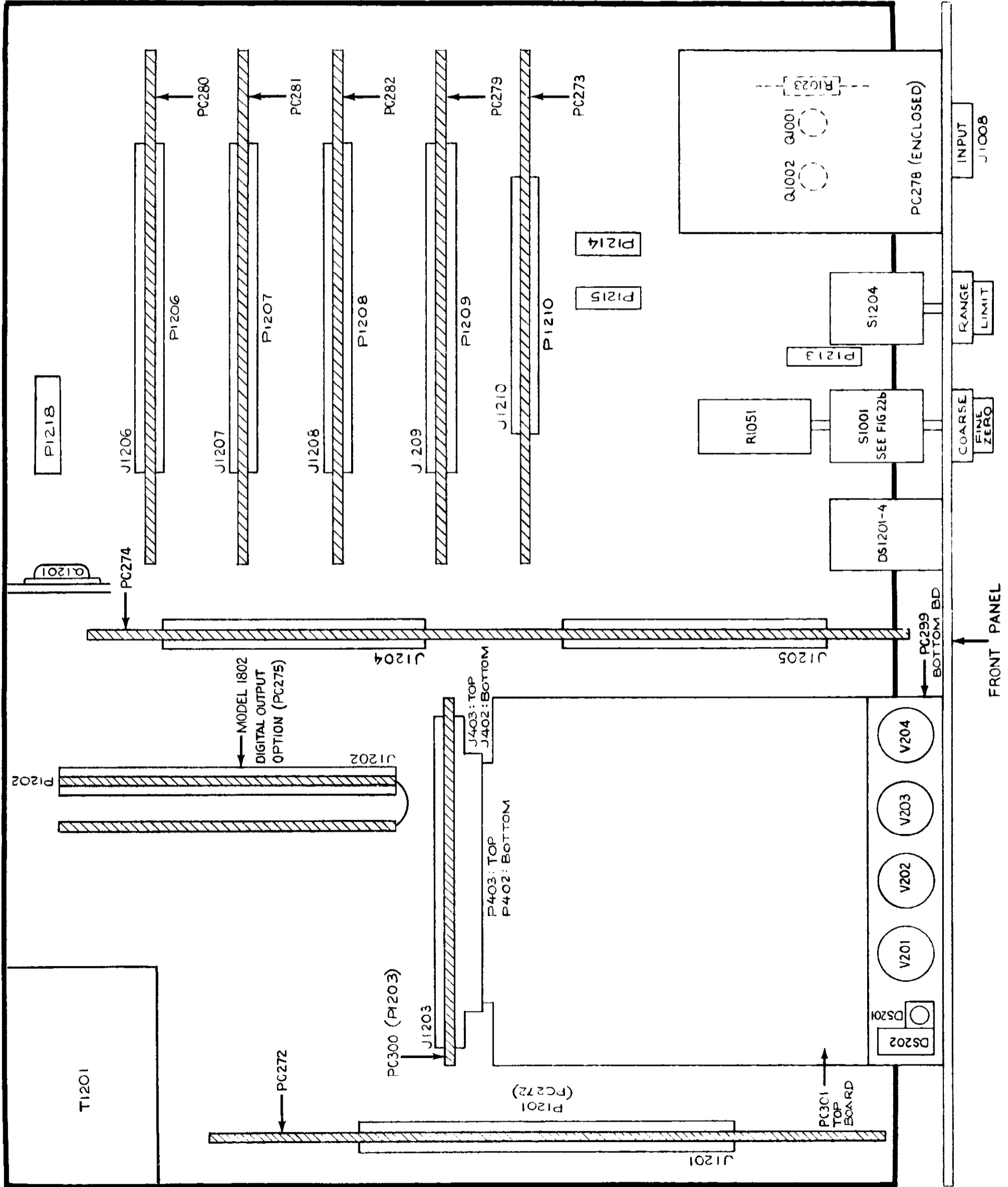


FIGURE 22. Chassis - Mother Board (PC-771)

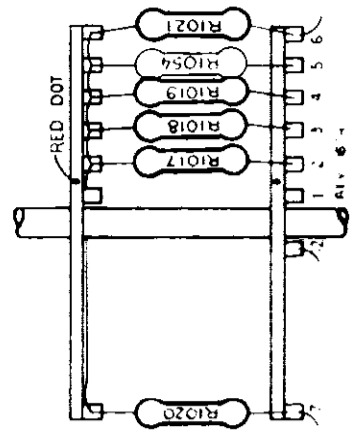
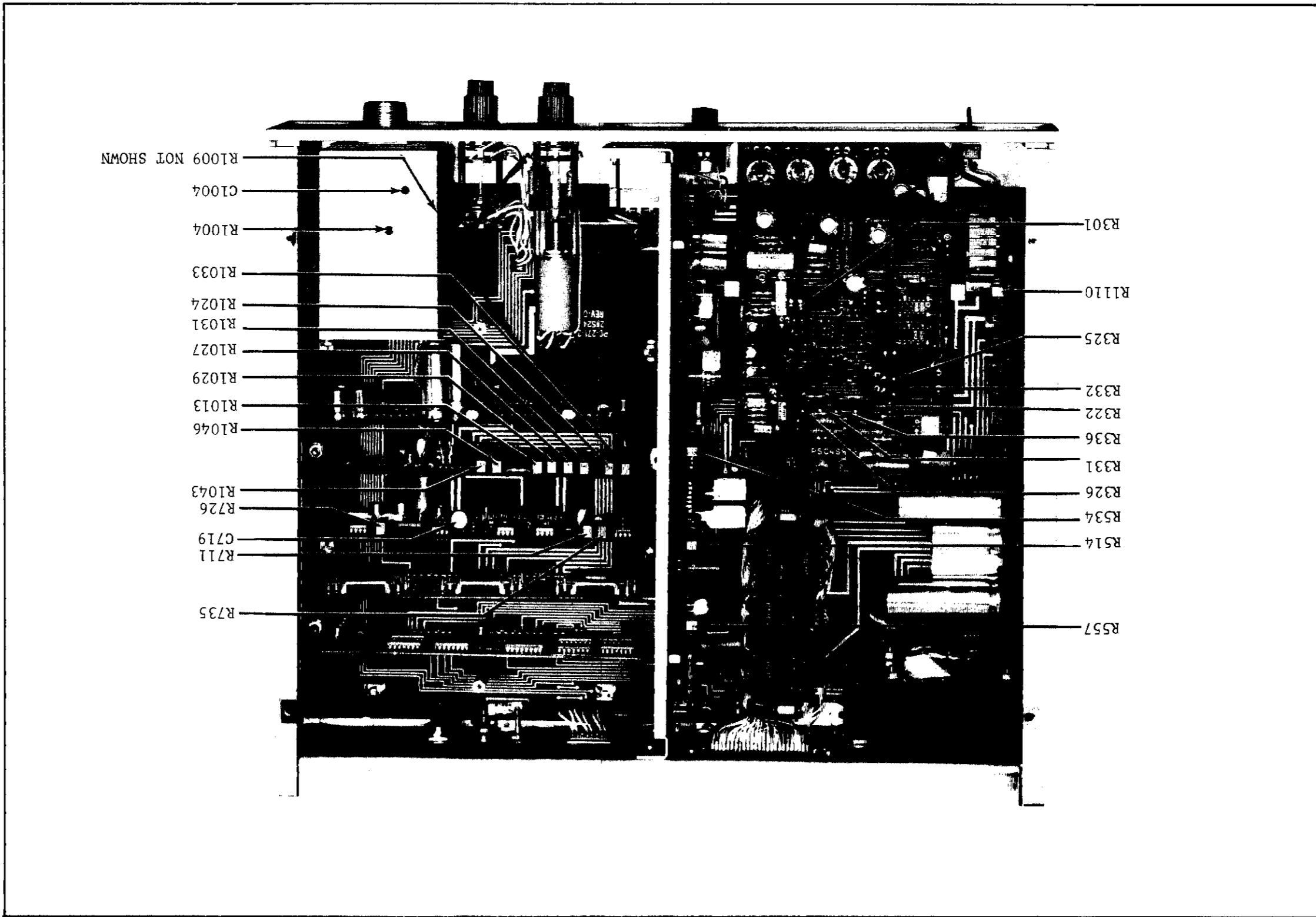


FIGURE 22b. Zero Suppress Switch S1001. 52a

FIGURE 23. Calibration Controls.



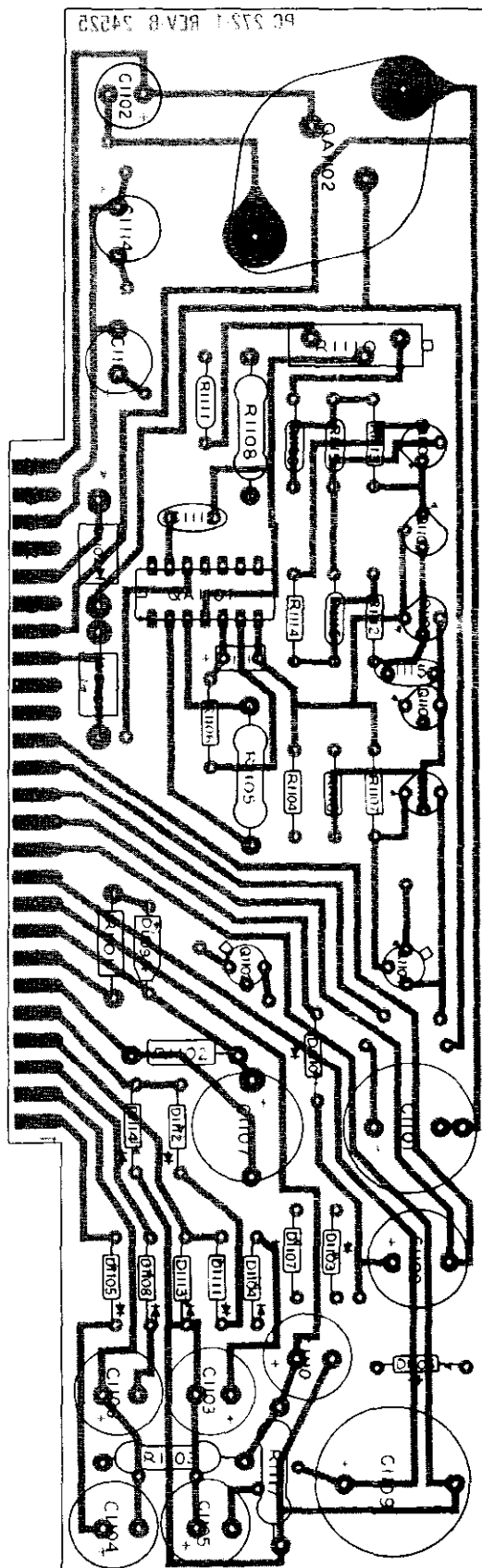


FIGURE 24. Component Layout, PC-272

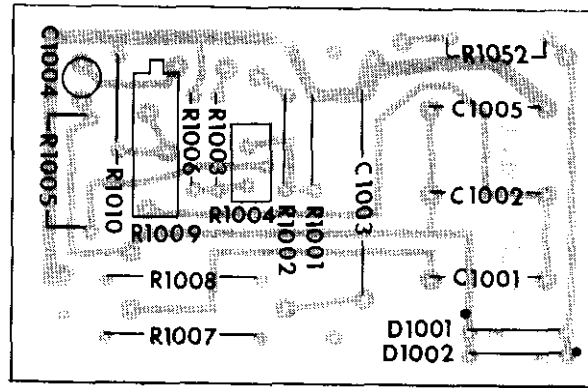


FIGURE 25. Component Layout, PC-278

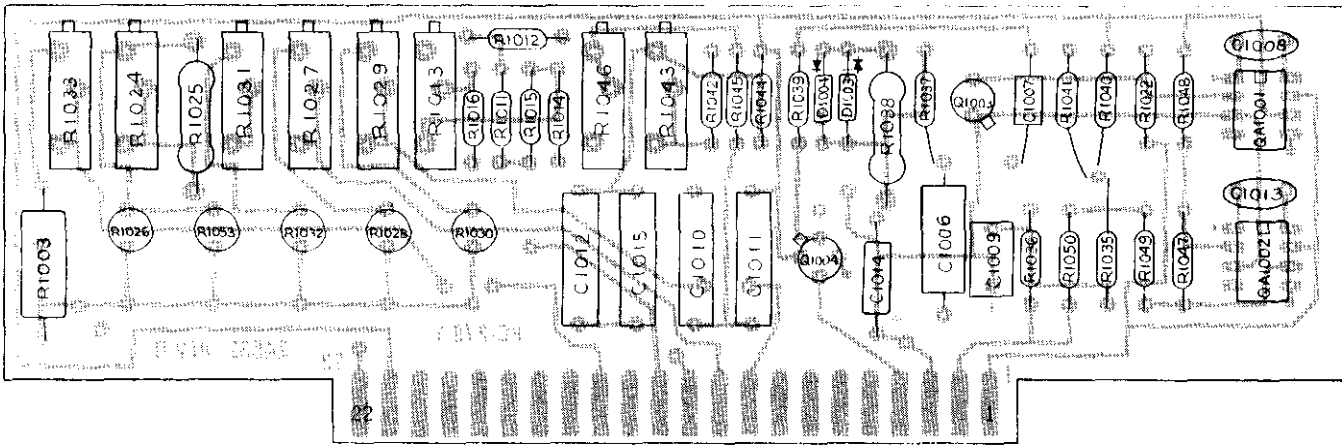


FIGURE 26. Component Layout, PC-279

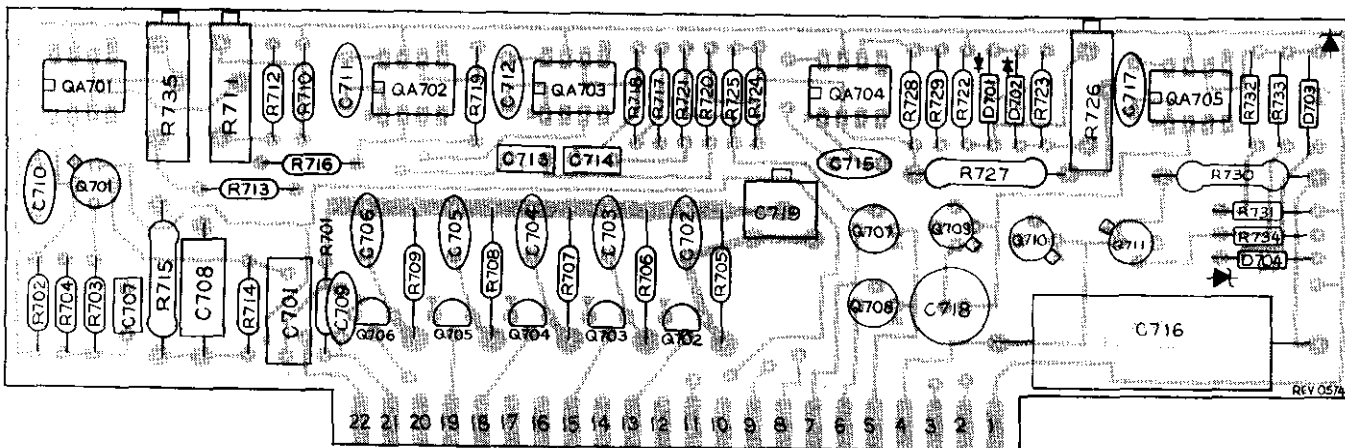


FIGURE 27. Component Layout, PC-282

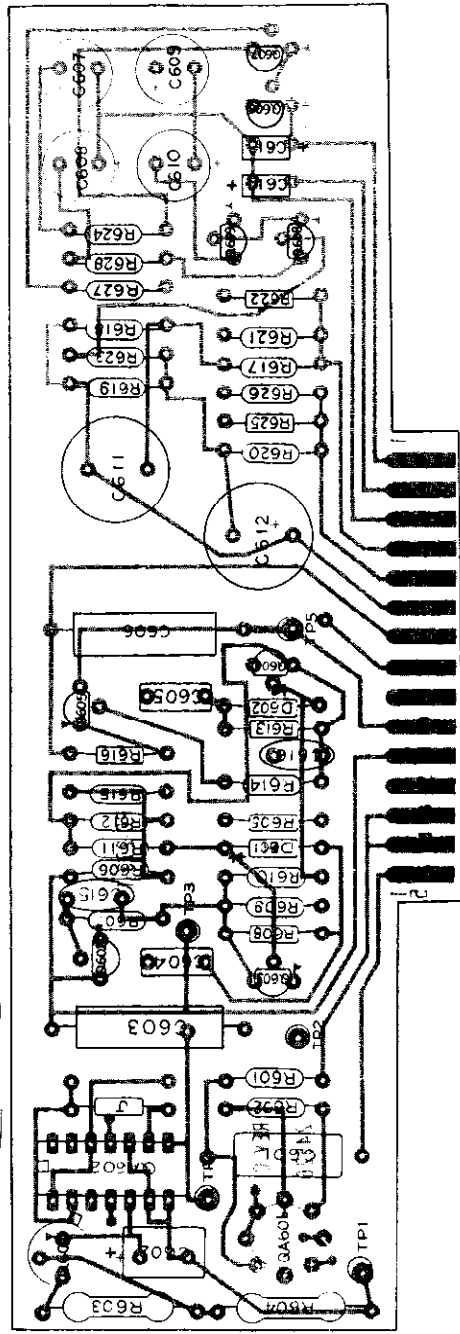


FIGURE 28. Component Layout, PC-273

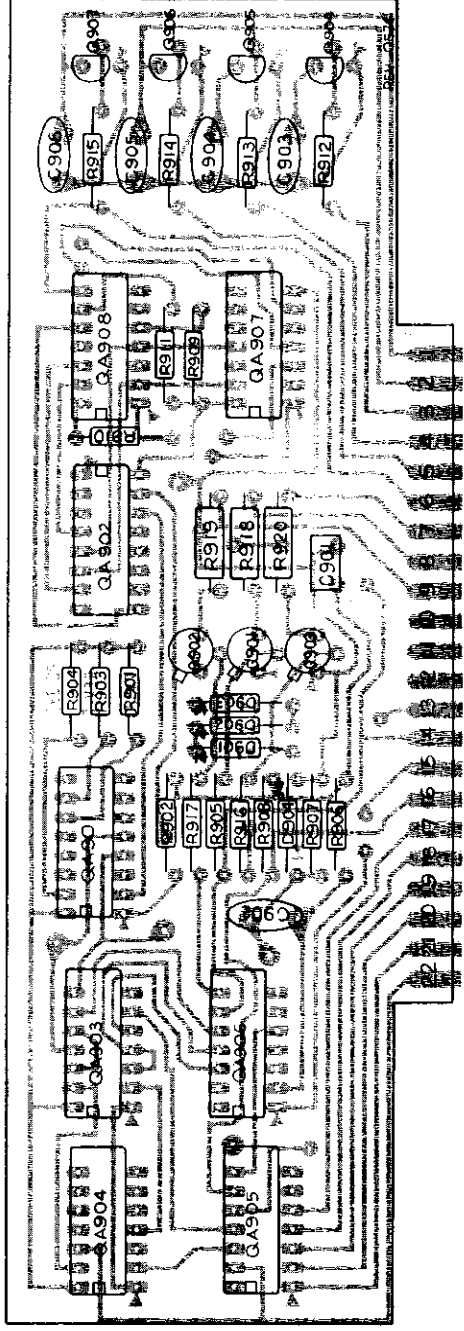


FIGURE 30. Component Layout, PC-280

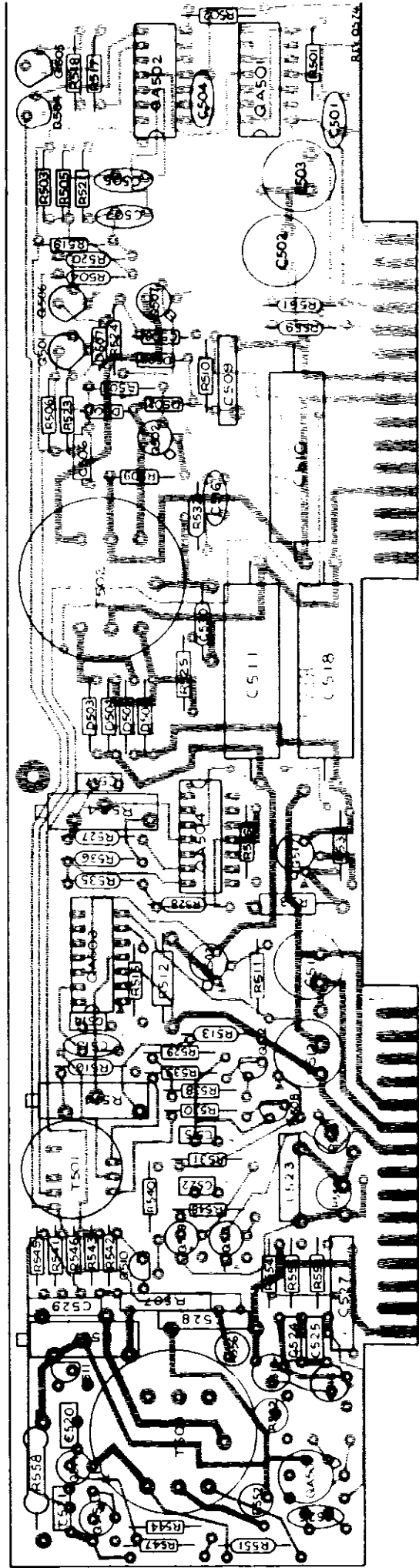


FIGURE 29. Component Layout, PC-274

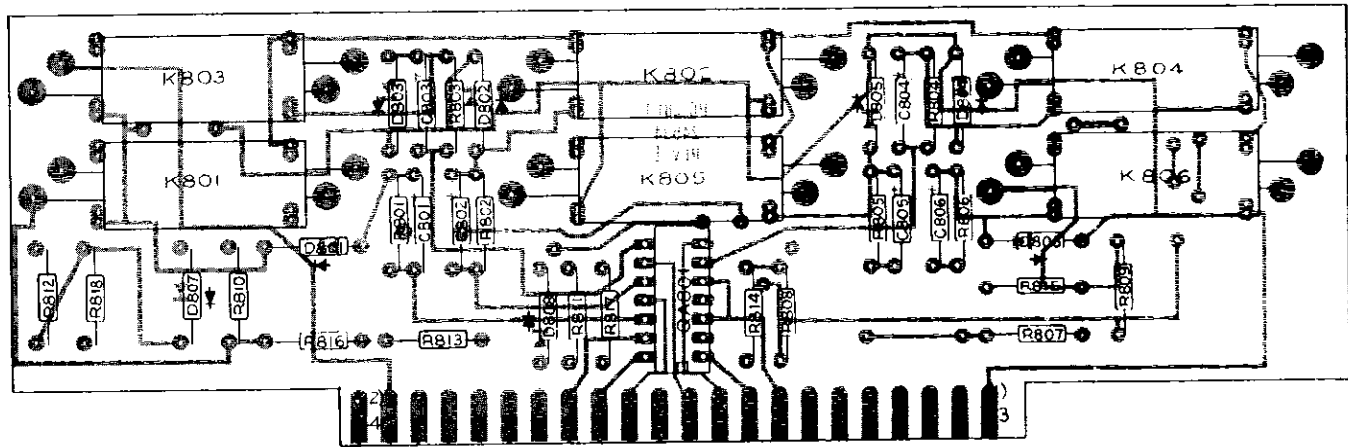


FIGURE 31. Component Layout, PC-281

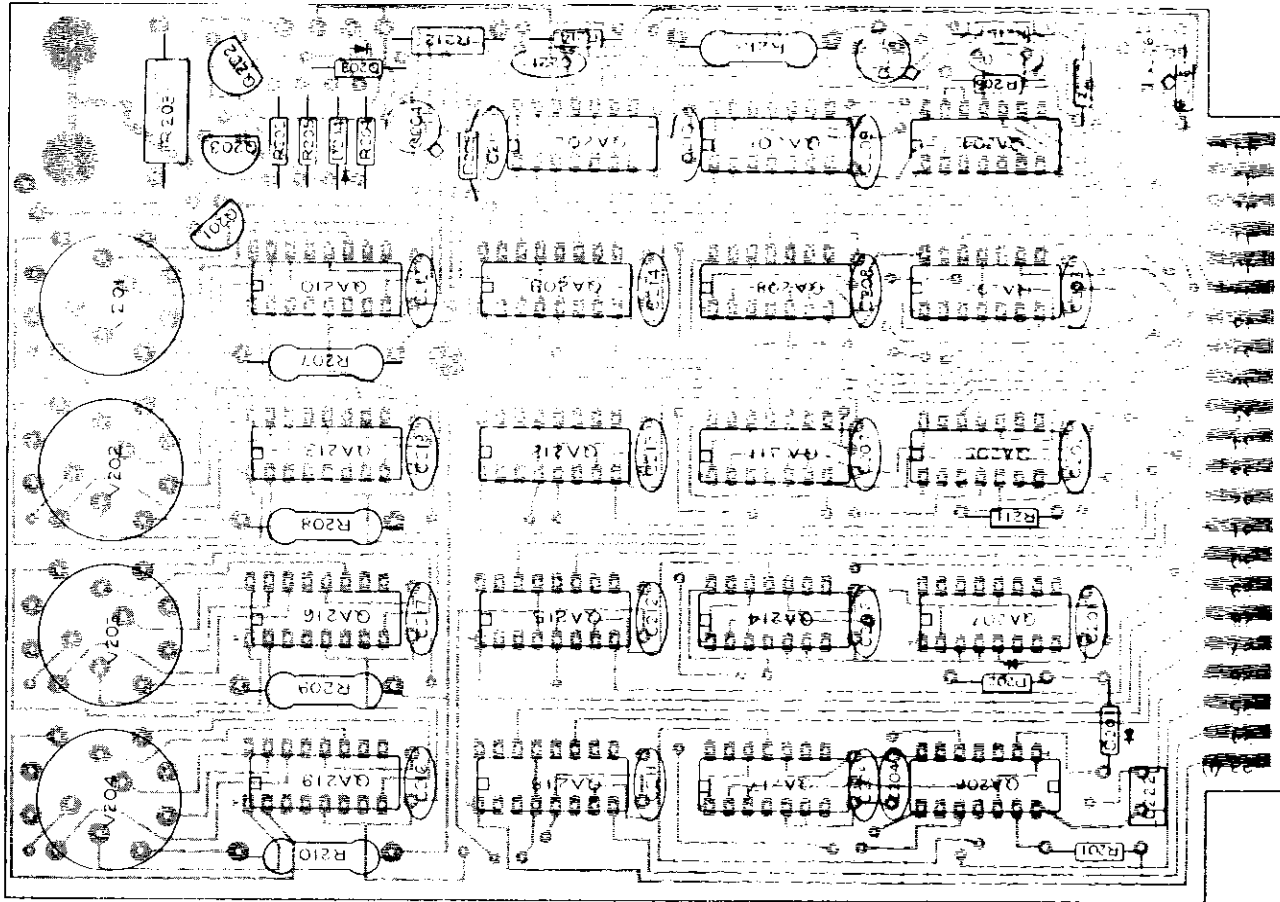


FIGURE 32. Component Layout, PC-299

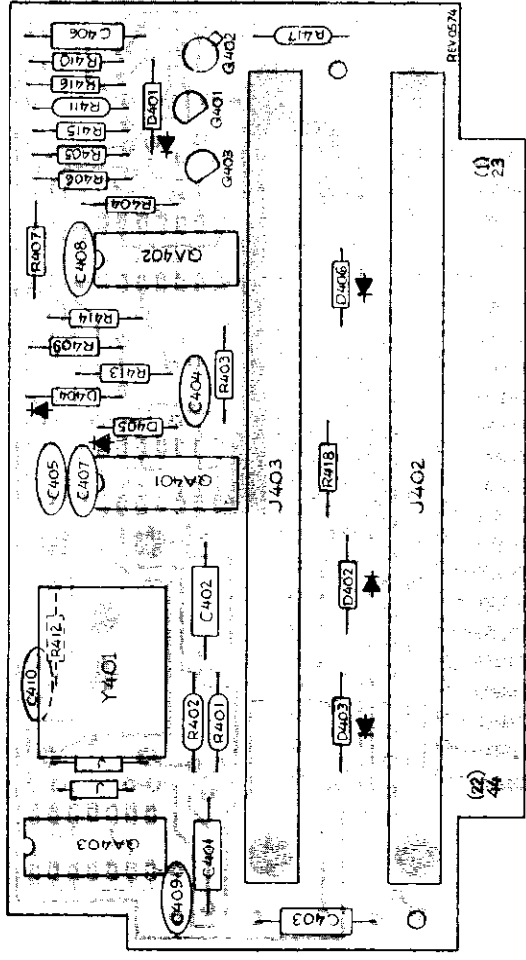


FIGURE 33. Component Layout, PC-300

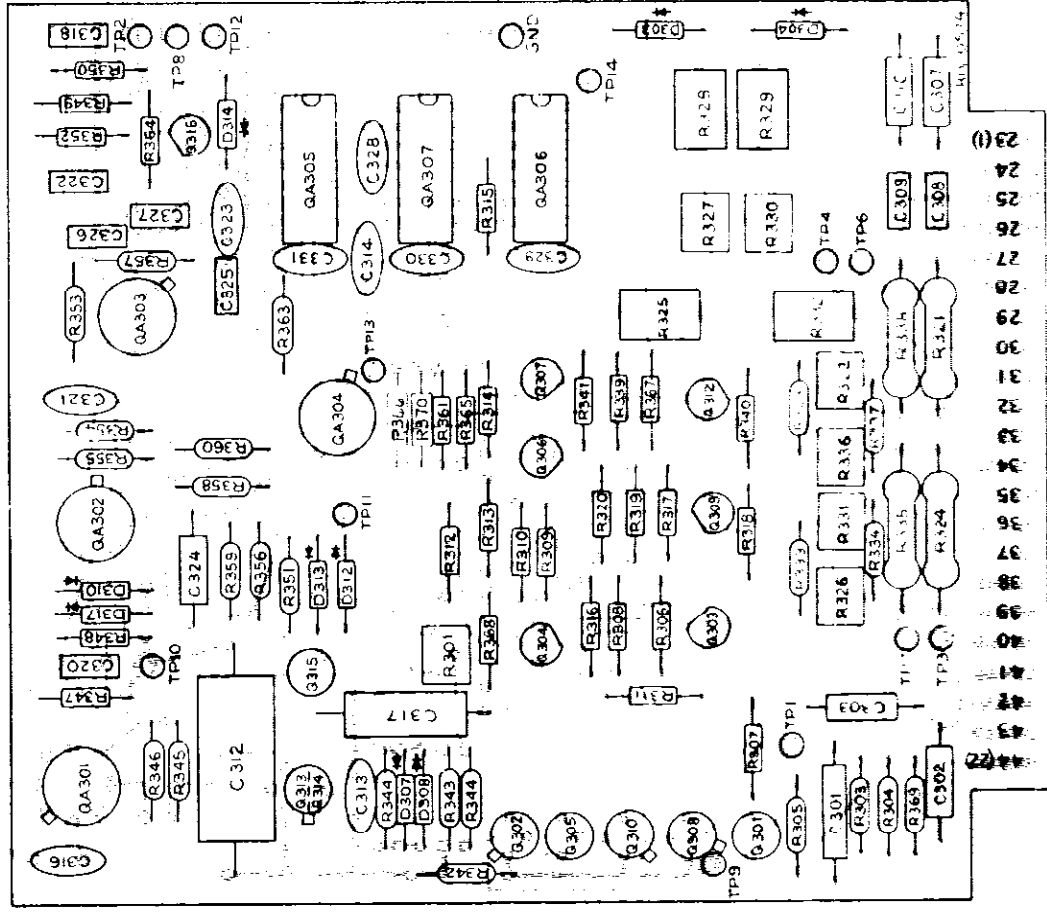


FIGURE 34. Component Layout, PC-301

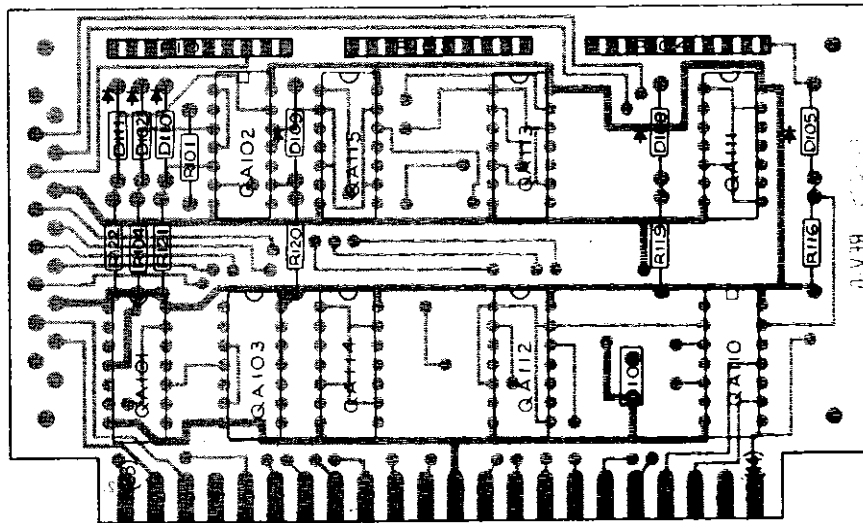


FIGURE 35. Component Layout, PC-275 (Part 1)

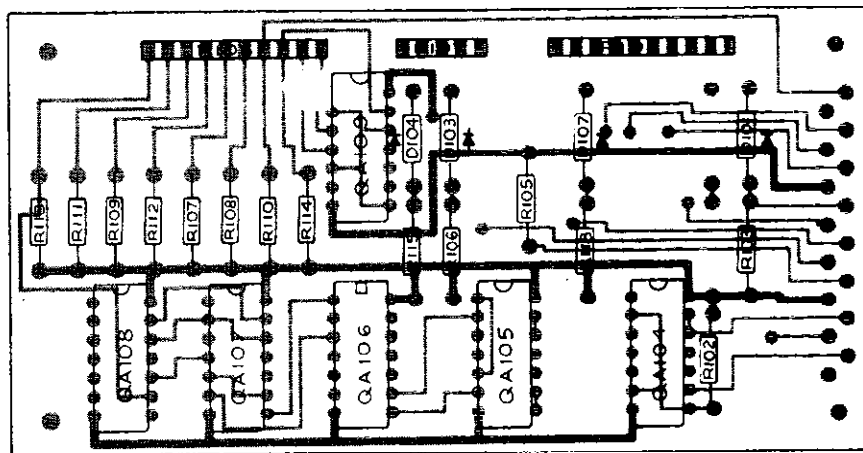


FIGURE 36. Component Layout, PC-275, (Part 2)

SECTION 7. CALIBRATION

7-1. GENERAL. This section contains information necessary to maintain the instrument to published specifications.

7-2. REQUIRED TEST EQUIPMENT. Minimum requirements for test equipment are given in Table 7-1.

7-3. ADJUSTMENT AND CALIBRATION. This procedure should be used whenever it is necessary to calibrate the instrument to ensure that it meets published specifications. Calibration should be accomplished every 90 days to ensure accuracy or more frequently if ambient temperature conditions are changed.

a. Environment. The calibration should be performed in a controlled environment. The factory calibration is performed at 25°C ±1°C. Recommended temperature range for recalibration is 23°C to 27°C.

b. Temperature. To maintain a constant internal temperature of the Model 180, a special Test Cover (Part No. 26072C) should be used. This Test Cover (included in Accessory Model 1803 Extender Card Kit) allows access to calibration adjustments without upsetting the internal temperature.

IMPORTANT

Apply power to the Model 180 and allow instrument to warm-up and stabilize with test cover in place for a minimum of 4 hours prior to calibration.

c. Preamplifier Zero.

1. Connect Model 1488 Shorting Plug.
2. Connect Null Detector (D) to Model 180 Analog Output.
3. Select 1000mV range on Model 180.
4. Adjust front panel "1V ZERO" (R1202) on Model 180 to obtain zero ±20µV reading on Null Detector at Analog Output of Model 180.
5. Select 1mV range on Model 180.
6. Check for zero at Analog Output on Model 180 on 1mV range. Adjust potentiometer R1013 (Internal Zero Adj.) as necessary (within noise on 1mV range).
7. Select 0.1mV range. Monitor Analog Output which should be within about 1mV of zero. Peak-to-peak noise in 100's of µV is to be expected.
8. Select 1000mV range. Recheck Analog Output zero. Output should be zero ±20µV.
9. Check Analog Output on 1mV, 10mV, and 100mV ranges. Output should be within ±75µV of zero on each range.

TABLE 7-1.
Recommended Test Equipment for Adjustment & Calibration Procedure..

Item	Description	Mfr.	Model
A	Voltage Source, 0.002% of setting accuracy	Fluke Fluke (alternate)	343A 3330B (alternate)
B	Voltage Divider 1,10,100,1000 ohm steps	ESI	SR-1010
C	Shorting Plug	Keithley	1488
D	Null Detector/Microvoltmeter	Keithley	R-132-1060
E	Low-Thermal Resistance, 1060 Ohm	Keithley	R132
F	Low-Thermal Resistance, 99 kilohm	Keithley	R-105-99K

d. Digital Zero.

1. Select 1000mV range on Model 180.
2. Observe digital display on Model 180.
3. Adjust potentiometer R301 (Digital Zero Adj.) to obtain zero reading such that polarity sign flashes between + and -.

e. Offset Current.

NOTE

Low-thermal source resistances are essential for this procedure. Low-thermal test resistors may be assembled by using parts of Model 1488 Shorting Plug and Model 1486 Male Connector. See Figure 37. Use a crimping tool from Model 1483 Low-Thermal Connection Kit for making low-thermal copper connections. Make certain resistances are enclosed to prevent disturbances from temperature variations (due to movement of air) or electrical noise pick-up. If this cannot be done, an alternative procedure is to use a Model 1506 cable. For shorted-input connections, clip leads together. For high and low resistance measurements clip on to leads of 1k Ω or 100k Ω resistors. In each case protect the connections from temperature variations due to air currents by wrapping the connection in polyurethane foam and place in a small box or other protective enclosure.

Low-Thermal Source Resistances.

Value	Type	Keithley Part No.
1k Ω	Low-Thermal, Wire-Wound	R132-1k Ω
100k Ω	Low-Thermal, Wire-Wound	R110-100k Ω

1. High Resistance Adjustment (100 kilohm source).

- a). Select 1mV range on Model 180.
- b). Connect Model 1488 Shorting Plug to Model 180 Input.
- c). Check front panel display for zero reading. Adjust front panel Zero Suppress (R1051) to obtain a reading of .0000 \pm .0001mV.
- d). Remove Model 1488 Shorting Plug.
- e). Connect Low-Thermal Resistance (100 kilohms) to Model 180 Input.
- f). Check front panel display for zero reading.
- g). Adjust potentiometer R1004 (Offset Current Adj.) to obtain a reading of .0000 \pm .0010mV.

2. Low-Resistance Adjustment (1 kilohm Source).

- a). Select 1mV range on Model 180.
- b). Connect Model 1488 Shorting Plug.
- c). Verify reading is .0000 \pm .0001 mV.
- d). Connect Low-Thermal Resistance (1 kilohm).
- e). Allow reading V_1 to stabilize. Record V_1 .
- f). With Low-Thermal Resistance connected, adjust capacitor C1004 such that displayed reading is:

$$V_2 = -2 V_1$$

(For example, if V_1 is a negative quantity, then V_2 should be set positive by a factor of $2V_1$.)

- g). Remove Low-Thermal Resistance (1 kilohm).
- h). Connect Model 1488 Shorting Plug.
- i). Record reading to the nearest $\frac{1}{2}$ digit as V_3 .

NOTE

The digital display can be read to within $\pm \frac{1}{2}$ digit by inspection. If the least significant digit remains at "0" with the polarity flashing between + and -, then the last digit is "0" $\pm \frac{1}{2}$ digit. If the display flashes between -1 and 0, then the last digit is $-\frac{1}{2}$ digit. If the display flashes between +1 and 0, then the display is $+\frac{1}{2}$ digit.

- j). Remove Model 1488 Shorting Plug.

- k). Connect Low-Thermal Resistance (1 kilohm).
- m). Record reading to the nearest $\frac{1}{2}$ digit as V_4 .

- n). Determine offset current from following:

$$I_{\text{offset}} = \frac{V_4 - V_3}{1000}$$

where V_4 is from step m.
 V_3 is from step i.

- p). Repeat steps a) through n) above until the offset current (I_{offset}) is within ± 100 pico-ampere. This is achieved when $V_4 = V_3$ within ± 1 digit.

EXAMPLE

if $V_1 = -.00015$, then $V_2 = +.0003$
if $V_3 = .0008$, $V_4 = .0007$, then $I = 100\text{pA}$.

- q). Repeat paragraph 7-4d in its entirety. Then skip ahead to paragraph 7-4g, unless a more sensitive adjustment is desired.

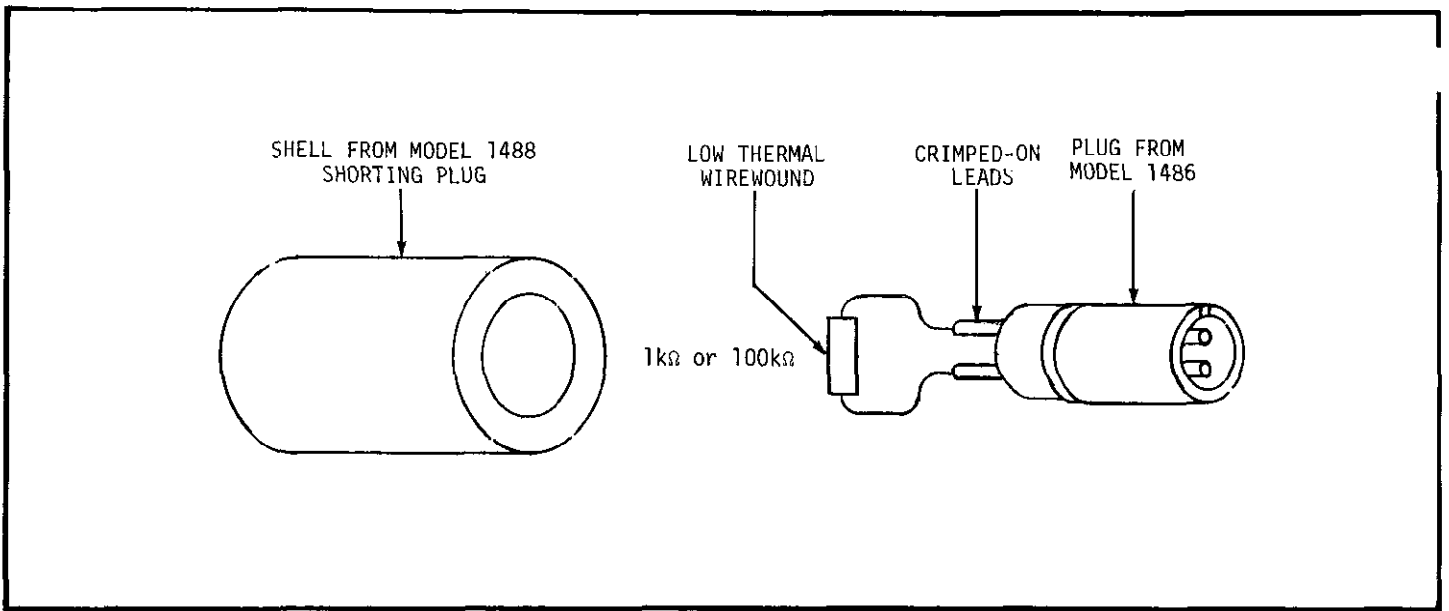


FIGURE 37. Assembly of Low-Thermal Resistance Source.

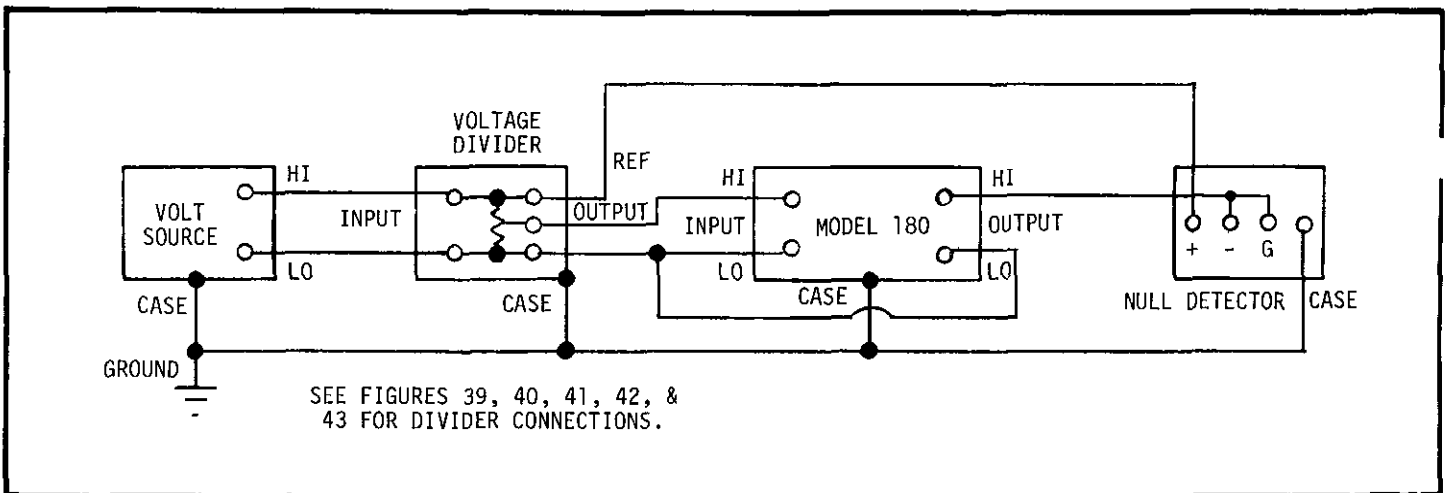


FIGURE 38. Test Set-up for Pre-Amp Gain Calibration.

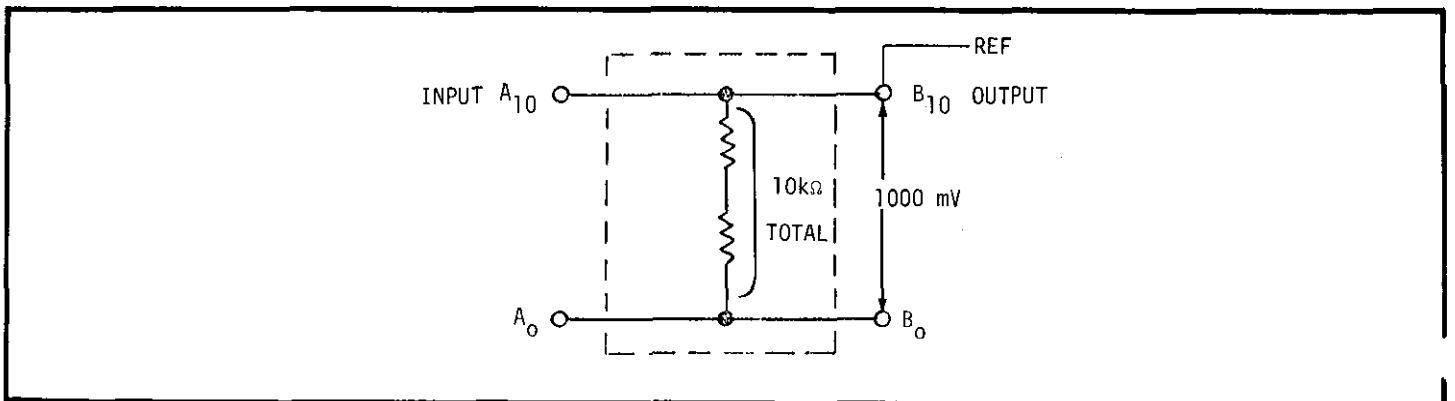


FIGURE 39. Voltage Divider Connections, 1000mV Output.

3. Optional Adjustment of Offset Current to below 100 pA. The offset current may be adjusted to better than 100 picoampere at a specific source resistance by repeating paragraph 7-4f2 with specific value of Low-Thermal Resistance.

f. Preamplifier Gain Calibration.

1. Assemble test equipment as shown in Figure 38.
2. Set potentiometer R557 (Gain Adj.) to approximately center rotation.
3. Set Null Detector to 1 mV range.
4. 1000 mV Gain Calibration.
 - a). Connect Voltage Divider for 1:1 division ratio as shown in Figure 39.
 - b). Set Voltage Source to zero.
 - c). Adjust front panel ZERO SUPPRESS on Model 180 to obtain zero within $\pm 20\mu\text{V}$ on Null Detector.
 - d). Set Voltage Source to approx. +1.9 V.
 - e). Adjust potentiometer R1024 (1000mV Gain Adj.) (located on PC-279) to obtain null on Null Detector. See Figure 23 for location.
 - f). If adjustment of R1024 is too coarse, set R1024 to a stable position. Then adjust R557 (Gain Adj.) to obtain a null.
 - g). Set Voltage Source to -1.9 V.
 - h). Observe null reading on Null Detector.
 - i). Adjust potentiometer R1024 to reduce the Null Detector reading to a "mid-point" reading (split the difference to compensate for non-linearity at twice full range).
 - j). Repeat steps 4a) to 4j) to obtain same null for positive and negative inputs.

NOTE

Typical readings are -350 microvolts from null when input signal is near twice full range. The minus reading indicates that the positive gain of the analog amplifier is high and the negative gain is low. See Figure 43.

OPTIONAL CHECK

Full range linearity may be checked by repeating steps 4a) to 4j) using a ± 1 volt input. Typical readings are 100 microvolts from null.

5. 1 mV Gain Calibration.

- a). Connect Voltage Divider for 1:1000 division ratio as shown in Figure 40.
- b). Set Voltage Source to zero.
- c). Adjust front panel ZERO SUPPRESS on Model 180 to obtain zero $\pm 40\mu\text{V}$ on Null Detector.
- d). Set Voltage Source to approx. +1.9 V.
- e). Adjust potentiometer R1031 (1mV Gain Adj.) to obtain null on Null Detector.
- f). Set Voltage Source to -1.9 V.
- g). Observe null reading on Null Detector.
- h). Adjust potentiometer R1031 to reduce the Null Detector reading to a "mid-point" reading (split the difference to compensate for non-linearity at twice full range).

6. 0.1 mV Gain Calibration.

- a). Connect Voltage Divider for 1:10,000 division ratio as shown in Figure 41.
- b). Set Voltage Source to zero.
- c). Adjust front panel ZERO SUPPRESS on Model 180 to obtain zero $\pm 170\mu\text{V}$ on Null Detector.
- d). Set Voltage Source to approx. +1.9 V.
- e). Adjust potentiometer R1033 (100 μV Gain Adj.) to obtain null on Null Detector.
- f). Set Voltage Source to -1.9 V.
- g). Observe null reading on Null Detector.
- h). Adjust potentiometer R1033 to reduce The Null Detector reading to a "mid-point" reading (split the difference to compensate for non-linearity at twice full range).

7. 10 mV Gain Calibration.

- a). Connect Voltage Divider for 1:100 division ratio as shown in Figure 42.
- b). Set Voltage Source to zero.
- c). Adjust front panel ZERO SUPPRESS on Model 180 to obtain zero $\pm 20\mu\text{V}$ on Null Detector.
- d). Set Voltage Source to approx. +1.9 V.
- e). Adjust potentiometer R1029 (10mV Gain Adj.) to obtain null on Null Detector.
- f). Set Voltage Source to -1.9 V.
- g). Observe null reading on Null Detector.
- h). Adjust potentiometer R1029 to reduce the Null Detector reading to a "mid-point" reading (split the difference to compensate for non-linearity at twice full range).

8. 100 mV Gain Calibration.

- a). Connect Voltage Divider for 1:10 division ratio as shown in Figure 43.
- b). Set Voltage Source to zero.
- c). Adjust front panel ZERO SUPPRESS on Model 180 to obtain zero $\pm 20\mu\text{V}$ on Null Detector.
- d). Set Voltage Source to approx. +1.9 V.
- e). Adjust potentiometer R1027 (100mV Gain Adj.) to obtain null on Null Detector.
- f). Set Voltage Source to -1.9 V.
- g). Observe null reading on Null Detector.
- j). Adjust potentiometer R1027 to reduce the Null Detector reading to a "mid-point" reading (split the difference to compensate for non-linearity at twice full range).

IMPORTANT

If at any time a particular gain adjustment cannot be performed, potentiometer R557 should be adjusted on the particular range. If adjustment of R557 is necessary, then the Pre-amplifier Gain Calibration must be performed starting with 1000 mV Gain Calibration (step g4).

g. A/D Gain Adjustment. (See schematic 25017D and Figure 23.)

1. Zero Adjustment.

- a). Connect Null Detector to Model 180 Output.
- b). Connect Model 1488 Shorting Plug to Input.

- c). Select 1000mV range on Model 180.
- d). Verify Analog Output within $\pm 20\mu\text{V}$ of zero.
- e). Check Model 180 display for zero reading.
- f). Adjust potentiometer R301 (Digital Zero Adj.) to obtain 0000.0 with polarity flashing. This is a sensitive adjustment. The display may occasionally flash to a +1 or -1 digit.
- g). Remove Model 1488 Shorting Plug.

2. \pm Reference Adjustment.

- a). Adjust potentiometers R326 (+ REF FINE ADJ.) and R331 (-REF FINE ADJ.) for center position (approx. 5 turns).
- b). Connect Voltage Source to Model 180.
- c). Apply +1.50005V from Voltage Source.
- d). Adjust potentiometer R330 (-REF. COARSE ADJ) to obtain approx. +1500.0 mV reading on Model 180.
- e). Adjust R331 (-REF FINE ADJ) to obtain a reading between +1500.0 and +1500.1 mV.
- f). Repeat steps c) through e) using -1.50005V input. Adjust potentiometers R327 and R326.

3. Verification of Linearity (1000 mV range).

- a). Connect Voltage Source to Model 180 Input.
- b). Apply voltages to Input as shown in Table 7-2.
- c). Verify that readings are within maximum deviation specified in Table 7-2.

TABLE 7-2.
Verification of Linearity

Input Voltage	Allowable Reading
+1900.0 mV	+1899.6 to +1900.4 mV
-1900.0 mV	-1899.6 to -1900.4 mV
+1500.0 mV	+1499.9 to +1500.1 mV
-1500.0 mV	-1499.9 to -1500.1 mV
+1000.0 mV	+ 999.8 to +1000.2 mV
-1000.0 mV	- 999.8 to -1000.2 mV
+500.0 mV	+499.8 to +500.2 mV
-500.0 mV	-499.8 to -500.2 mV
+100.0 mV	+999.8 to +100.2 mV
-100.0 mV	-999.8 to -100.2 mV
+ 50.0 mV	+ 49.8 to + 50.2 mV
- 50.0 mV	- 49.8 to - 50.2 mV

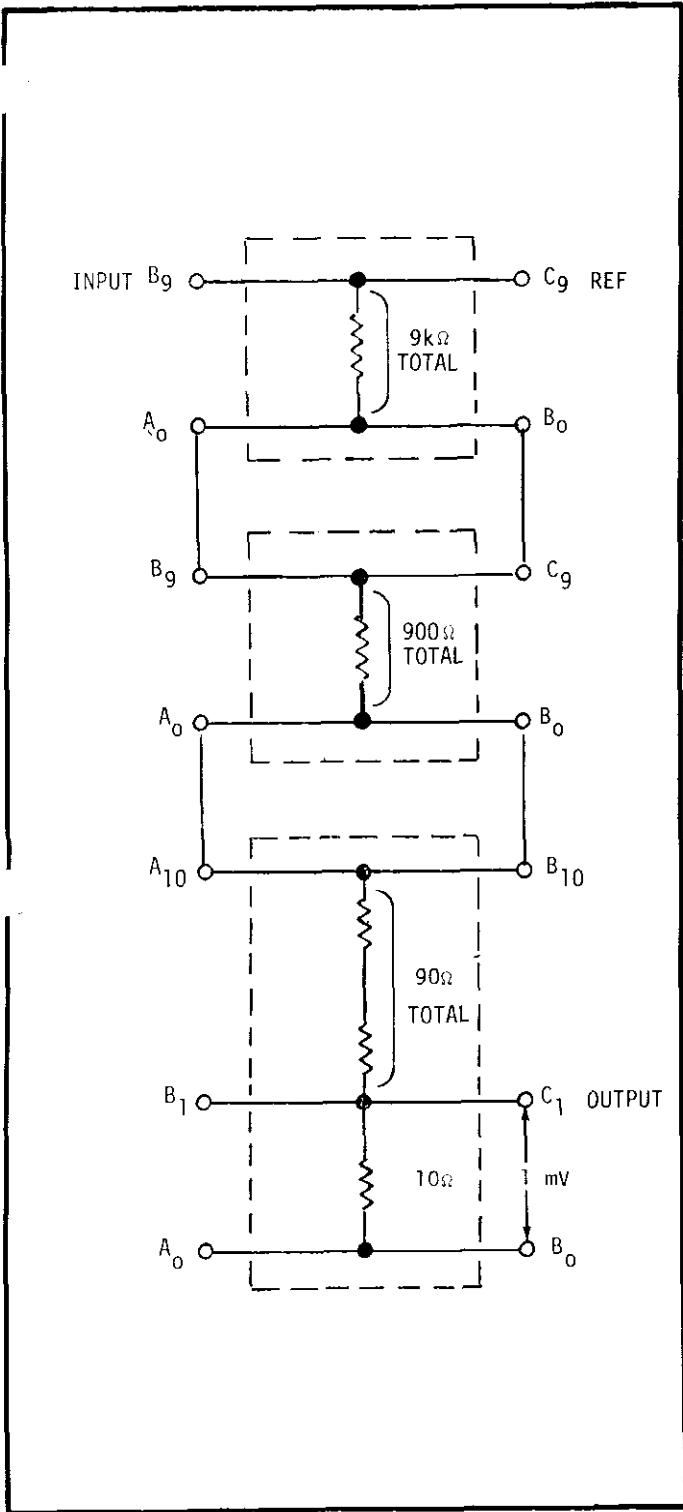


FIGURE 40. Voltage Divider Connections, 1mV Output.

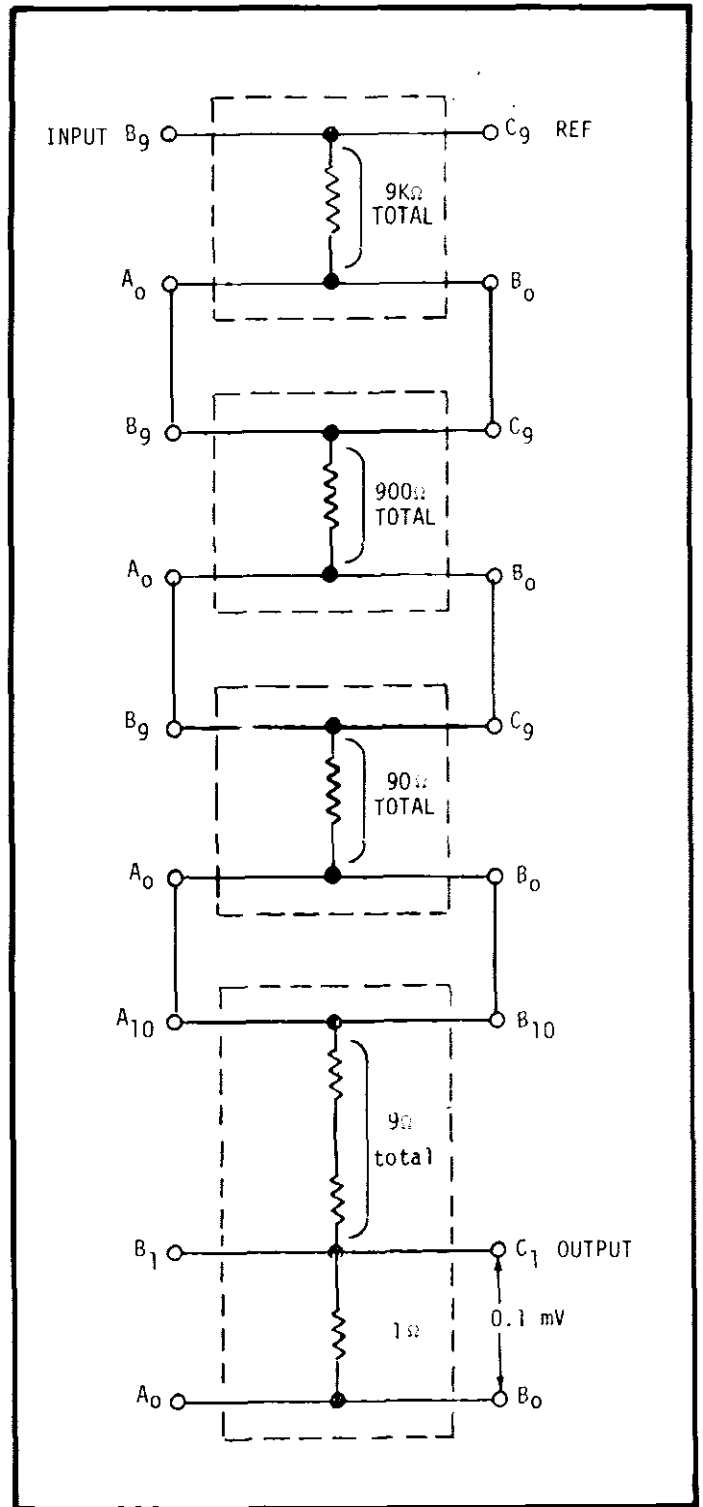


FIGURE 41. Voltage Divider Connections, 0.1mV Output.

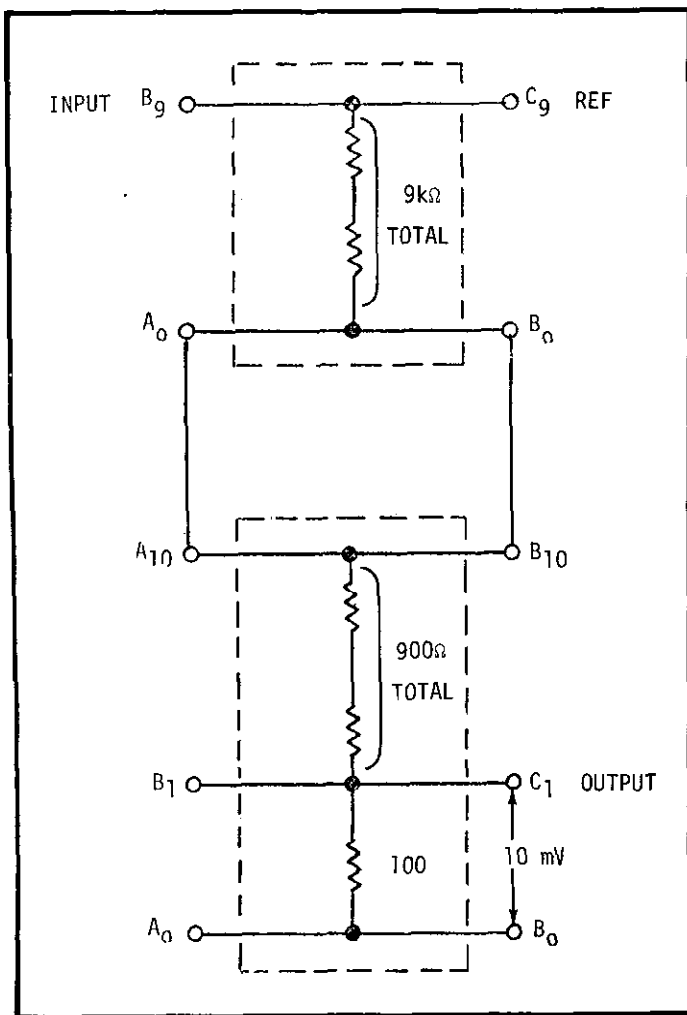


FIGURE 42. Voltage Divider Connections, 10mV Output.

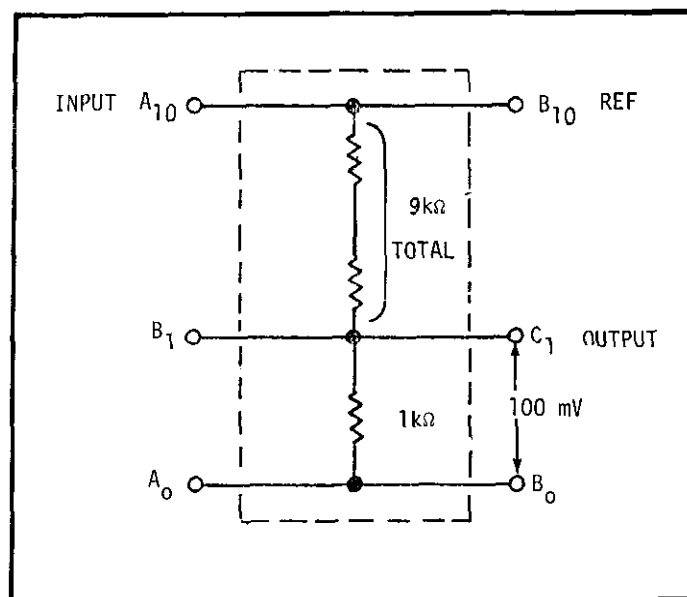


FIGURE 43. Voltage Divider Connections, 100mV Output.

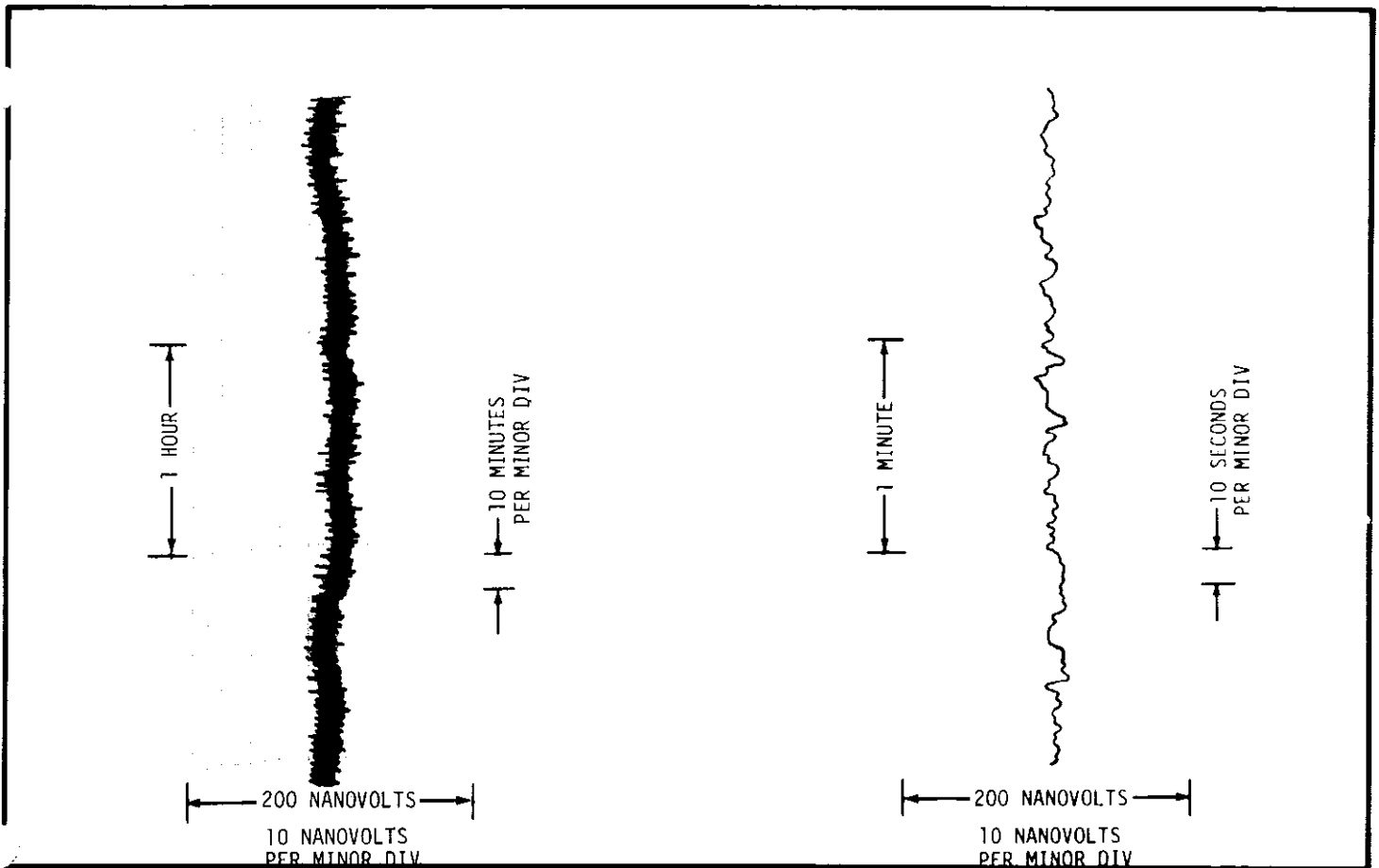


FIGURE 44a,b. Typical Drift and Noise Recordings.

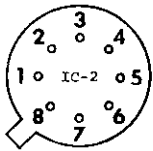
h. Drift Check.

1. Allow Model 180 to stabilize with power on for a least four hours.
2. Connect Model 1488 Shorting Plug to Model 180 Input.
3. Observe the long-term drift under a closely controlled environment, preferably held to within $\pm 1^{\circ}\text{C}$.
4. Typical long term drift is shown in Figure 44a. This data was recorded on an Esterline-Angus chart recorder (Model 602) by monitoring the Model 180 Analog Output. Measurement was made in a laboratory with temperature controlled to $\pm 1^{\circ}\text{C}$ with very slow temperature variations.

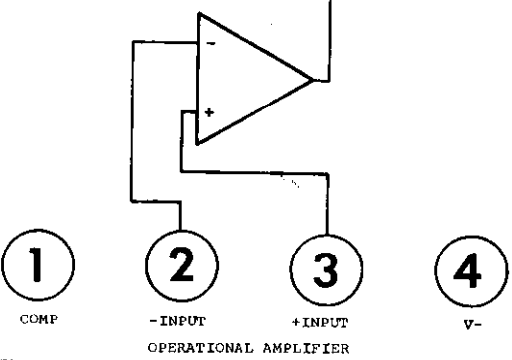
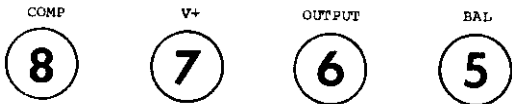
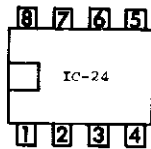
i. Noise Check.

1. Allow Model 180 to stabilize as above in paragraph 6-31.
2. Connect Model 1488 Shorting Plug.
3. Observe noise at the Model 180 display, Analog Output, or Digital Output. "Noise" is intended to mean the peak-to-peak excursion over a span of 30 seconds observed at the display or Digital Output. Typical noise at the Analog Output is shown in Figure 44b. Wide-band recorders may indicate higher noise levels than shown. The Model 180 A/D converter section will average faster variations.

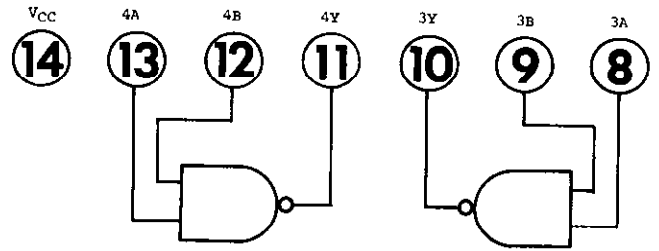
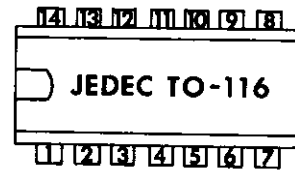
KEITHLEY PART NO. IC-2,24



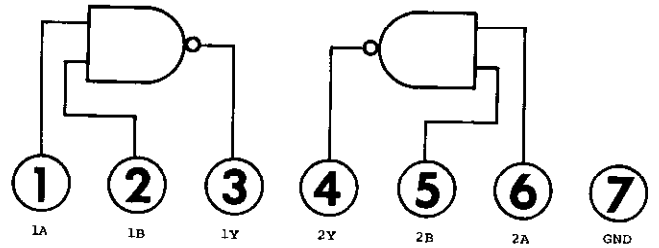
TO-99



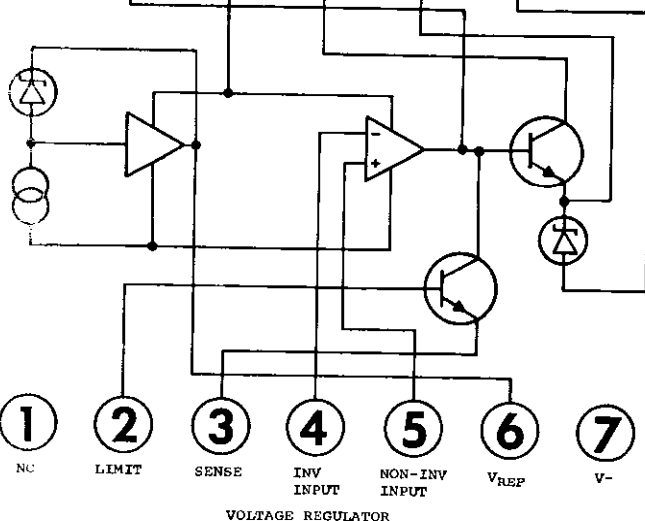
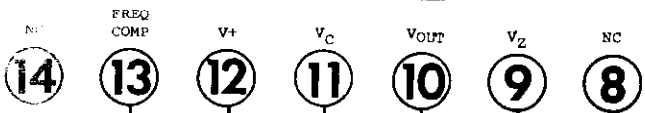
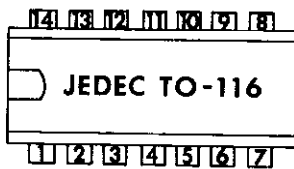
KEITHLEY PART NO. IC-22



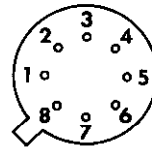
QUAD NAND GATE
OPEN COLLECTOR



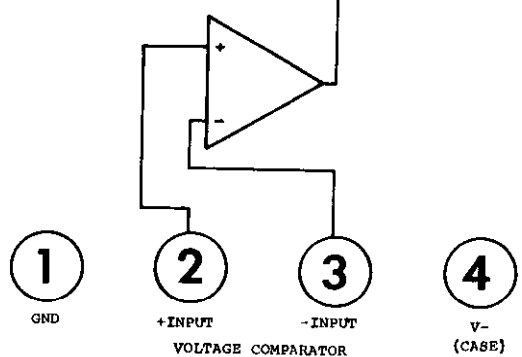
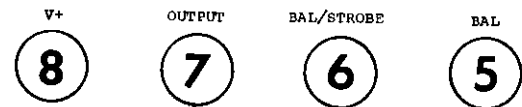
KEITHLEY PART NO. IC-25



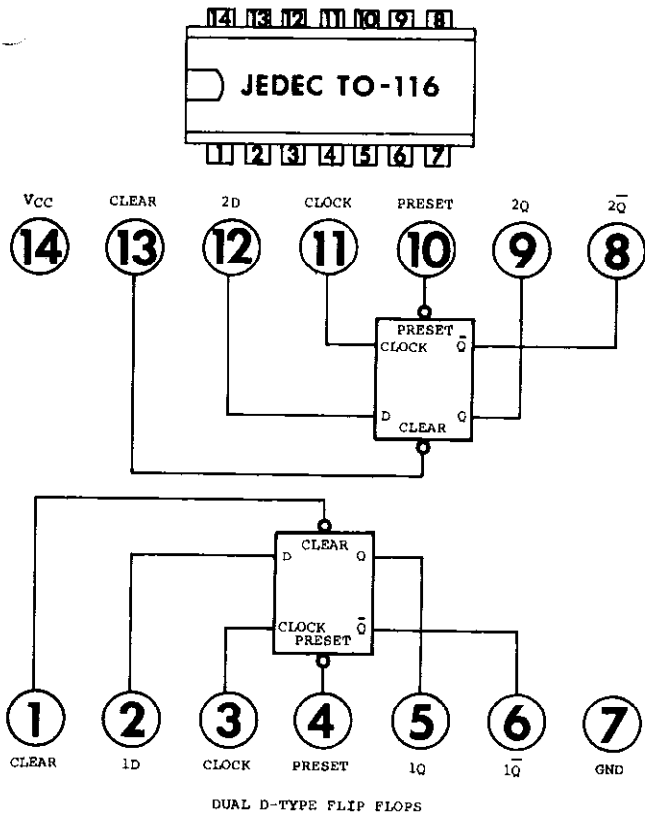
KEITHLEY PART NO. IC-29



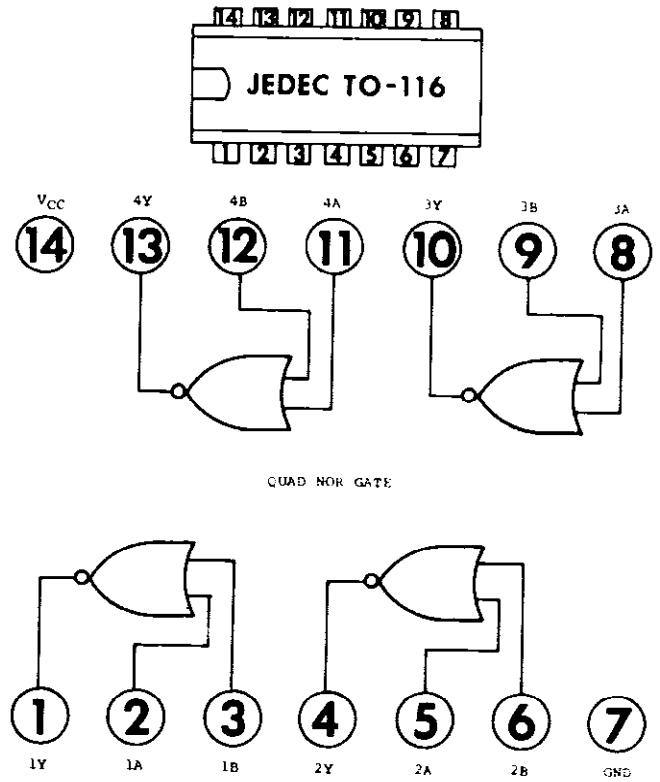
TO-99



KEITHLEY PART NO. IC-31

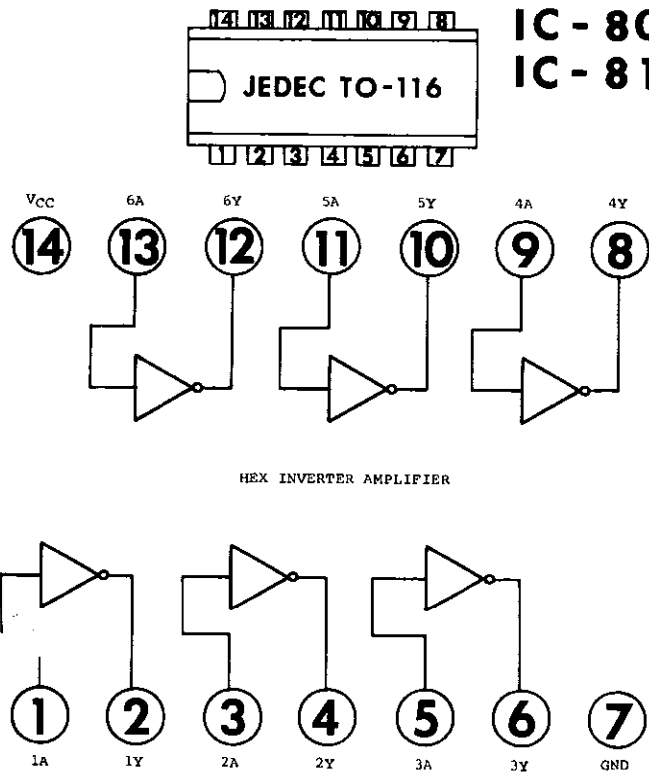


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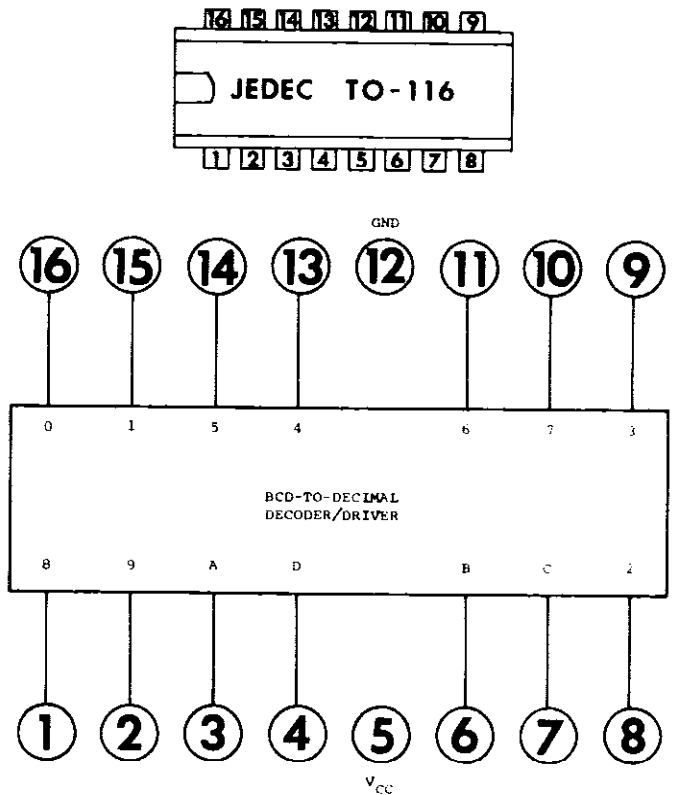


KEITHLEY PART NO. IC-33

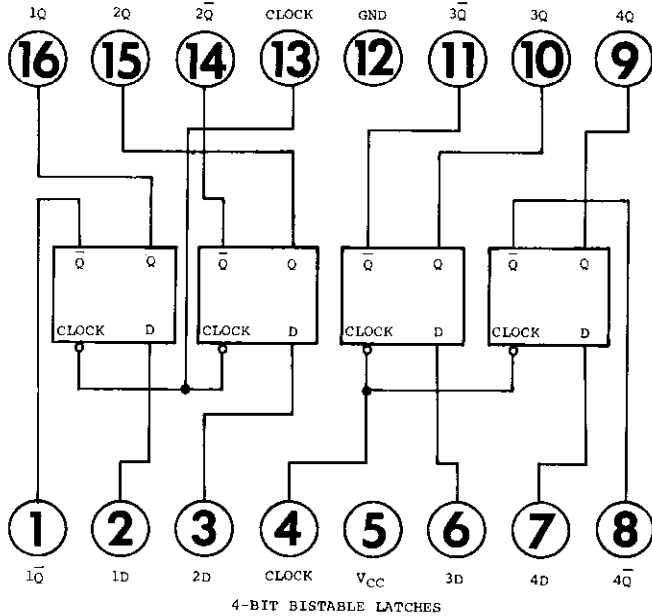
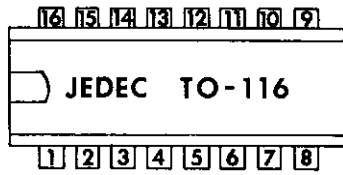
IC-45
IC-80
IC-81



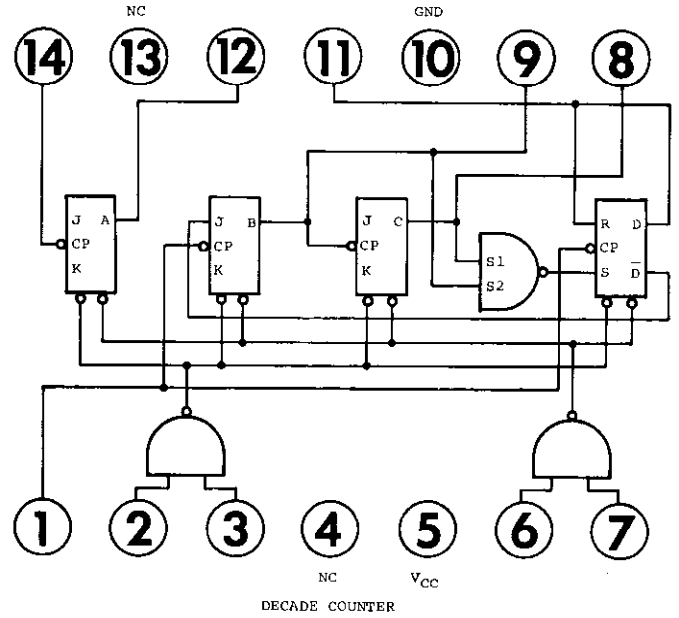
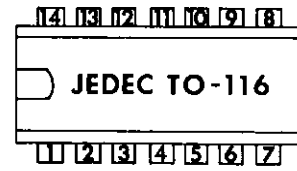
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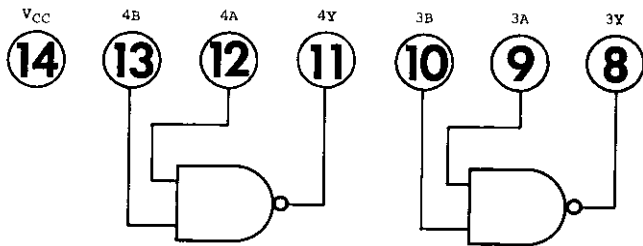
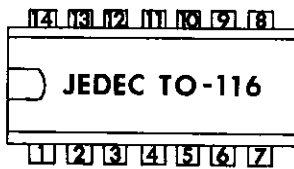
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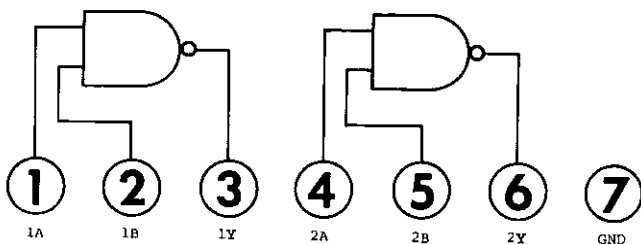
KEITHLEY PART NO. IC-37



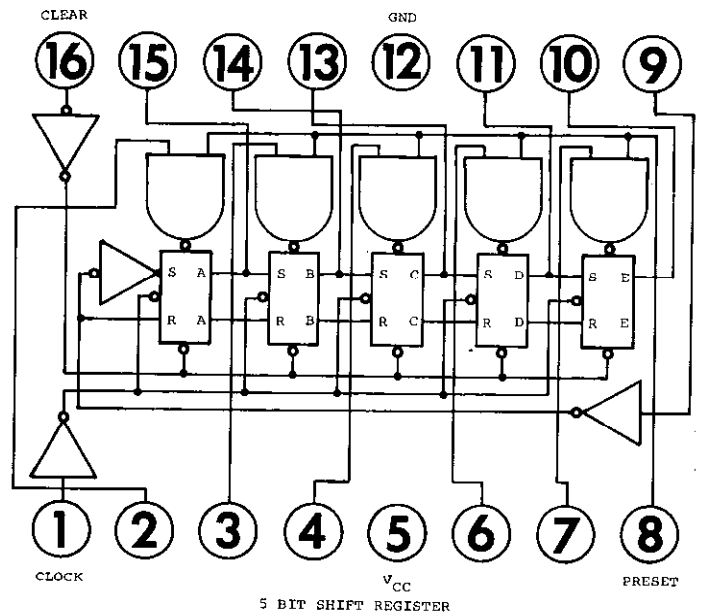
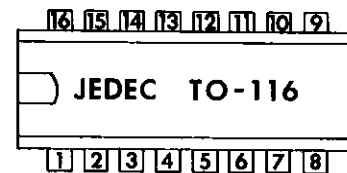
KEITHLEY PART NO. IC-38



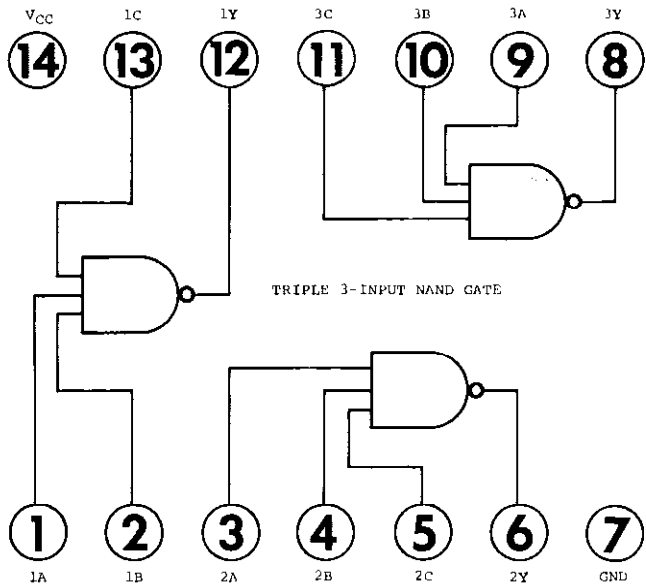
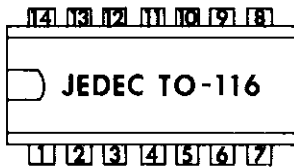
QUAD NAND GATE



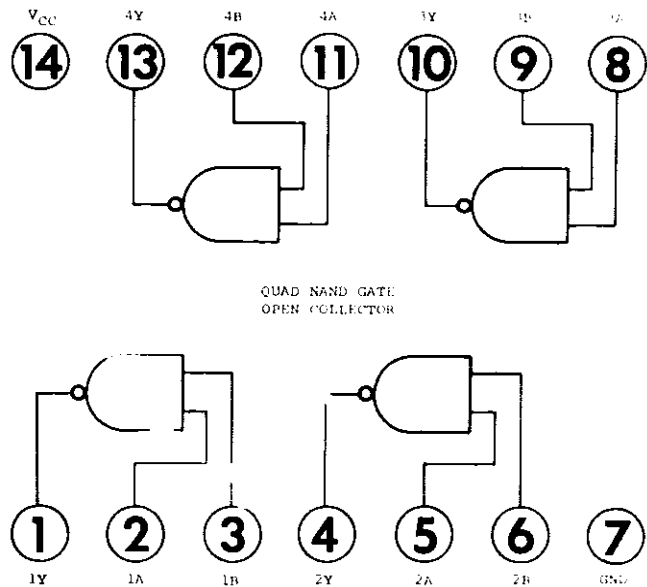
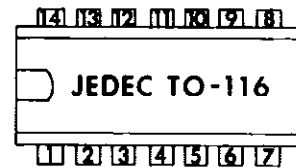
KEITHLEY PART NO. IC-39



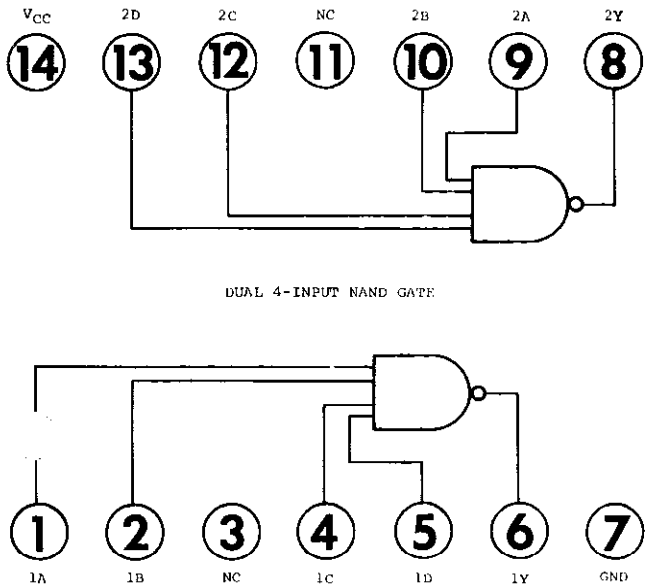
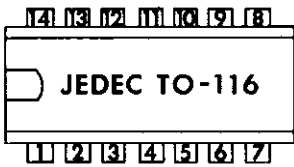
KEITHLEY PART NO. IC-43



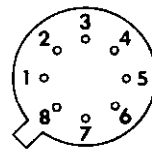
KEITHLEY PART NO. IC-47



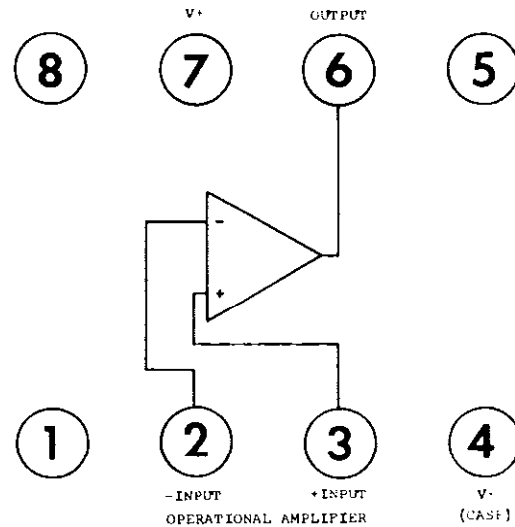
KEITHLEY PART NO. IC-48

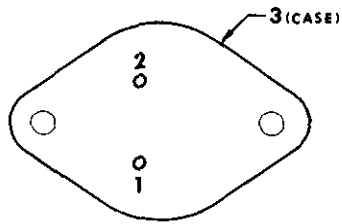


KEITHLEY PART NO. IC-56

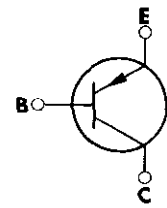
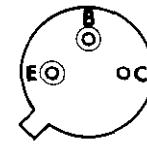
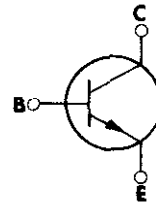


TO-99

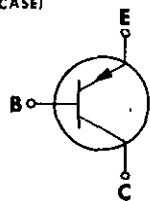
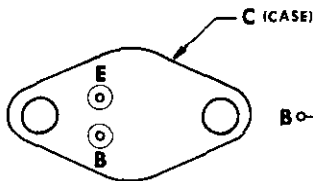
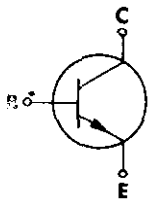




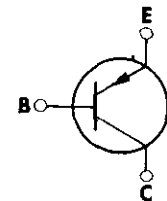
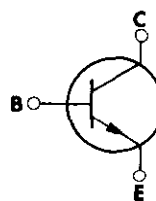
TO-3



TO-5

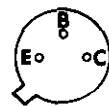
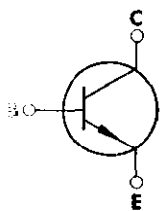


TO-66



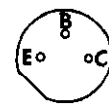
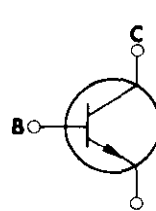
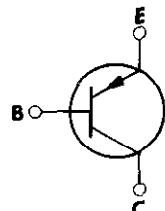
TO-92

BOTTOM VIEW



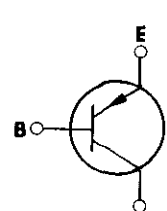
TO-104

BOTTOM VIEW



TO-106

BOTTOM VIEW

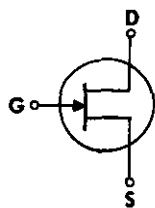


KEITHLEY PART NO. TG-41



TO-92

BOTTOM VIEW



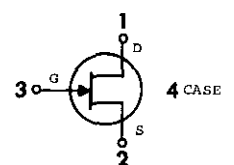
N-CHANNEL JFET

KEITHLEY PART NO. TG-42



TO-72

BOTTOM VIEW



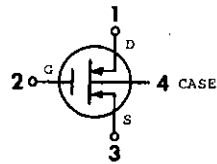
N-CHANNEL JFET

KEITHLEY PART NO. TG-51



TO-72

BOTTOM VIEW

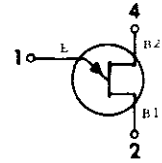


KEITHLEY PART NO. TG-52



TO-72

BOTTOM VIEW



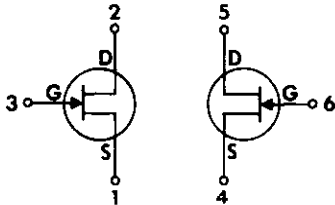
UNIUNCTION

KEITHLEY PART NO. TG-74



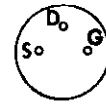
TO-71

BOTTOM VIEW



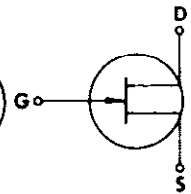
DUAL N-CHANNEL FET

KEITHLEY PART NO. TG-76



R-110

BOTTOM VIEW



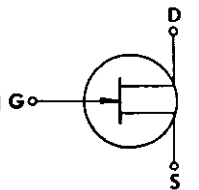
N-CHANNEL FET

KEITHLEY PART NO. TG-80



TO-18

BOTTOM VIEW



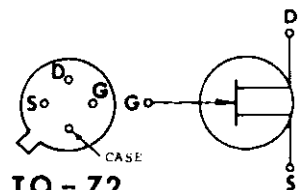
N-CHANNEL FET

KEITHLEY PART NO. TG-83



TO-72

BOTTOM VIEW



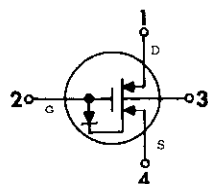
N-CHANNEL FET

KEITHLEY PART NO. TG-86



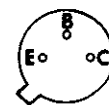
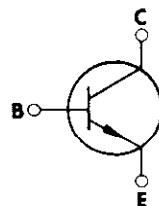
TO-72

BOTTOM VIEW

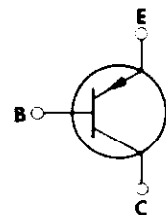


P-CHANNEL ENHANCEMENT

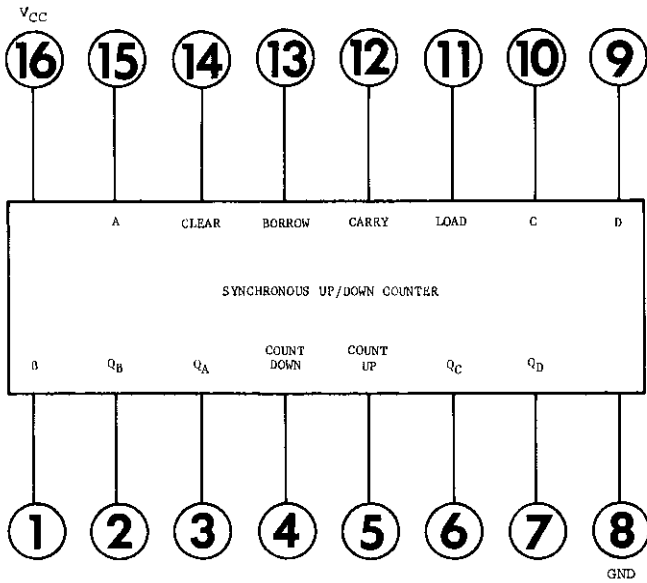
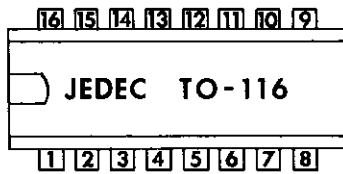
LEAD DESIG. TO-39



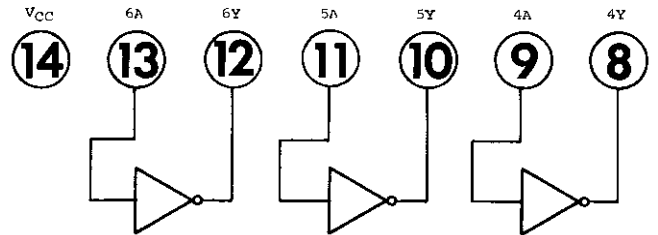
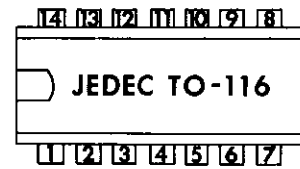
BOTTOM VIEW



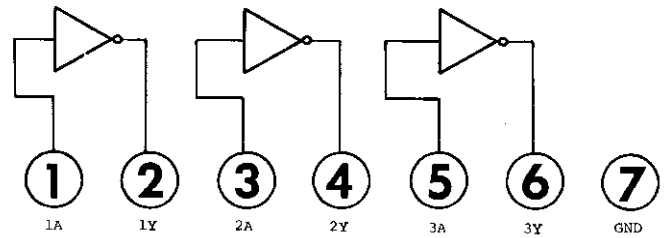
KEITHLEY PART NO. IC-44



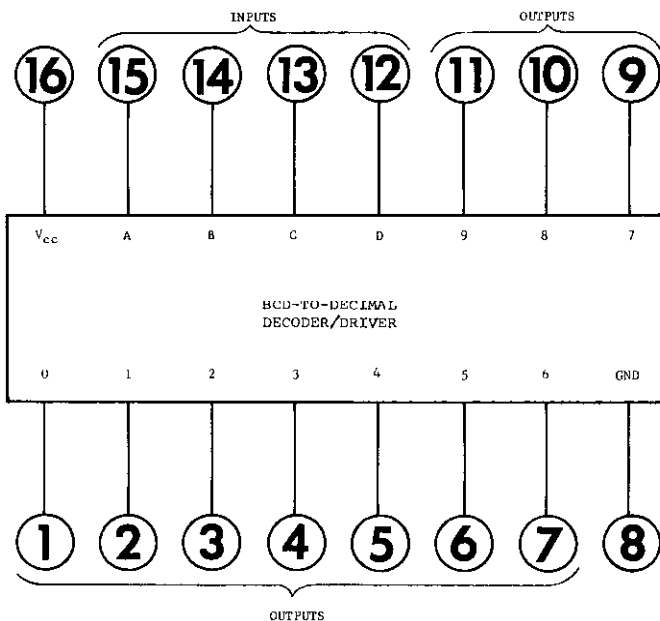
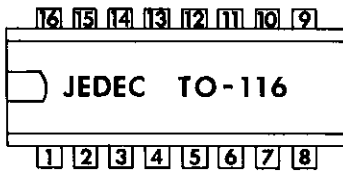
KEITHLEY PART NO. IC-33 IC-45



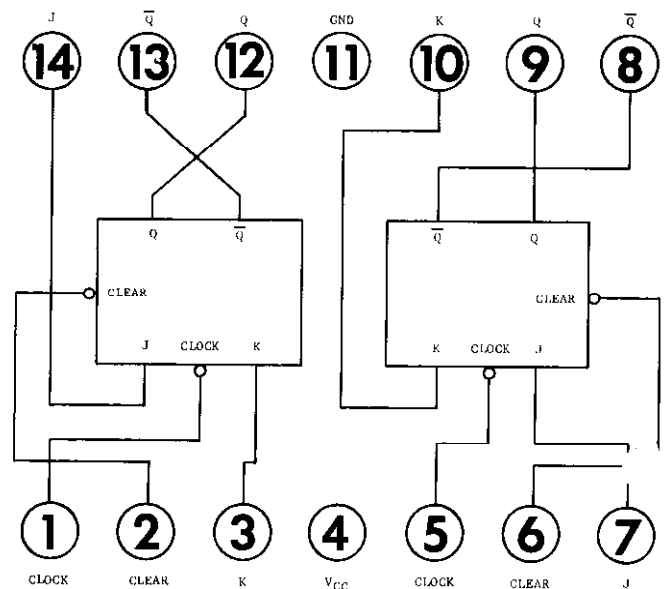
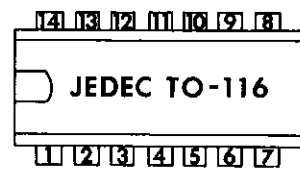
HEX INVERTER AMPLIFIER



KEITHLEY PART NO. IC-51



KEITHLEY PART NO. IC-54



DUAL J-K FLIP FLOP

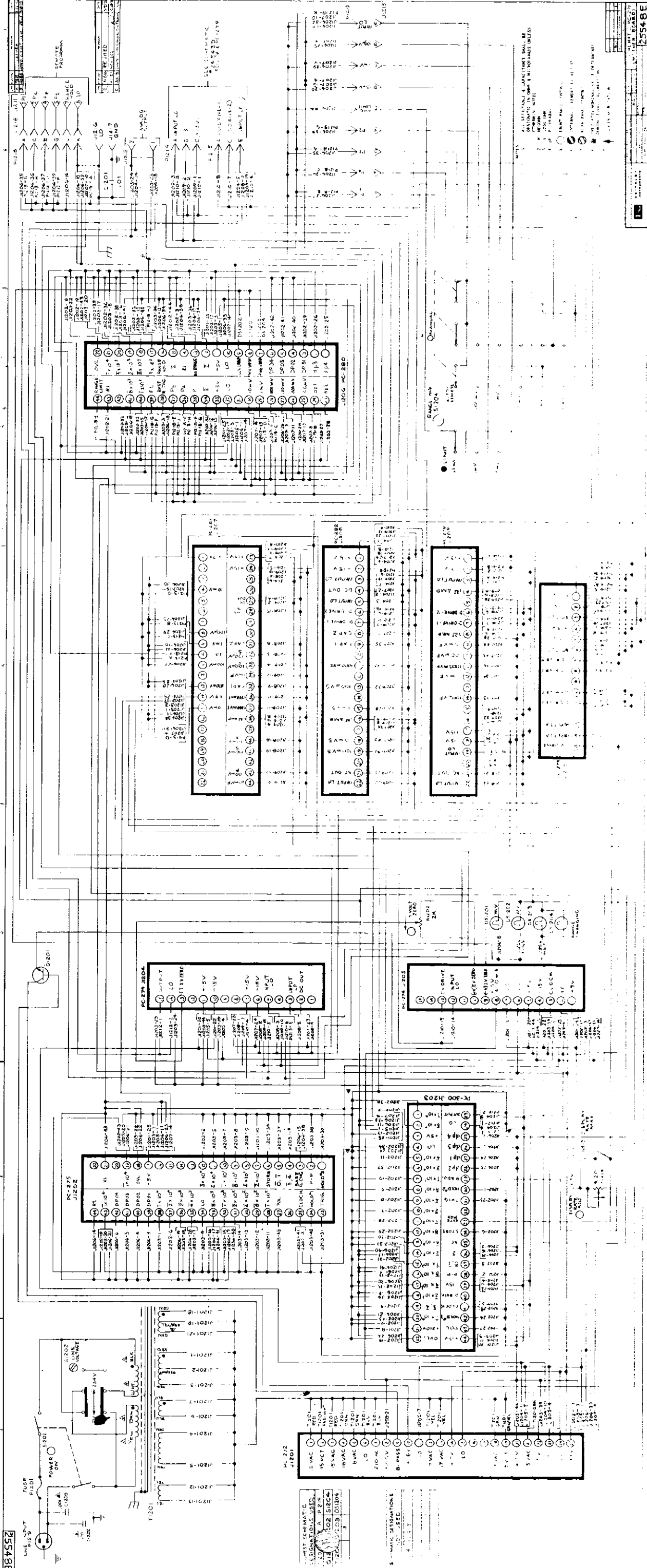
CODE—TO—NAME LIST

CODE TO NAME List of Suggested Manufacturers.
Reference: Federal Supply Code for Manufacturers, Cataloging Handbook H4-2.

00656	Aerovox Corp. New Bedford, Mass. 02745	07137	TEC, Inc. Eden Prairie, Minn.	56289	Sprague Electric Co. Visalia, Calif. 93278
00686	Film Capacitors, Inc. Passaic, N.J. 07055	07263	Fairchild Semiconductor Div. Mountain View, Calif.	14752	Electro Cube Inc. San Gabriel, Calif. 91776
01121	Allen-Bradley Corp. Milwaukee, Wisc. 53204	07716	TRC Div. of TRW Inc. Burlington, Iowa 52601	15238	ITT Semiconductors Div. of ITT Corp. Lawrence, Mass. 01841
01295	Texas Instruments, Inc. Semiconductor Div. Dallas, Texas 75231	08811	GL Electronics Div. GL Industries, Inc. Westville, N.J. 08093	17870	Daven Div. McGraw Edison Co. Livingston, N.J.
01686	RCL Electronics, Inc. Manchester, N.H. 03102	09052	Gulton Industries, Inc. Alkaline Battery Div. Metuchen, N.J.	16170	Teledyne Systems Co. Communications Div. Los Angeles, Calif. 90006
02101	Varo Inc. Electrokinetics Div. Santa Barbara, Calif. 93103	09823	Burgess Battery Co. Div. of Clevite Corp. Freeport, Ill.	17554	Components, Inc. Biddford, Me. 04005
02660	Amphenol Corp. Broadview, Ill. 60153	09922	Burndy Corp. Norwalk, Conn. 06852	17896	Siliconix Inc. Santa Clara, Calif. 95054
02734	RCA Defense Electronic Products Moorestown, N.J. 08540	10582	CTS of Asheville Inc. Skyland, N.C. 28776	18324	Signetics Corp. Sunnyvale, Calif. 94086
02735	RCA Solid State Div. Somerville, N.J. 08876	11502	TRC Div. of TRW Inc. Boone, N.C. 28607	22526	Berg Electronics, Inc. New Cumberland, Pa. 17070
02777	Hopkins Engineering Co. San Fernando, Calif. 91342	11534	Duncan Electronics, Inc. Costa Mesa, Calif. 92626	23020	General Reed Division Clark, N.J. 07066
02985	Tepro Electric Corp. Rochester, N.Y. 14606	11837	Electro Scientific Ind. Portland, Or. 97229	24655	General Radio Co. West Concord, Mass. 01781
03508	General Electric Co. Semiconductor Products Syracuse, N.Y. 13201	12040	National Semiconductor Corp. Danbury, Conn. 06810	27682	Hathaway Instruments, Inc. Denver, Colorado 80212
04009	Arrowhart, Inc. Hartford, Conn. 06106	12065	Transitron Electronic Corp. East Boston, Mass.	28520	Heyman Mfg. Co. Kenilworth, N.J. 07033
04713	Motorola Semicon. Prod. Phoenix, Ariz. 85008	12697	Clarostat Mfg. Co., Inc. Dover, N.H. 03820	29309	Richey Electronics Inc. Nashville, Tenn. 37213
05079	Transistor Electronics Bennington, Vt. 05201	12954	Dickson Electronics Corp. Scottsdale, Ariz. 85252	32293	Intersil, Inc. Cupertino, Calif. 95014
05397	Union Carbide Corp. Materials Systems Div. Cleveland, Ohio 44101	13050	Potter Co. Wesson, Miss. 39191	35529	Leeds and Northrup Philadelphia, Pa. 19144
06751	Components, Inc. Semcor Division Phoenix, Ariz. 85019	13327	Solitron Devices, Inc. Tappan, N.Y. 10983	37942	Mallory, P. R. and Co. Indianapolis, Ind. 46206
06980	Varian Eimac Division San Carlos, Calif. 94070	13934	Midwec Corp. Oshkosh, Nebr. 69154	44655	Ohmite Mfg. Co. Skokie, Ill. 60076
		14655	CornellDubilier Elec. Div. Newark, N.J. 07105	53021	Sangamo Electric Co. Springfield, Ill. 62705

CODE TO NAME List (Continued).

54294	Shallcross Mfg. Co. Selma, N.C. 27576	73690	Elco Resistor Co. New York, N.Y.	86684	RCA Electronic Components Harrison, N.J. 07029
56289	Sprague Electric Co. North Adams, Mass. 01247	74276	Signalite Inc. Neptune, N.J. 07753	87216	Philco Ford Corp. Lansdale Div. Lansdale, Pa. 19446
58474	Superior Electric Co. Bristol, Conn. 06010	74970	Johnson, E.F., Co. Waseca, Minn. 56093	90201	Mallory Capacitor Indianapolis, Ind. 46206
61637	Union Carbide Corp. New York, N.Y. 10017	75042	IRC Div. of TRW Inc. Philadelphia, Pa. 19108	90303	Mallory Battery Co. Tarrytown, N.Y. 10591
63060	Victoreen Instrument Co. Cleveland, Ohio 44104	75915	Littelfuse, Inc. Des Plaines, Ill. 60016	91637	Dale Electronics, Inc. Columbus, Nebr. 68601
02288	Allied Control Co., Inc. Plantsville, Conn. 06479	76055	Mallory Controls Div., Mallory P. R. & Co., Inc. Frankfort, Ind.	91662	Elco Corp. Willow Grove, Pa. 19090
70903	Belden Mfg. Co. Chicago, Ill. 60644	76493	Miller, J. W. Co. Compton, Calif. 90024	91737	ITT Gremar, Inc. Woburn, Mass. 01801
71002	Birnback Co., Inc. New York, N.Y. 10014	76545	Mueller Electric Co. Cleveland, Ohio 44114	91802	Industrial Devices Inc. Edgewater, N.J. 07020
71279	Cambridge Thermionic Corp. Cambridge, Mass. 02138	77764	Resistance Products Co. Harrisburgh, Pa. 17104	91929	Honeywell Inc. Micro Switch Div. Freeport, Ill. 61032
71400	Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo. 63017	79727	Continental-Wirt Electronics Corp. Philadelphia, Pa. 19144	93332	Sylvania Electric Prod. Semiconductor Prod. Div. Woburn, Mass. 01801
71450	CTS Corp. Elkhart, Ind. 46514	80164	Keithley Instruments, Inc. Cleveland, Ohio 44139	93656	Electric Cord Co. Fairfield, N.J. 07006
71468	ITT Cannon Electric, Inc. Los Angeles, Calif. 90031	80294	Bourns, Inc. Riverside, Calif. 92507	94144	Raytheon Co., Industrial Operation Components Div. Quincy, Mass.
71590	Centralab Div. of Globe-Union, Inc. Milwaukee, Wisc. 53201	81073	Grayhill, Inc. La Grange, Ill. 60525	94154	Tung-Sol Electric, Inc. Newark, New Jersey
71785	Cinch Mfg. Co. Howard B. Jones Div. Chicago, Ill. 60624	81483	International Rectifier Los Angeles, Calif. 90069	94310	Memcor, Inc. Components Division Huntington, Ind. 46750
72259	Nytronics, Inc. Pelham Manor, N.Y. 10803	82389	Switchcraft, Inc. Chicago, Ill. 60630	94696	Magnecraft Electric Co. Chicago, Ill.
72619	Dialight Corp. Brooklyn, N.Y. 11237	83125	General Instrument Corp. Capacitor Division Darlington, S.C. 29532	95263	Leecraft Mfg. Co., Inc. L.I. City, N.Y. 11101
72653	G-C Electronics Co. Rockford, Ill. 61101	83330	Smith, Herman H., Inc. Brooklyn, N.Y. 11207	95348	Gordos Corp. Bloomfield, N.J. 07003
72699	General Instrument Corp. Capacitor Division Newark, N.J. 07104	83594	Burroughs Corp. Electronic Components Div. Plainfield, N.J. 07061	95712	Dage Electric Co., Inc. Franklin, Ind.
72982	Erie Technological Prods. Erie, Pa. 16512	83701	Electronic Devices, Inc. Brooklyn, New York	97419	Standard Condenser Co. Chicago, Ill. 60613
73138	Beckman Instruments, Inc. Helipot Division Fullerton, Calif. 92634	84171	Arco Electronics, Inc. Great Neck, N.Y. 11022	97933	Raytheon Co. Components Div. Semiconductor Operation Mountain View, Calif.
73445	Amperex Electronic Div., North American Philips Co. Hicksville, N.Y.	84411	TRW Capacitor Div. Ogallala, Nebr.	99120	Plastic Capacitors, Inc. Chicago, Ill.
		84970	Sarkes Tarzian, Inc. Bloomington, Ind.		



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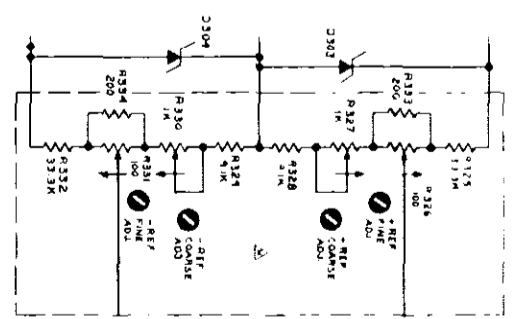
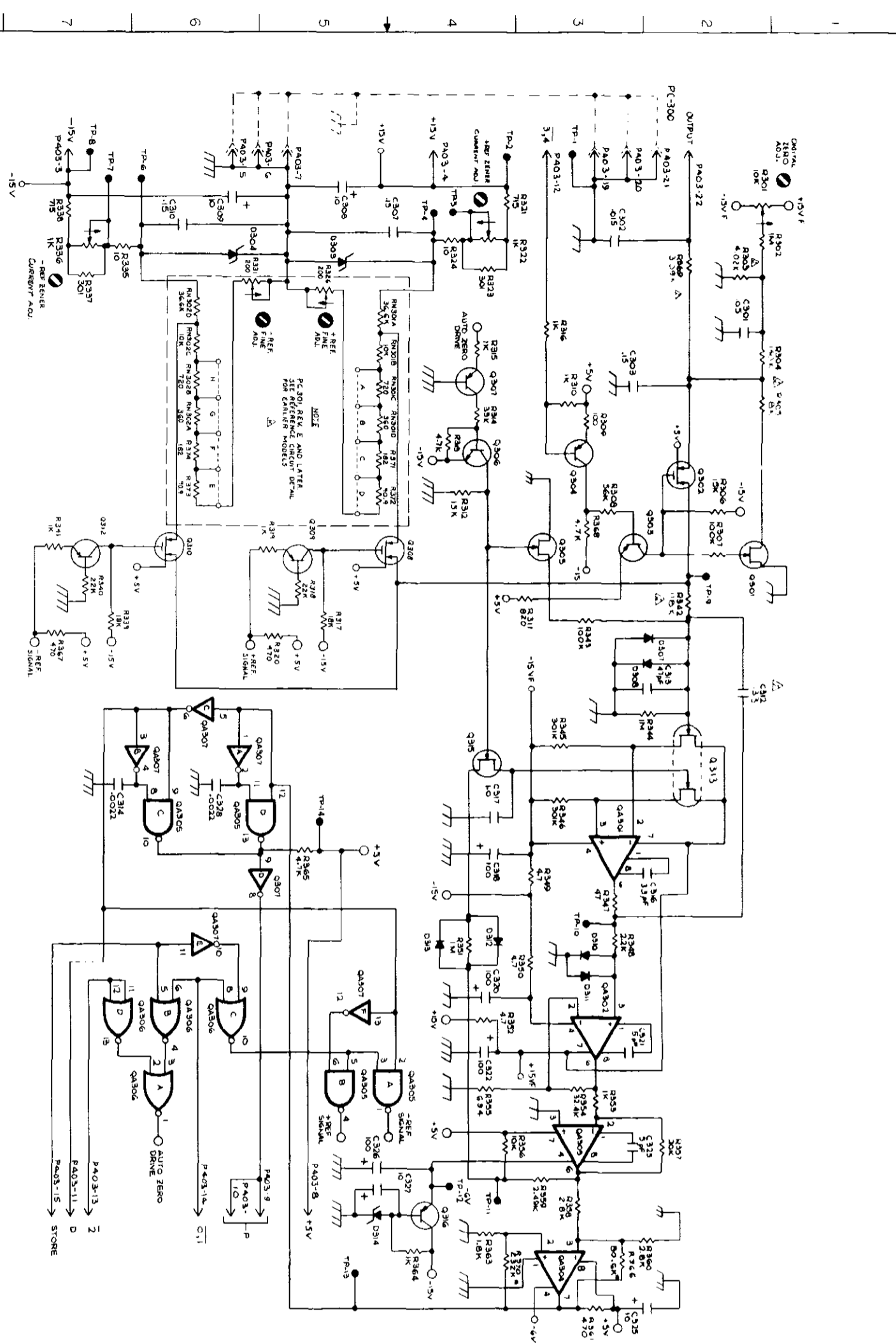
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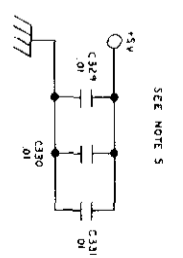
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SCHEMATIC IDENTIFICATION OF REV. 2 AND EARLIER

R301	R302	R303	R304	R305	R306	R307	R308	R309	R310
R311	R312	R313	R314	R315	R316	R317	R318	R319	R320
R321	R322	R323	R324	R325	R326	R327	R328	R329	R330
R331	R332	R333	R334	R335	R336	R337	R338	R339	R340
R341	R342	R343	R344	R345	R346	R347	R348	R349	R350



- NOTES:
1. TO DETERMINE THE PIN NUMBERS, REFER TO THE PIN LIST AND CONNECTION DIAGRAMS PROVIDED.
 2. Δ - IMPROVED COMPONENTS APPROVED.
 3. ∇ - 1000 OHM, 1% - PRECISION.
 4. ∇ - 100 OHM, 1% - PRECISION.
 5. ∇ - 100 OHM, 1% - PRECISION.
 6. ∇ - 100 OHM, 1% - PRECISION.
 7. ∇ - 100 OHM, 1% - PRECISION.
 8. ∇ - 100 OHM, 1% - PRECISION.
 9. ∇ - 100 OHM, 1% - PRECISION.
 10. ∇ - 100 OHM, 1% - PRECISION.
 11. ∇ - 100 OHM, 1% - PRECISION.
 12. ∇ - 100 OHM, 1% - PRECISION.
 13. ∇ - 100 OHM, 1% - PRECISION.
 14. ∇ - 100 OHM, 1% - PRECISION.
 15. ∇ - 100 OHM, 1% - PRECISION.
 16. ∇ - 100 OHM, 1% - PRECISION.
 17. ∇ - 100 OHM, 1% - PRECISION.
 18. ∇ - 100 OHM, 1% - PRECISION.
 19. ∇ - 100 OHM, 1% - PRECISION.
 20. ∇ - 100 OHM, 1% - PRECISION.

HIGHEST SCHEMATIC DESIGNATION

C311	R304	C314	D306
D314	C305	C314	D314
D316	C306	D301	D311
R316	C311	D302	D314
Q307	C315	D305	R342

SCHEMATIC DESIGNATIONS NOT USED

C304	C314	D304
C305	C314	D314
C306	D301	D311
C311	D302	D314
C315	D305	R342

DO NOT SCALE THIS DRAWING

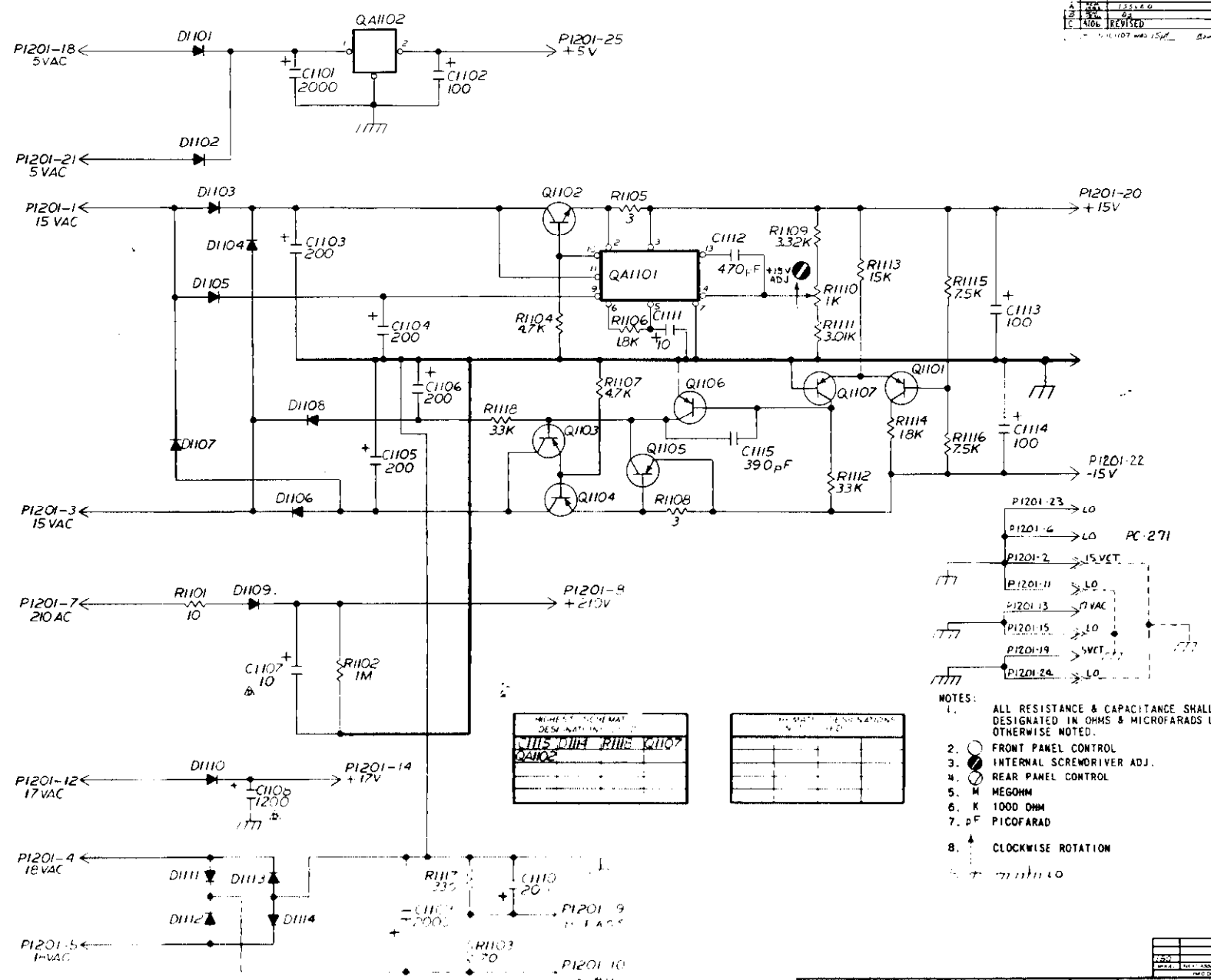
KEITHLEY INSTRUMENTS DIVISION

SCHEMATIC IDENTIFICATION OF REV. 2 AND EARLIER

25017E

25054D

REV	DATE	BY
A	12-20-60	W.P.
B	6	W.P.
C	REVIS	W.P.



Q1101	Q1102	Q1103	Q1104	Q1105	Q1106	Q1107	Q1108	Q1109
Q1110	Q1111	Q1112	Q1113	Q1114	Q1115	Q1116	Q1117	Q1118

R1101	R1102	R1103	R1104	R1105	R1106	R1107	R1108	R1109	R1110	R1111	R1112	R1113	R1114	R1115	R1116
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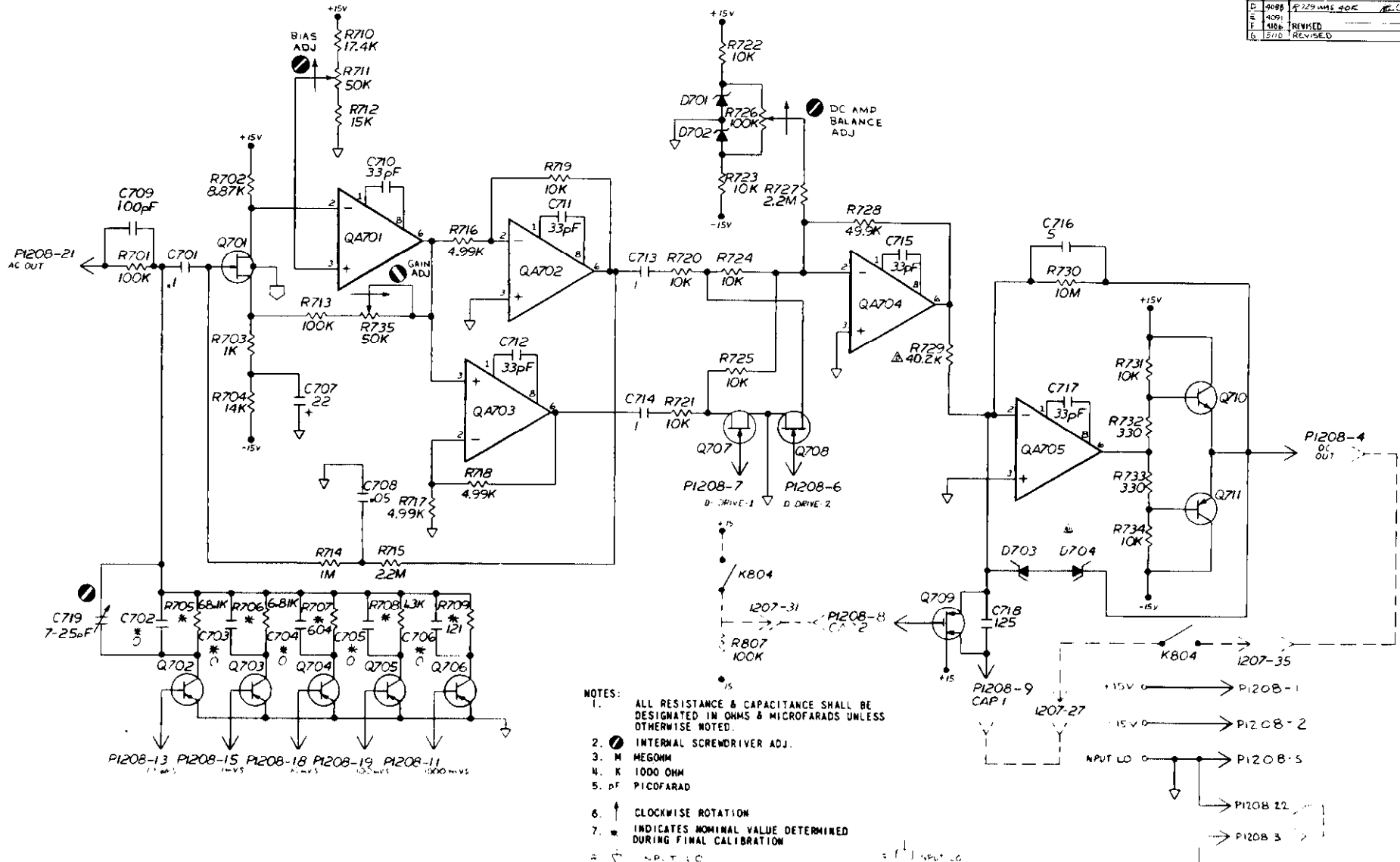
- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
 2. FRONT PANEL CONTROL
 3. INTERNAL SCREWDRIER ADJ.
 4. REAR PANEL CONTROL
 5. M MEGOHM
 6. K 1000 OHM
 7. P PICOFARAD
 8. CLOCKWISE ROTATION

REV	DATE	BY
A	12-20-60	W.P.
B	6	W.P.
C	REVIS	W.P.

25054D

011152

REV	DESCRIPTION	DATE
1	ISSUED	3-21-73
2	REVISED	3-22-73
3	REVISED	2-7-73
4	REVISED	3-8-73
5	REVISED	4-17-73
6	REVISED	5-21-73
7	REVISED	1-7-76



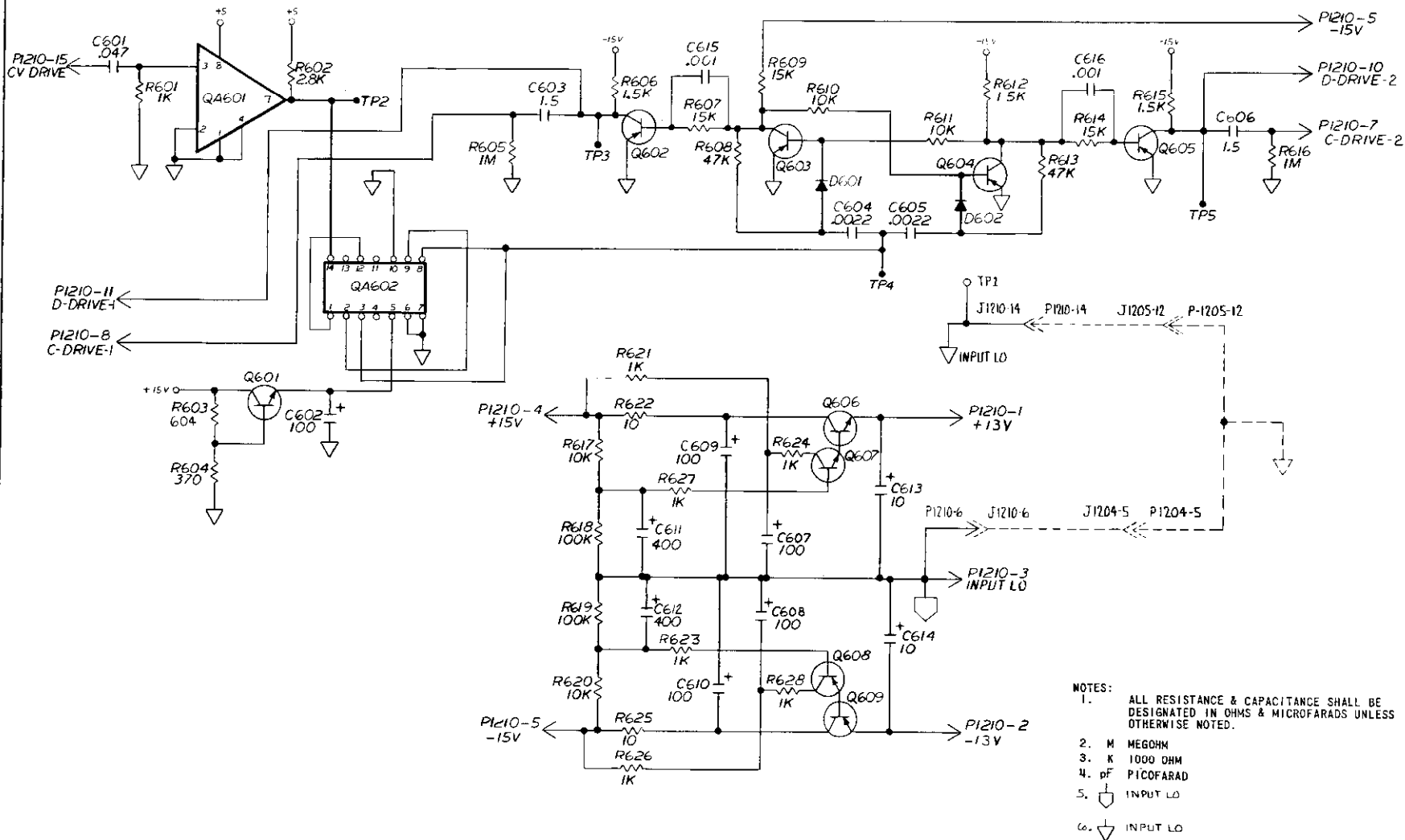
- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
 2. Ⓢ INTERNAL SCREWDRIIVER ADJ.
 3. M MEGOHM
 4. K 1000 OHM
 5. pF PICOFARAD
 6. ⤴ CLOCKWISE ROTATION
 7. * INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION
 8. ⤴ N.P.T. I.C.

REV	DESCRIPTION	DATE
1	ISSUED	3-21-73
2	REVISED	3-22-73
3	REVISED	2-7-73
4	REVISED	3-8-73
5	REVISED	4-17-73
6	REVISED	5-21-73
7	REVISED	1-7-76

25110

021152

REV	NO	REVISION	DATE
A	1	ISS. E.D.	5-22-52
B	2	REVISION	5-22-52



- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
 2. M MEGOHM
 3. K 1000 OHM
 4. pF PICOFARAD
 5. ∇ INPUT LO
 6. ∇ INPUT LO

HIGHEST SCHEMATIC DESIGNATIONS USED			
C616	Q605	R622	R628
C602			

SCHEMATIC DESIGNATIONS NOT USED			

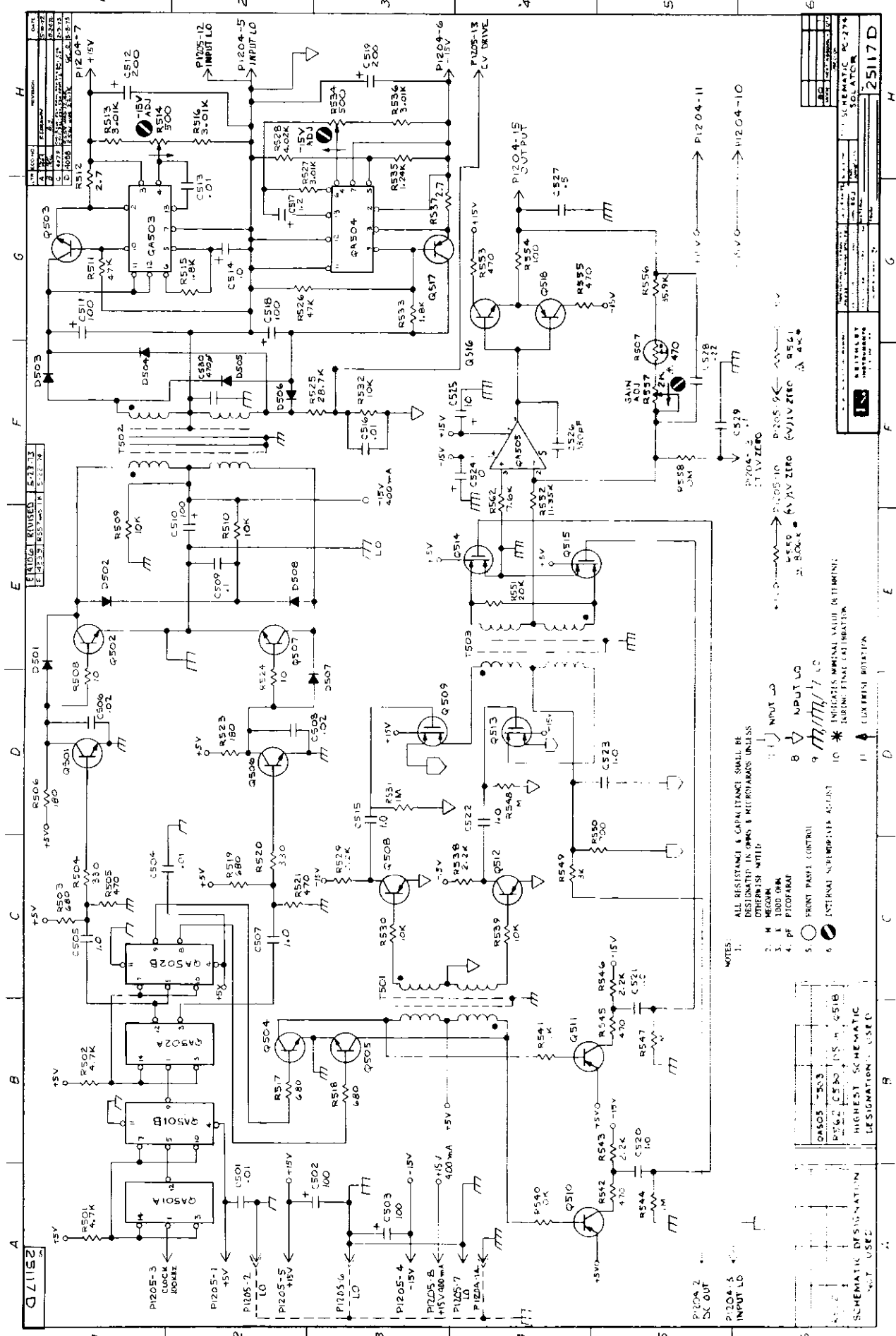
DO NOT SCALE THIS DRAWING

RESISTANCE TOLERANCES: 1% - 1.0% AND 5% DIMENSIONS: MAX - 2.000 FRACTIONAL SURFACE MOUNT

DATE: 5-71 SCALE: 1/8" = 1" MATERIAL: CUMULATIVE

WTL SCHEMATIC PC-273

NO: 251120



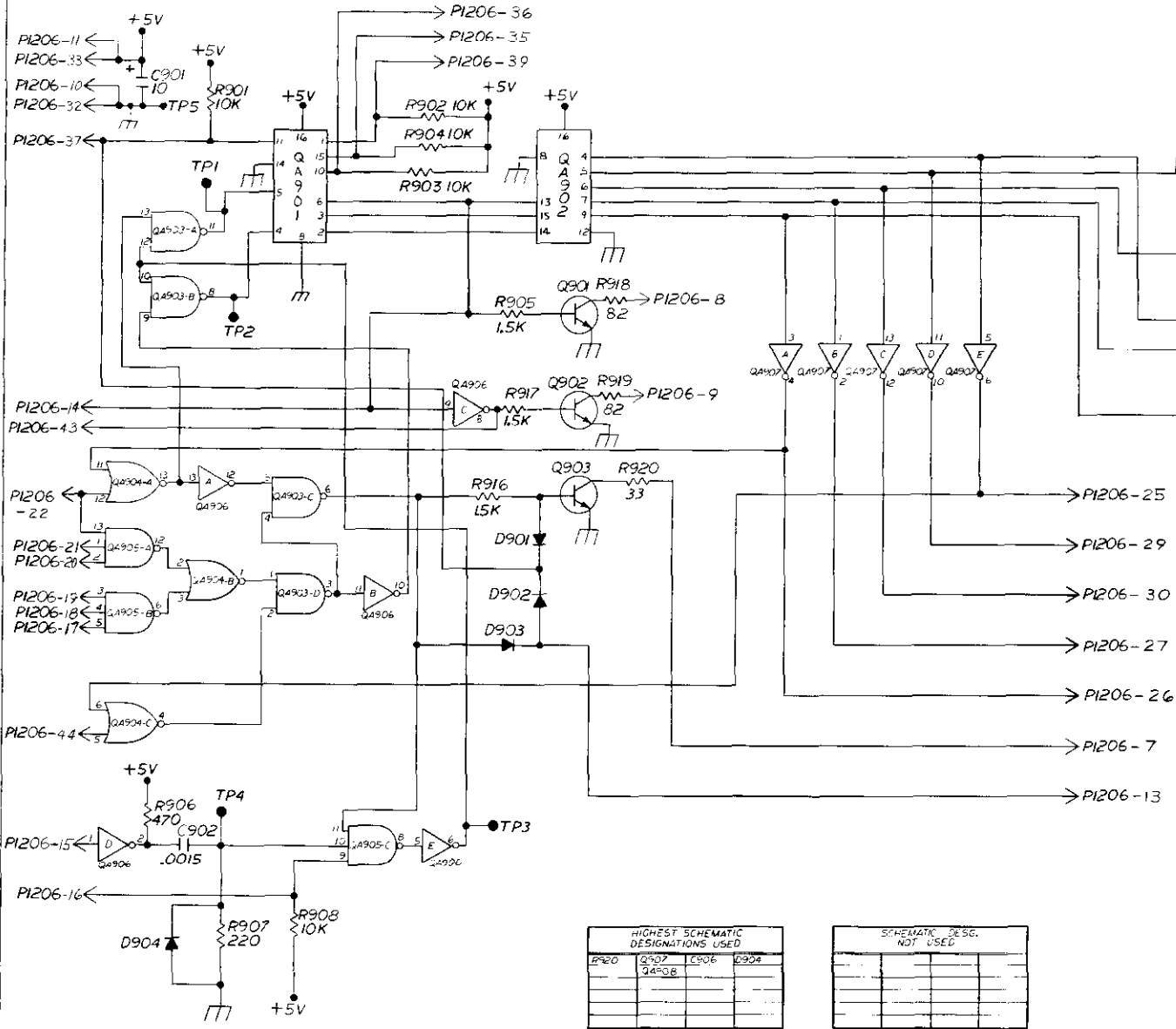
REVISED 5-23-72
 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 841. 842. 843. 844. 845. 846. 847. 848. 849. 850. 851. 852. 853. 854. 855. 856. 857. 858. 859. 860. 861. 862. 863. 864. 865. 866. 867. 868. 869. 870. 871. 872. 873. 874. 875. 876. 877. 878. 879. 880. 881. 882. 883. 884. 885. 886. 887. 888. 889. 890. 891. 892. 893. 894. 895. 896. 897. 898. 899. 900. 901. 902. 903. 904. 905. 906. 907. 908. 909. 910. 911. 912. 913. 914. 915. 916. 917. 918. 919. 920. 921. 922. 923. 924. 925. 926. 927. 928. 929. 930. 931. 932. 933. 934. 935. 936. 937. 938. 939. 940. 941. 942. 943. 944. 945. 946. 947. 948. 949. 950. 951. 952. 953. 954. 955. 956. 957. 958. 959. 960. 961. 962. 963. 964. 965. 966. 967. 968. 969. 970. 971. 972. 973. 974. 975. 976. 977. 978. 979. 980. 981. 982. 983. 984. 985. 986. 987. 988. 989. 990. 991. 992. 993. 994. 995. 996. 997. 998. 999. 1000.

- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROHMS UNLESS OTHERWISE NOTED
 2. M = MEGOHMS
 3. K = 1000 OHMS
 4. PF = PICO FARAD
 5. ○ = POINT PULSE CONTROL
 6. ○ * = INTERNAL SCHEMATIC AGENT
 7. ○ = INPUT LO
 8. ○ = INPUT LO
 9. ○ = INPUT LO
 10. * = INDICATES MINIMAL VALUE OBTAINING DURING FINAL CALIBRATION
 11. ○ = CURRENT INDICATION

| | | | |
|-------------------------------|-----|-------|-----|
| QAS03 | 303 | QAS03 | 303 |
| R557 | 557 | R557 | 557 |
| C518 | 518 | C518 | 518 |
| HIGHEST SCHEMATIC DESIGNATION | | | |
| NOT USED | | | |

| | |
|-------------------|---------|
| 25117 D | |
| REVISED | DATE |
| 1.0 | 5-23-72 |
| 2.0 | 5-23-72 |
| 3.0 | 5-23-72 |
| 4.0 | 5-23-72 |
| 5.0 | 5-23-72 |
| 6.0 | 5-23-72 |
| 7.0 | 5-23-72 |
| 8.0 | 5-23-72 |
| 9.0 | 5-23-72 |
| 10.0 | 5-23-72 |
| SOLICITOR | |
| SCHEMATIC NO. 274 | |

| | | |
|------|----------|-----|
| REV. | DATE | BY |
| 1 | 11-15-68 | WJH |
| 2 | 1-23-69 | WJH |
| 3 | 6-22-72 | WJH |
| 4 | 5-12-73 | WJH |



- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
 2. K 1000 OHM
 3. pF PICOFARAD
 4. /77 LO

| PIN | | PIN | |
|-----|---------------------|-----|-------------|
| NO. | NO. | NO. | NO. |
| 1 | dp 4 | 21 | TRK 4 |
| 2 | dp 3 | 22 | CVL |
| 3 | DPO1 | 23 | dp 2 |
| 4 | DPO2 | 24 | dp 1 |
| 5 | DPO3 | 25 | 100 mV |
| 6 | DPO4 | 26 | 1000 mV |
| 7 | RNG. LAMP | 27 | 100 mV |
| 8 | MV. LAMP | 28 | NO CONN. |
| 9 | NO. LAMP | 29 | 10 mV |
| 10 | NO. CONN. | 30 | 10 mV |
| 11 | NO. CONN. | 31 | 10 mV |
| 12 | NO. CONN. | 32 | 10 mV |
| 13 | BISE. R. CH. | 33 | +5V |
| 14 | R 2 | 35 | P 1 |
| 15 | 3 | 36 | P 4 |
| 16 | RANGE HOLD | 37 | P. SW. |
| 17 | T x 10 ³ | 39 | P 2 |
| 18 | S x 10 ³ | 43 | R 1 |
| 19 | T x 10 ² | 44 | RANGE LIMIT |
| 20 | T x 10 ¹ | | |

| HIGHEST SCHEMATIC DESIGNATIONS USED | | | |
|-------------------------------------|-------|------|------|
| R920 | Q907 | C906 | Q904 |
| | Q4906 | | |
| | | | |
| | | | |

| SCHEMATIC DESG. NOT USED | | | |
|--------------------------|--|--|--|
| | | | |
| | | | |
| | | | |

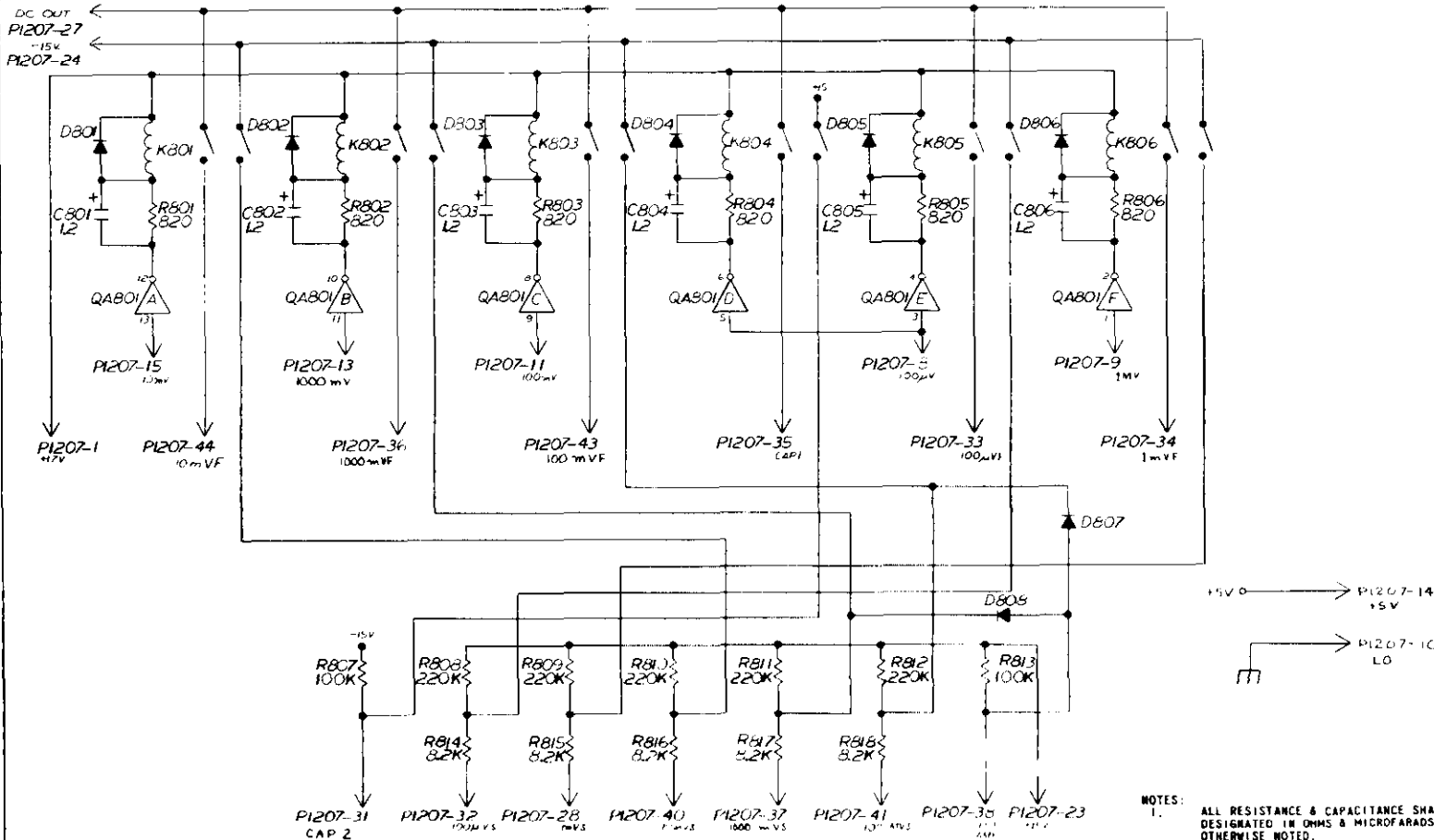
DO NOT SCALE THIS DRAWING

| | | | |
|----------------------|-------------|------------|-------------------|
| REITHLEY INSTRUMENTS | DATE: 09-70 | SCALE: 1:1 | SYMBOLS: SEE LIST |
| LEVEL AND 340 | DATE: 09-70 | SCALE: 1:1 | SYMBOLS: SEE LIST |
| SUPPLY: 110V | DATE: 09-70 | SCALE: 1:1 | SYMBOLS: SEE LIST |

NO. 25024D

000152

| | | |
|-----|----------|-----|
| REV | DATE | BY |
| 1 | 10/20/54 | WJL |
| 2 | 11/10/54 | WJL |
| 3 | 12/10/54 | WJL |



- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
 2. K 1000 OHM
 3. PIN 4 GRID +5V
 4. PIN 7 GRID LO
 5. 7 LO

| REV | DATE | BY |
|-----|----------|-----|
| 1 | 10/20/54 | WJL |

| REV | DATE | BY |
|-----|----------|-----|
| 1 | 10/20/54 | WJL |

WETLEY INSTRUMENTS

29100

28775 AURORA ROAD
CLEVELAND, OHIO 44139
SERVICE FORM

MODEL NO. _____ SERIAL NO. _____ P.O. NO. _____ DATE _____ R- _____

NAME _____ PHONE _____

COMPANY _____

ADDRESS _____ CITY _____ STATE _____ ZIP _____

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) _____

(Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. _____

4. Describe input signal source levels, frequencies, etc. _____

5. List and describe all cables used in the experiment (length, shielding, etc.).

6. List and describe all other equipment used in the experiment. Give control settings for each. _____

7. Environment:
Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) _____
What power line voltage is used? _____ Variation? _____ Frequency? _____
Ambient temperature? _____ °F. Variation? _____ °F. Rel. Humidity? _____
Other _____

8. Additional Information. (If special modifications have been made by the user, please describe below.) _____



KEITHLEY INSTRUMENTS, INC.

INSTRUCTION MANUAL CHANGE NOTICE MODEL 180 DIGITAL NANOVOLTMETER

INTRODUCTION: Since Keithley Instruments is continually improving product performance and reliability, it is often necessary to make changes to Instruction Manuals to reflect these improvements. Also, errors in Instruction Manuals occasionally occur that require changes. Sometimes, due to printing lead time and shipping requirements, we can't get these changes immediately into printed Manuals. The following new change information is supplied as a supplement to this Manual in order to provide the user with the latest improvements and corrections in the shortest possible time. Many users will transfer this change information directly to a Manual to minimize user error. All changes or additions are indicated in *italics*.

CHANGES:

Page 58
Table 7-1.

Item D should read:

| | | | |
|---|------------------------------|----------|-----|
| D | Null Detector/Microvoltmeter | Keithley | 155 |
|---|------------------------------|----------|-----|

Item E should read:

| | | | |
|---|----------------------------------|----------|-----------|
| E | Low-Thermal Resistance, 1060 Ohm | Keithley | R15E-1060 |
|---|----------------------------------|----------|-----------|



KEITHLEY INSTRUMENTS, INC.

28775 AURORA ROAD • CLEVELAND, OHIO 44139 • (216) 248-0400
TELEX 98-5469 • CABLE KEITHLEY