INSTRUCTION MANUAL

MODEL 840

AUTOLOC™ AMPLIFIER

KEITHLEY INSTRUMENTS

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AUTOLOC™ AMPLIFIER

KEITHLEY INSTRUMENTS, INC.

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PRINTED IN U.S.A.

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SPECIFICATIONS

SIGNAL CHANNEL

INPUT: Differential or single-ended; wideband (or tuned with accessory plug-in filters).

RANGE: 10 microvolts rms full-scale to 1 volt in calibrated 1X and 3X steps.

INPUT DYNAMIC RANGE: (Signal Extraction Ratio) 90 dB for 1 Hz to 100 Hz center frequencies decreasing to 60 dB at 10 kHz. Up to 140 dB with optional filter card.

USEABLE CENTER FREQUENCIES: 0.5 Hz to 15 kHz with full phase control.

OUTPUT ACCURACY: ±1% for sine-wave to rms conversion at 100 Hz, ±0.05%/°C.

METER ACCURACY: ±1% of full-scale.

FREQUENCY RESPONSE: ±1%, 10 Hz to 10 kHz; -3 dB at 1 Hz and 100 kHz.

INPUT IMPEDANCE: 11 megohms shunted by 35 picofarads either input to ground.

CMV: 10 volts p-p maximum on the .01 and .1 millivolt sensitivity settings, 100 volts p-p on higher settings.

CMRR: Greater than 50 dB for coherent signals on any range, 1 Hz to 10 kHz. Typical mid-band CMRR: Greater than 140 dB for non-coherent non-harmonically related signals.

INPUT NOISE FIGURE: Better than 3 dB at 1 kHz and 1 megohm.

INPUT NOISE (Shorted): Less than 0.1 μV rms per root Hz above 400 Hz. Less than 0.5 μV rms per root Hz at 10 Hz.

TIME CONSTANT: 3 milliseconds to 100 seconds in ten 1X and 3X steps. Off position provides less than 0.3 millisecond time constant. 6 dB/octave rolloff.

MAXIMUM NON-COHERENT INPUT: 700 X full-scale (57 dB Dynamic Reserve) on the 1X multiplier, deceasing to 7 times full-scale (17 dB Dynamic Reserve) on the 100X multiplier. Can be increased with optional filter up to 230,000 times full-scale (107 dB Dynamic Reserve).

MAXIMUM INPUT OVERLOAD: 100 volts rms on all ranges without damage.

OVERLOAD:INDICATOR: Lamp shows pre-filter, demodulator and dc amplifier overload.

OUTPUT: ±10 volts dc at up to 2 milliamperes.

CALIBRATED ZERO SUPPRESSION: 100 times full-scale on the 1X multiplier decreasing to 1 times full-scale on the 100X multiplier.

SUPPRESSION STABILITY: Better than 0.05%/°C of maximum suppression.

ZERO UNCERTAINTY: Less than 0.0025%/°C of full output on the 100X multiplier, increasing to 0.25%/°C on the 1X multiplier (after 1-hour warm-up).

REFERENCE CHANNEL

INPUT IMPEDANCE: 1 megohm shunted by 30 picofarads.

INPUT REQUIRED: Trigger: 0.5 Hz to 15 kHz, any waveform passing its mean twice per cycle by 12 millivolts minimum, 12 volts maximum (full phase control). 2nd-Harmonic: 0.5 Hz to 7.5 kHz (for detection of 1 Hz to 15 kHz) any symmetrical waveform passing its mean twice per cycle, 25 millivolts to 25 volts peak-to-peak (full phase control). Phase Elim.: 0.5 Hz to 15 kHz, any symmetrical waveform passing its mean twice per cycle, 25 millivolts to 25 volts peak-to-peak (no phase control).

MAXIMUM INPUT OVERLOAD: 100 volts peak-to-peak without damage.

PHASE CONTROL: Adjustable through 370°. Quadrature switching for 0°, 90°, 180°, 270°. Continuous control through 100° with 1/4° resolution.

PHASE ACCURACY: Total quadrature accuracy within 2°, incremental dial accuracy within 2°, 1 Hz to 10 kHz. ±5° absolute*, 10 Hz to 10 kHz; ±10° absolute* at 1 Hz.
(* For rated absolute phase accuracy, reference waveform must reach 12 millivolts within 0.5° (25 millivolt p-p square wave, 1-volt rms sine-wave, 5 volt p-p triangle wave). Any additional phase error caused by this factor must be added to absolute phase error.

PHASE STABILITY: Better than 0.1°/°C.

FREQUENCY SELECTION: 4 decade spans, 1 Hz to 10 kHz with 50% overlap on each span. Frequency lock provides calibrated phase control over each span without tuning for either fundamental or second-harmonic detection.

ACQUISITION TIME: Less than 10 seconds at any frequency.

GENERAL

MONITOR: Connectors permit simultaneous monitoring of ac amplifier output, demodulator output, dc output, demodulator drive, and demodulator frequency.

CONNECTORS: All BNC except auxiliary power which is Amphenol 126-1429.

POWER: 105-125 or 210-250 volts (switch-selected), 50-60 Hz, 13 watts.

DIMENSIONS, WEIGHT: 3-1/2" full-rack, overall bench size 4" high x 17" wide x 12-1/8" deep (100 x 432 x 308 mm). Net weight 14 lbs., (6,1 kg).

ACCESSORIES FURNISHED: Hardware for standard 3-1/2" x 19" rack mounting, 12" deep behind front panel.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL. The Model 840 AUTOLOC T.M. Amplifier is a complete, highly sophisticated lock-in amplifier. This instrument includes signal and reference amplifiers, phase shifting circuit, phase sensitive detector, and power supply, all on one chassis.

1-2. FEATURES.

a. Wideband Design. In wideband mode, the Model 840 has high linearity and wide dynamic range for extracting a signal buried in wideband noise.

b. Optional Tuned Filter. Accessory filter card can be plugged into the Model 840 to provide signal extraction capability up to 140 dB.

c. Differential Input. The choice of differential or single-ended input accommodates a wide variety of signal sources, useful when ground loops cannot be avoided.

d. Auxiliary Power Tap. DC power is provided for operating an accessory amplifier such as the Model 103A Nanovolt Amplifier.

e. Zero Suppression. The input signal can be suppressed up to 100 times full scale when measuring small changes in the signal.

f. Second Harmonic Operation. The reference channel can be triggered such that second harmonic signals can be detected.

g. Built-in Time Constants. The optimum time constant can be selected using a front panel switch over a range fron 3ms to 100 seconds.

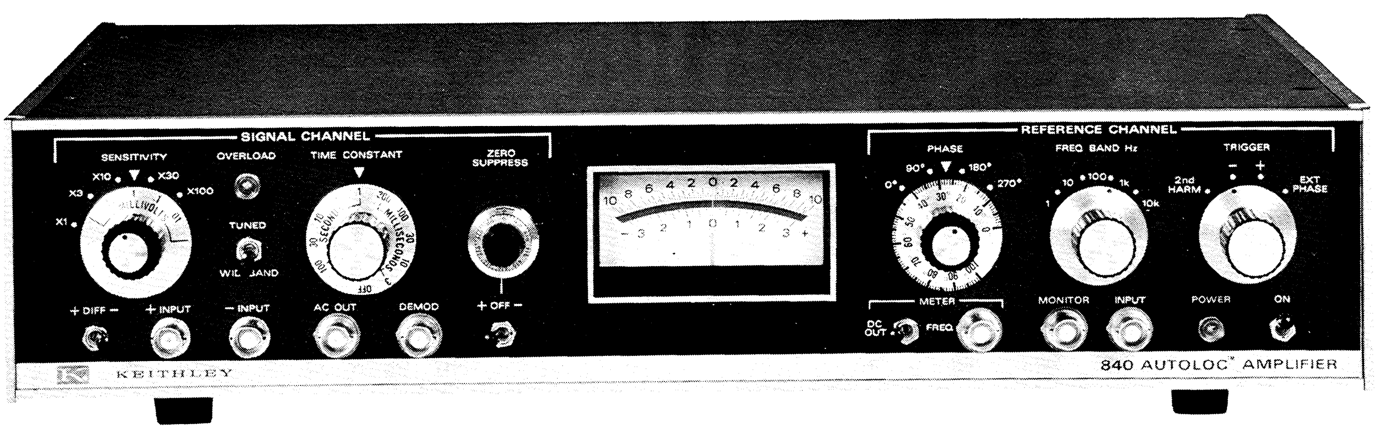


TABLE 1-1.
Front Panel Controls and Terminals

Control or Terminal	Functional Description	Para.
Signal Channel		
SENSITIVITY Switch (Inner Dial)(S202)	Sets DC Amplifier gain.	2-4 b
(Outer Dial)(S201)	Sets AC Amplifier gain.	
TUNED/WIDEBAND Switch (S1102)	Selects either wideband or tuned operation.	2-4 b
OVERLOAD Indicator (DS201)	Indicates overload condition.	2-4 b
TIME CONSTANT Switch (S1104)	Sets time constant from 3 ms to 100 seconds.	2-4 b
ZERO SUPPRESS Control (R1102)	Sets the zero suppression.	2-4 b
"+ OFF -" Switch (S1103)	Sets the polarity of zero suppression.	2-4 b
"+ DIFF -" Switch (S1101)	Sets the input for single ended or differential mode.	2-4 b
+ INPUT Receptacle (J1101)	Connection to + Input.	2-3 b
- INPUT Receptacle (J1102)	Connection to - Input.	2-3 b
AC OUT Receptacle (J1105)	Monitors ac amplifier output.	2-3 b
DEMOD Receptacle (J1106)	Monitors demodulator output.	2-3 b
Reference Channel		
PHASE Switch (Inner Dial)(S601)	Sets Phase Quadrant.	2-4 a
(Outer Dial)(R1101)	Sets Phase Shift from 0° to 100°.	
FREQ BAND Switch (S701)	Sets the frequency band for reference channel.	2-4 a
TRIGGER Switch (S901)	Sets the Trigger Mode.	2-4 a
INPUT Receptacle (J1103)	Connection to reference input.	2-3 a
MONITOR Receptacle (J1110)	Monitors the demodulator drive.	2-3 a
Outputs		
Meter (M1101)	Indicates full scale from 0-3 and 0-10, with center zero.	-
METER Switch (S1105)	Selects either DC or F-to-V meter readout.	2-4 d
METER Receptacle (J1108)	Connection to meter output.	2-3 c
Power		
POWER Indicator (DS1101)	Indicates power on.	-
ON Switch (S1107)	Controls power to instrument.	2-4 c

TABLE 1-2.
Rear Panel Terminals

Control or Terminal	Functional Description	Para.
Power Receptacle (FL1101)	Connection to line power.	2-3 f
Fuse (F1101)	Type 3 AG Slow Blow, 117V @ 1/4A 234V @ 1/8A	-
Line Power Switch (S1106)	Sets instrument for 117V or 234V.	2-4 e
F-V CONV OUTPUT (J1104)	Connection to F-V output.	2-3 e
DC OUTPUT (J1107)	Connection to DC output.	2-3 d
ACCESSORY POWER Receptacle (J1109)	Connection to ±18V Accessory Power.	2-3 g

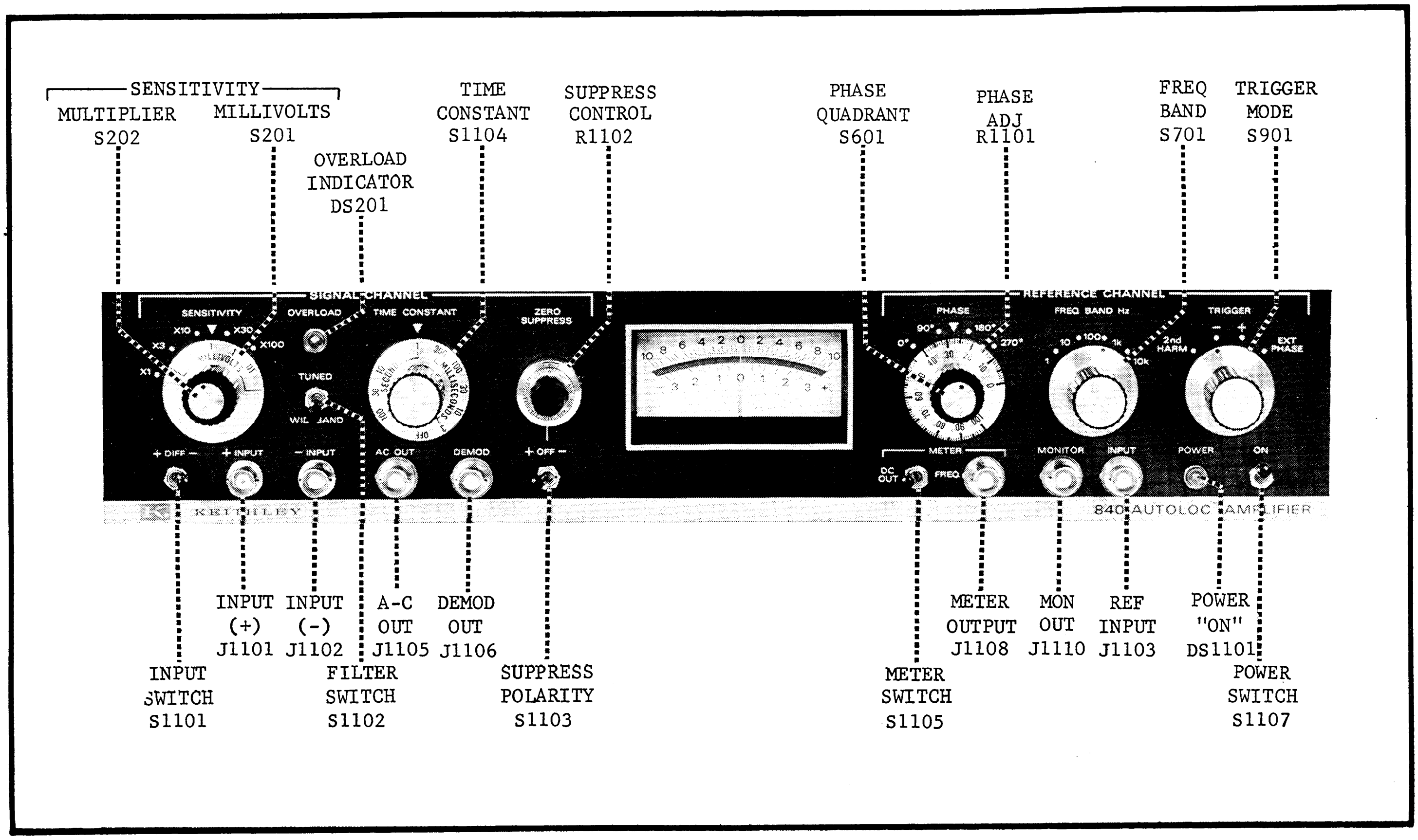


FIGURE 2. Front Panel Controls and Terminals.

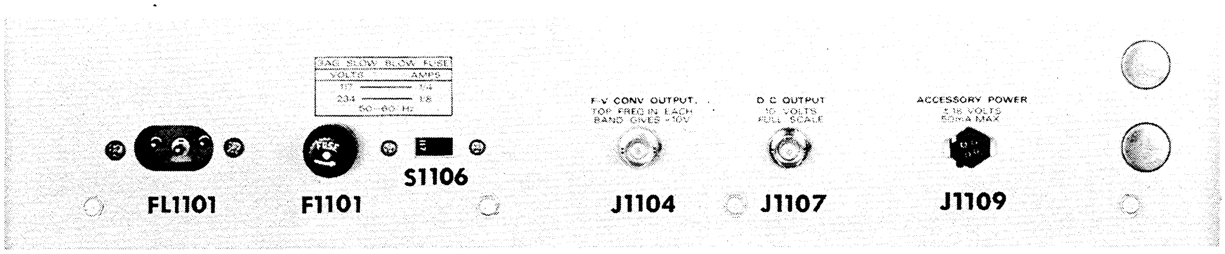


FIGURE 3. Rear Panel Terminals.

SECTION 2. OPERATION

2-1. THEORY.

a. Phase Sensitive Detection. The measurement of ac signals (0.1 Hz to 100 kHz) is largely affected by the presence of random noise, the limiting factor to resolution in measurement of small signals. An effective solution to this problem is the use of phase-sensitive detection. The phase-sensitive detector is a device which can be represented by the diagram in Figure 4. The reference voltage (from an oscillator, chopper, or switch) drives a gating circuit (demodulator) such that the input signal V_S is chopped at the reference frequency. When the reference and signal are of the same frequency and phase, the psd acts as a voltage rectifier and gives a mean direct voltage proportional to the amplitude of the signal voltage. When the reference and signal are out of phase the dc output is reversed. Quadrature signals produce a zero mean output. For signal-recovery purposes, an R-C filter is placed across the output as in Figure 6 so as to attenuate the ac output ripple of the psd. The degree of attenuation depends on the time constant given by the capacitor and the output resistance of the psd. The response of the R-C filtering is shown in Figure 8. Since the bandwidth is not dependent on the operating frequency the amount of filtering can be increased as far as practical using a simple R-C circuit. Since the psd has a "lock-in frequency" property it maintains the center of the psd response at the signal or reference frequency. This can be useful in experiments where the bandwidth might need to be set to 0.1 Hz even though the chopping frequency might vary by ±1 Hz.

b. Mathematical Relationships. For a sinusoidal input signal and reference the output voltage V_{OUT} is given by equation 1.

$$V_{OUT} \propto V_S \cos\alpha \quad \text{Eq. 1}$$

where V_S = Input signal amplitude
α = phase angle between signal and reference

The psd also gives an ac output due to asynchronous signal as in equation 2.

$$V_{AS} = \tfrac{1}{2} V_N \cos(\omega_N - \omega_R)t + \tfrac{1}{2} V_N \cos(\omega_N + \omega_R)t \quad \text{Eq. 2}$$

where V_N = magnitude of asynchronous signal
ω_N = asynchronous frequency
ω_R = reference frequency

The triggering of the reference signal produces a square wave gate drive regardless of the exact reference input waveform. Thus the Fourier components of the square wave should be considered. Eq. 3

$$V_R(t) = V_R \sin \omega_R t - 1/3\, V_R \sin 3\omega_R t + 1/5\, V_R \sin 5\omega_R t -$$

The results of Equation 3 can be represented by an output response as shown in Figure 8.

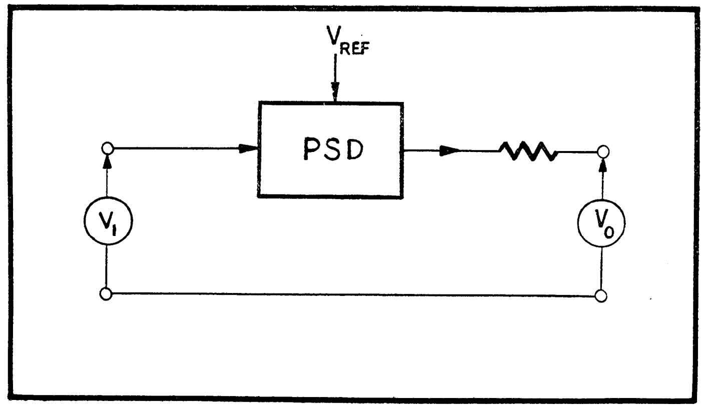


FIGURE 4. PSD as a Voltage Controlled Gate.

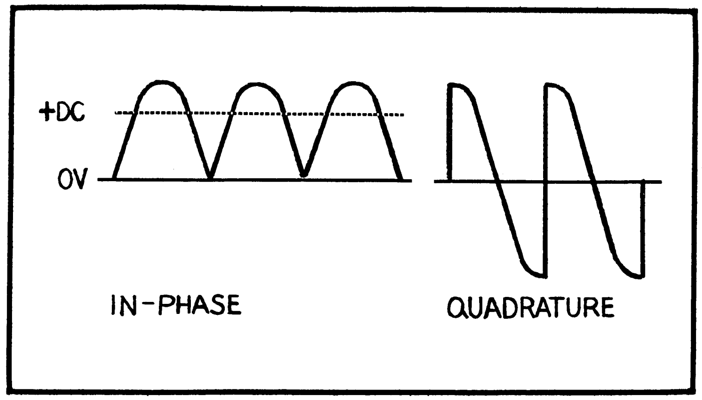


FIGURE 5. PSD Waveforms.

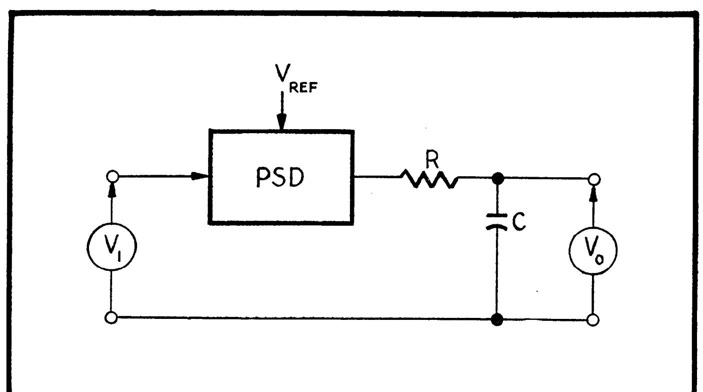


FIGURE 6. Time Constant.

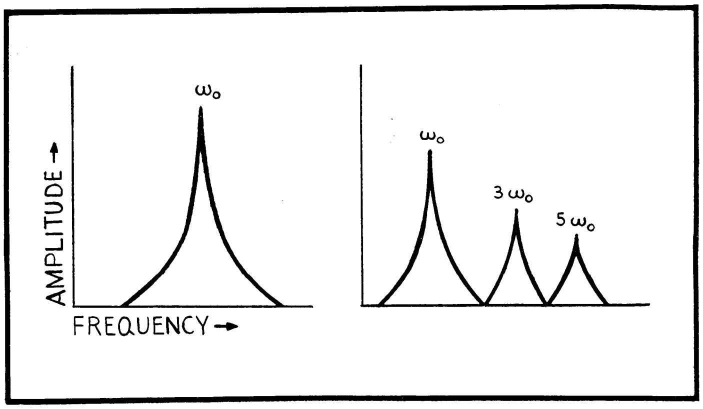


FIGURE 7. Response of PSD.

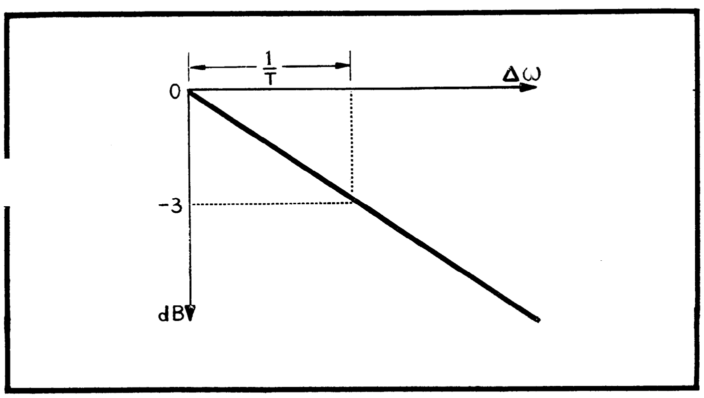


FIGURE 8. Response of Output Circuit.

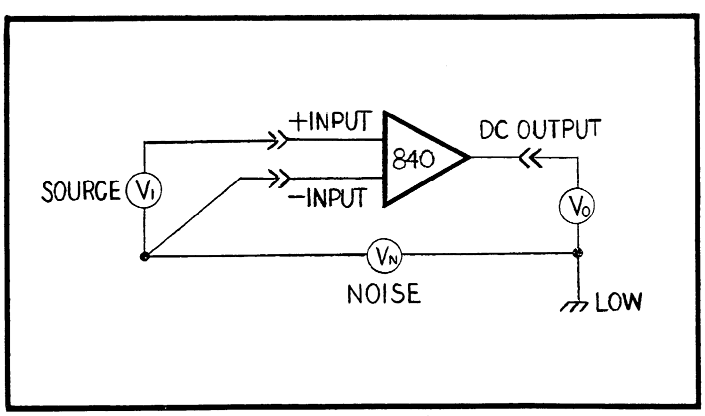


FIGURE 9. Use of Differential Input.

2-2. MEASUREMENT CONSIDERATIONS.

a. Noise Sources. The electrical source applied to the input of a lock-in amplifier system can be composed of a coherent ac signal and non-coherent (noise) signals. The noise signals represent the electrical uncertainty and can be classified in four general categories: "white", "1/f", discrete frequency, and quadrature.

1. "White" Noise. This type of noise has a characteristic of constant energy per unit bandwidth. Random noise should be distinguished as to noise generated in the source and noise in the signal-recovery system. An essential characteristic of resistive sources is thermal or "Johnson" noise, due to the thermal motion of the electrons in the material of the resistor. Because of this, any signal source with an intrinsic source resistance generates its own thermal noise - a noise which is present however perfect the amplifying equipment. Thermal noise has a "white" or flat frequency spectrum.

2. Flicker Noise (1/f). This noise has a characteristic of constant energy per percent bandwidth. Random noise such as generated by tubes and transistors shows a low-frequency characteristic or 1/f relationship.

3. Discrete Frequency Noise. This is noise generated by various discrete frequency sources such as power lines, radio frequency generators, etc.

4. Quadrature Noise. This type of noise (or unwanted signal) represents a signal which has been shifted in phase by 90° with respect to the reference frequency signal.

NOTE

Both the Johnson noise limitation of the source and the inherent noise in the instrumentation must be taken into account. Instrument noise and Johnson noise should be added in quadrature to obtain the total measurement noise which is the limit of resolution for the measurement.

Eq. 4

$$E_{\text{total noise}} = \sqrt{E^2_{\text{Johnson noise}} + E^2_{\text{instrument noise}}}$$

b. Grounding. The Model 840 has been designed to minimize the effects of electric field interference and ground loops in system connections. The differential input of the Model 840 provides common-mode rejection. Also the ground loop between instruments (such as for the System 84) is effectively broken. Thus special precautions usually required for system connections are not necessary when the Model 840 is operated in the "DIFF" mode. Figure 9 shows the equivalent circuit for a differential connection to the Model 840.

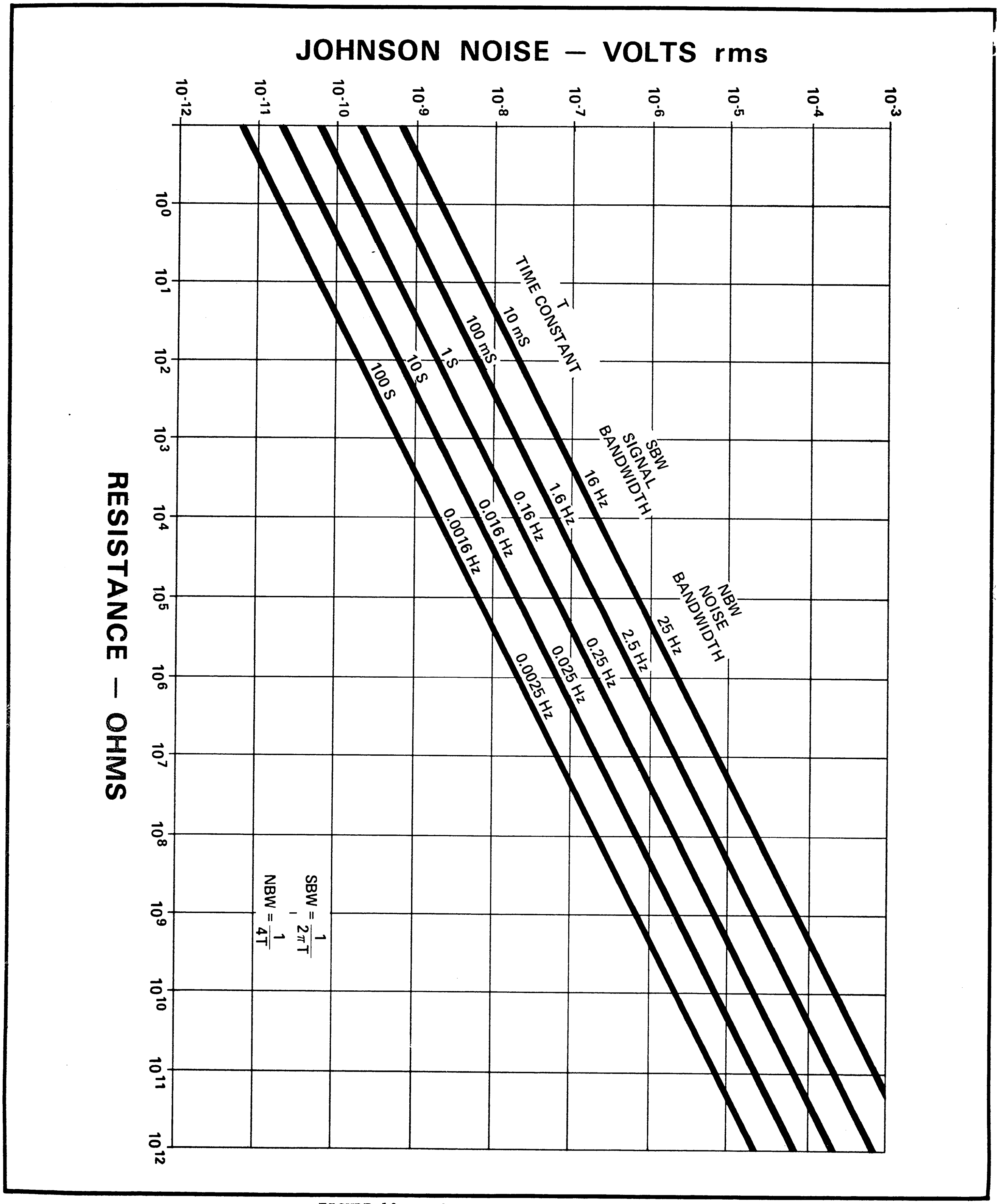


FIGURE 10. Johnson Voltage Noise Chart.

c. Signal-to-Noise Ratio.

1. Extraction of signal from noise. A Lock-in Amplifier extracts a signal from noise by multiplying the signal frequency with the reference frequency. Since the two frequencies are equal, and the result of the multiplication includes a signal at the frequency difference, a dc signal is generated. This dc signal may be "cleaned" of higher frequency components with a low-pass filter of time constant T. The overall filter characteristic given by this system (if the filter is first-order) is that of a second-order bandpass filter centered on the reference frequency whose equivalent noise bandwidth (for white noise) is:

$$\Delta f_{out} = \frac{1}{4T} \quad \text{Eq. 5}$$

With a time constant variable from 10ms to 100s and the equivalent noise bandwidth can therefore be varied between 25 Hz and 0.0025 Hz.

2. Signal/noise improvement with white noise. For a given white noise source the noise voltage is proportional to the square root of the noise bandwidth. Therefore the improvement in signal/noise ratio obtained with a Lock-in Amplifier is given by taking the square root of the ratio of the noise bandwidth of the input signal and the noise bandwidth of the lock-in filter:

$$\frac{\text{signal/noise ratio at output}}{\text{signal/noise ratio at input}} = \frac{\sqrt{\Delta f\ in}}{\sqrt{\Delta f\ out}} \quad \text{Eq. 6}$$

For example, the improvement in signal/noise ratio for Δf in = 100 kHz and T = 10s is:

$$\frac{\sqrt{\Delta f\ in}}{\sqrt{\Delta f\ out}} = 2 \times 10^3 \text{ or } 66 \text{ dB}$$

3. Signal/noise improvement with narrow-band noise. The lock-in can give an enormous improvement in signal/noise ratio when dealing with narrow-band noise. Under the heading "narrow-band noise" are included such interfering signals as line pick-up, etc. The usual reason for this lies in the high-order filtering effect of the readout equipment normally employed (moving-coil meters, chart recorders, etc.).

4. Signal Detection. Improvement of signal to noise is apparent when considering two extremes in signal detection.

a). Signal Buried by Noise. In this situation it is desired to determine the characteristics of a signal several decades below the noise level. Accuracy of signal magnitude is unimportant. In this case the signal channel must have wide ac dynamic range to handle large non-coherent signals.

b). Small Changes in Signal. In this situation it is desired to observe small changes in a relatively large signal above the noise level-but the small changes in the signal are obscured by noise. In this case the signal channel must handle large coherent signals. The instrument must have wide ac and demodulator dynamic range plus a wide dc output dynamic range.

e. Accessory Filters. Although a wideband "lock-in" system is quite adequate for the majority of measurement situations, there are occasions when additional filtering in the signal channel is beneficial or even a necessity. Such is likely to be the case when the experiment contains severe "noise" of one or several discrete frequencies. The Model 8401 Bandpass Filter and the Model 8402 Notch Filter are intended to improve the signal/noise ratio of the measurement when this condition exists. The Model 840 allows either the 8401 Filter or the 8402 Filter to be inserted into a connector inside the instrument and to be activated by a toggle switch ("Wideband-Tuned" Switch) on the front panel. The 8401 Bandpass Filter can be supplied to the user with a center frequency anywhere within the frequency range of the Model 840. This filter can extend the dynamic reserve and improve the input dynamic range of the signal channel significantly. For "noise" frequencies several octaves away from the frequency of operation an improvement in the input dynamic range of 48 dB is possible. This means that at operating frequencies below 100 Hz, the input dynamic range could be increased from 90 dB to 138 dB, and at an operating frequency of 10 kHz, the input dynamic range could be greater than 108 dB! For "noise" frequencies further away than several octaves, even greater improvements are possible. The potential increase in the dynamic reserve is not as straightforward because the amount of the increase depends on the setting of the Sensitivity Dial. If it is assumed that the interfering signals are again several octaves away, then the limiting factor on the dynamic reserve becomes the filter input instead of the output of the ac amplifier. The filter input overloads at 20 volts p-p (actually, even though the overload light comes on at 20 volts p-p, the filter input will swing a full 28 volts p-p or 10 volts rms) which is approximately 7 volts rms, and there is an amplifier with a gain of 3 in front of the filter. Thus, when the Sensitivity Dial is set to the ".01 μV" position, the maximum possible dynamic reserve is 107 dB or a factor of 230,000. This is the ratio of 2.3 volts rms (approximately one-third of 7 volts rms) to 10 μV rms. This is the maximum possible dynamic reserve it is possible to achieve with the Model 840. At other settings of the Sensitivity Dial, the ratio is not as great (see Specifications under "Maximum Non-coherent Input"), but always some improvement is possible through the use of the filter. The Model 8402 Notch Filter is intended for only two frequencies of operation. These two frequencies are 50 Hz and 60 Hz. The benefits of using the Notch Filter are essentially the same as those of the Bandpass Filter; however the actual numbers are different. The reason for this difference is that the maximum attenuation of the notch is only -34 dB. Thus, in this case, with either 50 Hz or 60 Hz overshadowing all other forms of "noise", the input dynamic range would be increased to 124 dB for operating frequencies below 100 Hz and to 94 dB for an operating frequency of 10 kHz. Again, the possible improvement in the dynamic reserve is a more complicated matter. With the "Sensitivity Dial" set in the ".01 μV" position, there is approximately 50 dB gain in the ac amplifier after the filter. Because the notch attenuates the signal by only 34 dB, the maximum signal at the input to the filter must be 16 dB below 20 V p-p. This means that the signal at the input to the filter must not exceed approximately 1.17 volts rms, and the signal at the input to the signal channel must not exceed approximately .39 volt rms. Therefore, the maximum possible dynamic reserve would be about 92 dB or a factor of 39,000 (the ratio of .39 volt rms to 10 μV rms). For other settings of the Sensitivity Dial, the input to the filter again becomes the limitation on the dynamic reserve, and the same improvement is possible as with the Bandpass Filter. When power line frequencies are the major form of "noise", then the 8402 is certainly the preferable filter, because the user is free to work at a variety of different frequencies without the need for a variety of different Bandpass Filters. In other words, with the Notch Filter, the user has virtually the same freedom as he has in the Wideband Mode of operation, because after only 1 octave, the Notch Filter introduces less than 1% error into the measurement.

e. Preamplification. In order to achieve greater sensitivity and lower noise figures than is possible with the Model 840 alone, additional ac amplification can be used.

1. System 84. This system is composed of the Model 103A Nanovolt Amplifier and the Model 840 AUTO-LOC™ amplifier. As a system, these units provide capability of resolving signals of approximately 1 nanovolt. Additional features include continuously variable gain, high-and low-cut filter, and low noise figures over a wide range of source resistances. The gain of the Model 103A(up to 10000) is more than adequate for all applications using the System 84. When the Model 1037 Transformer is used the System 84 can be adapted for source resistances below 100 ohms.

2. Model 1037 Transformer. The Model 1037 can be used ahead of the Model 840 or 103A to provide additional gain and low noise figure for source resistances below 100 ohms. The Model 1037 has a fixed gain of 100 which provides a full scale sensitivity of 100 nanovolts when connected to the Model 840 alone.

SPECIFICATIONS, SYSTEM 84 (Condensed)

SIGNAL CHANNEL:

RANGE: 10 nV rms full-scale to 10 mV in calibrated 1X and 3X steps. Gain is continuously variable between steps.

INPUT DYNAMIC RANGE (Signal Extraction Ratio): 90 dB to 110 dB for 1 Hz to 100 Hz center frequencies depending on high and low cut settings and interference frequency. Reduces to 60 to 80 dB at 10 kHz. Typically greater than 140 dB with optional filter card.

FREQUENCY RESPONSE: ±1%, 10 Hz to 10 kHz; -3 dB at 1 Hz and 100 kHz.

INPUT IMPEDANCE: Differential; 1000 MΩ shunted by 20 pF either input to ground. Single-ended; 500 MΩ shunted by 30 pF.

CMV: 1 V p-p max. to 10 kHz.

CMRR: Greater than 70 dB, 10 Hz to 10 kHz for coherent signals. Typical mid-band CMRR: Greater than 160 dB for non-coherent non-harmonically related signals.

INPUT NOISE (Shorted): Less than 4.2 nV rms per root Hz at 2 kHz; less than 15 nV rms per root at 10 Hz.

REFERENCE CHANNEL: Identical to Model 840.

2-3. CONNECTIONS.

a. Reference Channel.

1. Reference INPUT Receptacle (J1103). The Model 840 has a front panel BNC type receptacle which mates with coaxial cables such as Keithley Models 8201 and 8202 cables. The inner contact is connected to the reference channel high. The outer shell is circuit low.

a). Normal Reference Inputs. The reference input may be any waveform (1 Hz to 15 kHz) which passes its mean twice per cycle by 10 millivolts. (Input impedance is 1 megohm shunted by less than 30 picofarads.)

b). Special Reference Input. The reference input can be used with a photodiode or electronic switch if a resistor (10K ohm, 1/2 watt typical) is wired between special terminals located on the main chassis. The switching action (open to ground) will create a square-wave reference suitable for driving the reference channel.

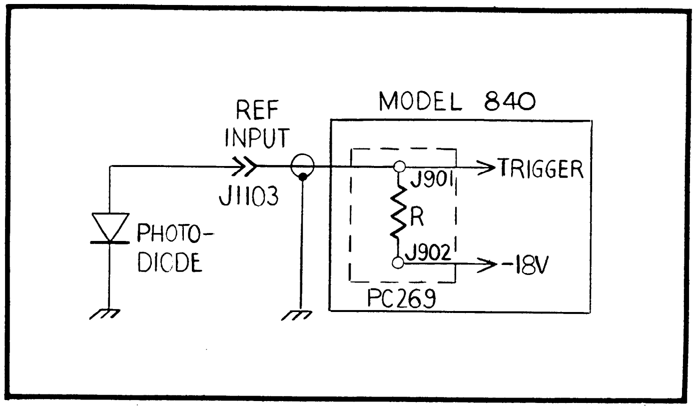


FIGURE 11. Special Reference Input.

2. MONITOR Receptacle (J1106). The Model 840 has a front panel BNC type receptacle for the purpose of monitoring the demodulator drive square waveform. The inner contact of the receptacle is connected to the demodulator signal which is divided down to a 0.9 volt p-p level. The outer shell is circuit low.

b. Signal Channel.

1. ± INPUT Receptacles (J1101, J1102). The Model 840 has two input receptacles designated "+ INPUT" and "- INPUT". These receptacles are BNC types which mate with coaxial cables such as Keithley Models 8201 and 8202. The inner contact of each receptacle is the circuit high. The outer shell is chassis ground. Either "+ INPUT" or "- INPUT" can be used for single-ended operation. For differential operation both inputs must be used. A complete discussion of input modes is given in section 2-5.

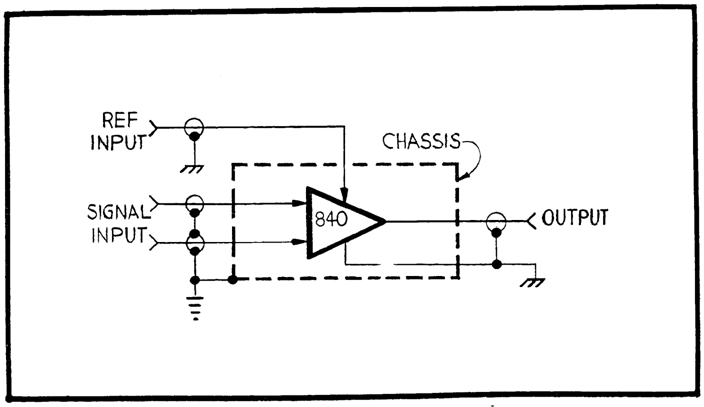


FIGURE 12. Input-Output Connections.

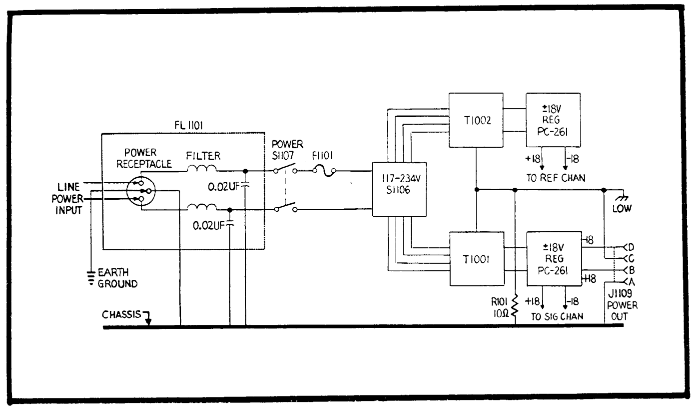


FIGURE 13. Line Power Connections.

2. AC OUT Receptacle (J1105). This receptacle can be used to monitor the ac amplifier output just ahead of the demodulator. The receptacle is a BNC type. The inner contact is connected to the ac amplifier output. The outer shell is circuit low.

3. DEMOD Receptacle (J1106). This receptacle can be used to monitor the demodulator output. The receptacle is a BNC type. The inner contact is connected to the demodulator output. The outer shell is circuit low.

c. METER Output Receptacle (J1108). This receptacle on the front panel can be used to monitor the normal meter output (DC OUT) or the frequency-to-voltage converter output (FREQ) depending on the position of METER Switch. The receptacle is a BNC type. The outer shell is circuit low.

d. DC OUTPUT Receptacle (J1107). This receptacle on the rear panel can be used to monitor the normal meter output. This output is not affected by the position of the front panel METER switch. The receptacle is a BNC type. The outer shell is circuit low.

e. F-V CONV OUTPUT Receptacle (J1104). This receptacle on the rear panel can be used to monitor the frequency-to-voltage converter output. This output is not affected by the position of the front panel meter switch. The receptacle is a BNC type. The outer shell is circuit low.

f. Line Voltage Receptacle (FL1101). This receptacle is a three-terminal connector which mates with Keithley part no. CO-6 line power cord.

NOTE

For maximum operator safety, connection should be made to earth ground through the third terminal provided on the line power cord. The line voltage is filtered by twin L-C filters as shown in Figure 13. Since the chassis is connected to each side of the line through a .02 μF capacitor , the chassis will float at 1/2 line potential if the power ground terminal is not connected to earth ground.

g. ACCESSORY POWER Receptacle (J1109). This receptacle can be used to supply power to an accessory instrument such as Keithley Model 103A Nanovolt Amplifier. The receptacle is an Amphenol 126-1430 connector which mates with Keithley Model 1083 Power Cable. The four terminals are designated A, B, C and D as shown in Figure 13.

2-4. CONTROLS. The front panel controls are arranged such that the Signal Channel is on the left with Reference Channel on the right side.

a. Reference Channel.

1. TRIGGER Switch (S901). This switch has four positions designated "2nd HARM", "- TRIGGER", "+ TRIGGER", and "EXT PHASE".

a). 2nd HARM Position. In this position the reference channel is automatically set to operate at twice the reference frequency applied.

b). ± TRIGGER Positions. These positions set the trigger circuit for triggering from positive or negative going waveforms.

c). EXT PHASE Position. This position connects the reference channel Schmitt trigger directly to the synchronous demodulator thus bypassing the phase shifting circuitry.

2. FREQ BAND Switch (S701). This switch has four positions which set the frequency band between 1-10 Hz, 10-100 Hz, 100-1 kHz, or 1K-10kHz.

3. PHASE Control (S601). This control is a dual-concentric type. The inner knob has four switch positions designated " 0° ", " 90° ", " 180° ", and " 270° ". The outer knob is a continuously variable potentiometer which is designated from 0° to 100°. The inner dial selects the quadrant while the outer dial provides fine adjustment with 1° calibrated markings.

b. Signal Channel.

1. SENSITIVITY Control (S201-2). This control is a dual-concentric type. The inner knob has five positions designated X1, X3, X10, X30, and X100. The outer knob has four positions designated 10, 1, .1, and .01 MILLIVOLTS.

a). Multiplier (Inner Knob) (S202). This control sets the gain of the DC amplifier stage up to 1000 maximum. The multiplier setting should be determined such that output level is sufficient for the useable meter deflection but not overloaded.

b). Millivolts (Outer Knob) (S201). This control sets the sensitivity of the ac amplifier stage up to 1000 max. The sensitivity designations correspond to the rms input voltage which will cause a full scale meter deflection when the multiplier is set to X1.

2. TIME CONSTANT Switch (S1104). This switch selects the time constant in milliseconds (from 3 to 300) and seconds (from 1 to 100). The "OFF" position sets the signal channel for a minimum time constant of 300 μs.

3. ZERO SUPPRESS Control (R1102). This vernier control sets the amount of zero suppression from 0 up to 100 times full scale. Dial resolution is 0.5 mV for 1 volt suppression. The control has a "locking" feature to prevent accidental change of the control.

4. ZERO SUPPRESS Switch (S1103). This switch has three positions designated "+", "OFF", and "-". The polarity of the suppression is relative to the output polarity. "+" setting suppresses a "+" output.

5. TUNED/WIDEBAND Switch (S1102). This switch has two positions designated "TUNED" and "WIDEBAND".

a). TUNED Position. This position connects an accessory filter card Model 8401 as shown in block diagram of Figure 18.

b). WIDEBAND Position. This position sets the Model 840 for normal wideband operation.

6. Input Mode Switch (S1101). This switch has three positions "+", "-", "DIFF".

c. Power Switch (S1106). This switch controls power to the Model,840. The switch is a double-pole type which disconnects both sides of the line after the filter. Thus the chassis will be referenced to either side of line through a 0.02 μF capacitor in the filter (FL1101) regardless of the position of the power switch.

d. METER Switch (S1105). This switch can be used to select the meter mode for monitoring either the dc Voltage Output or the Voltage-to-Frequency converter output on the meter as well as the meter receptacle.

e. Line Switch (S1107). This switch (located on the rear panel) sets the instrument for 117 or 234V line voltage operation.

2-5. OPERATING CONSIDERATIONS.

a. Reference Channel. The main purpose of the reference channel is to provide a square wave drive to the synchronous demodulator which can be shifted in phase with respect to the input signal. The Model 840 can accept a wide variety of waveforms at its reference channel input and still operate successfully. With the "TRIGGER" switch set in the "+" position, the Model 840 will trigger on positive - going waveforms; with the "TRIGGER" switch set in the "-" position, the Model 840 will trigger on negative - going waveforms. In either of these two triggering modes, reference inputs ranging from 12 mv. peak to 12 volts peak and of the sine, square, ramp, triangle, and pulse type can be accommodated. For applications in which larger signal amplitudes are present, an external divider must be used. When the "TRIGGER" switch is set to the "EXT PHASE" position, the output of the reference channel input Schmitt trigger is sent directly to the synchronous demodulator drive circuitry, and the internal phase shifting capability of the lock-in is by-passed. In this mode of operation, a symmetrical input waveform to the reference channel (crossing its mean only twice per cycle) is a must; reference levels of 25 mv. p-p to 25 v. p-p can be used. In the "2nd HARM" triggering mode, the reference channel runs at twice the frequency of the input signal, automatically. A symmetrical reference is required for this mode of operation as stated above. Set up of the Model 840 reference channel is quite simple. For most applications, the first step is to set the "TRIGGER" switch to the "+" position. With the switch in this position, the frequency-to-voltage converter is operative, and the correct frequency band can be selected even if the reference frequency is unknown. If the signal frequency is known, then the second step is to turn the "FREQUENCY BAND" switch to the correct frequency band. This is essentially all the set-up that is required for the lock-in to begin processing signals in the signal channel. If the signal frequency is not known, it is a simple matter to find out what the signal frequency is and to select the right frequency band. This is accomplished by switching the meter to read the output of the frequency-to-voltage converter instead of the output of the DC amplifier. With the "METER" switch in the "FREQ" position, the meter may read off-scale or nearly zero. In the off-scale case, a higher frequency band should be selected; in the nearly zero case, a lower frequency band is called for. In either case, a frequency band should be selected which gives a useable on-scale reading (Note that the meter reads negative.) The meter switch also serves as an indication of whether or not an acceptable signal level is present at the reference channel input because the meter will not deflect at all (with switch in the "FREQ" position) unless sufficient signal is present to trigger the Schmitt trigger, which in turn triggers the frequency-to-voltage converter. Another point which can be monitored as a check on reference channel operation is the BNC connector labeled "MONITOR" This output gives a divided down version of the square-wave drive to the synchronous demodulator. If no square-wave is present, then the reference channel is not operating properly; proper square-wave level is approximately .9 volts p-p. The "PHASE CONTROL" in the reference channel is also rather easy to set up in most cases. Where it becomes difficult is in those situations where an extremely noisy signal is being measured; however, the following general procedure is probably still the best to use; Adjustment of the phase control indicates whether or not there is some signal present. Once this has been determined, then the phase control should be set for a null. After a null is found, then a 90^o step on the quadrature switch will yield a maximum reading. This method will not yield very good results if an actual quadrature component exists ; however, finding the peak in this manner is usually fast.

b. Signal Channel. The signal channel of the Model 840 processes the signal of interest in basically three ways.

1. It amplifies the incoming ac signal with a wideband ac amplifier.

2. It converts the ac signal to a dc signal at the synchronous demodulator.

3. It amplifies the dc signal sufficiently so that a convenient level (10 volts full-scale) is present at the instrument output.

c. Frequency Band. Ease of set up and user convenience were important goals in the design of the Model 840. For this reason, a semi-automatic reference channel was incorporated. The reference channel is not fully automatic because the user is still required to set the decade band within which his frequency lies; however, the exact frequency need not be known, and no tuning is necessary. Complete set up of the reference channel is accomplished in two steps: the "TRIGGER" switch is set to "+" and the "FREQUENCY BAND" switch is set to the appropriate band. Even when the correct decade is unknown, set up is quick and easy. In this case the user has only to hold the "METER" switch to "FREQ" and monitor the output of the frequency-to-voltage converter on the meter. An off-scale reading indicates that a higher frequency band is required, and a nearly-zero reading indicates that a lower frequency band is called for. When the proper band is switched to, a "decent" on-scale reading will show to the user just what his frequency is.

(It is hoped that the user will forgive the negative frequency readings.) The output of the frequency-to-voltage converter is also brought out at the rear of the instrument where a DVM or other meter may be connected to give better reading accuracy. (Accuracy of the F-V connector is not rigidly specified but will probably be around 0.5%) Again, for convenience, the F-V converter can be monitored at the front panel "METER" output at any time by pressing the "METER" toggle switch to "FREQ".

d. Sensitivity. In the Model 840, two functions, ac gain and dc gain, are controlled with one dual-concentric switch, the "SENSITIVITY" switch. A maximum gain of 1000 is possible in both amplifiers for a total gain of 1 million. Because of this, 10 μV rms sine-wave at the input produces 10V dc at the output. The sensitivity switch reads out directly the input level which causes a full-scale reading at the output. As an example, assume that an experiment is producing a 1 mv. rms sine-wave at the input to the lock-in. One way of setting the "SENSITIVITY" switch would be to set the large dial at ".01 MV" and the small inner knob at "X100". Another possibility would be ".1 MV" on the dial and "X10" with the knob. A third possibility would read "1 MV" and "X1". These three different settings would all yield an output of +10 V dc after proper signal phasing with the "PHASE" control. An immediate question is then, "Why the variety of choices?" or "Which setting do I use?" The answer is relatively simple: "The correct setting depends upon the condition of the signal issuing from your experiment." However, many times the exact condition of the signal is unknown, but it is 100% safe to assume that the signal is noisy. The real question is "How much noise is present?" A setting that will give excellent results every time is achieved as follows: Set the large dial on the "SENSITIVITY" switch to ".01 MV" and the small inner knob to "X100". If the overload light is on, decrease the sensitivity of the Model 840 with the large dial until the light goes out (allow a few seconds on each range for switching transients to die away). Under these conditions, the input ac amplifier is accommodating all signal and all noise without overloading. Once this setting is found, it is only necessary to adjust the phase and add sufficient dc gain to give an adequate output level. Note that dc gain

TABLE 2-1.
Sensitivity Settings

Input Signal (rms)	Multiplier	Millivolts rms	DC Gain	AC Gain	Total Gain	(Volts DC) Meter Reading
.01 mV	X1	.01	1000	1000	10^6	10
.03 mV	X3	.01	333	1000	333000	10
.10 mV	X1	.1	1000	100	10^5	10
.30 mV	X3	.1	333	100	33300	10
1.0 mV	X1	1.0	1000	10	10^4	10
3.0 mV	X3	1.0	333	10	3330	10
10 mV	X1	10.0	1000	1	1000	10
30 mV	X3	10.0	333	1	333	10
100 mV	X10	10.0	100	1	100	10
300 mV	X30	10.0	33	1	33	10
1 V	X100	10.0	10	1	10	10

is increased by going to a smaller "SENSITIVITY" multiplier setting. There is only one caution here and it involves an unlikely situation. If too small a time constant is dialed out on the "TIME CONSTANT" switch, it is possible for a large ac signal to get through the dc amplifier and cause the overload indicator to light (even though the meter gives no indication of dc overload). When in doubt, a good time constant to start with is "1 sec". This size time constant gives adequate filtering against ac overload of the dc amplifier in almost all situations.

e. Time Constant. A single-pole low-pass filter is included in the first section of the dc amplifier. This filter characteristic is achieved by shunting capacitors across the feedback resistor of the first dc amplifier. It is these capacitors that are switched in and out by the "TIME CONSTANT" switch. Mounted on the "TIME CONSTANT" switch are capacitors ranging from 150 pF to 5 μF. These are high quality, ±5% capacitors and they yield time constants which range from 3 msec. to 100 sec. In the "OFF" position, the typical time constants of the dc amplifier is 300 μs. The main function of the "TIME CONSTANT" switch is to provide a variety of bandwidths around the dc component of the demodulated signal. An appropriate bandwidth can be chosen to remove most other ac components including interfering signals and wideband noise.

f. Phase. Phasing of input and reference signals is easily accomplished in the Model 840 with the use of one dual-concentric control, the "PHASE" control. The large outer dial provides continuous phase shifts between 0° and 100°, and the small inner knob switches between the four quadrants in 90° steps. Typical dial accuracy is within a few degrees, but this accuracy is degraded at both 1 Hz and 10 KHz due primarily to additional phase shifts in the signal channel. However, it is important for the user to know that even though absolute phase accuracy is not tightly maintained, relative phase shifts on the dial and 90° phase shift steps on the switch are held within 2° over the full frequency range of the instrument. Fast and accurate phasing of the Model 840 for maximum output can be achieved by first adjusting the "PHASE" control for a zero output and then incrementing the phase by 90°. With an extremely noisy signal, this is best accomplished by switching to a sizeable time constant, adjusting for equal fluctuations about zero on the meter, and being patient. Once a satisfactory "null" is arrived at, the user can be confident that a flick of the quadrant switch (by 90°) will yield an accurately maximized output. There is another interesting aspect to this matter of phasing. Because of the "AUTOTRAC™" feature in the Model 840, the user need not concern himself with problems associated with frequency drift. So long as the frequency drifts slowly and so long as the frequency remains roughly within the confines of a decade frequency band, the phase shift through the signal and reference channels will remain essentially fixed. This means that as long as the phase shift between the reference drive and the signal of interest remains essentially constant at the experiment, then the lock-in will give accurate phase and amplitude information in spite of frequency drift. This also means that a user could actually perform a frequency sweep as long as sweep speeds were kept low. For a step change in frequency, the Model 840 (frequency-to-voltage convertor) requires approximately 8 sec. to settle to within .1%. Finally this also means that once an experiment is set up, the user need not bother himself with periodic "re-tuning" to obtain accurate results. "Re-tuning" is performed automatically by the lock-in itself.

g. Input Modes. The Model 840 can be used with single-ended or differential inputs. The "Input Mode" switch (S1101) has three positions designated "+", "DIFF", and "-".

1. "+" Mode. In this mode the signal at the "+ INPUT" is amplified (non-inverted) as shown in Figure 14. The signal at the "- INPUT" is not amplified.

2. "-" Mode. In this mode the signal at the "- INPUT" is amplified (inverted) such that $V_o = G(V_2)$. The signal at the "+ INPUT" is not amplified.

3. "DIFF" Mode. In this mode the signals of both inputs are amplified as shown in Figure 15. The output is a function of $V_1 - V_2$.

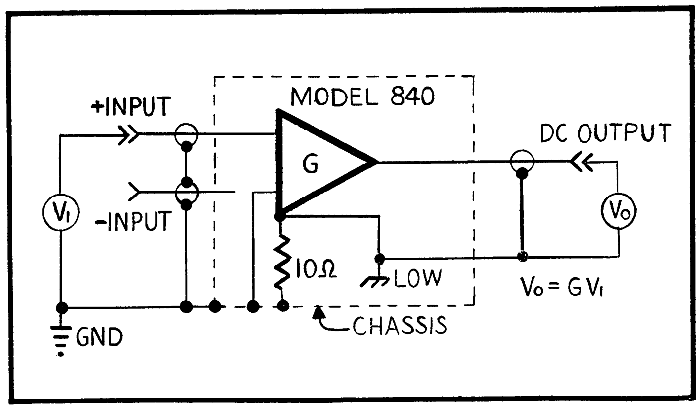


FIGURE 14. Single-Ended Mode.

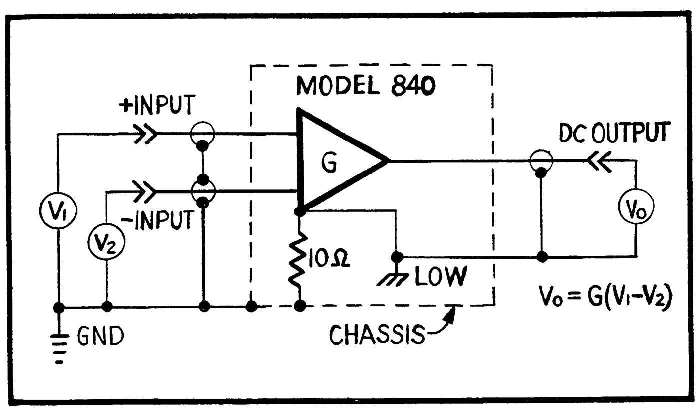


FIGURE 15. Differential Mode.

h. Zero Suppression. A calibrated zero suppression dial permits suppression of input signals up to 100 times full scale (referred to the input). A ten-turn potentiometer (R1102) provides resolution better than 0.5 mV for 1 volt suppression with accuracy better than 1 mV. The full scale suppression is a function of the multiplier setting as shown in Table 2-2. The suppression is accomplished in the ac amplifier circuitry ahead of the dc amplifier. Therefore once the suppression has been set for a particular MILLIVOLT Sensitivity setting the MULTIPLIER setting can be adjusted for increased sensitivity and the suppression will not be changed.

TABLE 2-2.

Multiplier Setting	Sensitivity Setting	Max. Suppression	X Full Scale Suppression
X1	10 mV	1 V	100
X3	10 mV	1 V	33
X10	10 mV	1 V	10
X30	10 mV	1 V	3.3
X100	10 mV	1 V	1

i. Overloads. Overloads are indicated at 3 points in the signal channel: the output of the ac amplifier, the output of the dc amplifier, and the input of the accessory bandpass filter. The overload indicator will light for dc overloads of either polarity as well as for ac overloads. Also, the overload circuit is fast, and will catch overloads due to only a very small percentage of noise peaks. The need to show an overload condition at the output of the ac amplifier is apparent - to indicate excessive noise or excessive signal (both coherent and non-coherent). In front of the accessory filter, it is necessary to detect overloads due to noise and non-coherent signal which never get through to the output of the ac amplifier. For the dc amplifier, the necessity of overload indication is not readily apparent because the meter is always present to show excessive signal levels. However, it is quite possible to have a severe overload in the dc amplifier and show an on-scale reading. This condition arises when an inadequate time constant has been selected so that the ac signals at the demodulator cause the output of the dc amplifier to clip.

OPERATING TECHNIQUE.

a. Summary of Operation.

1. Connect the REFERENCE Input. For further discussion of the Reference Channel input refer to "CONNECTIONS" in paragraph 2-3, a.

2. Select the TRIGGER mode. For further discussion of the Reference Channel triggering refer to "Reference Channel" in paragraph 2-5, a.

3. Connect the SIGNAL Input. For further discussion of the Signal Chanel input refer to "CONNECTIONS" in paragraph 2-3, b.

4. Set the FREQUENCY BAND. For further discussion of the frequency band settings refer to "Frequency Band" in paragraph 2-5, c.

5. Set the SENSITIVITY. For further discussion of the Sensitivity settings refer to "Sensitivity in paragraph 2-5, d.

6. Set the TIME CONSTANT. For further discussion of the Time Constant settings refer to "Time Constant" in paragraph 2-5, e.

7. Set PHASE. For further discussion of Phase shift adjustments refer to "Phase" in paragraph 2-5, f.

b. Illustrative Examples. The following examples are intended to illustrate methods for setting controls on the Model 840. The hypothetical situations are simplified but they illustrate the important operating features of the Model 840.

Example #1. This situation would be typical of those applications where the signal of interest is obscured by noise such as 60 Hz pickup.

Example #2. This situation would be typical of those applications where the signal of interest is accompanied by random noise.

Example #3. This situation would be typical of those applications where the noise is less than the signal of interest but it is necessary to detect small variations in the signal amplitude.

Example #1. In this example, the noise is large compared to the signal of interest, but the noise frequency is discrete (a decade lower than the center frequency).

Initial Conditions:

Reference: (provides drive signals to experiment and lock-in reference channel)
- waveform - sine
- frequency - 1 kHz
- level - several volts peak-to-peak

Source:
- waveform - sine
- frequency - 1 kHz
- level - 1 mV rms

Nature of interfering signal: 100 mV rms, 60 Hz.

Step 1).
Connect oscillator to reference channel input.

Step 2).
Set TRIGGER to + (for external phase setting capability, or for low-frequency "no-phase shift" experiments, the TRIGGER switch can be set to EXT. PHASE).

Step 3).
Set FREQUENCY BAND to 100 - 1 K. (NOTE: In general, for best results, user should select band so that his frequency lies at the top end of the band - even though each range has 50% overrange and at least 50% underrange.)

Step 4).
Select reasonable TIME CONSTANT of say 1 SEC. for a start (which gives equivalent noise bandwidth of 0.25 Hz).

Step 5).
Set SENSITIVITY control for 1 mV rms input level.

a). Set SENSITIVITY DIAL to .01 mV and SENSITIVITY MULT. to X100 (overload light will be on).

b). Back off on SENSITIVITY DIAL setting until overload light goes out (1 mV setting).

c). Increase sensitivity with MULTIPLIER for maximum "on-scale" output (X1 setting).

Step 6).
Adjust the PHASE control for maximum dc output, or as an alternative, adjust PHASE control for a null reading and then change phase by 90^{o} with switch.

Example #2. In this example, the noise is random and much larger than the signal of interest.

Initial Conditions:
Reference: (provides drive signals to experiment and lock-in reference channel)
waveform - sine
frequency - 1 kHz
level - several volts peak-to-peak

Source:
waveform - sine
frequency - 1 kHz
level - 30 μV rms

Interfering Signal:
waveform - noise
level - 1 mV p-p

Step 1).
Connect oscillator to reference channel input.

Step 2).
Set TRIGGER to +.

Step 3).
Set FREQUENCY BAND to 100 - 1 K.

Step 4).
Set TIME CONSTANT to 1 sec. for a start.

Step 5).
Set SENSITIVITY control.

a). Set SENSITIVITY DIAL to .01 mV and SENSITIVITY MULT. to X100 (overload light should not be on).

b). Do not change SENSITIVITY DIAL from .01 mV setting, because no overload is indicated. This setting of the DIAL allows maximum ac gain for best possible output stability.

c). Select suitable SENSITIVITY MULTIPLIER setting. In this case, a setting of X3 will give full-scale, or 10 volts, output; that is, a final setting of .01 mV x 3 says that 30 μ volts produces a full-scale reading.

Step 6).
If faster output response is desired, a smaller TIME CONSTANT can be chosen. (A fairly large TIME CONSTANT is to be selected for use during initial set up to avoid confusing ac amplifier and dc amplifier overloads. Once the proper SENSITIVITY setting is established, the TIME CONSTANT can be decreased as much as desired, provided no dc amplifier overload occurs.)

Step 7).
Make final adjustment on PHASE CONTROL for maximum dc output.

Example #3. In this example, the noise is less than the signal, and we are interested in looking at variations in the signal amplitude.

Initial Conditions:
Reference: (provides drive signals to experiment and lock-in reference channel)
waveform - sine
frequency - 1 kHz
level - several volts peak-to-peak

Source:
waveform - sine (with slowly-varying amplitude)
frequency - 1 kHz
level - 10 mV rms - 1 mV rms modulation

Nature of Interfering Signal: several millivolts peak-to-peak wideband noise and 60 Hz pick-up.

Step 1).
Connect oscillator to reference channel INPUT.

Step 2).
Set TRIGGER to +.

Step 3).
Set FREQUENCY BAND to 100 - 1K.

Step 4).
Select TIME CONSTANT of 1 sec.

Step 5).
Set SENSITIVITY CONTROL.

a). Set SENSITIVITY DIAL to .01 mV.

b). Set SENSITIVITY MULT. to X100.

c). Connect the signal source.

d). Reduce sensitivity on dial to .1 mV; overload light should go out.

e). Set MULTIPLIER switch in X100 position.

Step 6).
Proper phasing will bring output to the 10 volt level.

a). Set PHASE CONTROL for a null.

b). Change setting by 90° with small inner knob (QUADRANT SWITCH).

Step 7).
Dial in enough suppression so that main signal is bucked out and only fluctuations about zero remain. In this example, that means setting the 10-turn SUPPRESSION DIAL to 10.0 which gives "full-scale" suppression for this setting of the SENSITIVITY MULTIPLIER (X100).

Step 8).
If it is desired, the SENSITIVITY MULT. can now be set to X10 which will give another factor of 10 amplification to the modulation component of the signal. NOTE: the SENSITIVITY CONTROL would then be reading .1 mV x 10 or 1 mV rms for full-scale. Because the modulating signal has an amplitude of 1 mV rms, the output would then be varying between -5 volts and +5 volts (or - half-scale to + half-scale).

2-7. RACK MOUNTING. The Model 840 can be rack mounted in a standard 19" width rack as shown in Figure 16. The rack mounting hardware is supplied with the instrument. Assembly is accomplished as follows:

a. Remove the two flat-head socket screws (Item No. 24) in two places.

b. Attach an "angle bracket" (Item 21) on both corners using Phillips screws (Item 22) as shown in Figure 16.

c. Retain the original screws for future conversion back to bench mounting.

d. The plastic feet and tilt bail assemblies may be removed if necessary.

NOTE

Clearance should be provided behind the panel for access to power and monitoring cables. Recommended depth (measured from the front panel) is 12-1/8 inches.

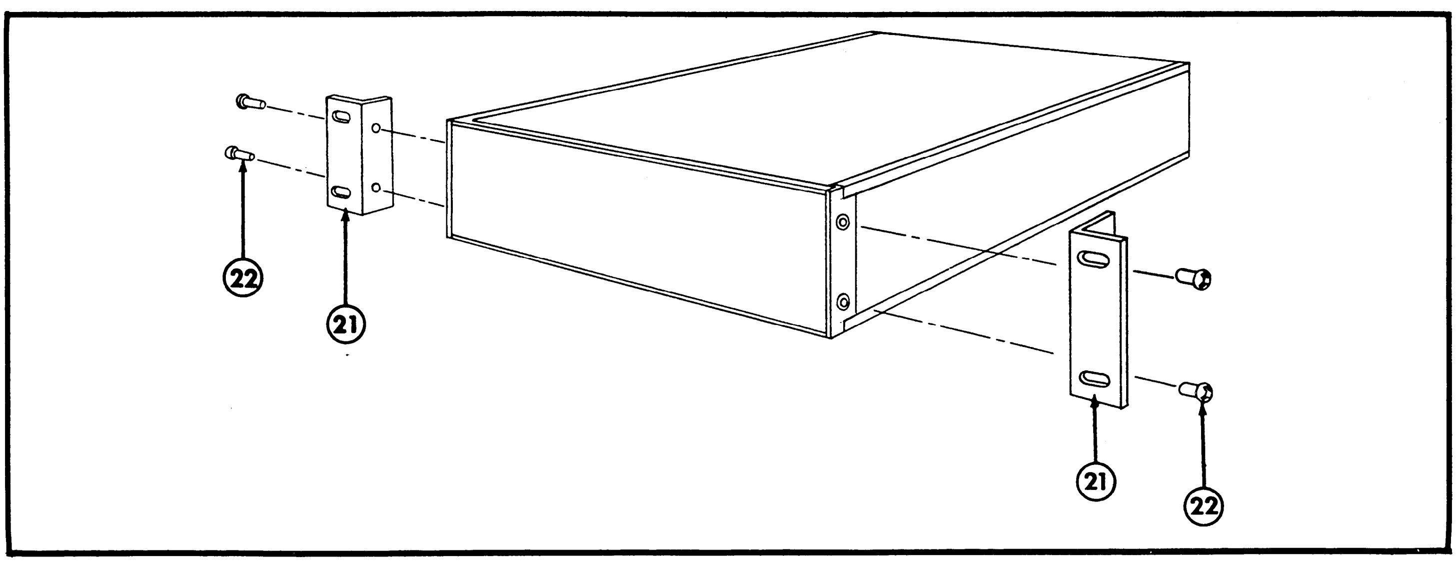


FIGURE 16. Rack Mounting.

SECTION 3. APPLICATIONS

3-1. GENERAL. The Model 840 can be used in applications which provide a reference signal from an oscillator chopper, or mechanical switch. The test signal derived from the reference may be amplified before the signal is applied to the Model 840 as shown in Figure 17.

3-2. MEASUREMENT SYSTEMS.

a. System 84. The Keithley System 84 is composed of the Model 103A Nanovolt Amplifier and the Model 840 as shown in Figure 17. The power for the Model 103A is provided by the Model 840 through the auxiliary power receptacle and Model 1083 cable. The System 84 can be used for a wide variety of applications requiring low noise, wideband amplification.

b. Current Measurements. A system composed of the Model 427 Current Amplifier and the Model 840 is shown in Figure 19. This system can be used in applications where a feedback current amplifier is required which has very low noise contribution. A typical example is a chopped beam from a photomultiplier tube or other high impedance current source.

3-3. TYPICAL MEASUREMENTS.

a. Thermistor Bridge Experiment. A thermistor is often used to detect small changes in temperature ($\sim 10^{-3}$°C), being run in a dc operated Wheatstone bridge so that temperature variations give changes in the output of the bridge which are measured with a sensitive galvanometer or dc amplifier. An alternate method is the use of a Phase Sensitive Detector with an ac signal. The bridge is operated with low frequency ac (15 Hz) and the output is measured with a Phase-Sensitive Detection system. This a-c frequency is chosen in order to reduce the effects of fluctuating thermal emfs in the bridge and connecting leads. The experimental arrangement is shown in Figure 18. The bridge output signal is amplified and fed into the signal input of the Phase Sensitive Detector whose reference is taken from the bridge-driving oscillator. The use of a Phase Sensitive Detector is required to minimize the effects of reactive components due to thermal time constants of the thermistor. The PSD will give an output for "in phase" or resistive components since the demodulator is triggered by the reference source. The high input impedance of the ac amplifier allows the bridge to be designed with increased resistance values so that the power dissipated in the thermistor can be reduced by a factor of 10 compared with the dc experiment and still give the same output for a given temperature change. The signal generator output is set to give the correct amplitude reference signal and then R is adjusted to give the required current through the bridge (say 10 mA). The amplifier gain is set low and the bridge is roughly balanced by varying the rheostat and monitoring the output voltage on the signal level indicator of the phase-sensitive

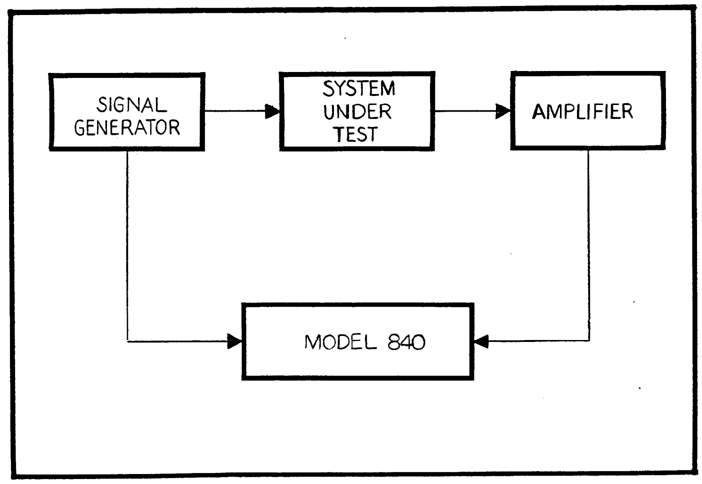


FIGURE 17. Phase Sensitive Detection.

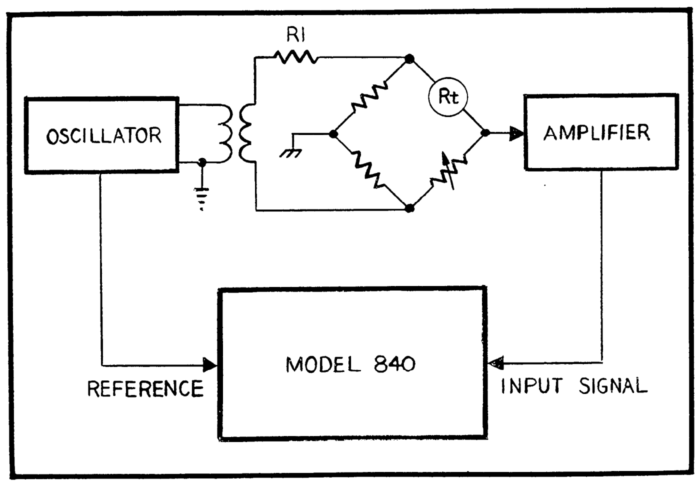


FIGURE 18. Thermistor Bridge Experiment.

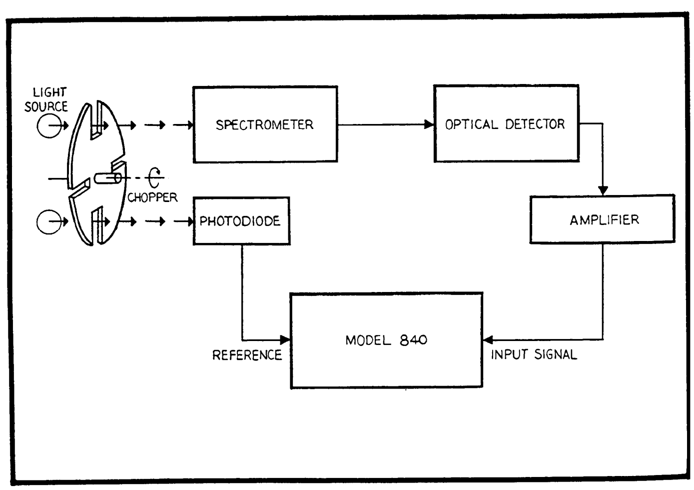


FIGURE 19. Chopped Light Beam Experiment.

detector. Fine balance is achieved by further adjustment of the rheostat as the gain of the amplifier is increased gradually to its maximum value. The attachment of a pen recorder to the output provides automatic plotting of temperature changes and once the initial setting up has been carried out, no further attention to the system is required.

b. Chopped Light Beam Experiment. In order to minimize error in optical measurements caused by unwanted radiation from surrounding objects in the laboratory, the frequency selective properties of the Phase Sensitive Detector are used in conjunction with a chopped beam. If the reference signal is taken from the chopper, the Phase Sensitive Detector will only give a dc output from those signals which have as their origin the chopped light source. There will also be a small fluctuating output due to that noise which happens to lie within the narrow bandwidth of the Phase Sensitive Detector. In the following description the term 'test signal' will refer only to that component of the signal from the optical detector which is of the same frequency as the reference signal. The test signal plus noise obtained from the photomultiplier is fed via an untuned amplifier into the signal input of the Phase Sensitive Detector. The reference signal is obtained by placing a photodiode next to the chopping wheel, with a small lamp to excite it. The output from the photodiode is fed into the reference input of the Phase Sensitive Detector. The phase of the reference signal with respect to the test signal depends on the position of the photodiode relative to the chopper blades. Maximum output from the Phase Sensitive Detector can be obtained, therefore, by adjusting the position of the photodiode so that the reference and test signals are in phase. The chopper frequency chosen depends on the type of optical detector used. It can range from 10 Hz when using thermocouples to 800 Hz when using detectors with a fast response time. The principle of combining a chopped beam with the Phase Sensitive Detector has enabled measurements of weak optical signals to be made despite the presence of large stray radiation. In the field of infra-red measurements this is especially important because of the impossibility of cutting out radiation from surrounding objects.

c. Photodiode Bias Technique. The Model 840 can be used for applications using a chopped light beam as described in paragraph 3-3b. A unique feature of the Model 840 provides a bias potential at the reference input for use with a photodiode. A special bias resistor must be connected between terminals provided on PC-269 as shown in Figure 11. When used with a chopper the photodiode provides a trigger signal for the reference channel.

IMPORTANT NOTICE

1. For most applications the signal source ahead of the Model 840 should be connected using two BNC shielded cables as a differential input. The Model 840 should be set to "DIFF" mode. This mode of operation minimizes the effects of system ground loops and provides the best common-mode noise rejection.

2. The system diagrams shown in this section include a preamplifier between the source and the Model 840. Since the Model 840 has 60 dB of ac gain in the signal channel, the optional preamplifier may not be necessary in some applications.

SECTION 4. ACCESSORIES

Model 8401 Filter Card

Description:

The Model 8401 is a bandpass filter card which plugs into a prewired receptacle (J1003) on the Model 840 chassis. The center frequency can be specified by the customer from a frequency range of 10 Hz to 1 kHz. The nominal center frequency can be varied -10% to +500% using an adjustment potentiometer on the card itself.

Application:

The Model 8401 can be used for applications requiring a specific bandpass filter ahead of the demodulator.

Specifications:

Provides bandpass of ±3% of center frequency with 1% flatness and less than 10° phase shift. Skirts roll off to -12 dB at one octave and 18 dB per octave thereafter. Supplied tuned to your specified frequency ±2%. Each may be readjusted for any frequency within the span indicated with a 0.3% ohmmeter;

Model 8402 Notch Filter Card

Description:

The Model 8402 is a notch filter which plugs into a prewired receptacle (J1003) on the Model 840 chassis. The frequency can be specified as either 50 Hz or 60 Hz.

Application:

The Model 8402 can be used for applications requiring line frequency rejection ahead of the demodulator. The Model 8402 Filter is connected in the signal channel only when the Model 840 "Filter" Switch is set to "TUNED".

Specifications:

Model 8402-60.

Provides notch of at least -34 dB at 60.0 Hz, returns to and remains within 1% of unity gain beyond 1 octave from notch.
Model 8402-50 (same as -60 except for 50 Hz)

Models 8201, 8202 Coaxial Cables

Description:

These cables are coaxial types with BNC connectors on each end. The Model 8201 cable is 10 inches long while the Model 8202 is 20 inches.

Application:

These cables mate with the BNC receptacles on the Models 103A and 840.

Model 103A Nanovolt Amplifier

Description:

The Model 103A is a low-noise ac voltage amplifier which can accept either single or differential inputs. Gain is adjustable from 100 to 10K in three steps. Frequency cutoffs permit selection of an optimum frequency bandwidth depending on the signal of interest.

Application:

The Model 103A is particularly well suited as a preamplifier for the Model 840. This combination, designated as the System 84 Lock-in Amplifier, measures ac voltages with noise rejection greater than 90 dB.

Specifications: (Condensed)

Input: Diff or single-ended.
Gain: 100 to 10k in three decade steps, adjustable between steps to a minimum gain below 10.
Frequency Response: (Wideband) -3dB at 0.1Hz to 300 kHz; ±1% at 100Hz.
Input Impedance: Diff: 1000 megohms shunted by 20pF. Single-ended: 50 megohms shunted by 30 pF.
Input Noise Figure:(Single-ended) Better than 3dB from a 1kΩ source between 2kHz and 10kHz.

SECTION 5. CIRCUIT DESCRIPTION

5-1. GENERAL. The Model 840 AUTOLOC™ Amplifier is designed around a very simple phase sensitive detector. This phase sensitive detector gives full-wave demodulation and employs essentially only two JFET's with capacitive compensation for dc offsets due to switching spikes. In support of this phase sensitive detector the Model 840 provides variable ac gain in front of the detector, variable dc gain after the detector, and processing for the reference signal required by the detector.

5-2. REFERENCE CHANNEL. In processing the reference signal the Model 840 does basically only two things. For one thing, it is designed to shift the phase of the reference signal continuously through 370° so that any desired phase relationship may be obtained between the reference signal and the signal of interest. For another thing, the reference channel takes the incoming reference signal and converts it into two symmetrical 18-volt square waves, 180° out of phase with one another, for driving the JFET switches of the demodulator. The circuitry used to accomplish these two tasks consists of a zero-crossing detector, a frequency-to-voltage converter, two ramp generators, two level detectors, and an 18-volt flip-flop.

a. Zero-crossing Detector. The zero-crossing detector consists of a discrete-component wideband amplifier with positive feedback around it. A dual JFET, Q901, is used on the input in order to achieve a 1 megohm input resistance. Positive feedback then is returned to the other gate of Q901 from the output emitter-follower Q906 via the three-component divider R923, C907, and R915. This positive feedback gives the circuit a hysteresis of 10-20 mV. Naturally, because of this hysteresis gap, the symmetry of the output square-wave will degrade with low-level input sine and triangle waveshapes. The reason for this is that the hysteresis gap is not centered about zero. So, in order to restore output symmetry, the 1 megohm input resistor, R909, is biased up or down with a "symmetry" network composed of resistors R902 through R906. This network allows the input gate of Q901 to be at the same potential as the center of the hysteresis gap. It is important to realize that this symmetry adjustment is only for the output square-wave of the zero-crossing detector; however, output dissymmetry here will affect the operation of the demodulator in the "2nd Harm." and "EXT. Phase" positions of the "Trigger Switch", S901. Both outputs of the zero-crossing detector are brought out in order to obtain 2nd Harmonic operation and triggering from both positive-going and negative-going waveforms. The square wave outputs are first shaped into pulses by capacitors C911 and C912 and resistors R930 and R932, and then the negative pulses are clipped by diodes D904 and D905 and resistors R931 and R933. The clipping action leaves only positive pulses which then are used to trigger flip-flops elsewhere in the reference channel. Also, because of the diode-resistor clipping networks, the two pulse outputs of the zero-crossing detector can be tied together as a simple means of generating the triggering for 2nd Harmonic operation. The diodes provide the necessary isolation that allows the zero-crossing detector outputs to be tied together.

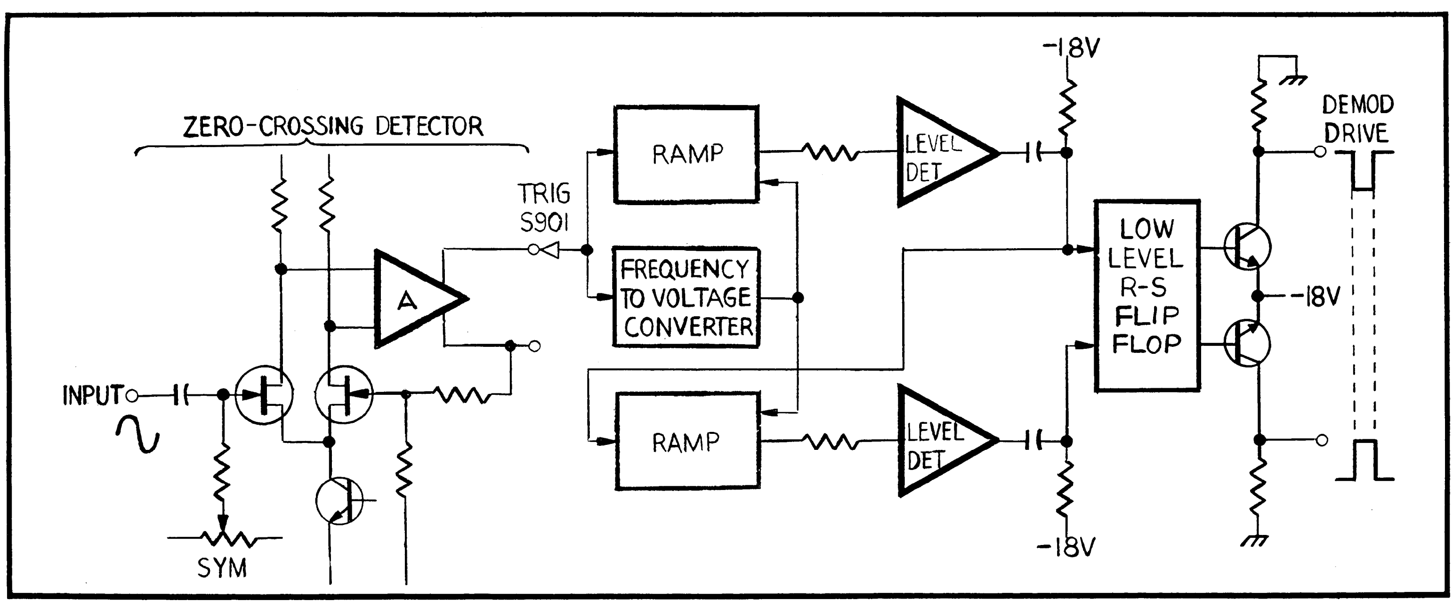


FIGURE 20. Reference Channel.

b. Frequency-to-Voltage Converter. The F-V Converter automatically supplies exactly the right voltage to the ramp generators so that each ramp has the proper slope to reach 5 volts during the period of one input cycle. Because of this, 5 volts on the ramp always corresponds to 360° on the input waveform, 2.5 volts always corresponds to 180°, 1.25 volts always corresponds to 90°, and so on. This principle is the basis for the phase-shifting circuitry of the Model 840 AUTOLOC™ Amplifier. The F-V Converter is the means used to provide automatic set-up of the ramps, or "automatic frequency tracking". Essentially, the F-V Converter is a monostable followed by a lowpass filter. More specifically, the monostable consists of the same circuitry as used in the ramp generators with only slight variations, and the lowpass filter is a three-pole Butterworth filter with -3 dB point at 0.25 Hz. In operation, a pulse comes into pin 13 of QA801 from the output of the zero-crossing detector. This pulse changes the output state of a flip-flop in QA801 and causes transistor Q803 to be switched off. Current then flows into integrating capacitor C802, and the ramp at the output of the integrator rises until it reaches approximately 5 volts. At this level, Q805 turns on, a positive voltage is applied to pin 2 of QA801, the flip-flop changes state, and Q803 is switched on. When this happens, the ramp is returned to zero in a few microseconds, Q805 is turned off "almost instantly", and the circuit awaits another pulse from the zero-crossing detector. During the time that the ramp is rising, Q803 is switched off, and the flip-flop output that drives Q803 is low. This same flip-flop output can be used to control another transistor switch also, in this case Q801. So then, while the ramp is rising, Q801 will be switched off, and its output will be at approximately +18 volts; while the ramp is clamped, Q801 will be switched on, and its output will be near 0 volts. Thus, the output of transistor Q801 is a rectangular waveform that switches between 0 volts and +18 volts; the average dc value of that waveform depends on how often the circuit is triggered. The V_{SAT} can be bucked out in a following amplifier, so that V_{dc} is a linear function of τ/T. If the circuit is triggered frequently τ is large with respect to T and V_{dc} is large also (approaching 18 volts); if the circuit is triggered infrequently, V_{dc} is small and the limiting value is zero volts for zero frequency. This is precisely the relationship that is required between the input frequency and the output voltage for controlling the integrators in the ramp generators. The remaining portion of the F-V Converter consists of the 3-pole Butterworth filter for removing the fundamental and harmonics of the rectangular wave, and a dc amplifier with a gain of approximately -1.1. The reason for this particular gain is that τ/T is set up to vary between .05 and .5 which gives dc outputs from approximately .9 V to 9 V. The amplifier takes this voltage range and supplies -1 V to -10 volts to the ramp generators. The exact voltage needed by the ramp generators for a specific frequency is obtained by adjusting τ slightly with internal trimpot R813. Trimpot R827 adjusts the output of the F-V Converter to zero (for no input frequency) by compensating for V_{SAT} of Q801 and any offsets in QA803 and QA804.

c. Ramp Generators. Each ramp generator in the Model 840 is essentially an integrator with a transistor switch across the integrating capacitor. The amplifier for each integrator consists of an IC op-amp and a dual JFET. The dual JFET is used as a dual source-follower on the input of the op-amp to lower the bias currents of the amplifier. The integrating capacitors for each integrator are .02 µF - 0.5%, and the input resistors for each integrator are 0.1% and range from 10 kΩ to 1 MΩ. In order to convert each simple integrator into a ramp generator, three things are necessary: 1) an R-S flip-flop for initiating and resetting the ramp, 2) a switch across the integrating capacitor, and 3) a simple comparator for sending a pulse to the R-S flip-flop once the ramp reaches a certain level. Operation of the circuit is simple and straightforward. A pulse from the zero-crossing detector comes into pin 13 of QA701 (a quad gate connected as two separate R-S flip-flops). The outputs of one flip-flop in QA701 change state, and Q703 switches off. With Q703 turned off, current from one of four input resistors, R703-R706, flows into integrating capacitor C706. The resulting ramp rises until it reaches approximately 4.15 volts, at which time Q706 turns on and a positive voltage is applied to pin 2 of QA701. This positive voltage returns the output of the flip-flop to its original state, which switches on Q703, which returns the ramp to its baseline voltage near 0 volts. The entire circuit action is repeated at the arrival of the next pulse from the zero-crossing detector. The operation of the second ramp generator is identical to

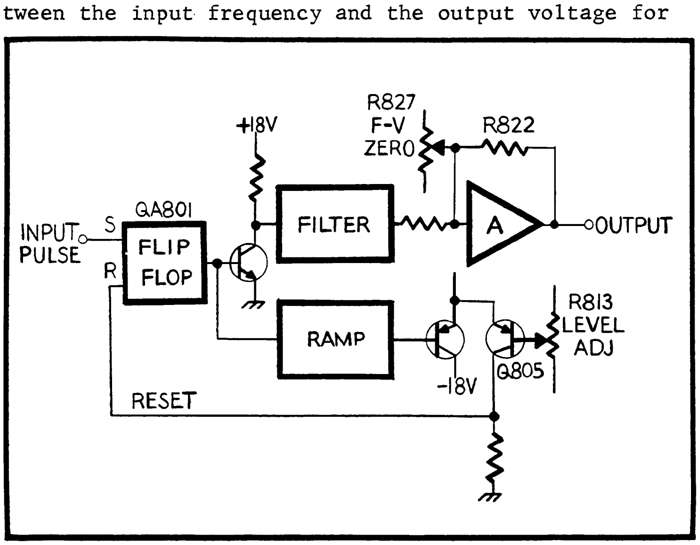


FIGURE 21. F-to-V Converter.

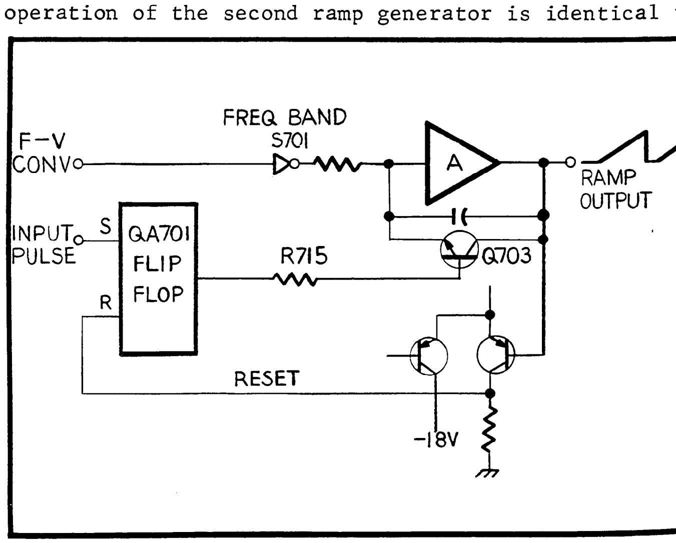


FIGURE 22. Ramp Circuit.

that of the first except that it is triggered from a different source. Briefly, what happens is this: There is a level detecting circuit connected to the output of ramp generator number one. The level at which this circuit changes state is determined by a voltage set by the Phase Control, R1101 and S601. (This voltage falls approximately between 1.25 volts and 3.89 volts; the remainder of the 5-volt ramp is not used. That explains why the ramp can be returned at approximately 4.15 volts.) When ramp number one reaches the level set by the Phase Control, the level detector output switches from low to high and an R-C network shapes this level change into a positive pulse. This pulse is then used to trigger a second flip-flop in QA701 which turns off Q704 and initiates the second ramp. The action of this second ramp is identical to that of the first.

d. Level Detectors and Demodulator Drive. The level detectors do just what their name implies; that is, they detect a specific level at the output of the ramp generators and simultaneously send a pulse to an R-S flip-flop. The level that they detect corresponds to a phase on the input waveform. If only one ramp were used, and if that one ramp could return from +5 volts to 0 volts instantaneously, then voltages along the ramp would be equivalent to phases from 0° to 360° on the input waveform to the reference channel. The Model 840 AUTOLOC™ Amplifier, however, employs two ramps to accomplish its processing of the reference signal. This approach requires only the center portion of each ramp to be used. Here is how it works. The Phase Control itself is made up of S601, the Phase Quadrant Switch, and R1101, the 0°-100° Phase Dial. The 0°-100° Phase Dial is part of a string of resistors, R601-R604, which is fed from a 1-transistor adjustable current source, Q601 and associated circuitry. By adjusting R605, the current through R1101 (Phase Dial) can be varied until there is 1.389 volts across R1101. This voltage is equivalent to 100° phase. Once the current through the string of resistors is set, then the two voltage tops of the string can be adjusted. First the voltage at J601 is adjusted by R604 to be 1.250 volts, and then the voltage at J602 is adjusted by R602 to be 2.500 volts. These two points that J601 and J602 monitor also go to points on S601, the Phase Quadrant Switch. S601 then switches R1101 to one of these two voltages - 2.500 volts if the dial is to adjust from 0° to 100°, and 1.250 volts if the dial is to adjust from 90° to 190°. Phases from 180° to 370° are obtained by interchanging the outputs of the two level detectors at the R-S flip-flop in QA603. An important aspect of the level-detecting circuitry is that only one ramp generator and one level detector, along with the Phase Control are needed to determine the phase delay through the reference channel. The other ramp generator and level detector are used to reset the output R-S flip-flop in QA603 exactly 180° after it has been set. The way this happens is that QA601 (the level detector set by the Phase Control) not only sends a pulse to the output R-S flip-flop when a specific level is reached, but also sends a pulse back to ramp generator number two. This pulse causes the second ramp to rise at exactly the same rate as the first (both generators are fed from the output voltage of the F-V Convertor, and tight-tolerance integrating components are used). When the second ramp reaches a level of 2.5 volts, the second level detector also sends out a pulse to the output R-S flip-flop. (Actually there is a potentiometer, R610, which can be adjusted both sides of 2.5 volts to set the symmetry of the flip-flop square-wave right on). Thus, the Model 840 generates its own symmetrical square-wave demodulator drive regardless of the shape of the input waveform to the reference channel. The outputs of the two level detectors, QA601 and QA602, do not go directly to the output flip-flop QA603, but instead go to the Phase Quadrant Switch, S601. Here the outputs can be interchanged before going on to the flip-flop in order to achieve a 180° reversal in phase at the demodulator. However, the wipers on switch S601 don't go directly to the output flip-flop either; instead, the wipers go to the Trigger Switch, S901, on the zero-crossing detector circuit board. At the Trigger Switch, the inputs to the flip-flop of QA603 are switched to the pulse outputs of the zero-crossing detector in the "EXT. PHASE" triggering mode, and the inputs are switched to the wipers of S601 in the "+", "-", and "2nd Harm." triggering modes. Thus in the "EXT. PHASE" triggering mode, the zero-crossing detector directly drives the flip-flop which in turn drives the demodulator and the level detector outputs are disconnected. Actually, the flip-flop does not drive the JFET switches of the demodulator by itself. The reason for this is just that the flip-flop is half of an RTL logic component. The flip-flop uses two of four 2-input NOR gates in a cross-coupled configuration. Because supply voltages for RTL components must be around 3.6 volts, the outputs of the flip-flop can only be used to drive two "high-voltage" switches and not the demodulator itself. In this case, the "high-voltage" switches are Q602 and Q603, two high-frequency transistors. These two transistors switch between the levels of -18 volts and 0 volts and drive the gates of the demodulating fets directly.

e. Synchronous Demodulator. The crossroads for the two channels of the Model 840 and the heart of the phase sensitive detector is the synchronous demodulator. The circuit itself is quite simple - and equally important, it is quite reliable. A total of six components make up the basic circuit, and no matching is required. Q501 and Q502 are both N-channel JFET's having an ON-resistance of approximately 30 ohms. Resistors R501 and R502 connect ac amplifier outputs to the drains of Q501 and Q502 and have a value of 4.99 kΩ. C501 and C502 are glass piston trimmer capacitors having a value of .8-11 pF, and they are used to compensate for dc offsets due to switching spikes. The value for resistors R501 and R502 was determined as follows. For large resistance values the best FET switch linearity was obtained. For small resistance values, the "smallest" switching spikes were obtained. A value of 4.99 kΩ seemed to give a good compromise between these two extremes, and 90 dB of non-coherent signal rejection was established at the lower frequencies of AUTOLOC™ Amplifier operation. It is worth mentioning that this 90 dB figure is given for a maximum non-coherent signal level of 20 volts p-p into the synchronous demodulator. At levels less than 20 volts p-p the rejection of non-coherent signals is greater than 90 dB. (At a reference signal frequency of 10 kHz the rejection of non-coherent signals is 60 dB at the 20 volt p-p level and greater than 60 dB at lower levels.) For capacitors C501 and C502, the values were chosen to accomplish the following. These capacitors were intended to cancel or remove the switching spikes injected into the signal channel by the output square wave of the reference channel. This, they were not able to do, but settings of C501 and C502 were found that could balance the contribution of the positive and negative spikes. The imbalance between the positive and negative switching spikes at the drains of Q501 and Q502 gives rise to a dc offset voltage which varies directly with frequency. This imbalance is caused by the difference between the ON-resistance and OFF-resistance of the switching FET. Briefly, what happens is this: When the square-wave drive to the FET changes from -18 volts to 0 volts, a part of this change is coupled into the drain of the FET by the drain-to-gate capacitance of the device. However, after this level change of the square-wave, the FET is "ON", and any signal coupled into the drain decays very rapidly through an ON-resistance of approximately 30 ohms. Such is not the case when the square-wave drive changes from 0 volts to -18 volts, because after this change, the FET is "OFF". So, in this case, any signal coupled into the drain must decay through essentially the 4.99 kΩ resistance. Thus, the negative-going spike is much "wider" than the positive-going spike, and there is a net negative dc voltage, the size of which is determined by the frequency of the square-wave drive signal. Because there are two square-wave drive signals, 180° out of phase with one another, it is possible to couple signal from the gate of one FET to the drain of the other FET and vice versa. This is the purpose of capacitors C501 and C502. For example, when the gate of Q501 is going negative, then the gate of Q502 is going positive. Thus, at the drain of Q501 there will be a negative spike due to coupling through the drain-to-gate capacitance, and there will also be a positive spike due to coupling through C501. This cross-coupling between the gates and drains of the two FET's provides a means of "spike cancellation" in the synchronous demodulator. The only other circuit elements are resistors R523 and R524, which reduce the effects of changing capacitance between the wires and tapes leading to the gates of the switching FET's and Q503 and R504. Q503 is a general purpose JFET, and R504 is a 20 kΩ resistor which together make up a source-follower used for monitoring one side of the synchronous demodulator. The output of the source-follower goes to the front panel connector labelled "DEMOD", and a half-wave demodulation waveform appears at this connector.

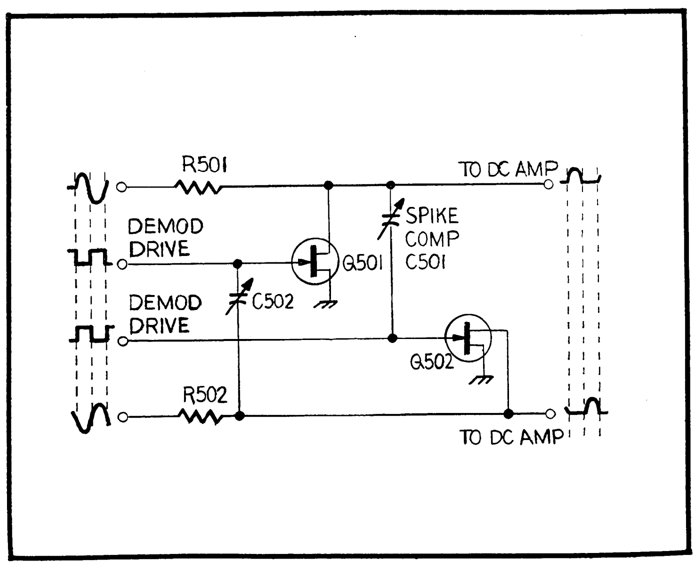


FIGURE 23. Synchronous Demodulator.

5-3 SIGNAL CHANNEL. The signal channel does essentially two things to the coherent signal or the "signal of interest". First, it amplifies the signal in an ac amplifier to boost its level at the synchronous demodulator. Secondly, it amplifies and filters the demodulated signal in a variable-gain, variable-bandwidth dc amplifier. In addition, provision has been made for adding fixed-frequency tuning or filtering to the input ac amplifier of the signal channel. If the user desires, he can insert a fixed-frequency bandpass filter, or a 50 or 60 Hz notch filter into the ac amplifier, and activate this filter with the "Wideband-Tuned" switch, S1102, on the front panel.

a. Input AC Amplifier. The path through the signal channel begins with a differential input amplifier. The actual differential amplifier is an op-amp, QA201, standardly connected for a differential gain of three. Buffering the inputs of QA201 are two enhanced source-followers comprised of dual JFET, Q201, dual PNP transsistor, Q202, and associated circuitry. These enhanced source-followers are characterized by very high input impedance, very low output impedance, and gain very close to unity; they make it possible to put 11 MΩ, 1-step attenuators at the inputs of the signal channel. The attenuators are capacitively compensated by fixed capacitors C203 and C206 and variable capacitors C202 and C205. The variable capacitors are adjusted to give gain accuracy and common-mode rejection at 10 kHz. At low frequencies, amplifier gain accuracy is determined by .1% - 50 ppm/°C metal film resistors; there is no gain adjustment. However, there is a CMRR adjustment for the low frequencies. That adjustment, R215, which varies the non-inverting gain of QA201, is capable of providing a CMRR of 90 dB. There are several other amplifiers which make up the overall input amplifier. These are QA202, QA203, and QA204. QA202 and QA203 are connected in circuit as non-inverting gains of 10; they are switched in and out of the signal path as the input attenuators are being switched to give four discrete gains of 0.3, 3, 30, 300 (the output ac amplifier has a fixed gain of 3.333). QA204 is one of the new voltage followers having low input current and internal stabilization. It is capacitively coupled to the rest of the circuit, and its purpose is to "remove" the dc from the signal so that low-voltage polar tantalum capacitors can be used on the input of the output differential amplifier. Included with the input ac amplifier section of the signal channel is the overload indicator circuitry. In this circuitry, a dual op-amp, QA205, serves as a dual comparator whose two outputs are "OR"ed together for driving a transistor switch which in turn drives the indicating lamp. One comparator is used for detecting positive overloads, the other for detecting negative overloads. Q203 and diodes D204-D206 along with filter capacitor C224 make up a half-wave rectifier which converts positive pulses into positive dc at one input of QA205. Q204 and diodes D201-D203 along with filter capacitor C225 handle negative overloads. Positive and negative overload conditions are detected in front of the accessory filter, at the output of the entire ac amplifier (or the input to the synchronous demodulator), and at the dc output of the instrument. The reason for detecting overloads at the ac output is obvious. In front of the filter, detection is necessary to catch overloads due to large interfering signals which would be "removed" from the ac output. At the dc output, it is necessary to indicate overloads due to excessive ac signal (for example, this might be the case if too small a time constant were used). The schematic for the input ac amplifier also shows resistors R245-R249. These are the feedback resistors for the variable-gain dc amplifier. They are included in the input section because they are switched by the Sensitivity Multiplier Switch which is concentric with the Sensitivity Dial. The advantages of variable dc gain will be discussed in the circuit description of the Phase Sensitive Detector.

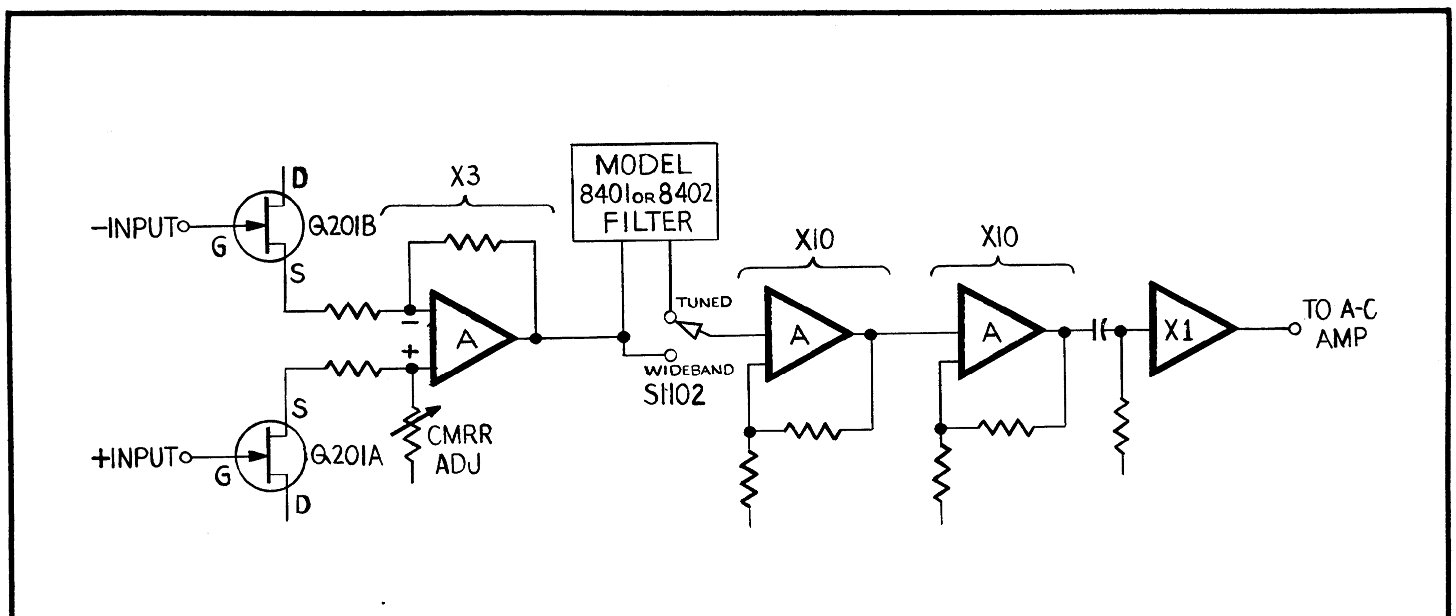


FIGURE 24. Input AC Amplifier.

b. Output AC Amplifier. The output ac amplifier is dc coupled into the synchronous demodulator so that its drift components affect the overall dc stability of the instrument. For this reason, the amplifier includes stabilization against common-mode dc drift at its output. Other than that, the amplifier is straightforward in concept. In order to achieve "differential" output, two op-amps are used. QA401 is hooked up as an inverting amplifier with an ac gain of -3.333, and QA402 is hooked up as a non-inverting amplifier with an ac gain of +3.333. The two 180° out-of-phase output signals are fed to the synchronous demodulator where they are combined to give full-wave demodulation (with proper phasing). Because the two amplifier outputs are dc coupled to the demodulator, their drifts are amplified along with drift components in the dc amplifier. If these two outputs drift in different directions, there is little problem because the algebraic sum of their drifts will be small. However, if these outputs drift in the same direction, the full effect of this drift will be seen at the input to the dc amplifier. It is the purpose of the stabilizing amplifier to feedback a signal (to the inputs) equal to the average of the two drifts, or in other words, equal to the net dc of the two drifts. The amplifier which does the stabilizing is nearly identical to the low-drift dc amplifier which follows the demodulator. On its input is a 5 μV/°C dual FET, Q401. The dual FET is followed by a dual PNP, Q402, and a Darlington output consisting of PNP transistors Q403 and Q404. The stabilizing amplifier sums the outputs of QA401 and QA402 through .1% resistors R417 and R418. It then amplifies this sum and feeds back a correction signal to both ac amplifiers, which forces the sum of the two outputs to zero. The net difference between the two outputs remains unchanged, but this difference becomes centered around zero. Because of the gain of the stabilizing amplifier, the net dc drift contribution of the ac amplifiers is quite small, and most of the drift of the system is due to the drift of the dual FET itself. It is interesting to note that the outputs of the two ac amplifiers can still drift apart. This means that with the particular op-amps used, one output could drift positive at 30 μV/°C while the other could drift negative at 30 μV/°C, for a total of 60 μV/°C. (The amplifiers have a gain of unity for dc voltage drift signals - not a gain of 3.333.) With a maximum gain of 1000 in the dc amplifier this 60 μV/°C would appear as 60 mV p-p sq. wave/°C at the dc output. Likewise, if the two ac amplifiers have different initial offsets, then there could be a square-wave of many volts amplitude at the dc output. In order to balance or set equal the initial offsets of QA401 and QA402, a dc voltage is fed into the input of QA401. The control which sets this voltage is R405, an internal "amplifier balance" adjustment. There is one other important control in the output ac amplifier, and that is R429, an internal zero adjustment for the dc output. What this control basically does is set the dc voltage at the gate of Q401A to zero by making up for the initial difference in V_{GS} between Q401A and Q401B. Actually, this is what the control would do if the dc amplifier had its own separate zero adjustment. However, because there is no zero adjustment in the dc amplifier, the "zero control", R429 sets a voltage at the gate of Q401A which will bring the dc output to zero (this voltage at the gate will probably not exceed 10-15 mV).

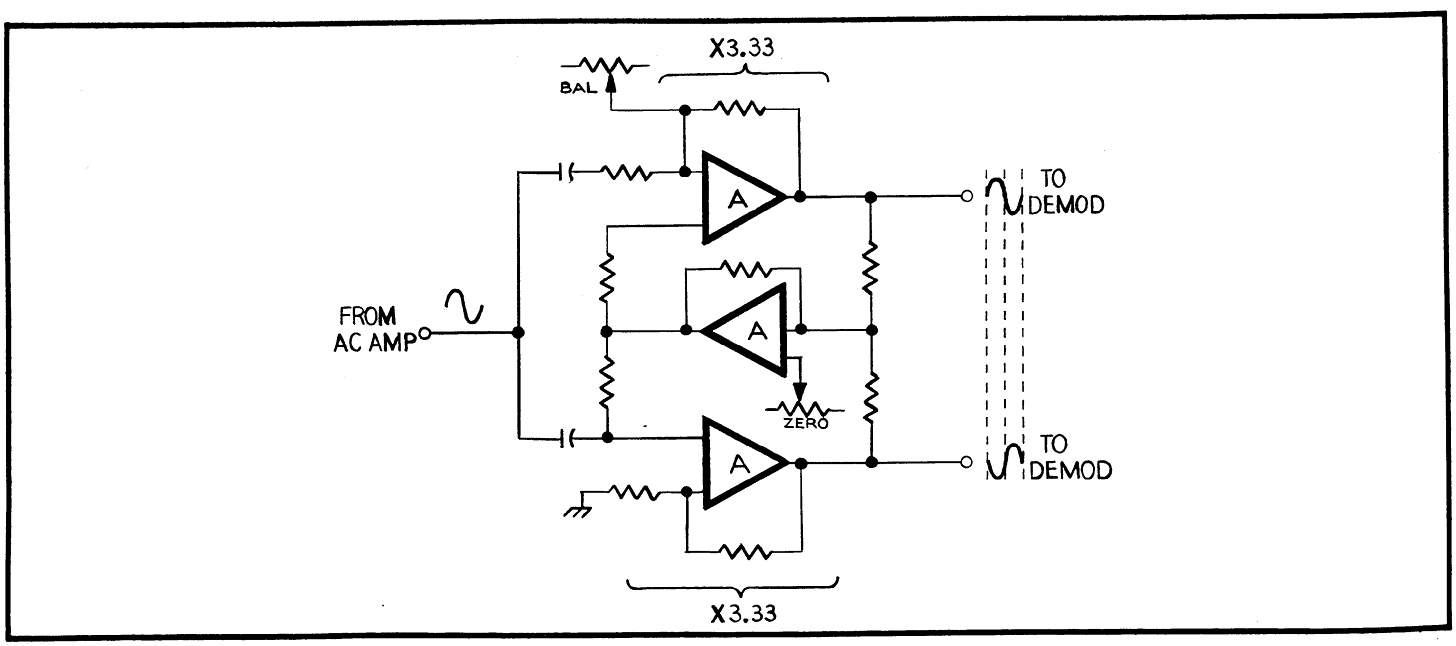


FIGURE 25. Output AC Amplifier.

c. Phase Sensitive Detector. The Phase Sensitive Detector includes the synchronous demodulator and the output dc amplifiers of the instrument. The synchronous demodulator is discussed elsewhere under its own heading. Two dc amplifiers follow the synchronous demodulator; their combined performance gives the Model 840 a good bit of its versatility. The first dc amplifier is a summing-type amplifier with a closed-loop gain of -10. This amplifier takes the two outputs of the synchronous demodulator and sums them for full-wave dc output. In addition to amplifying the signals issuing from the demodulator, this amplifier also filters these signals. The filtering is accomplished by placing a capacitor across the feedback resistor, R513. It is this capacitor that is switched by the Time Constant Switch, S1104, to give a sequence of time constants from 3 msec. to 100 sec. In order to keep the values of these different capacitors within reason, a 20 megohm feedback resistor (R513) is used. (The RC product of the feedback resistor and its shunting capacitor determine the time constant - thus 20 MΩ and 5 μF give a time constant of 100 seconds.) The input resistors, R505 and R506, then must have a value of 2 MΩ each to yield the desired gain of -10. These large resistor values surrounding the amplifier make a JFET input a natural. In this case a 5 μV/°C dual JFET, Q504, is used. The outputs at the drains of Q504 feed a dual PNP transistor, Q505. A PNP transistor Darlington consisting of Q506 and Q507 provides a low impedance, single-ended output for the amplifier. The amplifier was designed with discrete components because of the dc stability requirement. Various combinations of JFET's and op-amps were tried, but these combinations all proved unsatisfactory because of either poor dc stability or high frequency instability. C505 and R510 shape the frequency response of the amplifier, and D501 is included to prevent the output from "folding back" when overloaded in the positive direction. The output of the summing amplifier drives another inverting amplifier, QA501, which has five switch-selected gains of 1, 3.333, 10, 33.33, and 100. QA501 is a popular op-amp with a maximum voltage drift of 30 μV/°C which reflects back to the demodulator as an additional 3 μV/°C worst-case. R522 is included to help minimize drift due to temperature-sensitive input currents. The actual resistors which are switched vary in value from 4.99 kΩ to 499 kΩ and have an accuracy of .1% and a temperature coefficient of 50 ppm/°C. They are not mounted with the amplifier QA501, but instead are included on the Input ac amplifier PC board where they are switched by the Sensitivity Multiplier Switch. The System Gain Adjustment, R521, makes up for fixed gain losses in the entire signal channel. For example, the front-end enhanced source-followers might have a gain loss of a percent or so, the on-resistance of the demodulating JFET's might contribute half a percent gain loss, and the gain-setting resistors in the first dc amp (R505, R506, and R513) could add a percent or two additional error. But these errors are in the system at all times and can be corrected for with one gain adjustment. However, even if no gain errors were present in any of the places just mentioned, R521 would still be necessary to compensate for the "loss" in converting sine-wave rms to full-wave dc. One volt rms sine-wave yields almost exactly 0.9 volts full-wave dc for a "conversion gain" of nearly 0.9. To make up for this "loss", the actual closed-loop gains of QA501 are more like 1.111, 3.703, 11.11, 37.03, and 111.1. R521 is the internal adjustment which determines what the nominal value of these gains shall be. Signal suppression is also accomplished in the dc section of the instrument. Suppression is accomplished with a ten-turn pot, R1102 (across which a nominal 9 volts has been set with trimpot R1006), and a 20 MΩ resistor R507. The gain of the first dc amplifier to suppression voltages is set by R513 and R507 (both 20 MΩ resistors) and is unity. As the gain of the second dc amplifier is varied from "1.11" to "111" the signal suppression capability varies from "full-scale" to "100 times full-scale". The fact that

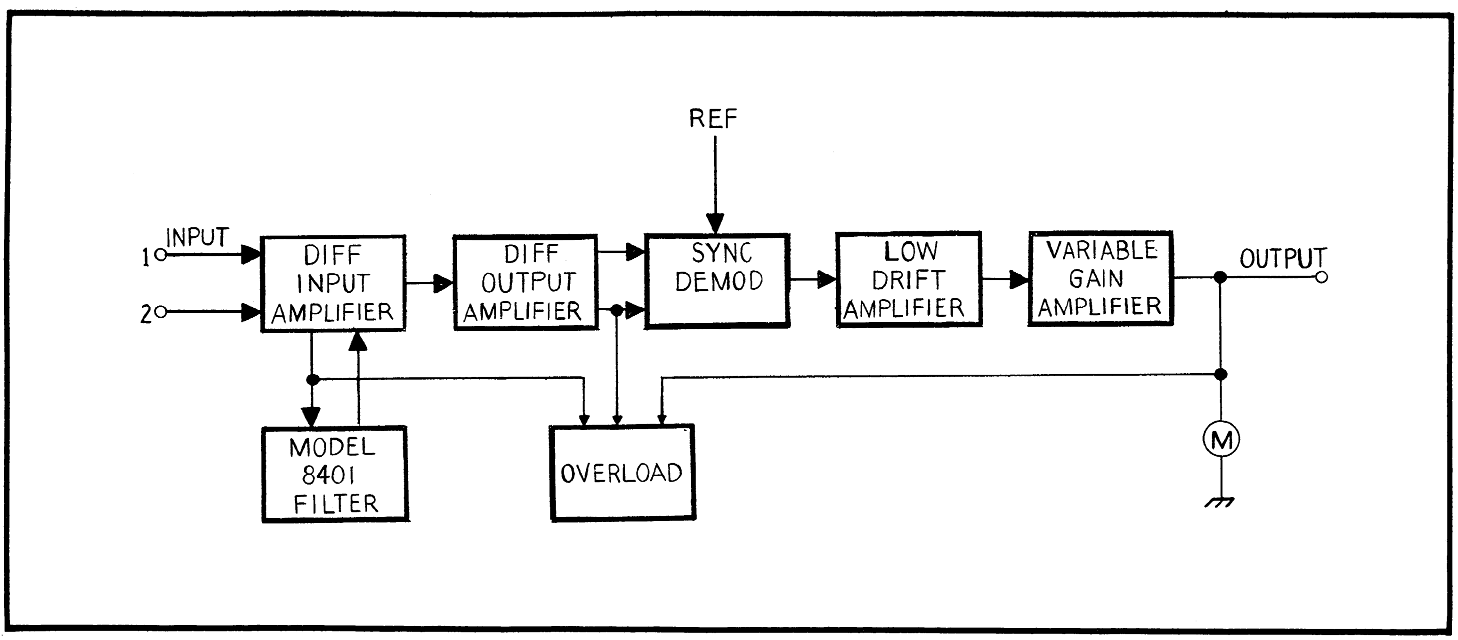


FIGURE 26. Signal Channel.

the gain can be changed after the point at which the main ac signal is suppressed, many times allows the fluctuations in the main signal to be "blown-up" and examined more accurately. An important design concept of the Model 840 revolves around the variable-gain dc amplifier. In the initial phases of the design it was felt that a case could be made for both low post-demodulator gain and high post-demodulator gain. The logical result of this divided opinion was that the Model 840 should have variable post-demodulator gain in order to achieve the greatest versatility. The basic trade-off is this: When the total dc gain after the demodulator is low, then for full-scale output (±10 V dc), signals at the demodulator must be large. Under these conditions, dc amplifier noise and drift voltages are comparatively small, and excellent output stability is achieved. When the total dc gain after the demodulator is high, then for full-scale output, signals at the demodulator must be small. With these conditions output stability will not be as good, but the signals themselves can tolerate much more wideband and discrete-frequency "noise" mixed with them without overloading the demodulator. Thus, the fundamental compromise is between output stability and demodulator dynamic reserve. Because the Model 840 has this particular capability, it can be optimized for essentially any signal within its range of 10 µV rms to 1 V rms. Optimization most often would mean: best possible output stability without signal channel overload.

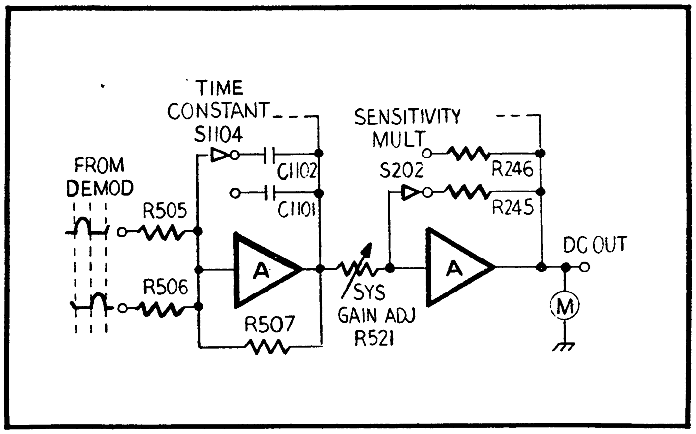


FIGURE 27. DC Amplifier.

d. Notch Filter. Two versions of the notch filter are available, one for 50 Hz and one for 60 Hz. The circuit which forms the notch is a variation on the standard twin-tee circuit. QA1201 is an IC voltage-follower which buffers the twin-tee, and allows large values of resistance to be used. The output of QA1201 is the output of the filter circuit; however, the response of the output is not just the usual twin-tee response. The reason for the changed filter characteristics is that the twin-tee is driven. A relatively low impedance divider consisting of resistors R1207 and R1208 feed a portion of the output signal to an op-amp, QA1202, which is hooked up as a voltage-follower. QA1202 then provides a low-impedance output for driving the twin-tee. The benefit derived from driving the twin-tee in this fashion is a "sharpening" of the notch characteristic response.

e. Bandpass Filter. The Bandpass Filter makes use of two IC voltage-followers, QA301 and QA302, and an IC op-amp, QA303. QA301 is the heart of an active circuit synthesis for a 3-pole, lowpass Butterworth filter. Likewise, QA302 is the heart of a 3-pole highpass Butterworth filter. These two sections are cascaded to yield a bandpass filter with "flat" peak, low Q, and "steep" roll-off. The three poles contribute an 18 dB/octave roll-off in either direction from center frequency; however the roll-off does not achieve its maximum rate immediately, so that the attenuation is only -12 dB at 1 octave either side of center. QA 303 is hooked up as a non-inverting amplifier with a nominal gain of 2. The reason for this nominal gain is that the center frequency for the filter is chosen to be the -3 dB point of both the highpass and the lowpass filters, and thus the cascaded gain is -6 dB from unity gain for a gain of 0.5 at the peak. The adjustable "gain-of-two" amplifier is needed to restore a gain of unity at the peak. (-12 dB at 1 octave is referenced to unity gain, thus at center frequency the filter has a gain of 1.00, and at 1 octave the filter has a gain of approximately 0.25.) R315 is used to adjust the filter for an accurate gain of unity. The filter is a bit unusual in that all six frequency-determining resistors are adjustable. Because of limitations on the resolution of the cermet trimpots, a frequency adjustment range of roughly 5 to 1 is about the best that can be achieved with any one particular filter; however, it might be possible to stretch this range to roughly 10 to 1 (with a skilled hand and large-handled screwdriver). The trimpots can be set by connecting an ohmmeter across each individual pot in succession and adjusting the pot to the appropriate value (a .3% accurate ohmmeter is adequate). The formulas for determining the resistance values are given in Table 3-1.

The three "standard" filters have basic center frequencies of 10 Hz, 100 Hz, and 1 kHz. Typical adjustment ranges for these three filter are:

10 Hz	-	9 Hz to 50 Hz
100 Hz	-	90 Hz to 500 Hz
1 kHz	-	900 Hz to 5 kHz

Any of these filters then can be adjusted to any frequency within its range. The filter can be ordered already adjusted for a specific center frequency; then at a later time, the frequency could be readjusted to a new frequency within its range (using the formulas).

TABLE 3-1.
Bandpass Filter Formulas

Resistor	Formula	Resistor	Formula
R1	$= \frac{109.2\ k\Omega}{F'}$	R4	$= \frac{29.92\ k\Omega}{F'}$
R2	$= \frac{779.7\ k\Omega}{F'}$	R5	$= \frac{76.20\ k\Omega}{F'}$
R3	$= \frac{140.8\ k\Omega}{F'}$	R6	$= \frac{524.2\ k\Omega}{F'}$

where F' = desired frequency÷center frequency.

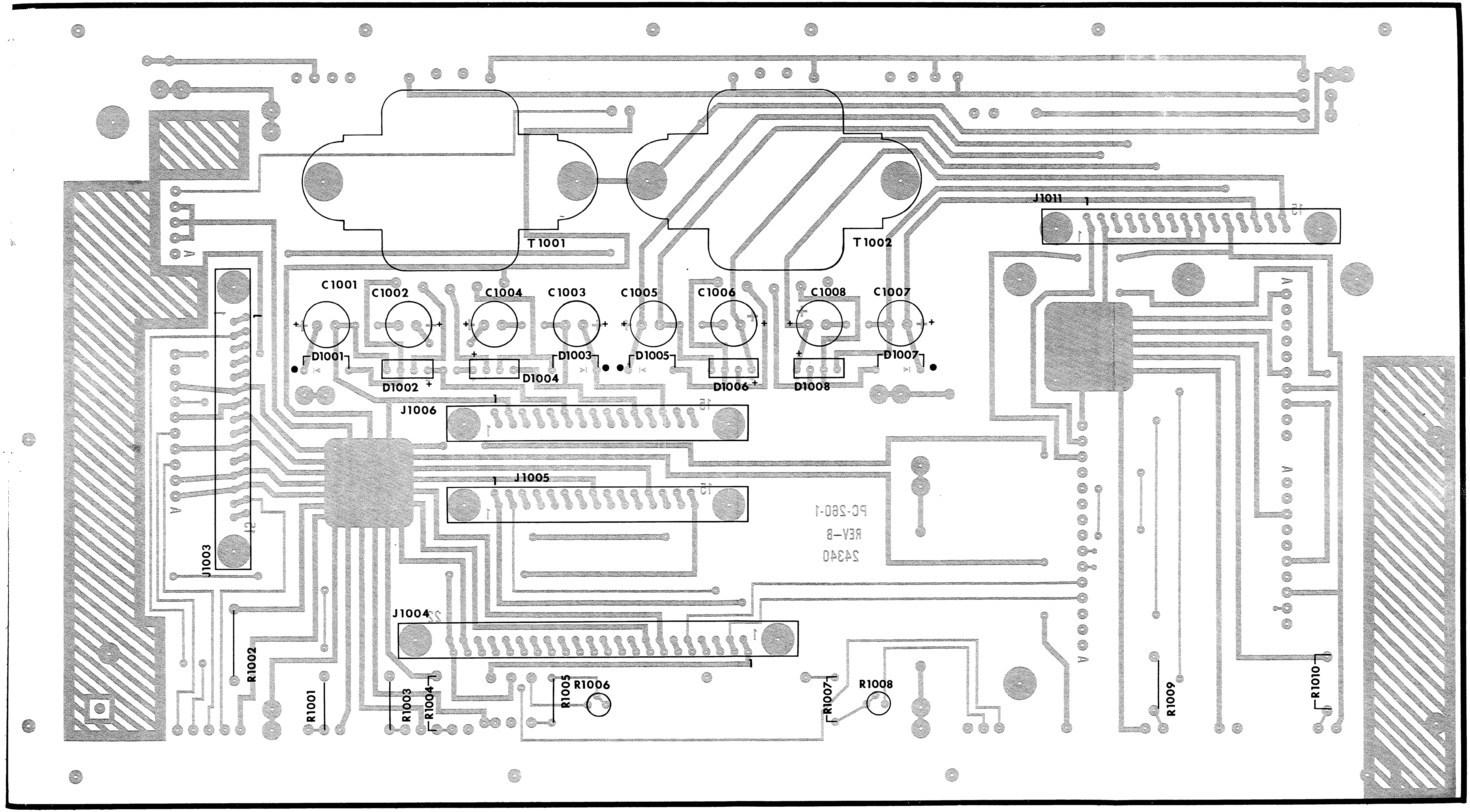


FIGURE 28. Component Layout, PC-260 (Mother Board)

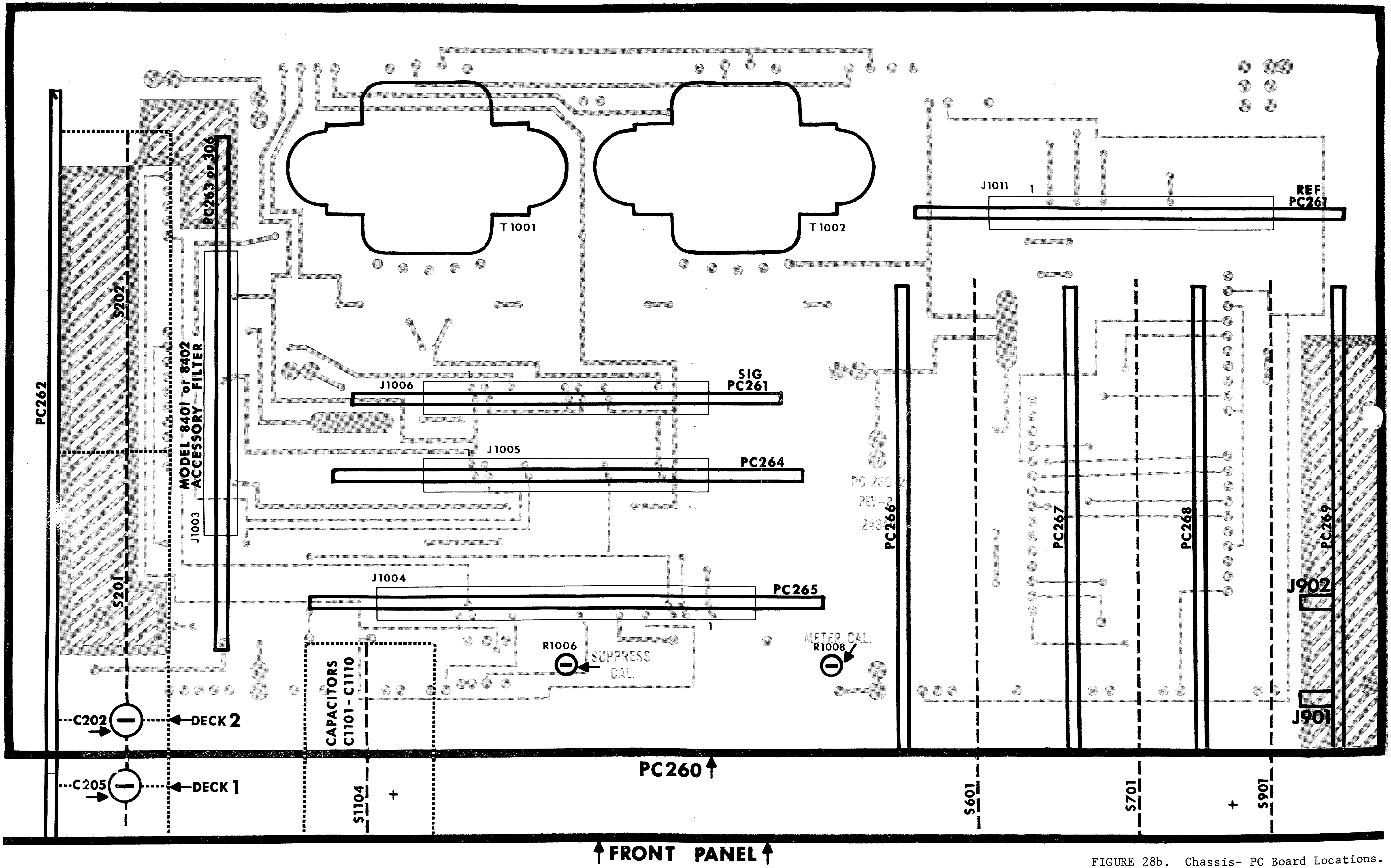
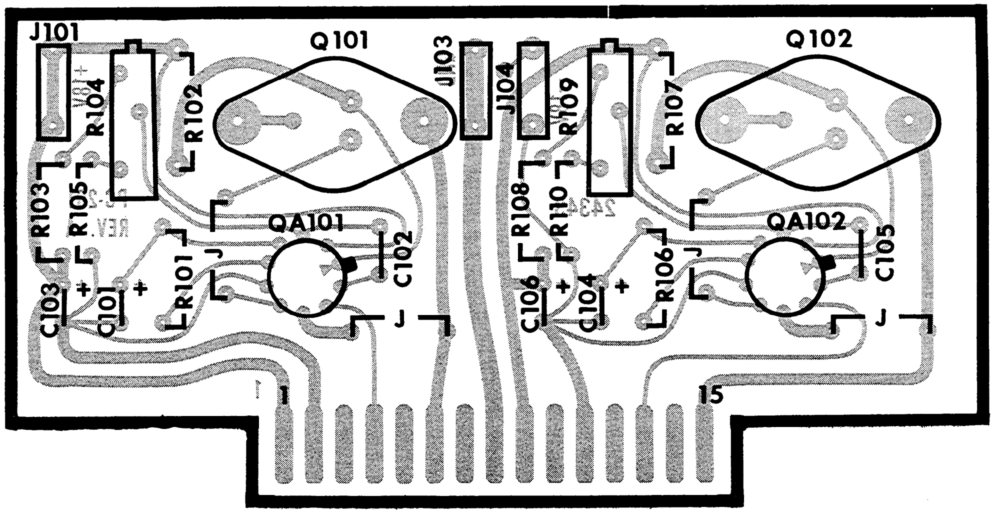
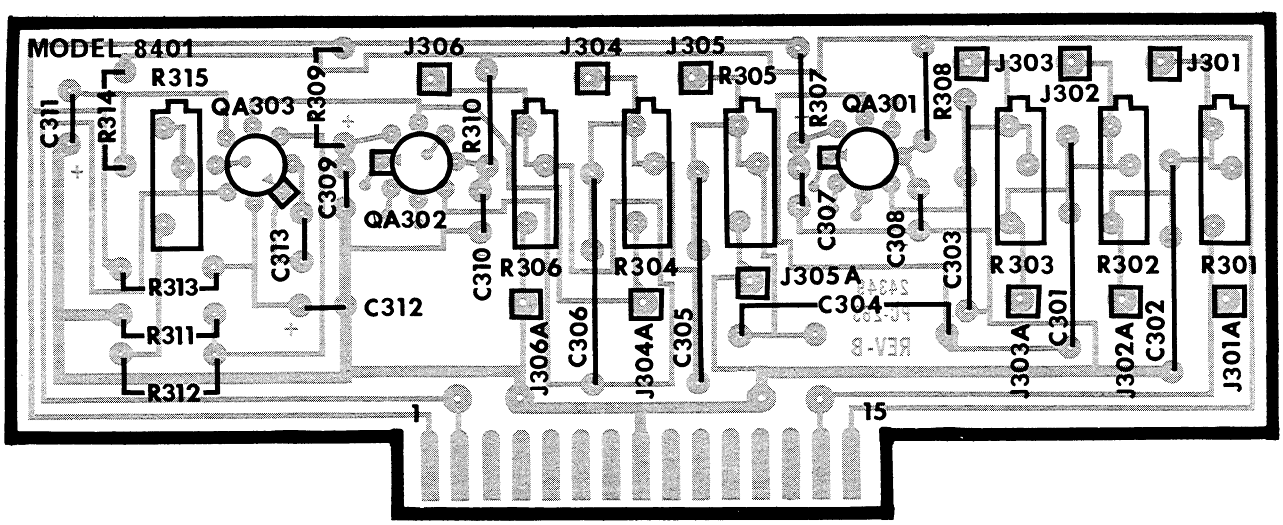


FIGURE 28b. Chassis- PC Board Locations.



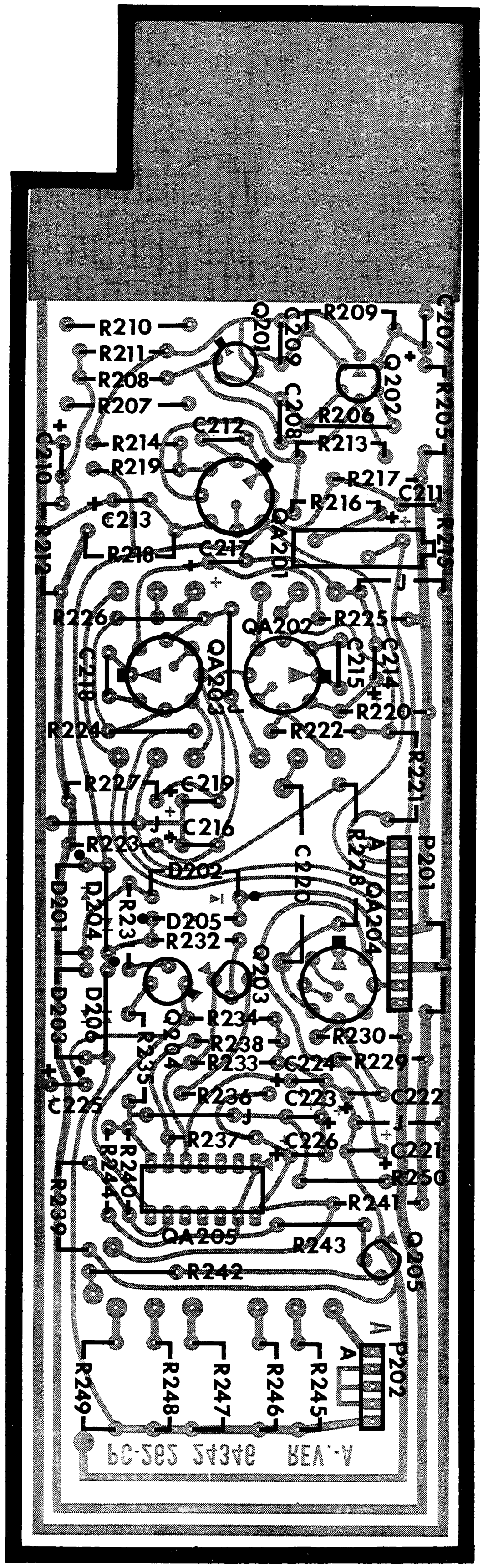
Component Layout, PC-261 (18V Regulator)

FIGURE 29.



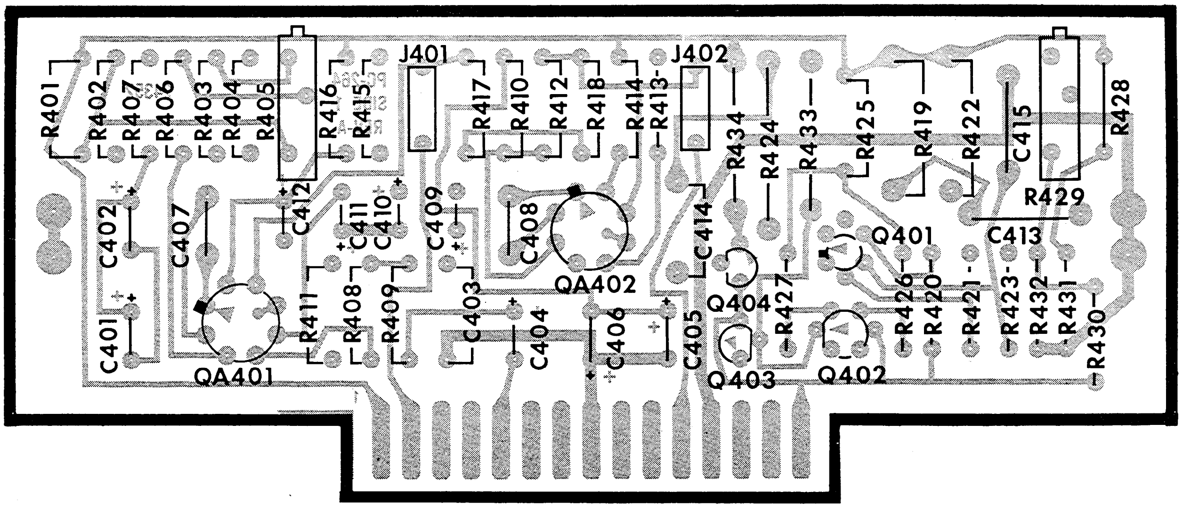
Component Layout, PC-263 (Model 8401 Filter)

FIGURE 30.



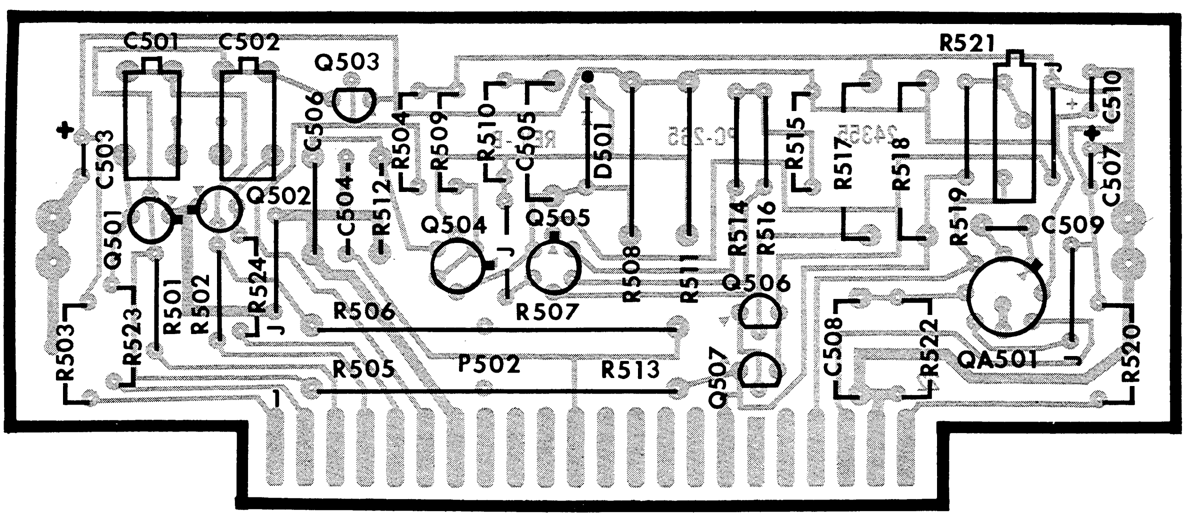
Component Layout, PC-262 (AC Input Amplifier)

FIGURE 31.



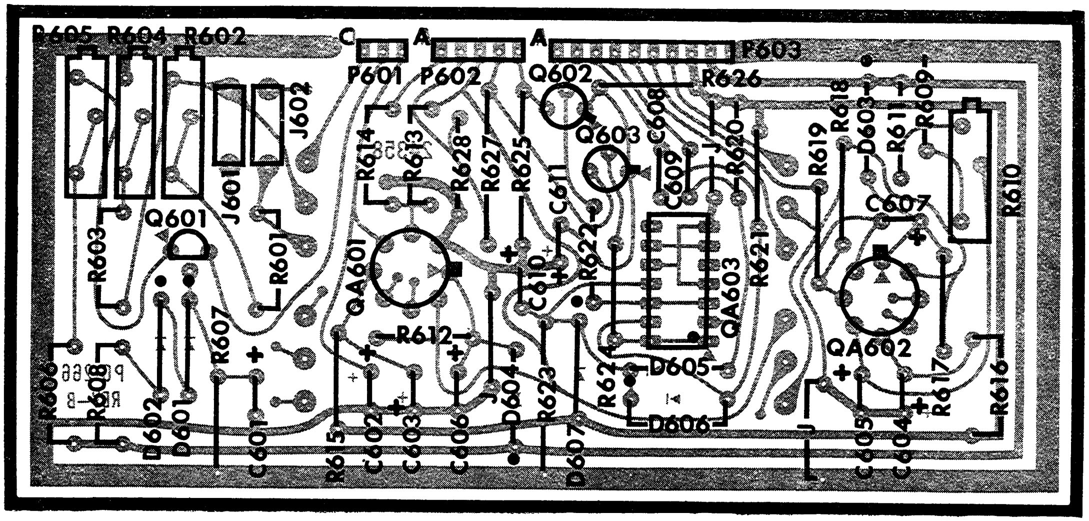
Component Layout, PC-264 (AC Output Amplifier)

FIGURE 32.



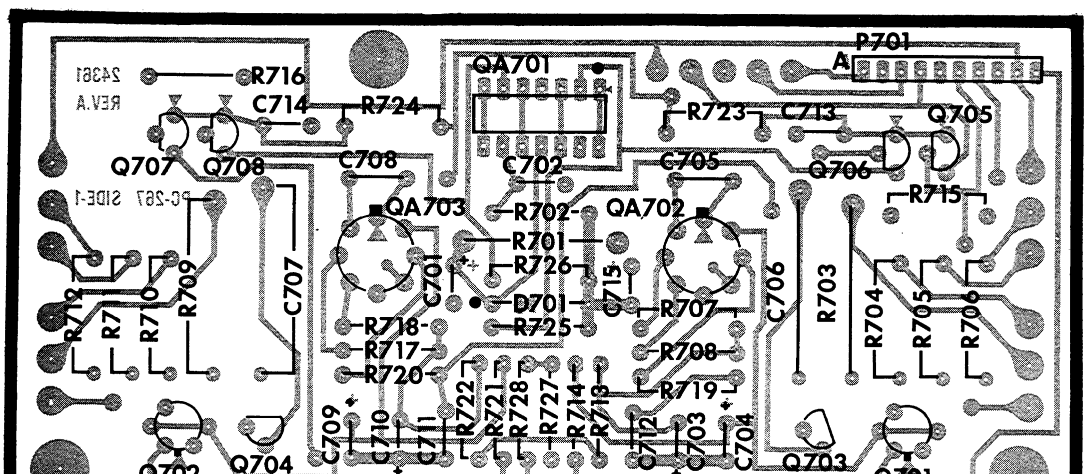
Component Layout, PC-265 (Phase Sensitive Detector)

FIGURE 33.



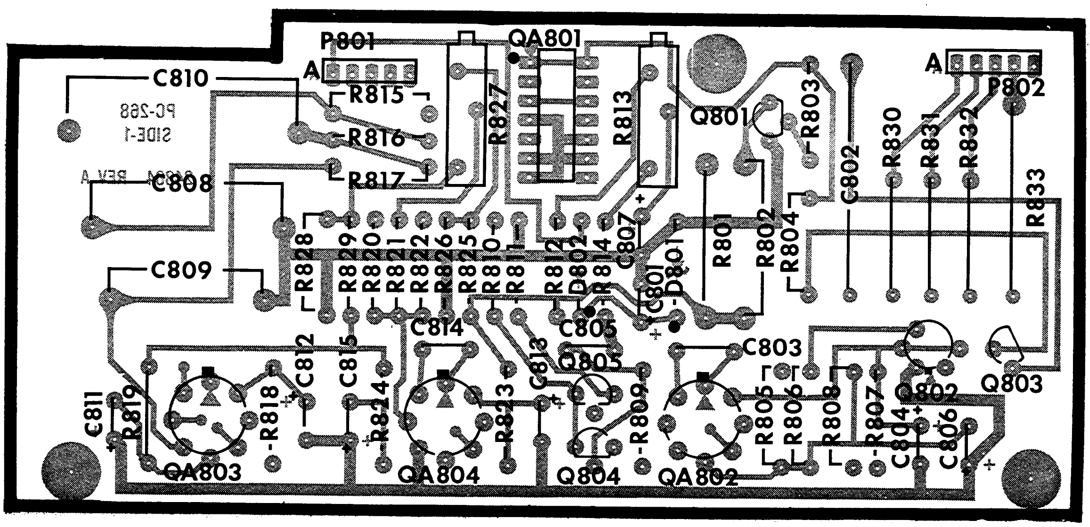
Component Layout, PC-266 (Phase Adjust)

FIGURE 34.



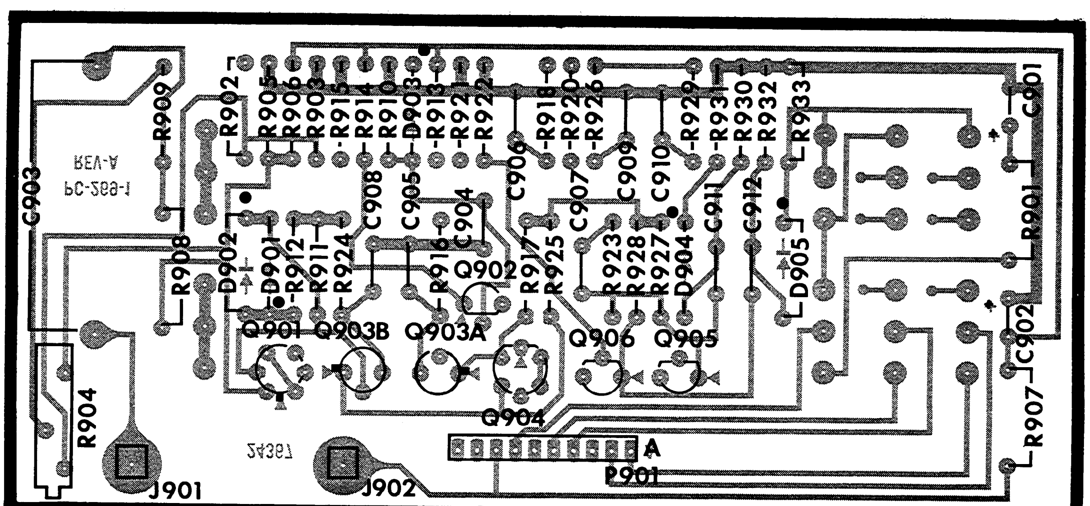
Component Layout, PC-267 (Ramp Circuitry)

FIGURE 35.



Component Layout, PC-268 (F-to-V Converter)

FIGURE 36.



Component Layout, PC-269. (Zero Detector)

FIGURE 37.

TABLE 3-2.
Internal Calibration Adjustments

Control Circuit Desig.	Name	Location	Schematic	Function
R104	-18 V ADJ	PC-261	24813D	Adjusts -18 V output
R109	+18 V ADJ	PC-261	24813D	Adjusts +18 V output
C202	N-INV INPUT ADJ	S201	24809E	Adjusts 10 kHz Gain
C205	INV INPUT ADJ	S201	24809E	Adjusts 10 kHz Gain
R215	LOW FREQ CMRR ADJ	PC-262	24809E	Adjusts CMRR
R301	-	PC-263	25047D	Adjusts Roll-off
R302	-	PC-263	25047D	Adjusts Roll-off
R303	-	PC-263	25047D	Adjusts Roll-off
R304	-	PC-263	25047D	Adjusts Roll-off
R305	-	PC-263	25047D	Adjusts Roll-off
R306	-	PC-263	25047D	Adjusts Roll-off
R315	GAIN ADJ	PC-263	25047D	Adjusts Gain
R405	AMPLIFIER BALANCE	PC-264	24863D	Adjusts Balance
R429	DC OUTPUT ZERO	PC-264	24863D	Adjusts Zero
C501	-	PC-265	24892D	Adjusts cross-coupling
C502	-	PC-265	24892D	Adjusts cross-coupling
R521	SYSTEM GAIN ADJ	PC-265	24892D	Adjusts System Gain
R602	180° PHASE ADJ	PC-266	25026D	Adjusts for 2.500 V
R604	90° PHASE ADJ	PC-266	25026D	Adjusts for 1.250 V
R605	100° PHASE ADJ	PC-266	25026D	Adjusts for 1.389 V
R610	DEMOD DRIVE SYM	PC-266	25026D	Adjusts drive symmetry
R813	F-V OUTPUT ADJ	PC-268	25027D	Adjusts F-V Output
R827	F-V OUTPUT ZERO	PC-268	25027D	Adjusts F-V Zero
R904	-	PC-269	24772D	Adjusts Symmetry
R1006	SUPPRESS CAL	PC-260	25028E	Adjusts Suppression
R1008	METER CAL	PC-260	25028E	Adjusts Meter Output
R1204	REJECTION ADJ	PC-306	25118C	Adjusts Notch Frequency

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

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.

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.

6-4. HOW TO ORDER PARTS.

a. Replaceable parts may be ordered through the Sales Service Department, Keithley Instruments, Inc. or your nearest Keithley representative.

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

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 8-2.
Schematics

Description	Assembly No.	Schematic No.
Block Diagram	--	25103D
± 18V Regulator	PC-261	24813D
Mother Board	PC-260	25028E
AC Input Amplifier	PC-262	24809E
Filter Board, Model 8401	PC-263	25047D
AC Output Amplifier	PC-264	24863D
Phase Sensitive Detector	PC-265	24892D
Phase Adjust Circuitry	PC-266	25026D
Ramp Circuitry	PC-267	25003D
Frequency to Voltage Converter	PC-268	25027D
Reference Channel	PC-269	24772D
Filter Board, Model 8402	PC-306	25118C

TABLE 8-3.
Circuit Designation Series

Series	Description	Circuit Designation	Page No.
100	± 18V Regulator	PC-261	39
200	AC Input Amplifier	PC-262	39
300	Filter (Accessory)	PC-263	51
400	AC Output Amplifier	PC-264	42
500	Phase Sensitive Detector	PC-265	43
600	Phase Adjust Circuitry	PC-266	44
700	Ramp Circuitry	PC-267	46
800	Frequency to Voltage Converter	PC-268	47
900	Reference Channel - Schmitt Trigger	PC-269	48
1000	Mother Board	PC-260	38
1100	Front and Rear Panels	-	50

TABLE 8-4.
Mechanical Parts List

Item No.	Description	Qty. Per Assembly	Keithley Part No.	Figure No.
-	Chassis Assembly	-	-	38
-	Front Panel Assembly	-	-	
1	Front Panel	1	24596D	
2	Screw, Slotted, 6-32 x 3/8	4	-	
3	Front Panel Overlay	1	24679D	
4	Rear Panel	1	24791B	
5	Side Extrusion Left	1	24836B	
6	Side Extrusion Right	1	24837B	
7	Corner Bracket	2	24745B	
8	Screw, Socket, 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	24755B	
-	Top Cover Assembly	-	-	
12	Top Cover	1	24818B	
13	Screw, Socket, 6-32 x 5/16	4	-	
-	Bottom Cover Assembly	-	24817B	39
14	Bottom Cover	1	24786D	
15	Screw, Socket, 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	-	-	16
21	Angle Bracket	2	24783A	
22	Screw, Phillips, 6-32 x 5/8	4	-	

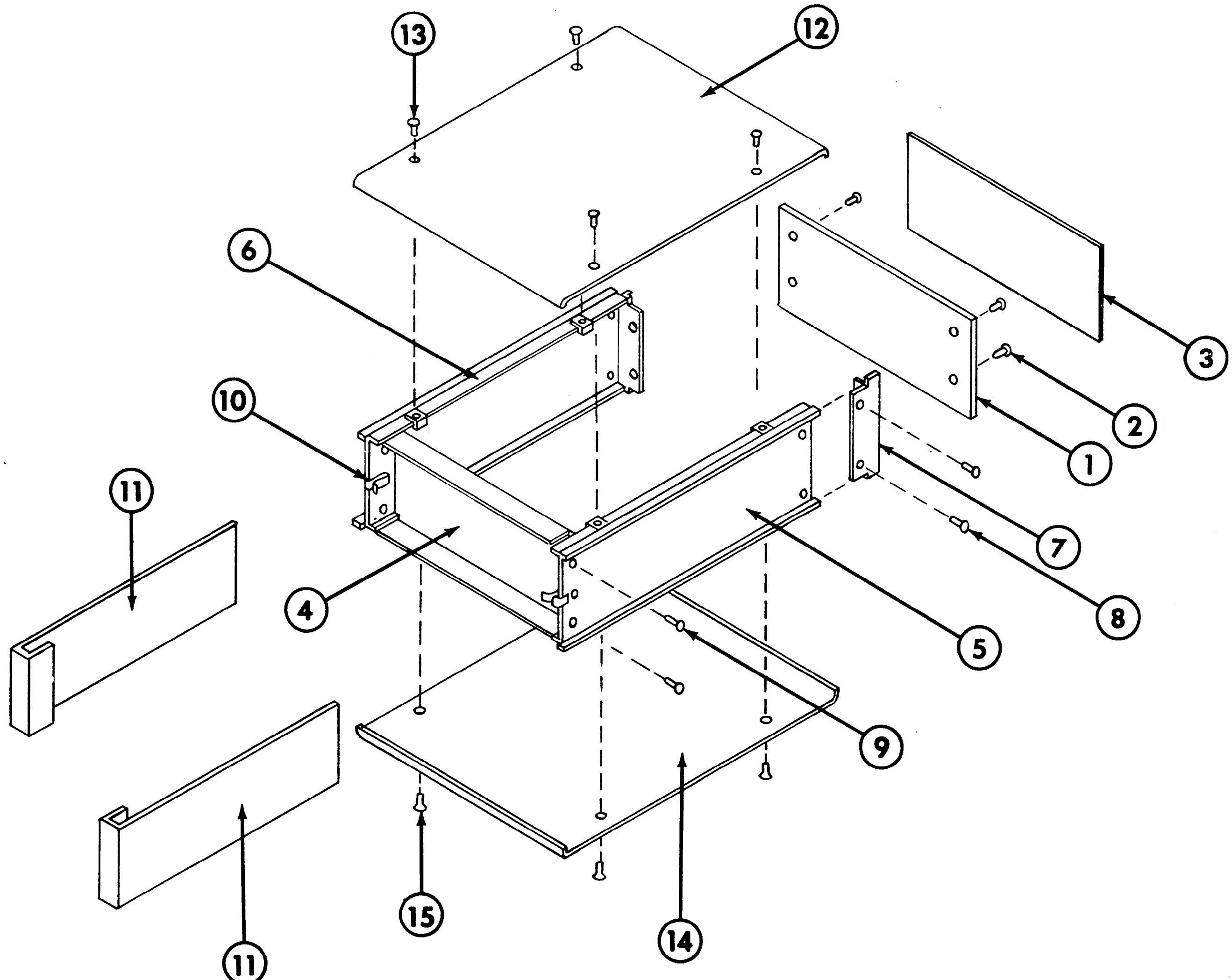


FIGURE 38. Chassis Assembly - Exploded View.

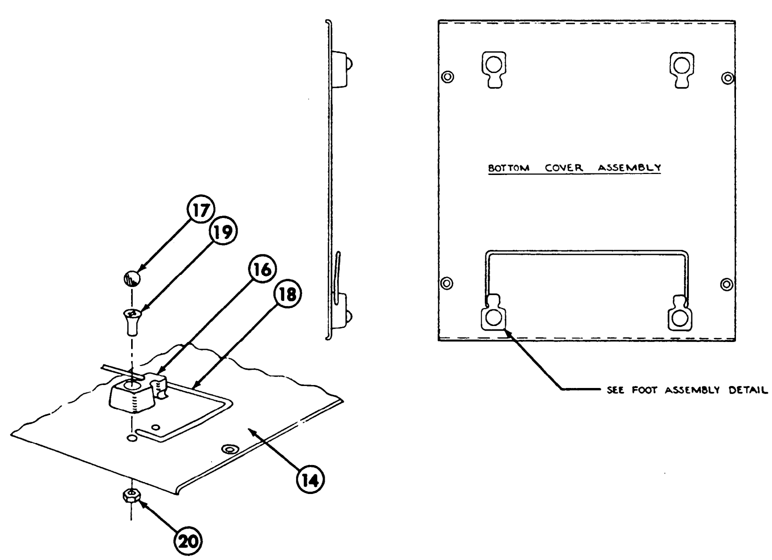


FIGURE 39. Bottom Cover Assembly

REPLACEABLE PARTS LIST
MOTHER BOARD "1000" SERIES (PC260)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C1001	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1002	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1003	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1004	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1005	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1006	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1007	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28
C1008	200 μF	35 V	EAL	90201	MTV200N35	C177-200M	28

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D1001	Silicon, Rectifier, 400mA, 225V	01295	1N645	RF-14	28
D1002	Full Wave Bridge, 2A, 100V	83701	PD-10	RF-36	28
D1003	Silicon, Rectifier, 400mA, 225V	01295	1N645	RF-14	28
D1004	Full Wave Bridge, 2A, 100V	83701	PD-10	RF-36	28
D1005	Silicon, Rectifier, 400mA, 225V	01295	1N645	RF-14	28
D1006	Full Wave Bridge, 2A, 100V	83701	PD-10	RF-36	28
D1007	Silicon, Rectifier, 400mA, 225V	01295	1N645	RF-14	28
D1008	Full Wave Bridge, 2A, 100V	83701	PD-10	RF-36	28

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
J1001	Connector, 10-Pin, Female Type		65039-039	CS-237	28
J1002	Connector, 5-Pin, Female Type		65039-040	CS-251	28
J1003	Connector, 15-Pin (Mates with PC-263)		PSC4SS15-12	CS-175	28
J1004	Connector, 15-Pin (Mates with PC-265)		PSC4SS15-12	CS-175	28
J1005	Connector, 15-Pin (Mates with PC-264)		PSC4SS15-12	CS-175	28
J1006	Connector, 15-Pin (Mates with PC-261)		PSC4SS15-12	CS-175	28
J1007	Connector, 10-Pin, Female Type		65039-039	CS-237	28
J1008	Connector, 5-Pin, Female Type		65039-040	CS-251	28
J1009	Connector, 10-Pin, Female Type		65039-039	CS-237	28
J1010	Connector, 10-Pin, Female Type		65039-039	CS-237	28
J1011	Connector, 15-Pin (Mates with PC-261)		PSC4SS15-12	CS-175	28
T1001	Transformer		-	TR-136	28
T1002	Transformer		-	TR-136	28

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R1001	10 kΩ	10%, 1/2 W	Comp	01121	EB-10K	R1-10k	28
R1002	10 Ω	10%, 1 W	Comp	01121	GB-10	R2-10	28
R1003	10 kΩ	10%, 1/2 W	Comp	01121	EB-10K	R1-10k	28
R1004	4.7 kΩ	10%, 1/2 W	Comp	01121	EB-4.7K	R1-4.7k	28
R1005	9.31 kΩ	1%, 1/8 W	MtF	07716	CEA-9.31K	R88-9.31k	28
R1006	2 kΩ	0.5 W	Var	80294	3329P-2K	RP88-2k	28
R1007	19.1 kΩ	1%, 1/8 W	MtF	07716	CEA-19.1K	R88-19.1k	28
R1008	2 kΩ	0.5 W	Var	80294	3329P-2K	RP88-2k	28
R1009	10 kΩ	10%, 1/2 W	Comp	01121	EB-10K	R1-10k	28
R1010	560 kΩ	10%, 1/2 W	Comp	01121	EB-560K	R1-560	28

± 18 V REGULATOR, "100" SERIES (PC261)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C101	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	29
C102	470 pF	1000 V	CerD	14655	BYA10T47	C64-470P	29
C103	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	29
C104	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	29
C105	470 µF	1000 V	CerD	14655	BYA10T47	C64-470P	29
C106	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	29

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
J101	Test Jack - Red	83330	430-102	TJ-7R	29
J102	Not Used	-	-	-	29
J103	Test Jack - Black	83330	430-103	TJ-7BL	29
J104	Test Jack - Green	83330	430-104	TJ-G	29
Q101	Transistor, Power, NPN, Case TO-66	02735	40312	TG-54	29
Q102	Transistor, Power, NPN, Case TO-66	02735	40312	TG-54	29
QA101	Integrated Circuit, 10-pin, Case TO-100	07263	U5R7723393	IC-14	29
QA102	Integrated Circuit, 10-pin, Case TO-100	07263	U5R7723393	IC-14	29

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R101	845 Ω	1%, 1/8 W	MtF	07716	CEA-845	R88-845	29
R102	3.0 Ω	5%, 1/2 W	Comp	01121	EB-3.0	R19-3.0	29
R103	2 kΩ	1%, 1/8 W	MtF	07716	CEA-2K	R88-2k	29
R104	200 Ω	.75 W	Comp	80294	3009P-200	RP-89-200	29
R105	1.3 kΩ	1%, 1/8 W	MtF	07716	CEA-1.3K	R88-1.3k	29
R106	845 Ω	1%, 1/8 W	MtF	07716	CEA-845	R88-845	29
R107	3.0 Ω	5%, 1/2 W	Comp	01121	EB-3.0	R19-3.0	29
R108	2 kΩ	1%, 1/8 W	MtF	07716	CEA-2K	R88-2k	29
R109	200 Ω	.75 W	Comp	80294	3009P-200	RP-89-200	29
R110	1.3 kΩ	1%, 1/8 W	MtF	07716	CEA-1.3K	R88-1.3k	29
R111		10%, 1/4W	Comp	44655	RC07	R76-100K	
R112		10%, 1/4W	Comp	44655	RC07	R76-100K	

DIFF. INPUT AC AMPLIFIER, "200" SERIES (PC262)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C201	.15 µF	200 V	MPC	14752	625B1C154K	C200-.15M	31
C202	7-25 pF	350 V	Cer	72982	53800092A	C207-7-25P	31
C203	150 pF	500 V	Poly	71590	CPR-150PF	C138-150P	31
C204	.15 µF	200 V	MPC	14752	625B1C154K	C200-.15M	31
C205	7-25 pF	350 V	Cer	72982	53800092A	C207-7-25P	31
C206	150 pF	500 V	Poly	71590	CPR-150PF	C138-150P	31
C207	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C208	10 pF	1000 V	CerD	-	DD-100	C64-10P	31
C209	10 pF	1000 V	CerD	-	DD-100	C64-10P	31
C210	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31

DIFF. INPUT AC AMPLIFIER, "200" SERIES (PC262)
CAPACITORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C211	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C212	8.2 pF	600 V	CerTB	71590	TCZ-8R2	C77-8.2P	31
C213	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C214	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C215	3.3 pF	600 V	CerT	71590	TCZ-3R3	C77-3.3P	31
C216	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C217	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C218	4.7 pF	600 V	CerTB	71590	TCZ-4R7	C77-4.7P	31
C219	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C220	1.5 µF	50 V	MPC	14752	625B1A -1.5µF	C201-1.5M	31
C221	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C222	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C223	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C224	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C225	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31
C226	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M	31

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D201	Rectifier, 75mA, 75V	01295	1N914	RF-28	31
D202	Rectifier, 75mA, 75V	01295	1N914	RF-28	31
D203	Rectifier, 75mA, 75V	01295	1N914	RF-28	31
D204	Rectifier, 75mA, 75V	01295	1N914	RF-28	31
D205	Rectifier, 75mA, 75V	01295	1N914	RF-28	31
D206	Rectifier, 75mA, 75V	01295	1N914	RF-28	31
D207	Zener, 13V, 0.25W	01295	1N717	DZ-27	--

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA201	Amplifier, 8-pin, Case TO-99	12040	LM301AH	IC-2	31
QA202	Amplifier, 8-pin, Case TO-99	12040	LM301AH	IC-2	31
QA203	Amplifier, 8-pin, Case TO-99	12040	LM301AH	IC-2	31
QA204	Amplifier, 8-pin, Case TO-99	12040	LM301H	IC-18	31
QA205	Amplifier (Dual), 14-pin DIP	07263	A749C	IC-27	31

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
P201	Connector, 10-Pins, Mates with J1001	80164	-	24249A	31
S201	Switch, Rotary, MILLIVOLTS	80164	-	SW-326	31
S202	Switch, Rotary, MULTIPLIER	80164	-	SW-326	
--	Knob, MULTIPLIER	80164	-	24677A	
--	Skirt, MILLIVOLTS	80164	-	24671A	

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q201	Dual N Channel JFET, Case TO-71	32293	2N3956	TG-74	31
Q202	Dual PNP	56289	TD401	TG-75	31
Q203	NPN, Planar, Case TO-106	07263	2N3565	TG-39	31
Q204	PNP, Silicon, Case TO-110a	07263	2N3638A	TG-33	31
Q205	NPN, Planar, Case TO-106	07263	2N3565	TG-39	31

DIFF. INPUT AC AMPLIFIER, "200" SERIES (PC262)

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R201	10 MΩ	0.1%, 1/2 W	-	14298	AME-70-10MΩ	R174-10M	31
R202	1.111 MΩ	0.1%, 1/2 W	MtF	07716	CECT1-1.111MΩ	R135-1.111M	31
R203	10 MΩ	0.1%, 1/2 W	-	14298	AME-70-10MΩ	R174-10M	31
R204	1.111 MΩ	0.1%, 1/2 W	MtF	07716	CECT1-1.111MΩ	R135-1.111M	31
R205	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R206	3.01 kΩ	1%, 1/8 W	MtF	07716	CEA-3.01K	R88-3.01k	31
R207	10 kΩ	10%, 1/2 W	Comp	01121	EB-10K	R1-10k	31
R208	4.75 kΩ	1%, 1/8 W	MtF	07716	CEA-4.75K	R88-4.75k	31
R209	3.01 kΩ	1%, 1/8 W	MtF	07716	CEA-3.01K	R88-3.01k	31
R210	10 kΩ	10%, 1/2 W	Comp	01121	EB-10K	R1-10k	31
R211	4.75 kΩ	1%, 1/8 W	MtF	07716	CEA-4.75K	R88-4.75k	31
R212	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R213	2.5 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-2.5K	R176-2.5k	31
R214	2.5 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-2.5K	R176-2.5k	31
R215	200 Ω	.75 W	Comp	80294	3009P-200	RP89-200	31
R216	7.4 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-7.4K	R176-7.4k	31
R217	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R218	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R219	7.5 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-7.5K	R176-7.5k	31
R220	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R221	1.111 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-1.111K	R176-1.111k	31
R222	10 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-10K	R176-10k	31
R223	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R224	1.111 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-1.111K	R176-1.111k	31
R225	10 Ω	10%, 1/4 W	Comp	44655	CB-10	R76-10	31
R226	10 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-10K	R176-10k	31
R227	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R228	5 MΩ	1%, 1/2 W	DCb	91637	DCF-1/2-5M	R12-5M	31
R229	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R230	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R231	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R232	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10	31
R233	47 kΩ	10%, 1/4 W	Comp	44655	CB-473	R76-47k	31
R234	47 kΩ	10%, 1/4 W	Comp	44655	CB-473	R76-47k	31
R235	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1k	31
R236	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1k	31
R237	10 kΩ	10%, 1/8 W	MtF	07716	CEA-10K	R88-10k	31
R238	12.4 kΩ	10%, 1/8 W	MtF	07716	CEA-12.4K	R88-12.4k	31
R239	12.4 kΩ	10%, 1/8 W	MtF	07716	CEA-12.4K	R88-12.4k	31
R240	10 kΩ	10%, 1/8 W	MtF	07716	CEA-10K	R88-10k	31
R241	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	31
R242	560 Ω	10%, 1/4 W	Comp	44655	CB-561	R76-560	31
R243	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	31
R244	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	31
R245	4.99 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-4.99K	R176-4.99k	31
R246	16.63 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-16.63K	R176-16.63k	31
R247	49.9 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-49.9K	R176-49.9k	31
R248	166.3 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-166.3K	R176-166.3k	31
R249	499 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-499K	R176-499k	31

DIFF. OUTPUT AC AMPLIFIER, "400" SERIES (PC264)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C401	33 μF	10 V	ETT	17554	TSD210-33μF	C180-33M	32
C402	33 μF	10 V	ETT	17554	TSD210-33μF	C180-33M	32
C403	0.1 μF	250 V	MtF	73445	C280AE-0.1μF	C178-.1M	32
C404	33 μF	10 V	ETT	17554	TSD210-33μF	C180-33M	32
C405	33 μF	10 V	ETT	17554	TSD210-33μF	C180-33M	32
C406	33 μF	10 V	ETT	17554	TSD210-33μF	C180-33M	32
C407	8.2 pF	600 V	CerTB	71590	TCZ-8R2	C77-8.2P	32
C408	8.2 pF	600 V	CerTB	71590	TCZ-8R2	C77-8.2P	32
C409	10 μF	20 V	ETT	17554	TSD-20-10μF	C179-10M	32
C410	10 μF	20 V	ETT	17554	TSD-20-10μF	C179-10M	32
C411	10 μF	20 V	ETT	17554	TSD-20-10μF	C179-10M	32
C412	10 μF	20 V	ETT	17554	TSD-20-10μF	C179-10M	32
C413	.22 μF	250 V	MtF	73445	C280AE-.22μF	C178-.22M	32
C414	0.1 μF	250 V	MtF	73445	C280AE-.1μF	C178-.1M	32
C415	0.1 μF	250 V	MtF	73445	C280AE-.1μF	C178-.1M	32

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA401	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	32
QA402	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	32
Q401	Transistor, Dual FET, Case TO-71	32293	2N5452	TG-70	32
Q402	Transistor Dual PNP	56289	TD-401	TG-75	32
Q403	Transistor, PNP, Case TO-92	04713	2N5087	TG-61	32
Q404	Transistor, PNP, Case TO-92	04713	2N3905	TG-53	32
J401	Test Jack, Red	83330	430-102	TJ-7	32
J402	Test Jack, Green	83330	430-104	TJ-7	32

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R401	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	32
R402	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1K	R88-1k	32
R403	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1K	R88-1k	32
R404	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	32
R405	1 kΩ	.75 W	Comp	80294	3009P-1K	RP89-1k	32
R406	100 kΩ	1%, 1/8 W	MtF	07716	CEA-100K	R88-100k	32
R407	3 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-3K	R176-3k	32
R408	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	32
R409	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	32
R410	4.286 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-4.286K	R176-4.286k	32
R411	100 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-100K	R176-100k	32
R412	100 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-100K	R176-100k	32
R413	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	32
R414	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	32
R415	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	32

DIFF. OUTPUT AC AMPLIFIER, "400" SERIES (PC264)

RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R416	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	32
R417	200 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-200K	R176-200k	32
R418	200 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-200K	R176-200k	32
R419	32.3 kΩ	1/4%, 1/3 W	WW	01686	7010-32.3K	R105-32.3k	32
R420	49.9 kΩ	1%, 1/8 W	MtF	07716	CEA-49.9K	R88-49.9k	32
R421	100 Ω	1%, 1/8 W	MtF	07716	CEA-100	R88-100	32
R422	32.3 kΩ	1/4%, 1/3 W	WW	01686	7010-32.3K	R105-32.3k	32
R423	100 kΩ	1%, 1/8 W	MtF	07716	CEA-100K	R88-100k	32
R424	10 MΩ	1%, 1/2 W	DCb	91637	CDF-1/2-10M	R12-10M	32
R425	261 kΩ	1%, 1/8 W	MtF	07716	CEA-261K	R88-261k	32
R426	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA-7.5K	R88-7.5k	32
R427	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA-7.5K	R88-7.5k	32
R428	100 kΩ	1%, 1/8 W	MtF	07716	CEA-100K	R88-100k	32
R429	1 kΩ	.75 W	Comp	80294	3009P-1K	RP89-1k	32
R430	100 kΩ	1%, 1/8 W	MtF	07716	CEA-100K	R88-100k	32
R431	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499	32
R432	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499	32
R433	1.5 MΩ	1%, 1/2 W	MtF	07716	CEC-1.5M	R94-1.5M	32
R434	3.01 kΩ	1%, 1/2 W	MtF	07716	CEC-3.01K	R94-3.01k	32

PHASE SENSITIVE DETECTOR, "500" SERIES (PC265)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C501	11 pF	1000 V	Hi-K Glass	72982	523000-11pF	C202-11P	33
C502	11 pF	1000 V	Hi-K Glass	72982	523000-11pF	C202-11P	33
C503	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	33
C504	0.1 μF	250 V	MtF	73445	C280AE-.1μF	C178-.1M	33
C505	.22 μF	250 V	MtF	73445	C280AE-.22μF	C178-.22M	33
C506	0.1 μF	250 V	MtF	73445	C280AE-.1μF	C178-.1M	33
C507	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	33
C508	0.1 μF	250 V	MtF	73445	C280AE-.1μF	C178-.1M	33
C509	150 pF	600 V	CerD	72982	ED-150pF	C22-150P	33
C510	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	33

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
P501	Card Edge, Part of PC-265	-	-	PC-265	33
P502	Connector	-	-	-	33
QA501	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	33
D501	Rectifier, 75mA, 75V	01295	1N914	RF-28	33

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R501	10 kΩ	1%, 1/8 W	MtF	07716	CEA-49.9K	R88-10k	33
R502	10 kΩ	1%, 1/8 W	MtF	07716	CEA-49.9K	R88-10k	33

PHASE SENSITIVE DETECTOR, "500" SERIES (PC265)

RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R503	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	33
R504	20 kΩ	1%, 1/8 W	MtF	07716	CEA-20K	R88-20k	33
R505	2 MΩ	1%, 1/2 W	MtF	07716	CEC-2M	R94-2M	33
R506	2 MΩ	1%, 1/2 W	MtF	07716	CEC-2M	R94-2M	33
R507	20 MΩ	1%, 1/2 W	MtF	14298	AME-70-20M	R175-20M	33
R508	32.3 kΩ	1/4%, 1/3 W	WW	01686	7010-32.3K	R105-32.3k	33
R509	49.9 kΩ	1%, 1/8 W	MtF	07716	CEA-49.9K	R88-49.9k	33
R510	100 Ω	1%, 1/8 W	MtF	07716	CEA-100	R88-100	33
R511	32.3 kΩ	1/4%, 1/3 W	WW	01686	7010-32.3K	R105-32.3k	33
R512	1 MΩ	1%, 1/8 W	MtF	07716	CEA-1M	R88-1M	33
R513	20 MΩ	1%, 1/2 W	-	14298	AME-70-20M	R175-20M	33
R514	7.5 kΩ	1%, 1/8 W	-	07716	CEA-7.5K	R88-7.5k	33
R515	261 kΩ	1%, 1/8 W	-	07716	CEA-261K	R88-261k	33
R516	7.5 kΩ	1%, 1/8 W	-	07716	CEA-7.5K	R88-7.5k	33
R517	1.5 MΩ	1%, 1/2 W	MtF	07716	CEC-1.5M	R94-1.5M	33
R518	3.01 kΩ	1%, 1/2 W	MtF	07716	CEC-3.01K	R94-3.01k	33
R519	4.02 kΩ	1%, 1/8 W	MtF	07716	CEA-4.02K	R88-4.02k	33
R520	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	33
R521	1 kΩ	.75 W	Comp	44655	CB-102	R76-10	33
R522	2.8 kΩ	1%, 1/8 W	MtF	07716	CEA-2.8K	R88-2.8k	33
R523	1.8 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.8k	33
R524	1.8 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.8k	33

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q501	N-Channel JFET, Case R110	32293	ITE4392	TG-76	33
Q502	N-Channel JFET, Case R110	32293	ITE4392	TG-76	33
Q503	N-Channel JFET, Case TO-92	04713	MPF103	TG-41	33
Q504	Dual FET, Case TO-71	32293	2N5452	TG-70	33
Q505	Dual PNP	56289	TD-401	TG-75	33
Q506	PNP, Case TO-92	04713	2N5087	TG-61	33
Q507	PNP, Case TO-92	04713	2N3905	TG-53	33

LEVEL DETECTORS, "600" SERIES (PC266)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C601	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C602	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C603	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C604	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C605	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C606	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C607	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C608	220 pF	1000 V	CerD	71590	DD-221-10%	C64-220P	34
C609	220 pF	1000 V	CerD	71590	DD-221-10%	C64-220P	34
C610	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34
C611	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	34

LEVEL DETECTORS, "600" SERIES (PC-266)

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D601	Silicon, 75mA, 75V	01295	1N914	RF-28	34
D602	Silicon, 75mA, 75V	01295	1N914	RF-28	34
D603	Zener 9.1V	06751	1N713A	DZ-38	34
D604	Zener 9.1V	06751	1N713A	DZ-38	34
D605	Silicon, 75mA, 75V	01295	1N914	RF-28	34
D606	Silicon, 75mA, 75V	01295	1N914	RF-28	34
D607	Zener 3.5V @ 5mA	06751	1N703A	DZ-42	34

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA601	Integrated Circuit, 8-pin, Case TO-99	12040	LM311	IC-29	34
QA602	Integrated Circuit, 8-pin, Case TO-99	12040	LM311	IC-29	34
QA603	Integrated Circuit, 14-pin, DIP	04713	MC824P	IC-5	34
Q601	Transistor, PNP, Case TO-92	04713	2N5087	TG-61	34
Q602	Transistor, NPN, Case TO-72	04713	MM3903	TG-85	34
Q603	Transistor, NPN, Case TO-72	04713	MM3903	TG-85	34
J601	Test Jack	83330	430-	TJ-7	34
J602	Test Jack	83330	430-	TJ-7	34
S601	Switch "PHASE QUADRANT"	80164	-		
--	Knob	80164	-	21150A	

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R601	154 Ω	1%, 1/8 W	MtF	07716	CEA-154	R88-154	34
R602	50 Ω	.75 W	Comp	80294	3009P-50	RP89-50	34
R603	154 Ω	1%, 1/8 W	MtF	07716	CEA0154	R88-154	34
R604	50 Ω	.75 W	Comp	80294	3009P-50	RP89-50	34
R605	500 Ω	.75 W	Comp	80294	3009P-500	RP89-500	34
R606	1.1 kΩ	1%, 1/8 W	MtF	07716	CEA-1.1K	R88-1.1k	34
R607	1 kΩ	1%, 1/8 W	MtF	07716	CEA01K	R88-1k	34
R608	1.1 kΩ	1%, 1/8 W	MtF	07716	CEA01.1K	R88-1.1k	34
R609	464 Ω	1%, 1/8 W	MtF	07716	CEA0464	R88-464	34
R610	50 Ω	.75 W	Comp	80294	3009P-50	RP89-50	34
R611	3.01 kΩ	1%, 1/8 W	MtF	07716	CEA-3.01K	R88-3.01k	34
R612	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1K	R88-3.01k	34
R613	162 kΩ	1%, 1/8 W	MtF	07716	CEA-162K	R88-162k	34
R614	402 Ω	1%, 1/8 W	MtF	07716	CEA-402	R88-402	34
R615	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	34
R616	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	34
R617	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1K	R88-1k	34
R618	162 kΩ	1%, 1/8 W	MtF	07716	CEA-162K	R88-162k	34
R619	402 Ω	1%, 1/8 W	MtF	07716	CEA-402K	R88-402	34
R620	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	34
R621	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	34
R622	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499	34
R623	1.15 kΩ	1%, 1/2 W	MtF	07716	CEC-1.15K	R94-1.15k	34
R624	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499	34
R625	1.21 kΩ	1%, 1/2 W	MtF	07716	CEC-1.21K	R94-1.21k	34
R626	4.7 Ω	10%, 1/4 W	Comp	44655	CB-472	R76-4.7	34
R627	1.15 kΩ	1%, 1/2 W	MtF	07716	CEC-1.15K	R94-1.15k	34
R628	60.4 Ω	1%, 1/8 W	MtF	07716	CEA-60.4	R88-60.4	34

RAMP GENERATORS, "700" SERIES (PC267)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C701	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	35
C702	100 pF	1000 V	CerD	72982	801000X5FO	C64-100P	35
C703	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	35
C704	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	35
C705	22 pF	600 V	CerTB	71590	TCZ-22	C77-22P	35
C706	.02 μF	1/2%, 50 V	Poly Film	97419	PYW-R-.02μF	C199-.02M	35
C707	.02 μF	1/2%, 50 V	Poly Film	97419	PYW-R-.02μF	C199-.02M	35
C708	22 pF	600 V	CerTB	71590	TCZ-22	C77-22P	35
C709	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	35
C710	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	35
C711	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	35
C712	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	35
C713	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	35
C714	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	35
C715	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	35

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D701	Zener Diode, 3.5 V @ 5 mA	06751	1N703A	DZ-42	35
QA701	Integrated Circuit, 14-pin DIP	04713	MC724P	IC-5	35
QA702	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	35
QA703	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	35
S701	Switch, FREQ. BAND	80164	-	SW-328	2
--	Knob Assembly	80164	-	25060A	2

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R701	639 Ω	1%, 1/2 W	MtF	07716	CEC-639	R94-649	35
R702	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	35
R703	10 MΩ	.1%, 1/2 W	-	14298	AME-70-10M	R174-10M	35
R704	1 MΩ	.1%, 1/8 W	-	91637	MMF-1/8-1M	R176-1M	35
R705	100 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-100K	R176-100k	35
R706	10 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-10K	R176-10k	35
R707	80.6 kΩ	1%, 1/8 W	MtF	07716	CEA-80.6K	R88-80.6k	35
R708	80.6 kΩ	1%, 1/8 W	MtF	07716	CEA-80.6K	R88-80.6k	35
R709	10 MΩ	.1%, 1/2 W	-	14298	AME-70-10M	R174-10M	35
R710	1 MΩ	.1%, 1/8 W	-	91637	MMF-1/8-1M	R176-1M	35
R711	100 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-100K	R176-100k	35
R712	10 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-10K	R176-10k	35
R713	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	35
R714	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	35
R715	470 Ω	10%, 1/4 W	Comp	44655	CB-471	R76-10	35
R716	470 Ω	10%, 1/4 W	Comp	44655	CB-471	R76-470	35
R717	80.6 kΩ	1%, 1/8 W	MtF	07716	CEA-80.6K	R88-80.6k	35
R718	80.6 kΩ	1%, 1/8 W	MtF	07716	CEA-80.6K	R88-80.6k	35
R719	100 Ω	10%, 1/4 W	Comp	44655	CB-10o	R76-100	35
R720	100 Ω	10%, 1/4 W	Comp	44655	CB-101	R76-100	35

RAMP GENERATORS, "700" SERIES (PC267)

RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R721	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	35
R722	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	35
R723	4.7 kΩ	10%, 1/4 W	Comp	44655	CB-472	R76-4.7k	35
R724	4.7 kΩ	10%, 1/4 W	Comp	44655	CB-472	R76-4.7k	35
R725	2.2 kΩ	10%, 1/4 W	Comp	44655	CB-222	R76-2.2k	35
R726	2.2 kΩ	10%, 1/4 W	Comp	44655	CB-232	R76-2.2k	35
R727	3.01 kΩ	1%, 1/8 W	MtF	07716	CEA-3.01K	R88-3.01k	35
R728	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	35

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q701	Dual Channel JFET, Case TO-18	32293	2N3956	TG-74	35
Q702	Dual Channel JFET, Case TO-18	32293	2N3956	TG-74	35
Q703	Silicon, NPN, TO-92 Case	80164	2N3902	25375A*	35
Q704	Silicon, NPN, TO-92 Case	80164	2N3902	25375A*	35
Q705	PNP, Case TO-92	04713	2N3905	TG-53	35

*Selected TG-49

F-TO-V CONVERTER, "800" SERIES (PC268)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C801	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C802	.018 μF	2%, 100 V	Poly Film	97419	PYW-R-.018μF	C198-.018M	36
C803	22 pF	600 V	CerTB	71590	TCZ-22	C77-22P	36
C804	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C805	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	36
C806	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C807	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C808	1.5 μF	50 V	MPC	14752	625B1A-1.5μF	C201-1.5M	36
C809	.22 μF	50 V	MPC	14752	625B1A-.22μF	C201-.22M	36
C810	4 μF	50 V	MPC	14752	625B1A-4μF	C201-4M	36
C811	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C812	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C813	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36
C814	220 pF	1000 V	CerD	72982	801000X5FO	C64-220P	36
C815	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	36

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D801	Diode, Zener 3.5V @ 5 mA	06751	1N703A	DZ-42	36
QA801	Integrated Circuit, 14-pin DIP	04713	MC824P	IC-5	36
QA802	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	36
QA803	Integrated Circuit, 8-pin, Case TO-99	12040	LM310H	IC-18	36
QA804	Integrated Circuit, 8-pin, Case TO-99	12040	LM301AH	IC-2	36
D802	Diode, Rectifier, 75mA, 75V	01295	1N914	RF-28	36

F-TO-V CONVERTER, "800" SERIES (PC268)

TRANSISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R801	1.15 kΩ	1%, 1/2 W	MtF	07716	CEC-1.15K	R94-1.15k	36
R802	1.82 kΩ	1%, 1/2 W	MtF	07716	CEC-1.82K	R94-1.82k	36
R803	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499	36
R804	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499	36
R805	80.6 kΩ	1%, 1/8 W	MtF	07716	CEA-80.6K	R88-80.6k	36
R806	80.6 kΩ	1%, 1/8 W	MtF	07716	CEA-80.6K	R88-80.6k	36
R807	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R808	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R809	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R810	4.75 kΩ	1%, 1/8 W	MtF	07716	CEA-4.75K	R88-4.75k	36
R811	2 kΩ	1%, 1/8 W	MtF	07716	CEA-2K	R88-2k	36
R812	6.04 kΩ	1%, 1/8 W	MtF	07716	CEA-6.04K	R88-6.04k	36
R813	500 Ω	.75 W	Comp	80294	3009P-500	RP89-500	36
R814	2.21 kΩ	1%, 1/8 W	MtF	07716	CEA-2.21K	R88-2.21k	36
R815	576 kΩ	1%, 1/8 W	MtF	07716	CEA-576K	R88-576k	36
R816	576 kΩ	1%, 1/8 W	MtF	07716	CEA-576K	R88-576k	36
R817	576 kΩ	1%, 1/8 W	MtF	07716	CEA-576K	R88-576k	36
R818	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R819	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R820	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	36
R821	11 kΩ	1%, 1/8 W	MtF	07716	CEA-11K	R88-11k	36
R822	11 kΩ	1%, 1/8 W	MtF	07716	CEA-11K	R88-11k	36
R823	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R824	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	36
R825	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	36
R826	237 Ω	1%, 1/8 W	MtF	07716	CEA-237	R88-237	36
R827	500 Ω	0.75 W	Comp	80294	3009P	RP89-500	36
R828	237 Ω	1%, 1/8 W	MtF	07716	CEA-237	R88-237	36
R829	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10K	R88-10k	36
R830	10 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-10K	R176-10k	36
R831	100 kΩ	.1%, 1/8 W	-	91637	MMF-1/8-100K	R176-10k	36
R832	1 MΩ	.1%, 1/8 W	-	91637	MMF-1/8-1M	R176-1M	36
R833	10 MΩ	.1%, 1/2 W	-	14298	AME-70-10M	R174-10M	36

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q801	NPN, Case TO-5	04713	2N3903	TG-43	36
Q802	Dual N-Channel JFET, Case TO-18	32293	2N3956	TG-74	36
Q803	Silicon, NPN, TO-92 Case	80164	2N3902	25375A*	36
Q804	PNP, Case TO-92	04713	2N3905	TG-53	36
Q805	PNP, Case TO-92	04713	2N3905	TG-53	36

*Selected TG-49

ZERO CROSSING DETECTOR, "900" SERIES (PC269)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C901	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	37
C902	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	37
C903	.15 μF	200 V	MPC	14752	625B1CJ-.15μF	C200-.15M	37

ZERO CROSSING DETECTOR, "900" SERIES (PC269)

CAPACITORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C904	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	37
C905	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	37
C906	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	37
C907	47 pF	1000 V	CerD	72982	801000X5FO	C64-47P	37
C908	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	37
C909	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	37
C910	.001 μF	1000 V	CerD	72982	801000X5FO	C64-.001M	37
C911	220 pF	1000 V	CerD	72982	801000X5FO	C64-220P	37
C912	220 pF	1000 V	CerD	72982	801000X5FO	C64-220P	37

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
D901	Rectifier, 75mA, 75V	01295	1N914	RF-28	37
D902	Rectifier, 75mA, 75V	01295	1N914	RF-28	37
D903	Rectifier, 75mA, 75V	01295	1N914	RF-28	37
D904	Rectifier, 75mA, 75V	01295	1N914	RF-28	37
D905	Rectifier, 75mA, 75V	01295	1N914	RF-28	37

MISCELLANEOUS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
J901	Terminal, Slotted	71279	2329	TE-30	37
J902	Terminal, Slotted	71279	2329	TE-30	37
S901	Switch, TRIGGER MODE	80164	-	SW-329	2
--	Knob Assembly	80164	-	25060A	2

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R901	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	37
R902	49.9 kΩ	1%, 1/8 W	MtF	07716	CEA-49.9K	R88-49.9k	37
R903	150 Ω	1%, 1/8 W	MtF	07716	CEA-150	R88-150	37
R904	500 Ω	0.5 W	Comp	80294	3009P-500	RP89-500	37
R905	150 Ω	1%, 1/8 W	MtF	07716	CEA-150	R88-150	37
R906	49.9 kΩ	1%, 1/8 W	MtF	07716	CEA-49.9K	R88-49.9k	37
R907	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	37
R908	2.2 kΩ	10%, 1/2 W	Comp	01121	EB-2.2K	R1-2.2k	37
R909	1 MΩ	10%, 1/4 W	Comp	44655	CB-105	R76-1M	37
R910	12.4 kΩ	1%, 1/8 W	MtF	07716	CEA-12.4	R88-12.4k	37
R911	20 kΩ	1%, 1/8 W	MtF	07716	CEA-20K	R88-20k	37
R912	20 kΩ	1%, 1/8 W	MtF	07716	CEA-20K	R88-20k	37
R913	4.99 kΩ	1%, 1/8 W	MtF	07716	CEA-4.99K	R88-4.99k	37
R914	4.99 kΩ	1%, 1/8 W	MtF	07716	CEA-4.99K	R88-4.99k	37
R915	33.2 Ω	1%, 1/8 W	MtF	07716	CEA-33.2	R88-33.2	37
R916	100 Ω	10%, 1/4 W	Comp	44655	CB-101	R76-100	37
R917	22 kΩ	10%, 1/4 W	Comp	44655	CB-223	R76-22	37
R918	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	37
R919	Not Used	---	--	--	--	---	--
R920	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1K	R88-1k	37

ZERO CROSSING DETECTOR, "900" SERIES (PC269)

RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R921	2.21 kΩ	1%, 1/8 W	MtF	07716	CEA-2.21K	R88-2.21k	37
R922	2.21 kΩ	1%, 1/8 W	MtF	07716	CEA-2.21K	R88-2.21k	37
R923	15 kΩ	1%, 1/8 W	MtF	07716	CEA-15K	R88-15k	37
R924	100 Ω	10%, 1/4 W	Comp	44655	CB-101	R76-100	37
R925	22 kΩ	10%, 1/4 W	Comp	44655	CB-223	R76-22k	37
R926	100 Ω	10%, 1/4 W	Comp	44655	CB-101	R76-100	37
R927	6.8 kΩ	10%, 1/4 W	Comp	44655	CB-682	R76-6.8k	37
R928	6.8 kΩ	10%, 1/4 W	Comp	44655	CB-682	R76-6.8k	37
R929	100 Ω	10%, 1/4 W	Comp	44655	CB-101	R76-100	37
R930	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	37
R931	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	37
R932	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	37
R933	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10k	37

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
Q901	Dual N-Channel JFET, Case TO-18	32293	2N3956	TG-74	37
Q902	NPN, Case TO-92	04713	2N3903	TG-49	37
Q903	Matched pair, NPN, Case TO-18	73445	A642L	TG-64	37
Q904	Dual PNP	56289	TD401	TG-75	37
Q905	NPN, Case TO-92	04713	2N3904	TG-47	37
Q906	NPN, Case TO-92	04713	2N3904	TG-47	37

CHASSIS PARTS LIST, "1100" SERIES

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.
C1101	5 μF	50 V	MPcb	14752	625B1A-5μF	C201-5M
C1102	1.5 μF	50 V	MPcb	14752	625B1A-1.5μF	C201-1.5M
C1103	.5 μF	50 V	MPcb	14752	625B1A-.5μF	C201-.5M
C1104	.15 μF	50 V	MPcb	14752	625B1A-.15μF	C201-.15M
C1105	.05 μF	50 V	MPcb	14752	625B1A-.05μF	C201-.05M
C1106	.015 μF	50 V	MPcb	14752	625B1A-.015μF	C201-.015M
C1107	5000 pF	500 V	Poly	71590	CPR-5000pF	C138-5000P
C1108	1500 pF	500 V	Poly	71590	CPR-1500pF	C138-1500P
C1109	510 pF	500 V	Poly	71590	CPR-510pF	C138-510P
C1110	150 pF	500 V	Poly	71590	CPR-150pF	C138-150P
C1111	47 pF	1000 V	CerD	71590	DD-470-10%	C64-47P

MISCELLANEOUS

Circuit Desig.	Description			Keithley Part No.
J1101	Receptacle, "+ INPUT", Type UG-1094A/U	02660	31-2221	CS-249
J1102	Receptacle, "- INPUT", Type UG-1094A/U	02660	31-2221	CS-249
J1103	Receptacle, "Reference INPUT", Type UG-1094A/U	02660	31-2221	CS-249
J1104	Receptacle, "F-V OUTPUT"			CS-15
J1105	Receptacle, "AC OUT", Type UG-1094A/U	02660	31-2221	CS-249

CHASSIS PARTS LIST, "1100" SERIES

MISCELLANEOUS (cont'd)

Circuit Desig.	Description			Keithley Part No.
J1106	Receptacle, "DEMOD", Type UG-1094A/U	02660	31-2221	CS-249
J1107	Receptacle, "DC OUTPUT"			CS-15
J1108	Receptacle, "METER"			CS-249
J1109	Receptacle, "ACCESSORY POWER"			CS-163
J1110	Receptacle, "MONITOR"			CS-249
S1101	Switch, "+ DIFF -"			SW-330
S1102	Switch, "TUNED-WIDEBAND"			SW-271
S1103	Switch, "+ OFF -"			SW-331
S1104	Switch, "TIME CONSTANT"			SW-325
S1105	Switch, "METER"			SW-332
S1106	Switch, "117-234 V"			SW-151
S1107	Switch, "ON"			SW-271
F1101	Fuse, 117 V, 1/4 A			FU-17
F1101	Fuse, 234 V, 1/8 A			FU-20
FL1101	Line Filter and Receptacle			LF-1
P1101	Line Cord, 3-wire			CO-6
R1101	Resistor, Variable, "PHASE"			RP90-200
R1102	Resistor, Variable, "ZERO SUPPRESS", 10kΩ			RP42-10k
R1103	Resistor			R1-10k
M1101	Meter			ME-90
DS1101	Pilot Lamp, "POWER", 10V		CF03ACS1869	PL-51

ACCESSORY FILTER, MODEL 8401 (10 Hz)

"300 SERIES (PC263)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
C301	.15 μF	50 V	MPcb	14752	625B1A-.15μF	C206-.15M	30
C302	.15 μF	50 V	MPcb	14752	625B1A-.15μF	C206-.15M	30
C303	.015 μF	50 V	MPcb	14752	625B1A-.015μF	C206-.015M	30
C304	.15 μF	50 V	MPcb	14752	625B1A-.15μF	C206-.15M	30
C305	.15 μF	50 V	MPcb	14752	625B1A-.15μF	C206-.15M	30
C306	.15 μF	50 V	MPcb	14752	625B1A-.15μF	C206-.15M	30
C307	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	30
C308	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	30
C309	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	30
C310	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	30
C311	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	30
C312	10 μF	20 V	ETT	17554	TSD1-20-10μF	C179-10M	30
C313	33 pF	600 V	CerD	72982	ED-33pF	C22-33P	30

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
QA301	Operational Amplifier, 8-pin, Case TO-99	12040	LM310H	IC-18	30
QA302	Operational Amplifier, 8-pin, Case TO-99	12040	LM310H	IC-18	30
QA303	Operational Amplifier, 8-pin, Case TO-99	12040	LM301AH	IC-2	30

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.	Fig. Ref.
R301	200 kΩ	.75 W	Comp	80294	3009P-200K	RP89-200k	30
R302	1 MΩ	.75 W	Comp	80294	3009P-1M	RP89-1M	30
R303	200 kΩ	.75 W	Comp	80294	3009P-200K	RP89-200k	30
R304	50 kΩ	.75 W	Comp	80294	3009P-50K	RP89-50k	30
R305	100 kΩ	.75 W	Comp	80294	3009P-100K	RP89-50k	30
R306	1 MΩ	.75 W	Comp	80294	3009P-1M	RP89-50k	30
R307	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	30
R308	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	30
R309	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	30
R310	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	30
R311	4.99 kΩ	1%, 1/8 W	MtF	07716	CEA-4.99K	R88-4.99k	30
R312	3.01 kΩ	1%, 1/8 W	MtF	07716	CEA-3.01K	R88-3.01k	30
R313	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	30
R314	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	30
R315	5 kΩ	.75 W	Comp	80294	3009P-5K	RP89-5k	30

ACCESSORY FILTER, MODEL 8402 (60 Hz) "1200" SERIES (PC306)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.
C1201	.005 µF	100 V	Poly	02799	1PE502B	C214-.005M
C1202	.005 µF	100 V	Poly	02799	1PE502B	C214-.005M
C1203	.005 µF	100 V	Poly	02799	1PE502B	C214-.005M
C1204	.005 µF	100 V	Poly	02799	1PE502B	C214-.005M
C1205	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M
C1206	10 µF	20 V	ETT	17554	TSD1-20-10µF	C179-10M

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.
QA1201	Operational Amplifier, 8-pin, Case TO-99	12040	LM310H	IC-18
QA1202	Operational Amplifier, 8-pin, DIP	07263	U6T7741393	IC-42

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Desig.	Keithley Part No.
R1201	630.6 kΩ	0.1%, 1/8 W	MtF	91637	MFF-1/8-630.6K	R179-630.6k
R1202	530.5 kΩ	0.1%, 1/8 W	MtF	91637	MFF-1/8-530.5K	R179-530.5k
R1203	255 kΩ	1%, 1/8 W	MtF	07716	CEA-255K	R88-255k
R1204	20 kΩ	.75 W	Comp	80294	3009P-20K	RP89-20k
R1205	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10
R1206	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10
R1207	499 Ω	1%, 1/8 W	MtF	07716	CEA-499	R88-499
R1208	15 kΩ	1%, 1/8 W	MtF	07716	CEA-15K	R88-15k

SECTION 7. CALIBRATION

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

7-2. REQUIRED TEST EQUIPMENT. Recommended test equipment for checking and adjusting the instrument is given in Table 7-1. Test equipment other than recommended may be substituted if specifications equal or exceed the stated characteristics.

7-3. PERFORMANCE VERIFICATION. Use the following procedures to verify proper operation of the instrument. All measurements should be made at ambient temperature of approx. 23°C and relative humidity below 50%. If the instrument is out of specification at any point, perform a complete calibration as given in Paragraph 7-4.

7-4. ADJUSTMENT/CALIBRATION PROCEDURE. This procedure should be used whenever it is necessary to calibrate the instrument to ensure that it meets all specifications.

a. Preliminary Calibration.

1. Power Supplies.

a). Plug Model 840 in to Variable Transformer (Item I) set to 117 VAC 60 Hz line and turn unit on.

b). Connect the DVM (Item B) to the +18 volts (red terminal J101) and ground (black terminal J103) on one of the ±18 volt regulator boards (PC-261).

c). Set the voltage between +17.99 and +18.01 volts using the +18 volt adjust pot (R104) adjacent to the test point.

d). Connect the DVM (B) to the -18 volts (green terminal J104) on the same board (PC-261). Set the voltage between -17.99 and -18.01 volts.

e). Repeat b), c), and d) above for the other ±18 volt regulator board (PC-261).

2. Line Regulation.

a). Connect the Model 840 to Variable Transformer (I) equipped with a Line Monitor.

b). Vary the line voltage between 105 VAC and 125 VAC. Monitor the Model 840 power supplies. They should not vary more than ±20mV from the reading at 117 VAC line voltage. (See 1,a) through e) above.)

3. 234 Volt Operation.

a). Set the rear panel LINE switch (S1106) to the 234V position.

TABLE 7-1.
Recommended Test Equipment for Calibration

Item	Description	Mfr.	Model
A	Oscilloscope (Main frame with Plug-ins) Amplifier Plug-in (1mV/Div.) Time-Base Plug-in (1μs/Div.)	Tektronix Tektronix Tektronix	561B 2A63 2B67
B	Digital Voltmeter (DVM) 3-1/2 digit, 0.1%, accuracy	Keithley	160 or 163
C	Digital Counter	Eldorado	1507 or 1607
D	Function Generator (2 units req'd)	Wavetek	110
E	AC Voltmeter	Keithley See Alternate*	661
F	Ratio Transformer	Gertsch	----
G	Potentiometer, precision 10-turn wire-wound 10 kilohms	Keithley	RP41-10K
H	Bandpass Filter (1kHz)	Keithley	8401-1kHz
I	Variable Transformer and Line Monitor	Variac RCA	

*A suitable substitute for the Keithley Model 661 would be a DVM such as the DANA Model 4800 (with AC capability). (Keithley substitute should have comparable accuracy to Model 661 at 20 Hz.)

b). Plug the Model 840 into a 234 volt, 60 Hz line and check the Model 840 power supplies. They should read the same as they did on 117 VAC line.

4. Schmitt Trigger Symmetry Adjust.

a). Set the Model 840 controls as follows:

Trigger - EXT. PHASE
All other controls may be in any position.

b). Connect Function Generator (D) to Reference Channel INPUT (J1103).

c). Apply 100 Hz, 100mV peak-to-peak sine wave to the Reference Channel INPUT (J1103).

d). Connect the Reference Channel MONITOR (J110) to the Oscilloscope (A) vertical input.

e). Set the Oscilloscope (A) controls as follows:

Timebase	- 1 MS/DIV.
Trigger	- INT
Vertical Input	- .5 VOLTS/DIV.
Couplings	- AC

f). Adjust the frequency of the Function Generator (D) so that one cycle occupies 10 horizontal divisions on the oscilloscope graticule.

g). Adjust the Schmitt-Trigger Symmetry Pot. (R904, PC-269) until one-half cycle occupies 5 horizontal divisions.

h). Reduce the level of the sine wave until the output square-wave gain becomes unsymmetrical and readjust the Schmitt-Trigger Symmetry Pot (R904).

i). Continue reducing the input level and adjusting the Schmitt-Trigger Symmetry Pot. (R904) until further reduction of the input level causes the output square wave to quit (about 10mV peak-to-peak sine wave).

j). Place Model 840 test covers on unit (both top and bottom).

5. Output Zero Adjustment.

a). Low Frequency Zero Adjustment.

1. Set the controls on the Model 840 as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
Time Constant	- 1 SEC.
Trigger	- EXT. PHASE

2. Place a shorting cap on the (+) input (J1101) and drive the reference channel input (J1103) with a 3 volt peak-to-peak, 100 Hz sine wave.

3. Connect DVM (A) to the front panel DC OUT (J1108) and adjust the Output Zero Pot. (R429, PC-264) for zero volts ±10mV on the DVM.

4. Decrease the Sensitivity Multiplier (S202) setting, while continuing to adjust for zero volts ±10mV on the DVM, until the X1 setting is reached on the Sensitivity Multiplier switch.

b). Output Square Wave Reduction.

1. Connect the Oscilloscope (A) to the Model 840 rear panel DC OUT (J1107) and change the Time Constant (S1104) setting to OFF.

2. Set the Sensitivity Multiplier (S202) switch to X1 and reduce the amplitude of the square wave on the Oscilloscope with the Amplifier Balance Pot. (R405, PC-264).

c). High Frequency Zero Adjustment.

1. Change the frequency of the reference channel drive to 10kHz while keeping the amplitude set for 3 volts peak-to-peak.

2. Connect the Oscilloscope to the DEMOD output (J1106) and adjust the left piston-trimmer capacitor (C502, PC-265) until the positive and negative spikes appear balanced on the Oscilloscope.

3. Set the Time Constant (S1104) switch to 1 SEC and adjust the right piston-trimmer capacitor (C501, PC-265) until the DVM reads zero volts ±10mV DC output, with the Model 840 Multiplier (S202) on the X1 setting.

6. Frequency-to-Voltage Converter Calibration.

a). Set the Model 840 Trigger switch (S901) to (+) and the Freq. Band switch (S701) to 10-100 Hz.

b). With a shorting cap on the Model 840 Reference Channel INPUT (J1103), set the F-V Converter (R837, PC-268) for zero volts ±1mV output.

c). Apply an accurately known 100.0 Hz (check on Digital Counter), 1 volt peak-to-peak sine wave signal to the Reference Channel INPUT (J1103) and set the F-V CONVERTER OUTPUT (J1104) for -10.00 volts ±10mV. (Use R813, PC-268.)

d). Set the Model 840 Freq. Band (S701) to 1-10 Hz. Apply an accurately known 2 Hz (check on Digital Counter, period = 500ms), 1 volt peak-to-peak sine-wave signal to the Reference Channel INPUT (J1103) and check the F-V CONVERTER OUTPUT (J1104) to be -2.00 volts ±20mV.

e). Set the Model 840 Freq. Band (S701) to 1-10kHz. Apply an accurately known 15kHz (check on Digital Counter), 1 volt peak-to-peak sine-wave signal to the Reference Channel INPUT (J1103) and check the F-V CONVERTER OUTPUT (J1104) to be -15.00 volts ±150mV.

7. Demodulator Drive Symmetry.

a). Set the Model 840 controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X10
Time Constant	- 300MS
Frequency Band	- 10-100 Hz
Trigger	- (+)

b). Set the Oscilloscope controls as follows:

Timebase	- 2MS/DIV.
Trigger	- EXT.
Vertical Input	- .5 VOLTS/DIV.
Coupling	- AC

c). Connect the Oscilloscope vertical input to the 840 AC OUTPUT (J1105). Connect the Oscilloscope trigger input to the Model 840 Reference Channel OUTPUT MONITOR (J1110).

d). Set one Function Generator (D) for 100 Hz and 1V rms. Connect sine-wave output to the 840 Reference Channel INPUT (J1103).

e). Connect the other Function Generator (D) to the 840 Signal Channel + INPUT (J1101) and set for 20 volts peak-to-peak at 200 Hz as monitored on the Oscilloscope at the Model 840 AC OUTPUT (J1105).

f). Disconnect the Oscilloscope from the Model 840 AC OUTPUT (J1105) and connect it to the Model 840 DEMOD OUTPUT (J1102). Adjust the frequency of the Function Generator connected to the Model 840 Signal Channel + INPUT (J1103) until a slowly-varying waveform is observed on the Oscilloscope. The Model 840 meter reading should now be slowly varying also.

g). Adjust the Demod. Drive Symmetry Pot. (R610, PC-266) for ±3 minor divisions at meter.

8. AC Amplifier Calibration.

a). Low Frequency Gain Adjust.

1. Set the Model 840 controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
Time Constant	- 1 SEC.
Trigger	- EXT. PHASE

2. Set the AC Voltmeter (E) Range to 5 volts AC, Null to 10mV, and dials to 1.0000.

3. Montior the output of the Function Generator (D) on the AC Voltmeter (E) and using the Precision 10KΩ Pot. (G) set the Function Generator (D) output for 1 volt ±1mV rms at 100 Hz. Apply this signal to the Model 840 Signal Channel + INPUT (J1101) and also to the Reference Channel INPUT (J1103).

4. Adjust the Model 840 System Gain Adjust Pot (R521, PC-265) for a +10.00 volt ±10mV reading on the DVM (connected to DC OUT).

b). Low Frequency Common Mode Adjust.

1. Leave the Model 840 controls set as they are except:

+ Diff -	- DIFF.
Sensitivity	- .1MV

2. Connect the Oscilloscope to the Model 840 AC OUTPUT (J1105) and apply a 100 Hz, 10 volt peak-to-peak sine wave to both the (+) and (-) Signal Channel INPUTS (J1101, J1102).

3. Adjust the Low Freq. CMRR Pot. (R215, PC-262) for less than 300mV peak-to-peak at the Model 840 AC OUTPUT (J1105). Check at 1 Hz for less than 3 volts peak-to-peak.

c). High Frequency Gain Adjust.

1. Set the Model 840 controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
Time Constant	- 1 SEC.
Trigger	- EXT. PHASE

2. Set the AC Voltmeter (E) Range to 5 volts AC, Null to 10mV, and dials to 1.0000.

3. Monitor the output of the Function Generator (D) on the AC Voltmeter (E) and using the Precision 10KΩ Pot. (G) set the Function Generator (D) output for 1 volt ±1mV RMS at 10kHz. Apply this signal to the Model 840 Signal Channel + INPUT (J1101) and also to the Reference Channel INPUT (J1103).

4. Connect the DVM (B) to the 840 DC OUTPUT (J1107).

5. Adjust the rear trimmer capacitor (C202, on PC-262) on the Model 840 input AC amplifier for a +10.00 volt ±10mV reading on the DVM.

d). High Frequency Common Mode Adjust.

1. Leave the Model 840 controls set as they are except:

+ Diff -	- DIFF.
Sensitivity	- 1MV

2. Connect the Oscilloscope to the Model 840 AC OUTPUT (J1105) and apply a 10kHz 10 volt peak-to-peak sine wave to both the (+) and (-) Signal Channel INPUTS (J1101, J1102).

3. Adjust the Front Trimmer capacitor (C205, with PC-262) for less than 300mV p-p at the AC OUTPUT (J1105).

9. Suppression Adjust.

a). Set the Model 840 controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
Time Constant	- 300MS
Trigger	- EXT. PHASE
Suppression	- (-)

b). Place a shorting cap on the Model 840 (+) INPUT (J1101) and set ZERO SUPPRESS (R1102) for 10.00 (Full CW).

c). Connect the DVM to the Model 840 DC OUTPUT (J1107) and adjust the Suppression Cal. Pot. (R1006, PC-260) for 10.00 volts ±10mV on the DVM. Check the Model 840 DC OUTPUT (J1107) with the SUPPRESS POLARITY Switch in the (+) position. Reset R1006 to split the difference between the (+) and (-) DVM readings.

d). Meter Calibration. With the Model 840 SUPPRESS POLARITY (S1103) in the (-) position, adjust the Meter Cal. Pot. (R1008, PC-260) for full-scale meter deflection in the positive direction. Check full-scale negative meter deflection by placing the Model 840 SUPPRESS POLARITY switch in the (+) position. Split difference such that pointer is slightly more than full scale in one direction and slightly less than full scale in the other direction.

b. Signal Channel Calibration.

1. Gain Accuracy.

a). Connect the Precision 10KΩ Pot. (G) to the Function Generator (D) output. Connect the Precision 10KΩ Pot. (G) output to the Ratio Transformer input, the AC Voltmeter (E) input and the Model 840 Reference Channel INPUT (J1103). Connect the output of the Ratio Transformer (F) to the Model 840 Signal Channel + INPUT (J1101).

b). Set the Model 840 Signal Channel controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
Time Constant	- 1 SEC.
Meter	- DC OUT
Trigger	- EXT. PHASE

c). Connect a DVM to the Model 840 METER OUTPUT (J1108) and set the AC Voltmeter (E) range to 5 volts AC, Null to 10mV and dials to 1.0000.

d). Set the Function Generator (D) for 100 Hz in frequency and monitor the amplitude on the AC Voltmeter (E). Set the amplitude for 1 volt ±1mV RMS.

e). Check the Model 840 meter to ensure that it is reading 10 major divisions ±1/2 minor divisions.

f). Set the Model 840 controls and the Ratio Transformer dials to the positions shown in Table 7-2. while monitoring the DVM. The DVM should read 9.90 volts to 10.10 volts for all settings in the table.

g). Set the Function Generator (D) for 1 volt RMS at 20 Hz and re-check gain accuracy at top four settings in Table 7-2.

h). Change Trigger to (+) and Freq. Band to 1-10kHz.

i). Set Function Generator (D) for 1 volt at 10kHz and re-check gain accuracy at top four settings in Table 7-2. Adjust Phase control (R1101) for max. out at each setting.) DVM should read 9.8 to 10.2.

j). Disconnect the Ratio Transformer from the Model 840 + INPUT (J1101).

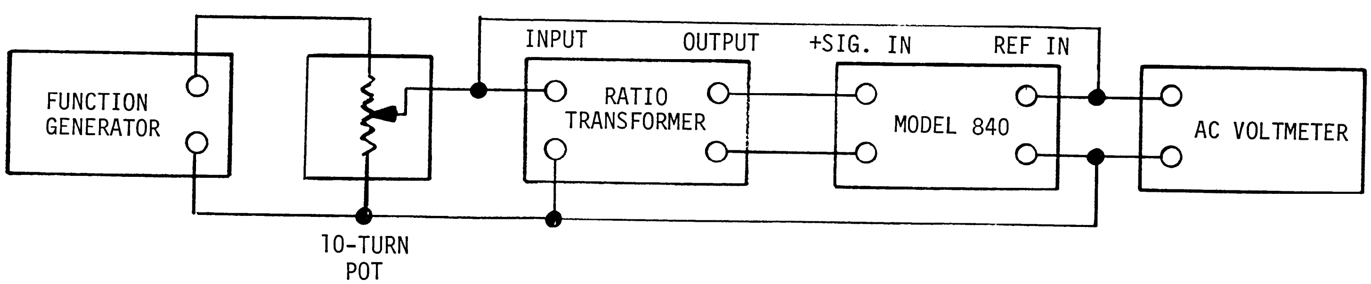


FIGURE 40. Signal Channel Gain Calibration.

TABLE 7-2.

SENSITIVITY	SENS. MULT.	Ratio Transformer 10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
.01 mV	100	0	0	1	0	0	0	0
.1 mmV	100	0	1	0	0	0	0	0
1 mV	100	1	0	0	0	0	0	0
10 mV	1	0	1	0	0	0	0	0
10 mV	3	0	3	0	0	0	0	0
10 mV	10	1	0	0	0	0	0	0
10 mV	30	3	0	0	0	0	0	0
10 mV	100	X	0	0	0	0	0	0

2. Frequency Response.

a). Set the Function Generator (D) for 2.8 volts peak-to-peak at 1 Hz as observed on the Oscilloscope and connect the Function Generator (D) to the Model 840 Signal Channel (+) INPUT (J1101).

b). Set the Model 840 controls as in 1b).

c). Connect the Oscilloscope to the Model 840 AC OUTPUT (J1105). The signal observed on the Oscilloscope should be greater than 2 volts peak-to-peak.

d). Set the Function Generator (D) for 2.8 volts peak-to-peak at 100kHz as observed on the Oscilloscope.

e). Connect the Oscilloscope to the Model 840 AC OUTPUT (J1105). The signal observed should be greater than 2 volts peak-to-peak.

3. Input Dynamic Range.

a). Set the Model 840 controls as follows:

+ Diff - - (+)
Sensitivity - 10MV
Sens. Mult - X1
Time Constant - 10 SEC.
Suppression - OFF
Trigger - EXT. PHASE

b). Connect Function Generator (D) to the Model 840 Reference Channel INPUT (J1103) and through a BNC TEE connector to one channel of the Oscilloscope. AC couple both Oscilloscope channels.

c). Set the Function Generator (D) for 100 Hz at 20 volts peak-to-peak.

d). Connect a Second Function Generator (D) to the Model 840 Signal Channel INPUT (J1101) and through a BNC TEE connector to the other channel of the oscilloscope.

e). Set the Second Function Generator (D) for 1000 Hz at 20 volts peak-to-peak, disconnect the Oscilloscope from the Signal Channel TEE and connect it to the Model 840 DC OUTPUT (J1107). Vary one Function Generator slightly so that low frequency beat signals are minimized. Connect DVM (B) to the 840 DC OUTPUT (J1107). The signal at the 840 DC OUTPUT (J1107) should be less than 250mV on DVM and can be either polarity.

f). Set the Model 840 Time Constant (S1104) to 300ms and the Function Generator (D) connected to the Model 840 Reference Channel INPUT (J1103) for 10kHz.

g). The DC signal at the Model 840 OUTPUT (J1107) should be less than 7 volts on DVM and can be either polarity.

4. Calibrated Zero Suppression.

a). Set the Model 840 controls as stated below:

+ Diff - - (+)
Sensitivity - 10MV
Sens. Mult - X100
Suppression Dial - 0
Suppression Switch - (+)

b). Connect a 5K ohm resistor to the Model 840 rear panel DC OUTPUT (J1107).

c). Connect the DVM to the Model 840 front panel DC OUTPUT (J1108) and turn the ZERO SUPPRESS (R1102) dial CW to 1.0. The DVM should read -.99 to -1.01 volts.

d). Continue turning the SUPPRESS (R1102) dial CW to 5.0. The DVM should read -4.95 to -5.05 volts.

e). Turn the SUPPRESS (R1102) dial full CW. The DVM should read -9.9 to -10.10 volts.

f). Set SUPPRESS POLARITY Switch to (-). The DVM should read +9.90 to +10.10 volts.

5. Noise (Input Shorted).

a). Set the Model 840 controls as follows:

+ Diff - - (+)
Sensitivity - .01MV
Sens. Mult - X1
Time Constant - 300MS
Suppression - OFF
Trigger - EXT. PHASE

b). Place a shorting cap on the Model 840 (+) INPUT (J1101) and connect one input channel of the Oscilloscope to the 840 DC OUTPUT (J1107).

c). Connect the Function Generator to the Model 840 Reference Channel INPUT (J1103) and through a BNC TEE connector to the other input channel of the Oscilloscope. AC couple both oscilloscope inputs.

d). Set the Function Generator (D) for 10 Hz at 20 volts peak-to-peak. The signal at the Model 840 DC OUTPUT (J1107) should be 2.5 volts peak-to-peak.or less.

e). Set the Function Generator (D) for 400 Hz at 20 volts peak-to-peak. The signal at the Model 840 DC OUTPUT (J1107) should be 500mV peak-to-peak or less.

6. Time Constant Check.

a). Set the Model 840 controls as follows:

+ Diff - - (+)
Sens. Mult - 10MV
Sensitivity - X100

b). Set the Oscilloscope for 2V/DIV and connect it to the Model 840 METER OUTPUT (J1108) BNC connector.

c). Set the Model 840 ZERO SUPPRESS (R1102) for 10 (full CW) with the SUPPRESS POLARITY set to OFF.

d). When the SUPPRESS POLARITY switch is turned to (-), the voltage at the Model 840 METER OUTPUT (J1108) will rise from zero to approximately +10 volts within a time period which is equal to 5 times the time constant setting on the Model 840.

e). Using the SUPPRESS POLARITY switch and the settings listed below, check to ensure that rise-time falls within the limits given.

TABLE 7-3.

Oscilloscope Sweep Speed	840 Time Constant	Rise Time 0 - 6.3V
.5 ms/Div.	OFF	< 1 ms
1 ms/Div.	3 ms	3 ms
5 ms/Div.	10 ms	10 ms
10 ms/Div.	30 ms	30 ms
50 ms/Div.	100 ms	100 ms
100 ms/Div.	300 ms	300 ms

f. For the Model 840 Time Constant (S1104) of 1 sec. through 100 sec. use the Oscilloscope settings shown with the following drawings and check to insure that the rise times look approximately like Figures 41 through 45.

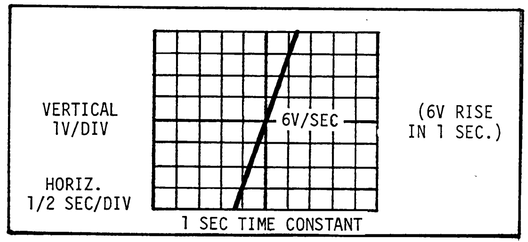


FIGURE 41. Time Constant Check.

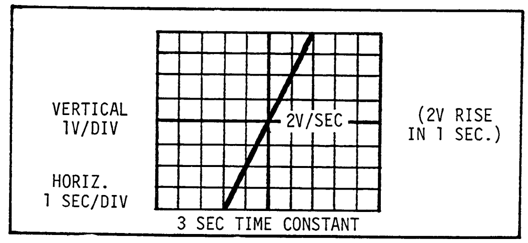


FIGURE 42. Time Constant Check.

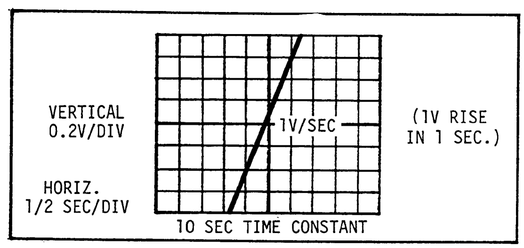


FIGURE 43. Time Constant Check.

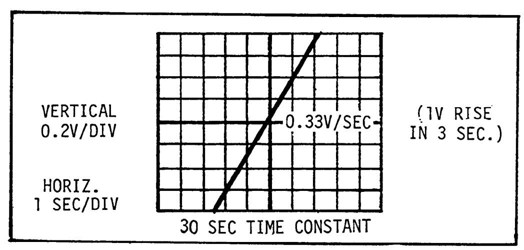


FIGURE 44. Time Constant Check.

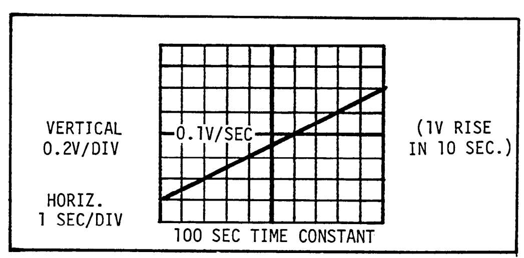


FIGURE 45. Time Constant Check.

c. Reference Channel Calibration.

1. Trigger Input.

a). Set the Model 840 Reference Channel controls as follows:

Trigger - EXT. PHASE
Freq. Band - 1 Hz - 10 Hz

b). Using the Precision 10KΩ Pot. (G) at the Function Generator (D) output set the Function Generator (D) for 25mV peak-to-peak output at 1 Hz as observed on the Oscilloscope. Use counter set to period 1000ms to check frequency.

c). Connect the Function Generator (D) to the Reference Channel INPUT (J1103) and connect the DVM to the F-V OUTPUT (J1104) on the Model 840 rear panel.

d). Step the Model 840 TRIGGER switch (S901) through all positions. The DVM should read 1 volt ±50mV for all positions of the trigger switch except at 2ND HARM where it should read 2 volts ±20mV.

e). Set the Function Generator (D) output for 25mV peak-to-peak at 15kHz and set the Model 840 Frequency Band to 1kHz - 10kHz. Use counter to check frequency to be 15.000kHz.

f). Step the Model 840 TRIGGER switch (S901) from EXT. PHASE through - TRIGGER. The DVM should read 15 volts ±150mV at each position.

g). Set the Function Generator (D) for 25mV peak-to-peak at 7.5kHz and set the Model 840 Trigger switch to 2ND HARM. The DVM should read 15 volts ±150mV.

2. Phase Accuracy Adjustment.

a). Check the 2.50V test point J602. The voltage should measure 2.50V ±10mV. Readjust R602 (PC-266) if necessary and set the Model 840 controls as follows:

+ Diff - - (+)
Sensitivity - 10MV
Sens. Mult - X100
Time Constant - 1 SEC.
Phase - 0°
Quadrature - 90°
Freq. Band - 10-100 Hz
Trigger - (+)

b). Connect DVM (B) to the Model 840 rear panel OUTPUT (J1107) and set DVM to the 10 volt range.

c). Connect the Function Generator (D) adjustable sine wave output to the AC Voltmeter (E) input and set the AC Voltmeter controls as follows:

Dials - 1.0000
Range Full Scale - 5 volts
Null Full Scale - 10MV
Function - AC

d). Connect the Function Generator (D) adjustable sine wave output to the Model 840 Signal Channel INPUT (J1101) and through a BNC TEE connector to the Model 840 Reference Channel INPUT (J1103). Set the Function Generator (D) for 1 volt ±1mV RMS at 100 Hz as monitored on the AC Voltmeter (E).

e). Adjust the 1.25 volt adjustment (R604, PC-266) on the Model 840 for a zero indication on the DVM while stepping the Model 840 Sensitivity Multiple switch (S202) down to X1. Reading on DVM at X1 Sensitivity Multiple should be 0 ± 1 volt.

f). Set Model 840 Phase (S601 to 90° and Quadrature (R1101) to 0° and adjust the Model 840 1.389 volt adjustment (R605, PC-266) as in step e) above.

g). Set Model 840 Phase (S601) to 0° and Quadrature (R1101) to 90° and recheck zero as in step e) above.

h). Recheck f) above.

i). Set the Model 840 Quadrature (S601) to 0° and adjust the Phase Dial (R1101) for 0 ± 1 volt on the DVM with the Model 840 Sens. Mult (S202) set to X1. Phase Dial (R1101) should read 90° ± 1°. If reading is accurate within 1° proceed to next step; if reading is not within 1°, go back to step h).

j). Without changing position of Phase Dial (R1101) or Quad switch (S601), set Freq. Band Switch (S701) at 100-1K band.

k). Adjust F-V Converter "zero pot" so that reading on DVM at X1 Sens. Mult (S202) is 0 ± 1 volt at the DC output (J1107).

l). Set Freq. Band Switch (S701) at 10-100 Hz Band.

m). Adjust Phase Dial (R1101) for 0 ± 1 volt on the DVM with the Model 840 Sens. Mult. (S202) set to X1. Phase Dial (R1101) should read 90° ± 1°. If reading is accurate within 1° proceed to next step; if reading is not within 1°, go back to step h).

n). Readjust Demod Symmetry: See 7-4a7.

3. Phase Accuracy Verification.

a). Leave the Model 840 reference channel set as it is and set the signal channel controls as follows:

+ Diff - - (+)
Sensitivity - 10MV
Sens. Mult - X100
Time Constant - 1 SEC.

b). Set the Model 840 Phase dial for a maximum reading on the DVM and readjust the Function Generator (D) amplitude for +10.00 volts at the 840 output.

c). Adjust the Model 840 Phase dial (R1101) for +8.66 volts at the Model 840 output (J1107). The Phase dial should read 30° ± 5°.

d). Adjust the Model 840 Phase dial (R1101) for +7.07 volts at the Model 840 output (J1107). The Phase dial should read 45° ± 5°.

e). Adjust the Model 840 Phase dial (R1101) for +5.00 volts at the Model 840 output (J1107). The Phase dial should read 60° ± 5°.

f). Adjust the Model 840 Phase dial (R1101) for 0.00 volts at the Model 840 output (J1107). The Phase dial should read 90° ± 5°.

g). Adjust the Model 840 Phase dial (R1101) for +5.00 volts at the 840 output. Set the Model 840 Quadrature switch (S601) to 90°; the reading on the DVM should be -8.48 to -8.83 volts.

h). Set the Model 840 Quadrature switch (S601) to 180°. The DVM should now read -4.69 to -5.30 volts.

i). Set the Model 840 Quadrature switch (S601) to 270°. The DVM should now read +8.48 to +8.83 volts.

j). Repeat steps b) through i) at 10 Hz (Freq. band at 1-10 Hz; Time constant at 10 sec.).

k). Repeat steps b) through i) at 10kHz (Freq. band at 1K-10kHz, Time constant at 1 sec.).

l). Set the Model 840 Phase dial (R1101) and Quadrature (S601) both to 0° and set the Function Generator (D) to 2.8 volt p-p at 0.5 Hz as observed on the Oscilloscope.

m). Connect the Function Generator (D) to the Model 840 Signal Channel + INPUT (J1101) and through a BNC TEE connector to the Model 840 Reference Channel (S1103).

n). Set the Model 840 controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
Time Constant	- 30 SEC.
Suppression	- OFF
Phase	- 0°
Quadrature	- 0°
Freq. Band	- 1-10Hz
Trigger	- (+)

o). Connect a DVM set on the 10V range to the Model 840 rear panel output (J1107). Adjust phase control for zero volts on DVM.

p). Change Quadrature (S601) setting by 90°, DVM should read 4-5 volts.

q). Set the Function Generator (D) for 1 volt RMS at 15kHz, the Model 840 Phase (R1101) to 0° and Freq. Band (S701) to 1kHz-10kHz. The DVM should read approximately 10V.

r). Set the Model 840 Phase control (R1101) for a reading of approximately zero on the DVM. The Phase control (R1101) should read 90° ± 10°.

4. Overload Indicator.

a). Insert 1kHz Bandpass Filter (H) into signal channel. See Figure 28B for location of PC-263.

b). Set the Model 840 controls as follows:

+ Diff -	- (+)
Sensitivity	- 10MV
Sens. Mult	- X100
WB-Tun Switch	- WIDEBAND
Time Constant	- 1 SEC.

c). Connect 1V peak-to-peak, 1kHz to reference channel input (J1103).

d). Connect Function Generator (D) (100 Hz and = 20V peak-to-peak) to Signal Channel INPUT (J1101)

e). Connect Oscilloscope to AC OUT (J1105).

f). Increase Function Generator slowly until OVERLOAD INDICATOR (DS201) first comes on (around 22 volts peak-to-peak).

g). Repeat f) above for signal channel frequencies of 10 Hz and 10kHz. Indicator should still come on at approximately 22V peak-to-peak.

h). Disconnect Oscilloscope from AC OUT (J1105) and connect Oscilloscope to Function Generator using T-connector.

i). Change Wideband-Tuned switch to TUNED.

j). Change SENSITIVITY Switch to 0.1mV.

k). For Function Generator (D) frequencies of 10 Hz, 100 Hz, and 10kHz, check to see that overload light comes on at approximately 7V peak-to-peak.

l). Disconnect Function Generator (D) from Signal Channel + INPUT (J1101) and put shorting BNC connector on + INPUT (J1101).

m). Set SUPPRESS Dial (R1102) to 1.0V and SUPPRESS POLARITY to (-).

n). Set Sens. Mult (S202) to X10.

o). Connect DVM to Model 840 DC OUTPUT (J1107).

p). Increase SUPPRESS (R1102) dial slowly until OVERLOAD INDICATOR (DS201) first comes on around +11 volts DC).

q). Change SUPPRESS POLARITY Switch (S1103) to (+). Check to see that OVERLOAD (DS202) comes on aroung -11 volts DC.

r). Return Wideband-Tuned Switch (S1102) to WIDEBAND and extract Bandpass Filter card (H).

CODE—TO—NAME LIST

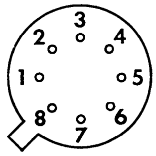
CODE TO NAME List of Suggested Manufacturers.
Reference: Federal Supply Code for Manufacturers, Cataloging Handbook H4-2.

00656	Aerovox Corp. 740 Belleville Ave. New Bedford, Mass. 02741
00686	Film Capacitors, Inc. 100 Eighth St. Passaic, N.J. 07055
01121	Allen-Bradley Corp. 1201 South 2nd St. Milwaukee, Wisc. 53204
01295	Texas Instruments, Inc. Semiconductor-Components Div. Dallas, Texas 75231
01686	RCL Electronics, Inc. 195 McGregor St. Manchester, N.H. 03102
02101	Varo Inc. Electrokinetics Div. Santa Barbara, Calif. 93102
02660	Amphenol Corp. 2801 South 25th Ave. Broadview, Ill. 60153
02734	Radio Corp. of America Defense Electronic Products Morrestown, N.J. 08057
02735	Radio Corp. of America Receiving Tube Div. Somerville, N.J. 08876
02777	Hopkins Engineering Co. 12900 Foothill Blvd. San Fernando, Calif. 91342
02985	Tepro Electric Corp. P. O. Box 1260 Clearwater, FL. 33517
03508	General Electric Co. Semiconductor Products Dept. Syracuse, N.Y. 13201
04009	Arrow-Hart & Hegeman Electric Co. 103 Hawthorne St. Hartford, Conn. 06106
04713	Motorola Semiconductor Prod. Inc. 5005 E. McDowell Rd. Phoenix, Ariz. 85008
05079	Tansistor Electronics, Inc. 1000 West Road Bennington, Vt. 05201
05397	Union Carbide Corp. 11901 Madison Avenue Cleveland, Ohio 44101
06751	Components, Inc. Arizona Div. Phoenix, Ariz. 85019
06980	Varian Assoc. EIMAC Div. 301 Industrial Way San Carlos, Calif. 94070
07137	Transistor Electronics Corp. 6700 Washington Ave S. Prairie, MN. 55343
07263	Fairchild Camera & Inst. Corp. 464 Ellis Street Mountain View, CA. 94042
07716	IRC, Inc. 2850 Mt. Pleasant Burlington, Iowa 52601
08811	GL Electronics Div. of GL Industries, Inc. Westville, N.J. 08093
09052	Gulton Industries, Inc. Alkaline Battery Div. Metuchen, N.J. 08840
09823	Burgess Battery Co. Div. of Servel Inc. Freeport, Ill. 61032
09922	Burndy Corp. Richards Ave. Norwalk, Conn. 06852
10582	CTS of Asheville Inc. Mills Gap Road Skyland, N.C. 28776
11502	IRC Inc. Greenway Road Boone, N.C. 28607
11837	Electro Scientific Indus., Inc. 13645 NW Science Park Dr. Portland, Or. 97229
12040	National Semiconductor Corp. Commerce Drive Danbury, Conn. 06813
12065	Transitron Electronic Corp. 144 Addison St. East Boston, Mass. 02128
12697	Clarostat Mfg. Co., Inc. Lower Washington St. Dover, N.H. 03820
12954	Dickson Electronics Corp. 8700 E Thomas Road Scottsdale, Ariz. 85252
13050	Potter Co. Highway 51 N. Wesson, Miss. 39191
13327	Solitron Devices, Inc. 256 Oak Tree Road Tappan, N.Y. 10983
13934	Midwec Corp. 602 Main Oshkosh, Nebr. 69154
14655	Cornell-Dubilier Electric Corp. 150 Avenue L Newark, N.J. 07101
14659	Sprague Electric Co. P.O. Box 1509 Visalia, Calif. 93278
15238	ITT Semiconductors Div. of ITT Corp. Lawrence, Mass. 01841
15909	Daven Div. of T.A. Edison Ind. McGraw Edison Co. Manchester, N.H. 03105
16170	Teledyne Systems Co. Communications Div. Los Angeles, Calif. 90066
17554	Components, Inc. Smith St. Biddeford, Ma. 04005
23020	General Reed Co. 174 Main St. Metuchen, N.J. 08840
24655	General Radio Co. 22 Baker Ave. West Concord, Mass. 01781
27682	Hathaway Instruments, Inc. 5800 E. Jewell Ave. Denver, Colorado 80222
28520	Heyman Mfg. Co. 147 N. Michigan Ave. Kenilworth, N.J. 07033
29309	Richey Electronics Inc. 1307 Dickerson Rd. Nashville, Tenn. 37213
35529	Leeds and Northrup 4901 Stenton Ave. Philadelphia, Pa. 19144
37942	Mallory, P. R. and Co., Inc. 3029 E. Washington St. Indianapolis, Ind. 46206
44655	Ohmite Mfg. Co. 3601 Howard St. Skokie, Ill. 60076
53201	Sangamo Electric Co. 1301 North 11th Springfield, Ill. 62705
54294	Shallcross Mfg. Co. 24 Preston St. Selma, N.C. 27576
56289	Sprague Electric Co. North Adams, Massachusetts 01247
58474	Superior Electric Co., The 383 Middle St. Bristol, Conn. 06012
61637	Union Carbide Corp. 270 Park Ave. New York, N.Y. 10017

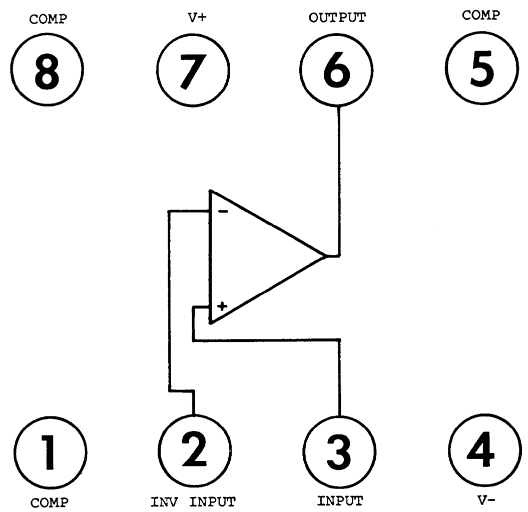
CODE TO NAME List (Continued).

63060	Victoreen Instrument Co. 10101 Woodland Avenue Cleveland, Ohio 44104
70309	Allied Control Co., Inc. 100 Relay Road Plantsville, CT. 06479
70903	Belden Mfg. Co. 415 So. Kilpatrick Chicago, Ill. 60644
71002	Birnbach Radio Co., Inc. 177 Hanse Avenue Freeport,.N.Y. 11520
71279	Cambridge Thermionic Corp. 455 Concord Avenue Cambridge, Mass. 02138
71400	Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo. 63107
71450	CTS Corp. 1142 W. Beardsley Ave. Elkhart, Ind. 46514
71468	ITT Cannon Electric, Inc. 666 E Dyre Road Santa Ana, CA. 92702
71590	Centralab Div. of Globe-Union, Inc. Milwaukee, Wisc. 53201
71785	Cinch Mfg. Co. and 1501 Morse Avenue Elkgrove Village, IL. 60007
72619	Dialight Corp. 60 Stewart Ave. Brooklyn, N.Y. 11237
72653	G-C Electronics Co. 400 S. Wyman Rockford, Ill. 61101
72699	General Instrument Corp. Capacitor Division Newark, N.J. 07104
72982	Erie Technological Prods Inc. 644 W. 12th St. Erie, Pa. 16512
73138	Beckman Instruments, Inc. Helipot Division Fullerton, Calif. 92634
73445	Amperex Electronic Co., Div. of North American Philips Co., Inc. Hicksville, N.Y. 11802
73690	Elco Resistor Co. 1158 Broadway New York, N.Y. 10001
74276	Signalite Inc. 1933 Heck Ave. Neptune, N.J. 07753
74970	Johnson, E. F., Co. 297 Tenth Ave. S.W. Waseca, Minn. 56093
75042	IRC Inc. 401 North Broad St. Philadelphia, Pa. 19108
75915	Littlefuse, Inc. 800 E. Northwest Hwy. Des Plaines, Ill. 60016
76055	Mallory Controls, Div. of Mallory P. R. & Co., Inc. Frankfort, Ind. 46041
76493	Miller, J. W. Co. 19070 Reyes Avenue. Compton, CA. 90224
76545	Mueller Electric Co. 1583 E. 31st St. Cleveland, Ohio 44114
77764	Resistance Products Co. 914 S. 13th St. Harrisburgh, Pa. 17104
79727	Continental-Wirt 550 Davisville Rd. Warminster, PA. 18974
80164	Keithley Instruments, Inc. 28775 Aurora Road Cleveland, Ohio 44139
80294	Bourns, Inc. 6135 Magnolia Ave. Riverside, Calif. 92506
81073	Grayhill, Inc. 561 Hillgrove Ave. La Grange, Ill. 60525
81483	International Rectifier Corp. 9220 Sunset Blvd Los Angeles, CA. 90069
82389	Switchcraft, Inc. 5555 N. Elston Ave. Chicago, Ill. 60630
83125	General Instrument Corp. Capacitor Division Darlington, S.C. 29532
83330	Smith, Herman H., Inc. 812 Snediker Ave. Brooklyn, N.Y. 11207
83594	Burroughs Corp. Electronic Components Div. Plainfield, N.J. 07061
83701	Electronic Devices, Inc. 21 Gray Oaks Avenue Yonkers, N.Y. 10710
84171	Arco Electronics, Inc. Community Drive Great Neck, N.Y. 11022
84411	TRW Capacitor Div. 112 W. First St. Ogallala, Nebr. 69153
84970	Sarkes Tarzian, Inc. E. Hillside Dr. Bloomington, Ind. 47401
86684	Radio Corp. of America Electronic Components & Devices Harrison, N.J. 07029
87216	Philco Corp. Lansdale Div., Church Rd. Lansdale, Pa. 19446
90201	Mallory Capacitor 3029 East Washington Indianapolis, Ind. 46206
90303	Mallory Battery Co. Tarrytown, New York 10591
91637	Dale Electronics, Inc. P.O. Box 609 Columbus, Nebr. 68601
91662	Elco Corp. Willow Grove, Pennsylvania 19090
91737	Gremar Mfg. Co., Inc. 922 S Lyon St. Santa Ana, CA. 92705
91802	Industrial Devices Inc. 982 River Rd. Edgewater, N.J. 07020
91929	Honeywell Inc. Micro Switch Div. Freeport, Ill. 61032
93332	Sylvania Electric Products, Inc. Semiconductor Products Div. Woburn, Mass. 01801
93656	Electric Cord Co. 1275 Bloomfield Ave. Fairfield, N.J. 07006
94144	Raytheon Co., Industrial Operation Components Div. Newton, Mass. 02101
94154	Tung-Sol Electric, Inc. Newark, New Jersey 07101
94310	Tru-Ohm Products Memcor Components Div. Huntington, Ind. 46750
94696	Magnecraft Electric Co. 5579 North Lynch Chicago, Ill. 60690
95348	Gordos Corp. 250 Glenwood Ave. Bloomfield, N.J. 07003
95712	Dage Electric Co., Inc. Hurricane Road Franklin, Ind. 46131
97933	Raytheon Co. Components Div. Semiconductor Operation Mountain View, Calif. 94040
99120	Plastic Capacitors, Inc. 2620 N. Clybourn Ave. Chicago, Ill. 60614

KEITHLEY PART NO. IC-1,2

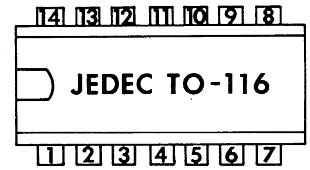


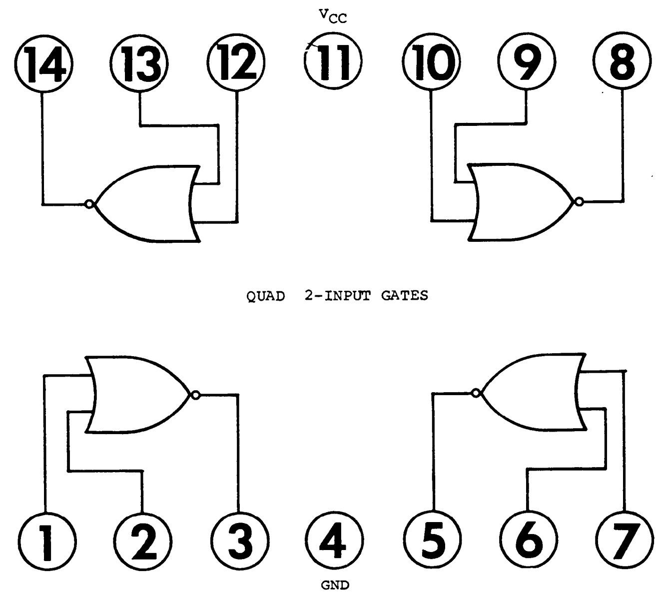
TO-99



OPERATIONAL AMPLIFIER

KEITHLEY PART NO. IC-5





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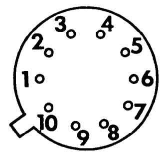
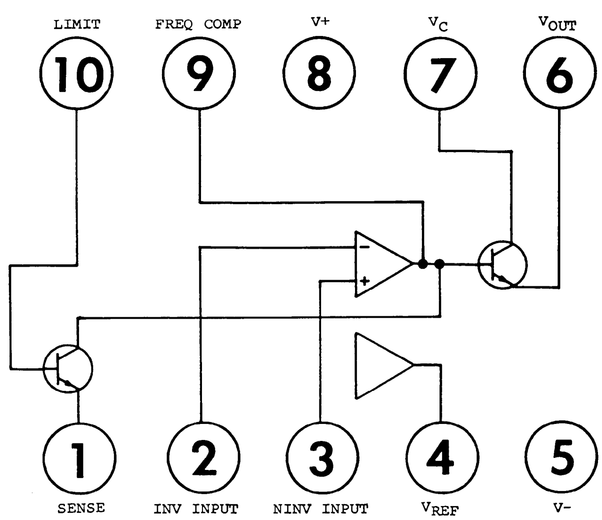
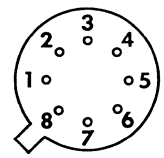


TO-100

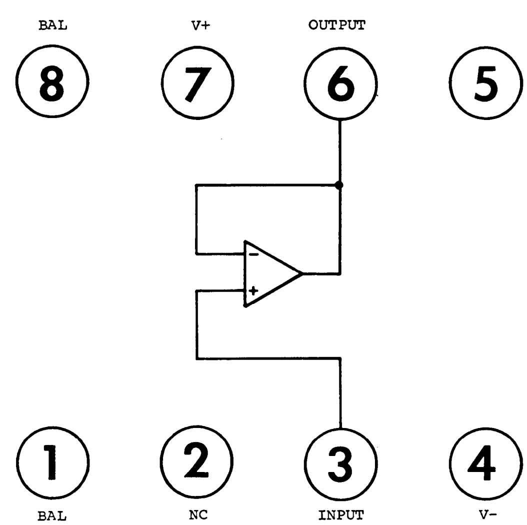


REGULATOR

KEITHLEY PART NO. IC-18

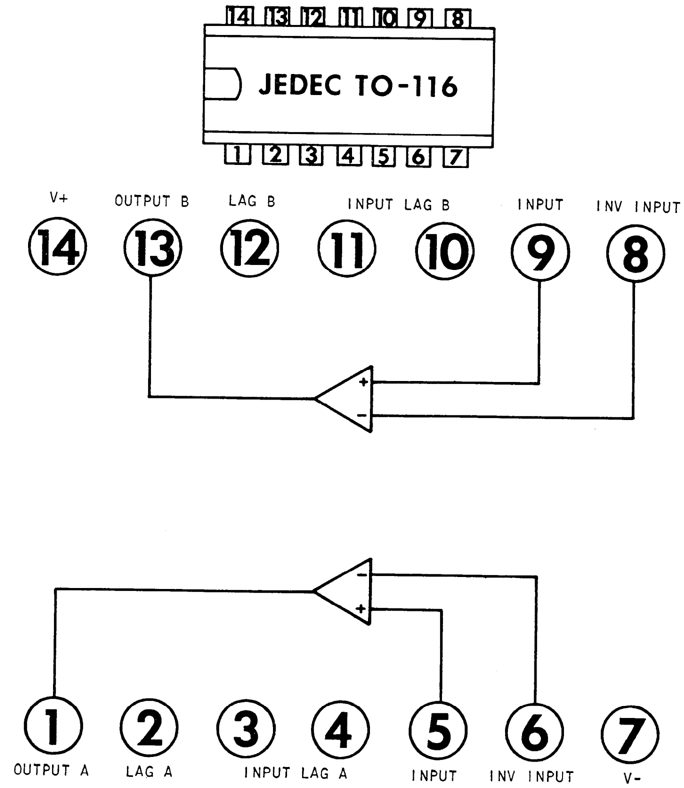


TO-99



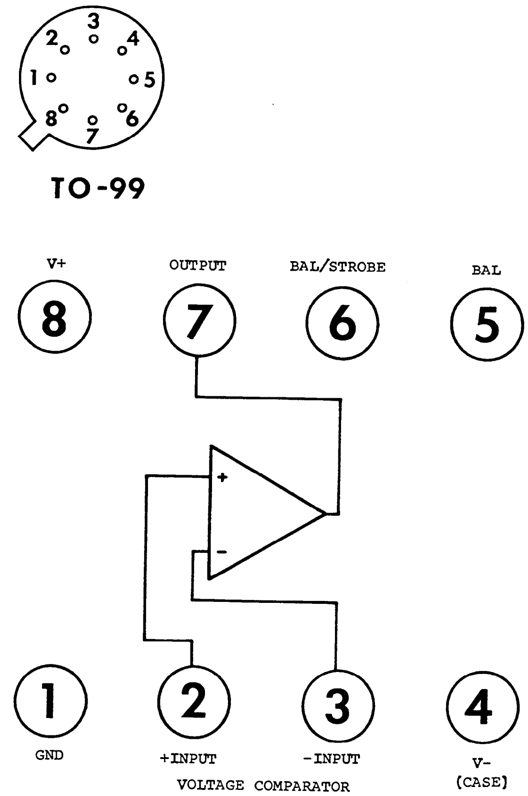
OPERATIONAL AMPLIFIER

KEITHLEY PART NO. IC-27



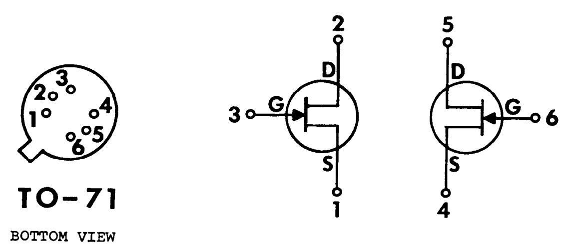
OPERATIONAL AMPLIFIER

KEITHLEY PART NO. IC-29



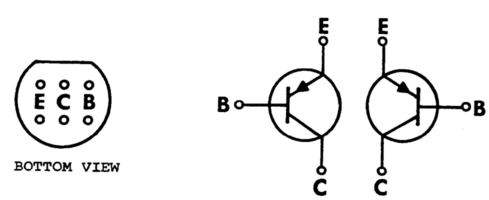
VOLTAGE COMPARATOR

KEITHLEY PART NO. TG-70 TG-74

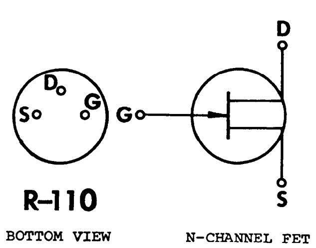


DUAL N-CHANNEL FET

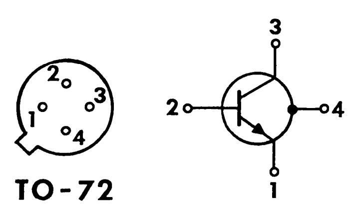
KEITHLEY PART NO. TG-75



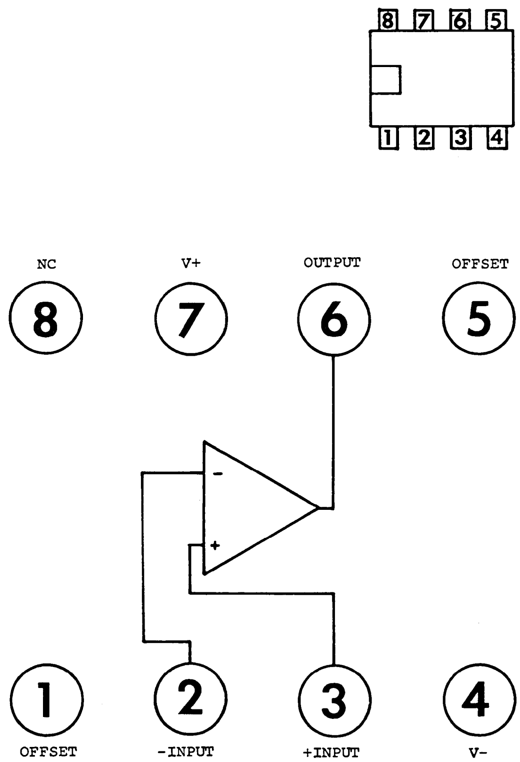
KEITHLEY PART NO. TG-76



KEITHLEY PART NO. TG-85

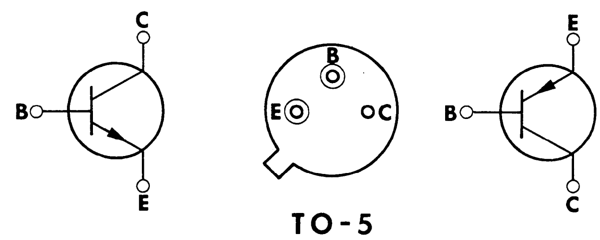


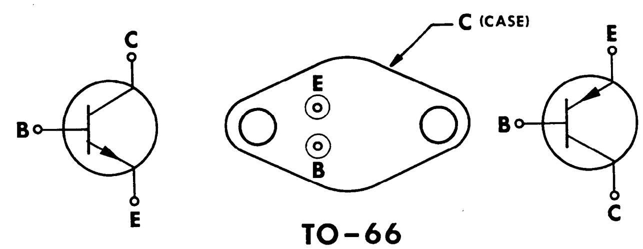
KEITHLEY PART NO. IC-42

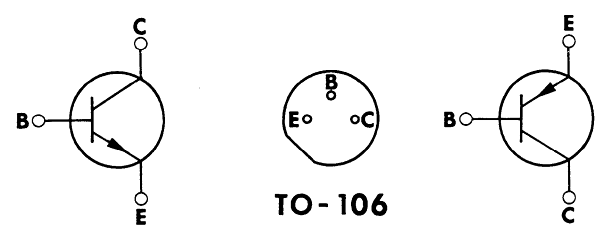


OPERATIONAL AMPLIFIER

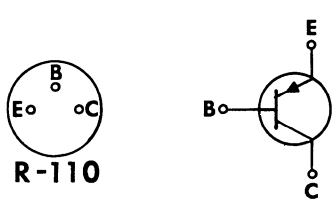
LEAD DESIG. TO-5





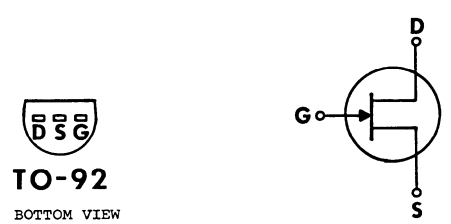


KEITHLEY PART NO. TG-33



BOTTOM VIEW

KEITHLEY PART NO. TG-41

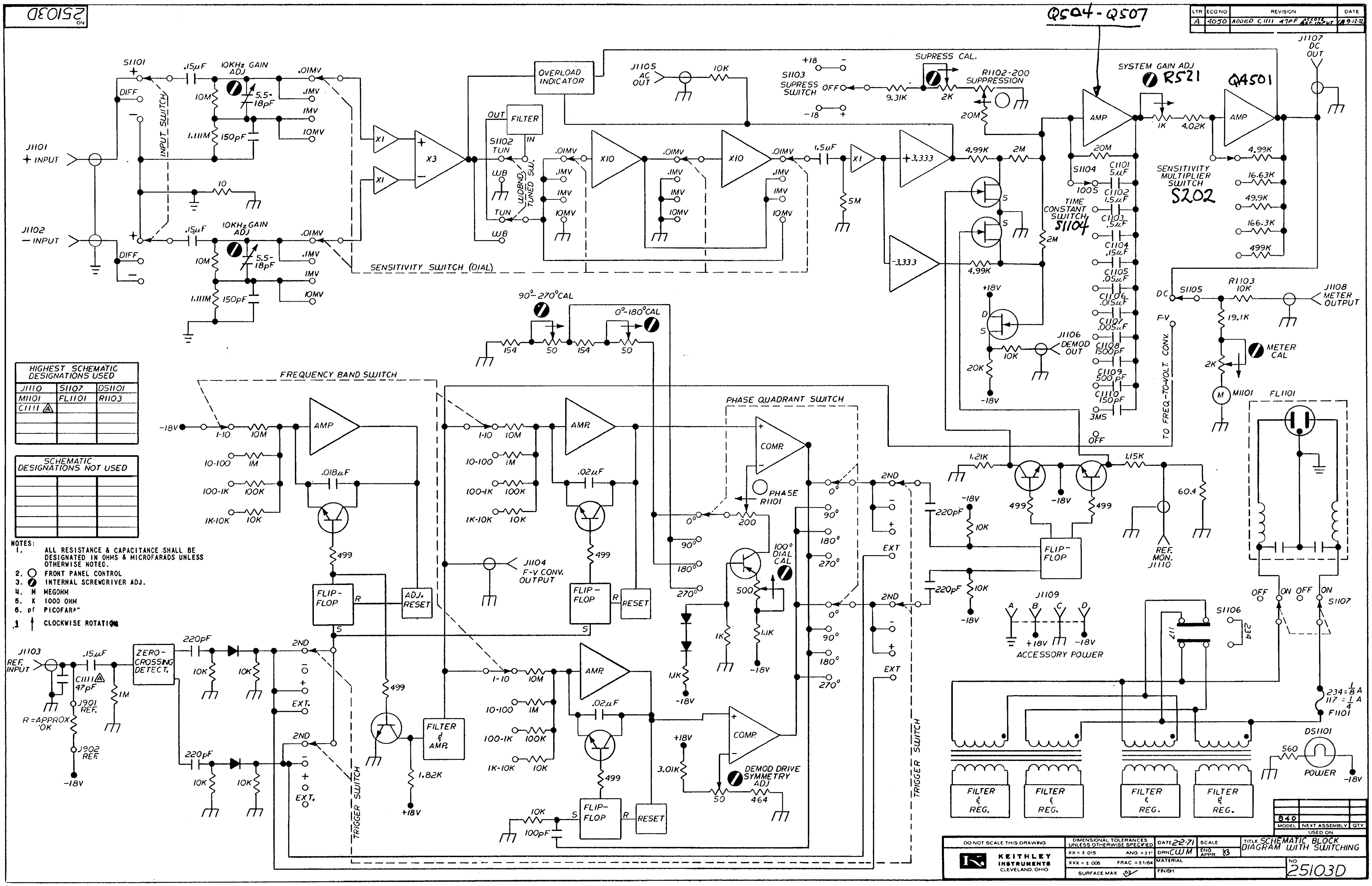


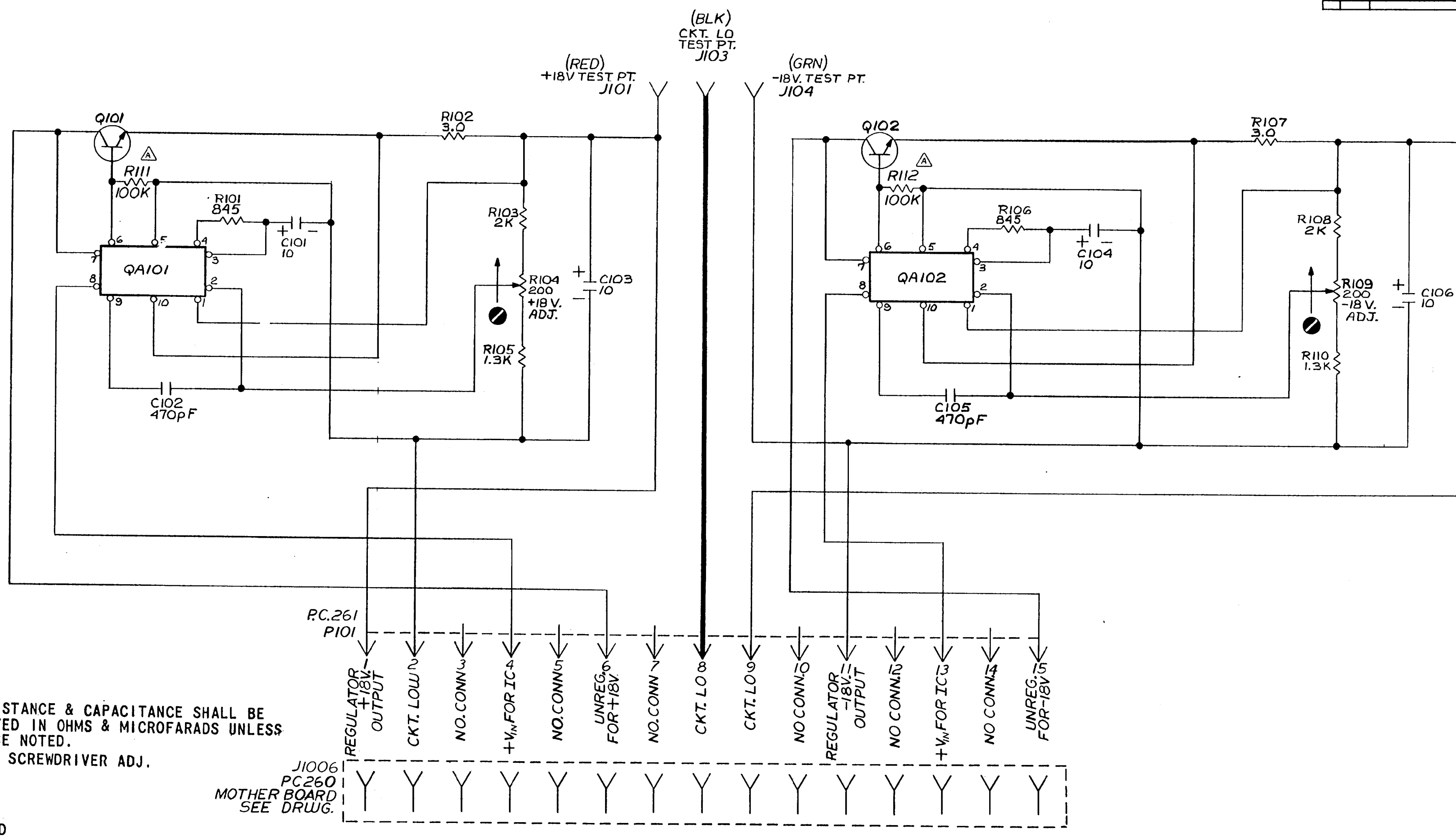
BOTTOM VIEW

N-CHANNEL JFET

SCHEMATICS

The following schematic diagrams describe the Model 840 and accessory cards (Models 8401 and 8402).


Q504 - Q507
25103D
LTR | ECO NO | REVISION | DATE
A | 4030 | ADDED C1111 47PF | 9-12-72
J1101 + INPUT
J1102 − INPUT
S1101
DIFF
INPUT SWITCH
10KHz GAIN ADJ
5.5-18pF
10M
1.111M
150pF
.15μF
.01MV
.1MV
1MV
10MV
SENSITIVITY SWITCH (DIAL)
X1
X3
OVERLOAD INDICATOR
FILTER
OUT
IN
S1102 TUN
WB
TUN
WDBND. TUNED SW.
X10
1.5μF
5M
+3.333
-3.333
4.99K
2M
J1105 AC OUT
10K
S1103 SUPRESS SWITCH
+18
-18
OFF
SUPRESS CAL.
9.31K
2K
R1102-200 SUPPRESSION
20M
SYSTEM GAIN ADJ
R521
AMP
1K
4.02K
Q4501
SENSITIVITY MULTIPLIER SWITCH
S202
16.63K
49.9K
166.3K
499K
S1104
100S
TIME CONSTANT SWITCH
S1104
C1101 5μF
C1102 1.5μF
C1103 .5μF
C1104 .15μF
C1105 .05μF
C1106 .015μF
C1107 .005μF
C1108 1500pF
C1109 500 pF
C1110 150pF
3MS
OFF
J1106 DEMOD OUT
20K
+18V
−18V
J1107 DC OUT
DC
S1105
R1103 10K
J1108 METER OUTPUT
19.1K
METER CAL
M1101
F-V
TO FREQ.-TO-VOLT. CONV.
90°-270°CAL
0°-180°CAL
154
50
FREQUENCY BAND SWITCH
1-10
10-100
100-1K
1K-10K
10M
1M
100K
.018μF
.02μF
499
FLIP-FLOP
ADJ. RESET
RESET
J1104 F-V CONV. OUTPUT
PHASE QUADRANT SWITCH
COMP.
PHASE R1101
200
100° DIAL CAL
500
1.1K
1K
0°
90°
180°
270°
DEMOD DRIVE SYMMETRY ADJ
3.01K
464
2ND
EXT
TRIGGER SWITCH
1.21K
1.15K
60.4
REF. MON. J1110
220pF
J1109
ACCESSORY POWER
FL1101
S1106
234
117
S1107
ON
234=1/8 A
117=1/4 A
F1101
DS1101
560
POWER
FILTER & REG.
J1103 REF. INPUT
C1111 47pF
J901 REF.
J902 REF.
R=APPROX 0K
ZERO-CROSSING DETECT.
FILTER & AMP.
1.82K
HIGHEST SCHEMATIC DESIGNATIONS USED
J1110 | S1107 | DS1101
M1101 | FL1101 | R1103
C1111
SCHEMATIC DESIGNATIONS NOT USED
NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. FRONT PANEL CONTROL
3. INTERNAL SCREWDRIVER ADJ.
4. M MEGOHM
5. K 1000 OHM
6. pf PICOFARAD
CLOCKWISE ROTATION
840
MODEL | NEXT ASSEMBLY | QTY
USED ON
DO NOT SCALE THIS DRAWING
KEITHLEY INSTRUMENTS CLEVELAND, OHIO
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
DATE 2-2-71
DRN CWM
SCALE
ENG APPR
MATERIAL
FINISH
TITLE SCHEMATIC BLOCK DIAGRAM WITH SWITCHING
NO 25103D



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. CLOCKWISE ROTATION

HIGHEST REFERENCE DESIGNATION					
Q102	QA102	C106	R112	P104	P101
J104					

SCHEMATIC DESIGNATION NOT USED					
J102					

LTR	ECO NO	REVISION	DATE
A	3966	ADDED R111 R112 100K	2-28-72

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ±.015, XXX = ±.005, ANG = ±1, FRAC = ±1/64, SURFACE MAX

DATE 7-28-70 | DRN C.W.M | ENG APPR | SCALE | MATERIAL | FINISH

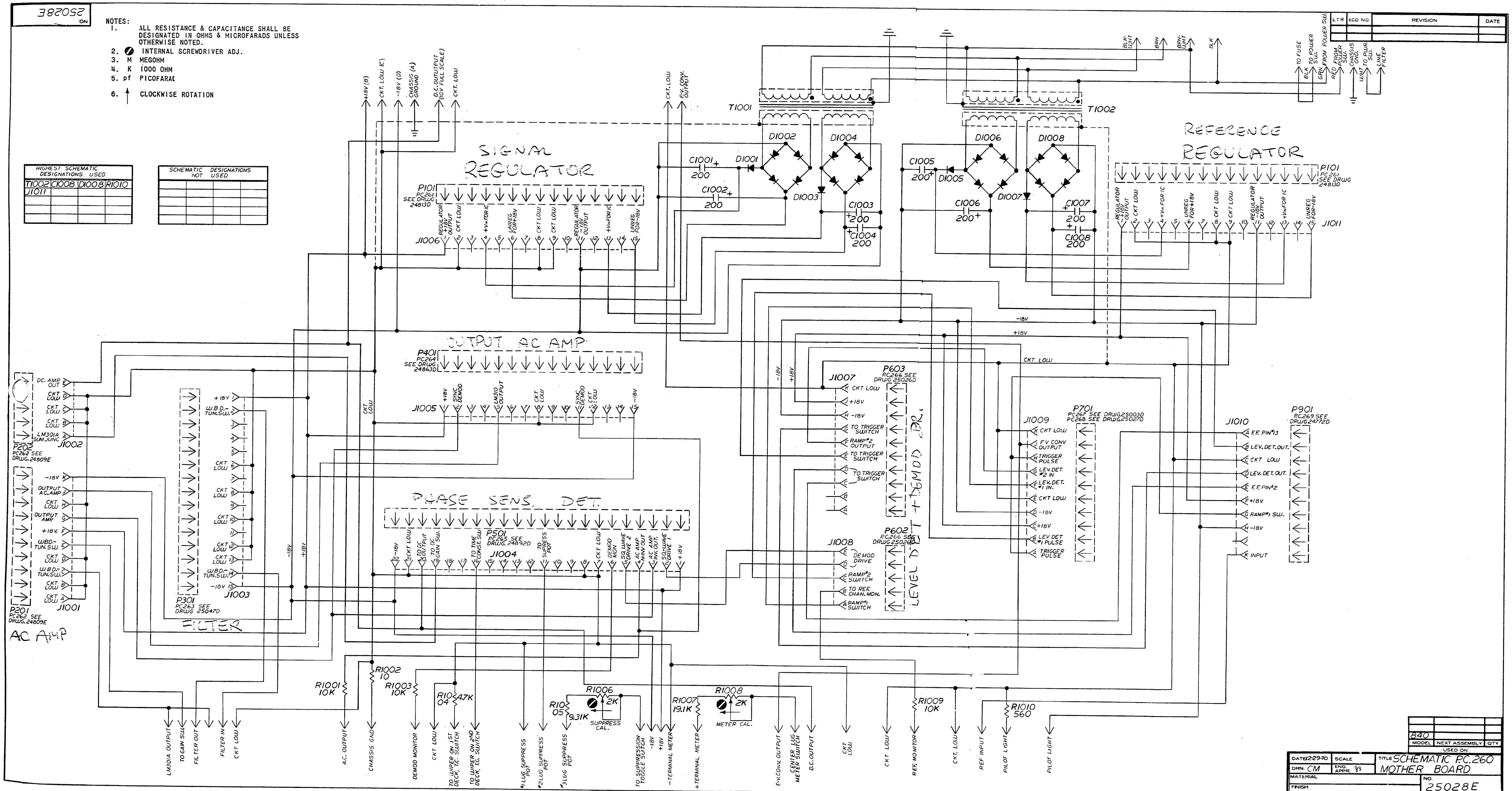
TITLE SCHEMATIC ±18-V IC REGULATOR (P.C.261)

MODEL	NEXT ASSEMBLY	QTY
180A		1
840		

USED ON

NO. 24813 D

24813 D



SCHEMATIC PC.260 MOTHER BOARD

25028E

NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pf PICOFARAD
6. ↑ CLOCKWISE ROTATION

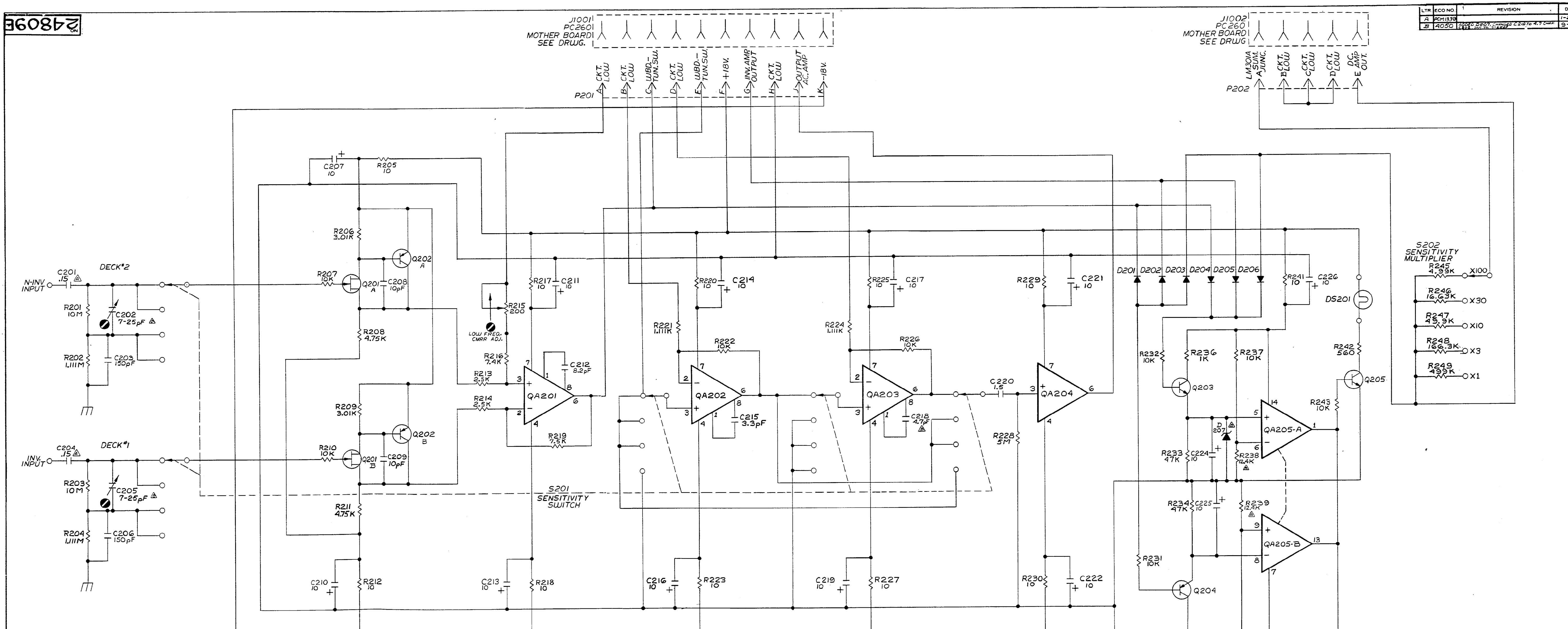
HIGHEST SCHEMATIC DESIGNATIONS USED			
T1002	C1008	D1008	R1010
J1011			

SCHEMATIC DESIGNATIONS NOT USED

840		
MODEL	NEXT ASSEMBLY	QTY
USED ON		

DATE 12-29-70	SCALE	TITLE SCHEMATIC PC.260 MOTHER BOARD
DRN. CM	ENG. APPR.	
MATERIAL		
FINISH		NO. 25028E

LTR.	ECO NO.	REVISION	DATE
A	PCM1339		1-26-71
B	4050	ADDED D207, CHANGED C218 TO 4.7 CHAN. C202, 205 TO 7-25pF	9-12-7?



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. ↑ CLOCKWISE ROTATION
7. COMPONENTS FOR DECKS #1 & 2 ARE MOUNTED ON SWITCH.
8. LAMP IS MOUNTED ON FRONT PANEL (DS201)

HIGHEST SCHEMATIC DESIGNATIONS USED					
R250	Q205	QA205	C226	D207	DS201
P202	S202				

SCHEMATIC DESIGNATIONS NOT USED					

MODEL	NEXT ASSEMBLY	QT
840		

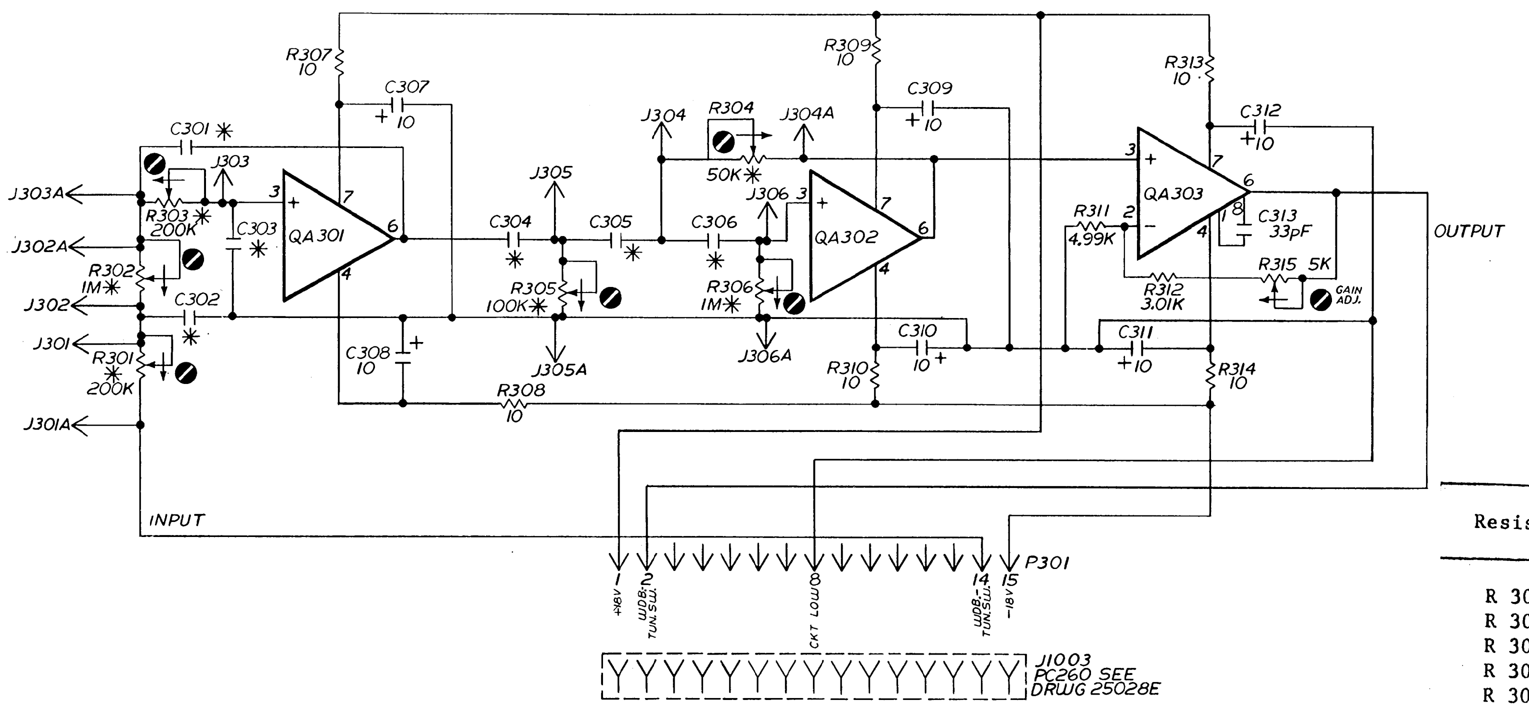
USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG. = ±1°
XXX = ± .005 FRAC. = ±1/64
SURFACE MAX. 63

DATE 8-10-70 | SCALE | TITLE SCHEMATIC P.C. 262 INPUT A.C. AMPLIFIER
DRN C.M. | ENG. APPR 83
MATERIAL
FINISH
NO. 24809E



Resistor		Value Required
R 301	=	109.2 kΩ/F'
R 302	=	779.7 kΩ/F'
R 303	=	140.8 kΩ/F'
R 304	=	29.92 kΩ/F'
R 305	=	76.20 kΩ/F'
R 306	=	524.2 kΩ/F'

Design Frequency	F'	C301	C302	C303	C304	C305	C306
1 Hz	F/1	1.5 µF	1.5 µF	.15 µF	1.5 µF	1.5 µF	1.5 µF
3 Hz	F/3	.5 µF	.5 µF	.05 µF	.5 µF	.5 µF	.5 µF
10 Hz	F/10	.15 µF	.15 µF	.015 µF	.15 µF	.15 µF	.15 µF
30 Hz	F/30	.05 µF	.05 µF	.005 µF	.05 µF	.05 µF	.05 µF
100 Hz	F/100	.015 µF	.015 µF	.0015 µF	.015 µF	.015 µF	.015 µF
300 Hz	F/300	.005 µF	.005 µF	500 pF	.005 µF	.005 µF	.005 µF
1 kHz	F/1k	.0015 µF	.0015 µF	150 pF	.0015 µF	.0015 µF	.0015 µF
3 kHz	F/3k	500 pF	500 pF	50 pF	500 pF	500 pF	500 pF

Where F = the desired tuned frequency.

Model 8401

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

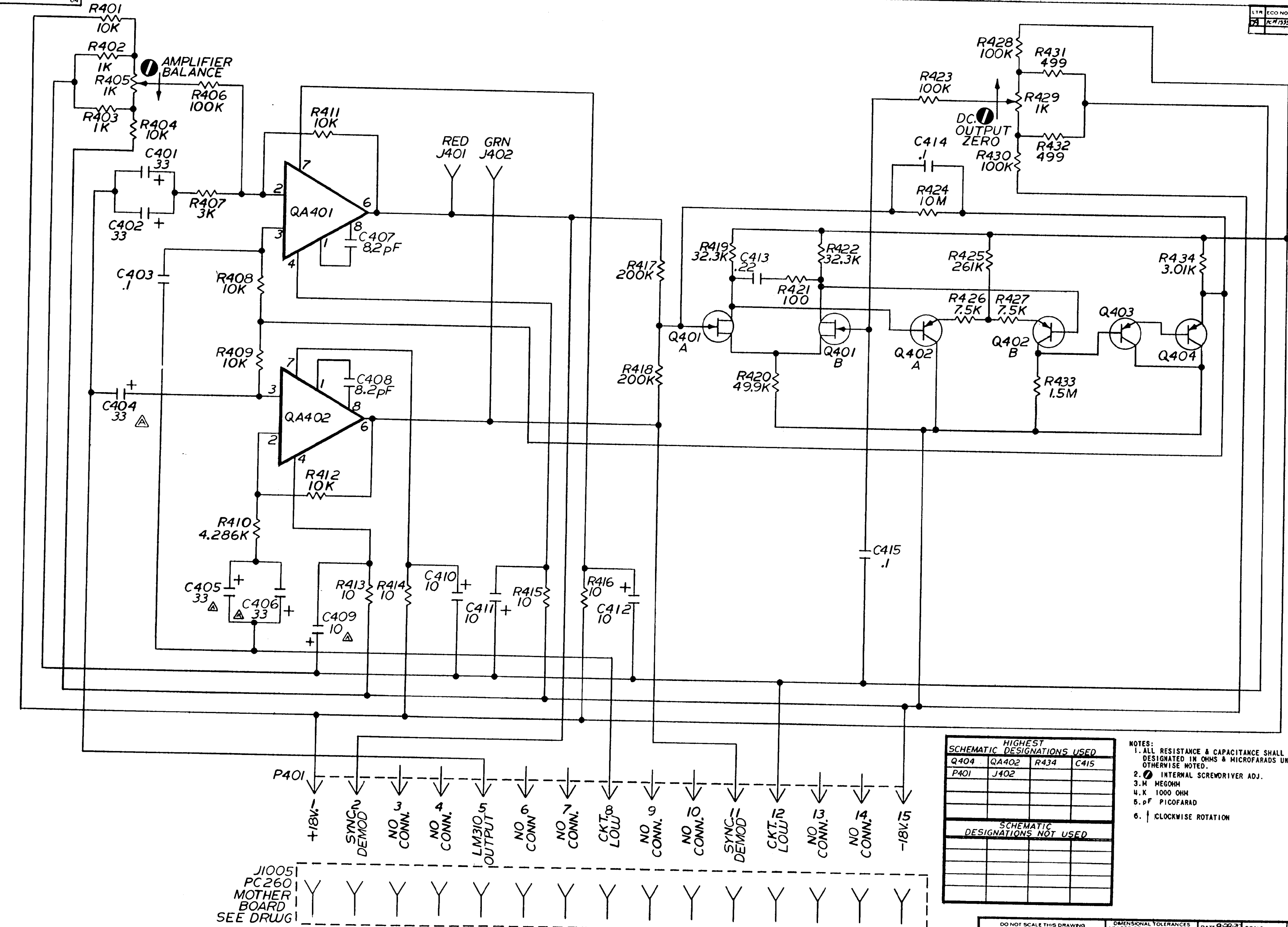
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

DATE 1-4-71 DRN CWM

TITLE SCHEMATIC PC263 ADJ. BAND PASS FILTER

840 MODEL

NO 25047D



HIGHEST SCHEMATIC DESIGNATIONS USED			
Q404	QA402	R434	C415
P401	J402		

SCHEMATIC DESIGNATIONS NOT USED			

NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. CLOCKWISE ROTATION

LTR	ECO NO	REVISION	DATE
A	K 1335		1-26-71

MODEL	NEXT ASSEMBLY	QTY
840		

DO NOT SCALE THIS DRAWING

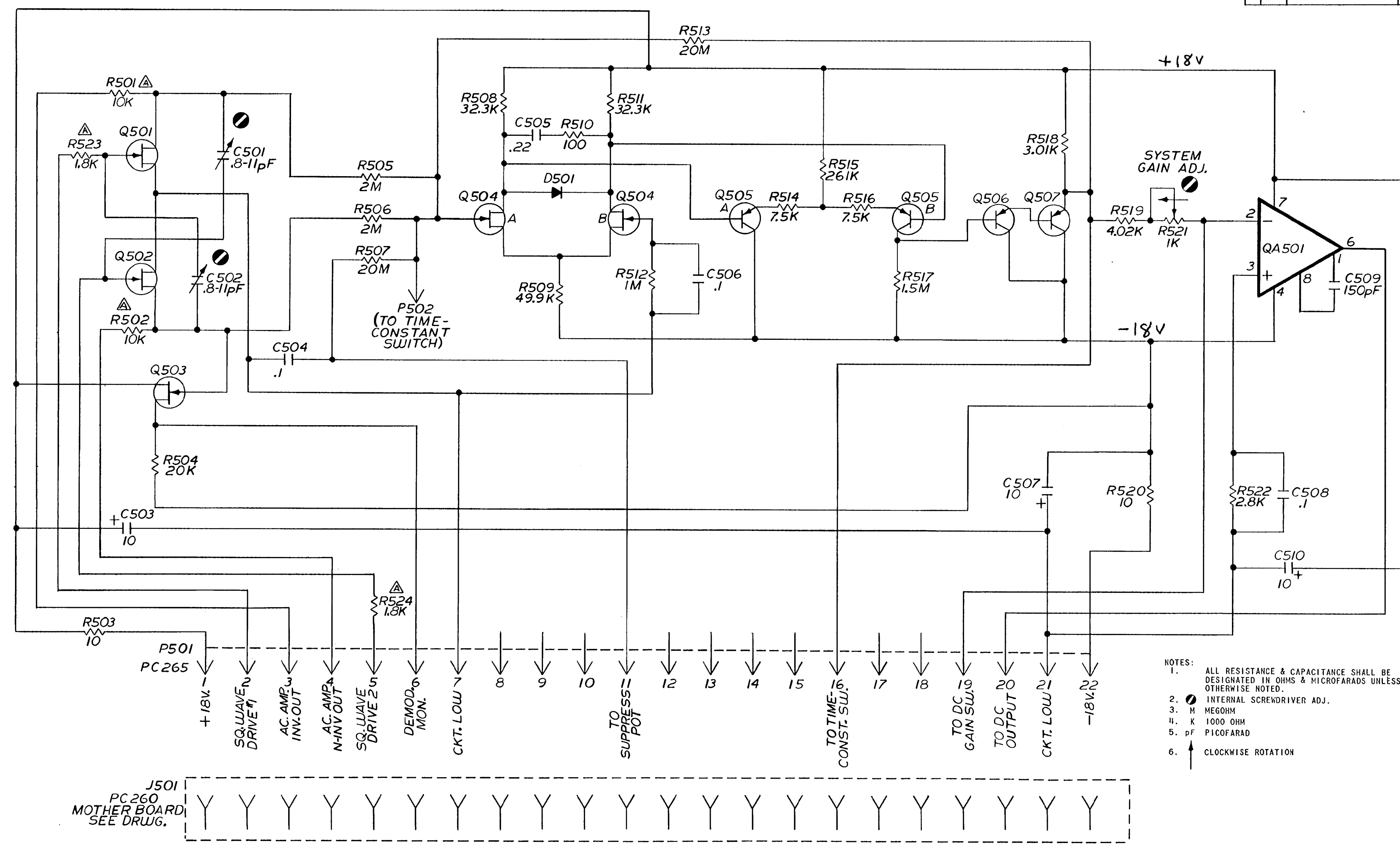
KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED XX ± .015 ANG ± 1° XXX ± .005 FRAC ± 1/64 SURFACE MAX

DATE 9-28-70 DRN C.W.M. ENG APPR

TITLE SCHEMATIC P.C.264 OUTPUT A.C. AMPLIFIER

NO 24863D



NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. ↑ CLOCKWISE ROTATION

HIGHEST SCHEMATIC DESIGNATIONS USED					SCHEMATIC DESIGNATIONS NOT USED				
C510	R524	QA501	Q507	P502					

LTR	ECO NO.	REVISION	DATE
A	4013	R514, 516 WAS 4.75K ... C.M.	2-11-72

MODEL	NEXT ASSEMBLY	QTY
840		

USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED XX ± .015 XXX ± .005 ANG ± 1 FRAC ± 1/64 SURFACE MAX

DATE 9-30-70 DRN C.W.H. ENG APPR 83 SCALE

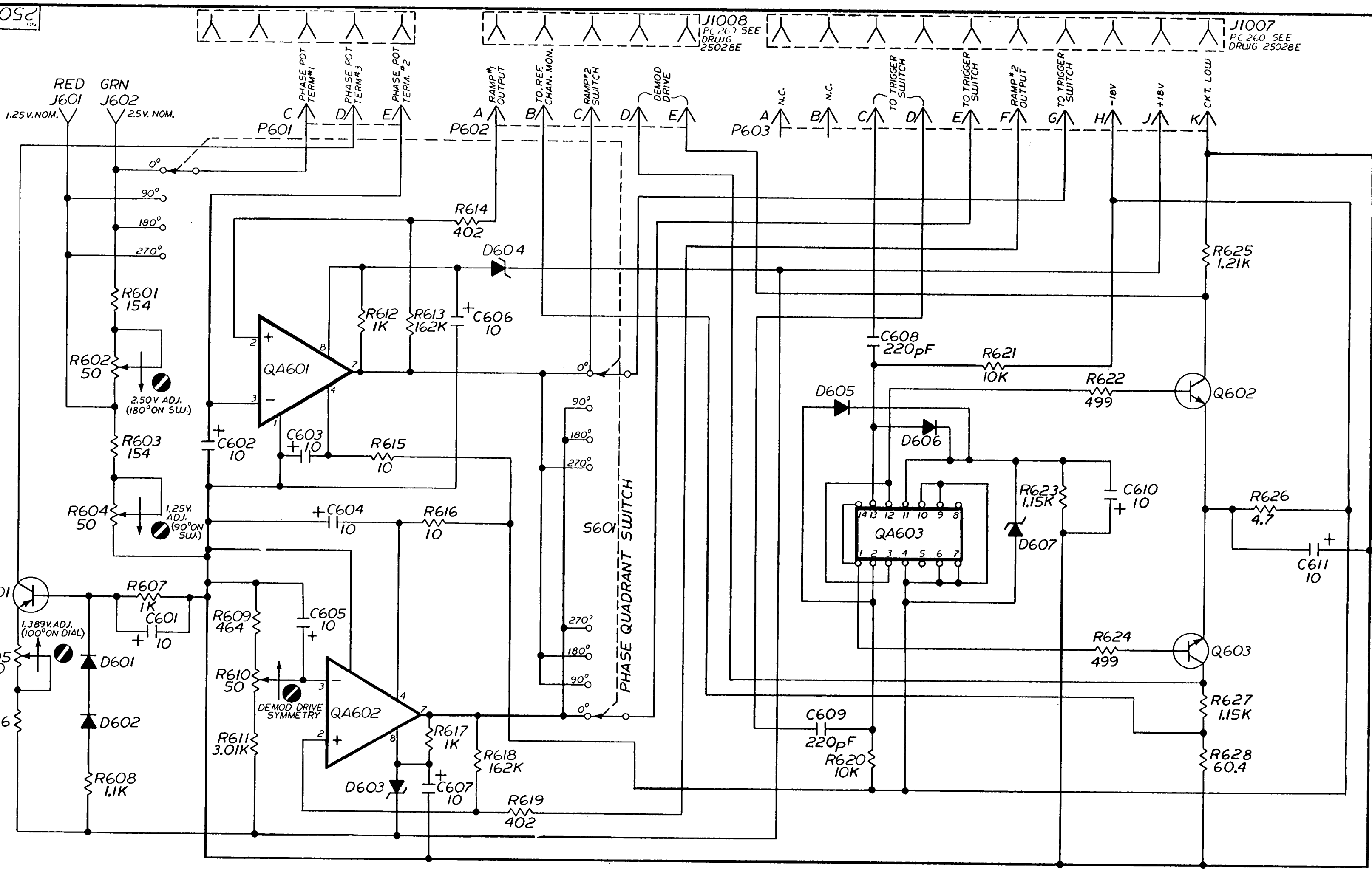
MATERIAL

FINISH

TITLE SCHEMATIC PC 265 PHASE SENSITIVE DETECTOR

NO. 24892 D

24892 D



NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. ↑ CLOCKWISE ROTATION

HIGHEST SCHEMATIC DESIGNATIONS USED			
R628	C611	D607	Q603
QA603	S601	P603	J602

SCHEMATIC DESIGNATIONS NOT USED			

MODEL	NEXT ASSEMBLY	QTY
840		

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DO NOT SCALE THIS DRAWING

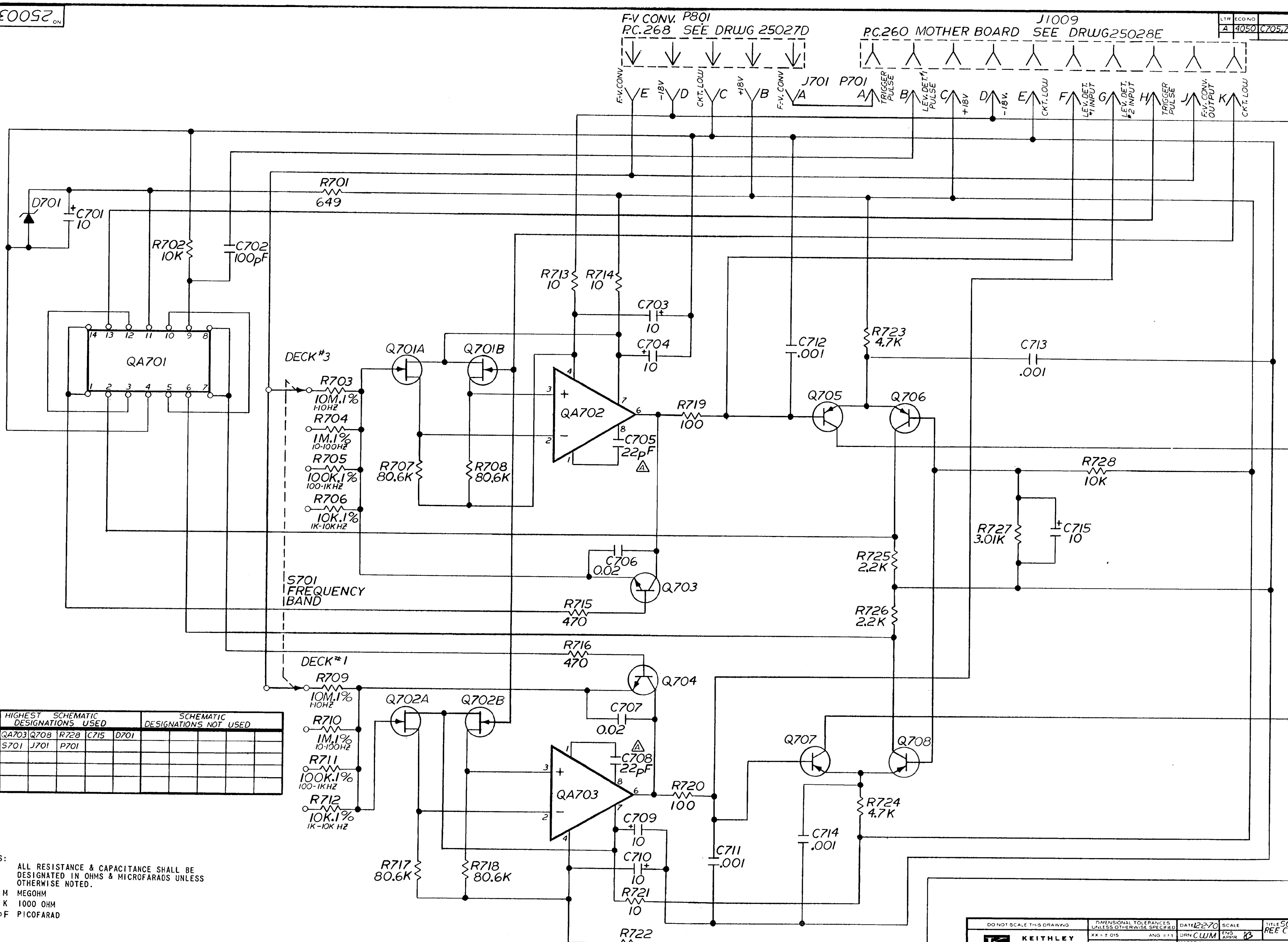
DATE 11-20-70 DWN CWM

TITLE SCHEMATIC PC 266 LEVEL DETECTORS AND DEMOD DRIVE

NO. 25026 D

25003D

LTR	ECO NO	REVISION	DATE
A	4050	C705, 708 WERE 15pF CM	9-13-72

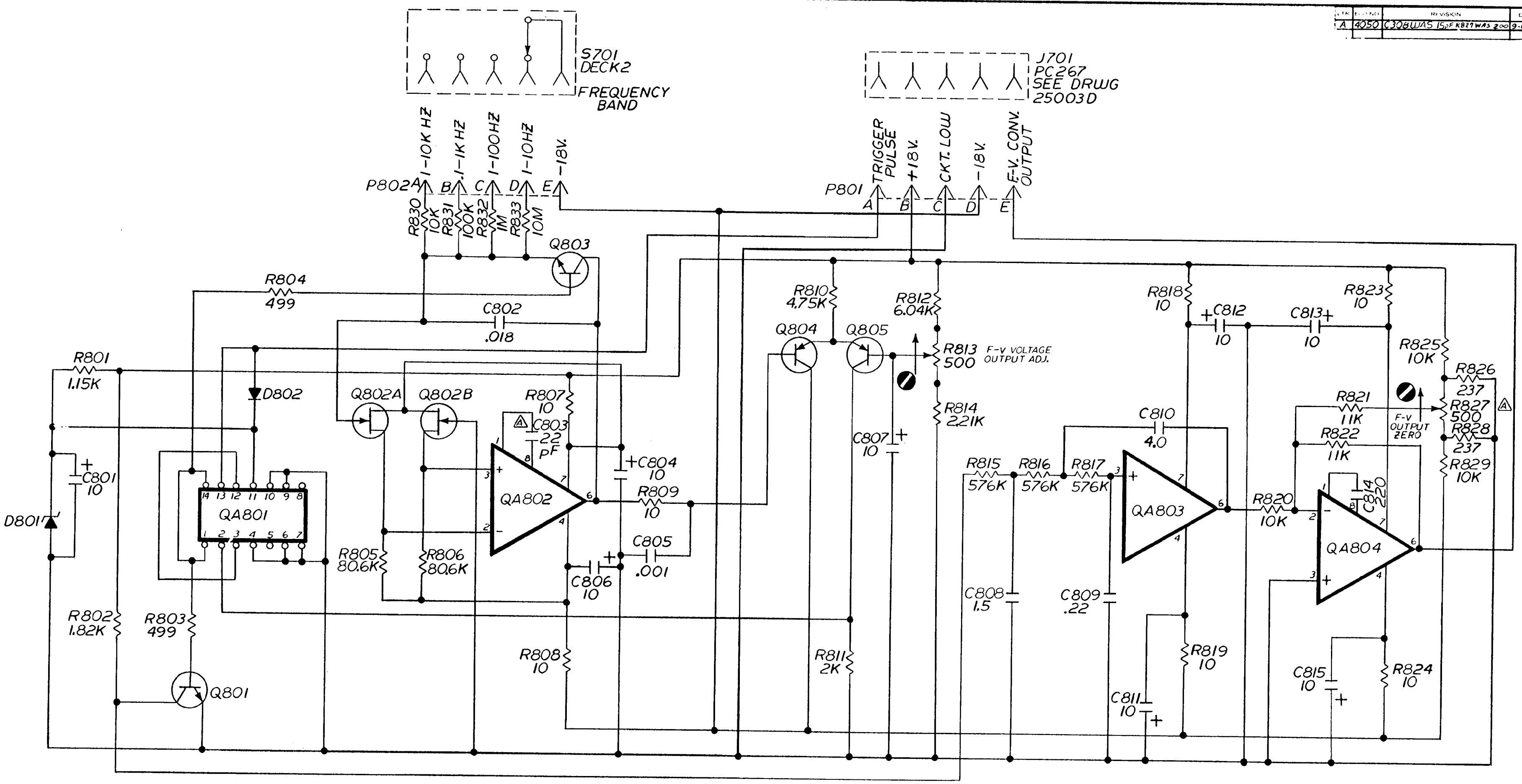


HIGHEST SCHEMATIC DESIGNATIONS USED					SCHEMATIC DESIGNATIONS NOT USED				
QA703	Q708	R728	C715	D701					
S701	J701	P701							

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

MODEL	NEXT ASSEMBLY	QTY
840		

DO NOT SCALE THIS DRAWING
KEITHLEY INSTRUMENTS CLEVELAND OHIO
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX ± .015 ANG ± 1
XXX ± .005 FRAC ± 1/64
SURFACE MAX
DATE 12-2-70
DRN CWM
ENG APPR
SCALE
MATERIAL
FINISH
TITLE SCHEMATIC PC267 REF CHANNEL RAMP CIRCUITRY
NO. 25003D



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. ↑ CLOCKWISE ROTATION

HIGHEST SCHEMATIC DESIGNATIONS USED			
R833	C815	Q805	QA804
D802	P802		

SCHEMATIC DESIGNATIONS NOT USED			

LTR	ECN NO.	REVISION	DATE
A	4050	C308 WAS 15pF R827 WAS 200	9-13-72

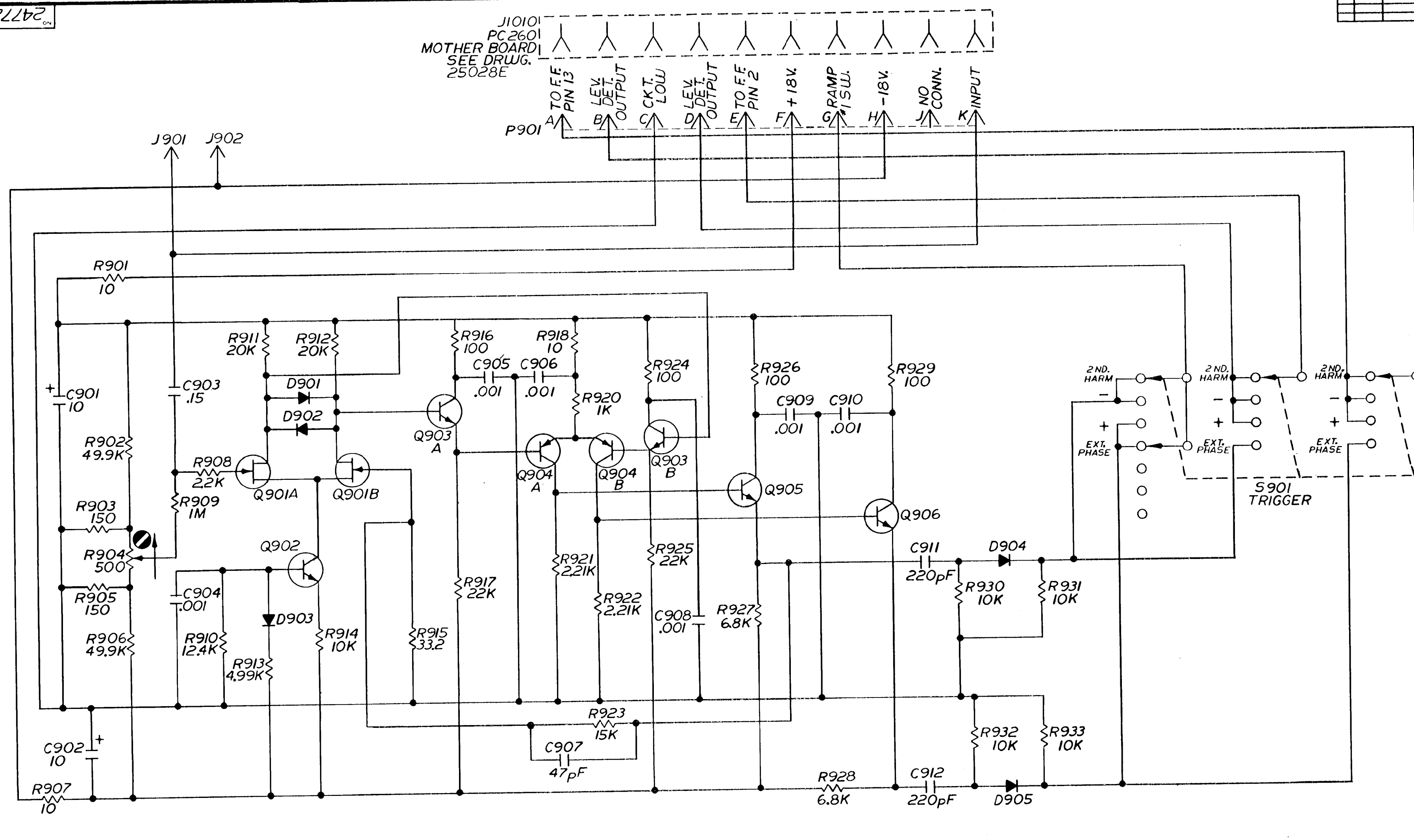
MODEL	NEXT ASSEMBLY	QTY
840		

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DATE 11-12-70 · DRN CWM · ENG APPR

TITLE SCHEMATIC PC268 FREQ.-TO-VOLTAGE CONV

NO. 25027D



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pF PICOFARAD
6. ↑ CLOCKWISE ROTATION

HIGHEST SCHEMATIC DESIGNATIONS USED				SCHEMATIC DESIGNATIONS NOT USED
S901	R933	D905	C912	R919
Q906	P901	J902		

LTR	ECO NO	REVISION	DATE

DO NOT SCALE THIS DRAWING
KEITHLEY INSTRUMENTS CLEVELAND OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ±.015, XXX = ±.005, ANG ±1°, FRAC ±1/64, SURFACE MAX

DATE 10-12-70 | DRN CWM | ENG APPR | SCALE | MATERIAL | FINISH

MODEL 840 | NEXT ASSEMBLY | QTY | USED ON

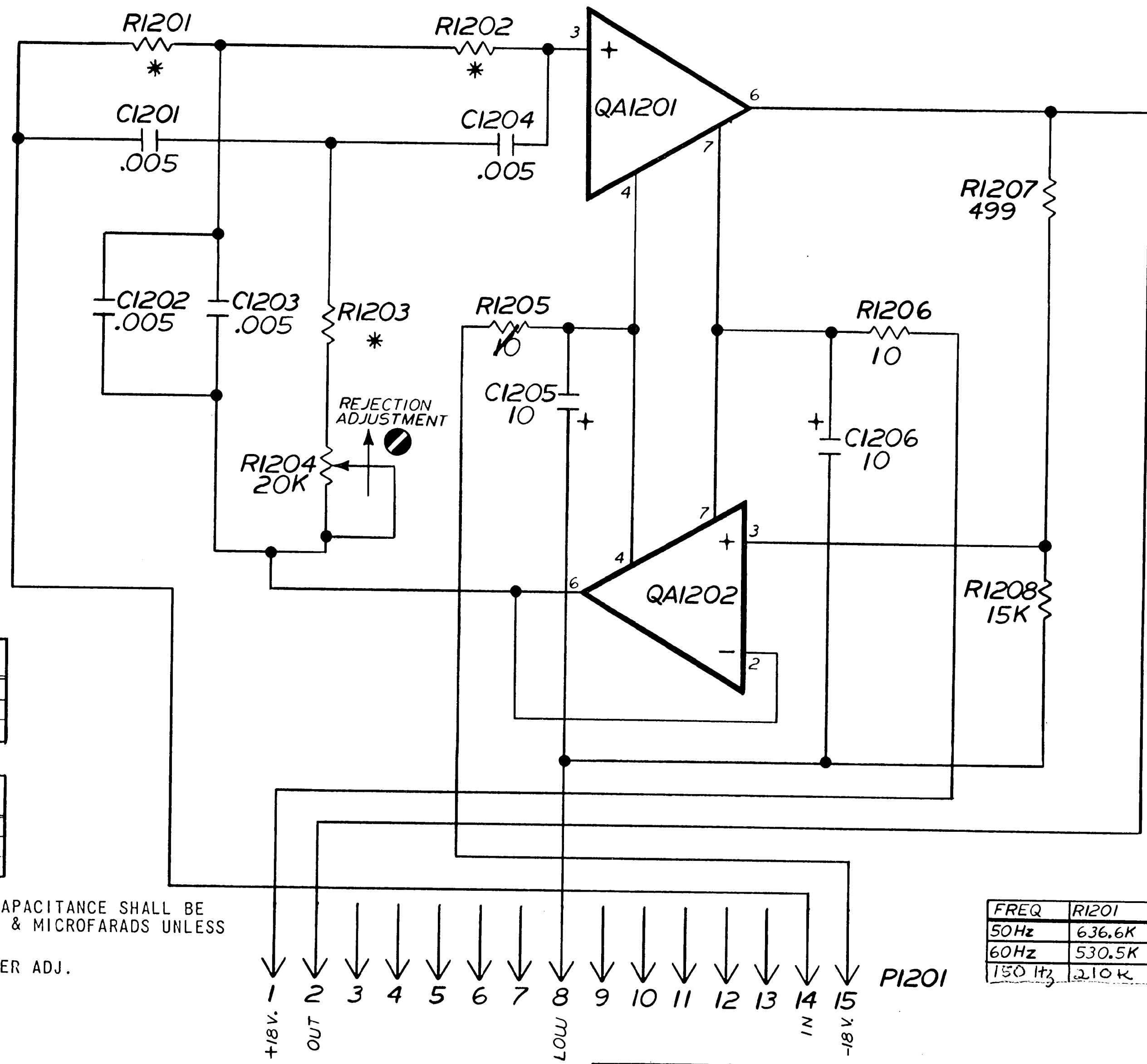
TITLE SCHEMATIC P.C. 269 ZERO CROSSING DETECTOR

NO 24772D

NO 24772D

081

LTR	ECO NO	REVISION	DATE



HIGHEST SCHEMATIC DESIGNATIONS USED		
R1208	C1206	QA1202
P1201		

SCHEMATIC DESIGNATIONS NOT USED		

NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ⊘ INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHM
5. pf PICOFARAD
6. ↑ CLOCKWISE ROTATION
7. * INDICATES NOMINAL VALUE PER CHART AT RIGHT.

Model 8402

FREQ	R1201	R1202	R1203
50Hz	636.6K	636.6K	309K
60Hz	530.5K	530.5K	255K
150 Hz	210K	210K	95.3K

JRY 5/2/77

MODEL	NEXT ASSEMBLY	QT
8402		

USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG = ±1°
XXX = ± .005 FRAC = ±1/64
SURFACE MAX 63

DATE 3-16-71
DRN C.W.M.
ENG APPR B
MATERIAL
FINISH
SCALE

TITLE SCHEMATIC P.C. 306 NOTCH FILTER

NO 25118C

KEITHLEY INSTRUMENTS, INC.
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 <u>all</u> 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.) ____________________

____

____________________ REV 0774

KEITHLEY INSTRUMENTS, INC.

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