KEITHLEY

Model 302
Operator's Manual
Contains Operating Instructions for the Model 302

Publication Date: May 5, 1983 Rev B.
Document Number: 29048

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We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay local domestic surface freight costs.

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SPECIFICATIONS

DC VOLTAGE GAIN, OPEN LOOP: Unloaded (min.): 12,000. Full load (min.): 10,000.

INPUT CHARACTERISTICS:

Input Impedance:

Resistance (minimum): $10^{12}\Omega$.

Shunt Capacitance (maximum): 5pF.

Overload Limit: ±100V continuous, ±400V momentary.

Current Stability: Offset 10^{-14}A.

vs. time (worst case): 10^{-15}A/24 hours.

vs. temperature (worst case): Doubles every 5°C.

vs. supply (worst case): 5×10^{-15}A/%.

Voltage Stability: Offset: Adjustable to zero.

vs. time (worst case): 2mV/week after 1-hour warmup.

vs. temperature (worst case): 150μV/°C.

vs. supply (worst case): 1mV/%.

Current Noise: 0.1-10Hz (max. peak-to-peak): 5×10^{-15}A.

Voltage Noise:

0.1-10Hz (maximum rms): 10μV.

10Hz-500kHz (maximum rms): 100μV.

FREQUENCY:

Gain Bandwidth Product (minimum): 150kHz.

Slewing Rate (minimum): 0.1V/μsec.

Rolloff (nominal): 6dB/octive.

OUTPUT: ±10V @ 5mA.

OPERATING TEMPERATURE: 0°C to +50°C.

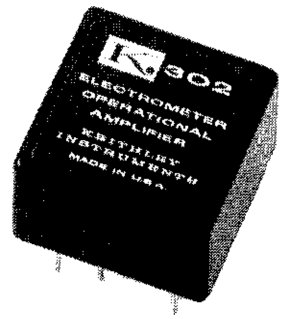
CONNECTORS: Input: Teflon-insulated feed through. All other: 0.025 pins, 0.2 in. long, 0.2 in. grid.

POWER REQUIREMENTS: Voltage: ±15V @ 5mA.

DIMENSIONS, WEIGHT: 18mm × 25mm (3/4" × 1" × 1"). Net weight, 10gm (1/3 oz.).

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL. The Model 302 is a completely solid-state, operational amplifier. It is an inverting, single-ended amplifier intended for use primarily as a current amplifier.



1-2. MOUNTING. The over-all dimensions of the case are given in Figure 2. The case has nine terminals which are suitable for soldered connections on a custom printed circuit board or plug-in connection to the Keithley Model 3021 Accessory Socket. The pin locations are given in Figure 3.

1-3. TERMINAL IDENTIFICATION. The numbered terminals are identified in Table 2.

TABLE 2.
Terminal Identification.

PIN NO.	DESCRIPTION	REMARKS
1	Input	This terminal is the high impedance input. It is teflon insulated from the case.
2	Common	This terminal is the low or common. The shield or system ground should be connected to this point.
3	Compensation	Refer to paragraph 2-5 for a discussion of frequency compensation.
4	+ V	This terminal should be connected to the positive voltage supply. Refer to paragraph 2-2 for a discussion of power requirements.
5	Compensation	Refer to paragraph 2-5.
6	Output	This terminal is the voltage output (inverted signal)
7	Not Used	-
8	- V	This terminal should be connected to the negative voltage supply. Refer to paragraph 2-2 for a discussion of power requirements.
9	Zero	Refer to paragraph 2-6 for a discussion of zero control.

NOTE

Since the Model 302 utilizes an epoxy cemented enclosure, repairs should not be attempted. If there is an apparent malfunction, check the external components and connections. If possible, connect the amplifier as a voltage gain amplifier and check the gain in this mode of operation. Indicate the exact nature of the difficulty if it is necessary to return the Model 302 for repair.

SECTION 2. OPERATION

2-1. CONNECTIONS.

a. Model 3021 Accessory Socket. The Model 3021 permits quick connections to the Model 302. The socket has plated terminals which are easily soldered. The 3021 provides a rigid shielded enclosure to minimize noise pickup.

b. Printed Circuit Connection. The Model 302 can also be soldered directly to a printed circuit board. When measuring very small currents, it is advisable to directly solder the Input terminal (Pin 1) to the current source. A clearance hole (.125 dia) can be drilled in the PC board to facilitate a direct soldered connection .

2-2. POWER SUPPLY REQUIREMENTS. The Model 302 has been designed to operate from a ± 15 volt, regulated supply. The amplifier will operate however from any supply voltage over the range ± 9 volts to ± 18 volts with a resulting modification of certain specifications. The regulation of the supply will depend on the stability requirements of the application. Voltage stability is specified as 1 millivolt/% change in supply voltage. The current required is 5 milliamperes for each supply.

2-3. MODES OF OPERATION. The Model 302 can be connected for use in several configurations or modes of operation.

a. Linear Current Amplifier. When connected in this mode, the Model 302 can be used as a current sensing amplifier. The gain of the amplifier in this configuration is determined by the feedback resistance R_f. The output voltage is given by the equation $Vo = I \times R_f$. Refer to paragraph 2-4a for circuit connections.

b. Linear Current Amplifier With Fractional Feedback. When connected in this mode, the Model 302 can be used as a current sensing amplifier. The gain of the amplifier is determined by the feedback resistor R_f and the fractional feedback divider made up of R_1 and R_2. The output voltage is given by the equation $Vo = I \times R_f \times (R_1 + R_2)/R_2$. Refer to paragraph 2-4b for circuit connections.

c. Linear Current Amplifier With Variable Damping. When connected in this mode, the Model 302 can be used as a current sensing amplifier with the overall response varied through the use of a capacitor C_d and resistive divider made up of R_3 and R_4. Refer to paragraph 2-4c for circuit connections. The value of capacitance required to damp oscillations may be from 3 to 100 picofarads.

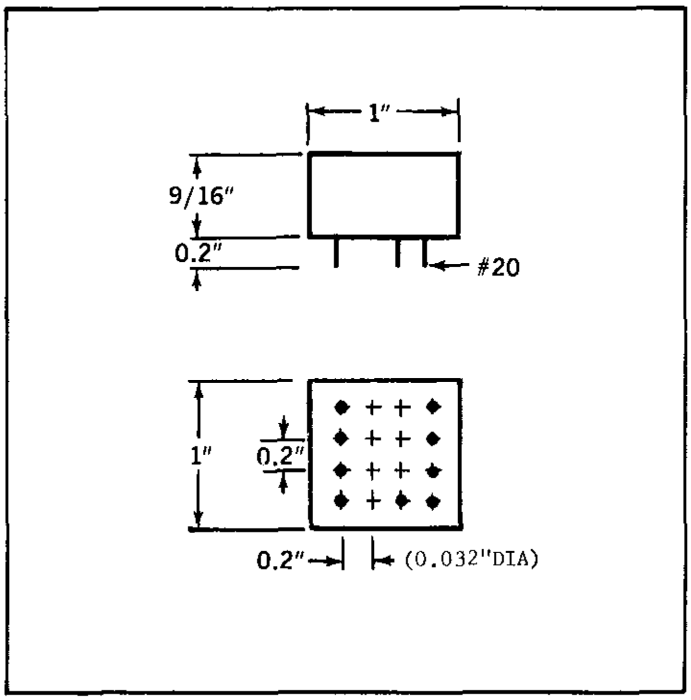


FIGURE 2. Case Dimensions.

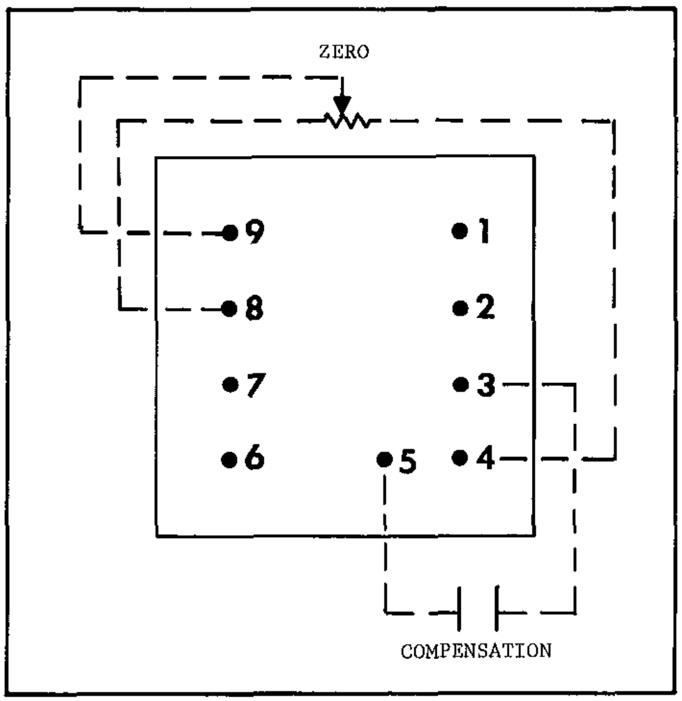


FIGURE 3. Pin Identification.

d. Logarithmic Current Amplifier. When connected in this mode, the Model 302 can be used as a current amplifier with a logarithmic gain. The output voltage is given by the equation Vo = -A log I. Refer to paragraph 2-4d for circuit connections.

NOTE

For further information send for the Keithley Product Note "Using the Model 300 Operational Amplifier as a Logarithmic Current Amplifier."

e. Current Integrator or Charge Amplifier. When connected in this mode, the Model 302 can be used as charge or current sensing amplifier. As a current integrator the output voltage is given by the equation $V_o = 1/C_f$ I dt. As a charge amplifier, the output voltage is given by the equation $V_o = Q/C_f$. Refer to paragraph 2-4e for circuit connections.

f. Unity Gain Isolation Amplifier. When connected in this mode, the Model 302 can be used as an impedance matching voltage amplifier where the output will follow the input within 100 ppm. Refer to paragraph 2-4f for circuit connections.

g. Voltage Gain Isolation Amplifier. When connected in this mode, the Model 302 can be used as a voltage amplifier with the output low floating with respect to the input low. The output voltage is given by the equation $V_o = V_1 (R_1 + R_2)/R_2$. Refer to paragraph 2-4g for circuit connections.

2-4. CIRCUIT CONNECTIONS.

a. Linear Current Amplifier. In this configuration, the selected feedback resistor R_f is connected between the Input (Pin 1) and the Output (Pin 6) as shown in Figure 4. Since the maximum amplifier output is ±10 volts (nominally), the full range current is determined by the ratio $10/R_f$. Since the offset current for the Model 302 is approximately 10^{-14} ampere, a feedback resistance of 10^{12} ohms is practical.

b. Linear Current Amplifier With Fractional Feedback. In this configuration, the feedback resistor R_f is connected between the Input (Pin 1) and a divider composed of R_1 and R_2 as shown in Figure 5. The value of R_1 and R_2 should be selected such that $R_1 + R_2$ is .01 times the value of R_f (that is, the divider current should be large compared to the current to be measured). Since the output current must be limited to 5 milliamperes or less, the output load R_L (in parallel with $R_1 + R_2$) should be 2kΩ or greater.

c. Linear Current Amplifier With Variable Damping. In this configuration, a damping capacitor C_d is connected between the Input (Pin 1) and the Output (Pin 6) for fixed damping or through a fractional feedback divider composed of R_3 and R_4 as shown in Figure 6.

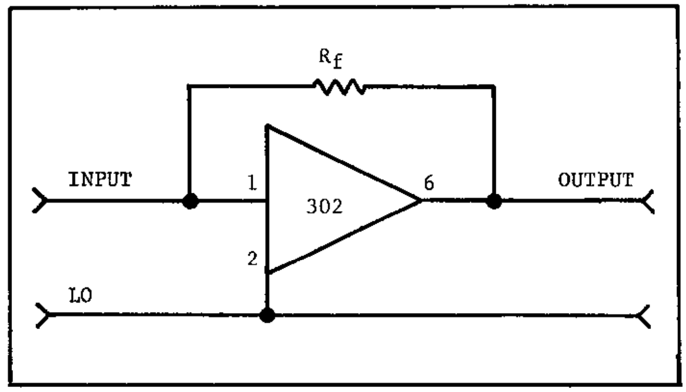


FIGURE 4. Linear Current Amplifier.

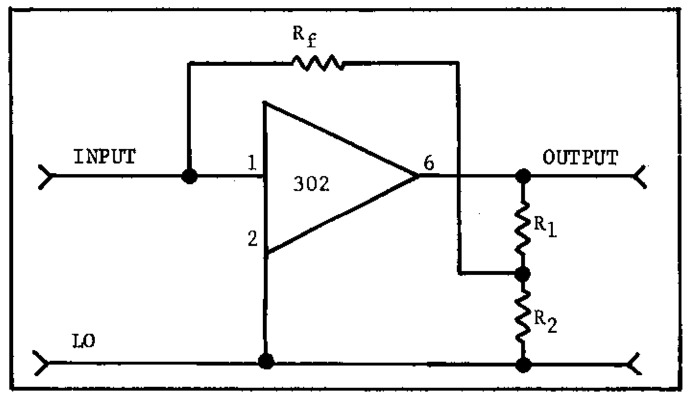


FIGURE 5. Linear Amplifier With Fractional Feedback.

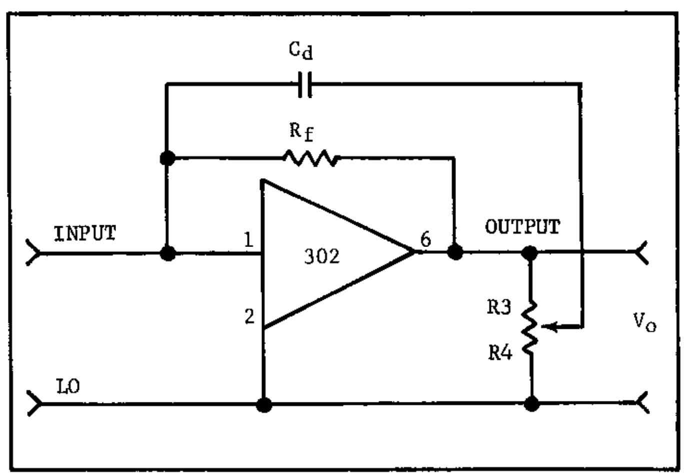


FIGURE 6. Linear Amplifier With Variable Damping.

TABLE 3.

Typical Performance Values for the Model 302 Used as a Linear Current Amplifier. Offset, drift and rise time are affected by the circuit used, but the table below shows some of the Model 302's capabilities. "% Feedback" refers to fractional feedback equation 100% is with no fractional feedback.

Feedback Resistor	10^{10} Ω	10^{10} Ω	10^{12} Ω	10^{12} Ω
% Feedback	100%	10%	100%	10%
Output Voltage	10 V	10 V	10 V	10 V
Input Current	10^{-9}A	10^{-10}A	10^{-11}A	10^{-12}A
Resolution	2.5 x 10^{-14}A	2.5 x 10^{-14}A	10^{-14}A	10^{-14}A
Current Offset, % of output	0.001%	0.01%	0.1%	1%
Drift/Week % of output	0.02%	0.2%	0.02%	0.2%
Observed Rise Time	10 msec	20 msec	200 msec	300 msec

d. Logarithmic Current Amplifier. A logarithmic device such as a silicon diode or transistor junction can be connected between the Input (Pin 1) and Output (Pin 6) to provide up to 9 decades of logarithmic response. The particular device used determines the log performance. The leakage current of the device should be at least two magnitudes less than the current to be measured. The addition of series devices and/or fractional feedback can be used to establish the magnitude of the scale factor "A". See Figure 7. Silicon NPN transistors are also useful as log elements where better response speed is needed. Using the basic circuit of Figure 8, positive currents can be amplified by using an NPN transistor in the feedback loop. Negative currents can be amplified by using a PNP transistor in the feedback loop. The base of the transistor is connected to ground. Connect the collector to the INPUT and the emitter to the OUTPUT.

1. To zero the output use a variable voltage between the log element in the feedback loop and the output. This variable voltage can be achieved by use of a biasing network that consists of a potentiometer connected as in Figure 7. Mount this network in series between the log element and the output. Adjusting the potentiometer will provide the voltage needed to zero the output. The resistance added by this biasing network should be small compared to the resistance of the diode network at maximum input current.

2. An alternate approach is to supply a buckout current to the input by means of a high megohm resistor and a potentiometer as shown in Figure 9. To minimize the effect on zero drift the resistance, R, should be at least as large as the resistance of the diode network at minimum input current.

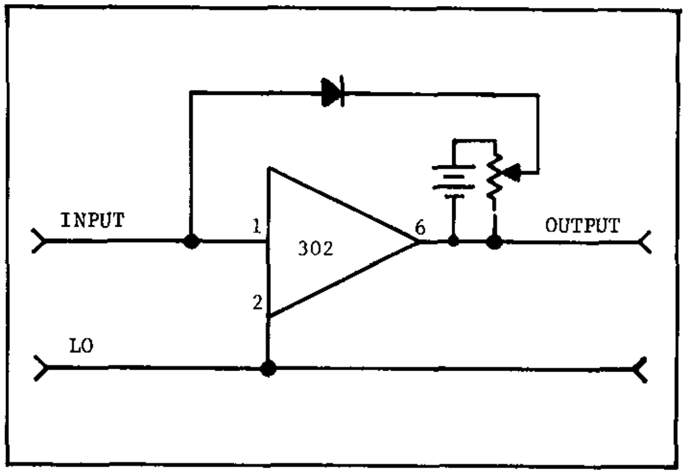


FIGURE 7. Logarithmic Current Amplifier

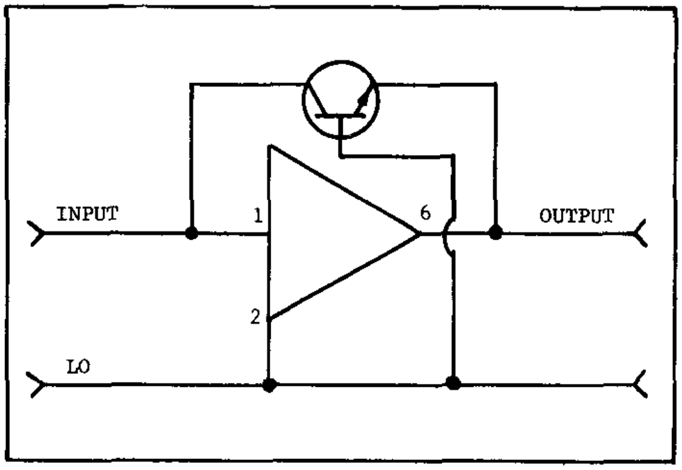


FIGURE 8. Logarithmic Current Amplifier

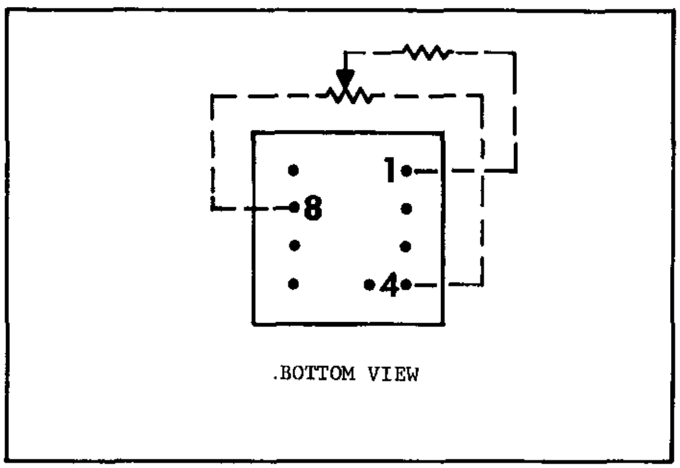


FIGURE 9. Output Zero Adjustment.

e. Current Integrator or Charge Amplifier. In this configuration, a feedback capacitor C_f is connected between the Input (Pin 1) and the Output (Pin 6). The capacitor should be a low-leakage type such as polystyrene, mylar, or polycarbonate. Fractional feedback can be used to vary the sensitivity without changing capacitors. See Figure 10.

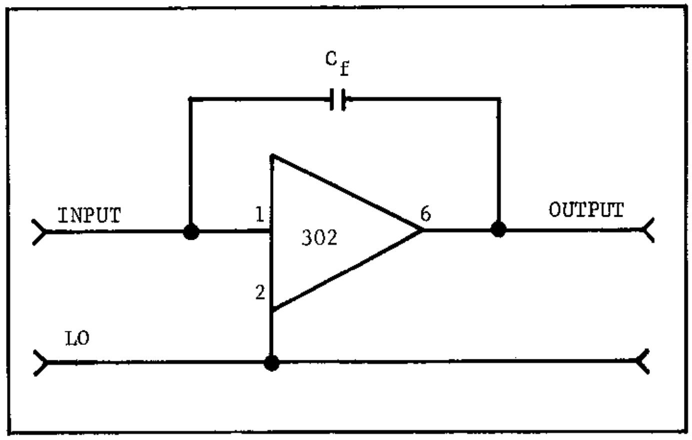


FIGURE 10. Current Integrator.

f. Unity Gain Isolation Amplifier. In this configuration, the input voltage signal is applied between the Input (Pin 1) and the Output (Pin 6). The unity gain voltage output is developed between the Output (Pin 6) and common (Pin 2). Since the common terminal is isolated from the input LO terminal, a floating power supply and monitoring device must be used. (The Common terminal (Pin 2) is used for power supply return). See Figure 11.

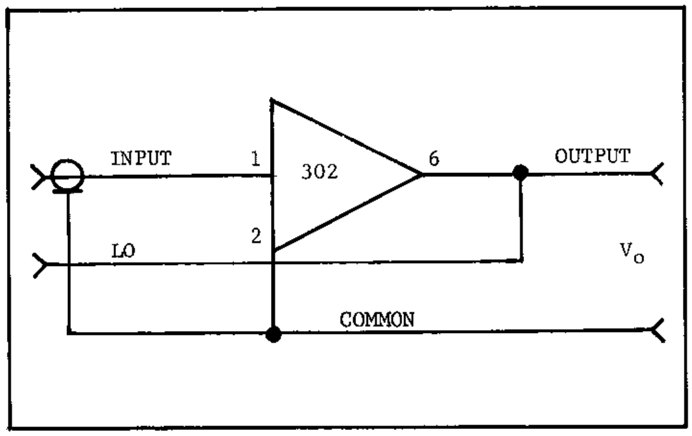


FIGURE 11. Unity Gain Amplifier.

g. Voltage Gain Isolation Amplifier. In this configuration, a resistor divider is used to provide voltage gain while maintaining high input impedance. The Input voltage signal is applied between the Input (Pin 1) and the divider network as shown in Figure 12. The output voltage is developed between the Output (Pin 6) and Common (Pin 2). Since the common terminal is isolated from the input LO terminal, a floating power supply and monitoring device must be used.

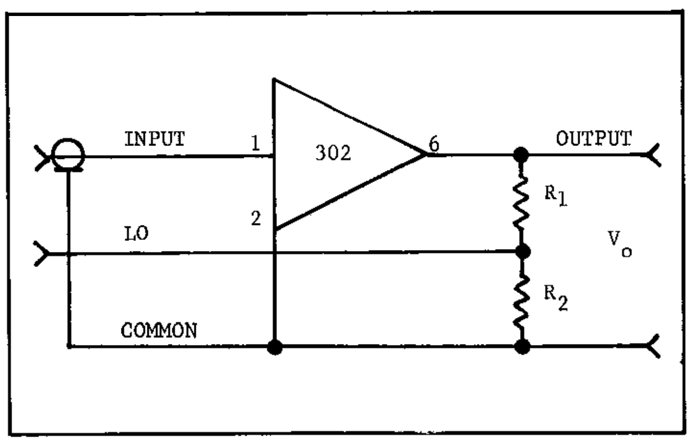


FIGURE 12. Voltage Gain Amplifier.

2-5. COMPENSATION. The Model 302 may require an external freq. comp. capacitor for stability. This can be accomplished by connecting a comp. capacitor between Pin 3 and Pin 5. A nominal value for this capacitor is 150 picofarad, although the value may be adjusted slightly to obtain optimum bandwidth. In some cases it may be necessary to add an additional damping capacitor C_d as described in paragraph 2-4c. The typical value of this capacitor should be 3 pF to 100 pF. The overall frequency response of the amplifier can be described by a voltage gain versus logarithm of frequency plot known as a "Bode" plot. When the response "rolls-off" at a slope of -6dB/octave, the amplifier is unconditionally stable. When the slope is between -6 and -12dB/octave, the amplifier is conditionally stable; that is, the amplifier may oscillate unless additional damping is added. When the slope is greater than -12dB/octave, the amplifier is unstable for gain greater than unity. Additional damping is definitely required in this situation. See Figure 3.

2-6. ZERO CONTROL. When the voltage offset must be adjusted to zero, an external control can be connected as shown in Figure 3. Since the Zero Terminal (Pin 9) has a 1 megohm input resistance, the potentiometer should be less than 1 megohm. If the power supplies are ± 15 volts, then the zero control will permit a variation of approximately ± 150 millivolts or .01 times the bias voltage.

KEITHLEY

SERVICE FORM

Model No. ____________ **Serial No.** ________ **P.O. No.** ________ **Date** ________

Name ______________________________ **Phone** ____________

Company ____

Address ____

City ____________ **State** ____________ **Zip** ____________

List all control settings and describe problem. ______________________________

____

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______________________________ (Attach additional sheets as necessary.)

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

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? ____________

Any additional information. (If special modifications have been made by the user, please describe below.)

____

____

*Be sure to include your name and phone number on this service form.

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