



## Optical Electronics Incorporated

### 20 MHz BIPOLAR LOGARITHMIC AMPLIFIER

#### FEATURES

- WIDE BANDWIDTH: 20MHz
- WIDE DYNAMIC RANGE: 80 dB
- LOG FUNCTION
- CURRENT AND VOLTAGE INPUTS

#### APPLICATIONS

- LOG FUNCTION
- ULTRASONIC MEASUREMENTS
- SONAR
- VIDEO LOG

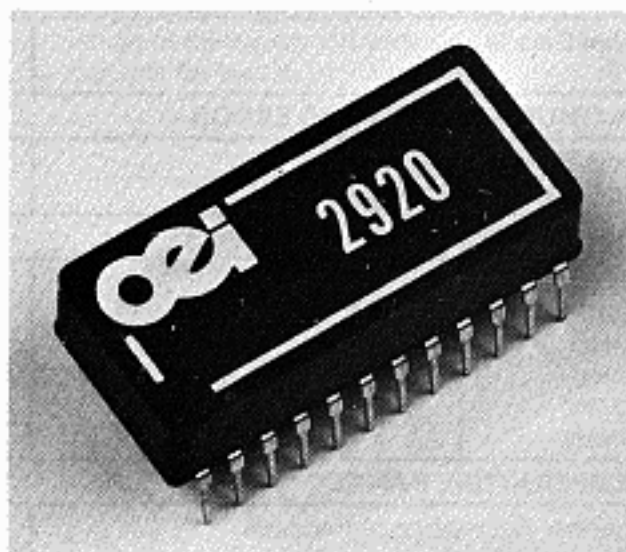
#### DESCRIPTION

The 2920 bipolar logarithmic amplifier is designed to perform logarithmic functions on the signals applied to its inputs. Its specifications make it most suitable to a variety of applications. The hybrid design, packaged in a 24 pin Dual-In-Line Package, allows use of standard sockets and takes up only a minimum of PC board real estate.

The 2920 has been designed to fill the gap that exists for logarithmic amplifiers, where wide available bandwidth and wide dynamic range at high frequencies are concerned. Most amplifiers of this kind have wide bandwidth and good dynamic range at frequencies near DC. The dynamic range of the device covers a minimum of 4 decades (80dB). Over 75% of this range (60dB) a logarithmic error of only  $\pm 0.7\%$  is typical, with a maximum error of only  $\pm 3\%$  at the upper portion of the dynamic range. The frequency response registers a full 1 to 20 MHz and the 2920 can therefore be used for a variety of video applications.

Another advantage of the design of the 2920 is the fact, that, although the device is current driven, appropriate scaling resistors, applied externally or by use of the built-in resistor, allow it to become a voltage driven amplifier.

The power supply requirements are standard  $\pm 15$  volt inputs, and range from  $\pm 5$  volts to  $\pm 20$  volts. The low power consumption, even at the maximum rated output, make the device energy efficient. The  $\pm 100$  to  $\pm 400$  mV output range can



be scaled to any requirements with the addition of an operational amplifier.

The 2920 can easily be compensated with the application of a single capacitor. Because of the influence of this capacitor on the dynamic range and frequency response, performance can easily be shaped to fit even filtering applications. As would be expected an increase in capacitance decreases the bandwidth of the device.

The 2920 finds applications in video and audio compression circuits and any other place where a logarithmic function is required. The wide frequency range also makes it ideal for ultrasonic measurements and in sonar devices.

# SPECIFICATIONS

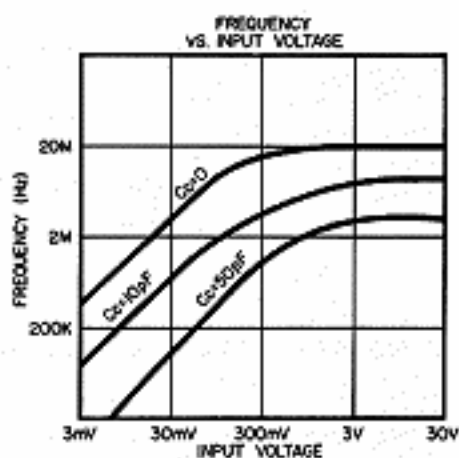
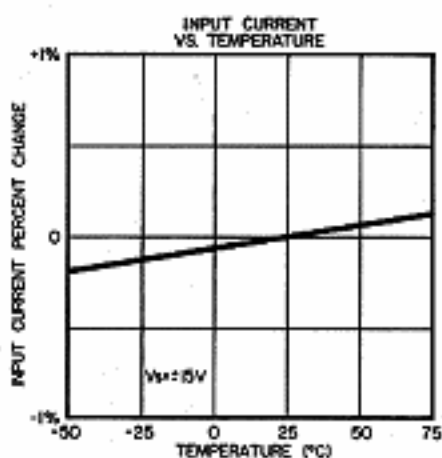
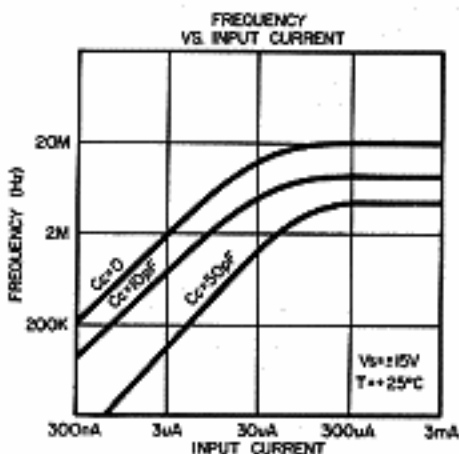
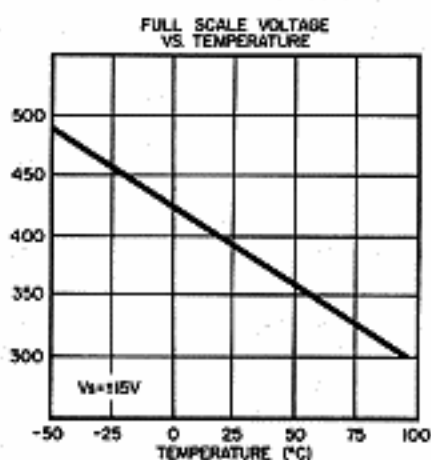
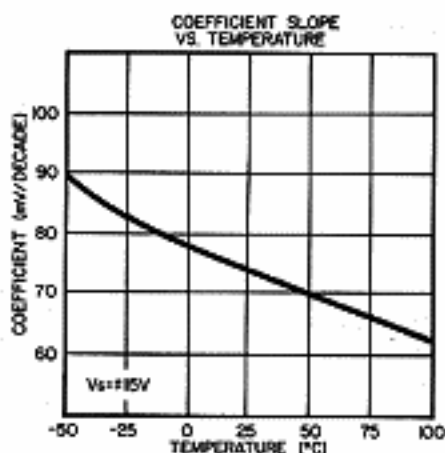
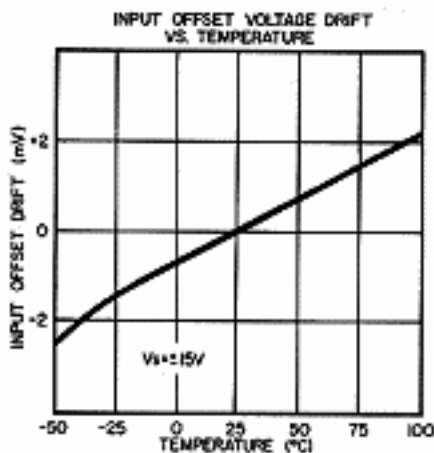
## ELECTRICAL

Specifications at  $T_A = +25^{\circ}\text{C}$ ,  $V_{CC} = \pm 15\text{VDC}$  unless otherwise noted.

MODEL		2920		
PARAMETER	MIN	TYP	MAX	UNITS
<b>DYNAMIC RANGE</b>				
	80			dB
<b>RATED OUTPUT</b>				
Voltage	$\pm 100$		$\pm 400$	mV
Current	$\pm 1$			mA
Dynamic Resistance			3	$\Omega$
Output Coefficient		75		mV
Temperature Coefficient		-1.6		$\text{mV}/^{\circ}\text{C}$
<b>INPUT</b>				
Dynamic Range	$\pm 3 \times 10^{-3}$		$\pm 3 \times 10^{-7}$	A
Dynamic Range			$\pm 3.0$	mV
Resistance Current Input			1	$\Omega$
Resistance Voltage Input		1000		$\Omega$
Polarity		Bipolar		
<b>INPUT OFFSET VOLTAGE</b>				
Initial Offset		ADJ		
Drift			$\pm 100$	$\mu\text{V}/^{\circ}\text{C}$
<b>INPUT BIAS CURRENT</b>				
Initial Bias		$\pm 30$		nA
Drift			$\pm 10$	$\text{nA}/^{\circ}\text{C}$
<b>MAXIMUM LOGARITHMIC ERROR</b>				
80dB Dynamic Range		1	3	%
60dB Dynamic Range		0.7		%
<b>FREQUENCY RESPONSE</b>				
10KHz	80			dB
100KHz	80			dB
1MHz	50			dB
3MHz	40			dB
10MHz	30			dB
20MHz	20			dB
<b>TEMPERATURE RANGE</b>				
Thermal Resistance of Package				CW
Quiescent Temperature Rise				$^{\circ}\text{C}$
Operating	-25		+85	$^{\circ}\text{C}$
Storage	-55		+150	$^{\circ}\text{C}$
<b>POWER SUPPLY</b>				
Rated Voltage	$\pm 5$	$\pm 15$	$\pm 20$	V
Current Quiescent		+12/-10		mA

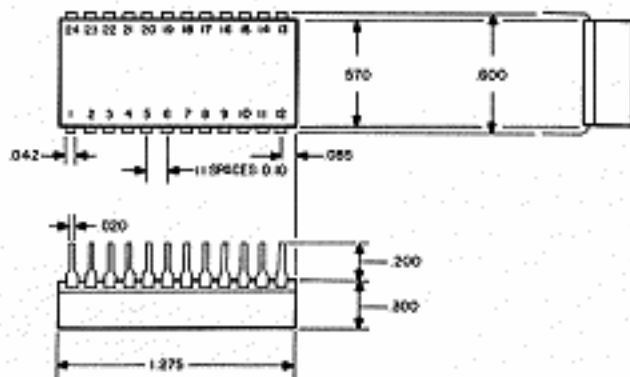
# 2920 TYPICAL PERFORMANCE CURVES

( $T_A = +25^\circ\text{C}$ ,  $V_{CC} = \pm 15\text{VDC}$  unless otherwise noted)

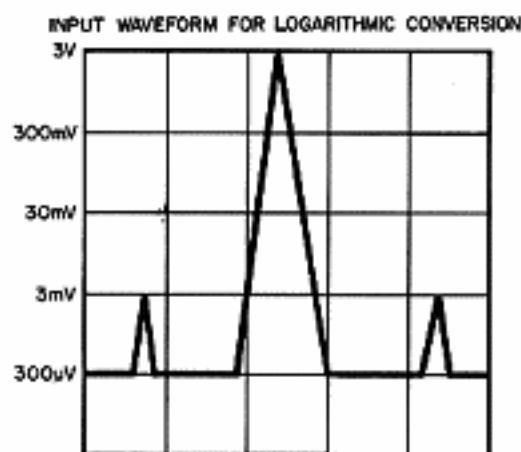


**MECHANICAL DESCRIPTION:** The 2920 is a standard 24-pin DIP. It uses glass-fiber-filled diallyl-phthalate cases with an epoxy encapsulant.

PIN CONNECTIONS	
3	COMMON
5	CURRENT IN
7	IK-R
9	TRIM
10	TRIM
12	-V SUPPLY
17	OUTPUT
19	COMPENSATION
24	+V SUPPLY



There are some misconceptions regarding the operation and function of logarithmic amplifiers. To explain this a bit better, the following figure is provided.



The vertical axis shows an input signal voltage of a given frequency. The horizontal axis indicates a time axis. No particular scale is shown because this axis is only representative. The voltage is a positive going signal that uses a +300µV offset with alternative spikes ranging to 3mV and 3V. It must be remembered that the logarithm of 0 is not defined and if a signal is suspected to go to a zero value, a small positive DC offset must be introduced.

If one assumes that a 30dB dynamic range is used, the 3V input signal will be represented by a 400mV output.

The 3mV signal is then 3 decades down from the 3V which translates to a 225mV difference so that the output appears as 400mV - 225mV = 175mV.

The advantage of the OEI devices is their ability to do logarithmic conversions at frequencies to 20MHz. Devices with outstanding DC characteristics abound on the market, but none is capable of operations at higher frequencies.

## INTRODUCTION

The 2920 bipolar logarithmic amplifier can be employed when a logarithmic function is required. Since the device is current driven, the input voltage to the device must be converted to a current by use of internal or external resistors. Input current levels range from 300 nanoamps to 3 milliamps and this 80dB range provides output voltages between 100 and 400 millivolts with an output coefficient of 75 mV/decade. The output follows the ideal logarithmic function with a high accuracy up to 20 MHz for small signals.

## THEORY OF OPERATION

The 2920 is basically an operational amplifier with diodes in its feedback loop. Thus, advantage is taken of the exponential relationship

between current and voltage exhibited by a pn junction.

The relationship of current through the diode and the voltage across it can be expressed by,

$$i_f = I_0 (e^{V_f/K} - 1)$$

where  $i_f$  current through diode

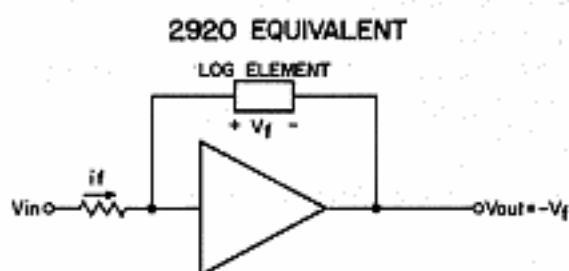
$I_0$  reverse current

$V_f$  voltage across diode

and where the factor  $K$  is dependent on junction material and temperature. If the diode is connected in the feedback-loop of an operational amplifier, the input current becomes  $i_f$  and the output voltage becomes  $V_f$  as shown in the diagram, below if it is between  $3 \times 10^{-3}$  and  $3 \times 10^{-7}$  Amp.

Since the input current  $i_f$  is equal to  $V_{in}/R$  the equation for the diode becomes:

$$V_0 = -K \ln \frac{V_{in}}{R} + K \ln I_0$$



For large enough output voltages, the exponential expression becomes very much larger than 1 and the equation can be simplified. If the natural logarithm is taken on both sides and the equation is rearranged, it reads:

$$V_0 = -K \ln \frac{V_{in}}{R} + K \ln I_0$$

This shows that the output voltage is proportional to the logarithm of the input voltage, plus a constant. The constant  $K$  as well as the inverse current  $I_0$  are constant for a constant temperature.

## APPLICATIONS

The transfer function and accuracy limitations of the 2920 are given below.

$$3 \times 10^{-7} \text{ A} \leq \frac{V_{in}}{R_{in}} \leq 3 \text{ mA}$$

$$V_0 = -K \ln \frac{V_{in}}{R_{in}} + K \ln I_0$$

$$\pm 100 \text{ mV} \leq V_0 \leq \pm 400 \text{ mV}$$

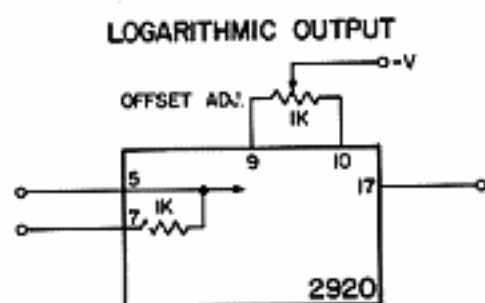
$$K = .0326 \text{ at } 25^\circ \text{C}$$

$$I_0 = 1.4 \times 10^{-8} \text{ Amp}$$

As is shown, the logarithmic relationship holds for  $V_O$  between 300 nanoamps to 3 milliamps. The constant  $K \ln I_O$  is approximately .6V at 25° C and may be subtracted to the offset adjustment.

Due to the temperature sensitivity of the pn junction  $K$  is temperature sensitive. In the transfer function,  $K$  is proportional to the temperature in degrees Kelvin. As a result, for a given input current, the output voltage will vary as a function of temperature. This behavior must also be taken into account, and appropriate means of compensation must be designed into the circuit. In the section with typical performance curves, data can be found for this purpose. For a  $\pm 25^\circ$  C temperature swing, the output voltage can vary as much as  $\pm 35$ mV.

When multiplying logarithmically the constant  $K$  will be additive and thus must be taken into account when designing with the 2920. Division of two numbers cancels the constant automatically. Conversion to logarithms of other bases can be accomplished by appropriate gain adjustment of the following stages.



For a logarithmic conversion use pin 17 to provide the output voltage  $V_O$ . A 1K ohm potentiometer (trimpot) is connected between pins 9 and 10. This offset adjustment pot must be included in any design with the 2920. The input can be applied to either pins 5 or 7. If an external resistor is used, or the input is a current, connection can be made to pin 5. However, for convenience, the 2920 also contains a 1K ohm resistor.

The offset voltage caused by some mismatch in the logarithmic elements, is small and can be adjusted by applying a bipolar signal to the input. The offset can then be adjusted, until the output swings to equal magnitude in both the positive and negative direction (dynamic trim).

## BASIC CONNECTIONS, TYPICAL APPLICATIONS.

The diagram in figure 1 shows the 2920 in the basic log connection. Pins 5 and 7 provide the input terminals and can be used for current or voltage sources. Voltage sources between  $\pm 0.3$  millivolts to  $\pm 3$  volts can make use of the internal resistor of 1K ohm

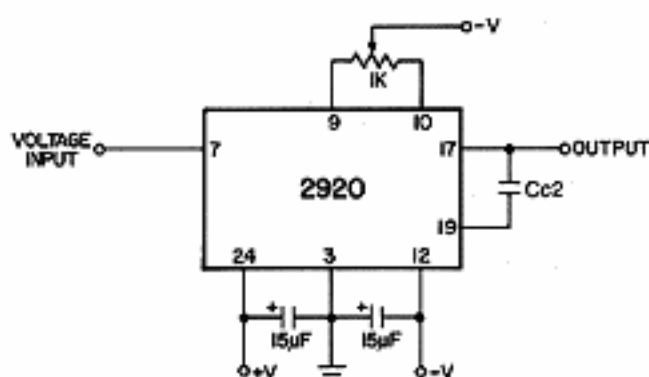


FIGURE 1: BASIC CONNECTIONS

available at pin 7. Pin 17 is the output connection. As mentioned before, the offset adjustment potentiometer, connected between pins 9, 10 and the negative power supply is mandatory. If this adjustment is not available the dynamic range of the circuit will suffer.  $C_{C2}$  is used to compensate for load capacitance.

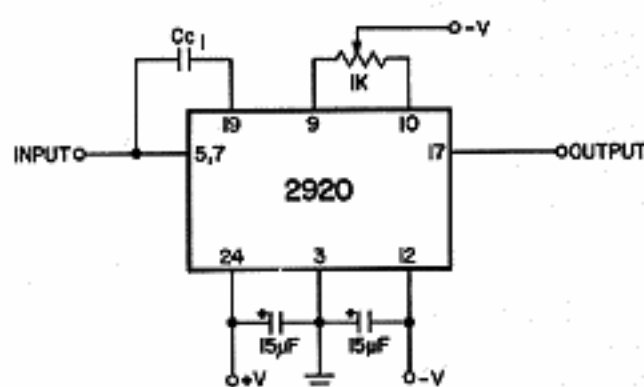


FIGURE 2: BASIC LOGARITHMIC CONNECTIONS

The diagram of figure 2 is, as the previous one, designed as a logarithmic amplifier. As shown there, input signals are applied to pins 5 or 7 with the same voltage ranges. This diagram differs from the one in figure 1 in that a compensation capacitor  $C_C$  is connected between pins 5 and 19. Polarity must be observed. This capacitor will overcompensate the 2920 and thus reduce the bandwidth the device is capable of providing. In most applications, this measure is not necessary and actually detrimental to the overall performance. However, when the circuit is particularly noisy,  $C_C$  will better the noise performance of the 2920.

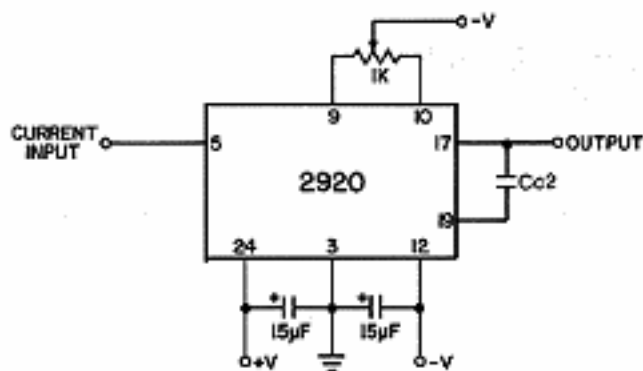


FIGURE 3: CURRENT INPUT CONNECTIONS

Figure 4 is essentially a repetition of the diagram of figure 3 except that the input is series connected to the signal source via a resistor. This then allows the source to be a voltage source. R must be selected to keep input currents inside the specified limits.

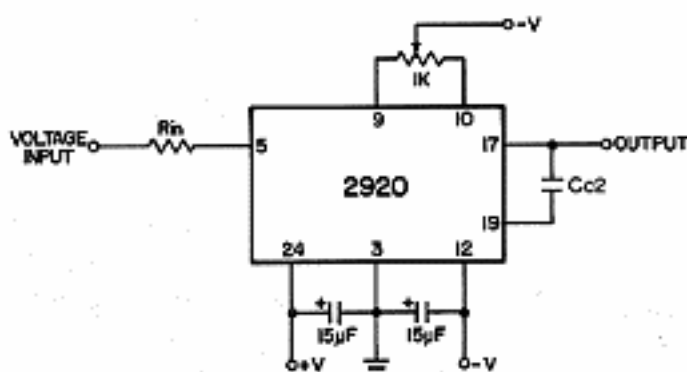


FIGURE 4: VOLTAGE INPUT CONNECTIONS

Throughout these discussions, mention has been made of the importance of the offset compensation of circuits employing the 2920. Figure 5 shows a circuit designed for cases where very

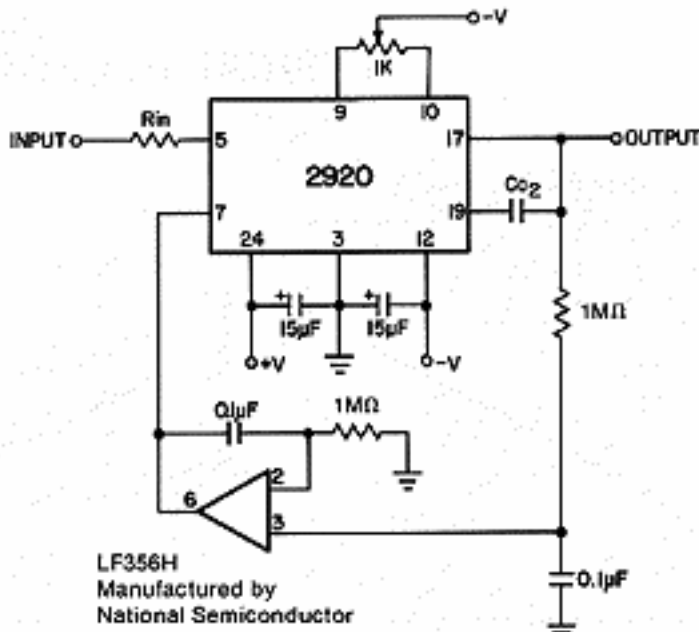


FIGURE 5: STABILIZED BIPOLAR OR LOW DUTY CYCLE PULSE LOGARITHMIC AMPLIFIER

accurate offset adjustments must be made. The circuit is a rivet circuit that allows coarse adjustment via the offset pot, which is connected between pins 9, 10 and the negative supply voltage. The input is again connected at pin 5. The output, taken off pin 17, is fed back via a 1 Megohm resistor to the input of the LF 356H operational amplifier. The .1µF capacitor shorts any possible AC voltage to ground, thus letting this input follow the average DC offset of the input. The other operational amplifier input is held at virtual ground via the 1 Megohm resistor. The output of this amplifier is connected to pin 7 of the 2920 and thus provides soft offset corrections automatically. This circuit is recommended when the dynamic range capability of the 2920 should be fully taken advantage of, for example, when processing bipolar or low duty cycle pulse signals.

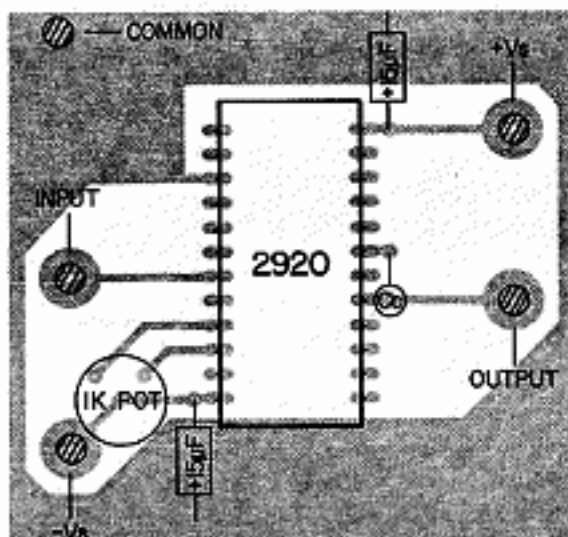


FIGURE 6: TYPICAL BOARD LAYOUT



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