Model 176 and 178 DC Amplifiers

Features*

- Drifts to <0.25µV/°C
- Input Impedance >100 MΩ
- CMR: 120 dB @ G = 1000
- Gain Linearity of ±.005%

*The key features of this amplifier series, listed above, do not necessarily apply to all units. Please check individual unit specifications.

Description

The 176 (all versions) and the 178 are general purpose differential input DC amplifiers. The best all-around unit is the 178. It features premium performance over a gain range of 1 to 1,000. With adjustable CMR, gain, and input and output offsets it truly approaches the ideal instrumentation amplifier.

Applications

Below are three typical applications showing the versatility of this instrumentation amplifier series.

Figure 1 shows the basic connections for a bridge amplifier. The bridge can be a transducer, strain gage or a load cell. The amplifier rejects the common mode voltage and noise of the bridge and only amplifies the difference between the + and - inputs. In most cases the bridge impedance is less than 1 kΩ which would make the 176 ideal.

Figure 2 shows a single ended application where the input signal has a high source impedance. Since the 178 has extremely high input impedance and low bias current, it would be the choice. Better balance and drift can be achieved by matching the source impedance with a resistor of equal value from the - input to common.

Figure 3 shows a thermocouple amplifier. By utilizing the two resistors on the inputs, the high common mode rejection of the amplifiers can be used to remove 60 Hz noise on the lines or external voltage floating on the input lines. The thermocouples can float to ±10 Volts. Since thermocouples are low impedance devices, the 176 is recommended.

Note: With either the 176 or 178 Amplifier it is required that the source common be electrically tied to signal common and the power source common. Both amplifiers are bipolar direct coupled and require a return path for the input signal current for stable operation.

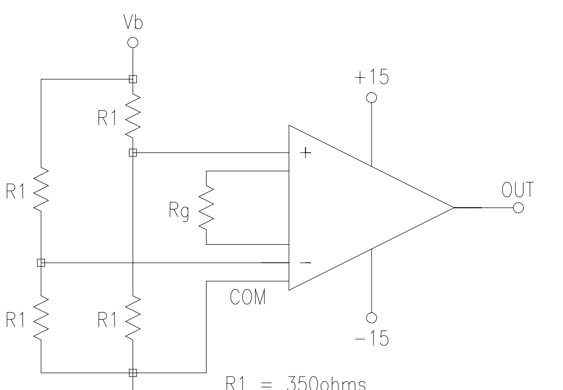

FIGURE 1. Basic Bridge Amplifier

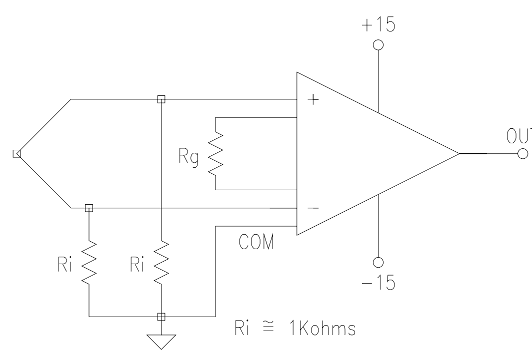

FIGURE 3. Thermocouple Amplifier

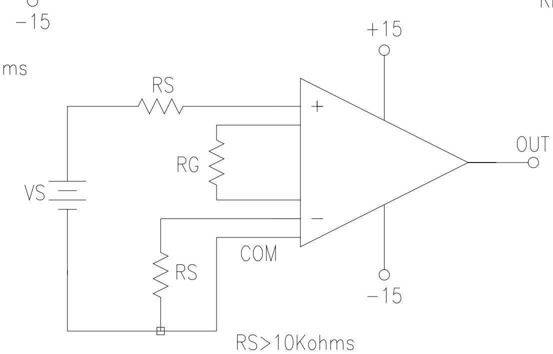

FIGURE 2. High Source Impedance Amplifier

Specifications Typical @ 25°C and ±15 VDC unless noted

Model	176J	176K	176L	178
Gain				
Range	10 to 1000			1 to 1000
Gain Formula	10 + 200 kilohm/R_g			1 + 20 kilohm/R_g
Gain Formula Accuracy	±2%	±0.2%	±0.2%	±0.2%
Gain Linearity, max.	±0.005%			
Gain Temperature Coefficient	20 ppm/°C max.			
Input				
Input Impedance - Diff.	10M			1000M
Input Impedance - CM	500M			1000M
Input Voltage Range - CM	±10V		±6V	±10V
Common Mode Rejection (CMR) DC to 60 Hz, Gain = 100	100 dB			
Input Offsets (Referred to Input)				
Initial Offsets Voltage (RTI) @ 25°C G = 1000 (Adj. to zero)	±300 µV	±100 µV	±50 µV	±300 µV
Vs. Temperature, max. G = 10	±10 µV/°C	±5 µV/°C	±3 µV/°C	±3 µV/°C
G = 1000	±3 µV/°C	±1 µV/°C	±0.25 µV/°C	±2 µV/°C
Vs. Supply, max.	50 µV/V			
Input Bias Current @ 25°C, max.	±50 nA	±40 nA	±250 nA	±10 nA
Input Difference Current Vs. Temperature, max.	±0.2 nA/°C	±0.05 nA/°C	±0.1 nA/°C	±0.03 nA/°C
Input Noise (R_s = 1 kohm)				
Voltage Noise (RTI), 0.1 Hz to 10 Hz G = 1000	0.05 µV RMS		0.01 µV RMS	
Voltage Noise (RTI), 10 Hz to 10 kHz G = 1000	5 µV RMS		1 µV RMS	
Output				
Rated Output Voltage, min.	±10V			
Current, min.	±5 mA			
Output Impedance, DC to 1 kHz	1 ohm			
Frequency Response				
Small Signal Response (E_{in} = 10 mV RMS) at G = 100 for ±1% Gain Accuracy	1 kHz min.			500 Hz min.
at G = 100, 3 dB down	10 kHz			5 kHz
Slew Rate	0.5 V/µs			0.1 V/µs
Power Supply Range				
Supply Voltage, Rated Specs	±14V to ±16V			
Quiescent Current Drain	±3.5 mA			±13 mA
Temperature Range				
Operating	-25°C to +71°C			

Mechanical Specifications

Dimensions given in inches.

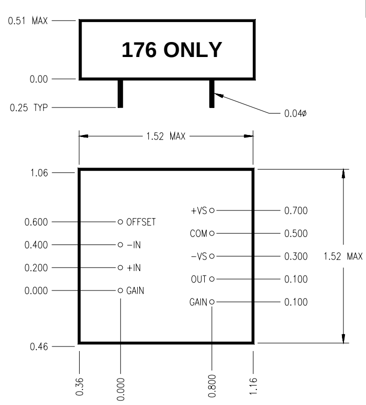

FIGURE 4.

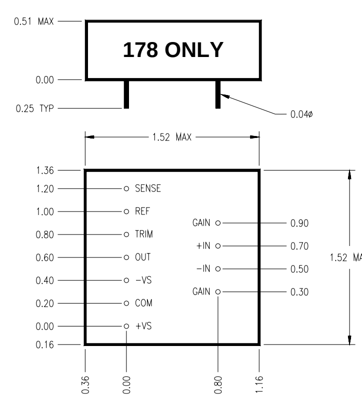

FIGURE 5.

Theory of Operation

In Figure 6, the amplifier differential gain is:

$$\frac{V_{out}}{V_1 - V_2} = 1 + \frac{R_f}{R_E} + \frac{2\,R_f}{R_g}$$

$\frac{R_f}{R_E}$ is chosen to be precisely 9 ±0.05%

Since R_f is equal to 100 kΩ, this results in a gain equation of

$$\frac{V_{out}}{V_1 - V_2} = 10 + \frac{200\ k\Omega}{R_g}$$

The accuracy of this equation depends on careful matching of the various resistors and the quality of the transistor input pair. The Model 176 uses a special input pair that is designed especially for high performance instrument amplifiers. Diodes between base and emitter provide input protection of up to ±20 Volts differential or common mode.

To provide the ultimate in CMR, a separate operational amplifier is used to feedback common-mode voltage to the input pair. A Common-mode voltage is generated across R_{cm} which is then fed into the common-mode amplifier input. This amplifier also serves as a current source for the input differential pair. Since some gain is provided by the input transistor, the op amp is operated at lower closed loop gains allowing gain linearity and bandwidth to be significantly better than when all gain is provided by a single op amp.

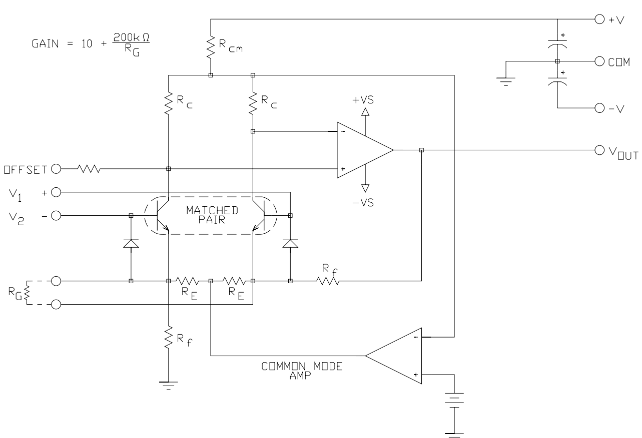

FIGURE 6. Simplified Schematic of Model 176

Frequency Response

Bode plots of the Model 176 gain for gains of 10,100 and 1000 are shown in Figure 7. The frequency response has been designed to equal a single pole roll-off with a damping ratio of approximately 0.7. This prevents a ringing response if the amplifier is used with square wave or pulse input signals. Gain error is less than ±1% and phase shift is less than 6° at frequencies lower than 1 /10 of the 3 dB down frequency for any gain. If gain accuracy of better than ±0.1 % is desired, gain magnitude should be adjusted so that the highest signal frequency to be amplified is less than 0.05 times the 3 dB down frequency.

TYPICAL SMALL SIGNAL FREQUENCY RESPONSE

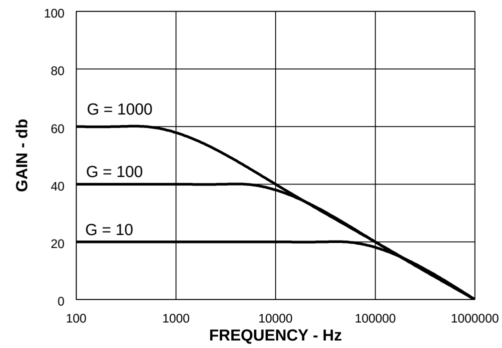

FIGURE 7.

Common Mode Rejection (CMR)

The Model 176 provides excellent CMR at DC and higher frequencies. One of the frequencies of interest is 60 Hz and it can be seen from Figure 8 that the CMR is virtually unchanged from DC to 60 Hz. Higher frequencies are important also and the Model 176 maintains good CMR to over 1 kHz. For example, it may be desired to operate a bridge circuit with an AC voltage source such as 400 Hz. The Model 176 can still function as a differential bridge amplifier with a CMR of almost 100 dB (G = 100) at that frequency.

CMR Vs. FREQUENCY

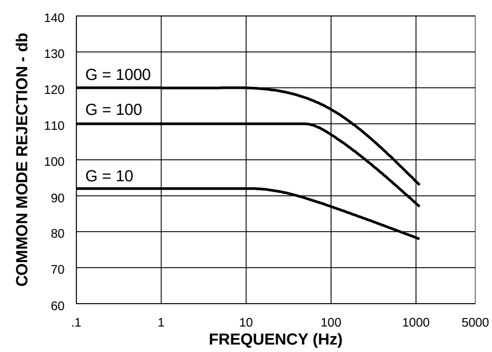

FIGURE 8.

Operation and Adjustment

Figure 10 shows pin connections for the Model 176 when used with external offset trim. Offset is quite low on the untrimmed unit and external trimming is normally not needed. If external trimming is used and ambient temperature varies widely, a potentiometer and resistor with good temperature coefficient should be used. Range of adjustment is ±3 mV referred to the input. Gain is adjusted by means of R_g which should be a low power, temperature stable, precision resistor. The wire leads to R_g should be kept as short as possible to avoid noise pickup. If it is necessary to locate R_g some distance from the amplifier, a shielded twisted pair should be used for the connection.

There must be a current path from the amplifier inputs to power supply common to allow the input bias current to flow. A floating signal source can generally be accommodated by connecting a 1 MΩ resistor between input signal ground and the amplifier common. This provides a return path for the amplifier input bias current.

Theory of Operation

The Model 178 is a committed gain amplifier with high input impedance looking into either input. A simplified block diagram is shown in Figure 9. The input stage is a matched dual IC op amp that is manufactured to CALEX specifications. The tight matching of the two high performance input amplifiers and their close physical proximity ensures excellent temperature tracking and very good rejection of common mode inputs.

The output stage is a low-drift, low-noise IC op amp. Remote sense and output reference terminals are provided at the output stage. In most applications, the sense terminal is simply connected to the amplifier output and the REF terminal is connected to the system common as shown in Figure 9; but these terminals can be used to externally trim CMR or to develop current amplifier configurations. In addition, an output offset can be applied to the amplifier by putting an offset voltage on the REF terminal.

The overall gain equation is:

$$GAIN = 1 + \frac{20\ k\Omega}{R_g}$$

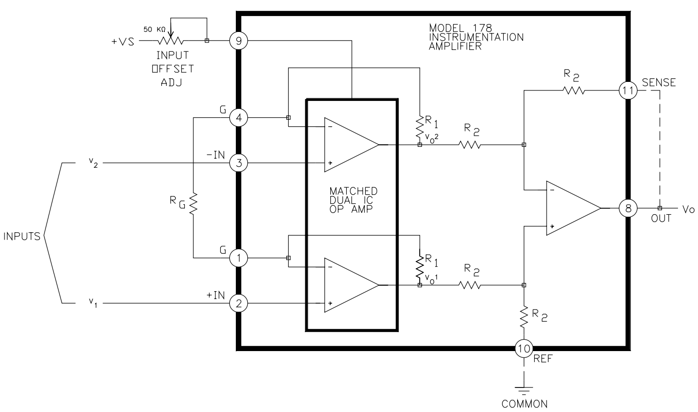

FIGURE 9. Simplified Circuit Diagram for Model 178

Description

Connections to the Model 178 are made as shown on the mounting kit (Figure 11). The gain setting impedance can be a fixed resistor or can be a potentiometer when variable gain is needed. Input offset is adjusted by means of the 50 kohm potentiometer between +15V and trim. If needed, common-mode-rejection can be externally trimmed by connecting a 249Ω resistor between sense and out and a 500Ω potentiometer between ref (pin 10) and com. The MK278 mounting kit has provisions for adjusting offset and CMR on the PC card.

Input Offset Adjustment

With gain set at any desired level above 10, connect both input leads (pins 2 and 3) to signal common (pin 6). Adjust the input offset adj pot for zero at the amplifier output. Offset at low gains is primarily due to offset of the output amplifier and will be less than +1 mV. If the amplifier gain is to be varied over a wide range, it is best to adjust input offset at the maximum gain to be used. The MK278 mounting kit has provisions for adjusting both offsets. With the amplifier connected for unity gain (open circuit between pins L and S on the connector) and the inputs connected to common, vary the output offset adj pot for zero at the amplifier output. Then connect the amplifier for the maximum gain of interest and adjust the offset by varying the input offset adj. Repeat both adjustments if necessary.

Output Offset

Offset of the output stage can be directly varied over a wide range by disconnecting the ref input pin (pin 10) from common and applying a voltage to the ref input. The output level can be adjusted over a range of +10V independent of initial offset adjustments. Source impedance of the offsetting voltage must be very low in order to not degrade CMR. The impedance at pin 10 is approximately 160 kΩ. For best results, the offsetting voltage should be supplied through an operational amplifier with low output impedance.

Gain Adjustment

The gain can be set by fixed resistors or a gain pot. Gain of the Model 178 is deliberately trimmed to be low by 3% to 5% for infinite RG, thus assuring that the amplifier can be set for unity gain. This is valid even with the external CMR adjustment circuit as shown in Figure 11. This makes the gain range somewhat greater than the nominal range of 1 to 1000. Above 100, gain is primarily determined by the 20 kΩ/R_G term, which is accurate to within ±0.2%. For Gain = 1, R_G will be 400 K to 1 megohm.

Common Mode Rejection

The key advantage of using a differential input instrumentation amplifier is its ability to reject common-mode inputs. The common-mode input generally consists of a DC component plus 60 Hz noise. To externally adjust CMR, connect the two inputs together (pins 2 and 3) and apply a low frequency ±10V sine wave. The gain should be set to the lowest value that will be used, then vary the CMR ADJ pot for minimum amplifier output. The CMR is $20 \log_{10} (A_d/A_{cm})$, where A_d is the differential gain setting and A_{cm} is the undesired common-mode gain. The Model 178 can be readily trimmed to CMR of better than 120 dB at DC.

Mounting Kits

Operation with Mounting Kit

When the Model 176 is mounted on a Model MK276 Mounting Kit, all necessary gain setting and offset adjustments are provided. A schematic and outline are shown in Figure 10. Gain can be set in several different ways. For committed gain applications, a fixed resistor may be soldered to the two terminals on the PC board. By jumpering pin L to M and pin S to N, gain may be adjusted from approximately 200 to 1000 with the fine gain adjust trimpot. By jumpering L to M, N to P and R to S, the gain may be adjusted with the fine and coarse adjust trimpots with a total gain range of about 30 to 1000. The low gain range from 10 to 30 is best accommodated by connecting a fixed resistor (10 kohms to 50 kohms) or external pot in series with the coarse gain pot.

For convenience during system checkout or troubleshooting, four testpoints are provided on the PC board which give access to both terminals and the amplifier output. They are located at the end of the board so that voltmeter or scope probes may be inserted even if a number of cards are stacked in a row.

The MK278 mounting kit has both fine and coarse gain adjustment pot. The fine gain adjustment pot can be used alone or for high gains (170 to 1000). Just connect pin L to pin M and pin N to pin S on the mounting kit. For mid-range gains (10 to 190), connect both pots in series between pins L and S. The low gain range is best accommodated by connecting a fixed resistor or external pot in series with the coarse gain pot. Also, the mounting kit has terminals on the PC board for connecting a fixed resistor. If necessary, the gain setting resistance may be located off the PC board, but this may degrade frequency response and increase the noise level. The output offset adjustment has a range of ±7.5 mV.

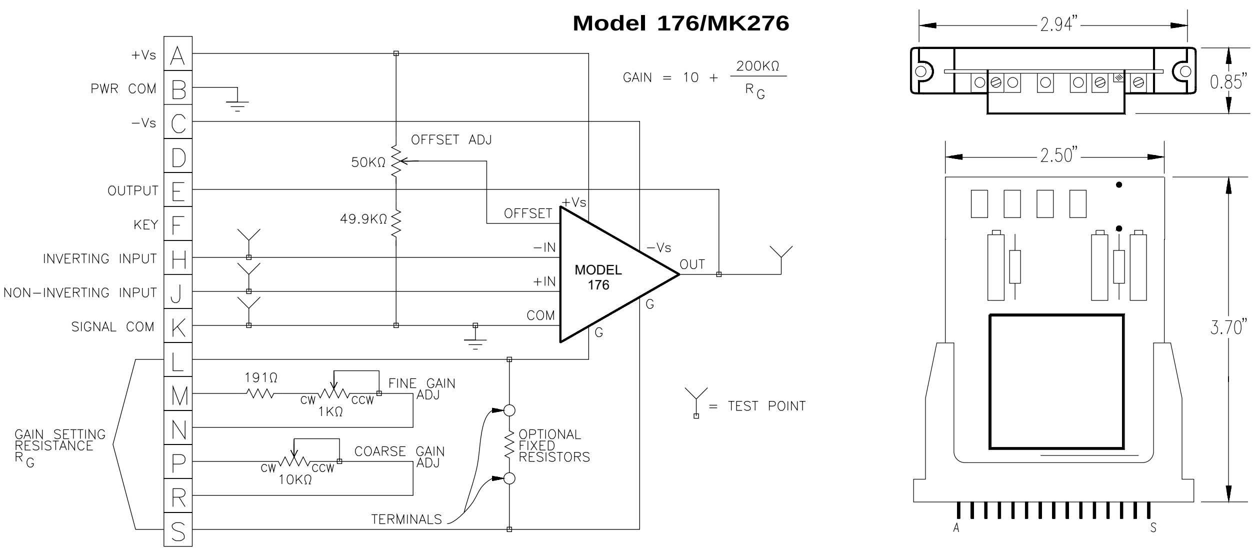

FIGURE 10. MK276 Electrical Schematic and Mechanical Outline

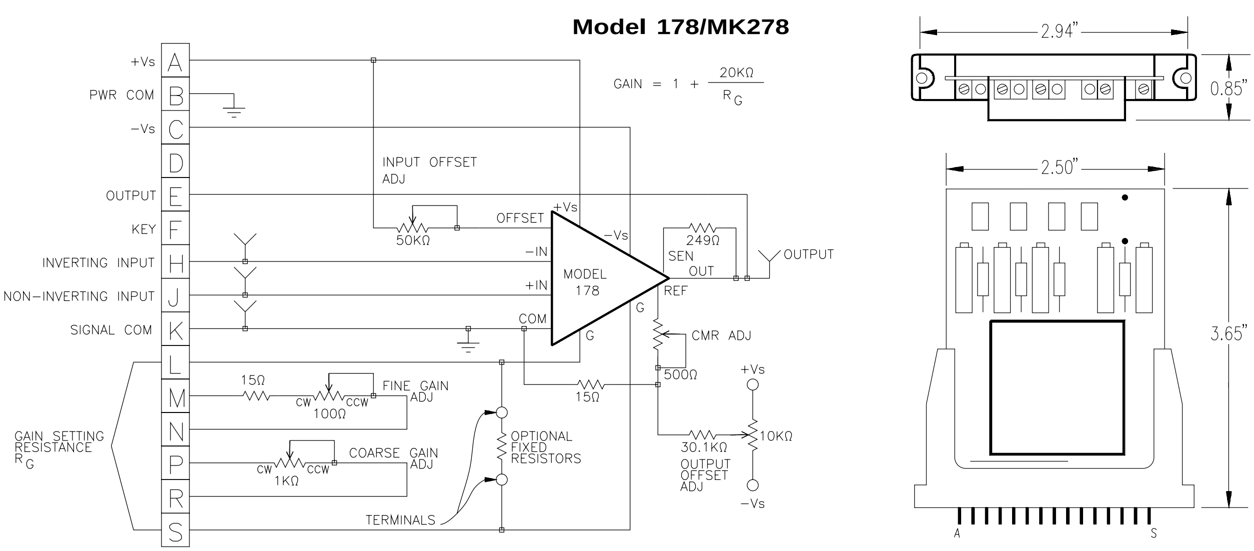

FIGURE 11. MK278 Electrical Schematic and Mechanical Outline