

LH0036/LH0036C Instrumentation Amplifier

General Description

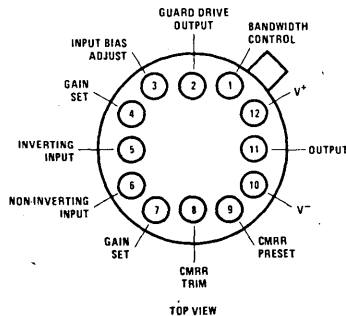
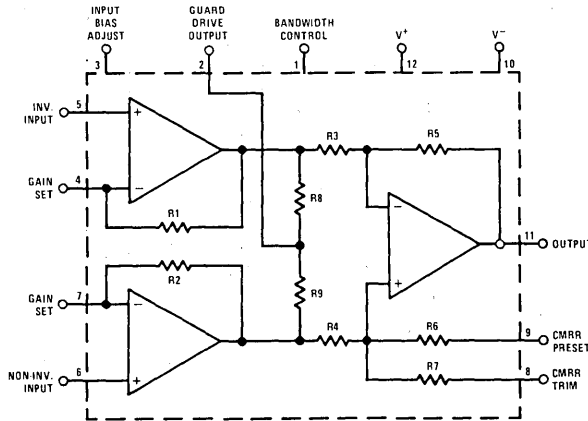
The LH0036/LH0036C is a true micro power instrumentation amplifier designed for precision differential signal processing. Extremely high accuracy can be obtained due to the 300 M Ω input impedance and excellent 100 dB common mode rejection ratio. It is packaged in a hermetic TO-8 package. Gain is programmable with one external resistor from 1 to 1000. Power supply operating range is between $\pm 1V$ and $\pm 18V$. Input bias current and output bandwidth are both externally adjustable or can be set by internally set values. The LH0036 is specified for operation over the $-55^{\circ}C$ to $+125^{\circ}C$ temperature range and the

LH0036C is specified for operation over the $-25^{\circ}C$ to $+85^{\circ}C$ temperature range.

Features

- High input impedance 300 M Ω
- High CMRR 100 dB
- Single resistor gain adjust 1 to 1000
- Low power 90 μ W
- Wide supply range $\pm 1V$ to $\pm 18V$
- Adjustable input bias current
- Adjustable output bandwidth
- Guard drive output

Equivalent Circuit and Connection Diagrams



Order Number LH0036G or LH0036CG
See NS Package H12B

Absolute Maximum Ratings

Supply Voltage	±18V	Short Circuit Duration	Continuous
Differential Input Voltage	±30V	Operating Temperature Range	LH0036 -55°C to +125°C
Input Voltage Range	±V _S	LH0036C	-25°C to +85°C
Shield Drive Voltage	±V _S	LH0036C	-65°C to +150°C
CMRR Preset Voltage	±V _S	Storage Temperature Range	-65°C to +150°C
CMRR Trim Voltage	±V _S	Lead Temperature, Soldering 10 seconds	300°C
Power Dissipation (Note 3)	1.5W		

Electrical Characteristics (Notes 1 and 2)

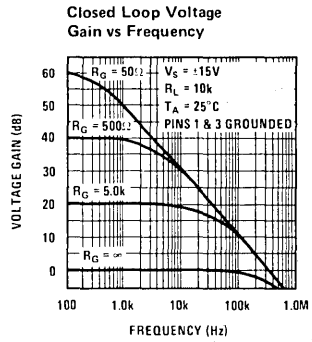
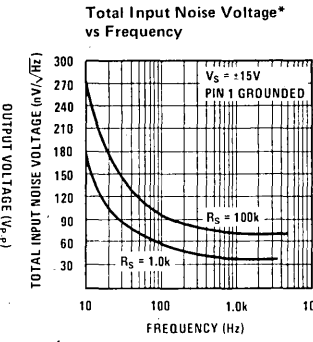
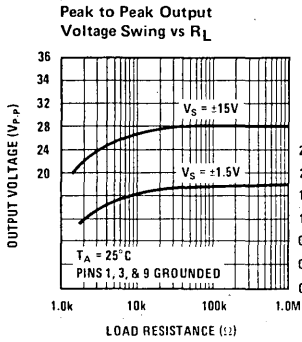
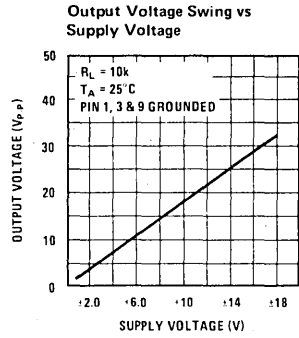
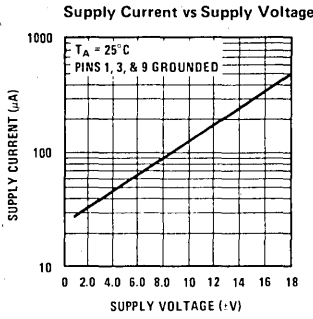
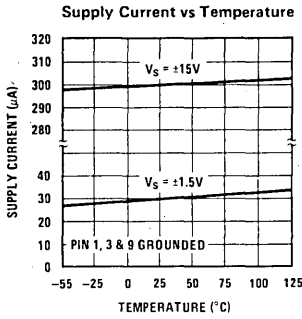
PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0036			LH0036C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage (V _{IOS})	R _S = 1.0kΩ, T _A = 25°C		0.5	1.0		1.0	2.0	mV
	R _S = 1.0kΩ			2.0			3.0	mV
Output Offset Voltage (V _{OOS})	R _S = 1.0kΩ, T _A = 25°C		2.0	5.0		5.0	10	mV
	R _S = 1.0kΩ			6.0			12	mV
Input Offset Voltage Tempco (ΔV _{IOS} /ΔT)	R _S ≤ 1.0kΩ		10			10		μV/°C
Output Offset Voltage Tempco (ΔV _{OOS} /ΔT)			15			15		μV/°C
Overall Offset Referred to Input (V _{OS})	A _V = 1.0		2.5			6.0		mV
	A _V = 10		0.7			1.5		mV
	A _V = 100		0.52			1.05		mV
	A _V = 1000		0.502			1.005		mV
Input Bias Current (I _B)	T _A = 25°C		40	100		50	125	nA
				150			200	nA
Input Offset Current (I _{OS})	T _A = 25°C		10	40		20	50	nA
				80			100	nA
Small Signal Bandwidth	A _V = 1.0, R _L = 10kΩ		350			350		kHz
	A _V = 10, R _L = 10kΩ		35			35		kHz
	A _V = 100, R _L = 10kΩ		3.5			3.5		kHz
	A _V = 1000, R _L = 10kΩ		350			350		Hz
Full Power Bandwidth	V _{IN} = ±10V, R _L = 10k, A _V = 1		5.0			5.0		kHz
Input Voltage Range	Differential	±10	±12		±10	±12		V
	Common Mode	±10	±12		±10	±12		V
Gain Nonlinearity			0.03			0.03		%
Deviation From Gain Equation Formula	A _V = 1 to 1000		±0.3	±1.0		±1.0	±3.0	%
PSRR	±5.0V ≤ V _S ≤ ±15V, A _V = 1.0		1.0	2.5		1.0	5.0	mV/V
	±5.0V ≤ V _S ≤ ±15V, A _V = 100		0.05	0.25		0.10	0.50	mV/V
CMRR	A _V = 1.0 DC to		1.0	2.5		2.5	5.0	mV/V
	A _V = 10 100 Hz		0.1	0.25		0.25	0.50	mV/V
	A _V = 100 ΔR _S = 1.0k		50	100		50	100	μV/V
Output Voltage	V _S = ±15V, R _L = 10kΩ,	±10	±13.5		±10	±13.5		V
	V _S = ±1.5V, R _L = 100kΩ	±0.6	±0.8		±0.6	±0.8		V
Output Resistance			0.5			0.5		Ω
Supply Current			300	400		400	600	μA
Equivalent Input Noise Voltage	0.1 Hz < f < 10 kHz, R _S < 50Ω		20			20		μV/p-p
Slew Rate	ΔV _{IN} = ±10V, R _L = 10kΩ, A _V = 1.0		0.3			0.3		V/μs
Settling Time	To ±10 mV, R _L = 10kΩ, ΔV _{OUT} = 1.0V							
	A _V = 1.0		3.8			3.8		μs
	A _V = 100		180			180		μs

Note 1: Unless otherwise specified, all specifications apply for V_S = ±15V, Pins 1, 3, and 9 grounded, -25°C to +85°C for the LH0036C and -55°C to +125°C for the LH0036.

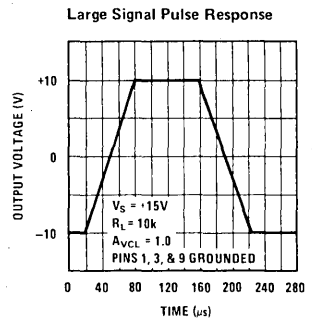
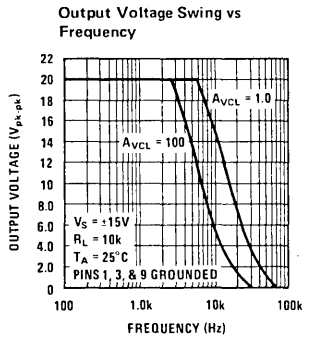
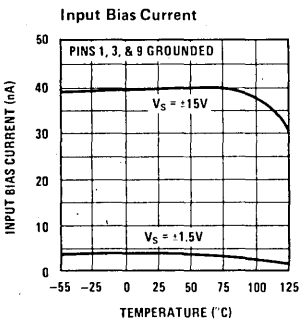
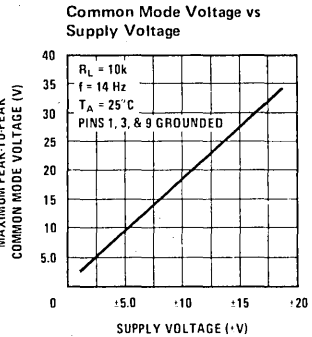
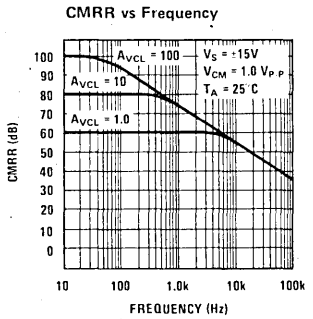
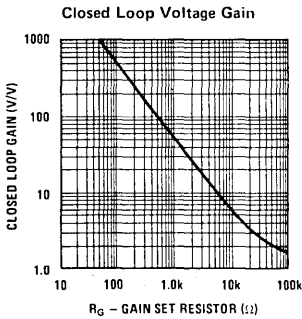
Note 2: All typical values are for T_A = 25°C.

Note 3: The maximum junction temperature is 150°C. For operation at elevated temperature derate the G package on a thermal resistance of 90°C/W, above 25°C.

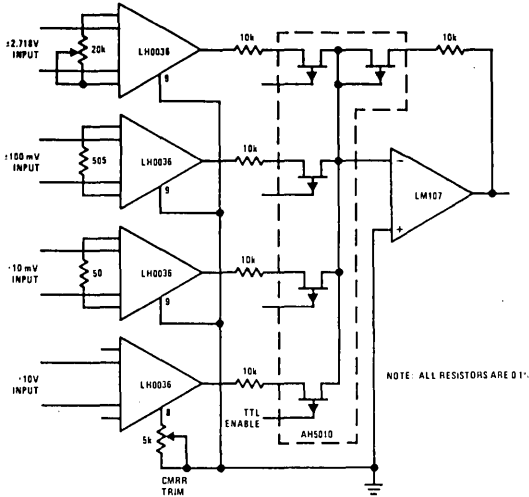
Typical Performance Characteristics



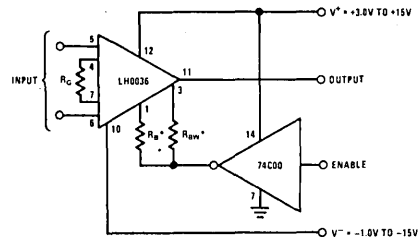
*Noise voltage includes contribution from source resistance



Typical Applications

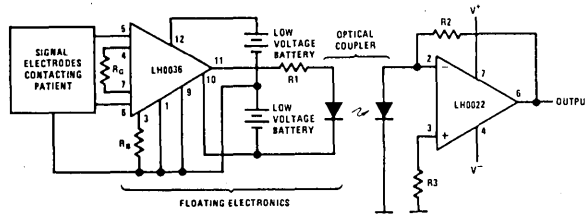


Pre MUX Signal Conditioning

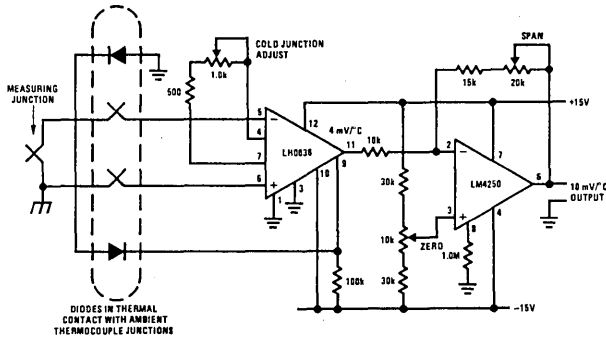


* R_{in} AND R_{fb} ARE OPTIONAL BANDWIDTH AND INPUT BIAS CURRENT CONTROLLING RESISTORS.

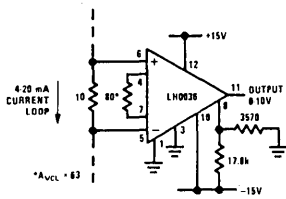
Instrumentation Amplifier with Logic Controlled Shut-Down



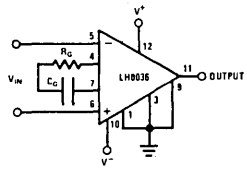
Isolation Amplifier for Medical Telemetry



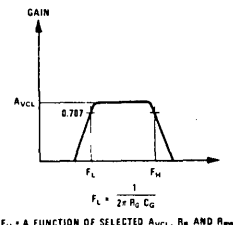
Thermocouple Amplifier with Cold Junction Compensation



Process Control Interface



High Pass Filter



$F_L = 1 / (2\pi R_1 C_1)$

Applications Information

THEORY OF OPERATION

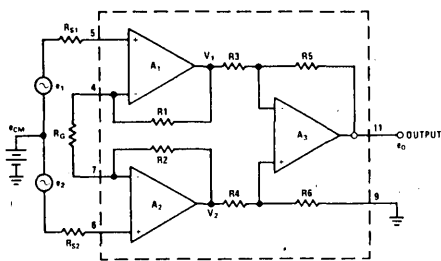


FIGURE 1. Simplified LH0036

The LH0036 is a 2 stage amplifier with a high input impedance gain stage comprised of A_1 and A_2 and a differential to single-ended unity gain stage, A_3 . Operational amplifier, A_1 , receives differential input signal, e_1 , and amplifies it by a factor equal to $(R_1 + R_G)/R_G$.

A_1 also receives input e_2 via A_2 and R_2 . e_2 is seen as an inverting signal with a gain of R_1/R_G . A_1 also receives the common mode signal e_{CM} and processes it with a gain of +1.

Hence:

$$V_1 = \frac{R_1 + R_G}{R_G} e_1 - \frac{R_1}{R_G} e_2 + e_{CM} \quad (1)$$

By similar analysis V_2 is seen to be:

$$V_2 = \frac{R_2 + R_G}{R_G} e_2 - \frac{R_2}{R_G} e_1 + e_{CM} \quad (2)$$

For $R_1 = R_2$:

$$V_2 - V_1 = \left[\left(\frac{2R_1}{R_G} \right) + 1 \right] (e_2 - e_1) \quad (3)$$

Also, for $R_3 = R_5 = R_4 = R_6$, the gain of $A_3 = 1$, and:

$$e_0 = (1)(V_2 - V_1) = (e_2 - e_1) \left[1 + \left(\frac{2R_1}{R_G} \right) \right] \quad (4)$$

As can be seen for identically matched resistors, e_{CM} is cancelled out, and the differential gain is dictated by equation (4).

For the LH0036, equation (4) reduces to:

$$A_{VCL} = \frac{e_0}{e_2 - e_1} = 1 + \frac{50k}{R_G} \quad (5a)$$

The closed loop gain may be set to any value from 1 ($R_G = \infty$) to 1000 ($R_G \cong 50\Omega$). Equation (5a) re-arranged in more convenient form may be used to select R_G for a desired gain:

$$R_G = \frac{50k}{A_{VCL} - 1} \quad (5b)$$

USE OF BANDWIDTH CONTROL (pin 1)

In the standard configuration, pin 1 of the LH0036 is simply grounded. The amplifier's slew rate in this configuration is typically $0.3V/\mu s$ and small

signal bandwidth 350 kHz for $A_{VCL} = 1$. In some applications, particularly at low frequency, it may be desirable to limit bandwidth in order to minimize the overall noise bandwidth of the device. A resistor R_{BW} may be placed between pin 1 and ground to accomplish this purpose. Figure 2 shows typical small signal bandwidth versus R_{BW} .

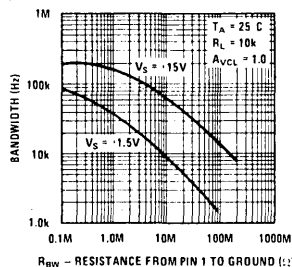


FIGURE 2. Bandwidth vs R_{BW}

It also should be noted that large signal bandwidth and slew rate may be adjusted down by use of R_{BW} . Figure 3 is plot of slew rate versus R_{BW} .

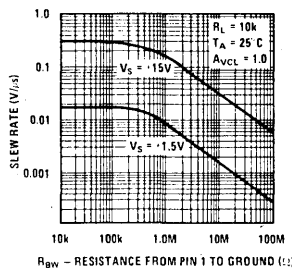


FIGURE 3. Output Slew Rate vs R_{BW}

CMRR CONSIDERATIONS

Use of Pin 9, CMRR Preset

Pin 9 should be grounded for nominal operation. An internal factory trimmed resistor, R_6 , will yield a CMRR in excess of 80 dB (for $A_{VCL} = 100$). Should a higher CMRR be desired, pin 9 should be left open and the procedure, in this section followed.

DC Off-set Voltage and Common Mode Rejection Adjustments

Off-set may be nulled using the circuit shown in Figure 4.

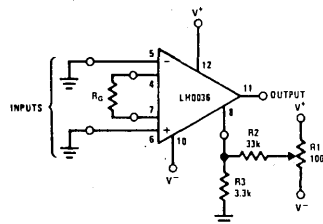


FIGURE 4. V_{OS} Adjustment Circuit

Pin 8 is also used to improve the common mode rejection ratio as shown in Figure 5. Null is

Applications Information (Cont'd)

achieved by alternately applying $\pm 10V$ (for V^+ & $V^- = 15V$) to the inputs and adjusting R1 for minimum change at the output.

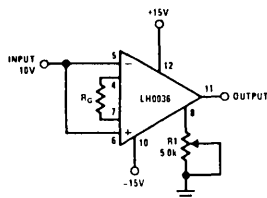


FIGURE 5. CMRR Adjustment Circuit

The circuits of Figure 4 and 5 may be combined as shown in Figure 6 to accomplish both V_{OS} and CMRR null. However, the V_{OS} and CMRR adjustment are interactive and several iterations are required. The procedure for null should start with the inputs grounded.

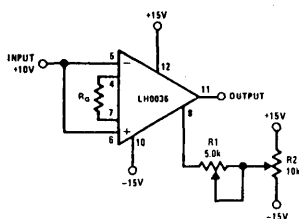
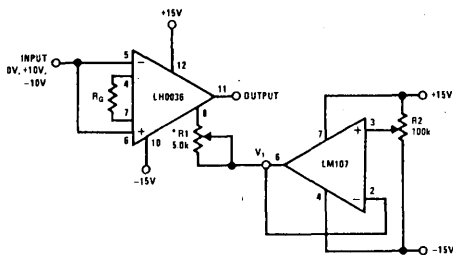


FIGURE 6. Combined CMRR, V_{OS} Adjustment Circuit

R2 is adjusted for V_{OS} null. An input of $+10V$ is then applied and R1 is adjusted for CMRR null. The procedure is then repeated until the optimum is achieved.

A circuit which overcomes adjustment interaction is shown in Figure 7. In this case, R2 is adjusted first for output null of the LH0036. R1 is then adjusted for output null with $+10V$ input. It is always a good idea to check CMRR null with a $-10V$ input. The optimum null achievable will yield the highest CMRR over the amplifiers common mode range.



* NOTE: NOMINAL VALUE R1 TO ACHIEVE OPTIMUM CMRR IS 3.0 k Ω .

FIGURE 7. Improved V_{OS} , CMRR Nulling Circuit

AC CMRR Considerations

The ac CMRR may be improved using the circuit of Figure 8.

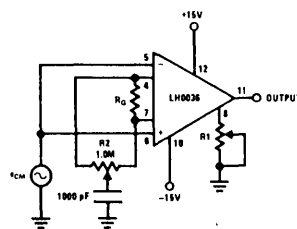


FIGURE 8. Improved AC CMRR Circuit

After adjusting R1 for best dc CMRR as before, R2 should be adjusted for minimum peak-to-peak voltage at the output while applying an ac common mode signal of the maximum amplitude and frequency of interest.

INPUT BIAS CURRENT CONTROL

Under nominal operating conditions (pin 3 grounded), the LH0036 requires input currents of 40 nA. The input current may be reduced by inserting a resistor (R_B) between 3 and ground or, alternatively, between 3 and V^- . For R_B returned to ground, the input bias current may be predicted by:

$$I_{BIAS} \approx \frac{V^+ - 0.5}{4 \times 10^8 + 800 R_B} \quad (6a)$$

or

$$R_B = \frac{V^+ - 0.5 - (4 \times 10^8) (I_{BIAS})}{800 I_{BIAS}} \quad (6b)$$

Where:

I_{BIAS} = Input Bias Current (nA)

R_B = External Resistor connected between pin 3 and ground (Ohms)

V^+ = Positive Supply Voltage (Volts)

Figure 9 is a plot of input bias current versus R_B .

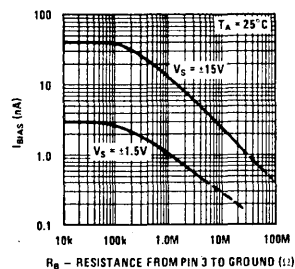


FIGURE 9. Input Bias Current as a Function of R_B

As indicated above, R_B may be returned to the negative supply voltage. Input bias current may then be predicted by:

$$I_{BIAS} \approx \frac{(V^+ - V^-) - 0.5}{4 \times 10^8 + 800 R_B}$$

Applications Information (Cont'd)

or

$$R_B \cong \frac{(V^+ - V^-) - 0.5 - (4 \times 10^8)(I_{BIAS})}{800 I_{BIAS}} \quad (8)$$

Where:

I_{BIAS} = Input Bias Current (nA)

R_B = External resistor connected between pin 3 and V^- (Ohms)

V^+ = Positive Supply Voltage (Volts)

V^- = Negative Supply Voltage (Volts)

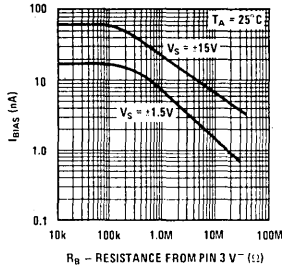


FIGURE 10. Input Bias Current as a Function of R_B

Figure 10 is a plot of input bias current versus R_B returned to V^- it should be noted that bandwidth is affected by changes in R_B . Figure 11 is a plot of bandwidth versus R_B .

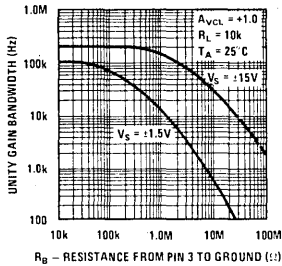


FIGURE 11. Unity Gain Bandwidth as a Function of R_B

BIAS CURRENT RETURN PATH CONSIDERATIONS

The LH0036 exhibits input bias currents typically in the 40 nA region in each input. This current must flow through R_{ISO} as shown in Figure 12.

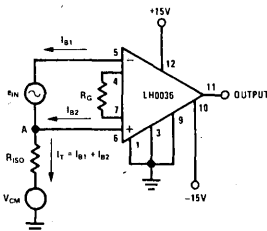


FIGURE 12. Bias Current Return Path

In a typical application, $V_S = \pm 15V$, $I_{B1} \cong I_{B2} \cong 40$ nA, the total current, I_T , would flow through R_{ISO} causing a voltage rise at point A. For values of $R_{ISO} \geq 150$ M Ω , the voltage at point A exceeds the +12V common range of the device. Clearly, for $R_{ISO} = \infty$, the LH0036 would be driven to positive saturation.

The implication is that a finite impedance must be supplied between the input and power supply ground. The value of the resistor is dictated by the maximum input bias current, and the common mode voltage. Under worst case conditions:

$$R_{ISO} \leq \frac{V_{CMR} - V_{CM}}{I_T} \quad (9)$$

Where:

V_{CMR} = Common Mode Range (10V for the LH0036)

V_{CM} = Common Mode Voltage

$I_T = I_{B1} + I_{B2}$

In applications in which the signal source is floating, such as a thermocouple, one end of the source may be grounded directly or through a resistor.

GUARD OUTPUT

Pin 2 of the LH0036 is provided as a guard drive pin in those stringent applications which require very low leakage and minimum input capacitance. Pin 2 will always be biased at the input common mode voltage. The source impedance looking into pin 2 is approximately 15 k Ω . Proper use of the guard/shield pin is shown in Figure 13.

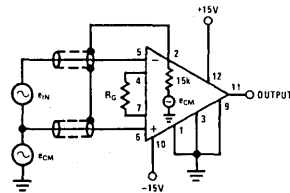


FIGURE 13. Use of Guard

For applications requiring a lower source impedance than 15 k Ω , a unity gain buffer, such as the LH0002 may be inserted between pin 2 and the input shields as shown in Figure 14.

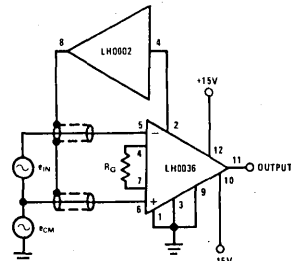


FIGURE 14. Guard Pin With Buffer

Definition of Terms

Bandwidth: The frequency at which the voltage gain is reduced to 0.707 of the low frequency (dc) value.

Closed Loop Gain, A_{VCL} : The ratio of the output voltage swing to the input voltage swing determined by $A_{VCL} = 1 + (50k/R_G)$. Where: R_G = Gain Set Resistor.

Common Mode Rejection Ratio: The ratio of input voltage range to the peak-to-peak change in offset voltage over this range.

Gain Equation Accuracy: The deviation of the actual closed loop gain from the predicted closed loop gain, $A_{VCL} = 1 + (50k/R_G)$ for the specified closed loop gain.

Input Bias Current: The current flowing at pin 5 and 6 under the specified operating conditions.

Input Offset Current: The difference between the input bias current at pins 5 and 6; i.e. $I_{OS} = |I_5 - I_6|$.

Input Stage Offset Voltage, V_{IOS} : The voltage which must be applied to the input pins to force the output to zero volts for $A_{VCL} = 100$.

Output Stage Offset Voltage, V_{OOS} : The voltage which must be applied to the input of the output stage to produce zero output voltage. It can be measured by measuring the overall offset at unity gain and subtracting V_{IOS} .

$$V_{OOS} = \left[V_{OS} \Big|_{A_{VCL} = 1} \right] - \left[V_{OS} \Big|_{A_{VCL} = 1000} \right]$$

Overall Offset Voltage:

$$V_{OS} = V_{IOS} + \frac{V_{OOS}}{A_{VCL}}$$

Power Supply Rejection Ratio: The ratio of the change in offset voltage, V_{OS} , to the change in supply voltage producing it.

Resistor, R_B : An optional resistor placed between pin 3 of the LH0036 and ground (or V^-) to reduce the input bias current.

Resistor, R_{BW} : An optional resistor placed between pin 1 of the LH0036 and ground (or V^-) to reduce the bandwidth of the output stage.

Resistor, R_G : A gain setting resistor connected between pins 4 and 7 of the LH0036 in order to program the gain from 1 to 1000.

Settling Time: The time between the initiation of an input step function and the time when the output voltage has settled to within a specified error band of the final output voltage.