LMC6482 CMOS Dual Rail-To-Rail Input and Output Operational Amplifier

Check for Samples: LMC6482

FEATURES

- **(Typical unless otherwise noted)**
- **Rail-to-Rail Input Common-Mode Voltage Range (Guaranteed Over Temperature)**
- **Rail-to-Rail Output Swing (within 20mV of supply rail, 100kΩ load)**
- **Guaranteed 3V, 5V and 15V Performance**
- **Excellent CMRR and PSRR: 82dB**
- **Ultra Low Input Current: 20fA**
- **High Voltage Gain (R_L = 500kΩ): 130dB**
- **Specified for 2kΩ and 600Ω loads**
- **Available in MSOP Package**

APPLICATIONS

- **Data Acquisition Systems**
- **Transducer Amplifiers**
- **Hand-held Analytic Instruments**
- **Medical Instrumentation**
- **Active Filter, Peak Detector, Sample and Hold, pH Meter, Current Source**
- **Improved Replacement for TLC272, TLC277**

DESCRIPTION

The LMC6482 provides a common-mode range that extends to both supply rails. This rail-to-rail performance combined with excellent accuracy, due to a high CMRR, makes it unique among rail-to-rail input amplifiers.

It is ideal for systems, such as data acquisition, that require a large input signal range. The LMC6482 is also an excellent upgrade for circuits using limited common-mode range amplifiers such as the TLC272 and TLC277.

Maximum dynamic signal range is assured in low voltage and single supply systems by the LMC6482's rail-to-rail output swing. The LMC6482's rail-to-rail output swing is guaranteed for loads down to 600Ω.

Guaranteed low voltage characteristics and low power dissipation make the LMC6482 especially well-suited for battery-operated systems.

LMC6482 is also available in MSOP package which is almost half the size of a SO-8 device.

See the LMC6484 data sheet for a Quad CMOS operational amplifier with these same features.

3V SINGLE SUPPLY BUFFER CIRCUIT

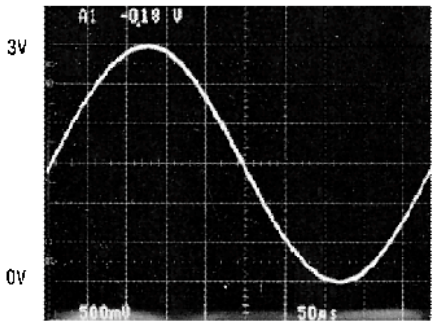


Figure 1. Rail-To-Rail Input

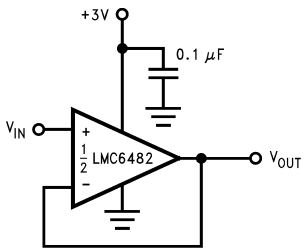


Figure 2.

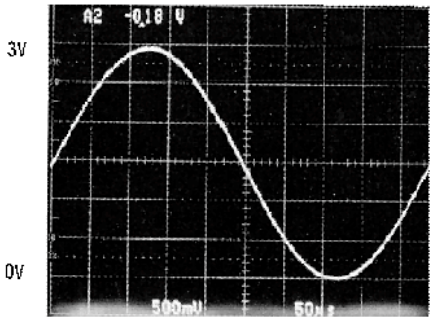
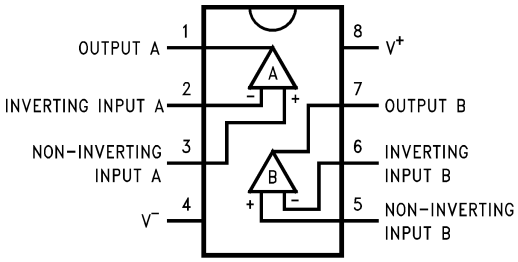


Figure 3. Rail-To-Rail Output

CONNECTION DIAGRAM



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings (1)

ESD Tolerance (2)	1.5kV
Differential Input Voltage	±Supply Voltage
Voltage at Input/Output Pin	(V^+) +0.3V, (V^-) −0.3V
Supply Voltage ($V^+ - V^-$)	16V
Current at Input Pin (3)	±5mA
Current at Output Pin (4) (5)	±30mA
Current at Power Supply Pin	40mA
Lead Temperature (Soldering, 10 sec.)	260°C
Storage Temperature Range	−65°C to +150°C
Junction Temperature (6)	150°C

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.
(2) Human body model, 1.5kΩ in series with 100pF. All pins rated per method 3015.6 of MIL-STD-883. This is a Class 1 device rating.
(3) Limiting input pin current is only necessary for input voltages that exceed absolute maximum input voltage ratings.
(4) Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C. Output currents in excess of ±30mA over long term may adversely affect reliability.
(5) Do not short circuit output to V^+, when V^+ is greater than 13V or reliability will be adversely affected.
(6) The maximum power dissipation is a function of $T_{J(max)}$, θ_{JA}, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(max)} - T_A)/\theta_{JA}$. All numbers apply for packages soldered directly into a PC board.

Operating Ratings

Supply Voltage	3.0V ≤ V+ ≤ 15.5V
Junction Temperature Range	
LMC6482AM	−55°C ≤ T_J ≤ +125°C
LMC6482AI, LMC6482I	−40°C ≤ T_J ≤ +85°C
Thermal Resistance (θ_{JA})	
N Package, 8-Pin Molded DIP	90°C/W
M Package, 8-Pin Surface Mount	155°C/W
MSOP package, 8-Pin Mini SO	194°C/W

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.

DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1M. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions		Typ (1)	LMC6482AI Limit (2)	LMC6482I Limit (2)	LMC6482M Limit (2)	Units
V_{OS}	Input Offset Voltage			0.11	0.750	3.0	3.0	mV
					1.35	**3.7**	**3.8**	max
TCV_{OS}	Input Offset Voltage Average Drift			1.0				µV/°C
I_B	Input Current	(3)		0.02	**4.0**	**4.0**	**10.0**	pA
								max
I_{OS}	Input Offset Current	(3)		0.01	**2.0**	**2.0**	**5.0**	pA
								max
C_{IN}	Common-Mode Input Capacitance			3				pF
R_{IN}	Input Resistance			>10				TeraΩ
CMRR	Common Mode Rejection Ratio	$0V \le V_{CM} \le 15.0V$ $V^+ = 15V$		82	70	65	65	dB min
					67	**62**	**60**	
		$0V \le V_{CM} \le 5.0V$ $V^+ = 5V$		82	70	65	65	
					67	**62**	**60**	
+PSRR	Positive Power Supply Rejection Ratio	$5V \le V^+ \le 15V$, $V^- = 0V$ $V_O = 2.5V$		82	70	65	65	dB
					67	**62**	**60**	min
−PSRR	Negative Power Supply Rejection Ratio	$-5V \le V^- \le -15V$, $V^+ = 0V$ $V_O = -2.5V$		82	70	65	65	dB
					67	**62**	**60**	min
V_{CM}	Input Common-Mode Voltage Range	V^+ = 5V and 15V For CMRR ≥ 50dB		V^- − 0.3	− 0.25	− 0.25	− 0.25	V
					0	**0**	**0**	max
				V^+ + 0.3V	V^+ + 0.25	V^+ + 0.25	V^+ + 0.25	V
					V^+	**V^+**	**V^+**	min
A_V	Large Signal Voltage Gain	R_L = 2kΩ (4) (5)	Sourcing	666	140	120	120	V/mV
					84	**72**	**60**	min
			Sinking	75	35	35	35	V/mV
					20	**20**	**18**	min
		R_L = 600Ω (4) (5)	Sourcing	300	80	50	50	V/mV
					48	**30**	**25**	min
			Sinking	35	20	15	15	V/mV
					13	**10**	**8**	min

(1) Typical Values represent the most likely parametric norm.
(2) All limits are guaranteed by testing or statistical analysis.
(3) Guaranteed limits are dictated by tester limitations and not device performance. Actual performance is reflected in the typical value.
(4) V^+ = 15V, V_{CM} = 7.5V and R_L connected to 7.5V. For Sourcing tests, $7.5V \le V_O \le 11.5V$. For Sinking tests, $3.5V \le V_O \le 7.5V$.
(5) Guaranteed limits are dictated by tester limitations and not device performance. Actual performance is reflected in the typical value.

DC Electrical Characteristics (continued)

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1M. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (1)	LMC6482AI Limit (2)	LMC6482I Limit (2)	LMC6482M Limit (2)	Units
V_O	Output Swing	V^+ = 5V R_L = 2kΩ to $V^+/2$	4.9	4.8	4.8	4.8	V
				4.7	**4.7**	**4.7**	min
			0.1	0.18	0.18	0.18	V
				0.24	**0.24**	**0.24**	max
		V^+ = 5V R_L = 600Ω to $V^+/2$	4.7	4.5	4.5	4.5	V
				4.24	**4.24**	**4.24**	min
			0.3	0.5	0.5	0.5	V
				0.65	**0.65**	**0.65**	max
		V^+ = 15V R_L = 2kΩ to $V^+/2$	14.7	14.4	14.4	14.4	V
				14.2	**14.2**	**14.2**	min
			0.16	0.32	0.32	0.32	V
				0.45	**0.45**	**0.45**	max
		V^+ = 15V R_L = 600Ω to $V^+/2$	14.1	13.4	13.4	13.4	V
				13.0	**13.0**	**13.0**	min
			0.5	1.0	1.0	1.0	V
				1.3	**1.3**	**1.3**	max
I_{SC}	Output Short Circuit Current V^+ = 5V	Sourcing, V_O = 0V	20	16	16	16	mA
				12	**12**	**10**	min
		Sinking, V_O = 5V	15	11	11	11	mA
				9.5	**9.5**	**8.0**	min
I_{SC}	Output Short Circuit Current V^+ = 15V	Sourcing, V_O = 0V	30	28	28	28	mA
				22	**22**	**20**	min
		Sinking, V_O = 12V (6)	30	30	30	30	mA
				24	**24**	**22**	min
I_S	Supply Current	Both Amplifiers V^+ = +5V, $V_O = V^+/2$	1.0	1.4	1.4	1.4	mA
				1.8	**1.8**	**1.9**	max
		Both Amplifiers V^+ = 15V, $V_O = V^+/2$	1.3	1.6	1.6	1.6	mA
				1.9	**1.9**	**2.0**	max

(6) Do not short circuit output to V^+, when V^+ is greater than 13V or reliability will be adversely affected.

AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5V, V^- = 0V, $V_{CM} = V_O = V^+/2$, and R_L > 1M. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (1)	LMC6482AI Limit (2)	LMC6482I Limit (2)	LMC6482M Limit (2)	Units
SR	Slew Rate	(3)	1.3	1.0	0.9	0.9	V/µs
				0.7	**0.63**	**0.54**	min
GBW	Gain-Bandwidth Product	V^+ = 15V	1.5				MHz
φ_m	Phase Margin		50				Deg

(1) Typical Values represent the most likely parametric norm.
(2) All limits are guaranteed by testing or statistical analysis.
(3) V^+ = 15V. Connected as Voltage Follower with 10V step input. Number specified is the slower of either the positive or negative slew rates.

AC Electrical Characteristics (continued)

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5V, V^- = 0V, $V_{CM} = V_O = V^+/2$, and R_L > 1M. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (1)	LMC6482AI Limit (2)	LMC6482I Limit (2)	LMC6482M Limit (2)	Units
G_m	Gain Margin		15				dB
	Amp-to-Amp Isolation	(4)	150				dB
e_n	Input-Referred Voltage Noise	F = 1kHz V_{cm} = 1V	37				nV/√Hz
I_n	Input-Referred Current Noise	F = 1kHz	0.03				pA/√Hz
T.H.D.	Total Harmonic Distortion	F = 10kHz, A_V = −2 R_L = 10kΩ, V_O = 4.1 V_{PP}	0.01				%
		F = 10kHz, A_V = −2 R_L = 10kΩ, V_O = 8.5 V_{PP} V^+ = 10V	0.01				%

(4) Input referred, V^+ = 15V and R_L = 100 kΩ connected to 7.5V. Each amp excited in turn with 1 kHz to produce V_O = 12 V_{PP}.

DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 3V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1M.

Symbol	Parameter	Conditions	Typ (1)	LMC6482AI Limit (2)	LMC6482I Limit (2)	LMC6482M Limit (2)	Units
V_{OS}	Input Offset Voltage		0.9	2.0	3.0	3.0	mV
				2.7	**3.7**	**3.8**	max
TCV_{OS}	Input Offset Voltage Average Drift		2.0				µV/°C
I_B	Input Bias Current		0.02				pA
I_{OS}	Input Offset Current		0.01				pA
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 3V	74	64	60	60	dB min
PSRR	Power Supply Rejection Ratio	3V ≤ V^+ ≤ 15V, V^- = 0V	80	68	60	60	dB min
V_{CM}	Input Common-Mode Voltage Range	For CMRR ≥ 50dB	V^- −0.25	0	0	0	V max
			V^+ + 0.25	V^+	V^+	V^+	V min
V_O	Output Swing	R_L = 2kΩ to $V^+/2$	2.8				V
			0.2				V
		R_L = 600Ω to $V^+/2$	2.7	2.5	2.5	2.5	V min
			0.37	0.6	0.6	0.6	V max
I_S	Supply Current	Both Amplifiers	0.825	1.2	1.2	1.2	mA
				1.5	**1.5**	**1.6**	max

(1) Typical Values represent the most likely parametric norm.
(2) All limits are guaranteed by testing or statistical analysis.

AC Electrical Characteristics

Unless otherwise specified, $V^+ = 3V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$, and $R_L > 1M$.

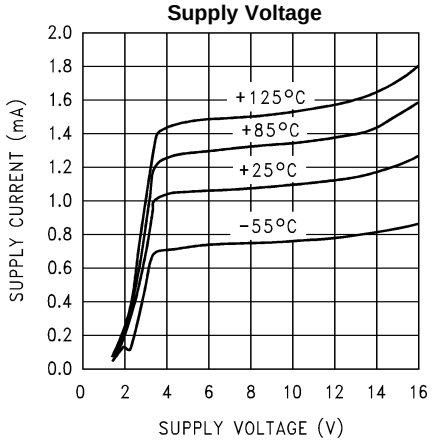
Symbol	Parameter	Conditions	Typ(1)	LMC6482AI	LMC6482I	LMC6482M	Units
				Limit(2)	Limit(2)	Limit(2)	
SR	Slew Rate	(3)	0.9				V/µs
GBW	Gain-Bandwidth Product		1.0				MHz
T.H.D.	Total Harmonic Distortion	F = 10kHz, $A_V = -2$ $R_L = 10k\Omega$, $V_O = 2\ V_{PP}$	0.01				%

(1) Typical Values represent the most likely parametric norm.
(2) All limits are guaranteed by testing or statistical analysis.
(3) Connected as voltage Follower with 2V step input. Number specified is the slower of either the positive or negative slew rates.

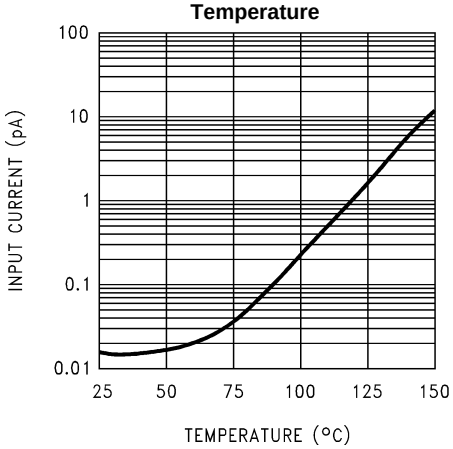
Typical Performance Characteristics

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

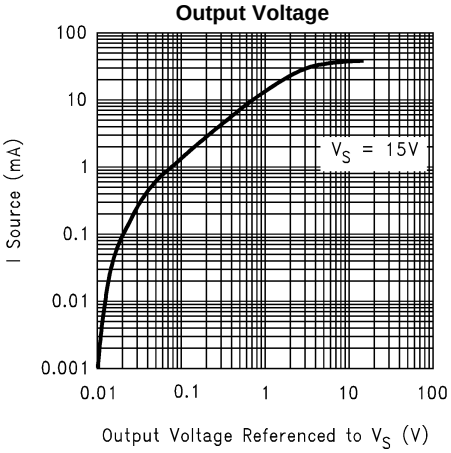
Supply Current vs. Supply Voltage



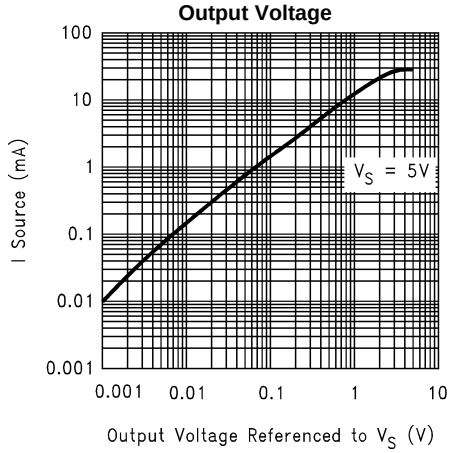
Input Current vs. Temperature



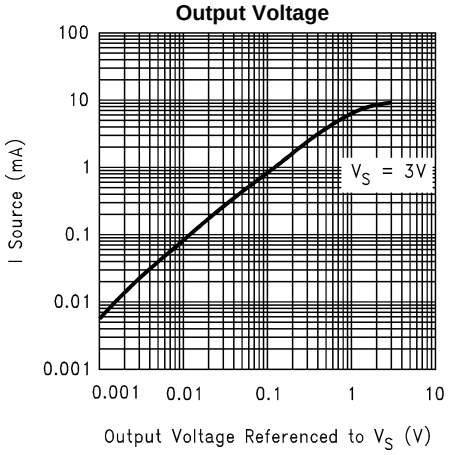
Sourcing Current vs. Output Voltage



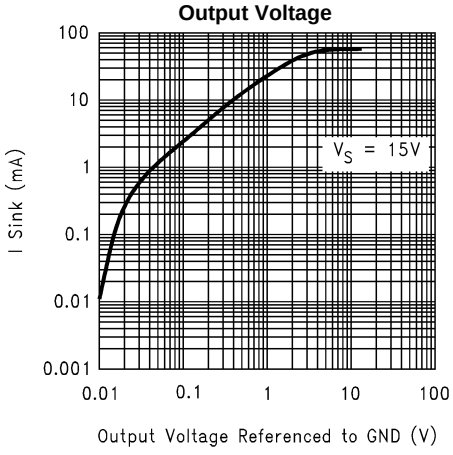
Sourcing Current vs. Output Voltage



Sourcing Current vs. Output Voltage



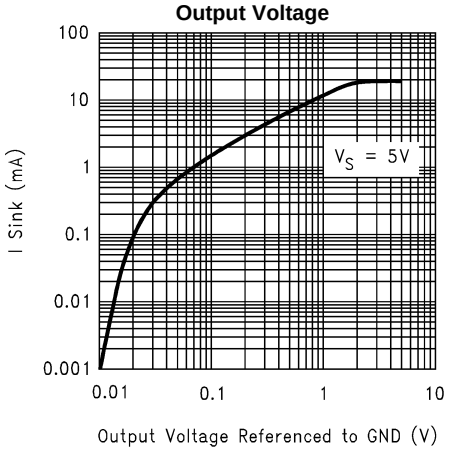
Sinking Current vs. Output Voltage



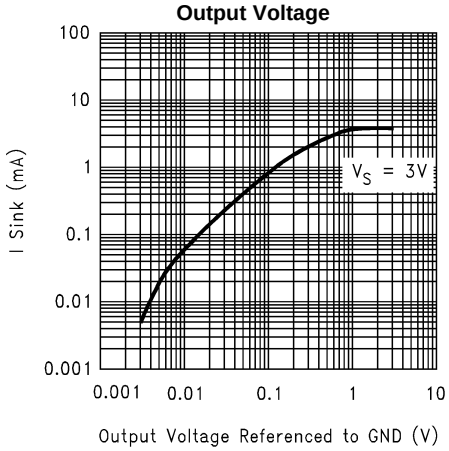
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

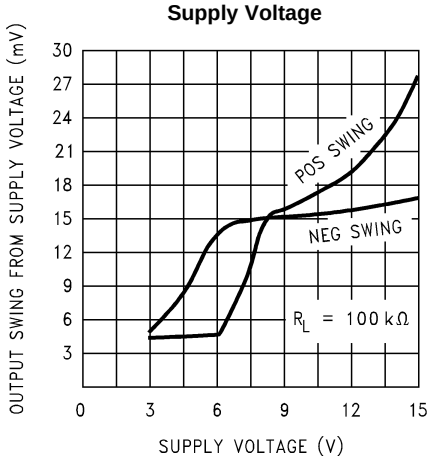
Sinking Current vs. Output Voltage



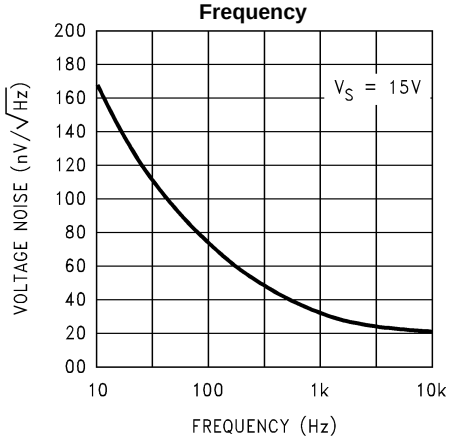
Sinking Current vs. Output Voltage



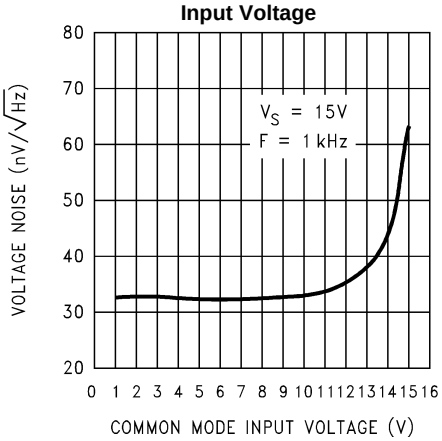
Output Voltage Swing vs. Supply Voltage



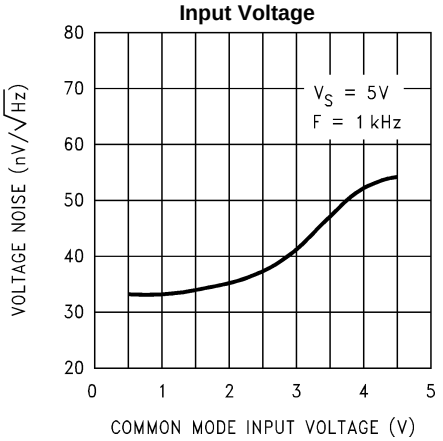
Input Voltage Noise vs. Frequency



Input Voltage Noise vs. Input Voltage



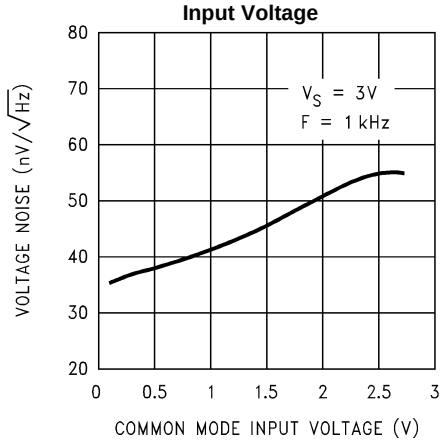
Input Voltage Noise vs. Input Voltage



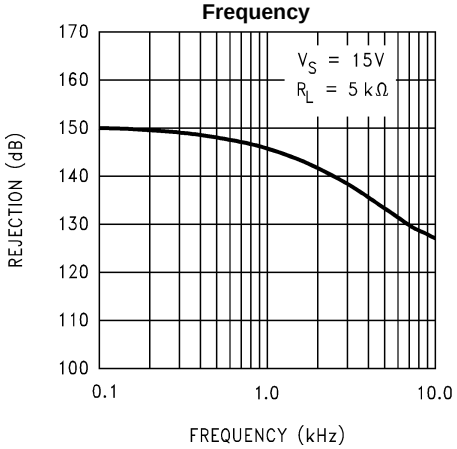
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

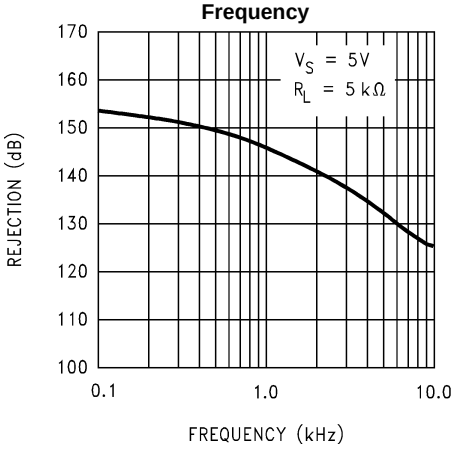
Input Voltage Noise vs. Input Voltage



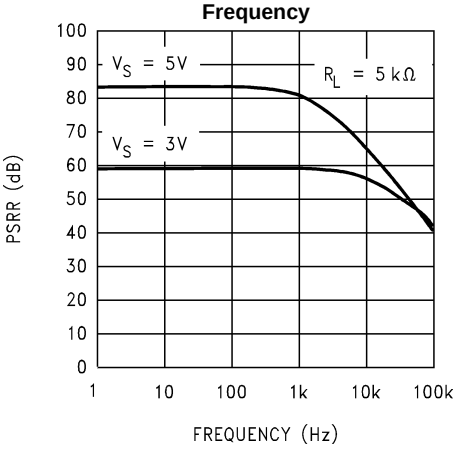
Crosstalk Rejection vs. Frequency



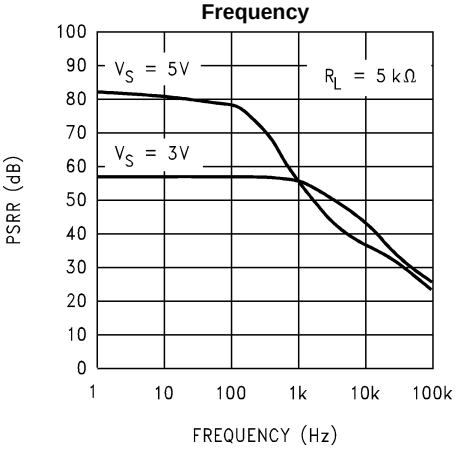
Crosstalk Rejection vs. Frequency



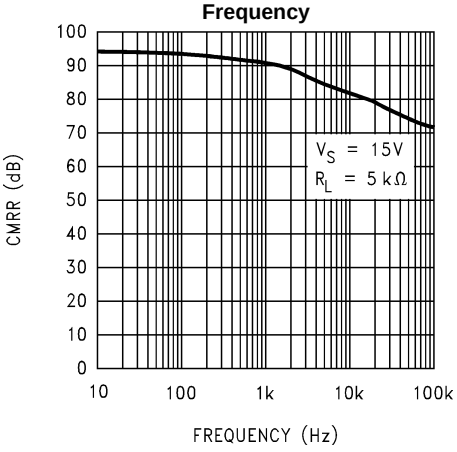
Positive PSRR vs. Frequency



Negative PSRR vs. Frequency



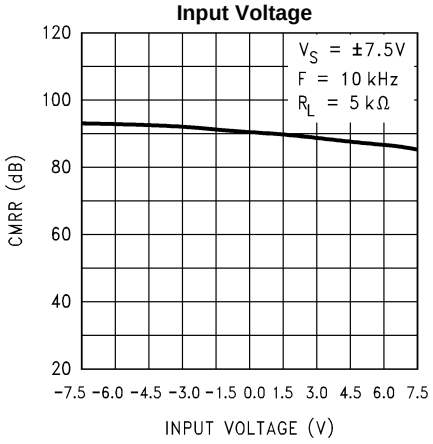
CMRR vs. Frequency



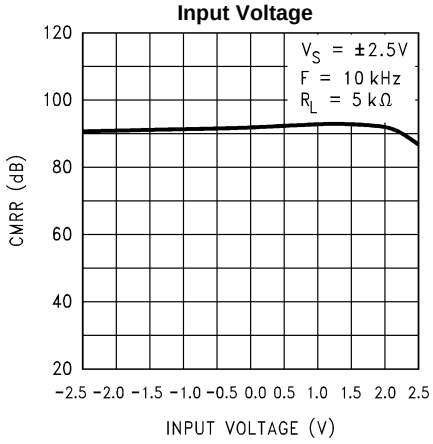
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

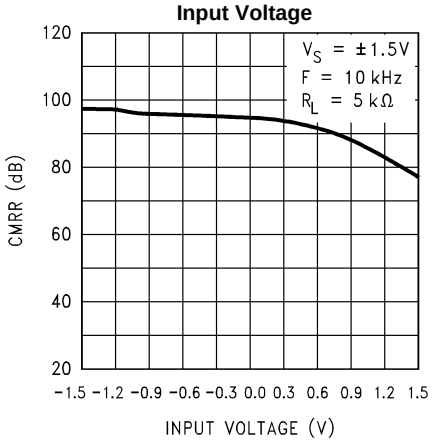
CMRR vs. Input Voltage



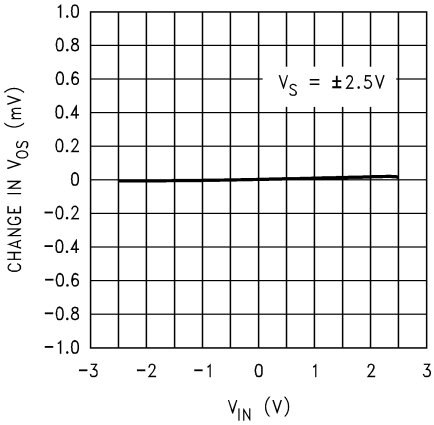
CMRR vs. Input Voltage



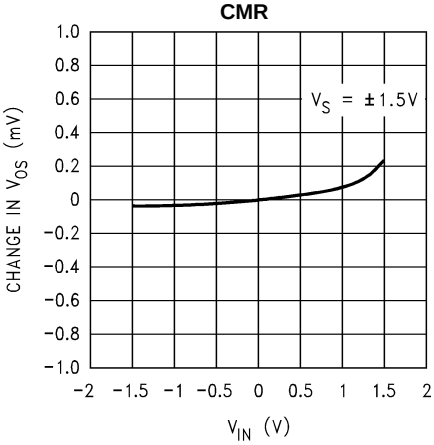
CMRR vs. Input Voltage



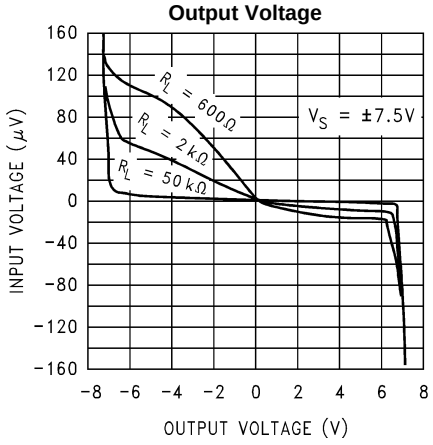
ΔV_{OS} vs. CMR



ΔV_{OS} vs. CMR



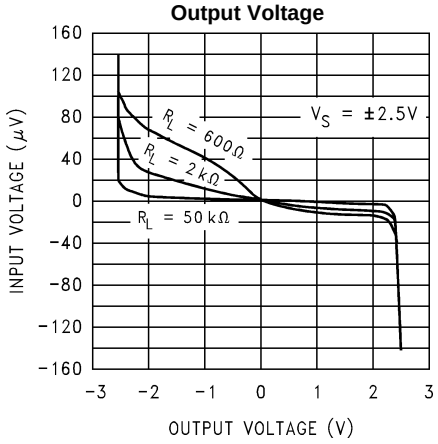
Input Voltage vs. Output Voltage



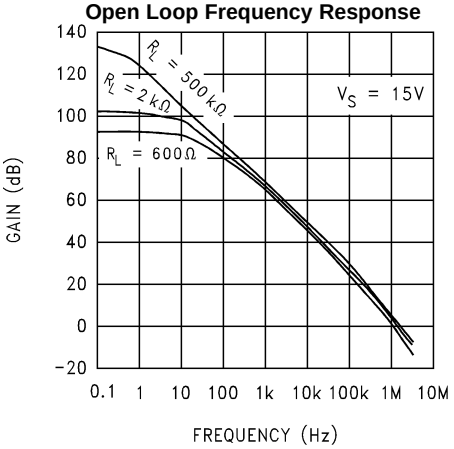
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

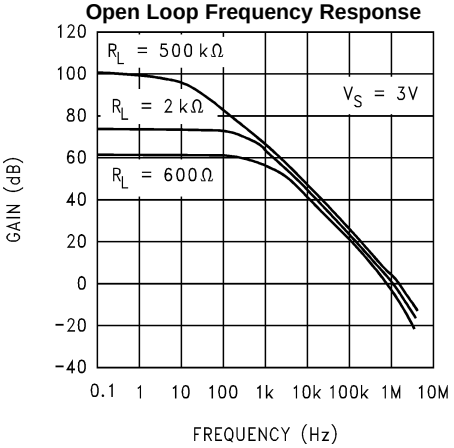
Input Voltage vs. Output Voltage



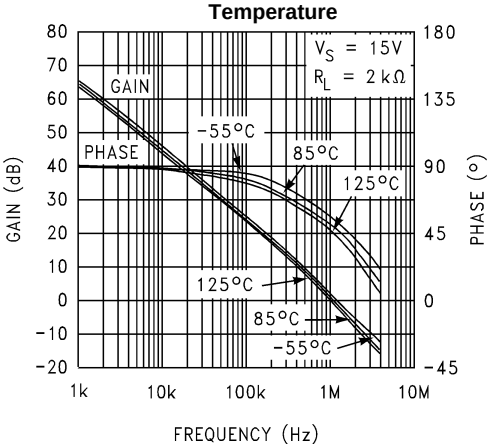
Open Loop Frequency Response



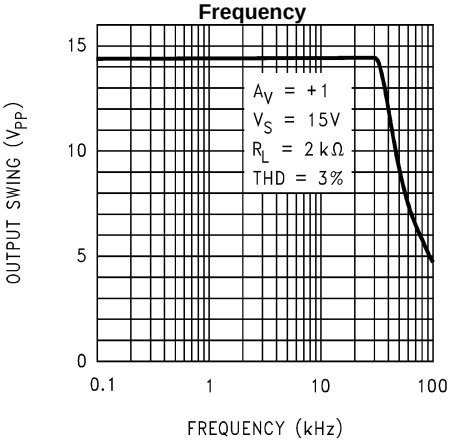
Open Loop Frequency Response



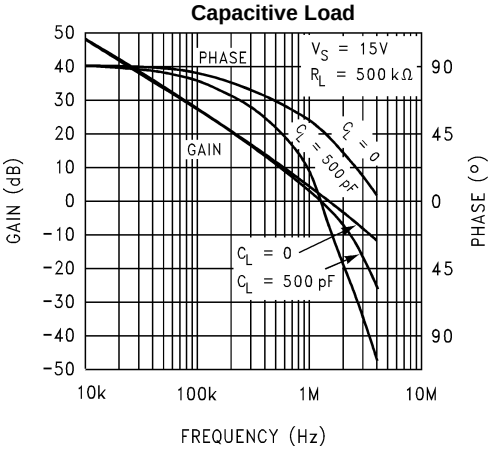
Open Loop Frequency Response vs. Temperature



Maximum Output Swing vs. Frequency



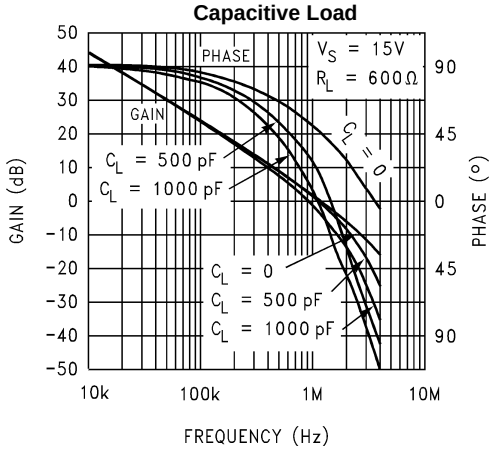
Gain and Phase vs. Capacitive Load



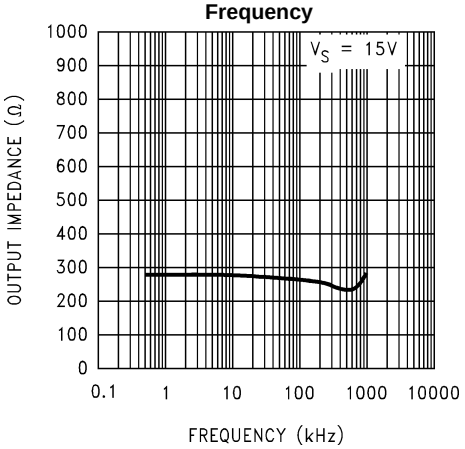
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

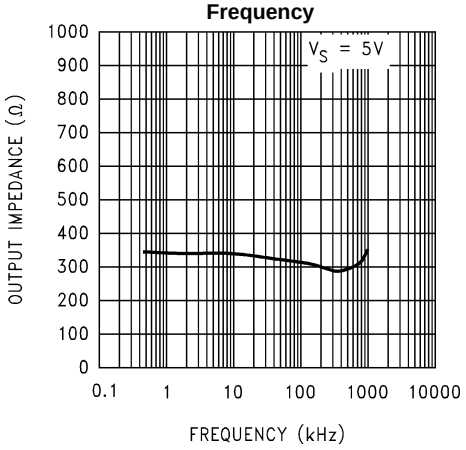
Gain and Phase vs. Capacitive Load



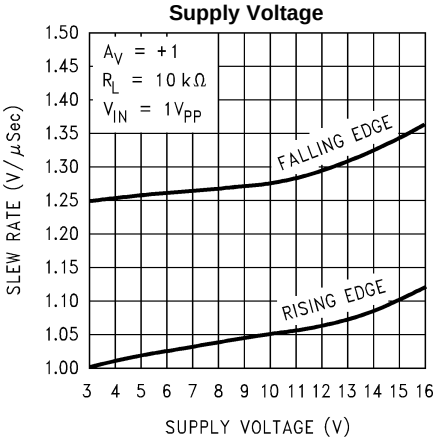
Open Loop Output Impedance vs. Frequency



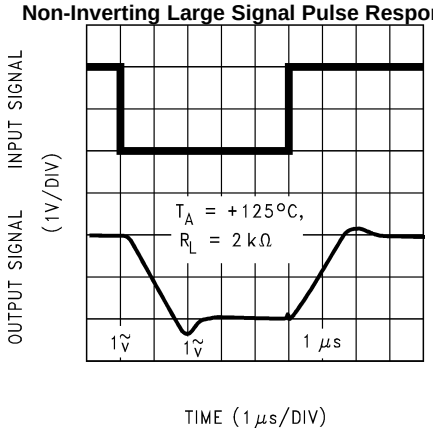
Open Loop Output Impedance vs. Frequency



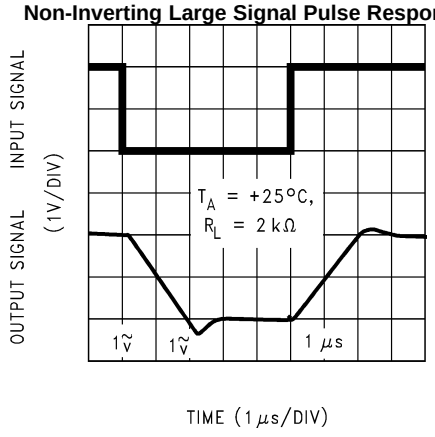
Slew Rate vs. Supply Voltage



Non-Inverting Large Signal Pulse Response



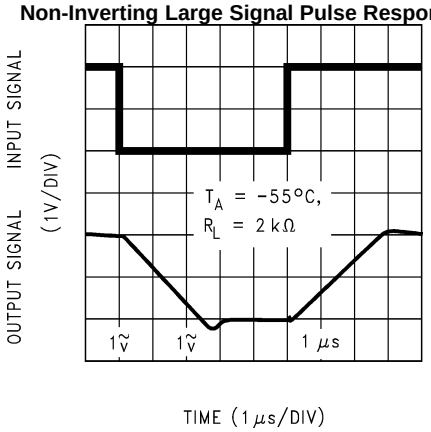
Non-Inverting Large Signal Pulse Response



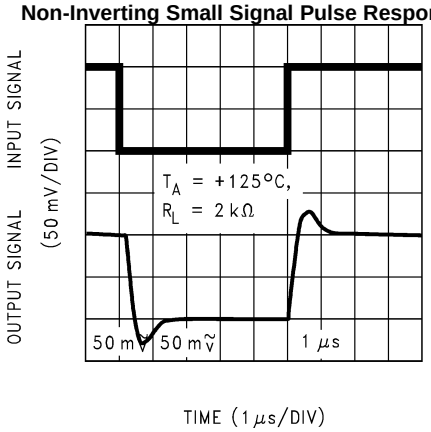
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

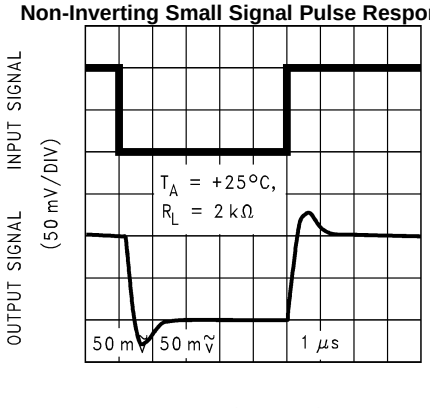
Non-Inverting Large Signal Pulse Response



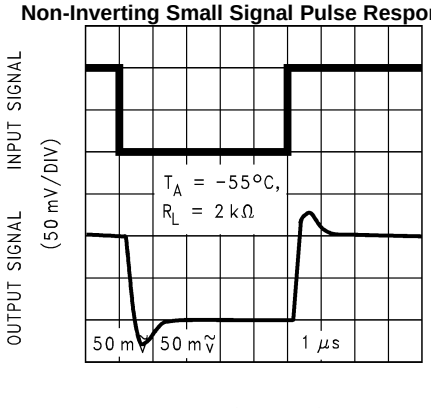
Non-Inverting Small Signal Pulse Response



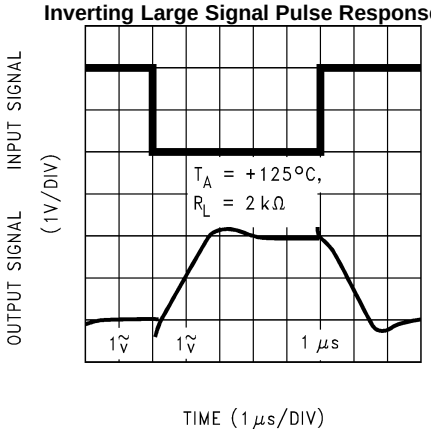
Non-Inverting Small Signal Pulse Response



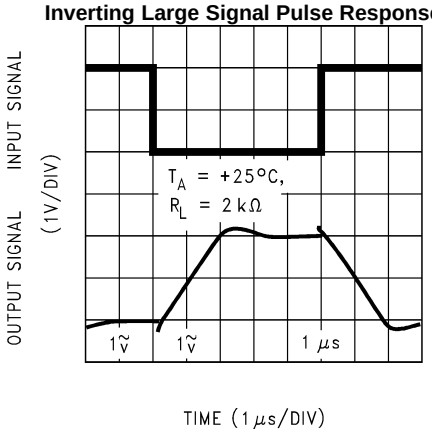
Non-Inverting Small Signal Pulse Response



Inverting Large Signal Pulse Response



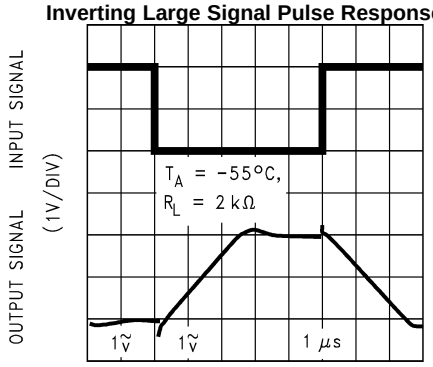
Inverting Large Signal Pulse Response



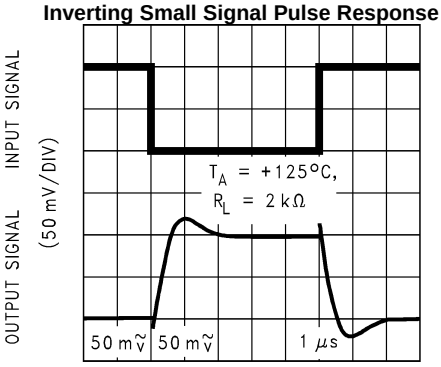
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

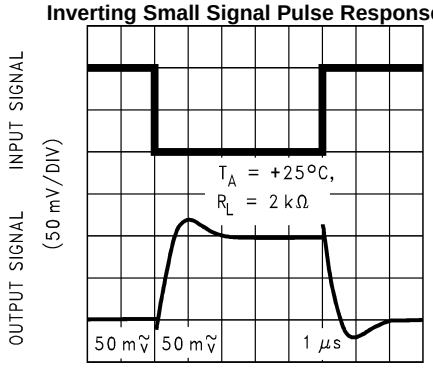
Inverting Large Signal Pulse Response



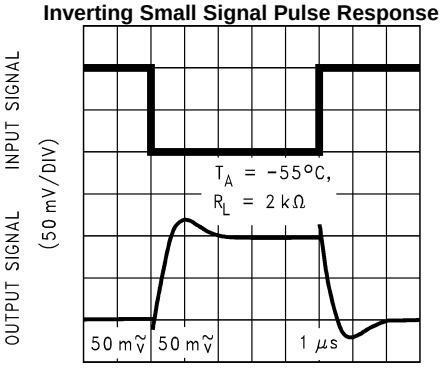
Inverting Small Signal Pulse Response



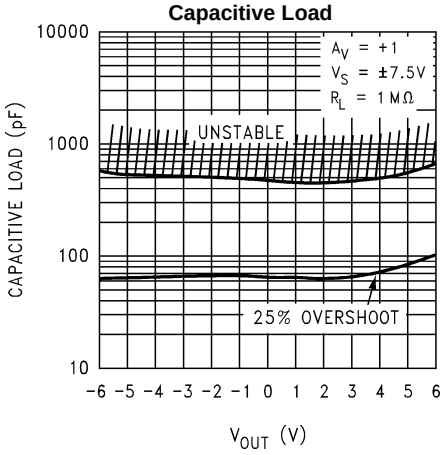
Inverting Small Signal Pulse Response



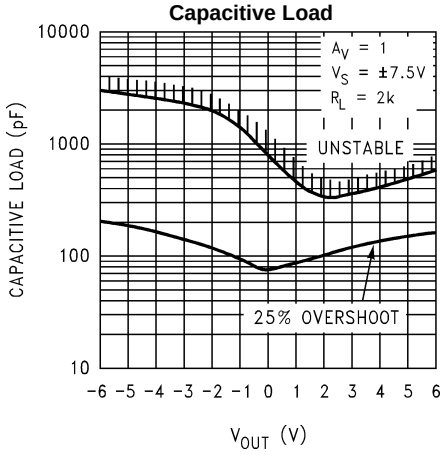
Inverting Small Signal Pulse Response



Stability vs. Capacitive Load



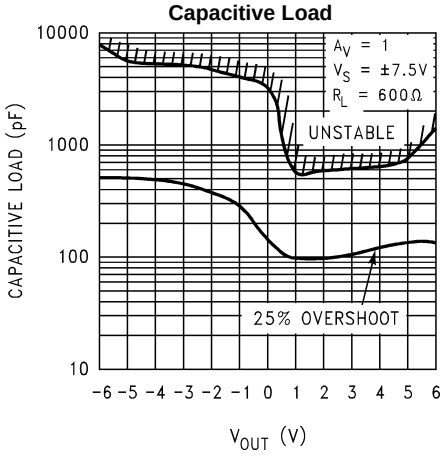
Stability vs. Capacitive Load



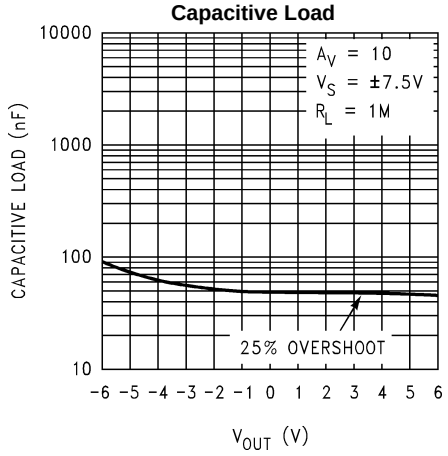
Typical Performance Characteristics (continued)

V_S = +15V, Single Supply, T_A = 25°C unless otherwise specified

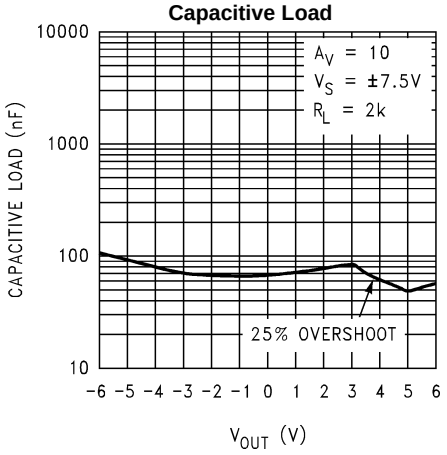
Stability vs. Capacitive Load



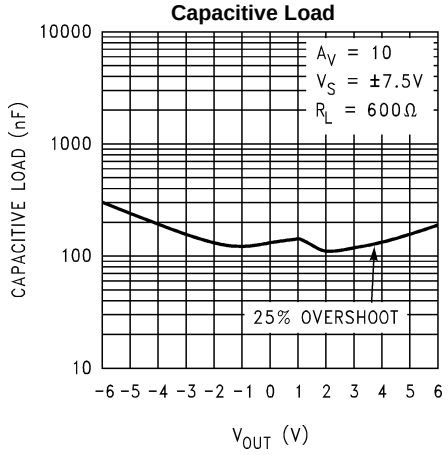
Stability vs. Capacitive Load



Stability vs. Capacitive Load



Stability vs. Capacitive Load



APPLICATION INFORMATION

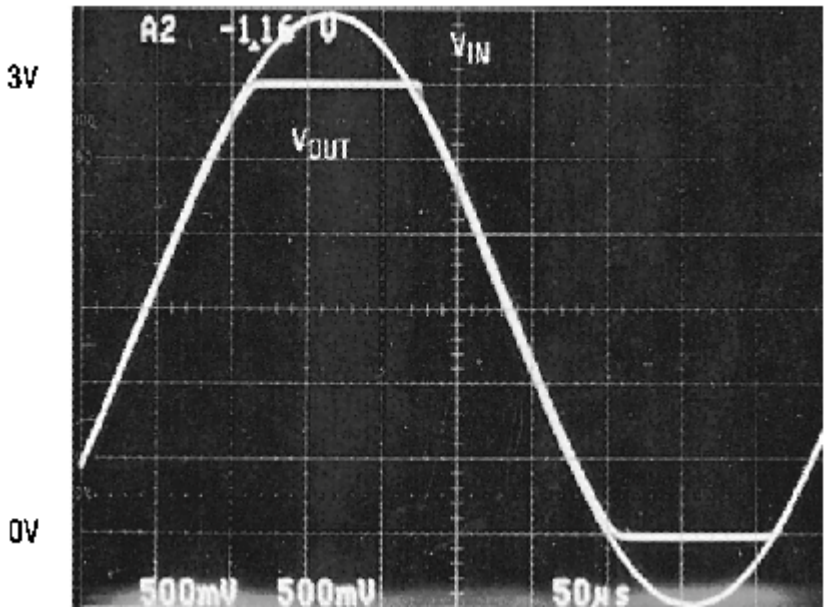
AMPLIFIER TOPOLOGY

The LMC6482 incorporates specially designed wide-compliance range current mirrors and the body effect to extend input common mode range to each supply rail. Complementary paralleled differential input stages, like the type used in other CMOS and bipolar rail-to-rail input amplifiers, were not used because of their inherent accuracy problems due to CMRR, cross-over distortion, and open-loop gain variation.

The LMC6482's input stage design is complemented by an output stage capable of rail-to-rail output swing even when driving a large load. Rail-to-rail output swing is obtained by taking the output directly from the internal integrator instead of an output buffer stage.

INPUT COMMON-MODE VOLTAGE RANGE

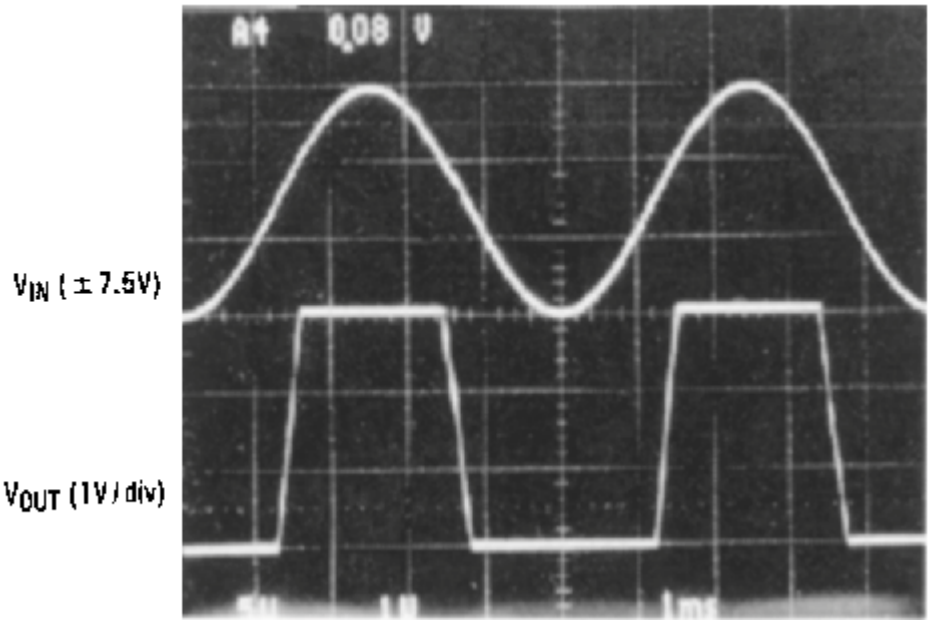
Unlike Bi-FET amplifier designs, the LMC6482 does not exhibit phase inversion when an input voltage exceeds the negative supply voltage. Figure 4 shows an input voltage exceeding both supplies with no resulting phase inversion on the output.



An input voltage signal exceeds the lmc6482 power supply voltages with no output phase inversion.

Figure 4. Input Voltage

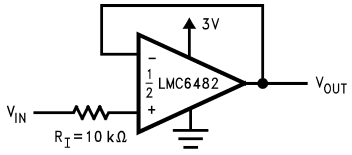
The absolute maximum input voltage is 300mV beyond either supply rail at room temperature. Voltages greatly exceeding this absolute maximum rating, as in Figure 5, can cause excessive current to flow in or out of the input pins possibly affecting reliability.



A ±7.5V input signal greatly exceeds the 3V supply in Figure 6 causing no phase inversion due to R_I.

Figure 5. Input Signal

Applications that exceed this rating must externally limit the maximum input current to ±5mA with an input resistor (R_I) as shown in Figure 6.



R_I input current protection for voltages exceeding the supply voltages.

Figure 6. R_I Input Current Protection for Voltages Exceeding the Supply Voltages

RAIL-TO-RAIL OUTPUT

The approximated output resistance of the LMC6482 is 180Ω sourcing and 130Ω sinking at V_S = 3V and 110Ω sourcing and 80Ω sinking at Vs = 5V. Using the calculated output resistance, maximum output voltage swing can be estimated as a function of load.

CAPACITIVE LOAD TOLERANCE

The LMC6482 can typically directly drive a 100pF load with V_S = 15V at unity gain without oscillating. The unity gain follower is the most sensitive configuration. Direct capacitive loading reduces the phase margin of op-amps. The combination of the op-amp's output impedance and the capacitive load induces phase lag. This results in either an under damped pulse response or oscillation.

Capacitive load compensation can be accomplished using resistive isolation as shown in Figure 7. This simple technique is useful for isolating the capacitive inputs of multiplexers and A/D converters.

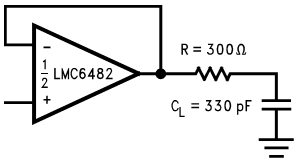


Figure 7. Resistive Isolation of a 330pF Capacitive Load

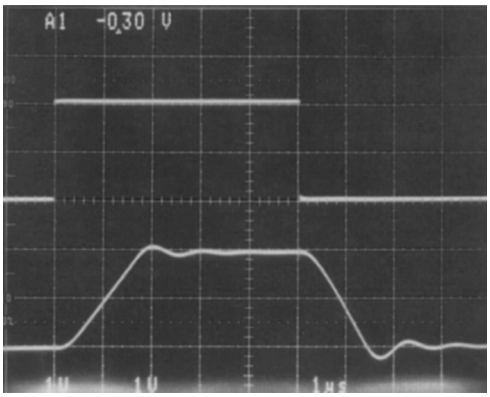
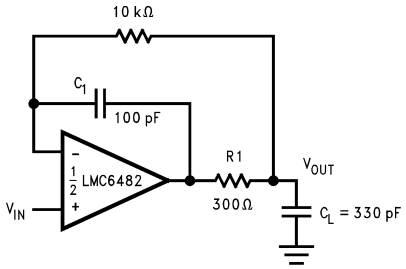


Figure 8. Pulse Response of the LMC6482 Circuit in Figure 7

Improved frequency response is achieved by indirectly driving capacitive loads, as shown in Figure 9.



Compensated to handle a 330pF capacitive load.

Figure 9. LMC6482 Noninverting Amplifier

R1 and C1 serve to counteract the loss of phase margin by feeding forward the high frequency component of the output signal back to the amplifiers inverting input, thereby preserving phase margin in the overall feedback loop. The values of R1 and C1 are experimentally determined for the desired pulse response. The resulting pulse response can be seen in Figure 10.

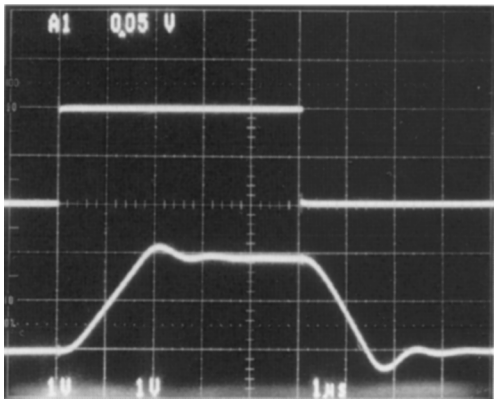


Figure 10. Pulse Response of LMC6482 Circuit in Figure 9

COMPENSATING FOR INPUT CAPACITANCE

It is quite common to use large values of feedback resistance with amplifiers that have ultra-low input current, like the LMC6482. Large feedback resistors can react with small values of input capacitance due to transducers, photo diodes, and circuits board parasitics to reduce phase margins.

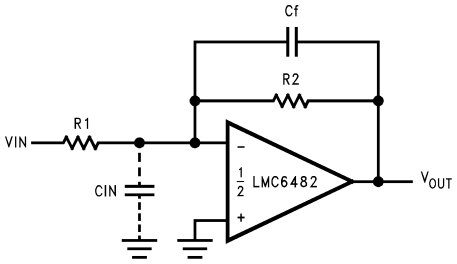


Figure 11. Canceling the Effect of Input Capacitance

The effect of input capacitance can be compensated for by adding a feedback capacitor. The feedback capacitor (as in Figure 11), C_f, is first estimated by:

$$\frac{1}{2\pi R_1 C_{IN}} \geq \frac{1}{2\pi R_2 C_f} \quad (1)$$

or

$$R_1 C_{IN} \leq R_2 C_f \quad (2)$$

which typically provides significant overcompensation.

Printed circuit board stray capacitance may be larger or smaller than that of a bread-board, so the actual optimum value for C_f may be different. The values of C_f should be checked on the actual circuit. (Refer to the LMC660 quad CMOS amplifier data sheet for a more detailed discussion.)

PRINTED-CIRCUIT-BOARD LAYOUT FOR HIGH-IMPEDANCE WORK

It is generally recognized that any circuit which must operate with less than 1000pA of leakage current requires special layout of the PC board. When one wishes to take advantage of the ultra-low input current of the LMC6482, typically less than 20fA, it is essential to have an excellent layout. Fortunately, the techniques of obtaining low leakages are quite simple. First, the user must not ignore the surface leakage of the PC board, even through it may sometimes appear acceptably low, because under conditions of high humidity or dust or contamination, the surface leakage will be appreciable.

To minimize the effect of any surface leakage, lay out a ring of foil completely surrounding the LM6482's inputs and the terminals of capacitors, diodes, conductors, resistors, relay terminals, etc. connected to the op-amp's inputs, as in Figure 12. To have a significant effect, guard rings should be placed on both the top and bottom of the PC board. This PC foil must then be connected to a voltage which is at the same voltage as the amplifier inputs, since no leakage current can flow between two points at the same potential. For example, a PC board trace-to-pad resistance of $10^{12}\Omega$, which is normally considered a very large resistance, could leak 5pA if the trace were a 5V bus adjacent to the pad of the input. This would cause a 250 times degradation from the LMC6482's actual performance. However, if a guard ring is held within 5 mV of the inputs, then even a resistance of $10^{11}\Omega$ would cause only 0.05pA of leakage current. See Figure 13 through Figure 15 for typical connections of guard rings for standard op-amp configurations.

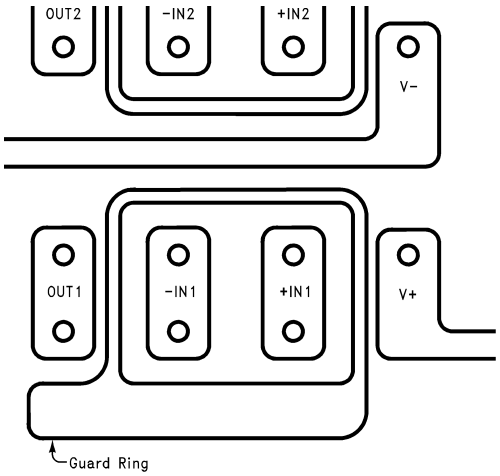


Figure 12. Example of Guard Ring in P.C. Board Layout Typical Connections of Guard Rings

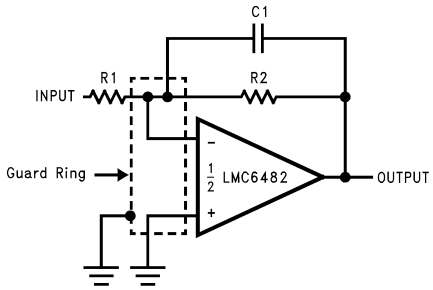


Figure 13. Inverting Amplifier Typical Connections of Guard Rings

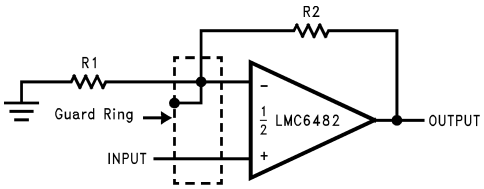


Figure 14. Non-Inverting Amplifier Typical Connections of Guard Rings

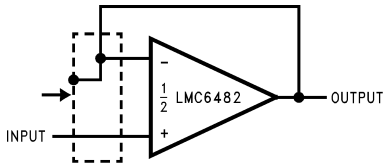
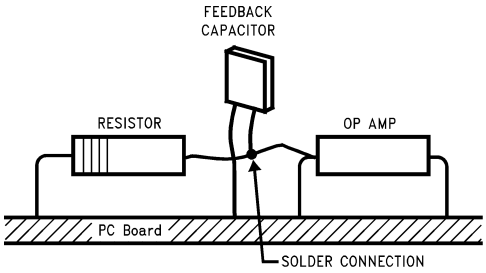


Figure 15. Follower Typical Connections of Guard Rings

The designer should be aware that when it is inappropriate to lay out a PC board for the sake of just a few circuits, there is another technique which is even better than a guard ring on a PC board: Don't insert the amplifier's input pin into the board at all, but bend it up in the air and use only air as an insulator. Air is an excellent insulator. In this case you may have to forego some of the advantages of PC board construction, but the advantages are sometimes well worth the effort of using point-to-point up-in-the-air wiring. See Figure 16.



(Input pins are lifted out of PC board and soldered directly to components. All other pins connected to PC board.)

Figure 16. Air Wiring

OFFSET VOLTAGE ADJUSTMENT

Offset voltage adjustment circuits are illustrated in Figure 17 and Figure 18. Large value resistances and potentiometers are used to reduce power consumption while providing typically ±2.5mV of adjustment range, referred to the input, for both configurations with V_S = ±5V.

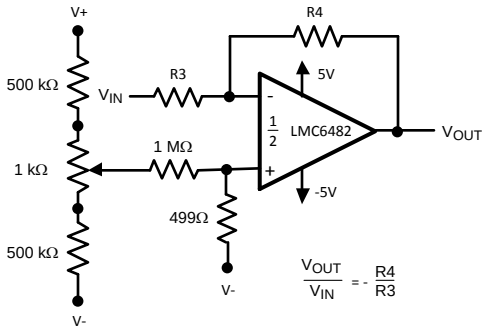


Figure 17. Inverting Configuration Offset Voltage Adjustment

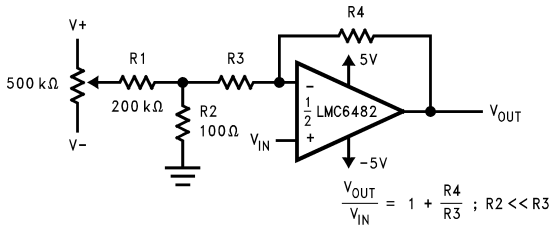


Figure 18. Non-Inverting Configuration Offset Voltage Adjustment

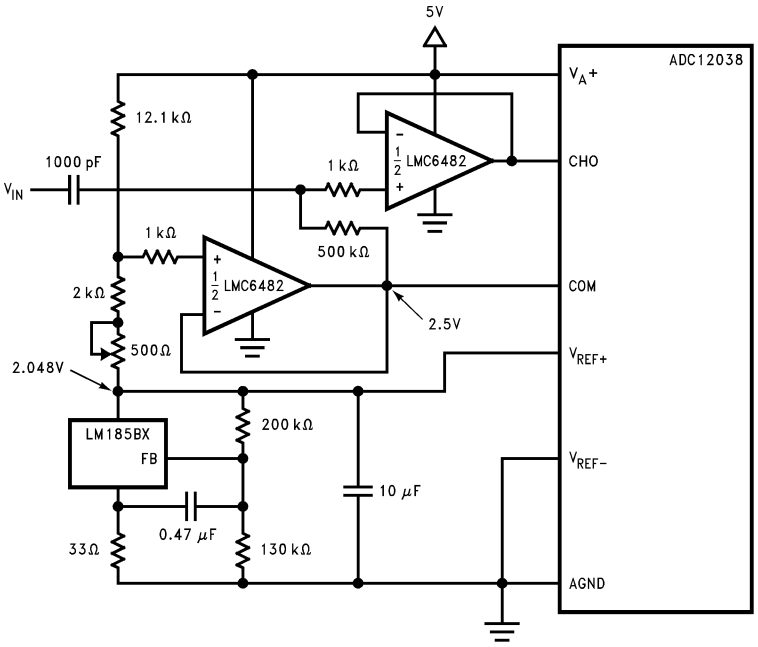
UPGRADING APPLICATIONS

The LMC6484 quads and LMC6482 duals have industry standard pin outs to retrofit existing applications. System performance can be greatly increased by the LMC6482's features. The key benefit of designing in the LMC6482 is increased linear signal range. Most op-amps have limited input common mode ranges. Signals that exceed this range generate a non-linear output response that persists long after the input signal returns to the common mode range.

Linear signal range is vital in applications such as filters where signal peaking can exceed input common mode ranges resulting in output phase inversion or severe distortion.

DATA ACQUISITION SYSTEMS

Low power, single supply data acquisition system solutions are provided by buffering the ADC12038 with the LMC6482 (Figure 19). Capable of using the full supply range, the LMC6482 does not require input signals to be scaled down to meet limited common mode voltage ranges. The LMC4282 CMRR of 82dB maintains integral linearity of a 12-bit data acquisition system to ±0.325 LSB. Other rail-to-rail input amplifiers with only 50dB of CMRR will degrade the accuracy of the data acquisition system to only 8 bits.



Operating from the same supply voltage, the LMC6482 buffers the ADC12038 maintaining excellent accuracy.

Figure 19. Buffering the ADC12038 with the LMC6482

INSTRUMENTATION CIRCUITS

The LMC6482 has the high input impedance, large common-mode range and high CMRR needed for designing instrumentation circuits. Instrumentation circuits designed with the LMC6482 can reject a larger range of common-mode signals than most in-amps. This makes instrumentation circuits designed with the LMC6482 an excellent choice of noisy or industrial environments. Other applications that benefit from these features include analytic medical instruments, magnetic field detectors, gas detectors, and silicon-based transducers.

A small valued potentiometer is used in series with R_g to set the differential gain of the 3 op-amp instrumentation circuit in Figure 20. This combination is used instead of one large valued potentiometer to increase gain trim accuracy and reduce error due to vibration.

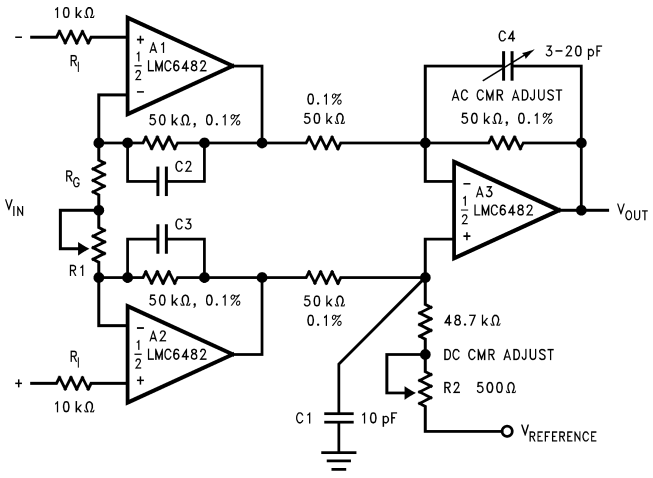


Figure 20. Low Power 3 Op-Amp Instrumentation Amplifier

A 2 op-amp instrumentation amplifier designed for a gain of 100 is shown in Figure 21. Low sensitivity trimming is made for offset voltage, CMRR and gain. Low cost and low power consumption are the main advantages of this two op-amp circuit.

Higher frequency and larger common-mode range applications are best facilitated by a three op-amp instrumentation amplifier.

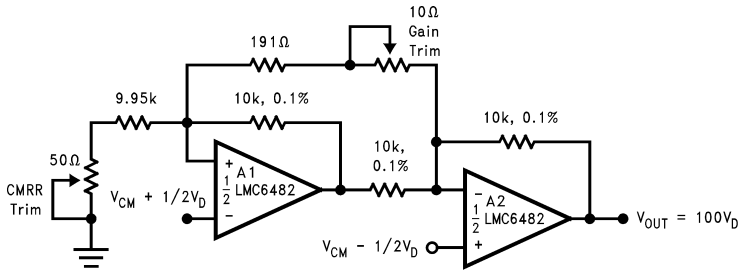


Figure 21. Low-Power Two-Op-Amp Instrumentation Amplifier

SPICE MACROMODEL

A spice macromodel is available for the LMC6482. This model includes accurate simulation of:

- Input common-mode voltage range
- Frequency and transient response
- GBW dependence on loading conditions
- Quiescent and dynamic supply current
- Output swing dependence on loading conditions

and many more characteristics as listed on the macromodel disk.

Contact your local National Semiconductor sales office to obtain an operational amplifier spice model library disk.

Typical Single-Supply Applications

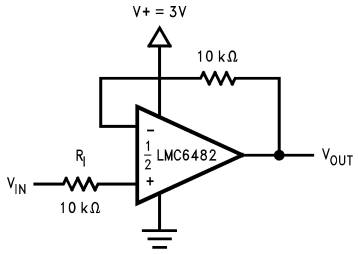


Figure 22. Half-Wave Rectifier with Input Current Protection (R_I)

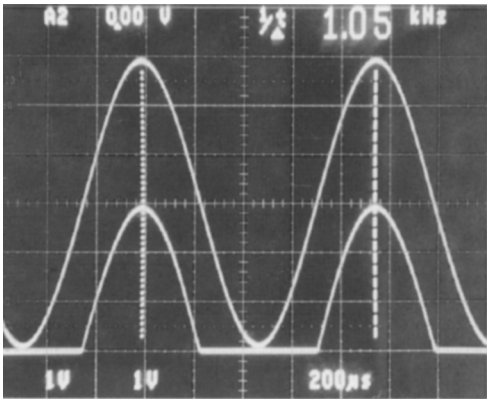


Figure 23. Half-Wave Rectifier Waveform

The circuit in Figure 22 uses a single supply to half wave rectify a sinusoid centered about ground. R_I limits current into the amplifier caused by the input voltage exceeding the supply voltage. Full wave rectification is provided by the circuit in Figure 24.

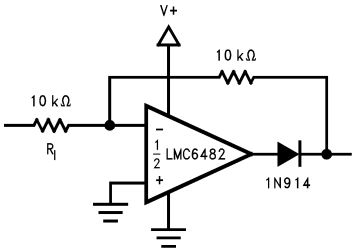


Figure 24. Full Wave Rectifier with Input Current Protection (R_I)

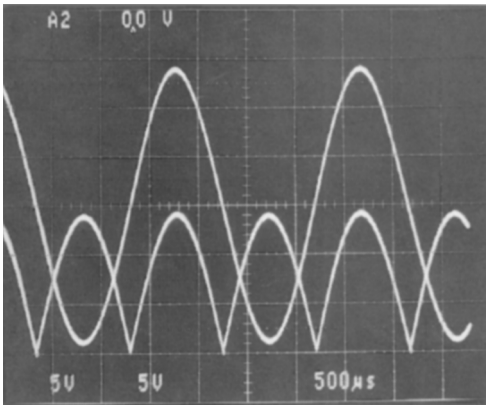


Figure 25. Full Wave Rectifier Waveform

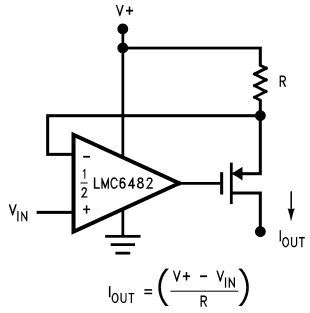


Figure 26. Large Compliance Range Current Source

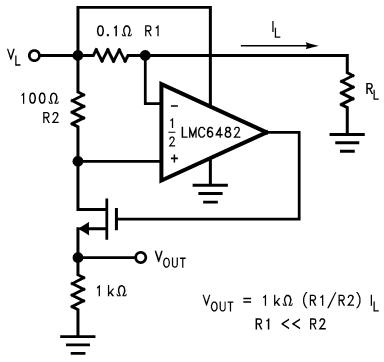


Figure 27. Positive Supply Current Sense

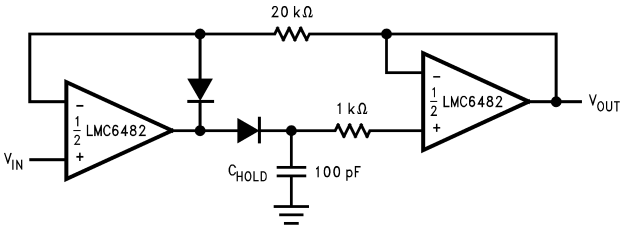


Figure 28. Low Voltage Peak Detector with Rail-to-Rail Peak Capture Range

In Figure 28 dielectric absorption and leakage is minimized by using a polystyrene or polyethylene hold capacitor. The droop rate is primarily determined by the value of C_H and diode leakage current. The ultra-low input current of the LMC6482 has a negligible effect on droop.

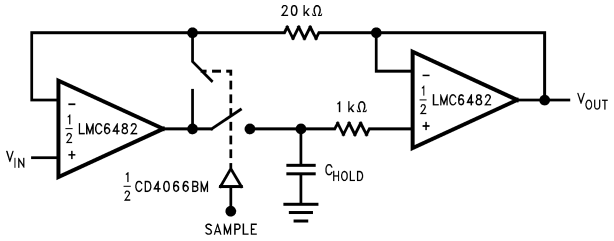


Figure 29. Rail-to-Rail Sample and Hold

The LMC6482's high CMRR (82dB) allows excellent accuracy throughout the circuit's rail-to-rail dynamic capture range.

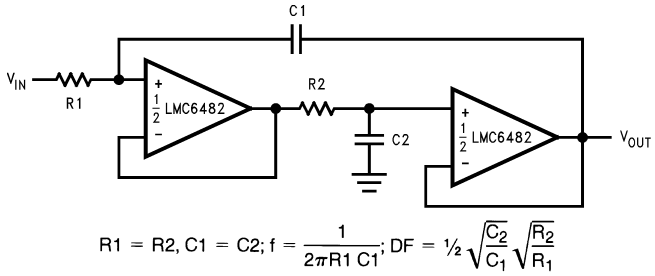


Figure 30. Rail-to-Rail Single Supply Low Pass Filter

The low pass filter circuit in Figure 30 can be used as an anti-aliasing filter with the same voltage supply as the A/D converter.

Filter designs can also take advantage of the LMC6482 ultra-low input current. The ultra-low input current yields negligible offset error even when large value resistors are used. This in turn allows the use of smaller valued capacitors which take less board space and cost less.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
LMC6482AIM	ACTIVE	SOIC	D	8	95	TBD	CU SNPB	Level-1-235C-UNLIM	-40 to 85	LMC64 82AIM	Samples
LMC6482AIM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMC64 82AIM	Samples
LMC6482AIMX	ACTIVE	SOIC	D	8	2500	TBD	CU SNPB	Level-1-235C-UNLIM	-40 to 85	LMC64 82AIM	Samples
LMC6482AIMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMC64 82AIM	Samples
LMC6482AIN	ACTIVE	PDIP	P	8	40	TBD	Call TI	Level-1-NA-UNLIM	-40 to 85	LMC64 82AIN	Samples
LMC6482AIN/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-40 to 85	LMC64 82AIN	Samples
LMC6482IM	ACTIVE	SOIC	D	8	95	TBD	CU SNPB	Level-1-235C-UNLIM	-40 to 85	LMC64 82IM	Samples
LMC6482IM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMC64 82IM	Samples
LMC6482IMM	ACTIVE	VSSOP	DGK	8	1000	TBD	CU SNPB	Level-1-260C-UNLIM	-40 to 85	A10	Samples
LMC6482IMM/NOPB	ACTIVE	VSSOP	DGK	8	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	A10	Samples
LMC6482IMMX	ACTIVE	VSSOP	DGK	8	3500	TBD	CU SNPB	Level-1-260C-UNLIM	-40 to 85	A10	Samples
LMC6482IMMX/NOPB	ACTIVE	VSSOP	DGK	8	3500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	A10	Samples
LMC6482IMX	ACTIVE	SOIC	D	8	2500	TBD	CU SNPB	Level-1-235C-UNLIM	-40 to 85	LMC64 82IM	Samples
LMC6482IMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMC64 82IM	Samples
LMC6482IN	ACTIVE	PDIP	P	8	40	TBD	SNPB	Level-1-NA-UNLIM	-40 to 85	LMC6482IN	Samples
LMC6482IN/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	SN	Level-1-NA-UNLIM	-40 to 85	LMC6482IN	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

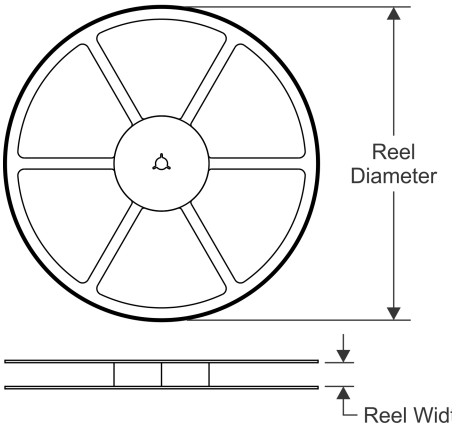
(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

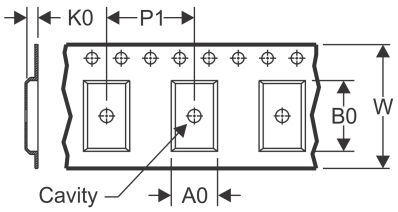
(4) Only one of markings shown within the brackets will appear on the physical device.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

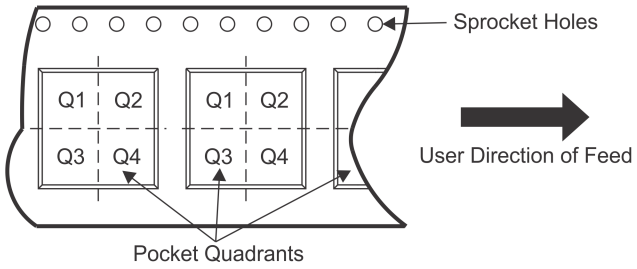


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

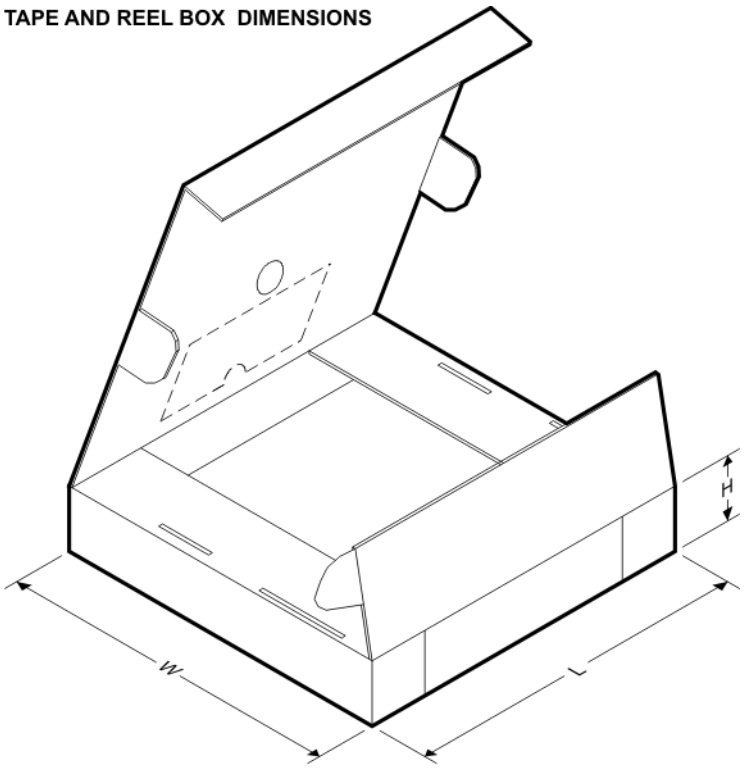
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMC6482AIMX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMC6482AIMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMC6482IMM	VSSOP	DGK	8	1000	178.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMC6482IMM/NOPB	VSSOP	DGK	8	1000	178.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMC6482IMMX	VSSOP	DGK	8	3500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMC6482IMMX/NOPB	VSSOP	DGK	8	3500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMC6482IMX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMC6482IMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1

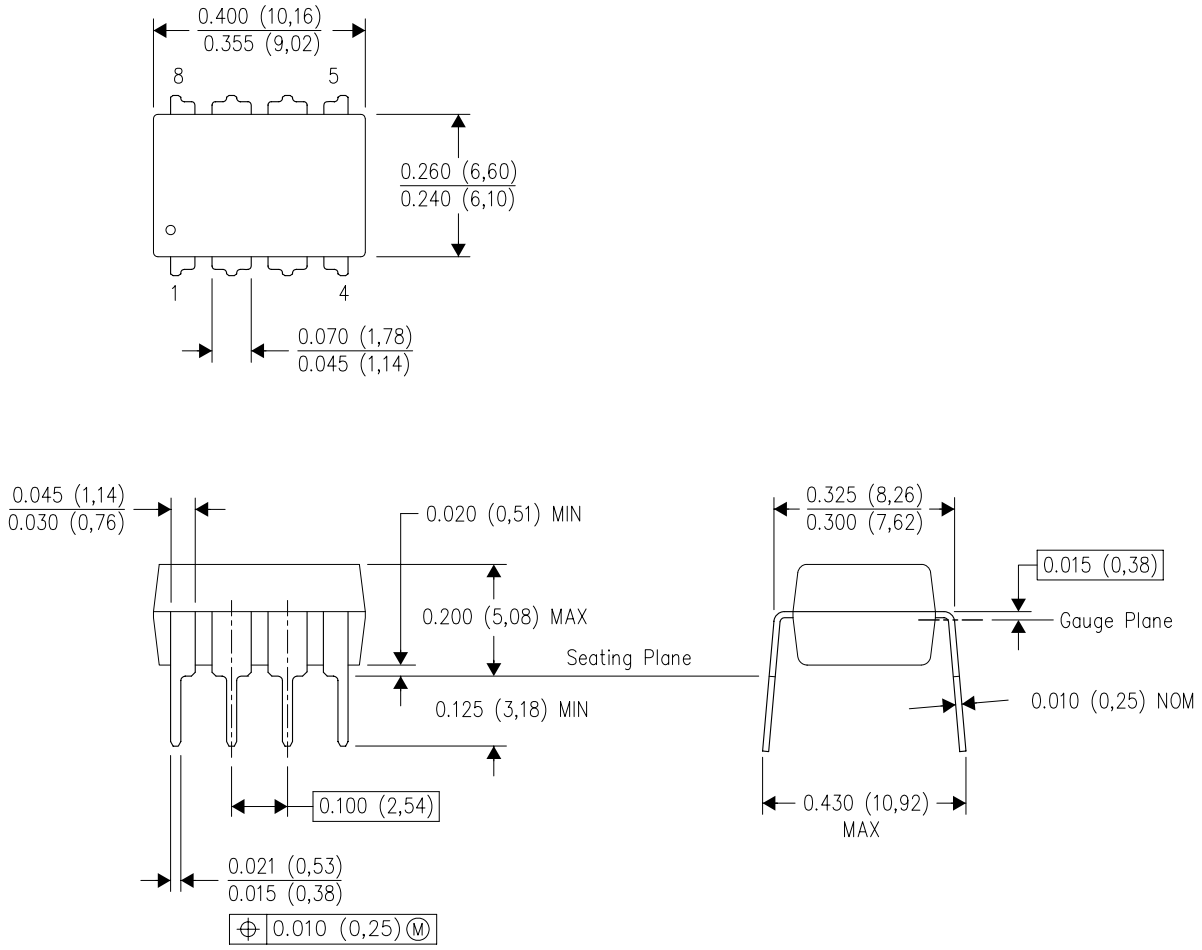
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

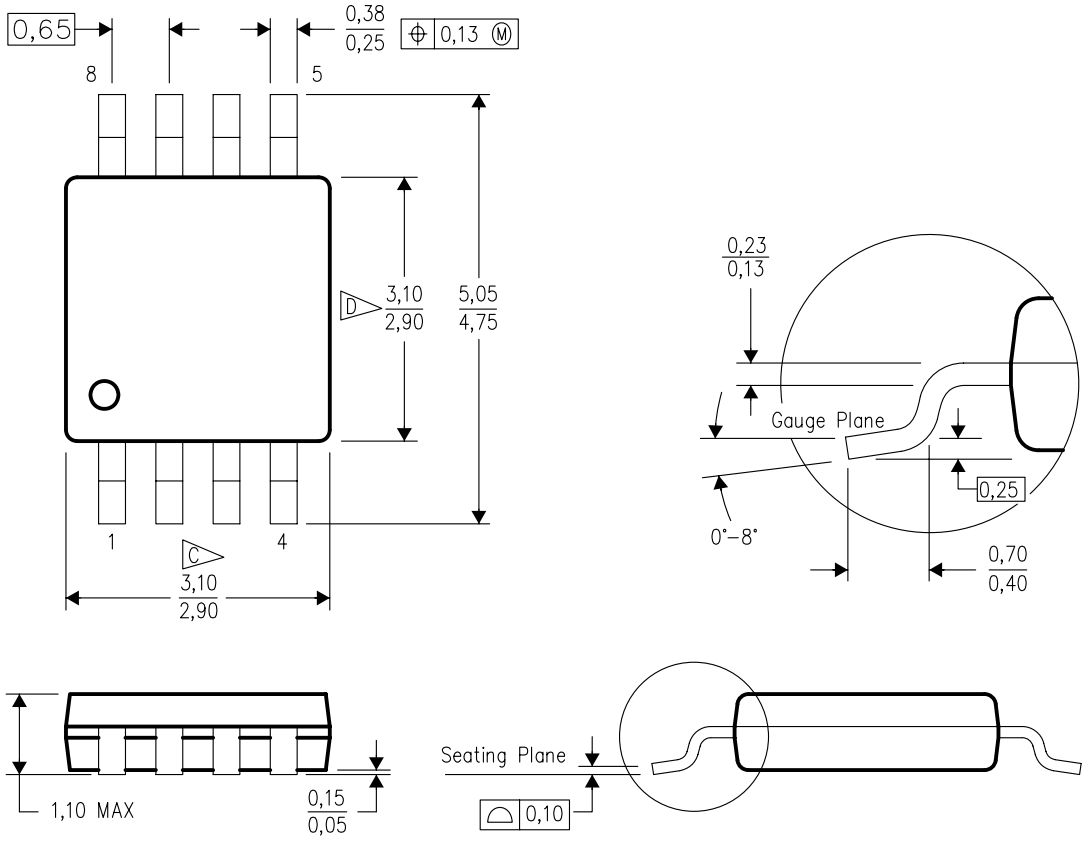
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMC6482AIMX	SOIC	D	8	2500	349.0	337.0	45.0
LMC6482AIMX/NOPB	SOIC	D	8	2500	349.0	337.0	45.0
LMC6482IMM	VSSOP	DGK	8	1000	203.0	190.0	41.0
LMC6482IMM/NOPB	VSSOP	DGK	8	1000	203.0	190.0	41.0
LMC6482IMMX	VSSOP	DGK	8	3500	349.0	337.0	45.0
LMC6482IMMX/NOPB	VSSOP	DGK	8	3500	349.0	337.0	45.0
LMC6482IMX	SOIC	D	8	2500	349.0	337.0	45.0
LMC6482IMX/NOPB	SOIC	D	8	2500	349.0	337.0	45.0

P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

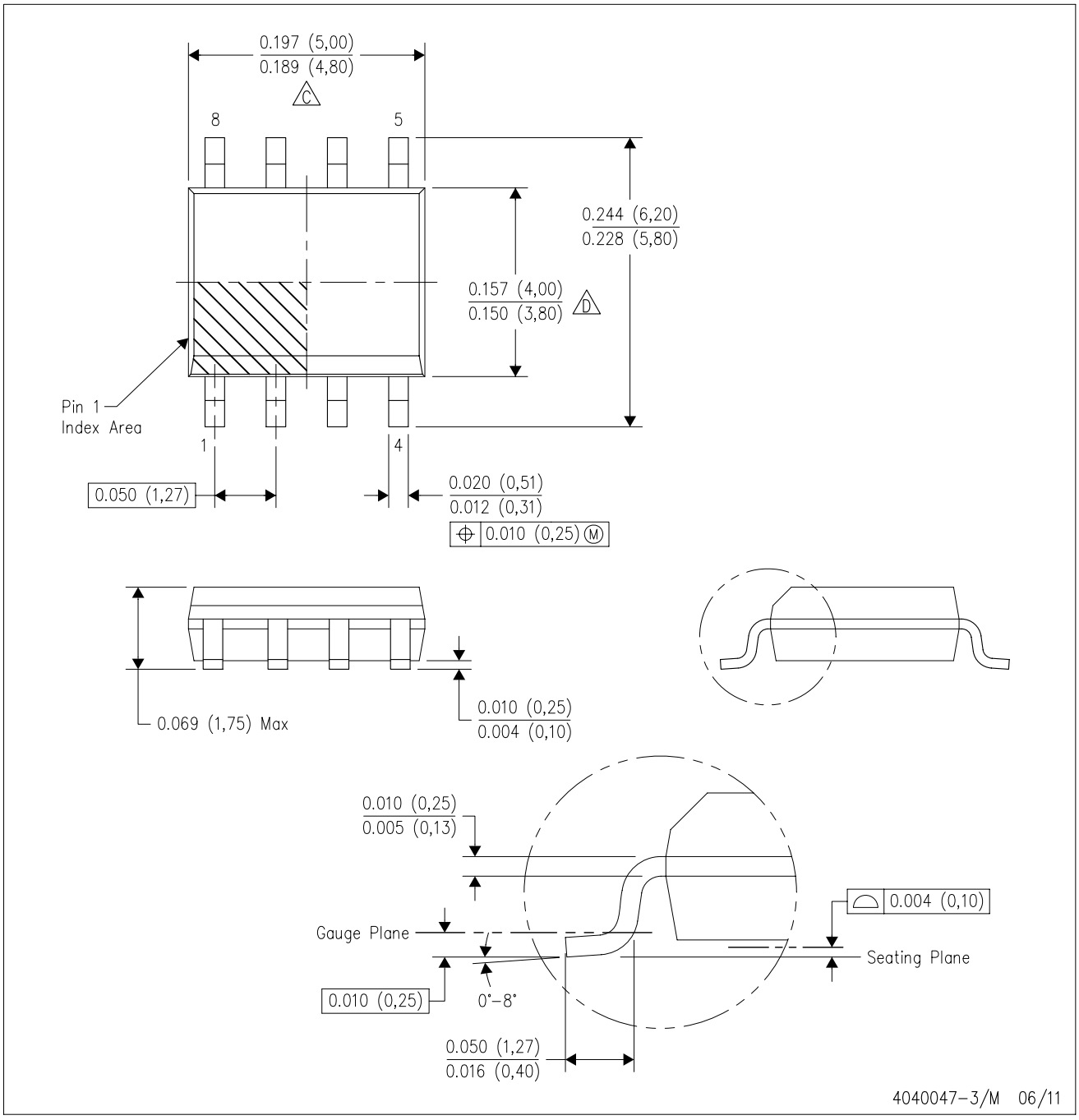
DGK (S–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



4073329/E 05/06

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO–187 variation AA, except interlead flash.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AA.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265