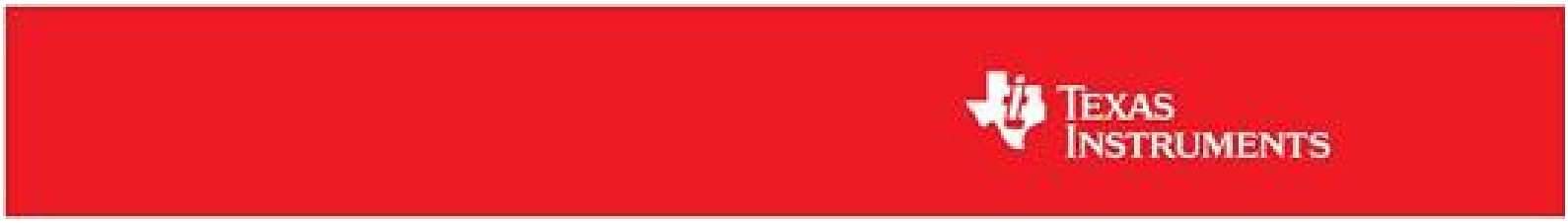
LM6142,LM6144

LM6142/LM6144 17 MHz Rail-to-Rail Input-Output Operational Amplifiers



Literature Number: SNOS726C

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November 2004

National Semiconductor

LM6142/LM6144
17 MHz Rail-to-Rail Input-Output Operational Amplifiers

General Description

Using patent pending new circuit topologies, the LM6142/LM6144 provides new levels of performance in applications where low voltage supplies or power limitations previously made compromise necessary. Operating on supplies of 1.8V to over 24V, the LM6142/LM6144 is an excellent choice for battery operated systems, portable instrumentation and others.

The greater than rail-to-rail input voltage range eliminates concern over exceeding the common-mode voltage range. The rail-to-rail output swing provides the maximum possible dynamic range at the output. This is particularly important when operating on low supply voltages.

High gain-bandwidth with 650µA/Amplifier supply current opens new battery powered applications where previous higher power consumption reduced battery life to unacceptable levels. The ability to drive large capacitive loads without oscillating functionally removes this common problem.

Features

At V_S = 5V. Typ unless noted.

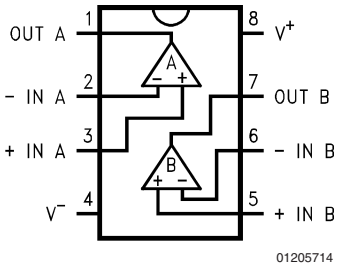
- Rail-to-rail input CMVR −0.25V to 5.25V
- Rail-to-rail output swing 0.005V to 4.995V
- Wide gain-bandwidth: 17MHz at 50kHz (typ)
- Slew rate:
  - Small signal, 5V/µs
  - Large signal, 30V/µs
- Low supply current 650µA/Amplifier
- Wide supply range 1.8V to 24V
- CMRR 107dB
- Gain 108dB with R_L = 10k
- PSRR 87dB

Applications

- Battery operated instrumentation
- Depth sounders/fish finders
- Barcode scanners
- Wireless communications
- Rail-to-rail in-out instrumentation amps

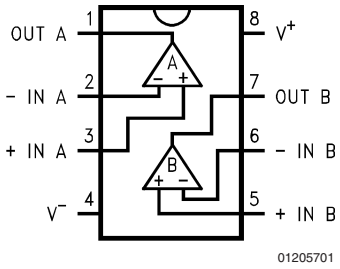
Connection Diagrams

8-Pin CDIP



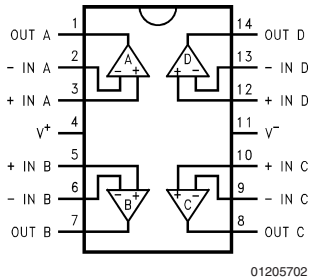
Top View

8-Pin DIP/SO



Top View

14-Pin DIP/SO



Top View

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Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

ESD Tolerance (Note 2)	2500V
Differential Input Voltage	15V
Voltage at Input/Output Pin	(V^+) + 0.3V, (V^-) − 0.3V
Supply Voltage $(V^+ - V^-)$	35V
Current at Input Pin	±10mA
Current at Output Pin (Note 3)	±25mA
Current at Power Supply Pin	50mA
Lead Temperature (soldering, 10 sec)	260˚C
Storage Temp. Range	−65˚C to +150˚C
Junction Temperature (Note 4)	150˚C

Operating Ratings (Note 1)

Supply Voltage	$1.8V \le V^+ \le 24V$
Temperature Range	
LM6142, LM6144	$-40˚C \le T_A \le +85˚C$
Thermal Resistance (θ_{JA})	
N Package, 8-Pin Molded DIP	115˚C/W
M Package, 8-Pin Surface Mount	193˚C/W
N Package, 14-Pin Molded DIP	81˚C/W
M Package, 14-Pin Surface Mount	126˚C/W

5.0V DC Electrical Characteristics (Note 8)

Unless otherwise specified, all limits guaranteed for $T_A = 25˚C$, $V^+ = 5.0V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$ and $R_L > 1\ M\Omega$ to $V^+/2$. **Boldface limits** apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6144AI LM6142AI Limit (Note 6)	LM6144BI LM6142BI Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		0.3	1.0 **2.2**	2.5 **3.3**	mV max
TCV_{OS}	Input Offset Voltage Average Drift		**3**			µV/˚C
I_B	Input Bias Current		170	250	300	nA max
		$0V \le V_{CM} \le 5V$	180	280 **526**	 **526**	
I_{OS}	Input Offset Current		3	30 **80**	30 **80**	nA max
R_{IN}	Input Resistance, C_M		126			MΩ
CMRR	Common Mode Rejection Ratio	$0V \le V_{CM} \le 4V$	107	84 **78**	84 **78**	dB min
		$0V \le V_{CM} \le 5V$	82 **79**	66 **64**	66 **64**	
PSRR	Power Supply Rejection Ratio	$5V \le V^+ \le 24V$	**87**	80 **78**	80 **78**	
V_{CM}	Input Common-Mode Voltage Range		−0.25	**0**	**0**	V
			5.25	**5.0**	**5.0**	
A_V	Large Signal Voltage Gain	R_L = 10k	270 **70**	100 **33**	80 **25**	V/mV min
V_O	Output Swing	R_L = 100k	0.005	0.01 **0.013**	0.01 **0.013**	V max
			4.995	4.98 **4.93**	4.98 **4.93**	V min
		R_L = 10k	0.02			V max
			4.97			V min
		R_L = 2k	0.06	0.1 **0.133**	0.1 **0.133**	V max
			4.90	4.86	4.86	V

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5.0V DC Electrical Characteristics (Note 8) (Continued)

Unless otherwise specified, all limits guaranteed for T_A = 25˚C, V^+ = 5.0V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1 MΩ to $V^+/2$. **Boldface limits** apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6144AI LM6142AI Limit (Note 6)	LM6144BI LM6142BI Limit (Note 6)	Units
				4.80	**4.80**	min
I_{SC}	Output Short Circuit Current LM6142	Sourcing	13	10	8	mA
				4.9	**4**	min
				35	**35**	mA
						max
		Sinking	24	10	10	mA
				5.3	**5.3**	min
				35	**35**	mA
						max
I_{SC}	Output Short Circuit Current LM6144	Sourcing	8	6	6	mA
				3	**3**	min
				35	**35**	mA
						max
		Sinking	22	8	8	mA
				4	**4**	min
				35	**35**	mA
						max
I_S	Supply Current	Per Amplifier	650	800	800	µA
				880	**880**	max

5.0V AC Electrical Characteristics (Note 8)

Unless Otherwise Specified, All Limits Guaranteed for T_A = 25˚C, V^+ = 5.0V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1 MΩ to $V^+/2$. **Boldface limits** apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6144AI LM6142AI Limit (Note 6)	LM6144BI LM6142BI Limit (Note 6)	Units
SR	Slew Rate	8 V_{PP} @ V^+ 12V	25	15	13	V/µs
		R_S > 1 kΩ		**13**	**11**	min
GBW	Gain-Bandwidth Product	f = 50 kHz	17	10	10	MHz
				6	**6**	min
ϕ_m	Phase Margin		38			Deg
	Amp-to-Amp Isolation		130			dB
e_n	Input-Referred Voltage Noise	f = 1 kHz	16			$\frac{nV}{\sqrt{Hz}}$
i_n	Input-Referred Current Noise	f = 1 kHz	0.22			$\frac{pA}{\sqrt{Hz}}$
T.H.D.	Total Harmonic Distortion	f = 10 kHz, R_L = 10 kΩ,	0.003			%

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2.7V DC Electrical Characteristics (Note 8)

Unless Otherwise Specified, All Limits Guaranteed for T_A = 25˚C, V^+ = 2.7V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1 MΩ to $V^+/2$. **Boldface** limits apply at the temperature extreme

Symbol	Parameter	Conditions	Typ (Note 5)	LM6144AI LM6142AI Limit (Note 6)	LM6144BI LM6142BI Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		0.4	1.8 **4.3**	2.5 **5**	mV max
I_B	Input Bias Current		150	250 **526**	300 **526**	nA max
I_{OS}	Input Offset Current		4	30 **80**	30 **80**	nA max
R_{IN}	Input Resistance		128			MΩ
CMRR	Common Mode	0V ≤ V_{CM} ≤ 1.8V	90			dB
	Rejection Ratio	0V ≤ V_{CM} ≤ 2.7V	76			min
PSRR	Power Supply Rejection Ratio	3V ≤ V+ ≤ 5V	79			
V_{CM}	Input Common-Mode		–0.25	0	0	V min
	Voltage Range		2.95	2.7	2.7	V max
A_V	Large Signal Voltage Gain	R_L = 10k	55			V/mV min
V_O	Output Swing	R_L = 100kΩ	0.019	0.08 **0.112**	0.08 **0.112**	V max
			2.67	2.66 **2.25**	2.66 **2.25**	V min
I_S	Supply Current	Per Amplifier	510	800 **880**	800 **880**	µA max

2.7V AC Electrical Characteristics (Note 8)

Unless Otherwise Specified, All Limits Guaranteed for T_A = 25˚C, V^+ = 2.7V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1 MΩ to $V^+/2$. **Boldface** limits apply at the temperature extreme

Symbol	Parameter	Conditions	Typ (Note 5)	LM6144AI LM6142AI Limit (Note 6)	LM6144BI LM6142BI Limit (Note 6)	Units
GBW	Gain-Bandwidth Product	f = 50 kHz	9			MHz
ϕ_m	Phase Margin		36			Deg
G_m	Gain Margin		6			dB

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24V Electrical Characteristics (Note 8)

Unless Otherwise Specified, All Limits Guaranteed for T_A = 25˚C, V^+ = 24V, V^- = 0V, $V_{CM} = V_O = V^+/2$ and R_L > 1 MΩ to $V^+/2$. **Boldface** limits apply at the temperature extreme

Symbol	Parameter	Conditions	Typ (Note 5)	LM6144AI LM6142AI Limit (Note 6)	LM6144BI LM6142BI Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		1.3	2	3.8	mV
				4.8	**4.8**	max
I_B	Input Bias Current		174			nA
						max
I_{OS}	Input Offset Current		5			nA
						max
R_{IN}	Input Resistance		288			MΩ
CMRR	Common Mode	0V ≤ V_{CM} ≤ 23V	114			dB
	Rejection Ratio	0V ≤ V_{CM} ≤ 24V	100			min
PSRR	Power Supply Rejection Ratio	0V ≤ V_{CM} ≤ 24V	87			
V_{CM}	Input Common-Mode		–0.25	0	0	V min
	Voltage Range		24.25	24	24	V max
A_V	Large Signal Voltage Gain	R_L = 10k	500			V/mV min
V_O	Output Swing	R_L = 10 kΩ	0.07	0.15	0.15	V
				0.185	**0.185**	max
			23.85	23.81	23.81	V
				23.62	**23.62**	min
I_S	Supply Current	Per Amplifier	750	1100	1100	µA
				1150	**1150**	max
GBW	Gain-Bandwidth Product	f = 50 kHz	18			MHz

Note 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 Charactenstics.

Note 2: Human body model, 1.5kΩ in series with 100pF.

Note 3: 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.

Note 4: 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.

Note 5: Typical values represent the most likely parametric norm.

Note 6: All limits are guaranteed by testing or statistical analysis.

Note 7: For guaranteed military specifications see military datasheet MNLM6142AM-X.

Note 8: Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No guarantee of parametric performance is indicated in the electrical tables under conditions of the internal self heating where $T_J > T_A$.

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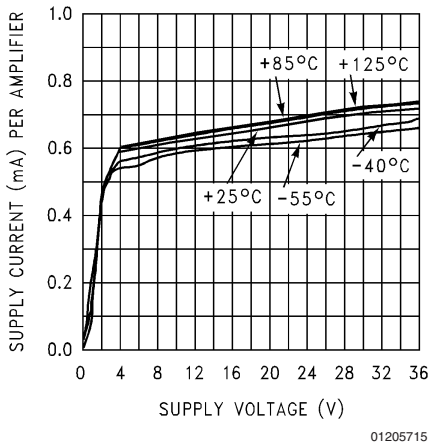
Typical Performance Characteristics T_A = 25˚C, R_L = 10 kΩ Unless Otherwise Specified

Supply Current vs. Supply Voltage



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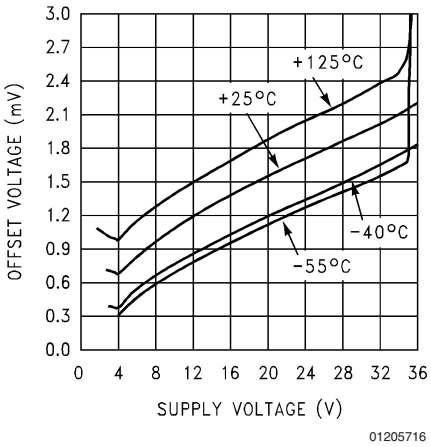
Offset Voltage vs. Supply Voltage



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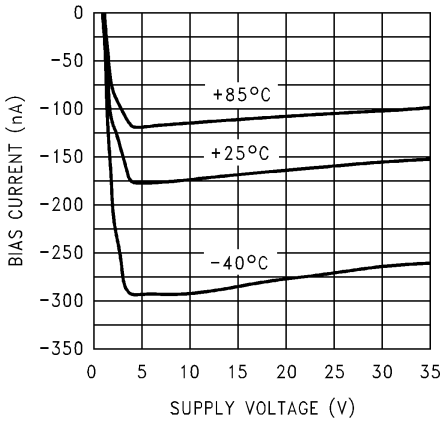
Bias Current vs. Supply Voltage



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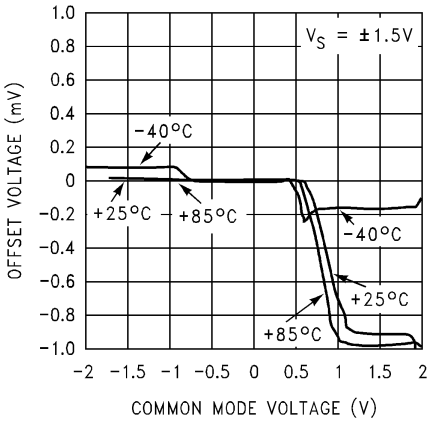
Offset Voltage vs. V_{CM}



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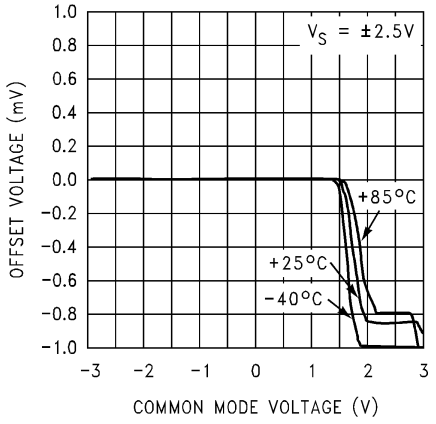
Offset Voltage vs. V_{CM}



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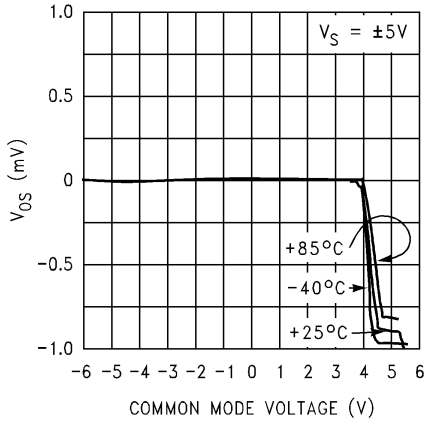
Offset Voltage vs. V_{CM}



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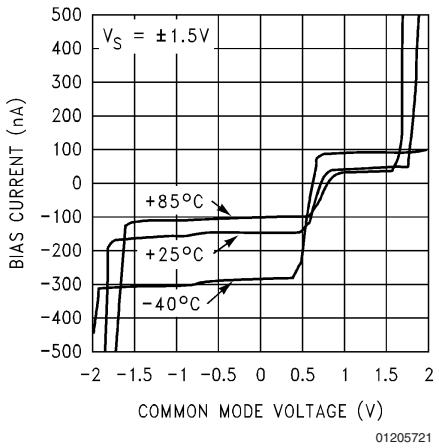
Typical Performance Characteristics T_A = 25˚C, R_L = 10 kΩ Unless Otherwise Specified (Continued)

Bias Current vs. V_{CM}



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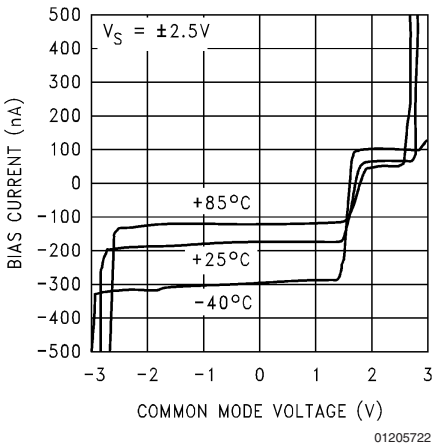
Bias Current vs. V_{CM}



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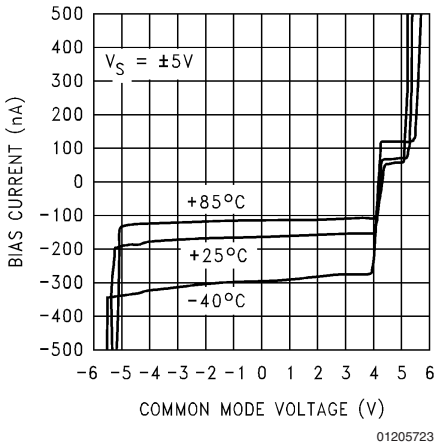
Bias Current vs. V_{CM}



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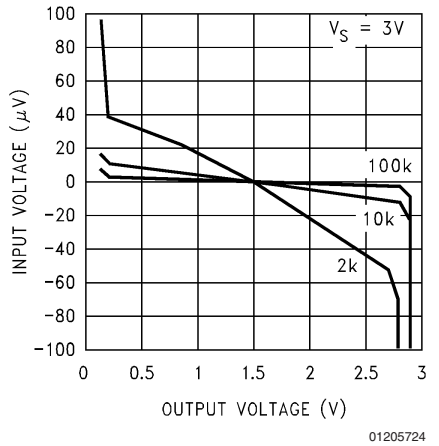
Open-Loop Transfer Function



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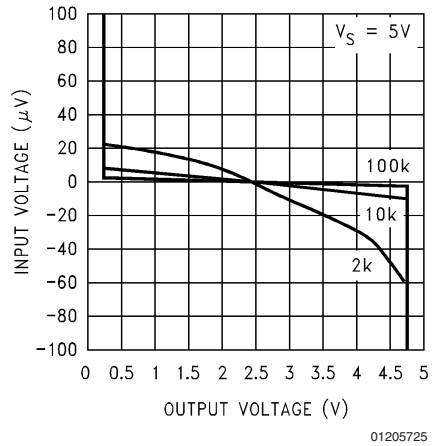
Open-Loop Transfer Function



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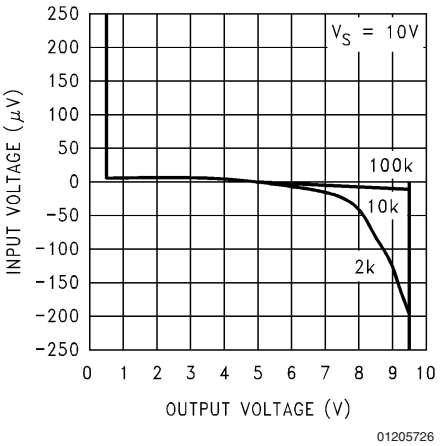
Open-Loop Transfer Function



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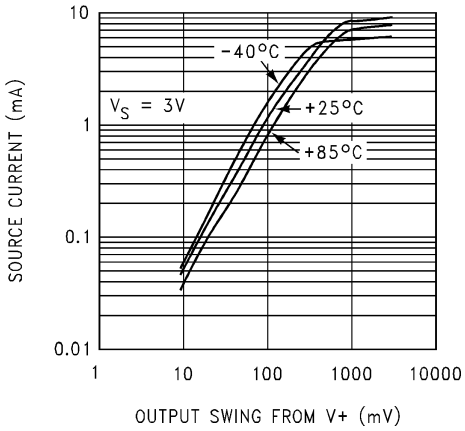
Typical Performance Characteristics T_A = 25˚C, R_L = 10 kΩ Unless Otherwise Specified (Continued)

Output Voltage vs. Source Current



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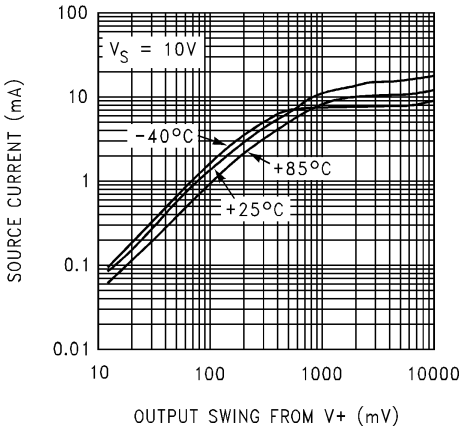
Output Voltage vs. Source Current



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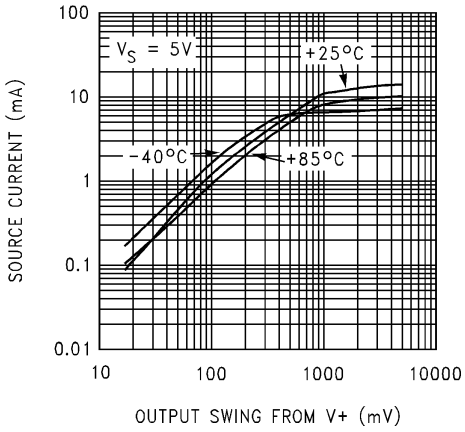
Output Voltage vs. Source Current



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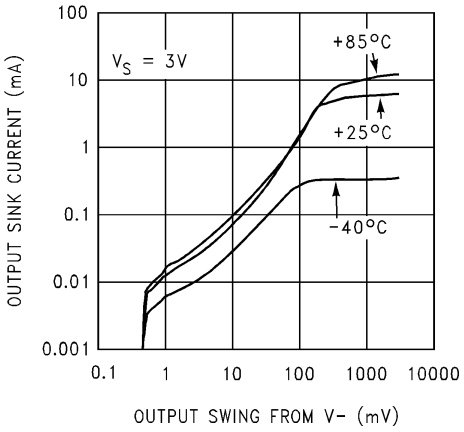
Output Voltage vs. Sink Current



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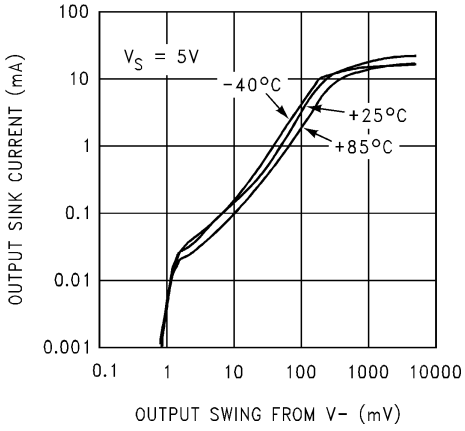
Output Voltage vs. Sink Current



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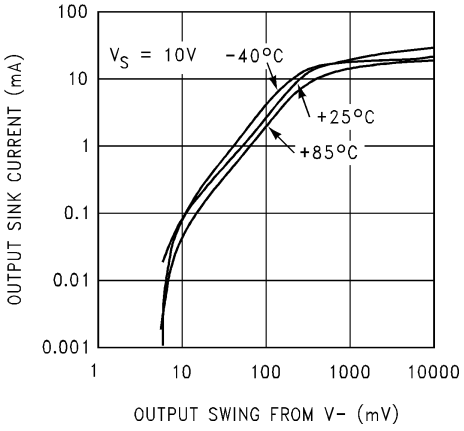
Output Voltage vs. Sink Current



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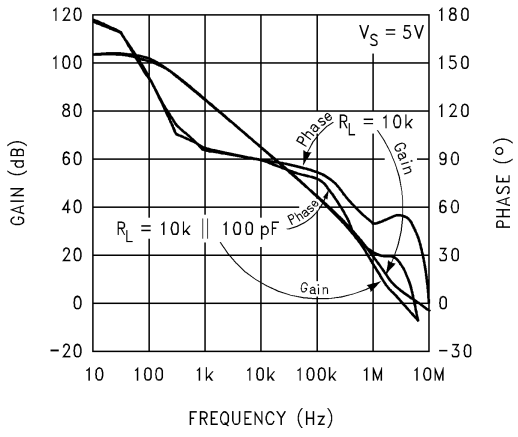
Typical Performance Characteristics T_A = 25˚C, R_L = 10 kΩ Unless Otherwise Specified (Continued)

Gain and Phase vs. Load



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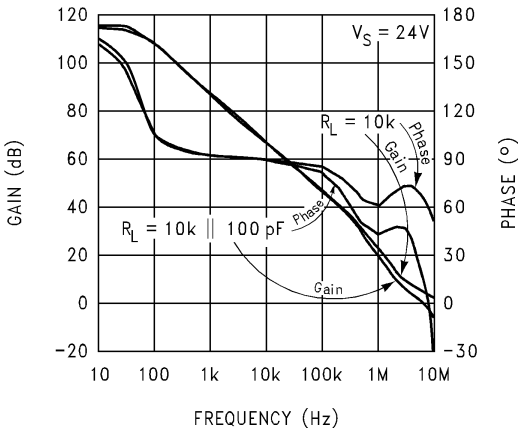
Gain and Phase vs. Load



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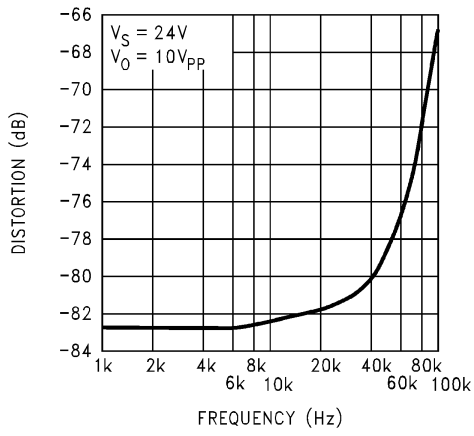
Distortion + Noise vs. Frequency



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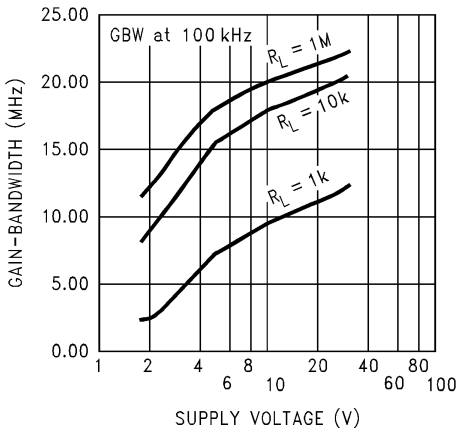
GBW vs. Supply



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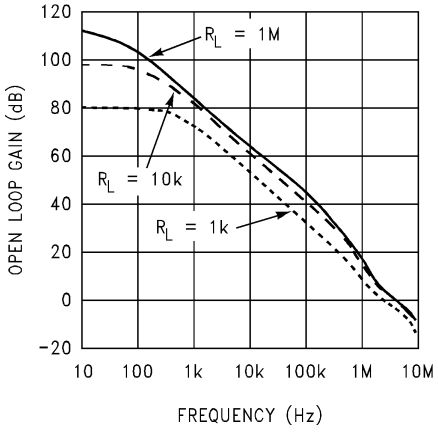
Open Loop Gain vs. Load, 3V Supply



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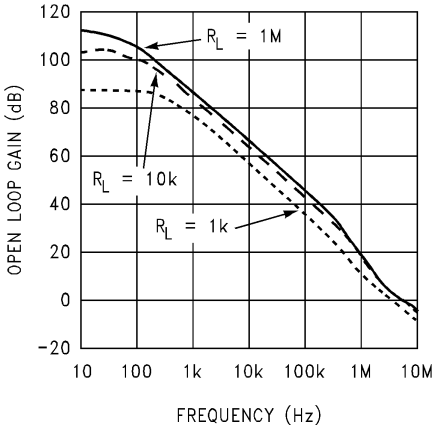
Open Loop Gain vs. Load, 5V Supply



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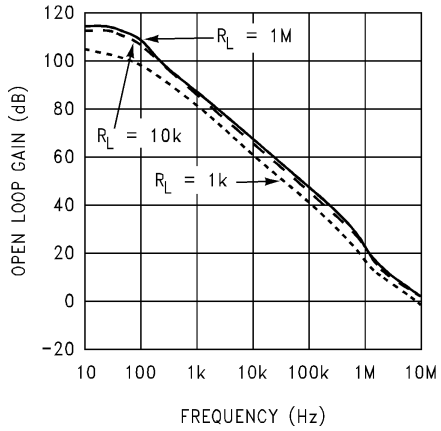
Open Loop Gain vs. Load, 24V Supply



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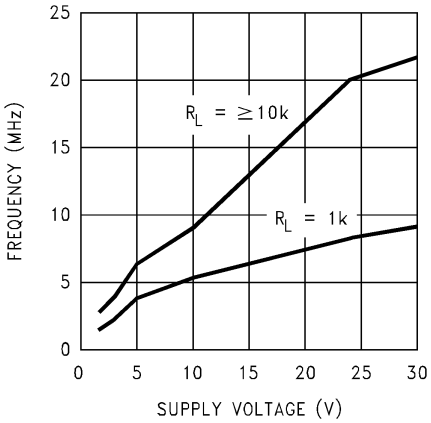
Unity Gain Frequency vs. V_S



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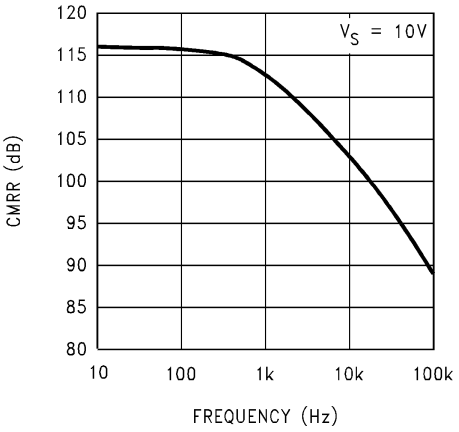
CMRR vs. Frequency



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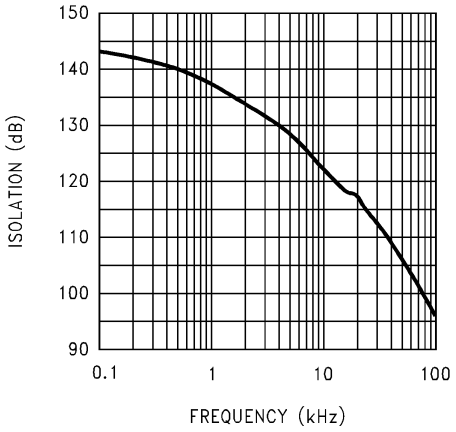
Crosstalk vs. Frequency



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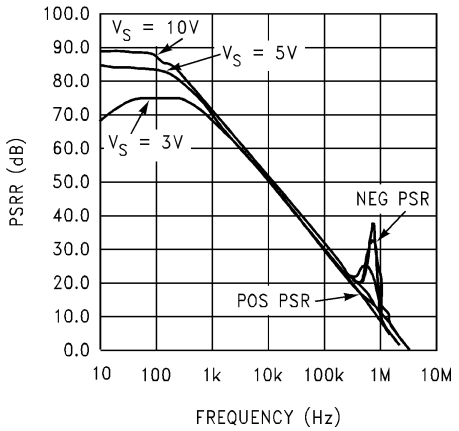
PSRR vs. Frequency



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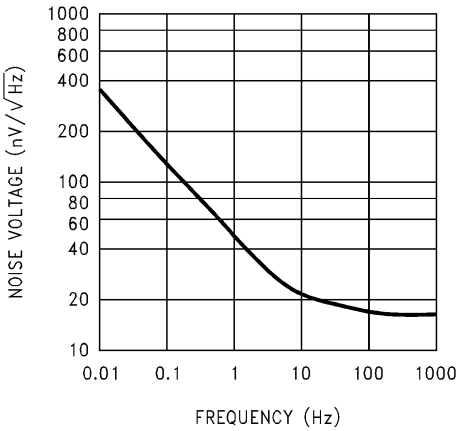
Noise Voltage vs. Frequency



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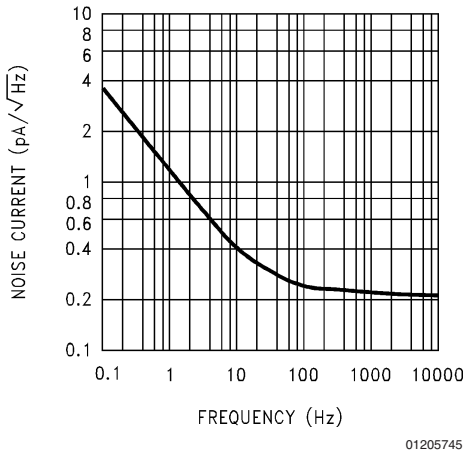
Noise Current vs. Frequency



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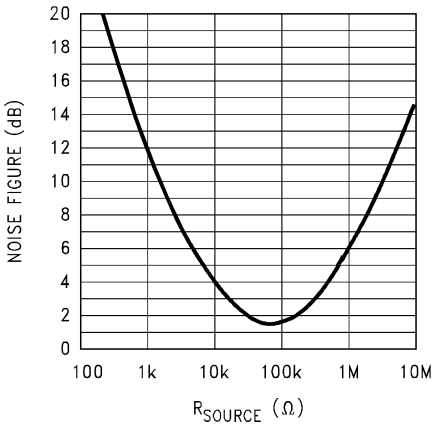
NF vs. R_{Source}



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LM6142/LM6144 Application Ideas

The LM6142 brings a new level of ease of use to op amp system design.

With greater than rail-to-rail input voltage range concern over exceeding the common-mode voltage range is eliminated.

Rail-to-rail output swing provides the maximum possible dynamic range at the output. This is particularly important when operating on low supply voltages.

The high gain-bandwidth with low supply current opens new battery powered applications, where high power consumption, previously reduced battery life to unacceptable levels.

To take advantage of these features, some ideas should be kept in mind.

ENHANCED SLEW RATE

Unlike most bipolar op amps, the unique phase reversal prevention/speed-up circuit in the input stage causes the slew rate to be very much a function of the input signal amplitude.

Figure 2 shows how excess input signal, is routed around the input collector-base junctions, directly to the current mirrors.

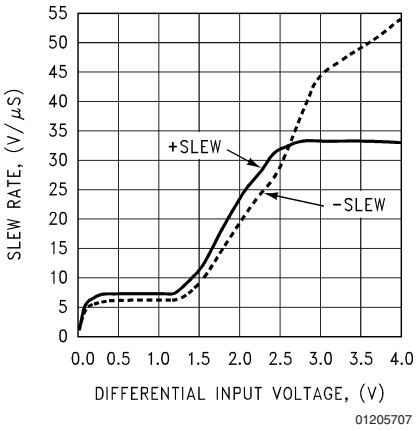
The LM6142/LM6144 input stage converts the input voltage change to a current change. This current change drives the current mirrors through the collectors of Q1–Q2, Q3–Q4 when the input levels are normal.

If the input signal exceeds the slew rate of the input stage, the differential input voltage rises above two diode drops. This excess signal bypasses the normal input transistors, (Q1–Q4), and is routed in correct phase through the two additional transistors, (Q5, Q6), directly into the current mirrors.

This rerouting of excess signal allows the slew-rate to increase by a factor of 10 to 1 or more. (See *Figure 1*.)

As the overdrive increases, the op amp reacts better than a conventional op amp. Large fast pulses will raise the slew-rate to around 30V to 60V/µs.

Slew Rate vs. Δ V_{IN}
V_S = ±5V



01205707

FIGURE 1.

This effect is most noticeable at higher supply voltages and lower gains where incoming signals are likely to be large.

This new input circuit also eliminates the phase reversal seen in many op amps when they are overdriven.

This speed-up action adds stability to the system when driving large capacitive loads.

DRIVING CAPACITIVE LOADS

Capacitive loads decrease the phase margin of all op amps. This is caused by the output resistance of the amplifier and the load capacitance forming an R-C phase lag network. This can lead to overshoot, ringing and oscillation. Slew rate limiting can also cause additional lag. Most op amps with a fixed maximum slew-rate will lag further and further behind when driving capacitive loads even though the differential input voltage raises. With the LM6142, the lag causes the slew rate to raise. The increased slew-rate keeps the output following the input much better. This effectively reduces phase lag. After the output has caught up with the input, the differential input voltage drops down and the amplifier settles rapidly.

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LM6142/LM6144 Application Ideas

(Continued)

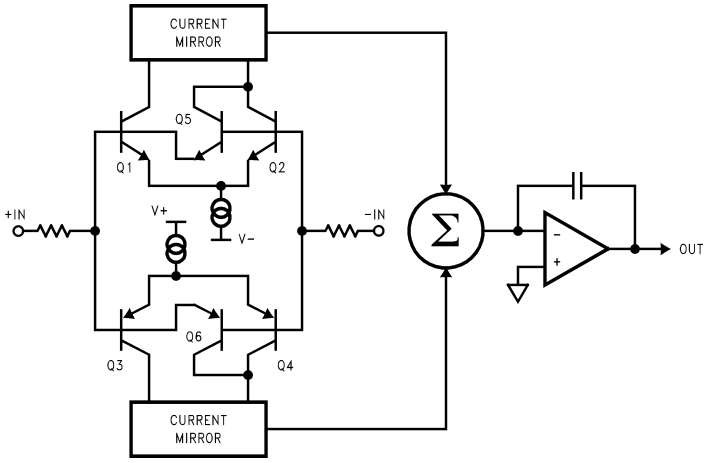

FIGURE 2.

These features allow the LM6142 to drive capacitive loads as large as 1000pF at unity gain and not oscillate. The scope photos (*Figure 3* and *Figure 4*) above show the LM6142 driving a l000pF load. In *Figure 3*, the upper trace is with no capacitive load and the lower trace is with a 1000pF load. Here we are operating on ±12V supplies with a 20 V_{PP} pulse. Excellent response is obtained with a C_f of l0pF. In *Figure 4*, the supplies have been reduced to ±2.5V, the pulse is 4 V_{PP} and C_f is 39pF. The best value for the compensation capacitor is best established after the board layout is finished because the value is dependent on board stray capacity, the value of the feedback resistor, the closed loop gain and, to some extent, the supply voltage.

Another effect that is common to all op amps is the phase shift caused by the feedback resistor and the input capacitance. This phase shift also reduces phase margin. This effect is taken care of at the same time as the effect of the capacitive load when the capacitor is placed across the feedback resistor.

The circuit shown in *Figure 5* was used for these scope photos.

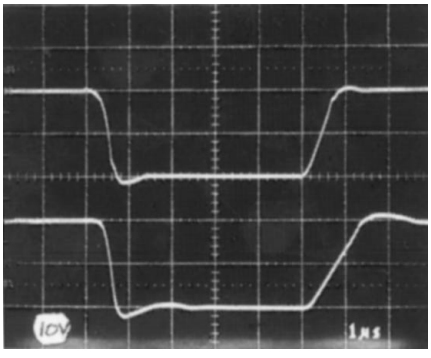

FIGURE 3.

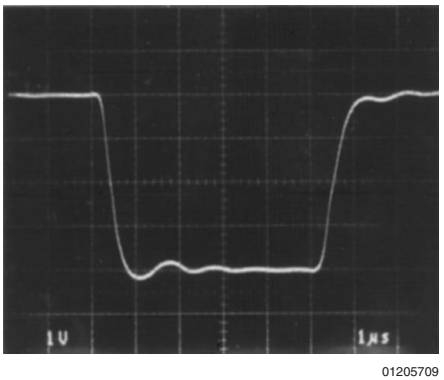

FIGURE 4.

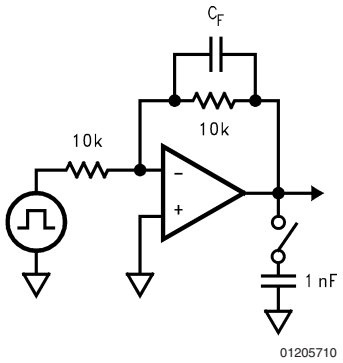

FIGURE 5.

Typical Applications

FISH FINDER/ DEPTH SOUNDER.

The LM6142/LM6144 is an excellent choice for battery operated fish finders. The low supply current, high gain-bandwidth and full rail to rail output swing of the LM6142 provides an ideal combination for use in this and similar applications.

ANALOG TO DIGITAL CONVERTER BUFFER

The high capacitive load driving ability, rail-to-rail input and output range with the excellent CMR of 82 dB, make the LM6142/LM6144 a good choice for buffering the inputs of A to D converters.

3 OP AMP INSTRUMENTATION AMP WITH RAIL-TO-RAIL INPUT AND OUTPUT

Using the LM6144, a 3 op amp instrumentation amplifier with rail-to-rail inputs and rail to rail output can be made. These features make these instrumentation amplifiers ideal for single supply systems.

Some manufacturers use a precision voltage divider array of 5 resistors to divide the common-mode voltage to get an input range of rail-to-rail or greater. The problem with this method is that it also divides the signal, so to even get unity gain, the amplifier must be run at high closed loop gains. This raises the noise and drift by the internal gain factor and

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Typical Applications (Continued)

lowers the input impedance. Any mismatch in these precision resistors reduces the CMR as well. Using the LM6144, all of these problems are eliminated.

In this example, amplifiers A and B act as buffers to the differential stage (*Figure 6*). These buffers assure that the input impedance is over 100MΩ and they eliminate the requirement for precision matched resistors in the input stage. They also assure that the difference amp is driven from a voltage source. This is necessary to maintain the CMR set by the matching of R1–R2 with R3–R4.

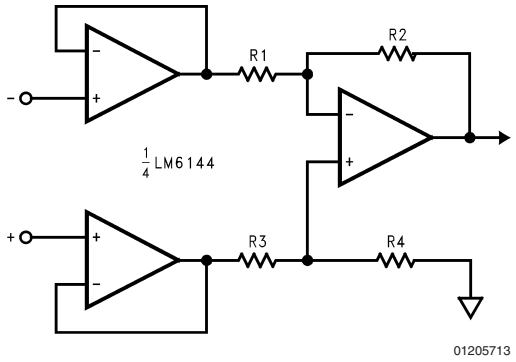

FIGURE 6.

The gain is set by the ratio of R2/R1 and R3 should equal R1 and R4 equal R2. Making R4 slightly smaller than R2 and adding a trim pot equal to twice the difference between R2 and R4 will allow the CMR to be adjusted for optimum.

With both rail to rail input and output ranges, the inputs and outputs are only limited by the supply voltages. Remember that even with rail-to-rail output, the output can not swing past the supplies so the combined common mode voltage plus the signal should not be greater than the supplies or limiting will occur.

SPICE MACROMODEL

A SPICE macromodel of this and many other National Semiconductor op amps is available at no charge from the NSC Customer Response Group at 800-272-9959.

Ordering Information

Package	Temperature Range Industrial –40˚C to +85˚C	Temperature Range Military –55˚C to +125˚C	NSC Drawing
8-Pin Molded DIP	LM6142AIN		N08E
	LM6142BIN		
8-Pin Small Outline	LM6142AIM		M08A
	LM6142AIMX		
	LM6142BIM		
	LM6142BIMX		
14-Pin Molded DIP	LM6144AIN		N14A
	LM6144BIN		
14-Pin Small Outline	LM6144AIM		M14A
	LM6144AIMX		
	LM6144BIM		
	LM6144BIMX		
8-Pin CDIP		LM6142AMJ-QML	J08A

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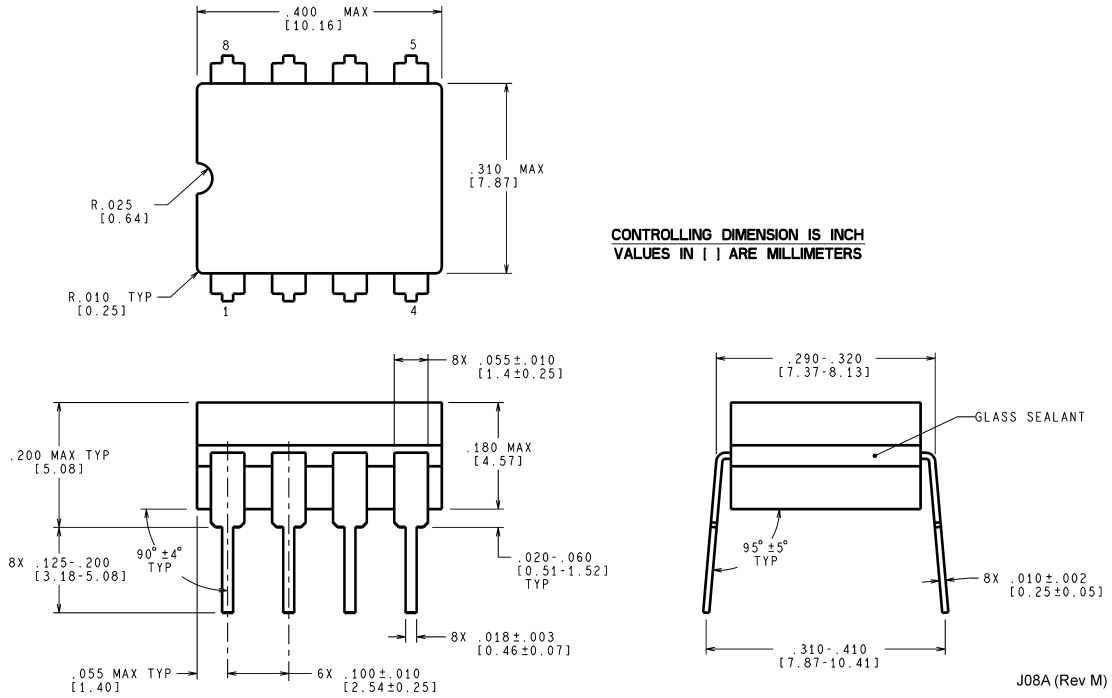
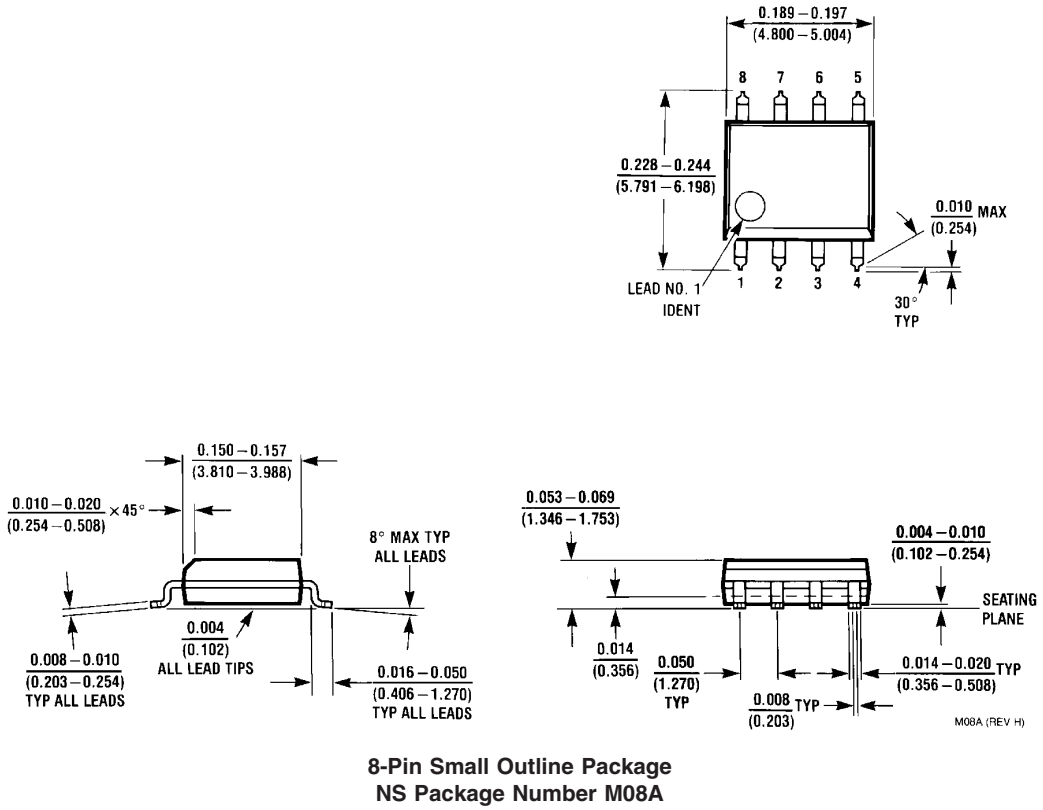
Physical Dimensions inches (millimeters)

unless otherwise noted



8-Pin Cerdip
Dual-In-Line Package
NS Package Number J08A



8-Pin Small Outline Package
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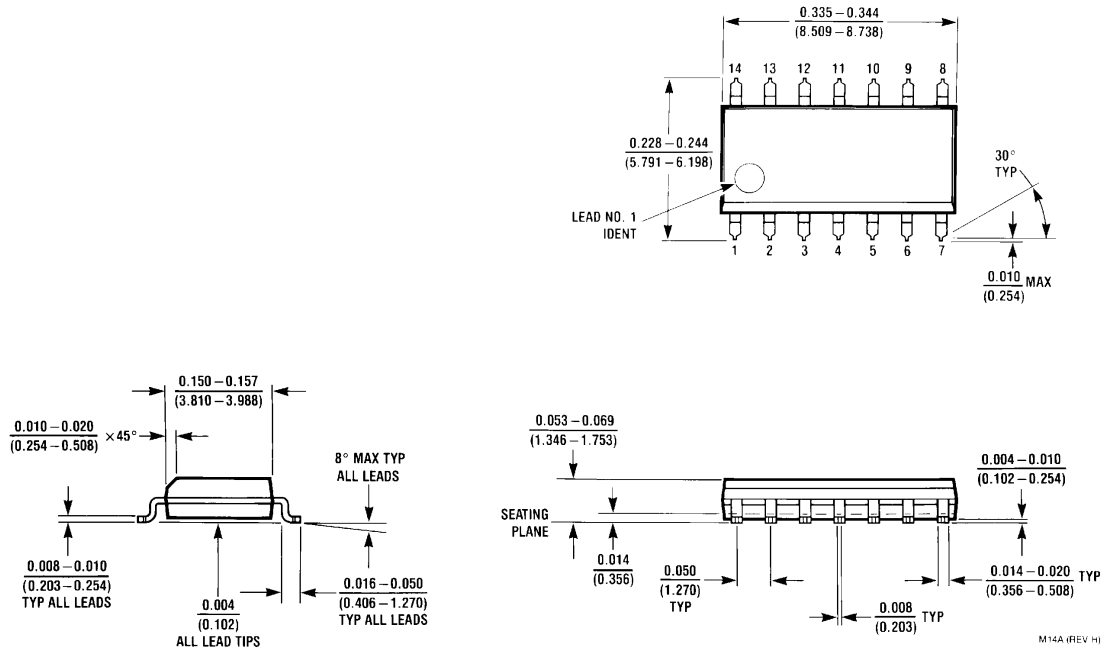

14-Pin Small Outline Package
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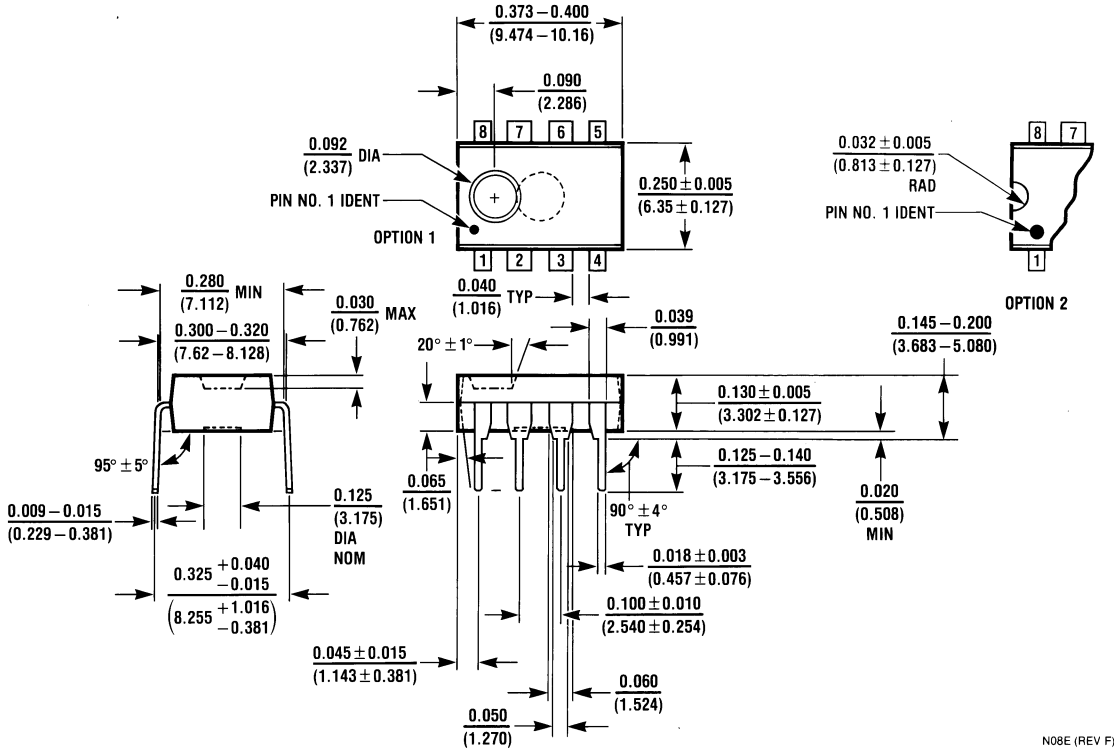

8-Pin Molded Dual-In-Line Package
NS Package Number N08E

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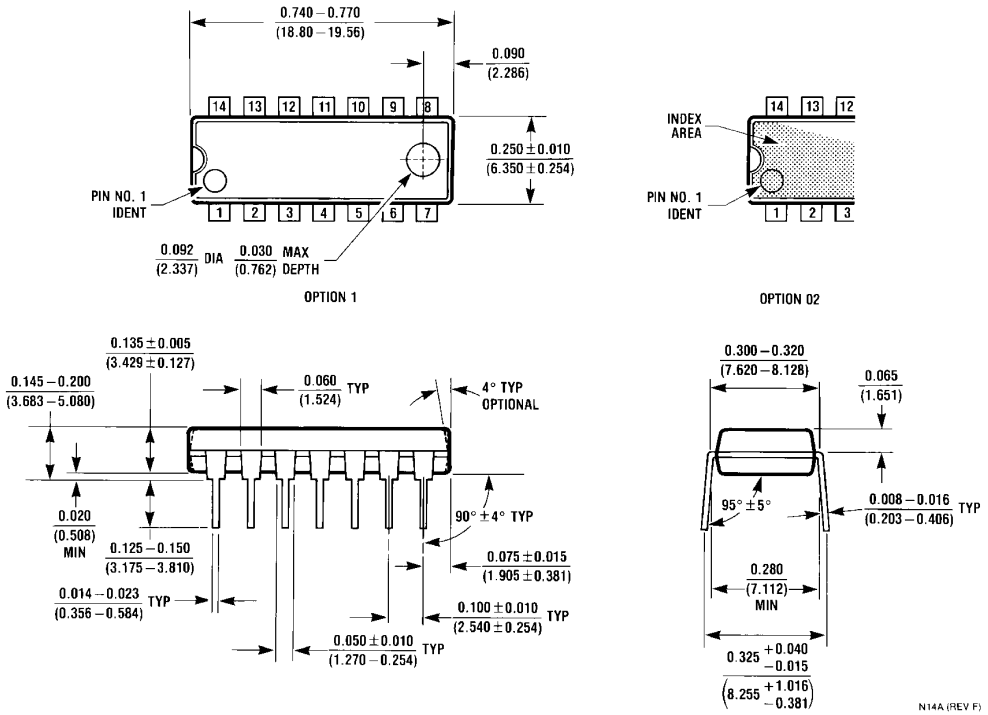

14-Pin Molded Dual-In-Line Package
NS Package Number N14A

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