

LT1006

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage $\pm 22\text{V}$
 Input Voltage Equal to Positive Supply Voltage
 Input Voltage 5V Below Negative Supply Voltage
 Differential Input Voltage 30V
 Output Short-Circuit Duration Indefinite

Operating Temperature Range

LT1006AM/LT1006M (**OBSOLETE**).... -55°C to 125°C

LT1006AC/LT1006C/LT1006S8 0°C to 70°C

Storage Temperature Range -65°C to 150°C

Lead Temperature (Soldering, 10 sec) 300°C

PACKAGE/ORDER INFORMATION

TOP VIEW ISY SET (NOTE 3) VOS TRIM -IN +IN V- V+ OUT VOS TRIM (NOTE 4) (CASE) H PACKAGE 8-LEAD TO-5 METAL CAN $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 150^{\circ}\text{C/W}$, $\theta_{JC} = 45^{\circ}\text{C}$	ORDER PART NUMBER	TOP VIEW VOS TRIM -IN +IN V- ISY SET (NOTE 3) V+ OUT VOS TRIM (NOTE 4) N8 PACKAGE 8-LEAD PDIP S8 PACKAGE 8-LEAD PLASTIC SO $T_{JMAX} = 100^{\circ}\text{C}$, $\theta_{JA} = 130^{\circ}\text{C/W}$ (N8) $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 200^{\circ}\text{C/W}$ (S8)	ORDER PART NUMBER
	LT1006AMH LT1006MH LT1006ACH LT1006CH		LT1006CN8 LT1006S8
			S8 PART MARKING
			1006
		J8 PACKAGE 8-LEAD Cerdip $T_{JMAX} = 100^{\circ}\text{C}$, $\theta_{JA} = 130^{\circ}\text{C/W}$	LT1006AMJ8 LT1006MJ8 LT1006ACJ8 LT1006CJ8
OBSOLETE PACKAGES Consider the N8 or S8 Package for Alternate Source			

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS $V_S = 5\text{V}$, $V_{CM} = 0\text{V}$, $V_{OUT} = 1.4\text{V}$, $T_A = 25^{\circ}\text{C}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1006AM/AC			LT1006M/C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1006S8		20	50		30	80	μV
							80	400	μV
$\frac{\Delta V_{OS}}{\Delta \text{Time}}$	Long-Term Input Offset Voltage Stability	LT1006S8		0.4			0.5		$\mu\text{V/Mo}$
							0.7		$\mu\text{V/Mo}$
I_{OS}	Input Offset Current			0.12	0.5		0.15	0.9	nA
I_B	Input Bias Current			9	15		10	25	nA
e_n	Input Noise Voltage	0.1Hz to 10Hz		0.55			0.55		μV_{P-P}
	Input Noise Voltage Density	$f_0 = 10\text{Hz}$		23	32		23	32	$\text{nV}/\sqrt{\text{Hz}}$
		$f_0 = 1000\text{Hz}$		22	25		22	25	$\text{nV}/\sqrt{\text{Hz}}$
i_n	Input Noise Current Density	$f_0 = 10\text{Hz}$		0.07			0.08		$\text{pA}/\sqrt{\text{Hz}}$
	Input Resistance	(Note 2)							
	Differential Mode		180	400		100	300		$\text{M}\Omega$
	Common Mode			5			4		$\text{G}\Omega$

1006fa

ELECTRICAL CHARACTERISTICS

$V_S = 5V$, $V_{CM} = 0V$, $V_{OUT} = 1.4V$, $T_A = 25^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1006AM/AC			LT1006M/C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
	Input Voltage Range		3.5 0	3.8 −0.3		3.5 0	3.8 −0.3		V V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to $3.5V$	100	114		97	112		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2V$ to $\pm 18V$, $V_O = 0V$	106	126		103	124		dB
A_{VOL}	Large-Signal Voltage Gain	$V_O = 0.03V$ to $4V$, $R_L = 10k$ $V_O = 0.03V$ to $3.5V$, $R_L = 2k$	1.0 0.5	2.5 2.0		0.7 0.3	2.0 1.8		V/ μV V/ μV
	Maximum Output Voltage Swing	Output Low, No Load Output Low, 600Ω to GND Output Low, $I_{SINK} = 1mA$ Output High, No Load Output High, 600Ω to GND		15 5 220 4.0 3.4	25 10 350		15 5 220 4.4 4.0	25 10 350	mV mV mV V V
SR	Slew Rate		0.25	0.4		0.25	0.4		V/ μs
I_S	Supply Current	$R_{SET} = \infty$ $R_{SET} = 180k$ Pin 8 to Pin 7 (Note 3)		340 90	520		350 90	570	μA μA
	Minimum Supply Voltage		2.7			2.7			V

The ● denotes the specifications which apply over the full operating temperature range. $V_S = 5V$, $0V$; $V_{CM} = 0.1V$; $V_O = 1.4V$; $-55^\circ C \leq T_A \leq 125^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1006AM			LT1006M			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage		●		40	180		60	250	μV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Input Offset Voltage Drift		●		0.2	1.3		0.3	1.8	$\mu V/^\circ C$
I_{OS}	Input Offset Current		●		0.4	2.0		0.5	4.0	nA
I_B	Input Bias Current		●		13	25		16	40	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = 0.05V$ to $3.5V$, $R_L = 2k$	●	0.25	0.8		0.15	0.7		V/ μV
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0.1V$ to $3.2V$	●	90	103		87	102		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2V$ to $\pm 18V$, $V_O = 0V$	●	100	117		97	116		dB
	Maximum Output Voltage Swing	Output Low, 600Ω to GND Output High, 600Ω to GND	● ●	3.2	6 3.8	15	3.1	6 3.8	18	mV V
I_S	Supply Current		●		380	630		400	680	μA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range. $V_S = 5V$, $0V$; $V_{CM} = 0V$; $V_O = 1.4V$; $0^\circ C \leq T_A \leq 70^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1006AC			LT1006C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	J8/H Package	●		30	110		45	160	μV
		N8 Package	●					50	190	μV
		S8 Package	●					110	560	μV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Input Offset Voltage Drift	J8/H Package	●		0.2	1.3		0.3	1.8	$\mu V/^\circ C$
		N8 Package	●					0.5	2.5	$\mu V/^\circ C$
		S8 Package	●					0.7	3.5	$\mu V/^\circ C$
I_{OS}	Input Offset Current		●		0.25	1.2		0.3	2.5	nA
I_B	Input Bias Current		●		11	20		12	30	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = 0.04V$ to $3.5V$, $R_L = 2k$	●	0.35	1.3		0.25	1.2		V/ μV
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to $3.4V$	●	96	109		92	108		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2V$ to $\pm 18V$, $V_O = 0V$	●	101	120		97	118		dB
	Maximum Output Voltage Swing	Output Low, 600Ω to GND	●		6	13		6	13	mV
		Output High, 600Ω to GND	●	3.3	3.9		3.2	3.9		V
I_S	Supply Current		●		350	570		360	620	μA

$V_S = \pm 15V$, $T_A = 25^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1006AM/AC			LT1006M/C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1006S8			30	100		50	180	μV
								100	525	μV
I_{OS}	Input Offset Current				0.1	0.5		0.15	0.9	nA
I_B	Input Bias Current				7.5	12.0		8	20	nA
	Input Voltage Range			13.5	13.8		13.5	13.8		V
				-15.0	-15.3		-15.0	-15.3		V
CMRR	Common Mode Rejection Ratio	$V_{CM} = +13.5V$, $-15V$		100	117		97	116		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2V$ to $\pm 18V$, $V_O = 0V$		106	126		103	124		dB
A_{VOL}	Large Signal Voltage Gain	$V_O = \pm 10V$, $R_L = 2k$		1.5	5.0		1.2	4.0		V/ μV
		$V_O = \pm 10V$, $R_L = 600\Omega$		0.8	1.5		0.5	1.0		V/ μV
V_{OUT}	Maximum Output Voltage Swing	$R_L = 2k$		± 13	± 14		± 12.5	± 14		V
SR	Slew Rate	$R_{SET} = \infty$		0.25	0.4		0.25	0.4		V/ μs
		$R_{SET} = 390\Omega$ Pin 8 to Pin 4		1.0	1.2		1.0	1.2		V/ μs
I_S	Supply Current				360	540		360	600	μA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range. $V_S = \pm 15V$, $-55^\circ C \leq T_A \leq 125^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1006AM			LT1006M			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage		●		80	320		110	460	μV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Input Offset Voltage Drift		●		0.5	2.2		0.6	2.8	$\mu V/^\circ C$
I_{OS}	Input Offset Current		●		0.2	2.0		0.3	3.0	nA
I_B	Input Bias Current		●		9	18		11	27	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm 10V$, $R_L = 2k$	●	0.5	1.5		0.25	1.0		V/ μV
CMRR	Common Mode Rejection Ratio	$V_{CM} = +13V$, $-14.9V$	●	97	114		94	113		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2V$ to $\pm 18V$, $V_O = 0V$	●	100	117		97	116		dB
	Maximum Output Voltage Swing	$R_L = 2k$	●	± 12	± 13.8		± 11.5	± 13.8		V
I_S	Supply Current		●		400	650		400	750	μA

The ● denotes the specifications which apply over the full operating temperature range. $V_S = \pm 15V$, $0^\circ C \leq T_A \leq 70^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1006AC			LT1006C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	J8/H Package	●		50	200		75	300	μV
		N8 Package	●					80	330	μV
		S8 Package	●					150	730	μV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Input Offset Voltage Drift	J8/H Package	●		0.5	2.2		0.6	2.8	$\mu V/^\circ C$
		N8 Package	●					0.7	3.5	$\mu V/^\circ C$
		S8 Package	●					1.0	4.5	$\mu V/^\circ C$
I_{OS}	Input Offset Current		●		0.15	1		0.25	2	nA
I_B	Input Bias Current		●		8	15		10	23	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm 10V$, $R_L = 2k$	●	1	3		0.7	2.5		V/ μV
CMRR	Common Mode Rejection Ratio	$V_{CM} = 13V$, $-15V$	●	98	116		94	114		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2V$ to $\pm 18V$, $V_O = 0V$	●	101	120		97	118		dB
	Maximum Output Voltage Swing	$R_L = 2k$	●	± 12.5	± 13.9		± 11.5	± 13.8		V
I_S	Supply Current		●		370	600		380	660	μA

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

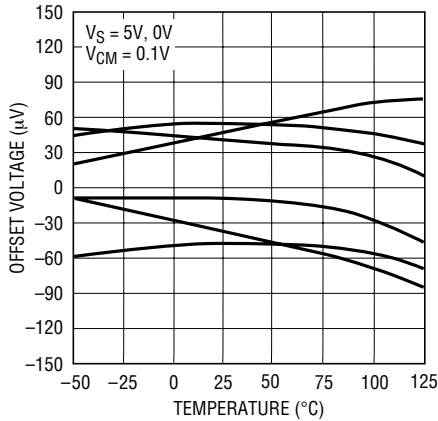
Note 2: This parameter is guaranteed by design and is not tested.

Note 3: Regular operation does not require an external resistor. In order to program the supply current for low power or high speed operation, connect an external resistor from Pin 8 to Pin 7 or from Pin 8 to Pin 4, respectively. Supply current specifications (for $R_{SET} = 180k$) do not include current in R_{SET} .

Note 4: Optional offset nulling is accomplished with a potentiometer connected between the trim terminals and the wiper to V^- . A 10k pot (providing a null range of $\pm 6mV$) is recommended for minimum drift of nulled offset voltage with temperature. For increased trim resolution and accuracy, two fixed resistors can be used in conjunction with a smaller potentiometer. For example, two 4.7k resistors tied to Pins 1 and 5, with a 500 Ω pot in the middle, will have a null range of $\pm 150\mu V$.

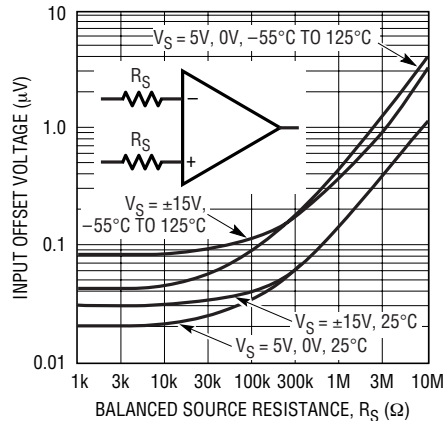
TYPICAL PERFORMANCE CHARACTERISTICS

Offset Voltage Drift with Temperature of Representative Units



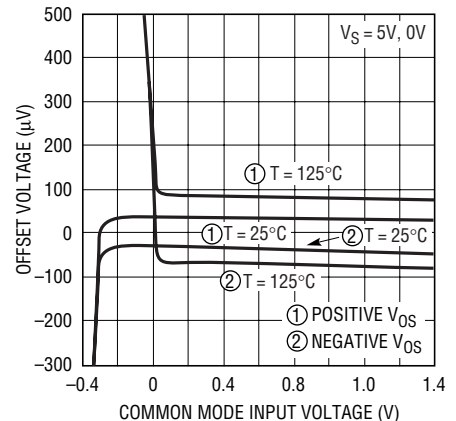
LT1006 • G02

Offset Voltage vs Balanced Source Resistor



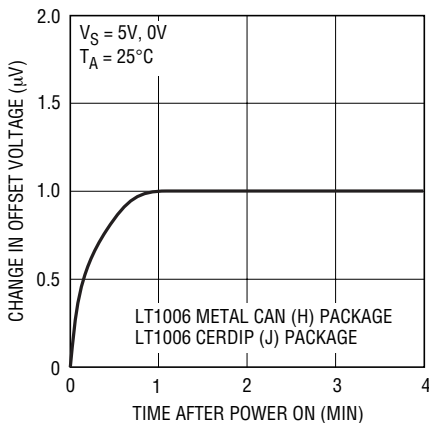
LT1006 • G03

V_{OS} vs Common Mode Voltage vs Temperature



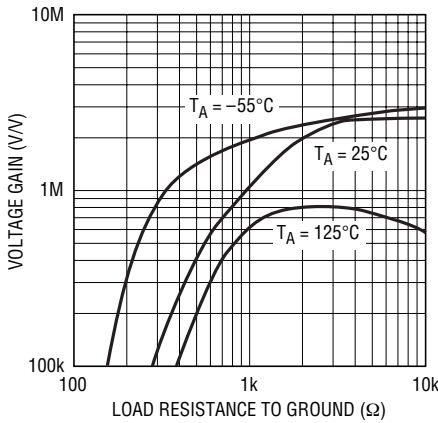
LT1006 • G04

Warm-Up Drift



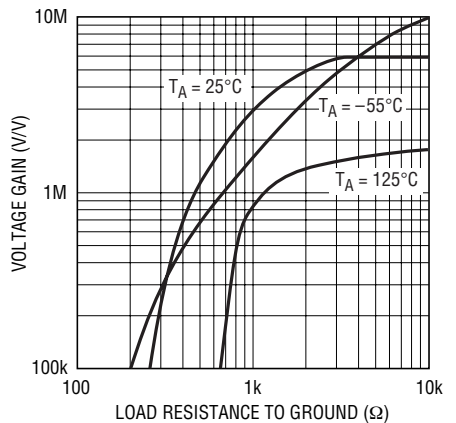
LT1006 • G05

Voltage Gain vs Load Resistance, $V_S = 5\text{V}, 0\text{V}$



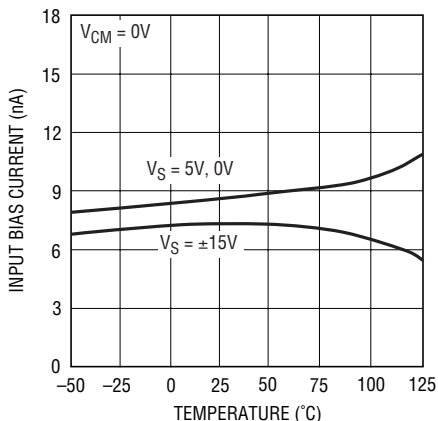
LT1006 • G06

Voltage Gain vs Load Resistance with $V_S = \pm 15\text{V}$



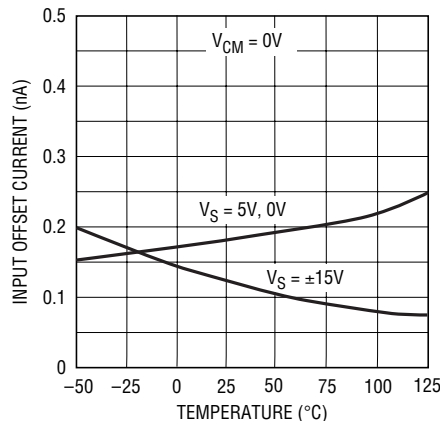
LT1006 • G07

Input Bias Current vs Temperature



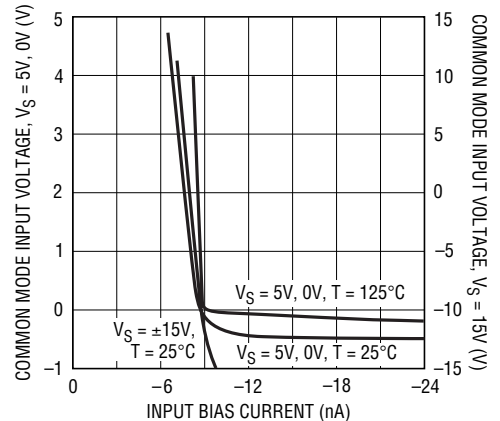
LT1006 • G08

Input Offset Current vs Temperature



LT1006 • G09

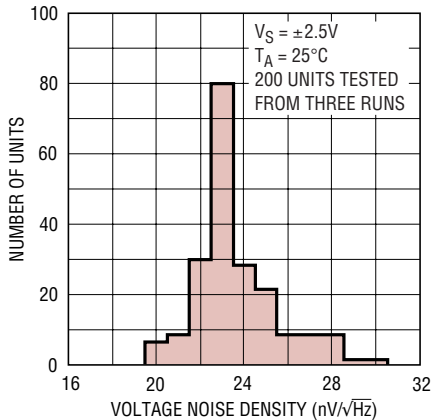
Input Bias Current vs Common Mode Voltage



LT1006 • G10

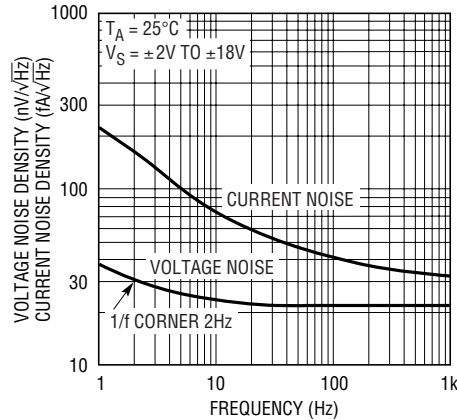
TYPICAL PERFORMANCE CHARACTERISTICS

10Hz Voltage Noise Distribution



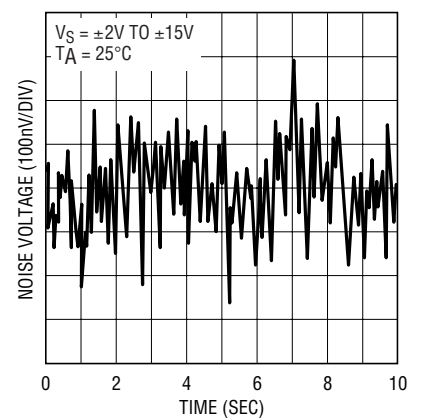
LT1006 • G11

Noise Spectrum



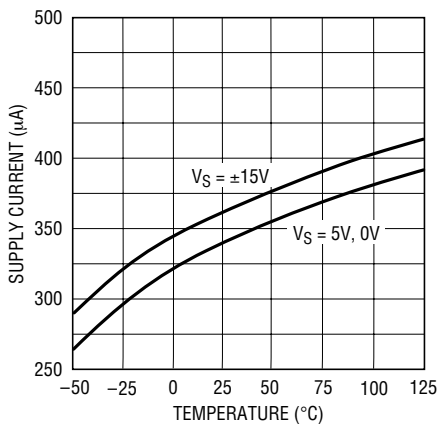
LT1006 • G12

0.1Hz to 10Hz Noise



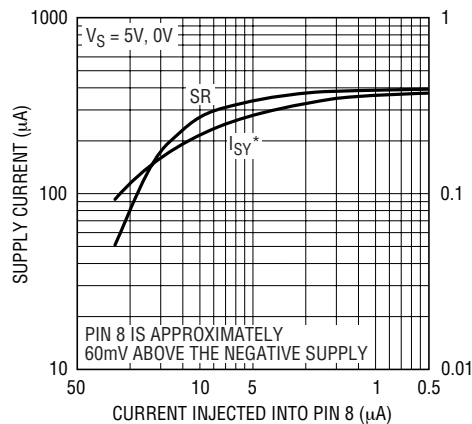
LT1006 • G13

Supply Current vs Temperature



LT1006 • G14

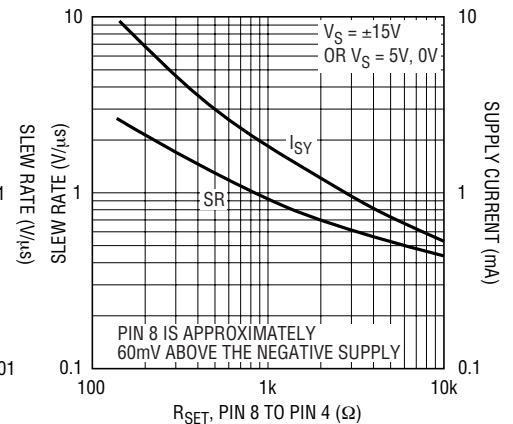
Reducing Power Dissipation



* I_{SY} DOES NOT INCLUDE CURRENT THROUGH R_{SET}

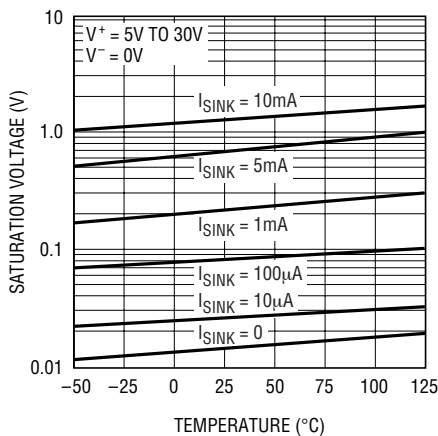
LT1006 • G15

Increasing Slew Rate (R_{SET} to V^-)



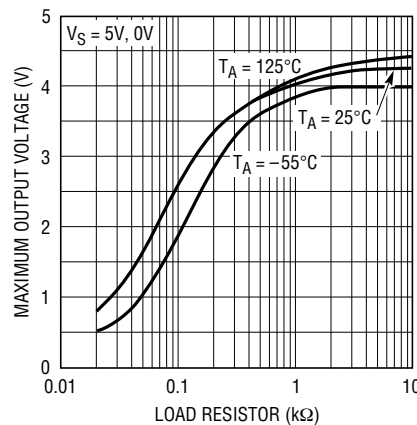
LT1006 • G16

Output Saturation vs Sink Current vs Temperature



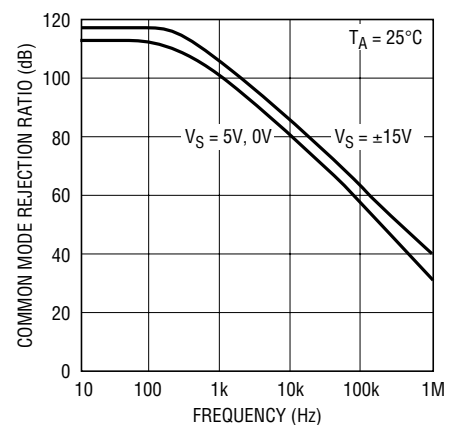
LT1006 • G17

Maximum Output Swing vs Load Resistor



LT1006 • G18

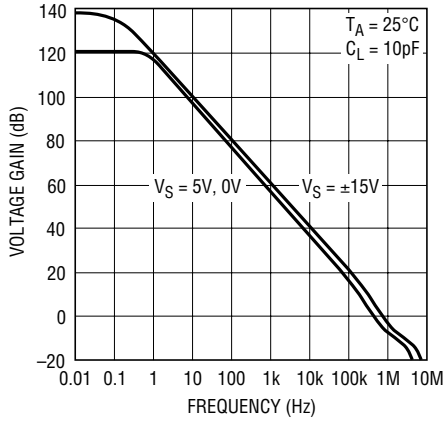
Common Mode Rejection Ratio vs Frequency



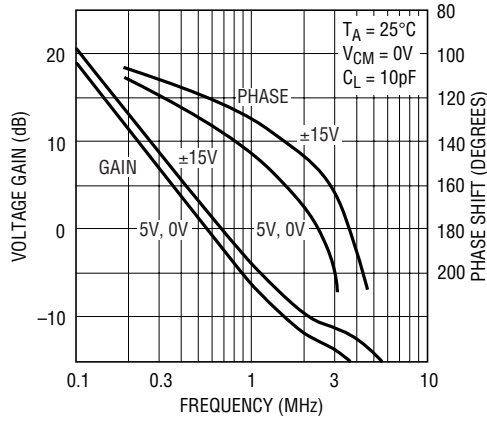
LT1006 • G19

TYPICAL PERFORMANCE CHARACTERISTICS

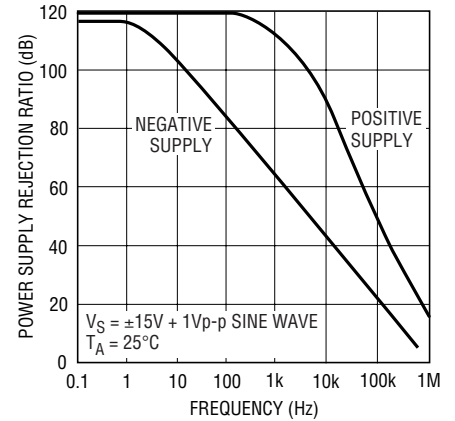
Voltage Gain vs Frequency



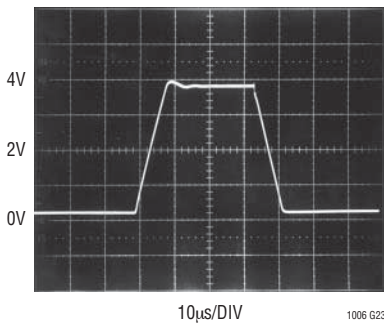
Gain, Phase vs Frequency



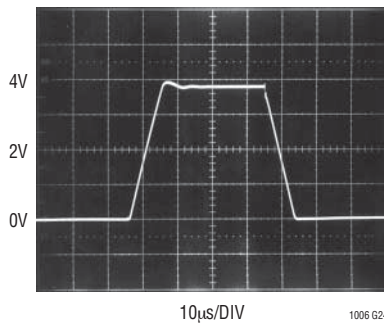
Power Supply Rejection Ratio vs Frequency



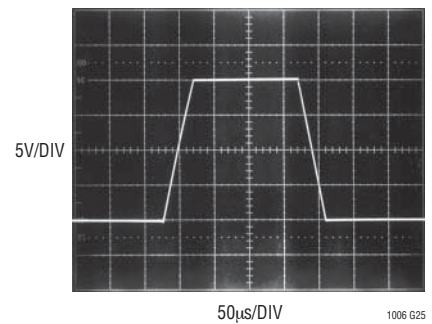
Large Transient Response,
VS = 5V, 0V



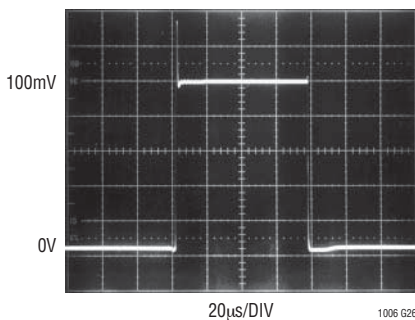
Large-Signal Transient Response,
VS = 5V, 0V



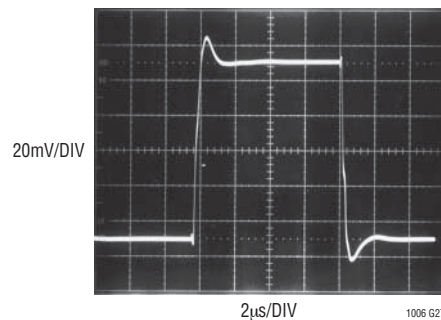
Large-Signal Transient Response,
VS = ±15V



Small-Signal Transient Response,
VS = 5V, 0V



Small-Signal Transient Response,
VCC = ±2.5V to ±15V



APPLICATIONS INFORMATION

The LT1006 is fully specified for single supply operation, (i.e., when the negative supply is 0V). Input common mode range includes ground; the output swings within a few millivolts of ground. Single supply operation, however, can create special difficulties, both at the input and at the output. The LT1006 has specific circuitry which addresses these problems.

At the input, the driving signal can fall below 0V—inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, two distinct problems can occur on previous single supply designs, such as the LM124, LM158, OP-20, OP-21, OP-220, OP-221, OP-420:

- When the input is more than a diode drop below ground, unlimited current will flow from the substrate (V^- terminal) to the input. This can destroy the unit. On the LT1006, the 400Ω resistors, in series with the input (see Schematic Diagram), protect the devices even when the input is 5V below ground.
- When the input is more than 400mV below ground (at 25°C), the input stage saturates (transistors Q3 and

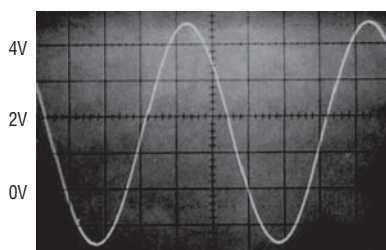
Q4) and phase reversal occurs at the output. This can cause lock-up in servo systems. Due to a unique phase reversal protection circuitry (Q21, Q22, Q27, Q28), the LT1006's output does not reverse, as illustrated below, even when the inputs are at -1.5V .

At the output, the aforementioned single supply designs either cannot swing to within 600mV of ground (OP-20) or cannot sink more than a few microamperes while swinging to ground (LM124, LM158). The LT1006's all-NPN output stage maintains its low output resistance and high gain characteristics until the output is saturated.

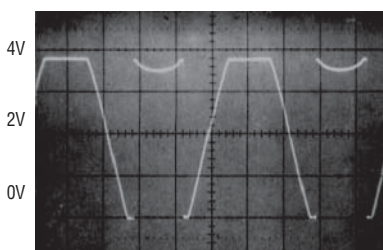
In dual supply operations, the output stage is crossover distortion free.

Since the output cannot go exactly to ground, but can only approach ground to within a few millivolts, care should be exercised to ensure that the output is not saturated. For example, a 1mV input signal will cause the amplifier to set up in its linear region in the gain 100 configuration shown below, but is not enough to make the amplifier function properly in the voltage follower mode.

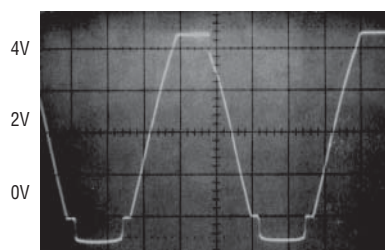
Voltage Follower with Input Exceeding the Negative Common Mode Range ($V_S = 5\text{V}$, 0V)



6V_{p-p} INPUT, -1.5V TO 4.5V 1006 TA11a

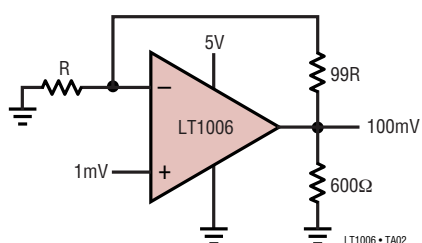


LM324, LM358, OP-20, OP-21
EXHIBIT OUTPUT PHASE
REVERSAL 1006 TA11b



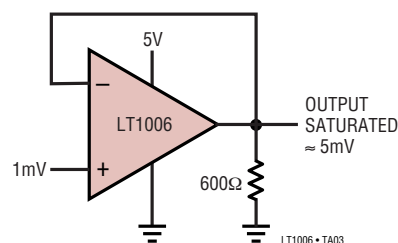
LT1006
NO PHASE REVERSAL 1006 TA11c

Gain 100 Amplifier



LT1006 • TA02

Voltage Follower



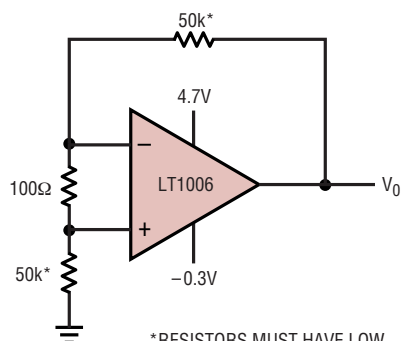
OUTPUT
SATURATED
 $\approx 5\text{mV}$

LT1006 • TA03

APPLICATIONS INFORMATION

In automated production testing the output is forced to 1.4V by the test loop; offset voltage is measured with a common mode voltage of zero and the negative supply at zero (Pin 4). Without the test loop, these exact conditions cannot be achieved. The test circuit shown ensures that the output will never saturate even with worst-case offset voltages ($-250\mu\text{V}$ over the -55°C to 125°C range). The effective common mode input is 0.3V with respect to the negative supply. As indicated by the common mode rejection specifications the difference is only a few microvolts between the two methods of offset voltage measurement.

Test Circuit for Offset Voltage and Offset Drift with Temperature



*RESISTORS MUST HAVE LOW THERMOELECTRIC POTENTIAL.
 **THIS CIRCUIT IS ALSO USED AS THE BURN-IN CONFIGURATION, WITH SUPPLY VOLTAGES INCREASED TO $\pm 20\text{V}$
 $V_O = 1000V_{OS}$

LT1006 • TA04

Low Supply Operation

The minimum guaranteed supply voltage for proper operation of the LT1006 is 2.7V. Typical supply current at this voltage is $320\mu\text{A}$; therefore, power dissipation is only $860\mu\text{W}$.

Noise Testing

For application information on noise testing and calculations, please see the LT1007 or LT1028 data sheet.

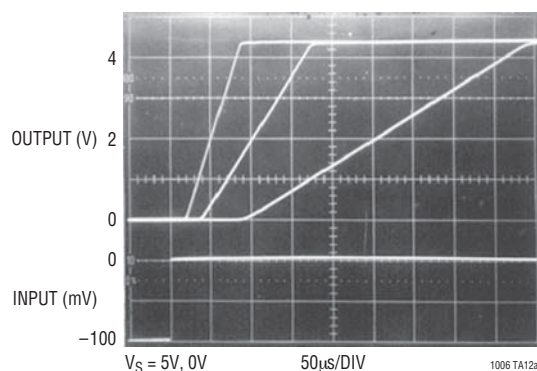
Supply Current Programming

Connecting an optional external resistor to Pin 8 changes the biasing of the LT1006 in order to increase its speed or to decrease its power consumption. If a higher slew rate is required, connect the external resistor for Pin 8 to Pin 4 [see performance curves for Increasing Slew Rate (R_{SET} to V^-)]. For lower power consumption, inject a current into Pin 8 (which is approximately 60mV above V^-) as shown on the Reducing Power Dissipation plot. This can be accomplished by connecting R_{SET} to the positive supply, or to save additional power, by obtaining the injected current from a low voltage battery.

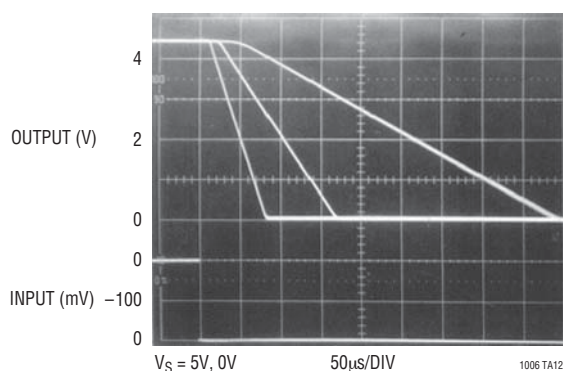
Comparator Applications

The single supply operation of the LT1006 and its ability to swing close to ground while sinking current lends itself to use as a precision comparator with TTL compatible output.

Comparator Rise Response Time to 10mV, 5mV, 2mV Overdrives

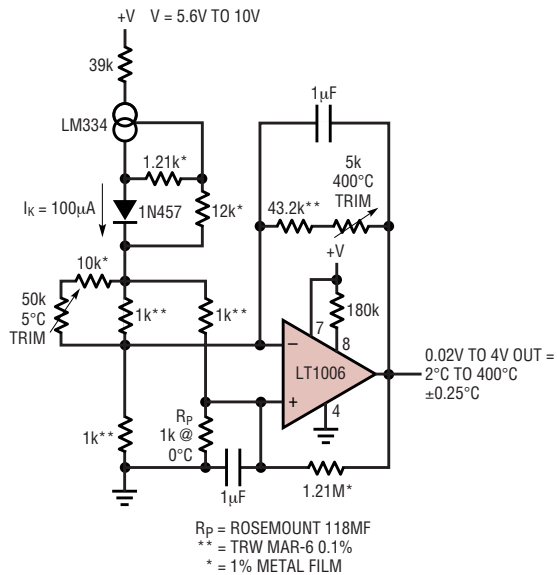


Comparator Fall Response Time to 10mV, 5mV, 2mV Overdrives



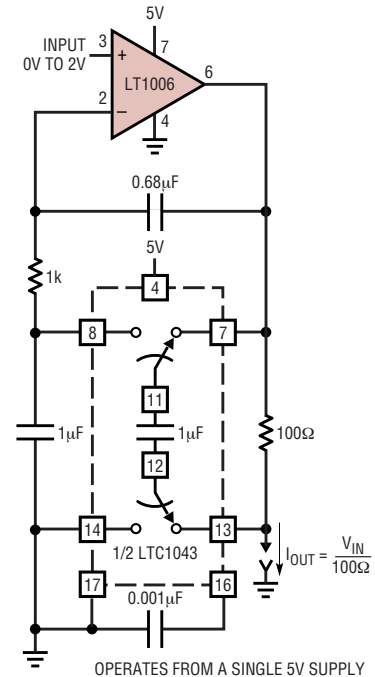
TYPICAL APPLICATIONS

**Platinum RTD Signal Conditioner
with Curvature Correction**



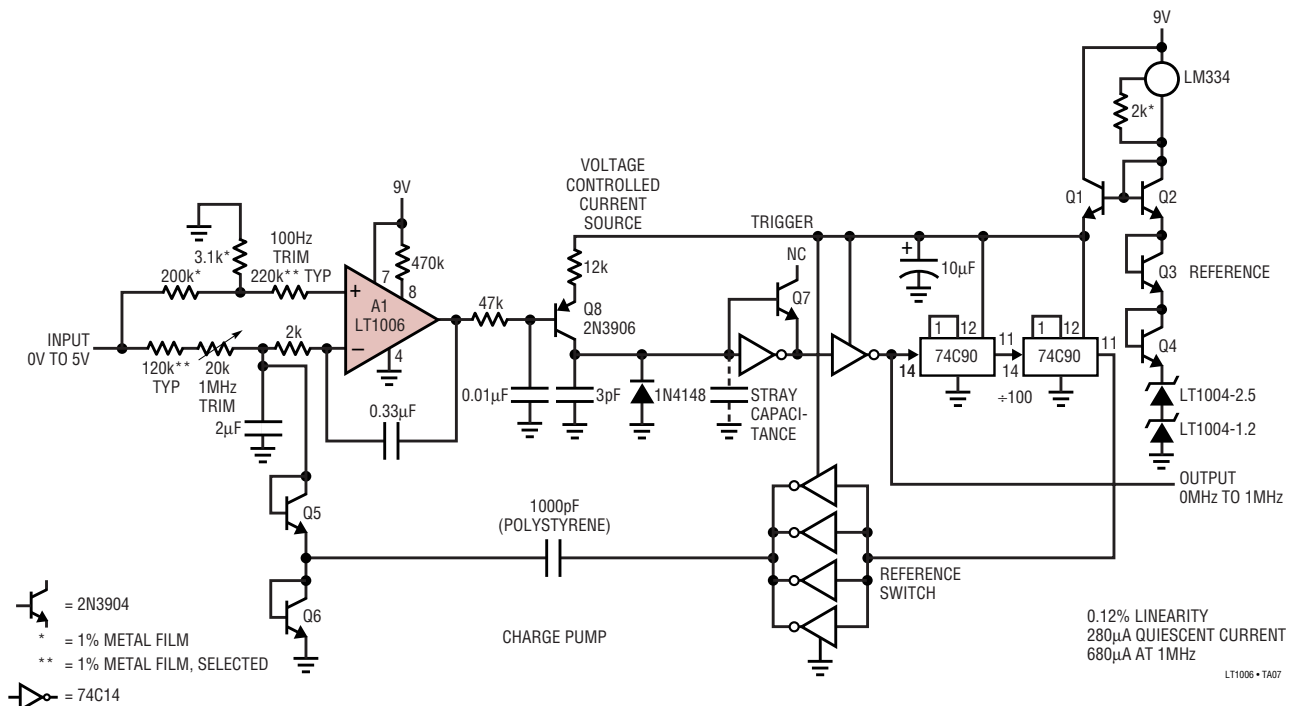
LT1006 • TA05

**Voltage Controlled Current Source
with Ground Referred Input and Output**



LT1006 • TA06

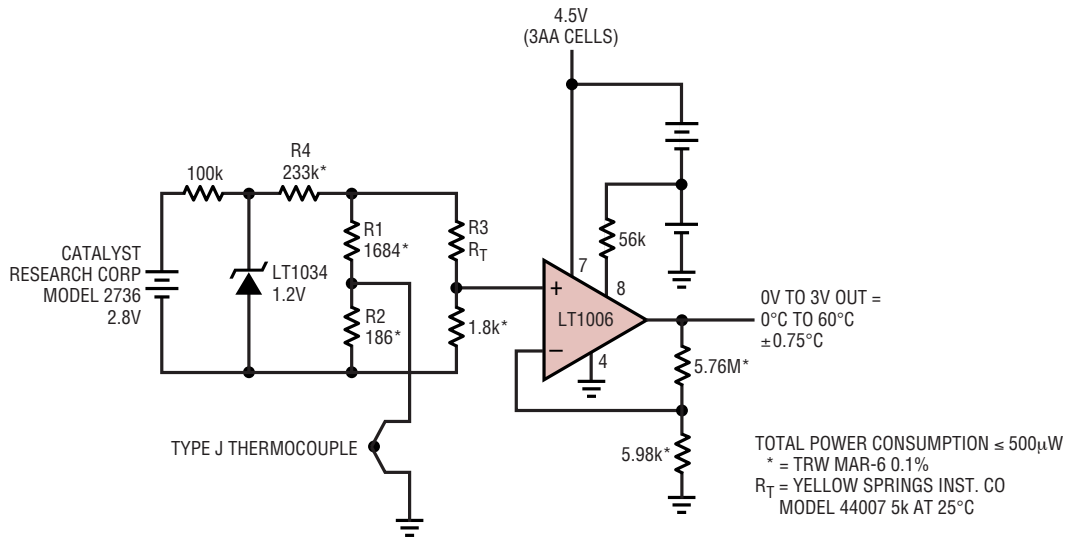
Micropower 1MHz V/F Converter



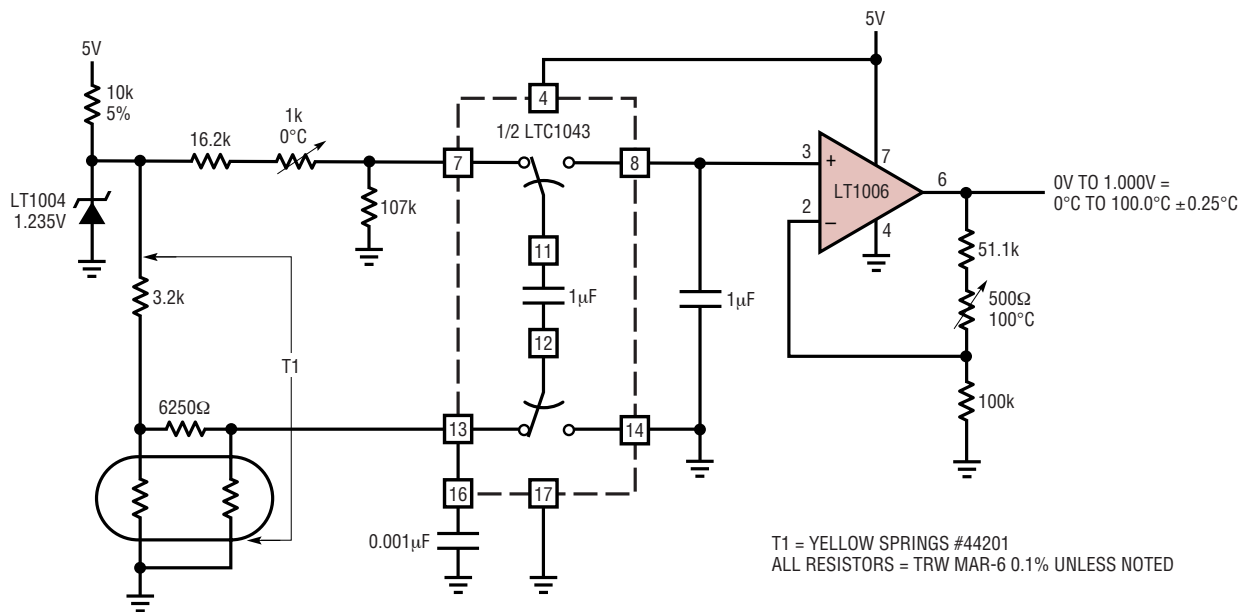
LT1006 • TA07

TYPICAL APPLICATIONS

Micropower Thermocouple Signal Conditioner with Cold Junction Compensation

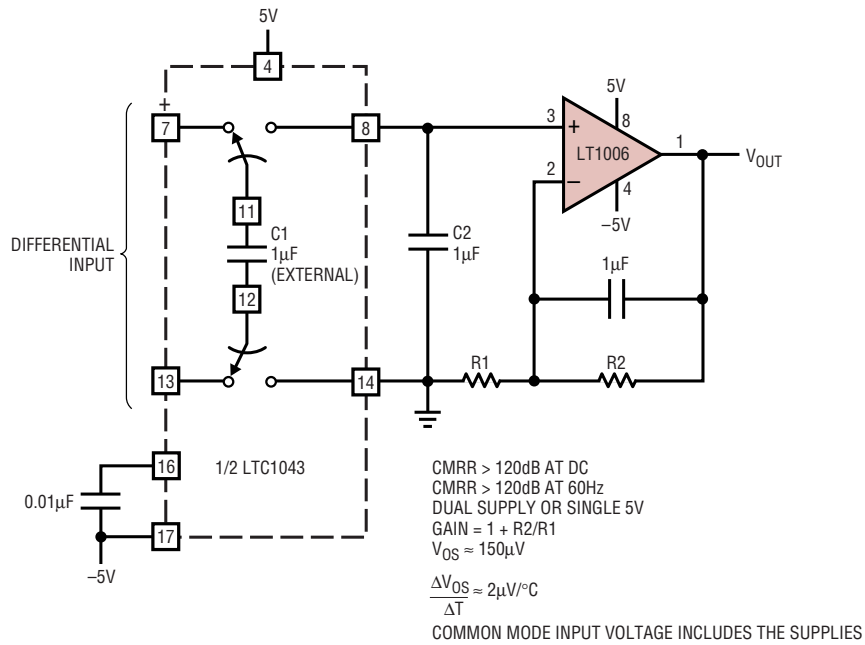


Linear Thermometer



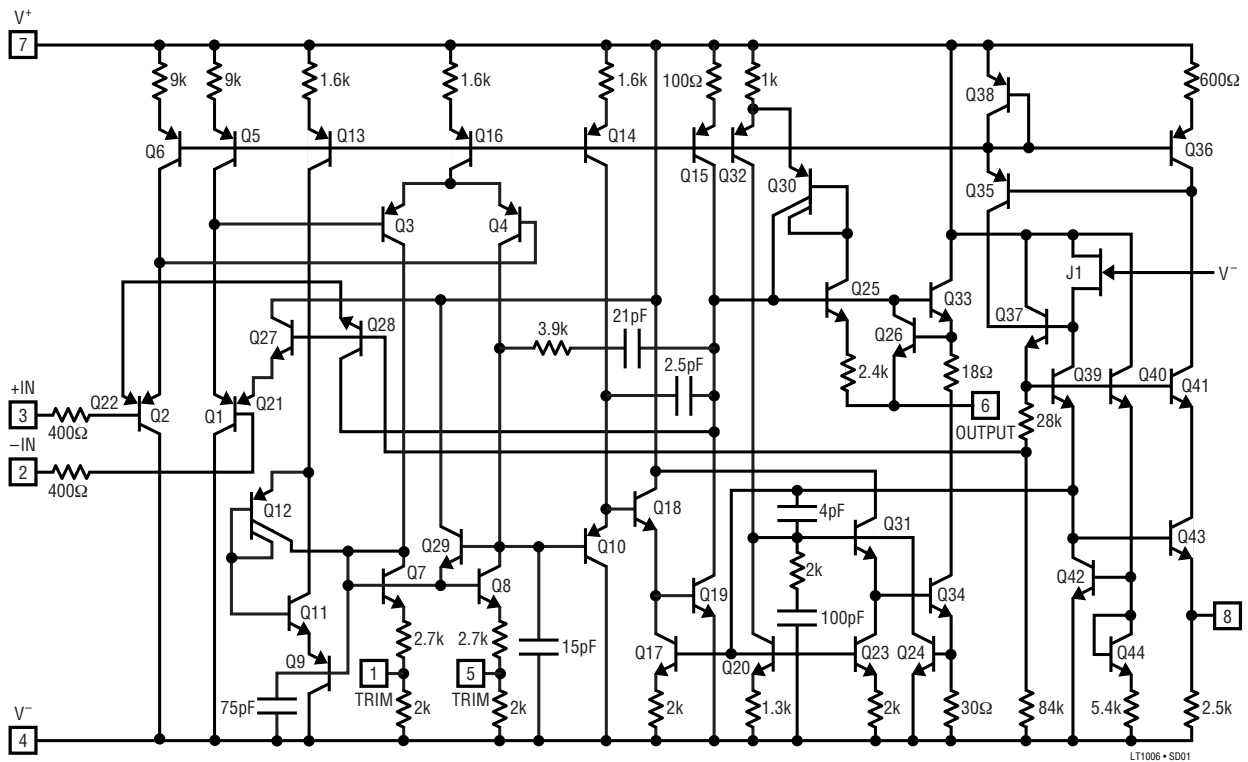
TYPICAL APPLICATIONS

$\pm 5V$ Precision Instrumentation Amplifier



LT1006 • TA10

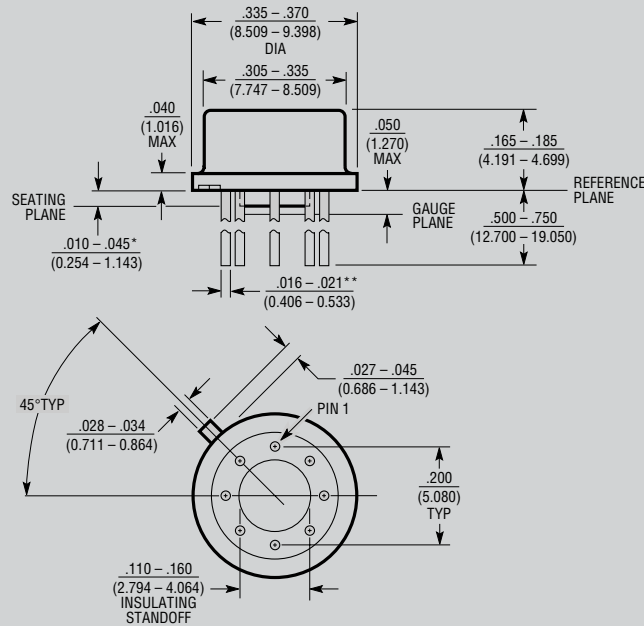
SCHEMATIC DIAGRAM



1006fa

PACKAGE DESCRIPTION

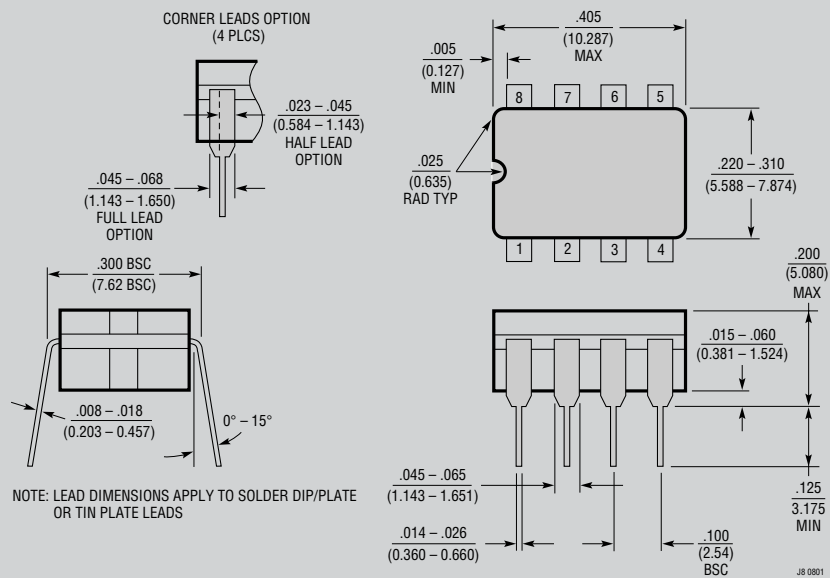
H Package 8-Lead TO-5 Metal Can (.200 Inch PCD) (Reference LTC DWG # 05-08-1320)



* LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND THE SEATING PLANE

** FOR SOLDER DIP LEAD FINISH, LEAD DIAMETER IS $\frac{.016-.024}{(0.406-0.610)}$ H8(TO-5) 0.200 PCD 0801

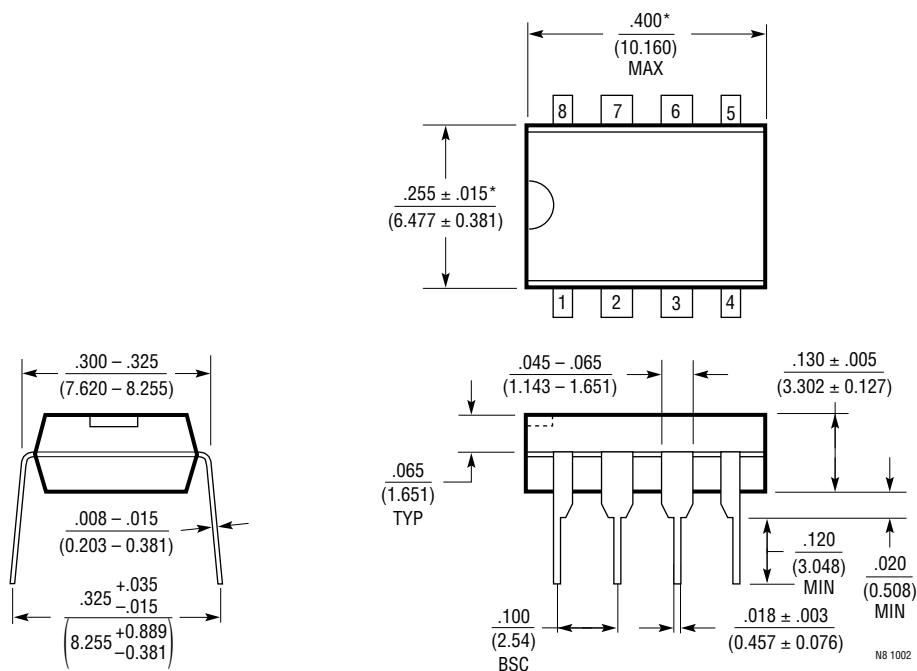
J8 Package 8-Lead Cerdip (Narrow .300 Inch, Hermetic) (Reference LTC DWG # 05-08-1110)



OBSOLETE PACKAGES

PACKAGE DESCRIPTION

N8 Package 8-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510)

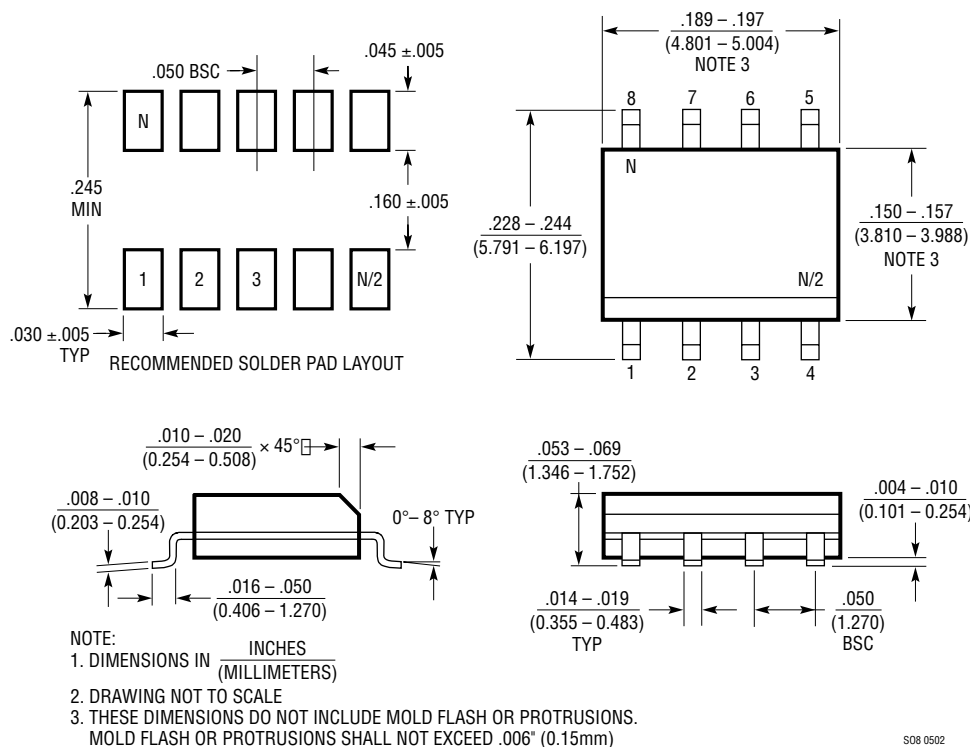


NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

PACKAGE DESCRIPTION

S8 Package 8-Lead Plastic Small Outline (Narrow .150 Inch) (Reference LTC DWG # 05-08-1610)



S08 0502