LINEAR TECHNOLOGY

Over-The-Top Micropower Rail-to-Rail Input and Output Op Amp

FEATURES

- **Rail-to-Rail Input and Output**
- **Micropower: 50µA I_Q, 44V Supply**
- **MSOP Package**
- Over-The-Top™: Input Common Mode Range Extends 44V Above V_{EE}, Independent of V_{CC}
- Low Input Offset Voltage: 225µV Max
- Specified on 3V, 5V and ±15V Supplies
- High Output Current: 18mA
- Output Shutdown
- Output Drives 10,000pF with Output Compensation
- Reverse Battery Protection to 27V
- High Voltage Gain: 2000V/mV
- High CMRR: 110dB
- 220kHz Gain-Bandwidth Product

APPLICATIONS

- Battery- or Solar-Powered Systems
     Portable Instrumentation
     Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- MUX Amplifiers
- 4mA to 20mA Transmitters

DESCRIPTION

The LT®1636 op amp operates on all single and split supplies with a total voltage of 2.7V to 44V drawing less than 50µA of quiescent current. The LT1636 can be shut down, making the output high impedance and reducing the quiescent current to 4µA. The LT1636 has a unique input stage that operates and remains high impedance when above the positive supply. The inputs take 44V both differential and common mode, even when operating on a 3V supply. The output swings to both supplies. Unlike most micropower op amps, the LT1636 can drive heavy loads; its rail-to-rail output drives 18mA. The LT1636 is unity-gain stable into all capacitive loads up to 10,000pF when a 0.22µF and 150Ω compensation network is used.
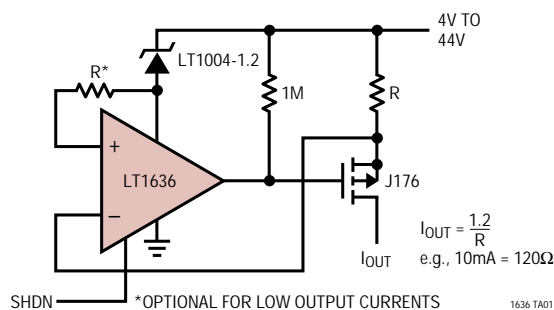
The LT1636 is reverse supply protected: it draws no current for reverse supply up to 27V. Built-in resistors protect the inputs for faults below the negative supply up to 22V. There is no phase reversal of the output for inputs 5V below V_{EE} or 44V above V_{EE}, independent of V_{CC}.

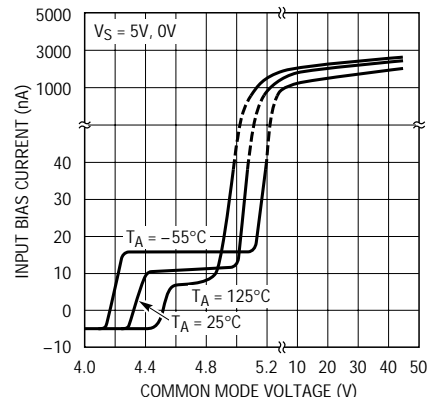The LT1636 op amp is available in the 8-pin MSOP, PDIP and SO packages.

LT, LTC and LT are registered trademarks of Linear Technology Corporation. Over-The-Top is a trademark of Linear Technology Corporation.

TYPICAL APPLICATION

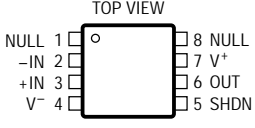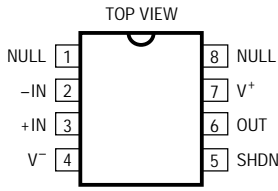### Over-The-Top Current Source with Shutdown

$$I_{OUT} = \frac{1.2}{R}$$
e.g., 10mA = 120Ω

*OPTIONAL FOR LOW OUTPUT CURRENTS

1636 TA01

Input Bias Current vs Common Mode Voltage

1636 G03

ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V$^+$ to V$^-$) 44V
Input Differential Voltage 44V
Input Current .... ±25mA
Shutdown Pin Voltage Above V$^-$ 32V
Shutdown Pin Current .... ±10mA
Output Short-Circuit Duration (Note 2) ....Continuous

Operating Temperature Range .... –40°C to 85°C
Specified Temperature Range (Note 3) .. –40°C to 85°C
Junction Temperature .... 150°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

TOP VIEW

NULL 1 — 8 NULL
–IN 2 — 7 V$^+$
+IN 3 — 6 OUT
V$^-$ 4 — 5 SHDN

MS8 PACKAGE
8-LEAD PLASTIC MSOP
T$_{JMAX}$ = 150°C, θ$_{JA}$ = 250°C/W

ORDER PART NUMBER
LT1636CMS8
MS8 PART MARKING
LTCL

TOP VIEW

NULL 1 — 8 NULL
–IN 2 — 7 V$^+$
+IN 3 — 6 OUT
V$^-$ 4 — 5 SHDN

N8 PACKAGE
8-LEAD PLASTIC DIP

S8 PACKAGE
8-LEAD PLASTIC SO
T$_{JMAX}$ = 150°C, θ$_{JA}$ = 130°C/W (N8)
T$_{JMAX}$ = 150°C, θ$_{JA}$ = 190°C/W (S8)

ORDER PART NUMBER
LT1636CN8
LT1636CS8
LT1636IN8
LT1636IS8
S8 PART MARKING
1636
1636I

Consult factory for Military grade parts.

3V, 5V ELECTRICAL CHARACTERISTICS

V$_S$ = 3V, 0V; V$_S$ = 5V, 0V; V$_{CM}$ = V$_{OUT}$ = half supply, Pin 5 = open or V$_{EE}$, Pins 1 and 8 open, T$_A$ = 25°C unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V$_{OS}$	Input Offset Voltage	N8 Package			50	225	μV
		0°C ≤ T$_A$ ≤ 70°C	●			400	μV
		–40°C ≤ T$_A$ ≤ 85°C	●			550	μV
		S8 Package			50	225	μV
		0°C ≤ T$_A$ ≤ 70°C	●			600	μV
		–40°C ≤ T$_A$ ≤ 85°C	●			750	μV
		MS8 Package			50	225	μV
		0°C ≤ T$_A$ ≤ 70°C	●			700	μV
		–40°C ≤ T$_A$ ≤ 85°C	●			850	μV
	Input Offset Voltage Drift (Note 8)	N8 Package, –40°C ≤ T$_A$ ≤ 85°C	●		1	5	μV/°C
		S8 Package, –40°C ≤ T$_A$ ≤ 85°C	●		2	8	μV/°C
		MS8 Package, –40°C ≤ T$_A$ ≤ 85°C	●		2	10	μV/°C
I$_{OS}$	Input Offset Current		●		0.1	0.8	nA
		V$_{CM}$ = 44V (Note 4)	●			0.6	μA
I$_B$	Input Bias Current		●		5	8	nA
		V$_{CM}$ = 44V (Note 4)	●		3	6	μA
		V$_S$ = 0V			0.1		nA
	Input Noise Voltage	0.1Hz to 10Hz			0.7		μV$_{P-P}$
e$_n$	Input Noise Voltage Density	f = 1kHz			52		nV/√Hz
i$_n$	Input Noise Current Density	f = 1kHz			0.035		pA/√Hz

3V, 5V ELECTRICAL CHARACTERISTICS

V_S = 3V, 0V; V_S = 5V, 0V; V_{CM} = V_{OUT} = half supply, Pin 5 = open or V_{EE}, Pins 1 and 8 open, T_A = 25°C unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
R_{IN}	Input Resistance	Differential		6	10		MΩ
		Common Mode, V_{CM} = 0V to 44V		7	15		MΩ
C_{IN}	Input Capacitance				4		pF
	Input Voltage Range		●	0		44	V
CMRR	Common Mode Rejection Ratio (Note 4)	V_{CM} = 0V to V_{CC} – 1V	●	84	110		dB
		V_{CM} = 0V to 44V (Note 7)	●	86	98		dB
A_{VOL}	Large-Signal Voltage Gain	V_S = 3V, V_O = 500mV to 2.5V, R_L = 10k		200	1300		V/mV
		V_S = 3V, 0°C ≤ T_A ≤ 70°C	●	133			V/mV
		V_S = 3V, – 40°C ≤ T_A ≤ 85°C	●	100			V/mV
		V_S = 5V, V_O = 500mV to 4.5V, R_L = 10k		400	2000		V/mV
		V_S = 5V, 0°C ≤ T_A ≤ 70°C	●	250			V/mV
		V_S = 5V, – 40°C ≤ T_A ≤ 85°C	●	200			V/mV
V_{OL}	Output Voltage Swing LOW	No Load	●		2	10	mV
		I_{SINK} = 5mA	●		480	875	mV
		V_S = 5V, I_{SINK} = 10mA	●		860	1600	mV
V_{OH}	Output Voltage Swing HIGH	V_S = 3V, No Load	●	2.95	2.985		V
		V_S = 3V, I_{SOURCE} = 5mA	●	2.55	2.8		V
		V_S = 5V, No Load	●	4.95	4.985		V
		V_S = 5V, I_{SOURCE} = 10mA	●	4.30	4.75		V
I_{SC}	Short-Circuit Current (Note 2)	V_S = 3V, Short to GND		7	15		mA
		V_S = 3V, Short to V_{CC}		20	42		mA
		V_S = 5V, Short to GND		12	25		mA
		V_S = 5V, Short to V_{CC}		25	50		mA
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 12.5V, V_{CM} = V_O = 1V	●	90	103		dB
	Reverse Supply Voltage	I_S = – 100µA	●	27	40		V
I_S	Supply Current (Note 5)				42	55	µA
			●			60	µA
	Supply Current, SHDN	V_{PIN5} = 2V, No Load (Note 5)	●		4	12	µA
I_{SD}	Shutdown Pin Current	V_{PIN5} = 0.3V, No Load (Note 5)	●		0.5	15	nA
		V_{PIN5} = 2V, No Load (Note 4)	●		1.1	5	µA
	Output Leakage Current	V_{PIN5} = 2V, No Load (Note 5)	●		0.05	1	µA
	Maximum Shutdown Pin Current	V_{PIN5} = 32V, No Load (Note 4)	●		27	150	µA
t_{ON}	Turn-On Time	V_{PIN5} = 5V to 0V, R_L = 10k			120		µs
t_{OFF}	Turn-Off Time	V_{PIN5} = 0V to 5V, R_L = 10k			2.5		µs
GBW	Gain Bandwidth Product (Note 4)	f = 1kHz		110	200		kHz
		0°C ≤ T_A ≤ 70°C	●	100			kHz
		– 40°C ≤ T_A ≤ 85°C	●	90			kHz
SR	Slew Rate (Note 6)	A_V = – 1, R_L = ∞		0.035	0.07		V/µs
		0°C ≤ T_A ≤ 70°C	●	0.031			V/µs
		– 40°C ≤ T_A ≤ 85°C	●	0.030			V/µs

±15V ELECTRICAL CHARACTERISTICS

$V_S = \pm 15V$, $V_{CM} = 0V$, $V_{OUT} = 0V$, Pin 5 = open or V_{EE}, Pins 1 and 8 open, $T_A = 25°C$ unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	N8 Package			100	450	µV
		$0°C \leq T_A \leq 70°C$	●			550	µV
		$-40°C \leq T_A \leq 85°C$	●			700	µV
		S8 Package			100	450	µV
		$0°C \leq T_A \leq 70°C$	●			750	µV
		$-40°C \leq T_A \leq 85°C$	●			900	µV
		MS8 Package			100	450	µV
		$0°C \leq T_A \leq 70°C$	●			850	µV
		$-40°C \leq T_A \leq 85°C$	●			1000	µV
	Input Offset Voltage Drift (Note 8)	N8 Package, $-40°C \leq T_A \leq 85°C$	●		1	4	µV/°C
		S8 Package, $-40°C \leq T_A \leq 85°C$	●		2	8	µV/°C
		MS8 Package, $-40°C \leq T_A \leq 85°C$	●		2	10	µV/°C
I_{OS}	Input Offset Current		●		0.2	1.0	nA
I_B	Input Bias Current		●		4	10	nA
	Input Noise Voltage	0.1Hz to 10Hz			1		$µV_{P-P}$
e_n	Input Noise Voltage Density	f = 1kHz			52		nV/√Hz
i_n	Input Noise Current Density	f = 1kHz			0.035		pA/√Hz
R_{IN}	Input Resistance	Differential		5.2	13		MΩ
		Common Mode, $V_{CM} = -15V$ to 14V			12000		MΩ
C_{IN}	Input Capacitance				4		pF
	Input Voltage Range		●	−15		29	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = -15V$ to 29V	●	86	103		dB
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm 14V$, $R_L = 10k$		100	500		V/mV
		$0°C \leq T_A \leq 70°C$	●	75			V/mV
		$-40°C \leq T_A \leq 85°C$	●	50			V/mV
V_{OL}	Output Voltage Swing LOW	No Load	●		−14.997	−14.95	V
		$I_{SINK} = 5mA$	●		−14.500	−14.07	V
		$I_{SINK} = 10mA$	●		−14.125	−13.35	V
V_{OH}	Output Voltage Swing HIGH	No Load	●	14.9	14.975		V
		$I_{SOURCE} = 5mA$	●	14.5	14.750		V
		$I_{SOURCE} = 10mA$	●	14.3	14.650		V
I_{SC}	Short-Circuit Current (Note 2)	Short to GND		±18	±30		mA
		$0°C \leq T_A \leq 70°C$	●	±15			mA
		$-40°C \leq T_A \leq 85°C$	●	±10			mA
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.35V$ to ±22V	●	90	114		dB
I_S	Supply Current		●		50	70	µA
			●			85	µA
	Positive Supply Current, SHDN	$V_{PIN5} = -20V$, $V_S = \pm 22V$, No Load	●		12	30	µA
I_{SHDN}	Shutdown Pin Current	$V_{PIN5} = -21.7V$, $V_S = \pm 22V$, No Load	●		0.7	15	nA
		$V_{PIN5} = -20V$, $V_S = \pm 22V$, No Load	●		1.2	8	µA
	Maximum Shutdown Pin Current	$V_{PIN5} = 32V$, $V_S = \pm 22V$	●		27	150	µA
	Output Leakage Current	$V_{PIN5} = -20V$, $V_S = \pm 22V$, No Load	●		0.1	2	µA
GBW	Gain Bandwidth Product	f = 1kHz		125	220		kHz
		$0°C \leq T_A \leq 70°C$	●	110			kHz
		$-40°C \leq T_A \leq 85°C$	●	100			kHz

$\pm$15V ELECTRICAL CHARACTERISTICS

$V_S = \pm15V$, $V_{CM} = 0V$, $V_{OUT} = 0V$, Pin 5 = open or V_{EE}, Pins 1 and 8 open, $T_A = 25°C$ unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
SR	Slew Rate	$A_V = -1$, $R_L = \infty$, $V_O = \pm10V$ Measured at $\pm5V$		0.0375	0.075		V/µs
		$0°C \le T_A \le 70°C$	●	0.033			V/µs
		$-40°C \le T_A \le 85°C$	●	0.030			V/µs

The ● denotes specifications that apply over the full specified temperature range.

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

Note 2: A heat sink may be required to keep the junction temperature below absolute maximum.

Note 3: The LT1636C is guaranteed to meet specified performance from 0°C to 70°C and is designed, characterized and expected to meet these extended temperature limits, but is not tested at −40°C and 85°C. The LT1636I is guaranteed to meet the extended temperature limits.

Note 4: $V_S = 5V$ limits are guaranteed by correlation to $V_S = 3V$, and $V_S = \pm15V$ or $V_S = \pm22V$ tests.

Note 5: $V_S = 3V$ limits are guaranteed by correlation to $V_S = 5V$, and $V_S = \pm15V$ or $V_S = \pm22V$ tests.

Note 6: Guaranteed by correlation to slew rate at $V_S = \pm15V$, and GBW at $V_S = 3V$ and $V_S = \pm15V$ tests.

Note 7: This specification implies a typical input offset voltage of 600µV at $V_{CM} = 44V$ and a maximum input offset voltage of 3mV at $V_{CM} = 44V$.
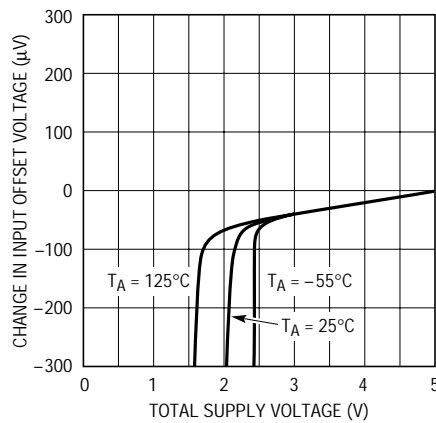
Note 8: This parameter is not 100% tested.

TYPICAL PERFORMANCE CHARACTERISTICS

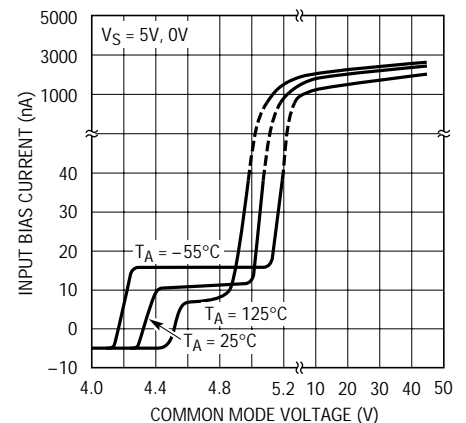Supply Current vs Supply Voltage
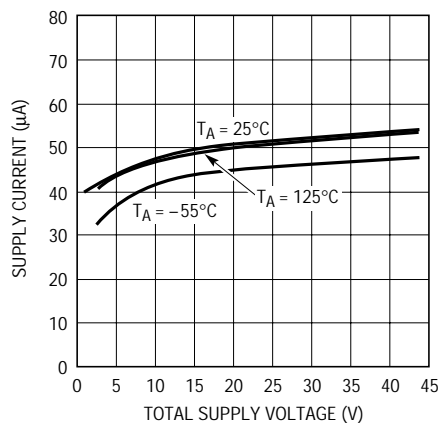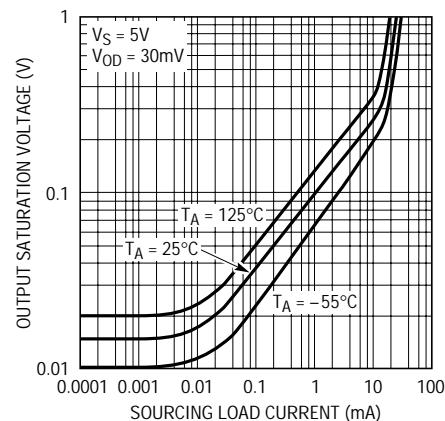
1636 G01

Minimum Supply Voltage

1636 G02

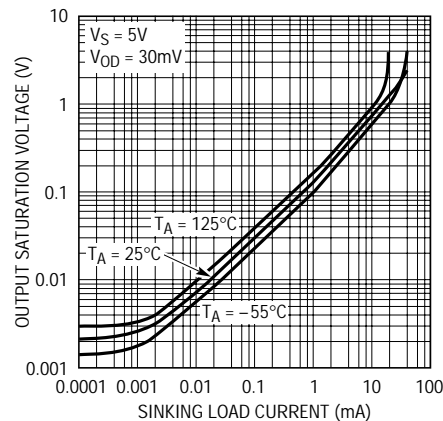Input Bias Current vs Common Mode Voltage

1636 G03

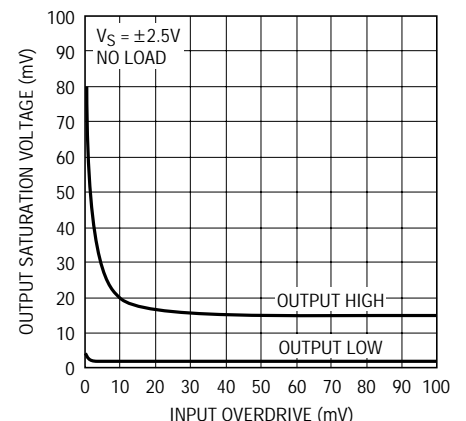Output Saturation Voltage vs Load Current (Output High)

1636 G04

Output Saturation Voltage vs Load Current (Output Low)
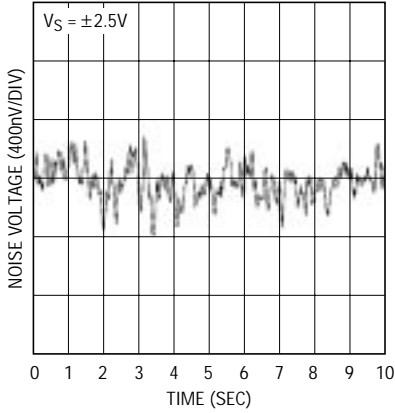
1636 G05
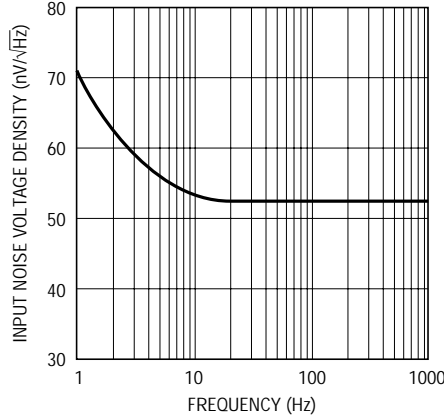

Output Saturation Voltage vs Input Overdrive

1636 G06

TYPICAL PERFORMANCE CHARACTERISTICS
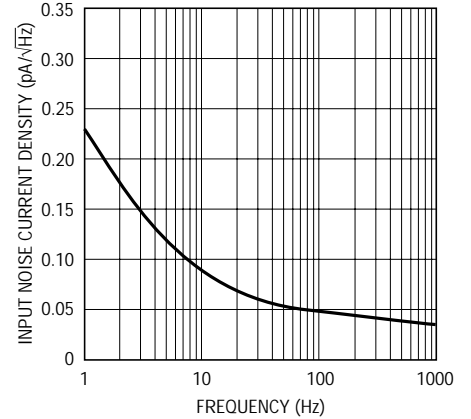
0.1Hz to 10Hz Noise Voltage

$V_S = \pm2.5V$

NOISE VOLTAGE (400nV/DIV)

TIME (SEC)

1636 G07

Noise Voltage Density vs Frequency

INPUT NOISE VOLTAGE DENSITY (nV/√Hz)

FREQUENCY (Hz)

1636 G08

Input Noise Current vs Frequency

INPUT NOISE CURRENT DENSITY (pA/√Hz)

FREQUENCY (Hz)

1635 G09

Open-Loop Gain and Phase Shift vs Frequency

$V_S = \pm2.5V$

GAIN (dB)

PHASE SHIFT (DEG)

PHASE
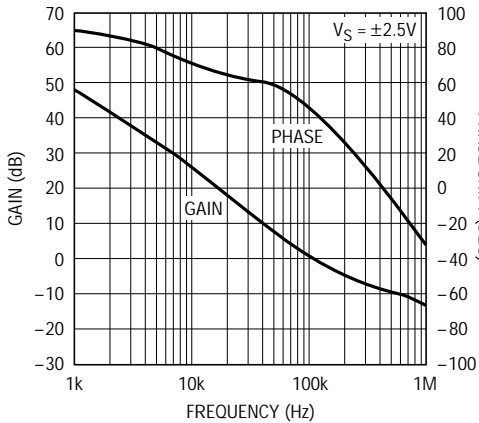
GAIN

FREQUENCY (Hz)

1636 G10

Gain-Bandwidth Product vs Temperature

f = 1kHZ

GAIN-BANDWIDTH PRODUCT (kHz)

$V_S = \pm15V$

$V_S = \pm1.5V$
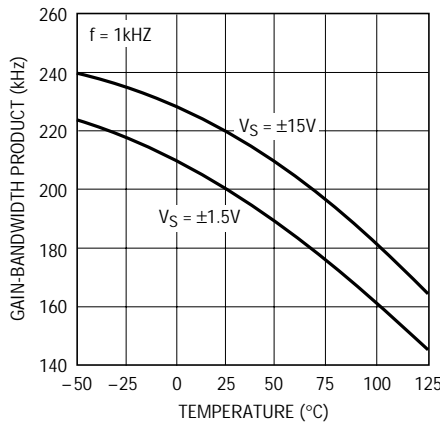
TEMPERATURE (°C)

1636 G11

Slew Rate vs Temperature

SLEW RATE (V/µs)

RISING, $V_S = \pm1.5V$

RISING, $V_S = \pm15V$

FALLING, $V_S = \pm15V$

FALLING, $V_S = \pm1.5V$

TEMPERATURE (°C)
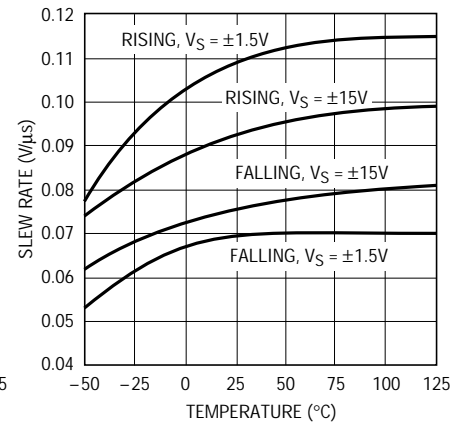
1636 G12

Gain-Bandwidth Product and Phase Margin vs Supply Voltage

$R_L = 10k$
f = 1kHz

GAIN-BANDWIDTH PRODUCT (kHz)

PHASE MARGIN (DEG)

PHASE MARGIN

GAIN BANDWIDTH

TOTAL SUPPLY VOLTAGE (V)
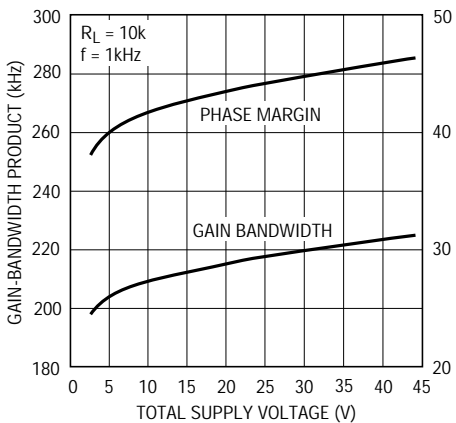
1636 G13

CMRR vs Frequency

COMMON MODE REJECTION RATIO (dB)

$V_S = \pm15V$

$V_S = \pm1.5V$
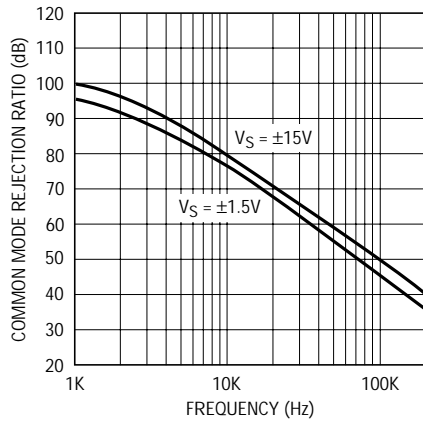
FREQUENCY (Hz)

1636 G14

PSRR vs Frequency

$V_S = \pm2.5V$

POWER SUPPLY REJECTION RATIO (dB)

POSITIVE SUPPLY

NEGATIVE SUPPLY
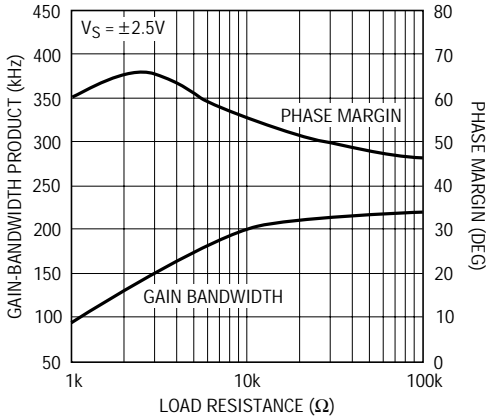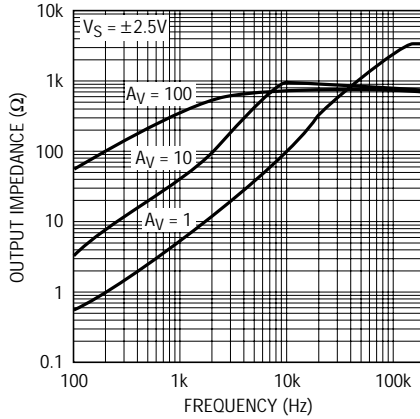
FREQUENCY (Hz)

1636 G15

LINEAR TECHNOLOGY
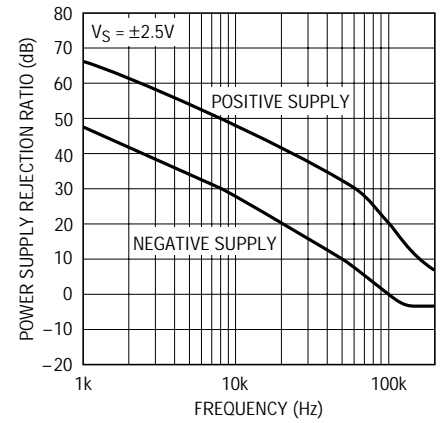
TYPICAL PERFORMANCE CHARACTERISTICS

Gain-Bandwidth Product and Phase Margin vs Load Resistance
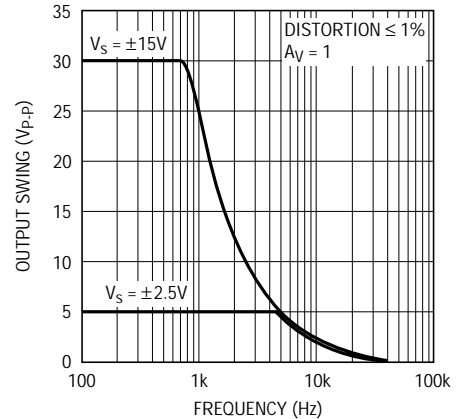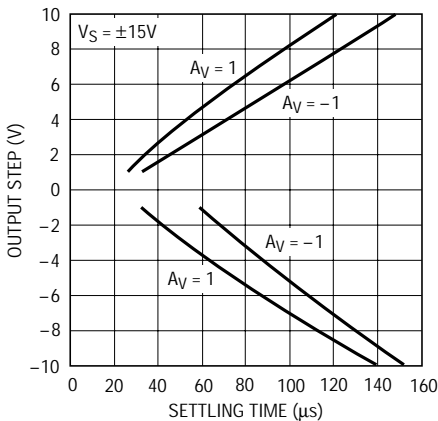

1636 G16

Output Impedance vs Frequency
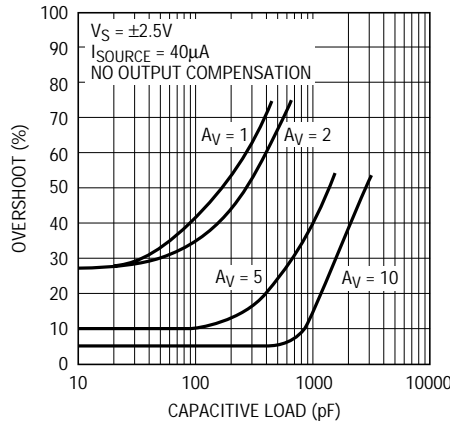

1635 G17

Undistorted Output Swing vs Frequency

1635 G18

Settling Time to 0.1% vs Output Step
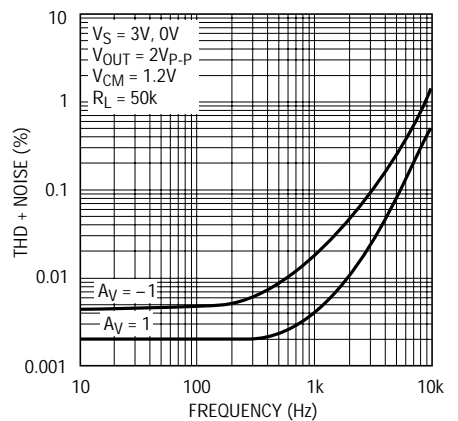

1636 G19

Capacitive Load Handling, Overshoot vs Capacitive Load
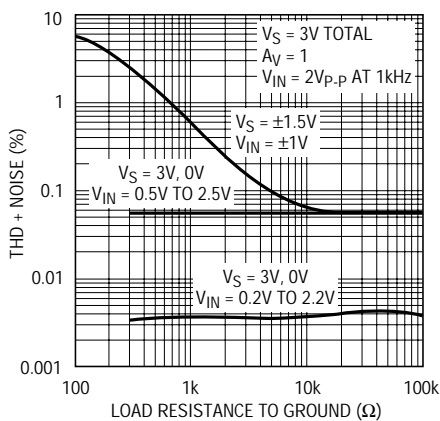

1636 G20

Total Harmonic Distortion + Noise vs Frequency
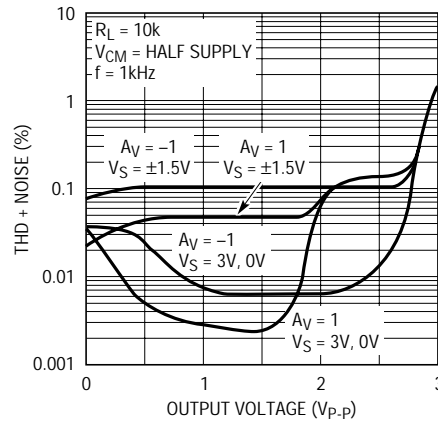

1636 G21

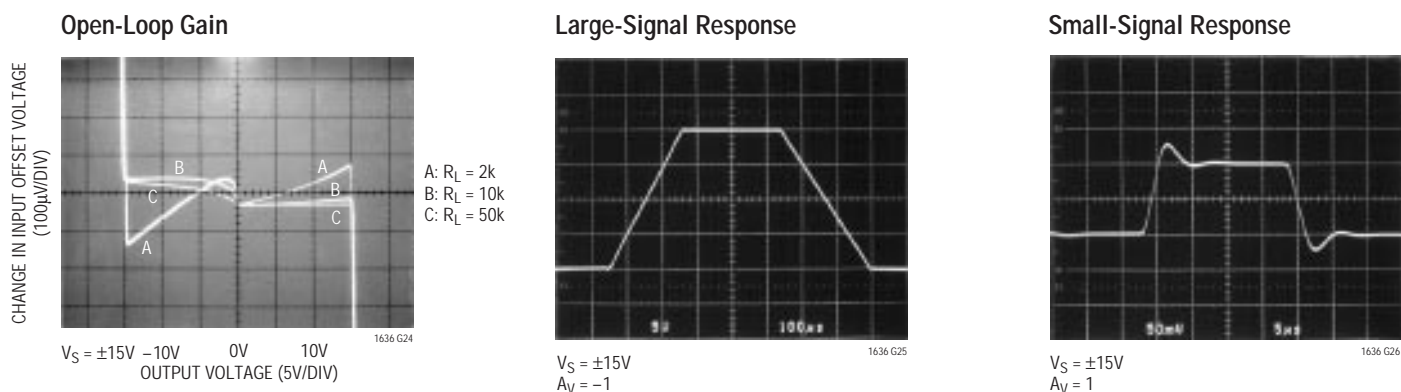### Total Harmonic Distortion + Noise vs Load Resistance

1636 G22

Total Harmonic Distortion + Noise vs Output Voltage

1636 G23

7

TYPICAL PERFORMANCE CHARACTERISTICS

Open-Loop Gain

CHANGE IN INPUT OFFSET VOLTAGE (100μV/DIV)

A: R_L = 2k
B: R_L = 10k
C: R_L = 50k

$V_S = \pm15V$ −10V 0V 10V
OUTPUT VOLTAGE (5V/DIV)

1636 G24

Large-Signal Response

$V_S = \pm15V$
$A_V = -1$

1636 G25

Small-Signal Response

$V_S = \pm15V$
$A_V = 1$

1636 G26

APPLICATIONS INFORMATION

Supply Voltage

The positive supply pin of the LT1636 should be bypassed with a small capacitor (about 0.01μF) within an inch of the pin. When driving heavy loads an additional 4.7μF electrolytic capacitor should be used. When using split supplies, the same is true for the negative supply pin.

The LT1636 is protected against reverse battery voltages up to 27V. In the event a reverse battery condition occurs, the supply current is less than 1nA.

When operating the LT1636 on total supplies of 20V or more, the supply must not be brought up faster than 1μs. This is especially true if low ESR bypass capacitors are used. A series RLC circuit is formed from the supply lead inductance and the bypass capacitor. 5Ω of resistance in the supply or the bypass capacitor will dampen the tuned circuit enough to limit the rise time.

Inputs

The LT1636 has two input stages, NPN and PNP (see Simplified Schematic), resulting in three distinct operating regions as shown in the Input Bias Current vs Common Mode typical performance curve.

For input voltages about 0.8V or more below V^+, the PNP input stage is active and the input bias current is typically −4nA. When the input voltage is about 0.5V or less from V^+, the NPN input stage is operating and the input bias current is typically 10nA. Increases in temperature will cause the voltage at which operation switches from the PNP stage to the NPN stage to move towards V^+. The input offset voltage of the NPN stage is untrimmed and is typically 600μV.

A Schottky diode in the collector of each NPN transistor of the NPN input stage allows the LT1636 to operate with either or both of its inputs above V^+. At about 0.3V above V^+ the NPN input transistor is fully saturated and the input bias current is typically 3μA at room temperature. The input offset voltage is typically 600μV when operating above V^+. The LT1636 will operate with its input 44V above V^- regardless of V^+.

The inputs are protected against excursions as much as 22V below V^- by an internal 1k resistor in series with each input and a diode from the input to the negative supply. There is no output phase reversal for inputs up to 5V below V^-. There are no clamping diodes between the inputs and the maximum differential input voltage is 44V.

Output

The output voltage swing of the LT1636 is affected by input overdrive as shown in the typical performance curves. When monitoring voltages within 100mV of V^+, gain should be taken to keep the output from clipping.

The output of the LT1636 can be pulled up to 27V beyond V^+ with less than 1nA of leakage current, provided that V^+ is less than 0.5V.

APPLICATIONS INFORMATION

The normally reverse biased substrate diode from the output to V⁻ will cause unlimited currents to flow when the output is forced below V⁻. If the current is transient and limited to 100mA, no damage will occur.

The LT1636 is internally compensated to drive at least 200pF of capacitance under any output loading conditions. A 0.22μF capacitor in series with a 150Ω resistor between the output and ground will compensate these amplifiers for larger capacitive loads, up to 10,000pF, at all output currents.

Distortion

There are two main contributors of distortion in op amps: output crossover distortion as the output transitions from sourcing to sinking current and distortion caused by nonlinear common mode rejection. Of course, if the op amp is operating inverting there is no common mode induced distortion. When the LT1636 switches between input stages there is significant nonlinearity in the CMRR. Lower load resistance increases the output crossover distortion, but has no effect on the input stage transition distortion. For lowest distortion the LT1636 should be operated single supply, with the output always sourcing current and with the input voltage swing between ground and (V⁺ – 0.8V). See the Typical Performance Characteristics curves.

Gain

The open-loop gain is less sensitive to load resistance when the output is sourcing current. This optimizes performance in single supply applications where the load is returned to ground. The typical performance photo of Open-Loop Gain for various loads shows the details.

Shutdown

The LT1636 can be shut down two ways: using the shutdown pin or bringing V⁺ to within 0.5V of V⁻. When V⁺ is brought to within 0.5V of V⁻ both the supply current and output leakage current drop to less than 1nA. When the shutdown pin is brought 1.2V above V⁻, the supply current drops to about 4μA and the output leakage current is less than 1μA, independent of V⁺. In either case the input bias current is less than 0.1nA (even if the inputs are 44V above the negative supply).

The shutdown pin can be taken up to 32V above V⁻. The shutdown pin can be driven below V⁻, however the pin current through the substrate diode should be limited with an external resistor to less than 10mA.

Input Offset Nulling

The input offset voltage can be nulled by placing a 10k potentiometer between Pins 1 and 8 with its wiper to V⁻ (see Figure 1). The null range will be at least ±1mV.
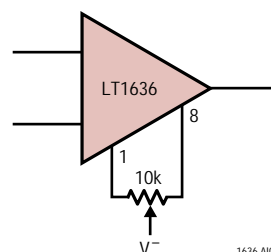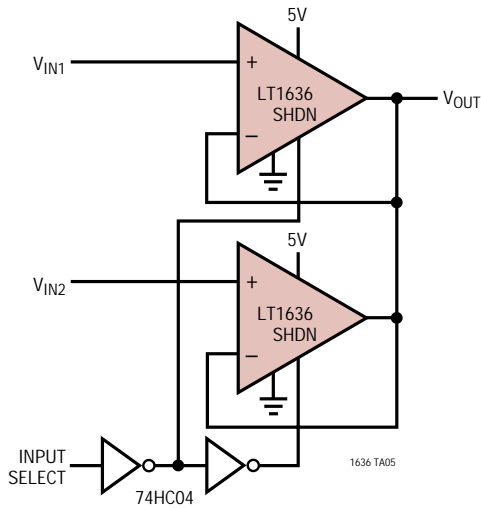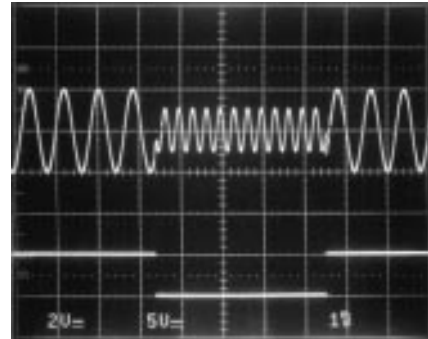

Figure 1. Input Offset Nulling

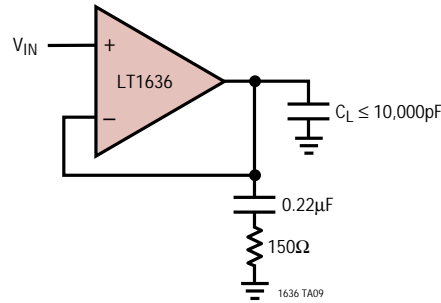# TYPICAL APPLICATIONS

MUX Amplifier
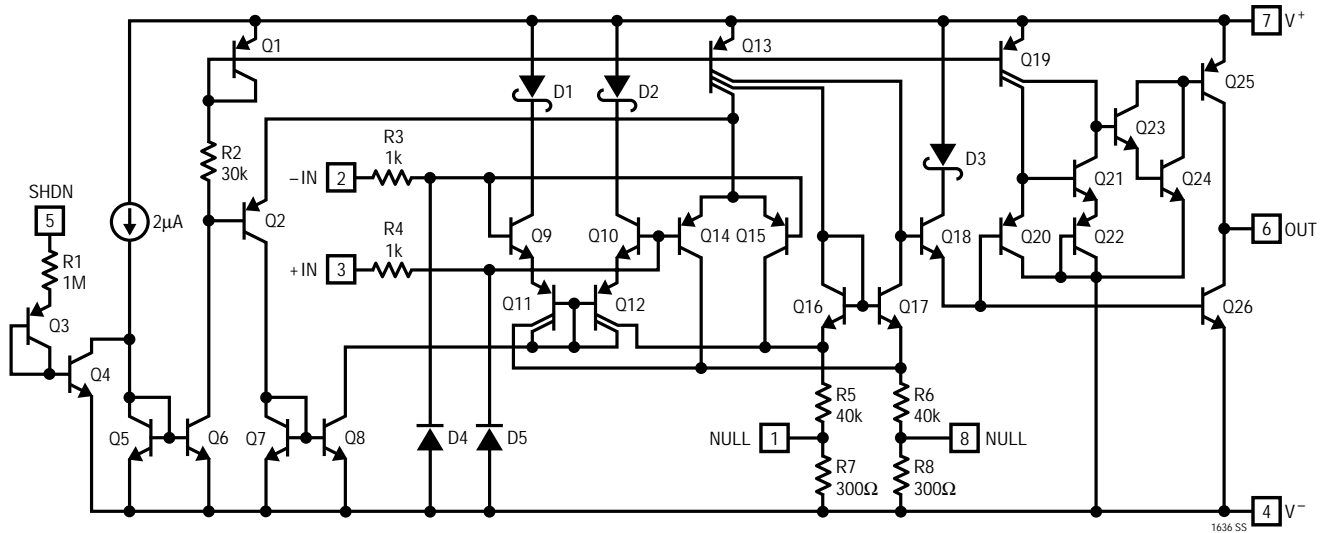

MUX Amplifier Waveforms

$V_S = 5V$
$V_{IN1} = 1.2kHz$ AT $4V_{P-P}$, $V_{IN2} = 2.4kHz$ AT $2V_{P-P}$
INPUT SELECT = 120Hz AT $5V_{P-P}$

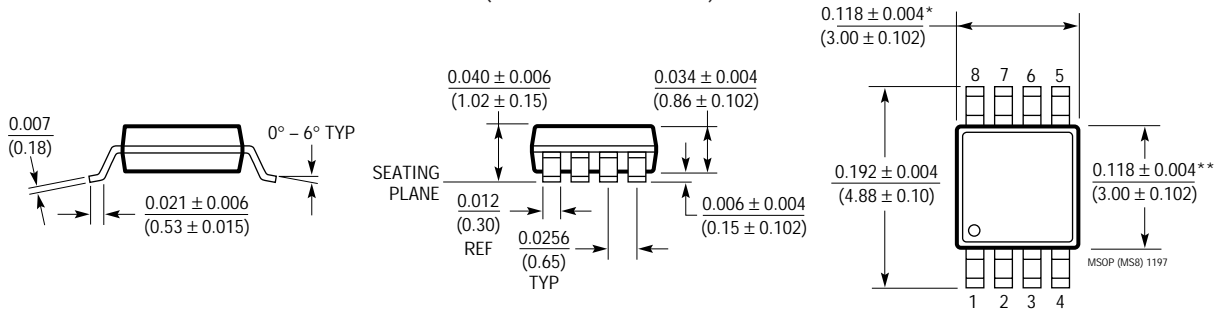### Optional Output Compensation for Capacitive Loads Greater Than 200pF
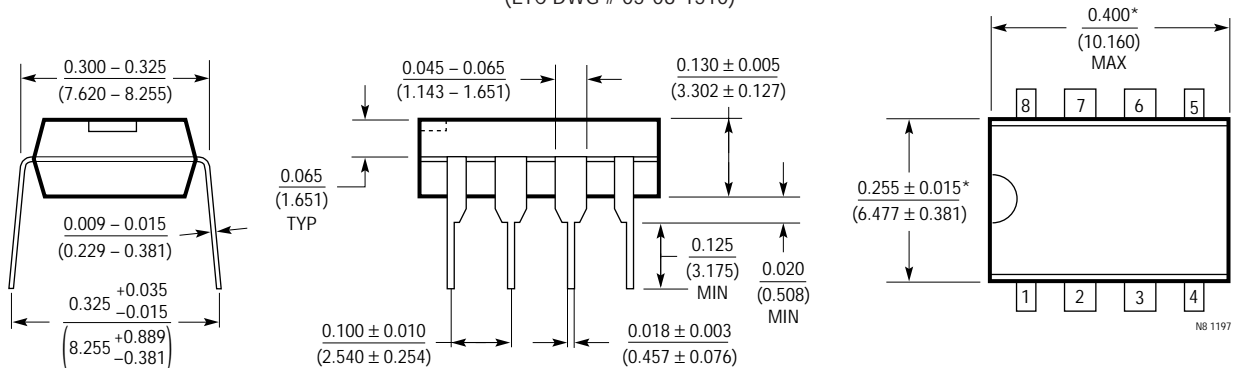

SIMPLIFIED SCHEMATIC

PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

MS8 Package
8-Lead Plastic MSOP
(LTC DWG # 05-08-1660)

0.007
(0.18)

0° – 6° TYP

0.021 ± 0.006
(0.53 ± 0.015)

0.040 ± 0.006
(1.02 ± 0.15)

0.034 ± 0.004
(0.86 ± 0.102)

SEATING
PLANE

0.012
(0.30)
REF

0.0256
(0.65)
TYP

0.006 ± 0.004
(0.15 ± 0.102)

0.118 ± 0.004*
(3.00 ± 0.102)

8 7 6 5

0.192 ± 0.004
(4.88 ± 0.10)

0.118 ± 0.004**
(3.00 ± 0.102)

1 2 3 4

MSOP (MS8) 1197

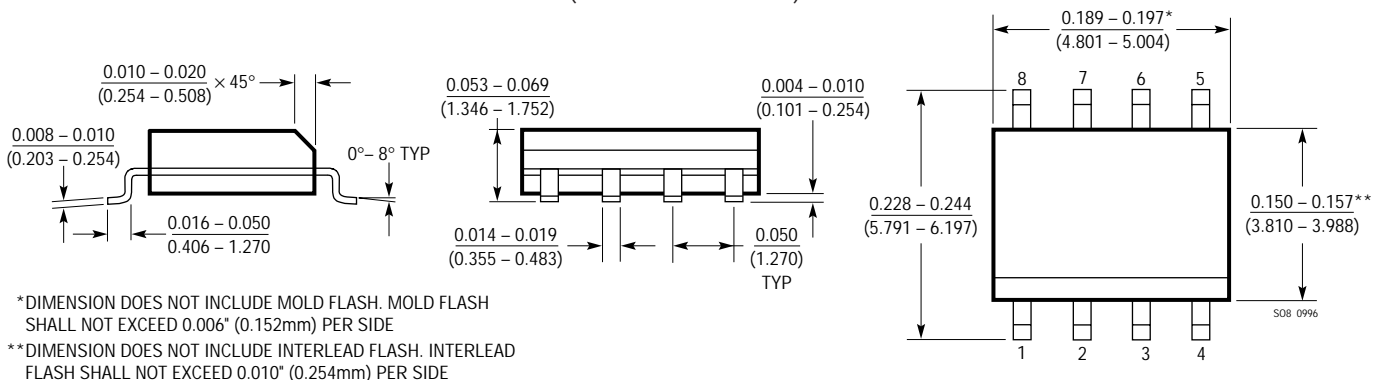* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH,
   PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

** DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
   INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)

0.300 – 0.325
(7.620 – 8.255)

0.009 – 0.015
(0.229 – 0.381)

$0.325 \begin{array}{c} +0.035 \\ -0.015 \end{array}$

$\left(8.255 \begin{array}{c} +0.889 \\ -0.381 \end{array} \right)$

0.045 – 0.065
(1.143 – 1.651)

0.065
(1.651)
TYP

0.130 ± 0.005
(3.302 ± 0.127)

0.125
(3.175)
MIN

0.020
(0.508)
MIN

0.100 ± 0.010
(2.540 ± 0.254)

0.018 ± 0.003
(0.457 ± 0.076)

0.400*
(10.160)
MAX

8 7 6 5

0.255 ± 0.015*
(6.477 ± 0.381)

1 2 3 4

N8 1197

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

S8 Package
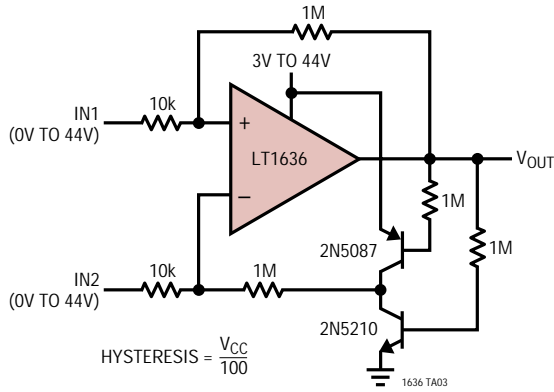### 8-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)

0.010 – 0.020
(0.254 – 0.508) × 45°

0.008 – 0.010
(0.203 – 0.254)

0°– 8° TYP

0.016 – 0.050
0.406 – 1.270

0.053 – 0.069
(1.346 – 1.752)

0.004 – 0.010
(0.101 – 0.254)

0.014 – 0.019
(0.355 – 0.483)

0.050
(1.270)
TYP

0.189 – 0.197*
(4.801 – 5.004)

8 7 6 5

0.228 – 0.244
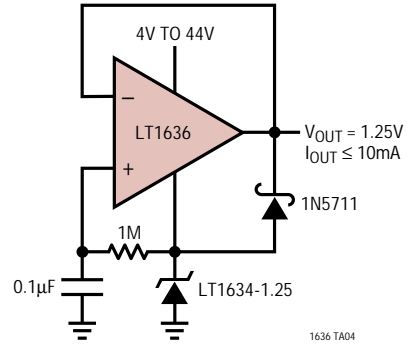(5.791 – 6.197)

0.150 – 0.157**
(3.810 – 3.988)

1 2 3 4

SO8 0996

*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH
 SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD
  FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

TYPICAL APPLICATIONS
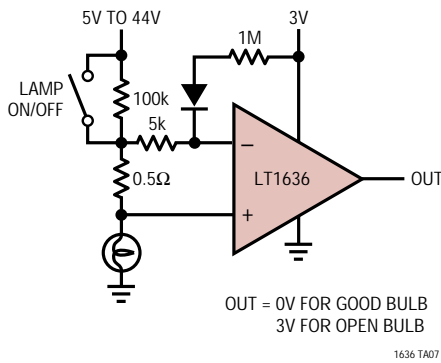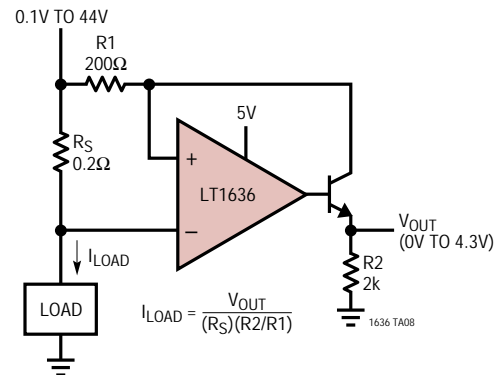
Over-The-Top Comparator with Hysteresis

$$\text{HYSTERESIS} = \frac{V_{CC}}{100}$$

IN1 (0V TO 44V) — 10k
IN2 (0V TO 44V) — 10k
3V TO 44V
1M
LT1636
2N5087
2N5210
1M
1M
V_{OUT}
1636 TA03

Self-Buffered Micropower Reference

4V TO 44V
LT1636
$V_{OUT} = 1.25V$
$I_{OUT} \leq 10mA$
1N5711
1M
0.1µF
LT1634-1.25
1636 TA04

Lamp Outage Detector

5V TO 44V
3V
LAMP ON/OFF
100k
5k
0.5Ω
1M
LT1636
OUT

OUT = 0V FOR GOOD BULB
3V FOR OPEN BULB
1636 TA07

Over-The-Top Current Sense

0.1V TO 44V
R1 200Ω
R_S 0.2Ω
5V
LT1636
V_{OUT} (0V TO 4.3V)
R2 2k
I_{LOAD}
LOAD

$$I_{LOAD} = \frac{V_{OUT}}{(R_S)(R2/R1)}$$

1636 TA08

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1460	Micropower Precision Series Reference	Accuracy: 0.075% Max, Drift: 10ppm/°C Max, 2.5V, 5V, 10V Versions Available
LT1466/LT1467	75µA Dual/Quad Rail-to-Rail Input and Output Op Amps	390µV $V_{OS(MAX)}$, Gain Bandwidth = 120kHz
LT1490/LT1491	50µA Dual/Quad Rail-to-Rail Input and Output Op Amps	950µV $V_{OS(MAX)}$, Gain Bandwidth = 200kHz
LT1495/LT1496	1.5µA Max, Dual/Quad Precision Rail-to-Rail Input and Output Op Amps	375µV $V_{OS(MAX)}$, 1.5µA Supply Current Max
LT2078/LT2079	55µA Dual/Quad Precision Single Supply Op Amps	120µV $V_{OS(MAX)}$, Gain Bandwidth = 200kHz
LT2178/LT2179	17µA Dual/Quad Precision Single Supply Op Amps	120µV $V_{OS(MAX)}$, Gain Bandwidth = 60kHz