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**
- **Operating Temperature Range: –40°C to 125°C**
- **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.

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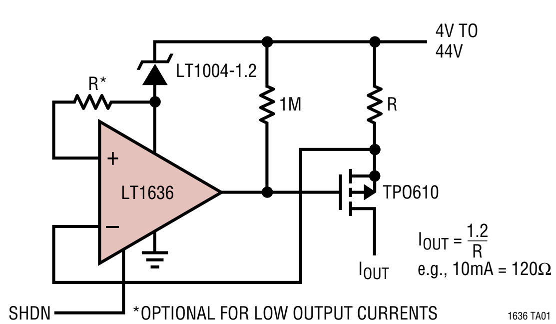
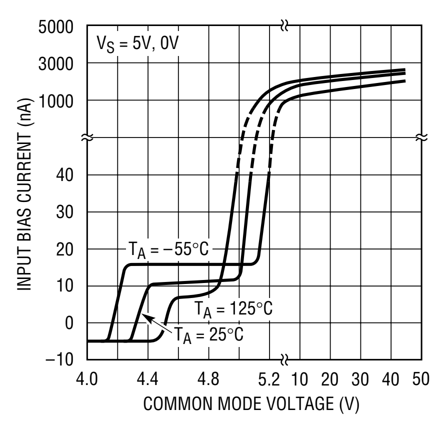
Over-The-Top is a trademark of Linear Technology Corporation.

TYPICAL APPLICATION

Over-The-Top Current Source with Shutdown



Input Bias Current vs Common Mode Voltage

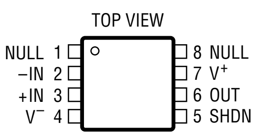
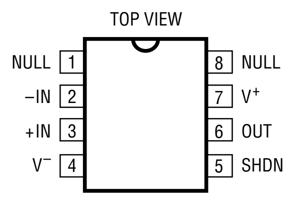


ABSOLUTE MAXIMUM RATINGS (Note 1)

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 (Note 3)
  LT1636C/LT1636I .... –40°C to 85°C
  LT1636H .... –40°C to 125°C

Specified Temperature Range (Note 4)
  LT1636C/LT1636I .... –40°C to 85°C
  LT1636H .... –40°C to 125°C
Junction Temperature .... 150°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER		ORDER PART NUMBER
 MS8 PACKAGE 8-LEAD PLASTIC MSOP T_{JMAX} = 150°C, θ_{JA} = 250°C/ W	LT1636CMS8	 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)	LT1636CN8 LT1636CS8 LT1636IN8 LT1636IS8 LT1636HS8
	MS8 PART MARKING		S8 PART MARKING
	LTCL		1636 1636I 1636H

Consult factory for parts specified with wider operating temperature ranges.

3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of –40°C ≤ T_A ≤ 85°C. V_S = 3V, 0V; V_S = 5V, 0V; V_{CM} = V_{OUT} = half supply unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1636C/LT1636I 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 9)	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 5)	●			0.6	µA

3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of −40°C ≤ T_A ≤ 85°C. V_S = 3V, 0V; V_S = 5V, 0V; V_{CM} = V_{OUT} = half supply unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1636C/LT1636I MIN	TYP	MAX	UNITS
I_B	Input Bias Current		●		5	8	nA
		V_{CM} = 44V (Note 5)	●		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
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	V_{CM} = 0V to V_{CC} – 1V	●	84	110		dB
	(Note 5)	V_{CM} = 0V to 44V (Note 8)	●	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 6)			42	55	μA
			●			60	μA
	Supply Current, SHDN	V_{PIN5} = 2V, No Load (Note 6)	●		4	12	μA
I_{SD}	Shutdown Pin Current	V_{PIN5} = 0.3V, No Load (Note 6)	●		0.5	15	nA
		V_{PIN5} = 2V, No Load (Note 5)	●		1.1	5	μA
	Output Leakage Current, SHDN	V_{PIN5} = 2V, No Load (Note 6)	●		0.05	1	μA
	Maximum Shutdown Pin Current	V_{PIN5} = 32V, No Load (Note 5)	●		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	f = 1kHz		110	200		kHz
	(Note 5)	0°C ≤ T_A ≤ 70°C	●	100			kHz
		−40°C ≤ T_A ≤ 85°C	●	90			kHz
SR	Slew Rate	A_V = −1, R_L = ∞		0.035	0.07		V/μs
	(Note 7)	0°C ≤ T_A ≤ 70°C	●	0.031			V/μs
		−40°C ≤ T_A ≤ 85°C	●	0.030			V/μs

±15V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of –40°C ≤ T_A ≤ 85°C. V_S = ±15V, V_{CM} = 0V, V_{OUT} = 0V, V_{SHDN} = V^- unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1636C/LT1636I MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	N8 Package			100	450	µV
		0°C ≤ T_A ≤ 70°C	●			550	µV
		–40°C ≤ T_A ≤ 85°C	●			700	µV
		S8 Package			100	450	µV
		0°C ≤ T_A ≤ 70°C	●			750	µV
		–40°C ≤ T_A ≤ 85°C	●			900	µV
		MS8 Package			100	450	µV
		0°C ≤ T_A ≤ 70°C	●			850	µV
		–40°C ≤ T_A ≤ 85°C	●			1000	µV
	Input Offset Voltage Drift (Note 9)	N8 Package, –40°C ≤ T_A ≤ 85°C	●		1	4	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		●		0.2	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		$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	f = 1kHz			0.035		$pA/\sqrt{Hz}$
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 = ±14V, R_L = 10k		100	500		V/mV
		0°C ≤ T_A ≤ 70°C	●	75			V/mV
		–40°C ≤ T_A ≤ 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 ≤ T_A ≤ 70°C	●	±15			mA
		–40°C ≤ T_A ≤ 85°C	●	±10			mA
PSRR	Power Supply Rejection Ratio	V_S = ±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 = ±22V, No Load	●		12	30	µA
I_{SHDN}	Shutdown Pin Current	V_{PIN5} = –21.7V, V_S = ±22V, No Load	●		0.7	15	nA
		V_{PIN5} = –20V, V_S = ±22V, No Load	●		1.2	8	µA
	Maximum Shutdown Pin Current	V_{PIN5} = 32V, V_S = ±22V	●		27	150	µA
	Output Leakage Current, SHDN	V_{PIN5} = –20V, V_S = ±22V, No Load	●		0.1	2	µA
GBW	Gain Bandwidth Product	f = 1kHz		125	220		kHz
		0°C ≤ T_A ≤ 70°C	●	110			kHz
		–40°C ≤ T_A ≤ 85°C	●	100			kHz

±15V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of $-40°C \le T_A \le 85°C$, otherwise specifications are at $T_A = 25°C$. $V_S = \pm15V$, $V_{CM} = 0V$, $V_{OUT} = 0V$, $V_{SHDN} = V^-$ unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1636C/LT1636I MIN	TYP	MAX	UNITS
SR	Slew Rate	$A_V = -1$, $R_L = \infty$, $V_O = \pm10V$ Measured at ±5V		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

3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of $-40°C \le T_A \le 125°C$. $V_S = 3V, 0V$; $V_S = 5V, 0V$; $V_{CM} = V_{OUT}$ = half supply unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1636H MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage				50	325	µV
			●			3	mV
	Input Offset Voltage Drift (Note 9)		●		3	10	µV/°C
I_{OS}	Input Offset Current		●			3	nA
		$V_{CM} = 44V$ (Note 5)	●			1	µA
I_B	Input Bias Current		●			30	nA
		$V_{CM} = 44V$ (Note 5)	●			10	µA
	Input Voltage Range		●	0.3		44	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0.3V$ to $V_{CC} - 1V$	●	72			dB
	(Note 5)	$V_{CM} = 0.3V$ to $44V$	●	74			dB
A_{VOL}	Large-Signal Voltage Gain	$V_S = 3V$, $V_O = 500mV$ to $2.5V$, $R_L = 10k$		200	1300		V/mV
			●	20			V/mV
		$V_S = 5V$, $V_O = 500mV$ to $4.5V$, $R_L = 10k$		400	2000		V/mV
			●	35			V/mV
V_{OL}	Output Voltage Swing LOW	No Load	●			15	mV
		$I_{SINK} = 2.5mA$	●			875	mV
V_{OH}	Output Voltage Swing HIGH	$V_S = 3V$, No Load	●	2.925			V
		$V_S = 3V$, $I_{SOURCE} = 5mA$	●	2.35			V
		$V_S = 5V$, No Load	●	4.925			V
		$V_S = 5V$, $I_{SOURCE} = 10mA$	●	4.10			V
PPSRR	Power Supply Rejection Ratio	$V_S = 2.7V$ to $12.5V$, $V_{CM} = V_O = 1V$	●	80			dB
	Minimum Supply Voltage		●	2.7			V
	Reverse Supply Voltage	$I_S = -100\mu A$	●	25			V
I_S	Supply Current	(Note 6)			42	55	µA
			●			75	µA
	Supply Current, SHDN	$V_{PIN5} = 2V$, No Load (Note 6)	●			15	µA
I_{SD}	Shutdown Pin Current	$V_{PIN5} = 0.3V$, No Load (Note 6)	●			200	nA
		$V_{PIN5} = 2V$, No Load (Note 5)	●			7	µA
	Output Leakage Current, SHDN	$V_{PIN5} = 2V$, No Load (Note 6)	●			5	µA
	Maximum Shutdown Pin Current	$V_{PIN5} = 32V$, No Load (Note 5)	●			200	µA
GBW	Gain Bandwidth Product	f = 1kHz (Note 5)		110	200		kHz
			●	60			kHz
SR	Slew Rate	$A_V = -1$, $R_L = \infty$ (Note 7)		0.035	0.07		V/µs
			●	0.015			V/µs

±15V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of –40°C ≤ T_A ≤ 125°C. V_S = ±15V, V_{CM} = 0V, V_{OUT} = 0V, V_{SHDN} = V^- unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1636H MIN	LT1636H TYP	LT1636H MAX	UNITS
V_{OS}	Input Offset Voltage		 ●		100	550 3.4	µV mV
	Input Offset Voltage Drift (Note 9)		●		3	11	µV/°C
I_{OS}	Input Offset Current		●			5	nA
I_B	Input Bias Current		●			50	nA
CMRR	Common Mode Rejection Ratio	V_{CM} = –14.7V to 29V	●	72			dB
A_{VOL}	Large-Signal Voltage Gain	V_O = ±14V, R_L = 10k	 ●	100 4	500		V/mV V/mV
V_O	Output Voltage Swing	No Load I_{OUT} = ±2.5mA	● ●			±14.8 ±14.3	V V
PSRR	Power Supply Rejection Ratio	V_S = ±1.35V to ±22V	●	84			dB
	Minimum Supply Voltage		●	±1.35			V
I_S	Supply Current		 ●		50	70 100	µA µA
	Positive Supply Current, SHDN	V_{PIN5} = –20V, V_S = ±22V, No Load	●			40	µA
I_{SHDN}	Shutdown Pin Current	V_{PIN5} = –21.7V, V_S = ±22V, No Load V_{PIN5} = –20V, V_S = ±22V, No Load	● ●			200 10	nA µA
	Maximum Shutdown Pin Current	V_{PIN5} = 32V, V_S = ±22V	●			200	µA
	Output Leakage Current, SHDN	V_{PIN5} = –20V, V_S = ±22V, No Load	●			100	µA
V_L	Shutdown Pin Input Low Voltage	V_S = ±22V	●			–21.7	V
V_H	Shutdown Pin Input High Voltage	V_S = ±22V	●	–20			V
GBW	Gain Bandwidth Product	f = 1kHz	 ●	125 75	220		kHz kHz
SR	Slew Rate	A_V = –1, R_L = ∞, V_O = ±10V Measured at V_O = ±5V	 ●	0.0375 0.02	0.075		V/µs V/µs

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 and LT1636I are guaranteed functional over the operating temperature range of –40°C to 85°C. The LT1636H is guaranteed functional over the operating temperature range of –40°C to 125°C.

Note 4: The LT1636C is guaranteed to meet specified performance from 0°C to 70°C. The LT1636C is designed, characterized and expected to meet specified performance from –40°C to 85°C but is not tested or QA sampled at these temperatures. The LT1636I is guaranteed to meet specified performance from –40°C to 85°C. The LT1636H is guaranteed to meet specified performance from –40°C to 125°C.

Note 5: V_S = 5V limits are guaranteed by correlation to V_S = 3V and V_S = ±15V or V_S = ±22V tests.

Note 6: V_S = 3V limits are guaranteed by correlation to V_S = 5V and V_S = ±15V or V_S = ±22V tests.

Note 7: Guaranteed by correlation to slew rate at V_S = ±15V and GBW at V_S = 3V and V_S = ±15V tests.

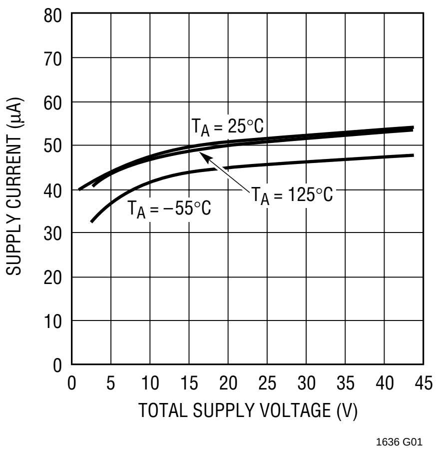
Note 8: This specification implies a typical input offset voltage of 600µV at V_{CM} = 44V and a maximum input offset voltage of 3mV at V_{CM} = 44V.

Note 9: This parameter is not 100% tested.

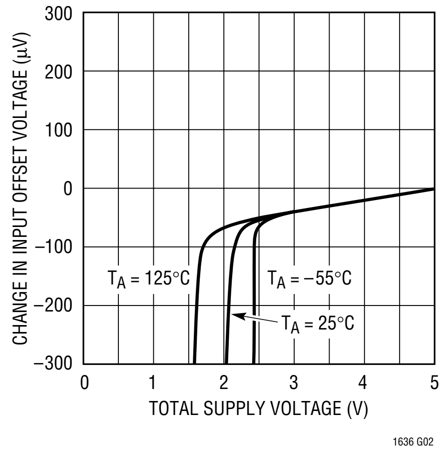
LINEAR TECHNOLOGY

TYPICAL PERFORMANCE CHARACTERISTICS

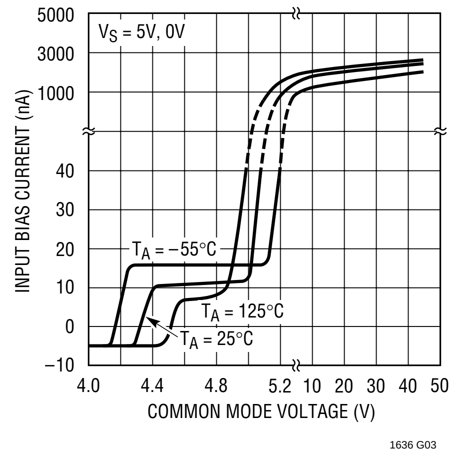
Supply Current vs Supply Voltage



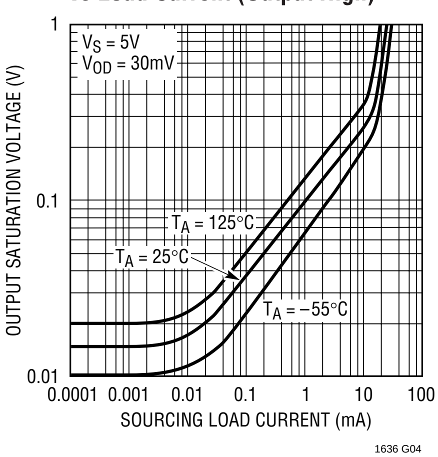
Minimum Supply Voltage



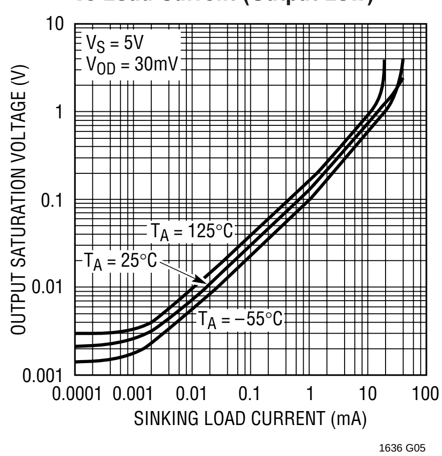
Input Bias Current vs Common Mode Voltage



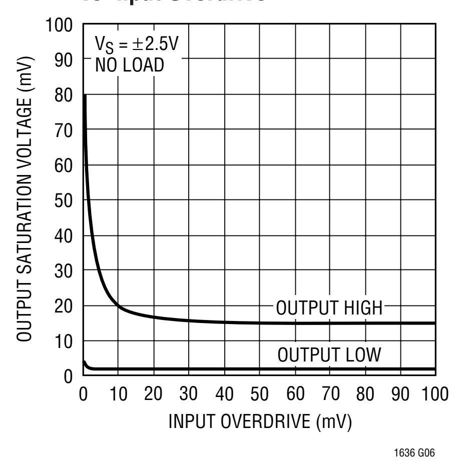
Output Saturation Voltage vs Load Current (Output High)



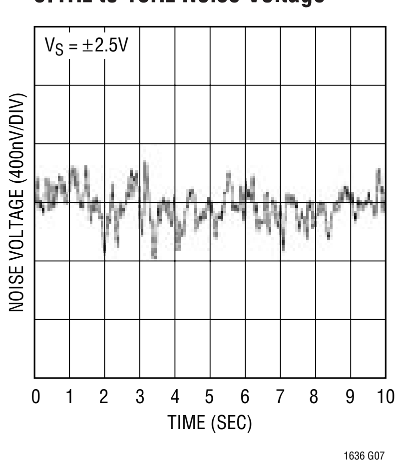
Output Saturation Voltage vs Load Current (Output Low)



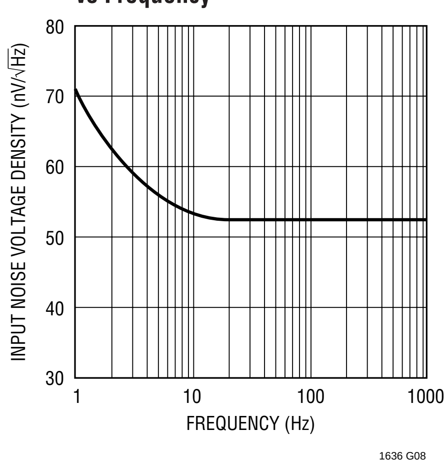
Output Saturation Voltage vs Input Overdrive



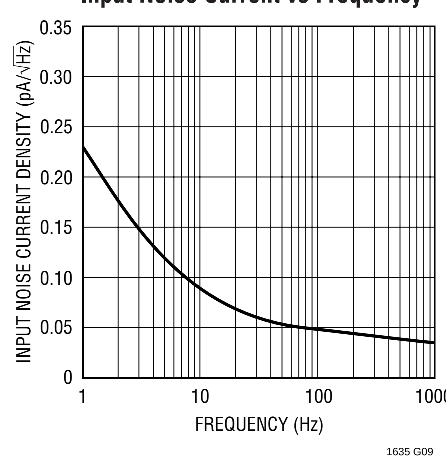
0.1Hz to 10Hz Noise Voltage



Noise Voltage Density vs Frequency

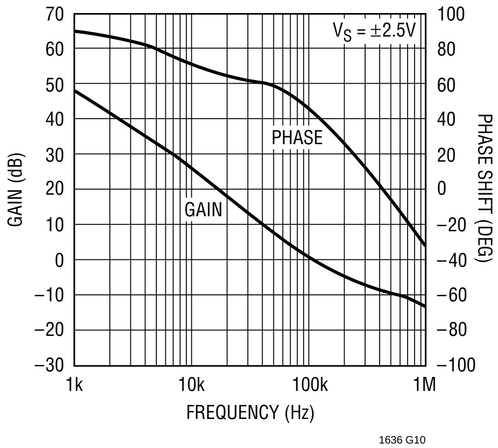


Input Noise Current vs Frequency

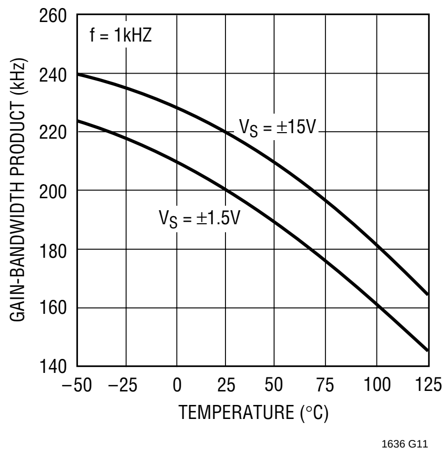


TYPICAL PERFORMANCE CHARACTERISTICS

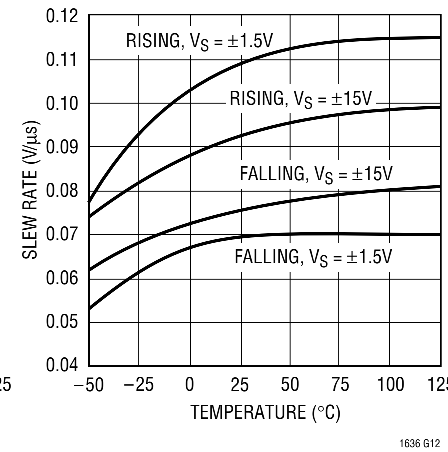
Open-Loop Gain and Phase Shift vs Frequency



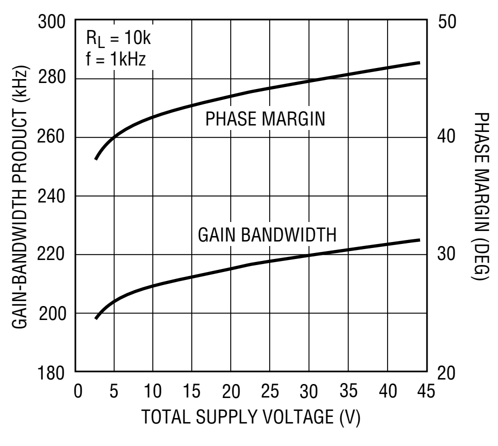
Gain-Bandwidth Product vs Temperature



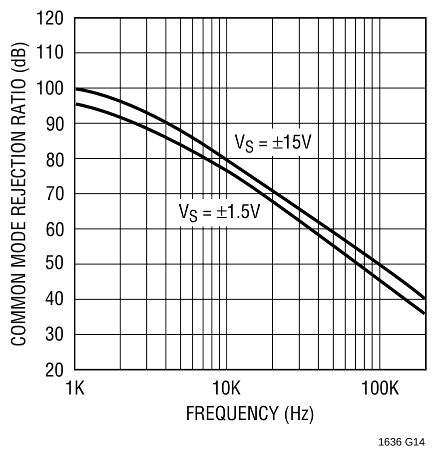
Slew Rate vs Temperature



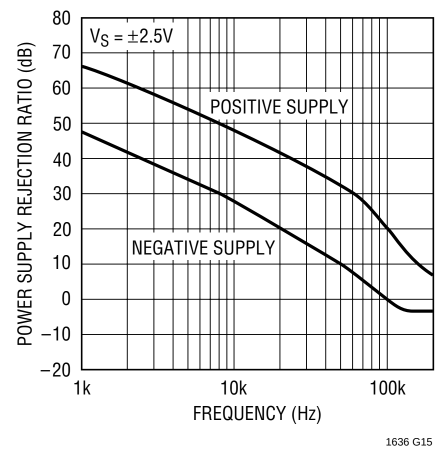
Gain-Bandwidth Product and Phase Margin vs Supply Voltage



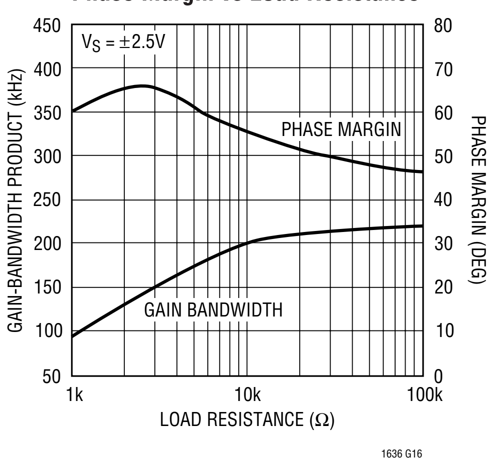
CMRR vs Frequency



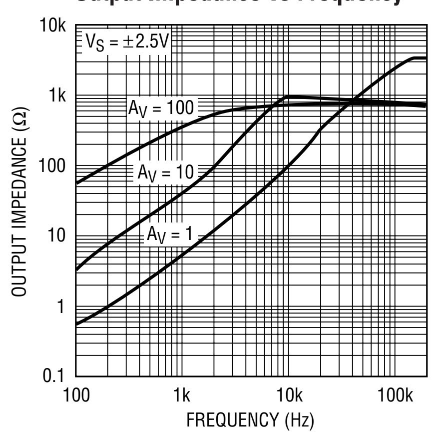
PSRR vs Frequency



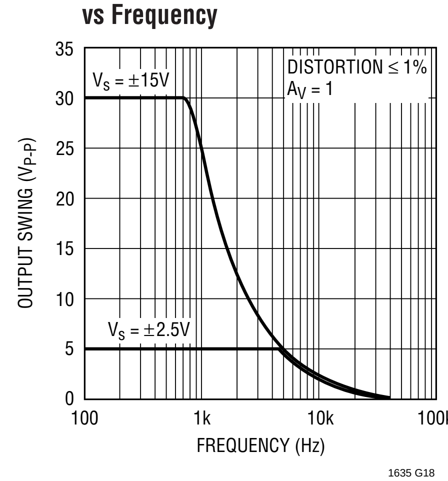
Gain-Bandwidth Product and Phase Margin vs Load Resistance



Output Impedance vs Frequency

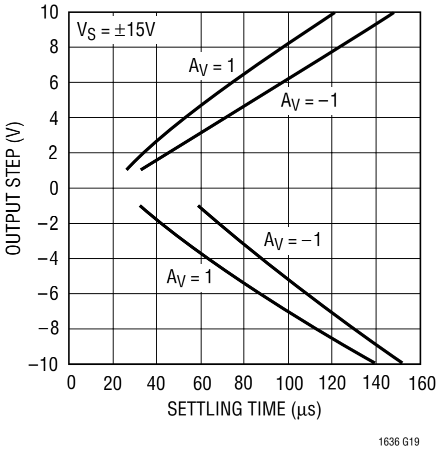


Undistorted Output Swing vs Frequency

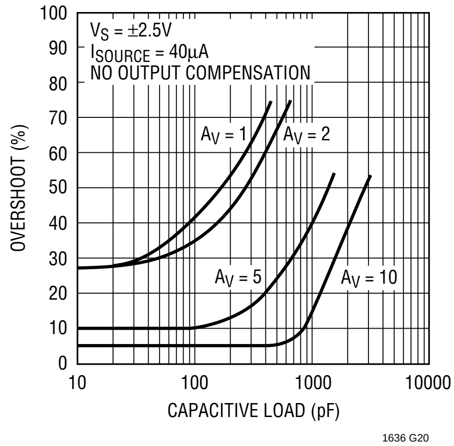


TYPICAL PERFORMANCE CHARACTERISTICS

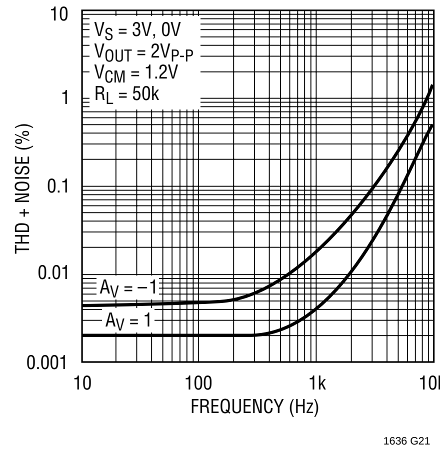
Settling Time to 0.1% vs Output Step



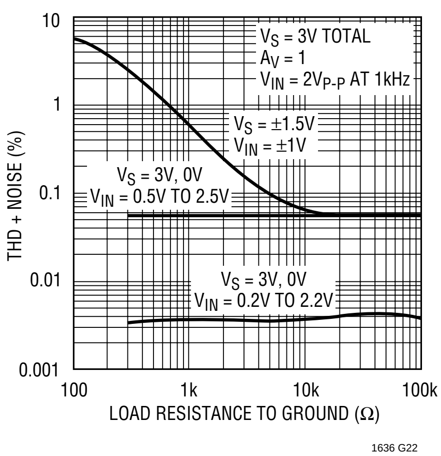
Capacitive Load Handling, Overshoot vs Capacitive Load



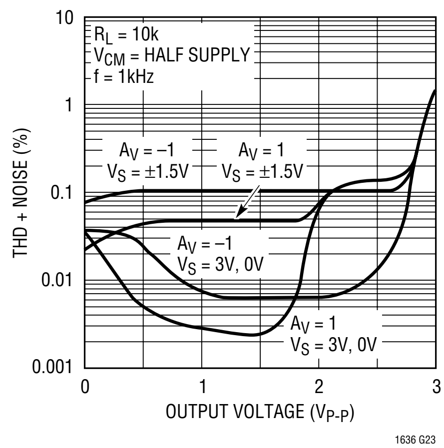
Total Harmonic Distortion + Noise vs Frequency



Total Harmonic Distortion + Noise vs Load Resistance

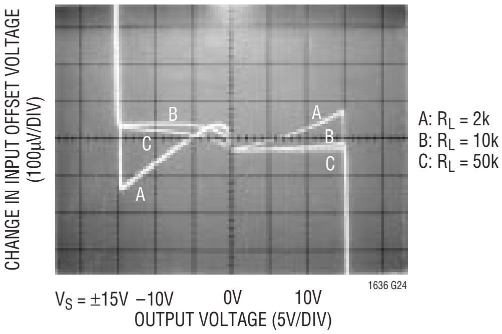


Total Harmonic Distortion + Noise vs Output Voltage

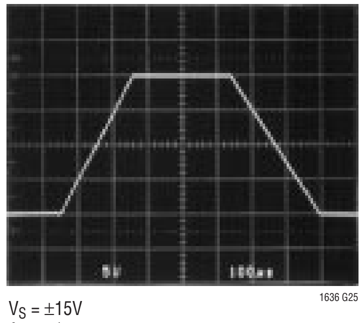


TYPICAL PERFORMANCE CHARACTERISTICS

Open-Loop Gain

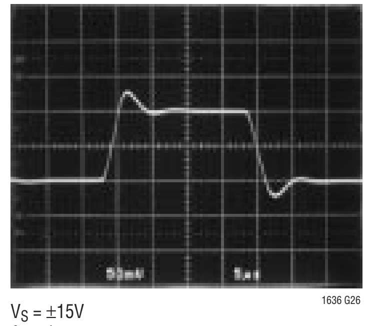


Large-Signal Response



V_S = ±15V
A_V = –1

Small-Signal Response



V_S = ±15V
A_V = 1

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.

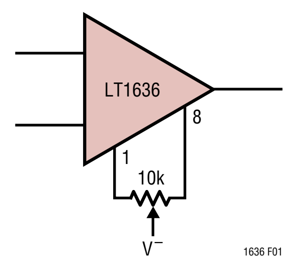
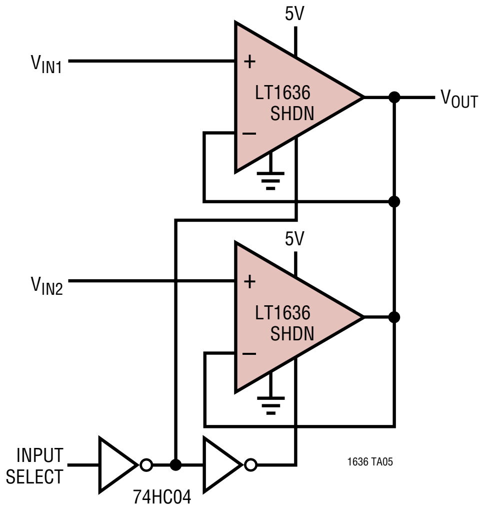


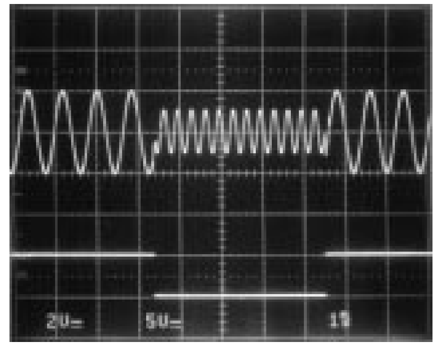
Figure 1. Input Offset Nulling

TYPICAL APPLICATIONS

MUX Amplifier

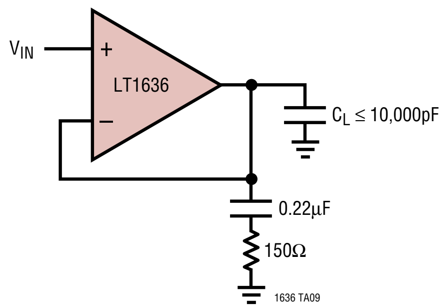


MUX Amplifier Waveforms

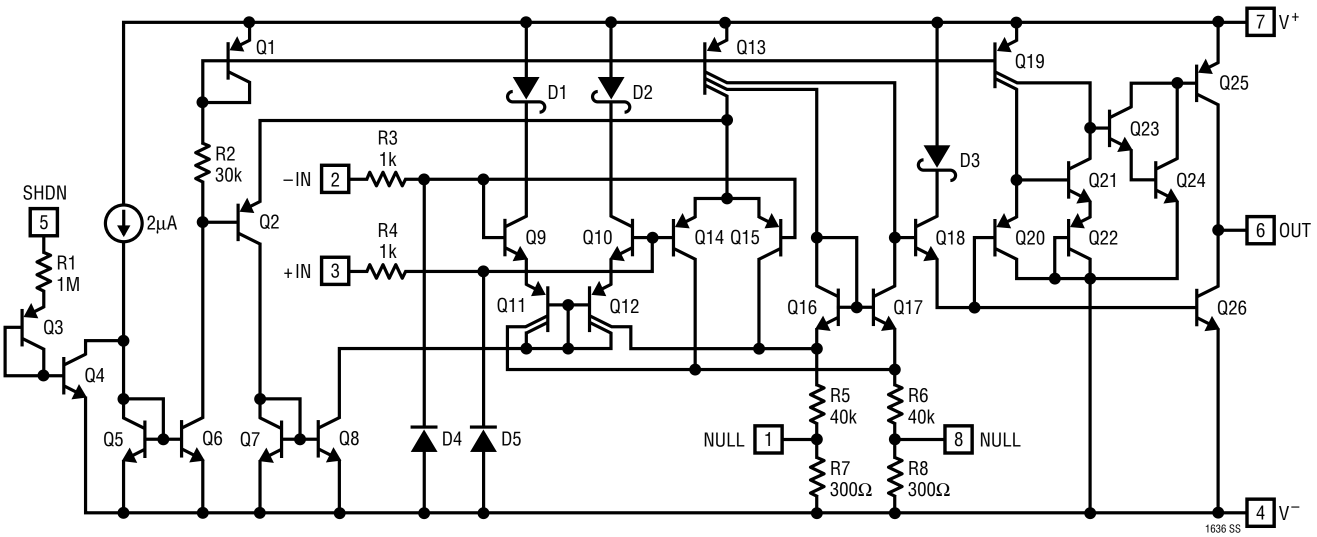


V_S = 5V
V_{IN1} = 1.2kHz AT $4V_{P-P}$, V_{IN2} = 2.4kHz AT $2V_{P-P}$
INPUT SELECT = 120Hz AT $5V_{P-P}$

Optional Output Compensation for Capacitive Loads Greater Than 200pF



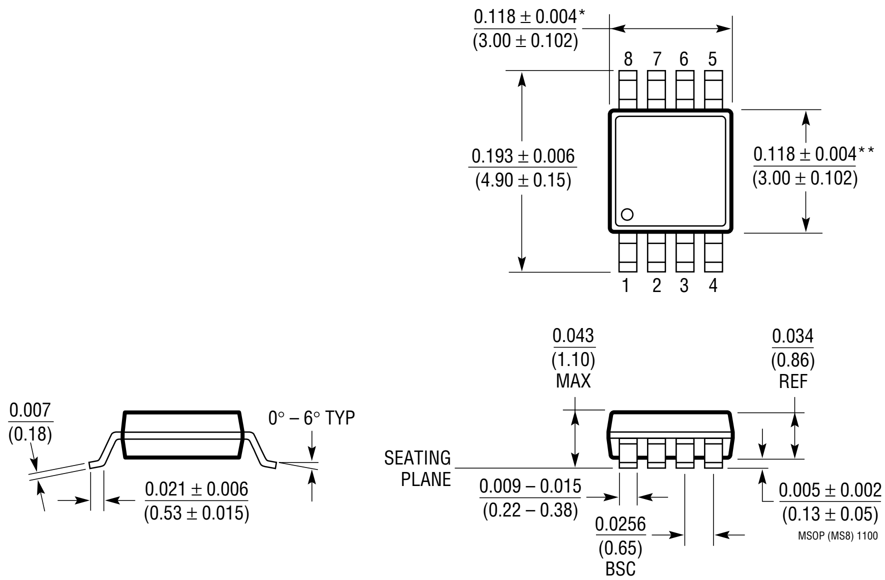
SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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



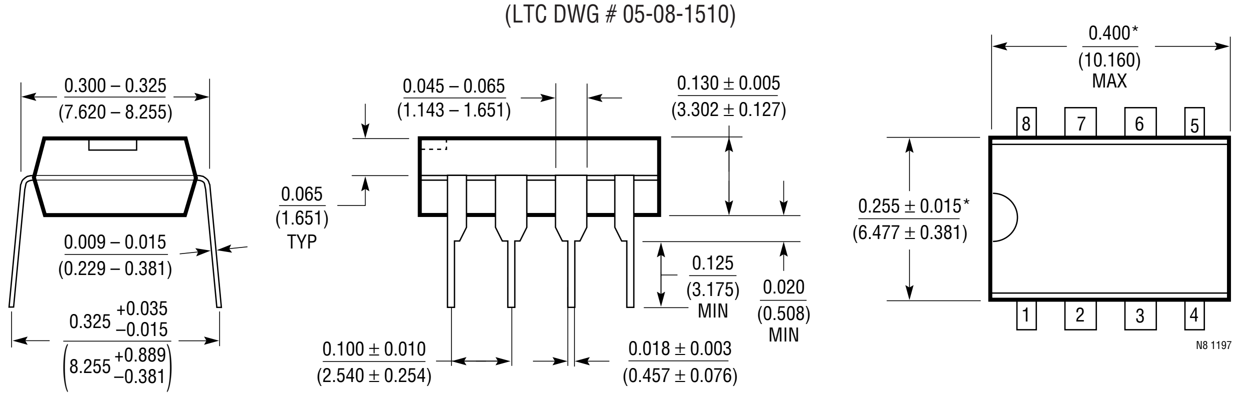
* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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

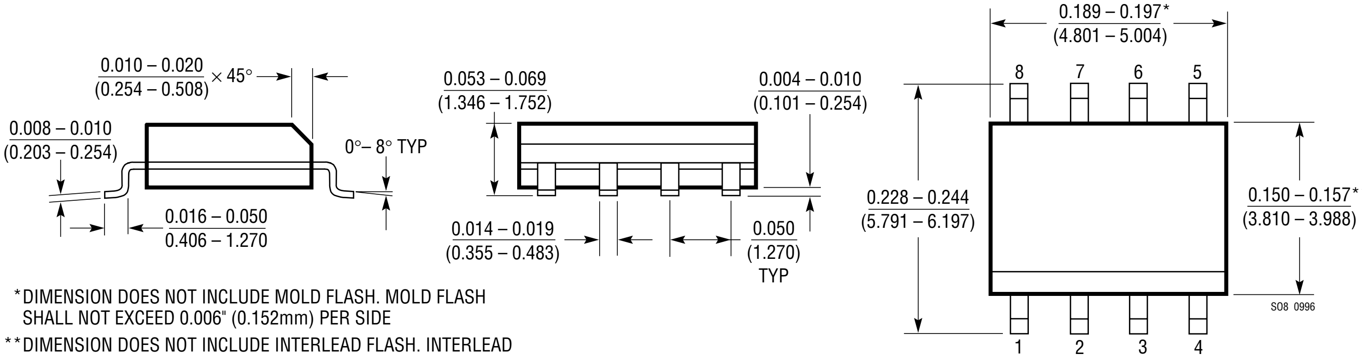


*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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



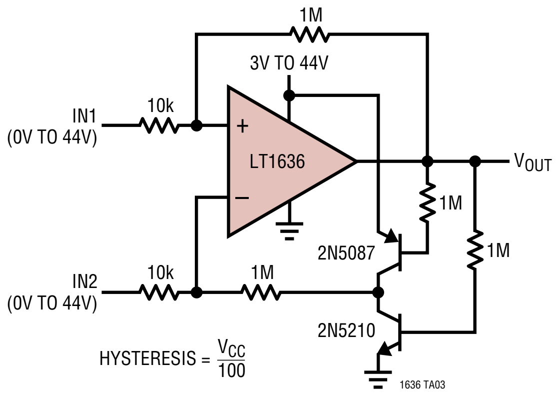
*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

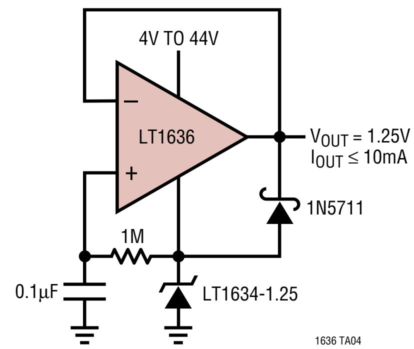
Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

TYPICAL APPLICATIONS

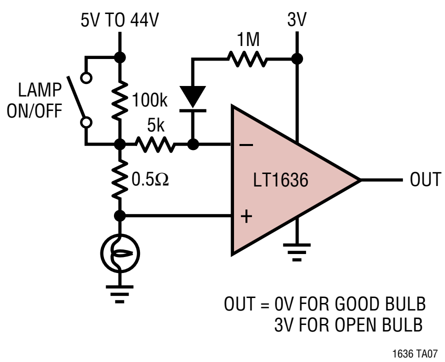
Over-The-Top Comparator with Hysteresis



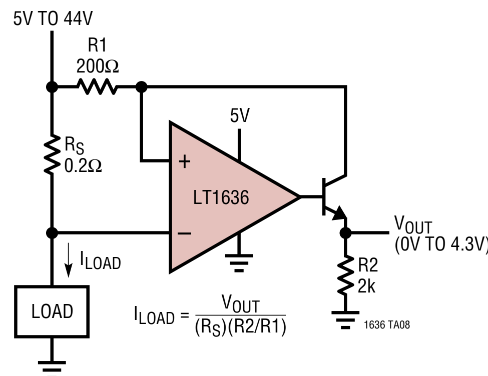
Self-Buffered Micropower Reference



Lamp Outage Detector



Over-The-Top Current Sense



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1078/LT1079 LT2078/LT2079	Dual/Quad 55μA Max, Single Supply, Precision Op Amps	Input/Output Common Mode Includes Ground, 70μV $V_{OS(MAX)}$ and 2.5μV/°C Drift (Max), 200kHz GBW, 0.07V/μs Slew Rate
LT1178/LT1179 LT2178/LT2179	Dual/Quad 17μA Max, Single Supply, Precison Op Amps	Input/Output Common Mode Includes Ground, 70μV $V_{OS(MAX)}$ and 4μV/°C Drift (Max), 85kHz GBW, 0.04V/μs Slew Rate
LT1366/LT1367	Dual/Quad Precision, Rail-to-Rail Input and Output Op Amps	475μV $V_{OS(MAX)}$, 500V/mV $A_{VOL(MIN)}$, 400kHz GBW
LT1490/LT1491	Dual/Quad Over-The-Top Micropower, Rail-to-Rail Input and Output Op Amps	Single Supply Input Range: –0.4V to 44V, Micropower 50μA per Amplifier, Rail-to-Rail Input and Output, 200kHz GBW
LT1637	Single Over-The-Top Micropower Rail-to-Rail Input and Output Op Amp	1.1MHz, V_{CM} Extends 44V above V_{EE}, Independent of V_{CC}; MSOP Package, Shutdown Function
LT1638/LT1639	Dual/Quad 1.2MHz Over-The-Top Micropower, Rail-to-Rail Input and Output Op Amps	0.4V/μs Slew Rate, 230μA Supply Current per Amplifier
LT1782	Micropower, Over-The-Top, SOT-23, Rail-to-Rail Input and Output Op Amp	SOT-23, 800μV $V_{OS(MAX)}$, I_S = 55μA (Max), Gain-Bandwidth = 200kHz, Shutdown Pin
LT1783	1.2MHz, Over-The-Top, Micropower, Rail-to-Rail Input and Output Op Amp	SOT-23, 800μV $V_{OS(MAX)}$, I_S = 300μA (Max), Gain-Bandwidth = 1.2MHz, Shutdown Pin

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