1.2MHz, 0.4V/µs Over-The-Top Micropower Rail-to-Rail Input and Output Op Amps

FEATURES

- **Operates with Inputs Above V⁺**
- **Rail-to-Rail Input and Output**
- **Low Power: 230µA per Amplifier Max**
- Gain Bandwidth Product: 1.2MHz
- Slew Rate: 0.4V/µs
- High Output Current: 25mA Min
- Specified on 3V, 5V and ±15V Supplies
- Reverse Battery Protection to 18V
- No Supply Sequencing Problems
- High Voltage Gain: 1500V/mV
- Single Supply Input Range: −0.4V to 44V
- High CMRR: 98dB
- No Phase Reversal
- Available in 14-Lead SO, 8-Lead MSOP and DFN Packages

APPLICATIONS

- Battery- or Solar-Powered Systems
    - Portable Instrumentation
    - Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- Micropower Active Filters
- 4mA to 20mA Transmitters

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Over-The-Top is a registered trademark of Linear Technology Corporation.
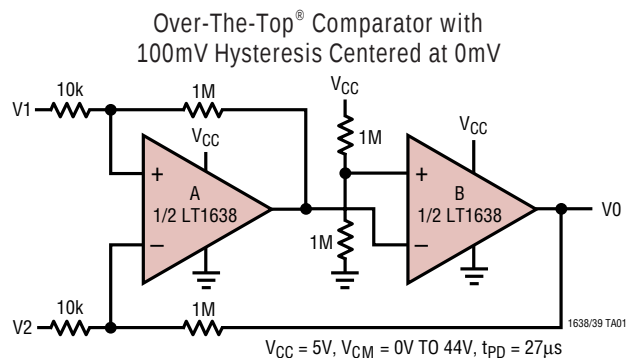All other trademarks are the property of their respective owners.

DESCRIPTION

The LT®1638 is a low power dual rail-to-rail input and output operational amplifier available in the standard 8-pin PDIP and SO packages as well as the 8-lead MSOP package. The LT1639 is a low power quad rail-to-rail input and output operational amplifier offered in the standard 14-pin PDIP and surface mount packages. For space limited applications the LT1638 is available in a 3mm x 3mm x 0.8mm dual fine pitch leadless package (DFN).
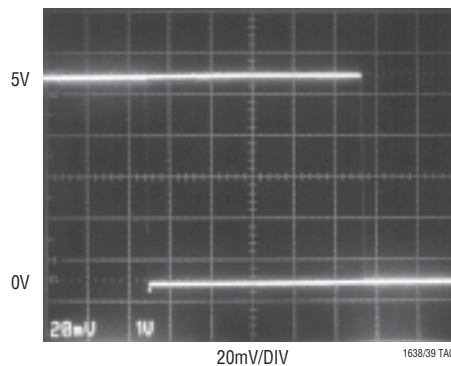
The LT1638/LT1639 op amps operate on all single and split supplies with a total voltage of 2.5V to 44V drawing only 170µA of quiescent current per amplifier. These amplifiers are reverse battery protected and draw no current for reverse supply up to 18V.

The input range of the LT1638/LT1639 includes both supplies, and a unique feature of this device is its capability to operate over the top with either or both of its inputs above V⁺. The inputs handle 44V, both differential and common mode, independent of supply voltage. The input stage incorporates phase reversal protection to prevent false outputs from occurring when the inputs are below the negative supply. Protective resistors are included in the input leads so that current does not become excessive when the inputs are forced below the negative supply. The LT1638/LT1639 can drive loads up to 25mA and still maintain rail-to-rail capability. The op amps are unity-gain stable and drive all capacitive loads up to 1000pF when optional output compensation is used.

TYPICAL APPLICATION

Over-The-Top® Comparator with
100mV Hysteresis Centered at 0mV

V_{CC} = 5V, V_{CM} = 0V TO 44V, t_{PD} = 27µs

1638/39 TA01

Output Voltage vs Input Voltage

20mV/DIV

1638/39 TA02

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ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the specified temperature range, otherwise specifications are at $T_A = 25°C$.
$V_S = 3V$, 0V; $V_S = 5V$, 0V; $V_{CM} = V_{OUT} = $ half supply, unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1638C/LT1639C, LT1638I/LT1639I MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1638 N, S Packages			200	600	µV
		$0°C \leq T_A \leq 70°C$	●			850	µV
		$-40°C \leq T_A \leq 85°C$	●			950	µV
		LT1639 N, S Packages			300	700	µV
		$0°C \leq T_A \leq 70°C$	●			950	µV
		$-40°C \leq T_A \leq 85°C$	●			1050	µV
		LT1638 MS8 Package			350	900	µV
		$0°C \leq T_A \leq 70°C$	●			1150	µV
		$-40°C \leq T_A \leq 85°C$	●			1450	µV
		LT1638 DD Package			400	1100	µV
		$0°C \leq T_A \leq 70°C$	●			1350	µV
		$-40°C \leq T_A \leq 85°C$	●			1450	µV
	Input Offset Voltage Drift (Note 9)	LT1638/LT1639 N, S Packages	●		2	6	µV/°C
		LT1638MS8, LT1638DD	●		2.5	7	µV/°C
I_{OS}	Input Offset Current		●		1	6	nA
		$V_{CM} = 44V$ (Note 5)	●			2.5	µA
I_B	Input Bias Current		●		20	50	nA
		$V_{CM} = 44V$ (Note 5)	●		8	30	µA
		$V_S = 0V$			0.1		nA
	Input Noise Voltage	0.1Hz to 10Hz			1		$µV_{P-P}$
e_n	Input Noise Voltage Density	f = 1kHz			20		nV/√Hz
i_n	Input Noise Current Density	f = 1kHz			0.3		pA/√Hz
R_{IN}	Input Resistance	Differential		1	2.5		MΩ
		Common Mode, $V_{CM} = 0V$ to 44V		1.4	5.5		MΩ
C_{IN}	Input Capacitance				5		pF
	Input Voltage Range		●	0		44	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to $V_{CC} - 1V$	●	88	98		dB
		$V_{CM} = 0V$ to 44V (Note 8)	●	80	88		dB
A_{VOL}	Large-Signal Voltage Gain	$V_S = 3V$, $V_O = 500mV$ to 2.5V, $R_L = 10k$		200	1500		V/mV
		$0°C \leq T_A \leq 70°C$	●	133			V/mV
		$-40°C \leq T_A \leq 85°C$	●	100			V/mV
		$V_S = 5V$, $V_O = 500mV$ to 4.5V, $R_L = 10k$		400	1500		V/mV
		$0°C \leq T_A \leq 70°C$	●	250			V/mV
		$-40°C \leq T_A \leq 85°C$	●	200			V/mV
V_{OL}	Output Voltage Swing Low	$V_S = 3V$, No Load	●		3	8	mV
		$V_S = 3V$, $I_{SINK} = 5mA$	●		250	450	mV
		$V_S = 5V$, No Load	●		3	8	mV
		$V_S = 5V$, $I_{SINK} = 10mA$	●		500	700	mV
V_{OH}	Output Voltage Swing High	$V_S = 3V$, No Load	●	2.94	2.98		V
		$V_S = 3V$, $I_{SOURCE} = 5mA$	●	2.25	2.40		V
		$V_S = 5V$, No Load	●	4.94	4.98		V
		$V_S = 5V$, $I_{SOURCE} = 10mA$	●	3.8	4.0		V
I_{SC}	Short-Circuit Current (Note 2)	$V_S = 3V$, Short to GND		10	15		mA
		$V_S = 3V$, Short to V_{CC}		15	25		mA
		$V_S = 5V$, Short to GND		15	20		mA
		$V_S = 5V$, Short to V_{CC}		15	25		mA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the specified temperature range, otherwise specifications are at $T_A = 25°C$.
$V_S = 3V$, $0V$; $V_S = 5V$, $0V$; $V_{CM} = V_{OUT}$ = half supply, unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1638C/LT1639C, LT1638I/LT1639I			UNITS
				MIN	TYP	MAX	
PSRR	Power Supply Rejection Ratio	$V_S = 3V$ to $12.5V$, $V_{CM} = V_O = 1V$	●	90	100		dB
	Reverse Supply Voltage	$I_S = -100\mu A$ per Amplifier	●	18	27		V
	Minimum Operating Supply Voltage		●		2.4	2.7	V
I_S	Supply Current per Amplifier (Note 6)		●		170	230 275	μA μA
GBW	Gain Bandwidth Product (Note 5)	$f = 5kHz$ $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	● ●	650 550 500	1075		kHz kHz kHz
SR	Slew Rate (Note 7)	$A_V = -1$, $R_L = \infty$ $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	● ●	0.210 0.185 0.170	0.38		V/μs V/μs V/μs

The ● denotes the specifications which apply over the specified temperature range, otherwise specifications are at $T_A = 25°C$.
$V_S = \pm15V$, $V_{CM} = 0V$, $V_{OUT} = 0V$, unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1638C/LT1639C, LT1638I/LT1639I			UNITS
				MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1638 N, S Packages $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	 ● ●		250	800 1000 1100	μV μV μV
		LT1639 N, S Packages $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	 ● ●		350	900 1100 1200	μV μV μV
		LT1638 MS8 Package $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	 ● ●		400	1050 1250 1550	μV μV μV
		LT1638 DDPackage $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	 ● ●		450	1250 1450 1550	μV μV μV
	Input Offset Voltage Drift (Note 9)	LT1638/LT1639 N, S Packages LT1638MS8, LT1638DD	● ●		2 2.5	6 7	μV/°C μV/°C
I_{OS}	Input Offset Current		●		1	6	nA
I_B	Input Bias Current		●		20	50	nA
	Input Noise Voltage	0.1Hz to 10Hz			1		μV_{P-P}
e_n	Input Noise Voltage Density	$f = 1kHz$			20		$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	$f = 1kHz$			0.3		$pA/\sqrt{Hz}$
R_{IN}	Input Resistance	Differential Common Mode, $V_{CM} = -15V$ to $14V$		1	2.5 500		MΩ MΩ
C_{IN}	Input Capacitance				4.5		pF
	Input Voltage Range		●	−15		29	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = -15V$ to $29V$	●	80	88		dB
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm14V$, $R_L = 10k$ $0°C \le T_A \le 70°C$ $-40°C \le T_A \le 85°C$	 ● ●	200 125 100	500		V/mV V/mV V/mV
V_O	Output Voltage Swing	No Load $I_{OUT} = \pm10mA$	● ●	±14.9 ±13.7	±14.95 ±14.0		V V

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ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the specified temperature range, otherwise specifications are at T_A = 25°C. V_S = ±15V, V_{CM} = 0V, V_{OUT} = 0V, unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1638C/LT1639C, LT1638I/LT1639I			UNITS
				MIN	TYP	MAX	
I_{SC}	Short-Circuit Current (Note 2)	Short to GND		25	40		mA
		0°C ≤ T_A ≤ 70°C	●	20			mA
		−40°C ≤ T_A ≤ 85°C	●	15			mA
PSRR	Power Supply Rejection Ratio	V_S = ±1.5V to ±22V	●	90	100		dB
I_S	Supply Current per Amplifier				205	280	μA
			●			350	μA
GBW	Gain Bandwidth Product	f = 5kHz		750	1200		kHz
		0°C ≤ T_A ≤ 70°C	●	650			kHz
		−40°C ≤ T_A ≤ 85°C	●	600			kHz
SR	Slew Rate	A_V = −1, R_L = ∞, V_O = ±10V,		0.225	0.4		V/μs
		0°C ≤ T_A ≤ 70°C	●	0.2			V/μs
		−40°C ≤ T_A ≤ 85°C	●	0.18			V/μs

The ● denotes the specifications which apply over the full operating temperature range of −40°C ≤ T_A ≤ 125°C. V_S = 3V, 0V; V_S = 5V, 0V; V_{CM} = V_{OUT} = Half Supply unless otherwise specified. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		LT1638H/LT1639H			UNITS
				MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1638S8			200	650	μV
			●			3	mV
		LT1639S			300	750	μV
			●			3.2	mV
	Input Offset Voltage Drift (Note 9)		●			15	μV/°C
I_{OS}	Input Offset Current		●			15	nA
		V_{CM} = 44V (Note 5)	●			10	μA
I_B	Input Bias Current		●			150	nA
		V_{CM} = 44V (Note 5)	●			100	μA
	Input Voltage Range		●	0.3		44	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0.3V to V_{CC} − 1V	●	76			dB
		V_{CM} = 0.3V to 44V	●	72			dB
A_{VOL}	Large-Signal Voltage Gain	V_S = 3V, V_O = 500mV to 2.5V, R_L = 10k		200	1500		V/mV
			●	20			V/mV
		V_S = 5V, V_O = 500mV to 4.5V, R_L = 10k		400	1500		V/mV
			●	35			V/mV
V_{OL}	Output Voltage Swing Low	No Load	●			15	mV
		I_{SINK} = 5mA	●			900	mV
		V_S = 5V, I_{SINK} = 10mA	●			1500	mV
V_{OH}	Output Voltage Swing High	V_S = 3V, No Load	●	2.9			V
		V_S = 3V, I_{SOURCE} = 5mA	●	2			V
		V_S = 5V, No Load	●	4.9			V
		V_S = 5V, I_{SOURCE} = 10mA	●	3.5			V
PSRR	Power Supply Rejection Ratio	V_S = 3V to 12.5V, V_{CM} = V_O = 1V	●	80			dB
	Minimum Supply Voltage		●	2.7			V
	Reverse Supply Voltage	I_S = −100μA	●	18			V
I_S	Supply Current (Note 6)				170	230	μA
			●			450	μA
GBW	Gain Bandwidth Product (Note 5)	f = 5kHz		650	1075		kHz
			●	350			kHz
SR	Slew Rate (Note 7)	A_V = −1, R_L = ∞		0.21	0.38		V/μs
			●	0.1			V/μs

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ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of $-40°C \leq T_A \leq 125°C$, 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		LT1638H/LT1639H MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1638S8			250	850	µV
			●			3.4	mV
		LT1639S			350	950	µV
			●			3.6	mV
	Input Offset Voltage Drift (Note 9)		●			15	µV/°C
I_{OS}	Input Offset Current		●			25	nA
I_B	Input Bias Current		●			250	nA
CMRR	Common Mode Rejection Ratio	$V_{CM} = -14.7V$ to $29V$	●	72			dB
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm14V$, $R_L = 10k$		200	500		V/mV
			●	15			V/mV
V_O	Output Voltage Swing	No Load	●	±14.8			V
		$I_{OUT} = \pm5mA$	●	±14			V
		$I_{OUT} = \pm10mA$	●	±13.4			V
PSRR	Power Supply Rejection Ratio	$V_S = \pm1.5V$ to $\pm22V$	●	84			dB
	Minimum Supply Voltage		●	±1.35			V
I_S	Supply Current				205	280	µA
			●			550	µA
GBW	Gain Bandwidth Product	$f = 5kHz$		750	1200		kHz
			●	400			kHz
SR	Slew Rate	$A_V = -1$, $R_L = \infty$, $V_O = \pm10V$,		0.225	0.4		V/µs
		Measure at $V_O = \pm5V$	●	0.1			V/µs

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: A heat sink may be required to keep the junction temperature below absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted.

Note 3: The LT1638C/LT1639C and LT1638I/LT1639I are guaranteed functional over the operating temperature range of $-40°C$ to $85°C$. The LT1638H/LT1639H are guaranteed functional over the operating temperature range of $-40°C$ to $125°C$.

Note 4: The LT1638C/LT1639C are guaranteed to meet specified performance from $0°C$ to $70°C$ and are designed, characterized and expected to meet specified performance from $-40°C$ to $85°C$ but not tested or QA sampled at these temperatures. The LT1638I/LT1639I are guaranteed to meet specified performance from $-40°C$ to $85°C$. The LT1638H/LT1639H are 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 $V_S = \pm15V$ or $V_S = \pm22V$ tests.

Note 6: $V_S = 3V$ limits are guaranteed by correlation to $V_S = 5V$ and $V_S = \pm15V$ or $V_S = \pm22V$ tests.

Note 7: Guaranteed by correlation to slew rate at $V_S = \pm15V$, and GBW at $V_S = 3V$ and $V_S = \pm15V$ tests.

Note 8: This specification implies a typical input offset voltage of 2mV at $V_{CM} = 44V$ and a maximum input offset voltage of 5mV at $V_{CM} = 44V$.

Note 9: This parameter is not 100% tested.

Note 10: The θ_{JA} specified for the DD package is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.
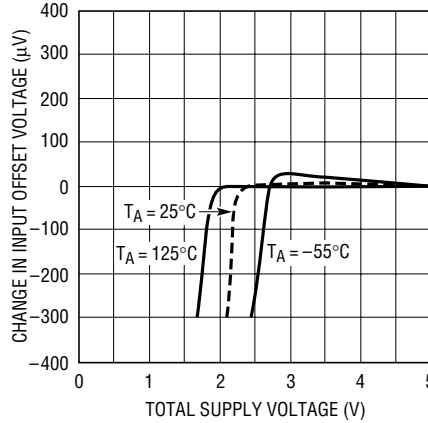
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LINEAR TECHNOLOGY

TYPICAL PERFORMANCE CHARACTERISTICS

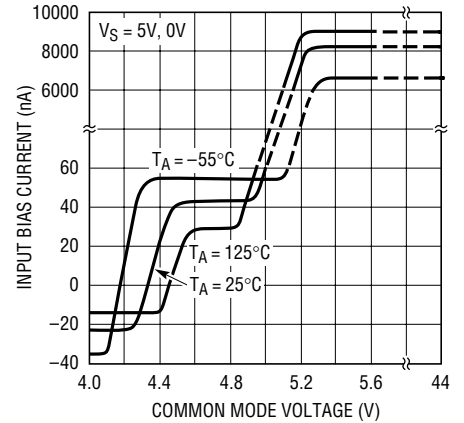### Supply Current vs Supply Voltage
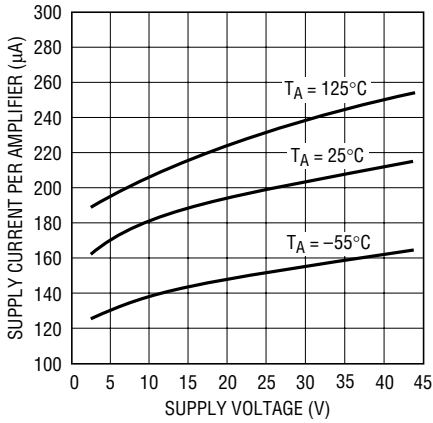
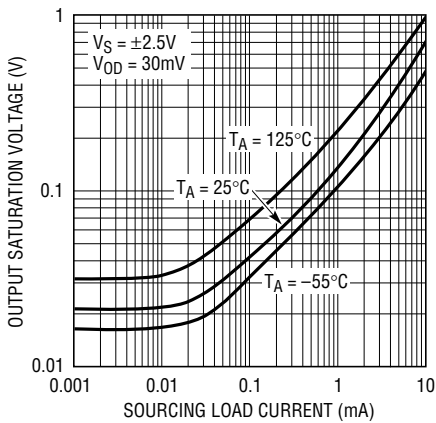1638/39 G01

Minimum Supply Voltage

1638/39 G02

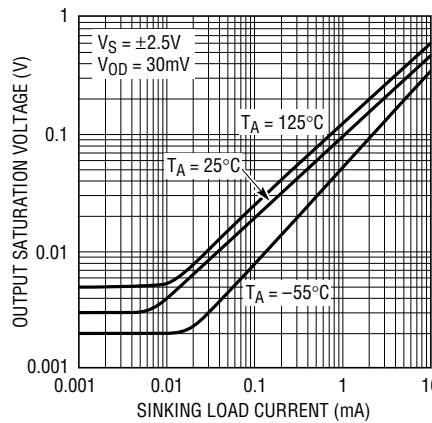### Input Bias Current vs Common Mode Voltage

1638/39 G03

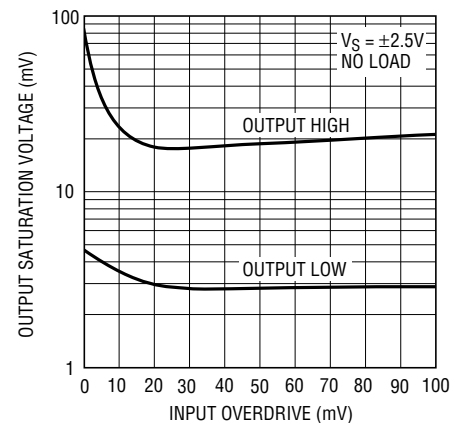### Output Saturation Voltage vs Load Current (Output High)

1638/39 G04

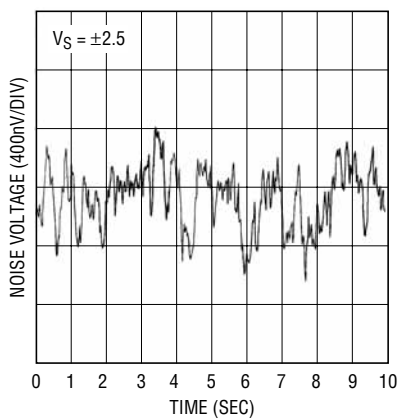### Output Saturation Voltage vs Load Current (Output Low)

1638/39 G05

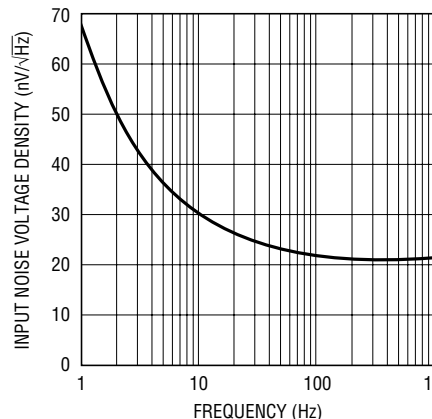### Output Saturation Voltage vs Input Overdrive
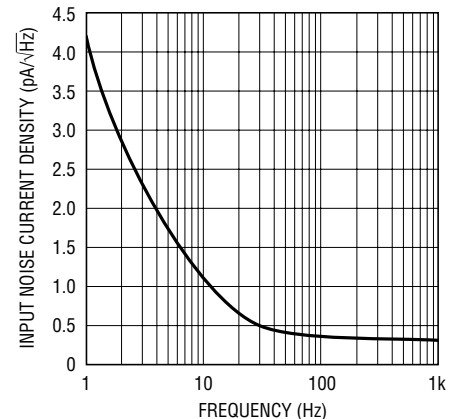

1638/39 G06

0.1Hz to 10Hz Noise Voltage

1638/39 G07

Noise Voltage Density vs Frequency

1638/39 G09

Input Noise Current Density vs Frequency

1638/39 G08

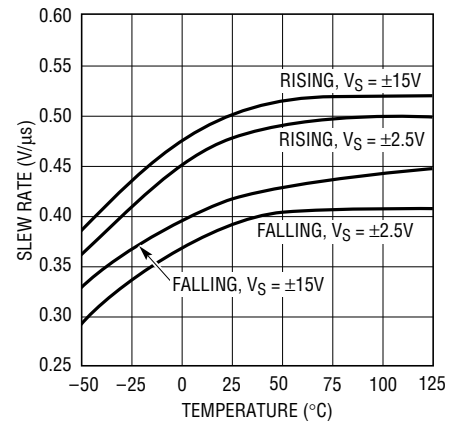# TYPICAL PERFORMANCE CHARACTERISTICS

Gain and Phase Shift vs Frequency
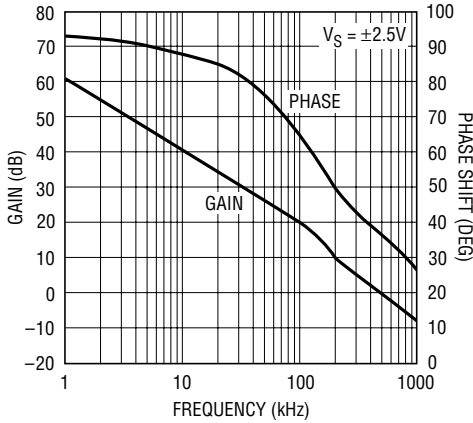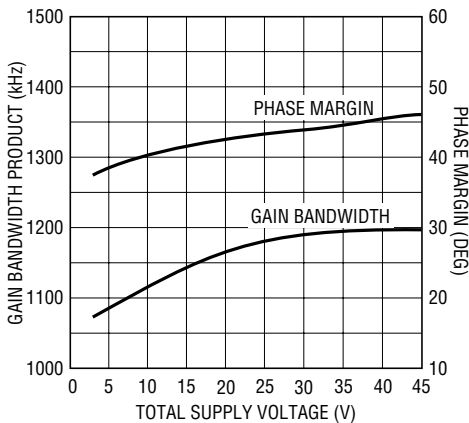

1638/39 G12

Gain Bandwidth Product vs Temperature
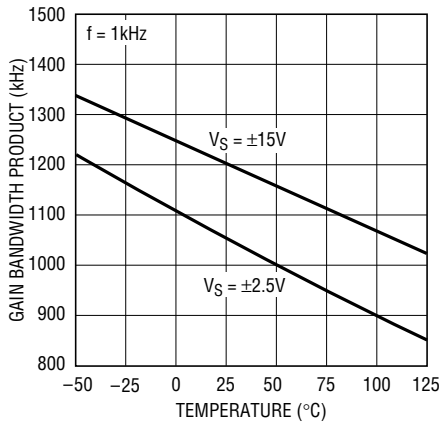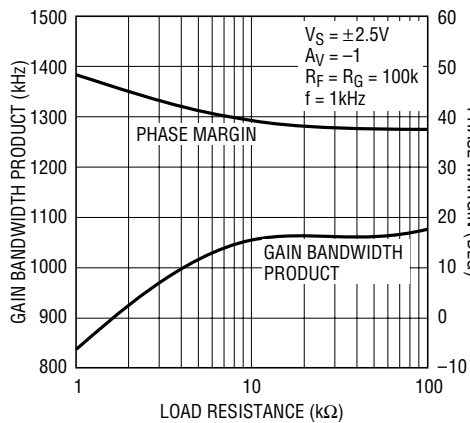

1638/39 G13

Slew Rate vs Temperature

1638/39 G14

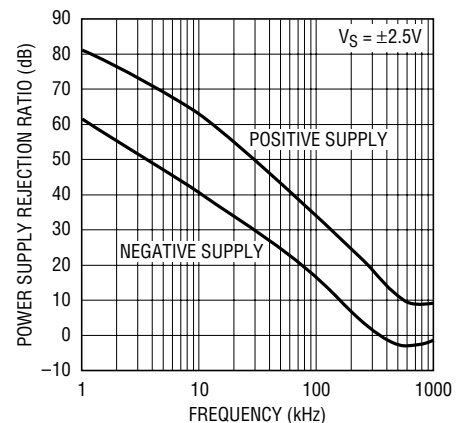**Gain Bandwidth Product and Phase Margin vs Supply Voltage**

1638/39 G15

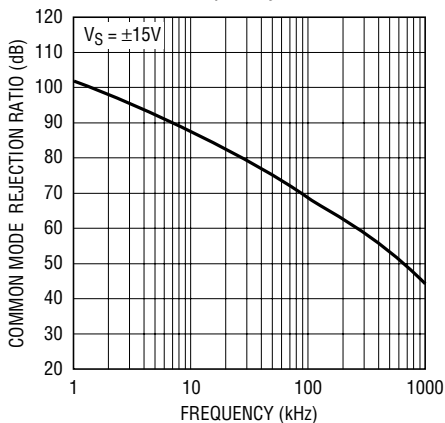**Gain Bandwidth Product and Phase Margin vs Load Resistance**
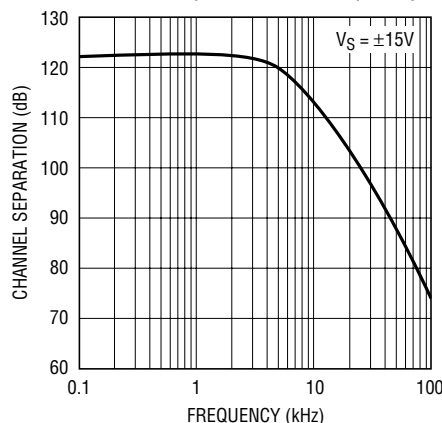

1638/39 G17

PSRR vs Frequency

1638/39 G16

CMRR vs Frequency
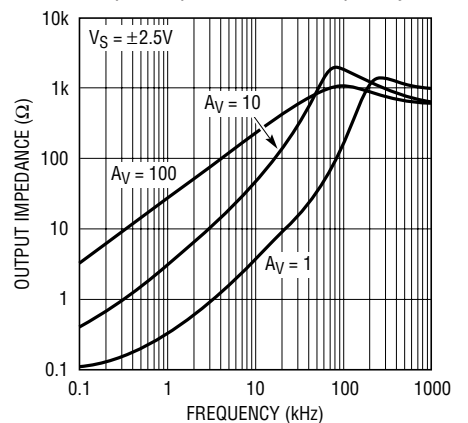

1638/39 G18

Channel Separation vs Frequency
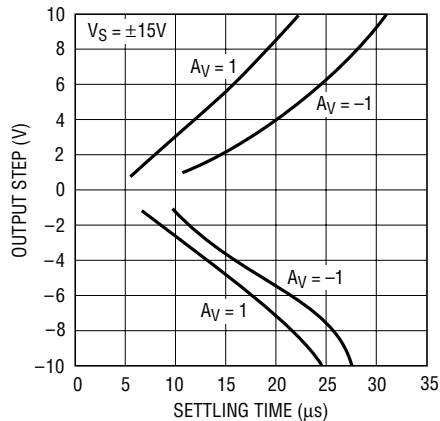

1638/39 G19

Output Impedance vs Frequency

1638/39 G20
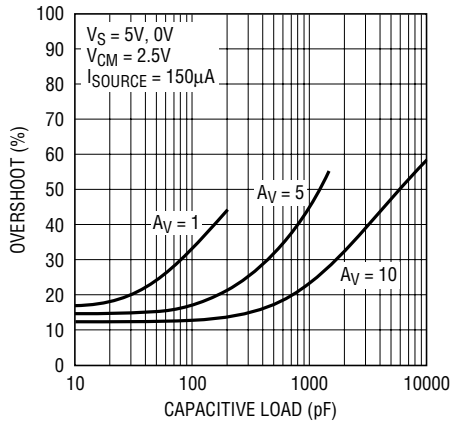
TYPICAL PERFORMANCE CHARACTERISTICS
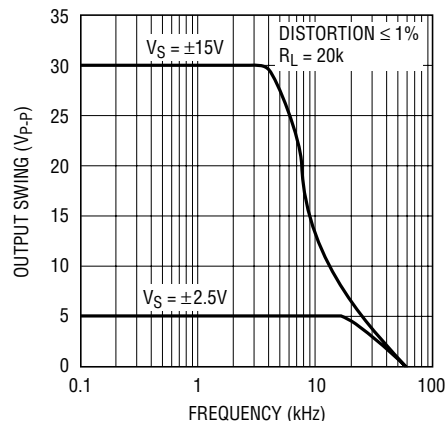
Settling Time to 0.1% vs Output Step

$V_S = \pm15V$

$A_V = 1$

$A_V = -1$

$A_V = -1$

$A_V = 1$

OUTPUT STEP (V)

SETTLING TIME (μs)

1638/39 G21

Capacitive Load Handling, Overshoot vs Capacitive Load

$V_S = 5V, 0V$
$V_{CM} = 2.5V$
$I_{SOURCE} = 150μA$

$A_V = 1$

$A_V = 5$

$A_V = 10$

OVERSHOOT (%)

CAPACITIVE LOAD (pF)

1638/39 G22

Undistorted Output Swing vs Frequency

$V_S = \pm15V$

DISTORTION ≤ 1%
$R_L = 20k$

$V_S = \pm2.5V$

OUTPUT SWING (V_P-P)

FREQUENCY (kHz)

1638/39 G23

Total Harmonic Distortion + Noise vs Frequency

$V_S = 3V, 0V$
$V_{OUT} = 2V_{P-P}$
$V_{CM} = 1.2V$
$R_L = 20k$

$A_V = -1$

$A_V = 1$

THD + NOISE (%)

FREQUENCY (Hz)
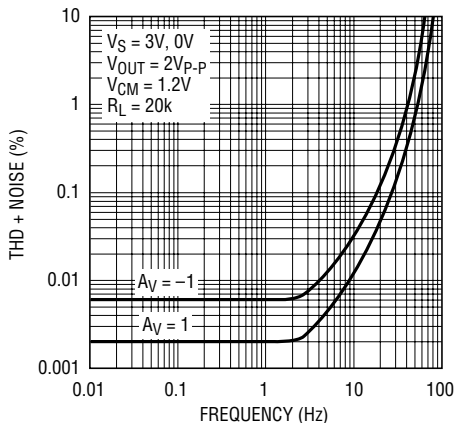
1638/39 G24

Total Harmonic Distortion + Noise vs Load Resistance

$V_S = 3V$ TOTAL
$A_V = 1$
$V_{IN} = 2V_{P-P}$ AT 1kHz

$V_S = \pm1.5V$
$V_{IN} = \pm1V$

$V_S = 3V, 0V$
$V_{IN} = 0.5V$ TO 2.5V

$V_S = 3V, 0V$
$V_{IN} = 0.2V$ TO 2.2V

THD + NOISE (%)

LOAD RESISTANCE TO GROUND (kΩ)
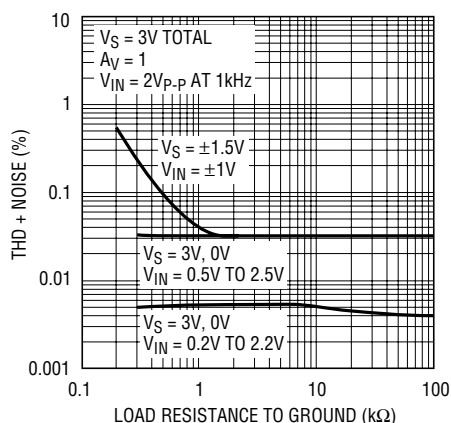
1638/39 G25

Total Harmonic Distortion + Noise vs Output Voltage

$R_L = 10k, f = 1kHz$
$V_{CM} = $ HALF SUPPLY
—— $A_V = -1, V_S = \pm1.5V$
– – – $A_V = -1, V_S = 3V, 0V$
–·–·– $A_V = 1, V_S = \pm1.5V$
········ $A_V = 1, V_S = 3V, 0V$

THD + NOISE (%)

OUTPUT VOLTAGE (V_P-P)
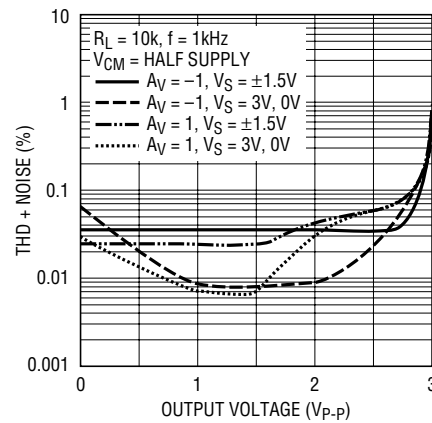
1638/39 G26

Open-Loop Gain

$V_S = \pm15V$

$R_L = 2k$

$R_L = 10k$

$R_L = 50k$

CHANGE IN INPUT OFFSET VOLTAGE (50μV/DIV)

OUTPUT VOLTAGE (5V/DIV)
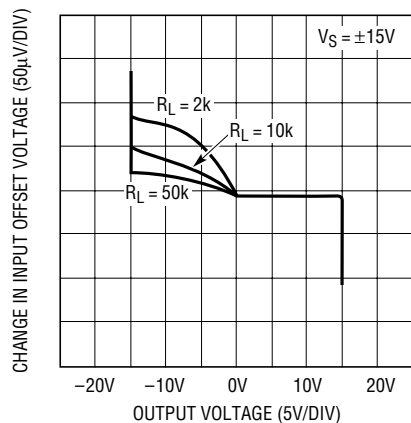
1638/39 G27

Large-Signal Response
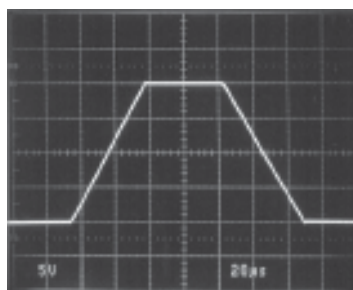
$V_S = \pm15V$
$A_V = 1$

1638/39 G28

Small-Signal Response
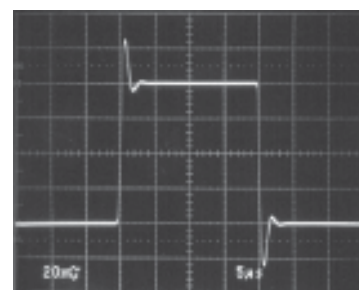
$V_S = \pm15V$
$A_V = 1$
$C_L = 15pF$

1638/39 G29

APPLICATIONS INFORMATION

Supply Voltage

The positive supply pin of the LT1638/LT1639 should be bypassed with a small capacitor (typically 0.1µF) 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 LT1638/LT1639 are protected against reverse battery voltages up to 18V. In the event a reverse battery condition occurs, the supply current is less than 1nA.

The LT1638/LT1639 can be shut down by removing V$^+$. In this condition the input bias current is less than 0.1nA, even if the inputs are 44V above the negative supply.

At temperatures greater than 70°C, when operating the LT1638/LT1639 on total supplies of 10V or more, the supply must not be brought up faster than 1V/µs. Increasing the bypass capacitor and/or adding a small resistor in series with the supply will limit the rise time.

Inputs

The LT1638/LT1639 have two input stages, NPN and PNP (see the 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 −20nA. When the input common mode voltage is within 0.5V of the positive rail, the NPN stage is operating and the input bias current is typically 40nA. Increases in temperature will cause the voltage at which operation switches from the PNP input stage to the NPN input 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 allow the LT1638/LT1639 to operate over the top, 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 8µA at room temperature. The input offset voltage is typically 2mV when operating above V$^+$. The LT1638/LT1639 will operate with its inputs 44V above V$^-$ regardless of V$^+$.

The inputs are protected against excursions of 2V below V$^-$ by an internal 1k resistor in series with each input and a diode from the input to the negative supply. If the inputs can go more than 2V below V$^-$, an additional external resistor is required. A 10k resistor will protect the input against excursions as much as 10V below V$^-$. The input stage of the LT1638/LT1639 incorporates phase reversal protection to prevent the output from phase reversing for inputs below V$^-$. There are no clamping diodes between the inputs and the maximum differential input voltage is 44V.

Output

The output of the LT1638/LT1639 can swing within 20mV of the positive rail with no load, and within 3mV of the negative rail with no load. When monitoring voltages within 20mV of the positive rail or within 3mV of the negative rail, gain should be taken to keep the output from clipping. The LT1638/LT1639 are capable of sinking and sourcing over 40mA on ±15V supplies; sourcing current capability is reduced to 20mA at 5V total supplies as noted in the electrical characteristics.

The LT1638/LT1639 are 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 1000pF, at all output currents.

Optional Output Compensation for
Capacitive Loads Greater than 200pF
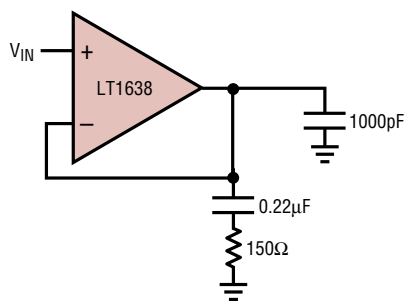
Distortion

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

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TYPICAL APPLICATIONS

The application in Figure 3 utilizes the Over-The-Top capabilities of the LT1638. The 0.2Ω resistor senses the load current while the op amp and NPN transistor form a closed loop making the collector current of Q1 proportional to the load current. As a convenient monitor, the 2k load resistor converts the current into a voltage. The positive supply rail, V⁺, is not limited to the 5V supply of the op amp and could be as high as 44V.
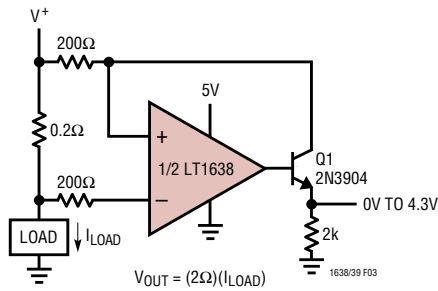
The Figure 4 application uses the LT1638 in conjunction with the LT1634 micropower shunt reference. The supply current of the op amp also biases the reference. The drop across resistor R1 is fixed at 1.2V generating an output current equal to 1.2V/R1.
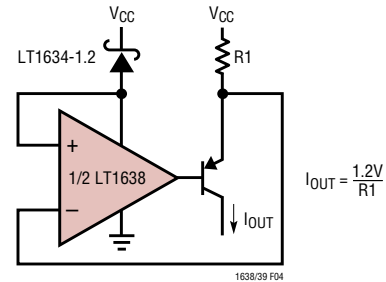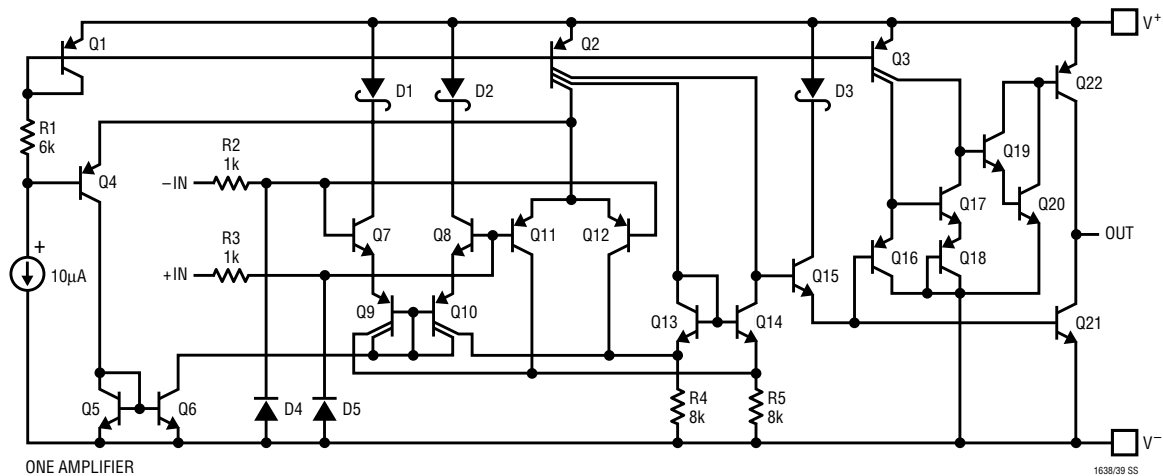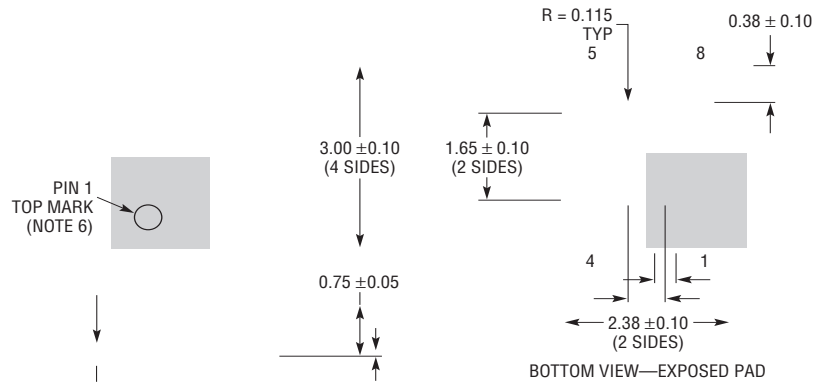

Figure 3. Positive Supply Rail Current Sense

Figure 4. Current Source

SIMPLIFIED SCHEMATIC

ONE AMPLIFIER

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PACKAGE DESCRIPTION

R = 0.115
TYP
5

0.38 ± 0.10
8

3.00 ±0.10
(4 SIDES)

1.65 ± 0.10
(2 SIDES)

PIN 1
TOP MARK
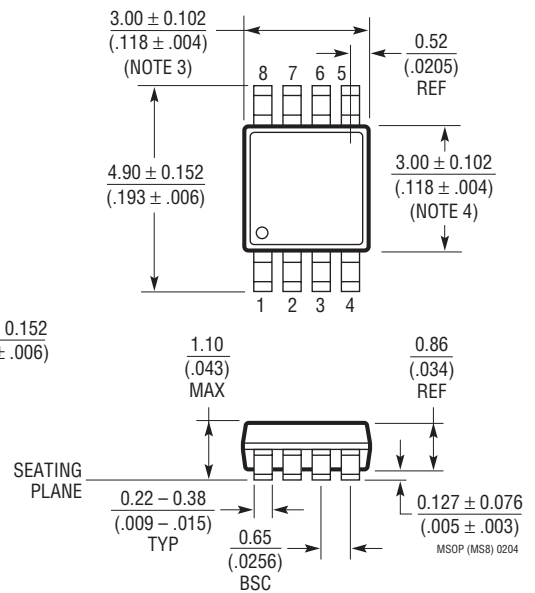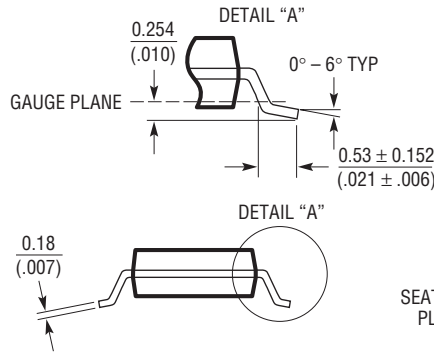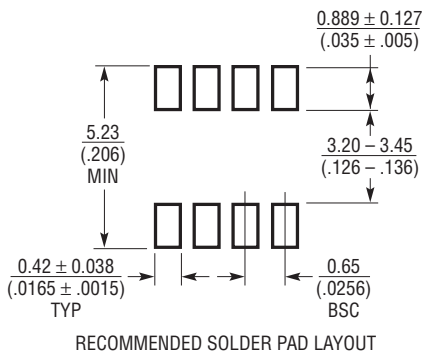(NOTE 6)

0.75 ±0.05

4   1

2.38 ±0.10
(2 SIDES)

BOTTOM VIEW—EXPOSED PAD

NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-1)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE
   MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION
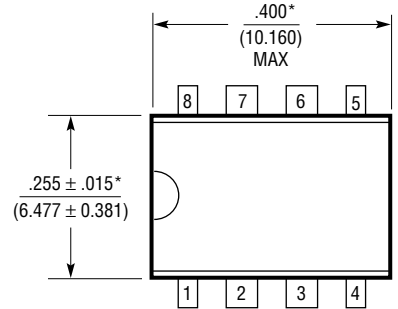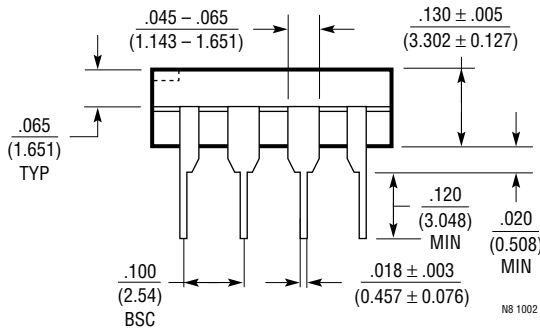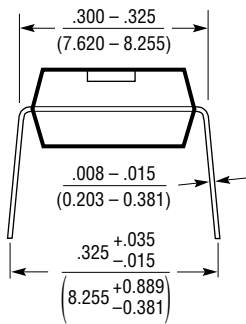   ON TOP AND BOTTOM OF PACKAGE

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

0.889 ± 0.127
(.035 ± .005)

5.23
(.206)
MIN

3.20 – 3.45
(.126 – .136)

0.42 ± 0.038
(.0165 ± .0015)
TYP

0.65
(.0256)
BSC

RECOMMENDED SOLDER PAD LAYOUT

DETAIL "A"

0.254
(.010)

0° – 6° TYP

GAUGE PLANE

0.53 ± 0.152
(.021 ± .006)

DETAIL "A"

0.18
(.007)

3.00 ± 0.102
(.118 ± .004)
(NOTE 3)

0.52
(.0205)
REF

8 7 6 5

3.00 ± 0.102
(.118 ± .004)
(NOTE 4)

4.90 ± 0.152
(.193 ± .006)

1 2 3 4

1.10
(.043)
MAX

0.86
(.034)
REF

SEATING
PLANE

0.22 – 0.38
(.009 – .015)
TYP

0.65
(.0256)
BSC

0.127 ± 0.076
(.005 ± .003)

MSOP (MS8) 0204

NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
   MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
   INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX
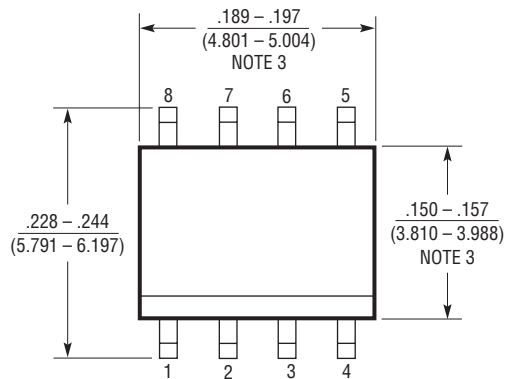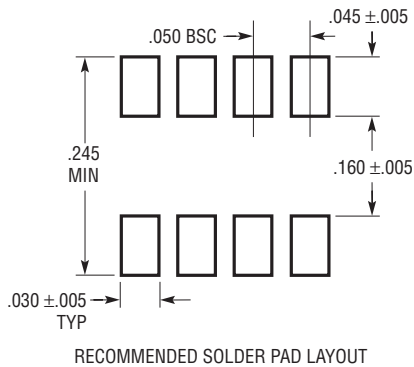
PACKAGE DESCRIPTION

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

.300 – .325
(7.620 – 8.255)

.008 – .015
(0.203 – 0.381)

.325 $^{+.035}_{-.015}$

$\left(8.255 ^{+0.889}_{-0.381}\right)$

.045 – .065
(1.143 – 1.651)

.130 ± .005
(3.302 ± 0.127)

.065
(1.651)
TYP

.120
(3.048)
MIN

.020
(0.508)
MIN

.100
(2.54)
BSC

.018 ± .003
(0.457 ± 0.076)

N8 1002

.400*
(10.160)
MAX

.255 ± .015*
(6.477 ± 0.381)

8 7 6 5

1 2 3 4

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

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

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

.050 BSC

.045 ±.005

.245
MIN

.160 ±.005

.030 ±.005
TYP

RECOMMENDED SOLDER PAD LAYOUT

.189 – .197
(4.801 – 5.004)
NOTE 3

8 7 6 5

.228 – .244
(5.791 – 6.197)

.150 – .157
(3.810 – 3.988)
NOTE 3

1 2 3 4

NOTE:
1. DIMENSIONS IN $\frac{INCHES}{(MILLIMETERS)}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE
   MOLD FLASH OR PROTRUSIONS.
   MOLD FLASH OR PROTRUSIONS SHALL
   NOT EXCEED .006" (0.15mm)

.010 – .020
(0.254 – 0.508) × 45°

.008 – .010
(0.203 – 0.254)

0° – 8° TYP

.016 – .050
(0.406 – 1.270)

.053 – .069
(1.346 – 1.752)

.004 – .010
(0.101 – 0.254)

.014 – .019
(0.355 – 0.483)
TYP

.050
(1.270)
BSC

SO8 0303

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LT LINEAR
TECHNOLOGY

PACKAGE DESCRIPTION

N Package
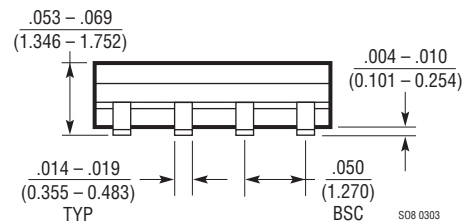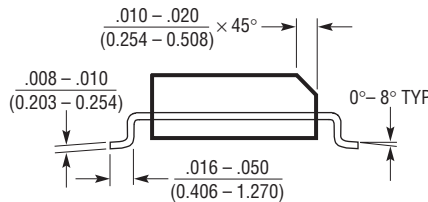**14-Lead PDIP (Narrow .300 Inch)**
(Reference LTC DWG # 05-08-1510)

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)

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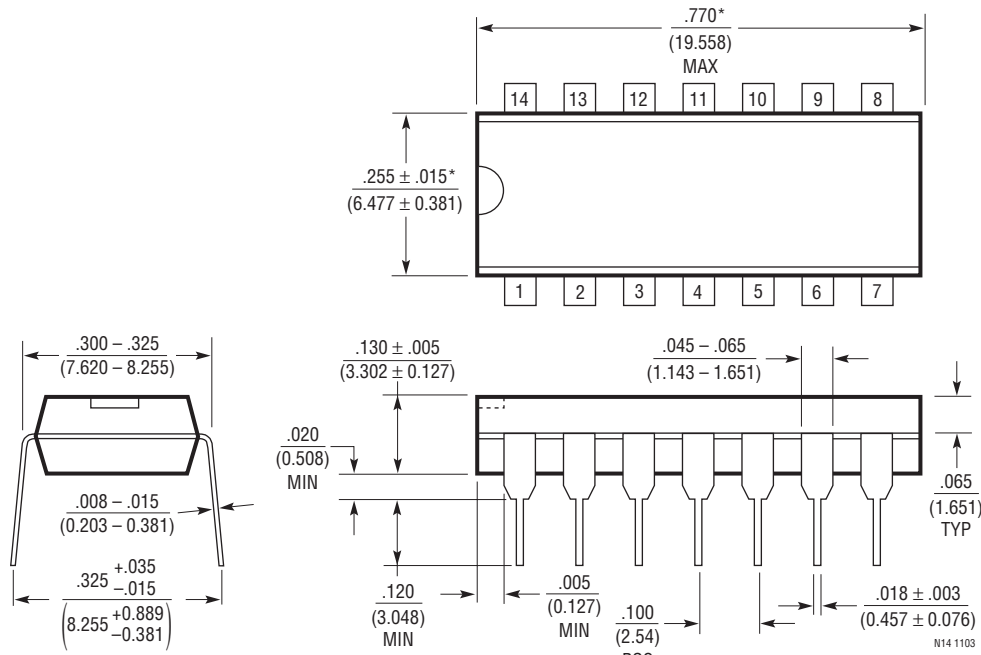(Reference LTC DWG # 05-08-1610)

RECOMMENDED SOLDER PAD LAYOUT

NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE
   MOLD FLASH OR PROTRUSIONS.
   MOLD FLASH OR PROTRUSIONS
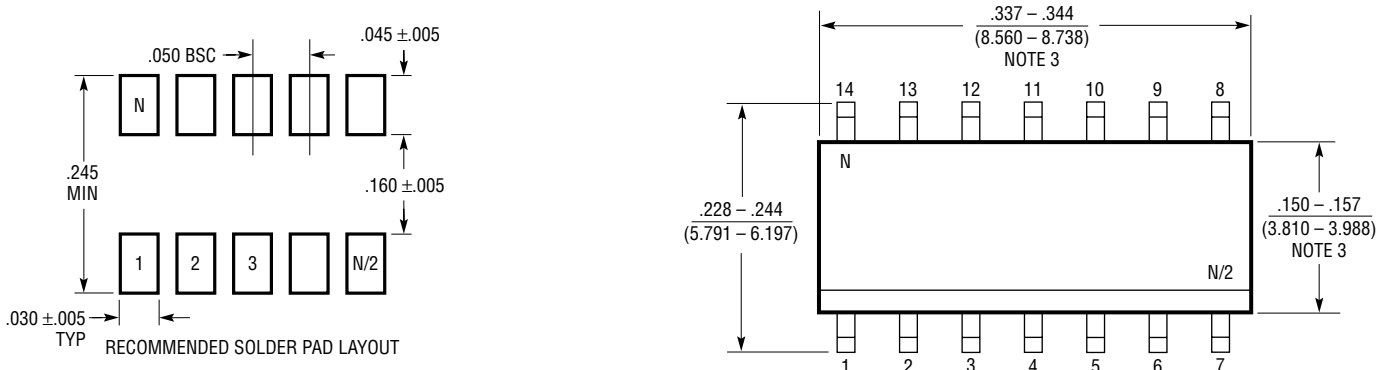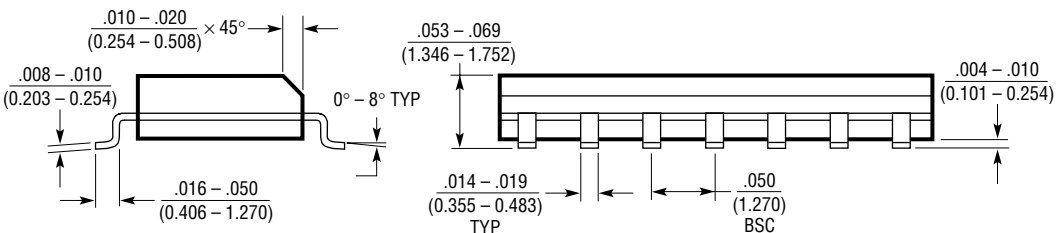   SHALL NOT EXCEED .006" (0.15mm)

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TYPICAL APPLICATION

The battery monitor in Figure 5 also demonstrates the LT1638's ability to operate with its inputs above the positive rail. In this application, a conventional amplifier would be limited to a battery voltage between 5V and ground, but the LT1638 can handle battery voltages as high as 44V. When the battery is charging, Amp B senses the voltage drop across R_S. The output of Amp B causes Q2 to drain sufficient current through R_B to balance the input of Amp B. Likewise, Amp A and Q1 form a closed loop when the battery is discharging. The current through Q1 or Q2 is proportional to the current in R_S and this current flows into R_G and is converted into a voltage. Amp D buffers and amplifies the voltage across R_G. Amp C compares the output of Amp A and Amp B to determine the polarity of current through R_S. The scale factor for V_{OUT} with S1 open is 1V/A. With S1 closed the scale factor is 1V/100mA and currents as low as 500µA can be measured.
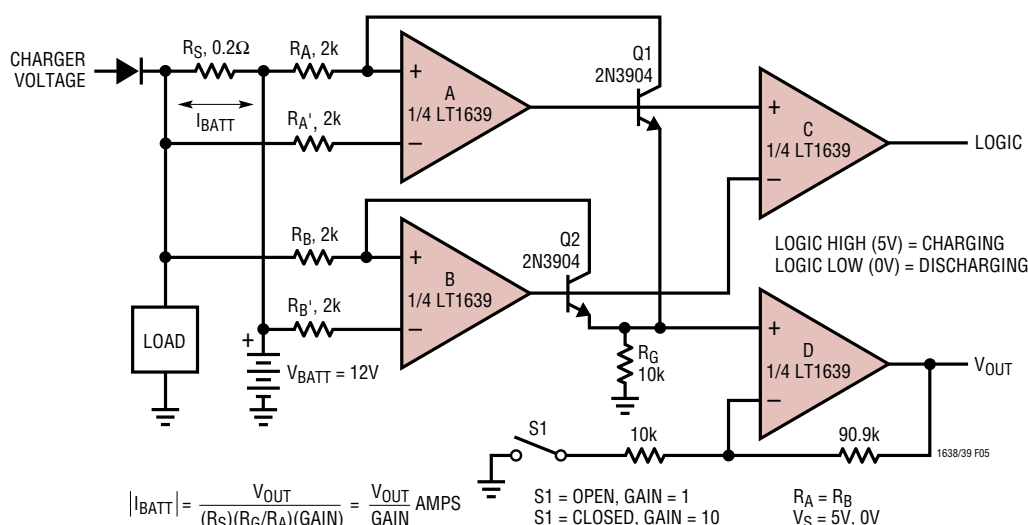

$$|I_{BATT}| = \frac{V_{OUT}}{(R_S)(R_G/R_A)(GAIN)} = \frac{V_{OUT}}{GAIN} \text{ AMPS}$$

S1 = OPEN, GAIN = 1
S1 = CLOSED, GAIN = 10

$R_A = R_B$
V_S = 5V, 0V

LOGIC HIGH (5V) = CHARGING
LOGIC LOW (0V) = DISCHARGING

Figure 5. Battery Monitor

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
LT1636	Single Over-The-Top Micropower Rail-to-Rail Input and Output Op Amp	55µA Supply Current, V_{CM} Extends 44V above V_{EE}, Independent of V_{CC}; MSOP Package, Shutdown Function

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