

Micropower Op Amp, Comparator and Reference

January 1998

FEATURES

- **Quiescent Current: 5 μ A Typ**
- **Outputs Swing Rail-to-Rail**
- **Low Op Amp Offset Voltage: 700 μ V Max**
- **Reference Output Drives 0.01 μ F Capacitor**
- **Internal 1.2V \pm 0.4% Reference Output**
- **Low Input Bias Current: 1nA Max**
- **Reference Output Can Source Up to 2mA**
- **Internal \pm 3mV Comparator Hysteresis**
- **Comparator and Op Amp Input Range Includes Ground**
- **Op Amp Capable of Driving Up to 1000pF Load**
- **Unity-Gain Stable and 12kHz Bandwidth**
- **2.5V to 12.6V Supply Voltage Range**
- **Pin Compatible Upgrade for MAX951**

APPLICATIONS

- Battery- or Solar-Powered Systems
- Automotive Keyless Entry
- Low Frequency, Local Area Alarms/Detectors
- Infrared Receivers for Remote Controls
- Smoke Detectors and Safety Sensors
- GSM Portable Phones

DESCRIPTION

The LTC®1541 combines a micropower amplifier, comparator and bandgap reference in an 8-pin package. The part operates from a single 2.5V to 12.6V or dual $\pm 1.25\text{V}$ to $\pm 6.3\text{V}$ supply with a typical supply current of $5\mu\text{A}$. Both the op amp and comparator feature a common mode input voltage range that extends from the negative supply to within 1.3V of the positive supply. The op amp output stage swings from rail-to-rail. The comparator's inverting input is internally connected to the reference output.

The reference output voltage is $1.2\text{V} \pm 1\%$ over the extended temperature range. The output can drive a bypass capacitor of up to $0.01\mu\text{F}$ without any oscillations. It can also source up to 2mA and sink up to $20\mu\text{A}$.

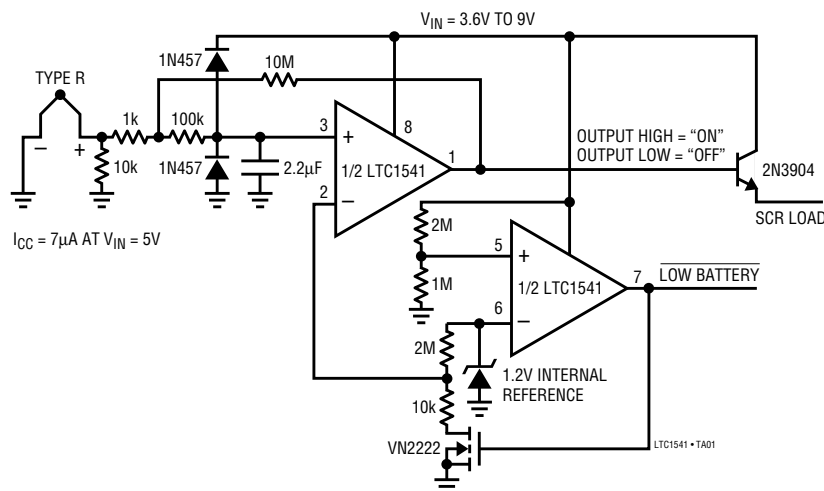
The op amp is internally compensated to be unity-gain stable with typical GBW at 12kHz and slew rate of 8V/ms. The comparator has $\pm 3\text{mV}$ of internal hysteresis to ensure clean output switching, even with slow moving input signals.

The LTC1541 is available in MSOP and SO-8 packages.

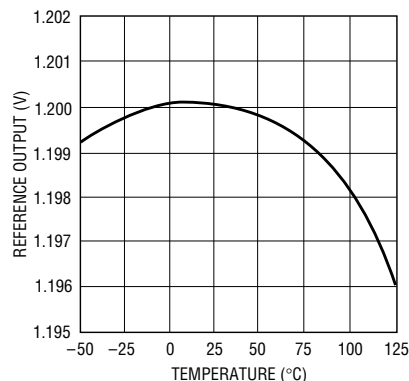
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TYPICAL APPLICATION

Pilot Light Flame Detector with Low-Battery Lockout



Reference Output vs Temperature



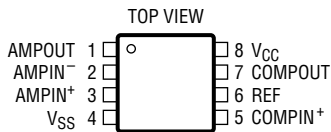
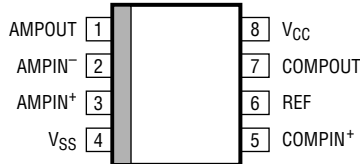
ABSOLUTE MAXIMUM RATINGS

Supply Voltage 13V
 Input Voltage -0.3V to 13V
 Output Voltage -0.3V to 13V
 Output Short-Circuit Duration Indefinite
 Storage Temperature Range -65°C to 150°C

Operating Temperature Range

Commercial 0°C to 70°C
 Industrial -40°C to 85°C
 Lead Temperature (Soldering, 10 sec) 300°C

PACKAGE/ORDER INFORMATION

 <p>MS8 PACKAGE 8-LEAD PLASTIC MSOP $T_{JMAX} = 125^{\circ}\text{C}$, $\theta_{JA} = 250^{\circ}\text{C/W}$</p>	ORDER PART NUMBER	 <p>S8 PACKAGE 8-LEAD PLASTIC SO $T_{JMAX} = 125^{\circ}\text{C}$, $\theta_{JA} = 150^{\circ}\text{C/W}$</p>	ORDER PART NUMBER
	LTC1541CMS8		LTC1541CS8 LTC1541IS8
	MS8 PART MARKING		S8 PART MARKING
	LTBE		1541 1541I

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS $V_{CC} = 5V$, $V_{SS} = 0V$, $T_A = 25^{\circ}\text{C}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply						
V_{CC}	Supply Voltage Range		●	2.5	12.6	V
I_{CC}	Supply Current (Note 1)	Commercial Grade	●	5	7.5	μA
		Industrial Grade	●		13	μA
			●		14	μA
Comparator						
V_{OS}	Input Offset Voltage (Note 2)	(SO-8)	●		1	mV
		Commercial Grade (SO-8)	●		1.5	mV
		Industrial Grade (SO-8)	●		2.0	mV
		(MSOP)	●		1.2	mV
			●		2.0	mV
V_{TRIP}	Trip Point (Note 3)		●	2 1	2.25 2.50 3.5	mV mV
I_{IN}	Input Leakage Current (Note 4)	$V_{COMPIN+} = 2.5V$	●	0.01	1	nA
V_{CM}	Input Common Mode Range		●	V_{SS}	$V_{CC} - 1.3V$	V
PSRR	Power Supply Rejection Ratio	$V_{CC} = 3V$ to 12V	●		0.25	mV/V
		Commercial Grade (SO-8)	●		0.30	mV/V
		Industrial Grade (SO-8)	●		0.35	mV/V
t_{PD}	Propagation Delay	Overdrive = 10mV		20		μs
		Overdrive = 100mV		8		μs
V_{OH}	Output High Voltage	$I_{OUT} = -2\text{mA}$	●	$V_{CC} - 0.2V$		V
V_{OL}	Output Low Voltage	$I_{OUT} = 1.8\text{mA}$	●		$V_{SS} + 0.3V$	V

ELECTRICAL CHARACTERISTICS

$V_{CC} = 5V$, $V_{SS} = 0V$, $T_A = 25^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Reference							
V_{REF}	Reference Voltage	No Load (SO-8)		1.195	1.200	1.205	V
		Commercial Grade (SO-8)	●	1.190		1.210	V
		Industrial Grade (SO-8)	●	1.188		1.212	V
		No Load (MSOP)	●	1.190	1.200	1.210	V
ΔV_{REF}	Load Regulation	$I_{SOURCE} = 2mA$ $I_{SINK} = 10\mu A$	●		2	6	mV
			●		0.2	1.5	mV
			●			5	mV
e_n	Voltage Noise	0.1Hz to 10Hz			16		μV_{P-P}
Op Amp							
V_{OS}	Input Offset Voltage	$V_{CM} = 2.5V$ (SO-8)				0.7	mV
		Commercial Grade (SO-8)	●			1.25	mV
		Industrial Grade (SO-8)	●			1.5	mV
		$V_{CM} = 2.5V$ (MSOP)	●			1.00	mV
I_B	Input Bias Current	$V_{CM} = 2.5V$	●		0.01	1	nA
A_{VOL}	Large-Signal Gain	AMPOUT = 0.5V to 4.5V, No Load		80	1000		V/mV
		AMPOUT = 0.5V to 4.5V, $R_{LOAD} = 100k$		60	500		V/mV
		Commercial Grade	●	38			V/mV
		Industrial Grade	●	35			V/mV
GBW	Gain Bandwidth	$A_V = 1V/V$			12		kHz
SR	Slew Rate	$A_V = 1V/V$			8		V/ms
V_{CM}	Input Common Mode Range		●	V_{SS}		$V_{CC} - 1.3V$	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = V_{SS}$ to $V_{CC} - 1.3V$				0.20	mV/V
		Commercial Grade	●			0.25	mV/V
		Industrial Grade	●			0.30	mV/V
PSRR	Power Supply Rejection Ratio	$V_{CC} = 3V$ to $12V$				0.19	mV/V
		Commercial Grade	●			0.21	mV/V
		Industrial Grade	●			0.23	mV/V
V_{OH}	Output High Voltage	$R_{LOAD} = 100k$ to V_{SS}		$V_{CC} - 0.05$			V/mV
		Commercial Grade	●	$V_{CC} - 0.10$			V/mV
		Industrial Grade	●	$V_{CC} - 0.12$			V/mV
V_{OL}	Output Low Voltage	$R_{LOAD} = 100k$ to V_{SS}			$V_{SS} + 0.05$		V/mV
		Commercial Grade	●		$V_{SS} + 0.10$		V/mV
		Industrial Grade	●		$V_{SS} + 0.12$		V/mV
I_{SOURCE}	Output Source Current		●	0.9	1.8		mA
			●	0.7			mA
I_{SINK}	Output Sink Current		●	1.3	1.8		mA
			●	0.9			mA
e_n	Input Noise Voltage	$f_0 = 0.1Hz$ to $10Hz$			3		μV_{P-P}

ELECTRICAL CHARACTERISTICS $V_{CC} = 3V$, $V_{SS} = 0V$, $T_A = 25^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Power Supply							
V_{CC}	Supply Voltage Range		●	2.5		12.6	V
I_{CC}	Supply Current (Note 1)	Commercial Grade	●		4.5	7.0	μA
		Industrial Grade	●			12	μA
			●			13	μA
Comparator							
V_{OS}	Input Offset Voltage (Note 2)	(SO-8)				1.0	mV
		Commercial Grade (SO-8)	●			1.5	mV
		Industrial Grade (SO-8)	●			2.0	mV
		(MSOP)				1.2	mV
			●			2.0	mV
V_{TRIP}	Trip Point (Note 3)		●	2.00	2.25	2.50	mV
			●	1.00		3.50	mV
I_{IN}	Input Leakage Current (Note 4)		●		0.01	1	nA
V_{CM}	Input Common Mode Range		●	V_{SS}		$V_{CC} - 1.3$	V
PSRR	Power Supply Rejection Ratio	$V_{CC} = 3V$ to 12V				0.25	mV/V
		Commercial Grade	●			0.30	mV/V
		Industrial Grade	●			0.35	mV/V
t_{PD}	Propagation Delay	Overdrive = 10mV			25		μs
		Overdrive = 100mV			12		μs
V_{OH}	Output High Voltage	$I_{OUT} = -2mA$	●	$V_{CC} - 0.2$			V
V_{OL}	Output Low Voltage	$I_{OUT} = 1.8mA$	●			$V_{SS} + 0.3$	V
Reference							
V_{REF}	Reference Voltage	No Load (SO-8)		1.195	1.200	1.205	V
		Commercial Grade (SO-8)	●	1.190		1.210	V
		Industrial Grade (SO-8)	●	1.188		1.212	V
		No Load (MSOP)		1.190	1.200	1.210	V
			●	1.185		1.215	V
ΔV_{REF}	Load Regulation	$I_{SOURCE} = 1mA$	●		2	6	mV
		$I_{SINK} = 10\mu A$	●		0.2	1.5	mV
			●			5	mV
e_n	Voltage Noise	0.1Hz to 10Hz			16		μV_{P-P}
Op Amp							
V_{OS}	Input Offset Voltage	$V_{CM} = 1.5V$ (SO-8)				0.70	mV
		Commercial Grade (SO-8)	●			1.25	mV
		Industrial Grade (SO-8)	●			1.50	mV
		$V_{CM} = 1.5V$ (MSOP)				1.00	mV
			●			1.75	mV
I_B	Input Bias Current	$V_{CM} = 1.5V$	●		0.01	1	nA
A_{VOL}	Large-Signal Gain	AMPOUT = 0.5V to 2.5V, No Load		80.0	1000		V/mV
		AMPOUT = 0.5V to 2.5V, $R_{LOAD} = 100k$		45.5	500		V/mV
		Commercial Grade	●	22.0			V/mV
		Industrial Grade	●	20.0			V/mV
GBW	Gain Bandwidth	$A_V = 1V/V$			12		kHz
SR	Slew Rate	$A_V = 1V/V$			8		V/ms
V_{CM}	Input Common Mode Range		●	V_{SS}		$V_{CC} - 1.3$	V

ELECTRICAL CHARACTERISTICS $V_{CC} = 3V$, $V_{SS} = 0V$, $T_A = 25^\circ C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0.15V$ to $V_{CC} - 1.3V$			0.35	mV/V
		Commercial Grade	●		0.52	mV/V
		Industrial Grade	●		1.30	mV/V
		$V_{CM} = V_{SS}$ to $V_{CC} - 1.3V$		0.3	1.00	mV/V
PSRR	Power Supply Rejection Ratio	$V_{CC} = 3V$ to $12V$			0.19	mV/V
		Commercial Grade	●		0.21	mV/V
		Industrial Grade	●		0.23	mV/V
V_{OH}	Output High Voltage	$R_{LOAD} = 100k$ to V_{SS}			$V_{CC} - 0.05$	V/mV
		Commercial Grade	●		$V_{CC} - 0.10$	V/mV
		Industrial Grade	●		$V_{CC} - 0.12$	V/mV
V_{OL}	Output Low Voltage	$R_{LOAD} = 100k$ to V_{CC}			$V_{CC} + 0.05$	V/mV
		Commercial Grade	●		$V_{CC} + 0.10$	V/mV
		Industrial Grade	●		$V_{CC} + 0.12$	V/mV
I_{SOURCE}	Output Source Current			0.6	0.95	mA
			●	0.4		mA
I_{SINK}	Output Sink Current			1.2	1.8	mA
			●	0.8		mA
e_n	Input Noise Voltage	$f_0 = 0.1Hz$ to $10Hz$		3		μV_{P-P}

The ● denotes specifications which apply over the full operating temperature range.

Note 1: Supply current is tested with $COMPIN^+ = (REF - 100mV)$.

Note 2: Input offset voltage is defined as the center of the input referred hysteresis, $V_{CM} = REF$.

Note 3: Trip point is defined as the differential input voltage required to make the comparator output change state. The difference between upper and lower trip point is equal to the width of the input referred hysteresis, $V_{CM} = REF$.

Note 4: The input leakage current is measured for $COMPIN^+$ at $1.5V$.

PIN FUNCTIONS

AMPOUT (Pin 1): Op Amp Output. The output can swing from rail-to-rail while driving a capacitive load of up to $1000pF$.

AMPIN⁻ (Pin 2): Inverting Input of Op Amp. The input common mode ranges from V_{SS} to $V_{CC} - 1.3V$. The input current is typically $10pA$ at $25^\circ C$.

AMPIN⁺ (Pin 3): Noninverting Input of Op Amp. The input common mode ranges from V_{SS} to $V_{CC} - 1.3V$. The input current is typically $10pA$ at $25^\circ C$.

V_{SS} (Pin 4): Negative Supply or Ground Connection.

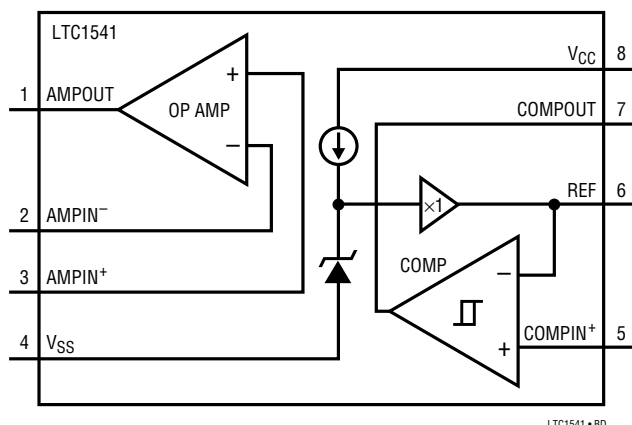
COMPIN⁺ (Pin 5): Noninverting Input of Comparator. The input common mode ranges from V_{SS} to $V_{CC} - 1.3V$. The input current is typically $10pA$ at $25^\circ C$.

REF (Pin 6): Reference Output. $V_{REF} = 1.2V \pm 1\%$ over industrial temperature range, and is also connected to inverting comparator input internally. This device can source up to $2mA$ and sink up to $20\mu A$. The output can drive a bypass capacitor of up to $0.01\mu F$ without oscillation.

COMPOUT (Pin 7): Comparator Output. The output can source $20mA$ and sink $5mA$.

V_{CC} (Pin 8): Positive Supply, $2.5V \leq V_{CC} \leq 12.6V$. The supply bypass capacitors are not required if the supply impedance is low. For single supply applications, it is a good general practice to bypass V_{CC} with a $0.1\mu F$ capacitor to ground.

BLOCK DIAGRAM



APPLICATIONS INFORMATION

The LTC1541 is a combination of a micropower op amp, comparator and $1.2V \pm 1\%$ reference in an 8-pin package. The LTC1541 has the negative input of the comparator internally connected to the reference output. The supply voltage range is from 2.5V to 12.6V for single supply and $\pm 1.25V$ to $\pm 6.3V$ for dual supplies. The supply current is a mere 5 μA (typical) with a 5V single supply.

Op Amp

The op amp is internally compensated to be unity-gain stable, with typical GBW at 12kHz and slew rate of 8V/ms. The output can drive a capacitive load of up to 1000pF and swings from rail-to-rail. The input range is from the negative rail to within 1.3V of the positive rail. The input bias current is less than 1nA maximum at the extended temperature range.

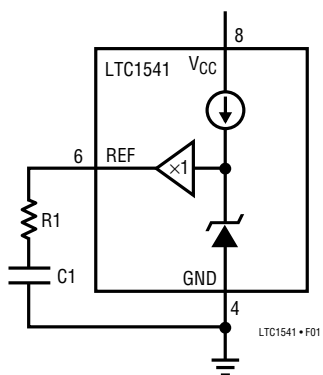


Figure 1. Damping the Reference Output

Comparator

The comparator has a high impedance differential input stage with a common input range from the negative rail to within 1.3V of the positive rail. The CMOS output stage can swing from rail-to-rail and source up to 20mA continuously. The output stage has been designed to eliminate the power supply glitches that normally occur when the output changes logic state. In addition, an internal hysteresis ($\pm 3mV$) ensures clean output switching even with slow moving input signals. The negative input is internally connected to the reference for the LTC1541.

Reference

The internal bandgap reference has an output voltage of $1.2V \pm 1\%$ in the industrial grade temperature range. The output can source up to 2mA and sink up to 20 μA with a 5V supply. The output can drive a bypass capacitor of up to 0.01 μF without oscillation and by inserting a series resistor, capacitance values up to 100 μF can be used (Figure 1). Figure 2 shows the resistor value required for different capacitor values to achieve critical damping. Bypassing the reference can help prevent false tripping of the comparator by preventing glitches on V_{CC} or reference load transients from disturbing the reference output voltage. Figures 3a and 3b show the bypass reference output with a square wave applied to the V_{CC} pin while resistor R1 damps the reference response. Note that the comparator output doesn't trip.

APPLICATIONS INFORMATION

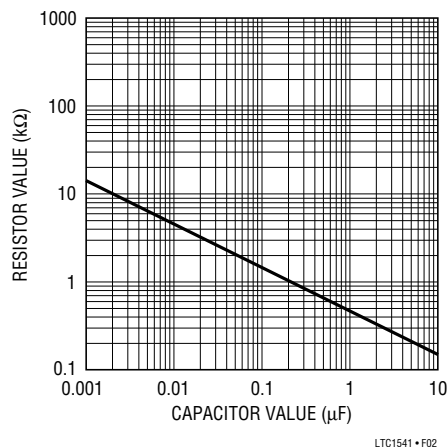


Figure 2. Damping Resistance vs Bypass Capacitor Value

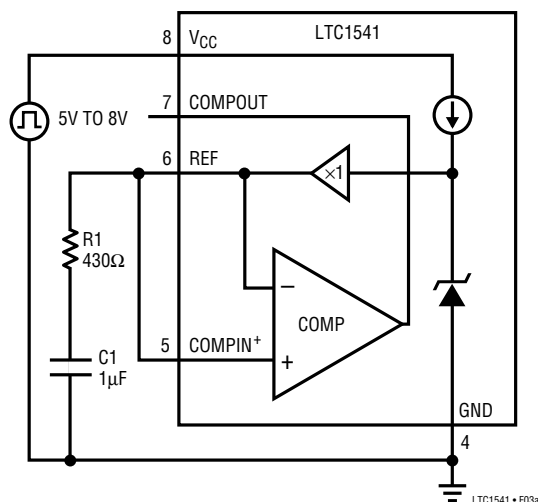


Figure 3a. Reference Transient Response Test Circuit

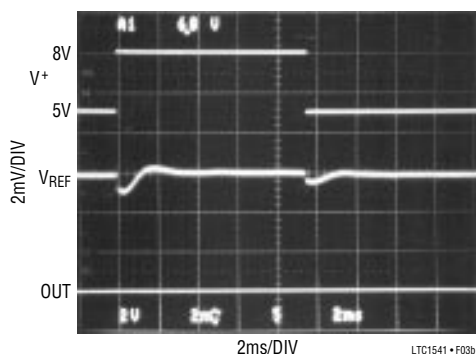


Figure 3b. Reference and Comparator Output Transient Response

Op Amp Stability

Unlike other industry standard micropower CMOS op amps, the op amp in the LTC1541 maintains stability in unity-gain configuration while driving heavy capacitive loads of up to 1000pF.

Although this family is primarily designed for low frequency applications, good layout is extremely important. Low power, high impedance circuits may increase the effects of board leakage and stray capacitance. For example, the combination of a 10M resistance (from leakage between traces on a contaminated, poorly designed PC board) and a 2pF stray capacitance provides a pole at approximately 8kHz, which is near the amplifier's bandwidth. Board routing and layout should minimize leakage and stray capacitance. In some cases, stray capacitance may be unavoidable and it may be necessary to add a small capacitor across the feedback resistor to compensate (Figure 4); select the smallest capacitor value that ensures stability.

Inputs

The input common mode range for both the op amp and comparator is from the negative supply to within 1.3V of the positive supply. The inputs can be taken more than 300mV below the negative supply without damaging the device if the current out of the pin is limited to less than 1mA. Unlike the bipolar input op amp and comparator, the output of the LTC1541 will not reverse phase when the inputs are taken above the common mode input range.

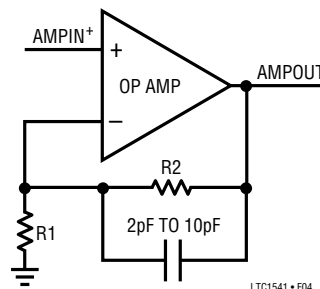
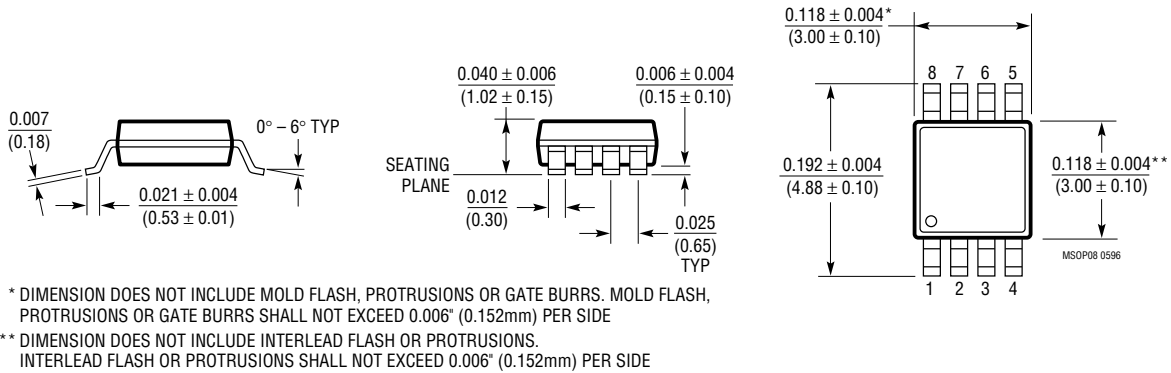


Figure 4. Compensation for Feedback Node Capacitance

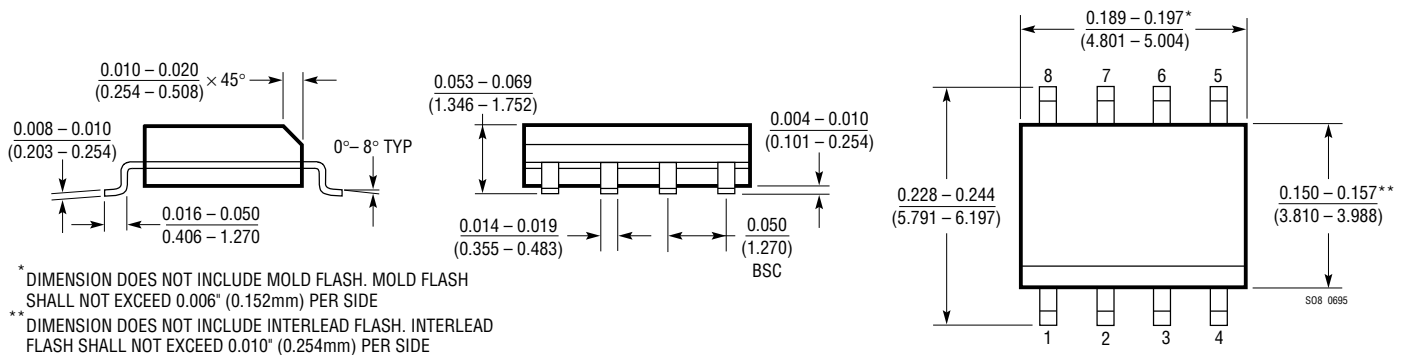
PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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



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

**RELATED PARTS**

PART NUMBER	DESCRIPTION	COMMENTS
LT [®] 1078/LT1079	Dual/Quad Micropower, Single Supply Precision Op Amps	70 μ V, V_{OS} Max and 0.4 μ V/ $^\circ$ C Drift, 200kHz GBW, 0.07V/ μ s Slew Rate, Input/Output Common Mode Includes Ground
LT1178/LT1179	Dual/Quad 17 μ A Max, Single Supply Precision Op Amps	70 μ V, V_{OS} Max and 2.5 μ V/ $^\circ$ C Drift Max, 85kHz GBW, 0.04V/ μ s Slew Rate, Input/Output Common Mode Includes Ground
LT1490/LT1491	Dual/Quad Micropower Rail-to-Rail Input and Output Op Amps	Single Supply Input Range: -0.4V to 44V, Micropower 50 μ A Amplifier, Rail-to-Rail Input and Output, 200kHz GBW
LT1635	Micropower Rail-to-Rail Op Amp and Reference	130 μ A of Supply Current, 1.3mV V_{OS} Max
LT2078/LT2079	Dual/Quad Micropower, Single Supply Precision Op Amps	SO-8 and 14-Lead Standard Pinout, 70 μ V V_{OS} Max, 200kHz GBW
LT2178/LT2179	Dual/Quad 17 μ A Max, Single Supply Precision Op Amps	SO-8 and 14-Lead Standard Pinout, 70 μ V V_{OS} Max, 85kHz GBW