



# 1.4nV/ $\sqrt{\text{Hz}}$ 175MHz Op Amp and Inverter / Filter Building Block

August 2001

## FEATURES

- Single-Ended to Differential Conversion
- Low Noise: 1.4nV/ $\sqrt{\text{Hz}}$
- 20 $\mu\text{V}_{\text{RMS}}$  Total Wideband Noise Filter with 2MHz  $f_c$
- Dynamic Range: 104dB SNR at  $\pm 5\text{V}$
- Supply Voltage 2.7V to 12V Total
- Rail-to-Rail Outputs
- DC Accurate: Op Amp  $V_{\text{OS}}$  1mV (Typ)
- Trimmed Bandwidth for Accurate Filters
- MSOP-8 Surface-Mount Package
- No External Clock Required

## APPLICATIONS

- Low Noise, High Speed Filters to 5MHz
- Cellular Base Stations
- Communication Channel or Roofing Filters
- Antialias or Reconstruction Filtering
- Video Signal Processing
- Single-Ended to Differential Conversion

## DESCRIPTION

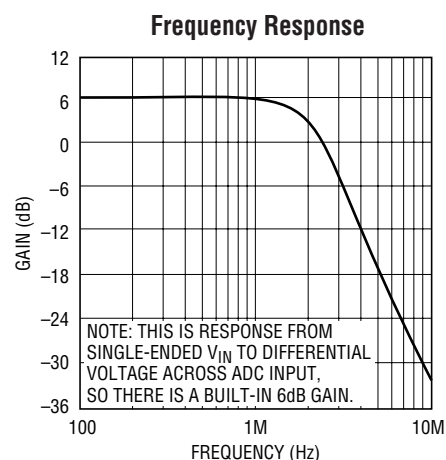
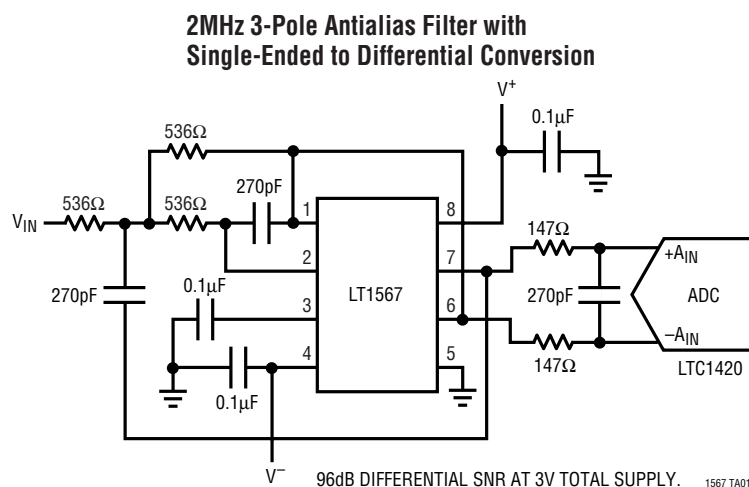
The LT<sup>®</sup>1567 is an analog building block optimized for very low-noise high-frequency filter applications. It contains two wideband operational amplifiers, one of them internally configured as a unity-gain inverter. With the addition of two capacitors, the LT1567 becomes a flexible second-order filter section with cutoff frequency ( $f_c$ ) up to 5MHz, ideal for antialiasing or for channel filtering in high-speed data communications systems.

In addition to low noise and high speed LT1567 features single-ended to differential conversion for direct driving of high speed A/D converters. The LT1567 operates from a total power-supply voltage of 2.7V to 12V and can support signal-to-noise ratios above 100dB.

The LT1567 is available in an 8-lead MSOP package.

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## TYPICAL APPLICATION

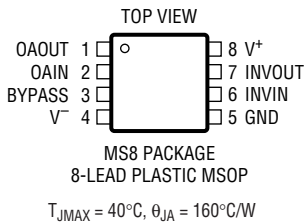


**ABSOLUTE MAXIMUM RATINGS**

(Note 1)

Total Supply Voltage ( $V^+$ to $V^-$ ) .....	12.6V
Input Voltage (Note 2) .....	$\pm V_S$
Input Current (Note 2) .....	$\pm 5\text{mA}$
Operating Temperature Range .....	$0^\circ\text{C}$ to $70^\circ\text{C}$
Storage Temperature Range .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead Temperature (Soldering, 10 sec) .....	$300^\circ\text{C}$

**PACKAGE/ORDER INFORMATION**

 <p>TOP VIEW</p> <p>OAOUT 1 8 <math>V^+</math></p> <p>OAIN 2 7 INVOUT</p> <p>BYPASS 3 6 INVIN</p> <p><math>V^-</math> 4 5 GND</p> <p>MS8 PACKAGE 8-LEAD PLASTIC MSOP</p> <p><math>T_{JMAX} = 40^\circ\text{C}</math>, <math>\theta_{JA} = 160^\circ\text{C/W}</math></p>	ORDER PART NUMBER
	LT1567CMS8
	MS8 PART MARKING
	LTWH

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

**ELECTRICAL CHARACTERISTICS**

The ● denotes the specifications that apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = \pm 2.5\text{V}$ ,  $R_L = 1\text{k}$ ,  $V_{OUT} = 0$  both amplifiers unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Total Supply Voltage		2.7		12	V
Supply Current	$V_S = \pm 1.5\text{V}$	●	8.5	15	mA
	$V_S = \pm 2.5\text{V}$	●	9	16	mA
	$V_S = \pm 5\text{V}$	●	11	19	mA
OA Output Positive Voltage Swing	$V_S = \pm 1.5\text{V}$ , $R_L = 1\text{k}$	●	1.30	1.45	V
	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$	●	2.20	2.40	V
	$V_S = \pm 2.5\text{V}$ , $R_L = 100$	●	2.00	2.25	V
	$V_S = \pm 5\text{V}$ , $R_L = 1\text{k}$	●	4.70	4.85	V
OA Output Negative Voltage Swing	$V_S = \pm 1.5\text{V}$ , $R_L = 1\text{k}$	●	-1.30	-1.45	V
	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$	●	-2.20	-2.44	V
	$V_S = \pm 2.5\text{V}$ , $R_L = 100$	●	-2.00	-2.20	V
	$V_S = \pm 5\text{V}$ , $R_L = 1\text{k}$	●	-4.70	-4.90	V
INV Output Positive Voltage Swing	$V_S = \pm 1.5\text{V}$ , $R_L = 1\text{k}$	●	1.30	1.40	V
	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$	●	2.20	2.40	V
	$V_S = \pm 5\text{V}$ , $R_L = 1\text{k}$	●	4.60	4.90	V
INV Output Negative Voltage Swing	$V_S = \pm 1.5\text{V}$ , $R_L = 1\text{k}$	●	-1.30	-1.40	V
	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$	●	-2.20	-2.40	V
	$V_S = \pm 5\text{V}$ , $R_L = 1\text{k}$	●	-4.50	-4.80	V
Common Mode (GND) Input Voltage Range (See Pin Functions)	$V_S = \pm 1.5\text{V}$	●	-0.25	0.25	V
	$V_S = \pm 5\text{V}$	●	-2.5	2.5	V
DC Common Mode Rejection Ratio (CMRR)	$V_S = \pm 1.5\text{V}$ , $V_{CM} = -0.25\text{V}$ to $0.25\text{V}$	●	90		dB
	$V_S = \pm 5\text{V}$ , $V_{CM} = -2.5\text{V}$ to $2.5\text{V}$	●	75	90	dB
DC Power-Supply Rejection Ratio (PSRR)	$V_S = \pm 1.5\text{V}$ to $\pm 5\text{V}$ , $V_{CM} = 0\text{V}$	●	80	100	dB
OA Input Offset Voltage Magnitude		●	1	3	mV
INV Output Offset Voltage Magnitude		●	6	9	mV

**ELECTRICAL CHARACTERISTICS** The ● denotes the specifications that apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = \pm 2.5\text{V}$ ,  $R_L = 1\text{K}$ ,  $V_{OUT} = 0$  both amplifiers unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
OA Input Bias Current		●		3	10	$\mu\text{A}$
GND Input Bias Current		●		6	15	$\mu\text{A}$
OA DC Open-Loop Gain	$V_S = \pm 1.5\text{V}$ , $R_L = 1\text{k}$ , $V_O = -1\text{V}$ to $1\text{V}$	●	7.5	23		$\text{V/mV}$
	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$ , $V_O = -2\text{V}$ to $2\text{V}$	●	10	35		$\text{V/mV}$
	$V_S = \pm 2.5\text{V}$ , $R_L = 100$ , $V_O = -1.5\text{V}$ to $1.5\text{V}$	●	1.2	4.0		$\text{V/mV}$
	$V_S = \pm 5\text{V}$ , $R_L = 1\text{k}$ , $V_O = -4\text{V}$ to $4\text{V}$	●	15	40		$\text{V/mV}$
INV DC Gain Magnitude	$V_S = \pm 1.5\text{V}$ , $R_L = 1\text{k}$ , $V_{IN} = -1\text{V}$ to $1\text{V}$	●	0.97		1.04	$\text{V/V}$
	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$ , $V_{IN} = -2\text{V}$ to $2\text{V}$	●	0.97		1.04	$\text{V/V}$
	$V_S = \pm 2.5\text{V}$ , $R_L = 100$ , $V_{IN} = -1.5\text{V}$ to $1.5\text{V}$	●	0.97		1.04	$\text{V/V}$
	$V_S = \pm 5\text{V}$ , $R_L = 1\text{k}$ , $V_{IN} = -4\text{V}$ to $4\text{V}$	●	0.97		1.04	$\text{V/V}$
INV DC Input Resistance	$V_S = \pm 2.5\text{V}$ , $R_L = 1\text{k}$ , $V_{IN} = -2\text{V}$ to $2\text{V}$	●	450	600	750	$\Omega$
OA Gain-Bandwidth Product	Measured at $2\text{MHz}$ , $V_S = \pm 1.5\text{V}$	●	100	160		$\text{MHz}$
	Measured at $2\text{MHz}$ , $V_S = \pm 2.5\text{V}$	●	110	175		$\text{MHz}$
	Measured at $2\text{MHz}$ , $V_S = \pm 5\text{V}$	●	120	190		$\text{MHz}$
INV AC Gain Magnitude	Measured at $2\text{MHz}$	●	0.96	1.0	1.05	$\text{V/V}$
OA Slew Rate Magnitude				49		$\text{V}/\mu\text{sec}$
OA Input Voltage Noise Density	$f = 100\text{kHz}$			1.4		$\text{nV}/\sqrt{\text{Hz}}$
OA Input Current Noise Density	$f = 100\text{kHz}$			1.0		$\text{pA}/\sqrt{\text{Hz}}$
Wideband Output Noise for a Second-Order Filter (Figure 1)	$f_C = 2\text{MHz}$ , $\text{BW} = 4\text{MHz}$			20		$\mu\text{V}_{\text{RMS}}$
	$f_C = 5\text{MHz}$ , $\text{BW} = 10\text{MHz}$			30		$\mu\text{V}_{\text{RMS}}$
Total Harmonic Distortion (THD) for a Second-Order Filter (Figure 1)	$f = 1\text{MHz}$ , $f_C = 2\text{MHz}$ , $V_{OUT} = 1\text{V}_{\text{RMS}}$			-88		$\text{dB}$
	$f = 2.5\text{MHz}$ , $f_C = 5\text{MHz}$ , $V_{OUT} = 1\text{V}_{\text{RMS}}$			-70		$\text{dB}$
Output Short-Circuit Current (Either Output)				35		$\text{mA}$
Output Impedance	$f = 100\text{kHz}$ , OA Connected as Unity-Gain Inverter			0.1		$\Omega$

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

**Note 2:** The inputs of each op amp are protected by back-to-back diodes. If either differential input voltage exceeds  $1.4\text{V}$ , the input current should be limited to less than  $5\text{mA}$ .

## PIN FUNCTIONS

**OAOUT (Pin 1):** Output of the Uncommitted Op Amp (OA). As with most wideband op amps, it is important to avoid connecting heavy capacitive loads (above about 10pF) directly to this output. Such loads, exhibiting low impedance (circa 100Ω) at the op amp's unity-gain crossover frequency (circa 100MHz), will impair AC stability.

**OAIN (Pin 2):** Inverting or “–” Input of the Uncommitted Op Amp (OA) in the LT1567. The noninverting or “+” input of this amplifier is shared with that of the INV amplifier and accessed via the GND and BYPASS pins. The OA amplifier is optimized for minimal wideband noise.

**BYPASS (Pin 3):** AC Ground Bypass. Designed for a decoupling capacitor, typically 0.1μF, to a printed circuit ground plane using the shortest possible wiring. Use GND for DC connection of the amplifier noninverting inputs as described in the GND (Pin 5) description.

**Power Supply Pins (Pins 4, 8):** The V<sup>–</sup> and V<sup>+</sup> pins should be bypassed with 0.1μF capacitors to an adequate analog ground plane using the shortest possible wiring. Electrically clean supplies and a low impedance ground are important for the high dynamic range and bandwidth available from the LT1567. Low noise linear power supplies are recommended. Switching supplies are not recommended because of the inevitable risk of their switching noise coupling into the signal path, reducing dynamic range.

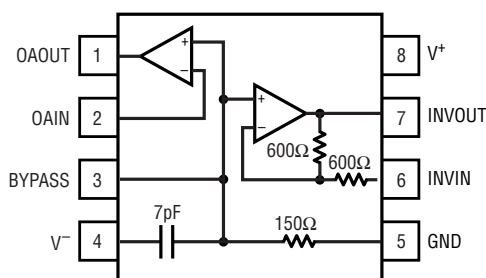
**GND (Pin 5):** DC Ground Input. Sets the noninverting inputs for the two internal amplifiers; designed for use as a DC reference, not a signal input. The GND input includes a small series resistor, both to balance DC offsets in the presence of input bias currents and also to suppress the “Q” factor of possible parasitic high-frequency resonant circuits introduced by wiring inductance. The on-chip ground reference at the noninverting inputs of the two amplifiers is decoupled for very high frequencies with a small internal capacitor to the chip substrate, nominally 7pF. An external capacitor, typically 0.1μF, to a nearby ground plane should be added at the BYPASS pin for a clean wideband ground reference.

**INVIN (Pin 6):** Unity-Gain Inverter Input. The “inverter” (INV) amplifier in the LT1567 is connected to internal resistors (nominally 600Ω each) to form a closed-loop amplifier with a wideband voltage gain of nominally –1. The amplifier in this position is similar to the uncommitted op amp (OA) but is optimized for high frequency linearity.

**INVOUT (Pin 7):** Output of the INV or “Inverter” Amplifier, with a Nominal Gain of –1 from the INVIN Pin. As with most wideband op amps, it is important to avoid connecting heavy capacitive loads (above about 10pF) directly to this output. Such loads, exhibiting low impedance (circa 100 ohms) at the op amp's unity-gain crossover frequency (circa 100MHz), will impair AC stability.

## BLOCK DIAGRAM

Block Diagram with Top View of Pins



## APPLICATIONS INFORMATION

### Functional Description

The LT1567 contains two low-noise wideband operational amplifiers, one of them connected internally as a unity-gain inverter. These two amplifiers can form a second-order multiple-feedback filter configuration (Figure 1) for megahertz signal frequencies, with exceptionally low total noise. The amplifier in the dedicated inverter (INV) is optimized for better high frequency linearity while the uncommitted operational amplifier (OA) is optimized for lower input noise voltage, according to the different sensitivities to these effects in the filter section. This combination produces a low-noise filter with better distortion performance than would be possible with identical amplifiers.

### Signal Ground

Both operational amplifiers within the LT1567 are designed for inverting operation (constant common mode input) and they share a single ground reference node on the chip. Two pins permit access to this node: GND and BYPASS. For a clean on-chip ground reference over a wide bandwidth, the normal procedure is to connect GND to a DC ground potential and BYPASS to a decoupling capacitor that returns to a ground plane.

### Differential Output Feature

The multiple-feedback filter section of Figure 1 inherently includes two outputs of opposite signal polarity: a DC-inverting output from the OA (Pin 1) and a DC noninverting output from the INV block (Pin 7). These two outputs maintain equal gain and 180° phase shift over a wide frequency range. This feature permits choosing the signal polarity in single-ended applications, and also performs single-ended-to-differential conversion. The latter property is useful in an antialias filter to drive standard monolithic A/D converters having differential inputs, as illustrated on page 1.

### Dealing with High Source Impedances

The voltage  $V_{IN}$  in Figure 1, on the left side of R1, is the signal voltage that the filter sees. If a voltage source with significant internal impedance drives the  $V_{IN}$  node in Figure 1, then the filter input  $V_{IN}$  may differ from the source's open-circuit output, and the difference can be complex, because the filter presents a complex impedance to  $V_{IN}$ . A rule of thumb is that a source impedance is negligibly "low" if it is much smaller than R1 at frequencies of interest. Otherwise, the source impedance (resistive or reactive) effectively adds to R1 and may change the signal frequency response compared to that with a low source impedance. If the source is resistive and predictable, then it may be possible to design for it by reducing R1. Unpredictable or nonresistive source impedances that are not well below R1 should be buffered.

### Construction and Instrumentation Cautions

Electrically clean construction is important in applications seeking the full dynamic range and bandwidth of the LT1567. Using the shortest possible wiring or printed-circuit paths will minimize parasitic capacitance and inductance. High quality supply bypass capacitors of 0.1  $\mu$ F near the chip, connected to a ground plane, provide good decoupling from a clean, low inductance power source. But several inches of wire (i.e., a few microhenrys of inductance) from the power supplies, unless decoupled by substantial capacitance ( $\geq 10 \mu$ F) near the chip, can cause a high Q LC resonance in the hundreds of kHz in the chip's supplies or ground reference. This may impair filter performance at those frequencies. In stringent filter applications we have often found that a compact, carefully laid out printed circuit board with good ground plane makes a difference in both stopband rejection and distortion. Finally, equipment to measure filter performance can itself introduce distortion or noise floors. Checking for these limits with a wire replacing the filter is a prudent routine procedure.

## APPLICATIONS INFORMATION

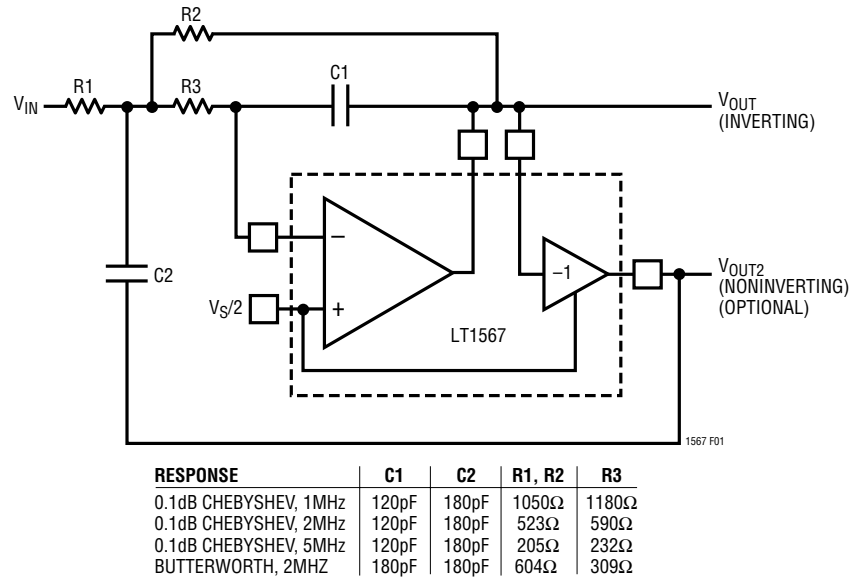
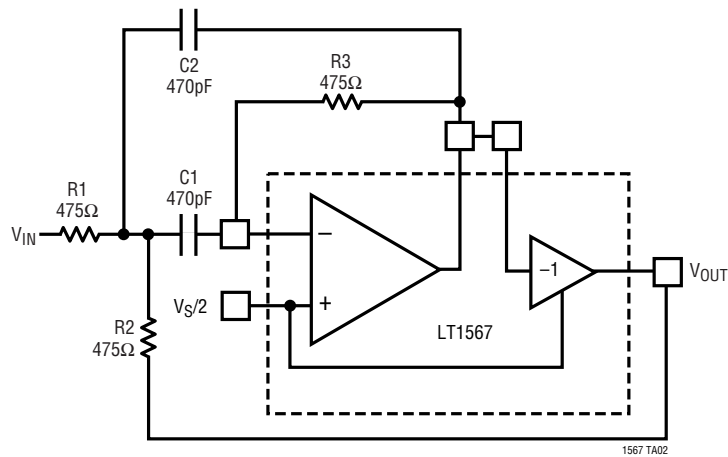


Figure 1. Basic 2nd-Order Lowpass Section Using One LT1567

## TYPICAL APPLICATION

### 2nd Order Bandpass Filter $f_{\text{CENTER}} = 1\text{MHz}$ , $-3\text{dB BW} = 0.707\text{MHz}$

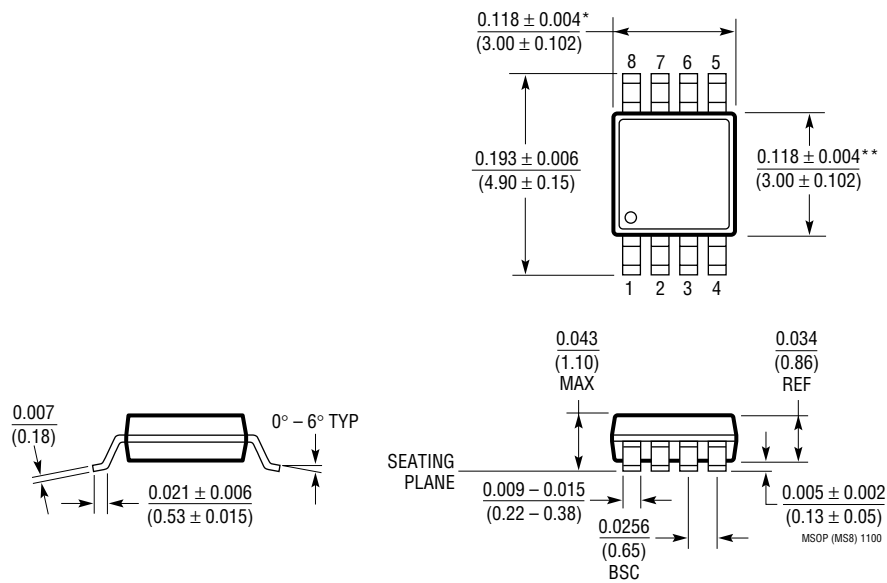


$$\text{IF } R2 = R3 = R \text{ AND } C1 = C2 = C, f_{\text{CENTER}} = \frac{\sqrt{(R/R1) + 1}}{2\pi RC}, -3\text{dB BW} = \frac{f_{\text{CENTER}}}{\sqrt{(R/R1) + 1}}$$

GAIN AT  $f_{\text{CENTER}} = R/R1$ , MAXIMUM  $f_{\text{CENTER}}$  IS  $\frac{5\text{MHz}}{\text{GAIN}}$

# PACKAGE DESCRIPTION

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

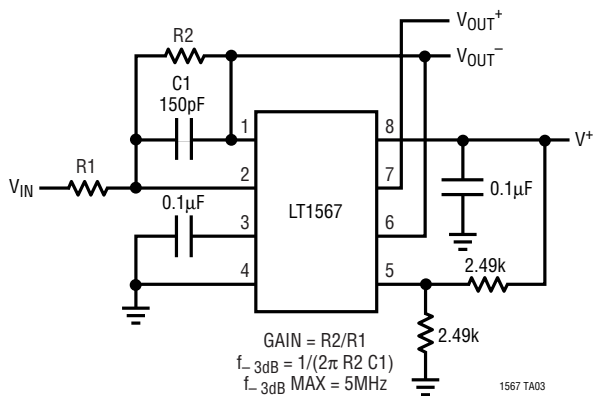


\* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

TYPICAL APPLICATION

Single Supply Single-Ended to Differential  
First Order Lowpass Filter with Gain



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1565-31	Differential 650kHz Lowpass Filter	For CDMA Base Stations
LTC1566-1	Differential 2.3MHz Lowpass Filter	For WCDMA Base Stations
LTC1564	10kHz to 150kHz Digitally Controlled Filter and 4-Bit PGA	Continuous Time Low Noise 8th Order Filter and PGA