LTC1051/LTC1053
Dual/Quad Precision Zero-Drift Operational Amplifiers With Internal Capacitors

FEATURES

- Dual/Quad Low Cost Precision Op Amp
- No External Components Required
- Maximum Offset Voltage: 5µV
- Maximum Offset Voltage Drift: 0.05µV/°C
- Low Noise 1.5µVp-p (0.1Hz to 10Hz)
- Minimum Voltage Gain: 120dB
- Minimum PSRR: 120dB
- Minimum CMRR: 114dB
- Low Supply Current: 1mA/Op Amp
- Single Supply Operation: 4.75V to 16V
- Input Common Mode Range Includes Ground
- Output Swings to Ground
- Typical Overload Recovery Time: 3ms
- Pin Compatible with Industry Standard Dual and Quad Op Amps

APPLICATIONS

- Thermocouple Amplifiers
- Electronic Scales
- Medical Instrumentation
- Strain Gauge Amplifiers
- High Resolution Data Acquisition
- DC Accurate R C Active Filters

DESCRIPTION

The LTC®-1051/LTC1053 are high performance, low cost dual/quad zero-drift operational amplifiers. The unique achievement of the LTC1051/LTC1053 is that they integrate on chip the sample-and-hold capacitors usually required externally by other chopper amplifiers. Further, the LTC1051/LTC1053 offer better combined overall DC and AC performance than is available from other chopper stabilized amplifiers with or without internal sample/hold capacitors.

The LTC1051/LTC1053 have an offset voltage of 0.5µV, drift of 0.01µV/°C, DC to 10Hz, input noise voltage typically 1.5µVp-p and typical voltage gain of 140dB. The slew rate of 4V/µs and gain bandwidth product of 2.5MHz are achieved with only 1mA of supply current per op amp.

Overload recover times from positive and negative saturation conditions are 1.5ms and 3ms respectively, about 100 or more times improvement over chopper amplifiers using external capacitors.

The LTC1051 is available in an 8-lead standard plastic dual-in-line package as well as a 16-pin SW package. The LTC1053 is available in a standard 14-pin plastic package and an 18-pin SO. The LTC1051/LTC1053 are plug in replacements for most standard dual/quad op amps with improved performance.

TYPICAL APPLICATION

High Performance Low Cost Instrumentation Amplifier

![High Performance Low Cost Instrumentation Amplifier Diagram]

R1 = 499Ω, 0.1%
R2 = 100k, 0.1%
GAIN = 201
MEASURED CMRR ~ 120dB AT DC
MEASURED INPUT VOS ~ 3µV
MEASURED INPUT NOISE 2µVp-p (DC – 10Hz)

LTC1051 Noise Spectrum

![LTC1051 Noise Spectrum Graph]
LTC1051/LTC1053

**ABSOLUTE MAXIMUM RATINGS**

Total Supply Voltage (V+ to V−) ................. 16.5V
Input Voltage ........................ (V+ + 0.3V) to (V− – 0.3V)
Output Short-Circuit Duration ..................... Indefinite

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

**OPERATING TEMPERATURE RANGE**

LTC1051M, LTC1051AM (OBSOLETE) ............... –55°C to 125°C
LTC1051C/LTC1053C ............................... –40°C to 85°C
Storage Temperature Range ..................... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ............... 300°C

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**PACKAGE/ORDER INFORMATION**

<table>
<thead>
<tr>
<th>ORDER PART NUMBER</th>
<th>TOP VIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC1051CN8</td>
<td><img src="image1" alt="N8 PACKAGE 8-LEAD PDIP" /></td>
</tr>
<tr>
<td>LTC1051M8</td>
<td><img src="image2" alt="J8 PACKAGE 8-LEAD CERDIP" /></td>
</tr>
<tr>
<td>LTC1051C8/LTC1053C8</td>
<td><img src="image3" alt="SW PACKAGE 16-LEAD PLASTIC SO" /></td>
</tr>
<tr>
<td>LTC1051AM8/LTC1053AM8</td>
<td><img src="image4" alt="SW PACKAGE 18-LEAD PLASTIC SO" /></td>
</tr>
</tbody>
</table>

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

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**ELECTRICAL CHARACTERISTICS**

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at TA = 25°C. VS = ±5V unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LTC1051/LTC1053</th>
<th>LTC1051A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MIN</td>
<td>TYP</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td></td>
<td>±0.5</td>
<td>±5</td>
</tr>
<tr>
<td>Average Input Offset Drift</td>
<td>●</td>
<td>±0.0</td>
<td>±0.05</td>
</tr>
<tr>
<td>Long Term Offset Drift</td>
<td></td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>LTC1051C/LTC1053C</td>
<td>±15</td>
<td>±65</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>(All Grades)</td>
<td>±30</td>
<td>±125</td>
</tr>
<tr>
<td>Input Noise Voltage (Note 2)</td>
<td></td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

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

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For a more detailed view of the specifications, including particular grades and temperature ranges, please refer to the full datasheet or consult LTC Marketing.
# LTC1051/LTC1053

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ C$. $V_S = \pm 5V$ unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LTC1051/LTC1053</th>
<th>LTC1051A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
</tr>
<tr>
<td>Input Noise Current</td>
<td>$f = 10Hz$</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Common Mode Rejection Ratio, CMRR</td>
<td>$V_{CM} = V^–$ to 2.7V</td>
<td>●</td>
<td>106</td>
</tr>
<tr>
<td>Differential CMRR</td>
<td>●</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Power Supply Rejection Ratio</td>
<td>$V_S = \pm 2.375V$ to $\pm 8V$</td>
<td>●</td>
<td>116</td>
</tr>
<tr>
<td>Large Signal Voltage Gain</td>
<td>$R_L = 10k, V_{OUT} = \pm 4V$</td>
<td>●</td>
<td>116</td>
</tr>
<tr>
<td>Maximum Output Voltage Swing</td>
<td>●</td>
<td>$\pm 4.5$</td>
<td>$\pm 4.85$</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>$R_L = 10k, C_L = 50pF$</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Gain Bandwidth Product</td>
<td>2.5</td>
<td>2.5</td>
<td>MHz</td>
</tr>
<tr>
<td>Supply Current/Op Amp</td>
<td>No Load</td>
<td>●</td>
<td>1</td>
</tr>
<tr>
<td>Internal Sampling Frequency</td>
<td>3.3</td>
<td>3.3</td>
<td>kHz</td>
</tr>
</tbody>
</table>

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ C$. $V_S = \pm 5V$ unless otherwise noted. $V_S = 5V$, GND unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LTC1051A/LTC1051/LTC1053</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>±0.5</td>
<td>±5</td>
<td>μV</td>
</tr>
<tr>
<td>Input Offset Drift</td>
<td>±0.01</td>
<td>±0.05</td>
<td>μV/°C</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>±10</td>
<td>±50</td>
<td>pA</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>±20</td>
<td>±80</td>
<td>pA</td>
</tr>
<tr>
<td>Input Noise Voltage</td>
<td>DC to 10Hz</td>
<td>1.8</td>
<td>μVP-P</td>
</tr>
<tr>
<td>Supply Current/Op Amp</td>
<td>No Load</td>
<td>●</td>
<td>1.5</td>
</tr>
</tbody>
</table>

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

Note 2: For guaranteed noise specification contact LTC Marketing.

Note 3: Differential CMRR for the LTC1053 is measured between amplifiers A and D, and amplifiers B and C.
**TYPICAL PERFORMANCE CHARACTERISTICS**

**Overload Recovery**

\[ A_V = -100 \]
\[ V_S = \pm 5V \]

**Small Signal Transient Response**

\[ A_V = 1, \ R_L = 10k, \ C_L = 100pF \]
\[ V_S = \pm 5V, \ T_A = 25^\circ C \]

**Large Signal Transient Response**

\[ A_V = 1, \ R_L = 10k, \ C_L = 100pF \]
\[ V_S = \pm 5V, \ T_A = 25^\circ C \]

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**LTC1051/LTC1053 DC to 10Hz Noise**

\[ V_S = \pm 5V \]
\[ T_A = 25^\circ C \]

\[ 1.4_{\mu}V_{P-P} \]

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**TEST CIRCUITS**

**Electrical Characteristics Test Circuit**

**DC 10Hz Noise Test Circuit**

FOR 1Hz NOISE BW INCREASE ALL THE CAPACITORS BY A FACTOR OF 10.
ACHIEVING PICOAMPERE/MICROVOLT PERFORMANCE

**Picoamperes**

In order to realize the picoampere level of accuracy of the LTC1051/LTC1053, proper care must be exercised. Leakage currents in circuitry external to the amplifier can significantly degrade performance. High quality insulation should be used (e.g., Teflon, Kel-F); cleaning of all insulating surfaces to remove fluxes and other residues will probably be necessary—particularly for high temperature performance. Surface coating may be necessary to provide a moisture barrier in high humidity environments.

Board leakage can be minimized by encircling the input connections with a guard ring operated at a potential close to that of the inputs: in inverting configurations, the guard ring should be tied to ground; in noninverting connections, to the inverting input. Guarding both sides of the printed circuit board is required. Bulk leakage reduction depends on the guard ring width.

**Microvolts**

Thermocouple effects must be considered if the LTC1051/LTC1053’s ultra low drift op amps are to be fully utilized. Any connection of dissimilar metals forms a thermoelectric junction producing an electric potential which varies with temperature (Seebeck effect.) As temperature sensors, thermocouples exploit this phenomenon to produce useful information. In low drift amplifier circuits, this effect is a primary source of error.

Connectors, switches, relay contacts, sockets, resistors, solder, and even copper wire are all candidates for thermal EMF generation. Junctions of copper wire from different manufacturers can generate thermal EMFs of 200nV/°C—4 times the maximum drift specification of the LTC1051/LTC1053. The copper/kovar junction, formed when wire or printed circuit traces contact a package lead, has a thermal EMF of approximately 35µV/°C—700 times the maximum drift specification of the LTC1051/LTC1053.

Minimizing thermal EMF-induced errors is possible if judicious attention is given to circuit board layout and component selection. It is good practice to minimize the number of junctions in the amplifier’s input signal path. Avoid connectors, sockets, switches and relays where possible. In instances where this is not possible, attempt to balance the number and type of junctions so that differential cancellation occurs. Doing this may involve deliberately introducing junctions to offset unavoidable junctions.

When connectors, switches, relays and/or sockets are necessary, they should be selected for low thermal EMF activity. The same techniques of thermally balancing and coupling the matching junctions are effective in reducing the thermal EMF errors of these components.

Resistors are another source of thermal EMF errors. Table 1 shows the thermal EMF generated for different resistors. The temperature gradient across the resistor is important, not the ambient temperature. There are two junctions formed at each end of the resistor and if these junctions are at the same temperature, their thermal EMFs will cancel each other. The thermal EMF numbers are approximate and vary with resistor value. High values give higher thermal EMF.

**Table 1. Resistor Thermal EMF**

<table>
<thead>
<tr>
<th>RESISTOR TYPE</th>
<th>THERMAL EMF/°C GRADIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tin Oxide</td>
<td>~mV/°C</td>
</tr>
<tr>
<td>Carbon Composition</td>
<td>~450µV/°C</td>
</tr>
<tr>
<td>Metal Film</td>
<td>~20µV/°C</td>
</tr>
<tr>
<td>Wire Wound</td>
<td>~2µV/°C</td>
</tr>
<tr>
<td>Evenohm</td>
<td>~2µV/°C</td>
</tr>
<tr>
<td>Manganin</td>
<td>~2µV/°C</td>
</tr>
</tbody>
</table>

**Input Bias Current, Clock Feedthrough**

At ambient temperatures below 60°C, the input bias current of the LTC1051/LTC1053 op amps’ is dominated by the small amount of charge injection occurring during the sampling and holding of the op amps’ input offset voltage. The average value of the resulting current pulses is 10pA to 15pA with sign convention shown in Figure 1.

![Figure 1. LTC1051 Bias Current](image-url)
As the ambient temperature rises, the leakage current of the input protection devices increases, while the charge injection component of the bias current, for all practical purposes, stays constant. At elevated temperatures (above 85°C) the leakage current dominates and the bias current of both inputs assumes the same sign.

The charge injection at the op amp input pins will cause small output spikes. This phenomenon is often referred to as “clock feedthrough” and can be easily observed when the closed-loop gain exceeds 10V/V (Figure 2). The magnitude of the clock feedthrough is temperature independent but it increases when the closed-loop gain goes up, when the source resistance increases and when the gain setting resistors increase (Figure 2a, 2b). It is important to note that the output small spikes are centered at 0V level and do not add to the output offset error budget. For instance, with $R_S = 1\, \text{M}\Omega$, the typical output offset voltage of Figure 2c is:

$$V_{OS(OUT)} = 10^8 \cdot I_B + 101V_{OS(IN)}$$

A 10pA bias current will yield an output of 1mV ±100μV. The output clock feedthrough can be attenuated by lowering the value of the gain setting resistors, i.e. $R_2 = 10k$, $R_1 = 100\Omega$, instead of 100k and 1k (Figure 2).

Clock feedthrough can also be attenuated by adding a capacitor across the feedback resistor to limit the circuit bandwidth below the internal sampling frequency (Figure 3).

### Input Capacitance

The input capacitance of the LTC1051/LTC1053 op amps is approximately 12pF. When the LTC1051/LTC1053 op amps are used with feedback factors approaching unity, the feedback resistor value should not exceed 7k for industrial temperature range and 5k for military temperature range. If a higher feedback resistor value is required, a feedback capacitor of 20pF should be placed across the feedback resistor. Note that the most common circuits with feedback factors approaching unity are unity gain followers and instrumentation amplifier front ends (See Figure 4.)
LTC1051/LTC1053

APPLICATIONS INFORMATION

LTC1051/LTC1053 as AC Amplifiers

Although initially chopper stabilized op amps were designed to minimize DC offsets and offset drifts, the LTC1051/LTC1053 family, on top of its outstanding DC characteristics, presents efficient AC performance. For instance, at single 5V supply, each op amp typically consumes 0.5mA and still provides 1.8MHz gain bandwidth product and 3V/µs slew rate. This, combined with almost distortionless swing to the supply rails (Figure 8), makes the LTC1051/LTC1053 op amps nearly general purpose. To further expand this idea (the “aliasing” phenomenon) which can occur under AC conditions, should be described and properly evaluated.

Aliasing

The LTC1051/LTC1053 are equipped with internal circuitry to minimize aliasing. Aliasing, no matter how small, occurs when the input signal approaches and exceeds the internal sampling rate. Aliasing is caused by the sampled data nature of the chopper op amps. A generalized study of this phenomenon is beyond the scope of a data sheet; however, a set of rules of thumb can answer many questions:

1. Alias signals can be generally defined as output AC signals at a frequency of \( nf_{CLK} \pm mf_{IN} \). The \( nf_{CLK} \) term is the internal sampling frequency of the chopper stabilized op amps and its harmonics; \( mf_{IN} \) is the frequency of the input signal and its harmonics, if any.

Figure 5a. Output Voltage Spectrum of 1/2 LTC1051 Operating as an Inverting Amplifier with Gain of 10, and Amplifying a 750Hz/800mV, Input AC Signal

Figure 5b. Same as Figure 5a, but the AC Input Signal is 900mV, 10kHz
2. If we arbitrarily accept that “aliasing” occurs when output alias signals reach an amplitude of 0.01% or more of the output signal, then: the approximate minimum frequency of an AC input signal which will cause aliasing is equal to the internal clock frequency multiplied by the square root of the op amp feedback factor. For instance, with closed-loop gain of –10, the feedback factor is 1/11 and if $f_{CLK} = 2.6\text{kHz}$, alias signals can be detected when the frequency of the input signal exceeds 750Hz to 800Hz (Figure 5a).

3. The number of alias signals increases when the input signal frequency increases (Figure 5b).

4. When the frequency, $f_{IN}$, of the input signal is less than $f_{CLK}$, the alias signal(s) amplitude(s) directly scale with the amplitude of the incoming signal. The output “signal to alias ratio” cannot be increased by just boosting the input signal amplitude. However, when the input AC signal frequency well exceeds the clock frequency, the amplitude of the alias signals does not directly scale with the input amplitude. The “signal to alias ratio” increases when the output swings closely to the rails. (See Figure 5b and Figure 7.) It is important to note that the LTC1051/LTC1053 op amps, under light loads ($R_L \geq 10k$), swing closely to the supply rails without generating harmonic distortion (Figure 8).
LTC1051/LTC1053

APPLICATIONS INFORMATION

5. For unity-gain inverting configuration, all the alias frequencies are 80dB to 84dB down from the output signal (Figures 6a, 6b). Combined with excellent THD under wide swing, the LTC1051/LTC1053 op amps make efficient unity gain inverters.

For gain higher than –1, the “signal to alias” ratio decreases at an approximate rate of –6dB per decade of closed-loop gain (Figure 9).

6. For closed-loop gains of –10 or higher, the “signal to alias” ratio degrades when the value of the feedback gain setting resistor increases beyond 50k. For instance, the 68dB value of Figure 7 decreases to 56dB if a (1k, 100k) resistor set is used to set the gain of –100.

7. When the LTC1051/LTC1053 are used as noninverting amplifiers, all the previous approximate rules of thumb apply with the following exceptions: when the closed-loop gain is 10(V/V) and below, the “signal to alias” ratio is 1dB to 3dB less than the inverting case; when the closed-loop gain is 100(V/V), the degradation can be up to 9dB, especially when the input signal is much higher than the clock frequency (i.e. f_{IN} = 10kHz).

8. The signal/alias ratio performance improves when the op amp has bandlimited loop gain.

Figure 7. Output Voltage Spectrum of 1/2 LTC1051 Operating as an Inverting Amplifier with a Gain of –100 and Amplifying a 90mVP-P, 10kHz Input Signal. With a 9VP-P Output Swing the Measured 2nd Harmonic (20kHz) was 75 Down from the 10kHz Input Signal

Figure 8. Output Voltage Swing vs Load

Figure 9. Signal to Alias Ratio vs Closed-Loop Gain
The dual chopper op amp buffers the inputs of A1 and corrects its offset voltage and offset voltage drift. With the R, C values shown, the power-up warm up time is typically 20 seconds. The step response of the composite amplifier does not present settling tails. The LT1007 should be used when extremely low noise; $V_{OS}$ and $V_{OS}$ drift are sought when the input source resistance is low—for instance a 350Ω strain gauge bridge. The LT1012 or equivalent should be used when low bias current (100pA) is also required in conjunction with DC to 10Hz low noise and low $V_{OS}$ and $V_{OS}$ drift. The measured typical input offset voltages were less than 2µV.

<table>
<thead>
<tr>
<th>A1</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>C1</th>
<th>C2</th>
<th>$e_{OUT}(DC – 1Hz)^{**}$</th>
<th>$e_{OUT}(DC – 10Hz)^{**}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT1007</td>
<td>3k</td>
<td>2k</td>
<td>340k</td>
<td>10k</td>
<td>100k</td>
<td>0.01µF</td>
<td>0.001µF</td>
<td>0.1µV&lt;sub&gt;P-P&lt;/sub&gt;</td>
<td>0.15µV&lt;sub&gt;P-P&lt;/sub&gt;</td>
</tr>
<tr>
<td>LT1012*</td>
<td>750Ω</td>
<td>57Ω</td>
<td>250k</td>
<td>10k</td>
<td>100k</td>
<td>0.01µF</td>
<td>0.001µF</td>
<td>0.3µV&lt;sub&gt;P-P&lt;/sub&gt;</td>
<td>0.4µV&lt;sub&gt;P-P&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

* Interchange connections (3) and (5).

** Noise measured in a 10 sec window. Peak-to-peak noise was also measured for 10 continuous minutes: With the LT1007 op amp the recorded noise was less than 0.2µV<sub>P-P</sub> for both DC-1Hz and DC-10Hz.
Typical Applications

Paralleling Choppers to Improve Noise

NOTE: This circuit can also be used as a difference amplifier for strain gauges. Connect R2/3 and R1/3 from noninverting inputs, shorted together, to ground and to source respectively.

\[ V_{\text{OUT}} = V_{\text{IN}} \times \frac{R2}{R1}; \text{INPUT DC – 10Hz NOISE} = 0.8 \mu \text{Vp-p} = \text{NOISE OF EACH PARALLELED OP AMP}/\sqrt{3} \]

Differential Voltage to Current Converter

\[ I_{\text{OUT}} = \frac{2(V2 - V1)}{R_G} \]

\[ \text{BW} = 100Hz \]

\[ I_{\text{OUT MAX}} = 1mA \]

Multiplexed Differential Thermometer

All fixed resistors are 1% metal film

Output (Differential Temperature)

Output = TREF – T1 or TREF – T2 (10mV per °C)

Accuracy = ±0.1% from 25°C to 150°C

All fixed resistors are 1% metal film

Output = TREF – T1 or TREF – T2 (10mV per °C)

Accuracy = ±0.1% from 25°C to 150°C

Linear Technology
TYPICAL APPLICATIONS

Six Decade Log Amplifier

Dual Instrumentation Amplifier

Linearized Platinum Signal Conditioner

Q1: TEL LAB TYPE Q81
ADJUST 2M FOR NONLINEARITIES

VIN
1nA < IIN < 1mA

VOUT = LOG VIN – 2V

CMRR > 100dB

Vos ≅ 3 µV

INPUT REFERRED NOISE ≅ 2 µVP-P

0V TO 4V = 0° TO 400° C

± 0.05° C

TRIM SEQUENCE:
SET SENSOR TO 0°C VALUE. ADJUST ZERO FOR 0V OUT
SET SENSOR TO 100°C VALUE. ADJUST GAIN FOR 1.000V OUT
SET SENSOR TO 400°C VALUE. ADJUST LINEARITY FOR 4.000V OUT
REPEAT AS REQUIRED. FOR MORE INFORMATION REFER TO AN3

RP = ROSEMOUNT 118M RTD
1% FILM RESISTOR

1051/53 AC07 (LINEARITY CORRECTION LOOP)
**PACKAGE DESCRIPTION**

### J Package
8-Lead CERDIP (Narrow 0.300, Hermetic)
(LTC DWG # 05-08-1110)

- **Corner Leads Option** (4 PLCS)
  - 0.045 – 0.066
  - (1.143 – 1.650)
- **Half Lead Option**
  - 0.045 – 0.065
  - (1.143 – 1.651)
- **Full Lead Option**
  - 0.014 – 0.026
  - (0.360 – 0.660)
- **Notes:**
  - Lead dimensions apply to solder dip/plate or tin plate leads.

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

- **Notes:**
  - Dimensions are inches.
  - These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010 inch (0.254 mm).

### N Package
14-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)

- **Notes:**
  - Dimensions are inches.
  - These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010 inch (0.254 mm).
SW Package
16-Lead Plastic Small Outline (Wide 0.300)
(LTC DWG # 05-08-1620)

Recommended Solder Pad Layout

NOTE 3

NOTE 4

MIN

MAX

NOTE 1.

1. DIMENSIONS IN INCHES (MILLIMETERS)

2. DRAWING NOT TO SCALE

3. PIN 1 IDENT, NOTCH ON TOP AND CAVITIES ON THE BOTTOM OF PACKAGES ARE THE MANUFACTURING OPTIONS.

4. THE PART MAY BE SUPPLIED WITH OR WITHOUT ANY OF THE OPTIONS.

5. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006” (0.15mm)

RECOMMENDED SOLDER PAD LAYOUT

SW Package
18-Lead Plastic Small Outline (Wide 0.300)
(LTC DWG # 05-08-1620)

Recommended Solder Pad Layout

NOTE 3

NOTE 4

MIN

MAX

NOTE 1.

1. DIMENSIONS IN INCHES (MILLIMETERS)

2. DRAWING NOT TO SCALE

3. PIN 1 IDENT, NOTCH ON TOP AND CAVITIES ON THE BOTTOM OF PACKAGES ARE THE MANUFACTURING OPTIONS.

4. THE PART MAY BE SUPPLIED WITH OR WITHOUT ANY OF THE OPTIONS.

5. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006” (0.15mm)
**TYPICAL APPLICATIONS**

DC Accurate, 3rd Order, 100Hz, Butterworth Antialiasing Filter

DC Accurate, 18-Bit, 4th Order Antialiasing Bessel (Linear Phase), 100Hz, Lowpass Filter

**RELATED PARTS**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC1047</td>
<td>Dual μPower Zero-Drift Op Amp</td>
<td>( I_S = 80\mu A/0p \text{ Amp, 16-Lead SW Package} )</td>
</tr>
<tr>
<td>LTC1049</td>
<td>Low Power Zero-Drift Op Amp</td>
<td>( I_S = 200\mu A, \text{ SO-8 Package} )</td>
</tr>
<tr>
<td>LTC1050</td>
<td>Precision Zero-Drift Op Amp with Internal Capacitors</td>
<td>( V_{OS} (\text{Max}) = 5\mu V, V_{SUPPLY} (\text{Max}) = 16.5V )</td>
</tr>
<tr>
<td>LTC2050/LTC2051/LTC2052</td>
<td>Single/Dual/Quad Zero-Drift Op Amps</td>
<td>SOT-23/MS8/GN16 Packages</td>
</tr>
<tr>
<td>LTC2053</td>
<td>Zero-Drift Instrumentation Amp</td>
<td>Resistor Programmable Gain, R-R</td>
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