Quad Precision Op Amp (LT1014)
Dual Precision Op Amp (LT1013)

**Features**
- Single Supply Operation
  - Input Voltage Range Extends to Ground
  - Output Swings to Ground While Sinking Current
- Pin Compatible to 1458 and 324 with Precision Specs
- Guaranteed Offset Voltage: 150µV Max
- Guaranteed Low Drift: 2µV/°C Max
- Guaranteed Offset Current: 0.8nA Max
- Guaranteed High Gain
  - 5mA Load Current: 1.5 Million Min
  - 17mA Load Current: 0.8 Million Min
- Guaranteed Low Supply Current: 500µA Max
- Low Voltage Noise, 0.1Hz to 10Hz: 0.55µVp-p
- Low Current Noise—Better than OP-07, 0.07pA/√Hz

**Applications**
- Battery-Powered Precision Instrumentation
- Strain Gauge Signal Conditioners
- Thermocouple Amplifiers
- Instrumentation Amplifiers
- 4mA to 20mA Current Loop Transmitters
- Multiple Limit Threshold Detection
- Active Filters
- Multiple Gain Blocks

**Description**

The LT®1014 is the first precision quad operational amplifier which directly upgrades designs in the industry standard 14-pin DIP LM324/LM348/OP-11/4156 pin configuration. It is no longer necessary to compromise specifications, while saving board space and cost, as compared to single operational amplifiers.

The LT1014’s low offset voltage of 50µV, drift of 0.3µV/°C, offset current of 0.15nA, gain of 8 million, common mode rejection of 117dB and power supply rejection of 120dB qualify it as four truly precision operational amplifiers. Particularly important is the low offset voltage, since no offset null terminals are provided in the quad configuration. Although supply current is only 350µA per amplifier, a new output stage design sources and sinks in excess of 20mA of load current, while retaining high voltage gain.

Similarly, the LT1013 is the first precision dual op amp in the 8-pin industry standard configuration, upgrading the performance of such popular devices as the MC1458/MC1558, LM158 and OP-221. The LT1013’s specifications are similar to (even somewhat better than) the LT1014’s.

Both the LT1013 and LT1014 can be operated off a single 5V power supply: input common mode range includes ground; the output can also swing to within a few millivolts of ground. Crossover distortion, so apparent on previous single-supply designs, is eliminated. A full set of specifications is provided with ±15V and single 5V supplies.

**Typical Application**

3-Channel Thermocouple Thermometer

![Diagram of 3-Channel Thermocouple Thermometer](image.png)

USE TYPE K THERMOCOUPLES. ALL RESISTORS = 1% FILM.
COLD JUNCTION COMPENSATION ACCURATE TO ±1°C FROM 0°C TO 60°C.
USE 4TH AMPLIFIER FOR OUTPUT C.

**LT1014 Distribution of Offset Voltage**

![Graph showing LT1014 distribution of offset voltage](graph.png)

**Notes:**

1. LT, LTC, LM, Linear Technology and the Linear logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage ....................................................... ± 22V  
Differential Input Voltage ........................................ ± 30V  
Input Voltage ....................................................... Equal to Positive Supply Voltage  
............. 5V Below Negative Supply Voltage  
Output Short-Circuit Duration .................................. Indefinite  
Storage Temperature Range  
All Grades ....................................................... –65°C to 150°C  

**Lead Temperature (Soldering, 10 sec.)** ............ 300°C  

**Operating Temperature Range**  

<table>
<thead>
<tr>
<th>Model</th>
<th>Range</th>
<th>Models</th>
<th>Range</th>
<th>Models</th>
<th>Range</th>
<th>Models</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>LT1013AM/LT1013M/</td>
<td>–55°C to 125°C</td>
<td>LT1014AM/LT1014M/</td>
<td>–55°C to 125°C</td>
<td>LT1013AC/LT1013C/LT1013D</td>
<td>0°C to 70°C</td>
<td>LT1013I/ LT1014I/</td>
<td>–40°C to 85°C</td>
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<tr>
<td>LT1014AC/LT1014C/LT1014D</td>
<td>0°C to 70°C</td>
<td>LT1013AC/LT1013C/LT1013D</td>
<td>0°C to 70°C</td>
<td>LT1014AC/LT1014C/LT1014D</td>
<td>0°C to 70°C</td>
<td>LT1013I/ LT1014I/</td>
<td>–40°C to 85°C</td>
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</table>

**PIN CONFIGURATION**

<table>
<thead>
<tr>
<th>LT1013</th>
<th>8-LEAD PLASTIC SO</th>
<th>8-LEAD PDIP</th>
<th>8-LEAD CERDIP</th>
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<tbody>
<tr>
<td>TOP VIEW</td>
<td>V*</td>
<td>OUTPUT B</td>
<td>V*</td>
</tr>
<tr>
<td>+IN A</td>
<td>1</td>
<td>2</td>
<td>OUT A</td>
</tr>
<tr>
<td>+IN B</td>
<td>3</td>
<td>4</td>
<td>IN A</td>
</tr>
<tr>
<td>−IN A</td>
<td>5</td>
<td>6</td>
<td>IN B</td>
</tr>
<tr>
<td>−IN B</td>
<td>7</td>
<td>8</td>
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**N8 PACKAGE**  

TJMAX = 150°C, θJA = 130°C  

**J8 PACKAGE**  

TJMAX = 150°C, θJA = 100°C  

**H PACKAGE**  

TJMAX = 150°C, θJA = 150°C  

**OBsolete PACKAGE**  

Consider the N or S8 Packages for Alternate Source  

<table>
<thead>
<tr>
<th>LT1014</th>
<th>16-LEAD PLASTIC SO</th>
<th>16-LEAD PDIP</th>
<th>14-LEAD PDIP</th>
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<tbody>
<tr>
<td>OUTPUT A</td>
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<td>2</td>
<td>IN D</td>
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<tr>
<td>−IN A</td>
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<td>4</td>
<td>IN D</td>
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<tr>
<td>+IN A</td>
<td>5</td>
<td>6</td>
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<td>+IN B</td>
<td>7</td>
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<td>+IN C</td>
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<tr>
<td>−IN B</td>
<td>9</td>
<td>10</td>
<td>−IN C</td>
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<td>OUTPUT B</td>
<td>11</td>
<td>12</td>
<td>OUT A</td>
</tr>
<tr>
<td>NC</td>
<td>13</td>
<td>14</td>
<td>OUT D</td>
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**J PACKAGE**  

TJMAX = 150°C, θJA = 130°C  

**OBsolete PACKAGE**  

Consider the N or SW Packages for Alternate Source
## ORDER INFORMATION

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<th>LEAD FREE FINISH</th>
<th>TAPE AND REEL</th>
<th>PART MARKING</th>
<th>PACKAGE DESCRIPTION</th>
<th>TEMPERATURE RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT1013DS8#PBF</td>
<td>LT1013DS8#TRPBF</td>
<td>1013</td>
<td>8-Lead Plastic SO</td>
<td>0°C to 70°C</td>
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<tr>
<td>LT1013IS8#PBF</td>
<td>LT1013IS8#TRPBF</td>
<td>1013I</td>
<td>8-Lead Plastic SO</td>
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<tr>
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<td>8-Lead PDIP</td>
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<tr>
<td>LT1013CN8#PBF</td>
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<td>LT1013CN8</td>
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<td>0°C to 70°C</td>
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<tr>
<td>LT1013DN8#PBF</td>
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<td>LT1013DN8</td>
<td>8-Lead PDIP</td>
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<tr>
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<td>LT1014DSW#PBF</td>
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<td>LT1014DSW</td>
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<td>LT1014ACN</td>
<td>14-Lead PDIP</td>
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<tr>
<td>LT1014CN#PBF</td>
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<td>LT1014CN</td>
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<tr>
<td>LT1014DN#PBF</td>
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<td>LT1014DN</td>
<td>14-Lead PDIP</td>
<td>0°C to 70°C</td>
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<tr>
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<td>LT1014IN</td>
<td>14-Lead PDIP</td>
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<td>8-Lead CERDIP</td>
<td>–55°C to 125°C (OBSOLETE)</td>
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<td>LT1013ACJ8</td>
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<td>0°C to 70°C       (OBSOLETE)</td>
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<tr>
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<td>LT1013CJ8</td>
<td>8-Lead CERDIP</td>
<td>0°C to 70°C       (OBSOLETE)</td>
</tr>
<tr>
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<td>LT1013AMH#TRPBF</td>
<td>LT1013AMH</td>
<td>8-Lead TO-5 Metal Can</td>
<td>–55°C to 125°C (OBSOLETE)</td>
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<td>LT1013MH</td>
<td>8-Lead TO-5 Metal Can</td>
<td>–55°C to 125°C (OBSOLETE)</td>
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<td>8-Lead TO-5 Metal Can</td>
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<td>LT1014CJ</td>
<td>14-Lead CERDIP</td>
<td>0°C to 70°C (OBSOLETE)</td>
</tr>
</tbody>
</table>

Consult LTC Marketing for parts specified with wider operating temperature ranges.
Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: [http://www.linear.com/leadfree/](http://www.linear.com/leadfree/)
For more information on tape and reel specifications, go to: [http://www.linear.com/tapeandreel/](http://www.linear.com/tapeandreel/)
## ELECTRICAL CHARACTERISTICS

$T_A = 25^\circ C, V_S = \pm 15V, V_{CM} = 0V$ unless otherwise noted.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>$LT1013/AM/AC$</th>
<th>$LT1014/AM/AC$</th>
<th>$LT1013C/D/I/M$</th>
<th>$LT1014C/D/I/M$</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
<td>MIN</td>
<td>TYP</td>
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<tr>
<td>$V_{OS}$</td>
<td>Input Offset Voltage</td>
<td>$LT1013$</td>
<td>40</td>
<td>150</td>
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<td>60</td>
<td>300</td>
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<td></td>
<td></td>
<td>$LT1014$</td>
<td>50</td>
<td>180</td>
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<td>300</td>
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<td>$LT1013D/I$, $LT1014D/I$</td>
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<td>200</td>
<td>800</td>
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<td>$I_{SO}$</td>
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<td>1.5</td>
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<td>$I_B$</td>
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<td>$e_n$</td>
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<td>$I_{IN}$</td>
<td>Input Noise Current Density</td>
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<tr>
<td>$I_{OS}$</td>
<td>Input Offset Voltage</td>
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<td>0.8</td>
<td>1.5</td>
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<td>$I_B$</td>
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<td>1.5</td>
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<tr>
<td>$A_{VOL}$</td>
<td>Large-Signal Voltage Gain</td>
<td>$V_O = \pm 10V$, $R_L = 2k$</td>
<td>1.5</td>
<td>8.0</td>
<td></td>
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<td>7.0</td>
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<tr>
<td></td>
<td></td>
<td>$V_O = \pm 10V$, $R_L = 600\Omega$</td>
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<td>0.5</td>
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<td>$V_{OUT}$</td>
<td>Output Voltage Swing</td>
<td>$R_L = 2k$</td>
<td>±13</td>
<td>±14</td>
<td>±12.5</td>
<td>±14</td>
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<td>$Slew Rate$</td>
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<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
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<tr>
<td>$I_S$</td>
<td>Supply Current</td>
<td>Per Amplifier</td>
<td>0.35</td>
<td>0.50</td>
<td>0.35</td>
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</table>

$T_A = 25^\circ C, V_S^+ = 5V, V_S^- = 0V, V_{OUT} = 1.4V, V_{CM} = 0V$ unless otherwise noted.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>$LT1013/AM/AC$</th>
<th>$LT1014/AM/AC$</th>
<th>$LT1013C/D/I/M$</th>
<th>$LT1014C/D/I/M$</th>
<th>UNITS</th>
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<tbody>
<tr>
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<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
<td>MIN</td>
<td>TYP</td>
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<td>$A_{VOL}$</td>
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<td>$V_O = 5mV$ to $4V$, $R_L = 500\Omega$</td>
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<td>$V_{OUT}$</td>
<td>Output Voltage Swing</td>
<td>Output Low, No Load</td>
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<tr>
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<td>Output Low, $600\Omega$ to Ground</td>
<td>3.5</td>
<td>3.8</td>
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<td>Output Low, $I_{SINK} = 1mA$</td>
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<td>$I_S$</td>
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<td>Per Amplifier</td>
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**ELECTRICAL CHARACTERISTICS**

The ● denotes the specifications which apply over the temperature range –55°C ≤ TA ≤ 125°C. VS = ±15V, VCM = 0V unless otherwise noted.

<table>
<thead>
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<th>SYMBOL</th>
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<th>CONDITIONS</th>
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<th>LT1014AM</th>
<th>LT1013M/LT1014M</th>
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<td></td>
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<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
</tr>
<tr>
<td>VOS</td>
<td>Input Offset Voltage</td>
<td>VS = 5V, 0V; VD = 1.4V</td>
<td>● 80</td>
<td>300</td>
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<tr>
<td></td>
<td></td>
<td>−55°C ≤ TA ≤ 100°C</td>
<td>● 80</td>
<td>450</td>
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<tr>
<td></td>
<td></td>
<td>VCM = 0.1V, TA = 125°C</td>
<td>● 120</td>
<td>450</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>VCM = 0V, TA = 125°C</td>
<td>● 250</td>
<td>900</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(Note 3)</td>
<td>● 0.4</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>IOS</td>
<td>Input Offset Current</td>
<td>VS = 5V, 0V; VD = 1.4V</td>
<td>● 0.3</td>
<td>2.5</td>
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<tr>
<td>Ib</td>
<td>Input Bias Current</td>
<td>VS = 5V, 0V; VD = 1.4V</td>
<td>● 0.6</td>
<td>6.0</td>
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<tr>
<td>AVOL</td>
<td>Large-Signal Voltage Gain</td>
<td>VD = ±10V, RL = 2k</td>
<td>● 15</td>
<td>30</td>
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<tr>
<td>CMRR</td>
<td>Common Mode Rejection</td>
<td>VCM = 13.0V, –14.9V</td>
<td>● 97</td>
<td>114</td>
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<tr>
<td>PSRR</td>
<td>Power Supply Rejection Ratio</td>
<td>VS = ±2V to ±18V</td>
<td>● 100</td>
<td>117</td>
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<tr>
<td>VOUT</td>
<td>Output Voltage Swing</td>
<td>RL = 2k</td>
<td>● ±12</td>
<td>±13.8</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>VS = 5V, 0V</td>
<td>● 6</td>
<td>15</td>
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<td></td>
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<td>RL = 600Ω to Ground</td>
<td>● 3.2</td>
<td>3.8</td>
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<tr>
<td>IS</td>
<td>Supply Current Per Amplifier</td>
<td>VS = 5V, 0V; VD = 1.4V</td>
<td>● 0.38</td>
<td>0.60</td>
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1013/455
# Electrical Characteristics

The ● denotes the specifications which apply over the temperature range 
\(-40°C \leq T_A \leq 85°C\) for LT1013I, LT1014I, \(0°C \leq T_A \leq 70°C\) for LT1013C, LT1013D, LT1014C, LT1014D. \(V_S = \pm 15V\), \(V_CM = 0V\) unless otherwise noted.

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<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LT1013AC</th>
<th>LT1014AC</th>
<th>LT1013C/D/I</th>
<th>LT1014C/D/I</th>
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<td>MAX</td>
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<td>Input Offset Voltage</td>
<td>LT1013D/I, LT1014D/I</td>
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<td>LT1013C/D/I</td>
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<td>●</td>
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<td></td>
<td>Average Input Offset Voltage Drift</td>
<td>(Note 3)</td>
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<td>2.0</td>
<td>0.4</td>
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<td>Input Offset Current</td>
<td>LT1013D/I, LT1014D/I</td>
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<td>V_S = 5V, 0V; V_O = 1.4V</td>
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<td>Input Bias Current</td>
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<td>V_S = 5V, 0V; V_O = 1.4V</td>
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<td>△VOL</td>
<td>Large-Signal Voltage Gain</td>
<td>V_O = ±10V, R_L = 2k</td>
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<td>5.0</td>
<td>1.0</td>
<td>5.0</td>
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<td>CMRR</td>
<td>Common Mode Rejection Ratio</td>
<td>V_CM = ±13.0V, −15.0V</td>
<td>98</td>
<td>116</td>
<td>98</td>
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<td>94</td>
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<td>PSRR</td>
<td>Power Supply Rejection Ratio</td>
<td>V_S = ±2V to ±18V</td>
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<td>119</td>
<td>101</td>
<td>119</td>
<td>97</td>
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<td>△OUT</td>
<td>Output Voltage Swing</td>
<td>R_L = 2k</td>
<td>±12.5</td>
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<td>±12.5</td>
<td>±13.9</td>
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<td>V_S = 5V, 0V; R_L = 600Ω</td>
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<td>13</td>
<td>6</td>
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<td>Output Low</td>
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<td>3.9</td>
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<td>Output High</td>
<td>3.3</td>
<td>3.9</td>
<td>3.3</td>
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<td>I S</td>
<td>Supply Current per Amplifier</td>
<td>V_S = 5V, 0V; V_O = 1.4V</td>
<td>0.36</td>
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<td>V_S = 5V, 0V; V_O = 1.4V</td>
<td>0.32</td>
<td>0.50</td>
<td>0.32</td>
<td>0.50</td>
<td>0.34</td>
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</table>

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

**Note 2:** This parameter is guaranteed by design and is not tested. Typical parameters are defined as the 60% yield of parameter distributions of individual amplifiers; i.e., out of 100 LT1014s (or 100 LT1013s) typically 240 op amps (or 120) will be better than the indicated specification.

**Note 3:** This parameter is not 100% tested.
TYPICAL PERFORMANCE CHARACTERISTICS

Offset Voltage Drift with Temperature of Representative Units

Offset Voltage vs Balanced Source Resistance

Warm-Up Drift

Common Mode Rejection Ratio vs Frequency

Power Supply Rejection Ratio vs Frequency

0.1Hz to 10Hz Noise

Noise Spectrum

10Hz Voltage Noise Distribution

Supply Current vs Temperature
**Typical Performance Characteristics**

**Input Bias Current vs Common Mode Voltage**

- $T_A = 25^\circ C$
- $V_S = \pm 15V$, $V_S = 5V$, $0V$

**Input Offset Current vs Temperature**

- $V_{CM} = 0V$
- $V_S = 5V$, $0V$
- $V_S = \pm 2.5V$
- $V_S = \pm 15V$

**Output Saturation vs Sink Current vs Temperature**

- $V^+ = 5V$ to $30V$
- $V^- = 0V$
- $I_{SINK} = 10mA$
- $I_{SINK} = 5mA$
- $I_{SINK} = 1mA$
- $I_{SINK} = 100\mu A$
- $I_{SINK} = 10\mu A$
- $I_{SINK} = 0$

**Small-Signal Transient Response, $V_S = \pm 15V$**

- $A_V = +1$
- $20\mu S/DIV$

**Large-Signal Transient Response, $V_S = 5V$, $0V$**

- $A_V = +1$
- $10\mu S/DIV$

**Small-Signal Transient Response, $V_S = 5V$, $0V$**

- $A_V = +1$
- $20\mu S/DIV$

- $R_L = 600\Omega$ to ground
- Input = 0V to 100mV pulse

**Large-Signal Transient Response, $V_S = 5V$, $0V$**

- $A_V = +1$
- $10\mu S/DIV$

- $R_L = 4.7k$ to 5V
- Input = 0V to 4V pulse

**Output Saturation vs Sink Current vs Temperature**

- $V^+ = 5V$ to $30V$
- $V^- = 0V$
- $I_{SINK} = 10mA$
- $I_{SINK} = 5mA$
- $I_{SINK} = 1mA$
- $I_{SINK} = 100\mu A$
- $I_{SINK} = 10\mu A$
- $I_{SINK} = 0$

**Large-Signal Transient Response, $V_S = 5V$, $0V$**

- $A_V = +1$
- $10\mu S/DIV$

- No load
- Input = 0V to 4V pulse
TYPICAL PERFORMANCE CHARACTERISTICS

Output Short-Circuit Current vs Time

Voltage Gain vs Load Resistance

Voltage Gain vs Frequency

Gain, Phase vs Frequency

Channel Separation vs Frequency

APPLICATIONS INFORMATION

Single Supply Operation

The LT1013/LT1014 are fully specified for single supply operation, i.e., when the negative supply is 0V. Input common mode range includes ground; the output swings within a few millivolts of ground. Single supply operation, however, can create special difficulties, both at the input and at the output. The LT1013/LT1014 have specific circuitry which addresses these problems.

At the input, the driving signal can fall below 0V—inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, two distinct problems can occur on previous single supply designs, such as the LM124, LM158, OP-20, OP-21, OP-220, OP-221, OP-420:

a) When the input is more than a diode drop below ground, unlimited current will flow from the substrate ($V^-$ terminal) to the input. This can destroy the unit. On the LT1013/LT1014, the 400Ω resistors, in series with the input (see Schematic Diagram), protect the devices even when the input is 5V below ground.
b) When the input is more than 400mV below ground (at 25°C), the input stage saturates (transistors Q3 and Q4) and phase reversal occurs at the output. This can cause lock-up in servo systems. Due to a unique phase reversal protection circuitry (Q21, Q22, Q27, Q28), the LT1013/LT1014’s outputs do not reverse, as illustrated below, even when the inputs are at –1.5V.

There is one circumstance, however, under which the phase reversal protection circuitry does not function: when the other op amp on the LT1013, or one specific amplifier of the other three on the LT1014, is driven hard into negative saturation at the output.

Phase reversal protection does not work on amplifier:
A when D’s output is in negative saturation. B’s and C’s outputs have no effect.
B when C’s output is in negative saturation. A’s and D’s outputs have no effect.
C when B’s output is in negative saturation. A’s and D’s outputs have no effect.
D when A’s output is negative saturation. B’s and C’s outputs have no effect.

At the output, the aforementioned single supply designs either cannot swing to within 600mV of ground (OP-20) or cannot sink more than a few microamperes while swinging to ground (LM124, LM158). The LT1013/LT1014’s all-NPN output stage maintains its low output resistance and high gain characteristics until the output is saturated.

In dual supply operations, the output stage is crossover distortion-free.

**Comparator Applications**

The single supply operation of the LT1013/LT1014 lends itself to its use as a precision comparator with TTL compatible output:

In systems using both op amps and comparators, the LT1013/LT1014 can perform multiple duties; for example, on the LT1014, two of the devices can be used as op amps and the other two as comparators.
APPLICATIONS INFORMATION

Low Supply Operation

The minimum supply voltage for proper operation of the LT1013/LT1014 is 3.4V (three Ni-Cad batteries). Typical supply current at this voltage is 290µA, therefore power dissipation is only one milliwatt per amplifier.

Noise Testing

For applications information on noise testing and calculations, please see the LT1007 or LT1008 data sheet.

TYPICAL APPLICATIONS

50MHz Thermal RMS-to-DC Converter

5V Single Supply Dual Instrumentation Amplifier

2% ACCURACY, DC–50MHz. 150:1 Crest Factor Capability. * 0.1% RESISTOR. T1–T2 = YELLOW SPRINGS INST. CO. THERMISTOR COMPOSITE #44018. ENCLOSE T1 AND T2 IN STYROFOAM. 7.5mW DISSIPATION.

OFFSET = 150mV GAIN = \( \frac{R_2}{R_1} \) \(+1\). CMRR = 120dB COMMON MODE RANGE IS 0V TO 5V.
**Hot-Wire Anemometer**

- **Components:**
  - Q5: CA3046
  - Q1–Q4: CA3046
  - Q6: TIP120 or equivalent
  - Q1–Q4: CA3046
  - LT1004-1.2
  - Q2: 2N4391
  - Q3: 150k

- **Adjustments:**
  - 100k: FULL-SCALE FLOW
  - 1µF: FLOW CALIB

- **Operation:**
  - Flow in pipe is inversely proportional to resistance of T1–T2 temperature difference.
  - A1–A2 provide gain. A3–A4 provide linearized frequency output.
  - TIE CA3046 PIN 13 to –15V do not use Q5.

**Liquid Flowmeter**

- **Components:**
  - Q6: TIP120 or equivalent
  - Q1–Q4: CA3046
  - 2N4391
  - 33k
  - 2k

- **Adjustments:**
  - 0.01µF: ZERO FLOW
  - 1µF: RESPONSE TIME ADJUST

- **Operation:**
  - Supplied with YSI thermistor network.
  - T1, T2 YSI thermistor network = #44201.
  - Flow in pipe is inversely proportional to resistance of T1–T2 temperature difference.
  - A1–A2 provide gain. A3–A4 provide linearized frequency output.

- **Supplementary:**
  - Remove lamp's glass envelope from 328 lamp.
  - A1 servos #328 lamp to constant temperature.
  - A2–A3 furnish linear output vs flow rate.

- **Notes:**
  - *1% resistor.
  - *1% film resistor.
  - **Supplied with YSI thermistor network.
  - 1% resistor.*
TYPICAL APPLICATIONS

5V Powered Precision Instrumentation Amplifier

![Circuit Diagram]

- 5V Powered Precision Instrumentation Amplifier
- Typical applications include
  - Voltage powered precision instrumentation
  - Gain equation: \( A = \frac{400,000}{R_G} + 1 \)
  - For high source impedances, use 2N2222 as diodes.
- Circuit diagram with labels for components:
  - Input and output connections
  - Gain equation calculation

9V Battery Powered Strain Gauge Signal Conditioner

![Circuit Diagram]

- 9V Battery Powered Strain Gauge Signal Conditioner
- Sampled operation gives low average operating current of 650μA.
- 4.7k-0.01μF RC protects strain bridge from long term drifts due to high \( \Delta V/\Delta T \) steps.
- Circuit diagram with labels for components:
  - Input and output connections
  - Reference and ratio connections
  - Gain calculation: \( A = \frac{400,000}{R_G} + 1 \)
5V Powered Motor Speed Controller
No Tachometer Required

1/2 LT1013

A1

1

2

3

330k

0.47

100k

6.8M

0.068

1M

1

4

5

6

8

+5V

EIN

0V TO 3V

A2

1/2 LT1013

MOTOR = CANON-FN30-R13N1B.
A1 DUTY CYCLE MODULATES MOTOR.
A2 SAMPLES MOTORS BACK EMF.

5V Powered EEPROM Pulse Generator

MEETS ALL Vpp PROGRAMMING SPECS WITH NO TRIMS AND
RUNS OFF 5V SUPPLY—NO EXTERNAL HIGH VOLTAGE SUPPLY REQUIRED.
SUITABLE FOR BATTERY POWERED USE (600µA QUIESCENT CURRENT).
*1% METAL FILM.
Methane Concentration Detector with Linearized Output

Low Power 9V to 5V Converter

L = DALE TE-3/03/TA.
SHORT CIRCUIT CURRENT = 30mA.
≈ 75% EFFICIENCY.
SWITCHING PREREGULATOR CONTROLS DROP ACROSS FET TO 200mV.
5V Powered 4mA to 20mA Current Loop Transmitter†

Fully Floating Modification to 4mA-20mA Current Loop†
5V Powered, Linearized Platinum RTD Signal Conditioner

OUTPUT 0V TO 4V = 0°C TO 400°C ±0.05°C

GAIN TRIM
1k
3.01k

LINEARITY
200k
2M

ZERO TRIM
8.25k
274k

GAIN TRIM
1/4 LT1014

ALL RESISTORS ARE TRW-MAR-6 METAL FILM.
RATIO MATCH 2M–200K ± 0.01%.
TRIM SEQUENCE:
SET SENSOR TO 0° VALUE.
ADJUST ZERO FOR 0V OUT.
SET SENSOR TO 100°C VALUE.
ADJUST GAIN FOR 1.000V OUT.
SET SENSOR TO 200°C.
ADJUST LINEARITY FOR 4.000V OUT, REPEAT AS REQUIRED.

Strain Gauge Bridge Signal Conditioner

1.2V REFERENCE TO A/D CONVERTER FOR RATIOMETRIC OPERATION
1mA MAXIMUM LOAD

VREF

PRESSURE TRANSDUCER 350Ω

* 1% FILM RESISTOR.
CIRCLED LETTER IS PIN NUMBER.
LVDT Signal Conditioner

- LT1013/LT1014
- Frequency = 1.5kHz
- LT1013
- 7
- 6
- 5
- 4
- 3
- 2
- 1
- 0
- 10k
- 30k
- 0.005
- 0.005
- 5V
- -5V
- 1N914
- 2N4038
- 10µF
- 7.5k
- 100k
- LVDT = SCHAEVITZ E-100.

Triple Op Amp Instrumentation Amplifier with Bias Current Cancellation

- Gain = \( 1 + \frac{2R_1}{R_G} \)
- R1
- R2
- R3
- -INPUT
- +INPUT
- R5M
- 2R
- 10M
- 5M
- 2R
- 10M
- 10pF
- V-
- V+
- OUTPUT
- INPUT BIAS CURRENT TYPICALLY <1nA
- INPUT RESISTANCE = 3R = 15M for values shown
- NEGATIVE COMMON MODE LIMIT = V- + IB x 2R + 30mV
  = 150mV for V- = 0V
  IB = 12nA

LT1013/14 TA17

- LT1004
- 1.2V
- 1µF
- LT1013
- 1.2V

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TYPICAL APPLICATIONS

Low Dropout Regulator for 6V Battery

Voltage Controlled Current Source with Ground Referred Input and Output
**Typical Applications**

6V to ±15V Regulating Converter

Low Power, 5V Driven, Temperature Compensated Crystal Oscillator (TXCO)

*1% FILM
3.5MHz XTL – AT CUT – 35°20’
MOUNT R1 NEAR XTAL
3mA POWER DRAIN

† THERMISTOR-AMPLIFIER-VARACTOR NETWORK GENERATES A TEMPERATURE COEFFICIENT OPPOSITE THE CRYSTAL TO MINIMIZE OVERALL OSCILLATOR DRIFT
H Package
8-Lead TO-5 Metal Can (.200 Inch PCD)
(Reference LTC DWG # 05-08-1320)

J8 Package
8-Lead CERDIP (Narrow .300 Inch, Hermetic)
(Reference LTC DWG # 05-08-1110)

J Package
14-Lead CERDIP (Narrow .300 Inch, Hermetic)
(Reference LTC DWG # 05-08-1110)

OBSOLETE PACKAGES
**PACKAGE DESCRIPTION**

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

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

**NOTE:**
1. DIMENSIONS ARE INCHES or MILLIMETERS.
2. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
3. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm).
**S6 Package**
6-Lead Plastic TSOT-23
(Reference LTC DWG # 05-08-1636)

**SW Package**
XX-Lead Plastic Small Outline (Wide .300 Inch)
(Reference LTC DWG # 05-08-1620)

---

**NOTE:**
1. DIMENSIONS IN 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)
**REVISION HISTORY** *(Revision history begins at Rev D)*

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

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<td>17µA Max I_S, 70µV Max V_OS</td>
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<td>LTC6078/LTC6079</td>
<td>Dual/Quad 72µA Precision Rail-to-Rail Amplifier</td>
<td>V_S = 2.7V to 6V, 72µA Max I_S, 25µV V_OS 0.7µV/°C TCVOS</td>
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