**General Description**

The MAX4207 logarithmic amplifier computes the log ratio of an input current relative to a reference current (externally or internally generated) and provides a corresponding voltage output with a default -0.25V/decade scale factor. The device operates from dual ±2.7V to ±5.5V supplies and is capable of measuring five decades of input current across a 10nA to 1mA range.

The MAX4207's uncommitted op amp can be used for a variety of functions, including filtering noise, adding offset, and adding additional gain. A 0.5V reference is also included to generate an optional precision current reference using an external resistor, which adjusts the log intercept of the MAX4207. The output-offset voltage and the adjustable scale factor are also set using external resistors.

The MAX4207 is available in a space-saving 16-pin thin QFN package (4mm x 4mm x 0.8mm), and is specified for operation over the -40°C to +85°C extended temperature range.

**Applications**

- Photodiode Current Monitoring
- Portable Instrumentation
- Medical Instrumentation
- Analog Signal Processing

**Features**

- ±2.7V to ±5.5V Dual-Supply Operation
- 5 Decades of Dynamic Range (10nA to 1mA)
- Monotonic Over a 1nA to 1mA Range
- -0.25V/Decade Internally Trimmed Output Scale Factor
- Adjustable Output Scale Factor
- Adjustable Output Offset Voltage
- Internal 10nA to 10μA Reference Current Source
- Input Amplifiers Summing Nodes at Ground
- Small 16-Pin Thin QFN Package (4mm x 4mm x 0.8mm)
- -40°C to +85°C Operating Temperature Range

**Ordering Information**

<table>
<thead>
<tr>
<th>PART</th>
<th>TEMP RANGE</th>
<th>PIN-PACKAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX4207ETE</td>
<td>-40°C to +85°C</td>
<td>16 Thin QFN-EP*</td>
</tr>
</tbody>
</table>

*EP = Exposed paddle.

**Typical Operating Circuit**

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim’s website at www.maxim-ic.com.
**Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range**

### ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND, unless otherwise noted.)

Continuous Current (REFIIN, LOGIIN) .............................................................. 10mA

Continuous Power Dissipation (TA = +70°C) ... 1349mW

Operating Temperature Range ... -40°C to +85°C

Junction Temperature ................................................................. +150°C

Storage Temperature Range ... -65°C to +150°C

Lead Temperature (soldering, 10s) ... +300°C

### DC ELECTRICAL CHARACTERISTICS—Dual-Supply Operation

(VCC = +5V, VEE = -5V, GND = 0, IREF = 1µA, ILOG = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, RSET > 1MΩ, TA = -40°C to +85°C. Typical values are at TA = +25°C, unless otherwise noted.) (Note 1)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>VCC (Note 2)</td>
<td>TA = +25°C</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>VEE (Note 2)</td>
<td>TA = +25°C</td>
<td>7.5</td>
<td>mA</td>
<td></td>
<td></td>
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<tr>
<td>Supply Current</td>
<td>ICC</td>
<td>TA = +25°C</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>LOGIIN Current Range (Notes 3, 4)</td>
<td>ILOG</td>
<td>Minimum</td>
<td>1</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOGIIN Current Range (Notes 3, 4)</td>
<td>ILOG</td>
<td>Maximum</td>
<td>1</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REFIIN Current Range (Notes 3, 4)</td>
<td>IREF</td>
<td>Minimum</td>
<td>10</td>
<td>nA</td>
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<tr>
<td>REFIIN Current Range (Notes 3, 4)</td>
<td>IREF</td>
<td>Maximum</td>
<td>10</td>
<td>nA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common-Mode Voltage</td>
<td>VCMVOUT</td>
<td></td>
<td>0</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common-Mode Voltage Input Range</td>
<td>VCMVIN</td>
<td></td>
<td>0</td>
<td>0.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Log Conformity Error</td>
<td>VLC</td>
<td>TA = +25°C</td>
<td>±2</td>
<td>±5</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Log Conformity Error</td>
<td>VLC</td>
<td>TA = -40°C to +85°C</td>
<td>±10</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logarithmic Slope (Scale Factor)</td>
<td>K</td>
<td>TA = +25°C</td>
<td>-237.5</td>
<td>-250</td>
<td>-262.5</td>
<td>mV/decade</td>
</tr>
<tr>
<td>Logarithmic Slope (Scale Factor)</td>
<td>K</td>
<td>TA = -40°C to +85°C</td>
<td>-231.25</td>
<td>-268.75</td>
<td>mV/decade</td>
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<tr>
<td>Logarithmic Slope (Scale Factor) Temperature Drift</td>
<td></td>
<td>TA = -40°C to +85°C</td>
<td>80</td>
<td>µV/decade/°C</td>
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<tr>
<td>Input Offset Voltage</td>
<td>VI0</td>
<td>TA = +25°C, IVCMVIN - VREFIIN, IVCMVIN - VLOGIIN</td>
<td>0.6</td>
<td>5</td>
<td>mV</td>
<td></td>
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<tr>
<td>Input Offset Voltage Temperature Drift</td>
<td>VI0S</td>
<td>IVCMVIN - VREFIIN, IVCMVIN - VLOGIIN</td>
<td>6</td>
<td>µV/°C</td>
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</tr>
<tr>
<td>Voltage Reference Output</td>
<td>VREFVOUT</td>
<td>TA = +25°C</td>
<td>1.218</td>
<td>1.238</td>
<td>1.258</td>
<td>V</td>
</tr>
<tr>
<td>Voltage Reference Output</td>
<td>VREFVOUT</td>
<td>TA = -40°C to +85°C (Note 4)</td>
<td>1.195</td>
<td>1.275</td>
<td>V</td>
<td></td>
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</tbody>
</table>
Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

DC ELECTRICAL CHARACTERISTICS—Dual-Supply Operation (continued)

(VCC = +5V, VEE = -5V, GND = 0, IREF = 1µA, ILOG = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, RSET > 1MΩ, TA = -40°C to +85°C. Typical values are at TA = +25°C, unless otherwise noted.) (Note 1)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
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<tbody>
<tr>
<td>Voltage Reference Output Current</td>
<td>IREFVOUT</td>
<td>1</td>
<td>490</td>
<td>510</td>
<td>mA</td>
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<tr>
<td></td>
<td>TA = +25°C</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>TA = -40°C to +85°C</td>
<td>482</td>
<td>500</td>
<td>518</td>
<td>mV</td>
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<tr>
<td>Current Reference Output Voltage</td>
<td>VREFISET</td>
<td>0.4</td>
<td>2</td>
<td>6</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td>TA = +25°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TA = -40°C to +85°C</td>
<td>0.4</td>
<td>2</td>
<td>6</td>
<td>nA</td>
</tr>
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**LOGV2 BUFFER**

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<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>VIO</td>
<td>TA = +25°C</td>
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<td>2</td>
<td>6</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TA = -40°C to +85°C</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>IB</td>
<td>(Note 4)</td>
<td>0.01</td>
<td>1</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td>VOH</td>
<td>RL to GND = 2kΩ</td>
<td>VCC</td>
<td>0.2</td>
<td>VCC - 0.3</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>VOL</td>
<td>RL to GND = 2kΩ</td>
<td>VEE</td>
<td>0.2</td>
<td>VEE + 0.08</td>
<td>V</td>
</tr>
<tr>
<td>Output Short-Circuit Current</td>
<td>IOUT+</td>
<td>Sourcing</td>
<td>34</td>
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<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>IOUT-</td>
<td>Sinking</td>
<td>58</td>
<td></td>
<td></td>
<td>V/µs</td>
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<tr>
<td>Slew Rate</td>
<td>SR</td>
<td></td>
<td>12</td>
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<td></td>
<td>V/µs</td>
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<tr>
<td>Unity-Gain Bandwidth</td>
<td>GBW</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
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</table>

AC ELECTRICAL CHARACTERISTICS—Dual-Supply Operation

(VCC = +5V, VEE = -5V, GND = 0, IREF = 1µA, ILOG = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, RSET > 1MΩ, TA = +25°C, unless otherwise noted.)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOGV2 Total Noise</td>
<td>0.1Hz to 10Hz, total output-referred noise, IREF = 10nA, ILOG = 100nA</td>
<td>17</td>
<td></td>
<td></td>
<td>µVRMS</td>
<td></td>
</tr>
<tr>
<td>LOGV2 Spot Noise Density</td>
<td>f = 5kHz, IREF = 10nA, ILOG = 100nA</td>
<td>0.8</td>
<td></td>
<td></td>
<td>µV/√Hz</td>
<td></td>
</tr>
<tr>
<td>REFVOUT Total Noise</td>
<td>1Hz to 10Hz, total output-referred noise</td>
<td>3.3</td>
<td></td>
<td></td>
<td>µVRMS</td>
<td></td>
</tr>
<tr>
<td>REFVOUT Spot Noise Density</td>
<td>f = 5kHz</td>
<td>266</td>
<td></td>
<td></td>
<td>nV/√Hz</td>
<td></td>
</tr>
<tr>
<td>REFISET Total Noise</td>
<td>1Hz to 10Hz, total output-referred noise</td>
<td>0.67</td>
<td></td>
<td></td>
<td>µVRMS</td>
<td></td>
</tr>
<tr>
<td>REFISET Spot Noise Density</td>
<td>f = 5kHz</td>
<td>23</td>
<td></td>
<td></td>
<td>nV/√Hz</td>
<td></td>
</tr>
<tr>
<td>Small-Signal Unity-Gain Bandwidth</td>
<td>IREF = 1µA, ILOG = 10µA, RCOMP = 300Ω, CCOMP = 32pF</td>
<td>1</td>
<td></td>
<td></td>
<td>MHz</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: All devices are 100% production tested at TA = +25°C. All temperature limits are guaranteed by design.

Note 2: Guaranteed and functionally verified.

Note 3: Log conformity error less than ±5mV with scale factor = 0.25V/decade.

Note 4: Guaranteed by design.
**Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range**

**Typical Operating Characteristics**

(Vcc = +5V, Vee = -5V, GND = 0V, Iref = 1µA, Ilog = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, RSET > 1MΩ, TA = +25°C, unless otherwise noted.)

**VLOGV1 vs. ILOG**

**VLOGV1 vs. IREF**

**NORMALIZED LOG CONFORMANCE ERROR vs. ILOG**

**NORMALIZED LOG CONFORMANCE ERROR vs. IREF**

**NORMALIZED LOG CONFORMANCE ERROR vs. ILOG**
**Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range**

**Typical Operating Characteristics (continued)**

(V<sub>CC</sub> = +5V, V<sub>EE</sub> = -5V, GND = 0V, I<sub>REF</sub> = 1µA, I<sub>LOG</sub> = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, R<sub>SET</sub> > 1MΩ, T<sub>A</sub> = +25°C, unless otherwise noted.)
**Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range**

*Typical Operating Characteristics (continued)*

(Vcc = +5V, VEE = -5V, GND = 0V, IREF = 1µA, ILOG = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, RSET > 1MΩ, TA = +25°C, unless otherwise noted.)
Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

Typical Operating Characteristics (continued)

(VCC = +5V, VEE = -5V, GND = 0V, IREF = 1µA, ILOG = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, RSET > 1MΩ, TA = +25°C, unless otherwise noted.)
Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

Pin Description

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 9</td>
<td>N.C.</td>
<td>No Connection. Not internally connected.</td>
</tr>
<tr>
<td>2</td>
<td>REFVOUT</td>
<td>1.238V Reference Voltage Output. Bypass REFVOUT to GND with a 0 to 1μF capacitor (optional).</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>4</td>
<td>VEE</td>
<td>Negative Power Supply. Bypass VEE to GND with a 0.1μF capacitor.</td>
</tr>
<tr>
<td>5</td>
<td>LOGV1</td>
<td>Logarithmic Amplifier Voltage Output 1. The output scale factor of LOGV1 is -0.25V/decade.</td>
</tr>
<tr>
<td>6</td>
<td>OSADJ</td>
<td>Offset Adjust Input. Apply a voltage at OSADJ to adjust the LOGV2 output offset voltage (see the Output Offset section).</td>
</tr>
<tr>
<td>7</td>
<td>SCALE</td>
<td>Scale Factor Input. Adjust the output scale factor for LOGV2 using a resistive divider (see the Scale Factor section).</td>
</tr>
<tr>
<td>8</td>
<td>LOGV2</td>
<td>Logarithmic Amplifier Voltage Output 2. Adjust the output scale factor for LOGV2 using a resistive divider between SCALE, GND, and LOGV2 (see the Scale Factor section).</td>
</tr>
<tr>
<td>10</td>
<td>VCC</td>
<td>Positive Power Supply. Bypass VCC to GND with a 0.1μF capacitor.</td>
</tr>
<tr>
<td>11</td>
<td>REFISET</td>
<td>Current Reference Adjust Input. A resistor (RSET), from REFISET to GND, adjusts the current at REFIOUT (see the Adjusting the Logarithmic Intercept section).</td>
</tr>
<tr>
<td>12</td>
<td>CMVOUT</td>
<td>0V Common-Mode Voltage Reference Output</td>
</tr>
<tr>
<td>13</td>
<td>REFIOUT</td>
<td>Current Reference Output. The internal current reference output is available at REFIOUT.</td>
</tr>
<tr>
<td>14</td>
<td>REFIIN</td>
<td>Current Reference Input. Apply an external reference current at REFIIN. IREFIIN is the reference current used by the logarithmic amplifier when generating LOGV1.</td>
</tr>
<tr>
<td>15</td>
<td>LOGIIN</td>
<td>Current Input to Logarithmic Amplifier. LOGIIN is typically connected to a photodiode anode or other external current source.</td>
</tr>
<tr>
<td>16</td>
<td>CMVIN</td>
<td>Common-Mode Voltage Input. VCMVIN is the common-mode voltage for the input and reference amplifiers (see the Common Mode section).</td>
</tr>
</tbody>
</table>

Figure 1. Functional Diagram
**Detailed Description**

**Theory**

Figure 2 shows a simplified model of a logarithmic amplifier. Two transistors convert the currents applied at LOGIIN and REFIIN to logarithmic voltages according to the following equation:

\[ V_{BE} = \left( \frac{kT}{q} \right) \ln \left( \frac{I_C}{I_S} \right) \]

where:
- \( V_{BE} \) = base-emitter voltage of a bipolar transistor
- \( k = 1.381 \times 10^{-23} \text{ J/K} \)
- \( T = \text{absolute temperature (K)} \)
- \( q = 1.602 \times 10^{-19} \text{ C} \)
- \( I_C \) = collector current
- \( I_S \) = reverse saturation current

The logarithmic amplifier compares \( V_{BE1} \) to the reference voltage \( V_{BE2} \), which is a logarithmic voltage for a known reference current, \( I_{REF} \). The temperature dependencies of a logarithmic amplifier relate to the thermal voltage, \((kT/q)\), and \( I_S \). Matched transistors eliminate the \( I_S \) temperature dependence of the amplifier in the following manner:

\[ V_{OUT} = V_{BE1} - V_{BE2} = \left( \frac{kT}{q} \right) \ln \left( \frac{\text{LOG}}{I_S} \right) - \ln \left( \frac{I_{REF}}{I_S} \right) \]

\[ = \left( \frac{kT}{q} \right) \left( \ln \left( \frac{\text{LOG}}{I_{REF}} \right) - \ln \left( \frac{I_{REF}}{I_S} \right) \right) \]

\[ = \left( \frac{kT}{q} \right) \ln \left( \frac{\text{LOG}}{I_S} \right) = k \times \log_{10}\left( \frac{\text{LOG}}{I_{REF}} \right) \]

(see Figure 3)

where:
- \( k \) = scale factor (V/decade)
- \( I_{LOG} \) = the input current at LOGIIN
- \( I_{REF} \) = the reference current at REFIIN

The MAX4207 uses internal temperature compensation to virtually eliminate the effects of the thermal voltage, \((kT/q)\), on the amplifier's scale factor, maintaining a constant slope over temperature.

**Definitions**

**Transfer Function**

The ideal logarithmic amplifier transfer function is:

\[ V_{IDEAL} = K \times \log_{10}\left( \frac{\text{LOG}}{I_{REF}} \right) \]

Adjust \( K \) (see the Scale Factor section) to increase the transfer-function slope as illustrated in Figure 3. Adjust \( I_{REF} \) using REFISET (see the Adjusting the Logarithmic Intercept section) to shift the logarithmic intercept to the left or right as illustrated in Figure 4.

**Log Conformity**

Log conformity is the maximum deviation of the MAX4207's output from the best-fit straight line of the VLOGV1 versus log (LOG/IREF) curve. It is expressed as a percent of the full-scale output or an output voltage.

**Referred-to-Input and Referred-to-Output Errors**

The log nature of the MAX4207 insures that any additive error at LOGV1 corresponds to multiplicative error at the input, regardless of input level.
Total error (TE) is defined as the deviation of the output voltage, $V_{\text{LOGV1}}$, from the ideal transfer function (see the Transfer Function section):

$$V_{\text{LOGV1}} = V_{\text{IDEAL}} \pm \text{TE}$$

TE is a combination of the associated gain, input offset current, input bias current, output offset voltage, and transfer characteristic nonlinearity (log conformity) errors:

$$V_{\text{LOGV2}} = K(1 \pm \Delta K) \left[ \log_{10} \left( \frac{\log_{\text{REF}}(I_{\text{LOG}})}{\log_{\text{REF}}(I_{\text{REF}})} \right) \pm 4 \left( \pm V_{\text{LC}} \pm V_{\text{OSOUT}} \right) \right]$$

where $V_{\text{LC}}$ and $V_{\text{OSOUT}}$ are the log conformity and output offset voltages, respectively. Output offset is defined as the offset occurring at the output of the MAX4207 when equal currents are presented to $I_{\text{LOG}}$ and $I_{\text{REF}}$. Because the MAX4207 is configured with a gain of $K = -0.25$ V/decade, a 4 should multiply the $(\pm V_{\text{LC}} \pm V_{\text{OSOUT}})$ term, if $V_{\text{LC}}$ and $V_{\text{OSOUT}}$ were derived from this default configuration.

$I_{\text{BIAS1}}$ and $I_{\text{BIAS2}}$ are currents in the order of 20 pA, significantly smaller than $I_{\text{LOG}}$ and $I_{\text{REF}}$, and can therefore be eliminated:

$$V_{\text{LOGV2}} = K(1 \pm \Delta K) \left[ \log_{10} \left( \frac{\log_{\text{REF}}(I_{\text{LOG}})}{\log_{\text{REF}}(I_{\text{REF}})} \right) \pm 4 \left( \pm V_{\text{LC}} \pm V_{\text{OSOUT}} \right) \right]$$

Expanding this expression:

$$V_{\text{LOGV2}} = K \log_{10} \left( \frac{\log_{\text{REF}}(I_{\text{LOG}})}{\log_{\text{REF}}(I_{\text{REF}})} \right) \pm K \Delta K \log_{10} \left( \frac{\log_{\text{REF}}(I_{\text{LOG}})}{\log_{\text{REF}}(I_{\text{REF}})} \right)$$

$$\pm 4K(1 + \Delta K)(\pm V_{\text{LC}} \pm V_{\text{OSOUT}})$$

The first term of this expression is the ideal component of $V_{\text{LOGV1}}$. The remainder of the expression is the TE:

$$\text{TE} = \pm K \Delta K \log_{10} \left( \frac{\log_{\text{REF}}(I_{\text{LOG}})}{\log_{\text{REF}}(I_{\text{REF}})} \right) \pm 4K(1 + \Delta K)(\pm \pm V_{\text{LC}} \pm V_{\text{OSOUT}})$$

In the second term, one can generally remove the products relating to $\Delta K$, because $\Delta K$ is generally much less than 1. Hence, a good approximation for TE is given by:

$$\text{TE} = \pm K \Delta K \log_{10} \left( \frac{\log_{\text{REF}}(I_{\text{LOG}})}{\log_{\text{REF}}(I_{\text{REF}})} \right) \pm 4(\pm V_{\text{LC}} \pm V_{\text{OSOUT}})$$

As an example, consider the following situation:

- Full-scale input = 5V
- $I_{\text{LOG}} = 100\mu$A
- $I_{\text{REF}} = 100n$A
- $K = 1 \pm 5\%$ V/decade (note that the uncommitted amplifier is configured for a gain of 4)
- $V_{\text{LC}} = \pm 5$mV (obtained from the Electrical Characteristics table)
- $V_{\text{OSOUT}} = \pm 2$mV (typ), and $T_{\text{A}} = +25^\circ$C.
Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

Substituting into the TE approximation,

$$TE \approx \pm (1\text{V/decade})(0.05 \log_{10} (100\mu A/100nA))$$

$$\pm 4 (\pm 5mV \pm 2mV) = \pm [0.15V \pm 4(\pm 7mV)]$$

As a worst case, one finds TE = ±178mV or ±3.6% of full scale.

When expressed as a voltage, TE increases in proportion with an increase in gain as the contributing errors are defined at a specific gain. Calibration using a look-up table eliminates the effects of gain and output offset errors, leaving conformity error as the only factor contributing to total error. For further accuracy, consider temperature monitoring as part of the calibration process.

Applications Information

Input Current Range

Five decades of input current across a 10nA to 1mA range are acceptable for ILOG and IREF. The effects of bias currents increase as ILOG and IREF fall below 10nA. Bandwidth decreases at low ILOG values (see the Frequency Response and Noise Considerations section). As ILOG and IREF increase to 1mA or higher, transistors become less logarithmic in nature. The MAX4207 incorporates leakage current compensation and high-current correction circuits to compensate for these errors.

Frequency Compensation

The MAX4207’s frequency response is a function of the input current magnitude and the selected compensation network at LOGIIN and REFIIN. The compensation network comprised of CCOMP and RCOMP ensures stability over the specified range of input currents by introducing an additional pole/zero to the system. For the typical application, select CCOMP = 32pF and RCOMP = 330Ω.

Frequency Response and Noise Considerations

The MAX4207 bandwidth is proportional to the magnitude of the IREF and ILOG currents, whereas the noise is inversely proportional to IREF and ILOG currents.

Common Mode

A 0V common-mode input voltage, VCMVOUT, is available at CMVOUT and can be used to bias the logging and reference amplifier inputs by connecting CMVOUT to CMVIN. A voltage between 0 and 0.5V, connected to CMVIN, may be used to bias the logging and reference transistor collectors, thereby optimizing performance.

Adjusting the Logarithmic Intercept

Adjust the logarithmic intercept by changing the reference current, IREF. A resistor from REFISET to GND (see Figure 5) adjusts the reference current, according to the following equation:

$$R_{SET} = \frac{V_{REFISET}}{10 \times I_{REF}}$$

where VREFISET is 0.5V. Select RSET between 5kΩ and 5MΩ. REFIOUT current range is 10nA to 10µA only.

Dual-Supply Operation

The MAX4207 operates only from dual ±2.7 to ±5.5V supplies. The relationship of inputs to outputs is a function of IREF, relative to ILOG, and the configuration of the uncommitted amplifier. The uncommitted amplifier can be configured in either inverting or noninverting mode. In an inverting configuration, the uncommitted amplifier output, LOGV2, is positive and LOGV1 is negative when ILOG exceeds IREF. When operating in a noninverting configuration, LOGV2 and LOGV1 are both negative when ILOG exceeds IREF (see Table 1). An inverting configuration of the uncommitted buffer is recommended when large output offset voltage adjustments are required using OSADJ. By connecting CMVOUT and CMVIN, the log and reference amplifier inputs (LOGIIN and REFIIN) are biased at 0V. Applying the external voltage (0 to 0.5V) to CMVIN optimizes the application’s performance.

Figure 5. Typical Operating Circuit
Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

Table 1. MAX4207 Example Configurations

<table>
<thead>
<tr>
<th>LOGV2 AMPLIFIER CONFIGURATION</th>
<th>INPUT CONDITIONS</th>
<th>( V_{LOGV1} )</th>
<th>( V_{LOGV2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverting</td>
<td>( I_{LOG} &gt; I_{REF} ) (constant)</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>( I_{LOG} &lt; I_{REF} ) (constant)</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Noninverting</td>
<td>( I_{LOG} &gt; I_{REF} ) (constant)</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>( I_{LOG} &lt; I_{REF} ) (constant)</td>
<td>Positive</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Output Offset

The inverting configuration utilized by the MAX4207 facilitates large output-offset voltage adjustments. The magnitude of the offset voltage is given by the following equation:

\[
\Delta V_{OFFSET} = V_{REFVOUT} \left( 1 + \frac{R_2}{R_1} \right)
\]

A resistive divider between \( V_{REFVOUT} \), \( V_{OSADJ} \), and \( V_{GND} \) can be used to adjust \( V_{OSADJ} \) (see Figure 5).

\[
V_{OSADJ} = V_{REFVOUT} \left( \frac{R_4}{R_3 + R_4} \right)
\]

Scale Factor

The scale factor, \( K \), is the slope of the logarithmic output. For the LOGV1 amplifier, \( K = -0.25 \) V/decade. Adjust the overall scale factor for the MAX4207 using the uncommitted LOGV2 amplifier and the following equation, which refers to Figure 5:

\[
R_2 = R_1 \left[ \frac{K}{0.25} \right]
\]

Select \( R_2 \) between 1 k\( \Omega \) and 100 k\( \Omega \).

Design Example

Desired:
- Logarithmic intercept: 1 \( \mu A \)
- Overall scale factor = +1 V/decade

\[
R_{SET} = \frac{0.5 \text{V}}{10 \times 1 \mu A} = 50 \text{k}\Omega
\]

Select \( R_1 = 10 \text{k}\Omega \):

\[
R_2 = 10 \text{k}\Omega \times \left[ \frac{1 \text{V/decade}}{-0.25} \right] = 40 \text{k}\Omega
\]

Photodiode Current Monitoring

Figure 6 shows the MAX4207 in an optical-power measurement circuit, common in fiberoptic applications. The MAX4007 current monitor converts the sensed APD current to an output current that drives the MAX4207 LOGIIN input (APD current is scaled by 0.1). The MAX4007 also buffers the high-voltage APD voltages from the lower MAX4207 voltages. The MAX4207’s internal current reference sources 10 nA (\( R_{SET} = 5 \text{M}\Omega \)) to the REFIIN input. This configuration sets the logarithmic intercept to 10 nA, corresponding to an APD current of 100 nA. The unity-gain configuration of the output buffer maintains the -0.25 V/decade gain present at the LOGV1 output.

Measuring Optical Absorbance

A photodiode provides a convenient means of measuring optical power, as diode current is proportional to the incident optical power. Measure absolute optical power using a single photodiode connected at LOGIIN, with the MAX4207’s internal current reference driving REFIIN. Alternatively, connect a photodiode to each of the MAX4207’s logging inputs, LOGIIN and REFIIN, to measure relative optical power (Figure 7).

In absorbance measurement instrumentation, a reference light source is split into two paths. The unfiltered path is incident upon the photodiode of the reference channel, REFIIN. The other path passes through a sample of interest, with the resulting filtered light incident on the photodiode of the second channel, LOGIIN. The MAX4207 outputs provide voltages proportional to the log ratio of the two optical powers—an indicator of the optical absorbance of the sample.

In wavelength-locking applications, often found in fiberoptic communication modules, two photodiode currents provide a means of determining whether a given optical channel is tuned to the desired optical frequency. In this application, two bandpass optical filters with overlapping “skirts” precede each photodiode. With proper filter selection, the MAX4207 output can vary monotonically (ideally linearly) with optical frequency.
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**Capacitive Loads**

The MAX4207 drives capacitive loads of up to 50pF. Reactive loads decrease phase margin and can produce excessive ringing and oscillation. Use an isolation resistor in series with LOGV1 or LOGV2 to reduce the effect of large capacitive loads. Recall that the combination of the capacitive load and the small isolation resistor limits AC performance.

**Power Dissipation**

The LOGV1 and LOGV2 amplifiers are capable of sourcing or sinking in excess of 30mA. Ensure that the continuous power dissipation rating for the MAX4207 is not exceeded.

**TQFN Package**

The 16-lead thin QFN package has an exposed paddle that provides a heat-removal path, as well as excellent electrical grounding to the PC board. The MAX4207’s exposed pad is internally connected to VEE, and can either be connected to the PC board VEE plane or left unconnected. Ensure that only VEE traces are routed under the exposed paddle.
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**Layout and Bypassing**

Bypass VCC and VEE to GND with ceramic 0.1µF capacitors. Place the capacitors as close to the device as possible. Bypass REFVOUT and/or CMVOUT to GND with a 0.1µF ceramic capacitor for increased noise immunity and a clean reference current. For low-current operation, it is recommended to use metal guard rings around LOGIIN, REFIIN, and REFSET. Connect this guard ring to CMVOUT.

**Chip Information**

TRANSISTOR COUNT: 754
PROCESS: BICMOS
Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)