Precision
LOGARITHMIC AND LOG RATIO AMPLIFIER

FEATURES

- **EASY-TO-USE COMPLETE CORE FUNCTION**
- **HIGH ACCURACY:** 0.01% FSO Over 5 Decades
- **WIDE INPUT DYNAMIC RANGE:**
  7.5 Decades, 100pA to 3.5mA
- **LOW QUIESCENT CURRENT:** 1mA
- **WIDE SUPPLY RANGE:** ±4.5V to ±18V

APPLICATIONS

- **LOG, LOG RATIO COMPUTATION:**
  Communication, Analytical, Medical, Industrial, Test, and General Instrumentation
- **PHOTODIODE SIGNAL COMPRESSION AMPS**
- **ANALOG SIGNAL COMPRESSION IN FRONT OF ANALOG-TO-DIGITAL (A/D) CONVERTERS**

DESCRIPTION

The LOG101 is a versatile integrated circuit that computes the logarithm or log ratio of an input current relative to a reference current.

The LOG101 is tested over a wide dynamic range of input signals. In log ratio applications, a signal current can come from a photodiode, and a reference current from a resistor in series with a precision external reference.

The output signal at \( V_{OUT} \) is trimmed to 1V per decade of input current allowing seven decades of input current dynamic range.

Low DC offset voltage and temperature drift allow accurate measurement of low-level signals over a wide environmental temperature range. The LOG101 is specified over the temperature range \(-5°C\) to \(+75°C\), with operation over \(-40°C\) to \(+85°C\).

Note: Protected under US Patent #6,667,650; other patents pending.

\[ V_{OUT} = (1V) \cdot \log\left(\frac{I_1}{I_2}\right) \]

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage, \(V_+\) to \(V_-\) ......................................................... 36V
Input Voltage ................................................................. \((V_-) - 0.5\) to \((V_+)+ 0.5V\)
Input Current ........................................................................ \(\pm 10\mu A\)
Output Short-Circuit(2) .......................................................... Continuous
Operating Temperature ......................................................... \(-40^\circ C\) to \(+85^\circ C\)
Storage Temperature .............................................................. \(-55^\circ C\) to \(+125^\circ C\)
Junction Temperature ............................................................ \(+150^\circ C\)
Lead Temperature (soldering, 10s) ...................................... \(+300^\circ C\)

NOTES:  (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. (2) Short-circuit to ground.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION(1)

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PACKAGE-LEAD</th>
<th>PACKAGE DESIGNATOR</th>
<th>SPECIFIED TEMPERATURE RANGE</th>
<th>PACKAGE MARKING</th>
<th>ORDERING NUMBER</th>
<th>TRANSPORT MEDIA, QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOG101AID</td>
<td>SO-8 D</td>
<td>-5°C to +75°C</td>
<td>LOG101</td>
<td>LOG101AID Rails, 100</td>
<td>LOG101AIDR Tape and Reel, 2500</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: (1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.

ELECTRICAL CHARACTERISTICS

**Boldface limits** apply over the specified temperature range, \(T_A = -5^\circ C\) to \(+75^\circ C\).

At \(T_A = +25^\circ C\), \(V_S = \pm 5V\), and \(R_{OUT} = 10k\Omega\), unless otherwise noted.

### PARAMETER

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>LOG101AID</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>TYP</td>
</tr>
<tr>
<td>(I_{IN}/V_{OUT} ) Equation</td>
<td>(V_O = (1V) \cdot \log (I_{1}/I_{2}))</td>
</tr>
<tr>
<td>LOG CONFORMITY ERROR(1)</td>
<td></td>
</tr>
<tr>
<td>Initial 1nA to 100(\mu)A (5 decades)</td>
<td>0.01</td>
</tr>
<tr>
<td>100pA to 3.5mA (7.5 decades)</td>
<td>0.06</td>
</tr>
<tr>
<td>over Temperature 1nA to 100(\mu)A (5 decades)</td>
<td>0.0001</td>
</tr>
<tr>
<td>100pA to 3.5mA (7.5 decades)</td>
<td>0.0005</td>
</tr>
<tr>
<td>GAIN(3)</td>
<td></td>
</tr>
<tr>
<td>Initial Value 1nA to 100(\mu)A</td>
<td>1</td>
</tr>
<tr>
<td>Gain Error 1nA to 100(\mu)A</td>
<td>0.15</td>
</tr>
<tr>
<td>vs Temperature (T_{MIN}) to (T_{MAX})</td>
<td>0.003</td>
</tr>
<tr>
<td>INPUT, A1 and A2</td>
<td></td>
</tr>
<tr>
<td>Offset Voltage (\text{vs} ) Temperature (V_S = 3.45V) to (\pm 18V)</td>
<td></td>
</tr>
<tr>
<td>vs Power Supply (PSRR) (V_S = \pm 5) to (\pm 18V)</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current (\text{vs} ) Temperature (T_{MIN}) to (T_{MAX})</td>
<td></td>
</tr>
<tr>
<td>Voltage Noise (f = 10)Hz to (10kHz)</td>
<td></td>
</tr>
<tr>
<td>(f = 1kHz)</td>
<td>3</td>
</tr>
<tr>
<td>Current Noise</td>
<td>4</td>
</tr>
<tr>
<td>Common-Mode Voltage Range (Positive)</td>
<td>((V_+)-2)</td>
</tr>
<tr>
<td>Common-Mode Voltage Range (Negative)</td>
<td>((V_-)+2)</td>
</tr>
<tr>
<td>Common-Mode Rejection Ratio (CMRR)</td>
<td>105</td>
</tr>
<tr>
<td>OUTPUT, A2 ((V_{OUT}))</td>
<td></td>
</tr>
<tr>
<td>Output Offset, (V_{OSO} ) Initial</td>
<td>(\pm 0.3)</td>
</tr>
<tr>
<td>vs Temperature Doubles Every 10°C (V_S = \pm 5V)</td>
<td>(\pm 2)</td>
</tr>
<tr>
<td>Full-Scale Output (FSO) (V_S = \pm 5V)</td>
<td>5</td>
</tr>
<tr>
<td>Short-Circuit Current</td>
<td></td>
</tr>
<tr>
<td>Short-Circuit Current (V_S = \pm 5V)</td>
<td></td>
</tr>
</tbody>
</table>

\(T_{MAX}\) is limited by \(V_S = \pm 5V\) for \(V_+\) and \(V_-\).
ELECTRICAL CHARACTERISTICS (Cont.)

Boldface limits apply over the specified temperature range, $T_A = -5^\circ C$ to $+75^\circ C$.

At $T_A = +25^\circ C$, $V_S = \pm 5V$, and $R_L = 10k\Omega$, unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITION</th>
<th>LOG101AID</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL ERROR$^{(4)(5)}$</td>
<td>$I_1$ or $I_2$ remains fixed while other varies.</td>
<td>MIN</td>
</tr>
<tr>
<td>Initial</td>
<td>$I_1$ or $I_2 = 3.5mA$</td>
<td>$\pm 75$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1mA$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100\mu A$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1\mu A$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100nA$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 10nA$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1nA$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 350pA$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100pA$</td>
<td>$\pm 20$ mV</td>
</tr>
<tr>
<td>vs Temperature</td>
<td>$I_1$ or $I_2 = 3.5mA$</td>
<td>$\pm 1.2$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1mA$</td>
<td>$\pm 0.4$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100\mu A$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1\mu A$</td>
<td>$\pm 0.05$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100nA$</td>
<td>$\pm 0.09$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 10nA$</td>
<td>$\pm 0.2$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1nA$</td>
<td>$\pm 0.3$ mV/$^\circ C$</td>
</tr>
<tr>
<td>vs Supply</td>
<td>$I_1$ or $I_2 = 3.5mA$</td>
<td>$\pm 0.3$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1mA$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100\mu A$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1\mu A$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100nA$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 10nA$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 1nA$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 350pA$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
<tr>
<td></td>
<td>$I_1$ or $I_2 = 100pA$</td>
<td>$\pm 0.1$ mV/$^\circ C$</td>
</tr>
</tbody>
</table>

FREQUENCY RESPONSE, CORE LOG$^{(6)}$

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW, 3dB</td>
<td>$I_2 = 10nA$</td>
<td>$C_C = 4500pF$</td>
<td>0.1</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$I_2 = 1\mu A$</td>
<td>$C_C = 1500pF$</td>
<td>38</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$I_2 = 10\mu A$</td>
<td>$C_C = 150pF$</td>
<td>40</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$I_2 = 1mA$</td>
<td>$C_C = 50pF$</td>
<td>45</td>
<td>kHz</td>
<td></td>
</tr>
</tbody>
</table>

Step Response

Increasing

| $I_2 = 1\mu A$ to 1mA | $C_C = 150pF$ | 11 | $\mu s$ |
| $I_2 = 100nA$ to 1$\mu A$ | $C_C = 150pF$ | 7 | $\mu s$ |
| $I_2 = 10nA$ to 100nA | $C_C = 150pF$ | 110 | $\mu s$ |

Decreasing

| $I_2 = 1mA$ to 1$\mu A$ | $C_C = 150pF$ | 45 | $\mu s$ |
| $I_2 = 1$ $\mu A$ to 100nA | $C_C = 150pF$ | 20 | $\mu s$ |
| $I_2 = 100nA$ to 10nA | $C_C = 150pF$ | 550 | $\mu s$ |

POWER SUPPLY

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Range</td>
<td>$V_S$</td>
<td>$\pm 4.5$</td>
<td>1</td>
<td>$\pm 18$</td>
<td>V</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>$I_Q = 0$</td>
<td>1</td>
<td>$\pm 1.5$</td>
<td>mA</td>
<td></td>
</tr>
</tbody>
</table>

TEMPERATURE RANGE

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified Range, $T_{MIN}$ to $T_{MAX}$</td>
<td>$-5$</td>
<td>75</td>
<td>$^\circ C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Range</td>
<td>$-40$</td>
<td>85</td>
<td>$^\circ C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Range</td>
<td>$-55$</td>
<td>125</td>
<td>$^\circ C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance, $\theta_{JA}$ SO-8</td>
<td></td>
<td>150</td>
<td>$^\circ C/W$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES: (1) Log Conformity Error is peak deviation from the best-fit straight line of $V_{OUT}$ versus log ($I_1/I_2$) curve expressed as a percent of peak-to-peak full-scale.

(2) May require higher supply for full dynamic range.

(3) Output core log function is trimmed to 1V output per decade change of input current.

(4) Worst-case Total Error for any ratio of $I_1/I_2$ is the largest of the two errors, when $I_1$ and $I_2$ are considered separately.

(5) Total $I_1 + I_2$ should be kept below 4.5mA on ±5V supply.

(6) Bandwidth (3dB) and transient response are a function of both the compensation capacitor and the level of input current.
TYPICAL CHARACTERISTICS

At $T_A = +25^\circ C$, $V_S = \pm 5V$, and $R_L = 10k\Omega$, unless otherwise noted.

**NORMALIZED TRANSFER FUNCTION**

$V_{OUT} = 1V \cdot \log(I_1/I_2)$

**ONE CYCLE OF NORMALIZED TRANSFER FUNCTION**

Normalized Output Voltage (V)

**TOTAL ERROR vs INPUT CURRENT**

Gain Error (%)

**MINIMUM VALUE OF COMPENSATION CAPACITOR**

Select $C_C$ for $I_1$ min. and $I_2$ max. Values below 2pF may be ignored.

**3dB FREQUENCY RESPONSE**

3dB Frequency Response (Hz)
TYPICAL CHARACTERISTICS (Cont.)

At $T_A = +25^\circ C$, $V_S = \pm 5V$, and $R_L = 10k\Omega$, unless otherwise noted.

APPLICATION INFORMATION

The LOG101 is a true logarithmic amplifier that uses the base-emitter voltage relationship of bipolar transistors to compute the logarithm, or logarithmic ratio of a current ratio. Figure 1 shows the basic connections required for operation of the LOG101. In order to reduce the influence of lead inductance of power-supply lines, it is recommended that each supply be bypassed with a $10\mu F$ tantalum capacitor in parallel with a $1000pF$ ceramic capacitor, as shown in Figure 1. Connecting the capacitors as close to the LOG101 as possible will contribute to noise reduction as well.

INPUT CURRENT RANGE

To maintain specified accuracy, the input current range of the LOG101 should be limited from 100pA to 3.5mA. Input currents outside of this range may compromise LOG101 performance. Input currents larger than 3.5mA result in increased nonlinearity. An absolute maximum input current rating of 10mA is included to prevent excessive power dissipation that may damage the logging transistor.

On $\pm 5V$ supplies, the total input current ($I_1 + I_2$) is limited to 4.5mA. Due to compliance issues internal to the LOG101, to accommodate larger total input currents, supplies should be increased.

Currents smaller than 100pA will result in increased errors due to the input bias currents of op amps $A_1$ and $A_2$ (typically 5pA). The input bias currents may be compensated for, as shown in Figure 2. The input stages of the amplifiers have FET inputs, with input bias current doubling every $10^\circ C$, which makes the nulling technique shown practical only where the temperature is fairly stable.

FIGURE 1. Basic Connections of the LOG101.

FIGURE 2. Bias Current Nulling.
SETTING THE REFERENCE CURRENT

When the LOG101 is used to compute logarithms, either \( I_1 \) or \( I_2 \) can be held constant and becomes the reference current to which the other is compared.

\[
V_{\text{OUT}} = (1V) \cdot \log \left( \frac{I_1}{I_2} \right) \quad (1)
\]

\( I_{\text{REF}} \) can be derived from an external current source (such as shown in Figure 3), or it may be derived from a voltage source with one or more resistors. When a single resistor is used, the value may be large depending on \( I_{\text{REF}} \). If \( I_{\text{REF}} \) is 10nA and +2.5V is used:

\[
R_{\text{REF}} = \frac{2.5V}{10nA} = 250M\Omega \quad (2)
\]

FREQUENCY RESPONSE

The frequency response curve seen in the Typical Characteristic Curves is shown for constant DC \( I_1 \) and \( I_2 \) with a small signal AC current on one input.

The 3dB frequency response of the LOG101 is a function of the magnitude of the input current levels and of the value of the frequency compensation capacitor. See Typical Characteristic Curve “3dB Frequency Response” for details.

The transient response of the LOG101 is different for increasing and decreasing signals. This is due to the fact that a log amp is a nonlinear gain element and has different gains at different levels of input signals. Smaller input currents require greater gains to maintain full dynamic range, and will slow the frequency response of the LOG101.

NEGATIVE INPUT CURRENTS

The LOG101 will function only with positive input currents (conventional current flows into pins 1 and 8). In situations where negative input currents are needed, the circuits in Figures 6, 7, and 8 may be used.
FIGURE 7. Precision Current Inverter/Current Source.

VOLTAGE INPUTS
The LOG101 gives the best performance with current inputs. Voltage inputs may be handled directly with series resistors, but the dynamic input range is limited to approximately three decades of input voltage by voltage noise and offsets. The transfer function of Equation (13) applies to this configuration.

APPLICATION CIRCUITS
LOG RATIO
One of the more common uses of log ratio amplifiers is to measure absorbance. A typical application is shown in Figure 9.

Absorbance of the sample is \( A = \log \frac{\lambda_2}{\lambda_1} \)  

If \( D_1 \) and \( D_2 \) are matched \( A \propto (1V) \log I_1/I_2 \) \( (4) \)

DATA COMPRESSION
In many applications the compressive effects of the logarithmic transfer function are useful. For example, a LOG101 preceding a 12-bit Analog-to-Digital (A/D) converter can produce the dynamic range equivalent to a 20-bit converter.

FIGURE 8. Precision Current Inverter/Current Source.


OPERATION ON SINGLE SUPPLY
Many applications do not have the dual supplies required to operate the LOG101. Figure 10 shows the LOG101 configured for operation with a single +5V supply.

FIGURE 10. Single +5V Power-Supply Operation.
Using the base-emitter voltage relationship of matched bipolar transistors, the LOG101 establishes a logarithmic function of input current ratios. Beginning with the base-emitter voltage defined as:

\[ V_{BE} = V_T \ln \frac{I_C}{I_S} \quad \text{where} \quad V_T = \frac{kT}{q} \]  

(1)

\[ k = \text{Boltzman's constant} = 1.381 \times 10^{-23} \]

\[ T = \text{Absolute temperature in degrees Kelvin} \]

\[ q = \text{Electron charge} = 1.602 \times 10^{-19} \text{ Coulombs} \]

\[ I_C = \text{Collector current} \]

\[ I_S = \text{Reverse saturation current} \]

From the circuit in Figure 11, we see that:

\[ V_L = V_{BE1} - V_{BE2} \]  

(2)

Substituting (1) into (2) yields:

\[ V_L = V_T \left( \ln \frac{I_1}{I_{S1}} - \ln \frac{I_2}{I_{S2}} \right) \]  

(3)

If the transistors are matched and isothermal and \( V_{T1} = V_{T2} \), then (3) becomes:

\[ V_L = V_T \left( \ln \frac{I_1}{I_{S1}} - \ln \frac{I_2}{I_{S2}} \right) \]  

(4)

\[ V_L = V_T \ln \frac{I_1}{I_2} \quad \text{and since} \]

\[ \ln x = 2.3 \log_{10} x \]  

(5)

\[ V_L = n V_T \log_{10} \frac{I_1}{I_2} \]  

(6)

where \( n = 2.3 \)

(7)

\[ \text{also} \]

\[ V_{OUT} = V_L \frac{R_{1} + R_{2}}{R_{1}} \]  

(9)

\[ V_{OUT} = \frac{R_{1} + R_{2}}{R_{1}} n V_T \log_{10} \frac{I_1}{I_2} \]  

(10)

or

\[ V_{OUT} = (1V) \cdot \log_{10} \frac{I_1}{I_2} \]  

(11)

It should be noted that the temperature dependence associated with \( V_T = kT/q \) is internally compensated on the LOG101 by making \( R_1 \) a temperature sensitive resistor with the required positive temperature coefficient.

**DEFINITION OF TERMS**

**TRANSFER FUNCTION**

The ideal transfer function is:

\[ V_{OUT} = 1V \cdot \log \left( \frac{I_1}{I_2} \right) \]  

(5)

Figure 12 shows the graphical representation of the transfer over valid operating range for the LOG101.

**ACCURACY**

Accuracy considerations for a log ratio amplifier are somewhat more complicated than for other amplifiers. This is because the transfer function is non-linear and has two inputs, each of which can vary over a wide dynamic range. The accuracy for any combination of inputs is determined from the total error specification.
TOTAL ERROR

The total error is the deviation (expressed in mV) of the actual output from the ideal output of $V_{OUT} = 1 \cdot \log(I_1/I_2)$.

Thus,

$$V_{OUT(Actual)} = V_{OUT(Ideal)} \pm \text{Total Error}. \quad (6)$$

It represents the sum of all the individual components of error normally associated with the log amp when operated in the current input mode. The worst-case error for any given ratio of $I_1/I_2$ is the largest of the two errors when $I_1$ and $I_2$ are considered separately. Temperature can affect total error.

ERRORS RTO AND RTI

As with any transfer function, errors generated by the function itself may be Referred-to-Output (RTO) or Referred-to-Input (RTI). In this respect, log amps have a unique property:

Given some error voltage at the log amp’s output, that error corresponds to a constant percent of the input regardless of the actual input level.

USING A LARGER REFERENCE VOLTAGE REDUCES OFFSET ERRORS

Using a larger reference voltage to create the reference current minimizes errors due to the LOG101’s input offset voltage. Maintaining an increasing output voltage as a function of increasing photodiode current is also important in many optical sensing applications. All zeros from the A/D converter output represent zero or low-scale photodiode current. Inputting the reference current into $I_1$, and designing $I_{REF}$ such that it is as large or larger than the expected maximum photodiode current is accomplished using this requirement. The LOG101 configured with the reference current connecting $I_1$ and the photodiode current connecting to $I_2$ is shown in Figure 13. The OPA703 is configured as a level shifter with inverting gain and is used to scale the photodiode current directly into the A/D converter input voltage range.

The wide dynamic range of the LOG101 is also useful for measuring avalanche photodiode current (APD) (see Figure 14).

LOG CONFORMITY

For the LOG101, log conformity is calculated the same as linearity and is plotted $I_1/I_2$ on a semi-log scale. In many applications, log conformity is the most important specification. This is because bias current errors are negligible (5pA compared to input currents of 100pA and above) and the scale factor and offset errors may be trimmed to zero or removed by system calibration. This leaves log conformity as the major source of error.

Log conformity is defined as the peak deviation from the best fit straight line of the $V_{OUT}$ versus log ($I_1/I_2$) curve. This is expressed as a percent of ideal full-scale output. Thus, the nonlinearity error expressed in volts over m decades is:

$$V_{OUT(NONLIN)} = 1/V_{DEC} \cdot 2N_{mV} \quad (7)$$

where $N$ is the log conformity error, in percent.

INDIVIDUAL ERROR COMPONENTS

The ideal transfer function with current input is:

$$V_{OUT} = (1V) \cdot \log I_1/I_2 \quad (8)$$

The actual transfer function with the major components of error is:

$$V_{OUT} = (1V)(1 \pm \Delta K) \log \frac{I_1 - I_{b1}}{I_2 - I_{b2}} \pm 2N_{mV} \pm V_{OSO} \quad (9)$$

FIGURE 13. Technique for Using Full-Scale Reference Current Such that $V_{OUT}$ Increases with Increasing Photodiode Current.
The individual component of error is:

\[ \Delta K = \text{gain accuracy (0.15\%, typ), as specified in the specification table.} \]

\[ I_{B1} = \text{bias current of } A_1 \text{ (5pA, typ)} \]

\[ I_{B2} = \text{bias current of } A_2 \text{ (5pA, typ)} \]

\[ N = \text{log conformity error (0.01\%, 0.06\%, typ)} \]

0.01\% for \( n = 5 \), 0.06\% for \( n = 7 \)

\[ V_{OSO} = \text{output offset voltage (3mV, typ)} \]

\[ n = \text{number of decades over which } N \text{ is specified:} \]

Example: what is the error when

\[ I_1 = 1\mu A \text{ and } I_2 = 100nA \]

\[ V_{OUT} = (1 \pm 0.0015)\log \left( 10^6 - 5 \cdot 10^{-12} \right) = 1.005055V \]

Since the ideal output is 1.000V, the error as a percent of reading is

\[ \% \text{error} = \frac{0.005055}{1} \cdot 100\% = 0.5\% \]

For the case of voltage inputs, the actual transfer function is

\[ V_{OUT} = \frac{(1V)(1 \pm \Delta K)\log \left( \frac{V_1 - I_{B1} \pm E_{OS1}}{R_1} \right) + 2Nn \pm V_{OSO}}{R_2 - I_{B2} \pm E_{OS2}} \]

Where \( E_{OS1} \) and \( E_{OS2} \) are considered to be zero for large values of resistance from external input current sources.
## PACKAGING INFORMATION

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOG101AID</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>8</td>
<td>75</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-3-260C-168 HR</td>
<td>-40 to 85</td>
<td>LOG101A</td>
<td>Samples</td>
</tr>
<tr>
<td>LOG101AIDE4</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>8</td>
<td>75</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-3-260C-168 HR</td>
<td>-40 to 85</td>
<td>LOG101A</td>
<td>Samples</td>
</tr>
<tr>
<td>LOG101AIDR</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>8</td>
<td>2500</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-3-260C-168 HR</td>
<td>-40 to 85</td>
<td>LOG101A</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check [http://www.ti.com/productcontent](http://www.ti.com/productcontent) for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) **MSL, Peak Temp.** - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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### TAPE AND REEL INFORMATION

#### REEL DIMENSIONS

![Reel Diagram]

#### TAPE DIMENSIONS

<table>
<thead>
<tr>
<th>A0</th>
<th>Dimension designed to accommodate the component width</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0</td>
<td>Dimension designed to accommodate the component length</td>
</tr>
<tr>
<td>K0</td>
<td>Dimension designed to accommodate the component thickness</td>
</tr>
<tr>
<td>W</td>
<td>Overall width of the carrier tape</td>
</tr>
<tr>
<td>P1</td>
<td>Pitch between successive cavity centers</td>
</tr>
</tbody>
</table>

#### TAPE AND REEL INFORMATION

*All dimensions are nominal.

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin1 Quadrant</th>
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<td>D</td>
<td>8</td>
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<td>5.2</td>
<td>2.1</td>
<td>8.0</td>
<td>12.0</td>
<td>Q1</td>
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### TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
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<tbody>
<tr>
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<td>SOIC</td>
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<td>2500</td>
<td>367.0</td>
<td>367.0</td>
<td>35.0</td>
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</tbody>
</table>
NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.
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