SBOS211B – DECEMBER 2001– REVISED APRIL 2005

# Precision LOGARITHMIC AND LOG RATIO AMPLIFIER

## FEATURES

- EASY-TO-USE COMPLETE LOG RATIO FUNCTION
- OUTPUT AMPLIFIERS FOR SCALING AND SIGNAL LOSS INDICATION
- HIGH ACCURACY: 0.15% FSO Total Error Over 6 Decades
- WIDE INPUT DYNAMIC RANGE: 6 Decades, 1nA to 1mA
- LOW QUIESCENT CURRENT: 1.25mA
- SO-14 PACKAGE

## APPLICATIONS

- ONET, OPTICAL POWER METERS
- LOG, LOG RATIO COMPUTATION: Communication, Analytical, Medical, Industrial, Test, General Instrumentation
- PHOTODIODE SIGNAL COMPRESSION AMP
- ANALOG SIGNAL COMPRESSION IN FRONT OF A/D CONVERTER
- ABSORBANCE MEASUREMENT
- OPTICAL DENSITY MEASUREMENT

## DESCRIPTION

The LOG102 is a versatile integrated circuit that computes the logarithm or log ratio of an input current relative to a reference current.

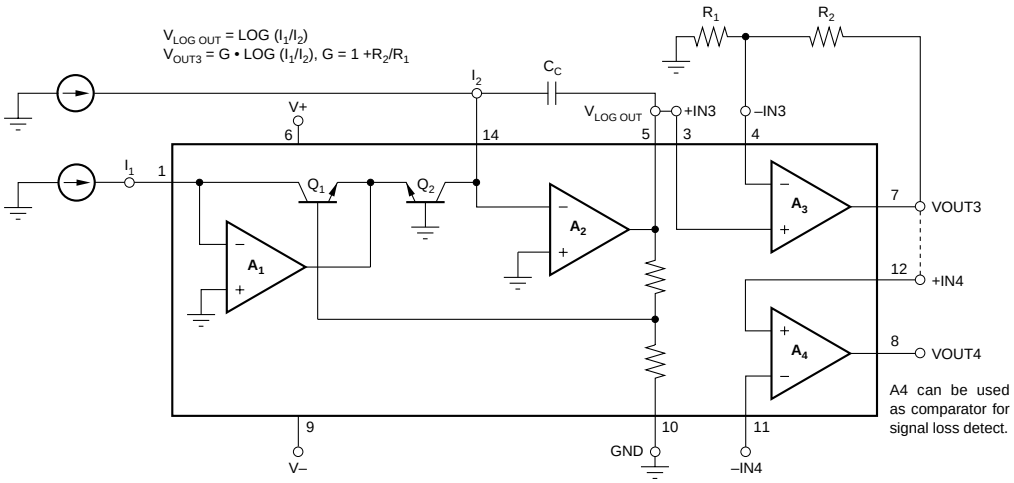
The LOG102 is tested over a wide dynamic range of input signals. In log ratio applications, a signal current can be generated by a photodiode, and a reference current from a resistor in series with a precision external voltage reference.

In the block diagram shown below, A3 and A4 are identical, uncommitted op amps that can be used for a variety of functions, such as filtering, offsetting, adding gain or as a comparator to detect loss of signal.

The output signal at $V_{LOG\ OUT}$ is trimmed to 1V per decade of input current. It can be scaled with an output amplifier, either A3 or A4.

Low dc offset voltage and temperature drift allow accurate measurement of low-level signals over a wide environmental temperature range. The LOG102 is specified over the temperature range, 0°C to +70°C, with operation over –40°C to +85°C.

NOTE: U.S. Patent Pending.




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.

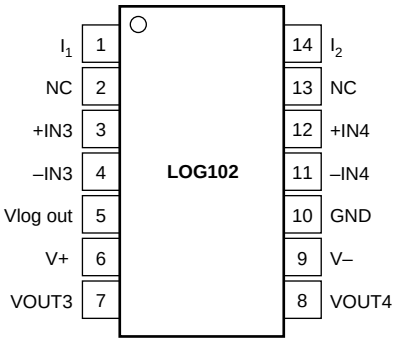
## ABSOLUTE MAXIMUM RATINGS[1]

| | |
|---|---|
| Supply Voltage, V+ to V– | 36V |
| Input Voltage | V– (–0.5) to V+ (+0.5V) |
| Input Current | ±10mA |
| Output Short-Circuit[2] | Continuous |
| Operating Temperature | –40°C to +85°C |
| Storage Temperature | –55°C to +125°C |
| Junction Temperature | +150°C |
| Lead Temperature (soldering, 10s) | +300°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, one amplifier per package.

## PIN DESCRIPTION

**Top View** **SO**




NC = No Internal Connection

## 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]

| PRODUCT | PACKAGE-LEAD | PACKAGE DESIGNATOR | PACKAGE MARKING |
|---|---|---|---|
| LOG102AID | SO-14 | D | LOG102A |

NOTES: (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

# ELECTRICAL CHARACTERISTICS

**Boldface** limits apply over the specified temperature range, **$T_A$ = 0°C to +70°C.**

At $T_A$ = +25°C, $V_S$ = ±5V, $R_L$ = 10kΩ, unless otherwise noted.

| PARAMETER | CONDITION | LOG102AID MIN | LOG102AID TYP | LOG102AID MAX | UNITS |
|---|---|---|---|---|---|
| **CORE LOG FUNCTION** | | | | | |
| $I_{IN}/V_{LOG\ OUT}$ Equation | | | $V_O = \log (I_1/I_2)$ | | |
| **LOG CONFORMITY ERROR[1]** | | | | | |
| Initial | 1nA to 100µA (5 decades) | | 0.04 | ±0.3 | % |
| | 1nA to 1mA (6 decades) | | 0.15 | | % |
| **over Temperature** | **1nA to 100µA (5 decades)** | | **0.0002** | | **%/°C** |
| | **1nA to 1mA (6 decades)** | | **0.002** | | **%/°C** |
| **GAIN[2]** | | | | | |
| Initial Value | 1nA to 100µA (5 decades) | | 1 | | V/decade |
| Gain Error | 1nA to 100µA (5 decades) | | 0.15 | ±1 | % |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **0.025** | **0.05** | **%/°C** |
| **INPUT, A1 and A2** | | | | | |
| Offset Voltage | | | ±0.3 | ±1.5 | mV |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **±2** | | **µV/°C** |
| vs Power Supply (PSRR) | $V_S$ = ±4.5V to ±18V | | 5 | 50 | µV/V |
| Input Bias Current | | | ±5 | | pA |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **Doubles Every 10°C** | | |
| Voltage Noise | f = 10Hz to 10kHz | | 3 | | µVrms |
| | f = 1kHz | | 30 | | nV/√Hz |
| Current Noise | f = 1kHz | | 4 | | fA/√Hz |
| Common-Mode Voltage Range (Positive) | | (V+) – 2 | (V+) – 1.5 | | V |
| (Negative) | | (V–) + 2 | (V–) + 1.2 | | V |
| CMRR | | 90 | 105 | | dB |
| **OUTPUT, A2 ($V_{LOGOUT}$)** | | | | | |
| Output Offset, $V_{OSO}$, Initial | | | ±3 | ±55 | mV |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | | **25** | **µV/°C** |
| Full-Scale Output (FSO) | $V_S$ = ±5V Supplies | (V–) + 1.2 | | (V+) – 1.5 | V |
| Short-Circuit Current | | | ±18 | | mA |

# ELECTRICAL CHARACTERISTICS (Cont.)

**Boldface** limits apply over the specified temperature range, **$T_A$ = 0°C to +70°C.**

At $T_A$ = +25°C, $V_S$ = ±5V, $R_L$ = 10kΩ, unless otherwise noted.

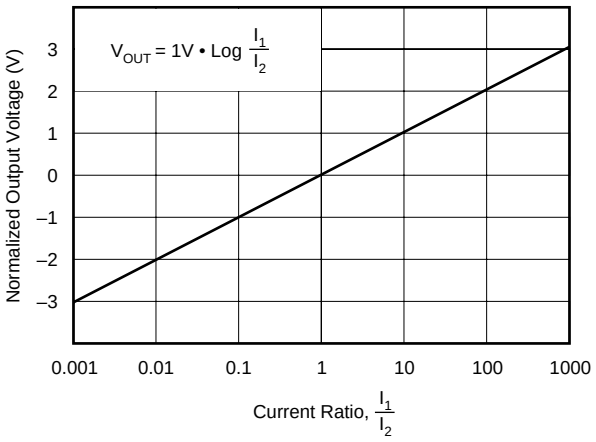
| PARAMETER | CONDITION | LOG102AID MIN | LOG102AID TYP | LOG102AID MAX | UNITS |
|---|---|---|---|---|---|
| **TOTAL ERROR**[3][4] | $I_1$ or $I_2$ remains fixed while other varies | | | | |
| Initial | min to max | | | | |
| | $I_1$ or $I_2$ = 1mA | | | ±55 | mV |
| | $I_1$ or $I_2$ = 100µA | | | ±30 | mV |
| | $I_1$ or $I_2$ = 10µA | | | ±25 | mV |
| | $I_1$ or $I_2$ = 1µA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 100nA | | | ±25 | mV |
| | $I_1$ or $I_2$ = 10nA | | | ±30 | mV |
| | $I_1$ or $I_2$ = 1nA | | | ±37 | mV |
| **vs Temperature** | **$I_1$ or $I_2$ = 1mA** | | **±0.4** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 100µA** | | **±0.07** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 10µA** | | **±0.07** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 1µA** | | **±0.07** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 100nA** | | **±0.07** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 10nA** | | **±0.07** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 1nA** | | **±0.4** | | **mV/°C** |
| vs Supply | $I_1$ or $I_2$ = 1mA | | ±0.15 | | mV/V |
| | $I_1$ or $I_2$ = 100µA | | ±0.15 | | mV/V |
| | $I_1$ or $I_2$ = 10µA | | ±0.25 | | mV/V |
| | $I_1$ or $I_2$ = 1µA | | ±0.2 | | mV/V |
| | $I_1$ or $I_2$ = 100nA | | ±0.2 | | mV/V |
| | $I_1$ or $I_2$ = 10nA | | ±0.15 | | mV/V |
| | $I_1$ or $I_2$ = 1nA | | ±0.25 | | mV/V |
| **FREQUENCY RESPONSE, core log**[5] | | | | | |
| BW, 3dB | | | | | |
| $I_2$ = 10nA | $C_C$ = 4500pF | | 0.1 | | kHz |
| $I_2$ = 1µA | $C_C$ = 150pF | | 38 | | kHz |
| $I_2$ = 10µA | $C_C$ = 150pF | | 40 | | kHz |
| $I_2$ = 1mA | $C_C$ = 50pF | | 45 | | kHz |
| Step Response | | | | | |
| Increasing | | | | | |
| $I_2$ = 1µA to 1mA (3 decade) | $C_C$ = 150pF | | 11 | | µs |
| $I_2$ = 100nA to 1µA (1 decade) | $C_C$ = 150pF | | 7 | | µs |
| $I_2$ = 10nA to 100nA (1 decade) | $C_C$ = 150pF | | 110 | | µs |
| Decreasing | | | | | |
| $I_2$ = 1mA to 1µA (3 decade) | $C_C$ = 150pF | | 45 | | µs |
| $I_2$ = 1µA to 100nA (1 decade) | $C_C$ = 150pF | | 20 | | µs |
| $I_2$ = 100nA to 10nA (1 decade) | $C_C$ = 150pF | | 550 | | µs |
| **OP AMPS, A3 AND A4** | | | | | |
| Input Offset Voltage | | | ±175 | ±750 | µV |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **±2** | | **µV/°C** |
| vs Power Supply | $V_S$ = ±4.5V to ±18V | | 10 | 50 | µV/V |
| Input Bias Current[5] | | | –10 | | nA |
| Input Offset Current | | | ±0.5 | | nA |
| Input Voltage Range | | (V–) | | (V+) – 1.5 | V |
| Common-Mode Rejection | | | 86 | | dB |
| Input Noise, f = 0.1Hz to 10Hz | | | 1 | | $\mu V_{PP}$ |
| f = 1kHz | | | 28 | | $nV/\sqrt{Hz}$ |
| Open Loop Voltage Gain | | | 88 | | dB |
| Gain-Bandwidth Product | | | 1.4 | | MHz |
| Slew Rate | G = 1, 2.5V step | | 0.5 | | V/µs |
| Settling Time, 0.01% | G = 1, 2.5V Step, $C_L$ =100pF | | 16 | | µs |
| Rated Output | $V_S$ = 5V, $R_L$ = 10kΩ | (V–) + 1.5 | | (V+) – 0.9 | V |
| Short-Circuit Current $-I_{SC}/+I_{SC}$ | | | –36/+60 | | mA |
| **POWER SUPPLY** | | | | | |
| Operating Range | $V_S$ | ±4.5 | | ±18 | V |
| Quiescent Current | $I_O$ = 0 | | 1.25 | 2 | mA |
| **TEMPERATURE RANGE** | | | | | |
| Specified Range, $T_{MIN}$ to $T_{MAX}$ | | 0 | | 70 | °C |
| Operating Range | | –40 | | +85 | °C |
| Storage Range | | –40 | | +125 | °C |
| Thermal Resistance, $\theta_{JA}$ | | | | | |
| SO-14 | | | 100 | | °C/W |

NOTES: (1) Log Conformity Error is peak deviation from the best-fit straight line of $V_O$ versus Log ($I_1/I_2$) curve expressed as a percent of peak-to-peak full-scale (2) Output core log function is trimmed to 1V output per decade change of input current. (3) 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. (4) Total $I_1$ + $I_2$ should be kept below 1.1mA on ±5V supply. (5) Bandwidth (3dB) and transient response are a function of both the compensation capacitor and the level of input current. (6) Positive conventional current flows into input terminals.

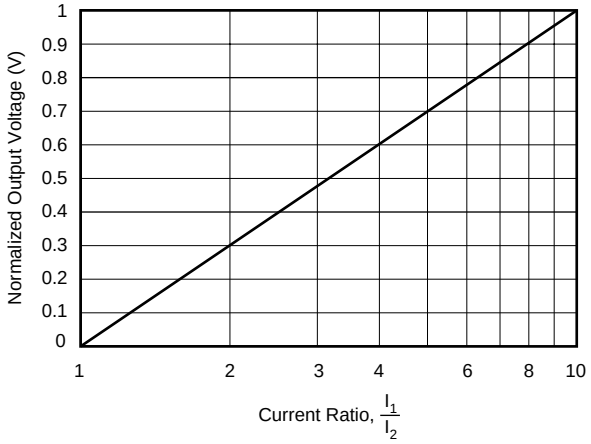
# TYPICAL CHARACTERISTICS

At $T_A$ = +25°C, $V_S$ = ±5V, $R_L$ = 10kΩ, unless otherwise noted.

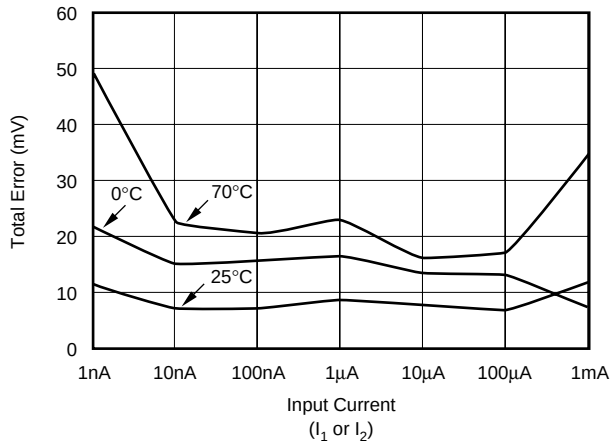
NORMALIZED TRANSFER FUNCTION



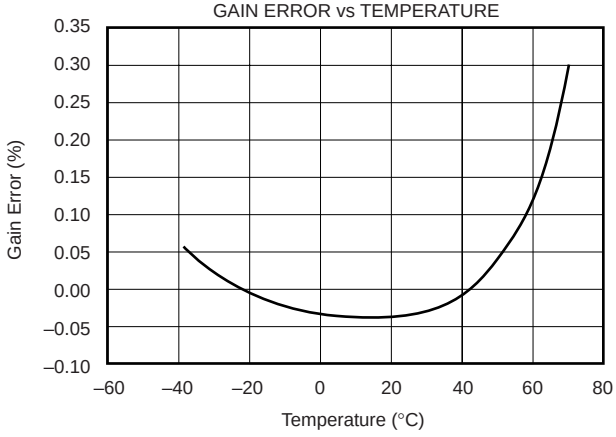

ONE CYCLE OF NORMALIZED TRANSFER FUNCTION



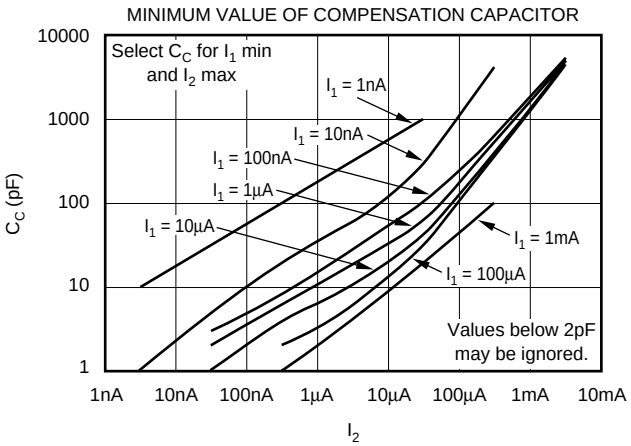

TOTAL ERROR vs INPUT CURRENT



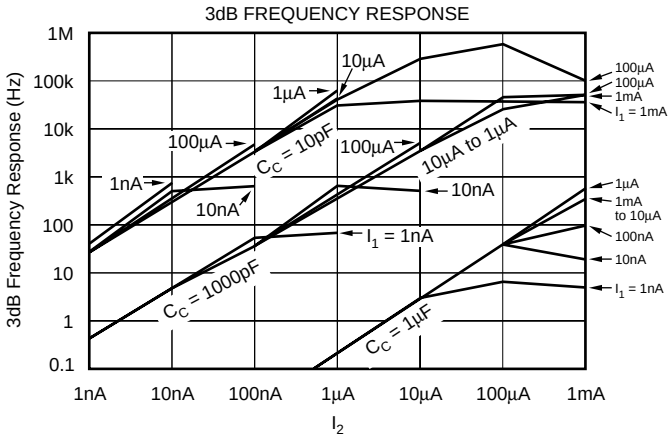

GAIN ERROR vs TEMPERATURE




MINIMUM VALUE OF COMPENSATION CAPACITOR



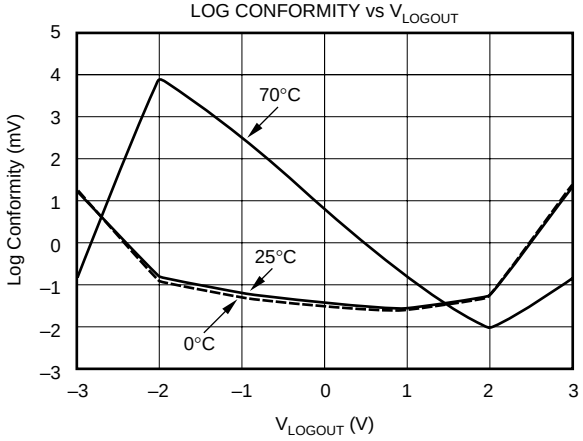

3dB FREQUENCY RESPONSE



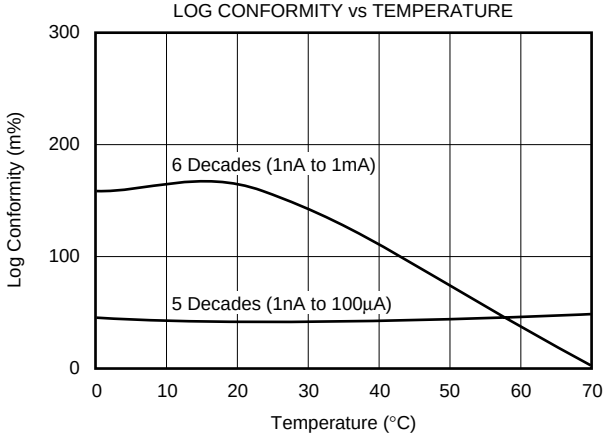
# TYPICAL CHARACTERISTICS (Cont.)

At $T_A$ = +25°C, $V_S$ = ±5V, $R_L$ = 10kΩ, unless otherwise noted.

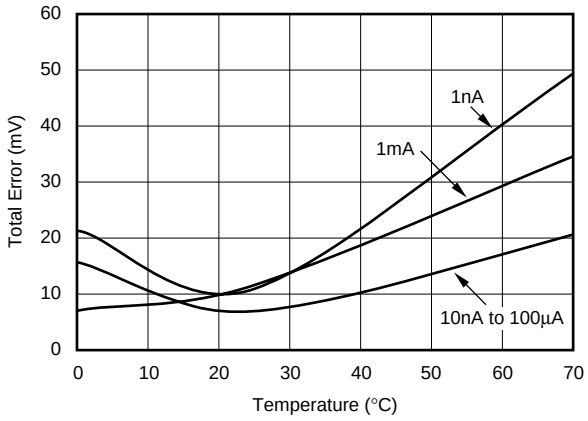
LOG CONFORMITY vs $V_{LOGOUT}$




LOG CONFORMITY vs TEMPERATURE




TOTAL ERROR vs TEMPERATURE



# APPLICATION INFORMATION

The LOG102 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. With two uncommitted on-chip operational amplifiers, the LOG102 provides design flexibility and simplicity.

Figure 1 shows the basic connections required for operation of the LOG102 with a gain factor. In order to reduce the influence of lead inductance of power supply lines, it is recommended that each supply be bypassed with a 10µF tantalum capacitor in parallel with a 1000pF ceramic capacitor, as shown in Figure 1. Connecting the capacitors as close to the LOG102 as possible will contribute to noise reduction as well.

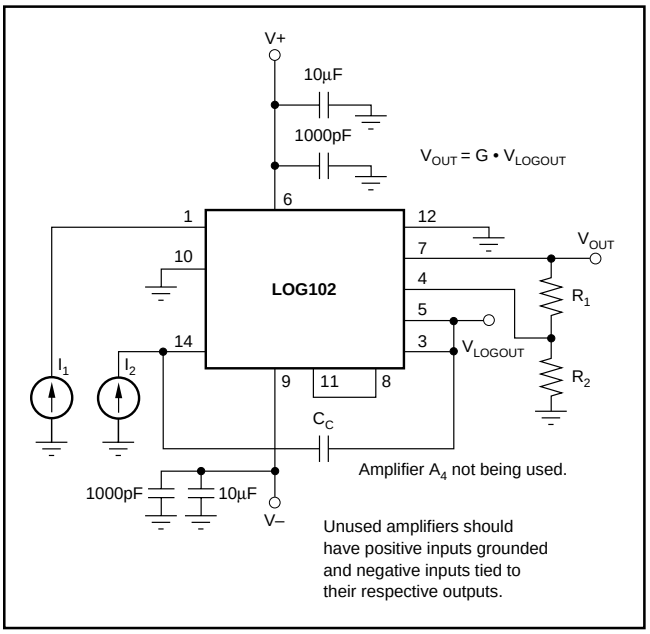



FIGURE 1. Basic Connections with Output Gain Factor of the LOG102.

## INPUT CURRENT RANGE

To maintain specified accuracy, the input current range of the LOG102 should be limited from 1nA to 1mA. Input currents outside of this range may compromise LOG102 performance. Input currents larger than 1mA 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 ±5V supplies the total input current ($I_1 + I_2$) is limited to 1.1mA. Due to compliance issues internal to the LOG102, to accommodate larger total input currents, supplies should be increased.

Currents smaller than 1nA will result in increased errors due 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°C, which makes the nulling technique shown practical only where the temperature is fairly stable.

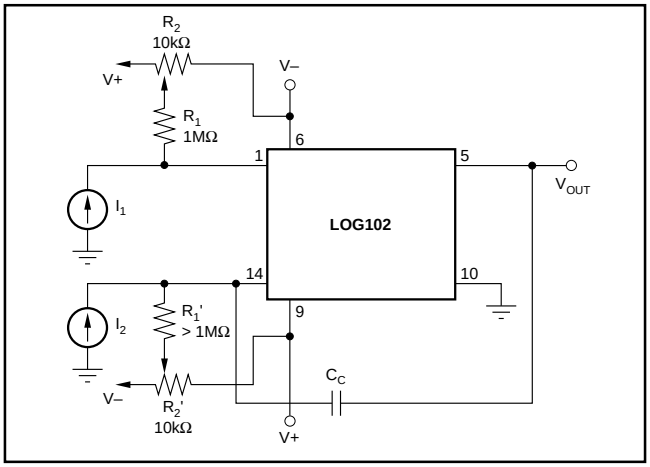



FIGURE 2. Bias Current Nulling.

## SETTING THE REFERENCE CURRENT

When the LOG102 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.

$V_{LOGOUT}$ is expressed as:

$$V_{LOGOUT} = (1V) \bullet \log (I_1/I_2) \qquad (1)$$

$I_{REF}$ 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 $I_{REF}$. If $I_{REF}$ is 10nA and +2.5V is used:

$$R_{REF} = 2.5V/10nA = 250M\Omega$$

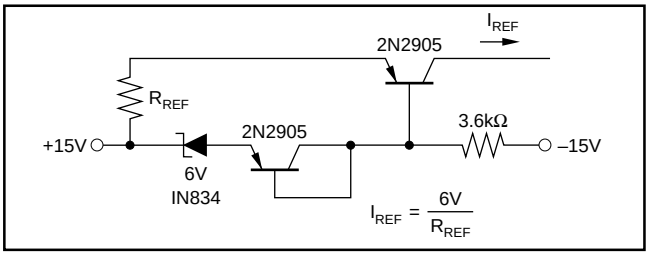



FIGURE 3. Temperature Compensated Current Source.

A voltage divider may be used to reduce the value of the resistor (as shown in Figure 4). When using this method, one must consider the possible errors caused by the amplifier's input offset voltage. The input offset voltage of amplifier $A_1$ has a maximum value of 1.5mV, making $V_{REF}$ a suggested value of 100mV.

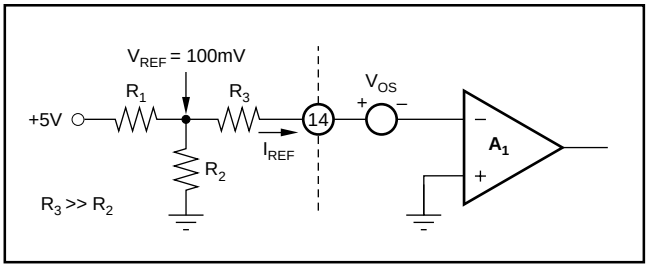



FIGURE 4. T Network for Reference Current.

Figure 5 shows a low-level current source using a series resistor. The low offset op-amp reduces the effect of the LOG102's input offset voltage.

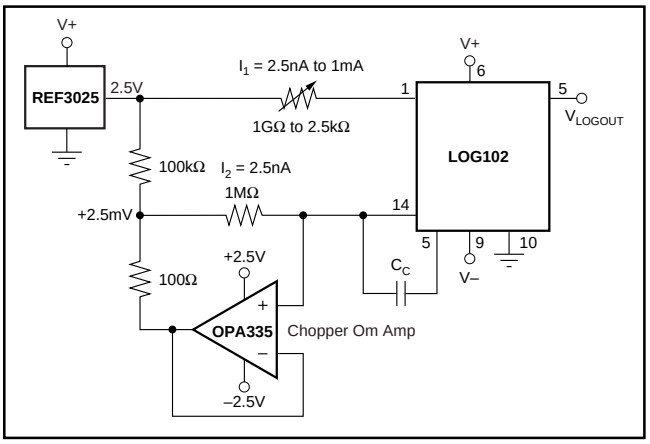



FIGURE 5. Current Source with Offset Compensation.

## FREQUENCY RESPONSE

The 3dB frequency response of the LOG102 is a function of the magnitude of the input current levels and of the value of the frequency compensation capacitor. See Typical Characteristic Curves for details.

The frequency response curves are shown for constant DC $I_1$ and $I_2$ with a small signal AC current on one of them.

The transient response of the LOG102 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 gain to maintain full dynamic range, and will slow the frequency response of the LOG102.

## FREQUENCY COMPENSATION

Frequency compensation for the LOG102 is obtained by connecting a capacitor between pins 5 and 14. The size of the capacitor is a function of the input currents, as shown in the Typical Characteristic Curves (Minimum Value of Compensation Capacitor). For any given application, the smallest value of the capacitor which may be used is determined by the maximum value of $I_2$ and the minimum value of $I_1$. Larger values of $C_C$ will make the LOG102 more stable, but will reduce the frequency response.

In an application, highest overall bandwidth can be achieved by detecting the signal level at $V_{OUT}$, then switching in appropriate values of compensation capacitors.

As seen on front page diagram, the voltage output of $V_{LOGOUT}$ can be scaled by increasing or decreasing the resistor ratio connected to pins 4 and 7. The gain, G, can be set according to the following equation:

$$G = 1 + R_2/R_1 \qquad (2)$$

## NEGATIVE INPUT CURRENTS

The LOG102 will function only with positive input currents (conventional current flow into pins 1 and 14). In situations where negative input currents are needed, the circuits in Figures 6, 7, 8, and 9, may be used.

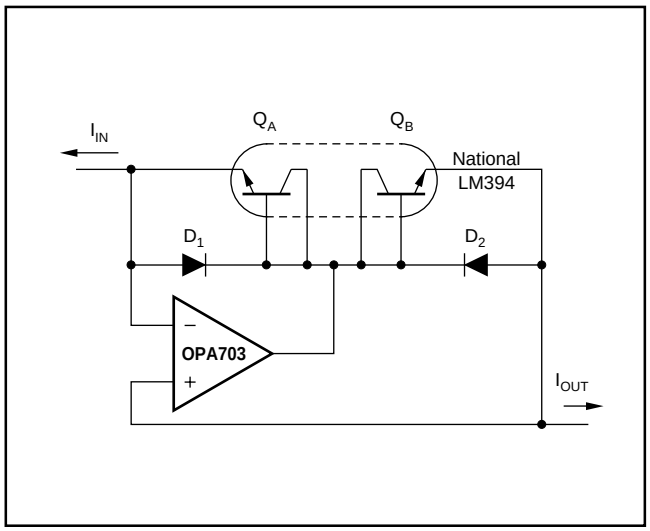



FIGURE 6. Current Inverter/Current Source.

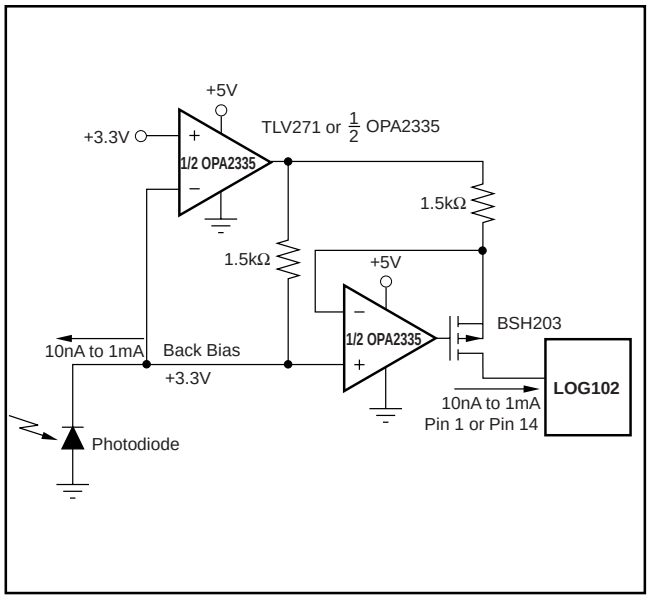



FIGURE 7. Precision Current Inverter/Current Source.

## VOLTAGE INPUTS

The LOG102 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 (14) applies to this configuration.

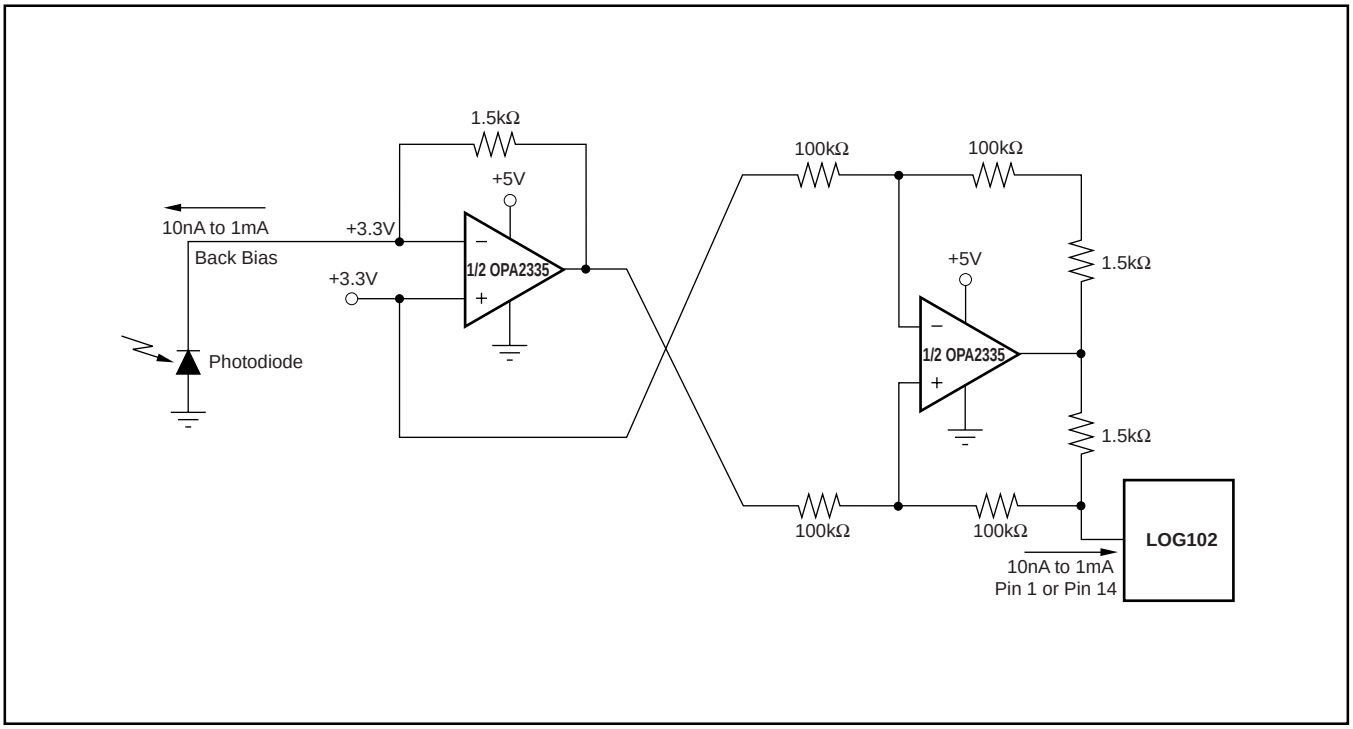
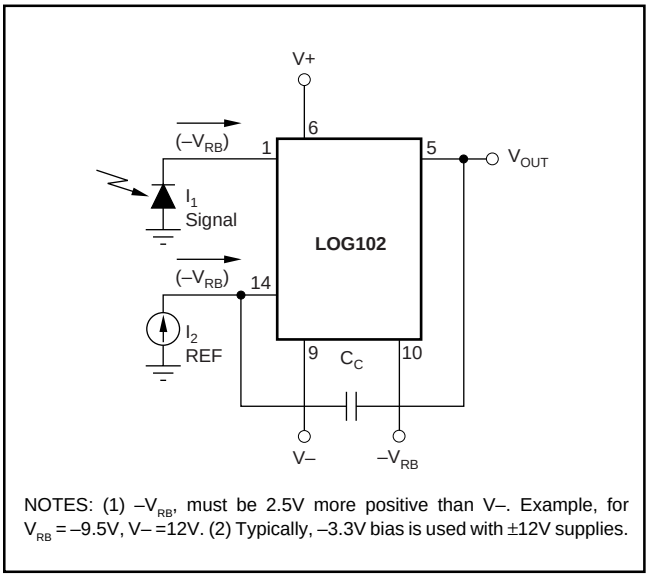



FIGURE 8. Precision Current Inverter/Current Source.




NOTES: (1) $-V_{RB}$, must be 2.5V more positive than V–. Example, for $V_{RB} = -9.5V$, V– =12V. (2) Typically, –3.3V bias is used with ±12V supplies.

FIGURE 9. Reverse Biased Photodiode Using Pin 10 on LOG102.

# 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 10.

Absorbance of the sample is $A = \log\lambda_1'/\lambda_1$ (3)

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 LOG102 preceding a 12-bit Analog-to-Digital (A/D) converter can produce the dynamic range equivalent to a 20-bit converter.

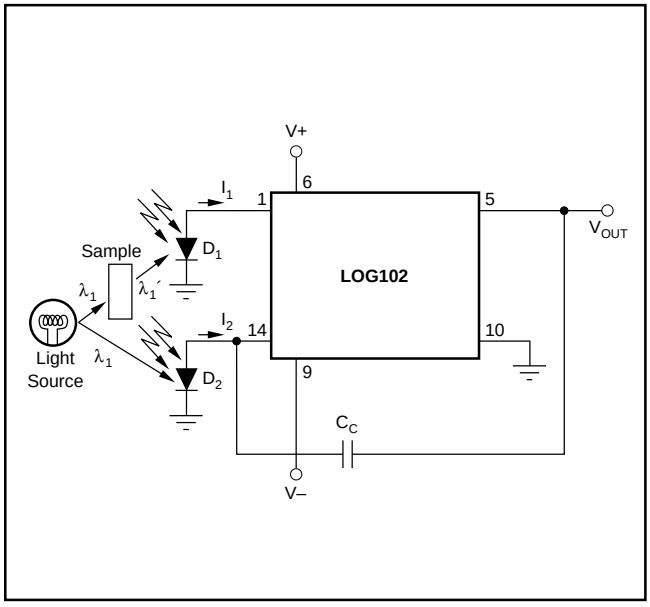



FIGURE 10. Absorbance Measurement.

# INSIDE THE LOG102

Using the base-emitter voltage relationship of matched bipolar transistors, the LOG102 establishes a logarithmic function of input current ratios. Beginning with the base-emitter voltage defined as

$$V_{BE} = V_T \ln \frac{I_C}{I_S} \quad \text{where: } V_T = \frac{kT}{q} \tag{1}$$

k = Boltzmann's constant = $1.381 \bullet 10^{-23}$

T = Absolute temperature in degrees Kelvin

q = Electron charge = $1.602 \bullet 10^{-19}$ Coulombs

$I_C$ = Collector current

$I_S$ = Reverse saturation current

From the circuit in Figure 11, we see that

$$V_L = V_{BE_1} - V_{BE_2} \tag{2}$$

Substituting (1) into (2) yields

$$V_L = V_{T_1} \ln \frac{I_1}{I_{S_1}} - V_{T_2} \ln \frac{I_2}{I_{S_2}} \tag{3}$$

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

$$V_L = V_{T_1} \left[ \ln \frac{I_1}{I_S} - \ln \frac{I_2}{I_S} \right] \tag{4}$$

$$V_L = V_T \ln \frac{I_1}{I_2} \text{ and since} \tag{5}$$

$$\ln x = 2.3 \log_{10} x \tag{6}$$

$$V_L = n V_T \log \frac{I_1}{I_2} \tag{7}$$

where n = 2.3 (8)

also

$$V_{OUT} = V_L \frac{R_1 + R_2}{R1} \tag{9}$$

$$= \log \frac{I_1}{I_2} \tag{10}$$

or

$$V_{OUT} = \frac{R_1 + R_2}{R1} n V_T \log \frac{I_1}{I_2} \tag{11}$$

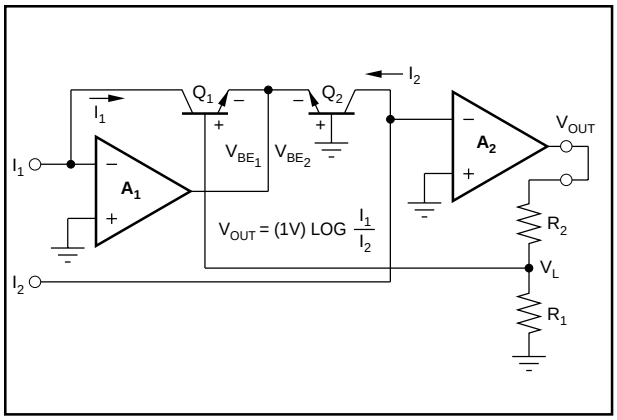



FIGURE 11. Simplified Model of Log Amplifier.

It should be noted that the temperature dependance associated with $V_T = kT/q$ is internally compensated on the LOG102 by making $R_1$ a temperature sensitive resistor with the required positive temperature coefficient.

## USING A LARGER REFERENCE VOLTAGE REDUCES OFFSET ERRORS

Using a larger reference voltage to create the reference current minimizes errors due to the LOG102'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 LOG102 configured with the reference current connecting $I_1$ and the photodiode current connecting to $I_2$ is shown in Figure 12. $A_3$ is configured as a level shifter with inverting gain and is used to scale the photodiode current directly into the A/D input voltage range.

The wide dynamic range of the LOG102 is useful for measuring avalanche photodiode current (APD) (see Figure 13).

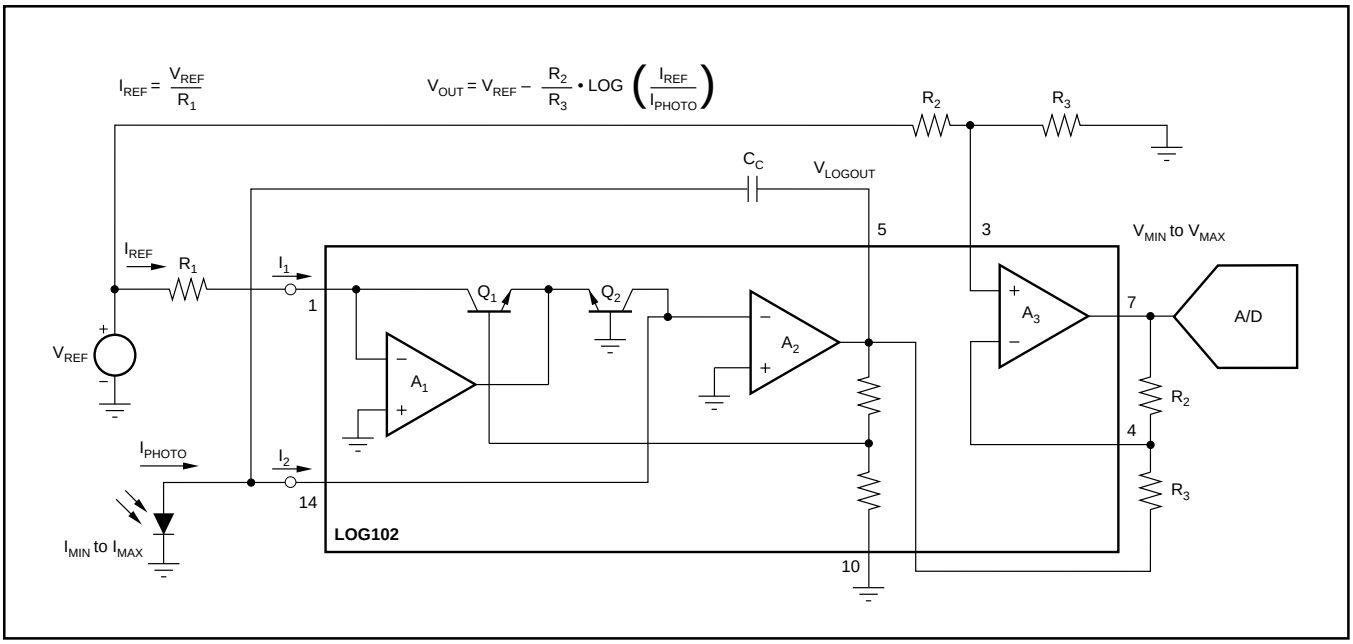



FIGURE 12. Technique for Using Full-Scale Reference Current such that $V_{OUT}$ Increases with Increasing Photodiode Current.

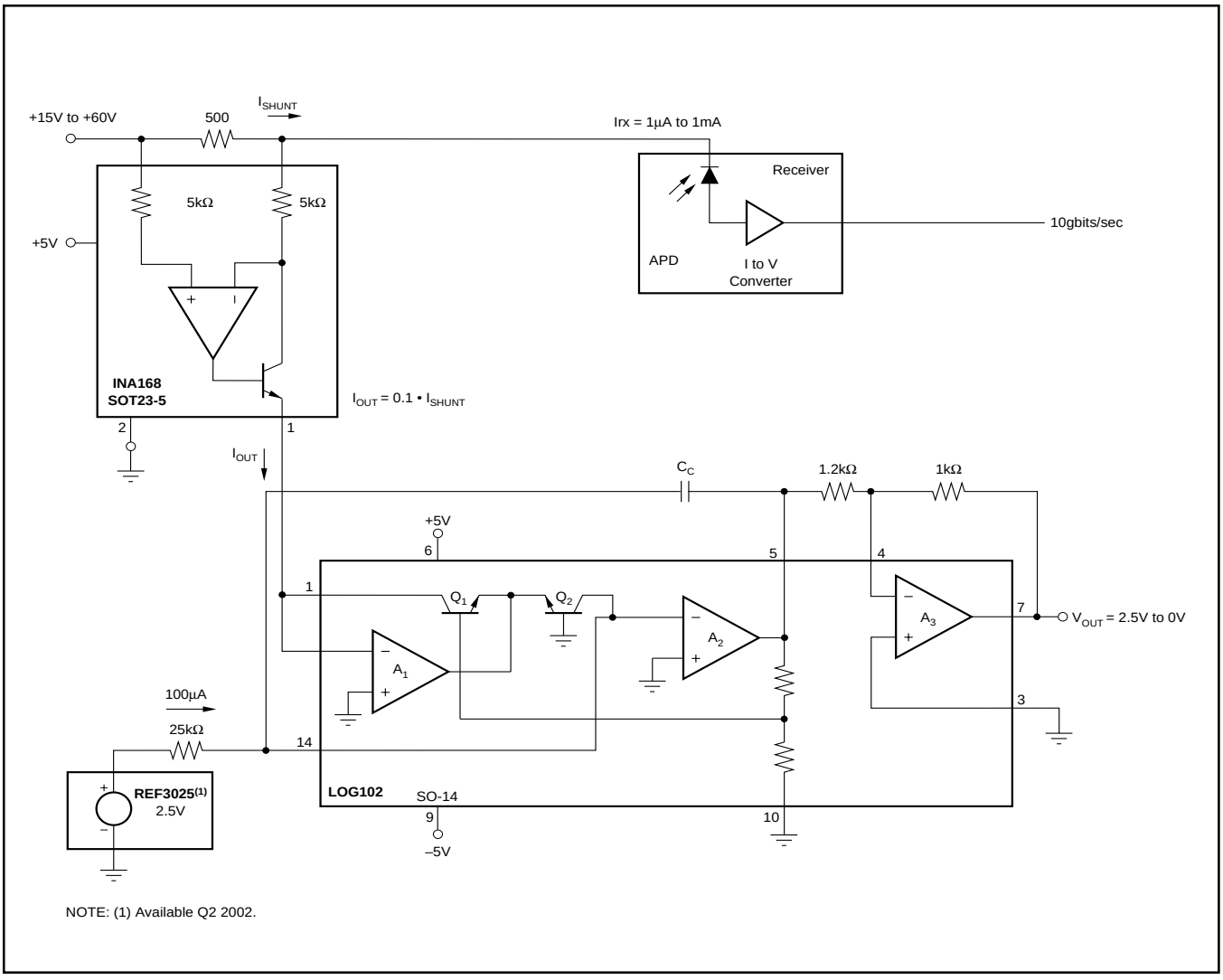



FIGURE 13. High Side Shunt for Avalanche Photodiode (APD) Measures 3 Decades of APD Current.

# DEFINITION OF TERMS

## TRANSFER FUNCTION

The ideal transfer function is:

$$V_{OUT} = 1V \bullet \log I_1/I_2 \quad (5)$$

Figure 14 shows the graphical representation of the transfer over valid operating range for the LOG102.

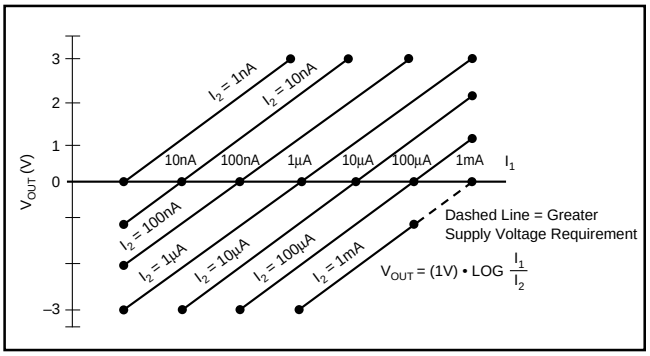



FIGURE 14. Transfer Function with Varying $I_2$ and $I_1$.

## ACCURACY

Accuracy considerations for a log ratio amplifier are somewhat more complicated than for other amplifiers. This is because the transfer function is nonlinear 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 $V_{OUT} = 1V \bullet \log(I_1/I_2)$.

Thus,

$$V_{OUT\ (ACTUAL)} = V_{OUT\ (IDEAL)} \pm \text{Total Error.} \quad (5)$$

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; this case is shown in Table I. Temperature can affect total error.

| $I_2$ (maximum error)(1) | $I_1$ (maximum error)(1) | | |
|---|---|---|---|
| | 10nA (30mV) | 100nA (25mV) | 1µA (20mV) |
| 100nA (25mV) | 30mV | 25mV | 25mV |
| 1µA (20mV) | 30mV | 25mV | 20mV |
| 10µA (25mV) | 30mV | 25mV | 25mV |

NOTE: (1) Maximum errors are in parenthesis.

TABLE I. $I_1/I_2$ and Maximum Errors.

## 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.

## LOG CONFORMITY

For the LOG102, 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 true because bias current errors are negligible (1pA compared to input currents of 1nA 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:

$$V_{OUT\ (NONLIN)} = 1V/dec \bullet 2Nm\ V \quad (6)$$

where N is the log conformity error, in percent.

## INDIVIDUAL ERROR COMPONENTS

The ideal transfer function with current input is:

$$V_{OUT} = (1V) \bullet \log \frac{I_1}{I_2} \quad (7)$$

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

$$V_{OUT} = (1V)(1 \pm \Delta K) \log \frac{I_1 - I_{B1}}{I_2 - I_{B2}} \pm 2Nm \pm V_{OS\ OUT} \quad (8)$$

The individual component of error is:

$\Delta K$ = gain accuracy (0.3%, typ), as specified in specification table.

$I_{B1}$ = bias current of $A_1$ (5pA, typ)
$I_{B2}$ = bias current of $A_2$ (5pA, typ)

N = log conformity error (0.04%, 0.15%, typ)

0.04% for n = 5, 0.15% for n = 6

$V_{OS\ OUT}$ = output offset voltage (1mV, typ)

n = number of decades over which N is specified:

Example: what is the error when

$$I_1 = 1\mu A \text{ and } I_2 = 100nA \quad (9)$$

$$\approx 1.003 \log \frac{10^{-6}}{10^{-7}} + 0.004 + 0.003 \quad (10)$$

$$= 1.003\ (1) + 0.004 + 0.0003 \quad (11)$$

$$= 1.0073V \quad (12)$$

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

$$\% \text{ error} = \frac{0.0073}{1} \bullet 100\% = 0.73\% \quad (13)$$

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

$$V_{OUT} = (1V)(1 \pm \Delta K) \log \frac{\frac{V_1}{R_1} - I_{B_1} \pm \frac{E_{OS_1}}{R_1}}{\frac{V_2}{R_2} - I_{B_2} \pm \frac{E_{OS_2}}{R_2}} \pm 2Nn \pm V_{OS\ OUT} \quad (14)$$

(15)

Where $\frac{E_{OS1}}{R_1}$ and $\frac{E_{OS2}}{R_2}$ are considered to be zero for large values of resistance from external input current sources.

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| LOG102AID | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR |
| LOG102AIDG4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR |
| LOG102AIDR | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR |
| LOG102AIDRG4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR |

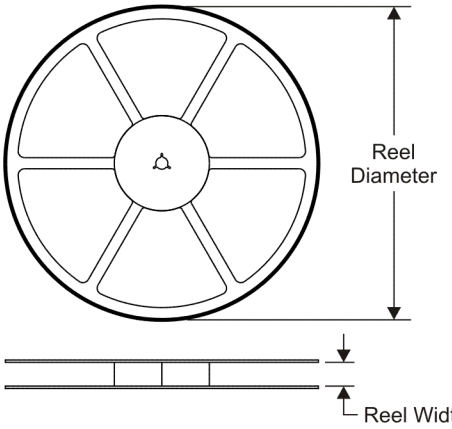
(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing 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 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)

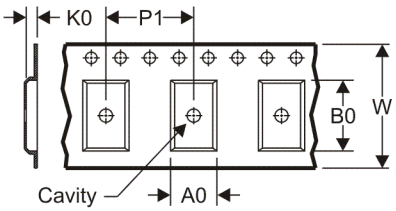
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

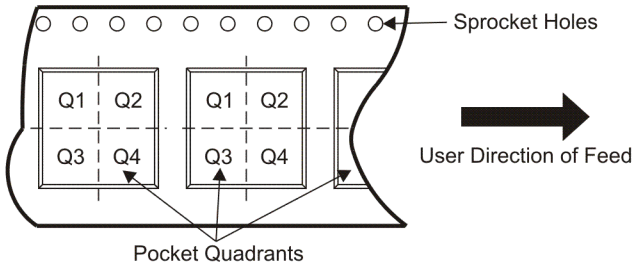



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

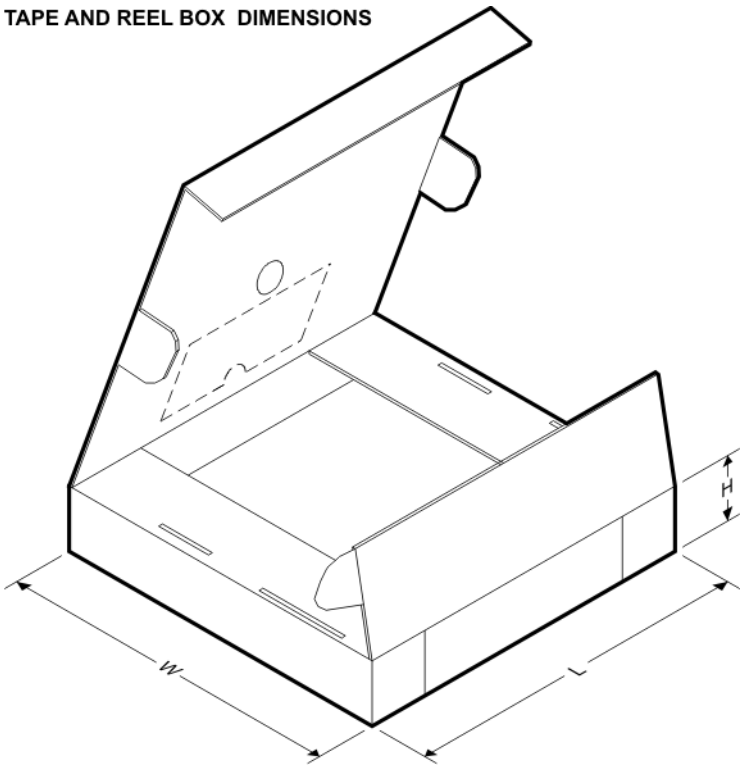
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOG102AIDR | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.0 | 2.1 | 8.0 | 16.0 | Q1 |

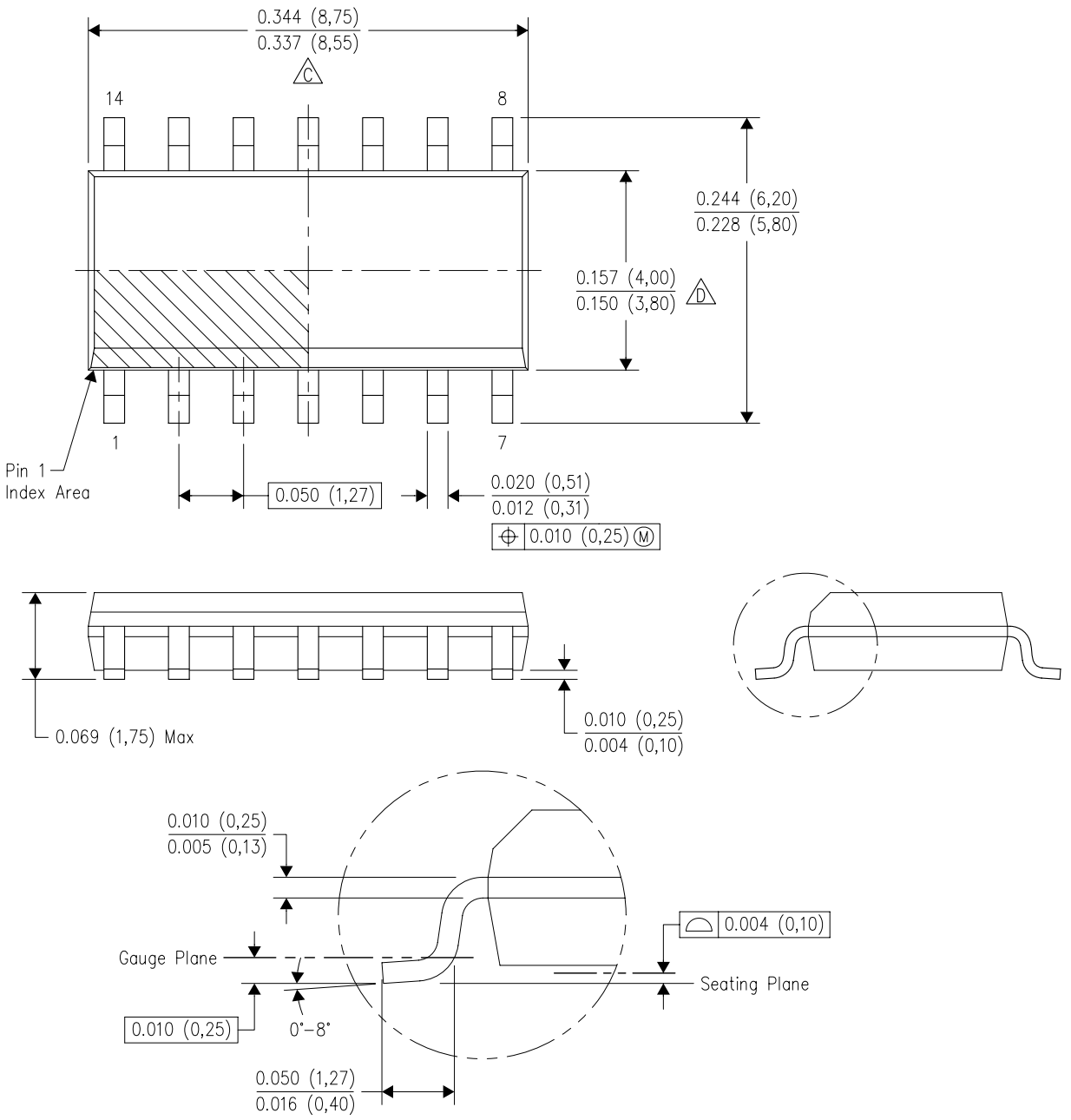
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LOG102AIDR | SOIC | D | 14 | 2500 | 346.0 | 346.0 | 33.0 |

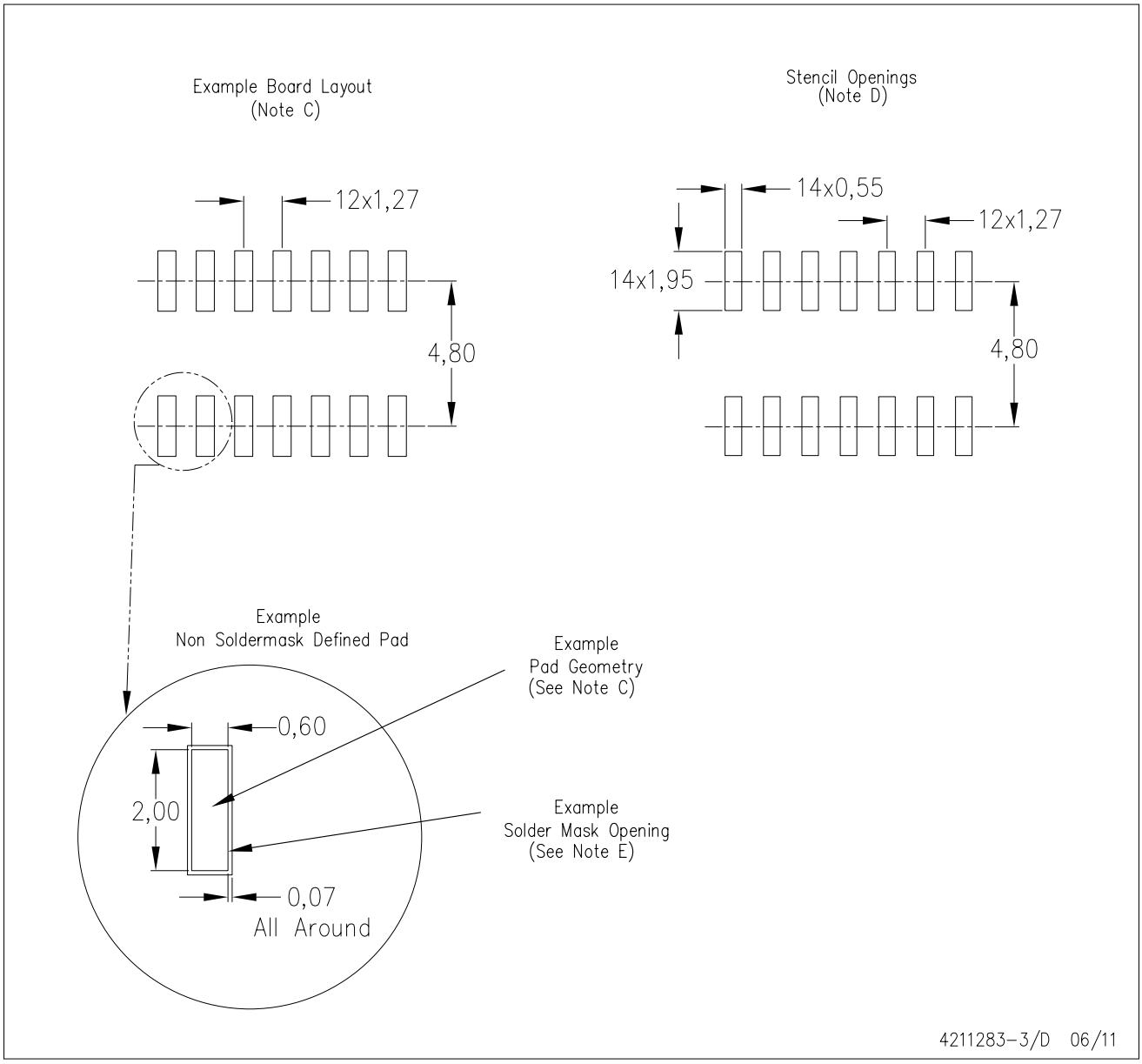
D (R–PDSO–G14) PLASTIC SMALL OUTLINE




4040047–5/M 06/11

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AB.

D (R–PDSO–G14) PLASTIC SMALL OUTLINE




NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| **Products** | | **Applications** | |
|---|---|---|---|
| Audio | www.ti.com/audio | Communications and Telecom | www.ti.com/communications |
| Amplifiers | amplifier.ti.com | Computers and Peripherals | www.ti.com/computers |
| Data Converters | dataconverter.ti.com | Consumer Electronics | www.ti.com/consumer-apps |
| DLP® Products | www.dlp.com | Energy and Lighting | www.ti.com/energy |
| DSP | dsp.ti.com | Industrial | www.ti.com/industrial |
| Clocks and Timers | www.ti.com/clocks | Medical | www.ti.com/medical |
| Interface | interface.ti.com | Security | www.ti.com/security |
| Logic | logic.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Power Mgmt | power.ti.com | Transportation and Automotive | www.ti.com/automotive |
| Microcontrollers | microcontroller.ti.com | Video and Imaging | www.ti.com/video |
| RFID | www.ti-rfid.com | Wireless | www.ti.com/wireless-apps |
| RF/IF and ZigBee® Solutions | www.ti.com/lprf | | |

**TI E2E Community Home Page** e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265