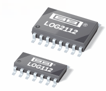
Burr-Brown Products
from Texas Instruments

# LOG112
# LOG2112



SBOS246C – JUNE 2002 – REVISED APRIL 2003

# Precision
# LOGARITHMIC AND LOG RATIO AMPLIFIERS

## FEATURES

- EASY-TO-USE COMPLETE FUNCTION
- OUTPUT SCALING AMPLIFIER
- ON-CHIP 2.5V VOLTAGE REFERENCE
- HIGH ACCURACY: 0.2% FSO Over 5 Decades
- WIDE INPUT DYNAMIC RANGE: 7.5 Decades, 100pA to 3.5mA
- LOW QUIESCENT CURRENT: 1.75mA
- WIDE SUPPLY RANGE: ±4.5V to ±18V
- PACKAGES: SO-14 (narrow) and SO-16

## APPLICATIONS

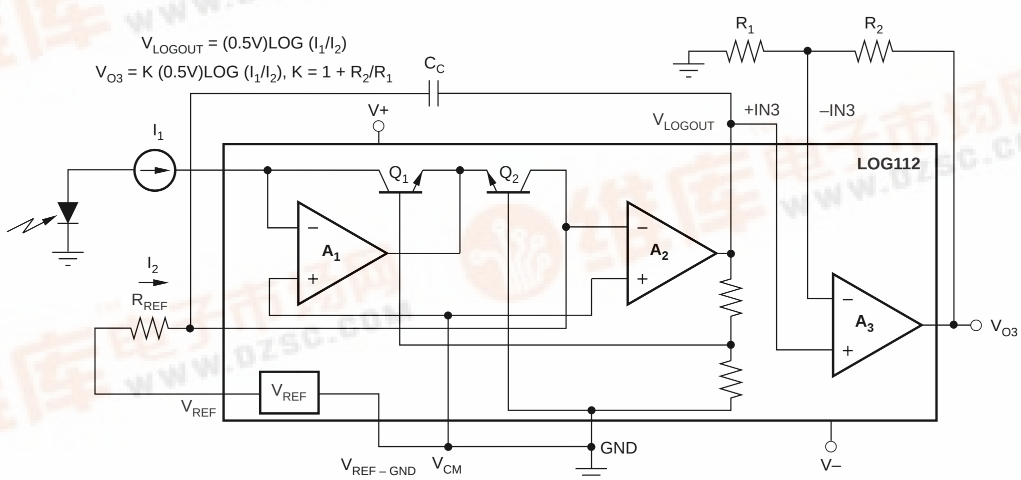
- LOG, LOG RATIO: Communication, Analytical, Medical, Industrial, Test, General Instrumentation
- PHOTODIODE SIGNAL COMPRESSION AMP
- ANALOG SIGNAL COMPRESSION IN FRONT OF ANALOG-TO-DIGITAL (A/D) CONVERTER
- ABSORBANCE MEASUREMENT
- OPTICAL DENSITY MEASUREMENT

## DESCRIPTION

The LOG112 and LOG2112 are versatile integrated circuits that compute the logarithm or log ratio of an input current relative to a reference current. $V_{LOGOUT}$ of the LOG112 and LOG2112 are trimmed to 0.5V per decade of input current, ensuring high precision over a wide dynamic range of input signals.

The LOG112 and LOG2112 features a 2.5V voltage reference that may be used to generate a precision current reference using an external resistor.

Low DC offset voltage and temperature drift allow accurate measurement of low-level signals over the specified temperature range of –5°C to +75°C.




NOTE: Internal resistors are used to compensate gain change over temperature.
The $V_{CM}$ pin is internally connected to GND in the LOG2112.

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.



TEXAS

## ABSOLUTE MAXIMUM RATINGS[1]

| | |
|---|---|
| Supply Voltage, V+ to V– | ±18V |
| Inputs | ±18V |
| Input Current | ±10mA |
| Output Short-Circuit Current[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) One output per package.

## 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.

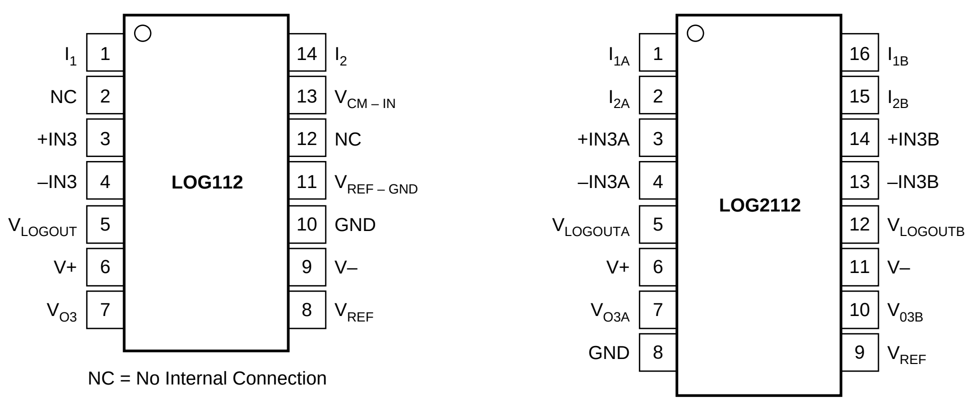
## PACKAGE/ORDERING INFORMATION

| PRODUCT | PACKAGE-LEAD | PACKAGE DESIGNATOR[1] | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|---|---|---|---|---|---|---|
| LOG112 | SO-14 | D | –5°C to +75°C | LOG112A | LOG112AID | Rails, 250 |
| " | " | " | " | " | LOG112AIDR | Tape and Reel, 2500 |
| LOG2112 | SO-16 | DW | –5°C to +75°C | LOG2112A | LOG2112AIDW | Rails, 250 |
| " | " | " | " | " | LOG2112AIDWR | Tape and Reel, 2500 |

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

## PIN CONFIGURATION

**Top View** **SO**



# ELECTRICAL CHARACTERISTICS

## **Boldface** limits apply over the specified temperature range, $T_A$ = –5°C to +75°C.

At $T_A$ = +25°C, $V_S$ = ±5V, and $R_{OUT}$ = 10kΩ, unless otherwise noted.

| | | LOG112, LOG2112 | | | |
|---|---|---|---|---|---|
| **PARAMETER** | **CONDITION** | **MIN** | **TYP** | **MAX** | **UNITS** |
| **CORE LOG FUNCTION** | | | | | |
| $V_{IN}/V_{OUT}$ Equation | | | $V_{LOGOUT}$ = (0.5V)LOG ($I_1/I_2$) | | V |
| **LOG CONFORMITY ERROR(1)** | | | | | |
| Initial | 1nA to 100µA (5 decades) | | 0.01 | 0.2 | % |
| | 100pA to 3.5mA (7.5 decades) | | 0.13 | | % |
| **over Temperature** | **1nA to 100µA (5 decades)** | | 0.0001 | | **%/°C** |
| | **100pA to 3.5mA (7.5 decades)** | | 0.005 | | **%/°C** |
| **GAIN(2)** | | | | | |
| Initial Value | 1nA to 100µA | | 0.5 | | V/decade |
| Gain Error | 1nA to 100µA | | 0.10 | ±1 | % |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **0.003** | **0.01** | **%/°C** |
| **INPUT, $A_{1A}$ and $A_{1B}$, $A_{2A}$, $A_{2B}$** | | | | | |
| 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 | 20 | 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 |
| Common-Mode Rejection Ratio (CMRR) | | | 10 | | µV/V |
| **OUTPUT, ($V_{LOG\ OUT}$) $A_{2A}$, $A_{2B}$** | | | | | |
| Output Offset, $V_{OSO}$, Initial | | | ±3 | ±15 | mV |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **±10** | | **µV/°C** |
| Full-Scale Output (FSO) | $V_S$ = ±5V | (V–) + 1.2 | | (V+) – 1.5 | V |
| Short-Circuit Current | | | ±18 | | mA |
| **TOTAL ERROR(3)(4)** | $I_1$ or $I_2$ remains fixed while other varies. | | | | |
| Initial | Min to Max | | | | |
| | $I_1$ or $I_2$ = 5mA ($V_S$ ≥ ±6V) | | | ±150 | mV |
| | $I_1$ or $I_2$ = 3.5mA | | | ±75 | mV |
| | $I_1$ or $I_2$ = 1mA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 100µA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 10µA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 1µA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 100nA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 10nA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 1nA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 350pA | | | ±20 | mV |
| | $I_1$ or $I_2$ = 100pA | | | ±20 | mV |
| **vs Temperature** | **$I_1$ or $I_2$ = 3.5mA** | | **±1.2** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 1mA** | | **±0.4** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 100µA** | | **±0.1** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 10µA** | | **±0.05** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 1µA** | | **±0.05** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 100nA** | | **±0.09** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 10nA** | | **±0.2** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 1nA** | | **±0.3** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 350pA** | | **±0.1** | | **mV/°C** |
| | **$I_1$ or $I_2$ = 100pA** | | **±0.3** | | **mV/°C** |
| vs Supply | $I_1$ or $I_2$ = 3.5mA | | ±3.0 | | mV/V |
| | $I_1$ or $I_2$ = 1mA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 100µA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 10µA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 1µA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 100nA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 10nA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 1nA | | ±0.25 | | mV/V |
| | $I_1$ or $I_2$ = 350pA | | ±0.1 | | mV/V |
| | $I_1$ or $I_2$ = 100pA | | ±0.1 | | mV/V |

NOTES: (1) Log Conformity Error is the 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 output. K, scale factor, equals 0.5V output per decade of input current. (2) Scale factor of core log function is trimmed to 0.5V output per decade change of input current. (3) Worst-case Total Error for any ratio of $I_1/I_2$, as the largest of the two errors, when $I_1$ and $I_2$ are considered separately. (4) Total Error includes offset voltage, bias current, gain, and log conformity. (5) Bandwidth (3dB) and transient response are a function of both the compensation capacitor and the level of input current.

# ELECTRICAL CHARACTERISTICS (Cont.)

**Boldface** limits apply over the specified temperature range, **$T_A$ = –5°C to +75°C.**

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

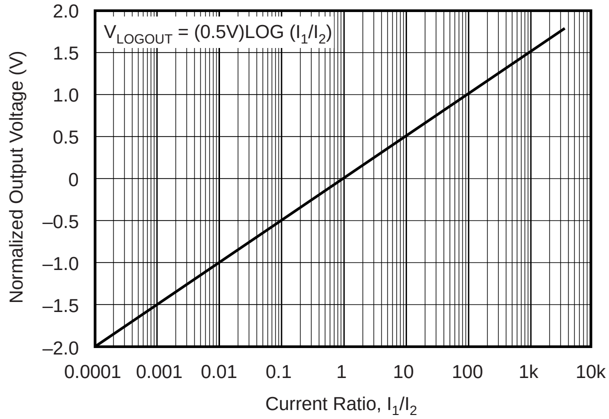
| | | LOG112, LOG2112 | | | |
|---|---|---|---|---|---|
| PARAMETER | CONDITION | MIN | TYP | MAX | UNITS |
| **FREQUENCY RESPONSE, CORE LOG**[5] | | | | | |
| BW, 3dB | | | | | |
| $I_2$ = 10nA | $C_C$ = 4500pF | | 0.1 | | kH |
| $I_2$ = 1µA | $C_C$ = 150pF | | 38 | | kH |
| $I_2$ = 10µA | $C_C$ = 150pF | | 40 | | kH |
| $I_2$ = 1mA | $C_C$ = 50pF | | 45 | | kHz |
| Step Response | | | | | |
| Increasing | | | | | |
| $I_1$ = 10nA to 100nA | $C_C$ = 120pF, $I_2$ = 31.6nA | | 1.1 | | ms |
| $I_1$ = 1µA to 100µA | $C_C$ = 375pF, $I_2$ = 10µA | | 1.6 | | µs |
| $I_1$ = 1µA to 1mA | $C_C$ = 950pF, $I_2$ = 31.6µA | | 1.5 | | µs |
| Decreasing | | | | | |
| $I_1$ = 100nA to 10nA | $C_C$ = 120pF, $I_2$ = 31.6nA | | 2.1 | | ms |
| $I_1$ = 100µA to 1µA | $C_C$ = 375pF, $I_2$ = 10µA | | 31.2 | | µs |
| $I_1$ = 1mA to 1µA | $C_C$ = 950pF, $I_2$ = 31.6µA | | 39 | | µs |
| Increasing | | | | | |
| $I_2$ = 10nA to 100nA | $C_C$ = 125pF, $I_1$ = 31.6nA | | 2.6 | | ms |
| $I_2$ = 1µA to 100µA | $C_C$ = 750pF, $I_1$ = 10µA | | 113 | | µs |
| $I_2$ = 1µA to 1mA | $C_C$ = 10.5nF, $I_1$ = 31.6µA | | 1.2 | | ms |
| Decreasing | | | | | |
| $I_2$ = 100nA to 10nA | $C_C$ = 125pF, $I_1$ = 31.6nA | | 630 | | µs |
| $I_2$ = 100µA to 1µA | $C_C$ = 750pF, $I_1$ = 10µA | | 6.6 | | µs |
| $I_2$ = 1mA to 1µA | $C_C$ = 10.5nF, $I_1$ = 31.6µA | | 13.3 | | µs |
| **OP AMP, A3** | | | | | |
| Input Offset Voltage | | | +250 | ±1000 | µV |
| **vs Temperature** | **$T_{MIN}$ to $T_{MAX}$** | | **±2** | | **µV/°C** |
| vs Supply | $V_S$ = ±4.5V to ±18V | | 5 | 50 | µV/V |
| Input Bias Current | | | –10 | | nA |
| Input Offset Current | | | ±0.5 | | nA |
| Input Voltage Range | | (V–) | | (V+) – 1.5 | V |
| Input Noise, f = 0.1Hz to 10Hz | | | 1 | | µVp-p |
| f = 1kHz | | | 28 | | nV/√Hz |
| Open-Loop Voltage Gain | | | 88 | | dB |
| Gain-Bandwidth Product | | | 1.4 | | MHz |
| Slew Rate | | | 0.5 | | V/µs |
| Settling Time, 0.01% | G = –1, 3V Step, $C_L$ = 100pF | | 16 | | µs |
| Rated Output | | (V–) + 1.5 | | (V+) – 0.9 | V |
| Short-Circuit Current | | | ±4 | | mA |
| **VOLTAGE REFERENCE** | | | | | |
| Bandgap Voltage | | | 2.5 | | V |
| Error, Initial | | | ±0.05 | ±0.5 | % |
| vs Temperature | $T_{MIN}$ to $T_{MAX}$ | | ±25 | | ppm/°C |
| vs Supply | $V_S$ = ±4.5V to ±18V | | ±10 | | ppm/V |
| vs Load | $I_{LOAD}$ = 10mA | | ±600 | | ppm/mA |
| Short-Circuit Current | | | 16 | | mA |
| **POWER SUPPLY** | | | | | |
| Operating Range | $V_S$ | ±4.5 | | ±18 | V |
| Quiescent Current | $I_O$ = 0 | | | | |
| LOG112 | | | ±1.25 | ±1.75 | mA |
| LOG2112 | | | ±2.5 | ±3.5 | mA |
| **TEMPERATURE RANGE** | | | | | |
| Specified Range, $T_{MIN}$ to $T_{MAX}$ | | –5 | | 75 | °C |
| Operating Range | | –40 | | 85 | °C |
| Storage Range | | –55 | | 125 | °C |
| Thermal Resistance, $\theta_{JA}$ SO-14 | | | 110 | | °C/W |
| SO-16 | | | 80 | | °C/W |

NOTES: (1) Log Conformity Error is the peak deviation from the best-fit-straight line of $V_O$ vs LOG($I_1/I_2$) curve expressed as a percent of peak-to-peak full-scale output. K, scale factor, equals 0.5V output per decade of input current. (2) Scale factor of core log function is trimmed to 0.5V output per decade change of input current. (3) Worst-case Total Error for any ratio of $I_1/I_2$, as the largest of the two errors, when $I_1$ and $I_2$ are considered separately. (4) Total Error includes offset voltage, bias current, gain, and log conformity. (5) Bandwidth (3dB) and transient response are a function of both the compensation capacitor and the level of input current.

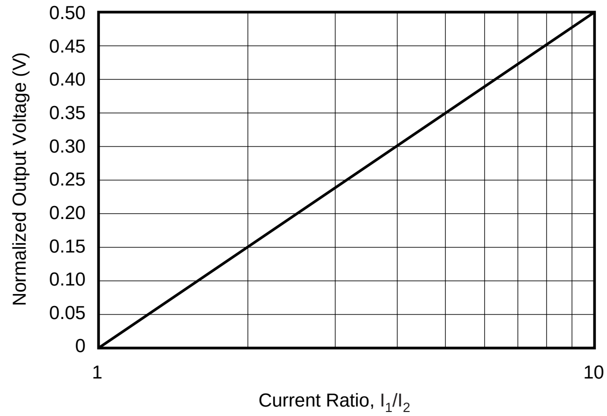
# TYPICAL CHARACTERISTICS

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

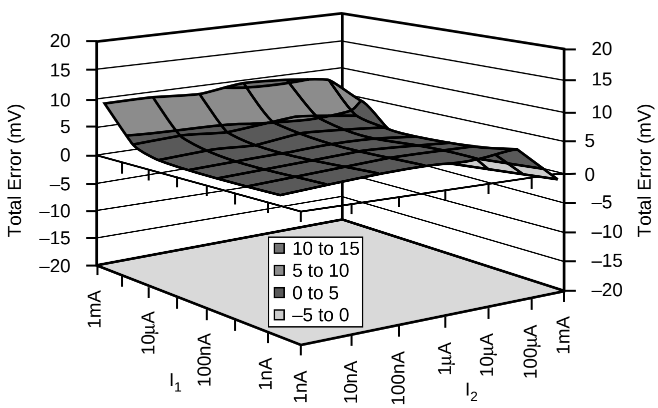
NORMALIZED TRANSFER FUNCTION



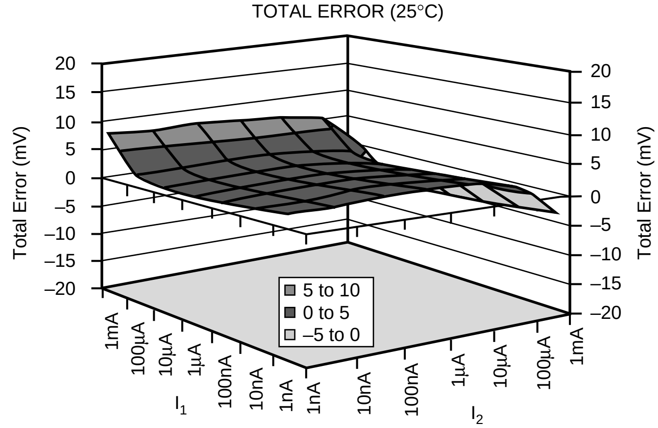

ONE CYCLE OF NORMALIZED TRANSFER FUNCTION



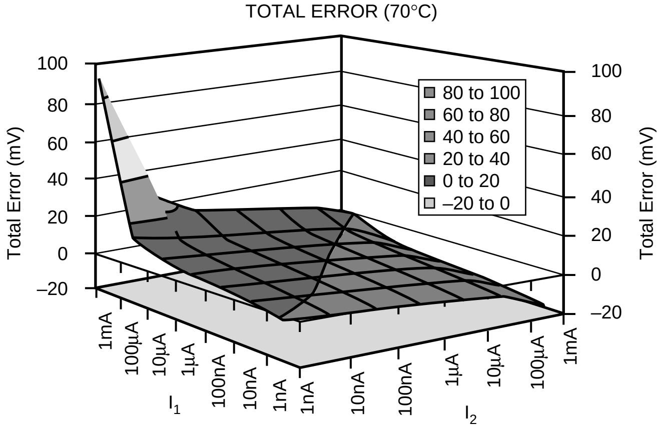

TOTAL ERROR (–5°C)



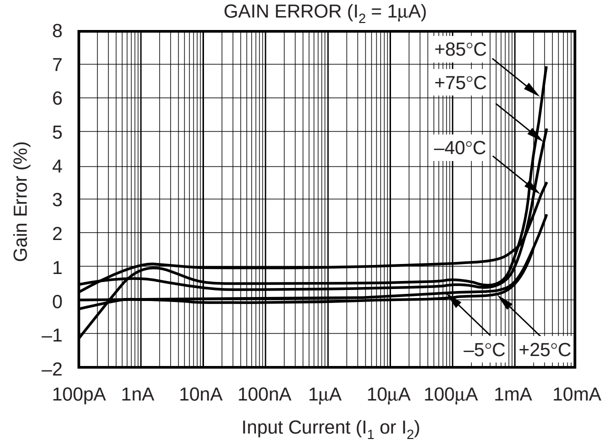

TOTAL ERROR (25°C)




TOTAL ERROR (70°C)

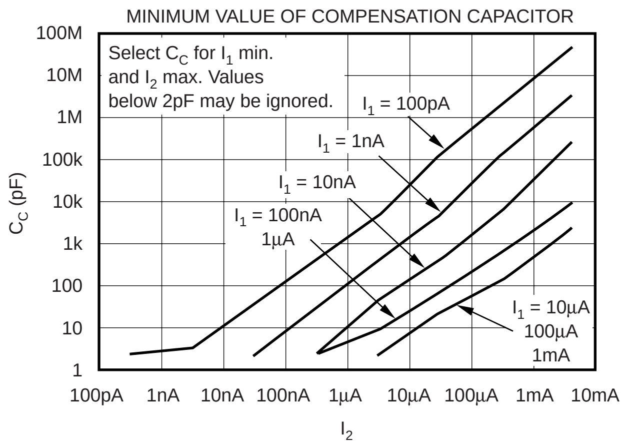


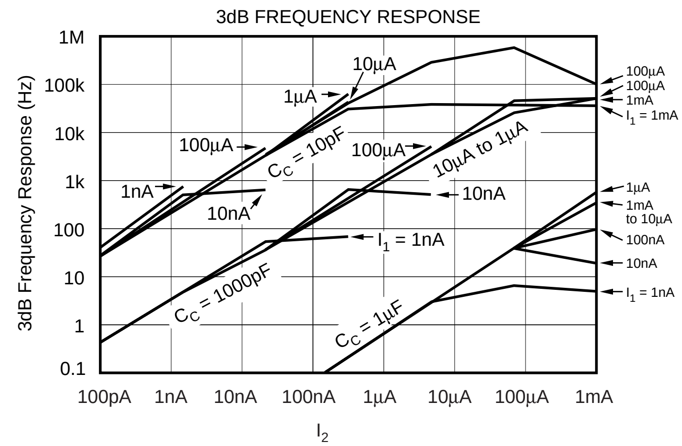

GAIN ERROR ($I_2$ = 1µA)

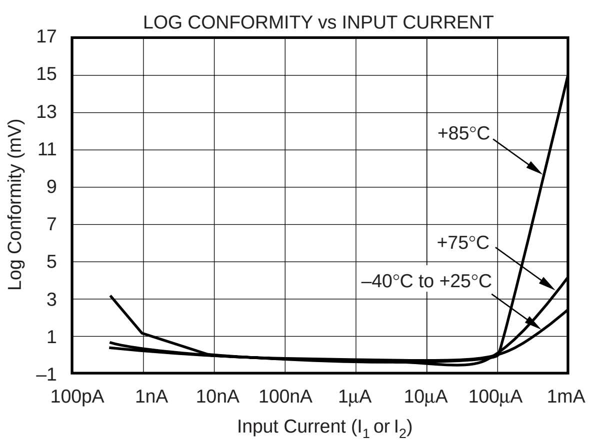


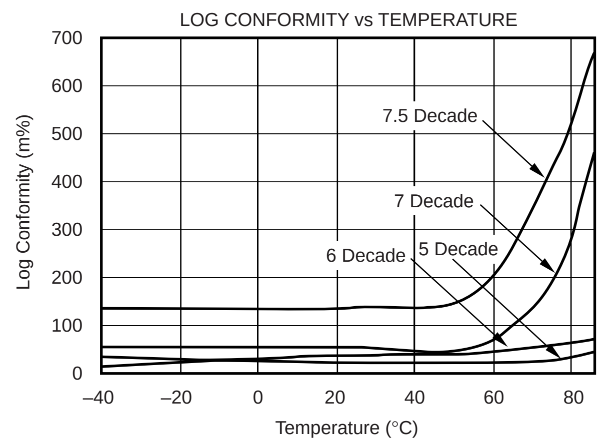
# TYPICAL CHARACTERISTICS (Cont.)

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



# APPLICATION INFORMATION

The LOG112 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 and Figure 2 show the basic connections required for operation of the LOG112 and LOG2112. 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 and Figure 2. Connecting the capacitors as close to the LOG112 and LOG2112 as possible will contribute to noise reduction as well.

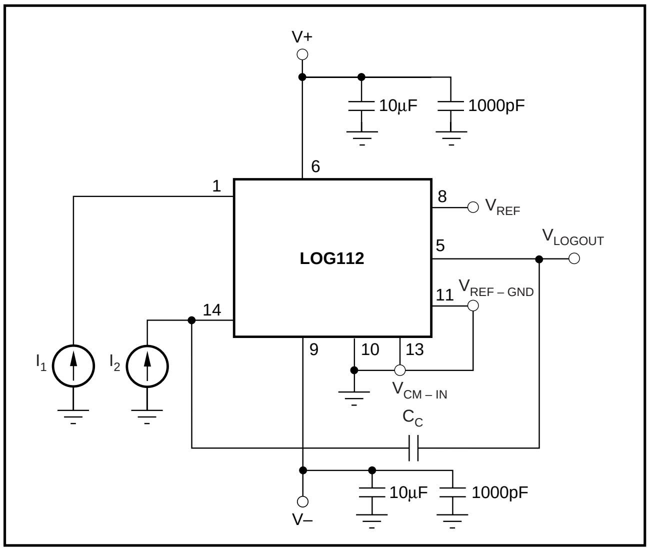



FIGURE 1. Basic Connections of the LOG112.

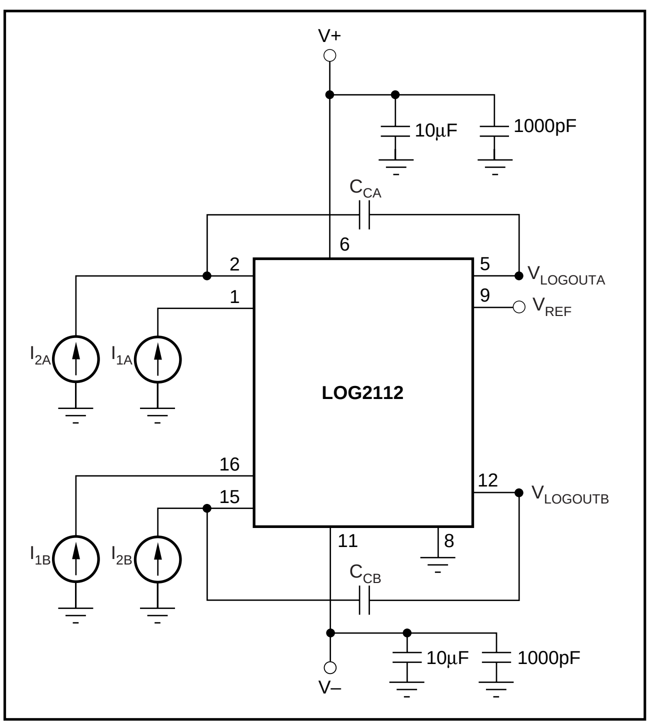



FIGURE 2. Basic Connections of the LOG2112.

### INPUT CURRENT RANGE

To maintain specified accuracy, the input current range of the LOG112 and LOG2112 should be limited from 100pA to 3.5mA. Input currents outside of this range may compromise the LOG112 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 input transistor.

On ±5V supplies, the total input current ($I_1 + I_2$) is limited to 4.5mA. Due to compliance issues internal to the LOG112 and LOG2112, to accommodate larger total input currents, supplies should be increased.

### SETTING THE REFERENCE CURRENT

When the LOG112 and LOG2112 are used to compute logarithms, either $I_1$ or $I_2$ can be held constant to become the reference current to which the other is compared.

$V_{LOGOUT}$ is expressed as:

$$V_{LOGOUT} = (0.5V)LOG\ (I_1/I_{REF}) \tag{1}$$

$I_{REF}$ can be derived from an external current source (such as that 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:

$$R_{REF} = 2.5V/10nA = 250M\Omega \tag{2}$$

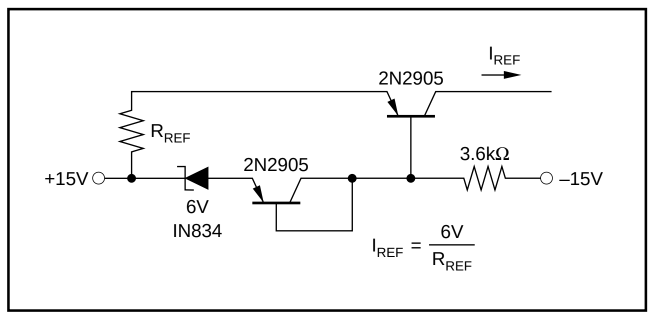



FIGURE 3. Temperature Compensated Current Source.

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.

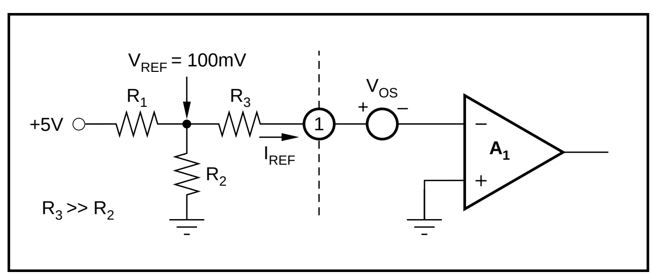



FIGURE 4. T Network for Reference Current.

Figure 5 shows a low-level current source using a series resistor. The low offset op amp reduces the effect of the LOG112 and LOG2112's input offset voltage.

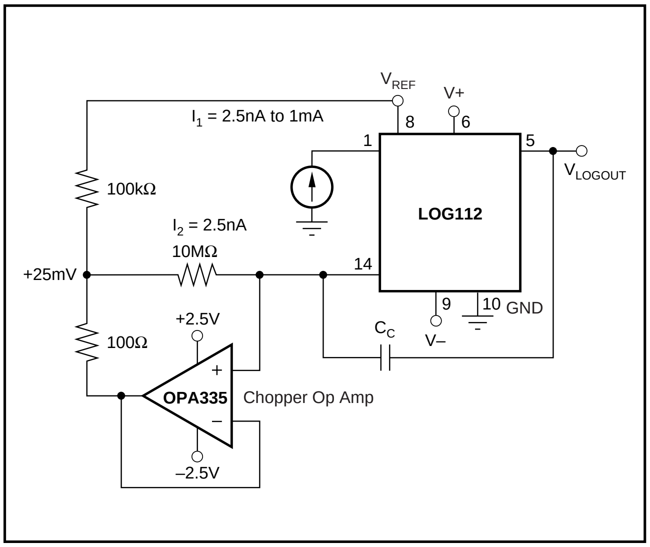



FIGURE 5. Current Source with Offset Compensation.

## FREQUENCY RESPONSE

The frequency response curves seen in the Typical Characteristic curves are shown for constant DC $I_1$ and $I_2$ with a small-signal AC current on one input.

The 3dB frequency response of the LOG112 and LOG2112 are 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 LOG112 and LOG2112 are 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 LOG112 and LOG2112.

## FREQUENCY COMPENSATION

Frequency compensation for the LOG112 is obtained by connecting a capacitor between pins 5 and 14. Frequency compensation for the LOG2112 is obtained by connecting a capacitor between pins 2 and 5, or 15 and 12. 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 $C_C$ make the LOG112 and LOG2112 more stable, but 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.

## NEGATIVE INPUT CURRENTS

The LOG112 and LOG2112 function only with positive input currents (conventional current flows into input current pins). In situations where negative input currents are needed, the circuits in Figures 6, 7, and 8 may be used.

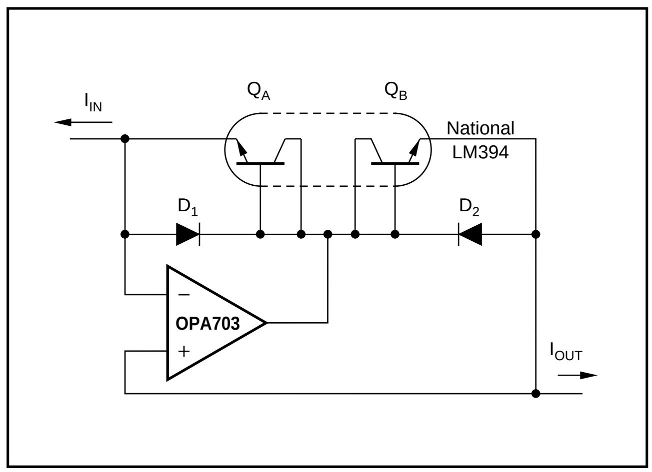



FIGURE 6. Current Inverter/Current Source.

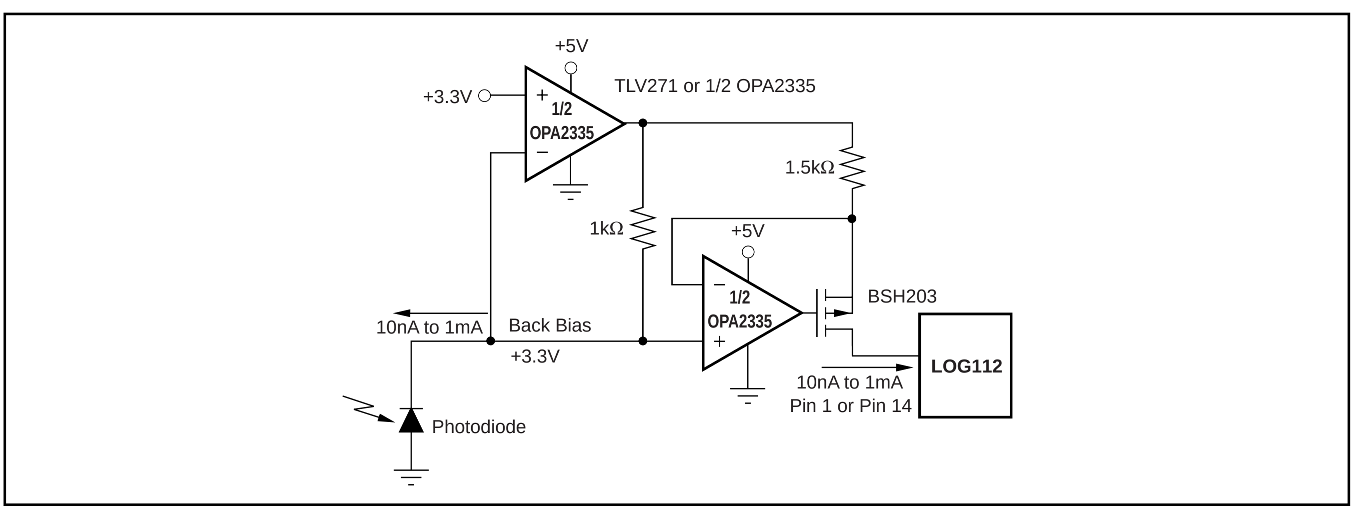



FIGURE 7. Precision Current Inverter/Current Source.

### VOLTAGE INPUTS

The LOG112 and LOG2112 give the best performances 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.

### ACHIEVING HIGHER ACCURACY WITH HIGHER INPUT CURRENTS

As input current to the LOG112 increases, output accuracy degrades. For a 4.5mA input current on ±5V supplies and a 10mA input current on ±12V supplies, total output error can be between 15% and 25%. Applying a common-mode voltage to $V_{CM}$ of at least +1V and up to 2.5V, brings the log transistors out of saturation and reduces output error to approximately 10%. To avoid forward biasing a photodiode, return the cathode to the $V_{CM}$ pin, as shown in Figure 9. To reverse bias the photodiode, apply a more positive voltage to the cathode than the anode.

# APPLICATION CIRCUITS

### LOG RATIO

One of the more common uses of log ratio amplifiers is to measure absorbance. See Figure 10 for a typical application.

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

If $D_1$ and $D_2$ are matched $A \propto (0.5V) \log I_1 / I_2$ (4)

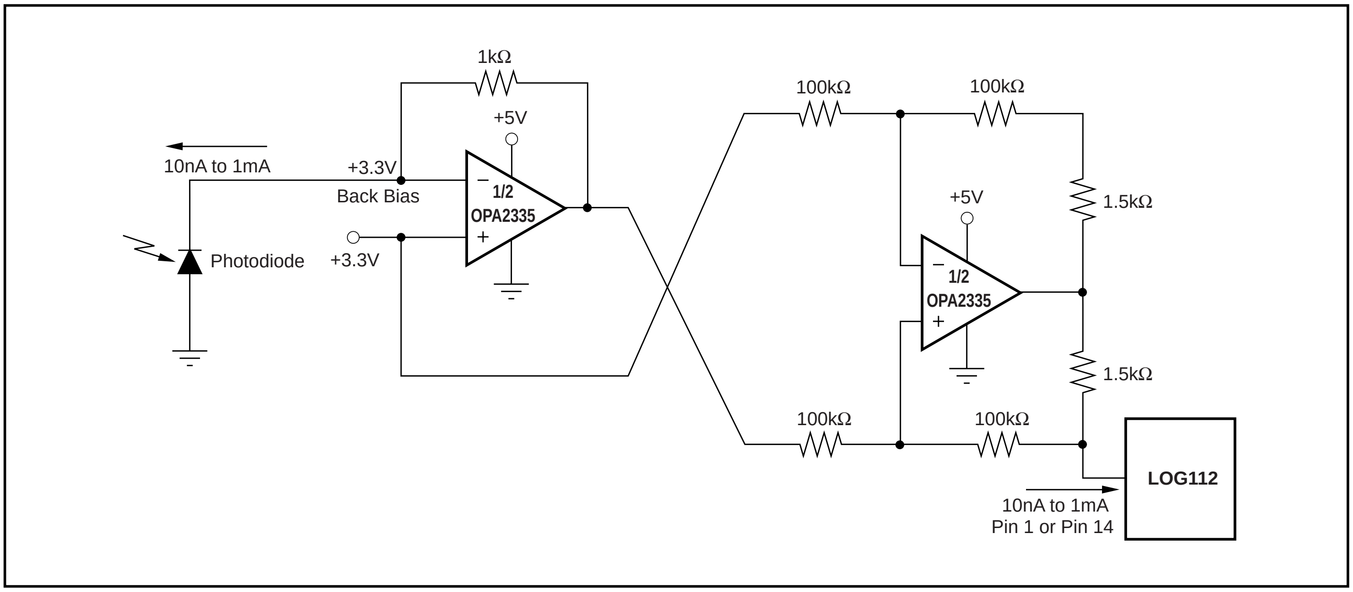



FIGURE 8. Precision Current Inverter/Current Source.

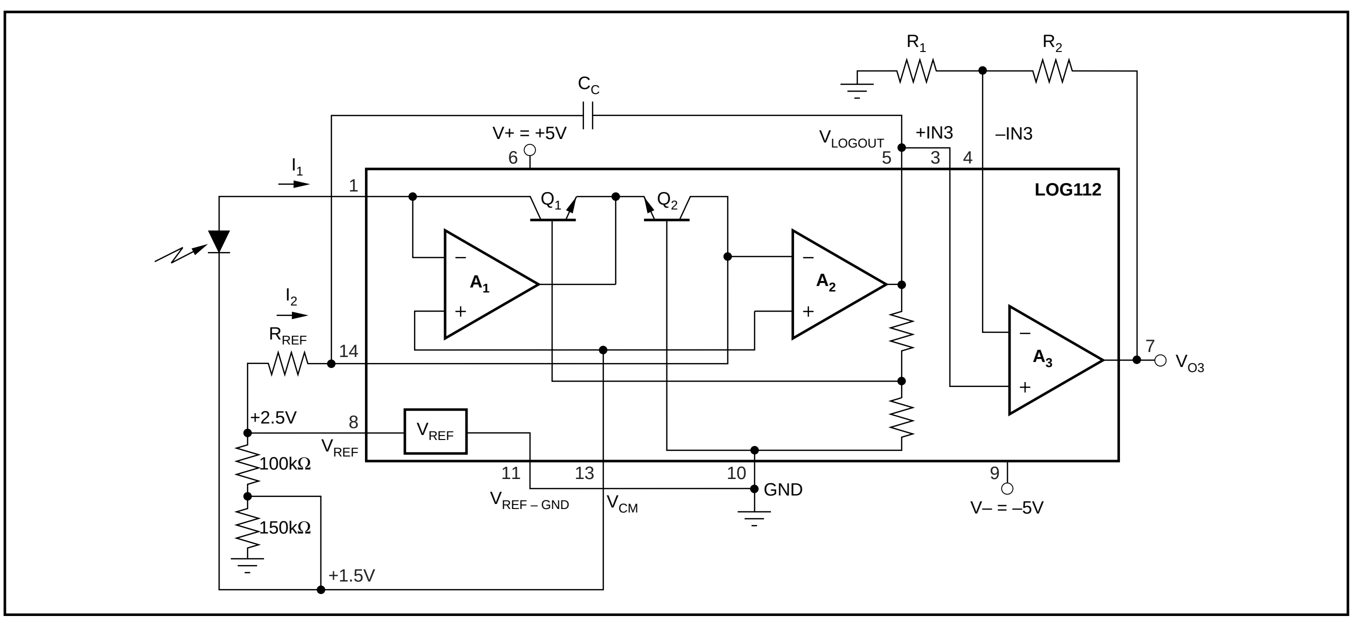



FIGURE 9. Extending Input Current Level and Improving Accuracy by Applying a Common-Mode Voltage.

## DATA COMPRESSION

In many applications, the compressive effects of the logarithmic transfer function are useful. For example, a LOG112 preceding a 12-bit A/D converter can produce the dynamic range equivalent to a 20-bit converter.

## OPERATION ON SINGLE SUPPLY

Many applications do not have the dual supplies required to operate the LOG112 and LOG2112. Figure 11 shows the LOG112 and LOG2112 configured for operation with a single +5V supply.

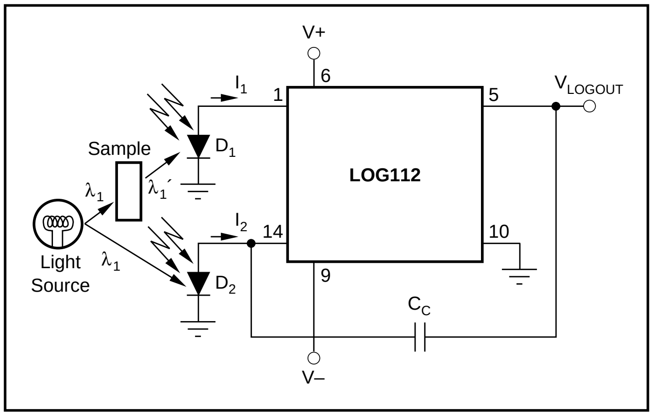



FIGURE 10. Absorbance Measurement.

## MEASURING AVALANCHE PHOTODIODE CURRENT

The wide dynamic range of the LOG112 and LOG2112 is useful for measuring avalanche photodiode current (APD), as shown in Figure 12.

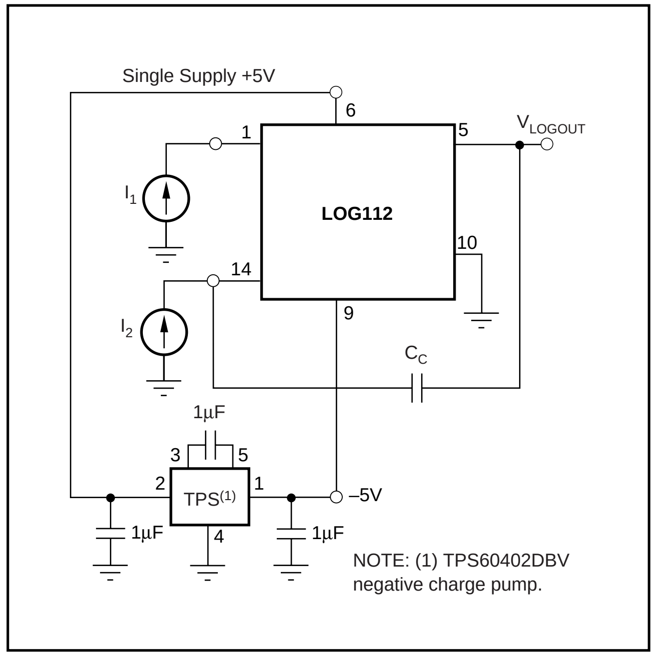



FIGURE 11. Single +5V Power-Supply Operation.

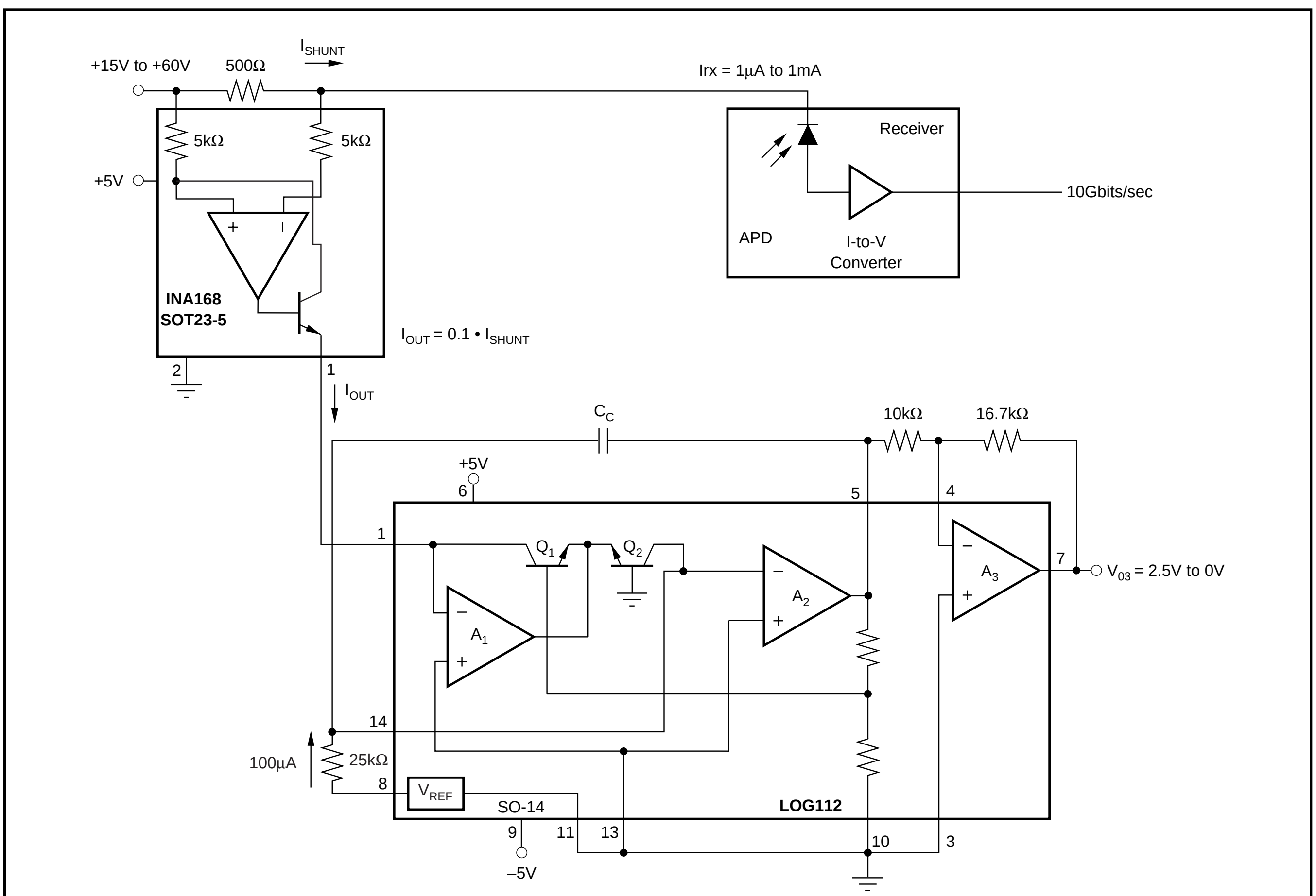



FIGURE 12. High-Side Shunt for APD Measures 3 Decades of APD Current.

# INSIDE THE LOG112

Using the base-emitter voltage relationship of matched bipolar transistors, the LOG112 establishes a logarithmic function of input current ratios. Beginning with the base-emitter voltage defined as:

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

k = Boltzman'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 12:

$$V_L = V_{BE_1} - V_{BE_2} \qquad (2)$$

Substituting (1) into (2) yields:

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

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

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

$$V_L = V_T \ln \frac{I_1}{I_2} \text{ and since} \qquad (5)$$

$$\ln x = 2.3 \log_{10} x \qquad (6)$$

$$V_L = n\, V_T \log \frac{I_1}{I_2} \qquad (7)$$

where n = 2.3 (8)

also

$$V_{OUT} = V_L \frac{R_1 + R_2}{R_1} \qquad (9)$$

$$V_{OUT} = \frac{R_1 + R_2}{R_1} n\, V_T \log \frac{I_1}{I_2} \qquad (10)$$

or

$$V_{OUT} = (0.5V)\text{LOG}\left(\frac{I_1}{I_2}\right) \qquad (11)$$

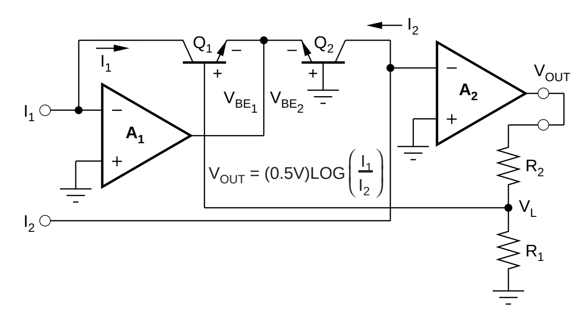



FIGURE 13. Simplified Model of a Log Amplifier.

NOTE: $R_1$ is a metal resistor used to compensate for gain over temperature.

# DEFINITION OF TERMS

## TRANSFER FUNCTION

The ideal transfer function is:

$$V_{LOGOUT} = (0.5V)\text{LOG}\ (I_1/I_2)$$

Figure 14 shows the graphical representation of the transfer over valid operating range for the LOG112 and LOG2112.

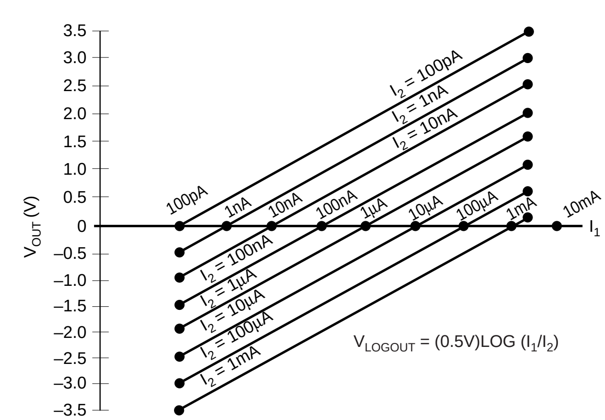



FIGURE 14. Transfer Function with Varying $I_2$ and $I_1$.

## 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 $V_{LOGOUT} = (0.5V)\text{LOG}\ (I_1/I_2)$. Thus,

$$V_{LOGOUT(ACTUAL)} = V_{LOGOUT(IDEAL)} \pm \text{Total Error} \qquad (6)$$

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 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 LOG112 and LOG2112, 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 (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 $V_{LOGOUT}$ 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:

$$V_{LOGOUT\ (NONLIN)} = 0.5\text{V/dec} \bullet 2N m\text{V} \tag{7}$$

where N is the log conformity error, in percent.

## INDIVIDUAL ERROR COMPONENTS

The ideal transfer function with current input is:

$$V_{LOGOUT} = (0.5\text{V})\text{LOG}\left(\frac{I_1}{I_2}\right) \tag{8}$$

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

$$V_{LOGOUT} = (0.5\text{V})(1 \pm \Delta K)\log\left(\frac{I_1 - I_{B1}}{I_2 - I_{B2}}\right) \pm Nm \pm V_{OSO} \tag{9}$$

The individual component of error is:

$\Delta K$ = gain error (0.10%, typ), as specified in the specification table.

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

N = log conformity error (0.01%, 0.13%, typ)

0.01% for m = 5, 0.13% for m = 7.5

$V_{OSO}$ = output offset voltage (3mV, typ)

m = number of decades over which N is specified

For example, what is the error when:

$$I_1 = 1\mu\text{A and } I_2 = 100\text{nA} \tag{10}$$

$$V_{LOGOUT} = (0.5 \pm 0.001)\log\left(\frac{10^{-6} - 5 \bullet 10^{-12}}{10^{-7} - 5 \bullet 10^{-12}}\right) \pm (2)(0.0001)5 \pm 3.0\text{mV} = 0.505\text{V} \tag{11}$$

Since the ideal output is 0.5V, the error as a percent of the reading is:

$$\%\ \text{error} = \frac{0.505\text{V}}{0.5} \bullet 100\% = 1.01\% \tag{12}$$

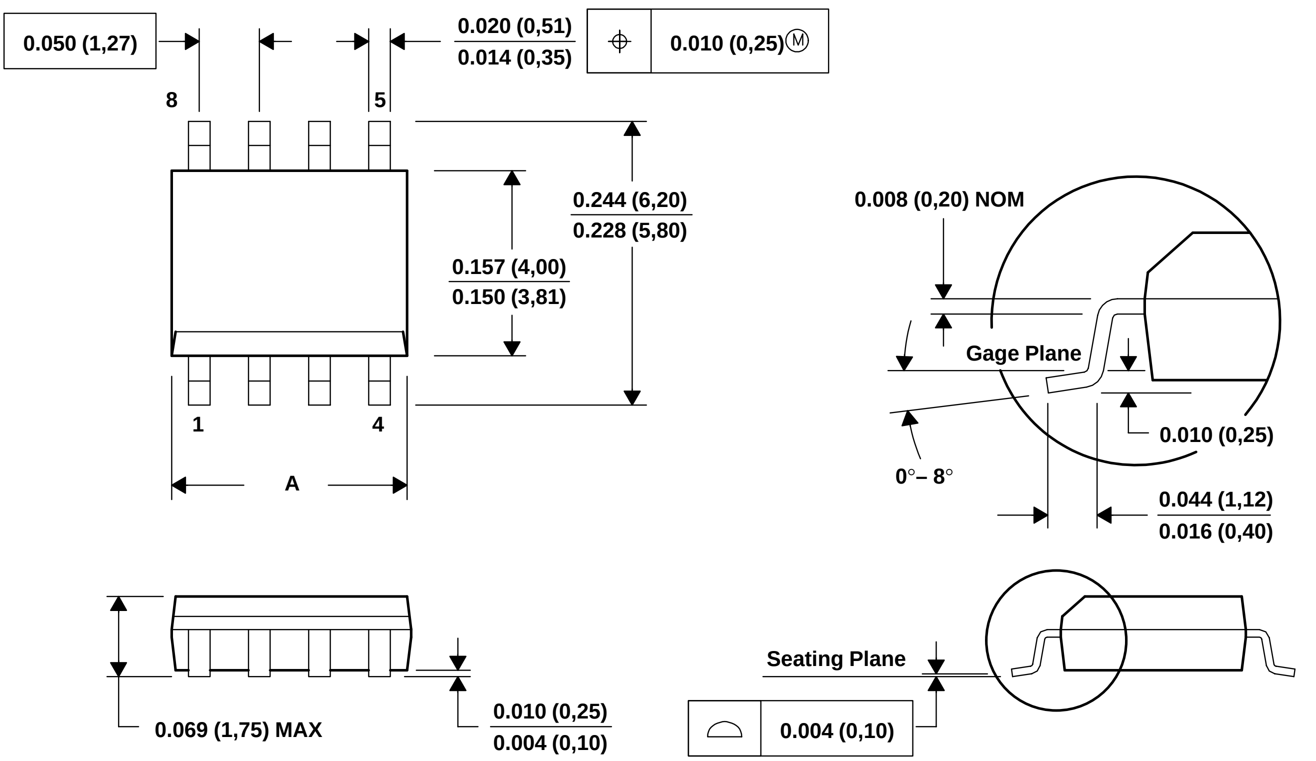
For the case of voltage inputs, the actual transfer function is:

$$V_{LOGOUT} = (0.5\text{V})(1 \pm \Delta K)\log\left(\frac{\frac{V_1}{R_1} - I_{B_1} \pm \frac{E_{OS_1}}{R_1}}{\frac{V_2}{R_2} - I_{B_2} \pm \frac{E_{OS_2}}{R_2}}\right) \pm Nm \pm V_{OSO} \tag{13}$$

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

## D (R-PDSO-G**) PLASTIC SMALL-OUTLINE PACKAGE

**8 PINS SHOWN**



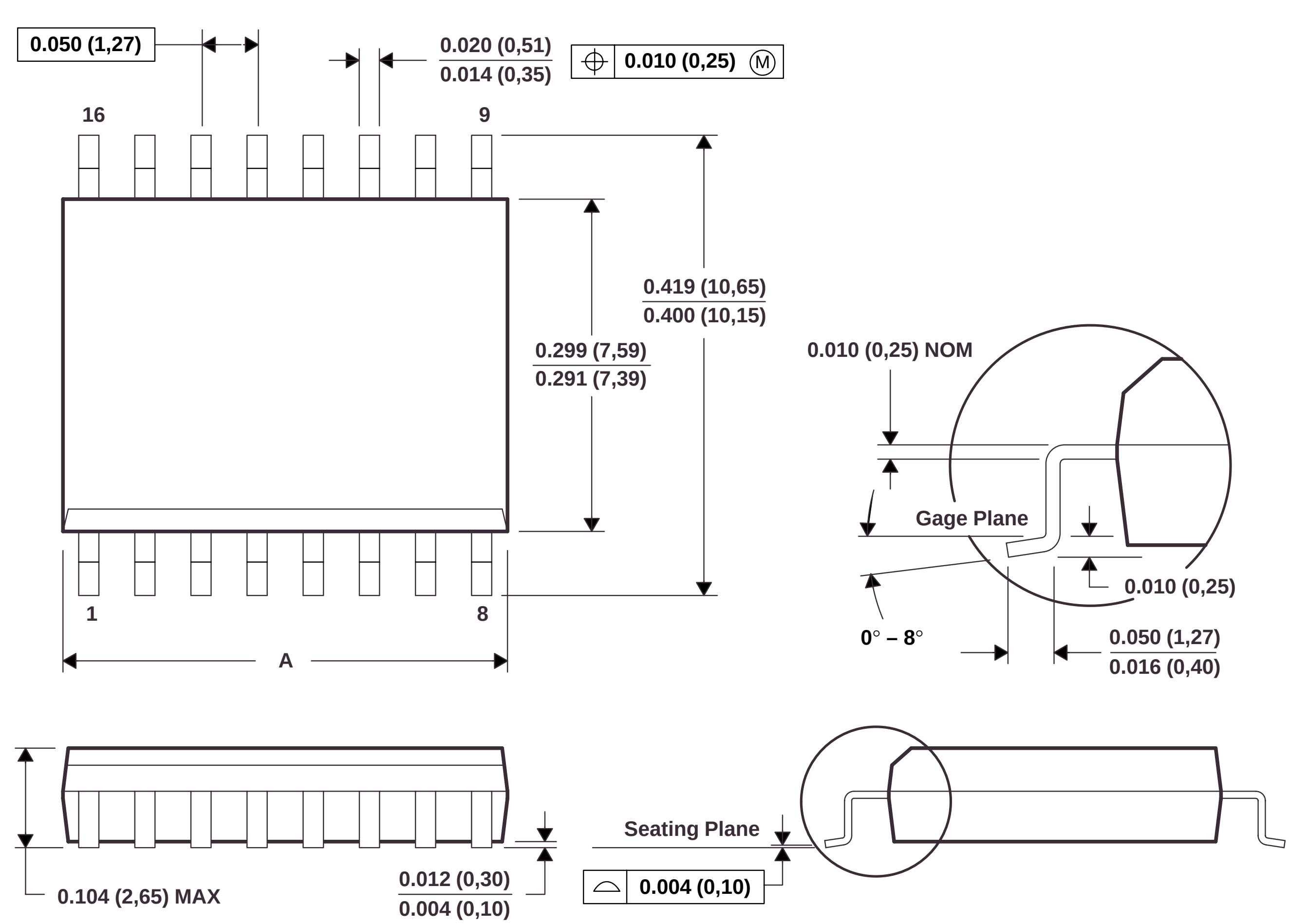

| DIM \ PINS ** | 8 | 14 | 16 |
|---|---|---|---|
| A MAX | 0.197 (5,00) | 0.344 (8,75) | 0.394 (10,00) |
| A MIN | 0.189 (4,80) | 0.337 (8,55) | 0.386 (9,80) |

4040047/E 09/01

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

**DW (R-PDSO-G**)** **PLASTIC SMALL-OUTLINE PACKAGE**

**16 PINS SHOWN**




| DIM \ PINS ** | 16 | 18 | 20 | 24 | 28 |
|---|---|---|---|---|---|
| A MAX | 0.410 (10,41) | 0.462 (11,73) | 0.510 (12,95) | 0.610 (15,49) | 0.710 (18,03) |
| A MIN | 0.400 (10,16) | 0.453 (11,51) | 0.500 (12,70) | 0.600 (15,24) | 0.700 (17,78) |

4040000 / E 08/01

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-013

# PACKAGE OPTION ADDENDUM



## PACKAGING INFORMATION

| ORDERABLE DEVICE | STATUS(1) | PACKAGE TYPE | PACKAGE DRAWING | PINS | PACKAGE QTY |
|---|---|---|---|---|---|
| LOG112AID | ACTIVE | SOIC | D | 14 | 58 |
| LOG112AIDR | ACTIVE | SOIC | D | 14 | 2500 |
| LOG2112AIDW | ACTIVE | SOIC | DW | 16 | 48 |
| LOG2112AIDWR | ACTIVE | SOIC | DW | 16 | 48 |

(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.

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