19-3071; Rev 1; 6/04

EVALUATION KIT AVAILABLE

MAXIM

# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

MAX4206

## General Description

The MAX4206 logarithmic amplifier computes the log ratio of an input current relative to a reference current (externally or internally generated) and provides a corresponding voltage output with a default 0.25V/decade scale factor. The device operates from a single +2.7V to +11V supply or from dual ±2.7V to ±5.5V supplies and is capable of measuring five decades of input current across a 10nA to 1mA range.

The MAX4206's uncommitted op amp can be used for a variety of functions, including filtering noise, adding offset, and adding additional gain. A 0.5V reference is also included to generate an optional precision current reference using an external resistor, which adjusts the log intercept of the MAX4206. The output-offset voltage and the adjustable scale factor are also set using external resistors.

The MAX4206 is available in a space-saving 16-pin thin QFN package (4mm x 4mm x 0.8mm), and is specified for operation over the -40°C to +85°C extended temperature range.

## Applications

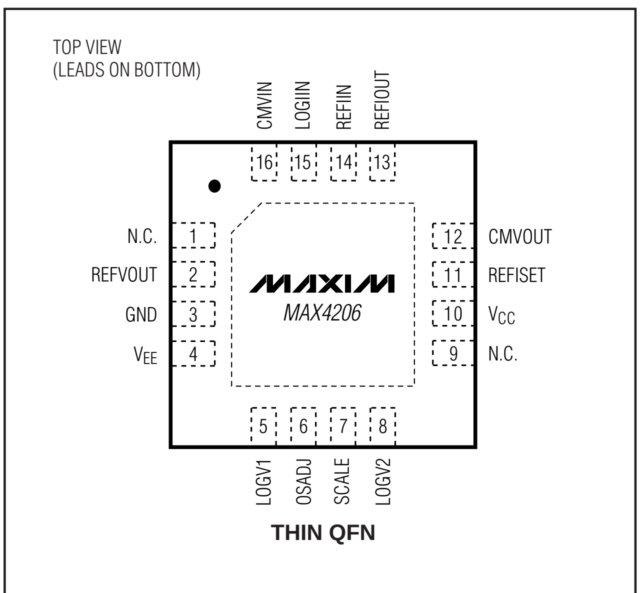
Photodiode Current Monitoring

Portable Instrumentation

Medical Instrumentation

Analog Signal Processing

## Pin Configuration




## Features

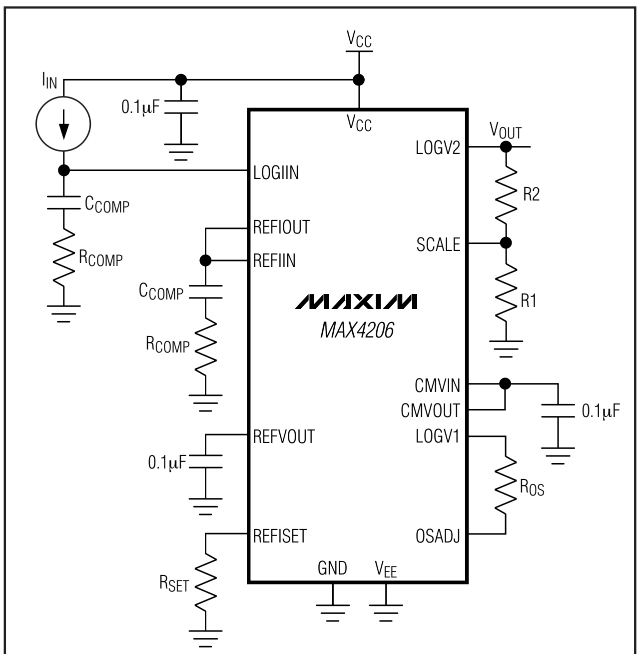
- ♦ **+2.7V to +11V Single-Supply Operation**
- ♦ **±2.7V to ±5.5V Dual-Supply Operation**
- ♦ **5 Decades of Dynamic Range (10nA to 1mA)**
- ♦ **Monotonic Over a 1nA to 1mA Range**
- ♦ **0.25V/Decade Internally Trimmed Output Scale Factor**
- ♦ **Adjustable Output Scale Factor**
- ♦ **Adjustable Output Offset Voltage**
- ♦ **Internal 10nA to 10µA Reference Current Source**
- ♦ **0.5V Input Common-Mode Voltage**
- ♦ **Small 16-Pin Thin QFN Package (4mm x 4mm x 0.8mm)**
- ♦ **-40°C to +85°C Operating Temperature Range**
- ♦ **Evaluation Kit Available**

## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE |
|---|---|---|
| MAX4206ETE | -40°C to +85°C | 16 Thin QFN-EP* |

*EP = Exposed paddle.

## Typical Operating Circuit



# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND, unless otherwise noted.)
$V_{CC}$ ........................................ -0.3V to +12V
$V_{EE}$ ........................................ -6V to +0.3V
Supply Voltage ($V_{CC}$ to $V_{EE}$) ........................ +12V
REFVOUT ........................................ ($V_{EE}$ - 0.3V) to +3.0V
OSADJ, SCALE, REFISET ........................ ($V_{EE}$ - 0.3V) to +5.5V
REFIIN, LOGIIN ........................................ ($V_{EE}$ - 0.3V) to $V_{CMVIN}$
LOGV1, LOGV2, CMVOUT,
REFIOUT ........................................ ($V_{EE}$ - 0.3V) to ($V_{CC}$ + 0.3V)
CMVIN ........................................ ($V_{EE}$ - 0.3V) to +1V
Continuous Current (REFIIN, LOGIIN) ........................ 10mA
Continuous Power Dissipation ($T_A$ = +70°C)
16-Pin Thin QFN (derate 16.9mW/°C above +70°C) .... 1349mW
Operating Temperature Range ........................ -40°C to +85°C
Junction Temperature ........................................ +150°C
Storage Temperature Range ........................ -65°C to +150°C
Lead Temperature (soldering, 10s) ........................ +300°C

*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

## DC ELECTRICAL CHARACTERISTICS—Single-Supply Operation

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = -40°C to +85°C. Typical values are at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | (Note 2) | | 2.7 | | 11.0 | V |
| Supply Current | $I_{CC}$ | $T_A$ = +25°C | | | 3.9 | 5 | mA |
| | | $T_A$ = -40°C to +85°C | | | | 7 | |
| LOGIIN Current Range (Notes 3, 4) | $I_{LOG}$ | Minimum | | 10 | | | nA |
| | | Maximum | | | | 1 | mA |
| REFIIN Current Range (Notes 3, 4) | $I_{REF}$ | Minimum | | 10 | | | nA |
| | | Maximum | | | | 1 | mA |
| Common-Mode Voltage | $V_{CMVOUT}$ | | | 480 | 500 | 520 | mV |
| Common-Mode Voltage Input Range | $V_{CMVIN}$ | | | 0.5 | | 1.0 | V |
| Log Conformity Error | $V_{LC}$ | $I_{REF}$ = 10nA, $I_{LOG}$= 10nA to 1mA, K = 0.25V/decade (Note 4) | $T_A$ = +25°C | | ±2 | ±5 | mV |
| | | | $T_A$ = -40°C to +85°C | | | ±10 | |
| Logarithmic Slope (Scale Factor) | K | $T_A$ = +25°C | | 237.5 | 250 | 262.5 | mV/decade |
| | | $T_A$ = -40°C to +85°C (Note 4) | | 231.25 | | 268.75 | |
| Logarithmic Slope (Scale Factor) Temperature Drift | | $T_A$ = -40°C to +85°C | | | 80 | | µV/decade/°C |
| Input Offset Voltage | $V_{IO}$ | $T_A$ = +25°C, $\lvert V_{CMVIN} - V_{REFIIN}\rvert$, $\lvert V_{CMVIN} - V_{LOGIIN}\rvert$ | | | 1 | 5 | mV |
| Input Offset Voltage Temperature Drift | $V_{IOS}$ | $\lvert V_{CMVIN} - V_{REFIIN}\rvert$, $\lvert V_{CMVIN} - V_{LOGIIN}\rvert$ | | | 6 | | µV/°C |
| Voltage Reference Output | $V_{REFVOUT}$ | $T_A$ = +25°C | | 1.218 | 1.238 | 1.258 | V |
| | | $T_A$ = -40°C to +85°C (Note 4) | | 1.195 | | 1.275 | |
| Voltage Reference Output Current | $I_{REFVOUT}$ | | | | 1 | | mA |
| Current Reference Output Voltage | $V_{REFISET}$ | $T_A$ = +25°C | | 490 | 500 | 510 | mV |
| | | $T_A$ = -40°C to +85°C (Note 4) | | 482 | | 518 | |

## DC ELECTRICAL CHARACTERISTICS—Single-Supply Operation (continued)

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = -40°C to +85°C. Typical values are at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **LOGV2 BUFFER** | | | | | | |
| Input Offset Voltage | $V_{IO}$ | $T_A$ = +25°C | | 0.4 | 2 | mV |
| | | $T_A$ = -40°C to +85°C (Note 4) | | | 6 | |
| Input Bias Current | $I_B$ | (Note 4) | | 0.01 | 1 | nA |
| Output Voltage Range | $V_{OH}$ | $R_L$ to GND = 2kΩ | | $V_{CC}$ - 0.2 | $V_{CC}$ - 0.3 | V |
| | $V_{OL}$ | $R_L$ to GND = 2kΩ | 0.2 | 0.08 | | |
| Output Short-Circuit Current | $I_{OUT+}$ | Sourcing | | 34 | | mA |
| | $I_{OUT-}$ | Sinking | | 58 | | |
| Slew Rate | SR | | | 12 | | V/µs |
| Unity-Gain Bandwidth | GBW | | | 5 | | MHz |

## AC ELECTRICAL CHARACTERISTICS—Single-Supply Operation

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| LOGV2 Total Noise | | 0.1Hz to 10Hz, total output-referred noise, $I_{REF}$ = 10nA, $I_{LOG}$ = 100nA | | 17 | | $µV_{RMS}$ |
| LOGV2 Spot Noise Density | | f = 5kHz, $I_{REF}$ = 10nA, $I_{LOG}$ = 100nA | | 0.8 | | $µV/\sqrt{Hz}$ |
| REFVOUT Total Noise | | 1Hz to 10Hz, total output-referred noise | | 3.3 | | $µV_{RMS}$ |
| REFVOUT Spot Noise Density | | f = 5kHz | | 266 | | $nV/\sqrt{Hz}$ |
| REFISET Total Noise | | 1Hz to 10Hz, total output-referred noise | | 0.67 | | $µV_{RMS}$ |
| REFISET Spot Noise Density | | f = 5kHz | | 23 | | $nV/\sqrt{Hz}$ |
| Small-Signal Unity-Gain Bandwidth | | $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, $R_{COMP}$ = 300Ω, $C_{COMP}$ = 32pF | | 1 | | MHz |

## DC ELECTRICAL CHARACTERISTICS—Dual-Supply Operation

($V_{CC}$ = +5V, $V_{EE}$ = -5V, GND = 0, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = -40°C to +85°C. Typical values are at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Supply Voltage (Note 2) | $V_{CC}$ | | 2.7 | | 5.5 | V |
| | $V_{EE}$ | | -2.7 | | -5.5 | |
| Supply Current | $I_{CC}$ | $T_A$ = +25°C | | 5 | 6 | mA |
| | | $T_A$ = -40°C to +85°C | | | 7.5 | |
| LOGIIN Current Range (Notes 3, 4) | $I_{LOG}$ | Minimum | 10 | | | nA |
| | | Maximum | | | 1 | mA |
| REFIIN Current Range (Notes 3, 4) | $I_{REF}$ | Minimum | 10 | | | nA |
| | | Maximum | | | 1 | mA |
| Common-Mode Voltage | $V_{CMVOUT}$ | | 480 | 500 | 520 | mV |

# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

## DC ELECTRICAL CHARACTERISTICS—Dual-Supply Operation (continued)

($V_{CC}$ = +5V, $V_{EE}$ = -5V, GND = 0, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = -40°C to +85°C. Typical values are at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Common-Mode Voltage Input Range | $V_{CMVIN}$ | | | 0.5 | | 1.0 | V |
| Log Conformity Error | $V_{LC}$ | $I_{REF}$ = 10nA, $I_{LOG}$= 10nA to 1mA, K = 0.25V/decade (Note 4) | $T_A$ = +25°C | | ±2 | ±5 | mV |
| | | | $T_A$ = -40°C to +85°C | | | ±10 | |
| Logarithmic Slope (Scale Factor) | K | $T_A$ = +25°C | | 237.5 | 250 | 262.5 | mV/ decade |
| | | $T_A$ = -40°C to +85°C | | 231.25 | | 268.75 | |
| Logarithmic Slope (Scale Factor) Temperature Drift | | $T_A$ = -40°C to +85°C | | | 80 | | µV/ decade/ °C |
| Input Offset Voltage | $V_{IO}$ | $T_A$ = +25°C, $\|V_{CMVIN} - V_{REFIIN}\|$, $\|V_{CMVIN} - V_{LOGIIN}\|$ | | | 1 | 5 | mV |
| Input Offset Voltage Temperature Drift | $V_{IOS}$ | $\|V_{CMVIN} - V_{REFIIN}\|$, $\|V_{CMVIN} - V_{LOGIIN}\|$ | | | 6 | | µV/°C |
| Voltage Reference Output | $V_{REFVOUT}$ | $T_A$ = +25°C | | 1.218 | 1.238 | 1.258 | V |
| | | $T_A$ = -40°C to +85°C (Note 4) | | 1.195 | | 1.275 | |
| Voltage Reference Output Current | $I_{REFVOUT}$ | | | | 1 | | mA |
| Current Reference Output Voltage | $V_{REFISET}$ | $T_A$ = +25°C | | 490 | 500 | 510 | mV |
| | | $T_A$ = -40°C to +85°C (Note 4) | | 482 | | 518 | |
| **LOGV2 BUFFER** | | | | | | | |
| Input Offset Voltage | $V_{IO}$ | $T_A$ = +25°C | | | 0.4 | 2 | mV |
| | | $T_A$ = -40°C to +85°C (Note 4) | | | | 6 | |
| Input Bias Current | $I_B$ | (Note 4) | | | 0.01 | 1 | nA |
| Output Voltage Range | $V_{OH}$ | $R_L$ to GND = 2kΩ | | | $V_{CC}$ - 0.2 | $V_{CC}$ - 0.3 | V |
| | $V_{OL}$ | $R_L$ to GND = 2kΩ | | $V_{EE}$ + 0.2 | $V_{EE}$ + 0.08 | | |
| Output Short-Circuit Current | $I_{OUT+}$ | Sourcing | | | 34 | | mA |
| | $I_{OUT-}$ | Sinking | | | 58 | | |
| Slew Rate | SR | | | | 12 | | V/µs |
| Unity-Gain Bandwidth | GBW | | | | 5 | | MHz |

## AC ELECTRICAL CHARACTERISTICS—Dual-Supply Operation

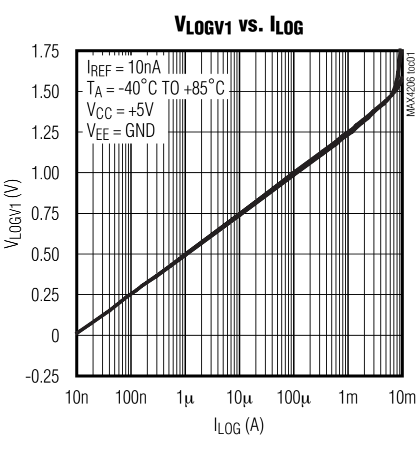
($V_{CC}$ = +5V, $V_{EE}$ = -5V, GND = 0, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)

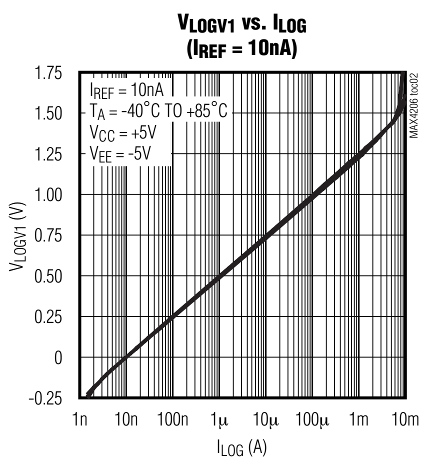
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| LOGV2 Total Noise | | 0.1Hz to 10Hz, total output-referred noise, $I_{REF}$ = 10nA, $I_{LOG}$ = 100nA | | 17 | | $µV_{RMS}$ |
| LOGV2 Spot Noise Density | | f = 5kHz, $I_{REF}$ = 10nA, $I_{LOG}$ = 100nA | | 0.8 | | µV/√Hz |
| REFVOUT Total Noise | | 1Hz to 10Hz, total output-referred noise | | 3.3 | | $µV_{RMS}$ |
| REFVOUT Spot Noise Density | | f = 5kHz | | 266 | | nV/√Hz |
| REFISET Total Noise | | 1Hz to 10Hz, total output-referred noise | | 0.67 | | $µV_{RMS}$ |
| REFISET Spot Noise Density | | f = 5kHz | | 23 | | nV/√Hz |
| Small-Signal Unity-Gain Bandwidth | | $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, $R_{COMP}$ = 300Ω, $C_{COMP}$ = 32pF | | 1 | | MHz |

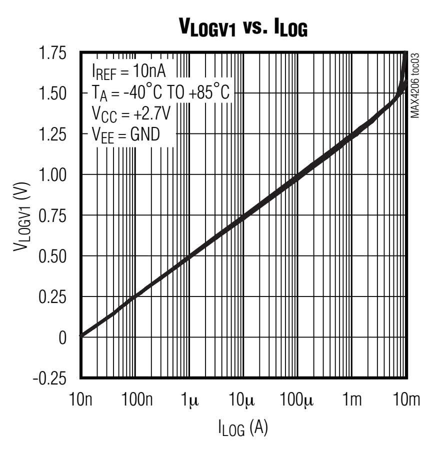
**Note 1:** All devices are 100% production tested at $T_A$ = +25°C. All temperature limits are guaranteed by design.
**Note 2:** Guaranteed and functionally verified.
**Note 3:** Log conformity error less than ±5mV with scale factor = 0.25V/decade.
**Note 4:** Guaranteed by design.

## *Typical Operating Characteristics*

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)



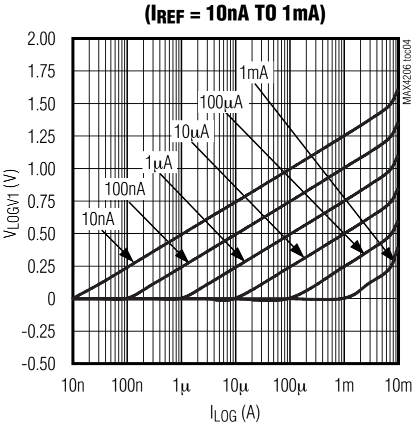



# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

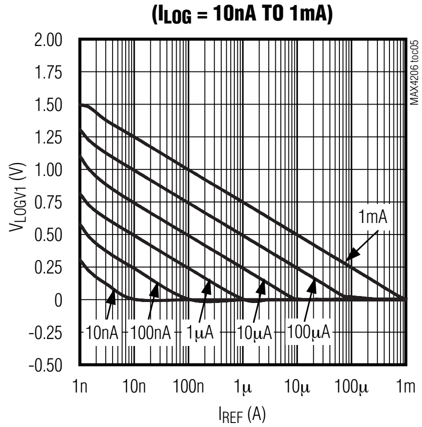
## Typical Operating Characteristics (continued)

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)

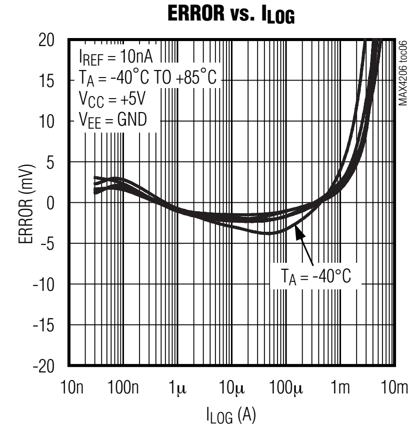
**$V_{LOGV1}$ vs. $I_{LOG}$ ($I_{REF}$ = 10nA TO 1mA)**



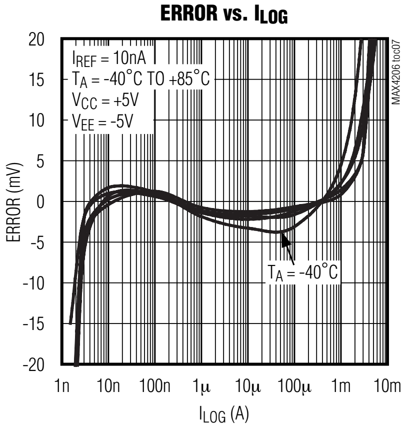

**$V_{LOGV1}$ vs. $I_{REF}$ ($I_{LOG}$ = 10nA TO 1mA)**



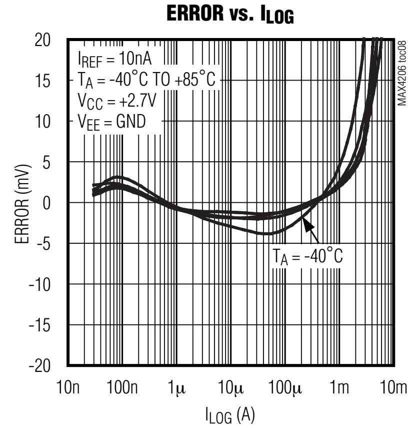

**NORMALIZED LOG CONFORMANCE ERROR vs. $I_{LOG}$**



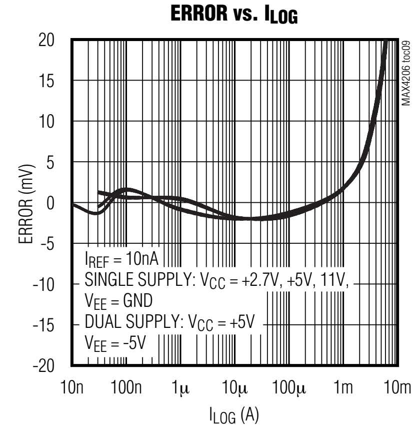

**NORMALIZED LOG CONFORMANCE ERROR vs. $I_{LOG}$**



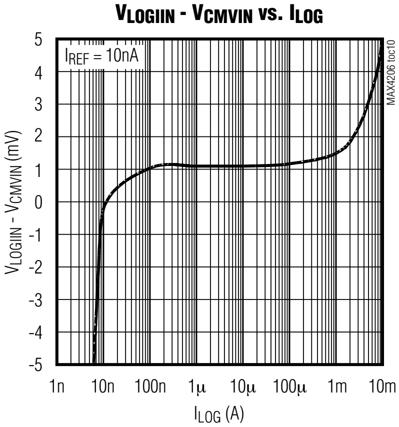

**NORMALIZED LOG CONFORMANCE ERROR vs. $I_{LOG}$**



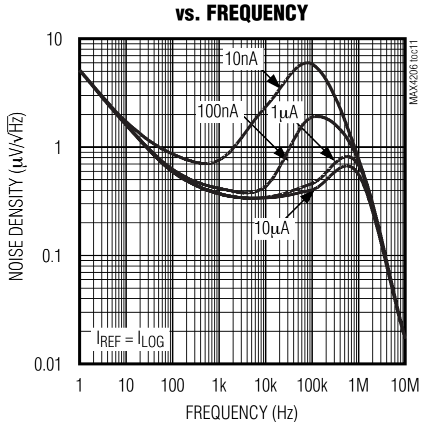

**NORMALIZED LOG CONFORMANCE ERROR vs. $I_{LOG}$**



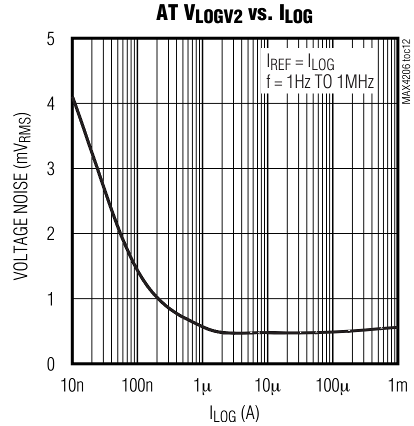

**$V_{LOGIIN}$ - $V_{CMVIN}$ vs. $I_{LOG}$**




**$V_{LOGV2}$ VOLTAGE-NOISE DENSITY vs. FREQUENCY**



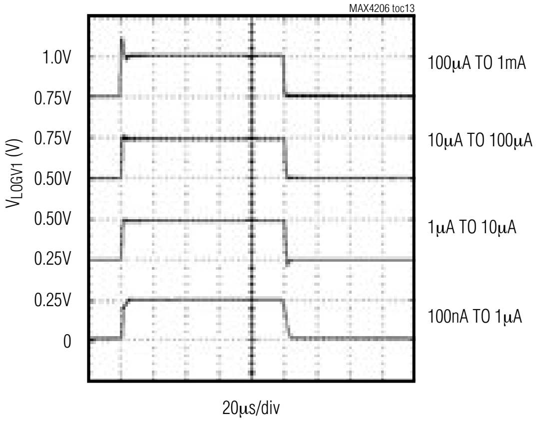

**TOTAL WIDEBAND VOLTAGE NOISE AT $V_{LOGV2}$ vs. $I_{LOG}$**



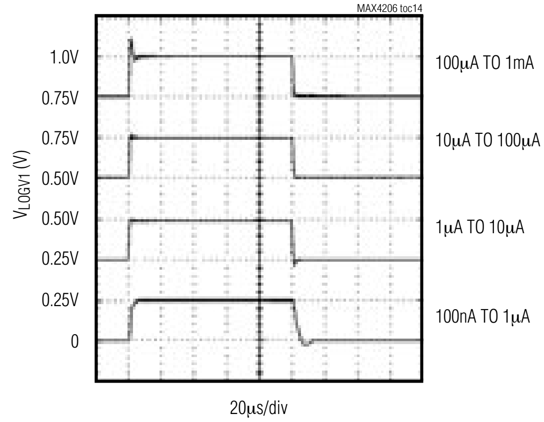
## Typical Operating Characteristics (continued)

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)

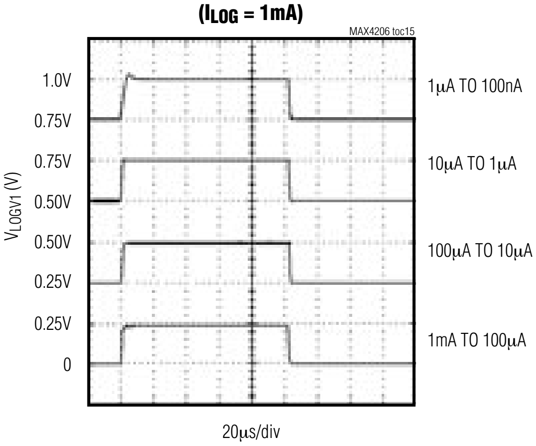
**$I_{LOG}$ PULSE RESPONSE ($I_{REF}$ = 100nA, $V_{CC}$ = 5V, $V_{EE}$ = GND)**



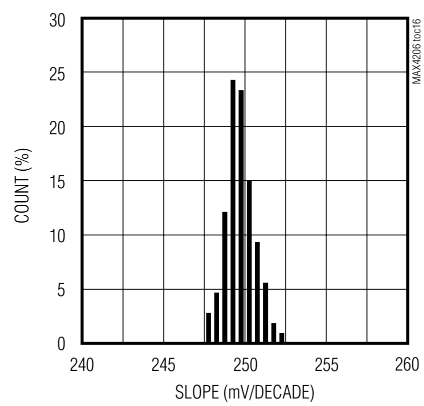

**$I_{LOG}$ PULSE RESPONSE ($I_{REF}$ = 100nA, $V_{CC}$ = 5V, $V_{EE}$ = -5V)**



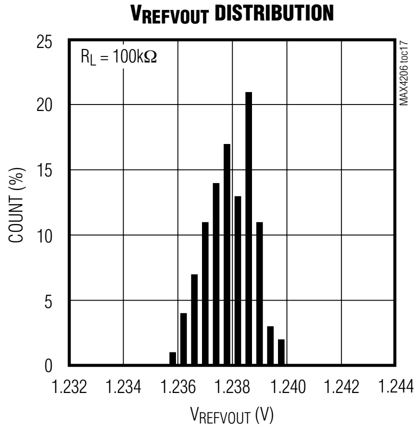

**$I_{REF}$ PULSE RESPONSE ($I_{LOG}$ = 1mA)**



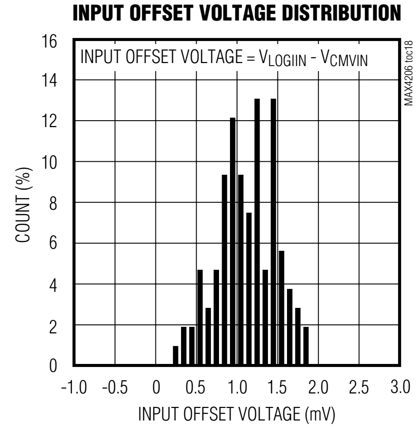

**LOGARITHMIC SLOPE DISTRIBUTION**




**$V_{REFVOUT}$ DISTRIBUTION**




**INPUT OFFSET VOLTAGE DISTRIBUTION**

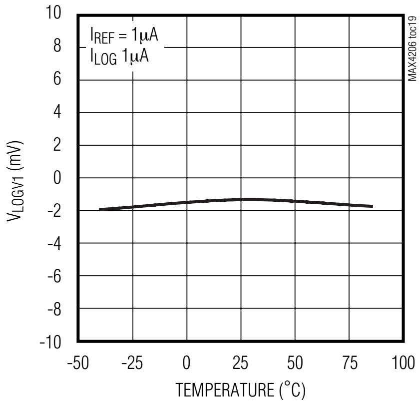


# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

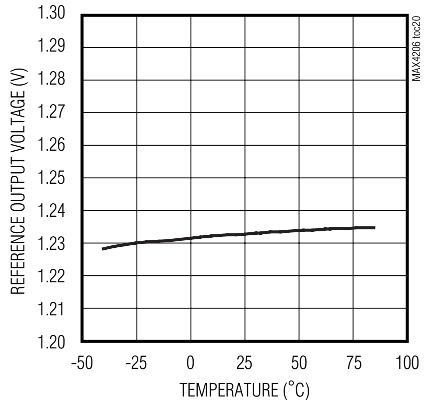
## Typical Operating Characteristics (continued)

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)

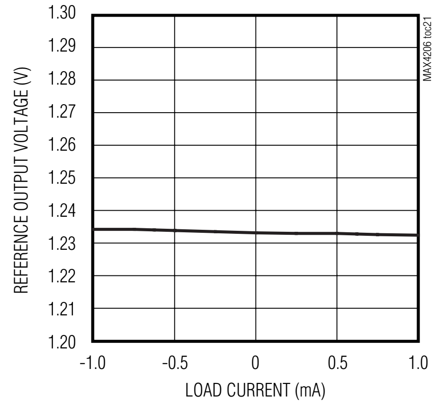
**OUTPUT OFFSET VOLTAGE vs. TEMPERATURE**



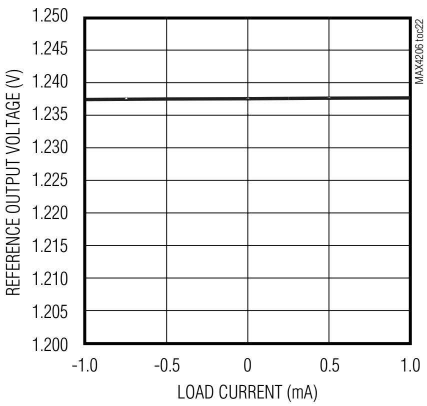

**REFERENCE OUTPUT VOLTAGE (VREFVOUT) vs. TEMPERATURE**



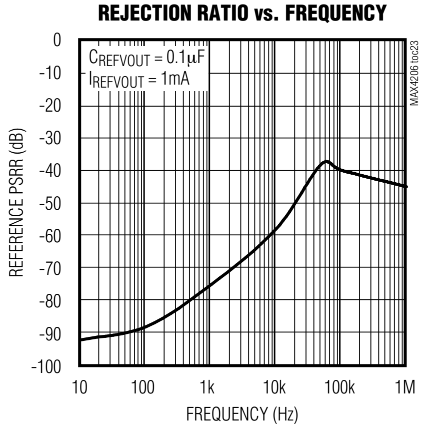

**REFERENCE OUTPUT VOLTAGE (VREFVOUT) vs. LOAD CURRENT**



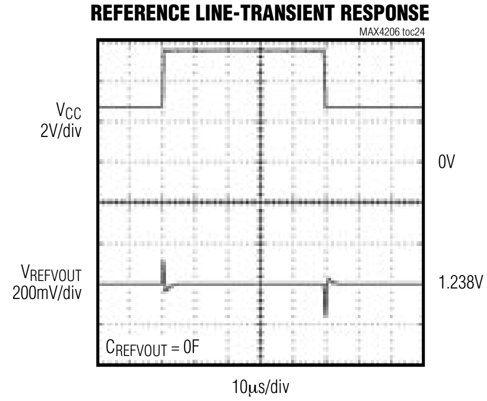

**REFERENCE OUTPUT VOLTAGE (VREFVOUT) vs. SUPPLY VOLTAGE**



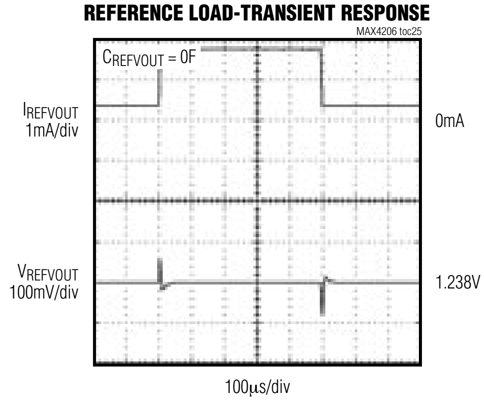

**REFERENCE POWER-SUPPLY REJECTION RATIO vs. FREQUENCY**



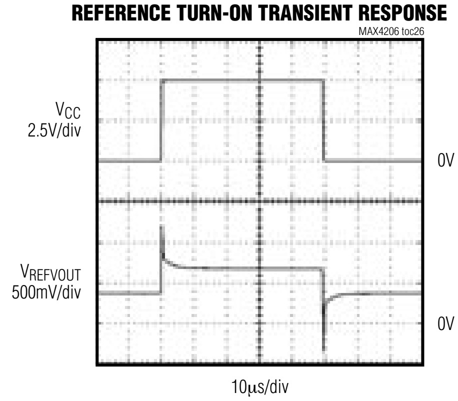

**REFERENCE LINE-TRANSIENT RESPONSE**




**REFERENCE LOAD-TRANSIENT RESPONSE**



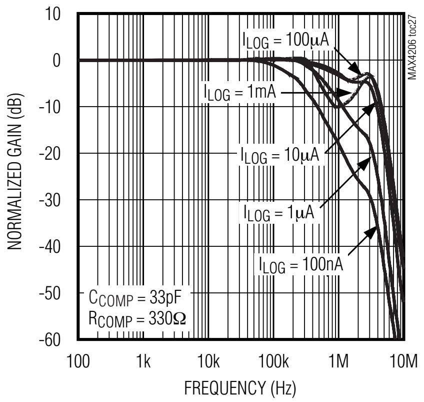

**REFERENCE TURN-ON TRANSIENT RESPONSE**



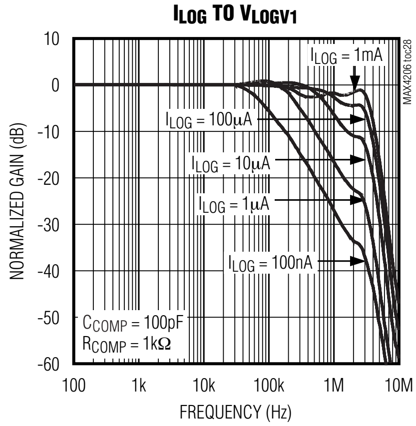
## Typical Operating Characteristics (continued)

($V_{CC}$ = +5V, $V_{EE}$ = GND = 0V, $I_{REF}$ = 1µA, $I_{LOG}$ = 10µA, LOGV2 = SCALE, LOGV1 = OSADJ, CMVIN = CMVOUT, $R_{SET}$ > 1MΩ, $T_A$ = +25°C, unless otherwise noted.)

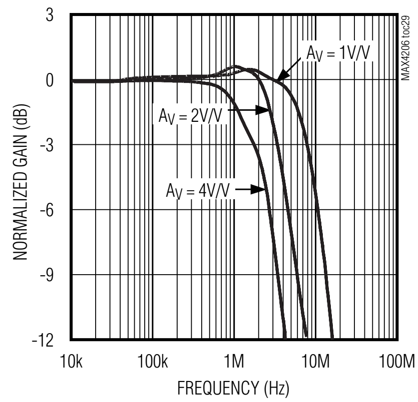
**SMALL-SIGNAL AC RESPONSE $I_{LOG}$ TO $V_{LOGV1}$**




**SMALL-SIGNAL AC RESPONSE $I_{LOG}$ TO $V_{LOGV1}$**




**SMALL-SIGNAL AC RESPONSE OF BUFFER**




## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1, 9 | N.C. | No Connection. Not internally connected. |
| 2 | REFVOUT | 1.238V Reference Voltage Output. Bypass REFVOUT to GND with a 0 to 1µF capacitor (optional). |
| 3 | GND | Ground |
| 4 | $V_{EE}$ | Negative Power Supply. Bypass $V_{EE}$ to GND with a 0.1µF capacitor. |
| 5 | LOGV1 | Logarithmic Amplifier Voltage Output 1. The output scale factor of LOGV1 is 0.25V/decade. |
| 6 | OSADJ | Offset Adjust Input. When operating from a single power supply, current applied to OSADJ adjusts the output offset voltage (see the *Output Offset* section). |
| 7 | SCALE | Scale Factor Input. Adjust the output scale factor for LOGV2 using a resistive divider (see the *Scale Factor* section). |
| 8 | LOGV2 | Logarithmic Amplifier Voltage Output 2. Adjust the output scale factor for LOGV2 using a resistive divider (see the *Scale Factor* section). |
| 10 | $V_{CC}$ | Positive Power Supply. Bypass $V_{CC}$ to GND with a 0.1µF capacitor. |
| 11 | REFISET | Current Reference Adjust Input. A resistor ($R_{SET}$), from REFISET to GND, adjusts the current at REFIOUT (see the *Adjusting the Logarithmic Intercept* section). |
| 12 | CMVOUT | 0.5V Common-Mode Voltage Reference Output. Bypass CMVOUT to GND with a 0.1µF capacitor. |
| 13 | REFIOUT | Current Reference Output. The internal current reference output is available at REFIOUT. |
| 14 | REFIIN | Current Reference Input. Apply an external reference current at REFIIN. $I_{REFIIN}$ is the reference current used by the logarithmic amplifier when generating LOGV1. |
| 15 | LOGIIN | Current Input to Logarithmic Amplifier. LOGIIN is typically connected to a photodiode anode or other external current source. |
| 16 | CMVIN | Common-Mode Voltage Input. $V_{CMVIN}$ is the common-mode voltage for the input and reference amplifiers (see the *Common Mode* section). |

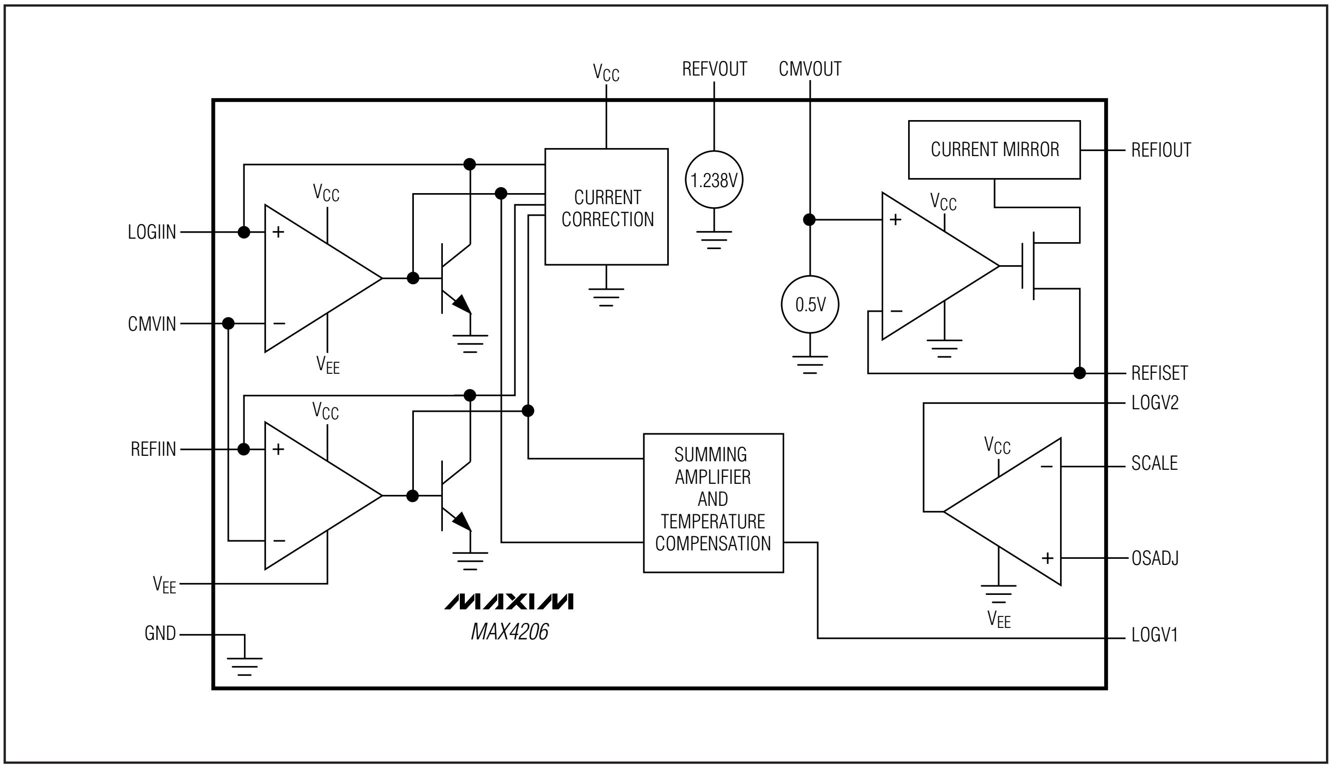



*Figure 1. Functional Diagram*

## Detailed Description

### Theory

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

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

where:

$V_{BE}$ = base-emitter voltage of a bipolar transistor

k = 1.381 x $10^{-23}$ J/K

T = absolute temperature (K)

q = 1.602 x $10^{-19}$ C

$I_C$ = collector current

$I_S$ = reverse saturation current

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

$$V_{OUT} = V_{BE1} - V_{BE2}$$

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

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

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

$$= \left(\frac{kT}{q}\right)(\ln(10))\left[\log_{10}\left(\frac{I_{LOG}}{I_{REF}}\right)\right]$$

$$= K \times \log_{10}\left(\frac{I_{LOG}}{I_{REF}}\right)$$ (see Figure 3)

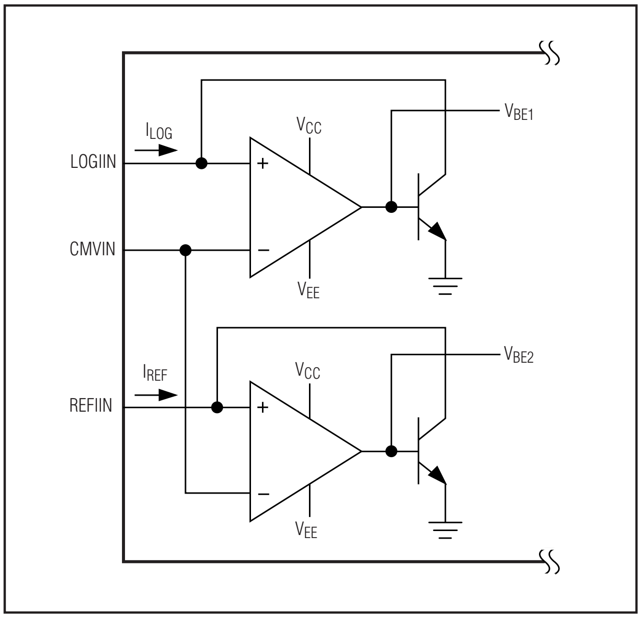



Figure 2. Simplified Model of a Logarithmic Amplifier

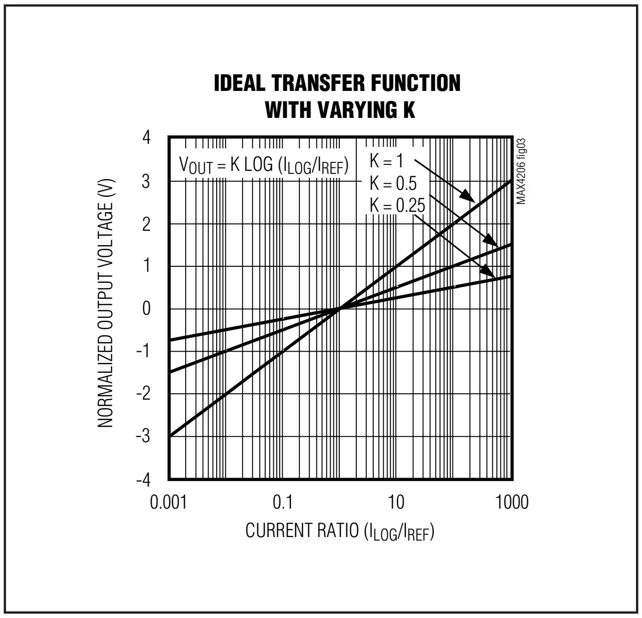



Figure 3. Ideal Transfer Function with Varying K

where:

K = scale factor (V/decade)

$I_{LOG}$ = the input current at LOGIIN

$I_{REF}$ = the reference current at REFIIN

The MAX4206 uses internal temperature compensation to virtually eliminate the effects of the thermal voltage, (kT/q), on the amplifier's scale factor, maintaining a constant slope over temperature.

## Definitions

### Transfer Function

The ideal logarithmic amplifier transfer function is:

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

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

### Log Conformity

Log conformity is the maximum deviation of the MAX4206's output from the best-fit straight line of the $V_{LOGV1}$ versus log ($I_{LOG}/I_{REF}$) curve. It is expressed as a percent of the full-scale output or an output voltage.

### Referred-to-Input and Referred-to-Output Errors

The log nature of the MAX4206 insures that any additive error at LOGV1 corresponds to multiplicative error at the input, regardless of input level.

### Total Error

Total error (TE) is defined as the deviation of the output voltage, $V_{LOGV1}$, from the ideal transfer function (see the *Transfer Function* section):

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

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

$$V_{LOGV2} = K(1 \pm \Delta K)\left[\log_{10}\left(\frac{I_{LOG} - I_{BIAS1}}{I_{REF} - I_{BIAS2}}\right) \pm 4\left(\pm V_{LC} \pm V_{OSOUT}\right)\right]$$

where $V_{LC}$ and $V_{OSOUT}$ are the log conformity and output offset voltages, respectively. Output offset is defined as the offset occurring at the output of the MAX4206 when equal currents are presented to $I_{LOG}$ and $I_{REF}$. Because the MAX4206 is configured with a gain of K = 0.25V/decade, a 4 should multiply the ($\pm V_{LC} \pm V_{OSOUT}$) term, if $V_{LC}$ and $V_{OSOUT}$ were derived from this default configuration.

# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

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

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

Expanding this expression:

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

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

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

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

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

As an example, consider the following situation:

Full-scale input = 5V

$I_{LOG}$ = 100µA

$I_{REF}$ = 100nA

K = 1 ±5% V/decade (note that the uncommitted amplifier is configured for a gain of 4)

$V_{LC}$ = ±5mV (obtained from the *Electrical Characteristics* table)

$V_{OSOUT}$ = ±2mV (typ)

$T_A$ = +25°C

Substituting into the total error approximation,

$$TE \cong \pm\ (1V/decade)(0.05\log_{10}\ (100\mu A/100nA)\ \pm 4\ (\pm 5mV\ \pm 2mV) = \pm[0.15V\ \pm 4(\pm 7mV)]$$

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

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

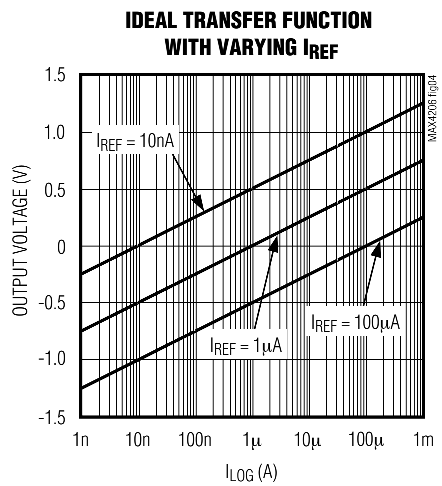



Figure 4. Ideal Transfer Function with Varying $I_{REF}$

## Applications Information

### Input Current Range

Five decades of input current across a 10nA to 1mA range are acceptable for $I_{LOG}$ and $I_{REF}$. The effects of leakage currents increase as $I_{LOG}$ and $I_{REF}$ fall below 10nA. Bandwidth decreases at low $I_{LOG}$ values (see the *Frequency Response and Noise Considerations* section). As $I_{LOG}$ and $I_{REF}$ increase to 1mA or higher, transistors become less logarithmic in nature. The MAX4206 incorporates leakage current compensation and high-current correction circuits to compensate for these errors.

### Frequency Compensation

The MAX4206's frequency response is a function of the input current magnitude and the selected compensation network at LOGIIN and REFIIN. The compensation network comprised of $C_{COMP}$ and $R_{COMP}$ ensures stability over the specified range of input currents by introducing an additional pole/zero to the system. For the typical application, select $C_{COMP}$ = 100pF and $R_{COMP}$ = 100Ω. Where high bandwidth at low current is required, $C_{COMP}$ = 32pF and $R_{COMP}$ = 330Ω are suitable compensation values.

### Frequency Response and Noise Considerations

The MAX4206 bandwidth is proportional to the magnitude of the $I_{REF}$ and $I_{LOG}$ currents, whereas the noise is inversely proportional to $I_{REF}$ and $I_{LOG}$ currents.

### Common Mode

A common-mode input voltage, $V_{CMVOUT}$, of 0.5V is available at CMVOUT and can be used to bias the logging and reference amplifier inputs by connecting CMVOUT to CMVIN. An external voltage between 0.5V and 1V can be applied to CMVIN to bias the logging and reference transistor collectors and to optimize the performance required for both single- and dual-supply operation.

### Adjusting the Logarithmic Intercept

Adjust the logarithmic intercept by changing the reference current, $I_{REF}$. A resistor from REFISET to GND (see Figures 5 and 6) adjusts the reference current, according to the following equation:

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

where $V_{REFISET}$ is 0.5V. Select $R_{SET}$ between 5kΩ and 5MΩ. REFIOUT current range is 10nA to 10µA only.

### Single-Supply Operation

When operating from a single +2.7V to +11V supply, $I_{LOG}$ must be greater than $I_{REF}$, resulting in a positive slope of the log output voltages, LOGV1 and LOGV2. Bias the log and reference amplifiers by connecting CMVOUT to CMVIN or connecting an external voltage reference between 0.5V and 1V to CMVIN. For single-supply operation, connect $V_{EE}$ to GND.

#### Output Offset

Select $R_{OS}$ and $I_{OS}$ to adjust the output offset voltage (see Figure 5). The magnitude of the offset voltage is given by:

$$V_{OS} = R_{OS} \times I_{OSADJ}$$

#### Scale Factor

The scale factor, K, is the slope of the logarithmic output. For the LOGV1 amplifier, K = 0.25V/decade. When operating in a single-supply configuration, adjust the overall scale factor for the MAX4206 using the uncommitted LOGV2 amplifier and the following equation, which refers to Figure 5:

$$R2 = R1\left(\frac{K}{0.25} - 1\right)$$

Select R1 between 1kΩ and 100kΩ, with an ideal value of 10kΩ. The noninverting amplifier ensures that the overall scale factor is greater than or equal to 0.25V/decade for single-supply operation.

#### Design Example

Desired:

Single-Supply Operation

Logarithmic intercept: 100nA

Overall scale factor = 1V/decade

Because there is no offset current applied to the circuit ($R_{OS}$ = 0Ω), the reference current, $I_{REF}$, equals the log intercept of 100µA. Therefore,

$$R_{SET} = \frac{0.5V}{10 \times 100nA} = 500k\Omega$$

Select $R_1$ = 10kΩ:

$$R2 = 10k\Omega\left(\frac{1V/V}{0.25} - 1\right) = 30k\Omega$$

### Dual-Supply Operation

When operating from dual ±2.7 to ±5.5V supplies, it is not required that $I_{LOG}$ be greater than $I_{REF}$. A positive output voltage results at LOGV1 when $I_{LOG}$ exceeds $I_{REF}$. A negative output voltage results at LOGV1 when $I_{LOG}$ is less than $I_{REF}$. Bias the log and reference amplifiers by connecting CMVOUT to CMVIN or connect an external 0.5V to 1V reference to CMVIN. For dual-supply operation with CMVIN < 0.5V, refer to the MAX4207 data sheet.

#### Output Offset

The uncommitted amplifier in the inverting configuration utilized by the MAX4206 facilitates large output-offset voltage adjustments when operated with dual supplies. The magnitude of the offset voltage is given by the following equation:

$$V_{OS} = V_{OSADJ}\left(1 + \frac{R_2}{R_1}\right)$$

A resistive divider between REFVOUT, OSADJ, and GND can be used to adjust $V_{OSADJ}$ (see Figure 6).

$$V_{OSADJ} = V_{REFOUT}\left(\frac{R_4}{R_3 + R_4}\right)$$

# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

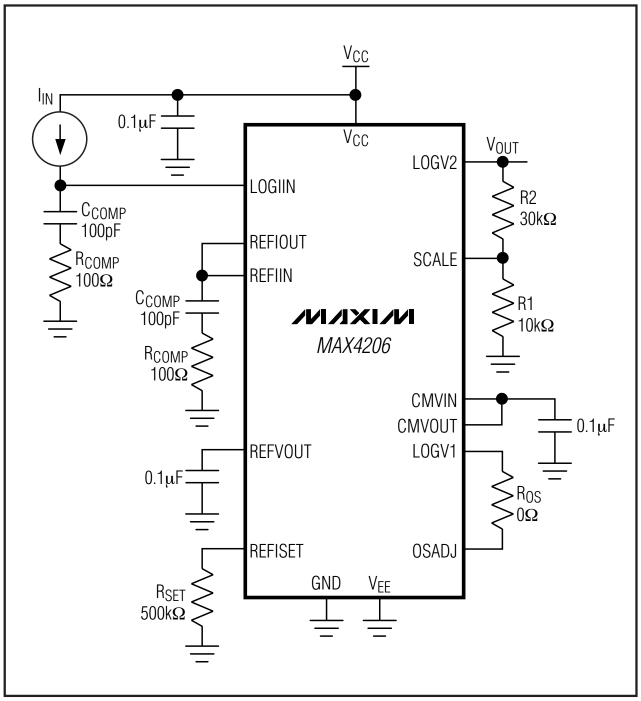



*Figure 5. Single-Supply Typical Operating Circuit*

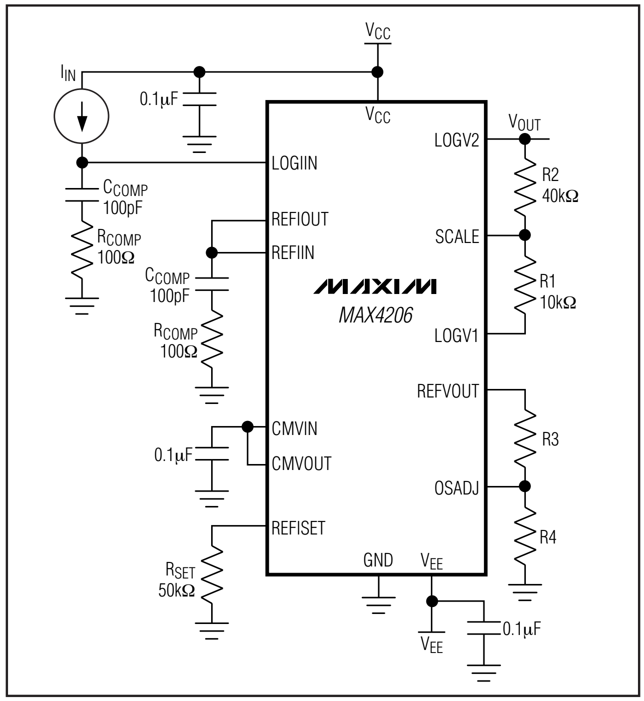



*Figure 6. Dual-Supply Typical Operating Circuit*

### Scale Factor

The scale factor, K, is the slope of the logarithmic output. For the LOGV1 amplifier, K = 0.25V/decade. When operating from dual supplies, adjust the overall scale factor for the MAX4206 using the uncommitted LOGV2 amplifier and the following equation, which refers to Figure 6:

$$R_2 = R_1\left(\frac{K}{0.25}\right)$$

Select $R_2$ between 1kΩ and 100kΩ.

### Design Example

Desired:

Dual-Supply Operation

Logarithmic intercept: 1μA

Overall scale factor = 1V/decade

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

Select $R_1$ = 10kΩ:

$$R2 = 10k\Omega \times \left(\frac{1V/decade}{0.25}\right) = 40k\Omega$$

### Measuring Optical Absorbance

A photodiode provides a convenient means of measuring optical power, as diode current is proportional to the incident optical power. Measure absolute optical power using a single photodiode connected at LOGIIN, with the MAX4206's internal current reference driving REFIIN. Alternatively, connect a photodiode to each of the MAX4206's logging inputs, LOGIIN and REFIIN, to measure relative optical power (Figure 7).

In absorbance measurement instrumentation, a reference light source is split into two paths. The unfiltered path is incident upon the photodiode of the reference channel, REFIIN. The other path passes through a sample of interest, with the resulting filtered light incident on the photodiode of the second channel, LOGIIN. The MAX4206 outputs provide voltages proportional to the log ratio of the two optical powers—an indicator of the optical absorbance of the sample.

In wavelength-locking applications, often found in fiberoptic communication modules, two photodiode currents provide a means of determining whether a given optical channel is tuned to the desired optical frequency. In this application, two bandpass optical filters with overlapping "skirts" precede each photodiode. With proper filter selection, the MAX4206 output can vary monotonically (ideally linearly) with optical frequency.

### Photodiode Current Monitoring

Figure 8 shows the MAX4206 in a single-supply, optical-power measurement circuit, common in fiberoptic applications. The MAX4007 current monitor converts the sensed APD current to an output current that drives the MAX4206 LOGIIN input (APD current is scaled by 0.1). The MAX4007 also buffers the high-voltage APD voltages from the lower MAX4206 voltages. The MAX4206's internal current reference sources 10nA ($R_{SET}$ = 5MΩ) to the REFIIN input. This configuration sets the logarithmic intercept to 10nA, corresponding to an APD current of 100nA. The unity-gain configuration of the output buffer maintains the 0.25V/decade gain present at the LOGV1 output.

### Capacitive Loads

The MAX4206 drives capacitive loads of up to 50pF. Reactive loads decrease phase margin and can produce excessive ringing and oscillation. Use an isolation resistor in series with LOGV1 or LOGV2 to reduce the effect of large capacitive loads. Recall that the combination of the capacitive load and the small isolation resistor limits AC performance.

### Power Dissipation

The LOGV1 and LOGV2 amplifiers are capable of sourcing or sinking in excess of 30mA. Ensure that the continuous power dissipation rating for the MAX4206 is not exceeded.

### TQFN Package

The 16-lead thin QFN package has an exposed paddle that provides a heat-removal path, as well as excellent electrical grounding to the PC board. The MAX4206's exposed pad is internally connected to $V_{EE}$, and can either be connected to the PC board $V_{EE}$ plane or left unconnected. Ensure that only $V_{EE}$ traces are routed under the exposed paddle.

### Layout and Bypassing

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

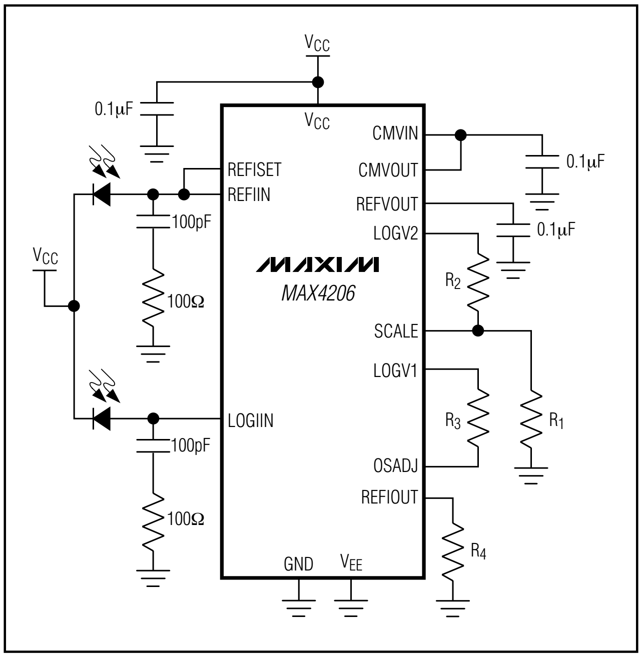



*Figure 7. Measuring Optical Absorbance*

### Evaluation Kit

An evaluation kit is available for the MAX4206. The kit is flexible and can be configured for either single-supply or dual-supply operation. The scale factor and reference current are selectable. Refer to the MAX4206 Evaluation Kit data sheet for more information.

## Chip Information

TRANSISTOR COUNT: 754

PROCESS: BiCMOS

# Precision Transimpedance Logarithmic Amplifier with Over 5 Decades of Dynamic Range

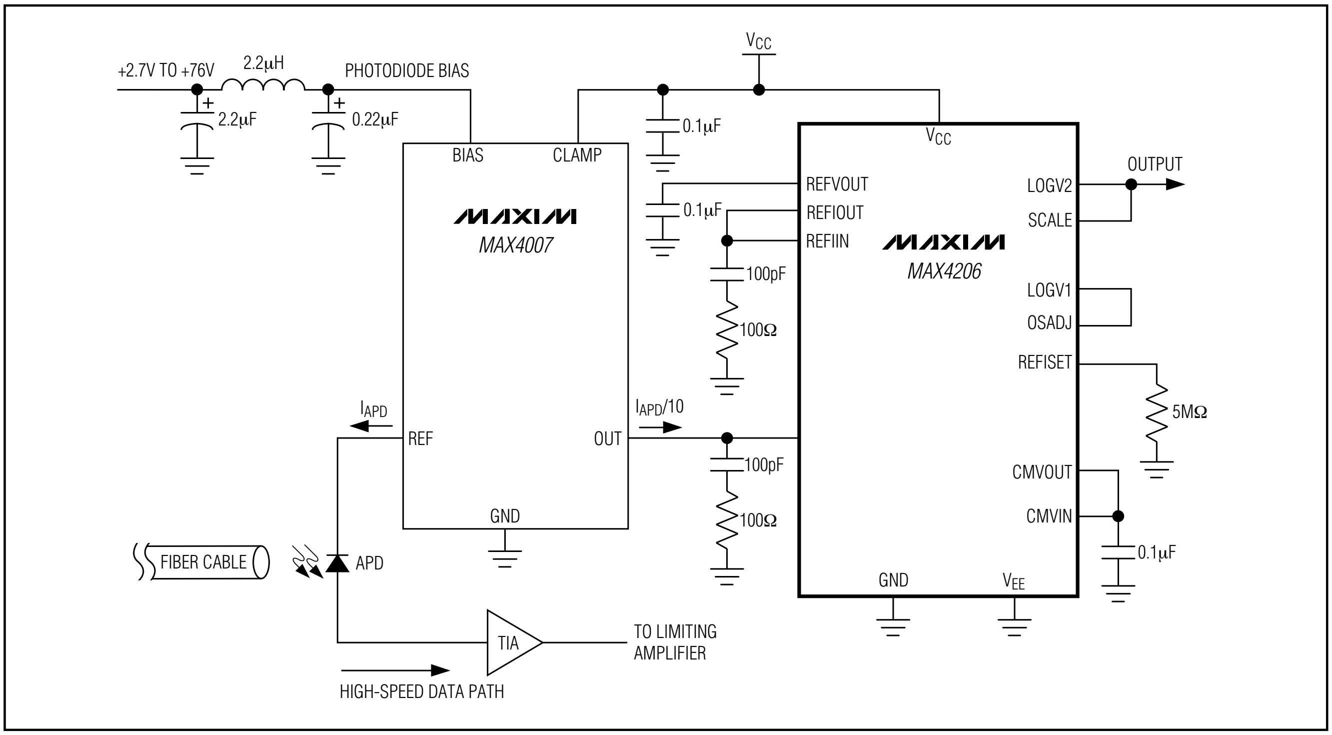
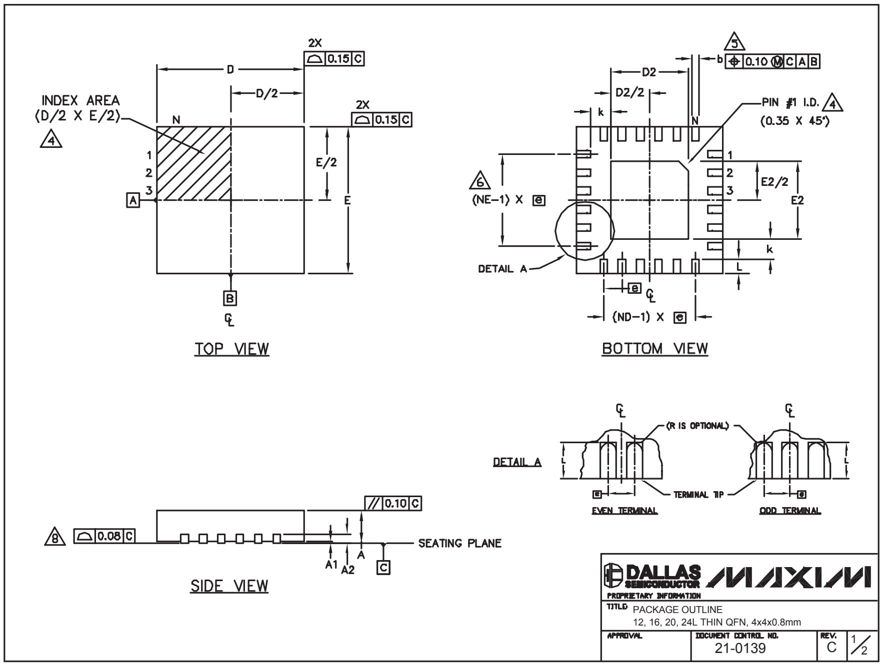



*Figure 8. Logarithmic Current-Sensing Amplifier with Sourcing Input*

## Package Information

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




**COMMON DIMENSIONS**

| PKG | 12L 4x4 | | | 16L 4x4 | | | 20L 4x4 | | | 24L 4x4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF. | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| A | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 |
| A1 | 0.0 | 0.02 | 0.05 | 0.0 | 0.02 | 0.05 | 0.0 | 0.02 | 0.05 | 0.0 | 0.02 | 0.05 |
| A2 | 0.20 REF | | | 0.20 REF | | | 0.20 REF | | | 0.20 REF | | |
| b | 0.25 | 0.30 | 0.35 | 0.25 | 0.30 | 0.35 | 0.20 | 0.25 | 0.30 | 0.18 | 0.23 | 0.30 |
| D | 3.90 | 4.00 | 4.10 | 3.90 | 4.00 | 4.10 | 3.90 | 4.00 | 4.10 | 3.90 | 4.00 | 4.10 |
| E | 3.90 | 4.00 | 4.10 | 3.90 | 4.00 | 4.10 | 3.90 | 4.00 | 4.10 | 3.90 | 4.00 | 4.10 |
| e | 0.80 BSC. | | | 0.65 BSC. | | | 0.50 BSC. | | | 0.50 BSC. | | |
| k | 0.25 | - | - | 0.25 | - | - | 0.25 | - | - | 0.25 | - | - |
| L | 0.45 | 0.55 | 0.65 | 0.45 | 0.55 | 0.65 | 0.45 | 0.55 | 0.65 | 0.30 | 0.40 | 0.50 |
| N | 12 | | | 16 | | | 20 | | | 24 | | |
| ND | 3 | | | 4 | | | 5 | | | 6 | | |
| NE | 3 | | | 4 | | | 5 | | | 6 | | |
| Jedec Var. | WGGB | | | WGGC | | | WGGD-1 | | | WGGD-2 | | |

**EXPOSED PAD VARIATIONS**

| PKG. CODES | D2 | | | E2 | | | DOWN BONDS ALLOWED |
|---|---|---|---|---|---|---|---|
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | |
| T1244-2 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | NO |
| T1244-3 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | YES |
| T1244-4 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | NO |
| T1644-2 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | NO |
| T1644-3 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | YES |
| T1644-4 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | NO |
| T2044-1 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | NO |
| T2044-2 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | YES |
| T2044-3 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | NO |
| T2444-1 | 2.45 | 2.60 | 2.63 | 2.45 | 2.60 | 2.63 | NO |
| T2444-2 | 1.95 | 2.10 | 2.25 | 1.95 | 2.10 | 2.25 | YES |
| T2444-3 | 2.45 | 2.60 | 2.63 | 2.45 | 2.60 | 2.63 | YES |
| T2444-4 | 2.45 | 2.60 | 2.63 | 2.45 | 2.60 | 2.63 | NO |

NOTES:

1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JESD 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
5. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.25 mm AND 0.30 mm FROM TERMINAL TIP.
6. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
8. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
9. DRAWING CONFORMS TO JEDEC MO220, EXCEPT FOR T2444-1, T2444-3 AND T2444-4.

DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE 12, 16, 20, 24L THIN QFN, 4x4x0.8mm
APPROVAL | DOCUMENT CONTROL NO. 21-0139 | REV. C | 2/2