# LM611 Operational Amplifier and Adjustable Reference

Check for Samples: LM611

## FEATURES

**OP AMP**

- **Low Operating Current: 300 µA (op amp)**
- **Wide Supply Voltage Range: 4V to 36V**
- **Wide Common-Mode Range: $V^-$ to ($V^+$−1.8V)**
- **Wide Differential Input Voltage: ±36V**
- **Available in Low Cost 8-pin DIP**
- **Available in Plastic Package Rated for Military Temperature Range Operation**

**REFERENCE**

- **Adjustable Output Voltage: 1.2V to 6.3V**
- **Tight Initial Tolerance Available: ±0.6%**
- **Wide Operating Current Range: 17 µA to 20 mA**
- **Reference Floats Above Ground**
- **Tolerant of Load Capacitance**

## APPLICATIONS

- **Transducer Bridge Driver**
- **Process and Mass Flow Control Systems**
- **Power Supply Voltage Monitor**
- **Buffered Voltage References for A/D's**

## DESCRIPTION

The LM611 consists of a single-supply op-amp and a programmable voltage reference in one space saving 8-pin package. The op-amp out-performs most single-supply op-amps by providing higher speed and bandwidth along with low supply current. This device was specifically designed to lower cost and board space requirements in transducer, test, measurement and data acquisition systems.

Combining a stable voltage reference with a wide output swing op-amp makes the LM611 ideal for single supply transducers, signal conditioning and bridge driving where large common-mode signals are common. The voltage reference consists of a reliable band-gap design that maintains low dynamic output impedance (1Ω typical), excellent initial tolerance (0.6%), and the ability to be programmed from 1.2V to 6.3V via two external resistors. The voltage reference is very stable even when driving large capacitive loads, as are commonly encountered in CMOS data acquisition systems.

As a member of TI's Super-Block family, the LM611 is a space-saving monolithic alternative to a multi-chip solution, offering a high level of integration without sacrificing performance.

## Connection Diagrams

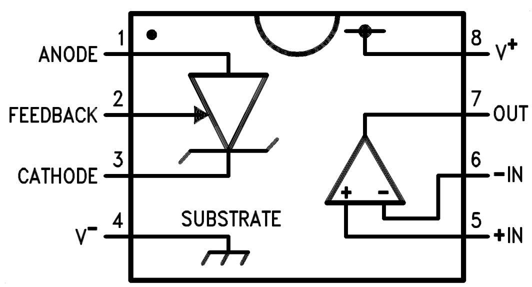



**Figure 1. Hermetic Dual-In-Line Package**

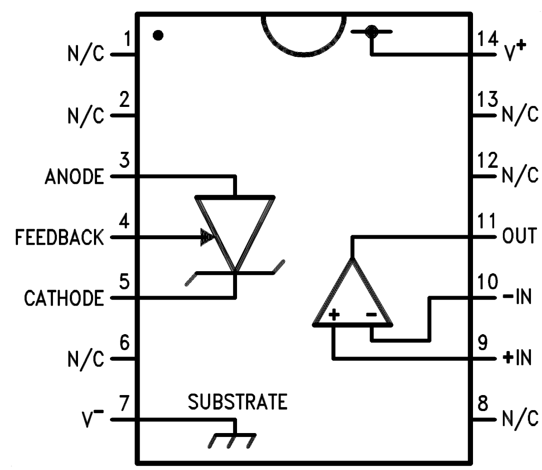



**Figure 2. Plastic Surface Mount Narrow Package**

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.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings[1][2]

| | |
|---|---|
| Voltage on Any Pins Except $V_R$ (referred to $V^-$ pin) | 36V (Max) |
| See[3] | −0.3V (Min) |
| Current through Any Input Pin and $V_R$ Pin | ±20 mA |
| Differential Input Voltage | |
| Military and Industrial | ±36V |
| Commercial | ±32V |
| Storage Temperature Range | $-65°C \le T_J \le +150°C$ |
| Maximum Junction Temperature | 150°C |
| Thermal Resistance, Junction-to-Ambient[4] | |
| N Package | 100°C/W |
| D Package | 150°C/W |
| Soldering Information Soldering (10 seconds) | |
| N Package | 260°C |
| D Package | 220°C |
| ESD Tolerance[5] | ±1 kV |

(1) Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
(3) More accurately, it is excessive current flow, with resulting excess heating, that limits the voltages on all pins. When any pin is pulled a diode drop below $V^-$, a parasitic NPN transistor turns ON. No latch-up will occur as long as the current through that pin remains below the Maximum Rating. Operation is undefined and unpredictable when any parasitic diode or transistor is conducting.
(4) Junction temperature may be calculated using $T_J = T_A + P_D \theta_{JA}$. The given thermal resistance is worst-case for packages in sockets in still air. For packages soldered to copper-clad board with dissipation from one op amp or reference output transistor, nominal $\theta_{JA}$ is 90°C/W for the N package and 135°C/W for the D package.
(5) Human body model, 100 pF discharged through a 1.5 kΩ resistor.

## Operating Temperature Range

| | |
|---|---|
| LM611AI, LM611I, LM611BI | $-40°C \le T_J \le +85°C$ |
| LM611AM, LM611M | $-55°C \le T_J \le +125°C$ |
| LM611C | $0°C \le T_J \le 70°C$ |

## Electrical Characteristics(1)

These specifications apply for $V^- = GND = 0V$, $V^+ = 5V$, $V_{CM} = V_{OUT} = 2.5V$, $I_R = 100\ \mu A$, FEEDBACK pin shorted to GND, unless otherwise specified. Limits in standard typeface are for $T_J = 25°C$; limits in **boldface type** apply over the **Operating Temperature Range.**

| Symbol | Parameter | Conditions | Typical(2) | LM611AM<br>LM611AI<br>Limits(3) | LM611M<br>LM611BI<br>LM611I<br>LM611C<br>Limits(3) | Units |
|---|---|---|---|---|---|---|
| $I_S$ | Total Supply Current | $R_{LOAD} = \infty$,<br>$4V \le V^+ \le 36V$ (32V for LM611C) | 210<br>**221** | 300<br>**320** | 350<br>**370** | μA max<br>μA max |
| $V_S$ | Supply Voltage Range | | 2.2<br>**2.9** | 2.8<br>**3** | 2.8<br>**3** | V min<br>V min |
| | | | 46<br>**43** | 36<br>**36** | 32<br>**32** | V max<br>V max |
| **OPERATIONAL AMPLIFIER** | | | | | | |
| $V_{OS1}$ | $V_{OS}$ Over Supply | $4V \le V^+ \le 36V$<br>($4V \le V^+ \le 32V$ for LM611C) | 1.5<br>**2.0** | 3.5<br>**6.0** | 5.0<br>**7.0** | mV max<br>mV max |
| $V_{OS2}$ | $V_{OS}$ Over $V_{CM}$ | $V_{CM}$ = 0V through $V_{CM}$ =<br>($V^+ - 1.8V$), $V^+ = 30V$, $V^- = 0V$ | 1.0<br>**1.5** | 3.5<br>**6.0** | 5.0<br>**7.0** | mV max<br>mV max |
| $\frac{V_{OS3}}{\Delta T}$ | Average $V_{OS}$ Drift | See(3) | **15** | | | μV/°C<br>max |
| $I_B$ | Input Bias Current | | 10<br>**11** | 25<br>**30** | 35<br>**40** | nA max<br>nA max |
| $I_{OS}$ | Input Offset Current | | 0.2<br>**0.3** | 4<br>**5** | 4<br>**5** | nA max<br>nA max |
| $\frac{I_{OS1}}{\Delta T}$ | Average Offset Drift Current | | **4** | | | pA/°C |
| $R_{IN}$ | Input Resistance | Differential | 1800 | | | MΩ |
| | | Common-Mode | 3800 | | | MΩ |
| $C_{IN}$ | Input Capacitance | Common-Mode | 5.7 | | | pF |
| $e_n$ | Voltage Noise | f = 100 Hz,<br>Input Referred | 74 | | | nV/ √Hz |
| $I_n$ | Current Noise | f = 100 Hz,<br>Input Referred | 58 | | | fA/√Hz |
| CMRR | Common-Mode Rejection-Ratio | $V^+ = 30V$, $0V \le V_{CM} \le (V^+ - 1.8V)$<br>CMRR = 20 log ($\Delta V_{CM}/\Delta V_{OS}$) | 95<br>**90** | 80<br>**75** | 75<br>**70** | dB min<br>dB min |
| PSRR | Power Supply Rejection-Ratio | $4V \le V^+ \le 30V$, $V_{CM} = V^+/2$,<br>PSRR = 20 log ($\Delta V^+/\Delta V_{OS}$) | 110<br>**100** | 80<br>**75** | 75<br>**70** | dB min<br>dB min |
| $A_V$ | Open Loop Voltage Gain | $R_L$ = 10 kΩ to GND, $V^+ = 30V$,<br>$5V \le V_{OUT} \le 25V$ | 500<br>**50** | 100<br>**40** | 94<br>**40** | V/mV<br>min |
| SR | Slew Rate | $V^+ = 30V$(4) | 0.70<br>**0.65** | 0.55<br>**0.45** | 0.50<br>**0.45** | V/μs |
| GBW | Gain Bandwidth | $C_L$ = 50 pF | 0.80<br>**0.50** | | | MHz |
| $V_{O1}$ | Output Voltage Swing High | $R_L$ = 10 kΩ to GND<br>$V^+ = 36V$ (32V for LM611C) | $V^+ - 1.4$<br>**$V^+ - 1.6$** | $V^+ - 1.7$<br>**$V^+ - 1.9$** | $V^+ - 1.8$<br>**$V^+ - 1.9$** | V min<br>V min |
| $V_{O2}$ | Output Voltage Swing Low | $R_L$ = 10 kΩ to $V^+$<br>$V^+ = 36V$ (32V for LM611C) | $V^- + 0.8$<br>**$V^- + 0.9$** | $V^- + 0.9$<br>**$V^- + 1.0$** | $V^- + 0.95$<br>**$V^- + 1.0$** | V max<br>V max |
| $I_{OUT}$ | Output Source Current | $V_{OUT} = 2.5V$, $V_{+IN} = 0V$,<br>$V_{-IN} = -0.3V$ | 25<br>**15** | 20<br>**13** | 16<br>**13** | mA min<br>mA min |

(1) Military RETS 611AMX electrical test specification is available on request. The LM611AMJ/883 can also be procured as a Standard Military Drawing.
(2) Typical values in standard typeface are for $T_J = 25°C$; values in **boldface type** apply for the full operating temperature range. These values represent the most likely parametric norm.
(3) All limits are specified at room temperature (standard type face) or at operating temperature extremes **(bold face type)**.
(4) Slew rate is measured with op amp in a voltage follower configuration. For rising slew rate, the input voltage is driven from 5V to 25V, and the output voltage transition is sampled at 10V and 20V. For falling slew rate, the input voltage is driven from 25V to 5V, and output voltage transition is sampled at 20V and 10V.

## Electrical Characteristics[1] (continued)

These specifications apply for $V^{-}$ = GND = 0V, $V^{+}$ = 5V, $V_{CM}$ = $V_{OUT}$ = 2.5V, $I_R$ = 100 µA, FEEDBACK pin shorted to GND, unless otherwise specified. Limits in standard typeface are for $T_J$ = 25°C; limits in **boldface type** apply over the **Operating Temperature Range.**

| Symbol | Parameter | Conditions | Typical[2] | LM611AM LM611AI Limits[3] | LM611M LM611BI LM611I LM611C Limits[3] | Units |
|---|---|---|---|---|---|---|
| $I_{SINK}$ | Output Sink Current | $V_{OUT}$ = 1.6V, $V_{+IN}$ = 0V, $V_{-IN}$ = 0.3V | 17<br>**9** | 14<br>**8** | 13<br>**8** | mA min<br>mA min |
| $I_{SHORT}$ | Short Circuit Current | $V_{OUT}$ = 0V, $V_{+IN}$ = 3V, $V_{-IN}$ = 2V, Source | 30<br>**40** | 50<br>**60** | 50<br>**60** | mA max<br>mA max |
| | | $V_{OUT}$ = 5V, $V_{+IN}$ = 2V, $V_{-IN}$ = 3V, Sink | 30<br>**32** | 60<br>**80** | 70<br>**90** | mA max<br>mA max |
| **VOLTAGE REFERENCE** | | | | | | |
| $V_R$ | Reference Voltage | See[5] | 1.244 | 1.2365<br>1.2515<br>(±0.6%) | 1.2191<br>1.2689<br>(±2.0%) | V min<br>V max |
| $\frac{\Delta V_R}{\Delta T_J}$ | Average Temperature Drift | See[6] | **10** | **80** | **150** | PPM/°C max |
| $\frac{\Delta V_R}{\Delta T_J}$ | Hysteresis | Hyst = (Vro′ − Vro)/$\Delta T_J$[7] | **3.2** | | | µV/°C |
| $\frac{\Delta V_R}{\Delta I_R}$ | $V_R$ Change with Current | $V_{R(100\ \mu A)} - V_{R(17\ \mu A)}$ | 0.05<br>**0.1** | 1<br>**1.1** | 1<br>**1.1** | mV max<br>mV max |
| | | $V_{R(10\ mA)} - V_{R(100\ \mu A)}$[8] | 1.5<br>**2.0** | 5<br>**5.5** | 5<br>**5.5** | mV max<br>mV max |
| R | Resistance | $\Delta V_{R(10\rightarrow 0.1\ mA)}$/9.9 mA<br>$\Delta V_{R(100\rightarrow 17\ \mu A)}$/83 µA | **0.2**<br>**0.6** | **0.56**<br>**13** | **0.56**<br>**13** | Ω max<br>Ω max |
| $\frac{\Delta V_R}{V_{RO}}$ | $V_R$ Change with High $V_{RO}$ | $V_{R(Vro = Vr)} - V_{R(Vro = 6.3V)}$ (5.06V between Anode and FEEDBACK) | 2.5<br>**2.8** | 7<br>**10** | 7<br>**10** | mV max<br>mV max |
| $\frac{\Delta V_R}{\Delta V+}$ | $V_R$ Change with $V^{+}$ Change | $V_{R(V+ = 5V)} - V_{R(V+ = 36V)}$ ($V^{+}$ = 32V for LM611C) | 0.1<br>**0.1** | 1.2<br>**1.3** | 1.2<br>**1.3** | mV max<br>mV max |
| | | $V_{R(V+ = 5V)} - V_{R(V+ = 3V)}$ | 0.01<br>**0.01** | 1<br>**1.5** | 1<br>**1.5** | mV max<br>mV max |
| $\frac{\Delta V_R}{\Delta V_{ANODE}}$ | $V_R$ Change with $V_{ANODE}$ Change | $V^{+} = V^{+}$ max, $\Delta V_R = V_R$ (@ $V_{ANODE} = V^{-}$ = GND) − $V_R$ (@ $V_{ANODE} = V^{+}$ − 1.0V) | 0.7<br>**3.3** | 1.5<br>**3.0** | 1.6<br>**3.0** | mV max<br>mV max |
| $I_{FB}$ | FEEDBACK Bias Current | $I_{FB}$; $V_{ANODE} \le V_{FB} \le$ 5.06V | 22<br>**29** | 35<br>**40** | 50<br>**55** | nA max<br>nA max |
| $e_n$ | $V_R$ Noise | 10 Hz to 10,000 Hz, $V_{RO} = V_R$ | 30 | | | $\mu V_{RMS}$ |

(5) $V_R$ is the cathode-feedback voltage, nominally 1.244V.
(6) Average reference drift is calculated from the measurement of the reference voltage at 25°C and at the temperature extremes. The drift, in ppm/°C, is $10^6 \cdot \Delta V_R/(V_{R[25°C]} \cdot \Delta T_J)$, where $\Delta V_R$ is the lowest value subtracted from the highest, $V_{R[25°C]}$ is the value at 25°C, and $\Delta T_J$ is the temperature range. This parameter is ensured by design and sample testing.
(7) Hysteresis is the change in $V_R$ caused by a change in $T_J$, after the reference has been “dehysterized”. To dehysterize the reference; that is minimize the hysteresis to the typical value, its junction temperature should be cycled in the following pattern, spiraling in toward 25°C: 25°C, 85°C, −40°C, 70°C, 0°C, 25°C.
(8) Low contact resistance is required for accurate measurement.

## Typical Performance Characteristics (Reference)

$T_J$ = 25°C, FEEDBACK pin shorted to $V^-$ = 0V, unless otherwise noted

**Reference Voltage vs Temp on 5 Representative Units**

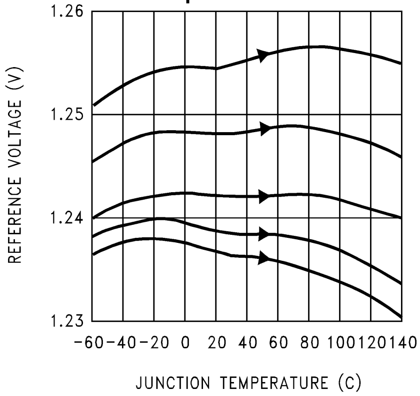



**Figure 3.**

**Reference Voltage Drift**

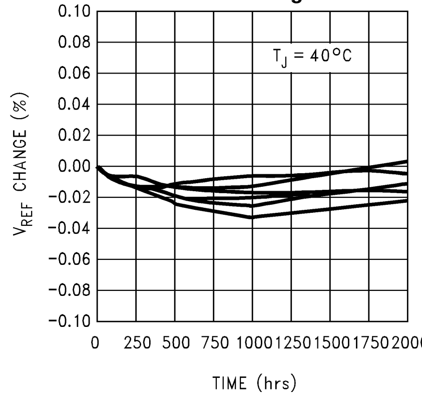



**Figure 4.**

**Accelerated Reference Voltage Drift vs Time**

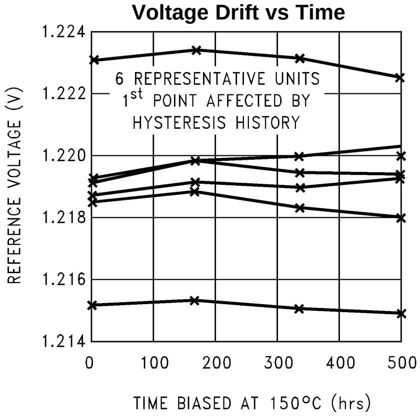



**Figure 5.**

**Reference Voltage vs Current and Temperature**

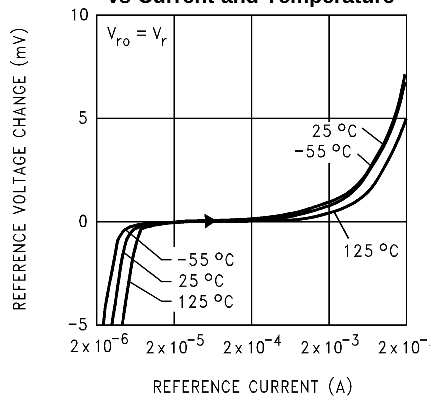



**Figure 6.**

**Reference Voltage vs Current and Temperature**

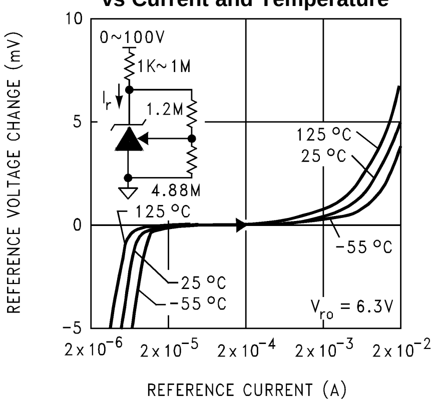



**Figure 7.**

**Reference Voltage vs Reference Current**

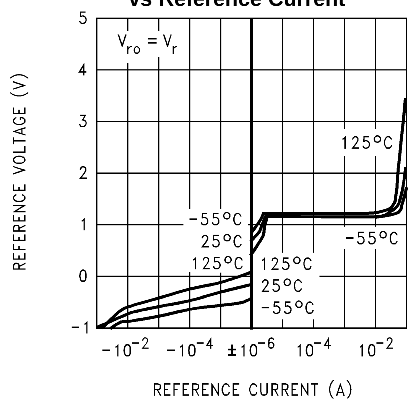



**Figure 8.**

## Typical Performance Characteristics (Reference) (continued)

$T_J$ = 25°C, FEEDBACK pin shorted to $V^-$ = 0V, unless otherwise noted

**Reference Voltage vs Reference Current**

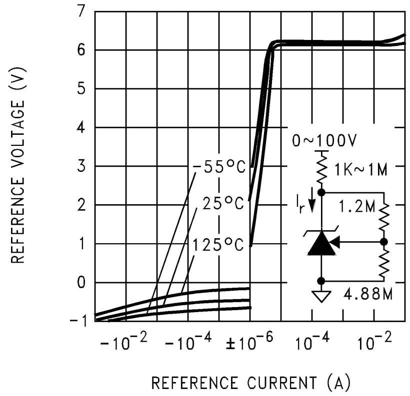



**Figure 9.**

**Reference AC Stability Range**

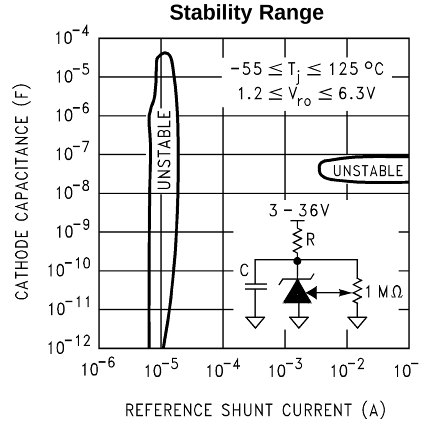



**Figure 10.**

**Feedback Current vs Feedback-to-Anode Voltage**

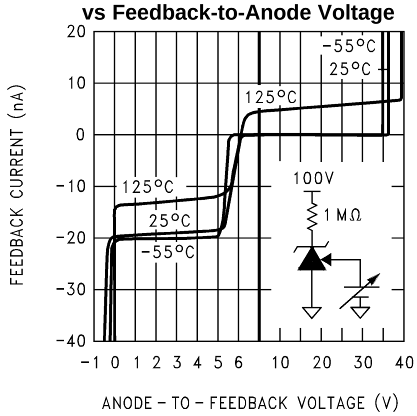



**Figure 11.**

**Feedback Current vs Feedback-to-Anode Voltage**

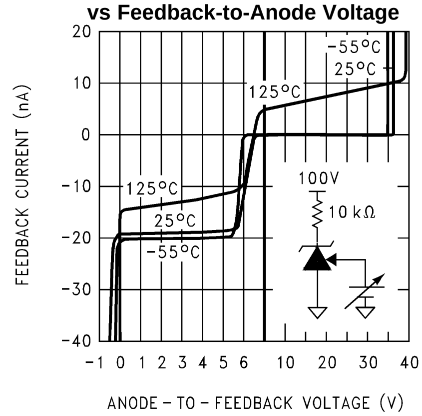



**Figure 12.**

**Reference Noise Voltage vs Frequency**

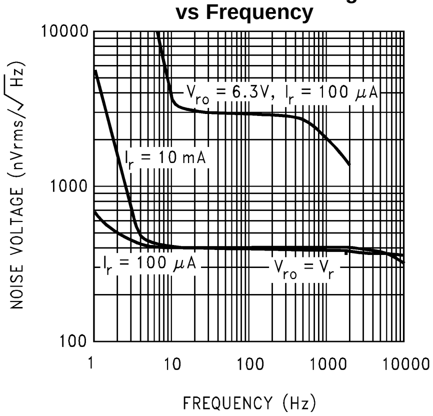



**Figure 13.**

**Reference Small-Signal Resistance vs Frequency**

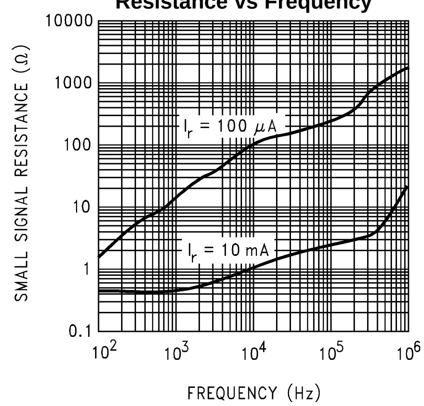



**Figure 14.**

## Typical Performance Characteristics (Reference) (continued)

$T_J$ = 25°C, FEEDBACK pin shorted to $V^-$ = 0V, unless otherwise noted

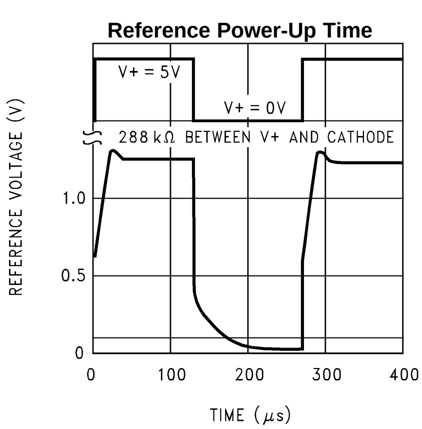



**Figure 15.**

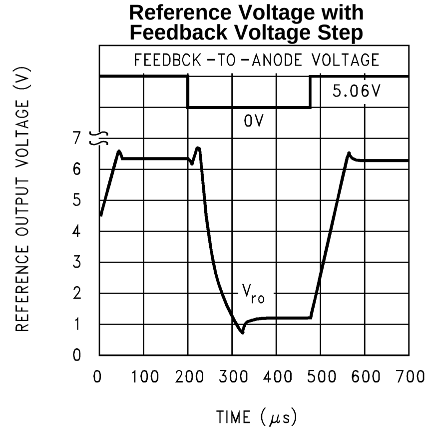



**Figure 16.**

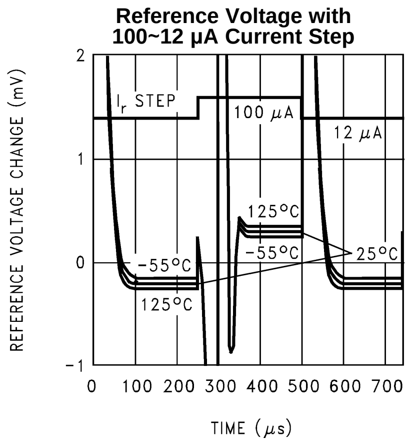



**Figure 17.**

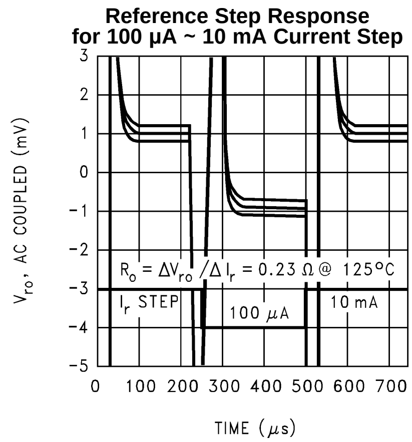



**Figure 18.**

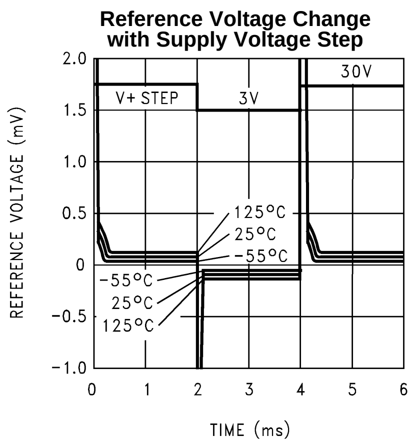



**Figure 19.**

## Typical Performance Characteristics (Op Amps)

$V^+ = 5V$, $V^- = GND = 0V$, $V_{CM} = V^+/2$, $V_{OUT} = V^+/2$, $T_J = 25°C$, unless otherwise noted

**Input Common-Mode Voltage Range vsTemperature**

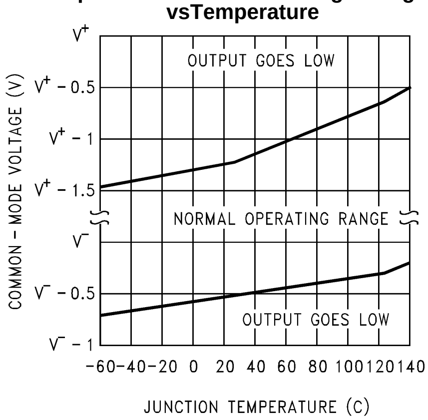



**Figure 20.**

**$V_{OS}$ vs Junction Temperature**

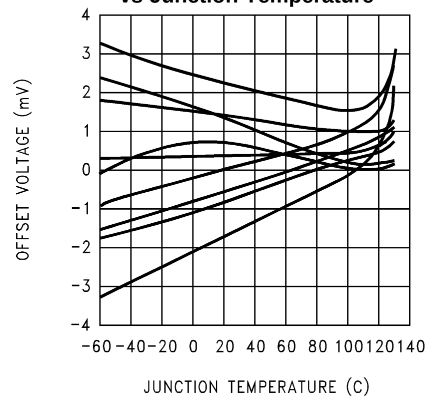



**Figure 21.**

**Input Bias Current vs Common-Mode Voltage**

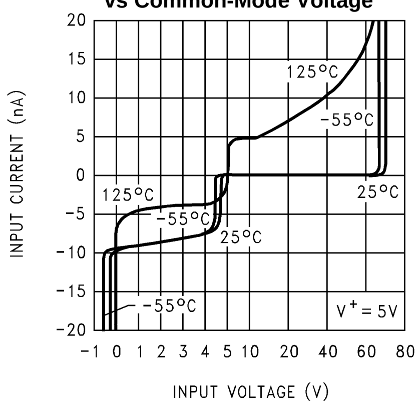



**Figure 22.**

**Reference Change vs Common-Mode Voltage**

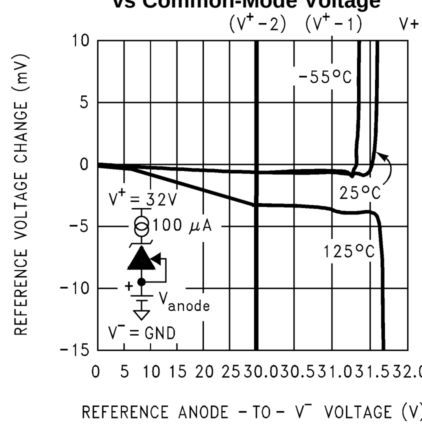



**Figure 23.**

**Large-Signal Step Response**

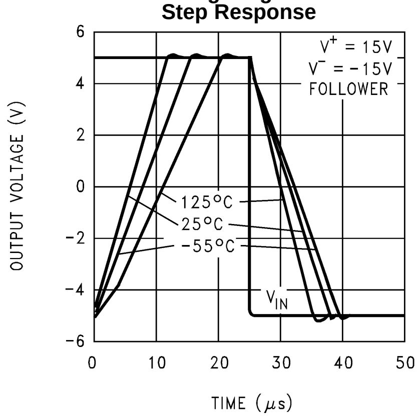



**Figure 24.**

**Output Voltage Swing vs Temp. and Current**

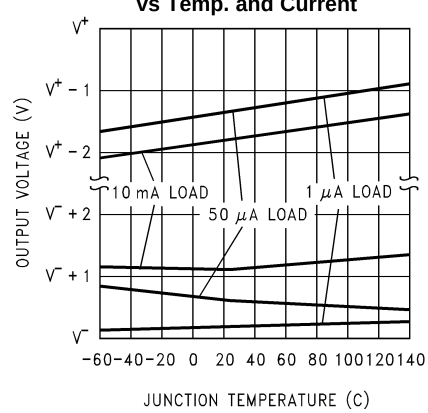



**Figure 25.**

## Typical Performance Characteristics (Op Amps) (continued)

$V^+$ = 5V, $V^-$ = GND = 0V, $V_{CM}$ = $V^+$/2, $V_{OUT}$ = $V^+$/2, $T_J$ = 25°C, unless otherwise noted

**Output Source Current vs Output Voltage and Temp.**

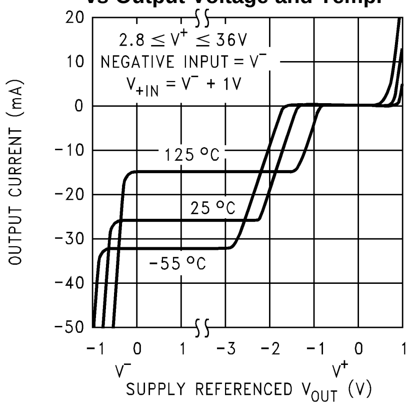



**Figure 26.**

**Output Sink Current vs Output Voltage**

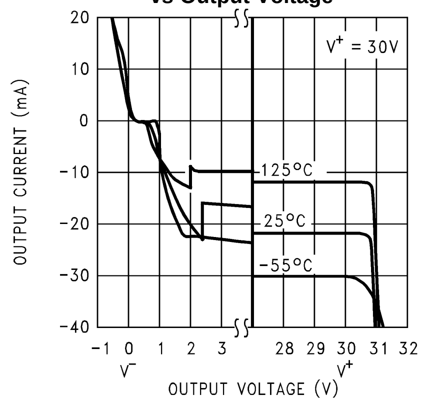



**Figure 27.**

**Output Swing, Large Signal**

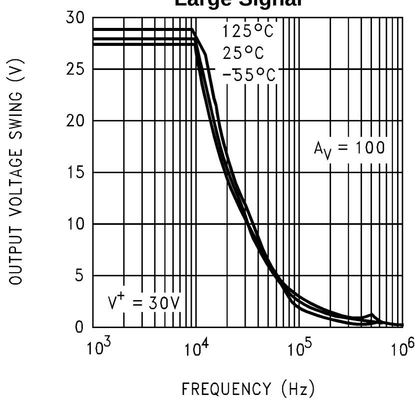



**Figure 28.**

**Output Impedance vs Frequency and Gain**

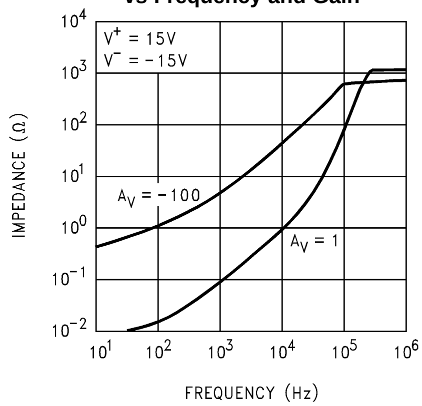



**Figure 29.**

**Small Signal Pulse Response vs Temp.**

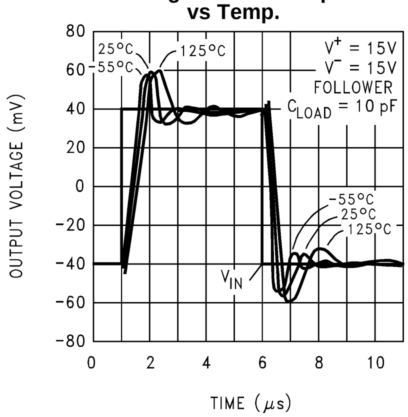



**Figure 30.**

**Small-Signal Pulse Response vs Load**

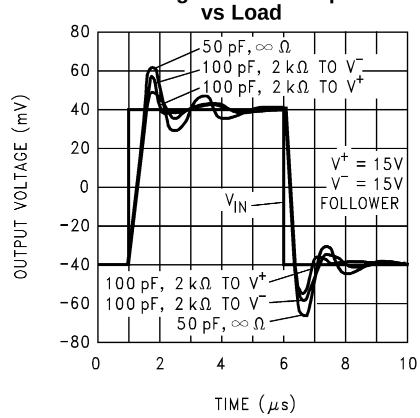



**Figure 31.**

## Typical Performance Characteristics (Op Amps) (continued)

$V^+ = 5V$, $V^- = GND = 0V$, $V_{CM} = V^+/2$, $V_{OUT} = V^+/2$, $T_J = 25°C$, unless otherwise noted

**Op Amp Voltage Noise vs Frequency**

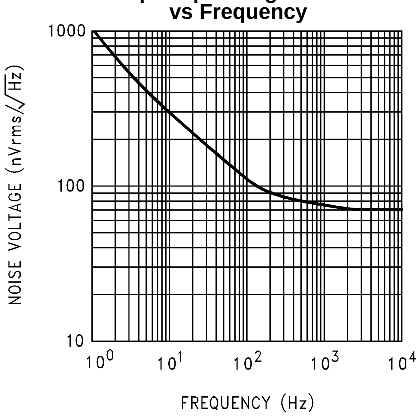



**Figure 32.**

**Op Amp Current Noise vs Frequency**

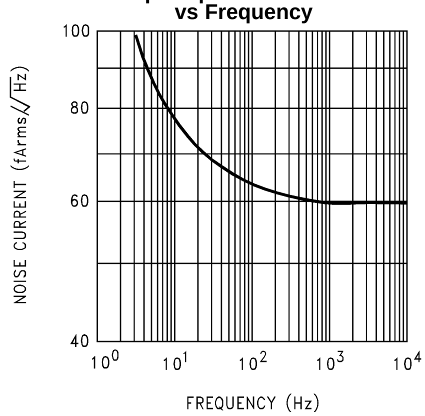



**Figure 33.**

**Small-Signal Voltage Gain vs Frequency and Temperature**

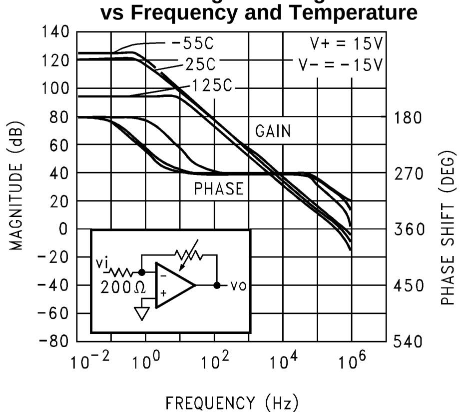



**Figure 34.**

**Small-Signal Voltage Gain vs Frequency and Load**

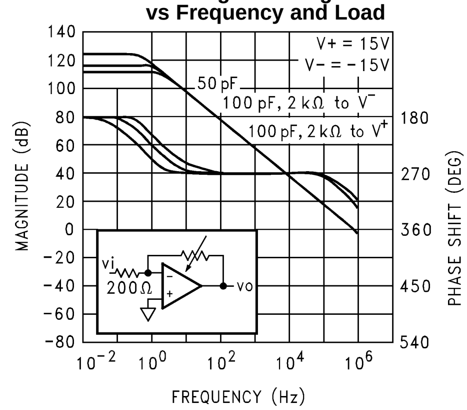



**Figure 35.**

**Follower Small-Signal Frequency Response**

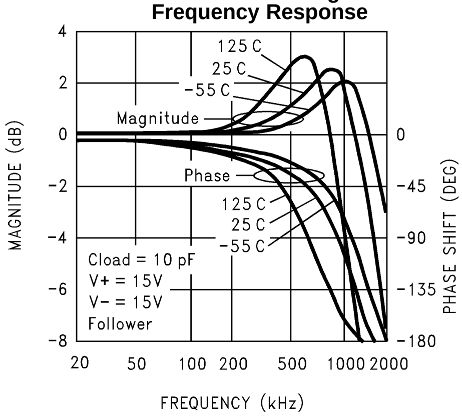



**Figure 36.**

**Common-Mode Input Voltage Rejection Ratio**

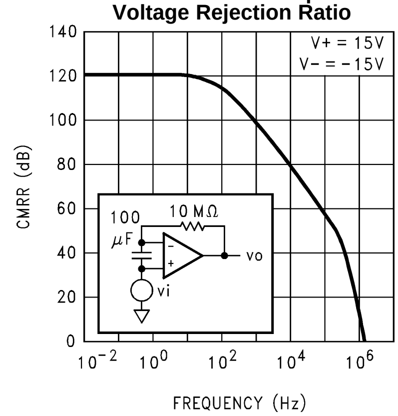



**Figure 37.**

## Typical Performance Characteristics (Op Amps) (continued)

$V^+ = 5V$, $V^- = GND = 0V$, $V_{CM} = V^+/2$, $V_{OUT} = V^+/2$, $T_J = 25°C$, unless otherwise noted

**Power Supply Current vs Power Supply Voltage**

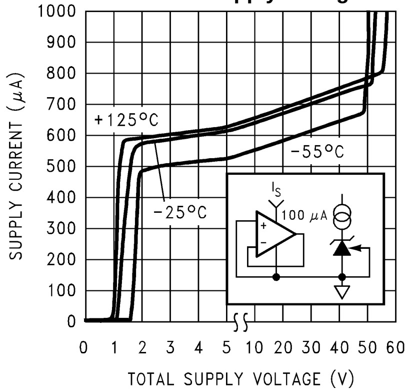



**Figure 38.**

**Positive Power Supply Voltage Rejection Ratio**

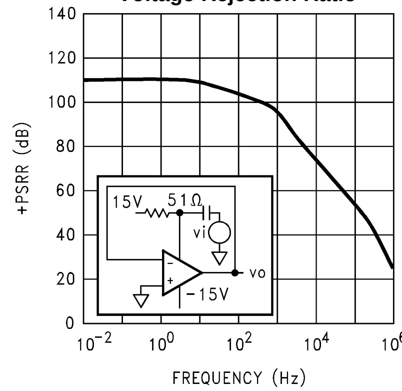



**Figure 39.**

**Negative Power Supply Voltage Rejection Ratio**

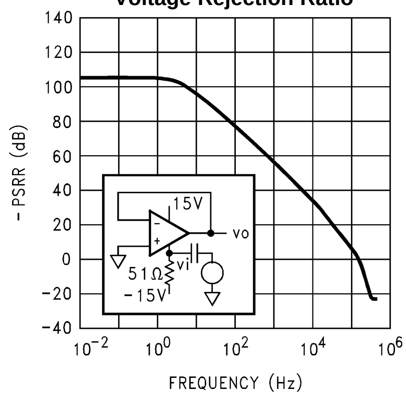



**Figure 40.**

**Slew Rate vs Temperature**

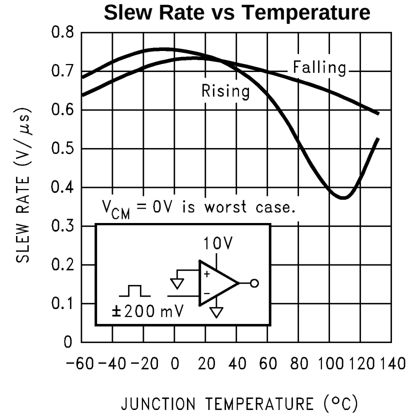



**Figure 41.**

**Input Offset Current vs Junction Temperature**

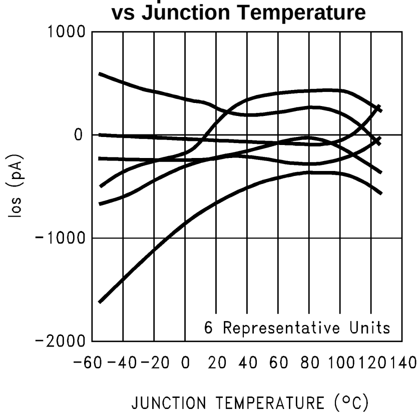



**Figure 42.**

**Input Bias Current vs Junction Temperature**

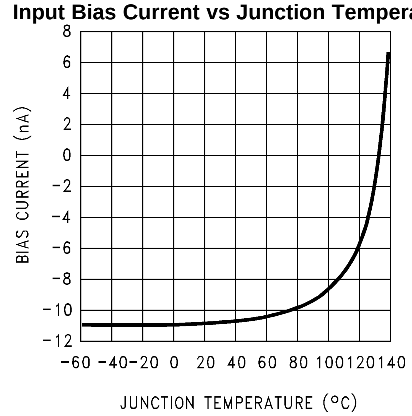



**Figure 43.**

## Typical Performance Distributions

**Average $V_{OS}$ Drift Military Temperature Range**

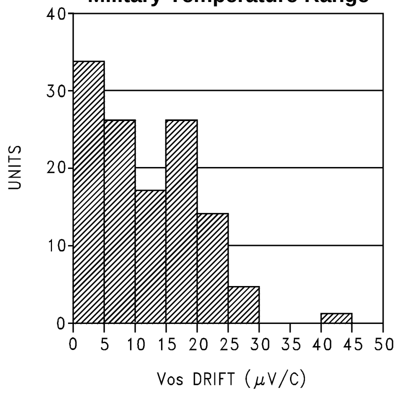



**Figure 44.**

**Average $V_{OS}$ Drift Industrial Temperature Range**

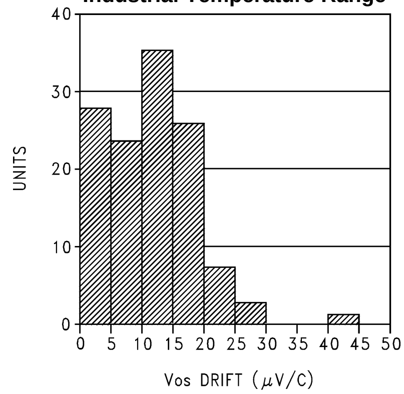



**Figure 45.**

**Average $V_{OS}$ Drift Commercial Temperature Range**

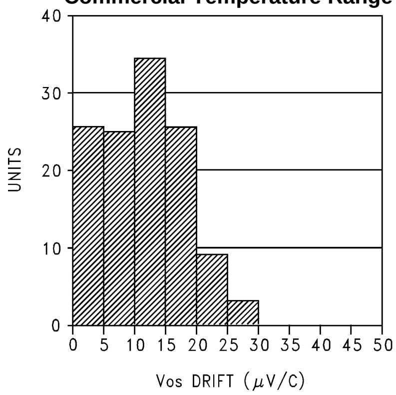



**Figure 46.**

**Average $I_{OS}$ Drift Military Temperature Range**

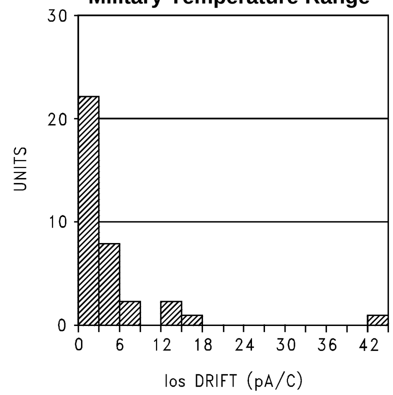



**Figure 47.**

**Average $I_{OS}$ Drift Industrial Temperature Range**

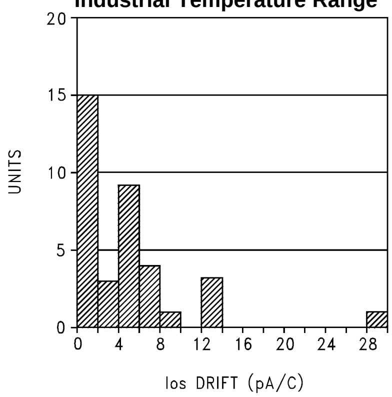



**Figure 48.**

**Average $I_{OS}$ Drift Commercial Temperature Range**

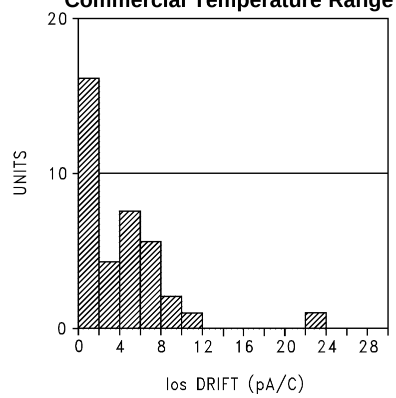



**Figure 49.**

## Typical Performance Distributions (continued)

**Voltage Reference Broad-Band Noise Distribution**

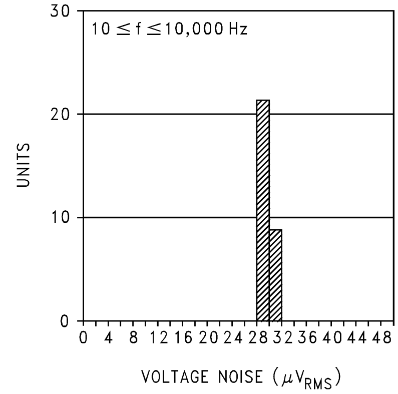



**Figure 50.**

**Op Amp Voltage Noise Distribution**

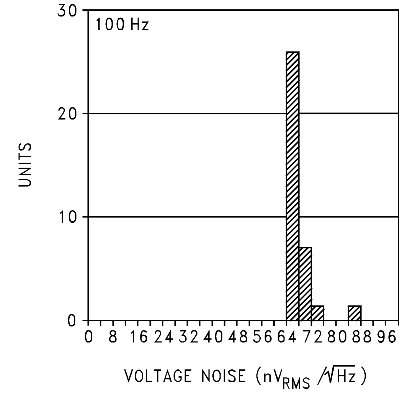



**Figure 51.**

**Op Amp Current Noise Distribution**

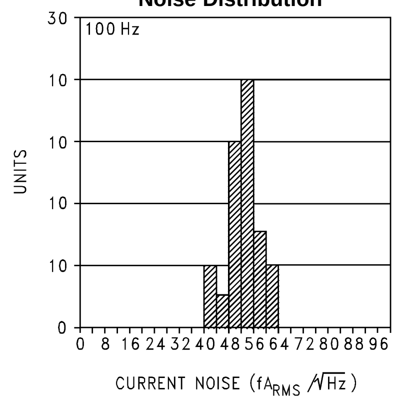



**Figure 52.**

## APPLICATION INFORMATION

## VOLTAGE REFERENCE

### Reference Biasing

The voltage reference is of a shunt regulator topology that models as a simple zener diode. With current $I_r$ flowing in the 'forward' direction there is the familiar diode transfer function. $I_r$ flowing in the reverse direction forces the reference voltage to be developed from cathode to anode. The applied voltage to the cathode may range from a diode drop below $V^-$ to the reference voltage or to the avalanche voltage of the parallel protection diode, nominally 7V. A 6.3V reference with V+ = 3V is allowed.

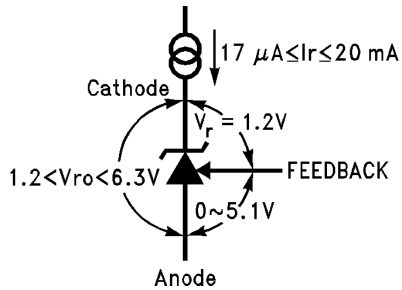



**Figure 53. Voltages Associated with Reference (Current Source $I_r$ is External)**

The reference equivalent circuit reveals how $V_r$ is held at the constant 1.2V by feedback, and how the FEEDBACK pin passes little current.

To generate the required reverse current, typically a resistor is connected from a supply voltage higher than the reference voltage. Varying that voltage, and so varying $I_r$, has small effect with the equivalent series resistance of less than an ohm at the higher currents. Alternatively, an active current source, such as the LM134 series, may generate $I_r$.

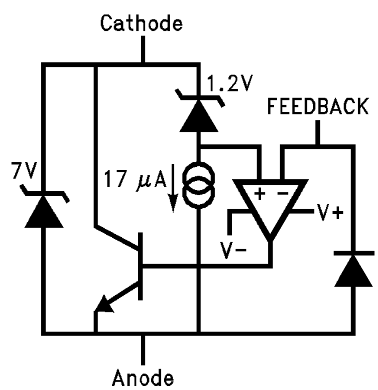



**Figure 54. Reference Equivalent Circuit**

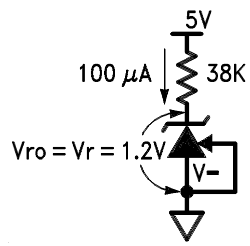



**Figure 55. 1.2V Reference**

Capacitors in parallel with the reference are allowed. See the Reference AC Stability Range curve for capacitance values—from 20 μA to 3 mA any capacitor value is stable. With the reference's wide stability range with resistive and capacitive loads, a wide range of RC filter values will perform noise filtering.

### Adjustable Reference

The FEEDBACK pin allows the reference output voltage, $V_{ro}$, to vary from 1.24V to 6.3V. The reference attempts to hold $V_r$ at 1.24V. If $V_r$ is above 1.24V, the reference will conduct current from Cathode to Anode; FEEDBACK current always remains low. If FEEDBACK is connected to Anode, then $V_{ro} = V_r = 1.24V$. For higher voltages FEEDBACK is held at a constant voltage above Anode—say 3.76V for $V_{ro} = 5V$. Connecting a resistor across the constant $V_r$ generates a current I=R1/$V_r$ flowing from Cathode into FEEDBACK node. A Thevenin equivalent 3.76V is generated from FEEDBACK to Anode with R2=3.76/I. Keep I greater than one thousand times larger than FEEDBACK bias current for <0.1% error—I≥32 μA for the military grade over the military temperature range (I≥5.5 μA for a 1% untrimmed error for a commercial part.)

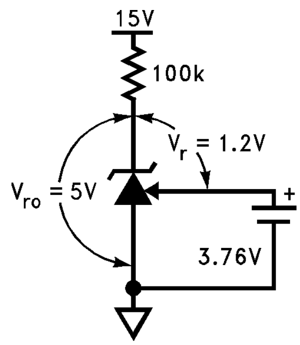
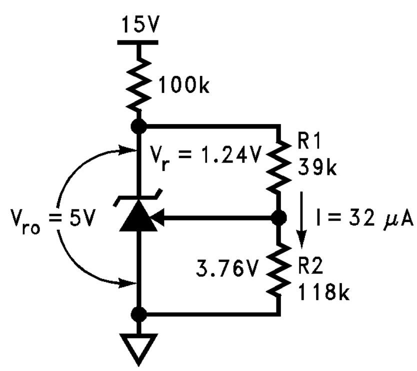



**Figure 56. Thevenin Equivalent of Reference with 5V Output**




R1 = Vr/I = 1.24/32μ = 39k

R2 = R1 {(Vro/Vr) − 1} = 39k {(5/1.24) − 1)} = 118k

**Figure 57. Resistors R1 and R2 Program Reference Output Voltage to be 5V**

Understanding that $V_r$ is fixed and that voltage sources, resistors, and capacitors may be tied to the FEEDBACK pin, a range of $V_r$ temperature coefficients may be synthesized.

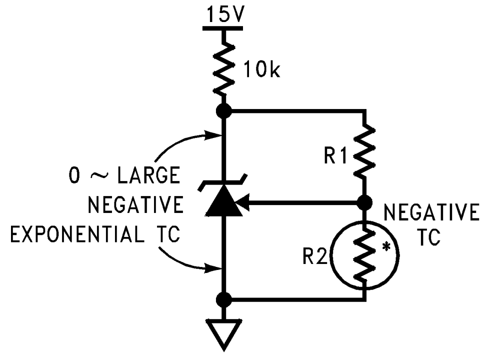



**Figure 58. Output Voltage has Negative Temperature Coefficient (TC) if R2 has Negative TC**

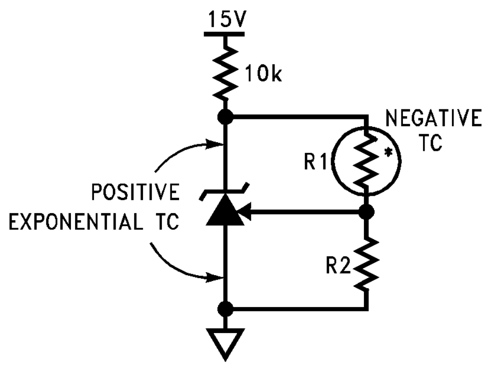



**Figure 59. Output Voltage has Positive TC if R1 has Negative TC**

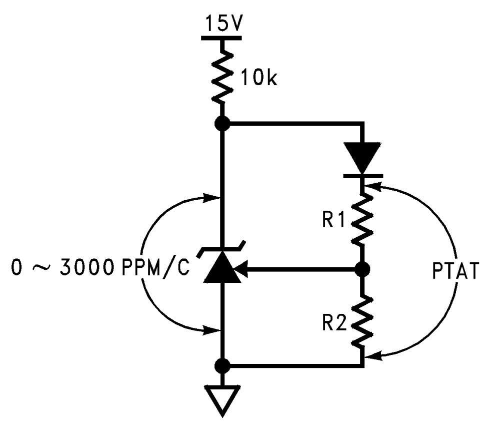
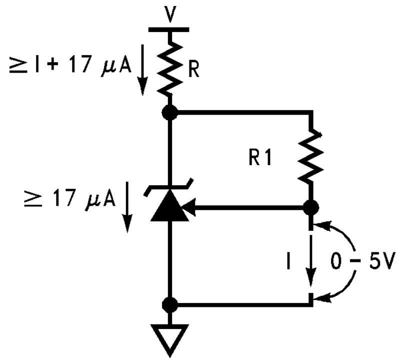



**Figure 60. Diode in Series with R1 Causes Voltage Across R1 and R2 to be Proportional to Absolute Temperature (PTAT)**

Connecting a resistor across Cathode-to-FEEDBACK creates a 0 TC current source, but a range of TCs may be synthesized.




$I = Vr/R1 = 1.24/R1$

**Figure 61. Current Source is Programmed by R1**

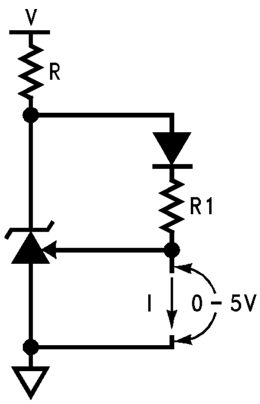



**Figure 62. Proportional-to-Absolute-Temperature Current Source**

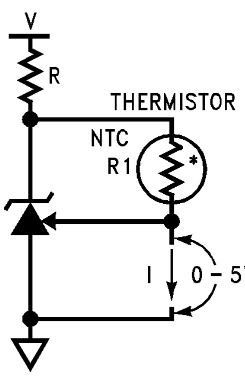



**Figure 63. Negative −TC Current Source**

## Hysteresis

The reference voltage depends, slightly, on the thermal history of the die. Competitive micro-power products vary—always check the data sheet for any given device. Do not assume that no specification means no hysteresis.

## OPERATIONAL AMPLIFIER

The amp or the reference may be biased in any way with no effect on the other, except when a substrate diode conducts (see [1] under Electrical Characteristics). The amp may have inputs outside the common-mode range, may be operated as a comparator, or have all terminals floating with no effect on the reference (tying inverting input to output and non-inverting input to $V^-$ on unused amp is preferred). Choosing operating points that cause oscillation, such as driving too large a capacitive load, is best avoided.

### Op Amp Output Stage

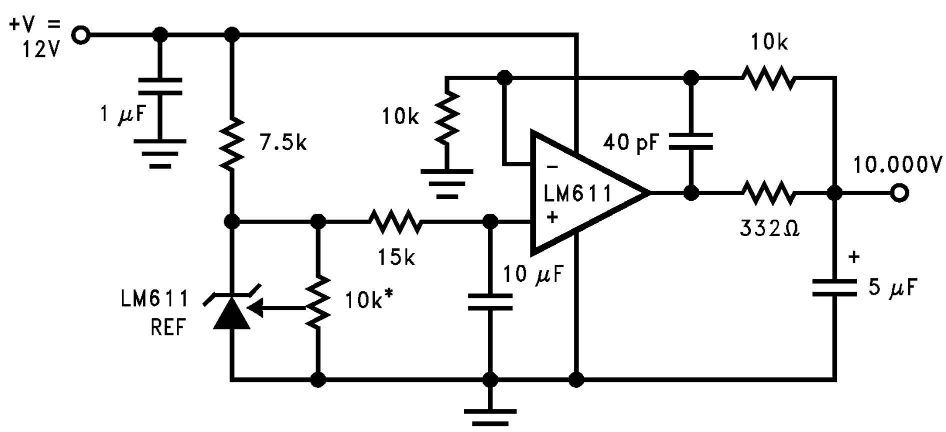
The op amp, like the LM124 series, has a flexible and relatively wide-swing output stage. There are simple rules to optimize output swing, reduce cross-over distortion, and optimize capacitive drive capability:

1. Output Swing: Unloaded, the 42 μA pull-down will bring the output within 300 mV of $V^-$ over the military temperature range. If more than 42 μA is required, a resistor from output to $V^-$ will help. Swing across any load may be improved slightly if the load can be tied to $V^+$, at the cost of poorer sinking open-loop voltage gain.
2. Cross-over Distortion: The LM611 has lower cross-over distortion (a 1 $V_{BE}$ deadband versus 3 $V_{BE}$ for the LM124), and increased slew rate as shown in the Typical Performance Charactersitics curves. A resistor pull-up or pull-down will force class-A operation with only the PNP or NPN output transistor conducting, eliminating cross-over distortion.
3. Capacitive Drive: Limited by the output pole caused by the output resistance driving capacitive loads, a pull-down resistor conducting 1 mA or more reduces the output stage NPN $r_e$ until the output resistance is that of the current limit 25Ω. 200 pF may then be driven without oscillation.

### Op Amp Input Stage

The lateral PNP input transistors, unlike those of most op amps, have $BV_{EBO}$ equal to the absolute maximum supply voltage. Also, they have no diode clamps to the positive supply nor across the inputs. These features make the inputs look like high impedances to input sources producing large differential and common-mode voltages.

## Typical Applications




*10k must be low t.c. trim pot.

**Figure 64. Ultra Low Noise 10.00V Reference. Total Output Noise is Typically 14 $\mu V_{RMS}$. Adjust the 10k pot for 10.000V.**

(1) Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

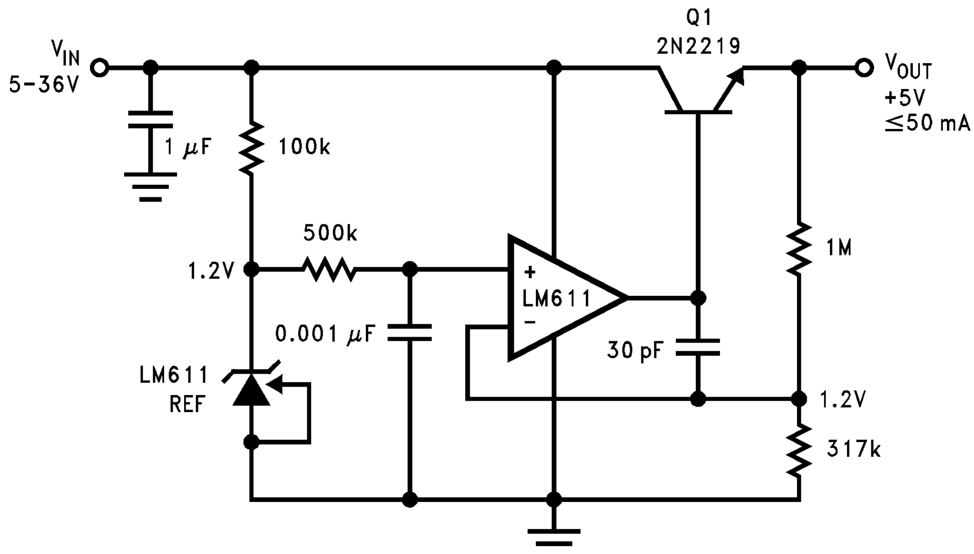
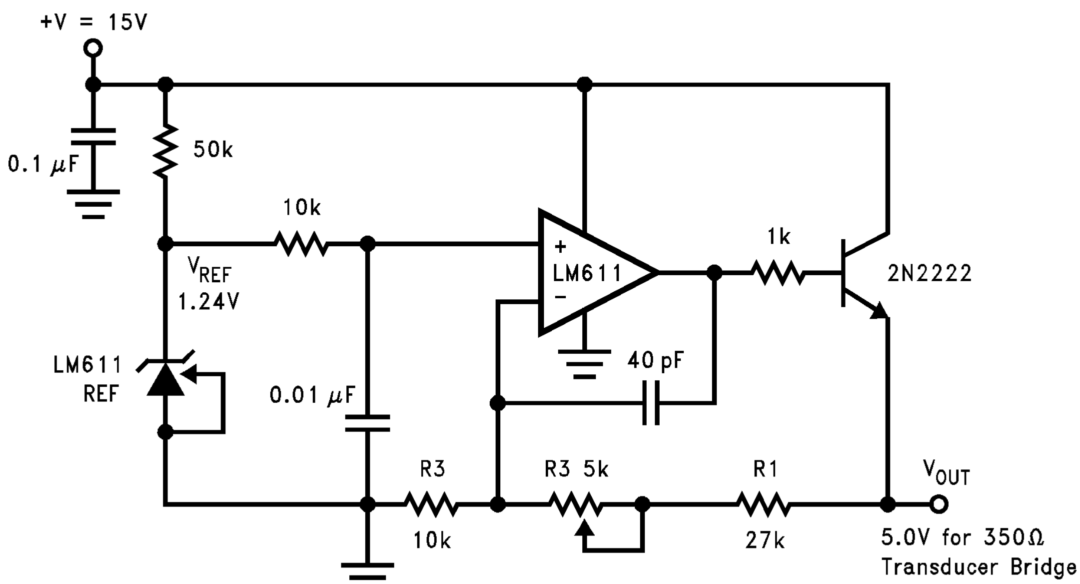



**Figure 65. Simple Low Quiescent Drain Voltage Regulator. Total Supply Current is approximately 320 µA when $V_{IN}$ = 5V, and output has no load.**




$V_{OUT}$ = (R1/R2 + 1) $V_{REF}$.
R1, R2 should be 1% metal film.
R3 should be low t.c. trim pot.

**Figure 66. Slow Rise-Time Upon Power-Up, Adjustable Transducer Bridge Driver. Rise-time is approximately 0.5 ms.**

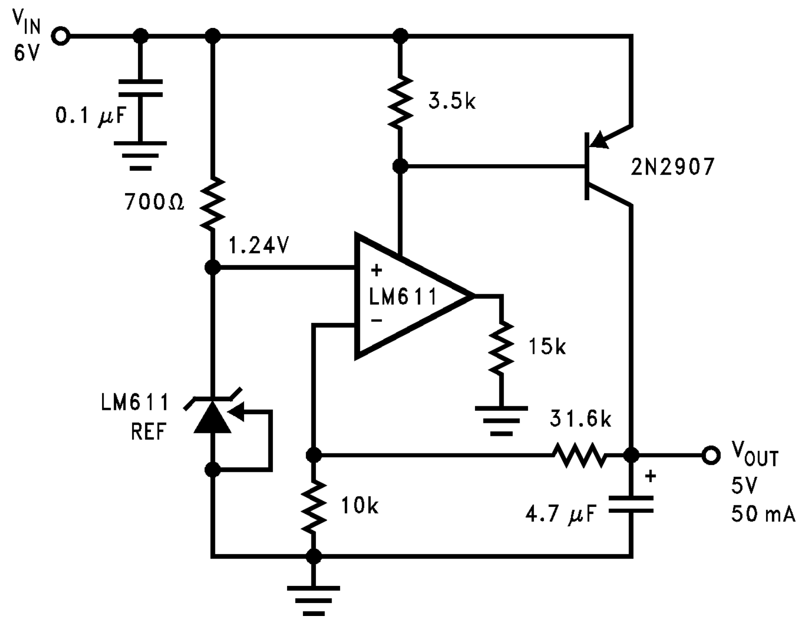



**Figure 67. Low Drop-Out Voltage Regulator Circuit. Drop out voltage is typically 0.2V.**

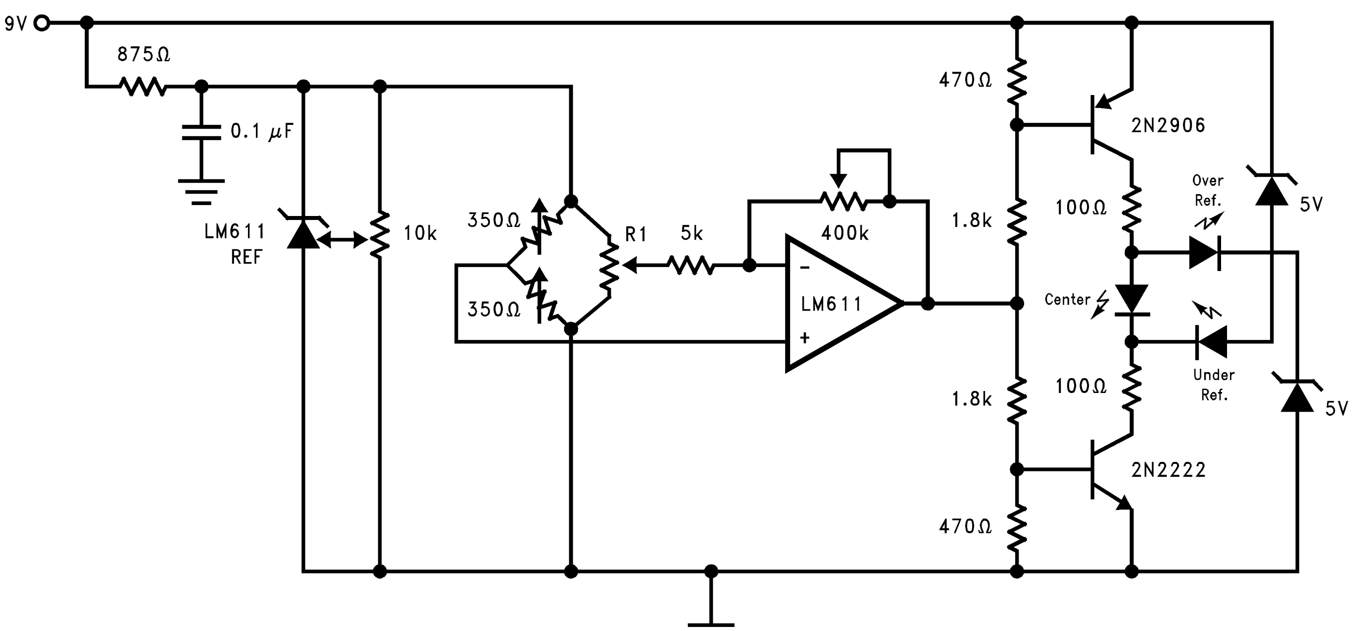



**Figure 68. Nulling Bridge Detection System. Adjust sensitivity via 400 kΩ pot. Null offset with R1, and bridge drive with the 10k pot.**

## Simplified Schematic Diagrams

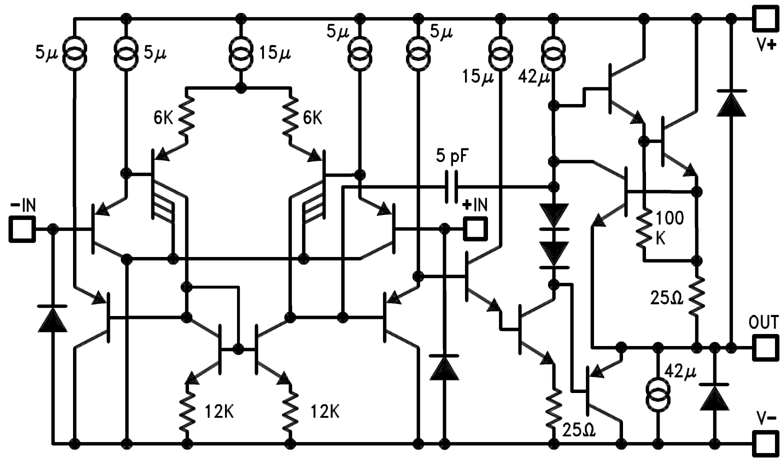



**Figure 69. Op Amp**

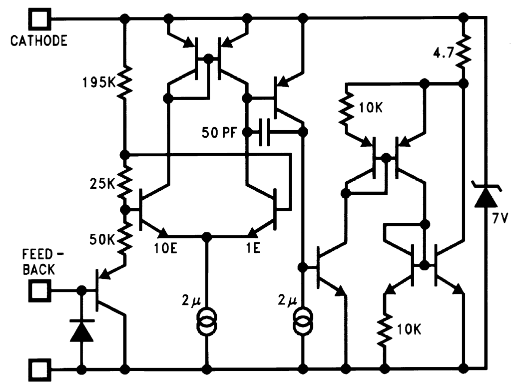



**Figure 70. Reference**

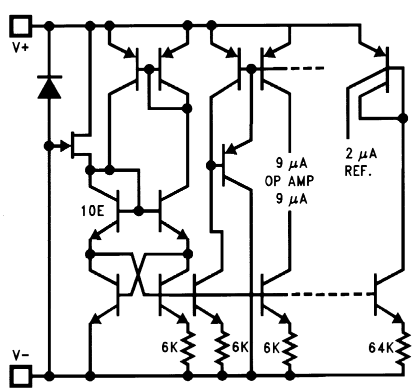



**Figure 71. Bias**

## REVISION HISTORY

| Changes from Revision B (March 2013) to Revision C | Page |
|---|---|
| • Changed layout of National Data Sheet to TI format ........................................................................................................... | 21 |

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LM611CM/NOPB | LIFEBUY | SOIC | D | 14 | 55 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM611CM | |
| LM611CMX/NOPB | LIFEBUY | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM611CM | |
| LM611IM/NOPB | LIFEBUY | SOIC | D | 14 | 55 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | LM611IM | |
| LM611IMX/NOPB | LIFEBUY | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | LM611IM | |

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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

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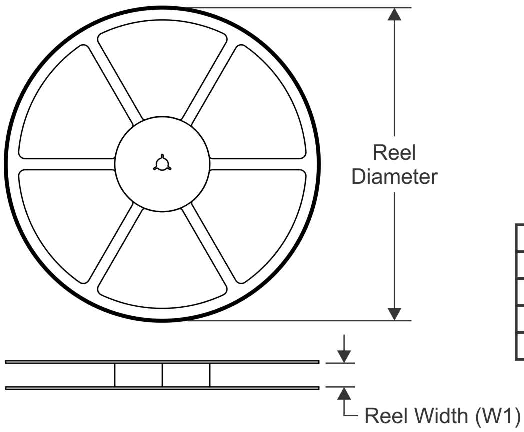
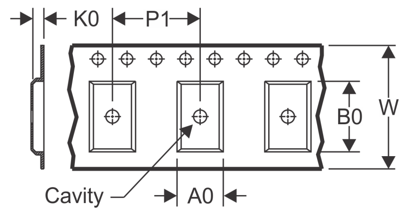
## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

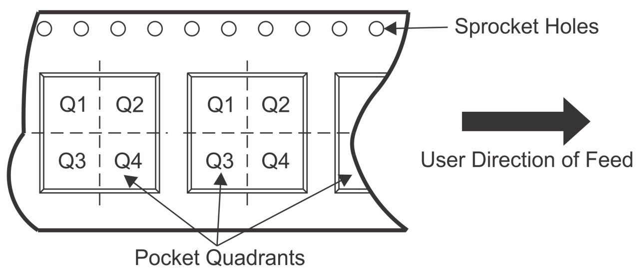



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

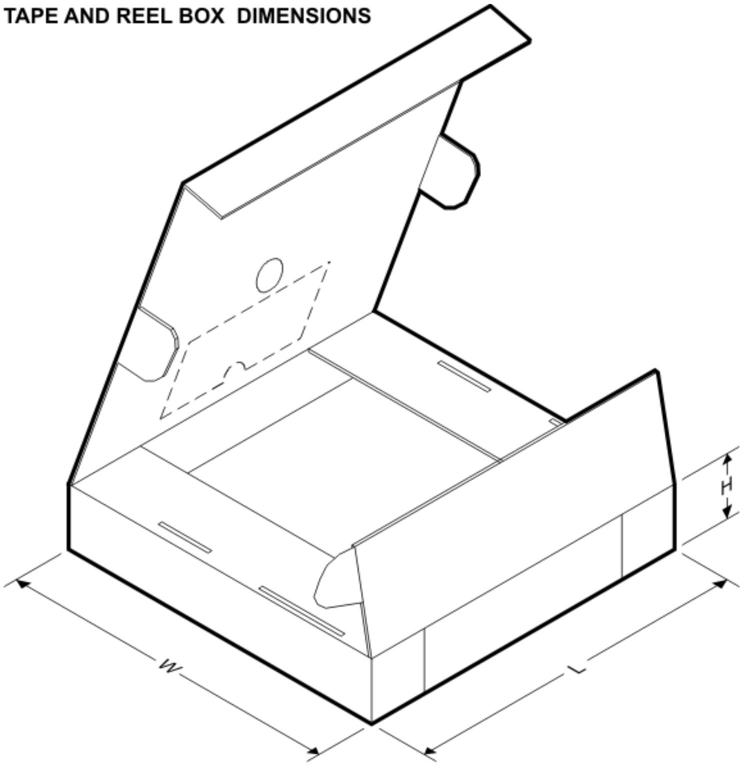
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM611CMX/NOPB | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LM611IMX/NOPB | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |

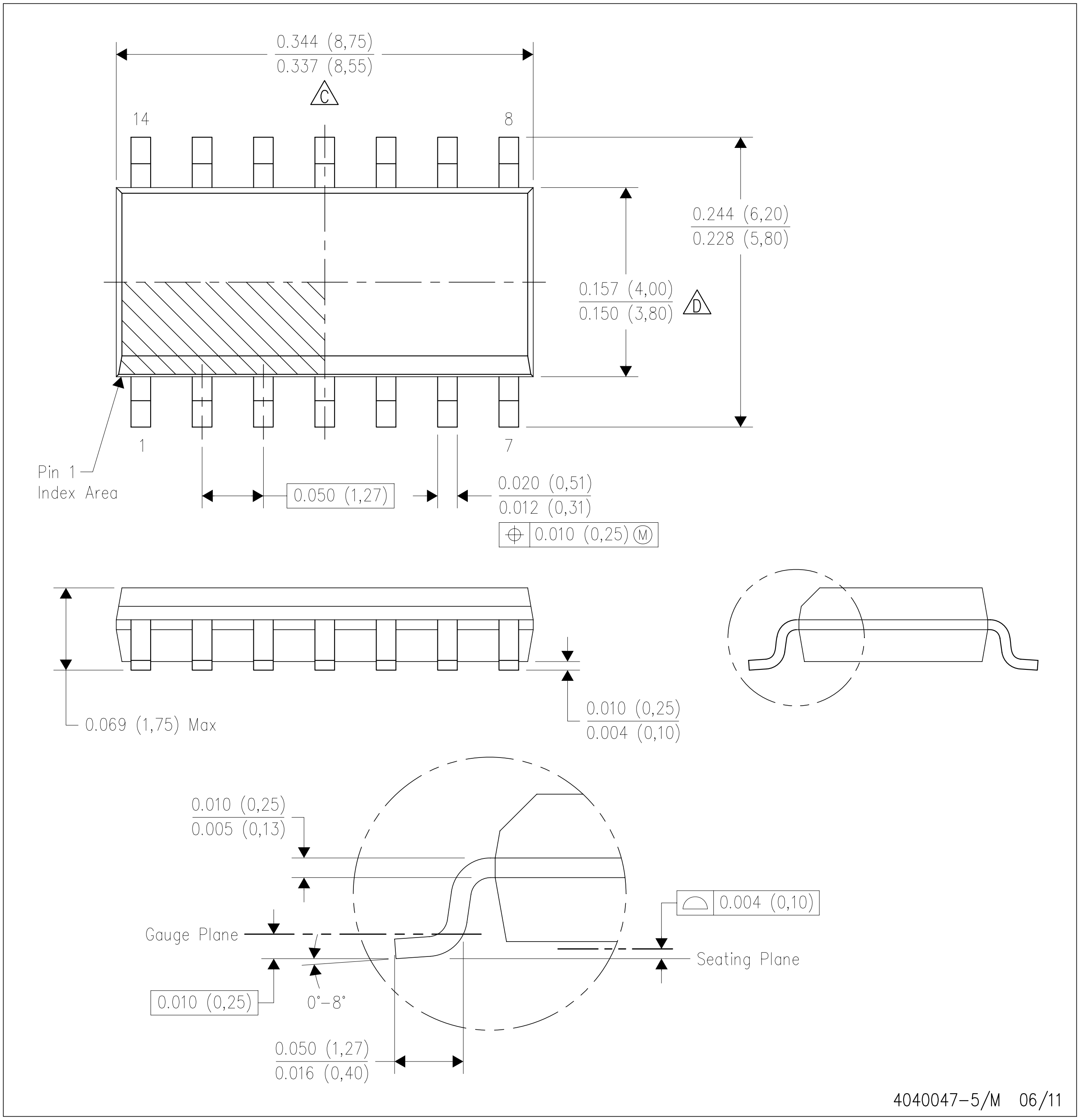
## TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LM611CMX/NOPB | SOIC | D | 14 | 2500 | 367.0 | 367.0 | 35.0 |
| LM611IMX/NOPB | SOIC | D | 14 | 2500 | 367.0 | 367.0 | 35.0 |

D (R–PDSO–G14) PLASTIC SMALL OUTLINE




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.

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