

LM614 Quad Operational Amplifier and Adjustable Reference

Check for Samples: [LM614](#)

FEATURES

Op Amp

- **Low Operating Current: 450 μ A**
- **Wide Supply Voltage Range: 4V to 36V**
- **Wide Common-Mode Range: V^- to $(V^+ - 1.8V)$**
- **Wide Differential Input Voltage: $\pm 36V$**

Reference

- **Adjustable Output Voltage: 1.2V to 5.0V**
- **Initial Tolerance: $\pm 2.0\%$**
- **Wide Operating Current Range: 17 μ A to 20mA**
- **Tolerant of Load Capacitance**

APPLICATIONS

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

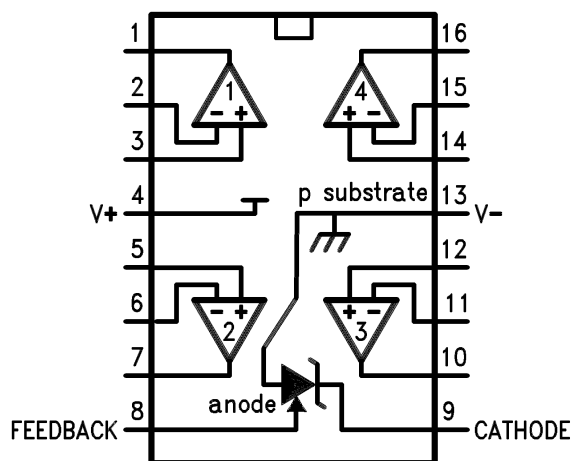
DESCRIPTION

The LM614 consists of four op-amps and a programmable voltage reference in a 16-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 four wide output swing op-amps makes the LM614 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), initial tolerance (2.0%), and the ability to be programmed from 1.2V to 5.0V 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 new Super-Block™ family, the LM614 is a space-saving monolithic alternative to a multichip solution, offering a high level of integration without sacrificing performance.

Connection Diagram



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

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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) ⁽³⁾ -0.3V (Min) ⁽⁴⁾ |
| Current through Any Input Pin & V_R Pin | | ±20 |
| Differential Input Voltage | LM614I | ±36V |
| | LM614C | ±32V |
| Storage Temperature Range | | -65°C ≤ T _J ≤ +150°C |
| Maximum Junction Temperature | | 150°C |
| Thermal Resistance, Junction-to-Ambient ⁽⁵⁾ | | 150°C |
| Soldering Information (Soldering, 10 sec.) | | 220°C |
| ESD Tolerance ⁽⁶⁾ | | ±1kV |

- (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) Input voltage above V_+ is allowed.
- (4) 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.
- (5) Junction temperature may be calculated using $T_J = T_A + P \theta_{JA}$. 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 comparator or reference output transistor, nominal θ_{JA} is 90°C/W for the DW package.
- (6) Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Operating Temperature Range

| | |
|--------|--------------------------------|
| LM614I | -40°C ≤ T _J ≤ +85°C |
| LM614C | 0°C ≤ T _J ≤ +70°C |

Electrical Characteristics

These specifications apply for $V^- = \text{GND} = 0\text{V}$, $V^+ = 5\text{V}$, $V_{CM} = V_{OUT} = 2.5\text{V}$, $I_R = 100\mu\text{A}$, 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 | Typ ⁽¹⁾ | LM614I LM614C Limits ⁽²⁾ | Units |
|------------------------------|--------------------------------------|---|--------------------|---|------------------|
| I _S | Total Supply Current | R _{LOAD} = ∞, 4V ≤ V ⁺ ≤ 36V (32V for LM614C) | 450 550 | 1000 1070 | μA max μA max |
| V _S | Supply Voltage Range | | 2.2 2.9 | 2.8 3 | V min V min |
| | | | 46 43 | 32 32 | V max V max |
| OPERATIONAL AMPLIFIER | | | | | |
| V _{OS1} | V _{OS} Over Supply | 4V ≤ V ⁺ ≤ 36V (4V ≤ V ⁺ ≤ 32V for LM614C) | 1.5 2.0 | 5.0 7.0 | mV max mV max |
| V _{OS2} | V _{OS} Over V _{CM} | V _{CM} = 0V through V _{CM} = (V ⁺ - 1.8V), V ⁺ = 30V | 1.0 1.5 | 5.0 7.0 | mV max mV max |
| $\frac{V_{OS3}}{\Delta T}$ | Average V _{OS} Drift | See ⁽²⁾ | 15 | | μV/°C max |
| I _B | Input Bias Current | | 10 11 | 35 40 | nA max nA max |
| I _{OS} | Input Offset Current | | 0.2 0.3 | 4 5 | nA max nA max |

- (1) 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.
- (2) All limits are ensured at room temperature (standard type face) or at operating temperature extremes (**bold type face**).

Electrical Characteristics (continued)

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

| Symbol | Parameter | Conditions | Typ ⁽¹⁾ | LM614 LM614C Limits ⁽²⁾ | Units |
|---|------------------------------------|--|--|---|------------------|
| $I_{\text{OS1}}/\Delta T$ | Average Offset Drift Current | | 4 | | pA/°C |
| R_{IN} | Input Resistance | Differential | 1800 | | MΩ |
| | | Common-Mode | 3800 | | MΩ |
| C_{IN} | Input Capacitance | Common-Mode Input | 5.7 | | pF |
| e_{n} | Voltage Noise | $f = 100\text{ Hz}$, Input Referred | 74 | | nV/√Hz |
| I_{n} | Current Noise | $f = 100\text{ Hz}$, Input Referred | 58 | | fA/√Hz |
| CMRR | Common-Mode | $V^+ = 30\text{V}$, $0\text{V} \leq V_{\text{CM}} \leq (V^+ - 1.8\text{V})$, | 95 | 75 | dB min |
| | Rejection Ratio | $\text{CMRR} = 20 \log (\Delta V_{\text{CM}}/\Delta V_{\text{OS}})$ | 90 | 70 | dB min |
| PSRR | Power Supply | $4\text{V} \leq V^+ \leq 30\text{V}$, $V_{\text{CM}} = V^+/2$, | 110 | 75 | dB min |
| | Rejection Ratio | $\text{PSRR} = 20 \log (\Delta V^+/\Delta V_{\text{OS}})$ | 100 | 70 | dB min |
| A_{V} | Open Loop Voltage Gain | $R_{\text{L}} = 10\text{ k}\Omega$ to GND, $V^+ = 30\text{V}$, | 500 | 94 | V/mV min |
| | | $5\text{V} \leq V_{\text{OUT}} \leq 25\text{V}$ | 50 | 40 | |
| SR | Slew Rate | $V^+ = 30\text{V}$ ⁽³⁾ | ±0.70 ±0.65 | ±0.50 ±0.45 | V/μs |
| GBW | Gain Bandwidth | $C_{\text{L}} = 50\text{ pF}$ | 0.8 | | MHz |
| | | | 0.52 | | MHz |
| V_{O1} | Output Voltage Swing High | $R_{\text{L}} = 10\text{ k}\Omega$ to GND $V^+ = 36\text{V}$ (32V for LM614C) | $V^+ - 1.4$ $V^+ - 1.6$ | $V^+ - 1.8$ $V^+ - 1.9$ | V min V min |
| V_{O2} | Output Voltage Swing Low | $R_{\text{L}} = 10\text{ k}\Omega$ to V^+ $V^+ = 36\text{V}$ (32V for LM614C) | $V^- + 0.8$ $V^- + 0.9$ | $V^- + 0.95$ $V^- + 1.0$ | V max V max |
| I_{OUT} | Output Source | $V_{\text{OUT}} = 2.5\text{V}$, $V_{+\text{IN}} = 0\text{V}$, $V_{-\text{IN}} = -0.3\text{V}$ | 25 | 16 | mA min |
| | | | 15 | 13 | mA min |
| I_{SINK} | Output Sink Current | $V_{\text{OUT}} = 1.6\text{V}$, $V_{+\text{IN}} = 0\text{V}$, $V_{-\text{IN}} = 0.3\text{V}$ | 17 | 13 | mA min |
| | | | 9 | 8 | mA min |
| I_{SHORT} | Short Circuit Current | $V_{\text{OUT}} = 0\text{V}$, $V_{+\text{IN}} = 3\text{V}$, $V_{-\text{IN}} = 2\text{V}$, Source | 30 | 50 | mA max |
| | | | 40 | 60 | mA max |
| | | | $V_{\text{OUT}} = 5\text{V}$, $V_{+\text{IN}} = 2\text{V}$, $V_{-\text{IN}} = 3\text{V}$, Sink | 30 | 70 |
| | | | 32 | 90 | mA max |
| VOLTAGE REFERENCE | | | | | |
| V_{R} | Voltage Reference | See ⁽⁴⁾ | 1.244 | 1.2191 1.2689 (±2.0%) | V min V max |
| $\frac{\Delta V_{\text{R}}}{\Delta T}$ | Average Temperature Drift | See ⁽⁵⁾ | 10 | 150 | PPM/°C max |
| $\frac{\Delta V_{\text{R}}}{\Delta T_{\text{J}}}$ | Hysteresis | See ⁽⁶⁾ | 3.2 | | μV/°C |
| $\frac{\Delta V_{\text{R}}}{\Delta I_{\text{R}}}$ | V_{R} Change with Current | $V_{\text{R}(100\mu\text{A})} - V_{\text{R}(17\mu\text{A})}$ | 0.05 0.1 | 1 1.1 | mV max mV max |
| | | $V_{\text{R}(10\text{mA})} - V_{\text{R}(100\mu\text{A})}$ ⁽⁷⁾ | 1.5 2.0 | 5 5.5 | mV max mV max |

- (3) 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 the output voltage transition is sampled at 20V and 10V.
- (4) V_{R} is the Cathode-feedback voltage, nominally 1.244V.
- (5) 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 $10^6 \cdot \Delta V_{\text{R}} / (V_{\text{R}[25^\circ\text{C}]} \cdot \Delta T_{\text{J}})$, where ΔV_{R} is the lowest value subtracted from the highest, $V_{\text{R}[25^\circ\text{C}]}$ is the value at 25°C, and ΔT_{J} is the temperature range. This parameter is ensured by design and sample testing.
- (6) 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, cycle its junction temperature in the following pattern, spiraling in toward 25°C: 25°C, 85°C, -40°C, 70°C, 0°C, 25°C.
- (7) Low contact resistance is required for accurate measurement.

Electrical Characteristics (continued)

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

| Symbol | Parameter | Conditions | Typ ⁽¹⁾ | LM614I LM614C Limits ⁽²⁾ | Units |
|--|---|--|---------------------|---|----------------------------|
| R | Resistance | $\Delta V_{\text{R}(10 \rightarrow 0.1 \text{ mA})} / 9.9 \text{ mA}$ | 0.2 | 0.56 | Ω max |
| | | $\Delta V_{\text{R}(100 \rightarrow 17 \mu\text{A})} / 83 \mu\text{A}$ | 0.6 | 13 | Ω max |
| $\frac{\Delta V_{\text{R}}}{\Delta V_{\text{RO}}}$ | V_{R} Change with High V_{RO} | $V_{\text{R}(V_{\text{ro}} = V_{\text{r}})} - V_{\text{R}(V_{\text{ro}} = 5.0\text{V})}$ (3.76V between Anode and FEEDBACK) | 2.5 2.8 | 7 10 | mV max mV max |
| $\frac{\Delta V_{\text{R}}}{\Delta V^+}$ | V_{R} Change with V^+ Change | $V_{\text{R}(V^+ = 5\text{V})} - V_{\text{R}(V^+ = 36\text{V})}$ ($V^+ = 32\text{V}$ for LM614C) | 0.1 0.1 | 1.2 1.3 | mV max mV max |
| | | $V_{\text{R}(V^+ = 5\text{V})} - V_{\text{R}(V^+ = 3\text{V})}$ | 0.01 0.01 | 1 1.5 | mV max mV max |
| I_{FB} | FEEDBACK Bias Current | $V_{\text{ANODE}} \leq V_{\text{FB}} \leq 5.06\text{V}$ | 22 29 | 50 55 | nA max nA max |
| e_{n} | Voltage Noise | BW = 10 Hz to 10 kHz, $V_{\text{RO}} = V_{\text{R}}$ | 30 | | μV_{RMS} |

Typical Performance Characteristics (Reference)

$T_J = 25^\circ\text{C}$, FEEDBACK pin shorted to $V^- = 0\text{V}$, unless otherwise noted

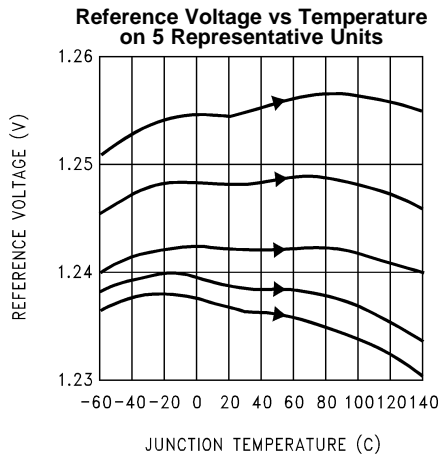


Figure 1.

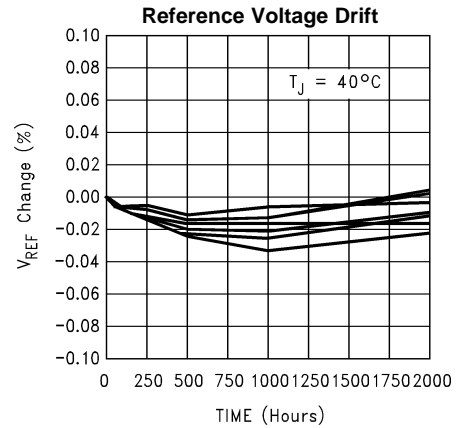


Figure 2.

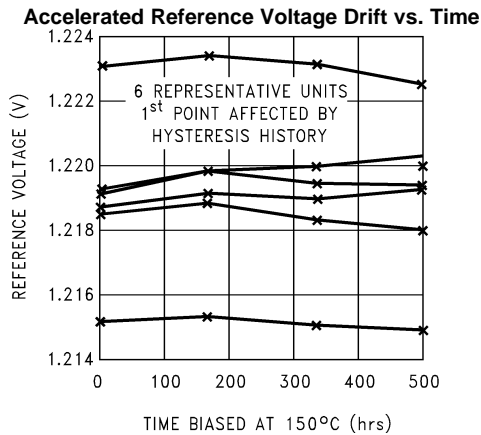


Figure 3.

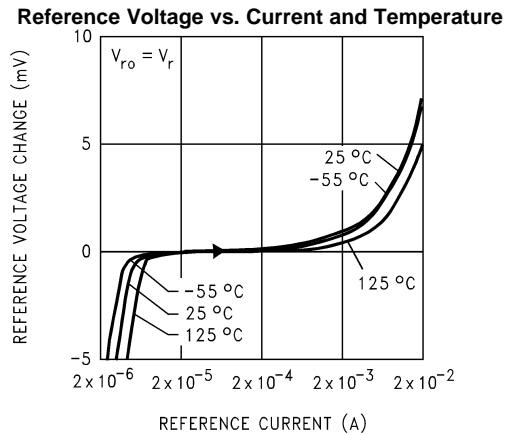


Figure 4.

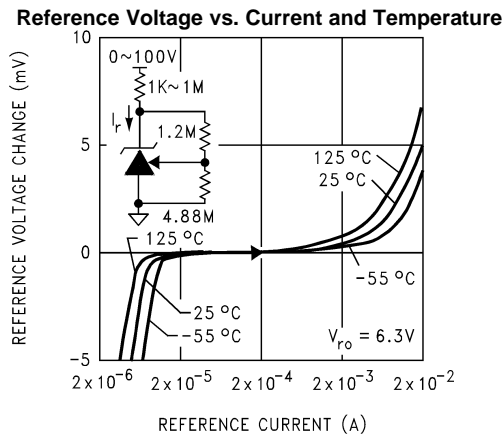


Figure 5.

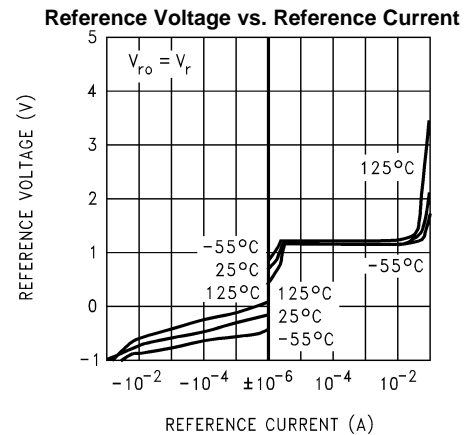


Figure 6.

Typical Performance Characteristics (Reference) (continued)

$T_J = 25^\circ\text{C}$, FEEDBACK pin shorted to $V^- = 0\text{V}$, unless otherwise noted

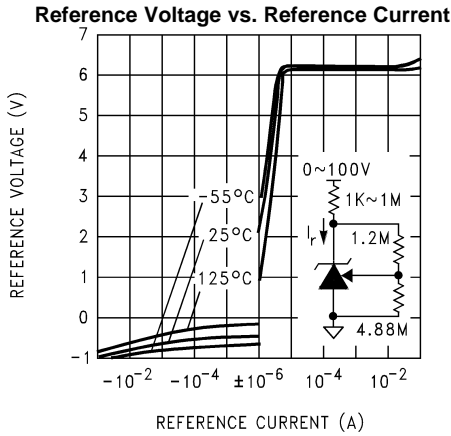


Figure 7.

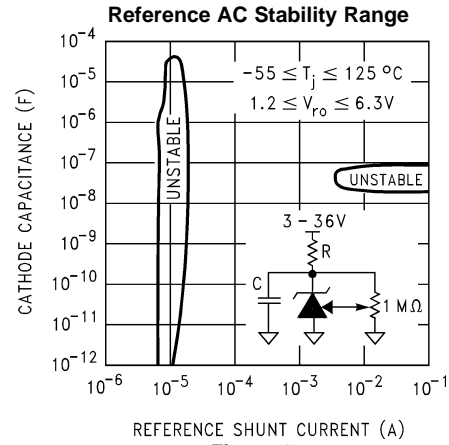


Figure 8.

FEEDBACK Current vs. FEEDBACK-to-Anode Voltage

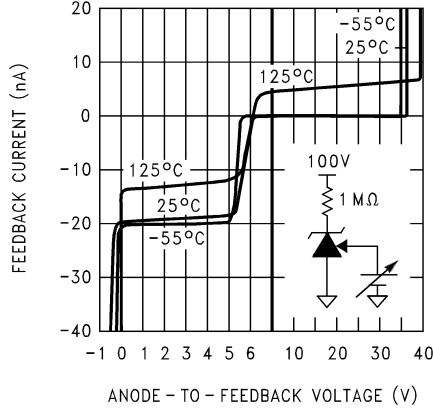


Figure 9.

FEEDBACK Current vs. FEEDBACK-to-Anode Voltage

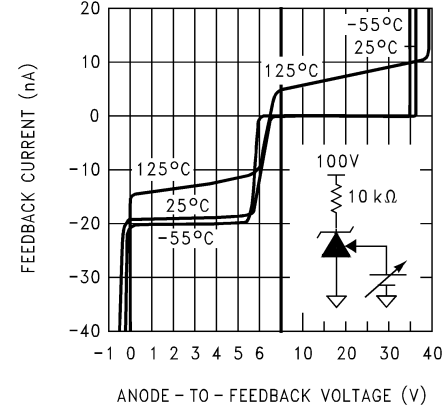


Figure 10.

Reference Noise Voltage vs. Frequency

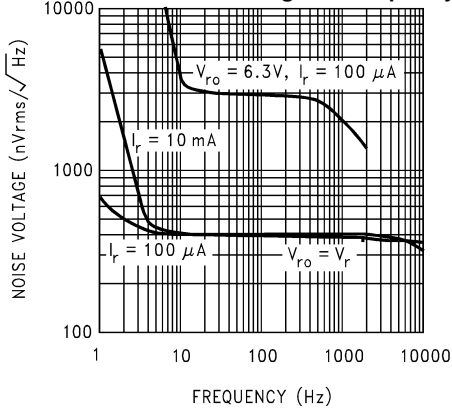


Figure 11.

Reference Small-Signal Resistance vs. Frequency

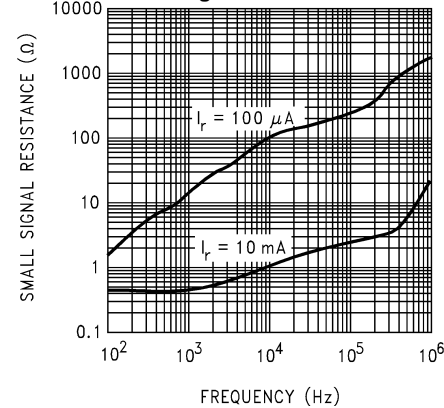


Figure 12.

Typical Performance Characteristics (Reference) (continued)

T_J = 25°C, FEEDBACK pin shorted to V⁻ = 0V, unless otherwise noted

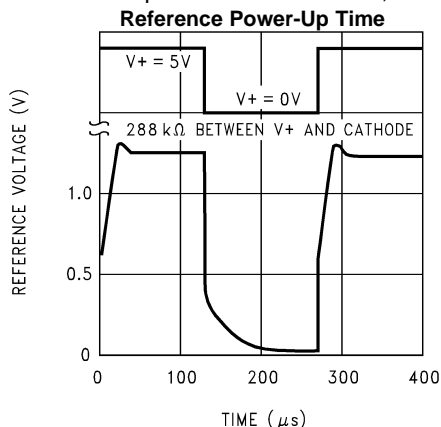


Figure 13.

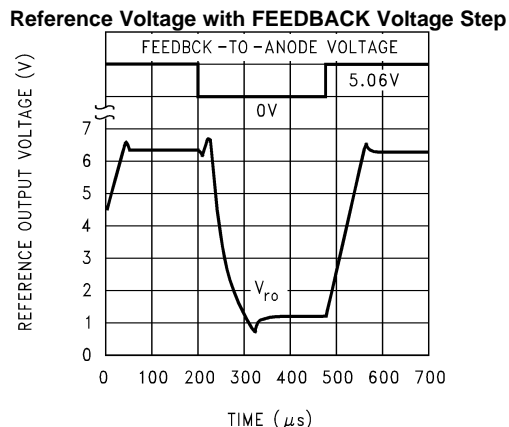


Figure 14.

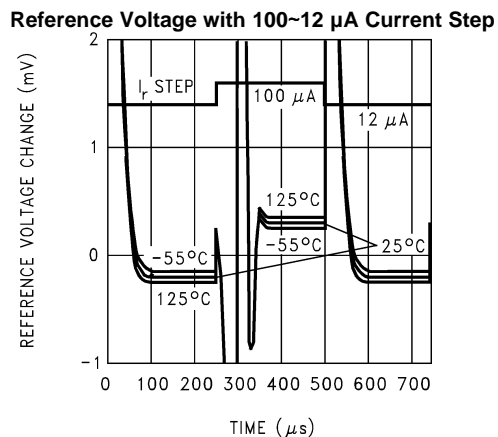


Figure 15.

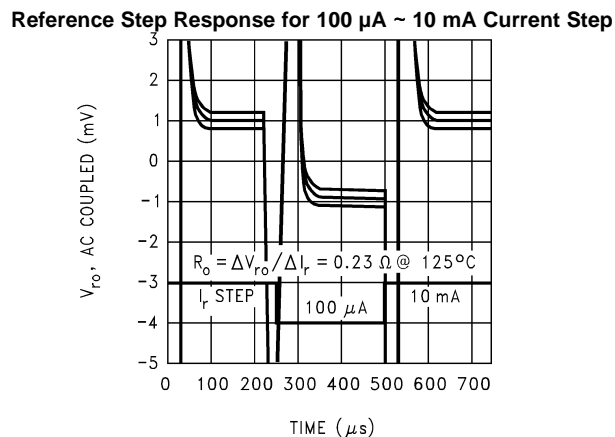


Figure 16.

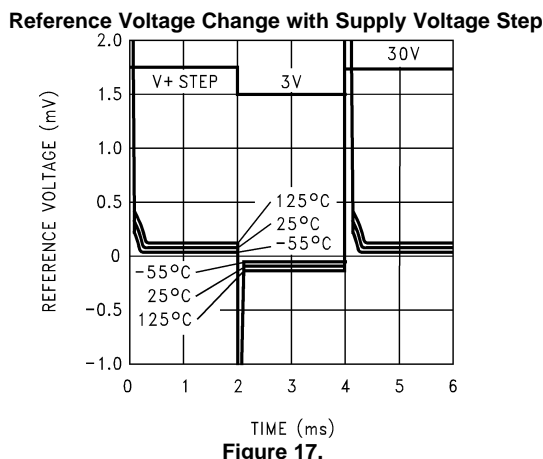


Figure 17.

Typical Performance Characteristics (Op Amps)

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

Input Common-Mode Voltage Range vs. Temperature

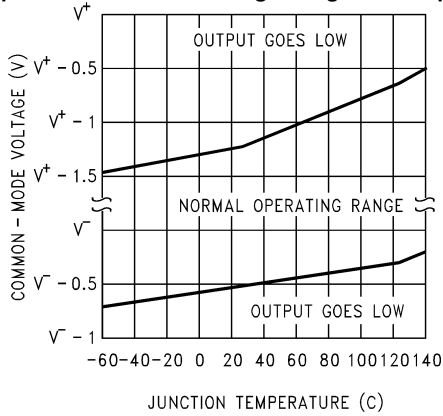


Figure 18.

V_{OS} vs. Junction Temperature on 9 Representative Units

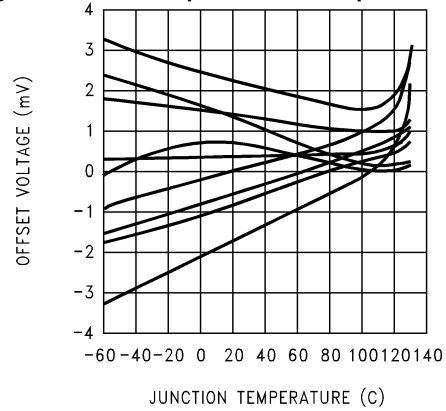


Figure 19.

Input Bias Current vs. Common-Mode Voltage

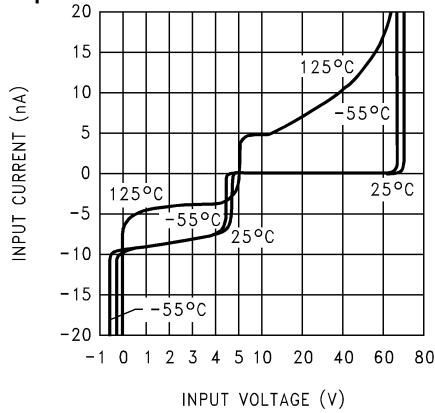


Figure 20.

Slew Rate vs. Temperature and Output Sink Current

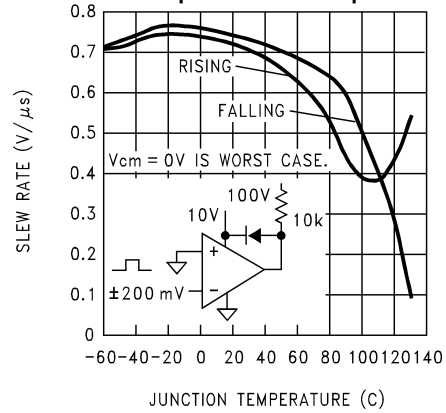


Figure 21.

Large-Signal Step Response

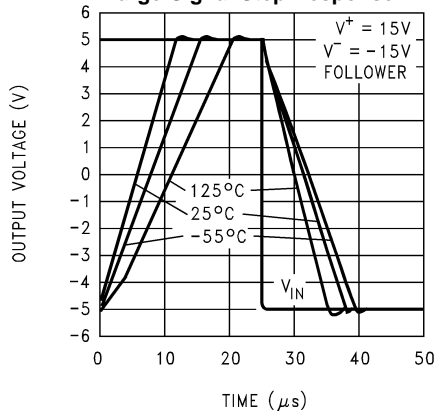


Figure 22.

Output Voltage Swing vs. Temp. and Current

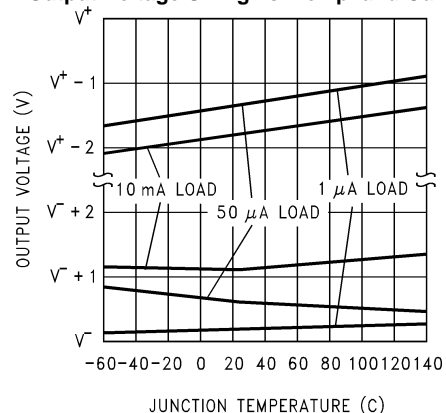


Figure 23.

Typical Performance Characteristics (Op Amps) (continued)

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

Output Source Current vs. Output Voltage and Temp.

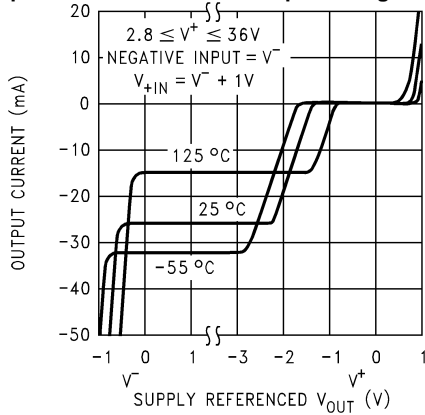


Figure 24.

Output Sink Current vs. Output Voltage and Temp.

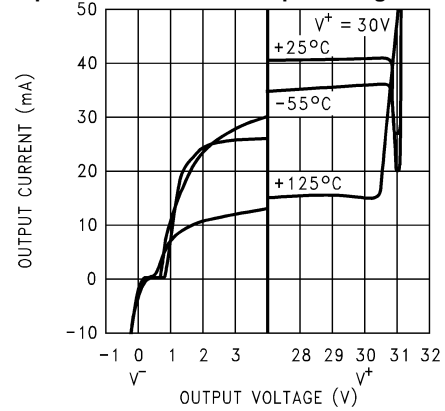


Figure 25.

Output Swing, Large Signal

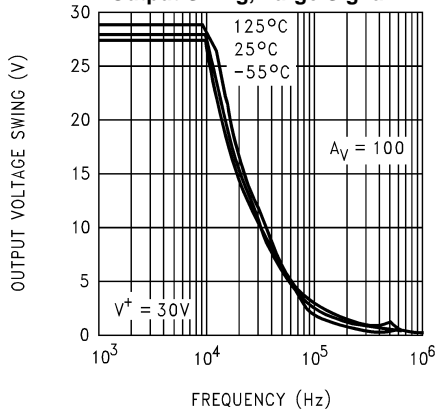


Figure 26.

Output Impedance vs. Frequency and Gain

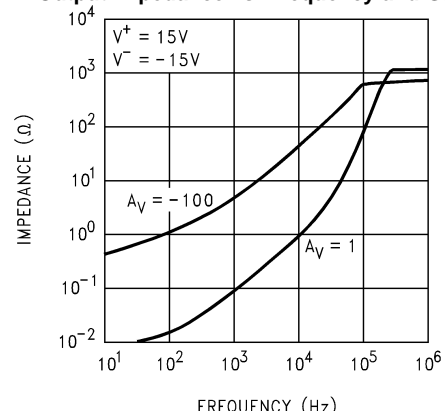


Figure 27.

Small-Signal Pulse Response vs. Temp.

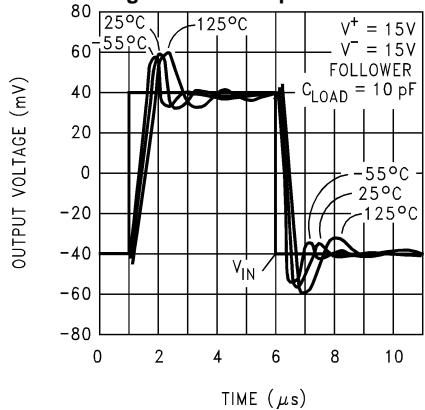


Figure 28.

Small-Signal Pulse Response vs. Load

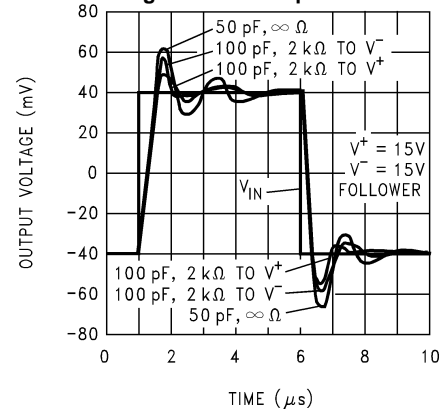


Figure 29.

Typical Performance Characteristics (Op Amps) (continued)

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

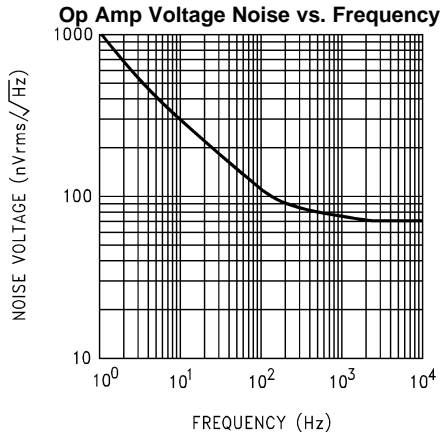


Figure 30.

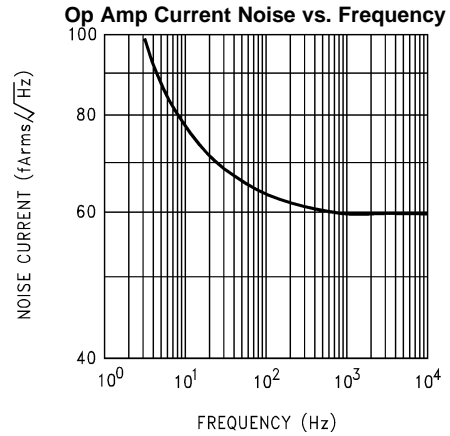


Figure 31.

Small-Signal Voltage Gain vs. Frequency and Temperature

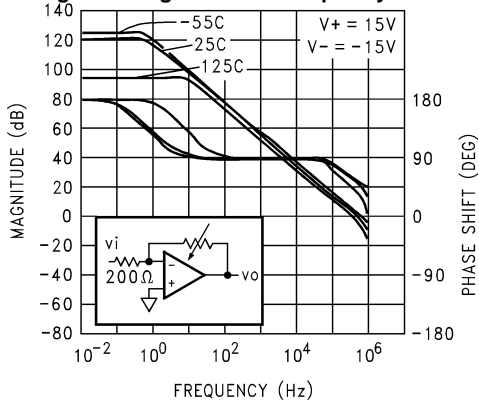


Figure 32.

Small-Signal Voltage Gain vs. Frequency and Load

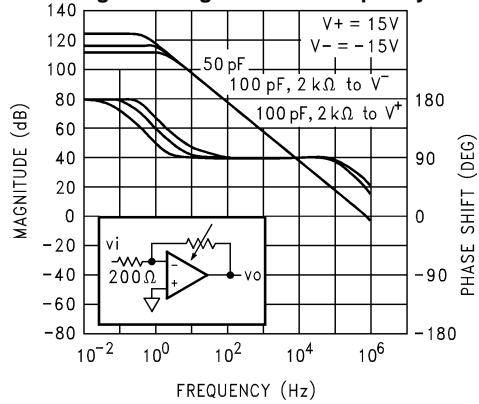


Figure 33.

Follower Small-Signal Frequency Response

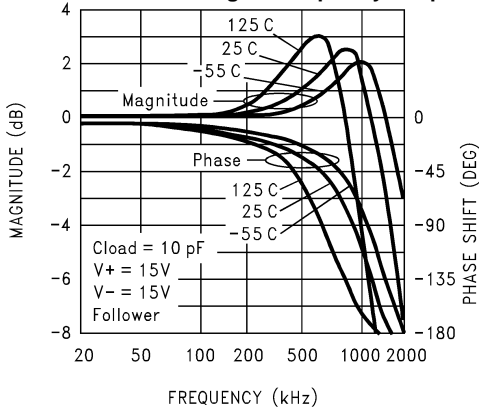


Figure 34.

Common-Mode Input Voltage Rejection Ratio

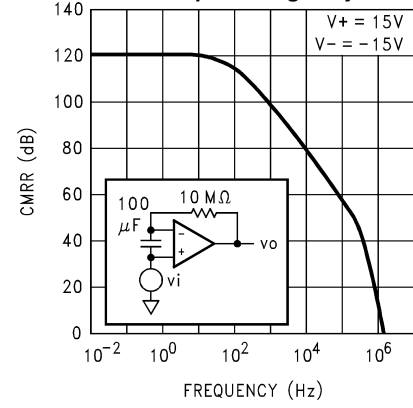


Figure 35.

Typical Performance Characteristics (Op Amps) (continued)

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

Power Supply Current vs. Power Supply Voltage

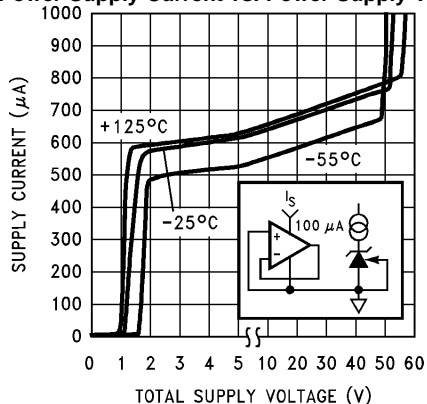


Figure 36.

Positive Power Supply Voltage Rejection Ratio

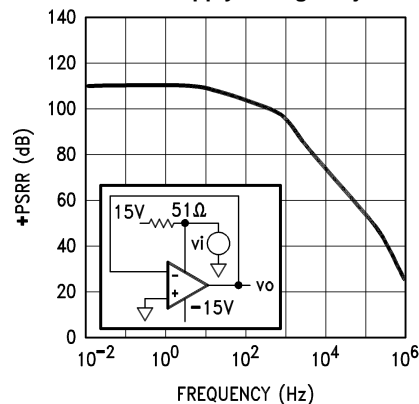


Figure 37.

Negative Power Supply Voltage Rejection Ratio

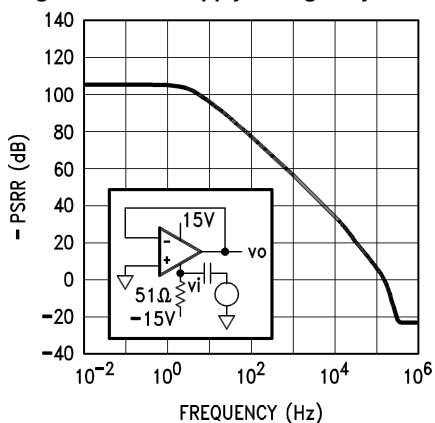


Figure 38.

Input Offset Current vs. Junction Temperature

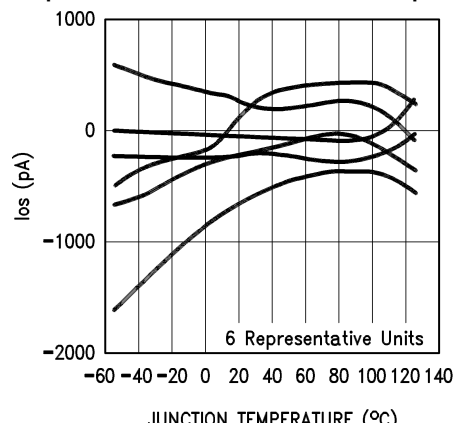


Figure 39.

Input Bias Current vs. Junction Temperature

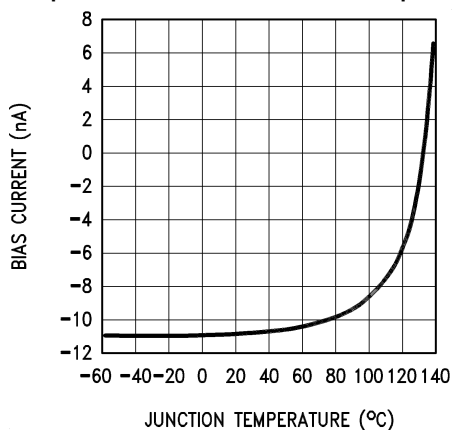
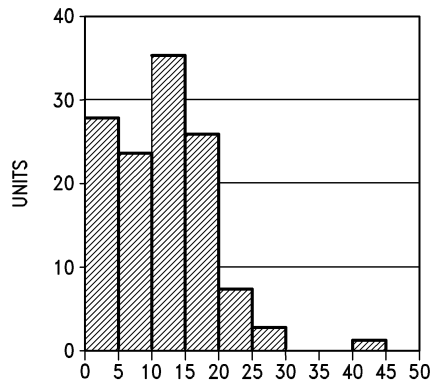


Figure 40.

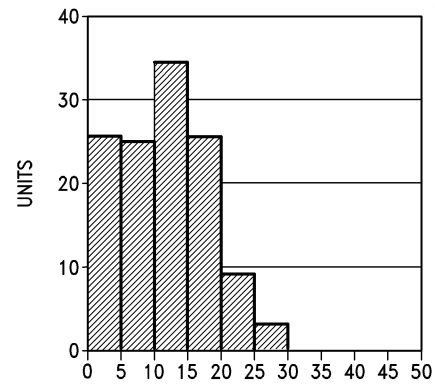
Typical Performance Distributions

Average V_{OS} Drift Industrial Temperature Range



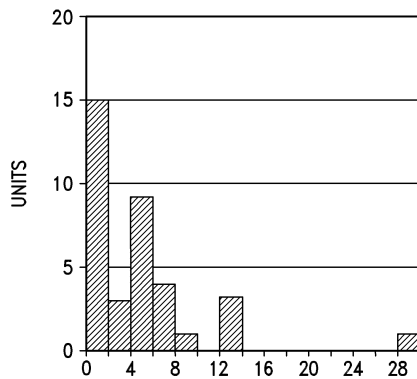
Vos DRIFT ($\mu V/C$)
Figure 41.

Average V_{OS} Drift Commercial Temperature Range



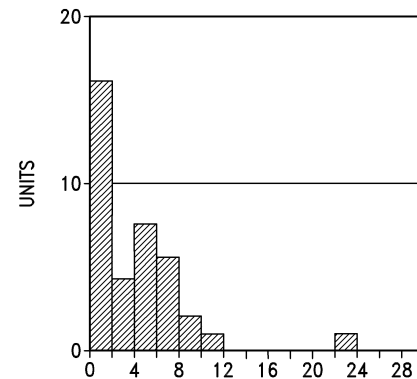
Vos DRIFT ($\mu V/C$)
Figure 42.

Average I_{OS} Drift Industrial Temperature Range



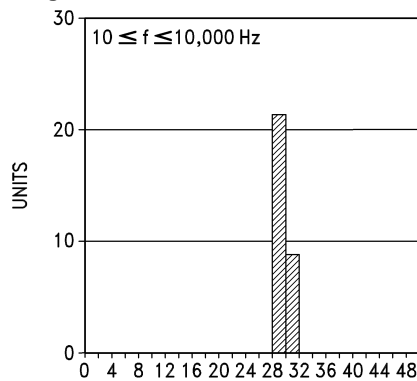
I_{OS} DRIFT (pA/C)
Figure 43.

Average I_{OS} Drift Commercial Temperature Range



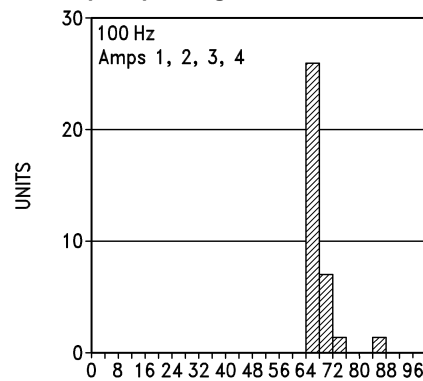
I_{OS} DRIFT (pA/C)
Figure 44.

Voltage Reference Broad-BandNoise Distribution



VOLTAGE NOISE (μV_{RMS})
Figure 45.

Op Amp Voltage Noise Distribution



VOLTAGE NOISE (nV_{RMS}/\sqrt{Hz})
Figure 46.

Typical Performance Distributions (continued)

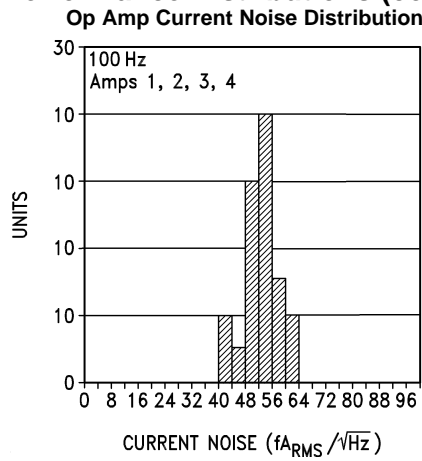


Figure 47.

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 cathode may swing from a diode drop below V^- to the reference voltage or to the avalanche voltage of the parallel protection diode, nominally 7V. A 5.0V reference with $V^+ = 3V$ is allowed.

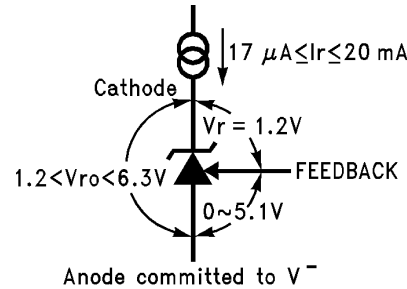


Figure 48. Voltages Associated with Reference (Current Source I_r is External)

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 .

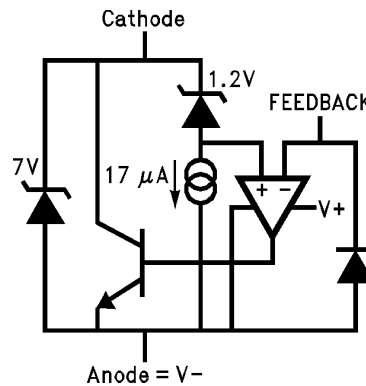


Figure 49. Reference Equivalent Circuit

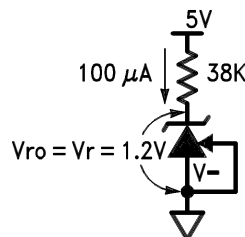


Figure 50. 1.2V Reference

Capacitors in parallel with the reference are allowed. See [Reference AC Stability Range](#) typical 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 5.0V. 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 $V_{ro} = V_r = 1.24\text{V}$. For higher voltages FEEDBACK is held at a constant voltage above Anode—say 3.76V for $V_{ro} = 5\text{V}$. Connecting a resistor across the constant V_r generates a current $I = V_r/R1$ flowing from Cathode into FEEDBACK node. A Thevenin equivalent 3.76V is generated from FEEDBACK to Anode with $R2 = 3.76/I$. For a 1% error, use R1 such that I is greater than one hundred times the FEEDBACK bias current. For example, keep $I \geq 5.5\mu\text{A}$.

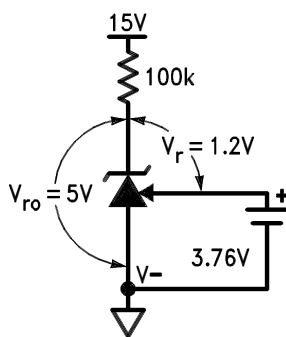
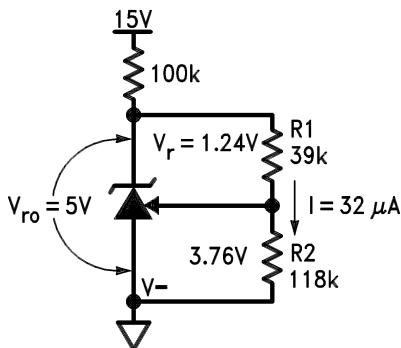


Figure 51. Thevenin Equivalent of Reference with 5V Output



$$R1 = Vr/I = 1.24/32\mu = 39k$$

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

Figure 52. 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.

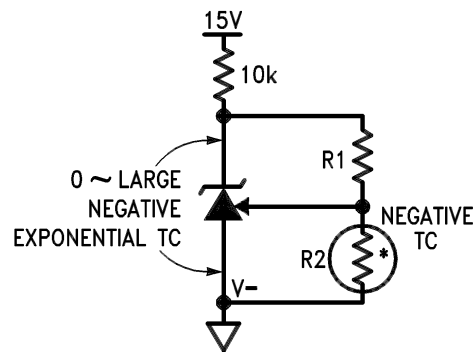


Figure 53. Output Voltage has Negative Temperature Coefficient (TC) if R2 has Negative TC

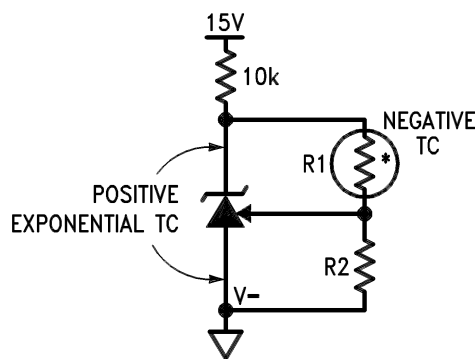


Figure 54. Output Voltage has Positive TC if R1 has Negative TC

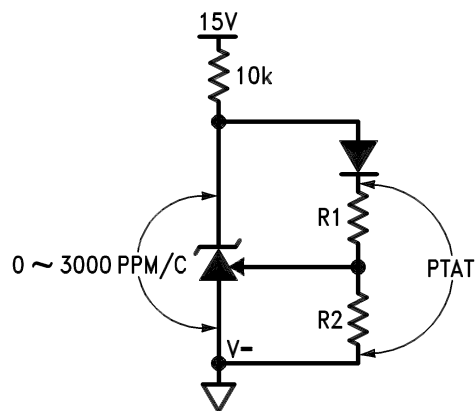
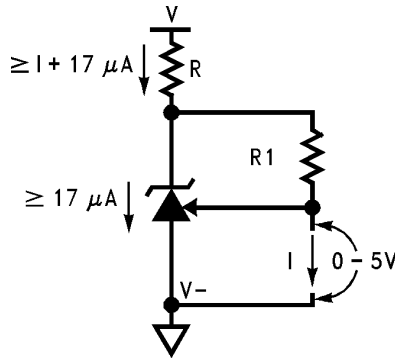


Figure 55. Diode in Series with R1 Causes Voltage across R1 and R2 to be Proportional to Absolute Temperature (PTAT)

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



$$I = V_T/R1 = 1.24/R1$$

Figure 56. Current Source is Programmed by R1

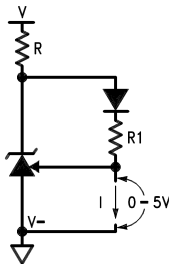


Figure 57. Proportional-to-Absolute-Temperature Current Source

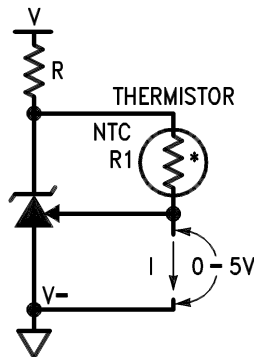


Figure 58. Negative-TC Current Source

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 AMPLIFIERS

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

Op Amp Output Stage

These op amps, like their LM124 series, have flexible and relatively wide-swing output stages. There are simple rules to optimize output swing, reduce cross-over distortion, and optimize capacitive drive capability:

1. **Output Swing:** Unloaded, the $42\mu\text{A}$ pull-down will bring the output within 300 mV of V^- over the military temperature range. If more than $42\mu\text{A}$ 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 LM614 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 [characteristic 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 . 200pF may then be driven without oscillation.

Op Amp Input Stage

The lateral PNP input transistors, unlike 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

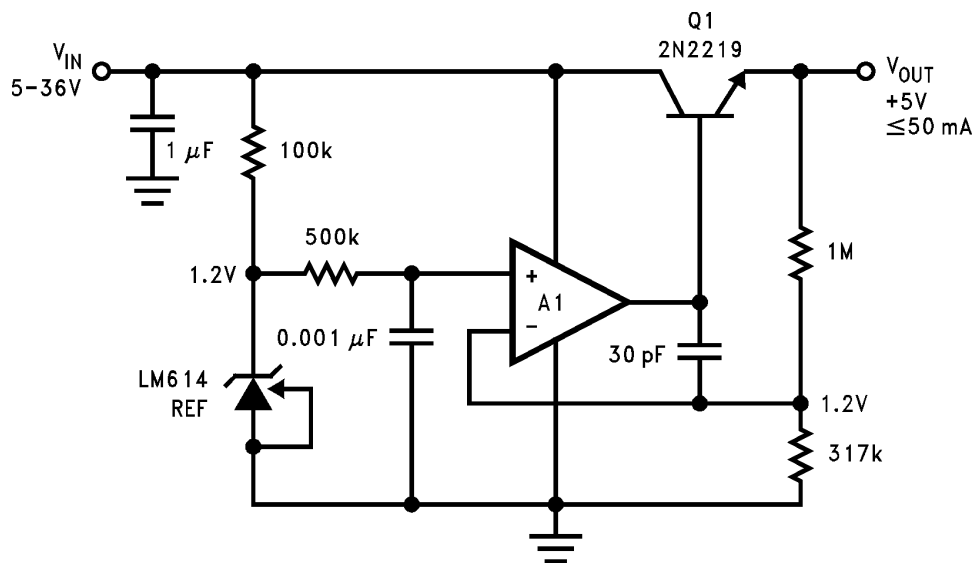
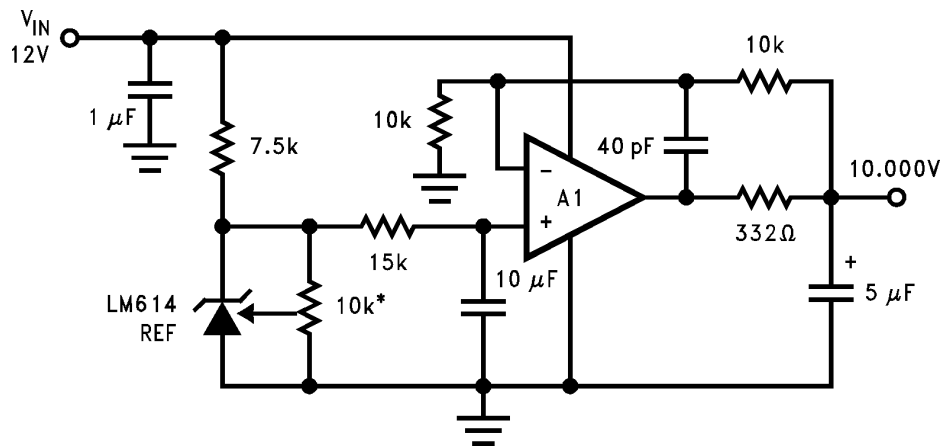
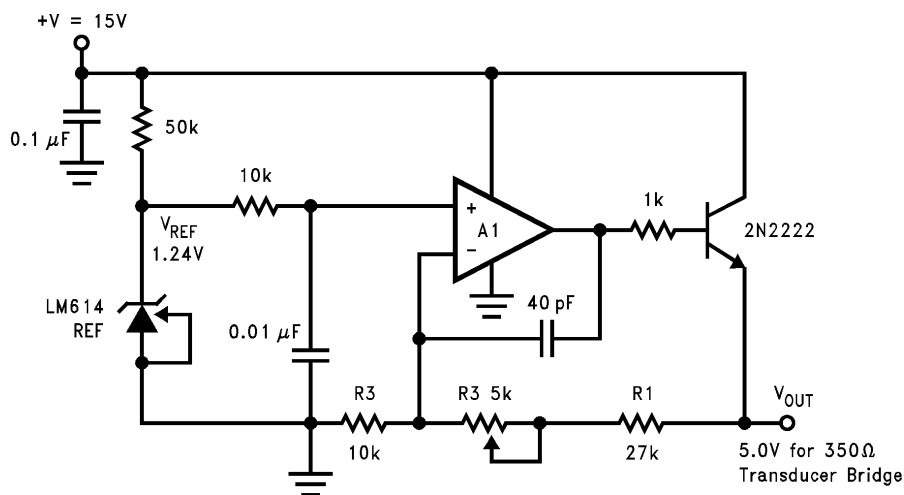


Figure 59. Simple Low Quiescent Drain Voltage Regulator.
Total supply current approximately $320\mu\text{A}$, when $V_{IN} = +5\text{V}$.



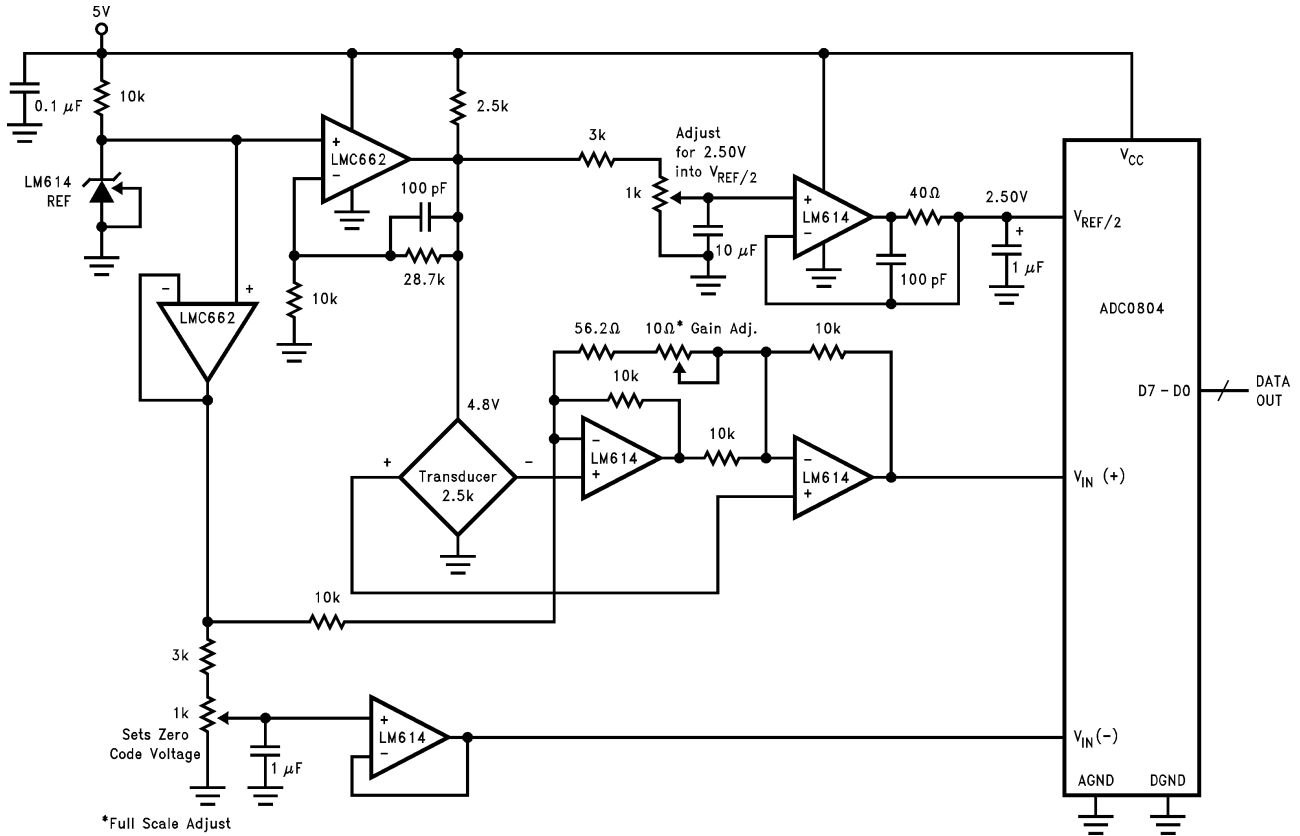
*10k must be low
t.c. trimpot.

Figure 60. Ultra Low Noise 10.00V Reference.
Total output noise is typically $14\mu\text{V}_{\text{RMS}}$.



$V_{\text{OUT}} = (R_1 / P_e + 1) V_{\text{REF}}$
 R_1, R_2 should be 1% metal film
 P_β should be low T.C. trim pot

Figure 61. Slow Rise Time Upon Power-Up, Adjustable Transducer Bridge Driver.
Rise time is approximately 1ms.



- (1) Set zero code voltage, then adjust 10Ω gain adjust pot for full scale.

Figure 62. Transducer Data Acquisition System.

Simplified Schematic Diagrams

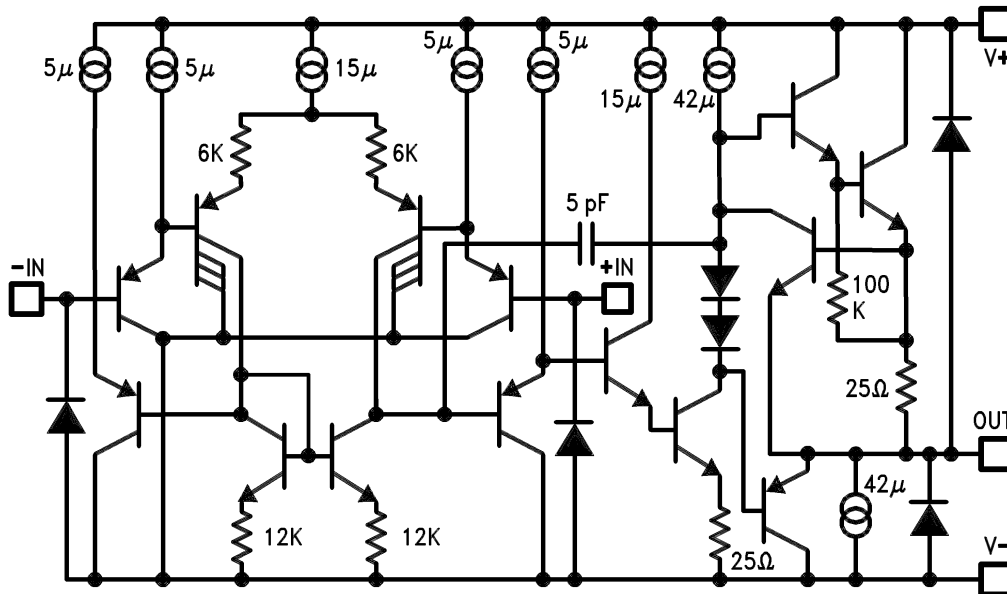


Figure 63. Op Amp

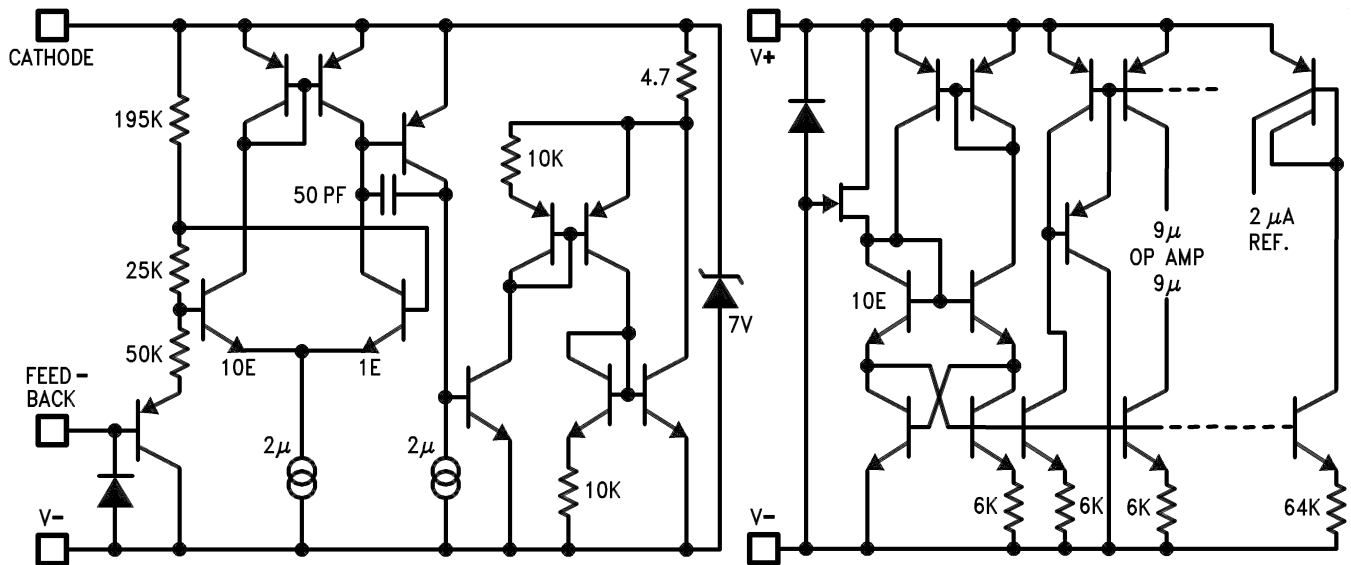


Figure 64. Reference / Bias

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 part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|-----------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| LM614 MDC | Active | Production | DIESALE (Y) 0 | 100 NOT REQUIRED | Yes | Call TI | Level-1-NA-UNLIM | -40 to 85 | |

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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