# LM2904-Q1, LM2904B-Q1, and LM2904BA-Q1 Industry-Standard Dual Operational Amplifiers for Automotive Applications

## 1 Features

- AEC Q-100 qualified for automotive applications
  - Temperature grade 1: –40°C to +125°C
  - Device HBM ESD classification 2
  - Device CDM ESD classification C5
- Wide supply range of 3 V to 36 V (LM2904B-Q1 and LM2904BA-Q1)
- Supply-current of 300 µA per channel (LM2904B-Q1 and LM2904BA-Q1, typical)
- Unity-gain bandwidth of 1.2 MHz (LM2904B-Q1 and LM2904BA-Q1)
- Common-mode input voltage range includes ground, enabling direct sensing near ground
- Low input offset voltage of 2 mV at 25°C (LM2904BA-Q1, maximum)
- Low input offset voltage of 3 mV at 25°C (LM2904B-Q1, maximum)
- Internal RF and EMI filter (LM2904B-Q1 and LM2904BA-Q1)
- Functional Safety-Capable
  - Documentation available to aid functional safety system design

## 2 Applications

- Automotive lighting
- Body electronics
- Automotive head unit
- Telematics control unit
- Emergency call (eCall)
- Passive safety: brake system
- Electric vehicle / hybrid electric:
  - Inverter and motor control
  - On-board (OBC) and wireless charger
  - Battery management system (BMS)

## 3 Description

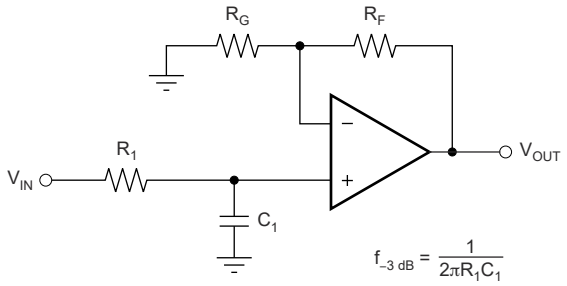
The LM2904-Q1, LM2904B-Q1, and LM2904BA-Q1 are industry-standard operational amplifiers that have been qualified for automotive use in accordance to the AEC-Q100 specifications. The LM2904B-Q1 and LM2904BA-Q1 are the next-generation versions of the LM2904-Q1, which include two high-voltage (36 V) operational amplifiers (op amps). The LM2904B-Q1 and LM2904BA-Q1 provide outstanding value for cost-sensitive applications, with features including low offset (3 mV and 2 mV maximum, respectively), common-mode input range to ground, and high differential input voltage capability.

The LM2904B-Q1 and LM2904BA-Q1 simplify circuit design with enhanced features such as unity-gain stability, lower offset voltage of 0.3 mV (typical), and lower quiescent current of 300 µA (typical). High ESD (2 kV, HBM) and integrated EMI and RF filters enable the LM2904B-Q1 and LM2904BA-Q1 devices to be used in the most rugged, environmentally challenging applications for the automotive marketplace.

**Device Information**

| PART NUMBER(1) | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| LM2904B-Q1 | SOIC (8) | 4.90 mm × 3.90 mm |
| | TSSOP (8) | 3.00 mm × 4.40 mm |
| | VSSOP (8) | 3.00 mm × 3.00 mm |
| LM2904BA-Q1 | SOIC (8) | 4.90 mm × 3.90 mm |
| | TSSOP (8) | 3.00 mm × 4.40 mm |
| | VSSOP (8) | 3.00 mm × 3.00 mm |
| LM2904-Q1 | SOIC (8) | 4.90 mm × 3.90 mm |
| | TSSOP (8) | 3.00 mm × 4.40 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.




$$\frac{V_{OUT}}{V_{IN}} = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + sR_1C_1}\right)$$

**Single-Pole, Low-Pass Filter**

## Table of Contents

**1 Features**....1
**2 Applications**....1
**3 Description**....1
**4 Revision History**....2
**5 Device Comparison Table**....4
**6 Pin Configuration and Functions**....5
**7 Specifications**....6
7.1 Absolute Maximum Ratings....6
7.2 ESD Ratings....6
7.3 Recommended Operating Conditions....7
7.4 Thermal Information....7
7.5 Electrical Characteristics: LM2904B-Q1 and LM2904BA-Q1....8
7.6 Electrical Characteristics: LM2904-Q1, LM2904AV-Q1, LM2904V-Q1....10
7.7 Typical Characteristics....11
**8 Parameter Measurement Information**....18
**9 Detailed Description**....19
9.1 Overview....19
9.2 Functional Block Diagram....19
9.3 Feature Description....20
9.4 Device Functional Modes....20
**10 Application and Implementation**....21
10.1 Application Information....21
10.2 Typical Application....21
**11 Power Supply Recommendations**....23
**12 Layout**....24
12.1 Layout Guidelines....24
12.2 Layout Examples....24
**13 Device and Documentation Support**....25
13.1 Documentation Support....25
13.2 Related Links....25
13.3 Receiving Notification of Documentation Updates....25
13.4 Support Resources....25
13.5 Trademarks....25
13.6 Electrostatic Discharge Caution....25
13.7 Glossary....25
**14 Mechanical, Packaging, and Orderable Information**....26

## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision J (February 2021) to Revision K (April 2022) | Page |
|---|---|
| • Added LM2904BA-Q1 to data sheet | 1 |
| • Increased ESD (CDM) rating for LM2904B-Q1 and LM2904BA-Q1 from ±750 V to ±1500 V | 6 |

| Changes from Revision I (June 2020) to Revision J (February 2021) | Page |
|---|---|
| • Updated the numbering format for tables, figures, and cross-references throughout the document | 1 |
| • Added Functional Safety-Capable feature and link to supporting document in *Features* section | 1 |
| • Deleted preview tag on VSSOP (8) package throughout the data sheet | 1 |
| • Deleted SOT-23 (8) package information throughout the data sheet | 1 |
| • Deleted preview tag from VSSOP package in *Pin Configuration and Functions* section | 5 |
| • Deleted DDF (SOT23-8) package in *Pin Configuration and Functions* section | 5 |
| • Updated VSSOP package thermal information in *Thermal Information* section | 7 |

| Changes from Revision H (December 2019) to Revision I (June 2020) | Page |
|---|---|
| • Added applications link in *Application* section | 1 |
| • Deleted preview tag on TSSOP (8) package in *Device Information* table | 1 |
| • Added information on VSSOP-8 package to *Device Information* table | 1 |
| • Added information on VSSOP-8 package to the *Device Comparison Table* section | 4 |
| • Deleted preview tag on TSSOP-8 package in the *Device Comparison Table* section | 4 |
| • Deleted preview tag from TSSOP package in *Pin Configuration and Functions* section | 5 |
| • Added VSSOP package information in *Pin Configuration and Functions* section | 5 |
| • Added VSSOP package to *Thermal Information* table | 7 |
| • Changed section title from *Community Resources* to *Support Resources* in the *Device and Documentation Support* section | 25 |

| Changes from Revision G (February 2019) to Revision H (December 2019) | Page |
|---|---|
| • Added information on SOT23-8 package to Device Information table | 1 |

- Added information on SOT23-8 package to the *Device Comparison Table* ..... 4
- Added the *Typical Characteristics* section for the LM2904B-Q1 device..... 11
- Added test circuit for THD+N and small-signal step response, G = –1 in the *Parameter Measurement Information* section..... 18
- Changed specific voltages to a *Recommended Operating Conditions* reference..... 19
- Changed the functional block diagram for LM2904B-Q1 in the *Detailed Description* section..... 19

**Changes from Revision F (April 2008) to Revision G (February 2019)** **Page**

- Added *Applications* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ..... 1
- Added new device to data sheet.....1
- Added AEC-Q100 qualification statement..... 1

## 5 Device Comparison Table

| PART NUMBER | SUPPLY VOLTAGE | AMBIENT TEMPERATURE RANGE | $V_{OS}$ (MAXIMUM AT 25°C) | $I_Q$ / CH (TYPICAL AT 25°C) | INTEGRATED EMI FILTER | PACKAGE |
|---|---|---|---|---|---|---|
| LM2904B-Q1 | 3 V to 36 V | –40°C to 125°C | 3 mV | 300 µA | Yes | D, DGK, PW |
| LM2904BA-Q1 | 3 V to 36 V | –40°C to 125°C | 2 mV | 300 µA | Yes | D, DGK, PW |
| LM2904-Q1 | 3 V to 26 V | –40°C to 125°C | 7 mV | 350 µA | No | D, PW |
| LM2904V-Q1 | 3 V to 32 V | –40°C to 125°C | 7 mV | 350 µA | No | D, PW |
| LM2904AV-Q1 | 3 V to 32 V | –40°C to 125°C | 2 mV | 350 µA | No | D, PW |

## 6 Pin Configuration and Functions

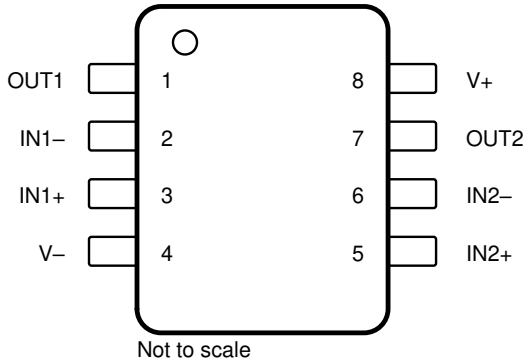



**Figure 6-1. D, DGK, and PW Package 8-Pin SOIC, VSSOP, and TSSOP Top View**

**Table 6-1. Pin Functions**

| PIN[(1)] | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| IN1– | 2 | I | Negative input |
| IN1+ | 3 | I | Positive input |
| IN2– | 6 | I | Negative input |
| IN2+ | 5 | I | Positive input |
| OUT1 | 1 | O | Output |
| OUT2 | 7 | O | Output |
| V– | 4 | — | Negative (lowest) supply or ground (for single-supply operation) |
| V+ | 8 | — | Positive (highest) supply |

(1) For a listing of which devices are available in what packages, see Section 5.

# 7 Specifications

## 7.1 Absolute Maximum Ratings

over operating ambient temperature range (unless otherwise noted)[1]

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| Supply voltage, $V_S$ = ([V+] – [V–]) | | LM2904B-Q1, LM2904BA-Q1 | | 40 | V |
| | | LM2904V-Q1, LM2904AV-Q1 | | 32 | |
| | | LM2904-Q1 | | 26 | |
| Differential input voltage, $V_{ID}$ [2] | | LM2904B-Q1, LM290BA-Q1, LM2904V-Q1, LM2904AV-Q1 | –32 | 32 | V |
| | | LM2904-Q1 | –26 | 26 | |
| Input voltage, $V_I$ | Either input | LM2904B-Q1, LM2904BA-Q1 | –0.3 | 40 | V |
| | | LM2904V-Q1, LM2904AV-Q1 | –0.3 | 32 | |
| | | LM2904-Q1 | –0.3 | 26 | |
| Duration of output short circuit (one amplifier) to V– at (or below) $T_A$ = 25°C, $V_S$ ≤ 15 V[3] | | | Unlimited | | s |
| Operating ambient temperature, $T_A$ | | | –40 | 125 | °C |
| Operating virtual-junction temperature, $T_J$ | | | | 150 | °C |
| Storage temperature, $T_{stg}$ | | | –65 | 150 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Differential voltages are at IN+, with respect to IN−.
(3) Short circuits from outputs to the supply pins can cause excessive heating and eventual destruction.

## 7.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| **LM2904B-Q1 and LM2904BA-Q1** | | | | |
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per AEC Q100-002[1] | ±2000 | V |
| | | Charged-device model (CDM), per AEC Q100-011 | ±1500 | |
| **LM2904-Q1, LM2904AV-Q1, AND LM2904V-Q1** | | | | |
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per AEC Q100-002[1] | ±1000 | V |
| | | Charged-device model (CDM), per AEC Q100-011 | ±500 | |

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

## 7.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_S$ | Supply voltage, $V_S$ = ([V+] – [V–]) | LM2904B-Q1, LM2904BA-Q1 | 3 | 36 | V |
| | | LM2904AV-Q1, LM2904V-Q1 | 3 | 30 | |
| | | LM2904-Q1 | 3 | 26 | |
| $V_{CM}$ | Common-mode voltage | | V– | (V+) – 2 | V |
| $T_A$ | Operating ambient temperature | | –40 | 125 | °C |

## 7.4 Thermal Information

| THERMAL METRIC[1] | | LM2904-Q1, LM2904AV-Q1, LM2904B-Q1, LM2904BA-Q1, LM2904V-Q1[2] | | | UNIT |
|---|---|---|---|---|---|
| | | D (SOIC) | DGK (VSSOP) | PW (TSSOP) | |
| | | 8 PINS | 8 PINS | 8 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 124.7 | 186.1 | 171.7 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 66.9 | 77.1 | 68.8 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 67.9 | 107.7 | 99.2 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 19.2 | 17.2 | 11.5 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 67.2 | 106.1 | 97.9 | °C/W |

(1) For more information about traditional and new thermal metrics, see *Semiconductor and IC Package Thermal Metrics*.
(2) For a listing of which devices are available in what packages, see Section 5.

## 7.5 Electrical Characteristics: LM2904B-Q1 and LM2904BA-Q1

$V_S$ = (V+) – (V–) = 5 V – 36 V (±2.5 V – ±18 V), $T_A$ = 25°C, $V_{CM}$ = $V_{OUT}$ = $V_S$ / 2, $R_L$ = 10k connected to $V_S$ / 2 (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| **OFFSET VOLTAGE** | | | | | | | | |
| $V_{OS}$ | Input offset voltage | LM2904B-Q1 | | | | ±0.3 | ±3.0 | mV |
| | | | | $T_A$ = –40°C to +125°C | | | ±4 | |
| | | LM2904BA-Q1 | | | | | ±2.0 | mV |
| | | | | $T_A$ = –40°C to +125°C | | | ±3.0 | mV |
| $dV_{OS}/d_T$ | Input offset voltage drift | | | $T_A$ = –40°C to +125°C(1) | | ±3.5 | 12 | µV/°C |
| PSRR | Power supply rejection ratio | | | | | ±2 | 15 | µV/V |
| | Channel separation, dc | f = 1 kHz to 20 kHz | | | | ±1 | | µV/V |
| **INPUT VOLTAGE RANGE** | | | | | | | | |
| $V_{CM}$ | Common-mode voltage range | $V_S$ = 3 V to 36 V | | | (V–) | | (V+) – 1.5 | V |
| | | $V_S$ = 5 V to 36 V | | $T_A$ = –40°C to +125°C | (V–) | | (V+) – 2 | |
| CMRR | Common-mode rejection ratio | (V–) ≤ $V_{CM}$ ≤ (V+) – 1.5 V | $V_S$ = 3 V to 36 V | | | 20 | 100 | µV/V |
| | | (V–) ≤ $V_{CM}$ ≤ (V+) – 2.0 V | $V_S$ = 5 V to 36 V | $T_A$ = –40°C to +125°C | | 25 | 316 | |
| **INPUT BIAS CURRENT** | | | | | | | | |
| $I_B$ | Input bias current | | | | | ±10 | ±35 | nA |
| | | | | $T_A$ = –40°C to +125°C(1) | | | ±50 | |
| $I_{OS}$ | Input offset current | | | | | 0.5 | 4 | nA |
| | | | | $T_A$ = –40°C to +125°C(1) | | | 5 | |
| $dI_{OS}/d_T$ | Input offset current drift | | | $T_A$ = –40°C to +125°C | | 10 | | pA/°C |
| **NOISE** | | | | | | | | |
| $E_n$ | Input voltage noise | f = 0.1 to 10 Hz | | | | 3 | | $µV_{PP}$ |
| $e_n$ | Input voltage noise density | f = 1 kHz | | | | 40 | | nV/√Hz |
| **INPUT IMPEDANCE** | | | | | | | | |
| $Z_{ID}$ | Differential | | | | | 10 \|\| 0.1 | | MΩ\|\| pF |
| $Z_{IC}$ | Common-mode | | | | | 4 \|\| 1.5 | | GΩ\|\| pF |
| **OPEN-LOOP GAIN** | | | | | | | | |
| $A_{OL}$ | Open-loop voltage gain | $V_S$ = 15 V; $V_O$ = 1 V to 11 V; $R_L$ ≥ 10 kΩ, connected to (V-) | | | 70 | 140 | | V/mV |
| | | | | $T_A$ = –40°C to +125°C | 35 | | | |
| **FREQUENCY RESPONSE** | | | | | | | | |
| GBW | Gain bandwidth product | | | | | 1.2 | | MHz |
| SR | Slew rate | G = + 1 | | | | 0.5 | | V/µs |
| $Θ_m$ | Phase margin | G = + 1, $R_L$ = 10 kΩ, $C_L$ = 20 pF | | | | 56 | | ° |
| $t_{OR}$ | Overload recovery time | $V_{IN}$ × gain > $V_S$ | | | | 10 | | µs |
| $t_s$ | Settling time | To 0.1%, $V_S$ = 5 V, 2-V Step , G = +1, $C_L$ = 100 pF | | | | 4 | | µs |
| THD+N | Total harmonic distortion + noise | G = + 1, f = 1 kHz, $V_O$ = 3.53 $V_{RMS}$, $V_S$ = 36 V, $R_L$ = 100k, $I_{OUT}$ ≤ ±50 µA, BW = 80 kHz | | | | 0.001% | | |
| **OUTPUT** | | | | | | | | |
| $V_O$ | Voltage output swing from rail | Positive rail (V+) | | $I_{OUT}$ = 50 µA | | 1.35 | 1.42 | V |
| | | | | $I_{OUT}$ = 1 mA | | 1.4 | 1.48 | |
| | | | | $I_{OUT}$ = 5 mA(1) | | 1.5 | 1.61 | |
| | | Negative rail (V-) | | $I_{OUT}$ = 50 µA | | 100 | 150 | mV |
| | | | | $I_{OUT}$ = 1 mA | | 0.75 | 1 | V |
| | | | $V_S$ = 5 V, RL ≤ 10 kΩ connected to (V–) | $T_A$ = –40°C to +125°C | | 5 | 20 | mV |
| $I_O$ | Output current | $V_S$ = 15 V; $V_O$ = V-; $V_{ID}$ = 1 V | Source(1) | | -20 | -30 | | mA |
| | | | | $T_A$ = –40°C to +125°C | -10 | | | |
| | | $V_S$ = 15 V; $V_O$ = V+; $V_{ID}$ = -1 V | Sink(1) | | 10 | 20 | | |
| | | | | $T_A$ = –40°C to +125°C | 5 | | | |
| | | $V_{ID}$ = -1 V; $V_O$ = (V-) + 200 mV | | | 60 | 100 | | µA |
| $I_{SC}$ | Short-circuit current | $V_S$ = 20 V, (V+) = 10 V, (V-) = -10 V, $V_O$ = 0 V | | | | ±40 | ±60 | mA |
| $C_{LOAD}$ | Capacitive load drive | | | | | 100 | | pF |
| $R_O$ | Open-loop output resistance | f = 1 MHz, $I_O$ = 0 A | | | | 300 | | Ω |
| **POWER SUPPLY** | | | | | | | | |

## 7.5 Electrical Characteristics: LM2904B-Q1 and LM2904BA-Q1 (continued)

$V_S$ = (V+) – (V–) = 5 V – 36 V (±2.5 V – ±18 V), $T_A$ = 25°C, $V_{CM}$ = $V_{OUT}$ = $V_S$ / 2, $R_L$ = 10k connected to $V_S$ / 2 (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_Q$ | Quiescent current per amplifier | $V_S$ = 5 V; $I_O$ = 0 A | $T_A$ = –40°C to +125°C | | 300 | 460 | µA |
| | | $V_S$ = 36 V; $I_O$ = 0 A | | | | 800 | |

(1) Specified by characterization only.

## 7.6 Electrical Characteristics: LM2904-Q1, LM2904AV-Q1, LM2904V-Q1

For $V_S$ = (V+) – (V–) = 5 V, $T_A$ = 25°C, $R_L$ = 10 kΩ connected to V– (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS[1] | | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| **OFFSET VOLTAGE** | | | | | | | | |
| $V_{OS}$ | Input offset voltage | $V_S$ = 5 V to maximum; $V_{CM}$ = 0 V; $V_O$ = 1.4 V | LM2904-Q1, LM2904V-A1 | | | ±3 | ±7 | mV |
| | | | | $T_A$ = –40°C to 125°C | | | ±10 | |
| | | | LM2904AV-Q1 | | | ±1 | ±2 | |
| | | | | $T_A$ = –40°C to 125°C | | | ±4 | |
| $dV_{OS}/d_T$ | Input offset voltage drift | | | $T_A$ = –40°C to 125°C | | ±7 | | μV/°C |
| PSRR | Input offset voltage vs power supply ($\Delta V_{IO}/\Delta V_S$) | $V_S$ = 5 V to 30 V | | | 65 | 100 | | dB |
| $V_{O1}$/ $V_{O2}$ | Channel separation | f = 1 kHz to 20 kHz | | | | 120 | | dB |
| **INPUT VOLTAGE RANGE** | | | | | | | | |
| $V_{CM}$ | Common-mode voltage range | $V_S$ = 5 V to maximum | | | (V–) | | (V+) – 1.5 | V |
| | | | | $T_A$ = –40°C to 125°C | (V–) | | (V+) – 2 | |
| CMRR | Common-mode rejection ratio | $V_S$ = 5 V to maximum; $V_{CM}$ = 0 V | | | 65 | 80 | | dB |
| **INPUT BIAS CURRENT** | | | | | | | | |
| $I_B$ | Input bias current | $V_O$ = (V–) + 1.4 V | | | | –20 | –250 | nA |
| | | | | $T_A$ = –40°C to 125°C | | | –500 | |
| $I_{OS}$ | Input offset current | $V_O$ = (V–) + 1.4 V | LM2904-Q1 | | | 2 | 50 | nA |
| | | | | $T_A$ = –40°C to 125°C | | | 300 | |
| | | | LM2904AV-Q1, LM2904V-Q1 | | | 2 | 50 | |
| | | | | $T_A$ = –40°C to 125°C | | | 150 | |
| $dI_{OS}/d_T$ | Input offset current drift | | | $T_A$ = –40°C to 125°C | | 10 | | pA/°C |
| **NOISE** | | | | | | | | |
| $e_n$ | Input voltage noise density | f = 1 kHz | | | | 40 | | nV/√Hz |
| **OPEN-LOOP GAIN** | | | | | | | | |
| $A_{OL}$ | Open-loop voltage gain | $V_S$ = 15 V; $V_O$ = (V–) + 1 V to (V–) + 11 V; $R_L$ ≥ 2 kΩ, connected to (V–) | | | 25 | 100 | | V/mV |
| | | | | $T_A$ = –40°C to 125°C | 15 | | | |
| **FREQUENCY RESPONSE** | | | | | | | | |
| GBW | Gain bandwidth product | | | | | 0.7 | | MHz |
| SR | Slew rate | G = +1 | | | | 0.3 | | V/μs |
| **OUTPUT** | | | | | | | | |
| $V_O$ | Voltage output swing from rail | Positive rail | $R_L$ ≥ 10 kΩ | | $V_S$ – 1.5 | | | V |
| | | | LM2904-Q1 | $V_S$ = maximum; $R_L$ = 2 kΩ; $T_A$ = –40°C to 125°C | 4 | | | |
| | | | | $V_S$ = maximum; $R_L$ ≥ 10 kΩ; $T_A$ = –40°C to 125°C | 3 | 2 | | |
| | | | LM2904AV-Q1, LM2904V-Q1 | $V_S$ = maximum; $R_L$ = 2 kΩ; $T_A$ = –40°C to 125°C | 6 | | | |
| | | | | $V_S$ = maximum; $R_L$ ≥ 10 kΩ; $T_A$ = –40°C to 125°C | 5 | 4 | | |
| | | Negative rail | $V_S$ = 5 V; $R_L$ ≤ 10 kΩ | $T_A$ = –40°C to 125°C | | 5 | 20 | mV |
| $I_O$ | Output current | $V_S$ = 15 V; $V_O$ = V–; $V_{ID}$ = 1 V | Source | | –20 | –30 | | mA |
| | | | | $T_A$ = –40°C to 125°C | –10 | | | |
| | | $V_S$ = 15 V; $V_O$ = V+; $V_{ID}$ = –1 V | Sink | | 10 | 20 | | |
| | | | | $T_A$ = –40°C to 125°C | 5 | | | |
| | | $V_{ID}$ = –1 V; $V_O$ = (V–) + 200 mV | LM2904-Q1 | | | 30 | | μA |
| | | | LM2904AV-Q1, LM2904V-Q1 | | 12 | 40 | | |
| $I_{SC}$ | Short-circuit current | $V_S$ = 10 V; $V_O$ = $V_S$ / 2 | | | | ±40 | ±60 | mA |
| **POWER SUPPLY** | | | | | | | | |
| $I_Q$ | Quiescent current per amplifier | $V_O$ = $V_S$ / 2; $I_O$ = 0 A | | $T_A$ = –40°C to 125°C | | 350 | 600 | μA |
| | | $V_S$ = maximum; $V_O$ = maximum / 2; $I_O$ = 0 A | | | | 500 | 1000 | |

(1) All characteristics are measured with zero common-mode input voltage, unless otherwise specified. Maximum $V_S$ for testing purposes is 26 V for LM2904-Q1 and 32 V for LM2904AV-Q1/LM2904V-Q1.

## 7.7 Typical Characteristics

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).

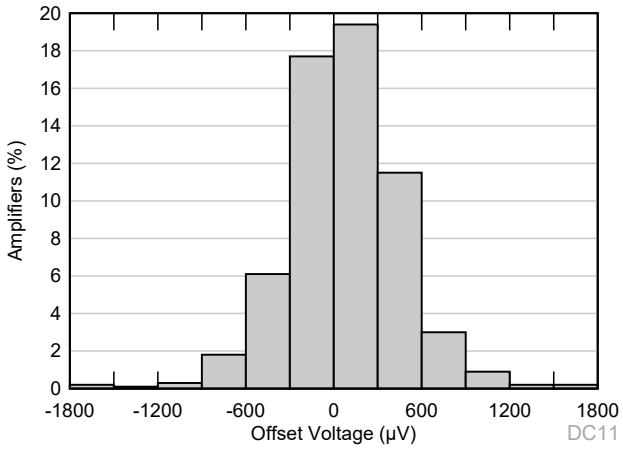



**Figure 7-1. Offset Voltage Production Distribution**

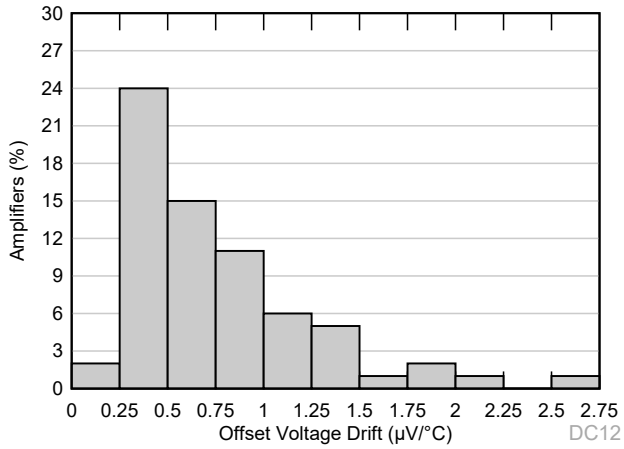



**Figure 7-2. Offset Voltage Drift Distribution**

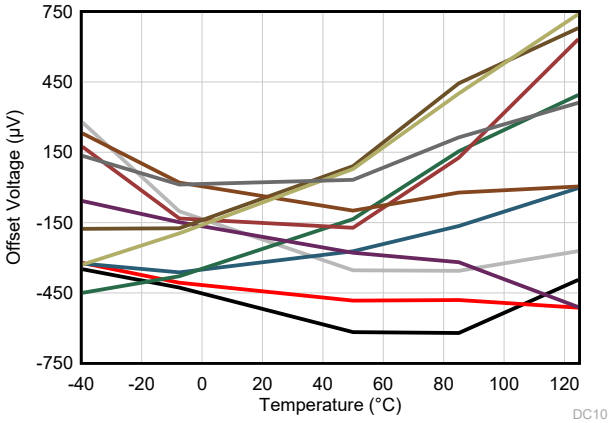



**Figure 7-3. Offset Voltage vs Temperature**

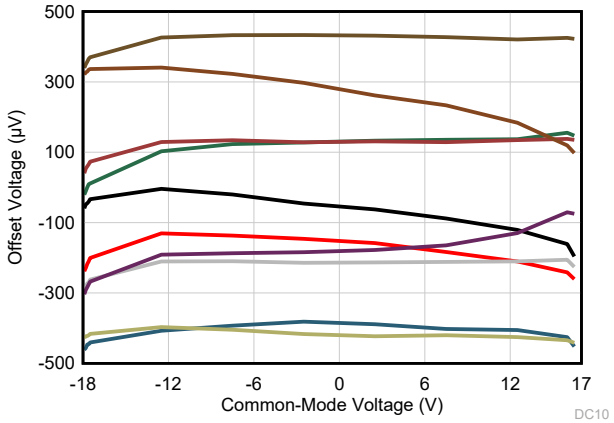



**Figure 7-4. Offset Voltage vs Common-Mode Voltage**

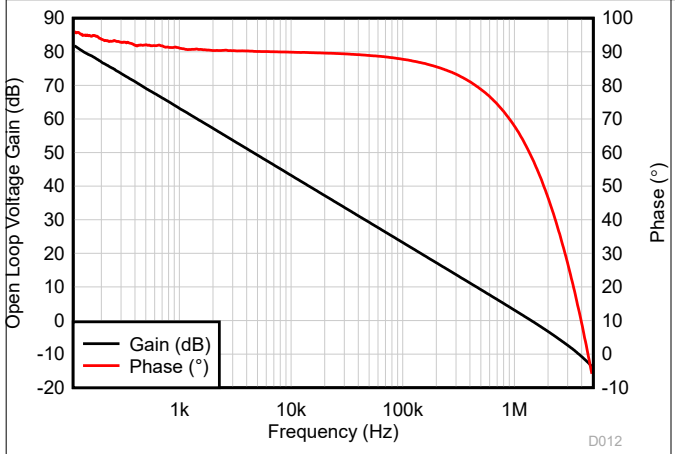



**Figure 7-5. Open-Loop Gain and Phase vs Frequency**

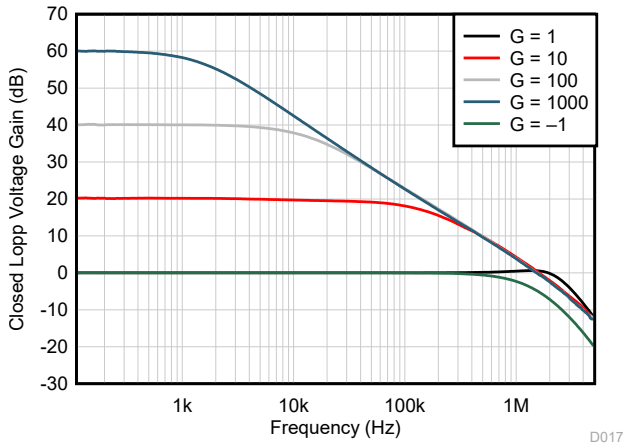



**Figure 7-6. Closed-Loop Gain vs Frequency**

## 7.7 Typical Characteristics (continued)

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).

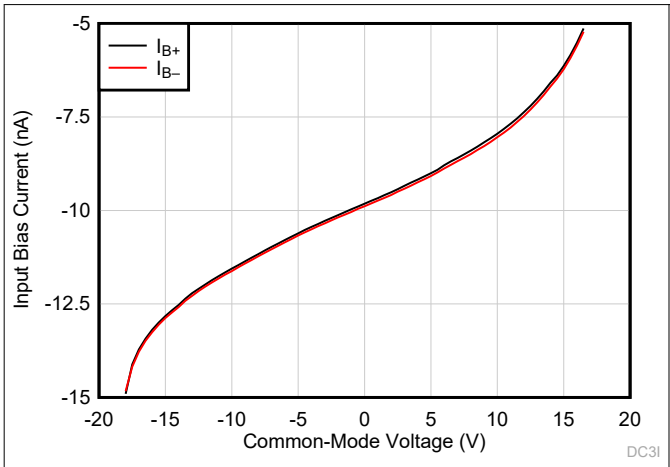



**Figure 7-7. Input Bias Current vs Common-Mode Voltage**

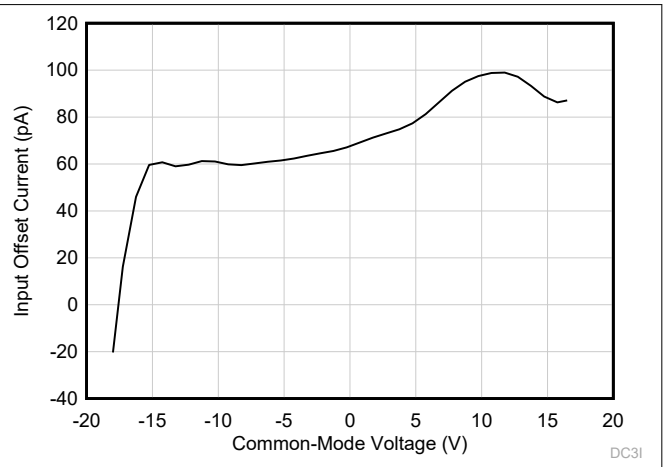



**Figure 7-8. Input Offset Current vs Common-Mode Voltage**

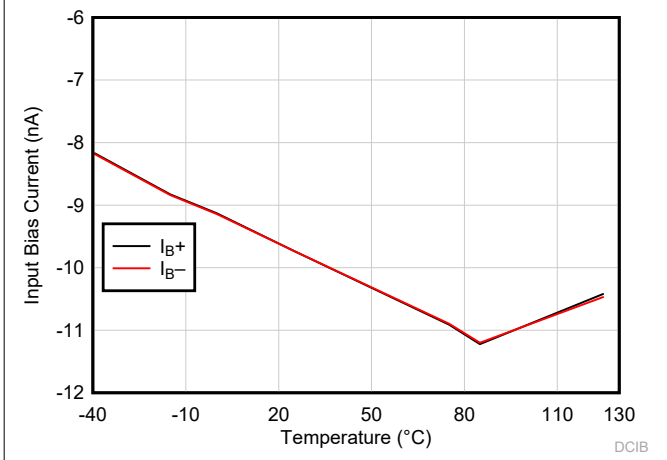



**Figure 7-9. Input Bias Current vs Temperature**

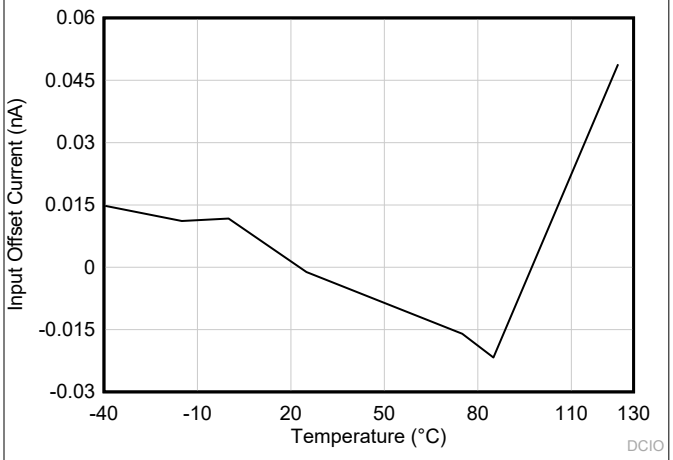



**Figure 7-10. Input Offset Current vs Temperature**

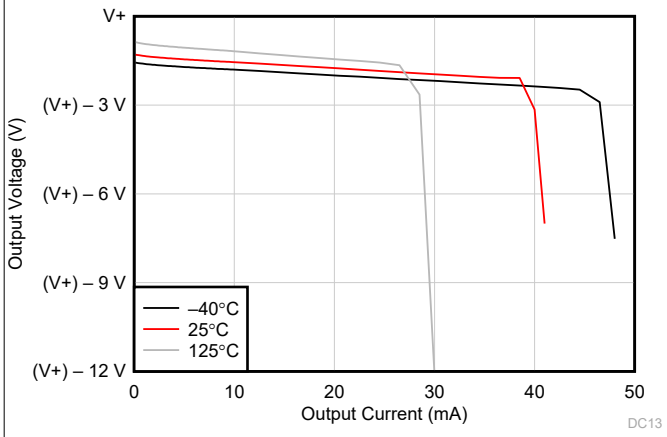



**Figure 7-11. Output Voltage Swing vs Output Current (Sourcing)**

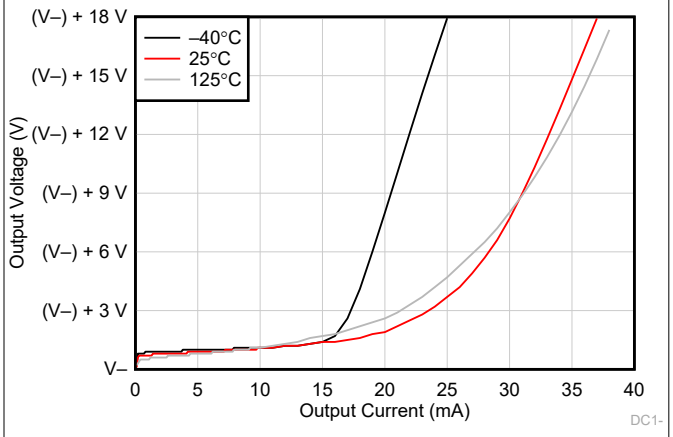



**Figure 7-12. Output Voltage Swing vs Output Current (Sinking)**

## 7.7 Typical Characteristics (continued)

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).

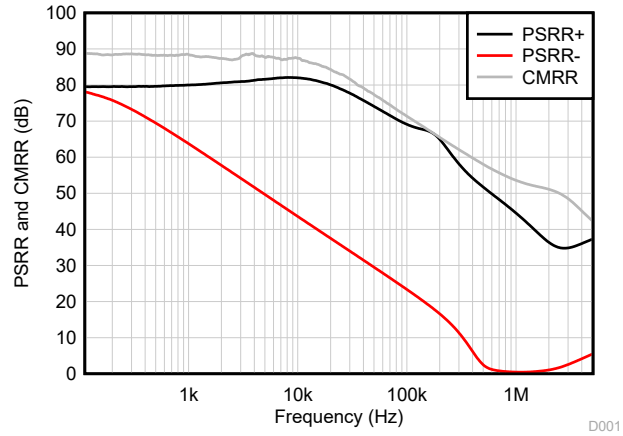



**Figure 7-13. CMRR and PSRR vs Frequency**

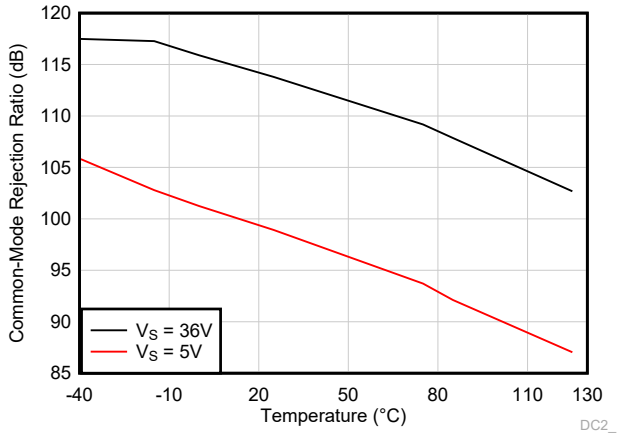
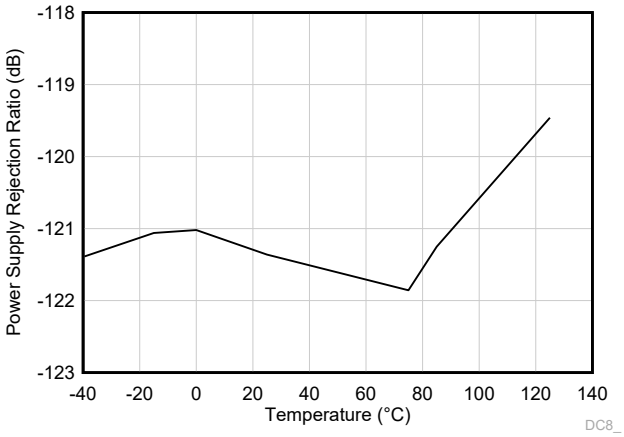



**Figure 7-14. Common-Mode Rejection Ratio vs Temperature (dB)**




$V_S$ = 5 V to 36 V

**Figure 7-15. Power Supply Rejection Ratio vs Temperature (dB)**

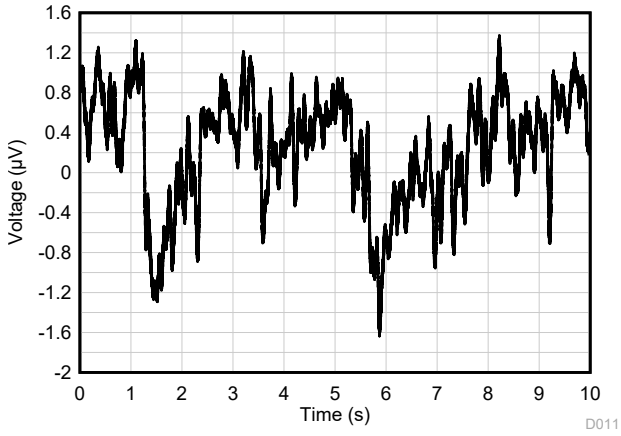



**Figure 7-16. 0.1-Hz to 10-Hz Noise**

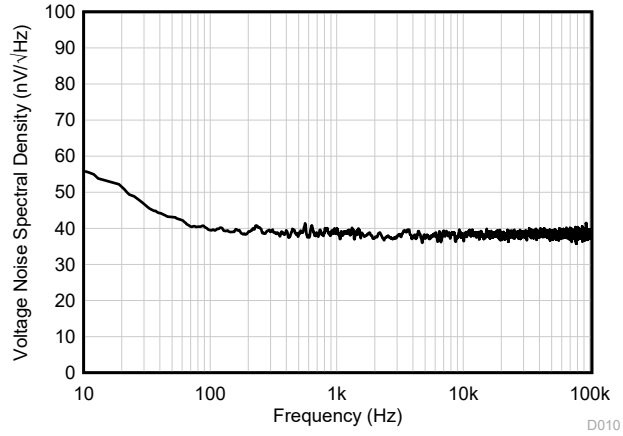
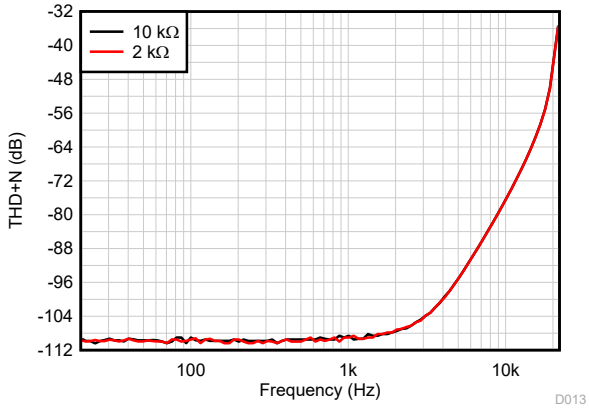



**Figure 7-17. Input Voltage Noise Spectral Density vs Frequency**

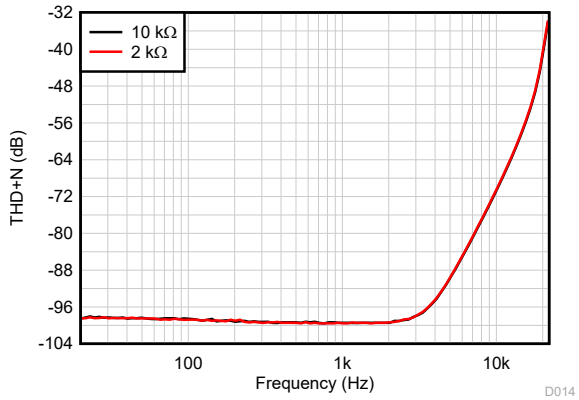



G = 1, f = 1 kHz, BW = 80 kHz,
$V_{OUT}$ = 10 $V_{PP}$, $R_L$ connected to V–

**Figure 7-18. THD+N Ratio vs Frequency, G = 1**

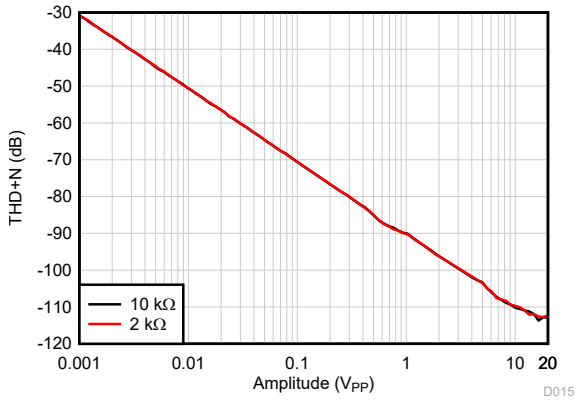
## 7.7 Typical Characteristics (continued)

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).



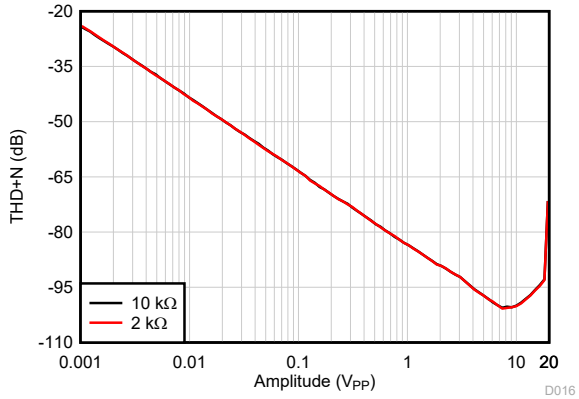

G = –1, f = 1 kHz, BW = 80 kHz,
$V_{OUT}$ = 10 $V_{PP}$, $R_L$ connected to V–
See Figure 8-3

**Figure 7-19. THD+N Ratio vs Frequency, G = –1**




G = 1, f = 1 kHz, BW = 80 kHz,
$R_L$ connected to V–

**Figure 7-20. THD+N vs Output Amplitude, G = 1**




G = –1, f = 1 kHz, BW = 80 kHz,
$R_L$ connected to V–
See Figure 8-3

**Figure 7-21. THD+N vs Output Amplitude, G = –1**

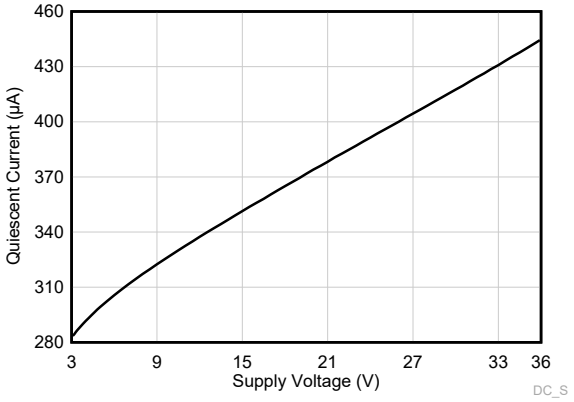



**Figure 7-22. Quiescent Current vs Supply Voltage**

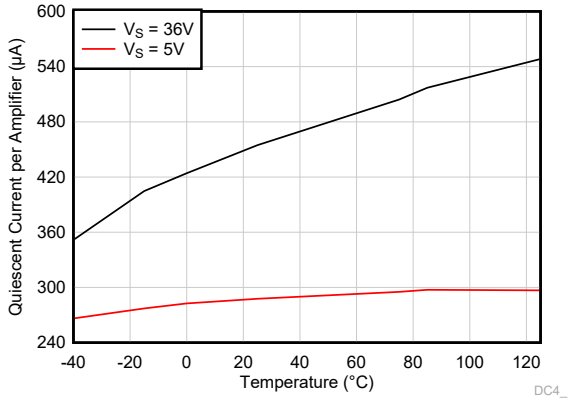



**Figure 7-23. Quiescent Current vs Temperature**

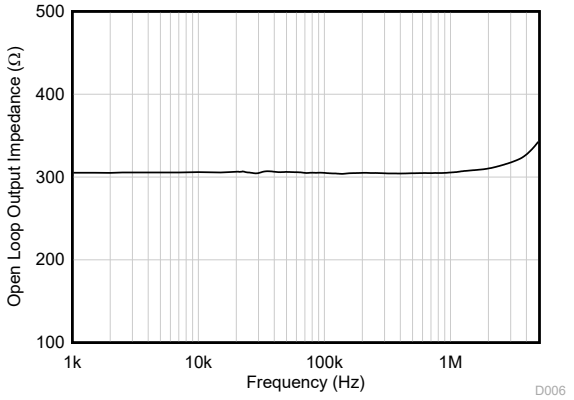
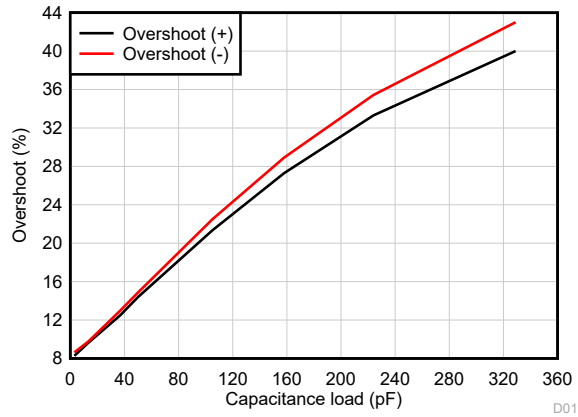



**Figure 7-24. Open-Loop Output Impedance vs Frequency**

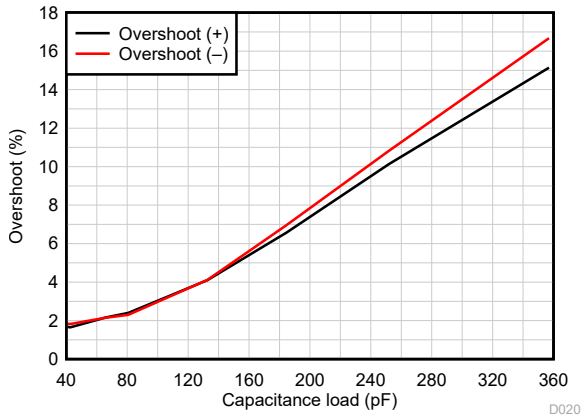
## 7.7 Typical Characteristics (continued)

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).




G = 1, 100-mV output step, $R_L$ = open

**Figure 7-25. Small-Signal Overshoot vs Capacitive Load**




G = –1, 100-mV output step, $R_L$ = open

**Figure 7-26. Small-Signal Overshoot vs Capacitive Load**

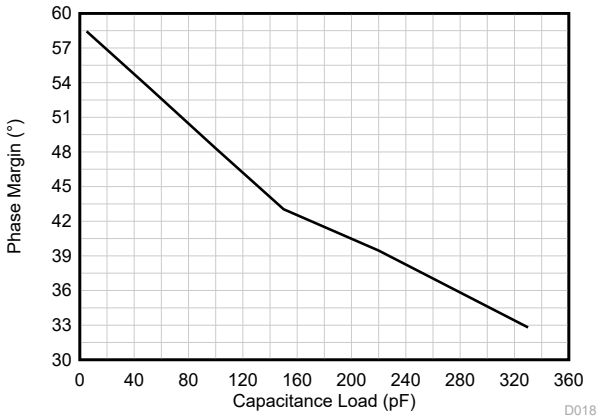
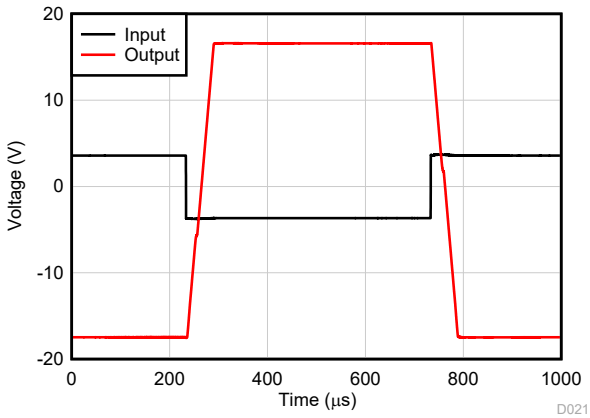
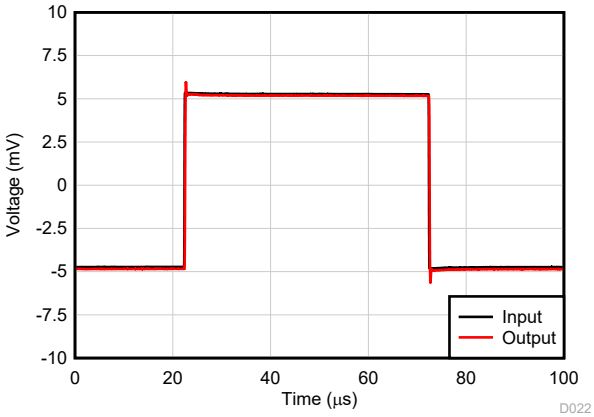



**Figure 7-27. Phase Margin vs Capacitive Load**



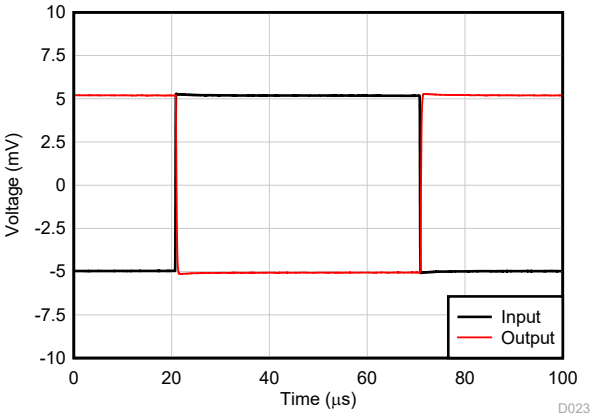

G = –10

**Figure 7-28. Overload Recovery**




G = 1, $R_L$ = open

**Figure 7-29. Small-Signal Step Response, G = 1**



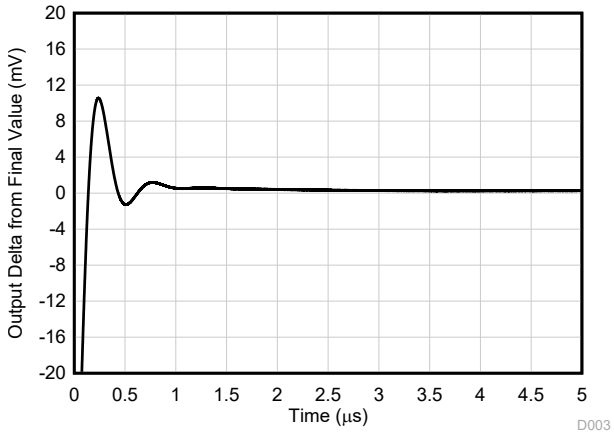

G = –1, $R_L$ = open, $R_{FB}$ = 10K

See Figure 8-3

**Figure 7-30. Small-Signal Step Response, G = –1**

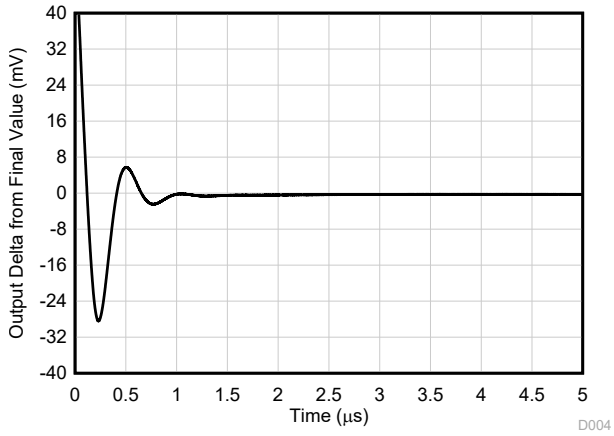
## 7.7 Typical Characteristics (continued)

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).



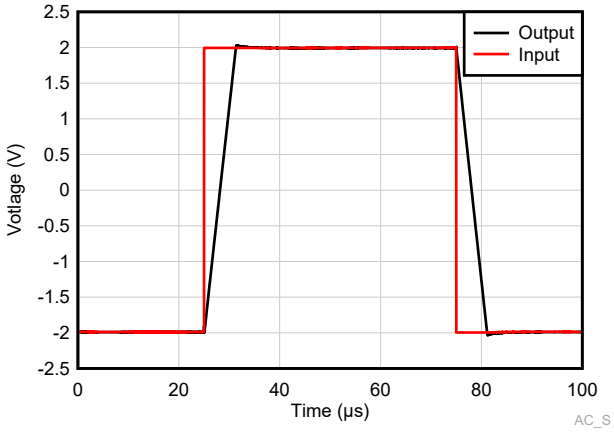

G = 1, $R_L$ = open

**Figure 7-31. Large-Signal Step Response (Rising)**




G = 1, $R_L$ = open

**Figure 7-32. Large-Signal Step Response (Falling)**




G = 1, $R_L$ = open

**Figure 7-33. Large-Signal Step Response**

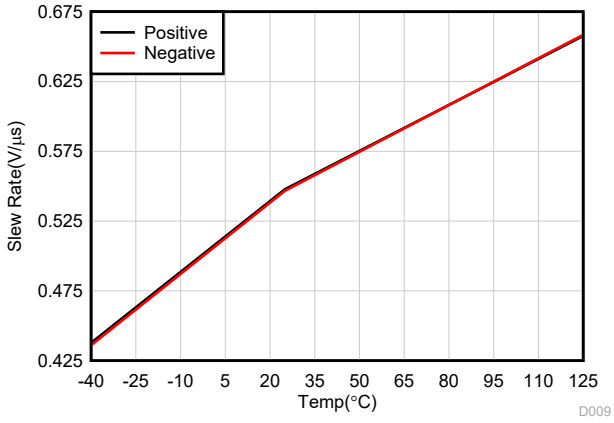



**Figure 7-34. Slew Rate vs Temperature**

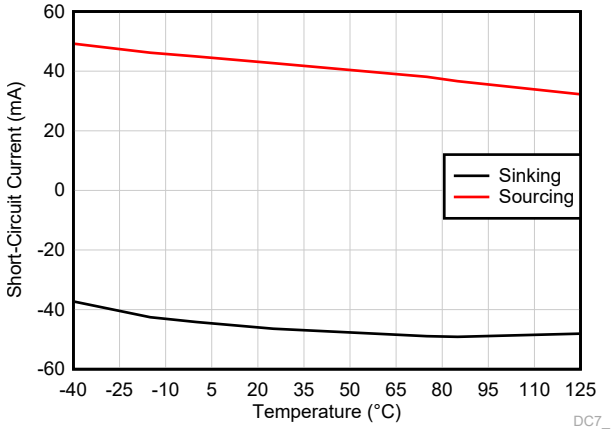
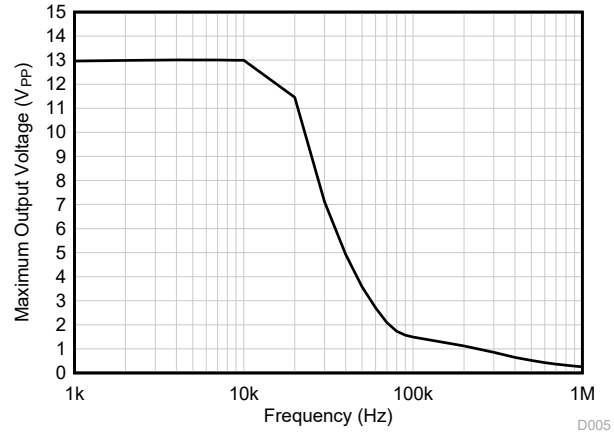



**Figure 7-35. Short-Circuit Current vs Temperature**




$V_S$ = 15 V

**Figure 7-36. Maximum Output Voltage vs Frequency**

## 7.7 Typical Characteristics (continued)

Typical characteristics section is applicable for LM2904B-Q1 and LM2904BA-Q1. The typical characteristics data section was taken with $T_A$ = 25°C, $V_S$ = 36 V (±18 V), $V_{CM}$ = $V_S$ / 2, $R_{LOAD}$ = 10 kΩ connected to $V_S$ / 2 (unless otherwise noted).

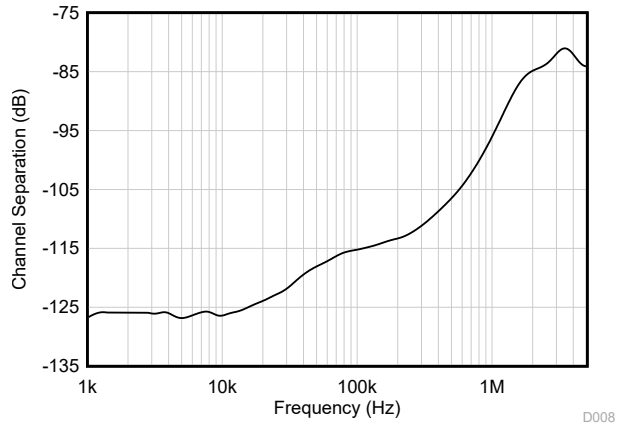



**Figure 7-37. Channel Separation vs Frequency**

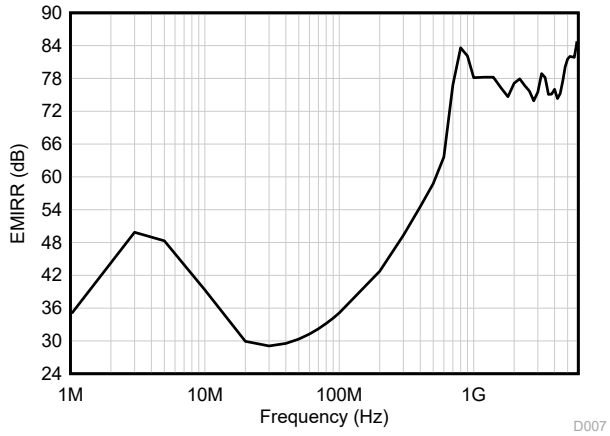



**Figure 7-38. EMIRR (Electromagnetic Interference Rejection Ratio) vs Frequency**

# 8 Parameter Measurement Information

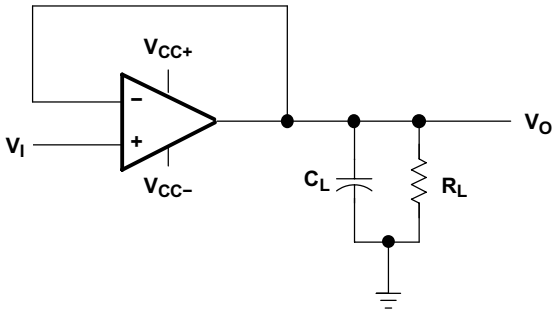



Figure 8-1. Unity-Gain Amplifier

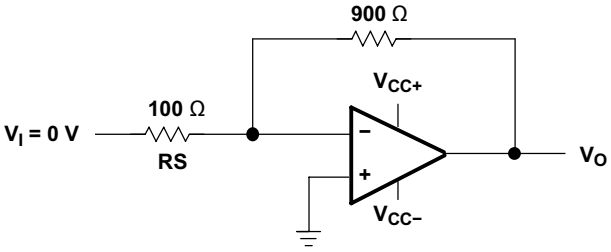



Figure 8-2. Noise-Test Circuit

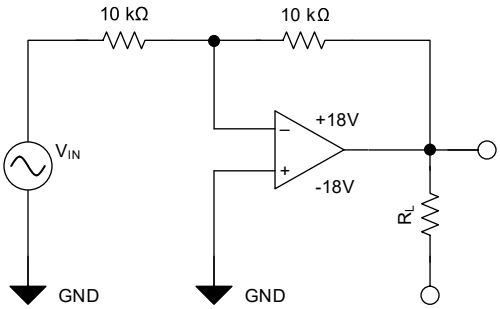



Figure 8-3. Test Circuit, G = –1, for THD+N and Small-Signal Step Response

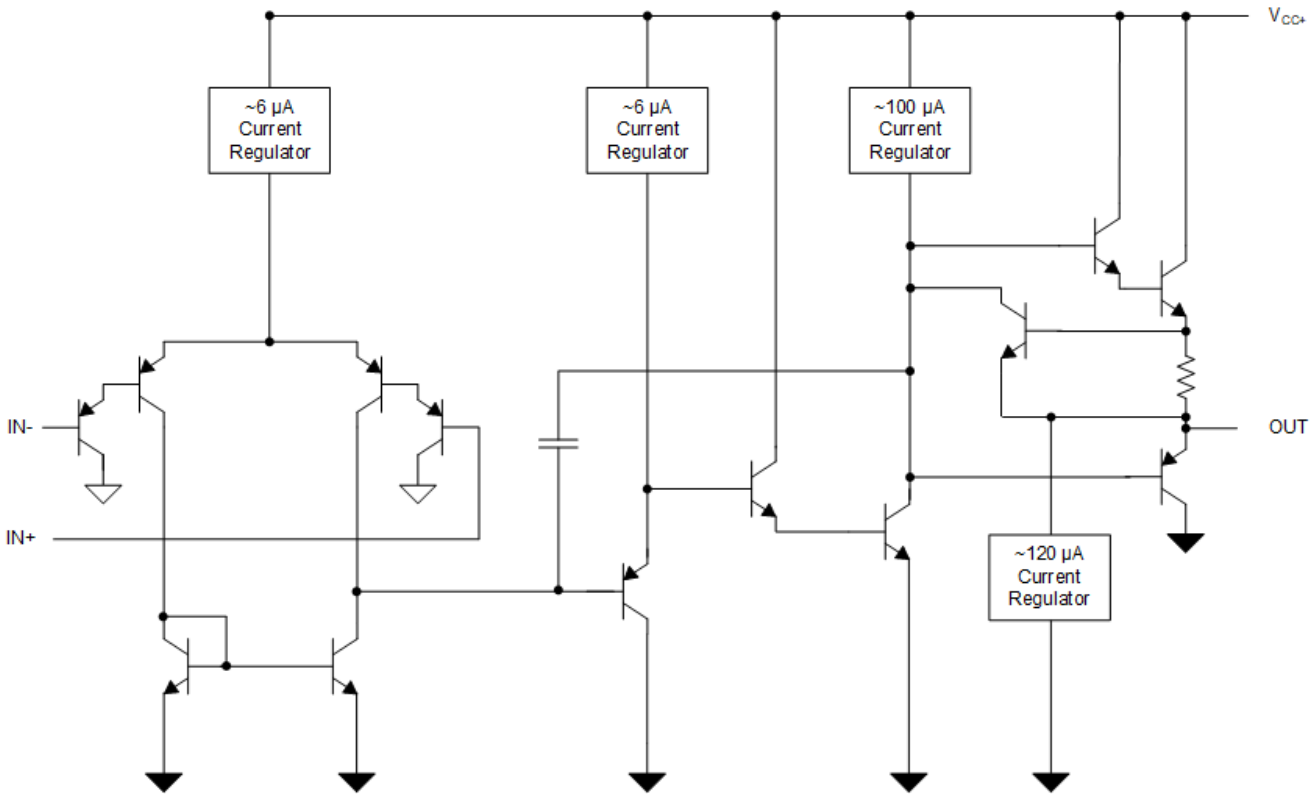
# 9 Detailed Description

## 9.1 Overview

The LM2904-Q1, LM2904B-Q1, and LM2904BA-Q1 devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is within the supply voltage range specified in Section 7.3, and $V_S$ is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, DC amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5-V supply used in digital systems and easily can provide the required interface electronics without additional ±5-V supplies.

## 9.2 Functional Block Diagram



## 9.3 Feature Description

### 9.3.1 Unity-Gain Bandwidth

The unity-gain bandwidth is the frequency up to which an amplifier with a unity gain may be operated without greatly distorting the signal. These devices have a 1.2-MHz unity-gain bandwidth (LM2904B-Q1 and LM2904BA-Q1).

### 9.3.2 Slew Rate

The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. These devices have a 0.5-V/µs slew rate (LM2904B-Q1 and LM2904BA-Q1).

### 9.3.3 Input Common Mode Range

The valid common mode range is from device ground to $V_S$ – 1.5 V ($V_S$ – 2 V across temperature). Inputs may exceed $V_S$ up to the maximum $V_S$ without device damage. At least one input must be in the valid input common-mode range for the output to be the correct phase. If both inputs exceed the valid range, then the output phase is undefined. If either input more than 0.3 V below V– then input current should be limited to 1 mA and the output phase is undefined.

## 9.4 Device Functional Modes

The LM2904-Q1, LM2904B-Q1, and LM2904BA-Q1 devices are powered on when the supply is connected. This device can be operated as a single-supply operational amplifier or dual-supply amplifier, depending on the application.

# 10 Application and Implementation

**Note**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

## 10.1 Application Information

The LM2904-Q1, LM2904B-Q1, LM2904BA-Q1 operational amplifiers are useful in a wide range of signal conditioning applications. Inputs can be powered before $V_S$ for flexibility in multiple supply circuits. For full application design guidelines related to this family of devices, please refer to the application report *Application design guidelines for LM324/LM358 devices*.

## 10.2 Typical Application

A typical application for an operational amplifier is an inverting amplifier. This amplifier takes a positive voltage on the input, and makes it a negative voltage of the same magnitude. In the same manner, it also makes negative voltages positive.

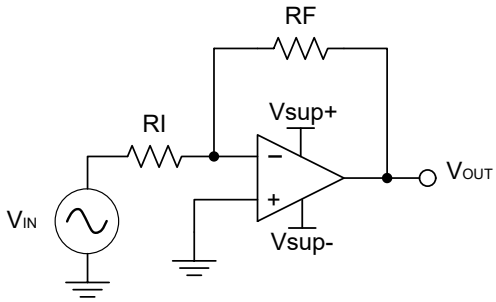



**Figure 10-1. Application Schematic**

### 10.2.1 Design Requirements

The supply voltage must be chosen such that it is larger than the input voltage range and output range. For instance, this application scales a signal of ±0.5 V to ±1.8 V. Setting the supply at ±12 V is sufficient to accommodate this application.

### 10.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using Equation 1 and Equation 2:

$$A_V = \frac{VOUT}{VIN} \tag{1}$$

$$A_V = \frac{1.8}{-0.5} = -3.6 \tag{2}$$

Once the desired gain is determined, choose a value for $R_I$ or $R_F$. Choosing a value in the kilohm range is desirable because the amplifier circuit uses currents in the milliampere range. This ensures the part does not draw too much current. This example uses 10 kΩ for $R_I$ which means 36 kΩ is used for $R_F$. This was determined by Equation 3.

$$A_V = -\frac{RF}{RI} \tag{3}$$

### 10.2.3 Application Curve

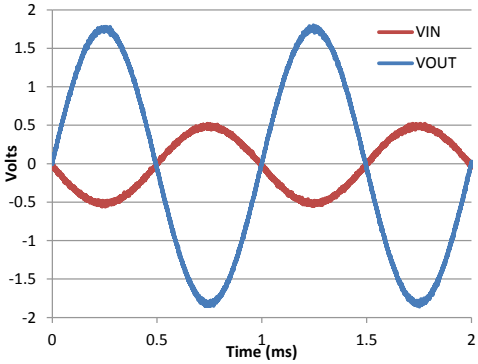



**Figure 10-2. Input and Output Voltages of the Inverting Amplifier**

## 11 Power Supply Recommendations

**CAUTION**

Supply voltages larger than specified in the recommended operating region can permanently damage the device (see Section 7.1).

Place 0.1-µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see Section 12.

# 12 Layout

## 12.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole, as well as the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-µF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds, paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping $R_F$ and $R_G$ close to the inverting input minimizes parasitic capacitance, as shown in Section 12.2.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

## 12.2 Layout Examples

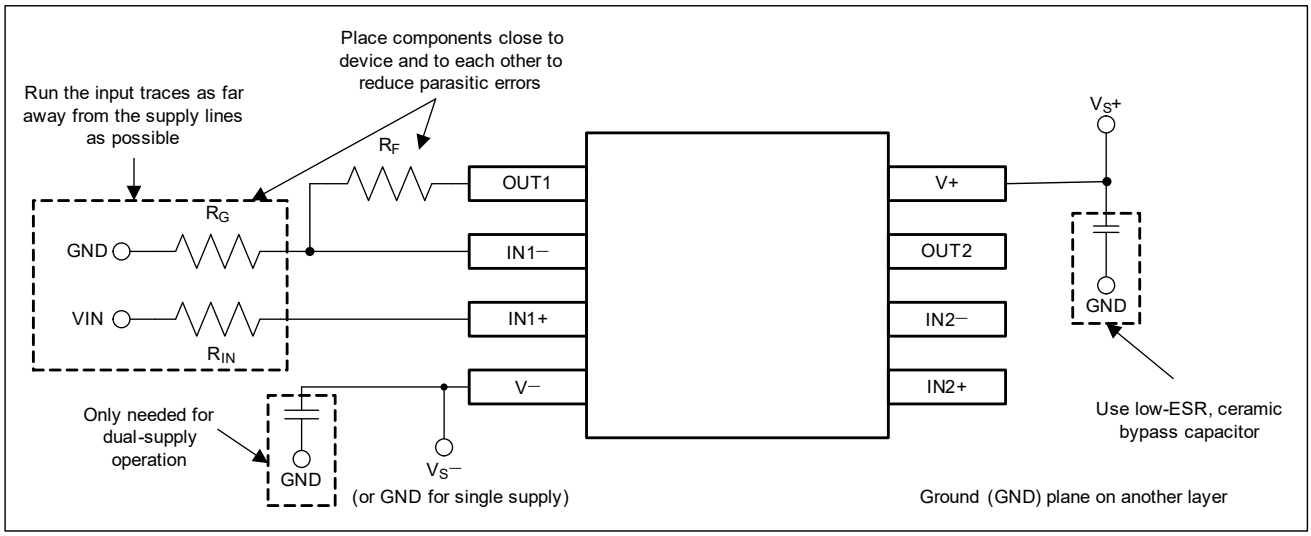



**Figure 12-1. Operational Amplifier Board Layout for Noninverting Configuration**

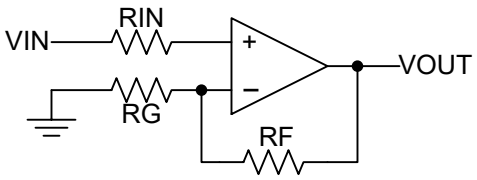



**Figure 12-2. Operational Amplifier Schematic for Noninverting Configuration**

# 13 Device and Documentation Support

## 13.1 Documentation Support

### 13.1.1 Related Documentation

For related documentation see the following:

Texas Instruments, *Application Design Guidelines for LM324/LM358 Devices* application report

## 13.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

**Table 13-1. Related Links**

| PARTS | PRODUCT FOLDER | ORDER NOW | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| LM2904-Q1 | Click here | Click here | Click here | Click here | Click here |
| LM2904B-Q1 | Click here | Click here | Click here | Click here | Click here |
| LM2904BA-Q1 | Click here | Click here | Click here | Click here | Click here |

## 13.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

## 13.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

## 13.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

## 13.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## 13.7 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

## 14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most-current data available for the designated devices. This data is subject to change without notice and without revision of this document. For browser based versions of this data sheet, see the left-hand navigation pane.

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LM2904AVQDRG4Q1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904AVQ | Samples |
| LM2904AVQDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904AVQ | Samples |
| LM2904AVQPWRG4Q1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904AVQ | Samples |
| LM2904AVQPWRQ1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904AVQ | Samples |
| LM2904BAQDGKRQ1 | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2EMB | Samples |
| LM2904BAQDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904BA | Samples |
| LM2904BAQPWRQ1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 294BAQ | Samples |
| LM2904BQDGKRQ1 | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 27ZB | Samples |
| LM2904BQDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904BQ | Samples |
| LM2904BQPWRQ1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904BQ | Samples |
| LM2904BTQDGKRQ1 | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 4BTQ | Samples |
| LM2904BTQDRQ1 | ACTIVE | SOIC | D | 8 | 3000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904TQ | Samples |
| LM2904BTQPWRQ1 | ACTIVE | TSSOP | PW | 8 | 3000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904BT | Samples |
| LM2904QDRG4Q1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904Q1 | Samples |
| LM2904QDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904Q1 | Samples |
| LM2904QPWRG4Q1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904Q1 | Samples |
| LM2904QPWRQ1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904Q1 | Samples |
| LM2904VQDRG4Q1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904VQ | Samples |
| LM2904VQDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904VQ1 | Samples |
| LM2904VQPWRG4Q1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904VQ | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LM2904VQPWRQ1 | ACTIVE | TSSOP | PW | 8 | 2000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2904VQ | Samples |

(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 finish/Ball material - Orderable Devices 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.

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF LM2904-Q1, LM2904B-Q1, LM2904BA-Q1 :**

- Catalog : LM2904, LM2904B, LM2904BA

- Enhanced Product : LM2904-EP

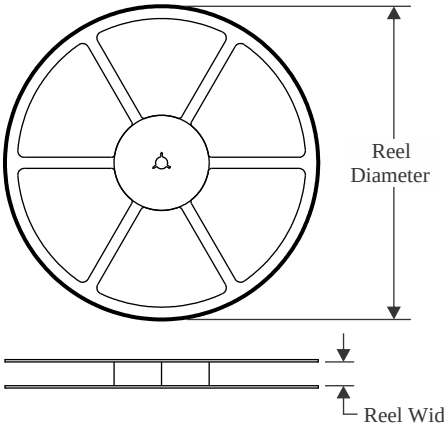
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

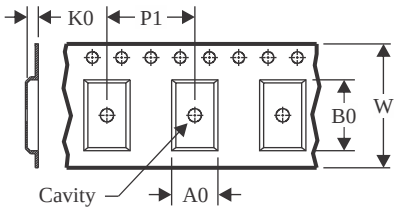
5-Nov-2024

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

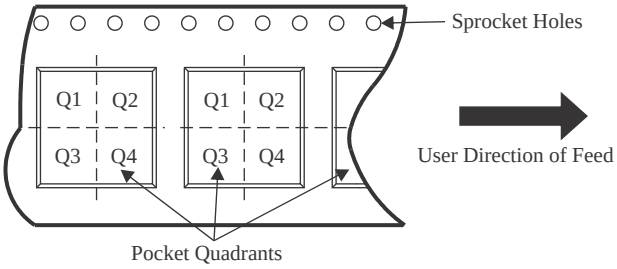



**TAPE DIMENSIONS**




| | |
|---|---|
| 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**



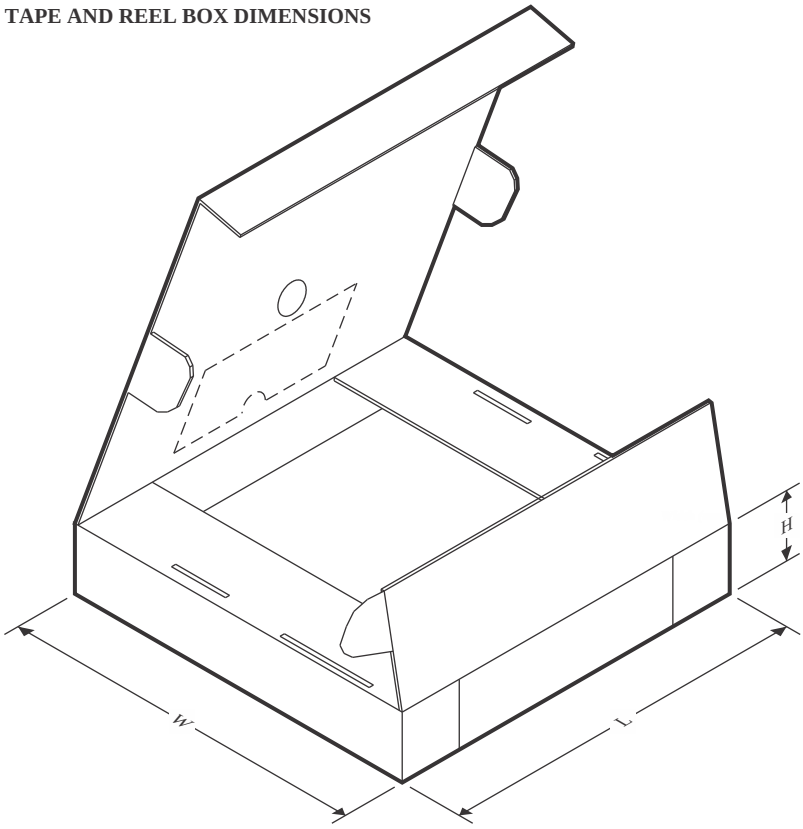

*All dimensions are nominal

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM2904AVQDRG4Q1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904AVQDRG4Q1 | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904AVQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904AVQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904AVQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904AVQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904AVQPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904BAQDGKRQ1 | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.25 | 3.35 | 1.25 | 8.0 | 12.0 | Q1 |
| LM2904BAQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904BAQPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904BQDGKRQ1 | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.25 | 3.35 | 1.25 | 8.0 | 12.0 | Q1 |
| LM2904BQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904BQPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904BTQDGKRQ1 | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.25 | 3.35 | 1.25 | 8.0 | 12.0 | Q1 |
| LM2904BTQDRQ1 | SOIC | D | 8 | 3000 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904BTQPWRQ1 | TSSOP | PW | 8 | 3000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |

5-Nov-2024

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM2904QDRG4Q1 | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904QDRG4Q1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904QDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904QDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904QPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904QPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904QPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904VQDRG4Q1 | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904VQDRG4Q1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904VQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904VQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2904VQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904VQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904VQPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2904VQPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

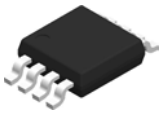
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LM2904AVQDRG4Q1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904AVQDRG4Q1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904AVQDRQ1 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |
| LM2904AVQDRQ1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904AVQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2904AVQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904AVQPWRQ1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904BAQDGKRQ1 | VSSOP | DGK | 8 | 2500 | 366.0 | 364.0 | 50.0 |
| LM2904BAQDRQ1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904BAQPWRQ1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904BQDGKRQ1 | VSSOP | DGK | 8 | 2500 | 366.0 | 364.0 | 50.0 |
| LM2904BQDRQ1 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |
| LM2904BQPWRQ1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904BTQDGKRQ1 | VSSOP | DGK | 8 | 2500 | 366.0 | 364.0 | 50.0 |
| LM2904BTQDRQ1 | SOIC | D | 8 | 3000 | 340.5 | 338.1 | 20.6 |
| LM2904BTQPWRQ1 | TSSOP | PW | 8 | 3000 | 356.0 | 356.0 | 35.0 |
| LM2904QDRG4Q1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904QDRG4Q1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |

5-Nov-2024

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LM2904QDRQ1 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |
| LM2904QDRQ1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904QPWRG4Q1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904QPWRG4Q1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904QPWRQ1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904VQDRG4Q1 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |
| LM2904VQDRG4Q1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904VQDRQ1 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |
| LM2904VQDRQ1 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2904VQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904VQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2904VQPWRQ1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |
| LM2904VQPWRQ1 | TSSOP | PW | 8 | 2000 | 356.0 | 356.0 | 35.0 |

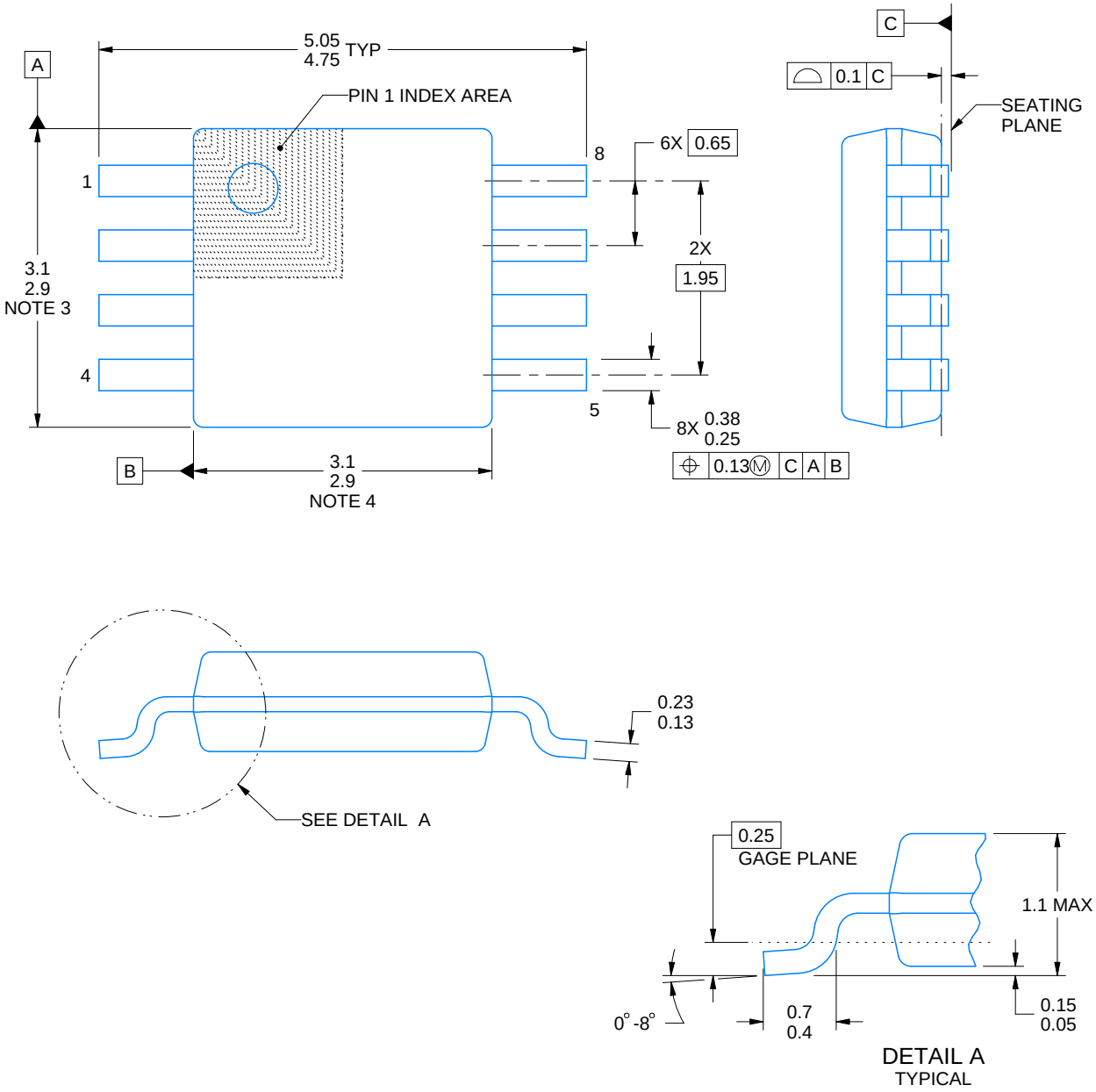
# PACKAGE OUTLINE

## DGK0008A



## VSSOP - 1.1 mm max height

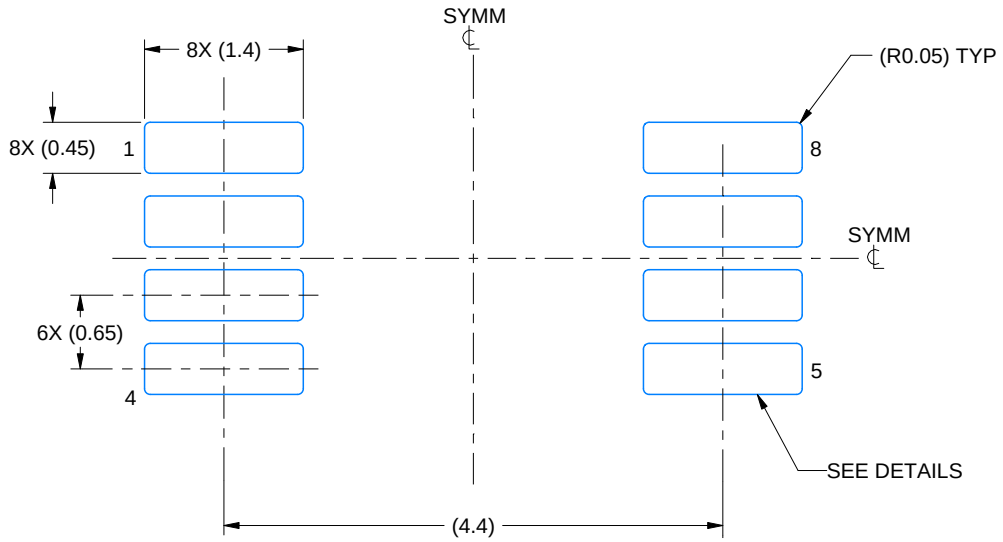
SMALL OUTLINE PACKAGE



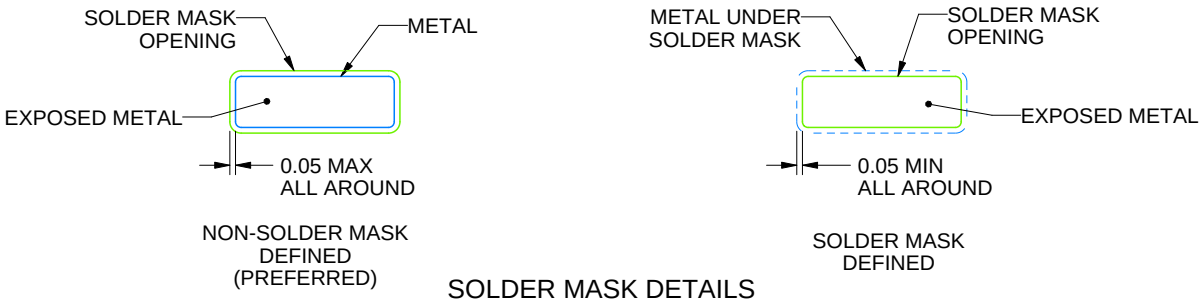

PowerPAD is a trademark of Texas Instruments.

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

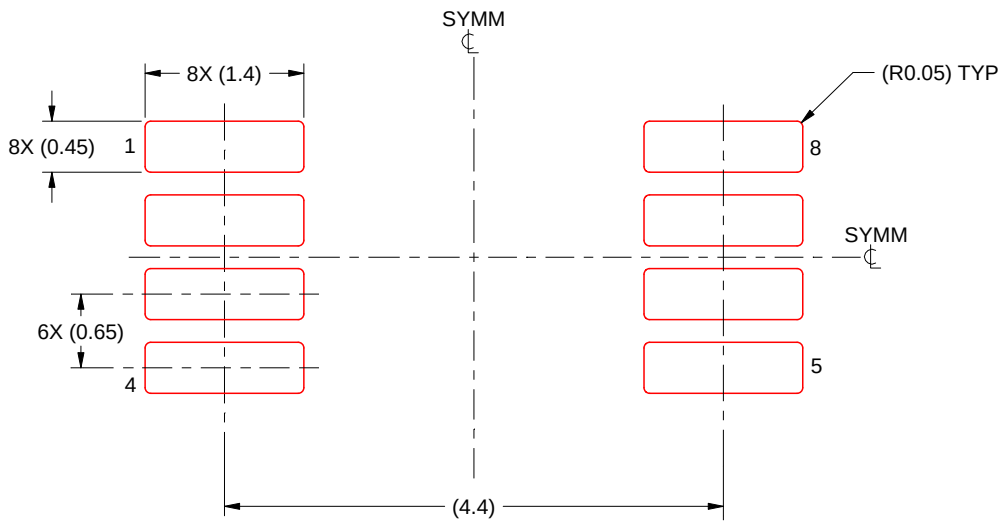



SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

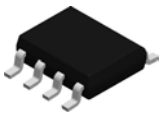



SOLDER PASTE EXAMPLE
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

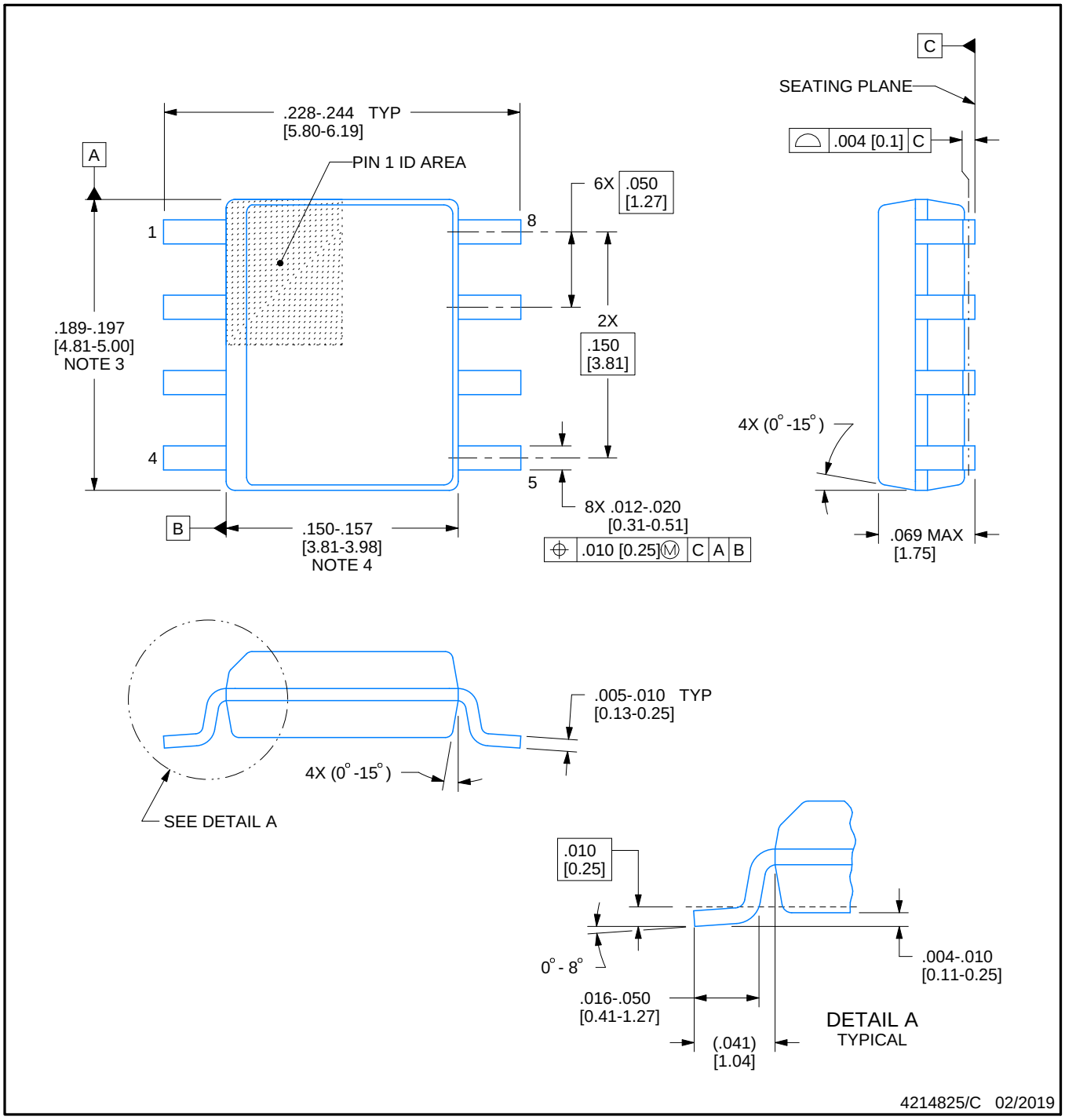


# PACKAGE OUTLINE

## D0008A

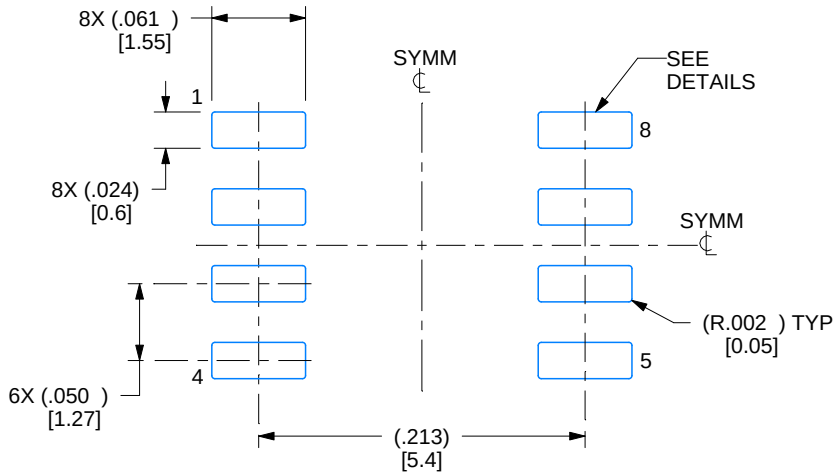
## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

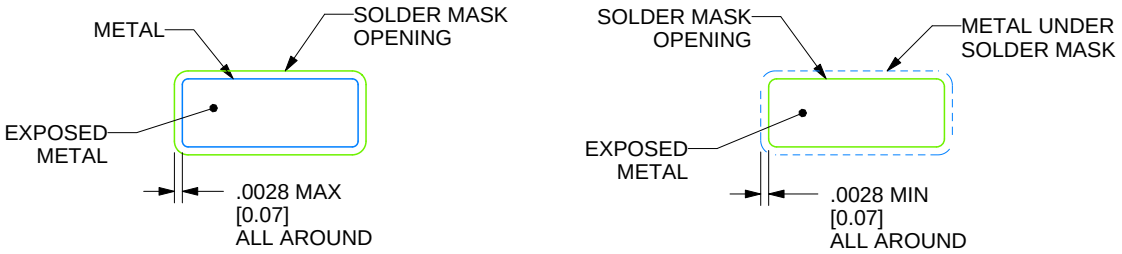



NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X




NON SOLDER MASK
DEFINED

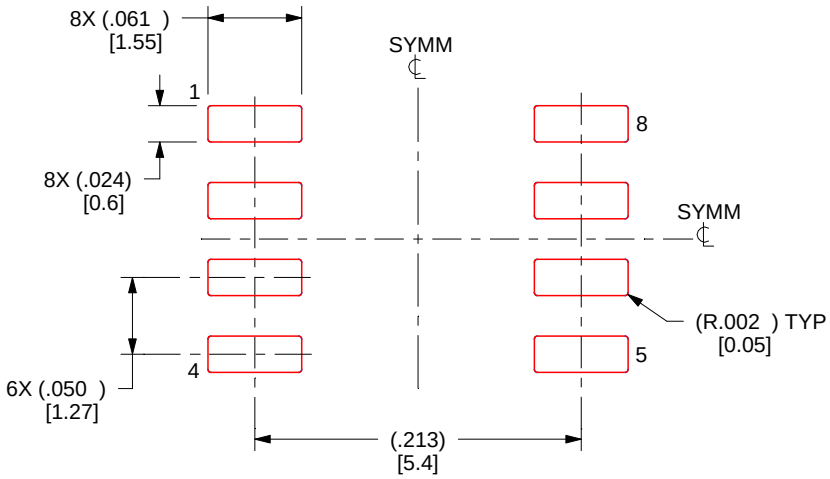
SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

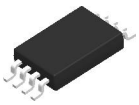



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

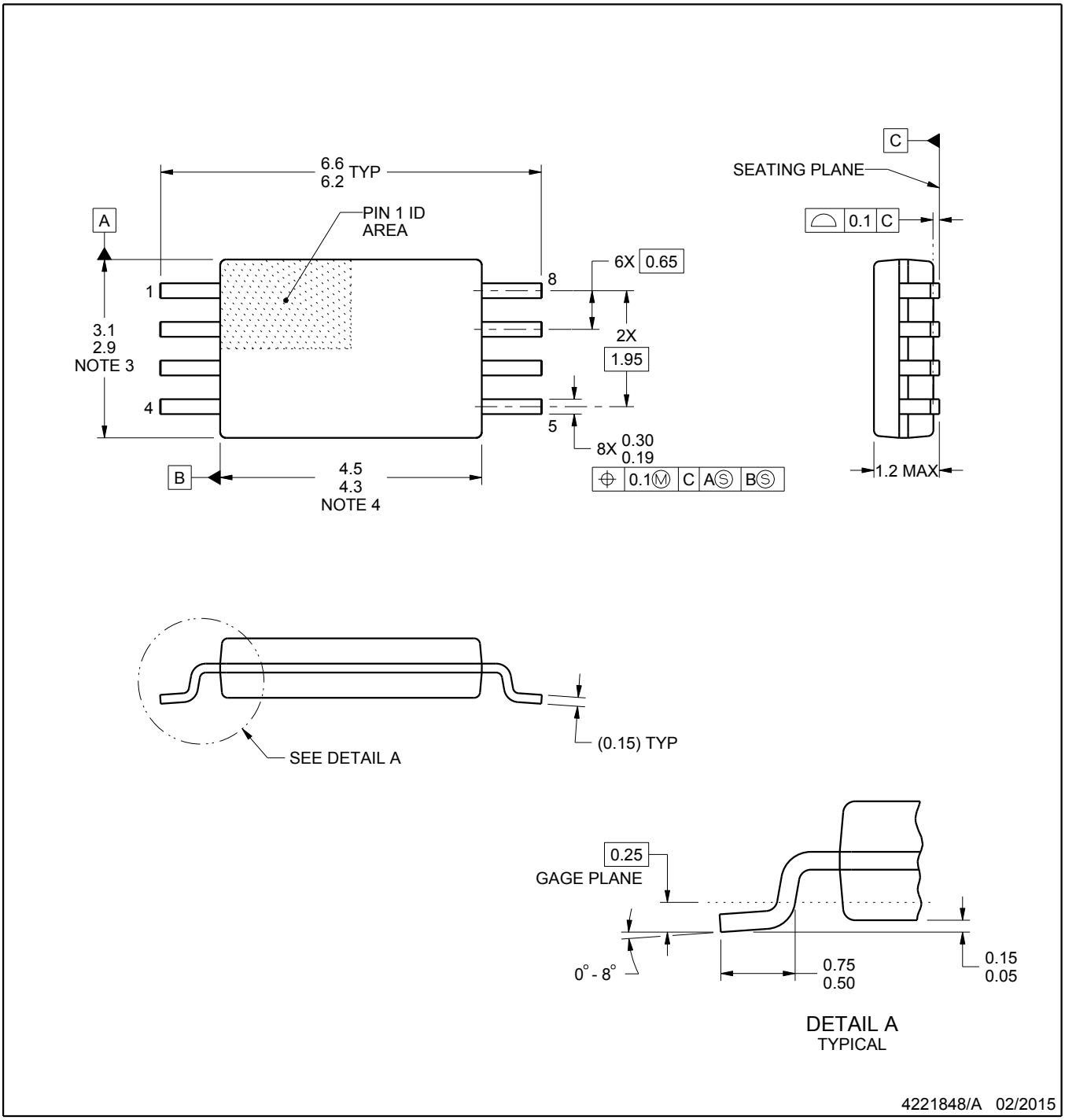


# PACKAGE OUTLINE

## PW0008A

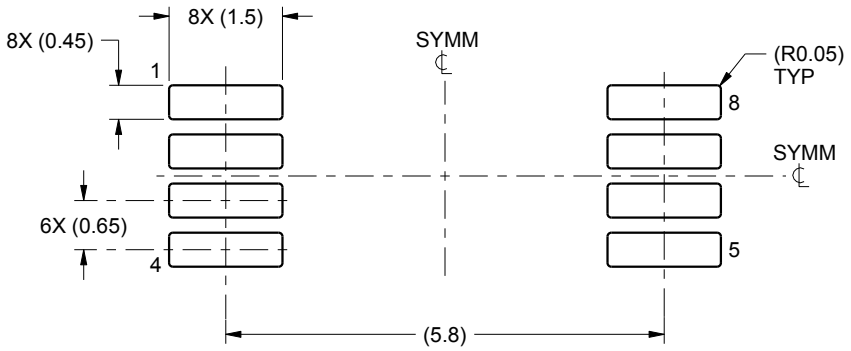
## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

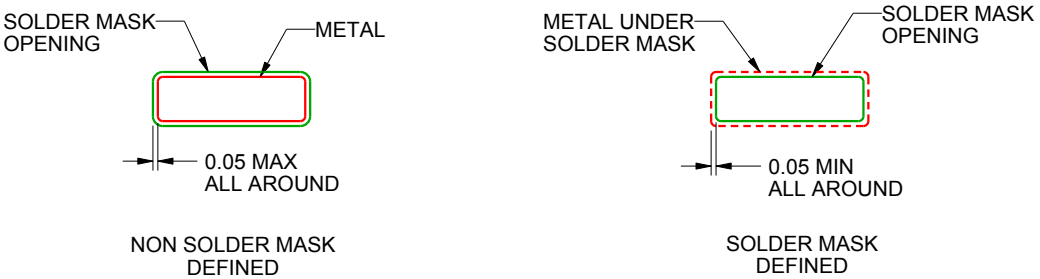



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.




LAND PATTERN EXAMPLE
SCALE:10X

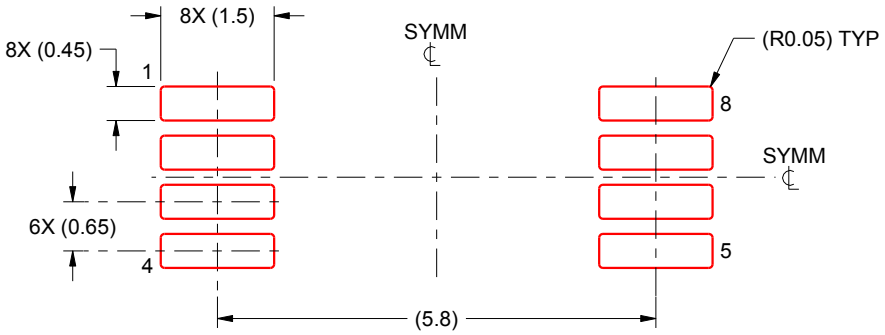



SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

4221848/A 02/2015

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.