

LM393, LM293, LM193, LM2903 Dual Differential Comparators

1 Features

- Single-Supply or Dual Supplies
- Wide Range of Supply Voltage
 - Maximum Rating: 2 V to 36 V
 - Tested to 30 V: Non-V Devices
 - Tested to 32 V: V-Suffix Devices
- Low Supply-Current Drain Independent of Supply Voltage: 0.4 mA (Typical) Per Comparator
- Low Input Bias Current: 25 nA (Typical)
- Low Input Offset Current: 3 nA (Typical) (LM193)
- Low Input Offset Voltage: 2 mV (Typical)
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage: ± 36 V
- Low Output Saturation Voltage
- Output Compatible With TTL, MOS, and CMOS
- On Products Compliant to MIL-PRF-38535, All Parameters Are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

2 Applications

- Chemical or Gas Sensor
- Desktop PC
- Motor Control: AC Induction
- Weigh Scale

3 Description

These devices consist of two independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies also is possible as long as the difference between the two supplies is 2 V to 36 V, and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

The LM193 device is characterized for operation from -55°C to $+125^{\circ}\text{C}$. The LM293 and LM293A devices are characterized for operation from -25°C to $+85^{\circ}\text{C}$. The LM393 and LM393A devices are characterized for operation from 0°C to 70°C . The LM2903, LM2903V, and LM2903AV devices are characterized for operation from -40°C to $+125^{\circ}\text{C}$.

Device Information⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|--|-----------|--------------------|
| LM193D, LM293D, LM293AD, LM393D, LM393AD, LM2903D, LM2903QD, LM2903VQD, LM2903AVQD | SOIC (8) | 4.90 mm x 6.00 mm |
| LM293DGK, LM293ADGK, LM393DGK, LM393ADGK, LM2903DGK | VSSOP (8) | 3.00 mm x 5.00 mm |
| LM293P, LM393P, LM393AP, LM2903P | PDIP (8) | 9.50 mm x 6.30 mm |
| LM393PS, LM393APS, LM2903PS | SO (8) | 6.20 mm x 7.90 mm |
| LM393PW, LM393APW, LM2903PW, LM2903VQPW, LM2903AVQPW | TSSOP (8) | 6.40 mm x 3.00 mm |
| LM193JG | CDIP (8) | 10.00 mm x 7.00 mm |
| LM193FK | LCCC (20) | 9.00 mm x 9.00 mm |

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

Simplified Schematic

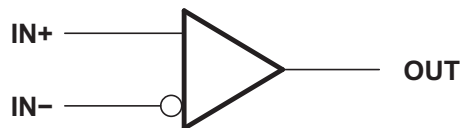


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4 Revision History

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

| Changes from Revision Y (June 2015) to Revision Z | Page |
|--|------|
| • Changed text from: LM139 to: LM193 | 1 |
| • Changed data sheet title | 1 |
| • Added LM2903 part numbers | 1 |
| • Added LM2903 part numbers | 1 |
| • Changed VCC and ground pin function from: input to: – | 3 |
| • Changed T_J to T_A , split part numbers | 4 |
| • Changed 25C to -25C due to typo in LM293 Temperature Tablenote | 6 |
| • Remove text "four comparators" from I_{CC} | 7 |
| • Changed 25C to -25C due to typo in LM293 Temperature Tablenote | 7 |
| • Changed input error in <i>Feature Description</i> text | 10 |
| • Changed Design Paramter maximum current from: 20 mA to: 4 mA | 11 |
| • Changed and revised text in <i>Response Time</i> section | 12 |
| • Added <i>Receiving Notification of Documentation Updates</i> section | 15 |

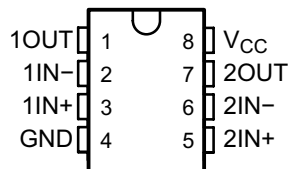
| Changes from Revision X (January 2014) to Revision Y | Page |
|--|------|
| • Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section. | 1 |

Changes from Revision W (July 2010) to Revision X
Page

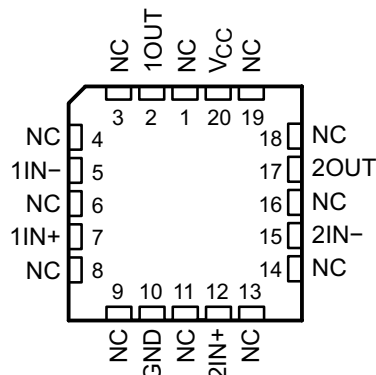
| | |
|---|--------------------|
| • Updated document to new TI data sheet format - no specification changes. | 1 |
| • Updated <i>Features</i> | 1 |
| • Removed <i>Ordering Information</i> table | 3 |
| • Added ESD warning. | 15 |

5 Pin Configuration and Functions

D, DGK, JG, P, PS, or PW
8-Pin SOIC, VSSOP, CDIP, PDIP, SO, or TSSOP
Top View



FK Package
20-Pin LCCC
Top View



NC – No internal connection

Pin Functions

| PIN | | | I/O | DESCRIPTION |
|-----------------|--|------|--------|-------------------------------------|
| NAME | SOIC, VSSOP, CDIP, PDIP, SO, and TSSOP | LCCC | | |
| 1OUT | 1 | 2 | Output | Output pin of comparator 1 |
| 1IN- | 2 | 5 | Input | Negative input pin of comparator 1 |
| 1IN+ | 3 | 7 | Input | Positive input pin of comparator 1 |
| GND | 4 | 10 | — | Ground |
| 2IN+ | 5 | 12 | Input | Positive input pin of comparator 2 |
| 2IN- | 6 | 15 | Input | Negative input pin of comparator 2 |
| 2OUT | 7 | 17 | Output | Output pin of comparator 2 |
| V _{CC} | 8 | 20 | — | Supply Pin |
| NC | — | 1 | N/A | No Connect (No Internal Connection) |
| | | 3 | | |
| | | 4 | | |
| | | 6 | | |
| | | 8 | | |
| | | 9 | | |
| | | 11 | | |
| | | 13 | | |
| | | 14 | | |
| | | 16 | | |
| | | 18 | | |
| | | 19 | | |

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| | | MIN | MAX | UNIT |
|------------------|---|------------|-----|------|
| V _{CC} | Supply voltage ⁽²⁾ | | 36 | V |
| V _{ID} | Differential input voltage ⁽³⁾ | | ±36 | V |
| V _I | Input voltage (either input) | –0.3 | 36 | V |
| I _{IK} | Input current ⁽⁴⁾ | | –50 | mA |
| V _O | Output voltage | | 36 | V |
| I _O | Output current | | 20 | mA |
| | Duration of output short circuit to ground ⁽⁵⁾ | Unlimited | | |
| T _J | Operating virtual-junction temperature | | 150 | °C |
| | Case temperature for 60 s | FK package | 260 | °C |
| | Lead temperature 1.6 mm (1/16 in) from case for 60 s | JG package | 300 | °C |
| T _{stg} | Storage temperature | –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 functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values, except differential voltages, are with respect to network ground.
- (3) Differential voltages are at IN+ with respect to IN–.
- (4) Input current flows thorough parasitic diode to ground and will turn on parasitic transistors that will increase ICC and may cause output to be incorrect. Normal operation resumes when input current is removed.
- (5) Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

6.2 ESD Ratings

| | | VALUE | UNIT |
|--------------------|-------------------------|--|------|
| V _(ESD) | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | 1000 |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | 750 |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| | | | MIN | MAX | UNIT |
|-----------------|-----------------------|---------------------------|-----|-----|------|
| V _{CC} | Supply voltage | non-V devices | 2 | 30 | V |
| | | V devices | 2 | 32 | V |
| T _A | Operating temperature | LM193 | –55 | 125 | °C |
| | | LM293, LM293A | –25 | 85 | °C |
| | | LM393, LM393A | 0 | 70 | °C |
| | | LM2903, LM2903V, LM2903AV | –40 | 125 | °C |

6.4 Thermal Information LM293, LM393, LM2903 (all suffixes)

| THERMAL METRIC ⁽¹⁾ | | LM293, LM393, LM2903 | | | | | UNIT |
|-------------------------------|--|----------------------|-------------|----------|---------|------------|------|
| | | D (SOIC) | DGK (VSSOP) | P (PDIP) | PS (SO) | PW (TSSOP) | |
| | | 8 PINS | 8 PINS | 8 PINS | 8 PINS | 8 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 131.8 | 199.4 | 73.7 | 139 | 194.1 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 78.4 | 90.2 | 62.6 | 98.9 | 77 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 72.2 | 120.8 | 50.8 | 83.7 | 123 | °C/W |
| Ψ_{JT} | Junction-to-top characterization parameter | 26.5 | 21.5 | 39.2 | 47.4 | 13.1 | °C/W |
| Ψ_{JB} | Junction-to-board characterization parameter | 71.7 | 119.1 | 50.7 | 83 | 121.3 | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

6.5 Thermal Information LM193

| THERMAL METRIC ⁽¹⁾ | | LM193 | | UNIT |
|-------------------------------|---|-----------|-----------|------|
| | | JG (GDIP) | FK (LCCC) | |
| | | 8 PINS | 20 PINS | |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 14.5 | 5.61 | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

6.6 Electrical Characteristics for LM193, LM293, and LM393 (without A suffix)

at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | T _A ⁽¹⁾ | LM193 | | | LM293 LM393 | | | UNIT |
|------------------|---|---|------------------------|-------------------------------|-------------------------------|------|-------------------------------|----------------|------|------|------|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} | Input offset voltage | V _{CC} = 5 V to 30 V, V _{IC} = V _{ICR} min, V _O = 1.4 V | | 25°C | 2 | 5 | | 2 | 5 | mV | |
| | | | | Full range | | 9 | | 9 | | | |
| I _{IO} | Input offset current | V _O = 1.4 V | | 25°C | 3 | 25 | | 5 | 50 | nA | |
| | | | | Full range | | 100 | | 250 | | | |
| I _{IB} | Input bias current | V _O = 1.4 V | | 25°C | −25 | −100 | | −25 | −250 | nA | |
| | | | | Full range | | −300 | | −400 | | | |
| V _{ICR} | Common-mode input-voltage range ⁽²⁾ | | | 25°C | 0 to V _{CC} − 1.5 | | 0 to V _{CC} − 1.5 | | V | | |
| | | | | Full range | 0 to V _{CC} − 2 | | 0 to V _{CC} − 2 | | | | |
| A _{VD} | Large-signal differential-voltage amplification | V _{CC} = 15 V, V _O = 1.4 V to 11.4 V, R _L ≥ 15 kΩ to V _{CC} | | 25°C | 50 | 200 | | 50 | 200 | V/mV | |
| I _{OH} | High-level output current | V _{OH} = 5 V | V _{ID} = 1 V | 25°C | 0.1 | | | 0.1 | 50 | nA | |
| | | V _{OH} = 30 V | V _{ID} = 1 V | Full range | 1 | | | 1 | | μA | |
| V _{OL} | Low-level output voltage | I _{OL} = 4 mA, V _{ID} = −1 V | | 25°C | 150 | 400 | | 130 | 400 | mV | |
| | | | | Full range | 700 | | | 700 | | | |
| I _{OL} | Low-level output current | V _{OL} = 1.5 V, | V _{ID} = −1 V | 25°C | 6 | | | 6 | | mA | |
| I _{CC} | Supply current | R _L = ∞ | V _{CC} = 5 V | 25°C | 0.8 | | 1 | 0.45 | 1 | mA | |
| | | | V _{CC} = 30 V | Full range | 2.5 | | | 0.55 | 2.5 | | |

- (1) Full range (minimum or maximum) for LM193 is –55°C to 125°C, for LM293 is –25°C to 85°C, and for LM393 is 0°C to 70°C. All characteristics are measured with zero common-mode input voltage, unless otherwise specified.
- (2) The voltage at either input should not be allowed to go negative by more than 0.3 V otherwise output may be incorrect and excessive input current can flow. The upper end of the common-mode voltage range is limited by $V_{CC} - 2\text{ V}$. However only one input needs to be in the valid common mode range, the other input can go up the maximum V_{CC} level and the comparator provides a proper output state. Either or both inputs can go to maximum V_{CC} level without damage.

6.7 Electrical Characteristics for LM293A and LM393A

at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A ⁽¹⁾ | LM293A LM393A | | | UNIT |
|--|--|----------------------|------------------|------------------------|------|---------------|
| | | | MIN | TYP | MAX | |
| V_{IO} Input offset voltage | $V_{CC} = 5\text{ V to }30\text{ V}$, $V_O = 1.4\text{ V}$ $V_{IC} = V_{ICR(min)}$ | 25°C | | 1 | 2 | mV |
| | | Full range | | | 4 | |
| I_{IO} Input offset current | $V_O = 1.4\text{ V}$ | 25°C | | 5 | 50 | nA |
| | | Full range | | | 150 | |
| I_{IB} Input bias current | $V_O = 1.4\text{ V}$ | 25°C | | –25 | –250 | nA |
| | | Full range | | | –400 | |
| V_{ICR} Common-mode input-voltage range ⁽²⁾ | | 25°C | | 0 to $V_{CC} - 1.5$ | | V |
| | | Full range | | 0 to $V_{CC} - 2$ | | |
| A_{VD} Large-signal differential-voltage amplification | $V_{CC} = 15\text{ V}$, $V_O = 1.4\text{ V to }11.4\text{ V}$, $R_L \geq 15\text{ k}\Omega$ to V_{CC} | 25°C | | 50 | 200 | V/mV |
| I_{OH} High-level output current | $V_{OH} = 5\text{ V}$, $V_{ID} = 1\text{ V}$ | 25°C | | 0.1 | 50 | nA |
| | $V_{OH} = 30\text{ V}$, $V_{ID} = 1\text{ V}$ | Full range | | | 1 | μA |
| V_{OL} Low-level output voltage | $I_{OL} = 4\text{ mA}$, $V_{ID} = -1\text{ V}$ | 25°C | | 110 | 400 | mV |
| | | Full range | | | 700 | |
| I_{OL} Low-level output current | $V_{OL} = 1.5\text{ V}$, $V_{ID} = -1\text{ V}$ | 25°C | | 6 | | mA |
| I_{CC} Supply current | $R_L = \infty$ | 25°C | | 0.60 | 1 | mA |
| | | Full range | | 0.72 | 2.5 | |

- (1) Full range (minimum or maximum) for LM293A is –25°C to 85°C, and for LM393A is 0°C to 70°C. All characteristics are measured with zero common-mode input voltage, unless otherwise specified.
- (2) The voltage at either input should not be allowed to go negative by more than 0.3 V otherwise output may be incorrect and excessive input current can flow. The upper end of the common-mode voltage range is limited by $V_{CC} - 2\text{ V}$. However only one input needs to be in the valid common mode range, the other input can go up the maximum V_{CC} level and the comparator provides a proper output state. Either or both inputs can go to maximum V_{CC} level without damage.

6.8 Electrical Characteristics for LM2903, LM2903V, and LM2903AV

at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | T _A ⁽¹⁾ | LM2903, LM2903V | | | LM2903AV | | | UNIT |
|------------------|---|--|------------------------|-------------------------------|-------------------------------|------|------|-------------------------------|------|------|------|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} | Input offset voltage | V _{CC} = 5 V to MAX ⁽²⁾ , V _O = 1.4 V , V _{IC} = V _{ICR(min)} , | | 25°C | 2 | 7 | | 1 | 2 | mV | |
| | | | | Full range | | | 15 | | | | 4 |
| I _{IO} | Input offset current | V _O = 1.4 V | | 25°C | 5 | 50 | | 5 | 50 | nA | |
| | | | | Full range | | | 200 | | | | 200 |
| I _{IB} | Input bias current | V _O = 1.4 V | | 25°C | −25 | −250 | | −25 | −250 | nA | |
| | | | | Full range | | | −500 | | | | −500 |
| V _{ICR} | Common-mode input-voltage range ⁽³⁾ | | | 25°C | 0 to V _{CC} − 1.5 | | | 0 to V _{CC} − 1.5 | | V | |
| | | | | Full range | 0 to V _{CC} − 2 | | | 0 to V _{CC} − 2 | | | |
| A _{VD} | Large-signal differential-voltage amplification | V _{CC} = 15 V, V _O = 1.4 V to 11.4 V, R _L ≥ 15 kΩ to V _{CC} | | 25°C | 25 | 100 | | 25 | 100 | V/mV | |
| I _{OH} | High-level output current | V _{OH} = 5 V, | V _{ID} = 1 V | 25°C | 0.1 | 50 | | 0.1 | 50 | nA | |
| | | V _{OH} = V _{CC} MAX ⁽²⁾ , | V _{ID} = 1 V | Full range | | | 1 | | | 1 | μA |
| V _{OL} | Low-level output voltage | I _{OL} = 4 mA, V _{ID} = −1 V, | | 25°C | 150 | 400 | | 150 | 400 | mV | |
| | | | | Full range | | | 700 | | | | 700 |
| I _{OL} | Low-level output current | V _{OL} = 1.5 V, | V _{ID} = −1 V | 25°C | 6 | | | 6 | | mA | |
| I _{CC} | Supply current | R _L = ∞ | V _{CC} = 5 V | 25°C | 0.8 | 1 | | 0.8 | 1 | mA | |
| | | | V _{CC} = MAX | Full range | | | 2.5 | | | | 2.5 |

- (1) Full range (minimum or maximum) for LM2903 is -40°C to 125°C . All characteristics are measured with zero common-mode input voltage, unless otherwise specified.
- (2) $V_{CC} \text{ MAX} = 30\text{ V}$ for non-V devices and 32 V for V-suffix devices.
- (3) The voltage at either input should not be allowed to go negative by more than 0.3 V otherwise output may be incorrect and excessive input current can flow. The upper end of the common-mode voltage range is limited by $V_{CC} - 2\text{ V}$. However only one input needs to be in the valid common mode range, the other input can go up the maximum V_{CC} level and the comparator provides a proper output state. Either or both inputs can go to maximum V_{CC} level without damage.

6.9 Switching Characteristics (all devices)

$V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | | TYP | UNIT |
|---------------|---|---------------------------------------|-----|---------------|
| Response time | R_L connected to 5 V through $5.1\text{ k}\Omega$, $C_L = 15\text{ pF}^{(1)(2)}$ | 100-mV input step with 5-mV overdrive | 1.3 | μs |
| | | TTL-level input step | 0.3 | |

- (1) C_L includes probe and jig capacitance.
- (2) The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V .

6.10 Typical Characteristics

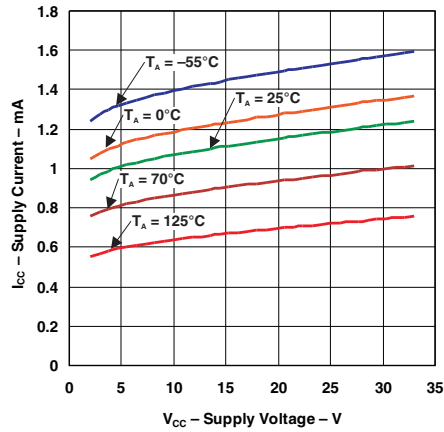


Figure 1. Supply Current vs Supply Voltage

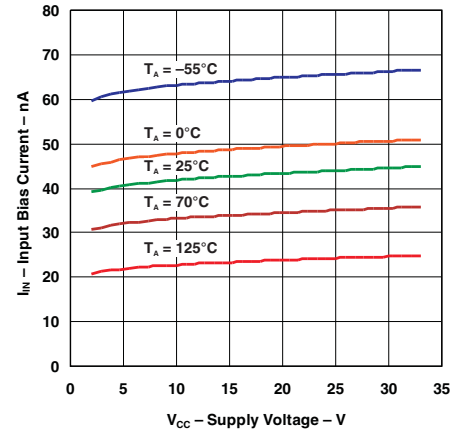


Figure 2. Input Bias Current vs Supply Voltage

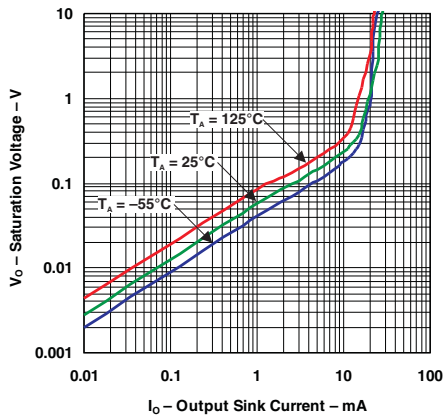
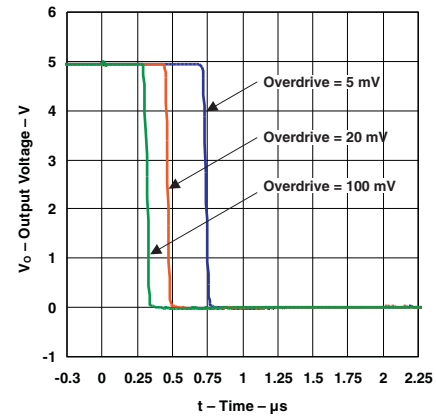
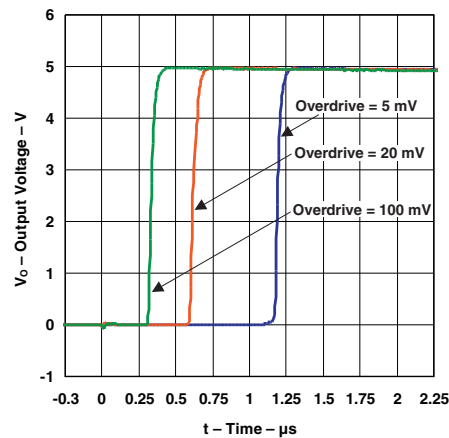


Figure 3. Output Saturation Voltage



**Figure 4. Response Time for Various Overdrives
Negative Transition**



**Figure 5. Response Time for Various Overdrives
Positive Transition**

7 Detailed Description

7.1 Overview

These dual comparators have the ability to operate up to absolute maximum of 36 V on the supply pin. This device has proven ubiquity and versatility across a wide range of applications. This is due to very wide supply voltages range (2 V to 36 V), low I_q and fast response of the devices.

The open-drain output allows the user to configure the output's logic high voltage (V_{OH}) and can be used to enable the comparator to be used in AND functionality.

7.2 Functional Block Diagram

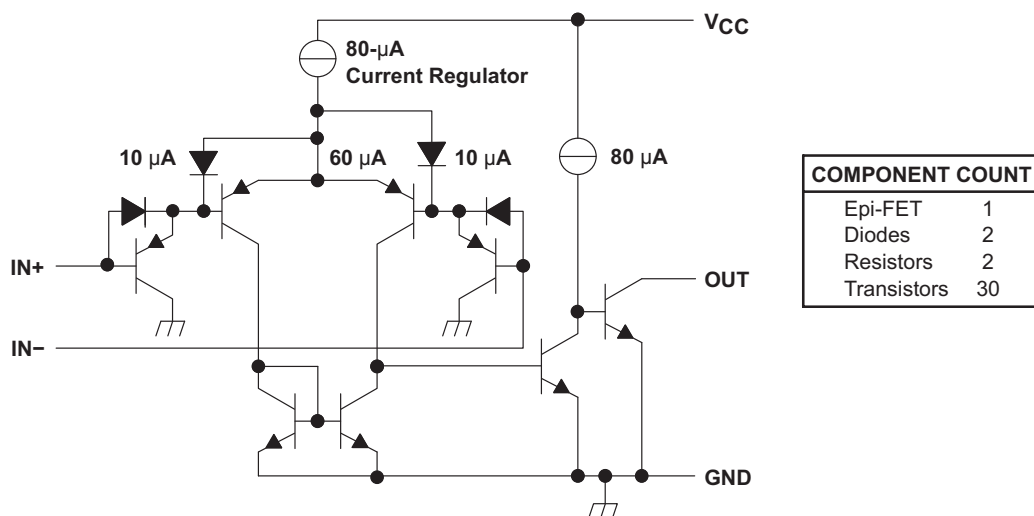


Figure 6. Schematic (Each Comparator)

7.3 Feature Description

The comparator consists of a PNP darlington pair input, allowing the device to operate with very high gain and fast response with minimal input bias current. The input Darlington pair creates a limit on the input common mode voltage capability, allowing the comparator to accurately function from ground to $V_{CC} - 1.5$ V input. Allow for $V_{CC} - 2$ V at cold temperature.

The output consists of an open drain NPN (pull-down or low side) transistor. The output NPN will sink current when the negative input voltage is higher than the positive input voltage and the offset voltage. The V_{OL} is resistive and will scale with the output current. See Figure 3 for V_{OL} values with respect to the output current.

7.4 Device Functional Modes

7.4.1 Voltage Comparison

The device operates solely as a voltage comparator, comparing the differential voltage between the positive and negative pins and outputting a logic low or high impedance (logic high with pullup) based on the input differential polarity.

8 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.

8.1 Application Information

The device will typically be used to compare a single signal to a reference or two signals against each other. Many users take advantage of the open drain output to drive the comparison logic output to a logic voltage level to an MCU or logic device. The wide supply range and high voltage capability makes this comparator optimal for level shifting to a higher or lower voltage.

8.2 Typical Application

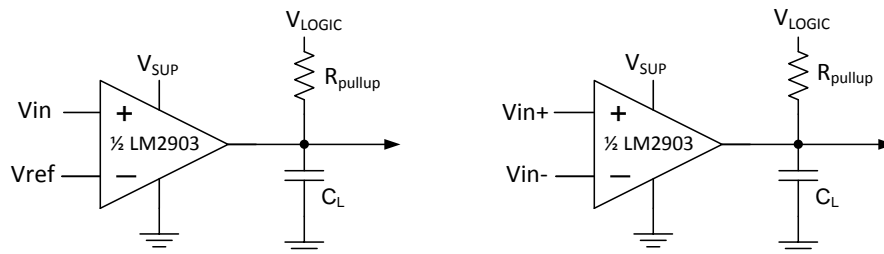


Figure 7. Single-Ended and Differential Comparator Configurations

8.2.1 Design Requirements

For this design example, use the parameters listed in [Table 1](#) as the input parameters.

Table 1. Design Parameters

| DESIGN PARAMETER | EXAMPLE VALUE |
|--------------------------|----------------------|
| Input Voltage Range | 0 V to Vsup-2 V |
| Supply Voltage | 4.5 V to VCC maximum |
| Logic Supply Voltage | 0 V to VCC maximum |
| Output Current (Rpullup) | 1 μ A to 4 mA |
| Input Overdrive Voltage | 100 mV |
| Reference Voltage | 2.5 V |
| Load Capacitance (CL) | 15 pF |

8.2.2 Detailed Design Procedure

When using the device in a general comparator application, determine the following:

- Input Voltage Range
- Minimum Overdrive Voltage
- Output and Drive Current
- Response Time

8.2.2.1 Input Voltage Range

When choosing the input voltage range, the input common mode voltage range (V_{ICR}) must be taken in to account. If temperature operation is below 25°C the V_{ICR} can range from 0 V to $V_{CC} - 2.0$ V. This limits the input voltage range to as high as $V_{CC} - 2.0$ V and as low as 0 V. Operation outside of this range can yield incorrect comparisons.

The following is a list of input voltage situation and their outcomes:

1. When both IN- and IN+ are both within the common-mode range:
 - a. If IN- is higher than IN+ and the offset voltage, the output is low and the output transistor is sinking current
 - b. If IN- is lower than IN+ and the offset voltage, the output is high impedance and the output transistor is not conducting
2. When IN- is higher than common-mode and IN+ is within common-mode, the output is low and the output transistor is sinking current
3. When IN+ is higher than common-mode and IN- is within common-mode, the output is high impedance and the output transistor is not conducting
4. When IN- and IN+ are both higher than common-mode, the output is low and the output transistor is sinking current

8.2.2.2 Minimum Overdrive Voltage

Overdrive Voltage is the differential voltage produced between the positive and negative inputs of the comparator over the offset voltage (V_{IO}). To make an accurate comparison the Overdrive Voltage (V_{OD}) should be higher than the input offset voltage (V_{IO}). Overdrive voltage can also determine the response time of the comparator, with the response time decreasing with increasing overdrive. [Figure 8](#) and [Figure 9](#) show positive and negative response times with respect to overdrive voltage.

8.2.2.3 Output and Drive Current

Output current is determined by the load/pull-up resistance and logic/pullup voltage. The output current will produce a output low voltage (V_{OL}) from the comparator. In which V_{OL} is proportional to the output current. Use [Typical Characteristics](#) to determine V_{OL} based on the output current.

The output current can also effect the transient response. See [Response Time](#) for more information.

8.2.2.4 Response Time

Response time is a function of input over drive. See [Application Curves](#) for typical response times. The rise and falls times can be determined by the load capacitance (C_L), load/pullup resistance (R_{PULLUP}) and equivalent collector-emitter resistance (R_{CE}).

- The rise time (τ_R) is approximately $\tau_R \sim R_{PULLUP} \times C_L$
- The fall time (τ_F) is approximately $\tau_F \sim R_{CE} \times C_L$
 - R_{CE} can be determine by taking the slope of [Typical Characteristics](#) in its linear region at the desired temperature, or by dividing the V_{OL} by I_{out}

8.2.3 Application Curves

The following curves were generated with 5 V on V_{CC} and V_{Logic} , $R_{PULLUP} = 5.1 \text{ k}\Omega$, and 50 pF scope probe.

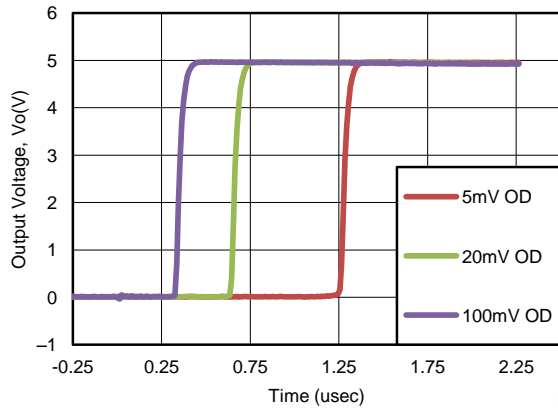


Figure 8. Response Time for Various Overdrives (Positive Transition)

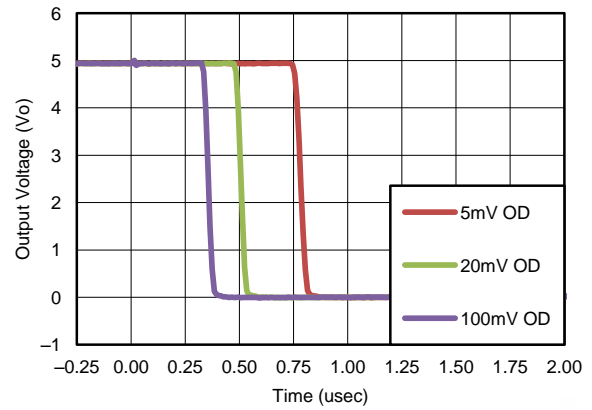


Figure 9. Response Time for Various Overdrives (Negative Transition)

9 Power Supply Recommendations

For fast response and comparison applications with noisy or AC inputs, TI recommends to use a bypass capacitor on the supply pin to reject any variation on the supply voltage. This variation can eat into the input common-mode range of the comparator and create an inaccurate comparison.

10 Layout

10.1 Layout Guidelines

For accurate comparator applications without hysteresis it is important maintain a stable power supply with minimized noise and glitches. To achieve this, it is best to add a bypass capacitor between the supply voltage and ground. This should be implemented on the positive power supply and negative supply (if available). If a negative supply is not being used, do not put a capacitor between the IC's GND pin and system ground.

Minimize coupling between outputs and inverting inputs to prevent output oscillations. Do not run output and inverting input traces in parallel unless there is a V_{CC} or GND trace between output and inverting input traces to reduce coupling. When series resistance is added to inputs, place resistor close to the device.

10.2 Layout Example

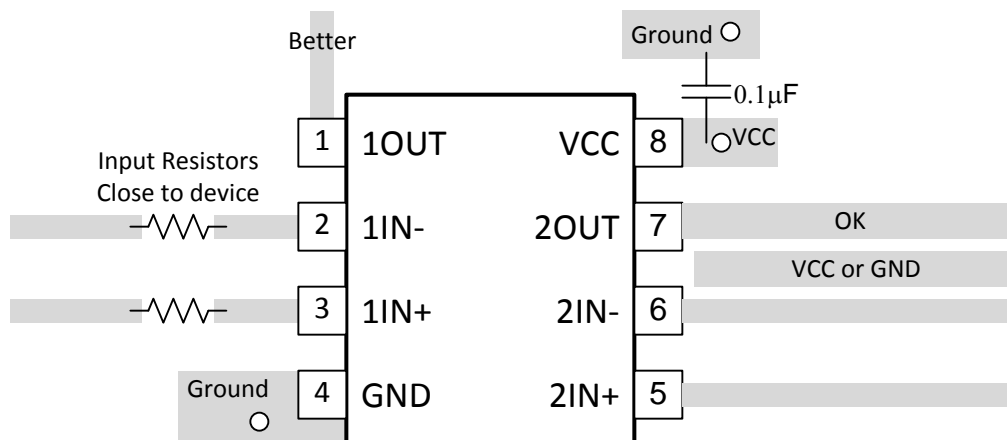


Figure 10. LM2903 Layout Example

11 Device and Documentation Support

11.1 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 2. Related Links

| PARTS | PRODUCT FOLDER | ORDER NOW | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| LM193 | Click here | Click here | Click here | Click here | Click here |
| LM293 | Click here | Click here | Click here | Click here | Click here |
| LM293A | Click here | Click here | Click here | Click here | Click here |
| LM393 | Click here | Click here | Click here | Click here | Click here |
| LM393A | Click here | Click here | Click here | Click here | Click here |
| LM2903 | Click here | Click here | Click here | Click here | Click here |
| LM2903V | Click here | Click here | Click here | Click here | Click here |

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* 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.

11.3 Community Resources

The following links connect to TI community resources. Linked contents are 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](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.4 Trademarks

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

11.5 Electrostatic Discharge Caution



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.

11.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

12 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 revision of this document. For browser based versions of this data sheet, refer to the left hand navigation.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM193DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -55 to 125 | LM193 | Samples |
| LM193DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -55 to 125 | LM193 | Samples |
| LM2903AVQDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903AV | Samples |
| LM2903AVQDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903AV | Samples |
| LM2903AVQPWR | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903AV | Samples |
| LM2903AVQPWRG4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903AV | Samples |
| LM2903D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903DE4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903DGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 125 | (MAP, MAS, MAU) | Samples |
| LM2903DGKRG4 | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 125 | (MAP, MAS, MAU) | Samples |
| LM2903DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903DRE4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903DRG3 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LM2903 | Samples |
| LM2903P | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | -40 to 125 | LM2903P | Samples |
| LM2903PE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | -40 to 125 | LM2903P | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM2903PSR | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903 | Samples |
| LM2903PSRG4 | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903 | Samples |
| LM2903PWR | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | -40 to 125 | L2903 | Samples |
| LM2903PWRE4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903 | Samples |
| LM2903PWRG3 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 125 | L2903 | Samples |
| LM2903PWRG4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903 | Samples |
| LM2903QD | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2903Q | Samples |
| LM2903QDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2903Q | Samples |
| LM2903QDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2903Q | Samples |
| LM2903VQDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903V | Samples |
| LM2903VQDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903V | Samples |
| LM2903VQPWR | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903V | Samples |
| LM2903VQPWRG4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | L2903V | Samples |
| LM293AD | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293A | Samples |
| LM293ADE4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293A | Samples |
| LM293ADG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293A | Samples |
| LM293ADGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -25 to 85 | (MDP, MDS, MDU) | Samples |
| LM293ADGKRG4 | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -25 to 85 | (MDP, MDS, MDU) | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM293ADR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | -25 to 85 | LM293A | Samples |
| LM293ADRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293A | Samples |
| LM293D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293DE4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293DGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -25 to 85 | (MCP, MCS, MCU) | Samples |
| LM293DGKRG4 | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -25 to 85 | (MCP, MCS, MCU) | Samples |
| LM293DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293DRE4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293DRG3 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | LM293 | Samples |
| LM293P | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU CU SN | N / A for Pkg Type | -25 to 85 | LM293P | Samples |
| LM293PE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | -25 to 85 | LM293P | Samples |
| LM393AD | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393A | Samples |
| LM393ADE4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393A | Samples |
| LM393ADG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393A | Samples |
| LM393ADGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | 0 to 70 | (M8P, M8S, M8U) | Samples |
| LM393ADGKRG4 | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | 0 to 70 | (M8P, M8S, M8U) | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM393ADR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | 0 to 70 | LM393A | Samples |
| LM393ADRE4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393A | Samples |
| LM393ADRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393A | Samples |
| LM393AP | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU CU SN | N / A for Pkg Type | 0 to 70 | LM393AP | Samples |
| LM393APE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | 0 to 70 | LM393AP | Samples |
| LM393APSR | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393A | Samples |
| LM393APSRE4 | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393A | Samples |
| LM393APSRG4 | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393A | Samples |
| LM393APWR | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | 0 to 70 | L393A | Samples |
| LM393APWRE4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393A | Samples |
| LM393APWRG4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393A | Samples |
| LM393D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |
| LM393DE4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |
| LM393DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |
| LM393DGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | 0 to 70 | (M9P, M9S, M9U) | Samples |
| LM393DGKRG4 | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | 0 to 70 | (M9P, M9S, M9U) | Samples |
| LM393DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |
| LM393DRE4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM393DRG3 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |
| LM393DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | LM393 | Samples |
| LM393P | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU CU SN | N / A for Pkg Type | 0 to 70 | LM393P | Samples |
| LM393PE3 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU SN | N / A for Pkg Type | 0 to 70 | LM393P | Samples |
| LM393PE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | 0 to 70 | LM393P | Samples |
| LM393PSR | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393 | Samples |
| LM393PSRG4 | ACTIVE | SO | PS | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393 | Samples |
| LM393PW | ACTIVE | TSSOP | PW | 8 | 150 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393 | Samples |
| LM393PWG4 | ACTIVE | TSSOP | PW | 8 | 150 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393 | Samples |
| LM393PWR | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU CU SN | Level-1-260C-UNLIM | 0 to 70 | L393 | Samples |
| LM393PWRG3 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | L393 | Samples |
| LM393PWRG4 | ACTIVE | TSSOP | PW | 8 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | L393 | 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/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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OTHER QUALIFIED VERSIONS OF LM2903, LM293 :

- Automotive: [LM2903-Q1](#)
- Enhanced Product: [LM293-EP](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

TAPE AND REEL INFORMATION


*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM193DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903AVQDR | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903AVQPWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903AVQPWRG4 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903DGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LM2903DR | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903DRG3 | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903DRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903DRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903PSR | SO | PS | 8 | 2000 | 330.0 | 16.4 | 8.2 | 6.6 | 2.5 | 12.0 | 16.0 | Q1 |
| LM2903PWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903PWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903PWRG3 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903PWRG4 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903QDRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM2903VQDR | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

| 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 |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM2903VQPWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2903VQPWRG4 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM293ADGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LM293ADR | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293ADR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293ADR | SOIC | D | 8 | 2500 | 330.0 | 15.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293ADR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293ADRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293ADRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293DGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LM293DR | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293DRG3 | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293DRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM293DRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393ADGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LM393ADR | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393ADR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393ADR | SOIC | D | 8 | 2500 | 330.0 | 15.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393ADR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393ADRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393ADRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393APSR | SO | PS | 8 | 2000 | 330.0 | 16.4 | 8.2 | 6.6 | 2.5 | 12.0 | 16.0 | Q1 |
| LM393APWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM393APWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM393APWRG4 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM393DGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LM393DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393DRG3 | SOIC | D | 8 | 2500 | 330.0 | 15.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393DRG3 | SOIC | D | 8 | 2500 | 330.0 | 12.8 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393DRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393DRG4 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LM393PSR | SO | PS | 8 | 2000 | 330.0 | 16.4 | 8.2 | 6.6 | 2.5 | 12.0 | 16.0 | Q1 |
| LM393PWR | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM393PWRG3 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| LM393PWRG4 | 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) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM193DR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 38.0 |
| LM2903AVQDR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2903AVQPWR | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2903AVQPWRG4 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2903DGKR | VSSOP | DGK | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM2903DR | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM2903DR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM2903DR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2903DRG3 | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM2903DRG4 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM2903DRG4 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2903PSR | SO | PS | 8 | 2000 | 367.0 | 367.0 | 38.0 |
| LM2903PWR | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2903PWR | TSSOP | PW | 8 | 2000 | 364.0 | 364.0 | 27.0 |
| LM2903PWRG3 | TSSOP | PW | 8 | 2000 | 364.0 | 364.0 | 27.0 |
| LM2903PWRG4 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2903QDRG4 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 38.0 |
| LM2903VQDR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM2903VQPWR | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM2903VQPWRG4 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM293ADGKR | VSSOP | DGK | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM293ADR | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM293ADR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM293ADR | SOIC | D | 8 | 2500 | 333.2 | 345.9 | 28.6 |
| LM293ADR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM293ADRG4 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM293ADRG4 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM293DGKR | VSSOP | DGK | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM293DR | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM293DR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM293DRG3 | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM293DRG4 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM293DRG4 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM393ADGKR | VSSOP | DGK | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM393ADR | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM393ADR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM393ADR | SOIC | D | 8 | 2500 | 333.2 | 345.9 | 28.6 |
| LM393ADR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM393ADRG4 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM393ADRG4 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM393APSR | SO | PS | 8 | 2000 | 367.0 | 367.0 | 38.0 |
| LM393APWR | TSSOP | PW | 8 | 2000 | 364.0 | 364.0 | 27.0 |
| LM393APWR | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM393APWRG4 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |
| LM393DGKR | VSSOP | DGK | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM393DR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM393DR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM393DRG3 | SOIC | D | 8 | 2500 | 333.2 | 345.9 | 28.6 |
| LM393DRG3 | SOIC | D | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| LM393DRG4 | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| LM393DRG4 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LM393PSR | SO | PS | 8 | 2000 | 367.0 | 367.0 | 38.0 |
| LM393PWR | TSSOP | PW | 8 | 2000 | 364.0 | 364.0 | 27.0 |
| LM393PWRG3 | TSSOP | PW | 8 | 2000 | 364.0 | 364.0 | 27.0 |
| LM393PWRG4 | TSSOP | PW | 8 | 2000 | 367.0 | 367.0 | 35.0 |

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- $\triangle C$ Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- $\triangle D$ Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



4211283-2/E 08/12

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

MECHANICAL DATA

PS (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

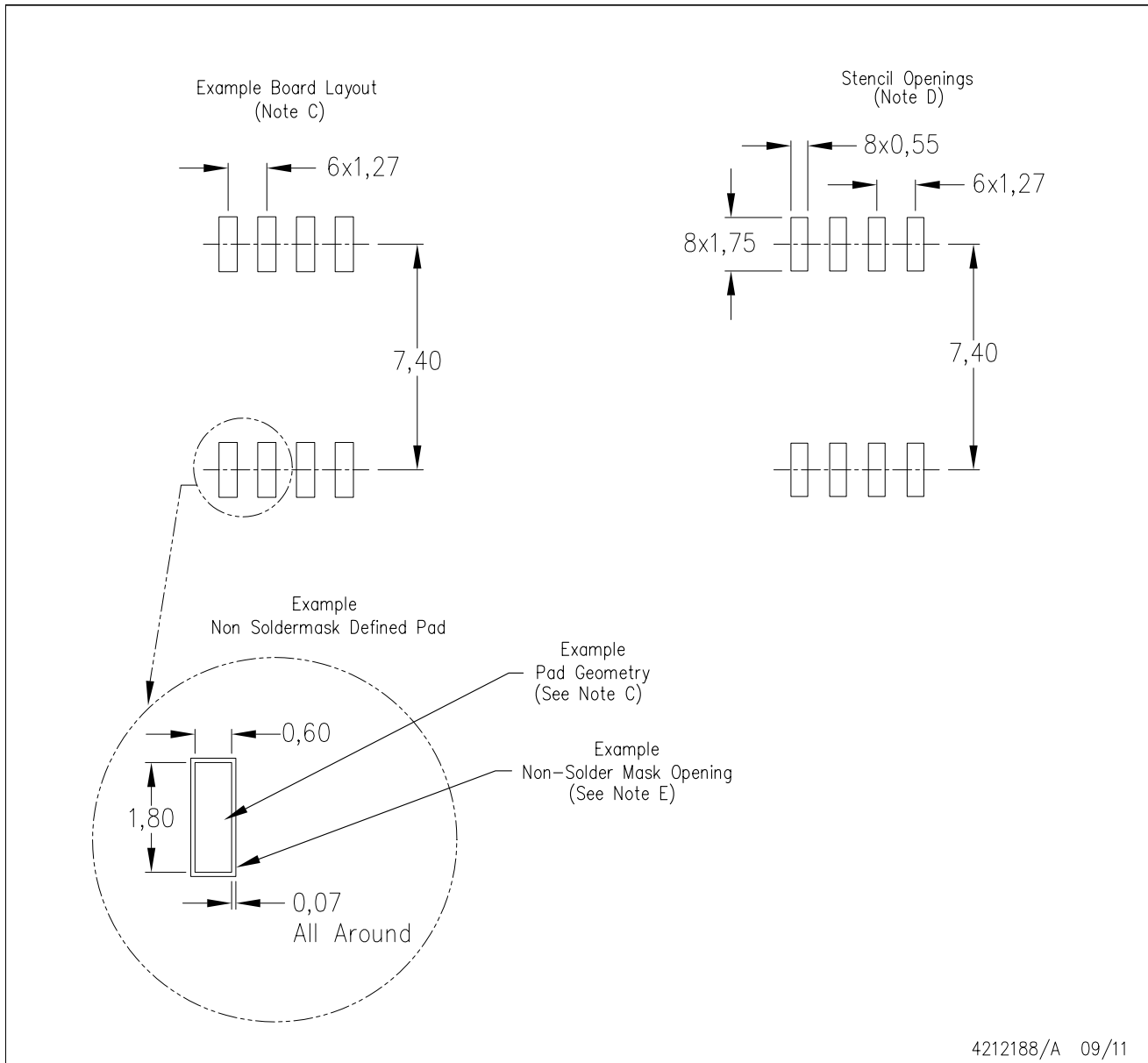


4040063/C 03/03

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

PS (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

P (R-PDIP-T8)

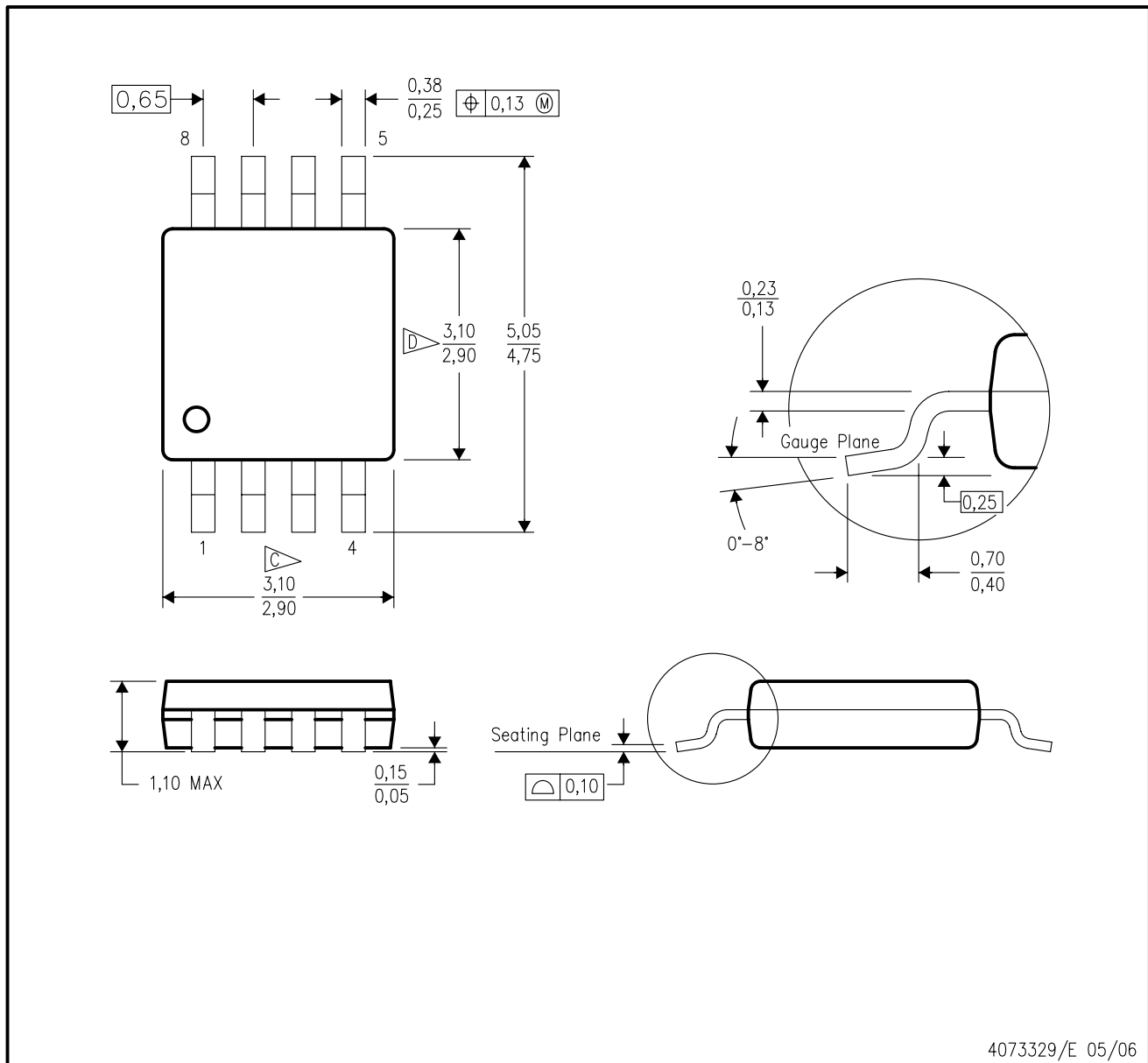
PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Falls within JEDEC MS-001 variation BA.

DGK (S-PDSO-G8)

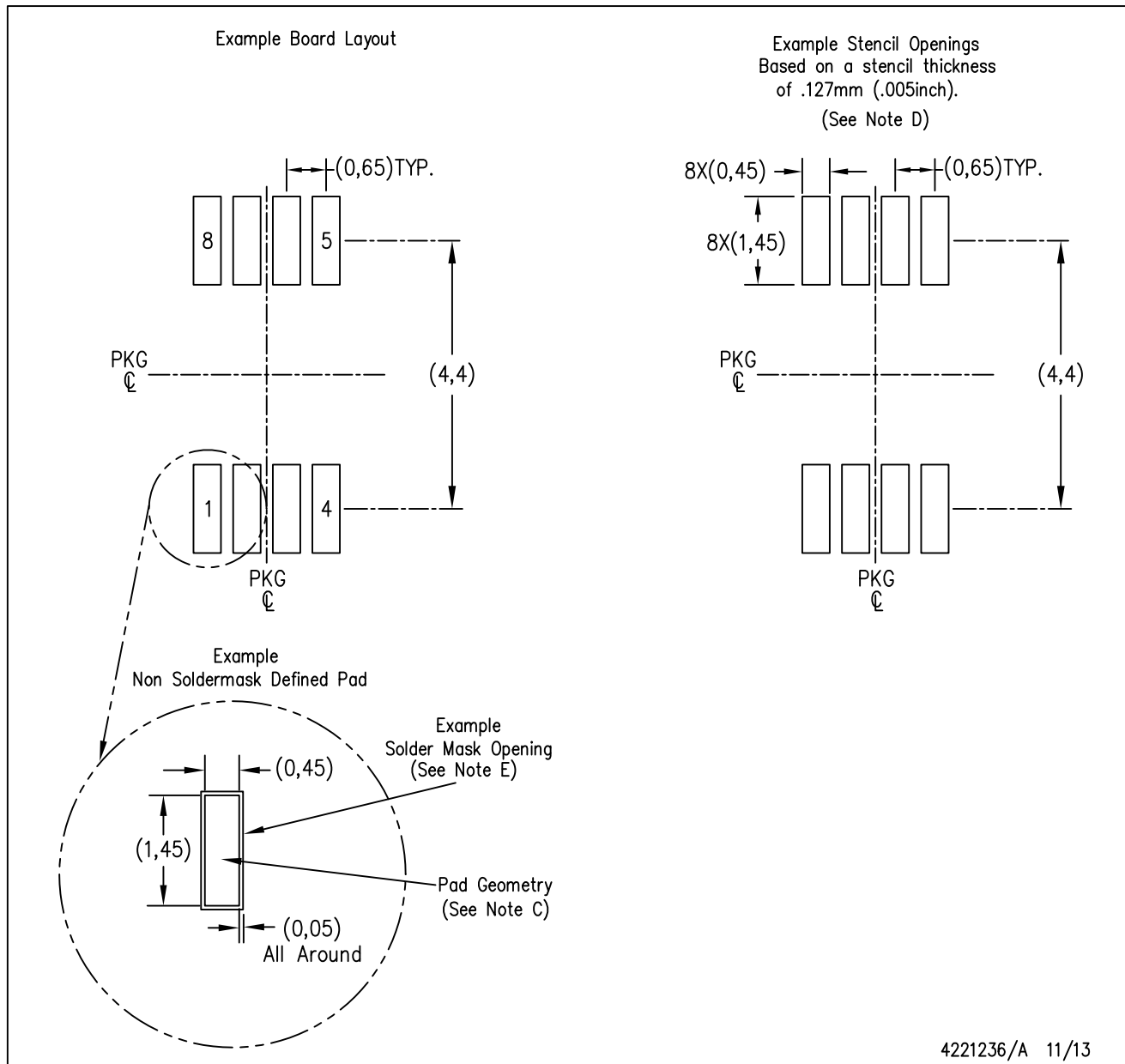
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
 - E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE



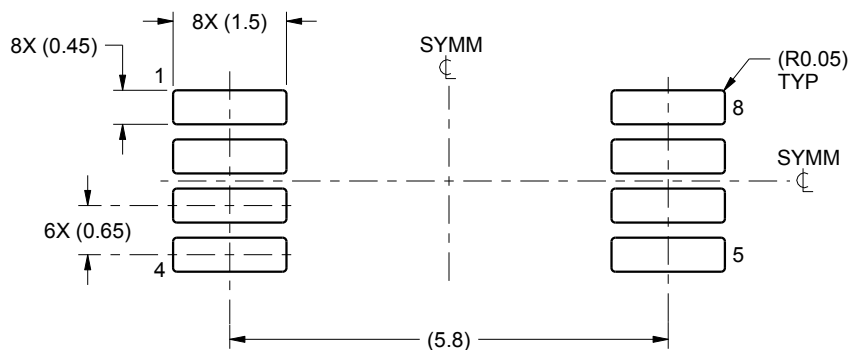
- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

EXAMPLE BOARD LAYOUT

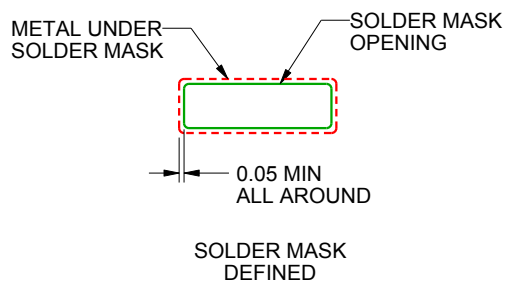
PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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.

EXAMPLE STENCIL DESIGN

PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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.

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