

LM193-MIL 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

The device 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.

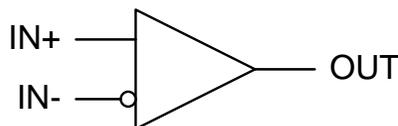
The LM193-MIL device is characterized for operation from -55°C to $+125^{\circ}\text{C}$.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM193-MIL	SOIC (8)	4.90 mm x 6.00 mm
	CDIP (8)	10.00 mm x 7.00 mm
	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



Copyright © 2017, Texas Instruments Incorporated



Table of Contents

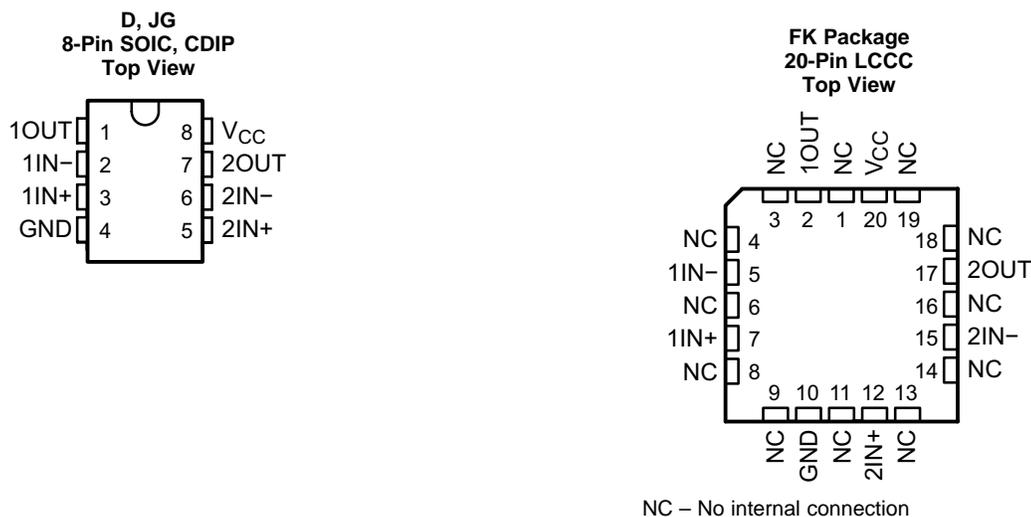
1 Features	1	7.4 Device Functional Modes.....	7
2 Applications	1	8 Application and Implementation	8
3 Description	1	8.1 Application Information.....	8
4 Revision History	2	8.2 Typical Application	8
5 Pin Configuration and Functions	3	9 Power Supply Recommendations	10
6 Specifications	4	10 Layout	10
6.1 Absolute Maximum Ratings	4	10.1 Layout Guidelines	10
6.2 ESD Ratings.....	4	10.2 Layout Example	10
6.3 Recommended Operating Conditions.....	4	11 Device and Documentation Support	11
6.4 Thermal Information	4	11.1 Related Links	11
6.5 Electrical Characteristics.....	5	11.2 Receiving Notification of Documentation Updates	11
6.6 Switching Characteristics	5	11.3 Community Resources.....	11
6.7 Typical Characteristics	6	11.4 Trademarks	11
7 Detailed Description	7	11.5 Electrostatic Discharge Caution.....	11
7.1 Overview	7	11.6 Glossary	11
7.2 Functional Block Diagram	7	12 Mechanical, Packaging, and Orderable	
7.3 Feature Description.....	7	Information	11

4 Revision History

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

DATE	REVISION	NOTES
June 2017	*	Initial release.

5 Pin Configuration and Functions



Pin Functions

PIN		I/O	DESCRIPTION	
NAME	SOIC, CDIP			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, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	N/A	No Connect (No Internal Connection)

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

THERMAL METRIC ⁽¹⁾	LM193-MIL		UNIT	
	JG (CDIP)	FK (LCCC)		
	8 PINS	20 PINS		
R _{θJC(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.

6.5 Electrical Characteristics

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

PARAMETER	TEST CONDITIONS	$T_A^{(1)}$	LM193-MIL			UNIT	
			MIN	TYP	MAX		
V_{IO} Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$, $V_{IC} = V_{ICR\text{ min}}$, $V_O = 1.4\text{ V}$	25°C		2	5	mV	
		Full range			9		
I_{IO} Input offset current	$V_O = 1.4\text{ V}$	25°C		3	25	nA	
		Full range			100		
I_{IB} Input bias current	$V_O = 1.4\text{ V}$	25°C		-25	-100	nA	
		Full range			-300		
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	$V_{CC} = 15\text{ V}$, $V_O = 1.4\text{ V to }11.4\text{ V}$, $R_L \geq 15\text{ k}\Omega\text{ to }V_{CC}$	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	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		150	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	$R_L = \infty$	$V_{CC} = 5\text{ V}$	25°C		0.8	1	mA
		$V_{CC} = 30\text{ V}$	Full range			2.5	

- (1) Full range (minimum or maximum) for LM193-MIL is -55°C to 125°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.

6.6 Switching Characteristics

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

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

6.7 Typical Characteristics

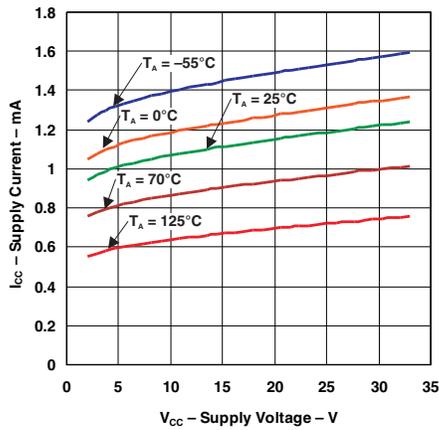


Figure 1. Supply Current vs Supply Voltage

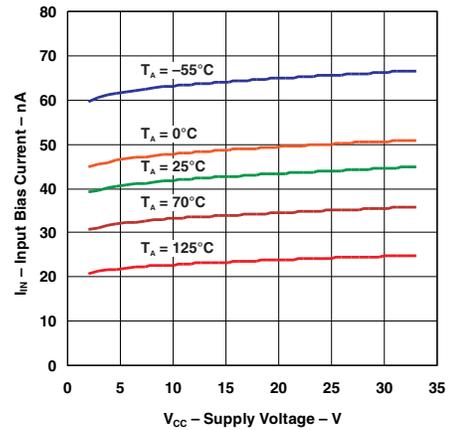


Figure 2. Input Bias Current vs Supply Voltage

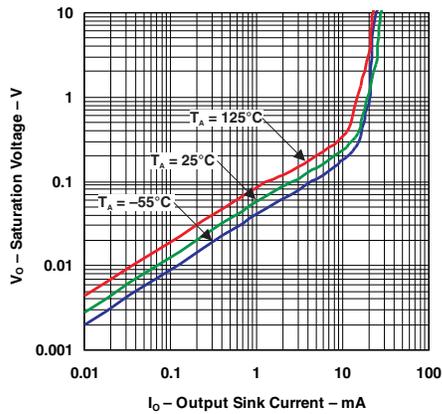


Figure 3. Output Saturation Voltage

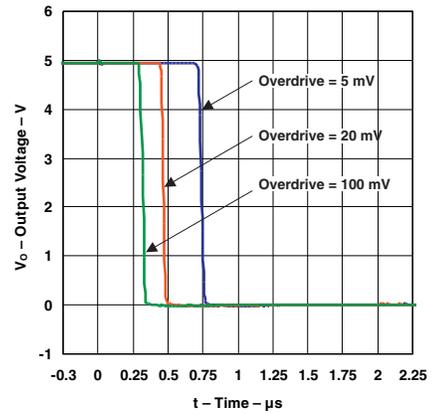


Figure 4. Response Time for Various Overdrives Negative Transition

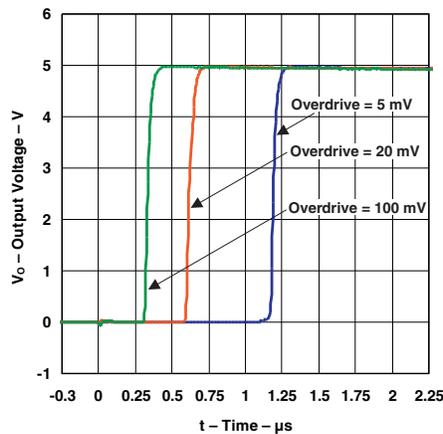


Figure 5. Response Time for Various Overdrives Positive Transition

7 Detailed Description

7.1 Overview

The dual comparator has 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 device.

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

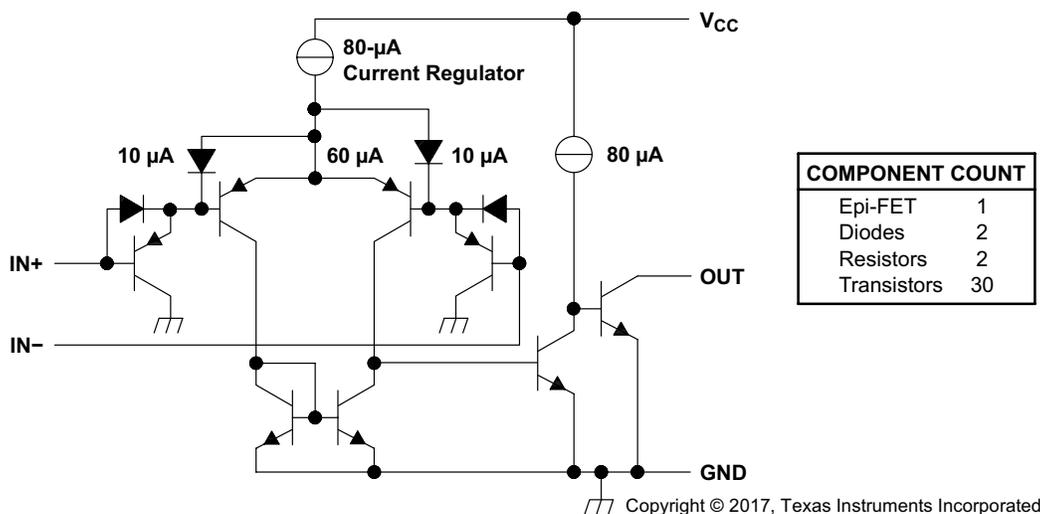


Figure 6. Schematic (Each Comparator)

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

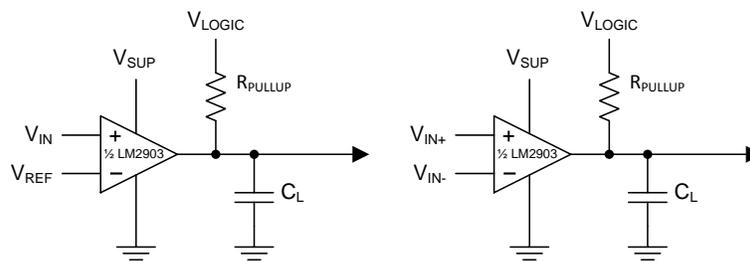
NOTE

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



Copyright © 2017, Texas Instruments Incorporated

Figure 7. Single-Ended and Differential Comparator Configurations Using the LM2903

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 $V_{sup}-2$ V
Supply Voltage	4.5 V to V_{CC} maximum
Logic Supply Voltage	0 V to V_{CC} maximum
Output Current (R_{PULLUP})	1 μ A to 4 mA
Input Overdrive Voltage	100 mV
Reference Voltage	2.5 V
Load Capacitance (C_L)	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.

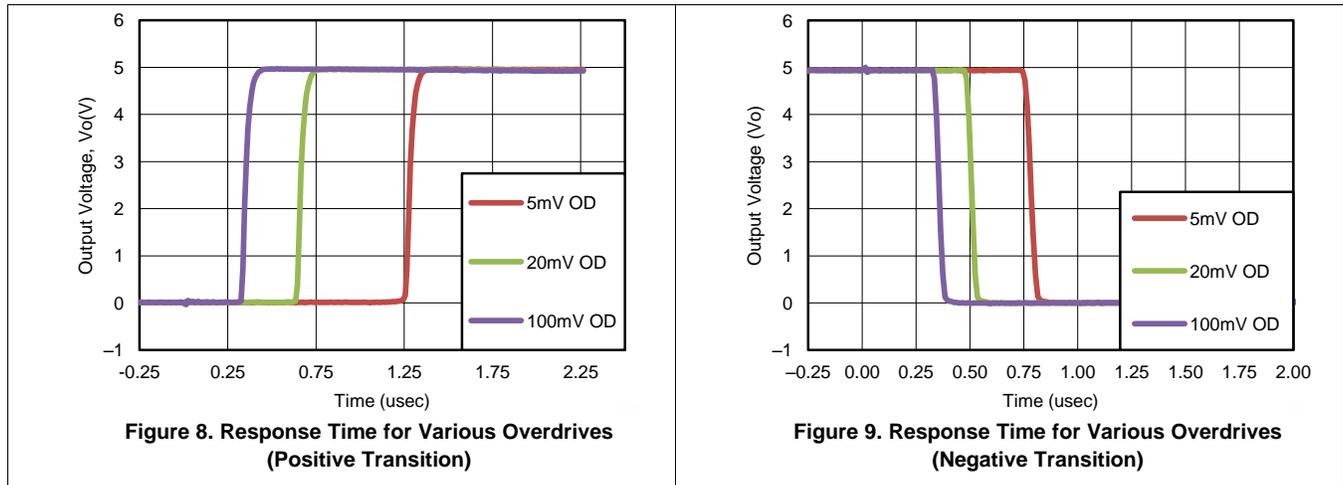
8.2.2.4 Response Time

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.



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 device'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

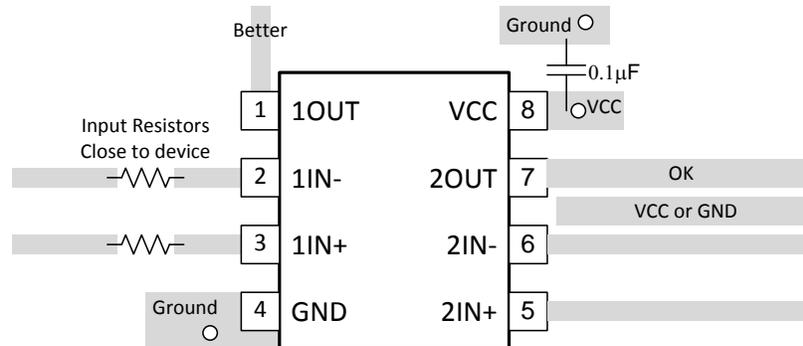


Figure 10. LM2903 Layout Example Used as an Example

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				
LM293	Click here				
LM293A	Click here				
LM393	Click here				
LM393A	Click here				
LM2903	Click here				
LM2903V	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 part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
5962-9452601Q2A	Active	Production	LCCC (FK) 20	55 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	5962- 9452601Q2A LM193FKB
5962-9452601QPA	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9452601QPA LM193
JM38510/11202BPA	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	JM38510 /11202BPA
JM38510/11202BPA.A	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	JM38510 /11202BPA
LM193FKB	Active	Production	LCCC (FK) 20	55 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	5962- 9452601Q2A LM193FKB
LM193FKB.A	Active	Production	LCCC (FK) 20	55 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	5962- 9452601Q2A LM193FKB
LM193JG	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	LM193JG
LM193JG.A	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	LM193JG
LM193JGB	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9452601QPA LM193
LM193JGB.A	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9452601QPA LM193
M38510/11202BPA	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	JM38510 /11202BPA

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

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

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

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

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

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

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

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.

GENERIC PACKAGE VIEW

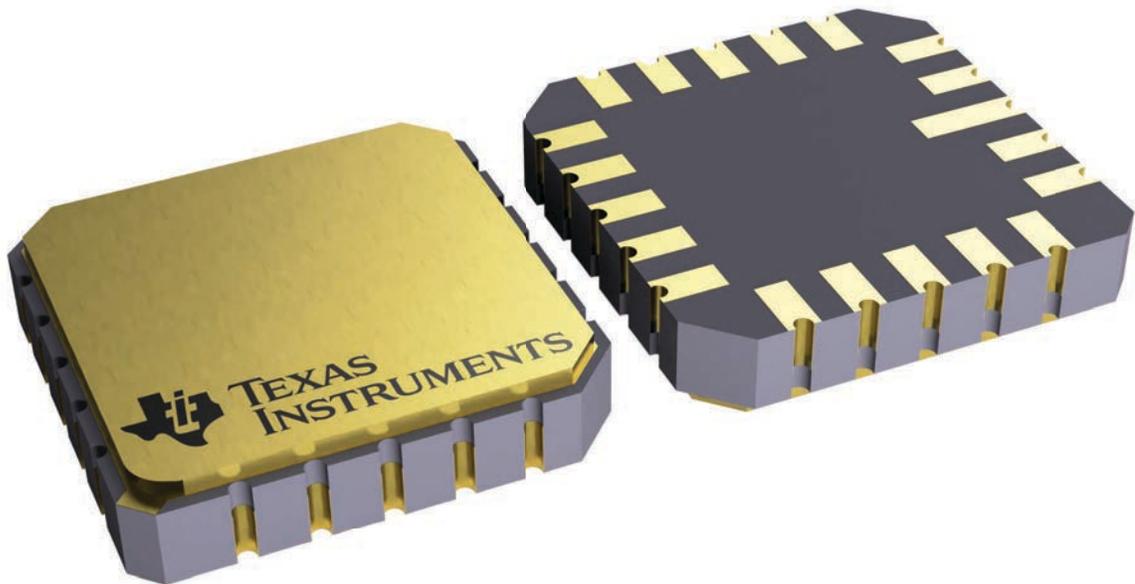
FK 20

LCCC - 2.03 mm max height

8.89 x 8.89, 1.27 mm pitch

LEADLESS CERAMIC CHIP CARRIER

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



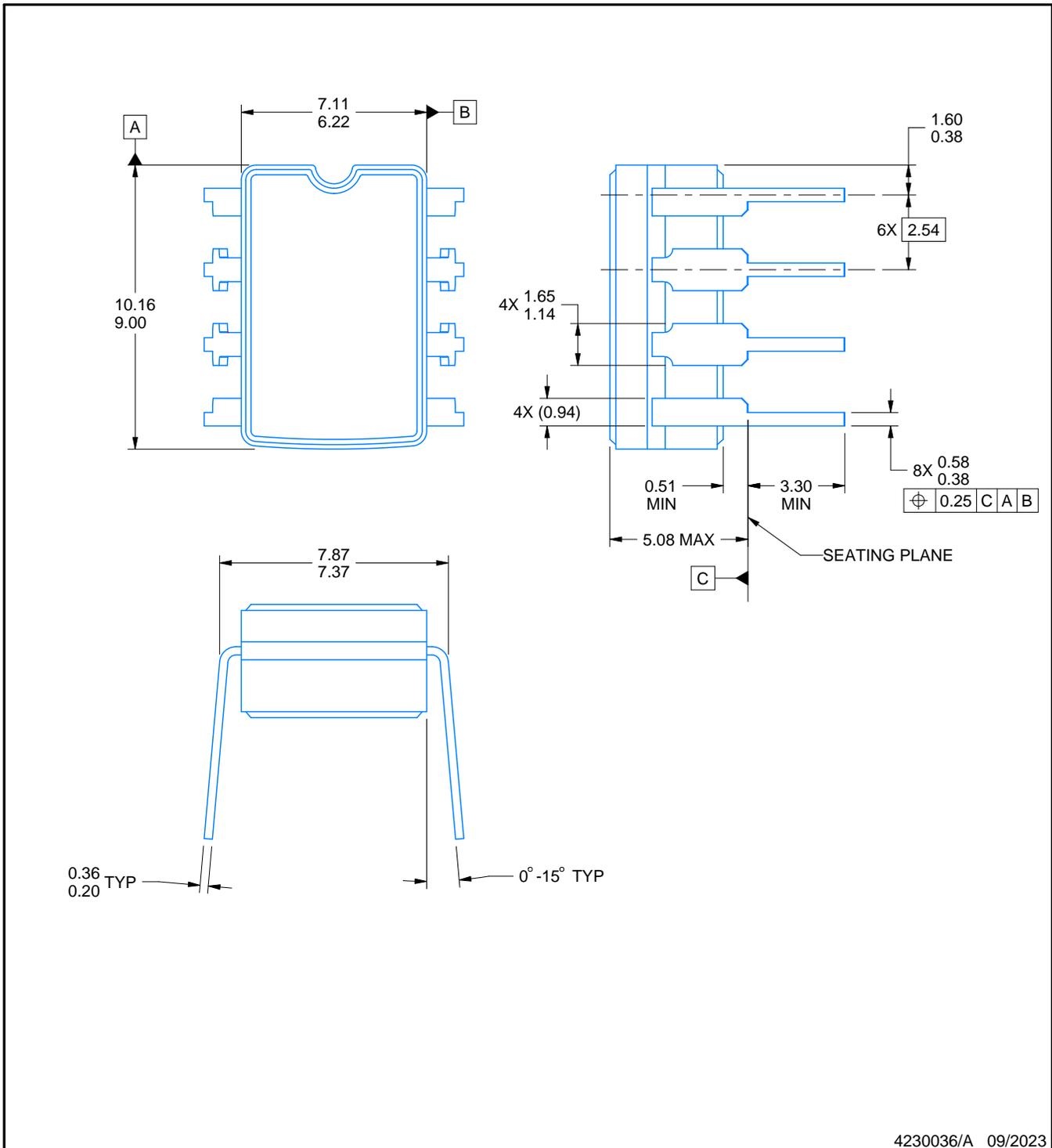
4229370VA\

PACKAGE OUTLINE

JG0008A

CDIP - 5.08 mm max height

CERAMIC DUAL IN-LINE PACKAGE



4230036/A 09/2023

NOTES:

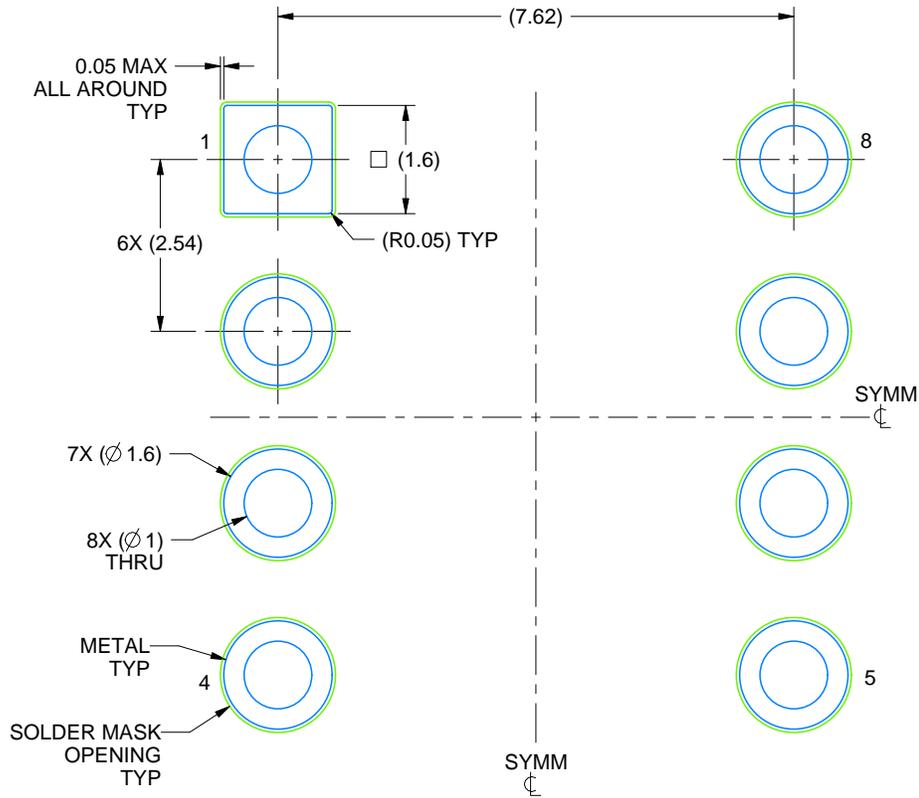
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package can be hermetically sealed with a ceramic lid using glass frit.
4. Index point is provided on cap for terminal identification.
5. Falls within MIL STD 1835 GDIP1-T8

EXAMPLE BOARD LAYOUT

JG0008A

CDIP - 5.08 mm max height

CERAMIC DUAL IN-LINE PACKAGE



LAND PATTERN EXAMPLE
NON SOLDER MASK DEFINED
SCALE: 9X

4230036/A 09/2023

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#), [TI's General Quality Guidelines](#), or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025