

## LM393-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
- Low Supply-Current Drain Independent of Supply Voltage: 0.4 mA (Typical) Per Comparator
- Low Input Bias Current: 25 nA (Typical)
- Low Input Offset Voltage: 2 mV (Typical)
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage:  $\pm 36$  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.

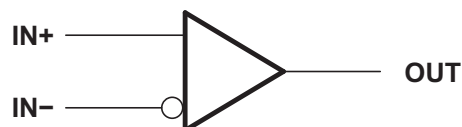
The LM393-MIL device is characterized for operation from 0°C to 70°C.

#### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM393-MILD	SOIC (8)	4.90 mm x 6.00 mm
LM393-MILDGK	VSSOP (8)	3.00 mm x 5.00 mm
LM393-MILP	PDIP (8)	9.50 mm x 6.30 mm
LM393-MILPS	SO (8)	6.20 mm x 7.90 mm
LM393-MILPW	TSSOP (8)	6.40 mm x 3.00 mm

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

#### Simplified Schematic



## Table of Contents

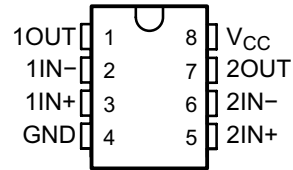
<b>1 Features</b> .....	<b>1</b>	7.3 Feature Description .....	<b>7</b>
<b>2 Applications</b> .....	<b>1</b>	7.4 Device Functional Modes .....	<b>7</b>
<b>3 Description</b> .....	<b>1</b>	<b>8 Application and Implementation</b> .....	<b>8</b>
<b>4 Revision History</b> .....	<b>2</b>	8.1 Application Information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

## 4 Revision History

DATE	REVISION	NOTES
June 2017	*	Initial release.

## 5 Pin Configuration and Functions

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



### Pin Functions

PIN		I/O	DESCRIPTION
NAME	SOIC, VSSOP, PDIP, SO, and TSSOP		
1OUT	1	Output	Output pin of comparator 1
1IN-	2	Input	Negative input pin of comparator 1
1IN+	3	Input	Positive input pin of comparator 1
GND	4	—	Ground
2IN+	5	Input	Positive input pin of comparator 2
2IN-	6	Input	Negative input pin of comparator 2
2OUT	7	Output	Output pin of comparator 2
V <sub>CC</sub>	8	—	Supply Pin

## 6 Specifications

### 6.1 Absolute Maximum Ratings

 over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage <sup>(2)</sup>		36	V
V <sub>ID</sub>	Differential input voltage <sup>(3)</sup>		±36	V
V <sub>I</sub>	Input voltage (either input)	–0.3	36	V
V <sub>O</sub>	Output voltage		36	V
I <sub>O</sub>	Output current		20	mA
	Duration of output short circuit to ground <sup>(4)</sup>		Unlimited	
T <sub>J</sub>	Operating virtual-junction temperature		300	°C
T <sub>stg</sub>	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) Short circuits from outputs to V<sub>CC</sub> can cause excessive heating and eventual destruction.

### 6.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	1000
		Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	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 <sub>CC</sub>		2	30	V
T <sub>J</sub>	Operating junction temperature	–40	125	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		LM393-MIL					UNIT
		D (SOIC)	DGK (VSSOP)	P (PDIP)	PS (SO)	PW (TSSOP)	
		8 PINS	8 PINS	8 PINS	8 PINS	8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	97	172	85	95	149	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	—	—	—	—	—	°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		MIN	TYP	MAX	UNIT	
$V_{IO}$	Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$ , $V_O = 1.4\text{ V}$		$T_A = 25^\circ\text{C}$	2	5	mV	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		9		
$I_{IO}$	Input offset current	$V_O = 1.4\text{ V}$		$T_A = 25^\circ\text{C}$	5	50	nA	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		250		
$I_{IB}$	Input bias current	$V_O = 1.4\text{ V}$		$T_A = 25^\circ\text{C}$	-25	-250	nA	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		-400		
$V_{ICR}$	Common-mode input-voltage range <sup>(1)</sup>			$T_A = 25^\circ\text{C}$	0 to $V_{CC} - 1.5$		V	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$	0 to $V_{CC} - 2$			
$A_{VD}$	Large-signal differential-voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1.4\text{ V to }11.4\text{ V}$ , $R_L \geq 15\text{ k}\Omega\text{ to }V_{CC}$		$T_A = 25^\circ\text{C}$	50	200	V/mV	
$I_{OH}$	High-level output current	$V_{OH} = 5\text{ V}$	$V_{ID} = 1\text{ V}$	$T_A = 25^\circ\text{C}$	0.1	50	nA	
		$V_{OH} = 30\text{ V}$	$V_{ID} = 1\text{ V}$	$T_A = 0^\circ\text{C to }70^\circ\text{C}$		1	$\mu\text{A}$	
$V_{OL}$	Low-level output voltage	$I_{OL} = 4\text{ mA}$ , $V_{ID} = -1\text{ V}$		$T_A = 25^\circ\text{C}$	150	400	mV	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		700		
$I_{OL}$	Low-level output current	$V_{OL} = 1.5\text{ V}$ , $V_{ID} = -1\text{ V}$		$T_A = 25^\circ\text{C}$	6		mA	
$I_{CC}$	Supply current	$R_L = \infty$		$V_{CC} = 5\text{ V}$	$T_A = 25^\circ\text{C}$	0.8	1	mA
				$V_{CC} = 30\text{ V}$	$T_A = 0^\circ\text{C to }70^\circ\text{C}$		2.5	
$V_{IO}$	Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$ , $V_O = 1.4\text{ V}$ $V_{IC} = V_{ICR(\text{min})}$		$T_A = 25^\circ\text{C}$	1	2	mV	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		4		
$I_{IO}$	Input offset current	$V_O = 1.4\text{ V}$		$T_A = 25^\circ\text{C}$	5	50	nA	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		150		
$I_{IB}$	Input bias current	$V_O = 1.4\text{ V}$		$T_A = 25^\circ\text{C}$	-25	-250	nA	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		-400		
$V_{ICR}$	Common-mode input-voltage range <sup>(1)</sup>			$T_A = 25^\circ\text{C}$	0 to $V_{CC} - 1.5$		V	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$	0 to $V_{CC} - 2$			
$A_{VD}$	Large-signal differential-voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1.4\text{ V to }11.4\text{ V}$ , $R_L \geq 15\text{ k}\Omega\text{ to }V_{CC}$		$T_A = 25^\circ\text{C}$	50	200	V/mV	
$I_{OH}$	High-level output current	$V_{OH} = 5\text{ V}$	$V_{ID} = 1\text{ V}$	$T_A = 25^\circ\text{C}$	0.1	50	nA	
		$V_{OH} = 30\text{ V}$	$V_{ID} = 1\text{ V}$	$T_A = 0^\circ\text{C to }70^\circ\text{C}$		1	$\mu\text{A}$	
$V_{OL}$	Low-level output voltage	$I_{OL} = 4\text{ mA}$ , $V_{ID} = -1\text{ V}$		$T_A = 25^\circ\text{C}$	150	400	mV	
				$T_A = 0^\circ\text{C to }70^\circ\text{C}$		700		
$I_{OL}$	Low-level output current	$V_{OL} = 1.5\text{ V}$ , $V_{ID} = -1\text{ V}$		$T_A = 25^\circ\text{C}$	6		mA	
$I_{CC}$	Supply current (four comparators)	$R_L = \infty$		$V_{CC} = 5\text{ V}$	$T_A = 25^\circ\text{C}$	0.8	1	mA
				$V_{CC} = 30\text{ V}$	$T_A = 0^\circ\text{C to }70^\circ\text{C}$		2.5	

(1) The voltage at either input or common-mode should not be allowed to go negative by more than 0.3 V. The upper end of the common-mode voltage range is  $V_{CC+} - 1.5\text{ V}$ , but either or both inputs can go to 30 V 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 $\Omega$ , $C_L = 15\text{ pF}$ <sup>(1)(2)</sup>	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

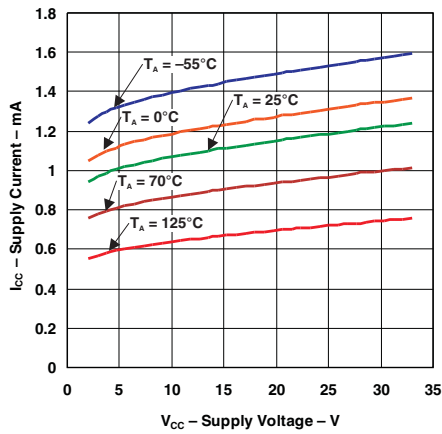


Figure 1. Supply Current vs Supply Voltage

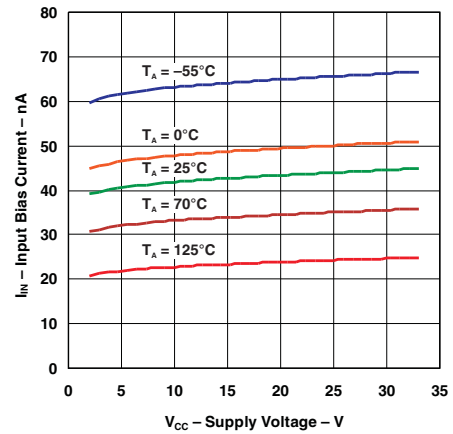


Figure 2. Input Bias Current vs Supply Voltage

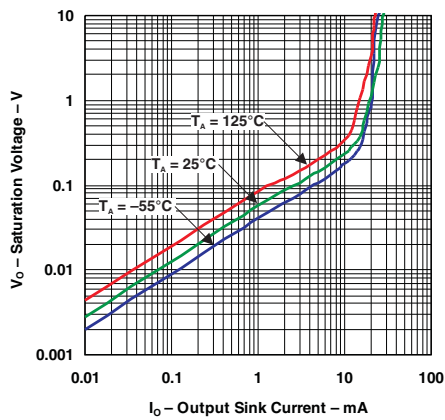


Figure 3. Output Saturation Voltage

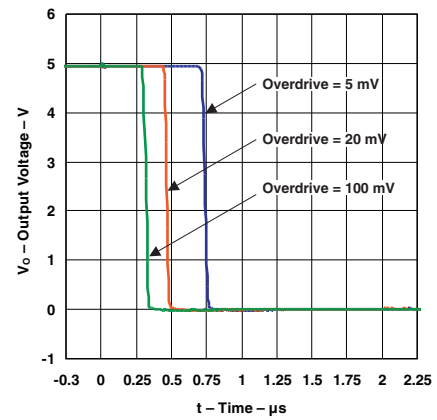


Figure 4. Response Time for Various Overdrives Negative Transition

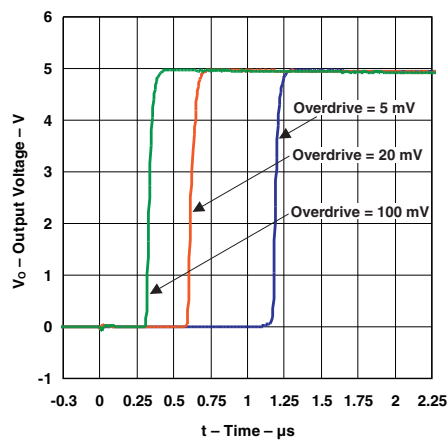


Figure 5. Response Time for Various Overdrives Positive Transition

## 7 Detailed Description

### 7.1 Overview

The LM393-MIL is a dual comparator with the ability to operate up to 36 V on the supply pin. This standard 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<sub>q</sub> and fast response of the devices.

The open-drain output allows the user to configure the output logic low voltage (V<sub>OL</sub>) and can be used to enable the comparator to be used in AND functionality.

### 7.2 Functional Block Diagram

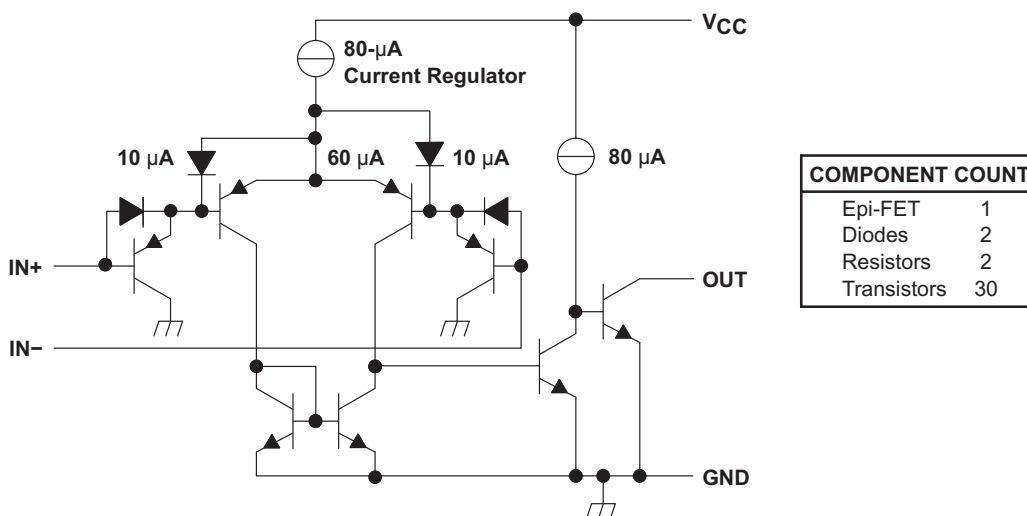


Figure 6. Schematic (Each Comparator)

### 7.3 Feature Description

LM393-MIL 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 LM393-MIL to accurately function from ground to V<sub>CC</sub>–1.5V differential input. This enables much head room for modern day supplies of 3.3 V and 5 V.

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

### 7.4 Device Functional Modes

#### 7.4.1 Voltage Comparison

The LM393-MIL 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

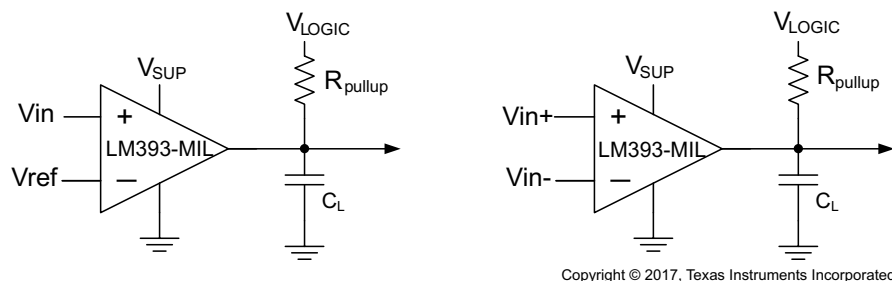
### NOTE

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

LM393-MIL 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 LM393-MIL 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**

#### 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-1.5 V
Supply Voltage	2 V to 36 V
Logic Supply Voltage	2 V to 36 V
Output Current (R <sub>PULLUP</sub> )	1 $\mu$ A to 20 mA
Input Overdrive Voltage	100 mV
Reference Voltage	2.5 V
Load Capacitance (C <sub>L</sub> )	15 pF

#### 8.2.2 Detailed Design Procedure

When using LM393-MIL 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 above or 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.



Below 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.

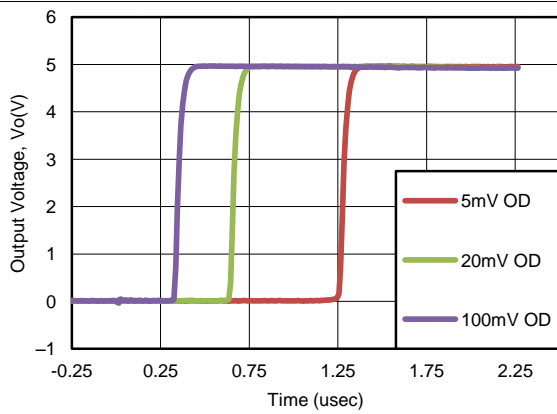
### 8.2.2.4 Response Time

The transient response can be determined by the load capacitance ( $C_L$ ), load/pullup resistance ( $R_{PULLUP}$ ) and equivalent collector-emitter resistance ( $R_{CE}$ ).

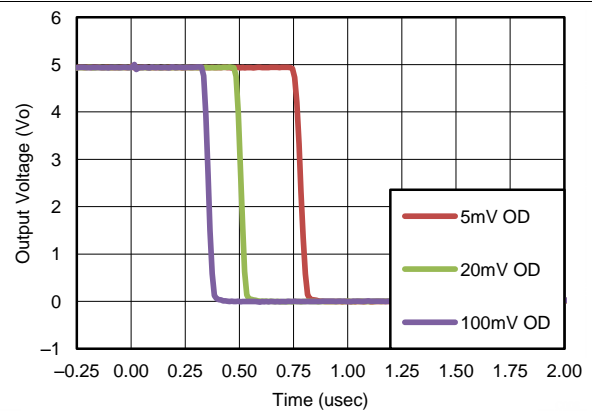
- The positive response time ( $\tau_P$ ) is approximately  $\tau_P \sim R_{PULLUP} \times C_L$
- The negative response time ( $\tau_N$ ) is approximately  $\tau_N \sim R_{CE} \times C_L$ 
  - $R_{CE}$  can be determine by taking the slope of [Typical Characteristics](#) in its linear region at the desired 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, which can affect the high level input common-mode voltage range. 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 GND pin and system ground.

### 10.2 Layout Example

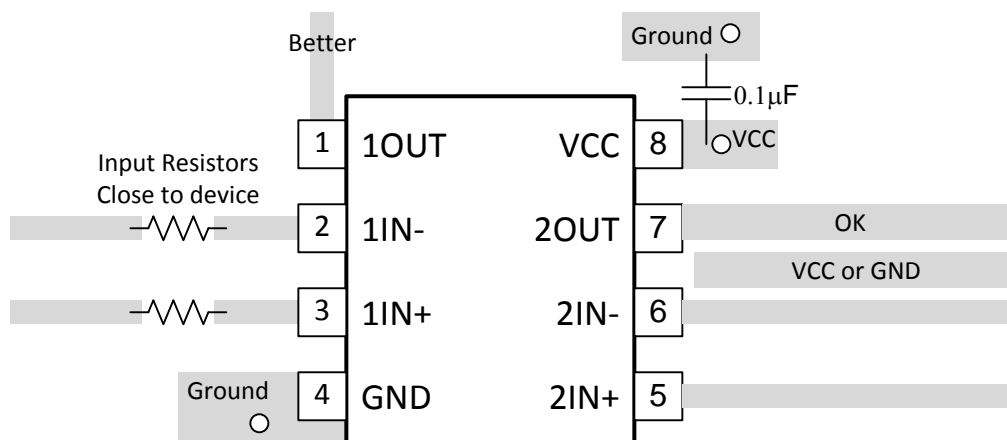


Figure 10. LM393-MIL Layout Example

## 11 Device and Documentation Support

### 11.1 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.

### 11.2 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.

### 11.3 Trademarks

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

### 11.4 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.

### 11.5 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)
LM393 MDC	Active	Production	DIESALE (Y)   0	400   NOT REQUIRED	Yes	Call TI	Level-1-NA-UNLIM	-40 to 85	

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

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

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

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

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

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

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

**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.

## 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 © 2025, Texas Instruments Incorporated

Last updated 10/2025