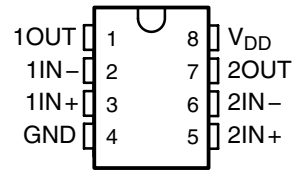


# TLC393-Q1 DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATOR

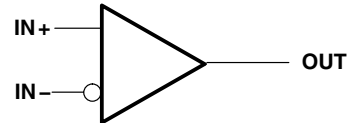
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- **Qualified for Automotive Applications**
- **ESD Protection Exceeds 500 V Per MIL-STD-883, Method 3015; Exceeds 50 V Using Machine Model (C = 200 pF, R = 0)**
- **Low Power . . . 110  $\mu$ W Typ at 5 V**
- **Fast Response Time . . .  $t_{PLH} = 2.5 \mu$ s Typ With 5-mV Overdrive**
- **Single Supply Operation:  
TLC393Q . . . 4 V to 16 V**

**D OR PW PACKAGE  
(TOP VIEW)**



**symbol (each comparator)**



## description/ordering information

The TLC393 consists of dual independent micropower voltage comparators designed to operate from a single supply. It is functionally similar to the LM393 but uses one-twentieth the power for similar response times. The open-drain MOS output stage interfaces to a variety of loads and supplies. For a similar device with a push-pull output configuration see the TLC3702 data sheet.

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

The TLC393Q is characterized for operation over the full automotive temperature range of  $T_A = -40^\circ\text{C}$  to  $125^\circ\text{C}$ .

## ORDERING INFORMATION†

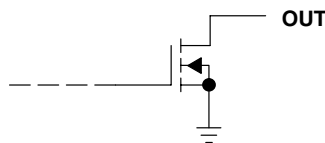
| $T_A$                                      | $V_{IO,max}$<br>AT $25^\circ\text{C}$ | PACKAGE‡   |               | ORDERABLE<br>PART NUMBER | TOP-SIDE<br>MARKING |
|--|---------------------------------------|------------|---------------|--------------------------|---------------------|
| $-40^\circ\text{C}$ to $125^\circ\text{C}$ | 5 mV                                  | SOIC (D)   | Tape and reel | TLC393QDRQ1              | C393Q1              |
|  |                                       | TSSOP (PW) | Tape and reel | TLC393QPWRQ1§            |                     |

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at <http://www.ti.com>.

‡ Package drawings, thermal data, and symbolization are available at <http://www.ti.com/packaging>.

§ Product Preview

## schematic



**OPEN-DRAIN CMOS OUTPUT**



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

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS  
INSTRUMENTS**

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# TLC393-Q1

## DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATOR

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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

|   |                    |
|---|--------------------|
| Supply voltage range, $V_{DD}$ (see Note 1)                             | –0.3 V to 18 V     |
| Differential input voltage, $V_{ID}$ (see Note 2)                       | ±18 V              |
| Input voltage range, $V_I$  | –0.3 V to $V_{DD}$ |
| Output voltage range, $V_O$   | –0.3 V to 16 V     |
| Input current, $I_I$  | ±5 mA              |
| Output current, $I_O$ (each output)                                     | 20 mA              |
| Total supply current into $V_{DD}$                                      | 40 mA              |
| Total current out of GND  | 40 mA              |
| Package thermal impedance, $\theta_{JA}$ (see Notes 3 and 4): D package | 126°C/W            |
| PW package  | 149°C/W            |
| Operating free-air temperature range: TLC393Q                           | –40°C to 125°C     |
| Storage temperature range   | –65°C to 150°C     |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D package | 260°C              |

† 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.

- NOTES:
1. All voltage values, except differential voltages, are with respect to network ground.
  2. Differential voltages are at  $IN+$  with respect to  $IN-$ .
  3. Maximum power dissipation is a function of  $T_J(\text{max})$ ,  $\theta_{JA}$ , and  $T_A$ . The maximum allowable power dissipation at any allowable ambient temperature is  $P_D = (T_J(\text{max}) - T_A)/\theta_{JA}$ . Operating at the absolute maximum  $T_J$  of 150°C can affect reliability.
  4. The package thermal impedance is calculated in accordance with JESD 51-7.

### recommended operating conditions

|                                       | MIN | NOM | MAX            | UNIT |
|---------------------------------------|-----|-----|----------------|------|
| Supply voltage, $V_{DD}$              | 4   | 5   | 16             | V    |
| Common-mode input voltage, $V_{IC}$   | 0   |     | $V_{DD} - 1.5$ | V    |
| Low-level output current, $I_{OL}$    |     |     | 20             | mA   |
| Operating free-air temperature, $T_A$ | –40 |     | 125            | °C   |



# TLC393-Q1

## DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATOR

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**electrical characteristics at specified operating free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER |                                   | TEST CONDITIONS†  | $T_A$          | MIN                 | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|----------------|---------------------|-----|-----|------|
| $V_{IO}$  | Input offset voltage              | $V_{IC} = V_{ICRmin}$ ,<br>$V_{DD} = 5\text{ V to }10\text{ V}$ ,<br>See Note 4 | 25°C           |                     | 1.4 | 5   | mV   |
|           |                                   |   | -40°C to 125°C |                     |     | 10  |      |
| $I_{IO}$  | Input offset current              | $V_{IC} = 2.5\text{ V}$   | 25°C           |                     | 1   |     | pA   |
|           |                                   |   | 125°C          |                     |     | 15  | nA   |
| $I_{IB}$  | Input bias current                | $V_{IC} = 2.5\text{ V}$   | 25°C           |                     | 5   |     | pA   |
|           |                                   |   | 125°C          |                     |     | 30  | nA   |
| $V_{ICR}$ | Common-mode input voltage range   |   | 25°C           | 0 to $V_{DD} - 1$   |     |     | V    |
|           |                                   |   | -40°C to 125°C | 0 to $V_{DD} - 1.5$ |     |     |      |
| CMMR      | Common-mode rejection ratio       | $V_{IC} = V_{ICRmin}$   | 25°C           | 84                  |     |     | dB   |
|           |                                   |   | 125°C          | 84                  |     |     |      |
|           |                                   |   | -40°C          | 84                  |     |     |      |
| $k_{SVR}$ | Supply-voltage rejection ratio    | $V_{DD} = 5\text{ V to }10\text{ V}$  | 25°C           | 85                  |     |     | dB   |
|           |                                   |   | 125°C          | 84                  |     |     |      |
|           |                                   |   | -40°C          | 84                  |     |     |      |
| $V_{OL}$  | Low-level output voltage          | $V_{ID} = -1\text{ V}$ , $I_{OL} = 6\text{ mA}$                                 | 25°C           | 300                 | 400 |     | mV   |
|           |                                   |   | 125°C          |                     | 800 |     |      |
| $I_{OH}$  | High-level output current         | $V_{ID} = 1\text{ V}$ , $V_O = 5\text{ V}$                                      | 25°C           | 0.8                 | 40  |     | nA   |
|           |                                   |   | 125°C          |                     | 1   |     | μA   |
| $I_{DD}$  | Supply current (both comparators) | Outputs low, No load  | 25°C           | 22                  | 40  |     | μA   |
|           |                                   |   | -40°C to 125°C |                     |     | 90  |      |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 5: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V (with a 2.5-kΩ load to  $V_{DD}$ ).

# TLC393-Q1

## DUAL MICROWPOWER LinCMOS™ VOLTAGE COMPARATOR

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switching characteristics,  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (see Figure 3)

| PARAMETER  | TEST CONDITIONS                               | MIN                                | TYP  | MAX | UNIT          |
|--|---|------------------------------------|------|-----|---------------|
| $t_{PLH}$ Propagation delay time, low-to-high level output | $f = 10\text{ kHz}$ ,<br>$C_L = 15\text{ pF}$ | Overdrive = 2 mV                   | 4.5  |     | $\mu\text{s}$ |
|  |   | Overdrive = 5 mV                   | 2.5  |     |               |
|  |   | Overdrive = 10 mV                  | 1.7  |     |               |
|  |   | Overdrive = 20 mV                  | 1.2  |     |               |
|  |   | Overdrive = 40 mV                  | 1.1  |     |               |
| $t_{PHL}$ Propagation delay time, high-to-low level output | $f = 10\text{ kHz}$ ,<br>$C_L = 15\text{ pF}$ | $V_I = 1.4\text{-V}$ step at $IN+$ | 1.1  |     | $\mu\text{s}$ |
|  |   | Overdrive = 2 mV                   | 3.6  |     |               |
|  |   | Overdrive = 5 mV                   | 2.1  |     |               |
|  |   | Overdrive = 10 mV                  | 1.3  |     |               |
|  |   | Overdrive = 20 mV                  | 0.85 |     |               |
|  | Overdrive = 40 mV                             | 0.55                               |      |     |               |
| $t_f$ Fall time, output                                    | $f = 10\text{ kHz}$ ,<br>$C_L = 15\text{ pF}$ | Overdrive = 50 mV                  | 22   |     | ns            |

### PARAMETER MEASUREMENT INFORMATION

The TLC393 contains a digital output stage which, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternatives for testing parameters such as input offset voltage, common-mode rejection ratio, etc., are suggested.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the  $V_{ICR}$  test, rather than changing the input voltages, to provide greater accuracy.

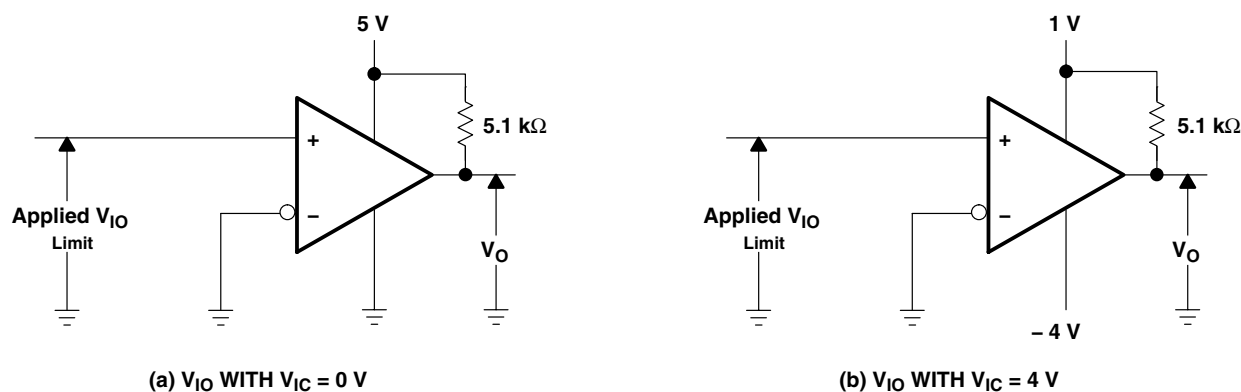


Figure 1. Method for Verifying That Input Offset Voltage Is Within Specified Limits

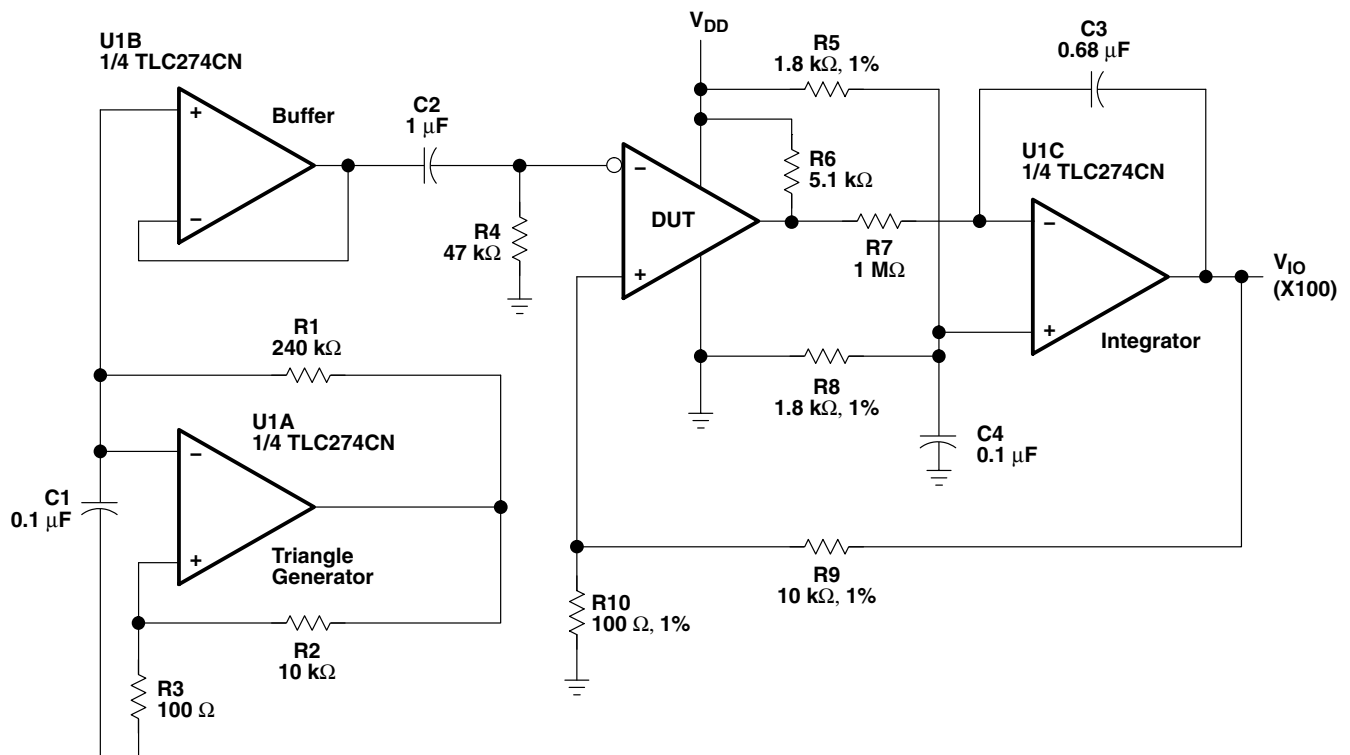
### PARAMETER MEASUREMENT INFORMATION

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output changes states.

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator in the linear region. The circuit consists of a switching-mode servo loop in which U1A generates a triangular waveform of approximately 20-mV amplitude. U1B acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1C through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is sliced symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

The voltage divider formed by R9 and R10 provides an increase in input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.



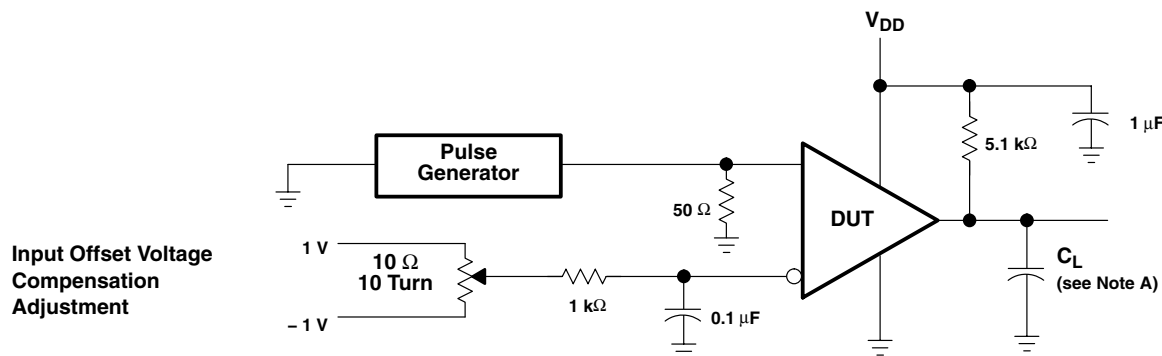
**Figure 2. Circuit for Input Offset Voltage Measurement**

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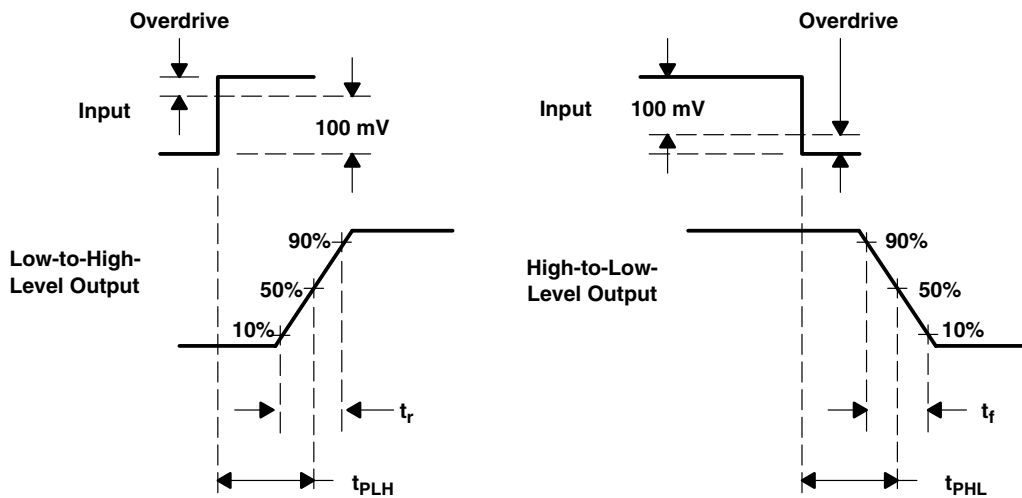
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## PARAMETER MEASUREMENT INFORMATION

Propagation delay time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Propagation delay time, low-to-high level output, is measured from the leading edge of the input pulse, while propagation delay time, high-to-low level output, is measured from the trailing edge of the input pulse. Propagation delay time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example, 105 mV or 5 mV overdrive, causes the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 3. Propagation Delay, Rise Time, and Fall Time Circuit and Voltage Waveforms

### TYPICAL CHARACTERISTICS

Table of Graphs

|           |   |   | FIGURE   |
|-----------|---|---|----------|
| $V_{IO}$  | Input offset voltage                            | Distribution  | 4        |
| $I_{IB}$  | Input bias current                              | vs Free-air temperature                                 | 5        |
| CMRR      | Common-mode rejection ratio                     | vs Free-air temperature                                 | 6        |
| $k_{SVR}$ | Supply-voltage rejection ratio                  | vs Free-air temperature                                 | 7        |
| $V_{OL}$  | Low-level output voltage                        | vs Low-level output current<br>vs Free-air temperature  | 8<br>9   |
| $I_{OH}$  | Low-level output current                        | vs High-level output voltage<br>vs Free-air temperature | 10<br>11 |
| $I_{DD}$  | Supply current                                  | vs Supply voltage<br>vs Free-air temperature            | 12<br>13 |
| $t_{PLH}$ | Low-to-high level output propagation delay time | vs Supply voltage                                       | 14       |
| $t_{PHL}$ | High-to-low level output propagation delay time | vs Supply voltage                                       | 15       |
|           | Low-to-high-level output response               | Low-to-high level output propagation delay time         | 16       |
|           | High-to-low level output response               | High-to-low level output propagation delay time         | 17       |
| $t_f$     | Fall time                                       | vs Supply voltage                                       | 18       |

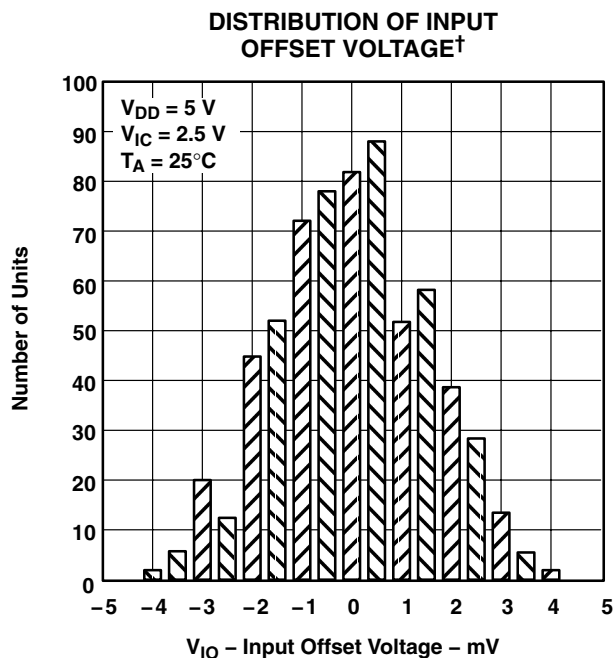


Figure 4

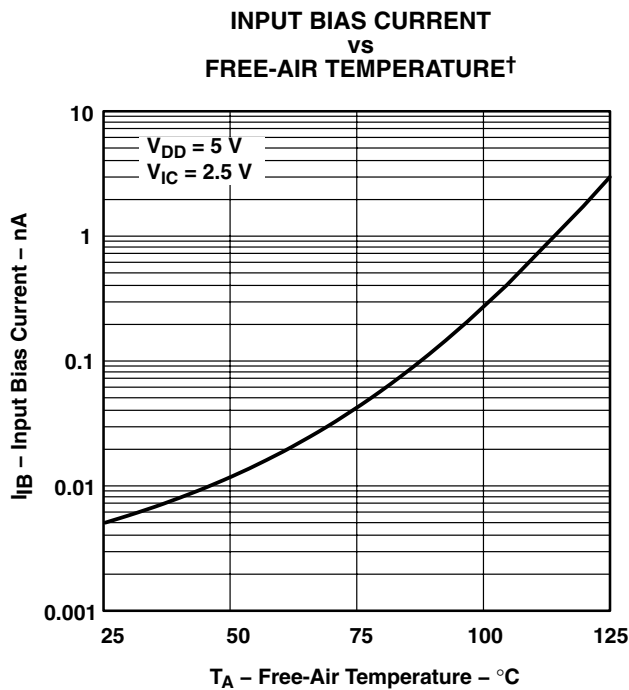


Figure 5

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TLC393-Q1 DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATOR

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## TYPICAL CHARACTERISTICS†

COMMON-MODE REJECTION RATIO  
vs  
FREE-AIR TEMPERATURE

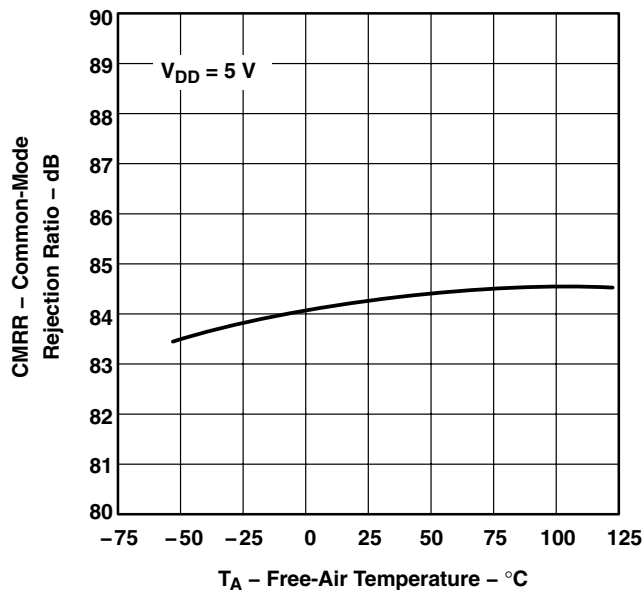


Figure 6

SUPPLY VOLTAGE REJECTION RATIO  
vs  
FREE-AIR TEMPERATURE

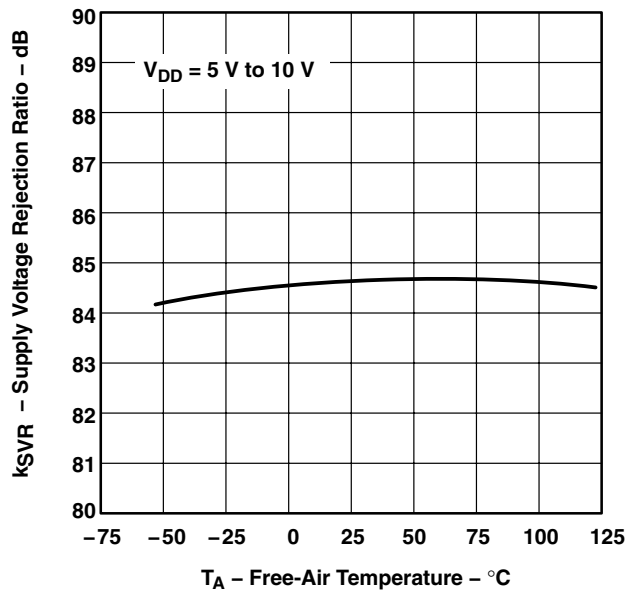


Figure 7

LOW-LEVEL OUTPUT VOLTAGE  
vs  
LOW-LEVEL OUTPUT CURRENT

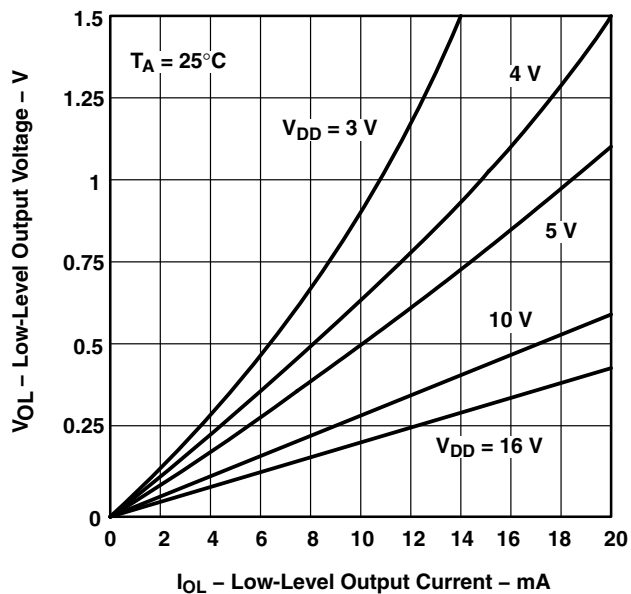


Figure 8

LOW-LEVEL OUTPUT VOLTAGE  
vs  
FREE-AIR TEMPERATURE

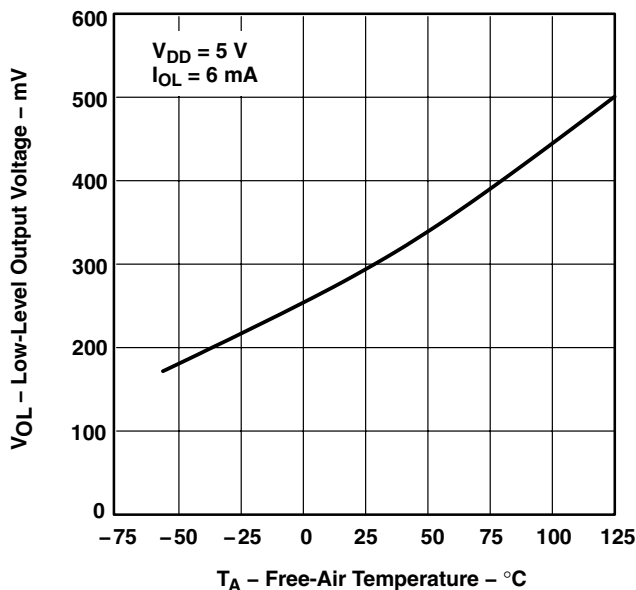


Figure 9

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





TYPICAL CHARACTERISTICS†

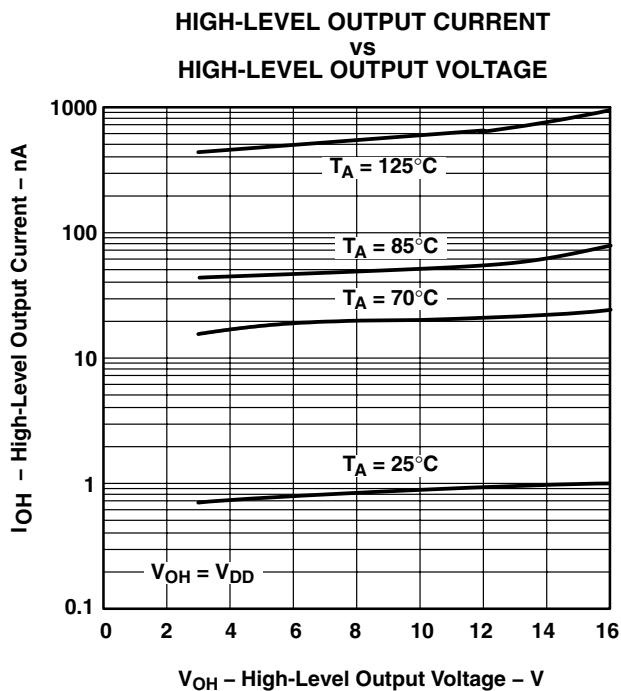


Figure 10

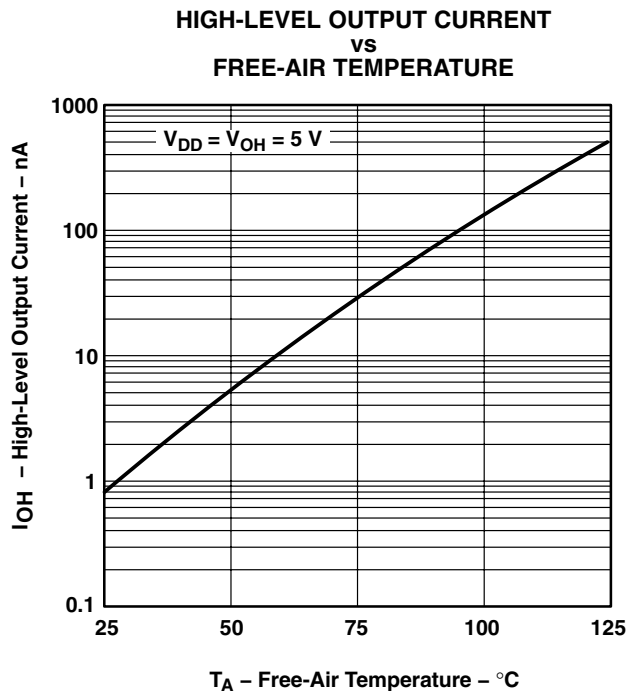


Figure 11

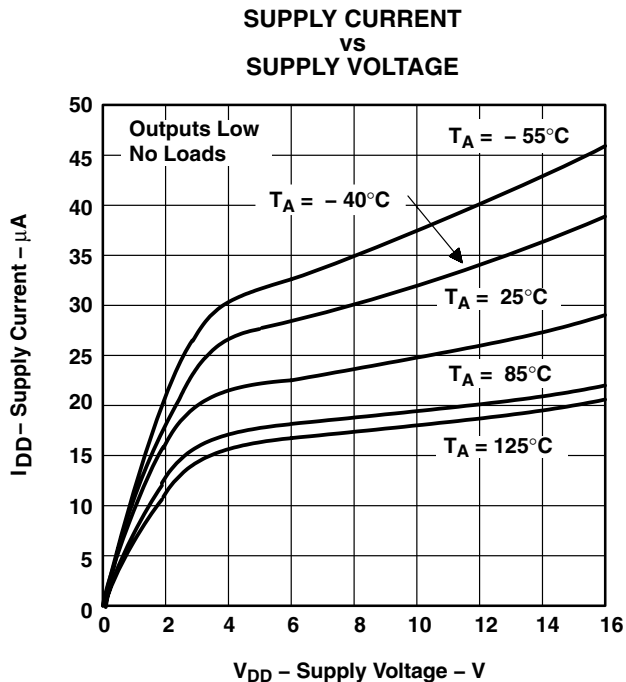


Figure 12

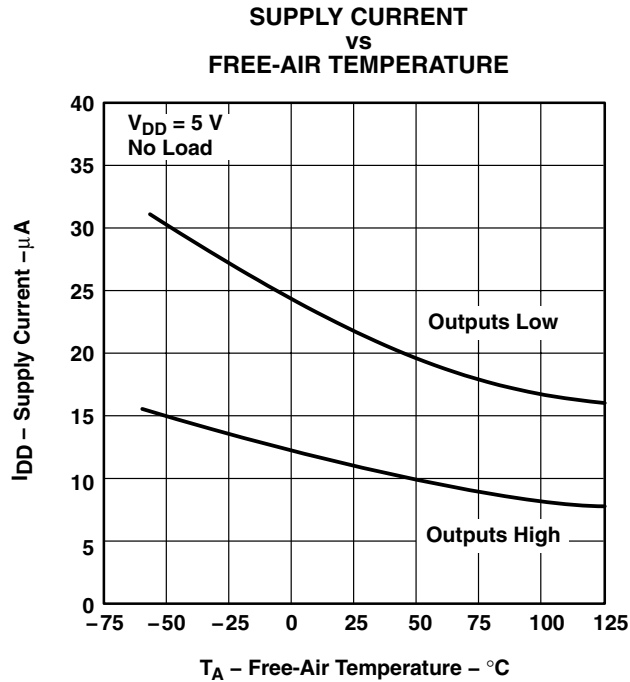


Figure 13

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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## TYPICAL CHARACTERISTICS

LOW-TO-HIGH-LEVEL  
OUTPUT RESPONSE TIME  
VS  
SUPPLY VOLTAGE

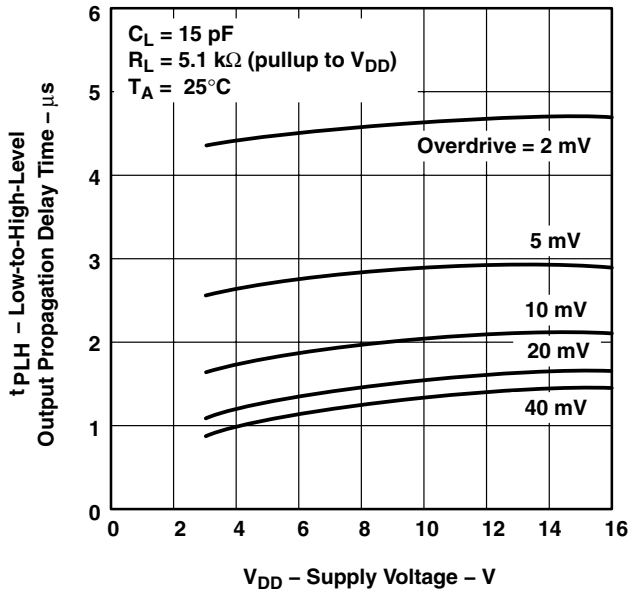


Figure 14

HIGH-TO-LOW-LEVEL  
OUTPUT RESPONSE TIME  
VS  
SUPPLY VOLTAGE

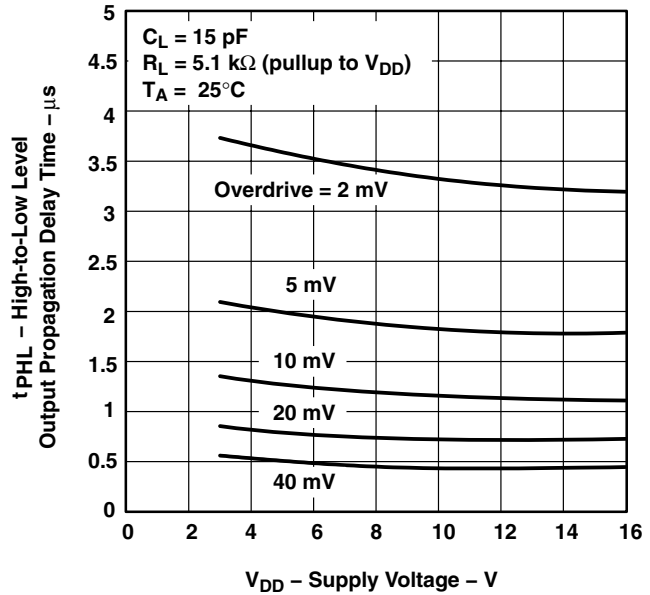


Figure 15

LOW-TO-HIGH-LEVEL OUTPUT  
PROPAGATION DELAY  
FOR VARIOUS INPUT OVERDRIVES

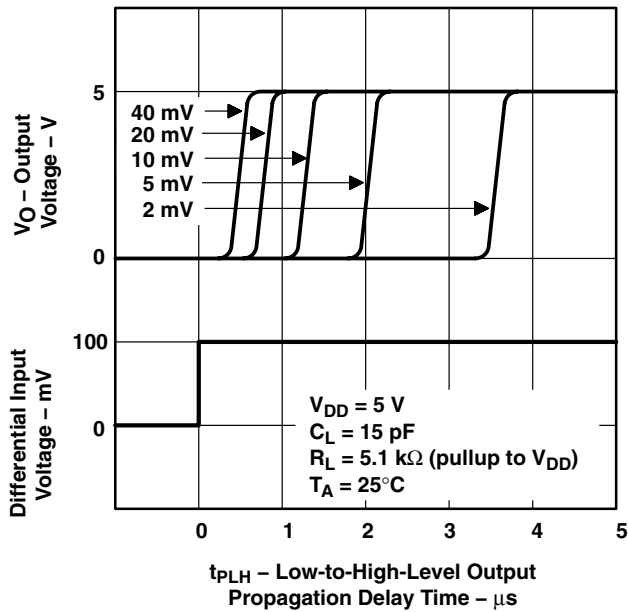


Figure 16

HIGH-TO-LOW-LEVEL OUTPUT  
PROPAGATION DELAY  
FOR VARIOUS INPUT OVERDRIVES

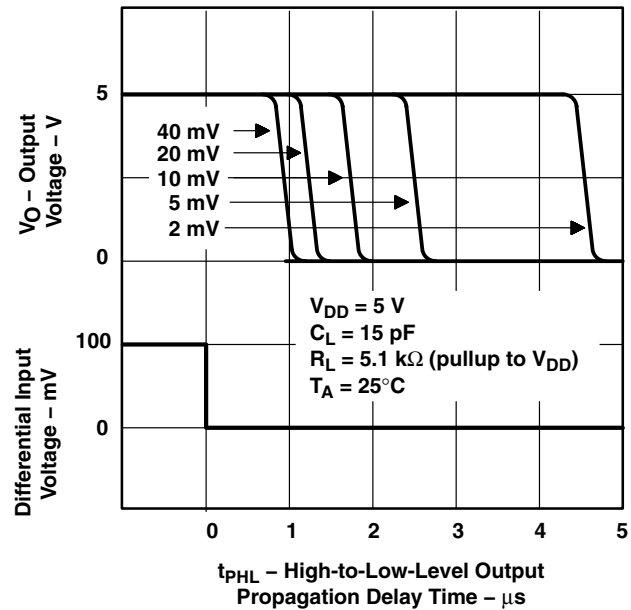
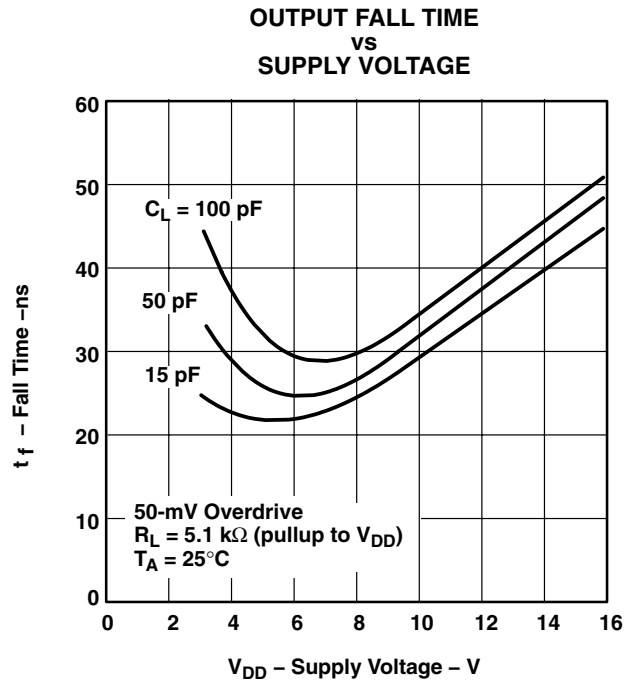


Figure 17

**TYPICAL CHARACTERISTICS**



**Figure 18**

**APPLICATION INFORMATION**

The input should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either input exceeds this range, the device will not be damaged as long as the input current is limited to less than 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with  $V_{DD} = 5\text{ V}$ , both inputs must remain between  $-0.2\text{ V}$  and  $4\text{ V}$  to assure proper device operation.

To assure reliable operation, the supply should be decoupled with a capacitor ( $0.1\text{-}\mu\text{F}$ ) positioned as close to the device as possible.

The TLC393 has internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices, as exposure to ESD may result in the degradation of the device parametric performance.

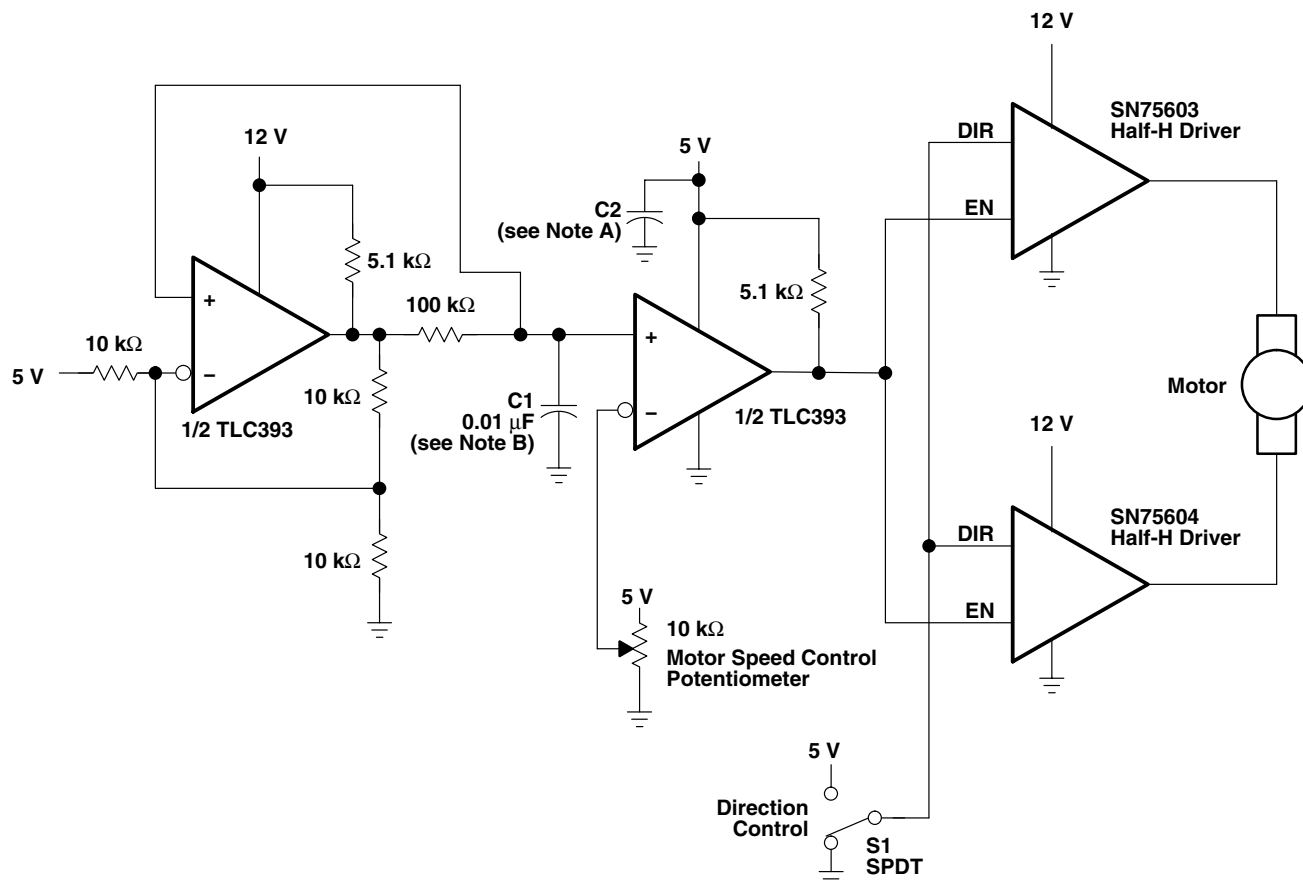
**Table of Applications**

|  | <b>FIGURE</b> |
|--|---------------|
| Pulse-width-modulated motor speed controller | 19            |
| Enhanced supply supervisor                   | 20            |
| Two-phase nonoverlapping clock generator     | 21            |
| Micropower switching regulator               | 28            |

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## APPLICATION INFORMATION



NOTES: A. The recommended minimum capacitance is 10 μF to eliminate common ground switching noise.  
B. Adjust C1 for change in oscillator frequency.

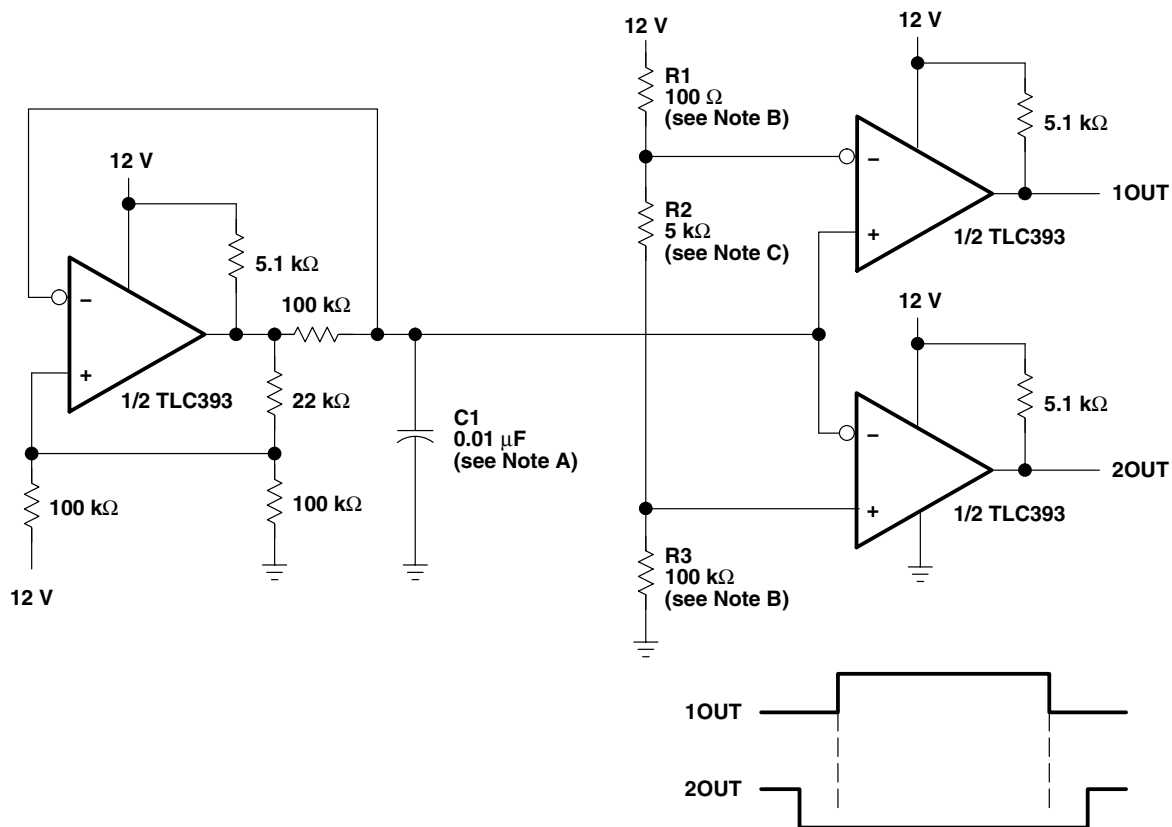
**Figure 19. Pulse-Width-Modulated Motor Speed Controller**



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## APPLICATION INFORMATION



- NOTES: A. Adjust C1 for a change in oscillator frequency where:  
 $1/f = 1.85(100 \text{ k}\Omega)C1$   
 B. Adjust R1 and R3 to change duty cycle  
 C. Adjust R2 to change deadtime

**Figure 21. Two-Phase Nonoverlapping Clock Generator**

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TLC393QDRG4Q1    | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| TLC393QDRQ1      | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**OTHER QUALIFIED VERSIONS OF TLC393-Q1 :**

- Catalog: [TLC393](#)

NOTE: Qualified Version Definitions:

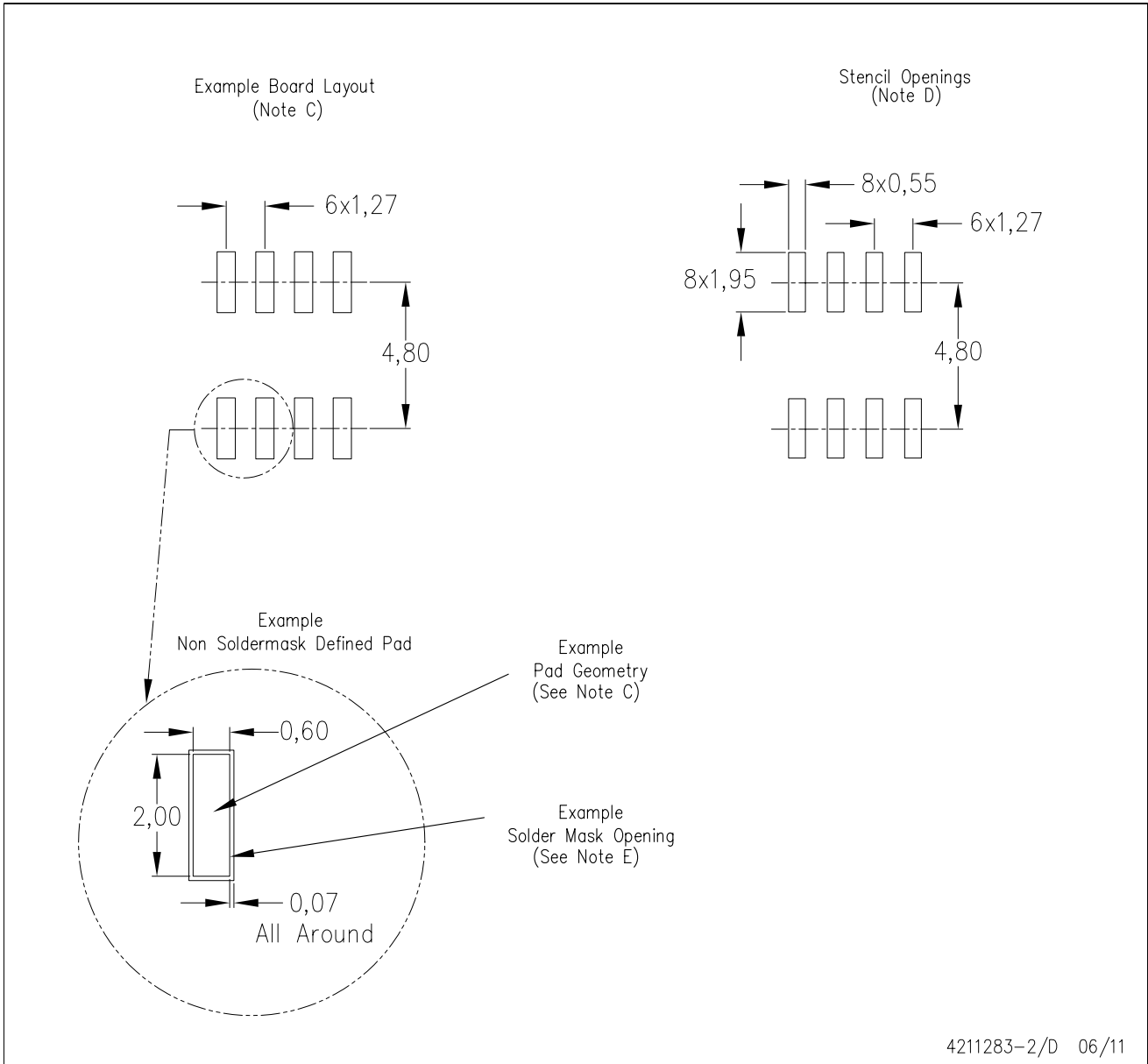
- Catalog - TI's standard catalog product





D (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.

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