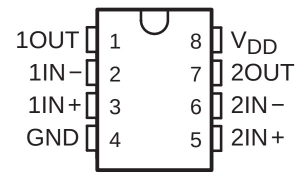
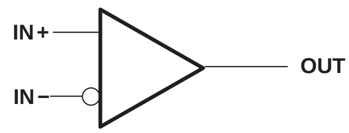
- **Qualified for Automotive Applications**
- **ESD Protection Exceeds 500 V Per MIL-STD-883, Method 3015; Exceeds 50 V Using Machine Model (C = 200 pF, R = 0)**
- **Low Power . . . 110 μW Typ at 5 V**
- **Fast Response Time . . . t_{PLH} = 2.5 μs Typ With 5-mV Overdrive**
- **Single Supply Operation:**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

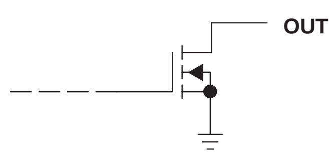
The TLC393Q is characterized for operation over the full automotive temperature range of T_A = −40°C to 125°C.

ORDERING INFORMATION†

T_A	V_{IO}max AT 25°C	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−40°C to 125°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

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, θ_{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(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. 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

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

PARAMETER		TEST CONDITIONS†	T_A	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}min$, V_{DD} = 5 V to 10 V, See Note 4	25°C		1.4	5	mV
			−40°C to 125°C			10	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			125°C			15	nA
I_{IB}	Input bias current	V_{IC} = 2.5 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	$V_{IC} = V_{ICR}min$	25°C		84		dB
			125°C		84		
			−40°C		84		
k_{SVR}	Supply-voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			125°C		84		
			−40°C		84		
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C		300	400	mV
			125°C			800	
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 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}).

switching characteristics, V_{DD} = 5 V, T_A = 25°C (see Figure 3)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high level output	f = 10 kHz, C_L = 15 pF	Overdrive = 2 mV		4.5		μs
			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	V_I = 1.4-V step at IN+			1.1		μs
		f = 10 kHz, C_L = 15 pF	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		
		V_I = 1.4-V step at IN+			0.10		
t_f	Fall time, output	f = 10 kHz, C_L = 15 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.

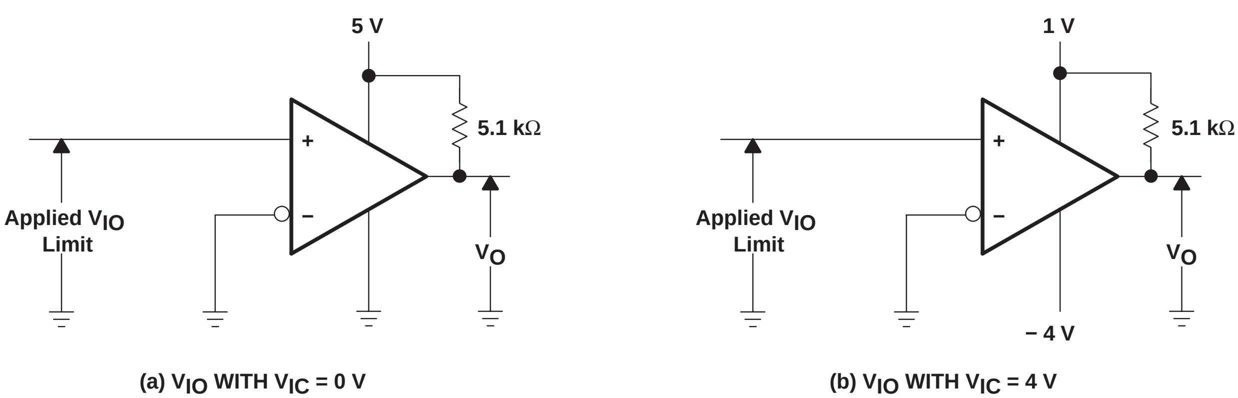


Figure 1. Method for Verifying That Input Offset Voltage Is Within Specified Limits

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.

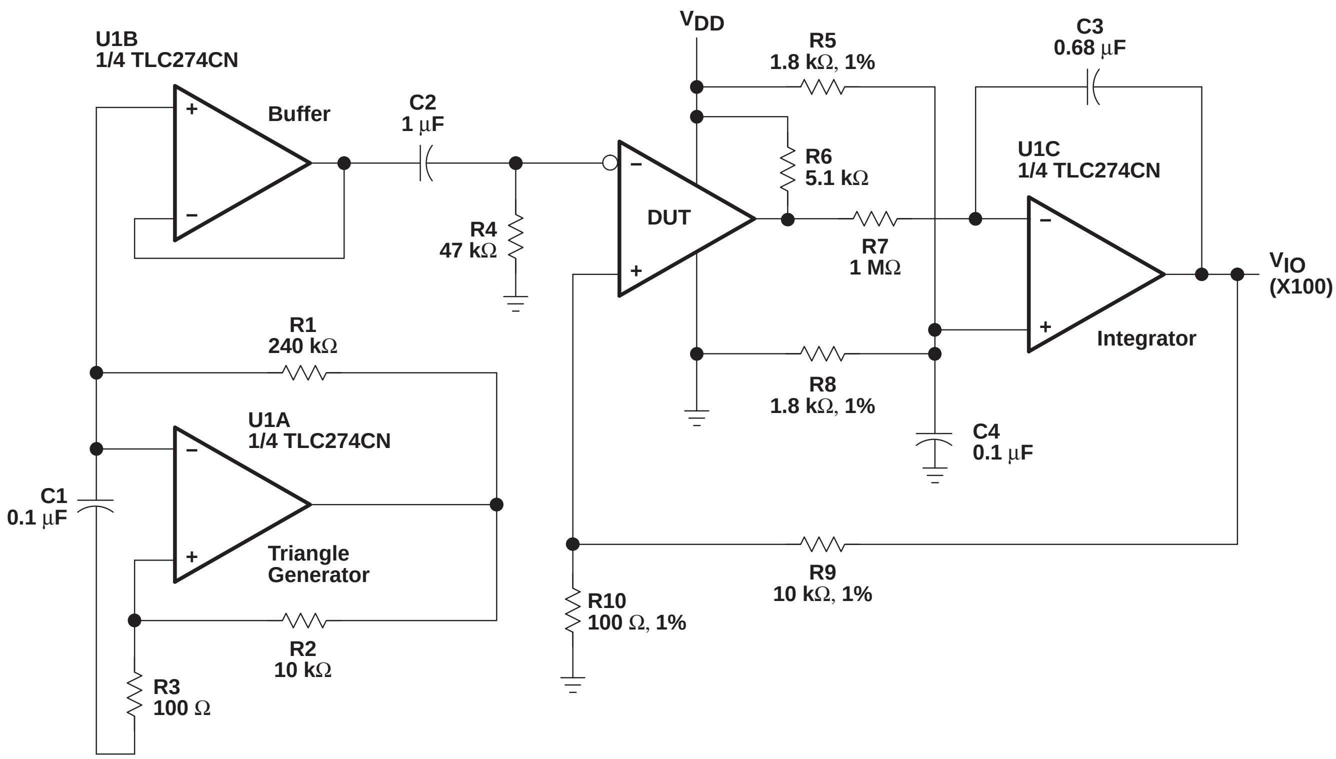
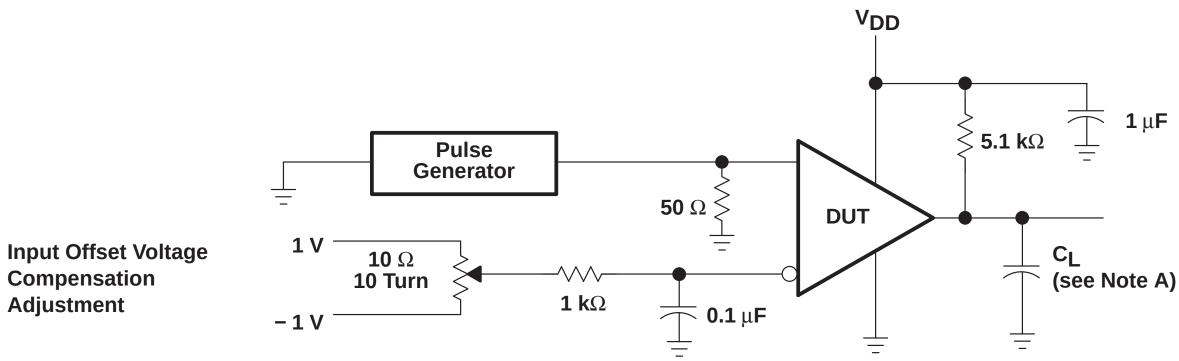


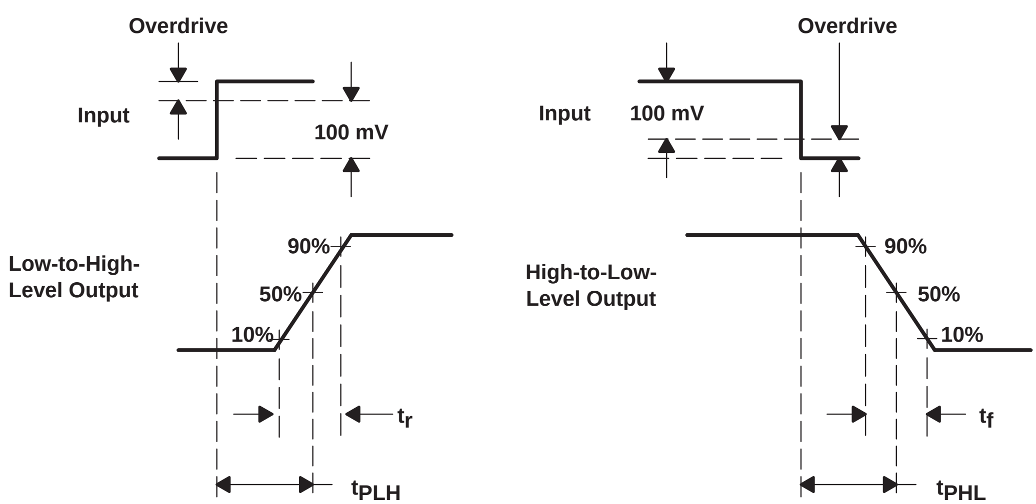
Figure 2. Circuit for Input Offset Voltage Measurement

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 vs Free-air temperature	8 9
I_{OH}	Low-level output current	vs High-level output voltage vs Free-air temperature	10 11
I_{DD}	Supply current	vs Supply voltage vs Free-air temperature	12 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

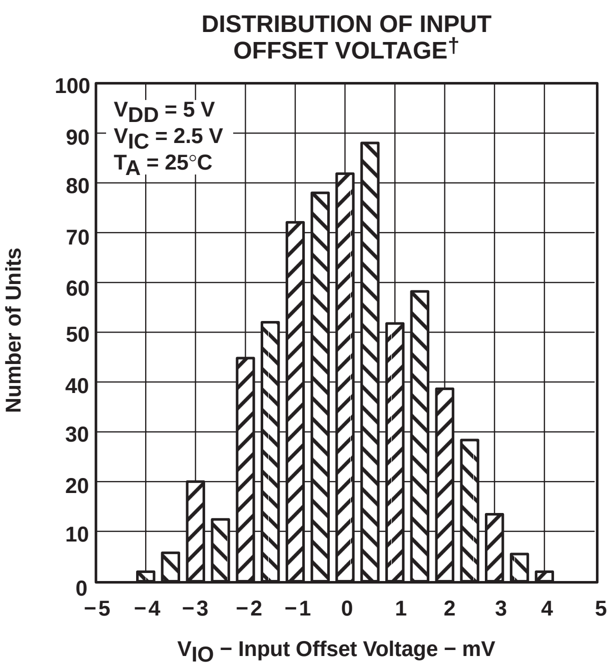


Figure 4

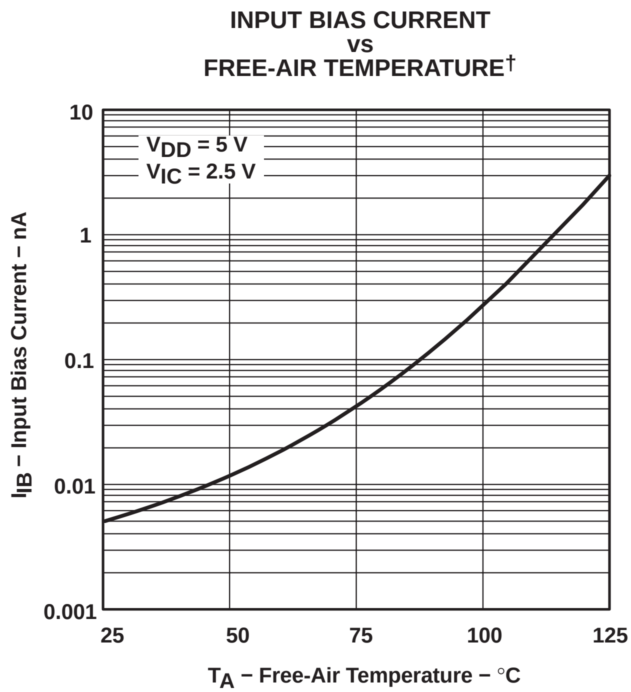


Figure 5

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

TYPICAL CHARACTERISTICS†

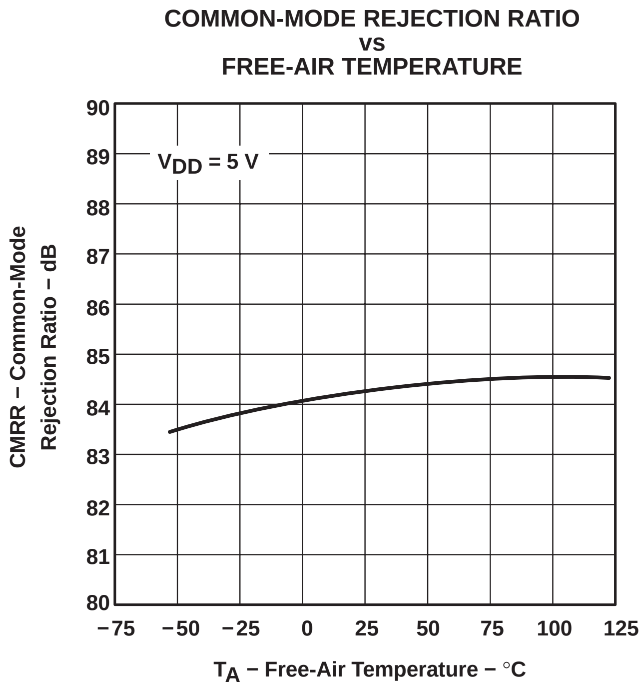


Figure 6

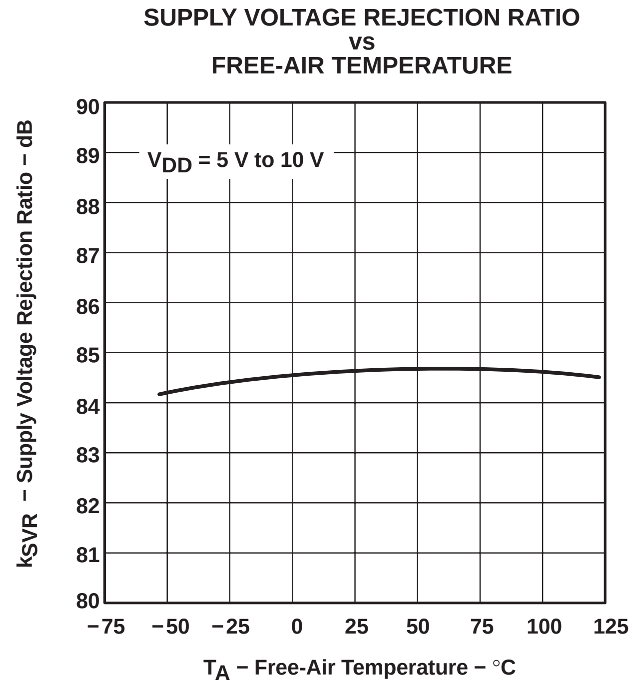


Figure 7

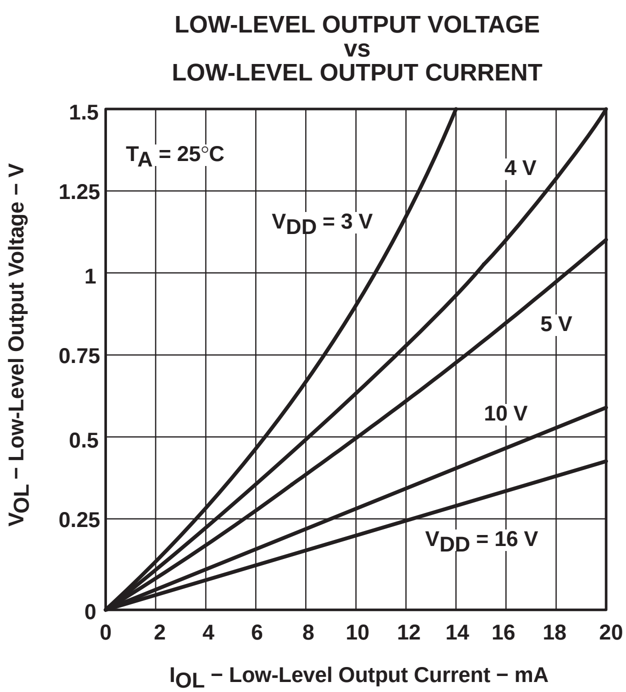


Figure 8

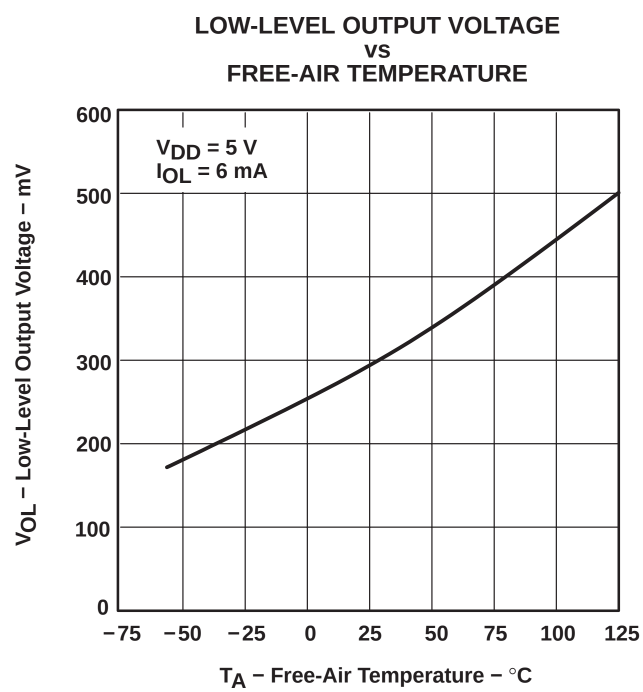


Figure 9

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

TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT CURRENT vs HIGH-LEVEL OUTPUT VOLTAGE

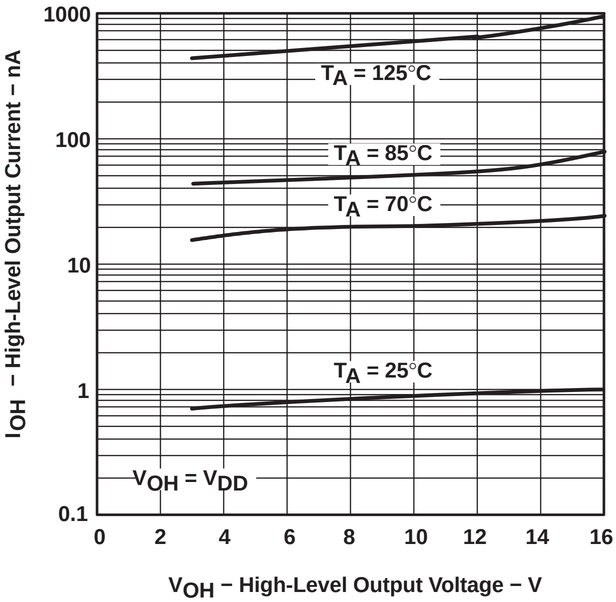


Figure 10

HIGH-LEVEL OUTPUT CURRENT vs FREE-AIR TEMPERATURE

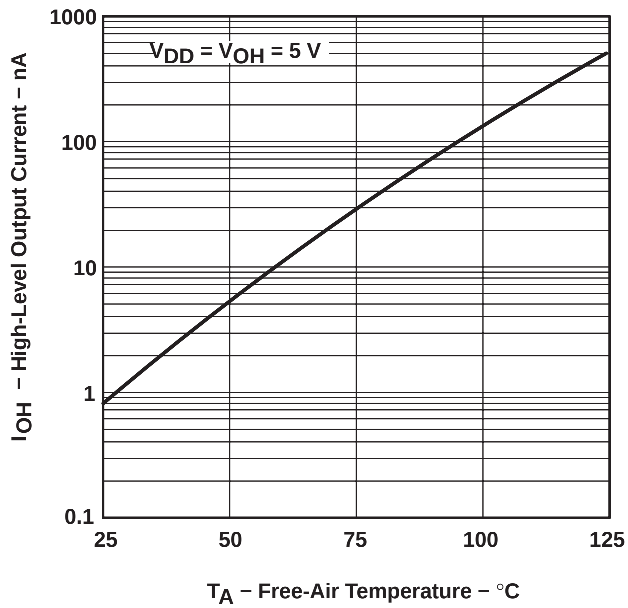


Figure 11

SUPPLY CURRENT vs SUPPLY VOLTAGE

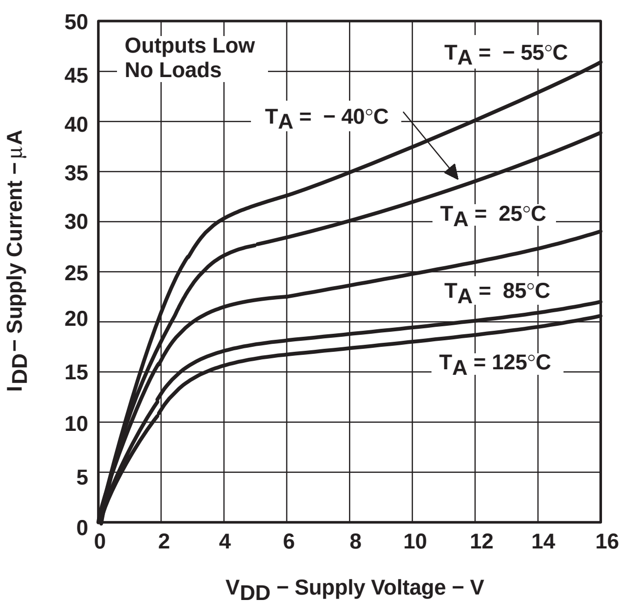


Figure 12

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

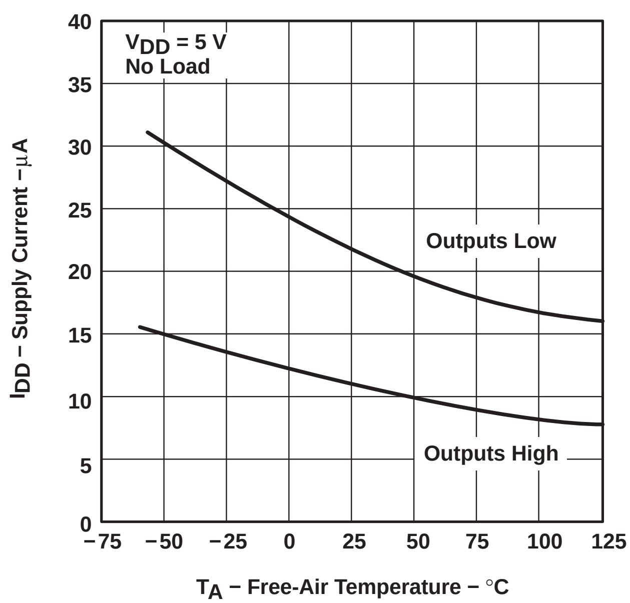


Figure 13

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

TYPICAL CHARACTERISTICS

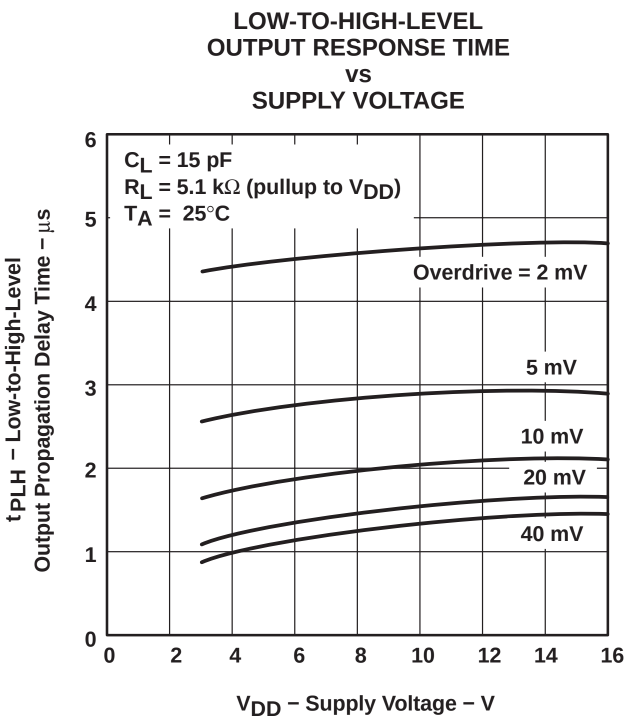


Figure 14

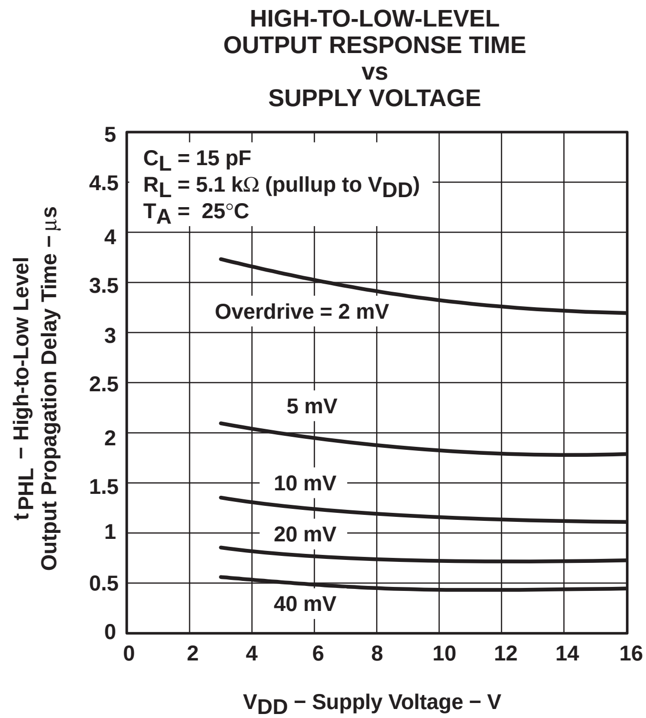


Figure 15

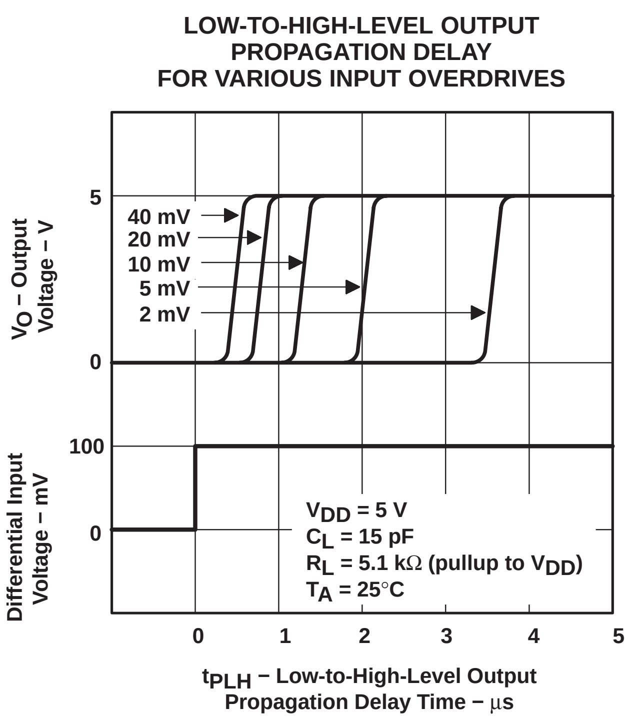


Figure 16

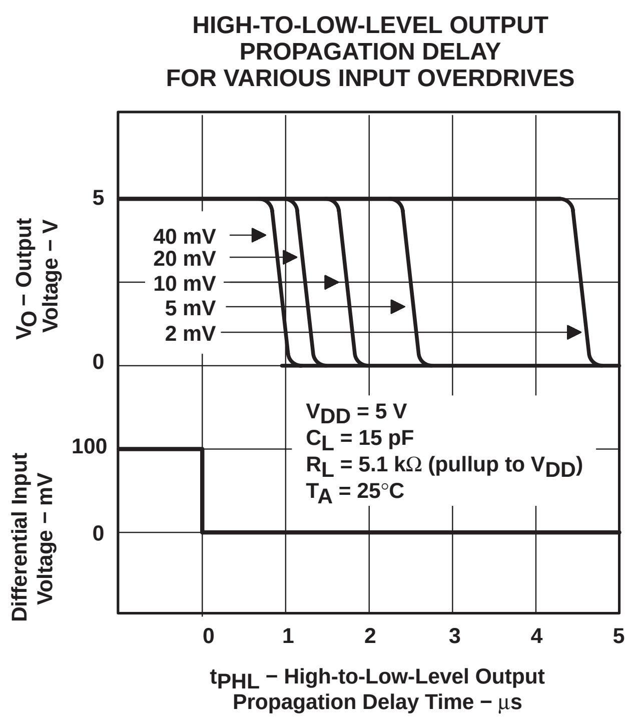


Figure 17

TYPICAL CHARACTERISTICS

**OUTPUT FALL TIME
vs
SUPPLY VOLTAGE**

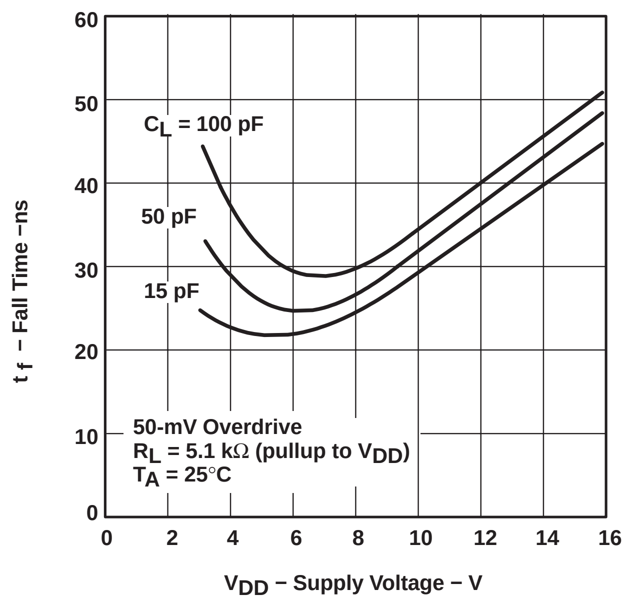


Figure 18

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 V, both inputs must remain between −0.2 V and 4 V to assure proper device operation.

To assure reliable operation, the supply should be decoupled with a capacitor (0.1-µF) 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

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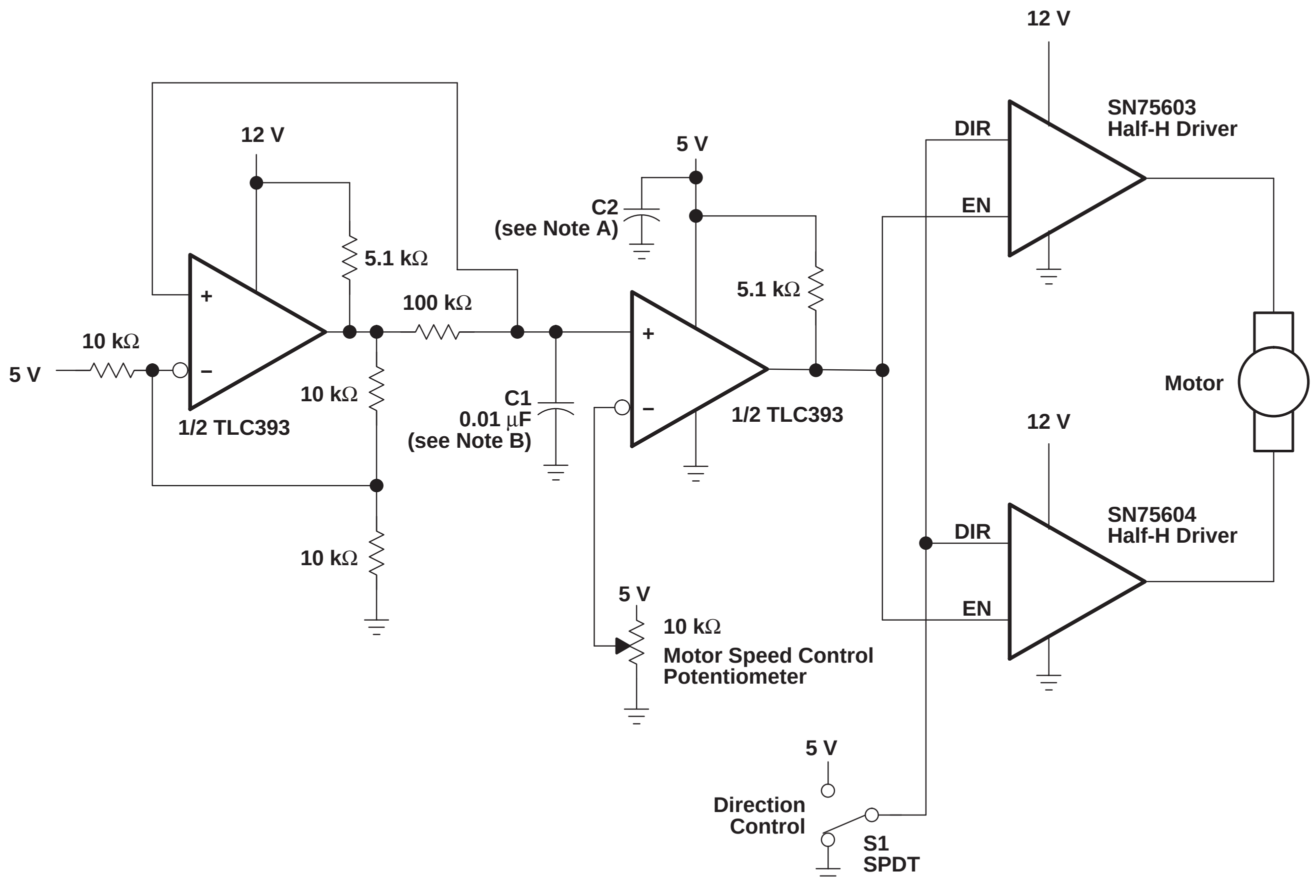
Two-phase nonoverlapping clock generator	21
Micropower switching regulator	28

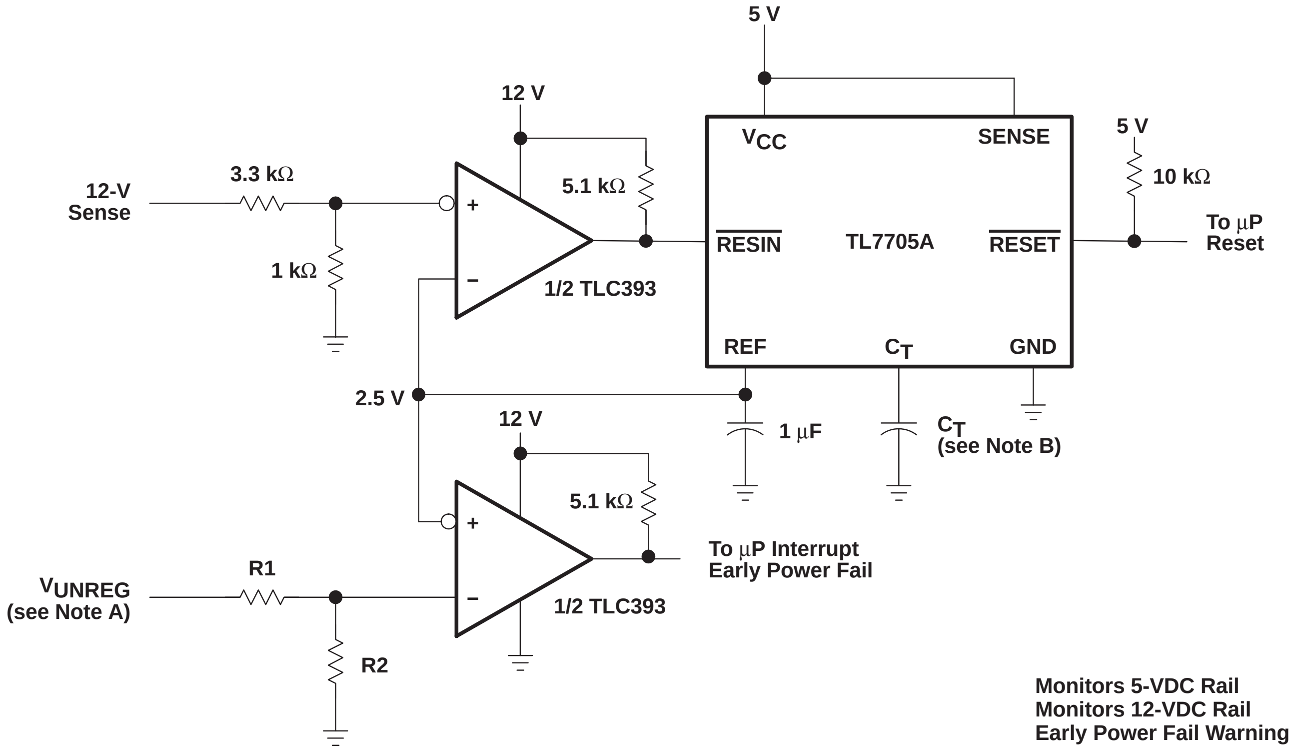
APPLICATION INFORMATION



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

APPLICATION INFORMATION

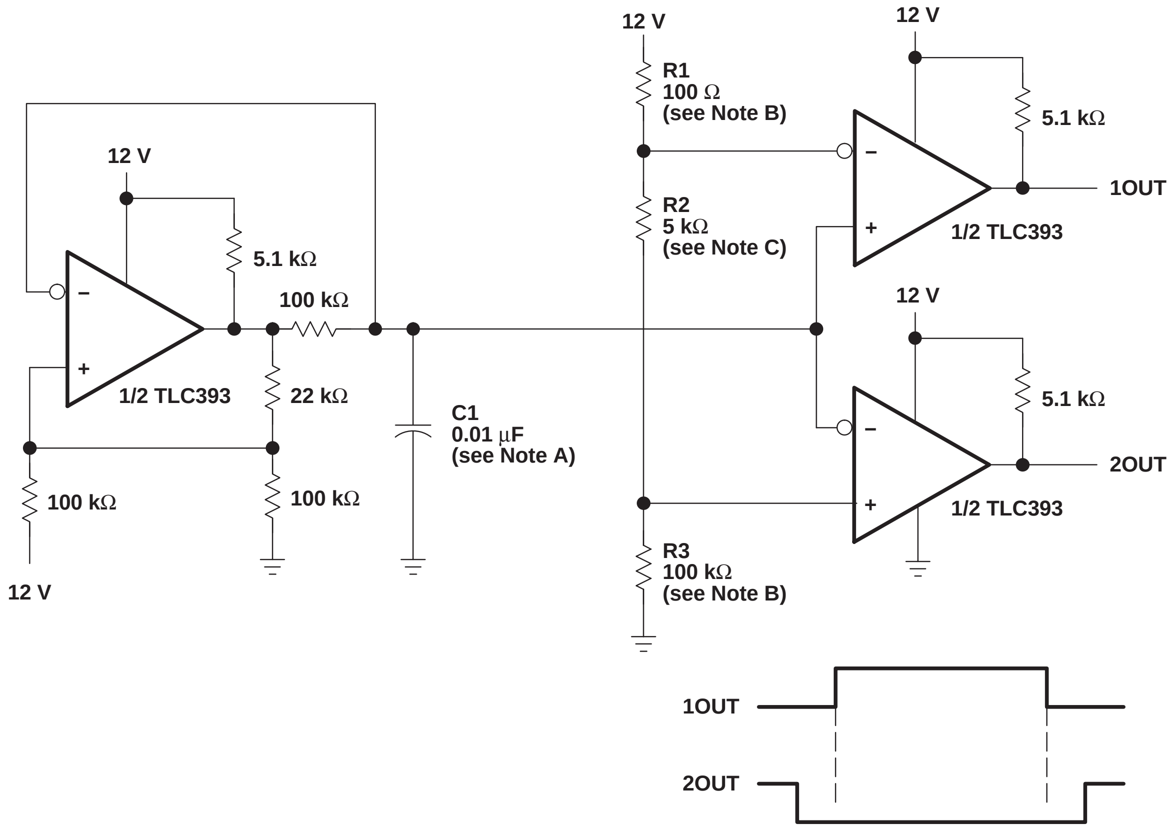


NOTES: A. $V_{UNREG} = 2.5\frac{(R1 + R2)}{R2}$

B. The value of C_T determines the time delay of reset.

Figure 20. Enhanced Supply Supervisor

APPLICATION INFORMATION



NOTES: A. Adjust C1 for a change in oscillator frequency where:
1/f = 1.85(100 kΩ)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 (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TLC393QDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC393QDRQ1	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM

(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) 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)

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

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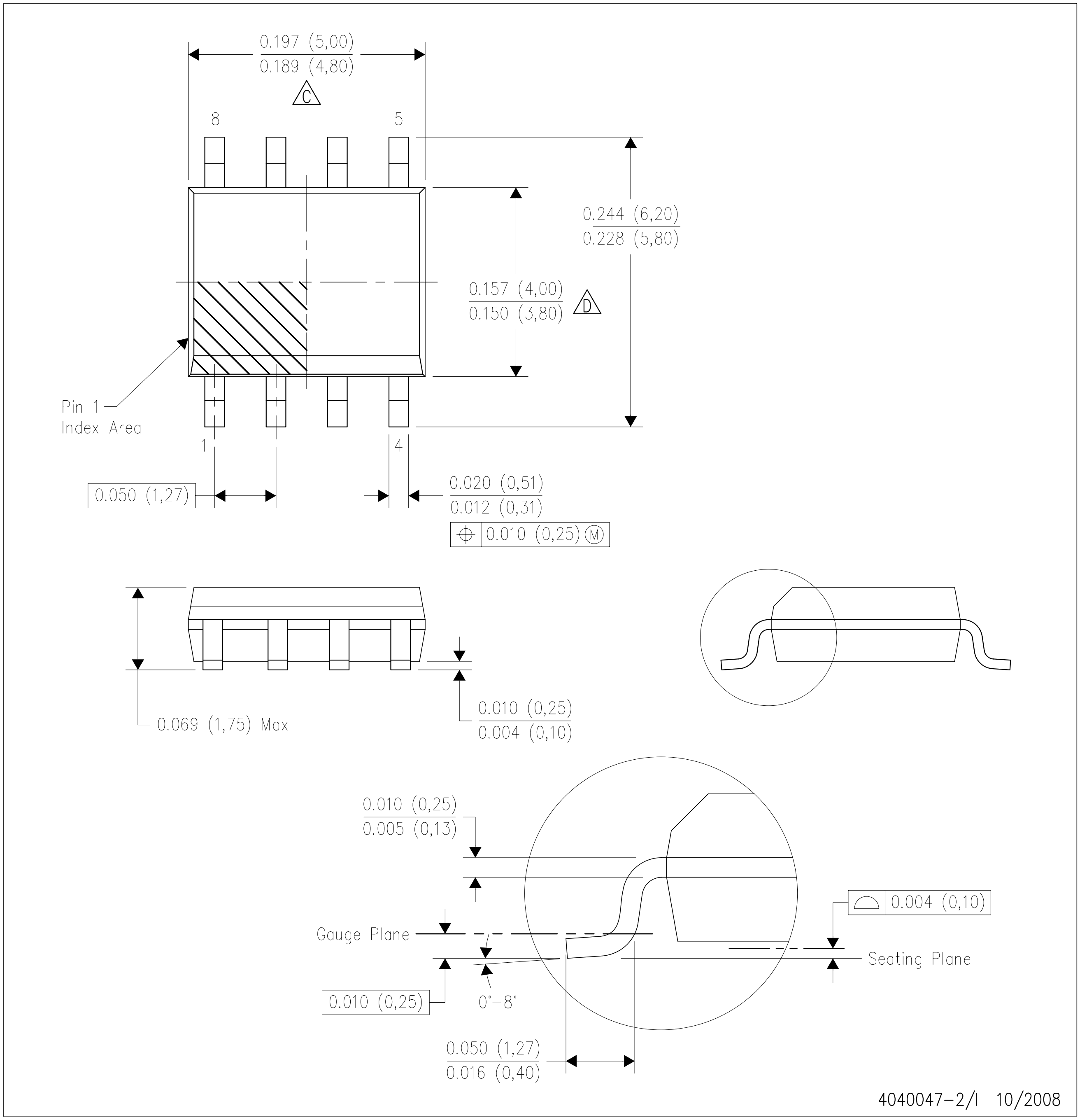
OTHER QUALIFIED VERSIONS OF TLC393-Q1 :
- Catalog: TLC393

NOTE: Qualified Version Definitions:
- Catalog - TI's standard catalog product

D (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in inches (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 .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS-012 variation AA.

IMPORTANT NOTICE

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

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Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
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Logic	logic.ti.com	Military	www.ti.com/military
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RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
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		Wireless	www.ti.com/wireless

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