



LMV33x-N / LMV393-N General-Purpose, Low-Voltage, Tiny Pack Comparators

1 Features

- (For 5-V Supply, Typical Unless Otherwise Noted)
- Ensured 2.7-V and 5-V Performance
- Industrial Temperature Range -40°C to 85°C
- Low Supply Current 60 $\mu\text{A}/\text{Channel}$
- Input Common Mode Voltage Range Includes Ground
- Low Output Saturation Voltage 200 mV
- Propagation Delay 200 ns
- Space-Saving 5-Pin SC70 and 5-Pin SOT23 Packages

2 Applications

- Mobile Communications
- Notebooks and PDAs
- Battery-Powered Electronics
- General-Purpose Portable Devices
- General-Purpose, Low-Voltage Applications

3 Description

The LMV393-N and LMV339-N are low-voltage (2.7 to 5 V) versions of the dual and quad comparators, LM393/339, which are specified at 5 to 30 V. The LMV331-N is the single version, which is available in space-saving, 5-pin SC70 and 5-pin SOT23 packages. The 5-pin SC70 is approximately half the size of the 5-pin SOT23.

The LMV393-N is available in 8-pin SOIC and VSSOP packages. The LMV339-N is available in 14-pin SOIC and TSSOP packages.

The LMV331-N/393-N/339-N is the most cost-effective solution where space, low voltage, low power, and price are the primary specification in circuit design for portable consumer products. They offer specifications that meet or exceed the familiar LM393/339 at a fraction of the supply current.

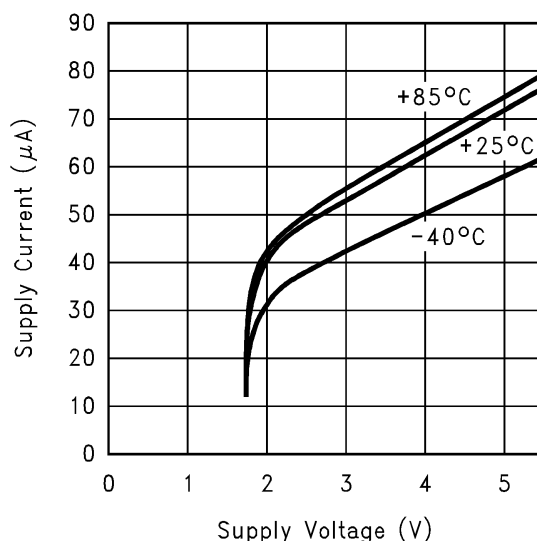
The chips are built with TI's advanced Submicron Silicon-Gate BiCMOS process. The LMV331-N/393-N/339-N have bipolar input and output stages for improved noise performance.

Table 1. Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LMV331-N	SC70 (5)	2.00 mm × 1.25 mm
	SOT-23 (5)	2.90 mm × 1.6 mm
LMV339-N	SOIC (14)	8.65 mm × 3.91 mm
	TSSOP (14)	5.00 mm × 4.40 mm
LMV393-N	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (8)	3.00 mm × 3.00 mm

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

Low Supply Current



Fast Response Time

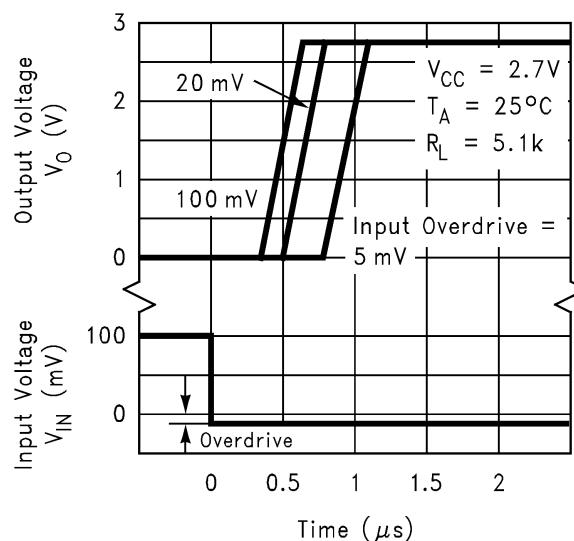


Table of Contents

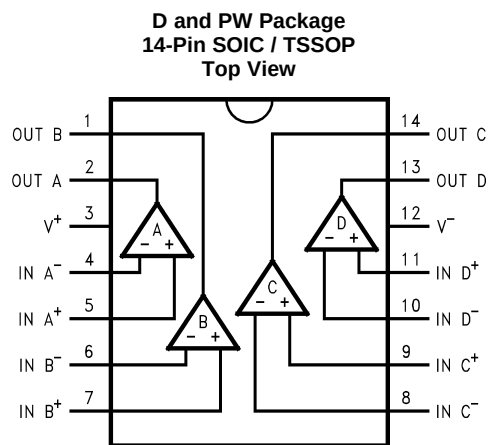
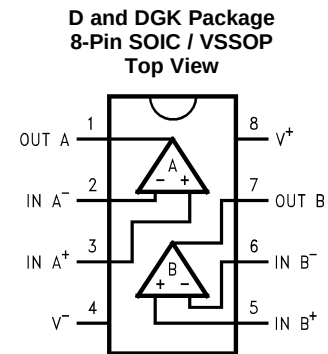
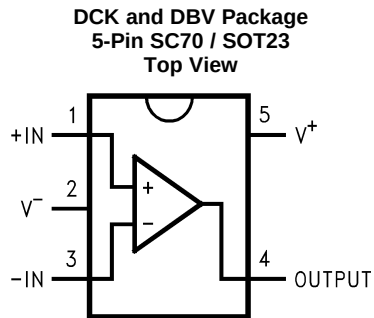
1 Features	1	7.3 Feature Description	9
2 Applications	1	7.4 Device Functional Modes	9
3 Description	1	8 Application and Implementation	10
4 Revision History	2	8.1 Application Information	10
5 Pin Configuration and Functions	3	8.2 Typical Applications	16
6 Specifications	4	9 Power Supply Recommendations	21
6.1 Absolute Maximum Ratings	4	10 Layout	21
6.2 ESD Ratings	4	10.1 Layout Guidelines	21
6.3 Recommended Operating Conditions	4	10.2 Layout Example	22
6.4 Thermal Information	4	11 Device and Documentation Support	23
6.5 2.7-V DC Electrical Characteristics	4	11.1 Device Support	23
6.6 2.7-V AC Electrical Characteristics	5	11.2 Documentation Support	23
6.7 5-V DC Electrical Characteristics	5	11.3 Related Links	23
6.8 5-V AC Electrical Characteristics	6	11.4 Trademarks	23
6.9 Typical Characteristics	7	11.5 Electrostatic Discharge Caution	23
7 Detailed Description	9	11.6 Glossary	23
7.1 Overview	9	12 Mechanical, Packaging, and Orderable Information	23
7.2 Functional Block Diagram	9		

4 Revision History

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

Changes from Revision G (February 2013) to Revision H	Page
Added <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section	1

5 Pin Configuration and Functions



Pin Functions

NAME	PIN			TYPE	DESCRIPTION
	LMV331-N DVB,DCK	LMV393-N D,DGK	LMV339-N PW		
+IN	1	-	-	I	Noninverting input
+IN A	-	3	5	I	Noninverting input, channel A
+IN B	-	5	7	I	Noninverting input, channel B
+IN C	-	-	9	I	Noninverting input, channel C
+IN D	-	-	11	I	Noninverting input, channel D
-IN	3	-	-	I	Inverting input
-IN A	-	2	4	I	Inverting input, channel A
-IN B	-	6	6	I	Inverting input, channel B
-IN C	-	-	8	I	Inverting input, channel C
-IN D	-	-	10	I	Inverting input, channel D
OUT	4	-	-	O	Output
OUT A	-	1	2	O	Output, channel A
OUT B	-	7	1	O	Output, channel B
OUT C	-	-	14	O	Output, channel C
OUT D	-	-	13	O	Output, channel D
V+	5	8	3	P	Positive (highest) power supply
V-	2	4	12	P	Negative (lowest) power supply

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾⁽²⁾

	MIN	MAX	UNIT
Differential Input Voltage		±Supply Voltage	
Voltage on any pin (referred to V ⁻ pin)		5.5	V
Soldering Information			
Infrared or Convection (20 sec)		235	°C
Junction Temperature ⁽³⁾		150	°C
Storage temperature, T _{stg}	-65	150	°C

- (1) Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under [Recommended Operating Conditions](#). Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office / Distributors for availability and specifications.
- (3) The maximum power dissipation is a function of T_{J(MAX)}, θ_{JA}. The maximum allowable power dissipation at any ambient temperature is P_D = (T_{J(MAX)} - T_A)/θ_{JA}. All numbers apply for packages soldered directly onto a PC board.

6.2 ESD Ratings

		VALUE	UNIT
V _(ESD) Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±800	V
	Machine model	±120	

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

6.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
Supply Voltage	2.7	5	V
Temperature Range ⁽²⁾	-40	85	°C

- (1) Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under [Recommended Operating Conditions](#). Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The maximum power dissipation is a function of T_{J(MAX)}, θ_{JA}. The maximum allowable power dissipation at any ambient temperature is P_D = (T_{J(MAX)} - T_A)/θ_{JA}. All numbers apply for packages soldered directly onto a PC board.

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾	LMV331-N		LMV339-N		LMV393-N		UNIT
	DCK	DBV	D	PW	D	DGK	
	5 PINS	5 PINS	14 PINS	14 PINS	8 PINS	8 PINS	
R _{θJA} Junction-to-ambient thermal resistance	478	265	145	155	190	23	°C/W

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

6.5 2.7-V DC Electrical Characteristics

Unless otherwise specified, all limits ensured for T_J = 25°C, V⁺ = 2.7V, V⁻ = 0V.

PARAMETER	TEST CONDITIONS	MIN (1)	TYP (2)	MAX (1)	UNIT
V _{OS} Input Offset Voltage			1.7	7	mV
TCV _{OS} Input Offset Voltage Average Drift	At the temperature extremes		5		μV/°C

- (1) All limits are ensured by testing or statistical analysis.
- (2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

2.7-V DC Electrical Characteristics (continued)

Unless otherwise specified, all limits ensured for $T_J = 25^\circ\text{C}$, $V^+ = 2.7\text{V}$, $V^- = 0\text{V}$.

PARAMETER		TEST CONDITIONS	MIN (1)	TYP (2)	MAX (1)	UNIT
I_B	Input Bias Current			10	250	nA
		At the temperature extremes			400	
I_{OS}	Input Offset Current			5	50	nA
		At the temperature extremes			150	
V_{CM}	Input Voltage Range			-0.1		V
				2.0		V
V_{SAT}	Saturation Voltage	$I_{SINK} \leq 1\text{ mA}$		120		mV
I_O	Output Sink Current	$V_O \leq 1.5\text{V}$	5	23		mA
I_S	Supply Current	LMV331-N		40	100	μA
		LMV393-N Both Comparators		70	140	μA
		LMV339-N All four Comparators		140	200	μA
	Output Leakage Current			.003		μA
		At the temperature extremes			1	

6.6 2.7-V AC Electrical Characteristics

$T_J = 25^\circ\text{C}$, $V^+ = 2.7\text{V}$, $R_L = 5.1\text{ k}\Omega$, $V^- = 0\text{V}$.

PARAMETER		TEST CONDITIONS	MIN (1)	TYP (2)	MAX (1)	UNIT
t_{PHL}	Propagation Delay (High to Low)	Input Overdrive = 10 mV		1000		ns
		Input Overdrive = 100 mV		350		ns
t_{PLH}	Propagation Delay (Low to High)	Input Overdrive = 10 mV		500		ns
		Input Overdrive = 100 mV		400		ns

(1) All limits are ensured by testing or statistical analysis.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

6.7 5-V DC Electrical Characteristics

Unless otherwise specified, all limits ensured for $T_J = 25^\circ\text{C}$, $V^+ = 5\text{V}$, $V^- = 0\text{V}$.

PARAMETER		TEST CONDITIONS	MIN (1)	TYP (2)	MAX (1)	UNIT
V_{OS}	Input Offset Voltage			1.7	7	mV
		At the temperature extremes			9	
TCV_{OS}	Input Offset Voltage Average Drift			5		$\mu\text{V}/^\circ\text{C}$
I_B	Input Bias Current			25	250	nA
		At the temperature extremes			400	
I_{OS}	Input Offset Current			2	50	nA
		At the temperature extremes			150	
V_{CM}	Input Voltage Range			-0.1		V
				4.2		V
A_V	Voltage Gain		20	50		V/mV

(1) All limits are ensured by testing or statistical analysis.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

5-V DC Electrical Characteristics (continued)

Unless otherwise specified, all limits ensured for $T_J = 25^\circ\text{C}$, $V^+ = 5\text{ V}$, $V^- = 0\text{ V}$.

PARAMETER		TEST CONDITIONS	MIN (1)	TYP (2)	MAX (1)	UNIT
V_{sat}	Saturation Voltage	$I_{\text{SINK}} \leq 4\text{ mA}$		200	400	mV
		At the temperature extremes			700	
I_O	Output Sink Current	$V_O \leq 1.5\text{ V}$		84	10	mA
I_S	Supply Current	LMV331-N		60	120	μA
		At the temperature extremes			150	
		LMV393-N Both Comparators		100	200	μA
		At the temperature extremes			250	
		LMV339-N All four Comparators		170	300	μA
		At the temperature extremes			350	
	Output Leakage Current			.003		μA
		At the temperature extremes			1	

6.8 5-V AC Electrical Characteristics

$T_J = 25^\circ\text{C}$, $V^+ = 5\text{ V}$, $R_L = 5.1\text{ k}\Omega$, $V^- = 0\text{ V}$.

PARAMETER		TEST CONDITIONS	MIN (1)	TYP (2)	MAX (1)	UNIT
t_{PHL}	Propagation Delay (High to Low)	Input Overdrive = 10 mV		600		ns
		Input Overdrive = 100 mV		200		ns
t_{PLH}	Propagation Delay (Low to High)	Input Overdrive = 10 mV		450		ns
		Input Overdrive = 100 mV		300		ns

- (1) All limits are ensured by testing or statistical analysis.
- (2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

6.9 Typical Characteristics

Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$

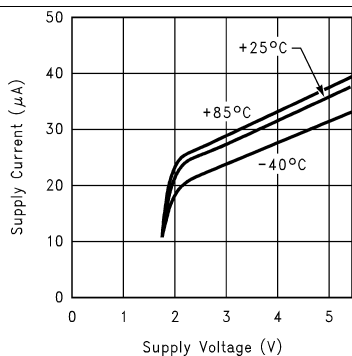


Figure 1. Supply Current vs. Supply Voltage Output High (LMV331-N)

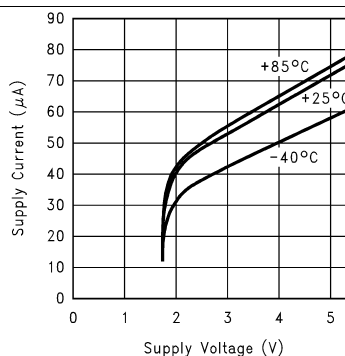


Figure 2. Supply Current vs. Supply Voltage Output Low (LMV331-N)

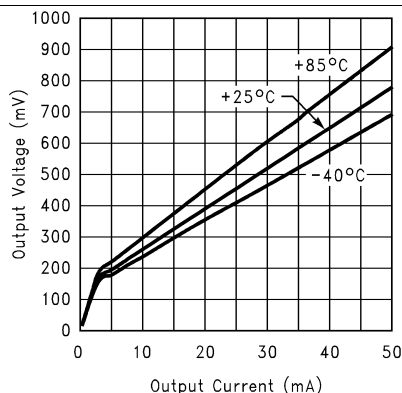


Figure 3. Output Voltage vs. Output Current at 5-V Supply

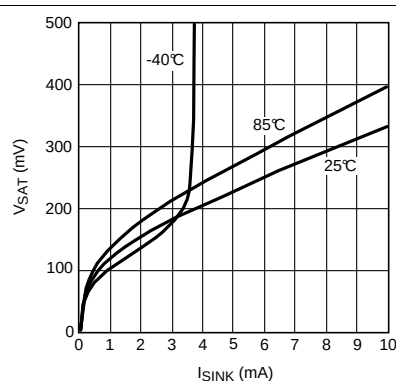


Figure 4. Output Voltage vs. Output Current at 2.7-V Supply

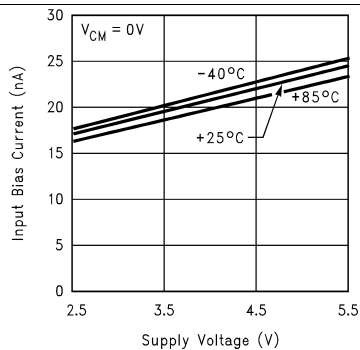


Figure 5. Input Bias Current vs. Supply Voltage

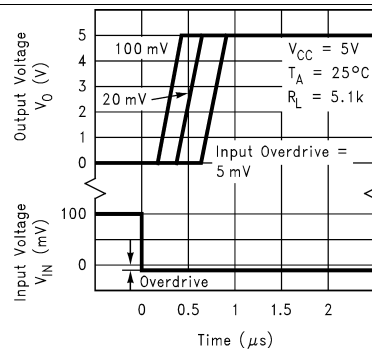


Figure 6. Response Time vs. Input Overdrive Negative Transition

Typical Characteristics (continued)

Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$

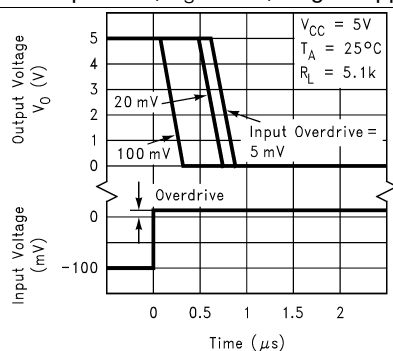


Figure 7. Response Time for Input Overdrive Positive Transition

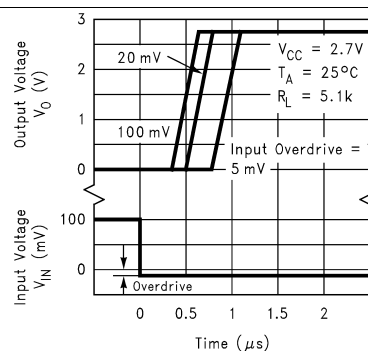


Figure 8. Response Time vs. Input Overdrive Negative Transition

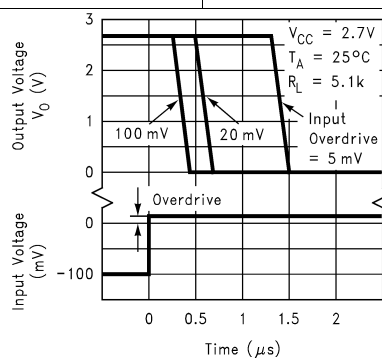


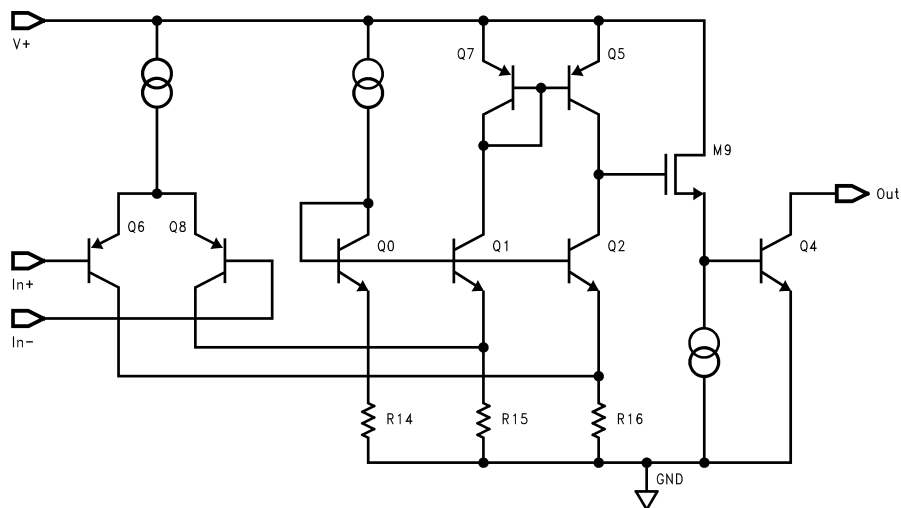
Figure 9. Response Time for Input Overdrive Positive Transition

7 Detailed Description

7.1 Overview

The LMV331-N/393-N/339-N comparators features a supply voltage range of 2.7 V to 5 V with a low supply current of 55 μ A/channel with propagation delays as low as 200ns. They are available in small, space-saving packages, which makes these comparators versatile for use in a wide range of applications, from portable to industrial. The open collector output configuration allows the device to be used in wired-OR configurations, such as a window comparators.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Open Collector Output

The output of the LMV331-N/393-N/339-N series is the uncommitted collector of a grounded-emitter NPN output transistor, which requires a pull-up resistor to a positive supply voltage for the output to switch properly. Many collectors can be tied together to provide an output OR'ing function. An output pull-up resistor can be connected to any available power supply voltage within the permitted V+ supply voltage range. The output pull-up resistor should be chosen high enough so as to avoid excessive power dissipation yet low enough to supply enough drive to switch whatever load circuitry is used on the comparator output. On the LMV331-N/393-N/339-N the pull-up resistor should range between 1 k to 10 k Ω .

7.3.2 Ground Sensing Input

The LMV331-N/393-N/339-N has a typical input common mode voltage range of -0.1 V below the ground to 0.8 V below Vcc.

7.4 Device Functional Modes

A basic comparator circuit is used for converting analog signals to a digital output.

The output is HIGH when the voltage on the non-inverting (+IN) input is greater than the inverting (-IN) input.

The output is LOW when the voltage on the non-inverting (+IN) input is less than the inverting (-IN) input.

The inverting input (-IN) is also commonly referred to as the "reference" or "V_{REF}" input.

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

8.1.1 Basic Comparator

The comparator compares the input voltage (V_{IN}) at the non-inverting pin to the reference voltage (V_{REF}) at the inverting pin. If V_{IN} is less than V_{REF} , the output voltage (V_O) is at the saturation voltage. On the other hand, if V_{IN} is greater than V_{REF} , the output voltage (V_O) is at V_{CC} .

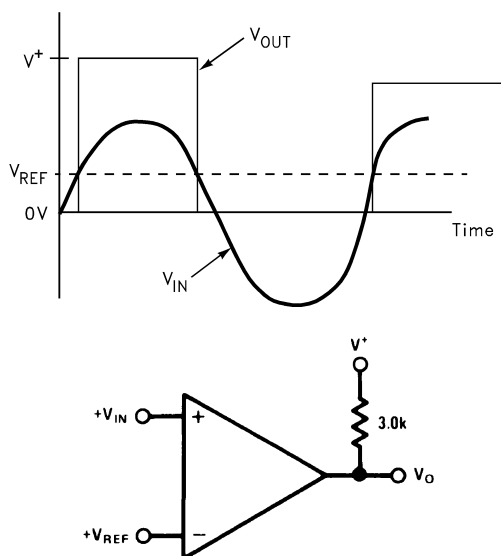


Figure 10. Basic Comparator

8.1.2 Comparator With Hysteresis

The basic comparator configuration may oscillate or produce a noisy output if the applied differential input voltage is near the comparator's offset voltage. This usually happens when the input signal is moving very slowly across the switching threshold of the comparator. This problem can be prevented by the addition of hysteresis or positive feedback.

8.1.2.1 Inverting Comparator With Hysteresis

The inverting comparator with hysteresis requires a three resistor network that are referenced to the supply voltage V_{CC} of the comparator. When V_{in} at the inverting input is less than V_a , the voltage at the non-inverting node of the comparator ($V_{in} < V_a$), the output voltage is high (for simplicity assume V_O switches as high as V_{CC}). The three network resistors can be represented as $R_1//R_3$ in series with R_2 . The lower input trip voltage V_{a1} is defined as:

$$V_{a1} = \frac{V_{CC} R_2}{(R_1 \parallel R_3) + R_2} \quad (1)$$

When V_{in} is greater than V_a ($V_{in} > V_a$), the output voltage is low very close to ground. In this case the three network resistors can be presented as $R_2//R_3$ in series with R_1 . The upper input trip voltage V_{a2} is defined as:

$$V_{a2} = \frac{V_{CC} (R_2 \parallel R_3)}{R_1 + (R_2 \parallel R_3)} \quad (2)$$

Application Information (continued)

The total hysteresis provided by the network is defined as:

$$\Delta V_a = V_{a1} - V_{a2} \quad (3)$$

To assure that the comparator will always switch fully to V_{CC} and not be pulled down by the load the resistors values should be chosen as follow:

$$R_{PULL-UP} \ll R_{LOAD} \quad (4)$$

$$\text{and } R_1 > R_{PULL-UP} \quad (5)$$

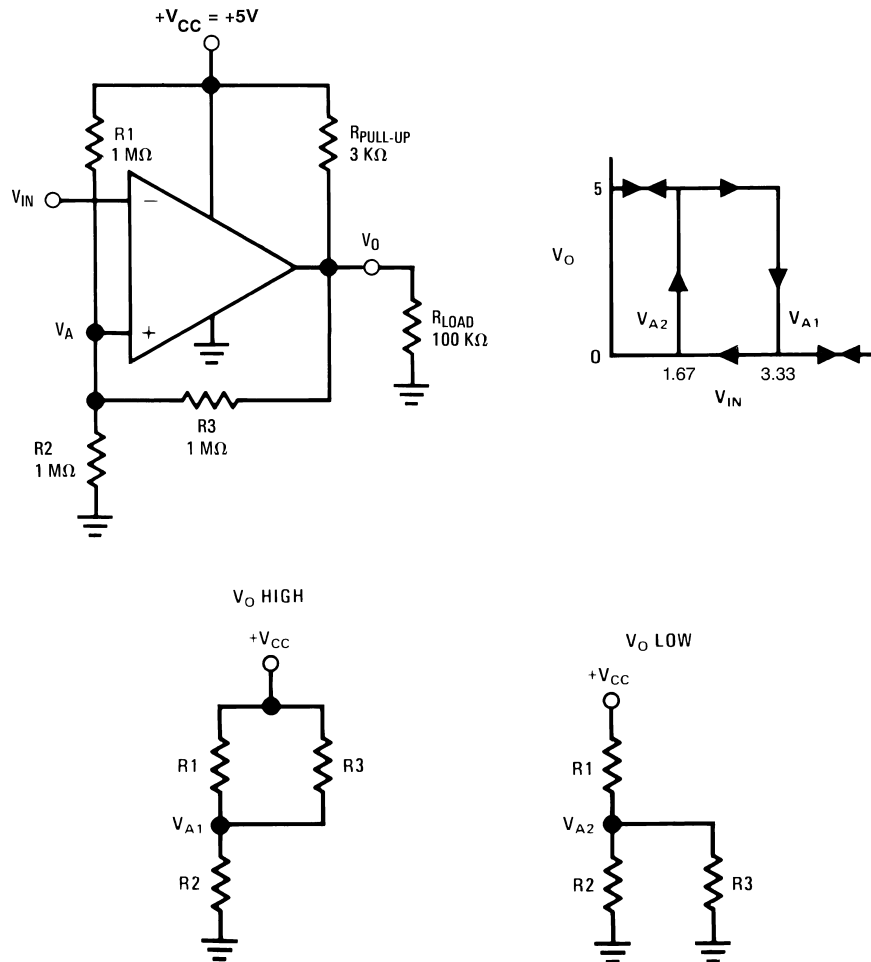


Figure 11. Inverting Comparator With Hysteresis

8.1.2.1.1 Non-inverting Comparator With Hysteresis

Non-inverting comparator with hysteresis requires a two resistor network, and a voltage reference (V_{ref}) at the inverting input. When V_{in} is low, the output is also low. For the output to switch from low to high, V_{in} must rise up to V_{in1} where V_{in1} is calculated by:

$$V_{in1} = \frac{V_{ref} (R_1 + R_2)}{R_2} \quad (6)$$

When V_{in} is high, the output is also high. To make the comparator switch back to its low state, V_{in} must equal V_{ref} before V_A will again equal V_{ref} . V_{in} can be calculated by:

$$V_{in2} = \frac{V_{ref} (R_1 + R_2) - V_{CC} R_1}{R_2} \quad (7)$$

The hysteresis of this circuit is the difference between V_{in1} and V_{in2} .

Application Information (continued)

$$\Delta V_{in} = V_{CC} R_1 / R_2$$

(8)

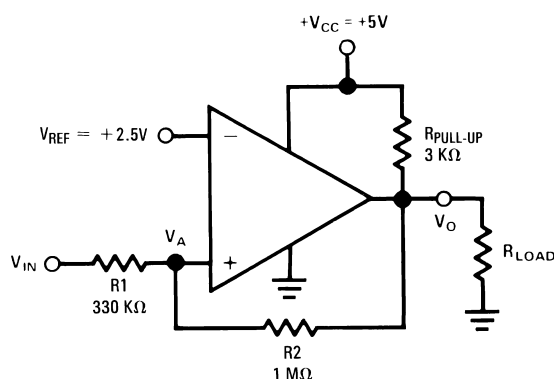


Figure 12. Noninverting Comparator With Hysteresis

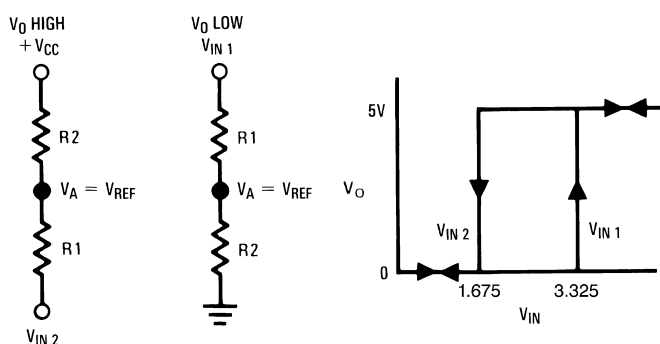


Figure 13. Hysteresis Threshold Points

8.1.3 ORing the Output

By the inherent nature of an open-collector comparator, the outputs of several comparators can be tied together with a shared pull-up resistor to V_{CC} . If one or more of the comparators outputs goes low, the output V_O will go low.

Application Information (continued)

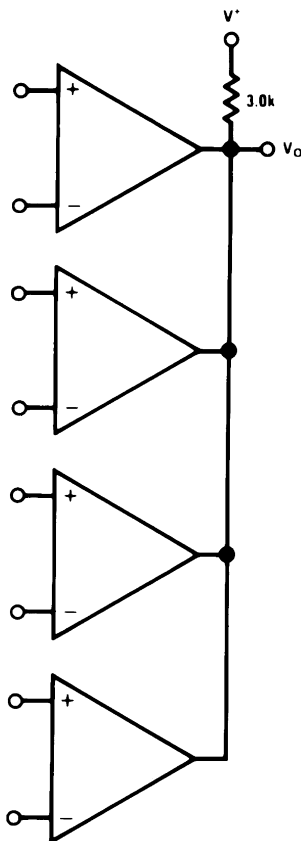


Figure 14. ORing the Outputs

8.1.4 Driving CMOS and TTL

The output of the comparator is capable of driving CMOS and TTL Logic circuits. The pull-up resistor may be pulled-up to any voltage equal to, or less than the supply voltage on V^+ . However, it must not be pulled-up to a voltage higher than V^+ .

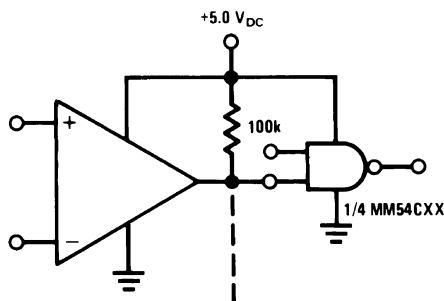


Figure 15. Driving CMOS

Application Information (continued)

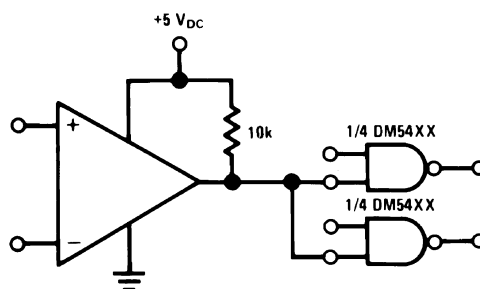


Figure 16. Driving TTL

8.1.5 AND Gates

The comparator can be used as three input AND gate. The operation of the gate is as follows:

The resistor divider at the inverting input establishes a reference voltage at that node. The non-inverting input is the sum of the voltages at the inputs divided by the voltage dividers. The output will go high only when all three inputs are high, causing the voltage at the non-inverting input to go above that at inverting input. The circuit values shown work for a 0 equal to ground and a 1 equal to 5 V.

The resistor values can be altered if different logic levels are desired. If more inputs are required, diodes are recommended to improve the voltage margin when all but one of the inputs are high.

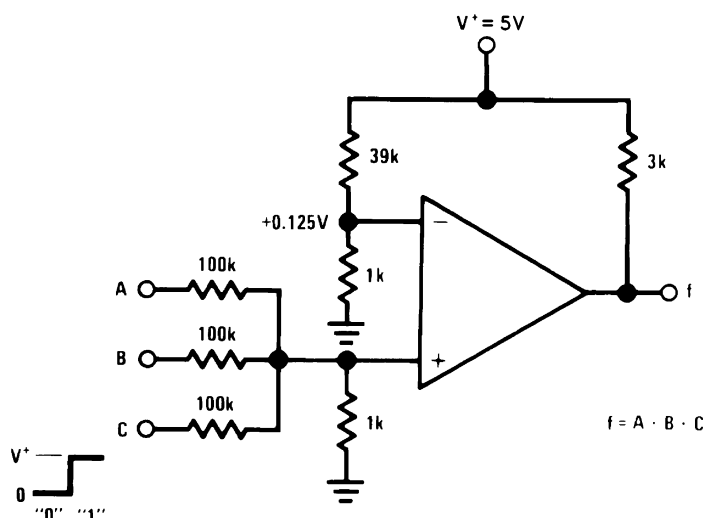


Figure 17. AND Gate

8.1.6 OR Gates

A three input OR gate is achieved from the basic AND gate simply by increasing the resistor value connected from the inverting input to V_{CC} , thereby reducing the reference voltage.

A logic 1 at any of the inputs will produce a logic 1 at the output.

Application Information (continued)

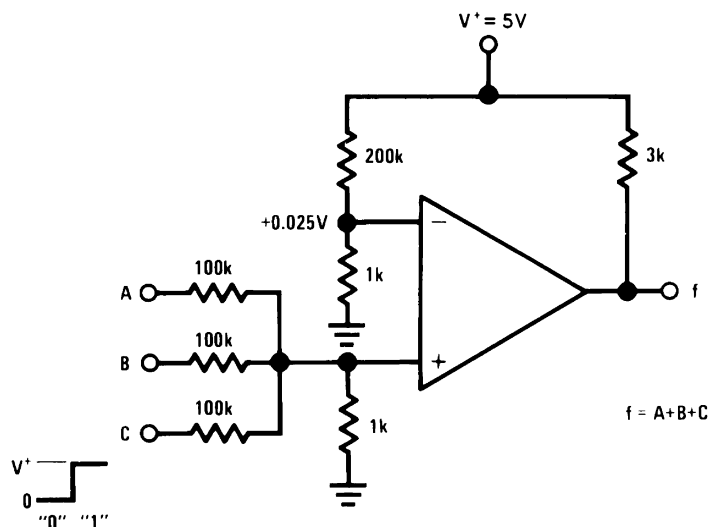


Figure 18. OR Gate

8.1.7 Large Fan-In Gate

Extra logic inputs may be added by ORing the input with multiple diodes.

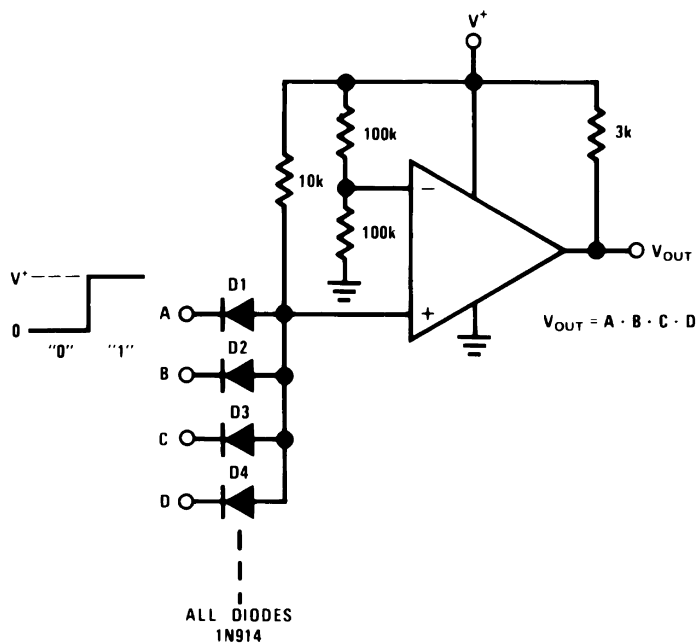


Figure 19. Large Fan-In and Gate

8.2 Typical Applications

8.2.1 Squarewave Oscillator

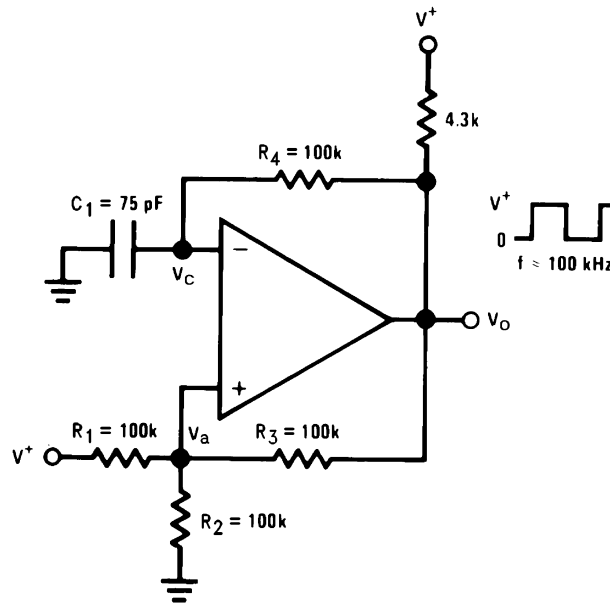


Figure 20. Squarewave Oscillator

8.2.1.1 Design Requirements

Comparators are ideal for oscillator applications. This square wave generator uses the minimum number of components. The output frequency is set by the RC time constant of the capacitor C_1 and the resistor in the negative feedback R_4 . The maximum frequency is limited only by the large signal propagation delay of the comparator in addition to any capacitive loading at the output, which would degrade the output slew rate.

8.2.1.2 Detailed Design Procedure

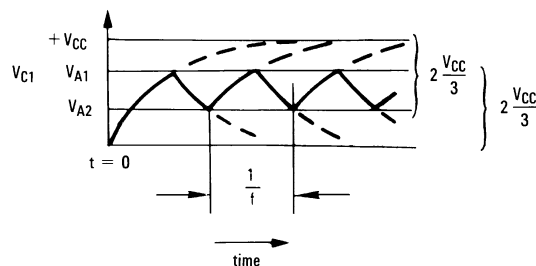


Figure 21. Squarewave Oscillator Timing Thresholds

To analyze the circuit, assume that the output is initially high. For this to be true, the voltage at the inverting input V_c has to be less than the voltage at the non-inverting input V_a . For V_c to be low, the capacitor C_1 has to be discharged and will charge up through the negative feedback resistor R_4 . When it has charged up to value equal to the voltage at the positive input V_{a1} , the comparator output will switch.

V_{a1} will be given by:

$$V_{a1} = \frac{V_{CC} R_2}{R_2 + (R_1 // R_2)} \quad (9)$$

Typical Applications (continued)

If:

$$R_1 = R_2 = R_3 \quad (10)$$

Then:

$$V_{a1} = 2V_{CC}/3 \quad (11)$$

When the output switches to ground, the value of V_a is reduced by the hysteresis network to a value given by:

$$V_{a2} = V_{CC}/3 \quad (12)$$

Capacitor C_1 must now discharge through R_4 towards ground. The output will return to its high state when the voltage across the capacitor has discharged to a value equal to V_{a2} .

For the circuit shown, the period for one cycle of oscillation will be twice the time it takes for a single RC circuit to charge up to one half of its final value. The time to charge the capacitor can be calculated from:

$$V_C = V_{max} e^{-\frac{t}{RC}} \quad (13)$$

Where V_{max} is the max applied potential across the capacitor = $(2V_{CC}/3)$

and $V_C = V_{max}/2 = V_{CC}/3$

One period will be given by:

$$1/freq = 2t \quad (14)$$

or calculating the exponential gives:

$$1/freq = 2(0.694) R_4 C_1 \quad (15)$$

Resistors R_3 and R_4 must be at least two times larger than R_5 to ensure that V_O will go all the way up to V_{CC} in the high state. The frequency stability of this circuit should strictly be a function of the external components.

8.2.1.3 Application Curve

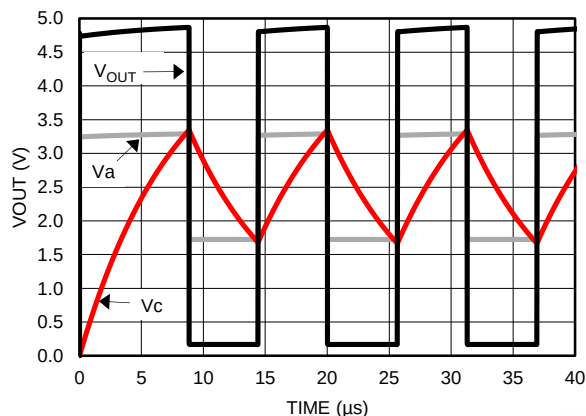


Figure 22. Waveforms for Circuit in *Typical Applications*

Typical Applications (continued)

8.2.2 Crystal Controlled Oscillator

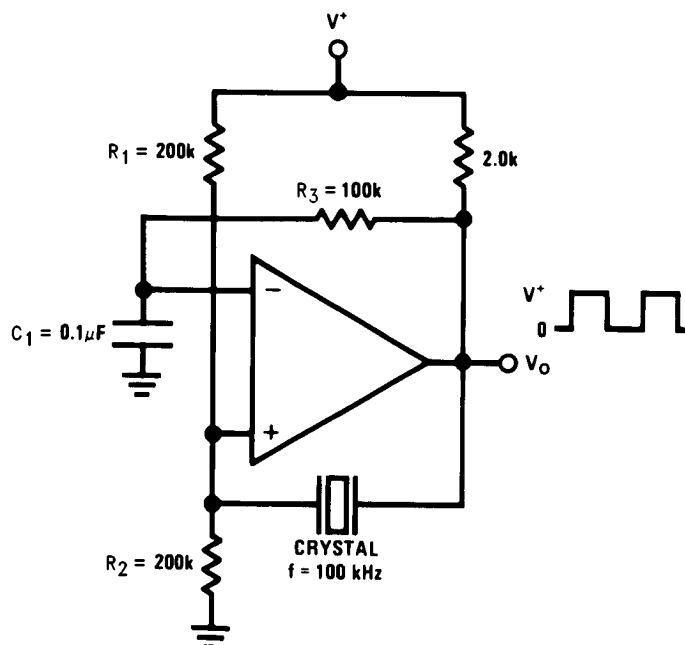


Figure 23. Crystal Controlled Oscillator

A simple yet very stable oscillator that generates a clock for slower digital systems can be obtained by using a resonator as the feedback element. It is similar to the squarewave oscillator, except that the positive feedback is obtained through a quartz crystal. The circuit oscillates when the transmission through the crystal is at a maximum, so the crystal is in its series-resonant mode.

The value of R_1 and R_2 are equal so that the comparator will switch symmetrically about $+V_{CC}/2$. The RC constant of R_3 and C_1 is set to be several times greater than the period of the oscillating frequency, insuring a 50% duty cycle by maintaining a DC voltage at the inverting input equal to the absolute average of the output waveform.

When specifying the crystal, be sure to order series resonant with the desired temperature coefficient.

Typical Applications (continued)

8.2.3 Pulse Generator With Variable Duty Cycle

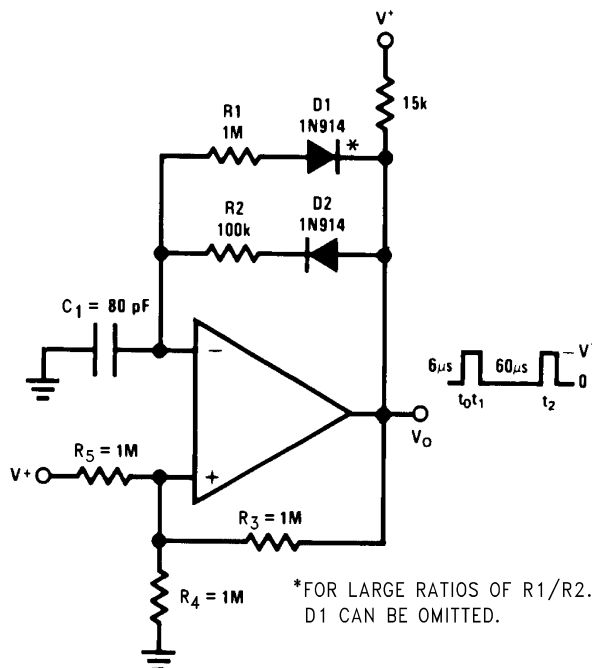


Figure 24. Pulse Generator With Variable Duty Cycle

The pulse generator with variable duty cycle is just a minor modification of the basic square wave generator. Providing a separate charge and discharge path for capacitor C_1 generates a variable duty cycle. One path, through R_2 and D_2 will charge the capacitor and set the pulse width (t_1). The other path, R_1 and D_1 will discharge the capacitor and set the time between pulses (t_2).

By varying resistor R_1 , the time between pulses of the generator can be changed without changing the pulse width. Similarly, by varying R_2 , the pulse width will be altered without affecting the time between pulses. Both controls will change the frequency of the generator. The pulse width and time between pulses can be found from:

$$V_1 = V_{\max} \left(1 - e^{-t_1/R_4 C_1}\right) \quad \text{rise time}$$

$$V_1 = V_{\max} e^{-t_2/R_5 C_1} \quad \text{fall time}$$

Where

$$V_{\max} = \frac{2 V_{CC}}{3}$$

and

$$V_1 = \frac{V_{\max}}{3} = \frac{V_{CC}}{3}$$

Which gives

$$\frac{1}{2} = e^{-t_1/R_4 C_1}$$

t_2 is then given by:

$$\frac{1}{2} = e^{-t_2/R_5 C_1}$$

(16)

Typical Applications (continued)

Solving these equations for t_1 and t_2

$$t_1 = R_4 C_1 \ln 2 \quad (17)$$

$$t_2 = R_5 C_1 \ln 2 \quad (18)$$

These terms will have a slight error due to the fact that $V_{\max}$ is not exactly equal to $2/3 V_{CC}$ but is actually reduced by the diode drop to:

$$V_{\max} = \frac{2}{3} (V_{CC} - V_{BE}) \quad (19)$$

$$\frac{1}{2(1 - V_{BE})} = e^{-t_1/R_4 C_1} \quad (20)$$

$$\frac{1}{2(1 - V_{BE})} = e^{-t_2/R_5 C_1} \quad (21)$$

8.2.4 Positive Peak Detector

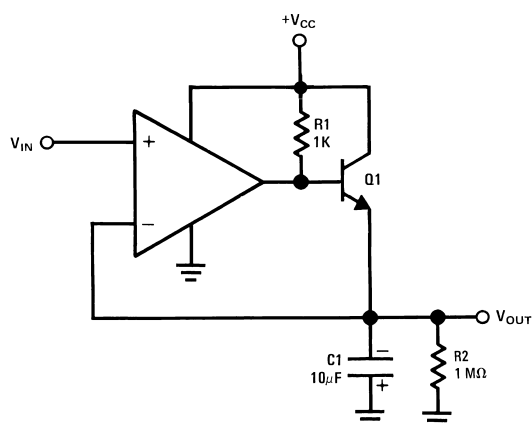


Figure 25. Positive Peak Detector

Positive peak detector is basically the comparator operated as a unit gain follower with a large holding capacitor from the output to ground. Additional transistor is added to the output to provide a low impedance current source. When the output of the comparator goes high, current is passed through the transistor to charge up the capacitor. The only discharge path will be the 1-MΩ resistor shunting C1 and any load that is connected to the output. The decay time can be altered simply by changing the 1-MΩ resistor. The output should be used through a high impedance follower to avoid loading the output of the peak detector.

8.2.5 Negative Peak Detector

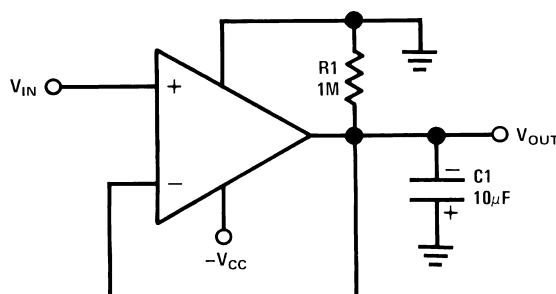


Figure 26. Negative Peak Detector

For the negative detector, the output transistor of the comparator acts as a low impedance current sink. The only discharge path will be the 1-MΩ resistor and any load impedance used. Decay time is changed by varying the 1-MΩ resistor.

9 Power Supply Recommendations

The TLV170x is specified for operation from 2.2 V to 36 V (± 1.1 to ± 18 V); many specifications apply from -40°C to $+125^{\circ}\text{C}$. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the [Typical Characteristics](#).

CAUTION

Supply voltages larger than 5.5 V can permanently damage the device; see the [Specifications](#) section.

Place 0.1- μF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high impedance power supplies. For more detailed information on bypass capacitor placement, refer to the [Layout Guidelines](#) section

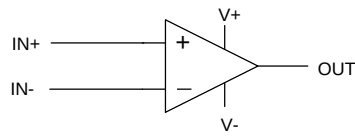
10 Layout

10.1 Layout Guidelines

Comparators are very sensitive to input noise. For best results, the following layout guidelines should be maintained:

- Use a printed circuit board (PCB) with a good, unbroken low-inductance ground plane. Proper grounding (use of ground plane) helps maintain specified performance of the comparator
- Connect low-ESR, 0.1- μF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from $V+$ to ground is applicable for single supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current. For more detailed information refer to [SLOA089](#), *Circuit Board Layout Techniques*.
- In order to reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible, as shown in [Layout Example](#).
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- For slow-moving input signals, take care to prevent parasitic feedback. A small capacitor (1000 pF or less) placed between the inputs can help eliminate oscillations in the transition region. This capacitor causes some degradation to propagation delay when the impedance is low. Run the topside ground plane between the output and inputs.

10.2 Layout Example



(Schematic Representation)

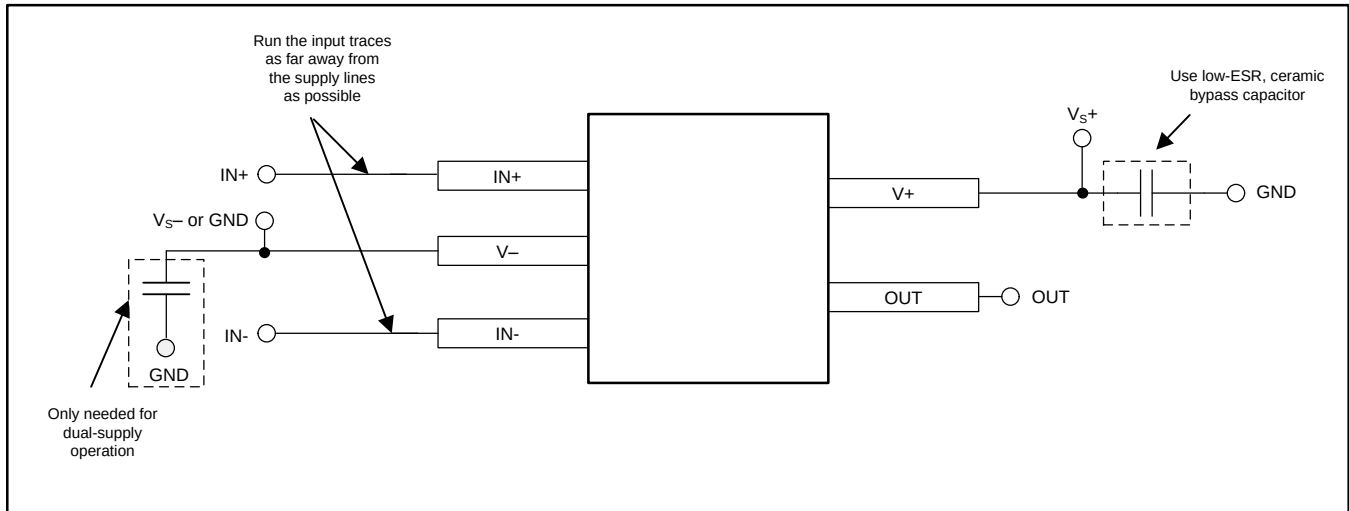


Figure 27. Comparator Board Layout

11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

LMV331-N PSPICE Model, [SNOM073](#)

LMV339-N PSPICE Model, [SNOM074](#)

LMV393-N PSPICE Model, [SNOM059](#)

TINA-TI SPICE-Based Analog Simulation Program, <http://www.ti.com/tool/tina-ti>

DIP Adapter Evaluation Module, <http://www.ti.com/tool/dip-adapter-evm>

TI Universal Operational Amplifier Evaluation Module, <http://www.ti.com/tool/opampevm>

11.2 Documentation Support

11.2.1 Related Documentation

AN-74 - A Quad of Independently Functioning Comparators, [SNOA654](#)

11.3 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 2. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LMV331-N	Click here	Click here	Click here	Click here	Click here
LMV339-N	Click here	Click here	Click here	Click here	Click here
LMV393-N	Click here	Click here	Click here	Click here	Click here

11.4 Trademarks

All trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LMV331M5	ACTIVE	SOT-23	DBV	5	1000	TBD	Call TI	Call TI	-40 to 85	C12	Samples
LMV331M5/NOPB	ACTIVE	SOT-23	DBV	5	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	C12	Samples
LMV331M5X	NRND	SOT-23	DBV	5	3000	TBD	Call TI	Call TI	-40 to 85	C12	
LMV331M5X/NOPB	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	C12	Samples
LMV331M7	NRND	SC70	DCK	5	1000	TBD	Call TI	Call TI	-40 to 85	C13	
LMV331M7/NOPB	ACTIVE	SC70	DCK	5	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	C13	Samples
LMV331M7X	NRND	SC70	DCK	5	3000	TBD	Call TI	Call TI	-40 to 85	C13	
LMV331M7X/NOPB	ACTIVE	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	C13	Samples
LMV339M	NRND	SOIC	D	14	55	TBD	Call TI	Call TI	-40 to 85	LMV339M	
LMV339M/NOPB	ACTIVE	SOIC	D	14	55	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMV339M	Samples
LMV339MT	NRND	TSSOP	PW	14	94	TBD	Call TI	Call TI	-40 to 85	LMV339 MT	
LMV339MT/NOPB	ACTIVE	TSSOP	PW	14	94	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMV339 MT	Samples
LMV339MTX	NRND	TSSOP	PW	14	2500	TBD	Call TI	Call TI	-40 to 85	LMV339 MT	
LMV339MTX/NOPB	ACTIVE	TSSOP	PW	14	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMV339 MT	Samples
LMV339MX/NOPB	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMV339M	Samples
LMV393M	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LMV 393M	
LMV393M/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMV 393M	Samples
LMV393MM	NRND	VSSOP	DGK	8	1000	TBD	Call TI	Call TI	-40 to 85	V393	
LMV393MM/NOPB	ACTIVE	VSSOP	DGK	8	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	V393	Samples
LMV393MMX	NRND	VSSOP	DGK	8	3500	TBD	Call TI	Call TI	-40 to 85	V393	

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LMV393MMX/NOPB	ACTIVE	VSSOP	DGK	8	3500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	V393	Samples
LMV393MX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	LMV 393M	
LMV393MX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LMV 393M	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBsolete: TI has discontinued the production of the device.

(2) 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.

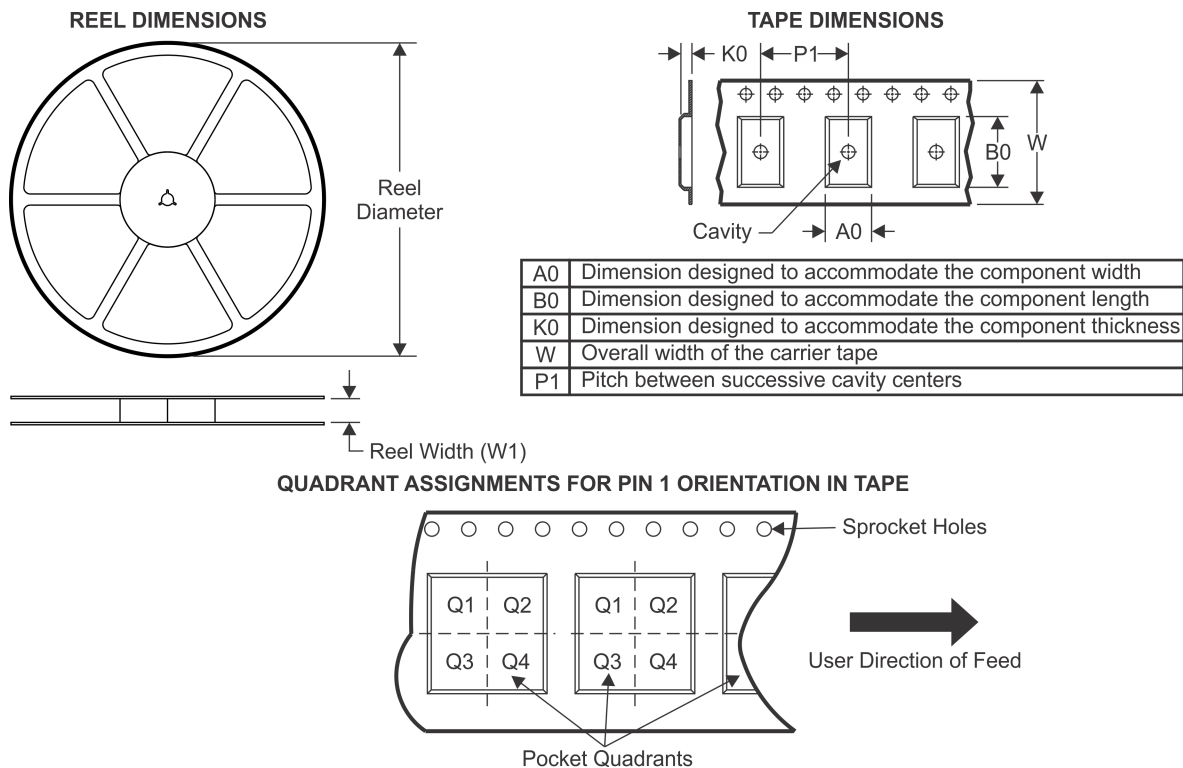
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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.

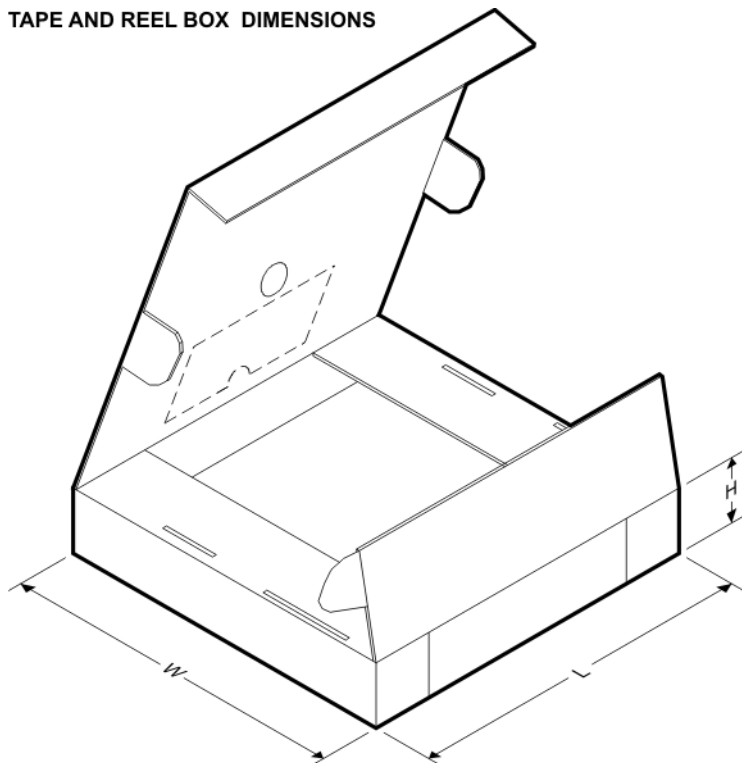
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMV331M5	SOT-23	DBV	5	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMV331M5/NOPB	SOT-23	DBV	5	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMV331M5X	SOT-23	DBV	5	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMV331M5X/NOPB	SOT-23	DBV	5	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMV331M7	SC70	DCK	5	1000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMV331M7/NOPB	SC70	DCK	5	1000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMV331M7X	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMV331M7X/NOPB	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMV339MTX	TSSOP	PW	14	2500	330.0	12.4	6.95	5.6	1.6	8.0	12.0	Q1
LMV339MTX/NOPB	TSSOP	PW	14	2500	330.0	12.4	6.95	5.6	1.6	8.0	12.0	Q1
LMV339MX/NOPB	SOIC	D	14	2500	330.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LMV393MM	VSSOP	DGK	8	1000	178.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMV393MM/NOPB	VSSOP	DGK	8	1000	178.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMV393MMX	VSSOP	DGK	8	3500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMV393MMX/NOPB	VSSOP	DGK	8	3500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LMV393MX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMV393MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

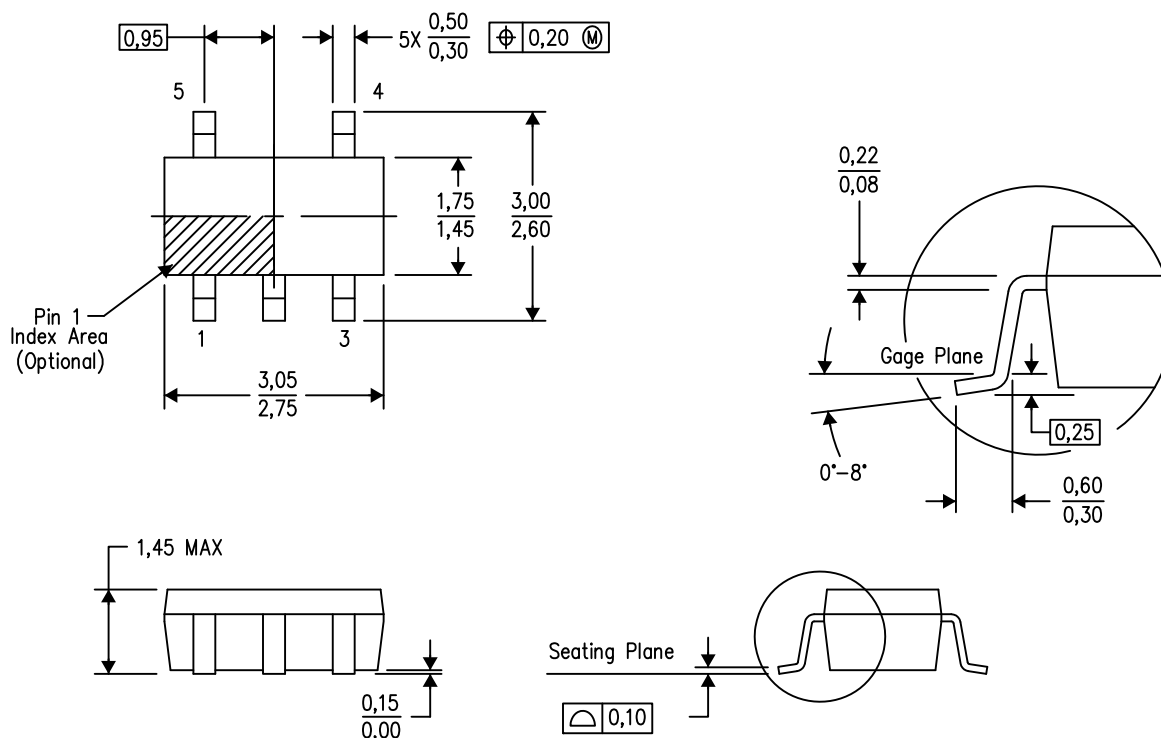


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMV331M5	SOT-23	DBV	5	1000	210.0	185.0	35.0
LMV331M5/NOPB	SOT-23	DBV	5	1000	210.0	185.0	35.0
LMV331M5X	SOT-23	DBV	5	3000	210.0	185.0	35.0
LMV331M5X/NOPB	SOT-23	DBV	5	3000	210.0	185.0	35.0
LMV331M7	SC70	DCK	5	1000	210.0	185.0	35.0
LMV331M7/NOPB	SC70	DCK	5	1000	210.0	185.0	35.0
LMV331M7X	SC70	DCK	5	3000	210.0	185.0	35.0
LMV331M7X/NOPB	SC70	DCK	5	3000	210.0	185.0	35.0
LMV339MTX	TSSOP	PW	14	2500	367.0	367.0	35.0
LMV339MTX/NOPB	TSSOP	PW	14	2500	367.0	367.0	35.0
LMV339MX/NOPB	SOIC	D	14	2500	367.0	367.0	35.0
LMV393MM	VSSOP	DGK	8	1000	210.0	185.0	35.0
LMV393MM/NOPB	VSSOP	DGK	8	1000	210.0	185.0	35.0
LMV393MMX	VSSOP	DGK	8	3500	367.0	367.0	35.0
LMV393MMX/NOPB	VSSOP	DGK	8	3500	367.0	367.0	35.0
LMV393MX	SOIC	D	8	2500	367.0	367.0	35.0
LMV393MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0

DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE

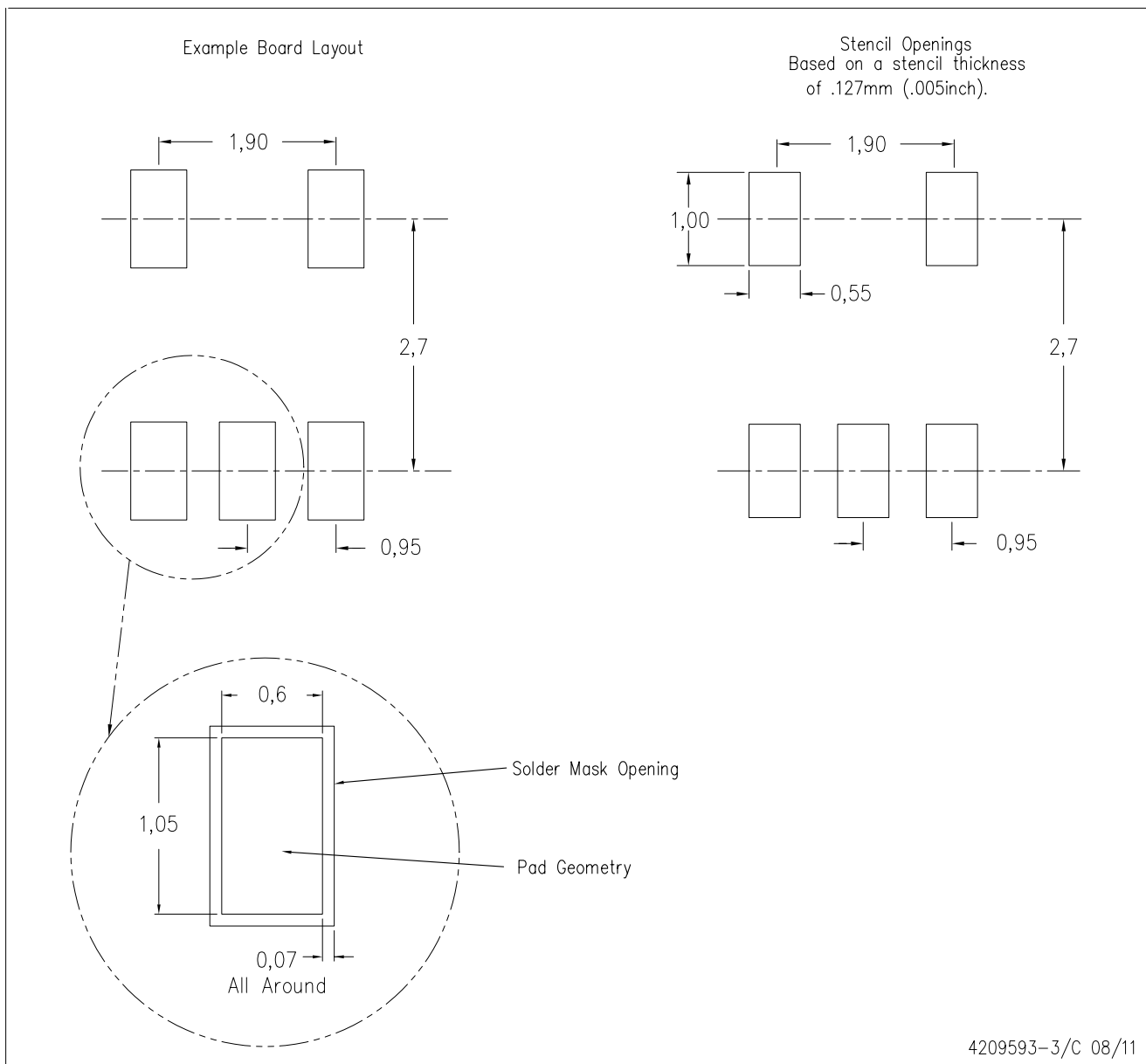


4073253-4/N 12/14

- NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO-178 Variation AA.

DBV (R-PDSO-G5)

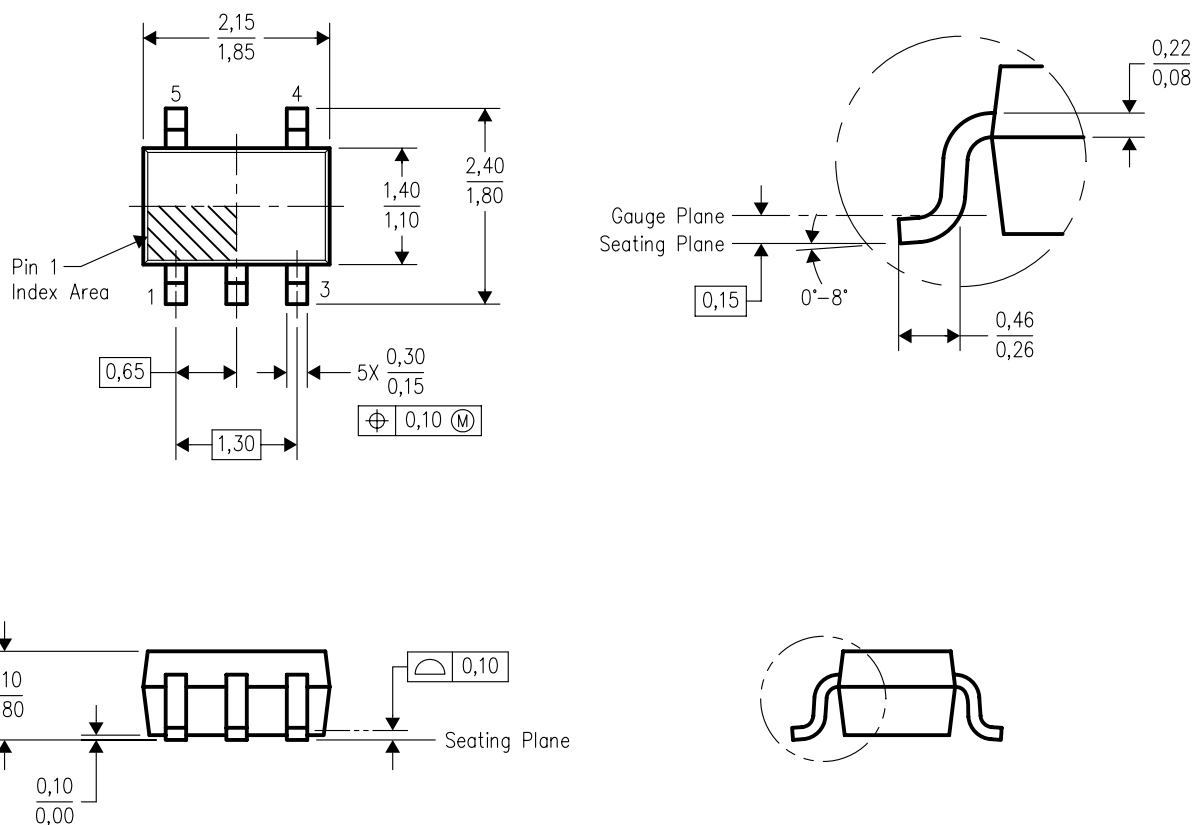
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
 - D. Publication IPC-7351 is recommended for alternate designs.
 - E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

DCK (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE

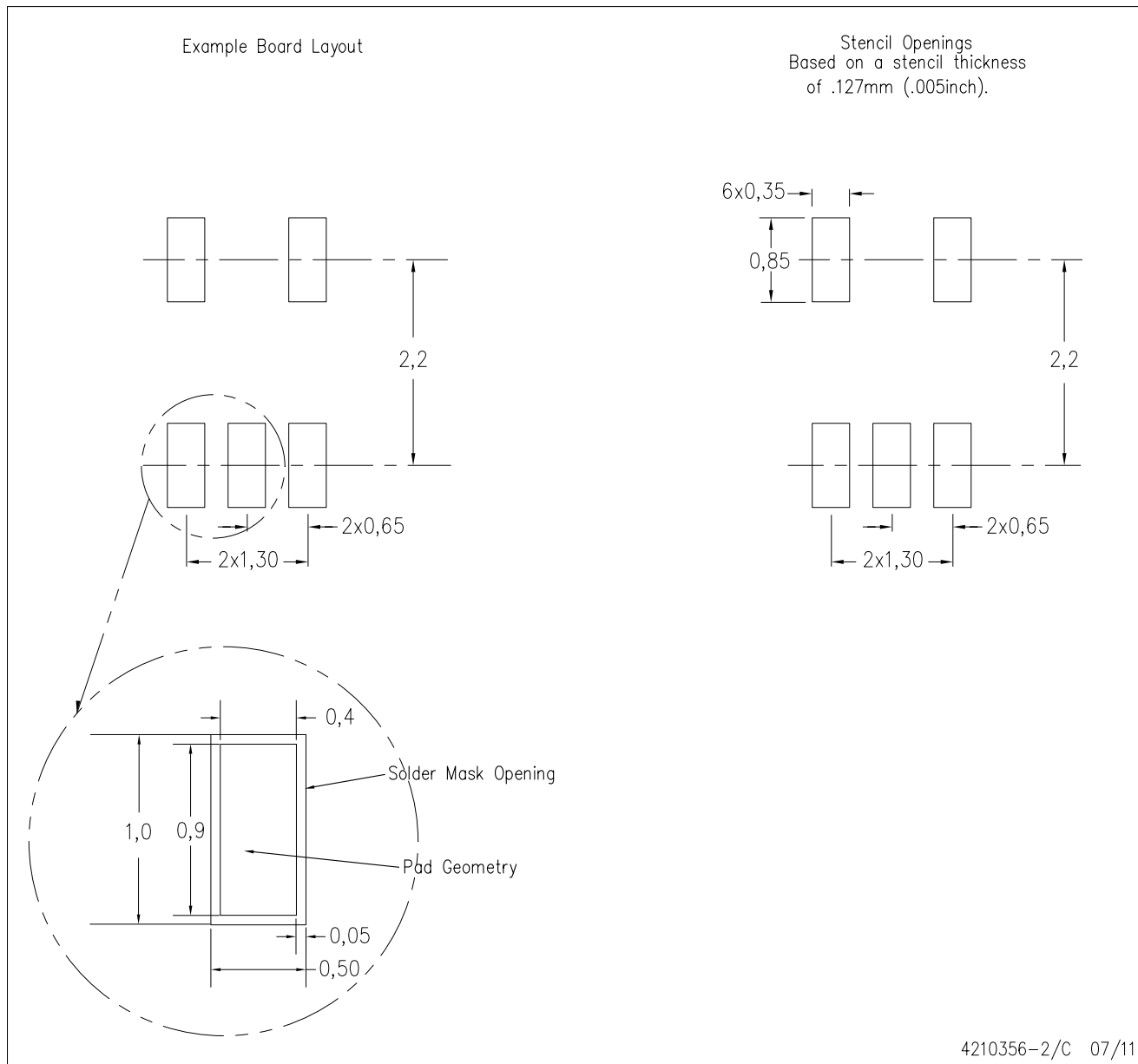


4093553-3/G 01/2007

- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - Falls within JEDEC MO-203 variation AA.

DCK (R-PDSO-G5)

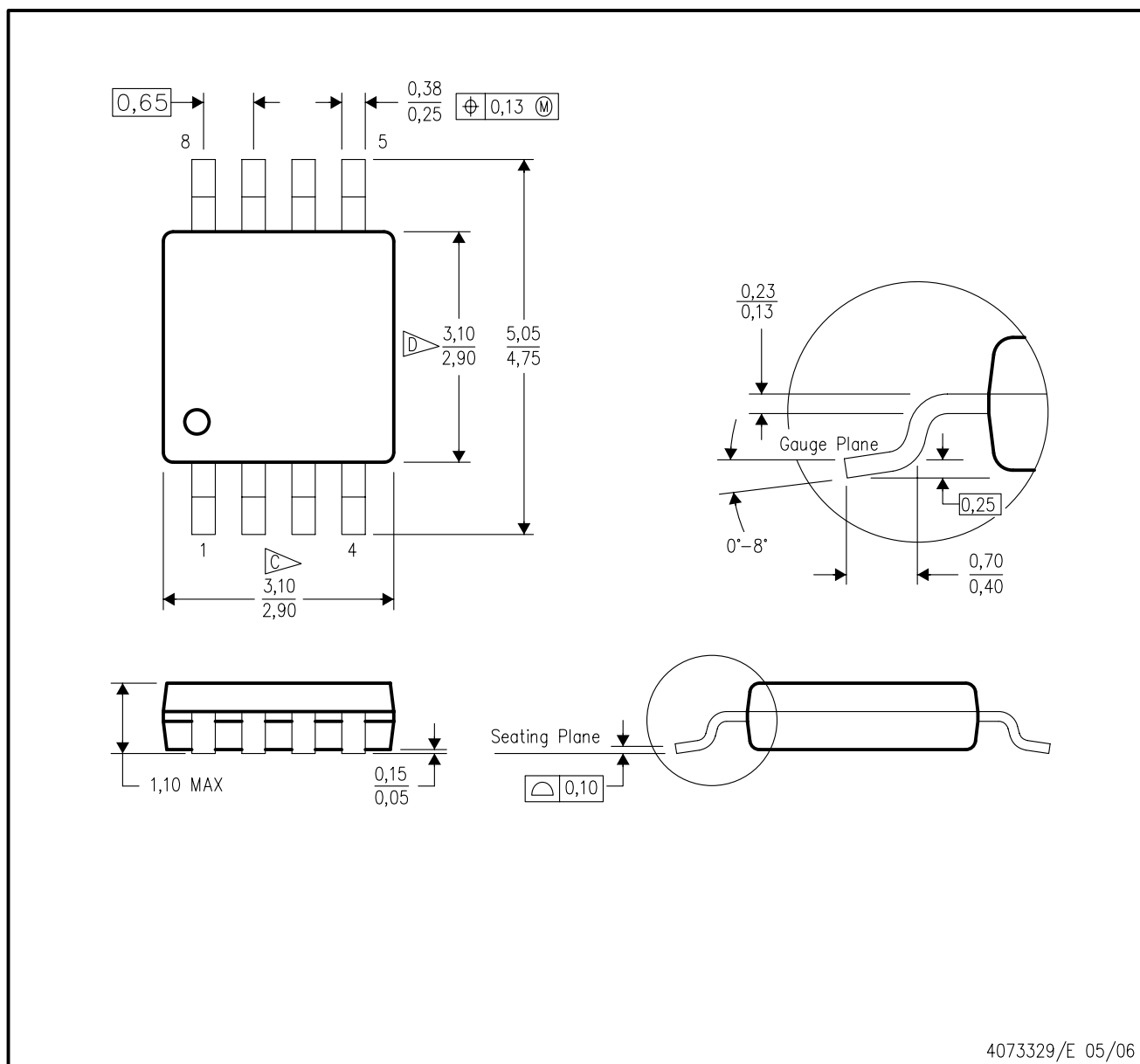
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
 - D. Publication IPC-7351 is recommended for alternate designs.
 - E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

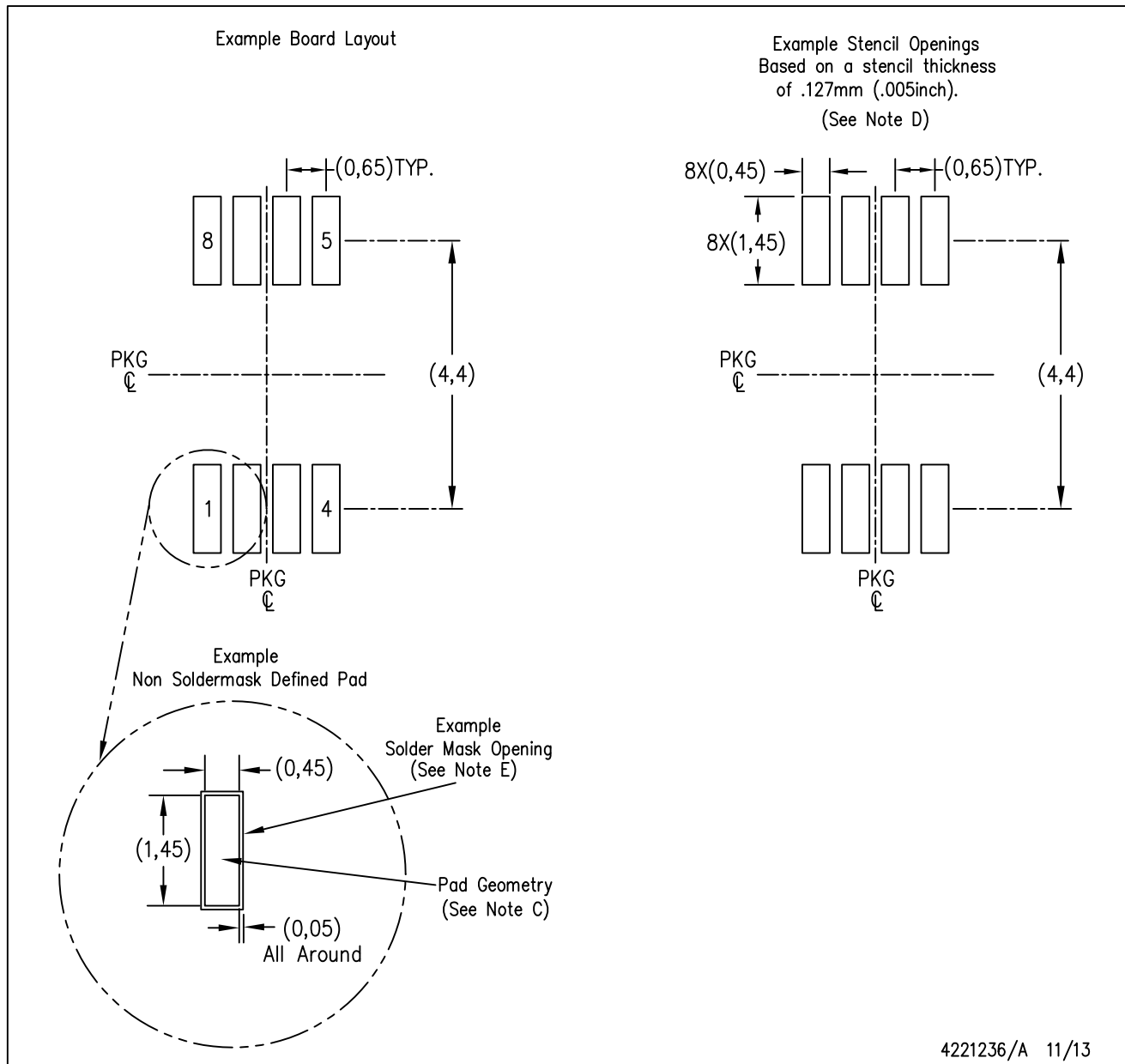


NOTES:

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

DGK (S-PDSO-G8)

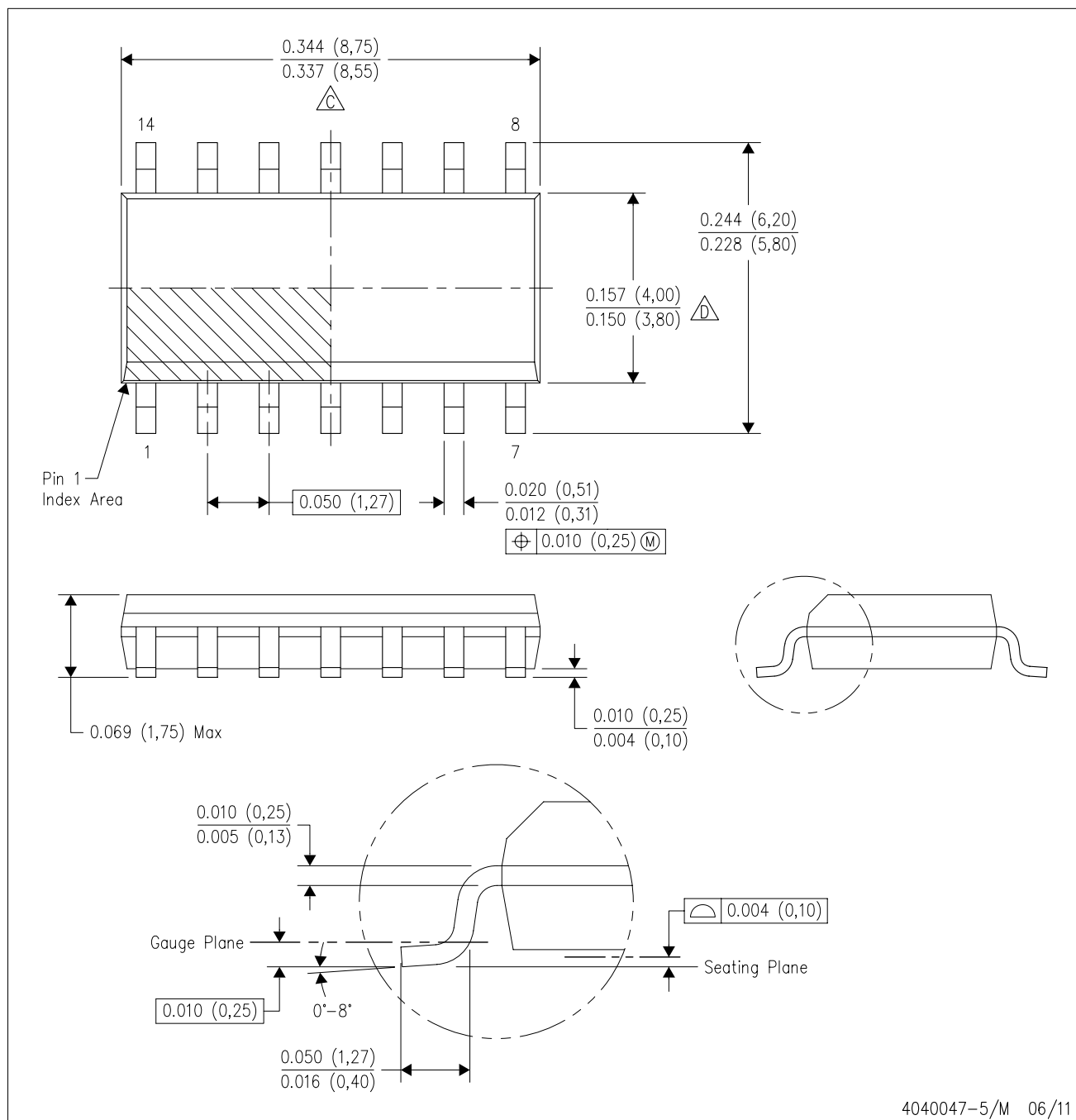
PLASTIC SMALL OUTLINE PACKAGE



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

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE

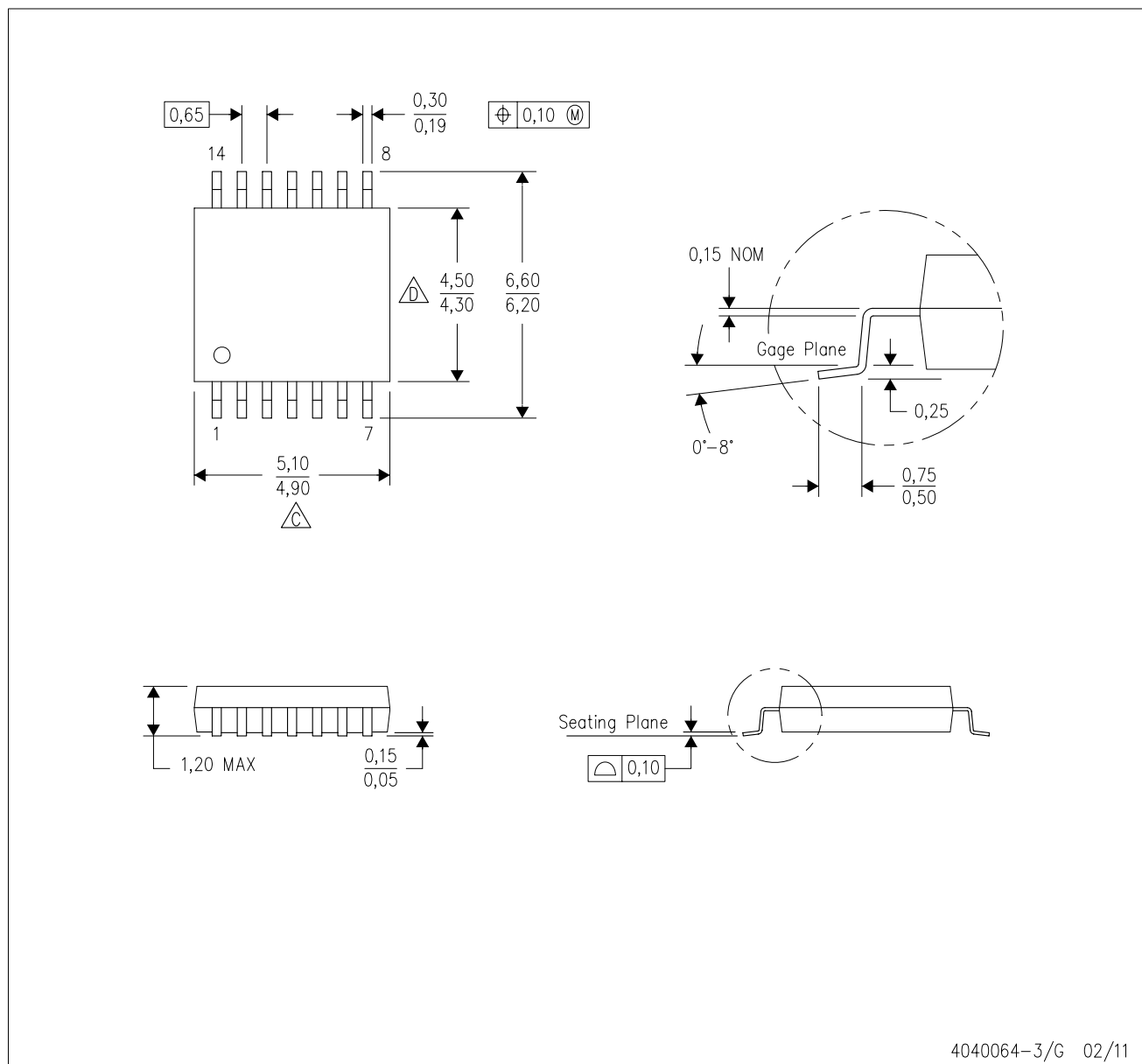


NOTES:

- 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 0.006 (0,15) each side.
D Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS-012 variation AB.

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE

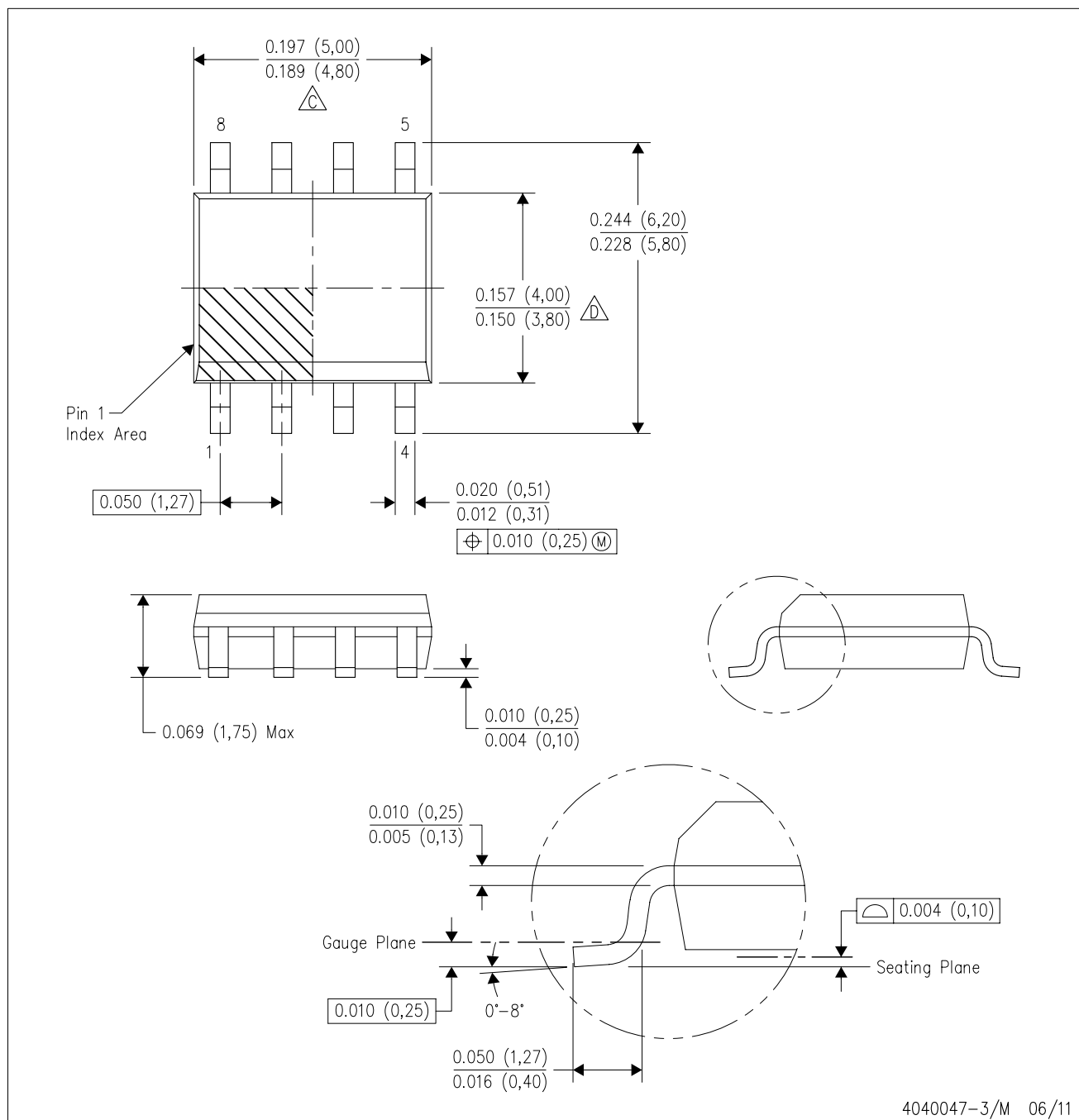


4040064-3/G 02/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
 - E. Falls within JEDEC MO-153

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



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

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com