

August 1999

# LMV331 Single / LMV393 Dual / LMV339 Quad General Purpose, Low Voltage, TinyPack Comparators

## General Description

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

The LMV393 is available in 8-pin SOIC and 8-pin MSOP. The LMV339 is available in 14-pin SOIC and 14-pin TSSOP.

The LMV331/393/339 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 National's advanced Submicron Silicon-Gate BiCMOS process. The LMV331/393/339 have bipolar input and output stages for improved noise performance.

## Features

(For 5V Supply, Typical Unless Otherwise Noted)

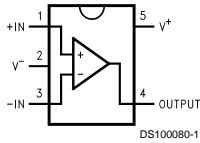
- Space Saving SC70-5 Package (2.0 x 2.1 x 1.0 mm)
- Space Saving SOT23-5 Package (3.00 x 3.01 x 1.43 mm)
- Guaranteed 2.7V and 5V Performance
- Industrial Temperature Range -40°C to +85°C
- Low Supply Current 60µA/Channel
- Input Common Mode Voltage Range Includes Ground
- Low Output Saturation Voltage 200 mV

## Applications

- Mobile Communications
- Notebooks and PDA's
- Battery Powered Electronics
- General Purpose Portable Device
- General Purpose Low Voltage Applications

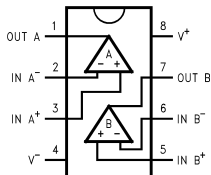
## Connection Diagrams

5-Pin SC70-5/SOT23-5



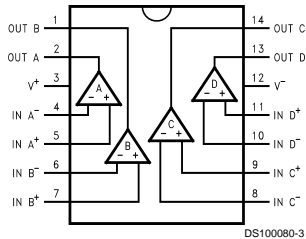
Top View

8-Pin SO/MSOP



Top View

14-Pin SO/TSSOP



Top View

## Ordering Information

Package	Temperature Range	Packaging Marking	Transport Media	NSC Drawing
	Industrial –40°C to +85°C			
5-pin SC70-5	LMV331M7	C13	1k Units Tape and Reel	MAA05
	LMV331M7X	C13	3k Units Tape and Reel	
5-pin SOT23-5	LMV331M5	C12	1k Units Tape and Reel	MA05B
	LMV331M5X	C12	3k Units Tape and Reel	
8-pin Small Outline	LMV393M	LMV393M	Rails	M08A
	LMV393MX	LMV393M	2.5k Units Tape and Reel	
8-pin MSOP	LMV393MM	LMV393	1k Units Tape and Reel	MUA08A
	LMV393MMX	LMV393	3.5k Units Tape and Reel	
14-pin Small Outline	LMV339M	LMV339M	Rails	M14A
	LMV339MX	LMV339M	2.5k Units Tape and Reel	
14-pin TSSOP	LMV339MT	LMV339MT	Rails	MTC14
	LMV339MTX	LMV339MT	2.5k Units Tape and Reel	

## Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

### ESD Tolerance (Note 2)

Human Body Model	
LMV331/ 393/ 339	800V
Machine Model LMV331/339/393	120V
Differential Input Voltage	± Supply Voltage
Voltage on any pin (referred to V <sup>-</sup> pin)	5.5V
Soldering Information	
Infrared or Convection (20 sec)	235°C
Storage Temp. Range	-65°C to +150°C
Junction Temperature (Note 3)	150°C

## Operating Ratings (Note 1)

Supply Voltage	2.7V to 5.0V
Temperature Range	
LMV393, LMV339, LMV331	-40°C ≤ T <sub>J</sub> ≤ +85°C
Thermal Resistance (θ <sub>JA</sub> )	
M Package, 8-pin Surface Mount	190°C/W
M Package, 14-pin Surface Mount	145°C/W
MTC Package, 14-pin TSSOP	155°C/W
MAA05 Package, 5-pin SC70-5	478°C/W
M05A Package 5 -pin SOT23-5	265°C/W
MM Package, 8-pin Mini Surface Mount	235°C/W

## 2.7V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T<sub>J</sub> = 25°C, V<sub>+</sub> = 2.7V, V<sub>-</sub> = 0V. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 4)	LMV331/ 393/339 Limit (Note 5)	Units
V <sub>OS</sub>	Input Offset Voltage		1.7	7	mV max
TCV <sub>OS</sub>	Input Offset Voltage Average Drift		5		μV/°C
I <sub>B</sub>	Input Bias Current		10	250 <b>400</b>	nA max
I <sub>OS</sub>	Input Offset Current		5	50 <b>150</b>	nA max
V <sub>CM</sub>	Input Voltage Range		-0.1 2.0		V V
V <sub>SAT</sub>	Saturation Voltage	I <sub>sink</sub> ≤ 1mA	200		mV
I <sub>O</sub>	Output Sink Current	V <sub>O</sub> ≤ 1.5V	23	5	mA min
I <sub>S</sub>	Supply Current	LMV331	40	100	μA max
		LMV393 Both Comparators	70	140	μA max
		LMV339 All four Comparators	140	200	μA max
	Output Leakage Current		.003	1	μA max

## 2.7V AC Electrical Characteristics

T<sub>J</sub> = 25°C, V<sub>+</sub> = 2.7V, R<sub>L</sub> = 5.1 kΩ, V<sub>-</sub> = 0V.

Symbol	Parameter	Conditions	Typ (Note 4)	Units
t <sub>PHL</sub>	Propagation Delay (High to Low)	Input Overdrive = 10 mV	1000	ns
		Input Overdrive = 100 mV	350	ns
t <sub>PLH</sub>	Propagation Delay (Low to High)	Input Overdrive = 10 mV	500	ns
		Input Overdrive = 100 mV	400	ns

## 5V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V_+ = 5\text{V}$ ,  $V_- = 0\text{V}$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 4)	LMV331/ 393/339 Limit (Note 5)	Units
$V_{OS}$	Input Offset Voltage		1.7	7 <b>9</b>	mV max
$TCV_{OS}$	Input Offset Voltage Average Drift		5		$\mu\text{V}/^\circ\text{C}$
$I_B$	Input Bias Current		25	250 <b>400</b>	nA max
$I_{OS}$	Input Offset Current		2	50 <b>150</b>	nA max
$V_{CM}$	Input Voltage Range		-0.1		V
			4.2		V
$A_V$	Voltage Gain		50	20	V/mV min
$V_{sat}$	Saturation Voltage	$I_{sink} \leq 4\text{ mA}$	200	400 <b>700</b>	mV max
$I_O$	Output Sink Current	$V_O \leq 1.5\text{V}$	84	10	mA
$I_S$	Supply Current	LMV331	60	120 <b>150</b>	$\mu\text{A}$ max
		LMV393 Both Comparators	100	200 <b>250</b>	$\mu\text{A}$ max
		LMV339 All four Comparators	170	300 <b>350</b>	$\mu\text{A}$ max
	Output Leakage Current		.003	<b>1</b>	$\mu\text{A}$ max

## 5V AC Electrical Characteristics

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

Symbol	Parameter	Conditions	Typ (Note 4)	Units
$t_{PHL}$	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

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical characteristics.

**Note 2:** : Human body model, 1.5k $\Omega$  in series with 100 pF. Machine model, 200 $\Omega$  in series with 100 pF.

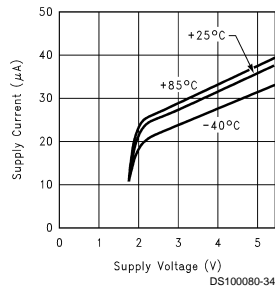
**Note 3:** The maximum power dissipation is a function of  $T_{J(max)}$ ,  $\theta_{JA}$ , and  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{J(max)} - T_A)/\theta_{JA}$ . All numbers apply for packages soldered directly into a PC board.

**Note 4:** Typical Values represent the most likely parametric norm.

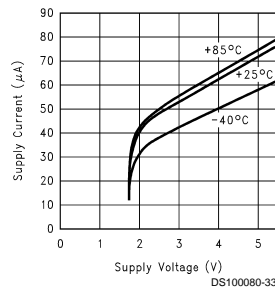
**Note 5:** All limits are guaranteed by testing or statistical analysis.

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

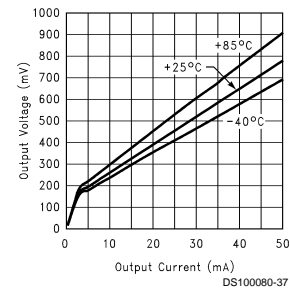
**Supply Current vs  
Supply Voltage Output High  
(LMV331)**



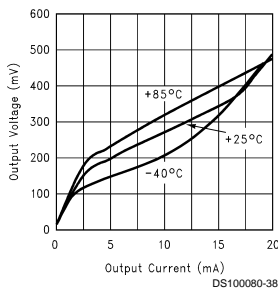
**Supply Current vs  
Supply Voltage Output Low  
(LMV331)**



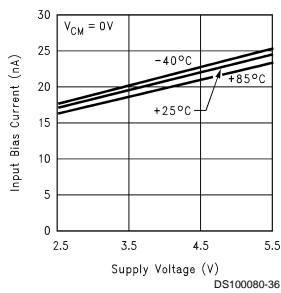
**Output Voltage vs  
Output Current at 5V Supply**



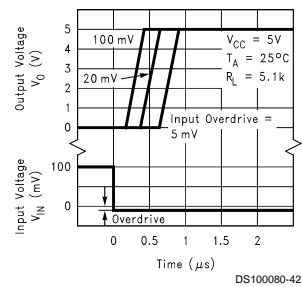
**Output Voltage vs  
Output Current  
at 2.7 Supply**



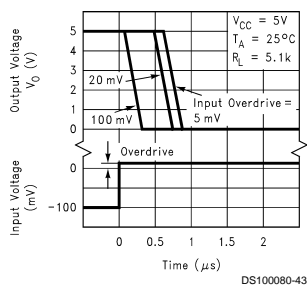
**Input Bias Current vs  
Supply Voltage**



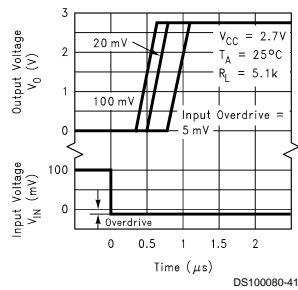
**Response Time vs  
Input Overdrives  
Negative Transition**



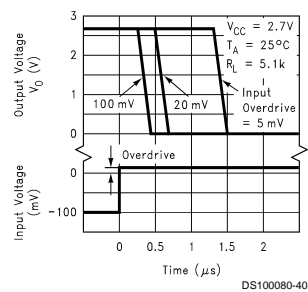
**Response Time for  
Input Overdrive  
Positive Transition**



**Response Time vs  
Input Overdrives  
Negative Transition**



**Response Time for  
Input Overdrive  
Positive Transition**



### Simplified Schematic



## Application Circuits

### Basic Comparator

A basic comparator circuit is used for converting analog signals to a digital output. The LMV331/393/339 have an open-collector output stage, which requires a pull-up resistor to a positive supply voltage for the output to switch properly. When the internal output transistor is off, the output voltage will be pulled up to the external positive voltage.

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 LMV331/393/339 the pull-up resistor should range between 1k to 10kΩ.

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  $V_{cc}$ .

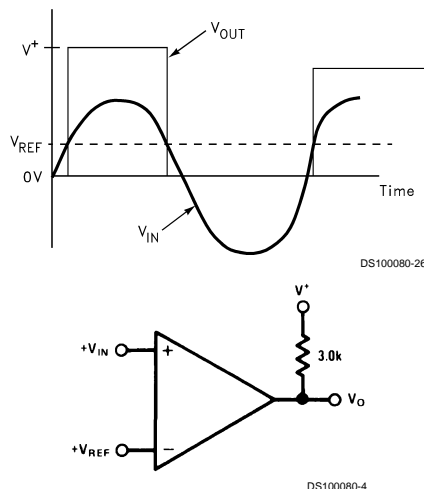


FIGURE 1. Basic Comparator

### 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 comparator's switching threshold. This problem can be prevented by the addition of hysteresis or positive feedback.

### 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  $V_{a1}$ , the voltage at the non-inverting node of the comparator ( $V_{in} < V_{a1}$ ), 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

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

When  $V_{in}$  is greater than  $V_{a1}$  ( $V_{in} > V_{a1}$ ), 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 trip voltage  $V_{a2}$  is defined as

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

The total hysteresis provided by the network is defined as

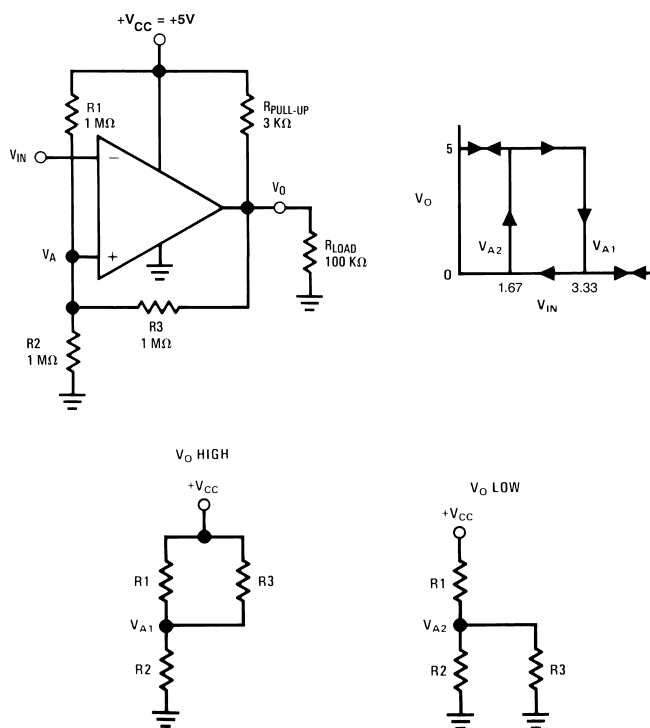
$$\Delta V_a = V_{a1} - V_{a2}$$

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:

$$R_{pull-up} \ll R_{load}$$

$$\text{and } R_1 > R_{pull-up}$$

## Application Circuits (Continued)



DS100080-25

**FIGURE 2. Inverting Comparator with Hysteresis**

### 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

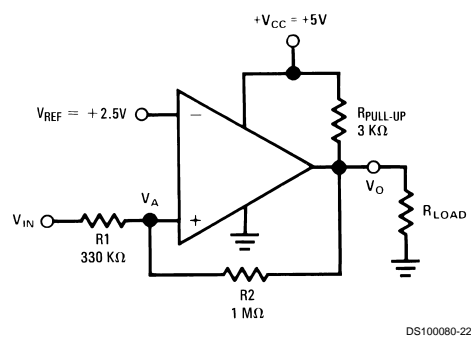
$$V_{in1} = \frac{V_{ref}(R_1 + R_2)}{R_2}$$

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:

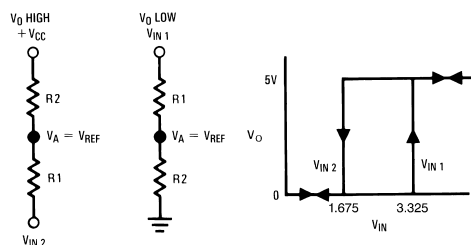
$$V_{in2} = \frac{V_{ref}(R_1 + R_2) - V_{CC}R_1}{R_2}$$

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

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



DS100080-22



DS100080-23



## Application Circuits (Continued)

### Square Wave Oscillator

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.

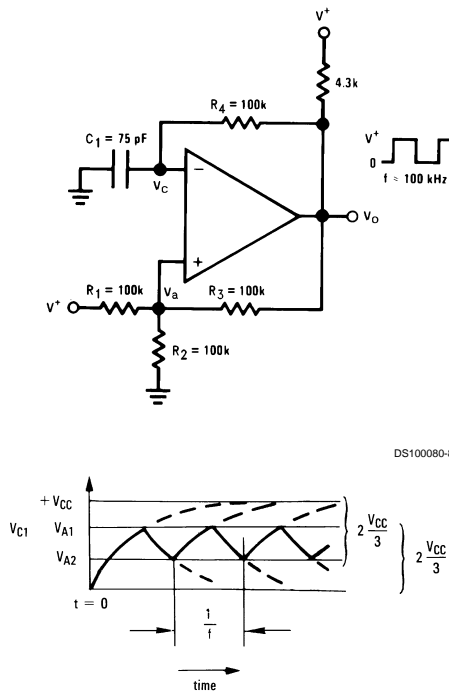


FIGURE 5. Squarewave Oscillator

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:

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

If:

$$R_1 = R_2 = R_3$$

Then:

$$V_{a1} = 2V_{CC}/3$$

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

$$V_{a2} = V_{CC}/3$$

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

$$V_C = V_{max} e^{-\frac{t}{RC}}$$

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:

$$1/\text{freq} = 2t$$

or calculating the exponential gives:

$$1/\text{freq} = 2(0.694) R_4 C_1$$

Resistors  $R_3$  and  $R_4$  must be at least two times larger than  $R_5$  to insure 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.

### Free Running Multivibrator

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 free running multivibrator, 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 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

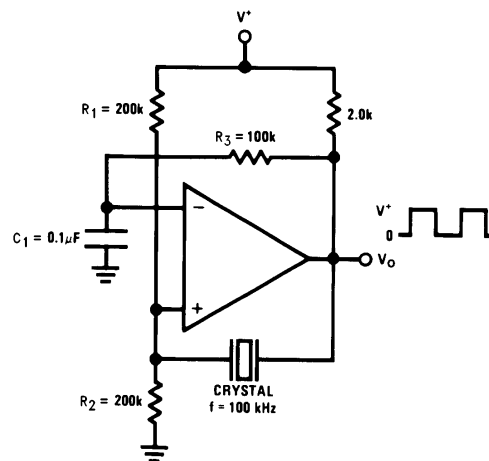


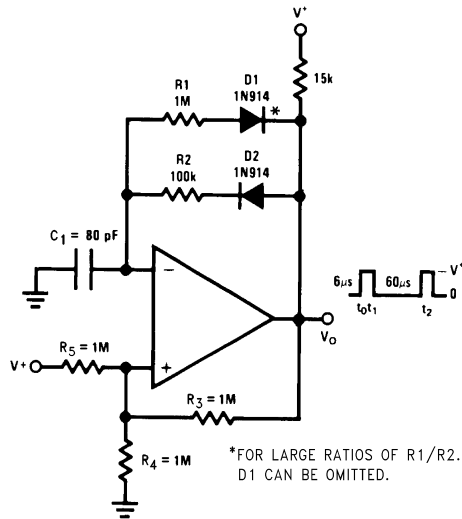
FIGURE 6. Crystal controlled Oscillator

## Application Circuits (Continued)

### 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:



DS100080-9

FIGURE 7. Pulse Generator

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

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

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:

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

Solving these equations for  $t_1$  and  $t_2$

$$t_1 = R_4 C_1 \ln 2$$

$$t_2 = R_5 C_1 \ln 2$$

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:

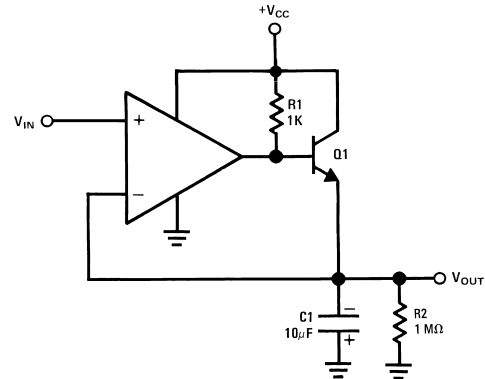
$$V_{\max} = \frac{2}{3} (V_{CC} - V_{BE})$$

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

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

### 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 1M ohm resistor shunting  $C_1$  and any load that is connected to the output. The decay time can be altered simply by changing the 1M ohm resistor. The output should be used through a high impedance follower to avoid loading the output of the peak detector.

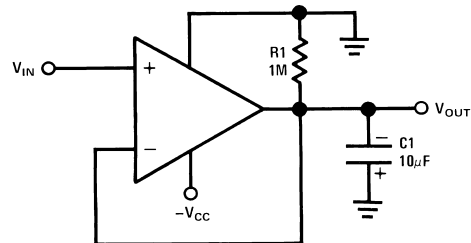


DS100080-17

FIGURE 8. Positive Peak Detector

### 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



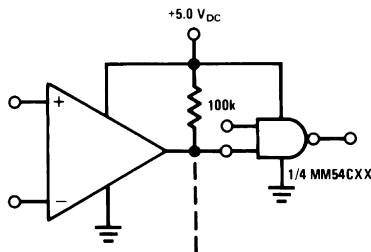
DS100080-18

FIGURE 9. Negative Peak Detector

## Application Circuits (Continued)

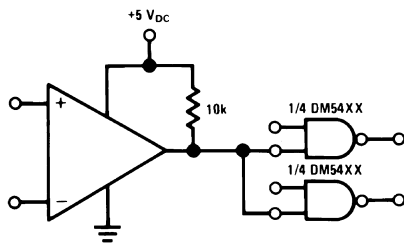
### Driving CMOS and TTL

The comparator's output is capable of driving CMOS and TTL Logic circuits.



DS100080-5

FIGURE 10. Driving CMOS



DS100080-6

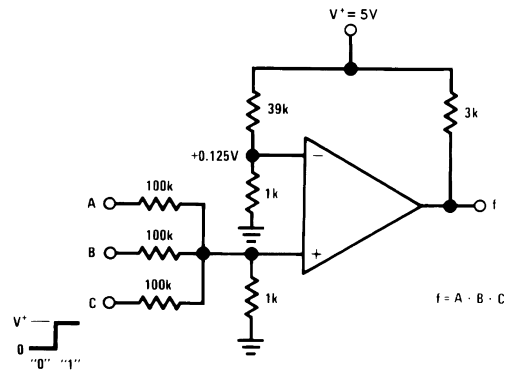
FIGURE 11. Driving TTL

### 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 5V.

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.



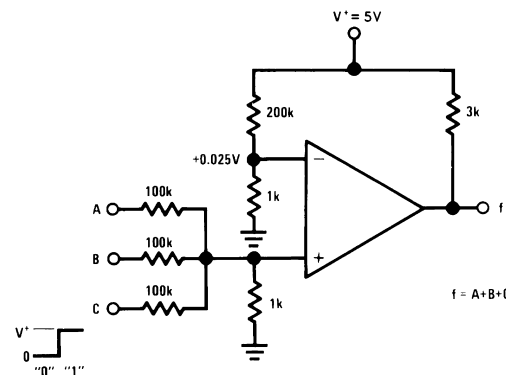
DS100080-11

FIGURE 12. AND Gate

### 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.



DS100080-10

FIGURE 13. OR Gate

### ORing the Output

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

## Application Circuits (Continued)

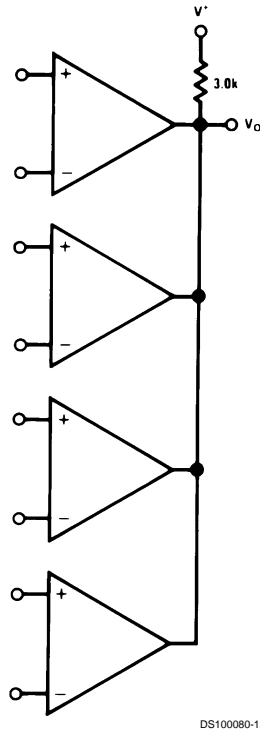


FIGURE 14. ORing the Outputs

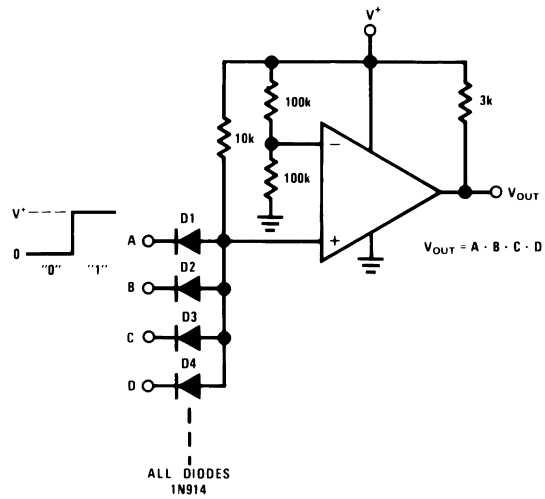
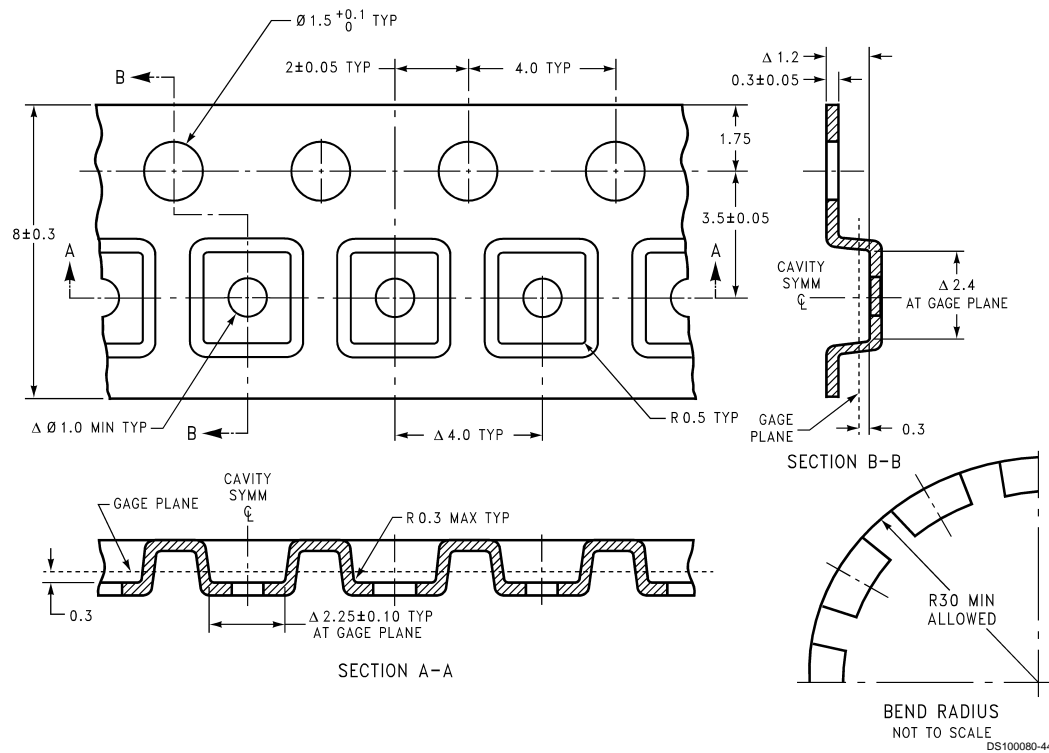


FIGURE 15. Large Fan-In AND Gate

## SC70-5 Tape and Reel Specification



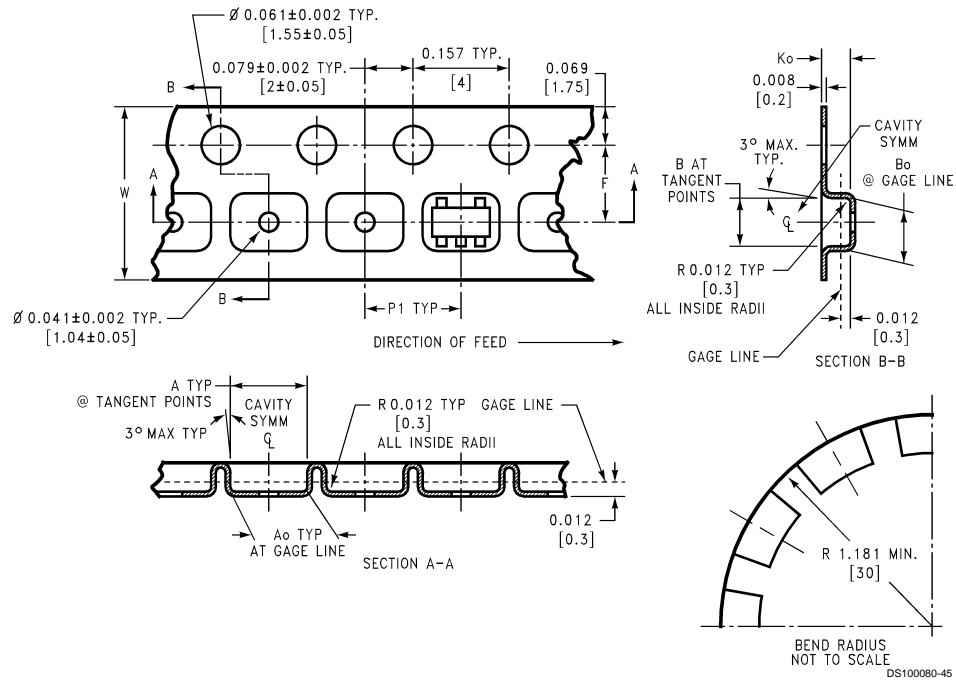
## SOT-23-5 Tape and Reel Specification

### TAPE FORMAT

Tape Section	# Cavities	Cavity Status	Cover Tape Status
Leader (Start End)	0 (min)	Empty	Sealed
	75 (min)	Empty	Sealed
Carrier	3000	Filled	Sealed
	250	Filled	Sealed
Trailer (Hub End)	125 (min)	Empty	Sealed
	0 (min)	Empty	Sealed

## SOT-23-5 Tape and Reel Specification (Continued)

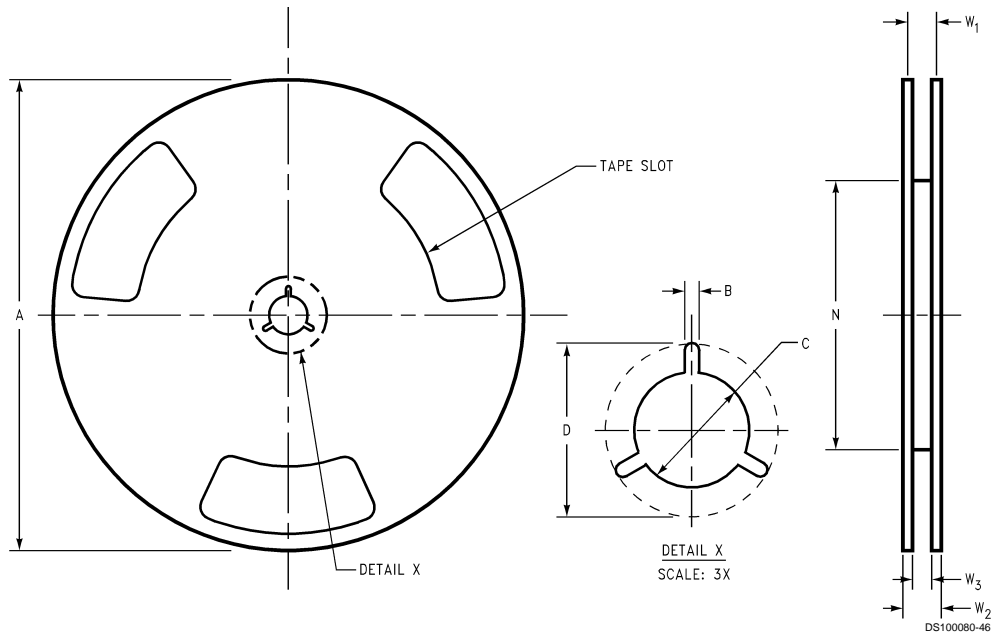
### TAPE DIMENSIONS



8 mm	0.130 (3.3)	0.124 (3.15)	0.130 (3.3)	0.126 (3.2)	0.138 $\pm$ 0.002 (3.5 $\pm$ 0.05)	0.055 $\pm$ 0.004 (1.4 $\pm$ 0.11)	0.157 (4)	0.315 $\pm$ 0.012 (8 $\pm$ 0.3)
Tape Size	DIM A	DIM Ao	DIM B	DIM Bo	DIM F	DIM Ko	DIM P1	DIM W

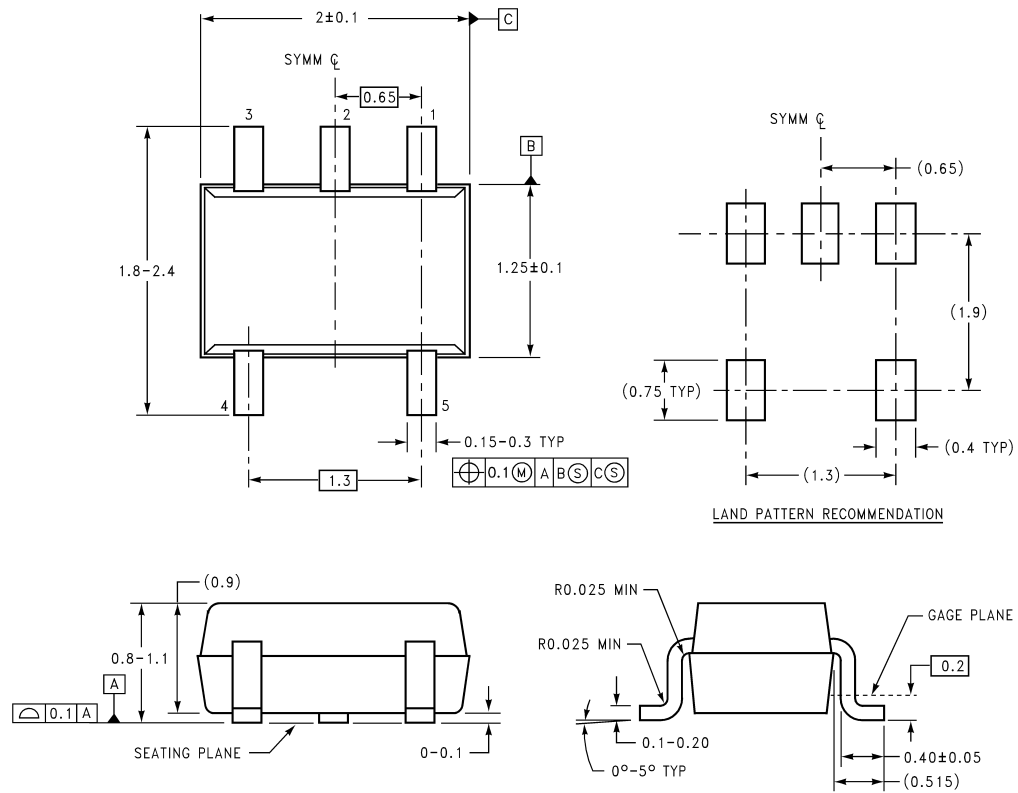
## SOT-23-5 Tape and Reel Specification (Continued)

### REEL DIMENSIONS



8 mm	7.00	0.059	0.512	0.795	2.165	0.331 + 0.059/-0.000	0.567	W1 + 0.078/-0.039
	330.00	1.50	13.00	20.20	55.00	8.40 + 1.50/-0.00	14.40	W1 + 2.00/-1.00
Tape Size	A	B	C	D	N	W1	W2	W3

**Physical Dimensions** inches (millimeters) unless otherwise noted



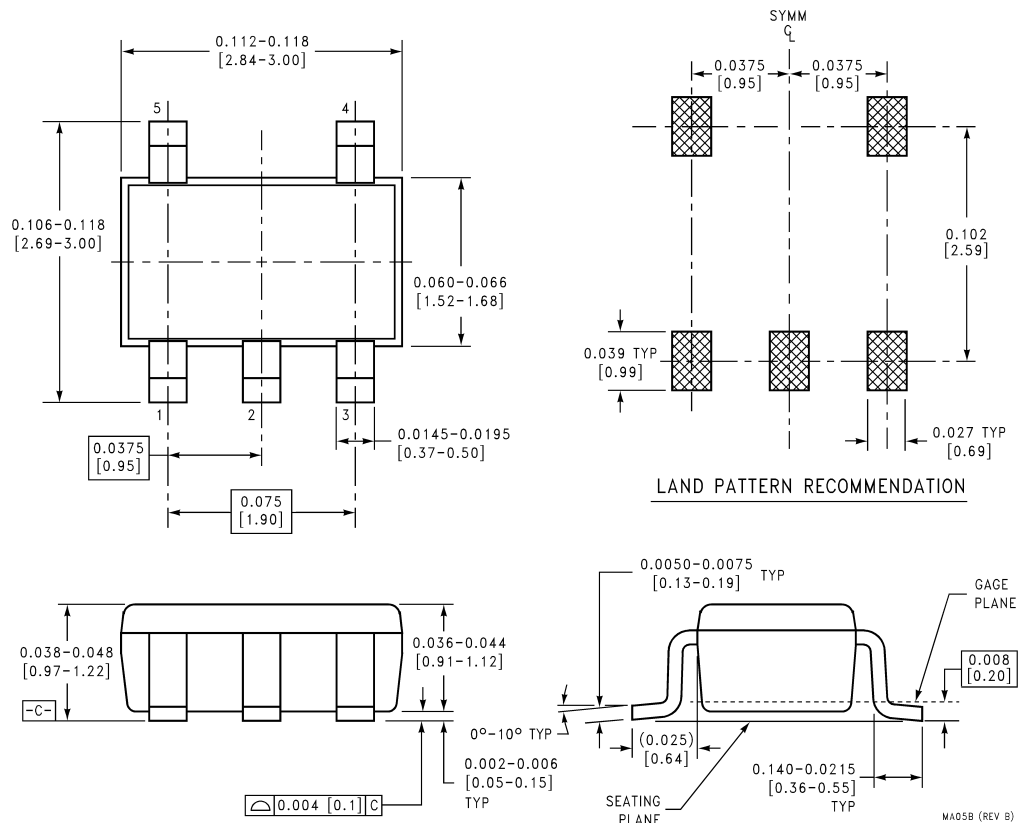
DIMENSIONS ARE IN MILLIMETERS

MAA05A (REV B)

**5-Pin SC70-5 Tape and Reel**  
**Order Number LMV331M7 and LMV331M7X**  
**NS Package Number MAA05A**

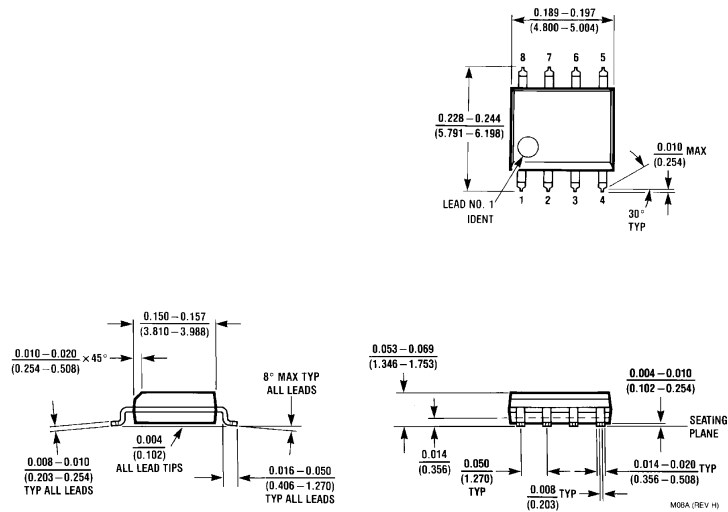


**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



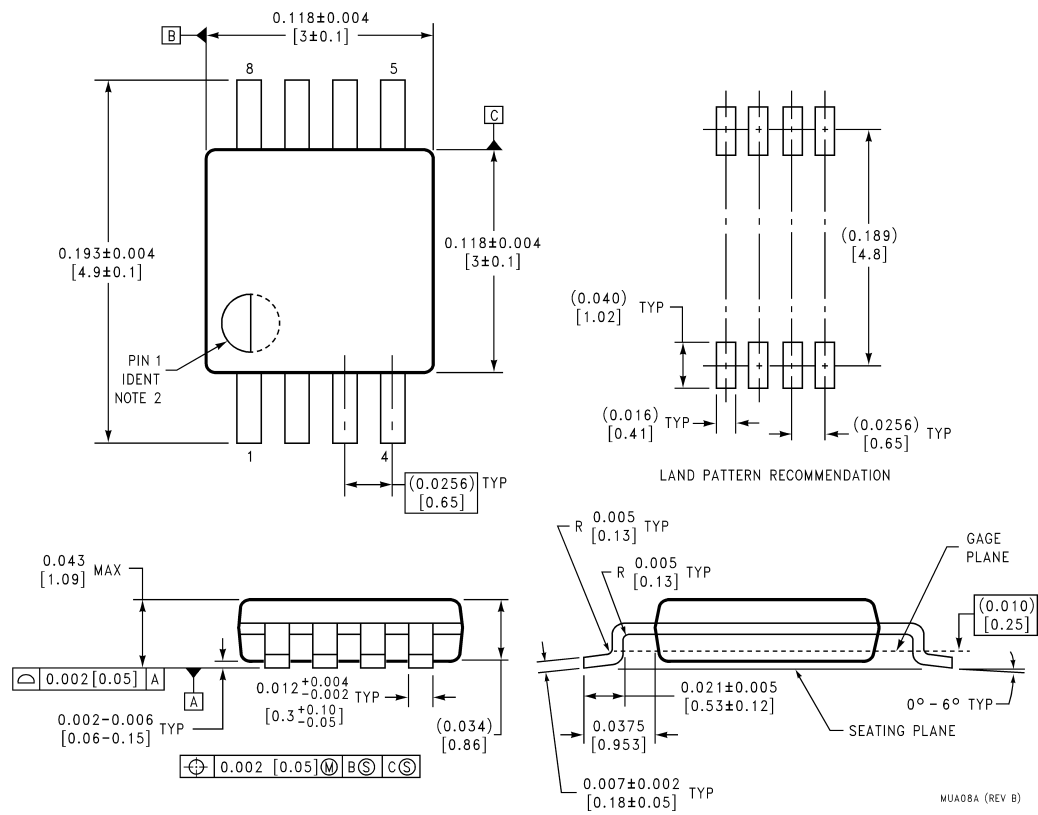
**5-Pin SOT23-5 Tape and Reel**  
**Order Number LMV331M5 and LMV331M5X**  
**NS Package Number MA05B**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



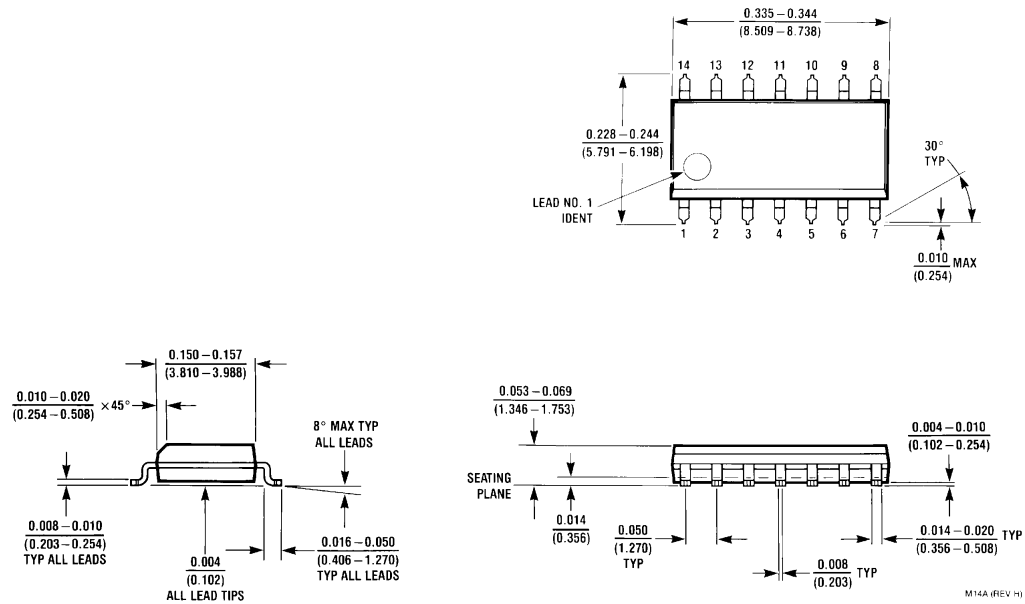
**8-Pin Small Outline**  
**Order Number LMV393M and LMV393MX**  
**NS Package Number M08A**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



**8-Pin MSOP**  
**Order Number LMV393MM and LMV393MMX**  
**NS Package Number MUA08A**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



**14-Pin Small Outline**  
**Order Number LMV339M and LMV339MX**  
**NS Package Number M14A**

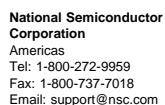
**LMV331 Single / LMV393 Dual / LMV339 Quad General Purpose, Low Voltage, TinyPack Comparators**



## LIFE SUPPORT POLICY

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



**National Semiconductor**  
**Europe**

Fax: +49 (0) 1 80-530 85 86  
Email: [europe.support@nsc.com](mailto:europe.support@nsc.com)

Deutsch Tel: +49 (0) 1 80-530 85 85  
English Tel: +49 (0) 1 80-532 78 32  
Français Tel: +49 (0) 1 80-532 93 58  
Italiano Tel: +49 (0) 1 80-534 16 80

**National Semiconductor**  
**Asia Pacific Customer**  
**Response Group**  
Tel: 65-2544466  
Fax: 65-2504466  
Email: [sea.support@nsc.com](mailto:sea.support@nsc.com)

**National Semiconductor  
Japan Ltd.**  
Tel: 81-3-5639-7560  
Fax: 81-3-5639-7507