



General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

LMX331/LMX393/LMX339

General Description

The LMX331/LMX393/LMX339 single/dual/quad comparators are drop-in, pin-for-pin-compatible replacements for the LMV331/LMV393/LMV339. The LMX331H/LMX393H/LMX339H offer the performance of the LMX331/LMX393/LMX339 with the added benefit of internal hysteresis to provide noise immunity, preventing output oscillations even with slow-moving input signals.

Advantages of the LMX331/LMX393/LMX339 series include low supply voltage, small package, and low cost. The LMX331 is available in both 5-pin SC70 and SOT23 packages, LMX393 is available in both 8-pin μ MAX and smaller SOT23 packages, and the LMX339 is available in 14-pin TSSOP and SO packages. They are manufactured using advanced submicron CMOS technology. Designed with the most modern techniques, the LMX331/LMX393/LMX339 achieve superior performance over BiCMOS or bipolar versions on the market.

The LMX331/LMX393/LMX339 offer performance advantages such as wider supply voltage range, wider operating temperature range, better CMRR and PSRR, improved response time characteristics, reduced offset, reduced output saturation voltage, reduced input bias current, and improved RF immunity.

Applications

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

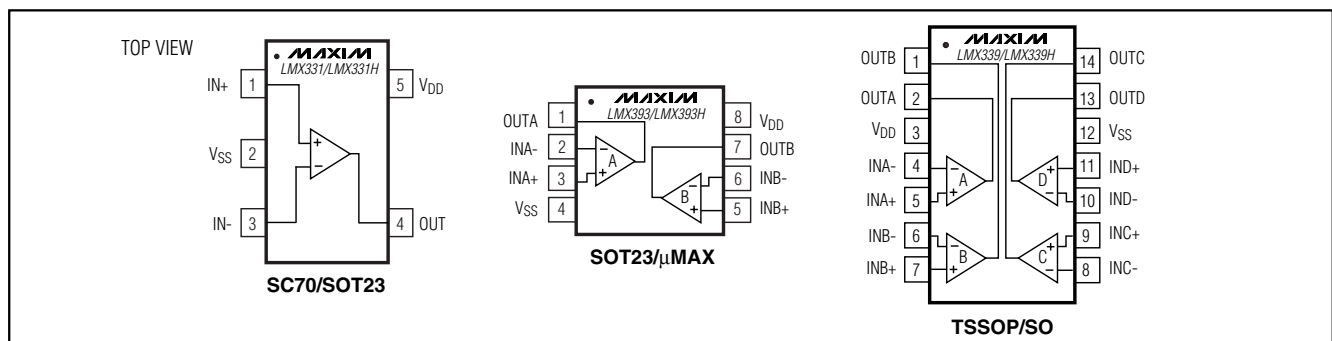
Features

- ◆ Guaranteed +1.8V to +5.5V Performance
- ◆ -40°C to +125°C Automotive Temperature Range
- ◆ Low Supply Current (60 μ A/Comparator at $V_{DD} = +5.0V$)
- ◆ Input Common-Mode Voltage Range Includes Ground
- ◆ No Phase Reversal for Overdriven Inputs
- ◆ Low Output Saturation Voltage (100mV)
- ◆ Internal 2mV Hysteresis (LMX331H/LMX393H/LMX339H)
- ◆ 5-Pin SC70 Space-Saving Package (2.0mm \times 2.1mm \times 1.0mm) (LMX331/LMX331H)

Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE | TOP MARK |
|--------------|-----------------|-------------|----------|
| LMX331AXK-T | -40°C to +125°C | 5 SC70-5 | ACD |
| LMX331AUK-T | -40°C to +125°C | 5 SOT23-5 | ADQR |
| LMX331HAXK-T | -40°C to +125°C | 5 SC70-5 | ACE |
| LMX331HAUK-T | -40°C to +125°C | 5 SOT23-5 | ADQS |
| LMX393AKA-T | -40°C to +125°C | 8 SOT23-8 | AAIF |
| LMX393AUA | -40°C to +125°C | 8 μ MAX | — |
| LMX393HAKA-T | -40°C to +125°C | 8 SOT23-8 | AAIG |
| LMX393HAUA | -40°C to +125°C | 8 μ MAX | — |
| LMX339AUD | -40°C to +125°C | 14 TSSOP | — |
| LMX339ASD | -40°C to +125°C | 14 SO | — |
| LMX339HAUD | -40°C to +125°C | 14 TSSOP | — |
| LMX339HASD | -40°C to +125°C | 14 SO | — |

Pin Configurations



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ABSOLUTE MAXIMUM RATINGS

| | | | |
|-------------------------------------------------|------------------------------|--------------------------------------------------|-----------------|
| Supply Voltage (VDD to VSS)..... | -0.3V to +6V | 14-Pin TSSOP (derate 9.1mW/°C above +70°C) | 727mW |
| All Other Pins | (VSS - 0.3V) to (VDD + 0.3V) | 14-Pin SO (derate 8.3mW/°C above +70°C)..... | 666.7mW |
| Continuous Power Dissipation (TA = +70°C) | | Operating Temperature Range | -40°C to +125°C |
| 5-Pin SC70 (derate 3.1mW/°C above +70°C)..... | 247mW | Junction Temperature | +150°C |
| 5-Pin SOT23 (derate 7.1mW/°C above +70°C)..... | 571mW | Storage Temperature Range | -65°C to +150°C |
| 8-Pin SOT23 (derate 8.9mW/°C above +70°C)..... | 714mW | Lead Temperature (soldering, 10s) | +300°C |
| 8-Pin μMAX (derate 10.3mW/°C above +70°C) | 825mW | | |

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS—2.7V OPERATION

(VDD = +2.7V, VSS = 0, VCM = 0, RL = 5.1kΩ connected to VDD. Typical values are at TA = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------------------------|--------|---------------------------------------|-----|-------|------|-------|
| Input Offset Voltage | VOS | | | 0.2 | 7 | mV |
| Input Voltage Hysteresis | VHYST | LMX331H/LMX393H/LMX339H only | | 2 | | mV |
| Input Offset Voltage Average Temperature Drift | TCVOS | | | 5 | | μV/°C |
| Input Bias Current | IB | TA = +25°C | | ±0.05 | ±250 | nA |
| | | TA = -40°C to +85°C | | | ±400 | |
| | | TA = -40°C to +125°C | | | ±400 | |
| Input Offset Current | IOS | TA = +25°C | | ±0.05 | ±50 | nA |
| | | TA = -40°C to +85°C | | | ±150 | |
| | | TA = -40°C to +125°C | | | ±150 | |
| Input Voltage Range | VCM | | | -0.1 | | V |
| | | | | 2.0 | | |
| Voltage Gain | AV | LMX331/LMX393/LMX339 only | | 50 | | V/mV |
| Output Saturation Voltage | VSAT | ISINK ≤ 1mA | | 50 | | mV |
| Output Sink Current | IO | VO ≤ 1.5V | 5 | 37 | | mA |
| Supply Current (Note 2) | IS | LMX331/LMX331H | | 50 | 100 | μA |
| | | LMX393/LMX393H (both comparators) | | 70 | 140 | |
| | | LMX339/LMX339H (all four comparators) | | 140 | 200 | |
| Output Leakage Current | | TA = +25°C | | 0.003 | | μA |
| | | TA = -40°C to +85°C | | | 1 | |
| | | TA = -40°C to +125°C | | | 2 | |

AC ELECTRICAL CHARACTERISTICS—2.7V OPERATION

(VDD = +2.7V, VSS = 0, VCM = 0, RL = 5.1kΩ connected to VDD. Typical values are at TA = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--------------------------------------|--------|----------------------------------|-----|-----|-----|-------|
| Propagation Delay Output High to Low | tPHL | Input overdrive = 10mV (Note 3) | | 500 | | ns |
| | | Input overdrive = 100mV (Note 3) | | 100 | | |
| Propagation Delay Output Low to High | tPLH | Input overdrive = 10mV (Note 3) | | 500 | | ns |
| | | Input overdrive = 100mV (Note 3) | | 100 | | |

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LMX331/LMX393/LMX339

DC ELECTRICAL CHARACTERISTICS—5.0V OPERATION

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = 0, R_L = 5.1kΩ connected to V_{DD}. Typical values are at T_A = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------------------------|-------------------|------------------------------------------|----------------------------------|-------|------|-------|
| Input Offset Voltage | V _{OS} | T _A = +25°C | | 0.25 | 7 | mV |
| | | T _A = -40°C to +85°C | | | 9 | |
| | | T _A = -40°C to +125°C | | | 9 | |
| Input Voltage Hysteresis | | LMX331H/LMX393H/LMX339H only | | 2 | | mV |
| Input Offset Voltage Average Temperature Drift | TCV _{OS} | | | 5 | | μV/°C |
| Input Bias Current | I _B | T _A = +25°C | | ±0.05 | ±250 | nA |
| | | T _A = -40°C to +85°C | | | ±400 | |
| | | T _A = -40°C to +125°C | | | ±400 | |
| Input Offset Current | I _{OS} | T _A = +25°C | | ±0.05 | ±50 | nA |
| | | T _A = -40°C to +85°C | | | ±150 | |
| | | T _A = -40°C to +125°C | | | ±150 | |
| Input Voltage Range | V _{CM} | | | -0.1 | | V |
| | | | | 4.2 | | |
| Voltage Gain | A _v | LMX331/LMX393/LMX339 only | 20 | 50 | | V/mV |
| Output Saturation Voltage | V _{SAT} | I _{SINK} ≤ 4mA | T _A = +25°C | 70 | 400 | mV |
| | | | T _A = -40°C to +85°C | | 700 | |
| | | | T _A = -40°C to +125°C | | 700 | |
| Output Sink Current | I _O | V _O ≤ 1.5V | 10 | 73 | | mA |
| Supply Current (Note 2) | I _S | LMX331/LMX331H | T _A = +25°C | 60 | 120 | μA |
| | | | T _A = -40°C to +85°C | | 150 | |
| | | | T _A = -40°C to +125°C | | 170 | |
| | | LMX393/LMX393H (both comparators) | T _A = +25°C | 100 | 200 | |
| | | | T _A = -40°C to +85°C | | 250 | |
| | | | T _A = -40°C to +125°C | | 300 | |
| | | LMX339/LMX339H (all four comparators) | T _A = +25°C | 170 | 300 | |
| | | | T _A = -40°C to +85°C | | 350 | |
| | | | T _A = -40°C to +125°C | | 430 | |
| Output Leakage Current | | T _A = +25°C | | 0.003 | | μA |
| | | T _A = -40°C to +85°C | | | 1 | |
| | | T _A = -40°C to +125°C | | | 2 | |

AC ELECTRICAL CHARACTERISTICS—5.0V OPERATION

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = 0, R_L = 5.1kΩ connected to V_{DD}. Typical values are at T_A = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|-----------------------------------------|------------------|----------------------------------|-----|-----|-----|-------|
| Propagation Delay Output High to Low | t _{PHL} | Input overdrive = 10mV (Note 3) | | 400 | | ns |
| | | Input overdrive = 100mV (Note 3) | | 90 | | |
| Propagation Delay Output Low to High | t _{PLH} | Input overdrive = 10mV (Note 3) | | 600 | | ns |
| | | Input overdrive = 100mV (Note 3) | | 200 | | |

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DC ELECTRICAL CHARACTERISTICS—1.8V OPERATION

($V_{DD} = +1.8V$, $V_{SS} = 0$, $V_{CM} = 0$, $R_L = 5.1k\Omega$ connected to V_{DD} . Typical values are at $T_A = +25^\circ C$.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------------------------|------------|---------------------------------------|-----|-------|-----|------------------|
| Input Offset Voltage | V_{OS} | | | 0.2 | 5 | mV |
| Input Voltage Hysteresis | | LMX331H/LMX393H/LMX339H only | | 2 | | mV |
| Input Offset Voltage Average Temperature Drift | TCV_{OS} | | | 5 | | $\mu V/^\circ C$ |
| Input Bias Current | I_B | | | 0.05 | | nA |
| Input Offset Current | I_{OS} | | | 0.05 | | nA |
| Input Voltage Range | V_{CM} | | | -0.1 | | V |
| | | | | 1 | | |
| Output Saturation Voltage | V_{SAT} | $I_{SINK} \leq 1mA$ | | 35 | | mV |
| Power-Supply Rejection Ratio | PSRR | $V_{DD} = +1.8V$ to $+5.5V$ | 60 | 70 | | dB |
| Output Sink Current | I_O | $V_O \leq +1.5V$ | | 15 | | mA |
| Supply Current (Note 2) | I_S | LMX331/LMX331H | | 40 | 100 | μA |
| | | LMX393/LMX393H (both comparators) | | 65 | 140 | |
| | | LMX339/LMX339H (all four comparators) | | 120 | 200 | |
| Output Leakage Current | | | | 0.003 | | μA |

AC ELECTRICAL CHARACTERISTICS—1.8V OPERATION

($V_{DD} = +1.8V$, $V_{SS} = 0$, $V_{CM} = 0$, $R_L = 5.1k\Omega$ connected to V_{DD} . Typical values are at $T_A = +25^\circ C$.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|-----------------------------------------|-----------|----------------------------------|-----|-----|-----|-------|
| Propagation Delay Output High to Low | t_{PHL} | Input overdrive = 10mV (Note 3) | | 500 | | ns |
| | | Input overdrive = 100mV (Note 3) | | 100 | | |
| Propagation Delay Output Low to High | t_{PLH} | Input overdrive = 10mV (Note 3) | | 500 | | ns |
| | | Input overdrive = 100mV (Note 3) | | 100 | | |

Note 1: All devices are production tested at $+25^\circ C$. All temperature limits are guaranteed by design.

Note 2: Supply current when output is high.

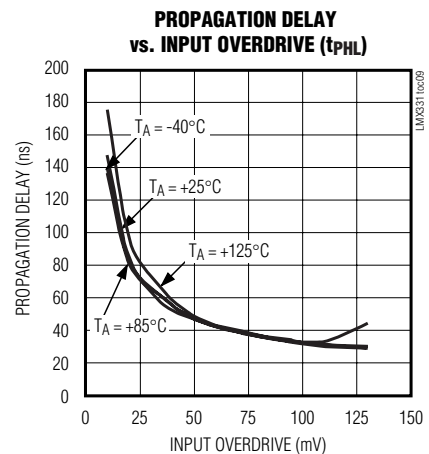
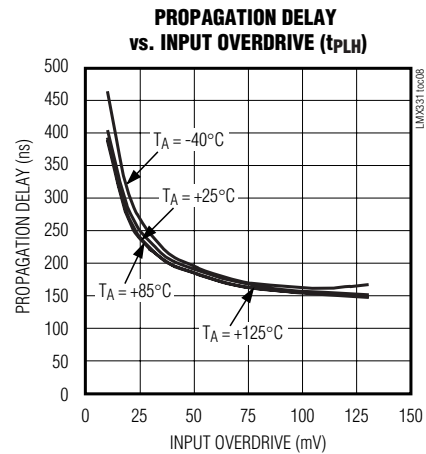
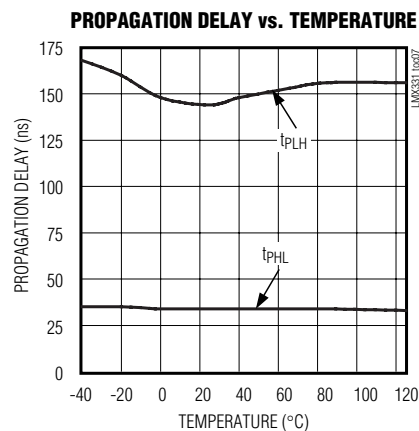
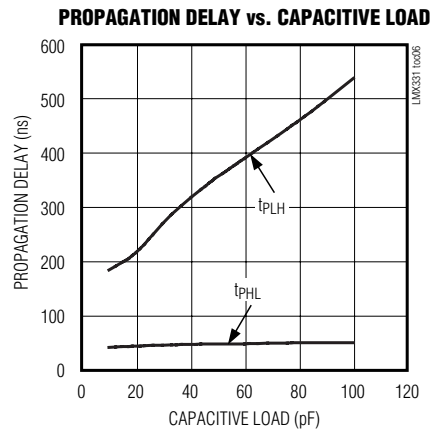
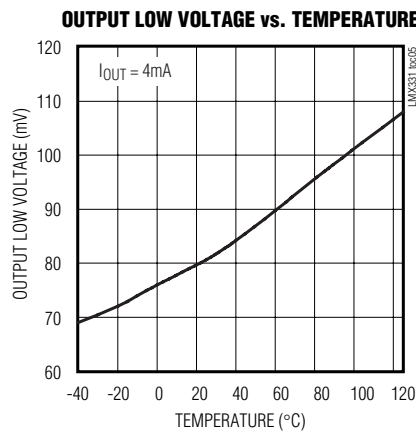
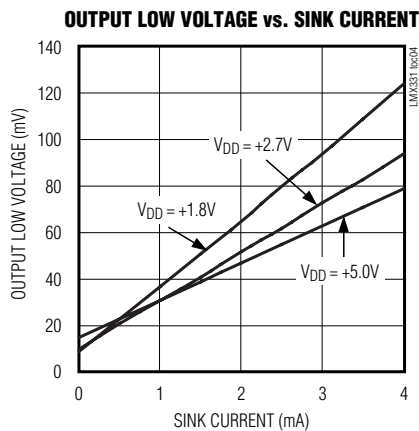
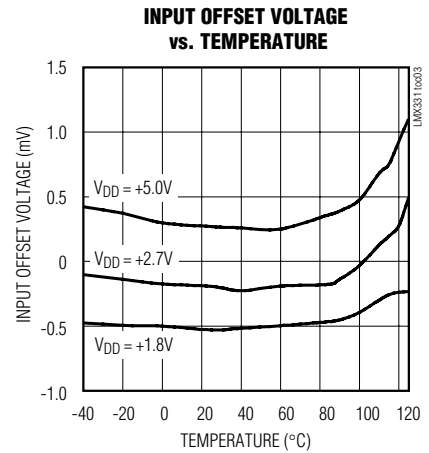
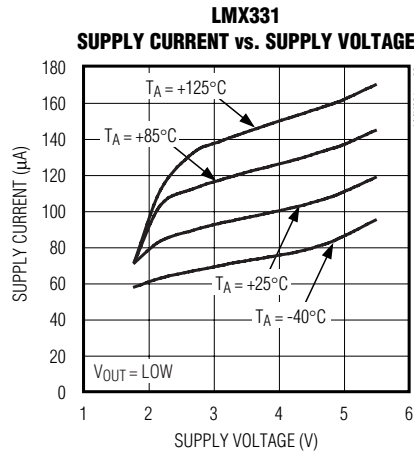
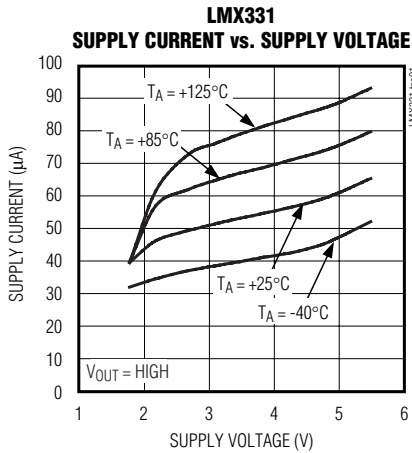
Note 3: Input overdrive is the overdrive voltage beyond the offset and hysteresis-determined trip points.

General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

Typical Operating Characteristics

($V_{DD} = +5V$, $V_{SS} = 0$, $V_{CM} = 0$, $R_L = 5.1k\Omega$, $C_L = 10pF$, overdrive = 100mV, $T_A = +25^\circ C$, unless otherwise noted.)

LMX331/LMX3393/LMX339

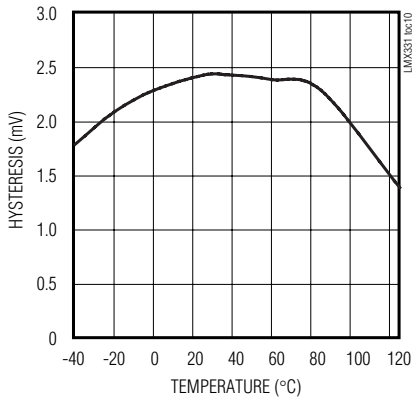


General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

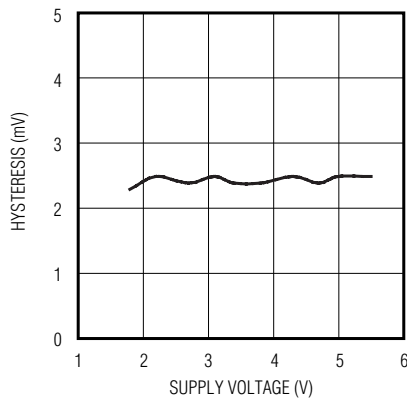
Typical Operating Characteristics (continued)

($V_{DD} = +5V$, $V_{SS} = 0$, $V_{CM} = 0$, $R_L = 5.1k\Omega$, $C_L = 10pF$, overdrive = 100mV, $T_A = +25^\circ C$, unless otherwise noted.)

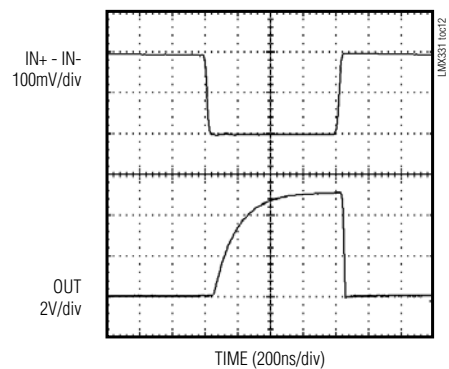
**LMX331H/LMX393H/LMX339H
HYSTERESIS vs. TEMPERATURE**



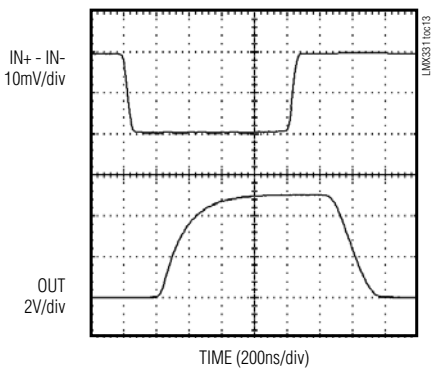
**LMX331H/LMX393H/LMX339H
HYSTERESIS vs. SUPPLY VOLTAGE**



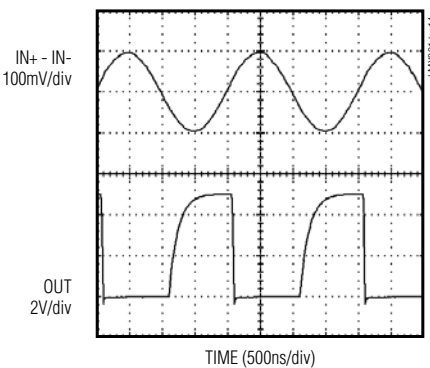
**PROPAGATION DELAY
100mV OVERDRIVE**



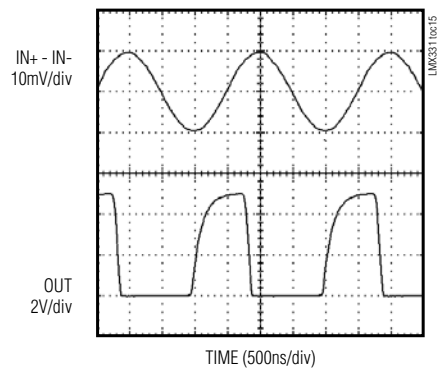
**PROPAGATION DELAY
10mV OVERDRIVE**



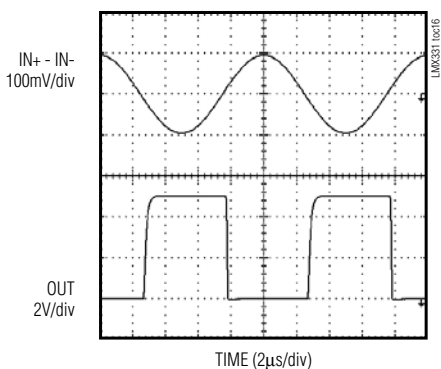
**500kHz RESPONSE
100mV OVERDRIVE**



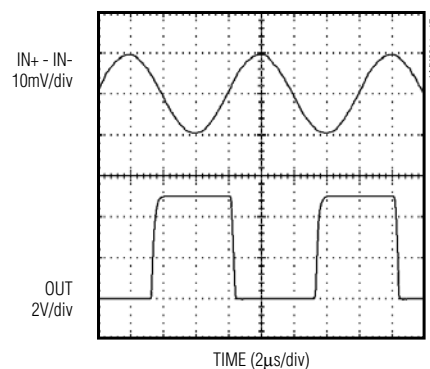
**500kHz RESPONSE
10mV OVERDRIVE**



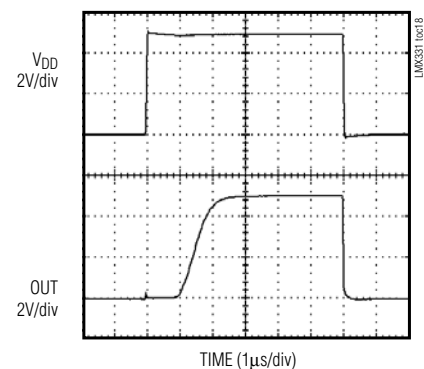
**100kHz RESPONSE
100mV OVERDRIVE**



**100kHz RESPONSE
10mV OVERDRIVE**



POWER-UP RESPONSE



General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

Pin Description

LMX331/LMX393/LMX339

| PIN | | | NAME | FUNCTION |
|--------|--------|--------|-----------------|----------------------------------|
| LMX331 | LMX393 | LMX339 | | |
| 1 | — | — | IN+ | Noninverting Input |
| 2 | 4 | 12 | V _{SS} | Negative Supply (Connect to GND) |
| 3 | — | — | IN- | Inverting Input |
| 4 | — | — | OUT | Comparator Output (Open-Drain) |
| 5 | 8 | 3 | V _{DD} | Positive Supply |
| — | 1 | 2 | OUTA | Comparator A Output (Open-Drain) |
| — | 7 | 1 | OUTB | Comparator B Output (Open-Drain) |
| — | 2 | 4 | INA- | Comparator A Inverting Input |
| — | 3 | 5 | INA+ | Comparator A Noninverting Input |
| — | 5 | 7 | INB+ | Comparator B Noninverting Input |
| — | 6 | 6 | INB- | Comparator B Inverting Input |
| — | — | 8 | INC- | Comparator C Inverting Input |
| — | — | 9 | INC+ | Comparator C Noninverting Input |
| — | — | 10 | IND- | Comparator D Inverting Input |
| — | — | 11 | IND+ | Comparator D Noninverting Input |
| — | — | 13 | OUTD | Comparator D Output (Open-Drain) |
| — | — | 14 | OUTC | Comparator C Output (Open-Drain) |

Detailed Description

The LMX331/LMX393/LMX339 are single/dual/quad, low-cost, general-purpose comparators. They have a single-supply operating voltage of +1.8V to +5V. The common-mode input range extends from -0.1V below the negative supply to within +0.7V of the positive supply. They require approximately 60μA per comparator with a +5V supply and 40μA with a +2.7V supply.

The LMX331H/LMX393H/LMX339H have 2mV of hysteresis for noise immunity. This significantly reduces the chance of output oscillations even with slow-moving input signals. The LMX331/LMX393/LMX339 and LMX331H/LMX393H/LMX339H are ideal for automotive applications because they operate from -40°C to +125°C. See *Typical Operating Characteristics*.

Applications Information

Hysteresis

Many comparators oscillate in the linear region of operation because of noise or undesired parasitic feedback. This tends to occur when the voltage on one input is equal or very close to the voltage on the other input. The LMX331H/LMX393H/LMX339H have internal hysteresis to counter parasitic effects and noise.

The hysteresis in a comparator creates two trip points: one for the rising input voltage and one for the falling

input voltage (Figure 1). The difference between the trip points is the hysteresis. When the comparator's input voltages are equal, the hysteresis effectively causes one comparator input to move quickly past the other, thus taking the input out of the region where oscillation occurs. This provides clean output transitions for noisy, slow-moving input signals.

Additional hysteresis can be generated with two resistors, using positive feedback (Figure 2). Use the following procedure to calculate resistor values:

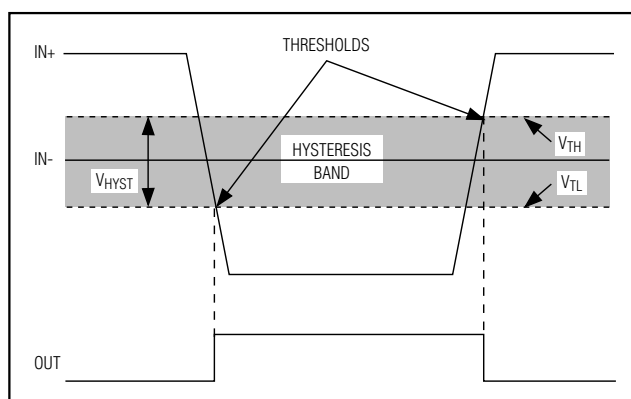


Figure 1. Threshold Hysteresis Band (Not to Scale)

General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

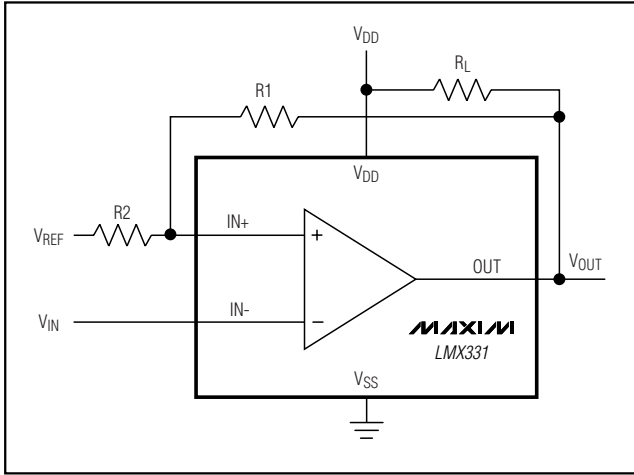


Figure 2. Adding Hysteresis with External Resistors

- 1) Find output voltage when output is high:

$$V_{OUT(HIGH)} = V_{DD} - I_{LOAD} \times R_L$$

- 2) Find the trip points of the comparator using these formulas:

$$V_{TH} = V_{REF} + ((V_{OUT(HIGH)} - V_{REF})R_2) / (R_1 + R_2)$$

$$V_{TL} = V_{REF}(1 - (R_2 / (R_1 + R_2)))$$

where V_{TH} is the threshold voltage at which the comparator switches its output from high to low as V_{IN} rises above the trip point, and V_{TL} is the threshold voltage at which the comparator switches its output from low to high as V_{IN} drops below the trip point.

- 3) The hysteresis band will be:

$$V_{HYST} = V_{TH} - V_{TL} = V_{DD}(R_2 / (R_1 + R_2))$$

In this example, let $V_{DD} = +5V$, $V_{REF} = +2.5V$, $I_{LOAD} = 50nA$, $R_L = 5.1k\Omega$:

$$V_{OUT(HIGH)} = 5.0V - (50 \times 10^{-9} \times 5.1 \times 10^3\Omega) \approx 5.0V$$

$$V_{TH} = 2.5V + 2.5V(R_2 / (R_1 + R_2))$$

$$V_{TL} = 2.5V(1 - (R_2 / (R_1 + R_2)))$$

Select R_2 . In this example, we will choose $1k\Omega$.

Select V_{HYST} . In this example, we will choose $50mV$.

Solve for R_1 :

$$V_{HYST} = V_{OUT(HIGH)}(R_2 / (R_1 + R_2)) V$$

$$0.050V = 5(1000 / (R_1 + 1000)) V$$

where $R_1 \approx 100k\Omega$, $V_{TH} = 2.525V$, and $V_{TL} = 2.475V$.

Choose R_1 and R_2 to be large enough as not to exceed the amount of current the reference can supply.

The source current required is $V_{REF} / (R_1 + R_2)$.

The sink current is $(V_{OUT(HIGH)} - V_{REF}) \times (R_1 + R_2)$.

Choose R_L to be large enough to avoid drawing excess current, yet small enough to supply the necessary current to drive the load. R_L should be between $1k\Omega$ and $10k\Omega$.

Board Layout and Bypassing

Use $0.1\mu F$ bypass capacitors from V_{DD} to V_{SS} . To maximize performance, minimize stray inductance by putting this capacitor close to the V_{DD} pin and reducing trace lengths. For slow-moving input signals (rise time $> 1ms$), use a $1nF$ capacitor between $IN+$ and $IN-$ to reduce high-frequency noise.

Chip Information

LMX331/LMX331H TRANSISTOR COUNT: 112

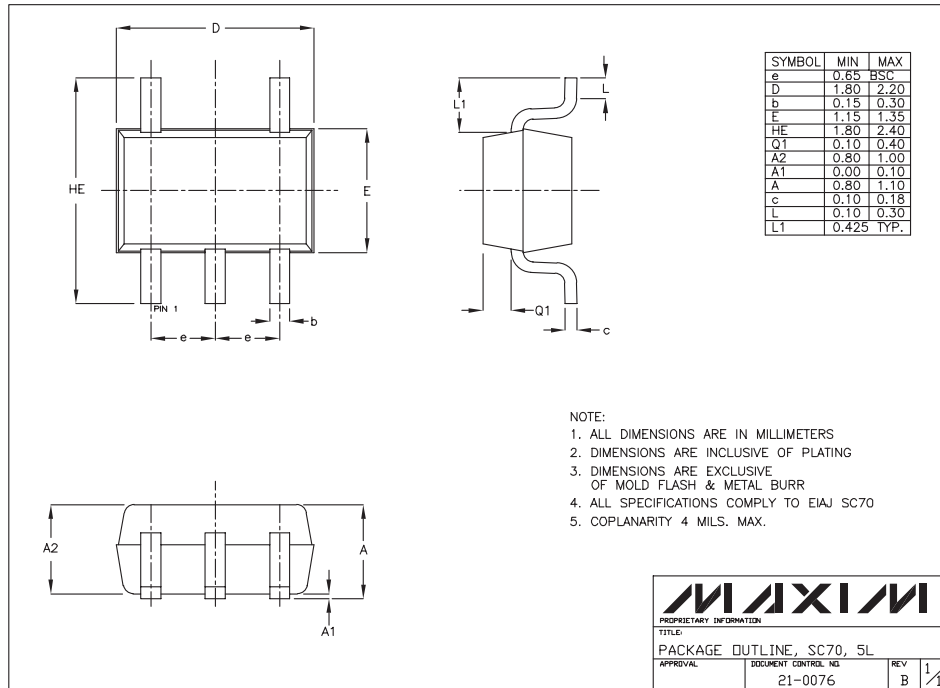
LMX393/LMX393H TRANSISTOR COUNT: 211

LMX339/LMX339H TRANSISTOR COUNT: 411

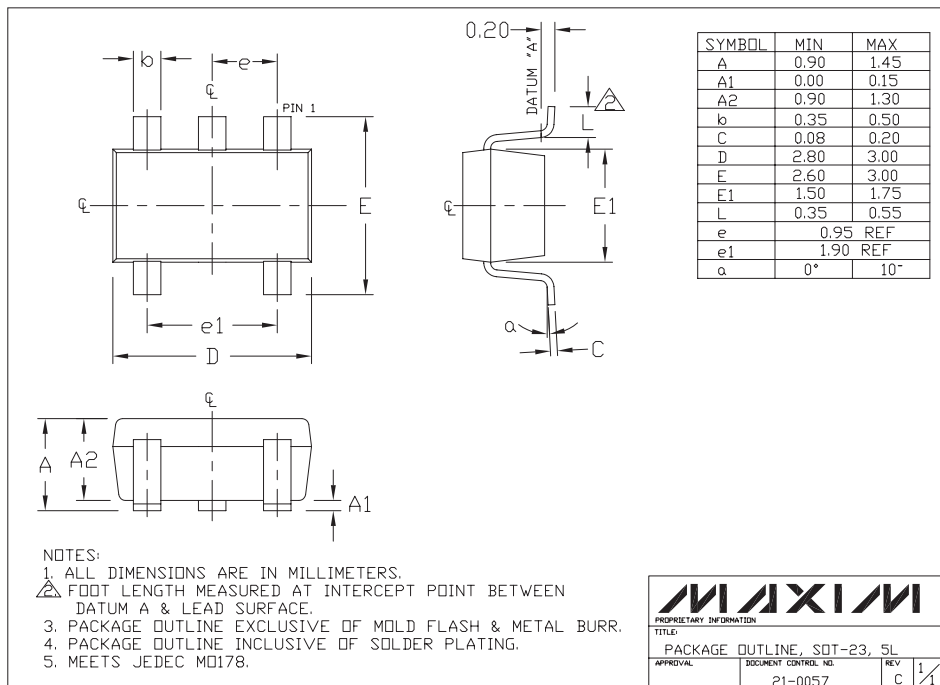
General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

Package Information

LMX331/LMX393/LMX339



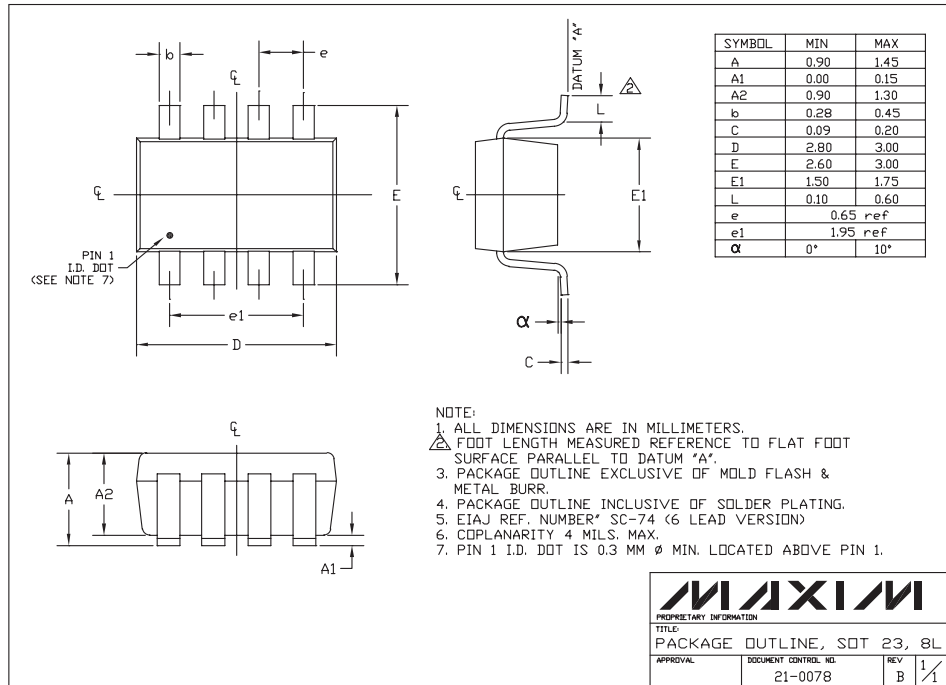
SC70-5LEFS



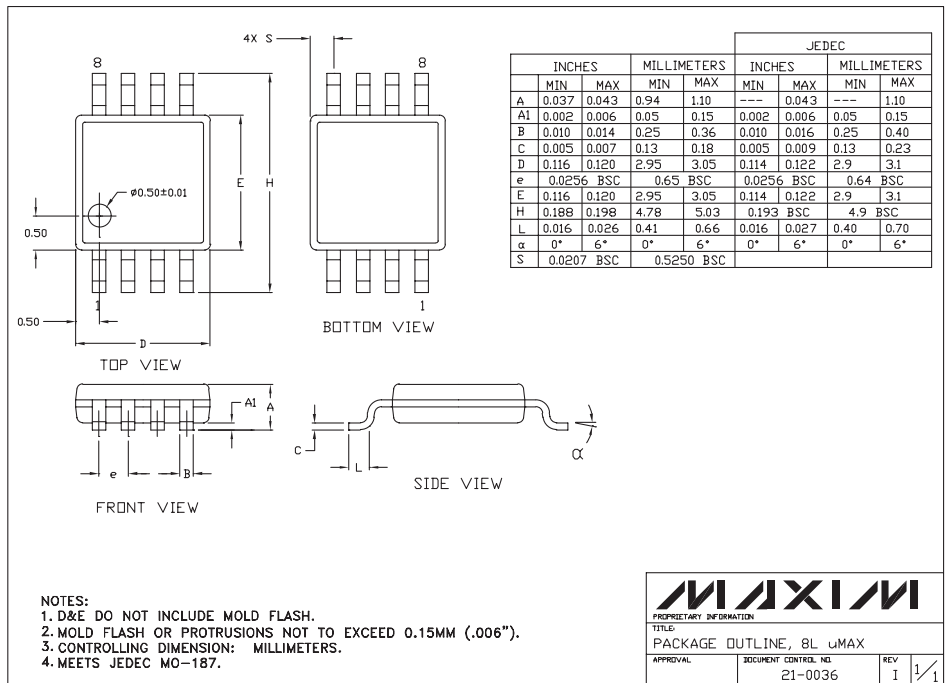
SOT23EFS

General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

Package Information (continued)



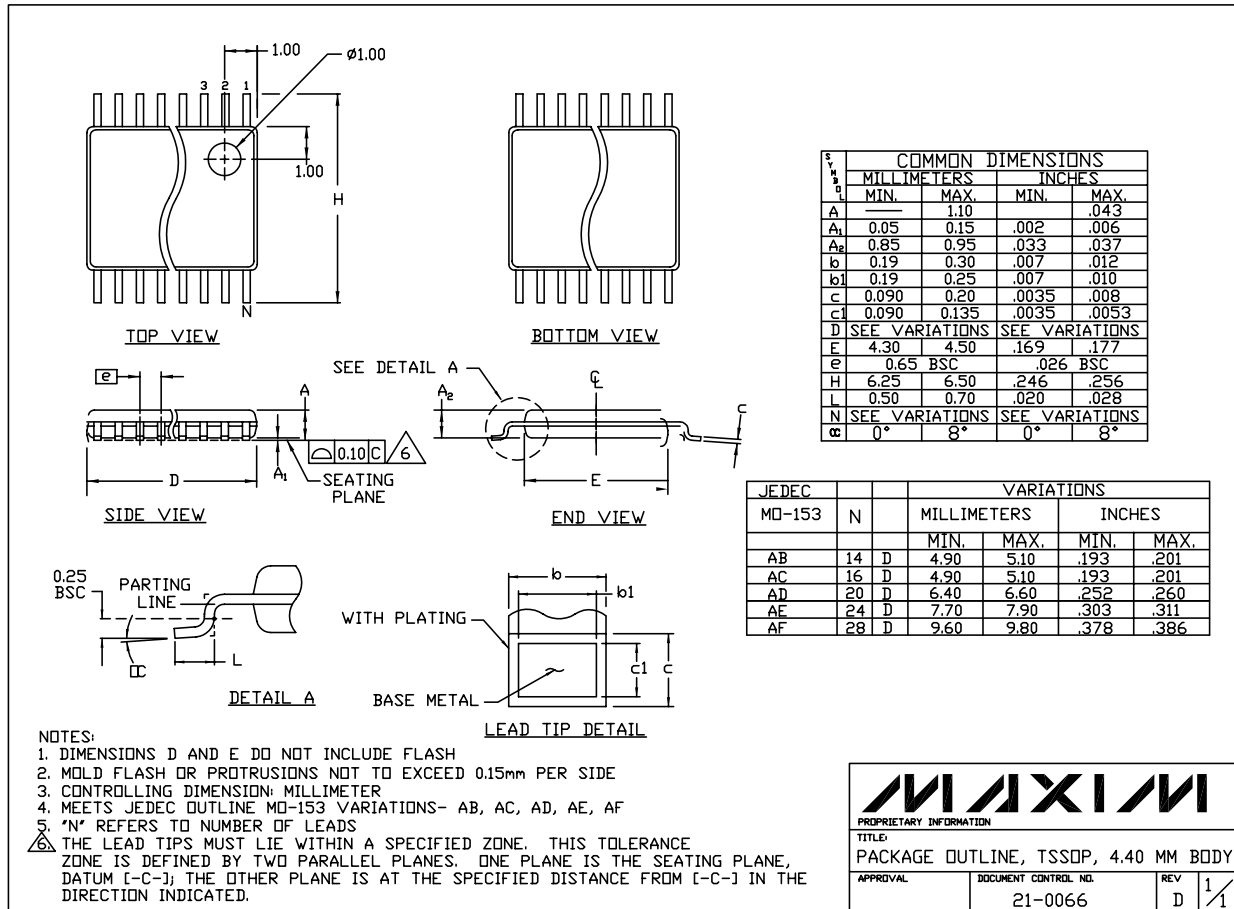
SOT23-8LEPS



8LUMAXDLEPS

General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

Package Information (continued)

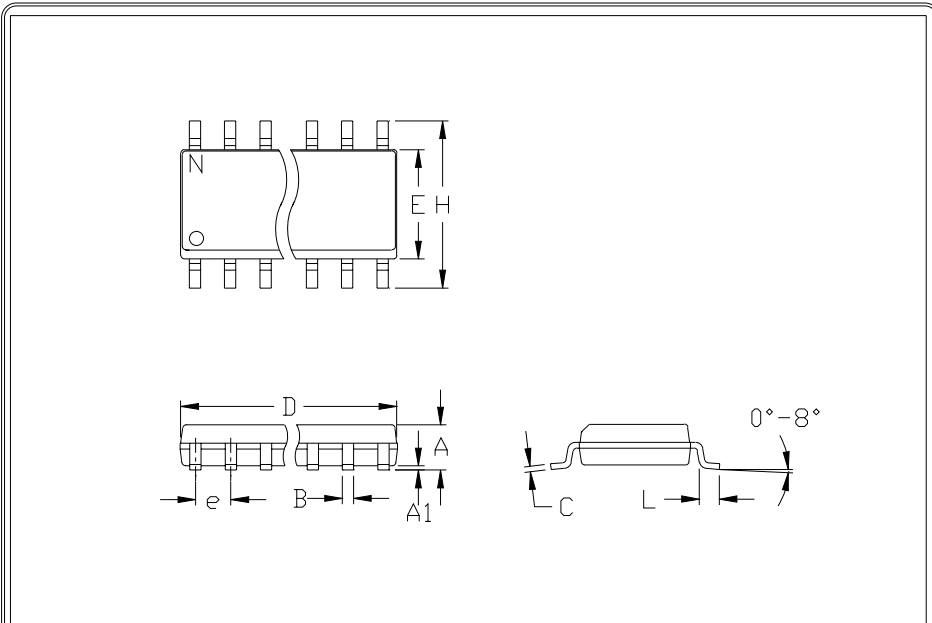


TSSOP, NO PADS, EPS

LMX3331/LMX393/LMX339

General-Purpose, Low-Voltage, Single/Dual/Quad, Tiny-Pack Comparators

Package Information (continued)



| | INCHES | | MILLIMETERS | |
|----|--------|-------|-------------|------|
| | MIN | MAX | MIN | MAX |
| A | 0.053 | 0.069 | 1.35 | 1.75 |
| A1 | 0.004 | 0.010 | 0.10 | 0.25 |
| B | 0.014 | 0.019 | 0.35 | 0.49 |
| C | 0.007 | 0.010 | 0.19 | 0.25 |
| e | 0.050 | | 1.27 | |
| E | 0.150 | 0.157 | 3.80 | 4.00 |
| H | 0.228 | 0.244 | 5.80 | 6.20 |
| h | 0.010 | 0.020 | 0.25 | 0.50 |
| L | 0.016 | 0.050 | 0.40 | 1.27 |

| | INCHES | | MILLIMETERS | | N | MS012 |
|---|--------|-------|-------------|-------|----|-------|
| | MIN | MAX | MIN | MAX | | |
| D | 0.189 | 0.197 | 4.80 | 5.00 | 8 | A |
| D | 0.337 | 0.344 | 8.55 | 8.75 | 14 | B |
| D | 0.386 | 0.394 | 9.80 | 10.00 | 16 | C |

- NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
 2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
 3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
 4. CONTROLLING DIMENSION: MILLIMETER
 5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
 6. N = NUMBER OF PINS

| | | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------|
|  <small>120 SAN GABRIEL DR. SUNNYVALE CA 94086 FAX (408) 737-7794 PROPRIETARY INFORMATION</small> | PACKAGE FAMILY OUTLINE: SOIC .150" |  | 21-0041 A <small>DOCUMENT CONTROL NUMBER REV</small> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------|

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