National Semiconductor

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LMC7221
Tiny CMOS Comparator with Rail-To-Rail Input and Open Drain Output

General Description

The LM7221 is a micropower CMOS comparator available in the space saving SOT23-5 package. This makes this comparator ideal for space and weight critical designs. The LMC7221 is also available in conventional DIP and SO-8 packages. The LMC7221 is supplied in two offset voltage grades, 5 mV and 15 mV.

The open drain output can be pulled up with a resistor to a voltage which can be higher or lower than the supply voltage—this makes the part useful for mixed voltage systems.

For a tiny comparator with a push-pull output, please see the LMC7211 datasheet.

Features

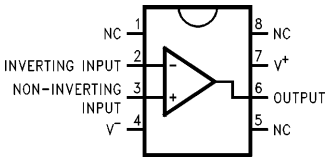
- Tiny SOT 23-5 package saves space
- Package is less than 1.43 mm thick
- Guaranteed specs at 2.7V, 5V, 15V supplies
- Typical supply current 7 μA at 5V
- Response time of 4 μs at 5V
- LMC7221—open drain output
- Input common-mode range beyond V− and V+
- Low input current

Applications

- Mixed voltage battery powered products
- Notebooks and PDAs
- PCMCIA cards
- Mobile communications
- Alarm and security circuits
- Driving low current LEDs
- Direct sensor interface

Connection Diagrams

8-Pin DIP/SO-8



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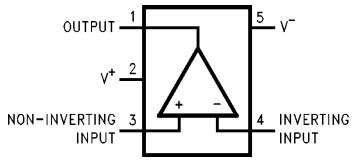
Top View

5-Pin SOT23-5



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Top View

Ordering Information

Package	Ordering Information	NSC Drawing Number	Package Marking	Transport Media
8-Pin DIP	LMC7221AIN	N08E	LMC7221AIN	Rails
8-Pin DIP	LMC7221BIN	N08E	LMC7221BIN	Rails
8-Pin SO-8	LMC7221AIM	M08A	LMC7221AIM	Rails
8-Pin SO-8	LMC7221BIM	M08A	LMC7221BIM	Rails
8-Pin SO-8	LMC7221AIMX	M08A	LMC7221AIM	2.5k Units Tape and Reel
8-Pin SO-8	LMC7221BIMX	M08A	LMC7221BIM	2.5k Units Tape and Reel
5-Pin SOT 23-5	LMC7221AIM5X	MA05A	C01A	3k Units Tape and Reel
5-Pin SOT 23-5	LMC7221BIM5X	MA05A	C01B	3k Units Tape and Reel

RRD-B30M115/Printed in U. S. A.

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)	2 kV
Differential Input Voltage	(V_{CC}) +0.3V to $(-V_{CC})$−0.3V
Voltage at Input/Output Pin	(V_{CC}) + 0.3V to $(-V_{CC})$−0.3V
Supply Voltage ($V^+ - V^-$)	16V
Current at Input Pin (Note 7)	±5 mA
Current at Output Pin (Notes 3, 8)	±30 mA
Current at Power Supply Pin	40 mA
Lead Temperature (soldering, 10 sec.)	260°C
Storage Temperature Range	−65°C to +150°C
Junction Temperature (Note 4)	150°C

Operating Ratings (Note 1)

Supply Voltage	$2.7 \le V_{CC} \le 15V$
Junction Temperature Range	
LMC7221AI, LMC7221BI	$-40°C \le T_J \le +85°C$
Thermal Resistance (θ_{JA})	
N Package, 8-pin Molded DIP	112°C/W
SO-8 Package, 8-Pin Surface Mount	180°C/W
M05A Package, 5-Pin Surface Mount	325°C/W

2.7V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25°C$, $V^+ = 2.7V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$. **Boldface** limits apply at the temperature extremes

Symbol	Parameter	Conditions	Typ (Note 5)	LMC7221AI Limit (Note 6)	LMC7221BI Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		3	5 **8**	15 **18**	mV max
TCV_{OS}	Input Offset Voltage Temperature Drift		1.0			µV/°C
	Input Offset Voltage Average Drift	(Note 10)	3.3			µV/Month
I_B	Input Current		0.04			pA
I_{OS}	Input Offset Current		0.02			pA
CMRR	Common Mode Rejection Ratio	$0V \le V_{CM} \le 2.7V$	75			dB
PSRR	Power Supply Rejection Ratio	$2.7V \le V^+ \le 15V$	80			dB
A_V	Voltage Gain		100			dB
CMVR	Input Common-Mode Voltage Range	CMRR > 55 dB	3.0	2.9 **2.7**	2.9 **2.7**	V min
		CMRR > 55 dB	−0.3	−0.2 **0.0**	−0.2 **0.0**	V max
V_{OL}	Output Voltage Low	$I_{load} = 2.5$ mA	0.2	0.3 **0.4**	0.3 **0.4**	V max
I_S	Supply Current	V_{OUT} = low	7	12 **14**	12 **14**	µA max

5.0V and 15.0V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5.0V and 15V, V^- = 0V, $V_{CM} = V_O = V^+/2$. **Boldface** limits apply at the temperature extremes

Symbol	Parameter	Conditions	Typ (Note 5)	LMC7221AI Limit (Note 6)	LMC7221BI Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		3	5 **8**	15 **18**	mV max
TCV_{OS}	Input Offset Voltage Temperature Drift	V^+ = 5V	1.0			μV/°C
		V^+ = 15V	4.0			
	Input Offset Voltage Average Drift	V^+ = 5V (Note 10)	3.3			μV/Month
		V^+ = 15V (Note 10)	4.0			
I_B	Input Current		0.04			pA
I_{OS}	Input Offset Current		0.02			pA
CMRR	Common Mode Rejection Ration	V^+ = 5.0V	75			dB
		V^+ = 15.0V	82			dB
PSRR	Power Supply Rejection Ratio	$5V \le V^+ \le 10V$	80			dB
A_V	Voltage Gain		100			dB
CMVR	Input Common-Mode Voltage Range	V^+ = 5.0V CMRR > 55 dB	5.3	5.2 **5.0**	5.2 **5.0**	V min
		V^+ = 5.0V CMRR > 55 dB	−0.3	−0.2 **0.0**	−0.2 **0.0**	V max
		V^+ = 15.0V CMRR > 55 dB	15.3	15.2 **15.0**	15.2 **15.0**	V min
		V^+ = 15.0V CMRR > 55 dB	−0.3	−0.2 **0.0**	−0.2 **0.0**	V max
V_{OL}	Output Voltage Low	V^+ = 5V I_{load} = 5 mA	0.2	0.40 **0.55**	0.40 **0.55**	mV max
		V^+ = 15V I_{load} = 5 mA	0.2	0.40 **0.55**	0.40 **0.55**	mV max
I_S	Supply Current	V_{OUT} = Low	7	14 **18**	14 **18**	μA max
I_{SC}	Short Circuit Current	Sinking (Note 8)	45			mA

Leakage Characteristics

T_J = 25°C

Symbol	Parameter	Conditions	Typ (Note 5)	LMC7221AI Limit (Note 6)	LMC7221BI Limit (Note 6)	Units
$I_{LEAKAGE}$	Output Leakage Current	V^+ = 2.7V $V_{IN}(+)$ = 0.5V $V_{IN}(-)$ = 0V V_{OUT} = 15V	0.1	500	500	nA

AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25°C$, $V^+ = 5V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$. **Boldface** limits apply at the temperature extreme

Symbol	Parameter	Conditions		Typ (Note 5)	LMC7221AI Limit (Note 6)	LMC7221BI Limit (Note 6)	Units
t_{rise}	Rise Time	f = 10 kHz, C_L = 50 pF, (Note 9) Overdrive = 10 mV, 5 kΩ Pullup		0.3			μs
t_{fall}	Fall Time	f = 10 kHz, C_L = 50 pF, (Note 9) Overdrive = 10 mV, 5 kΩ Pullup		0.3			μs
t_{PHL}	Propagation Delay (High to Low) (Note 11)	f = 10 kHz, C_L = 50 pF, 5 kΩ Pullup (Note 9)	10 mV	10			μs
			100 mV	4			
		V+ = 2.7V, f = 10 kHz, C_L = 50 pF, 5 kΩ Pullup (Note 9)	10 mV	10			μs
			100 mV	4			
t_{PLH}	Propagation Delay (Low to High) (Note 11)	f = 10 kHz, C_L = 50 pF, 5 kΩ Pullup (Note 9)	10 mV	6			μs
			100 mV	4			
		V+ = 2.7V, f = 10 kHz, C_L = 50 pF, 5 kΩ Pullup (Note 9)	10 mV	7			μs
			100 mV	4			

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, 1.5 kΩ in series with 100 pF.

Note 3: Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C. Output currents in excess of ±30 mA may adversely affect reliability.

Note 4: The maximum power dissipation is a function of $T_{J(max)}$, θ_{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 5: Typical values represent the most likely parametric norm.

Note 6: All limits are guaranteed by testing or statistical analysis.

Note 7: Limiting input pin current is only necessary for input voltages which exceed the absolute maximum input voltage rating.

Note 8: Do not short circuit the output to V+ when V+ is greater than 12V or reliability will be adversely affected.

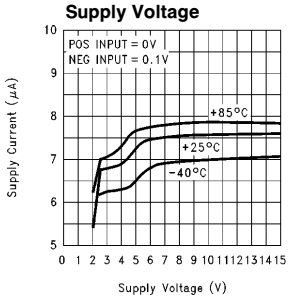
Note 9: C_L includes the probe and test jig capacitance.

Note 10: Input offset voltage average drift is calculated by dividing the accelerated operating life V_{OS} drift by the equivalent operational time. This represents worst case input conditions and includes the first 30 days of drift.

Note 11: Input step voltage for propagation delay measurement is 2V.

Typical Performance Characteristics Single Supply $T_A = 25°C$ unless specified

Supply Current vs Supply Voltage



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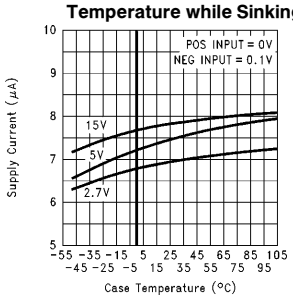
Supply Current vs Temperature while Sinking



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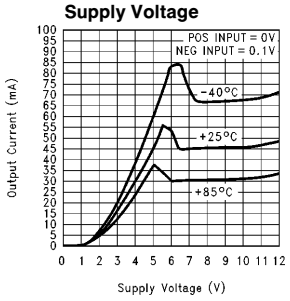
Output Sinking Current vs Supply Voltage



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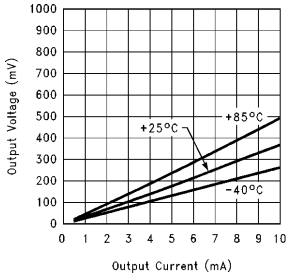
Output Sinking Current vs Output Voltage @ 5V



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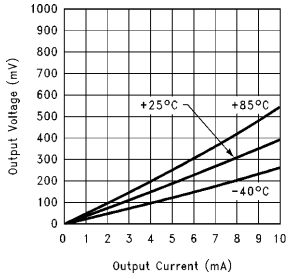
Output Sinking Current vs Output Voltage @ 15V



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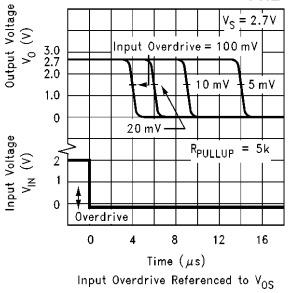
Response Time for Various Input Overdrives — t_{PHL}



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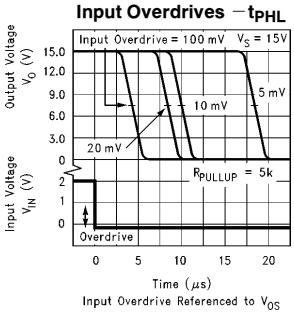
Typical Performance Characteristics Single Supply, $T_A = 25°C$ unless specified (Continued)

Response Time vs Various Input Overdrives — t_{PHL}



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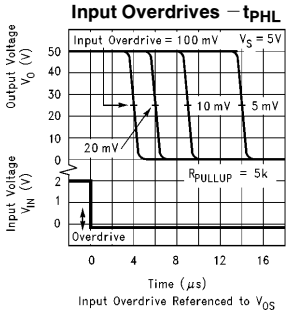
Response Time vs Various Input Overdrives — t_{PHL}



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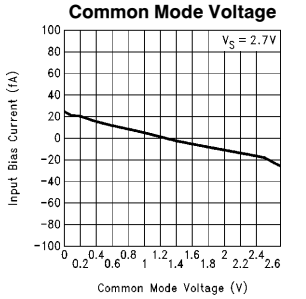
Input Bias Current vs Common Mode Voltage



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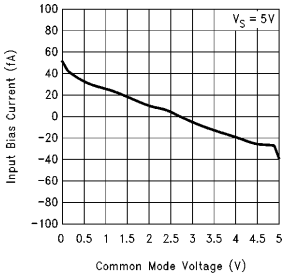
Input Bias Current vs Common Mode Voltage



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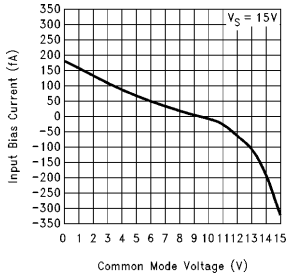
Input Bias Current vs Common Mode Voltage



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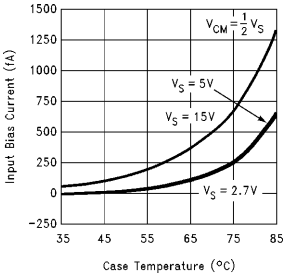
Input Bias Current vs Temperature



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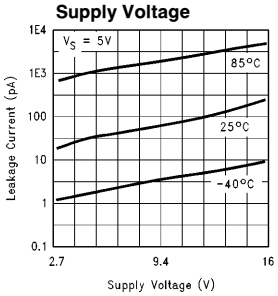
Leakage Current vs Supply Voltage



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Application Information

1.0 Benefits of the LMC7221 Tiny Comparator

Size. The small footprint of the SOT 23-5 packaged Tiny Comparator, (0.120 x 0.118 inches, 3.05 x 3.00 mm) saves space on printed circuit boards, and enable the design of smaller electronic products. Because they are easier to carry, many customers prefer smaller and lighter products.

Height. The height (0.056 inches, 1.43 mm) of the Tiny Comparator makes it possible to use it in PCMCIA type III cards.

Simplified Board Layout. The Tiny Comparator can simplify board layout in several ways. First, by placing a comparator where comparators are needed, instead of routing signals to a dual or quad device, long pc traces may be avoided.

By using multiple Tiny Comparators instead of duals or quads, complex signal routing and possibly crosstalk can be reduced.

DIPs available for prototyping. LMC7221 comparators packaged in conventional 8-pin dip packages can be used for prototyping and evaluation without the need to use surface mounting in early project stages.

Low Supply Current. The typical 7 μA supply current of the LMC7221 extends battery life in portable applications, and may allow the reduction of the size of batteries in some applications.

Wide Voltage Range. The LMC7221 is characterized at 15V, 5V and 2.7V. Performance data is provided at these popular voltages. This wide voltage range makes the LMC7221 a good choice for devices where the voltage may vary over the life of the batteries.

Digital Outputs Representing Signal Level. Comparators provide a high or low digital output depending on the voltage levels of the (+) and (−) inputs. This makes comparators useful for interfacing analog signals to microprocessors and other digital circuits. The LMC7221 can be thought of as a one-bit a/d converter.

Open Drain Output. The open drain output is like the open collector output of a logic gate. This makes the LMC7221 very useful for mixed voltage systems.

Driving LEDs (Light Emitting Diodes). With a 5 volt power supply, the LMC7221's output sinking current can drive small, high efficiency LEDs for indicator and test point circuits. The small size of the Tiny package makes it easy to find space to add this feature to even compact designs.

Input range to Beyond Rail to Rail. The input common mode range of the LMC7221 is slightly larger than the actual power supply range. This wide input range means that the comparator can be used to sense signals close to the power supply rails. This wide input range can make design easier by eliminating voltage dividers, amplifiers, and other front end circuits previously used to match signals to the limited input range of earlier comparators. This is useful to power supply monitoring circuits which need to sense their own power supply, and compare it to a reference voltage which is close to the power supply voltage. The wide input range can also be useful for sensing the voltage drop across a current sense resistor for battery chargers.

Zero Crossing Detector. Since the LMC7221's common mode input range extends below ground even when powered by a single positive supply, it can be used with large input resistors as a zero crossing detector.

Low Input Currents and High Input Impedance. These characteristics allow the LMC7221 to be used to sense high impedance signals from sensors. They also make it possible to use the LMC7221 in timing circuits built with large value resistors. This can reduce the power dissipation of timing circuits. For very long timing circuits, using high value resistors can reduce the size and cost of large value capacitors for the same R-C time constant.

Direct Sensor Interfacing. The wide input voltage range and high impedance of the LMC7221 may make it possible to directly interface to a sensor without the use of amplifiers or bias circuits. In circuits with sensors which can produce outputs in the tens to hundreds of millivolts, the LMC7221 can compare the sensor signal with an appropriately small reference voltage. This may be done close to ground or the positive supply rail. Direct sensor interfacing may eliminate the need for an amplifier for the sensor signal. Eliminating the amplifier can save cost, space, and design time.

2.0 Low Voltage Operation

Comparators are the common devices by which analog signals interface with digital circuits. The LMC7221 has been designed to operate at supply voltages of 2.7V without sacrificing performance to meet the demands of 3V digital systems.

At supply voltages of 2.7V, the common-mode voltage range extends 200 mV (guaranteed) below the negative supply. This feature, in addition to the comparator being able to sense signals near the positive rail, is extremely useful in low voltage applications.

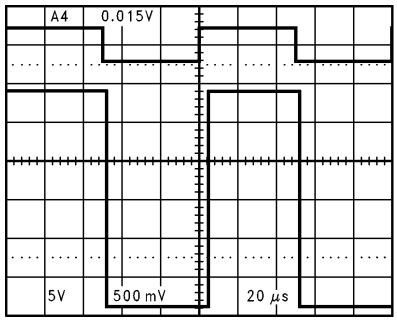

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FIGURE 1. Even at Low-Supply Voltage of 2.7V, an Input Signal which Exceeds the Supply Voltages Produces No Phase Inversion at the Output

At $V^+ = 2.7V$ propagation delays are $t_{PLH} = 4\ \mu s$ and $t_{PHL} = 4\ \mu s$ with overdrives of 100 mV.

Please refer to the performance curves for more extensive characterization.

Application Information (Continued)

3.0 Open Drain Output

Output Stage

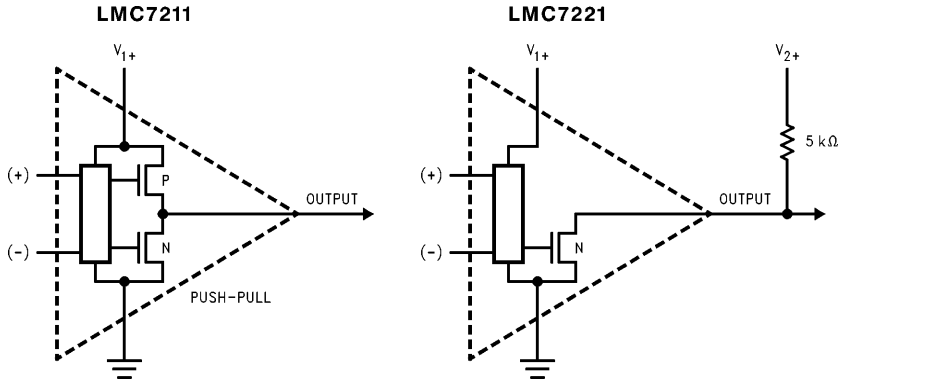

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FIGURE 2

Figure 2 shows the difference between push-pull output and open drain output.

Push pull outputs will have a conventional high or low digital output, the same as a logic gate. Low will be the negative supply rail (usually ground) and high will be the positive supply rail.

This is useful if the chips you are interfacing to run on the same supply voltage as the comparator. An example would be an all +5V system.

Open drain outputs will only pull low—for the high output they depend on an external pull-up resistor. This can pull up to a voltage higher or lower than the comparator supply voltage. This voltage can be as high as 15V. This makes the open drain parts useful in mixed voltage systems. An example would be where the comparator runs at 5V and the logic circuits are at 3.3V. The pull-up resistor would go to the 3.3V supply.

Open drain outputs are the CMOS equivalent of open collector outputs.

4.0 Output Short Circuit Current

The LMC7221 has short circuit protection of 40 mA. However, it is not designed to withstand continuous short circuits, transient voltage or current spikes, or shorts to any voltage beyond the supplies. A resistor in series with the output should reduce the effect of shorts. For outputs which send signals off PC boards additional protection devices, such as diodes to the supply rails, and varistors may be used.

5.0 Input Protection

If input signals are like to exceed the common mode range of the LMC7221, or it is likely that signals may be present when power is off, damage to the LMC7221 may occur. Large value (100 kΩ to MΩ) input resistors may reduce the likelihood of damage by limiting the input currents. Since the LMC7221 has very low input leakage currents, the effect on accuracy will be small. Additional protection may require the use of diodes, as shown in *Figure 3*. Note that diode leakage current may affect accuracy during normal operation.

The R-C time constant of R_{IN} and the diode capacitance may also slow response time.

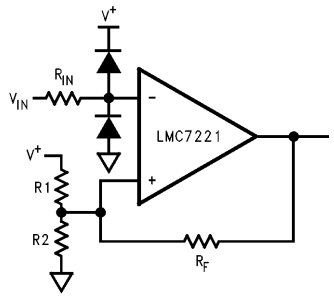

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FIGURE 3

6.0 Layout Considerations

The LMC7221 is not an especially fast comparator, so high speed design practices are not required. The LMC7221 is capable of operating with very high impedance inputs, so precautions should be taken to reduce noise pickup with high impedance (~ 100 kΩ and greater) designs and in electrically noisy environments.

Keeping high value resistors close to the LMC7221 and minimizing the size of the input nodes is a good practice. With multilayer designs, try to avoid long loops which could act as inductors (coils). Sensors which are not close to the comparator may need twisted pair or shielded connections to reduce noise.

7.0 Push-Pull Outputs, Dual Versions

The LMC7211 is a comparator similar to the LMC7221, but with push-pull outputs which can source current.

The performance of the LMC7221 is available in a dual device. Please see the LMC6772 datasheet. For a dual device with push-pull outputs, please see the LMC6762 datasheet.

Application Information (Continued)

Rail-to-Rail Input Low Power Comparators—

Push-Pull Output

LMC7221	Tiny, SOT23-5, DIP	Single
LMC6762	SO-8, DIP	Dual

Open Drain Output

LMC7221	Tiny, SOT23-5, DIP	Single
LMC6772	SO-8, DIP	Dual

8.0 Additional SOT23-5 Tiny Devices

National Semiconductor has additional parts available in the space saving SOT23 Tiny package, including amplifiers, voltage references, and voltage regulators. These devices include—

LMC7101 1 MHz gain-bandwidth rail-to-rail input and output amplifier—high input impedance and high gain 700 μA typical current 2.7V, 3V, 5V and 15V specifications.

LMC7111 Low power 50 kHz gain-bandwidth rail-to-rail input and output amplifier with 25 μA typical current specified at 2.7V, 3.0V, 3.3V, 5V and 10V.

LM7131 Tiny Video amp with 70 MHz gain bandwidth 3V, 5V and ±5V specifications.

LP2980 Micropower SOT 50 mA Ultra Low-Dropout Regulator.

LM4040 Precision micropower shunt voltage reference. Fixed voltages of 2.500V, 4.096V, 5.000V, 8.192V and 10.000V.

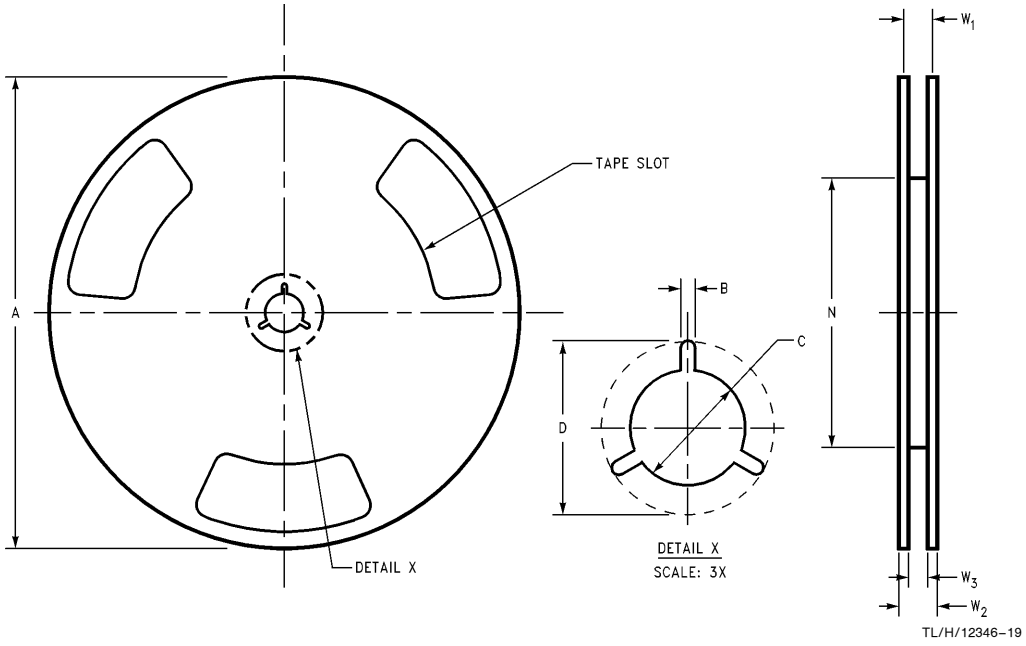
LM4041 Precision micropower shut voltage reference 1.225V and adjustable.

Contact your National Semiconductor representative for the latest information.

9.0 Spice Macromodel

A Spice Macromodel is available for the LMC7221 comparator on the National Semiconductor Amplifier Macromodel disk. Contact your National Semiconductor representative to obtain the latest version.

REEL DIMENSIONS



TL/H/12346–19

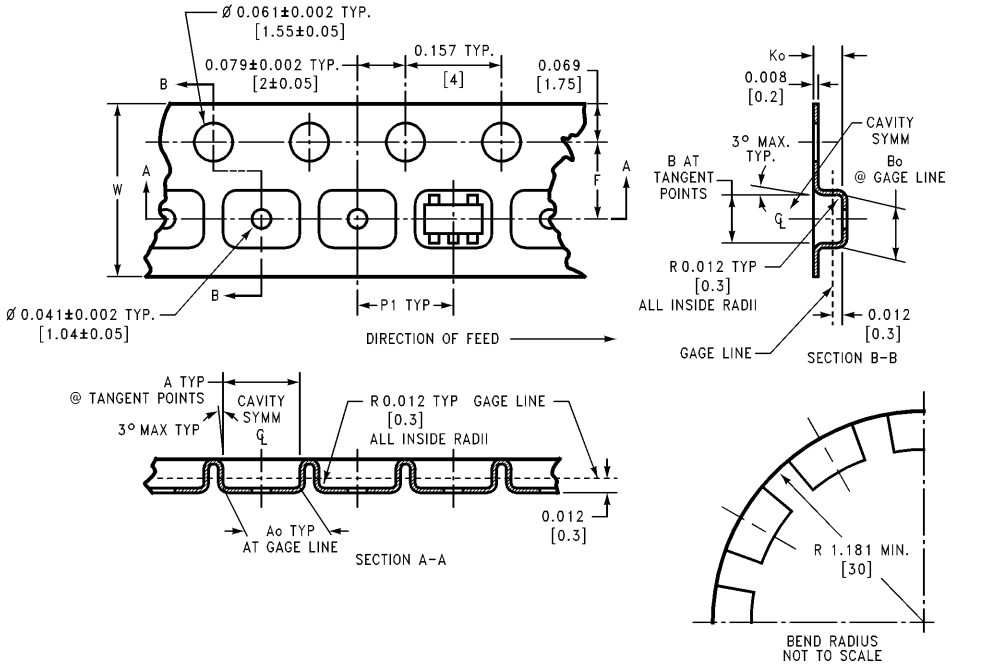
8 mm	7.00 330.00	0.059 1.50	0.512 13.00	0.795 20.20	2.165 55.00	0.331 + 0.059/−0.000 8.40 + 1.50/−0.00	0.567 14.40	W1+ 0.078/−0.039 W1 + 2.00/−1.00
Tape Size	A	B	C	D	N	W1	W2	W3

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

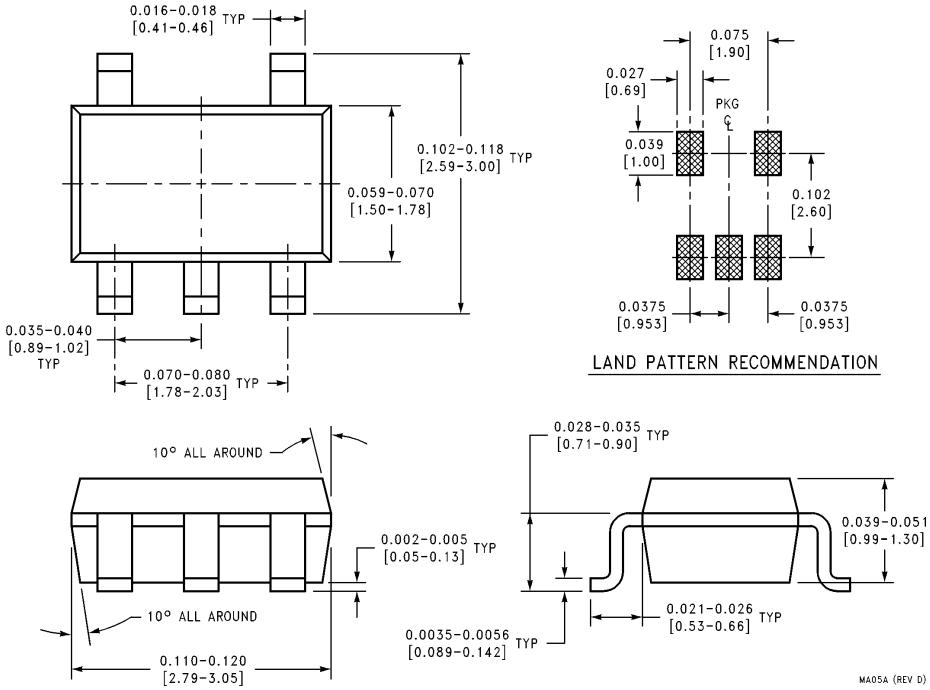
TAPE DIMENSIONS



TL/H/12346–20

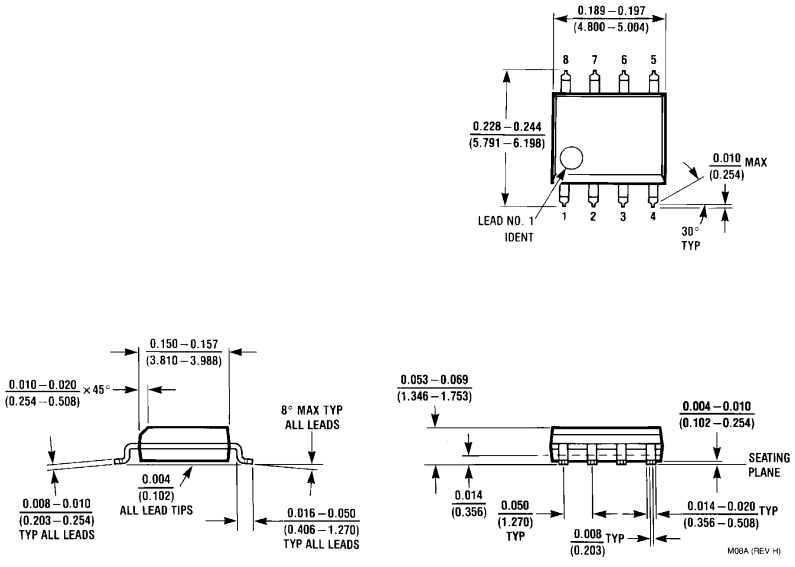
8 mm	0.130 (3.3)	0.124 (3.15)	0.130 (3.3)	0.126 (3.2)	0.138 ± 0.002 (3.5 ± 0.05)	0.055 ± 0.004 (1.4 ± 0.11)	0.157 (4)	0.315 ±0.012 (8 ± 0.3)
Tape Size	DIM A	DIM Ao	DIM B	DIM Bo	DIM F	DIM Ko	DIM P1	DIM W

Physical Dimensions inches (millimeters)



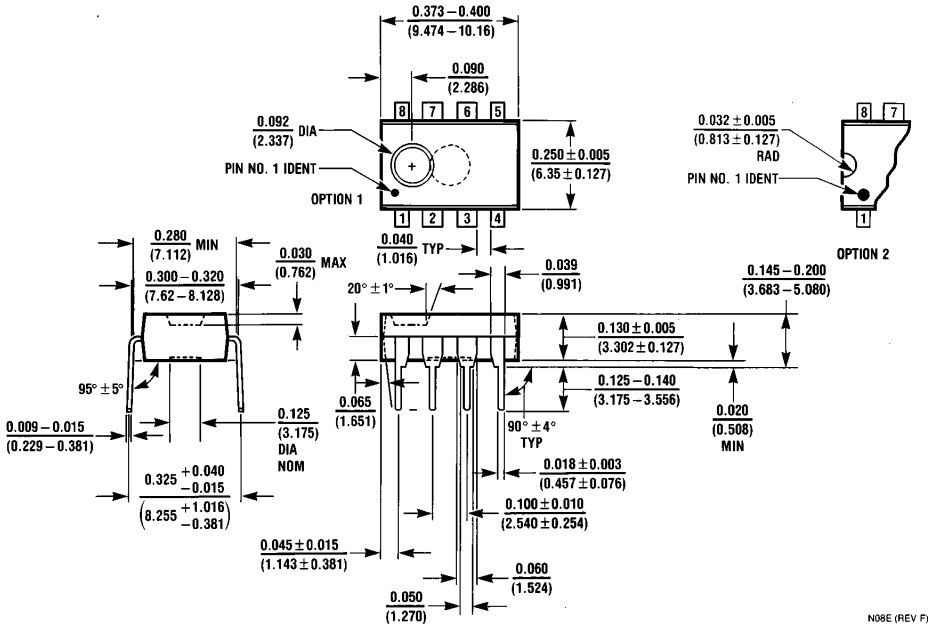
*Suffix indicates number of units. See Ordering Information on first page.

5-Pin SOT Package
Order Package Number LMC7221AIM5* or LMC7221BIM5*
NS Package Number MA05A



8-Pin Small Outline Package
Order Number LMC7221AIM or LMC7221BIM
NS Package Number M08A

Physical Dimensions inches (millimeters) (Continued)



8-Pin Molded DIP
8-Lead (0.300″ Wide) Molded Dual-In-Line Package
Order Package Number LMC7221AIN or LMC7221BIN
NS Packagke Number N08E

LIFE SUPPORT POLICY

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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.

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