National Semiconductor

September 2006

# 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 5-Pin SOT23 package. This makes this comparator ideal for space and weight critical designs. The LMC7221 is also available in the 8-Pin SOIC package. 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

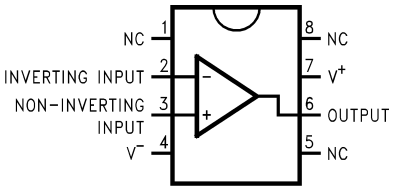
- Tiny 5-Pin SOT23 package saves space
- Package is less than 1.43 mm thick
- Guaranteed specs at 2.7V, 5V, 15V supplies
- Typical supply current 7 µA at 5V
- Response time of 4 µs at 5V
- LMC7221 — open drain output
- Input common-mode range beyond $V^-$ and $V^+$
- Low input current

## Applications

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

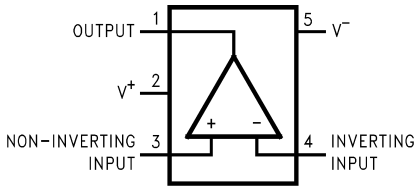
## Connection Diagrams

**8-Pin SOIC**




**Top View**

**5-Pin SOT23**




**Top View**

## Ordering Information

| Package | Part Number | Package Marking | Transport Media | NSC Drawing |
|---|---|---|---|---|
| 8-Pin SOIC | LMC7221AIM | LMC7221AIM | 95 Units/Rail | M08A |
| | LMC7221AIMX | | 2.5k Units Tape and Reel | |
| | LMC7221BIM | LMC7221BIM | 95 Units/Rail | |
| | LMC7221BIMX | | 2.5k Units Tape and Reel | |
| 5-Pin SOT23 | LMC7221AIM5 | C01A | 1k Units Tape and Reel | MF05A |
| | LMC7221AIM5X | | 3k Units Tape and Reel | |
| | LMC7221BIM5 | C01B | 1k Units Tape and Reel | |
| | LMC7221BIM5X | | 3k Units Tape and Reel | |

© 2006 National Semiconductor Corporation 

## 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 | $V^+$ +0.3V, $V^-$ −0.3V |
| Voltage at Input | $V^+$ +0.3V, $V^-$ −0.3V |
| Voltage at Output Pin | 15V |
| Supply Voltage ($V^+$–$V^-$) | 16V |
| Current at Input Pin (Note 6) | ±5 mA |
| Current at Output Pin (Notes 3, 7) | ±30 mA |
| Current at Power Supply Pin | 40 mA |
| Lead Temperature (soldering, 10 sec.) | 260˚C |
| Junction Temperature (Note 4) | 150˚C |

## Operating Ratings (Note 1)

| | |
|---|---|
| Supply Voltage | $2.7 \le V_{CC} \le 15V$ |
| Temperature Range (Note 4) | |
| LMC7221AI, LMC7221BI | −40˚C to +85˚C |
| Thermal Resistance ($\theta_{JA}$) | |
| 8-Pin SOIC | 180˚C/W |
| 5-Pin SOT23 | 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<br>**8** | 15<br>**18** | mV<br>max |
| $TCV_{OS}$ | Input Offset Voltage Temperature Drift | | 1.0 | | | µV/˚C |
| | Input Offset Voltage Average Drift | (Note 9) | 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<br>**2.7** | 2.9<br>**2.7** | V<br>min |
| | | CMRR > 55 dB | −0.3 | −0.2<br>**0.0** | −0.2<br>**0.0** | V<br>max |
| $V_{OL}$ | Output Voltage Low | $I_{LOAD}$ = 2.5 mA | 0.2 | 0.3<br>**0.4** | 0.3<br>**0.4** | V<br>max |
| $I_S$ | Supply Current | $V_{OUT}$ = Low | 7 | 12<br>**14** | 12<br>**14** | µA<br>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<br>**8** | 15<br>**18** | mV<br>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 9) | 3.3 | | | µV/Month |
| | | $V^+$ = 15V (Note 9) | 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 ≤ $V^+$ ≤ 10V | 80 | | | dB |
| $A_V$ | Voltage Gain | | 100 | | | dB |
| CMVR | Input Common-Mode Voltage Range | $V^+$ = 5.0V<br>CMRR > 55 dB | 5.3 | 5.2<br>**5.0** | 5.2<br>**5.0** | V<br>min |
| | | $V^+$ = 5.0V<br>CMRR > 55 dB | –0.3 | –0.2<br>**0.0** | –0.2<br>**0.0** | V<br>max |
| | | $V^+$ = 15.0V<br>CMRR > 55 dB | 15.3 | 15.2<br>**15.0** | 15.2<br>**15.0** | V<br>min |
| | | $V^+$ = 15.0V<br>CMRR > 55 dB | –0.3 | –0.2<br>**0.0** | –0.2<br>**0.0** | V<br>max |
| $V_{OL}$ | Output Voltage Low | $V^+$ = 5V<br>$I_{LOAD}$ = 5 mA | 0.2 | 0.40<br>**0.55** | 0.40<br>**0.55** | mV<br>max |
| | | $V^+$ = 15V<br>$I_{LOAD}$ = 5 mA | 0.2 | 0.40<br>**0.55** | 0.40<br>**0.55** | mV<br>max |
| $I_S$ | Supply Current | $V_{OUT}$ = Low | 7 | 14<br>**18** | 14<br>**18** | µA<br>max |
| $I_{SC}$ | Short Circuit Current | Sinking (Note 7) | 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<br>$V_{IN}(+)$ = 0.5V<br>$V_{IN}(-)$ = 0V<br>$V_{OUT}$ = 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 8) Overdrive = 10 mV, 5 kΩ Pullup | | 0.3 | | | µs |
| $t_{fall}$ | Fall Time | f = 10 kHz, $C_L$ = 50 pF, (Note 8) Overdrive = 10 mV, 5 kΩ Pullup | | 0.3 | | | µs |
| $t_{PHL}$ | Propagation Delay (High to Low) (Note 10) | f = 10 kHz, $C_L$ = 50 pF, 5 kΩ Pullup (Note 8) | 10 mV | 10 | | | µs |
| | | | 100 mV | 4 | | | |
| | | $V^+$ = 2.7V, f = 10 kHz, $C_L$ = 50 pF, 5 kΩ Pullup (Note 8) | 10 mV | 10 | | | µs |
| | | | 100 mV | 4 | | | |
| $t_{PLH}$ | Propagation Delay (Low to High) (Note 10) | f = 10 kHz, $C_L$ = 50 pF, 5 kΩ Pullup (Note 8) | 10 mV | 6 | | | µs |
| | | | 100 mV | 4 | | | |
| | | $V^+$ = 2.7V, f = 10 kHz, $C_L$ = 50 pF, 5 kΩ Pullup (Note 8) | 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, applicable std. MIL-STD-883, Method 3015.7. Machine Model, applicable std. JESD22-A115-A (ESD MM std. of JEDEC)

Field-Induced Charge-Device Model, applicable std. JESD22-C101-C (ESD FICDM std. of JEDEC).

**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 $T_{J(MAX)}$, $\theta_{JA}$. 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 onto a PC Board.

**Note 5:** 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 guaranteed on shipped production material.

**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.

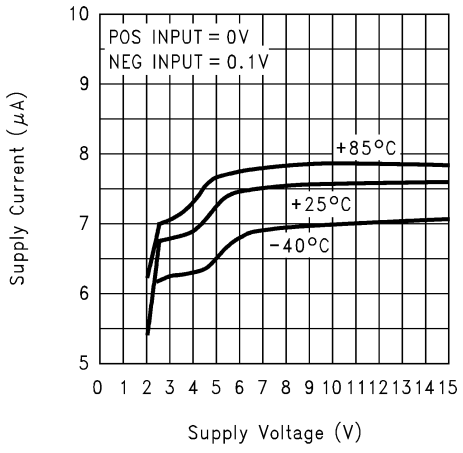
**Note 9:** $C_L$ includes the probe and test jig capacitance.

**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.

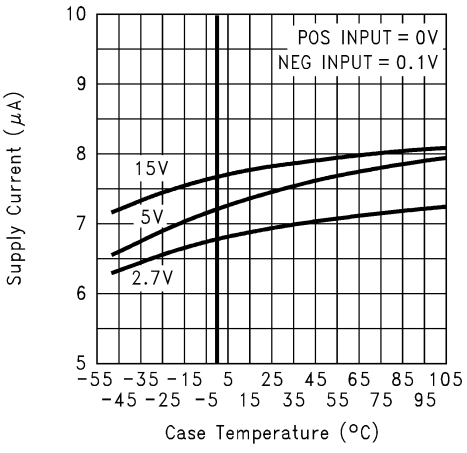
# Typical Performance Characteristics

**Supply Current vs. Supply Voltage**



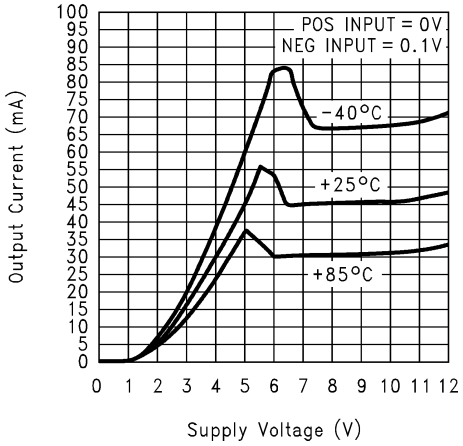

01234603

**Supply Current vs. Temperature while Sinking**



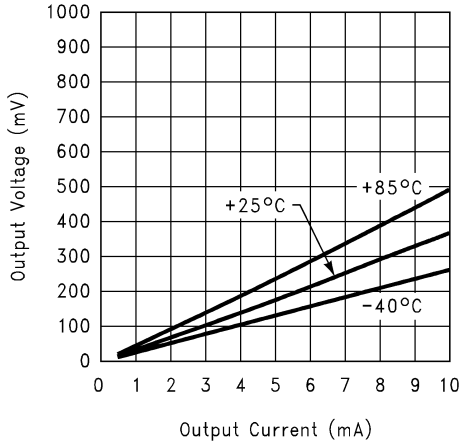

01234604

**Output Sinking Current vs. Supply Voltage**



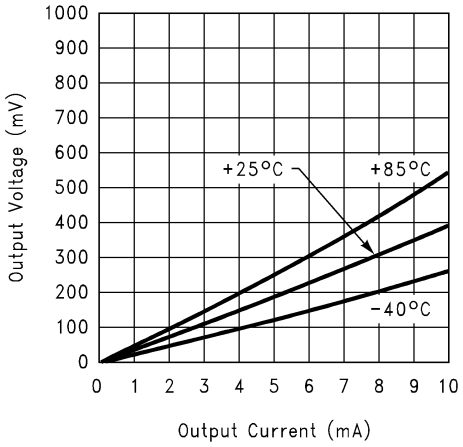

01234605

**Output Sinking Current vs. Output Voltage @ 5V**



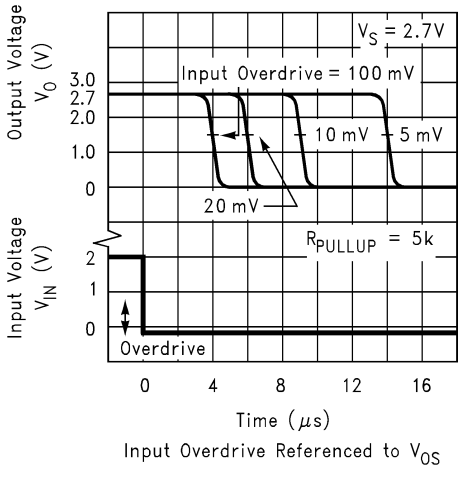

01234606

**Output Sinking Current vs. Output Voltage @ 15V**




01234607

**Response Time for Various Input Overdrives $-t_{PHL}$**

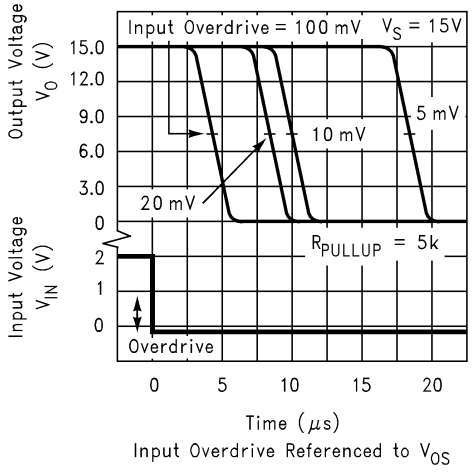



Input Overdrive Referenced to $V_{OS}$

01234608

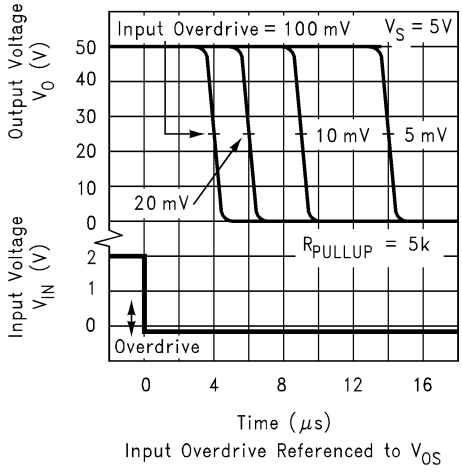
## Typical Performance Characteristics (Continued)

**Response Time vs. Various Input Overdrives –$t_{PHL}$**



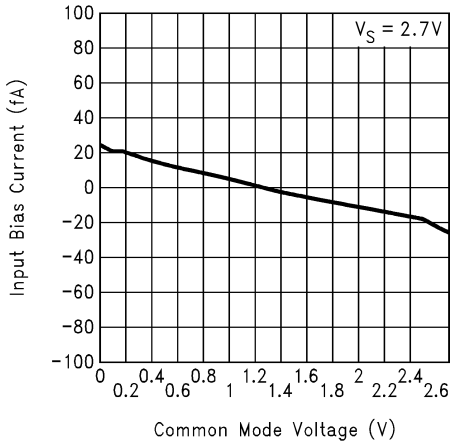

01234609

**Response Time vs Various Input Overdrives –$t_{PHL}$**



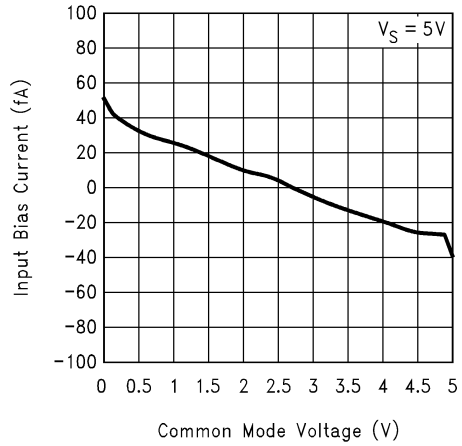

01234610

**Input Bias Current vs. Common Mode Voltage**



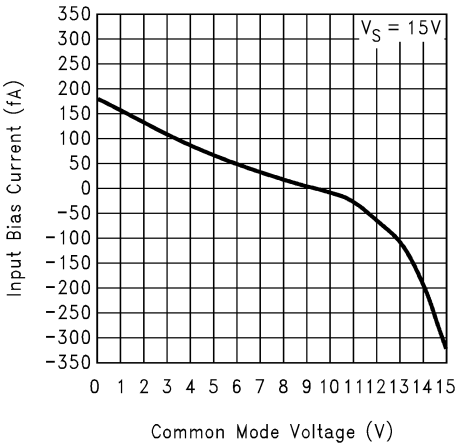

01234611

**Input Bias Current vs. Common Mode Voltage**



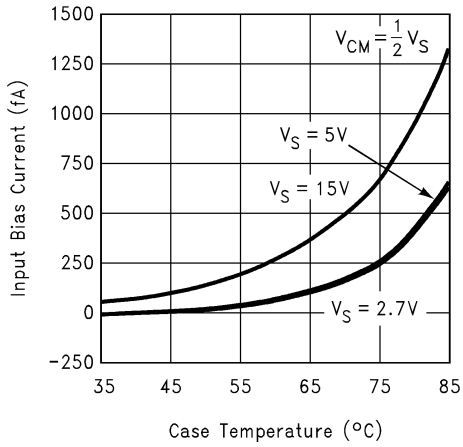

01234612

**Input Bias Current vs. Common Mode Voltage**




01234613

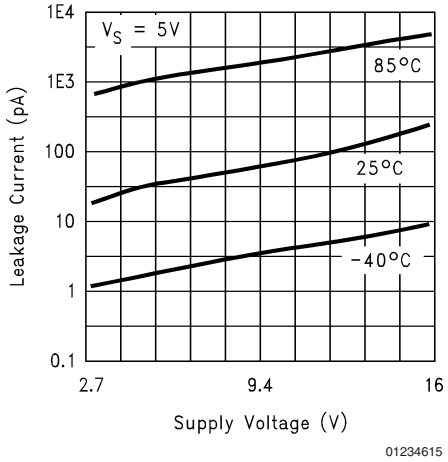
**Input Bias Current vs. Temperature**




01234614

## Typical Performance Characteristics (Continued)

**Leakage Current vs. Supply Voltage**




01234615

## Application Information

### 1.0 BENEFITS OF THE LMC7221 TINY COMPARATOR

**Size**

The small footprint of the 5-Pin SOT23 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.

**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.

# Application Information (Continued)

### 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.

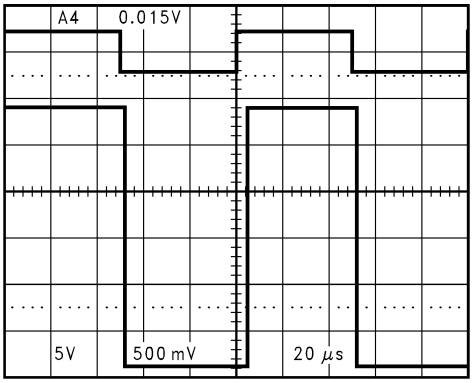



**FIGURE 1. Even at Low-Supply Voltage of 2.7V, an Input Signal which Exceeds the Supply Voltages Produces No Phase Inversion at the Output**

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

Please refer to the performance curves for more extensive characterization.

### 3.0 OPEN DRAIN OUTPUT

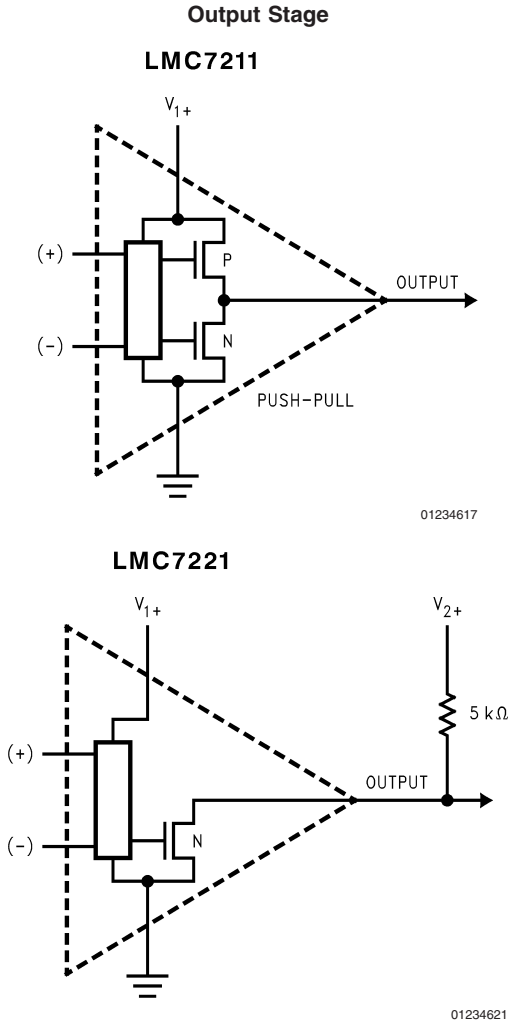



**FIGURE 2.**

*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.

## Application Information (Continued)

### 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 likely 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.

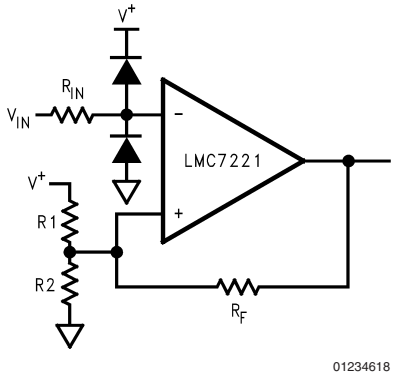



**FIGURE 3.**

### 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.

**Rail-to-Rail Input Low Power Comparators—**

**Push-Pull Output**

| | | |
|---|---|---|
| LMC7221 | 5-Pin SOT23, 8-Pin SOIC | Single |
| LMC6762 | 8-Pin SOIC | Dual |

**Open Drain Output**

| | | |
|---|---|---|
| LMC7221 | 5-Pin SOT23, 8-Pin SOIC | Single |
| LMC6772 | 8-Pin SOIC | Dual |

### 8.0 ADDITIONAL 5-Pin SOT23 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.

**LM385** Low current voltage reference. Fixed Voltages of 1.2V and 2.5V.

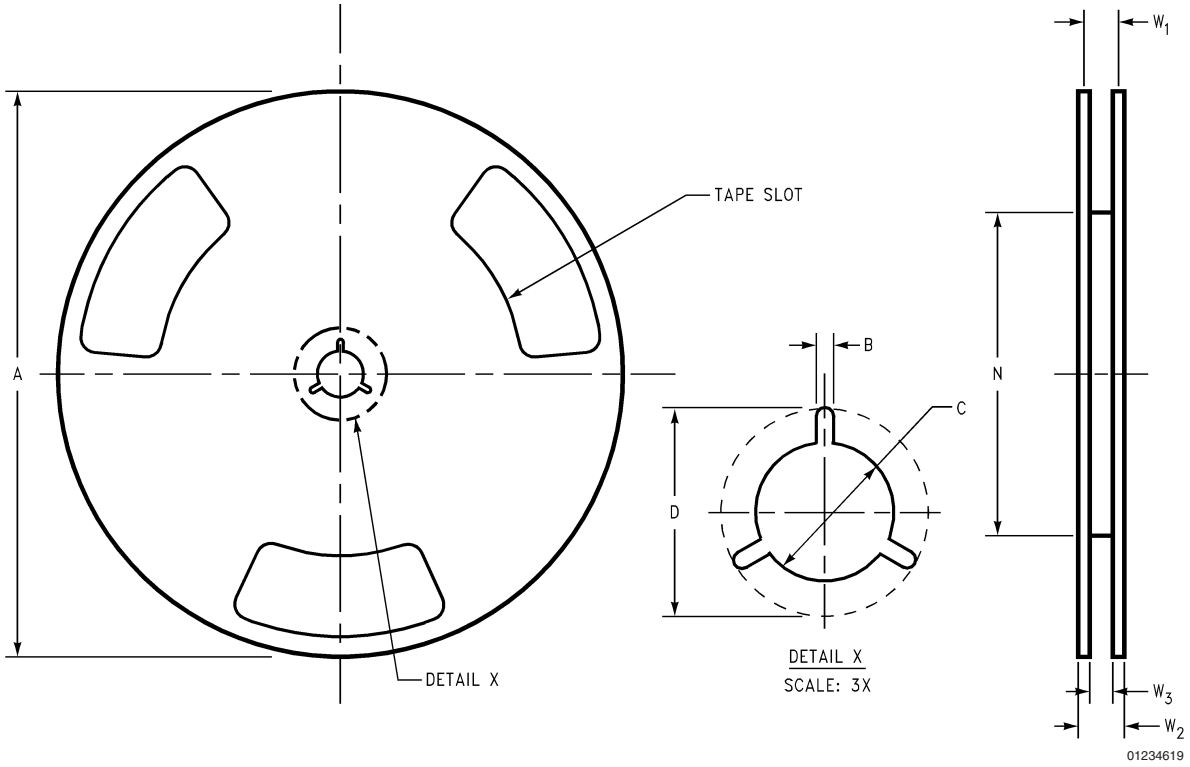
Contact your National Semiconductor representative for the latest information.

### 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.

## Application Information (Continued)

**REEL DIMENSIONS**




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

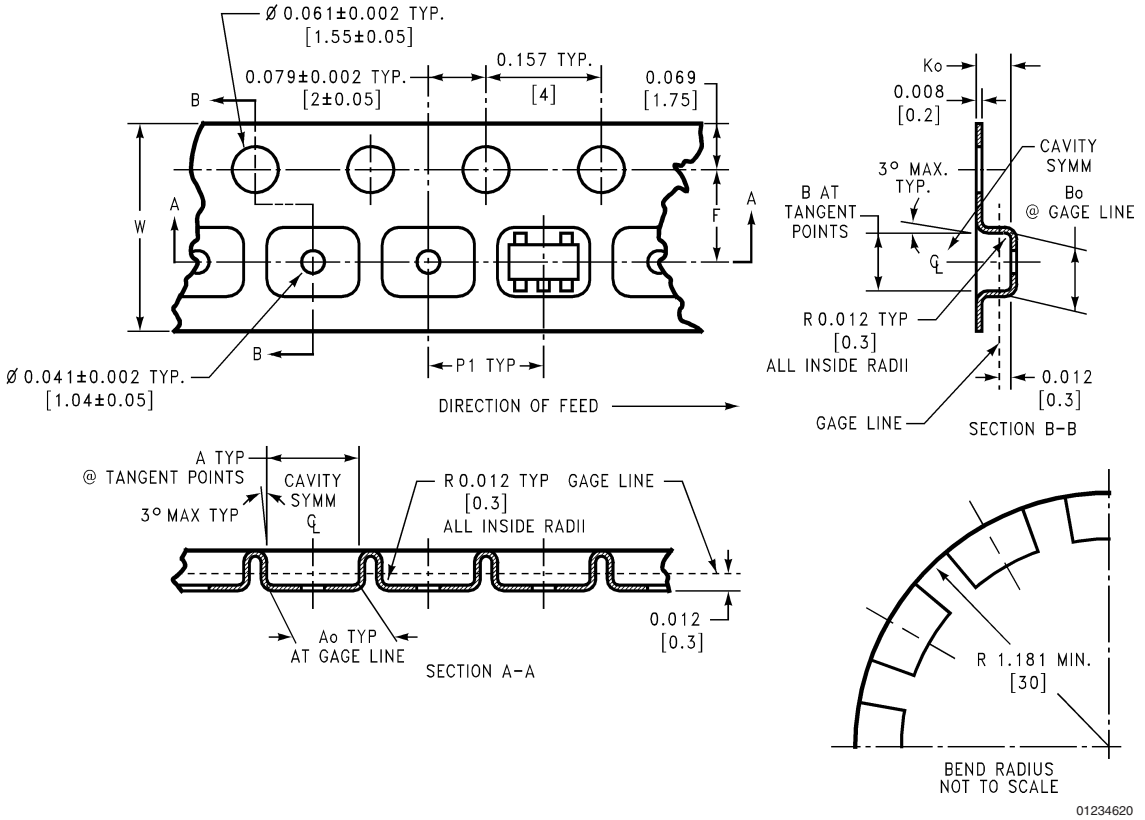
## SOT-23-5 Tape and Reel Specification

**TAPE FORMAT**

| Tape Section | # Cavities | Cavity Status | Cover Tape Status |
|---|---|---|---|
| Leader | 0 (min) | Empty | Sealed |
| (Start End) | 75 (min) | Empty | Sealed |
| Carrier | 3000 | Filled | Sealed |
| | 1000 | Filled | Sealed |
| Trailer | 125 (min) | Empty | Sealed |
| (Hub End) | 0 (min) | Empty | Sealed |

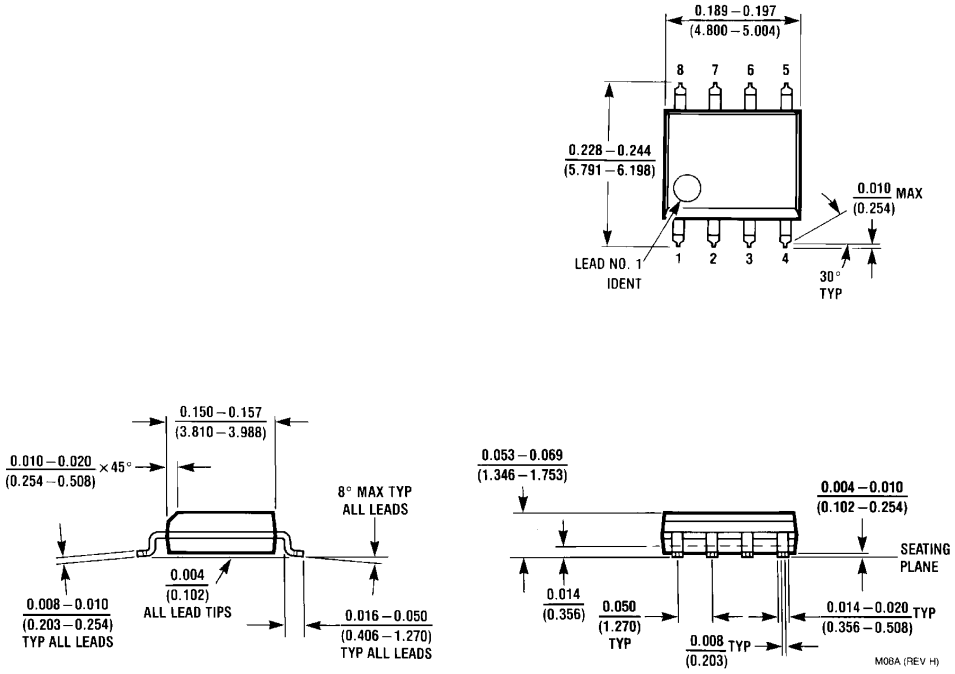
## SOT-23-5 Tape and Reel Specification (Continued)

**Tape Dimensions**

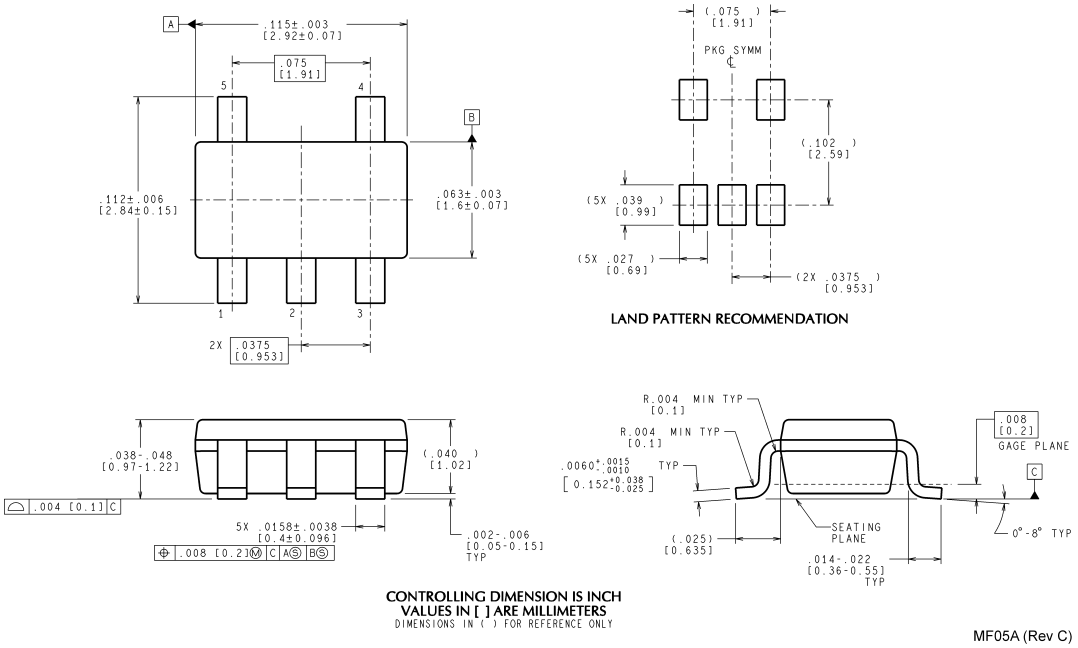



| 8 mm | 0.130 (3.3) | 0.124 (3.15) | 0.130 (3.3) | 0.126 (3.2) | 0.138 ± 0.002 (3.5 ± 0.05) | 0.055 ± 0.004 (1.4 ± 0.11) | 0.157 (4) | 0.315 ±0.012 (8 ± 0.3) |
|---|---|---|---|---|---|---|---|---|
| Tape Size | DIM A | DIM Ao | DIM B | DIM Bo | DIM F | DIM Ko | DIM P1 | DIM W |

## Physical Dimensions inches (millimeters) unless otherwise noted




**8-Pin Small Outline Package**
**NS Package Number M08A**




**5-Pin SOT Package**
**NS Package Number MF05A**

## Notes

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

For the most current product information visit us at www.national.com.

**LIFE SUPPORT POLICY**

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

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.

**BANNED SUBSTANCE COMPLIANCE**

National Semiconductor follows the provisions of the Product Stewardship Guide for Customers (CSP-9-111C2) and Banned Substances and Materials of Interest Specification (CSP-9-111S2) for regulatory environmental compliance. Details may be found at: www.national.com/quality/green.

Lead free products are RoHS compliant.

**National Semiconductor**
**Americas Customer**
**Support Center**
Email: new.feedback@nsc.com
Tel: 1-800-272-9959

www.national.com

**National Semiconductor**
**Europe Customer Support Center**
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +44 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor**
**Asia Pacific Customer**
**Support Center**
Email: ap.support@nsc.com

**National Semiconductor**
**Japan Customer Support Center**
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560