

## LMV7291

# Single 1.8V Low Power Comparator with Rail-to-Rail Input

### General Description

The LMV7291 is a rail-to-rail input low power comparator, characterized at supply voltage 1.8V, 2.7V and 5.0V. It consumes only 9 $\mu$ A supply current per channel while achieving a 800ns propagation delay.

The LMV7291 is available in SC70 package. With this tiny package, the PC board area can be significantly reduced. It is ideal for low voltage, low power and space critical designs.

The LMV7291 features a push-pull output stage which allows operation with minimum power consumption when driving a load.

The LMV7291 is built with National Semiconductor's advance submicron silicon-gate BiCMOS process. It has bipolar inputs for improved noise performance and CMOS outputs for rail-to-rail output swing.

### Features

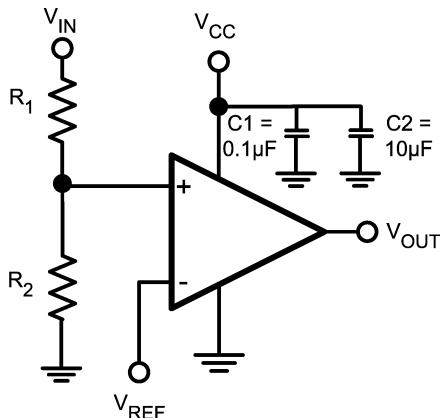
( $V_S = 1.8V$ ,  $T_A = 25^\circ C$ , Typical values unless specified).

- Single Supply
- Ultra low supply current 9 $\mu$ A per channel
- Low input bias current 10nA
- Low input offset current 200pA
- Low guaranteed  $V_{OS}$  4mV
- Propagation delay 880ns (20mV overdrive)
- Input common mode voltage range 0.1V beyond rails

### Applications

- Mobile communications
- Laptops and PDA's
- Battery powered electronics
- General purpose low voltage applications

### Typical Circuit



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FIGURE 1. Threshold Detector

**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	2kV (Note 2)
	200V (Note 6)
V <sub>IN</sub> Differential	±Supply Voltage
Supply Voltage (V <sup>+</sup> - V <sup>-</sup> )	5.5V
Voltage at Input/Output pins	V <sup>+</sup> +0.1V, V <sup>-</sup> -0.1V
Soldering Information	
Infrared or Convection (20 sec.)	235°C

Wave Soldering (10 sec.)

260°C

Storage Temperature Range

-65°C to +150°C

Junction Temperature (Note 4)

+150°C

**Operating Ratings** (Note 1)

Operating Temperature Range

-40°C to +85°C

Package Thermal Resistance (Note 3)

SC-70

265°C/W

**1.8V Electrical Characteristics**

Unless otherwise specified, all limits guaranteed for T<sub>J</sub> = 25°C, V<sup>+</sup> = 1.8V, V<sup>-</sup> = 0V. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
V <sub>OS</sub>	Input Offset Voltage			0.3	4 6	mV
TC V <sub>OS</sub>	Input Offset Temperature Drift	V <sub>CM</sub> = 0.9V (Note 7)		10		uV/C
I <sub>B</sub>	Input Bias Current			10		nA
I <sub>OS</sub>	Input Offset Current			200		pA
I <sub>S</sub>	Supply Current	LMV7291		9	12 14	μA
I <sub>SC</sub>	Output Short Circuit Current	Sourcing, V <sub>O</sub> = 0.9V Sinking, V <sub>O</sub> = 0.9V	3.5 4	6 6		mA
V <sub>OH</sub>	Output Voltage High	I <sub>O</sub> = 0.5mA I <sub>O</sub> = 1.5mA	1.7 1.58	1.74 1.63		V
V <sub>OL</sub>	Output Voltage Low	I <sub>O</sub> = -0.5mA I <sub>O</sub> = -1.5mA		52 166	70 220	mV
V <sub>CM</sub>	Input Common Mode Voltage Range	CMRR > 45 dB			1.9	V
				-0.1		V
CMRR	Common Mode Rejection Ratio	0 < V <sub>CM</sub> < 1.8V	47	78		dB
PSRR	Power Supply Rejection Ratio	V <sup>+</sup> = 1.8V to 5V	55	80		dB
I <sub>LEAKAGE</sub>	Output Leakage Current	V <sub>O</sub> = 1.8V		2		pA

**1.8V AC Electrical Characteristics**

Unless otherwise specified, all limits guaranteed for T<sub>J</sub> = 25°C, V<sup>+</sup> = 1.8V, V<sup>-</sup> = 0V, V<sub>CM</sub> = 0.5V, V<sub>O</sub> = V<sup>+</sup>/2 and R<sub>L</sub> > 1MΩ to V<sup>-</sup>. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
t <sub>PHL</sub>	Propagation Delay (High to Low)	Input Overdrive = 20mV Load = 50pF//5kΩ		880		ns
		Input Overdrive = 50mV Load = 50pF//5kΩ		570		ns
t <sub>PLH</sub>	Propagation Delay (Low to High)	Input Overdrive = 20mV Load = 50pF//5kΩ		1100		ns
		Input Overdrive = 50mV Load = 50pF//5kΩ		800		ns

## 2.7V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V^+ = 2.7\text{V}$ ,  $V^- = 0\text{V}$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$V_{OS}$	Input Offset Voltage			0.3	4 <b>6</b>	mV
$TC\ V_{OS}$	Input Offset Temperature Drift	$V_{CM} = 1.35\text{V}$ (Note 7)		10		$\mu\text{V/C}$
$I_B$	Input Bias Current			10		nA
$I_{OS}$	Input offset Current			200		pA
$I_S$	Supply Current	LMV7291		9	13 <b>15</b>	$\mu\text{A}$
$I_{SC}$	Output Short Circuit Current	Sourcing, $V_O = 1.35\text{V}$	12	15		mA
		Sinking, $V_O = 1.35\text{V}$	12	15		
$V_{OH}$	Output Voltage High	$I_O = 0.5\text{mA}$	2.63	2.66		V
		$I_O = 2.0\text{mA}$	2.48	2.55		
$V_{OL}$	Output Voltage Low	$I_O = -0.5\text{mA}$		50	70	mV
		$I_O = -2\text{mA}$		155	220	
$V_{CM}$	Input Common Voltage Range	$CMRR > 45\text{dB}$			2.8	V
			-0.1			V
CMRR	Common Mode Rejection Ratio	$0 < V_{CM} < 2.7\text{V}$	47	78		dB
PSRR	Power Supply Rejection Ratio	$V^+ = 1.8\text{V}$ to $5\text{V}$	55	80		dB
$I_{LEAKAGE}$	Output Leakage Current	$V_O = 2.7\text{V}$		2		pA

## 2.7V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V^+ = 2.7\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{CM} = 0.5\text{V}$ ,  $V_O = V^+/2$  and  $R_L > 1\text{M}\Omega$  to  $V^-$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$t_{PHL}$	Propagation Delay (High to Low)	Input Overdrive = 20mV Load = 50pF//5k $\Omega$		1200		ns
		Input Overdrive = 50mV Load = 50pF//5k $\Omega$		810		ns
$t_{PLH}$	Propagation Delay (Low to High)	Input Overdrive = 20mV Load = 50pF//5k $\Omega$		1300		ns
		Input Overdrive = 50mV Load = 50pF//5k $\Omega$		860		ns

## 5V 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	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$V_{OS}$	Input Offset Voltage			0.3	4 <b>6</b>	mV
$TC\ V_{OS}$	Input Offset Temperature Drift	$V_{CM} = 2.5\text{V}$ (Note 7)		10		$\mu\text{V/C}$
$I_B$	Input Bias Current			10		nA
$I_{OS}$	Input Offset Current			200		pA
$I_S$	Supply Current	LMV7291		10	14 <b>16</b>	$\mu\text{A}$
$I_{SC}$	Output Short Circuit Current	Sourcing, $V_O = 2.5\text{V}$	28	34		mA
		Sinking, $V_O = 2.5\text{V}$	28	34		

## 5V Electrical Characteristics (Continued)

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	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$V_{OH}$	Output Voltage High	$I_O = 0.5\text{mA}$	4.93	4.96		V
		$I_O = 4.0\text{mA}$	4.70	4.77		
$V_{OL}$	Output Voltage Low	$I_O = -0.5\text{mA}$		27	70	mV
		$I_O = -4.0\text{mA}$		225	300	
$V_{CM}$	Input Common Voltage Range	$\text{CMRR} > 45\text{dB}$			5.1	V
			-0.1			
CMRR	Common Mode Rejection Ratio	$0 < V_{CM} < 5.0\text{V}$	47	78		dB
PSRR	Power Supply Rejection Ratio	$V^+ = 1.8\text{V}$ to $5\text{V}$	55	80		dB
$I_{LEAKAGE}$	Output Leakage Current	$V_O = 5\text{V}$		2		pA

## 5.0V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V^+ = 5.0\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{CM} = 0.5\text{V}$ ,  $V_O = V^+/2$  and  $R_L > 1\text{M}\Omega$  to  $V^-$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$t_{PHL}$	Propagation Delay (High to Low)	Input Overdrive = 20mV Load = 50pF//5k $\Omega$		2100		ns
		Input Overdrive = 50mV Load = 50pF//5k $\Omega$		1380		ns
$t_{PLH}$	Propagation Delay (Low to High)	Input Overdrive = 20mV Load = 50pF//5k $\Omega$		1800		ns
		Input Overdrive = 50mV Load = 50pF//5k $\Omega$		1100		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,  $1.5\text{k}\Omega$  in series with 100pF.

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

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

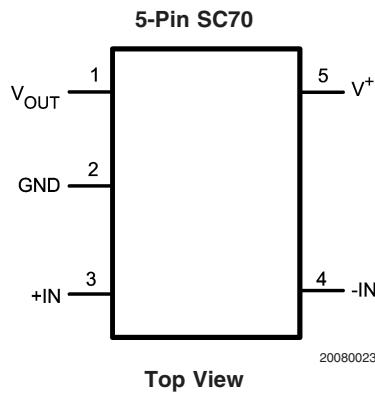
**Note 5:** All limits are guaranteed by testing or statistical analysis.

**Note 6:** Machine Model,  $0\Omega$  in series with 200pF.

**Note 7:** Offset Voltage average drift determined by dividing the change in  $V_{OS}$  at temperature extremes into the total temperature change.

**Note 8:** Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.

## Connection Diagram

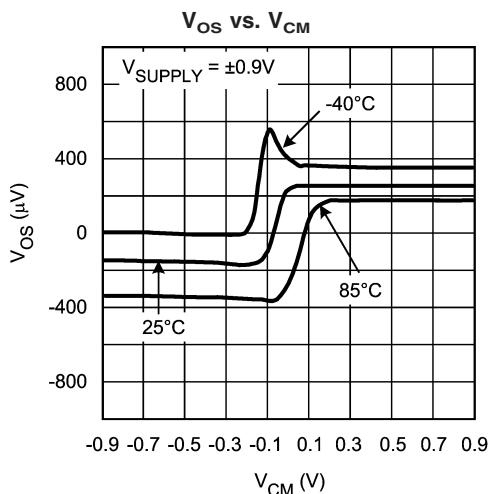


## Ordering Information

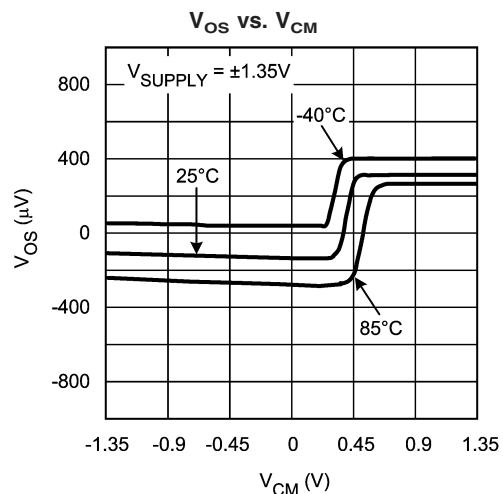
Package	Part Number	Package Marking	Transport Media	NSC Drawing
5-Pin SC70	LMV7291MG	C36	1k Units Tape and Reel	MAA05A
	LMV7291MGX		3k Units Tape and Reel	

## Typical Performance Characteristics

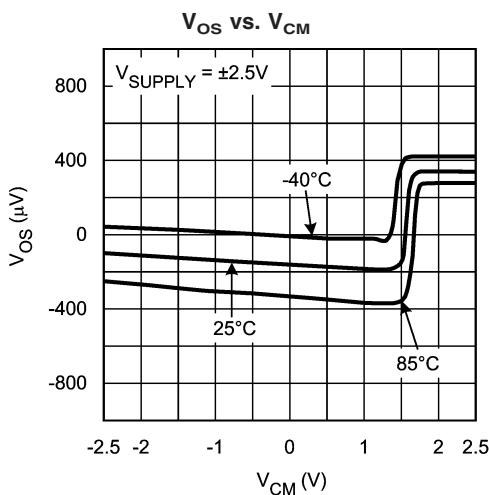
( $T_A = 25^\circ\text{C}$ , Unless otherwise specified).



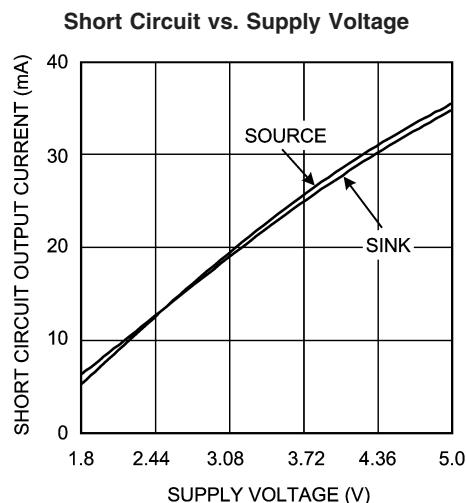
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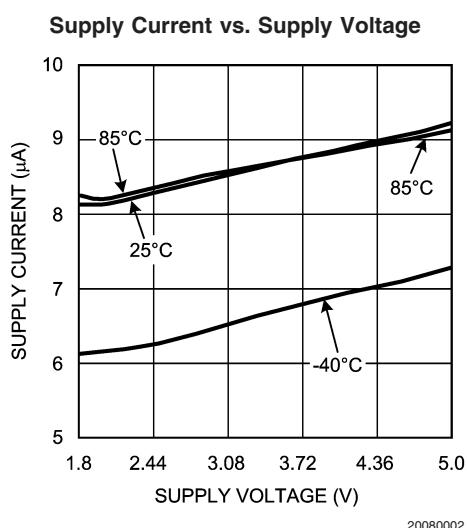
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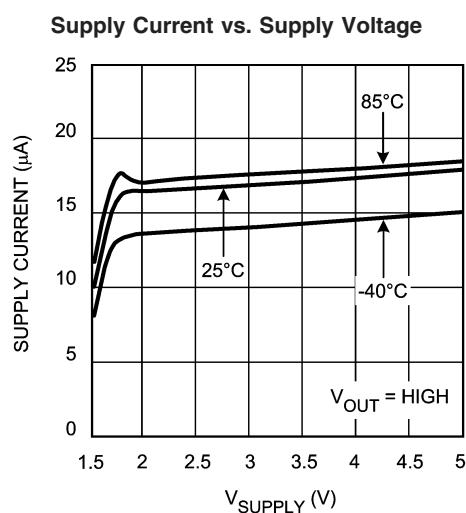
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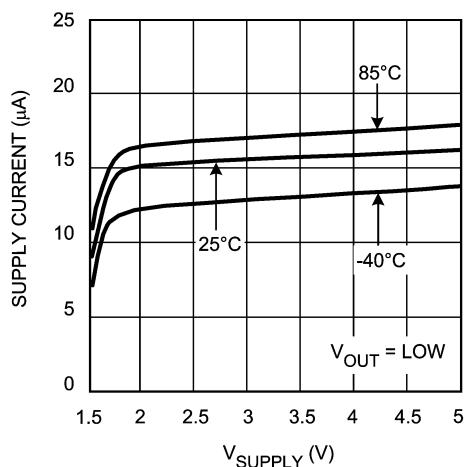
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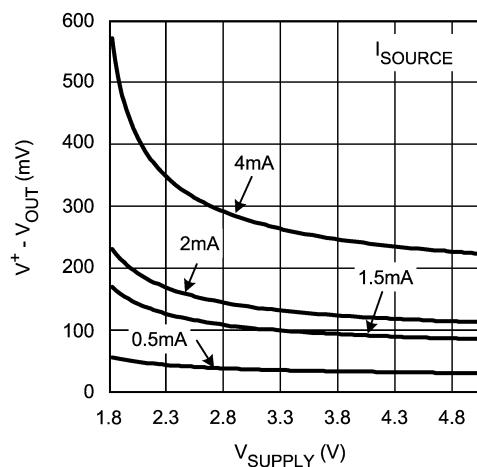
## Typical Performance Characteristics ( $T_A = 25^\circ\text{C}$ , Unless otherwise specified). (Continued)

Supply Current vs. Supply Voltage



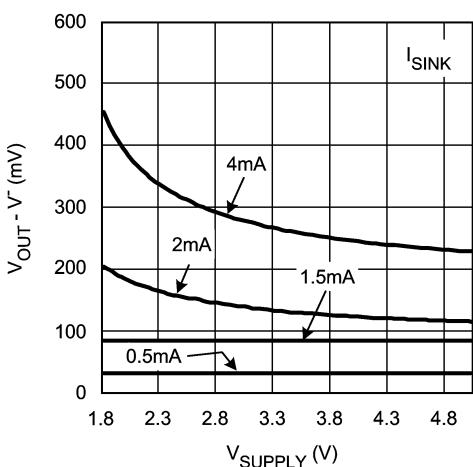
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Output Positive Swing vs.  $V_{\text{SUPPLY}}$



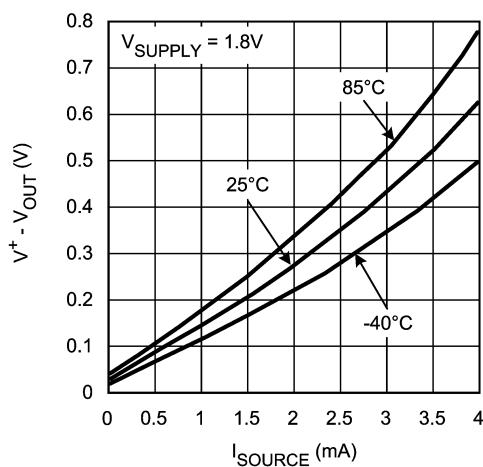
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Output Negative Swing vs.  $V_{\text{SUPPLY}}$



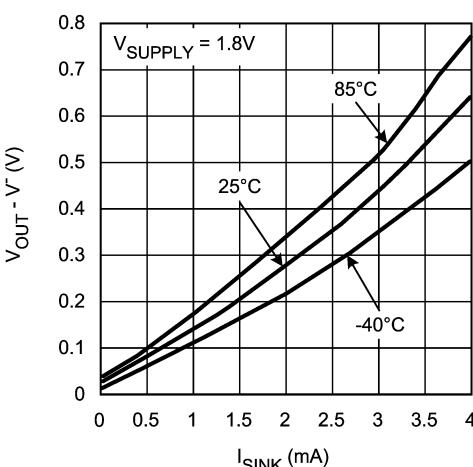
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Output Positive Swing vs.  $I_{\text{SOURCE}}$



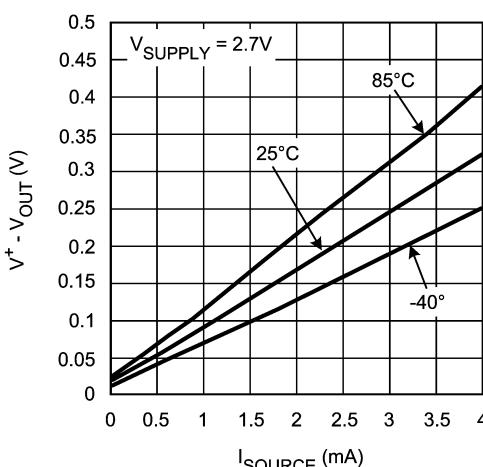
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Output Negative Swing vs.  $I_{\text{SINK}}$

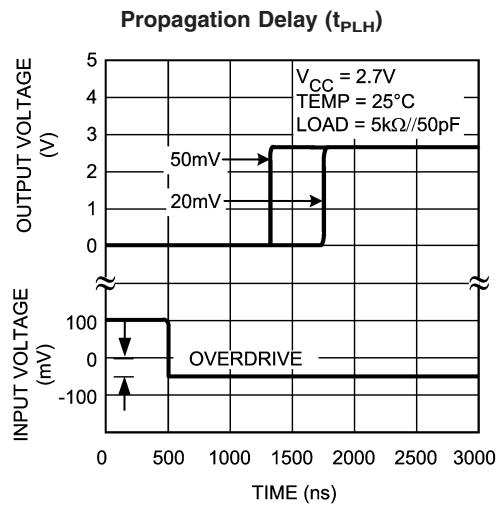
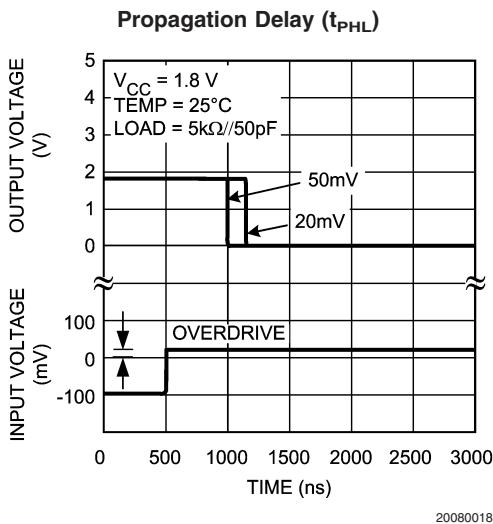
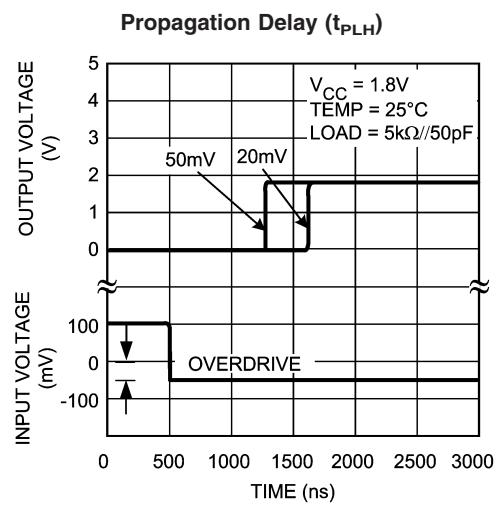
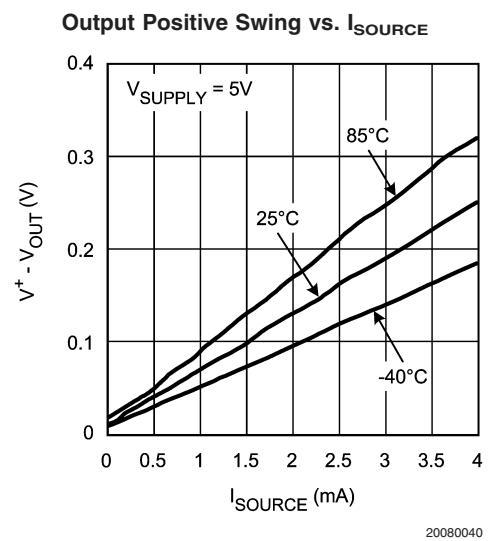
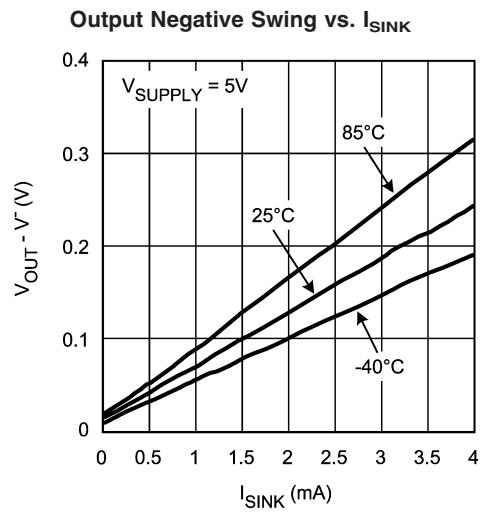
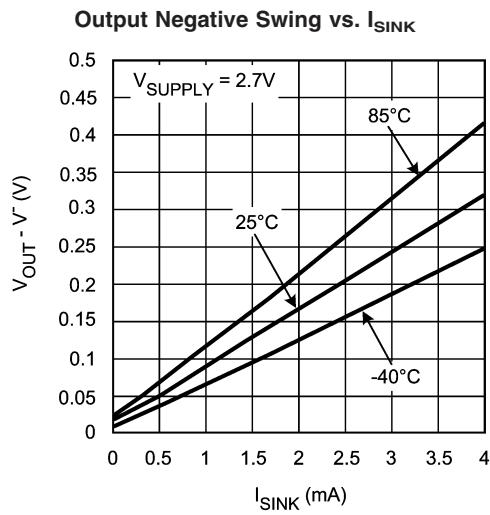


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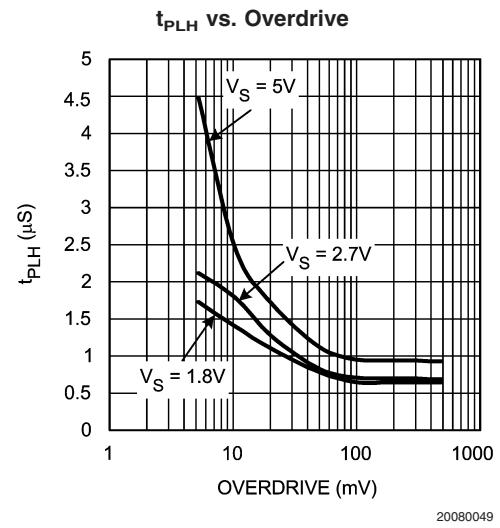
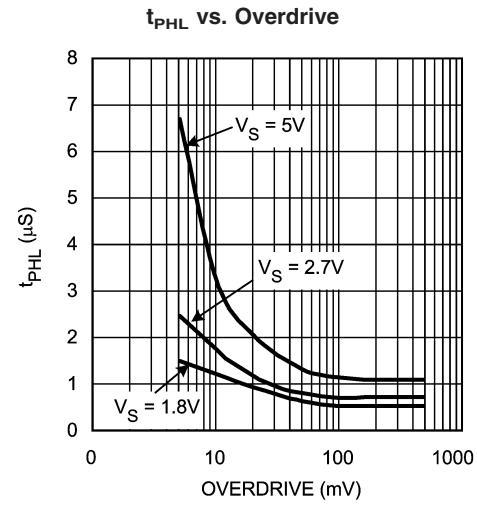
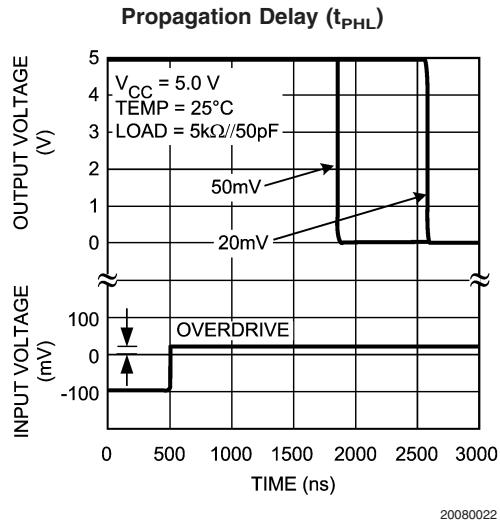
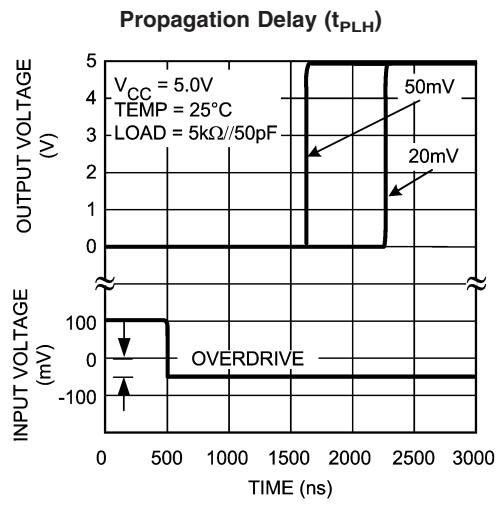
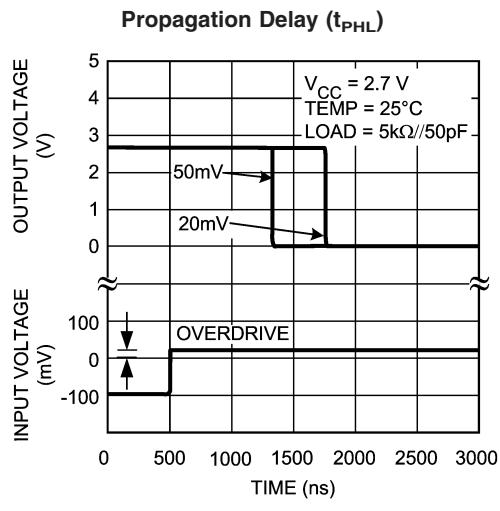
Output Positive Swing vs.  $I_{\text{SOURCE}}$



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Typical Performance Characteristics ( $T_A = 25^\circ\text{C}$ , Unless otherwise specified). (Continued)

## Typical Performance Characteristics ( $T_A = 25^\circ\text{C}$ , Unless otherwise specified). (Continued)



## Application Notes

### BASIC COMPARATOR

A comparator is often used to convert an analog signal to a digital signal. As shown in *Figure 2*, the comparator compares an input voltage ( $V_{IN}$ ) to a reference voltage ( $V_{REF}$ ). If

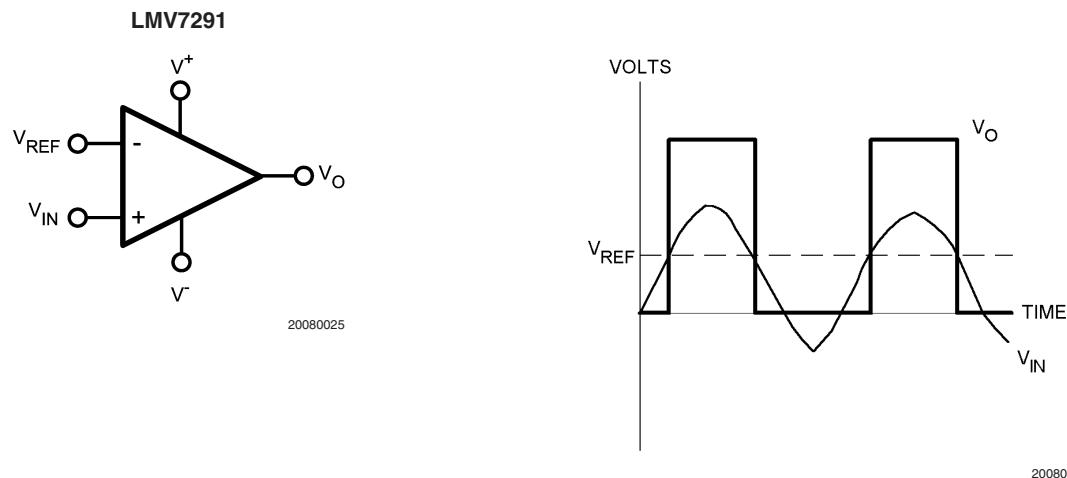


FIGURE 2. LVM7291 Basic Comparator

### RAIL-TO-RAIL INPUT STAGE

The LVM7291 has an input common mode voltage range ( $V_{CM}$ ) of  $-0.1V$  below the  $V^-$  to  $0.1V$  above  $V^+$ . This is achieved by using paralleled PNP and NPN differential input pairs. When the  $V_{CM}$  is near  $V^+$ , the NPN pair is on and the PNP pair is off. When the  $V_{CM}$  is near  $V^-$ , the NPN pair is off and the PNP pair is on. The crossover point between the NPN and PNP input stages is around  $950mV$  from  $V^+$ . Since each input stage has its own offset voltage ( $V_{OS}$ ), the  $V_{OS}$  of the comparator becomes a function of the  $V_{CM}$ . See curves for  $V_{OS}$  vs.  $V_{CM}$  in Typical Performance Characteristics section. In application design, it is recommended to keep the  $V_{CM}$  away from the crossover point to avoid problems. The wide input voltage range makes LVM7291 ideal in power supply monitoring circuits, where the comparators are used to sense signals close to gnd and power supplies.

### OUTPUT STAGE

The LVM7291 has a push-pull output stage. This output stage keeps the total system power consumption to the absolute minimum. The only current consumed is the low supply current and the current going directly into the load. When output switches, both PMOS and NMOS at the output stage are on at the same time for a very short time. This allows current to flow directly between  $V^+$  and  $V^-$  through output transistors. The result is a short spike of current (shoot-through current) drawn from the supply and glitches in the supply voltages. The glitches can spread to other parts of the board as noise. To prevent the glitches in supply lines, power supply bypass capacitors must be installed. See section for supply bypassing in the Application Notes for details.

$V_{IN}$  is less than  $V_{REF}$ , the output ( $V_O$ ) is low. However, if  $V_{IN}$  is greater than  $V_{REF}$ , the output voltage ( $V_O$ ) is high.

### HYSTERESIS

It is a standard procedure to use hysteresis (positive feedback) around a comparator, to prevent oscillation, and to avoid excessive noise on the output because the comparator is a good amplifier of its own noise.

#### 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 (*Figure 3*). When  $V_{IN}$  at the inverting input is less than  $V_A$ , the voltage at the non-inverting node of the comparator ( $V_{IN} < V_A$ ), the output voltage is high (for simplicity assume  $V_O$  switches as high as  $V_{CC}$ ). The three network resistors can be represented as  $R_1||R_3$  in series with  $R_2$ . The lower input trip voltage  $V_{A1}$  is defined as

$$V_{A1} = \frac{V_{CC} R_2}{(R_1||R_3) + R_2}$$

When  $V_{IN}$  is greater than  $V_A$  ( $V_{IN} > V_A$ ), the output voltage is low and 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

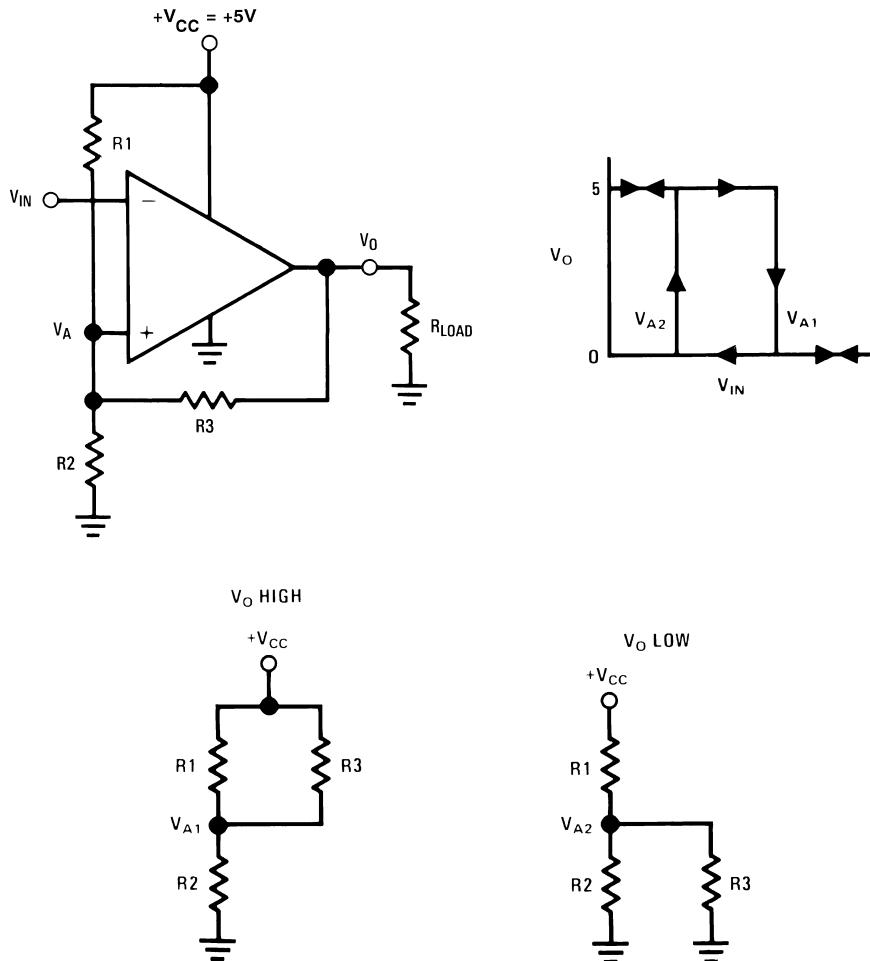
$$V_{A2} = \frac{V_{CC} (R_2||R_3)}{R_1 + (R_2||R_3)}$$

The total hysteresis provided by the network is defined as

$$\Delta V_A = V_{A1} - V_{A2}$$

A good typical value of  $\Delta V_A$  would be in the range of 5 to 50 mV. This is easily obtained by choosing  $R_3$  as 1000 to 100 times  $(R_1||R_2)$  for 5V operation, or as 300 to 30 times  $(R_1||R_2)$  for 1.8V operation.

## Application Notes (Continued)



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**FIGURE 3. Inverting Comparator with Hysteresis**

### Non-Inverting Comparator with Hysteresis

A non-inverting comparator with hysteresis requires a two resistor network, and a voltage reference ( $V_{REF}$ ) at the inverting input (Figure 4). 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  $V_{IN2}$ .

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

## Application Notes (Continued)

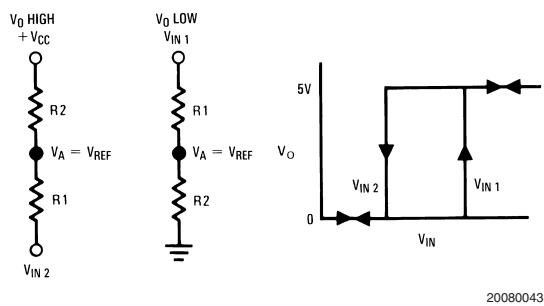
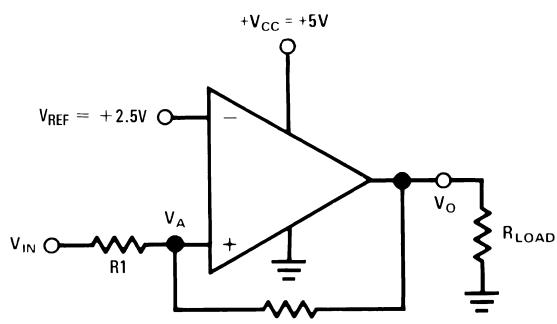


FIGURE 4. Non-Inverting Comparator with Hysteresis

### CIRCUIT TECHNIQUES FOR AVOIDING OSCILLATIONS IN COMPARATOR APPLICATIONS

Feedback to almost any pin of a comparator can result in oscillation. In addition, when the input signal is a slow voltage ramp or sine wave, the comparator may also burst into oscillation near the crossing point. To avoid oscillation or instability, PCB layout should be engineered thoughtfully. Several precautions are recommended:

1. Power supply bypassing is critical, and will improve stability and transient response. Resistance and inductance from power supply wires and board traces increase power supply line impedance. When supply current changes, the power supply line will move due to its impedance. Large enough supply line shift will cause the comparator to mis-operate. To avoid problems, a small bypass capacitor, such as 0.1uF ceramic, should be placed immediately adjacent to the supply pins. An additional 6.8μF or greater tantalum capacitor should be placed at the point where the power supply for the comparator is introduced onto the board. These capacitors act as an energy reservoir and keep the supply impedance low. In dual supply application, a 0.1μF capacitor is recommended to be placed across V<sup>+</sup> and V<sup>-</sup> pins.
2. Keep all leads short to reduce stray capacitance and lead inductance. It will also minimize any unwanted coupling from any high-level signals (such as the output). The comparators can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. This shows up only during the output voltage transition intervals as the comparator changes states. Try to avoid a long loop which could act as an inductor (coil).
3. It is a good practice to use an unbroken ground plane on a printed circuit board to provide all components with a

low inductive ground connection. Make sure ground paths are low-impedance where heavier currents are flowing to avoid ground level shift. Preferably there should be a ground plane under the component.

4. The output trace should be routed away from inputs. The ground plane should extend between the output and inputs to act as a guard.
5. When the signal source is applied through a resistive network to one input of the comparator, it is usually advantageous to connect the other input with a resistor with the same value, for both DC and AC consideration. Input traces should be laid out symmetrically if possible.
6. All pins of any unused comparators should be tied to the negative supply.

## Typical Applications

### POSITIVE PEAK DETECTOR

A positive peak detect circuit is basically a comparator operated in a unity gain follower configuration, with a capacitor as a load to maintain the highest voltage. A diode is added at the output to prevent the capacitor from discharging through the output, and a 1MΩ resistor added in parallel to the capacitor to provide a high impedance discharge path. When the input V<sub>IN</sub> increases, the inverting input of the comparator follows it, thus charging the capacitor. When it decreases, the cap discharges through the 1MΩ resistor. The decay time can be modified by changing the resistor. The output should be accessed through a follower circuit to prevent loading.

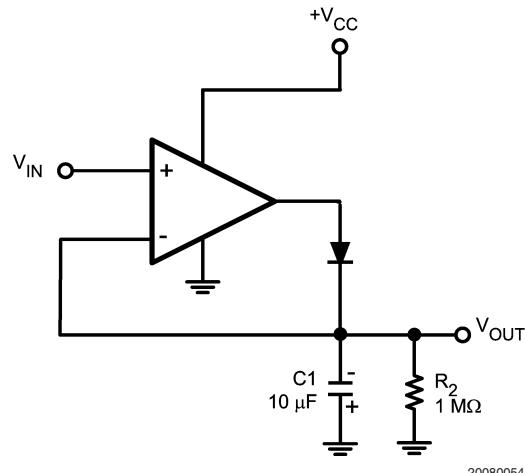


FIGURE 5. Positive Peak Detector

### NEGATIVE PEAK DETECTOR

For the negative detector, the output transistor of the comparator acts as a low impedance current sink. Since there is no pull-up resistor, the only discharge path will be the 1MΩ resistor and any load impedance used. Decay time is changed by varying the 1MΩ resistor.

## Typical Applications (Continued)

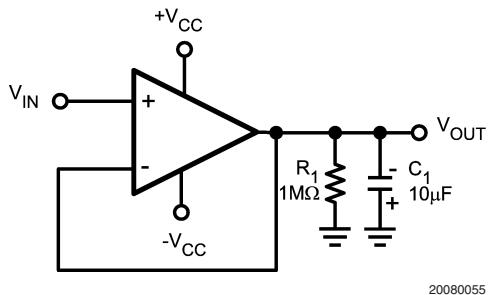


FIGURE 6. Negative Peak Detector

### SQUARE WAVE GENERATOR

A typical application for a comparator is as a square wave oscillator. The circuit below generates a square wave whose period is set by the RC time constant of the capacitor  $C_1$  and resistor  $R_4$ . The maximum frequency is limited by the large signal propagation delay of the comparator, and by the capacitive loading at the output, which limits the output slew rate.

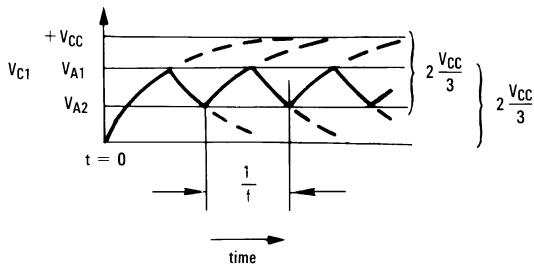
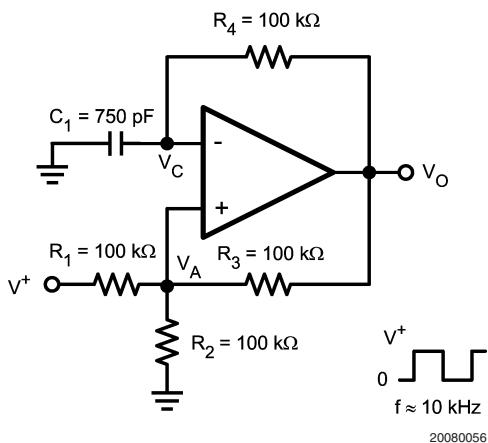


FIGURE 7. Squarewave Oscillator

To analyze the circuit, consider it when the output is high. That implies that the inverted input ( $V_C$ ) is lower than the non-inverting input ( $V_A$ ). This causes the  $C_1$  to get charged through  $R_4$ , and the voltage  $V_C$  increases till it is equal to the non-inverting input. The value of  $V_A$  at this point is

$$V_{A1} = \frac{V_{CC} \cdot R_2}{R_2 + R_1 \parallel R_3}$$

If  $R_1 = R_2 = R_3$  then  $V_{A1} = 2V_{CC}/3$

At this point the comparator switches pulling down the output to the negative rail. The value of  $V_A$  at this point is

$$V_{A2} = \frac{V_{CC} (R_2 \parallel R_3)}{R_1 + (R_2 \parallel R_3)}$$

If  $R_1 = R_2 = R_3$  then  $V_{A2} = V_{CC}/3$

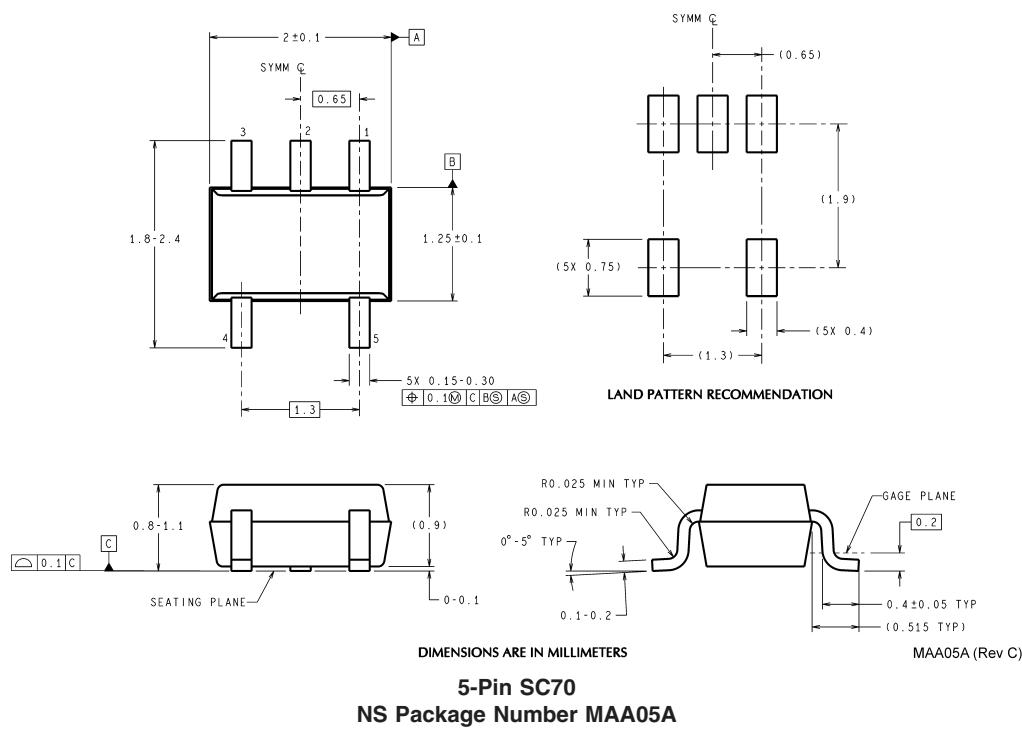
The capacitor  $C_1$  now discharges through  $R_4$ , and the voltage  $V_C$  decreases till it is equal to  $V_{A2}$ , at which point the comparator switches again, bringing it back to the initial stage. The time period is equal to twice the time it takes to discharge  $C_1$  from  $2V_{CC}/3$  to  $V_{CC}/3$ , which is given by  $R_4 C_1 \ln 2$ . Hence the formula for the frequency is:

$$F = 1/(2 \cdot R_4 \cdot C_1 \cdot \ln 2)$$

# LMV7291 Single 1.8V Low Power Comparator with Rail-to-Rail Input

## Physical Dimensions inches (millimeters)

unless otherwise noted



5-Pin SC70  
NS Package Number MAA05A

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