45ns, Ultra Low Power, Low Voltage, Rail-to-Rail Input Comparator with Open-Drain/Push-Pull Output

General Description

The HT7235/39 are ultra low power, low voltage, 45ns comparators. They are guaranteed to operate over the full supply voltage range of 2.7V to 5V. These devices achieve a 45ns propagation delay while consuming only 65µA of supply current at 5V.

The HT7235/39 have a greater than rail-to-rail common mode voltage range. The input common mode voltage range extends 200mV below ground and 200mV above supply, allowing both ground and supply sensing.

The HT7235 features an open drain output. By connecting an external resistor, the output of the comparator can be used as a level shifter.

The HT7239 features a push-pull output stage. This feature allows operation without the need of an external pull-up resistor.

The HT7235/39 are available in the SC70-5 and SOT23-5 packages, which are ideal for systems where small size and low power is critical.

Features

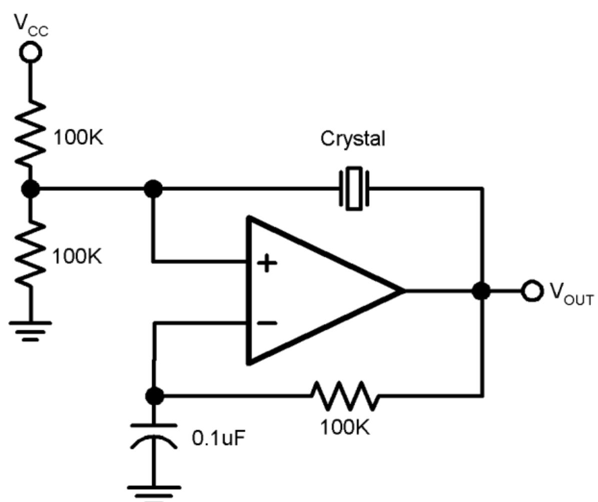
(V_S = 5V, T_A = 25˚C, Typical values unless otherwise specified)

- Propagation delay 45ns
- Low supply current 65µA
- Rail-to-Rail input
- Open drain and push-pull output
- Ideal for 2.7V and 5V single supply applications
- Available in space saving packages: 5-pin SOT23-5 and 5-pin SC70-5

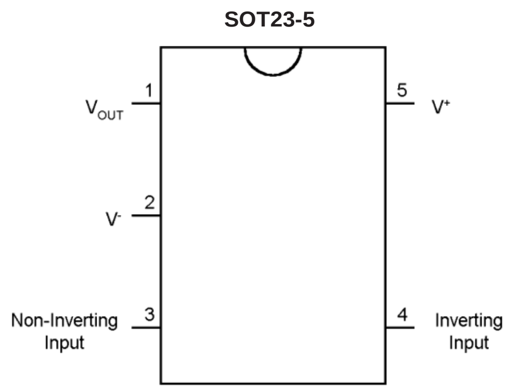
Applications

- Portable and battery powered systems
- Scanners
- Set top boxes
- High speed differential line receiver
- Window comparators
- Zero-crossing detectors
- High speed sampling circuits

Typical Application

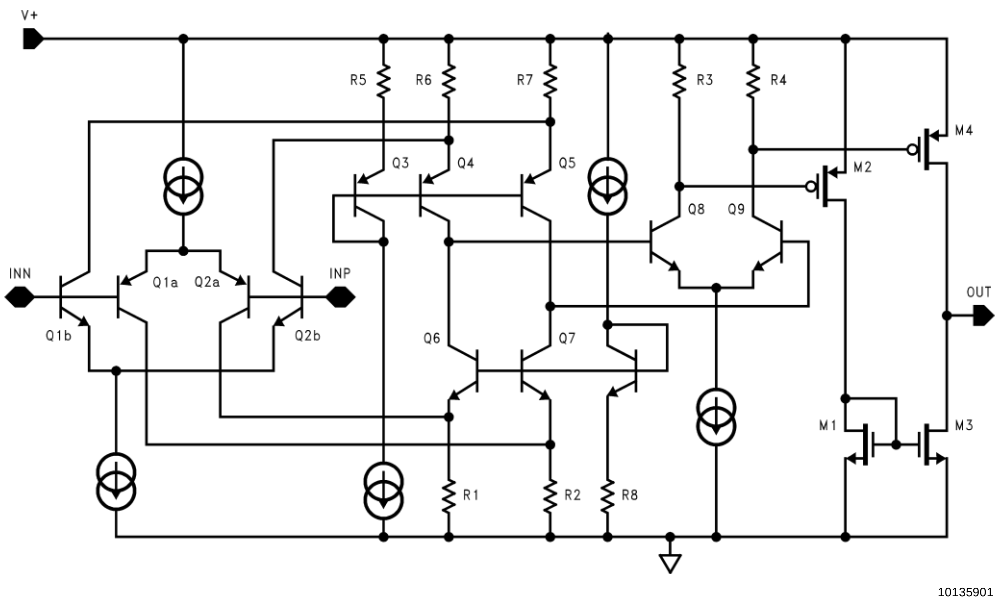


Connection Diagram



Top View

Simplified Schematic



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)	
Machine Body	100V
Human Model Body	1000V
Differential Input Voltage	± Supply Voltage
Output Short Circuit Duration	(Note 3)
Supply Voltage (V^+ - V^-)	5.5V
Soldering Information	
Infrared or Convection (20 sec)	235˚C
Wave Soldering (10 sec)	260˚C (lead temp)
Voltage at Input/Output Pins	(V^+) +0.3V (V^-) −0.3V
Current at Input Pin (Note 9)	±10mA

Operating Ratings

Supply Voltages (V^+ - V^-)	2.7V to 5V
Junction Temperature Range (Note 4)	−40˚C to +85˚C
Storage Temperature Range	−65˚C to +150˚C
Package Thermal Resistance	
SC70-5	478˚C/W
SOT23-5	265˚C/W

2.7V Electrical Characteristics

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

Symbol	Parameter	Conditions	Typ (Note 5)	Limits (Note 6)	Units
V_{OS}	Input Offset Voltage		0.8	6 **8**	mV max
I_B	Input Bias Current		30	400 **600**	nA max
I_{OS}	Input Offset Current		5	200 **400**	nA max
CMRR	Common Mode Rejection Ratio	0V < V_{CM} < 2.7V (Note 7)	62	52	dB min
PSRR	Power Supply Rejection Ratio	V^+ = 2.7V to 5V	85	65	dB min
V_{CM}	Input Common-Mode Voltage Range	CMRR > 50dB	V^+ +0.2	V^+ +0.1 **V^+**	V min
			−0.2	−0.1 **0**	V max
V_O	Output Swing High (HT7239 only)	I_L = 4mA, V_{ID} = 500mV	V^+ −0.26	V^+ −0.35	V min
		I_L = 0.4mA, V_{ID} = 500mV	V^+ −0.02		V min
	Output Swing Low (HT7239/HT7235)	I_L = −4mA, V_{ID} = −500mV	230	350 **450**	mV max
		I_L = −0.4mA, V_{ID} = −500mV	15		mV max
I_{SC}	Output Short Circuit Current	Sourcing, V_O = 0V (HT7239 only) (Note 3)	15		mA
		Sinking, V_O = 2.7V (HT7235 R_L = 10k) (Note 3)	20		mA
I_S	Supply Current	No load	52	85 **100**	μA max

2.7V Electrical Characteristics (Continued)

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

Symbol	Parameter	Conditions	Typ (Note 5)	Limits (Note 6)	Units
t_{PD}	Propagation Delay	Overdrive = 20mV (Note 10)	68		ns
		Overdrive = 50mV (Note 10)	63		ns
		Overdrive = 100mV (Note 10)	50		ns
t_{SKEW}	Propagation Delay Skew (HT7239 only)	(Note 8)	5		ns
t_r	Output Rise Time	HT7239 10% to 90%	1.7		ns
		HT7235 10% to 90% (Note 10)	112		ns
t_f	Output Fall Time	90% to 10%	1.7		ns
$I_{LEAKAGE}$	Output Leakage Current (HT7235 only)		3		nA

5V Electrical Characteristics

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

Symbol	Parameter	Conditions	Typ (Note 5)	Limits (Note 6)	Units
V_{OS}	Input Offset Voltage		1	6 **8**	mV ma
I_B	Input Bias Current		30	400 **600**	nA ma
I_{OS}	Input Offset Current		5	200 **400**	nA ma
CMRR	Common Mode Rejection Ratio	$0V < V_{CM} < 5V$	67	52	dB min
PSRR	Power Supply Rejection Ratio	$V^+ = 2.7V$ to $5V$	85	65	dB min
V_{CM}	Input Common-Mode Voltage Range	CMRR > 50dB	$V^+ +0.2$	$V^+ +0.1$ $\mathbf{V^+}$	V min
			−0.2	−0.1 **0**	V max
V_O	Output Swing High (HT7239 only)	$I_L = 4mA$, $V_{ID} = 500mV$	$V^+ -0.15$	$V^+ -0.25$	V min
		$I_L = 0.4mA$, $V_{ID} = 500mV$	$V^+ -0.01$		V min
	Output Swing Low (HT7239/HT7235)	$I_L = -4mA$, $V_{ID} = -500mV$	230	350 **450**	mV ma
		$I_L = -0.4mA$, $V_{ID} = -500mV$	10		mV ma

5V Electrical Characteristics (Continued)

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

Symbol	Parameter	Conditions	Typ (Note 5)	Limits (Note 6)	Units
I_{SC}	Output Short Circuit Current	Sourcing, $V_O = 0V$ (HT7239 only) (Note 3)	55	25 **15**	mA min
		Sinking, $V_O = 5V$ (HT7235 R_L = 10k) (Note 3)	60	30 **20**	mA min
I_S	Supply Current	No load	65	95 **110**	µA max
t_{PD}	Propagation Delay	Overdrive = 20mV (Note 10)	62		ns max
		Overdrive = 50mV (Note 10)	57		ns max
		Overdrive = 100mV (Note 10)	45		ns max
t_{SKEW}	Propagation Delay Skew (HT7239 only)	(Note 8)	5		ns
t_r	Output Rise Time	HT7239 10% to 90%	1.2		ns
		HT7235 10% to 90% (Note 10)	100		ns
t_f	Output Fall Time	90% to 10%	1.2		ns
$I_{LEAKAGE}$	Output Leakeage Current (HT7235 only)		3		nA

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, 1.5kΩ in series with 100pF. Machine model, 200pF.

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 ±30mA over long term 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: CMRR is not linear over the common mode range. Limits are guaranteed over the worst case from 0 to $V_{CC/2}$ or $V_{CC/2}$ to V_{CC}.

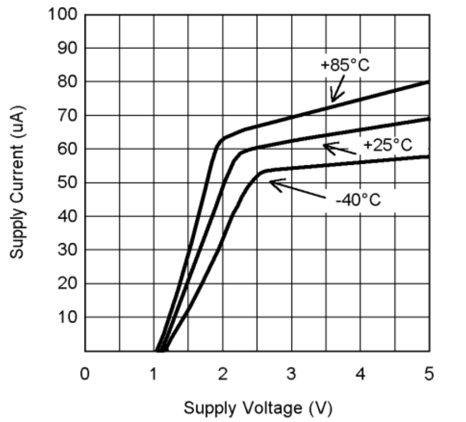
Note 8: Propagation Delay Skew is defined as the absolute value of the difference between t_{PDLH} and t_{PDHL}.

Note 9: Limiting input pin current is only necessary for input voltages that exceed absolute maximum input voltage ratings.

Note 10: A 10k pull-up resistor was used when measuring the HT7235. The rise time of the HT7235 is a function of the R-C time constant.

Typical Performance Characteristics (Unless otherwise specified, V_S = 5V, C_L = 10pF, T_A = 25˚C).

Supply Current vs. Supply Voltage



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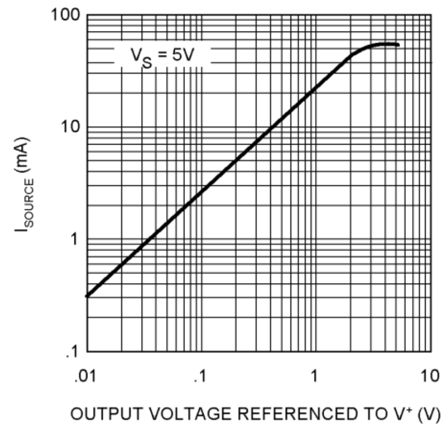
Sourcing Current vs. Output Voltage



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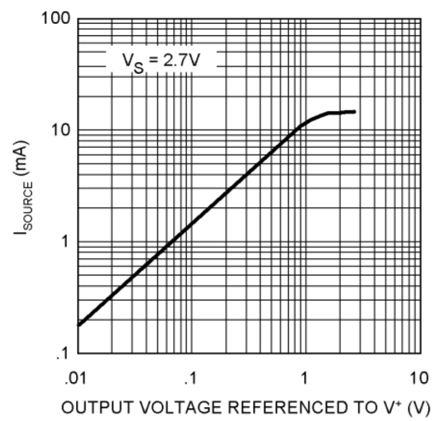
Sourcing Current vs. Output Voltage



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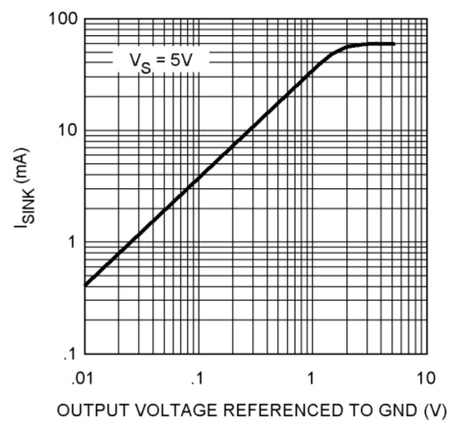
Sinking Current vs. Output Voltage



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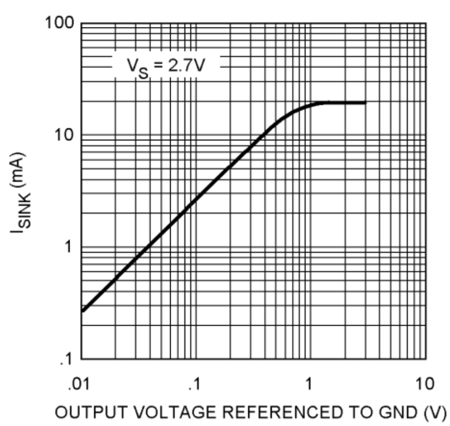
Sinking Current vs. Output Voltage



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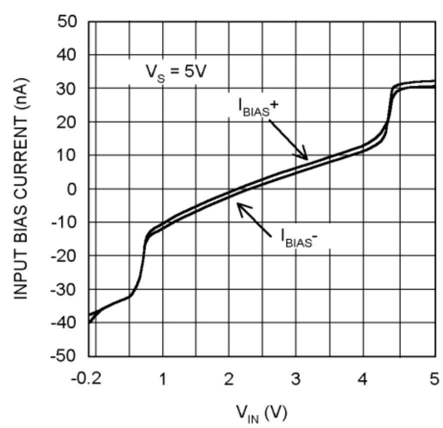
Input Bias Current vs. Input Voltage



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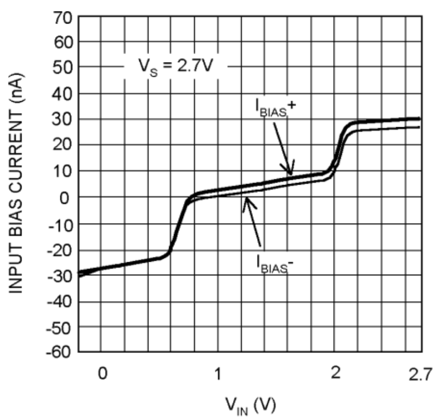
Typical Performance Characteristics (Unless otherwise specified, V_S = 5V, C_L = 10pF, T_A = 25˚C). (Continued)

Input Bias Current vs. Input Voltage



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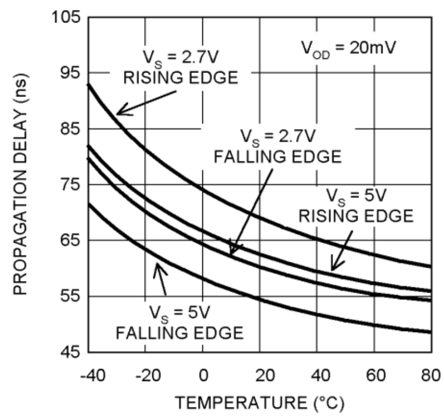
Propagation Delay vs. Temperature



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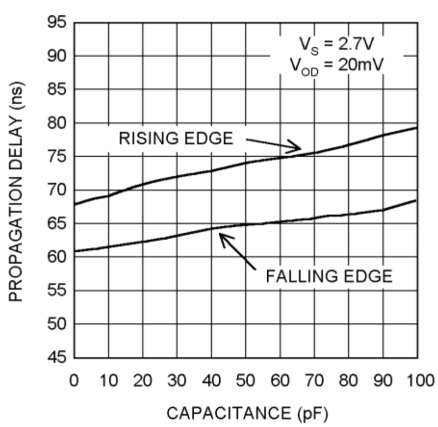
Propagation Delay vs. Capacitive Load



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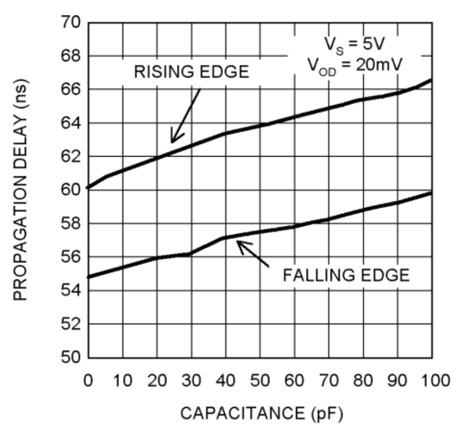
Propagation Delay vs. Capacitive Load



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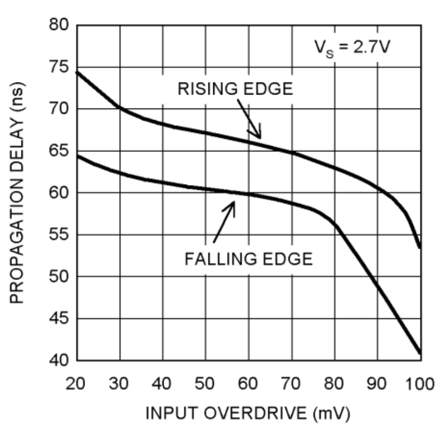
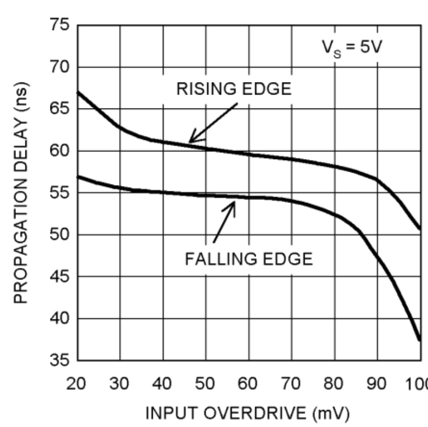
Propagation Delay vs. Input Overdrive

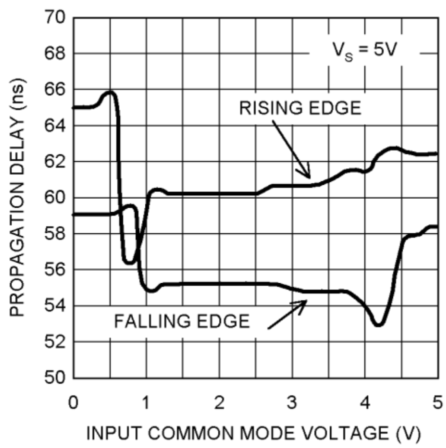


Propagation Delay vs. Input Overdrive



Typical Performance Characteristics (Unless otherwise specified, V_S = 5V, C_L = 10pF, T_A = 25˚C). (Continued)

Propagation Delay vs. Common Mode Voltage



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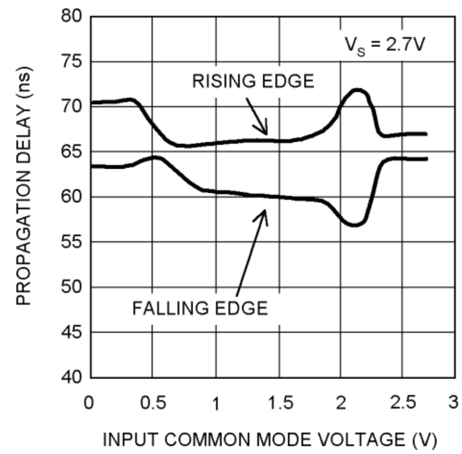
Propagation Delay vs. Common Mode Voltage



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Application Section

The HT7235/HT7239 are single supply comparators with 45ns of propagation delay and only 65µA of supply current.

The HT7235/HT7239 are rail-to-rail input and output. The typical input common mode voltage range of −0.2V below the ground to 0.2V above the supply. The HT7235/39 use a complimentary PNP and NPN input stage in which the PNP stage senses common mode voltage near V^- and the NPN stage senses common mode voltage near V^+. If either of the input signals falls below the negative common mode limit, the parasitic PN junction formed by the substrate and the base of the PNP will turn on resulting in an increase of input bias current.

If one of the input goes above the positive common mode limit, the output will still maintain the correct logic level as long as the other input stays within the common mode range. However, the propagation delay will increase. When both inputs are outside the common mode voltage range, current saturation occurs in the input stage, and the output becomes unpredictable.

The propagation delay does not increase significantly with large differential input voltages. However, large differential voltages greater than the supply voltage should be avoided to prevent damage to the input stage.

The HT7239 has a push-pull output. When the output switches, there is a direct path between V_{CC} and ground, causing high output sinking or sourcing current during the transition. After the transition, the output current decreases and the supply current settles back to about 65µA at 5V, thus conserving power consumption.

The HT7235 has an open drain that requires a pull-up resistor to a positive supply voltage for the output to switch properly. When the internal output transistor is off, the output voltage will be pulled up to the external positive voltage.

Comparator with Hysteresis

The basic comparator configuration may oscillate or produce a noisy output if the applied differential input voltage is near the comparator's offset voltage. This usually happens when the input signal is moving very slowly across the comparator's switching threshold. This problem can be prevented by the addition of hysteresis or positive feedback.

Inverting Comparator with Hysteresis

The inverting comparator with hysteresis requires a three resistor network that is referenced to the supply voltage V_{CC} of the comparator. 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 R1//R3 in series with R2. The lower input trip voltage V_{A1} is defined as

$$V_{A1} = V_{CC}R2 / ((R1//R3) + R2)$$

When V_{IN} is greater than V_A ($V_{IN} > V_A$), the output voltage is low, very close to ground. In this case the three network resistors can be presented as R2//R3 in series with R1. The upper trip voltage V_{A2} is defined as

$$V_{A2} = V_{CC} (R2//R3) / ((R1+(R2//R3)$$

The total hysteresis provided by the network is defined as

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

To assure that the comparator will always switch fully to V_{CC} and not be pulled down by the load the resistors, values should be chosen as follow:

$$R_{PULL\text{-}UP} << R_{LOAD}$$

Application Section (Continued)

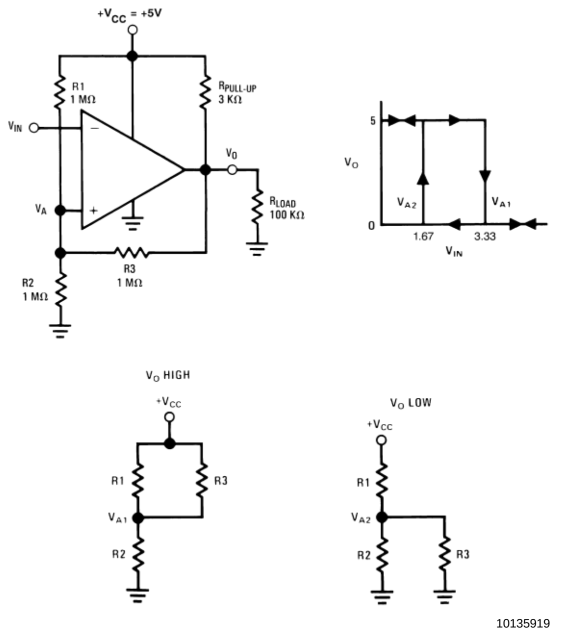


FIGURE 1.

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. 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.

$$V_{IN1} = R1*(V_{REF}/R2) + V_{REF}$$

When V_{IN} is high, the output is also high, to make the comparator switch back to it's low state, V_{IN} must equal V_{REF} before V_A will again equal V_{REF}. V_{IN} can be calculated by

$$V_{IN2} = (V_{REF}\ (R1+ R2) - V_{CC}R1)/R2$$

The hysteresis of this circuit is the difference between V_{IN1} and V_{IN2}.

Delta $V_{IN} = V_{CC}R1/R2$

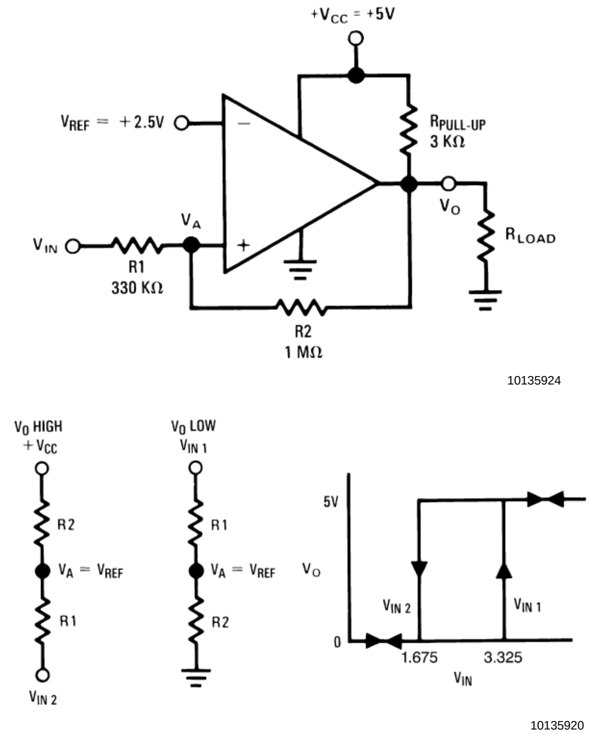


FIGURE 2. Non-Inverting Comparator with Hysteresis

Circuit Layout and Bypassing

The HT7235/39 require high speed layout. Follow these layout guidelines:

1. Use printed circuit board with a good, unbroken low-inductance ground plane.
2. Place a decoupling capacitor (0.1µF ceramic surface mount capacitor) as close as possible to V_{CC} pin.
3. On the inputs and the output, keep lead lengths as short as possible to avoid unwanted parasitic feedback around the comparator. Keep inputs away from output.
4. Solder the device directly to the printed circuit board rather than using a socket.
5. For slow moving input signals, take care to prevent parasitic feedback. A small capacitor (1000pF or less) placed between the inputs can help eliminate oscillations in the transition region. This capacitor causes some degradation to t_{PD} when the source impedance is low.
6. The topside ground plane runs between the output and inputs.
7. Ground trace from the ground pin runs under the device up to the bypass capacitor, shielding the inputs from the outputs.

Application Section (Continued)

Zero-Crossing Detector

The inverting input is connected to ground and the non-inverting input is connected to 100mVp-p signal. As the signal at the non-inverting input crosses 0V, the comparator's output changes state.

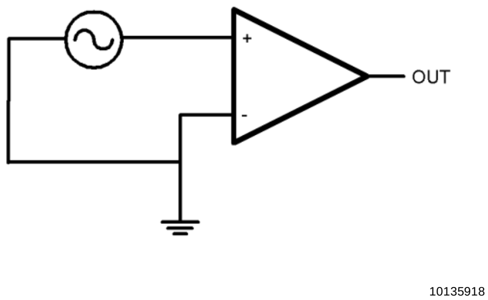


FIGURE 3. Zero-Crossing Detector

Threshold Detector

Instead of tying the inverting input to 0V, the inverting input can be tied to a reference voltage. The non-inverting input is connected to the input. As the input passes the V_{REF} threshold, the comparator's output changes state.

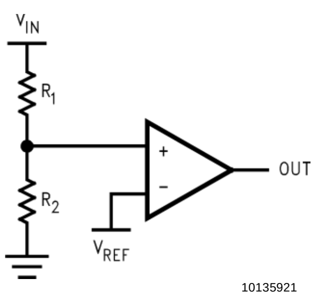


FIGURE 4. Threshold Detector

Crystal Oscillator

A simple crystal oscillator using the HT7239 is shown below. Resistors R1 and R2 set the bias point at the comparator's non-inverting input. Resistors R3, R4 and C1 sets the inverting input node at an appropriate DC average level based on the output. The crystal's path provides resonant positive feedback and stable oscillation occurs. The output duty cycle for this circuit is roughly 50%, but it is affected by resistor tolerances and to a lesser extent by the comparator offset.

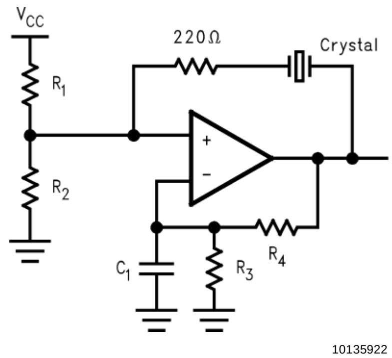


FIGURE 5. Crystal Oscillator

IR Receiver

The HT7239 is an ideal candidate to be used as an infrared receiver. The infrared photo diode creates a current relative to the amount of infrared light present. The current creates a voltage across R_D. When this voltage level cross the voltage applied by the voltage divider to the inverting input, the output transitions.

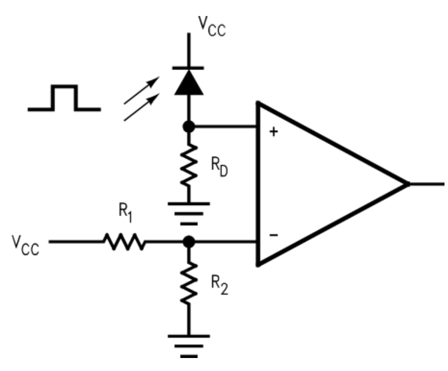
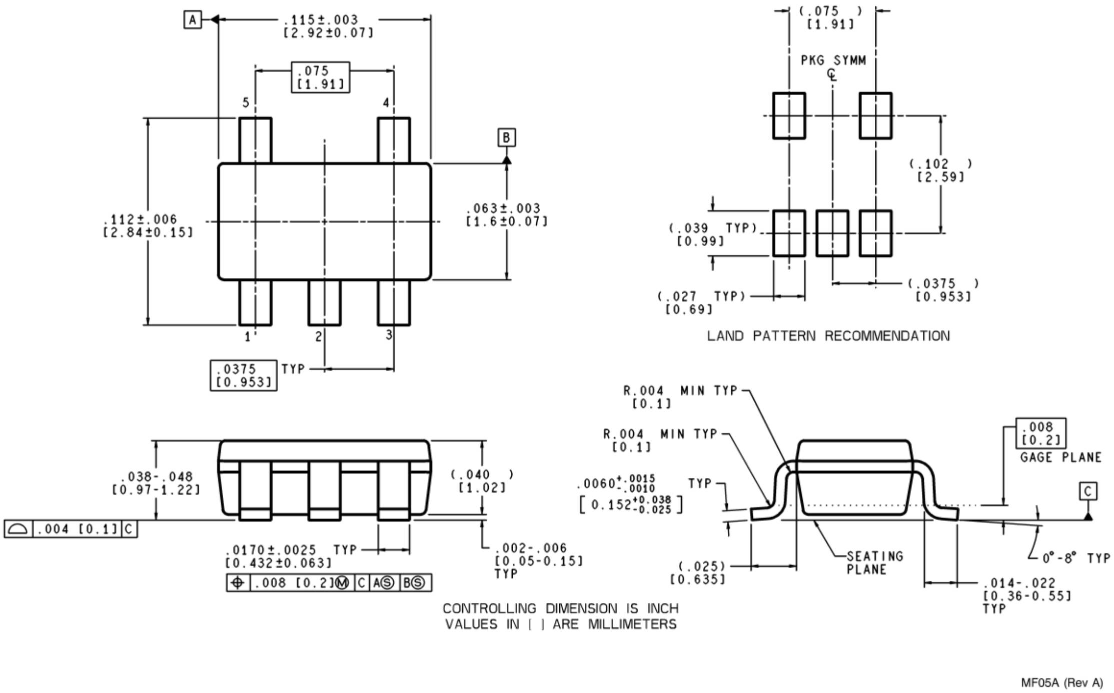


FIGURE 6. IR Receiver

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



5-Pin SOT23-5
NS Package Number MF05A