SM72375 SolarMagic Dual Micropower Rail-To-Rail Input CMOS Comparator with Open Drain Output

Check for Samples: SM72375

FEATURES

- **Renewable Energy Grade (Typical Unless Otherwise Noted)**
- **Low Power Consumption (Max): I_S = 10 µA/comp**
- **Wide Range of Supply Voltages: 2.7V to 15V**
- **Rail-to-Rail Input Common Mode Voltage Range**
- **Open Drain Output**
- **Short Circuit Protection: 40 mA**
- **Propagation Delay (@V_S = 5V, 100 mV Overdrive): 5 µs**
- **−40°C to 125°C Temperature Range**

APPLICATIONS

- **Metering Systems**
- **RC Timers**
- **Alarm and Monitoring Circuits**
- **Window Comparators, Multivibrators**

DESCRIPTION

The SM72375 is an ultra low power dual comparator with a maximum 10 µA/comparator power supply current. It is designed to operate over a wide range of supply voltages, with a minimum supply voltage of 2.7V.

The common mode voltage range of the SM72375 exceeds both the positive and negative supply rails, a significant advantage in single supply applications. The open drain output of the SM72375 allows for wired-OR configurations. The open drain output also offers the advantage of allowing the output to be pulled to any voltage rail up to 15V, regardless of the supply voltage of the SM72375.

The SM72375 is targeted for systems where low power consumption is the critical parameter. Guaranteed operation at supply voltages of 2.7V and rail-to-rail performance makes this comparator ideal for battery-powered applications.

Connection Diagram

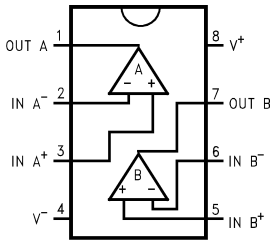

Figure 1. 8-Pin VSSOP - Top View
Package Number DGK

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

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Absolute Maximum Ratings[1][2]

ESD Tolerance[3]	1.5 kV
Differential Input Voltage	(V^+)+0.3V to (V^-)−0.3V
Voltage at Input/Output Pin	(V^+)+0.3V to (V^-)−0.3V
Supply Voltage (V^+–V^-)	16V
Current at Input Pin[4]	±5 mA
Current at Output Pin[5][6]	±30 mA
Current at Power Supply Pin, SM72375	40 mA
Lead Temperature (Soldering, 10 seconds)	260°C
Storage Temperature Range	−65°C to +150°C
Junction Temperature[7]	150°C

(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.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
(3) Human body model, 1.5 kΩ in series with 100 pF. The output pins of the two comparators (pin 1 and pin 7) have an ESD tolerance of 1.5 kV. All other pins have an ESD tolerance of 2 kV.
(4) Limiting input pin current is only necessary for input voltages that exceed absolute maximum input voltage ratings.
(5) 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 over long term may adversely affect reliability.
(6) Do not short circuit output to V^+, when V+ is > 12V or reliability will be adversely affected.
(7) 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.

Operating Ratings[1]

Supply Voltage		$2.7 \le V_S \le 15V$
Temperature Range		$– 40°C \le T_A \le +125°C$
Thermal Resistance (θ_{JA})	8-Pin VSSOP	172°C/W

(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.

2.7V Electrical Characteristics

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

Symbol	Parameter	Conditions	Min[1]	Typ[2]	Max[1]	Units
V_{OS}	Input Offset Voltage			3	10 **13**	mV
TCV_{OS}	Input Offset Voltage Temperature Drift			2.0		µV/Month
	Input Offset Voltage Average Drift	See[3]		3.3		
I_B	Input Current			0.02		pA
I_{OS}	Input Offset Current			0.01		pA
CMRR	Common Mode Rejection Ratio			75		dB
PSRR	Power Supply Rejection Ratio	±1.35V < V_S < ±7.5V		80		dB
A_V	Voltage Gain	(By Design)		100		dB
V_{CM}	Input Common-Mode Voltage Range	CMRR > 55 dB	2.9 **2.7**	3.0		V
				−0.3	−0.2 **0.0**	

(1) All limits are guaranteed by testing or statistical analysis.
(2) Typical Values represent the most likely parametric norm.
(3) Input offset voltage Average Drift is calculated by dividing the accelerated operating life drift average by the equivalent operational time. The input offset voltage average drift represents the input offset voltage change at worst-case input conditions.

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2.7V Electrical Characteristics (continued)

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

Symbol	Parameter	Conditions	Min(1)	Typ(2)	Max(1)	Units
V_{OL}	Output Voltage Low	I_{LOAD} = 2.5 mA		0.2	0.3 **0.45**	V
I_S	Supply Current	For Both Comparators		12	20 **25**	µA
$I_{Leakage}$	Output Leakage Current	V_{IN}(+) = 0.5V, V_{IN}(−) = 0V, V_O = 15V	500	0.1		nA

5.0V and 15.0V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_A = 25°C, V^+ = 5.0V and 15.0V, V^- = 0V, V_{CM} = V^+/2. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min(1)	Typ(2)	Max(1)	Units
V_{OS}	Input Offset Voltage			3	10 **13**	mV
TCV_{OS}	Input Offset Voltage Temperature Drift	V^+ = 5V		2.0		µV/°C
		V^+ = 15V		0.4		
	Input Offset Voltage Average Drift	V^+ = 5V(3)		3.3		µV/Month
		V^+ = 15V(3)		4.0		
I_B	Input Current	V = 5V		0.04		pA
I_{OS}	Input Offset Current	V^+ = 5V		0.02		pA
CMRR	Common Mode Rejection Ratio	V^+ = 5V		75		dB
		V^+ = 15V		82		dB
PSRR	Power Supply Rejection Ratio	±2.5V < V_S < ±5V		80		dB
A_V	Voltage Gain	(By Design)		100		dB
V_{CM}	Input Common-Mode Voltage Range	V^+ = 5.0V CMRR > 55 dB	5.2 **5.0**	5.3		V
				−0.3	−0.2 **0.0**	
		V^+ = 15.0V CMRR > 55 dB	15.2 **15.0**	15.3		
				−0.3	−0.2 **0.0**	
V_{OL}	Output Voltage Low	V^+ = 5V I_{LOAD} = 5 mA		0.2	0.4 **0.55**	V
		V^+ = 15V I_{LOAD} = 5 mA		02	0.4 **0.55**	
I_S	Supply Current	For Both Comparators (Output Low)		12	20 **25**	µA
I_{SC}	Short Circuit Current	V^+ = 15V, Sinking, V_O = 12V(4)	45			mA

(1) All limits are guaranteed by testing or statistical analysis.
(2) Typical Values represent the most likely parametric norm.
(3) Input offset voltage Average Drift is calculated by dividing the accelerated operating life drift average by the equivalent operational time. The input offset voltage average drift represents the input offset voltage change at worst-case input conditions.
(4) Do not short circuit output to V^+, when V+ is > 12V or reliability will be adversely affected.

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AC Electrical Characteristics

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

Symbol	Parameter	Conditions		Min (1)	Typ (2)	Max (1)	Units
t_{RISE}	Rise Time	f = 10 kHz, C_L = 50 pF, Overdrive = 10 mV (3)			0.3		µs
t_{FALL}	Fall Time	f = 10 kHz, C_L = 50 pF, (3)			0.3		µs
t_{PHL}	Propagation Delay (High to Low)	f = 10 kHz, C_L = 50 pF (3)	10 mV		10		µs
			100 mV		4		
		V^+ = 2.7V, f = 10 kHz, C_L = 50 pF (3)	10 mV		10		µs
			100 mV		4		
t_{PLH}	Propagation Delay (Low to High)	f = 10 kHz, C_L = 50 pF (3)	10 mV		10		µs
			100 mV		4		
		V^+ = 2.7V, f = 10 kHz, C_L = 50 pF (3)	10 mV		8		µs
			100 mV		4		

(1) All limits are guaranteed by testing or statistical analysis.
(2) Typical Values represent the most likely parametric norm.
(3) C_L inlcudes the probe and jig capacitance. The rise time, fall time and propagation delays are measured with a 2V input step.

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Typical Performance Characteristics

V^+ = 5V, Single Supply, T_A = 25°C unless otherwise specified

Input Current vs. Common-Mode Voltage

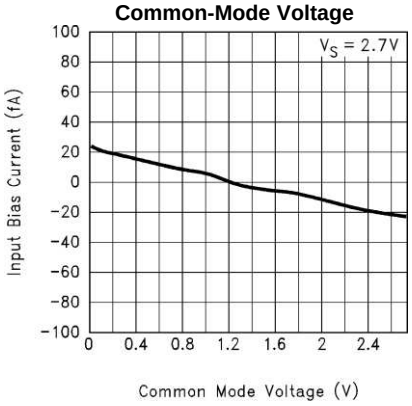

Figure 2.

Input Current vs. Common-Mode Voltage

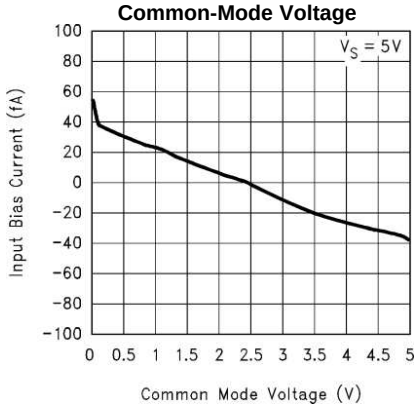

Figure 3.

Input Current vs. Common-Mode Voltage

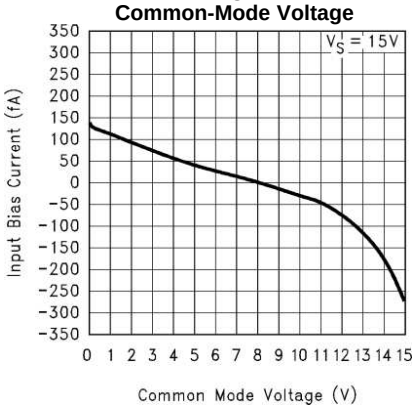

Figure 4.

Input Current vs. Temperature

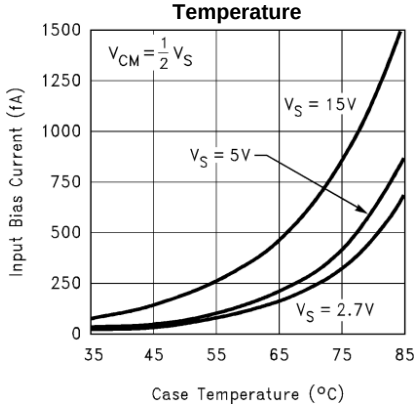

Figure 5.

ΔV_{OS} vs ΔV_{CM}, V_S = 2.7V

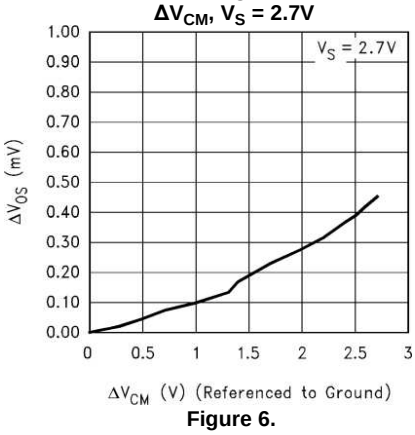

Figure 6.

ΔV_{OS} vs ΔV_{CM}, V_S = 5V

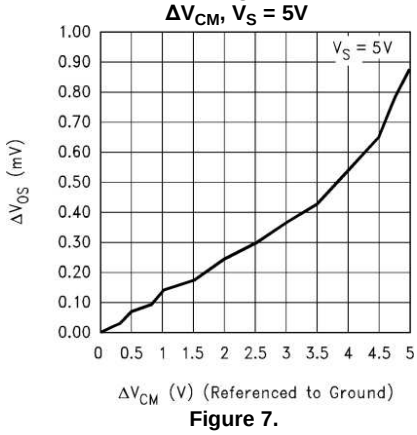

Figure 7.

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Typical Performance Characteristics (continued)

V^+ = 5V, Single Supply, T_A = 25°C unless otherwise specified

ΔV_{OS} vs ΔV_{CM}, V_S = 15V

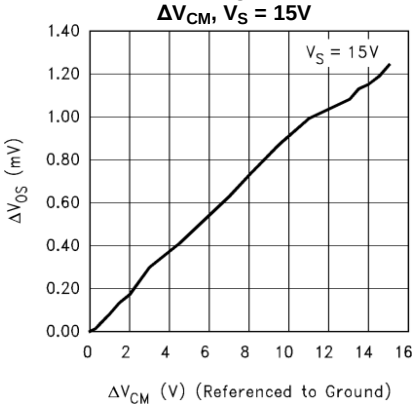

Figure 8.

Response Time for Overdrive (t_{PLH})

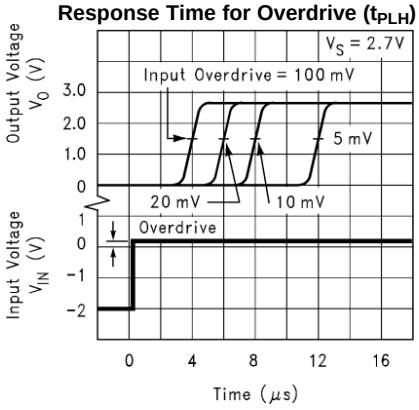

Figure 9.

Response Time for Overdrive (t_{PHL})

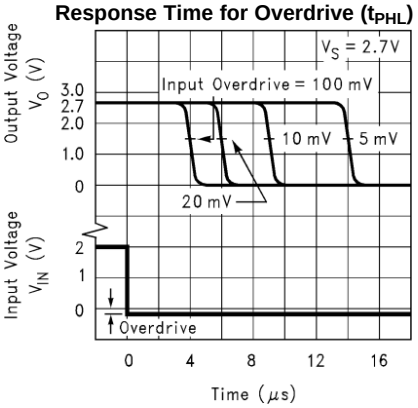

Figure 10.

Response Time for Overdrive (t_{PLH})

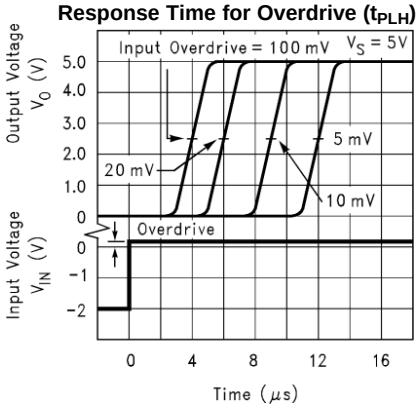

Figure 11.

Response Time for Overdrive (t_{PHL})

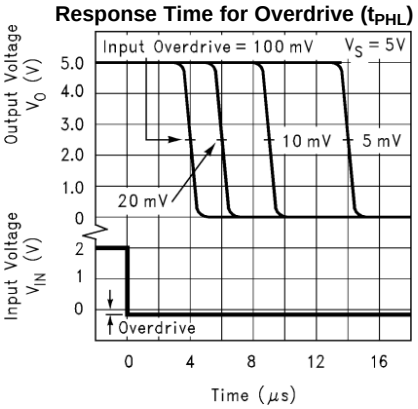

Figure 12.

Response Time for Overdrive (t_{PLH})

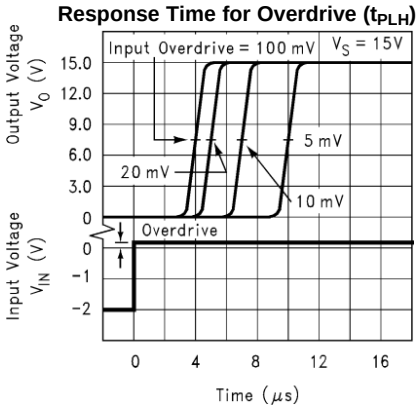

Figure 13.

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Typical Performance Characteristics (continued)

V^+ = 5V, Single Supply, T_A = 25°C unless otherwise specified

Response Time for Overdrive (t_{PHL})

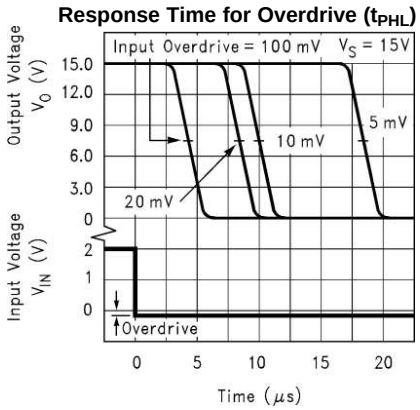

Figure 14.

Response Time vs. Capacitive Load

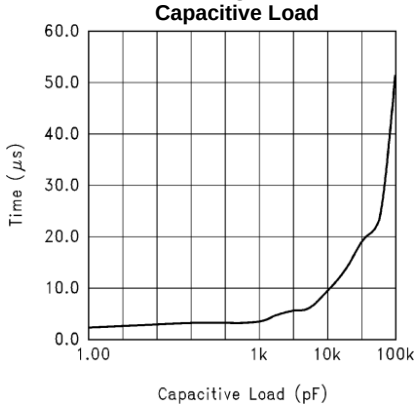

Figure 15.

Supply Current vs. Supply Voltage (Output High)

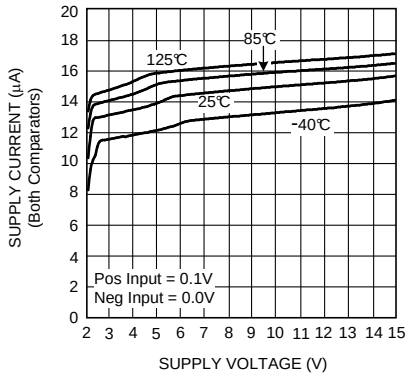

Figure 16.

Supply Current vs. Supply Voltage (Output Low)

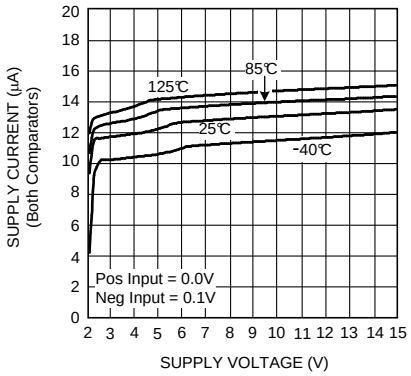

Figure 17.

Output Voltage vs. Output Current (Sinking)

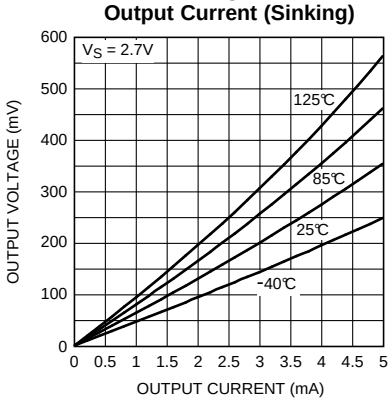

Figure 18.

Output Voltage vs. Output Current (Sinking)

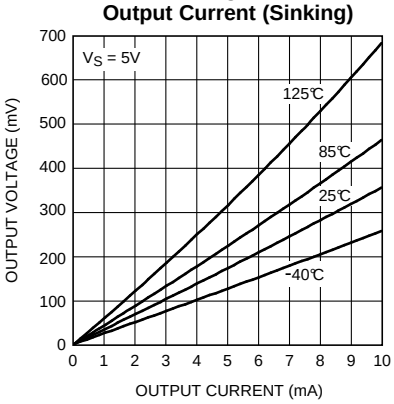

Figure 19.

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Typical Performance Characteristics (continued)

V^+ = 5V, Single Supply, T_A = 25°C unless otherwise specified

Output Voltage vs. Output Current (Sinking)

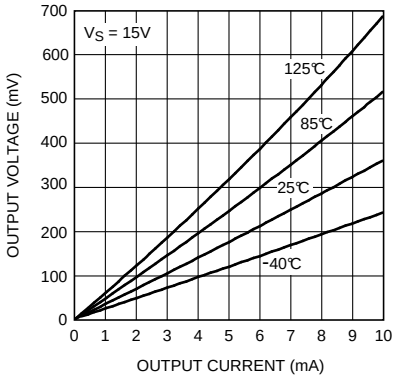

Figure 20.

Output Short Circuit Current vs. Supply

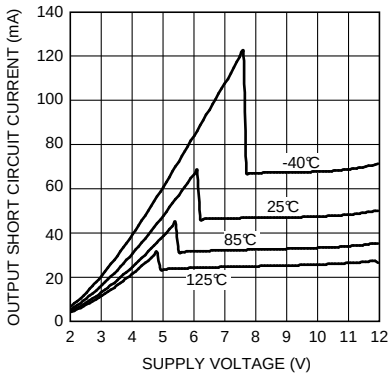

Figure 21.

Output Leakage vs. Output Voltage

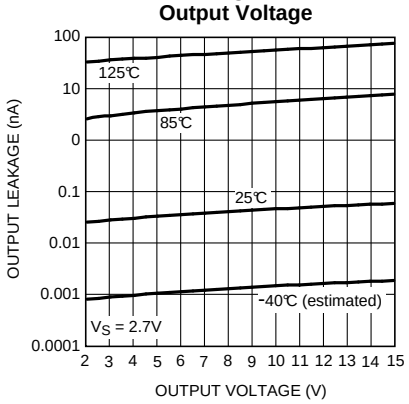

Figure 22.

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APPLICATION INFORMATION

1.0 INPUT COMMON-MODE VOLTAGE RANGE

At supply voltages of 2.7V, 5V and 15V, the SM72375 has an input common-mode voltage range (CMVR) which exceeds both supplies. As in the case of operational amplifiers, CMVR is defined by the V_{OS} shift of the comparator over the common-mode range of the device. A common-mode rejection ratio (CMRR, defined as $\Delta V_{OS}/\Delta V_{CM}$) of 75 dB (typical) implies a shift of < 1 mV over the entire common-mode range of the device. The absolute maximum input voltage at V^+ = 5V is 200 mV beyond either supply rail at room temperature.

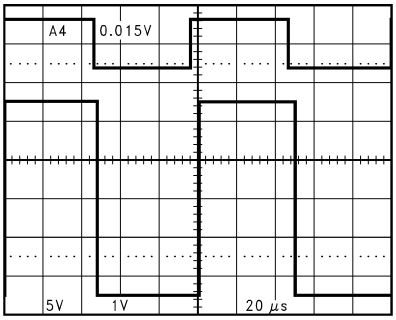

Figure 23. An Input Signal Exceeds the SM72375 Power Supply Voltages with No Output Phase Inversion

A wide input voltage range means that the comparator can be used to sense signals close to ground and also to the power supplies. This is an extremely useful feature in power supply monitoring circuits.

An input common-mode voltage range that exceeds the supplies, 20 fA input currents (typical), and a high input impedance makes the SM72375 ideal for sensor applications. The SM72375 can directly interface to sensors without the use of amplifiers or bias circuits. In circuits with sensors which produce outputs in the tens to hundreds of millivolts, the SM72375 can compare the sensor signal with an appropriately small reference voltage. This reference voltage can be close to ground or the positive supply rail.

2.0 LOW VOLTAGE OPERATION

Comparators are the common devices by which analog signals interface with digital circuits. The SM72375 is 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.

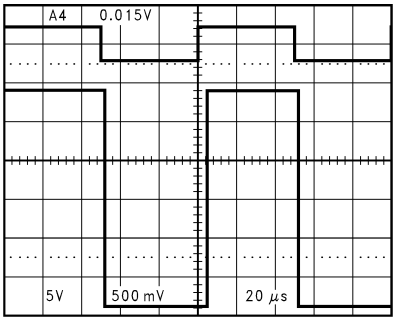

Figure 24. Even at Low-Supply Voltage of 2.7V, an Input Signal which Exceeds the Supply Voltages Produces No Phase Inversion at the Output

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 Typical Performance Characteristics section for more extensive characterization.

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3.0 OUTPUT SHORT CIRCUIT CURRENT

The SM72375 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 is 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.

4.0 HYSTERESIS

If the input signal is very noisy, the comparator output might trip several times as the input signal repeatedly passes through the threshold. This problem can be addressed by making use of hysteresis as shown below.

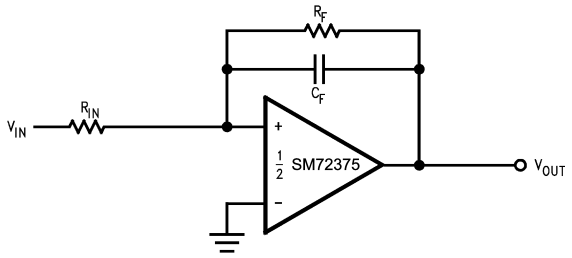

Figure 25. Canceling the Effect of Input Capacitance

The capacitor added across the feedback resistor increases the switching speed and provides more short term hysteresis. This can result in greater noise immunity for the circuit.

Typical Applications

UNIVERSAL LOGIC LEVEL SHIFTER

The output of the SM72375 is the uncommitted drain of the output NMOS transistor. Many drains can be tied together to provide an output OR'ing function. An output pullup resistor can be connected to any available power supply voltage within the permitted power supply range.

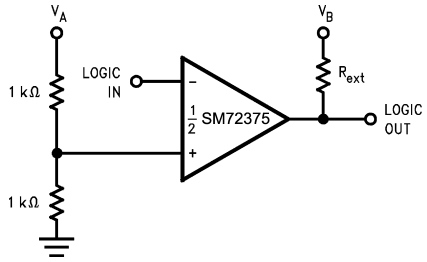

Figure 26. Universal Logic Level Shifter

The two 1 kΩ resistors bias the input to half of the power supply voltage. The pull-up resistor should go to the output logic supply. Due to its wide operating range, the SM72375 is ideal for the logic level shifting applications.

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ONE-SHOT MULTIVIBRATOR

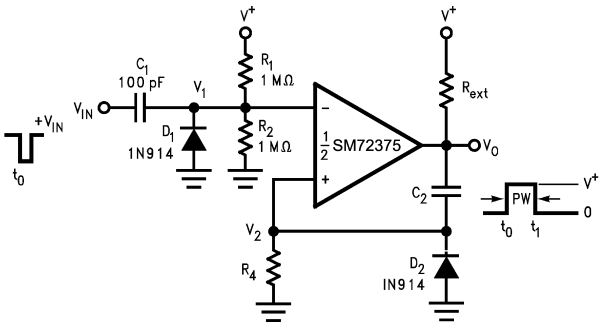

Figure 27. One-Shot Multivibrator

A monostable multivibrator has one stable state in which it can remain indefinitely. It can be triggered externally to another quasi-stable state. A monostable multivibrator can thus be used to generate a pulse of desired width.

The desired pulse width is set by adjusting the values of C_2 and R_4. The resistor divider of R_1 and R_2 can be used to determine the magnitude of the input trigger pulse. The SM72375 will change state when $V_1 < V_2$. Diode D_2 provides a rapid discharge path for capacitor C_2 to reset at the end of the pulse. The diode also prevents the non-inverting input from being driven below ground.

BI-STABLE MULTIVIBRATOR

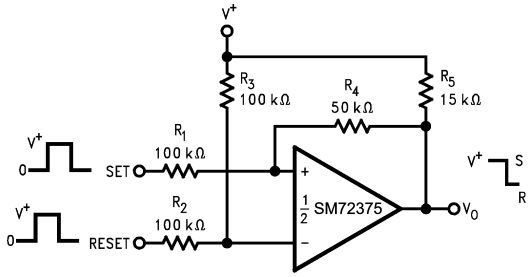

Figure 28. Bi-Stable Multivibrator

A bi-stable multivibrator has two stable states. The reference voltage is set up by the voltage divider of R_2 and R_3. A pulse applied to the SET terminal will switch the output of the comparator high. The resistor divider of R_1, R_4, and R_5 now clamps the non-inverting input to a voltage greater than the reference voltage. A pulse applied to RESET will now toggle the output low.

ZERO CROSSING DETECTOR

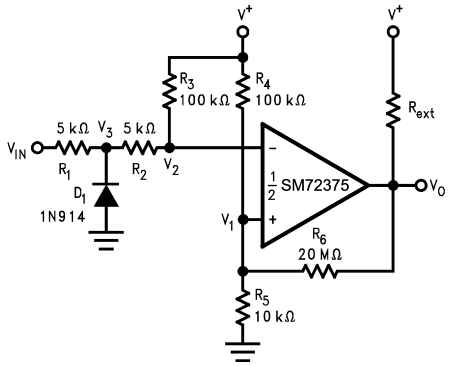

Figure 29. Zero Crossing Detector

A voltage divider of R_4 and R_5 establishes a reference voltage V_1 at the non-inverting input. By making the series resistance of R_1 and R_2 equal to R_5, the comparator will switch when V_{IN} = 0. Diode D_1 insures that V_3 never drops below −0.7V. The voltage divider of R_2 and R_3 then prevents V_2 from going below ground. A small amount of hysteresis is setup to ensure rapid output voltage transitions.

OSCILLATOR

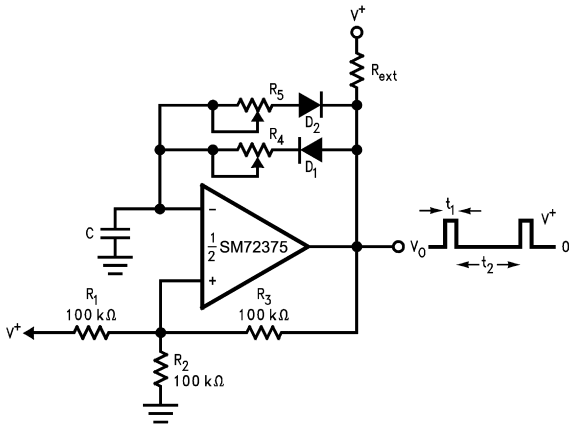

Figure 30. Square Wave Generator

Figure 30 shows the application of the SM72375 in a square wave generator circuit. The total hysteresis of the loop is set by R_1, R_2 and R_3. R_4 and R_5 provide separate charge and discharge paths for the capacitor C. The charge path is set through R_4 and D_1. So, the pulse width t_1 is determined by the RC time constant of R_4 and C. Similarly, the discharge path for the capacitor is set by R_5 and D_2. Thus, the time t_2 between the pulses can be changed by varying R_5, and the pulse width can be altered by R_4. The frequency of the output can be changed by varying both R_4 and R_5.

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Figure 31. Time Delay Generator

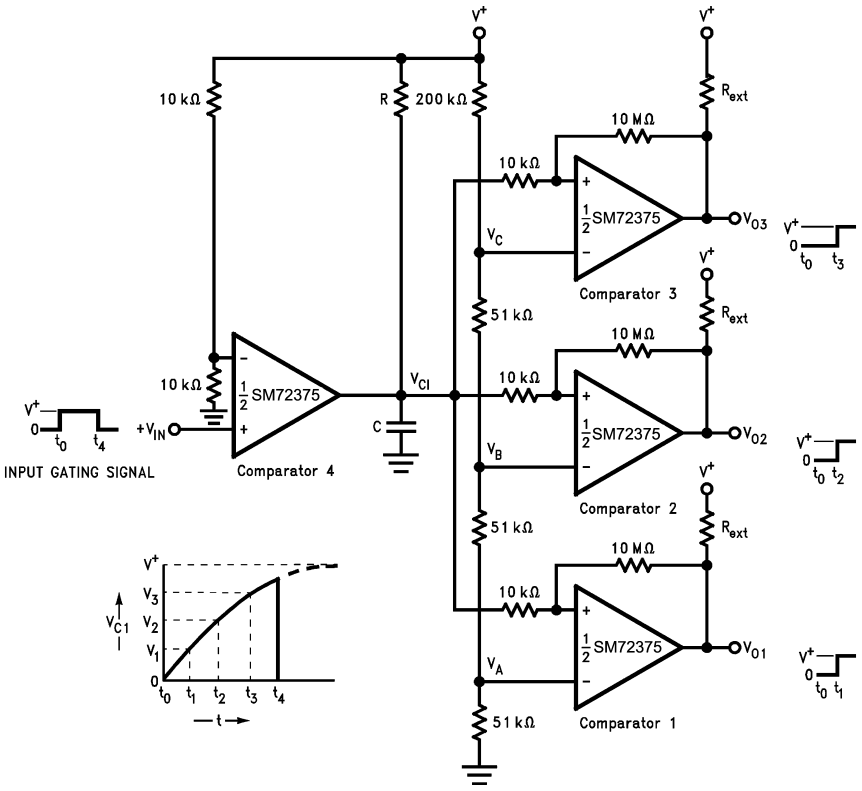

Figure 32. Time Delay Generator

The circuit shown above provides output signals at a prescribed time interval from a time reference and automatically resets the output when the input returns to ground. Consider the case of V_{IN} = 0. The output of comparator 4 is also at ground. This implies that the outputs of comparators 1, 2, and 3 are also at ground. When an input signal is applied, the output of comparator 4 swings high and C charges exponentially through R. This is indicated above. The output voltages of comparators 1, 2, and 3 swtich to the high state when V_{C1} rises above the reference voltages V_A, V_B and V_C. A small amount of hysteresis has been provided to insure fast switching when the RC time constant is chosen to give long delay times.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
SM72375MM/NOPB	ACTIVE	VSSOP	DGK	8	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S375	Samples
SM72375MME/NOPB	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S375	Samples
SM72375MMX/NOPB	ACTIVE	VSSOP	DGK	8	3500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S375	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
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Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Only one of markings shown within the brackets will appear on the physical device.

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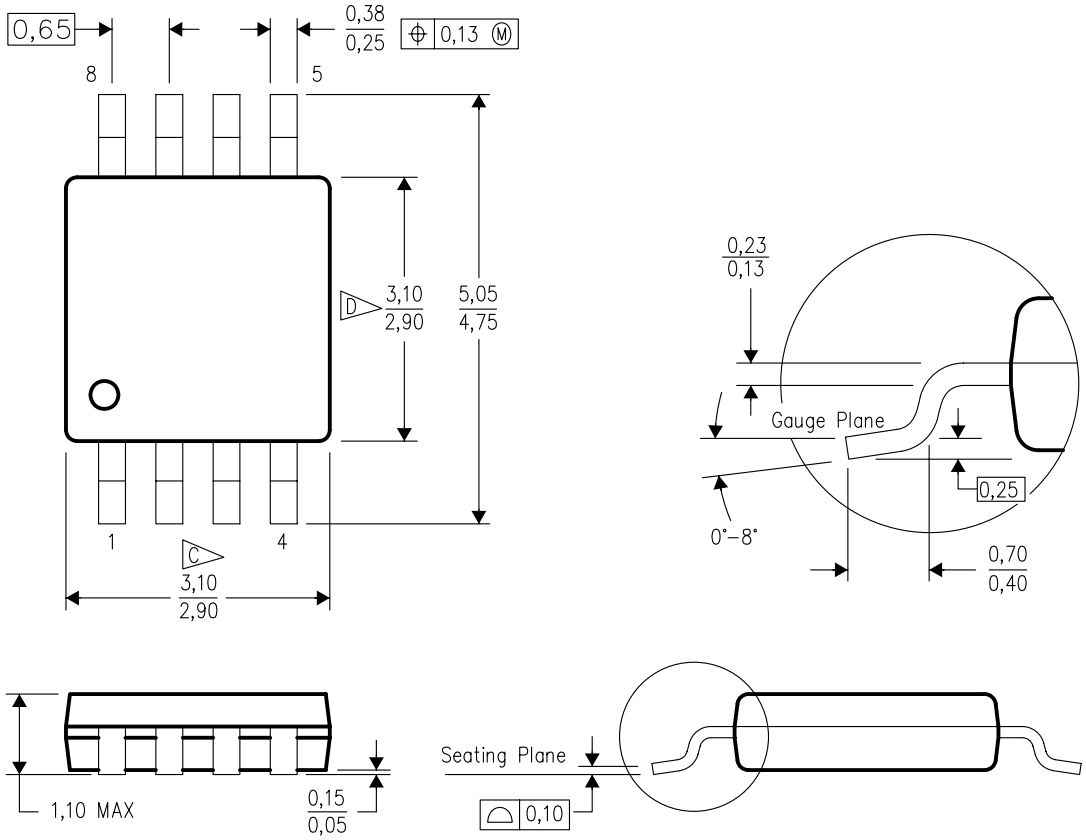

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NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO–187 variation AA, except interlead flash.

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