

## Linear Building Block – Dual Low-Power Comparator and Voltage Reference with Shutdown

### FEATURES

- Combines Two Comparators and a Voltage Reference in a Single Package
- Optimized for Single-Supply Operation
- Small Package .....8-Pin MSOP (Occupies Only Half the Area of an 8-Pin SOIC)
- Ultra Low Input Bias Current ..... Less than 100 pA
- Low Quiescent Current .... Operating 10 $\mu$ A (Typ.) Shutdown 0.05 $\mu$ A (Typ.)
- Rail-to-Rail Inputs and Outputs
- Operates Down to  $V_{DD} = 1.8V$

### APPLICATIONS

- Power Supply Circuits
- Battery Operated Equipment
- Consumer Products
- Replacements for Discrete Components

### GENERAL DESCRIPTION

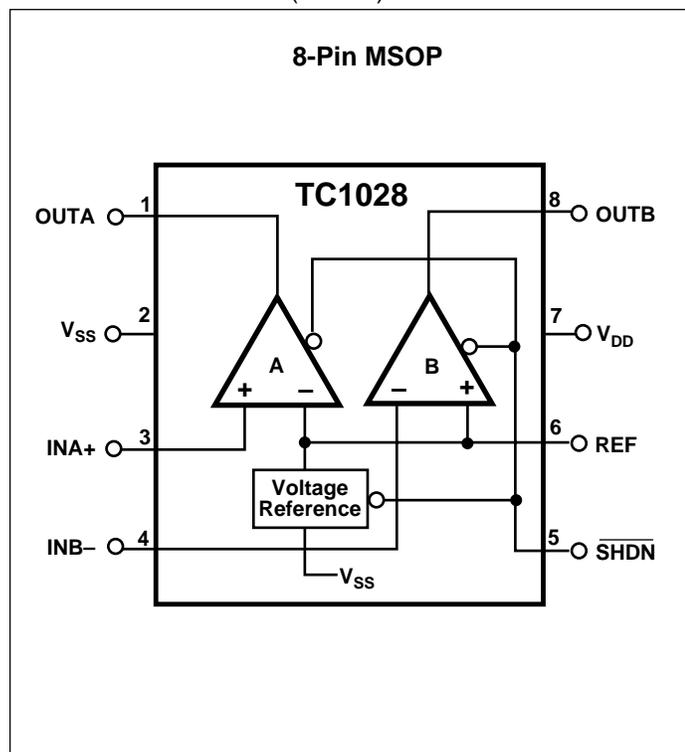
The TC1028 is a mixed-function device combining two comparators and a voltage reference in a single 8-pin package. The inverting input of comparator A and the non-inverting input of comparator B are internally connected to the reference.

This increased integration allows the user to replace two packages, which saves space, lowers supply current, and increases system performance. The TC1028 operates from two 1.5V alkaline cells down to  $V_{DD} = 1.8V$ . It requires only 10 $\mu$ A, typical, of supply current, which significantly extends battery life. A low-power shutdown input (SHDN) disables the entire chip, placing all outputs in a high-impedance state. This mode saves battery power and allows comparator outputs to share common analog lines (multiplexing). Shutdown current is 0.05 $\mu$ A, typical.

Rail-to-rail inputs and outputs allow operation from low supply voltages with large input and output signal swings.

Packaged in an 8-Pin MSOP, the TC1028 is ideal for applications requiring low-power level detection.

### PIN CONFIGURATION (MSOP)



### ORDERING INFORMATION

Part No.	Package	Temp. Range
TC1028CEUA	8-Pin MSOP	-40°C to +85°C
<b>TC1043EV Evaluation Kit for Linear Building Block Family</b>		

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## TC1028

### ABSOLUTE MAXIMUM RATINGS\*

Supply Voltage ..... 6.0V  
 Voltage on Any Pin:  
 (With Respect to Supplies) .. ( $V_{SS} - 0.3V$ ) to ( $V_{DD} + 0.3V$ )  
 Operating Temperature Range: .....  $-40^{\circ}C$  to  $+85^{\circ}C$   
 Storage Temperature Range .....  $-55^{\circ}C$  to  $+150^{\circ}C$   
 Lead Temperature (Soldering, 10 sec) .....  $+260^{\circ}C$

\* Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

**ELECTRICAL CHARACTERISTICS:** Typical values apply at  $25^{\circ}C$  and  $V_{DD} = 3V$ . Minimum and maximum values apply for  $T_A = -40^{\circ}$  to  $+85^{\circ}C$  and  $V_{DD} = 1.8V$  to  $5.5V$ , unless otherwise specified.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
$V_{DD}$	Supply Voltage		1.8	—	5.5	V
$I_Q$	Supply Current, Operating	All outputs unloaded, $\overline{SHDN} = V_{DD}$	—	10	15	$\mu A$
$I_{SHDN}$	Supply Current, Shutdown	$\overline{SHDN} = V_{SS}$	—	0.05	0.1	$\mu A$

### Shutdown Input

$V_{IH}$	Input High Threshold		$80\% V_{DD}$	—	—	V
$V_{IL}$	Input Low Threshold		—	—	$20\% V_{DD}$	V
$I_{SI}$	Shutdown Input Current		—	—	$\pm 100$	nA

### Comparators

$R_{OUT(SD)}$	Output Resistance in Shutdown	$\overline{SHDN} = V_{SS}$	20	—	—	$M\Omega$
$C_{OUT(SD)}$	Output Capacitance in Shutdown	$\overline{SHDN} = V_{SS}$	—	—	5	pF
$T_{SEL}$	Select Time	$V_{OUT}$ Valid from $\overline{SHDN} = V_{IH}$ $R_L = 10K\Omega$ to $V_{SS}$	—	20	—	$\mu sec$
$T_{DESEL}$	Deselect Time	$V_{OUT}$ Invalid from $\overline{SHDN} = V_{IL}$ $R_L = 10K\Omega$ to $V_{SS}$	—	500	—	nsec
$V_{IR}$	Input Voltage Range		$V_{SS} - 0.2$	—	$V_{DD} + 0.2$	V
$V_{OS}$	Input Offset Voltage	$V_{DD} = 3V, T_A = 25^{\circ}C$ $T_A = -40^{\circ}C$ to $85^{\circ}C$	-5 -5	—	+5 +5	mV
$I_B$	Input Bias Current	$T_A = 25^{\circ}C, INA+, INB- = V_{DD}$ to $V_{SS}$	—	—	$\pm 100$	pA
$V_{OH}$	Output High Voltage	$R_L = 10K\Omega$ to $V_{SS}$	$V_{DD} - 0.3$	—	—	V
$V_{OL}$	Output Low Voltage	$R_L = 10K\Omega$ to $V_{DD}$	—	—	0.3	V
CMRR	Common Mode Rejection Ratio	$T_A = 25^{\circ}C, V_{DD} = 5V$ $V_{CM} = V_{DD}$ to $V_{SS}$	66	—	—	dB
PSRR	Power Supply Rejection Ratio	$T_A = 25^{\circ}C$ $V_{DD} = 1.8V$ to $5V$	60	—	—	dB
$I_{SRC}$	Output Source Current	$INA+ = V_{DD}, INB- = V_{SS}$ Output Shorted to $V_{SS}$ $V_{DD} = 1.8V$	1	—	—	mA
$I_{SINK}$	Output Sink Current	$INA+ = V_{SS}, INB- = V_{DD}$ Output Shorted to $V_{DD}$ $V_{DD} = 1.8V$	2	—	—	mA
$t_{PD1}$	Response Time	100 mV Overdrive, $C_L = 100pF$	—	4	—	$\mu sec$
$t_{PD2}$	Response Time	10 mV Overdrive, $C_L = 100pF$	—	6	—	$\mu sec$

### Voltage Reference

$V_{REF}$	Reference Voltage		1.176	1.200	1.224	V
$I_{REF(SOURCE)}$	Source Current		50	—	—	$\mu A$
$I_{REF(SINK)}$	Sink Current		50	—	—	$\mu A$
$C_{L(REF)}$	Load Capacitance		—	—	100	pF

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TC1028

**ELECTRICAL CHARACTERISTICS: (CONT.)** Typical values apply at 25°C and  $V_{DD} = 3V$ . Minimum and maximum values apply for  $T_A = -40^\circ$  to  $+85^\circ C$  and  $V_{DD} = 1.8V$  to  $5.5V$ , unless otherwise specified.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
<b>Voltage Reference</b>						
$R_{OUT(SD)}$	Output Resistance in Shutdown	$\overline{SHDN} = V_{SS}$	20	—	—	$M\Omega$
$C_{OUT(SD)}$	Output Capacitance in Shutdown	$\overline{SHDN} = V_{SS}$	—	—	5	pF
$T_{SEL}$	Select Time	REF Valid from $\overline{SHDN} = V_{IH}$ $R_L = 100K\Omega$ to $V_{SS}$	—	200	—	$\mu sec$
$T_{DESEL}$	Deselect Time	REF Invalid from $\overline{SHDN} = V_{IL}$ $R_L = 100K\Omega$ to $V_{SS}$	—	10	—	$\mu sec$
$C_{L(REF)}$	Load Capacitance		—	—	100	pF
$N_{VREF}$	Voltage Noise	100 Hz to 100 KHz	—	20	—	$\mu V_{RMS}$
	Noise Density	1 KHz	—	1.0	—	$\mu V/\sqrt{Hz}$

## DETAILED DESCRIPTION

The TC1028 is one of a series of very low-power, linear building block products targeted at low-voltage, single-supply applications. The TC1028 minimum operating voltage is 1.8V and typical supply current is only 10  $\mu A$  (fully enabled). It combines two comparators and a voltage reference in a single package. The shutdown mode disables both comparators and the reference. All of the outputs are in a high impedance state during shutdown.

### Comparators

The TC1028 contains two comparators. The comparator's input range extends beyond both supply voltages by 200mV and the outputs will swing to within several millivolts of the supplies depending on the load current being driven. The inverting input of comparator A and the non-inverting input of comparator B are internally connected to the output of the voltage reference.

The comparators exhibit a propagation delay and supply current which are largely independent of supply voltage. The low input bias current and offset voltage make them suitable for high impedance precision applications.

Both comparators are disabled during shutdown and have high impedance outputs.

### Voltage Reference

A 2.0 percent tolerance, internally biased, 1.20V bandgap voltage reference is included in the TC1028. It has a push-pull output capable of sourcing and sinking 50  $\mu A$ . The voltage reference is disabled during shutdown, with a high impedance output.

### Shutdown Input

$\overline{SHDN}$  at  $V_{IL}$  disables the entire part. The  $\overline{SHDN}$  input cannot be allowed to float; when not used, connect it to  $V_{DD}$ .

All outputs are in a high impedance state when shutdown is active. The disabled comparators' inputs and outputs can be driven from rail-to-rail by an external voltage when the TC1028 is in shutdown. No latchup will occur when the device is driven to its enabled state when  $\overline{SHDN}$  is set to  $V_{IH}$ .

## TYPICAL APPLICATIONS

The TC1028 lends itself to a wide variety of applications, particularly in battery-powered systems. It typically finds application in power management, processor supervisory, and interface circuitry.

### Wake-Up Timer

Many microcontrollers have a low-power "sleep" mode that significantly reduces their supply current. Typically, the microcontroller is placed in this mode via a software instruction, and returns to a fully-enabled state upon reception of an external signal ("wake-up"). The wake-up signal is usually supplied by a hardware timer. Most system applications demand that this timer have a long duration (typically seconds or minutes), and consume as little supply current as possible.

The circuit shown in Figure 1 is a wake-up timer made from comparator A. Capacitor C1 charges through R1 until a voltage equal to  $V_R$  is reached, at which point the WAKE-UP is driven active. Upon wake-up, the microcontroller resets the timer by forcing a logic low on a dedicated, open drain I/O port pin. This discharges C1 through R4 (the value of R4 is chosen to limit maximum current sunk by the I/O port pin). With a 3V supply, the circuit as shown consumes typically 10  $\mu A$  and furnishes a nominal timer duration of 25 seconds.

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## TC1028

### Precision Battery Monitor

Figure 2 is a precision battery low/battery dead monitoring circuit. Typically, the battery low output warns the user that a battery dead condition is imminent. Battery dead typically initiates a forced shutdown to prevent operation at low internal supply voltages (which can cause unstable system operation).

The circuit of Figure 2 uses a single TC1028, a TC1034, and only six external resistors. COMPA and COMPB provide precision voltage detection using  $V_R$  as a reference. Resistors R2 and R4 set the detection threshold for BATT LOW, while resistors R1 and R3 set the detection threshold for BATT FAIL. The component values shown assert BATT LOW at 2.2V (typical) and BATT FAIL at 2.0 (typical). Total current consumed by this circuit is typically 16  $\mu$ A at 3V. Resistors R5 and R6 provide hysteresis for comparators COMPA and COMPB, respectively.

### External Hysteresis

Hysteresis can be set externally with two resistors using positive feedback techniques (see Figure 3). The design procedure for setting external comparator hysteresis is as follows:

1. Choose the feedback resistor  $R_C$ . Since the input bias current of the comparator is at most 100 pA, the current through  $R_C$  can be set to 100 nA (i.e. 1000 times the input bias current) and retain excellent accuracy. The current through  $R_C$  at the comparator's trip point is  $V_R / R_C$  where  $V_R$  is the stable reference voltage.

2. Determine the hysteresis voltage ( $V_{HY}$ ) between the upper and lower thresholds.

3. Calculate  $R_A$  as follows.

$$R_A = R_C \left( \frac{V_{HY}}{V_{DD}} \right)$$

Equation 1.

4. Choose the rising threshold voltage for  $V_{SRC}$  ( $V_{THR}$ ).

5. Calculate  $R_B$  as follows:

$$R_B = \left[ \frac{1}{\left( \frac{V_{THR}}{V_R * R_A} \right) - \frac{1}{R_A} - \frac{1}{R_C}} \right]$$

Equation 2.

6. Verify the threshold voltages with these formulas:

$V_{SRC}$  rising:

$$V_{THR} = (V_R) (R_A) \left[ \left( \frac{1}{R_A} \right) + \left( \frac{1}{R_B} \right) + \left( \frac{1}{R_C} \right) \right]$$

Equation 3.

$V_{SRC}$  falling:

$$V_{THF} = V_{THR} - \left[ \frac{(R_A * V_{DD})}{R_C} \right]$$

Equation 4.

### EVALUATION KIT

The TC1043EV consists of a four-inch by six-inch pre-wired application circuit board. Pre-configured circuits include a pulse width modulator, wake-up timer, function generator, and others. On-board current meter terminals, voltage regulator, and a user-prototyping area speed circuit development. Please contact your local Microchip Technology representative for more information.

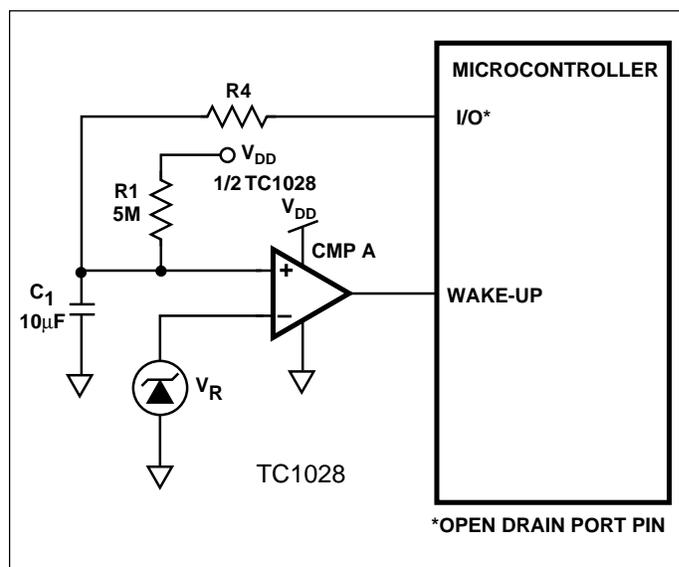


Figure 1. Wake-Up Timer

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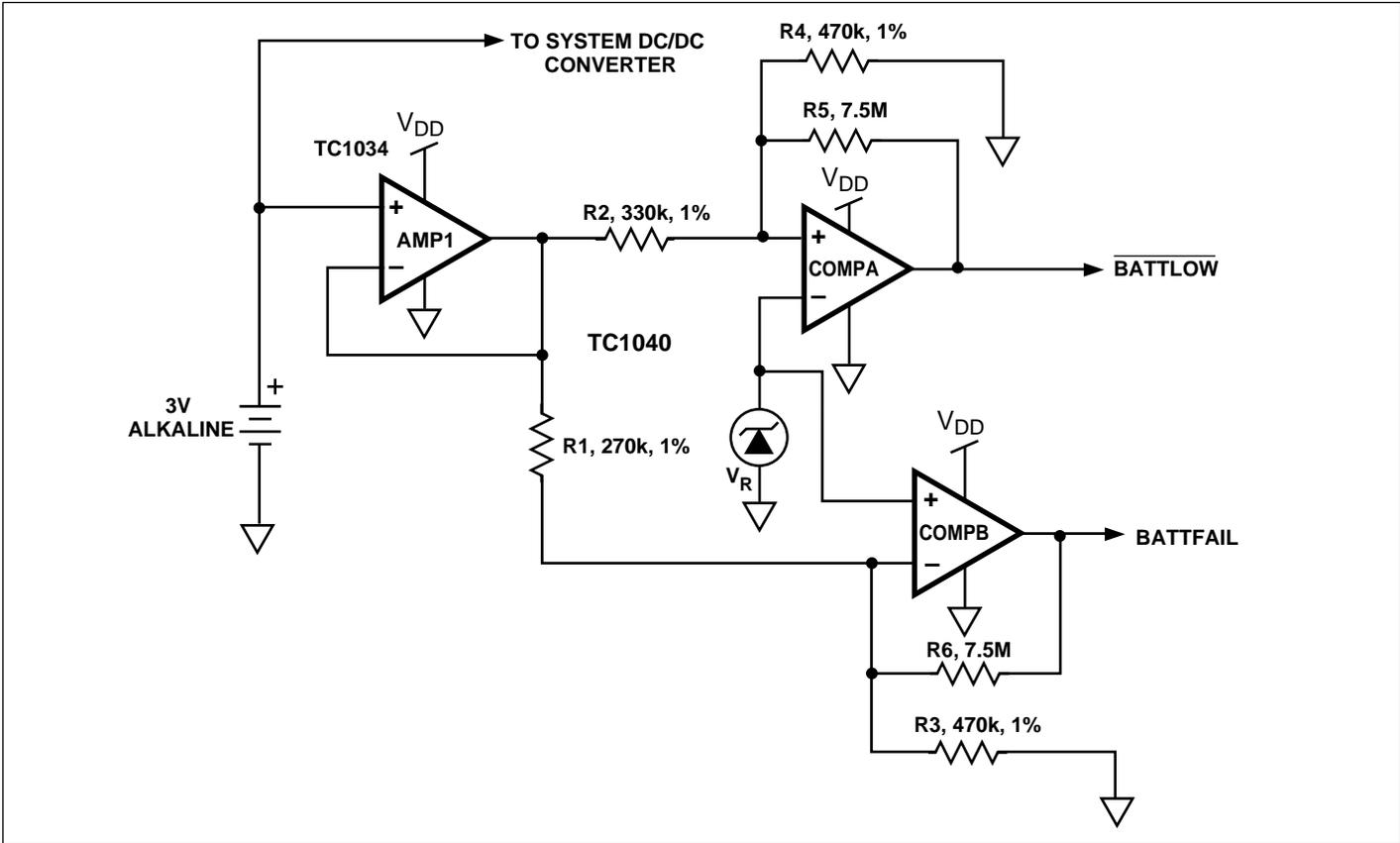


Figure 2. Precision Battery Monitor

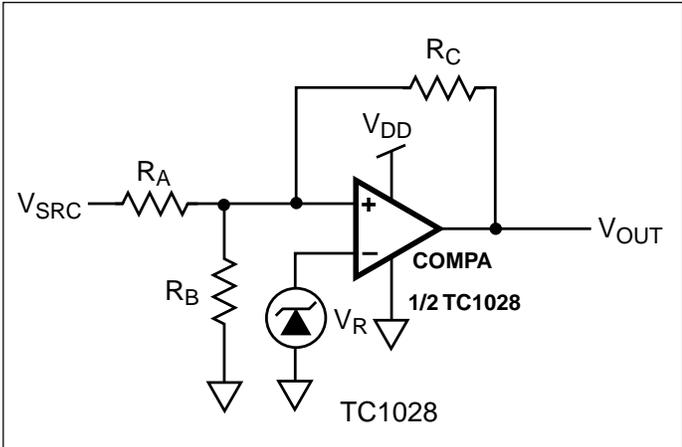
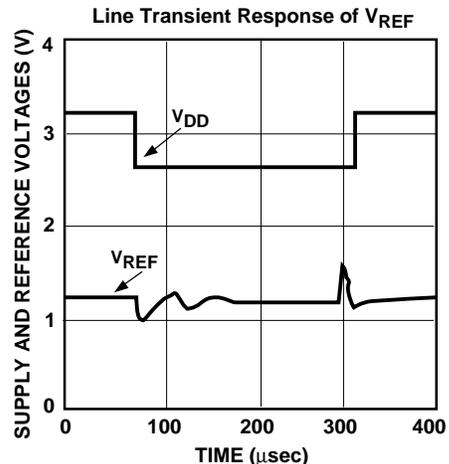
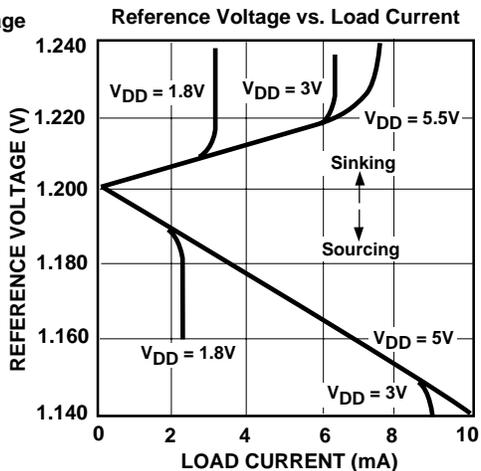
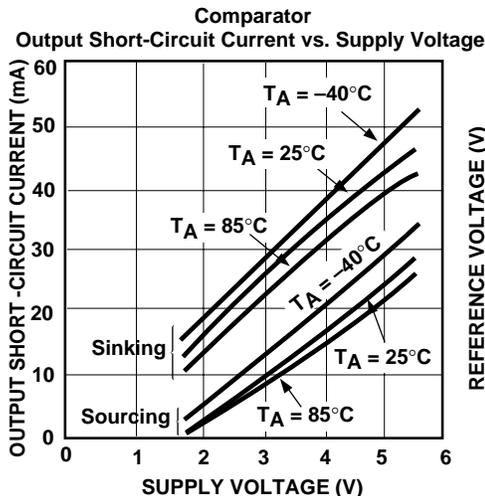
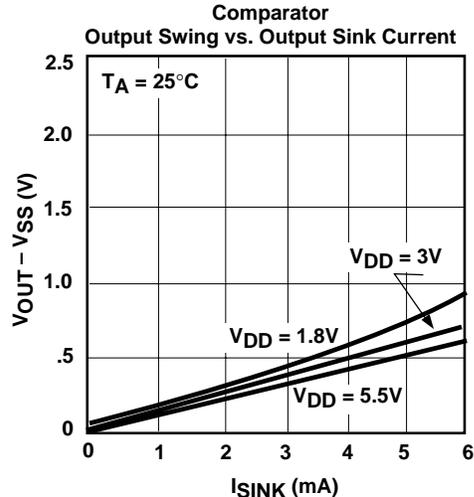
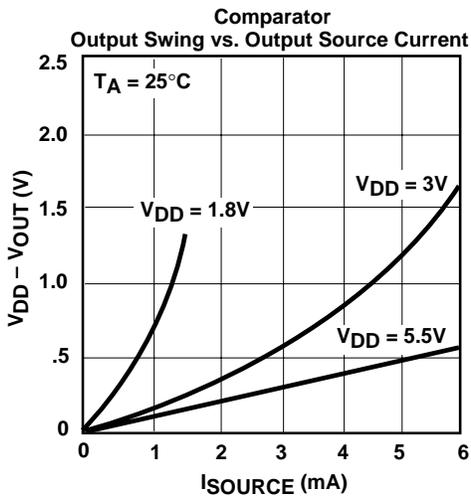
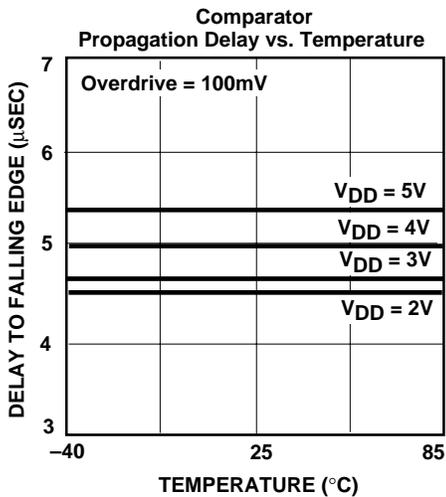
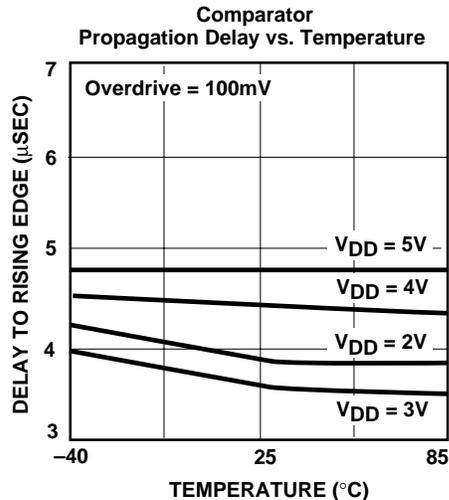
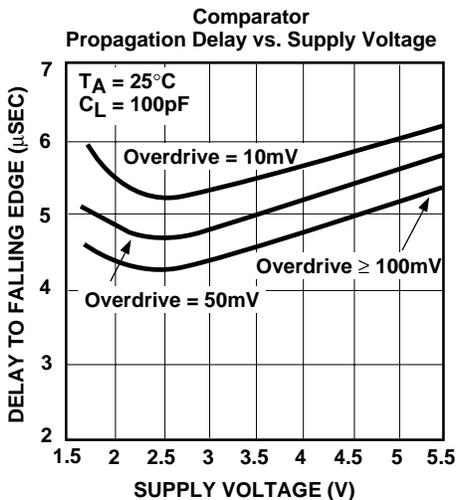
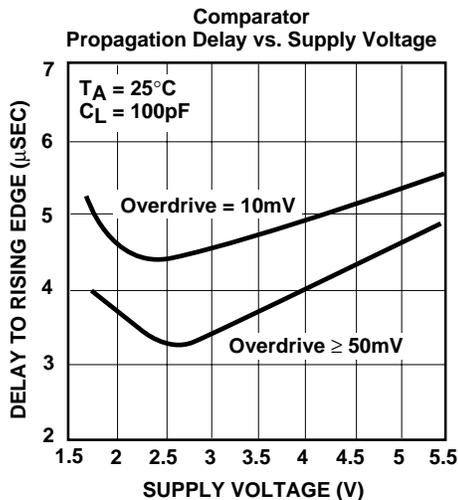


Figure 3. Comparator External Hysteresis Configuration

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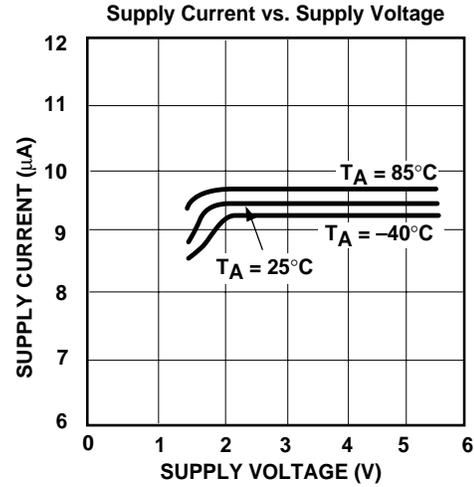
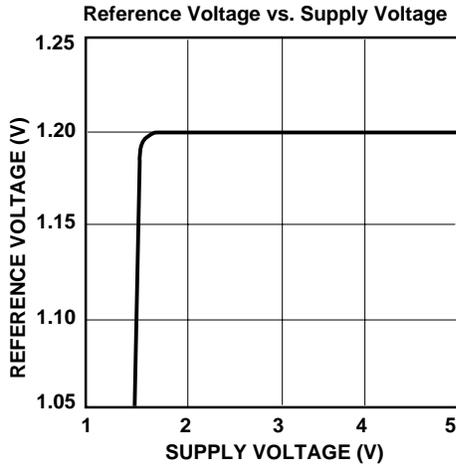
## TYPICAL CHARACTERISTICS



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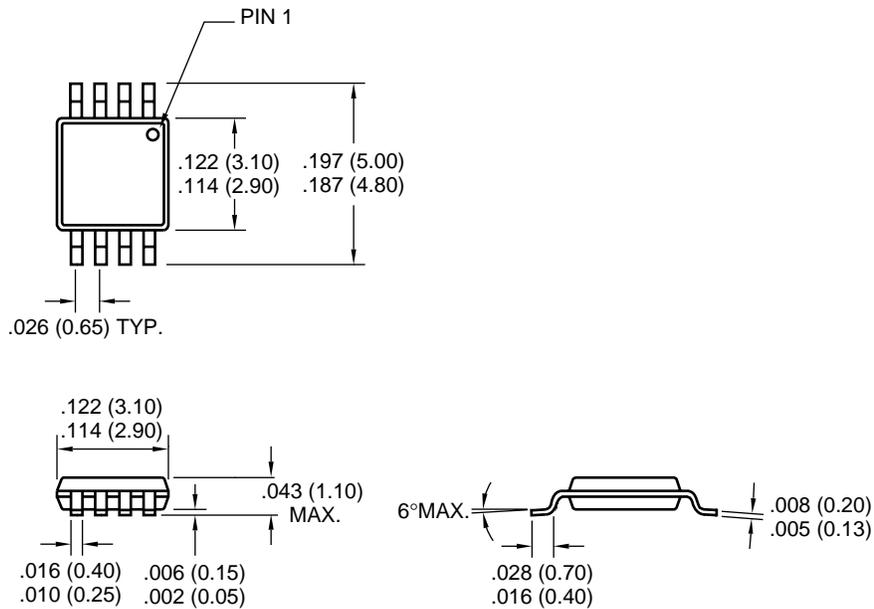
TC1028

## TYPICAL CHARACTERISTICS



## PACKAGE DIMENSIONS

### 8-Pin MSOP



Dimensions: inches (mm)



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