

## 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
- Ultra Low Input Bias Current: Less than 100pA
- Low Quiescent Current, Operating: 10 $\mu$ A (Typ.) Shutdown Mode: 6 $\mu$ A (Typ.)
- Rail-to-Rail Inputs and Outputs
- Operates Down to  $V_{DD} = 1.8V$
- Reference and One Comparator Remain Active in Shutdown to Provide Supervisory Functions

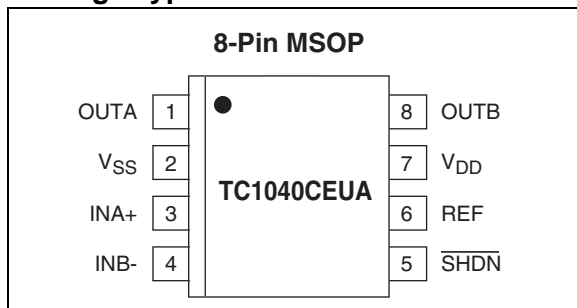
### Applications

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

### Device Selection Table

Part Number	Package	Temperature Range
TC1040CEUA	8-Pin MSOP	-40°C to +85°C

### Package Type



### General Description

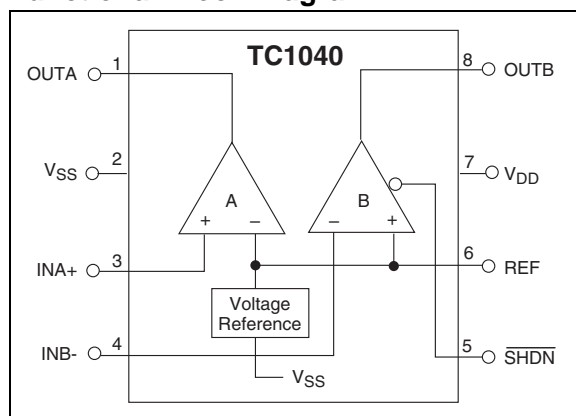
The TC1040 is a mixed-function device combining two comparators and a voltage reference in a single 8-pin package. The inverting input of Comparator A and the non-inverting input of Comparator B are internally connected to the reference.

This increased integration allows the user to replace two packages, which saves space, lowers supply current and increases system performance. The TC1040 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 one of the comparators, placing its outputs in a high-impedance state. This mode saves battery power and allows comparator outputs to share common analog lines (multiplexing). Shutdown current is 6 $\mu$ 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 TC1040 is ideal for applications requiring low power level detection.

### Functional Block Diagram



# TC1040

## 1.0 ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS\*

Supply Voltage .....	6.0V
Voltage on Any Pin .....	( $V_{SS} - 0.3V$ ) to ( $V_{DD} + 0.3V$ )
Junction Temperature .....	+150°C
Operating Temperature Range.....	-40°C to +85°C
Storage Temperature Range .....	-55°C to +150°C

\*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 operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

### TC1040 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Typical values apply at 25°C and $V_{DD} = 3.0V$ . Minimum and maximum values apply for $T_A = -40^\circ$ to +85°C and $V_{DD} = 1.8V$ to 5.5V, unless otherwise specified.						
Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$V_{DD}$	Supply Voltage	1.8	—	5.5	V	
$I_Q$	Supply Current Operating	—	10	15	$\mu A$	All outputs unloaded, $\overline{SHDN} = V_{DD}$
$I_{SHDN}$	Supply Current, Shutdown	—	0.05	0.1	$\mu A$	$\overline{SHDN} = V_{SS}$
<b>Shutdown Input</b>						
$V_{IH}$	Input High Threshold	80% $V_{DD}$	—	—	V	
$V_{IL}$	Input Low Threshold	—	—	20% $V_{DD}$	V	
$I_{SI}$	Shutdown Input Current	—	—	$\pm 100$	nA	
<b>Comparators</b>						
$R_{OUT(SD)}$	Output Resistance in Shutdown	20	—	—	$M\Omega$	$\overline{SHDN} = V_{SS}$ , COMPB only
$C_{OUT(SD)}$	Output Capacitance in Shutdown	—	—	5	pF	$\overline{SHDN} = V_{SS}$ , COMPB only
$T_{SEL}$	Select Time (For Valid Output)	—	20	—	$\mu sec$	( $\overline{SHDN} = V_{IH}$ to $V_{OUT}$ ) $R_L = 10k\Omega$ to $V_{SS}$ , COMPB only
$T_{DESEL}$	Deselect Time	—	500	—	nsec	( $\overline{SHDN} = V_{IL}$ to $V_{OUT}$ ) $R_L = 10k\Omega$ to $V_{SS}$ , COMPB only
$V_{IR}$	Input Voltage Range	$V_{SS} - 0.2$	—	$V_{DD} + 0.2$	V	
$V_{OS}$	Input Offset Voltage	-5 -5	—	+5 +5	mV	$V_{DD} = 3V$ , $T_A = 25^\circ C$ $T_A = -40^\circ C$ to $85^\circ C$
$I_B$	Input Bias Current	—	—	$\pm 100$	pA	$T_A = 25^\circ C$ , $INA+$ , $INB-$ = $V_{DD}$ to $V_{SS}$
$V_{OH}$	Output High Voltage	$V_{DD} - 0.3$	—	—	V	$R_L = 10k\Omega$ to $V_{SS}$
$V_{OL}$	Output Low Voltage	—	—	0.3	V	$R_L = 10k\Omega$ to $V_{DD}$
PSRR	Power Supply Rejection Ratio	60	—	—	dB	$T_A = 25^\circ C$ $V_{DD} = 1.8V$ to 5V
$I_{SRC}$	Output Source Current	1	—	—	mA	$INA+ = V_{DD}$ , $INB- = V_{SS}$ Output Shorted to $V_{SS}$ $V_{DD} = 1.8V$
$I_{SINK}$	Output Sink Current	2	—	—	mA	$INA+ = V_{SS}$ , $INB- = V_{DD}$ , Output Shorted to $V_{DD}$ $V_{DD} = 1.8V$
$t_{PD1}$	Response Time	—	4	—	$\mu sec$	100mV Overdrive, $C_L = 100pF$
$t_{PD2}$	Response Time	—	6	—	$\mu sec$	10mV Overdrive, $C_L = 100pF$
<b>Voltage Reference</b>						
$V_{REF}$	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	
$E_{VREF}$	Voltage Noise	—	20	—	$\mu V_{RMS}$	100Hz to 100kHz
$e_{VREF}$	Noise Density	—	1.0	—	$\mu V/\sqrt{Hz}$	1kHz

## 2.0 PIN DESCRIPTION

The description of the pins are listed in Table 2-1.

**TABLE 2-1: PIN FUNCTION TABLE**

Pin No. (8-Pin MSOP)	Symbol	Description
1	OUTA	Comparator output.
2	$V_{SS}$	Negative power supply.
3	INA+	Non-inverting input to Comparator A.
4	INB-	Inverting input to Comparator B.
5	$\overline{\text{SHDN}}$	Shutdown input.
6	REF	Voltage reference output.
7	$V_{DD}$	Positive power supply.
8	OUTB	Comparator output.

# TC1040

## 3.0 DETAILED DESCRIPTION

The TC1040 is one of a series of very low power, linear building block products targeted at low voltage, single supply applications. The TC1040 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. A shutdown mode is incorporated for easy adaptation to system power management schemes. During shutdown, one comparator is disabled (i.e., powered down with output at a high impedance). The “still awake” comparator and voltage reference can be used as a wake-up timer, power supply monitor, LDO controller or other continuous duty circuit function.

### 3.1 Comparators

The TC1040 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.

Comparator B is disabled during shutdown and has a high impedance output. Comparator COMPA remains active.

### 3.2 Voltage Reference

A 2.0 percent tolerance, internally biased, 1.20V bandgap voltage reference is included in the TC1040. It has a push-pull output capable of sourcing and sinking 50 $\mu$ A. The voltage reference remains fully enabled during shutdown.

### 3.3 Shutdown Input

$\overline{\text{SHDN}}$  at  $V_{IL}$  disables one comparator. The  $\overline{\text{SHDN}}$  input cannot be allowed to float; when not used, connect it to  $V_{DD}$ . The disabled comparator's output is in a high impedance state when shutdown is active. The disabled comparator's inputs and outputs can be driven from rail-to-rail by an external voltage when the TC1040 is in shutdown. No latching will occur when the device is driven to its enabled state when  $\overline{\text{SHDN}}$  is set to  $V_{IH}$ .

## 4.0 TYPICAL APPLICATIONS

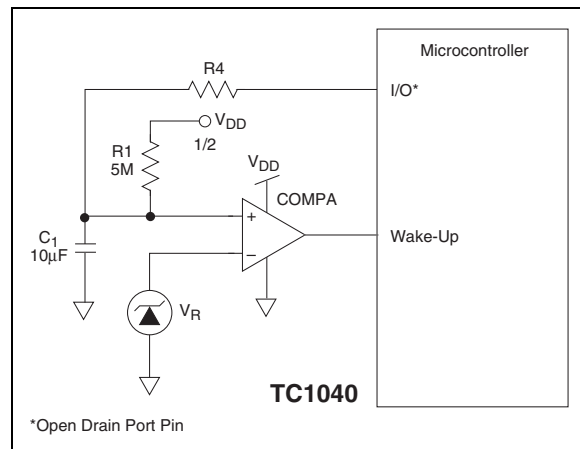
The TC1040 lends itself to a wide variety of applications, particularly in battery powered systems. It typically finds application in power management, processor supervisory and interface circuitry.

### 4.1 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 4-1 is a wake-up timer made from Comparator A. (Comparator A is used because the wake-up timer must operate when  $\overline{\text{SHDN}}$  is active.) 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 8 $\mu$ A and furnishes a nominal timer duration of 25 seconds.

FIGURE 4-1: WAKE-UP TIMER



## 4.2 Precision Battery Monitor

Figure 4-2 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 in Figure 4-2 uses a single TC1040, one-half of a TC1029, 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 R7 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 22 $\mu$ A at 3V. Resistors R5 and R6 provide hysteresis for comparators COMPA and COMPB, respectively.

## 4.3 External Hysteresis (Comparator)

Hysteresis can be set externally with two resistors using positive feedback techniques (see Figure 4-3). 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 100pA, the current through  $R_C$  can be set to 100nA (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 a stable reference voltage.
2. Determine the hysteresis voltage ( $V_{HY}$ ) between the upper and lower thresholds.

3. Calculate  $R_A$  as follows:

### EQUATION 4-1:

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

4. Choose the rising threshold voltage for  $V_{SRC}$  ( $V_{THR}$ ).
5. Calculate  $R_B$  as follows:

### EQUATION 4-2:

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

6. Verify the threshold voltages with these formulas:

$V_{SRC}$  rising:

### EQUATION 4-3:

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

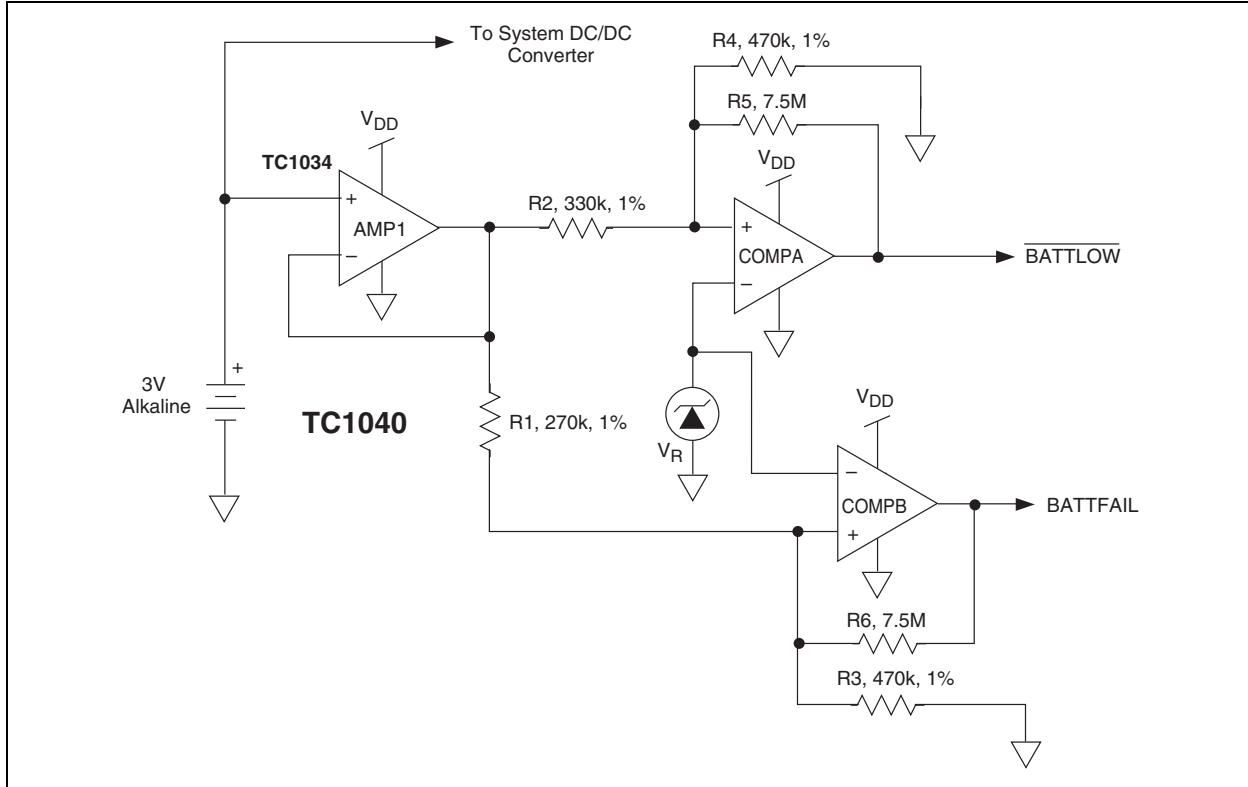
$V_{SRC}$  falling:

### EQUATION 4-4:

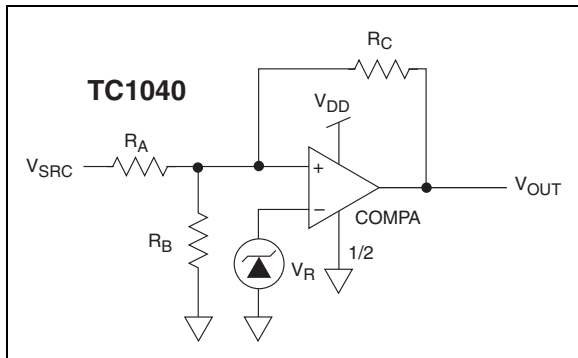
$$V_{THF} = V_{THR} - \left[ \left( \frac{R_A \times V_{DD}}{R_C} \right) \right]$$

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**FIGURE 4-2: PRECISION BATTERY MONITOR**

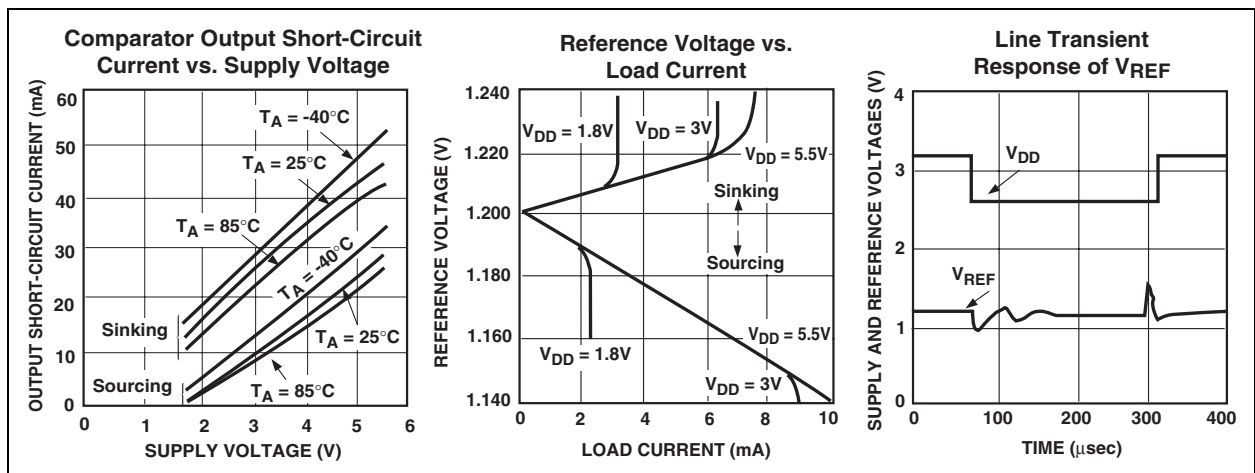
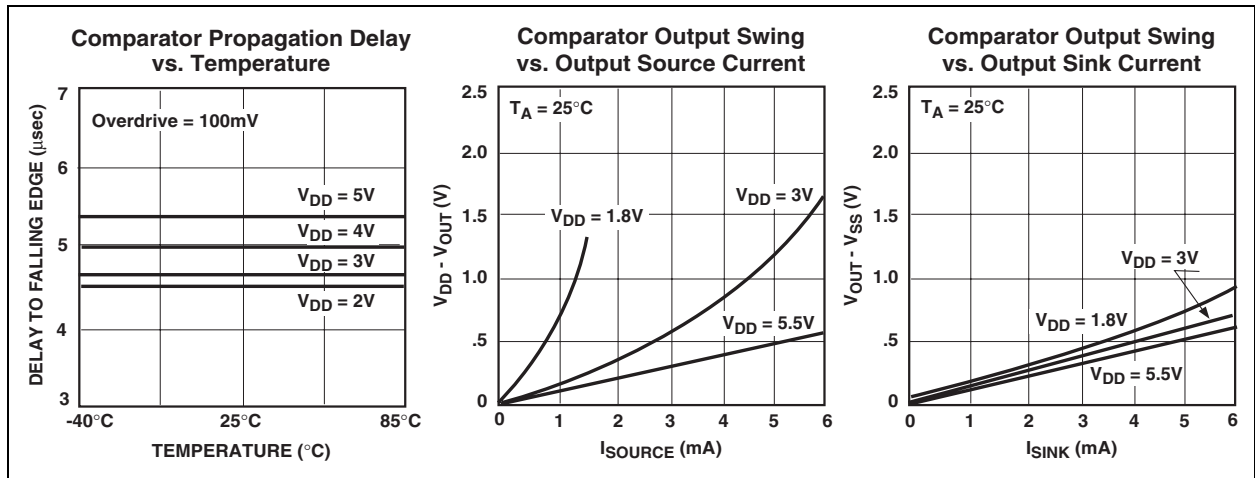
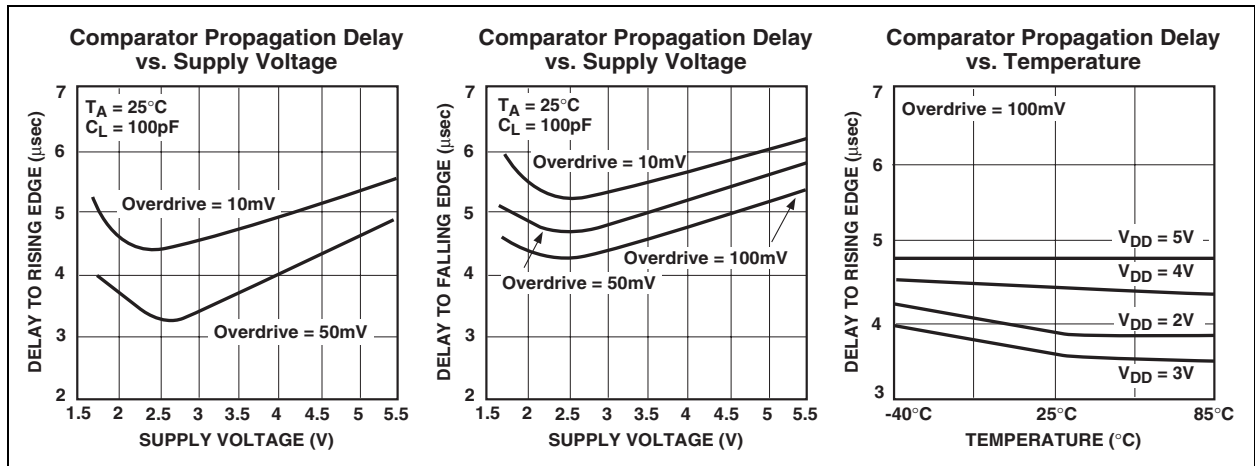


**FIGURE 4-3: COMPARATOR EXTERNAL HYSTERESIS CONFIGURATION**



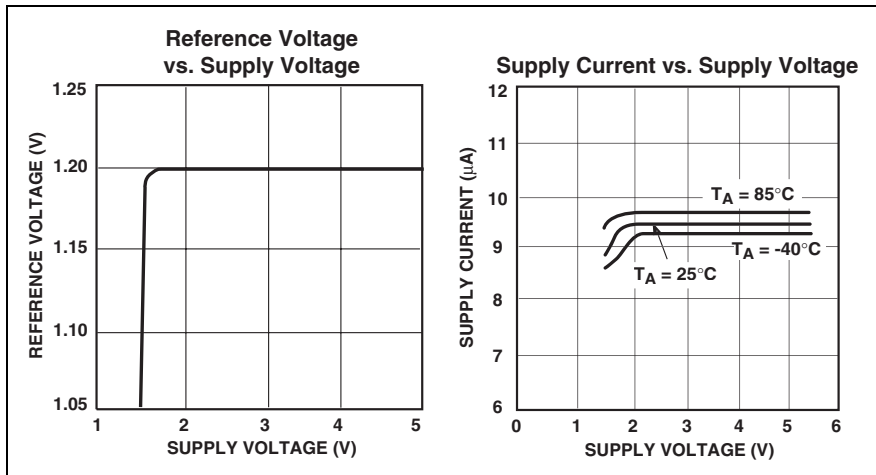
## 5.0 TYPICAL CHARACTERISTICS

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.



# TC1040

## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)



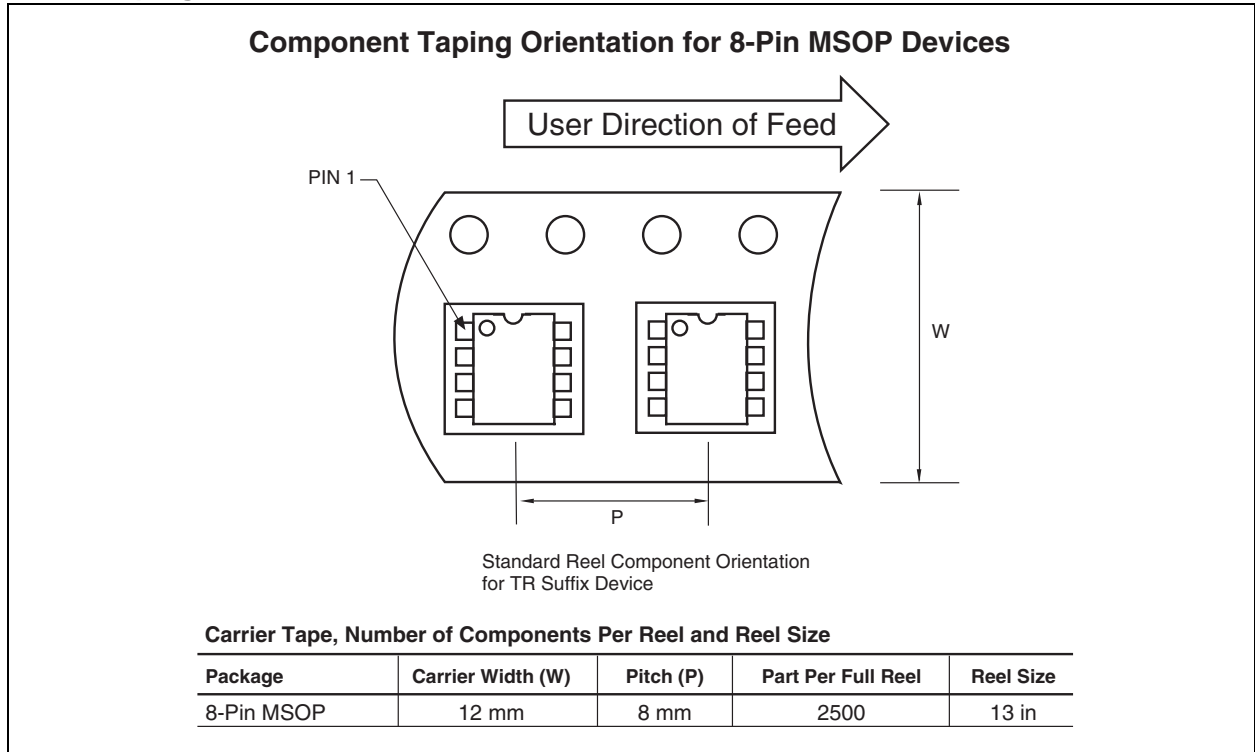


## 6.0 PACKAGING INFORMATION

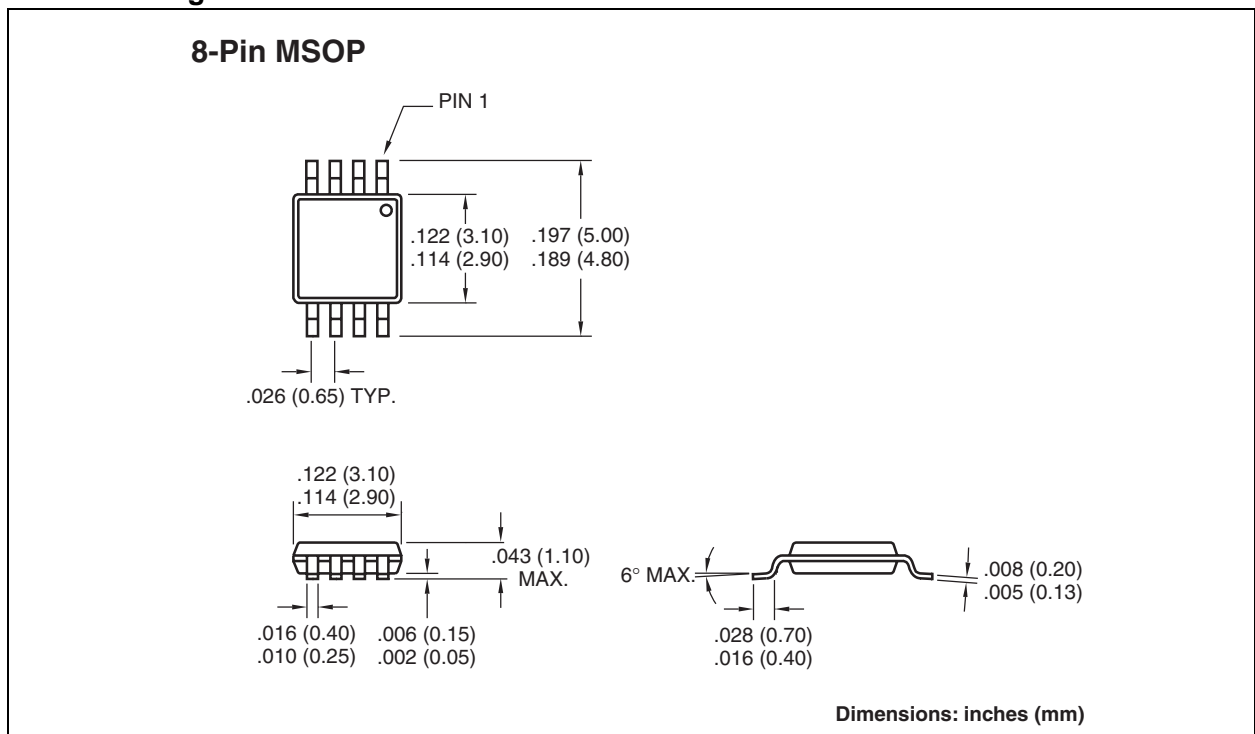
### 6.1 Package Marking Information

Package marking data not available at this time.

### 6.2 Taping Form



### 6.3 Package Dimensions



# TC1040

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NOTES:

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