

## 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

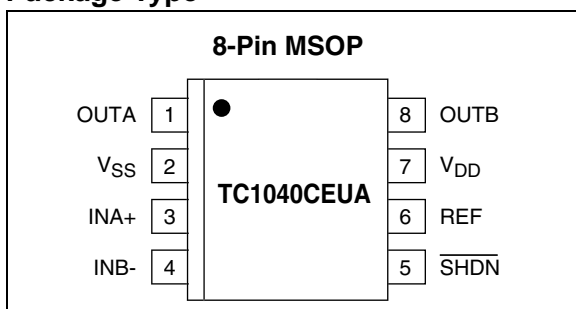
### Applications

- 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

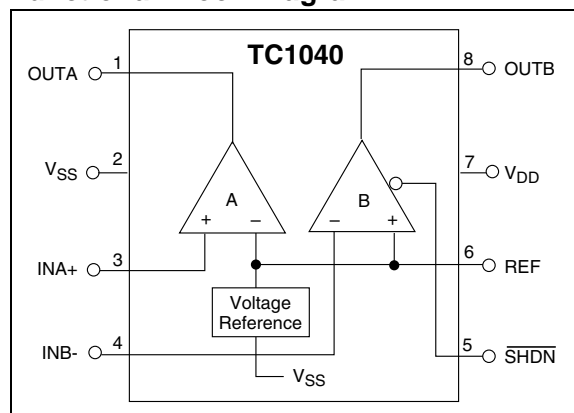
The TC1040 is a mixed-function device combining two comparators and a voltage reference in a single 8-pin package. The inverting input of Comparator A and the non-inverting input of Comparator B are internally connected to the reference.

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.

## 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

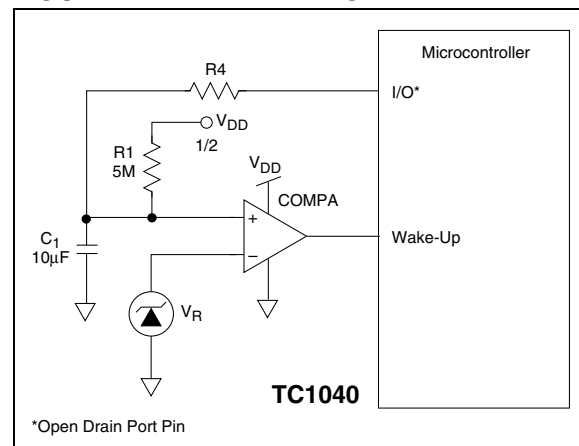
The TC1040 lends itself to a wide variety of applications, particularly in battery powered systems. It typically finds application in power management, processor supervisory and interface circuitry.

### 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:

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

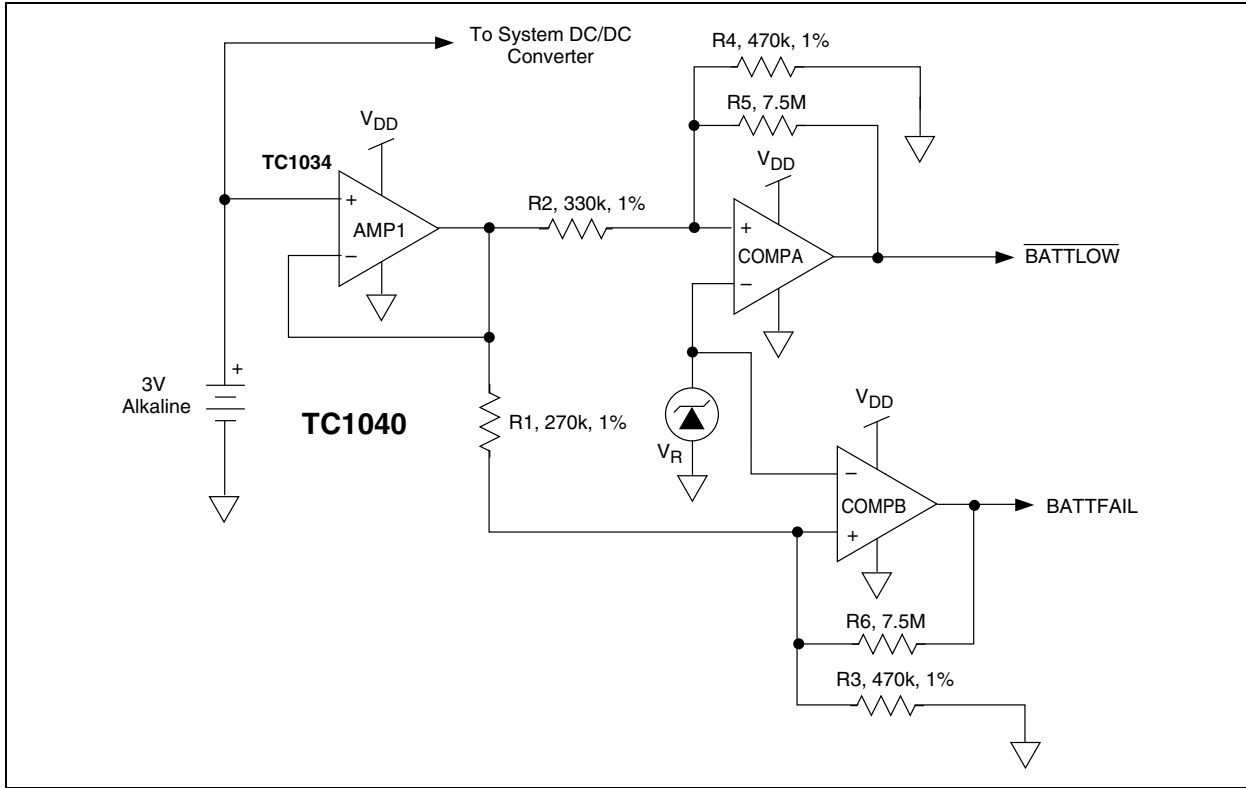
$V_{SRC}$  falling:

### EQUATION 4-4:

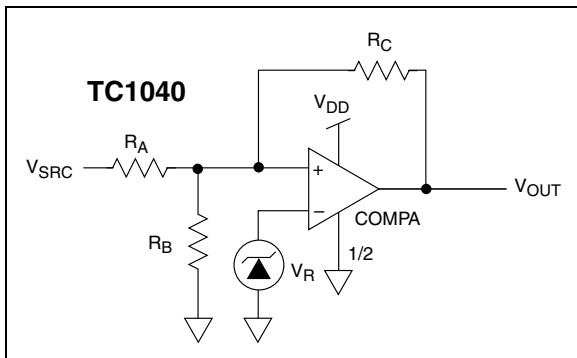
$$V_{THF} = V_{THR} - \left[ \left( \frac{R_A \times V_{DD}}{R_C} \right) \right]$$

# TC1040

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

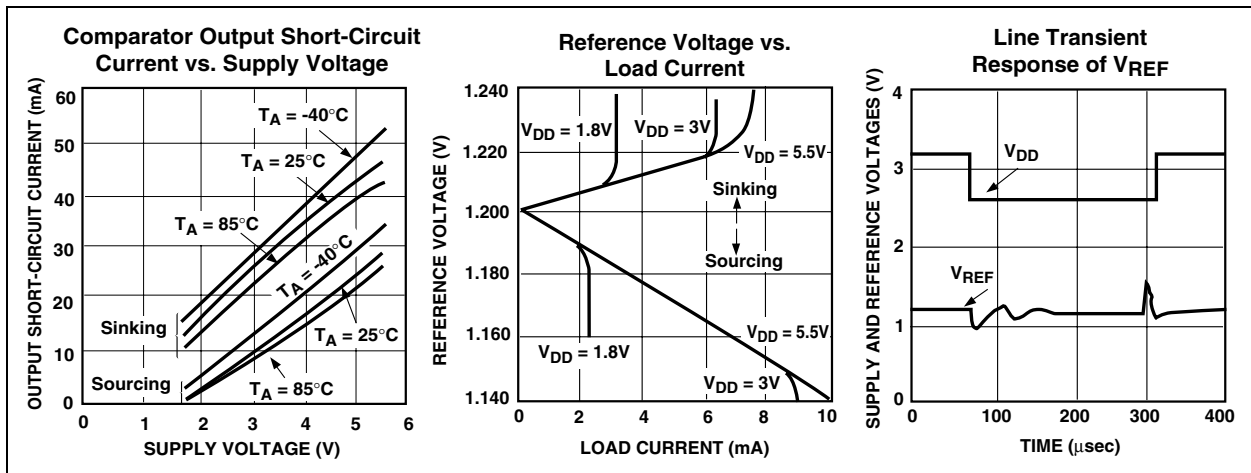
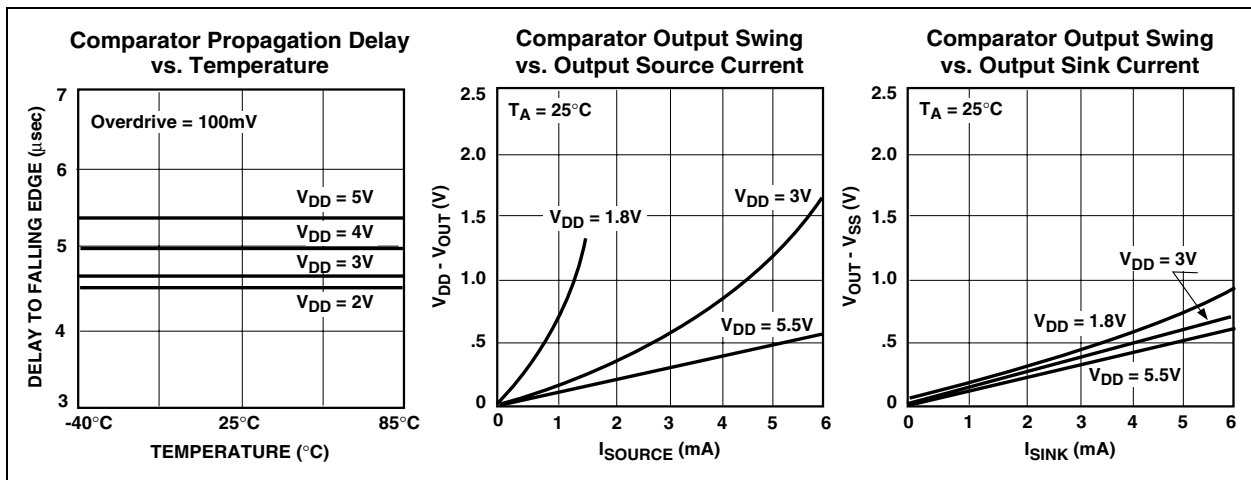
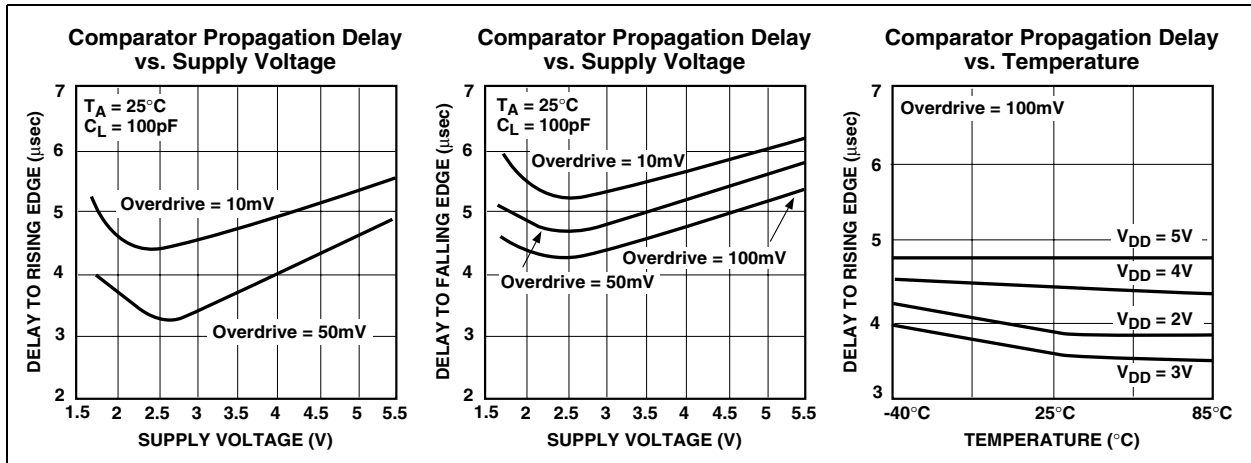


**FIGURE 4-3: COMPARATOR EXTERNAL HYSTERESIS CONFIGURATION**



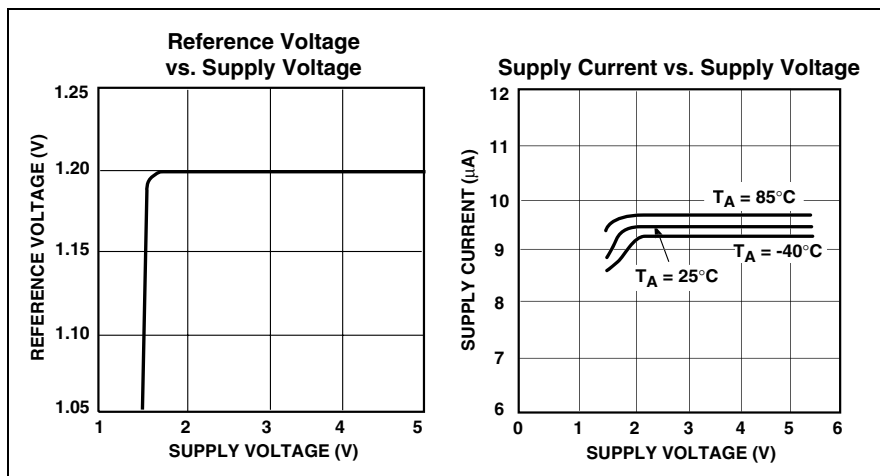
## 5.0 TYPICAL CHARACTERISTICS

**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)



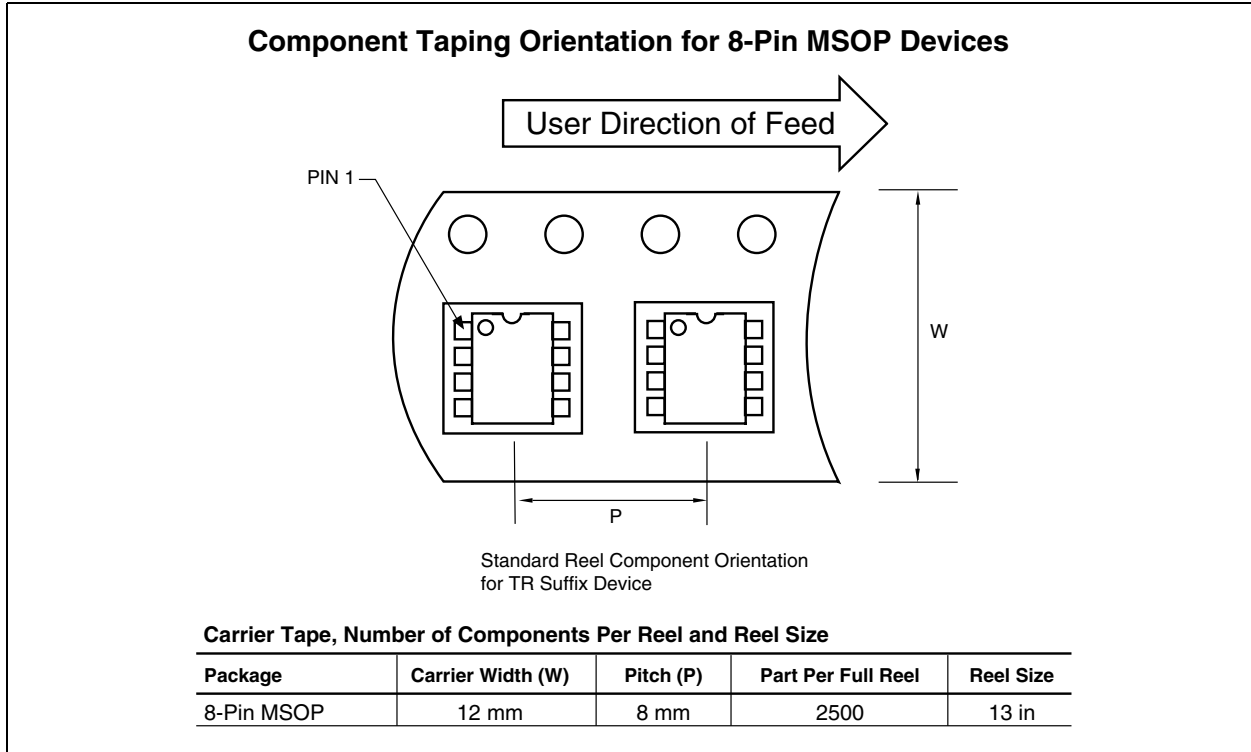


## 6.0 PACKAGING INFORMATION

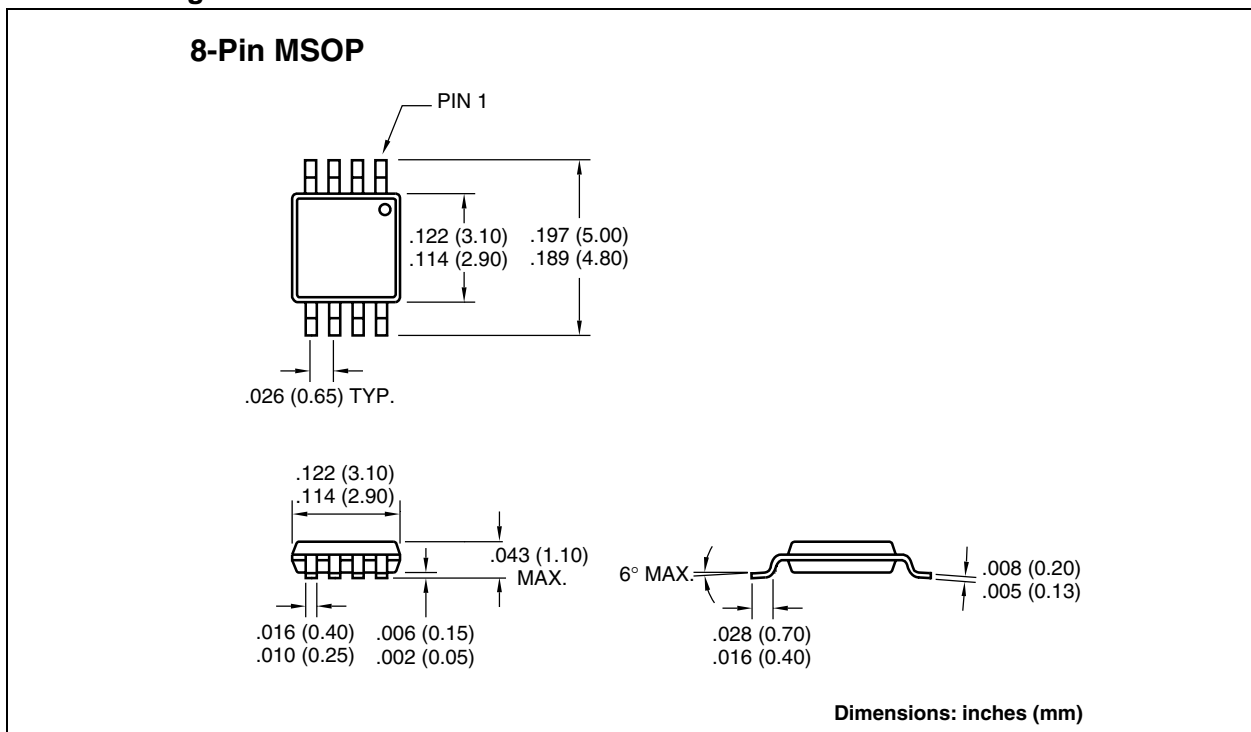
### 6.1 Package Marking Information

Package marking data not available at this time.

### 6.2 Taping Form



### 6.3 Package Dimensions



# TC1040

---

---

NOTES:

## **Sales and Support**

### **Data Sheets**

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
3. The Microchip Worldwide Site ([www.microchip.com](http://www.microchip.com))

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

### **New Customer Notification System**

Register on our web site ([www.microchip.com/cn](http://www.microchip.com/cn)) to receive the most current information on our products.

# TC1040

---

NOTES:

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

## Trademarks


The Microchip name and logo, the Microchip logo, FilterLab, KEELOQ, microID, MPLAB, PIC, PICmicro, PICMASTER, PICSTART, PRO MATE, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

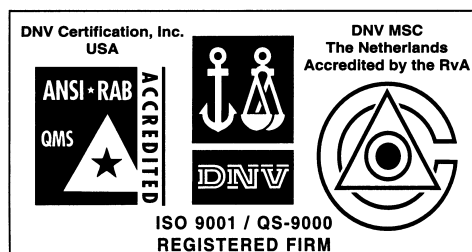
dsPIC, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, MXDEV, PICC, PICDEM, PICDEM.net, rfPIC, Select Mode and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A.

Serialized Quick Turn Programming (SQTP) is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2002, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.



*Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001 certified.*



# MICROCHIP

## WORLDWIDE SALES AND SERVICE

### AMERICAS

#### Corporate Office

2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200 Fax: 480-792-7277  
Technical Support: 480-792-7627  
Web Address: <http://www.microchip.com>

#### Rocky Mountain

2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7966 Fax: 480-792-7456

#### Atlanta

500 Sugar Mill Road, Suite 200B  
Atlanta, GA 30350  
Tel: 770-640-0034 Fax: 770-640-0307

#### Boston

2 Lan Drive, Suite 120  
Westford, MA 01886  
Tel: 978-692-3848 Fax: 978-692-3821

#### Chicago

333 Pierce Road, Suite 180  
Itasca, IL 60143  
Tel: 630-285-0071 Fax: 630-285-0075

#### Dallas

4570 Westgrove Drive, Suite 160  
Addison, TX 75001  
Tel: 972-818-7423 Fax: 972-818-2924

#### Detroit

Tri-Atria Office Building  
32255 Northwestern Highway, Suite 190  
Farmington Hills, MI 48334  
Tel: 248-538-2250 Fax: 248-538-2260

#### Kokomo

2767 S. Albright Road  
Kokomo, Indiana 46902  
Tel: 765-864-8360 Fax: 765-864-8387

#### Los Angeles

18201 Von Karman, Suite 1090  
Irvine, CA 92612  
Tel: 949-263-1888 Fax: 949-263-1338

#### New York

150 Motor Parkway, Suite 202  
Hauppauge, NY 11788  
Tel: 631-273-5305 Fax: 631-273-5335

#### San Jose

Microchip Technology Inc.  
2107 North First Street, Suite 590  
San Jose, CA 95131  
Tel: 408-436-7950 Fax: 408-436-7955

#### Toronto

6285 Northam Drive, Suite 108  
Mississauga, Ontario L4V 1X5, Canada  
Tel: 905-673-0699 Fax: 905-673-6509

### ASIA/PACIFIC

#### Australia

Microchip Technology Australia Pty Ltd  
Suite 22, 41 Rawson Street  
Epping 2121, NSW  
Australia  
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

#### China - Beijing

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Beijing Liaison Office  
Unit 915  
Bei Hai Wan Tai Bldg.  
No. 6 Chaoyangmen Beidajie  
Beijing, 100027, No. China  
Tel: 86-10-85282100 Fax: 86-10-85282104

#### China - Chengdu

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Chengdu Liaison Office  
Rm. 2401, 24th Floor,  
Ming Xing Financial Tower  
No. 88 TIDU Street  
Chengdu 610016, China  
Tel: 86-28-6766200 Fax: 86-28-6766599

#### China - Fuzhou

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Fuzhou Liaison Office  
Unit 28F, World Trade Plaza  
No. 71 Wusi Road  
Fuzhou 350001, China  
Tel: 86-591-7503506 Fax: 86-591-7503521

#### China - Shanghai

Microchip Technology Consulting (Shanghai)  
Co., Ltd.  
Room 701, Bldg. B  
Far East International Plaza  
No. 317 Xian Xia Road  
Shanghai, 200051  
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

#### China - Shenzhen

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Shenzhen Liaison Office  
Rm. 1315, 13/F, Shenzhen Kerry Centre,  
Renminnan Lu  
Shenzhen 518001, China  
Tel: 86-755-2350361 Fax: 86-755-2366086

#### Hong Kong

Microchip Technology Hongkong Ltd.  
Unit 901-6, Tower 2, Metroplaza  
223 Hing Fong Road  
Kwai Fong, N.T., Hong Kong  
Tel: 852-2401-1200 Fax: 852-2401-3431

#### India

Microchip Technology Inc.  
India Liaison Office  
Divyasree Chambers  
1 Floor, Wing A (A3/A4)  
No. 11, O'Shaugnessey Road  
Bangalore, 560 025, India  
Tel: 91-80-2290061 Fax: 91-80-2290062

### Japan

Microchip Technology Japan K.K.  
Benex S-1 6F  
3-18-20, Shinyokohama  
Kohoku-Ku, Yokohama-shi  
Kanagawa, 222-0033, Japan  
Tel: 81-45-471-6166 Fax: 81-45-471-6122

### Korea

Microchip Technology Korea  
168-1, Youngbo Bldg. 3 Floor  
Samsung-Dong, Kangnam-Ku  
Seoul, Korea 135-882  
Tel: 82-2-554-7200 Fax: 82-2-558-5934

### Singapore

Microchip Technology Singapore Pte Ltd.  
200 Middle Road  
#07-02 Prime Centre  
Singapore, 188980  
Tel: 65-6334-8870 Fax: 65-6334-8850

### Taiwan

Microchip Technology Taiwan  
11F-3, No. 207  
Tung Hua North Road  
Taipei, 105, Taiwan  
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

### EUROPE

#### Denmark

Microchip Technology Nordic ApS  
Regus Business Centre  
Lautrup høj 1-3  
Ballerup DK-2750 Denmark  
Tel: 45 4420 9895 Fax: 45 4420 9910

#### France

Microchip Technology SARL  
Parc d'Activite du Moulin de Massy  
43 Rue du Saule Trapu  
Batiment A - 1er Etage  
91300 Massy, France  
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

#### Germany

Microchip Technology GmbH  
Gustav-Heinemann Ring 125  
D-81739 Munich, Germany  
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

#### Italy

Microchip Technology SRL  
Centro Direzionale Colleoni  
Palazzo Taurus 1 V. Le Colleoni 1  
20041 Agrate Brianza  
Milan, Italy  
Tel: 39-039-65791-1 Fax: 39-039-6899883

#### United Kingdom

Arizona Microchip Technology Ltd.  
505 Eskdale Road  
Winnersh Triangle  
Wokingham  
Berkshire, England RG41 5TU  
Tel: 44 118 921 5869 Fax: 44-118 921-5820

03/01/02

