



# MICROCHIP

# TC1037/TC1038/TC1039

## Linear Building Block – Single Comparator in SOT Packages

### Features

- Tiny SOT-23A Packages
- Optimized for Single Supply Operation
- Ultra Low Input Bias Current: Less than 100pA
- Low Quiescent Current: 4µA (TC1037), Shutdown Mode: 4µA, 0.05µA (TC1038), 6µA (TC1039)
- Shutdown Mode (TC1038)
- 2.0% Accurate Independent Voltage Reference (TC1039)
- Rail-to-Rail Inputs and Outputs
- Operation Down to  $V_{DD} = 1.8V$

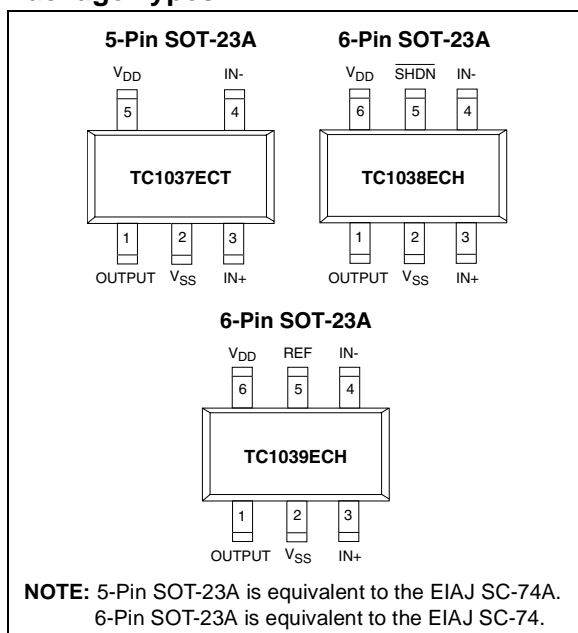
### Applications

- Power Management Circuits
- Battery Operated Equipment
- Consumer Products

### Device Selection Table

Part Number	Package	Temperature Range
TC1037CECT	5-Pin SOT-23A	-40°C to +85°C
TC1038CECH	6-Pin SOT-23A	-40°C to +85°C
TC1039CECH	6-Pin SOT-23A	-40°C to +85°C

### Package Types



### General Description

The TC1037/TC1038/TC1039 are single, low-power comparators designed for low-power applications.

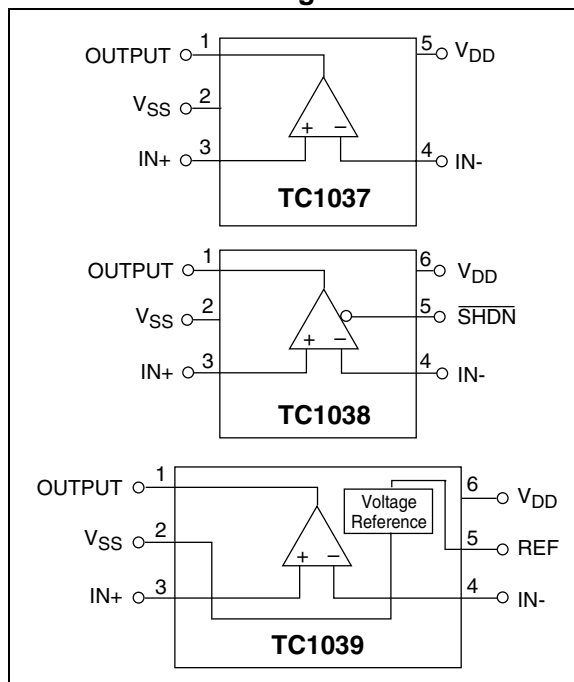
These comparators are specifically designed for operation from a single supply. However, operation from dual supplies also is possible, and power supply current is independent of the magnitude of the power supply voltage. The TC1037/TC1038/TC1039 operate from two 1.5V alkaline cells down to  $V_{DD} = 1.8V$ . Active supply current is 4µA for the TC1037/TC1038 and 6µA for the TC1039. Input and output swing of these devices is rail-to-rail.

An active low shutdown input,  $\overline{SHDN}$ , is available on the TC1038 and disables the comparator, placing its output in a high-impedance state. The TC1038 draws only 0.05µA (typical) when the shutdown mode is active.

An internally biased 1.20V bandgap reference is included in the TC1039. The reference is accurate to 2.0 percent tolerance. This reference is independent of the comparator in the TC1039.

Packaged in a 5-Pin SOT-23A (TC1037) or 6-Pin SOT-23A (TC1038/TC1039), these single comparators are ideal for applications requiring high integration, small size and low power.

### Functional Block Diagram



# TC1037/TC1038/TC1039

## 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.

### TC1037/TC1038/TC1039 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 (TC1039) (TC1037/TC1038)	— —	6 4	10 8	$\mu A$ $\mu A$	All Outputs Unloaded, $\overline{SHDN} = V_{DD}$ for TC1038
$I_{SHDN}$	Supply Current Shutdown Mode (TC1038 Only)	—	—	0.3	$\mu A$	$\overline{SHDN} = V_{SS}$
<b>Shutdown Input (TC1038 Only)</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>Comparator</b>						
$R_{OUT(SD)}$	Output Resistance in Shutdown	20	—	—	M $\Omega$	$\overline{SHDN} = V_{SS}$ (TC1038 Only)
$C_{OUT(SD)}$	Output Capacitance in Shutdown	—	—	5	pF	$\overline{SHDN} = V_{SS}$ (TC1038 Only)
$T_{SEL}$	Select Time	—	20	—	$\mu sec$	$V_{OUT}$ Valid from $\overline{SHDN} = V_{IH}$ $R_L = 10k\Omega$ to $V_{SS}$ (TC1038 Only)
$T_{DESEL}$	Deselect Time	—	500	—	nsec	$V_{OUT}$ Valid from $\overline{SHDN} = V_{IL}$ $R_L = 10k\Omega$ to $V_{SS}$
$V_{ICMR}$	Common Mode Input Voltage Range	$V_{SS} - 0.2$	—	$V_{DD} + 0.2$	V	
$A_{VOL}$	Large Signal Voltage Gain	—	100	—	V/mV	$R_L = 10k\Omega$ , $V_{DD} = 5V$
GBWP	Gain Bandwidth Product	—	90	—	kHz	$V_{DD} = 1.8V$ to 5.5V; $V_O = V_{DD}$ to $V_{SS}$
$V_{OS}$	Input Offset Voltage	-5 -5	—	+5 +5	mV mV	$V_{DD} = 3V$ , $V_{CM} = 1.5V$ , $T_A = 25^\circ C$ , $T_A = -40^\circ C$ to 85°C
$I_B$	Input Bias Current	—	—	$\pm 100$	pA	$T_A = 25^\circ C$ ; $IN+$ , $IN-$ = $V_{DD}$ 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 $V_{DD}$
CMRR	Common Mode Rejection Ratio	66	—	—	dB	$T_A = 25^\circ C$ ; $V_{DD} = 5V$ ; $V_{CM} = V_{DD}$ to $V_{SS}$
PSRR	Power Supply Rejection Ratio	60	—	—	dB	$T_A = 25^\circ C$ ; $V_{CM} = 1.2V$ ; $V_{DD} = 1.8V$ to 5V
$I_{SRC}$	Output Source Current	1	—	—	mA	$IN+ = V_{DD}$ , $IN- = V_{SS}$ Output Shorted to $V_{SS}$ $V_{DD} = 1.8V$
$I_{SINK}$	Output Sink Current	2	—	—	mA	$IN+ = V_{SS}$ , $IN- = V_{SS}$ Output Shorted to $V_{SS}$ $V_{DD} = 1.8V$
$T_{PD1}$	Response Time	—	4	—	$\mu sec$	100mV Overdrive, $C_L = 100pF$
$T_{PD2}$	Response Time	—	6	—	$\mu sec$	10mV Overdrive, $C_L = 100pF$

# TC1037/TC1038/TC1039

## TC1037/TC1038/TC1039 ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Typical values apply at 25°C and  $V_{DD} = 3.0V$ . Minimum and maximum values apply for  $T_A = -40^\circ$  to  $+85^\circ C$  and  $V_{DD} = 1.8V$  to  $5.5V$ , unless otherwise specified.

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
<b>Voltage Reference (TC1039 Only)</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	
$E_{VREF}$	Noise Voltage	—	20	—	$\mu V_{RMS}$	100Hz to 100kHz
$e_{VREF}$	Noise Voltage Density	—	1.0	—	$\mu V/\sqrt{HZ}$	1kHz

# TC1037/TC1038/TC1039

## 2.0 PIN DESCRIPTIONS

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

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

Pin No. TC1037 (5-Pin SOT-23A)	Symbol	Description
1	OUTPUT	Comparator output.
2	$V_{SS}$	Negative power supply.
3	IN+	Comparator non-inverting input.
4	IN-	Comparator inverting input.
5	$V_{DD}$	Positive power supply.

Pin No. TC1038 (6-Pin SOT-23A)	Symbol	Description
1	OUTPUT	Comparator output.
2	$V_{SS}$	Negative power supply.
3	IN+	Comparator non-inverting input.
4	IN-	Comparator inverting input.
5	$\overline{SHDN}$	Active low shutdown input (TC1038 only). A low input on this pin disables the comparator and places the output terminal in a high impedance state.
6	$V_{DD}$	Positive power supply.

Pin No. TC1039 (6-Pin SOT-23A)	Symbol	Description
1	OUTPUT	Comparator output.
2	$V_{SS}$	Negative power supply.
3	IN+	Comparator non-inverting input.
4	IN-	Comparator inverting input.
5	REF	1.20V bandgap voltage reference output (TC1039 only).
6	$V_{DD}$	Positive power supply.

## 3.0 DETAILED DESCRIPTION

The TC1037/TC1038/TC1039 are a series of very low power, linear building block products targeted at low voltage, single supply applications. The TC1037/TC1038/TC1039 minimum operating voltage is 1.8V and typical supply current is only 4µA for the TC1037 and TC1038 (fully enabled) and 6µA for the TC1039.

### 3.1 Comparator

The TC1037/8/9 contain one comparator. 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 comparator exhibits a propagation delay and supply current which is largely independent of supply voltage. The low input bias current and offset voltage makes it suitable for high impedance precision applications.

The TC1038 comparator is disabled during shutdown and has a high impedance output.

### 3.2 Voltage Reference

A 2.0% tolerance, internally biased, 1.20V bandgap voltage reference is included in the TC1039. It has a push-pull output capable of sourcing and sinking at least 50µA.

### 3.3 Shutdown Input (TC1038 Only)

$\overline{\text{SHDN}}$  at  $V_{IL}$  disables the comparator and reduces the supply current to less than 0.3µA. The  $\overline{\text{SHDN}}$  input cannot be allowed to float. When not used, connect it to  $V_{DD}$ . The comparator's output is in a high impedance state when the TC1038 is disabled. The comparator's inputs can be driven from rail-to-rail by an external voltage when the TC1038 is disabled. 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 TC1037/TC1038/TC1039 family 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 External Hysteresis (Comparator)

Hysteresis can be set externally with two resistors using positive feedback techniques (see Figure 4-1). 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:

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

## 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 TC1034, a TC1037 and a TC1039, and only six external resistors. AMP 1 is a simple buffer, while CMPTR1 and CMPTR2 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 2.0V (typical). Total current consumed by this circuit is typically 16 $\mu$ A at 3V. Resistors R5 and R6 provide hysteresis for comparators CMPTR1 and CMPTR2, respectively.

## 4.3 32.768 kHz “Time Of Day Clock” Crystal Controlled Oscillator

A very stable oscillator driver can be designed by using a crystal resonator as the feedback element. Figure 4-3 shows a typical application circuit using this technique to develop a clock driver for a Time Of Day (TOD) clock chip. The value of  $R_A$  and  $R_B$  determine the DC voltage level at which the comparator trips – in this case one-half of  $V_{DD}$ . The RC time constant of  $R_C$  and  $C_A$  should be set several times greater than the crystal oscillator's period, which will ensure a 50% duty cycle by maintaining a DC voltage at the inverting comparator input equal to the absolute average of the output signal.

## 4.4 Non-Retriggerable One Shot Multivibrator

Using two comparators, a non-retriggerable one shot multivibrator can be designed using the circuit configuration of Figure 4-4. A key feature of this design is that the pulse width is independent of the magnitude of the supply voltage because the charging voltage and the intercept voltage are a fixed percentage of  $V_{DD}$ . In addition, this one shot is capable of pulse width with as much as a 99% duty cycle and exhibits input lockout to ensure that the circuit will not re-trigger before the output pulse has completely timed out. The trigger level is the voltage required at the input to raise the voltage at node A higher than the voltage at node B, and is set by the resistive divider R4 and R10 and the impedance network composed of R1, R2 and R3. When the one shot has been triggered, the output of CMPTR2 is high, causing the reference voltage at the non-inverting input of CMPTR1 to go to  $V_{DD}$ . This prevents any additional input pulses from disturbing the circuit until the output pulse has timed out.

The value of the timing capacitor C1 must be small enough to allow CMPTR1 to discharge C1 to a diode voltage before the feedback signal from CMPTR2 (through R10) switches CMPTR1 to its high state and allows C1 to start an exponential charge through R5. Proper circuit action depends upon rapidly discharging C1 through the voltage set by R6, R9 and D2 to a final voltage of a small diode drop. Two propagation delays after the voltage on C1 drops below the level on the non-inverting input of CMPTR2, the output of CMPTR1 switches to the positive rail and begins to charge C1 through R5. The time delay which sets the output pulse width results from C1 charging to the reference voltage set by R6, R9 and D2, plus four comparator propagation delays. When the voltage across C1 charges beyond the reference, the output pulse returns to ground and the input is again ready to accept a trigger signal.

## 4.5 Oscillators and Pulse Width Modulators

Microchip's linear building block comparators adapt well to oscillator applications for low frequencies (less than 100kHz). Figure 4-5 shows a symmetrical square wave generator using a minimum number of components. The output is set by the RC time constant of R4 and C1, and the total hysteresis of the loop is set by R1, R2 and R3. The maximum frequency of the oscillator is limited only by the large signal propagation delay of the comparator in addition to any capacitive loading at the output which degrades the slew rate.

To analyze this circuit, assume that the output is initially high. For this to occur, the voltage at the inverting input must be less than the voltage at the non-inverting input. Therefore, capacitor C1 is discharged. The voltage at the non-inverting input ( $V_H$ ) is:

**EQUATION 4-5:**

$$V_H = \frac{R2(V_{DD})}{[R2 + (R1 \parallel R3)]}$$

where, if  $R1 = R2 = R3$ , then:

**EQUATION 4-6:**

$$V_H = \frac{2(V_{DD})}{3}$$

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Capacitor C1 will charge up through R4. When the voltage of the comparator's inverting input is equal to  $V_H$ , the comparator output will switch. With the output at ground potential, the value at the non-inverting input terminal ( $V_L$ ) is reduced by the hysteresis network to a value given by:

**EQUATION 4-7:**

$$V_L = \frac{V_{DD}}{3}$$

Using the same resistors as before, capacitor C1 must now discharge through R4 toward ground. The output will return to a high state when the voltage across the capacitor has discharged to a value equal to  $V_L$ . The period of oscillation will be twice the time it takes for the RC circuit to charge up to one half its final value. The period can be calculated from:

**EQUATION 4-8:**

$$\frac{1}{\text{FREQ}} = 2(0.694)(R4)(C1)$$

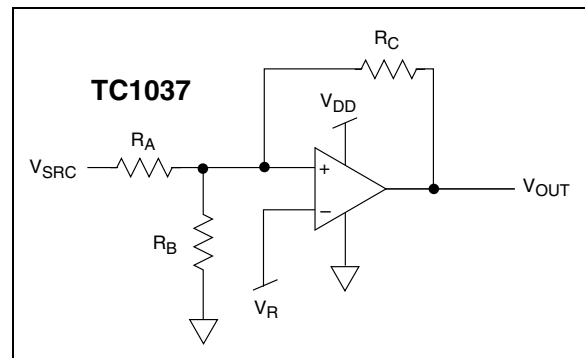
The frequency stability of this circuit should only be a function of the external component tolerances.

Figure 4-6 shows the circuit for a pulse width modulator circuit. It is essentially the same as in Figure 4-5 with the addition of an input control voltage. When the input control voltage is equal to one-half  $V_{DD}$ , operation is

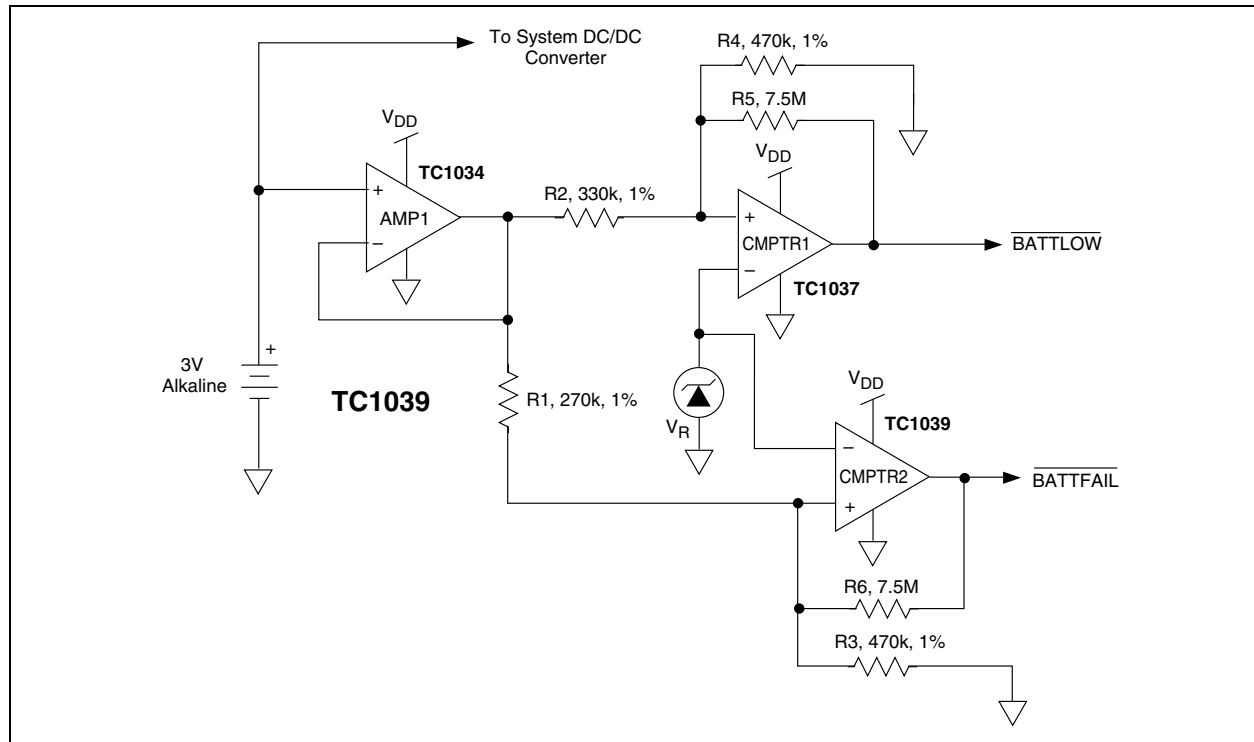
basically the same as described for the free-running oscillator. If the input control voltage is moved above or below one-half  $V_{DD}$ , the duty cycle of the output square wave will be altered. This is because the addition of the control voltage at the input has now altered the trip points. The equations for these trip points are shown in Figure 4-6 (see  $V_H$  and  $V_L$ ).

Pulse width sensitivity to the input voltage variations can be increased by reducing the value of R6 from 10K $\Omega$  and conversely, sensitivity will be reduced by increasing the value of R6. The values of R1 and C1 can be varied to produce the desired center frequency.

**FIGURE 4-1: COMPARATOR EXTERNAL HYSTERESIS CONFIGURATION**



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



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FIGURE 4-3: 32.768 kHz "TIME OF DAY" CLOCK OSCILLATOR

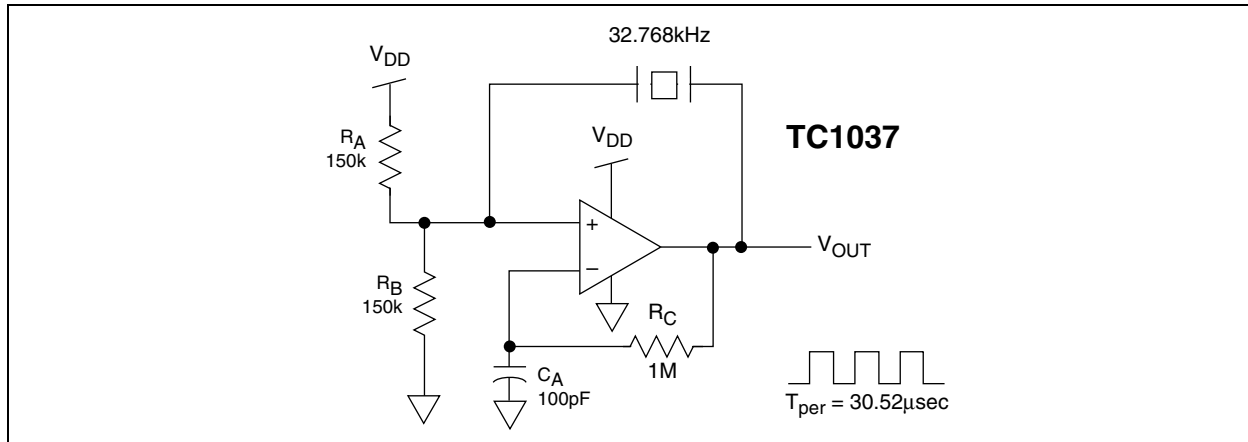


FIGURE 4-4: NON-RETRIGGERABLE MULTIVIBRATOR

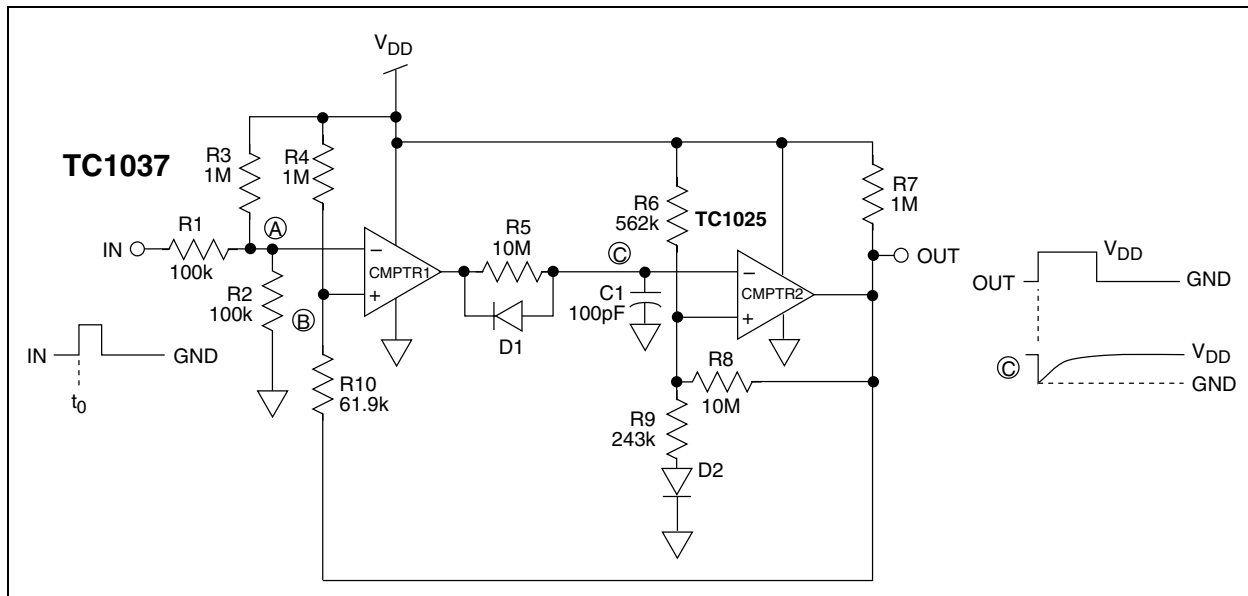
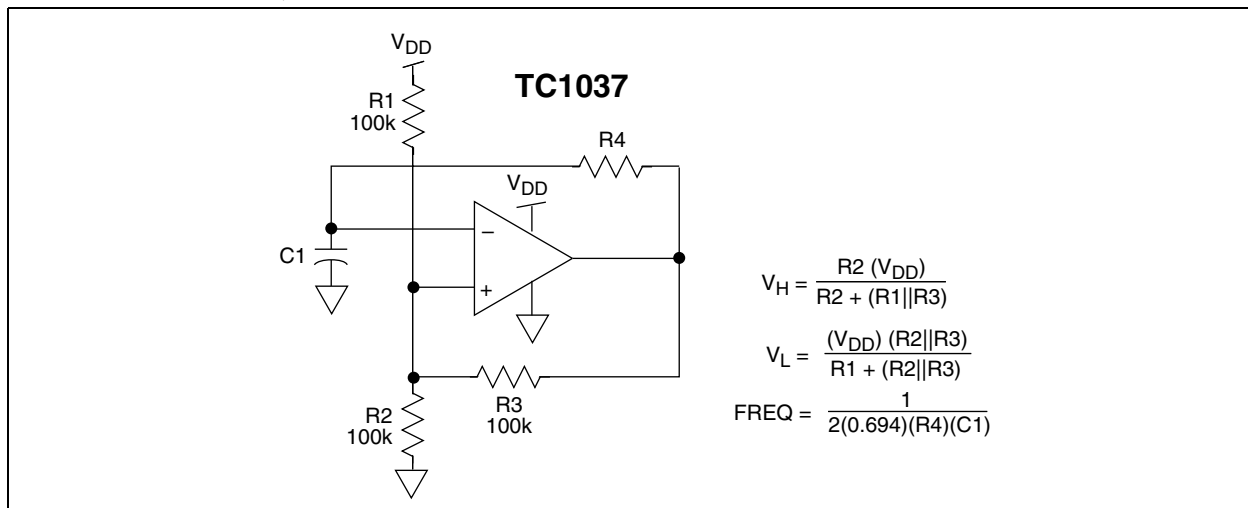
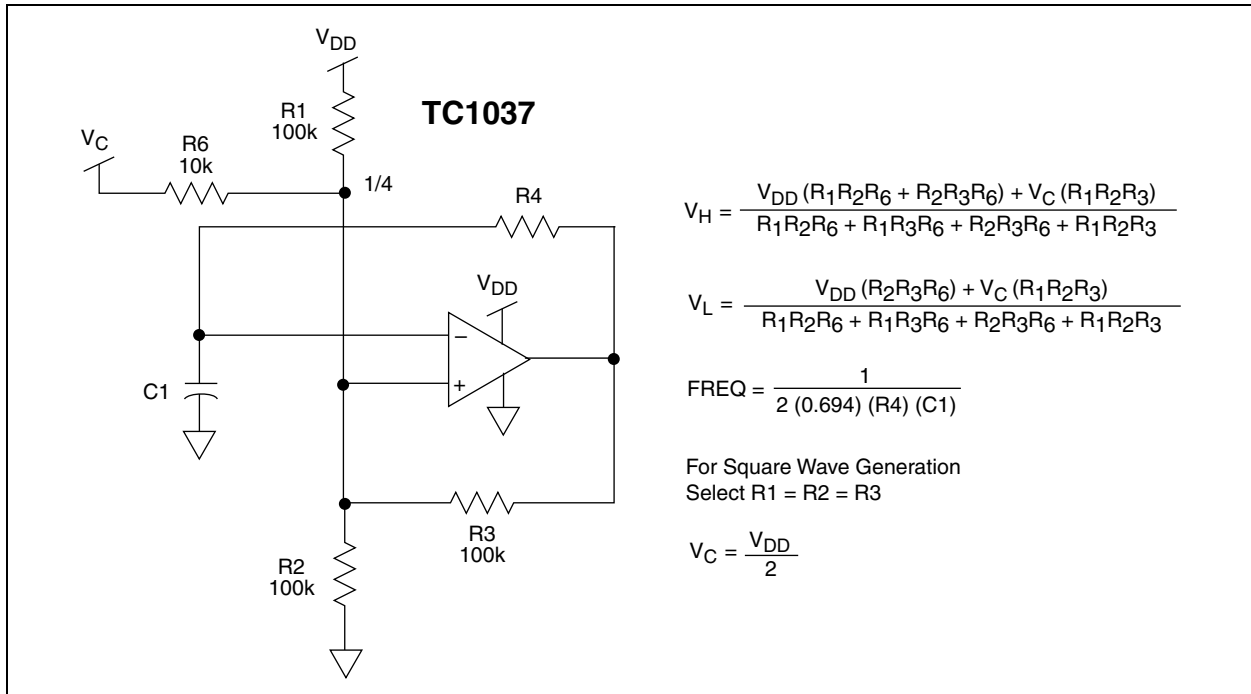


FIGURE 4-5: SQUARE WAVE GENERATOR





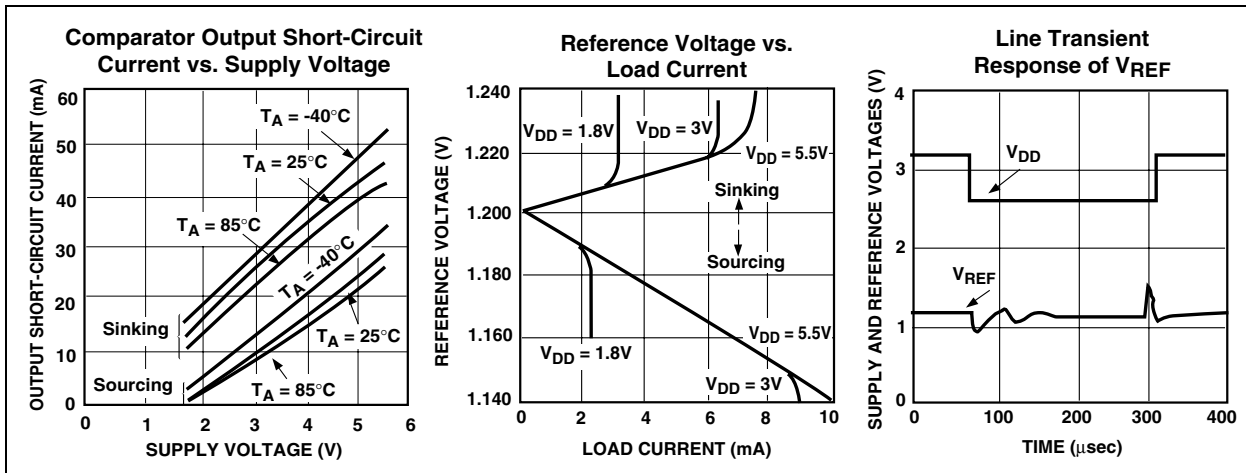
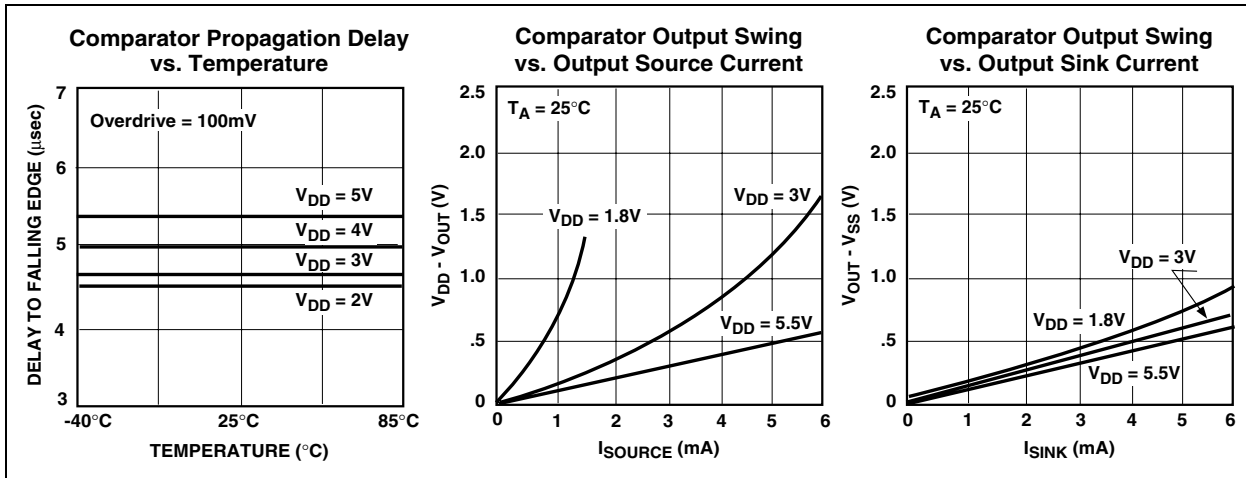
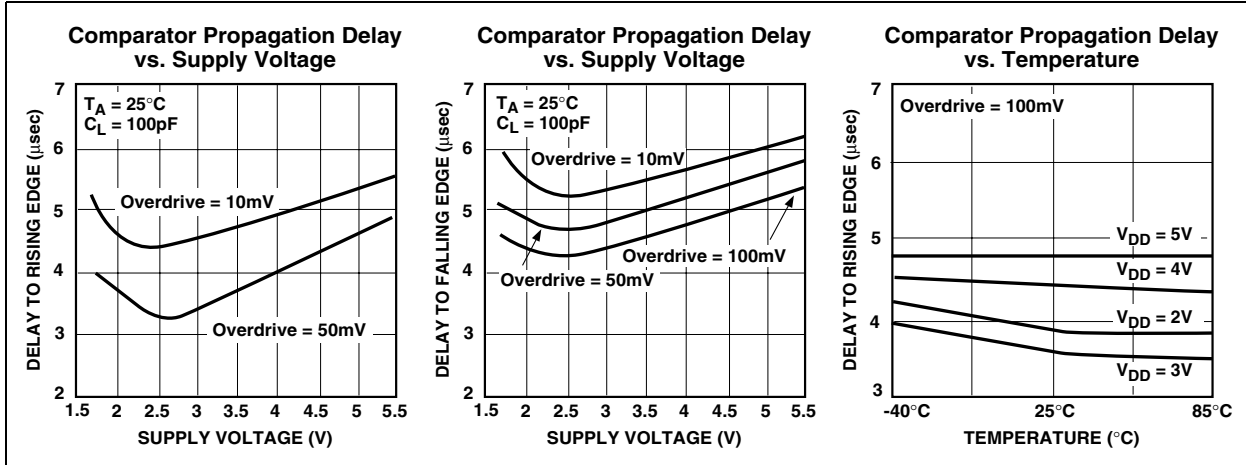
**FIGURE 4-6: PULSE WIDTH MODULATOR**



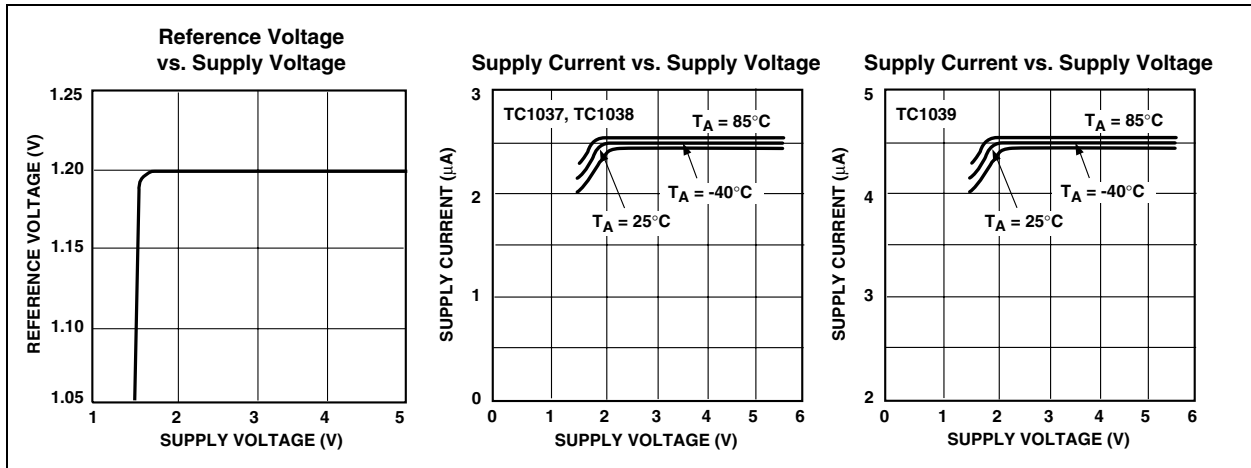
# TC1037/TC1038/TC1039

## 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.



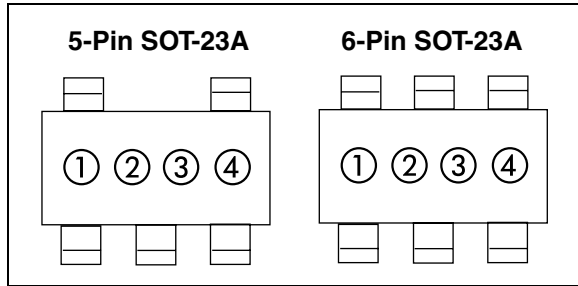
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)



# TC1037/TC1038/TC1039

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information



1 & 2 = part number code + temperature range and voltage

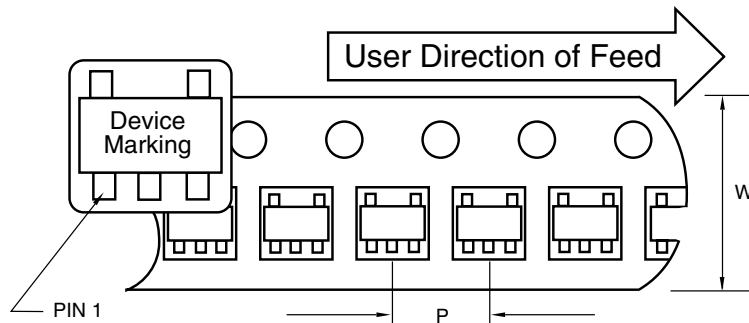
Part Number	Code
TC1037CECT	AR
TC1038CECH	AS
TC1039CECH	AT

3 = year and quarter code

4 = lot ID number

### 6.2 Taping Form

#### Component Taping Orientation for 5-Pin SOT-23A (EIAJ SC-74A) Devices



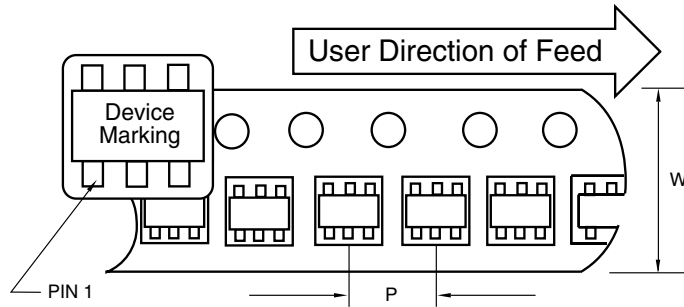
Standard Reel Component Orientation  
TR Suffix Device  
(Mark Right Side Up)

#### Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
5-Pin SOT-23A	8 mm	4 mm	3000	7 in

## 6.3 Taping Form (Continued)

### Component Taping Orientation for 6-Pin SOT-23A (EIAJ SC-74) Devices



Standard Reel Component Orientation  
For TR Suffix Device  
(Mark Right Side Up)

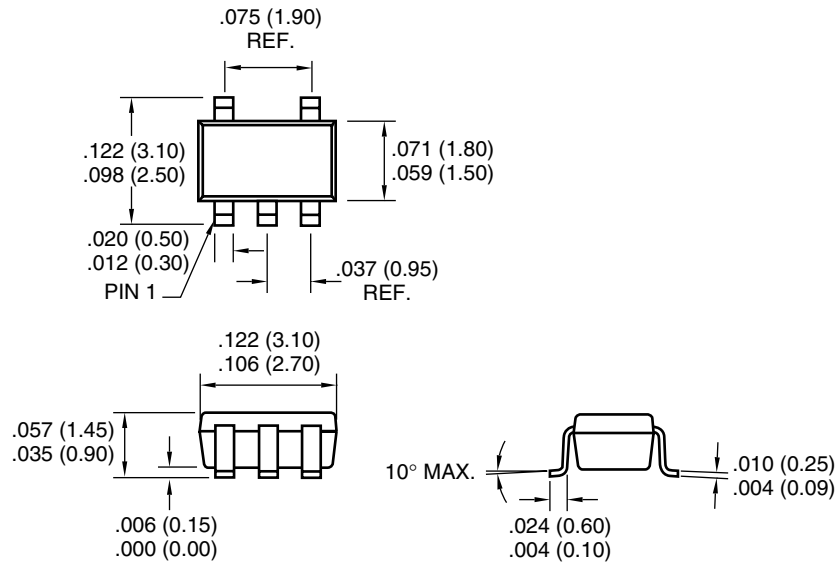
#### Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
6-Pin SOT-23A	8 mm	4 mm	3000	7 in

# TC1037/TC1038/TC1039

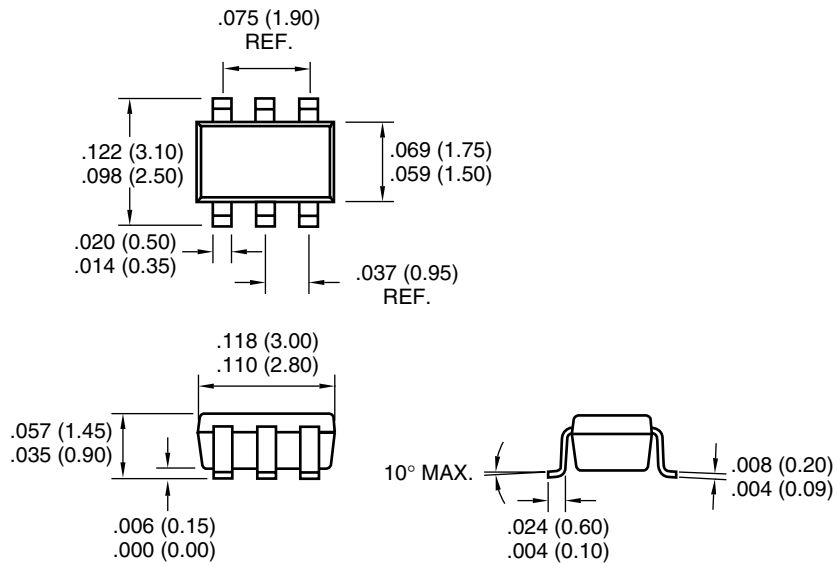
## 6.3 Package Dimensions

### SOT-23A-5



Dimensions: inches (mm)

### SOT-23A-6



Dimensions: inches (mm)

## **Sales and Support**

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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.

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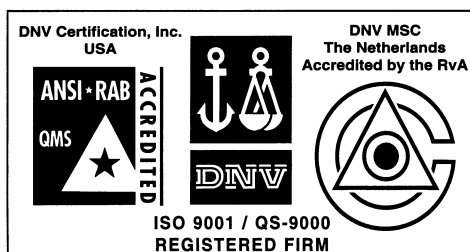
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*Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company's quality system processes 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.*



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