



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: 4 μ A (TC1037), Shutdown Mode: 4 μ A, 0.05 μ A (TC1038), 6 μ A (TC1039)
- Shutdown Mode (TC1038)
- 2.0% Accurate Independent Voltage Reference (TC1039)
- Rail-to-Rail Inputs and Outputs
- Operation Down to $V_{DD} = 1.8V$

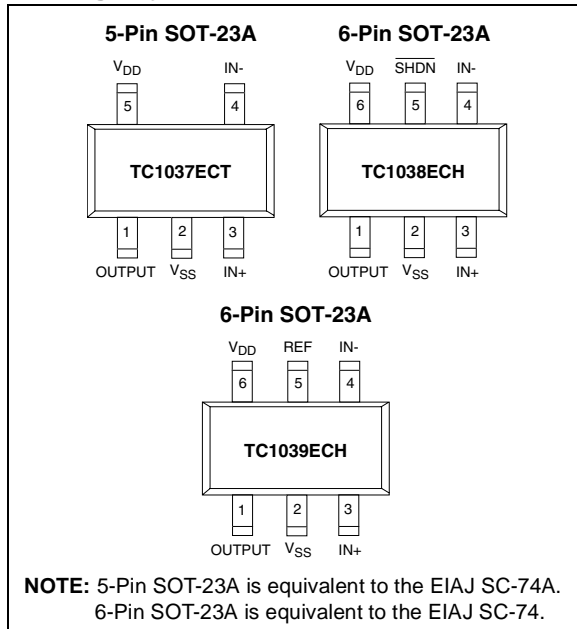
Applications

- 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.

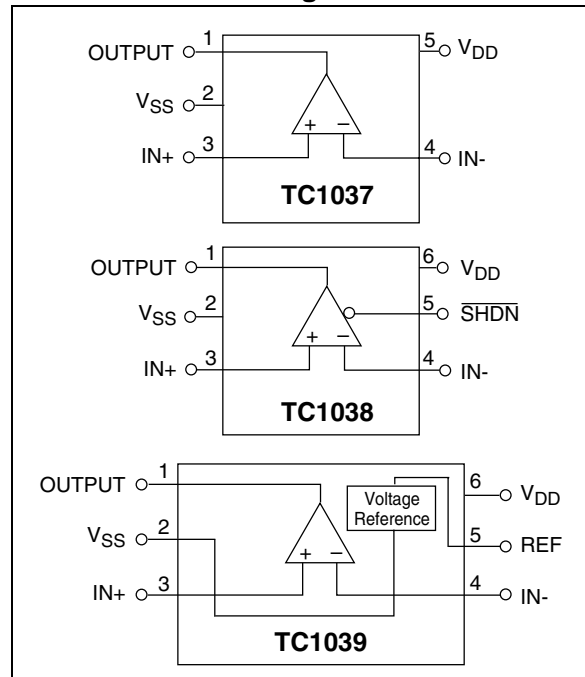
These comparators are specifically designed for operation from a single supply. However, operation from dual supplies also is possible, and power supply current is independent of the magnitude of the power supply voltage. The TC1037/TC1038/TC1039 operate from two 1.5V alkaline cells down to $V_{DD} = 1.8V$. Active supply current is 4 μ A for the TC1037/TC1038 and 6 μ A 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 0.05 μ A (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	μA μA	All Outputs Unloaded, $\overline{SHDN} = V_{DD}$ for TC1038
I_{SHDN}	Supply Current Shutdown Mode (TC1038 Only)	—	—	0.3	μA	$\overline{SHDN} = V_{SS}$
Shutdown Input (TC1038 Only)						
V_{IH}	Input High Threshold	80% V_{DD}	—	—	V	
V_{IL}	Input Low Threshold	—	—	20% V_{DD}	V	
I_{SI}	Shutdown Input Current	—	—	± 100	nA	
Comparator						
$R_{OUT(SD)}$	Output Resistance in Shutdown	20	—	—	M Ω	$\overline{SHDN} = V_{SS}$ (TC1038 Only)
$C_{OUT(SD)}$	Output Capacitance in Shutdown	—	—	5	pF	$\overline{SHDN} = V_{SS}$ (TC1038 Only)
T_{SEL}	Select Time	—	20	—	μsec	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	—	—	± 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	—	μsec	100mV Overdrive, $C_L = 100pF$
T_{PD2}	Response Time	—	6	—	μsec	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
Voltage Reference (TC1039 Only)						
V_{REF}	Reference Voltage	1.176	1.200	1.224	V	
$I_{REF(SOURCE)}$	Source Current	50	—	—	μA	
$I_{REF(SINK)}$	Sink Current	50	—	—	μA	
$C_{L(REF)}$	Load Capacitance	—	—	100	pF	
E_{VREF}	Noise Voltage	—	20	—	μV_{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	$\overline{\text{SHDN}}$	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 $\overline{\text{BATT LOW}}$, while resistors R1 and R3 set the detection threshold for $\overline{\text{BATT FAIL}}$. The component values shown assert $\overline{\text{BATT LOW}}$ at 2.2V (typical) and $\overline{\text{BATT FAIL}}$ at 2.0V (typical). Total current consumed by this circuit is typically 16 μ 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:

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

TC1037/TC1038/TC1039

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 Ω 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

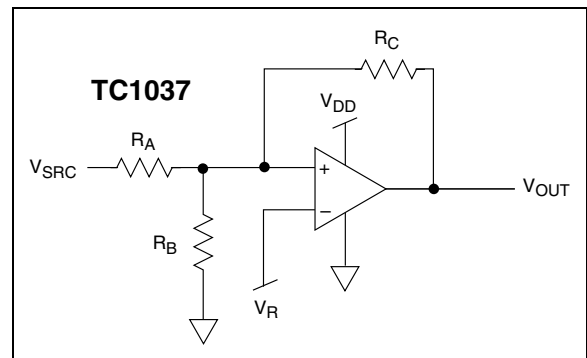
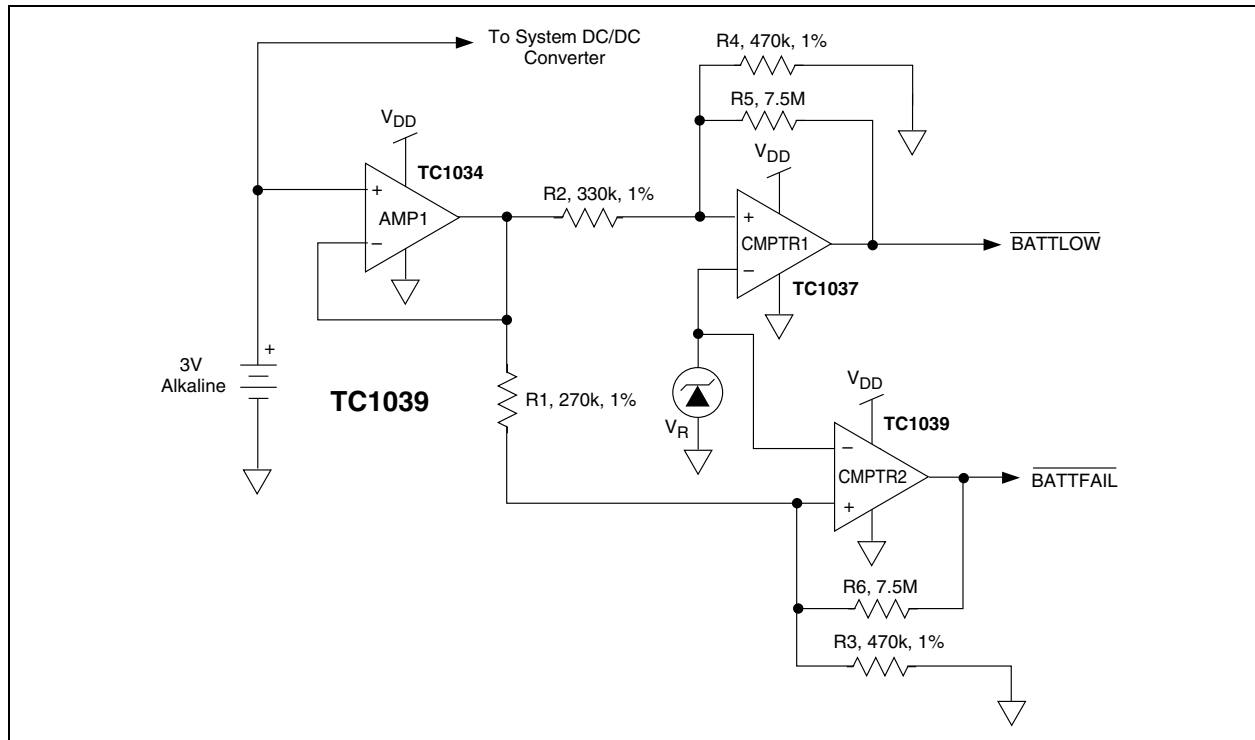


FIGURE 4-2: PRECISION BATTERY MONITOR



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

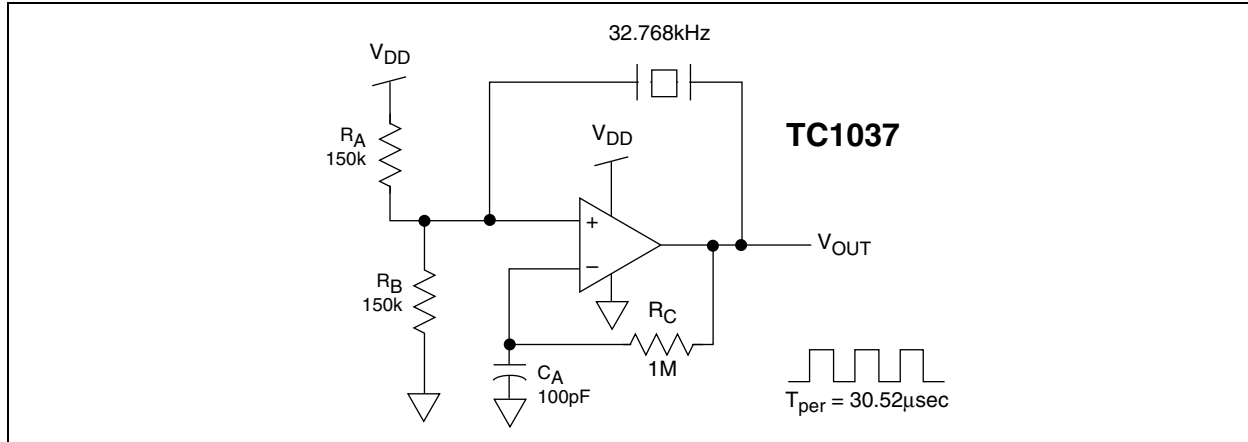


FIGURE 4-4: NON-RETRIGGERABLE MULTIVIBRATOR

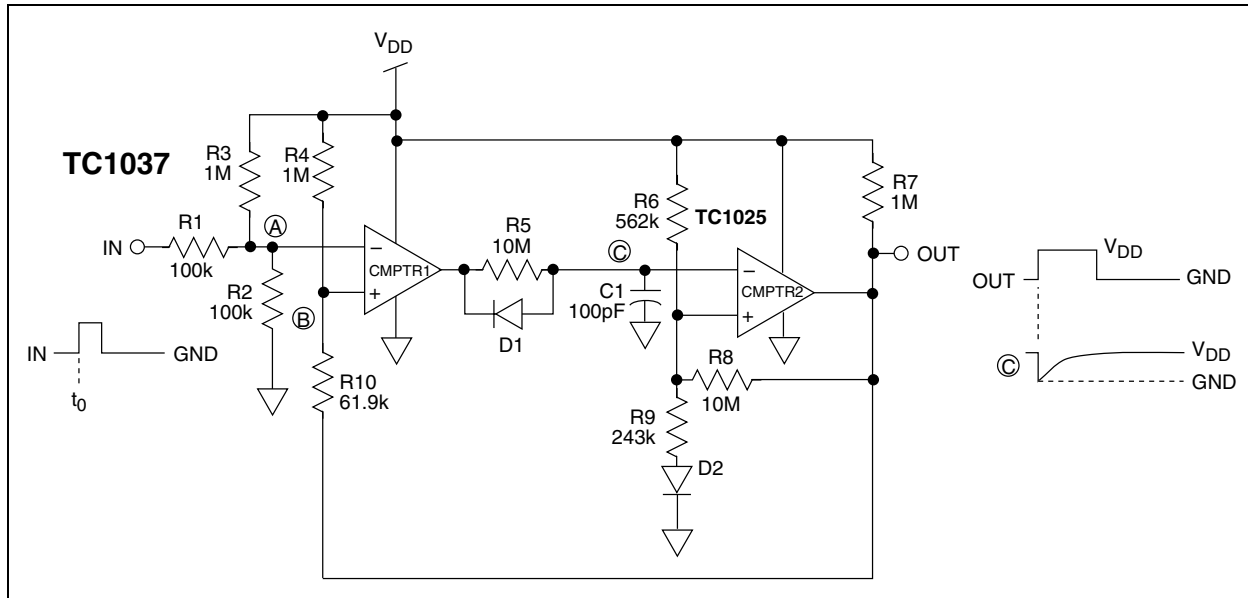


FIGURE 4-5: SQUARE WAVE GENERATOR

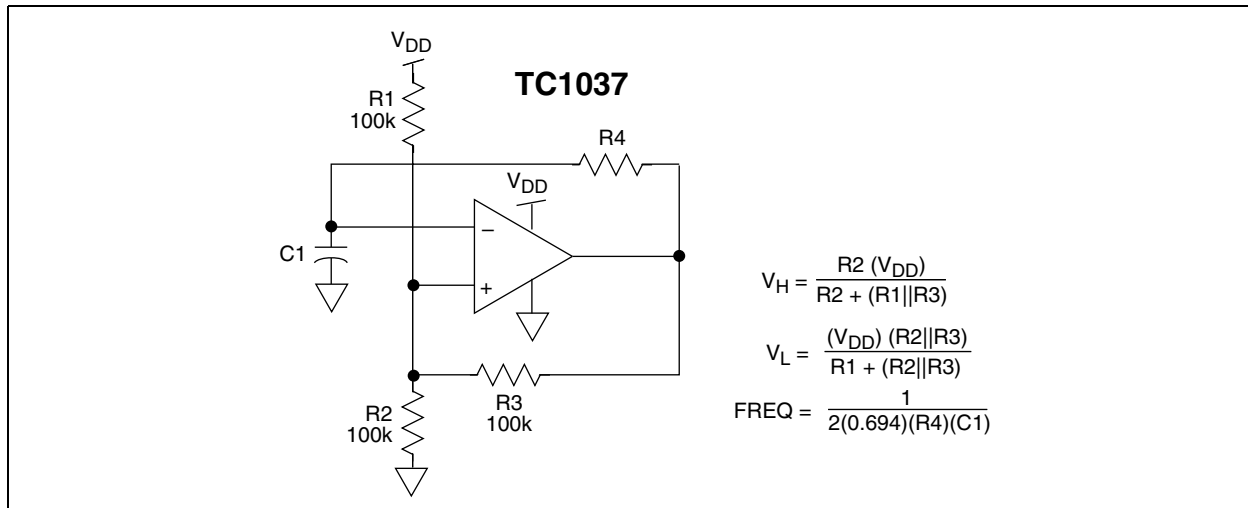
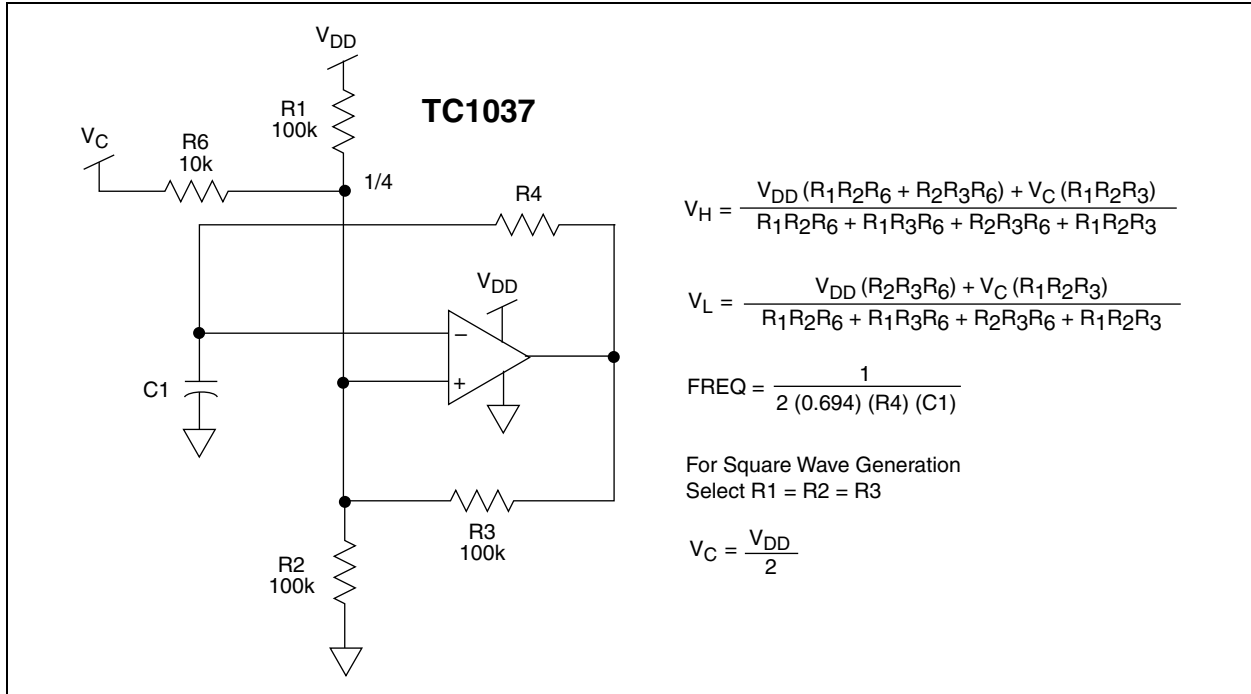


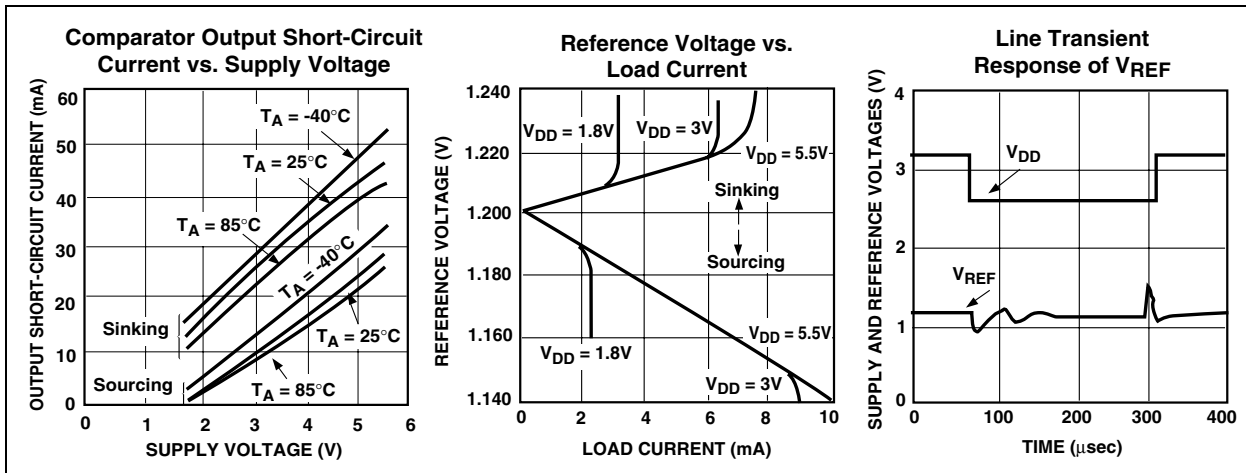
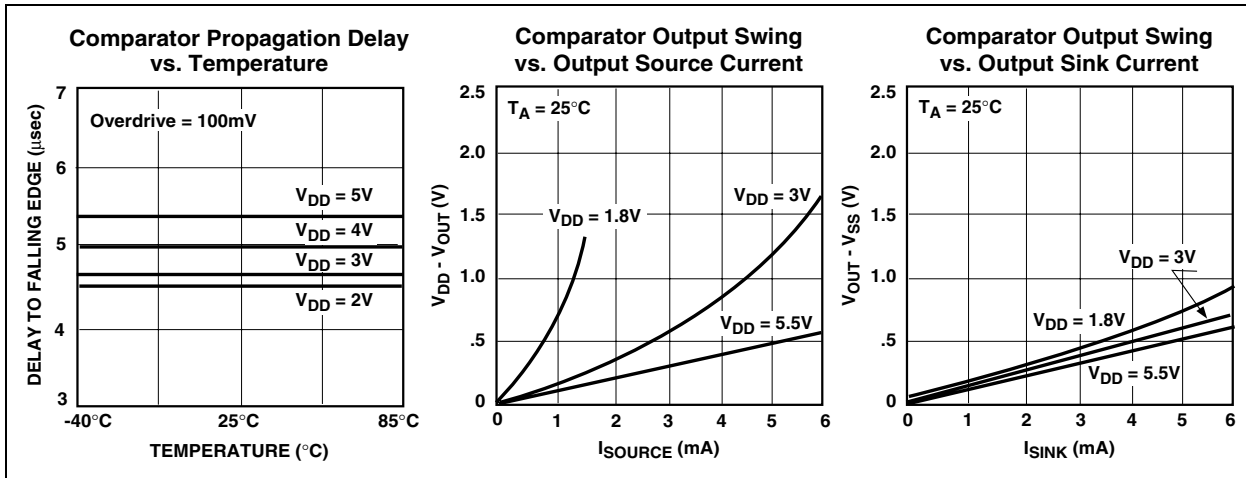
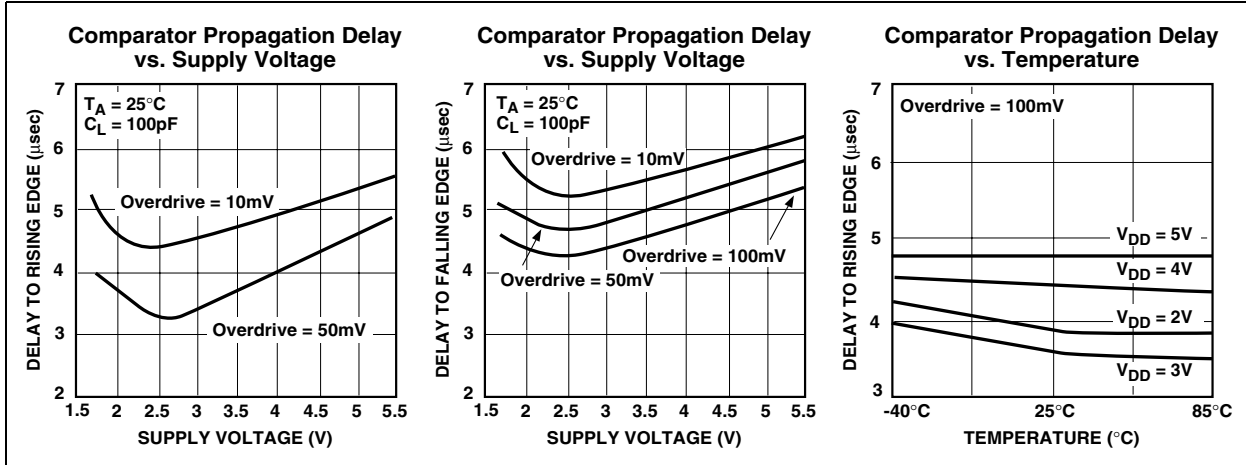
FIGURE 4-6: PULSE WIDTH MODULATOR



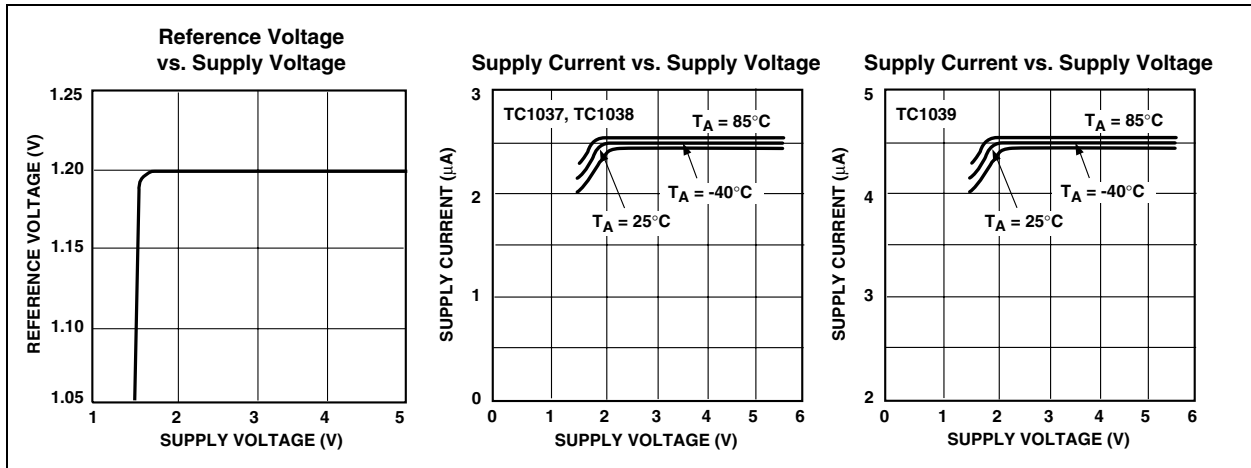
TC1037/TC1038/TC1039

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.



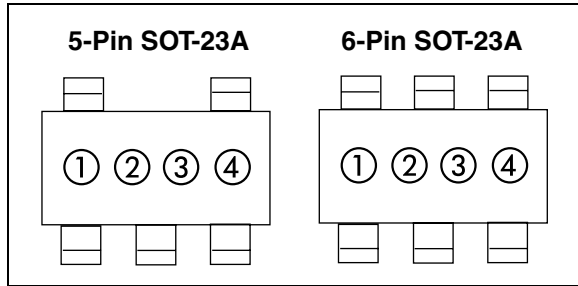
5.0 TYPICAL CHARACTERISTICS (CONTINUED)



TC1037/TC1038/TC1039

6.0 PACKAGING INFORMATION

6.1 Package Marking Information



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

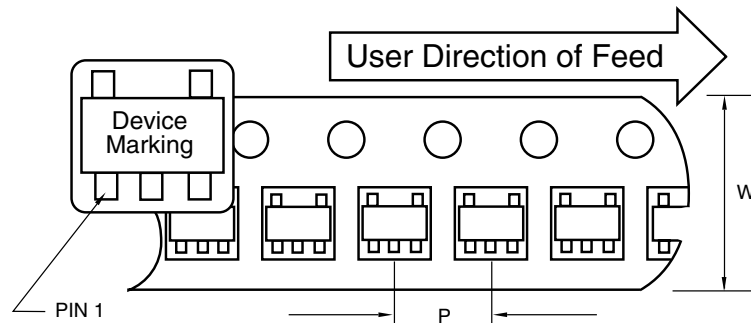
Part Number	Code
TC1037CECT	AR
TC1038CECH	AS
TC1039CECH	AT

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



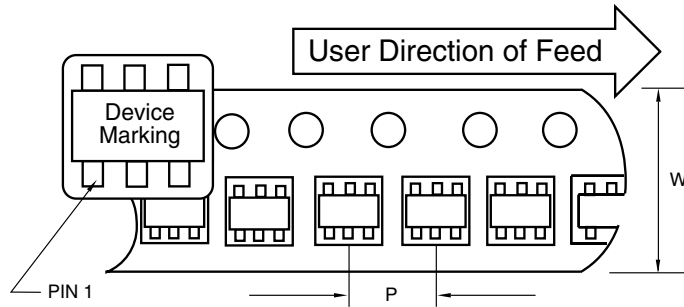
Standard Reel Component Orientation
TR Suffix Device
(Mark Right Side Up)

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)

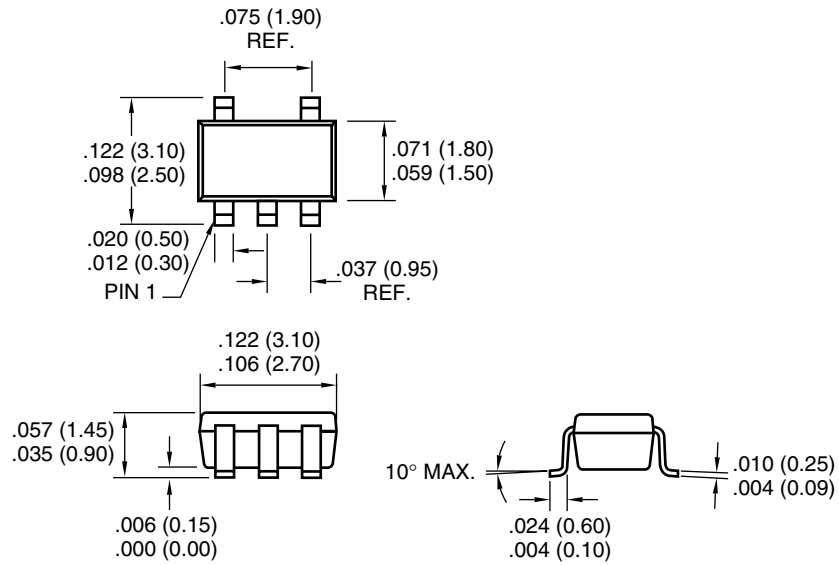
Carrier Tape, Number of Components Per Reel and Reel Size

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

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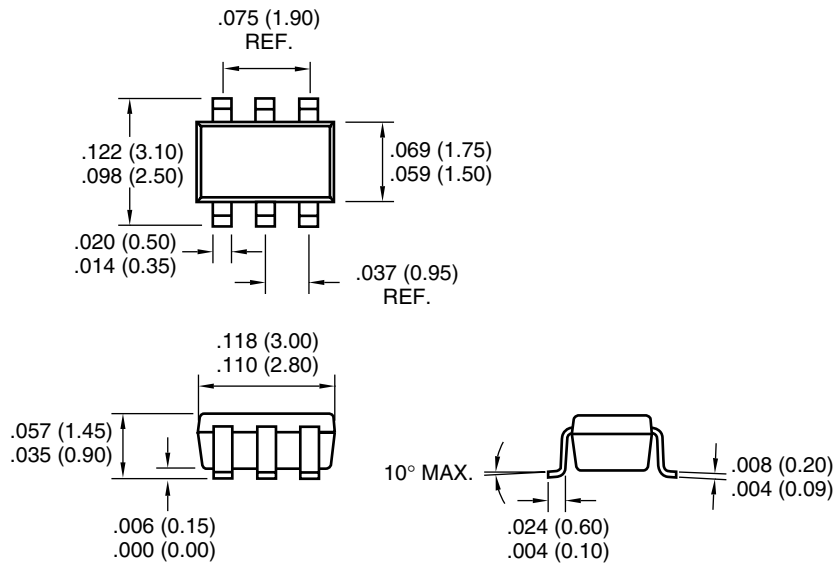
6.3 Package Dimensions

SOT-23A-5



Dimensions: inches (mm)

SOT-23A-6



Dimensions: inches (mm)

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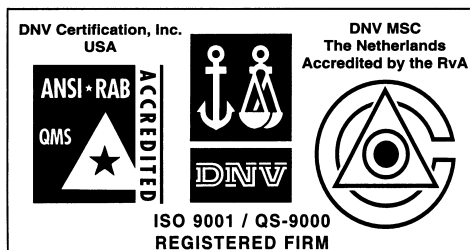
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Tel: 978-692-3848 Fax: 978-692-3821

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

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