MICROCHIP

TC1026

Linear Building Block – Low Power Comparator with Op Amp and Voltage Reference

Features

- Combines Low-Power Op Amp, Comparator and Voltage Reference in a Single Package
- Optimized for Single Supply Operation
- Small Packages: 8-Pin MSOP, 8-Pin SOIC, 8-Pin PDIP
- Ultra Low Input Bias Current: Less than 100pA
- Low Quiescent Current: 12µA (Typ.)
- Rail-to-Rail Inputs and Outputs
- Operates Down to V_{DD} = 1.8V, Min

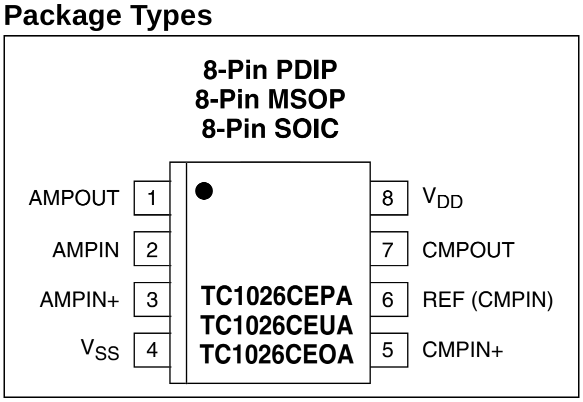
Applications

- Power Management Circuits
- Battery Operated Equipment
- Consumer Products

Device Selection Table

Part Number	Package	Temperature Range
TC1026CEPA	8-Pin PDIP	-40°C to +85°C
TC1026CEUA	8-Pin MSOP	-40°C to +85°C
TC1026CEOA	8-Pin SOIC	-40°C to +85°C

Package Types



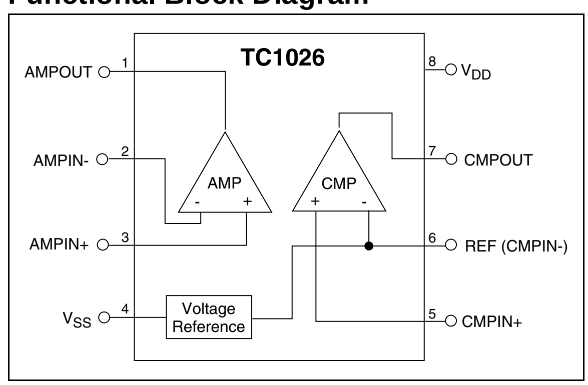
General Description

The TC1026 is a mixed-function device combining a general-purpose op amp, comparator and voltage reference in a single 8-pin package. This increased integration allows the user to replace two or three packages, which saves space, lowers supply current and increases system performance.

Both the op amp and comparator have rail-to-rail inputs and outputs which allows operation from low supply voltages with large input and output swings. The TC1026 is optimized for low voltage (V_{DD} = 1.8V), low supply current (12µA typ) operation.

Packaged in a space-saving 8-Pin MSOP, the TC1026 consumes half the board area of an 8-Pin SOIC and is ideal for applications requiring high integration, small size and low power. It is also available in 8-Pin SOIC and 8-Pin PDIP packages.

Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage 6.0V

Package Power Dissipation:

8-Pin PDIP ....730 mW

8-Pin SOIC..470 mW

8-Pin MSOP ....320 mW

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.

TC1026 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Typical values apply at 25°C and V_{DD} = 3.0V; T_A = -40° 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	—	12	18	µA	All outputs unloaded
Op Amp						
A_{VOL}	Large Signal Voltage Gain	—	100	—	V/mV	R_L = 10kΩ, V_{DD} = 5V
V_{ICMR}	Common Mode Input Range	V_{SS} – 0.2	—	V_{DD} + 0.2	V	
V_{OS}	Input Offset Voltage		±100 ±0.3	±500 ±1.5	µV mV	V_{DD} = 3V, V_{CM} = 1.5V, T_A = 25°C T_A = -40°C to 85°C
I_B	Input Bias Current	-100	50	100	pA	T_A = 25°C, V_{CM} = V_{DD} to V_{SS}
$V_{OS\ (DRIFT)}$	Input Offset Voltage Drift	—	±4	—	µV/°C	V_{DD} = 3V, V_{CM} = 1.5V
GBWP	Gain-Bandwidth Product	—	90	—	kHz	V_{DD} = 1.8V to 5.5V; V_O = V_{DD} to V_{SS}
SR	Slew Rate	—	35	—	mV/µsec	C_L = 100pF R_L = 1MΩ to GND Gain = 1 V_{IN} = V_{SS} to V_{DD}
V_{OUT}	Output Signal Swing	V_{SS} + 0.05	—	V_{DD} – 0.05	V	R_L = 10kΩ
CMRR	Common Mode Rejection Ratio	66	—	—	dB	T_A = 25°C, V_{DD} = 5V V_{CM} = V_{DD} to V_{SS}
PSRR	Power Supply Rejection Ratio	80	—	—	dB	T_A = 25°C, V_{CM} = V_{SS} V_{DD} = 1.8V to 5V
I_{SRC}	Output Source Current	3	—	—	mA	V_{IN}+ = V_{DD}, V_{IN}- = V_{SS} Output Shorted to V_{SS} V_{DD} = 1.8V, Gain = 1
I_{SINK}	Output SInk Current	—	125	—	nV/Hz	IN+ = V_{SS}, IN- = V_{DD} Output Shorted to V_{DD} V_{DD} = 1.8V, Gain = 1
En	Input Noise Voltage	—	10	—	µVpp	0.1Hz to 10Hz
en	Input Noise Voltage Density	—	125	—	nV/$\sqrt{Hz}$	1kHz
Comparator						
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°C T_A = -40°C to 85°C
I_B	Input Bias Current	—	—	±100	pA	T_A = 25°C, IN+ = V_{DD} to V_{SS}
V_{OH}	Output High Voltage	V_{DD} – 0.3	—	—	V	R_L = 10kΩ to V_{SS}
V_{OL}	Output Low Voltage	—	—	0.3	V	R_L = 10kΩ to V_{DD}

TC1026 ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: Typical values apply at 25°C and V_{DD} = 3.0V; T_A = -40° to +85°C, and V_{DD} = 1.8V to 5.5V, unless otherwise specified.

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
PSRR	Power Supply Rejection Ratio	60	—	—	dB	T_A = 25°C V_{DD} = 1.8V to 5V
I_{SRC}	Output Source Current	1	—	—	mA	IN+ = V_{DD} Output Shorted to V_{SS} V_{DD} = 1.8V
I_{SINK}	Output Sink Current	2	—	—	mA	IN+ = V_{SS} Output Shorted to V_{DD} 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
Voltage Reference						
V_{REF}	Reference Voltage	1.176	1.200	1.221	V	
$I_{REF(SOURCE)}$	Source Current	50	—	—	µA	
$I_{REF(SINK)}$	Sink Current	50	—	—	µA	
$C_{L(REF)}$	Load Capacitance	—	—	100	pF	

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 PDIP) (8-Pin MSOP) (8-Pin SOIC)	Symbol	Description
1	AMPOUT	Op amp output.
2	AMPIN-	Inverting op amp input.
3	AMPIN+	Non-inverting op amp input.
4	V_{SS}	Negative power supply.
5	CMPIN+	Non-inverting comparator input.
6	REF(CMPIN)	Inverting comparator input and voltage reference output voltage.
7	CMPOUT	Comparator output.
8	V_{DD}	Positive power supply.

3.0 DETAILED DESCRIPTION

The TC1026 is one of a series of very low power, linear building block products targeted at low voltage, single supply applications. The TC1026 minimum operating voltage is 1.8V, and typical supply current is only 12µA. It combines a comparator, an op amp and a voltage reference in a single package.

3.1 Comparator

The TC1026 contains 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 inverting input is internally connected to the output of the reference.

The comparator exhibits propagation delay and supply current which are largely independent of supply voltage. The low input bias current and offset voltage make it suitable for high impedance precision applications.

3.2 Operational Amplifier

The TC1026 contains one rail-to-rail op amp. The amplifier's input range extends beyond both supplies by 200mV and the outputs will swing to within several millivolts of the supplies depending on the load current being driven.

The amplifier design is such that large signal gain, slew rate and bandwidth are largely independent of supply voltage. The low input bias current and offset voltage of the TC1026 make it suitable for precision applications.

3.3 Voltage Reference

A 2.0% tolerance, internally biased, 1.20V bandgap voltage reference is included in the TC1026. It has a push-pull output capable of sourcing and sinking at least 50µA.

4.0 TYPICAL APPLICATIONS

The TC1026 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 three 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:

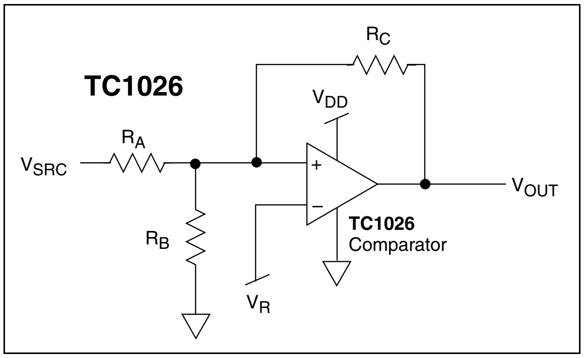
$$V_{THR} = (V_R)(R_A)\left[\left(\frac{1}{R_A}\right) + \left(\frac{1}{R_B}\right) + \left(\frac{1}{R_C}\right)\right]$$

V_{SRC} falling:

EQUATION 4-4:

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

FIGURE 4-1: COMPARATOR EXTERNAL HYSTERESIS CONFIGURATION



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 of Figure 4-2 uses two TC1026 devices 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 R1and 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 28µA at 3V. Resistors R5 and R6 provide hysteresis for comparators CMPTR1 and CMPTR2, respectively.

4.3 Voice Band Receive Filter

The majority of spectral energy for human voices is in a 2.7kHz frequency band from 300Hz to 3kHz. To properly recover a voice signal in applications such as radios, cellular phones and voice pagers, a low-power bandpass filter that is matched to the human voice spectrum can be implemented using Microchip's CMOS op amps. Figure 4-3 shows a unity-gain multi-pole Butterworth filter with ripple less than 0.15dB in the human voice band. The lower 3dB cut-off frequency is 70Hz (single-order response), while the upper cut-off frequency is 3.5kHz (fourth-order response).

4.4 Supervisory Audio Tone (SAT) Filter for Cellular

Supervisory Audio Tones (SAT) provide a reliable transmission path between cellular subscriber units and base stations. The SAT tone functions much like the current/voltage used in land line telephone systems to indicate that a phone is off the hook. The SAT tone may be one of three frequencies: 5970, 6000 or 6030Hz. A loss of SAT implies that channel conditions are impaired, and if SAT is interrupted for more than 5 seconds, a cellular call is terminated.

Figure 4-4 shows a high Q (30) first order SAT detection bandpass filter using Microchip's CMOS op amp architecture. This circuit nulls all frequencies except the three SAT tones of interest.

FIGURE 4-2: PRECISION BATTERY MONITOR

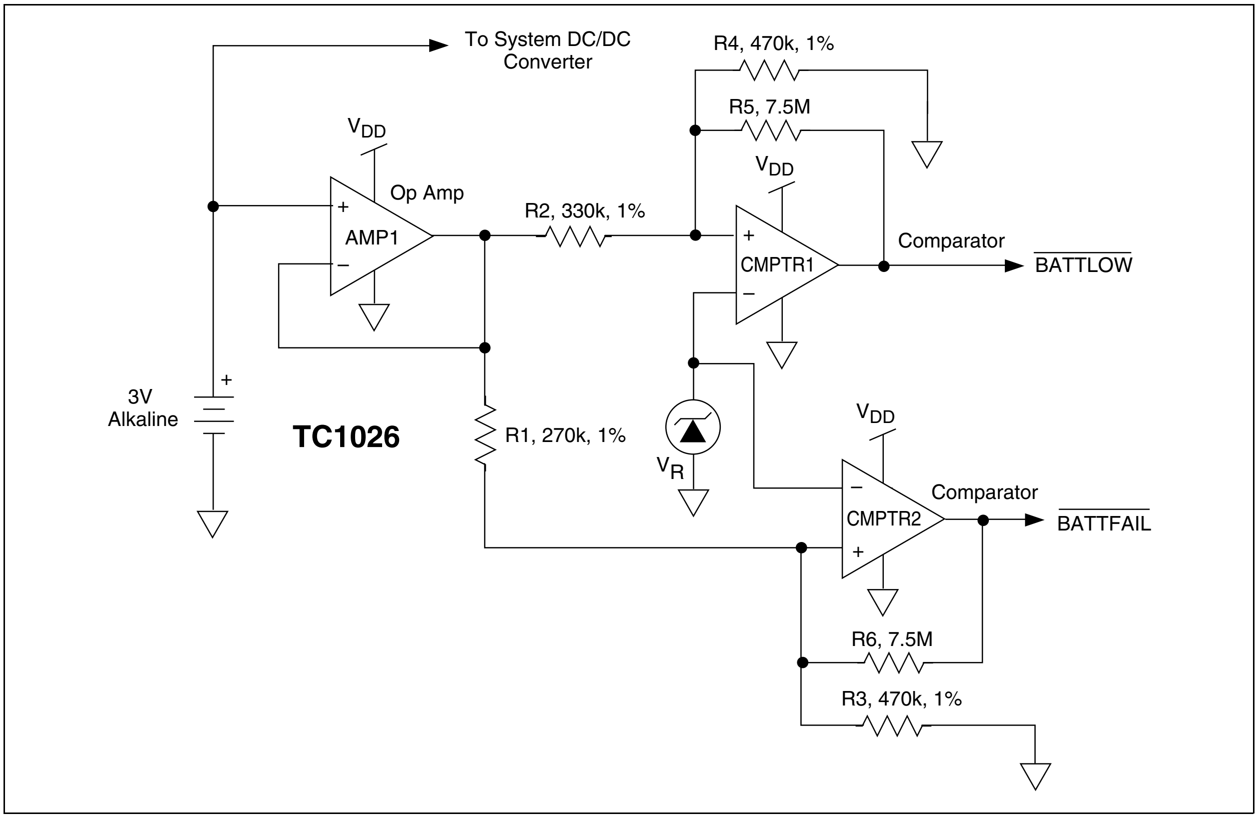


FIGURE 4-3: MULTI-POLE BUTTERWORTH VOICE BAND RECEIVE FILTER

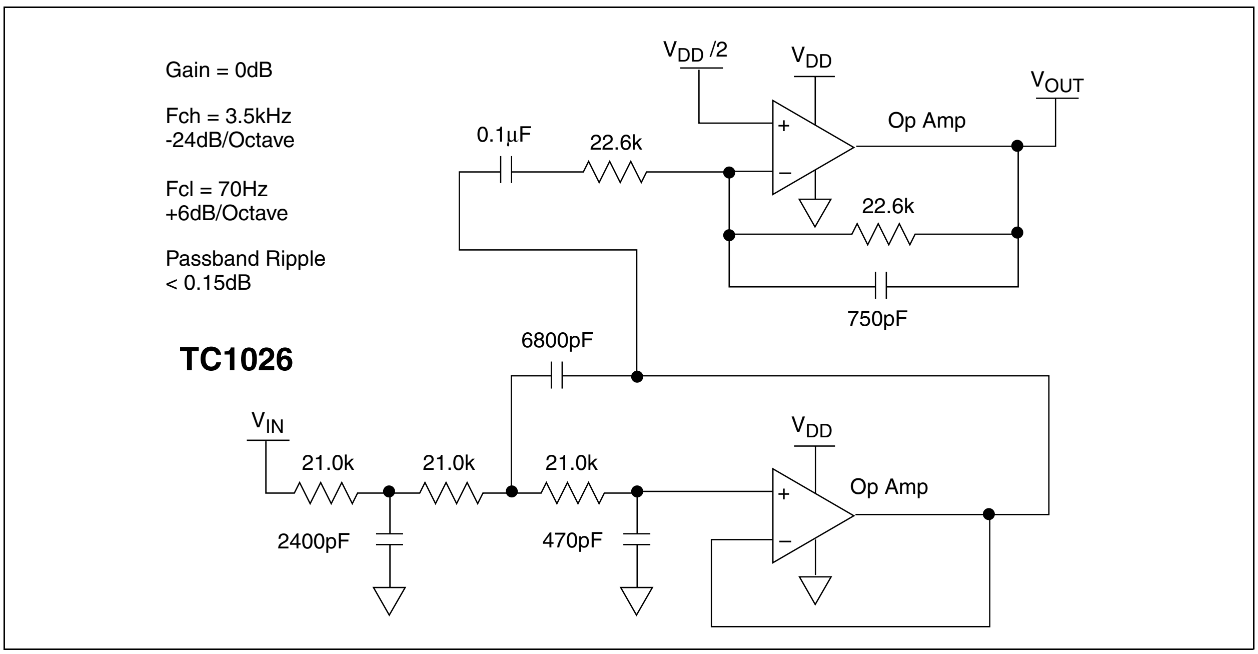
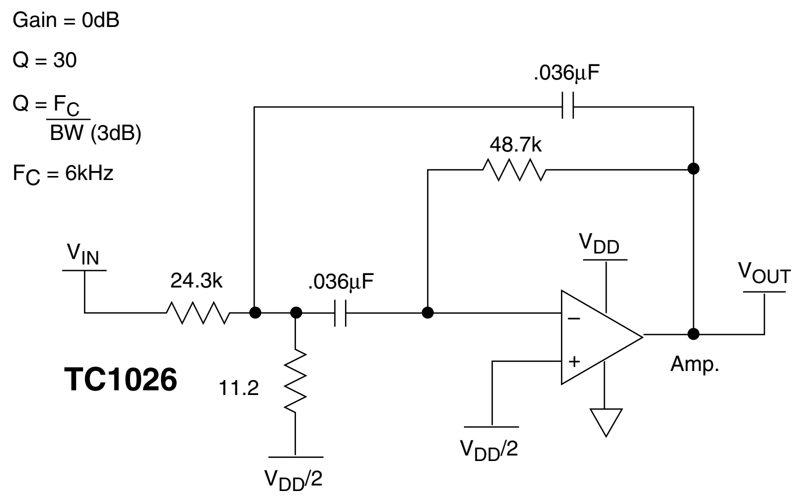


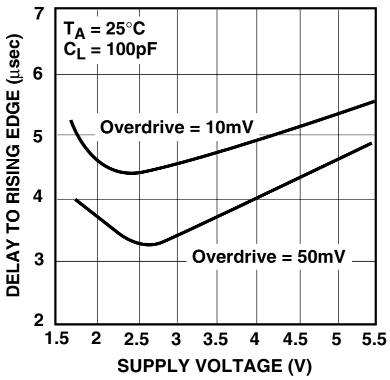
FIGURE 4-4: SECOND ORDER SAT BANDPASS FILTER



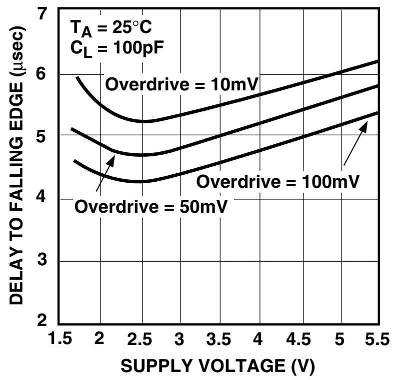
5.0 TYPICAL CHARACTERISTICS

> **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.

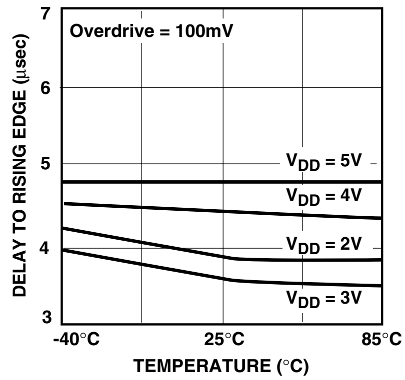
Comparator Propagation Delay vs. Supply Voltage



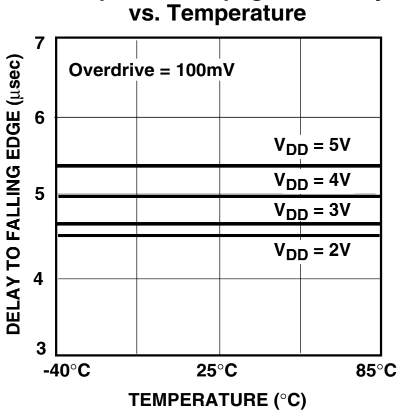
Comparator Propagation Delay vs. Supply Voltage



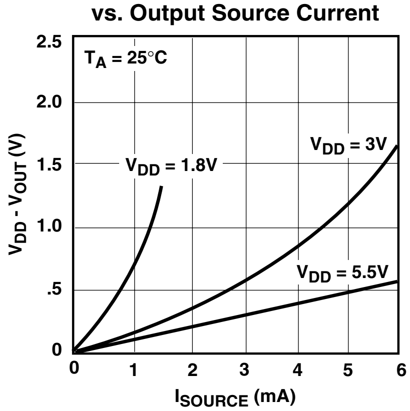
Comparator Propagation Delay vs. Temperature



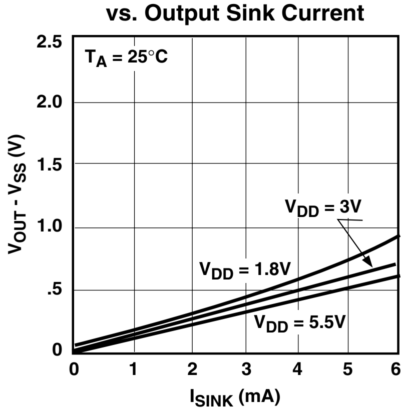
Comparator Propagation Delay vs. Temperature



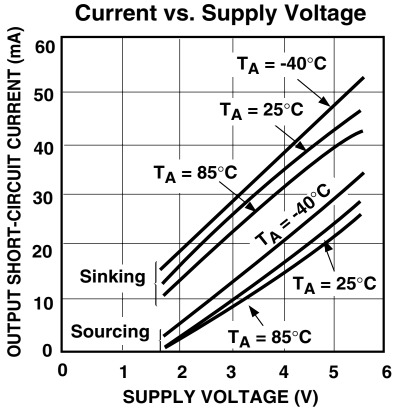
Comparator Output Swing vs. Output Source Current



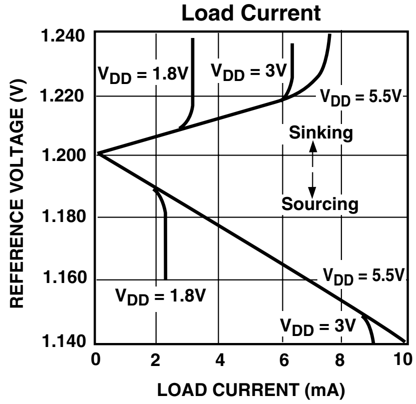
Comparator Output Swing vs. Output Sink Current



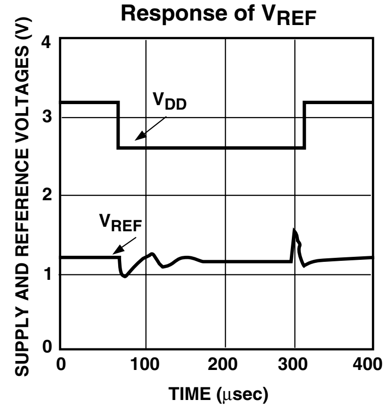
Comparator Output Short-Circuit Current vs. Supply Voltage



Reference Voltage vs. Load Current

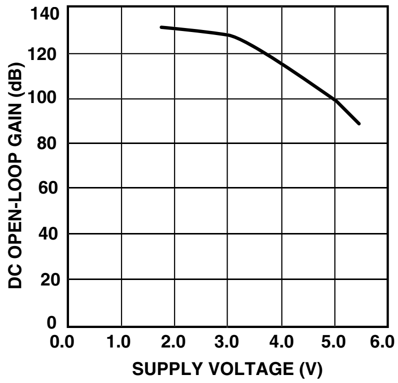


Line Transient Response of V_{REF}

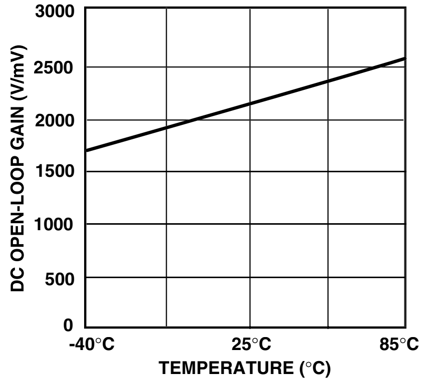


5.0 TYPICAL CHARACTERISTICS (CONTINUED)

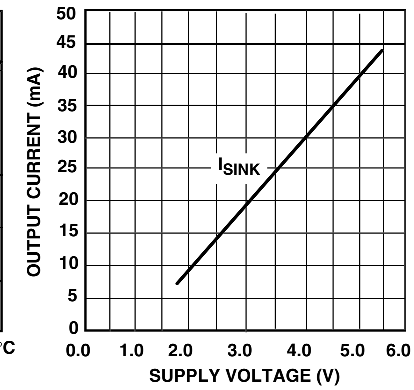
Op Amp DC Open-Loop Gain vs. Supply Voltage



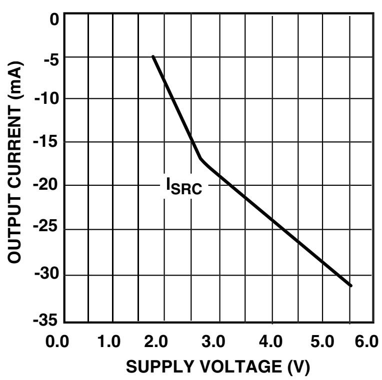
Op Amp DC Open-Loop Gain vs. Temperature



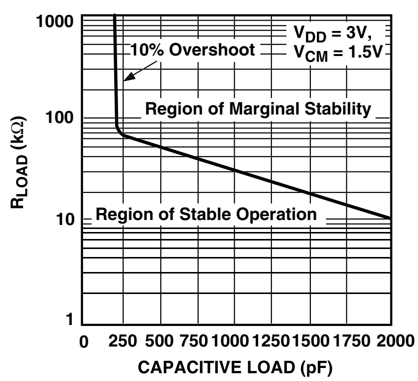
Op Amp Short-Circuit Current vs. Supply Voltage



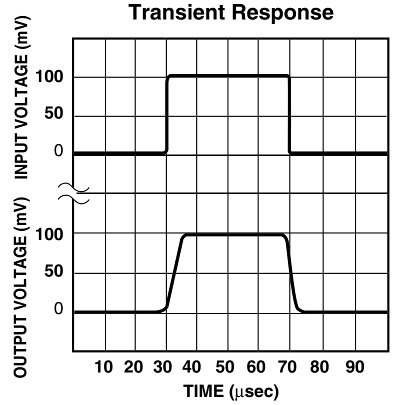
Op Amp Short-Circuit Current vs. Supply Voltage



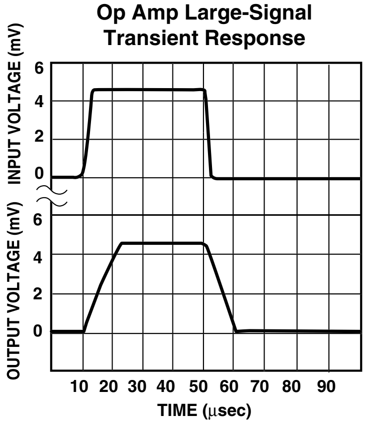
Op Amp Load Resistance vs. Load Capacitance



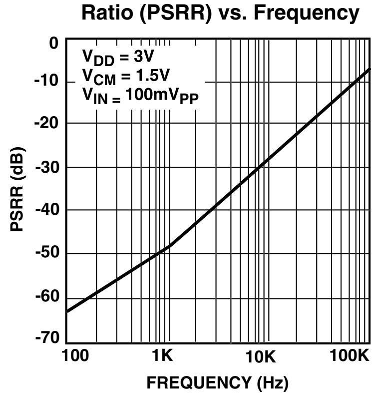
Op Amp Small-Signal Transient Response



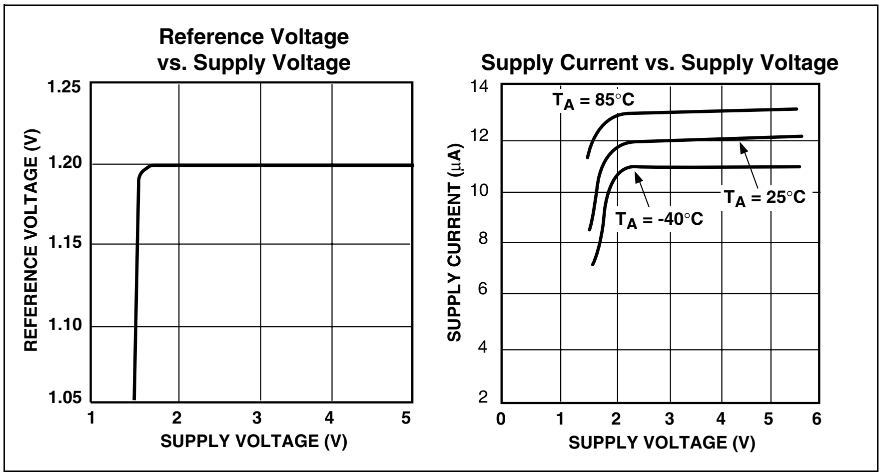
Op Amp Large-Signal Transient Response



Op Amp Power Supply Rejection Ratio (PSRR) vs. Frequency



5.0 TYPICAL CHARACTERISTICS (CONTINUED)



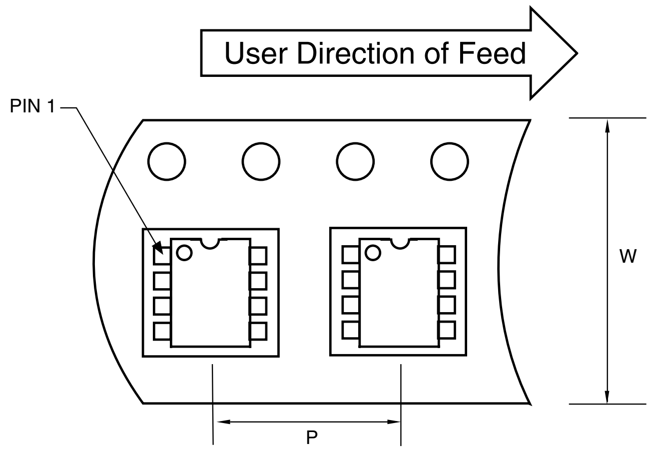
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

Package marking data not available at this time.

6.2 Taping Form

Component Taping Orientation for 8-Pin MSOP Devices

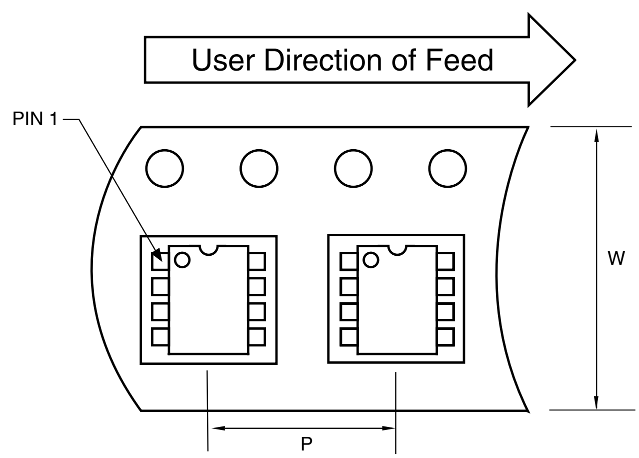


Standard Reel Component Orientation
for TR Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
8-Pin MSOP	12 mm	8 mm	2500	13 in

Component Taping Orientation for 8-Pin SOIC (Narrow) Devices



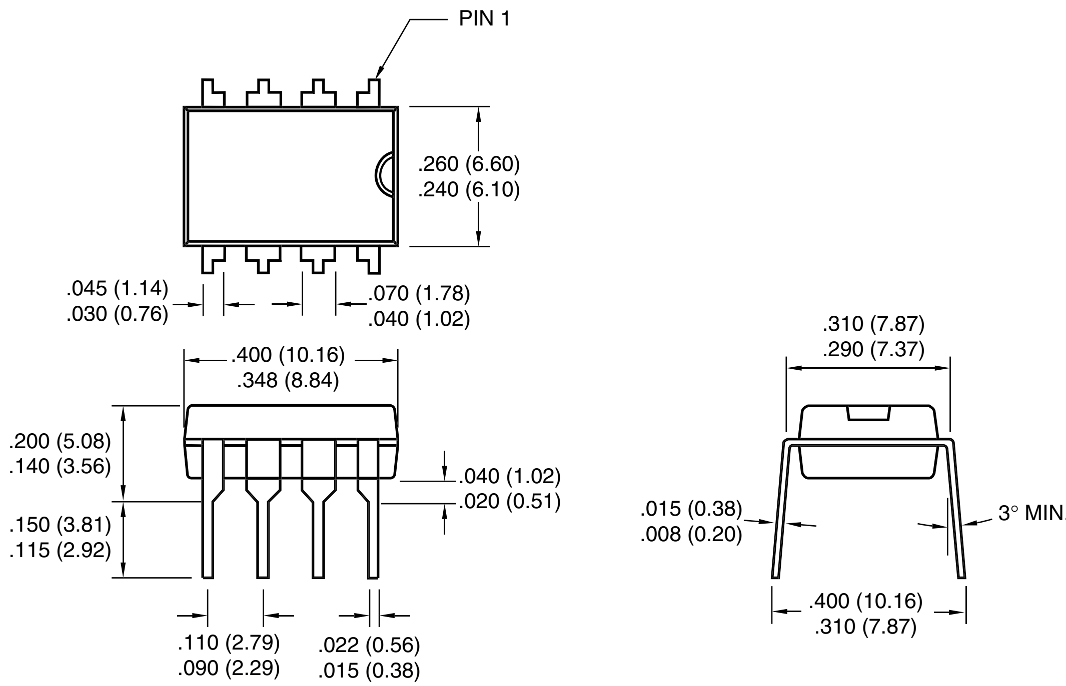
Standard Reel Component Orientation
for TR Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
8-Pin SOIC (N)	12 mm	8 mm	2500	13 in

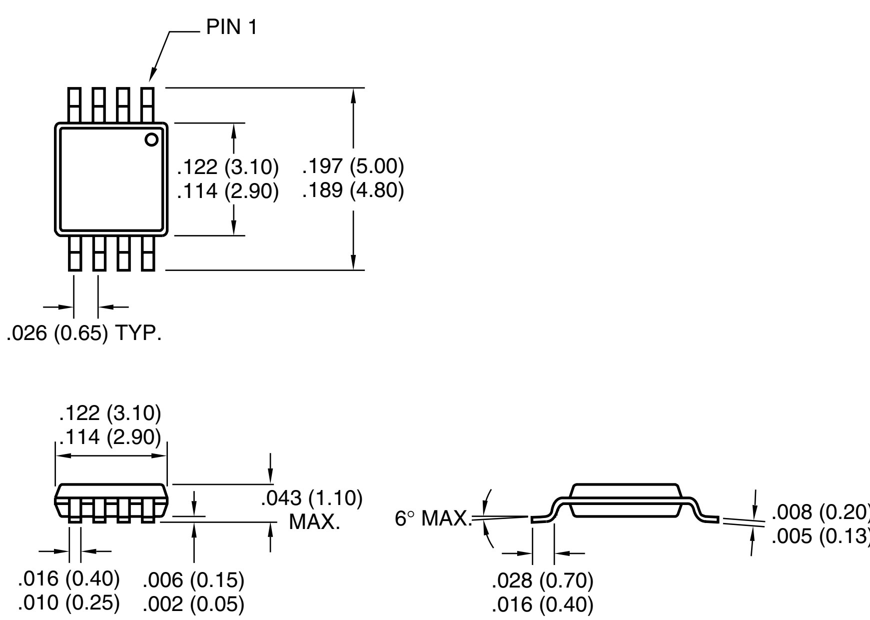
6.3 Package Dimensions

8-Pin Plastic DIP



Dimensions: inches (mm)

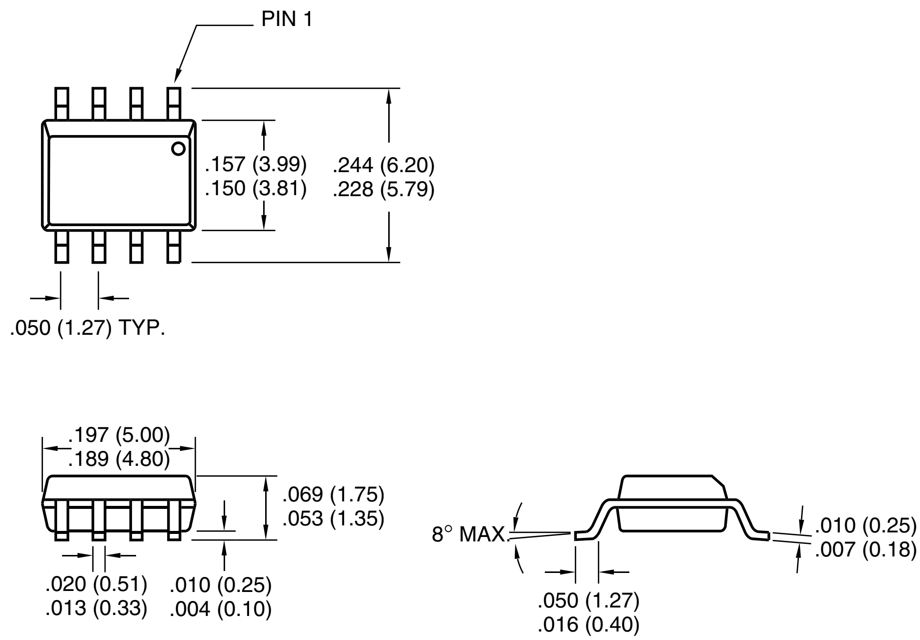
8-Pin MSOP



Dimensions: inches (mm)

6.3 Package Dimensions (Continued)

8-Pin SOIC



Dimensions: inches (mm)

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)

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) to receive the most current information on our products.

NOTES:

DNV Certification, Inc. USA

DNV MSC The Netherlands Accredited by the RvA

ISO 9001 / QS-9000 REGISTERED FIRM

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.

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 hoj 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 - ler 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