

Switched Capacitor Voltage Converters

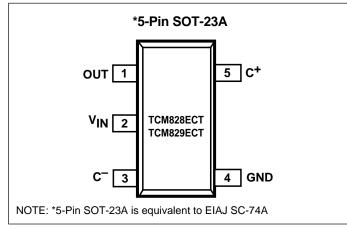
FEATURES

- Charge Pump in 5-Pin SOT-23A Package
- >95% Voltage Conversion Efficiency
- Voltage Inversion and/or Doubling
- Low 50µA (TCM828) Quiescent Current
- Operates from +1.5V to +5.5V
- Up to 25mA Output Current
- Only Two External Capacitors Required

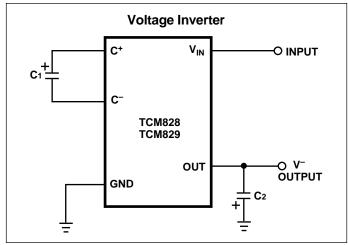
APPLICATIONS

- LCD Panel Bias
- Cellular Phones
- Pagers
- PDAs, Portable Dataloggers
- Battery-Powered Devices

PIN CONFIGURATION



TYPICAL OPERATING CIRCUIT



GENERAL DESCRIPTION

The TCM828/829 are CMOS "charge-pump" voltage converters in ultra-small 5-Pin SOT-23A packages. They invert and/or double an input voltage which can range from +1.5V to +5.5V. Conversion efficiency is typically >95%. Switching frequency is 12kHz for the TCM828 and 35kHz for the TCM829.

External component requirement is only two capacitors $(3.3\mu F nominal)$ for standard voltage inverter applications. With a few additional components a positive doubler can also be built. All other circuitry, including control, oscillator, power MOSFETs are integrated on-chip. Supply current is 50 μ A (TCM828) and 115 μ A (TCM829).

The TCM828 and TCM829 are available in a 5-Pin SOT-23A surface mount package.

ORDERING INFORMATION

Part No.	Package	Temp. Range
TCM828ECT	5-Pin SOT-23A	- 40°C to +85°C
TCM829ECT	5-Pin SOT-23A	– 40°C to +85°C

NOTE: 5-Pin SOT-23A is equivalent to EIAJ SC-74A.

ABSOLUTE MAXIMUM RATINGS*

Input Voltage (V _{IN} to GND)	+6.0V, -0.3V
Output Voltage (OUT to GND)	–6.0V, + 0.3V
Current at OUT Pin	50mA
Short-Circuit Duration - OUT to GND	Indefinite
Operating Temperature Range	– 40°C to +85°C

Power Dissipation ($T_A \le 70^{\circ}C$)

ELECTRICAL CHARACTERISTICS: $T_A = 0^{\circ}C$ to +85°C, $V_{IN} = +5V$, $C1 = C2 = 10\mu$ F (TCM828), $C1 = C2 = 3.3\mu$ F (TCM829), unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$.

Symbol	Parameter	Device	Test Conditions	Min	Тур	Max	Unit
I _{DD}	Supply Current	TCM828 TCM829	$T_A = +25^{\circ}C$	_	50 115	90 260	μΑ
V ⁺	Minimum Supply Voltage		R_{LOAD} = 10k Ω : T_A = 0°C to +85°C	1.5	-	-	V
V ⁺	Maximum Supply Voltage		$R_{LOAD} = 10 k\Omega$	_	_	5.5	V
F _{OSC}	Oscillator Frequency	TCM828 TCM829	T _A = +25°C	8.4 24.5	12 35	15.6 45.5	kHz
P _{EFF}	Power Efficiency		$I_{LOAD} = 3mA, T_A = +25^{\circ}C$	_	96		%
VEFF	Voltage Conversion Efficiency		R _{LOAD} = ∞	95	99.9	-	%
R _{OUT}	Output Resistance		$I_{OUT} = 5mA$, $T_A = 25^{\circ}C$ $T_A = 0^{\circ}C$ to +85°C	_	25 —	50 65	Ω

NOTE: 1. Capacitor contribution is approximately 20% of the output impedance [ESR = 1 / pump frequency x capacitance)].

ELECTRICAL CHARACTERISTICS: $T_A = -40^{\circ}C$ to $+85^{\circ}C$, $V_{IN} = +5V$, $C1 = C2 = 10\mu F$ (TCM828), $C1 = C2 = 3.3\mu F$ (TCM829) unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$. (Note 2)

Symbol	Parameter	Device	Test Conditions	Min	Тур	Max	Unit
I _{DD}	Supply Current	TCM828			_	115	μA
		TCM829		_	_	325	
V ⁺	Supply Voltage Range		$R_{LOAD} = 10k\Omega$	1.5	—	5.5	V
Fosc	Oscillator Frequency	TCM828		6	_	20	kHz
		TCM829		19	_	54.3	
ROUT	Output Resistance		I _{OUT} = 5mA	_	—	65	Ω

NOTE: 2. All – 40°C to +85°C specifications above are guaranteed by design.

PIN DESCRIPTION

Pin No. (5-Pin SOT-23A)	Symbol	Description	
1	OUT	Inverting charge pump output.	
2	V _{IN}	Positive power supply input.	
3	C ₁	Commutation capacitor negative terminal.	
4	GND	Ground.	
5	C ⁺ ₁	Commutation capacitor positive terminal.	

DETAILED DESCRIPTION

The TCM828/829 charge pump converters invert the voltage applied to the V_{IN} pin. Conversion consists of a twophase operation (Figure 1). During the first phase, switches S2 and S4 are open and S1 and S3 are closed. During this time, C1 charges to the voltage on V_{IN} and load current is supplied from C2. During the second phase, S2 and S4 are closed, and S1 and S3 are open. This action connects C1 across C2, restoring charge to C2.

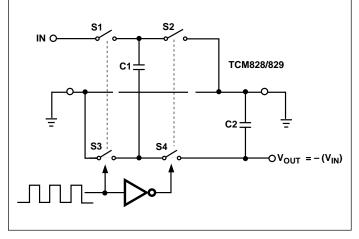


Figure 1. Ideal Switched Capacitor Charge Pump

APPLICATIONS INFORMATION

Output Voltage Considerations

The TCM828/829 perform voltage conversion but do not provide *regulation*. The output voltage will droop in a linear manner with respect to load current. The value of this equivalent output resistance is approximately 25Ω nominal at +25°C and V_{IN} = +5V. V_{OUT} is approximately –5V at light loads, and droops according to the equation below:

 $V_{DROOP} = I_{OUT} \times R_{OUT}$ $V_{OUT} = - (V_{IN} - V_{DROOP})$

Charge Pump Efficiency

The overall power efficiency of the charge pump is affected by four factors:

- (1) Losses from power consumed by the internal oscillator, switch drive, etc. (which vary with input voltage, temperature and oscillator frequency).
- (2) I²R losses due to the on-resistance of the MOSFET switches on-board the charge pump.
- (3) Charge pump capacitor losses due to effective series resistance (ESR).

(4) Losses that occur during charge transfer (from the commutation capacitor to the output capacitor) when a voltage difference between the two capacitors exists.

Most of the conversion losses are due to factors (2), (3) and (4) above. These losses are given by Equation 1.

$$P_{\text{LOSS}(2, 3, 4)} = I_{\text{OUT}}^{2} \times R_{\text{OUT}}$$
$$\cong I_{\text{OUT}}^{2} \times \left[\frac{1}{(f_{\text{OSC}}) \text{ C1}} + 8R_{\text{SWITCH}} + 4\text{ESR}_{\text{C1}} + \text{ESR}_{\text{C2}} \right]$$

Equation 1.

The $1/(f_{OSC})(C1)$ term in Equation 1 is the effective output resistance of an ideal switched capacitor circuit (Figures 2a, 2b).

The losses in the circuit due to factor (4) above are also shown in Equation 2. The output voltage ripple is given by Equation 3.

$$P_{LOSS (4)} = \left[(0.5)(C1)(V_{IN}^2 - V_{OUT}^2) + (0.5)(C2)(V_{RIPPLE}^2 - 2V_{OUT}V_{RIPPLE}) \right] x f_{OSC}$$

Equation 2.

$$V_{\text{RIPPLE}} = \frac{I_{\text{OUT}}}{(f_{\text{OSC}})(\text{C2})} + 2(I_{\text{OUT}})(\text{ESR}_{\text{C2}})$$



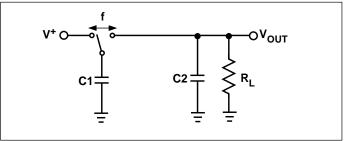


Figure 2a. Ideal Switched Capacitor Model

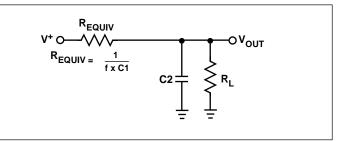


Figure 2b. Equivalent Output Resistance

Capacitor Selection

In order to maintain the lowest output resistance and output ripple voltage, it is recommended that low ESR capacitors be used. Additionally, larger values of C1 will lower the output resistance and larger values of C2 will reduce output ripple. (See Equation 1(b)).

Table 1 shows various values of C1 and the corresponding output resistance values @ +25°C. It assumes a 0.1 Ω ESR_{C1} and 2 Ω R_{SW}. Table 2 shows the output voltage ripple for various values of C2. The V_{RIPPLE} values assume 10mA output load current and 0.1 Ω ESR_{C2}.

C1(μF)	TCM828 R _{OUT} (Ω)	TCM829 R _{OUT} (Ω)
0.1	850	302
1	100	45
3.3	42	25
10	25	19
47	18	17
100	17	17

Table 1. Output Resistance vs. C1 (ESR = 0.1 Ω)

Table 2. Output Voltage	Ripple vs. C2	$(ESR = 0.1\Omega)$ Jour 10	mΑ

	U 11 1	,
C2(μ F)	TCM828 V _{RIPPLE} (mV)	TCM829 V _{RIPPLE} (mV)
1	835	286
3.3	254	88
10	85	31
47	20	8
100	10	5

Input Supply Bypassing

The V_{IN} input should be capacitively bypassed to reduce AC impedance and minimize noise effects due to the switching internal to the device. The recommended capacitor depends on the configuration of the TCM828/829.

If the device is loaded from OUT to GND it is recommended that a large value capacitor (at least equal to C1) be connected from the input to GND. If the device is loaded from IN to OUT a small (0.1 μ F) capacitor from IN to OUT is sufficient.

Voltage Inverter

The most common application for charge pump devices is the inverter (Figure 3). This application uses two external capacitors – C1 and C2 (plus a power supply bypass capacitor, if necessary). The output is equal to $V_{\overline{IN}}$ plus any voltage drops due to loading. Refer to Table 1 and Table 2 for capacitor selection.

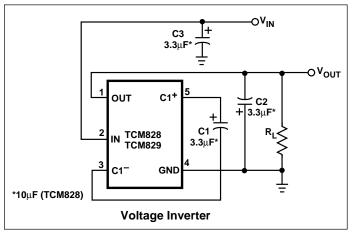


Figure 3. Test Circuit

Cascading Devices

Two or more TCM828/829's can be cascaded to increase output voltage (Figure 4). If the output is lightly loaded, it will be close to $(-2 \times V_{IN})$ but will droop at least by R_{OUT} of the first device multiplied by the I_Q of the second. It can be seen that the output resistance rises rapidly for multiple cascaded devices. For large negative voltage requirements see the TC682 or TCM680 data sheets.

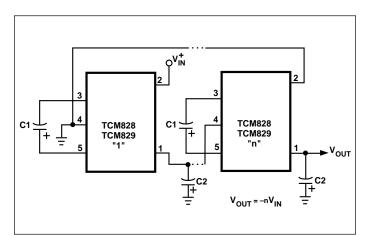


Figure 4. Cascading TCM828s or TCM829s to Increase Output Voltage

Paralleling Devices

To reduce the value of R_{OUT}, multiple TCM828/829s can be connected in parallel (Figure 5). The output resistance will be reduced by a factor of N where N is the number of TCM828/829's. Each device will require it's own pump capacitor (C1), but all devices may share one reservoir capacitor (C2). However, to preserve ripple performance the value of C2 should be scaled according to the number of paralleled TCM828/829's.

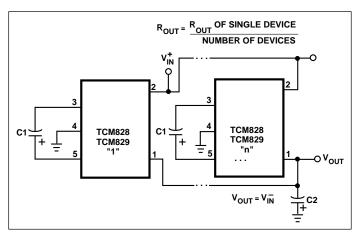


Figure 5. Paralleling TCM828s or TCM829s to Reduce Output Resistance

Voltage Doubler/Inverter

Another common application of the TCM828/829 is shown in Figure 6. This circuit performs two functions in combination. C1 and C2 form the standard inverter circuit described above. C3 and C4 plus the two diodes form the voltage doubler circuit. C1 and C3 are the pump capacitors and C2 and C4 are the reservoir capacitors. Because both sub-circuits rely on the same switches if either output is loaded, both will droop toward GND. Make sure that the total current drawn from both the outputs does not total more than 40mA.

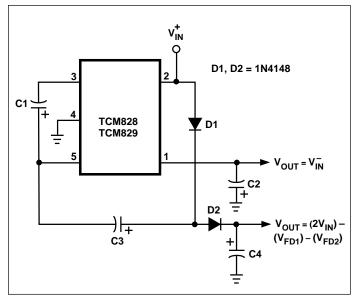


Figure 6. Combined Doubler and Inverter

Diode Protection for Heavy Loads

When heavy loads require the OUT pin to sink large currents being delivered by a positive source, diode protection may be needed. The OUT pin should not be allowed to be pulled above ground. This is accomplished by connecting a Schottky diode (1N5817) as shown in Figure 7.

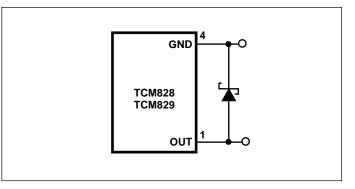


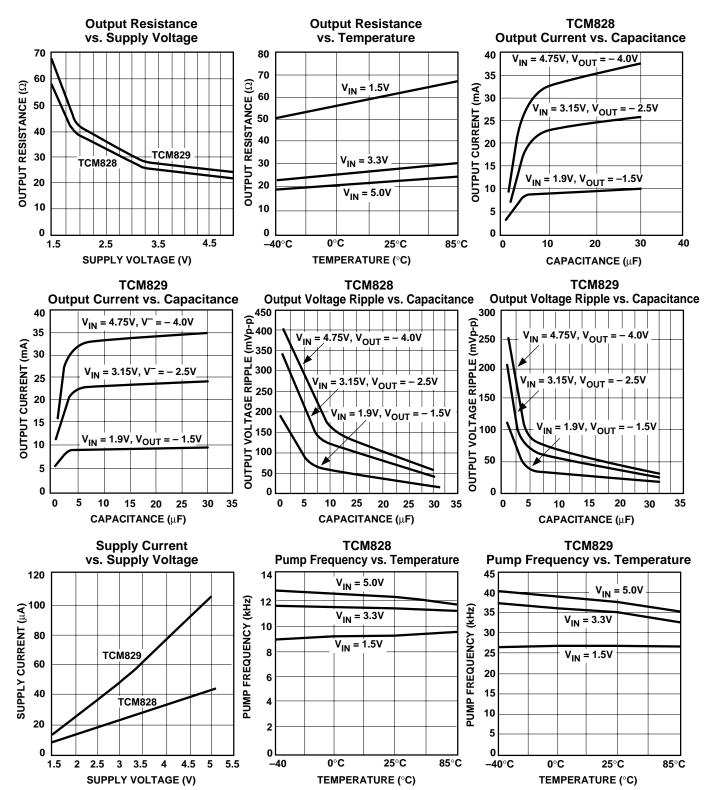
Figure 7. High V⁻ Load Current

Layout Considerations

As with any switching power supply circuit good layout practice is recommended. Mount components as close together as possible to minimize stray inductance and capacitance. Also use a large ground plane to minimize noise leakage into other circuitry.

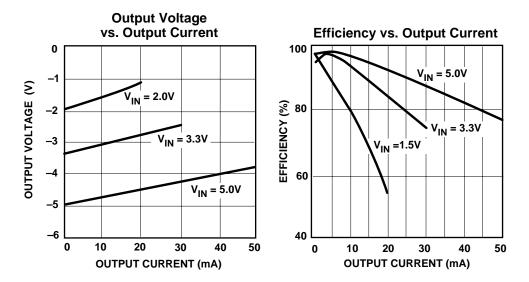
TYPICAL CHARACTERISTICS

Circuit of Figure 3, V_{IN} = +5V, C1 = C2 = C3, T_A = +25°C, unless otherwise noted.

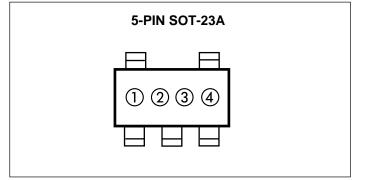


TYPICAL CHARACTERISTICS (Cont.)

Circuit of Figure 3, V_{IN} = +5V, C1 = C2 = C3, T_A = +25°C, unless otherwise noted.



MARKING



Part Numbers and Part Marking

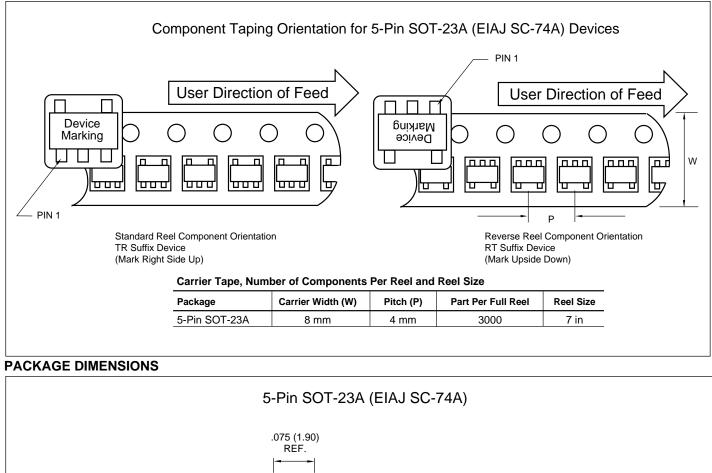
 & 2 = part number code + temperature range (two-digit code).

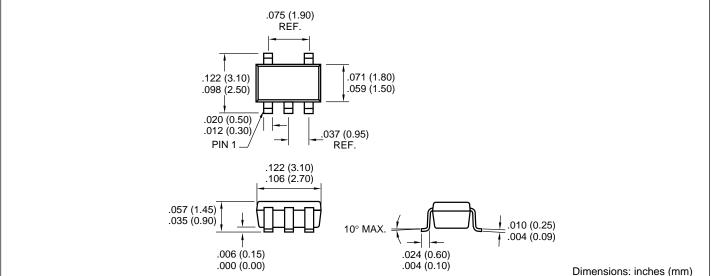
TCM828/829	Code
TCM828ECT	CA
TCM829ECT	CB

ex: TCM828ECT = ©A))

- ③ represents year and quarter code
- ④ represents lot ID number

TAPING FORM







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.

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 Austin Analog Product Sales 8303 MoPac Expressway North Suite A-201 Austin, TX 78759 Tel: 512-345-2030 Fax: 512-345-6085 Boston 2 Lan Drive, Suite 120 Westford, MA 01886 Tel: 978-692-3848 Fax: 978-692-3821 Boston Analog Product Sales Unit A-8-1 Millbrook Tarry Condominium 97 Lowell Road Concord, MA 01742 Tel: 978-371-6400 Fax: 978-371-0050 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

Dayton Two Prestige Place, Suite 130 Miamisburg, OH 45342 Tel: 937-291-1654 Fax: 937-291-9175

Detroit Tri-Atria Office Building 32255 Northwestern Highway, Suite 190 Farmington Hills, MI 48334

Farmington Hills, MI 48334 Tel: 248-538-2250 Fax: 248-538-2260 Los Angeles

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

Mountain View

Analog Product Sales 1300 Terra Bella Avenue Mountain View, CA 94043-1836 Tel: 650-968-9241 Fax: 650-967-1590

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

China - Beijing Microchip Technology Beijing Office Unit 915 New China Hong Kong Manhattan Bldg. No. 6 Chaoyangmen Beidajie Beijing, 100027, No. China Tel: 86-10-85282100 Fax: 86-10-85282104 China - Shanghai Microchip Technology Shanghai Office 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 Hong Kong Microchip Asia Pacific RM 2101, 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, OíShaugnessey Road Bangalore, 560 025, India Tel: 91-80-2290061 Fax: 91-80-2290062 Japan Microchip Technology Intl. Inc. 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 Tel: 82-2-554-7200 Fax: 82-2-558-5934

ASIA/PACIFIC (continued)

Singapore Microchip Technology Singapore Pte Ltd. 200 Middle Road #07-02 Prime Centre Singapore, 188980 Tel: 65-334-8870 Fax: 65-334-8850 **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

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 Denmark Microchip Technology Denmark ApS Regus Business Centre Lautrup hoj 1-3 Ballerup DK-2750 Denmark Tel: 45 4420 9895 Fax: 45 4420 9910 France Arizona Microchip Technology SARL Parc díActivite 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 Arizona Microchip Technology GmbH Gustav-Heinemann Ring 125 D-81739 Munich, Germany Tel: 49-89-627-144 0 Fax: 49-89-627-144-44 Germany Analog Product Sales Lochhamer Strasse 13 D-82152 Martinsried, Germany Tel: 49-89-895650-0 Fax: 49-89-895650-22 Italy Arizona 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 01/09/01

All rights reserved. © 2001 Microchip Technology Incorporated. Printed in the USA. 1/01 Printed on recycled paper.

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 Microchips 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, except as maybe explicitly expressed herein, under any intellectual property rights. The Microchip logo and name are registered trademarks of Microchip Technology Inc. in the U.S.A. and other countries. All rights reserved. All other trademarks mentioned herein are the property of their respective companies.