

Positive Doubling Charge Pump with Shutdown in SOT Package

FEATURES

- Space Saving 6-Pin SOT-23A Package
- >99% Typical Voltage Conversion Efficiency
- Voltage Doubling
- Operates from +2.5V to +4.0V
- Low Output Resistance (17Ω Typical)
- Only Two External Capacitors Required
- Consumes 180μA (Typical) in Active Mode
- Power-Saving Shutdown Mode (1μA Maximum)
- Fully Compliant with 1.8V Logic Sysems

APPLICATIONS

- Cellular Phones
- Pagers
- PDAs, Portable Data Loggers
- Battery-Powered Devices
- Handheld Instruments

GENERAL DESCRIPTION

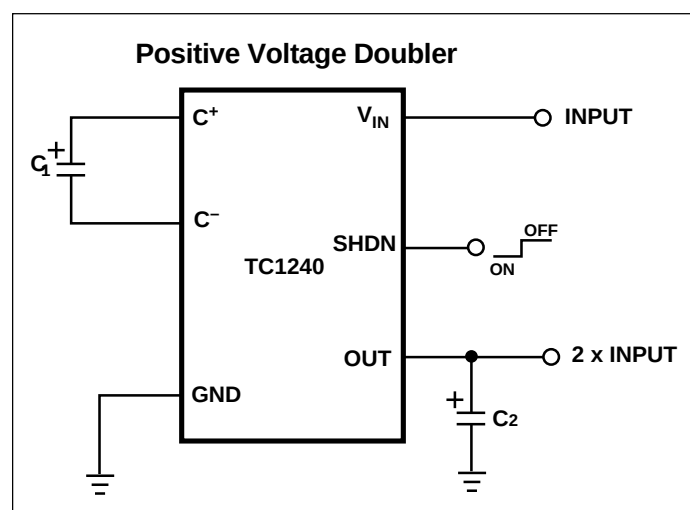
The TC1240 is a doubling CMOS charge-pump voltage converter in a small 6-Pin SOT-23A package. TC1240 doubles an input voltage which can range from +2.5V to +4.0V. Conversion efficiency is typically >99%. Internal oscillator frequency is 160kHz for the TC1240. The TC1240 has an active high shutdown which limits the current consumption of the device to less than 1μA.

External component requirement is only two capacitors for standard voltage doubler applications. All other circuitry, including control, oscillator, power MOSFETs are integrated on-chip. Typical supply current is 180μA and the device is available in a 6-Pin SOT-23A surface mount package.

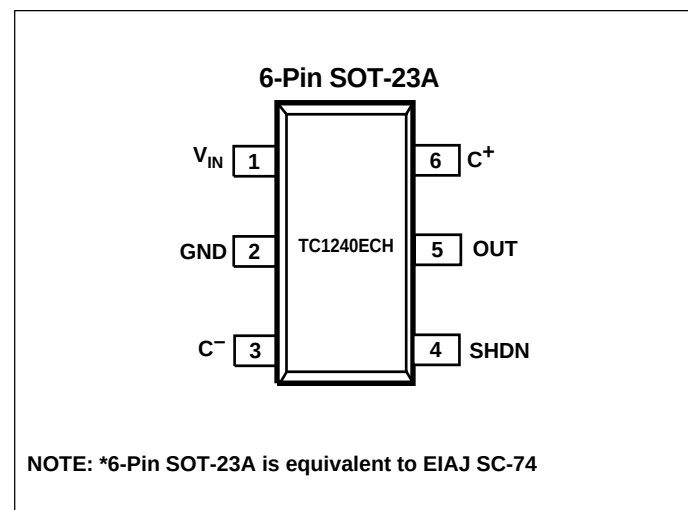
ORDERING INFORMATION

Part Number	Package	Temp. Range
TC1240ECH	6-Pin SOT-23A	-40°C to +85°C

TYPICAL OPERATING CIRCUIT



PIN CONFIGURATION



Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

ABSOLUTE MAXIMUM RATINGS*

Input Voltage (V_{IN} to GND) +4.5V, -0.3V
Output Voltage (OUT to GND) +9.0V, $V_{IN} - 0.3V$
Current at OUT Pin 50 mA
Short-Circuit Duration –OUT to GND Indefinite
Operating Temperature Range -40 °C to +85°C
Power Dissipation ($T_A \leq 70^\circ\text{C}$)
 6-Pin SOT-23A 240 mW
Storage Temperature (Unbiased) -65 °C to +150°C
Lead Temperature (Soldering, 10 sec) +300°C

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. 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 operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: $T_A = -40$ to $+85^\circ\text{C}$, $V_{IN} = +2.8V$, $C1 = C2 = 3.3\mu\text{F}$, SHDN = GND, unless otherwise noted. Typical values are at $T_A = +25^\circ\text{C}$.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
IDD	Supply Current	$R_{LOAD} = \infty$	—	180	300	μA
ISHDN	Shutdown Supply Current	SHDN = V_{IN}	—	0.1	1.0	μA
V_{MIN}	Minimum Supply Voltage	$R_{LOAD} = 1.0K\Omega$	2.5	—	—	V
V_{MAX}	Maximum Supply Voltage	$R_{LOAD} = 1.0K\Omega$	—	—	4.0	V
FOSC	Oscillator Frequency	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	—	160	—	kHz
FSW	Switching Frequency	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	40	80	125	kHz
V_{IH}	Shutdown Input Logic High	$V_{IN} = V_{MIN}$ to V_{MAX}	1.4	—	—	V
V_{IL}	Shutdown Input Logic Low	$V_{IN} = V_{MIN}$ to V_{MAX}	—	—	0.4	V
P_{EFF}	Power Efficiency	$R_{LOAD} = 1.0K\Omega$	86	93	—	%
V_{EFF}	Voltage Conversion Efficiency	$R_{LOAD} = \infty$	97.5	99.96	—	%
R_{OUT}	Output Resistance (Note 1)	$R_{LOAD} = 1.0K\Omega$ $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	— —	17 —	— 30	Ω

NOTE: 1. Capacitor contribution is approximately 26% of the output impedance [$ESR = 1 / \text{pump frequency} \times \text{capacitance}$].
2. Switching frequency is one-half internal oscillator frequency.

PIN DESCRIPTION

Pin No. (6-Pin SOT-23A)	Symbol	Description
1	V_{IN}	Power Supply Input.
2	GND	Ground.
3	C –	Commutation Capacitor Negative Terminal.
4	SHDN	Shutdown Input (Active High).
5	OUT	Doubled Output Voltage.
6	C+	Commutation Capacitor Positive Terminal.

Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

DETAILED DESCRIPTION

The TC1240 charge pump converter doubles the voltage applied to the V_{IN} pin. Conversion consists of a two-phase 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.

During this second phase, C1 is level shifted upward by V_{IN} volts. This connects C1 to the reservoir capacitor C2, allowing energy to be delivered to the output as needed. The actual voltage is slightly lower than $2 \times V_{IN}$ since the four switches (S1 - S4) have an on-resistance and the load drains charge from reservoir capacitor C2.

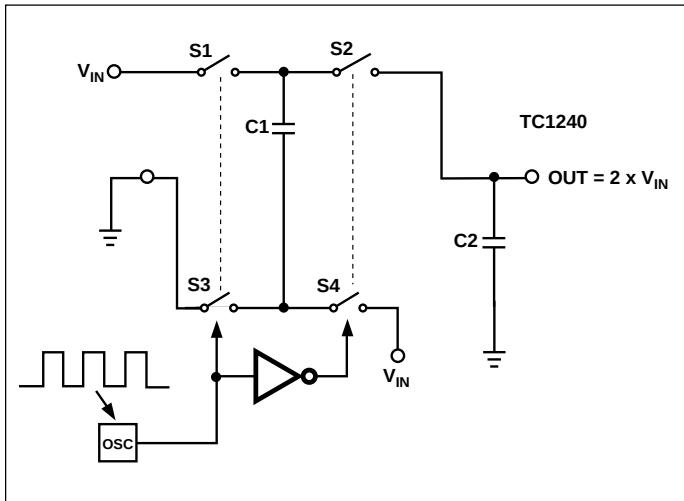


Figure 1. Ideal Switched Capacitor Charge Pump Doubler

APPLICATIONS INFORMATION

Output Voltage Considerations

The TC1240 performs voltage doubling but does 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 17Ω nominal at $+25^\circ\text{C}$ and $V_{IN} = +2.8\text{V}$. V_{OUT} is approximately $+5.6\text{V}$ at light loads, and droops according to the equation below:

$$V_{DROOP} = I_{OUT} \times R_{OUT}$$

$$V_{OUT} = 2 \times V_{IN} - V_{DROOP}$$

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) I^2R 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 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) and (3) above. These losses are given by Equation 1(b).

$$(a) P_{LOSS(2,3)} = I_{OUT}^2 \times R_{OUT}$$

$$(b) \cong I_{OUT}^2 \times \left[\frac{1}{(f_{PUMP}) C1} + 8R_{SWITCH} + 4ESR_{C1} + ESR_{C2} \right]$$

Equation 1.

The pump frequency in Equation 1(b) is defined as one-half the oscillator frequency (i.e. $f_{PUMP} = f_{OSC}/2$). The $1/(f_{PUMP})(C1)$ term in Equation 1(b) is the effective output resistance of an ideal switched capacitor circuit (Figures 2a, 2b). The value of R_{SWITCH} can be approximated at 1.4Ω for the TC1240.

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

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

Equation 2.

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

Equation 3.

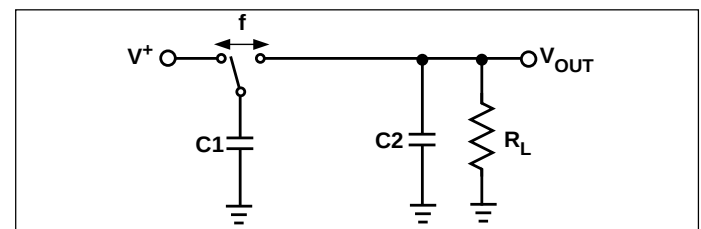


Figure 2a. Ideal Switched Capacitor Model

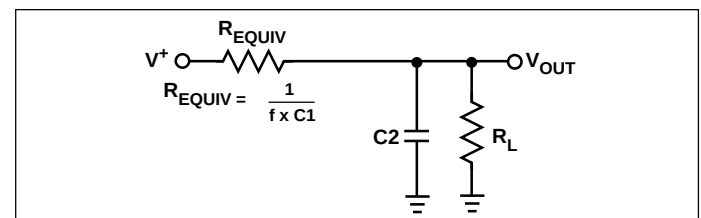


Figure 2b. Equivalent Output Resistance

Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

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 0.1Ω ESR_{C1} and 1.2Ω R_{SW}. Table 2 shows the output voltage ripple for various values of C2. The V_{RIPPLE} values assume 5 mA output load current and 0.1Ω ESR_{C2}.

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

C1 (μF)	TC1240 R _{OUT} (Ω)
0.47	47
1	28.5
2.2	19.5
3.3	17
4.7	15.5
10	13.6
47	12.5
100	12.2

Table 2. Output Voltage Ripple vs. C2 (ESR = 0.1Ω) I_{OUT} 5mA

C1 (μF)	TC1240 V _{RIPPLE} (mV)
0.47	142
1	67
2.2	30
3.3	20
4.7	14
10	6.7
47	2.5
100	1.6

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 should be a large value (at least equal to C1) connected from the input to GND.

SHUTDOWN INPUT

The TC1240 is disabled when SHDN is high, and enabled when SHDN is low. This input cannot be allowed to float.

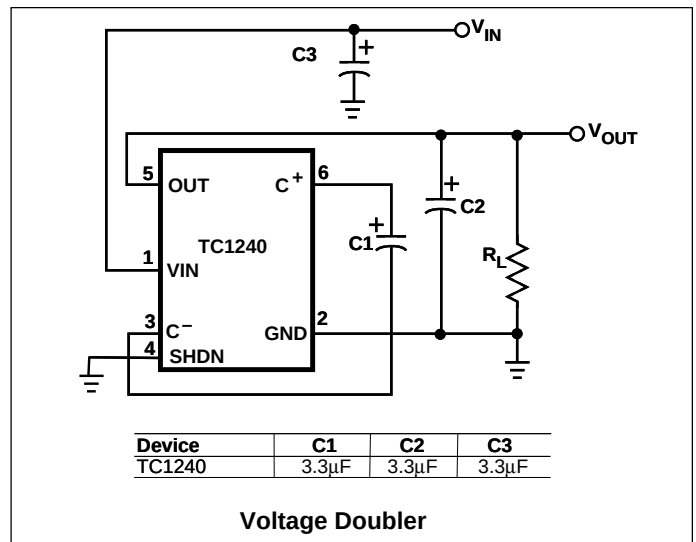


Figure 3. Test Circuit

VOLTAGE DOUBLER

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

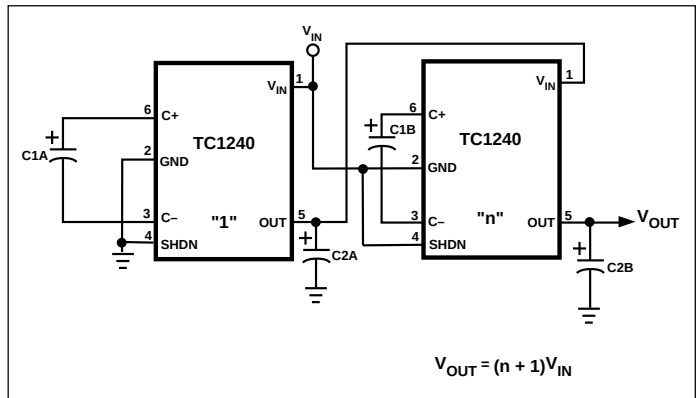


Figure 4. Cascading Multiple Devices to Increase Output Voltage

CASCADING DEVICES

Two or more TC1240s can be cascaded to increase output voltage (Figure 4). If the output is lightly loaded, it will be close to ((n + 1) x V_{IN}) but will droop at least by R_{OUT} of the first device multiplied by the I_O of the second. It can be seen that the output resistance rises rapidly for multiple cascaded devices. For the case of the two-stage 'tripler' output resistance can be approximated as R_{OUT} = 2 x R_{OUT1} + R_{OUT2}, where R_{OUT1} is the output resistance of the first stage, and R_{OUT2} is the output resistance of the second stage.

Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

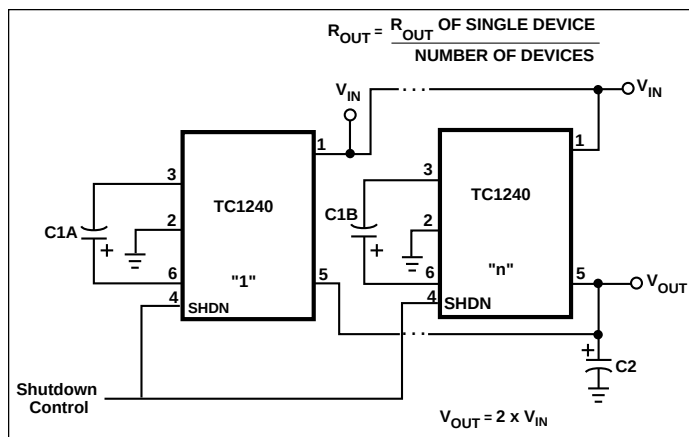


Figure 5. Paralleling Multiple Devices to Reduce Output Resistance

PARALLELING DEVICES

To reduce the value of R_{OUT} , multiple TC1240s can be connected in parallel (Figure 5). The output resistance will be reduced by a factor of N where N is the number of TC1240s. Each device will require its own pump capacitor ($C1x$), 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 TC1240s.

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.

TC1240 DEMO CARD

The TC1240 Demo Card is a 1.25" x 1.0" card containing a TC1240 and all of the necessary external components that allow the user to evaluate the device's ability to generate a 2X non-regulated output voltage. The demo card is fully assembled with the required external capacitors along with a variable load resistor that allows the user to vary the output load current of the output stage. For convenience, several test points and jumpers are available for measuring various voltages and currents on the circuit board.

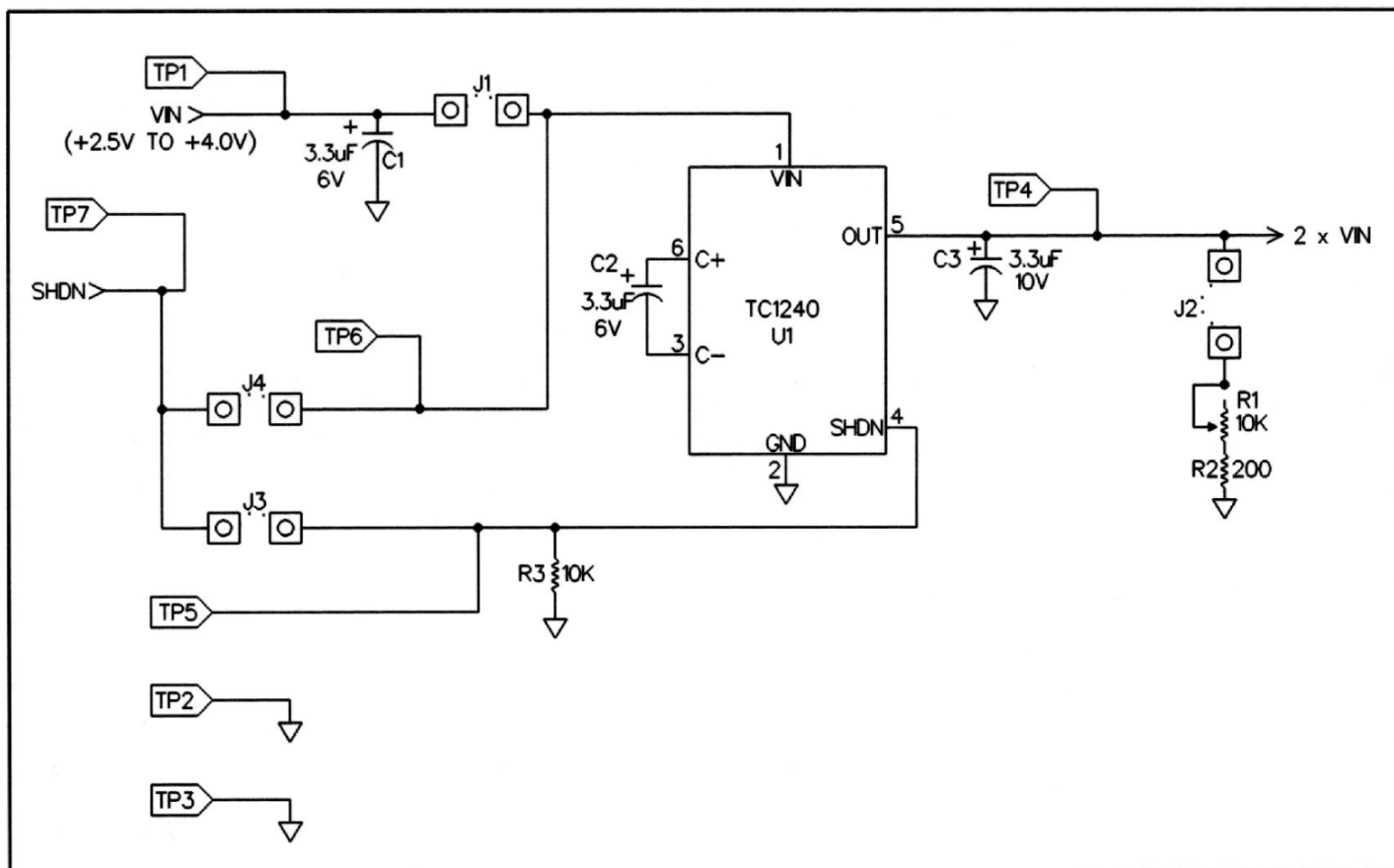


Figure 6. TC1240 Demo Card Schematic

Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

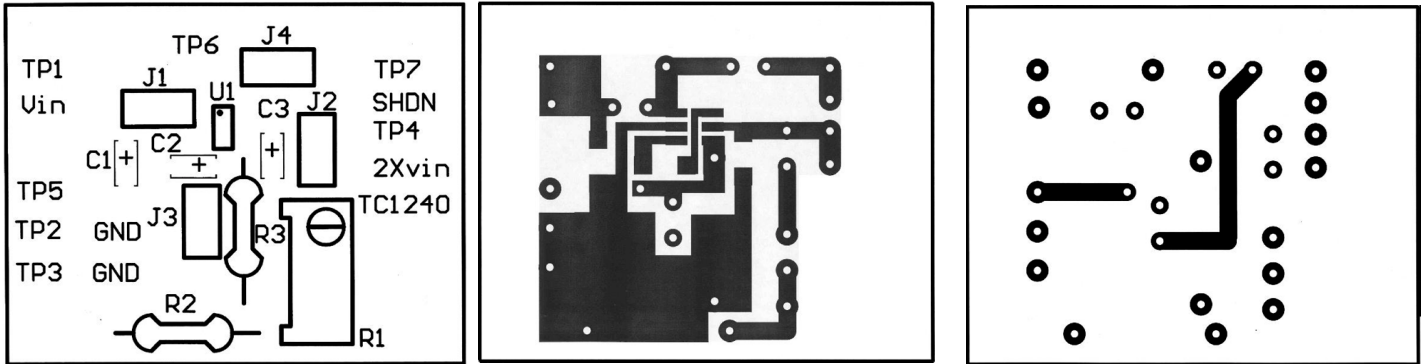


Figure 7. TC1240 Demo Card Assembly Drawing and Artwork

Figure 6 is a schematic of the TC1240 Demo Card, and Figure 7 shows the assembly drawing and artwork for the board. Table 3 lists the voltages that are monitored by the test points and Table 4 lists the currents that can be measured using the jumpers or the specific jumper function.

Table 3. TC1240 Demo Card Test Points

TEST POINT	VOLTAGE MEASUREMENT
TP1	DEMO CARD POWER SUPPLY INPUT[+2.5V to +4.0V]
TP2	GROUND
TP3	GROUND
TP4	TC1240 OUTPUT (2 x VIN)
TP5	TC1240 SHDN INPUT
TP6	TC1240 VIN SUPPLY VOLTAGE
TP7	EXTERNAL SHDN INPUT

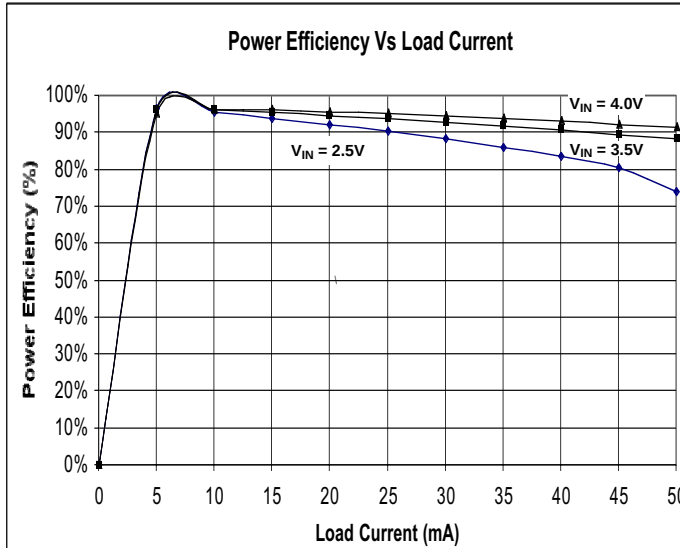
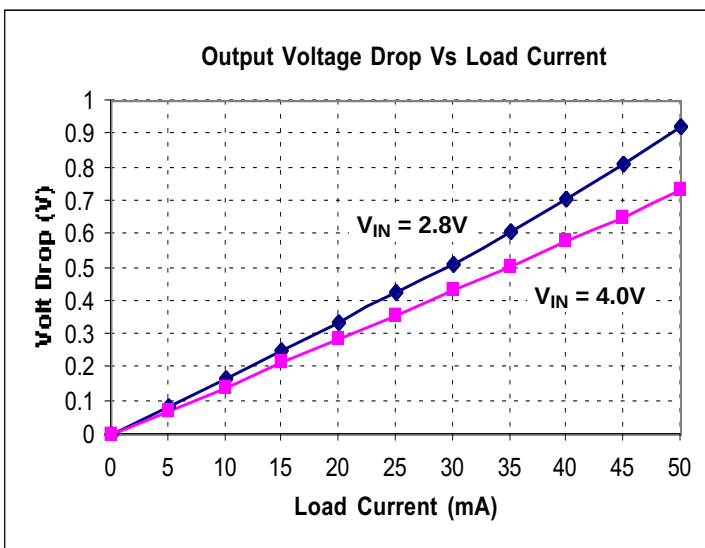
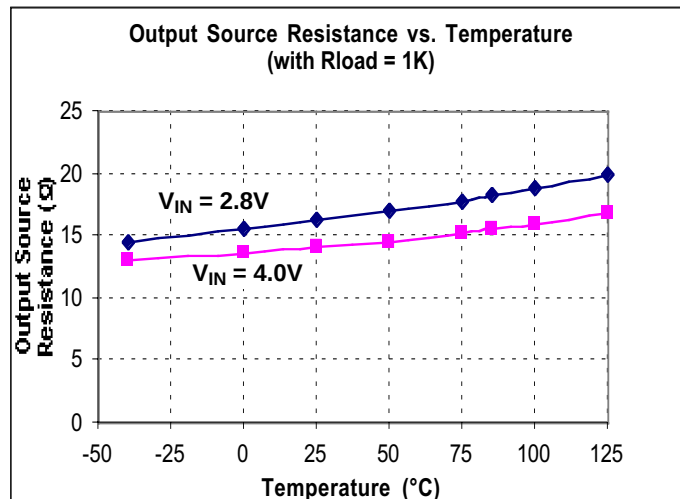
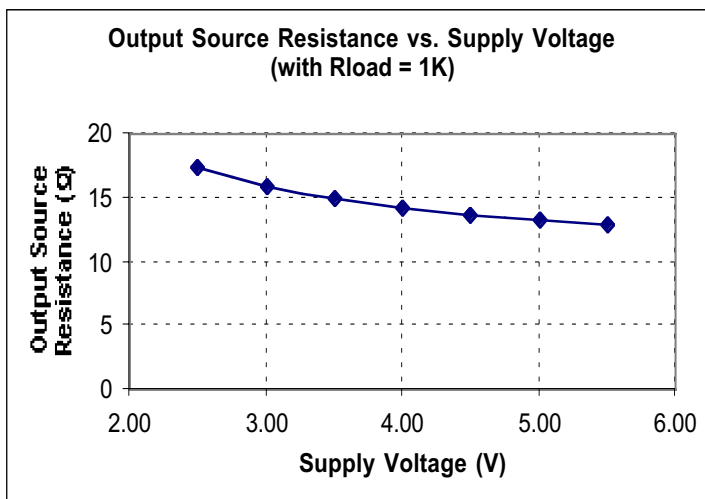
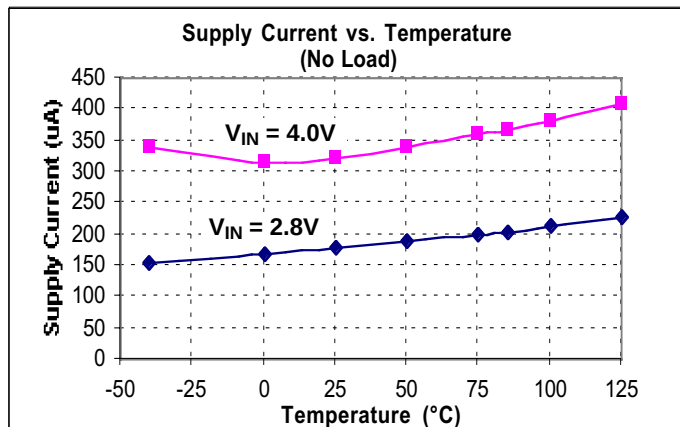
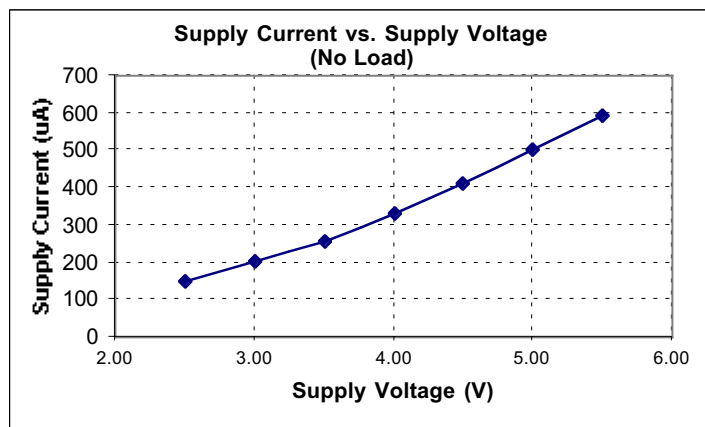
Table 4. TC1240 Demo Card Jumpers

JUMPER	CURRENT MEASUREMENT / JUMPER FUNCTION
J1	TC1240 QUIESCENT CURRENT
J2	TC1240 LOAD CURRENT
J3	TC1240 SHDN INPUT CURRENT
J4	CONNECT EXTERNAL SHDN INPUT TO VIN (i.e. SHDN ENABLE)

Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

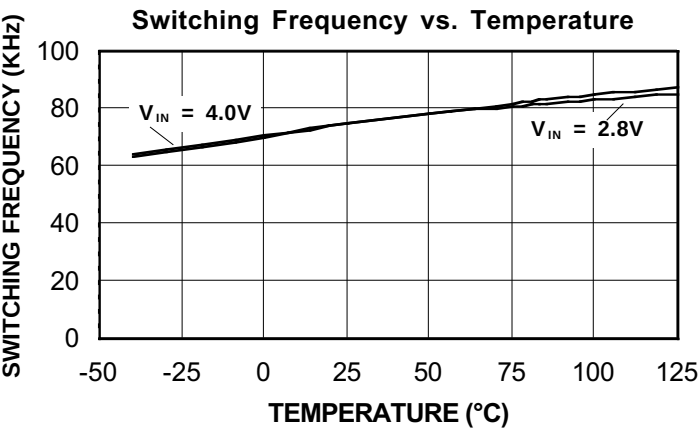
TYPICAL CHARACTERISTICS



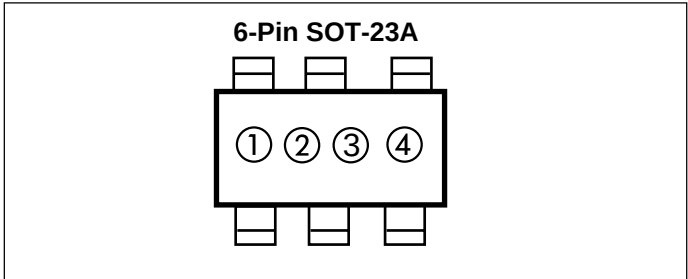
Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

TYPICAL CHARACTERISTICS (Cont.)



MARKING



① & ② represent part number code + temperature range (two-digit code)

TC1240 **Code**

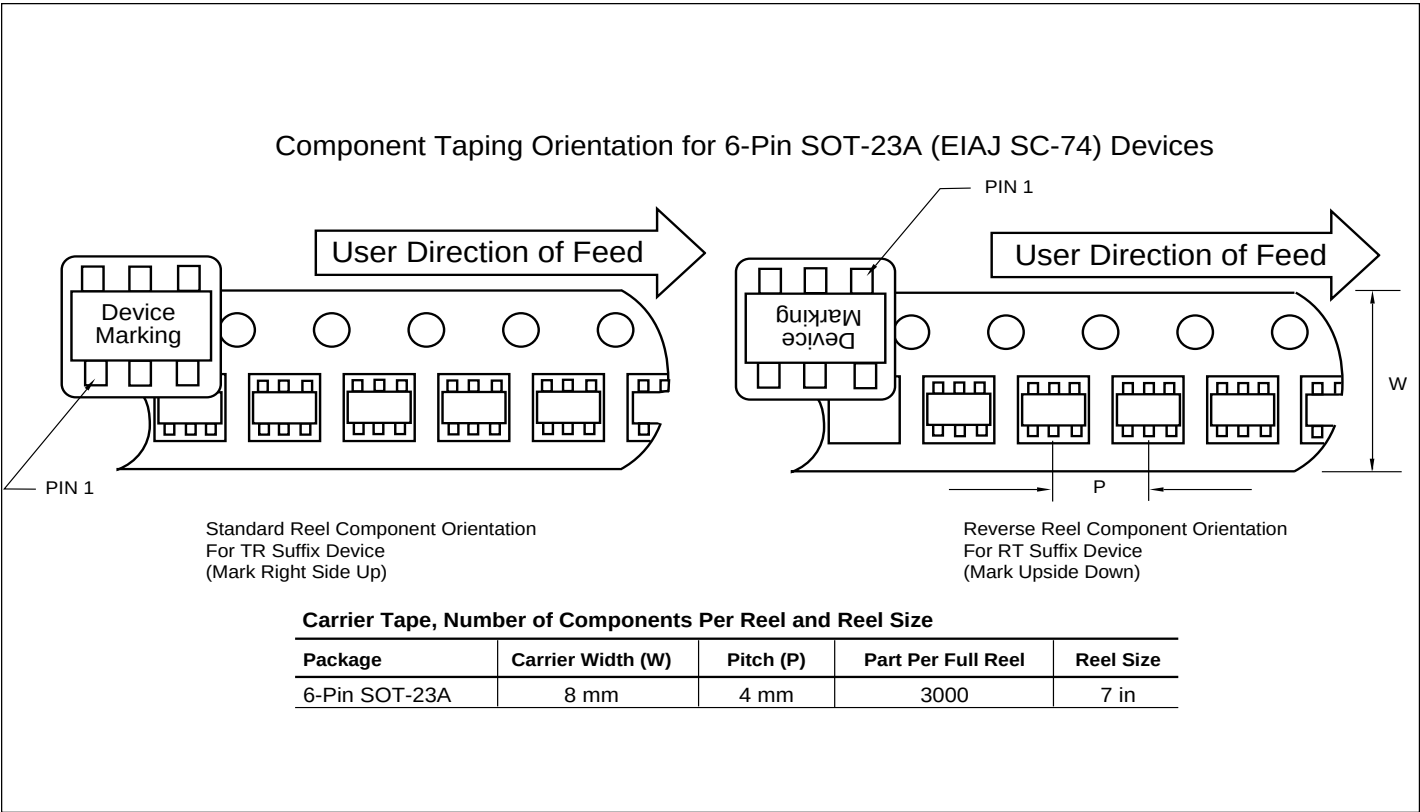
1240ECH DN

Ex: 1240ECH = (D) (N) ○ ○

③ represents year and 2-month code

④ represents lot ID number

TAPING FORM

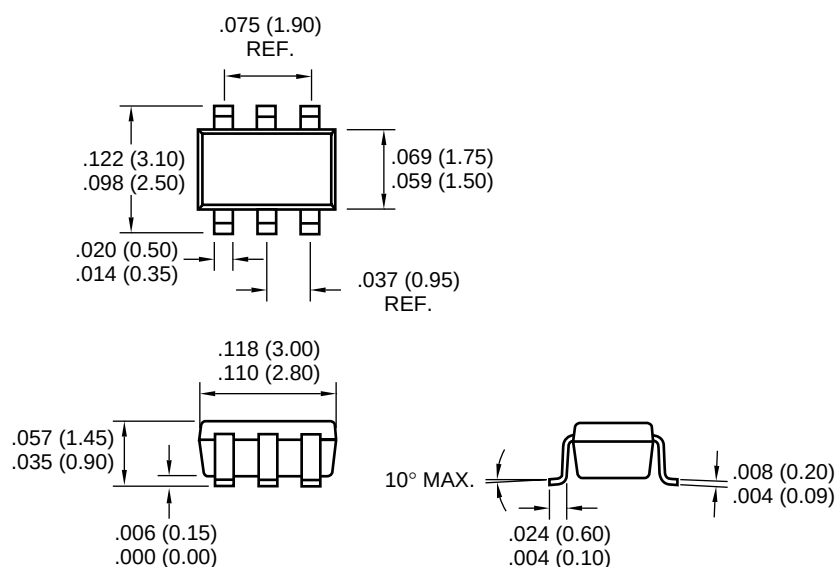


Positive Doubling Charge Pump with Shutdown in SOT Package

TC1240

PACKAGE DIMENSIONS

6-Pin SOT-23A (EIAJ SC-74)



Dimensions: inches (mm)

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

Trademarks

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

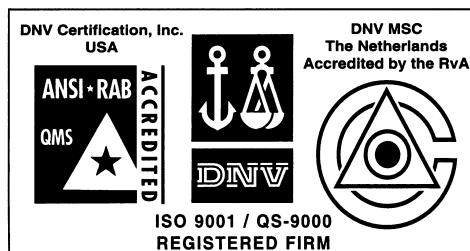
Total Endurance, ICSP, In-Circuit Serial Programming, Filter-Lab, MXDEV, microID, *Flex*ROM, *fuzzy*LAB, MPASM, MPLINK, MPLIB, PICC, PICDEM, PICDEM.net, ICEPIC, Migratable Memory, FanSense, ECONOMONITOR, Select Mode and microPort are trademarks of Microchip Technology Incorporated in the U.S.A.

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

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

© 2001, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.



Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs and microperipheral 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

Austin - Analog

13740 North Highway 183
Building J, Suite 4
Austin, TX 78750
Tel: 512-257-3370 Fax: 512-257-8526

Boston

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

Boston - Analog

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
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

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
Rm. 531, North Building
Fujian Foreign Trade Center Hotel
73 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7557563 Fax: 86-591-7557572

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'Shaughnessey 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: 65-334-8870 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

Denmark

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

France

Arizona 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

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

Lochamer 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

08/01/01