

## Inverting Voltage Doubler

### Features:

- 99.9% Voltage Conversion Efficiency
- 92% Power Conversion Efficiency
- Wide Input Voltage Range:
  - +2.4V to +5.5V
- Only 3 External Capacitors Required
- 185  $\mu$ A Supply Current
- Space-Saving 8-Pin SOIC and 8-Pin PDIP Packages

### Applications:

- -10V from +5V Logic Supply
- -6V from a Single 3V Lithium Cell
- Portable Handheld Instruments
- Cellular Phones
- LCD Display Bias Generator
- Panel Meters
- Operational Amplifier Power Supplies

### Device Selection Table

Part Number	Package	Operating Temp. Range
TC682COA	8-Pin SOIC	0°C to +70°C
TC682CPA	8-Pin PDIP	0°C to +70°C
TC682EOA	8-Pin SOIC	-40°C to +85°C
TC682EPA	8-Pin PDIP	-40°C to +85°C

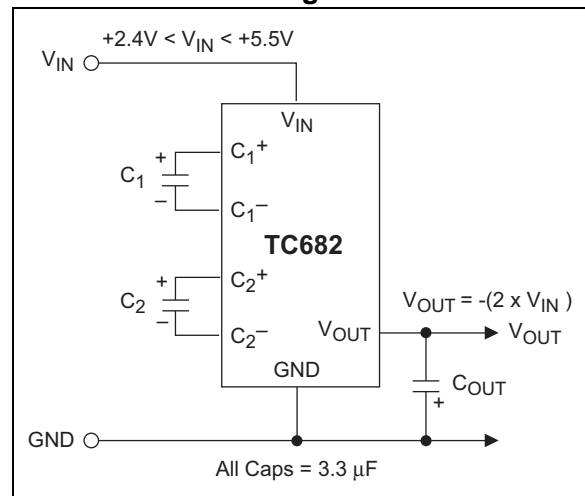
### General Description:

The TC682 is a CMOS charge pump converter that provides an inverted doubled output from a single positive supply. An on-board 12 kHz (typical) oscillator provides the clock and only 3 external capacitors are required for full circuit implementation.

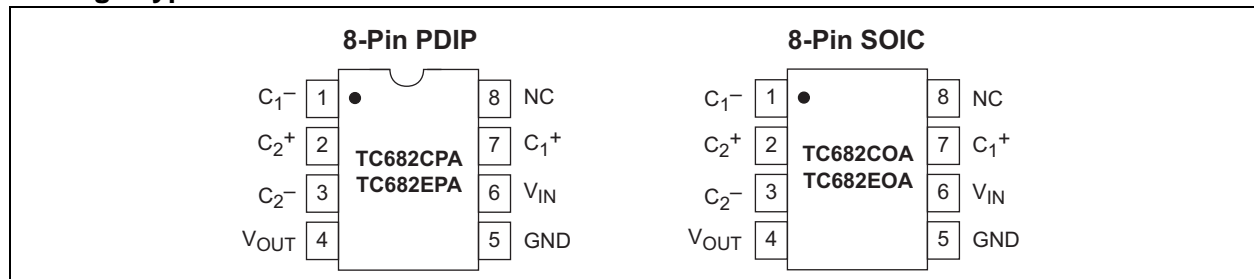
Low output source impedance (typically 140 $\Omega$ ), provides output current up to 10 mA. The TC682 features low quiescent current and high efficiency, making it the ideal choice for a wide variety of applications that require a negative voltage derived from a single positive supply (for example: generation of -6V from a 3V lithium cell or -10V generated from a +5V logic supply).

The minimum external parts count and small physical size of the TC682 make it useful in many medium-current, dual voltage analog power supplies.

### Functional Block Diagram



### Package Type



# TC682

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings\*

$V_{IN}$ .....	+5.8V
$V_{IN}$ dV/dT .....	1V/ $\mu$ sec
$V_{OUT}$ .....	-11.6V
Short-Circuit Duration - $V_{OUT}$ .....	Continuous
Power Dissipation ( $T_A \leq 70^\circ\text{C}$ )	
8-Pin PDIP .....	730 mW
8-Pin SOIC .....	470 mW
Operating Temperature Range.....	-40°C to +85°C
Storage Temperature (Unbiased) .....	-65°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.

### TC682 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Over operating temperature range, $V_{IN} = +5\text{V}$ , test circuit Figure 3-1 unless otherwise noted.						
Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$V_{IN}$	Supply Voltage Range	2.4	—	5.5	V	$R_L = 2\text{ k}\Omega$
$I_{IN}$	Supply Current	—	185	300	$\mu\text{A}$	$R_L = \infty, T_A = 25^\circ\text{C}$ $R_L = \infty$
$R_{OUT}$	$V_{OUT}$ Source Resistance	—	140	180	$\Omega$	$I_L^- = 10\text{ mA}, T_A = 25^\circ\text{C}$ $I_L^- = 10\text{ mA}$ $I_L^- = 5\text{ mA}, V_{IN} = 2.8\text{V}$
$F_{OSC}$	Oscillator Frequency	—	12	—	kHz	
$P_{EFF}$	Power Efficiency	90	92	—	%	$R_L = 2\text{ k}\Omega, T_A = 25^\circ\text{C}$
$V_{OUTEFF}$	Voltage Conversion Efficiency	99	99.9	—	%	$V_{OUT}, R_L = \infty$

## 2.0 PIN DESCRIPTION

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

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

Pin No. (8-Pin PDIP, SOIC)	Symbol	Description
1	C1-	Input. Capacitor C1 negative terminal.
2	C2+	Input. Capacitor C2 positive terminal.
3	C2-	Input. Capacitor C2 negative terminal.
4	V <sub>OUT</sub>	Output. Negative output voltage (-2V <sub>IN</sub> ).
5	GND	Input. Ground.
6	V <sub>IN</sub>	Input. Power supply voltage.
7	C1+	Input. Capacitor C1 positive terminal.
8	NC	No connection.

# TC682

## 3.0 DETAILED DESCRIPTION

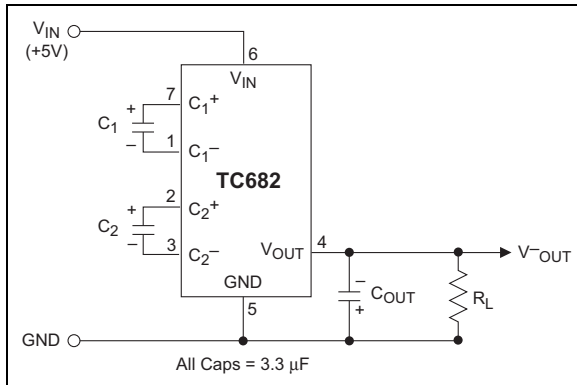


FIGURE 3-1: TC682 Test Circuit

### 3.1 Phase 1

$V_{SS}$  charge storage – before this phase of the clock cycle, capacitor  $C_1$  is already charged to +5V.  $C_1^+$  is then switched to ground and the charge in  $C_1^-$  is transferred to  $C_2^-$ . Since  $C_2^+$  is at +5V, the voltage potential across capacitor  $C_2$  is now -10V.

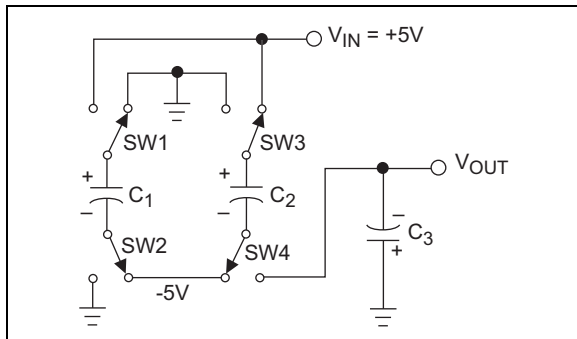


FIGURE 3-2: Charge Pump – Phase 1

### 3.2 Phase 2

$V_{SS}$  transfer – phase two of the clock connects the negative terminal of  $C_2$  to the negative side of reservoir capacitor  $C_3$  and the positive terminal of  $C_2$  to ground, transferring the generated -10V to  $C_3$ . Simultaneously, the positive side of capacitor  $C_1$  is switched to +5V and the negative side is connected to ground.  $C_2$  is then switched to  $V_{CC}$  and GND and Phase 1 begins again.

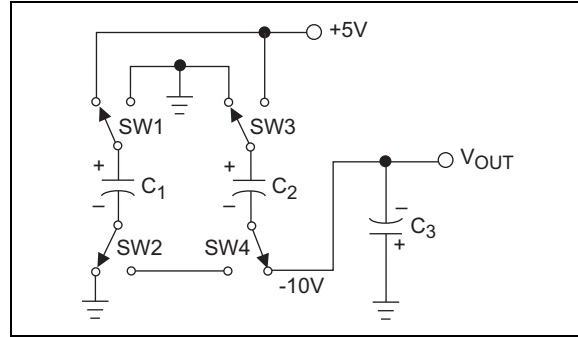


FIGURE 3-3: Charge Pump – Phase 2

### 3.3 Maximum Operating Limits

The TC682 has on-chip Zener diodes that clamp  $V_{IN}$  to approximately 5.8V, and  $V_{OUT}$  to -11.6V. Never exceed the maximum supply voltage or excessive current will be shunted by these diodes, potentially damaging the chip. The TC682 will operate over the entire operating temperature range with an input voltage of 2V to 5.5V.

### 3.4 Efficiency Considerations

Theoretically a charge pump voltage multiplier can approach 100% efficiency under the following conditions:

- The charge pump switches have virtually no offset and are extremely low on resistance.
- Minimal power is consumed by the drive circuitry.
- The impedances of the reservoir and pump capacitors are negligible.

For the TC682, efficiency is as shown below:

$$\begin{aligned} \text{Voltage Efficiency} &= V_{OUT} / (-2V_{IN}) \\ V_{OUT} &= -2V_{IN} + V_{DROP} \\ V_{DROP} &= (I_{OUT}) (R_{OUT}) \end{aligned}$$

$$\text{Power Loss} = I_{OUT} (V_{DROP})$$

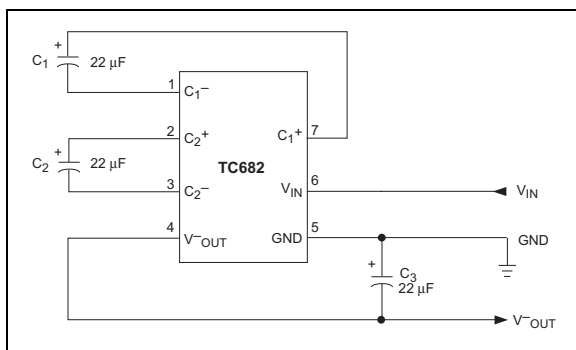
There will be a substantial voltage difference between  $V_{OUT}$  and  $-2V_{IN}$  if the impedances of the pump capacitors  $C_1$  and  $C_2$  are high with respect to their respective output loads.

Larger values of reservoir capacitor  $C_3$  will reduce output ripple. Larger values of both pump and reservoir capacitors improve the efficiency. See **Section 4.2 “Capacitor Selection”** “Capacitor Selection”.

## 4.0 TYPICAL APPLICATIONS

### 4.1 Negative Doubling Converter

The most common application of the TC682 is as a charge pump voltage converter which provides a negative output of two times a positive input voltage (Figure 4-1).



**FIGURE 4-1:** Inverting Voltage Doubler

### 4.2 Capacitor Selection

The output resistance of the TC682 is determined, in part, by the ESR of the capacitors used. An expression for  $R_{OUT}$  is derived as shown below:

$$R_{OUT} = 2(R_{SW1} + R_{SW2} + ESR_{C1} + R_{SW3} + R_{SW4} + ESR_{C2}) + 2(R_{SW1} + R_{SW2} + ESR_{C1} + R_{SW3} + R_{SW4} + ESR_{C2}) + 1/(f_{PUMP} \times C1) + 1/(f_{PUMP} \times C2) + ESR_{C3}$$

Assuming all switch resistances are approximately equal:

$$R_{OUT} = 16R_{SW} + 4ESR_{C1} + 4ESR_{C2} + ESR_{C3} + 1/(f_{PUMP} \times C1) + 1/(f_{PUMP} \times C2)$$

$R_{OUT}$  is typically 140Ω at +25°C with  $V_{IN} = +5V$  and 3.3 µF low ESR capacitors. The fixed term ( $16R_{SW}$ ) is about 80-90Ω. It can be seen easily that increasing or decreasing values of C1 and C2 will affect efficiency by changing  $R_{OUT}$ . However, be careful about ESR. This term can quickly become dominant with large electrolytic capacitors. Table 4-1 shows  $R_{OUT}$  for various values of C1 and C2 (assume 0.5Ω ESR). C1 must be rated at 6VDC or greater while C2 and C3 must be rated at 12VDC or greater.

Output voltage ripple is affected by C3. Typically the larger the value of C3 the less the ripple for a given load current. The formula for p-p  $V_{RIPPLE}$  is given below:

$$V_{RIPPLE} = \{1/[2(f_{PUMP} \times C3)] + 2(ESR_{C3})\} (I_{OUT})$$

For a 10 µF (0.5Ω ESR) capacitor for C3,  $f_{PUMP} = 10$  kHz and  $I_{OUT} = 10$  mA the peak-to-peak ripple voltage at the output will be less than 60 mV. In most applications ( $I_{OUT} < 10$  mA) a 10-20 µF capacitor and 1-5 µF pump capacitors will suffice. Table 4-2 shows  $V_{RIPPLE}$  for different values of C3 (assume 1Ω ESR).

**TABLE 4-1: OUTPUT RESISTANCE VS. C1, C2**

C1, C2 (µF)	$R_{OUT}(\Omega)$
0.05	4085
0.10	2084
0.47	510
1.00	285
3.30	145
5.00	125
10.00	105
22.00	94
100.00	87

**TABLE 4-2:  $V_{RIPPLE}$  PEAK-TO-PEAK VS. C3 ( $I_{OUT} 10mA$ )**

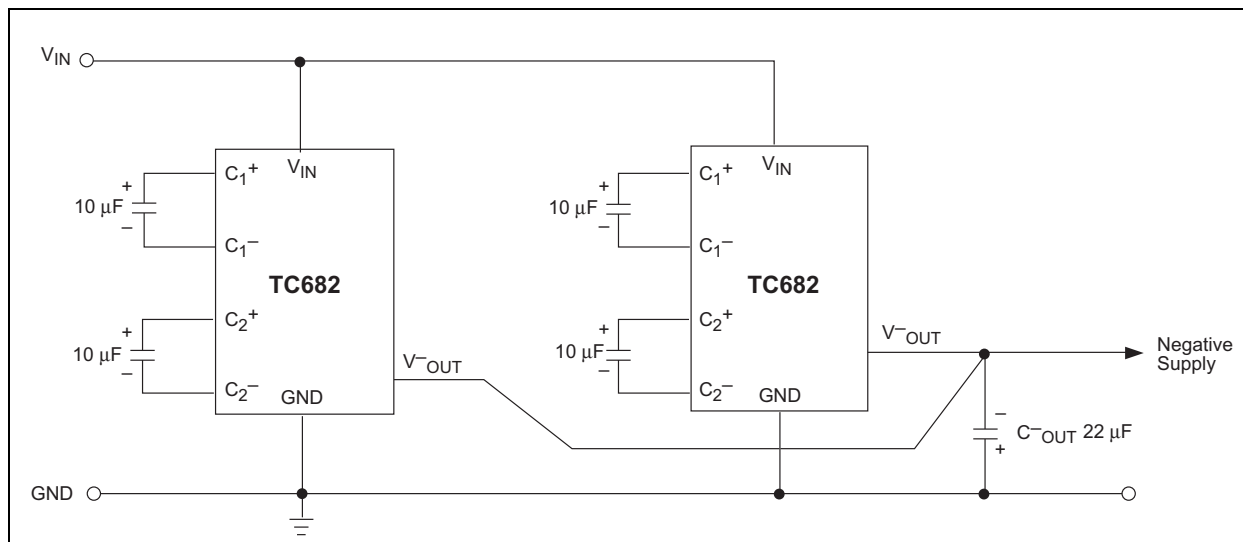
C3 (µF)	$V_{RIPPLE} (mV)$
0.50	1020
1.00	520
3.30	172
5.00	120
10.00	70
22.00	43
100.00	25

## 4.3 Paralleling Devices

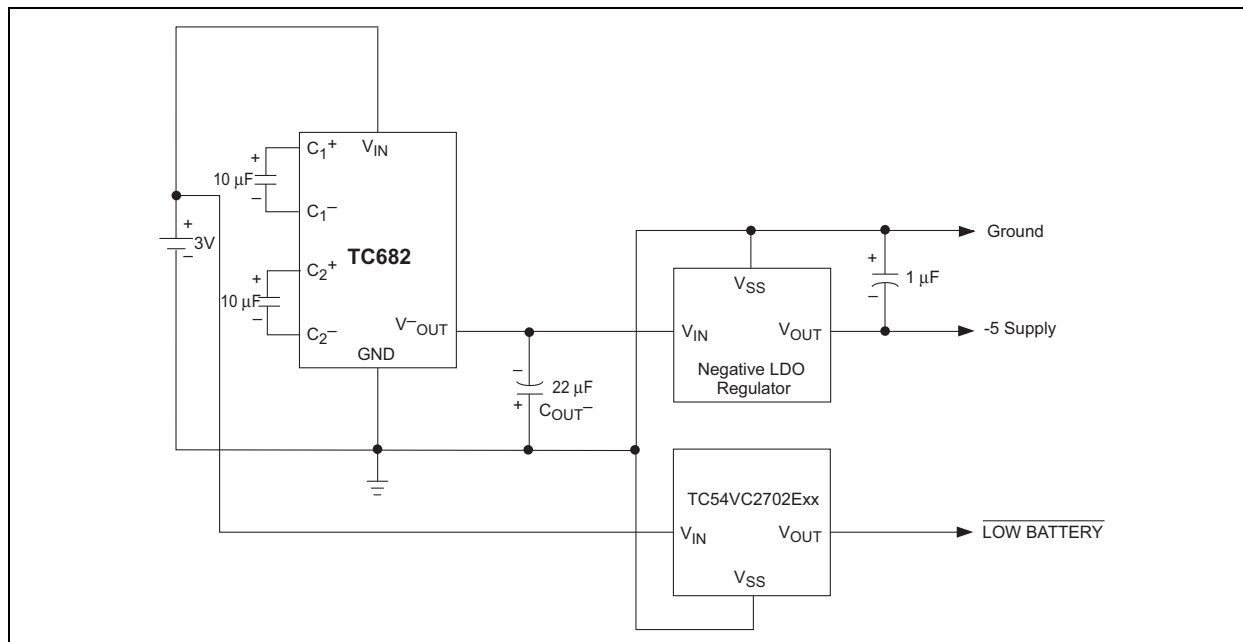
Paralleling multiple TC682s reduces the output resistance of the converter. The effective output resistance is the output resistance of a single device divided by the number of devices. As illustrated in Figure , each requires separate pump capacitors  $C_1$  and  $C_2$ , but all can share a single reservoir capacitor.

## 4.4 -5V Regulated Supply From A Single 3V Battery

Figure 4-3 shows a -5V power supply using one 3V battery. The TC682 provides -6V at  $V_{OUT}$ , which is regulated to -5V by the negative LDO. The input to the TC682 can vary from 3V to 5.5V without affecting regulation appreciably. A TC54 device is connected to the battery to detect undervoltage. This unit is set to detect at 2.7V. With higher input voltage, more current can be drawn from the outputs of the TC682. With 5V at  $V_{IN}$ , 10 mA can be drawn from the regulated output. Assuming  $150\Omega$  source resistance for the converter, with  $I_L^- = 10$  mA, the charge pump will droop 1.5V.



**FIGURE 4-2:** Paralleling TC682 for Lower Output Source Resistance

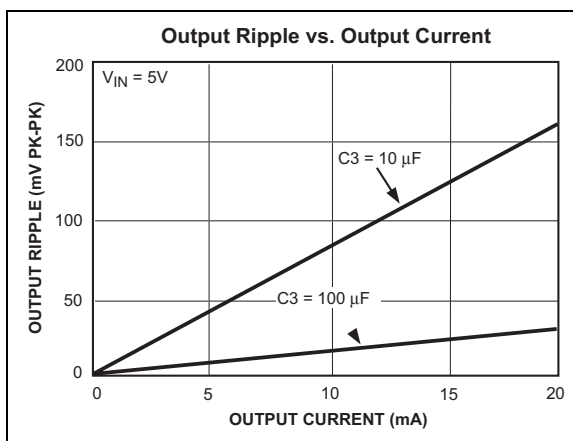
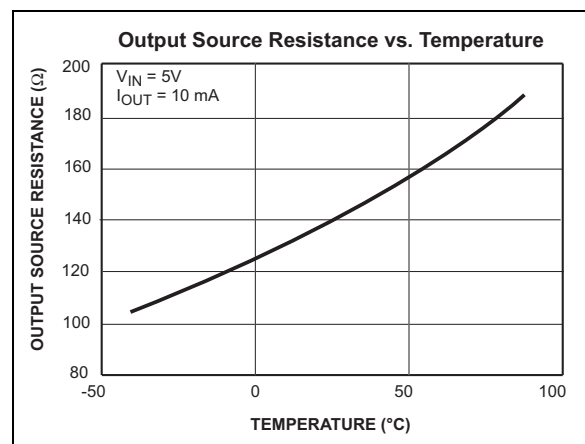
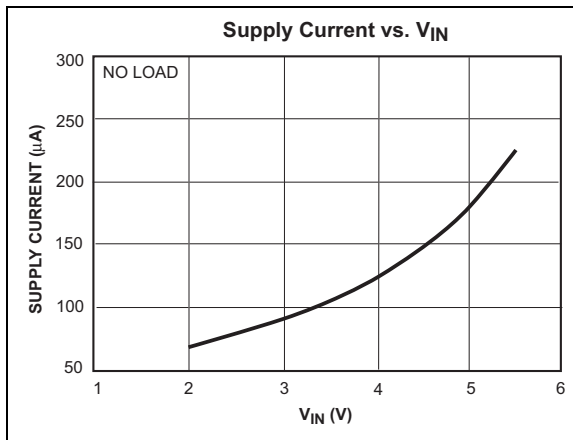
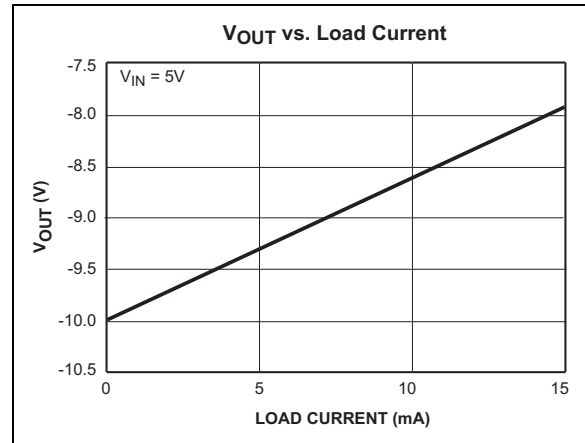
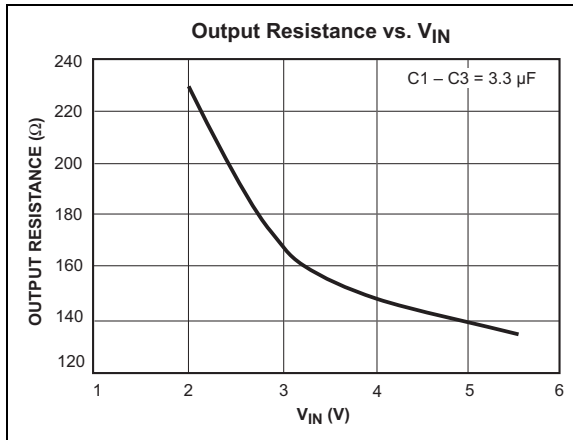


**FIGURE 4-3:** Negative Supply Derived from 3V Battery

## 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.

Circuit of Figure 3-1,  $C_1 = C_2 = C_{OUT} = 3.3 \mu\text{F}$ ,  $T_A = 25^\circ\text{C}$  unless otherwise noted.



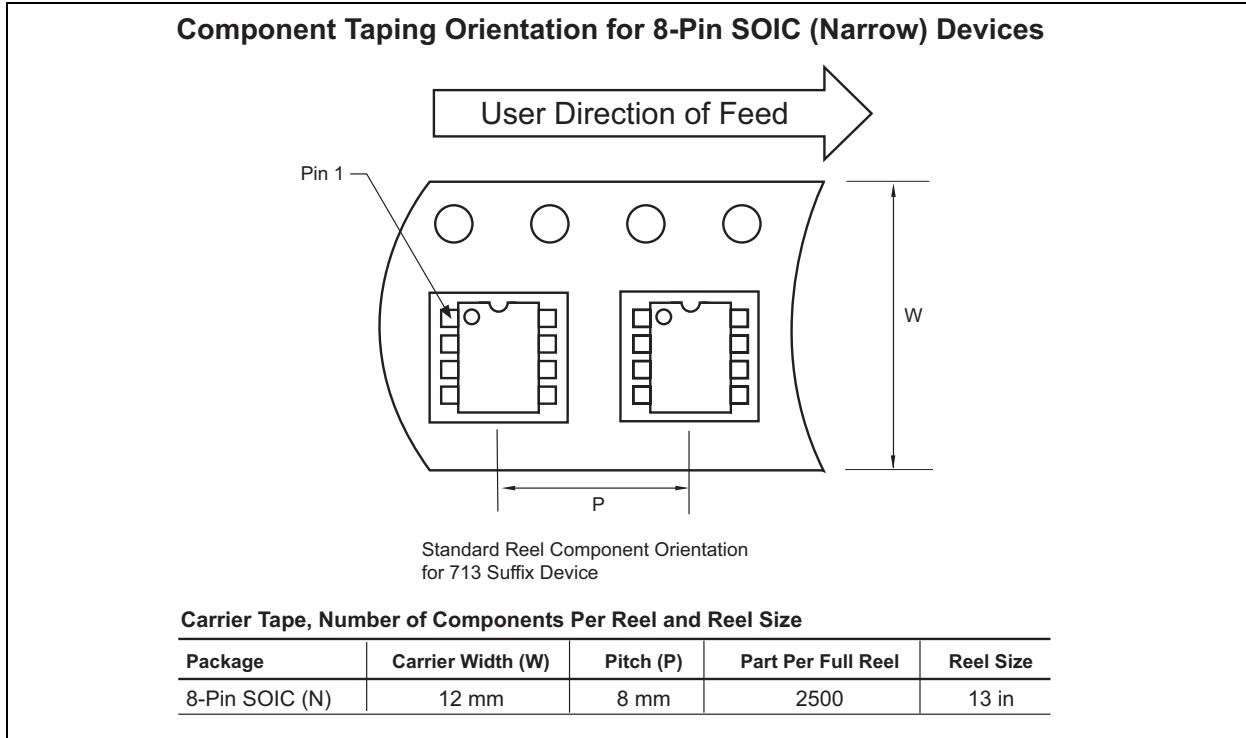
# TC682

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

Package marking data not available at this time.

### 6.2 Taping Form

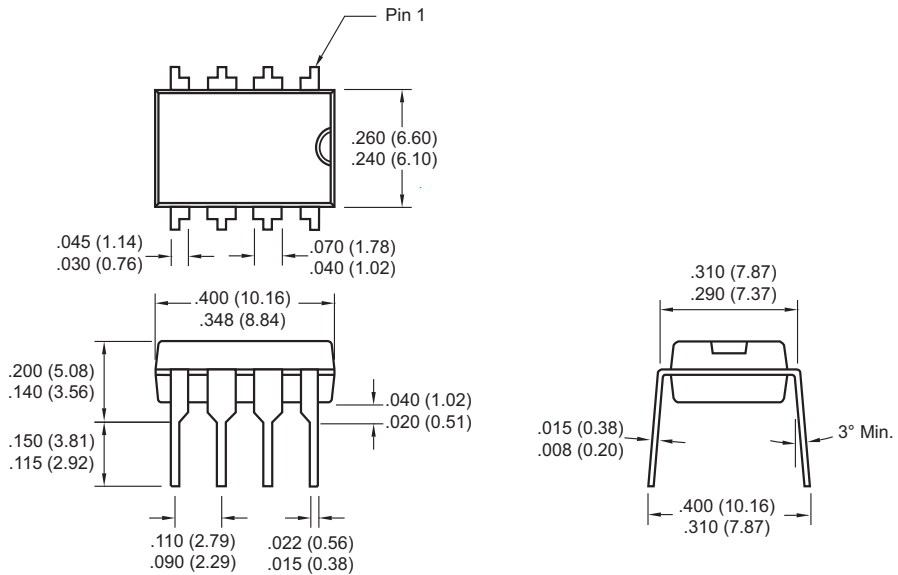




## 6.3 Package Dimensions

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>

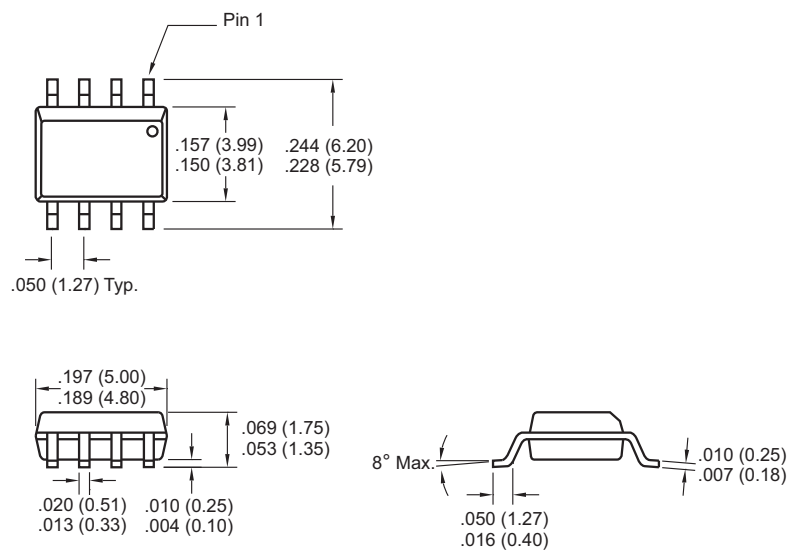
### 8-Pin Plastic DIP



Dimensions: inches (mm)

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>

### 8-Pin SOIC



Dimensions: inches (mm)

## 7.0 REVISION HISTORY

### Revision D

Added a note to each package outline drawing.

---

## THE MICROCHIP WEB SITE

Microchip provides online support via our WWW site at [www.microchip.com](http://www.microchip.com). This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

## CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at [www.microchip.com](http://www.microchip.com). Under "Support", click on "Customer Change Notification" and follow the registration instructions.

## CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

**Technical support is available through the web site at: <http://microchip.com/support>**

## READER RESPONSE

It is our intention to provide you with the best documentation possible to ensure successful use of your Microchip product. If you wish to provide your comments on organization, clarity, subject matter, and ways in which our documentation can better serve you, please FAX your comments to the Technical Publications Manager at (480) 792-4150.

Please list the following information, and use this outline to provide us with your comments about this document.

TO: Technical Publications Manager Total Pages Sent \_\_\_\_\_

RE: Reader Response

From: Name \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City / State / ZIP / Country \_\_\_\_\_

Telephone: (\_\_\_\_\_) \_\_\_\_\_ - \_\_\_\_\_ FAX: (\_\_\_\_\_) \_\_\_\_\_ - \_\_\_\_\_

Application (optional):

Would you like a reply?  Y  N

Device: TC682

Literature Number: DS21453D

Questions:

1. What are the best features of this document?

\_\_\_\_\_  
\_\_\_\_\_

2. How does this document meet your hardware and software development needs?

\_\_\_\_\_  
\_\_\_\_\_

3. Do you find the organization of this document easy to follow? If not, why?

\_\_\_\_\_  
\_\_\_\_\_

4. What additions to the document do you think would enhance the structure and subject?

\_\_\_\_\_  
\_\_\_\_\_

5. What deletions from the document could be made without affecting the overall usefulness?

\_\_\_\_\_  
\_\_\_\_\_

6. Is there any incorrect or misleading information (what and where)?

\_\_\_\_\_  
\_\_\_\_\_

7. How would you improve this document?

\_\_\_\_\_  
\_\_\_\_\_

---

**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

---

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

#### **Trademarks**

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC<sup>32</sup> logo, rPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniclient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICtail, REAL ICE, rLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. & KG, a subsidiary of Microchip Technology Inc., in other countries.

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

© 2002-2012, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 9781620768341

*Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC<sup>®</sup> MCUs and dsPIC<sup>®</sup> DSCs, KEELOQ<sup>®</sup> code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*

---

**QUALITY MANAGEMENT SYSTEM**  
**CERTIFIED BY DNV**  
**== ISO/TS 16949 ==**



# MICROCHIP

## 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:  
<http://www.microchip.com/support>  
Web Address:  
[www.microchip.com](http://www.microchip.com)

**Atlanta**  
Duluth, GA  
Tel: 678-957-9614  
Fax: 678-957-1455

**Boston**  
Westborough, MA  
Tel: 774-760-0087  
Fax: 774-760-0088

**Chicago**  
Itasca, IL  
Tel: 630-285-0071  
Fax: 630-285-0075

**Cleveland**  
Independence, OH  
Tel: 216-447-0464  
Fax: 216-447-0643

**Dallas**  
Addison, TX  
Tel: 972-818-7423  
Fax: 972-818-2924

**Detroit**  
Farmington Hills, MI  
Tel: 248-538-2250  
Fax: 248-538-2260

**Indianapolis**  
Noblesville, IN  
Tel: 317-773-8323  
Fax: 317-773-5453

**Los Angeles**  
Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608

**Santa Clara**  
Santa Clara, CA  
Tel: 408-961-6444  
Fax: 408-961-6445

**Toronto**  
Mississauga, Ontario,  
Canada  
Tel: 905-673-0699  
Fax: 905-673-6509

### ASIA/PACIFIC

**Asia Pacific Office**  
Suites 3707-14, 37th Floor  
Tower 6, The Gateway  
Harbour City, Kowloon  
Hong Kong  
Tel: 852-2401-1200  
Fax: 852-2401-3431

**Australia - Sydney**  
Tel: 61-2-9868-6733  
Fax: 61-2-9868-6755

**China - Beijing**  
Tel: 86-10-8569-7000  
Fax: 86-10-8528-2104

**China - Chengdu**  
Tel: 86-28-8665-5511  
Fax: 86-28-8665-7889

**China - Chongqing**  
Tel: 86-23-8980-9588  
Fax: 86-23-8980-9500

**China - Hangzhou**  
Tel: 86-571-2819-3187  
Fax: 86-571-2819-3189

**China - Hong Kong SAR**  
Tel: 852-2943-5100  
Fax: 852-2401-3431

**China - Nanjing**  
Tel: 86-25-8473-2460  
Fax: 86-25-8473-2470

**China - Qingdao**  
Tel: 86-532-8502-7355  
Fax: 86-532-8502-7205

**China - Shanghai**  
Tel: 86-21-5407-5533  
Fax: 86-21-5407-5066

**China - Shenyang**  
Tel: 86-24-2334-2829  
Fax: 86-24-2334-2393

**China - Shenzhen**  
Tel: 86-755-8864-2200  
Fax: 86-755-8203-1760

**China - Wuhan**  
Tel: 86-27-5980-5300  
Fax: 86-27-5980-5118

**China - Xian**  
Tel: 86-29-8833-7252  
Fax: 86-29-8833-7256

**China - Xiamen**  
Tel: 86-592-2388138  
Fax: 86-592-2388130

**China - Zhuhai**  
Tel: 86-756-3210040  
Fax: 86-756-3210049

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444  
Fax: 91-80-3090-4123

**India - New Delhi**  
Tel: 91-11-4160-8631  
Fax: 91-11-4160-8632

**India - Pune**  
Tel: 91-20-2566-1512  
Fax: 91-20-2566-1513

**Japan - Osaka**  
Tel: 81-6-6152-7160  
Fax: 81-6-6152-9310

**Japan - Tokyo**  
Tel: 81-3-6880-3770  
Fax: 81-3-6880-3771

**Korea - Daegu**  
Tel: 82-53-744-4301  
Fax: 82-53-744-4302

**Korea - Seoul**  
Tel: 82-2-554-7200  
Fax: 82-2-558-5932 or  
82-2-558-5934

**Malaysia - Kuala Lumpur**  
Tel: 60-3-6201-9857  
Fax: 60-3-6201-9859

**Malaysia - Penang**  
Tel: 60-4-227-8870  
Fax: 60-4-227-4068

**Philippines - Manila**  
Tel: 63-2-634-9065  
Fax: 63-2-634-9069

**Singapore**  
Tel: 65-6334-8870  
Fax: 65-6334-8850

**Taiwan - Hsin Chu**  
Tel: 886-3-5778-366  
Fax: 886-3-5770-955

**Taiwan - Kaohsiung**  
Tel: 886-7-213-7828  
Fax: 886-7-330-9305

**Taiwan - Taipei**  
Tel: 886-2-2508-8600  
Fax: 886-2-2508-0102

**Thailand - Bangkok**  
Tel: 66-2-694-1351  
Fax: 66-2-694-1350

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
Tel: 45-4450-2828  
Fax: 45-4485-2829

**France - Paris**  
Tel: 33-1-69-53-63-20  
Fax: 33-1-69-30-90-79

**Germany - Munich**  
Tel: 49-89-627-144-0  
Fax: 49-89-627-144-44

**Italy - Milan**  
Tel: 39-0331-742611  
Fax: 39-0331-466781

**Netherlands - Drunen**  
Tel: 31-416-690399  
Fax: 31-416-690340

**Spain - Madrid**  
Tel: 34-91-708-08-90  
Fax: 34-91-708-08-91

**UK - Wokingham**  
Tel: 44-118-921-5869  
Fax: 44-118-921-5820

11/29/12