

# Micro Power Inverting Charge Pump

- Low Power Voltage Conversion
- +2.4V to +5.5V Input Range
- 99% Voltage Conversion Efficiency
- Typical 60 $\mu$ A Supply Current
- Requires Only Three External Capacitors
- Includes Low Power Shutdown Option
- Ideal in Portable Applications Such As
  - Handheld Instruments
  - Cellular Phones
  - Personal Digital Assistants
  - Laptops and Notebooks
- Pin Compatible Upgrade to Microchip's TC682



## APPLICATIONS

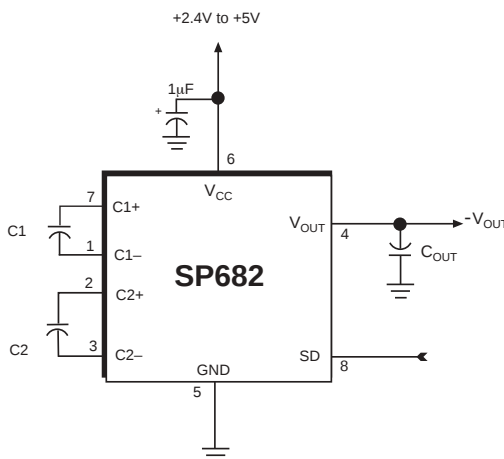
- LCD Display
- Negative bias supply for op amps
- Serial interface protocol circuits

## DESCRIPTION

The **SP682** is a monolithic charge pump voltage converter that produces a doubled, negative voltage from a single positive supply. The **SP682** charge pump outputs a  $-10V$  voltage from a  $+5V$  input. Three external charge pump capacitors are required to support the voltage conversion and voltage doubling process. An internal oscillator generates a 12kHz clock which cycles the internal switching that charges the storage and transfer capacitors. The charge pump architecture is fabricated using a low power BiCMOS process technology.

The **SP682** charge pump is ideal for low power applications requiring a typical  $+3V$  battery source such as a lithium cell. Typical applications are handheld instruments, notebook and laptop computers, cellular phones, and data acquisition or GP systems. The **SP682** is packaged in either 8-pin NSOIC, 8-pin MSOP for surface mount applications, and 8 Pin PDIP.

## TYPICAL APPLICATION CIRCUIT



## ABSOLUTE MAXIMUM RATINGS

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

$V_{CC}$ .....+7V  
 $V_{OUT}$ .....-11V  
 Storage Temperature.....-65°C to +150°C

Power Dissipation:

8-pin NSOIC.....500mW  
 8-pin MSOP.....320mW  
 8-pin PDIP.....750mW

Package Derating:

8-pin NSOIC:  
 $\theta_{JA}$ .....128°C/W  
 8-pin MSOP:  
 $\theta_{JA}$ .....216°C/W  
 8-pin PDIP:  
 $\theta_{JA}$ .....97°C/W

## ELECTRICAL CHARACTERISTICS

$T_A = T_{MIN}$  to  $T_{MAX}$  and  $V_{CC} = +5V$ . Charge pump cap = 3.3μF, unless otherwise noted.

|                              | MIN. | TYP.  | MAX. | UNITS | CONDITIONS                                      |
|------------------------------|------|-------|------|-------|-------------------------------------------------|
| <b>SUPPLY CURRENT</b>        |      |       |      |       | <b>CHARGE PUMP CAPACITORS: 3.3μF</b>            |
| $I_{CC}$                     |      | 60    | 120  | μA    | $R_L = \infty$ , $T_A = +25^\circ\text{C}$      |
| in shutdown                  |      |       | 200  | μA    | $R_L = \infty$                                  |
|                              |      |       | 1    | μA    | $T_A = +25^\circ\text{C}$ , SD = +5V            |
| <b>CHARGE PUMP OUTPUT</b>    |      |       |      |       | <b>CHARGE PUMP CAPACITORS: 3.3μF</b>            |
| $V_{OUT}$                    | -9.9 | -9.99 |      | Volts | $R_L = \infty$                                  |
|                              | -9.0 | -9.5  |      | Volts | $R_L = 2k\Omega$                                |
| <b>SOURCE RESISTANCE</b>     |      |       |      |       |                                                 |
| $R_{OUT}$                    |      | 140   | 180  | Ω     | $I_L = 10\text{mA}$ , $T_A = +25^\circ\text{C}$ |
|                              |      |       | 230  | Ω     | $I_L = 10\text{mA}$                             |
|                              |      | 380   | 450  | Ω     | $I_L = 5\text{mA}$ , $V_{CC} = +2.8V$           |
| <b>OSCILLATOR FREQUENCY</b>  |      |       |      |       |                                                 |
| $f_{OSC}$                    |      | 12    | 20   | kHz   | $f_{osc} = 2 \times f_{C1+}$                    |
| <b>CONVERSION EFFICIENCY</b> |      |       |      |       |                                                 |
| $V_{OUT\ EFF}$               | 99   | 99.9  |      | %     | $R_L = \infty$                                  |
| $V_{OUT\ EFF}$               | 90   | 95    |      | %     | $R_L = 2k\Omega$                                |
| <b>START-UP TIMING</b>       |      |       |      |       |                                                 |
| $V_{OUT}$ Power On Delay     |      | 12    |      | ms    | $R_L = 2k\Omega$                                |
| <b>SHUTDOWN TIMING</b>       |      |       |      |       |                                                 |
| Shutdown to $V_{OUT}$ Delay  |      | 5     |      | ms    | $R_L = 2k\Omega$                                |
| <b>SUPPLY VOLTAGE</b>        |      |       |      |       |                                                 |
| $V_{CC}$                     | +2.4 |       | +5.5 | Volts |                                                 |
| Operating Temperature Range  |      |       |      |       |                                                 |
| - C                          | 0    |       | +70  | °C    |                                                 |
| - E                          | -40  |       | +85  | °C    |                                                 |

The **SP682**'s charge pump design is a simplified version of **Sipex**'s original patented charge pump design (5,306,954) except that it only generates a negative output. The charge pump utilizes external capacitors to store the charge. Figure 1 shows the waveform found on the negative side of capacitor C2. There is a free-running oscillator, running at 12kHz, that controls the two phases of the voltage shifting. A description of each phase follows.

### Phase 1

**V<sub>OUT</sub> charge storage** — During this phase of the clock cycle, the positive side of capacitors C<sub>1</sub> and C<sub>2</sub> are initially charged to +5V. C<sub>1</sub><sup>+</sup> is then switched to ground and the charge on C<sub>1</sub><sup>-</sup> is transferred to C<sub>2</sub><sup>-</sup>. Since C<sub>2</sub><sup>+</sup> is connected to +5V, the voltage potential across capacitor C<sub>2</sub> is now 10V.

### Phase 2

**V<sub>OUT</sub> transfer** — Phase two of the clock connects the negative terminal of C<sub>2</sub> to the V<sub>OUT</sub> storage capacitor and the positive terminal of C<sub>2</sub> to ground, and transfers the generated -10V to C<sub>3</sub>. Simultaneously, the positive side of capacitor C<sub>1</sub> is switched to +5V and the negative side is connected to ground.

The oscillator frequency or clock rate for the charge pump is designed for low power operation. The oscillator operates at a frequency of

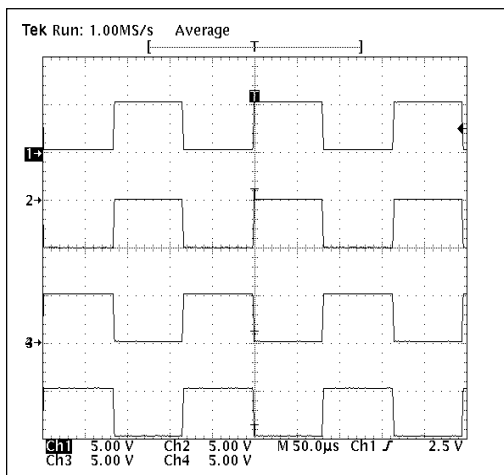


Figure 1. Charge Pump Waveform

about 12kHz (20kHz maximum) which conserves power as opposed to higher frequency which operation typically draws more power from V<sub>CC</sub>. The external charge pump capacitors specified are 3.3μF but the absolute minimum should be 1μF.

### EFFICIENCY INFORMATION

A charge pump theoretically produces a doubled voltage at 100% efficiency. However in the real world, there is a small voltage drop on the output which reduces the output efficiency. The **SP682** can usually run 99.9% efficient without driving a load. While driving a 1kΩ load, the **SP682** remains over 90% efficiency.

$$\text{Output Voltage Efficiency} = V_{\text{OUT}} / (-2 * V_{\text{CC}});$$

$$V_{\text{OUT}} = -2 * V_{\text{CC}} + V_{\text{DROP}}$$

$$V_{\text{DROP}} = (I_{\text{OUT}}) * (R_{\text{OUT}})$$

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

The efficiency changes as the external charge pump capacitors are varied. Larger capacitor values will strengthen the output and reduce output ripple. Although smaller capacitors will cost less and save board space, lower values will reduce the output drive capability and also increase the output ripple.

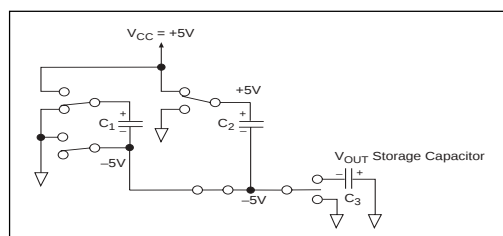


Figure 2. Charge Pump Phase 1

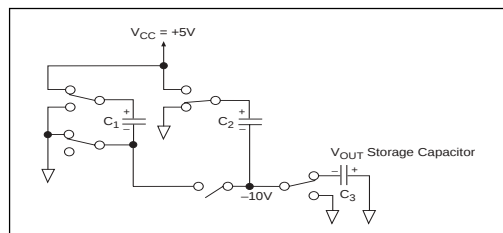


Figure 3. Charge Pump Phase 2

The ESR of the charge pump capacitors also determine the output resistance. Assuming that switch resistances are approximately equal, the output resistance can be derived as shown below:

$$R_{OUT} = 16 * (R_{SW1-4}) + 4 * (ESR_{C1} + ESR_{C2}) + ESR_{C3} + 1 / (f_{OSC} * C1) + 1 / (f_{OSC} * C2)$$

$R_{OUT}$  is typically  $140\Omega$  at  $+25^{\circ}\text{C}$  with  $V_{CC}$  at  $+5\text{V}$  using  $3.3\mu\text{F}$  capacitors. The total internal switch resistance ( $16 * R_{SW}$ ) is approximately  $90\Omega$ . The table below shows the comparison of  $R_{OUT}$  versus  $C1\&C2$ .

| C1, C2 ( $\mu\text{F}$ ) | $R_{OUT}$ ( $\Omega$ ) |
|--------------------------|------------------------|
| 0.05                     | 4085                   |
| 0.10                     | 2084                   |
| 0.47                     | 510                    |
| 1.00                     | 285                    |
| 3.30                     | 140                    |
| 4.70                     | 125                    |
| 10.00                    | 105                    |
| 22.00                    | 94                     |

**Table 1.  $R_{OUT}$  vs.  $C1, C2$**

The output voltage ripple is also affected by the capacitors, specifically  $C_{OUT}$ . Larger values will reduce the output ripple for a given output current load of current. The formula representation is:

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

To minimize the output ripple, the  $C_{OUT}$  storage capacitor can be increased to over  $10\mu\text{F}$  whereas the pump capacitors can range from  $1\mu\text{F}$  to  $5\mu\text{F}$ . Table 2 shows the typical  $V_{RIPPLE}$  for given  $C_{OUT}$  values.

| $C_{OUT}$ ( $\mu\text{F}$ ) | $V_{RIPPLE}$ (mV) |
|-----------------------------|-------------------|
| 0.50                        | 1020              |
| 1.00                        | 520               |
| 3.30                        | 172               |
| 4.70                        | 120               |
| 10.00                       | 70                |
| 22.00                       | 43                |

**Table 2.  $C3$  vs.  $V_{RIPPLE}$**

## SHUTDOWN FEATURE

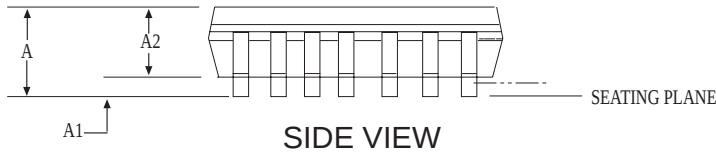
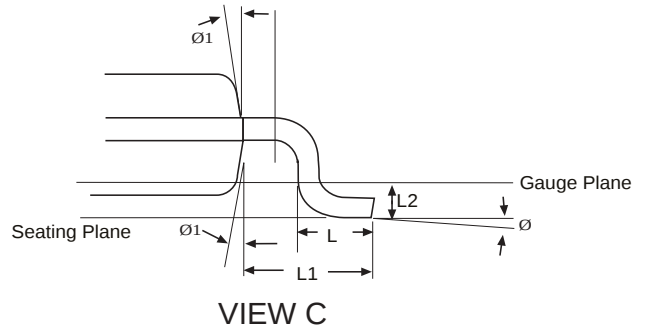
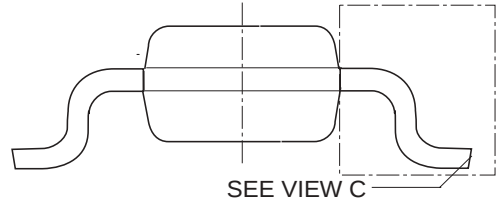
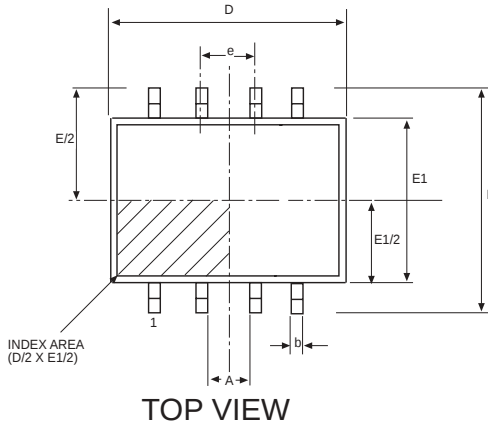
The **SP682** charge pump includes a shutdown feature (pin 8) which disables the charge pump when the  $V_{OUT}$  is not needed. A logic "1" will activate the shutdown mode. If shutdown is not needed, it can be left open where an internal pull-down resistor will always keep the charge pump active. Typical input current for the shutdown pin is  $3\mu\text{A}$ . The shutdown feature is another option for conserving power in portable applications, reducing current to only  $1\mu\text{A}$ .

## PARALLEL DEVICES

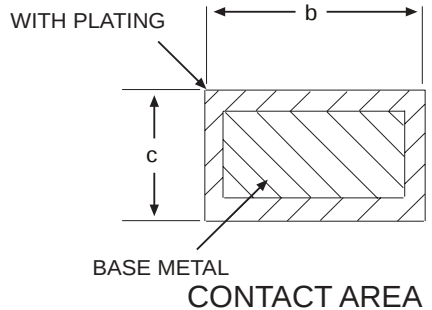
Multiple **SP682** charge pumps can be connected in parallel. However, the effective output resistance now is the output resistance of a single device divided by the number of devices. Connecting multiple pumps allows the user to save on the storage capacitor. The charge pump capacitors still must be separate for each device.

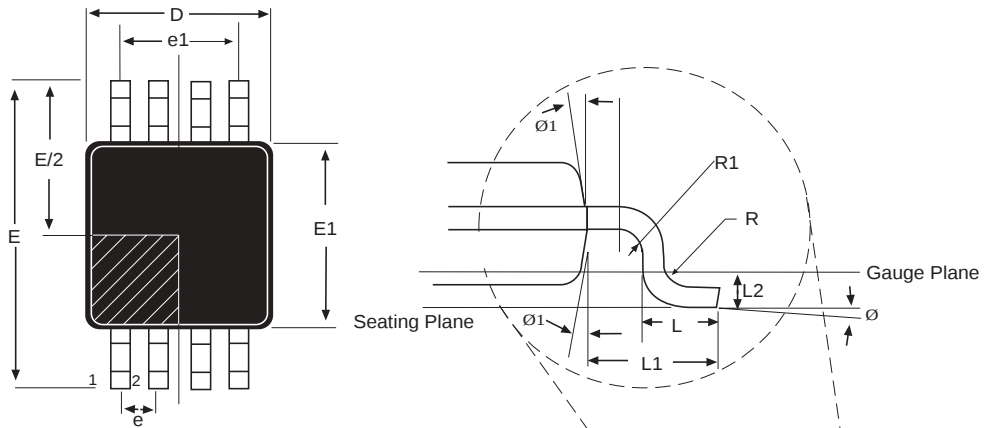
## APPLICATIONS INFORMATION

The **SP682** charge pump produces a doubled, inverted voltage from the  $V_{CC}$  input. As such, it can serve in many applications where a negative  $-5\text{V}$  to  $-10\text{V}$  output is needed. Typical applications include powering analog switches, and biasing LCD displays and panels.



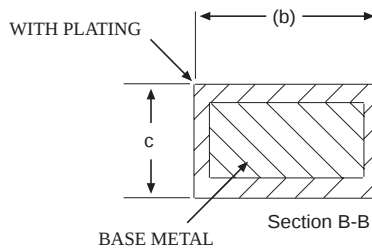
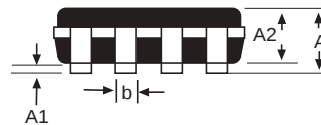
| DIMENSIONS<br>Minimum/Maximum<br>(mm) | 8 Pin NSOIC<br>(JEDEC MS-012,<br>AA - VARIATION) |     |      |
|---------------------------------------|--------------------------------------------------|-----|------|
| COMMON HEIGHT DIMENSION               |                                                  |     |      |
| SYMBOL                                | MIN                                              | NOM | MAX  |
| A                                     | 1.35                                             | -   | 1.75 |
| A1                                    | 0.10                                             | -   | 0.25 |
| A2                                    | 1.25                                             | -   | 1.65 |
| b                                     | 0.31                                             | -   | 0.51 |
| c                                     | 0.17                                             | -   | 0.25 |
| D                                     | 4.90 BSC                                         |     |      |
| E                                     | 6.00 BSC                                         |     |      |
| E1                                    | 3.90 BSC                                         |     |      |
| e                                     | 1.27 BSC                                         |     |      |
| L                                     | 0.40                                             | -   | 1.27 |
| L1                                    | 1.04 REF                                         |     |      |
| L2                                    | 0.25 BSC                                         |     |      |
| Ø                                     | 0°                                               | -   | 8°   |
| Ø1                                    | 5°                                               | -   | 15°  |


**PACKAGE: 8 PIN NSOIC**

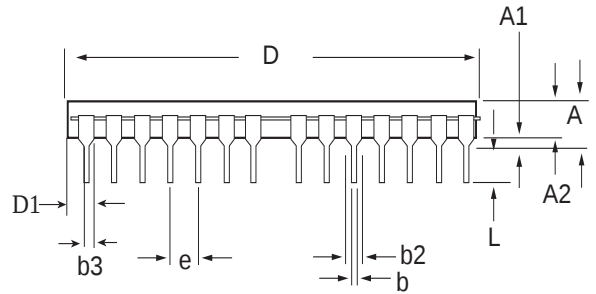
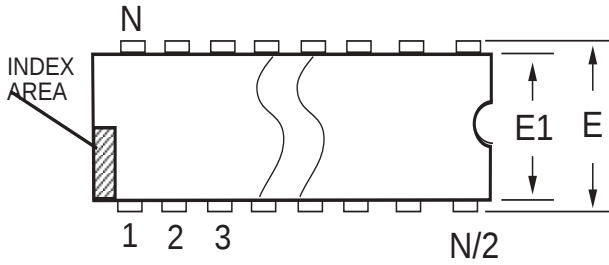


Pin #1 identifier must be indicated within this shaded area ( $D/2 * E1/2$ )

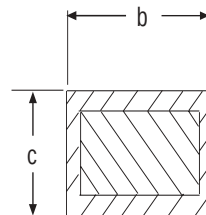
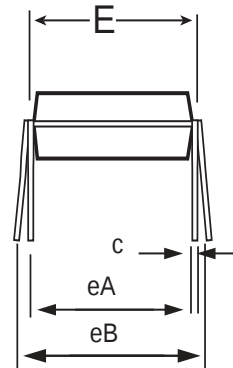
| 8-PIN MSOP<br>JEDEC MO-187<br>(AA) Variation | Dimensions in (mm) |      |      |
|----------------------------------------------|--------------------|------|------|
|                                              | MIN                | NOM  | MAX  |
| A                                            | -                  | -    | 1.10 |
| A1                                           | 0                  | -    | 0.15 |
| A2                                           | 0.75               | 0.85 | 0.95 |
| b                                            | 0.22               | -    | 0.38 |
| c                                            | 0.08               | -    | 0.23 |
| D                                            | 3.00 BSC           |      |      |
| E                                            | 4.90 BSC           |      |      |
| E1                                           | 3.00 BSC           |      |      |
| e                                            | 0.65 BSC           |      |      |
| e1                                           | 1.95 BSC           |      |      |
| L                                            | 0.40               | 0.60 | 0.80 |
| L1                                           | 0.95 REF           |      |      |
| L2                                           | 0.25 BSC           |      |      |
| N                                            | -                  | 8    | -    |
| R                                            | 0.07               | -    | -    |
| R1                                           | 0.07               | -    | -    |
| Ø                                            | 0°                 | -    | 8°   |
| Ø1                                           | 0°                 | -    | 15°  |



## 8-PIN MSOP



| 8 PIN PDIP<br>JEDEC MS-001<br>(BA) Variation | Dimensions in inches |      |      |
|----------------------------------------------|----------------------|------|------|
|                                              | MIN                  | NOM  | MAX  |
| A                                            | -                    | -    | .210 |
| A1                                           | .015                 | -    | -    |
| A2                                           | .115                 | .130 | .195 |
| b                                            | .014                 | .018 | .022 |
| b2                                           | .045                 | .060 | .070 |
| b3                                           | .030                 | .039 | .045 |
| c                                            | .008                 | .010 | .014 |
| D                                            | .355                 | .365 | .400 |
| D1                                           | .005                 | -    | -    |
| E                                            | .300                 | .310 | .325 |
| E1                                           | .240                 | .250 | .280 |
| e                                            | .100 BSC             |      |      |
| eA                                           | .300 BSC             |      |      |
| eB                                           | -                    | -    | .430 |
| L                                            | .115                 | .130 | .150 |



## 8 PIN PDIP

| <b>Part Number</b> | <b>Temperature Range</b> | <b>Package Types</b> |
|--------------------|--------------------------|----------------------|
| SP682CN .....      | -0°C to +70°C .....      | 8-pin NSOIC          |
| SP682CN/TR .....   | -0°C to +70°C .....      | 8-pin NSOIC          |
| SP682CP .....      | -0°C to +70°C .....      | 8-pin PDIP           |
| SP682CU .....      | -0°C to +70°C .....      | 8-pin MSOP           |
| SP682CU/TR .....   | -0°C to +70°C .....      | 8-pin MSOP           |
| SP682EN .....      | -40°C to +85°C .....     | 8-pin NSOIC          |
| SP682EN/TR .....   | -40°C to +85°C .....     | 8-pin NSOIC          |
| SP682EP .....      | -40°C to +85°C .....     | 8-pin PDIP           |
| SP682EU .....      | -40°C to +85°C .....     | 8-pin MSOP           |
| SP682EU/TR .....   | -40°C to +85°C .....     | 8-pin MSOP           |

/TR = Tape and Reel

Pack quantity is 2,500 for NSOIC and MSOP.



## ANALOG EXCELLENCE

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