

## Absolute Maximum Ratings

|                                    |             |
|------------------------------------|-------------|
| $V_{CC}$ .....                     | +6.2V       |
| $V+$ .....                         | +12V        |
| $V-$ .....                         | -12V        |
| $V-$ Short-Circuit Duration .....  | Continuous  |
| $V+$ Current .....                 | 75mA        |
| $V_{CC}$ $\Delta V/\Delta T$ ..... | 1V/ $\mu$ s |

|                                                                                        |                                               |
|----------------------------------------------------------------------------------------|-----------------------------------------------|
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )                             |                                               |
| 8-Pin Plastic DIP (derate 9.09mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) .....   | 727mW                                         |
| 8-Pin Narrow SO (derate 5.88mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) .....     | 471mW                                         |
| 8-Pin CERDIP (derate 8.00mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) .....        | 640mW                                         |
| 14-Pin Plastic DIP (derate 10.00mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) ..... | 800mW                                         |
| Storage Temperature Range .....                                                        | -65 $^\circ\text{C}$ to +160 $^\circ\text{C}$ |
| Lead Temperature (soldering, 10sec) .....                                              | +300 $^\circ\text{C}$                         |

Stresses beyond 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 beyond 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.

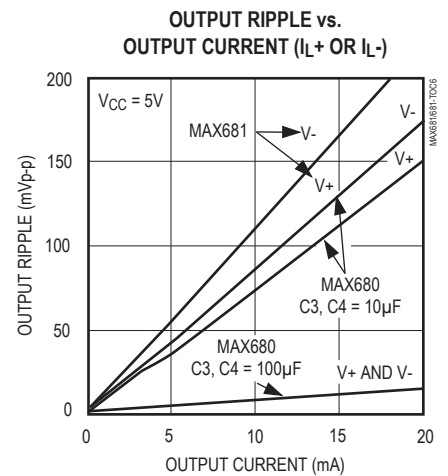
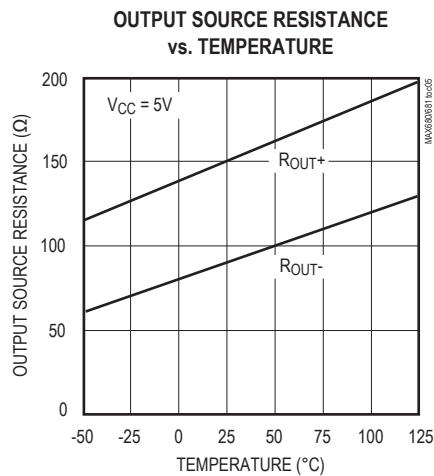
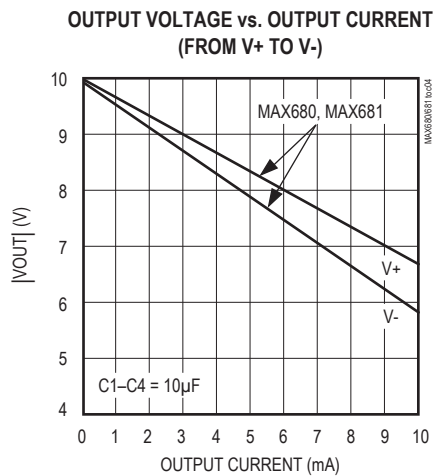
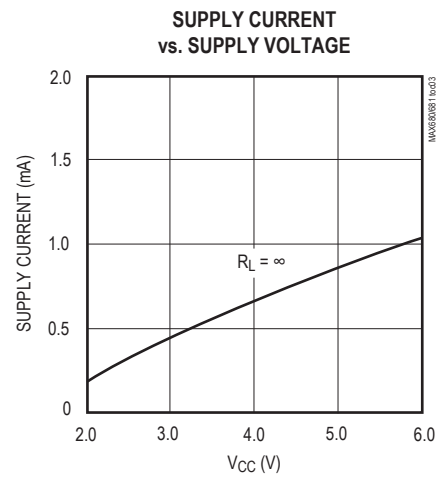
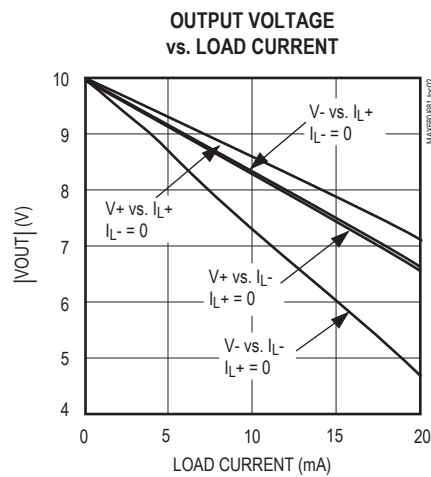
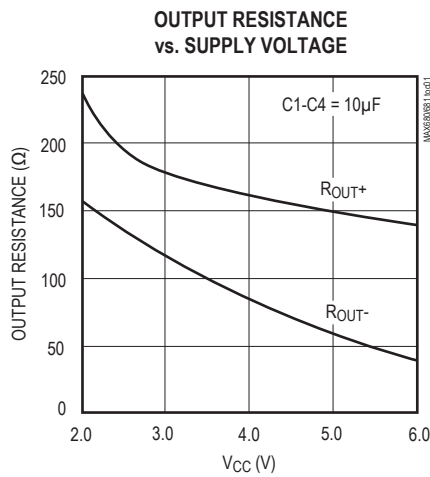
## Electrical Characteristics

( $V_{CC} = +5V$ , test circuit Figure 1,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                                     | CONDITIONS                                                                                  | MIN                                                  | TYP        | MAX | UNITS    |
|-----------------------------------------------|---------------------------------------------------------------------------------------------|------------------------------------------------------|------------|-----|----------|
| Supply Current                                | $V_{CC} = 3V$ , $T_A = +25^\circ\text{C}$ , $R_L = \infty$                                  |                                                      | 0.5        | 1   | mA       |
|                                               | $V_{CC} = 5V$ , $T_A = +25^\circ\text{C}$ , $R_L = \infty$                                  |                                                      | 1          | 2   |          |
|                                               | $V_{CC} = 5V$ , $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$ , $R_L = \infty$          |                                                      |            | 2.5 |          |
|                                               | $V_{CC} = 5V$ , $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ , $R_L = \infty$        |                                                      |            | 3   |          |
|                                               | $V_{CC} = 5V$ , $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ , $R_L = \infty$       |                                                      |            | 3   |          |
| Supply-Voltage Range                          | $\text{MIN} \leq T_A \leq \text{MAX}$ , $R_L = 10k\Omega$                                   | 2.0                                                  | 1.5 to 6.0 | 6.0 | V        |
| Positive Charge-Pump Output Source Resistance | $I_{L+} = 10\text{mA}$ , $I_{L-} = 0\text{mA}$ , $V_{CC} = 5V$ , $T_A = +25^\circ\text{C}$  |                                                      | 150        | 250 | $\Omega$ |
|                                               | $I_{L+} = 5\text{mA}$ , $I_{L-} = 0\text{mA}$ , $V_{CC} = 2.8V$ , $T_A = +25^\circ\text{C}$ |                                                      | 180        | 300 |          |
|                                               | $I_{L+} = 10\text{mA}$ ,<br>$I_{L-} = 0\text{mA}$ ,<br>$V_{CC} = 5V$                        | $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$    |            | 325 |          |
|                                               |                                                                                             | $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$  |            | 350 |          |
|                                               |                                                                                             | $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ |            | 400 |          |
| Negative Charge-Pump Output Source Resistance | $I_{L-} = 10\text{mA}$ , $I_{L+} = 0\text{mA}$ , $V+ = 10V$ , $T_A = +25^\circ\text{C}$     |                                                      | 90         | 150 | $\Omega$ |
|                                               | $I_{L-} = 5\text{mA}$ , $I_{L+} = 0\text{mA}$ , $V+ = 5.6V$ , $T_A = +25^\circ\text{C}$     |                                                      | 110        | 175 |          |
|                                               | $I_{L-} = 10\text{mA}$ ,<br>$I_{L+} = 0\text{mA}$ ,<br>$V_{CC} = 10V$                       | $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$    |            | 200 |          |
|                                               |                                                                                             | $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$  |            | 200 |          |
|                                               |                                                                                             | $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ |            | 250 |          |
| Oscillator Frequency                          |                                                                                             | 4                                                    | 8          |     | kHz      |
| Power Efficiency                              | $R_L = 10k\Omega$                                                                           |                                                      | 85         |     | %        |
| Voltage-Conversion Efficiency                 | $V+$ , $R_L = \infty$                                                                       | 95                                                   | 99         |     | %        |
|                                               | $V+$ , $R_L = \infty$                                                                       | 90                                                   | 97         |     |          |

## Typical Operating Characteristics

( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



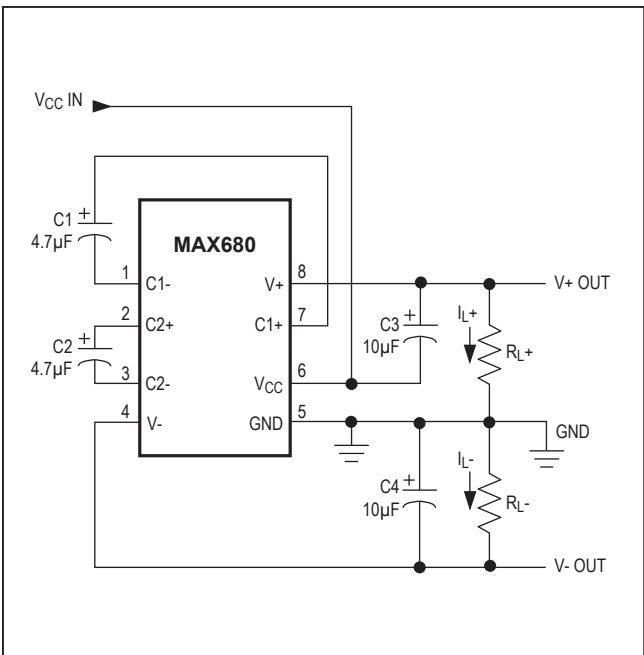


Figure 1. Test Circuit

Detailed Description

The MAX681 contains all circuitry needed to implement a dual charge pump. The MAX680 needs only four capacitors. These may be inexpensive electrolytic capacitors with values in the  $1\mu\text{F}$  to  $100\mu\text{F}$  range. The MAX681 contains two  $1.5\mu\text{F}$  capacitors as C1 and C2, and two  $2.2\mu\text{F}$  capacitors as C3 and C4. See *Typical Operating Characteristics*.

Figure 2a shows the idealized operation of the positive voltage converter. The on-chip oscillator generates a 50% duty-cycle clock signal. During the first half of the cycle, switches S2 and S4 are open, S1 and S3 are closed, and capacitor C1 is charged to the input voltage  $V_{CC}$ . During the second half-cycle, S1 and S3 are open, S2 and S4 are closed, and C1 is translated upward by  $V_{CC}$  volts. Assuming ideal switches and no load on C3, charge is transferred onto C3 from C1 such that the voltage on C3 will be  $2V_{CC}$ , generating the positive supply.

Figure 2b shows the negative converter. The switches of the negative converter are out of phase from the positive converter. During the second half of the clock cycle, S6 and S8 are open and S5 and S7 are closed, charging C2 from  $V+$  (pumped up to  $2V_{CC}$  by the positive charge pump) to GND. In the first half of the clock

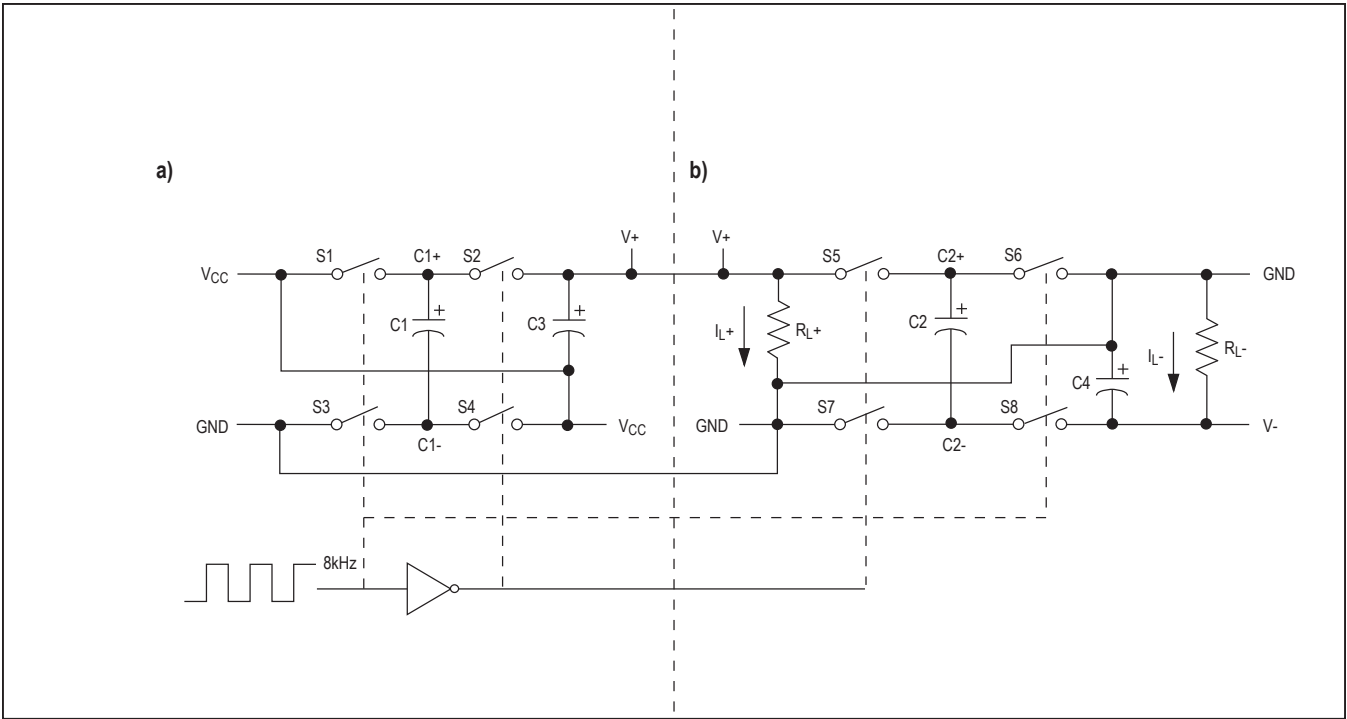


Figure 2. Idealized Voltage Quadrupler: a) Positive Charge Pump; b) Negative Charge Pump

cycle, S5 and S7 are open, S6 and S8 are closed, and the charge on C2 is transferred to C4, generating the negative supply. The eight switches are CMOS power MOSFETs. S1, S2, S4, and S5 are P-channel switches, while S3, S6, S7, and S8 are N-channel switches.

### 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 extremely low on-resistance
- Minimal power is consumed by the drive circuitry
- The impedances of the reservoir and pump capacitors are negligible

For the MAX680/MAX681, the energy loss per clock cycle is the sum of the energy loss in the positive and negative converters as below:

$$\begin{aligned} \text{LOSS}_{\text{TOT}} &= \text{LOSS}_{\text{POS}} + \text{LOSS}_{\text{NEG}} \\ &= \frac{1}{2} C1 [(V+)^2 - (V+)(V_{CC})] + \\ &\quad \frac{1}{2} C2 [(V+)^2 - (V-)^2] \end{aligned}$$

There will be a substantial voltage difference between  $(V+ - V_{CC})$  and  $V_{CC}$  for the positive pump, and between  $V+$  and  $V-$ , if the impedances of pump capacitors C1 and C2 are high relative to their respective output loads.

Larger C3 and C4 reservoir capacitor values reduce output ripple. Larger values of both pump and reservoir capacitors improve efficiency.

### Maximum Operating Limits

The MAX680/MAX681 have on-chip zener diodes that clamp  $V_{CC}$  to approximately 6.2V,  $V+$  to 12.4V, and  $V-$  to -12.4V. Never exceed the maximum supply voltage: excessive current may be shunted by these diodes, potentially damaging the chip. The MAX680/MAX681 operate over the entire operating temperature range with an input voltage of +2V to +6V.

## Applications

### Positive and Negative Converter

The most common application of the MAX680/MAX681 is as a dual charge-pump voltage converter that provides positive and negative outputs of two times a positive input voltage. For applications where PC board space is at a premium, the MAX681, with its capacitors internal to the package, offers the smallest footprint. The simple circuit shown in Figure 3 performs the same function using the MAX680 with external capacitors C1 and C3 for the positive pump and C2 and C4 for the negative pump. In most applications, all four capacitors are low-cost, 10µF or 22µF polarized electrolytics. When using the MAX680 for low-current applications, 1µF can be used for C1 and C2 charge-pump capacitors, and 4.7µF for C3 and C4 reservoir capacitors. C1 and C3 must be rated at 6V or greater, and C2 and C4 must be rated at 12V or greater.

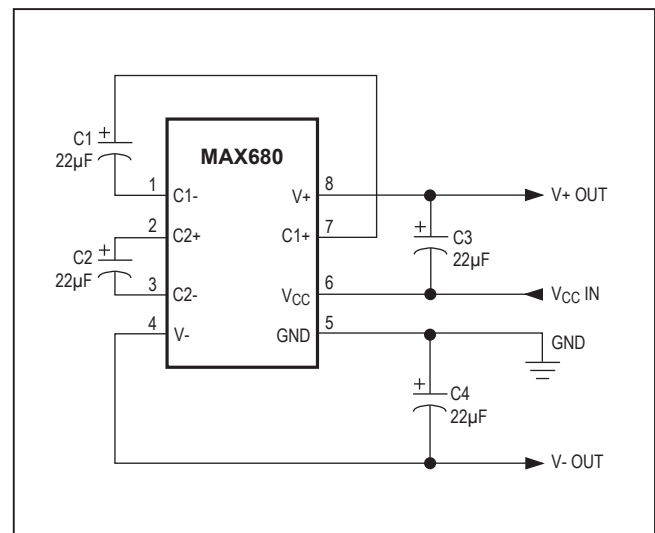


Figure 3. Positive and Negative Converter

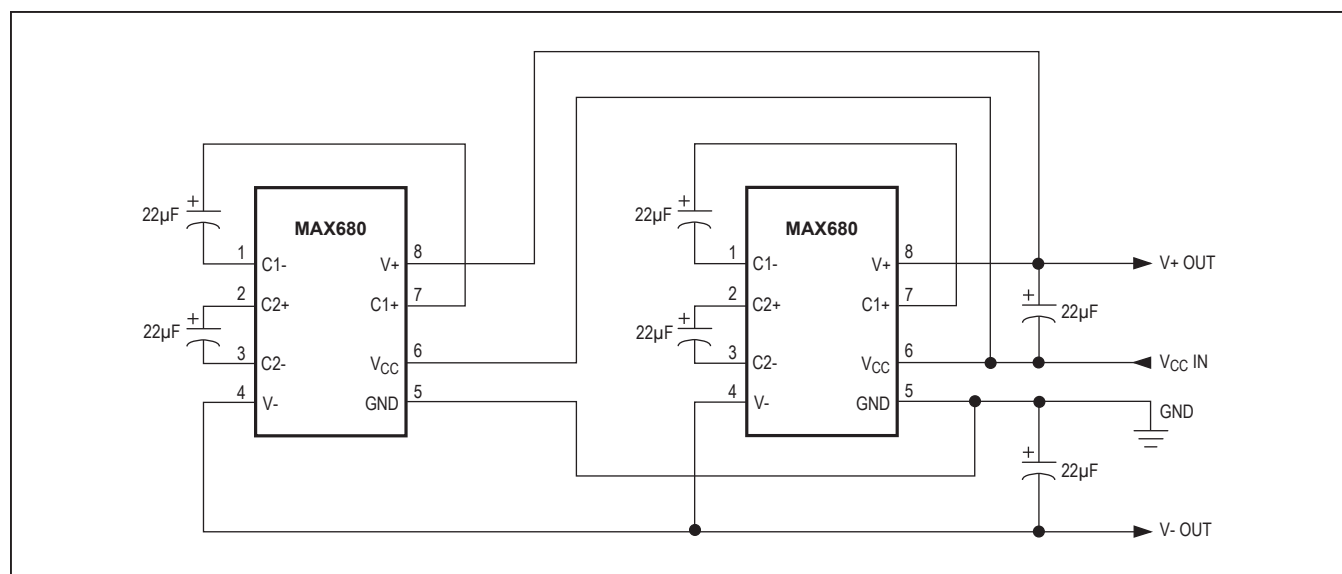


Figure 4. Paralleling MAX680s For Lower Source Resistance

The MAX680/MAX681 are **not** voltage regulators: the output source resistance of either charge pump is approximately  $150\Omega$  at room temperature with  $V_{CC}$  at 5V. Under light load with an input  $V_{CC}$  of 5V,  $V+$  will approach +10V and  $V-$  will be at -10V. However **both**,  $V+$  and  $V-$  will droop toward GND as the current drawn from **either**  $V+$  or  $V-$  increases, since the negative converter draws its power from the positive converter's output. To predict output voltages, treat the chips as two separate converters and analyze them separately. First, the droop of the negative supply ( $V_{DROP-}$ ) equals the current drawn from  $V-$  ( $I_{L-}$ ) times the source resistance of the negative converter ( $RS-$ ):

$$V_{DROP-} = I_{L-} \times RS-$$

Likewise, the positive supply droop ( $V_{DROP+}$ ) equals the current drawn from the positive supply ( $I_{L+}$ ) times the positive converter's source resistance ( $RS+$ ), except that the current drawn from the positive supply is the sum of the current drawn by the load on the positive supply ( $I_{L+}$ ) plus the current drawn by the negative converter ( $I_{L-}$ ):

$$(V_{DROP+}) = I_{L+} \times RS+ = (I_{L+} + I_{L-}) \times RS+$$

The positive output voltage will be:

$$V+ = 2V_{CC} - V_{DROP+}$$

The negative output voltage will be:

$$V- = (V+ - V_{DROP-}) = -(2V_{CC} - V_{DROP+} - V_{DROP-})$$

The positive and negative charge pumps are tested and specified separately to provide the separate values of output source resistance for use in the above formulas. When the positive charge pump is tested, the negative charge pump is unloaded. When the negative charge pump is tested, the positive supply  $V+$  is from an external source, isolating the negative charge pump.

Calculate the ripple voltage on either output by noting that the current drawn from the output is supplied by the reservoir capacitor alone during one half-cycle of the clock. This results in a ripple of:

$$V_{RIPPLE} = \frac{1}{2} I_{OUT} (1/f_{PUMP})(1/CR)$$

For the nominal  $f_{PUMP}$  of 8kHz with  $10\mu F$  reservoir capacitors, the ripple will be 30mV with  $I_{OUT}$  at 5mA. Remember that in most applications, the positive charge pump's  $I_{OUT}$  is the load current **plus** the current taken by the negative charge pump.

### Paralleling Devices

Paralleling multiple MAX680/MAX681s reduces the output resistance of both the positive and negative converters. The effective output resistance is the output resistance of a single device divided by the number of devices. As Figure 4 shows, each MAX680 requires separate pump capacitors C1 and C2, but all can share a single set of reservoir capacitors.

### $\pm 5V$ Regulated Supplies from a Single 3V Battery

Figure 5 shows a complete  $\pm 5V$  power supply using one 3V battery. The MAX680/MAX681 provide +6V at V+, which is regulated to +5V by the MAX666, and -6V, which is regulated to -5V by the MAX664. The MAX666 and MAX664 are pretrimmed at wafer sort and require

no external setting resistors, minimizing part count. The combined quiescent current of the MAX680/MAX681, MAX663, and MAX664 is less than 500 $\mu A$ , while the output current capability is 5mA. The MAX680/MAX681 input can vary from 3V to 6V without affecting regulation appreciably. With higher input voltage, more current can be drawn from the MAX680/MAX681 outputs. With 5V at V<sub>CC</sub>, 10mA can be drawn from both regulated outputs simultaneously. Assuming 150 $\Omega$  source resistance for both converters, with  $(I_{L+} + I_{L-}) = 20mA$ , the positive charge pump will droop 3V, providing +7V for the negative charge pump. The negative charge pump will droop another 1.5V due to its 10mA load, leaving -5.5V at V- sufficient to maintain regulation for the MAX664 at this current.

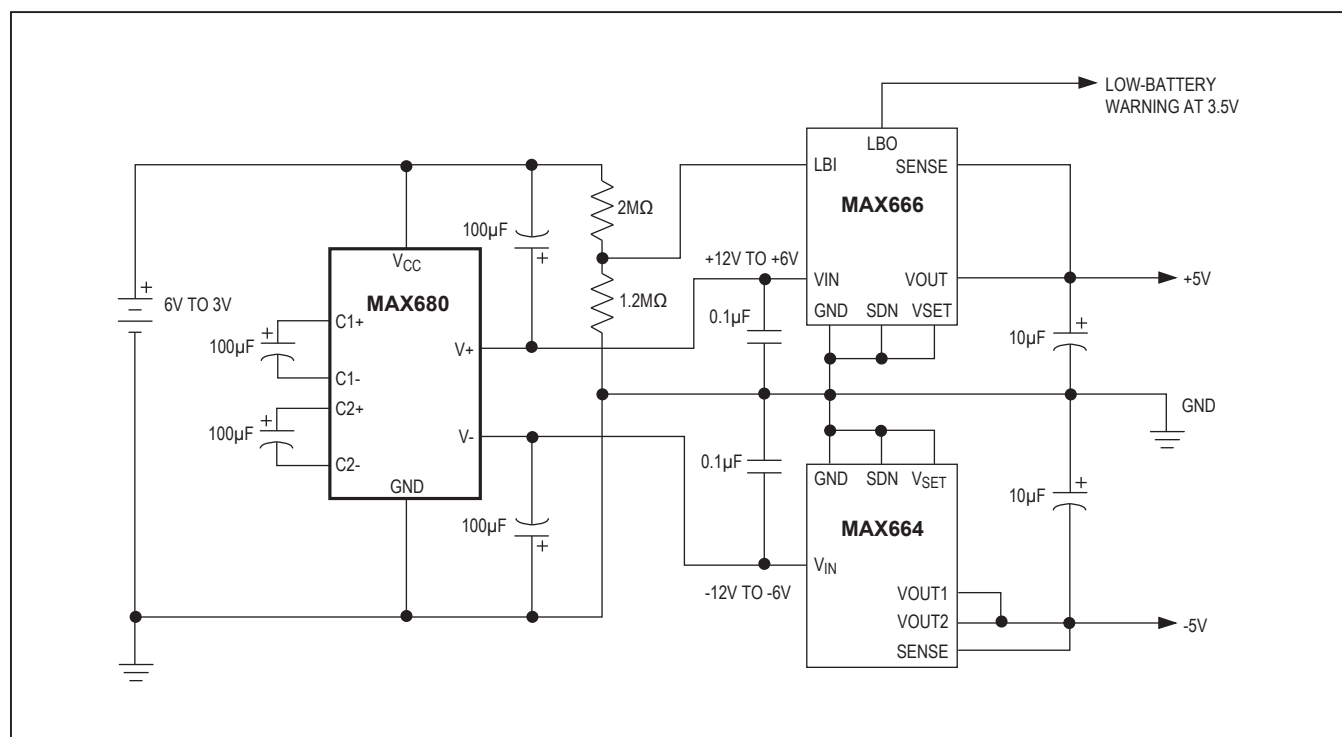
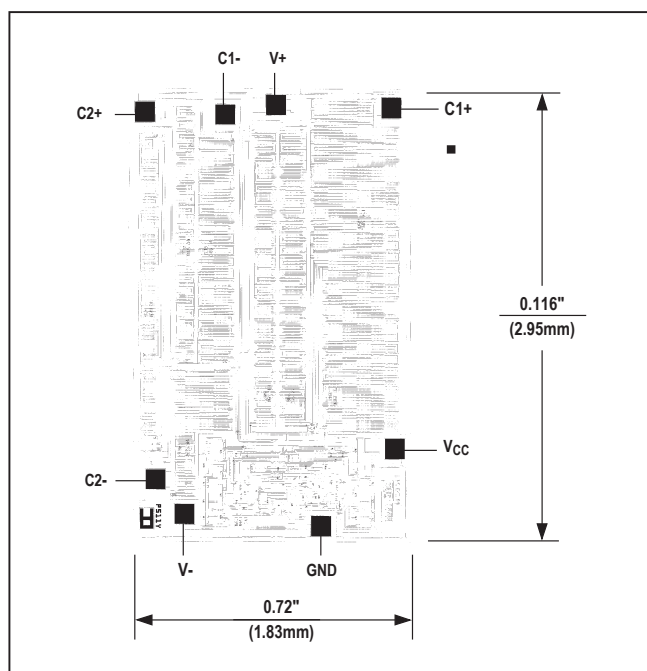


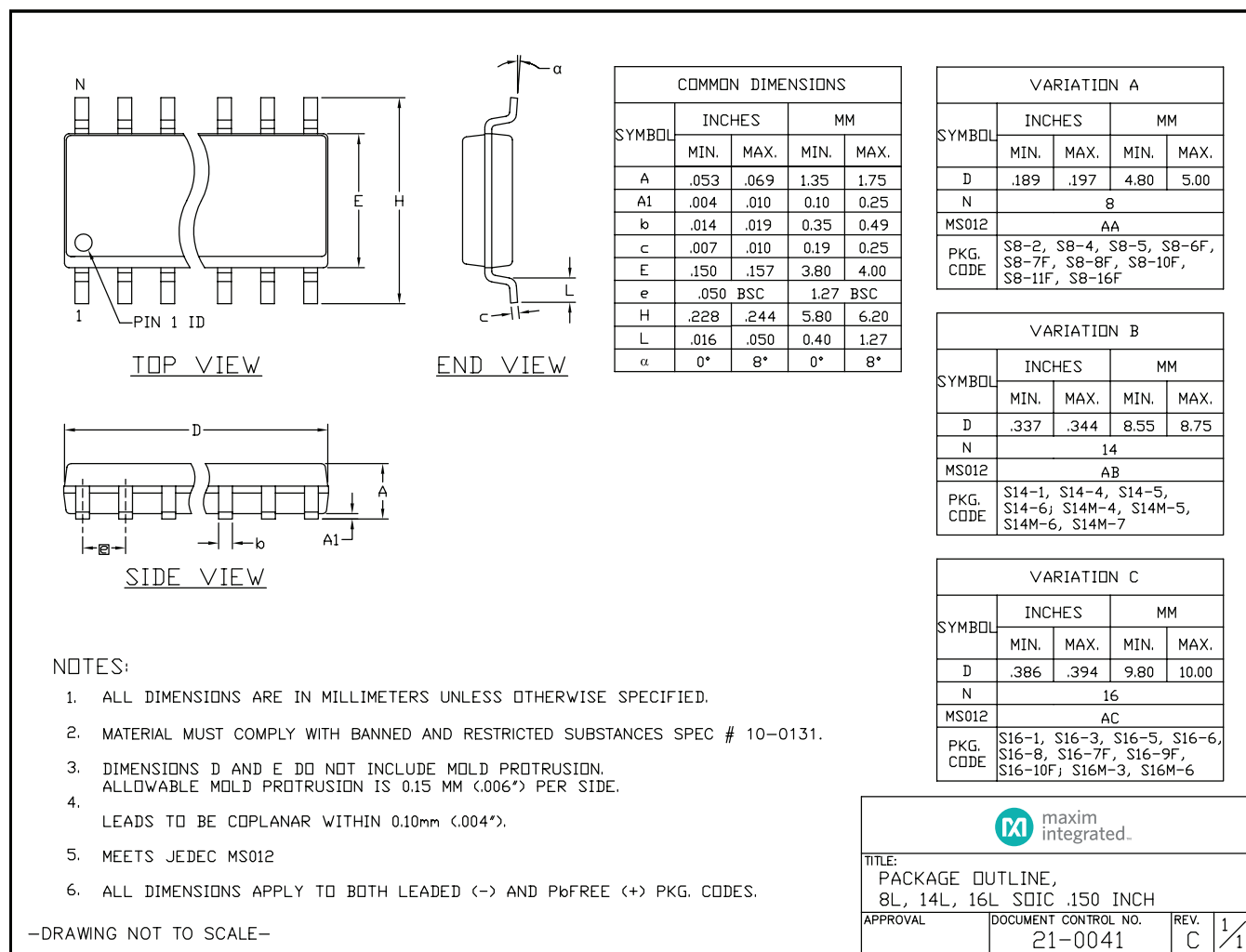
Figure 5. Regulated +5V and -5V from a Single Battery

## Chip Topography



## Package Information

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.



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