+5V to ±10V Voltage Converters

General Description

The MAX680/MAX681 are monolithic CMOS dual charge pump voltage converters that provide ±10V outputs from a +5V input voltage. The MAX680/MAX681 provide both a positive stepup charge pump to develop +10V from +5V input and an inverting charge pump to generate the -10V output. Both parts have an on-chip 8kHz oscillator. The MAX681 has the capacitors internal to the package, and the MAX680 requires 4 external capacitors to produce both positive and negative voltages from a single supply.

The output source impedances are typically 150Ω, providing useful output currents up to 10mA. The low quiescent current and high efficiency make this device suitable for a variety of applications that need both positive and negative voltages generated from a single supply.

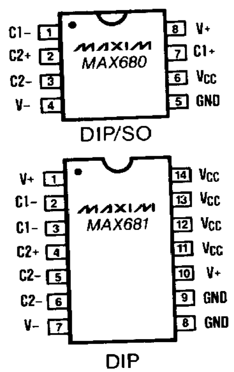
Applications

The MAX680/MAX681 can be used wherever a single positive supply is available and positive and negative voltages are required. Common applications include the generation of ±6V from a 3V battery and generation of ±10V from the standard +5V logic supply for use with analog circuitry. Typical applications include:

±10V from +5V Logic Supply
±6V from a 3V Lithium Cell
Handheld Instruments
Battery Operated Equipment
Data Acquisition Systems
Panel Meters
Operational Amplifier Power Supplies

Pin Configurations

Top View



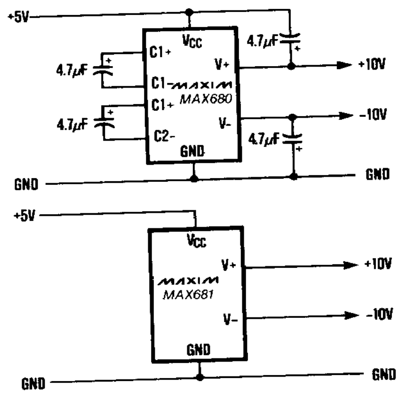
Features

- ◆ 95% Voltage Conversion Efficiency
- ◆ 85% Power Conversion Efficiency
- ◆ Wide Voltage Range: +2.0V to +6.0V
- ◆ Only 4 External Capacitors Required — MAX680
- ◆ No Capacitors Required — MAX681
- ◆ 500μA Supply Current
- ◆ Monolithic CMOS Design

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX680CPA	0°C to +70°C	8 Plastic DIP
MAX680CSA	0°C to +70°C	8 Narrow SO
MAX680C/D	0°C to +70°C	Dice
MAX680EPA	-40°C to +85°C	8 Plastic DIP
MAX680ESA	-40°C to +85°C	8 Narrow SO
MAX680EJA	-40°C to +85°C	8 CERDIP
MAX680MJA	-55°C to +125°C	8 CERDIP
MAX681CPD	0°C to +70°C	14 Plastic DIP
MAX681BCPD	0°C to +70°C	14 Plastic DIP
MAX681EPD	-40°C to +85°C	14 Plastic DIP

Typical Operating Circuit



+5V to ±10V Converter

MAX681 ONLY 4 PINS REQUIRED

ABSOLUTE MAXIMUM RATINGS

V_{CC} .... +6.2V
V+ .... +12V
V− .... −12V
V− Short-Circuit Duration .... Continuous
V+ Current 75mA
V_{CC} dV/dT 1V/µs

Power Dissipation
Plastic DIP (derate 8.33mW/°C above +50°C) 625mW
Small Outline (derate 6mW/°C above +50°C) 450mW
CERDIP (derate 8mW/°C above +50°C) 800mW
Storage Temperature .... −65°C to +160°C
Lead Temperature (Soldering, 10 sec.) .... +300°C

Stresses beyond "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.

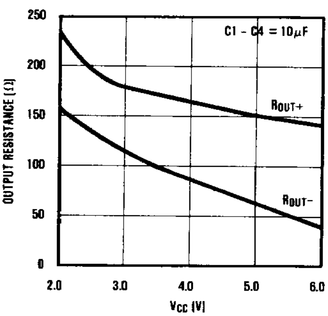
ELECTRICAL CHARACTERISTICS

(V_{CC} = +5V, T_A = +25°C, test circuit Figure 1, unless otherwise noted.)

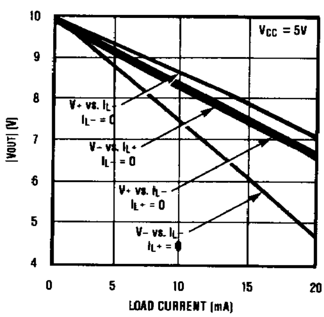
PARAMETER	CONDITIONS	MAX680/MAX681 MIN	TYP	MAX	MAX681B MIN	TYP	MAX	UNITS
Supply Current	V_{CC} = 3V, T_A = +25°C, R_L = ∞ V_{CC} = 5V, T_A = +25°C, R_L = ∞ V_{CC} = 5V, 0°C ≤ T_A ≤ +70°C, R_L = ∞ V_{CC} = 5V, −40°C ≤ T_A ≤ +85°C, R_L = ∞ V_{CC} = 5V, −55°C ≤ T_A ≤ +125°C, R_L = ∞		0.5 1	1 2 2.5 3 3		0.5 1	1 2 2.5	mA
Supply Voltage Range	MIN. ≤ T_A ≤ MAX., R_L = 10kΩ	2.0	1.5 to 6.0	6.0	2.0	1.5 to 6.0	6.0	V
Positive Charge Pump Output Source Resistance	I_L+ = 10mA, I_L- = 0mA, V_{CC} = 5V, T_A = +25°C I_L+ = 5mA, I_L- = 0mA, V_{CC} = 2.8V, T_A = +25°C I_L+ = 10mA, I_L- = 0mA, V_{CC} = 5V 0°C ≤ T_A ≤ +70°C −40°C ≤ T_A ≤ +85°C −55°C ≤ T_A ≤ +125°C		150 180	250 300 325 350 400		150 180 380	250 300 600	Ω
Negative Charge Pump Output Source Resistance	I_L- = 10mA, I_L+ = 0mA, V+ = 10V, T_A = +25°C I_L- = 5mA, I_L+ = 0mA, V+ = 5.6V, T_A = +25°C I_L- = 10mA, I_L+ = 0mA, V+ = 10V 0°C ≤ T_A ≤ +70°C −40°C ≤ T_A ≤ +85°C −55°C ≤ T_A ≤ +125°C		90 110	150 175 200 200 250		175 180 300	300 325 500	Ω
Oscillator Frequency		4	8		4	8		kHz
Power Efficiency	R_L = 10kΩ		85			85		%
Voltage Conversion Efficiency	V+, R_L = ∞ V−, R_L = ∞	95 90	99 97		95 90	99 97		%

Typical Operating Characteristics

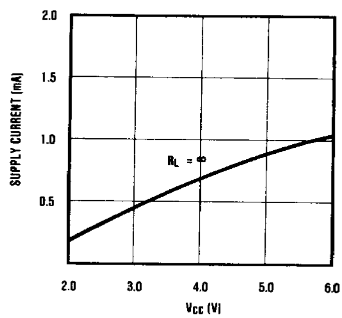
OUTPUT RESISTANCE vs. V_{CC}



VOUT vs. LOAD CURRENT

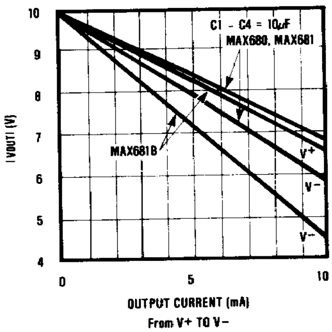


SUPPLY CURRENT vs. V_{CC}

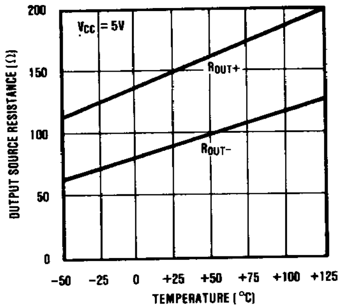


Typical Operating Characteristics

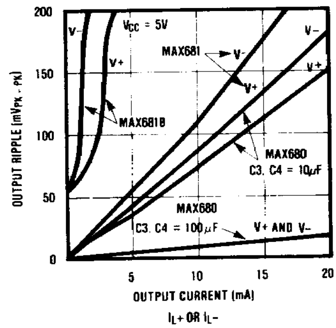
OUTPUT VOLTAGE vs. OUTPUT CURRENT FROM V+ TO V-



OUTPUT SOURCE RESISTANCE vs. TEMPERATURE



OUTPUT RIPPLE vs. OUTPUT CURRENT



Detailed Description

All circuitry needed to implement a dual charge pump is contained in the MAX681. Only four capacitors are needed on the MAX680. These may be inexpensive electrolytic capacitors with values in the range of 1μF to 100μF. The MAX681B contains 1μF capacitor and exhibits somewhat more output ripple than the MAX681. See Typical Operating Characteristics.

Figure 2A illustrates 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, switches S1 and S3 are closed, and the capacitor C1 is charged to the input voltage V_{CC}. During the second half cycle, switches S1 and S3 are open, S2 and S4 are closed, and the capacitor 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 illustrates 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, S5 and S7 are closed, thus charging C2 from V+ (pumped up to $2V_{CC}$ by the positive charge pump) to GND. In the first half of the clock 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. Switches S1, S2, S4 and S5 are P-channel devices while switches S3, S6, S7, and S8 are N-channel devices.

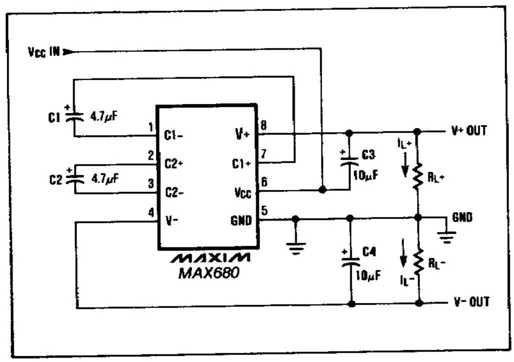


Figure 1. Test Circuit

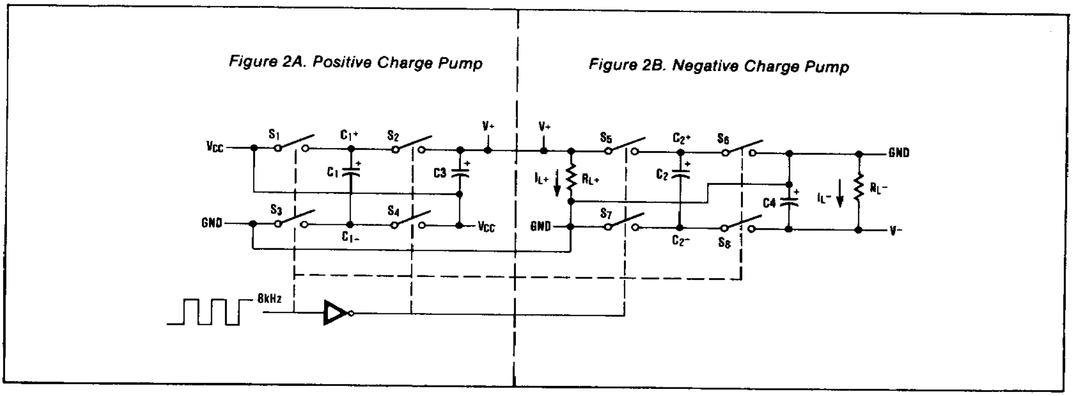


Figure 2. Idealized Voltage Quadrupler

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 MAX680/681, the energy loss per clock cycle is the sum of the energy loss in the positive and negative converters as below:

$$Loss_{TOT} = Loss_{POS} + Loss_{NEG}$$
$$= \frac{1}{2} C_1[(V+)^2 - 2(V+)(V_{CC})] + \frac{1}{2} C_2[(V+)^2 - (V-)^2]$$

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 the pump capacitors C1 and C2 are high with respect to their respective output loads.

Larger values of reservoir capacitors C3 and C4 will reduce output ripple. Larger values of both pump and reservoir capacitors improve the 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 or excessive current may be shunted by these diodes, potentially damaging the chip. The MAX680/MAX681 will 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 which 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 of Figure 3 performs the same function using the MAX680 and 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 may be used for C1 and C2 charge pump capacitors, and 4.7μF for the reservoir capacitors C3 and C4. Capacitors C1 and C3 must be rated at 6V or greater, and capacitors C2 and C4 must be rated at 12V or greater.

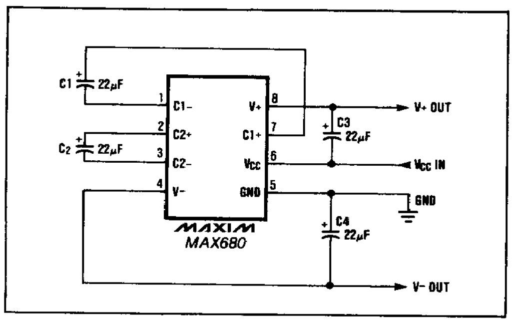


Figure 3. Positive and Negative Converter

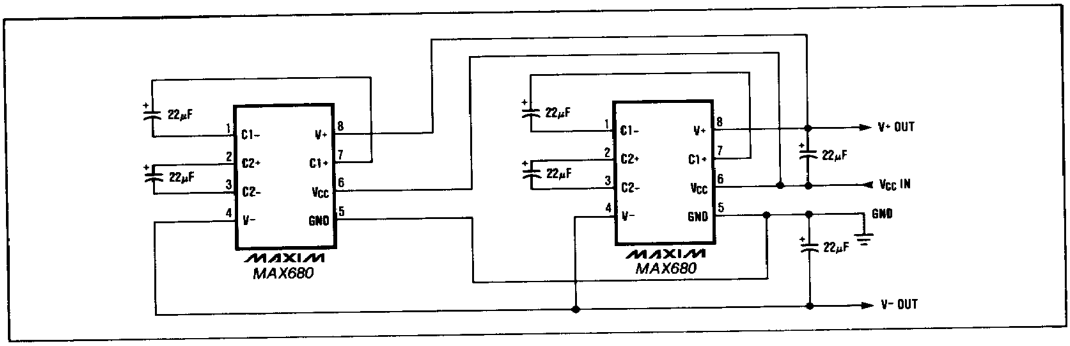


Figure 4. Paralleling MAX680s For Lower Source Resistance

The MAX680/MAX681 are NOT voltage regulators: the output source resistance of either charge pump is approximately 150Ω at room temperature with V_{CC} at 5V. This means that with an input V_{CC} of 5V, under light load V+ will approach +10V and V- will be at -10V, but BOTH V+ and V- will droop towards GND as the current drawn from EITHER V+ or V- increases since the negative converter draws its power from the output of the positive converter. To predict the 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 droop of the positive supply ($V_{DROP}+$) equals the current drawn from the positive supply (I_L+) times the source resistance of the positive converter (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.

The ripple voltage on either output can be calculated 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:

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

For the nominal f_{PUMP} of 8kHz with 10μF reservoir capacitors, the ripple will be 30mV with I_{OUT} at 5mA. Remember that in most applications, the I_{OUT} of the positive charge pump 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 illustrated in Figure 4, each MAX680 requires separate pump capacitors C1 and C2, but all can share a single set of reservoir capacitors.

±5V Regulated Supplies From A Single 3V Battery

Figure 5 shows a complete ±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

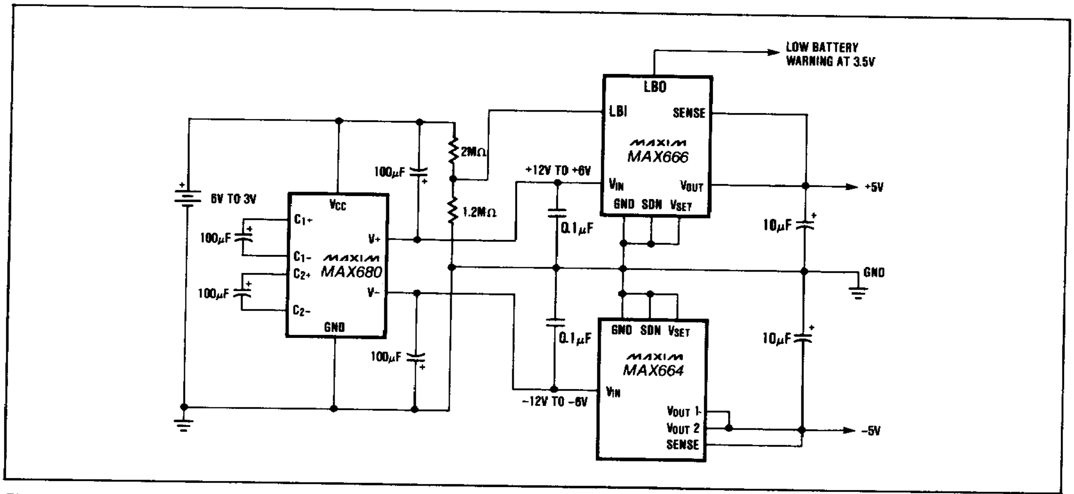
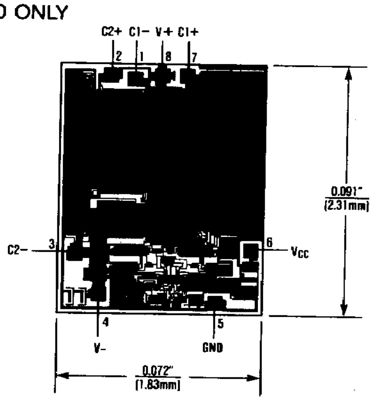


Figure 5. Regulated +5V and -5V From a Single Battery

MAX666 and MAX664 are pre-trimmed at wafer sort and require no external setting resistors, minimizing parts count. The combined quiescent current of the MAX680/MAX681, MAX663, and MAX664 is less than 500µA, while the output current capability is 5mA. The input to the MAX680/MAX681 can vary from 3V to 6V without affecting regulation appreciably. With higher input voltage, more current can be drawn from the outputs of the MAX680/MAX681. With 5V at V_{CC}, 10mA can be drawn from both regulated outputs simultaneously. Assuming 150Ω 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.

Chip Topography

MAX680 ONLY



Note: Connect substrate to V+.

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