# *MAXIM*

# Switched-Capacitor Voltage Converters

**MAX1044/ICL7660**

## General Description

The MAX1044 and ICL7660 are monolithic, CMOS switched-capacitor voltage converters that invert, double, divide, or multiply a positive input voltage. They are pin compatible with the industry-standard ICL7660 and LTC1044. Operation is guaranteed from 1.5V to 10V with no external diode over the full temperature range They deliver 10mA with a 0 5V output drop. The MAX1044 has a BOOST pin that raises the oscillator frequency above the audio band and reduces external capacitor size requirements.

The MAX1044/ICL7660 combine low quiescent current and high efficiency. Oscillator control circuitry and four power MOSFET switches are included on-chip. Applications include generating a -5V supply from a +5V logic supply to power analog circuitry. For applications requiring more power, the MAX660 delivers up to 100mA with a voltage drop of less than 0.65V.

## Applications

-5V Supply from +5V Logic Supply

Personal Communications Equipment

Portable Telephones

Op-Amp Power Supplies

EIA/TIA-232E and EIA/TIA-562 Power Supplies

Data-Acquisition Systems

Hand-Held Instruments

Panel Meters

## Typical Operating Circuit



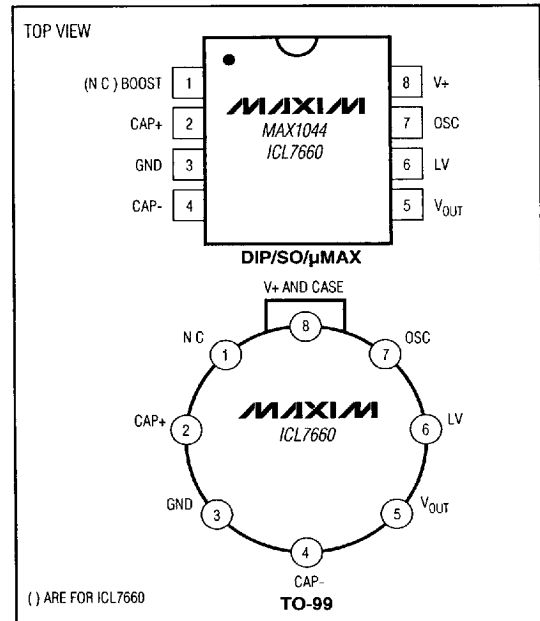**NEGATIVE VOLTAGE CONVERTER**
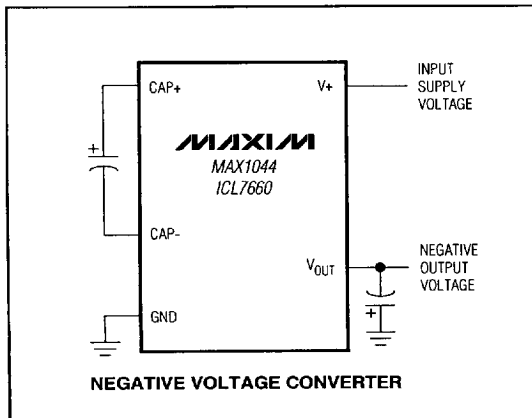
## Features

♦ **Miniature μMAX Package**

♦ **1.5V to 10.0V Operating Supply Voltage Range**

♦ **98% Typical Power-Conversion Efficiency**

♦ **Invert, Double, Divide, or Multiply Input Voltages**

♦ **BOOST Pin Increases Switching Frequencies (MAX1044)**

♦ **No-Load Supply Current: 200μA Max at 5V**

♦ **No External Diode Required for Higher-Voltage Operation**

## Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE |
|------|-------------|-------------|
| **MAX1044CPA** | 0°C to +70°C | 8 Plastic DIP |
| MAX1044CSA | 0°C to +70°C | 8 SO |
| MAX1044C/D | 0°C to +70°C | Dice* |
| MAX1044EPA | -40°C to +85°C | 8 Plastic DIP |

*Ordering Information continued at end of data sheet.*
* Contact factory for dice specifications

## Pin Configurations



**DIP/SO/μMAX**

**TO-99**

( ) ARE FOR ICL7660

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# Switched-Capacitor Voltage Converters

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V+ to GND, or GND to $V_{OUT}$). .     10 5V
Input Voltage on Pins 1, 6, and 7    -0 3V ≤ $V_{IN}$ ≤ (V+ + 0 3V)
LV Input Current   . . . . . . . . .    20μA
Output Short-Circuit Duration (V+ ≤ 5 5V)    Continuous
Continuous Power Dissipation ($T_A$ = +70°C)
   Plastic DIP (derate 9 09mW/°C above +70°C)    727mW
   SO (derate 5 88mW/°C above +70°C)    471mW
   μMAX (derate 4 1mW/°C above +70°C)    330mW

CERDIP (derate 8 00mW/°C above +70°C) . . . .   640mW
TO-99 (derate 6 67mW/°C above +70°C) .    533mW
Operating Temperature Ranges
   MAX1044C_ _ /ICL7660C_ _    . . . .   0°C to +70°C
   MAX1044E_ _ /ICL7660E_ _    . . . .   -40°C to +85°C
   MAX1044M_ _ /ICL7660M_ _    -55°C to +125°C
Storage Temperature Range    . -65°C to + 150°C
Lead Temperature (soldering, 10sec)    +300°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

(Circuit of Figure 1, V+ = 5.0V, LV pin = 0V, BOOST pin = open, $I_{LOAD}$ = 0mA, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted )

| PARAMETER | CONDITIONS | | MAX1044 MIN TYP MAX | | | ICL7660 MIN TYP MAX | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| Supply Current | $R_L$ = ∞, pins 1 and 7 no connection, LV open | $T_A$ = +25°C | | 30 | 200 | | 80 | 175 | μA |
| | | $T_A$ = 0°C to +70°C | | | 200 | | | 225 | |
| | | $T_A$ = -40°C to +85°C | | | 200 | | | 250 | |
| | | $T_A$ = -55°C to +125°C | | | 200 | | | 250 | |
| | $R_L$ = ∞, pins 1 and 7 = V+ = 3V | | | | 10 | | | | |
| Supply Voltage Range (Note 1) | $R_L$ = 10kΩ, LV open | | | | | 3 0 | | 10 0 | V |
| | $R_L$ = 10kΩ, LV to GND | | 1 5 | | 10 | 1 5 | | 3 5 | |
| Output Resistance | $I_L$ = 20mA, $f_{OSC}$ = 5kHz, LV open | $T_A$ = +25°C | | 65 | 100 | | 55 | 100 | Ω |
| | | $T_A$ = 0°C to +70°C | | | 130 | | | 120 | |
| | | $T_A$ = -40°C to +85°C | | | 130 | | | 140 | |
| | | $T_A$ = -55°C to +125°C | | | 150 | | | 150 | |
| | $f_{OSC}$ = 2 7kHz (ICL7660), $f_{OSC}$ = 1kHz (MAX1044), V+ = 2V, $I_L$ = 3mA, LV to GND | $T_A$ = +25°C | | | 325 | | | 250 | |
| | | $T_A$ = 0°C to +70°C | | | 325 | | | 300 | |
| | | $T_A$ = -40°C to +85°C | | | 325 | | | 300 | |
| | | $T_A$ = -55°C to +125°C | | | 400 | | | 400 | |
| Oscillator Frequency | $C_{OSC}$ = 1pF, LV to GND (Note 2) | V+ = 5V | 5 | | | | 10 | | kHz |
| | | V+ = 2V | 1 | | | | | | |
| Power Efficiency | $R_L$ = 5kΩ, $T_A$ = +25°C, $f_{OSC}$ 5kHz, LV open | | 95 | 98 | | 95 | 98 | | % |
| Voltage Conversion Efficiency | $R_L$ = ∞, $T_A$ = +25°C, LV open | | 97 0 | 99 9 | | 99 0 | 99 9 | | % |
| Oscillator Sink or Source Current | $V_{OSC}$ = 0V or V+, LV open | Pin 1 = 0V | | | 3 | | | | μA |
| | | Pin 1 = V+ | | | 20 | | | | |
| Oscillator Impedance | $T_A$ = +25°C | V+ = 2V | | 1 0 | | | 1 0 | | MΩ |
| | | V+ = 5V | | 100 | | | 100 | | kΩ |

**Note 1:** The Maxim ICL7660 and MAX1044 can operate without an external output diode over the full temperature and voltage ranges The Maxim ICL7660 can also be used with an external output diode in series with pin 5 (cathode at $V_{OUT}$) when replacing the Intersil ICL7660 Tests are performed without diode in circuit.

**Note 2:** $f_{OSC}$ is tested with $C_{OSC}$ = 100pF to minimize the effects of test fixture capacitance loading. The 1pF frequency is correlated to this 100pF test point, and is intended to simulate pin 7's capacitance when the device is plugged into a test socket with no external capacitor For this test, the LV pin is connected to GND for comparison to the original manufacturer's device, which automatically connects this pin to GND for (V+ > 3V)
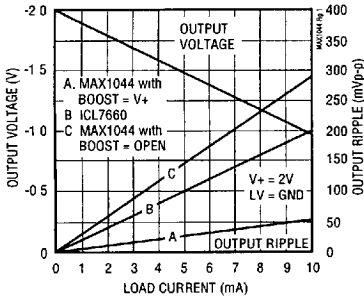
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# Switched-Capacitor Voltage Converters

MAX1044/ICL7660

_____Typical Operating Characteristics

(V+ = 5V, $C_{BYPASS}$ = 0 1μF, C1 = C2 = 10μF, LV = open, OSC = open, $T_A$ = +25°C; unless otherwise noted )
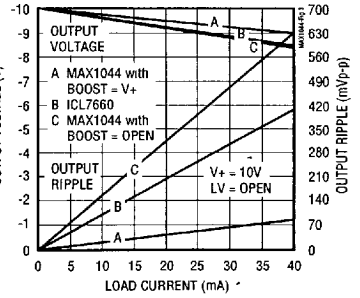
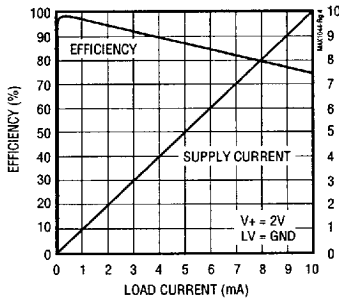**OUTPUT VOLTAGE and OUTPUT RIPPLE vs. LOAD CURRENT**

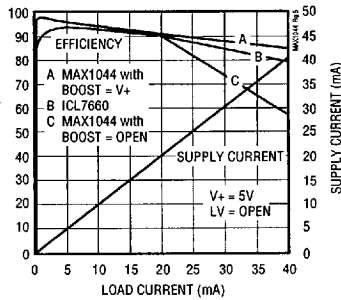**OUTPUT VOLTAGE and OUTPUT RIPPLE vs. LOAD CURRENT**
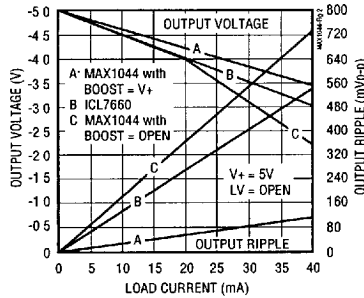
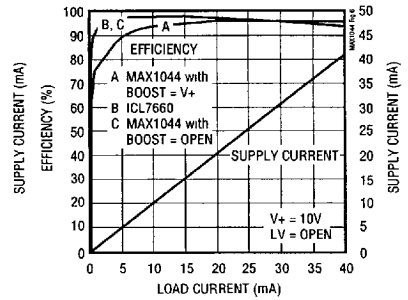**OUTPUT VOLTAGE and OUTPUT RIPPLE vs. LOAD CURRENT**

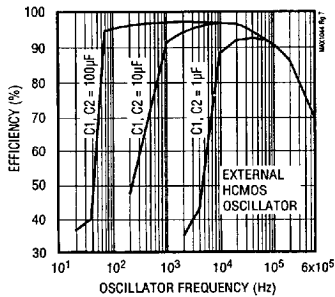**EFFICIENCY and SUPPLY CURRENT vs. LOAD CURRENT**

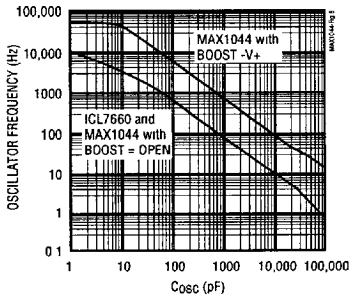**EFFICIENCY and SUPPLY CURRENT vs. LOAD CURRENT**
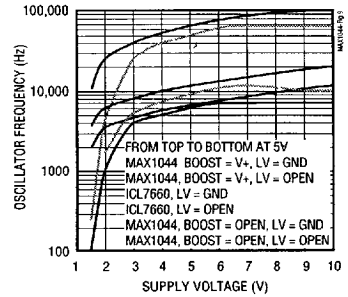
**EFFICIENCY and SUPPLY CURRENT vs. LOAD CURRENT**

**EFFICIENCY vs. OSCILLATOR FREQUENCY**

**OSCILLATOR FREQUENCY vs. EXTERNAL CAPACITANCE**
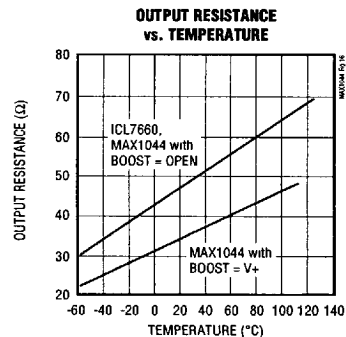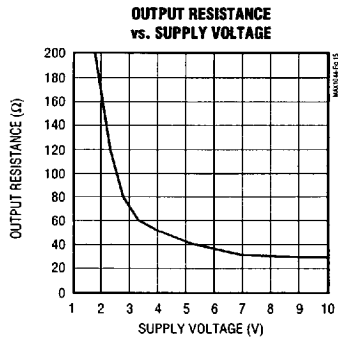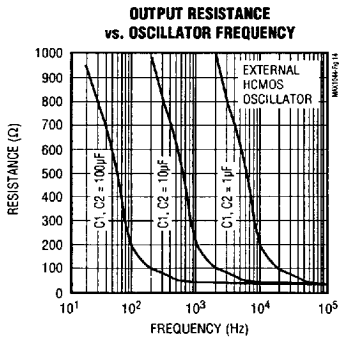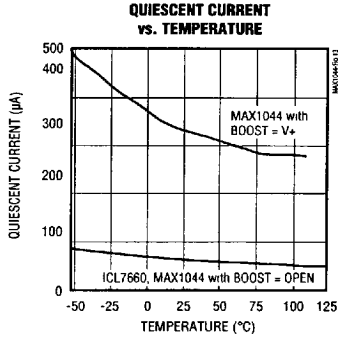
**OSCILLATOR FREQUENCY vs. SUPPLY VOLTAGE**

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# Switched-Capacitor Voltage Converters

### OSCILLATOR FREQUENCY vs. TEMPERATURE

A MAX1044 with BOOST = V+
B ICL7600
C MAX1044 with BOOST = OPEN

### QUIESCENT CURRENT vs. OSCILLATOR FREQUENCY

USING EXTERNAL CAPACITOR

USING EXTERNAL HCMOS OSCILLATOR

### QUIESCENT CURRENT vs. SUPPLY VOLTAGE

A MAX1044, BOOST = V+ LV = GND
B MAX1044, BOOST = V+, LV = OPEN
C ICL7660 and MAX1044 with BOOST = OPEN, LV = GND, ABOVE 5V, MAX1044 ONLY
D ICL7660 and MAX1044 with BOOST = OPEN, LV = OPEN

### QUIESCENT CURRENT vs. TEMPERATURE

MAX1044 with BOOST = V+

ICL7660, MAX1044 with BOOST = OPEN

### OUTPUT RESISTANCE vs. OSCILLATOR FREQUENCY

EXTERNAL HCMOS OSCILLATOR

C1, C2 = 100µF
C1, C2 = 10µF
C1, C2 = 1µF

### OUTPUT RESISTANCE vs. SUPPLY VOLTAGE

### OUTPUT RESISTANCE vs. TEMPERATURE

ICL7660, MAX1044 with BOOST = OPEN

MAX1044 with BOOST = V+

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# Switched-Capacitor Voltage Converters

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | BOOST (MAX1044) | Frequency Boost  Connecting BOOST to V+ increases the oscillator frequency by a factor of six  When the oscillator is driven externally, BOOST has no effect and should be left open |
| | N C (ICL7660) | No Connection |
| 2 | CAP+ | Connection to positive terminal of Charge-Pump Capacitor |
| 3 | GND | Ground  For most applications, the positive terminal of the reservoir capacitor is connected to this pin |
| 4 | CAP- | Connection to negative terminal of Charge-Pump Capacitor |
| 5 | V$_{OUT}$ | Negative Voltage Output  For most applications, the negative terminal of the reservoir capacitor is connected to this pin |
| 6 | LV | Low-Voltage Operation  Connect to ground for supply voltages below 3 5V ICL7660  Leave open for supply voltages above 5V |
| 7 | OSC | Oscillator Control Input  Connecting an external capacitor reduces the oscillator frequency  Minimize stray capacitance at this pin |
| 8 | V+ | Power-Supply Positive Voltage Input  (1.5V to 10V). V+ is also the substrate connection |
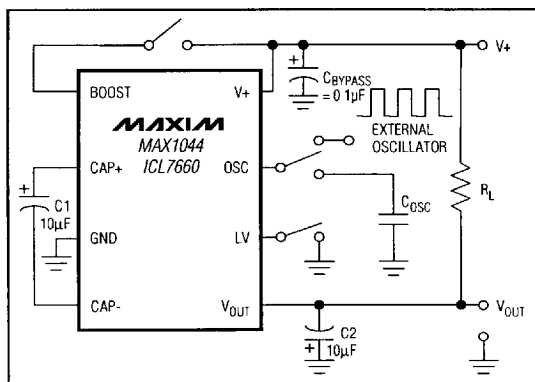


Figure 1  Maxim MAX1044/ICL7660 Test Circuit

## Detailed Description

The MAX1044/ICL7660 are charge-pump voltage converters. They work by first accumulating charge in a bucket capacitor and then transfer it into a reservoir capacitor. The ideal voltage inverter circuit in Figure 2 illustrates this operation.

During the first half of each cycle, switches S1 & S3 close and switches S2 & S4 open, which connects the bucket capacitor C1 across V+ and charges C1. During the second half of each cycle, switches S2 & S4 close and switches S1 & S3 open, which connects the positive terminal of C1 to ground and shifts the negative terminal to V$_{OUT}$. This connects C1 in parallel with the reservoir capacitor C2. If the voltage across C2 is smaller than the voltage across C1, then charge flows from C1 to C2 until the voltages across them are equal. During successive cycles, C1 will continue pouring charge into C2 until the voltage across C2 reaches - (V+). In an actual voltage inverter, the output is less than - (V+) since the switches S1–S4 have resistance and the load drains charge from C2.

Additional qualities of the MAX1044/ICL7660 can be understood by using a switched-capacitor circuit model. Switching the bucket capacitor, C1, between the input and output of the circuit synthesizes a resistance (Figures 3a and 3b.)

When the switch in Figure 3a is in the left position, capacitor C1 charges to V+. When the switch moves to the right position, C1 is discharged to V$_{OUT}$. The charge transferred per cycle is: $\Delta Q = C1(V+ - V_{OUT})$. If the switch is cycled at frequency f, then the resulting

# Switched-Capacitor Voltage Converters

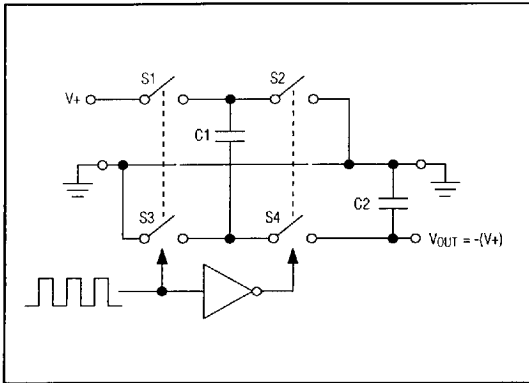Figure 2  Ideal Voltage Inverter



Figure 3a  Switched Capacitor Model



Figure 3b  Equivalent Circuit

current is: $I = f \times \Delta Q = f \times C1(V+ - V_{OUT})$. Rewriting this equation in Ohm's law form defines an equivalent resistance synthesized by the switched-capacitor circuit where.

$$I = \frac{(V+ - V_{OUT})}{1 / (f \times C1)}$$

and

$$R_{EQUIV} = \frac{1}{f \times C1}$$

where f is one-half the oscillator frequency. This resistance is a major component of the output impedance of switched-capacitor circuits like the MAX1044/ICL7660.

As shown in Figure 4, the MAX1044/ICL7660 contain MOSFET switches, the necessary transistor drive circuitry, and a timing oscillator.

## Design Information

The MAX1044/ICL7660 are designed to provide a simple, compact, low-cost solution where negative or doubled supply voltages are needed for a few low-power components. Figure 5 shows the basic negative voltage converter circuit. For many applications, only two external capacitors are needed. The type of capacitor used is not critical.

### Proper Use of the Low-Voltage (LV) Pin

Figure 4 shows an internal voltage regulator inside the MAX1044/ICL7660. Use the LV pin to bypass this regulator, in order to improve low-voltage performance
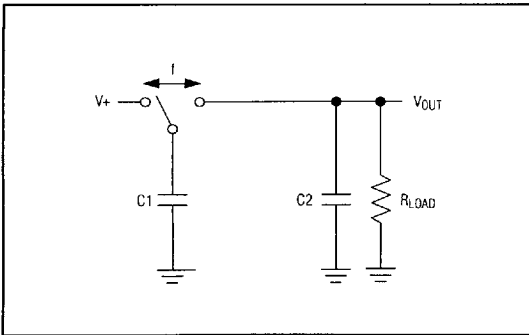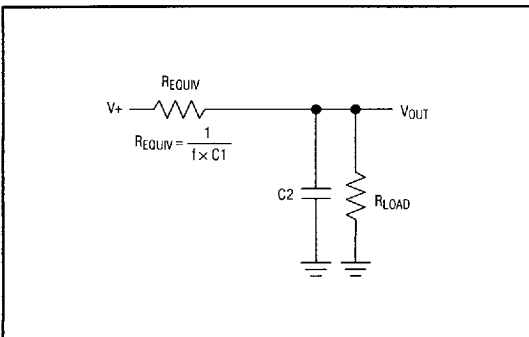


Figure 4  MAX1044 and ICL7660 Functional Diagram

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Figure 5  Basic Negative Voltage Converter



Figure 6  Negative Voltage Converter with $C_{OSC}$ and BOOST
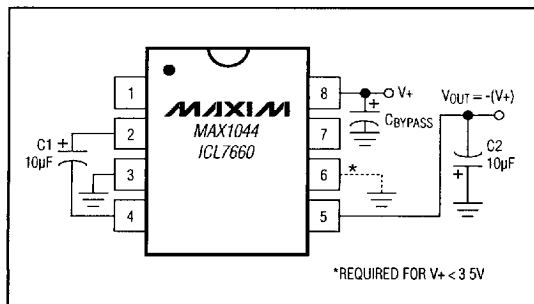
and allow operation down to 1.5V. For low-voltage operation and compatibility with the industry-standard LTC1044 and ICL7660, the LV pin should be connected to ground for supply voltages below 3.5V and left open for supply voltages above 3.5V.

The MAX1044's LV pin can be grounded for all operating conditions. The advantage is improved low-voltage performance and increased oscillator frequency. The disadvantage is increased quiescent current and reduced efficiency at higher supply voltages For Maxim's ICL7660, the LV pin must be left open for supply voltages above 5V.

When operating at low supply voltages with LV open, connections to the LV, BOOST, and OSC pins should be short or shielded to prevent EMI from causing oscillator jitter.

### Oscillator Frequency Considerations
For normal operation, leave the BOOST and OSC pins of the MAX1044/ICL7660 open and use the nominal oscillator frequency. Increasing the frequency reduces audio interference, output resistance, voltage ripple, and required capacitor sizes. Decreasing frequency reduces quiescent current and improves efficiency

### Oscillator Frequency Specifications
The MAX1044/ICL7660 do not have a precise oscillator frequency. Only minimum values of 1kHz and 5kHz for the MAX1044 and a typical value of 10kHz for the ICL7660 are specified If a specific oscillator frequency is required, use an external oscillator to drive the OSC pin.

### Increasing Oscillator Frequency Using the BOOST Pin
For the MAX1044, connecting the BOOST pin to the V+ pin raises the oscillator frequency by a factor of about 6.
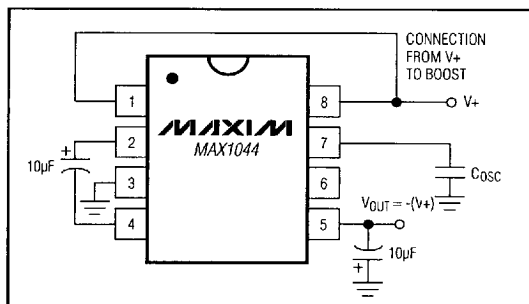
Figure 6 shows this connection. Higher frequency operation lowers output impedance, reduces output ripple, allows the use of smaller capacitors, and shifts switching noise out of the audio band  When the oscillator is driven externally, BOOST has no effect and should be left open. The BOOST pin should also be left open for normal operation.

### Reducing the Oscillator Frequency Using $C_{OSC}$
An external capacitor can be connected to the OSC pin to lower the oscillator frequency (Figure 6) Lower frequency operation improves efficiency at low load currents by reducing the IC's quiescent supply current. It also increases output ripple and output impedance This can be offset by using larger values for C1 and C2.

Connections to the OSC pin should be short to prevent stray capacitance from reducing the oscillator frequency.

### Overdriving the OSC Pin with an External Oscillator
Driving OSC with an external oscillator is useful when the frequency must be synchronized, or when higher frequencies are required to reduce audio interference The MAX1044/ICL7660 can be driven up to 400kHz. The pump and output ripple frequencies are one-half the external clock frequency. Driving the MAX1044/ICL7660 at a higher frequency increases the ripple frequency and allows the use of smaller capacitors It also increases the quiescent current

The OSC input threshold is V+ - 2.5V when V+ ≥ 5V, and is V+ / 2 for V+ < 5V. If the external clock does not swing all the way to V+, use a 10kΩ pull-up resistor (Figure 7).

### Output Voltage Considerations
The MAX1044/ICL7660 output voltage is not regulated. The output voltages will vary under load according to the output resistance  The output resistance is primarily
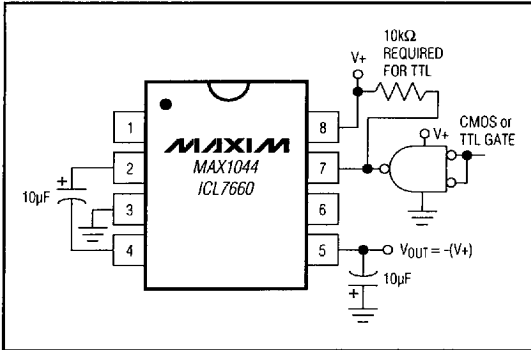
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# Switched-Capacitor Voltage Converters

Figure 7  External Clocking

a function of oscillator frequency and the capacitor value. Oscillator frequency, in turn, is influenced by temperature and supply voltage. For example, with a 5V input voltage and 10µF charge-pump capacitors, the output resistance is typically 50Ω. Thus, the output voltage is about -5V under light loads, and decreases to about -4 5V with a 10mA load current.

Minor supply voltage variations that are inconsequential to digital circuits can affect some analog circuits. Therefore, when using the MAX1044/ICL7660 for powering sensitive analog circuits, the power-supply rejection ratio of those circuits must be considered. The output ripple and output drop increase under heavy loads  If necessary, the MAX1044/ICL7660 output impedance can be reduced by paralleling devices, increasing the capacitance of C1 and C2, or connecting the MAX1044's BOOST pin to V+ to increase the oscillator frequency.

### Inrush Current and EMI Considerations
During start-up, pump capacitors C1 and C2 must be charged. Consequently, the MAX1044/ICL7660 develop inrush currents during start-up  While operating, short bursts of current are drawn from the supply to C1, and then from C1 to C2 to replenish the charge drawn by the load during each charge-pump cycle  If the voltage converters are being powered by a high-impedance source, the supply voltage may drop too low during the current bursts for them to function properly  Furthermore, if the supply or ground impedance is too high, or if the traces between the converter IC and charge-pump capacitors are long or have large loops,

switching noise and EMI may be generated. To reduce these effects:

1) Power the MAX1044/ICL7600 from a low-impedance source.

2) Add a power-supply bypass capacitor with low effective series resistance (ESR) close to the IC between the V+ and ground pins.

3) Shorten traces between the IC and the charge-pump capacitors.

4) Arrange the components to keep the ground pins of the capacitors and the IC as close as possible.

5) Leave extra copper on the board around the voltage converter as power and ground planes. This is easily done on a double-sided PC board.

### Efficiency, Output Ripple, and Output Impedance
The power efficiency of a switched-capacitor voltage converter is affected by the internal losses in the converter IC, resistive losses of the pump capacitors, and conversion losses during charge transfer between the capacitors  The total power loss is:

$$\Sigma\, P_{LOSS} = P_{\substack{INTERNAL\\LOSSES}} + P_{\substack{SWITCH\\LOSSES}} + P_{\substack{PUMP\\CAPACITOR\\LOSSES}} + P_{\substack{CONVERSION\\LOSSES}}$$

The internal losses are associated with the IC's internal functions such as driving the switches, oscillator, etc. These losses are affected by operating conditions such as input voltage, temperature, frequency, and connections to the LV, BOOST, and OSC pins.

The next two losses are associated with the output resistance of the voltage converter circuit. Switch losses occur because of the on-resistances of the MOSFET switches in the IC. Charge-pump capacitor losses occur because of their ESR.  The relationship between these losses and the output resistance is as follows:

$$P_{\substack{PUMP\\CAPACITOR\\LOSSES}} + P_{\substack{SWITCH\\LOSSES}} = I_{OUT}^{2} \times R_{OUT}$$

where:

$$R_{OUT} \cong \frac{1}{(f_{OSC}/2) \times C1} + 4\left(2R_{SWITCHES} + ESR_{C1}\right) + ESR_{C2}$$

and $f_{OSC}$ is the oscillator frequency.

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The first term is the effective resistance from the switched-capacitor circuit.

Conversion losses occur during the transfer of charge between capacitors C1 and C2 when there is a voltage difference between them. The power loss is:

$$P_{CONV\ LOSS} = \left[\frac{1}{2}C1\left((V+)^2 - V_{OUT}^2\right) + \frac{1}{2}C2\left(V_{RIPPLE}^2 - 2V_{OUT}V_{RIPPLE}\right)\right] \times f_{OSC}\ /\ 2$$

### Increasing Efficiency

Efficiency can be improved by lowering output voltage ripple and output impedance  Both output voltage ripple and output impedance can be reduced by using large capacitors with low ESR

The output voltage ripple can be calculated by noting that the output current is supplied solely from capacitor C2 during one-half of the charge-pump cycle.

$$V_{RIPPLE} \cong \left(\frac{1}{2 \times f_{OSC} \times C2} + 2 \times ESR_{C2}\right)I_{OUT}$$

Slowing the oscillator frequency reduces quiescent current.  The oscillator frequency can be reduced by connecting a capacitor to the OSC pin.

Reducing the oscillator frequency increases the ripple voltage in the MAX1044/ICL7660.  Compensate by increasing the values of the bucket and reservoir capacitors. For example, in a negative voltage converter, the pump frequency is around 4kHz or 5kHz. With the recommended 10µF bucket and reservoir capacitors, the circuit consumes about 70µA of quiescent current while providing 20mA of output current. Setting the oscillator to 400Hz by connecting a 100pF capacitor to OSC reduces the quiescent current to about 15µA. Maintaining 20mA output current capability requires increasing the bucket and reservoir capacitors to 100µF

Note that lower capacitor values can be used for lower output currents  For example, setting the oscillator to 40Hz by connecting a 1000pF capacitor to OSC provides the highest efficiency possible. Leaving the bucket and reservoir capacitors at 100µF gives a maximum $I_{OUT}$ of 2mA, a no-load quiescent current of 10µA, and a power conversion efficiency of 98%.

### General Precautions

1) Connecting any input terminal to voltages greater than V+ or less than ground may cause latchup  Do not apply any input sorces operating from external supplies before device power-up

2) Never exceed maximum supply voltage ratings

3) Do not connect C1 and C2 with the wrong polarity.

4) Do not short V+ to ground for extended periods with supply voltages above 5.5V present on other pins.

5) Ensure that $V_{OUT}$ (pin 5) does not go more positive than GND (pin 3). Adding a diode in parallel with C2, with the anode connected to $V_{OUT}$ and cathode to LV, will prevent this condition.

## Application Circuits

### Negative Voltage Converter

Figure 8 shows a negative voltage converter, the most popular application of the MAX1044/ICL7660. Only two external capacitors are needed  A third power-supply bypass capacitor is recommended (0.1µF to 10µF)
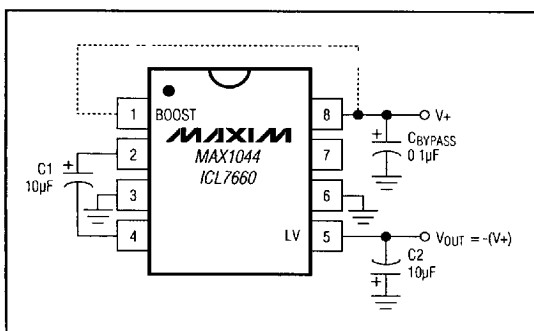
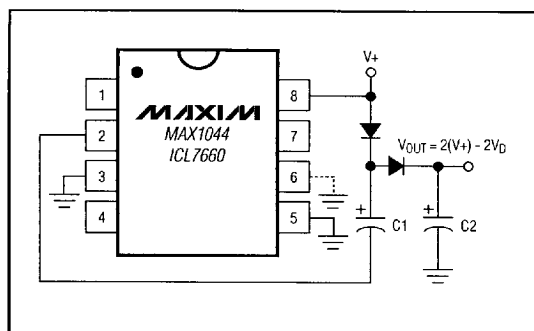Figure 8   Negative Voltage Converter with BOOST and LV Connections

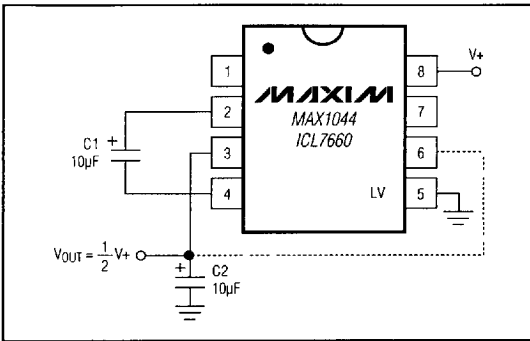Figure 9   Voltage Doubler

# Switched-Capacitor Voltage Converters

MAX1044/ICL7660



Figure 10  Voltage Divider



Figure 11  Combined Positive and Negative Converter

### Positive Voltage Doubler

Figure 9 illustrates the recommended voltage doubler circuit for the MAX1044/ICL7660. To reduce the voltage drops contributed by the diodes ($V_D$), use Schottky diodes. For true voltage doubling or higher output currents, use the MAX660

### Voltage Divider

The voltage divider shown in Figure 10 splits the power supply in half  A third capacitor can be added between V+ and $V_{OUT}$.

### Combined Positive Multiplication and Negative Voltage Conversion

Figure 11 illustrates this dual-function circuit. Capacitors C1 and C3 perform the bucket and reservoir functions for generating the negative voltage. Capacitors C2 and C4 are the bucket and reservoir
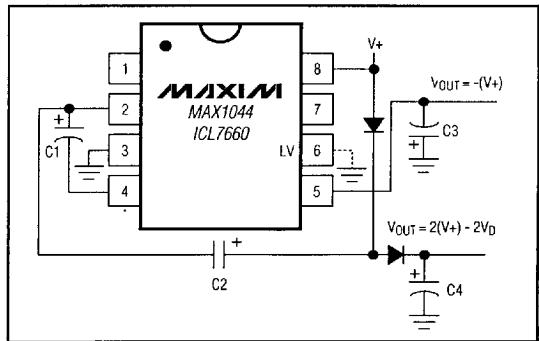
capacitors for the doubled positive voltage. This circuit has higher output impedances resulting from the use of a common charge-pump driver

### Cascading Devices

Larger negative multiples of the supply voltage can be obtained by cascading MAX1044/ICL7660 devices (Figure 12). The output voltage is nominally $V_{OUT} = -n(V+)$ where n is the number of devices cascaded.  The output voltage is reduced slightly by the output resistance of the first device, multiplied by the quiescent current of the second, etc. Three or more devices can be cascaded in this way, but output impedance rises dramatically. For example, the output resistance of two cascaded MAX1044s is approximately five times the output resistance of a single voltage converter. A better solution may be an inductive switching regulator, such as the MAX755, MAX759, MAX764, or MAX774.
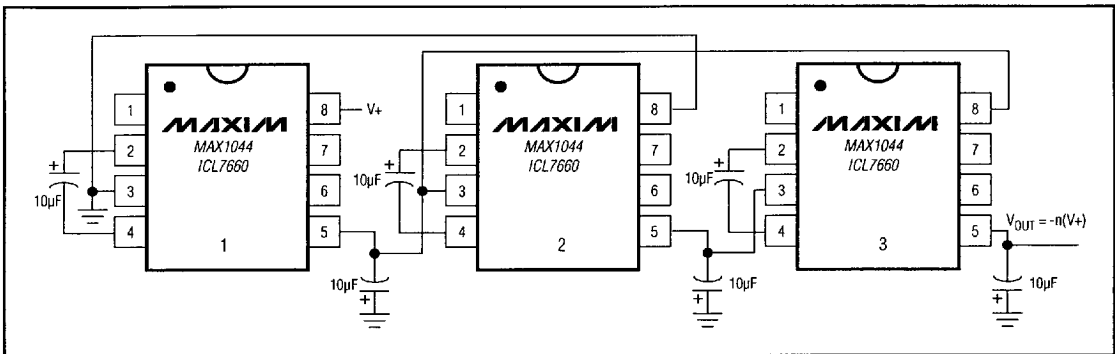


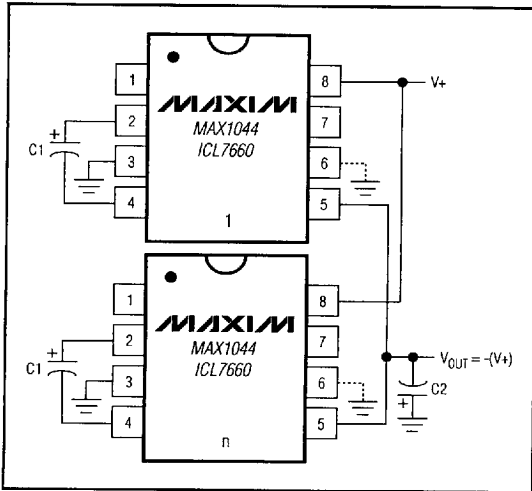Figure 12  Cascading MAX1044/ICL7660 for Increased Output Voltage

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# Switched-Capacitor Voltage Converters

MAX1044/ICL7660



Figure 13  Paralleling MAX1044/ICL7660 to Reduce Output Resistance



Figure 14a-14c  Shutdown Schemes for MAX1044/ICL7660

## Paralleling Devices

Paralleling multiple MAX1044/ICL7660s reduces output resistance and increases current capability   As illustrated in Figure 13, each device requires its own pump capacitor C1, but the reservoir capacitor C2 serves all devices. The equation for calculating output resistance is:

$$R_{OUT} = \frac{R_{OUT}(\text{of MAX1044 or ICL7660})}{n \text{ (number of devices)}}$$

## Shutdown Schemes

Figures 14a–14c illustrate three ways of adding shutdown capability to the MAX1044/ICL7660. When using these circuits, be aware that the additional capacitive loading on the OSC pin will reduce the oscillator frequency. The first circuit has the least loading on the OSC pin and has the added advantage of controlling shutdown with a high or low logic level, depending on the orientation of the switching diode.
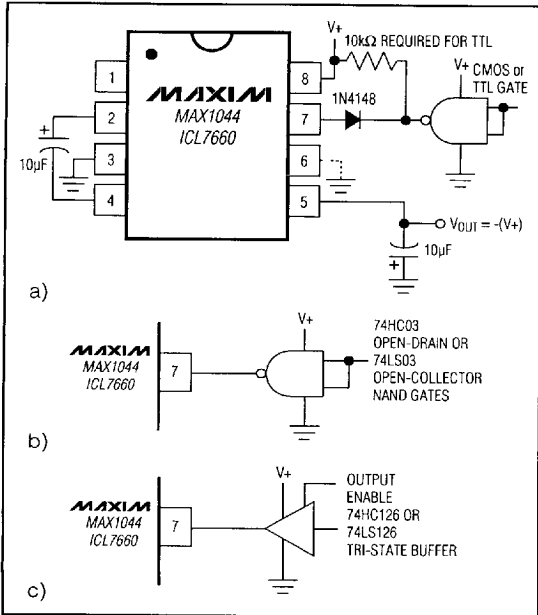
## _Ordering Information (continued)

| PART | TEMP. RANGE | PIN-PACKAGE |
|---|---|---|
| MAX1044ESA | -40°C to +85°C | 8 SO |
| MAX1044MJA | -55°C to +125°C | 8 CERDIP** |
| **ICL7660CPA** | 0°C to +70°C | 8 Plastic DIP |
| ICL7660CSA | 0°C to +70°C | 8 SO |
| ICL7660CUA | 0°C to +70°C | 8 µMAX |
| ICL7660C/D | 0°C to +70°C | Dice* |
| ICL7660EPA | -40°C to +85°C | 8 Plastic DIP |
| ICL7660ESA | -40°C to +85°C | 8 SO |
| ICL7660AMJA† | -55°C to +125°C | 8 CERDIP** |
| ICL7660AMTV† | -55°C to +125°C | 8 TO-99** |

\* Contact factory for dice specifications
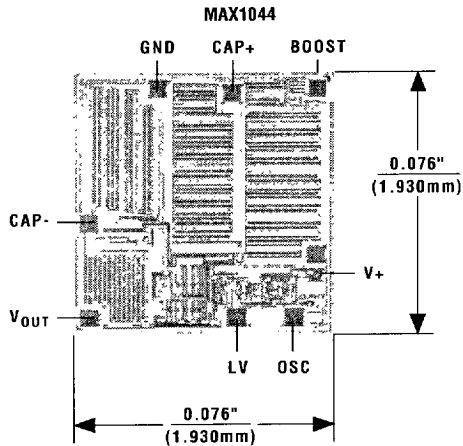\*\* Contact factory for availability
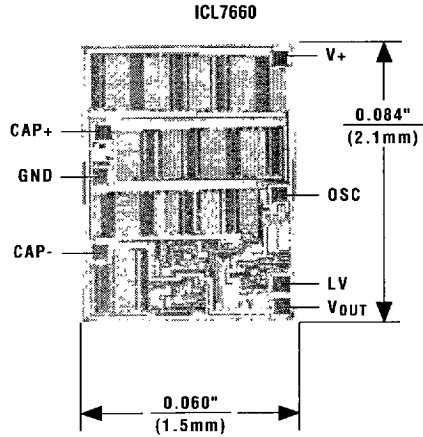† The Maxim ICL7660 meets or exceeds all "A" and "S" specifications

# Switched-Capacitor Voltage Converters

_____Chip Topographies

### MAX1044

GND    CAP+    BOOST

CAP-

V<sub>OUT</sub>

LV    OSC

V+

0.076"
(1.930mm)

0.076"
(1.930mm)

TRANSISTOR COUNT  72
SUBSTRATE CONNECTED TO V+

### ICL7660

V+

CAP+

GND

OSC

CAP-

LV
V<sub>OUT</sub>

0.084"
(2.1mm)

0.060"
(1.5mm)

TRANSISTOR COUNT. 71
SUBSTRATE CONNECTED TO V+

| DIM | INCHES | | MILLIMETERS | |
|-----|--------|--------|--------|--------|
|     | MIN    | MAX    | MIN    | MAX    |
| A   | 0.036  | 0.044  | 0.91   | 1.11   |
| A1  | 0.004  | 0.008  | 0.10   | 0.20   |
| B   | 0.010  | 0.014  | 0.25   | 0.36   |
| C   | 0 005  | 0.007  | 0.13   | 0.18   |
| D   | 0.116  | 0.120  | 2.95   | 3.05   |
| E   | 0.116  | 0.120  | 2.95   | 3.05   |
| e   | 0.0256 |        | 0.65   |        |
| H   | 0.188  | 0.198  | 4.78   | 5.03   |
| L   | 0.016  | 0.026  | 0.41   | 0.66   |
| α   | 0°     | 6°     | 0°     | 6°     |

21-0036

E    H

D

0.127mm
0.004 in

C

α

e    B    A1    A    L

**8-PIN µMAX
PACKAGE**

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