

# Switched-Capacitor Voltage Converter

## Features

- 99.7% Open Circuit Voltage Conversion Efficiency
- 98% Power Efficiency
- Operating Voltage Range of 1.5 to 10 V
- Requires Only Two Capacitors

## Benefits

- Inexpensive Negative Supply from Positive Supply
- Easy to Use
- Minimum Parts Count
- Small Size
- No Diode Drop at Output
- Low Cost

## Applications

- Conversion of 5-V Logic Supply to  $\pm 5$ -V Supplies
- Negative Supply for Dynamic RAMs
- RS-232 Power Supply
- Negative Supplies for Analog Circuits
- Data Acquisition Systems
- Hand-Held Instruments
- High-Side Load Switches

## Description

The Si7660 is a monolithic CMOS switched-capacitor voltage converter that inverts ( $V_{OUT} = -V_{IN}$ ), doubles ( $V_{OUT} = 2 V_{IN}$ ), divides ( $V_{OUT} = V_{IN}/2$ ), or multiplies ( $V_{OUT} = \pm n V_{IN}$ ) an input voltage. Operation with no external diode is guaranteed over the full temperature range for input voltages ranging from 1.5 V to 10 V.

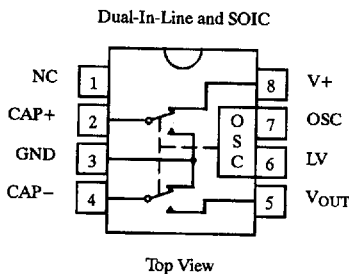
The Si7660 combines low quiescent current with high efficiency and reliability. Included on chip are an oscillator, control circuitry and four power MOS switches. An epitaxial layer prevents latchup.

The oscillator, when unloaded, runs at a nominal 12 kHz. The OSC pin may be used to change the running frequency. The LV pin should be tied to ground to improve low voltage operation ( $V+ \leq 3.5$  V). For  $V+ > 3.5$  V, the LV pin should be left disconnected.

Typical applications include generating a  $-5$ -V supply from a 5-V logic supply to power analog circuits, generating 6 V from a 3-V lithium cell, or 3 V from a single 1.5-V cell.

For additional information please refer to Applications Note AN401.

## Functional Block Diagram and Pin Configuration



### Ordering Information

Temp Range	Package	Part Number
0 to 70°C	8-Pin Plastic MiniDIP	Si7660CI
-40 to 85°C	8-Pin Plastic MiniDIP	Si7660DJ
	8-Pin Narrow SOIC	Si7660DY

## Absolute Maximum Ratings

Supply Voltage (V+ to GND or GND to VOUT) .....	11 V
Oscillator Input Voltage:	
(V+ < 5.5 V) .....	-0.3 V to (V+) +0.3 V
(V+ > 5.5 V) .....	(V+) -5.5 V to (V+) +0.3 V
LV .....	No connection for V+ > 3.5 V
Storage Temperature .....	-65 to 125°C

Power Dissipation: <sup>a</sup>	
8-Pin Plastic DIP <sup>b</sup> .....	300 mW
8-Pin SOIC <sup>b</sup> .....	300 mW

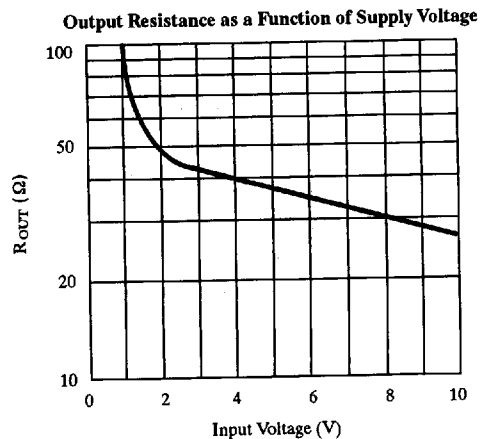
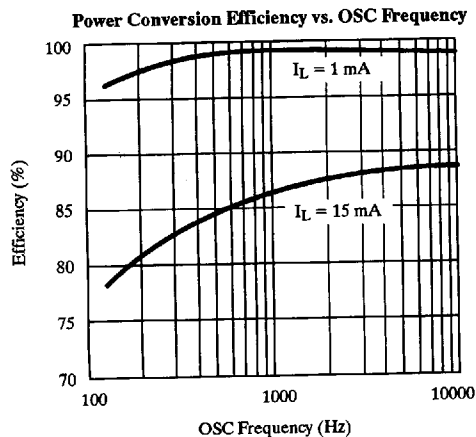
- Notes:  
 a. All leads soldered or welded to PC board.  
 b. Derate 10 mW/°C above 75°C

## Specifications

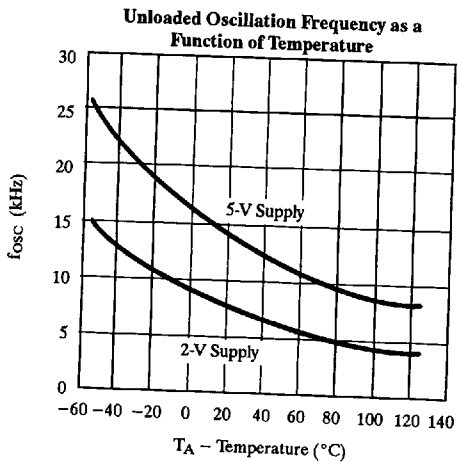
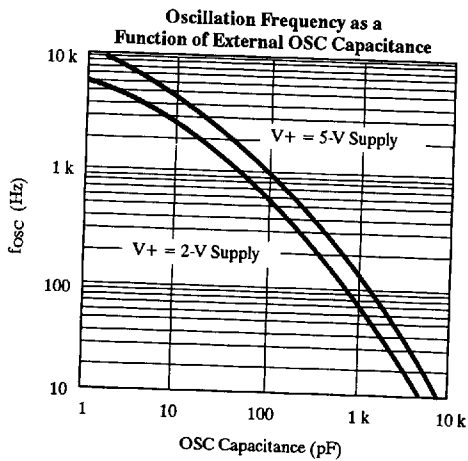
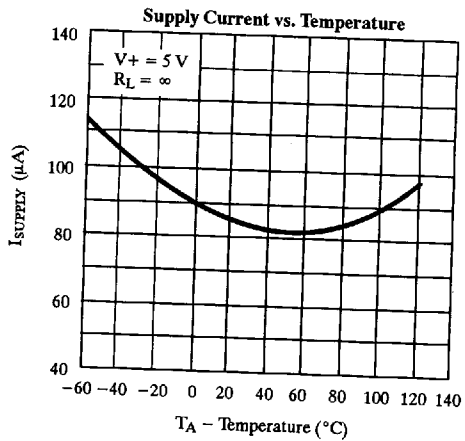
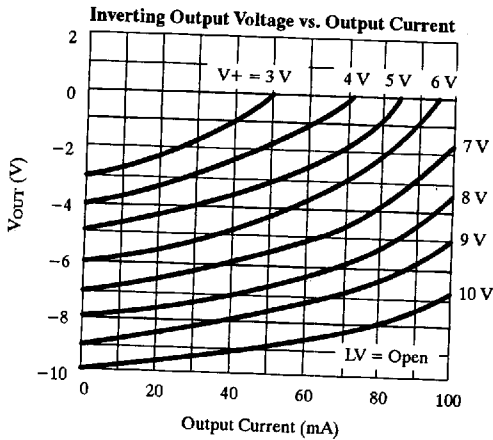
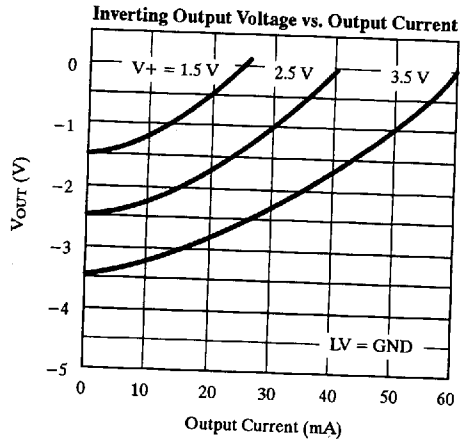
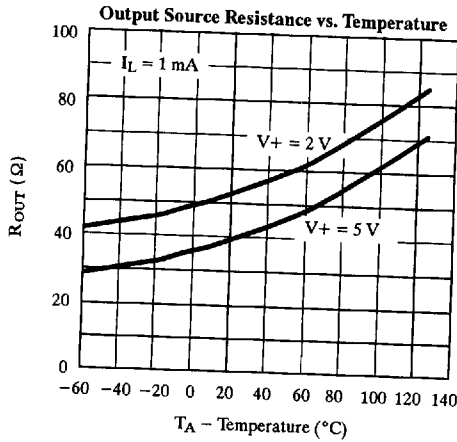
Parameter	Symbol	Test Conditions Unless Otherwise Specified V+ = 5 V, C <sub>OSC</sub> = 0 <sup>d</sup>	Temp <sup>a</sup>	Limits			Unit
				Min <sup>b</sup>	Typ <sup>c</sup>	Max <sup>b</sup>	
<b>Input</b>							
Supply Voltage Range Low	V+L	R <sub>L</sub> = 10 kΩ, LV = GND	Full	1.5		3.5	V
Supply Voltage Range High	V+H	R <sub>L</sub> = 10 kΩ, LV = Open	Full	3		10	V
Supply Current	I+	R <sub>L</sub> = ∞, LV = Open	Full		100	175	μA
<b>Output</b>							
Output Source Resistance	R <sub>OUT</sub>	V+ = 5 V, LV = Open, I <sub>O</sub> = 20 mA	Room		55	100	Ω
		Full			120		
		V+ = 2 V, LV = GND, I <sub>O</sub> = 3 mA	Full			300	
Power Conversion Efficiency	PE <sub>1</sub>	R <sub>L</sub> = 5 kΩ	Room	95	98		%
Voltage Conversion Efficiency	V <sub>OUT</sub> E <sub>1</sub>	R <sub>L</sub> = ∞	Room	99	99.9		%
<b>Dynamic</b>							
Oscillator Frequency <sup>d</sup>	f <sub>OSC</sub>		Room		12		kHz
Oscillator Impedance	Z <sub>OSC</sub>	V+ = 2 V, LV = GND	Room		1		MΩ
		V+ = 5 V	Room		100		kΩ

- Notes:  
 a. Room = 25°C, Full = as determined by the operating temperature suffix.  
 b. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.  
 c. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.  
 d. For C<sub>OSC</sub> > 1000 pF, C<sub>1</sub> and C<sub>2</sub> should be increased to 100 μF. C<sub>1</sub> = Pump Capacitor, C<sub>2</sub> = Reservoir Capacitor.

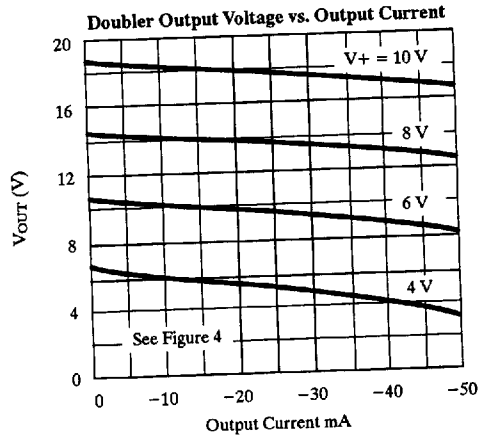
## Typical Characteristics



**Typical Characteristics (Cont'd)**



## Typical Characteristics (Cont'd)



## Schematic Diagram

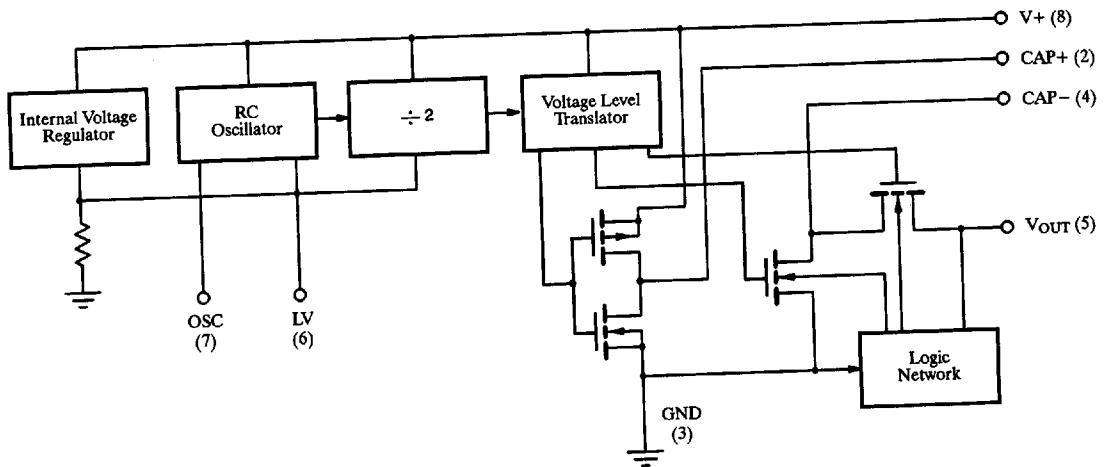


Figure 1.

## Test Circuit

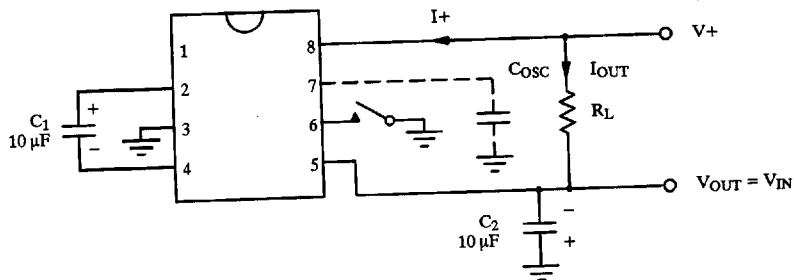


Figure 2.

**Applications**

There are many applications where a low current supply made with a charge pump does just as well as a conventional, fully regulated negative supply or dc-to-dc converter module. The Si7660 contains all the circuitry necessary to make a charge pump for voltage inversion, doubling, division, multiplication, etc. Only two external capacitors are needed and they may be inexpensive electrolytics. Since the output resistance is in the tens of ohms, heavy load currents will reduce the output voltage and eventually may cause the device to go into shutdown.

If the output ripple of the Si7660 is too great for a particular application, the value of the pump ( $C_1$ , Figure 3) and reservoir ( $C_2$ , Figure 3) capacitors can be increased to reduce this effect. However, it is important to note that increasing the capacitor size can lead to surge currents at turn-on. If the current is too great, the power dissipation of

the device can be exceeded. The maximum recommended capacitor size is 1000  $\mu\text{F}$ .

A previous version of the Si7660 required a diode in series with Pin 5 when operating above 6.5 V. The current Si7660 does not require this diode, but will work in existing circuits which have the diode.

Figure 4 shows a circuit that will produce two output voltages utilizing both of the Si7660 features (i.e. inversion and doubling). The combined output current must be limited so the maximum device dissipation is not exceeded.

Two Si7660s can be paralleled to reduce the effective output resistance of the converter. The output voltage at a given current is increased since the voltage drop is halved when the devices are connected as shown in Figure 6.

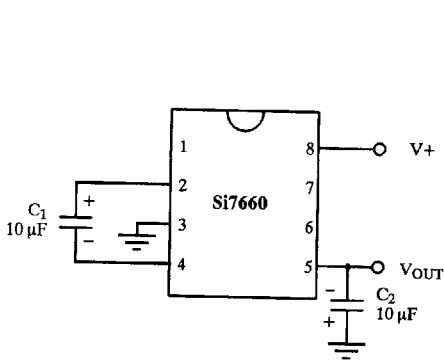


Figure 3. Basic Inverter Circuit

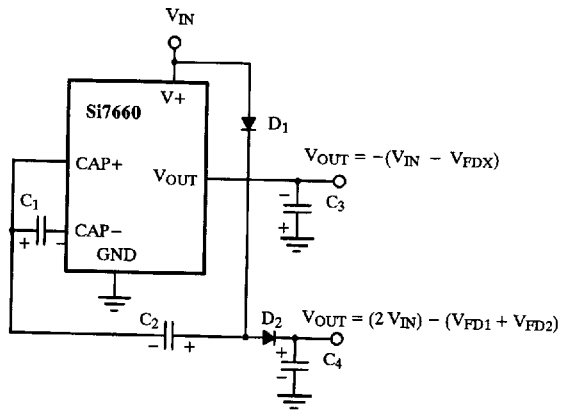


Figure 4. Combination Inverter/Doubler Circuit

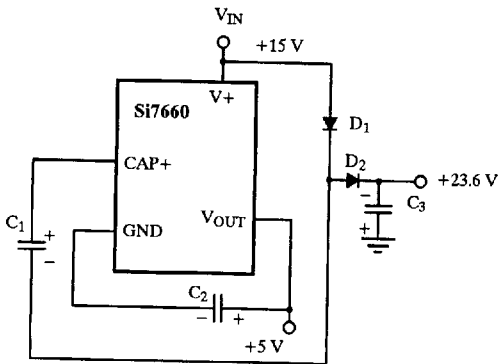


Figure 5. Creating +23.6 V from +15 V and +5 V

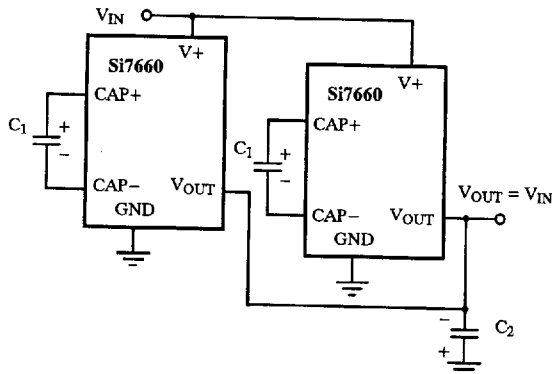


Figure 6. Paralleling Two Si7660s to Reduce the Effective Output Resistance

## Applications (Cont'd)

### Battery Splitter

To obtain supplies from a single battery or power supply, the circuit shown in Figure 7 offers a simple solution. It generates symmetrical  $\pm$  output voltages equal to one-half the input voltage. Both output voltages are referenced to Pin 3 (output common). To improve low voltage operation, Pin 6 should be connected to Pin 3 when the input voltage is less than 3.5 V.

### High Precision Voltage Divider

A high precision voltage divider is shown in Figure 8. Increasing the load current beyond 100 nA will cause a small loss in accuracy.

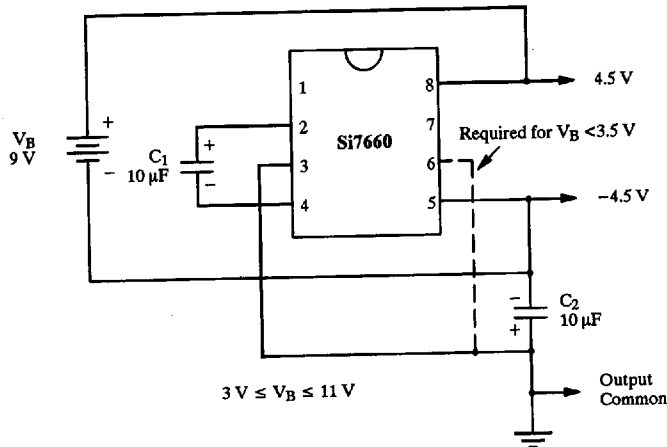


Figure 7. Battery Splitter

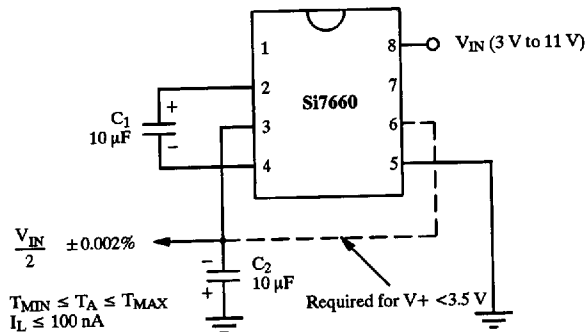
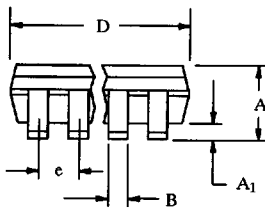
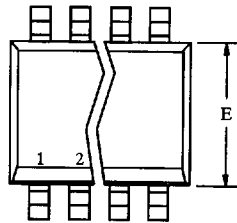


Figure 8. High Precision Voltage Divider

### SO Package (Y Suffix), 8-16 Leads



Dim	Millimeters		Inches	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A <sub>1</sub>	0.10	0.20	0.004	0.008
B	0.35	0.45	0.014	0.018
C	0.18	0.23	0.007	0.009
D-8	4.60	5.20	0.181	0.205
D-14	8.35	8.95	0.329	0.352
D-16	9.60	10.20	0.378	0.402
E	3.55	4.05	0.140	0.160
e	1.27 BSC		0.050 BSC	
H	5.70	6.30	0.224	0.248
L	0.60	0.80	0.024	0.031
Θ	0°	8°	0°	8°

