HIGH FREQUENCY 7660 DC-TO-DC VOLTAGE CONVERTER

FEATURES
- Pin Compatible with 7660, High Frequency Performance DC-to-DC Converter
- Low Cost, Two Low Value External Capacitors Required ................................................ (1.0µF)
- Converts +5V Logic Supply to ±5V System
- Wide Input Voltage Range ............... 1.5V to 10V
- Voltage Conversion .......................... 99.7%
- Power Efficiency .............................. 85%
- Available in 8-Pin SOIC and 8-Pin PDIP Packages

GENERAL DESCRIPTION
The TC7660H is a pin-compatible, high frequency upgrade to the Industry standard TC7660 charge pump voltage converter. It converts a +1.5V to +10V input to a corresponding –1.5V to –10V output using only two low-cost capacitors, eliminating inductors and their associated cost, size and EMI.

The TC7660H operates at a frequency of 120kHz (versus 10kHz for the TC7660), allowing the use of 1.0µF external capacitors. Oscillator frequency can be reduced (for lower supply current applications) by connecting an external capacitor from OSC to ground.

The TC7660H is available in 8-pin DIP and small outline (SOIC) packages in commercial and extended temperature ranges.

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Package</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC7660HCOA</td>
<td>8-Pin SOIC</td>
<td>0°C to +70°C</td>
</tr>
<tr>
<td>TC7660HCPA</td>
<td>8-Pin Plastic DIP</td>
<td>0°C to +70°C</td>
</tr>
<tr>
<td>TC7660HEOA</td>
<td>8-Pin SOIC</td>
<td>– 40°C to +85°C</td>
</tr>
<tr>
<td>TC7660HEPA</td>
<td>8-Pin Plastic DIP</td>
<td>– 40°C to +85°C</td>
</tr>
<tr>
<td>TC7660EV</td>
<td>Evaluation Kit for Charge Pump Family</td>
<td></td>
</tr>
</tbody>
</table>

PIN CONFIGURATION (DIP and SOIC)

NC = NO INTERNAL CONNECTION

FUNCTIONAL BLOCK DIAGRAM

Downloaded from Arrow.com.
TC7660H

**ABSOLUTE MAXIMUM RATINGS**

Supply Voltage ...................................................... +10.5V
LV and OSC Inputs
Voltage (Note 1) ........................ – 0.3V to (V+ + 0.3V)
for V+ < 5.5V
(V+ – 5.5V) to (V+ + 0.3V)
for V+ > 5.5V
Current Into LV (Note 1) ..................... 20µA for V+ > 3.5V
Output Short Duration (VSUPPLY ≤ 5.5V) ........ Continuous
Power Dissipation (T_A ≤ 70°C) (Note 2)
SOIC ...............................................................470mW
Plastic DIP ...................................................... 730mW
Operating Temperature Range
C Suffix .................................................. 0°C to +70°C
E Suffix ............................................ – 40°C to +85°C
Storage Temperature Range .......... – 65°C to +150°C
Lead Temperature (Soldering, 10 sec) ............. +300°C

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above 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 above those indicated in the operation sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**ELECTRICAL CHARACTERISTICS:**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>I+</td>
<td>Supply Current</td>
<td>RL = ∞</td>
<td>—</td>
<td>0.46</td>
<td>1.0</td>
<td>mA</td>
</tr>
<tr>
<td>V_H</td>
<td>Supply Voltage Range, High</td>
<td>Min ≤ T_A ≤ Max, RL = 5kΩ, LV Open</td>
<td>3</td>
<td>—</td>
<td>10</td>
<td>V</td>
</tr>
<tr>
<td>V_L</td>
<td>Supply Voltage Range, Low</td>
<td>Min ≤ T_A ≤ Max, RL = 5kΩ, LV to GND</td>
<td>1.5</td>
<td>—</td>
<td>3.5</td>
<td>V</td>
</tr>
<tr>
<td>R_OUT</td>
<td>Output Source Resistance</td>
<td>I_OUT = 20mA, T_A = 25°C</td>
<td>—</td>
<td>55</td>
<td>80</td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I_OUT = 20mA, 0°C ≤ T_A ≤ +70°C (C Device)</td>
<td>—</td>
<td>—</td>
<td>95</td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I_OUT = 20mA, – 40°C ≤ T_A ≤ +85°C (E Device)</td>
<td>—</td>
<td>—</td>
<td>110</td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V+ = 2V, I_OUT = 3mA, LV to GND, 0°C ≤ T_A ≤ +70°C</td>
<td>—</td>
<td>150</td>
<td>250</td>
<td>Ω</td>
</tr>
<tr>
<td>F_OSC</td>
<td>Oscillator Frequency</td>
<td>—</td>
<td>120</td>
<td>—</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>P_EFF</td>
<td>Power Efficiency</td>
<td>I_OUT = 10mA, Min ≤ T_A ≤ Max</td>
<td>81</td>
<td>85</td>
<td>—</td>
<td>%</td>
</tr>
<tr>
<td>V_EFF</td>
<td>Voltage Efficiency</td>
<td>RL = ∞</td>
<td>99</td>
<td>99.7</td>
<td>—</td>
<td>%</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Connecting any input terminal to voltages greater than V+ or less than GND may cause destructive latch-up. It is recommended that no inputs from sources operating from external supplies be applied prior to "power up" of the TC7660H.
2. Derate linearly above 50°C by 5.5mW/°C.
Detailed Description

The TC7660H contains all the necessary circuitry to implement a voltage inverter, with the exception of two external capacitors, which may be inexpensive 1.0 µF non-polarized capacitors. Operation is best understood by considering Figure 2, which shows an idealized voltage inverter. Capacitor C1 is charged to a voltage, V+, for the half cycle when switches S1 and S3 are closed. (Note: Switches S2 and S4 are open during this half cycle.) During the second half cycle of operation, switches S2 and S4 are closed, with S1 and S3 open, thereby shifting capacitor C1 negatively by V+ volts. Charge is then transferred from C1 to C2, such that the voltage on C2 is exactly V+, assuming ideal switches and no load on C2.

To improve low-voltage operation, the LV pin should be connected to GND. For supply voltages greater than 3.5V, the LV terminal must be left open to ensure latch-up-proof operation and prevent device damage.

Theoretical Power Efficiency Considerations

In theory, a capacitative charge pump can approach 100% efficiency if certain conditions are met:

1. The drive circuitry consumes minimal power.
2. The output switches have extremely low ON resistance and virtually no offset.
3. The impedances of the pump and reservoir capacitors are negligible at the pump frequency.

The TC7660H approaches these conditions for negative voltage multiplication if large values of C1 and C2 are used. Energy is lost only in the transfer of charge between capacitors if a change in voltage occurs. The energy lost is defined by:

\[ E = \frac{1}{2} C_1 (V_1^2 - V_2^2) \]

V1 and V2 are the voltages on C1 during the pump and transfer cycles. If the impedances of C1 and C2 are relatively high at the pump frequency (refer to Figure 1), compared to the value of RL, there will be a substantial difference in voltages V1 and V2. Therefore, it is not only desirable to make C2 as large as possible to eliminate output voltage ripple, but also to employ a correspondingly large value for C1 in order to achieve maximum efficiency of operation.

Do's and Don'ts

- Do not exceed maximum supply voltages.
- Do not connect LV terminal to GND for supply voltages greater than 3.5V.
- Do not short circuit the output to V+ supply for voltages above 5.5V for extended periods; however, transient conditions including start-up are okay.
- When using polarized capacitors in the inverting mode, the + terminal of C1 must be connected to pin 2 of the TC7660H and the + terminal of C2 must be connected to GND Pin 3.
TC7660H

**Simple Negative Voltage Converter**

Figure 3 shows typical connections to provide a negative supply where a positive supply is available. A similar scheme may be employed for supply voltages anywhere in the operating range of +1.5V to +10V, keeping in mind that pin 6 (LV) is tied to the supply negative (GND) only for supply voltages below 3.5V.

The output characteristics of the circuit in Figure 3 are those of a nearly ideal voltage source in series with 70Ω. Thus, for a load current of −10 mA and a supply voltage of +5V, the output voltage would be −4.3V.

The dynamic output impedance of the TC7660H is due, primarily, to capacitive reactance of the charge transfer capacitor (C1). Since this capacitor is connected to the output for only 1/2 of the cycle, the equation is:

\[ X_C = \frac{2}{2\pi f C_1} = 2.12\Omega, \]

where \( f = 150\text{kHz} \) and \( C_1 = 1.0\mu\text{F} \).

**Paralleling Devices**

Any number of TC7660H voltage converters may be paralleled to reduce output resistance (Figure 4). The reservoir capacitor, \( C_2 \), serves all devices, while each device requires its own pump capacitor, \( C_1 \). The resultant output resistance would be approximately:

\[ R_{OUT} = \frac{R_{OUT\ (of\ TC7660H)}}{n\ (number\ of\ devices)} \]

**Cascading Devices**

The TC7660H may be cascaded as shown in (Figure 4) to produce larger negative multiplication of the initial supply voltage. However, due to the finite efficiency of each device, the practical limit is probably 10 devices for light loads. The output voltage is defined by:

\[ V_{OUT} = -n\ (V_{IN}) \]

where \( n \) is an integer representing the number of devices cascaded. The resulting output resistance would be approximately the weighted sum of the individual TC7660H \( R_{OUT} \) values.

**Changing the TC7660H Oscillator Frequency**

It may be desirable in some applications (due to noise or other considerations) to increase or decrease the oscillator frequency. This can be achieved by overdriving the oscillator from an external clock, as shown in Figure 6. In order to prevent possible device latch-up, a 1kΩ resistor must be used in series with the clock output. In a situation where the designer has generated the external clock frequency using TTL logic, the addition of a 10kΩ pull-up resistor to \( V^+ \) supply is required. Note that the pump frequency with external clocking, as with internal clocking, will be 1/2 of the clock frequency. Output transitions occur on the positive-going edge of the clock.
Combined Negative Voltage Conversion and Positive Supply Multiplication

Figure 8 combines the functions shown in Figures 3 and 8 to provide negative voltage conversion and positive voltage multiplication simultaneously. This approach would be, for example, suitable for generating +9V and −5V from an existing +5V supply. In this instance, capacitors C1 and C3 perform the pump and reservoir functions, respectively, for the generation of the negative voltage, while capacitors C2 and C4 are pump and reservoir, respectively, for the multiplied positive voltage. There is a penalty in this configuration which combines both functions, however, in that the source impedances of the generated supplies will be somewhat higher due to the finite impedance of the common charge pump driver at pin 2 of the device.

Positive Voltage Multiplication

The TC7660H may be employed to achieve positive voltage multiplication using the circuit shown in Figure 7. In this application, the pump inverter switches of the TC7660H are used to charge C1 to a voltage level of \( V^+ - V_F \) (where \( V^+ \) is the supply voltage and \( V_F \) is the forward voltage drop of diode D1). On the transfer cycle, the voltage on C1 plus the supply voltage (\( V^+ \)) is applied through diode D2 to capacitor C2. The voltage thus created on C2 becomes \( 2V^+ - 2V_F \), or twice the supply voltage minus the combined forward voltage drops of diodes D1 and D2.

The source impedance of the output (\( V_{OUT} \)) will depend on the output current, but for \( V^+ = 5V \) and an output current of 10mA, it will be approximately 60Ω.
Efficient Positive Voltage Multiplication/Conversion

Since the switches that allow the charge pumping operation are bidirectional, the charge transfer can be performed backwards as easily as forwards. Figure 9 shows a TC7660H transforming −5V to +5V (or +5V to +10V, etc.). The only problem here is that the internal clock and switch-drive section will not operate until some positive voltage has been generated. An initial inefficient pump, as shown in Figure 9, could be used to start this circuit up, after which it will bypass the diode and resistor shown dotted in Figure 9.

TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 1)
HIGH FREQUENCY 7660 DC-TO-DC VOLTAGE CONVERTER

TC7660H

PACKAGE DIMENSIONS

8-Pin Plastic DIP

8-Pin SOIC

Dimensions: inches (mm)
HIGH FREQUENCY 7660 DC-TO-DC VOLTAGE CONVERTER

New York
150 Motor Parkway, Suite 202
Hauppauge, NY. 11788
Tel: 631-273-5305 Fax: 631-273-5335

San Jose
Micropchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

Toronto
6285 Northham Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

China - Beijing
Micropchip Technology Beijing Office
Unit 915
New China Hong Kong Manhattan Bldg.
No. 6 Chaoyangmen Bedaje
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

Hong Kong
Micropchip Asia Pacific
RM 2101, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

India
Micropchip Technology Inc.
India Liaison Office
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, OSHaughnessy Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Micropchip Technology Intl. Inc.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471-6166 Fax: 81-45-471-6122

Korea
Micropchip Technology Korea
168-1, Youngbo Bldg, 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea
Tel: 82-2-554-7200 Fax: 82-2-558-5934

ASIA/PACIFIC (continued)

Singapore
Micropchip Technology Singapore Pte Ltd.
200 Middle Road
07-02 Prime Centre
Singapore, 188980
Tel: 65-334-8870 Fax: 65-334-8850

Taiwan
Micropchip Technology Taiwan
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Australia
Micropchip Technology Australia Pty Ltd
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

Denmark
Micropchip Technology Denmark ApS
Regus Business Centre
Laadrup hq 1-3
Ballup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Arizona Microchip Technology SARL
Parc d’activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - 1er Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Arizona Microchip Technology GmbH
Gustav-Heinemann Ring 125
D-81739 Munich, Germany
Tel: 49-99-627-144 0 Fax: 49-99-627-144-44

Germany
Analogue Product Sales
Lochhammer Strasse 13
D-82152 Martinsried, Germany
Tel: 49-89-8955650-0 Fax: 49-89-8955650-22

Italy
Arizona Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

United Kingdom
Arizona Microchip Technology Ltd.
505 Eddak Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44 118 921 5820