General Description

The ultra-small MAX828/MAX829 monolithic, CMOS charge-pump inverters accept input voltages ranging from +1.5V to +5.5V. The MAX828 operates at 12kHz, and the MAX829 operates at 35kHz. Their high efficiency (greater than 90% over most of the load-current range) and low operating current (60µA for the MAX828) make these devices ideal for both battery-powered and board-level voltage-conversion applications.

The MAX828/MAX829 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. Both parts come in a 5-pin SOT23-5 package and can deliver 25mA with a voltage drop of 500mV.

For a similar device with logic-controlled shutdown, refer to the MAX1719/MAX1720/MAX1721. For applications requiring more power, the MAX860 delivers up to 50mA with a voltage drop of 600mV, in a space-saving µMAX package.

Features

- 5-Pin SOT23-5 Package
- 95% Voltage Conversion Efficiency
- Inverts Input Supply Voltage
- 60µA Quiescent Current (MAX828)
- +1.5V to +5.5V Input Voltage Range
- Requires Only Two Capacitors
- 25mA Output Current

Applications

- Small LCD Panels
- Cell Phones
- Medical Instruments
- Handy-Terminals, PDAs
- Battery-Operated Equipment

Ordering Information

<table>
<thead>
<tr>
<th>PART</th>
<th>TEMP. RANGE</th>
<th>PIN-PACKAGE</th>
<th>SOT</th>
<th>TOP MARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX828EUK</td>
<td>-40°C to +85°C</td>
<td>5 SOT23-5</td>
<td>AABI</td>
<td></td>
</tr>
<tr>
<td>MAX829EUK</td>
<td>-40°C to +85°C</td>
<td>5 SOT23-5</td>
<td>AABJ</td>
<td></td>
</tr>
</tbody>
</table>

For price, delivery, and to place orders, please contact Maxim Distribution at 1-888-629-4642, or visit Maxim’s website at www.maxim-ic.com.
Switched-Capacitor Voltage Inverters

ABSOLUTE MAXIMUM RATINGS
IN to GND .................................................................+6.0V, -0.3V
OUT to GND .................................................................-6.0V, +0.3V
OUT Output Current ......................................................50mA
OUT Short-Circuit to GND ............................................Indefinite
Continuous Power Dissipation (TA = +70°C)
SOT23-5 (derate 7.1mW/°C above +70°C) ....................571mW

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
(VIN = +5V, C1 = C2 = 10µF (MAX828), C1 = C2 = 3.3µF (MAX829), TA = 0°C to +85°C, unless otherwise noted. Typical values are at TA = +25°C.)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Current</td>
<td>TA = +25°C</td>
<td>MAX828</td>
<td>60</td>
<td>90</td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAX829</td>
<td>150</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>Minimum Supply Voltage</td>
<td>RLOAD = 10kΩ, TA = +25°C</td>
<td>1.25</td>
<td>1.0</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>RLOAD = 10kΩ, TA = 0°C to +85°C</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Supply Voltage</td>
<td>RLOAD = 10kΩ, TA = +25°C</td>
<td>5.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Oscillator Frequency</td>
<td>TA = +25°C</td>
<td>MAX828</td>
<td>8.4</td>
<td>12</td>
<td>15.6 kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAX829</td>
<td>24.5</td>
<td>35</td>
<td>45.5 kHz</td>
</tr>
<tr>
<td>Power Efficiency</td>
<td>RLOAD = 1kΩ, TA = +25°C</td>
<td>94</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Voltage Conversion Efficiency</td>
<td>RLOAD = ∞, TA = +25°C</td>
<td>95</td>
<td>99.9</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Output Resistance</td>
<td>IOUT = 5mA, TA = +25°C</td>
<td>20</td>
<td>50</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td>IOUT = 5mA, TA = 0°C to +85°C</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Capacitor contribution is approximately 20% of the output impedance [ESR + 1 / (pump frequency x capacitance)].

ELECTRICAL CHARACTERISTICS
(VIN = +5V, C1 = C2 = 10µF (MAX828), C1 = C2 = 3.3µF (MAX829), TA = -40°C to +85°C, unless otherwise noted. Typical values are at TA = +25°C.) (Note 2)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Current</td>
<td>MAX828</td>
<td>115</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>MAX829</td>
<td>325</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Voltage Range</td>
<td>RLOAD = 10kΩ</td>
<td>1.5</td>
<td>5.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Oscillator Frequency</td>
<td>MAX828</td>
<td>6</td>
<td>20</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td>MAX829</td>
<td>19</td>
<td>54.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Resistance</td>
<td>IOUT = 5mA</td>
<td>65</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
</tbody>
</table>

Note 2: All -40°C to +85°C specifications above are guaranteed by design.
Switched-Capacitor Voltage Inverters

Typical Operating Characteristics

(Circuit of Figure 1, \( V_{IN} = +5V \), \( C1 = C2 = C3 \), \( TA = +25^\circ C \), unless otherwise noted.)
Switched-Capacitor Voltage Inverters

Typical Operating Characteristics (continued)
(Circuit of Figure 1, V_{IN} = +5V, C_1 = C_2 = C_3, T_A = +25°C, unless otherwise noted.)

**Pin Description**

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OUT</td>
<td>Inverting Charge-Pump Output</td>
</tr>
<tr>
<td>2</td>
<td>IN</td>
<td>Positive Power-Supply Input</td>
</tr>
<tr>
<td>3</td>
<td>C1-</td>
<td>Flying Capacitor’s Negative Terminal</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>5</td>
<td>C1+</td>
<td>Flying Capacitor’s Positive Terminal</td>
</tr>
</tbody>
</table>

Figure 1. Test Circuit
**Detailed Description**

The MAX828/MAX829 capacitive charge pumps invert the voltage applied to their input. For highest performance, use low equivalent series resistance (ESR) capacitors. During the first half-cycle, switches S2 and S4 open, switches S1 and S3 close, and capacitor C1 charges to the voltage at IN (Figure 2). During the second half-cycle, S1 and S3 open, S2 and S4 close, and C1 is level shifted downward by \( V_{IN} \) volts. 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 voltage across C2 reaches \( -V_{IN} \). The actual voltage at the output is more positive than \(-V_{IN}\), since switches S1–S4 have resistance and the load drains charge from C2.

**Charge-Pump Output**

The MAX828/MAX829 are not voltage regulators: the charge pump’s output source resistance is approximately 20Ω at room temperature (with \( V_{IN} = +5V \)), and \( V_{OUT} \) approaches \(-5V\) when lightly loaded. \( V_{OUT} \) will droop toward GND as load current increases. The droop of the negative supply (\( V_{DROOP-} \)) equals the current draw from OUT (\( I_{OUT} \)) times the negative converter’s source resistance (\( R_S- \)):

\[
V_{DROOP-} = I_{OUT} \times R_S-
\]

The negative output voltage will be:

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

**Efficiency Considerations**

The efficiency of the MAX828/MAX829 is dominated by its quiescent supply current (\( I_Q \)) at low output current and by its output impedance (\( R_{OUT} \)) at higher output current; it is given by:

\[
\eta = \frac{I_{OUT}}{I_{OUT} + I_Q} \left( 1 - \frac{I_{OUT} \times R_{OUT}}{V_{IN}} \right)
\]

\( R_{1f} \times C_1 + R_{4ESR} = R_{OUT} \)

\( \theta = \frac{1}{f_{OSC} \times C_1} + 2R_{SW} + 4ESR_{C1} + ESR_{C2} \)

The first term is the effective resistance of an ideal switched-capacitor circuit (Figures 3a and 3b), and \( R_{SW} \) is the sum of the charge pump’s internal switch resistances (typically 8Ω to 9Ω at \( V_{IN} = +5V \)). The typical output impedance is more accurately determined from the Typical Operating Characteristics.

**Applications Information**

**Capacitor Selection**

To maintain the lowest output resistance, use capacitors with low ESR (Table 1). The charge-pump output resistance is a function of C1’s and C2’s ESR. Therefore, minimizing the charge-pump capacitor’s ESR minimizes the total output resistance.
Switched-Capacitor Voltage Inverters

**Flying Capacitor (C1)**
Increasing the flying capacitor’s size reduces the output resistance. Small C1 values increase the output resistance. Above a certain point, increasing C1’s capacitance has a negligible effect, because the output resistance becomes dominated by the internal switch resistance and capacitor ESR.

**Output Capacitor (C2)**
Increasing the output capacitor’s size reduces the output ripple voltage. Decreasing its ESR reduces both output resistance and ripple. Smaller capacitance values can be used with light loads if higher output ripple can be tolerated. Use the following equation to calculate the peak-to-peak ripple:

\[ V_{\text{Ripple}} = \frac{1}{f_{\text{OSC}}} \times \frac{I_{\text{OUT}}}{C_2} + 2 \times I_{\text{OUT}} \times \text{ESR}_{C_2} \]

**Input Bypass Capacitor**
Bypass the incoming supply to reduce its AC impedance and the impact of the MAX828/MAX829’s switching noise. The recommended bypassing depends on the circuit configuration and on where the load is connected.

When the inverter is loaded from OUT to GND, current from the supply switches between 2 x I_{OUT} and zero. Therefore, use a large bypass capacitor (e.g., equal to the value of C1) if the supply has a high AC impedance.

When the inverter is loaded from IN to OUT, the circuit draws 2 x I_{OUT} constantly, except for short switching spikes. A 0.1µF bypass capacitor is sufficient.

**Voltage Inverter**
The most common application for these devices is a charge-pump voltage inverter (Figure 1). This application requires only two external components—capacitors C1 and C2—plus a bypass capacitor, if necessary. Refer to the Capacitor Selection section for suggested capacitor types and values.

**Cascading Devices**
Two devices can be cascaded to produce an even larger negative voltage (Figure 4). The unloaded output voltage is normally -2 x VIN, but this is reduced slightly by the output resistance of the first device multiplied by the quiescent current of the second. When cascading more than two devices, the output resistance rises dramatically. For applications requiring larger negative voltages, see the MAX864 and MAX865 data sheets.

**Paralleling Devices**
Paralleling multiple MAX828s or MAX829s reduces the output resistance. Each device requires its own pump capacitor (C1), but the reservoir capacitor (C2) serves all devices (Figure 5). Increase C2’s value by a factor of n, where n is the number of parallel devices. The equation for calculating output resistance is also shown in Figure 5.

**Combined Doubler/Inverter**
In the circuit of Figure 6, capacitors C1 and C2 form the inverter, while C3 and C4 form the doubler. C1 and C3 are the pump capacitors; C2 and C4 are the reservoir capacitors. Because both the inverter and doubler use part of the charge-pump circuit, loading either output causes both outputs to decline toward GND. Make sure the sum of the currents drawn from the two outputs does not exceed 40mA.

### Table 1. Low-ESR Capacitor Manufacturers

<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>PHONE</th>
<th>FAX</th>
<th>DEVICE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVX</td>
<td>(803) 946-0690</td>
<td>(803) 626-3123</td>
<td>Surface-mount, TPS series</td>
</tr>
<tr>
<td>Matsuo</td>
<td>(714) 969-2491</td>
<td>(714) 960-6492</td>
<td>Surface-mount, 267 series</td>
</tr>
<tr>
<td>Sanyo</td>
<td>USA</td>
<td>Japan</td>
<td>Through-hole, OS-CON series</td>
</tr>
<tr>
<td></td>
<td>(619) 661-6835</td>
<td>(619) 661-1055</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>81-7-2070-6306</td>
<td>81-7-2070-1174</td>
</tr>
<tr>
<td>Sprague</td>
<td>(603) 224-1961</td>
<td>(603) 224-1430</td>
<td>Surface-mount, 595D series</td>
</tr>
</tbody>
</table>
Heavy Output Current Loads

When under heavy loads, where higher supply is sourcing current into OUT, the OUT supply must not be pulled above ground. Applications that sink heavy current into OUT require a Schottky diode (1N5817) between GND and OUT, with the anode connected to OUT (Figure 7).

Layout and Grounding

Good layout is important, primarily for good noise performance. To ensure good layout, mount all components as close together as possible, keep traces short to minimize parasitic inductance and capacitance, and use a ground plane.

Shutting Down the MAX828/MAX829

For a similar device with logic-controlled shutdown, please refer to the MAX1719/MAX1720/MAX1721. To add manual shutdown control to the MAX828/MAX829, use the circuit in Figure 8. The output resistance of the MAX828/MAX829 will typically be 20Ω plus two times the output resistance of the buffer driving IN. The 0.1µF capacitor at the IN pin absorbs the transient input currents of the MAX828/MAX829.

The output resistance of the buffer driving the IN pin can be reduced by connecting multiple buffers in parallel. The polarity of the SHUTDOWN signal can also be changed by using a noninverting buffer to drive IN.
Switched-Capacitor Voltage Inverters

Figure 8. Shutdown Control

Chip Information

TRANSISTOR COUNT: 58
SUBSTRATE CONNECTED TO IN

Package Information

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