Technical Article

Pump It up with Charge Pumps – Part 1

Life was simple when I first became interested in electronics. Components were so big I could solder them without a microscope. Switching converters switched at a whopping 25 kHz, digital circuits all used a 5-V supply voltage and all the computers I came across used the RS-232 serial interface to communicate.

The RS-232 standard specifies that a logic 0 is represented by voltages between 5 V and 25 V, and a logic 1 by voltages between –5 V and –25 V. My problem was that although almost all the components on my boards needed only a 5-V supply, I still had to generate those two extra rails for my RS-232 interface.

Then I came across the MAX232. This device was an inspired product, combining two line drivers, two line receivers, and a positive and negative charge pump. With that bad boy running off a single 5-V supply, I could generate the additional supply voltages I needed and transmit and receive serial data.

Charge pumps are useful little DC/DC converters that use a capacitor to store energy instead of an inductor. They can be found in dedicated charge-pump devices such as the LM2775/LM2776 devices, as auxiliary rails in LCD bias supplies such as the TPS65150, or as external circuits put together from a couple of diodes and a couple of capacitors.

Generally speaking, charge pumps are:

- Simple, often comprising no more than two diodes and two capacitors.
- More forgiving than DC/DC converters.
- Good for output currents in the tens of milliamps range (but not so good for currents much higher than 250 mA).
- Less efficient than inductor-based DC/DC converters, unless they are unregulated and running open -loop.

Figure 1 is a simplified circuit diagram of an unregulated charge pump. The charge pump operates in two phases:

- During the charge phase, switches S1 and S4 are open and switches S2 and S3 are closed. Current flows through S2 and S3 and charges the flying capacitor, C_{FLY}, up to a voltage of V_I.
- During the discharge phase, switches S1 and S4 are closed and switches S2 and S3 are open. The negative terminal of C_{FLY} is now at V_I and the positive terminal (which is V_I volts higher) is now at $2V_I$. Current flows from V_I through the flying capacitor C_{FLY} and switches S1 and S4. Charge is transferred from C_{FLY} to the output capacitor, C_O, to generate an output voltage approximately equal to $2V_I$.

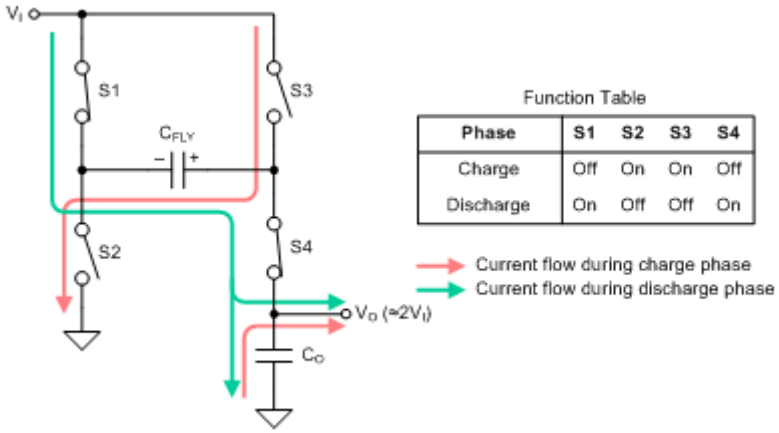

Figure 1. Simplified Charge-pump Block Diagram (Voltage Doubler)

You can rearrange the same four components (S1, S2, S3 and S4) to generate a negative output voltage equal to approximately $-V_I$ (see Figure 2).

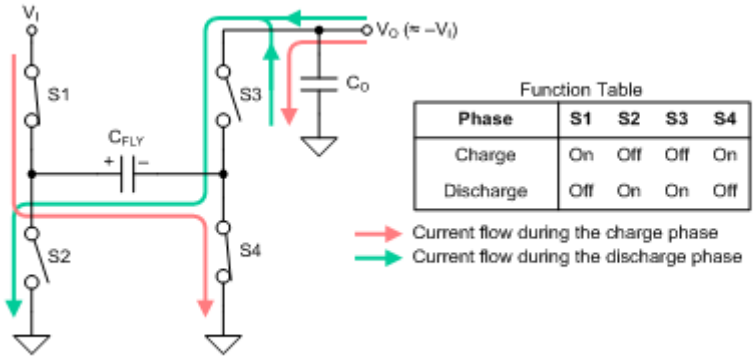

Figure 2. Simplified Charge-pump Block Diagram (Voltage Inverter)

The circuit just described works well, but its output voltage is unregulated. Such a simple circuit is sufficient is some applications, but a charge pump with a regulated output is much more useful.

The usual way to regulate the output voltage of a charge pump is to put an adjustable current source, I_1, in series with switch S1, or S2 in the case of an inverting charge pump (see Figure 3). The error amplifier, A1, adjusts the value of I_1 until the output voltage is correct. Under steady-state conditions, I_1 is exactly twice the value of I_O.

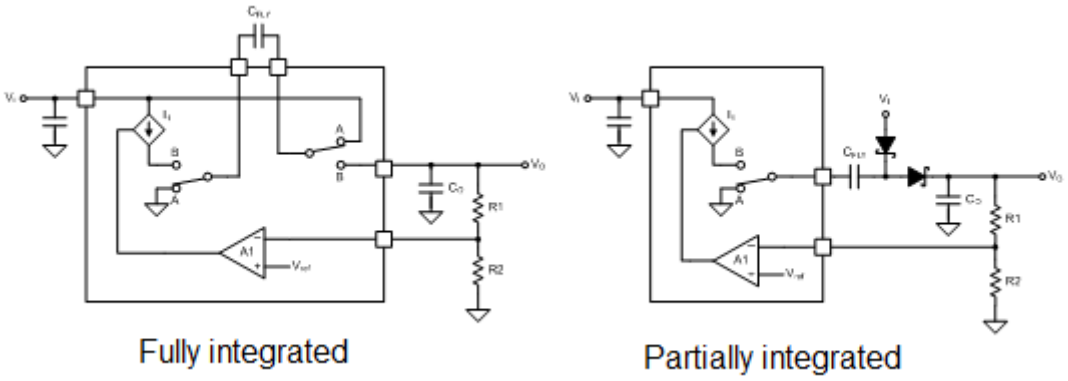

Figure 3. Different Charge-pump Integration Levels

Note that a simple, regulated voltage doubler can only regulate its output voltage in the range of V_I to $2V_I$. It cannot generate output voltages lower than V_I. There are some fancy tricks you can do to make a buck-boost charge pump, but these kinds of devices are more complicated than the one shown in Figure 3.

Additional Resources:

- Find help deciding between a charge pump, inductor-based converter or LDO.
- Browse the charge pump portfolio.
- Learn more about "The Forgotten Converter" in this white paper.

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