

# DESIGN *FAQs*

## Frequently Asked Questions:

### VOLTAGE CONVERSION WITHOUT MAGNETIC COMPONENTS

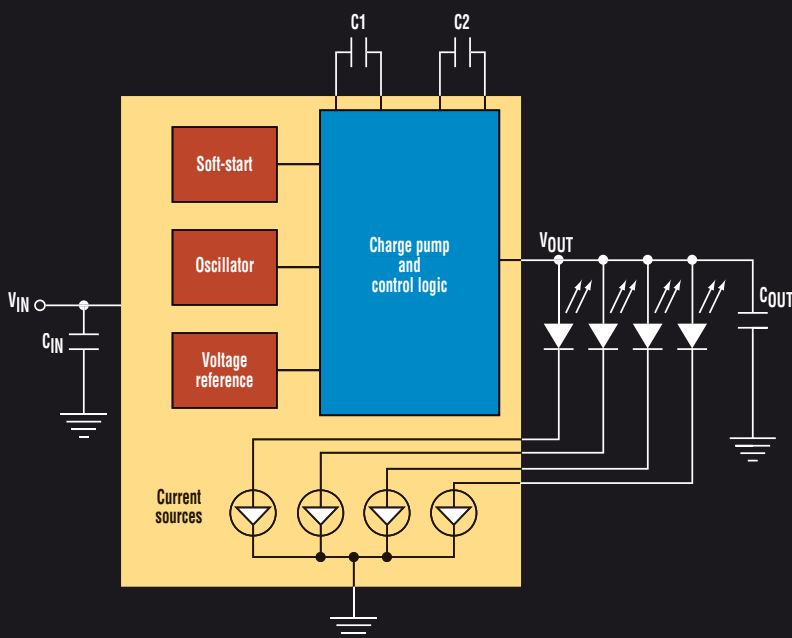
Sam Davis, Contributing Editor

#### What are typical charge pump applications?

Charge pumps have come far in the past decade, from unregulated single-output ICs to regulated ICs with multiple output voltages. Output power and efficiency also have improved, so the charge pump can now deliver up to 250 mA at 75% efficiency (average). Most applications are in battery-based systems like cell phones, pagers, Bluetooth systems, and portable electronics. Major applications include powering white LEDs for backlighting LCDs and powering milliwatt-range digital processors (*see the figure*).

#### How does a charge pump work?

Charge pump (switched-capacitor) ICs provide dc-dc voltage conversion using a switch network to charge and discharge two or more capacitors. The basic charge pump switch network toggles between the capacitors' charge and discharge states. C1 (the "flying capacitor") shuttles charge, and C2 (the "reservoir capacitor") holds charge and filters the output voltage.



A simplified charge pump IC circuit employs two external capacitors to produce a 2X dc output that supplies constant current to four LEDs. It does not require an inductor or transformer.

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Additional "flying capacitors" and switch arrays enable multiple gains.

#### What operating modes are available with charge pumps?

A charge pump IC can operate as an inverter, splitter, or booster. The inverter converts the input voltage to a negative output. As a splitter, the output is a fraction of the input voltage, i.e. 1/2 or 2/3. As a booster, it can provide I/O gain of 1.5X or 2X. Many portable systems use a single lithium-ion or two nickel-metal-hydride batteries. So operating in the 2X mode, the charge pump can supply the proper forward voltage for white LEDs, which typically range from 3.3 to 4.0 V.

#### Is the charge pump output regulated?

The basic charge pump lacks regulation, so virtually all present-day charge pump ICs add linear regulation or charge pump modulation. Linear regulation offers the lowest output noise and provides better performance at a lower efficiency. Charge pump modulation, which controls the switch resistance, offers higher efficiency and more output current for a given die size (or cost) because the regulator IC doesn't include a series pass transistor.

#### What is the major advantage of the charge pump?

The charge pump eliminates the magnetic fields and electromagnetic interference that comes with an inductor or transformer. Yet there is one minor possible noise source—the high charging current that flows to a "flying capacitor" when it connects to an input source or another capacitor with a different voltage. Also, the "splitter" charge pump provides efficiency improvements over LDOs without the complexity of an inductive step-down regulator.

#### Can a charge pump's output adapt to its input voltage?

Charge pumps can dynamically change their output based on the battery voltage input. For example, a charge pump can operate at either the 1.5X or 1X mode. When the battery's input voltage is low, this charge pump produces an output 1.5 times the input. The charge pump operates in the 1X mode when the battery voltage is high and the load

doesn't need a voltage boost. So, the charge pump merely passes the input voltage to the load. This reduces the input current and power dissipation when the input voltage is high.

### What happens after increasing the capacitor switching frequency?

Increasing the switching frequency increases the IC's quiescent current, but it also allows smaller capacitance values for C1 and C2. A constant frequency architecture provides a low-noise regulated output as well as lower input noise than conventional charge pump regulators. High-frequency operation simplifies filtering to further reduce conducted noise.

### What are the best capacitor types for a charge pump?

For highest performance, use capacitors with low equivalent series resistance (ESR). Low-ESR capacitors should be used at the IC's output to minimize output ripple and output resistance and maximize efficiency. Ceramic capacitors can achieve this, but certain tantalum capacitors may be adequate.

### What is the effect of soft-start for the charge pump?

Soft-start prevents excessive current flow at  $V_{IN}$  during startup. It increases the amount of current available to the output charge storage capacitor linearly over a fixed time period. It's usually enabled whenever the device is brought out of shutdown and disabled shortly after achieving regulation.

### How can the charge pump IC minimize power consumption?

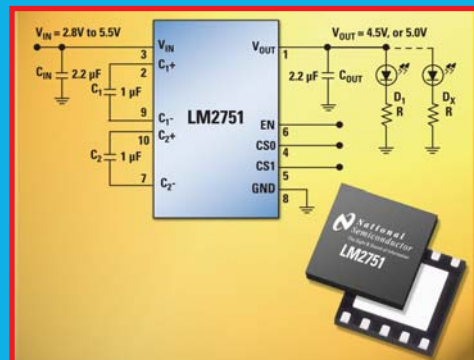
Using pulse-frequency modulation (PFM), the IC pumps only when charge must be delivered to maintain output regulation. When the output is above the target regulation voltage, the IC idles and consumes minimal supply current because the charge stored in the output capacitor supplies the load current. As this capacitor discharges and the output voltage falls below the target regulation voltage, the charge pump activates and delivers charge to the output. This charge supplies the load current and boosts the voltage on the output capacitor. **ED Online 10704**

# PRODUCT Q&As

## LM2751: Regulated 2X, 1.5X Switched Capacitor White LED Driver

With over 90% peak efficiency, the LM2751 is a constant frequency switched capacitor charge pump with regulated output of 4.5 V or 5.0 V at  $\pm 5\%$  regulation. Over the 2.8- to 5.5-V input range, the LM2751 can provide up to 120 mA at 4.5-V output or 60 mA at 5.0-V output.

Using constant frequency pre-regulation, the LM2751 minimizes conducted noise on the input and provides a predictable switching frequency, which is programmable to 650, 262, 32, or 8 kHz.



## LM2753: Charge Pump Flash LED Driver

With a 3.6-V input, the LM2753 charge pump doubler can drive a flash LED at 250 mA. It operates over an input supply range of 3.0 to 5.5 V and provides a regulated 5-V output. Its output takes less than 10 ns to turn on a flash LED whose current is set by an external resistor.

The LM2753 uses pulse-frequency modulation (PFM) regulation. Typical operating frequency is 650 kHz. Under no-load conditions, the LM2753 operates on only 60  $\mu$ A.

The LM2751 and LM2753 are both housed in an LLP-10 package.

## LM2770: High-Efficiency Switched Capacitor Step-Down Buck Regulator

The LM2770 is a switched capacitor (charge pump) step-down (buck) regulator intended for powering low-voltage digital circuits in portable systems. It can supply load currents of up to 250 mA with conversion efficiencies of up to 85%. Also, it includes a pin-selectable output voltage and a low-power sleep mode to improve standby efficiency in battery-operated devices.

The LM2770 is the ideal solution for systems in which both efficiency and size are important considerations.



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