Tiny DC/DC Buck Controller Provides High Efficiency and Low Ripple

by Theo Phillips

Introduction

To secure a foothold in today's congested circuit boards, a power controller must deliver the most functionality in the smallest package. With a blend of popular features squeezed into a SOT-23 or 3mm × 2mm DFN, the LTC3772 makes a power supply designer's job easy. This versatile DC-DC controller supports a wide input voltage range, 2.5V to 9.8V, and maintains high efficiency over a variety of output current levels. Its 550kHz switching frequency trims solution size by permitting the use of small passive components. Its No R_{SENSE}™ constant frequency architecture also eliminates the need for a sense resistor.

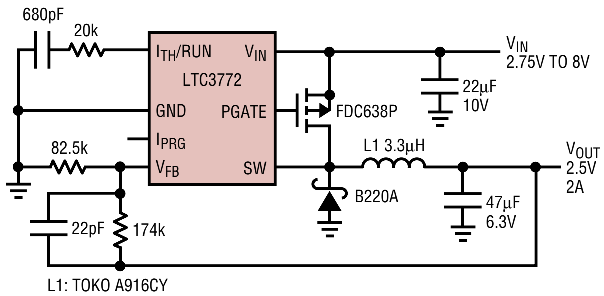

Figure 1. Typical application delivering 2.5V at 2A

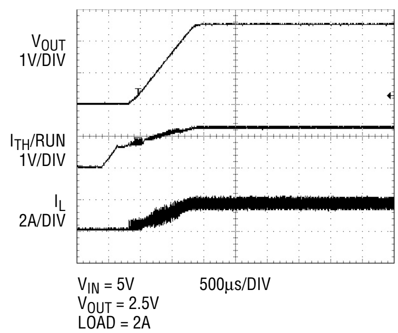

Figure 2. The output voltage rises smoothly without requiring a soft-start capacitor as seen in this startup waveform for the converter in Figure 1.

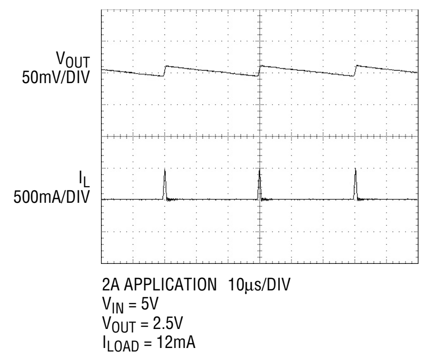

Figure 3. The LTC3772's Burst Mode operation maintains light load efficiency while holding output voltage ripple to just 20mV in this application.

Circuit Description

Figure 1 shows a typical application for the LTC3772. This circuit provides a regulated output of 2.5V from a typical input voltage of 5V, but it can also be powered from any input voltage between 2.75V and 9.8V (depending on the voltage rating of the P-channel power MOSFETs). This wide input range makes the LTC3772 suitable for a variety of input supplies, including 1- and 2-cell Li-Ion and 9V batteries, as well as 3.3V and 5V supply rails. The internal soft-start ramps the output voltage smoothly from 0V to its final value in 1ms (Figure 2).

At low load currents (≤10% of I_{MAX}), the LTC3772 enters Burst Mode operation. Compared with other power saving schemes, this variant of Burst Mode operation surrenders a modicum of efficiency to obtain very low output voltage ripple. Typically producing just 30mV for a typical application using ceramic output capacitors, the LTC3772 is ideal for noise-sensitive portable applications. Figure 3 illustrates inductor current and output voltage waveforms for Burst Mode operation.

The LTC3772 uses the drain to source voltage (V_{DS}) of the power P-Channel MOSFET to sense the inductor current. The maximum load current that the converter can provide is determined by the $R_{DS(ON)}$ of the MOSFET, which is a function of the input supply voltage (which supplies the gate drive). The maximum load current can also be changed using the current limit programming pin I_{PRG}, which sets the peak current sense voltage across the MOSFET to one of three states; each voltage is associated with its own inductor current limit. With I_{PRG} floating, the circuit of Figure 1 can reliably provide 2.5V at 2A from a 3.3V input supply. Efficiency for this circuit exceeds 93%, as shown in Figure 4. In drop out, the LTC3772 can operate at 100% duty

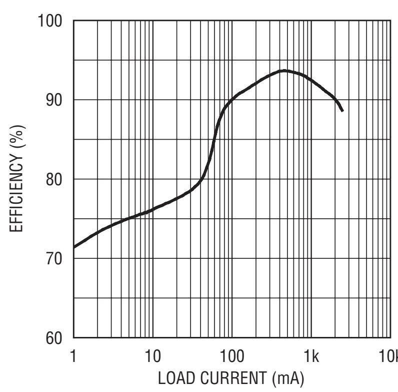

Figure 4. Efficiency vs load current for the converter in Figure 1, with input of 3.3V

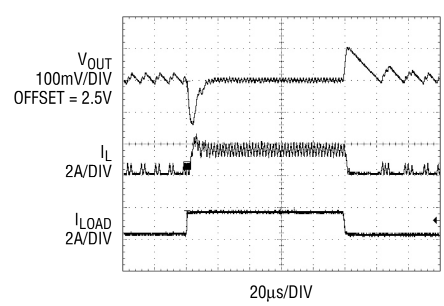

Figure 5. Transient performance of the converter in Figure 1, with input of 5V

cycle, providing maximum operating life in battery-powered systems.

OPTI-LOOP Compensation

To meet stringent transient response requirements, some switching regulators use many large and expensive output capacitors to reduce the output voltage droop during a load step. The LTC3772, with OPTI-LOOP compensation, is stable for a wide variety of output capacitors, including tantalum, aluminum electrolytic, and ceramic capacitors. The ITH pin of the LTC3772 allows users to choose the proper component values to compensate the loop so that the transient response can be optimized with the minimum number of output capacitors. Figure 4 shows a transient response for the circuit in Figure 1, using just one 47µF output capacitor. The response is quite fast, even though it involves a transition from Burst Mode operation to continuous conduction mode.

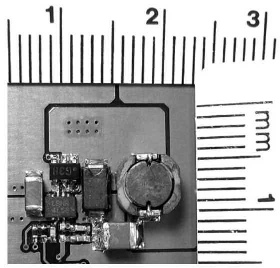

Figure 6. A typical LTC3772 application occupies just 1.5 square centimeters.

Conclusion

For single-output designs with load currents as high as 5A from input voltages up to 9.8V, the LTC3772 delivers the most popular features of PFET controllers in a very small package. With small ancillary components and no sense resistor, the overall solution is unmatched where board space is at a premium.

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which can be made in various shapes including very thin cells, ideal for cell phones and other small handheld devices. Although the discharge characteristics and performance of the different types of Li-Ion cells vary, the charging characteristics are essentially the same.

Rechargeable lithium battery technology is relatively new, and because of that, many improvements in future battery performance are almost guaranteed. Different materials, chemicals and construction will undoubtedly produce a battery that is ever closer to that perfect battery.

The recommended charge voltage is a compromise between cell capacity, cell life and cell safety. Higher charge voltages increase the mAhr cell capacity, but shorten the cell lifetime. There are also upper limits that must be adhered to for safety reasons. The most common charge voltage is 4.2V±1% although future battery designs may have a slightly higher voltage. In applications that favor cycle life over cell capacity, a lower charge voltage greatly increases cycle life. Shallow rather than deep discharge cycles increase cycle life as well. The end of life for a Li-Ion battery is typically when its capacity drops to 80% of its rating.

One lesser known fact about Li-Ion batteries is their aging characteristics. Li-Ion batteries have a limited lifetime whether they are stored or in daily use. The permanent capacity loss, especially for lithium manganese chemistries, increases with charge level and temperature. For example, storing a battery at a 40% charge level at 25°C for a year could result in a permanent capacity loss of 4%, whereas if stored at a 100% charge level, the permanent capacity loss would be close to 20%. Stored at 100% charge level at 40°C could produce a permanent capacity loss up to 35% after one year. Of course, further improvements in Li-Ion battery technology will surely minimize aging

Li-Ion batteries cannot absorb overcharge. Charge current must be completely stopped when the battery reaches full charge. Overcharge can cause internal lithium metal plating, which is a safety concern. Also, Li-Ion batteries should not be discharged below 2.5V to 3V ,depending on battery chemistry, as internal copper plating can form causing a short circuit.

Battery Pack Protection: What Is It?

Most manufacturers of Li-Ion batteries will not sell batteries unless they include built in battery pack protection circuitry for safety and to prolong battery life. The circuitry includes a FET switch in series with the battery that turns off in the event of an over voltage, under voltage, over current and over temperature condition when either charging or discharging the battery. A prolonged overvoltage when charging can result in the battery overheating, bursting or even exploding. When discharging, the pack protection disconnects the battery if the battery voltage drops below a predetermined threshold level or if the battery current exceeds a preset limit. Without pack protection, Li-Ion batteries can easily be damaged or worse, can cause damage to other circuitry or bodily injury.

Conclusion

The LTC4063 Li-Ion battery charger provides the user with an excellent combination of packaging (3mm × 3mm DFN), high charge current (1A), tight float voltage (0.35%), low I_{DETECT} current capability (5mA), choice of termination and an integrated 100mA LDO regulator. Two other chargers share similar charging characteristics but differ on features. The LTC4061 has no regulator but includes a NTC temperature qualification input, a USB current select input and an additional status output. The LTC4062 replaces the LDO regulator with a programmable comparator and reference and also includes a USB current select input.