Inductorless, Efficient Step-Down DC/DC Converter Provides Dual Low Noise Outputs in Space-Constrained Designs

by Bill Walter

Introduction

Linear Technology's new LTC3252 switched capacitor step-down DC/DC converter squeezes dual adjustable outputs into a space saving 3mm by 4mm DFN package. Each output is programmable within a range of 0.9V to 1.6V, is capable of 250mA of current, and operates from a single 2.7V to 5.5V supply. To keep the converter footprint small, the LTC3252 operates at high frequency, allowing the use of tiny low cost ceramic capacitors—no inductors are required.

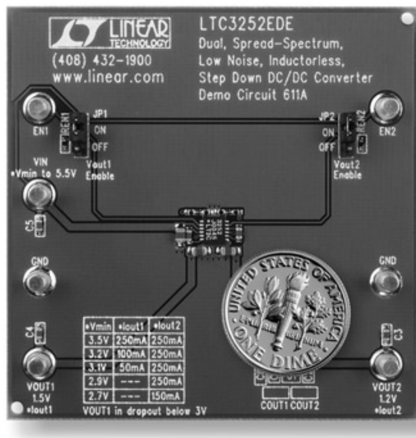

Figure 1. A complete dual output Li-Ion converter

Improve Efficiency and Save Space

The 2-to-1 switched capacitor fractional conversion architecture of the LTC3252 is twice as efficient as a linear regulator, which translates to battery run times that are double that of an LDO. Five tiny ceramic capacitors and four surface mount resistors are all that are required for operation.

Reduce Noise

The LTC3252 employs a unique spread spectrum architecture that continually switches, which not only provides a low input and output noise, but also significantly reduces EMI (Electro-Magnetic Interference). Regulation is achieved by sensing the output voltage and regulating the amount of charge transferred per cycle. This method of regulation provides much lower input and output ripple than that of conventional switched capacitor charge pumps. The spread spectrum feature of the LTC3252 randomly modulates the charge transfer rate between 1.0 MHz and 1.6MHz on a cycle-by-cycle basis. Modulating the frequency in this manner virtually eliminates high frequency harmonic EMI that can be conducted into other circuits.

Increase Battery Run Time

The LTC3252 also features Burst Mode® operation, which allows the LTC3252 to achieve high efficiency even with lightly loaded outputs. While in Burst Mode operation the LTC3252 delivers a minimum amount of charge for a few cycles then goes into a low current state until the output drops enough to require another burst of charge. A current sense circuit is used to detect when the required output current of both outputs drops below about 30mA. When this occurs, the oscillator shuts down and the part goes into a low current operating state. The LTC3252 remains in the low current operating state until either output has dropped enough to require another burst of current. The current transferred to the output is limited by internal circuitry, thus providing a nearly fixed output ripple of about $12mV_{P-P}$. The unloaded operating current of the part is just 35µA with one output enabled and 60µA with both outputs enabled.

Circuit Protection Features

The LTC3252 has built-in short-circuit current limiting as well as over temperature protection. During a short-circuit condition the part automatically limits the output current to approximately 500mA. The LTC3252 shuts down and stops all charge transfer when the IC temperature exceeds approximately 160°C. Under normal operating conditions, the part should not go into thermal shutdown but the function is included to protect the IC from excessively high ambient temperatures, or from excessive power dissipation inside the IC (i.e., over-current or short circuit). The

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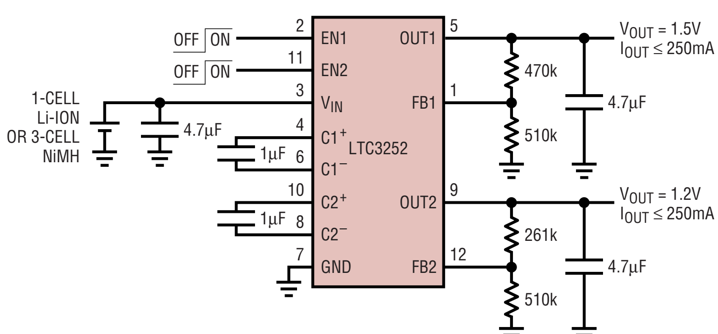

Figure 2. Space saving, low noise, inductorless dual output DC-DC converter: Li-Ion to 1.5V/250mA and 1.2V/250mA

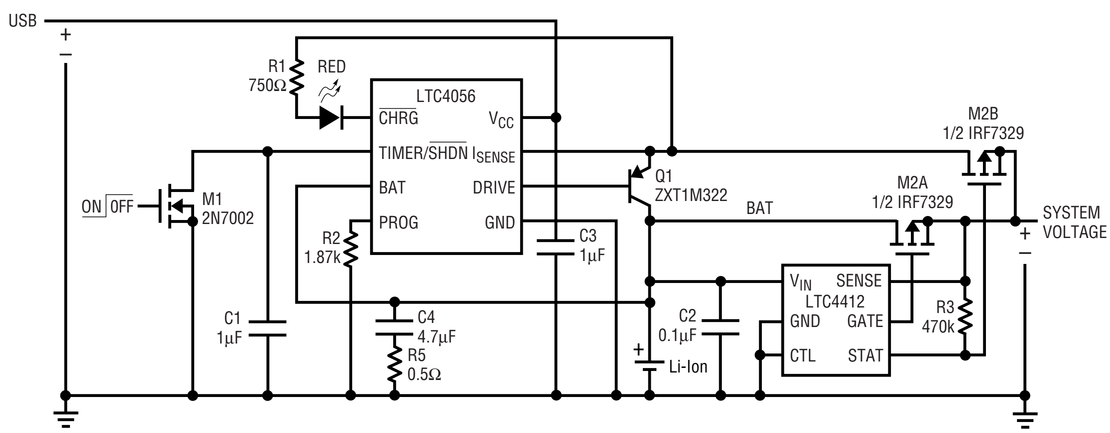

Figure 2. Complete USB PowerPath control and battery charger solution

supply just under 500mA (in Figure 2 the charger is programmed for 490mA). The total impedance between the V_{CC} pin and I_{SENSE} pin is typically 0.2Ω, so the maximum drop is just 100mV (at 500mA) allowing the peripheral device to operate at a voltage significantly higher than a single Li-Ion battery when the USB supply is present.

It is important to keep in mind that the LTC4056 can only control charge current. If the system load is less than 500mA, then the LTC4056 simply reduces the charge current by an amount equal to the system load current. For instance, if the system load is 110mA, then the charge current is reduced from 490mA to 380mA to keep the total USB input current at 490mA, thereby meeting the specification. The 110mA system load, however, is now being provided at approximately 5V rather than the battery voltage. Assuming a nominal battery voltage of 3.85V, the circuit in Figure 2 can provide approximately 23% more power to the system than the circuit in Figure 1 for a given battery charge current.

Of course, if the system load is increased beyond 500mA the LTC4056 will reduce the charge current to zero, and all of the system load will be provided by the USB input. This scenario violates the USB power specification. In order to avoid this situation, it is important to ensure that the system load never exceeds 500mA.

Note that even the $\overline{\text{CHRG}}$ LED is connected to I_{SENSE}. This is a good example of a peripheral load current. When the LTC4056 is charging a battery, the $\overline{\text{CHRG}}$ pin is pulled low drawing 4mA to 5mA through R1. This load current reduces the amount of current delivered to the battery by an equal amount.

To ensure that the system voltage is always present (even when USB power is not), the LTC4412 provides automatic switchover of the system load between a battery and the USB input supply. This feature reduces the current drain on the battery to just a few microamps when a USB input is present. Figure 2 shows a dual FET solution to minimize voltage drop between the USB input voltage and the system voltage (a Schottky diode can also be used in place of M2B). The combination of the LTC4412 and M2A forms an ideal diode from BAT to SYSTEMVOLTAGE. M2B serves as a switch that is ON when the ideal diode is not conducting and OFF otherwise. Therefore, as long as the USB input is present and the voltage on the I_{SENSE} pin is higher than BAT, M2B is ON and M2A is OFF. As soon as the USB input supply drops below the battery voltage, M2A turns on and acts as an ideal diode.

Conclusion

The USB specification allows for up to 500mA of current to be delivered from the USB port. Portable devices are increasingly using the USB power provided by a host computer to power the device system bus and to charge batteries. When used in a PowerPath control configuration, the LTC4056 makes the most of this 500mA to efficiently charge the battery, even while the system draws power from the USB.

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charge transfer reactivates once the junction temperature drops back to approximately 150°C. The LTC3252 can cycle in and out of thermal shutdown, without latch-up or damage, until the fault condition is removed.

The EN1 and EN2 pins are used to individually enable OUT1 and OUT2 respectively. When both EN pins are low the outputs become high impedance and all control circuitry is disabled leaving only a few nanoamps of supply current. The LTC3252 includes a soft-start feature that limits the inrush currents required to charge the output capacitor when an output is enabled, thereby minimizing input supply transients caused by the power on phase of the IC. The soft-start is implemented whenever an output is brought out of shutdown.

Conclusion

The LTC3252 is well suited for medium to low power step-down applications requiring multiple low noise outputs in a small footprint. It is an especially good match for single cell Li-Ion and multi-cell NiMH/NiCd battery powered applications and where EMI is a concern.