LM2788

Powering Portable Devices: Alternatives To Linear Regulators In Step-Down Conversion

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Powering Portable Devices: Alternatives To Linear Regulators In Step-Down Conversion

Application Brief 123

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Highlights

- **High-efficiency Baseband Power at 2.0V, 1.8V, and 1.5V Output**
- **120 mA Output Current Capable**
- **35 µA Typical Supply Current**
- **No Inductors Required**

In portable products such as PDAs and laptop computers—powering the microprocessor from a Li-Ion battery generally means choosing a small and power-efficient step-down DC-DC converter. In terms of efficiency, a switching regulator is the best choice. However, when component height limitations rule out the use of inductors (as sometimes happens in small devices like cell phones), a converter might take the form of a low dropout (LDO) linear regulator. The small and inexpensive LDO works most efficiently when the microprocessor voltage is close to the battery voltage—but the LDOs efficiency can be poor when the voltages are far apart.

Consider the example of a Li-Ion battery charged to 3.6V that powers a microprocessor requiring only 1.8V. Connecting the battery voltage to a 1.8V LDO creates a quiet, stable supply for the microprocessor, but the power loss is significant. The LDO will dissipate power (PD) equal to the load current (I_{LOAD}) times the input to output voltage drop (PD = I_{LOAD}* (3.6V-1.8V) = I_{LOAD}*1.8V). In other words, the LDO as a step-down converter is only 50% efficient in this example. As supply voltages for microprocessors and other logic devices drop, the LDO solution becomes less efficient.

One recent alternative to linear regulators in step-down conversion is the switched capacitor DC-DC converter, also known as a charge pump. The switched capacitor is more efficient than linear regulators due to voltage gain, which is simply the input to output voltage ratio achieved by stacking or paralleling capacitors in two phases (the charging phase and the delivery phase). The gain configuration behaves much like a step-down transformer, delivering power at V_{OUT} equal to the power supplied at V_{IN}.

For example, a switched capacitor converter in a gain configuration of 1/2 will transform an input voltage of 3.6V to an output voltage of 1.8V with very little power loss. For a 10 mA load on V_{OUT}, 5 mA is drawn from V_{IN}. This high-efficiency, though, holds true only when the target output voltage is close to V_{IN} multiplied by the gain. Using the previous example, consider the efficiency of the converter in a gain of 1/2, but V_{IN} is 4.2V. The V_{OUT} generated by the converter is 2.1V, 300 mV above the desired 1.8V.

The extra 300 mV times the load current is lost power. As V_{IN} continues to increase, the V_{OUT} generated by the converter increases, causing more power "leakage" and a decrease in efficiency. Also, note that if the V_{IN} is less than 3.6V, the converter output is lower than 1.8V. To operate below V_{IN}=3.6V, a gain greater than 1/2 is needed.

The LM2788 is a buck mode switched capacitor converter that applies three fractional voltage gains to yield an average power conversion efficiency over 84%. An LDO in the same application shows only 45% efficiency. The secret of the new converter's performance lies in the intelligent selection of the gains equal to 1/2, 2/3 and 1. The proper gain is chosen by dynamically sensing battery voltage and output loading.

Figure 1 charts power efficiency versus the V_{IN} from the battery. Efficiency is equal to V_{OUT}/gain∗V_{IN}. The efficiency for the gain = 1/2 example is plotted for V_{IN} > 3.6V and as shown, decreases with V_{IN}.

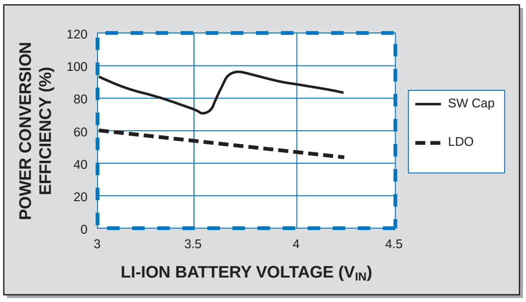

Figure 1: Power Efficiency vs. Battery Voltage

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To produce a regulated output voltage, pulse frequency modulation is often used. The output impedance of any switched capacitor converter is proportional to the switching frequency. By modulating the impedance, more or less voltage is dropped across the converter for a given load. Feedback adjusts the frequency to regulate the output voltage. To ensure stability, the output capacitor should be roughly a minimum of 10 times the value of the flying capacitor. The switching frequency and the size of the output capacitor determines the amplitude of the output voltage ripple. If the ripple is too large for a given application, a larger output capacitor can be used. Another option is to add an LDO to the output of the converter. In this case, the converter output voltage is set to the LDO output voltage plus the LDO dropout voltage. This solution provides low noise with the added benefit of higher efficiency.

The LM2788 can be used to drive a microcontroller or other digital device as shown in *Figure 2*. In this case, the power source is a Li-Ion battery. The output voltage is 1.8V and the current required by the micro is 100 mA. With a 10 µF output capacitor, the ripple is typically about 25 mV. The total solution size is about 0.28 in^2. The average power efficiency over the Li-Ion discharge is about 75% or 45% better than an LDO. This solution only requires one LM2788, two 1.0 µF flying capacitors, two 10 µF hold capacitors, and no inductors.

0.18µ and smaller geometries have allowed the current requirements for various digital processors to drop to 100 mA and below. At these current levels, switched capacitor DC-DC converters become a viable and efficient alternative to inductive based switchers.

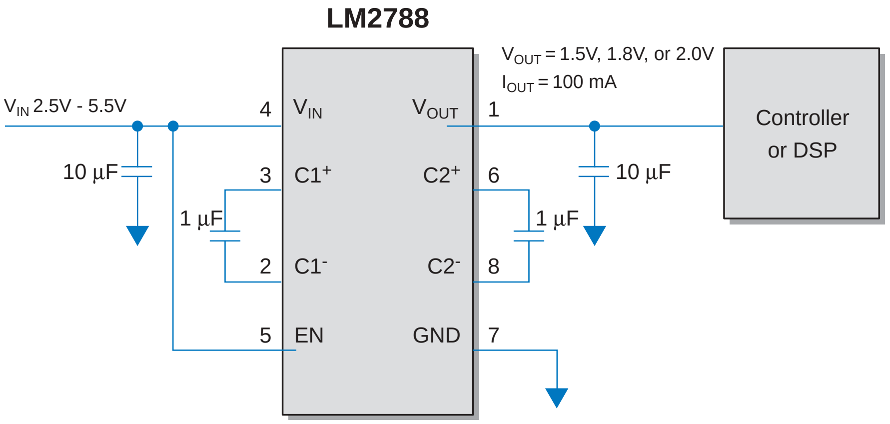

Figure 2: LM2788 Block Diagram

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