DESIGN NOTES

Micropower Buck/Boost Circuits, Part 1: Converting Three Cells to 3.3V* – Design Note 109

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Two combinations of cell count and output voltage are to be strictly avoided: three cells converted to 3.3V and four cells converted to 5V. These combinations are troublesome because no ordinary regulator (boost, buck or linear) can accommodate a situation where the input voltage range overlaps the desired output voltage.

This design note presents four circuits capable of solving the 3-cell dilemma. Design Note 110 will discuss 4-cell, 5V circuits. The LT®1303 and LT1372 high efficiency DC/DC converters are used throughout, giving a fair comparison of each topology's efficiency. The LT1303 is optimized for battery operation and includes a low-battery detector which is required to implement one of the topologies. The LT1372 500kHz converter is used for compact layouts at higher current levels.

You can expect 200mA output from LT1303 based circuits and 300mA from the LT1372 circuit without modification. All of the circuits feature output disconnect; in shutdown the outputs fall to 0V. The input range of LT1303 based converters extends well beyond the 3-cell source shown. These function at 1.8V, and although not fully characterized for efficiency, can accept inputs of up to 10V. The LT1372 converter operates from 2.7V to 10V.

 *For 4-cell to 5V buck/boost circuits, see Design Note 110.

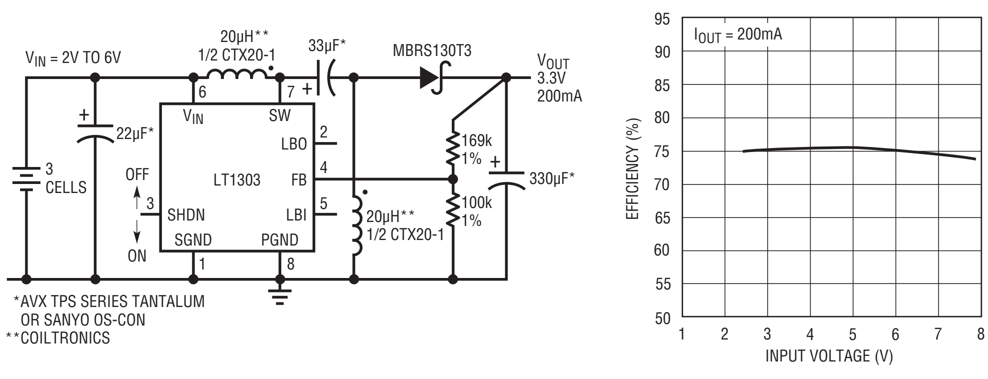

Figure 1. 3-Cell to 3.3V SEPIC

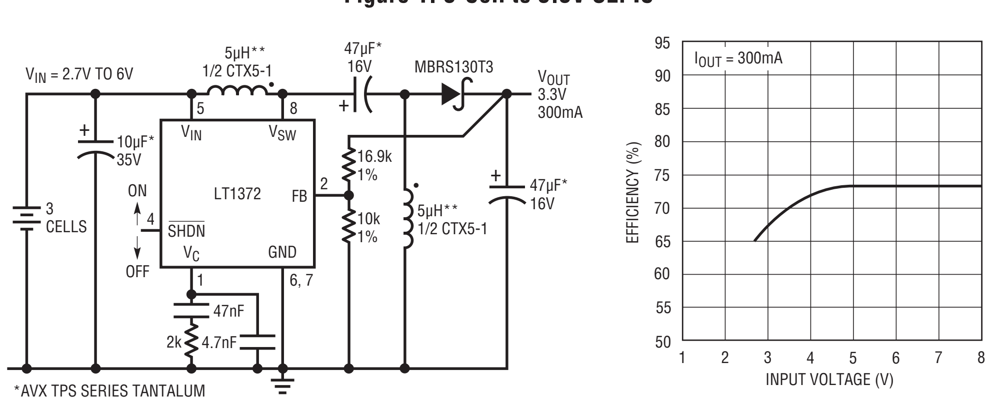

Figure 2

The circuits in Figures 1 and 2 are based on the SEPIC (Single-Ended Primary Inductance Converter) topology. Although not stellar, the efficiency is quite consistent over a wide input voltage range. Peculiar to the SEPIC topology is its use of two inductors. These, however, are wound together on a single core and consume no more space than a simple 2-terminal inductor of similar rating. A wide selection of stock 2-winding, 4-terminal inductors are available from Coiltronics and other magnetics vendors.

Peak efficiency improves in Figure 3 using a bipolar buck/boost topology. This circuit is essentially a boost converter with a linear post regulator. For $V_{IN} < V_{OUT}$, the LT1303 boosts the input driving the bipolar emitter just high enough to maintain the desired output voltage—the transistor is saturated. For $V_{IN} > V_{OUT}$, the LT1303 drives the emitter to a value just higher than the *input voltage* sufficient to develop the base current necessary to support any load current. In this condition the transistor serves as a linear post regulator, cascoding the output of the boost converter and dissipating power as would any linear regulator.

Highest peak efficiency is obtained with the circuit in Figure 4 using a MOSFET buck/boost converter. For $V_{IN} < V_{OUT}$, the circuit operates as a boost converter and the MOSFET, driven by the LT1303's low-battery detector/amplifier, is held 100% ON. The output voltage is developed and controlled by the boost converter.

For $V_{IN} > V_{OUT}$, the boost function can no longer control the output voltage and it begins to rise. Staggered feedback (R3, R4, R5) allows the low-battery detector/amplifier to take control using the MOSFET as a linear pass element. Because the MOSFET requires no base drive, and because it has such a low ON resistance, the efficiency peaks at well over 90%. Furthermore, the efficiency peak occurs in the vicinity of a NiCd's nominal terminal voltage of $3 \times 1.25 = 3.75V$, right where the efficiency is needed most.

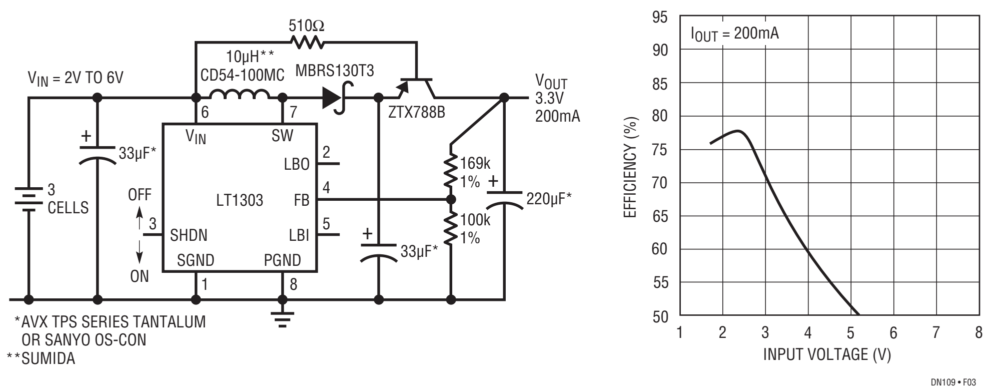

Figure 3. 3-Cell to 3.3V Bipolar Buck/Boost

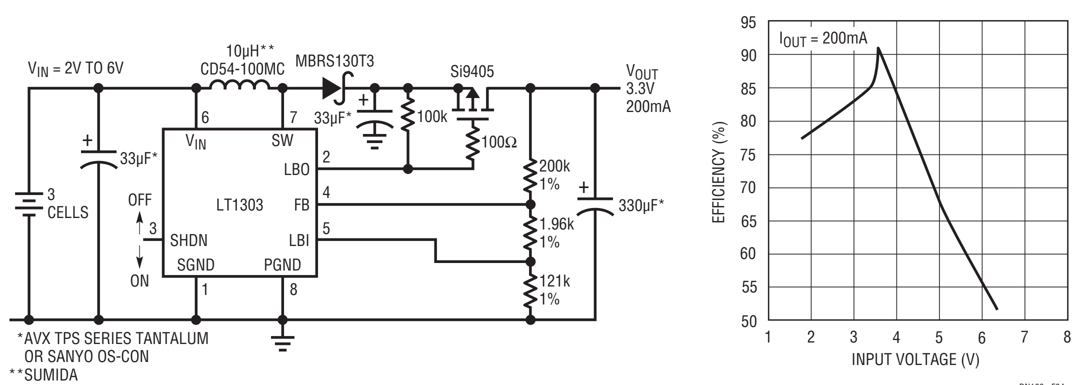

Figure 4. 3-Cell to 3.3V MOSFET Buck/Boost

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