Fixed Frequency, 500kHz, 4.5A Step-Down Converter in an SO-8 Operates from a 5V Input

by Karl Edwards

Introduction

The LT1506 is a 500kHz monolithic buck mode switching regulator, functionally identical to the LT1374 but optimized for lower input voltage applications. Its high 4.5A switch rating makes this device suitable for use as the primary regulator in small to medium power systems. The small SO-8 footprint and input operating range of 4V to 15V is ideal for local onboard regulators operating from 5V or 12V system supplies. The 4.5A switch is included on the die, along with the necessary oscillator, control and logic circuitry to simplify design. The part's high switching frequency allows a considerable reduction in the size of external components, providing a compact overall solution.

The LT1506 is available in standard 7-pin DD and fused-lead SO-8 packages. It maintains high efficiency over a wide output current range by keeping quiescent supply current to 4mA and by using a supply-boost capacitor to saturate the power switch. The topology is current mode for fast transient response and good loop stability. Full cycle-by-cycle short-circuit protection and thermal shutdown are provided. Both fixed 3.3V and adjustable output voltage parts are available.

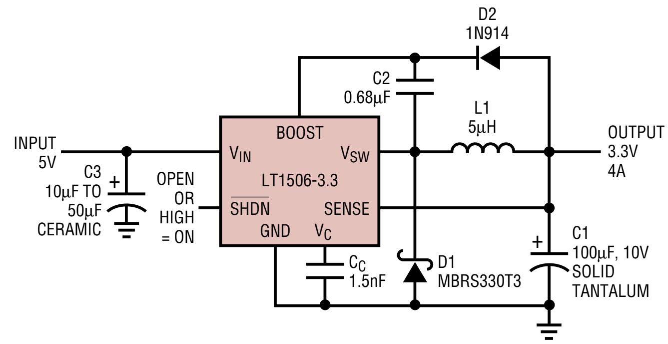

Figure 1. 5V to 3.3V step-down converter

5V to 3.3V Buck Converter

The circuit in Figure 1 is a step-down converter suitable for use as a local regulator to supply 3.3V logic from a 5V power bus. The high efficiency, shown in Figure 2, removes the need for bulky heat sinks or separate power devices, allowing the circuit to be placed in confined locations. Since the boost circuit only needs 3V to operate, the boost diode can still be connected to the output, improving efficiency. Figure 1's circuit shows the shutdown pin option. If this pin is pulled to a logic low, the output is disabled and the part goes into shutdown mode, reducing supply current to 20µA. An internal pull-up ensures correct operation when the pin is left open. The SYNC pin, an option for the DD package, can be used to synchronize the internal oscillator to a system clock. A logic-level clock signal applied to the SYNC pin can synchronize the switching frequency in the range of 580kHz to 1MHz.

Current Sharing Multiphase Supply

The circuit in Figure 3 uses multiple LT1506s to produce a 5V, 12A power supply. There are several advantages to using a multiple switcher approach compared to a single larger switcher. The inductor size is considerably reduced. Inductor size is proportional to the energy that needs to be stored in the core. Three 4A inductors store less energy ($1/2Li^2$) than a single 12A coil, so they are much smaller. In addition, synchronizing three converters 120° out of phase with each other reduces input and output ripple currents. This reduces the ripple rating, size and cost of the filter capacitors.

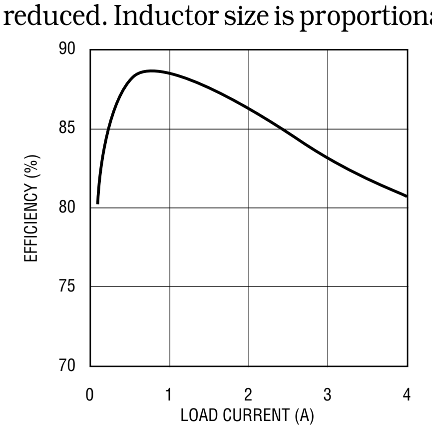

Figure 2. Efficiency vs load current for Figure 1's circuit

Current Sharing/ Split Input Supplies

Current sharing is accomplished by connecting the V_C pins to a common compensation capacitor. The output of the error amplifier is a g_m stage, so any number of devices can be connected together. The effective g_m of the composite error amplifier is the product of the individual devices. In Figure 3, the compensation capacitor, C4, has been increased by 3×. Tolerances in the reference voltages cause small offset currents to flow between the V_C pins. The overall effect is that the loop regulates the output at a voltage somewhere between the minimum and maximum references of the devices used. Switch-current matching between devices will be typically better than 300mA over the full current range. The negative temperature coefficient of the V_C-to-switch-current transconductance prevents current hogging.

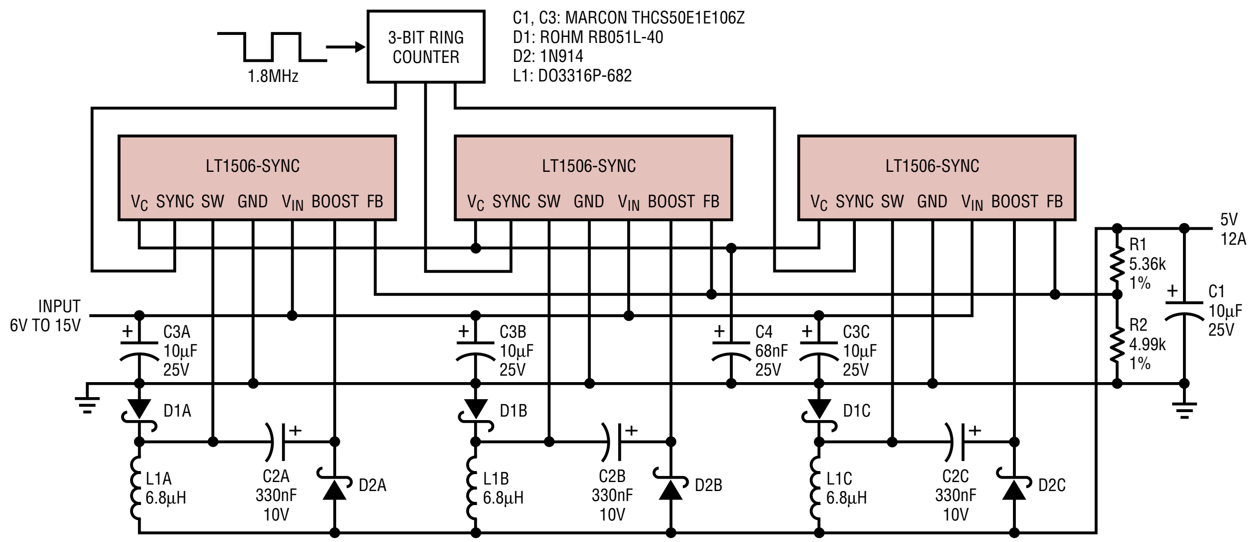

Figure 3. Current-sharing 5V/12A supply

A common V_C voltage forces each LT1506 to operate at the same switch current, not at the same duty cycle. Each device operates at the duty cycle defined by its input voltage. This is a useful feature in a distributed power system. The input voltage to each device could vary due to drops across the backplane, copper losses, connectors and so on. The common V_C signal ensures that loading is still shared between the devices.

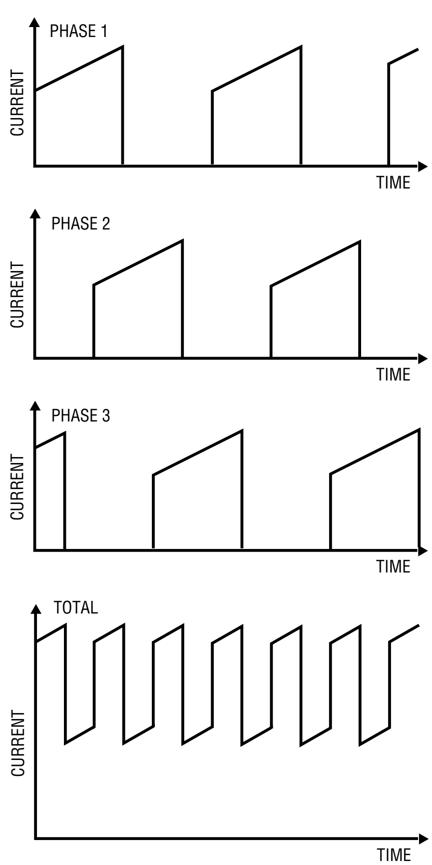

Figure 4. Input current

Synchronized Ripple Currents

A ring counter generates three synchronization signals at 600kHz, 33% duty cycle, phased 120° apart. The sync input will operate over a wide range of duty cycles, so no further pulse conditioning is needed. At full load, each device's input ripple current is a 4A trapezoidal wave at 600kHz, as shown in Figure 4. Summing these waveforms gives the effective input ripple for the complete system. The resultant waveform, shown at the bottom of Figure 4, remains at 4A but its frequency has increased to 1.8MHz. The higher frequency eases the requirements on the value of input filter without the 3× increase in ripple current rating that would normally occur. Although only a single input capacitor is required, practical layout restrictions usually dictate an individual capacitor at each device. Figure 5 shows the output ripple current waveforms. The resultant 1.8MHz triangular waveform has a maximum amplitude of 350mA at an input voltage of 10V. This is significantly lower than would be expected for a 12A output. Interestingly, at inputs of 7.6V and 15V, the theoretical summed output ripple current cancels completely. To reduce board space and ripple voltage, C1 and C3 are ceramic capacitors. Loop compensation capacitor C4 must be adjusted when using ceramic output capacitors, due to the lack of effective series resistance (ESR). The typical

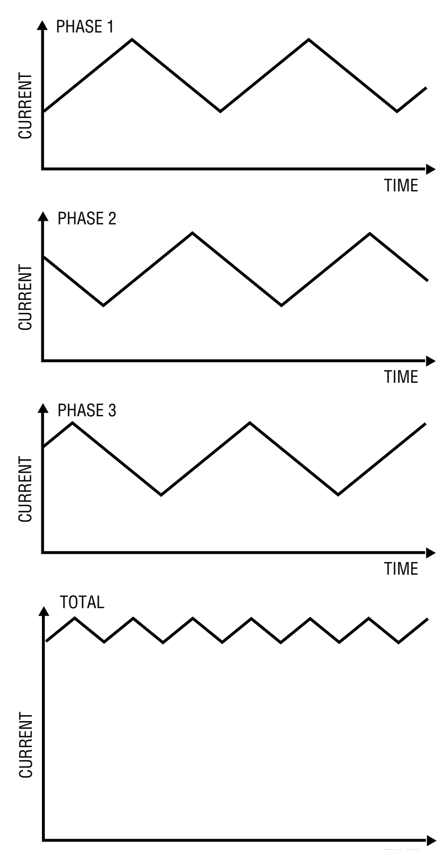

Figure 5. Output current

tantalum compensation value of 1.5nF is increased to 22nF (×3) for the ceramic output capacitor. If synchronization is not used and the internal oscillators free run, the circuit will operate correctly, but ripple cancellation will not occur. Input and output capacitors must be ripple rated for the individual output currents.

Redundant Operation

The circuit shown in Figure 3 is fault tolerant when operating at less than 8A of output current. If one power stage fails open circuit, the output will remain in regulation. The feedback loop will compensate by raising the voltage on the V_C pin, increasing the switch current of the two remaining devices.

5V to 3.3V at 2.5A on 0.25in^2 of board space, 0.125in High

In many space-sensitive applications, the component that dominates both board area and overall height is the inductor. One of the factors affecting inductor value choice is maximum ripple current. Using the high current switch rating of the LT1506, higher ripple current can be tolerated, allowing the use of small, low value, high current inductors. A ceramic output capacitor also reduces board area and improves voltage ripple. Using Figure 1's circuit with the SO-8 LT1506 and the component changes in Table 1, a very small, low profile, step-down converter can be implemented.

Table 1. Component changes for a low profile version of Figure 1's circuit

Part	Value	Vendor/ Part#
C1, C3	22µF, 10V	Tokin 1210ZG226Z
C_C	22nF	
L1	2.2µH	Sumida CD43 2R2

Conclusion

The LT1506 is a compact, easy to use, monolithic switcher. The internal 4.5A switch covers a wide range of medium power applications. Its input operating range of 4V to 15V and availability in SO-8 or DD packages make it ideal for very space-efficient, local onboard DC/DC converters.

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