

Versatile New Switching Regulator Fits in SO-8

by Craig Varga

Introduction

Linear Technology recently introduced the LTC1530 synchronous buck regulator controller. Although packaged in an 8-pin SO, it has proven to be remarkably capable and versatile. The part is loosely based on the popular LTC1430, but with numerous enhancements. Features include current limiting that senses the voltage across the $R_{DS(ON)}$ of the high-side MOSFET (no sense resistor required), built in soft-start, 1% accurate reference, gate drivers capable of handling large MOSFETs, and micropower shutdown. The error amplifier transconductance is higher than that of previous generation parts and is trimmed for accuracy and stabilized over temperature. The I_{MAX} current, which programs current limit, has a positive temperature coefficient to

help cancel the positive temperature coefficient of the MOSFET's $R_{DS(ON)}$. This allows for more consistent current limit over temperature. Although intended primarily for buck regulator designs, the part has been successfully designed into boost, positive-to-negative and negative-to-positive converters.

A Quick Look at the Insides

Figure 1 is the basic block diagram. The LTC1530 is a voltage mode control, synchronous buck regulator controller. An on-chip oscillator generates a 300kHz ramp waveform. The output of the error amplifier is compared to this ramp by the PWM comparator. So far, nothing extraordinary. Current-limit circuitry, however, is a little more unusual.

Instead of the traditional current sense resistor, the LTC1530 relies on the $R_{DS(ON)}$ of the high-side MOSFET as its source of load current information. This saves the space, cost and the power dissipation of an additional resistor in the power path. The programming current (I_{MAX}) has a positive temperature coefficient that approximates the positive TC of a MOSFET's $R_{DS(ON)}$. This tends to flatten the current-limit trip point as a function of temperature. In a slight overload, the LTC1530 provides "square current limiting." In other words, the regulator starts to look like a current source. In the event of a significant overload, should the output fall to less than one-half of the nominal output voltage, the soft-start capacitor will be discharged very quickly. This forces

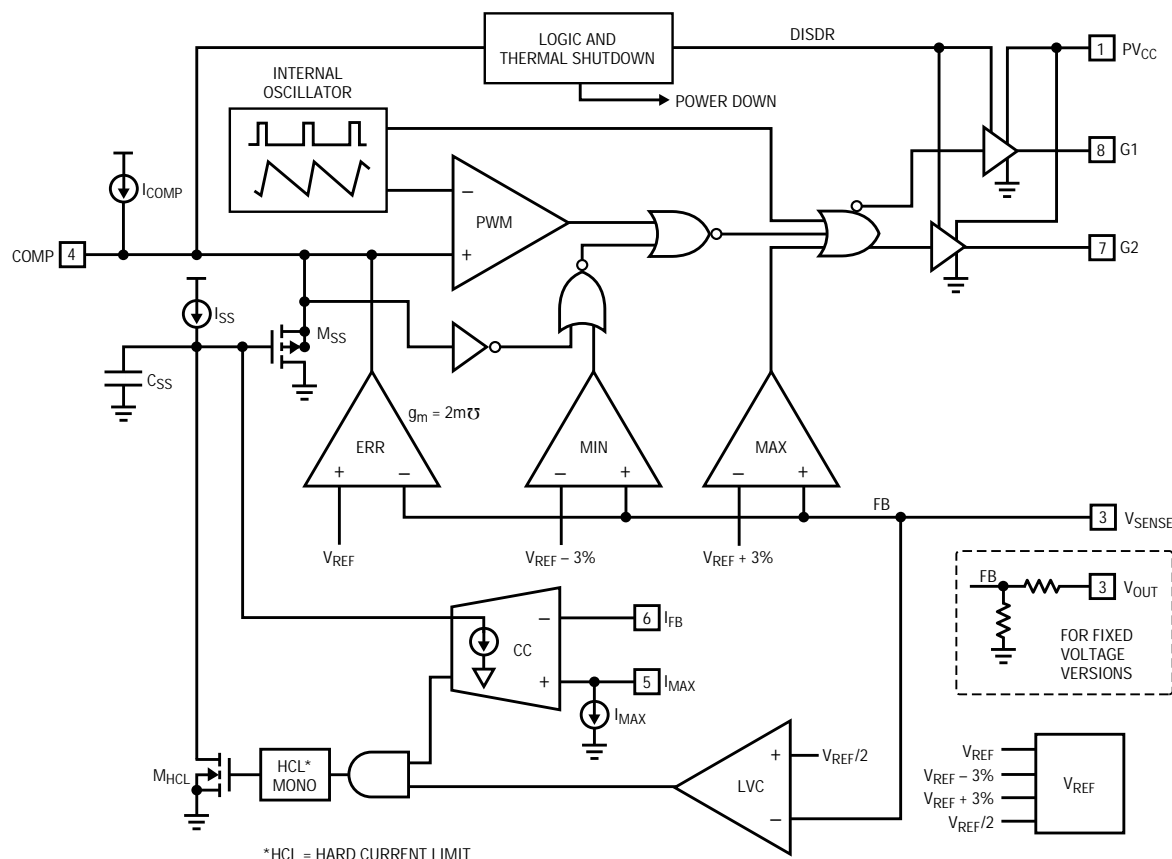


Figure 1. LTC1530 block diagram

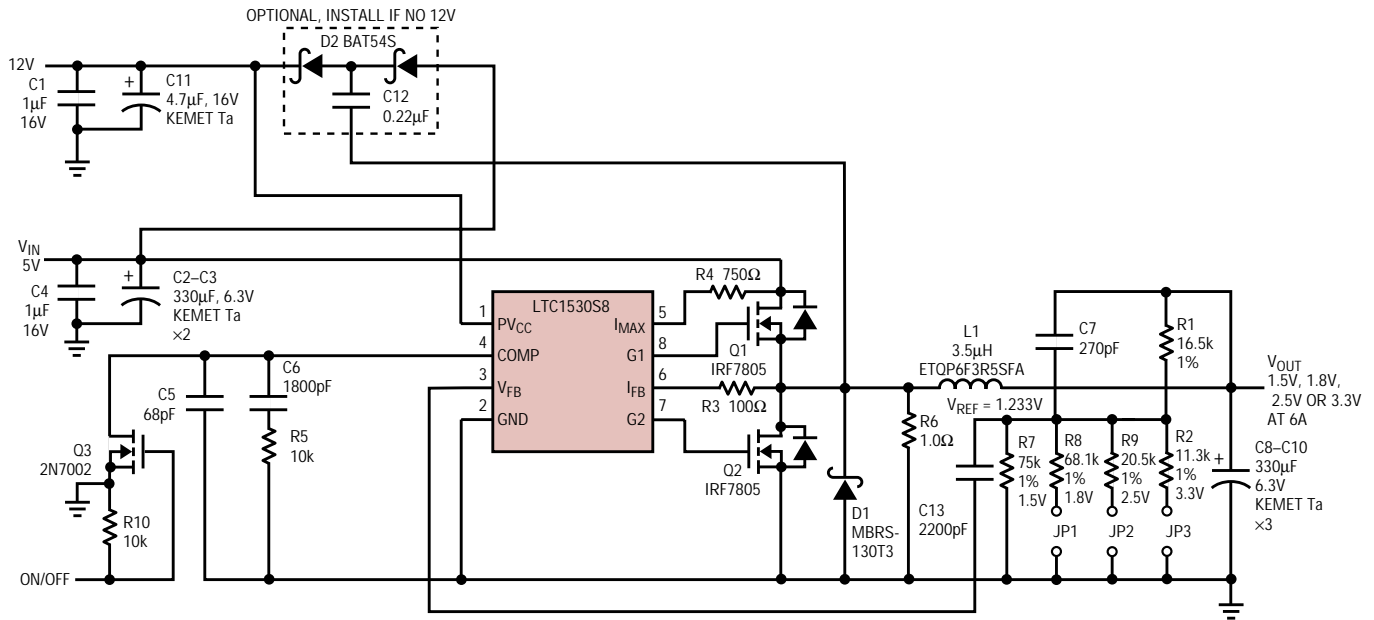


Figure 2. 6A buck regulator; output voltage is jumper selectable for 1.5V, 1.8V, 2.5V or 3.3V.

the regulator into shutdown for a period of time, typically a few milliseconds. After the time delay, the supply attempts to restart. If the overload still exists, the hiccup mode operation will continue. Once the short is removed, the regulator will start normally.

Unlike its predecessor, the LTC1530's soft-start capacitor is internal. The start-up rise time was chosen to satisfy the vast majority of application requirements. Turn on is clean, well controlled and monotonic.

Since dynamic performance is of extreme importance in many of today's systems, the LTC1530 incorporates several features to provide improved response times to load transients. First are the min/max comparators.

These are a pair of comparators that continuously monitor the output voltage. If the output is more than 3% on either side of nominal, the appropriate comparator forces the duty factor to maximum or zero in an attempt to restore the output to the correct level as quickly as possible. Eventually, the error amplifier and main feedback loop will catch up and force the output to settle nicely. The error amplifier is also an improvement over earlier designs. The transconductance and output impedance have both been increased substantially from the LTC1430 values. This has the effect of raising the DC open-loop gain of the amplifier, resulting in better line and load regulation. Transconductance is also trimmed to ensure accuracy. The result is more predictable and repeatable loop response. The amplifier g_m is temperature compensated so loop gain stays nearly constant over temperature extremes.

The LTC1530 also has a low power shutdown mode. If the Comp pin is pulled to ground with an open collector or open drain transistor, the LTC1530's quiescent current will drop to approximately 45µA.

Virtually all integrated circuits have some quirks that will get you in trouble if you don't pay attention. The LTC1530 is no exception. Care must

be taken in choosing the power MOSFETs used in circuits that depend on a charge pump to supply gate-drive power. It is essential to select a FET for the upper device that will be almost fully enhanced before the PV_{CC} supply voltage reaches 8V with whatever main input voltage happens to be available. Failure to heed this requirement can lead to a circuit that may not start up properly at all times. Standard logic-level FETs work fine. Be sure V_{TH} is less than 2V in the worst case.

The cause of this start-up phenomenon is related to the way the current limit circuit behaves. Below a PV_{CC} level of 8V, current limit is disabled. Assume for the sake of this discussion that the main input supply is derived from 5V. At turn on, as the charge pump gradually pushes the PV_{CC} supply upward, the current-limit circuit wakes up at 8V on PV_{CC} . If the 5V supply is exactly 5V, the gate drive available for the FET is only 3V (8V - 5V). If the FET's $R_{DS(ON)}$ is very high relative to its nominal value at this point, the current-limit circuit may activate in a misguided attempt to maintain control of the output current. If, at the same time, the output voltage has come up to less than one-half of its final value, the LTC1530 will respond by discharging the soft-

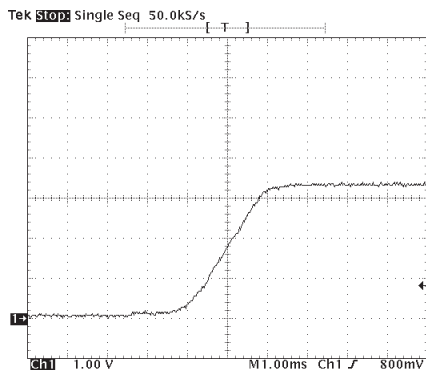


Figure 3. Output voltage at turn-on for Figure 2's circuit

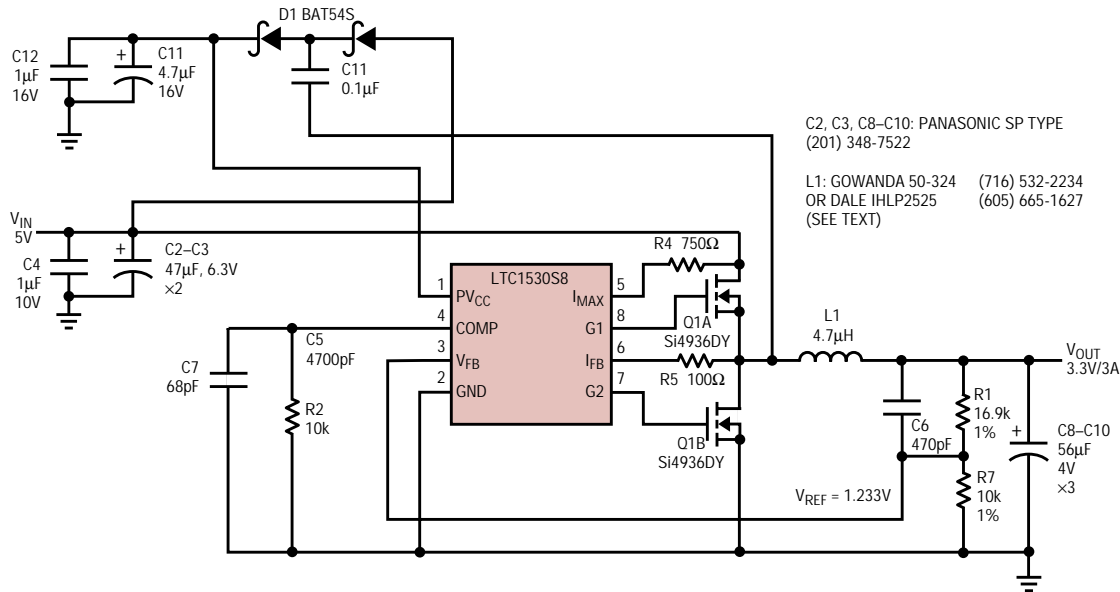


Figure 4. 3.3V/3A regulator

start capacitor and trying to initiate a restart.

As long as the output voltage has reached a level of greater than one-half of its final value before the PV_{CC} voltage reaches 8V, the output will continue to rise in current limit. If the output is below this level, start-up is not ensured. If the PV_{CC} supply is derived from a 12V source instead of charge pumped from the 5V supply, this problem cannot occur.

A Few Circuit Examples

The LTC1530 turns out to be a rather versatile device. Although intended as a buck regulator, the part has been

successfully used in boost and buck-boost designs. Figure 2 is a classic buck topology. The circuit was designed to handle approximately 6A while maintaining a low profile. Input and output capacitors are tantalum devices. The inductor is a very low DC resistance design for high efficiency. The input is 5V, while the output voltage can be jumper selected for 3.3V, 2.5V, 1.8V or 1.5V. The photo in Figure 3 shows the output voltage rise at turn on. A clean, monotonic rise is evident.

Figure 4 is a 3A design that has a total height of less than 2.4mm. The inductor is a Gowanda part #50-324,

which mounts through a hole in the PCB for a total height above the board of approximately 1.5mm. Output ripple voltage is approximately $10mV_{P-P}$ at a 3A load with the specified Panasonic SP series output capacitors. There are several options for the main inductor. The overall smallest size available is an IHLP-2525 by Dale Electronics. It's 3mm tall but only 6.4mm on a side. Output ripple is about 50% higher with this inductor.

Figure 5 is an example of a synchronous boost regulator. The input is 3.3V and the output is 5V. The circuit is rated for a maximum output current of 6A. Since the output cur-

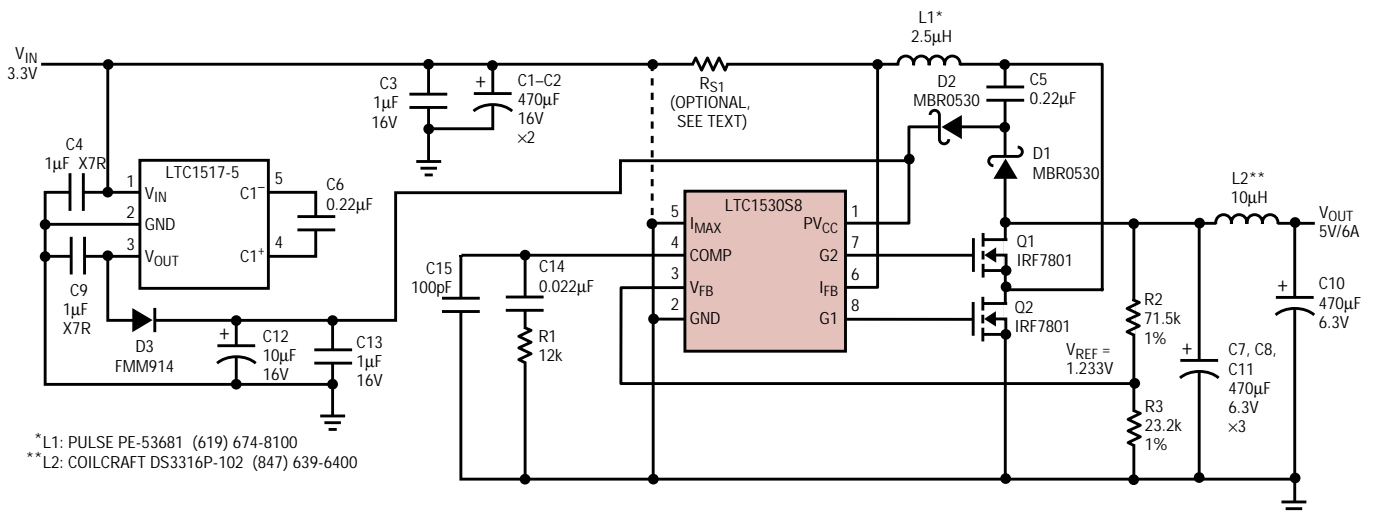


Figure 5. 5V/6A synchronous boost regulator

