

# 36V, 3.5A DC/DC Buck Regulators for Automotive, Industrial and Wall Adapter Applications Offer High Efficiency in a Small Package

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## Introduction

Automotive batteries, industrial power supplies, distributed supplies and wall transformers are all sources of wide-ranging, high voltage inputs. The easiest way to step down the voltage from these sources is with a high voltage monolithic step-down switching regulator that can directly accept a wide input range and produce a well-regulated output. The LT3680 and LT3693 are new step-down switching regulators that accept inputs up to 36V and provide excellent line and load regulations and dynamic response. Both regulators offer high efficiency solutions over wide load range. The LT3680 adds low ripple Burst Mode<sup>®</sup> operation to maximize efficiency at light load currents.

## LT3680 and LT3693 Features

Available in either a 10-pin MSOP or a 3mm x 3mm DFN package, the LT3680 and LT3693 offer an integrated 5A power switch and external compensation for design flexibility. Both regulators employ a constant frequency, current mode architecture. The switching frequency can be set be-

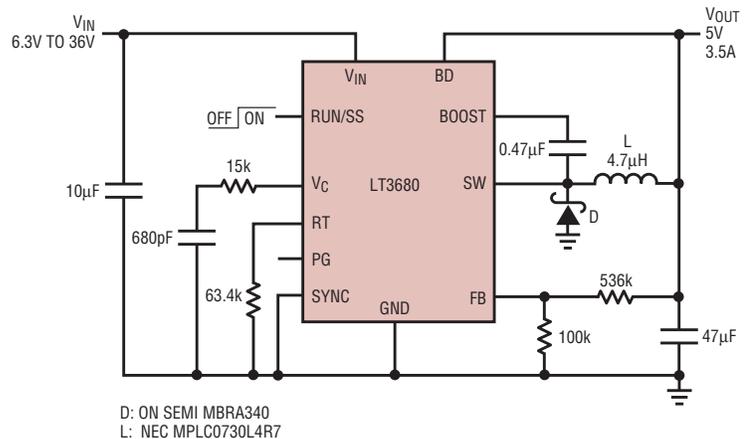


Figure 1. This 600kHz 6.3V–36V input DC/DC converter delivers 3.5A at 5V output.

*The easiest way to step down the voltage from a wide ranging, high voltage source is with a monolithic step-down switching regulator that can directly convert the input to a well-regulated output.*

tween 200kHz and 2.4MHz by using a resistor tied from the RT pin to ground. This allows a trade off between component size and efficiency. The switching frequency can also be synchronized to an external clock for noise sensitive applications. An external resistor divider programs the output voltage to any value above the part's 0.79V reference.

The LT3680 and LT3693 offer soft-start via a resistor and capacitor on the RUN/SS pin, thus reducing maximum inrush currents during start-up. Both regulators can withstand a shorted output. A cycle-by-cycle internal current limit protects the circuit in overload and limits output power; when the output voltage is pulled to ground by a hard short, the LT3680 and LT3693 reduce the operating frequency to limit dissipation and peak switch current. This lower frequency allows the inductor current to safely discharge, thus preventing current runaway. The high side bootstrapping boost diode is integrated into the IC to minimize solution size and cost. When

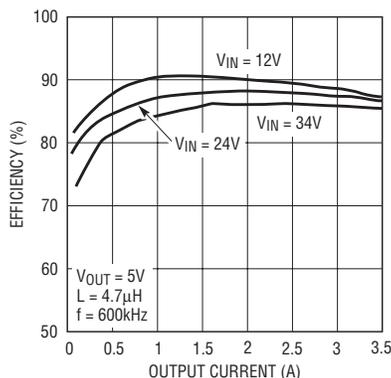


Figure 2. Efficiency vs load current for circuit in Figure 1

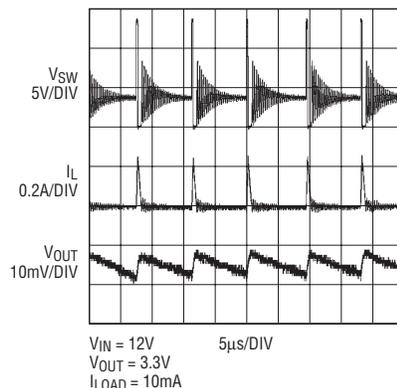
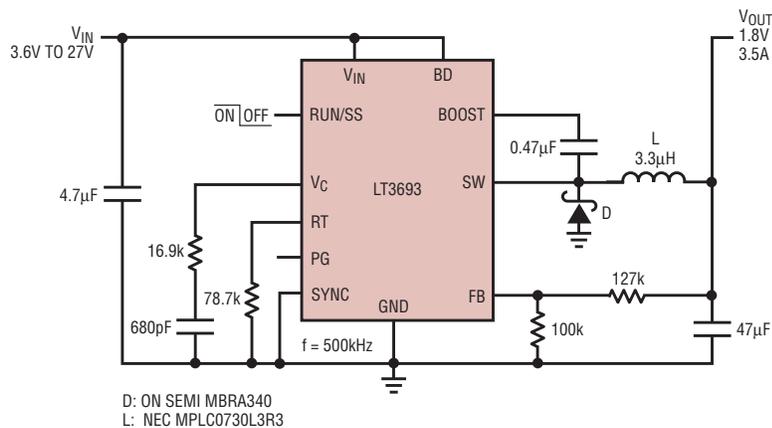


Figure 3. LT3680 Burst Mode operation at 10mA load



**Figure 4.** This 500kHz 3.6V–27V input DC/DC converter delivers 3.5A at 1.8V output.

the output voltage is above 2.5V, the anode of the boost diode can be connected to output. For output voltages lower than 2.5V, the boost diode can be tied to a separate rail or to the input. For systems that rely on a well-regulated power source, the LT3680 and LT3693 provide a power good flag that signals when  $V_{OUT}$  reaches 90% of the programmed output voltage.

### Low Ripple Burst Mode Operation of LT3680

The only difference between LT3680 and LT3693 is that the LT3680 offers low ripple Burst Mode operation, which can be selected by applying a logic low to the SYNC pin. Low ripple Burst Mode operation maintains high efficiency at light load while keeping the output voltage ripple low. During Burst Mode operation, the LT3680 delivers single cycle bursts of current to the output capacitor followed by sleep periods when the output power is delivered to the load only by the output

capacitor. Between bursts, all circuitry associated with controlling the output switch is shut down, reducing the input supply current and BD quiescent current to 30µA and 80µA, respectively. As the load current decreases to a no load condition, the percentage of time that LT3680 operates in sleep mode increases and the average input current is greatly reduced, resulting in high efficiency. Both LT3680 and LT3693 have a very low (less than 1µA) shutdown current which significantly extends battery life in applications that spend long periods of shutdown mode. For applications that require constant frequency operation at no load or light load, the LT3693 can be used.

### 6.3V–36V to 5V, 3.5A DC/DC Converter with All Ceramic Capacitors

Figure 1 shows the LT3680 producing 5V at 3.5A from an input of 6.3V to 38V with 65V transient. The circuit is programmed for a 600kHz switching

frequency and requires 100mm<sup>2</sup> of PCB. Figure 2 shows the circuit efficiency at 12V and 24V inputs. At 12V input, the efficiency peaks above 90% and remains high across the entire load range.

The SYNC pin is tied to the ground to enable Burst Mode operation and achieve high efficiency at light load. Figure 3 shows the inductor current and output voltage ripple under single pulse Burst Mode operation at 10mA load. The output voltage ripple  $V_{P-P}$  is less than 20mV as a result of low ripple Burst Mode operation.

An external signal can drive the RUN/SS pin through a resistor and capacitor to program the LT3680's soft-start, reducing maximum inrush current during start-up.

### 3.5V–27V $V_{IN}$ to 1.8V $V_{OUT}$ , 3.5A DC/DC Converter with All Ceramic Capacitors

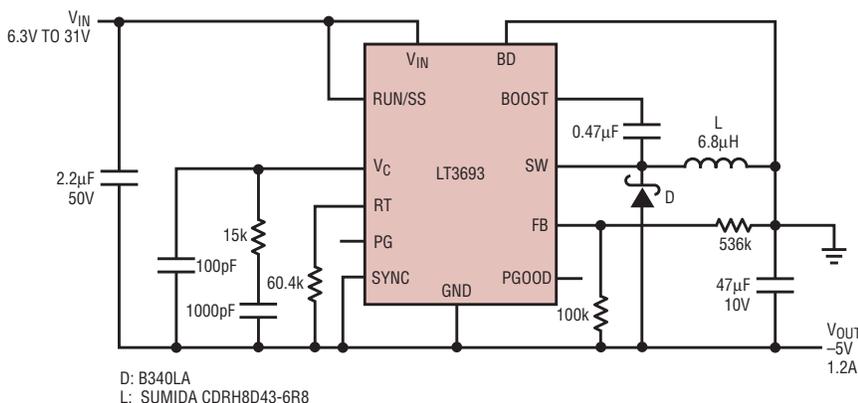
For output voltages lower than 2.5V, the integrated boost diode can be tied to the input or a separate rail greater than 2.8V. Figure 4 shows a 1.8V output converter using the LT3680 with the integrated boost diode tie to input. In this application, the maximum input voltage is 27V so that the maximum voltage rating of Boost pin and BD pin are not exceeded.

### Negative Output from Buck Regulators

Negative output supplies are required for many applications. The circuit in Figure 5 can generate a negative voltage of –5V from buck regulators such as LT3680 or LT3693. The circuit sets the input ground reference and the LT3680 ground reference to –5V to generate negative 5V supply.

### Conclusion

The wide input range, small size and robustness of the LT3680 and LT3693 make them easy fit in automotive, industrial and distributed power applications. They are highly efficient over the entire load range. The unique low ripple Burst Mode operation of LT3680 helps to save battery power life while maintaining low output ripple. **LT**



**Figure 5.** This negative output DC/DC converter delivers 1.2A at –5V output.