Intermediate Bus Buck Regulator Maintains 5V Gate Drive During Automobile Cold Crank Conditions

Theo Phillips and Tick Houk

DC/DC converters in today's automobiles often take their inputs from a loosely regulated 5V intermediate bus, instead of directly from the battery voltage (which can vary from 4V during cold crank to above 24V from double-battery jump-starts and other transients). Incorporating an intermediate voltage bus has a number of advantages, one of which is the expanded range of DC/DC converter options available to power downstream electronics. Power supply designers can choose from a wide variety of low dropout (LDO) and switching post-regulators that have 6V absolute maximum input voltage ratings. Because typical post-regulator outputs are substantially lower than 5V—from 3.3V down to 1V—they can continue to operate even as their inputs drop below the nominal 5V. With this in mind, the ideal intermediate step-down regulator would continue to provide power even under cold crank conditions, where the battery voltage can drop below 5V.

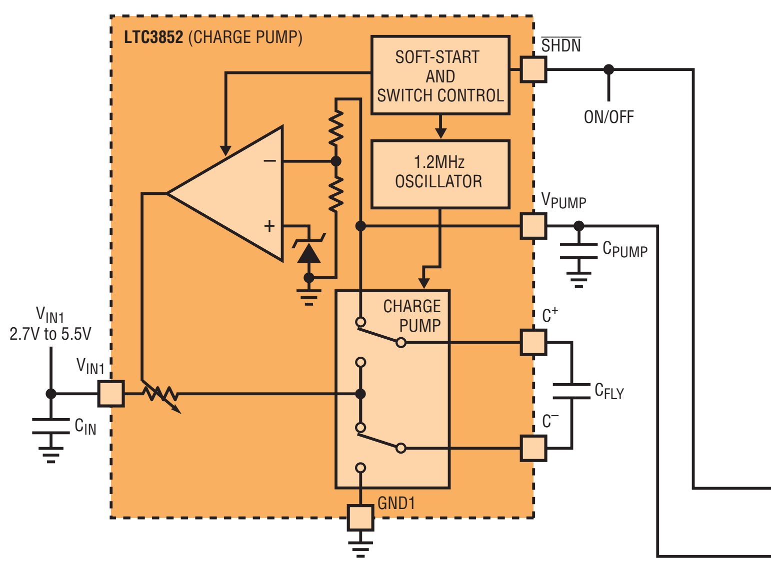
A synchronous buck regulator often makes the best intermediate bus converter for these applications because of its high efficiency over a wide input range when compared to linear regulators. In this buck topology, 40V MOSFETs are necessary to tolerate double battery and high voltage transients, so the regulator should provide the required minimum 4.5V gate drive for the power MOSFETs during cold engine cranking.

Buck regulator controllers have traditionally provided gate drive power through either an external 5V supply or through an onboard LDO. Both of these supply options can only step down an input voltage, so the gate drive potential drops with the input voltage, limiting the operating range of the regulator. The ideal controller would require no auxiliary supply and would provide the required 5V gate drive voltage even when the input supply voltage drops below the minimum specified V_{GS} rating of the power MOSFETs.

BEST OF BOTH WORLDS

The LTC3852 is a synchronous step-down DC/DC controller with a low voltage charge pump designed to provide 5V drive to external MOSFETs even when the input drops below 5V. Figure 1 shows the block diagram of the IC. The

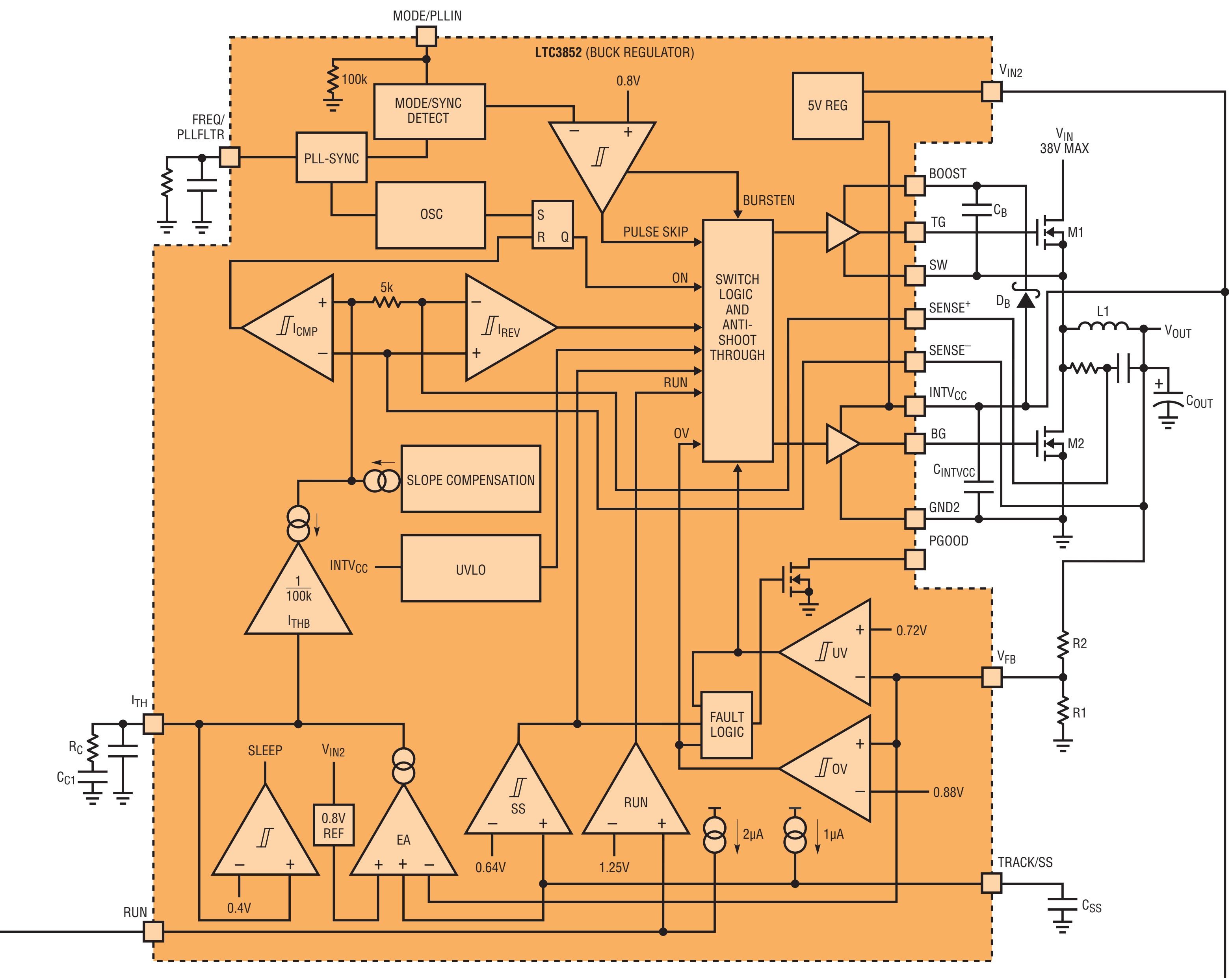
Figure 1. The two core circuit blocks of the LTC3852: a step-down DC/DC controller block and a charge pump doubler block, which allows the controller to continue running even when inputs drop below 5V.



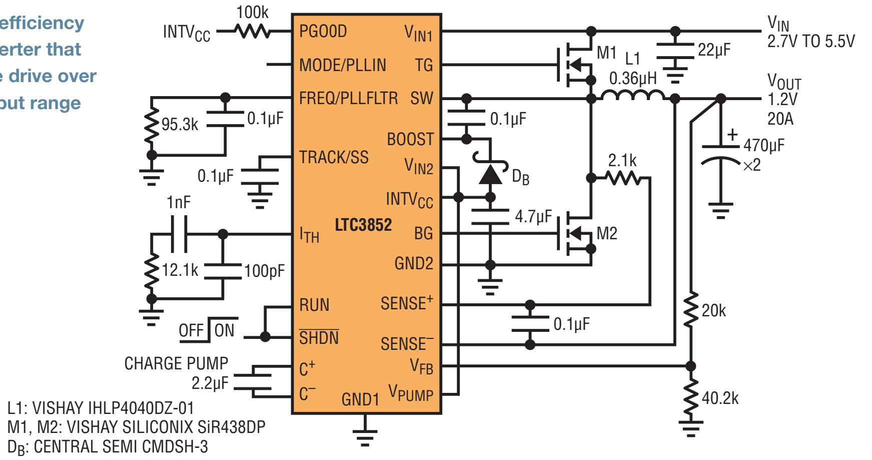
The ideal intermediate step-down regulator would continue to provide power even under cold crank conditions, where the battery voltage can drop below 5V. The LTC3852 does just that—even when its input drops below 5V, its integrated low voltage charge pump produces the necessary 5V drive for the external MOSFETs.

LTC3852 contains two core circuit blocks, a step-down DC/DC controller and a charge pump doubler. The LTC3852 can be configured to operate from voltages as low as 2.7V, as shown in Figure 2, or as high as 38V, as shown in Figure 3. Figure 4 shows a DC/DC converter that operates over a wide input voltage range and provides 5V gate drive to the MOSFETs even when V_{IN} falls below 5V.

The charge pump doubler inside the LTC3852 provides a regulated 5V output at V_{PUMP}. As the schematic of Figure 4 shows, V_{PUMP} is typically connected to V_{IN2}, the main supply for the DC/DC buck



If V_{IN} falls below 5V, the switching regulator enters dropout operation. V_{OUT} also falls, but remains high enough for the post-regulator LDOs to continue regulating their output voltages.



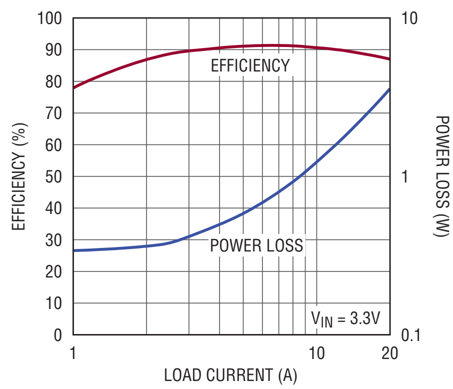
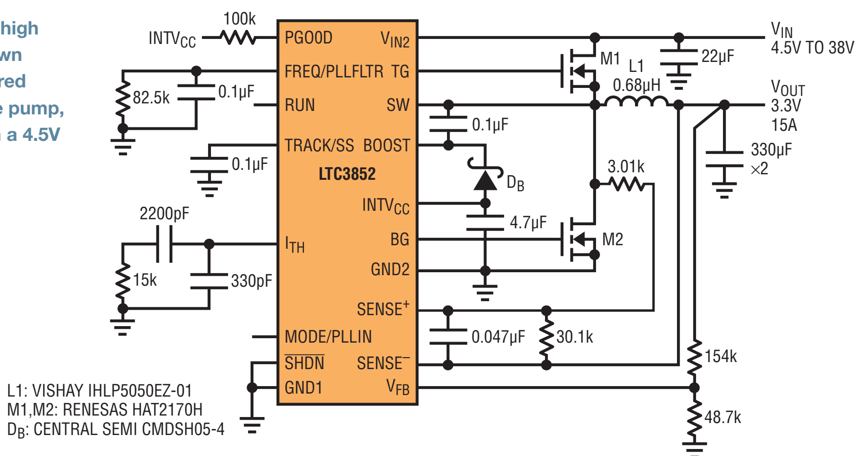


Figure 2. A high efficiency step-down converter that provides 5V gate drive over a 2.7V to 5.5V input range



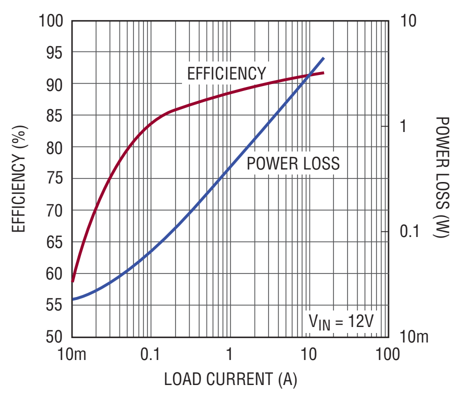


Figure 3. A similar high efficiency step-down converter, configured without the charge pump, that operates from a 4.5V to 38V input range

converter, and $INTV_{CC}$, the gate drive supply to the external MOSFETs M1 and M2.

The input to the charge pump (V_{IN1}) draws its supply current from one of two sources. At start-up, Q1, D1 and R1 form a simple linear regulator, supplying current to the charge pump from the input voltage. Once V_{OUT} is up and regulating, diode D2 turns off Q1 and supplies voltage to the charge pump from the output of the converter. This bootstrap configuration increases the power supply's efficiency, since the current required to drive the power MOSFETs comes from the DC/DC converter itself.

If V_{IN} falls below 5V, the switching regulator in Figure 4 enters dropout operation, keeping M1 on most of the time. V_{OUT} also falls, but remains high enough for the post-regulator LDOs to continue regulating their output voltages. Meanwhile, the charge pump maintains its 5V output, providing solid gate drive to the MOSFETs, as shown in Figure 5.

Under normal operating conditions the converter has a 12V input and the LTC3852 behaves just like a conventional synchronous buck controller. Figure 6 shows the efficiency vs load current for the converter in Figure 4. The peak efficiency is 96% at a load current of 6A and efficiency remains high over a wide range of load currents.

The LTC3852 can be configured to operate from voltages as low as 2.7V, with no external gate drive supply required, or as high as 38V.

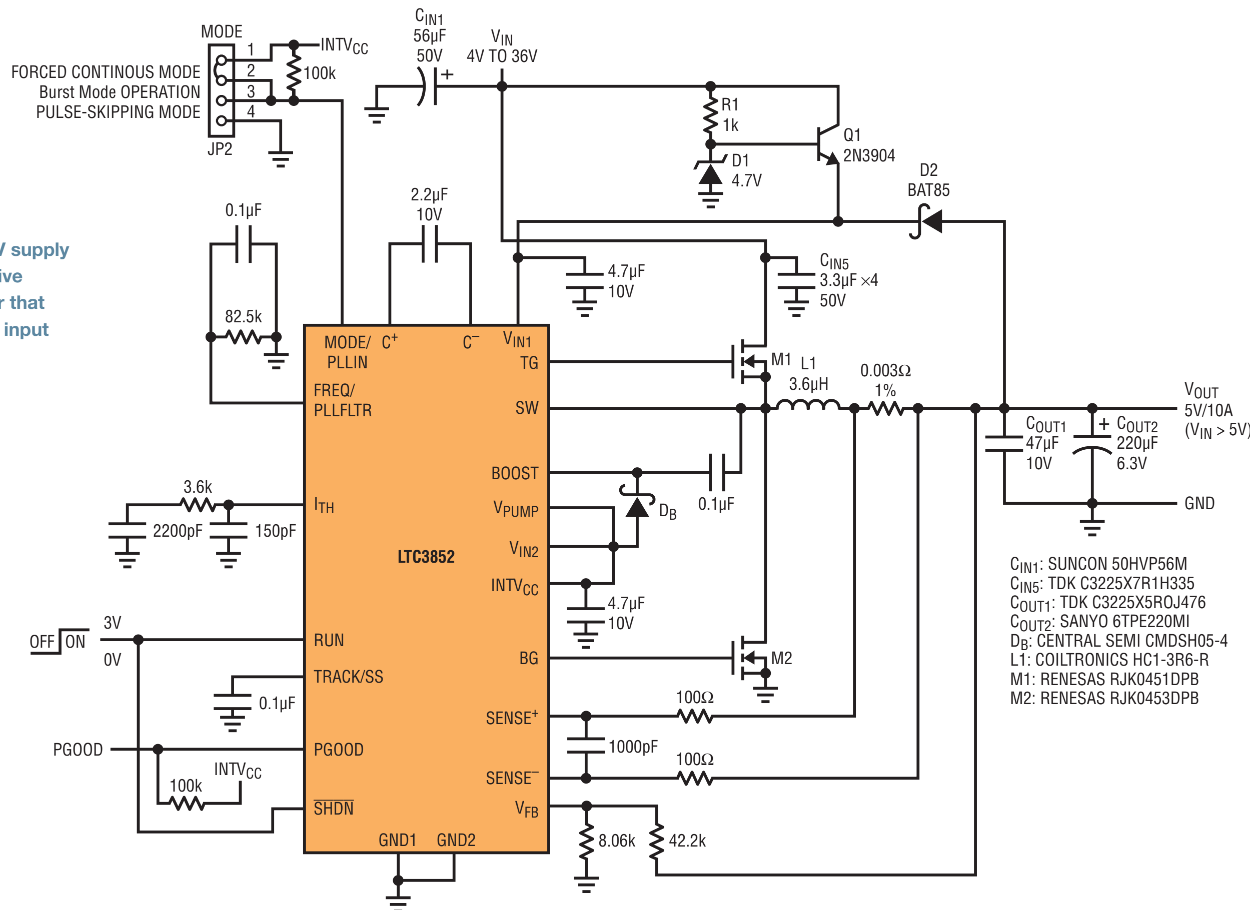


Figure 4. No access to a 5V supply is needed for this automotive intermediate bus converter that produces 5V gate drive for input voltages below 5V

CONCLUSION

The LTC3852 is a synchronous step-down DC/DC controller with a charge pump doubler that provides 5V gate drive, even when V_{IN} drops below 5V. The application presented here powers an intermediate 5V bus from an automotive 12V battery input. Strong drive to the MOSFETs is maintained even during cold crank events, and high efficiency is maintained over all operation conditions. The LTC3852 is offered in a 3mm × 5mm thermally enhanced QFN package. ■

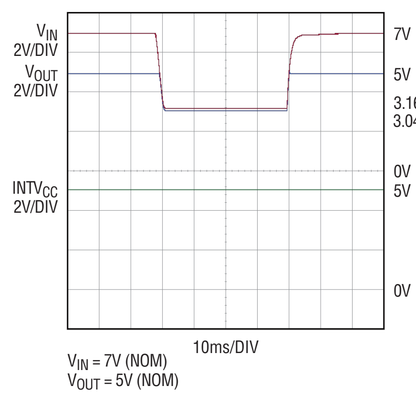


Figure 5. Line transient response for the intermediate bus converter in Figure 4, illustrating 5V gate drive during a cold crank event

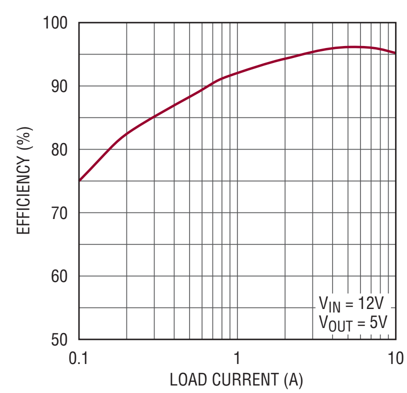


Figure 6. Efficiency vs load current for the intermediate bus converter in Figure 4