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POWER SUPPLIES FOR AUTOMOTIVE START/STOP SYSTEMS

In order to curb fuel consumption, many automobile makers are implementing the "Start/Stop" function into their next generation of vehicles and significant numbers of such vehicles are already on the road. These systems turn off the engine when the vehicle comes to a stop and then automatically turn it back on when the foot is moved from the brake pedal to the accelerator pedal – or, in the case of a manual transmission, when the clutch pedal is depressed to re-engage gear. This helps reduce fuel consumption in city driving and stop-and-go rush hour traffic.

Such systems introduce some unique engineering challenges to the vehicle's electronics however, since the battery voltage can drop to 6.0 V or lower when the engine re-starts. In addition, typical electronic modules have a reverse polarity diode included to protect the electronics in the event the car is jump-started (bopsted) with the jumper cables accidentally reversed. This diode causes another 0.7 V drop in the battery voltage, leaving 5.3 V or less for down-stream circuitry. With many modules still requiring a 5 V supply, power sources are simple running out of headroom to operate properly.

BOOST SUPPLY

One approach is a boost supply. This takes a lower input voltage and creates a higher voltage on the output. Many suppliers are currently employing some type of boost supply at the front end of electronic modules in order for them to operate properly through dropout conditions caused by the Start/Stop system. The following article looks at various solutions available to the designer, including low dropout linear regulators, reverse battery protection schemes, and different boost options for these Start/Stop systems.

As with most engineering problems, there are a number of ways to solve an issue. If the battery voltage only drops down to 6V at the input, then the first and simplest solution is to find an extremely low drop-out linear regulator that requires less than 0.3V of headroom. This can work for modules with lower current requirements, but one soon runs out of options for modules with higher current needs.

An alternative approach is to replace the standard P-N junction diode used for reverse battery protection on the front end with either a Schottky diode or a P-channel MOSFET. A Schottky diode has about half of the forward voltage drop of a standard rectifier, so it adds a few more tenths of a volt to the headroom. Changing to a Schottky diode is straight-forward enough, since it typically fits right onto the same PCB pads as the standard diode, eliminating the need for layout changes.

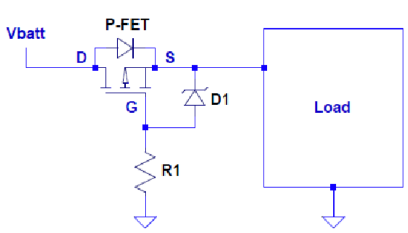

Figure 1: *Reverse battery with P-FET*

The P-channel MOSFET however requires a PCB change, along with some extra circuitry.

Figure 1 illustrates the three components that are required; a P-FET, a Zener diode, and a resistor. The P-FET needs to be sized so that it can handle the voltages applied to the input of the module, along with the load currents required. In addition, it is important to consider the thermal requirements of the system, since the power dissipation in the FET is the current squared times the on-resistance of the FET. The Zener diode protects the MOSFET's gate oxide from damage due to over-voltage conditions. Most P-FETs can handle between 15-20V from their gate to source connections, so the Zener has to be chosen to clamp before this point. The resistor pulls the gate down to ground to turn on the P-FET, but it also must be sized appropriately. It cannot have too little resistance, because then too much current will be allowed to flow through the Zener – thereby creating power dissipation issues for it. However, if it gets too large, then the P-FET may not turn on as hard as preferred, and the whole idea for this scheme is to reduce the voltage drop across the drain to source connection.

VOLTAGE DIPS TO UNDER 5V

It is likely that one, or a combination, of the above schemes, will work for a given application. But what happens if the input voltage actually drops below 5V? Some manufacturers are looking at 4.5V during "cold cranking" conditions. If this is the case, then a switching power supply needs to be used in order to boost the input voltage. The three most common switchers are the boost supply, the buck/boost supply, and the SEPIC power supply.

The boost supply uses one inductor, one N-FET, one diode, and one capacitor. It is the simplest design, but it also has some drawbacks. If the output should be shorted, there is no way to protect it because there is a direct path from the input to the output. Also, when the input voltage rises above the output voltage set point, there is nothing to keep the output from also rising, since the input voltage can go right through the inductor and diode to the output.

For example, most modules on a vehicle must pass the load dump test. In this test, a voltage spike is generated and applied to Vin. In a boost supply, this voltage spike would propagate right to the output. Thus, if a 40-V spike comes down the line, everything connected to Vout has to be able to handle this voltage.

The next possibility is the non-inverting buck/boost design. This uses only one inductor and capacitor, but it requires two switches and two diodes. The scheme however does allow a designer to keep the output voltage from rising when the input goes higher than the output. It also enables protection from output short circuits by opening up the first switch (FET1). The downside to this design is its efficiency, as now there are losses in two diodes and two switches to take into account.

The Single-Ended Primary-Inductor Converter (SEPIC) design is very similar in layout to the straight boost converter except that it adds an inductor to ground and a DC blocking capacitor. The negative side here is the addition of another inductor and capacitor, but on the positive side there are no more issues with the output being short circuited as the DC blocking capacitor is now in series with the output. The output now is not affected by the input voltage, so it can be lower or higher than the input. One thing to note is that with all of the switching topologies shown, a reverse battery protection scheme is still needed, since reverse current can still flow from ground through the body diode of the FET back to input voltage.

In summary, there are many issues to consider when going to a Start/Stop alternator system. This article has touched just on the power supplies for electronic modules, but there are also other concerns that need to be addressed. For example, both interior and exterior lighting will dim during these voltage dips. Interior lights blinking can be annoying though not critical, but brake lights and headlights directly affect safety, so these will also need power supply solutions to keep them up and running. Fortunately, there are now solutions in existence for these problems.

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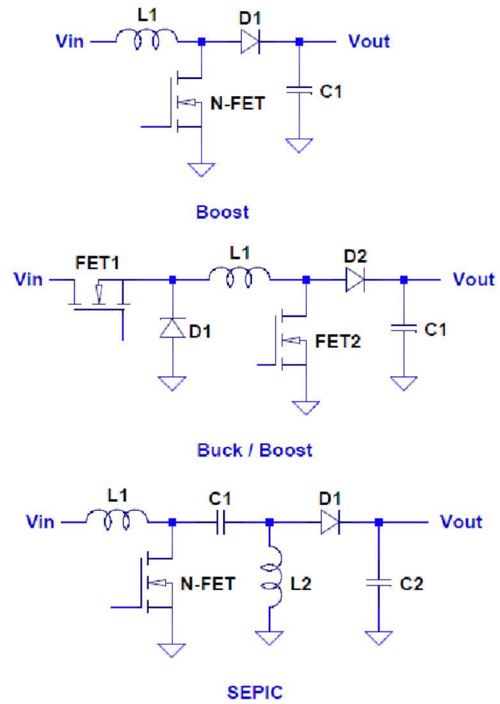

Figure 2: *Various Boost Supplies*