Technical Article

How to Overcome Automotive Front-end Design Challenges

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You've likely had the experience of starting your car, only to hear a click rather than the turning of the engine. This is caused by a dead battery, and although there are many reasons why this could happen, in the majority of cases it is human error (has anyone ever left an interior light on overnight?). Human error can also occur when jump-starting the car.

Figure 1. Battery with Jump-start Cables Connected Correctly.

Automotive system designers must prepare for two likely conditions as a result of mistakes made during jump starting a car engine: reverse battery and double battery conditions. Reverse battery is when the battery has the red terminal of the jumper cables connected to the ground of the battery and the black terminal to the positive of the battery, the opposite to Figure 1. In such circumstances a diode will protect the system, but at the same time, a diode generates system losses in normal operation. Depending on the system's power rating, the forward-drop voltage can be anywhere from 0.5V to 1.0V. This generates heat and adds to overall system inefficiency.

Trucks and buses work on two batteries in series, while automobiles have only a single battery. It's possible that the only vehicle around to jump-start your car might be a truck. This causes the double-battery condition, where the voltage applied to the whole system is now twice the amount. This puts a lot of strain on the system.

Load dump is another condition that the engineer has to design the system to tolerate and survive. This does not occur through user error like reverse battery, as it relates to the system itself generating a problem.

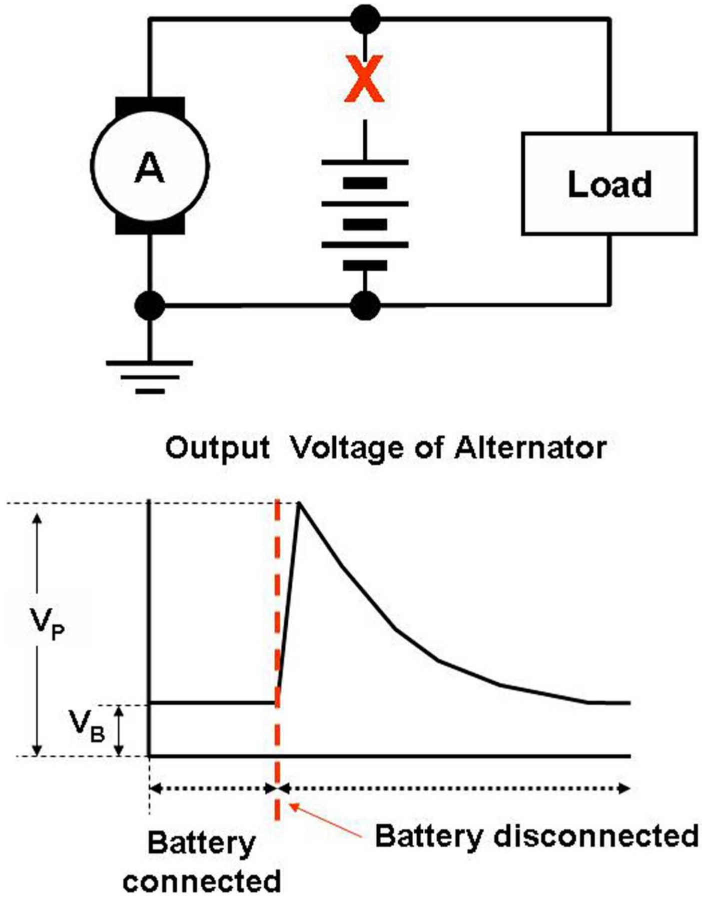


Figure 2. Diagram of a Load Dump Condition.

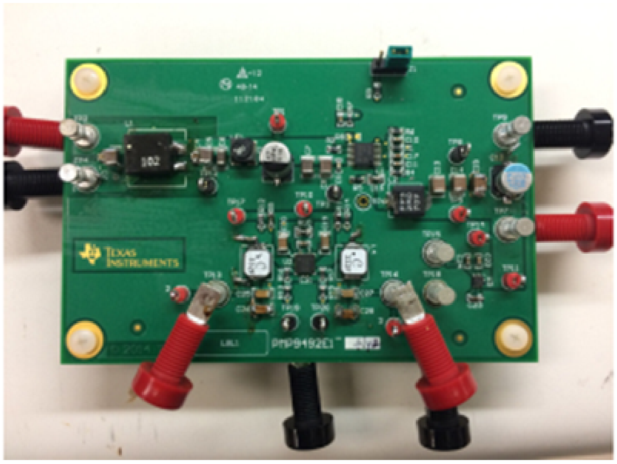
Load dump (as can be seen in Figure 2) occurs when the ground of the alternator or battery is disconnected from the system due to corrosion or even bad installation. This disconnection generates a large voltage spike that can hit the whole system. The alternator plays an important part in automotive electrical system operation, so without it you will have a dead battery.

All of the conditions discussed present major challenges to the automotive front end design in how to protect electronics such as control units, sensors and entertainment systems against damaging surges, voltage transients, electrostatic discharge (ESD) and noise present on the power line. Transient voltage suppressors (TVSs) are a low cost solution for automotive electronic protection and have several important parameters for these automotive applications, including power rating, standoff voltage, breakdown voltage and maximum breakdown voltage. You must also make sure that you use higher-V_{IN} downstream DC/DC converters so that the system doesn't have issues with spikes, as TVSs cannot suppress everything.

In front-end power supplies, switching regulators are essential to the system's overall power density and efficiency when converting the battery voltage down to the voltage that the processors need. The problem with a switching regulator is that it creates noise while it is operating. Switching entails changing electrical conditions rapidly: that includes the current into the switch; switch-node voltage changes; and the output-voltage ripple, and other factors relating to external component selection. Some of these factors cannot be changed due to the laws of physics when controlling large amounts of power circulating in many directions. All of these conditions contribute to electromagnetic compatibility, simply known as EMC.

The main standard for automotive EMC is called CISPR 25, which includes several classes based on how severe the end equipment requirement is and how low the EMC needs to be. You can often hear the noise generated by the EMC on your radio's AM band. This is very undesirable, so you will need to suppress this noise with filtering. An automotive specific switching regulator is designed to minimize the electromagnetic noise through a combination of architecture (current mode is the most common architecture in automotive), component placement (close as possible to the switching regulator and as few as possible) and even device pinout. It can never be zero, but it can be reduced.

At TI, we developed a reference design that gives front-end automotive power-supply designers the capability to meet all of these automotive system standards and address the issues discussed in this blog.



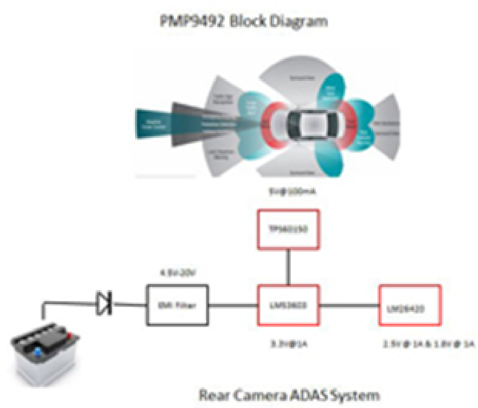


Figure 3. TI's CISPR 25 class 5 multi-output reference design for automotive rear camera and ADAS systems.

The TI Designs reference design shown in Figure 3 is a conducted electromagnetic interference (EMI)-optimized multi-output design that meets the CISPR 25 class 5 automotive standard. This 9W design is well-suited for wide-range V_{IN} automotive advanced driver-assistance system (ADAS) applications that support cold-crank conditions. The reference design features the LM53603-Q1 DC/DC regulator (used as a buck), the LM26420 DC/DC regulator (used as a dual buck) and TPS60150 switched capacitor voltage converter (used as a charge pump for a 5V output). The design accepts an input voltage of $4.5V_{IN}$ to $20V_{IN}$ and provides outputs of 3.3V at 1.0A, 2.5V at 1.0A, 1.8V at 1.0A and 5V at 100mA. It is small in size, inexpensive, efficient and customized for ADAS and other automotive-related applications. The four-layer printed circuit board (PCB) dimensions are 65mm by 100mm.

The CISPR 25 class 5 multi-output reference design for automotive rear camera and ADAS systems reference design ensures compliance with all related EMC, transient voltage and even size constraints faced by the automotive power supply design engineer. The design also protects against the fault conditions discussed earlier such as double battery and reverse battery, which are often not related to the switching regulator but are part of the complete system design.

Additional Resources

- Consider the LM53603-Q1 for your next automotive power supply design.
- Download the CISPR 25 class 5 multi-output power supply reference design for rear camera, automotive ADAS systems.
- Start a design now with WEBENCH Automotive Power Designer.
- Watch the video, "TI's LM53603-Q1 high-performance 2.1 MHz synchronous DC/DC converter."
- View more automotive reference designs from TI.

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