High-Power and Hybrid Vehicles Increase Demand For Load-Dump Protection

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*by **Sweetman Kim**, Vishay General Semiconductor Taiwan*

Growth in the number of electronic loads and the spread of hybrid vehicles is driving adoption of larger alternators, which increases transient and surge energy when load-dump occurs.

The evolution of the automobile reflects a continual increase in the number of electronically controlled devices. This trend has increased requirements for electrical energy and demanded the use of bigger alternators than were needed in vehicles of the past. However, with a larger alternator or integrated-starter alternator (ISA) in mild-hybrid vehicles, transient and surge energy is increased in the load-dump condition.

As the alternate size increases, load-dump protection is becoming even more important than ever for vehicle safety. Addressing the problem begins with an understanding of how the application issues affect the severity of load-dump surges, and the options available to meet the growing demands for load-dump protection.

Sources of Transients

Forty years ago, vehicles were produced with only one electronic component: the radio. Today's vehicles, however, feature a myriad of automotive electronics, such as electronic control units, sensors, and entertainment systems, and they are all connected in parallel to one power line.

The power sources for these electronics are the battery and alternator, both of which have unstable output voltages that are subject to temperature, operating status, and other conditions.

Additionally, ESD, spike noise, and several kinds of transient and surge voltages are introduced into the power and signal line from automotive systems that use solenoid loads, such as fuel injection, valve, motor, electrical, and hydrolytic controllers.

The worst instances of surge voltage are generated when the battery is disconnected while the engine is in operation and the alternator is supplying current to the power line of the vehicle (Figure 1). This condition is known as “load dump,” and most vehicle manufactures and industry associations specify a maximum voltage, line impedance, and time duration for the load dump status.

In parallel-connected electronic systems (Figure 2), transient energy is not shared evenly between all connected electronic systems on the line because transients gravitate to the protection devices with the lowest impedance. Hence, when designing automotive electronics, it is important to note that one protection device can end up accepting all of the transient energy during a load dump condition.

Protection of Large-Size Alternators And ISAS

Some alternator manufacturers have announced large-size alternators and ISAs (belt alternator system or start-stop system) for new-generation vehicles. Current conventional alternator outputs are 14 V and 60 A to 120 A. Large-size alternators have 14-V and 220-A to 300-A outputs to meet the high-power requirements of vehicles that are equipped with several electric-powered driving convenience systems. Such systems include electric braking systems, electric power steering, information, entertainment, drive assistant, and others.

And ISAs for mild-hybrid systems have 14-V, 120-A output for light vehicles, or 42-V, 60-A to 80-A output to idling engines without fuel injection during braking and while stopped.

For large-size alternators in 14-V systems, the internal impedance (Ri) is 0.33 Ω for 220-A types and 0.24 Ω for 300-A types, as determined by the Equation 1 below from the ISO7637-2 and ISO-8854 standards:

$$Ri = (10 \times Unom \times Nact) / (0.8 \times Irated \times 12{,}000 min^{-1})$$

where Unom is the specified voltage of the alternator, Nact is the actual alternator speed, in reciprocal minutes; and Irated is the specified current at an alternator speed of 6,000min-1 (as given in ISO8854).

Customers need to suppress the surge voltage at 35 V in load-dump conditions, and the surge suppressor is handling more current than in this same situation for current conventional alternators.

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42-V ISA For Mild-Hybrid Vehicles

Although the safety, stability, and reliability of 42-V vehicle systems have been questioned, they are being used for the power buses and alternators of some recent mild-hybrid vehicles. The basic concept of a 42-V power system over a 12-V power system is to improve power efficiency and reduce the weight of the power harness in vehicles. This new 42-V power system impacts semiconductors by requiring much higher dielectric strength than 12-V systems.

Specification of polarity reversal in the 12-V power system is customary and often allowed to reach -2 V for 1 minute at +25 °C. The common solution is to use one rectifier for the power input line of each electronics unit in the vehicle for low-current consumption, not for high-current applications.

The enhanced technology of mild-hybrid vehicles uses many high-current applications, such as the motor driving the engine without injection when stopped, non-hydraulic power control, electric power steering, and electric brake systems. These all require high current, in addition to dc-dc converter modules for 14-V power lines in mild-hybrid vehicles.

One solution for polarity protection in high-current applications is to use high-forward-current capability rectifiers or load-dump TVS devices without polarity protection diodes in the power line, as shown in Figure 3.

Comparison of Load Dump Protection Circuits and Devices

There are several types of circuits and devices for load-dump protection, and they can be divided into three operational types, as show in Figure 4.

The shunt type senses the input voltage and turns on the devices, which crosses the power line to ground. This type is used for switching devices in shunt regulating or protection circuits in transistors and thyristors. Avalanche breakdown diodes, zener diodes, and thyristors (TVS and MOV) are self-

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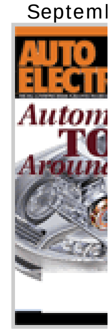

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triggered devices in this protection type. They have the advantage of a simple structure, but the disadvantage of requiring a high-power capability from the switching device.

A self-recovery cut-off switch is normally used for high-current protection when the load has malfunctioned or there has been an electrical short. Some power management ICs integrate this function for the customer's convenience, as it provides an easy design and saves space by not requiring a protection device to handle high current. The disadvantage of this type is that it requires a high-storage capacitor to supply energy to load when the switch cuts off power in the load-dump status.

The linear-regulator type has good characteristics for controlling the supplied energy, but has the disadvantage of requiring a high-power transistor to dissipate the voltage gap between the output voltage and high surge voltage of the device itself.

In a suppressing model, the self recovery cut-off switch and linear regulator have high impedance in load-dump status, and that high energy flows to the weakest protection device of the connected electronics or electric equipment. For this reason, the common design topology for load dump protection is the shunt type.

Shunt type protection circuits are classified in two groups based on their operating characteristics: crowbar and clamping. Crowbar operation is similar to an electrical short when the device is turned on, making it unsuitable for automotive protection.

The general protection method for automotive electronic systems is to clamp the peak voltage to a specified level with a device or circuit. Avalanche breakdown diodes, zener diodes, and metal oxide varistors (MOVs) are all popular devices for load dump protection.

An MOV is similar to a ceramic capacitor, with a basic structure composed of a zinc-oxide (ZnO) compound. The device has a bi-directional breakdown characteristic, and thus no way to protect against reversed input. The multi-layer and multi-pass structure of the MOV causes a time delay in response to high-energy transients. In addition, the degradation of the grain of the MOV under continuous transients affects the clamping voltage and reduces its surge capability.

A zener diode is similar to an avalanche breakdown diode, but in major applications it is regulating, not protecting against, high-energy transients due to its lower surge power capability.

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