

Redundant power supplies in automotive applications – priority switching done right

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Introduction

Safety-critical systems in automotive applications often depend on redundant power supplies to achieve the required Automotive Safety Integrity Level. Systems designed specifically for autonomous driving must work under all circumstances, at least to a degree where the vehicle can achieve a safe state. For redundant power supplies, designers typically use one of two implementations: ORing or priority switching. While both implementations are nearly identical, there are some details that can cause issues if not properly addressed.

The differences between ORing and priority switching

An ORing application connects two or more inputs with diodes, or ideal diodes or ORing controllers if the system requirements call for higher power. **Figure 1** shows the typical implementation of such an ORing scheme. This implementation delivers whatever input voltage is the highest to the output. Equal input voltages are all loaded relatively equally.

The ORing approach is easy to implement and a good fit for systems that offer equally usable supplies. Because both power supplies will load simultaneously when their voltage levels are close to each other, the transition from one supply to the other happens somewhat smoothly. The use of back-to-back field-effect transistors (FETs) is optional in this implementation, as long as there is no need to disconnect one or both power sources.

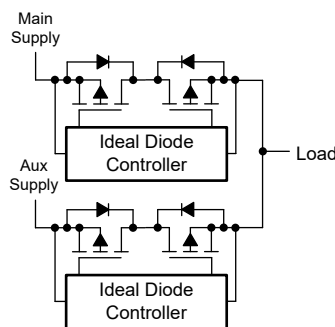


Figure 1. Input ORing

For an electric vehicle, which has a high-voltage traction battery with a powerful step-down converter and a small 12V or 48V auxiliary battery, the standard ORing approach may not be suitable. This is because of the low capacity of the auxiliary battery and charging circuit, which are both designed for emergency operation only. In such cases, the priority switching approach achieves redundancy without unnecessarily loading the small auxiliary battery.

As shown in **Figure 2**, priority switching monitors the main power supply through the ideal diode controller of the auxiliary supply and only switches over to the auxiliary supply if the main supply drops below a certain threshold. The ideal diode controller must support an overvoltage protection feature, which in this case is used to detect an undervoltage event on the main power supply. The LM74900-Q1 device family would be an example of ideal diode controllers that have an overvoltage protection feature. The use of back-to-back FETs in this application is mandatory, in order to avoid current draw from the disabled source.

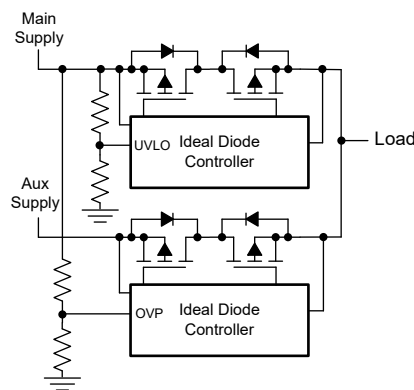


Figure 2. Priority switching

Priority switching details

In general, the circuits used for ORing and priority switching are not particularly different from one another, but the behavior of the priority switching implementation requires some attention to detail.

While the ORing solution enables both power paths if they are somewhat equal, the priority switching approach keeps the auxiliary power path disabled until the voltage of the main power path drops below a certain threshold. Reaching this threshold disables the main power path and enables the auxiliary power path, causing a sudden load shift from one supply to the other and generating a sudden voltage step on both supplies. Because of this sudden load shift, the voltage on the main power supply will often spike for a short period before completely collapsing, although this depends on the failure causing the initial drop.

Because the auxiliary supply switches based on the voltage on the main supply, a voltage spike can cause the system to switch back to the primary supply, which immediately lowers the primary voltage and causes the system to revert to the auxiliary supply. This results in uncontrolled oscillation between the two power supplies and creates a large ripple on the output, which may disrupt system functionality. The reason behind the voltage shift on each supply is the sum of all parasitic resistances and inductances within the power path, such as printed circuit board traces, wiring, and the MOSFET drain-to-source on-resistance ($R_{DS(on)}$).

Figure 3 shows an example of such behavior. During a disconnect of the primary power supply, a short burst occurs right when the input voltage drops below the switchover threshold. Channel 1 in **Figure 3** shows the voltage on the auxiliary supply, while Channel 3 shows the output voltage. The auxiliary supply voltage in this scenario has a lower value than the primary supply voltage, with the switchover threshold set right above the voltage level of the auxiliary supply.

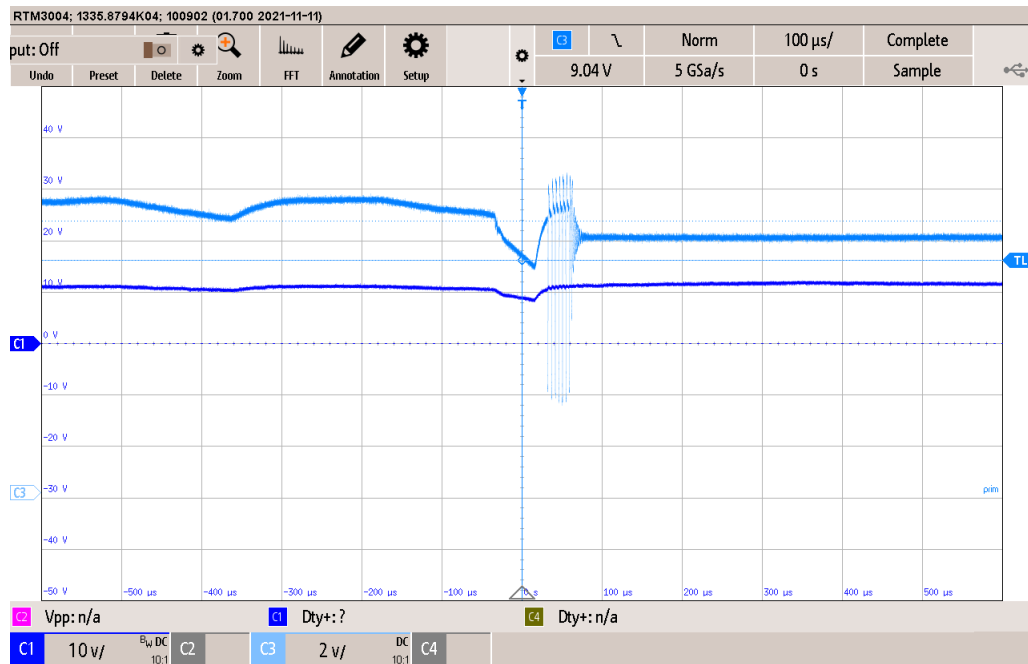


Figure 3. Oscillation during input switchover in a priority switching system

Depending on what problem causes the main supply to drop, this oscillation may even be continuous; for example, if the cable for the main supply is partially damaged and causing a huge voltage drop instead of a complete disconnect. In many cases the hysteresis built into the ideal diode controllers, together with a sufficiently high input capacitance, can suppress this behavior. But in some cases the hysteresis may not be enough to avoid unnecessarily large input capacitors.

Although it is not possible to change the internal hysteresis, on some devices there is a simple solution to increase it externally. Many devices such as the LM74910H-Q1 offer a fault output that you can use to add external hysteresis with minimal component count. On the LM74910H-Q1, the fault pin is an open-drain output that pulls low for overvoltage conditions and other faults. This output can also control an external transistor, which alters the feedback divider for the overvoltage input. **Figure 4** illustrates a typical implementation.

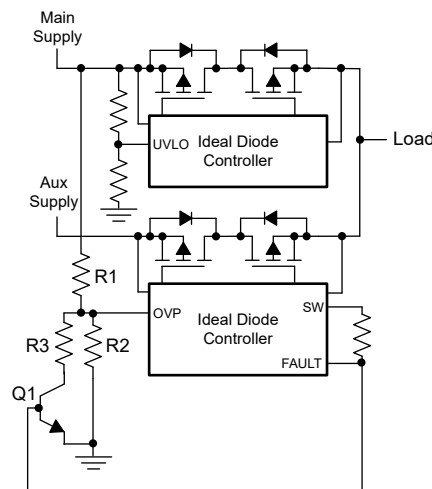


Figure 4. External hysteresis

Since the fault output is an open-drain output, you will need a bias resistor to turn on the bipolar junction transistor. This resistor connects to the software pin of the integrated circuit, which offers a switchable low-current path to the input that becomes disabled when the system shut downs to minimize quiescent current.

As long as the primary power supply is above the switchover threshold, the auxiliary controller is in an overvoltage fault state, disabling the power switches and pulling the fault output low. Pulling down the fault output disables transistor Q1; therefore, the feedback divider for the overvoltage input only consists of R1 and R2. This results in an overvoltage feedback voltage defined by the ratio of both resistors and the switchover threshold, as expressed by **Equation 1**:

$$V_{ov_falling} = V_{sense_falling} \frac{R1}{R2} \quad (1)$$

As soon as the primary supply voltage drops below this overvoltage threshold, the fault output no longer pulls low and the transistor switches on, connecting R3 in parallel to R2 and reducing the voltage appearing at the overvoltage input.

Equation 2 now gives a new value for the rising threshold:

$$V_{ov_rising} = V_{sense_rising} \frac{R1}{\frac{R2 \cdot R3}{R2 + R3}} \quad (2)$$

Changing the value of R3 easily adjusts the resulting hysteresis, offering great design flexibility.

Conclusion

The choice between an ORing or priority switching redundant power solution depends on your system design. While both designs offer the same function, the ORing implementation is less critical when it comes to actual hardware.

Parasitic effects such as board inductance, board resistance, the $R_{DS(on)}$ of the power transistors and cable resistance can negatively affect the switchover behavior of a priority switching implementation. In some instances, the internal hysteresis of the controllers is enough to counteract the influence of the parasitic elements, but not always.

The circuit described in this article shows a simple workaround for adding external hysteresis with minimal component count. The only requirement is a controller, which offers a suitable signal for switching between the two voltage levels. This controller helps reduce the capacitance on the supply inputs required for a clean switchover, resulting in a stable system and cost savings.

About the author

As part of the Power Design Services team, Björn Görner has eight years of experience designing custom power solutions and reference designs, with his main focus on automotive applications. He is a regular presenter at TI's Power Supply Design Seminars, which Texas Instruments offers biannually to educate and support engineers interested in power conversion.

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Last updated 10/2025