AN1197

Power ORing Application Using Ideal Diode Controllers

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Introduction

Redundant power supply configurations called “Power ORing” utilize multiple power sources to ensure continuous power delivery to a load, thereby enhancing system reliability, availability, and safety. This is particularly critical in automotive applications involving safety-sensitive functions, such as autonomous driving, where power interruptions can lead to severe consequences.

ORing circuits automatically select the power source with the highest voltage, while power multiplexing enables dynamic switching between sources based on predefined priorities or operational conditions. Traditional implementations have relied on Schottky diodes, P-channel MOSFETs, or hybrid arrangements to manage source selection and isolation.

However, ideal diode controllers—integrated circuits designed to control external N-channel MOSFETs—offer a more efficient alternative. These controllers emulate the behavior of ideal diodes and provide benefits such as reduced power losses, higher current handling, reverse polarity, and reverse current protection, as well as features like inrush current limiting and load dump protection.

This application note explores the principles and advantages of ORing and power multiplexing using ideal diode controllers, examines various circuit topologies, and addresses the key design challenges and mitigation strategies for automotive power systems.

What is Power ORing?

In an ORing configuration, the system automatically selects the input with the highest voltage to supply the load. Ideal diodes function as directional switches, conducting only when the input voltage exceeds the output voltage, and blocking current when the input voltage falls below the output. This mechanism prevents reverse current flow and cross-conduction between sources. When input voltages are closely matched, both supplies may share the load without circulating current, making reverse current blocking the key requirement for effective ORing. Figure 1 shows a typical power ORing application using the AP74700Q ideal diode controller from Diodes Incorporated (Diodes).

Figure 2 and Figure 3 show power supply ORing switch-over performance between two power supply rails; VIN1 = 12V, VIN2 = 15V.

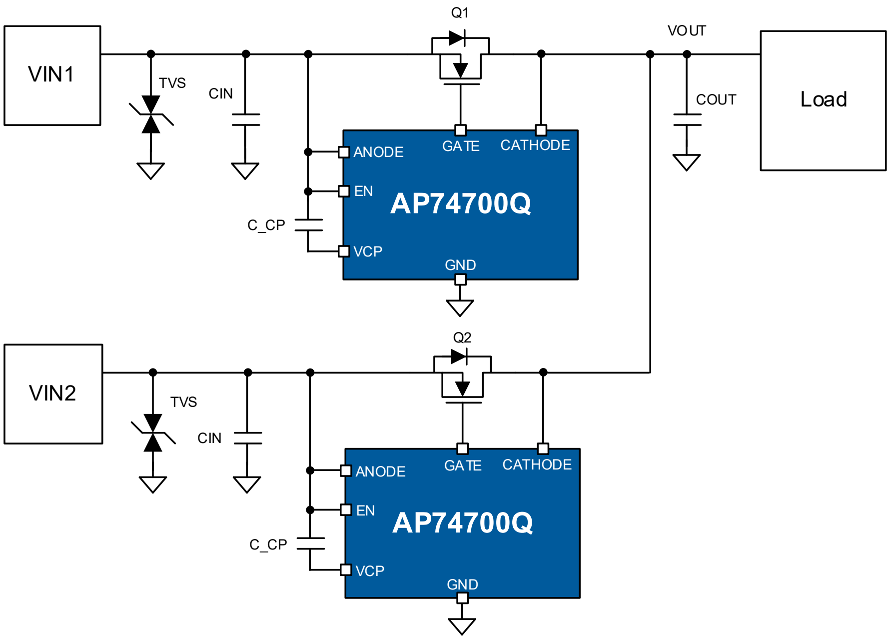

Figure 1 Typical Power ORing Application

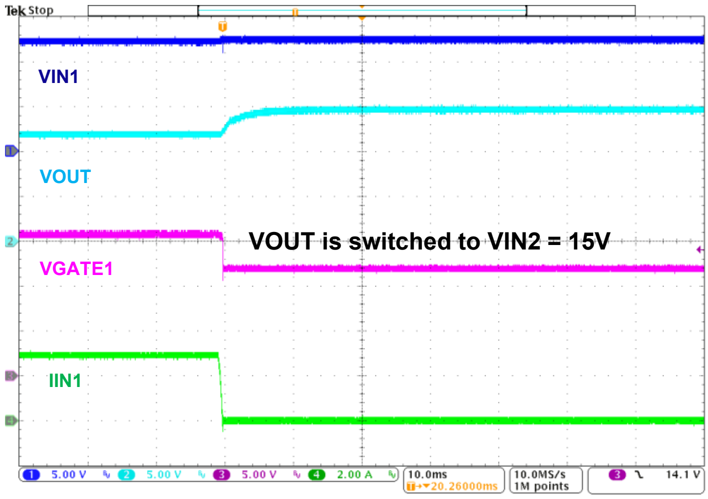

Figure 2 ORing VIN1 to VIN2 Switch Over

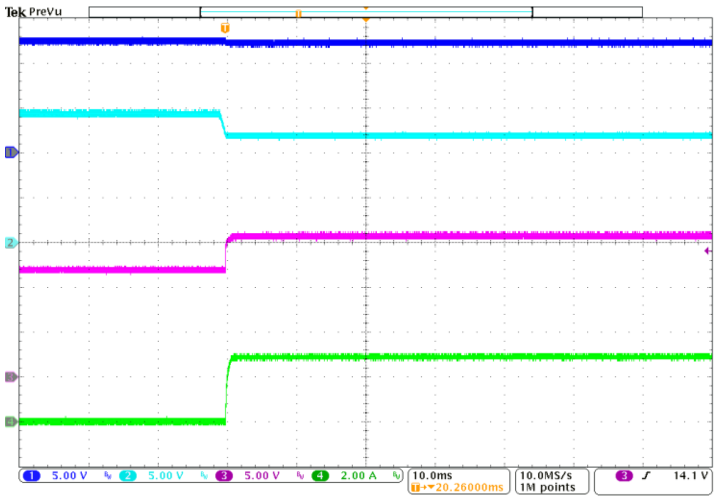

Figure 3 ORing VIN2 to VIN1 Switch Over

Power ORing Applications

ORing circuits are widely used in automotive subsystems such as infotainment units, body control modules, advanced driver-assistance systems (ADAS), and lighting systems to enhance power redundancy and system reliability in the event of a power supply failure or disconnection. Figure 2 illustrates several ORing topologies that utilize ideal diode controller ICs in conjunction with external N-channel MOSFETs.

For an effective solution, the system must respond rapidly to changes in input conditions to minimize reverse current during a supply fault. Ideal diode controllers continuously monitor the voltage differential between their anode and cathode terminals—corresponding to the input voltage (VIN1, VIN2) and the shared output (VOUT). When the input voltage drops below the output voltage by a small threshold (typically a few millivolts), a high-speed comparator disables the gate drive via a fast pulldown mechanism, typically within microseconds. In addition to fast reverse-current detection, Diodes' ideal diode controllers incorporate linear gate regulation to ensure smooth operation.

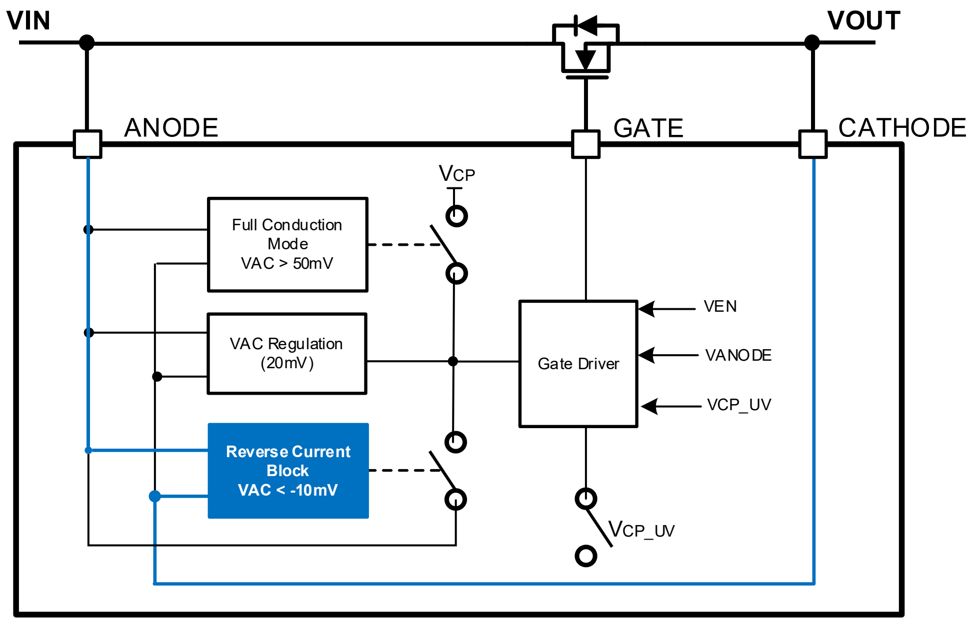

Figure 4 AP74700Q Reverse Current Block Diagram

In some applications, it is necessary to disconnect the load from all power sources to reduce quiescent current or to isolate the system during fault conditions. Figure 5 demonstrates a dual-input ORing configuration with load disconnect capability, implemented using Diodes' AP74800Q and AP74700Q controllers. In this setup, FETs Q1 and Q2 provide ORing functionality, while Q3—controlled by the AP74800Q—enables load isolation. When VIN1 exceeds VIN2, the AP74800Q independently controls Q2 to block reverse current and keeps Q3 active to connect VIN1 to the load.

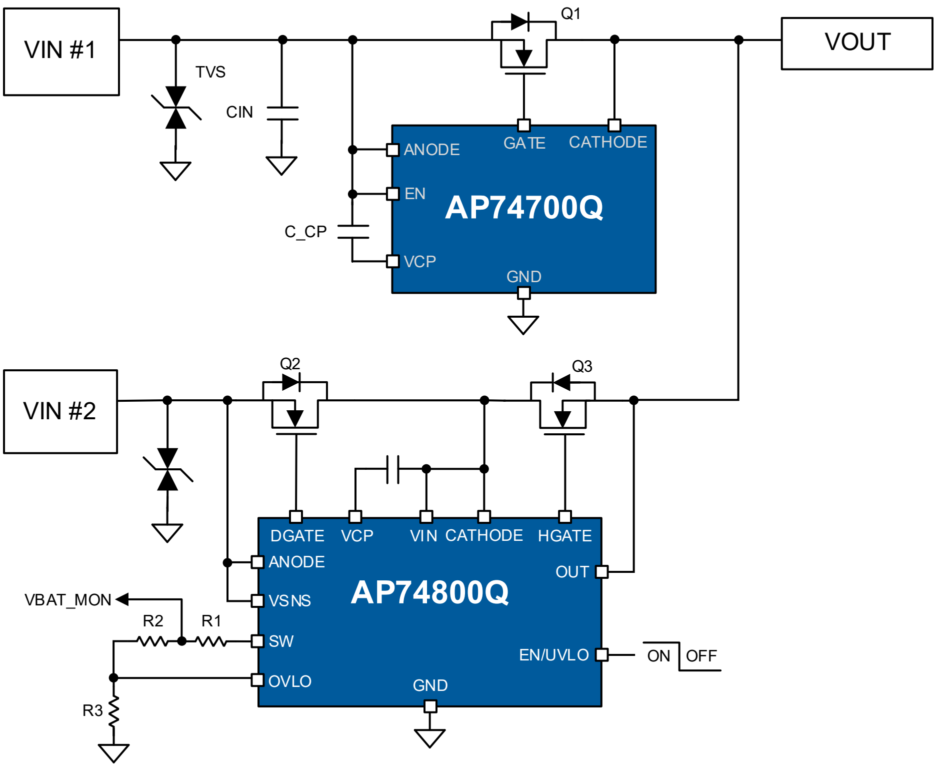

Figure 5 ORing with a Common Load Disconnect

Figure 6 Figure 6presents an alternative approach, where load disconnect functionality is applied individually to each input rail. This allows designers to define separate disconnect criteria for each power source.

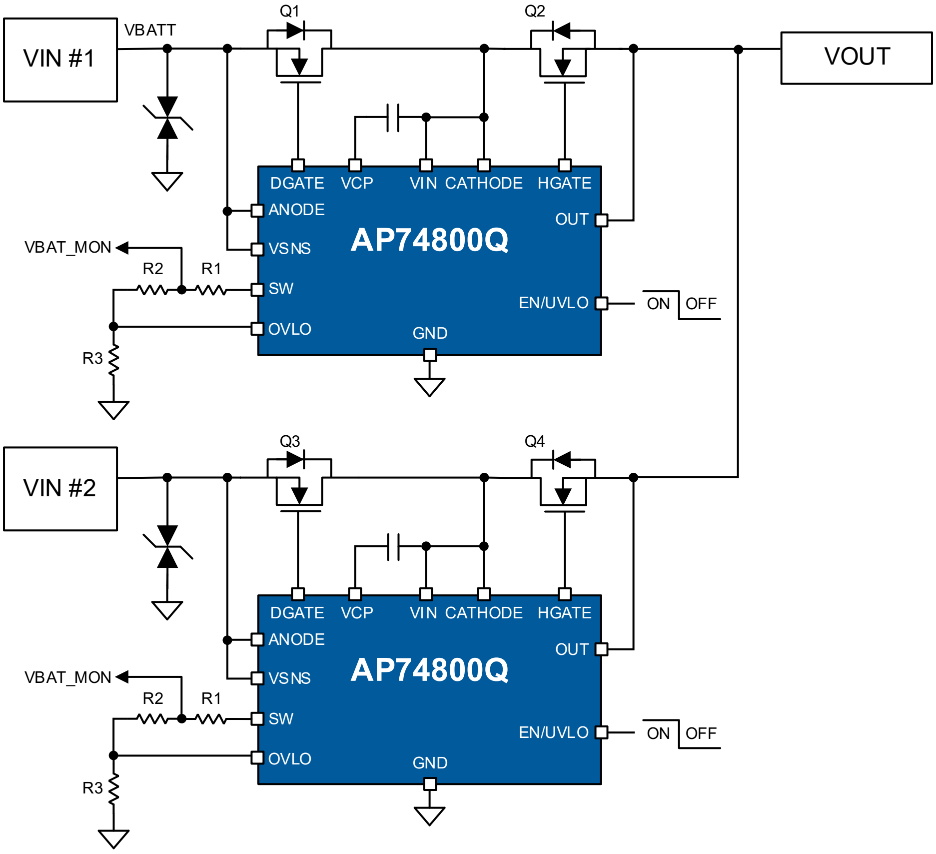

Figure 6 ORing with Load Disconnect Functionality

How to Select Appropriate Power MOSFETs

Ideal diode controllers, such as ORing MOSFET controllers, require one or two back-to-back N-channel MOSFETs to function effectively. Selecting the appropriate MOSFET is critical to ensure system robustness and reliable operation under all conditions. The following criteria should guide your selection:

1. **Voltage Rating**

Choose an N-channel MOSFET with a drain-to-source breakdown voltage (V_{DS}) that exceeds the system bus voltage. For instance, in a 48V system, a MOSFET rated for at least 60V is recommended to provide adequate margin.

2. **Current Handling Capability**

Ensure the MOSFET can support the maximum expected load current. In redundant power systems where one supply may fail, the remaining supply must be able to handle the full load. For example, if the system load is 40A, the selected MOSFET must be rated to carry more than 40A continuously.

3. **On-Resistance ($R_{DS(ON)}$) Considerations**

The MOSFET's $R_{DS(ON)}$ directly impacts power dissipation and thermal management. Select a device with a low enough $R_{DS(ON)}$ to:

- Maintain voltage regulation with sufficient margins.
- Minimize power losses and heat generation under worst-case conditions.
- Reduce or eliminate the need for extensive heat sinking or forced airflow.

This selection may require iterative optimization based on thermal constraints, efficiency goals, and cost trade-offs. In high-power applications, investing in a lower $R_{DS(ON)}$ FET can reduce overall system costs by minimizing cooling requirements. Further considerations on $R_{DS(ON)}$ selection are discussed in the section, *Maximizing Efficiency with FETs in Redundant Power Systems*.

4. **Gate Drive Compatibility**

Ensure the MOSFET performs well with the ideal diode controller's gate drive voltage. For example, the AP74700Q controller provides a gate drive of 15V above the source. Always evaluate the MOSFET's characteristics at this gate-source voltage ($V_{GS(ON)}$ >= 15V).

5. **Switching Speed**

Since ORing applications involve slow switching transitions, fast switching characteristics and a low gate charge are not critical. Focus instead on conduction performance and thermal behavior.

Maximizing Efficiency with FETs in Redundant Power Systems

To fully realize the advantages of using MOSFETs over diodes in redundant power distribution systems, the design objective should be to minimize power dissipation under worst-case conditions—achieving levels significantly lower than what diodes can offer.

In a typical diode-based system, each diode may dissipate approximately 10W during normal operation. If one diode fails, the remaining diode must conduct the full load (e.g. 40A), resulting in a forward voltage drop of 0.6V and a worst-case power dissipation of 24W.

By contrast, in a MOSFET-based system, the worst-case scenario also involves one device carrying the full load. However, by selecting a MOSFET with a low $R_{DS(ON)}$, power losses can be substantially reduced. For example, a 60V, 100A-rated MOSFET with an $R_{DS(ON)}$ of 4.3mΩ at 125°C can be sourced for under $1 in 1k-unit quantities. Under a 40A load, the power dissipation would be:

$$P = I^2 \times R_{DS\_ON} = 40^2 \times 0.0043 = 6.88W$$

This is significantly lower than the diode-based alternative. Under normal conditions, each MOSFET would carry only 20A, resulting in even lower conduction losses due to reduced $R_{DS(ON)}$ at lower temperatures.

To select an appropriate FET:

- Use distributor search tools to filter by key parameters such as breakdown voltage, current rating, and $R_{DS(ON)}$.
- Evaluate cost-performance trade-offs, as lower $R_{DS(ON)}$ devices may reduce or eliminate the need for heat sinks or forced airflow, potentially lowering overall system costs.
- Confirm that the voltage drop across the FET under a full load remains within acceptable limits. For instance, with 40A through a 4.3mΩ device, the voltage drop is:

$$V = I \times R_{DS\_ON} = 40 \times 0.0043 = 0.172V$$

This results in a voltage deviation of only 0.3% from a 48V rail—well within typical regulation tolerances.

Finally, use this power dissipation data to inform thermal design decisions, considering the cumulative heat load from all system components and any planned cooling strategies.

IMPORTANT NOTICE