

Redundant supply topologies for automotive applications using ideal diode controllers

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Introduction

Redundant power supplies use more than one power-supply unit to provide the necessary power for a load. They help increase a system's reliability and availability, and ensure system safety in case one of the power-supply units fails. Redundant power supplies are especially important in automotive systems for safety-critical applications, such as automated driving, where a loss of power could result in serious consequences.

ORing and priority power multiplexing are two popular techniques for implementing redundant power supplies in automotive systems. In ORing, the system selects the highest-voltage power source from multiple inputs, while power multiplexing allows the system to switch between different power sources based on priority levels or other criteria. Designers have traditionally used Schottky diodes, P-channel field-effect transistors or a combination of both for redundant circuits in a power supply.

Ideal diode controllers are integrated circuits (ICs) that can control external metal-oxide semiconductor field-

effect transistors (MOSFETs) to emulate the behavior of ideal diodes. They offer several advantages over conventional diodes, such as lower power dissipation, higher current capability, reverse polarity protection, reverse current blocking and load dump protection. Ideal diode controllers can also provide inrush current limiting and overvoltage and overcurrent protection.

In this article, we will discuss the concept and benefits of ORing and power multiplexing using ideal diode controllers, the different types and architectures of ORing and power multiplexing circuits, and the challenges and solutions for implementing ORing and power multiplexing using ideal diode controllers in automotive systems.

ORing and power multiplexing techniques

Both ORing and power multiplexing techniques use ideal diodes to connect multiple input power sources to a single output load, but they differ in how they select and switch between different input sources. **Figure 1** shows a typical use case for power supply ORing and priority multiplexing.

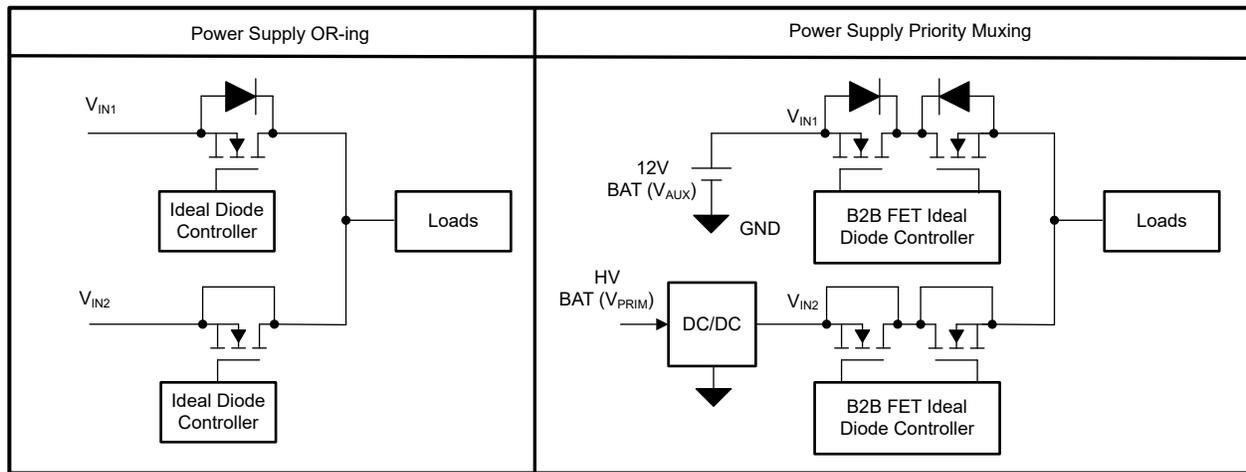


Figure 1. Typical use case of ORing and priority power multiplexer solution.

An ORing circuit facilitates system selection of the best available power source from multiple inputs, based on the highest input voltage. The ideal diodes act as switches that turn on when the input voltage is higher than the output voltage, and turn off when the input voltage is lower than the output voltage. This way, the ORing circuit ensures that the input source with the highest voltage is connected to the output, and prevents reverse current flow and cross conduction between the input sources. If the input power supplies are almost equal, it is possible that both power supplies share the load without any circulating current between them. Thus, reverse current blocking is the primary feature required for realizing an ORing circuit.

A power multiplexing circuit allows the system to switch between different power sources irrespective of the voltage magnitude, based on criteria such as source priority or input voltage availability and magnitude. In this configuration, the control circuit needs to switch power paths between each power supply and load on and off, controlled by its own priority logic or an external signal, such as a microcontroller general-purpose input/output pin. The power multiplexing circuit ensures that only one input source is connected to the output at any point in time, and prevents reverse current flow and cross conduction between the input sources. The circuit in this configuration is therefore required to have both

reverse current blocking and load path on and off control features to enable the prioritized power supply to serve the load.

Typical application circuits for power-supply ORing

ORing circuits are popular in automotive subsystems such as infotainment, body control modules, advanced driver assistance systems and lighting modules; they provide redundancy and reliability in case of a power-supply failure or disconnection. **Figure 2** shows different ORing topologies using ideal diode controller ICs combined with external N-channel MOSFETs.

An effective ORing solution needs to be extremely fast in order to limit the duration and amount of reverse current in case one of the supplies fails. The ideal diode controllers in an ORing configuration constantly sense the voltage difference between the anode and cathode pins, which are the voltage levels at the power sources (V_{IN1} , V_{IN2}) and the common-load (V_{OUT}) point, respectively. A fast comparator shuts down the gate drive through a fast pulldown – within microseconds as soon as $V_{IN} - V_{OUT}$ falls below a designated reverse threshold, typically a few millivolts. Along with a fast reverse-current detection comparator, TI ideal diode controllers have a linear gate regulation scheme that

ensures zero DC reverse current in the event of an input supply loss.

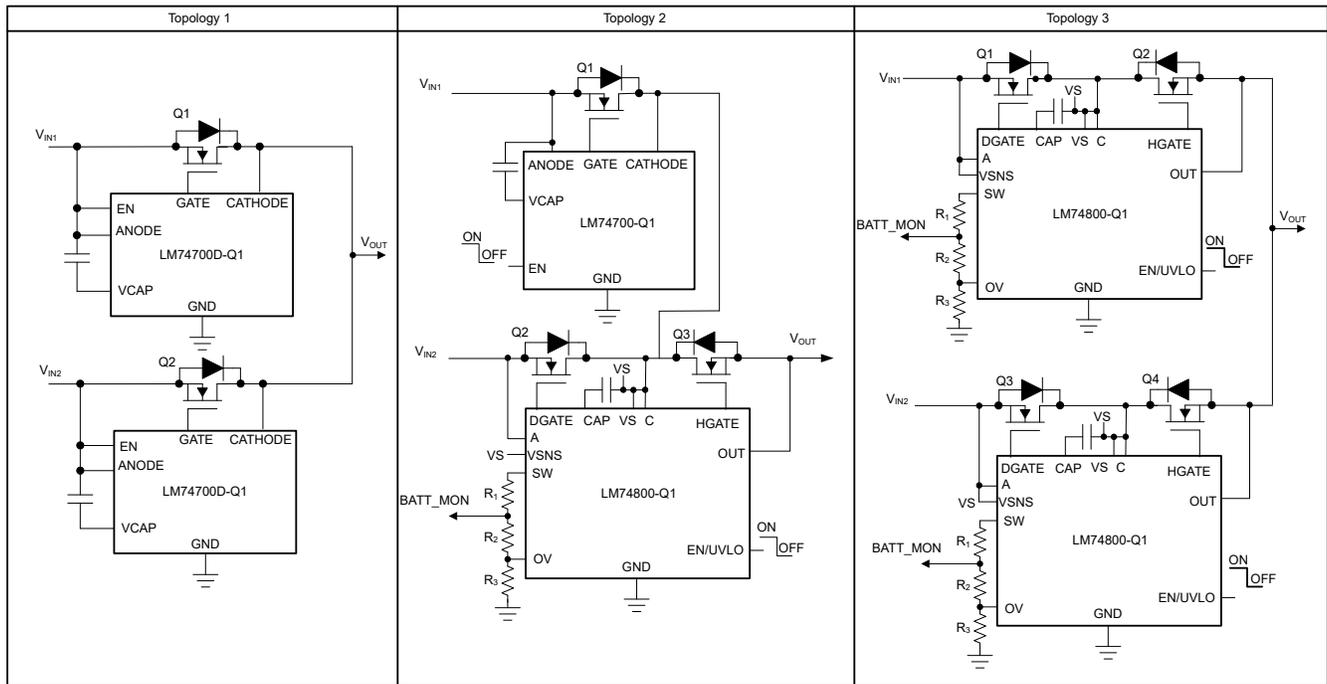


Figure 2. Typical ORing topologies using ideal diode controllers.

Few subsystems require disconnecting the load from the power supplies to achieve low quiescent current or to protect the system from fault conditions. Topology No. 2 in Figure 2 shows a typical application circuit for a dual-supply input ORing with a common load disconnect control using TI's LM7480-Q1 and LM7470-Q1 devices. FET Q1 and Q2, driven by the LM7470-Q1 and LM7480-Q1, respectively, provide ORing functionality, whereas the Q3 FET driven by the LM7480-Q1 can isolate the load from power supplies. When V_{IN1} is greater than V_{IN2} , the independent control of FETs by the LM7480-Q1

allows Q2 to block reverse current, while Q3 remains on, connecting V_{IN1} to V_{OUT} .

Topology No. 3 in Figure 2 shows a typical application circuit for ORing with load disconnect functionality for individual rails, thus allowing system designers to assign different load disconnect criteria for each rail.

Figure 3 and Figure 4 shows power-supply ORing switchover performance between two power-supply rails where $V_{IN1} = 12V$ and $V_{IN2} = 15V$.

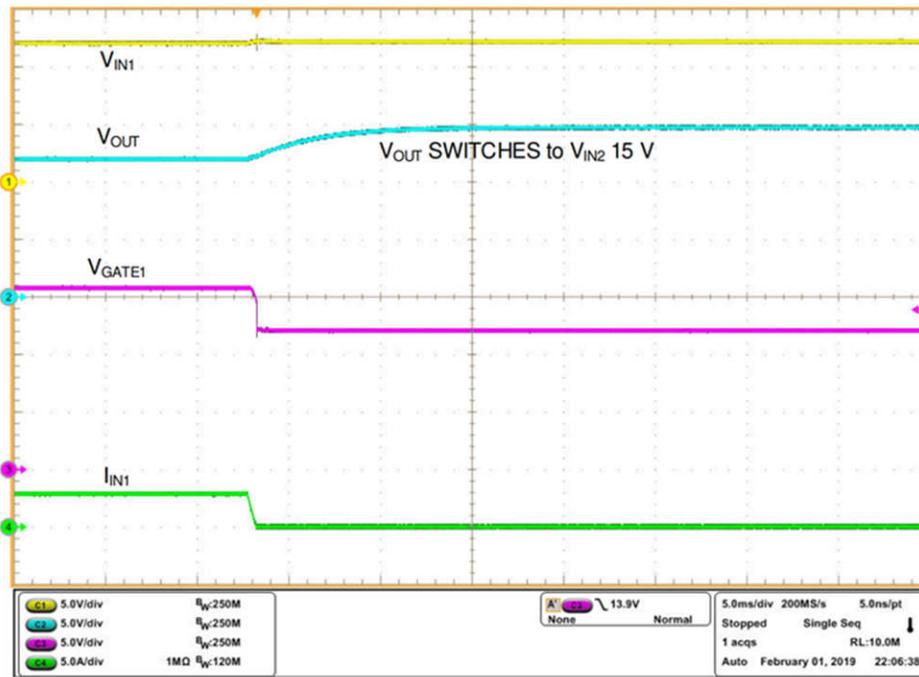


Figure 3. Supply switchover from VIN1 to VIN2.

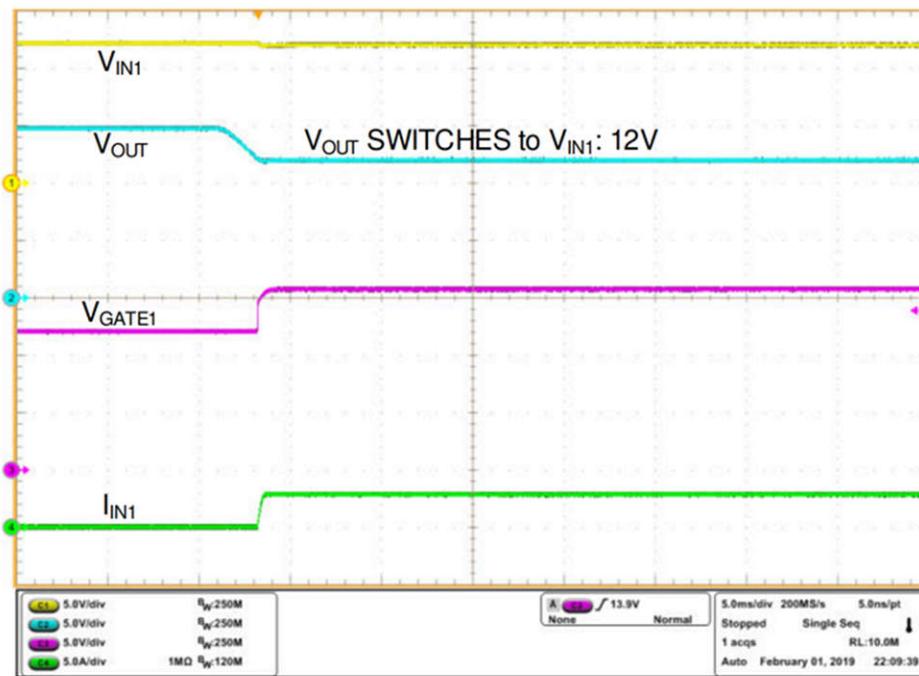


Figure 4. Supply switchover from VIN2 to VIN1.

Priority power multiplexer configuration

A priority power multiplexer automatically transitions the primary power supply to an auxiliary (AUX) or secondary power supply when the primary supply voltage drops below a designated threshold. When available and within acceptable limits, the primary power supply is always the first source for powering the load. For example, if an upstream smart fuse in a power distribution unit trips on the primary power supply to a subsystem, the priority power multiplexer circuit automatically connects the AUX supply to the output and disconnects the primary supply from that output to avoid any disruptions in the subsystem operation. If the upstream smart fuse is reset and the primary supply voltage rises to an acceptable threshold, then the priority power multiplexer circuit automatically connects the primary supply back to the output and disconnects the AUX supply.

A power multiplexer circuit requires a controller such as the LM74800-Q1 or **LM74900-Q1** to control two back-to-back MOSFETs on each power-supply rail. When both

primary and AUX power supplies are present and within the acceptable range, and the primary is powering the load, the AUX path controller must block reverse current when the primary power-supply voltage is higher than the AUX supply. Likewise, the AUX path controller must block forward current when the primary voltage is lower than the AUX. This ensures that the primary supply, which has the highest priority, powers the load and the AUX supply is isolated from both the primary supply and the load.

The **LM74900-Q1** ideal diode controller drives and controls external back-to-back N-channel MOSFETs to emulate an ideal diode rectifier with power path on or off control and overcurrent and overvoltage protection. **Figure 5** is a schematic for a priority power multiplexer using two **LM74900-Q1** devices in a common drain topology. The overvoltage pin of the **LM74900-Q1** in the V_{AUX} path is configured such that the V_{AUX} power supply connects to the load immediately when V_{PRIM} is disconnected for any reason and ensures continuous supply to the load.

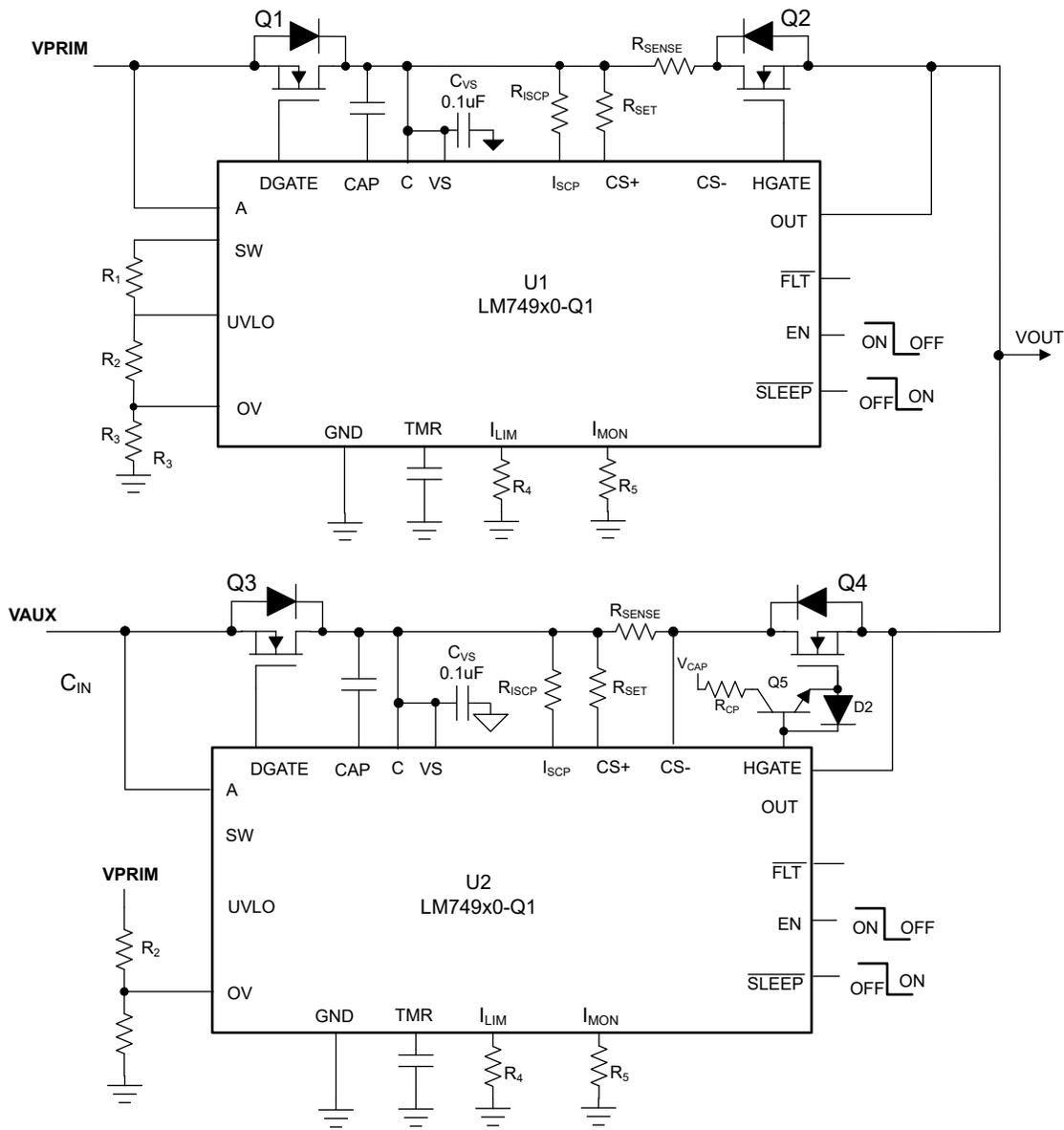


Figure 5. Typical priority power multiplexer application circuit using the LM74900-Q1.

A power multiplexer circuit aims to keep the output voltage drop low while the load switches to power from V_{AUX} when V_{PRIM} is cut off or out of the acceptable range. To keep the output voltage drop low during the transition, the load switch FET (Q4), driven by the **LM74900-Q1** in the V_{AUX} path, must be turned on very quickly while the power path of the V_{PRIM} is turned off (by turning off Q2). But the HGATE pin is designed to source only 55µA of gate current to achieve slow startup for inrush current limiting, which is too low to turn the HGATE high quickly. A small circuit with a resistor (R_{CP}),

a transistor (Q5) and a diode (D2) can increase the HGATE source current. It is also possible to increase the gate source current by connecting the emitter of Q5 to the gate of Q4, as Q5 allows the charge-pump capacitor to pull the HGATE high directly. Alternately, you could adjust the Q4 gate source current by changing the resistor value of R_{CP} . D2 provides a path around Q5 to turn off Q4.

Figure 6 shows the waveform captured during the instance that V_{PRIM} disconnects and the load transitions to the V_{AUX} rail quickly. The HGATE of the AUX rail turns on within $20\mu\text{s}$ to reduce the drop-in output voltage.

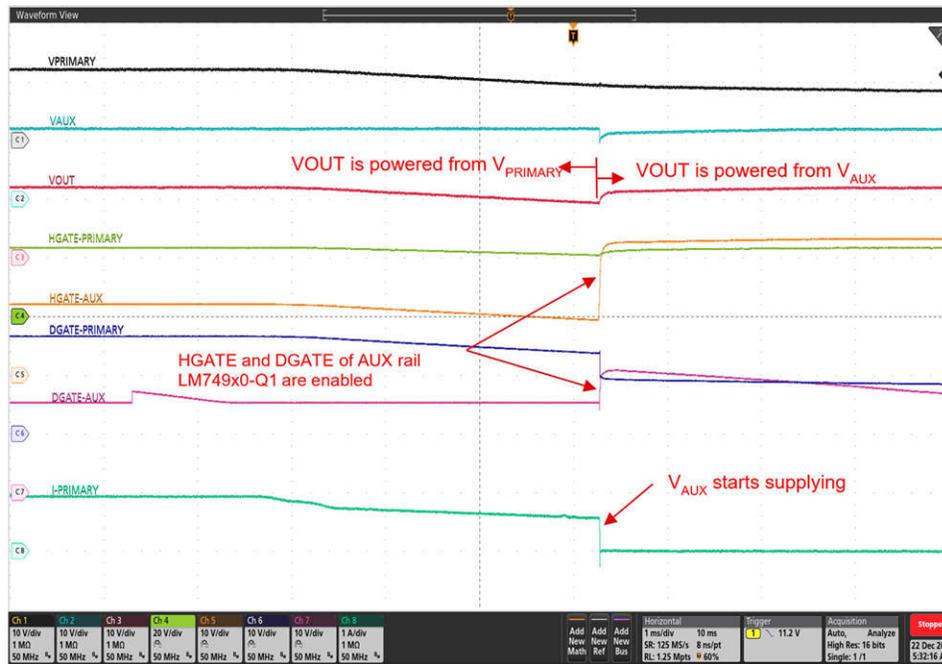


Figure 6. V_{PRIM} to V_{AUX} switchover in a power multiplexer application

Figure 7 shows a waveform of the instant when V_{PRIM} recovers back to an acceptable level and the priority power multiplexer circuit smoothly transitions the load with minimal voltage drop to V_{PRIM} , as it has higher priority over V_{AUX} .

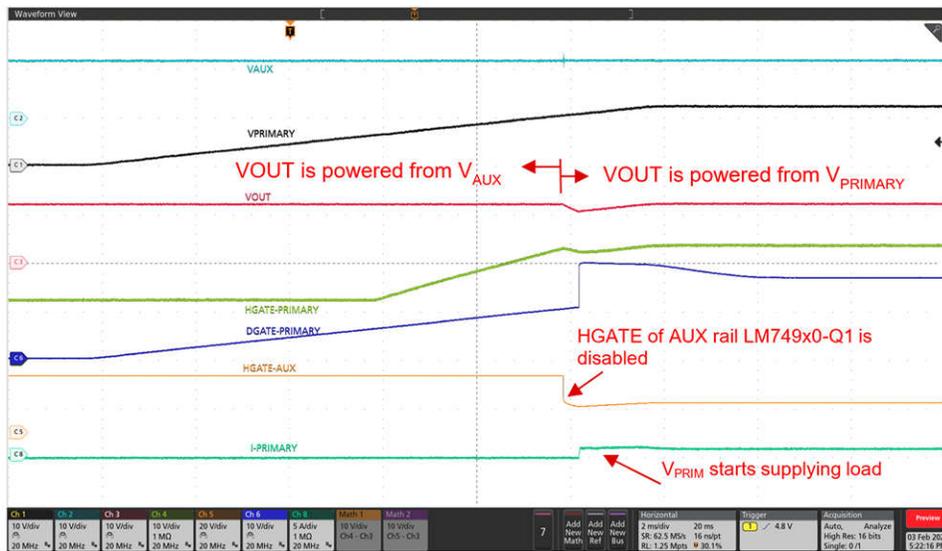


Figure 7. V_{AUX} to V_{PRIM} switchover in a power multiplexer application.

Table 1 shows various ideal diode controllers and the redundant supply topologies that they can support based on individual feature sets.

Ideal diode controller	ORing configuration	Power multiplexing configuration (back-to-back FET control)	
		Common drain topology	Common source topology
LM5050-1-Q1	✓	✗	✗
LM70700-Q1	✓	✗	✗
LM7480-Q1	✓	✓	✓
LM74720-Q1	✓	✓	✗
LM74900-Q1	✓	✓	✗
LM74930-Q1	✓	✗	✓

Table 1. List of ideal diode controllers for redundant supply topologies.

Conclusion

Ideal diode controllers with advanced features enable the different architectures of ORing and power multiplexing circuits. Ideal diode controllers offer features and advantages such as reverse polarity protection, reverse current blocking, load dump protection, active rectification, overvoltage protection and inrush current limiting, thus enabling complete input power-path protection and helping ensure system reliability and safety.

References

1. Texas Instruments: [Six System Architectures with Robust Reverse-Battery Protection Using an Ideal-Diode Controller.](#)
2. Texas Instruments: [Addressing Automotive Reverse Battery Protection Topologies with LM749x0-Q1..](#)
3. Texas Instruments: [Priority Power MUX Using Ideal Diodes in Automotive Zonal Modules.](#)

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