

# Addressing Automotive Reverse Battery Protection Topologies with LM749x0-Q1



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## ABSTRACT

With the emergence of new trends in automotive electronics such as autonomous driving, Advanced Driver Assistance Systems (ADAS), advanced car infotainment systems, system designers are facing new challenges, particularly in designing automotive front-end power systems. With rise in Electronic Control Unit (ECU) processing power typically ranging from 100 W–1000 W, traditional reverse polarity protection solutions such as Schottky diodes and P-FETs no longer become a viable solution at these system power levels due to poor efficiency, need of thermal management, and an increase in PCB space. Keeping system level safety in mind, redundancy requirements especially in autonomous driving are pushing need for newer system architectures like input supply ORing and power MUXing in dual battery-based systems. Robust protection requirements during stringent automotive Electromagnetic Compatibility (EMC) testing adds another layer of complexity while designing these front-end power systems.

This application note highlights how the new LM749x0-Q1 dual gate drive ideal diode controller with integrated overvoltage and overcurrent protection enables various front-end protection circuit design architectures based on system requirements.

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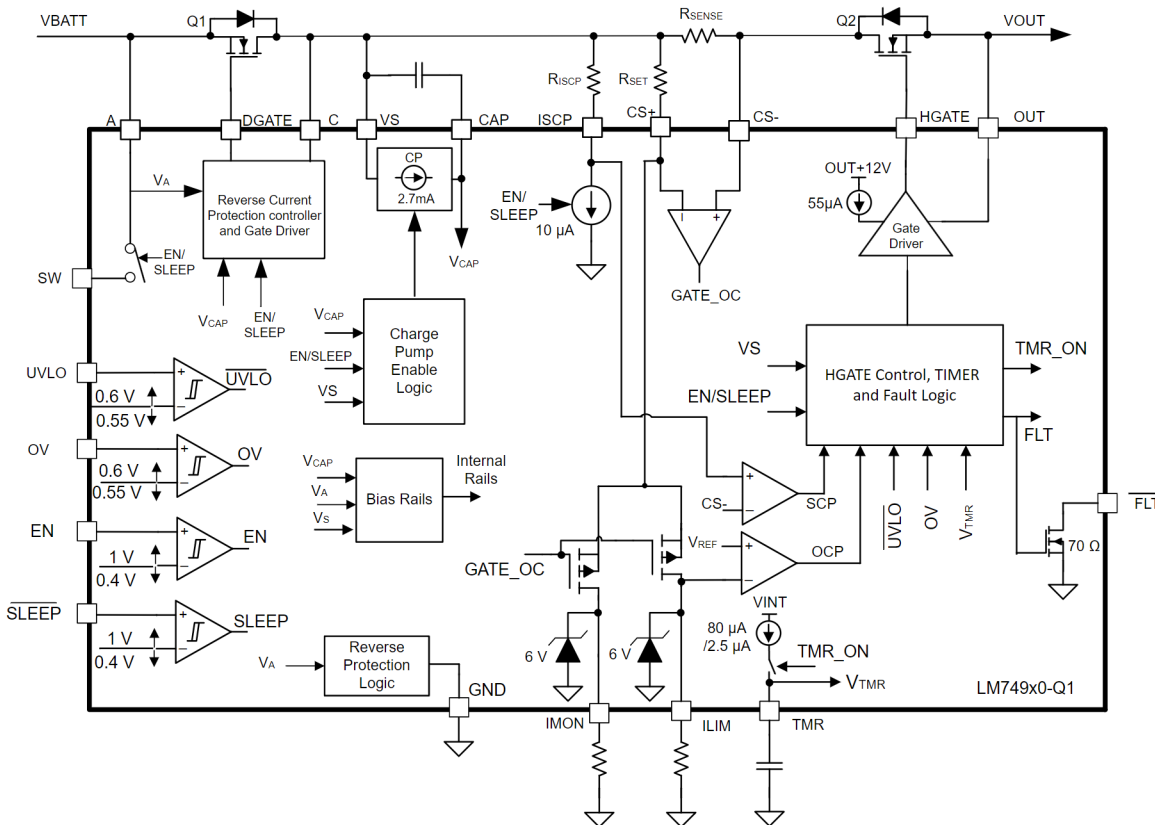
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**1 LM749x0-Q1 Ideal Diode Controller Overview**

The LM749x0-Q1 family of Ideal Diode controller drive back-to-back external N-Channel MOSFETs to realize low loss power path protection with circuit breaker, under and over voltage protection functionality. The wide input supply of 3 V to 65 V allows protection and control of 12-V and 24-V automotive battery powered ECUs. The device can withstand and protect the loads from negative supply voltages down to -65 V. An integrated ideal diode controller (DGATE) drives the first MOSFET to replace a Schottky diode for reverse input protection and output voltage holdup. With a second MOSFET in the power path the device allows load disconnect (ON/OFF control) and overvoltage protection using HGATE control. The device features an adjustable overvoltage cut-off protection feature. With Common Drain configuration of the power MOSFETs, the mid-point can be used for OR-ing designs using another ideal diode. The LM749x0-Q1 has a maximum voltage rating of 65 V. The device has accurate current sensing output (IMON) with typical accuracy of (+/-10%) enabling systems for energy management. The device has integrated two level over current protection with FLT output with complete ability for adjustments of thresholds and response time. Auto-retry and latch-off fault behavior can be configured. The device offers adjustable over voltage and under voltage protection, providing robust load disconnect in case of voltage transient events.

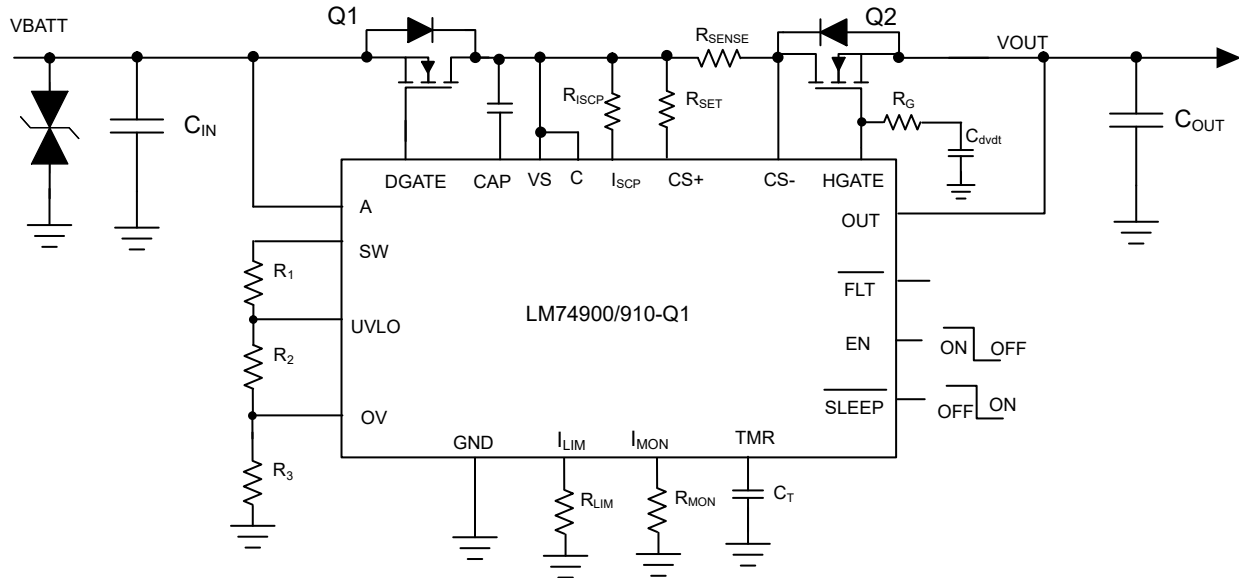
LM749x0-Q1 features two different low power modes based on status of EN and SLEEP pin. In SLEEP mode (SLEEP =Low, EN=High) the device consumes only 6-µA current by turning off both the external MOSFET gate drives and internal charge pump but at the same time providing internal bypass path to power up always ON loads with limited current capacity. With the enable pin low, device enters into ultra low power mode by completely cutting off loads with typical current consumption of 2.87 µA. The high voltage rating of LM749x0-Q1 helps to simplify the system designs for automotive ISO7637 protection. The LM749x0-Q1 is also suitable for ORing and priority power MUX applications.



**Figure 1-1. Functional Block Diagram**

## 2 Design 1: Automotive Reverse Battery Protection with Overvoltage, Undervoltage and Overcurrent Protection with Fault Output

A typical application circuit of LM749x0-Q1 configured in common-drain topology to provide reverse battery protection with overvoltage protection is shown in [Figure 2-1](#)

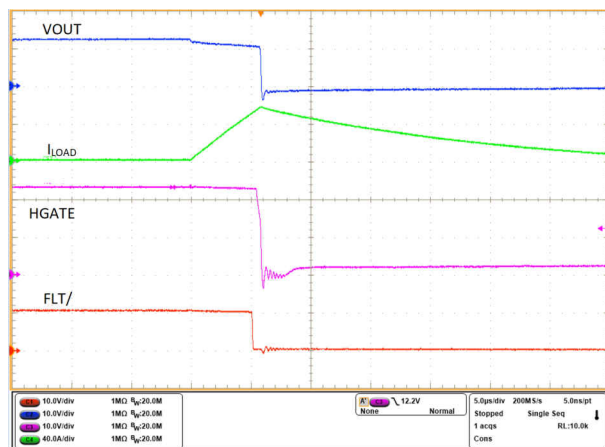


**Figure 2-1. Typical Application Circuit for 12-V Reverse Battery Protection Solution**

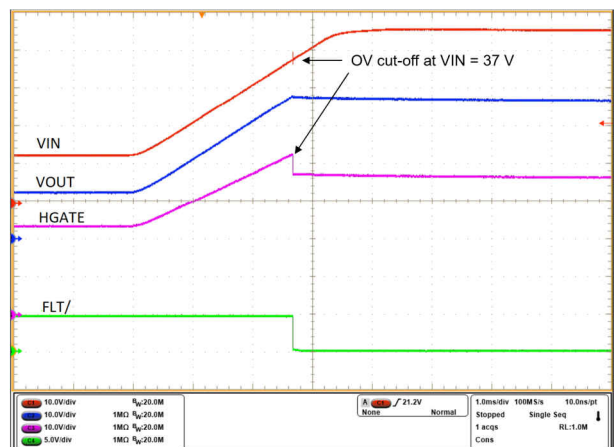
LM749x0-Q1 DGATE drives an ideal diode FET Q1 while HGATE drives load disconnect FET Q2. Ideal diode FET provides protection against system events such as input reverse battery connection, reverse current blocking during automotive transients such as ISO7637-2 Pulse 1, input short interruption events (LV124 E-10) and AC ripple on the battery line (ISO16750-2, LV124 E-06).

Load disconnect FET Q2 provides powepath cut-off functionality in case of input undervoltage, overvoltage and output short circuit and overload conditions. LM749x0-Q1 offers fully adjustable undervoltage, overvoltage, overcurrent and short circuit thresholds to ensure device offers robust performance against various automotive EMC transients. For more details on the design process, refer to [LM749x0-Q1 device data sheet](#).

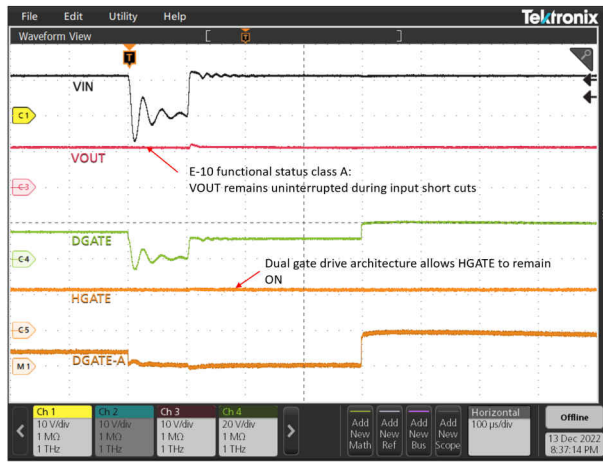
[Figure 2-2](#) to [Figure 2-5](#) shows some of the key performance plots of LM749x0-Q1 used as back to back FET driver for input powerpath protection.



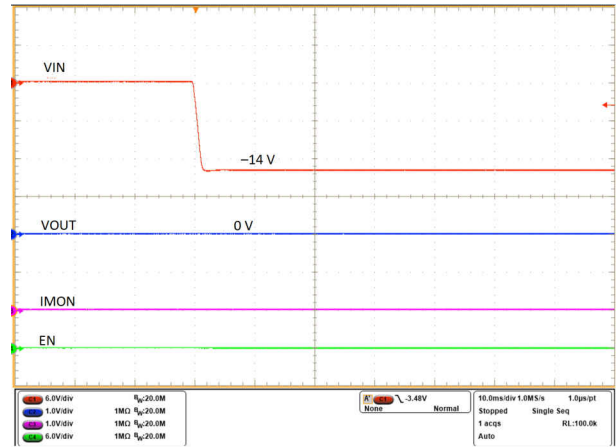
**Figure 2-2. Performance During Output Short-Circuit Event**



**Figure 2-3. Performance During Input Overvoltage Event (HGATE Cut-Off)**



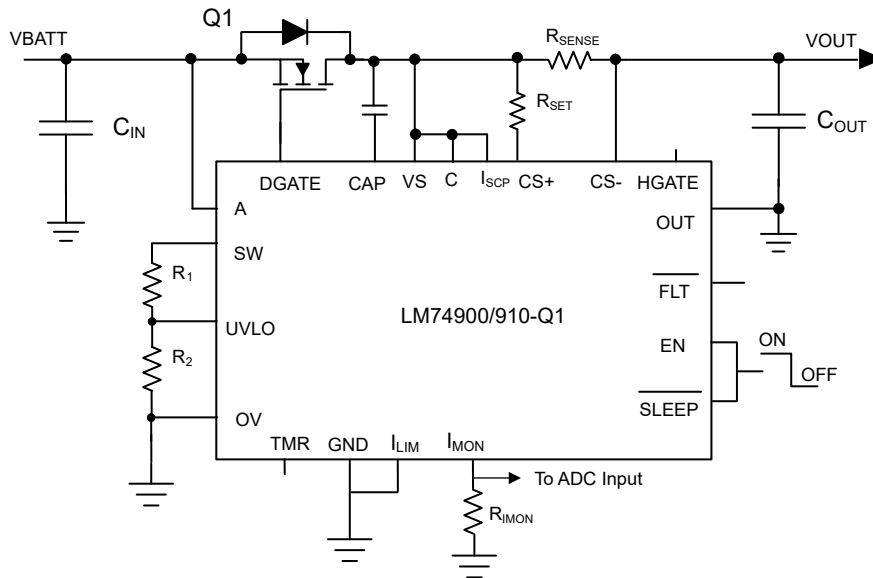
**Figure 2-4. Performance During Input Microshort Testing – 100- $\mu$ s Input Short Duration**



**Figure 2-5. Performance During Input Reverse Voltage Hot-Plug**

### 3 Design 2: LM749x0-Q1 as Ideal Diode Controller with Current Monitoring, Overcurrent and Undervoltage Fault Indication

Figure 3-1 shows the LM749x0-Q1 configuration for ideal diode-only designs.



**Figure 3-1. Typical Application Circuit for Ideal Diode-Only Designs**

In this configuration, the device will drive only ideal diode FET providing input reverse polarity protection and reverse current blocking functionality. As application diagram depicts powerpath disconnect functionality is not available. Device can monitor load current using integrated current sense amplifier and provide the load current information on IMON pin for system power budgeting. Certain system fault indication (no fault protection) are still present over device fault pins such as input undervoltage, load overcurrent, load short circuit events. For application where only fault indication is required, user can populate respective components to configure undervoltage (UVLO), overcurrent (ILIM), and short circuit (ISCP) thresholds.

LM749x0-Q1 when used to drive only ideal diode FET following pin configuration can be followed for unused pins

HGATE, TMR, SLEEPOV: needs to be left floating

ILIM, OV, OUT: needs to be connected to GND



## 5 Feature Comparison: LM749x0-Q1 as Ideal Diode FET and High Side Driver Topology

Table 5-1 showcase the list of functionality and features achievable with LM749x0-Q1 Ideal Diode FET only and High-side switch controller topology.

**Table 5-1. Feature Comparison : LM749x0-Q1 as Ideal Diode FET and High Side Driver**

Functionality/Feature	LM749x0-Q1 as Ideal Diode FET controller (Design 2)	LM749x0-Q1 as High Side Driver (Design 3)
Input Reverse Polarity Protection	√	×
Reverse Current Blocking	√	×
Input Undervoltage Lockout	√ (Only undervoltage indication)	√
Overvoltage Protection	×	√
Overcurrent and Short Circuit Protection	×	√
Inrush Current Control	×	√
Current Monitoring	√	√
Fault Indication	√	√
SLEEP Mode	√ (Ideal diode FET body diode conducts when FET is OFF. No overcurrent or overvoltage protection)	√ (Internal bypass FET conducts in SLEEP mode with protections such as overcurrent and overvoltage latch off)

## 6 Design 4: Dual Supply OR-ing with Common Powerpath Disconnect Function

System designs with redundancy are common architecture in safety-critical designs such as ADAS systems. In these designs, the ECU input power can be from more than one supply connection.

Figure 6-1 shows the application circuit for a dual-supply input ORing with load disconnect control using the LM749x0-Q1 and LM74700-Q1 devices.

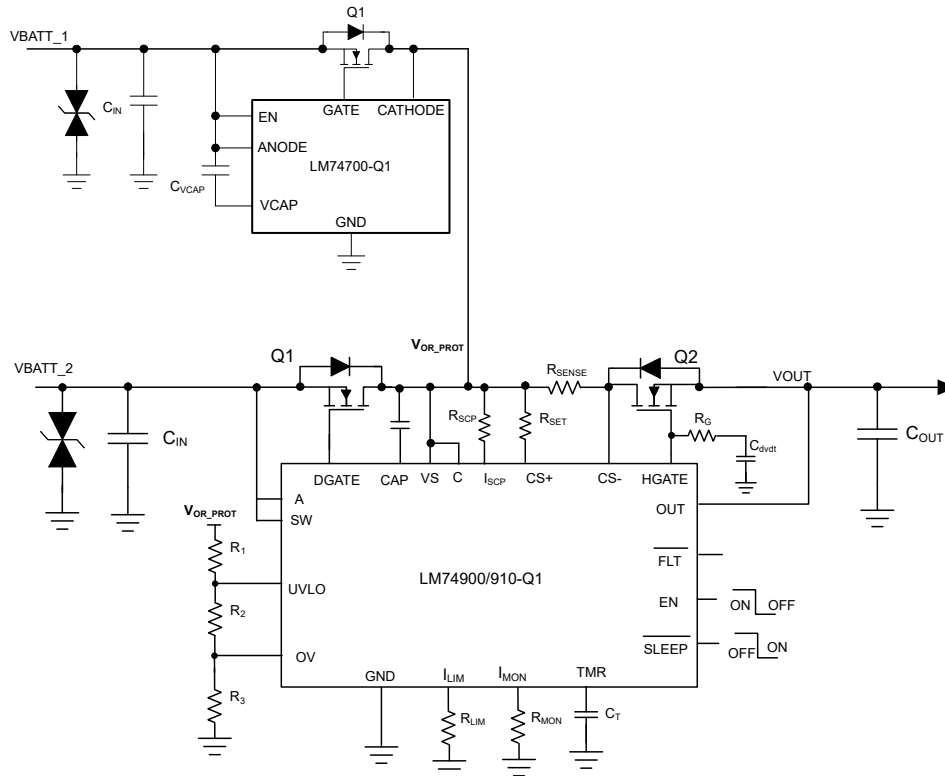


Figure 6-1. Typical Application Circuit for Supply ORing With Load Disconnect Control Designs

Based on the system redundancy architecture VBATT\_1 and VBATT\_2 can either be powered from two separate battery sources or can be connected to a common battery source through separate cables running through the fuse box. The downstream supply comes from ORed inputs and the various system fault protection features and disconnect switch operation is similar to as described in Section 2.



## 7 Design 5: LM749x0-Q1 as Priority Power MUX Controller

Another architecture of power-supply redundancy is based on a system with one primary source like a vehicle battery and an auxiliary supply source like a DC/DC converter or a large storage capacitor. When both the supplies are present, then the priority should be given to the primary source and the system should be powered from the primary source path independent of the supply voltage levels. In the absence of the primary supply or when the primary supply drops to a specified undervoltage level, then the downstream should switch over to the auxiliary power path. The transition should be fast enough ensuring that the output voltage does not drop below the undervoltage lock out level of the downstream circuit.

Figure 7-1 shows LM749x0-Q1 application circuit for Priority Power MUX design.

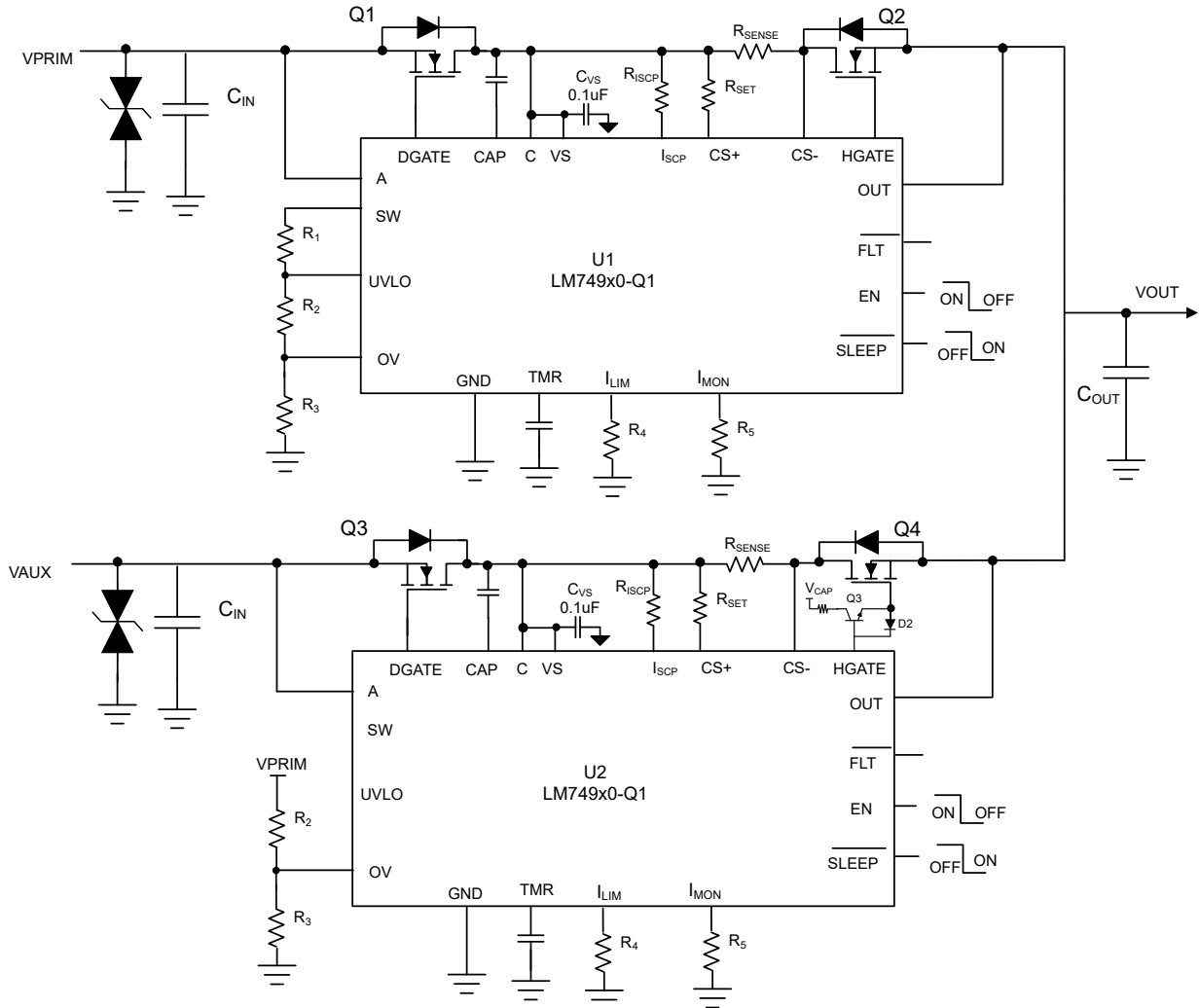


Figure 7-1. Typical Application Circuit for Priority Power MUXing Designs

The OV pin connection of the AUX channel is from the primary supply path. The OV falling threshold of U2 is set at the undervoltage level of primary supply. During normal operation, primary path is ON. OV of U2 is high and this keeps GATE of Q<sub>4</sub> OFF, disconnecting the auxiliary supply path to the load. When the primary supply is dropped or when it reaches a set undervoltage level, then Q<sub>2</sub> turns OFF, disconnecting the primary path. At the same time, OV threshold of U2 goes low and HGATE starts rising after a delay of 8-μs (typical). HGATE has gate drive strength, I<sub>(HGATE)</sub> of 53 μA. Q<sub>5</sub> enables higher GATE drive levels up to 600-μA for fast turn ON of Q<sub>4</sub>. U1 on the primary path remains active as its Vs supply is powered from the auxiliary path through the body diode of FET Q<sub>2</sub>. When the primary supply is connected back, then the system output immediately gets connected to the primary path. OV of U2 goes high and Q<sub>4</sub> turns OFF within 4-μs (typical).

## 8 Feature Comparison: Dual OR-ing and Priority Power MUX Controller Topologies

Table 8-1 showcase the list of functionality and features achievable with LM749x0-Q1 Dual OR-ing with load disconnect and Priority power MUX topology.

**Table 8-1. Feature Comparison: LM749x0-Q1 as Dual OR-ing and Priority Power MUX Controller**

Functionality/Feature	LM749x0-Q1 as Dual OR-ing and Load disconnect Controller (Design 4)	LM749x0-Q1 as Priority Power MUX controller (Design 5)
Supply Priority	×	√
Input Reverse Polarity Protection	√	√
Reverse Current Blocking	√	√
Input Undervoltage Lockout*	√	√
Overvoltage Protection*	√	√ (No overvoltage protection on auxillary rail $V_{AUX}$ )
Overcurrent and Short Circuit Protection*	√	√
Inrush Current Control*	√	√
Current Monitoring*	√	√
Fault Indication*	√	√
SLEEP Mode*	√	√

### Note

\* For Dual OR-ing with load disconnect topology, all the protection features and respective thresholds will be common for both the rails. While for priority power MUX topology, each controller can be configured with separate protection feature threshold providing higher degree of flexibility.

## 9 Summary

LM74900-Q1, LM74910-Q1 offers a complete automotive reverse battery input powerpath protection. The device offers adjustable overvoltage, undervoltage, and two level current protection to provide complete design flexibility to tune these features as per end application requirements. LM749x0-Q1 with dual gate drive architecture can address various MOSFET control topologies such as Ideal Diode FET only, High side switch controller only, Dual OR-ing with load disconnect, and Priority power muxing. This process enables system designers to use LM749x0-Q1 as a plug and place component to meet various automotive front end protection solutions with a common controller.

## 10 References

- Texas Instruments, [Automotive Ideal Diode With Circuit Breaker, Undervoltage and Overvoltage Protection With Fault Output](#), data sheet.
- Texas Instruments, [LM74700-Q1 Low  \$I\_Q\$  Reverse Battery Protection Ideal Diode Controller](#), data sheet.
- Texas Instruments, [Basics of Ideal Diodes](#), application note.
- Texas Instruments, [Six System Architectures With Robust Reverse Battery Protection Using an Ideal Diode Controller](#), application note.

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