

# 3 Ways to Design a Low Quiescent-current ( $I_Q$ ) Automotive Reverse Battery Protection System



Dilip Jain

The increasing number of electronic circuits in vehicles is placing greater demand on the amount of power consumed from the battery. The battery supply remains on even when the car is parked or turned off, in order to support such features as remote key entry and security.

Since all vehicles run on a finite battery supply, it's important to find a way to add more functionality – particularly when designing automotive front-end power systems – without adding significant drain on the battery. The need to comply with stringent electromagnetic compatibility (EMC) standards such as the International Organization for Standardization's ISO7637 and the LV 124 standard, which was established by German automotive manufacturers, directly affects the overall design of front-end reverse battery protection systems. Several original equipment manufacturers specify the total current consumption when the vehicle is in a parked state at  $<100 \mu\text{A}$  per electronic control unit (ECU) in 12-V battery-powered systems and  $<500 \mu\text{A}$  in 24-V battery-powered systems.

In this article, I will review three approaches to designing a low quiescent-current ( $I_Q$ ) automotive reverse battery protection system.

## Using a T15 as an Ignition or Wakeup Signal

The first approach to designing a low  $I_Q$  reverse battery protection system is to use a terminal 15 (T15) as an ignition or wakeup signal. The T15 is a wire terminal that disconnects from the battery when the vehicle's ignition is off. Using a T15 as an external wakeup signal is one of the most traditional ways to operate ECUs in sleep or active mode. [Figure 1](#) shows one example.

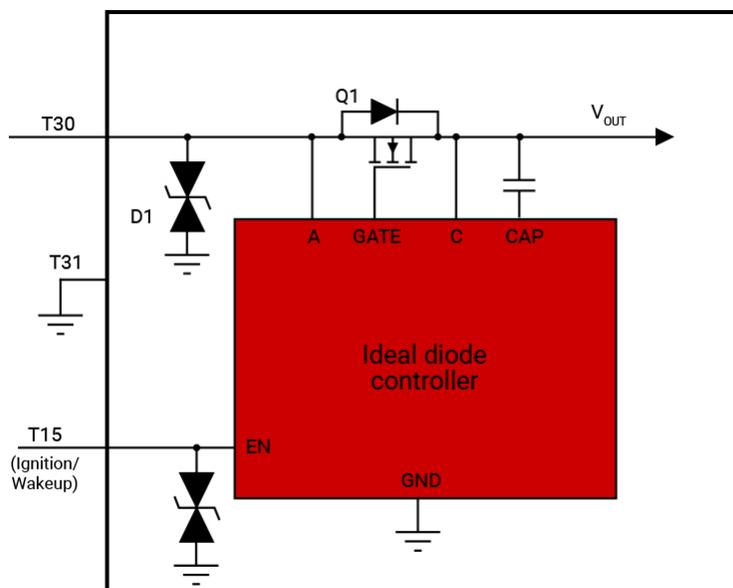
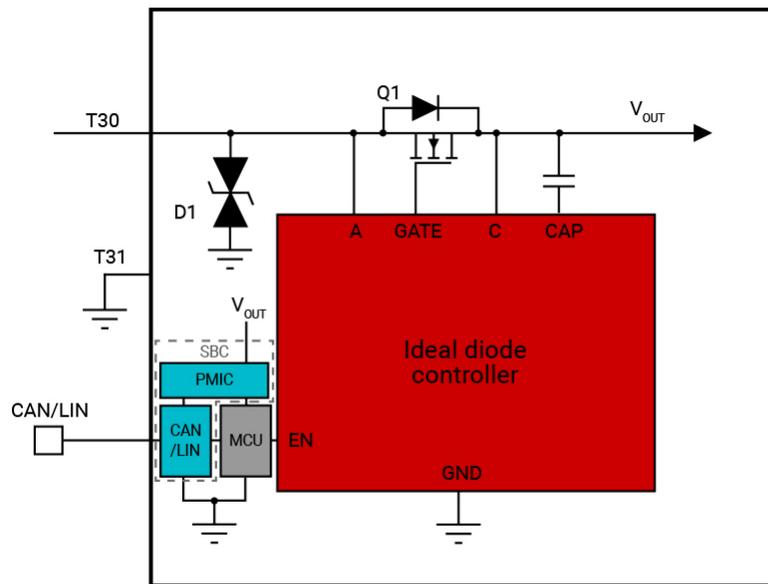


Figure 1. Reverse Battery Protection in an Automotive ECU Using a T15 for Wakeup

When the ignition is on, the T15 connects to the battery voltage ( $V_{BATT}$ ) potential, which drives the enable (EN) pin of the ideal diode logic high. The ideal diode controller, in active mode, while enabling the charge pump, control and field-effect transistor (FET) driver circuits, actively controls the external FET for ideal diode operation. When the vehicle is being parked, the T15 drops to 0 V, and the ideal diode controller responds by entering a shutdown state, which turns the charge pump and control blocks off, resulting in an  $I_Q$  consumption of  $< 3 \mu A$ . In this mode of operation, the external FET turns off and the body diode of the FET forms the forward conduction path to power the load. This scheme requires an additional wiring line to the ECUs.

### Using the System's MCU and CAN Wakeup Signal

The second approach is to use the system's microcontroller (MCU) and Controller Area Network (CAN) wakeup. In many cases, the communication channels of the system make a low- $I_Q$  shutdown mode possible. [Figure 2](#) shows an example system design using this approach.



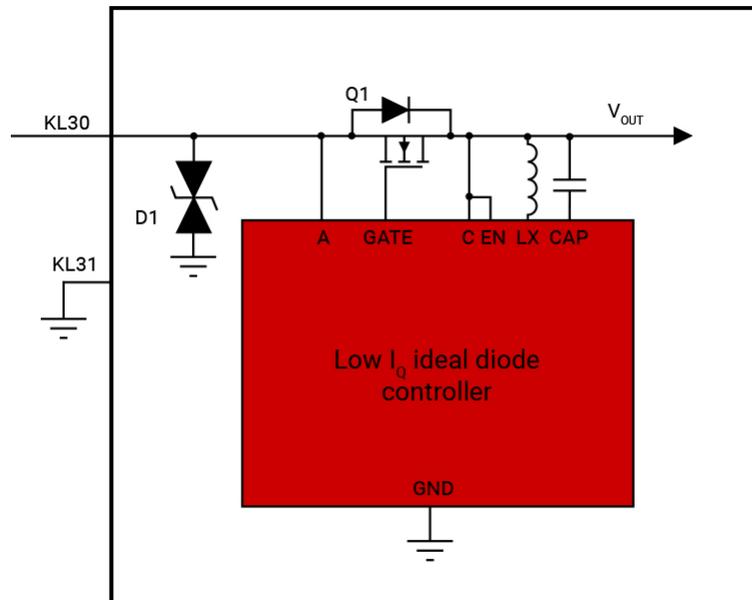
**Figure 2. Low  $I_Q$  Reverse Battery Protection Using an MCU and CAN Wakeup Signal for Enable Control**

The CAN transceivers in the vehicle translate messages from the communication bus to their respective controller – typically an MCU. The transceivers can indicate when functions are unnecessary by issuing a command to go into a standby mode until they are awakened. They then relay the message instructing the controller to place the system in a low-power state – in this case, by driving the EN signal of the ideal diode controller logic low. With more advanced transceivers and system-basis chips, one device can handle multiple functions of this process, transitioning to a low-power state or waking up.

This scheme requires an internal control signal from an MCU (via CAN control).

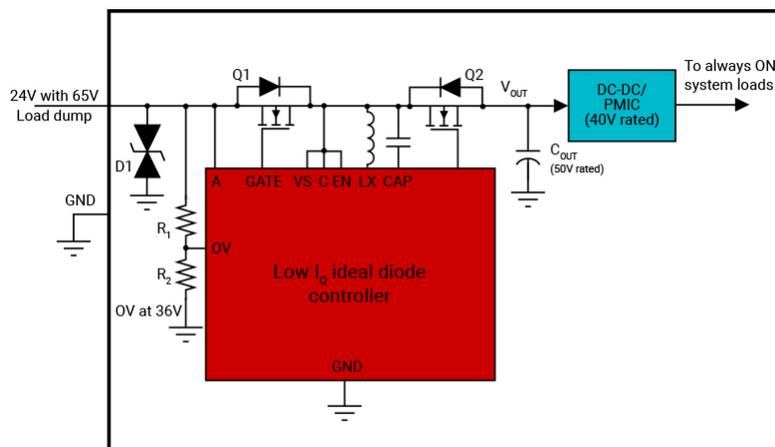
### Using an Always-on Ideal Diode Controller

A third approach is to use an always-on ideal diode controller. Imagine a system design that does not require control signals to enter low-power states. This would eliminate the need for additional wiring or system software dependencies while allowing the ideal diode controller to always be enabled, even during sleep mode. This type of system design is possible using a low- $I_Q$  ideal diode controller such as the LM74720-Q1, LM74721-Q1 or LM74722-Q1, shown in [Figure 3](#). These devices integrate all of the necessary control blocks for an EMC-compliant reverse battery protection design, along with a boost regulator to drive the high-side external MOSFET, which results in  $27 \mu A$  of  $I_Q$  during normal operation. Learn more in the application note, "[Basics of Ideal Diodes.](#)"



**Figure 3. Using an Always-on low- $I_Q$  Ideal Diode Controller without External Enable Control for Reverse Battery Protection**

These ideal diode controllers support reverse battery protection with active rectification and load-disconnect FET control with a back-to-back FET topology to protect the downstream during system faults such as an overvoltage event, as shown in [Figure 4](#).



**Figure 4. Reverse Battery Protection in a 24-v Automotive ECU Using the LM74720-Q1**

With an adjustable overvoltage protection feature, you can use 50-V-rated downstream filter capacitors (instead of 80- to 100-V-rated capacitors) and 40-V-rated DC/DC converters (instead of 65-V rated converters) for a 24-V automotive battery input-based system design.

The LM74720-Q1 and LM74721-Q1 provide fast reverse (0.45  $\mu\text{s}$ ) and forward comparators (1.9  $\mu\text{s}$ ), and a strong 30-mA boost regulator to support and enable resilient and efficient active rectification during automotive AC superimposed testing up to a 100-kHz frequency. The LM74722-Q1 offers two times faster rectification speed than the LM74720-Q1 and LM74721-Q1 devices, with a forward comparator response of 0.8  $\mu\text{s}$ , enabling active rectification frequency up to 200 KHz. The LM74721-Q1 features an integrated drain-to-source voltage (VDS) clamp that enables transient voltage suppressor (TVS)-less reverse battery protection design, resulting in denser system solutions. Read more about active rectification in our application report, "[Active Rectification and its Advantages in Automotive ECU Designs](#)."

---

## Conclusion

The LM74720-Q1, LM74721-Q1 and LM74722-Q1 low- $I_Q$  always-on ideal diode controllers enable you to design an automotive reverse battery protection system without the need for external enable control. With low  $I_Q$ , back-to-back FET driving capabilities and over-voltage protection, these ideal diode controllers enable designs to use downstream components such as capacitors with lower voltage ratings, and reduce the size of printed circuit boards for space-constrained ECUs.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2023, Texas Instruments Incorporated