Technical Article

Understanding the Open-Load Diagnostic in Automotive Motor Drivers: Why Inductive Loads Are Different Than Resistive Loads

Frank Qin

This document was translated from a simplified Chinese source. (ZHCTA16)

In automotive electronic applications, open-load detection, or OLD, is a common diagnostic feature in motor drivers. It helps the system determine whether load connections are abnormal, for example, whether motors, solenoid valves, relay coils, LEDs, or resistive loads maintain a valid connection to the drive output.

During practical debugging, engineers usually verify the open-load diagnostic with a resistive load first. For resistive loads, the diagnostic result is often straightforward: No open load is reported when the load is connected, an error triggers when the load is disconnected, and the system returns to normal via CLR_FLT or other fault-clear mechanisms after reconnection. However, when the load is replaced with a motor, solenoid valve, or other inductive loads, the diagnostic result may no longer be straightforward. In some cases, the system may detect an open load even if the load is physically connected, or the fault bit may be set again after fault clear.

Such conditions cannot be simply interpreted as a false chip report or register clear failure. To analyze the open-load diagnostic, it is necessary to return to the electrical mechanism of the diagnostics.

Judgment Mechanism of Open-Load Diagnostic

From TI's description of open-load detection in motor drivers, the essence of OLD is to judge if there is a valid electrical connection between the load and the drive output. This is usually not done by directly detecting the mechanical state of the connector, but indirectly through the voltage, current, or body diode conduction characteristics of the output node, OUTx.

For passive OLD, for example, the driver's MOSFET is typically kept in Hi-Z during the diagnostics. Inside the device, a diagnostic current is injected into the output node through a current source, and then an internal comparator is used to detect whether the OUTx voltage is above or below the set threshold. If the response of the output node satisfies the open-load criterion, the device either asserts the corresponding OLD status bit or pulls down the nFAULT.

Therefore, the criterion for open-load diagnostic can be summarized as:

Whether the OUTx node exhibits the electrical response expected when a load is connected under a specific drive state, specific diagnostic current path, specific comparator threshold, and specific filter time.

This mechanism is also at the root of many problems. The diagnostic target at the system level is to determine whether the load is connected correctly, while the chip detects whether the current electrical state satisfies the diagnostic criterion. These two are generally consistent for resistive loads, but not necessarily for inductive loads.

Why It Is Easy to Verify the OLD Feature With a Resistive Load

A resistive load is a good diagnostic object. It does not store any energy, and the relationship between current and voltage is almost static. It also has a stable response to either a small diagnostic current in passive OLD or a load current threshold in active OLD.

Copyright © 2026 Texas Instruments Incorporated

In passive OLD, after the resistor is disconnected, the OUTx node can be pulled to the expected state by an internal pull-up or pull-down current source. When the resistor is connected, the diagnostic current forms a path through the load, and the comparator result is relatively deterministic.

In active OLD, if a MOSFET is already on, the device can verify the presence of an open-load condition by detecting whether the MOSFET current remains below IOLD for a time longer than tOLD. For resistive loads, the load current is determined primarily by the supply voltage, load resistance, and conduction path, with a relatively predictable variation.

Therefore, it makes sense to verify the OLD feature with a resistive load. It verifies that the device configuration, fault status, nFAULT, CLR_FLT, and basic hardware connections are OK. However, the resistive load test is not fully representative of the diagnostic behavior under real automotive loads such as motors, solenoid valves, or relay coils.

Inductive Loads Change the Initial Condition of the OUTx Node

Automotive motor drivers often drive loads that are not purely resistive, but rather loads with significant inductive properties. The key characteristic of inductive loads is that the current cannot change abruptly. When the driver changes its switching state, the inductor maintains current continuity through available paths.

These paths may include: High-side MOSFET body diode, low-side MOSFET body diode, on-state MOSFET, synchronous rectification paths, external clamp paths, TVS, or the parasitic paths for loads and harnesses.

Therefore, the OUTx node does not necessarily immediately return to the static state assumed by passive OLD during driver off, PWM off, brake, coast, or direction switch. It is also mentioned in the open-load detection section in the datasheet of the DRV824x-Q1 that, for passive OLD, diagnostics are performed after it is confirmed that the initial voltage on the output node and the capacitive charging and discharging process will not influence the diagnostic result. This indicates that the initial state of OUTx before the diagnosis starts directly affects the judgment of the comparator.

For inductive loads, the stored energy release process must also be considered. Even if the MCU has stopped driving, the load current may still decay through the body diode or MOSFET freewheeling path. At this point, the OUTx voltage may be pulled above VM, below GND, or stay at an intermediate level. If OLD is enabled immediately or re-diagnostics are performed immediately following fault clear, the device may still detect a transient state that does not meet the diagnostic assumption.

Active OLD Is Closely Related to the Freewheeling Path

In addition to passive OLD, automotive motor drivers also commonly have diagnostic needs for active OLD. Active OLD is generally performed during load operation, where an open load is detected based on the load current or body diode voltage during freewheeling.

In DRV8873-Q1 and DRV824x-Q1 devices, for example, active OLD is related to the voltage of the high-side MOSFET body diode during current freewheeling, as introduced in the datasheet. When the energy stored in the inductive load is sufficient to cause the body diode to overshoot beyond VOLA over VM, the device will not detect an open load. If no sufficient voltage spikes are detected, the device may detect an open load. This indicates that the result of active OLD depends not only on the load connection state, but also on whether the freewheeling path conforms to the diagnostic design assumption. The DRV8873-Q1 datasheet explicitly states that in PH/EN and PWM modes, the drive current decays through high-side freewheeling. However, in independent PWM mode, the motor may enter a brake state through high-side or low-side freewheeling. If the system uses low-side freewheeling, the VF of the high-side FET diode may be lower than VOLA, causing the device to report the open-load fault, even though the load is actually connected between OUT1 and OUT2. It is therefore recommended in the datasheet that OLA mode should not be used in this case. This example shows that the open-load fault is not always caused by a physically open load. Under a particular control mode and freewheeling path, the diagnostic mechanism may not observe the electrical signature it requires and therefore interprets the current state as an open load.

Copyright © 2026 Texas Instruments Incorporated

The Negative-Current OLD Is Designed to Handle Specific Freewheeling Scenarios

The DRV89xx-Q1 chips support negative-current active OLD. The datasheet illustrates that in the synchronous rectification scenario, the load current may flow back through the high-side MOSFET or the low-side MOSFET in the form of negative current. If the default OLD is based only on the positive current threshold, the device may incorrectly report an open load because the MOSFET current is below the positive IOLD threshold.

An example waveform of false open-load detection is given in the DRV8912-Q1 datasheet: When OLD_NEG_EN = 0, negative current recirculation may result in false OLD. When OLD_NEG_EN is enabled, the device uses IOLD_NEG as the negative-current detection threshold to avoid this false detection.

This further explains that OLD in automotive motor drivers cannot be analyzed separately from the control mode, PWM state, and current direction. For inductive loads, the current direction and recirculation path are as important as whether the load is actually open.

What Are the Commonalities and Differences in the OLD Mechanisms of Different Devices

Passive OLD, active OLD, and negative-current OLD discussed earlier describe different diagnostic methods. They do not imply that all automotive motor drivers use the same implementation. Even if the feature name is the same, the electrical signatures, allowable drive states, and fault recovery conditions actually observed by the device may differ. Therefore, when comparing the DRV824x-Q1, DRV89xx-Q1, and DRV887x-Q1, it is necessary to further clarify the specific model and interface version, rather than determining the diagnostic method solely based on the family name.

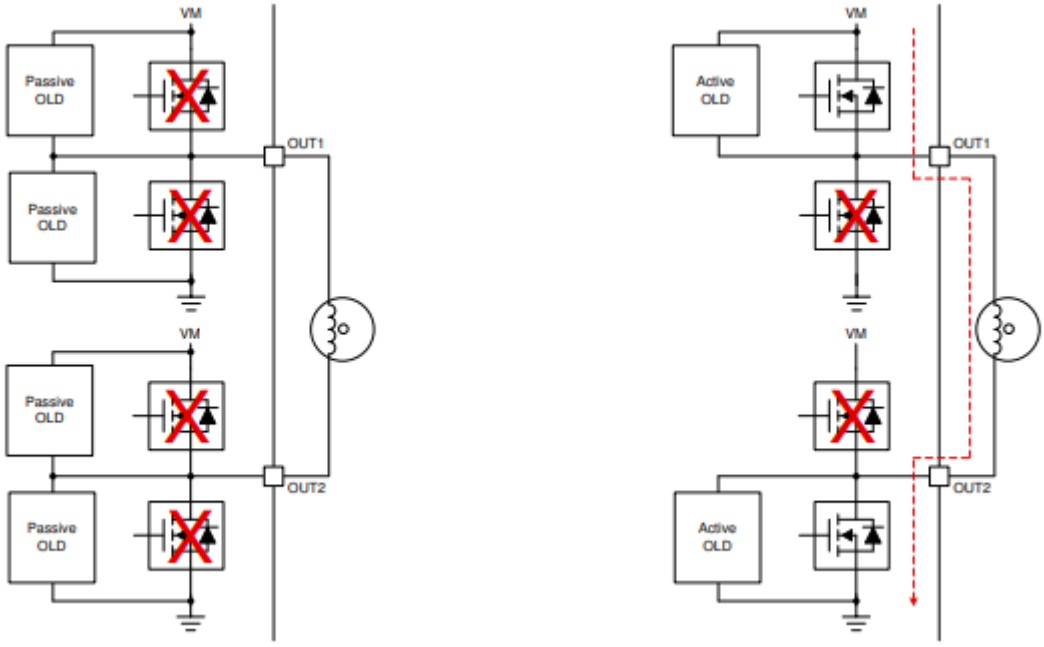


Figure 1. Passive and Active OLD for Load Connected in H-Bridge Configuration

What these devices all have in common is that OLD is indirectly based on the electrical response generated by the load connection. In Passive OLD, the device generally observes the output voltage through an internal bias network when the power MOSFET is off. In active OLD, however, it observes the current or freewheeling signatures during operation. Although the load is physically connected, an open-load indication may still appear if the current state does not produce the response required by the diagnostics.

Their main differences are as follows. The DRV887x-Q1 family uses the DRV8873-Q1 as an example. Its features should not be assumed to apply to the entire family. [1–3]

Copyright © 2026 Texas Instruments Incorporated

Example Device	Primary Basis for Active OLD	Support for Passive OLD	Differences of Interest in Application
DRV8245-Q1	OLA detects the voltage signature that the OUTx voltage is higher than VM, which is generated by the freewheeling of the high-side body diode during the PWM switching dead band	In STANDBY state, the connection state is detected based on the output bias combination and OLP_CMP	OLA only applies to the SPI version and requires a valid high-side freewheeling window
DRV8904/06/08/10/12-Q1	Active OLD detects if the current of the on-state MOSFET remains below the threshold for a time longer than the deglitch time	The DRV8904/06/08-Q1 supports passive OLD; the DRV8910/12-Q1 does not	Low-current OLD and negative-current OLD are supported, but each applies under specific conditions
DRV8873-Q1	OLA detects the voltage signature generated by the freewheeling of the high-side body diode	OLP is supported, but the trigger mode is different for the hardware version and SPI version	The freewheeling path, output capacitance, and OLP detection delay must be checked

The most confusing thing here is the meaning of active OLD. The normal active OLD of the DRV89xx-Q1 is based on the on-state current, while OLA of the DRV824x-Q1 and DRV8873-Q1 is based on the voltage signature during a particular freewheeling period. Therefore, a resistive load can be used for basic verification of the first mechanism, but cannot replace the motor to verify the second mechanism; without inductive energy storage, the freewheeling signature required for detection cannot be guaranteed. [4]

Also, for the DRV89xx-Q1, low-current OLD must be clearly differentiated from negative-current OLD. The former is used for smaller normal operating currents and only applies to low-side MOSFETs, changing their on-resistance and over-current threshold; the latter is used for reverse freewheeling detection during synchronous rectification, to avoid normal negative currents being judged wrongly by the positive current threshold. The two address issues related to current magnitude and current direction, respectively. [2]

Therefore, migrating an OLD configuration from one device to another requires re-checking the detection criteria, valid drive status, timing, and recovery rules. Do not simply match feature names or register names.

Fault Clear Does Not Imply That the External Conditions Have Recovered

The OLD fault of many motor drivers is a latched fault. That is, once an open load is detected, the nFAULT or status bit remains in a fault state until the system executes CLR_FLT, an nSLEEP reset pulse, or other clearing actions specified in the datasheet. However, fault clear simply clears the device's internal latch state and allows the device to re-evaluate the current condition. It does not change the state of the external load, nor does it actively eliminate inductor current, harness capacitor voltage, or residual voltage at the output node. Therefore, if the diagnostic is re-enabled immediately after fault clear and the OUTx node is still in an abnormal electrical state, or the freewheeling path still does not satisfy the OLD judgment assumption, the fault bit may still be set again.

It is also noted in the DRV89xx-Q1 datasheet that after the open-load fault error is removed, normal operation can be resumed and the OLD bit reset only by writing the CLR_FLT command. The order is important: Writing CLR_FLT does not necessarily resume normal operation, but the open-load condition must disappear before clearing the fault makes sense.

In engineering practice, to determine if the open-load condition has disappeared for inductive loads, it is not sufficient to solely check whether the connector or the load is reconnected. Whether the OUTx waveform and load current have returned to a condition suitable for re-diagnostics must also be observed.

Signals of Interest When Debugging

For automotive motors, solenoid valves, or other inductive loads, it is not recommended to only read the fault bit when debugging OLD. Observe at least the following signals at the same time:

1. VM or PVDD supply voltage;
2. Waveforms of OUTx to GND;
3. Voltage across load;
4. Load current direction and decay process;
5. IN, EN, PWM, or PH/EN control signal;
6. nFAULT;

Copyright © 2026 Texas Instruments Incorporated

7. SPI fault status;
8. Time of CLR_FLT or other fault clear commands;
9. Time of OLD enable;
10. The driver is currently in Hi-Z, brake, coast, PWM on-time, or PWM off-time state.

If the fault only occurs in some control modes, first compare the freewheeling paths in different modes, instead of directly assuming that fault clear fails. If the fault only occurs near small currents, small duty cycles, or direction switching, also see the datasheet for instructions that the operating mode, peripheral circuitry, and output capacitance can affect OLD.

Application Examples - Run and Stop Diagnostics of Automotive Damper Motors

Taking the automotive HVAC damper actuator as an example, consider using the SPI version of the DRV8245-Q1 to drive a brushed DC motor connected between OUT1 and OUT2, with the direction and PWM controlled via PH/EN. There are EMI suppression capacitors at the motor end and at the driver board end, and the system wants to monitor for abnormal connections during operation and perform an offline check after stopping. The following is an example application design based on the device mechanism.

During normal PWM driving, OLA needs to observe the output voltage signature at high-side freewheeling. For this device, OLA triggers if the desired voltage signature is not detected for three consecutive freewheeling switching cycles. Therefore, the diagnostic result is related to both the motor connection and the current and freewheeling path at the switching moment.

Near low-duty-cycle start-up, light-load operation, or direction switching, the current at the switching moment may not be enough to produce a valid diagnostic signature even if the motor is connected properly. This is a boundary condition that must be verified by practical tests and cannot be judged based on the motor current rating alone. Similarly, during the continuous conduction phase without a valid PWM toggle window, the absence of new OLA faults cannot be taken as evidence that a connection check has been completed.

When the motor reaches the target position, the system stops driving, but the current and back-EMF do not disappear immediately. If offline diagnostics follow immediately, the output node may still be affected by freewheeling or capacitive charging and discharging. Therefore, the software should process the motor energy according to the designed stop strategy before performing off-state diagnostics in the STANDBY state, which meets the device requirements, and read OLP_CMP after each set of bias conditions is established and the output is stable.

For the DRV8245-Q1, offline diagnostics should be performed comprehensively based on the input combinations and truth table in the datasheet. A single high or low OLP_CMP level should not be directly interpreted as "open-load" or "normal".

If OLA has already occurred during operation, it is recommended to save the fault status and corresponding conditions before performing the stop, offline check, and restore process. Clearing the historical fault bit and verifying that the motor is connected properly should be two separate steps: The first clears the status log, while the second requires a valid diagnostic that meets the prerequisites.

Copyright © 2026 Texas Instruments Incorporated

Design Recommendation Checklist

For automotive-grade motor driver applications, it is recommended to verify the following items when designing and validating the OLD feature:

- Verify if the device supports passive OLD, active OLD, low-current active OLD, or negative-current active OLD;
- Verify the driver state for which the OLD applies, such as Hi-Z, driver disabled, PWM operation, or high-side recirculation;
- Verify that the freewheeling path in the current control mode meets the prerequisites for OLD specified in the datasheet;
- For inductive loads, allow sufficient time for the load current and OUTx node to stabilize before fault clear or re-diagnostics;
- Instead of verifying the end application with resistive loads only, use real motors, solenoid valves, or coil loads for application-level verification;
- For operating conditions such as small currents, small duty cycles, direction switching, and brake/coast switching, individually verify whether OLD might trigger falsely;
- If the device supports negative-current OLD, evaluate whether to enable it based on synchronous rectification and current direction;
- If the device datasheet specifies that OLA is not recommended for a certain freewheeling path, avoid evaluating OLD under that condition;
- In the software flow for fault clear, distinguish between “clear latched state” and “external condition recovered”;
- Production testing may involve the use of resistive loads to verify basic functionalities, but system-level validation must cover real automotive loads and control modes.

Conclusion

In automotive motor drivers, open-load diagnostic is an electrical-state-based diagnostic mechanism. It relies on driver state, internal diagnostic current, comparator thresholds, filter time, load current direction, and freewheeling path. For resistive loads, the diagnostic results are usually straightforward. But for inductive loads such as motors and solenoid valves, freewheeling paths, residual energy, and output node transients may change the conditions for diagnostics.

Therefore, when analyzing the open-load fault, avoid relying solely on the register clear logic; instead, make a judgment by combining the OUTx waveform, load current, and control mode, as well as the OLD prerequisites defined in the datasheet. In this way, it is possible to differentiate between a true open load, diagnostic conditions not met, and a false OLD that may occur under particular freewheeling paths.

Copyright © 2026 Texas Instruments Incorporated

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), 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 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, TI’s General Quality Guidelines, or other applicable terms available either on 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. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

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

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025