Technical Article

Driving HVAC System Flaps with an Integrated, Multichannel Motor Driver

TEXAS INSTRUMENTS

Hector Hernandez Luque

Automotive heating, ventilation and air-conditioning systems (HVAC) systems contain multiple flaps, each driven by a corresponding motor. Integrated, multichannel motor drivers give designers the ability to drive multiple motors independently in both directions. Having the ability to drive all motors (also known as flap actuators) from a single device saves not only board space but also cost, albeit introducing challenges.

One design challenge when integrating multiple half bridges in one device is how to handle the thermals of the integrated field-effect transistors (FETs) in the operating ambient temperature range. Driving multiple motors with the least amount of pulse width modulation (PWM) signals is a complex task. There are cases where one of these multichannel devices is not enough to drive all of the HVAC system flaps, and multiple device communication setups are required.

Another design challenge is how to control the movement speed of the flap loads. This speed control is typically achieved using a pulse-width modulation (PWM) drive, which requires the generation of PWM signals within the device.

To solve these challenges, TI created the integrated, multichannel DRV8912-Q1 motor-driver family. These drivers can drive up to six motors simultaneously in both directions or up to 11 motors separately in a single integrated circuit. Figure 1 shows the pinout of the device, highlighting its integration of 12 half-bridge outputs, the use of Serial Peripheral Interface (SPI) communication and no PWM input pins.

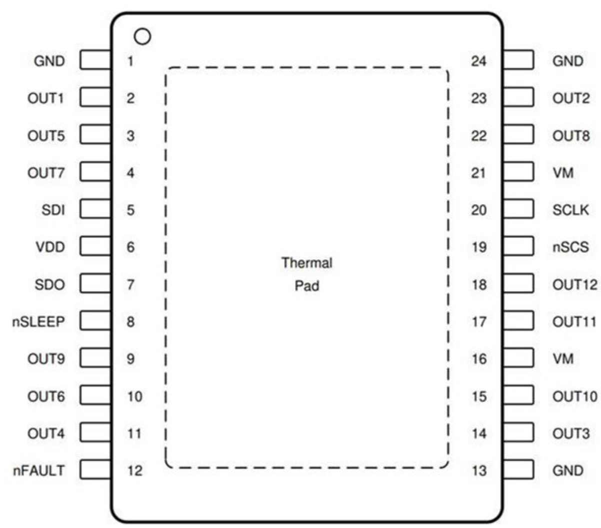
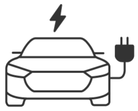


Figure 1. DRV8912-Q1 package

Drive more motors with fewer brushed-DC drivers



Reduce design time and increase reliability in your automotive HVAC design with the DRV8912-Q1 family of scalable, multi-channel brushed-DC motor drivers with advanced diagnostics.

Thermal performance

Thermal management, which is managing the die temperature of the device, is one of the biggest challenges with integrated multi-half-bridge drivers. Figure 2 shows the low drain-to-source on-state resistance ($R_{DS[on]}$) of the integrated FETs in the DRV8912-Q1 motor-driver family across an ambient temperature (T_A) and with an operating voltage range from 4.5 V to 32 V. The ability to drive multiple loads while keeping the die temperature below 150°C is essential for a multi-half-bridge device in HVAC systems.

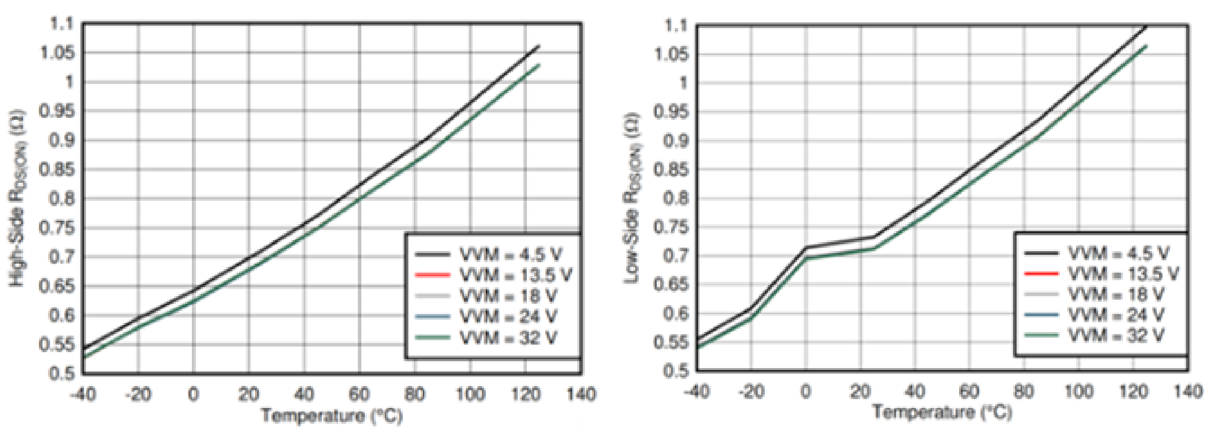


Figure 2. High- and low side $R_{DS(on)}$ vs. T_A

Daisy-chain communication and PWM generators

For cars that have multiple HVAC zones and options, there could be a need for multiple devices to drive a large number of flap actuators. This does not mean that you need to increase the number of microcontrollers in your design, however, as the DRV8912-Q1 family does daisy-chain in SPI-based communication. As shown in Figure 3, one microcontroller is a master communication device, and multiple drivers are slaves using a single SPI communication. This feature of the motor driver reduces hardware expenses and overall system size.

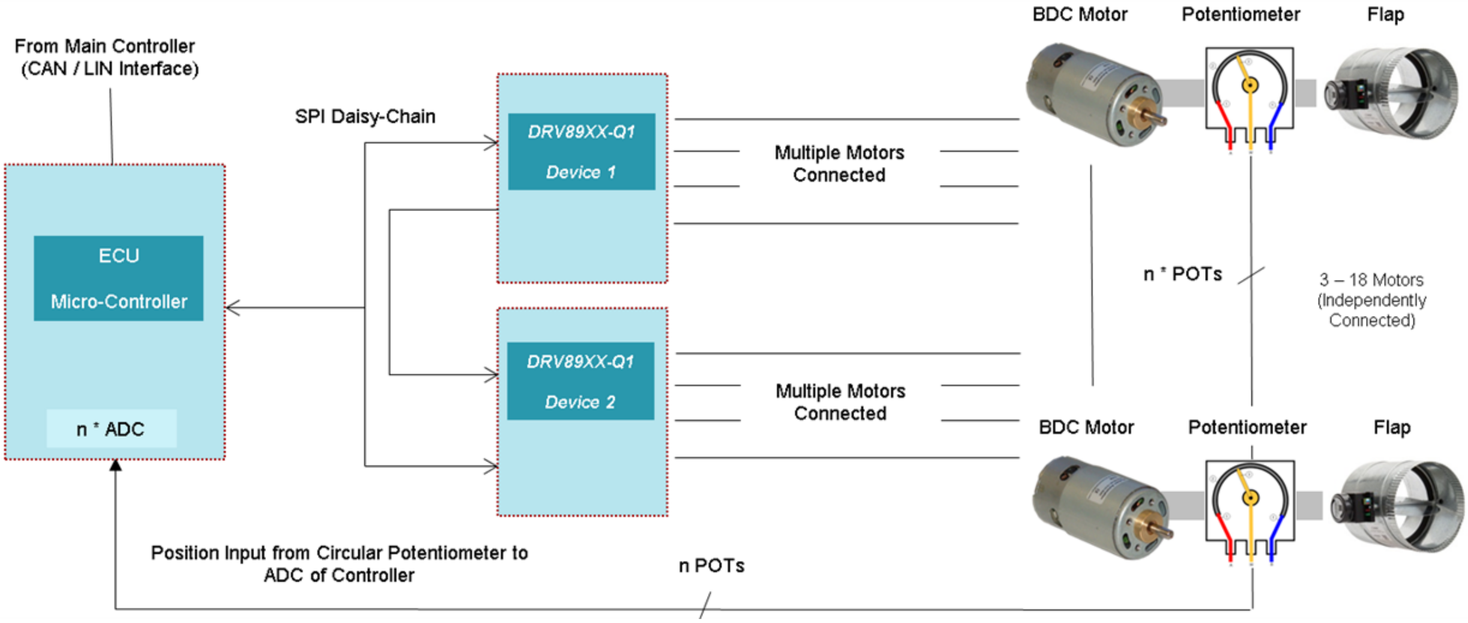


Figure 3. MCU to flaps with daisy-chain

Speed control is a benefit of using PWM control in HVAC systems. The motor drivers in the DRV8912-Q1 family have four integrated PWM generators. These generators enable the configuration of duty cycle and frequency, as well as PWM generator assignments to one or more channels. For example, you can assign one PWM generator to half bridges 1, 3, 5 and 6, while assigning a second PWM generator to half bridges 2 and 4. This setup enables you to drive up to two groups of loads with two PWM generators.

Advanced diagnostics in HVAC systems: open-load detection

Open-load detection (OLD) is a diagnostic feature that determines whether or not there is an open electrical circuit between the HVAC control module and the flap motor. In HVAC systems, disconnected load detection is challenging because the current required to drive the motor changes when the airflow changes. These current changes can cause false open-load faults.

The DRV8912-Q1 motor driver family provides four types of OLD diagnostics to meet HVAC load disconnection diagnostic needs:

- **Active OLD**. Active OLD ensures a driver-to-motor connection when the motor is driving. Figure 4 is an example where the OLD current threshold, I_{OLD}, must drop below the motor current, I_{OUTx}, for a duration larger than t_{OLD} to cause an OLD event. Fault clearing occurs when I_{OUTx} becomes greater than I_{OLD}. This OLD diagnostic gives you the ability to detect load disconnections while the load is driving and stops the system from continuing operation.

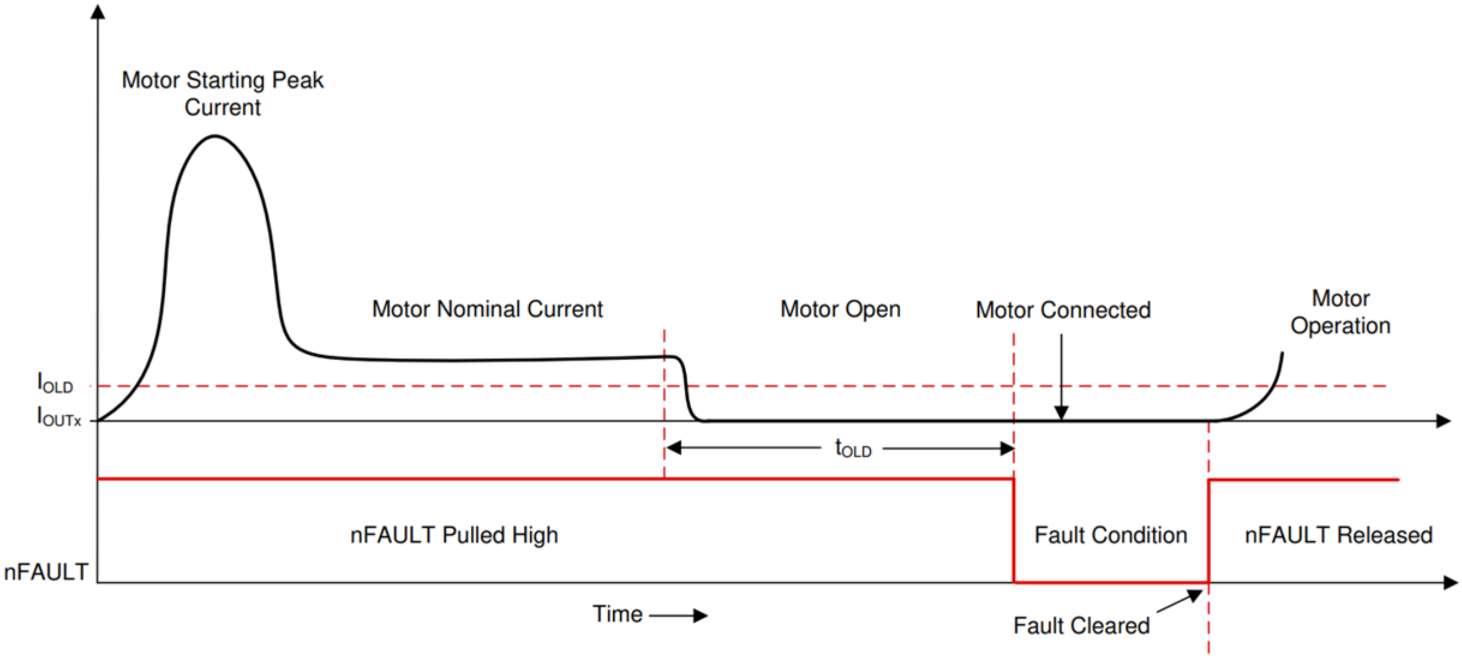


Figure 4. Active OLD operation

- **Low-current active OLD**. The OLD current threshold is around one-tenth the magnitude of the active OLD current threshold. In HVAC systems, the airflow traversing through the driven flaps causes the motor to require less torque (current) to drive the flaps. The motor's driving current could drop to a value below the I_{OLD} of active OLD, creating a false OLD flag. With a lower OLD threshold, driving motors when the required drive current is less than the active OLD current threshold can prevent false OLD flags from occurring.
- **Negative-current active OLD**. When the current OLD threshold is negative, this diagnostic uses the current recirculating through either the body diode of the recirculation FET or the FET itself to prevent a false OLD flag seen in active OLD. Figure 5 shows the false flag occurring with negative current enabled in Figure 5a, and the flag prevented without negative-current enabled in Figure 5b.

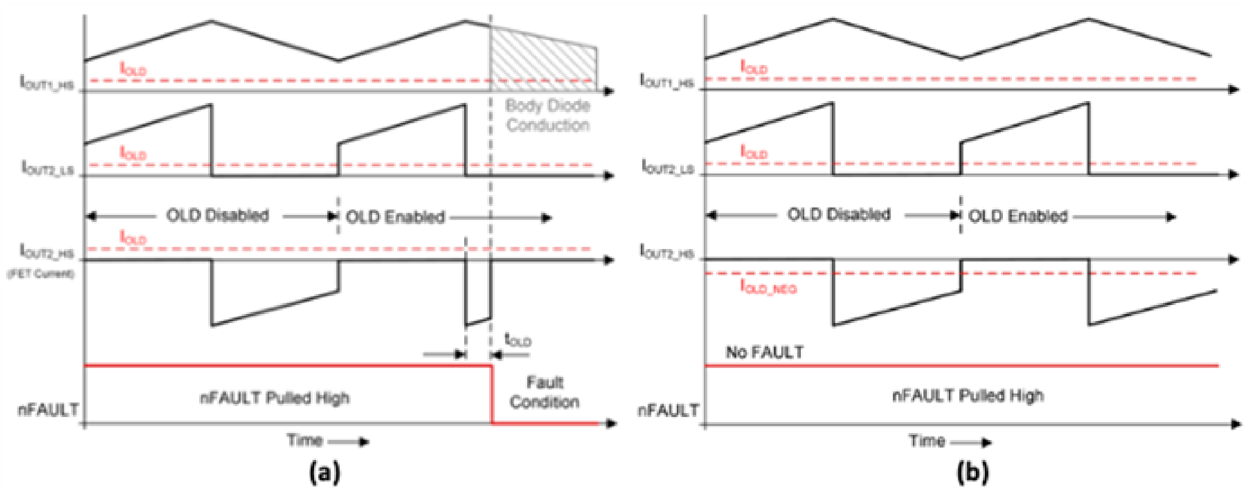


Figure 5. False OLD flag during high-side current recirculation with (a) and without (b) negative-current enabled

- **Passive OLD**. Passive OLD detects an open-load condition before the driver outputs are enabled. All of the FETs are in a high-Z state, while a minimal amount of diagnostic current flows through the load for a short amount of time to test the load's connection to the FETs. The diagnostic current must be minimal to avoid load rotation. With this OLD diagnostic, you can detect a motor disconnection even if the motor is not driving.

Simplifying flap driving

HVAC systems vary in complexity and automation level, depending on vehicle class. The DRV8912-Q1 family is pin-to-pin compatible between all devices. With low $R_{DS(on)}$ for thermal performance, SPI daisy-chaining, internal PWM generation and unique open-load detection, the benefits of the DRV8912-Q1 device family for HVAC systems are numerous.

Additional resources:

- To learn more about HVAC system flap driving, read the technical article, Understanding flap actuators and what drives them in automotive HVAC systems.
- Download the DRV8912-Q1 data sheet.
- Learn how to connect and control multiple flap motors with the Automotive HVAC control reference design with HMI.
- Check out the "Open Load Detection in Motor Drivers" and "Protecting automotive motor-drive systems from reverse polarity conditions" application reports.