Competitive Advantage of TI Multi-Channel Half-Bridge Drivers in Automotive HVAC Damper Applications

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Analog Signal Chain / Motor Drives

TI training summary

Automotive Multi-Channel Half-Bridge Drivers Family for HVAC Damper Applications:

The number of motors in a vehicle is increasing exponentially, catering to enhanced user comfort. The automotive HVAC system plays a significant role in enhancing the user experience in terms of comfort, performance and cost. Damper-servo assembly is the backbone of the automotive HVAC system, which controls the air-flow in a vehicle.

This training presents TI's automotive multi-channel brushed DC motor driver family (DRV89XX-Q1), which can drive multiple HVAC damper servo-motors (with 4, 6, 8, 10 or 12 channels). This family is AEC-Q100 qualified and supports Grade-1 temperature classification for automotive applications. The device family has very optimized voltage and current ranges with easy configurability and detailed diagnostics for troubleshooting. The device consists of enhanced integrated protection features such as UVLO, OVP, POR, OCP, OLC and OTW/TSD to protect against any unwanted scenario. The device family shows a clear and distinctive advantages over current solutions in the market.

What you'll learn:

Understanding the automotive HVAC system:

- Key requirements of the automotive HVAC damper and how it gets implemented in actual system/product.
- DRV89XX-Q1 – Key specs, key features and differentiation
- Comparative features of DRV89XX-Q1

Detailed agenda

- Automotive HVAC systems
  - Car climate control system
  - Dampers-servo subsystems
- Understanding the DRV89XX-Q1 device
  - Key specifications
  - Device functionality and protection
  - Feature differentiation
- Competitive advantages
  - Operation and features
  - Protections
- Adjacent socket – Side mirror
  - System block diagram
  - How DRV89XX-Q1 fits this application

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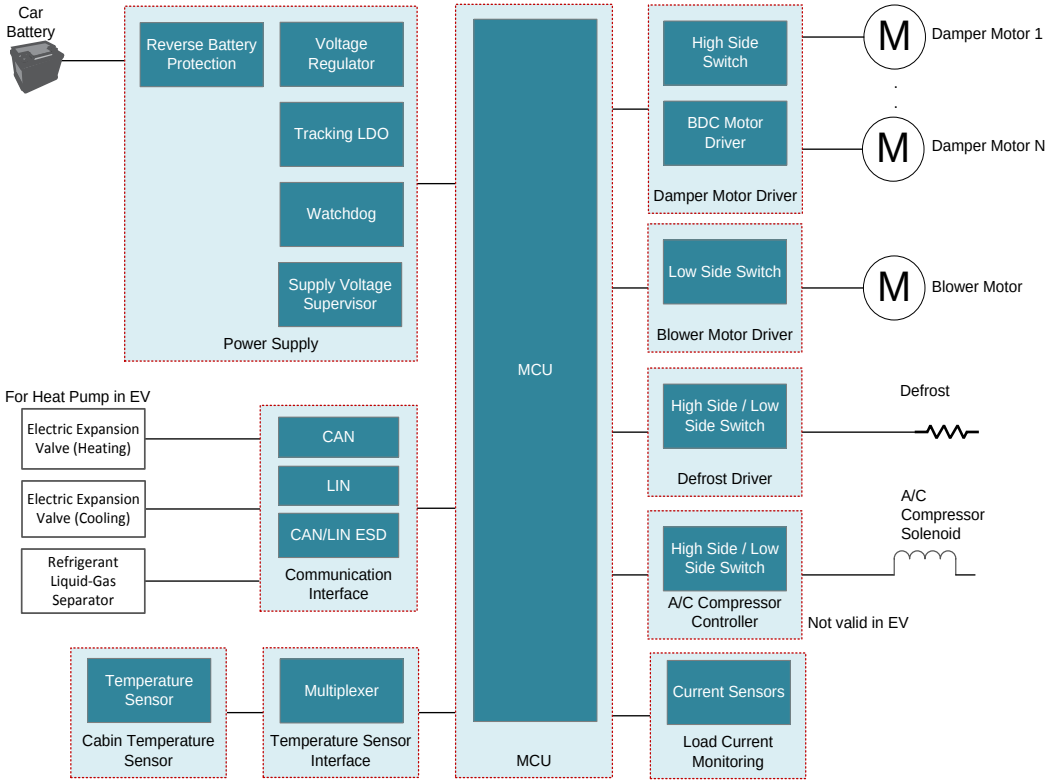
Auto-HVAC systems

Damper Control System

- Multiple brushed DC motors are used for mixing the air (warm and cold air) and controlling the air-flow in car.
- The motor is connected with the gear assembly for increasing torque ratio.
- The position of motor is sensed using a potentiometer.
- A majority of the motors in the automotive HVAC damper require a bi-directional control. Therefore, a full-bridge (H-bridge) is used for driving a single motor.



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DRV89XX-Q1

Automotive Multi-Channel Half-Bridge Drivers

Features

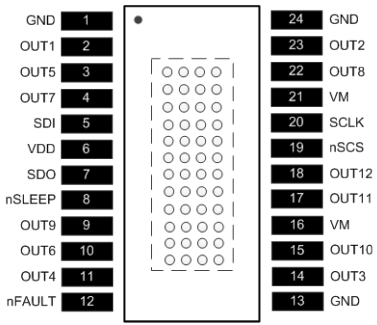
- Qualified for Automotive AEC-Q100 (Grade-1)
- Multi-Channel Half Bridge Drivers (4, 6, 8, 10 and 12 channels)
  - Supply voltage: 4.5-V to 20-V/32-V (EXT_OVP) operating (40 V load dump)
  - Output current: 1.0-A rms per bridge (3.0 A max for all output)
  - $R_{DS(ON)}$: 1.5Ω (HS + LS) @ 13.5 V, 0.5 A, 25°C
- SPI Interface (16-bit, 5 MHz) for configurability with daisy chain support
- Very low power consumption in sleep mode (3 µA)
- PWM mode with internal PWM generation on each channel
  - 4 PWM frequency options: 80-Hz, 100-Hz, 200-Hz and 2000-Hz
  - 8 bit duty resolution (~0.4 % duty)
  - Slew rate control for supporting 2000-Hz
- Per-channel SPI diagnosis with the global error flag
  - nFAULT pin for hardware monitoring
  - Supply under-voltage (UVLO) and over-voltage protection (OVP)
  - Logic supply power on reset (POR)
  - Overcurrent protection (OCP) on each FET
  - Open Load detection (OLD) on Each FETs
  - Thermal warning and shutdown (OTW / OTSD)

Applications

- HVAC Flap DC motors
- Side mirror x-y adjustment and mirror fold
- LEDs

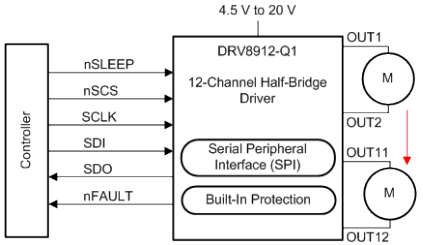
Benefits

- Well optimized for 12V standard supplies and also support 24-V DC rail
- Support brushed DC, stepper motors and solenoid loads with a single IC
- Lower BOM cost (No extra charge-pump capacitor)
- Scalable family of low pin count and small package size drivers
- Low R_{DSON} increases efficiency and improves thermal performance
- High peak current capacity for in-rush current
- Drive output via SPI to reduce pin-count
- Higher system reliability and reduced design complexity with integrated current protection and fault detect features



DRV89XX-Q1 Pinout (12 channel DRV8912-Q1)

24-pin HTSSOP (3.9 x 8.65 mm)



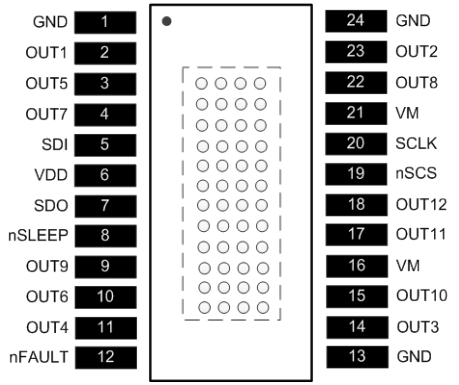
DRV89XX-Q1 Driving Multiple Brushed DC Motors

DRV89XX-Q1

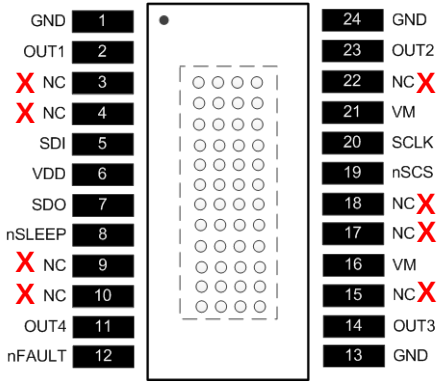
Automotive Multi-Channel Half-Bridge Drivers

Part #	Channels	# of Motors	Package	I/F
DRV8904-Q1	4	2	24-pin HTSSOP	SPI
DRV8906-Q1	6	3		SPI
DRV8908-Q1	8	4		SPI
DRV8910-Q1	10	5		SPI
DRV8912-Q1	12	6		SPI

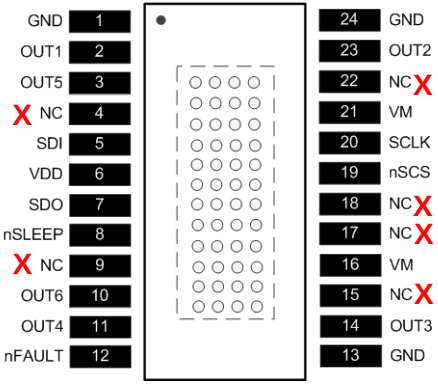
Number of Channels Decreasing



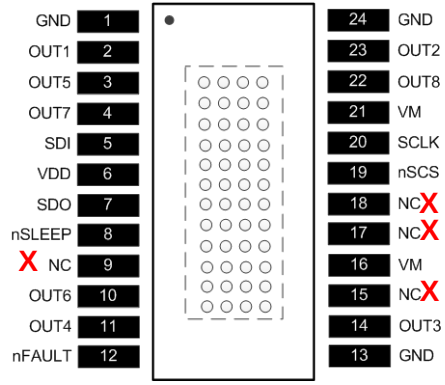
DRV8912-Q1



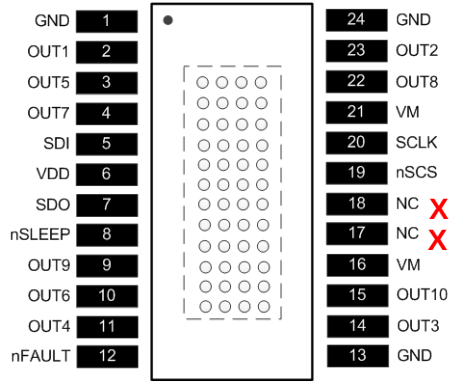
DRV8904-Q1



DRV8906-Q1



DRV8908-Q1



DRV8910-Q1

Application: DRV89XX-Q1 for multiple BDC motor (HVAC)

Automotive Multi-Channel Half-Bridge Drivers

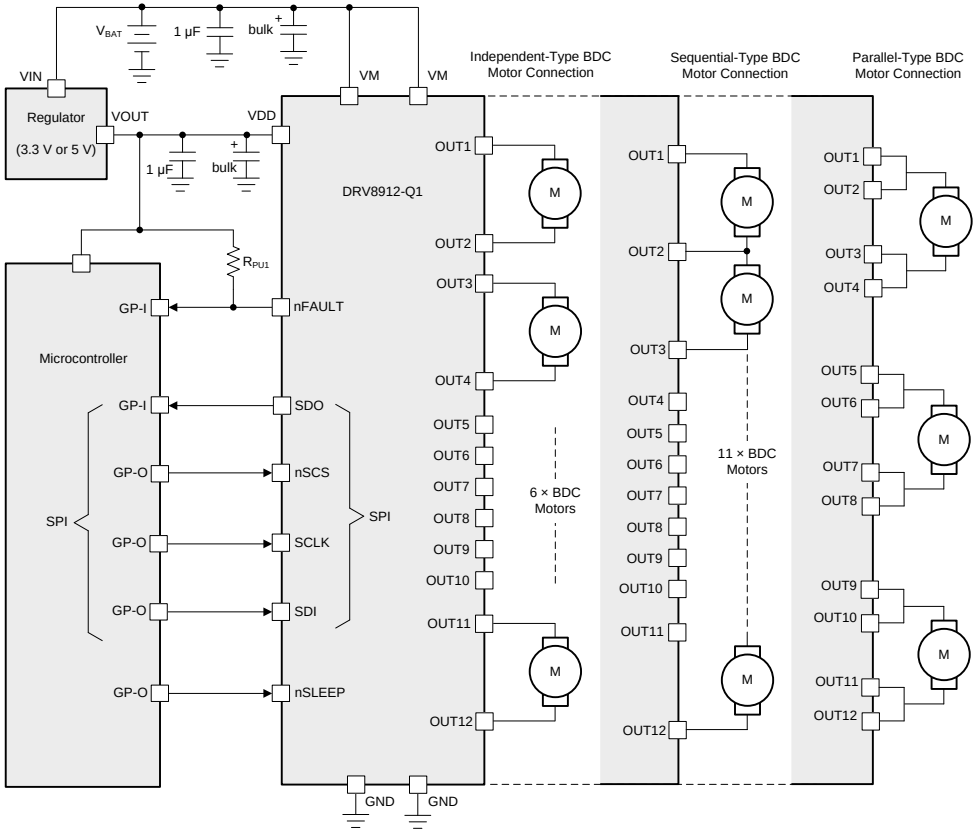
DRV89XX-Q1 driving brushed DC motors

- ***Different brushed DC motor connection type:***

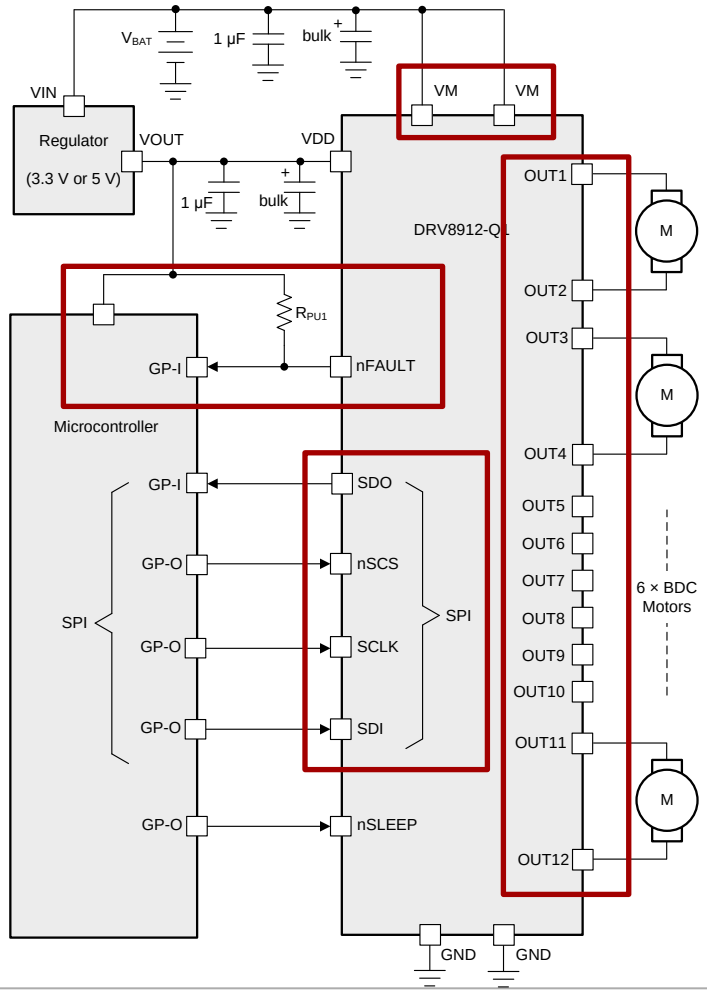
✓ Independent-type BDC motor connection
  ✓ Can drive (n/2) motors in ‘n’ channel driver

✓ Sequential-type BDC motor connection
  ✓ Can drive (n-1) motors in ‘n’ channel driver

✓ Parallel-type BDC motor connection
  ✓ Can drive higher current BDC motor based on the number of channels required

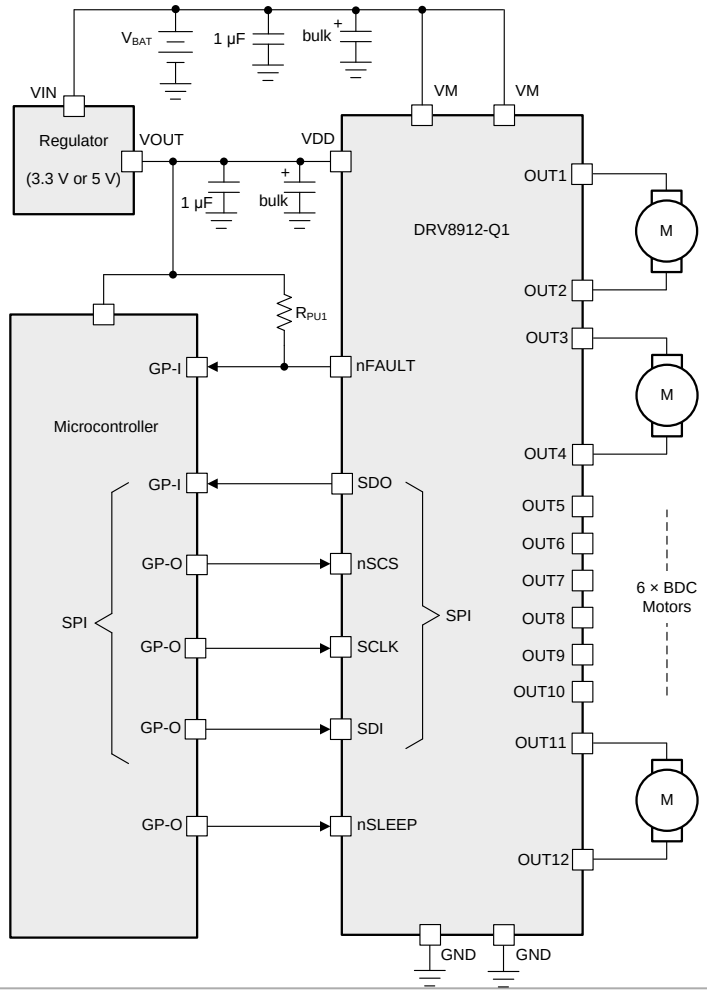


DRV89XX-Q1 driving brushed DC motors



DRV89XX-Q1 differentiation

- *Extended supply range for supporting 24-V battery applications*
  - *By extended OVP operation (EXT_OVP)*
- *For avoiding repeated SPI reads for fault monitoring*
  - *By using nFAULT Pin*
- *Faster communications with multiple device interface*
  - *SPI with 5MHz operation and daisy chain support*
- *Better open load detection schemes*
  - *Provision for negative current detection for free-wheeling operation (during synchronous rectification)*
- *Motor operation with PWM current chopping*
  - *2kHz PWM switching supported*
- *Better thermal management*
  - *Lower Rdson of integrated FETs*



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- Negative open load detect
- Thermal advantage
- 2kHz PWM operation
- nFAULT pin
- Extended OVP operation

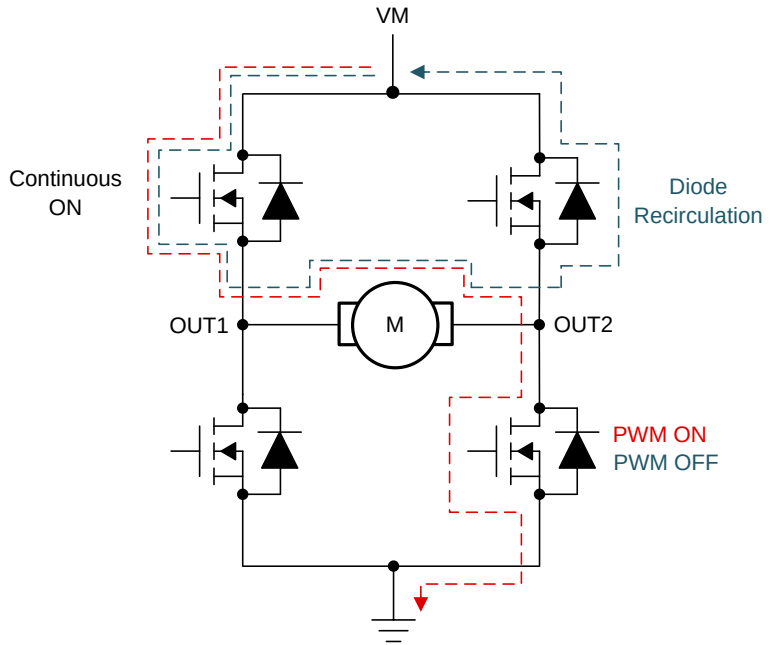
Negative open load detection

This mode allows TI device to avoid any unwanted fault due to reverse current flowing into FET.

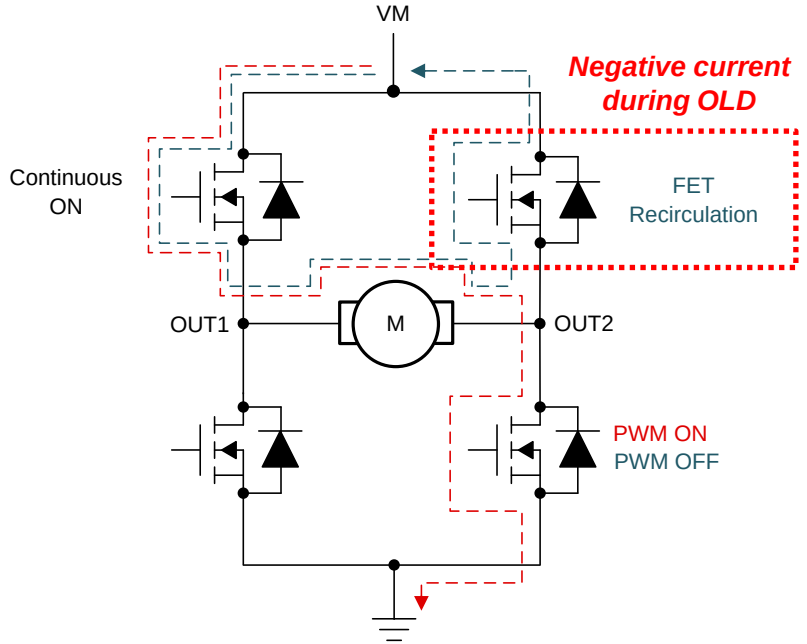
DRV89XX-Q1 – Open load detection with negative current detect

Automotive Multi-Channel Half-Bridge Drivers

Asynchronous rectification – No issues

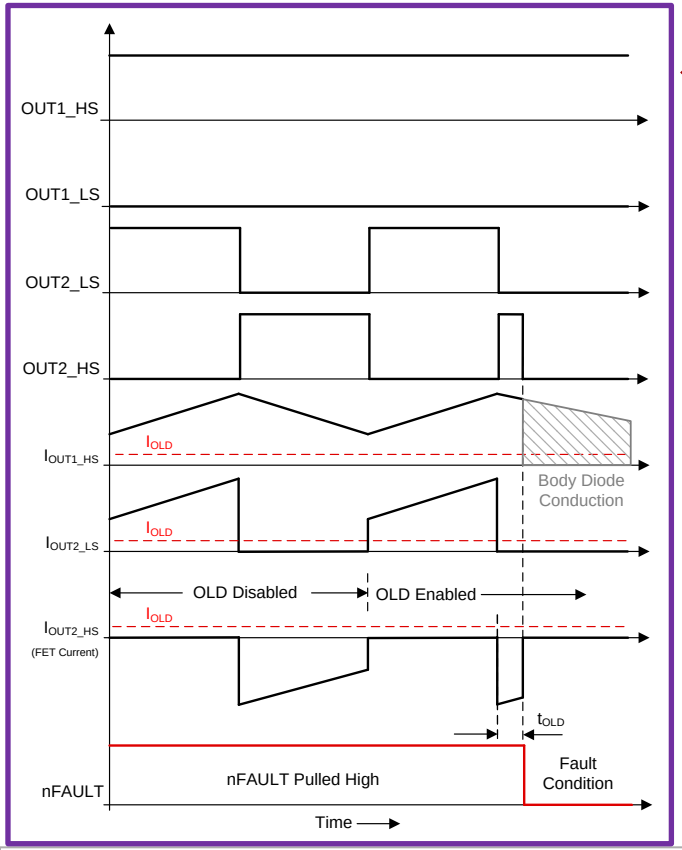


Synchronous rectification – Negative current OLD



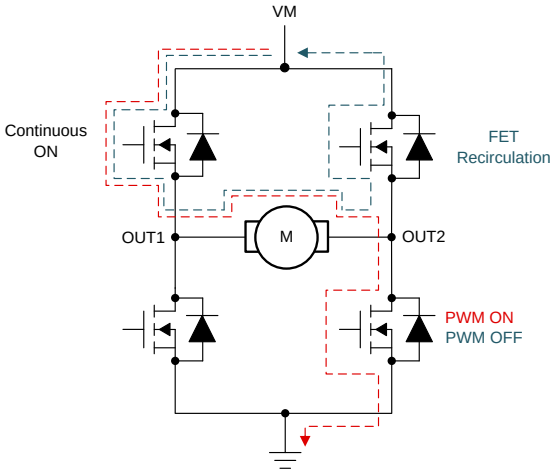
DRV89XX-Q1 – Open load detection with negative current detect

Automotive Multi-Channel Half-Bridge Drivers

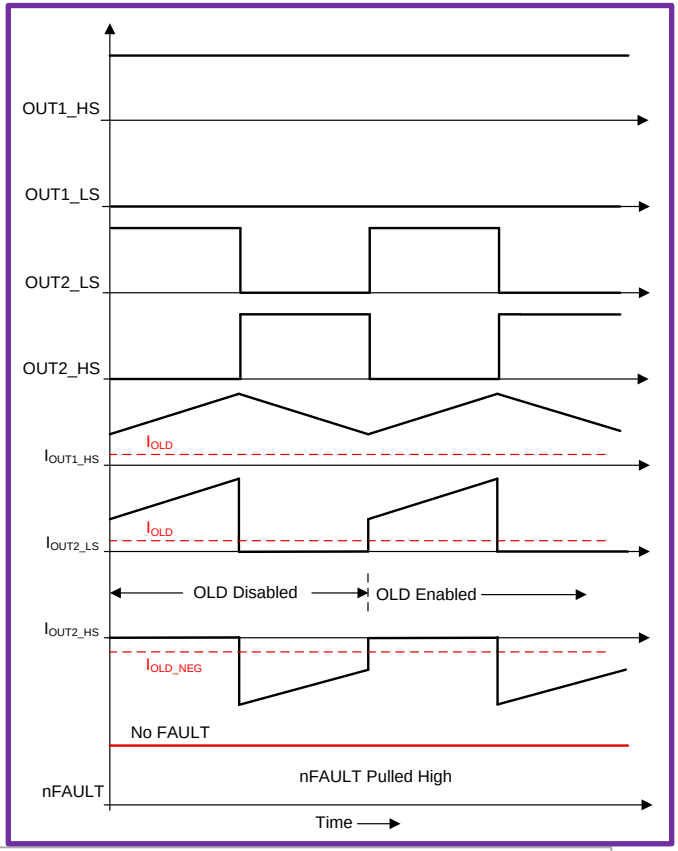


Negative OLD disabled

Negative OLD enabled



Driver operation

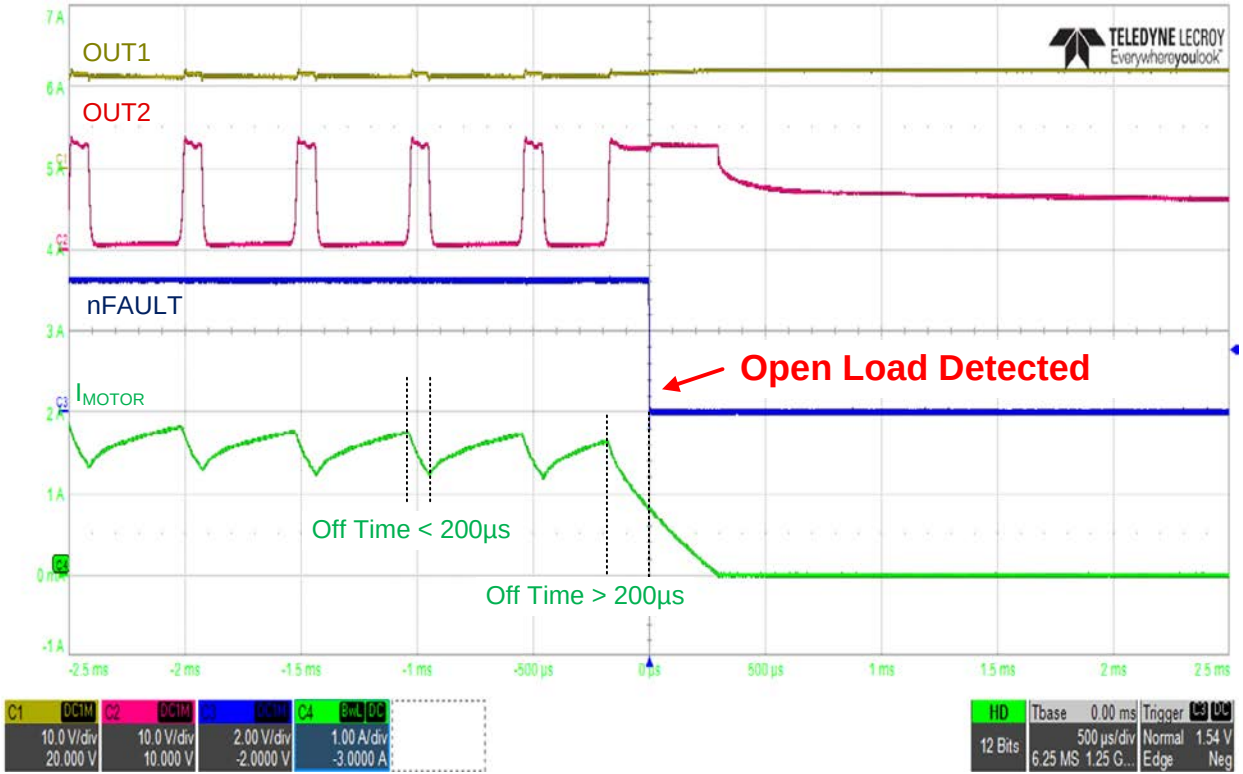


DRV89XX-Q1 – Open load detection without negative current detect

Automotive Multi-Channel Half-Bridge Drivers

Setup details

- **1.5-A brushed DC motor driven in parallel mode of DRV89XX-Q1**
- **Off time is kept lower than 200µs and then increased higher than 200µs**



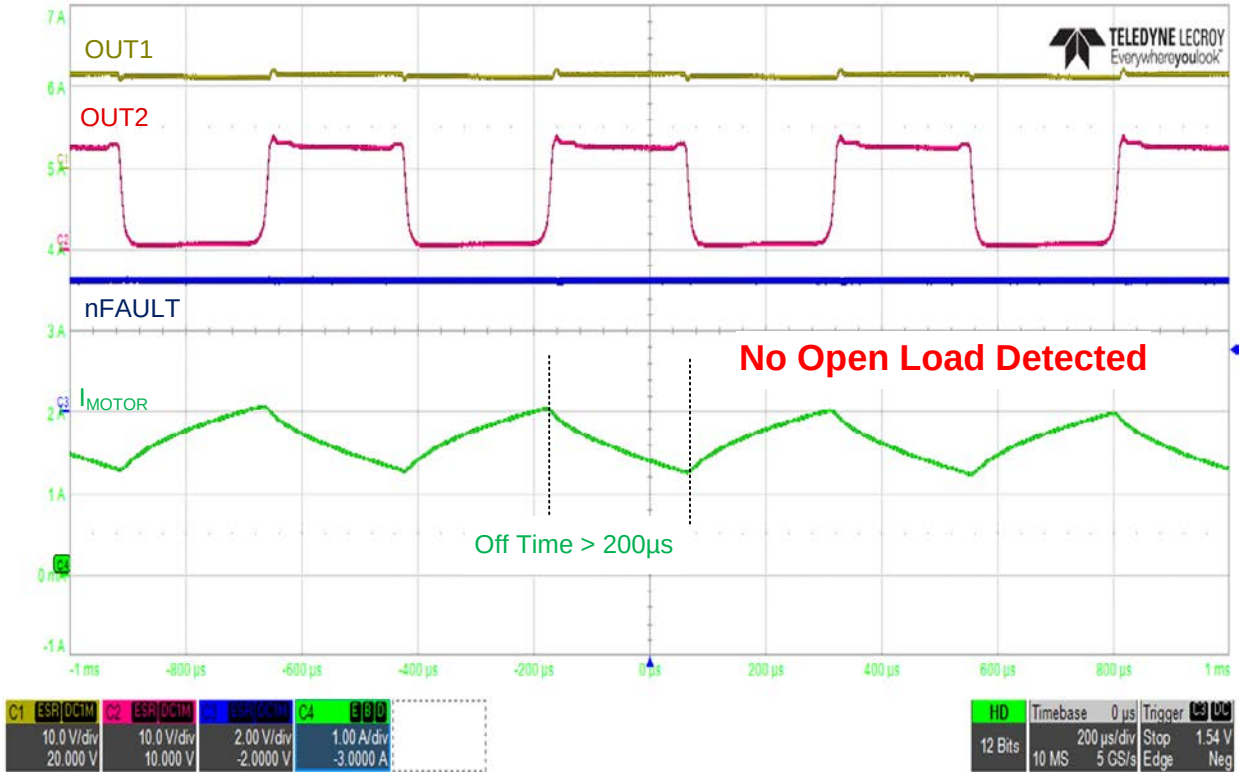
Motor Operation

DRV89XX-Q1 – Open load detection with negative current detect

Automotive Multi-Channel Half-Bridge Drivers

Setup details

- **1.5-A brushed DC motor driven in parallel mode of DRV89XX-Q1**
- **Off time is kept higher than OLD deglitch time of 200µs**



Motor Operation

Thermal advantage

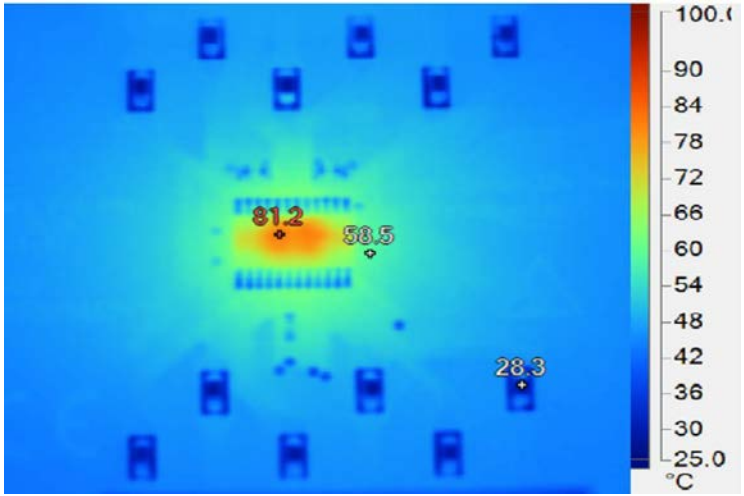
- Due to Better Rdson ~ 12% lower (0.75Ω vs 0.85Ω) in TI device
- ***TI device thermal performance is 15% better than competitor performance***

DRV89XX-Q1 – Thermals (both tested on TI's EVM)

Automotive Multi-Channel Half-Bridge Drivers

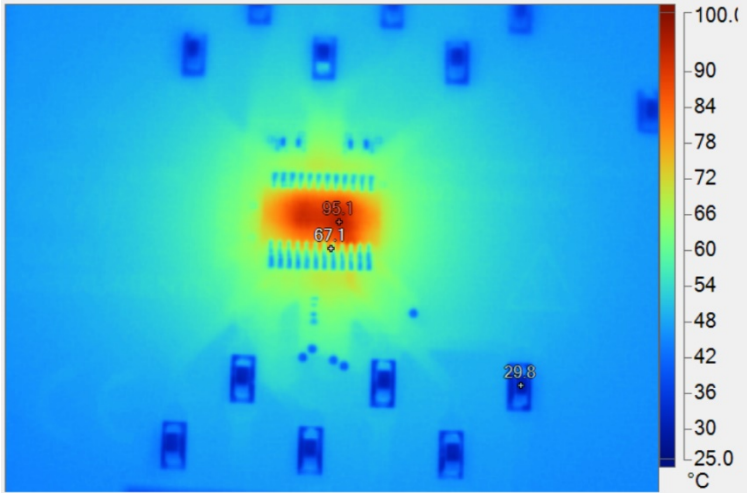
- Test conditions: 25C ambient; set OUT1,4,5,6,7,9 high; OUT2,3,8,10,11,12 low and total 3A DC Load between high and low on DRV8912-Q1EVM

DRV8912-Q1 hot spot 81.2C



DRV8912-Q1 EVM

Competitor's hot spot 95.5C



DRV8912-Q1 thermal pad is 4x2.9mm; Competitor's thermal pad is 6.4x2.65mm.

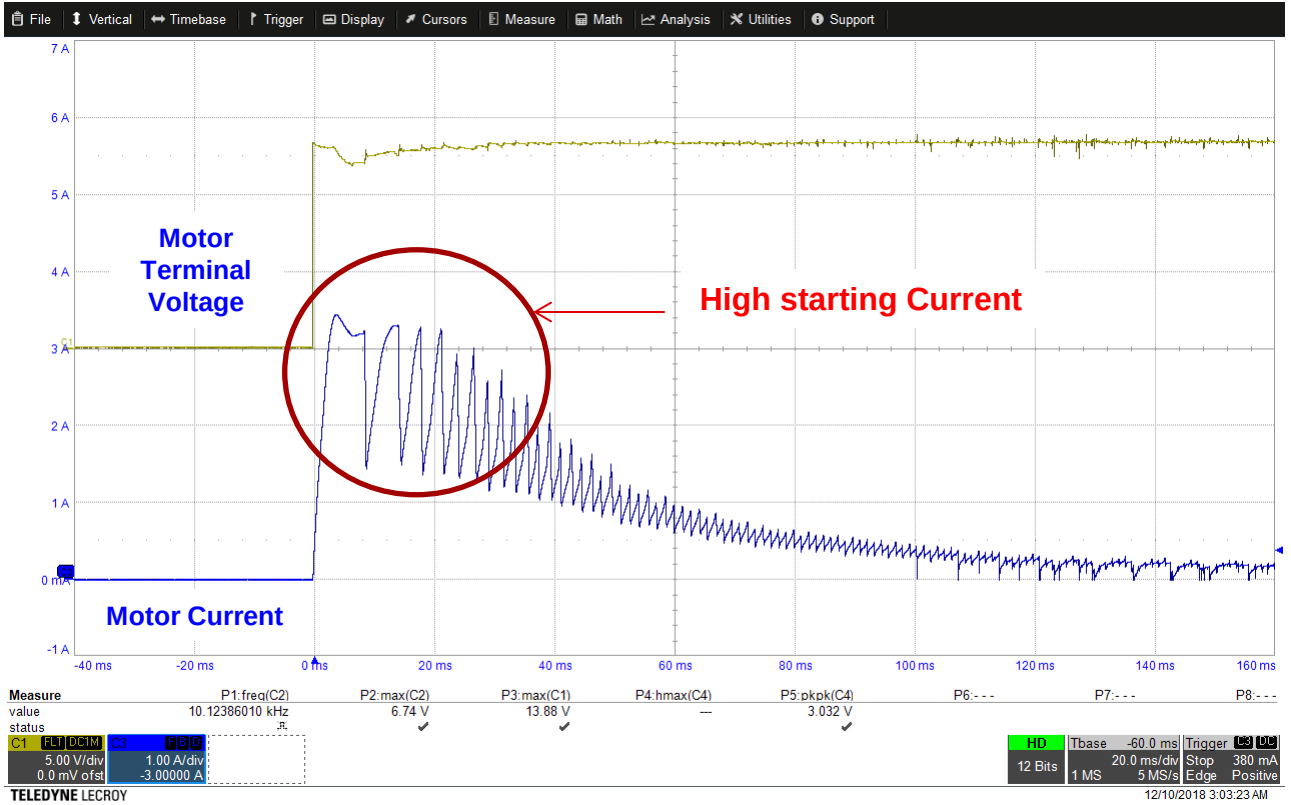
2kHz PWM frequency operation

- **Limiting motor starting current by using lower PWM duty at higher frequency (2kHz)**

- Lower PWM frequency (80-Hz, 100-Hz and 200-Hz) can cause a discontinuous current conduction
  - Very high current ripple
  - Audible noise
  - Motor might not start

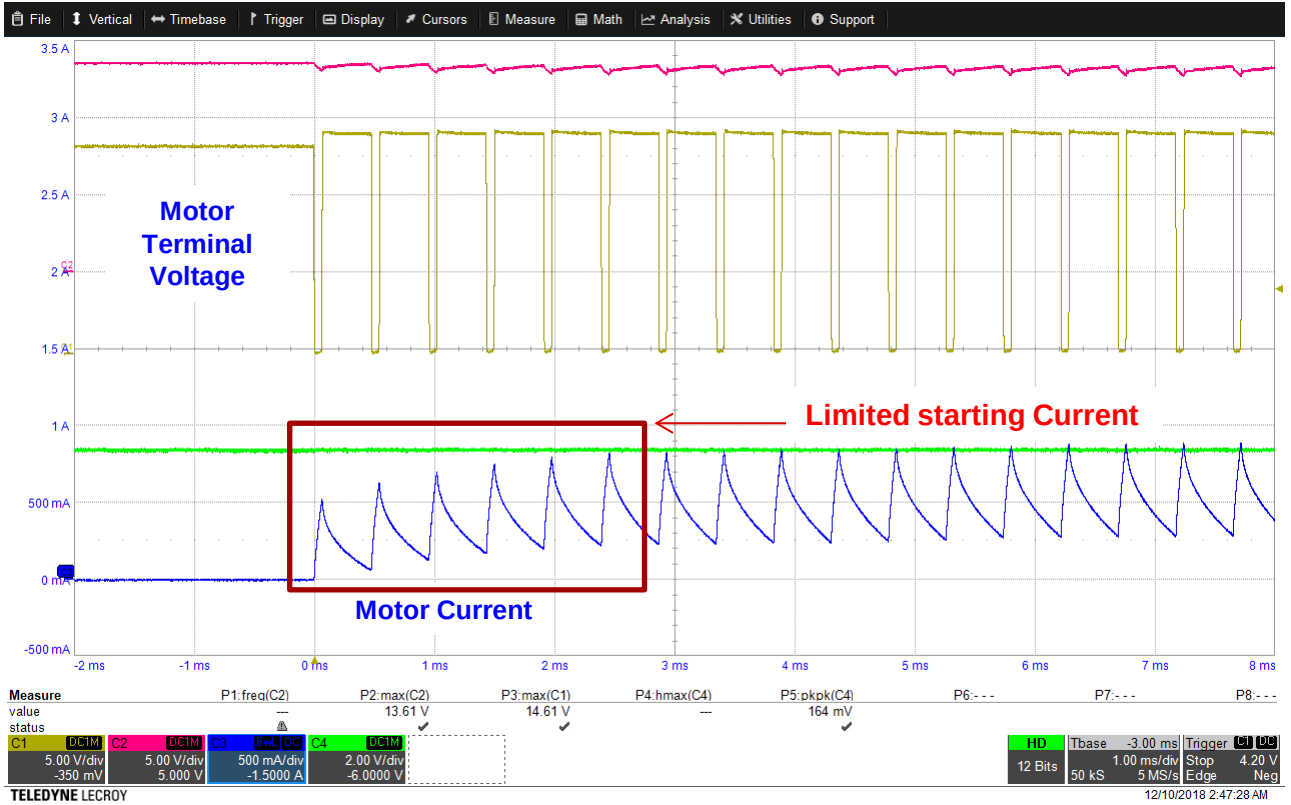
Motor starting current with no PWM

High starting current in motor when no PWM is applied.



2kHz PWM frequency operation

Peak starting current is limited by starting the brushed DC motor in PWM operation.

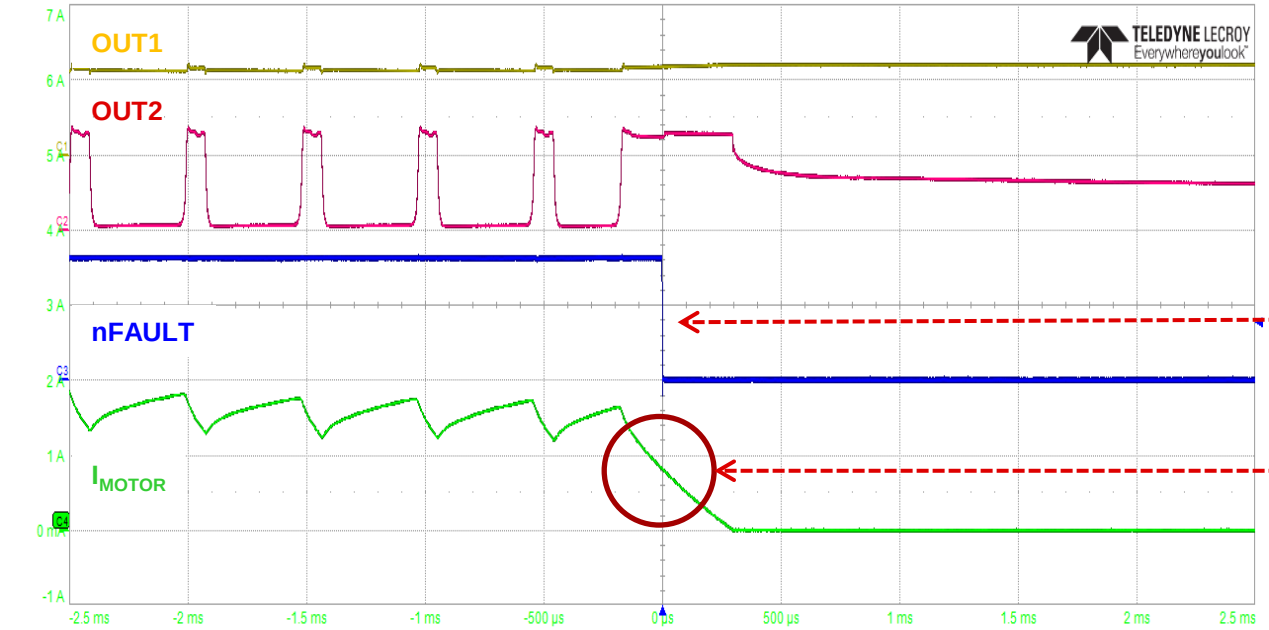


nFAULT pin functionality

- **Hardware pin which stops continuous scanning of the status register**

- Requires extra GPIO pin
- Saves repeated SPI read and makes processor available for other tasks

nFAULT pin operation in OLD



nFAULT pin becomes low showing a fault state

Open load detected

Extended OVP operation

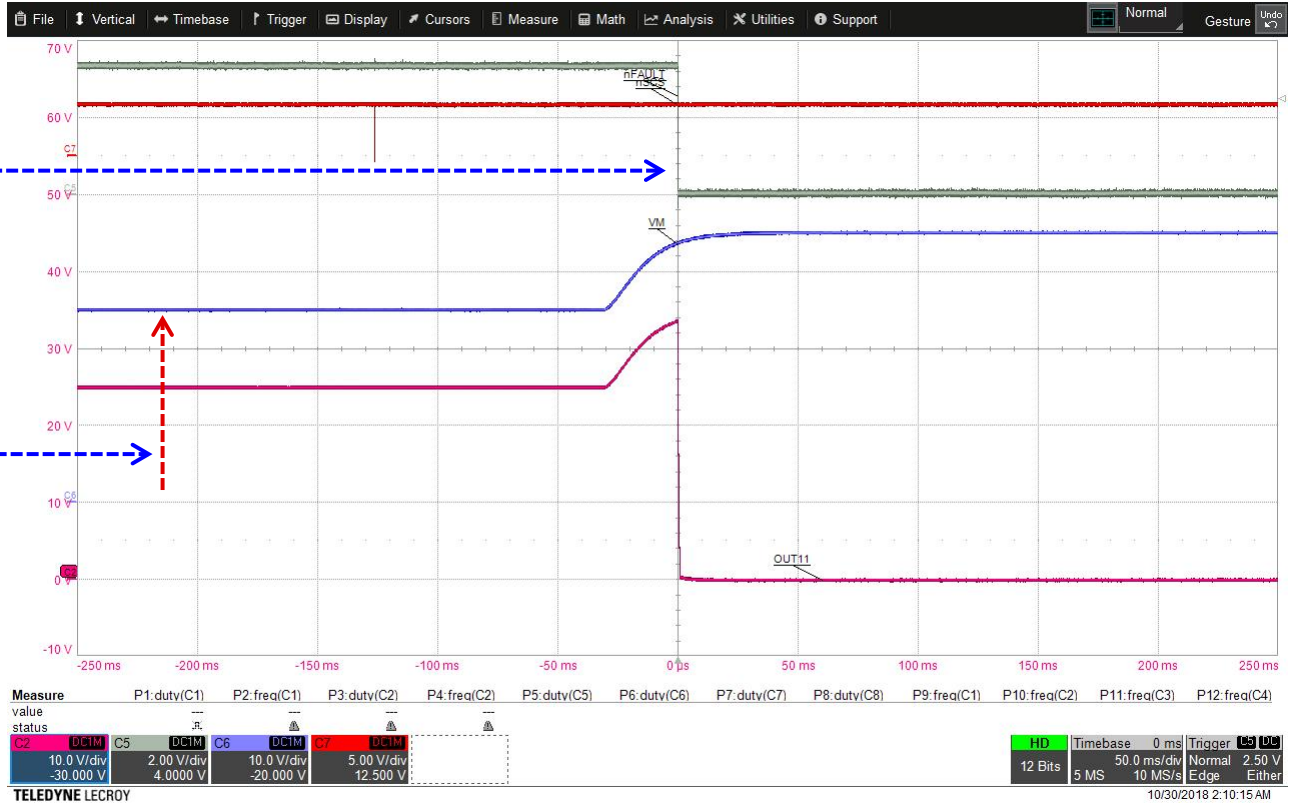
- **Allows 24-V battery operation**

- Device is designed to operate up to 32-V for supporting any 24-V battery application.
- This mode is enabled by setting the EXT_OVP (Extended Over Voltage Protection) bit in the CONFIG_CTRL (Configuration Control) Register.
- There is no change in the load dump voltage of 40-V.

32-V OVP operation

Device showing an OVP hit at >32-V

Device operating at 24-V nominal



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Application: DRV89XX-Q1 for mirror application

Automotive Multi-Channel Half-Bridge Drivers

DRV89XX-Q1 for mirror application

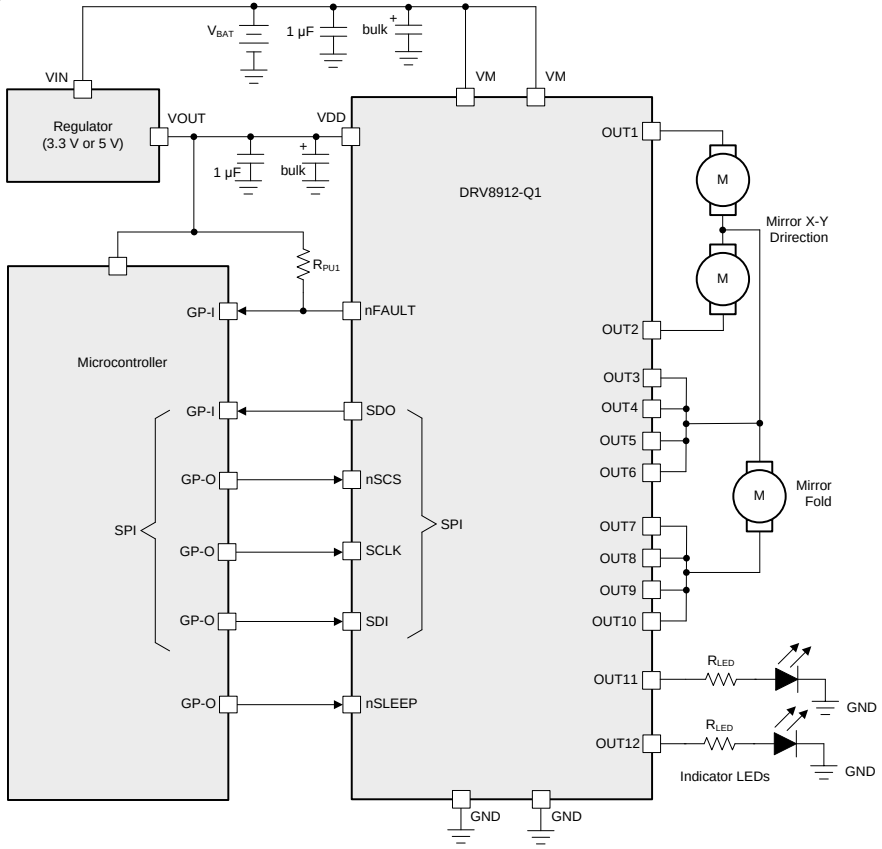
- ***Mirror X-Y, mirror fold and side indicators:***

✓ Mirror X-Y connection
  - ✓ Operation of X and Y adjustment (single at one time)
  - ✓ Two channels with common connection on the mirror fold high current channel

✓ Mirror fold
  - ✓ High-current BDC motor with Rdson per channel reduced to 1/4th for better thermals.

✓ Side indicators
  - ✓ Driving PWM enabled LED channel

DRV89XX-Q1 for mirror application



Thank you