TI Motor Drives

Automotive Body Motors Webinar - June 24, 2021

Smarter, safer, smaller motor driver solutions

Texas Instruments

Agenda

- Introductions
- EMC and Thermal — Clark Kinnaird
- Brushed and steppers — Ryan Kehr
  - Current sensing
  - Diagnostics and protection
    - Power off braking
- Brushless — Adam Sidelsky
  - Current sensing
  - Diagnostics and protection

Introductions

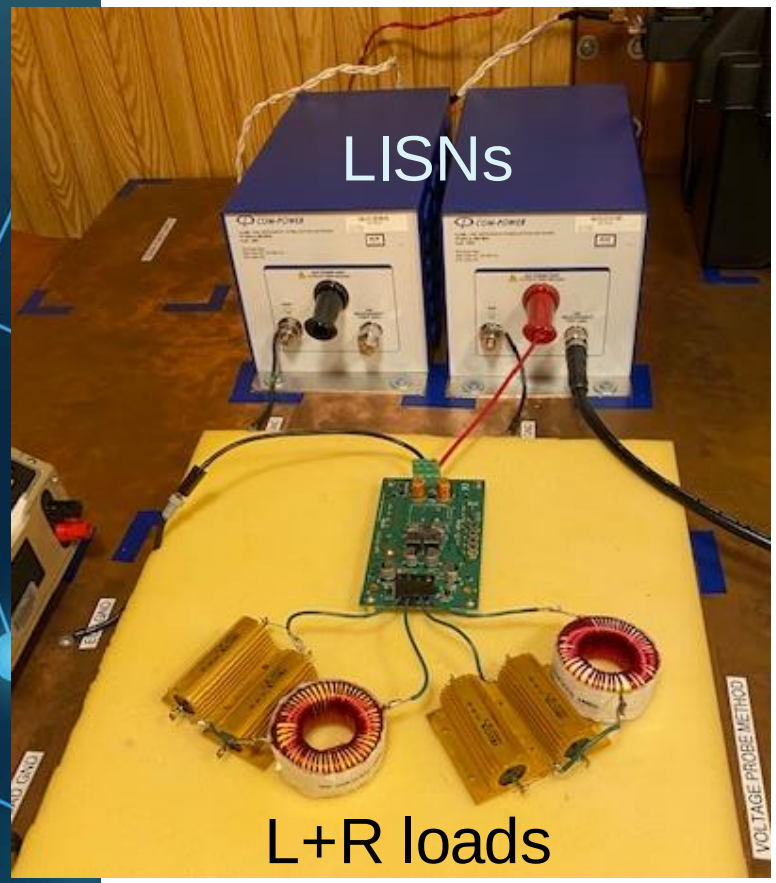
- Clark Kinnaird is a systems engineer responsible for developing automotive electronics solutions at Texas Instruments. Clark is a senior member of IEEE, has US patents issued and pending, and has published articles in SAE and IEEE journals, trade magazines, and conference proceedings.

- Ryan Kehr is an Application Manager at Texas Instruments. His team supports customers worldwide who drive stepper motors, brushed motors, and other loads with a wide portfolio of motor drivers. He attended Purdue University and earned his Bachelor of Science degree in Electrical Engineering.

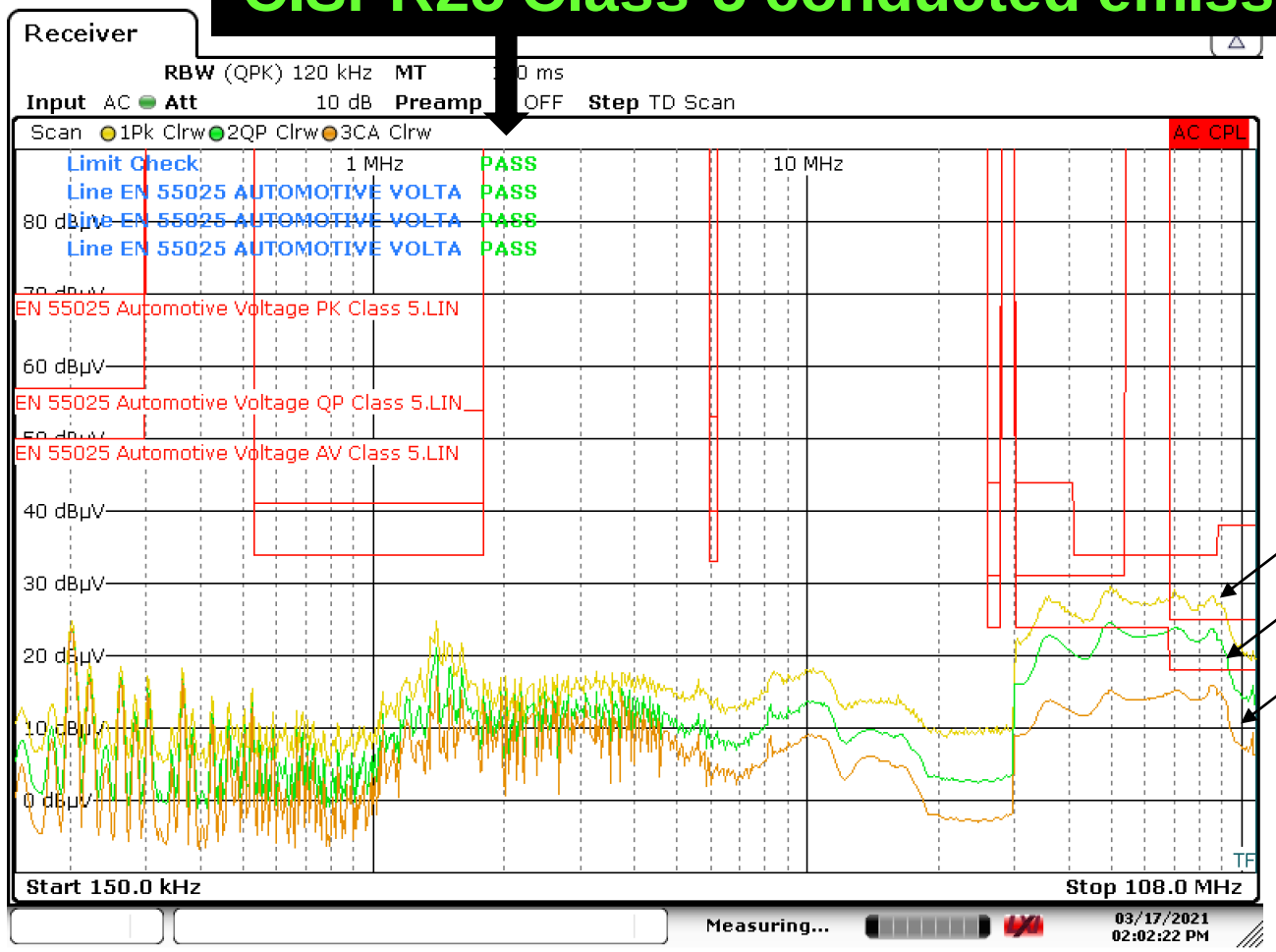
- Adam Sidelsky is an applications engineer within the Brushless DC (BLDC) Motor Drive group at Texas Instruments. He attended the University of Texas at Dallas and earned his Bachelor of Science degree in Electrical Engineering. Adam currently supports Automotive and Functional Safety oriented customers as they strive to build the next generation of smart BLDC motor devices.

EMC test results with DRV8706-Q1

Dual window lift drive

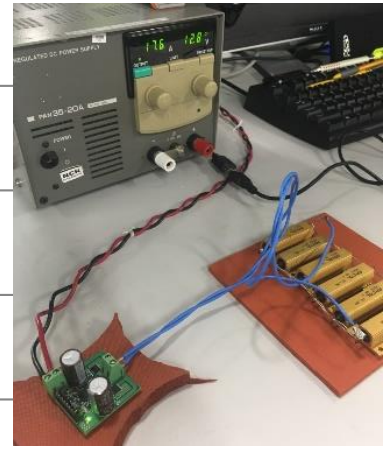


CISPR25 Class-5 conducted emissions: PASS



Peak
Quasi-peak
Average

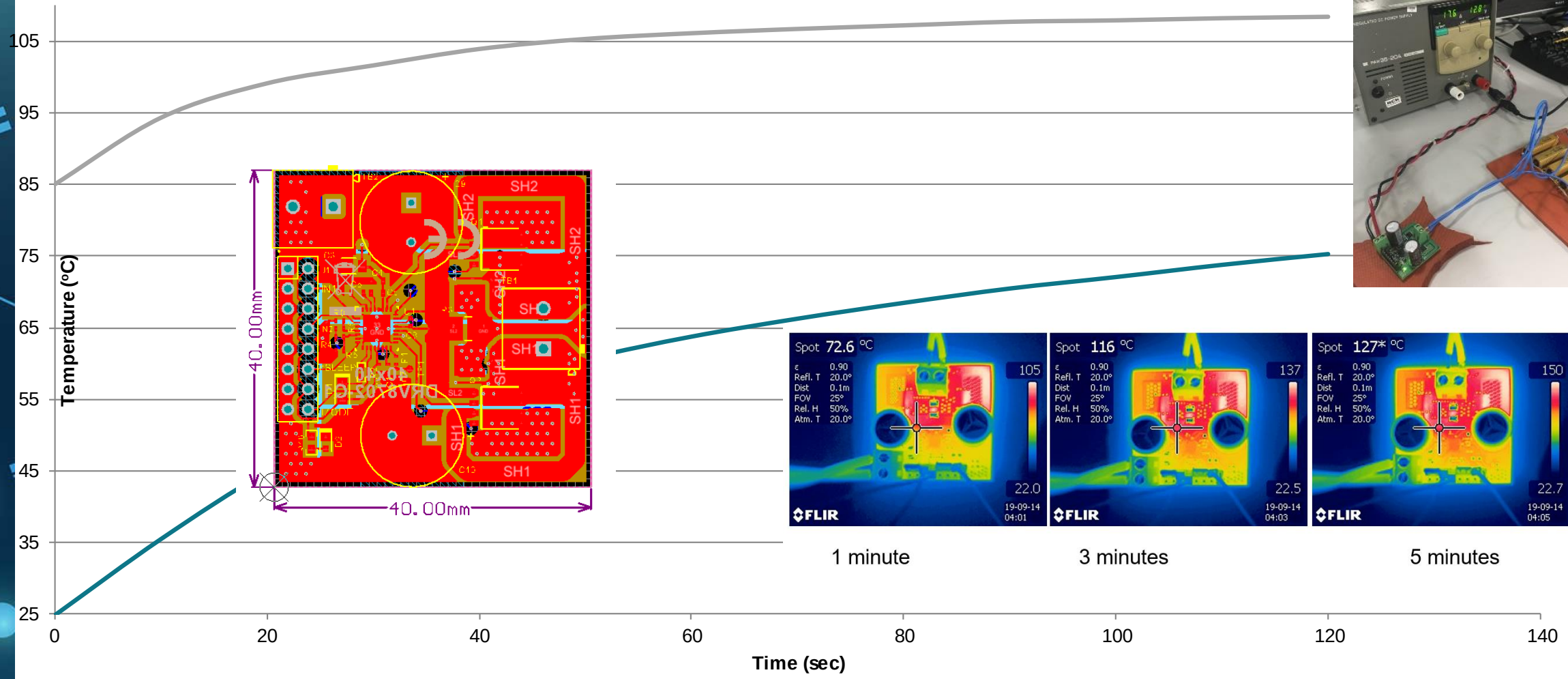
Thermal test results – temperature rise at 85ºC and 25ºC with 18A load



1 minute

3 minutes

5 minutes



Resources for EMC and Thermal

- Tips for successfully designing with automotive EMC/EMI
  - https://www.ti.com/lit/an/slyt636/slyt636.pdf
- Automotive electric motor EMC overview
  - https://training.ti.com/automotive-electric-motor-emc-overview
- Addressing EMI challenges for high side switches and motor drivers in body electronics
  - https://www.ti.com/lit/SLYP697
- Automotive EMC-compliant reverse-battery protection with ideal-diode
  - https://www.ti.com/lit/an/slyt802/slyt802.pdf
- How to Design a Thermally-Efficient Integrated BLDC Motor Drive PCB
  - https://www.ti.com/lit/pdf/slva938
- Thermal considerations when selecting an integrated motor driver
  - https://training.ti.com/engineer-it-thermal-considerations-when-selecting-integrated-motor-driver
- External or internal FETs for motor drive in automotive applications
  - https://www.ti.com/lit/pdf/slva968

Brushed DC
Motor Drivers

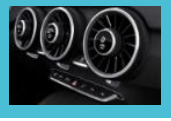
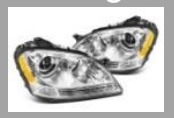
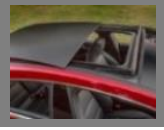
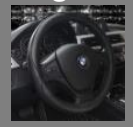
Brushless DC
Motor Drivers

Stepper
Motor Drivers

Motor Drive solutions to keep the world spinning

Design intelligent and efficient motor systems with accurate, small-size motor drivers

Motor Drive Business

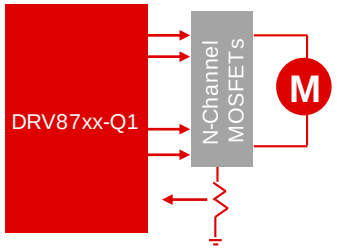
Trunk 	Power Seats 	HVAC Damper 
Doors 	Headlights 	Shifter Systems 
Roof 	Side Mirror 	Window 
On-board Charger 	Steering Column 	Pumps 
Head Up Display 	Battery Management 	Motor Bikes 
Engine Actuators 	Lidar 	Alarms 

- In motor driver market for over **>15 years**
- Ship **>500+Mu/year** motor drivers!
- Driving motors in **500+** applications across the industrial, automotive, and personal electronics business sectors
- **150+ Auto** customers World Wide

BSM Automotive Portfolio

Brushed Gate Drivers

- 1-8 channel scalable portfolio
- Smart gate drive w/ programmable slew rate for EMI optimization
- Inline current sense amplifier for ripple counting & sensorless position control
- Offline Diagnostics and protection



Future Investment Potential

- Grade-0 + ISO26262
- Smart motor drivers for domain control

Integrated H-bridge Drivers

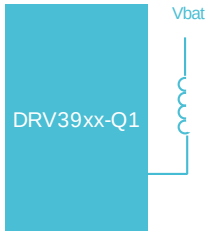
- 0-30A+ scalable portfolio
- Best in class power density with innovative small packaging and integrated external components
- Reliable motion control with highly accurate integrated current sensing

Future Investment Potential

- Lower Rdson -> Higher power
- Solenoid, Contactor, Pyro disconnect drivers
- Targeted application integration

Contactors Pyro Drivers

- Fully integrated compact solution
- Shunt less accurate current sense
- Integrated clamp for Quick Turn off
- Built in Diagnostics & Redundancy
- ASIL - ISO 26262 Complaint



Future Investment Potential

- Industrial Contactors
- Linear Solenoid driver

Integrated Current Sensing Technology

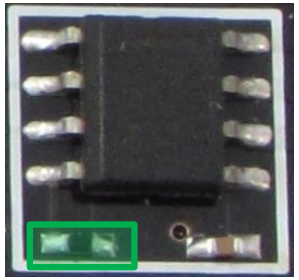
Eliminates all current sense resistors while providing accurate current regulation

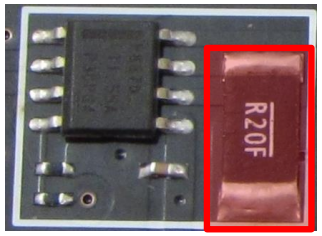
Benefits to customer:

- Eliminate bulky and expensive sense resistors **(system cost)**
- No power loss over the sense resistor **(power budget)**
- Fewer components on the board **(manufacturability)**
- Easy device layout with no sense routing **(development)**

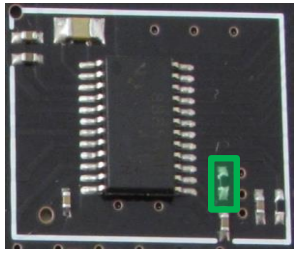
Integrated VS Non Integrated

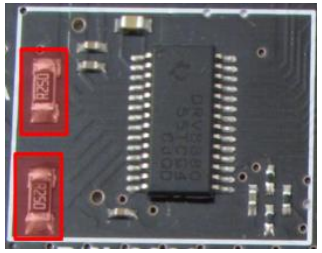
Integrated FET





Stepper Motor Driver



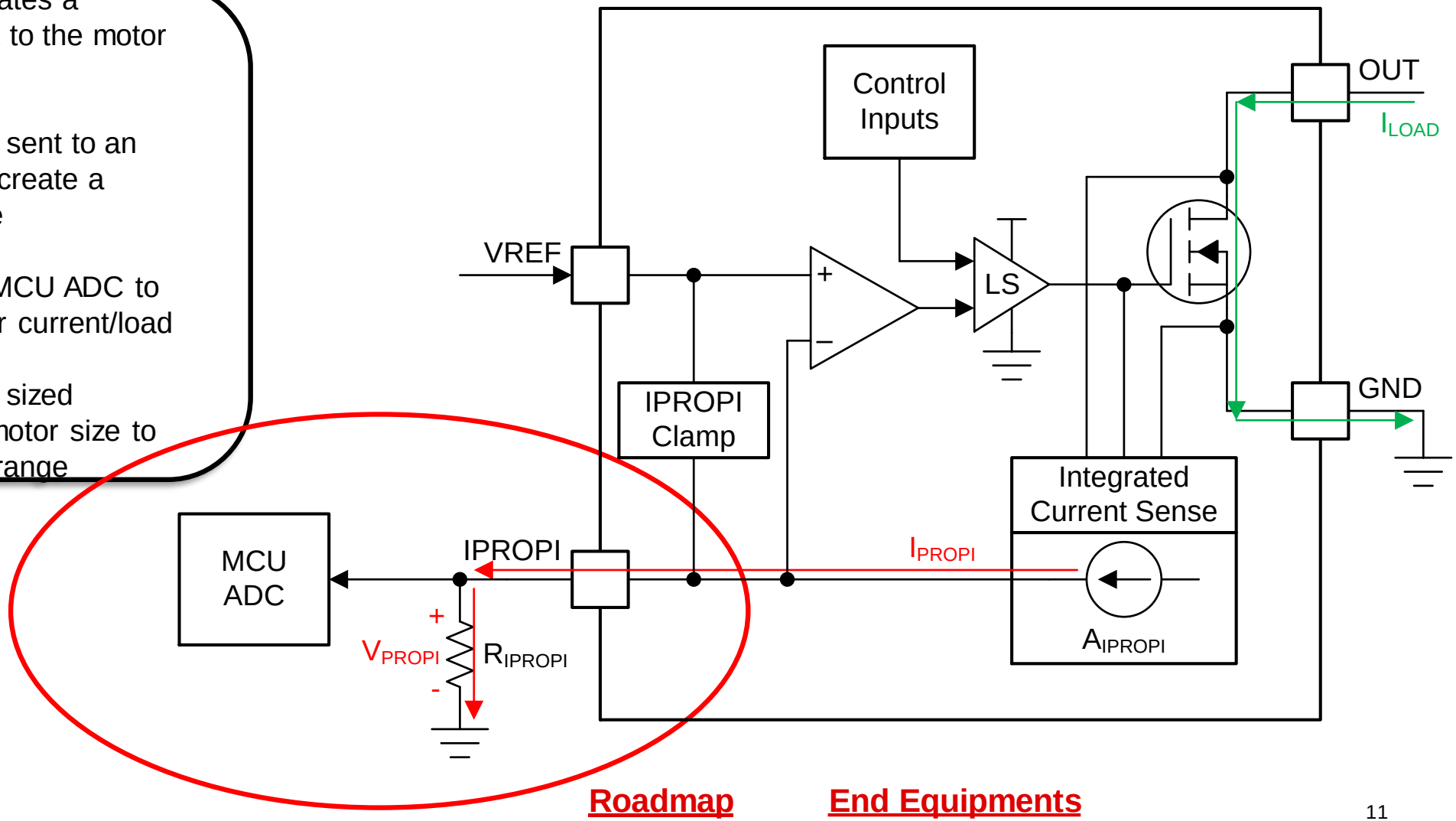


Roadmap End Equipments

DRV824x-Q1

Current Feedback

- DRV824x-q1 generates a proportional current to the motor current
- This current can be sent to an external resistor to create a proportional voltage
- Voltage is read by MCU ADC to determine the motor current/load
- The resistor can be sized accordingly to the motor size to utilize the full ADC range



Roadmap End Equipments

Inline Current Sense Amplifier

Inline current sensing overcomes short comings seen with low-side or high-side current sensing while allowing for advance features such as anti-pinch and ripple counting

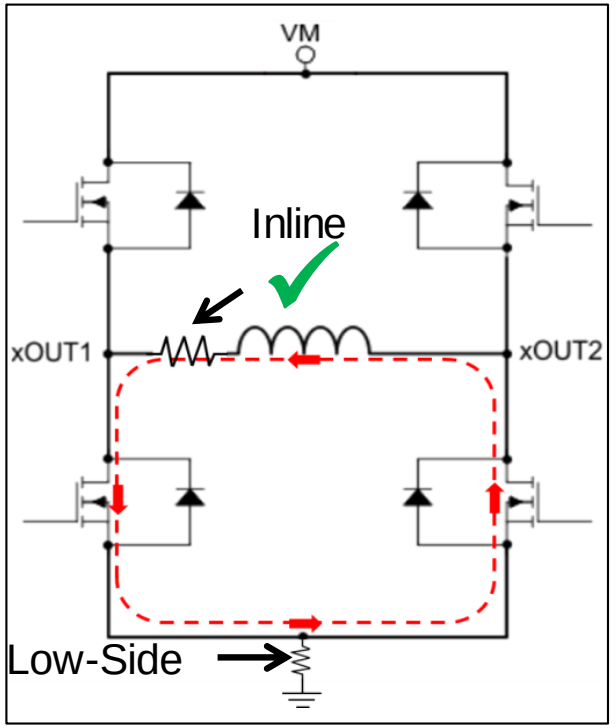
Key Benefits:

- Advanced Diagnostic Capability
  - Ability to detect both short to battery and short to ground.
  - Accurate stall detection.
- 100% Current Sensing
  - Provide continuous current feedback irrespective of where the current is flowing through the H-Bridge.
- Enable Advance Features
  - Determine position through the motor current ripple without the need for position sensors.
  - Utilize accurate current feedback to implement sensorless modern safety features such as anti-pinch

Supported Parts: DRV8106-Q1, DRV8706-Q1, DRV871X-Q1

Sensorless Anti-Pinch

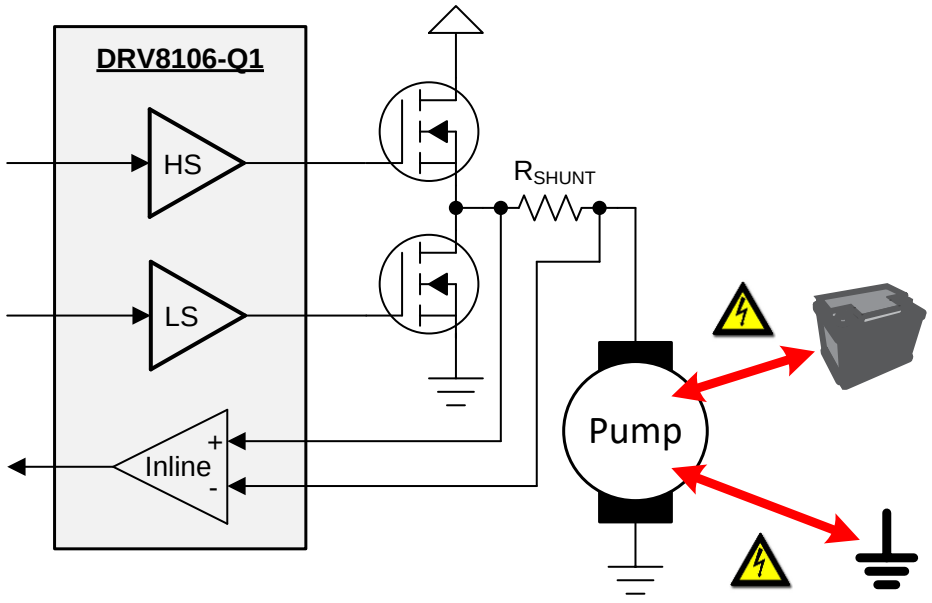
Current Recirculation Detection



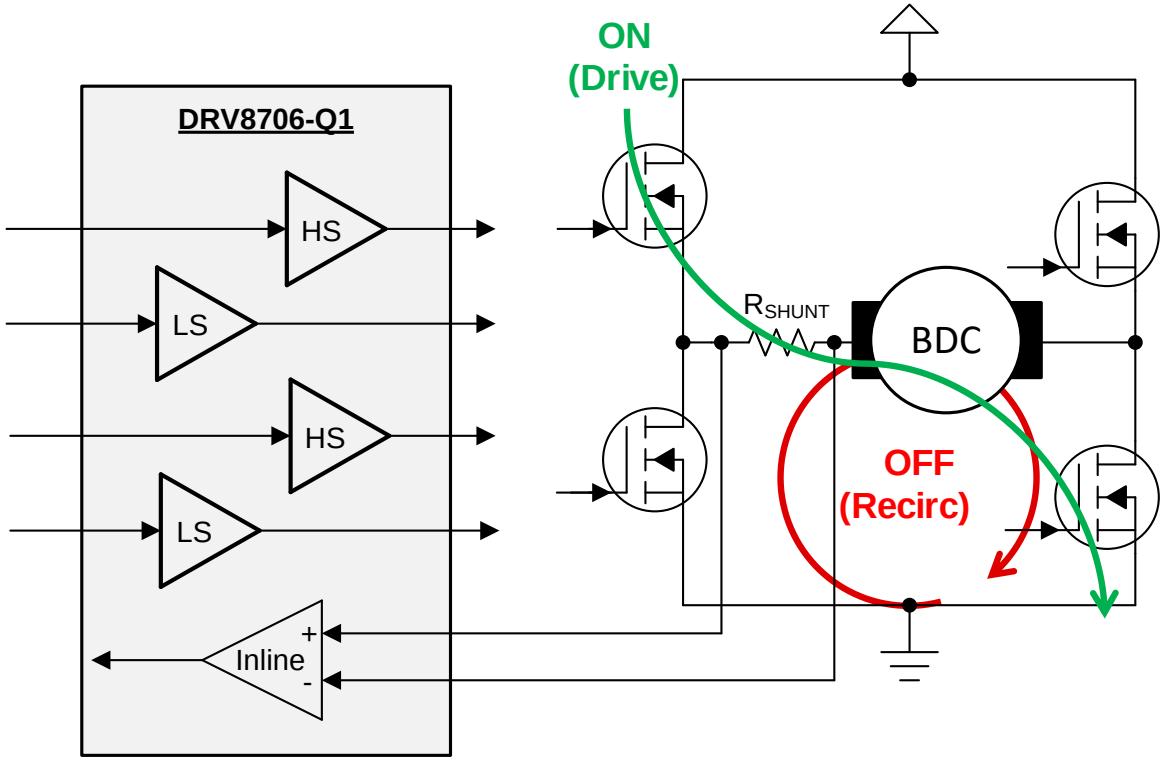
Key Features

Inline Shunt Amplifier (Fault Diagnostics & 100% Sensing)

- Inline current sensing provides detection of both short to battery and short to ground conditions of the load.



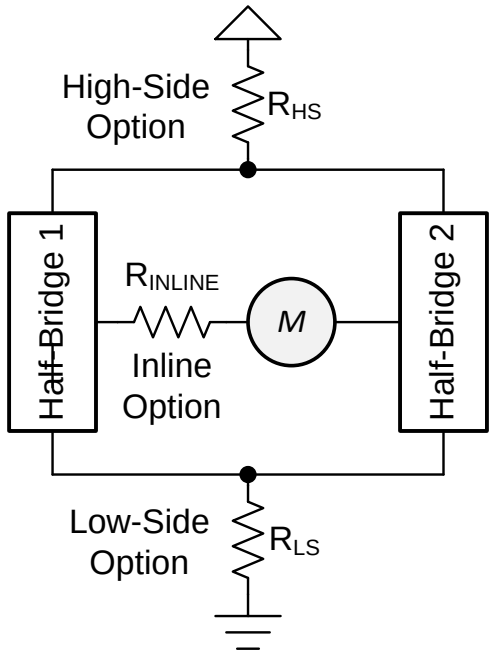
- Inline current sensing provides 100% current sensing during PWM ON and OFF periods allowing for more accurate stall and pinch detection



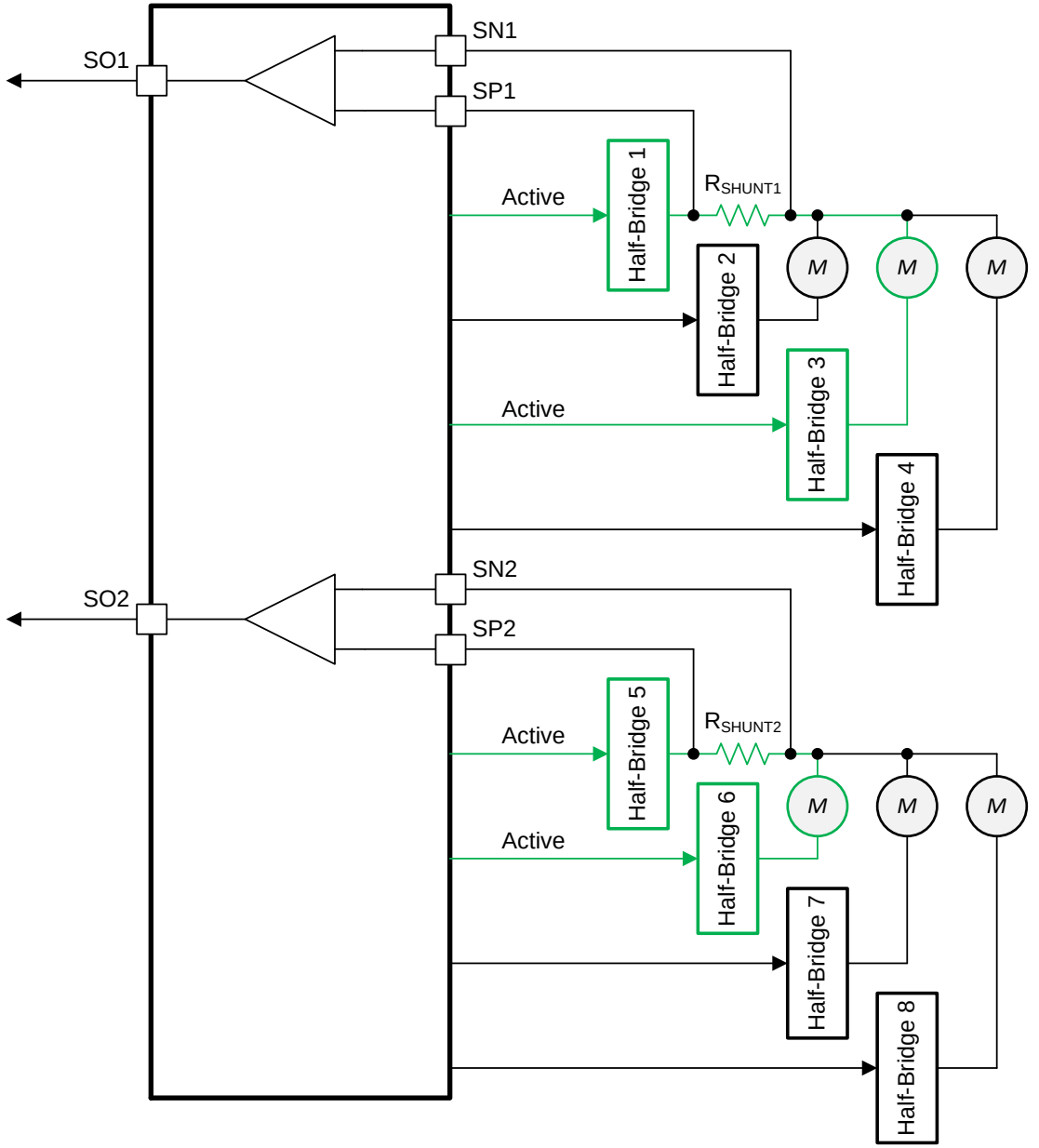
Key Features

Inline Shunt Amplifier (Grouping/Zoning)

- Inline current sensing enables current shunt resistor sharing in grouped motor control schemes for measuring both the PWM ON and OFF window current.



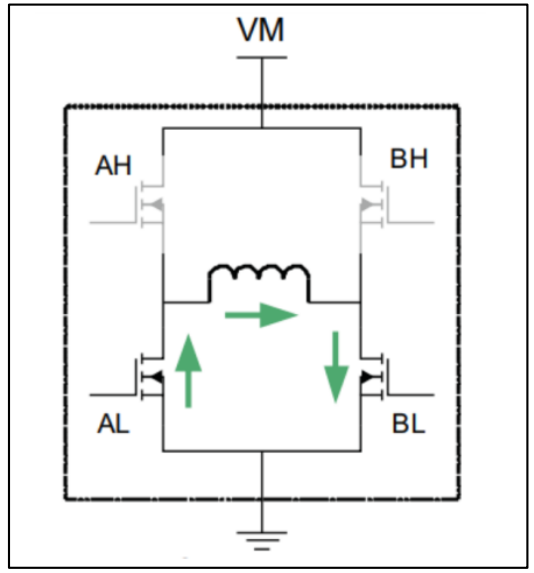
- The wide common range of the amplifier allows it to be used for either inline, low-side, or high-side configurations depending on the application needs



Integrated Back EMF Overvoltage Protection

Protect the motor system from overvoltage conditions typically caused by manual force applied to the motor. TI's Back EMF overvoltage protection automatically recirculates the current safely if an overvoltage condition occurs when in sleep mode.

Low Side Recirculation



Key Benefits:

- Protection 24/7
  - Protect your system even during deep sleep
- Configurable
  - Adjustable voltage threshold to meet your unique requirements
- Save Cost and Space
  - Eliminate costly and bulky components

Manually Opening Lift Gate

Adjusting Seat for Factory Installation

Supported Parts: DRV871X-Q1

Roadmap End Equipments

BLDC Automotive End Equipment

12-V functional safety Gate Drivers

- SafeTI package and SeOOC analysis w/ TPS65x safety PMIC enables seamless system functional safety development
- Grade 0 qualified for high temperature mission profile usages
- 4.5 V operation for easy start-stop

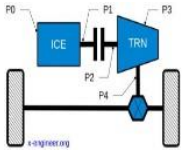


End Equipment

- Electric Power Steering
- Brake boosters
- Transmission Control Unit
- Functionally safe body applications

48-V Motor drive systems

- Comprehensive protection features slows safe high-kW motor systems' implementations
- Sufficient gate-drive current driving multiple MOSFETs in parallel for high power motors
- Negative transient voltage support down to -15 V (for < 1 us)



End Equipment

- Belt starter generators (BSG)
- P0/1 Integrated starter generators (ISG)
- P2/3/4 48-V traction inverters
- 48-V Electric Power Steering

12-V Engine Management

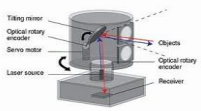
- Flexibility to drive FET independently
- Integrated current sense amplifiers
- Fully protected for reliable and robust performance
- Grade 0 qualified for high temperature mission profile usages (oil pumps, VVT control, etc.)

End Equipment

- Oil pump control module
- Fuel pump control module
- Variable valve timing control module
- Engine actuators
- Compressors

12-V Body and ADAS

- Flexibility to drive FET independently
- Integrated current sense amplifiers
- Fully protected for reliable and robust performance
- Sensored trapezoidal control algorithm for accurate position
- Sensorless FOC control algorithm for superior audible performance

End Equipment

- HVAC blowers
- Seat comfort modules
- Grill shutter control modules
- Mechanical scanning LIDAR

DRV8x Protection Features

Overcurrent

Protects Against:

Motor winding shorts, motor stall

PCB defects (pin-to-pin shorts)

What it does:

If there is an abnormally high current through the driver, a fault condition is recognized and the driver will shut itself down and report the condition. The driver may or may not retry (device dependent)

How it works:

1. Analog current limit in the FETs
2. Deglitch time to prevent false trips
3. Digital threshold for OCP
4. Shutdown of the output
5. Reports the condition

Undervoltage

Protects Against:

Supply disconnection

Supply drop-out

What it does:

If the supply voltage drops below the undervoltage lockout threshold, a fault condition is recognized and the outputs are disabled until the voltage rises above the UVLO threshold. The driver restarts automatically.

How it works:

1. On-chip supply monitoring circuit
2. Supply drops, device disables
3. Hysteresis on UVLO threshold
4. Shutdown of the output
5. Reports the condition

Overtemperature

Protects Against:

Thermal runoff due to high ambient

Abnormally high load current

What it does:

If there is an abnormally high current through the driver, a fault condition is reported and the driver will shut itself down and report the condition. The driver may or may not retry (device dependent)

How it works:

1. On-chip temperature sensor
2. Deglitch time to prevent false trips
3. Hysteresis on recovery temp
4. Shutdown of the output
5. Reporting the condition

Other Protection

Protects Against:

PCB defects (pin-to-pin short, open)

Abnormal system conditions

What it does:

Several other protection features exist on different devices to further enhance the IC protection. These features protect internal device circuitry or external components.

Other protection features:

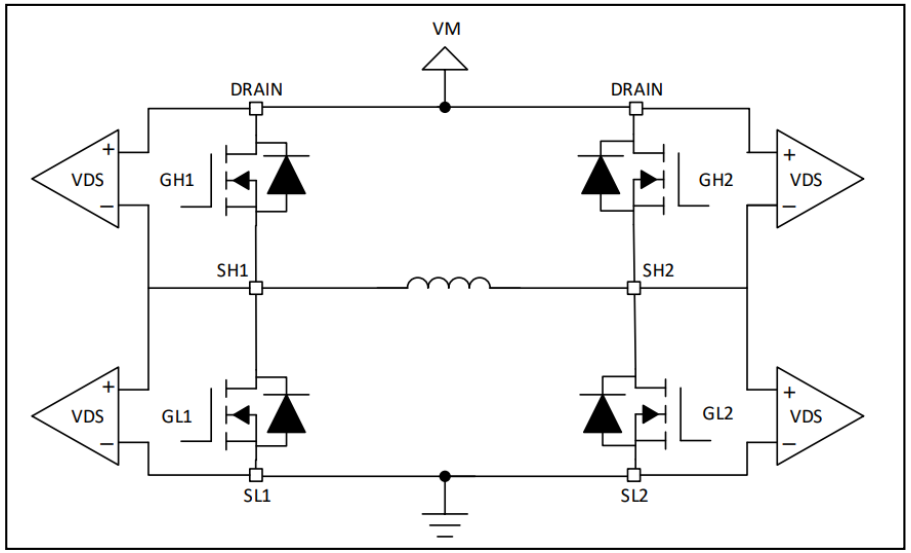
1. Charge pump undervoltage
2. Shoot-through protection
3. Regulator current limit
4. External FET VDS monitor
5. Smart Gate Drive

VDS Monitors in Gate Drivers

VDS monitors continuously check the current flowing through each MOSFET. By monitoring the FETs, the gate driver is able to detect and protect the system from overcurrent and shorts.

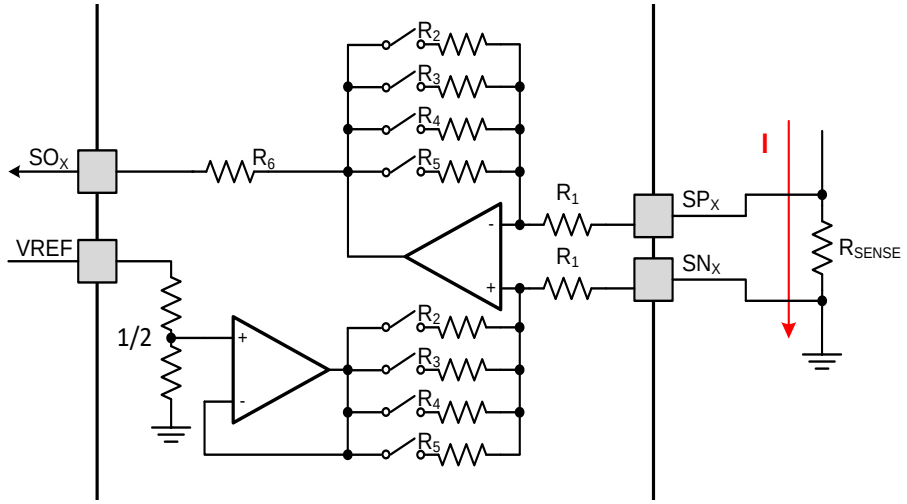
Key Benefits:

- Detects Both Short to Battery and Short To Ground
- Adjustable Deglitch Time
  - Select optimal deglitch time to avoid premature triggering of faults
- Multiple Modes Available:
  - Latch, Cycle By Cycle, Warning and Disabled.
- Precision Thresholds
  - Up to 16 levels
  - High accuracy monitors



DRV834x-Q1 - Integrated current sense amplifiers

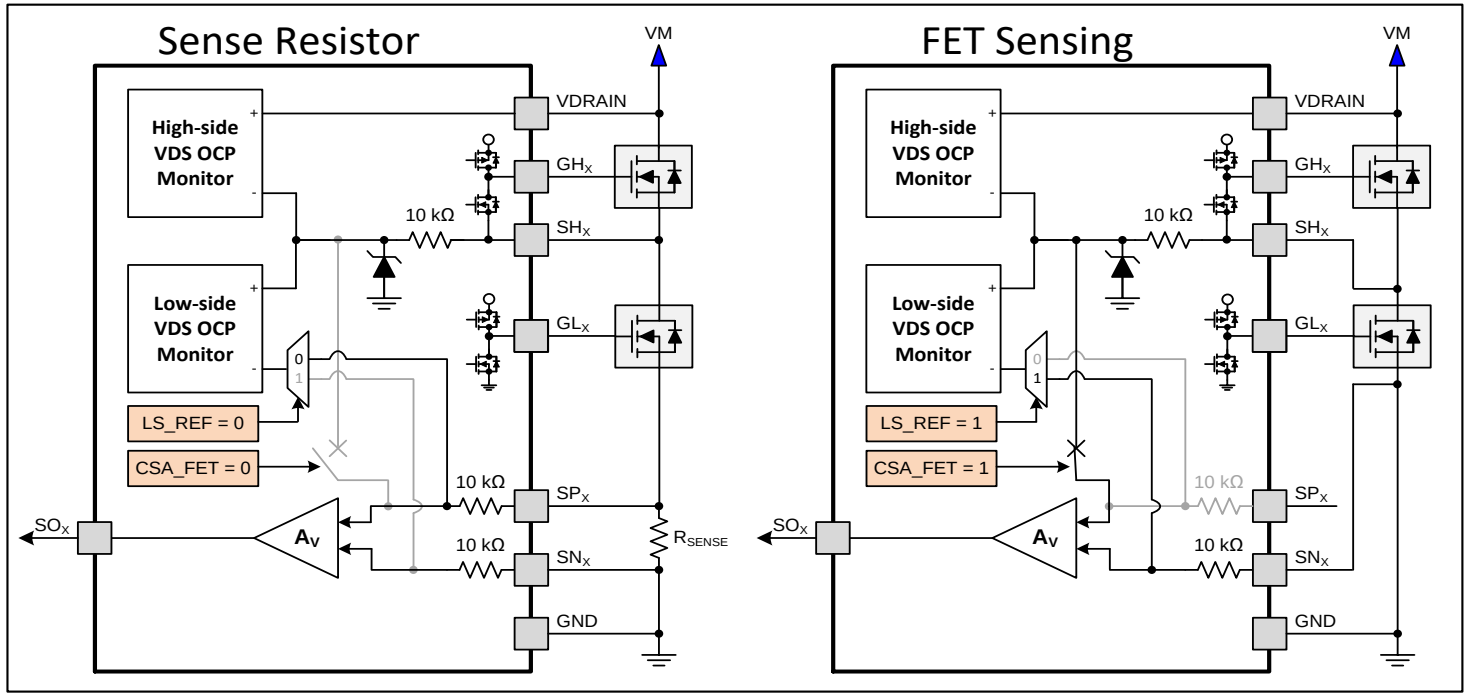
Current sense amplifier (CSA)



- Gain options = 5, 10, 20, 40 V/V.
- Offset calibration possible.
- Sense amplifier can operate in bidirectional or unidirectional mode.
- Unidirectional mode available on SPI only.

Sense amplifier - MOSFET V_{DS} sense mode (SPI Only)

- Eliminates the need of external shunt resistor and hence reduces cost and power loss.
- The CSA amplify the voltage across the external low-side MOSFET V_{DS}.



Over Current detection of Power FETs

TI Products
DRV325x-Q1
DRV83xx-Q1

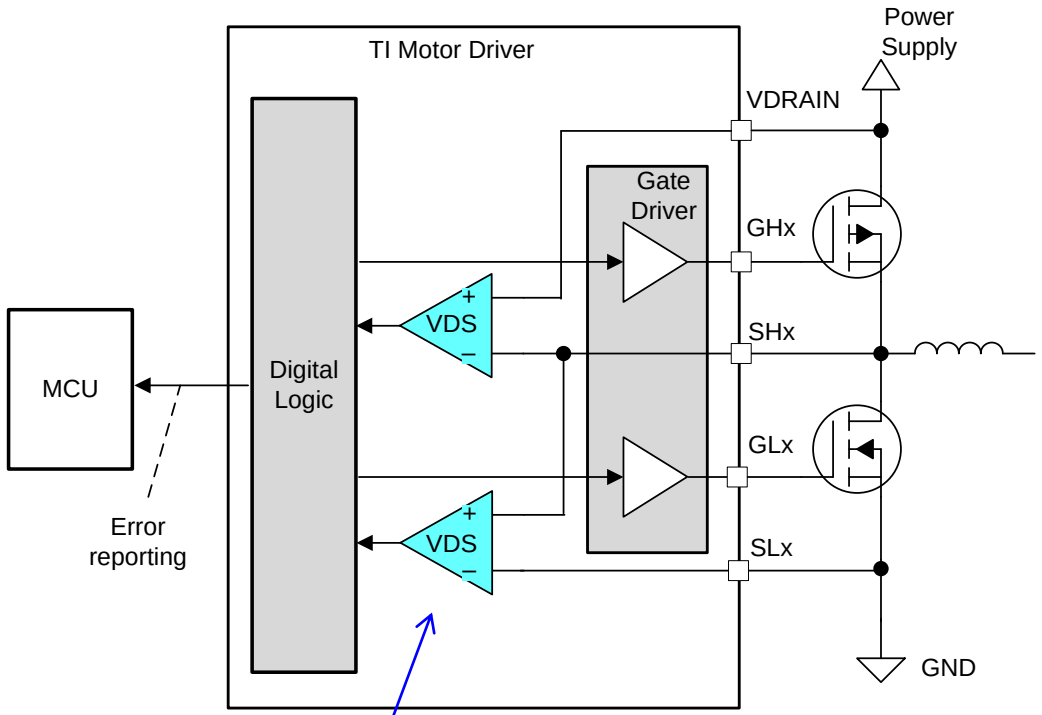
System Requirement

- Detection of power FETs from overcurrent
- Immediate shutdown of power FETs after the fault detection
- Fault is reported to MCU

Advantages

- Reduction of external components for overcurrent protection.
- Programmability of features allows user to change thresholds and times to meet system requirements.

Solution



Integrated comparators to monitor drain-source voltage of external power FETs.

Offline Short Detection of Motor Connection

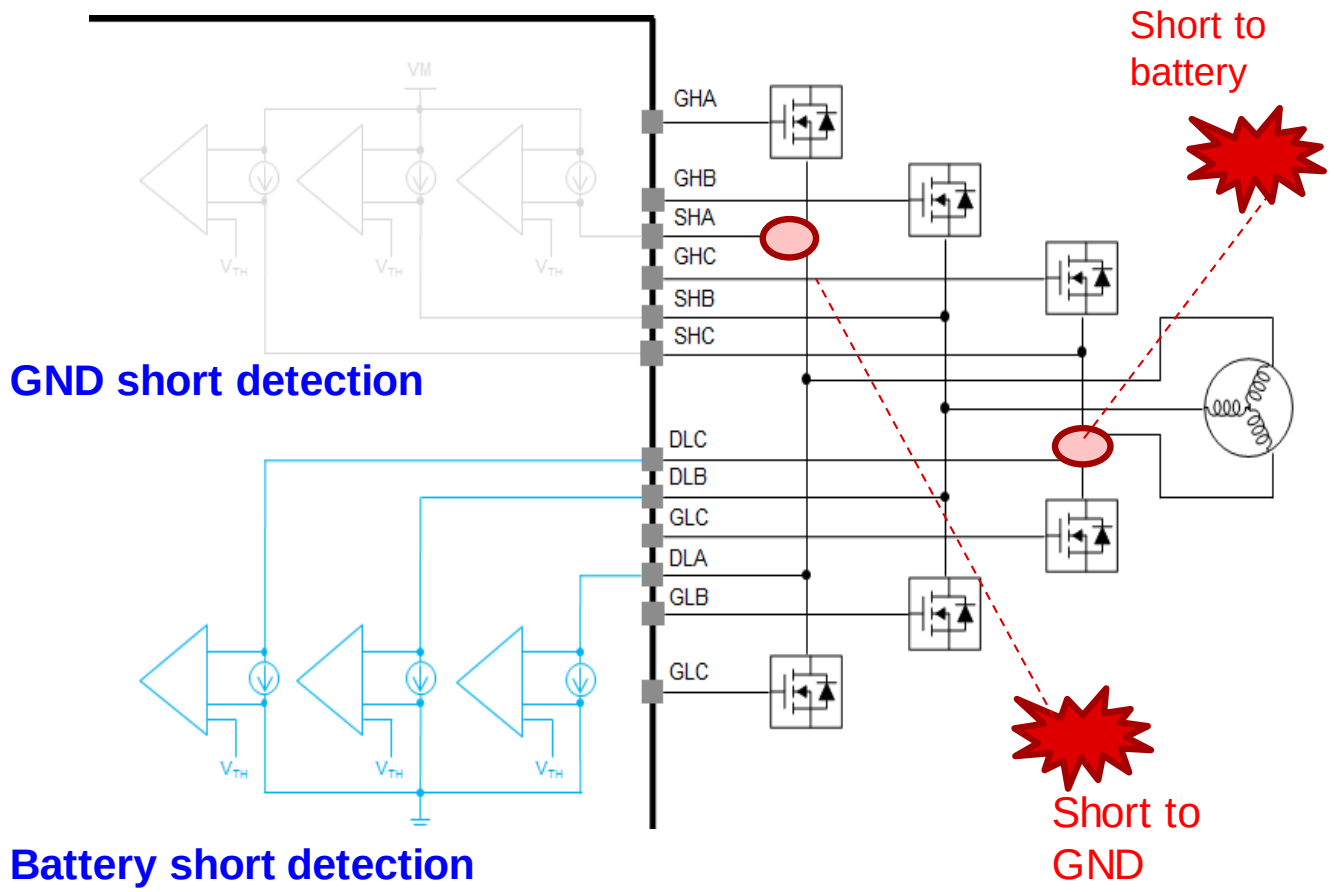
System Requirement

- Short detection of motor connection (to GND and to Battery) before running motor

Advantages

- Reduction of external components for fault detection
- MCU can take action to avoid system damage before the operation

Solution



Offline Open Load Detection

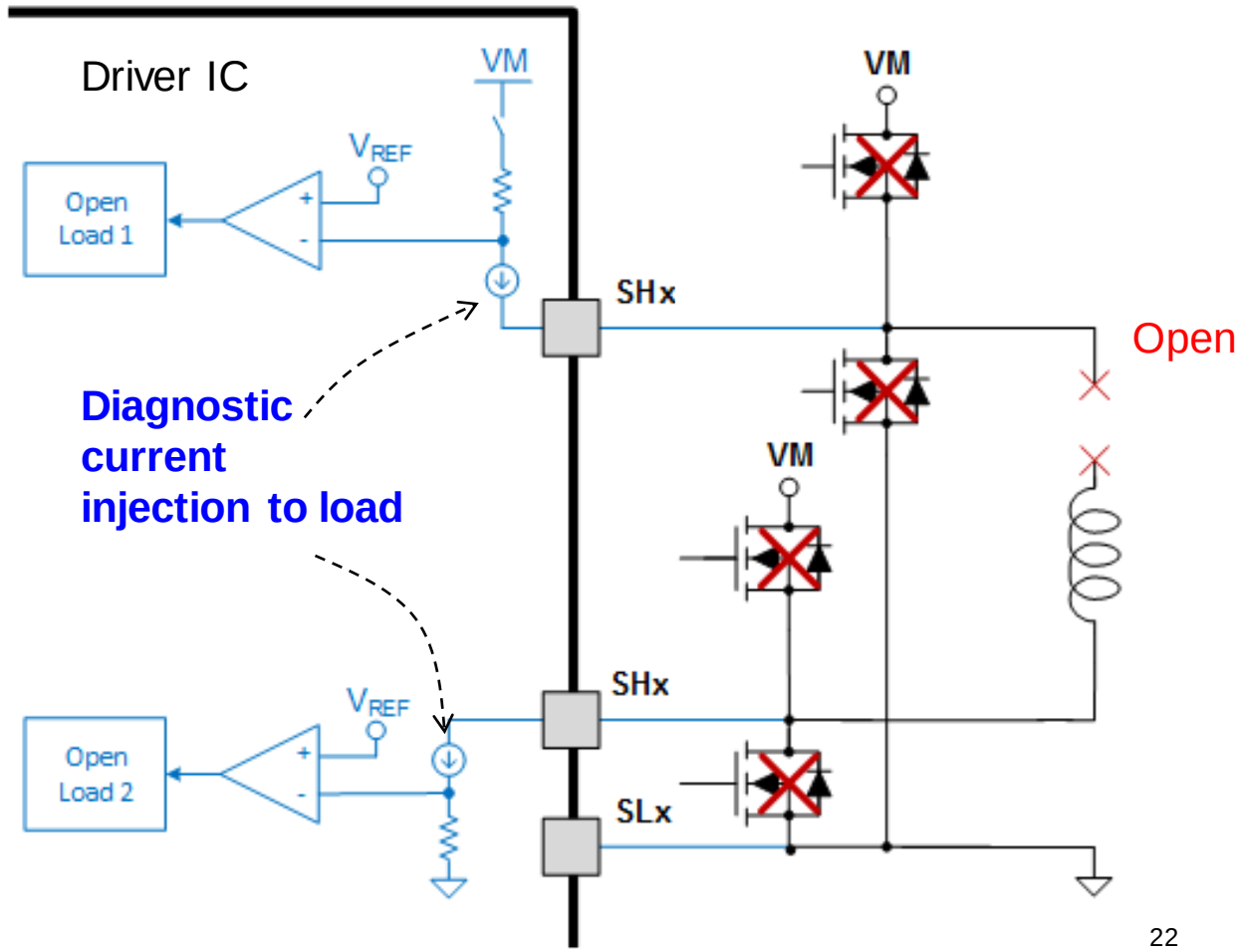
System Requirement

- Open detection of power FETs or Motor load before running motor
- Fault is reported to MCU

Advantages

- Reduction of external components for fault detection
- MCU can take action to avoid system damage before the operation

Solution



DRV3255-Q1

SafeTI

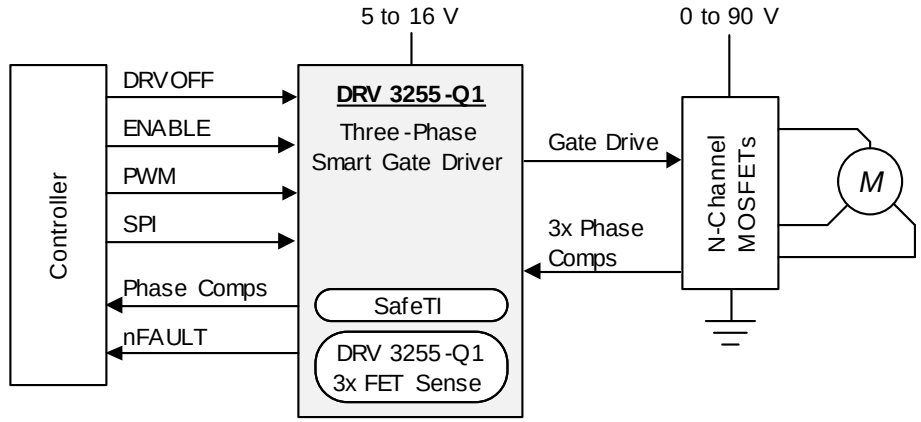
90-V, 3.5A / 4.5A Source/Sink, High Power Three-Phase Smart Gate Driver

Features

- AEC-Q100, Grade 0/1, 90-V 3.5A / 4.5A Triple Half-Bridge Gate Driver
  - Drives HS and LS N-Channel MOSFETS
  - Supports 100% PWM Duty Cycle (Trickle Charge Pump)
- Smart Gate Drive Architecture
  - Adjustable MOSFET Slew Rate Control and Diagnostics
- High Voltage Support (90-V DC Pin Capability)
- **DRV3255-Q1 Option:** Dedicated Half-Bridge Drain Sense Pins
- **Advanced Automotive Protection Suite:**
  - Overtemperature, MOSFET V_{DS} Overcurrent and Gate Fault
  - Dead-Time, Offline Open Load, Short Circuit Detection
  - Built In Self Test (BIST), SPI CRC, Clock and Supply Monitors

Benefits

- Wide voltage range to support automotive 48-V battery applications
- Highly efficient bootstrap design with trickle charge pump to support 100% duty cycle operation
- 10x10 mm 64-Pin HTQFP leaded package
- Individual MOSFET drain sense connections for optimal V_{DS} overcurrent detection
- Adjustable gate drive current settings to tune MOSFET switching performance and slew rates for efficiency and EMI
- Advanced on-chip protection and diagnosis (online and offline) to reduce design complexity and enable higher system reliability



Applications

- ISG, BSG, eAxle
- eTurbo, eBooster
- Compressor, Fans, Stabilizer
- Oil, Transmission, and Water Pumps

10x10 mm HTQFP
64-Pin

App Notes & White paper

- Advantages of Integrated Current Sensing
- Benefits of a Wide Common Mode, Differential
- Detecting Short to Battery and Ground Conditions with TI Motor Gate Drivers
- Integrated Protection Against Back EMF Overvoltage in
- Driving Parallel MOSFETs Using the DRV3255-Q1 (Rev. A)
- How to build a small, functionally safe 48-V, 30-kW MHEV Motor-Drive System

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