Motor Technology: Current Sensing and Regulation

TI Precision Labs – Motor Drivers

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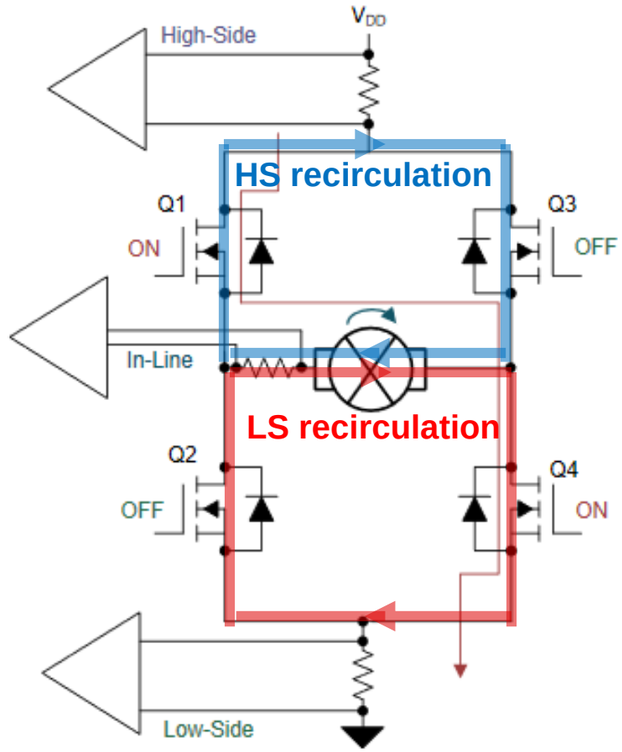
What is current sensing?

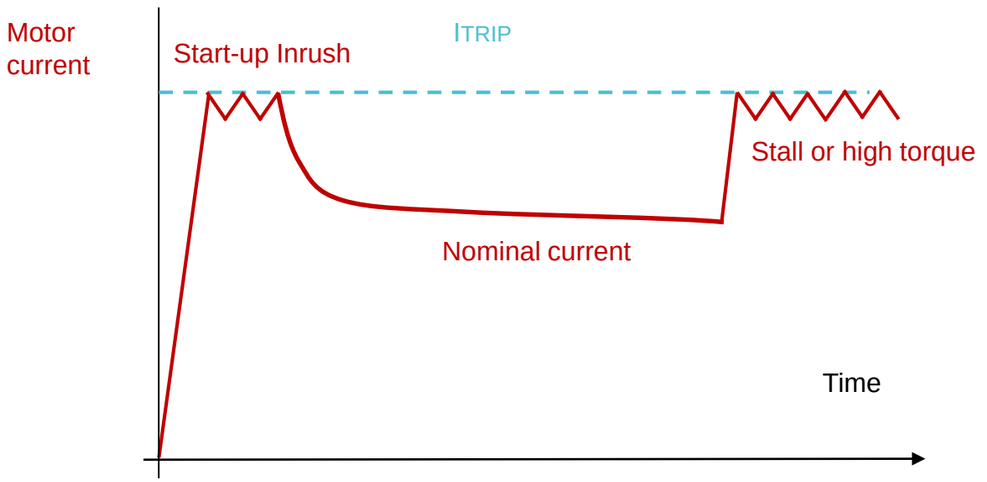
- Current sensing is a technique used to monitor current through a load.
- Current information can be used to monitor load condition changes and for advanced control methods such as current-controlled systems and field-oriented control (FOC). [1]
- Current sensing topologies include high-side, low-side, and in-line current sensing. [2]
- Current sensing can be used to monitor and regulate the current of a motor during startup and stall.

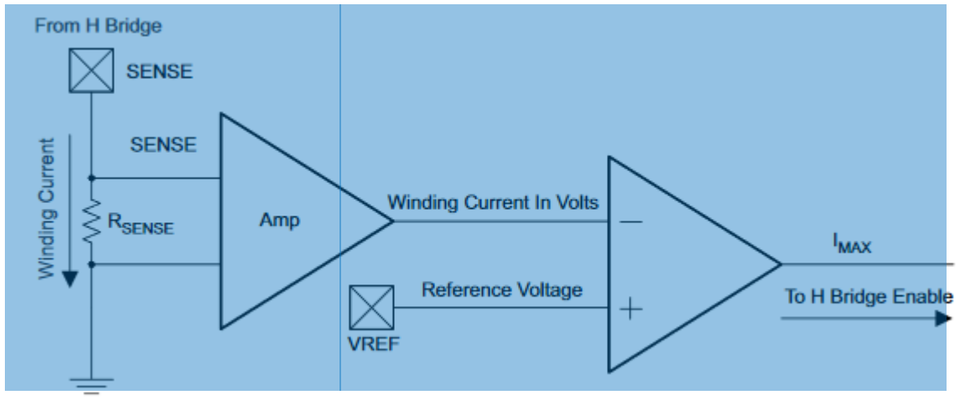


Current regulation

- Current regulation limits the output current to a fixed value
- Issues with motor start-up and stall:
  - High in-rush current
  - Large power consumption
- Current regulation circuit:
  - The voltage across R_{SENSE} is amplified which gives the winding current in volts.
  - A comparator compares the winding current in volts to a reference voltage.
  - The driver goes into current regulation once the winding current is above the current limit set by VREF.

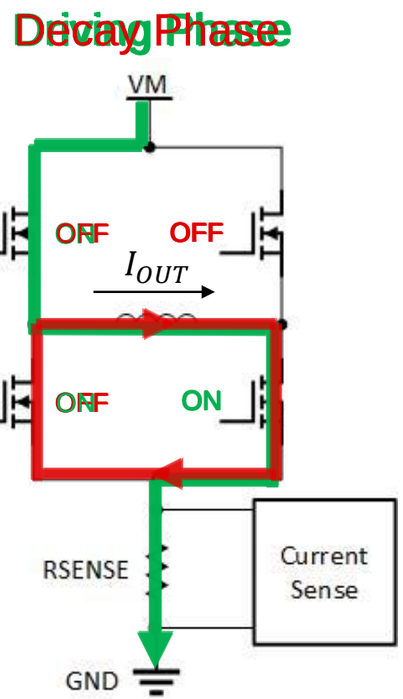
Current regulation to limit maximum motor current

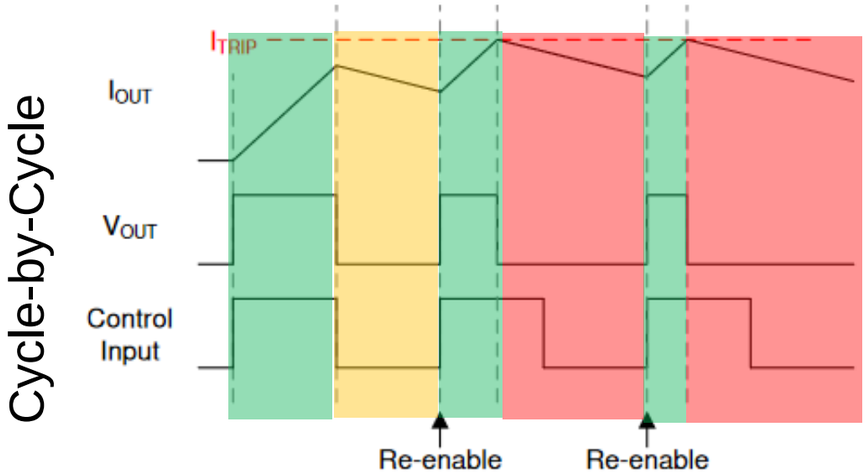


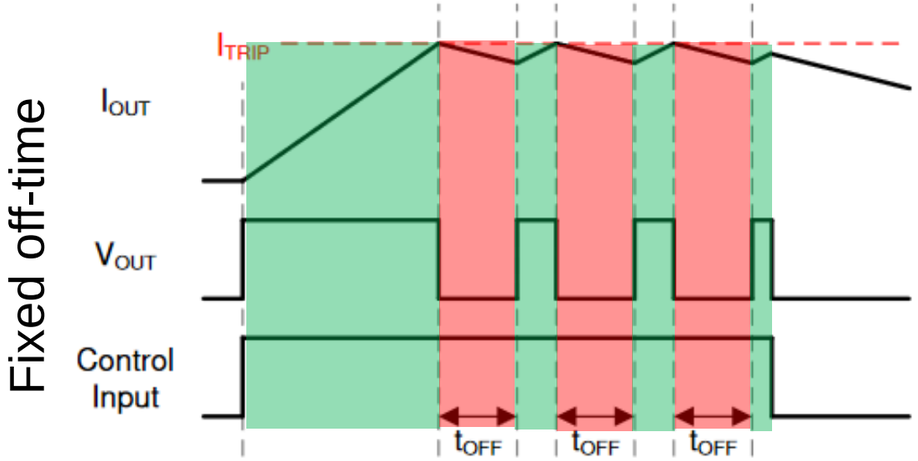


How current regulation works?

- When $I_{OUT} < I_{TRIP}$ the H-bridge is in the driving phase.
- When $I_{OUT} > I_{TRIP}$ the H-bridge is in the decay phase.
- In fixed off-time current regulation scheme, the decay phase lasts for a fixed period of time.
- In cycle-by-cycle current regulation scheme, the decay phase lasts until the next control input edge rise. [3]







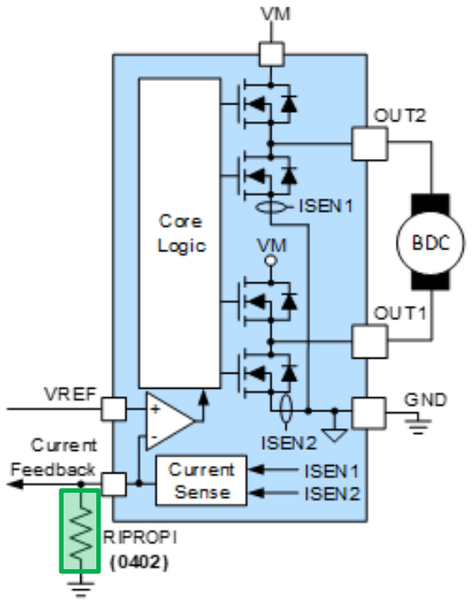
Integrated vs external current sensing

Technical Consideration	Low-side shunt resistor (External)	Current mirror (Integrated)
Board area	Additional PCB area needed for shunt resistor and amplifier	No additional PCB area needed for sensing circuitry
Heat dissipation	The shunt resistor dissipates additional heat due to I^2R heating.	No additional heat dissipation
Sense Accuracy	Shunt resistor accuracy depends on the shunt resistor tolerances and amplifier so choosing an amplifier with higher accuracy and shunt resistor with low tolerance can increase the sense accuracy.	The current mirror accuracy is fixed. Therefore designers will need to determine if the accuracy is acceptable for their systems.
Sensing during the decay phase	The sense signal from and amplifier can only be measured during PWM on time. This may require a sample-and-hold or special synchronization in MCU firmware.	The current mirror can provide a sense signal during PWM on time and off time.
Impedance in path of motor current	A shunt resistor adds impedance which may cause motor current to be low at low-battery conditions. With reduced current, the motor may not generate enough torque to move the load. This can limit effective battery lifetime in battery-powered applications.	The current mirror uses analog circuitry on the motor driver power FET, so a shunt resistor is not needed.

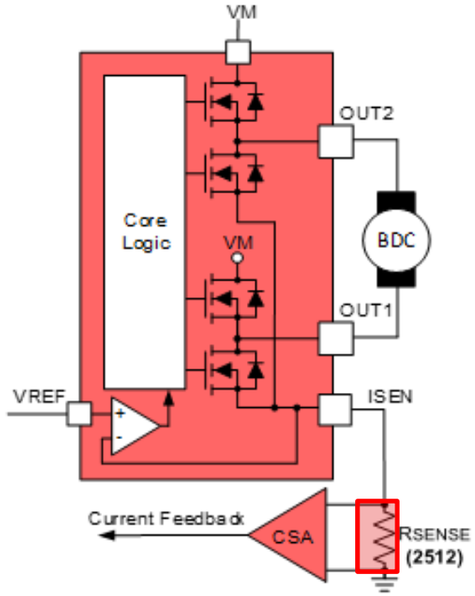
Integrated current sensing

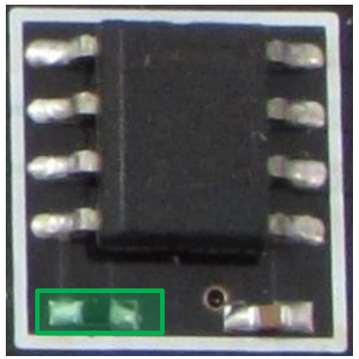
- Integrated current sensing use a current mirror circuit to measure the load current and an external resistor (IPROPI) to generate a proportional voltage (V_{IPROPI}) to the load current.
- External current sensing use a high power rated shunt resistor and require external current sense amplifiers for current feedback.
- Advantages of integrated current sensing:
  - Smaller external resistor.
  - Board size reduction [3]
  - PCB design simplification
  - Allow for current monitoring during the decay phase.

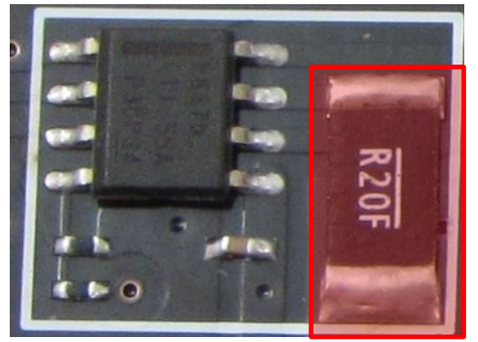
Integrated
Current sense



External
Current sense



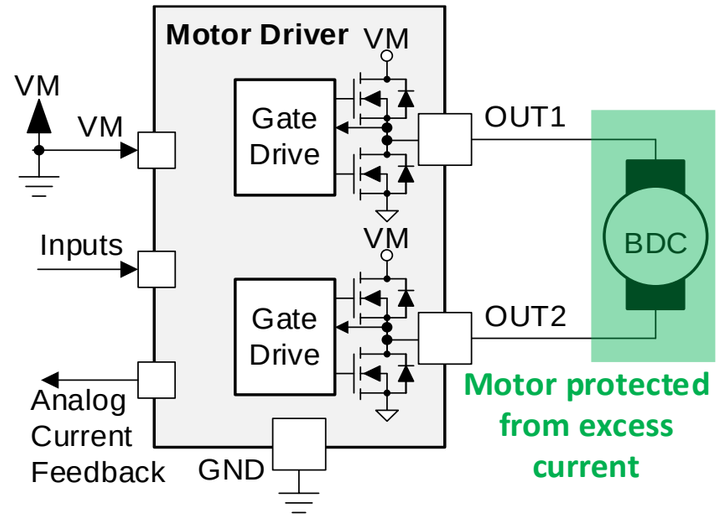




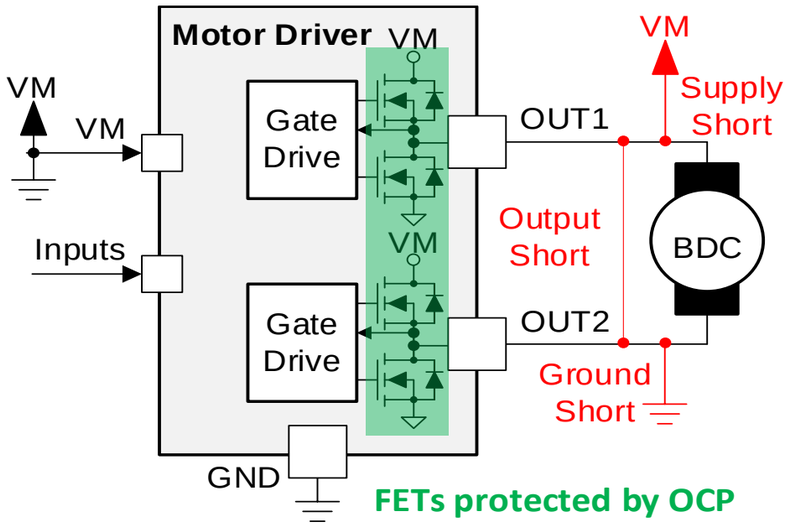
Current regulation vs over-current protection (OCP)

- Current regulation limits the output current to protect the motor from excess current.
- Over-current protection (OCP) protects the motor driver from large currents caused by shorts in the motor terminals. [4]

Current regulation



OCP



To find more motor driver technical resources and search products, visit ti.com/motor-drivers/overview.html

Resouces

- [1] “Field Oriented Control (FOC) Made Easy for Brushless DC (BLDC) Motors Using TI Smart Gate Drivers” ti.com
- [2] “TI Precision Labs – Current Sensing with Different Types of Amplifiers”, training.ti.com
- [3] “Advantages of Integrated Current Sensing”, ti.com
- [4] “Overcurrent Protection (OCP) vs Current Regulation”, e2e.ti.com