10 Diagnostics and Protection

The TMC2160 supplies a complete set of diagnostic and protection capabilities, like short circuit protection and undervoltage detection. Open load detection allows testing if a motor coil connection is interrupted. See the *DRV_STATUS* table for details.

10.1 Temperature Sensors

The driver integrates a four level temperature sensor (120°C pre-warning and selectable 136°C / 143°C / 150°C thermal shutdown) for diagnostics and for protection of the IC and the power MOSFETs and adjacent components against excess heat. Choose the overtemperature level to safely cover error conditions like missing heat convection. Heat is mainly generated by the power MOSFETs, and, at increased voltage, by the internal voltage regulators. For many applications, already the overtemperature pre-warning will indicate an abnormal operation situation and can be used to initiate user warning or power reduction measures like motor current reduction. The thermal shutdown is just an emergency measure and temperature rising to the shutdown level should be prevented by design.

After triggering the overtemperature sensor (*ot* flag), the driver remains switched off until the system temperature falls below the pre-warning level (*otpw*) to avoid continuous heating to the shutdown level.

10.2 Short Protection

The TMC2160 protects the MOSFET power stages against a short circuit or overload condition by monitoring the voltage drop in the high-side MOSFETs, as well as the voltage drop in sense resistor and low-side MOSFETs (Figure 10.1). A programmable short detection delay (*shortdelay*) allows adjusting the detector to work with very slow switching slopes. Additionally, the short detector allows filtering of the signal. This helps to prevent spurious triggering caused by effects of PCB layout, or long, adjacent motor cables (*SHORTFILTER*). All control bits are available via register *SHORT_CONF*. Additionally, the short detection is protected against single events, e.g. caused by ESD discharges, by retrying three times before switching off the motor continuously.

Parameter	Description	Setting	Comment
S2VS_LEVEL	Short or overcurrent detector level for lowside FETs. Checks for voltage drop in LS MOSFET and sense resistor. *Hint:* 6 to 8 recommended, down to 4 at low current scale	4…15	4 (highest sensitivity) … 15 (lowest sensitivity) *(Reset Default: OTP 6 or 12)*
S2G_LEVEL	*S2G_LEVEL*: Short to GND detector level for highside FETs. Checks for voltage drop on high side MOSFET. *Hint:* 6 to 14 recommended (minimum 12 if the bridge supply voltage can exceed 52V)	*2…15*	2 (highest sensitivity) … 15 (lowest sensitivity) *(Reset Default: OTP 6 or 12)*
SHORT_ FILTER	Spike filtering bandwidth for short detection *Hint:* A good PCB layout will allow using setting 0. Increase value, if erroneous short detection occurs.	0…3	0 (lowest, 100ns), 1 (1µs) (*Reset Default*), 2 (2µs), 3 (3µs)
shortdelay	*shortdelay*: Short detection delay The short detection delay shall cover the bridge switching time. 0 will work for most applications.	0/1	0=750ns: normal, 1=1500ns: high
CHOPCONF. diss2vs	Allows to disable short to VS protection.	0/1	Leave detection enabled for normal use (0).
CHOPCONF. diss2g	Allows to disable short to GND protection.	0/1	Leave detection enabled for normal use (0).

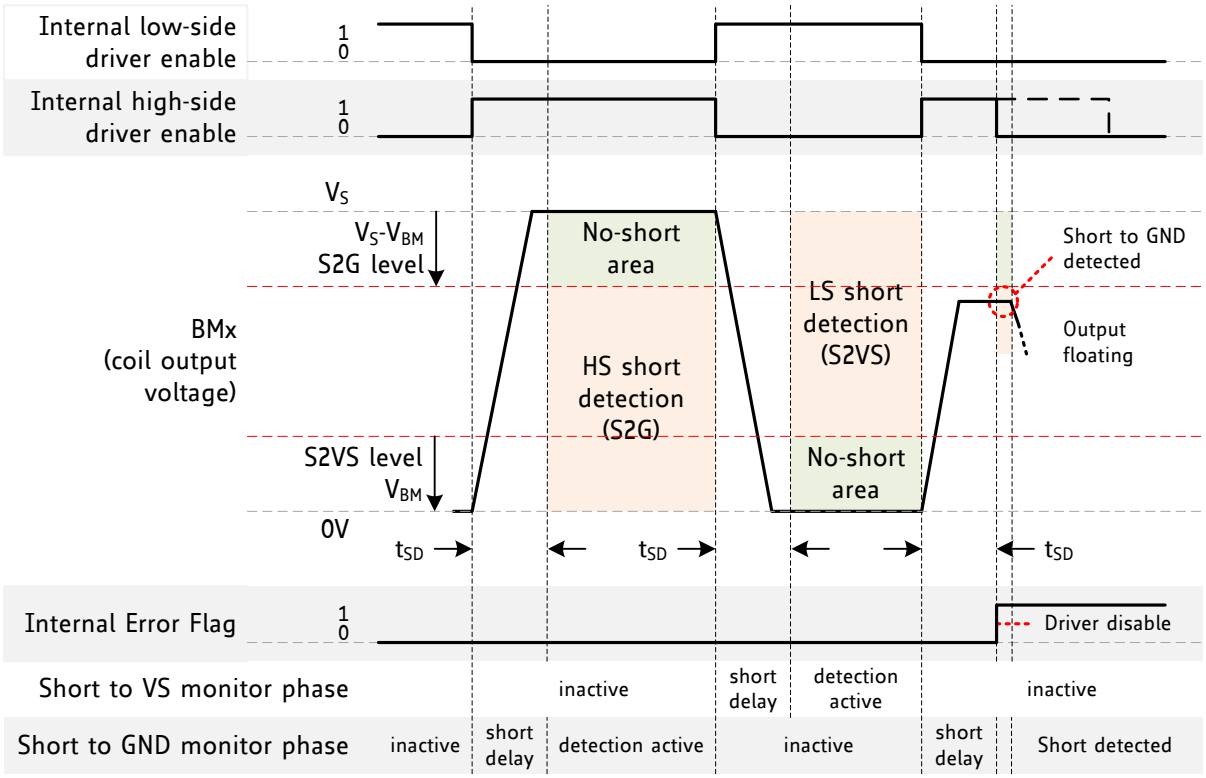

Figure 10.1 Short detection

As the low-side short detection includes the sense resistor, it can be set to a high sensitivity and provides good precision of current detection. This way, it will safely cover most overcurrent conditions, i.e. when the motor stalls, or is abruptly stopped in stealthChop mode.

Hint
Once a short condition is safely detected, the corresponding driver bridge (A or B) becomes switched off, and the *s2ga* or *s2gb* flag, respectively *s2vsa* or *s2vsb* becomes set.
To restart the motor, disable and re-enable the driver.

Attention
Short protection cannot protect the system and the power stages for all possible short events, as a short event is rather undefined and a complex network of external components may be involved. Therefore, short circuits should basically be avoided.

Hint
Set low-side short protection (S2VS) to sensitively detect an overcurrent condition (at 150 to 200% of nominal peak current). Especially with low resistive motors an overcurrent can easily be triggered by false settings, or motor stall when using stealthChop. Therefore, a sensitive short to VS setting will protect the power stage.

Attention
High-side short detection (S2G) sensitivity may increase at voltages above 52V. Therefore, a higher setting is required if motor supply voltage can overshoot up to 55V. We recommend a setting of 12 to 15 in this case. For fine tuning of overcurrent detection, trim the S2VS detector threshold. High-side short detection may falsely trigger if motor supply voltage overshoots 55V..

10.3 Open Load Diagnostics

Interrupted cables are a common cause for systems failing, e.g. when connectors are not firmly plugged. The TMC2160 detects open load conditions by checking, if it can reach the desired motor coil current. This way, also undervoltage conditions, high motor velocity settings or short and overtemperature conditions may cause triggering of the open load flag, and inform the user, that motor torque may suffer. In motor stand still, open load cannot be measured, as the coils might eventually have zero current.

Open load detection is provided for system debugging.
In order to safely detect an interrupted coil connection, read out the open load flags at low or nominal motor velocity operation, only. If possible, use spreadCycle for testing, as it provides the most accurate test. However, the *ola* and *olb* flags have just informative character and do not cause any action of the driver.