11 stallGuard2 Load Measurement

stallGuard2 provides an accurate measurement of the load on the motor. It can be used for stall detection as well as other uses at loads below those which stall the motor, such as coolStep load-adaptive current reduction. The stallGuard2 measurement value changes linearly over a wide range of load, velocity, and current settings, as shown in Figure 11.1. At maximum motor load, the value goes to zero or near to zero. This corresponds to a load angle of 90° between the magnetic field of the coils and magnets in the rotor. This also is the most energy-efficient point of operation for the motor.

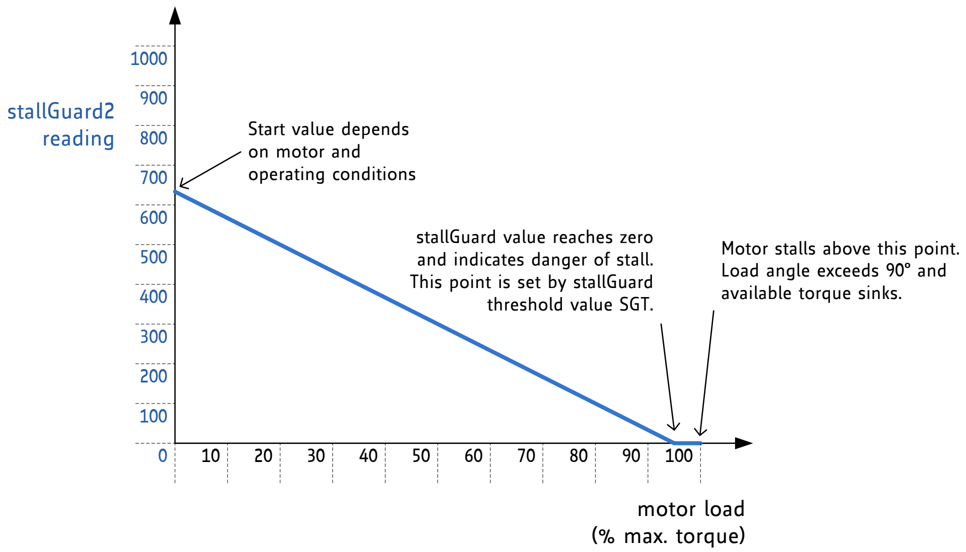

Figure 11.1 Function principle of stallGuard2

Parameter	Description	Setting	Comment
SGT	This signed value controls the stallGuard2 threshold level for stall detection and sets the optimum measurement range for readout. A lower value gives a higher sensitivity. Zero is the starting value working with most motors. A higher value makes stallGuard2 less sensitive and requires more torque to indicate a stall.	0	indifferent value
		+1… +63	less sensitivity
		-1… -64	higher sensitivity
sfilt	Enables the stallGuard2 filter for more precision of the measurement. If set, reduces the measurement frequency to one measurement per electrical period of the motor (4 fullsteps).	0	standard mode
		1	filtered mode
Status word	**Description**	**Range**	**Comment**
SG_RESULT	This is the *stallGuard2 result*. A higher reading indicates less mechanical load. A lower reading indicates a higher load and thus a higher load angle. Tune the *SGT* setting to show a *SG_RESULT* reading of roughly 0 to 100 at maximum load before motor stall.	0… 1023	0: highest load low value: high load high value: less load

Hint
In order to use stallGuard2 and coolStep, the stallGuard2 sensitivity should first be tuned using the SGT setting!

11.1 Tuning stallGuard2 Threshold SGT

The stallGuard2 value *SG_RESULT* is affected by motor-specific characteristics and application-specific demands on load and velocity. Therefore, the easiest way to tune the stallGuard2 threshold *SGT* for a specific motor type and operating conditions is interactive tuning in the actual application.

INITIAL PROCEDURE FOR TUNING STALLGUARD SGT

1. Operate the motor at the normal operation velocity for your application and monitor *SG_RESULT*.
2. Apply slowly increasing mechanical load to the motor. If the motor stalls before *SG_RESULT* reaches zero, decrease *SGT*. If *SG_RESULT* reaches zero before the motor stalls, increase *SGT*. A good *SGT* starting value is zero. *SGT* is signed, so it can have negative or positive values.
3. Set *TCOOLTHRS* to a value above *TSTEP* and monitor the stallGuard output signal (configure DIAG0 or DIAG1 to output stall detection). Stop the motor when a pulse is seen on the respective output. Make sure, that the motor is safely stopped whenever it is stalled. Increase *SGT* if the motor becomes stopped before a stall occurs.
4. The optimum setting is reached when *SG_RESULT* is between 0 and roughly 100 at increasing load shortly before the motor stalls, and *SG_RESULT* increases by 100 or more without load. *SGT* in most cases can be tuned for a certain motion velocity or a velocity range. Make sure, that the setting works reliable in a certain range (e.g. 80% to 120% of desired velocity) and also under extreme motor conditions (lowest and highest applicable temperature).

OPTIONAL PROCEDURE ALLOWING AUTOMATIC TUNING OF SGT

The basic idea behind the SGT setting is a factor, which compensates the stallGuard measurement for resistive losses inside the motor. At standstill and very low velocities, resistive losses are the main factor for the balance of energy in the motor, because mechanical power is zero or near to zero. This way, SGT can be set to an optimum at near zero velocity. This algorithm is especially useful for tuning SGT within the application to give the best result independent of environment conditions, motor stray, etc.

1. Operate the motor at low velocity < 10 RPM (i.e. a few to a few fullsteps per second) and target operation current and supply voltage. In this velocity range, there is not much dependence of *SG_RESULT* on the motor load, because the motor does not generate significant back EMF. Therefore, mechanical load will not make a big difference on the result.
2. Switch on *sfilt*. Now increase *SGT* starting from 0 to a value, where *SG_RESULT* starts rising. With a high *SGT*, *SG_RESULT* will rise up to the maximum value. Reduce again to the highest value, where *SG_RESULT* stays at 0. Now the *SGT* value is set as sensibly as possible. When you see *SG_RESULT* increasing at higher velocities, there will be useful stall detection.

The upper velocity for the stall detection with this setting is determined by the velocity, where the motor back EMF approaches the supply voltage and the motor current starts dropping when further increasing velocity.

SG_RESULT goes to zero when the motor stalls and the stall output becomes activated. The external motion controller should react to a single pulse by stopping the motor, if desired. Set *TCOOLTHRS* to match the lower velocity threshold where stallGuard delivers a good result.

The power supply voltage also affects *SG_RESULT*, so tighter voltage regulation results in more accurate values. stallGuard measurement has a high resolution, and there are a few ways to enhance its accuracy, as described in the following sections.

Quick Start
For a quick start, see the Quick Configuration Guide in chapter 18.
For detail procedure see Application Note AN002 - *Parameterization of stallGuard2 & coolStep*

11.1.1 Variable Velocity Limits *TCOOLTHRS* and *THIGH*

The *SGT* setting chosen as a result of the previously described *SGT* tuning can be used for a certain velocity range. Outside this range, a stall may not be detected safely, and coolStep might not give the optimum result.

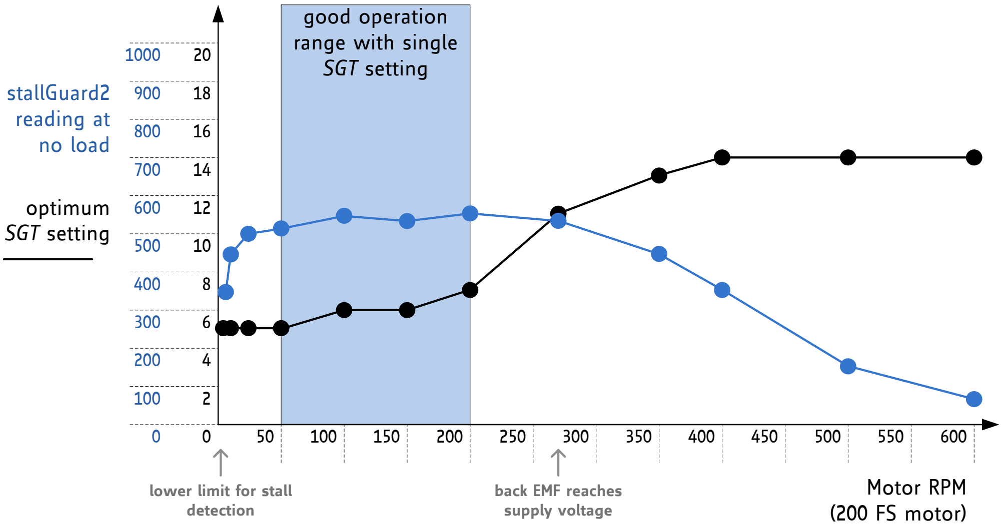

Figure 11.2 Example: optimum SGT setting and stallGuard2 reading with an example motor

In many applications, operation at or near a single operation point is used most of the time and a single setting is sufficient. The driver provides a lower and an upper velocity threshold to match this. The stall detection is disabled outside the determined operation point, e.g. during acceleration phases preceding a sensorless homing procedure when setting *TCOOLTHRS* to a matching value. An upper limit can be specified by *THIGH*.

In some applications, a velocity dependent tuning of the *SGT* value can be expedient, using a small number of support points and linear interpolation.

11.1.2 Small Motors with High Torque Ripple and Resonance

Motors with a high detent torque show an increased variation of the stallGuard2 measurement value SG with varying motor currents, especially at low currents. For these motors, the current dependency should be checked for best result.

11.1.3 Temperature Dependence of Motor Coil Resistance

Motors working over a wide temperature range may require temperature correction, because motor coil resistance increases with rising temperature. This can be corrected as a linear reduction of *SGT* at increasing temperature, as motor efficiency is reduced.

11.1.4 Accuracy and Reproducibility of stallGuard2 Measurement

In a production environment, it may be desirable to use a fixed *SGT* value within an application for one motor type. Most of the unit-to-unit variation in stallGuard2 measurements results from manufacturing tolerances in motor construction. The measurement error of stallGuard2 – provided that all other parameters remain stable – can be as low as:

$$stallGuard\ measurement\ error = \pm max(1, |SGT|)$$

11.2 stallGuard2 Update Rate and Filter

The stallGuard2 measurement value *SG_RESULT* is updated with each full step of the motor. This is enough to safely detect a stall, because a stall always means the loss of four full steps. In a practical application, especially when using coolStep, a more precise measurement might be more important than an update for each fullstep because the mechanical load never changes instantaneously from one step to the next. For these applications, the *sfilt* bit enables a filtering function over four load measurements. The filter should always be enabled when high-precision measurement is required. It compensates for variations in motor construction, for example due to misalignment of the phase A to phase B magnets. The filter should be disabled when rapid response to increasing load is required and for best results of sensorless homing using stallGuard.

11.3 Detecting a Motor Stall

For best stall detection, work without stallGuard filtering (*sfilt*=0). To safely detect a motor stall the stall threshold must be determined using a specific *SGT* setting. Therefore, the maximum load needs to be determined, which the motor can drive without stalling. At the same time, monitor the *SG_RESULT* value at this load, e.g. some value within the range 0 to 100. The stall threshold should be a value safely within the operating limits, to allow for parameter stray. The response at an *SGT* setting at or near 0 gives some idea on the quality of the signal: Check the *SG* value without load and with maximum load. They should show a difference of at least 100 or a few 100, which shall be large compared to the offset. If you set the *SGT* value in a way, that a reading of 0 occurs at maximum motor load, the stall can be automatically detected by the motion controller to issue a motor stop. In the moment of the step resulting in a step loss, the lowest reading will be visible. After the step loss, the motor will vibrate and show a higher *SG_RESULT* reading.

11.4 Homing with stallGuard

The homing of a linear drive requires moving the motor into the direction of a hard stop. As stallGuard needs a certain velocity to work (as set by *TCOOLTHRS*), make sure that the start point is far enough away from the hard stop to provide the distance required for the acceleration phase. After setting up *SGT* and the ramp generator registers, start a motion into the direction of the hard stop and activate the stop on stall function of your controller. Best results are yielded at 30% to 70% of nominal motor current and typically 1 to 5 RPS (motors smaller than NEMA17 may require higher velocities).

11.5 Limits of stallGuard2 Operation

stallGuard2 does not operate reliably at extreme motor velocities: Very low motor velocities (for many motors, less than one revolution per second) generate a low back EMF and make the measurement unstable and dependent on environment conditions (temperature, etc.). The automatic tuning procedure described above will compensate for this. Other conditions will also lead to extreme settings of *SGT* and poor response of the measurement value *SG_RESULT* to the motor load.

Very high motor velocities, in which the full sinusoidal current is not driven into the motor coils also leads to poor response. These velocities are typically characterized by the motor back EMF reaching the supply voltage.