

## 12 coolStep Operation

coolStep is an automatic smart energy optimization for stepper motors based on the motor mechanical load, making them "green".

### 12.1 User Benefits



- |                                    |                                   |
|------------------------------------|-----------------------------------|
| <i>Energy efficiency</i>           | - consumption decreased up to 75% |
| <i>Motor generates less heat</i>   | - improved mechanical precision   |
| <i>Less cooling infrastructure</i> | - for motor and driver            |
| <i>Cheaper motor</i>               | - does the job!                   |

coolStep allows substantial energy savings, especially for motors which see varying loads or operate at a high duty cycle. Because a stepper motor application needs to work with a torque reserve of 30% to 50%, even a constant-load application allows significant energy savings because coolStep automatically enables torque reserve when required. Reducing power consumption keeps the system cooler, increases motor life, and allows reducing cost in the power supply and cooling components.

**Reducing motor current by half results in reducing power by a factor of four.**

### 12.2 Setting up for coolStep

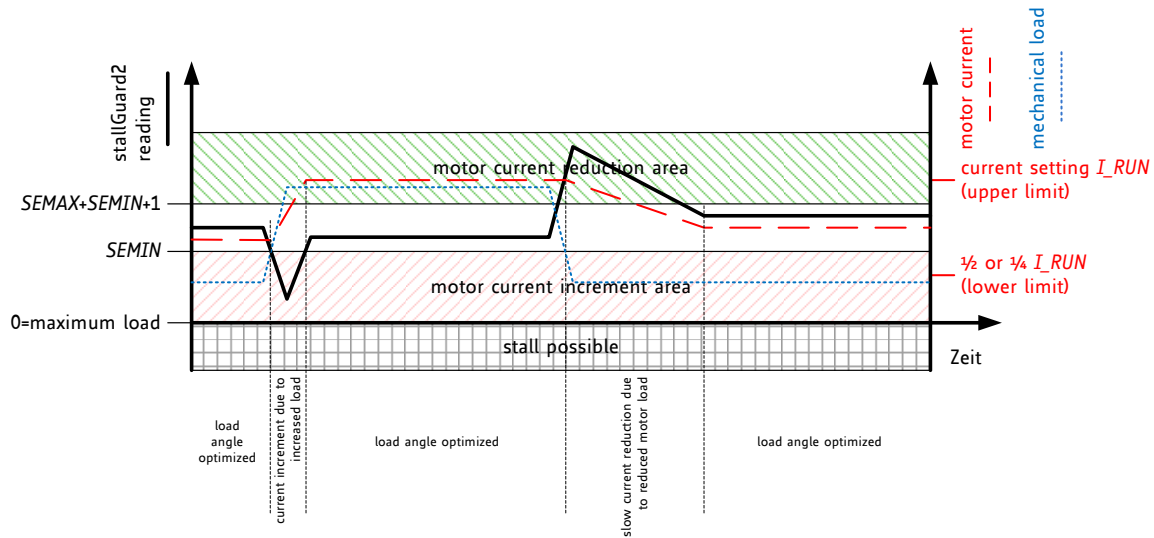
coolStep is controlled by several parameters, but two are critical for understanding how it works:

Parameter	Description	Range	Comment
SEMIN	4-bit unsigned integer that sets a <i>lower threshold</i> . If SG goes below this threshold, coolStep increases the current to both coils. The 4-bit SEMIN value is scaled by 32 to cover the lower half of the range of the 10-bit SG value. (The name of this parameter is derived from smartEnergy, which is an earlier name for coolStep.)	0	disable coolStep
		1...15	threshold is SEMIN*32
SEMAX	4-bit unsigned integer that controls an <i>upper threshold</i> . If SG is sampled equal to or above this threshold enough times, coolStep decreases the current to both coils. The upper threshold is (SEMIN + SEMAX + 1)*32.	0...15	threshold is (SEMIN+SEMAX+1)*32

Figure 12.1 shows the operating regions of coolStep:

- The black line represents the SG measurement value.
- The blue line represents the mechanical load applied to the motor.
- The red line represents the current into the motor coils.

When the load increases, SG\_RESULT falls below SEMIN, and coolStep increases the current. When the load decreases, SG\_RESULT rises above (SEMIN + SEMAX + 1) \* 32, and the current is reduced.



**Figure 12.1 coolStep adapts motor current to the load**

Five more parameters control coolStep and one status value is returned:

Parameter	Description	Range	Comment
<i>SEUP</i>	Sets the <i>current increment step</i> . The current becomes incremented for each measured stallGuard2 value below the lower threshold.	0...3	step width is 1, 2, 4, 8
<i>SEDN</i>	Sets the number of stallGuard2 readings above the upper threshold necessary for each <i>current decrement</i> of the motor current.	0...3	number of stallGuard2 measurements per decrement: 32, 8, 2, 1
<i>SEIMIN</i>	Sets the <i>lower motor current limit</i> for coolStep operation by scaling the <i>IRUN</i> current setting.	0 1	0: 1/2 of IRUN 1: 1/4 of IRUN
<i>TCOOL THRS</i>	Lower velocity threshold for switching on coolStep and stop on stall. Below this velocity coolStep becomes disabled (not used in STEP/DIR mode). Adapt to the lower limit of the velocity range where stallGuard2 gives a stable result.  <i>Hint:</i> May be adapted to disable coolStep during acceleration and deceleration phase by setting identical to <i>VMAX</i> .	1... 2 <sup>20</sup> -1	Specifies lower coolStep velocity by comparing the threshold value to <i>TSTEP</i>
<i>THIGH</i>	Upper velocity threshold value for coolStep and stop on stall. Above this velocity coolStep becomes disabled. Adapt to the velocity range where stallGuard2 gives a stable result.	1... 2 <sup>20</sup> -1	Also controls additional functions like switching to fullstepping.
Status word	Description	Range	Comment
<i>CSACTUAL</i>	This status value provides the <i>actual motor current scale</i> as controlled by coolStep. The value goes up to the <i>IRUN</i> value and down to the portion of <i>IRUN</i> as specified by <i>SEIMIN</i> .	0...31	1/32, 2/32, ... 32/32

## 12.3 Tuning coolStep

Before tuning coolStep, first tune the stallGuard2 threshold level *SGT*, which affects the range of the load measurement value *SG\_RESULT*. coolStep uses *SG\_RESULT* to operate the motor near the optimum load angle of +90°.

The current increment speed is specified in *SEUP*, and the current decrement speed is specified in *SEDN*. They can be tuned separately because they are triggered by different events that may need different responses. The encodings for these parameters allow the coil currents to be increased much more quickly than decreased, because crossing the lower threshold is a more serious event that may require a faster response. If the response is too slow, the motor may stall. In contrast, a slow response to crossing the upper threshold does not risk anything more serious than missing an opportunity to save power.

coolStep operates between limits controlled by the current scale parameter *IRUN* and the *seimin* bit.

### 12.3.1 Response Time

For fast response to increasing motor load, use a high current increment step *SEUP*. If the motor load changes slowly, a lower current increment step can be used to avoid motor oscillations. If the filter controlled by *sfilt* is enabled, the measurement rate and regulation speed are cut by a factor of four.

#### Hint

The most common and most beneficial use is to adapt coolStep for operation at the typical system target operation velocity and to set the velocity thresholds according. As acceleration and decelerations normally shall be quick, they will require the full motor current, while they have only a small contribution to overall power consumption due to their short duration.

### 12.3.2 Low Velocity and Standby Operation

Because coolStep is not able to measure the motor load in standstill and at very low RPM, a lower velocity threshold is provided for enabling coolStep. It should be set to an application specific default value. Below this threshold the normal current setting via *IRUN* respectively *IHOLD* is valid. An upper threshold is provided by the *VHIGH* setting. Both thresholds can be set as a result of the stallGuard2 tuning process.