2014-APR-09

# AN009

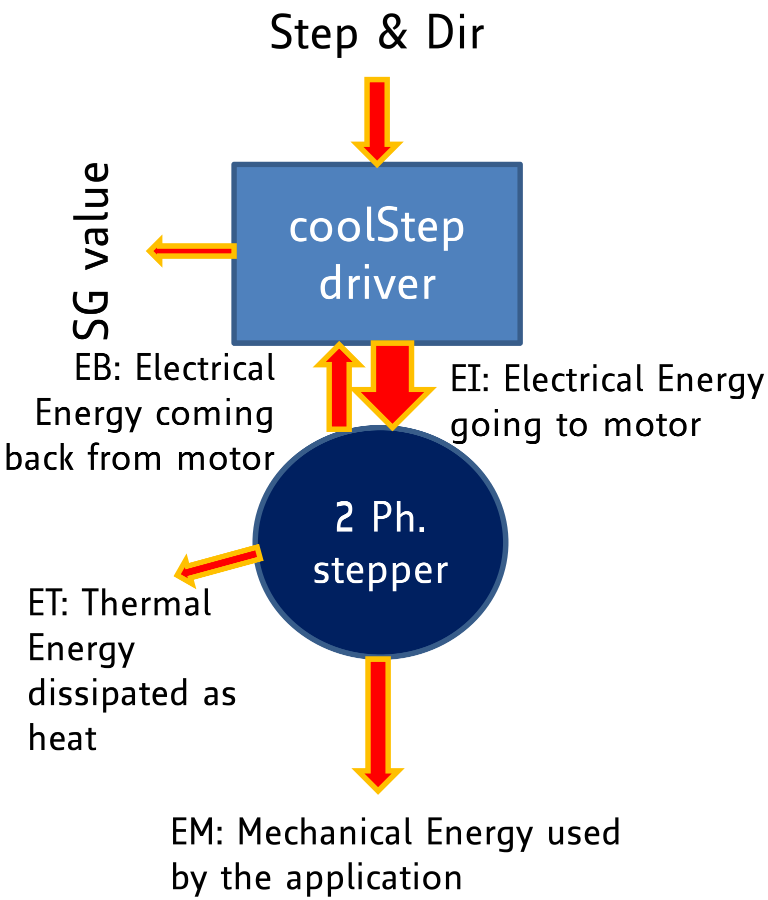
# Tuning coolStep

coolStep and stallGuard optimized for low velocity
Automatic tuning algorithm

# INTRODUCTION

- stallGuard and coolStep optimally work when motor efficiency is high, typically starting between 1 or 2 RPS up to the upper velocity, where the motor back EMF reaches the supply voltage range
- At low velocities <1 RPS, the motor efficiency is relatively low, because resistive losses in the coil ($R*I^2$) are high compared to mechanical power. This makes setting tricky.
- For low speed operation, the integrated coolStep algorithm fails due to large current dependent influence on the stallGuard result.

# BACKGROUND (1)



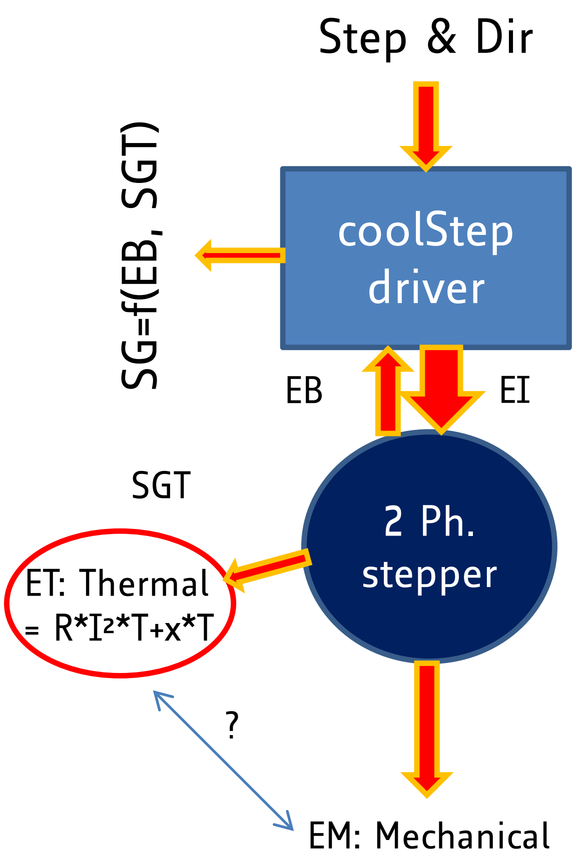

**stallGuard2 measures excess energy**

- stallGuard2 computes energy coming back from the motor to the power supply (EB). This energy was not used up in the drive system. If it is above zero, motor current is higher than required.

**coolStep regulates the motor current**

- coolStep regulates the motor current based on stallGuard2 to minimize energy fed back

# BACKGROUND (2)




- The driver cannot see, if energy difference EI - EB is fed to mechanics, or goes to thermal energy (ET). Therefore, a parameter has been introduced, describing the energy going to thermal dissipation
- SGT defines a per-choppercycle loss of energy in motor coil resistance. This compensates the measurement of EB for different motor velocities. It avoids EB becoming negative.

# BACKGROUND (3)

- SGT is normally tuned to describe a certain point of operation. This is good, as long as all conditions are stable, and ET is relatively small.
- When coolStep modifies the motor current, the conditions for which SGT was tuned, change. This especially is true, as thermal losses correspond to the square of the motor current. In case, the change in ET is too large compared to the absolute value of EI, a more dedicated algorithm for motor current regulation based on SG is required.

# PROPOSED ALGORITHM (1)

**Idea**

- The idea is to tune SGT in a way, that stallGuard2 becomes most sensible. SGT especially must be tuned for different current settings, because the current has a major influence.
- The tuning of SGT will depend on motor stray, motor temperature, and supply voltage. Therefore, tuning has to be done interactively within the application. Correctly tuned, a stall will be safely detected and motor current can be regulated in dependence of the SG result (coolStep).

# PROPOSED ALGORITHM (2)

**First, measure the motor at different current settings.**

- The measurement should precede motion, and therefore must be quick and simple and not depend on mechanical load.

**Proposed measurement**

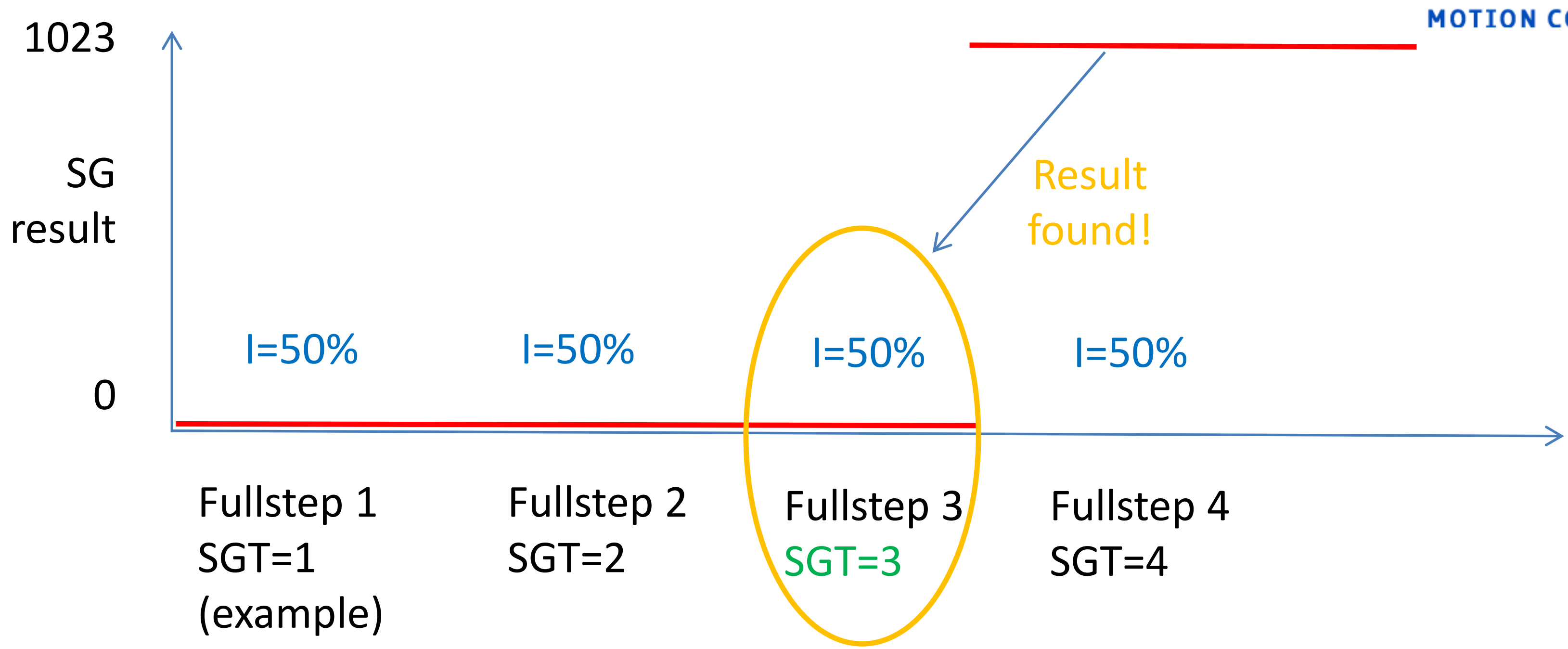
- Operate the motor at very low speed (a few to a few ten fullsteps per second, depending on the motor). In this speed range, mechanical output power is nearly zero. Therefore, thermal dissipation can be measured independently of mechanical conditions.
- Now SGT can be tuned exactly for the actual current setting as follows:

# PROPOSED ALGORITHM (3)

**Start to determine SGT for the lowest target current.**

- Let the motor turn slowly at the lowest desired current, i.e. 50% Imax. Start with SGT as determined by previous run of the algorithm. (In case the results cannot be stored, a successive approximation within the expected range can be done, e.g. using 3 steps to cover SGT=3 to 3+8, or start with SGT=0.)
- Read out SG after each fullstep. If SG is 0, increase SGT. If SG is 1023, decrease SGT. Repeat, until the first result shows an intermediate value, or the value changes from 0 to 1023 or vice versa (to be determined in the application, which way is better). This way, the most sensible SGT setting is determined after a few fullsteps. Using SGFILT activated, might improve the result, but will need 4 times more fullsteps to be done.

# PROPOSED ALGORITHM (4)

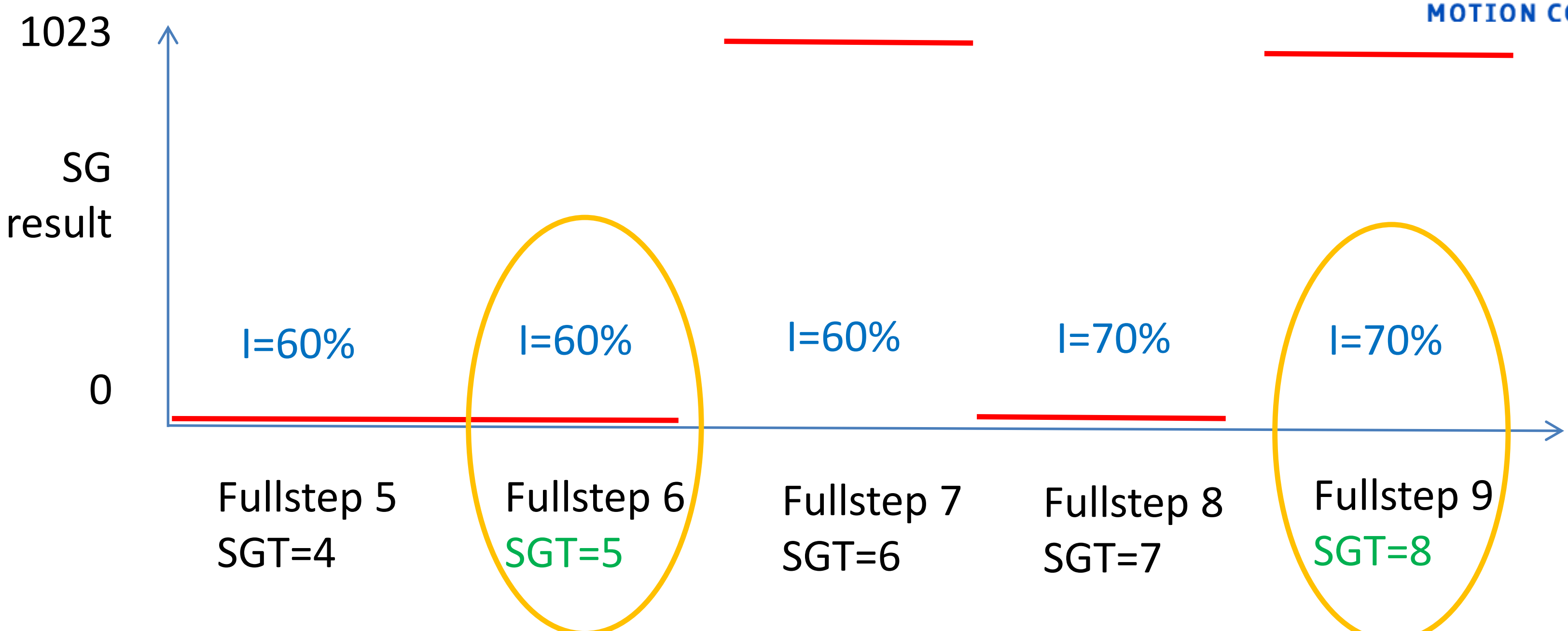



In the example SGT=3 delivers the most sensitive result.

SGT=4 also might work well.

The algorithm is finished after 4 fullsteps (for the first current setting)

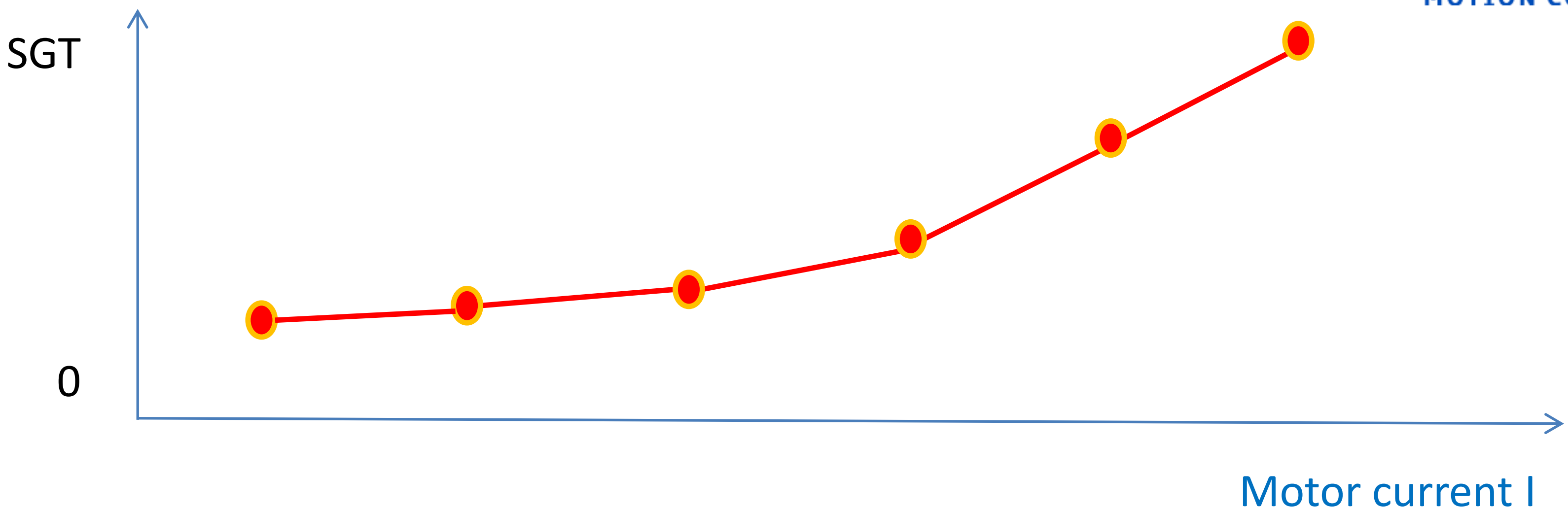
# PROPOSED ALGORITHM (5)




**Repeat for one or more additional current settings.**

- Continue to turn slowly at the next desired current, i.e. 60% Imax. Be sure to increase the current scale CS right at the beginning of the fullstep, or skip one fullstep. Start with SGT as determined by previous measurement and increment SGT until the new value is found.

# PROPOSED ALGORITHM (6)



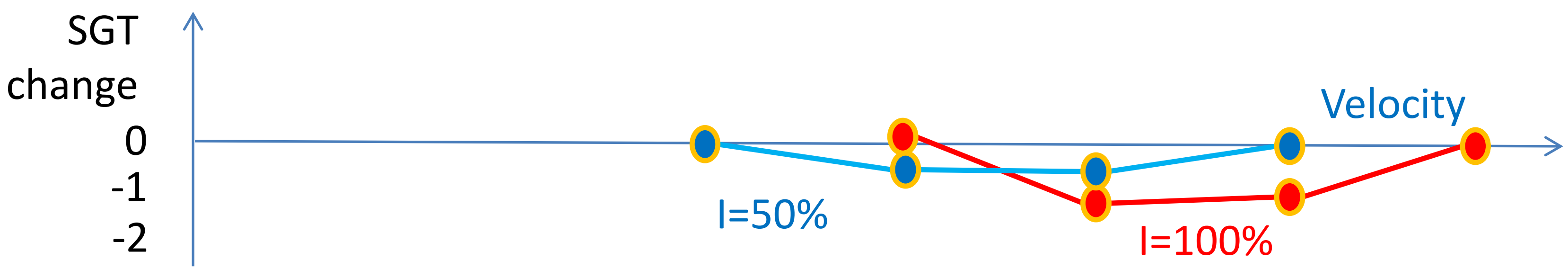

**Interpolate measurements if desired**

- To extend the number of SGT settings, an interpolation may be done for the discrete results determined.

# PROPOSED ALGORITHM (7)

**Correction at or near resonance frequency**

- Using the resulting wave might fail at resonance frequency, because resonance will modify the measurement results. If motion at or near resonance is required, velocity dependent correction factors should be determined. The velocity dependent correction could be stored as an additional offset curve, added to SGT for the critical velocity. As the resonance frequency shifts with motor current, this compensation will show a current dependency.



# SUMMARY

- An algorithm is shown tuning SGT setting as sensible as possible for a number of different current settings and low motor speed (10 to 60 RPM)
- The resulting settings can be used for homing (stallGuard – best used with SGFILT off) or regulating motor current based on the stallGuard measurement (coolStep), either using a software algorithm, or using the integrated regulator.
- The algorithm will adapt to the actual motor conditions
- Slowly moving the motor a few fullsteps (e.g. before homing algorithm) is required.
- The results could also be stored as a number of curves. E.g. SGT(I,t,U)