stealthChop Performance (qualitative)

Valid for TMC5130A, TMC2130, TMC2100, TMC5072 and TMC5041

This application note compares the performance of stealthChop™ (pat.) with spreadCycle™ (pat.). stealthChop perfectly complements the universal spreadCycle driver in the low velocity range. This application note focusses on qualitative comparison and actual usage. AN0021 compares torque curves.

For correct settings of stealthChop and spreadCycle please refer the respective datasheet.

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1 Microstep Wave

stealthChop is a voltage controlled chopper principle in contrast to current controlled chopper principles like spreadCycle. This becomes visible, when measuring the microstep current in series with the coil (see Figure 1.1). The driver makes less effort to match the motor current to the microstep wave. Therefore it does not need to use fast decay cycles. It just drives the coil with a sequence of on, slow-decay, on, slow-decay. In contrast, a current controlled principle like spreadCycle needs fast decay cycles to achieve exact coil currents (see Figure 1.2). spreadCycle uses the sequence on, slow-decay, on reverse (=fast decay), slow decay. Thus current ripple seen in each chopper cycle is reduced in stealthChop.

Test motor: QSH418-35-10-027

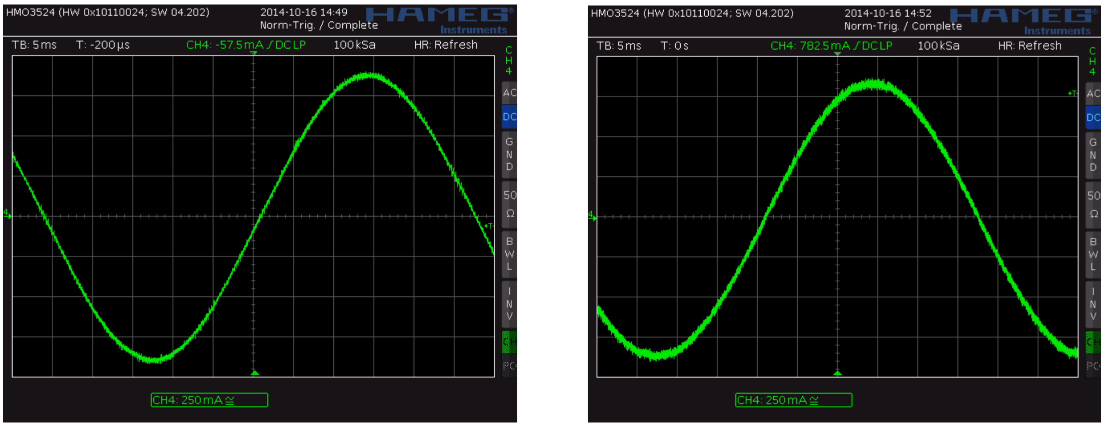

Figure 1.1 Low current ripple with stealthChop, slightly more with perfectly tuned spreadCycle

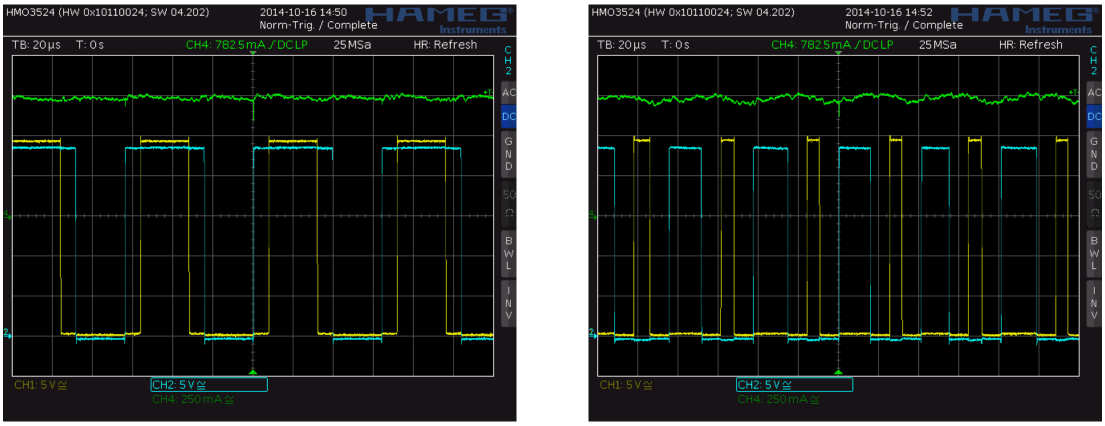

Figure 1.2 Coil voltages with stealthChop vs. spreadCycle showing chopper states

2 Power Dissipation

Due to the reduction of current ripple in stealthChop, power dissipation in the motor can be reduced. This is, because current ripple leads to eddy currents the stator magnet material. The contribution of this effect strongly depends on the motor metal characteristics. Especially at high motor velocity, motor temperature might be reduced significantly with stealthChop.

3 Motor Noise

stealthChop reduces motor noise due to elimination of regulation swinging caused by direct current control loops. As spreadCycle and other current regulated chopper principles always react to the coil current measurement on a cycle-by-cycle base, a few millivolts of noise – which are always present in complex systems – as well as electric and magnetic coupling between both coils within the motor lead to small variations of the resulting motor currents and thus influence the chopper. These variations of the current are in a fractional frequency can lead to hissing and chirping sounds caused by magnetostriction of the stator material and subsequent vibration of the motor axis.

In contrast, stealthChop works with a fixed chopper frequency and there are no variations of the frequency other than those variations commanded by the microstep wave sequencer when the motor is to be moved.

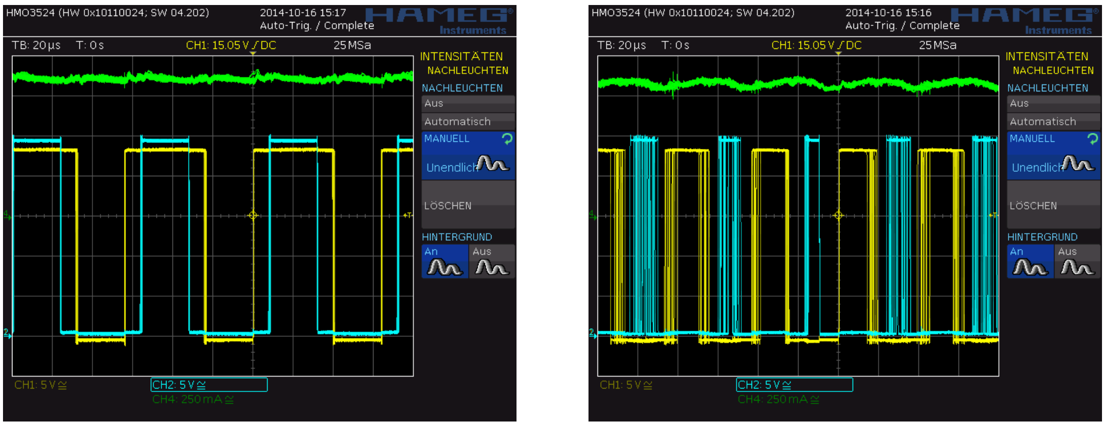

Figure 3.1 No jitter with stealthChop vs. frequency jitter with spreadCycle

Example measurements show 10 dB reduction in motor noise at low velocities.

4 Motor Vibration

stealthChop can reduce motor vibration especially for motors with bad microstep performance, like tin can motors. This results from slower current regulation allowing the motor to run more evenly due to its rotor's flywheel mass. This effect becomes tangible at velocities around the motor's resonance frequency. Especially motors with less equidistant microstep angle run more smoothly with stealthChop.

➔ Measurements to be done

5 Combined Performance

COMPARISON OF STEALTHCHOP AND SPREADCYCLE

Feature	stealthChop	spreadCycle
Motor noise	Low, mainly ball bearings	Some chopper noise audible depending on layout quality and motor / supply voltage selection and chopper settings
Motor vibration	Extremely low at low and medium velocity, dampening required at higher velocity (belt drive, flywheel mass)	Low with good microstep resolution
Torque	Full torque, unless automatic current regulation cannot follow in high acceleration phase	Full torque at all velocities
Motor power dissipation	Low, due to reduced current ripple	Normal, can be reduced by coolStep
High acceleration and deceleration	Limited by regulation parameters for automatic scaling, no special limit with feed forward scaling	No special limit
Low velocity performance	Extremely smooth, even with motors not optimum for microstepping	Smooth
High velocity performance	Depending on motor and load situation – flywheel mass or dampening by load is required	Very good
coolStep	Automatic load dependent current in high velocity range	Using stallGuard in medium velocity range
stallGuard	No, but load can be estimated from PWM duty cycle (*PWM_STATUS*) at medium and high velocity	Yes, in medium velocity range
Current regulation	Automatic, slower using PI regulator, or feed forward using input pulse width. Lower current limit determined by motor resistance and supply voltage in automatic scaling mode	Direct cycle-by-cycle, can regulate high and low currents and reacts as fast as possible

To give best motor performance at any velocity, stealthChop drivers allow mixing of modes. Some applications may benefit from spreadCycle high speed performance, as well as from coolStep™ or dcStep™. For these applications, a velocity based switching, or a case-by-case switching can be considered. As stealthChop provides unprecedented performance at low velocity settings, an upper limit can be defined for switching to a different mode. This way, no cut-backs have to be made when deciding to use stealthChop for lowest noise operation, i.e. at low velocity and standstill. For selection of the threshold velocity it is important to check within the application, unless a very low threshold (*VPWMTHRS* resp. *TPWMTHRS*) is chosen. Figure 5.1 shows a number of examples for different use cases. For the simplicity of use, automatic current scaling is proposed, and thus some limitation to the upper acceleration. A jerk occurs in the motor when switching between both modes, because a system immanent feature is that the current controlled chopper directly brings the current into the coil as given by the microstep wave, while the voltage controlled PWM applies a voltage as defined by the actual microstep wave position. The coil current in voltage mode is delayed, due to the motor back EMF subtracting depending on the load angle from the PWM voltage. At low velocity and standstill, thus there is no perceptible difference, but at increased velocity a difference of up to one fullstep can build up (see read triangle in Figure 5.1). Switching at this velocity will lead to a jerk in the load angle, which will reduce motor torque for a short moment and thus might stall the motor under certain conditions (especially with high acceleration setting). This risk is avoided with a low switching velocity.

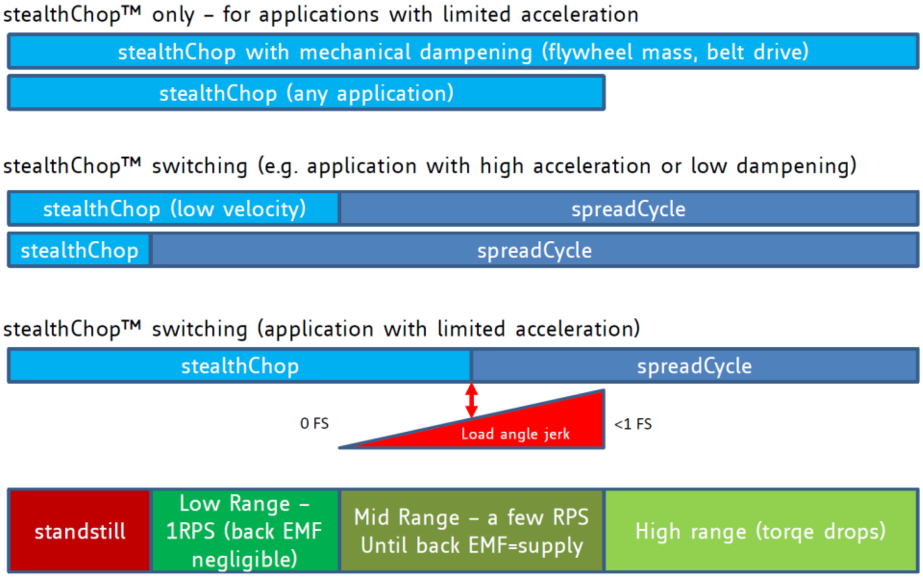

Figure 5.1 Scenarios for combining stealthChop and spreadCycle

6 Disclaimer

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7 Revision History

7.1 Document Revision

Version	Date	Author BD – Bernhard Dwersteg	Description
1.00	2014-OCT-24	BD	Initial version
1.01	2015-MAR-05	BD	Update comparison table and switching
1.02	2016-FEB-18	BD	Link to AN021

8 References

AN021: stealthChop Torque Comparison, www.trinamic.com
TMC5130 datasheet, www.trinamic.com
TMC2130 datasheet, www.trinamic.com
TMC2100 datasheet, www.trinamic.com