stealthChop Torque Comparison

Valid for TMC5130A, TMC2130, TMC2100, TMC5072 and TMC5041

This application note compares the pull out torque performance of stealthChop™ chopper mode (pat. pending) with the spreadCycle™ chopper mode (patented) and classic constant Toff chopper mode.

For correct settings of the different chopper modes please refer the respective datasheet.

1 Introduction

stealthChop™ is a new PWM mode for stepper motor operation. It is a voltage controlled chopper principle in contrast to current controlled chopper principles, which are typically used with many stepper motor solutions.
stealthChop results in noiseless stepper motor operation and smooth movement. By reducing vibrations, overall mechanical noise of an application can be further damped.
Since it is a different chopper principle questions arise with respect to its quality and performance. Therefore, a general qualitative comparison of stealthChop vs. spreadCycle can be found in Trinamic's application note number 15 – "stealthChop Performance"
(http://www.trinamic.com/_scripts/download.php?file=_articles%2Fproducts%2Fintegrated-circuits%2Ftmc5130%2F_appnotes%2FAN015+-+stealthChop_Performance.pdf)

In this short application note the torque output of stealthChop is compared with other chopper modes and at different microstep resolutions.

2 Measurement Setup

The measurement of the torque performance was done with a motor test rig as shown in the image below. A magnetic power break is used to apply load. A torque sensor (T) measures the torque. An additional flywheel mass (F) and a dampener (D) is used to reduce vibrations. The motor is connected via a fitting coupling (C) to the torque sensor and brake shaft. There is an additional high resolution encoder for speed measurement on the right side of the test rig.

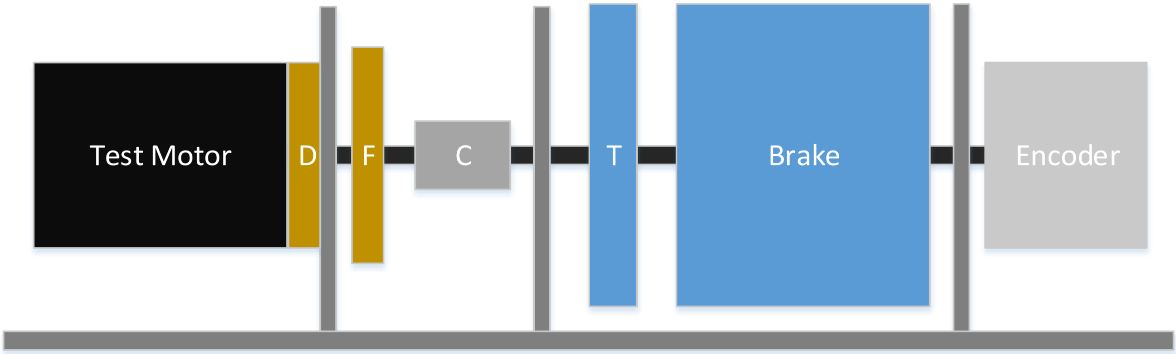

Figure 1: Principle architecture of the motor test rig

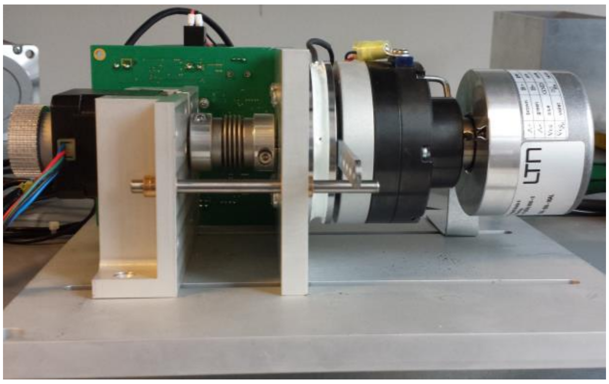

Figure 2: Test rig

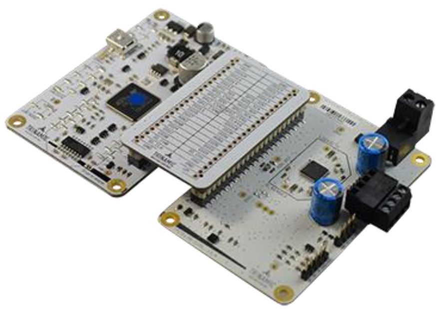

Figure 3: TMC5130A-TA evaluation board

The motor driver that has been used for testing is based on the TMC5130A-TA evaluation board and is operated at 24V in this setup (http://www.trinamic.com/products/integrated-circuits/integrated-motion-controller-stepper-driver/tmc5130). It allows for evaluation of all chopper modes.

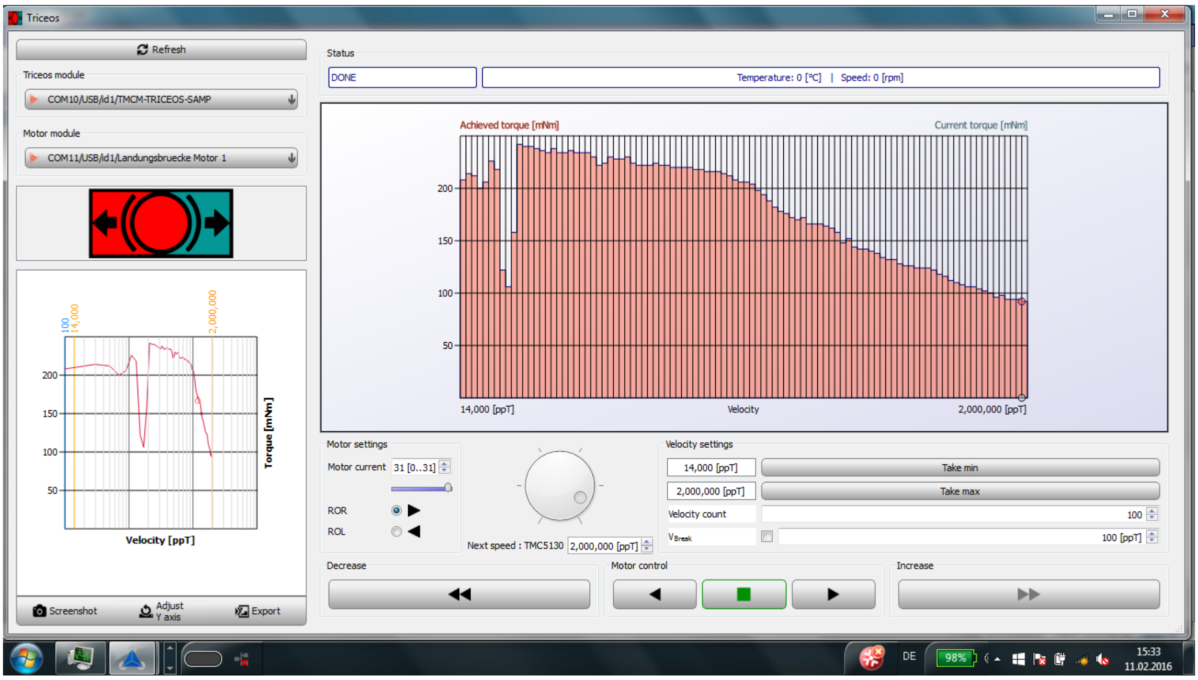

Figure 4: View of motor test rig GUI after one complete test series

The following motors have been used for testing (standard off-the-shelf NEMA17 motors with 1.8° full step angle).

- Delta Line 42SH47-1004B (1.0A rated phase current, ca. 350mNm holding torque)
- Moons 17HD3423-01 (1.0A rated phase current, ca. 430mNm holding torque)

3 Results

Different test series have been protocolled with the test rig. We used the chopper modes stealthChop, spreadCycle, and standard constant Toff with a microstep resolution of 256µSteps and 16µSteps
All measurements have been done with **36V** if not stated otherwise.

1.1 Motor 1: Delta Line 42SH47-1004B

Figure 5 shows the manufacturer's pull out torque diagram. The major motor parameters are as follows:

Rated voltage:	4.5V
Rated phase current:	1.0A
Phase resistance @ 20°C:	4.5 Ohm
Phase inductance (typ):	7.5mH
Holding torque:	350mNm (ca. 50 oz-in)

Testing conditions: driver supply voltage +24V DC, coil current 1.0A RMS, half step operation

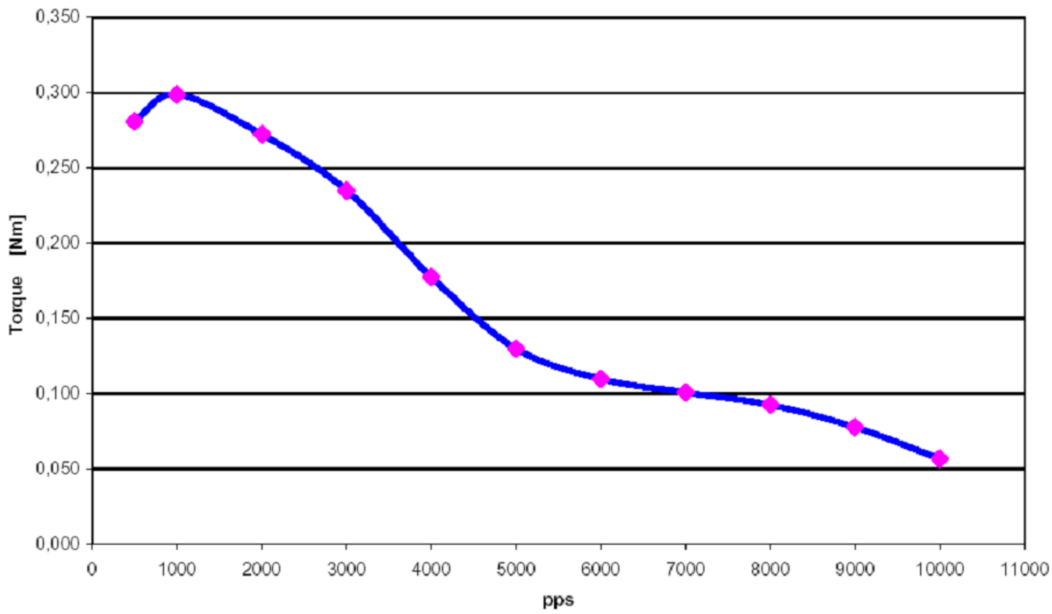

Figure 5: Manufacturers pull out torque diagram (@ 24V, half step operation 400pps = 60rpm, 2000pps = 300rpm)

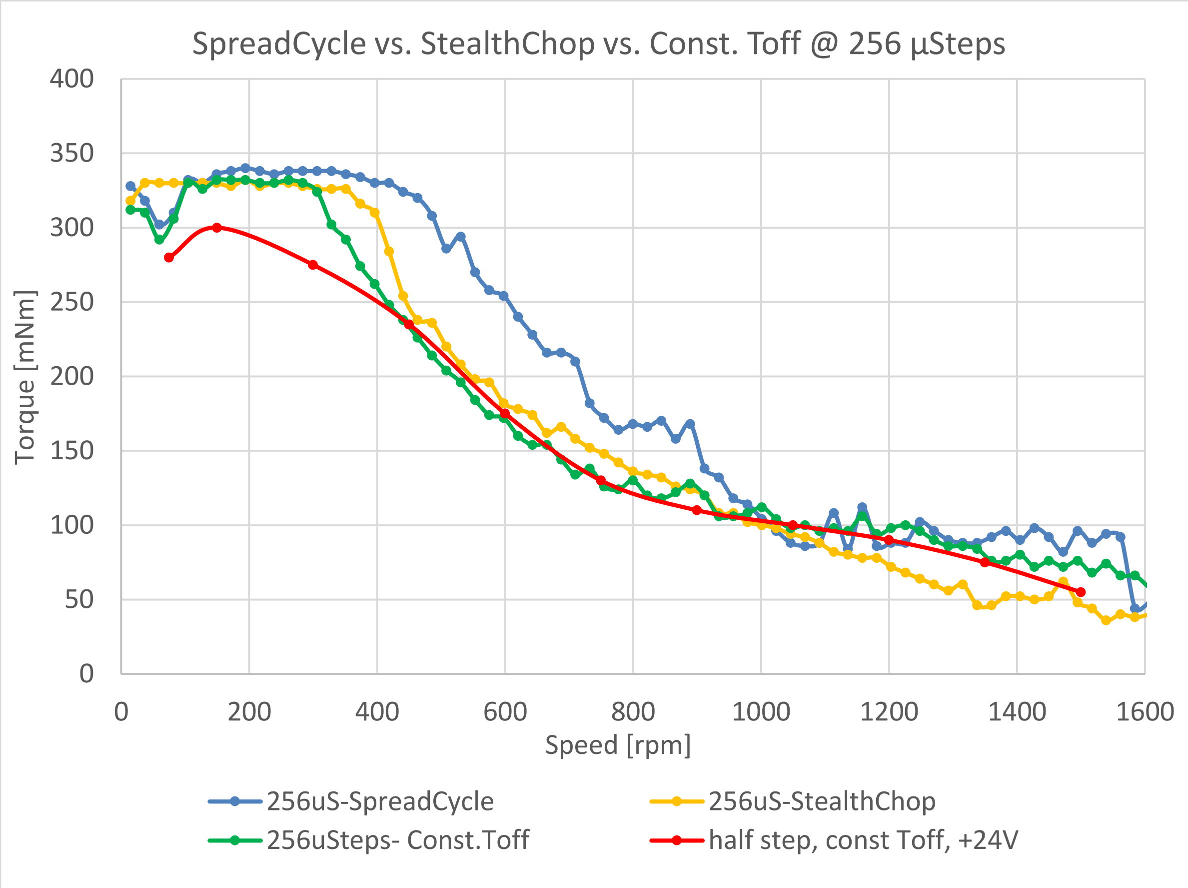

Figure 6: Torque/speed chart with comparison of three chopper modes @ 256 µSteps

The first diagram in Figure 6 shows three test series. All three chopper modes are compared at 256 microsteps and 36V supply. In addition, we overlayed the manufacturer's pull out torque curve for comparison (@24V and half stepping).

Especially during the slow velocities, stealthChop performs best because of the reduction of vibrations (and noise) within the motor's specific resonance speed range. We see that the specified 350nNm of the motor are true according to the manufacturer's data sheet. The point of the motors inherent resonance frequency seems to be at ca. 80 to 100rpm, which is typical.

The overall torque is stable and nearly equal for all chopper modes within the motors linear torque speed range. This range can be extended by using a higher supply voltage, which in general improves dynamic response. There is no significant torque difference within the low and mid speed ranges.

Classic constant Toff chopper performs worst within the motors higher speed ranges (>400rpm).
stealthChop shows slightly higher torque output compared to constant Toff and shows also the most stable / smooth behavior.
spreadCycle shows slightly higher torque in this configuration because the given test setup tends to mechanical oscillations. spreadCycle dampens mechanical oscillations better than stealthChop. We assume this is the reason for the torque difference between stealthChop and spreadCycle in the medium speed range.

In the highest speed ranges >900rpm all chopper modes perform similar. The test series stop at ca. 1600 rpm since the performance below 50mNm cannot be detected reliably with the given test setup. Nevertheless, the original pull out torque curve from the manufacturer (@24V and half stepping) is similar in the highest speed ranges.

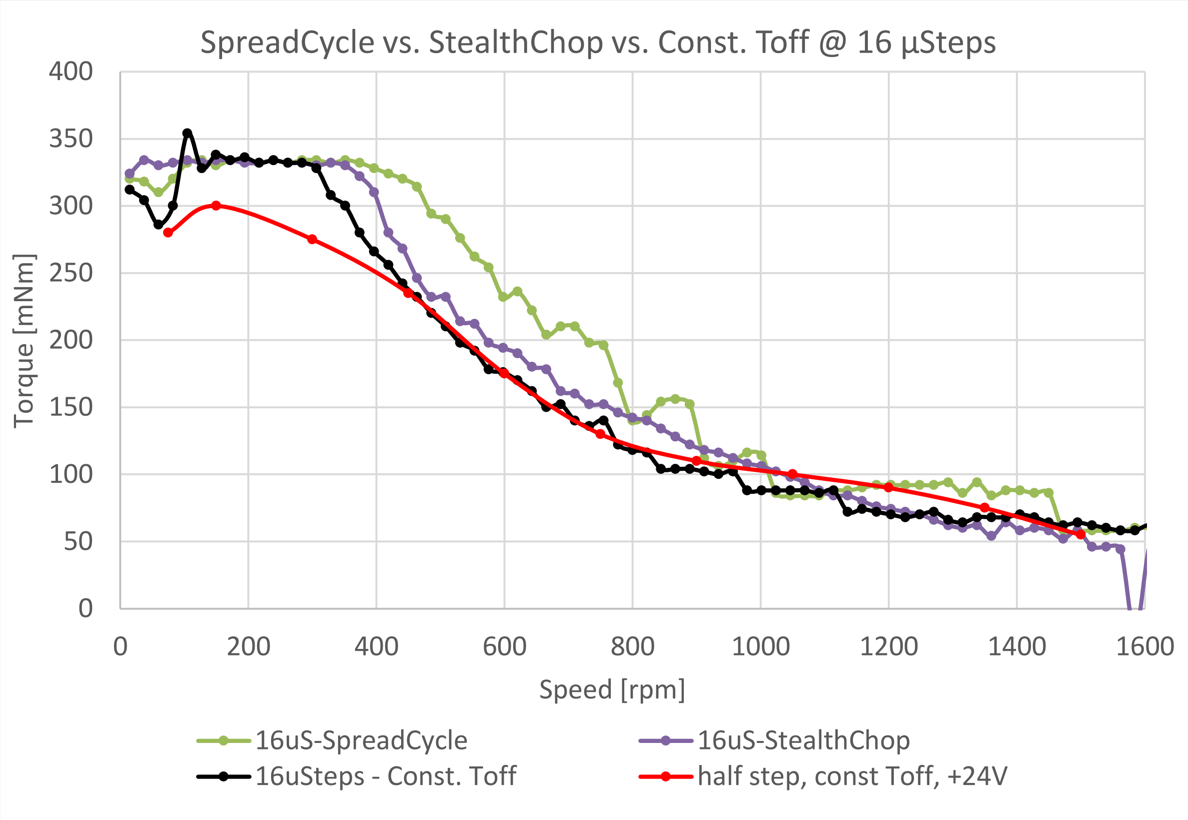

Figure 7: Torque/speed chart with comparison of three chopper modes @ 16µSteps

The second diagram in Figure 7 shows similar behavior as diagram 1. All 3 chopper modes are compared at 16 microsteps and 36V supply. In addition, we overlayed the manufacturer's pull out torque curve for comparison (@24V and half stepping).

There are no big changes compared to 256 µStepping regarding the relations of the chopper modes. The typical resonance point is visible at ca. 80 to 100, except with stealthChop, which shows stable pull out torque even at this point.

We see that half stepping offers a bit more torque in the highest speed regions >900 relative to const. Toff and stealthChop at 16µSteps but the difference is marginal.

Again, we stopped measurement at 1600 rpm since we ran below the minimum torque level of the test setup.

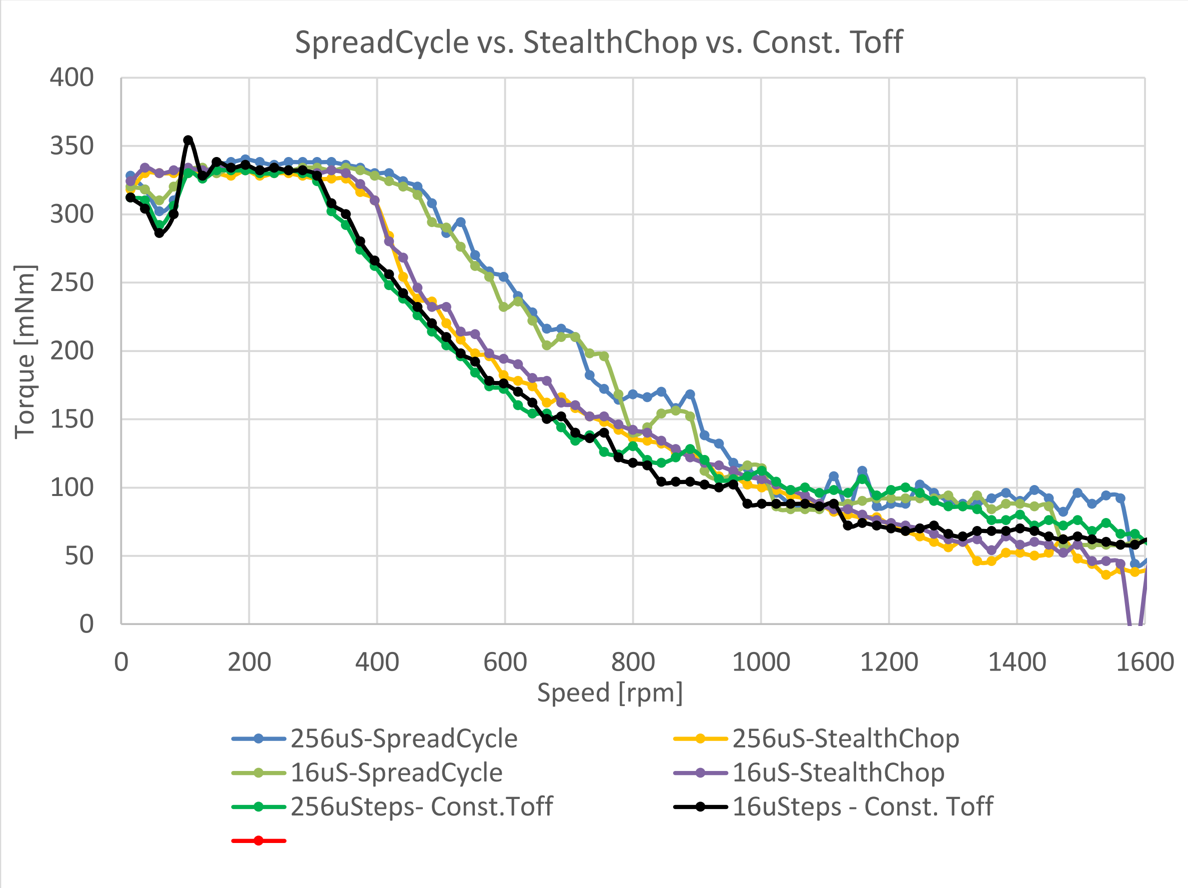

Figure 8: Combined torque/speed chart with comparison of three chopper modes @ 16 and 256 µSteps and the original manufacturers pull out torque curve @ 24V and half stepping.

This diagram shows all test results in a single diagram for comparison including the manufacturer's pull out torque curve for comparison (@24V and half stepping).

1.2 Motor 2: Moons 17HD3423-01

The second motor is similar to the first one but with a bit higher specified holding torque. Figure 9 shows the manufacturer's pull out torque diagram. The major motor parameters are as follows:

Rated voltage:	5.3V
Rated phase current:	1.0A
Phase resistance @ 20°C:	5.3 Ohm
Phase inductance (typ):	9.0mH
Holding torque:	430mNm (ca. 61 oz-in)

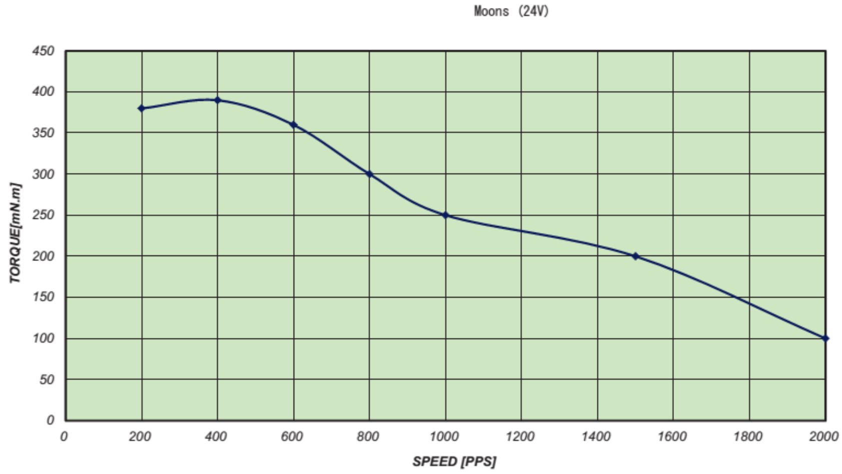

Figure 9: Manufacturers pull out torque diagram (@ 24V, constant Toff, no dampening, full step operation, 200pps = 60rpm, 1000pps = 300rpm, 2000pps = 600rpm)

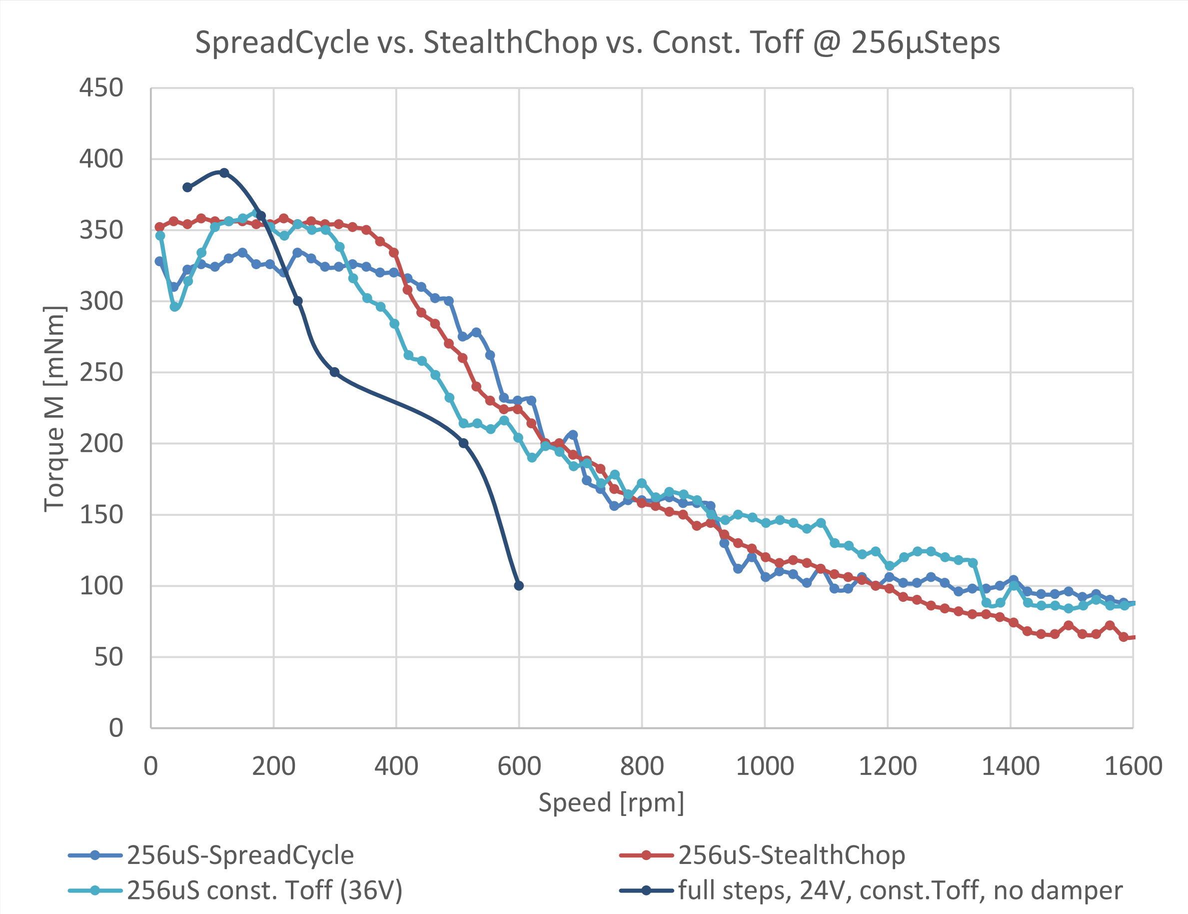

Figure 10: Torque/speed chart with comparison of three chopper modes @ 256 µSteps

The diagram in Figure 10 shows three test traces. All three chopper modes are compared at 256 microsteps and 36V supply.
In addition, we overlayed the manufacturer's pull out torque curve for comparison (@24V and full stepping using constant Toff chopper).

What we see is a strong difference to the manufacturer's pull out torque trace, which already shows a strong decrease of torque at >200rpm. This is because of two things: the lower supply voltage of 24V, which reduces dynamic behavior, and the fact that the test setup of the motor manufacturer did not use a dampening provision to reduce mechanical vibrations in the test rig, which strongly affect measurement results.

stealthChop and spreadCycle show again a quite stable pull out torque up to ca. 400rpm while stealthChop has bit more torque compared to spreadCycle since vibrations and resonances are suppressed. This is also visible at the small resonance peak at ca. 50-80rpm for spreadCycle and constant Toff. With constant Toff chopper mode, torque is similar to stealthChop in the low speed regions but it drops earlier at ca. 300rpm with this motor and setup.

Upon 400rpm all traces show a falling pull out torque with increasing speed. All three chopper modes show a similar behavior with only small differences in the middle and high speed ranges. Nevertheless, the stealthChop trace shows the most constant and smooth behavior.

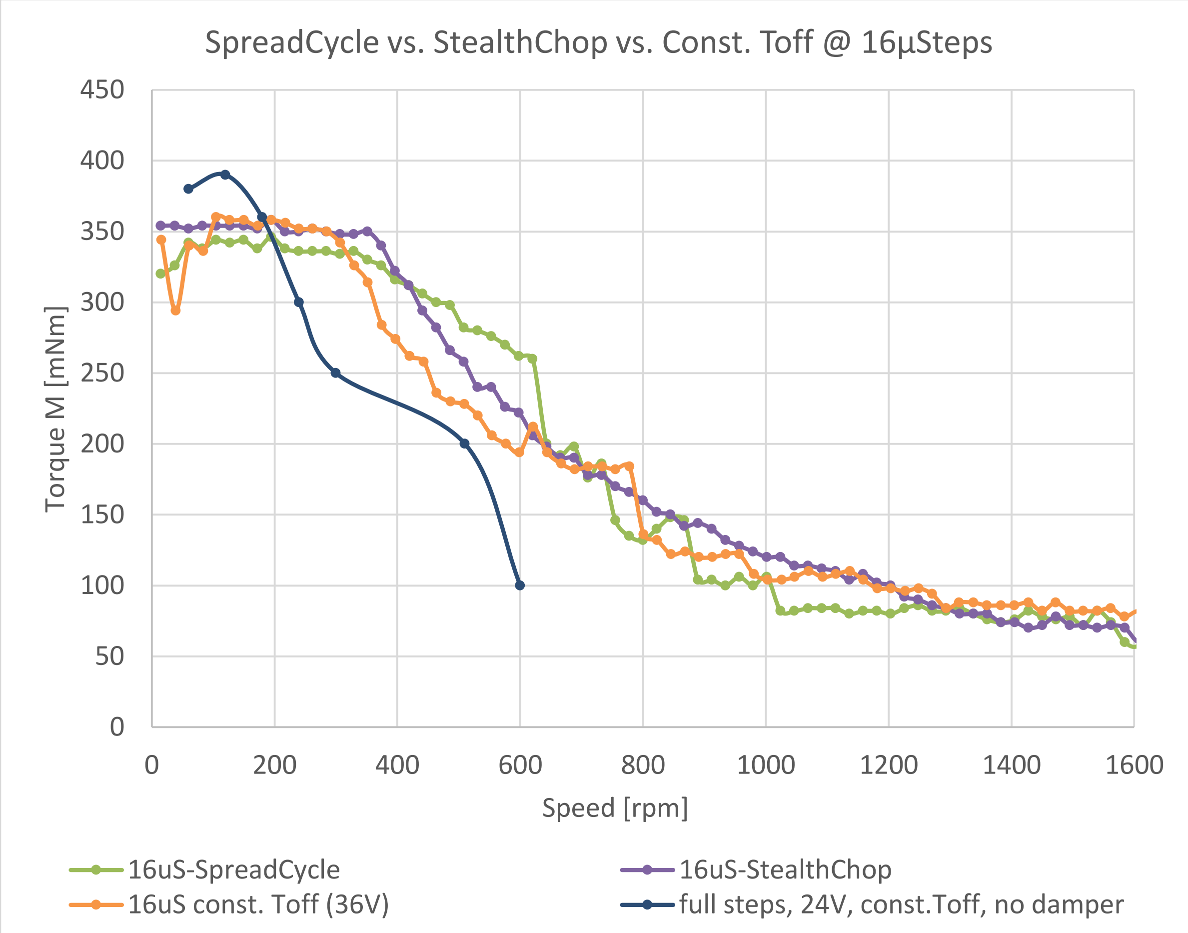

Figure 11: Torque/speed chart with comparison of three chopper modes @ 16 µSteps

The diagram in Figure 11 shows three test traces comparing all chopper modes at 16 microsteps and 36V supply voltage.

Basically, the result and the relations of the different chopper modes are similar compared to Figure 10. stealthChop can suppress resonance peaks in the low speed regions and shows in general a more smooth behavior.

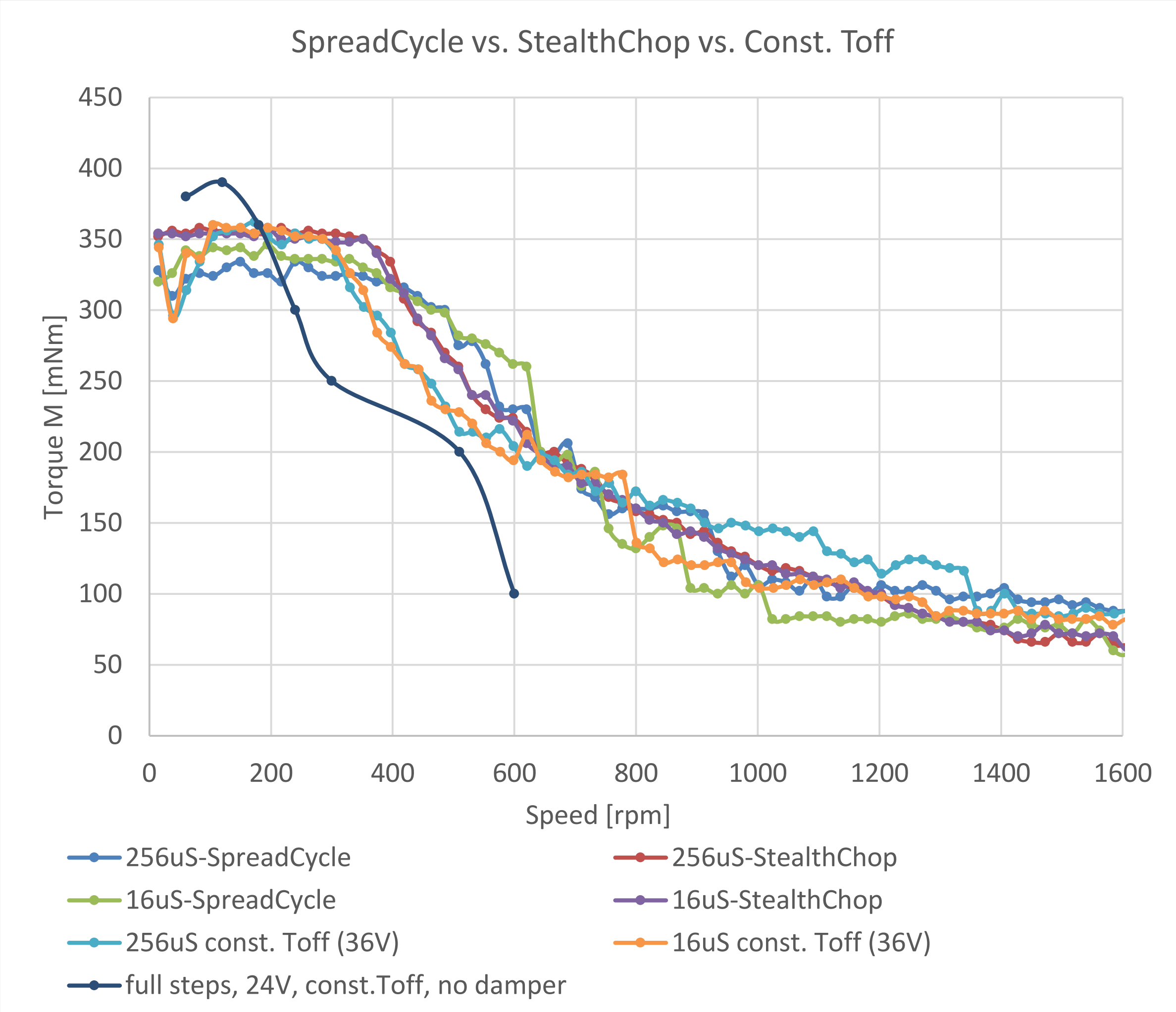

Figure 12: Combined torque/speed chart with comparison of all chopper modes @ 16 and 256 µSteps and the original manufacturers pull out torque curve @ 24V and full stepping.

The diagram in Figure 12 shows all six test traces comparing all chopper modes at 256 and 16 microsteps using 36V supply.
Again, we overlayed the manufacturer's pull out torque curve for comparison (@24V and full stepping using constant Toff chopper).

Interestingly, there is no big difference in the traces for stealthChop at 16 and at 256 microsteps while there are some differences for spreadCycle and constant Toff. This again is due to stealthChops reduction of noise and vibrations and resonances.

Using only single measurement traces (as we did it in this document) shows that vibrations may lead to a certain unsteadiness and outliers within the traces for spreadCycle and constant Toff. Averaging multiple measurements of the same test condition may give a more smooth result.

4 Disclaimer

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5 Document Revision History

Version	**Date**	**Author** BD – Bernhard Dwersteg SK – Stephan Kubisch	**Description**
1.00	2016-FEB-08	SK, LB, BD	Initial version
1.10	2016-FEB-15	SK, LB, BD	- Corrected Test Motor 1 manufacturer pull out torque curve - Added Motor 2 test results
1.11	2016-Feb-18	SK	- Added 2 additional traces to second motor

6 References

TMC5130A-TA datasheet, www.trinamic.com
TMC2130-LA datasheet, www.trinamic.com
TMC2100-LA datasheet, www.trinamic.com
TMC5072-LA datasheet, www.trinamic.com
TMC5041-LA datasheet, www.trinamic.com