REPORT TITLE:

Test and analysis on PMD MC58420 motion controller and Permanent-Magnet Synchronous Motor (PMSM) drive.

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Contents

No.	Topic	Page
1.0	Aim and objective	3
2.0	Test Plan 2.1 List of equipment 2.2 Test rig setup 2.3 Parameter settings	4 4 4 5
3.0	Results and discussions 3.1 Current control loop test 3.2 Position control test	6 6 9
4.0	Conclusions	13
5.0	References / Appendices	13

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1.0 Aim and objective

- **To perform a motor test on current and position control for PMSM which is controlled by PMD MC58420 motion controller drive. (Speed control is not ready to use, since it is not avliable for BLDC control)**
- **To analyse the results of the motor test from Pro-Motion software and commercial oscilloscope.**
- **To discuss the performance and compare to the stepper motor.**

2.0 Test Plan

The system integration in between PMSM and the PMD motion controller MC58420 is established to test the motor drive performance. Initially, RS232 serial is used as the communication protocol for PMD MC58420 motion controller and Host PC interfacing. The further details of equipment's list, test rig setup and parameters settings are discussed in the following sections.

2.1 List of equipment

a. **PMD MC58420 Motion Controller Developer's Kit**
b. **Three-phase PMSM 60BY86-68EC1000-001, with 1000 line resolution encoder (10000 counts per mechanical rotation), 200W**
c. **Regulated DC Power Supply**
d. **Tektronix oscilloscope**
e. **Fluke current probe**
f. **Host PC with Windows 7**

2.2 Test rig setup

Figure 1 and 2 below show the system integration proposed for the motor drive test.

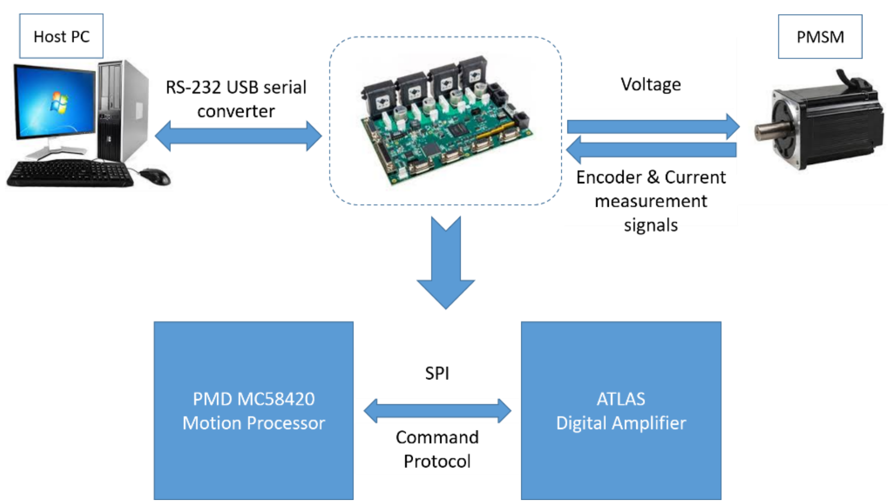

Figure 1: System integration, interface connection

Figure 2: Actual motor drive test setup

2.3 Parameter settings

The tests are run under low power level to evaluate the performance based on current loop and position control. Table I shows the main parameters used in the tests.

Table I

Parameter	Setting
DC bus voltage	13.5 V
Encoder resolution	2000 counts per electrical cycle = 10000 counts per mechanical rotation
Load	No load
PWM frequency	20 kHz
Position feedback	Incremental
Motor limit	6.8 A

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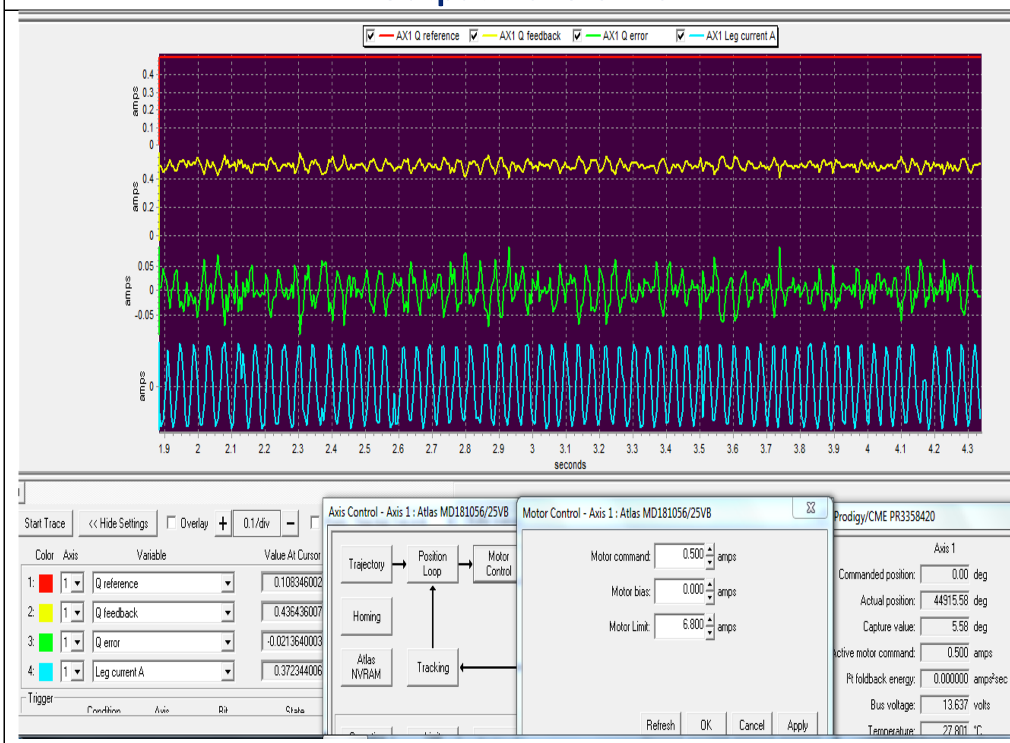
3.0 Results and discussions

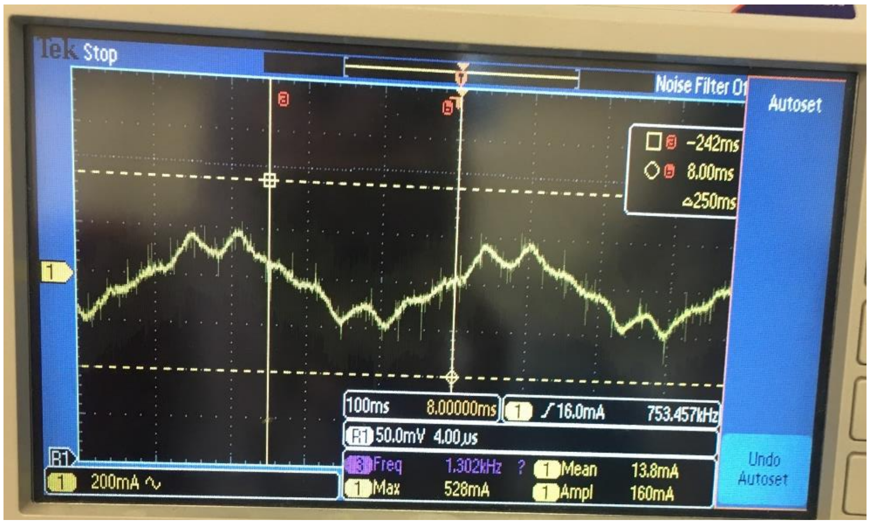
The tests are run according to specific control parameters setting i.e PI gains parameter Kp,Ki for current loop and position control.

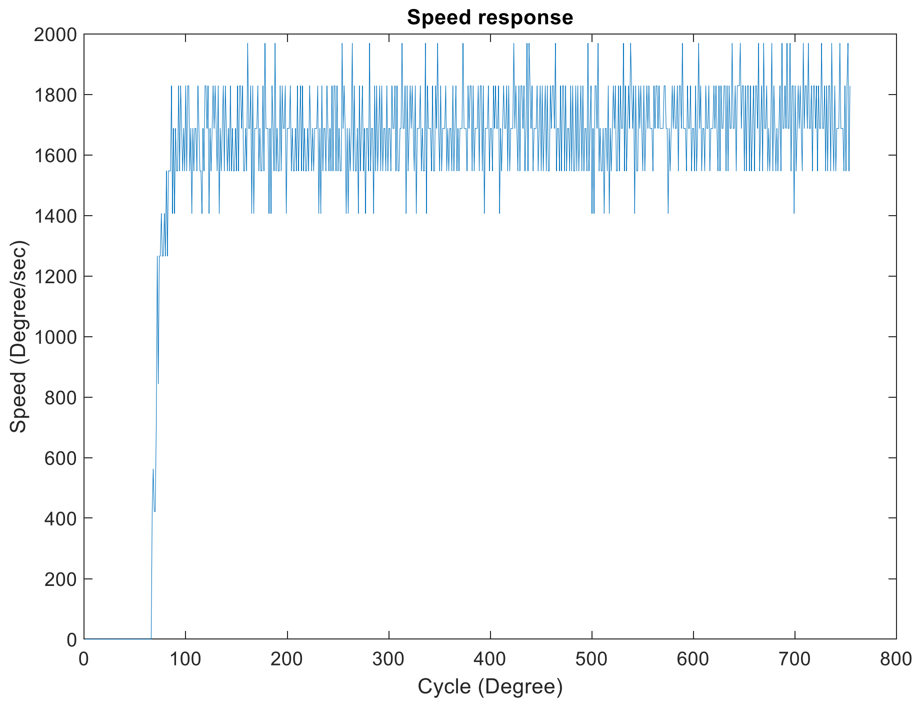
3.1 Current control loop test

Control method: Field-oriented control (FOC). Settings of PI gains: Kp = 0.744 ~= 1, Ki = 74.

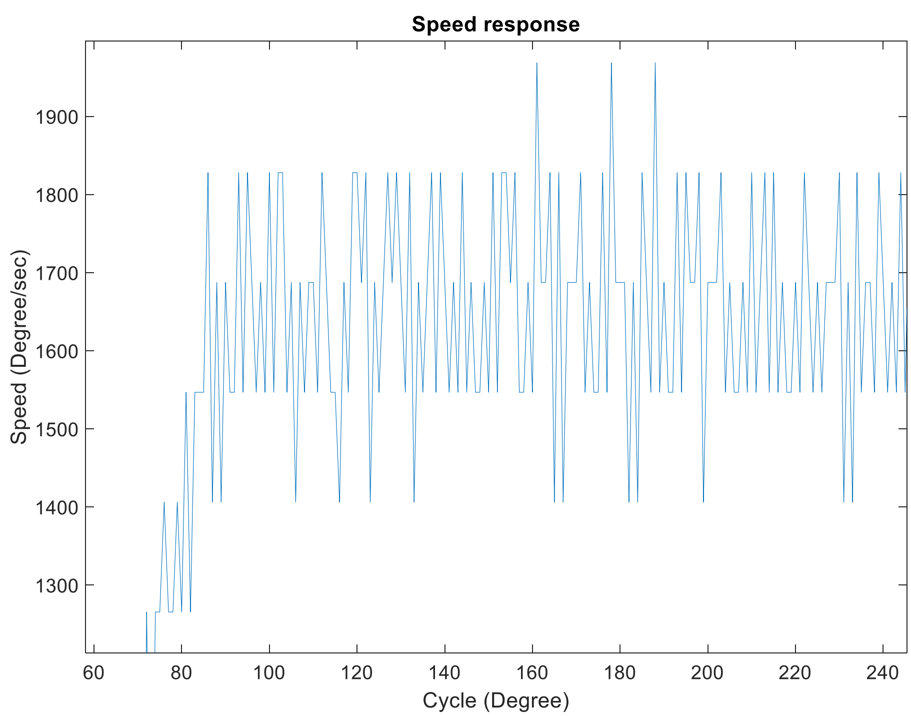
During the test, only the Current Loop control is enable and the motor current commanded is 0.5A. The following output waveforms illustrate the currents response (dq-currents, leg current, and actual motor phase current) recorded by the PMD Pro-Motion software and oscilloscope.

<table>
<tr><th>Output waveforms</th><th>Analysis of results</th></tr>
<tr><td>
</td><td>By PMD Pro-Motion Software:
*From the Iq current response, it can be observed that with the PI gains setting, the error is less than 0.05A. Practically, it is possible to be tuned for better result and comply with the application requirement.
*The ripple shown on both low and high frequency is to be further investigated, either it's cause by the converter board or/and motor itself.</td></tr>
</table>

Output waveforms	Analysis of results
	**By Oscilloscope:** ***Measured phase current using current probe across one of the motor phase feedback.** ***The phase current waveform shown is almost equivalent to sinusoidal signal.** ***Apparently, both low and high frequency ripple can be seen, which is still under investigation , i.e torque ripple or current ripple or switching ripple factor.**



(Zoom in figure on ripples):



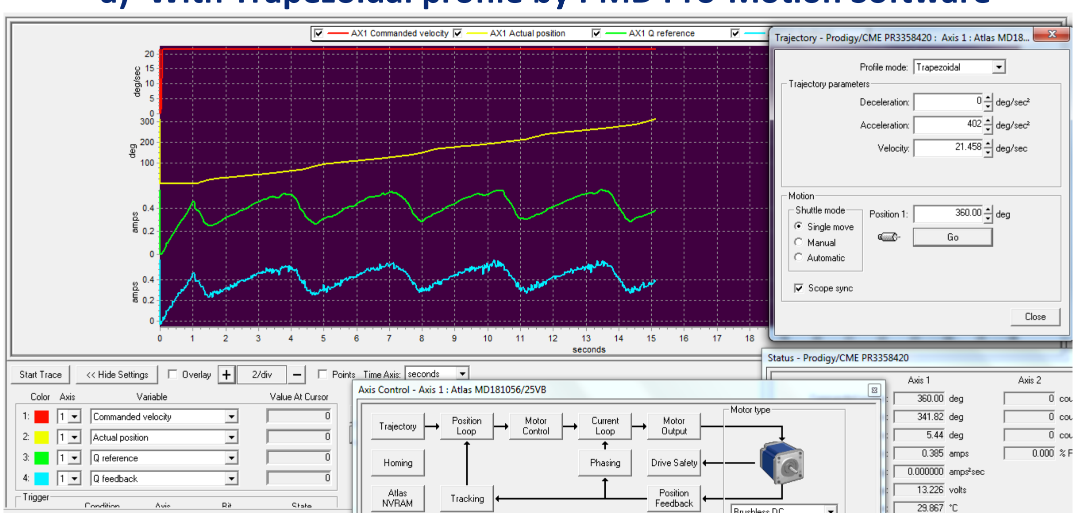
By Matlab;
***Extracted data of speed during current loop control from PMD Pro-Motion software scope.**
***The same trend as the ripple still can be seen for both low and high frequency ripple. It may be suspected that the low frequency ripple in current is cause from the motor, while high frequency ripple is cause by the converter.**

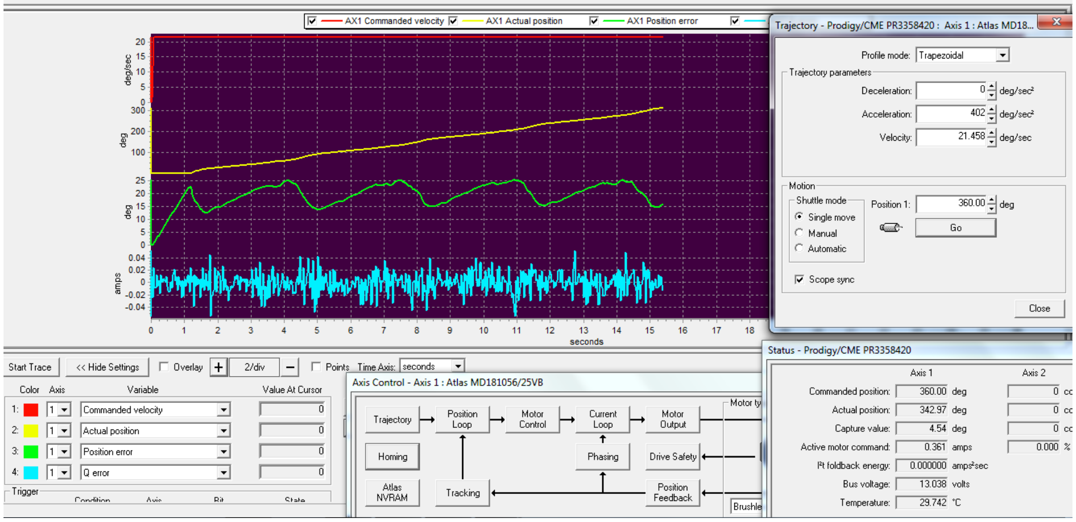
3.2 Position control test

During the test at low speed, a commanded speed has been set to be constant at 21.46 degree/sec (i.e. 3.58rpm) and 30 degree/sec, with acceleration and deceleration are equal to 402 degree/sec.

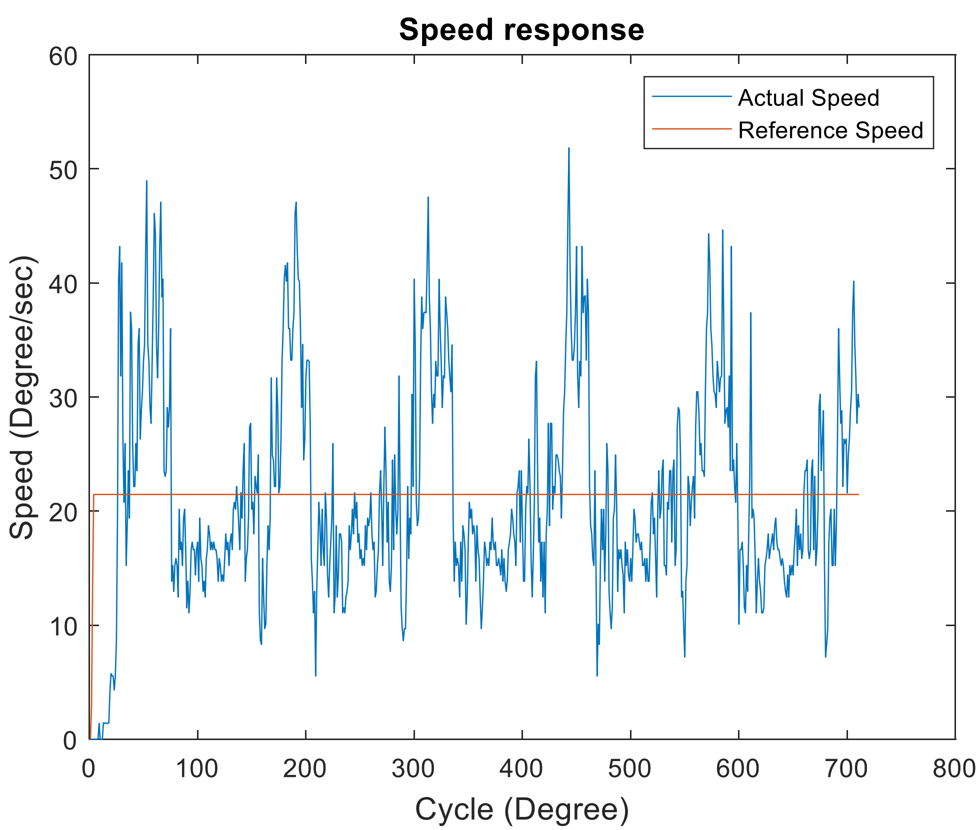
In position control, the PI gains are set with two parameters of Kp and Ki. Firstly, Kp = 1 and Ki = 1. Secondly, Kp = 50 and Ki = 1.

The corresponding output waveforms of commanded speed, commanded position, feedback of actual speed and position, and Iq currents are shown below. In addition, the results data are extracted for derivation and plotting purpose by Matlab software.

Output waveforms	Analysis of result
1. Kp = 1, Ki = 1. (Without PI tuning) a) With Trapezoidal profile by PMD Pro-Motion Software 	By PMD Pro-Motion software: *The position error with this parameter settings shown is 25degree maximum.



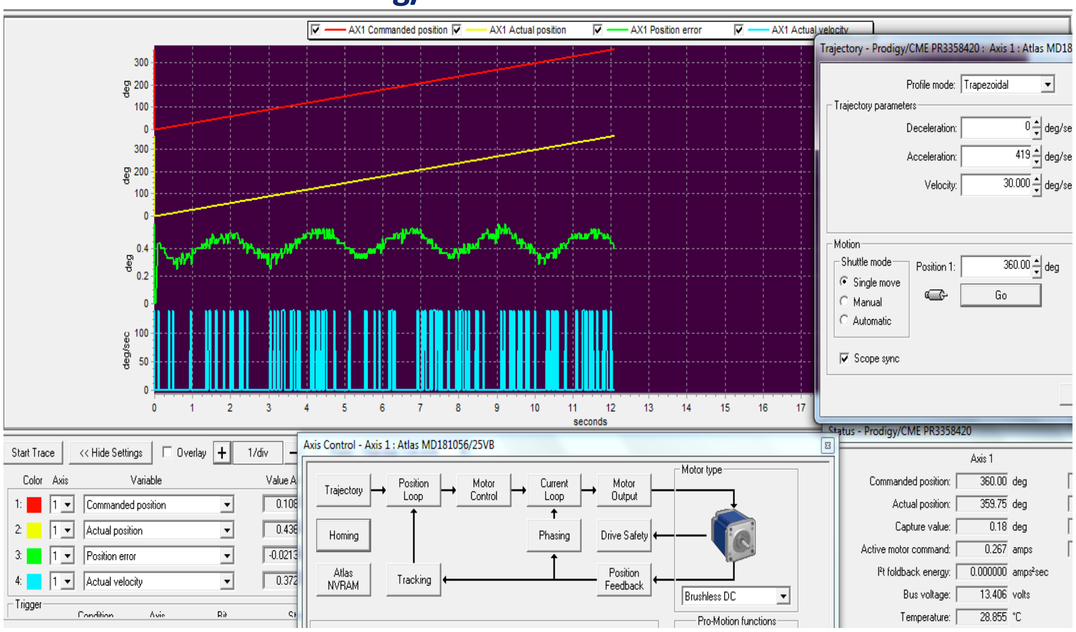
b) Speed response during position control – extracted data plotted by Matlab



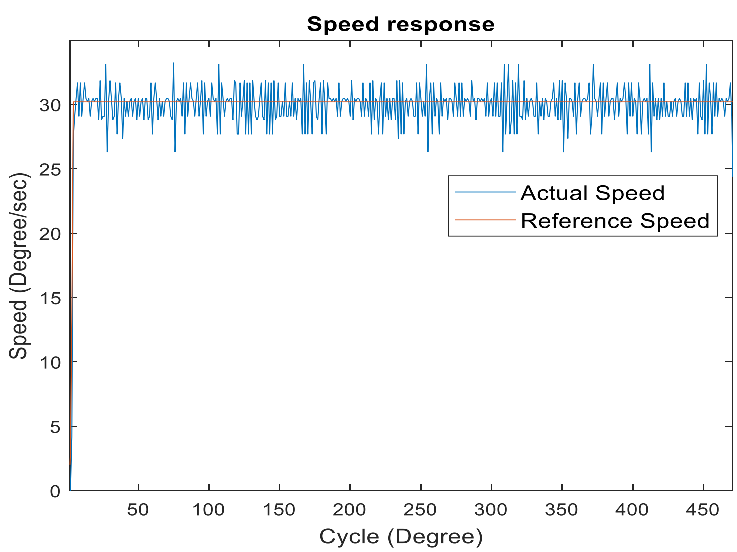
***The speed response during the position control is plotted by Matlab, which generated from the derivation extracted data from PMD Pro-Motion software. *Ripple of the same frequency presents both in Q current and speed. The ripple seems**

to be caused by the commutation of the converter.

2. **Kp = 50, Ki = 1. (PI tuned)**
   a) **With Trapezoidal profile by PMD Pro-Motion Software – speed reference: 30deg/sec.**



   b) **Speed response during position control – extracted data plotted by Matlab**



*With PI tuning, this parameter settings are improved on the position error, which less than 0.5 degree maximum. Practically, the PI gains still can be tuned for better response.

*The speed response during the position control is plotted by Matlab is showing the speed ripple due to converter as shown in the previous

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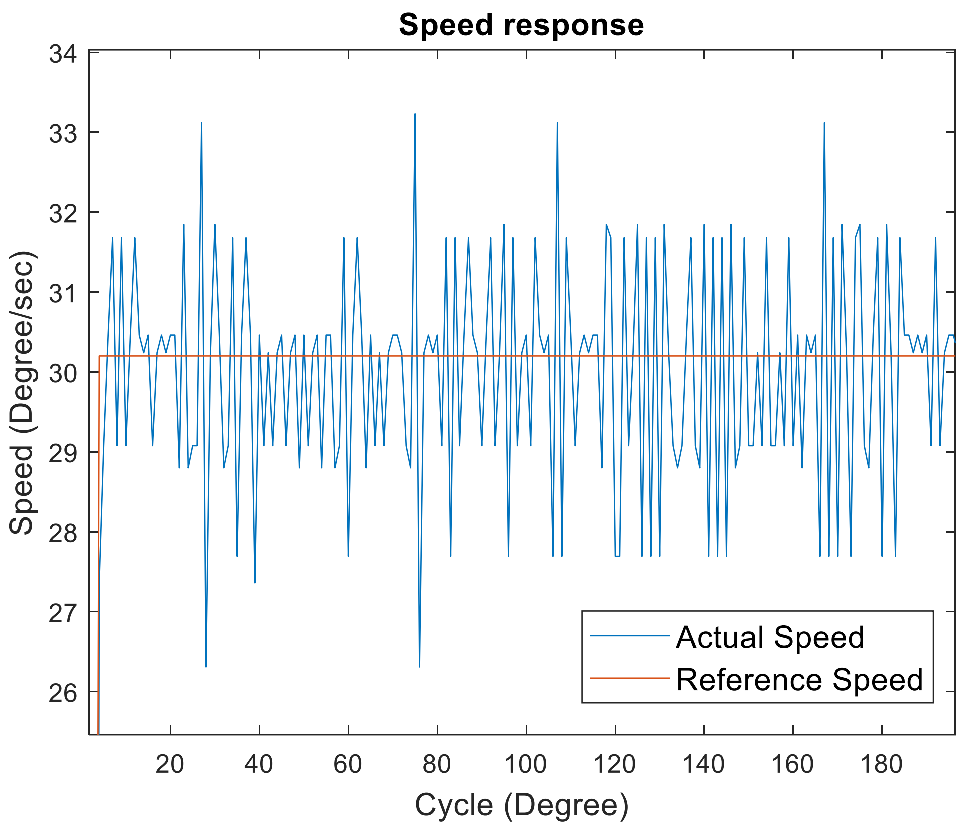
(Zoom in figure on ripples);



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section has been reduced since the bandwidth of the controller is higher.

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4.0 Conclusions

According to the observation output waveforms discussed in previous section, the PMSM is considered can be controlled by the PMD MC58420 motion controller, but some issue should be taken into account. As known that this drive controller is dedicated for Brushless DC, DC brush, and Stepper motors only, it provides equivalent control method as used for PMSM i.e FOC, sinusoidal commutation, and high performance torque control by ATLAS digital amplifier, but it is still not clear and under investigation on how this controller can be applied for PMSM since the drive current and Back EMF of sinusoidal are different from Brushless DC with trapezoidal. On the other hand, it may be concluded that if the PMSM with a sinusoidal Back EMF shape is used, this controller can be applied but the produced current / torque response is:

- Firstly, not constant but made up from portions of a sine wave, which also lead to ripples. This is due to its being the combination of a trapezoidal current control strategy and of a sinusoidal Back EMF. A sinusoidal Back EMF shape motor controlled with a sine wave strategy (three phase ON) produces a constant torque.
- Secondly, the torque value produced is weaker.

5.0 References

1. Prodigy/CME Machine-Controller Motion Control Board User's Guide
2. Magellan Motion Control IC User's Guide
3. Atlas Digital Amplifier Complete Technical Reference
4. Pro-Motion Software Manual User's Guide
5. Magellan Motion Control IC Programmers Command Reference