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Comparison test between PMD MC58113 and YAKO SSD2608H stepper motor drive

[September 2018]

List of equipment

The equipment used in the test are listed as below:
1, PMD MC58113 **Developer's Kit**
2, YAKO SSD2608H closed loop stepper motor **drive**
3, YAKO two-phase hybrid stepper **motor** YK260EC86E1, with 1000 line per revolution encoder (i.e. 4000 counts per mechanical resolution)
4, DIGIMESS Concept series DC **power supply** PM3006-3
5, YOKOGAWA DLM2024 mixed signal **oscilloscope** 2.5GS/s 200MHz

Contents

Test plan

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Test rig set-ups

The following figure is drawn to summarise the potential interface between the two drives and the motor.

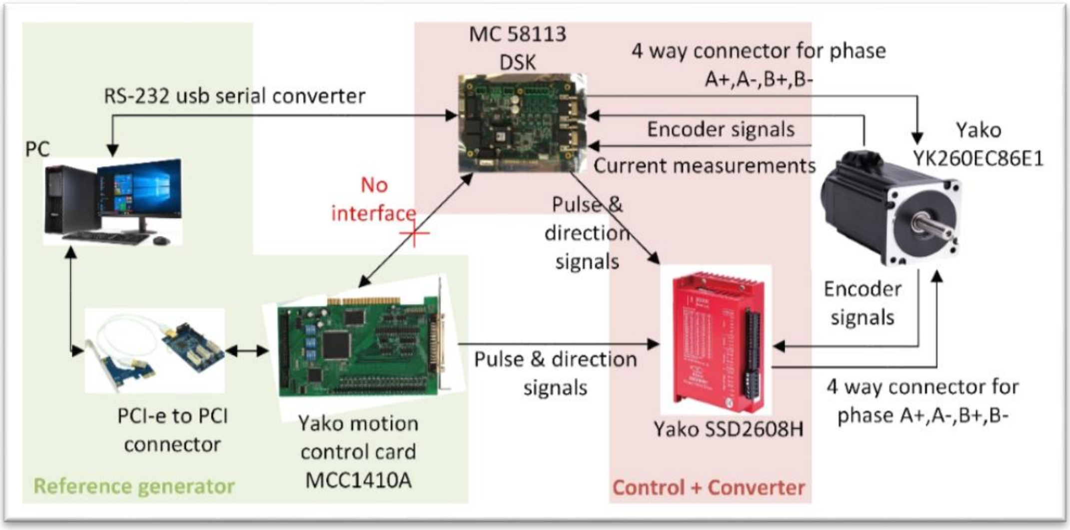


Fig.1 potential interface

Since the MC58113 and SSD2608H support different type of interface to the reference signals, it is impossible to drive the two drives with the YAKO motion control card. Alternatively, the following connections are proposed:

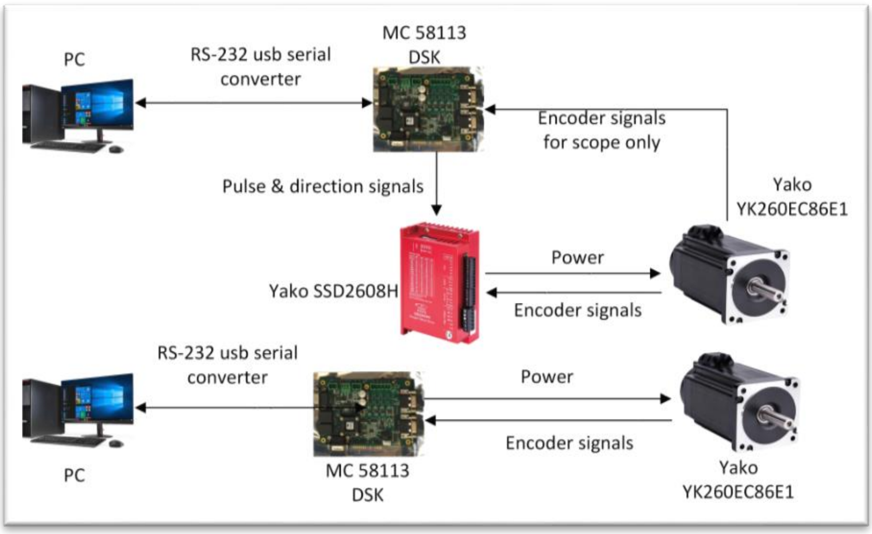


Fig.2 proposed connections

Control settings

To ensure a fair comparison, the control settings need to be equivalent in the two drives. The key parameters are as listed in Table 1.

Table 1

<table>
<tr><th></th><th>PMD MC58113</th><th>YAKO SSD2608H</th></tr>
<tr><td>DC bus voltage U_{dc}</td><td colspan="2">60V</td></tr>
<tr><td>Micro-stepping resolution</td><td colspan="2">51200 micro-steps per mechanical revolution</td></tr>
<tr><td>Encoder resolution</td><td colspan="2">4000 counts per mechanical revolution</td></tr>
<tr><td>Step size of motor</td><td colspan="2">1.8 degree</td></tr>
<tr><td>Load</td><td colspan="2">No Load</td></tr>
<tr><td rowspan="2">Current loop control method and parameters for the PI controller</td><td>Phase A/B*1
Kp=80, Ki=500</td><td rowspan="5">Unknown
Unable to tune
Tested as it is</td></tr>
<tr><td>FOC*2
Kp=80, Ki=500</td></tr>
<tr><td>Speed loop</td><td>No speed loop</td></tr>
<tr><td>Position loop</td><td>No position loop</td></tr>
<tr><td>Anti-stall</td><td>Available*3</td></tr>
</table>

. **1 Phase A/B control is the scalar control, which is also known as the* ***open loop control*** *that only controls the amplitude of current. The current is controlled in the A/B two-phase stationary frame.*

2 FOC denotes the field oriented control, which is the vector control or the* ***closed loop control* *that also controls the angle of the current vector. The currents are controlled in DQ rotary frame.*

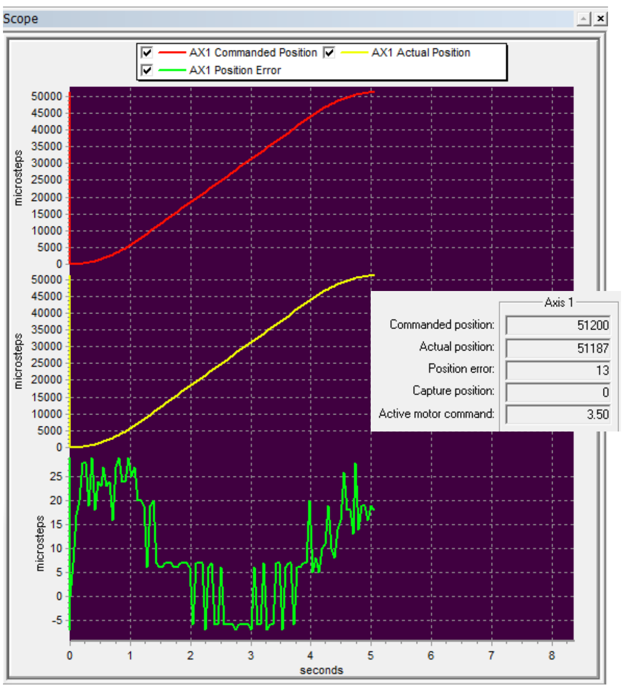
**3 Stall detection can be achieved if the position error is beyond an user-defined threshold. The actions to be taken after a stall is also user-defined. The function has NOT been tested since a stall would typically occurs when there is a variation in load, and load is not available in current set-ups.*

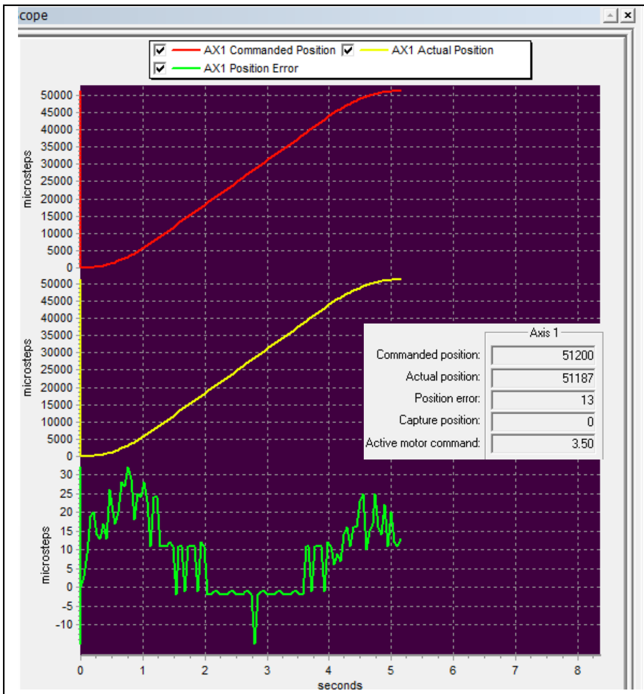
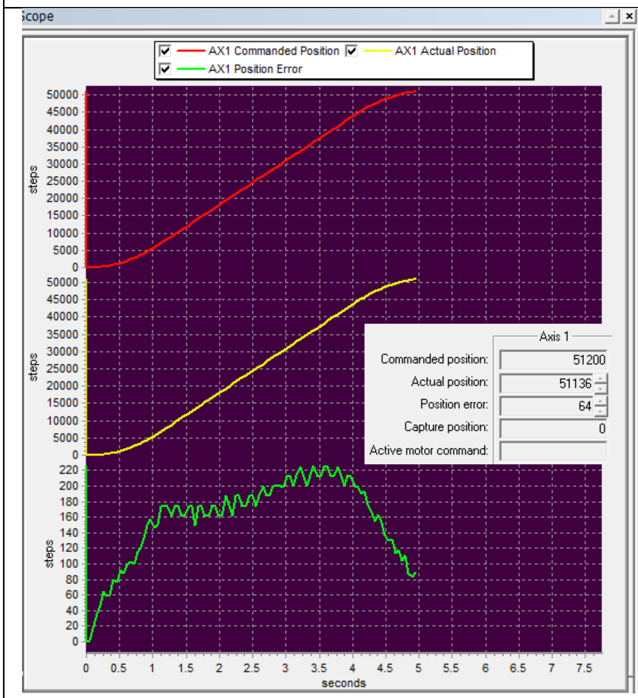
Results and Discussions

One mechanical cycle rotation test

During the test, a position reference of 51200 micro-steps (i.e. one mechanical revolution) has been commanded with the acceleration/deceleration and velocity (where the velocity is **15 rpm**) all equal to 12800 micro-steps/sec.

The corresponding commanded position, actual position, and position error waveforms recorded by the PMD Pro-Motion software are compared as below:

Waveforms	Results
	**With PMD FOC current control** The maximum position error during the movement is < 29 micro-steps, which is: 29/51200*360=0.2 degree (mechanical) 29/1024*360=10.2 degree (electrical) The position error at the end of movement is 13 micro-steps, which is : 13/51200*360=0.091 degree (mechanical) 13/1024*360=4.57 degree (electrical)

	**With PMD Phase A/B current control** The maximum position error during the movement is 33 micro-steps, which is: 33/51200*360=0.23 degree (mechanical) 33/1024*360=11.6 degree (electrical) The position error at the end of movement is 13 micro-steps, which is : 13/51200*360=0.091 degree (mechanical) 13/1024*360=4.57 degree (electrical)
	**With YAKO drive** The maximum position error during the movement is 222 micro-steps, which is: 222/51200*360=1.56 degree (mechanical) 222/1024*360=78 degree (electrical) The position error at the end of movement is 64 micro-steps, which is : 64/51200*360=0.45 degree (mechanical) 64/1024*360=22.5 degree (electrical)

Discussions:

- PMD **FOC** vs PMD **Phase A/B** current control:
  It can be seen that the FOC is better than the Phase A/B control since it provides smaller position error during the movement.

  13 micro-steps position error remains at the end of movement can be the encoder measurement error due to the limitation of its resolution, and not necessarily the real position error. The number of encoder pulses per revolution is 4000, while the total number of micro-steps per revolution is 51200. Therefore, the 'actual position' measured from the encoder can have a maximum error of 12.8 micro-steps.

- **PMD** FOC vs **YAKO** closed-loop control:
  The position errors during the movement and after the movement are much bigger in the YAKO drive. However, the results for YAKO may be bigger than its real position error since:
  It is possible that more delays and noises have been added during the transmission, such that the actual position reference received by the YAKO controller may has been delayed or distorted.

  The most accurate way of measuring the position error in YAKO drive is to compare the encoder counts with the local position command that has been received in YAKO. However, due to the limitation of the testing rig, we are unable to read the position command directly from the YAKO drive. Hence, we are measuring the YAKO drive from the PMD software.

  Still, **the PMD FOC seems better since it is able to reduce the position error the constant speed region to around zero possibly through feedforward (a guess), while the YAKO drive seems not having this function**.

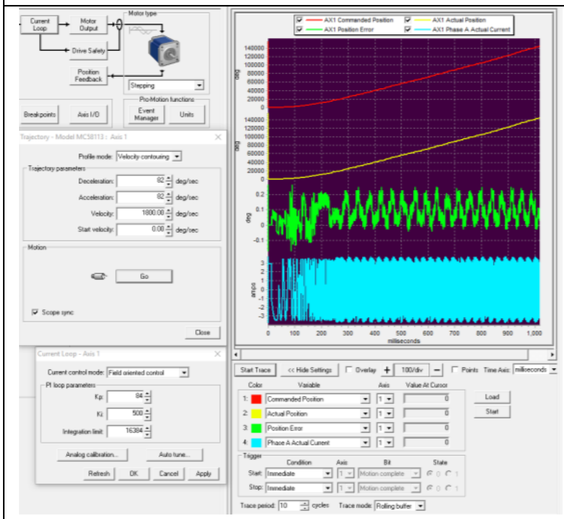
Another constant speed operation test will be discussed in the next section.

Constant speed test

During the test, a mechanical speed reference 1800 degree/sec (i.e. **300rpm**) has been commanded with the acceleration/deceleration both equal to 82 degree/sec.

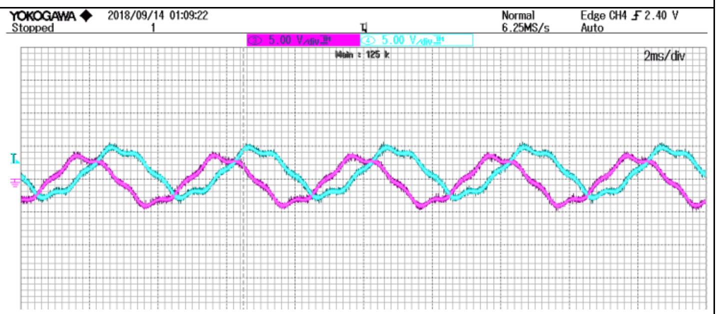
The corresponding current control error, commanded position, actual position, and position error waveforms recorded by the PMD Pro-Motion software are compared as below. Moreover, the current waveforms measured from the oscilloscope are shown.

<table>
<tr><th colspan="2">With PMD FOC current control</th></tr>
<tr>
<td>



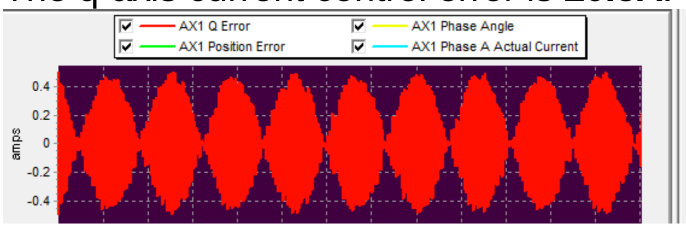
The position error is mechanically maximum 0.25 degree.

</td>
<td>



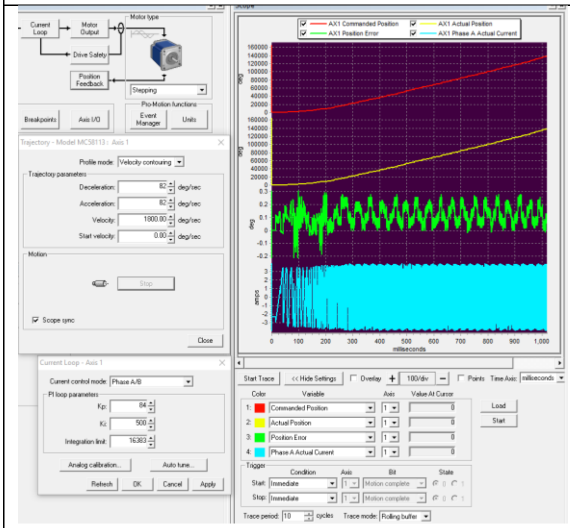
The phase A and B currents in constant speed region are shown as above.

The q-axis current control error is **±0.5A**.

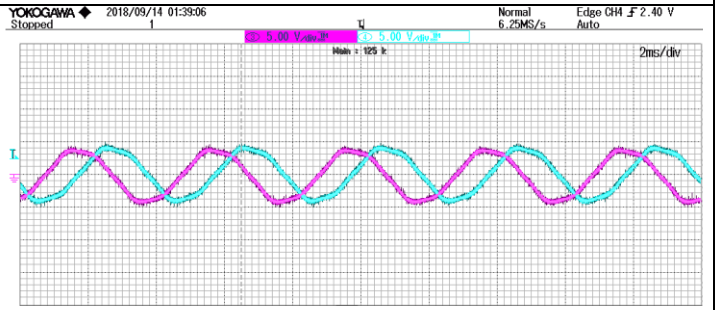


</td>
</tr>
</table>

With PMD Phase A/B current control

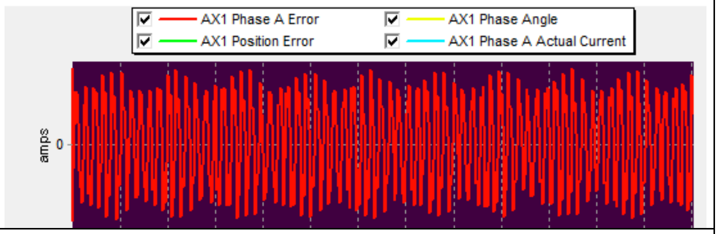


The position error is mechanically maximum 0.28 degree.

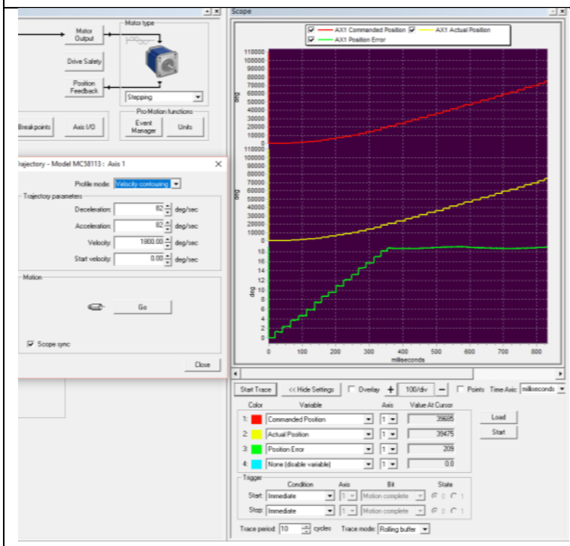


The phase A and B currents in constant speed region are shown as above.

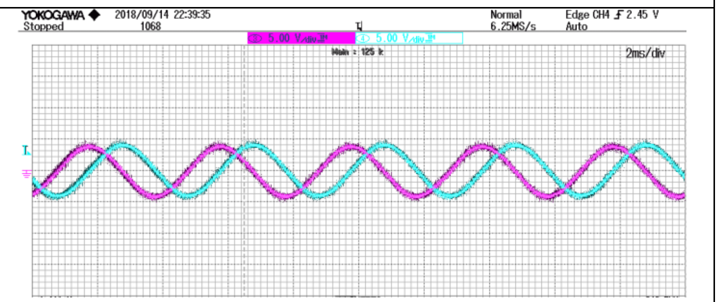
The q-axis current control error is **more than ±0.6A**.



With YAKO drive



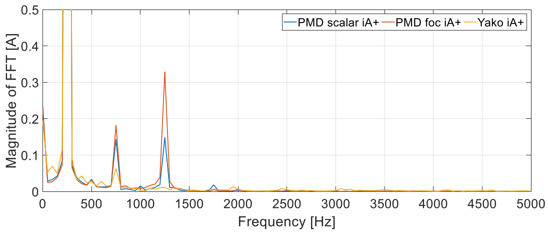
The position error is mechanically maximum 19 degree.

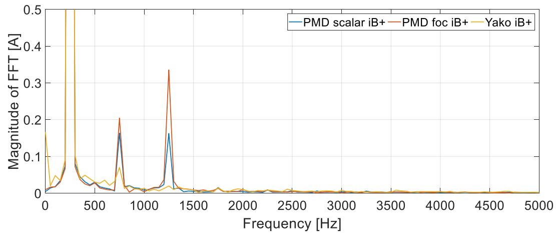


The phase A and B currents in constant speed region are shown as above.

Discussions:

- **Current ripple** vs **fast speed tracking**
  The FFT results of the currents waveforms in the three test conditions above are compared:





  As shown, the PMD FOC has the most current ripple (3rd and 5th harmonics) whereas the **YAKO drive has the least current ripple**. This can be because that the current loop bandwidth in the PMD has been set higher than in the YAKO. Although it is possible to reduce the current ripple by reducing the current loop PI gains, there is little point to do so since faster current loop provides faster speed tracking performance. **From the position error point of view, PMD tracks the speed reference faster and performs better**.
  Again, the position error of YAKO is much bigger than PMD. Further verification is required if we can read directly the reference effectively been received by YAKO and the encoder pulsed counted in the YAKO.

- **Software confusion**
  It is confusion that the time axis of the plot from the PMD software is not the real time.
  For example, although the YAKO test and PMD test used the same acceleration/deceleration/velocity settings, and the exactly same settings are set for the plotting, the position command profiles look different. In the PMD tests, the commanded position reaches 2000 degree at around 250 milliseconds. Whereas, in the YAKO test, the commanded position reaches 20000 degree at around 350 milliseconds.
  Moreover, none of them match the real calculation. The real time for the commanded position to reach 20000 degree should be around 23.3 seconds. Since the observation of the motor behaviour still matches the setting, it is believed that this is only a display problem.

Besides, the position error values remain the same in repeated tests. Therefore, the discussions mainly focus on the position error.

p.s. the Pro-motion software is running in compatibility mode on a win10 PC.

Conclusion

Due to the limitation of the rig, the direct measurement from the YAKO drive is not available. Therefore, the results for the YAKO drive is not the most accurate results, but can be used as a guide value. The main conclusions are as below:

- The initial goal of the tests is to compare the current noise level between the PMD board and the YAKO drive. With the same constant speed reference, the two-phase currents in the Yako drive is more sinusoidal than the two-phase currents in PMD (contains 3^{rd} and 5^{th} harmonics).
- With the same references, PMD performs better then YAKO in terms of reference tracking. Much smaller tracking errors are observed using PMD. A guess is that in the current loop of PMD, feedforward terms have been included, such that better dynamics are achieved compared with YAKO.
- The FOC is better than the phase A/B(i.e. open loop control or scalar control). Not only smaller position error, but also smaller current control error has been achieved with FOC.