Position control of BLDC Motor Using Proportional Integral Sliding Mode (PISMC) Control with LabVIEW Real-Time, Simulation & Experiment

Bondhan Novandy

http://bono02.wordpress.com/

Introduction

- SMC is one of the robust controller with ability to compensate the uncertain parameters, incomplete dynamics model and reject disturbances.
- The additional of PI on the SMC give several “extra” freedoms and flexibility in tuning and obtaining the desired performance.

Design Scheme

- First, select a PI sliding surface.
- Second, from the sliding surface we derive the equivalent control
- Third, the control output is achieved by adding the switching control output.

  The mathematics derivation is straight forward, and will be explained in next page.

Mathematical Derivation

- Since one advantage of SMC is the ability to compensate the incomplete dynamic model, we use a simple common motor dynamics:

$$J\ddot{\theta}+B\dot{\theta}=T_m+T_d$$

- Where J is motor inertia, B is damping, Tm is motor torque, Td is disturbance (is zero), Theta double dot is acceleration and Theta dot is velocity.

Sliding Surface

- A PI sliding surface

$$S = Kp\tilde{\theta} + Ki\int_0^t \tilde{\theta}\,dt + \dot{\tilde{\theta}}, where\ \tilde{\theta} = \theta_m - \theta_d$$

- The derivation of sliding surface

$$\begin{aligned}\dot{S} &= Kp\dot{\tilde{\theta}} + Ki\,\tilde{\theta} + \ddot{\tilde{\theta}} \\ &= Kp\left(\dot{\theta}_m - \dot{\theta}_d\right) + Ki\left(\theta_m - \theta_d\right) + \left(\ddot{\theta}_m - \ddot{\theta}_d\right)\end{aligned}$$

- We try to force the state trajectory to slide on our surface so that: $S = 0$

$$\dot{S} = 0$$

$$\dot{S} = Kp\dot{\tilde{\theta}} + Ki\,\tilde{\theta} + \ddot{\tilde{\theta}}$$

$$= Kp\left(\dot{\theta}_m - \dot{\theta}_d\right) + Ki\left(\theta_m - \theta_d\right) + \left(\ddot{\theta}_m - \ddot{\theta}_d\right)$$

$$= Kp\left(\dot{\theta}_m - \dot{\theta}_d\right) + Ki\left(\theta_m - \theta_d\right) + \frac{T_m}{J} - \frac{B}{J}\dot{\theta}_m - \ddot{\theta}_d = 0$$

Since $T_m = K_t I_a$, then

$$I_{eq} = (-JKp\left(\dot{\theta}_m - \dot{\theta}_d\right) - JK_i\left(\theta_m - \theta_d\right) + B\dot{\theta}_m) / Kt$$

Then the full control output:

$$I = I_{eq} + I_{switching}, where\ I_{switching} = -K * sat(s/\phi)$$

and *sat* is the function:

$$sign(s) \quad if \quad \text{abs}(s) > \phi$$

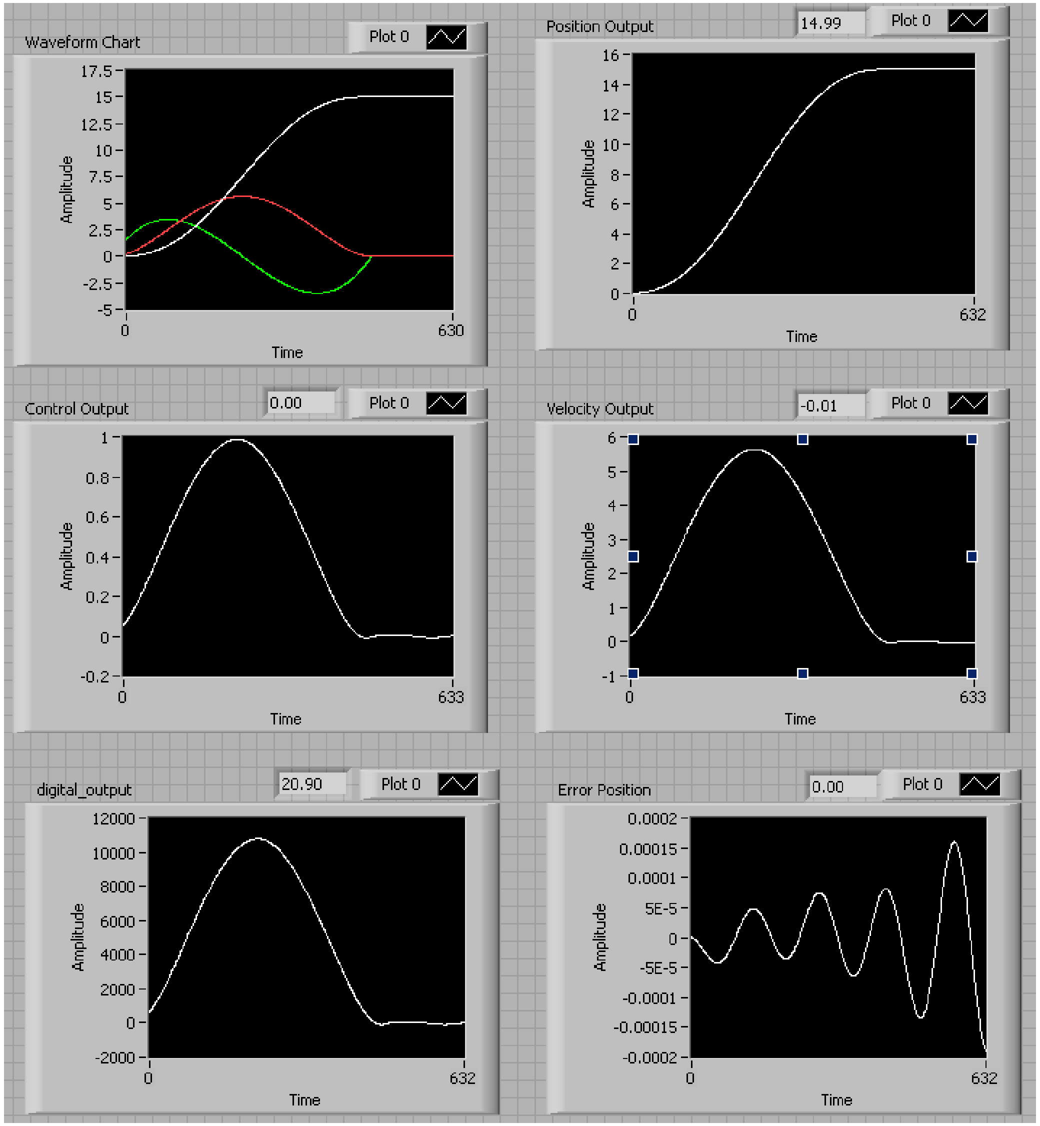
$$s/\phi \quad if \quad \text{abs}(s) < \phi$$

Stability

- The stability can be proven using Lyapunov function. (Left for the reader to proof ☺)
- You may refer to:

  http://bono02.files.wordpress.com/2008/01/smc.pdf

Simulation



- Quintic Input
- Motor parameters:

  j=0.01;

  b=0.1;

  Kt=0.01;

  Kb=0.29098;

  Ra=1;

  La=0.5;
- Controller parameters:

  Kp = 10

  Ki = 2

  K =1

  Delta = 0.9

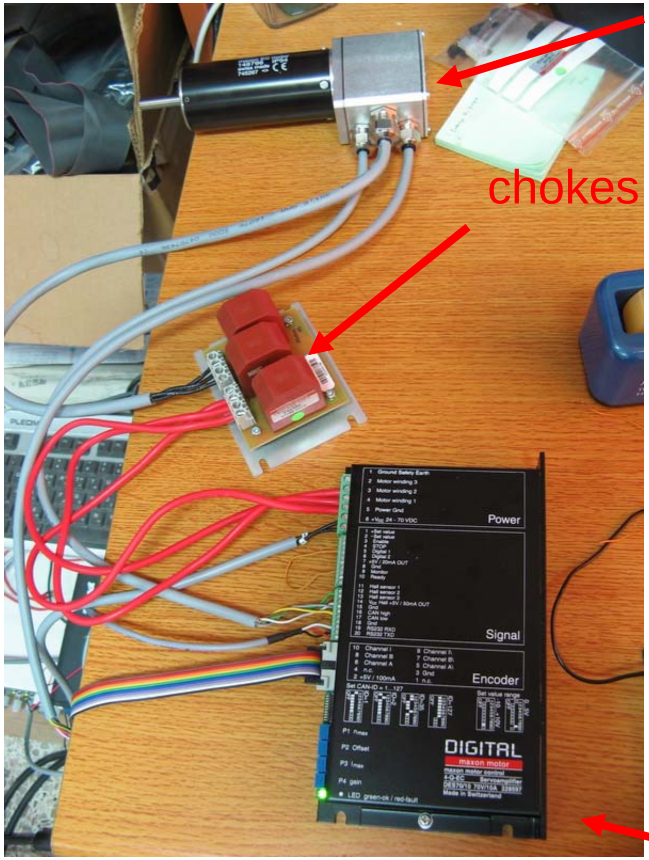
Experiment

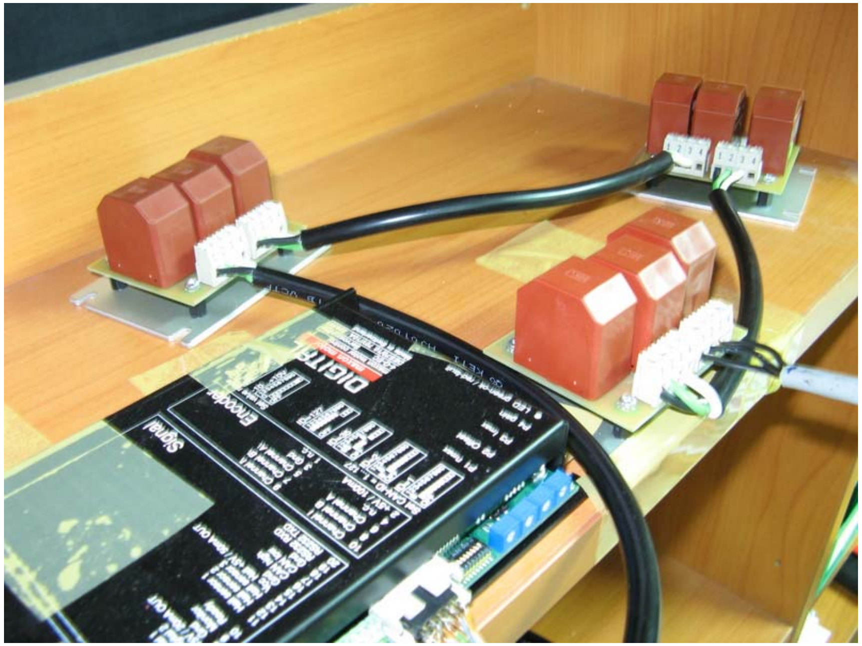
- Hardware
  - MAXON Servo amplifier DES 70/10
  - Maxon BLDC Motor EC 45
  - 3 Choke inductor (recommended inductance is 400 uH, the maxon engineer said to me :p)
  - NI Motion controller PXI-7358
- Software
  - Labview Real-Time
  - Maxon DES Program (For monitoring)

Hardware

Maxon EC 45 Motor

chokes

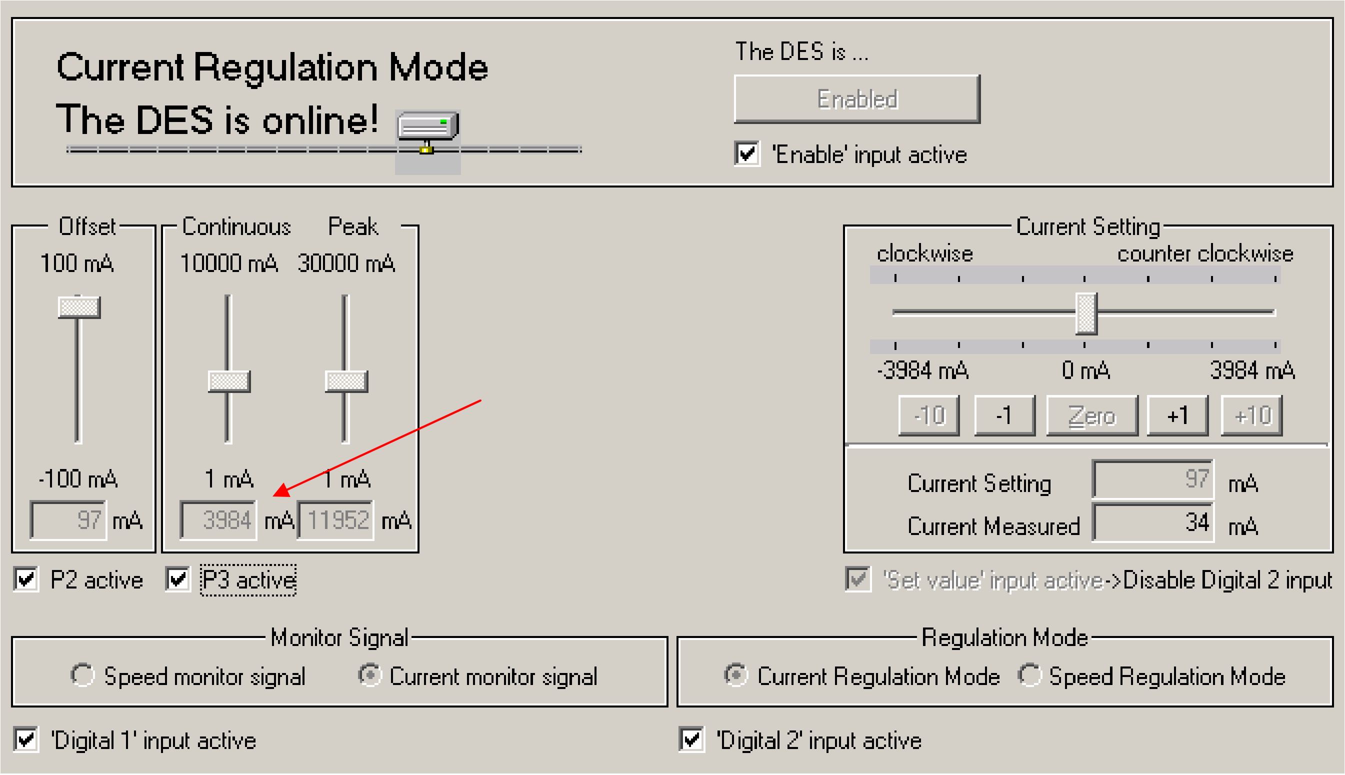




Driver DES 70/10

Notes

- You must read the manual of DES 70/10 and adjust the potentiometer of the driver! You may also adjust through the software provided! We are using torque mode!

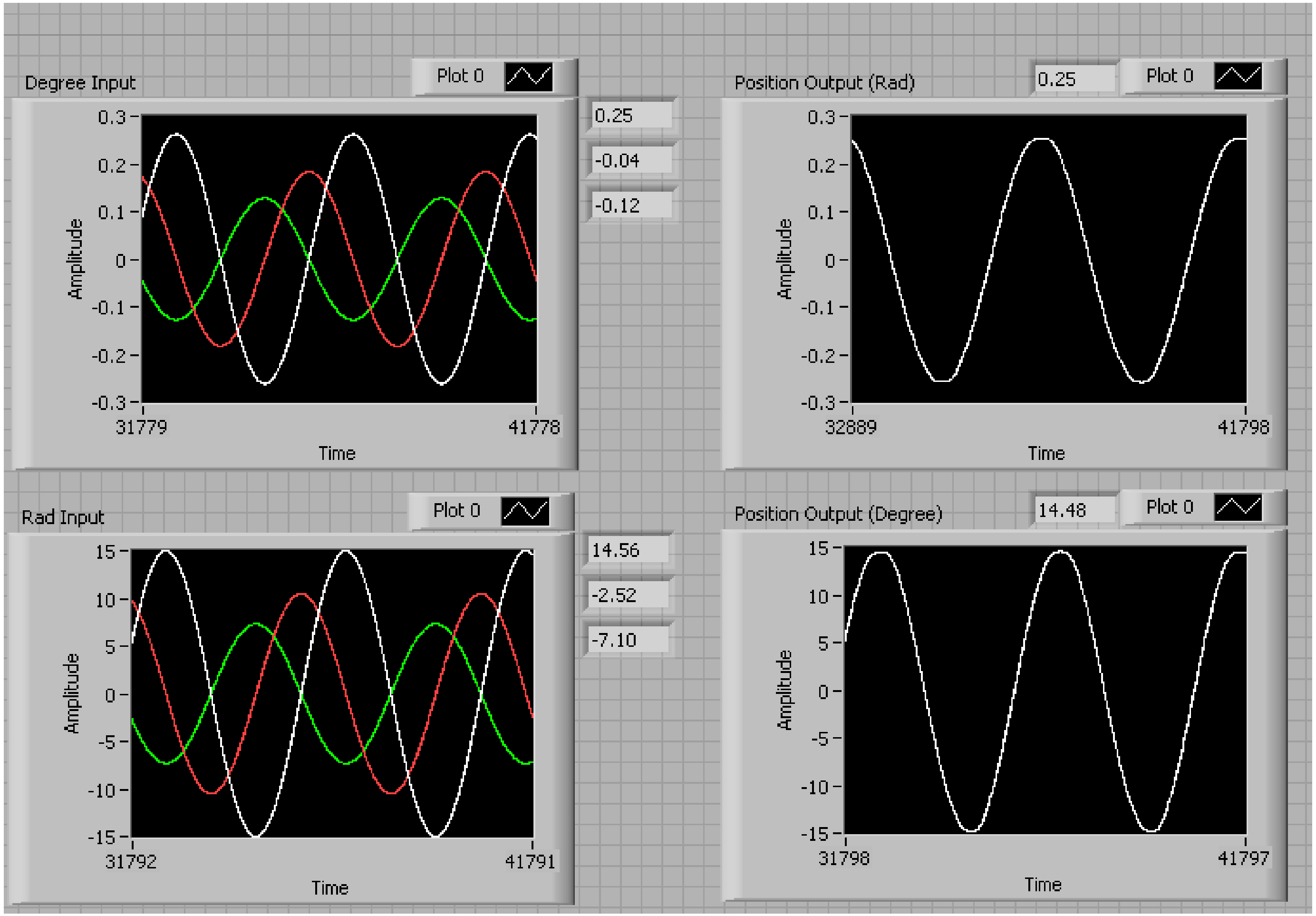


Notes Cont'd

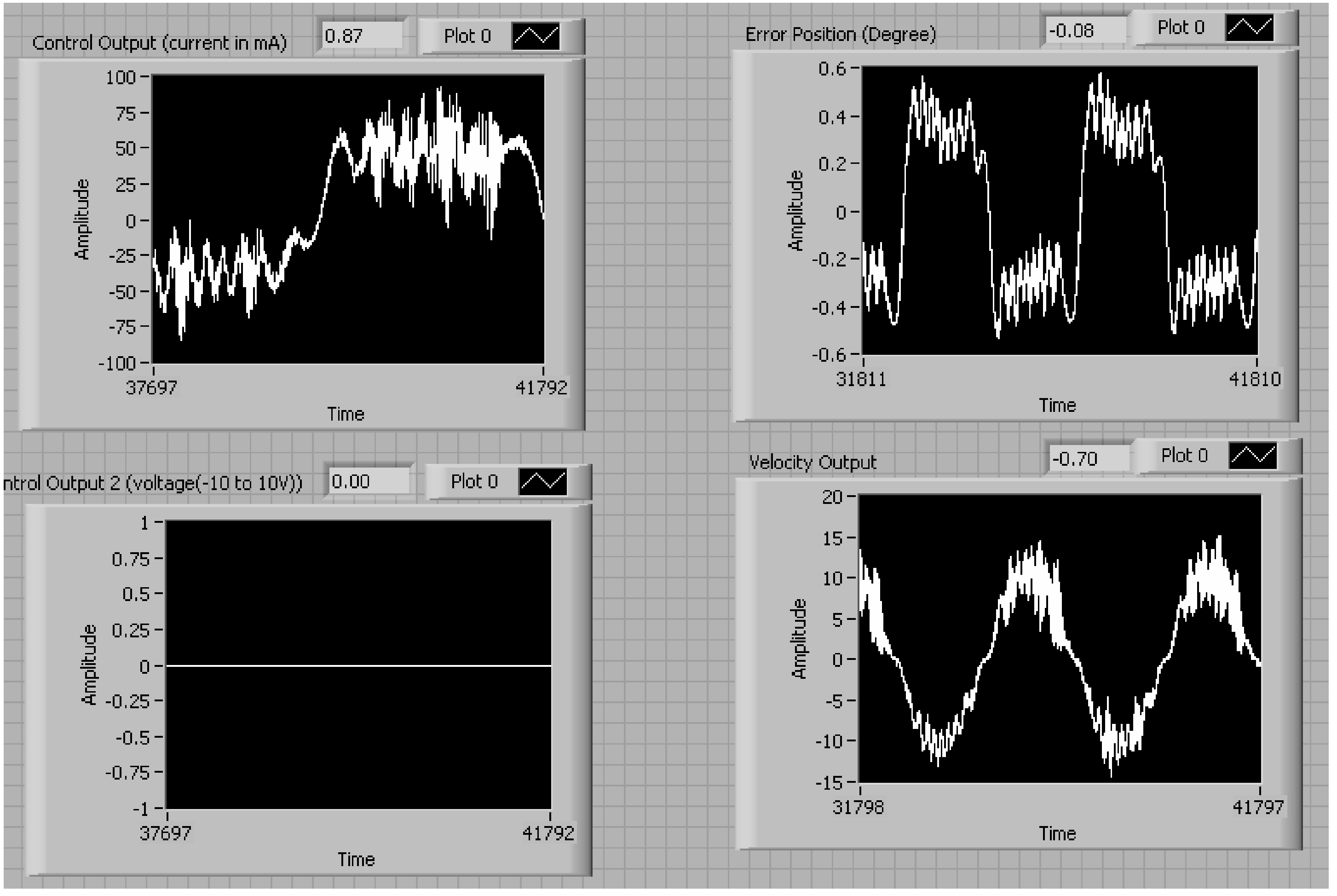
- Read the motor manual, for this motor, the parameters are:
  - j = 0.0000209; (available in manual)
  - b = 0.00209; (trial and error, b=100*j)
  - Kt = 0.025; (available in manual)
  - Ra =0.143; (available in manual)
- Power supplies: Read the DES manual, I am using 60 V, 6 A max power supply.
- The video is available at http://bono02.wordpress.com/

Results

- Sinusoidal Input, Steady State error around 0.5 degree



Results



Control Output (current in mA)
0.87
Plot 0
100
75
50
25
0
-25
-50
-75
-100
Amplitude
37697
41792
Time
Error Position (Degree)
-0.08
Plot 0
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Amplitude
31811
41810
Time
ntrol Output 2 (voltage(-10 to 10V))
0.00
Plot 0
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
Amplitude
37697
41792
Time
Velocity Output
-0.70
Plot 0
20
15
10
5
0
-5
-10
-15
Amplitude
31798
41797
Time