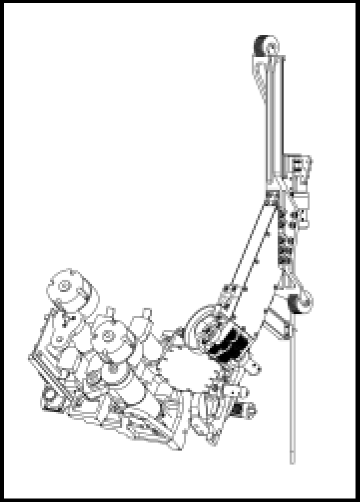
EE 449 Project Presentation II



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Automatic Cable Winding For Surgical Robot Arms

Milestone II

- Project Description
- System Block Diagram
- Equations
- Model Parameters
- Simulation
- Controllability and Observability
- Updated Project Plan
- Bibliography

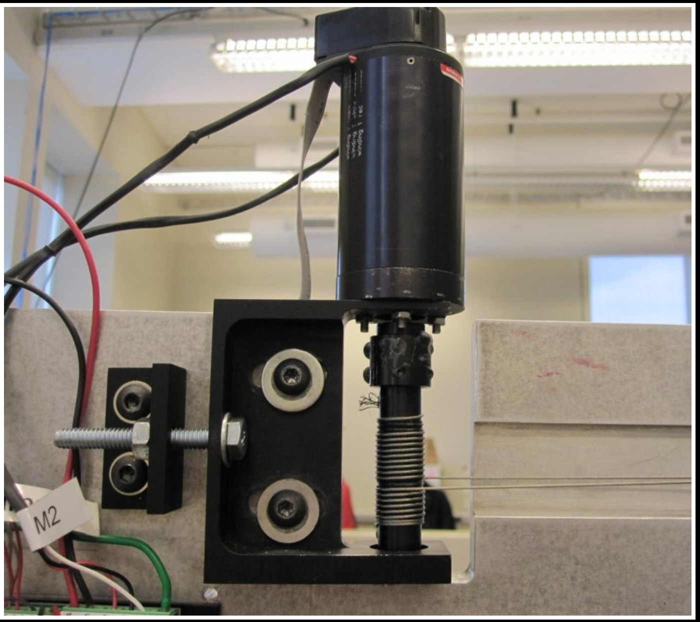
Project Description

The controller we create will wind the cable onto the capstan automatically.

One end of the cable is attached to the capstan while the other end will be attached to a unwinding bobbin which will provide constant torque.

The system should be able to wind the cable in two different directions.

The user can specify the velocity and number of turns. (Ranges from ~10-20 rotation per minute).



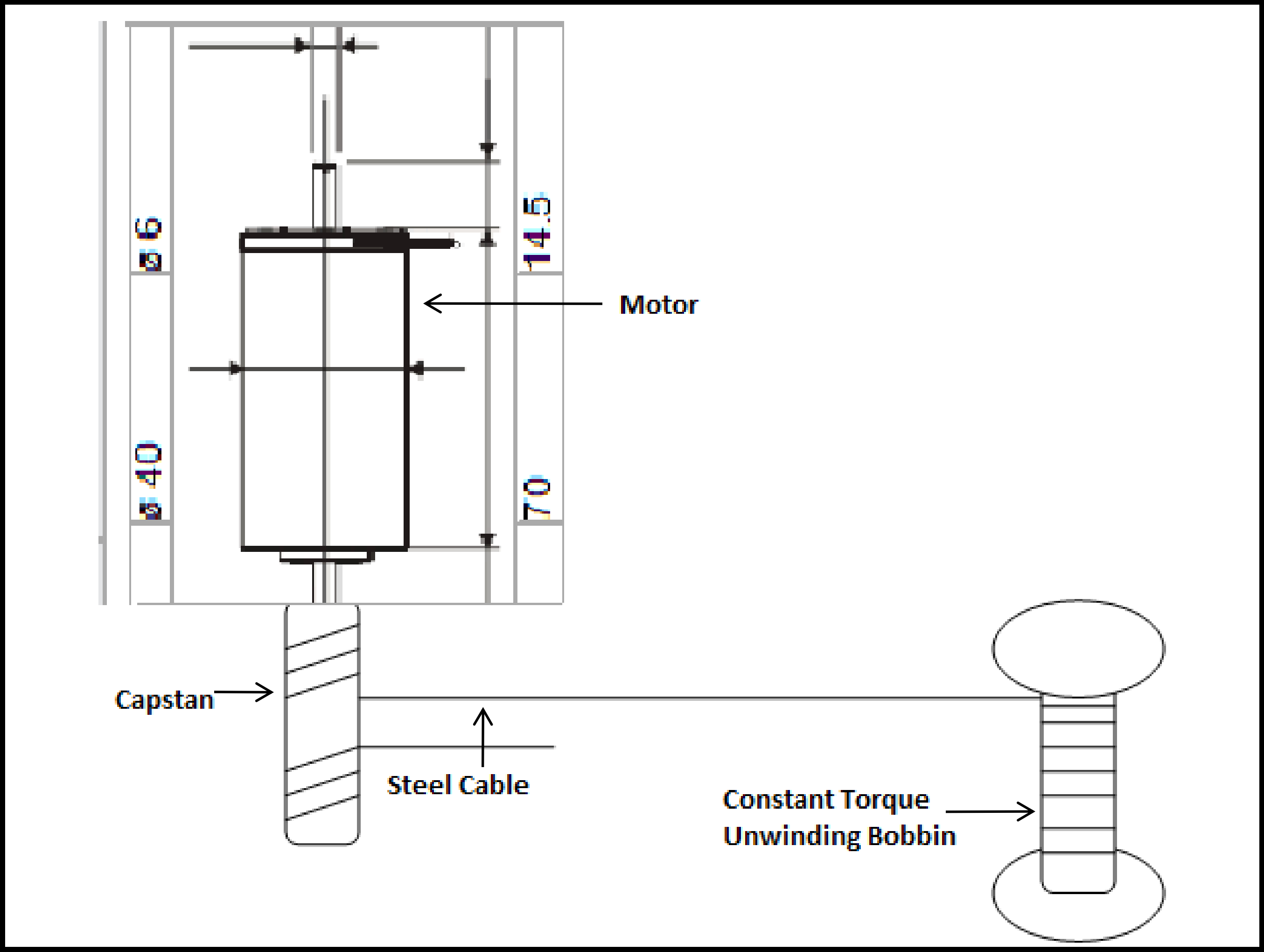
Performance Criteria

The controller should be able to track the specified velocity with 95%+ accuracy.

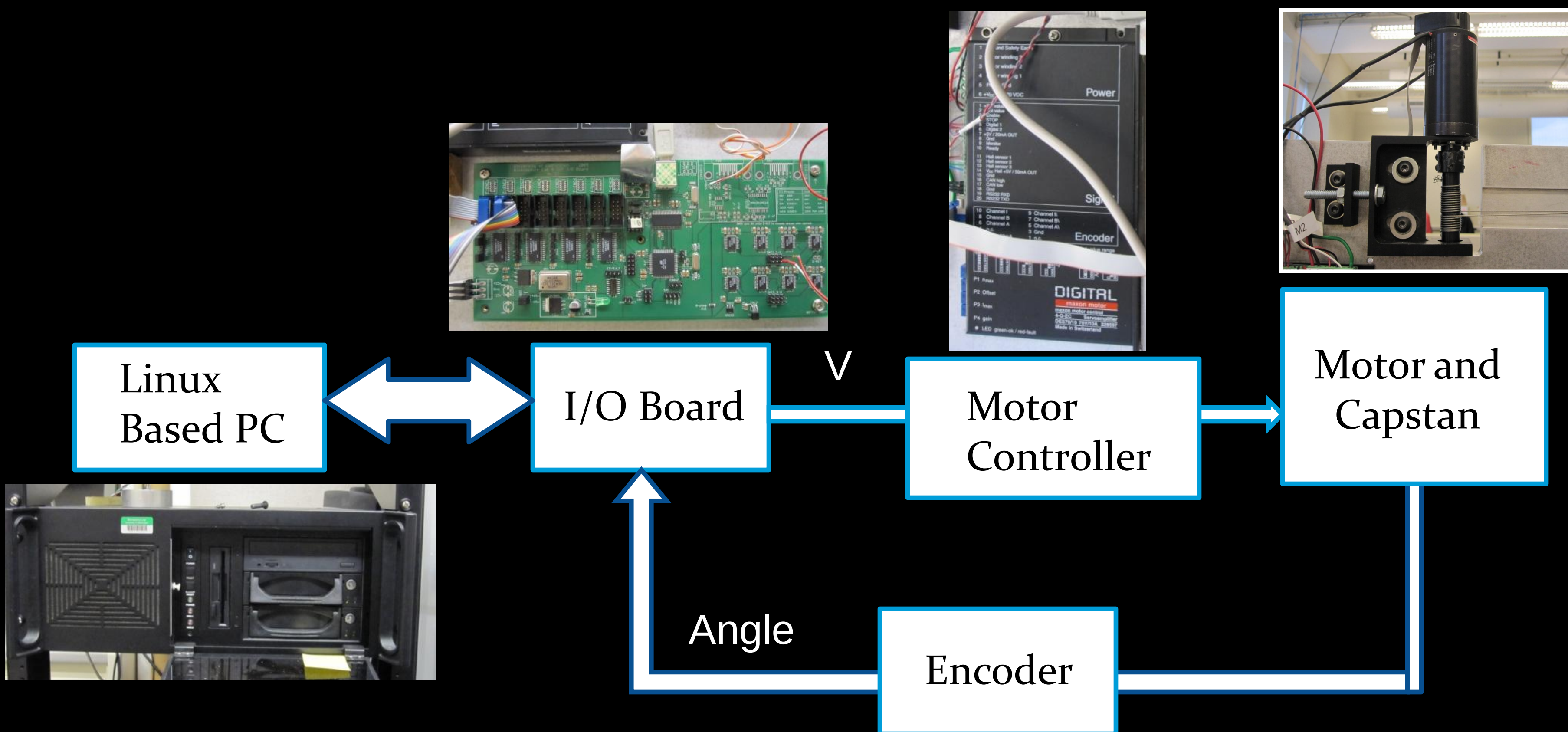
The controller should detect and stop the motor in under 1sec if the cable gets dislodged from the capstan.

The system should hold the position of the capstan at a reasonable amount of time (~1-5minute) after the cable is wound.

Parts Diagram

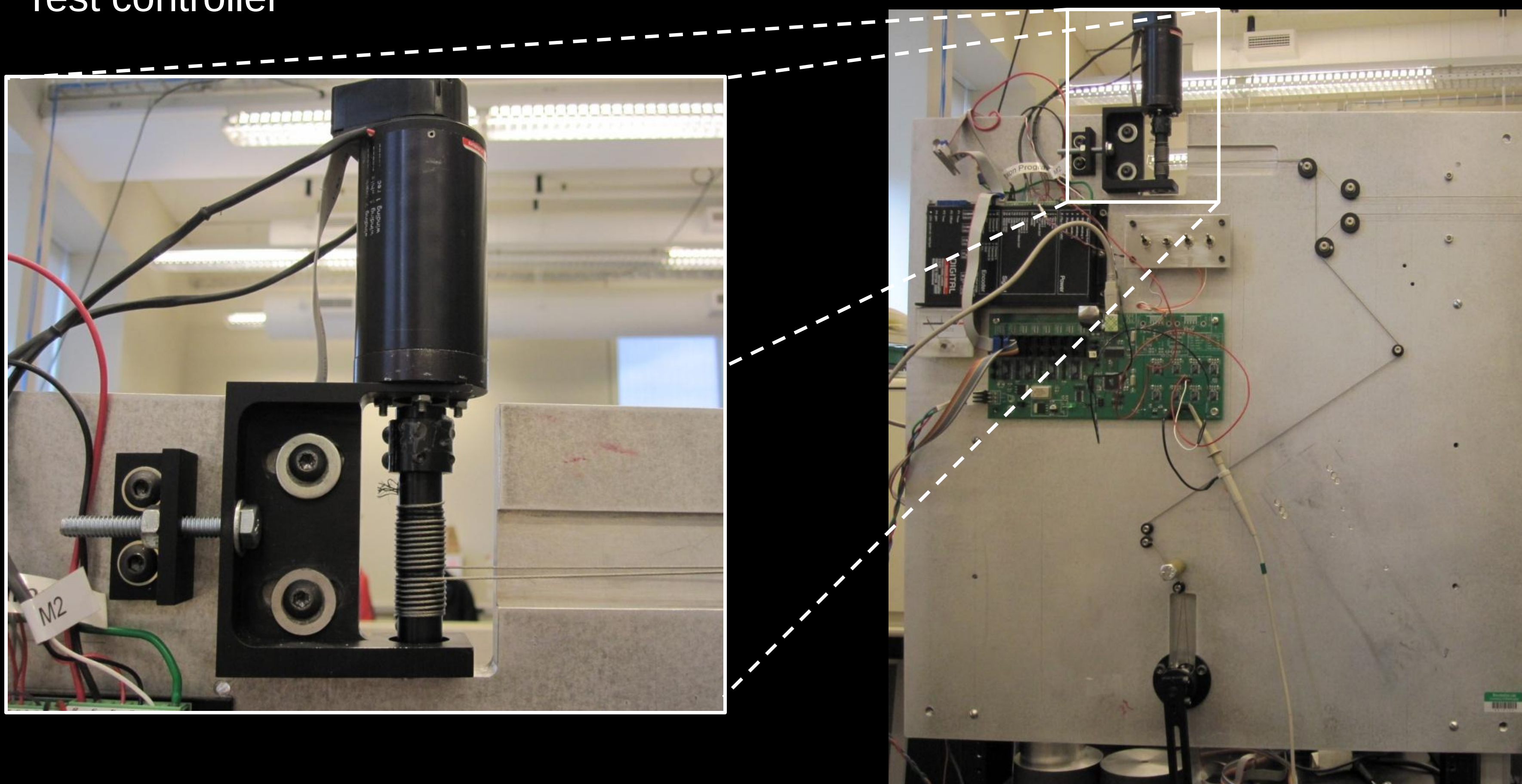


System Block Diagram



Pulley Board

Pulley Board
Test controller



Equations

- Electrical Equation:

  Va (t) = La di(t)/dt + Rm i(t) + Kv w(t)

- Mechanical Equation:

  Tl(t) = Kt i(t) – bm w(t) – Jm dw(t)/dt

State Space Model

$$X = \begin{bmatrix} X1 \\ X2 \\ X3 \end{bmatrix} = \begin{bmatrix} I \\ \Theta \\ w \end{bmatrix} \begin{matrix} \text{amps} \\ \text{rad} \\ \text{rad/sec} \end{matrix} \qquad u = \begin{bmatrix} u1 \\ u2 \end{bmatrix} = \begin{bmatrix} V \\ Tl \end{bmatrix} \begin{matrix} \text{volts} \\ \text{N-m} \end{matrix}$$

$$\begin{bmatrix} dX1/dt \\ dX2/dt \\ dX3/dt \end{bmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{bmatrix} -Rm/La & 0 & -K/La & X1 \\ 0 & 0 & 1 & X2 \\ K/Jm & 0 & 0 & X3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -bm(X3)/Jm \end{bmatrix} + \begin{bmatrix} KA/La & \Theta \\ 0 & 0 \\ 0 & -1/Jm \end{bmatrix} \begin{bmatrix} u1 \\ u2 \end{bmatrix}$$

Model Parameters

Electrical Parameters:

- Self inductance (La) = 1280 mH
- Terminal Resistance (Rm) = 4.94 ohms

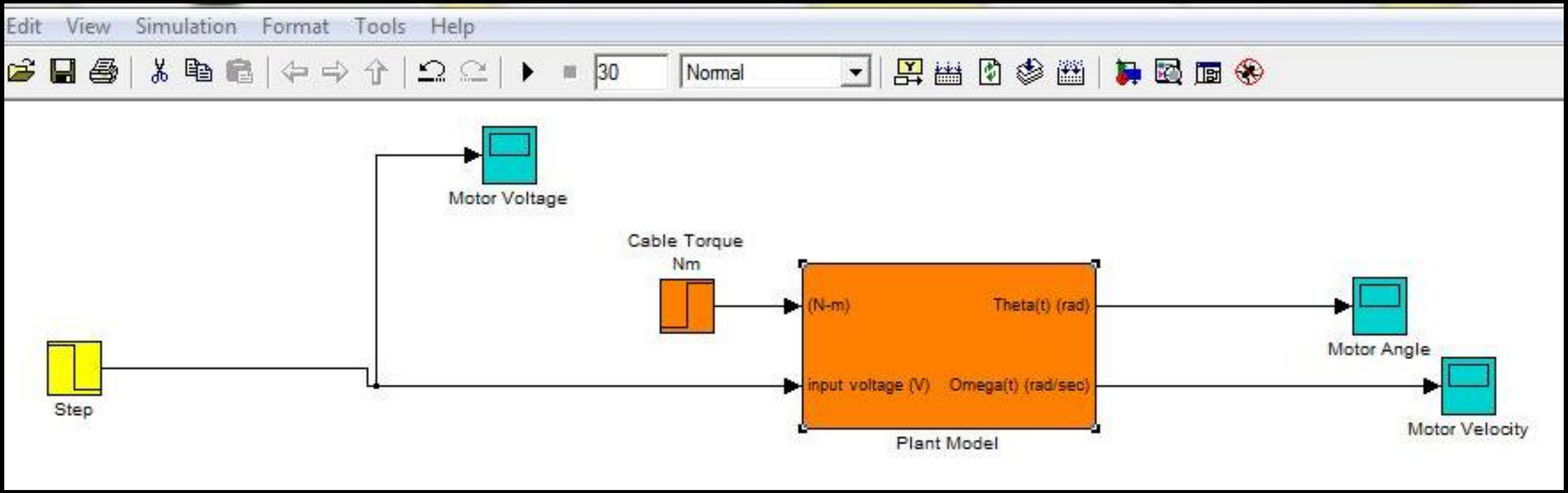
Mechanical Parameters:

- Torque to Speed Ratio (Bm) = 1.1507e-3 Nm/(rad/sec)
- Plant inertia (Jm) = 85 gcm^2 + 21.932 gcm^2
- Torque constant (Kt) = 0.09167 Nm/Amp

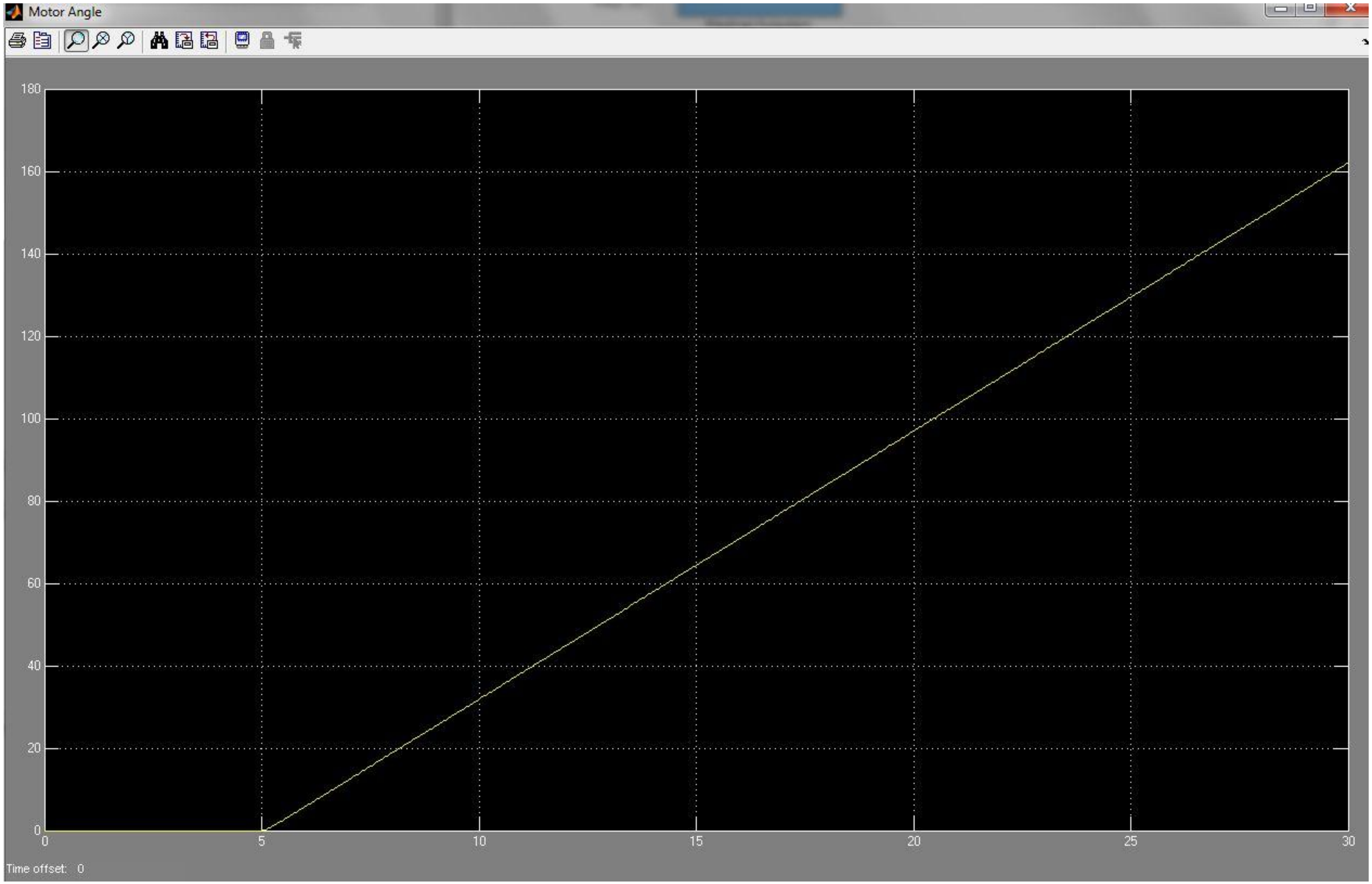
External cable torque (T_L) = 0.04 Nm

Simulation

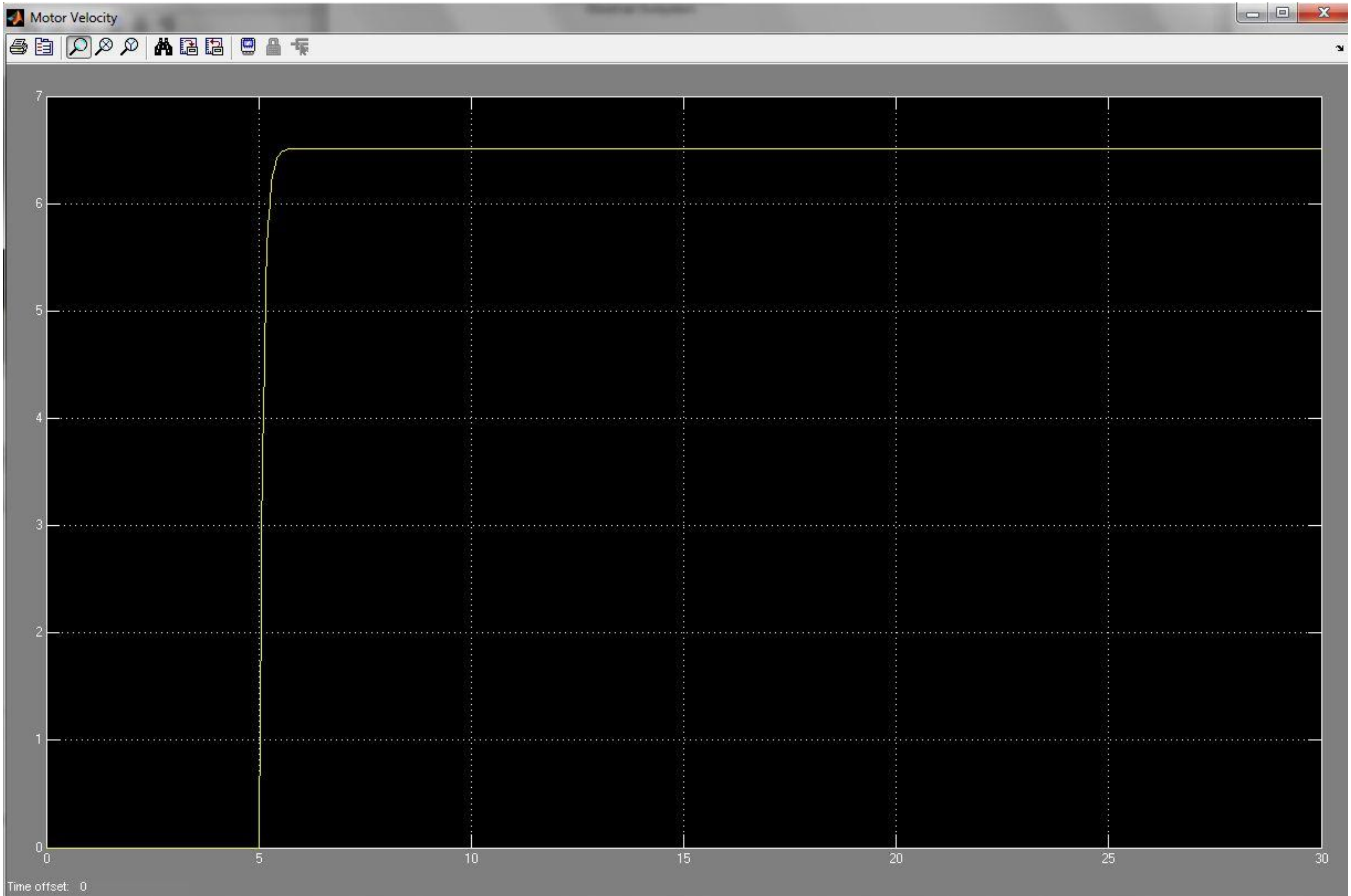
- A Simulink block was created with the plant model to simulate a response to a constant voltage and torque.



Simulation Results – Motor Angle



Simulation Results- Motor Velocity



Controllability and Observability

Matlab was used to calculate the rank for both the controllability and observability matrix. The rank for both of them were 3 showing that the plant is both controllable and observable

```
>> Cm = ctrb(A,B)

Cm =

  1.0e+009 *

    0.0000         0   -0.0000   -0.0000    0.0000    0.0007
         0         0         0   -0.0001    0.0000    0.0101
         0   -0.0001    0.0000    0.0101   -0.0007   -1.1382

>> rank(Cm)

ans =

     3
```

Controllability matrix

```
>> Om=obsv(A,C)

Om =

  1.0e+003 *

         0    0.0010         0
         0         0    0.0010
    8.5672         0   -0.1075

>> rank(Om)

ans =

     3
```

Observability Matrix

Updated Project Plan

Task	Week
Get familiar with the interfaces.	2
System modeling and model simulation	3-4
Finish the N-turns at specified velocity and specified acceleration (pulley-board)	5
Create a closed loop controller (pulley-board)	6-7
Start collecting data parameters from the actual surgical robot.	8
Implementing the controller on the surgical robot.	9-10

Bibliography

Atef Saleh Othman Al Mashakbeh, “Proportional Integral and Derivative Control of Brushless DC Motor” European Journal of Scientific Research
ISSN 1450-216X Vol.35 No.2 (2009), pp.198-203
-Used the author’s method to model the BLDC motor.

Norman S. Nise, “Control Systems Engineering”, Wiley 2008
-The techniques for assessing controlability and observability were obtained from this book

Uy-Loi Ly, “DC Motor Control”, 2010, https://courses.washington.edu
/aa448/DCMotorControl_LabDescription.pdf
-Used to determine the simulink simulation.

“dcmodel”, 2010. https://courses.washington.edu/aa448/dcmodel.pdf
-Used to determine the State Space equation.

“Maxon EC Motor Data Sheet”, 2010. http://shop.maxonmotor.com/ishop
/article/article/118898.xml
- Used to get the model parameters