ME-180 HW8: Logbook for MyRIO Project

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1. Write down the Transfer function for the system.

Dynamic equation of the motor with the linkage on its shaft, and the linkage will only rotate horizontally:

$$I\ddot{\theta} = \tau - B\dot{\theta}$$

The transfer function is：

$$G_\tau(s) = \frac{\theta}{\tau} = \frac{1}{Is^2 + Bs}$$

Torque $\boldsymbol{\tau}$ is approximately proportional to the duty cycle $\boldsymbol{D}$:

$$\tau = AD$$

Where $A = 0.003865$ is calculated from the Motor's instruction menu.

So, the Transfer Function for the Duty cycle and position is:

$$G(s) = \frac{\theta}{D} = \frac{A}{Is^2 + Bs} = \frac{A/I}{s^2 + \frac{B}{I}s}$$

Inertia: The inertia is calculated by assume the mass of the linkage is evenly distributed in the entire linkage, and the inertia of the motor rotor could be neglected.

$$I = 1.9149 \times 10^{-5} kg \cdot m^2$$

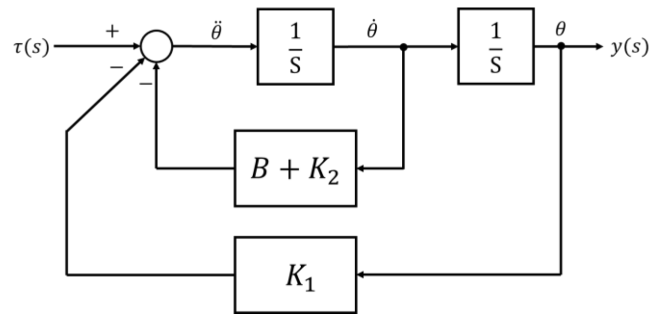
Damping: The Damping B is already calculated from previous logbook by the rising time of the velocity response of the motor, add a linkage do not affect the Damping, so the damping is:

$$B = 2.7945 \times 10^{-6}$$

Torque Duty cycle ration: calculated from the motor's instruction menu.

$$A = 0.003865$$

2. Design the feedback control for System



The block diagram of the motor linkage system is shown above:

Desired Characteristic polynomial is:

$$\phi(s) = s^2 + bs + k$$

$$K_1 = b - \frac{B}{I}\ ;\ \ K_2 = k$$

Sub VI for the system (without gravity compensation)

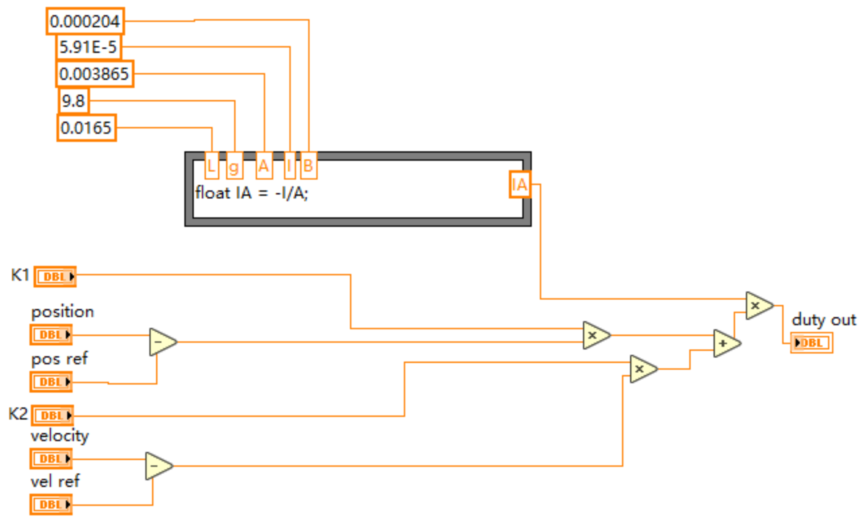


Fig. Controller SubVI

The reference velocity should be zero at any time since we are doing position control.

3. Design the Observer in State Space.

Phase variables of the system:

$$x_1 = \theta$$
$$x_2 = \dot{\theta}$$

Write out the state space representation of the system in phase variable canonical form:

$$\dot{\boldsymbol{x}} = \begin{bmatrix} 0 & 1 \\ 0 & -\frac{B}{I} \end{bmatrix} \boldsymbol{x} + \begin{bmatrix} 0 \\ A/I \end{bmatrix} \boldsymbol{u}$$

$$\boldsymbol{y} = [1 \quad 0]\boldsymbol{x}$$

Where

$$\boldsymbol{A} = \begin{bmatrix} 0 & 1 \\ 0 & -\frac{B}{I} \end{bmatrix}$$

$$\boldsymbol{C} = [1 \quad 0]$$

Get the characteristic equation of the system from the state space representation with observer gains:

$$\mathbf{det}(\lambda \boldsymbol{I} - \boldsymbol{A} + \boldsymbol{LC}) = \mathbf{det}\left(\begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ 0 & -\frac{B}{I} \end{bmatrix} + \begin{bmatrix} L_1 & 0 \\ L_2 & 0 \end{bmatrix}\right) = \mathbf{det}\left(\begin{bmatrix} \lambda + L_1 & -1 \\ L_2 & \lambda + \frac{B}{I} \end{bmatrix}\right)$$

$$\mathbf{det}(\lambda \boldsymbol{I} - \boldsymbol{A} + \boldsymbol{LC}) = \lambda^2 + \left(L_1 + \frac{B}{I}\right)\lambda + \left(\frac{B}{I}L_1 + L_2\right)$$

Desired Characteristic polynomial is:

$$\phi_{obs}(\lambda) = \lambda^2 + b_{obs}\lambda + k_{obs}$$

So:

$$L_1 = b_{obs} - \frac{B}{I}$$
$$L_2 = k_{obs} - \frac{B}{I}L_1 = k_{obs} - \frac{B}{I}\left(b_{obs} - \frac{B}{I}\right)$$

We can calculate the L_1, L_2 term inside the VI as shown below.

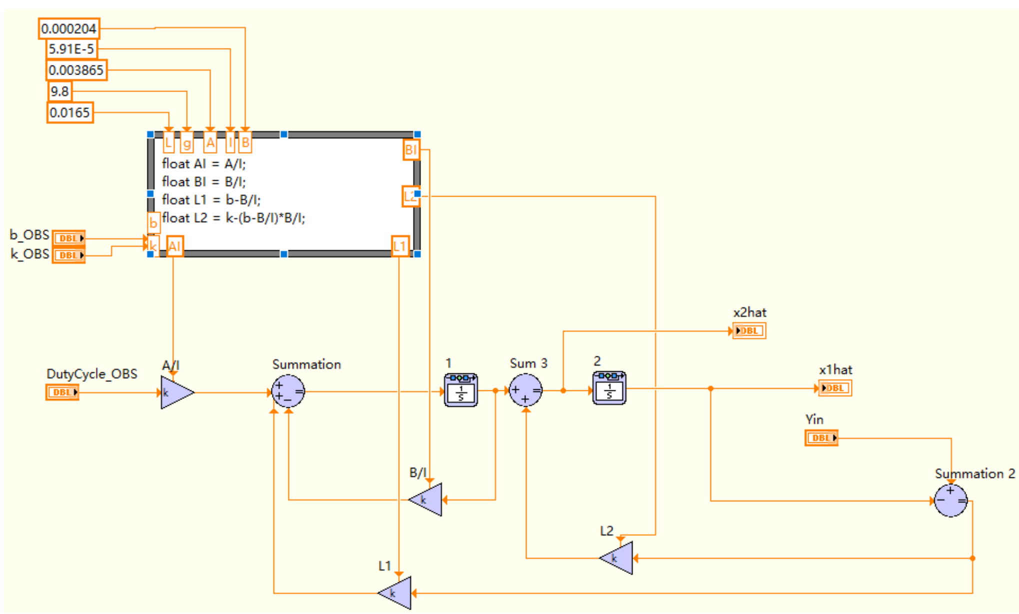


Fig.2 Observer SubVI

4. Use the Observer Control:

Using the estimated states variables $\hat{x}_1$ and $\hat{x}_2$, which represent the position and the velocity of the motor respectively, to accomplish the pole placement controller.

NOTE: <u>You must use a shift register</u> to do this, other wise VI will give you a feedback node which may affect the performance of the code

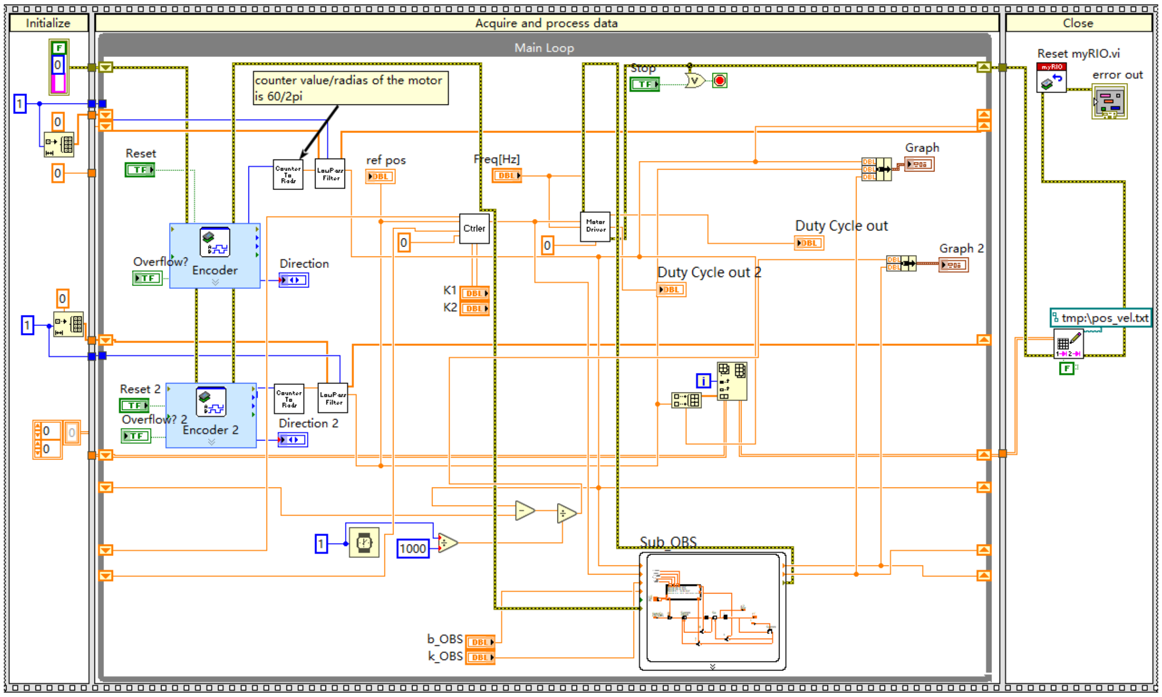


Fig.3 The whole system VI

4. Run the VI and compare the result:

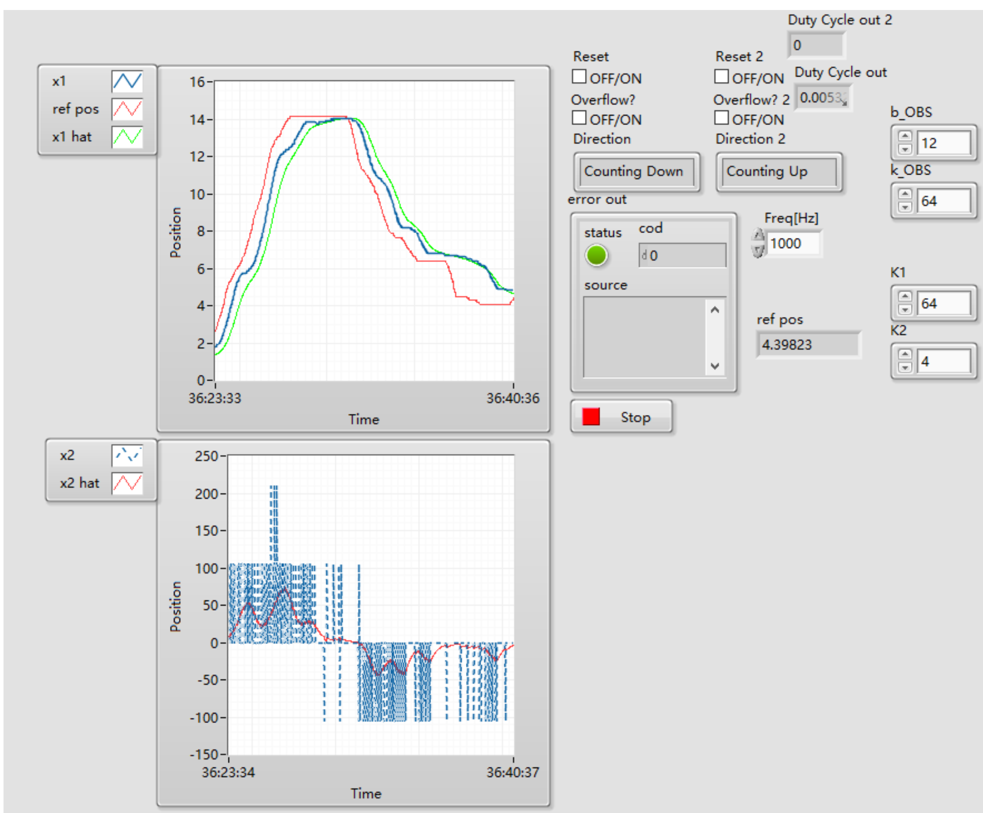


Fig.4 The Response of the system with turning the second motor.

Clearly, the observer gives us a smoother velocity reading curve and a reasonable position reading with a little lag according to the real position of the motor. The control performance is significantly improved after using the observer to estimate the velocity other than take the derivative of the position dat