Lab 1 Robot Control
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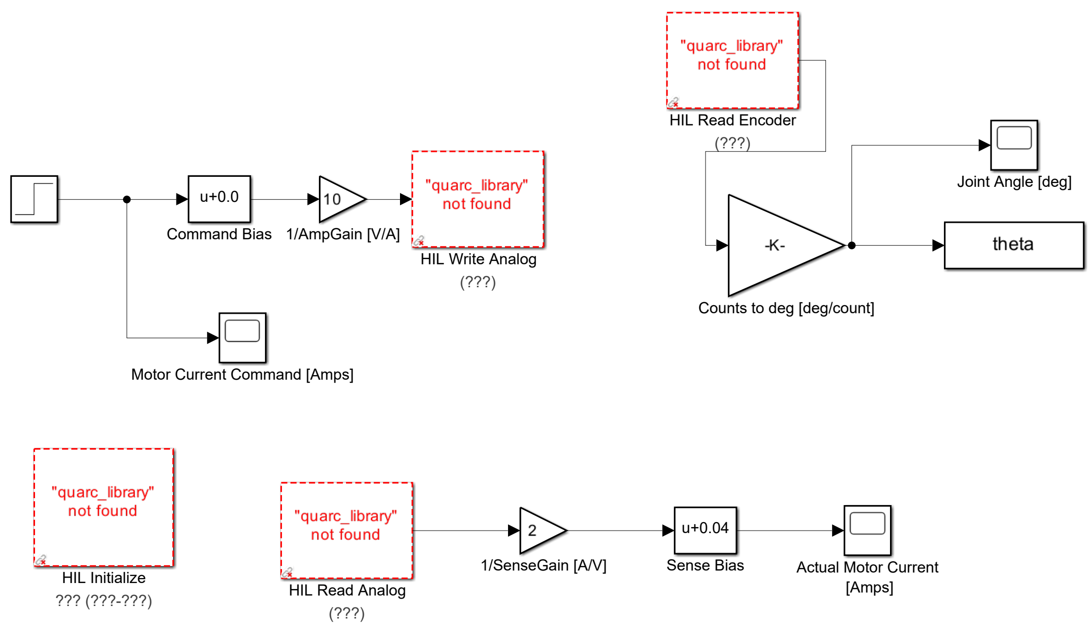
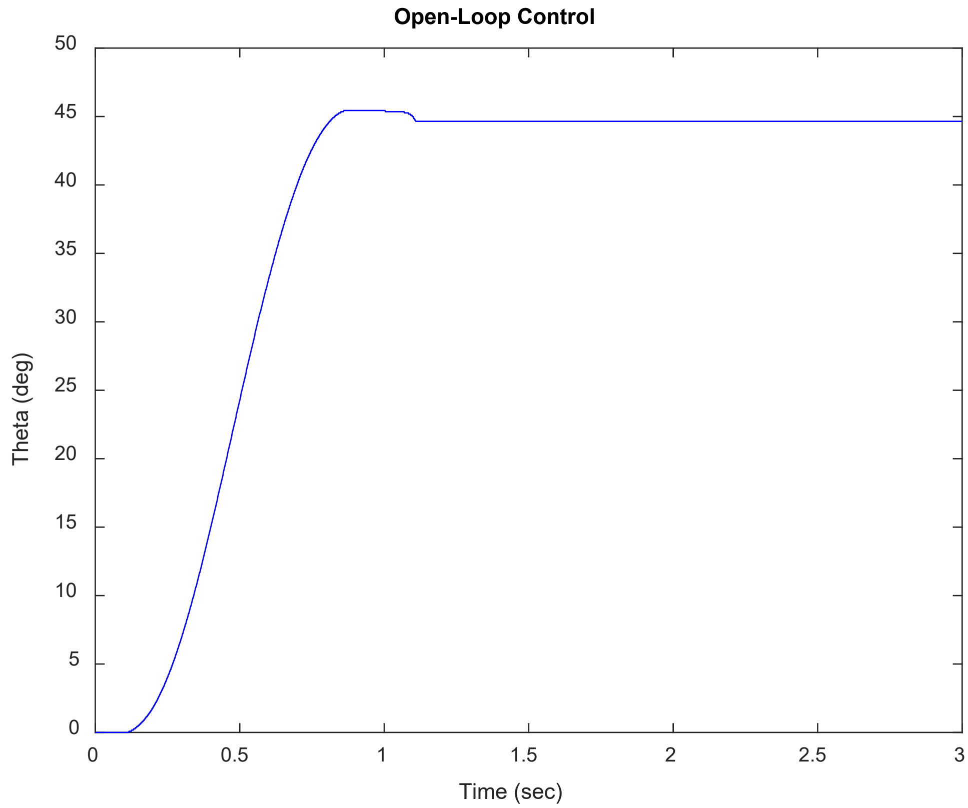
Note: I had to take screenshots outside of lab, and I don't' have access to the Quanser quarc_library license. The titles are easy to read, so the thing still makes sense.

1. **Open-Loop Control:** Following the procedure in the QUARC tutorial, set up a Simulink model to measure the open-loop step response of the SRV02. Use this to test the functionality of your analog output and counter inputs. Use the correct gain to convert the encoder counts to degrees. The encoders have 1024 counts per revolution, and the decoders have a 4x multiplication factor. Rotate the link 360 degrees with your hand and verify that you used the correct magnitude of encoder gain. Also verify that a positive step in motor voltage results in a positive step in encoder angle. Show a plot of the open-loop step response.

Simulink Model:



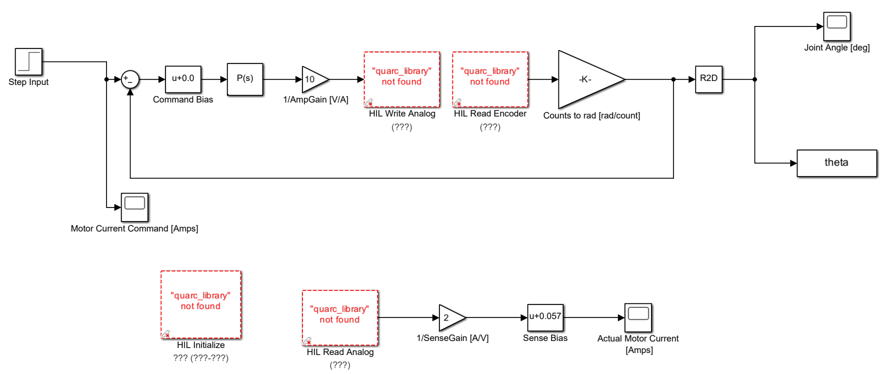
Open Loop Step Response



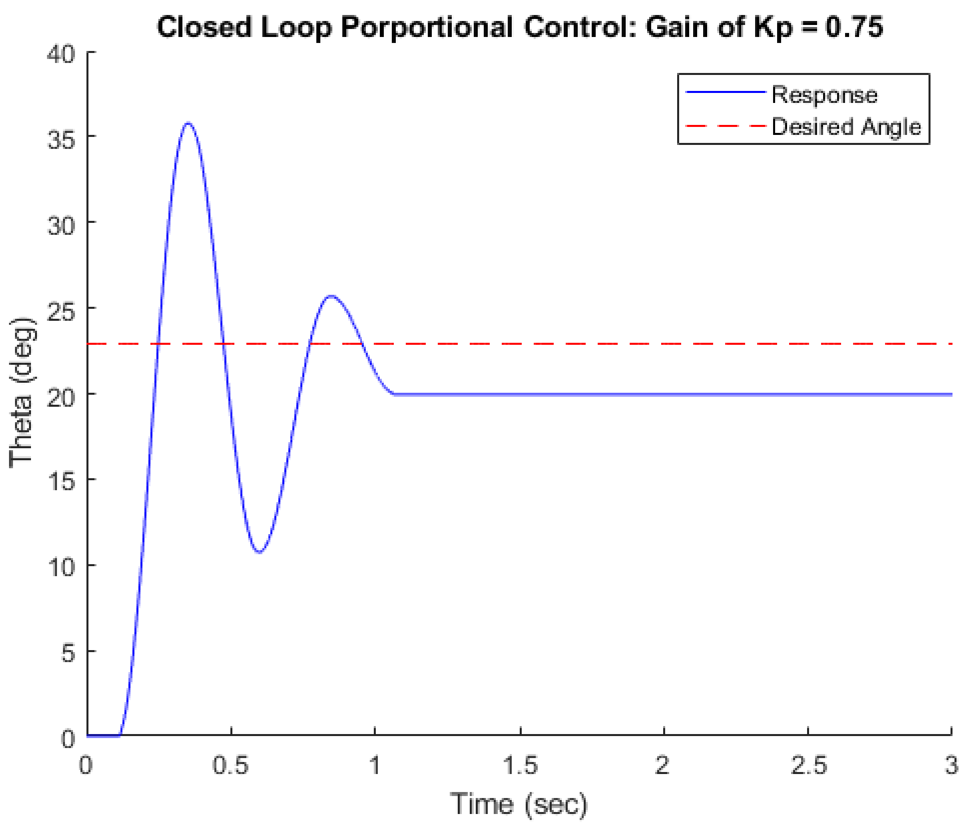
- Encoder counts were verified to be positive in the step response direction. If they weren't the following questions wouldn't have worked

2. **Proportional Control:** Set up a feedback loop in your Simulink model to implement closed-loop proportional control. Start out with a low gain and feel the virtual stiffness of the link as you increase the gain. Provide plots of the step response at a couple different levels of gain. What gain would you choose to optimize the response? What is the settling time and % overshoot at this gain?

Simulink Model

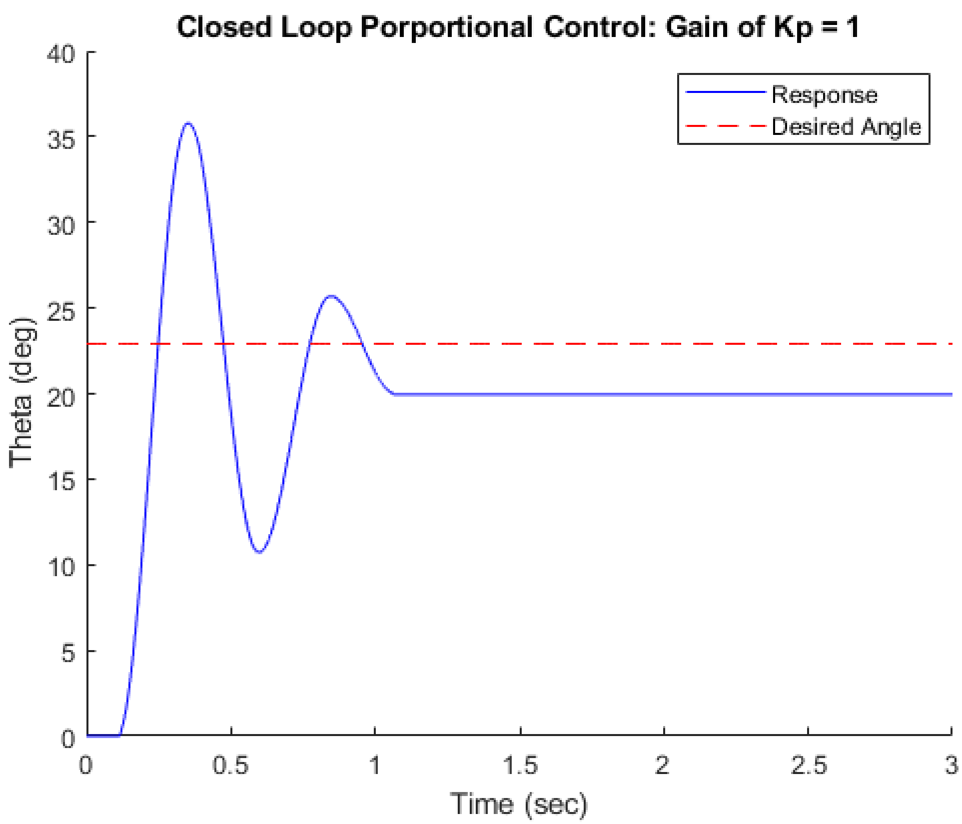


P = 0.75 Plots and Step Response Info



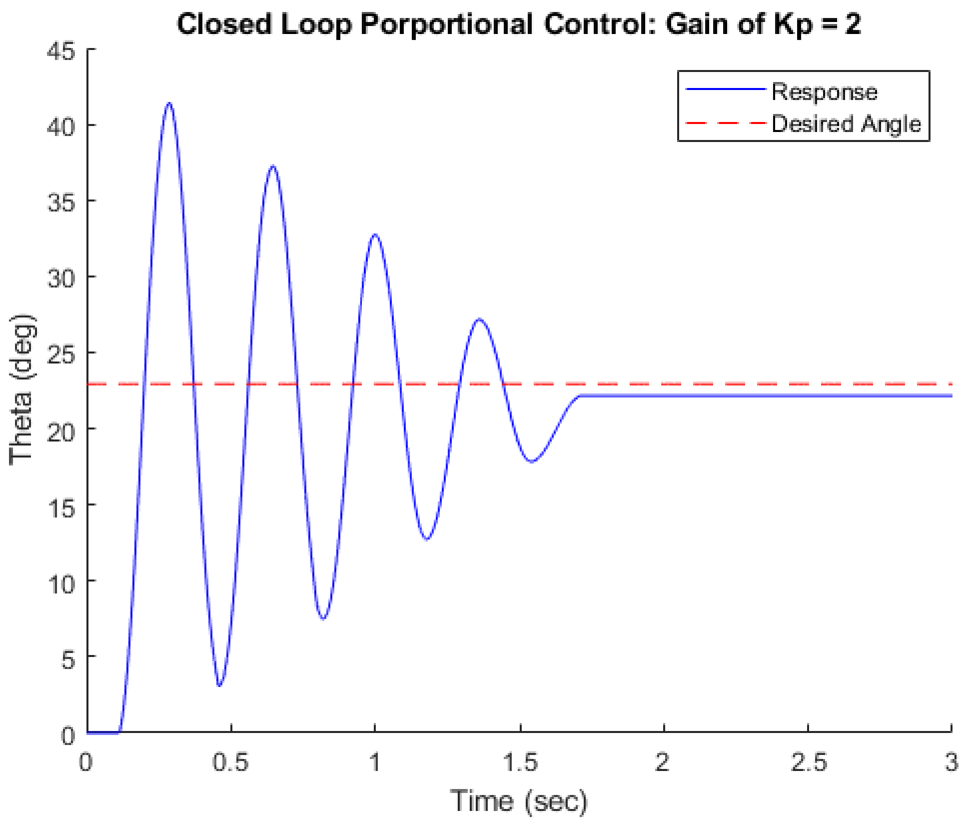
```
     RiseTime: 0.1041
TransientTime: 0.8946
 SettlingTime: 0.8946
  SettlingMin: 12.9199
  SettlingMax: 31.2891
    Overshoot: 62.5571
   Undershoot: 0
         Peak: 31.2891
     PeakTime: 0.3820
```

P = 1 Plots and Step Response Info




```
     RiseTime: 0.0854
TransientTime: 1.0355
 SettlingTime: 1.0355
  SettlingMin: 10.7227
  SettlingMax: 35.7715
    Overshoot: 79.2952
   Undershoot: 0
         Peak: 35.7715
     PeakTime: 0.3450
```

<u>P = 2 Plots and Step Response Info</u>

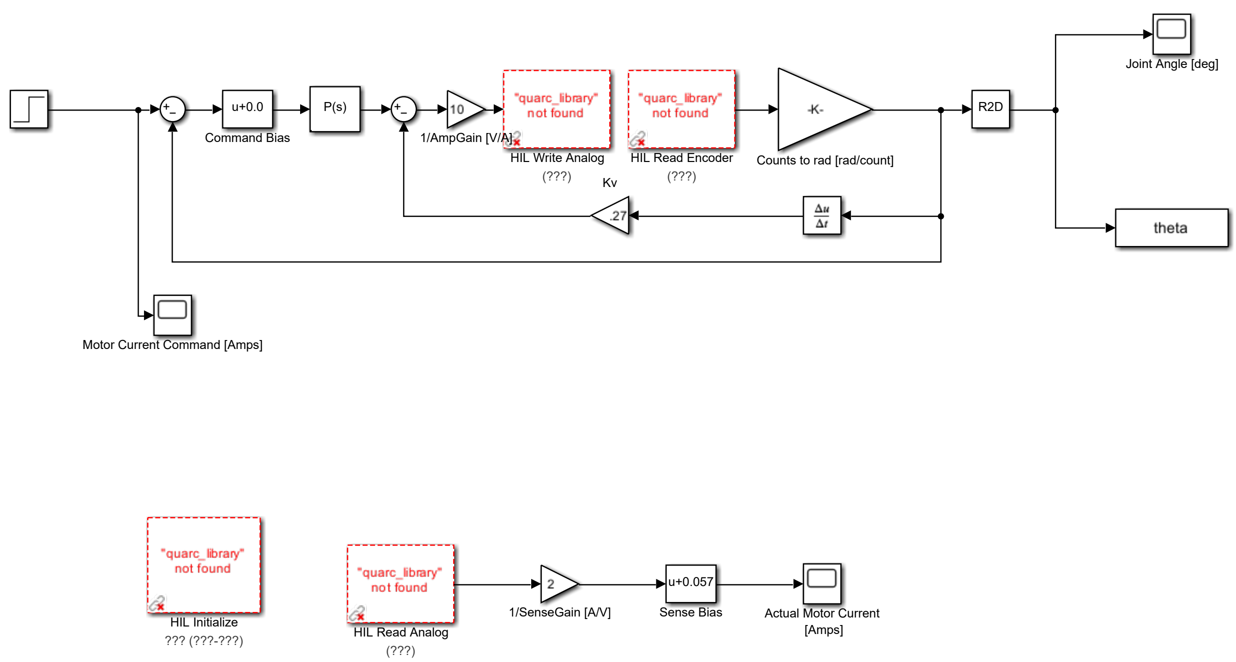



```
       RiseTime: 0.0604
  TransientTime: 1.6790
   SettlingTime: 1.6790
    SettlingMin: 3.0762
    SettlingMax: 41.3965
      Overshoot: 86.9048
     Undershoot: 0
           Peak: 41.3965
       PeakTime: 0.2850
```

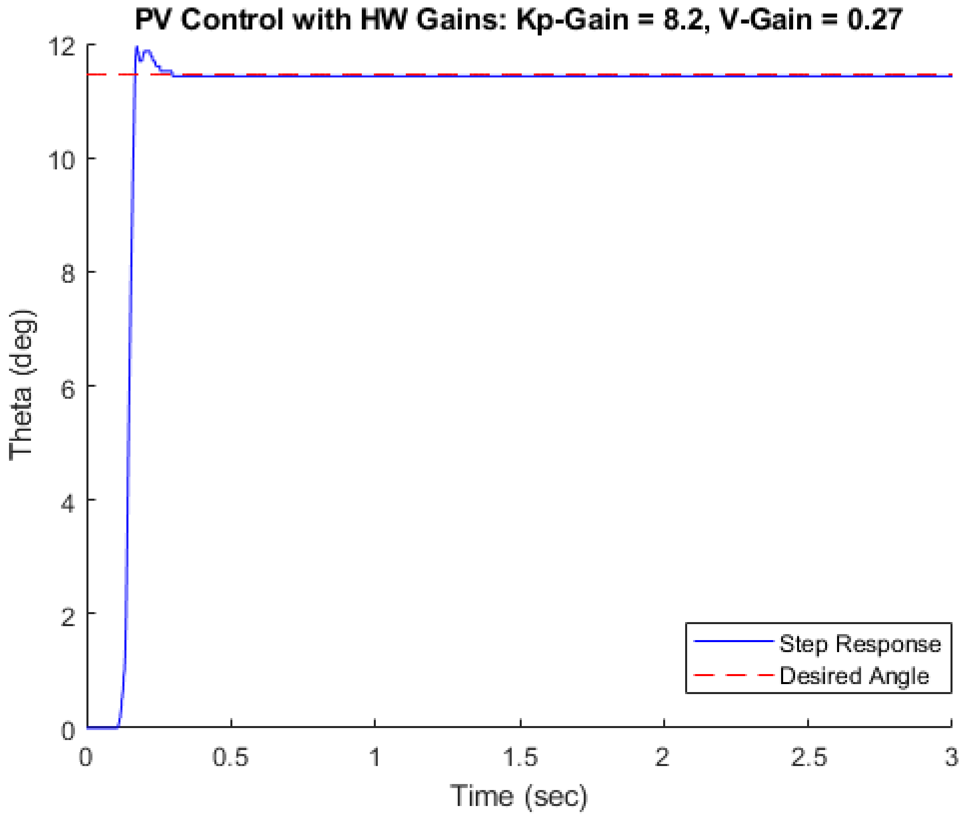
- What would I choose to optimize the response?
  - I'd choose the Kp = 0.75 response, as it does the best job of balancing a relatively low oscillation response with a low steady state error. If settling time is our main concern, then I'd choose Kp = 0.75. If steady state error is our primary concern then I'd choose a higher Kp.
  - Steady state error and step response is shown below each plot.

3. **PV Control:** Add velocity feedback to your proportional control. First set the proportional gain very low and turn up the velocity gain to feel the virtual damping effect. Now turn up both the P and V gains together to see how fast you can make the settling time while maintaining a reasonable amount of overshoot. If you increase them too much, the system will eventually become unstable. As you increase the gains, you may also need to decrease the magnitude of your step in order to avoid saturating the amp. Find a favorable set of gains and provide a plot of the step response. What is the smallest settling time you can achieve without risking instability? Try the set of PV gains you designed in PS#4 and compare the performance of your experimental response to your simulated response. Note: be mindful of your units when trying your gains from PS#4 (e.g. you may need to convert between A/radian and A/degree).

<u>Simulink Model</u>

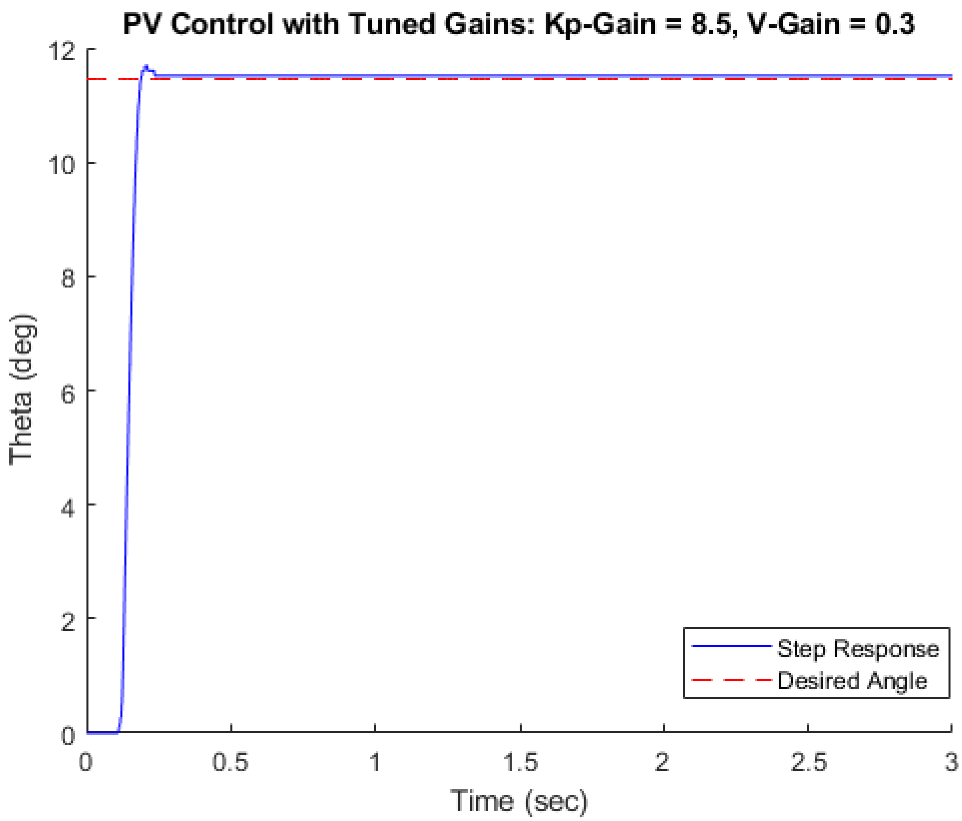


PV Control with HW Gains Kp = 8.2 V = 0.27




```
       RiseTime: 0.0303
  TransientTime: 0.2384
   SettlingTime: 0.2384
    SettlingMin: 10.4590
    SettlingMax: 11.9531
      Overshoot: 4.6154
     Undershoot: 0
           Peak: 11.9531
       PeakTime: 0.1730
```

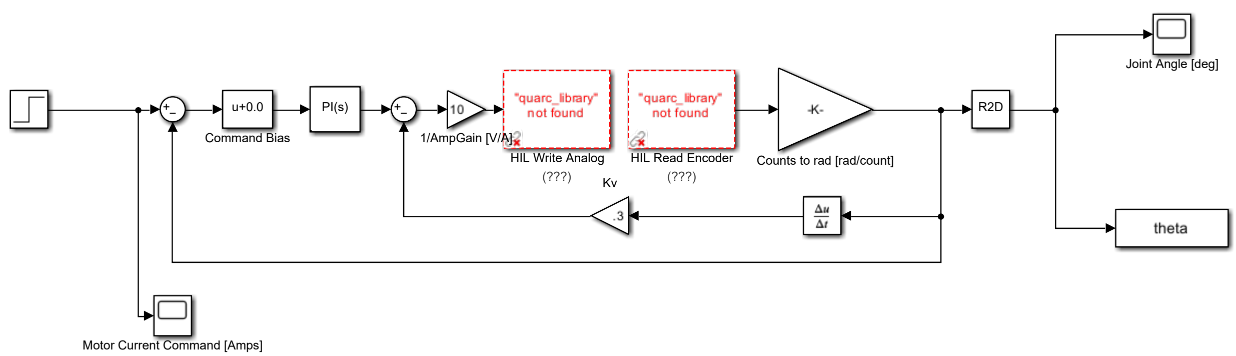
PV Control with Tuned Gains Kp = 8.5 V = 0.3

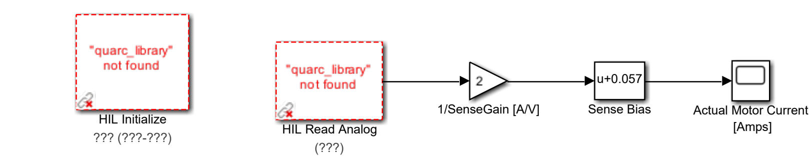



```
    RiseTime: 0.0469
TransientTime: 0.1854
SettlingTime: 0.1854
 SettlingMin: 10.3711
 SettlingMax: 11.6895
   Overshoot: 1.5267
  Undershoot: 0
        Peak: 11.6895
    PeakTime: 0.2020
```

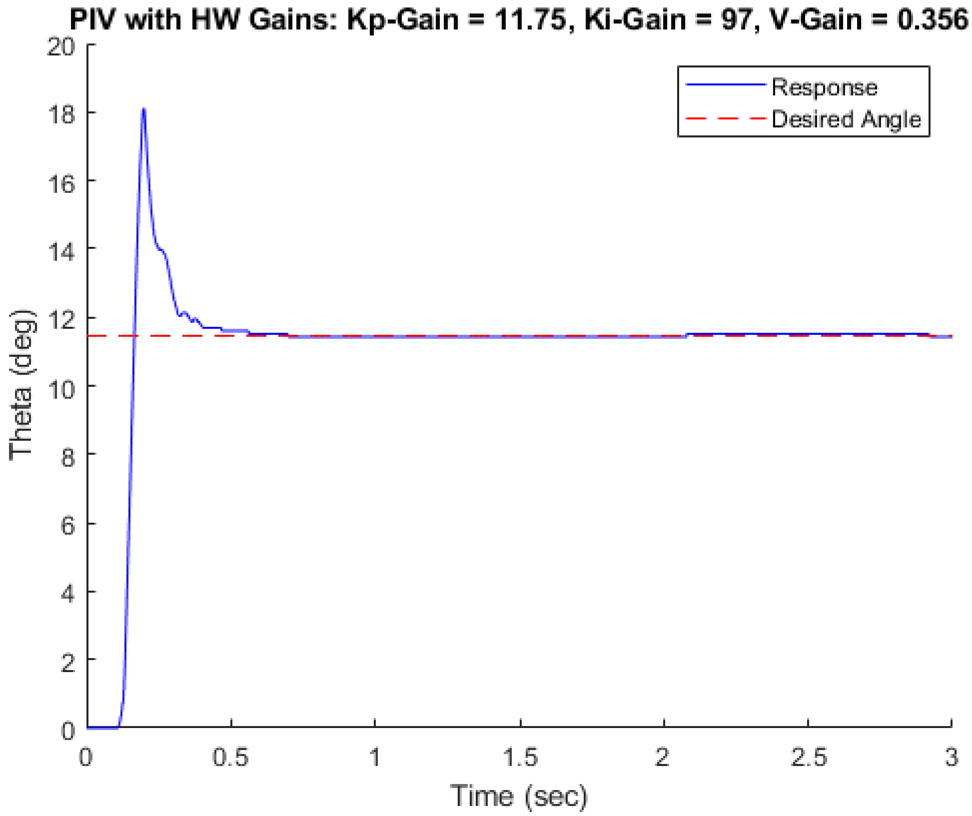
4. **PIV Control:** Now add integral control. Start with a low set of PV gains (such the step response exhibits significant steady-state error). Then turn on the integral control, beginning with a very small integral gain. Note how the steady-state error goes away faster as you continue to increase the integral gain. Also, use your hand to apply disturbance forces to the link, and notice how the disturbance rejection is improved as the integral gain is increased. Provide plots of the step response at a couple different levels of integral gain. Try the set of PIV gains you designed in PS#4 and compare the performance of your experimental response to your simulated response. Note: be mindful of your units when trying your gains from PS#4 (e.g. you may need to convert between A/radian and A/degree).

Simulink Model



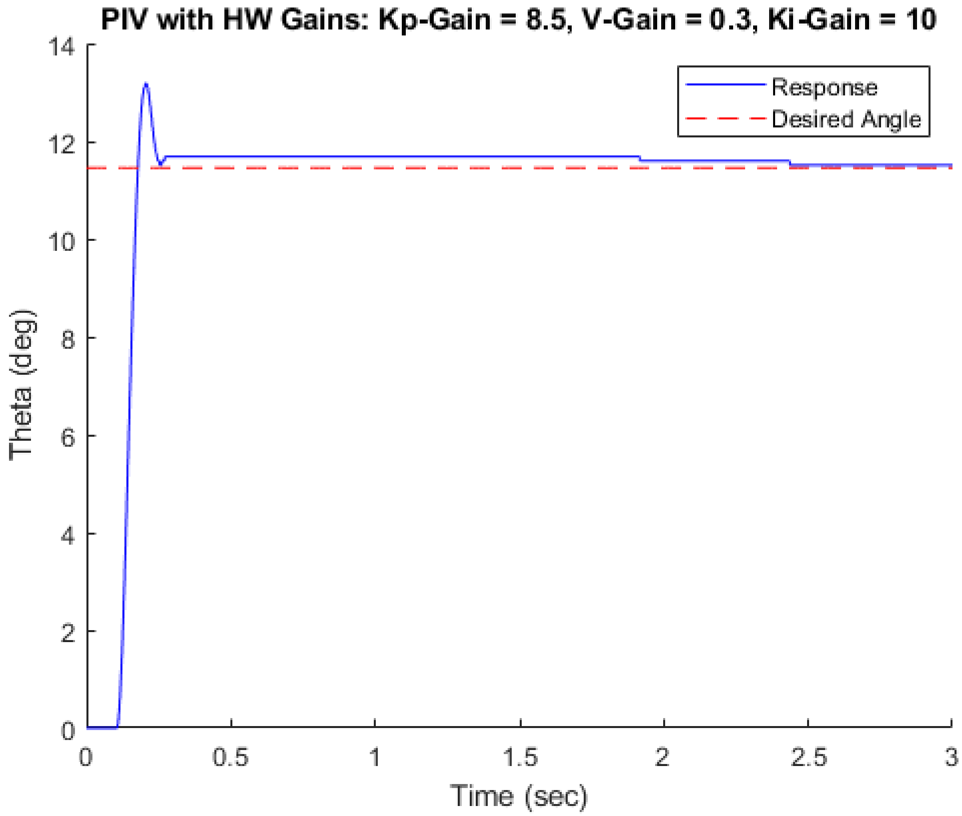


PIV Control HW Gains Kp = 11.75, Ki = 97, V = 0.356



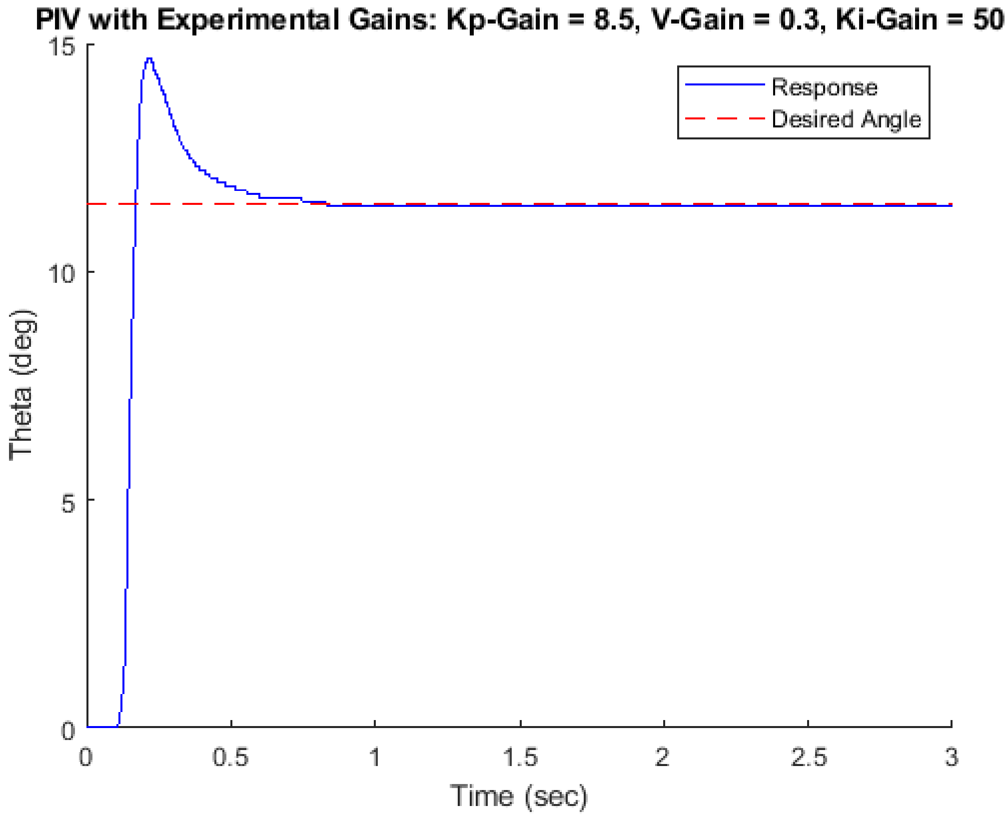

```
     RiseTime: 0.0318
TransientTime: 0.4664
 SettlingTime: 0.4664
  SettlingMin: 10.3711
  SettlingMax: 18.1055
    Overshoot: 58.4615
   Undershoot: 0
         Peak: 18.1055
     PeakTime: 0.1960
```

Experimental Gains Kp = 8.5 Kv = 0.3 Ki = 10



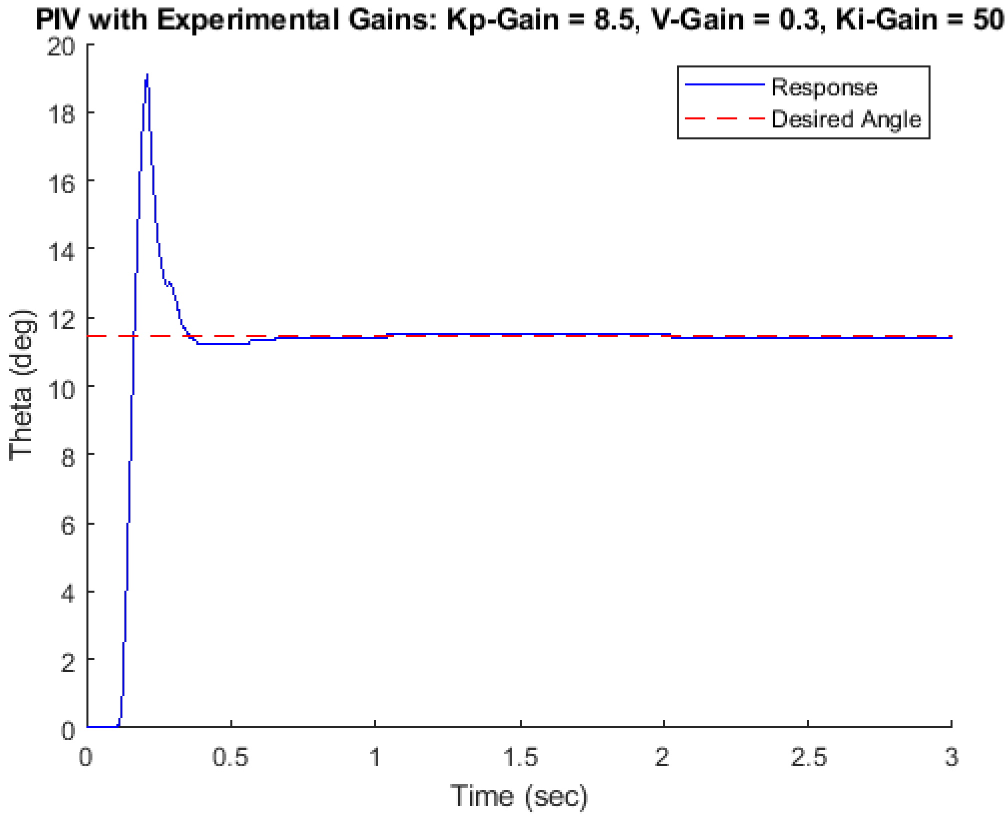

```
    RiseTime: 0.0504
TransientTime: 0.2424
 SettlingTime: 0.2424
  SettlingMin: 10.4590
  SettlingMax: 13.1836
    Overshoot: 14.5038
   Undershoot: 0
         Peak: 13.1836
     PeakTime: 0.2030
```

Experimental Gains Kp = 8.5 Kv = 0.3 Ki = 50




```
   RiseTime: 0.0347
TransientTime: 0.5984
 SettlingTime: 0.5984
  SettlingMin: 10.3711
  SettlingMax: 14.6777
    Overshoot: 28.4615
   Undershoot: 0
         Peak: 14.6777
     PeakTime: 0.2110
```

Experimental Gains Kp = 8.5 Kv = 0.3 Ki = 100




```
     RiseTime: 0.0357
TransientTime: 0.3434
 SettlingTime: 0.3434
  SettlingMin: 10.5469
  SettlingMax: 19.0723
    Overshoot: 66.9231
   Undershoot: 0
         Peak: 19.0723
     PeakTime: 0.2090
```

- Comparing
  - Clearly, the homework gains were by far better than the experimental gains we used. The higher our integral gain the higher our settling time and overshoot became, but we also achieved lower steady state errors. Interestingly our settling min didn't seem to be affected much by higher or lower integral gains. That said, the overshoot was very different.