Selective Laser Sintering 3D Printer

ELEC 341 Project 2017 - Part 2

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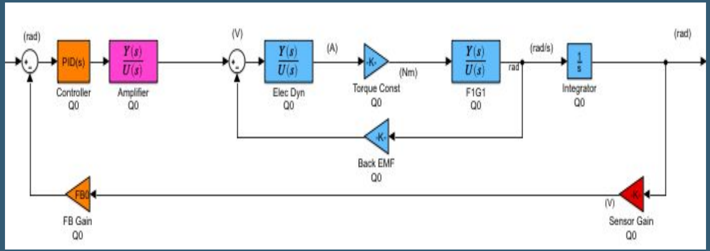
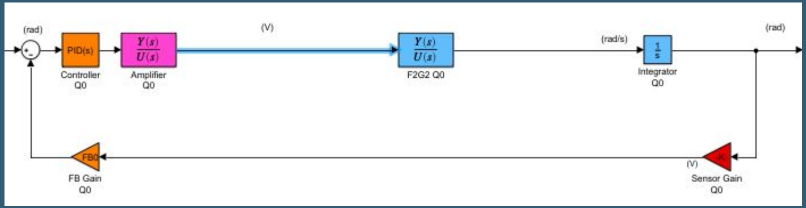
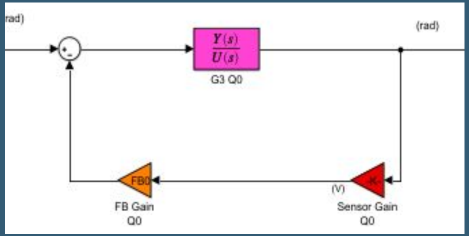
Q0 Open-Loop Gain







$$F2G2 = \frac{ED0 * \tau_{const0} * MD0}{1 + ED0 * \tau_{const0} * MD0 * BackEMF0}$$

$$A_{OL} = \mathrm{GH0} = \frac{Amp0 * F2G2}{s}$$

$$\boxed{GH0 = \frac{1.2815 \times 10^8}{(s + 1.523 \times 10^4)(s + 49.17)(s^2 + 1.95s + 96.77)}}$$

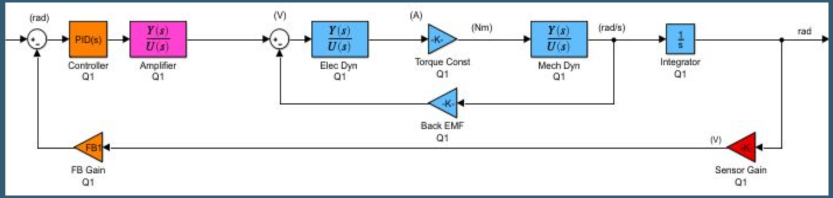
Q1 Open-Loop Gain

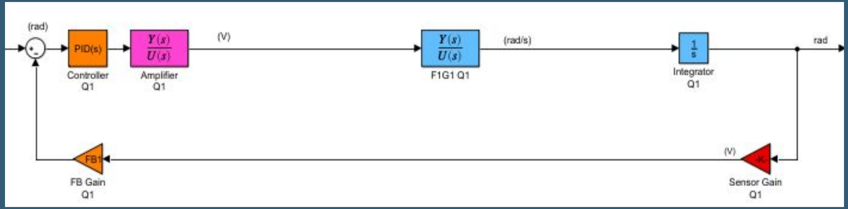
$$G1 = ED1 * \tau_{const1} * MD1$$

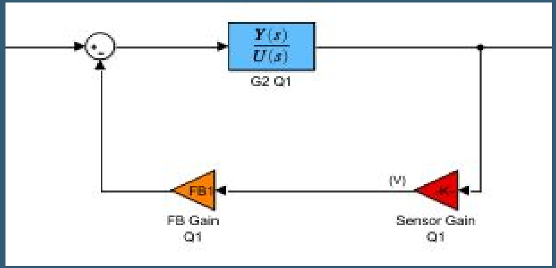
$$F1G1 = \frac{G1}{1 + BackEMF1 * G1}$$

$$A_{OL} = GH1 = \frac{Amp1 * F1G1}{s}$$

$$GH1 = \frac{1.4146 \times 10^{10}}{s(s + 4.045 \times 10^4)(s + 50.6)(s + 49.17)}$$







Closed-Loop Gains

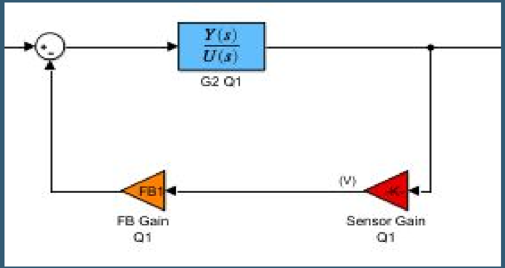
For an ideal system, the feedback gain would be unity. This can be achieved by making

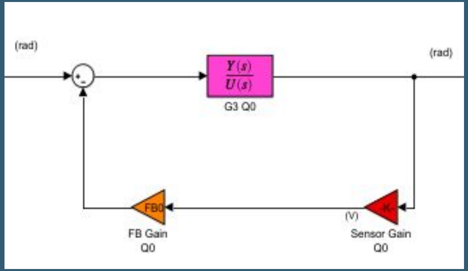
$$FB = \frac{1}{Sensor\ Gain}$$

∴ The closed-loop gains for the joints are:

$$A_{CL0} = \frac{GH0}{1 + GH0}$$

$$A_{CL1} = \frac{GH1}{1 + GH1}$$

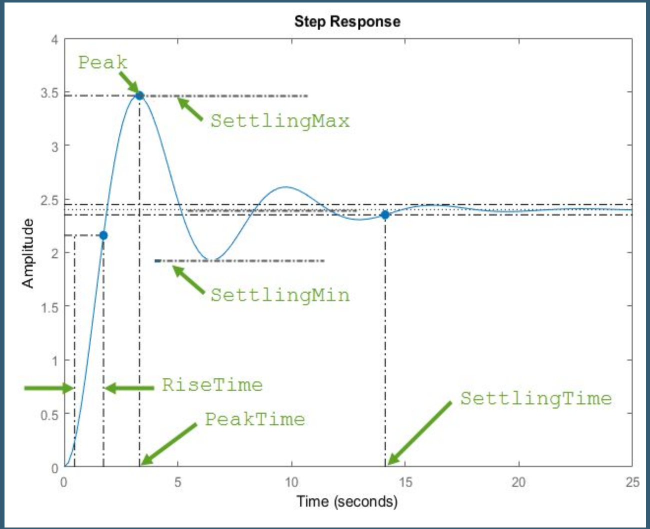


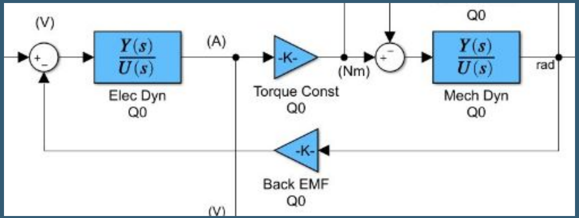


Choosing the Motors

- The 25 combinations of motors were compared using performance measures.
- Used disp(stepinfo($T(s)$)) to get the step information
- Optimized for lowest settle time while having a low peak value
  → motors that stabilize quickly

Q0 = AMAX22_6W_SB
Q1 = AMAX12_p75W_SB





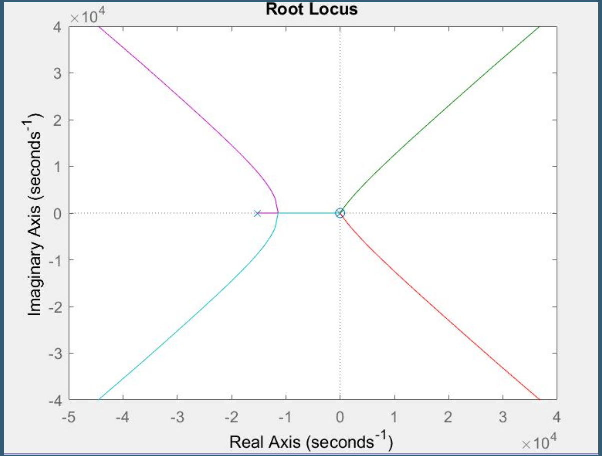
$$G(s) = Elec\ Dyn\ \times Torque\ Const\ \times Mech\ Dyn$$

$$H(s) = Back\ EMF$$

$$T(s) = \frac{G(s)}{1 + H(s)G(s)}$$

Joint Q0 PID

$$GH0 = \frac{1.2815 \times 10^8}{(s + 1.523 \times 10^4)(s + 49.17)(s^2 + 1.95s + 96.77)}$$



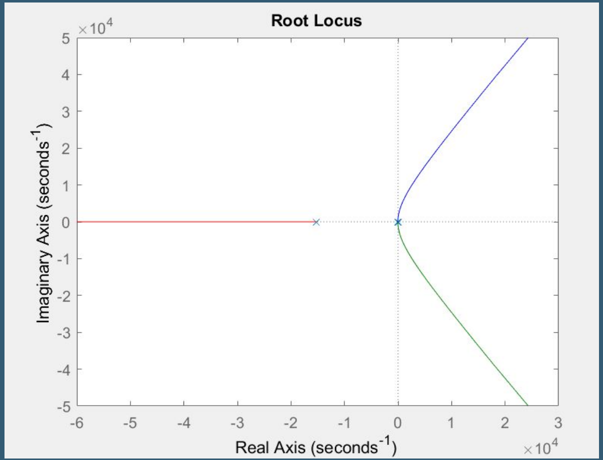
Root locus of open loop gain

Use PID method to remove the complex pole pair

Set $\frac{K_d\left(s^2 + \frac{K+p}{K_d}s + \frac{K_i}{K_d}\right)}{s}$ = $(s^2 + 1.95s + 96.77)$

So $K_p = 1.95K$ $K_i = 96.77K$ $K_d = 1K$ (K=gain)

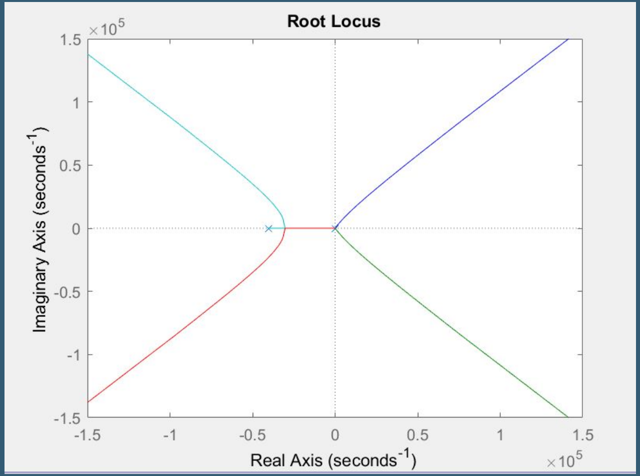
$$GH0_{PID} = \frac{1.2815 \times 10^8}{s(s + 1.523 \times 10^4)(s + 49.17)}$$



Root locus of open loop gain stabilized by PID

Joint Q1 PID

$$GH1 = \frac{1.4146 \times 10^{10}}{s(s+4.045 \times 10^4)(s+50.6)(s+49.17)}$$



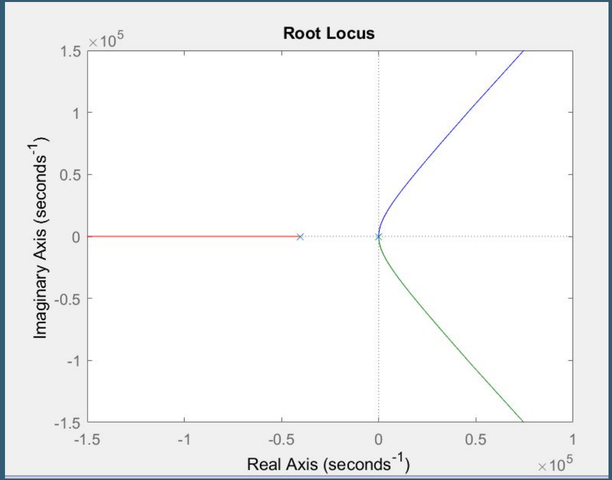
Root locus of open loop gain

Use PID method to remove the pole closest to the RH plane

Set $\frac{K_d\left(s^2 + \frac{K+p}{K_d}s + \frac{K_i}{K_d}\right)}{s}$ = $s(s+49.17)$

So $K_p = 49.17K$ $K_i = 0K$ $K_d = 1K$ (K=gain)

$$GH1_{PID} = \frac{1.4146 \times 10^{10}}{s(s+4.045 \times 10^4)(s+50.6)}$$



Root locus of open loop gain stabilized by PID

Tuning methods

- Expressions for each of the PID constants are created in terms of the values from the PID simplification along with the starting gains (K)
- Each constant is multiplied by a scaling factor, which are then adjusted to alter the performance of the system

    Ex: Kd0 = SFD0(Ku0), where SFD0 is the scale factor for Kd0 and Ku0 is the starting K for joint Q0*

- The table below was used as a guide to changing the scaling factors

Parameter Increase	Rise time	Overshoot	Settling Time	Steady-state error
Kp	↓	↑	Small Change	↓
Ki	↓	↑	↑	Great reduce
Kd	Small Change	↓	↓	Small Change

Example: initially, with all the scale factors at 1, the plot would not reach its desired magnitude. So Kp was increased to increase overshoot.

Starting K value

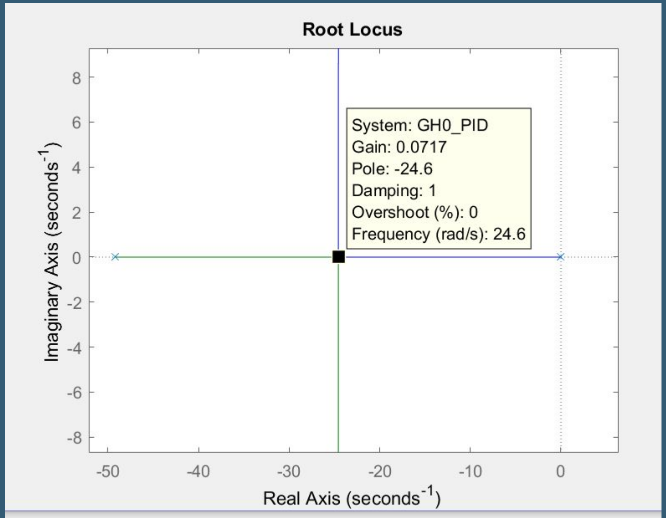
- Chose gain values that corresponding to the break-away points

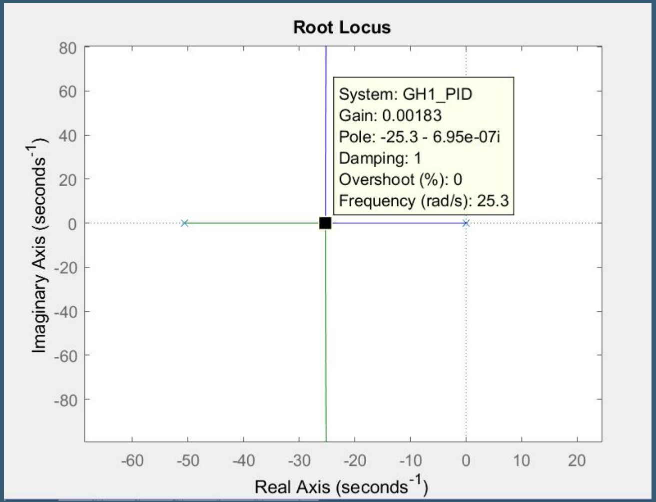
- These values of K ensure that the system is stable

- These K values cause the right-most pole the of the system the farthest away from the imaginary axis

Q0: K = 0.0717

Q1: K = 0.00183





PID Tuning and Value Comparison

- Once the system response and error are decreased to a reasonable point, the numeric values of the PID matrices are extracted.
- Then, the numbers are changed individually to fine tune controllers.
- The values are rounded to 3 significant figures.

```
% PID0
Kp0 = 0.108;
Ki0 = 9.115;
Kd0 = 0.0987;

% PID1
Kp1 = 0.126;
Ki1 = 0;
Kd1 = 0.002;
```

0.68954
9.6796
0.01228

The PID values for motor Q0 are relatively close to those generated by the tuner.

0.35735
1.6745
0.014846

The tuned values and the values determined manually are not very close.