Control of a DC Servo Motor

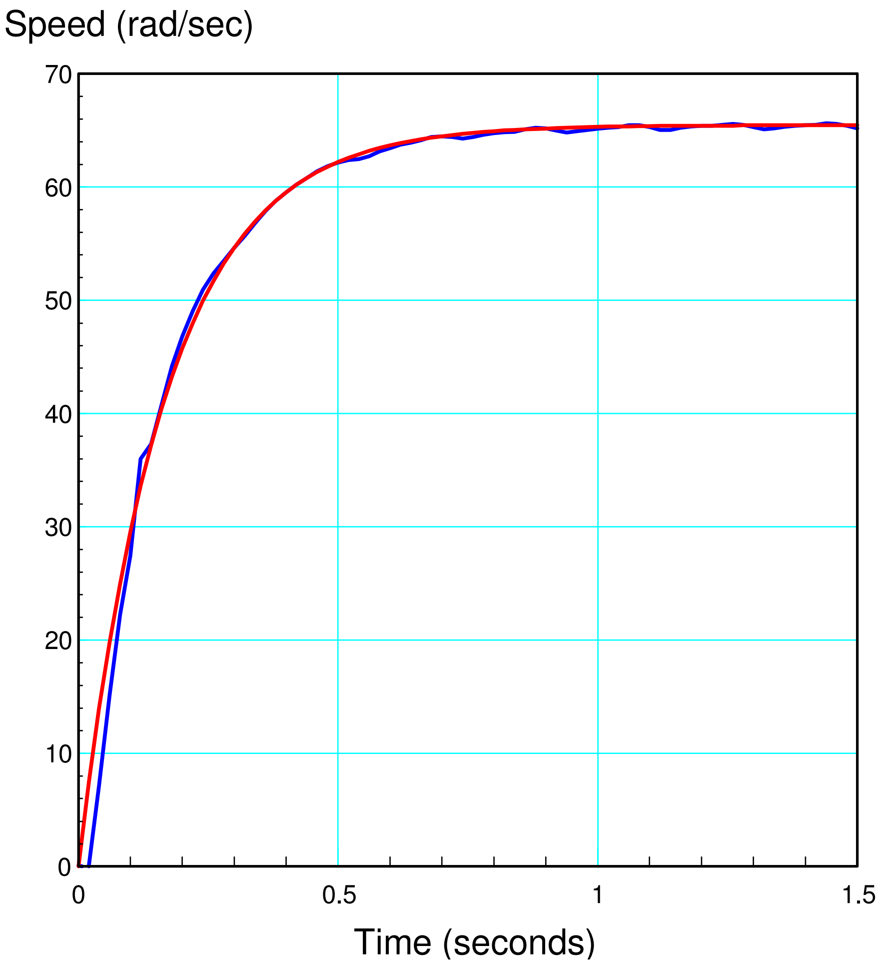
ECE 461/661 Controls Systems

Jake Glower - Lecture #25

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

Problem:

- Control the speed of a DC servo motor
- Control the position of a DC servo motor



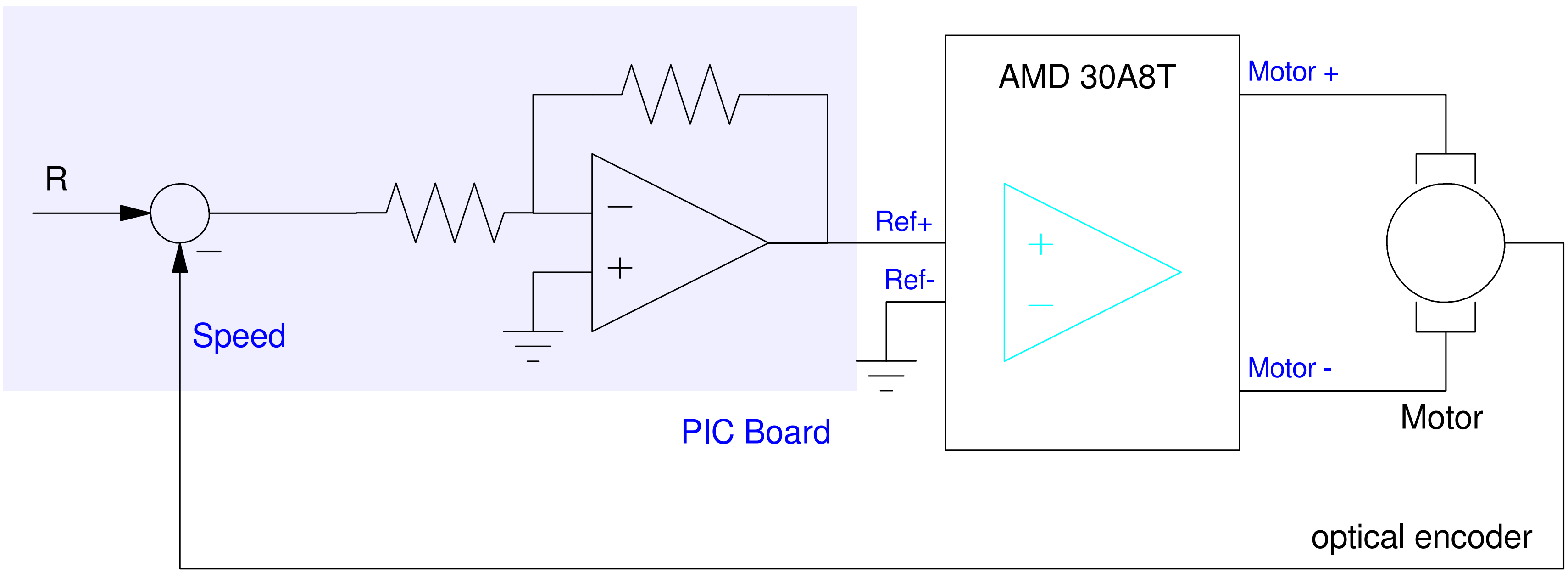
The mathematical model from before:

- Clifton 000-053479-002

$$\omega \approx \left(\frac{39.28}{s+6}\right) V_a$$

$$\theta \approx \left(\frac{39.28}{s(s+6)}\right) V_a$$

Hardware Setup

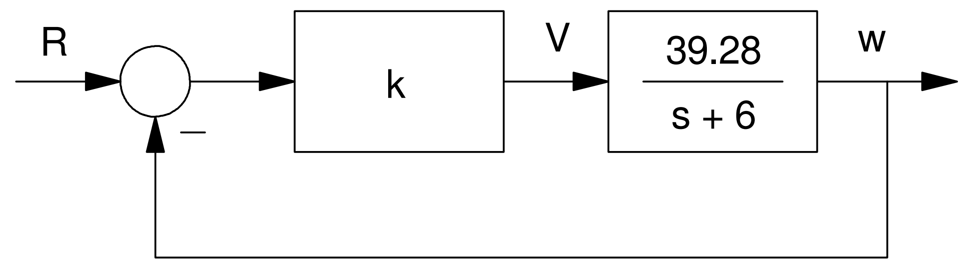


Speed Control: Gain Compensation

$$G(s) = \left(\frac{39.28}{s+6}\right)$$

$$K(s) = k$$

$$GK = \left(\frac{39.28k}{s+6}\right)$$



Type-0 Systems

- Kp = 6.547 k
- Steady-State Error for a Step Input

Predicted Response

$$(GK)_s = -1$$

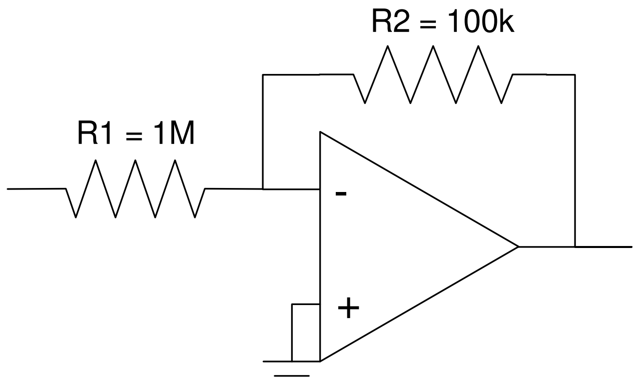
s = -10

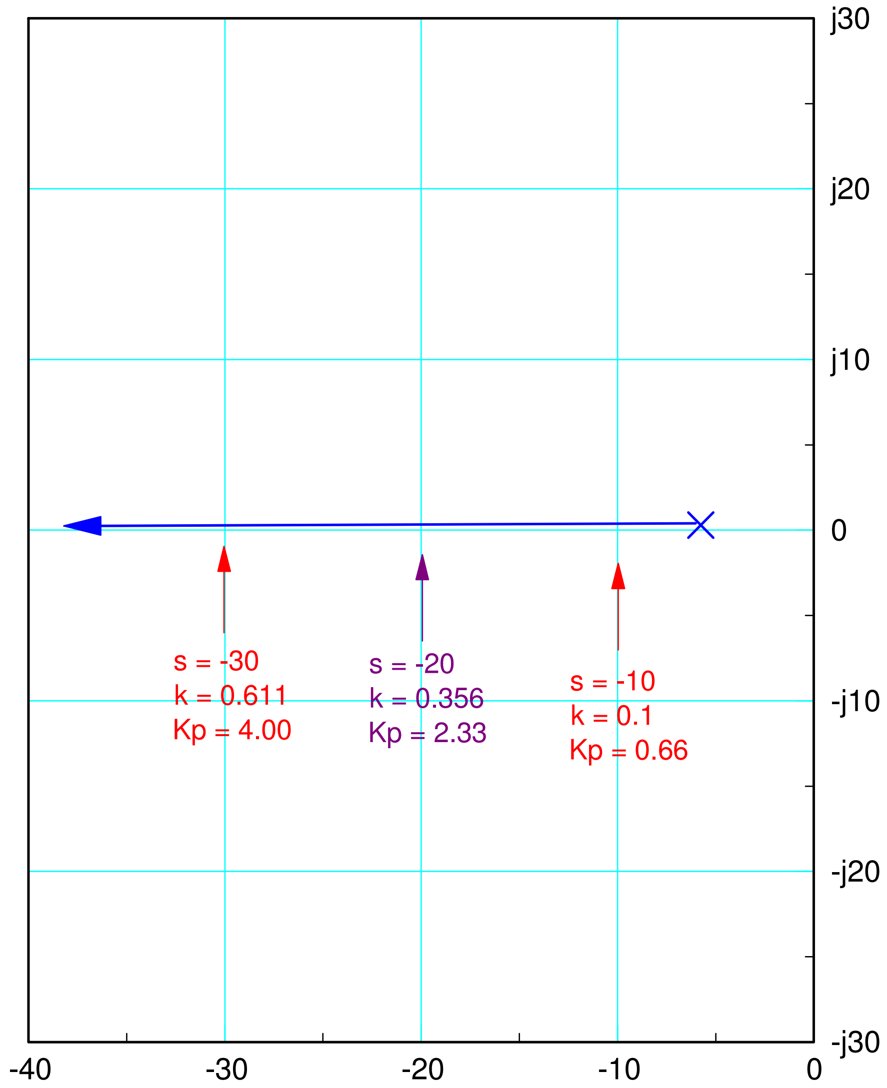
$$\left(\frac{39.28k}{s+6}\right)_{s=-10} = -1$$

$$k = 0.1$$

$$K_p = (GK)_{s=0} = 0.66$$

$$E_{step} = \frac{1}{K_p+1} = 0.602$$





Experimental Results:

s = -10

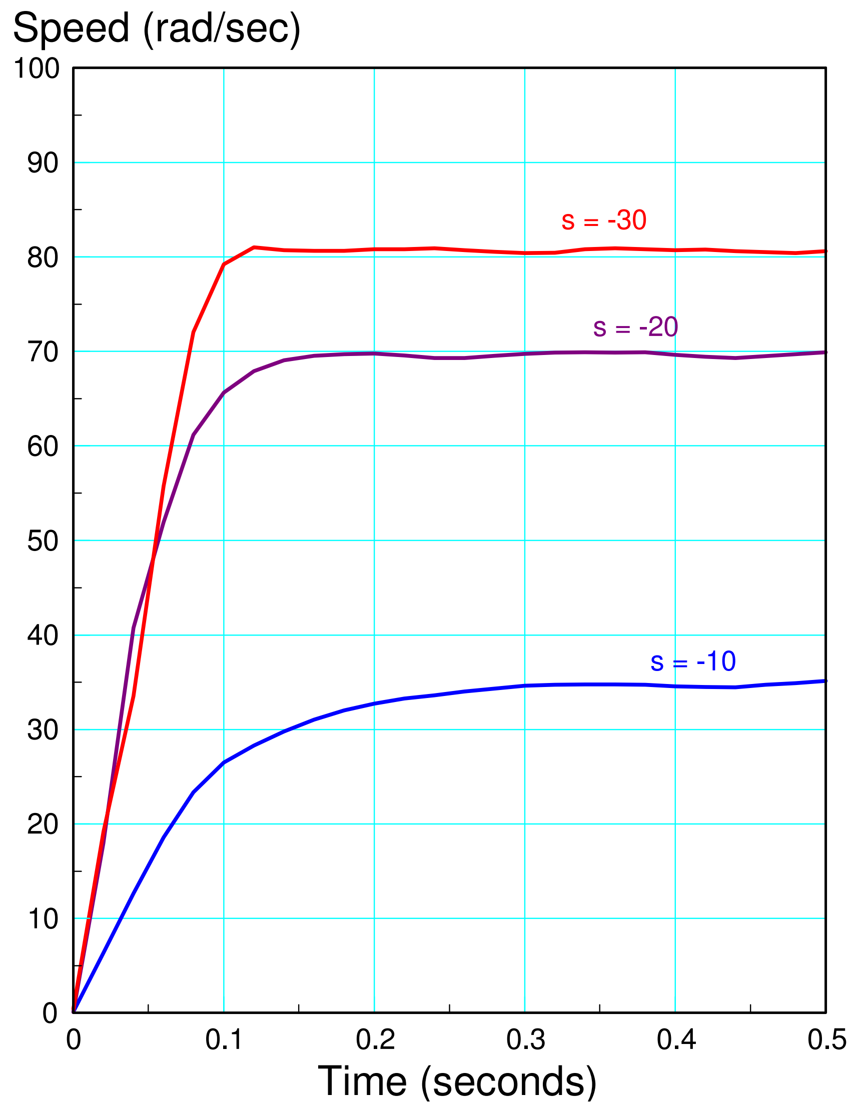
- k = 0.1
- R2 = 100k

s = -20

- k = 0.356
- R2 = 356k

s = -30

- k = 0.611
- R2 = 611k

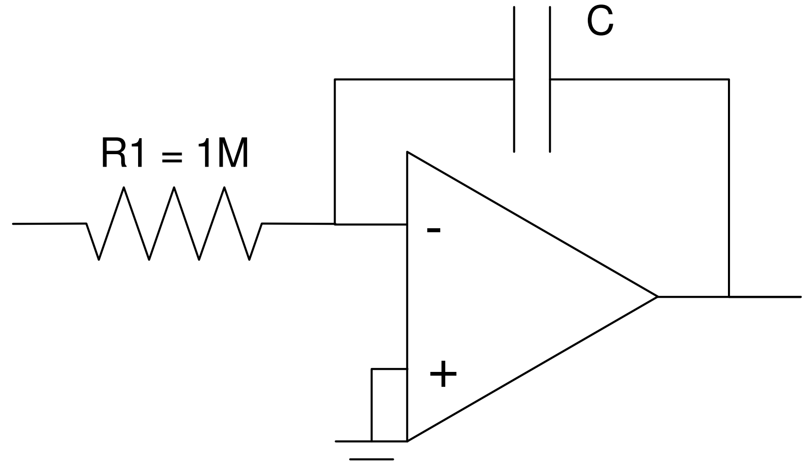


Speed Control: I Compensation

$$K(s) = \left(\frac{k}{s}\right)$$

$$k = \left(\frac{1}{R_1 C}\right)$$

$$GK = \left(\frac{39.68k}{s(s+6)}\right)$$



Type-1 System

- No Error for a Step Input

I Compensation

s = -0.5

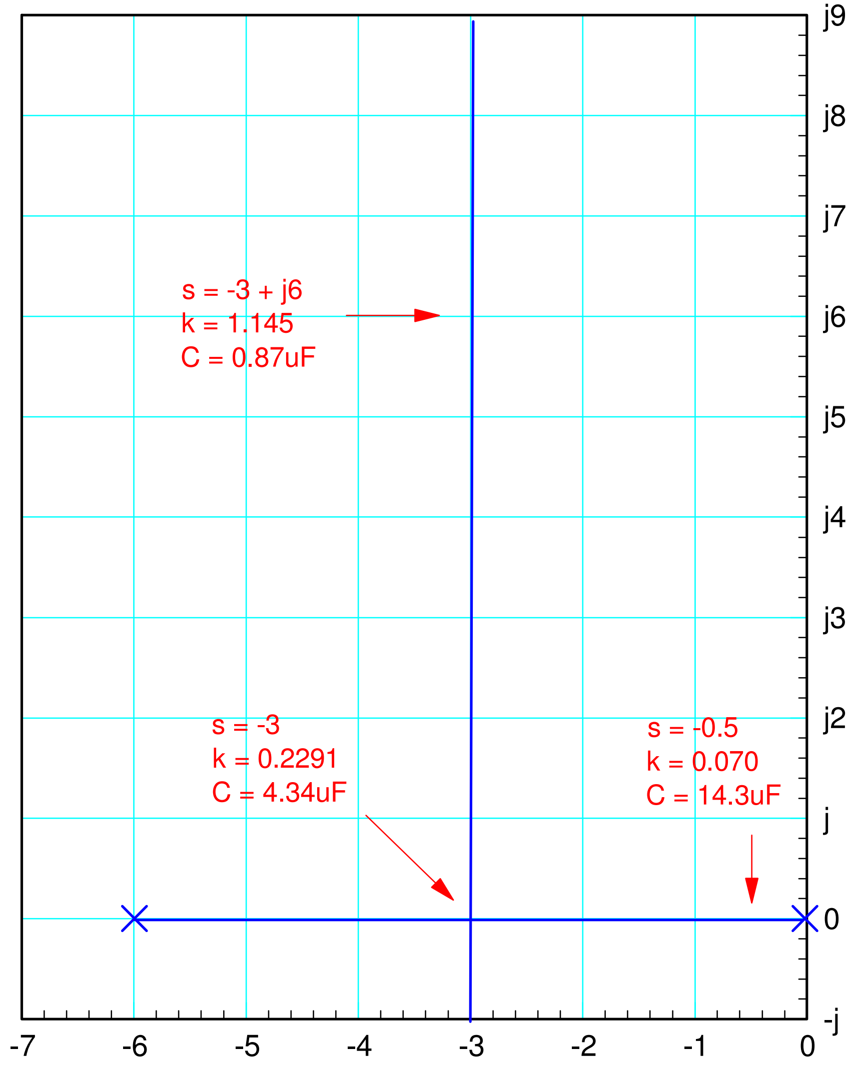
- $\left(\frac{39.68k}{s(s+6)}\right)_{s=-0.5} = -1$
- k = 0.070, C = 14.3uF

s = -3

- $\left(\frac{39.68k}{s(s+6)}\right)_{s=-3} = -1$
- k = 0.2291, C = 4.34uF

s = -3 + j6

- $\left(\frac{39.68k}{s(s+6)}\right)_{s=-3+j6} = -1$
- k = 1.145, C = 0.87uF



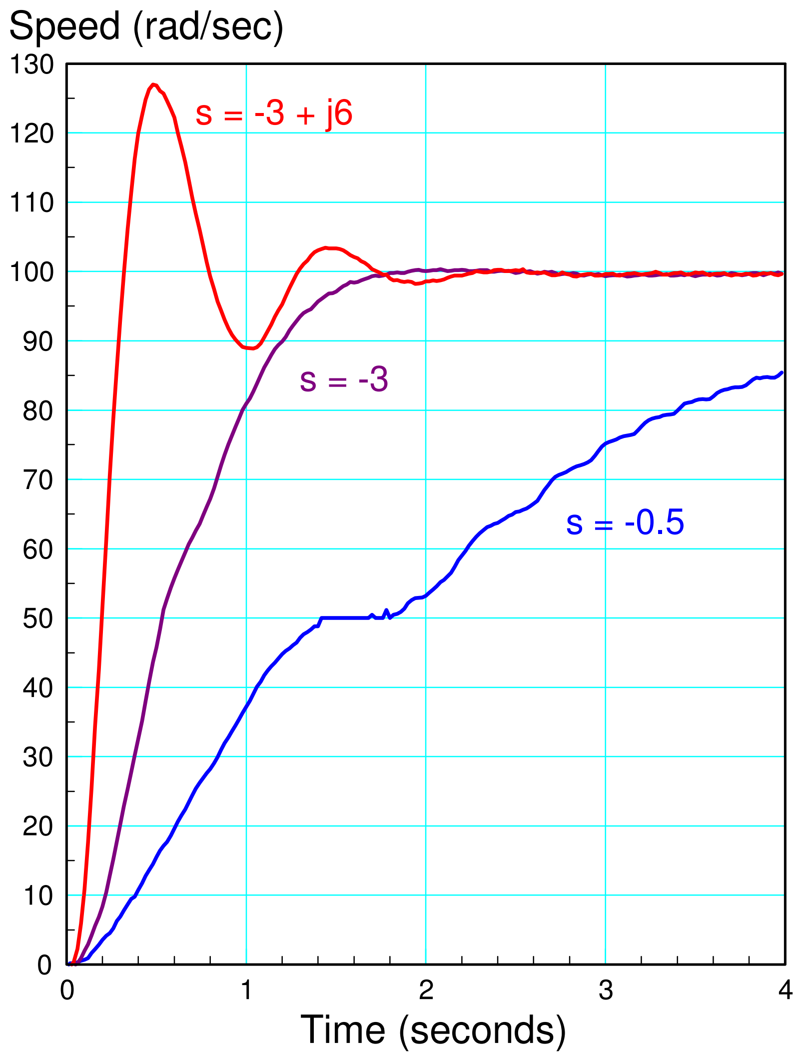
Experimental Results

- I Compensation

Steady-state speed = 100 rad/sec

- No Error for a step input
- Type-1 system

The response is what the root locus plot predicted



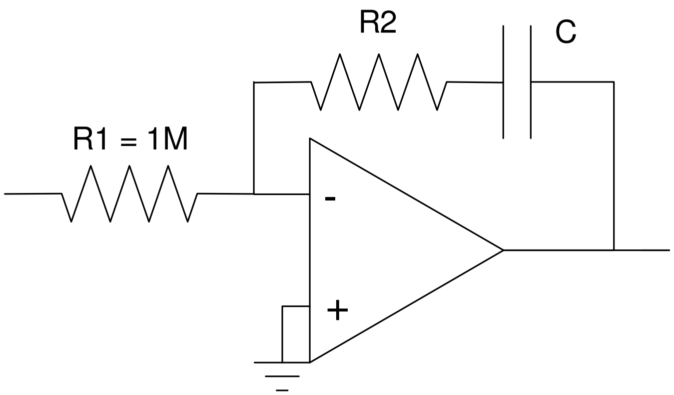
Speed Control: PI Control

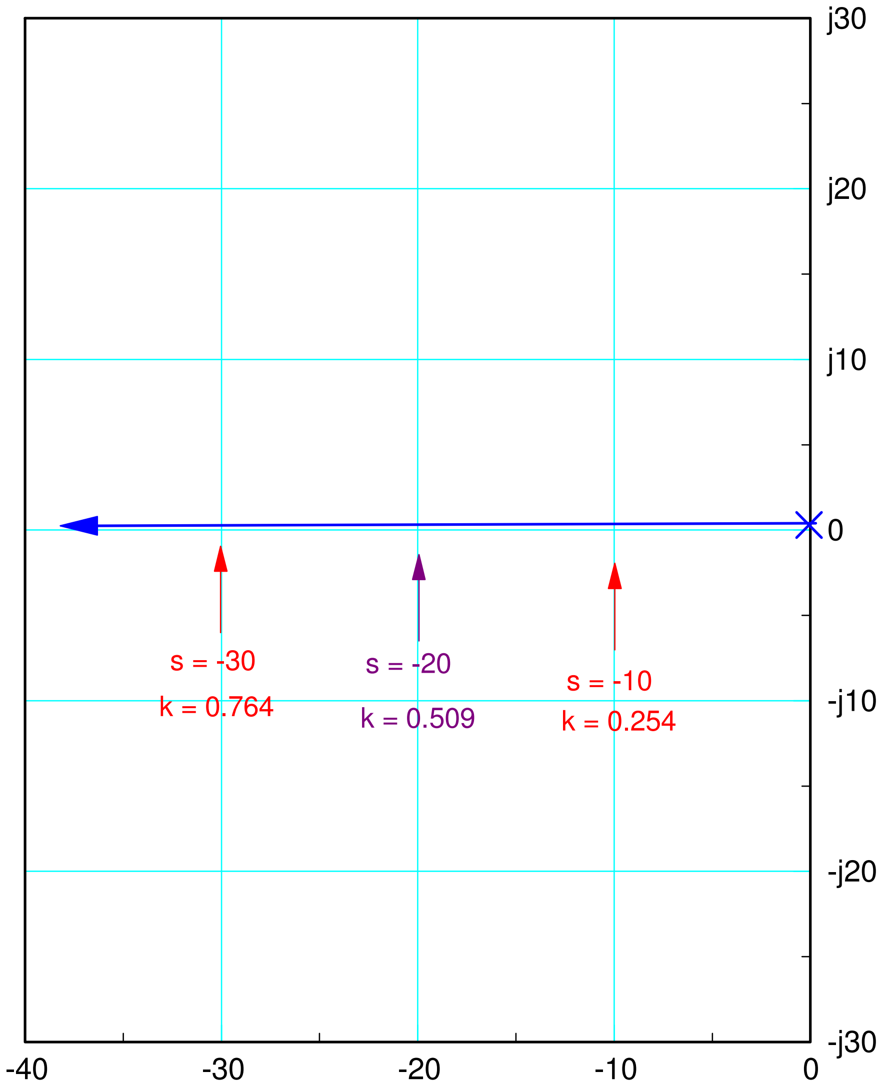
$$K(s) = k\left(\frac{s+6}{s}\right)$$

$$GK = k\left(\frac{39.28}{s}\right)$$

$$\left(\frac{1}{R_2 C}\right) = 6$$

$$k = \left(\frac{R_2}{R_1}\right)$$





PI Control: Experimental Results

s = -10

$$K(s) = 0.254\left(\frac{s+6}{s}\right)$$

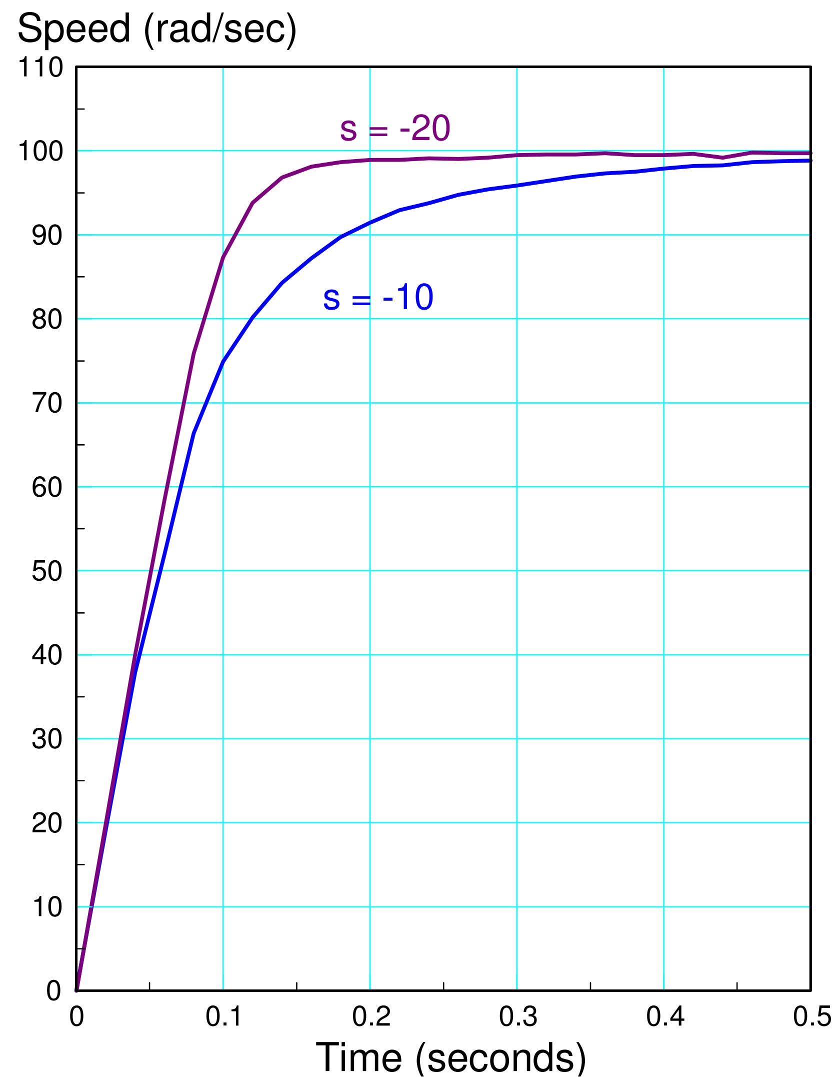
- R = 254k, C = 0.656uF

s = -20

$$K(s) = 0.509\left(\frac{s+6}{s}\right)$$

- R = 509k, C = 0.328uF

k = 0.509

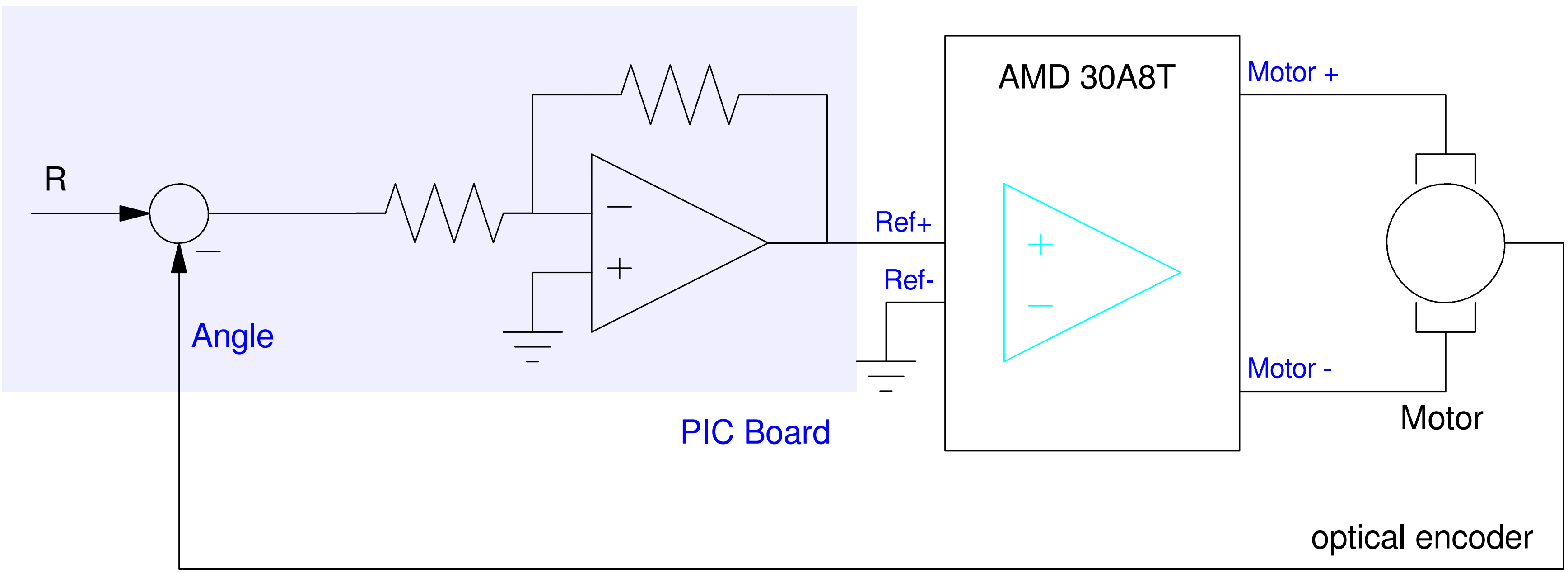


Again, the results are what the root locus plot predicts

Position Control:

- Change the sensor to an angle sensor and you have position control

$$\theta = \left(\frac{39.28}{s(s+6)}\right) V_a$$



Position Control: K(s) = k

s = -3.0

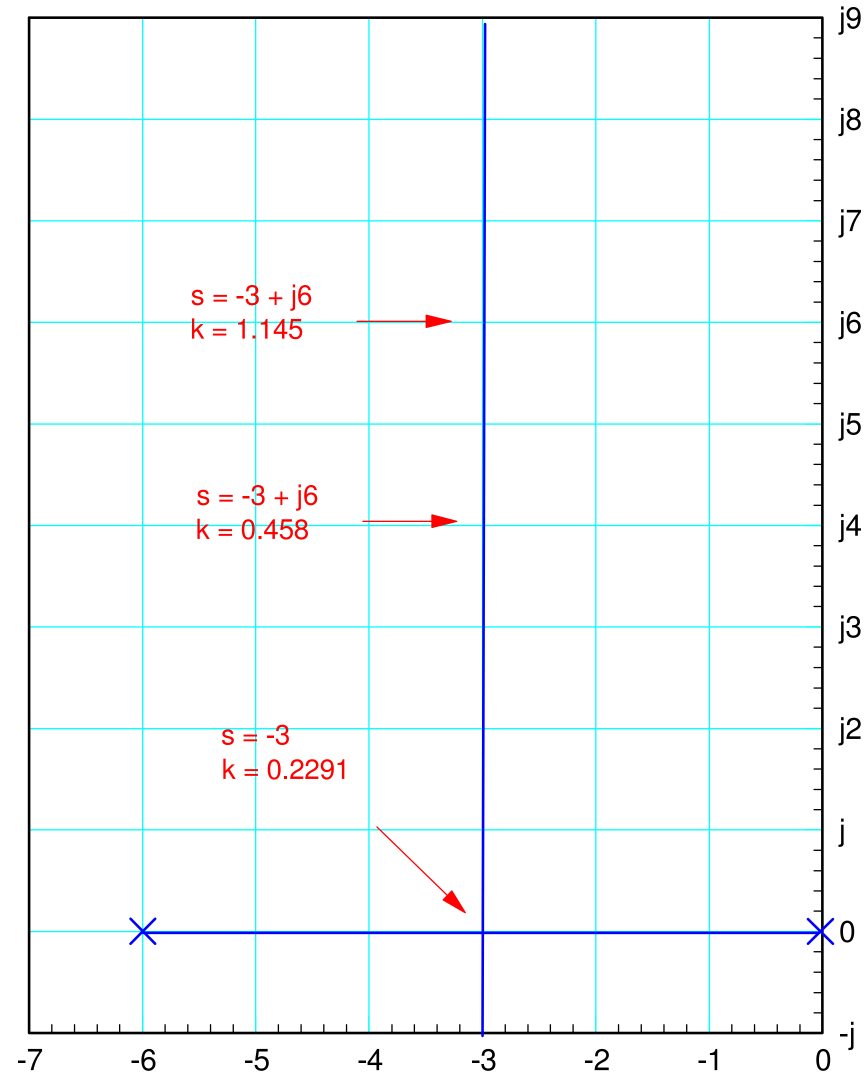
k = 0.2291

s = -3 + j3

k = 0.458

s = -3 + j6

k = 1.1456



Position Control: K(s) = k

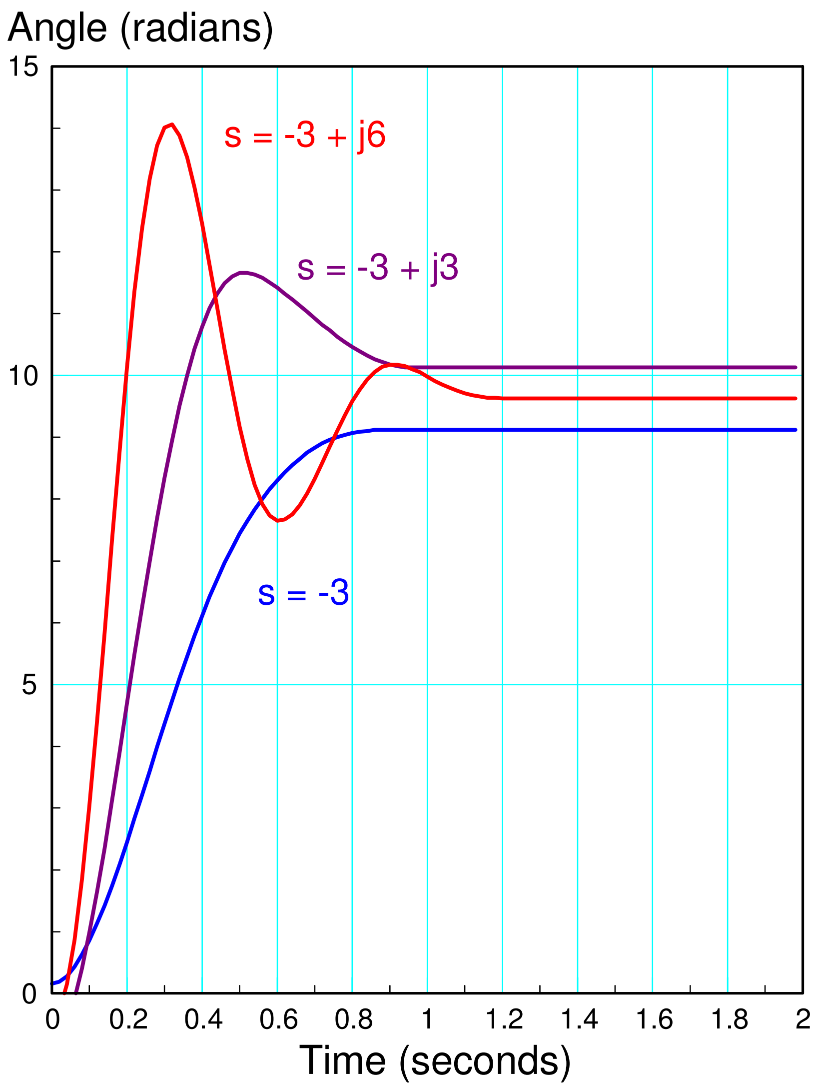
- Experimental Results

In theory, the steady-state error is zero

- Type-1 System

In practice, static friction causes a slight error

Otherwise, the response is what the root locus plot predicts

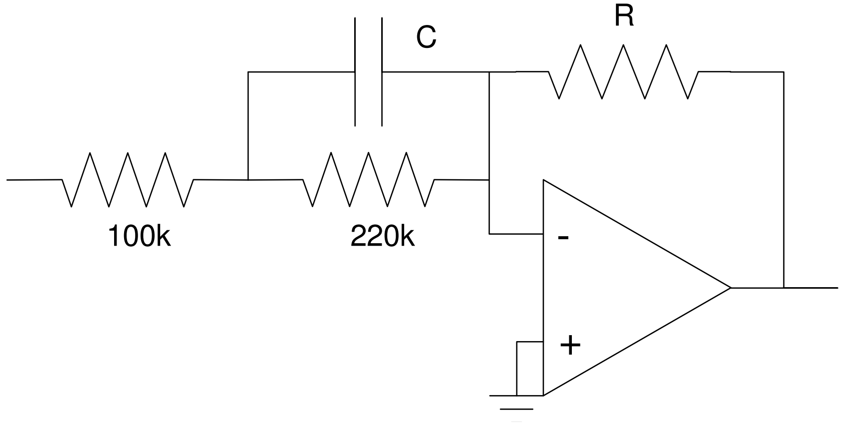


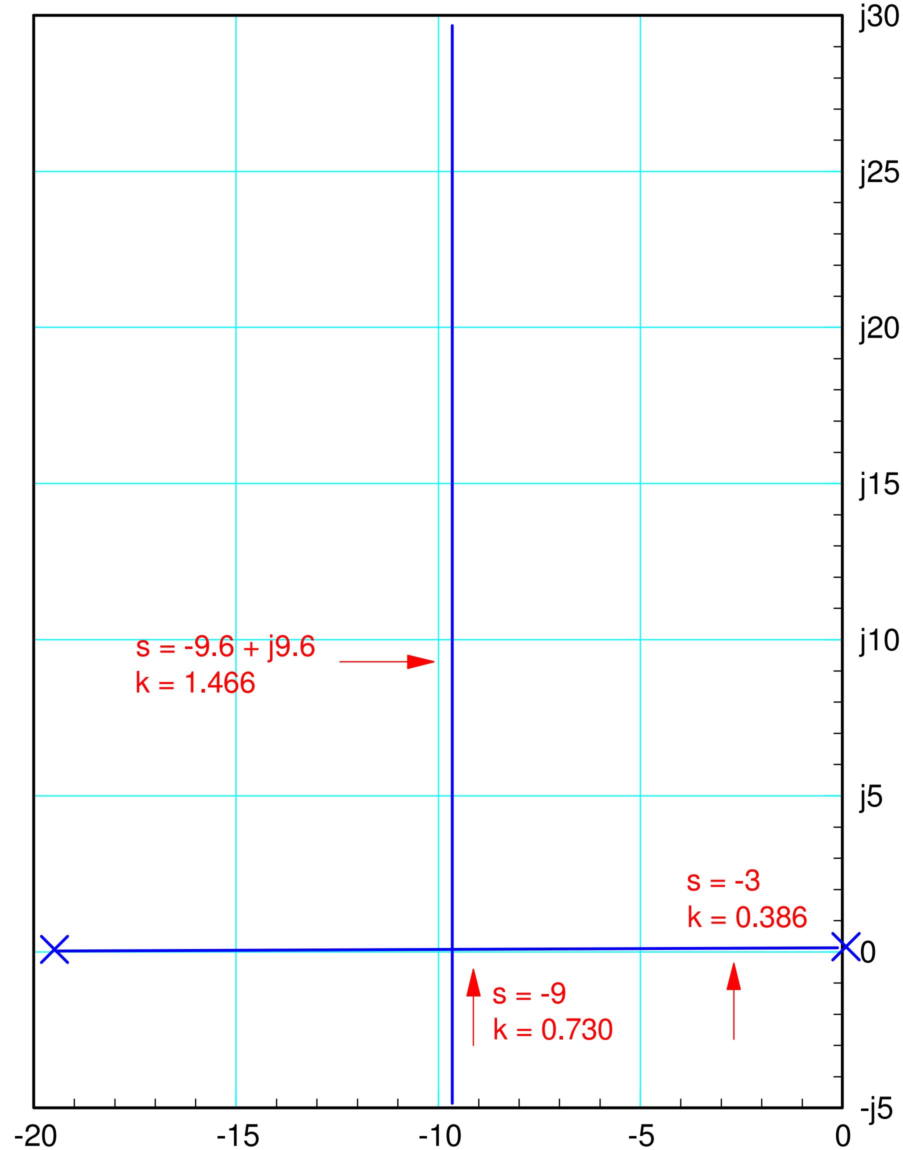
Lead Compensation

- Cancel the pole at -6
- Replace it with a pole at -19.2

$$K(s) = 3.2k\left(\frac{s+6}{s+19.2}\right)$$

$$\left(\frac{1}{220k \cdot C}\right) = 6 \qquad C = 757nF$$





Lead Compensation:

s = -3

- k = 0.386, R = 1.23M

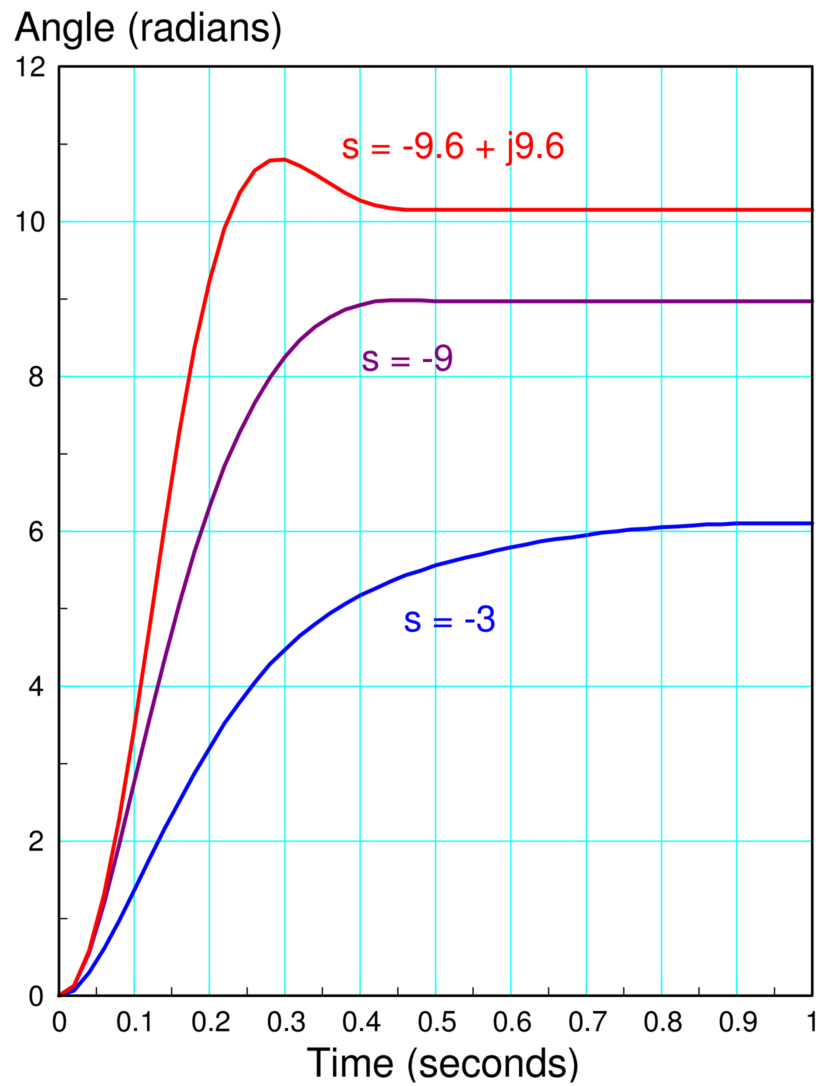
s = -9

- k = 0.730, R = 2.336M

s = -9.6 + j9.6

- k = 1.466, R = 4.69M

Again, the experimental results are what root locus plots predicted



Summary

Root locus really works

- It predicts how the system will behave as the gain changes
- The response is as the root locus plot predicts