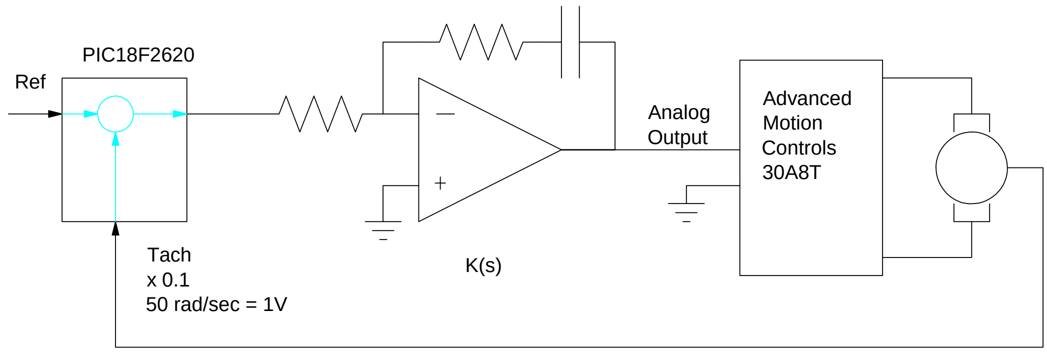
Homework #12: ECE 461

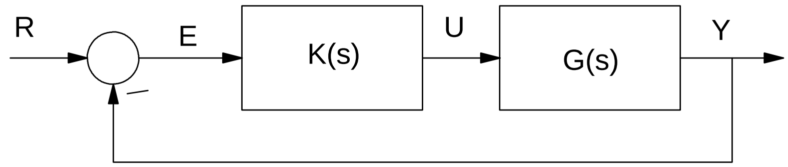
Part 1: Analog PI Control of a DC Motor - Monday November 20th



A DC Servo motor is set up in room 237 with a PIC controller. The PIC serves as a tachometer:

- It measures the speed of the motor using the optical encoder, and
- Outputs a voltage proportional to the error (x 0.1)
- The push-button (Step input) lets you change the set point from -50 rad/sec to +50 rad/sec

If you lump the x0.1 gain for the tachometer along with the power amplifier and motor, the block diagram for this system is then



$$G(s) = \left(\frac{3.2}{s+6}\right)$$

The speed of the motor is output on the serial port at

- 9600 baud
- No flow control
- 20ms / sample (50 samples / second)

If you capture the resulting data and import it into Matlab, you can plot the resulting step responses:

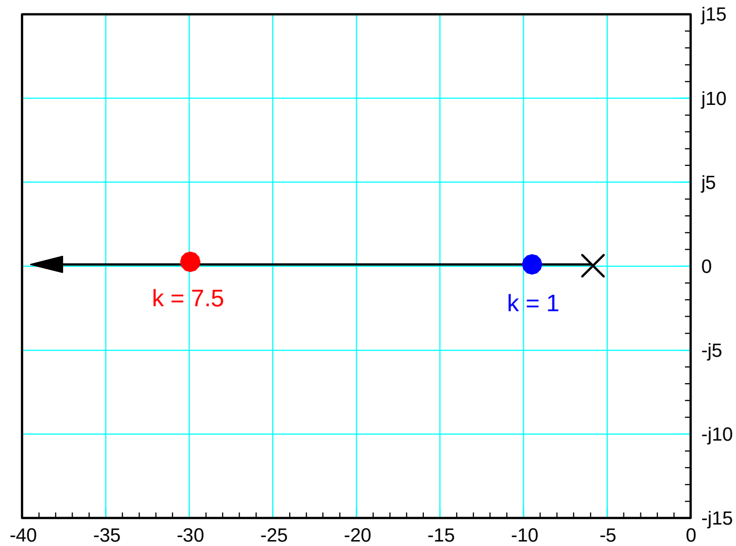
```
DATA = [  <paste data here ];
t = [1 : length(DATA)]'  * 0.02;
plot(t,DATA)
```

Proportional Feedback: K(s) = k

$$G(s) = \left(\frac{3.2}{s+6}\right)$$

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

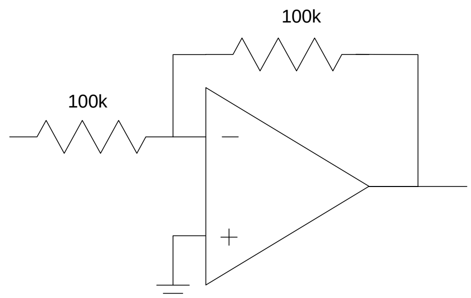
This gives the following root locus:



k = 1

Circuit:

- R1 = 100k
- R2 = 100K



Curent Program:

```
ERROR = REF - SPEED;
D2A(0.1*ERROR);
```

Software Implementation of P Compensator:

```
ERROR = REF - SPEED
U = ERROR;
D2A(0.1*U);
```

Open-Loop System

$$GK = \left(\frac{3.2}{s+6}\right)$$

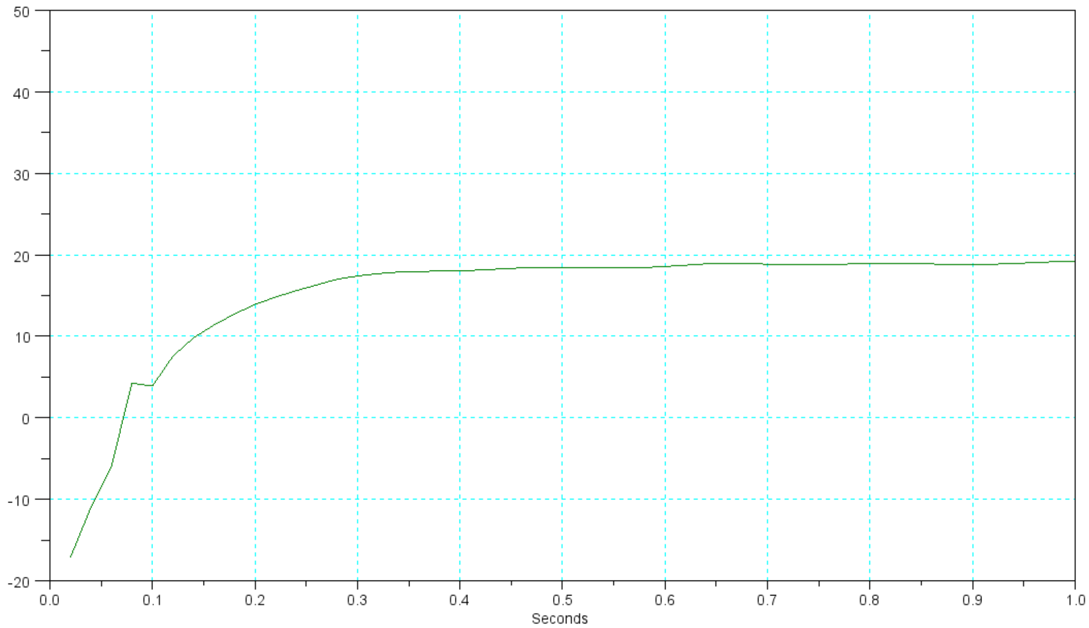
Closed-Loop System

$$\left(\frac{GK}{1+GK}\right) = \left(\frac{3.2}{s+9.2}\right)$$

This results in

- DC gain = 0.347 *17.39 rad/sec when R = 50*
- 2% Settling Time = 4/9.2 = 0.434 seconds
- No overshoot

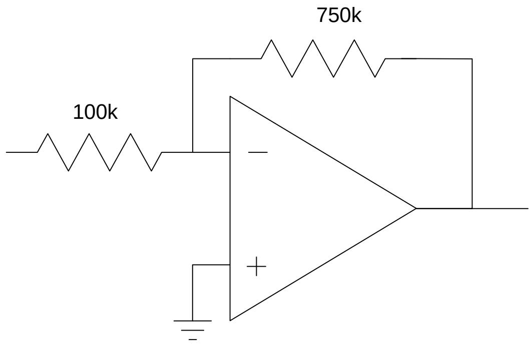
	Expected	Actual
DC Speed (rad/sec)	17.39	18.78
2% Settling Time	434ms	400ms
Overshoot	0	0



k = 7.5:

Circuit Implementation:

- R1 = 750k
- R2 = 100k



Software:

```
ERROR = REF - SPEED;
D2A(0.1*ERROR);
```

Software Implementation of P Compensator:

```
ERROR = REF - SPEED
U = 7.5*ERROR;
D2A(0.1*U);
```

Program:

```
ERROR = REF - SPEED;
U = 7.5*ERROR;
D2A(0.1*U);
```

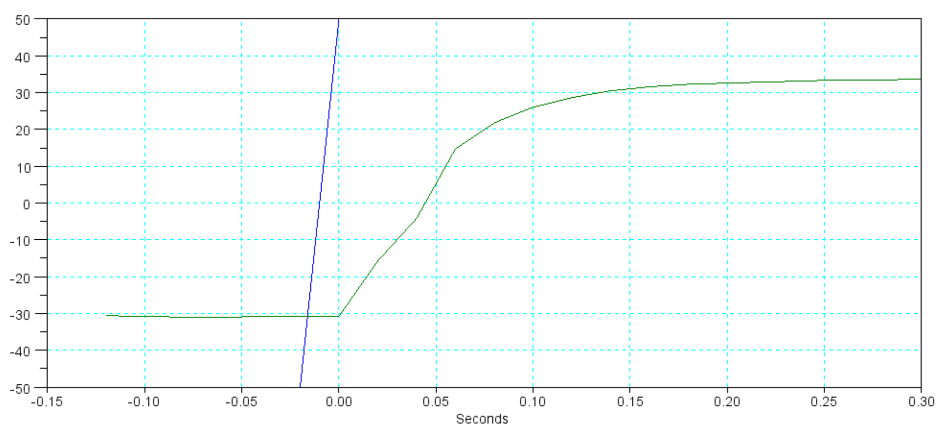
Open-Loop System:

$$GK = \left(\frac{3.2}{s+6}\right) \cdot 7.5$$

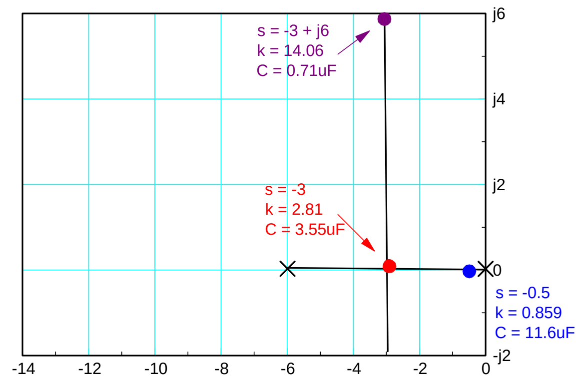
Closed-Loop System:

$$\left(\frac{GK}{1+GK}\right) = \left(\frac{24}{s+30}\right)$$

	Expected	Actual
DC Speed (rad/sec)	40	33.7
2% Settling Time	133ms	150ms
Overshoot	0	0



Integral Feedback: K(s) = k/s



a) s = -0.5

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

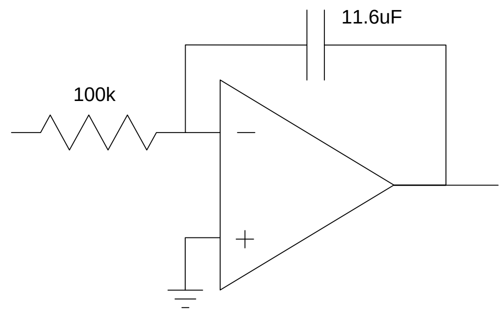
$$k = 0.859$$

Op-Amp Circuit:

- R = 100k
- C = 11.6uF

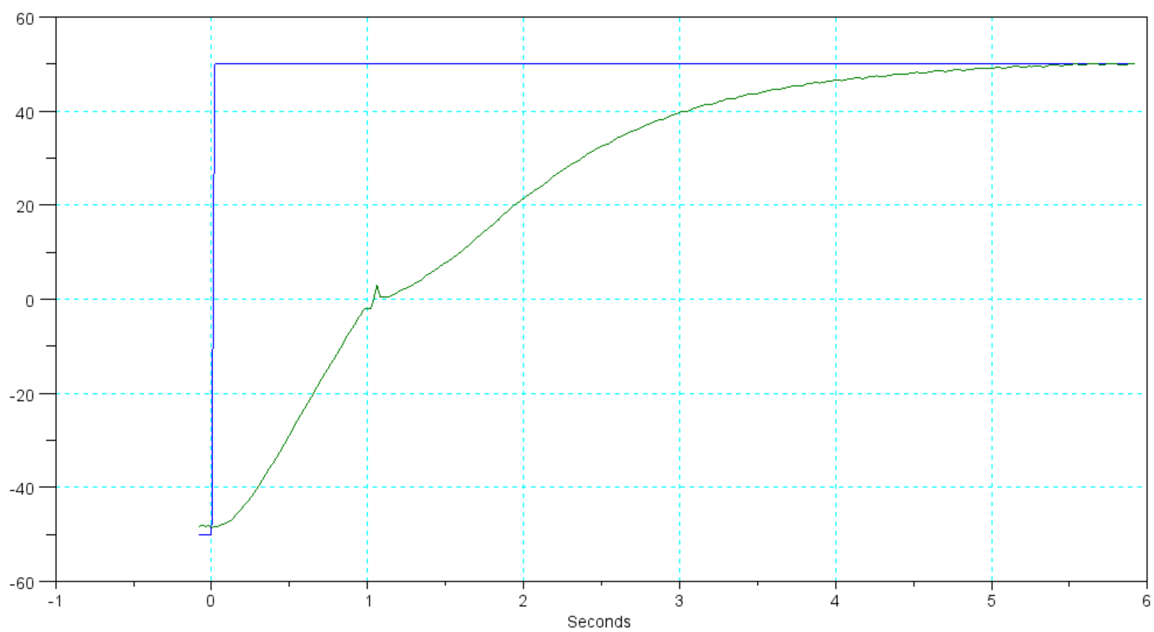
Software Implementation of I Compensator:

```
ERROR = REF - SPEED;
U = U + 0.859*ERROR;
D2A(0.1*U);
```



Results: (10uF)

	Expected	Actual
DC Speed (rad/sec)	50	50
2% Settling Time	8 sec	6 sec
Overshoot	0%	0%

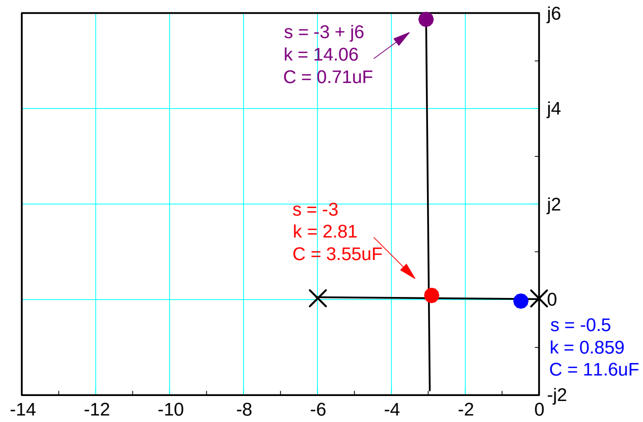


Integral Feedback:

b) s = -3

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

$$k = 2.81$$

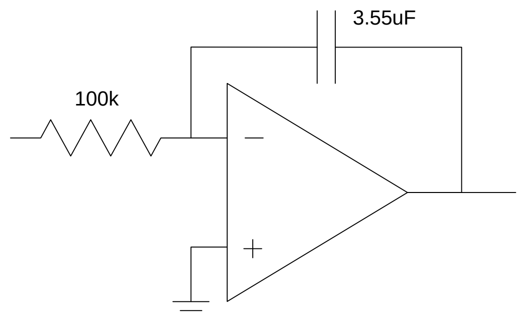


Op-Amp Circuit:

- R = 100k
- C = 3.55uF

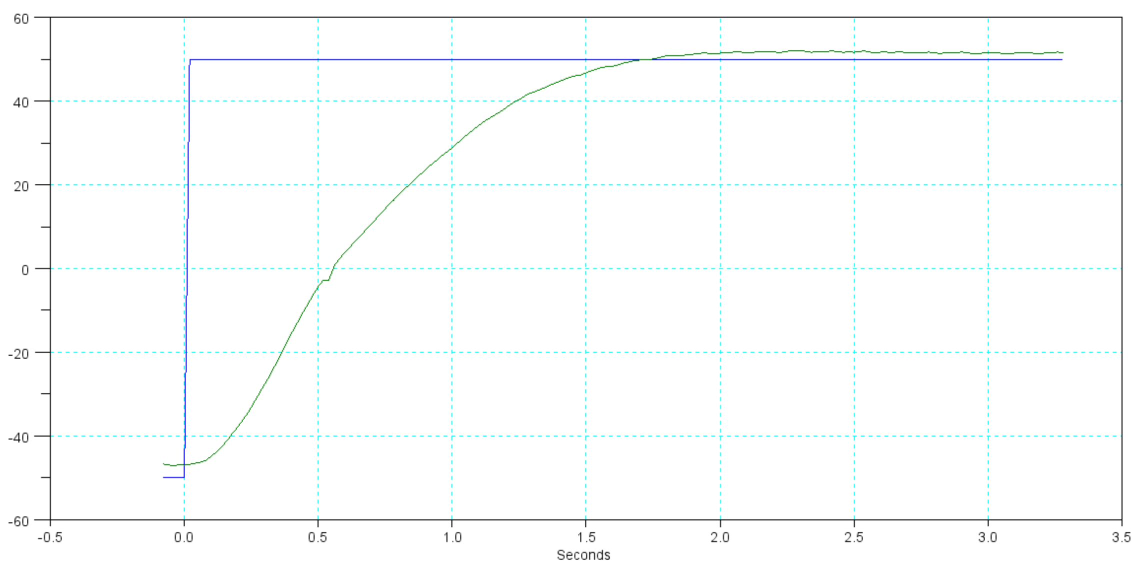
Software Implementation of I Compensator:

```
ERROR = REF - SPEED;
U = U + 2.81*ERROR;
D2A(0.1*U);
```



Results: (4uF)

	Expected	Actual
DC Speed (rad/sec)	50	51.5
2% Settling Time	1.33 sec	2.0 sec
Overshoot	0%	0%



Integral Feedback: K(s) = k/s

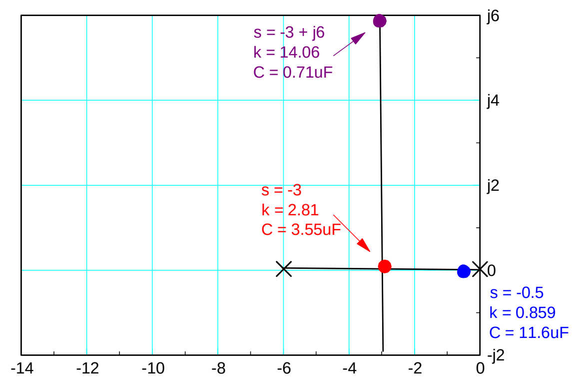
b) s = -3 + j6

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

k = 14.06

Op-Amp Circuit:

- R = 100k
- C = 0.71uF

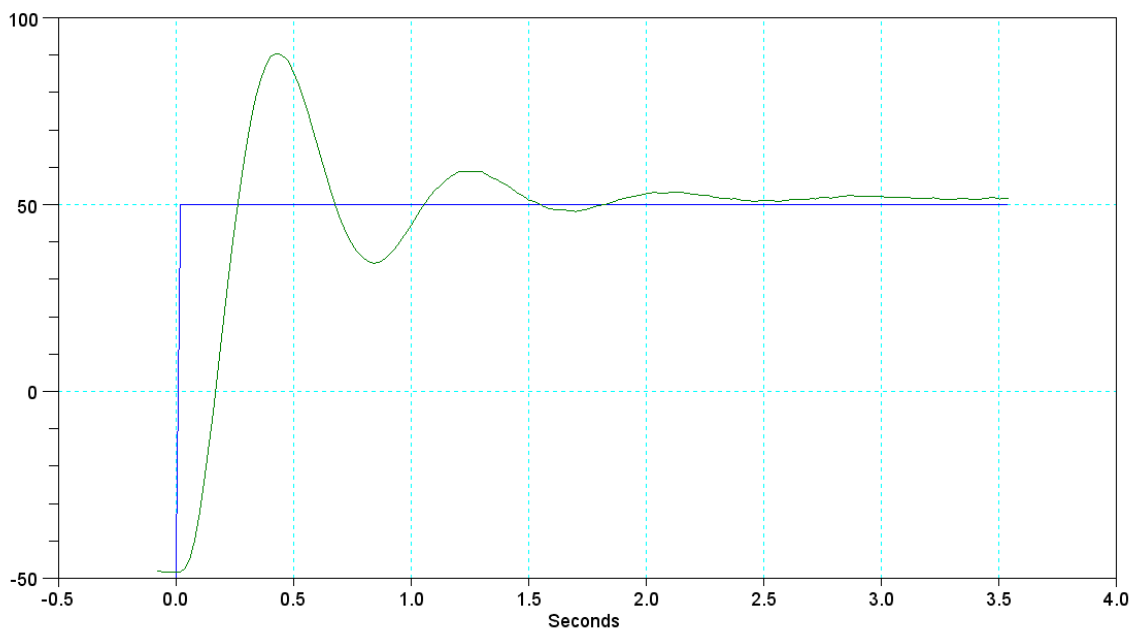


Software Implementation of I Compensator:

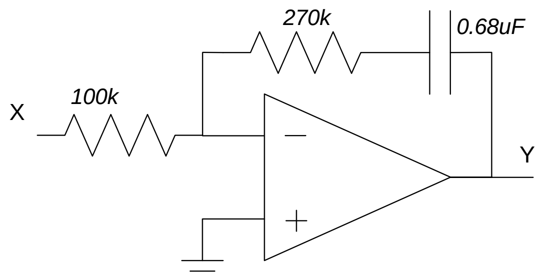
```
ERROR = REF - SPEED;
U = U + 14.06*ERROR;
D2A(0.1*U);
```

Results: (0.68uF)

	Expected	Actual
DC Speed (rad/sec)	50	51.5
2% Settling Time	1.33 sec	2.0 sec
Overshoot	20% 20 rad/sec	40% 40 rad/sec



Proportional - Integral Feedback: $K(s) = k(\frac{s+a}{s})$



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

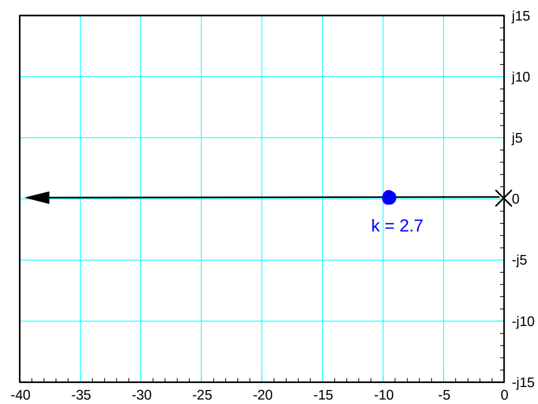
$$GK = \left(\frac{3.2k}{s}\right)$$

For placing the closed-loop pole at s = =8.64

k = 2.7

Circuit:

- R2 = 270k
- C2 = -0.68uF
- R1 = 100k



Software Implementation of PI Compensator:

```
E1 = E0;
E0 = REF - SPEED;

U = U + 2.7*(E0 - E1);
```

Results:

	Expected	Actual
DC Speed (rad/sec)	50	51.5
2% Settling Time	462 ms	400 ms
Overshoot	0%	0%