S2 lab si3g19

Phase Lead Compensation of an Inverted Pendulum

3.1 Position control

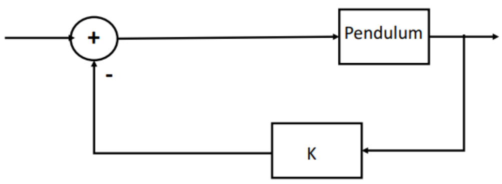
$Y = X + L\sin(\theta) \approx Y = X + L\theta$

X position represented by V_X

$\therefore V_Y = V_X + aV\theta$

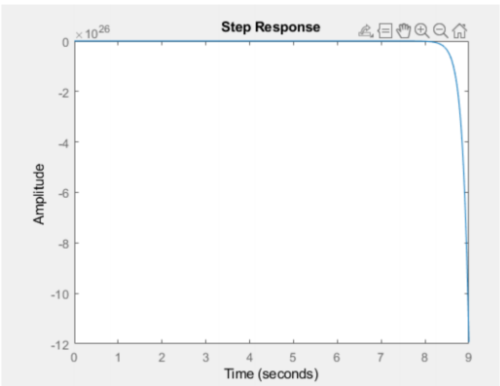
3.2 Proportional control

5. Negative feedback

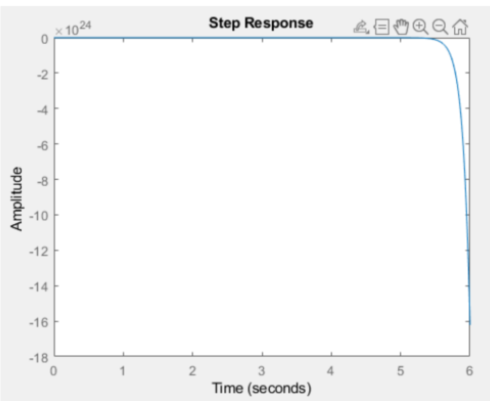


pendulum = tf(-49.05,[1,0,-49.05])

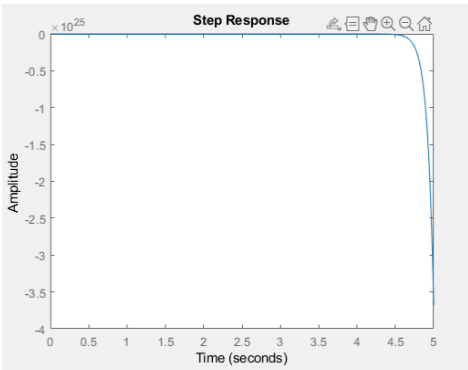
- K=0



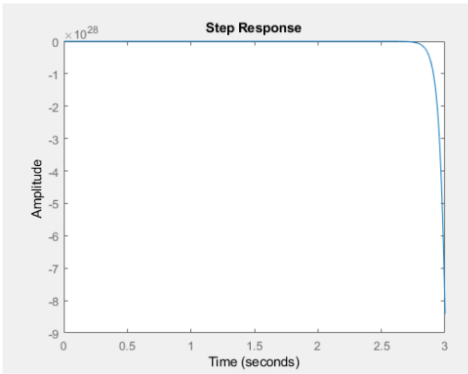
- K=1



- K=2

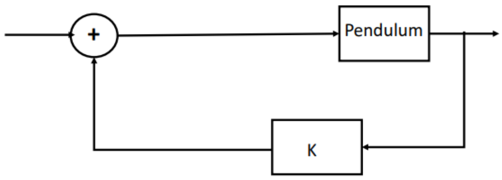


- K=10

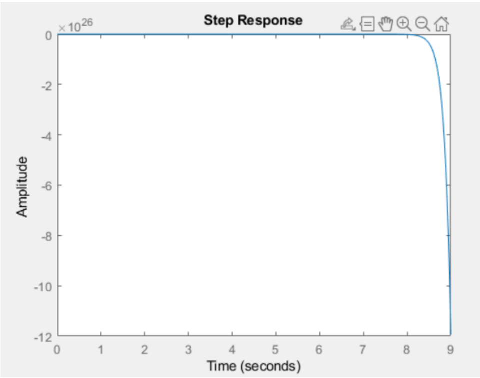


➔ System is unstable

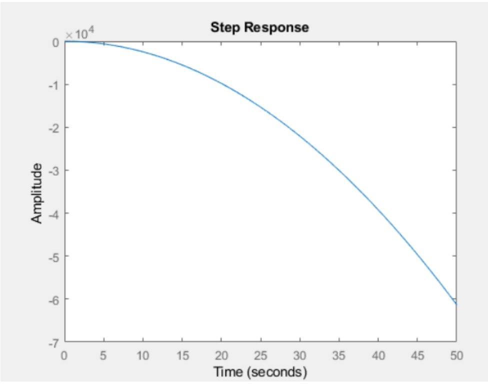
6. Positive feedback



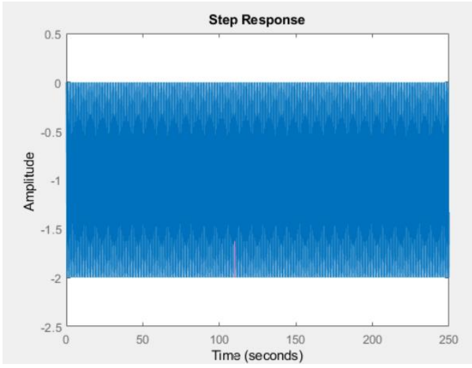
- K=0



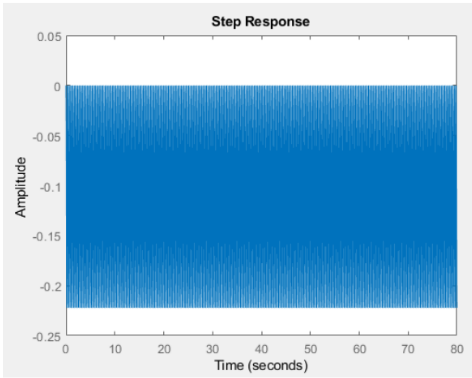
- K=1



- K=2



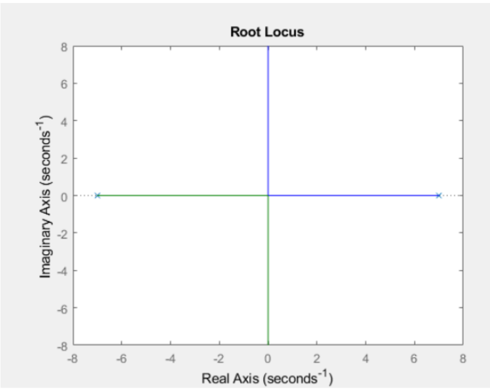
- K=10



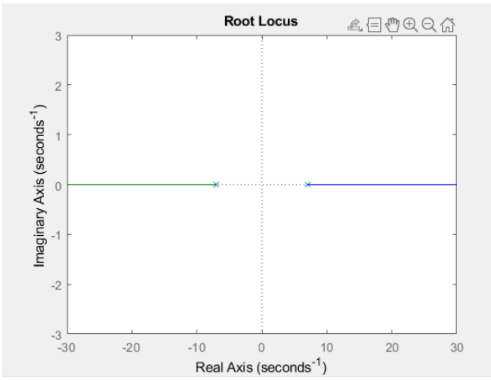
→ System becomes more stable, as k increases, the system no longer tends towards ±∞

7.

Positive feedback



Negative feedback



8.

- ➔ System is unstable
- ➔ Not all roots are stable
- ➔ Blue pole becomes more unstable
- ➔ Green pole becomes more stable

- ➔ System becomes (marginally) stable
- ➔ Both poles move towards stable/unstable: marginal stability to ±∞

9. Compare the behaviour qualitatively for different values of the gain. Is it consistent with the root-locus predictions?

As gain increases, pendulum accelerates increasingly to the side the pendulum leans.

Large gain: pendulum becomes erratic and unstable.

Corresponding to root loci, showing as K increases → system= unstable

3.3 Lead compensation

$$H(s) = \frac{1 + c\tau s}{1 + \tau s}$$

Place zero of compensator. Directly cancel stable pole of plant, choosing

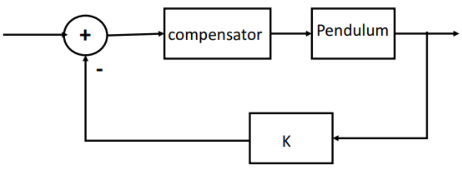
$$\omega = \frac{1}{c\tau}$$

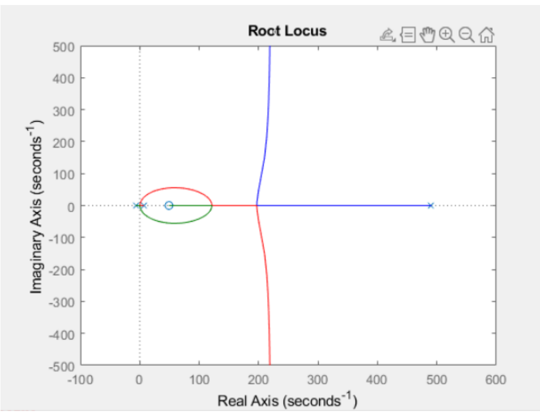
Use 'high' value of c, e.g. c=10

Use compensator of the form

$H_1(s) = \frac{1+0.1s}{1+0.01s}$

10.

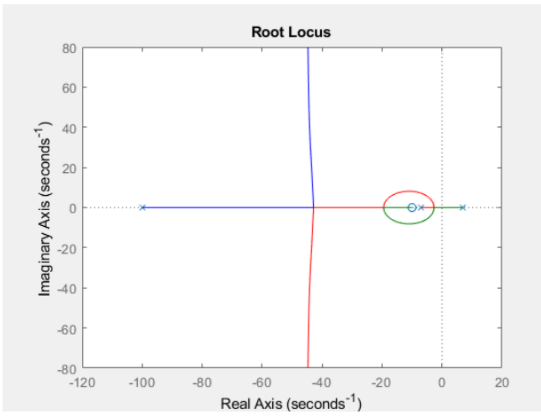




- → System is initially unstable
- → System remains unstable
- → 2 poles are marginally stable but become unstable

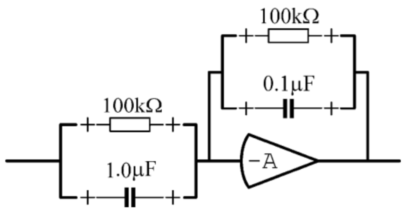
11.

compensator2 = tf([0,0.1,1],[0,0.01,1])



- → 2 poles circle 1 root, ending at green point
- → Another starts becoming stable, tends to ∞ (red)
- → Blue pole starts becoming unstable, then tends to ∞

$H_1(s)$= op-amp compensator circuit



V_0= output voltage

V_1= input voltage

Z_f= feedback impedance

Z_1= impedance between V_1 and summing junction

$V_0 / V_1 = Z_F / Z_1$

For parallel circuit

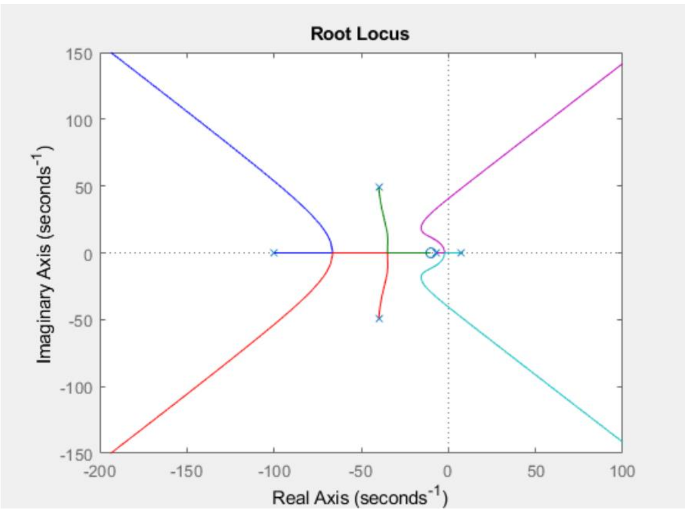
R= resistor

C_1= capacitor

$1/ Z_1 = (1/R) + C_1s$ and $1/ Z_f = (1/R) + C_fs$

$\therefore V_0 / V_1 = - (1+R\, C_1s)/ (1+R\, C_fs)$

12.Explain using the root-locus plot why small values of the gain P2 do not lead to a stable closed loop.



- ➔ Small gain, green pole= unstable
- ➔ ∴ whole system = unstable
- ➔ System becomes stable after 1 pole crosses y axis
- ➔ All other poles are stable in the beginning

3.4 The neglected servo dynamics

$G(s) = \frac{1}{0.00025s^2+0.02s+1}$

Natural frequency: $\omega = 10Hz$

Damping ratio $\zeta = 0.7$

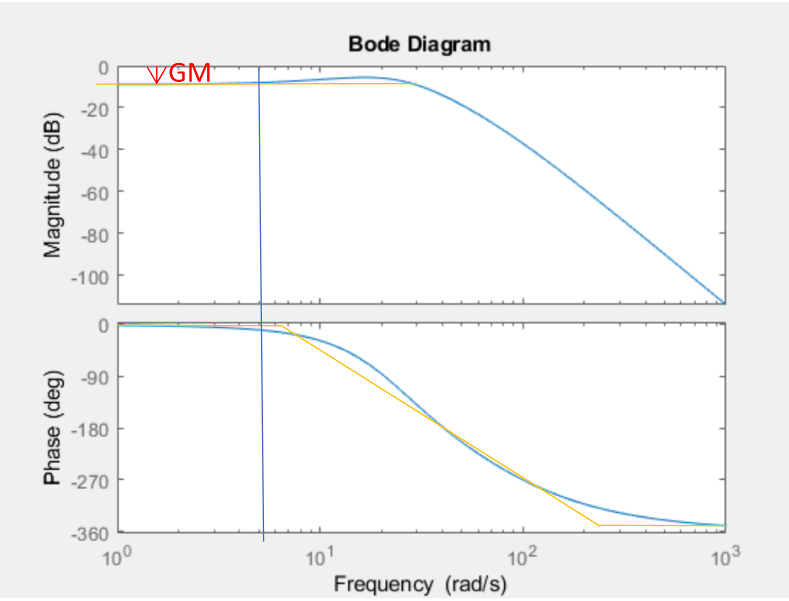
13.

Upper limit: 8.7965

Lower limit: 0.9915

When gain > upper limit, pendulum becomes unstable and fails to balance

14.



Gain k:

(max) Gain margin: 8.83db

Phase margin: 344 degrees (?)

15.

Tapping the weight: system responds more aggressively to tapping

Makes small sudden changes before adjusting

16.

Moving the weight to the bottom of the rod causes the system to vibrate a lot and moves very quickly to adjust to the tap.