Lecture - 1

Control System Engg (part 2)

Topics:

1) Analysis of Performance & robustness

- Control system design objective
- GM, PM (Review)
- (4) Sensitivity (S) & Complementary Sensitivity (T) functions & their roles
- Relation among S, GM, PM
- Loop behaviours desired for a good design (ie for good performance & robustness)

- plots of desired S & T

2) Compensation methods

- Lead, lag, lead-lag controller design (Frequency domain method)
- pole-placement based controller design (1-DOF & 2-DOF) – time domain method

(7-8)

- P, PI, PID Controllers

3) Sample-data systems

- overview of computer controlled systems

(4)

- Z-transform of sampled signals & systems

- Stability of discrete-time systems
- Sampling theorem, aliasing effect & its remedy
- Controller design via digital redesign / direct digital design

Books

1) Modern Control systems
   — Dorf & Bishop (Modelling)
2) Modern control Engg
   — Ogata (general)

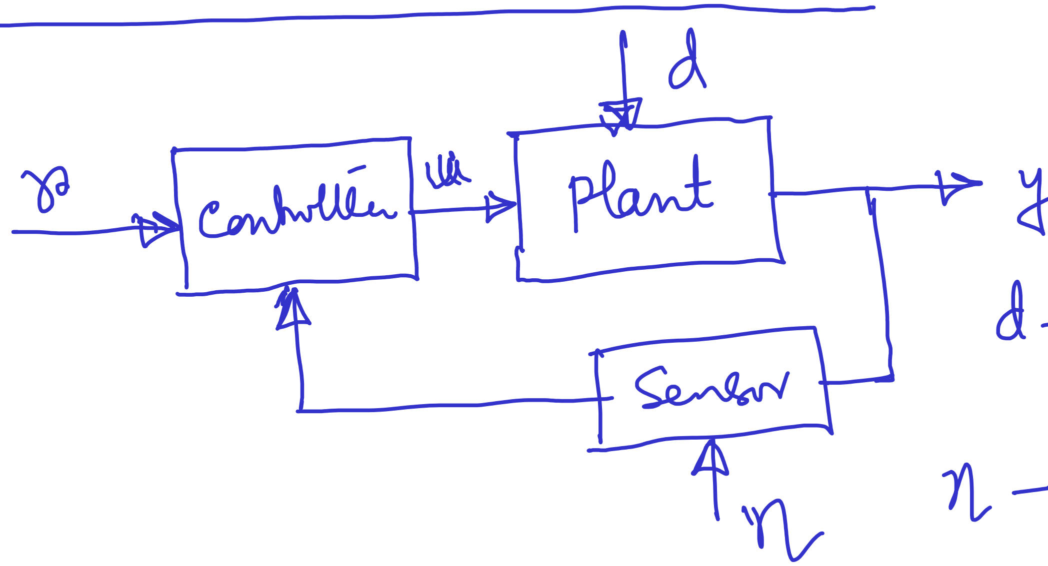
3) Automatic Control systems
— Kuo (general)

4) Automatic Control system
— Wolovich (Pole-Placement, 2-DOF, Loop shaping)

5) Feedback Control system
— N. K. Sinha (Frequency domain design)

6) Automatic Control system
— Nise (Root locus based design)

Control system design objectives



d - disturbance (Process)

n - measurement noise

Basic feedback control system diagram

objectives

- Nominal Stability (NS)
- Robust Stability (RS)
- Nominal performance (NP)
- Robust performance (RP)

$\Bigg\}$ subject to $|u| < u_{max}$

$\boxed{NS}$ — All the closed-loop poles should be in the LHP

$\boxed{RS}$ — The closed-loop system should be stable even in presence of uncertainties in the system parameters & neglected dynamics during modelling

$\boxed{NP}$ — Settling time, P.O, Steady-state error. (desired)

$\boxed{RP}$ — system should ensure desired performance even in presence of uncertainties in the system

Disturbance (process) — load torque in speed control, wind gust in missile system, the diff. between ambient temp & room temp in room temp control system — all are low freq signal compared to the system BW.

<u>Noise (n)</u> — measurement noise (high freq signal compared to the system BW)

• $\boxed{\text{Disturbance \& noise attenuation}}$

— Disturbance & noise should not affect

the system behaviour much. They should be attenuated well in the loop.

RS : Capacity to tolerate uncertainties in the system.

uncertainties — 1) parametric uncertainties

2) uncertainties due to neglected dynamics or un-modelled dynamics

$$G(s) = \frac{10}{(s+1)(s+10)}$$

$$\approx \frac{1}{s+1}$$

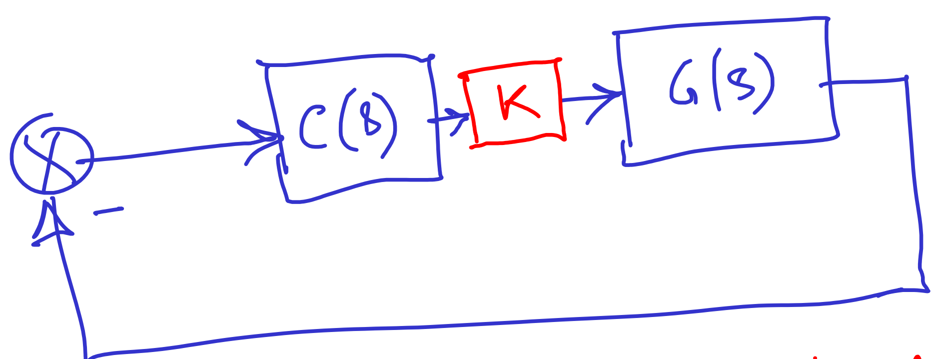
$\Rightarrow$ $s = -10$ pole is neglected. — neglected dynamics

Robustness measures

— GM, PM (classical measures)

— ∞-norms of Sensitivity & complementary Sensitivity functions. (Modern)

Gain margin : It is a factor by which the loop gain can be increased (or decreased) till the system remains stable



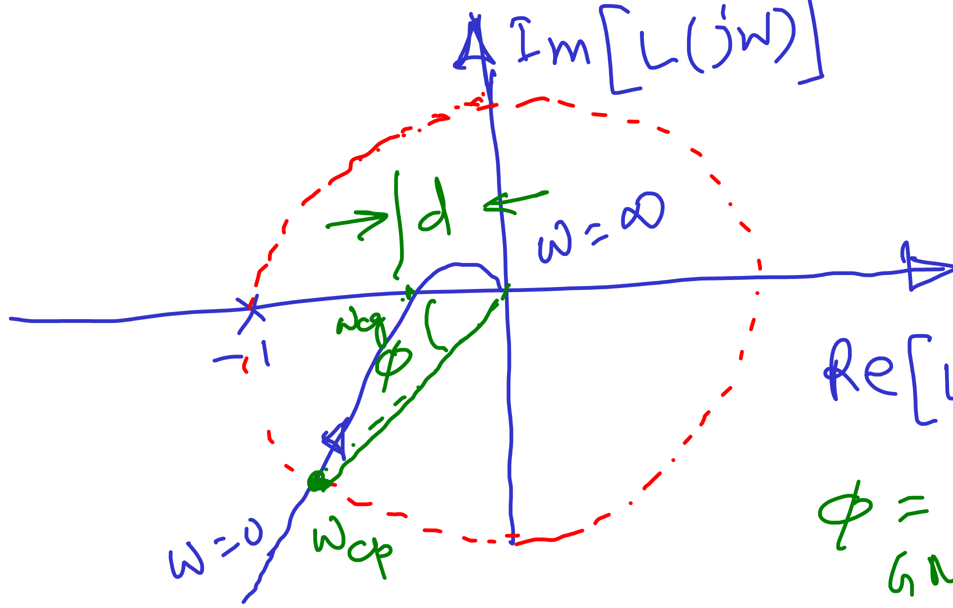
K = 1 under nominal Condition

$K_{min} < K < K_{max}$

Increased side GM = K_{max}

Decreased side GM = K_{min}

Phase margin: The amount of −ve (or +ve) phase that can be introduced in the loop till the system remains stable is called phase margin



$L(s) = G(s)C(s)$

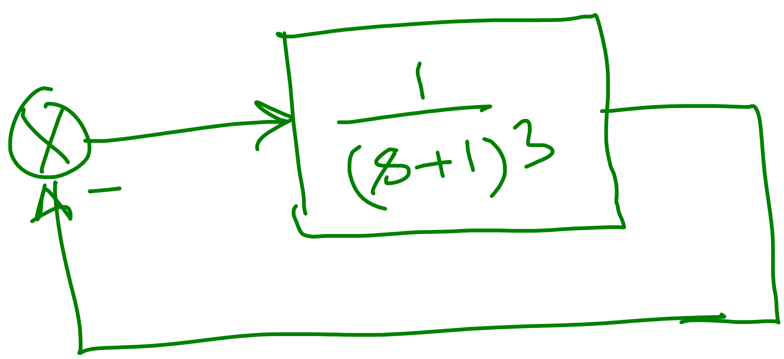
= nominal loop TF

$\phi = PM$

$GM = \frac{1}{d}$ (+ve side GM)

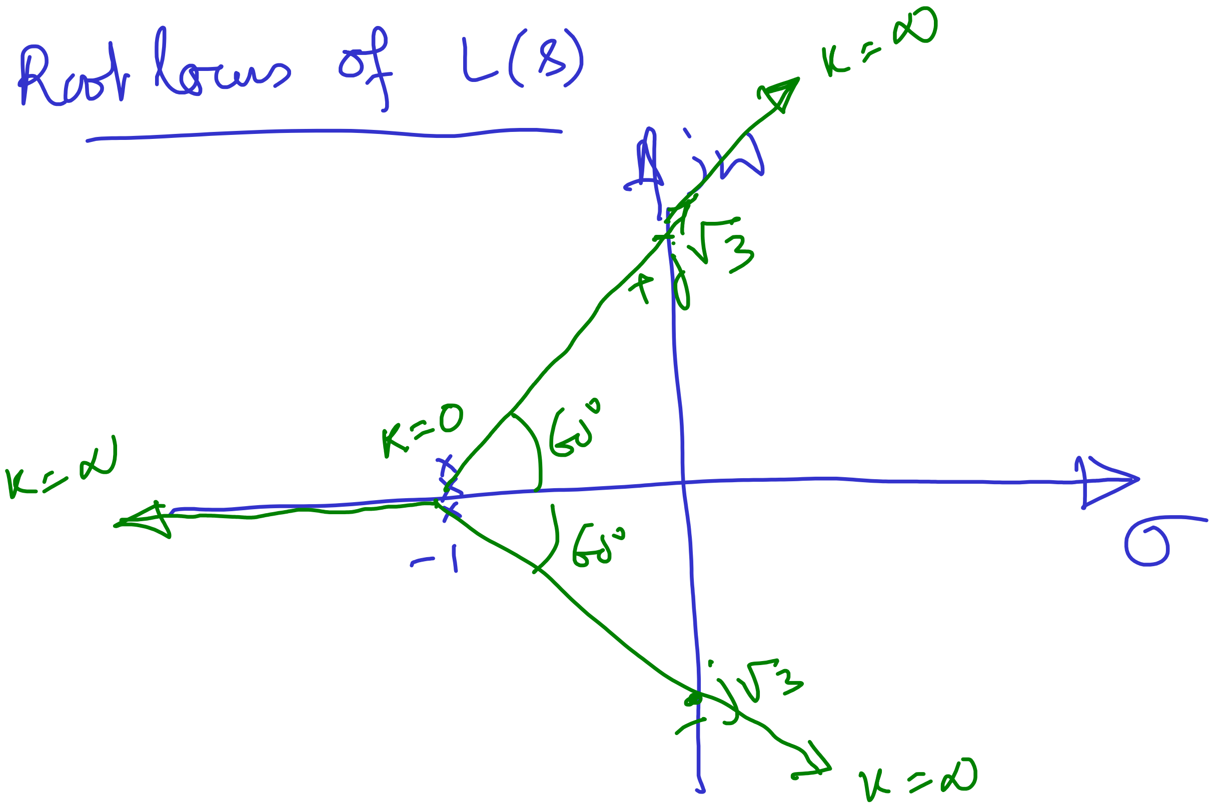
Examples of GM

EX1



$L(s) = \frac{1}{(s+1)^3}$, nominal $K = 1$

Root locus of $L(s)$



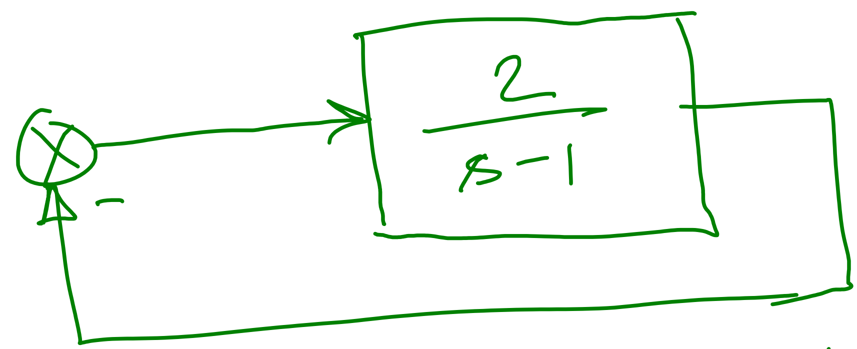
The value of K for which the root locus branches cross $j\omega$ axis is $K = \dfrac{1}{|L(s)|_{s=j\sqrt{3}}}$

$= 8$

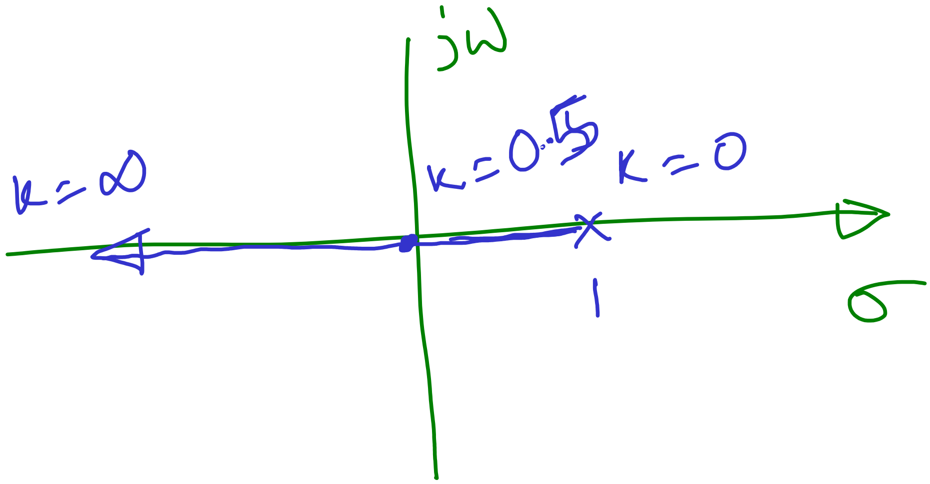
$\boxed{GM = 8}$ → increased side GM

Decreased side $GM = 0 = -\infty$ dB

Ex 2



$L(s) = \frac{2}{s-1}$



Nominal $K=1$

Decreased side $GM = 0.5 = -6\,dB$

Increased ... $= \infty$