MODERN CONTROL ENGG. :
D ROYCHOWDHURY

LINEAR CONTROL THEORY LCT (IEE/T/214)(3-1-0)

– daily life – room temperature control, automobile steering control, traffic control systems, CHEMICAL plants, IRON & STEEL industry, economic regulation systems,

AS ALSO : Space vehicles, missile guidance, aircraft positioning

steps for control of dynamic systems :

1. Define system and components
2. Formulate mathematical model
3. Write differential eqns. describing model
4. Solve for desired o/p variables
5. Examine solutions and ASSUMPTIONS
6. Reanalyze or proceed with design.

2. PLANT: Set of m/c parts functioning together for a particular operation

3. PROCESS: involves progressively continuing sequential opn. leading towards a particular goal or result.

1. SYSTEM: combination of components acting together to perform certain objective.

4. DISTURBANCE: unwanted signal that adversely affects system o/p.

5. FEEDBACK CONTROL: o/p fed back to i/p

in-phase: POSITIVE (OSCILLATORS) REGENERATIVE

out of phase: NEGATIVE (usually) - used to generate ERROR - drives controller

8. SERVO MECHANISM: negative f/b control; o/p is mechanical position

6. AUTOMATIC CONTROL SYSTEM (ACS): maintains actual o/p at desired value in presence of disturbances or for slowly varying ref. i/p

REGULATION TRACKING

7. PROCESS CONTROL SYSTEM: ACS in which o/p is a PROCESS VARIABLE (level, flow, pressure, temp, conc.)

TRANSDUCER:

LIAPUNOV - energy concepts 1892 → accepted in 1960s

HEAVISIDE - operational calculus 1892-1898 (attributed to LAPLACE)

POPOV ← TSYPKIN
(circle criterion) (phase plane)

BELL LABS: Black 1927 ⟷ Nyquist (polar plot) → Bode 1938
reduce distortion in repeater amplifier - negative f/b
mag, phase plot
- GM, PM concepts

World War: control and navigation of ships - SPERRY 1910 - gyroscope
- MINORSKY (P-I-D) controller for ship steering - N/L effects

MIT Radiation Laboratory: work on radars - NICHOLS, EVANS
- freq. domain techniques.

1942 - Wiener - stochastic processes - optimal filter

SPACE AGE: 1960 Charles Draper - INS
Optimal control - minimize transit time or some PI
with some constraints
- BELLMAN / PONTRYAGIN ← EULER calculus of variations

KALMAN & co-workers - TIME DOMAIN
Linear & Non linear

concepts of STATE, CONTROLLABILITY, OBSERVABILITY
- observer design.

- nowadays MATRIX design equations
intuition from root-locus plots - TIME DOMAIN
or frequency domain techniques

13.8

DIGITAL SYSTEM: uses stream of bits or discrete quantities to represent signal

DISCRETE TIME SYSTEMS: processing block with i/p: sequence of samples, o/p sequence of samples

actual processing < sample by sample
sequence of data blocks.

CONTINUOUS TIME SYSTEMS: varying signal (expressed as fn. of time (usually)) real valued cont. variable
which may or may not be continuous

10. SISO
MIMO

11. TI
TV
example:
booster stage
of spacevehicle
(SV)
mass varies as
fuel consumed.

12. LINEAR
NONLINEAR

13. DISCRETE-TIME
CONTINUOUS
w.r.t. signals

(DIGITAL)

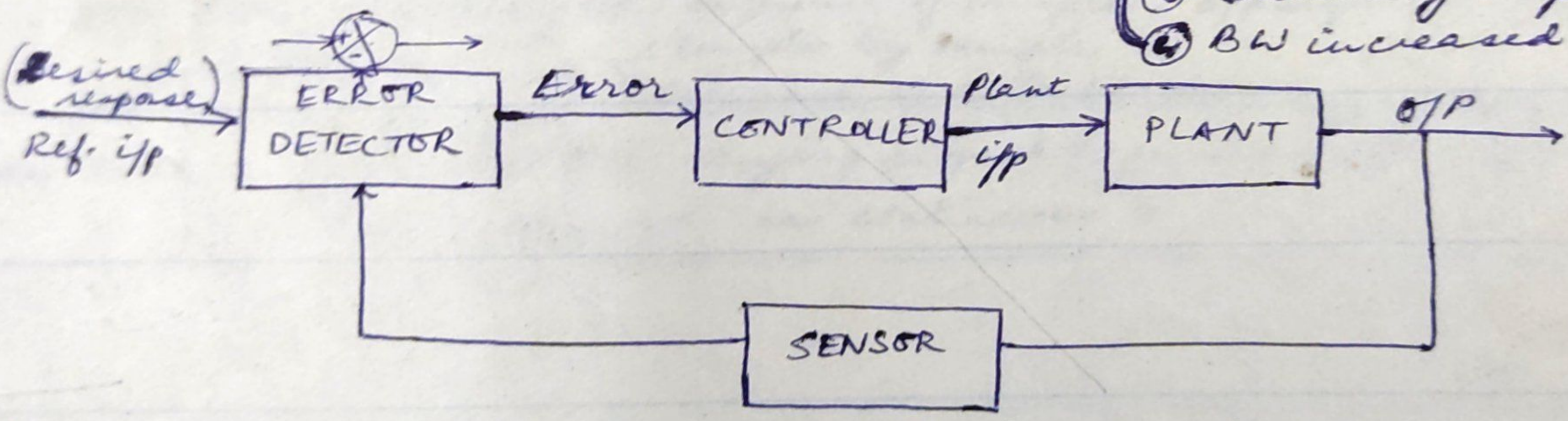
CONTROL SYSTEM

OL: O/P has no effect on control action

CL: O/P f/b (negative) to i/p for error actuating signal

negative f/b:

1. noise reduced/eliminat
2. gain reduced
3. stability improved.
4. BW increased



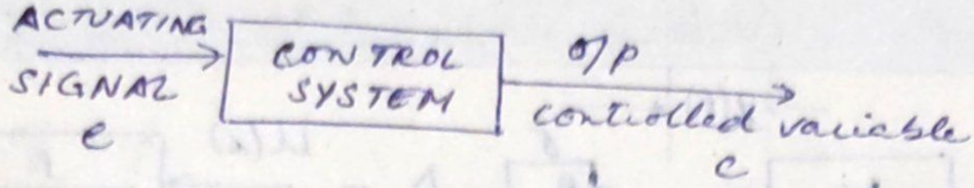
9. Indirect control – primary variable inaccessible

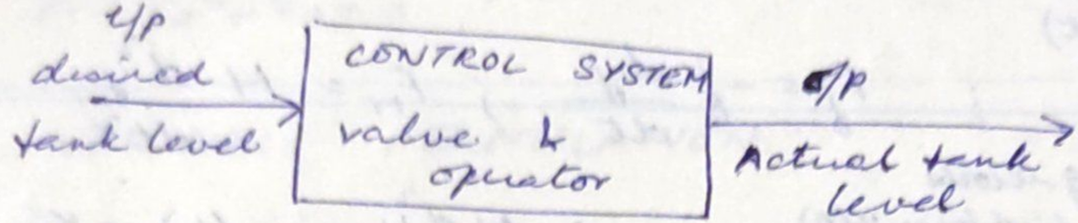
Direct control

Adaptive control – dynamic scenario, system ~~variable~~ non-stationary or system parameters change with time

Learning control – NN or ANN (Adaptive)

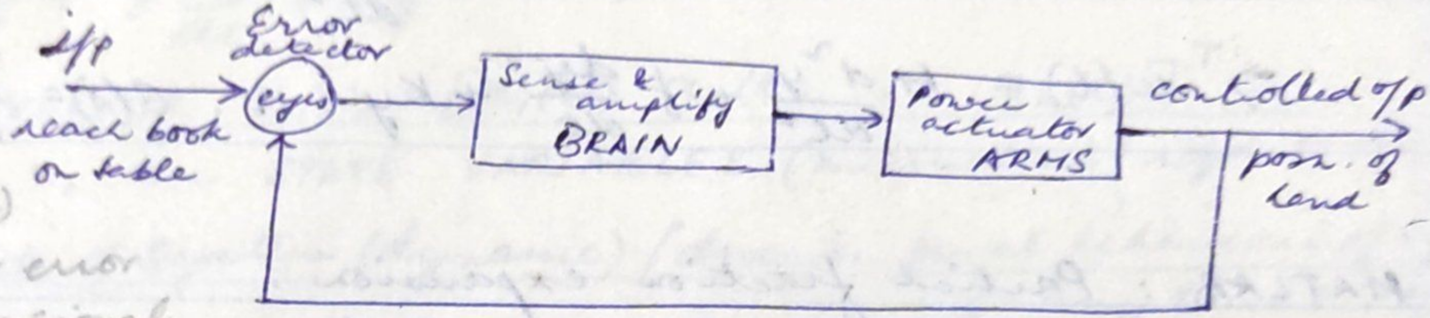
O : control
o/p has no effect on control action (NPP)

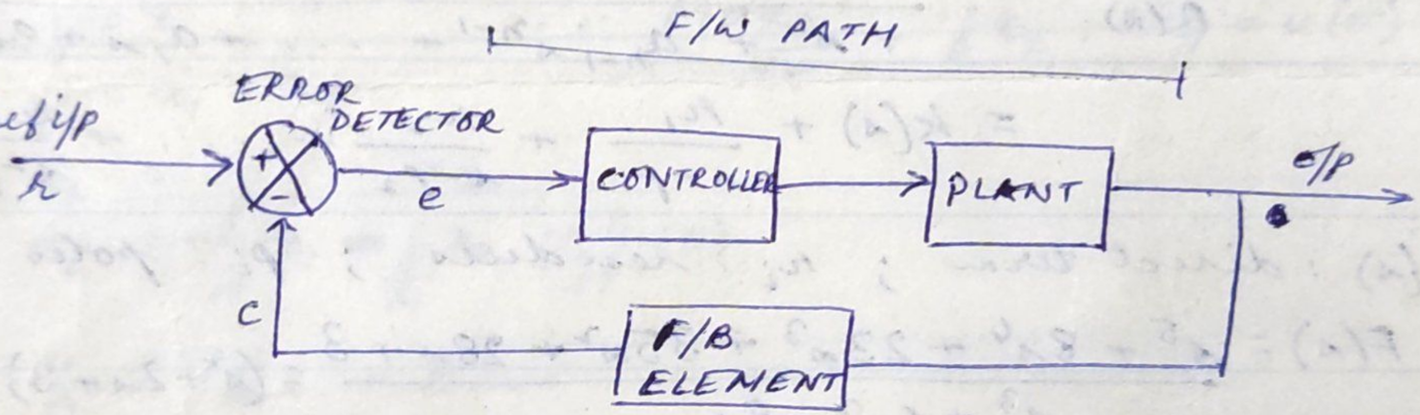




VII(a)

C : control
o/p f/b (-ve) to i/p for error actuating signal





MERITS OF F/B:

1. reduces sensitivity of system to parameter variations.

unknown, unwanted · qualitatively known unwanted

2. reduce effect of noise and disturbance on system response

3. improves BW, impedance characteristics & transient & freq. response.

stability

DEMERITS

1. increases system components and hence complexity

2. reduces system gain

3. may introduce instability — +ve feedback, effect of system delay, phase mismatch

Laplace Transform for Transfer function:

Transfer fn. $G(s) = \dfrac{\mathcal{L}(o/p)}{\mathcal{L}(i/p)} = \dfrac{P(s)}{Q(s)}$

Values of s for which $P(s) = 0 \longrightarrow$ ZEROS o $G(s) = 0$

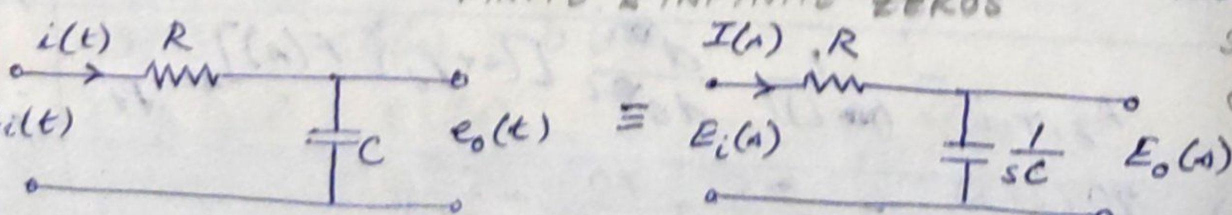
$Q(s) = 0 \longrightarrow$ POLES × $G(s) = \infty$

(EIGENVALUES)

characteristic equation of system — characteristic roots

$G(s)$ is a RATIONAL fn. ∴ η(zeros) = η(poles) including those at ∞.

FINITE & INFINITE ZEROS



S=∞ in expression yields G(s) = 0.

$$\therefore\ G(s) = \frac{E_o(s)}{E_i(s)} = \frac{1/sC}{R + \frac{1}{sC}} = \frac{1}{1 + sRC}$$