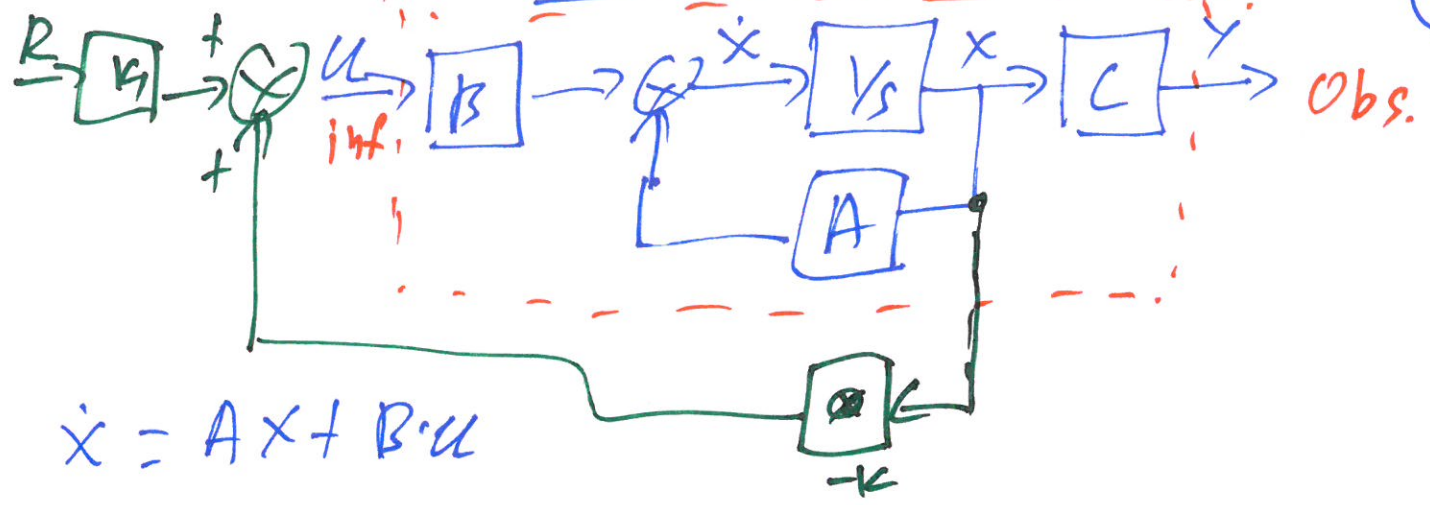


Revision



$$\dot{x} = Ax + B \cdot u$$

$$Y = C \cdot x$$

$$u = R \cdot K_1 - K \cdot x$$

- $R=0$ (Regulator?)

$$u = -Kx$$

$$\dot{x} = Ax + B \cdot (-Kx)$$

$$= \underbrace{(A - BK)}_{\substack{\text{CL S.M} \\ A_{cl}}} \cdot x$$

pole placement

CHECK

CTRB

(93)

poles $\rightarrow -\infty$ $\left\{ \begin{array}{l} \rightarrow \text{Faster sys} \\ \rightarrow \text{increase } K \end{array} \right.$

$$u = -Kx$$

LQR

$$J = \int (x^T Q x + u^T R u) dt$$

\downarrow speed \downarrow energy

$K = ?$

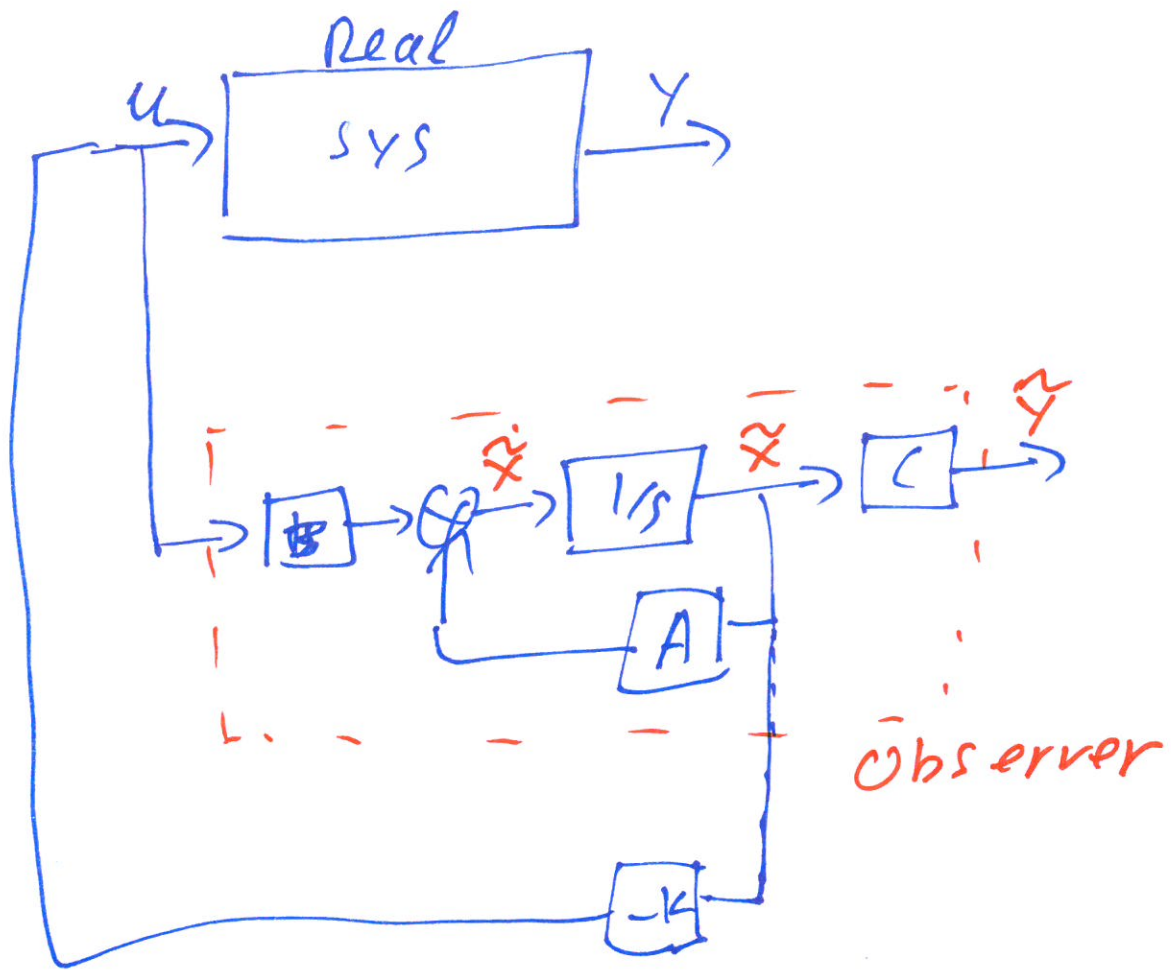
$$A^T P + P A - P B R^{-1} B^T P + Q = 0$$

$P = \dots$

$$K = R^{-1} B^T P$$

Estimation

(94)



$$\dot{\hat{x}} = A\hat{x} + B \cdot u, \quad \hat{y} = C \cdot \hat{x}$$

$$x(0) \neq \hat{x}(0)$$

$$\hat{x} \rightarrow x \quad \text{as } t \rightarrow \infty$$

$$e = x - \hat{x}$$

$$\lim_{t \rightarrow \infty} e = 0$$

$$e = x - \tilde{x}$$

$$\dot{e} = \dot{x} - \dot{\tilde{x}} \rightarrow Ax + Bu$$

$$\downarrow$$

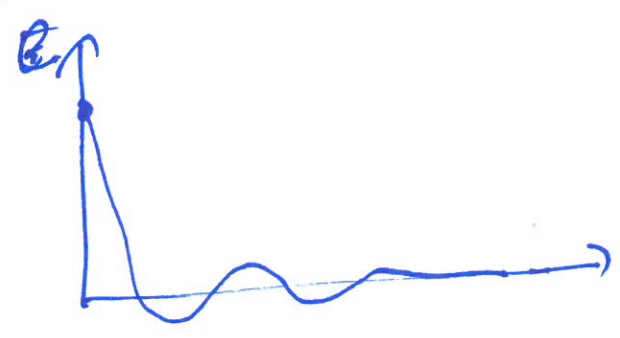
$$Ax + Bu$$

$$= Ax + Bu - (A\tilde{x} + Bu)$$

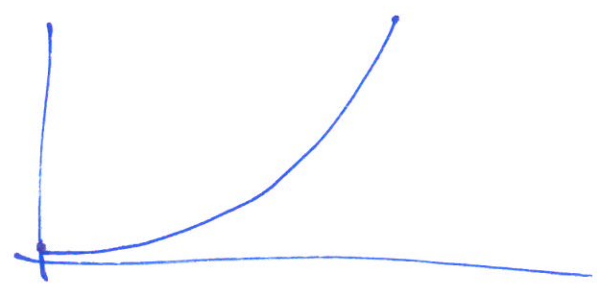
$$\dot{e} = A \cdot (x - \tilde{x})$$

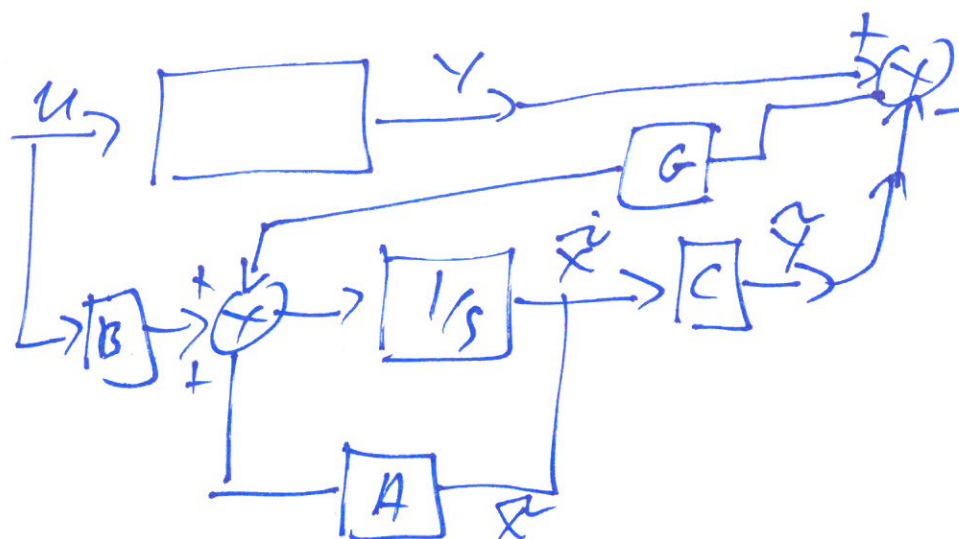
$$\dot{e} = A \cdot e$$

- $A \rightarrow$ stable eigenvalues
 \Rightarrow Error ODE = stable



- $A \rightarrow$ unstable eigs.
 \Rightarrow Error ODE = unstable





$$e = x - \tilde{x} \rightarrow 0$$

$$y - \tilde{y} \rightarrow 0$$

$$e = x - \tilde{x}$$

$$\dot{e} = \dot{x} - \dot{\tilde{x}} = Ax + \cancel{Bu} - (A\tilde{x} + \cancel{Bu} + G(y - \tilde{y}))$$

$$= Ax - A\tilde{x} - G \cdot (C \cdot x - C \cdot \tilde{x})$$

$$= Ae - G \cdot C(x - \tilde{x})$$

$$= Ae - G \cdot C \cdot e$$

$$= (A - G \cdot C) \cdot e$$

\downarrow
 C.L.S.M BUT Estimator

OBSV

$$A-B \cdot K$$

$$K = \text{place}(A, B, P)$$

(97)

↓
des
pole loc.

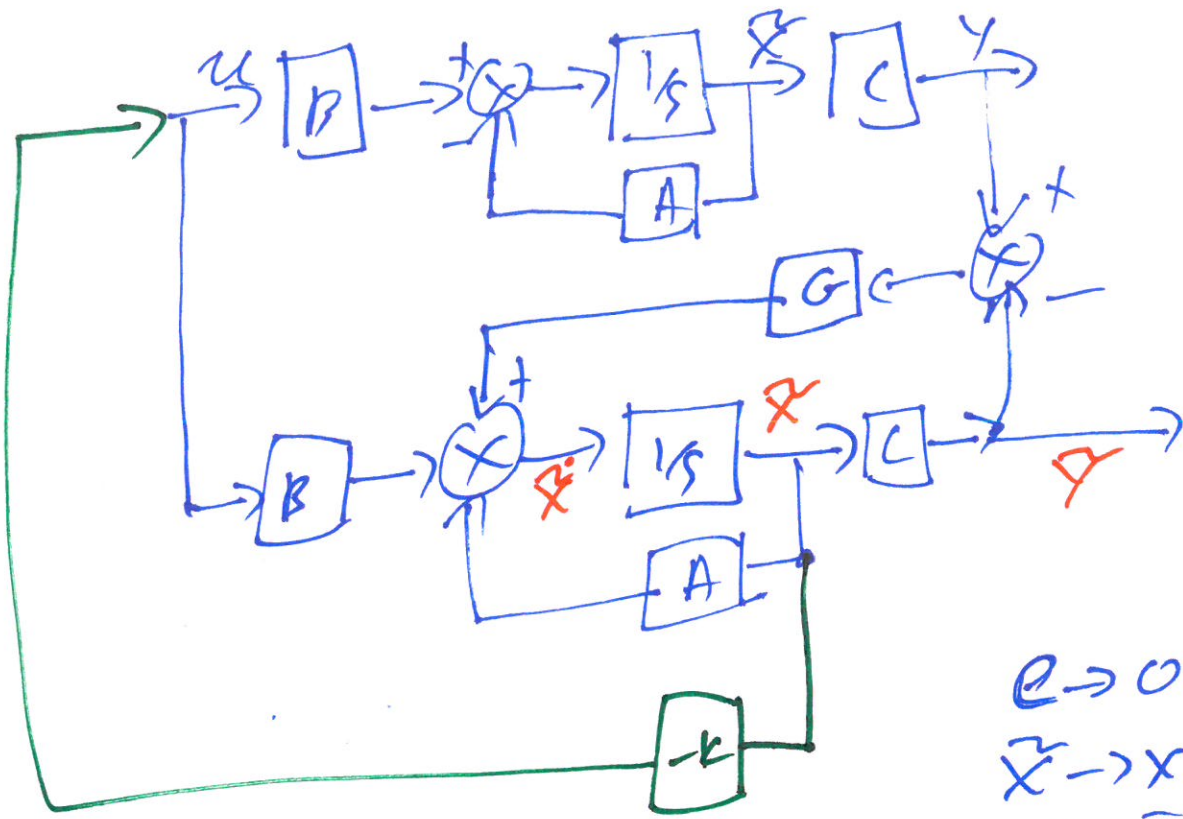
$$A-G \cdot C$$

$$(A-G \cdot C)'$$

$$A' - C' \cdot G'$$

$$G = \left(\text{place}(A', C', P) \right)'$$

(98)



$$\dot{e} = (A - GC) \cdot e$$

$$e \rightarrow 0$$

$$\tilde{x} \rightarrow x$$

$$u = -k\tilde{x}$$

$$= -kx$$

$$\dot{x} = Ax + Bu$$

$$+ B(-kx) = \dots \Rightarrow \dot{x} = (A - Bk) \cdot x$$

$$\dot{x} = Ax + B \cdot (-k\tilde{x})$$

$$= Ax - Bk\tilde{x}$$

$$= Ax - Bk\tilde{x} + (Bkx - Bkx)$$

$$= \underbrace{Ax} - \underbrace{Bk\tilde{x}} + \underbrace{Bkx} - \underbrace{Bkx}$$

$$= Ax - Bkx + Bkx - Bk\tilde{x}$$

$$\dot{x} = (A - Bk) \cdot x + Bk e$$

$$\dot{e} = (A - GC) \cdot e + 0 \cdot x$$

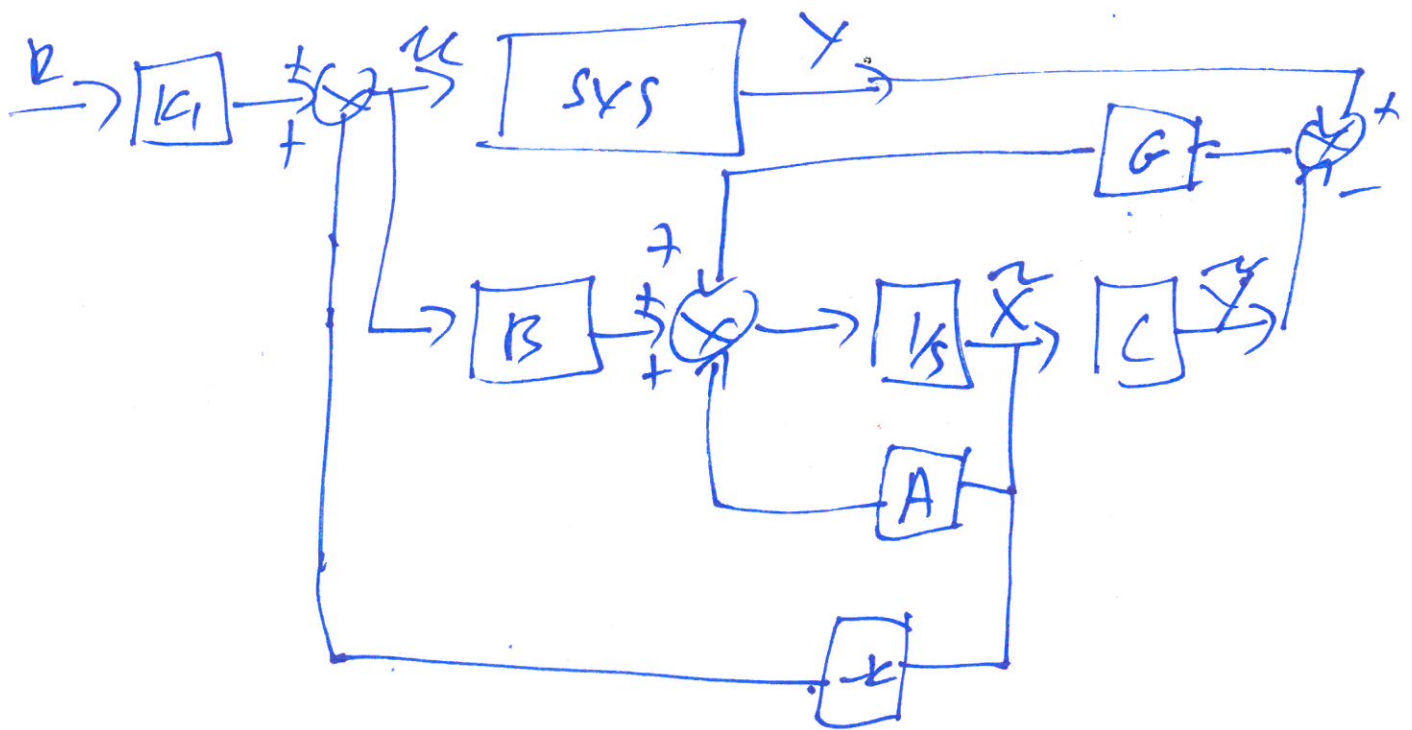
$$\begin{bmatrix} \dot{x} \\ \dot{e} \end{bmatrix} = \begin{bmatrix} A-BK & BK \\ 0 & A-GC \end{bmatrix} \cdot \begin{bmatrix} x \\ e \end{bmatrix}$$

(99)

eig \curvearrowright

$$| \lambda I - (A-BK) | | \lambda I - (A-GC) | = 0$$

Tracking.



R : Dem. out

$R = r_{ss} = \text{constant}$

SISO

$Y \rightarrow Y_{ss} = R = r_{ss}$

①

Des out

$x \rightarrow x_{ss}$

②

Des state

$u \rightarrow u_{ss}$

③

Des control signal

$$u = R \cdot K_1 - K \cdot X = K_1 \cdot r_{ss} - KX$$

100

$$u \rightarrow u_{ss}$$



$$\text{if } u = u_{ss} - K(X - X_{ss})$$