PMR3523 Controle Moderno

Apoio à Aula

Projeto de controladores por realimentação dos estados
(alocação de polos)
Distúrbio e Referência (Servo)

- CAP 3 - LIVRO TEXTO

- OBJETIVO ANTERIOR $x(t) \to 0$, $x(0) \neq 0$ (REGULADOR)

- OBJETIVO AGORA É ACOMPANHAR TRAJETÓRIA (SET-POINT)

$$y = C.x \to y_d \text{ (set-point)}$$

USAREMOS $u = -G.x + v_d$

$$\Rightarrow \quad \dot{x} = Ax + Bu = Ax + B(-Gx + v_d)$$

$$\dot{x} = (A - BG)x + B.v_d$$

$\Rightarrow$ NO EQUILÍBRIO $\dot{x} = 0$ E $x = x_d$ TAL QUE $y_d = C.x_d$

$$0 = (A - BG).x_d + B.v_d \Rightarrow x_d = -(A - BG)^{-1}.B.v_d$$

$$y_d = C.x_d = -C.(A - BG)^{-1}.B.v_d$$

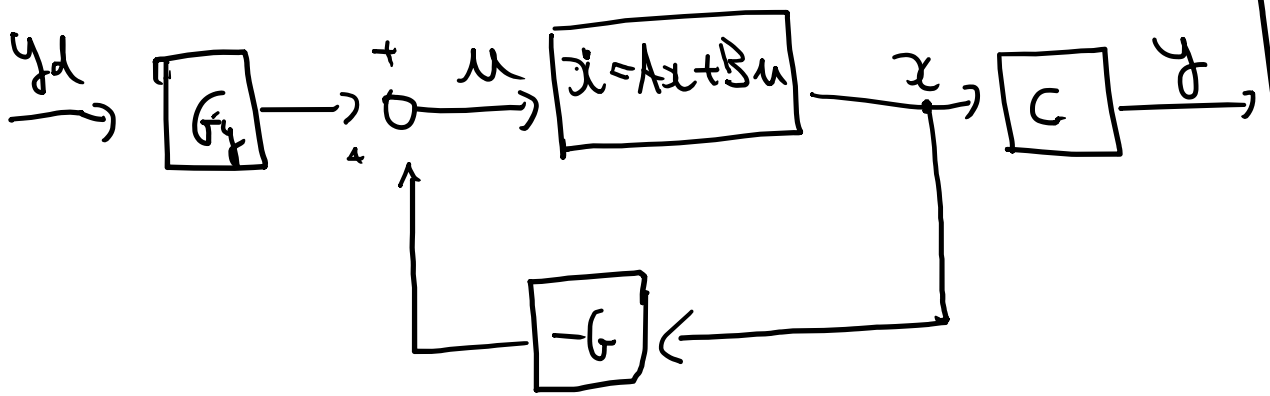
$$y_d = C \cdot x_d = -C \cdot (A - BG)^{-1} \cdot B \cdot v_d$$

$$\boxed{v_d = -\left[C \cdot (A - BG)^{-1} \cdot B\right]^{-1} \cdot y_d}$$

MATRIZ PRÉ COMPENSAÇÃO SET-POINT $= G_y$

OBS: $(A-BG)^{-1}$ EXISTE E POSSUI POLOS ESTÁVEIS POIS É A MATRIZ DO SISTEMA EM MALHA FECHADA.

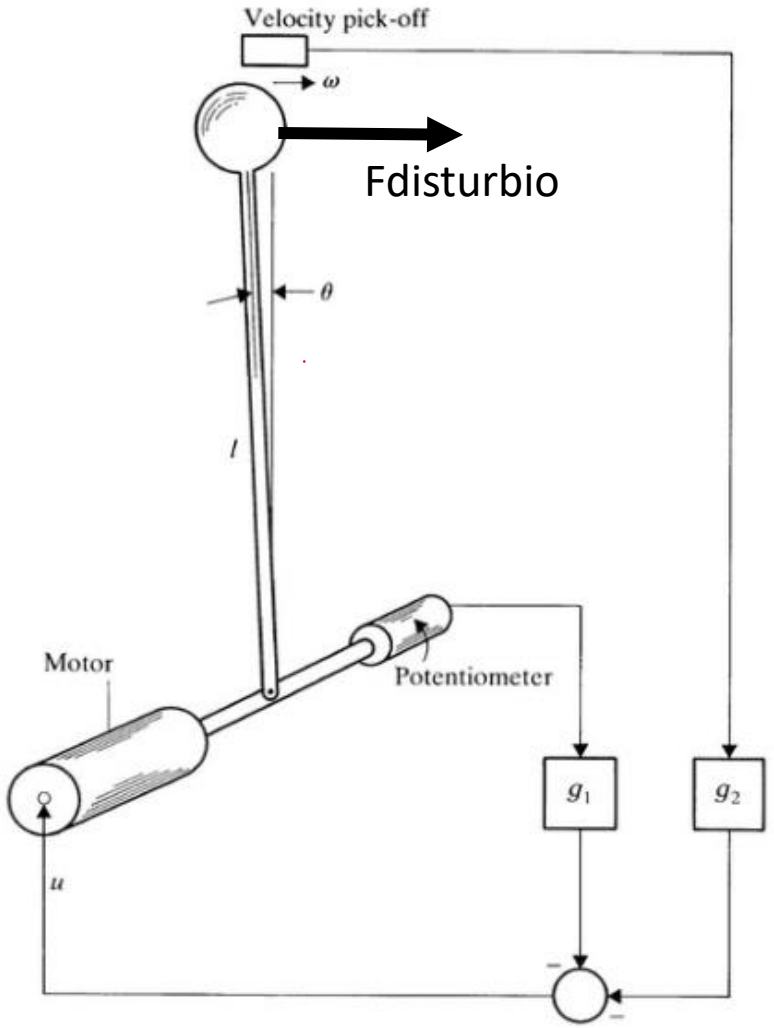
OBS2)



OBS3) VALE P/ y_d CONSTANTE, MAS PODE SER USADA SE y_d VARIAR LENTAMENTE

OBS4) SE A e B NÃO FOREM CONHECIDOS COM EXATIDÃO

$y \rightarrow y_d' \neq y_d$



$$\dot{\theta} = \omega$$

$$\dot{\omega} = \Omega^2\theta - \alpha\omega + \beta u$$

$$\alpha = -K^2/JR \quad \beta = K/JR \qquad J = J_m + ml^2 \qquad \Omega^2 = \frac{mgl}{J + ml^2} = \frac{g}{l + J/ml}$$

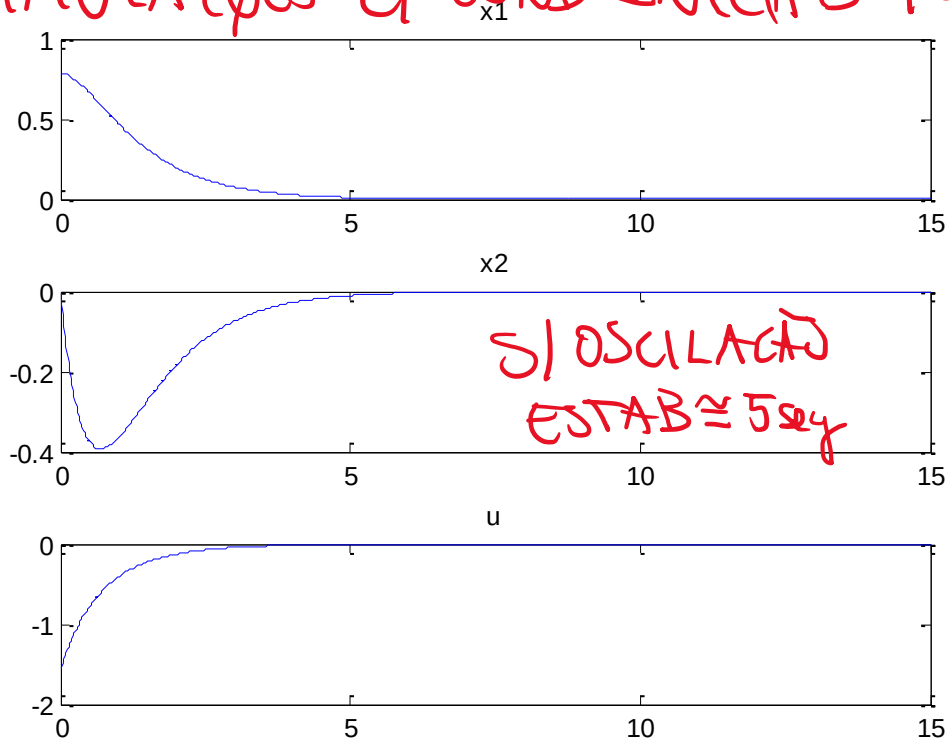
$$A = \begin{bmatrix} 0 & 1 \\ \Omega^2 & -\alpha \end{bmatrix} \qquad b = \begin{bmatrix} 0 \\ \beta \end{bmatrix}$$

DISTÚRBIO

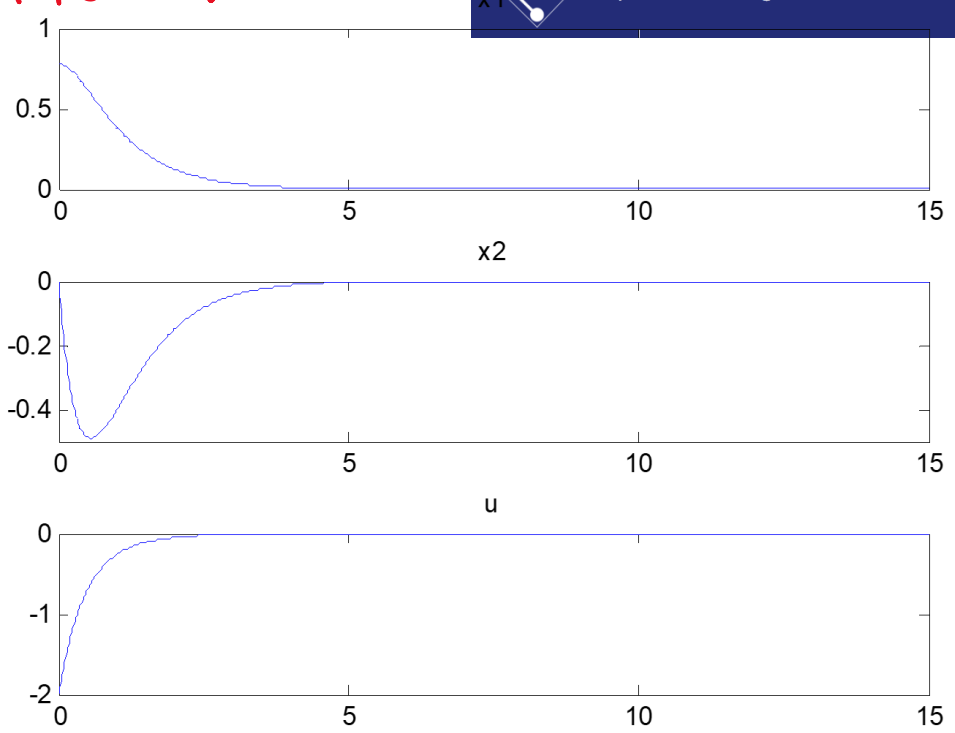
$$\begin{pmatrix} \dot{\theta} \\ \dot{\omega} \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ 2 & -0{,}1 \end{pmatrix} \begin{pmatrix} \theta \\ \omega \end{pmatrix} + \begin{pmatrix} 0 \\ 2 \end{pmatrix} \cdot u + \begin{pmatrix} 0 \\ 1 \end{pmatrix} w$$

$$y = \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} \theta \\ \omega \end{pmatrix}$$

SIMULAÇÕES c/ COND. INICIAIS ≠0 (SEM SETPOINT)



S/ OSCILAÇÃO
ESTAB ≅ 5seg

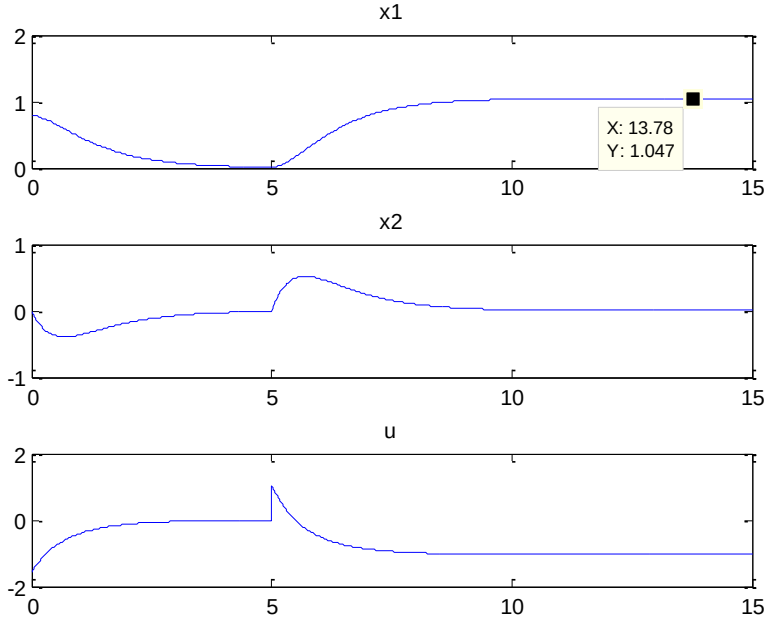


PROJETADO G
CONSIDERANDO 20% ERRO A
E -20% ERRO B
⇓
COMPORTAMENTO "ROBUSTO"

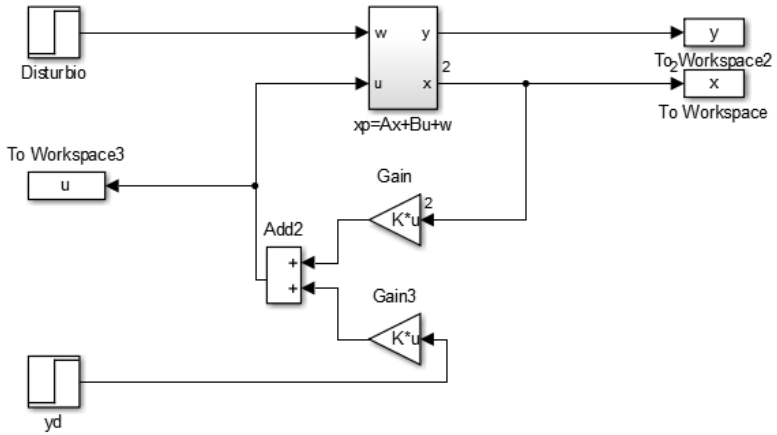
```
A = [0 1
     2 -0.1];
B = [0;2];
C = [1 0];
sys = ss(A,B,eye(2),0);

g = place(A,B,[-1 -2])
```

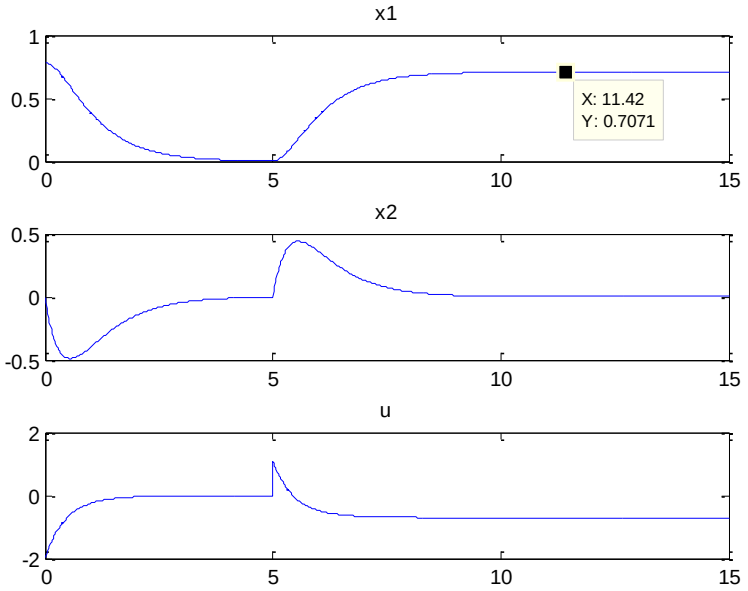
2 POLOS REAIS

Simulação com SetPoint de 60deg aplicado em t=5s




```
Gyd = inv(C*inv(A-B*g)*B);
```






```
Gyd = inv(C*inv(1.2A-0.8B*g)*0.8B);
```

COM ERROS 20%, O PENDULO ESTABILIZOU LONGE DOS 60° DO SET-POINT

⇒ POUCO "ROBUSTO"

CONTROLE INTEGRAL

DISTURBIO E TRACKING

$$\dot{x} = Ax + Bu + w$$
$$y = C \cdot x$$

NOVA VARIÁVEL $z = \int y - y_d \, dt$

$$\dot{z} = y - y_d$$

SIST. EXTENDIDO

$$\begin{pmatrix} \dot{x} \\ \dot{z} \end{pmatrix} = \begin{pmatrix} Ax + Bu + w \\ y - y_d \end{pmatrix} = \begin{pmatrix} Ax + Bu + w \\ Cx - y_d \end{pmatrix}$$

$$\begin{pmatrix} \dot{x} \\ \dot{z} \end{pmatrix} = \left(\begin{array}{c|c} A & 0 \\ \hline C & 0 \end{array}\right) \begin{pmatrix} x \\ z \end{pmatrix} + \begin{pmatrix} B \\ \hline 0 \end{pmatrix} u + \begin{pmatrix} w \\ -y_d \end{pmatrix}$$

$$u = -G_{ext} \cdot x_{ext} = -Gx - G_i z$$

COM G, G_i OBTIDO POR ALOCAÇÃO DE POLOS DE $\left(\begin{array}{c|c} A & 0 \\ \hline C & 0 \end{array}\right) \left(\begin{array}{c} B \\ \hline 0 \end{array}\right)$

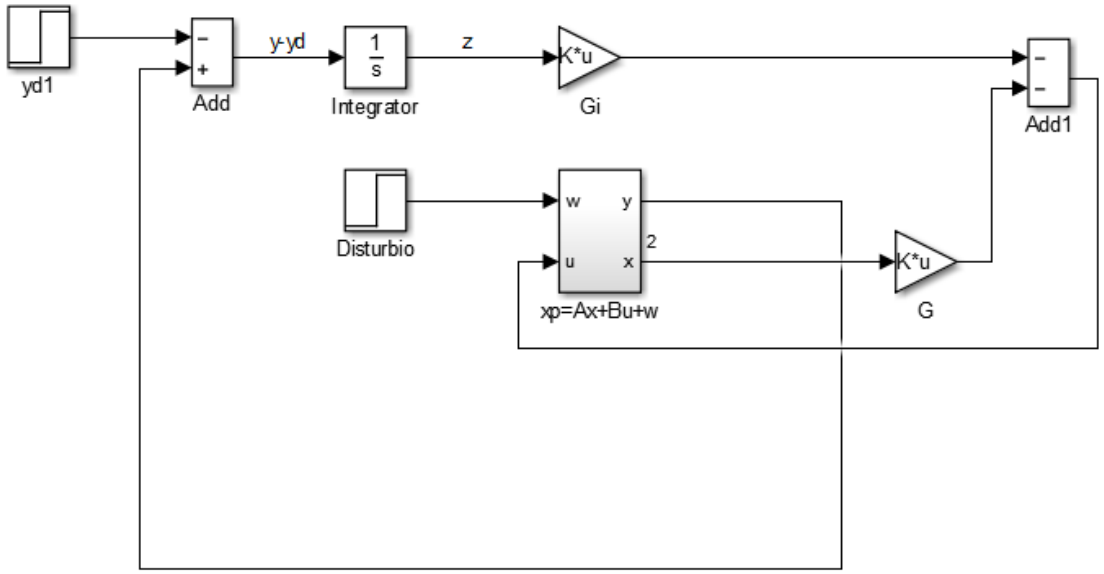
COM ISSO $\Rightarrow \dot{x}_{ext} \to 0 \Rightarrow$

$$\begin{pmatrix} \dot{x} \\ \dot{z} \end{pmatrix} = 0 \Rightarrow \dot{z} = 0 \Rightarrow y \to y_d$$

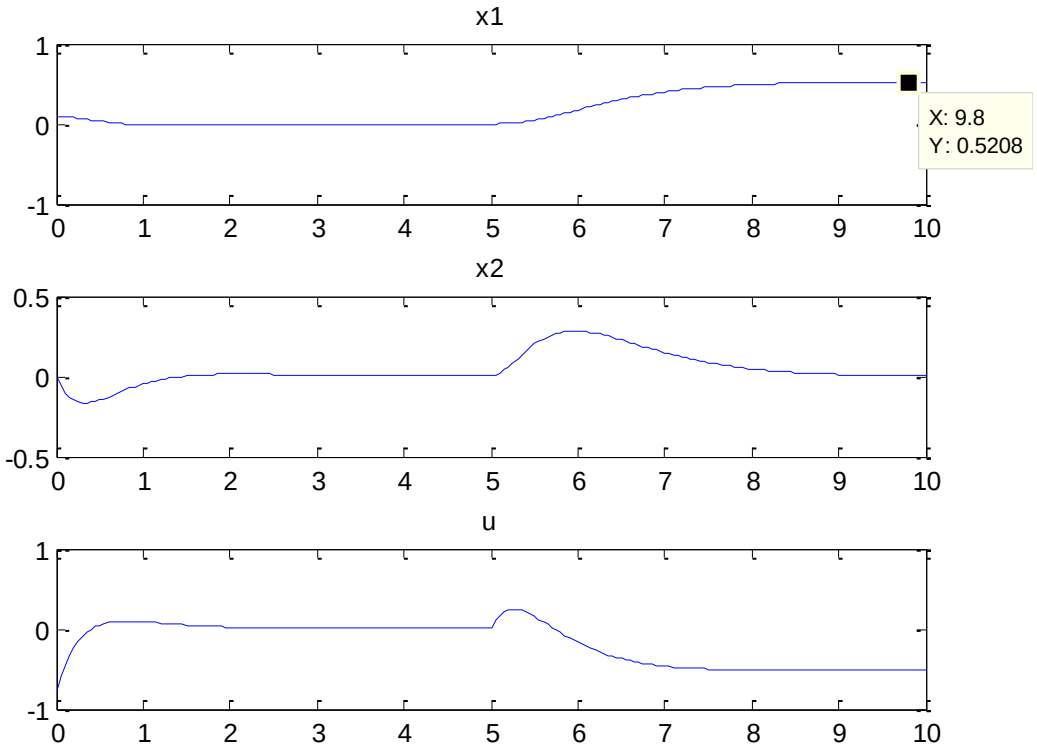
VAMOS GARANTIR QUE

$$\begin{pmatrix} \dot{x} \\ \dot{z} \end{pmatrix} = 0 \Rightarrow \quad \dot{z} = y - y_d \Rightarrow \boxed{y \to y_d}$$

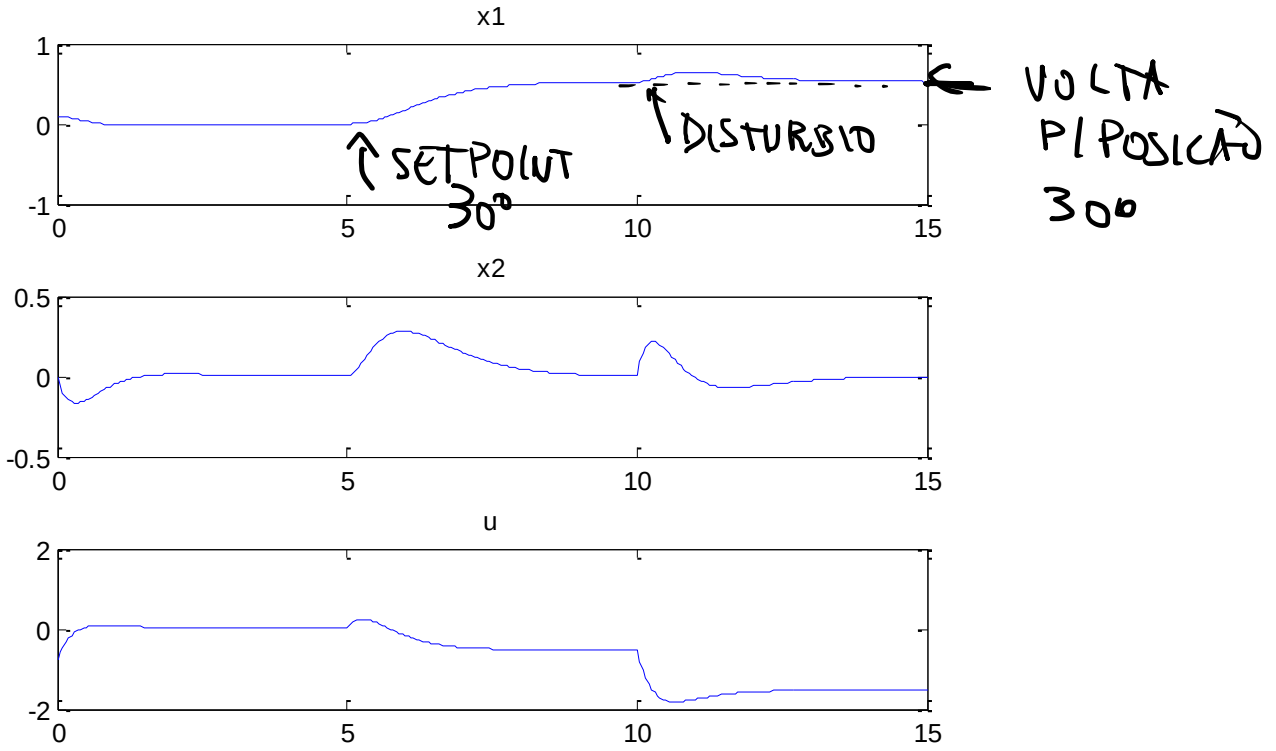
↳ INDEPENDENTE DO DISTURBIO w



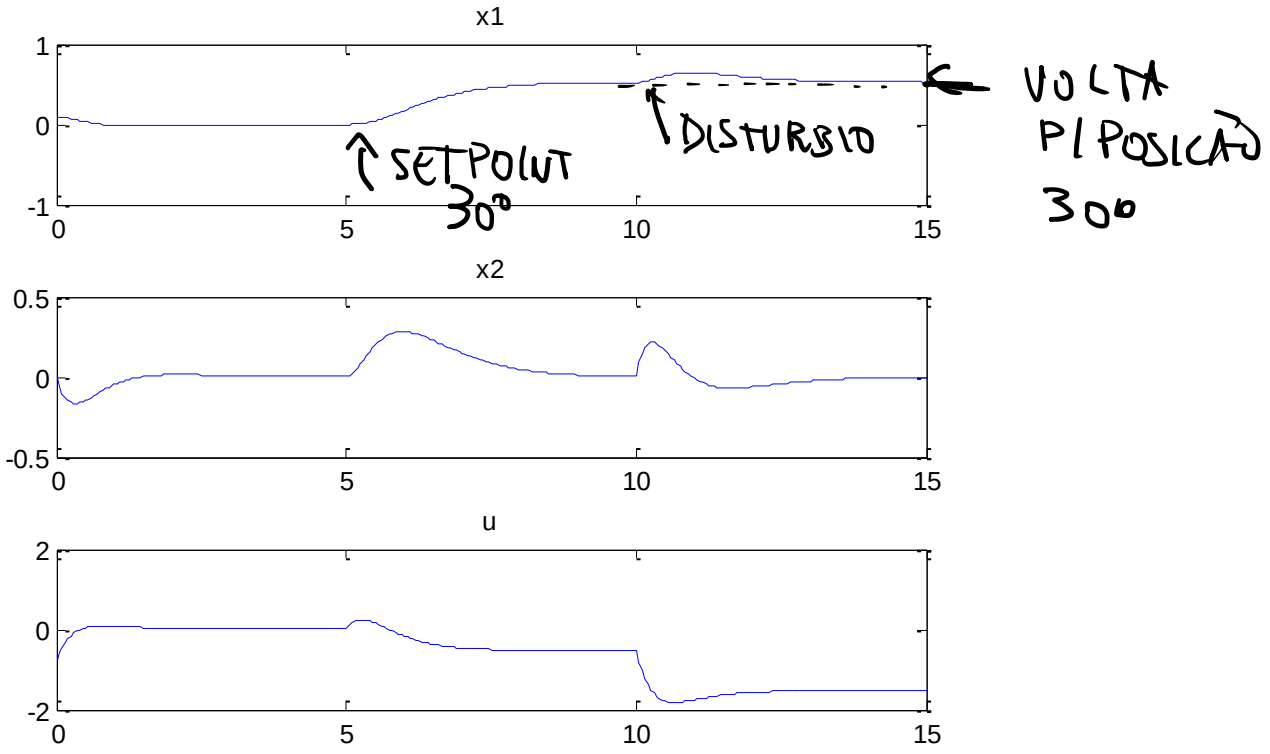

```
% com integral
Ae = [A zeros(2,1)
      C 0           ];
Be = [B
      0];

g2 = place(Ae,Be,[-3 -2 -1.5]);
```



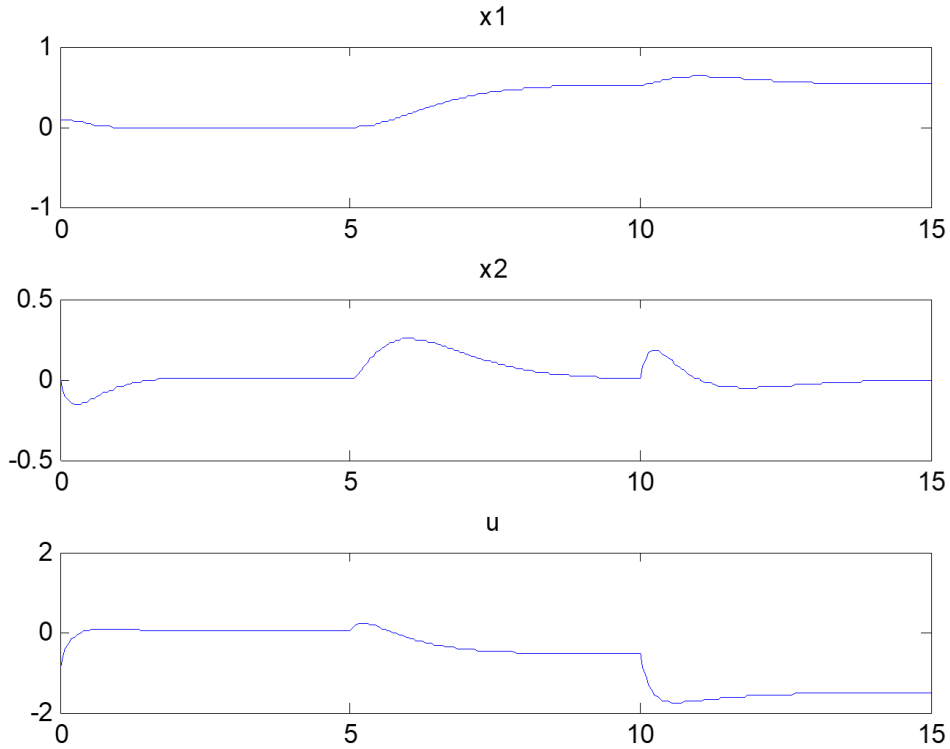
SET POINT 30°



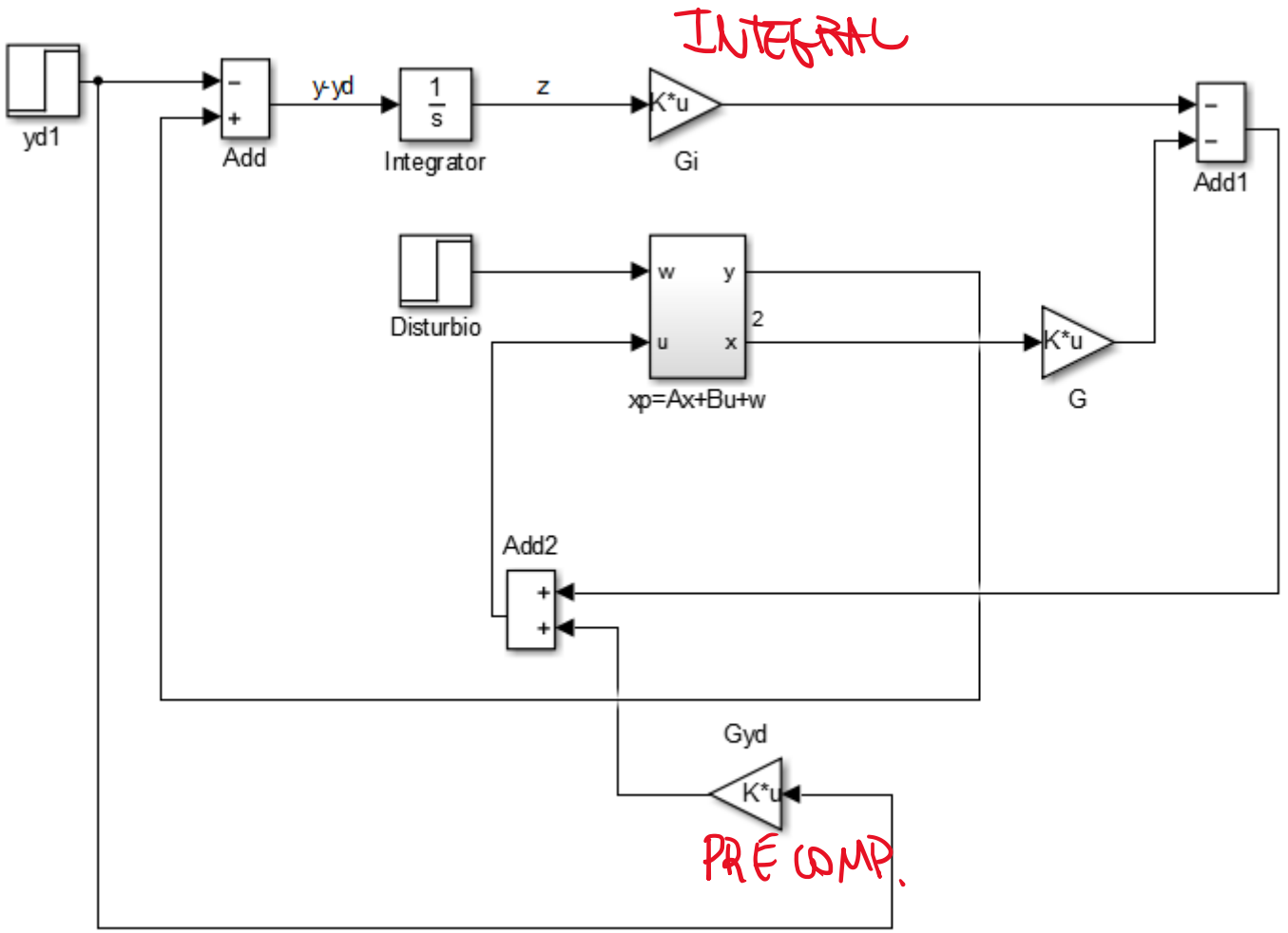
ROBUSTEZ DISTÚRBIO



ROBUSTEZ DISTÚRBIO



PROJETO COM 20% ERRO MODELO → PODE-SE ATESTAR BOA ROBUSTEZ CONTROLE INTEGRAL.

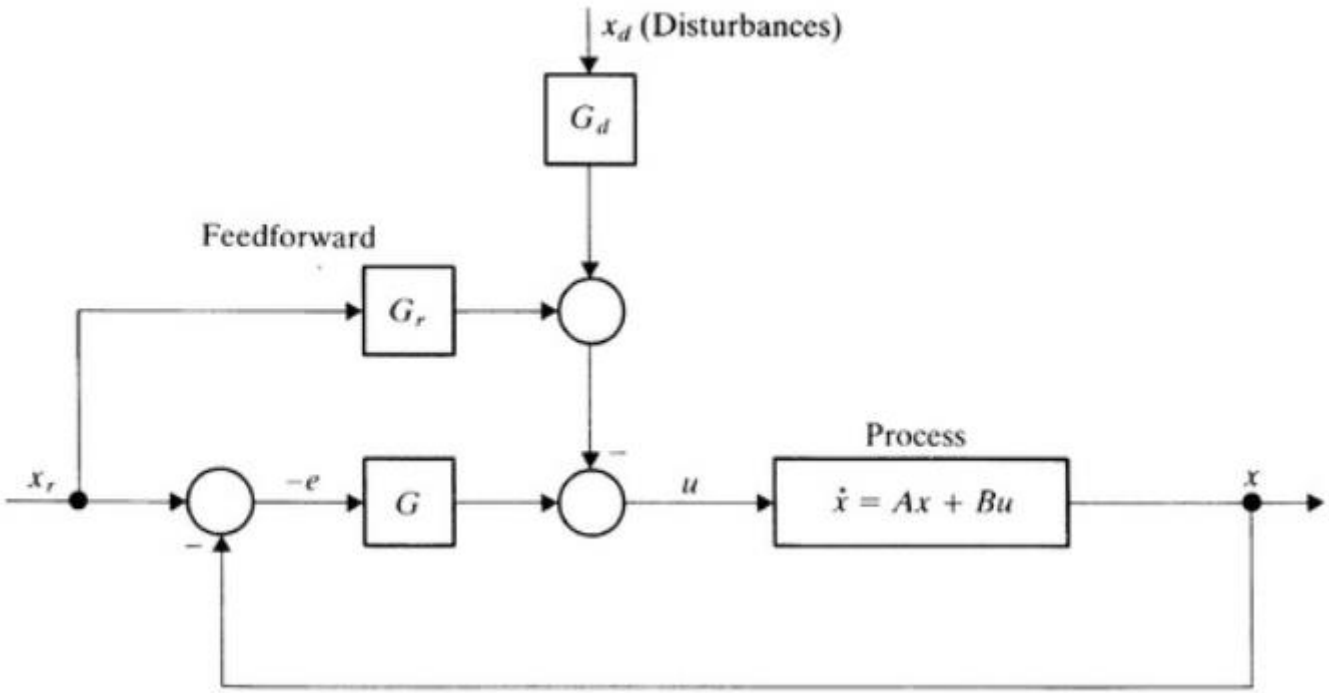


ASSOCIANDO

- CONTROLE INTEGRAL
  +
- CONTROLE PRÉ COMPENSADO
  SET POINT

→ ROBUSTEZ

↓ RÁPIDO


x_d (Disturbances)
G_d
Feedforward
G_r
Process
$\dot{x} = Ax + Bu$
x_r
$-e$
G
u
x