```
clear
close all
```

Definição do Sistema

```
H_s = tf(2, [1 2 1]);
time_limit = 30;
cont_step_time = 0.01;
```

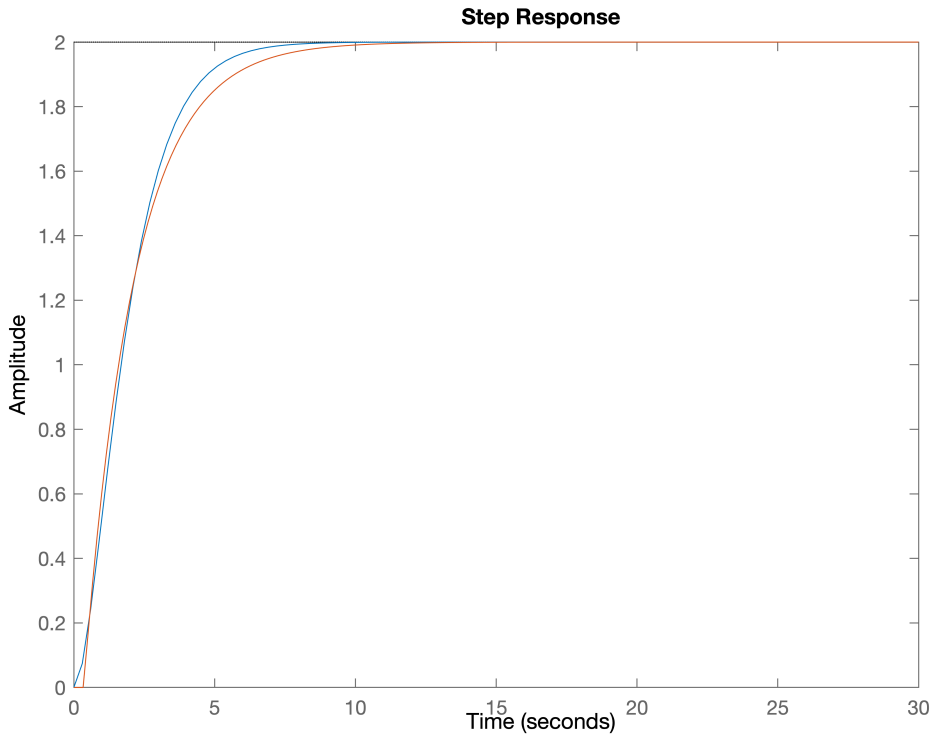
Análise de Malha Aberta

```
[y_ol, t_ol] = step(H_s, time_limit);
info = stepinfo(y_ol, t_ol)
```

```
info = struct with fields:
         RiseTime: 3.3681
    TransientTime: 5.8432
     SettlingTime: 5.8432
      SettlingMin: 1.8016
      SettlingMax: 2.0000
        Overshoot: 0
       Undershoot: 0
             Peak: 2.0000
         PeakTime: 30
```

Aproximação de 1° Grau

```
K = 2;
T = 0.35;
tau = 1.79;
M_s = tf(K, [tau 1], 'inputDelay', T);

figure(1)
step(H_s, time_limit); hold on;
step(M_s, time_limit); hold off;
```



Controlador CHR

```
Ti = tau;
Td = T / 2;

Kp = (0.6 * tau)/(K * T)
```

```
Kp = 1.5343
```

```
Ki = Kp / Ti
```

```
Ki = 0.8571
```

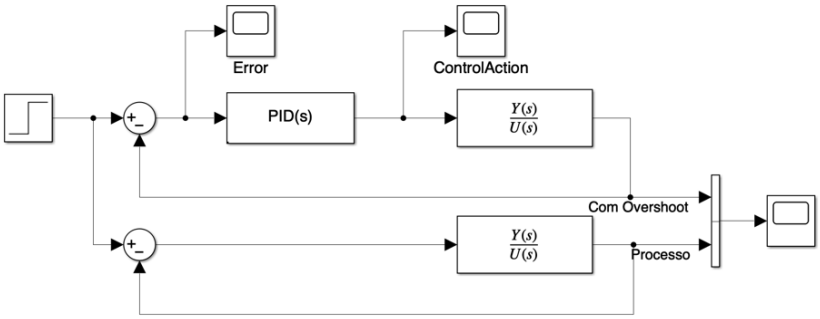
```
Kd = Kp * Td
```

```
Kd = 0.2685
```

```


C_s = tf(Kd, 1) + tf(Ki, [1 0]) + tf([Kd 0], [Kd/20 1])
```

```
C_s =

  0.2721 s^2 + 0.28 s + 0.8571
  ----------------------------
        0.01343 s^2 + s

Continuous-time transfer function.
```

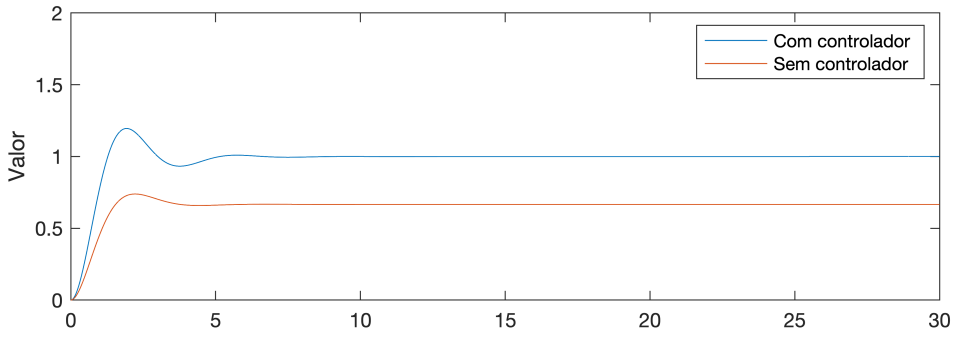
Simulação Contínua

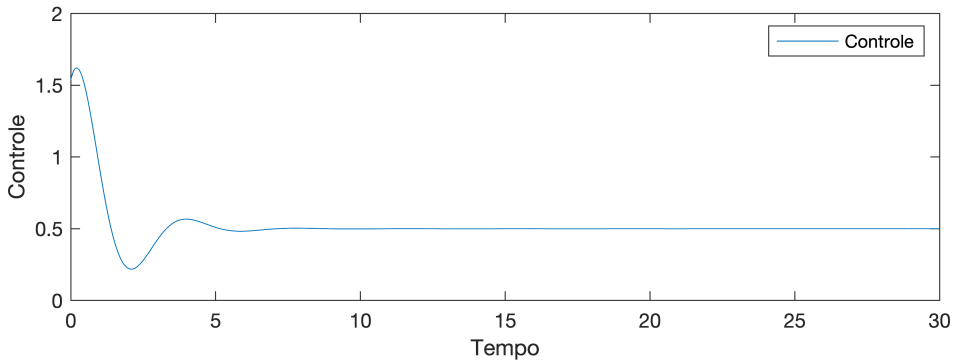



```
sim_cont = sim("cont.slx");
```

Verificação da Simulação

```
error_cont = sim_cont.Error(:,2);
time_cont = sim_cont.Error(:,1);
control_cont = sim_cont.ControlAction(:,2);
output_cont = sim_cont.Output(:,2);
model_cont = sim_cont.Output(:,3);

figure(2)

subplot(211);
plot(time_cont, output_cont); hold on;
plot(time_cont, model_cont); hold on;
ylim([0,2]);
legend("Com controlador", "Sem controlador");
ylabel("Valor");

subplot(212);
plot(time_cont, control_cont); hold on;
ylim([0,2]);
legend("Controle");
ylabel("Controle");
xlabel("Tempo");
```






```
IAE = 0;
ITAE = 0;

for i = 1:(20/cont_step_time)
    error_abs_ist = abs(error_cont(i));
    IAE = IAE + error_abs_ist;
    ITAE = ITAE + time_cont(i) * error_abs_ist;
end

IAE = IAE * cont_step_time
```

```
IAE = 1.0223
```

```
ITAE = ITAE * cont_step_time
```

```
ITAE = 1.1752
```

```
max_value = max(output_cont);
settling_value = output_cont(end);

overshoot = max_value - settling_value
```

```
overshoot = 0.1954
```

```
v10 = settling_value * 0.1;
v90 = settling_value * 0.9;
output_bigger_v10 = find(output_cont >= v10);
output_less_v90 = find(output_cont <= v90);
```

```
t10 = time_cont(output_bigger_v10(1));
t90 = time_cont(output_less_v90(end));
RT = t90 - t10
```

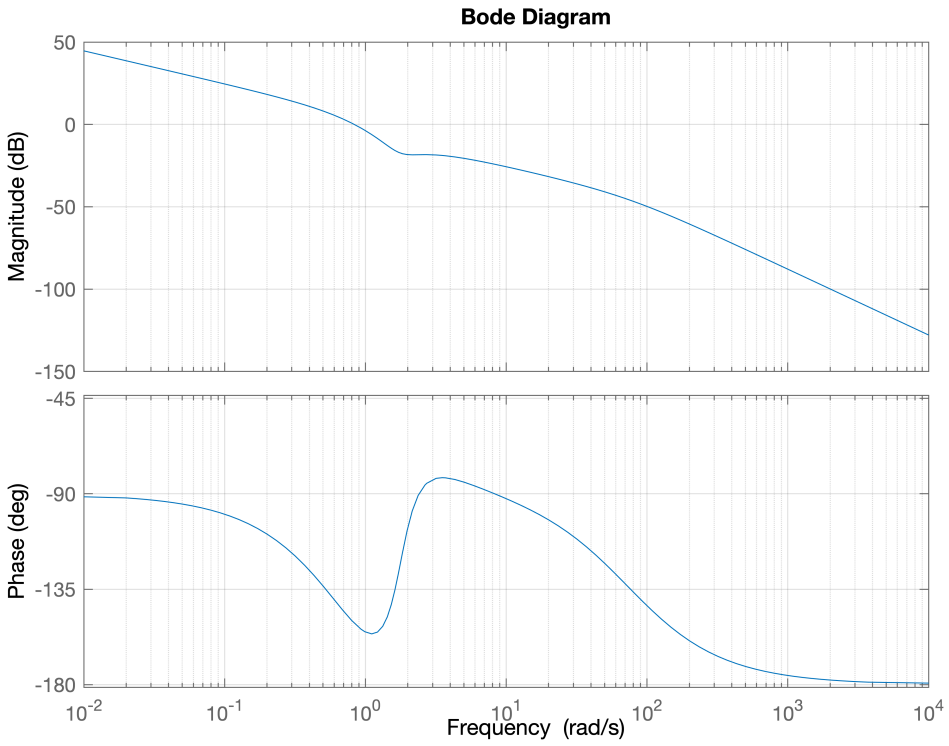
```
RT = 0.8500
```

Frequência de Corte e Largura de Faixa

```
G_s = C_s * H_s
```

```
G_s =

        0.5442 s^2 + 0.56 s + 1.714
  ---------------------------------------
  0.01343 s^4 + 1.027 s^3 + 2.013 s^2 + s

Continuous-time transfer function.
```

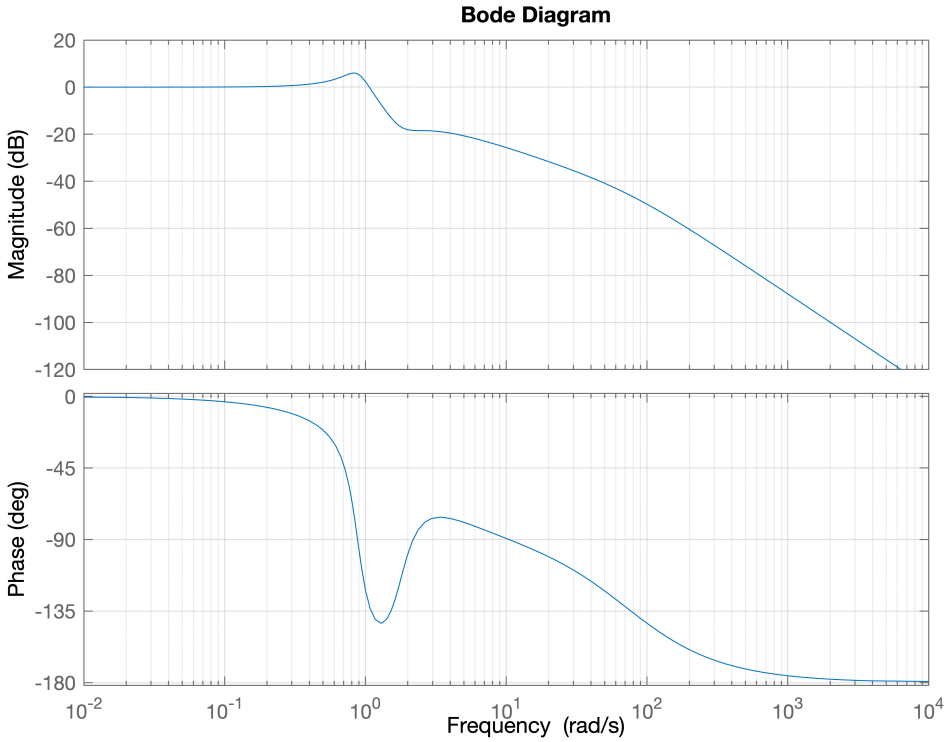
```
figure(3)
bode(G_s); grid on;
```




```
fc = 0.834
```

```
fc = 0.8340
```

```
figure(4)
bode(feedback(G_s,1)); grid on;
```




```
Wbw = bandwidth(feedback(G_s,1))
```

```
Wbw = 1.1520
```

```
wa = Wbw * 40;
dt_max = 2*pi/wa
```

```
dt_max = 0.1364
```

```
delta_time = 0.075;
```

Discretização

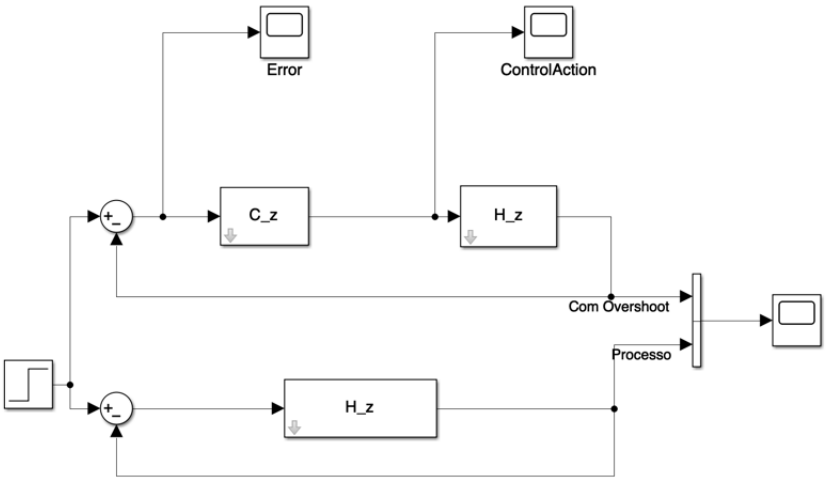
```
sf = tf([1, -1], delta_time,delta_time);
sb = tf([1,-1],[delta_time, 0 ],delta_time);
C_z = Kp + Ki/sf + Kd*sb/(Kd/20*sb+1)
```

```
C_z =

   0.03031 z^3 - 0.05157 z^2 + 0.02162 z
  ----------------------------------------
  0.006632 z^3 - 0.007639 z^2 + 0.001007 z

Sample time: 0.075 seconds
Discrete-time transfer function.
```

```
H_z = c2d(H_s,delta_time)
```

```
H_z =

  0.005352 z + 0.005091
  ----------------------
  z^2 - 1.855 z + 0.8607

Sample time: 0.075 seconds
Discrete-time transfer function.
```

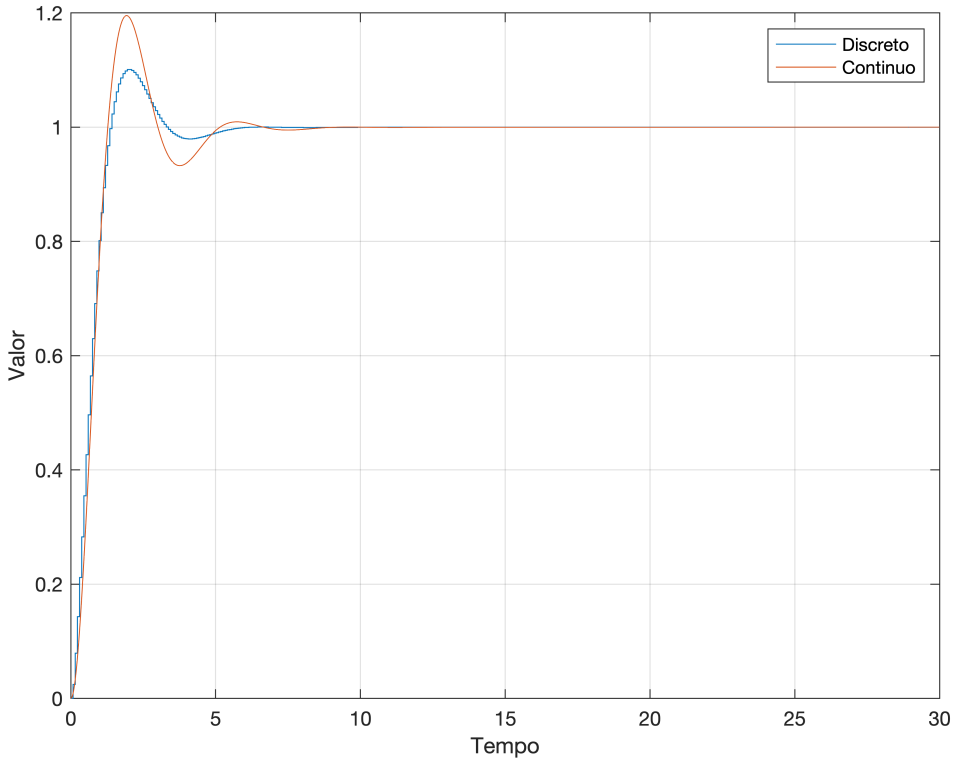
Simulação Discreta




```
sim_disc = sim("disc.slx");
```

Validação da Discretização

```
time_disc = sim_disc.Error(:,1);
output_disc = sim_disc.Output(:,2);
control_disc = sim_disc.ControlAction(:,2);

figure(5)

stairs(time_disc, output_disc); hold on;
plot(time_cont, output_cont); hold on;
grid on;
legend("Discreto", "Continuo")
xlabel("Tempo")
ylabel("Valor")
```



Equação de Diferenças

$$C(z) = \frac{0{,}03031z^3 - 0{,}05157z^2 + 0{,}02162z}{0{,}006632z^3 - 0{,}007639z^2 + 0{,}001007z}$$

$$C(z) = \frac{0{,}03031z^2 - 0{,}05157z + 0{,}02162}{0{,}006632z^2 - 0{,}007639z + 0{,}001007}$$

$$C(z) = \frac{4{,}5703z^2 - 7{,}7759z + 3{,}2599}{z^2 - 1{,}5118z + 0{,}1518}$$

$$\frac{U(z)}{E(z)} = \frac{4{,}5003z^2 - 7{,}7759z + 3{,}2599}{z^2 - 1{,}5118z + 0{,}1518}$$

$$z^2U(z) - 1{,}1512zU(z) + 0{,}1518U(z) = 4{,}5703z^2E(z) - 7{,}7759zE(z) + 3{,}2599E(z)$$

$$u[k+2] - 1{,}1512u[k+1] - 0{,}1518u[k] = 4{,}5703e[k+2] - 7{,}7759e[k+1] + 3{,}2599e[k]$$

$$u[k+2] = 1{,}1512u[k-1] + 0{,}1518u[k] + 4{,}5703e[k+2] - 7{,}7759e[k+1] + 3{,}2599e[k]$$

$$H(z) = \frac{0{,}005352z + 0{,}005091}{z^2 - 1{,}855z + 0{,}8607}$$

$$\frac{Y(z)}{U(z)} = \frac{0{,}005352z + 0{,}005091}{z^2 - 1{,}855z + 0{,}8607}$$

$$z^2Y(z) - 1{,}855zY(z) + 0{,}8607z = 0{,}005352zU(z) + 0{,}005091U(z)$$

$$y[k+2] - 1{,}855y[k+1] + 0{,}8607y[k] = 0{,}005352u[k+1] + 0{,}005091u[k]$$

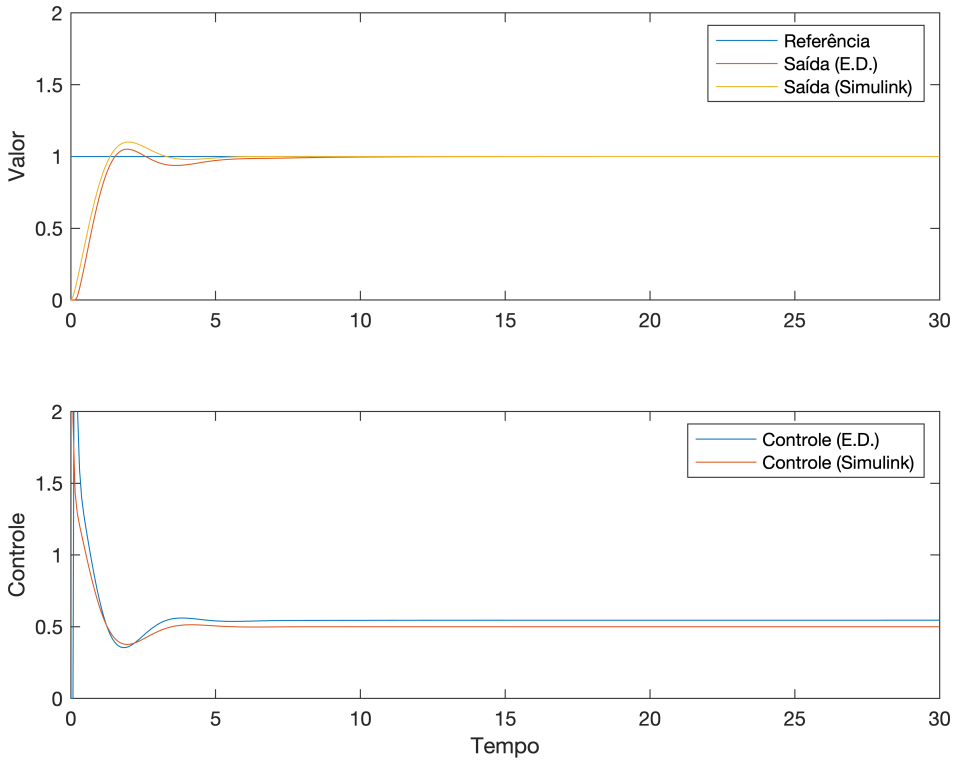
$$y[k+2] = 0{,}005352u[k+1] + 0{,}005091u[k] + 1{,}855y[k+1] - 0{,}8607y[k]$$

Simulação por Equação de Diferenças

```
t = 0:delta_time:30;
w = ones(size(t));
[e, u, y] = discrete_simulation(delta_time, 30, w);
```

Validação Equação de Diferenças

```
figure(6)

subplot(211);
plot(t, w); hold on;
plot(t, y); hold on;
plot(time_disc, output_disc); hold on;
ylim([0,2]);
legend("Referência", "Saída (E.D.)", "Saída (Simulink)");
ylabel("Valor");

subplot(212);
plot(t, u); hold on;
plot(time_disc, control_disc); hold on;
ylim([0,2]);
legend("Controle (E.D.)", "Controle (Simulink)");
ylabel("Controle");
xlabel("Tempo");
```


Referência
Saída (E.D.)
Saída (Simulink)
Valor
0
0.5
1
1.5
2
0
5
10
15
20
25
30

Controle (E.D.)
Controle (Simulink)
Controle
0
0.5
1
1.5
2
0
5
10
15
20
25
30
Tempo