Risposte di Funzioni Di Trasferimento (FDT)

Setup

```
close all;
clear all;
clc;
FS = 18; % FontSize
LW = 2; % LineWidth
```

Variabili simboliche

```
syms Yel(s)
syms yel(t)
```

Esempio

Asse del tempo

```
tt = linspace(0, 10, 1000);
```

Esercizio 2.11.1

FDT

```
G = tf([9 1], [2 3 2])
```

```
G =

      9 s + 1
  ---------------
  2 s^2 + 3 s + 2

Continuous-time transfer function.
Model Properties
```

Modello del sistema

```
[A,B,C,D] = tf2ss(G.Numerator{1}, G.Denominator{1})
```

```
A = 2×2
   -1.5000   -1.0000
    1.0000         0
B = 2×1
     1
     0
C = 1×2
    4.5000    0.5000
D =
0
```

Autovalori

```
eig(A)
```

```
ans = 2×1 complex
  -0.7500 + 0.6614i
  -0.7500 - 0.6614i
```

Evoluzione libera

Trasformata

```
Yel(s) = simplify(free_evolution(A, C, ones(size(C))'));
pretty(Yel)
```

```
   20 s - 13
--------------
   2
4 s  + 6 s + 4
```

Evoluzione libera nel dominio del tempo

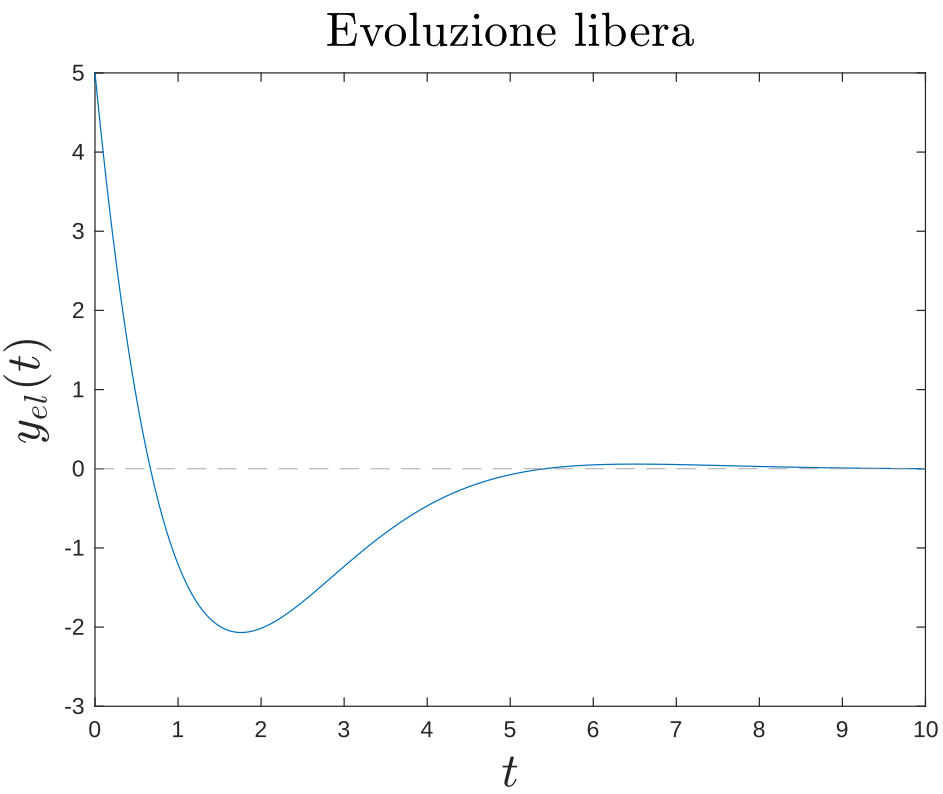
```
yel(t) = simplify(ilaplace(Yel));
pretty(vpa(yel, 4))
```

```
exp(-0.75 t) (cos(0.6614 t) - sin(0.6614 t) 2.117) 5.0
```

Grafico

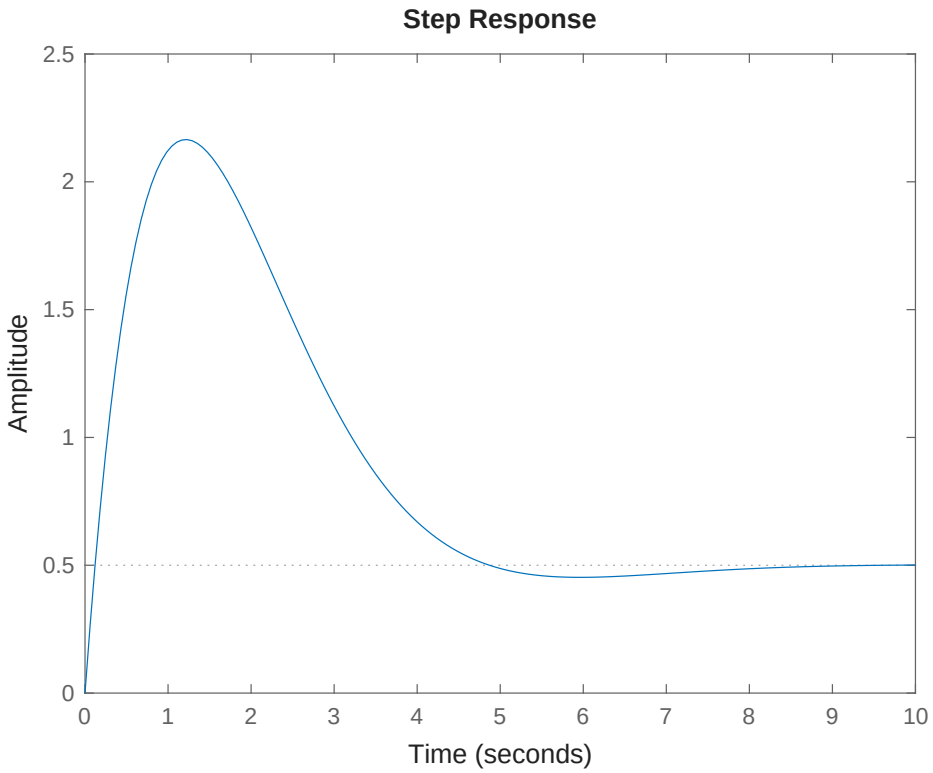
Evoluzione libera

```
figure(Name='Evoluzione libera')
plot(tt, yel(tt))
xlim([tt(1) tt(end)])
xlabel('$$t$$', Interpreter='latex', FontSize=20)
ylabel('$$y_{el}(t)$$', Interpreter='latex', FontSize=20)
yline(double(yel(tt(end))), '--', LineWidth=0.5, Color=[0.6 0.6 0.6])
title("Evoluzione libera", Interpreter='latex', FontSize=20)
```



Risposta al gradino

```
figure(Name='Risposta al gradino')
step(G)
```



G1

Funzione di trasferimento

```
G1 = zpk([], [-2], 10)
```

```
G1 =

   10
  -----
  (s+2)

Continuous-time zero/pole/gain model.
Model Properties
```

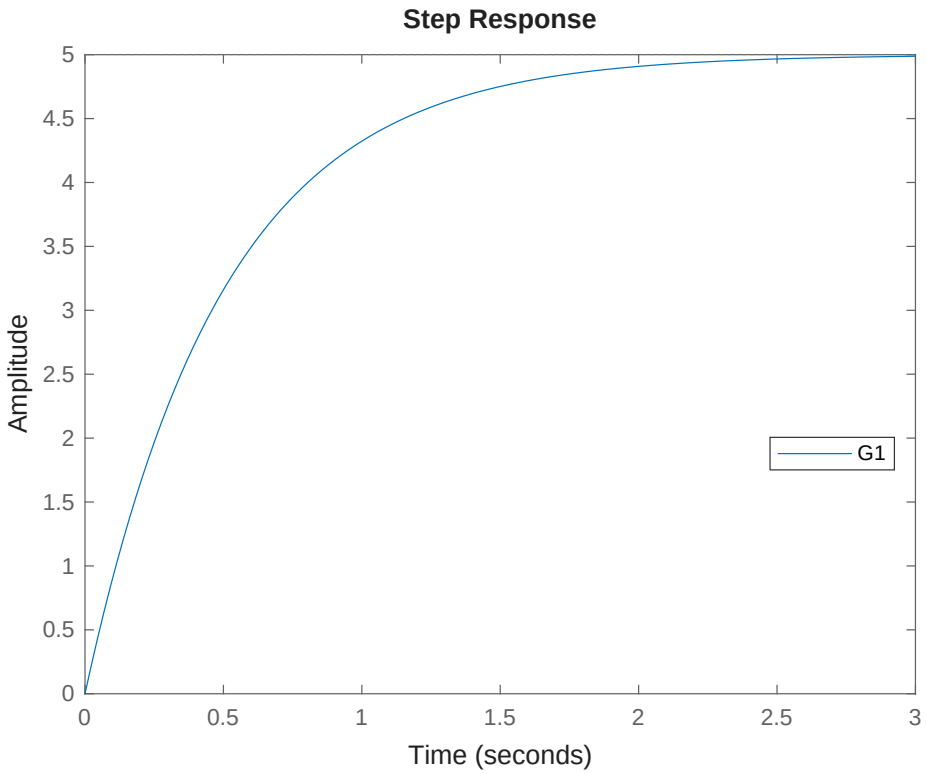
```
G1 = tf(G1)
```

```
G1 =

   10
  -----
  s + 2

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='G1')
step(G1)
set(findall(gcf, Property='FontSize'), FontSize=FS)
```

```
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



G2

Funzione di trasferimento

```
G2 = zpk([], [-2, -10-10j, -10+10j], 2000)
```

```
G2 =

           2000
  -----------------------
  (s+2) (s^2 + 20s + 200)

Continuous-time zero/pole/gain model.
Model Properties
```

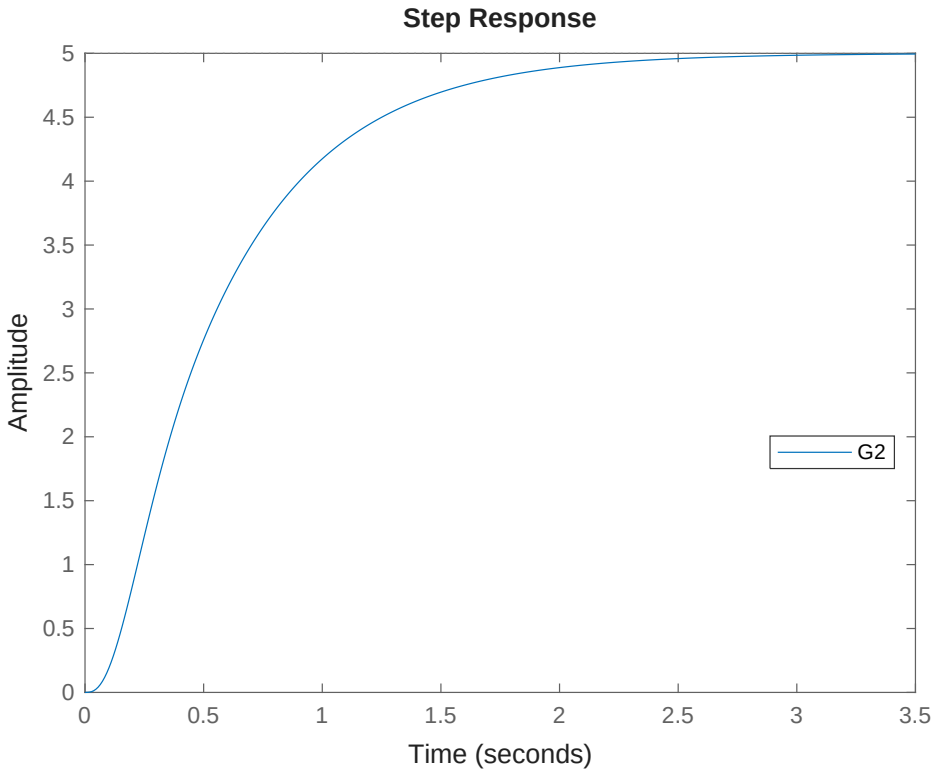
```
G2 = tf(G2)
```

```
G2 =

             2000
  --------------------------
  s^3 + 22 s^2 + 240 s + 400

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='G2')
```

```
step(G2)
set(findall(gcf, Pproperty='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



G3

Funzione di trasferimento

```
G3 = zpk([], [-2, -2-2j, -2+2j], 80)
```

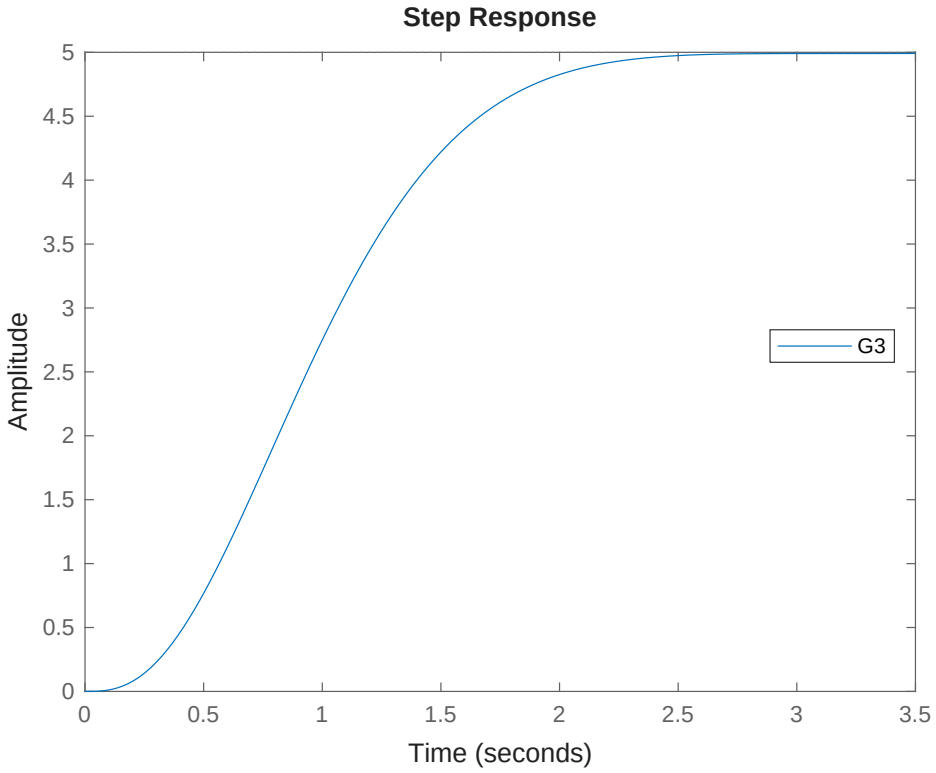
```
G3 =

          80
  --------------------
  (s+2) (s^2 + 4s + 8)

Continuous-time zero/pole/gain model.
Model Properties
```

```
G3 = tf(G3)
```

```
G3 =

           80
  ------------------------
  s^3 + 6 s^2 + 16 s + 16

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='G3')
step(G3)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



G4

Funzione di trasferimento

```
G4 = zpk([], [-2, -2-20j, -2+20j], 4040)
```

```
G4 =

           4040
  ----------------------
  (s+2) (s^2 + 4s + 404)

Continuous-time zero/pole/gain model.
Model Properties
```

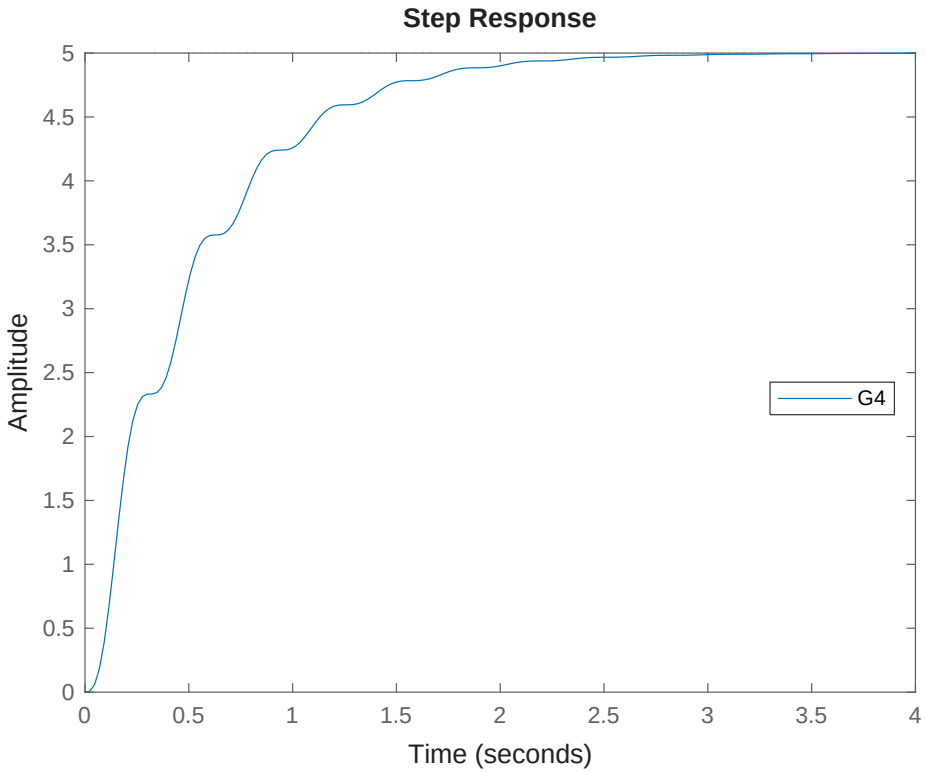
```
G4 = tf(G4)
```

```
G4 =

            4040
  -------------------------
  s^3 + 6 s^2 + 412 s + 808
```

```
Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='G4')
step(G4)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



G5

Funzione di trasferimento

```
G5 = zpk([], [-10, -2-20j, -2+20j], 20200)
```

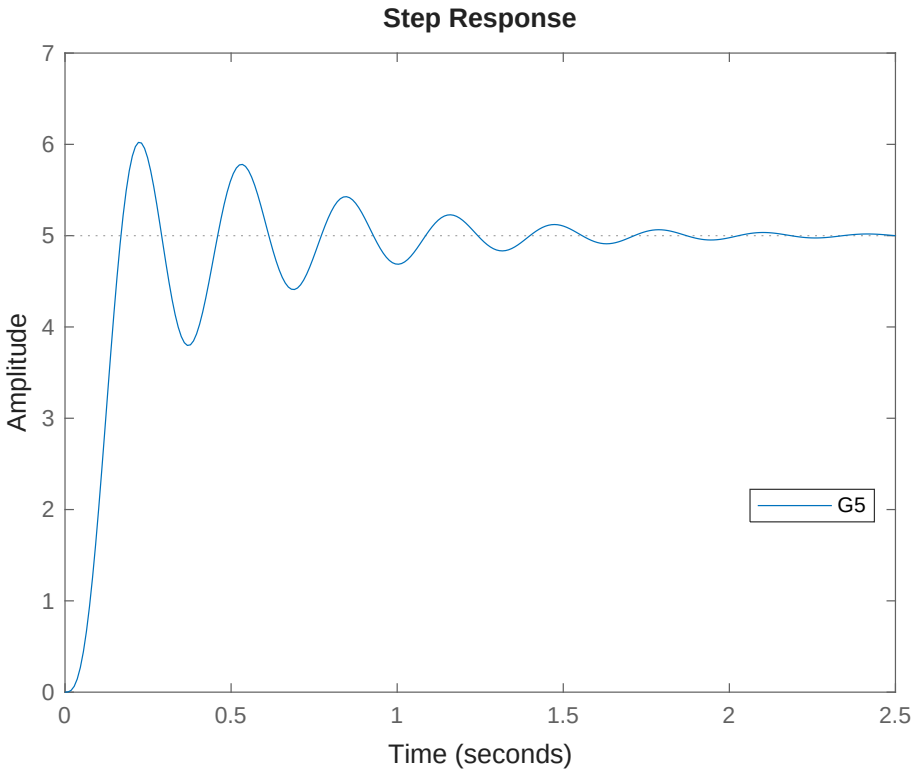
```
G5 =

           20200
  ------------------------
  (s+10) (s^2 + 4s + 404)

Continuous-time zero/pole/gain model.
Model Properties
```

```
G5 = tf(G5)
```

```
G5 =

            20200
  --------------------------
  s^3 + 14 s^2 + 444 s + 4040

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='G5')
step(G5)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



H1

Funzione di trasferimento

```
H1 = zpk([], [-2, -10-100j, -10+100j], 101000)
```

```
H1 =

           1.01e+05
  --------------------------
  (s+2) (s^2 + 20s + 1.01e04)
```

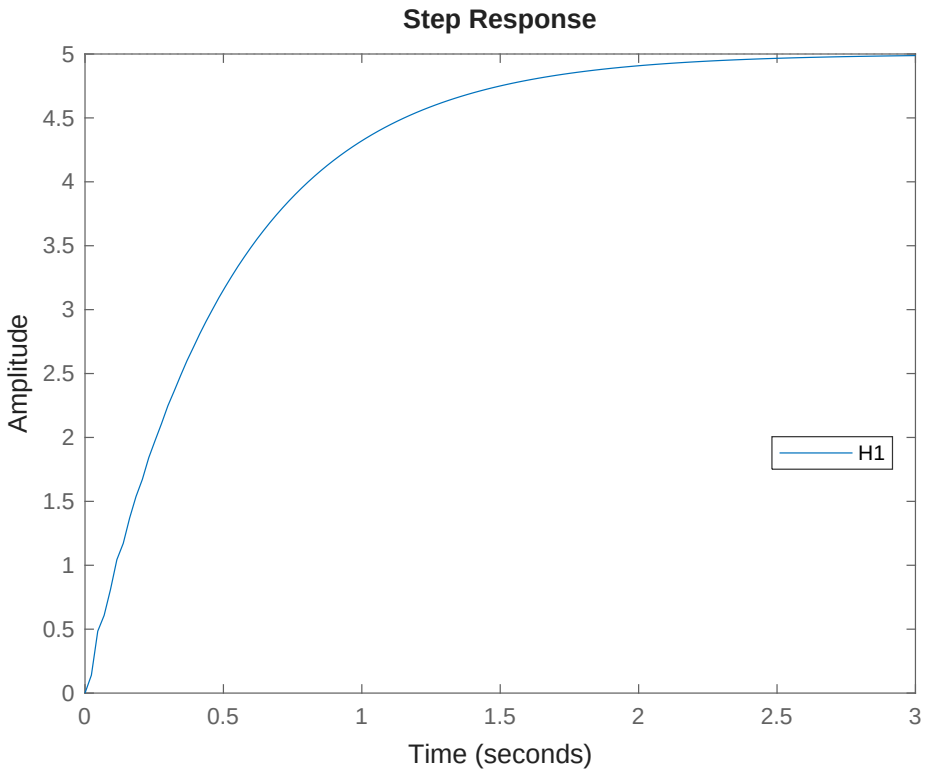
```
Continuous-time zero/pole/gain model.
Model Properties
```

```
H1 = tf(H1)
```

```
H1 =

              101000
  -----------------------------
  s^3 + 22 s^2 + 10140 s + 20200

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='H1')
step(H1)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



H2

Funzione di trasferimento

```
H2 = zpk([-1.9], [-2, -10-100j, -10+100j], 101000/1.9)
```

```
H2 =
```

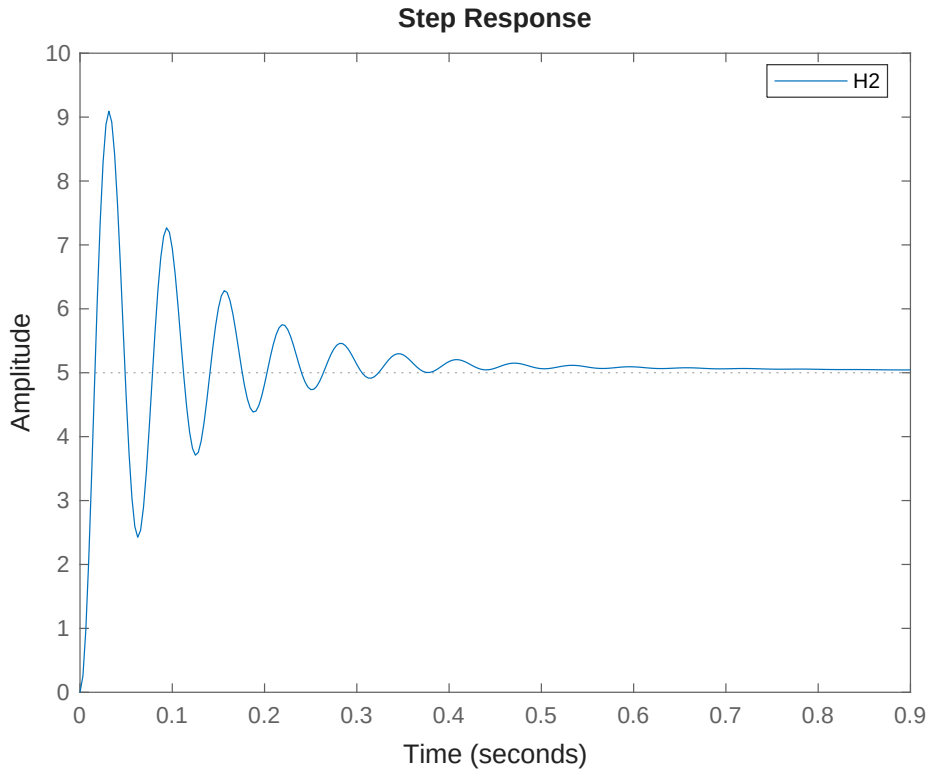
```
        53158 (s+1.9)
  --------------------------
  (s+2) (s^2 + 20s + 1.01e04)

Continuous-time zero/pole/gain model.
Model Properties
```

```
H2 = tf(H2)
```

```
H2 =

       5.316e04 s + 101000
  -----------------------------
  s^3 + 22 s^2 + 10140 s + 20200

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='H2')
step(H2)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



H3

Funzione di trasferimento

```
H3 = zpk([-5], [-2, -10-100j, -10+100j], 20200)
```

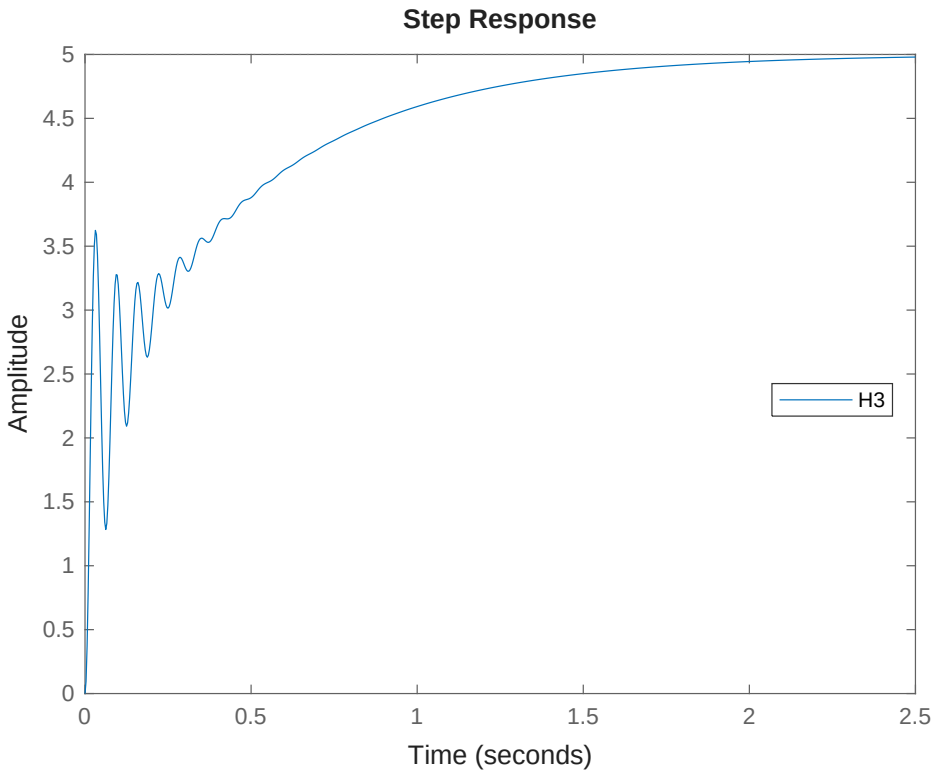
```
H3 =

          20200 (s+5)
  --------------------------
  (s+2) (s^2 + 20s + 1.01e04)

Continuous-time zero/pole/gain model.
Model Properties
```

```
H3 = tf(H3)
```

```
H3 =

         20200 s + 101000
  -----------------------------
  s^3 + 22 s^2 + 10140 s + 20200

Continuous-time transfer function.
Model Properties
```

Risposta al gradino

```
figure(Name='H3')
step(H3)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



H4

Funzione di trasferimento

```
H4 = zpk([2], [-2, -10-100j, -10+100j], -50500)
```

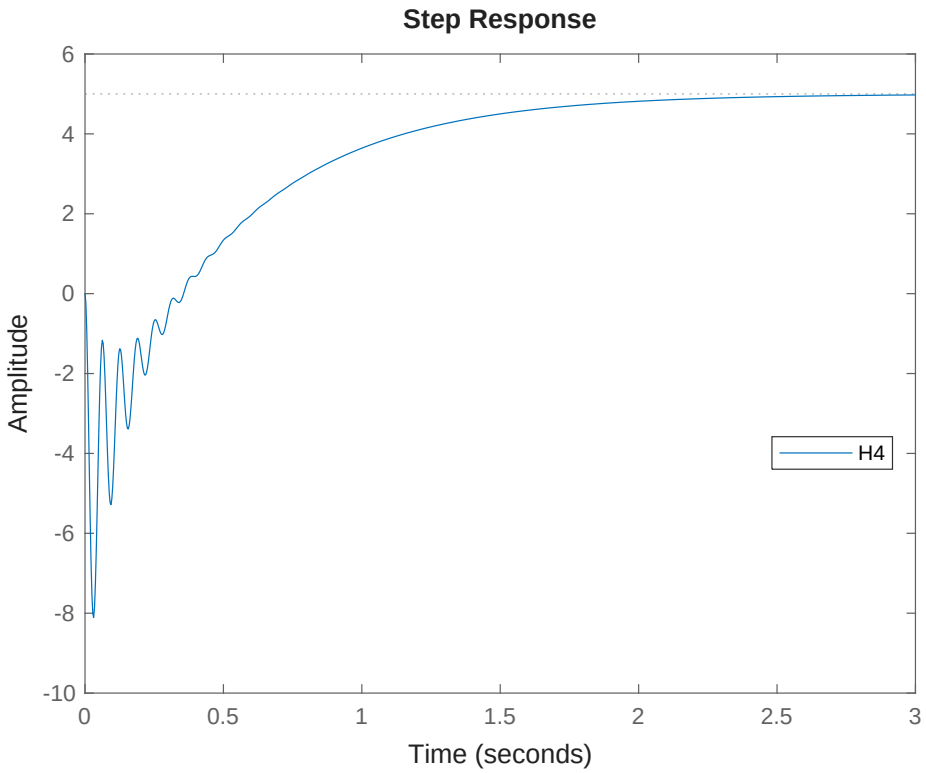
```
H4 =

         -50500 (s-2)
  --------------------------
  (s+2) (s^2 + 20s + 1.01e04)

Continuous-time zero/pole/gain model.
Model Properties
```

```
H4 = tf(H4)
```

```
H4 =

        -50500 s + 101000
  ----------------------------
  s^3 + 22 s^2 + 10140 s + 20200

Continuous-time transfer function.
Model Properties
```

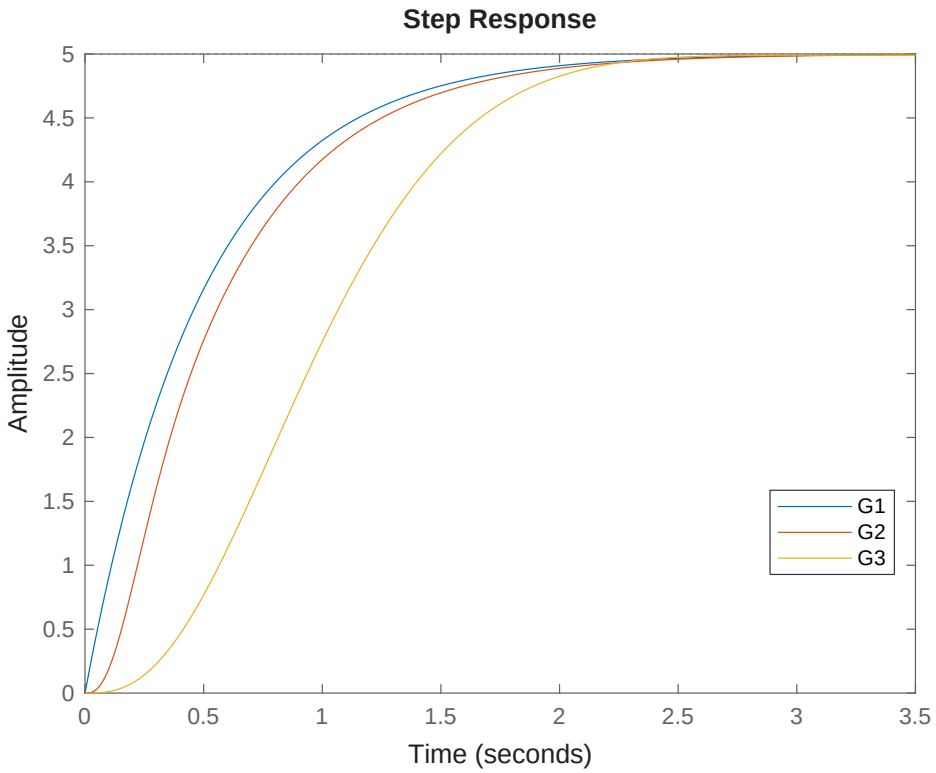
Risposta al gradino

```
figure(Name='H4')
step(H4)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```

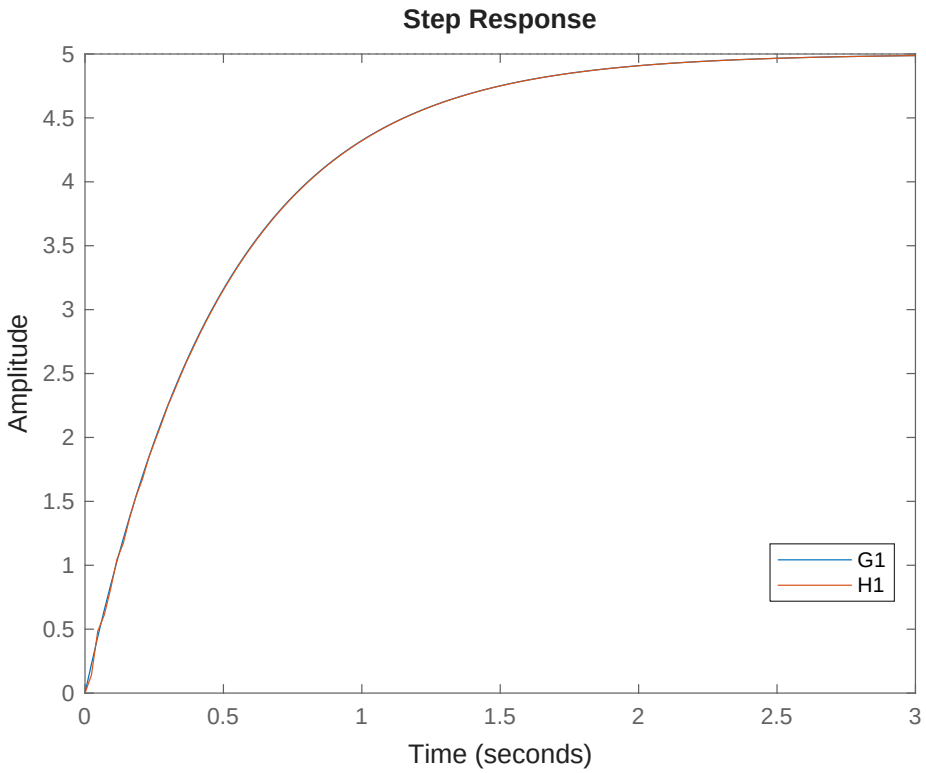


Comparazioni tra più grafici

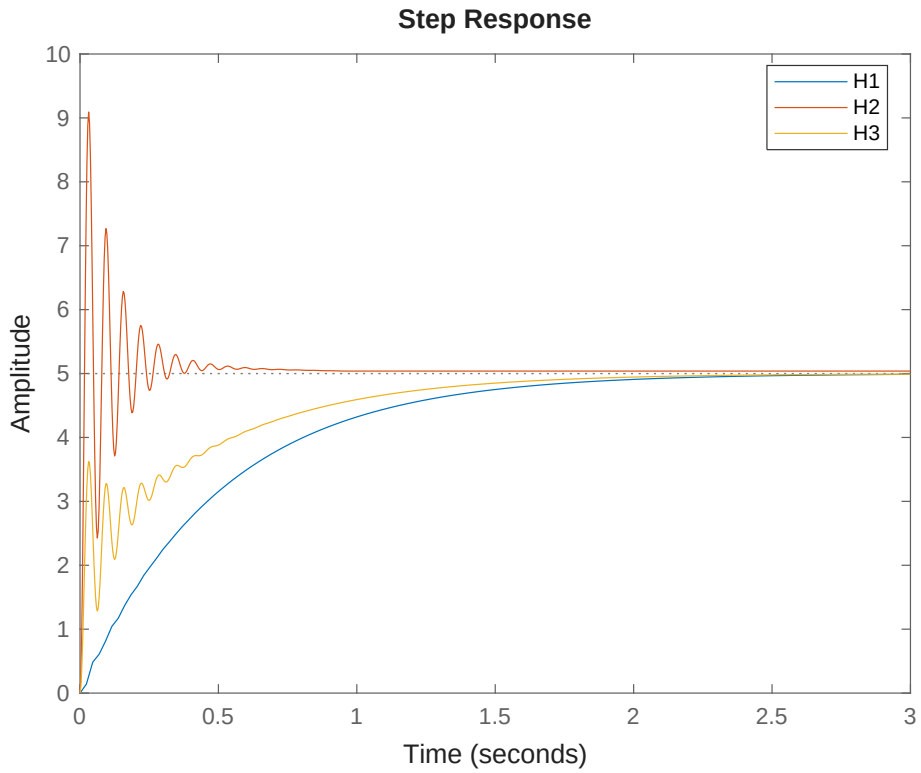
```
step(G1, G2, G3)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```




```
step(G1, H1)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```

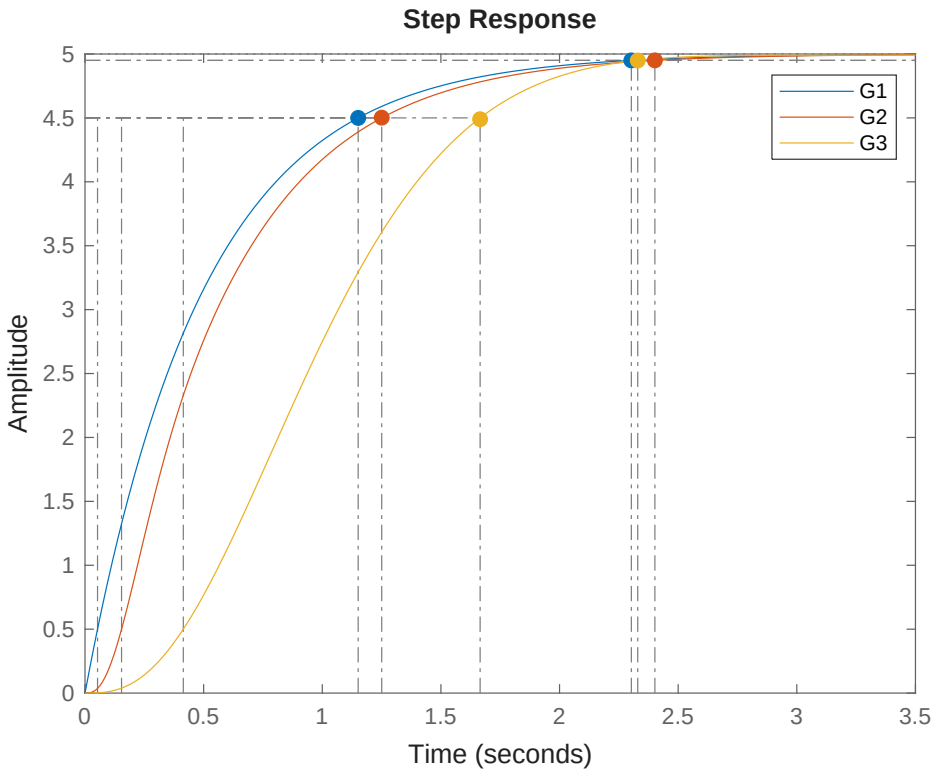



```
step(H1, H2, H3)
set(findall(gcf, Property='FontSize'), FontSize=FS)
set(findall(gcf, Type='Line'), LineWidth=LW)
legend(Location='best');
```



Valutazione Tempo di salita e Tempo di assestamento

```
RT = [0.1, 0.9];  % RiseTime limits
ST = 0.01;  % SettingTime threshold
sp = stepplot(G1, G2, G3);
sp.Characteristics.RiseTime.Visible = 'on';
sp.Characteristics.RiseTime.Limits = RT;
sp.Characteristics.SettlingTime.Visible = 'on';
sp.Characteristics.SettlingTime.Threshold = ST;
legend('G1', 'G2', 'G3');
```



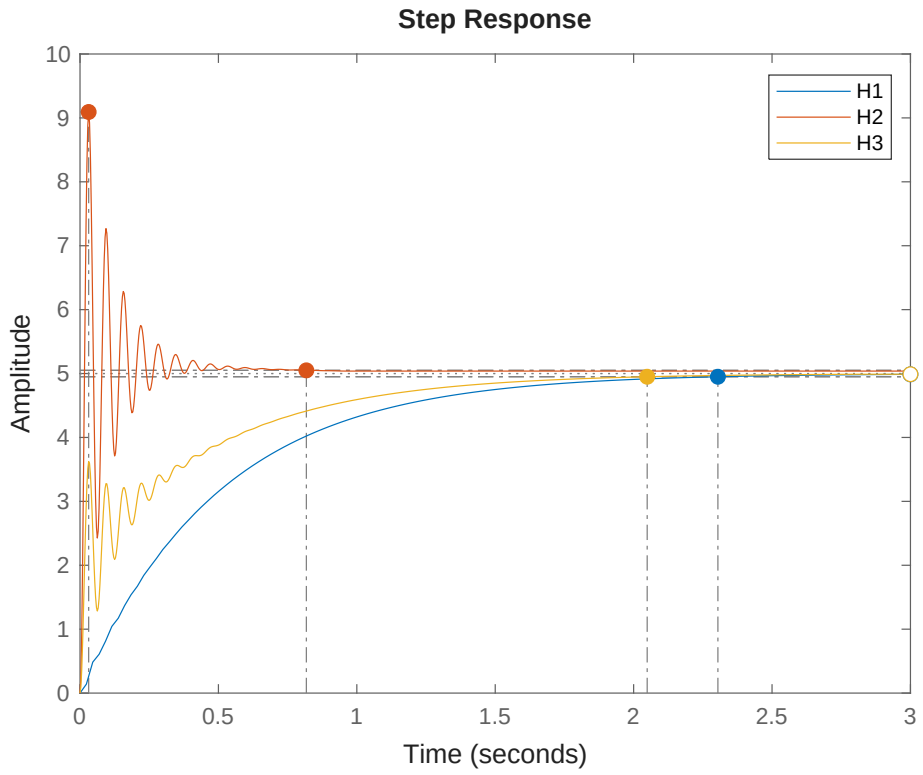

```
si = stepinfo([G1, G2, G3], RiseTimeLimits=RT, SettlingTimeThreshold=ST);
table({si.RiseTime}', {si.SettlingTime}', ...
    RowNames=string({sp.Responses.Name}), ...
    VariableNames=["RiseTime [s]", "SettlingTime [s]"])
```

ans = 3×2 table

	RiseTime [s]	SettlingTime [s]
1 G1	1.0986	2.3026
2 G2	1.0966	2.4018
3 G3	1.2509	2.3294

Valutazione overshoot e tempo di assestamento

```
ST = 0.01;  % SettingTime threshold
sp = stepplot(H1, H2, H3);
sp.Characteristics.PeakResponse.Visible = 'on';
sp.Characteristics.SettlingTime.Visible = 'on';
sp.Characteristics.SettlingTime.Threshold = ST;
legend('H1', 'H2', 'H3');
```




```
si = stepinfo([H1, H2, H3], SettlingTimeThreshold=ST);
table({si.Overshoot}', {si.SettlingTime}', ...
    RowNames=string({sp.Responses.Name}), ...
    VariableNames=["Overshoot [%]", "SettlingTime [s]"])
```

ans = 3×2 table

	Overshoot [%]	SettlingTime [s]
1 H1	0	2.3044
2 H2	81.8519	0.8177
3 H3	0	2.0490