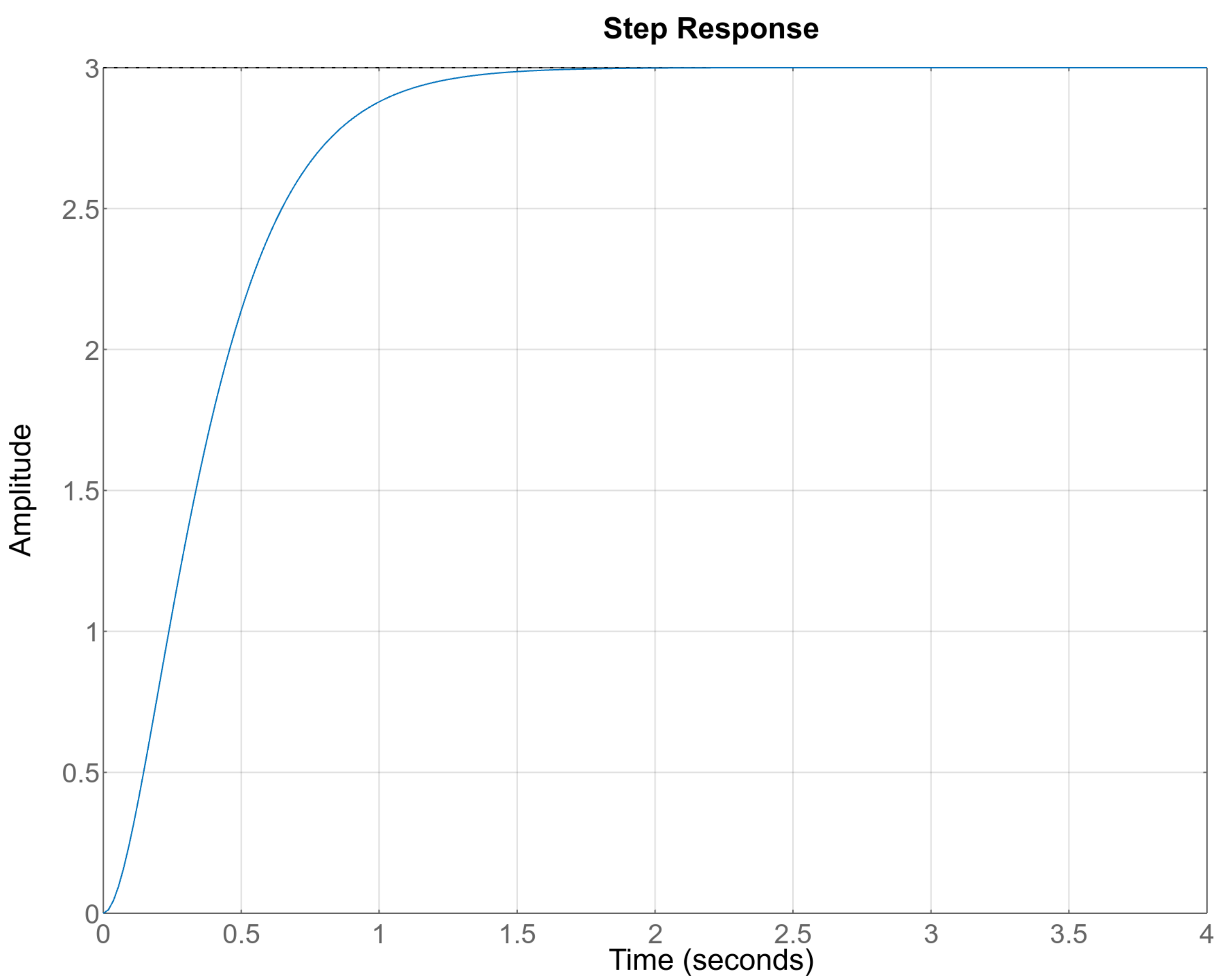
IMC control with constant "Q" parameter (keeping open-loop poles unmodified in closed loop)

Objective: designing an IMC controller that does not change the dynamics with respect to the open-loop one because it's considered satisfactory... it's ***very easy***: just set Q to the inverse of the DC gain.

Video-presentation: http://personales.upv.es/asala/YT/V/imcQcteEN.html

Process to be controlled

```
s=tf('s');
G=3/(0.2*s+1)^2; %  75/(s+5)^2
step(G,4), grid on
```




```
dcgain(G)
```

```
ans = 3
```

Desired closed-loop behaviour and IMC controller

Settling time is assumed to be reasonable, we do not want to change the position of the poles or the setpoint response, we just with to make the gain 1 with respect to reference.

That is trivial in open loop: $u = \frac{1}{3} r$.

In closed loop, IMC it would be basically the same (that's the "trick" of IMC, it is designed as it we were in an open loop):

```
Q=1/3; %explicit IMC
```

Equivalently, the resulting controller (implicit IMC) is:

```
K=Q/(1-G*Q);
zpk(K)
```

```
ans =

  0.33333 (s+5)^2
  ---------------
     s (s+10)

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

As predicted by theory, the IMC results in a regulator with integral action. It will reject constant disturbances with no steady-state error.

Analysis of the resulting closed loop

The closed loop will be:

```
T1=zpk(feedback(G*K,1)) %setpoint to output;
```

```
T1 =

  25 (s+5)^2
  ----------
   (s+5)^4

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

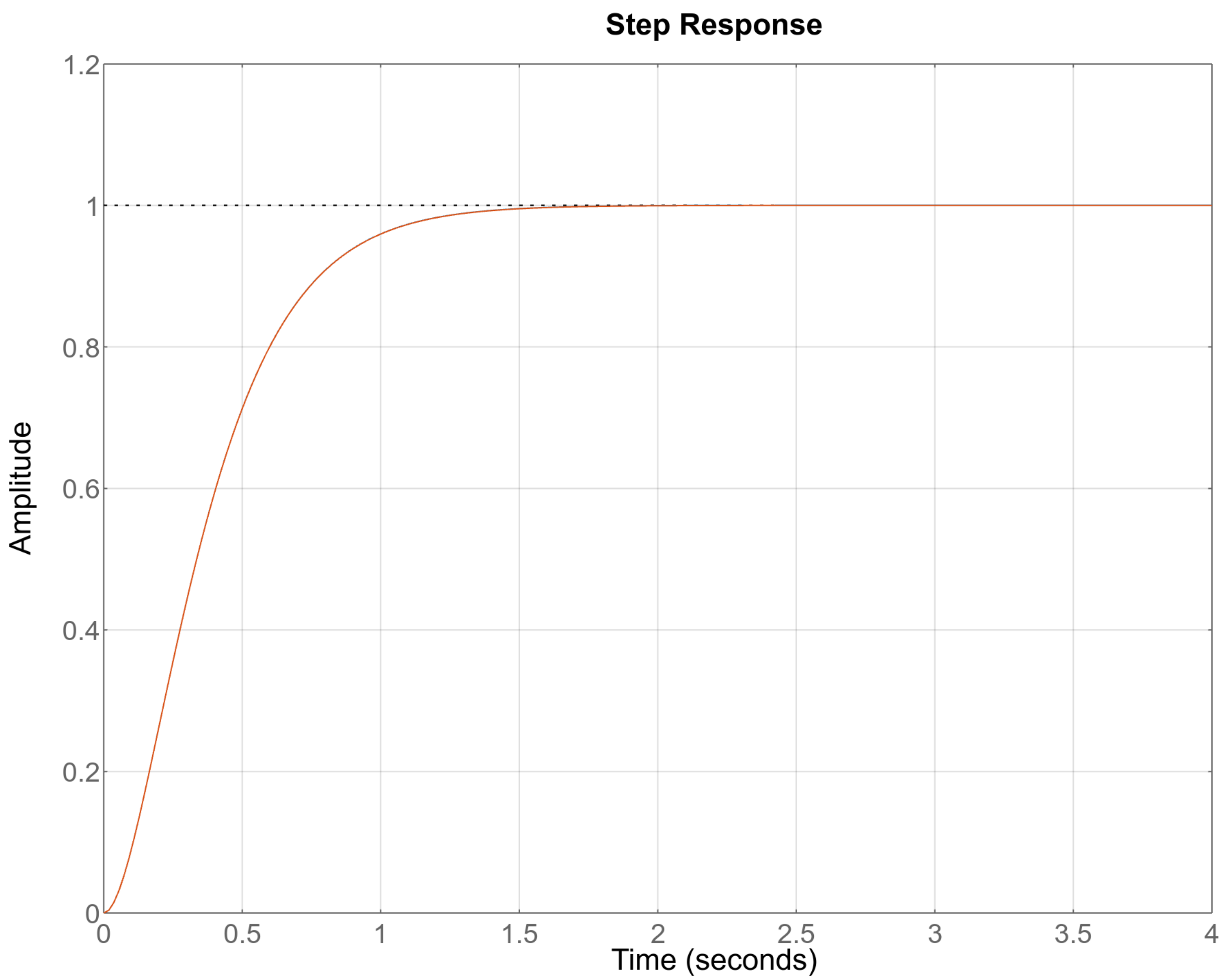
```
T=minreal(T1,3e-4) %after cancelling with some tolerance
```

```
T =

          25
  ------------------
  (s^2 + 9.999s + 25)

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

```
norm(T-G*Q) %T is GQ, apart from numeric round-off issues.
```

```
ans = 1.8544e-04
```

```
step(T,G/dcgain(G),4), grid on %CL versus OL , setpoint
```




```
KS=K*S;zpk(KS)
```

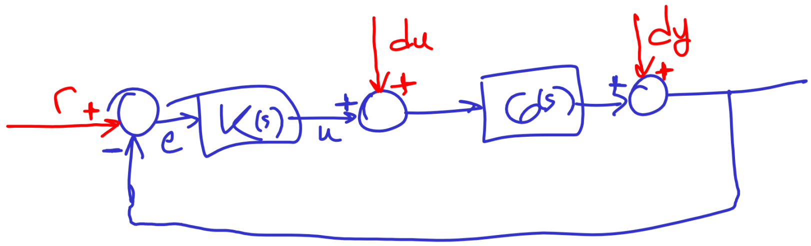
```
ans =

  0.33333 s (s+10) (s+5)^4
  ------------------------
      s (s+10) (s+5)^4

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

```
minreal(zpk(KS),3e-4) %control is just setpoint/3, as in open loop.
```

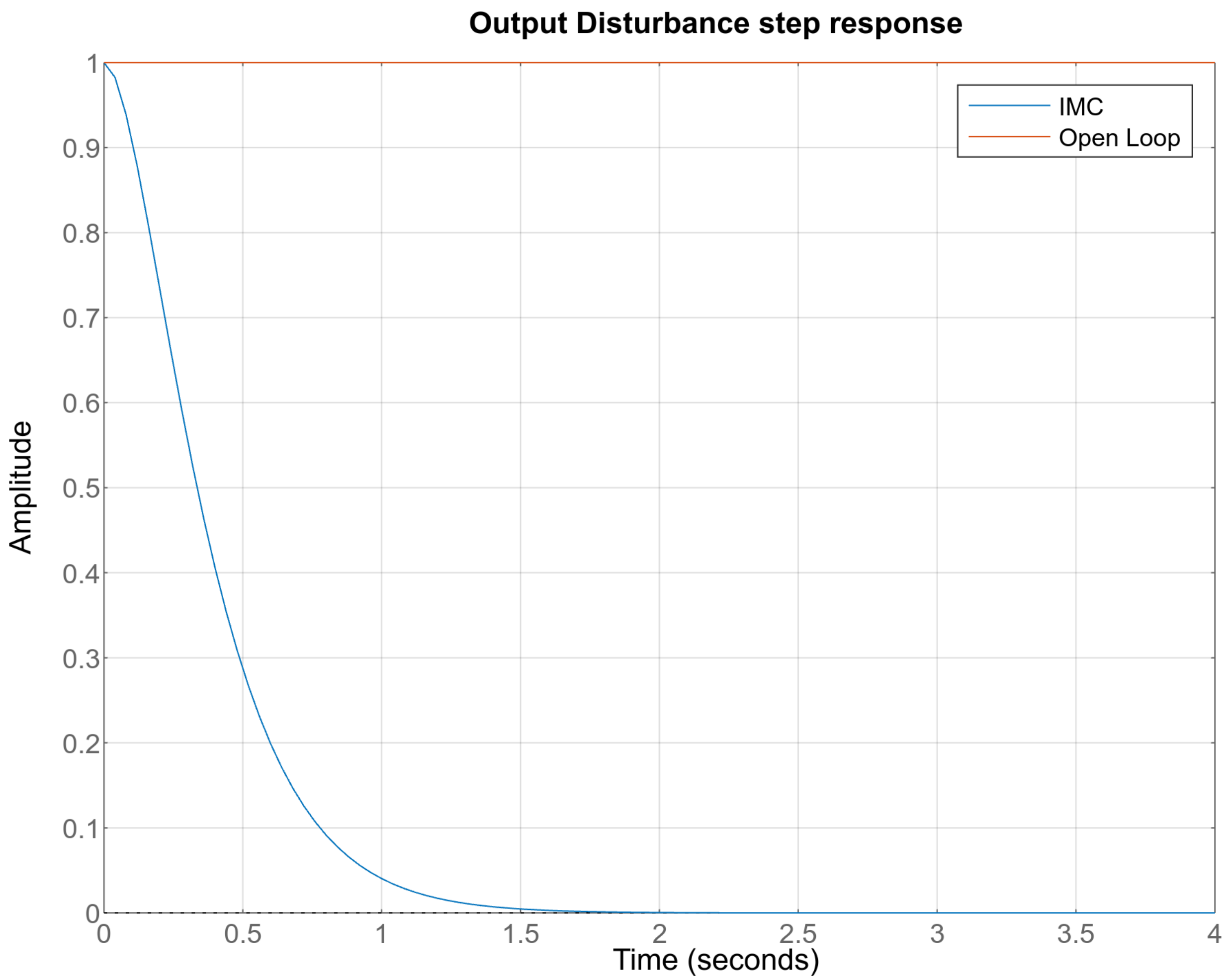
```
ans =

  0.33333

Static gain.
```

Recall that, from theory, KS is Q.

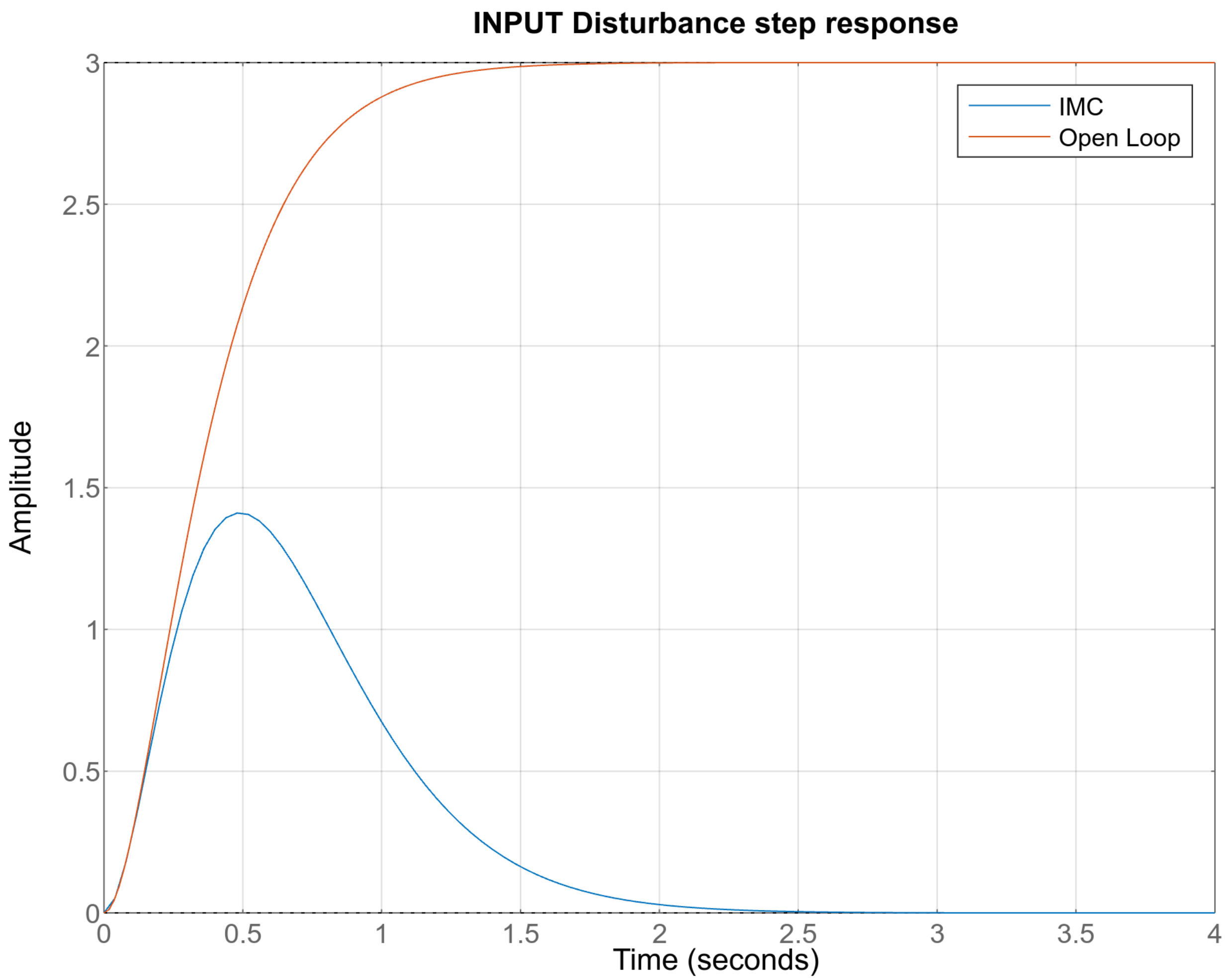
Disturbance response:




```
S=feedback(1,G*K); %dy to y
GS=G*S; %du to y [feedback(G,K) would also work]
step(S,tf(1),4), grid on %OL versus CL in dy
title("Output Disturbance step response"), legend("IMC","Open Loop")
```




```
step(GS,G,4), grid on %bc versus ba en du
title("INPUT Disturbance step response"), legend("IMC","Open Loop")
```


INPUT Disturbance step response
IMC
Open Loop
Amplitude
Time (seconds)
0
0.5
1
1.5
2
2.5
3
3.5
4