



Trabajo Práctico 5 Integrador

Análisis en Frecuencia

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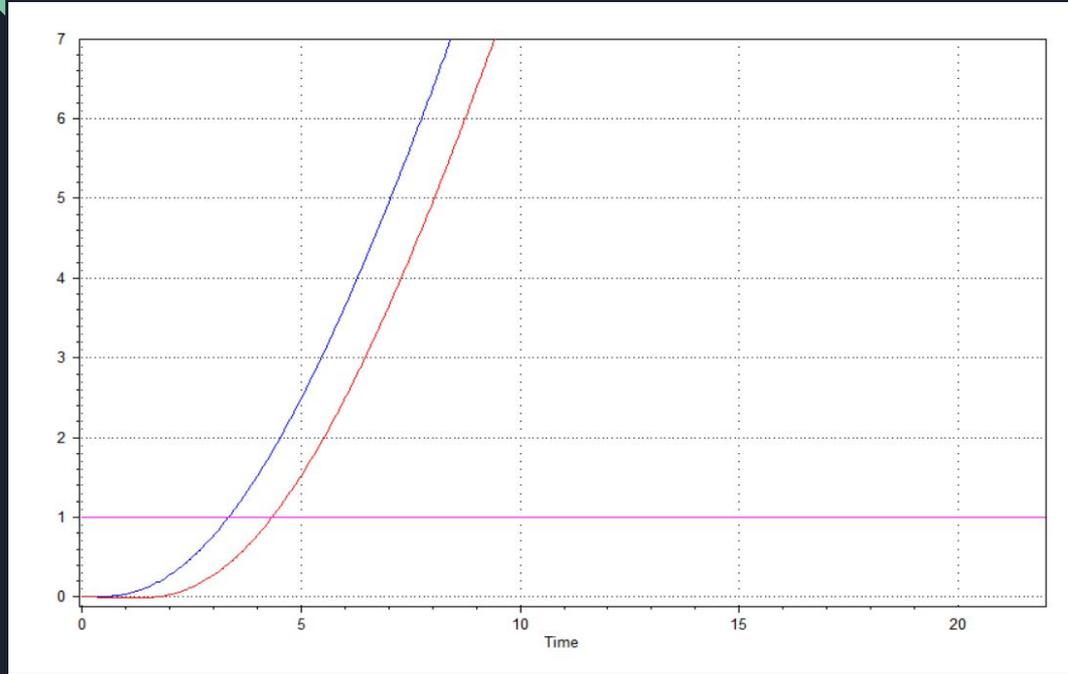
Función de transferencia a analizar

$$G5 = \frac{2 * e^{-1s}}{((s) * (s + 1) * (5s + 1) * (0,1s + 1))}$$

$$H5 = 1$$

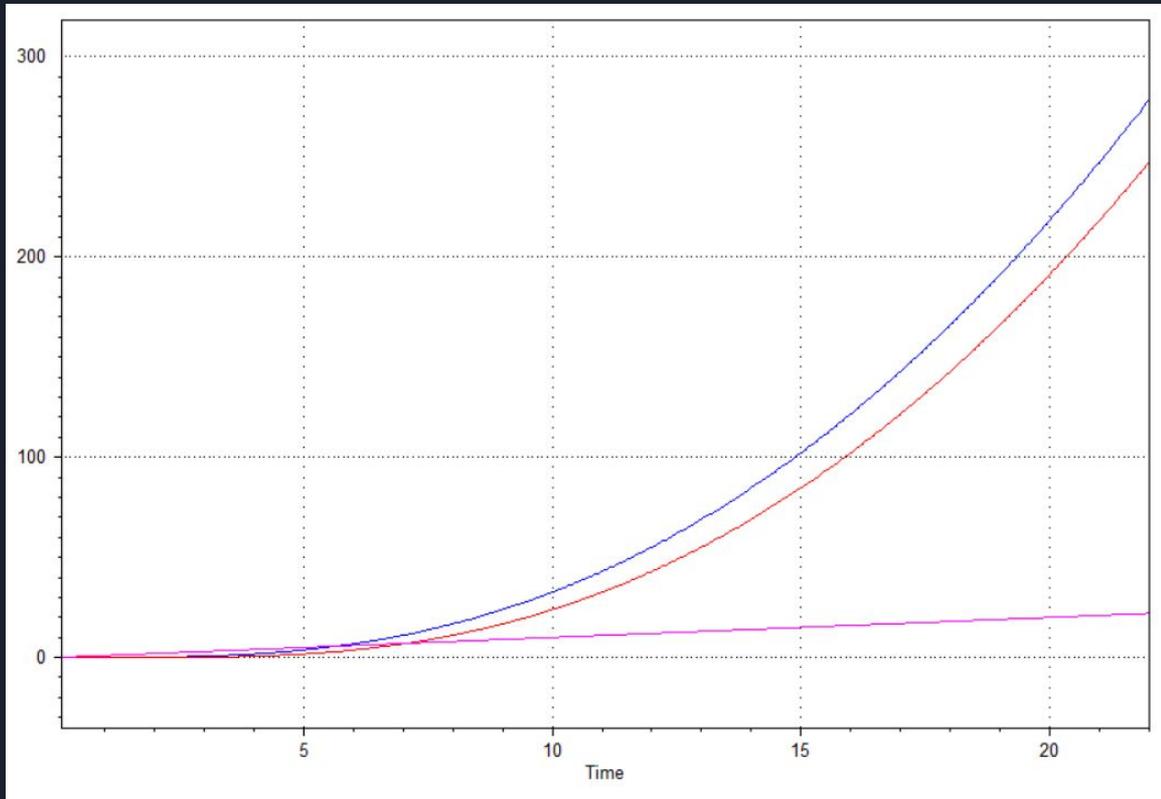
Ejercicio 1 Gráficos a las respuestas a lazo abierto:

❑ Escalón unitario



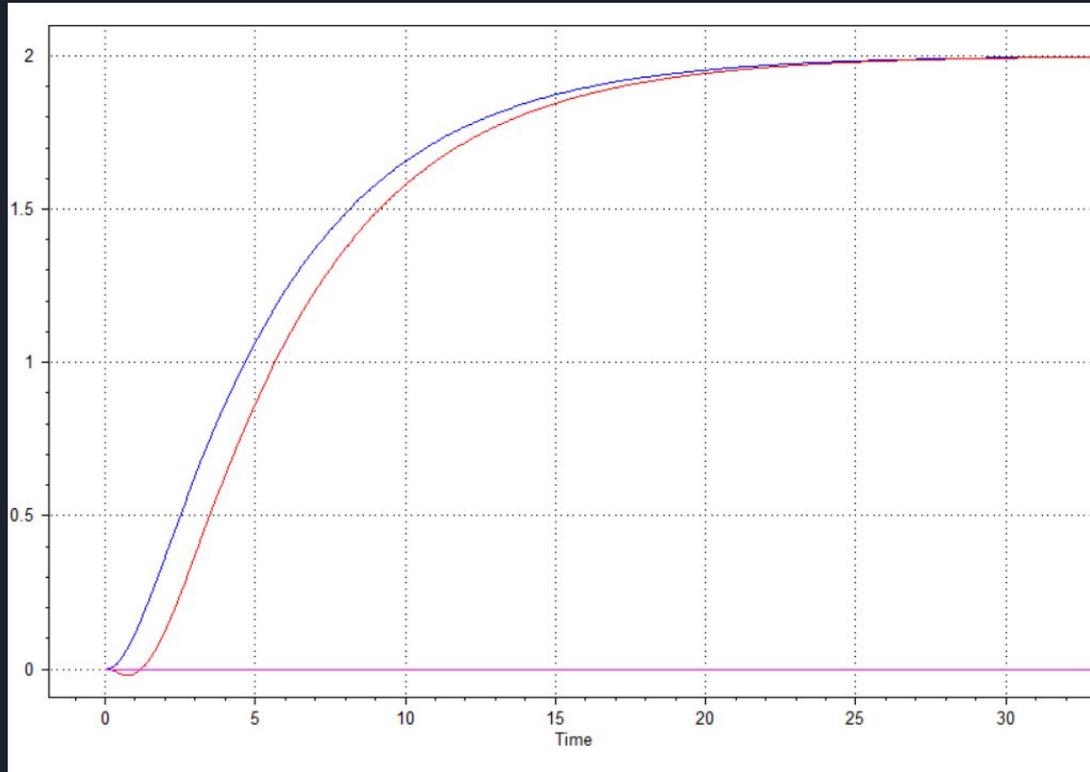
```
CC>aprox=pade(1,1)
CC>gp=2/((s)^(s+1)^(5*s+1)^(0.1*s+1))
CC>time(gp, gp^aprox, 1)
```

□ Rampa unitaria



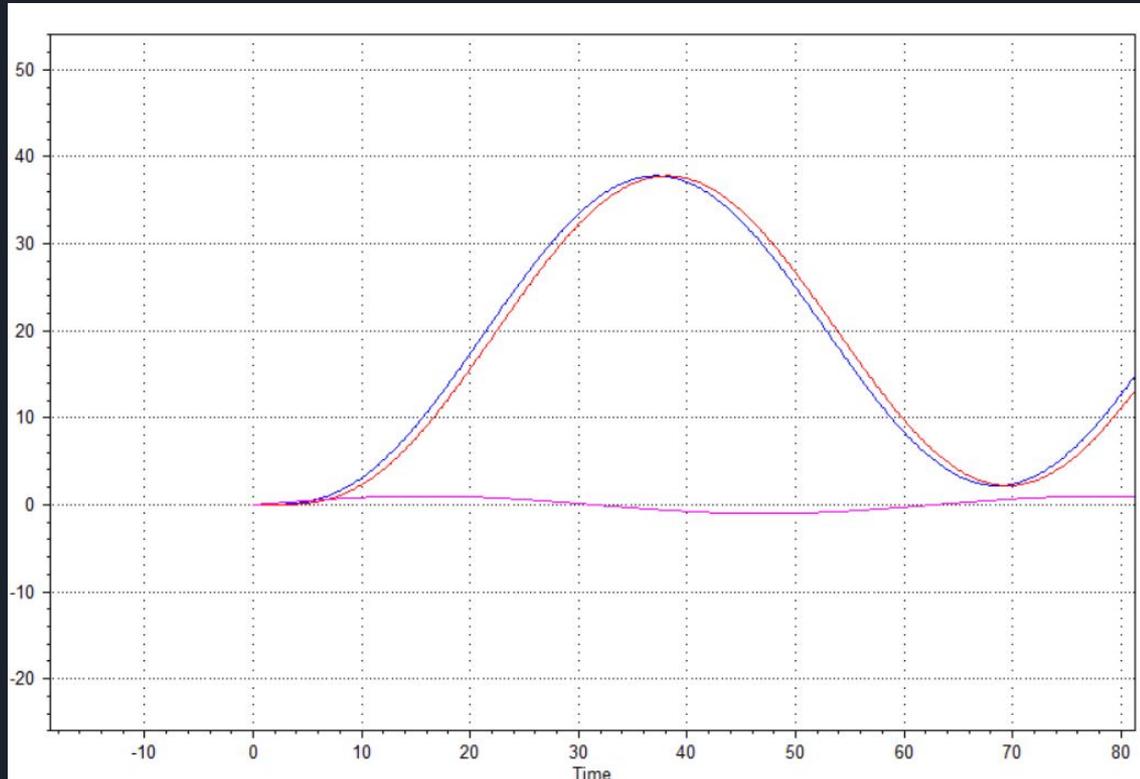
```
CC>aprox=pade(1,1)
CC>gp=2/((s)^(s+1)^(5*s+1)^(0.1*s+1))
CC>time(gp^1/s, gp^aprox^1/s, 1/s)
```

Impulso unitario



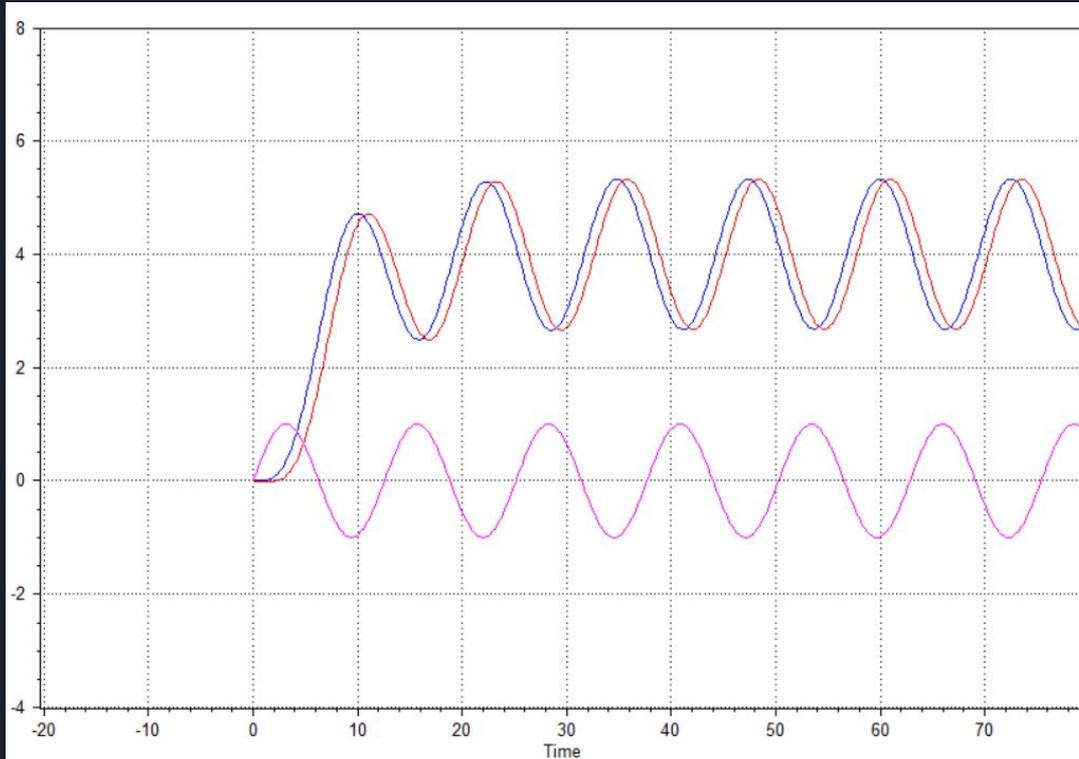
```
CC>aprox=pade(1,1)
CC>gp=2/((s)^(s+1)^(5*s+1)^(0.1*s+1))
CC>time(gp*s, gp*aprox*s, s)
```

☐ Seno(ωt) con $\omega=0.1$



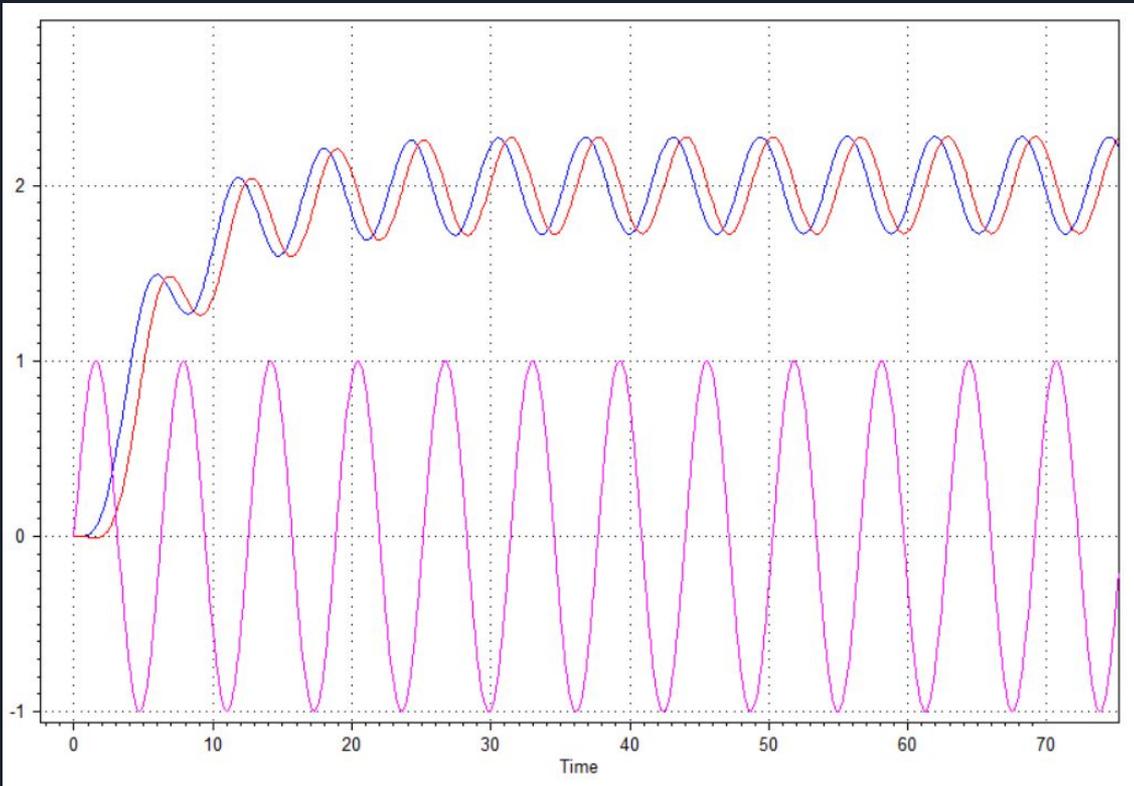
```
CC>aprox=pade(1,1)
CC>gp=2/((s)*(s+1)*(5*s+1)*(0.1*s+1))
CC>U01=0.1/(s^2+0.1^2)
CC>time(gp*U01*s, gp*aprox*U01*s, U01*s)
```

□ Seno(ωt) con $\omega=0.5$



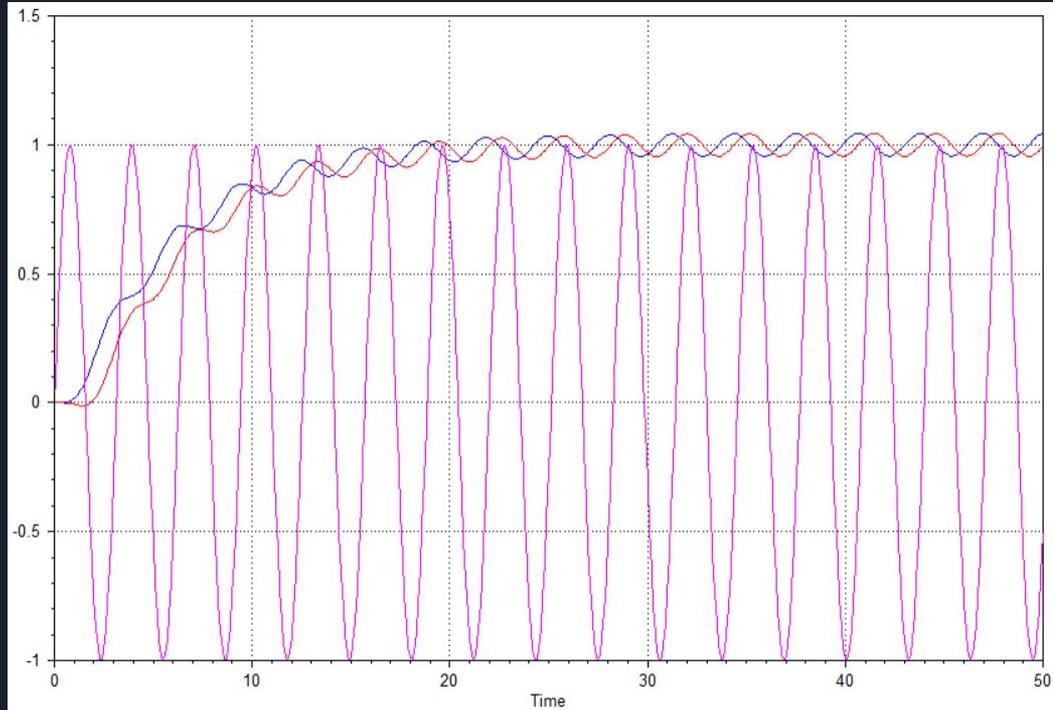
```
CC>aprox=pade(1,1)
CC>gp=2/((s)*(s+1)*(5*s+1)*(0.1*s+1))
CC>U05=0.5/(s^2+0.5^2)
CC>time(gp*U05*s, gp*aprox*U05*s, U05*s)
```

□ Seno(ωt) con $\omega=1$



```
CC>aprox=pade(1,1)
CC>gp=2/((s)*(s+1)*(5*s+1)*(0.1*s+1))
CC>U1=1/(s^2+1^2)
CC>time(gp*U1*s, gp*aprox*U1*s ,U1*s)
```

□ Seno(ωt) con $\omega=2$



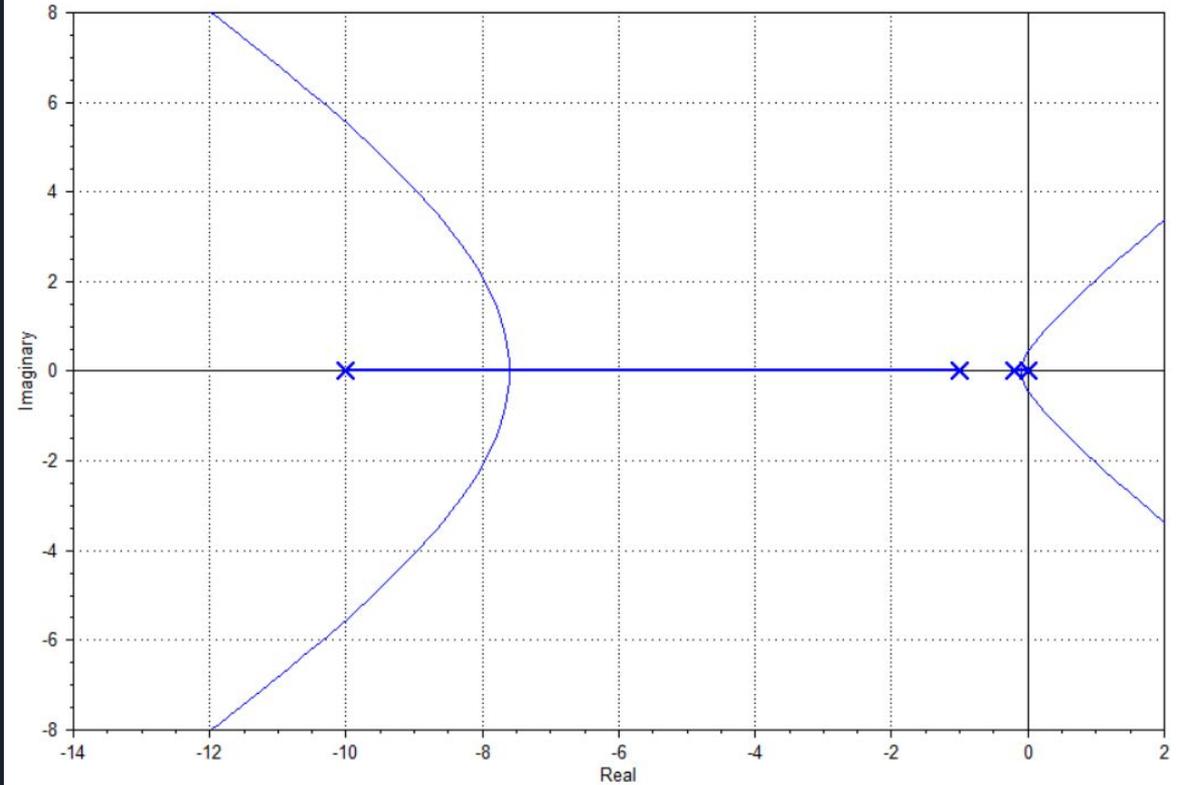
```
CC>aprox=pade(1,1)
CC>gp=2/((s)*(s+1)*(5*s+1)*(0.1*s+1))
CC>U2=2/(s^2+2^2)
CC>time(gp*U2*s, gp*aprox*U2*s, U2*s)
```

Ejercicio 2.1

Lugar de Raíces

$$K_c \approx 0,53$$

$$T = 2\pi / 0,42 \approx 14,9$$



$s = -0.00111 + 0.4198j$ (Mag= 0.4198, Zeta= 0.002644)
gain= 0.5286 +0j (Mag= 0.5286, Phase= 0 deg)

Ejercicio 2.2

Método de Routh

$$0,5s^4 + 5,6s^3 + 6,1s^2 + s$$

s^4	0.5	6.1	2Kc
s^3	5.6	1	0
s^2	6.01	2Kc	0
s^1	$1 - (11.2Kc/6.01)$	0	0
s^0	2Kc	0	0

$$b1 = 6.1 - (0.5/5.6) = 6.01$$

$$b2 = 2Kc - (0.5/5.6)*0 = 2Kc$$

$$c1 = 1 - (5.6/6.01)*2Kc$$

$$d1 = 2Kc$$

$$2Kc > 0 \longrightarrow Kc > 0$$

$$1 - (11.2Kc/6.01) > 0 \longrightarrow Kc < 6.01/11.2 = 0.5366$$

Ejercicio 2.2

Método de Sustitución directa

$$0.5(i\omega)^4 + 5.6(i\omega)^3 + 6.1(i\omega)^2 + (i\omega) + 2K_c = 0$$

$$(0.5\omega^4 - 6.1\omega^2 + 2K_c) + i(-5.6\omega^3 + \omega) = 0 + i\omega$$

$$0.5\omega^4 - 6.1\omega^2 + 2K_c = 0$$

$$-5.6\omega^3 + \omega = 0$$

$$\omega = 0 \longrightarrow K_c = 0$$

$$\omega = 0.4226 \longrightarrow K_c = 0.5367$$

$$T = 2\pi/\omega = 14.868$$

Ejercicio 2.2

Ajustes óptimos de Ziegler-Nichols

Tomando los valores calculados por sustitución directa: $T_u=14,86$ y $K_u=0,54$:

$$\underline{P}: K_p=0,5 \cdot K_u = \underline{0,27}$$

$$\underline{P+I}: K_p=0,45 \cdot K_u = \underline{0,24} \quad | \quad T_i=0,83 \cdot T_u = \underline{12,33}$$

$$\underline{P+D}: K_p=0,8 \cdot K_u = \underline{0,43} \quad | \quad T_d=0,13 \cdot T_u = \underline{1,93}$$

$$\underline{P+I+D}: K_p=0,59 \cdot K_u = \underline{0,32} \quad | \quad T_i=0,5 \cdot T_u = \underline{7,43} \quad | \quad T_d=0,13 \cdot T_u = \underline{1,93}$$



Ejercicio 3.1

Graficamos la respuesta en el tiempo de la función $G_o(s)$ para la función $\text{sen}(wt)$ con frecuencias:

- $w=0.1$
- $w=0.5$
- $w=1$
- $w=2$

A continuación hacemos un análisis de la amplitud y frecuencia en los gráficos de la entrada y la respuesta.



$w = 0.1$

Amplitud Salida : 17,45

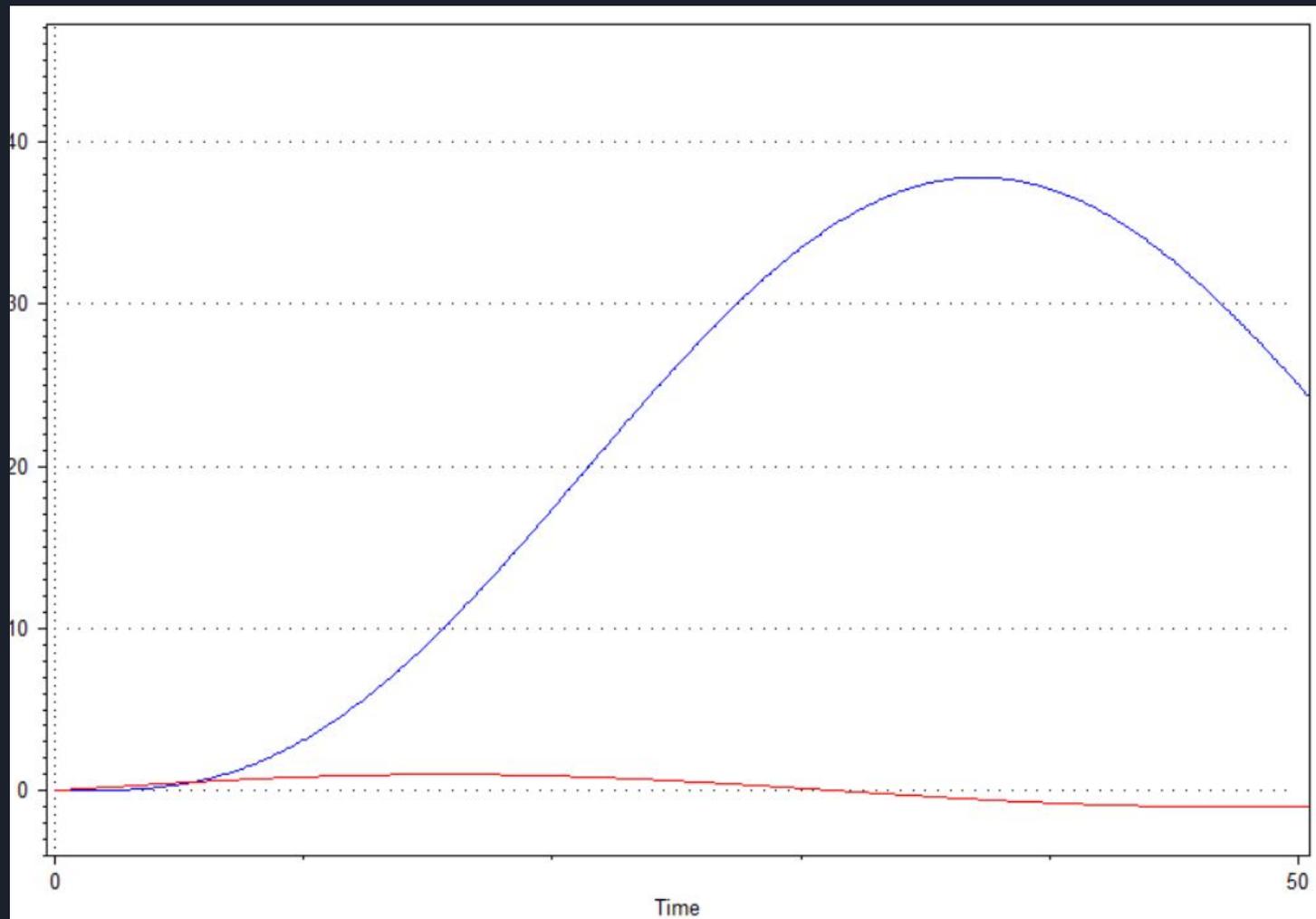
Periodo: 62,8 s

Desfase (s): 21,33 s

Resultados:

Amplitud: 24,83 dB

Desfase: 122,27 °





$w = 0.5$

Amplitud Salida : 1,33

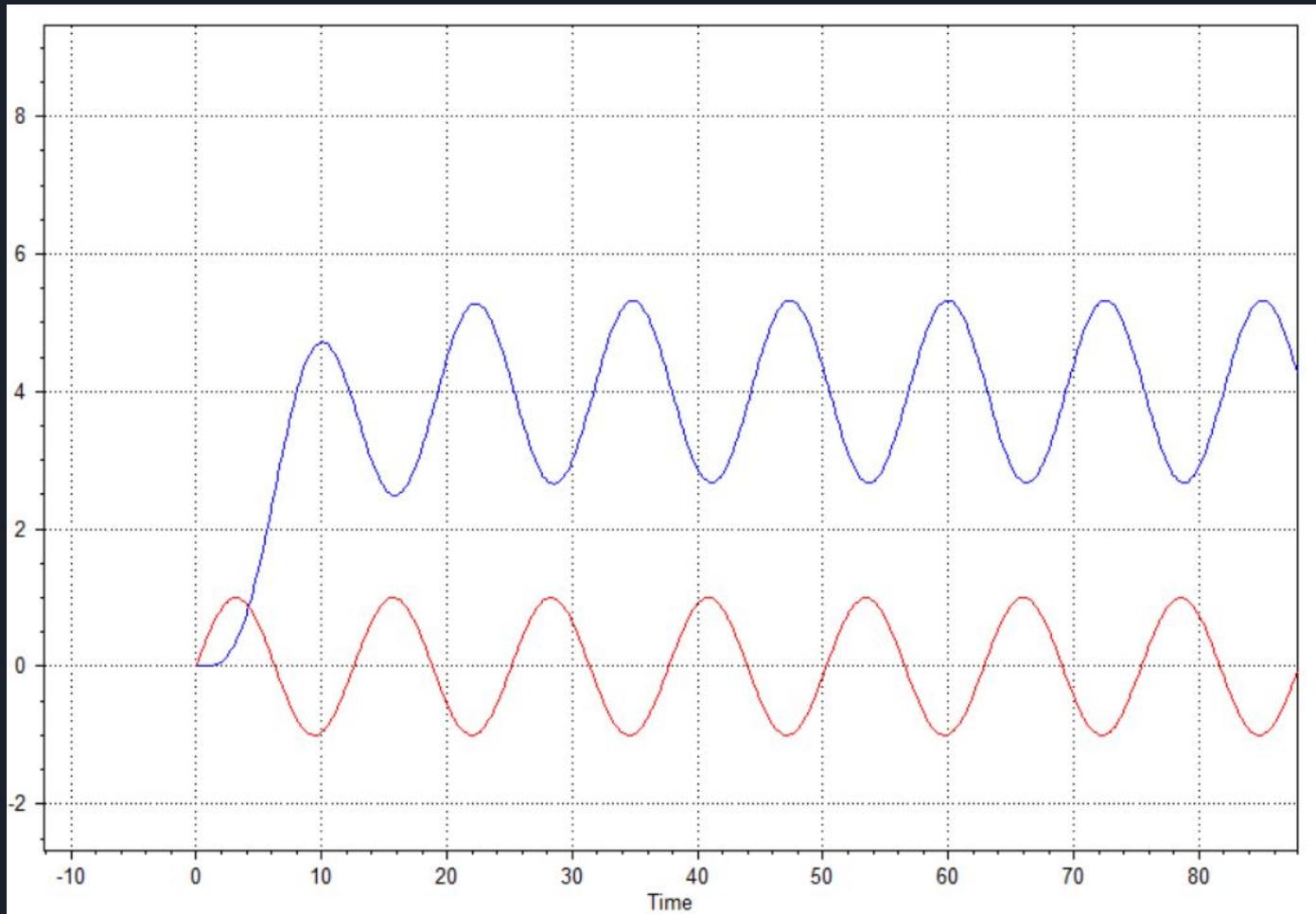
Periodo: 12,57 s

Desfase (s): 6,57s

Resultados:

Amplitud: 2,47 dB

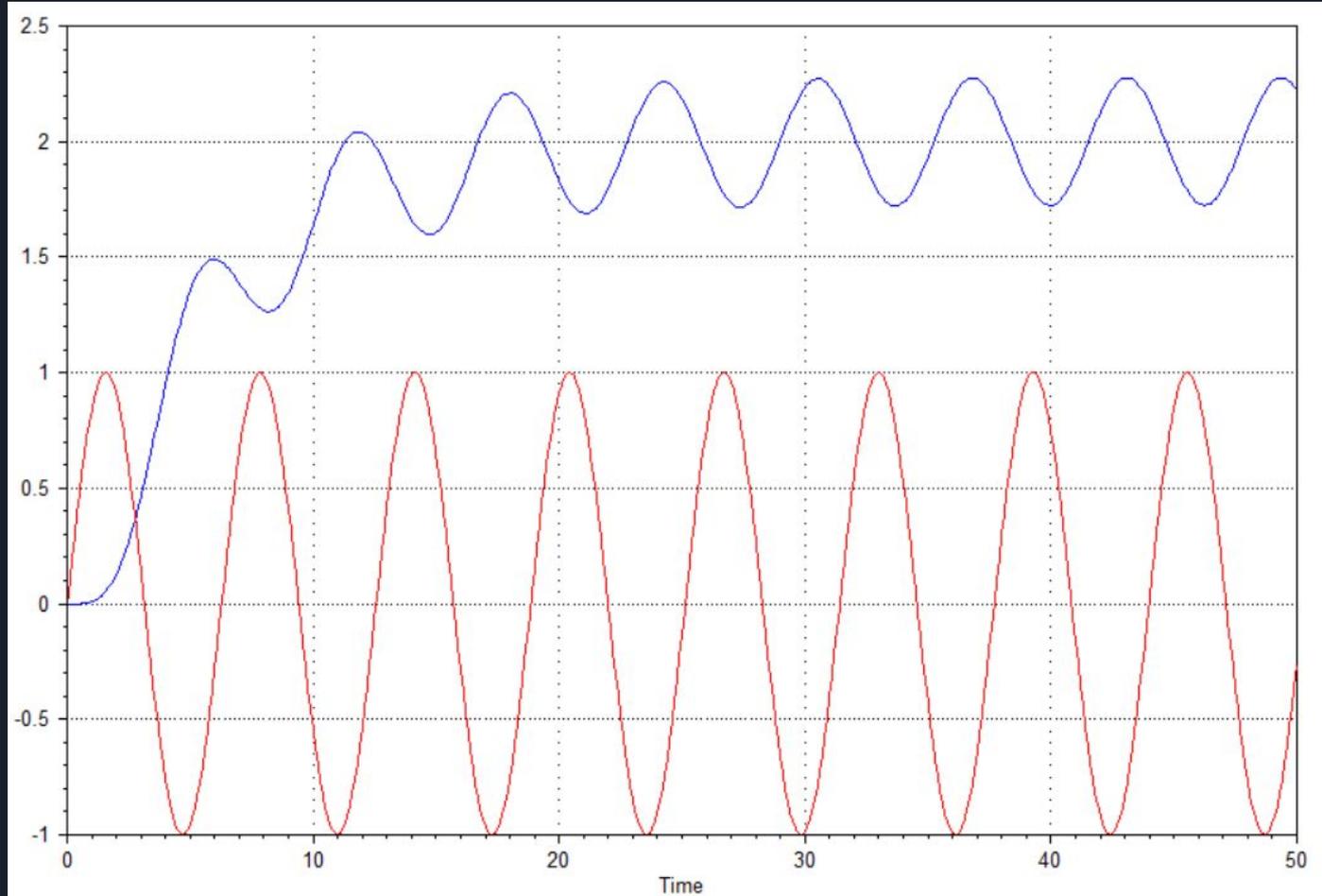
Desfase: 188,16 °




$$w = 1$$

Amplitud Salida : 0,27
Periodo: 6,28 s
Desfase (s): 3,82s

Resultados:
Amplitud: -11,37 dB
Desfase: 218,86°





$$w = 2$$

Amplitud Salida : 0,045

Periodo: 3,14 s

Desfase (s): 2,17 s

Resultados:

Amplitud: -26,93 dB

Desfase: 248,66°

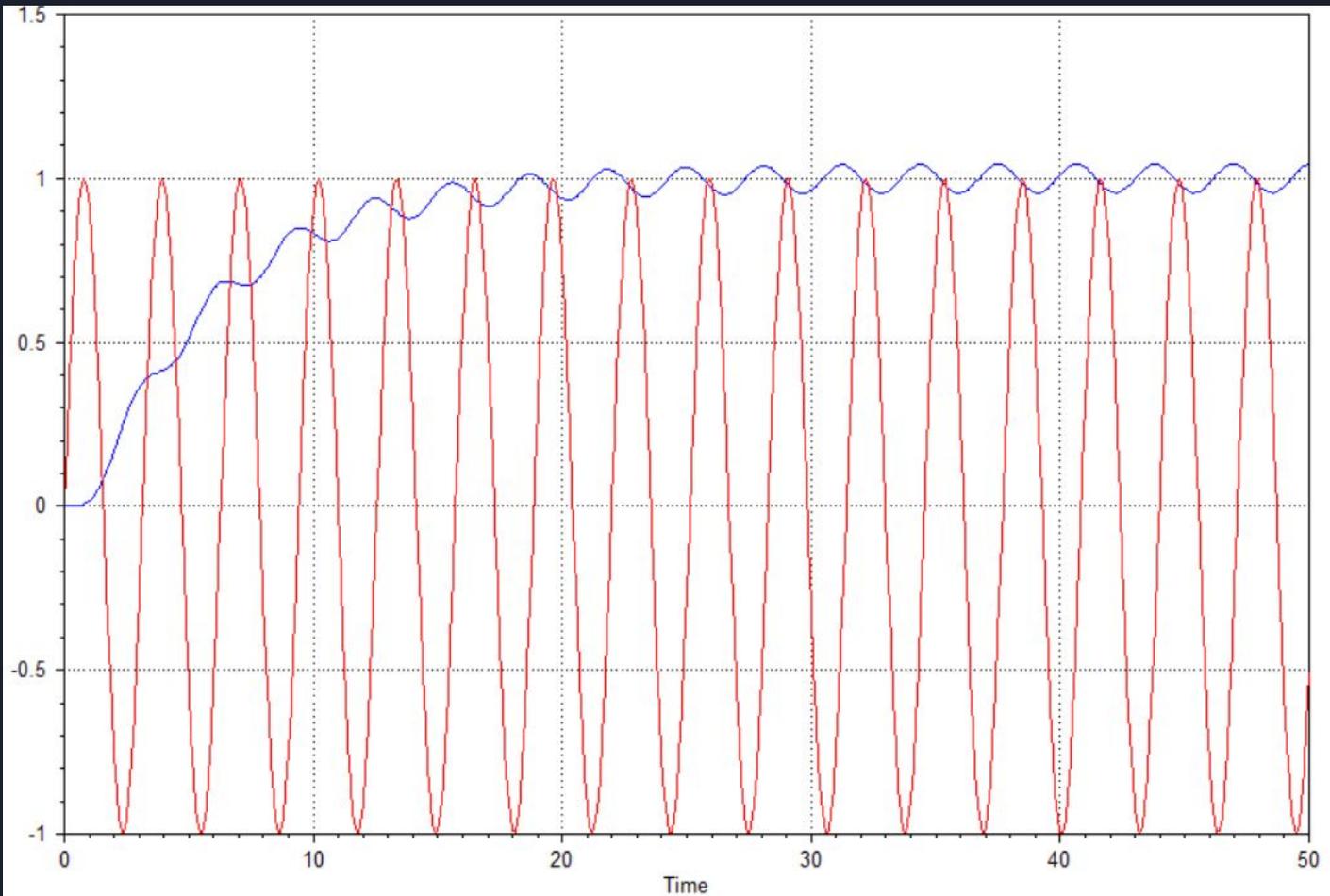
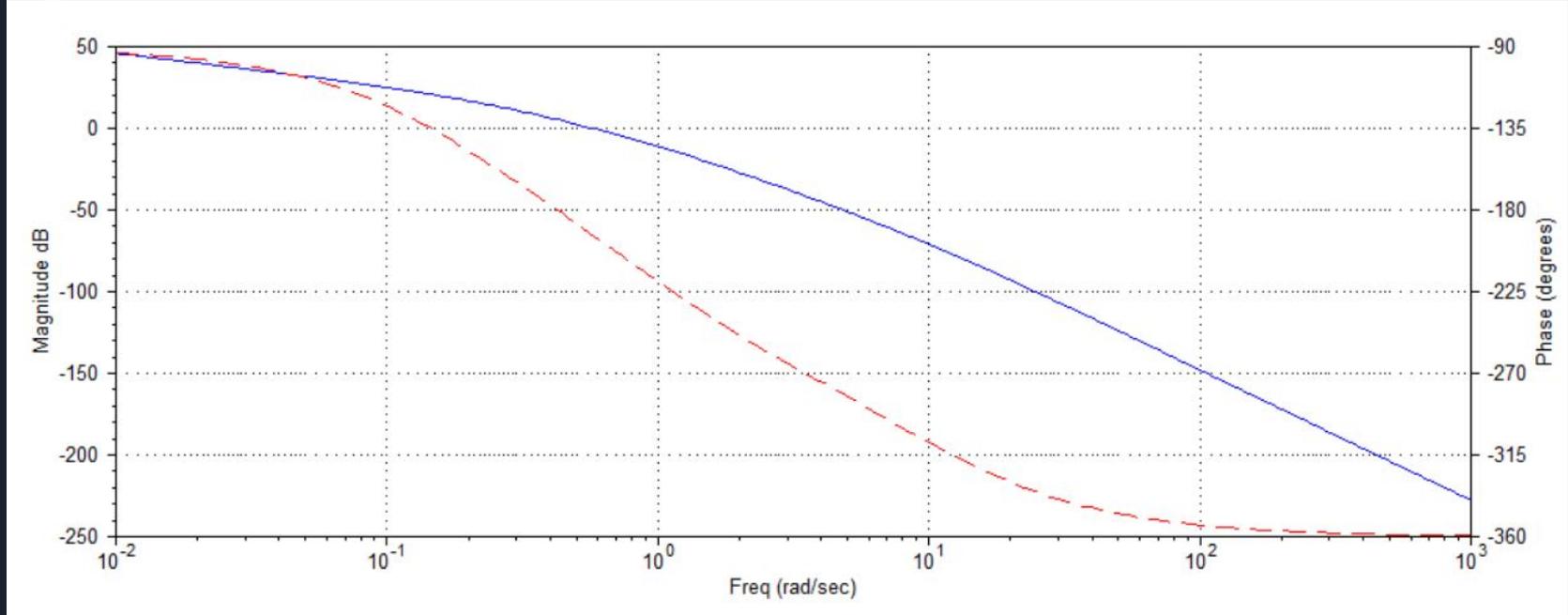
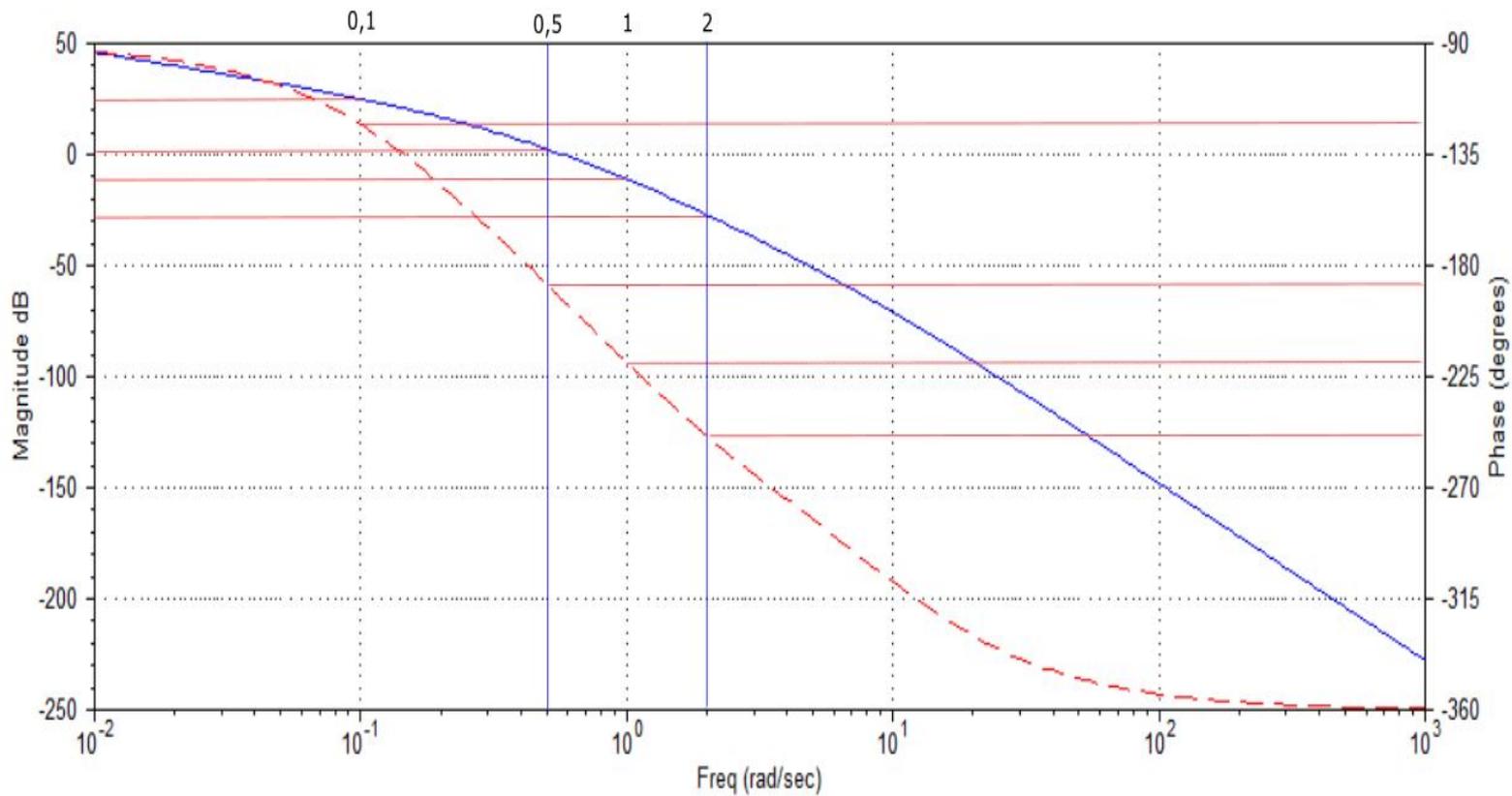


Gráfico de Bode

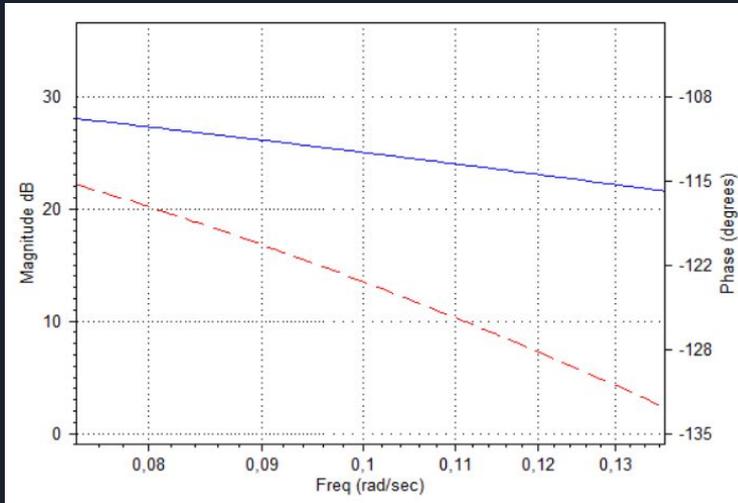






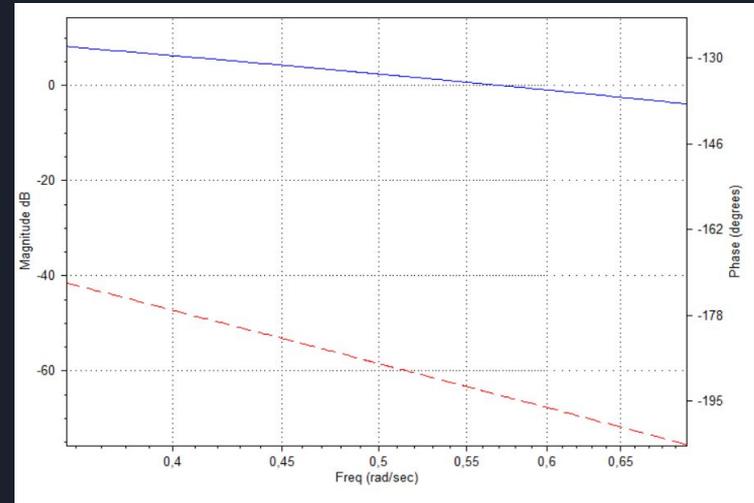
0,1:

25 dB , -122,8°



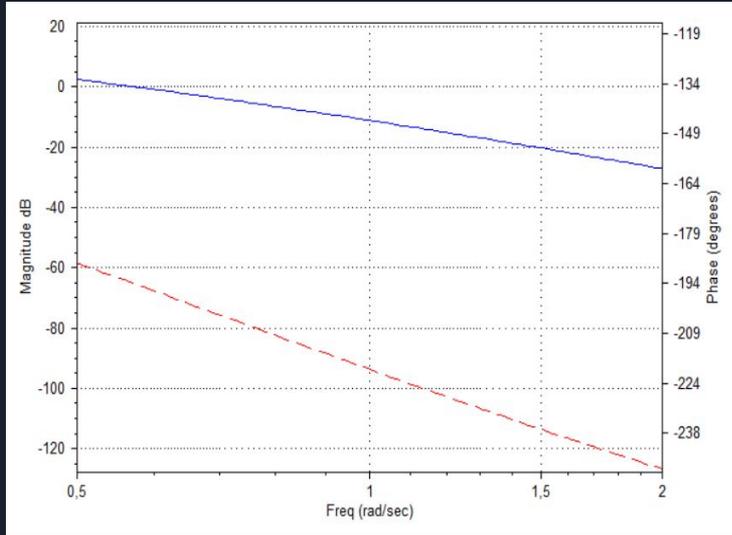
0,5:

2,46 dB , -187,6°



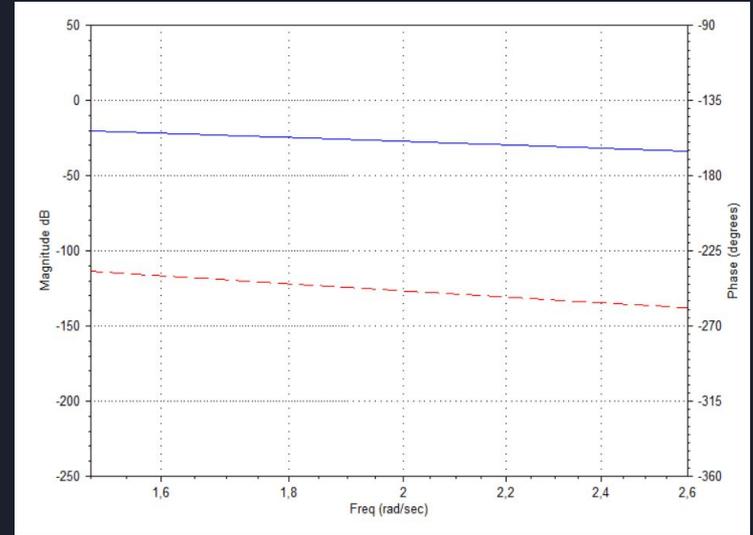
1:

-11,19 dB , -219,4°



2:

-27,21 dB , -249,1°



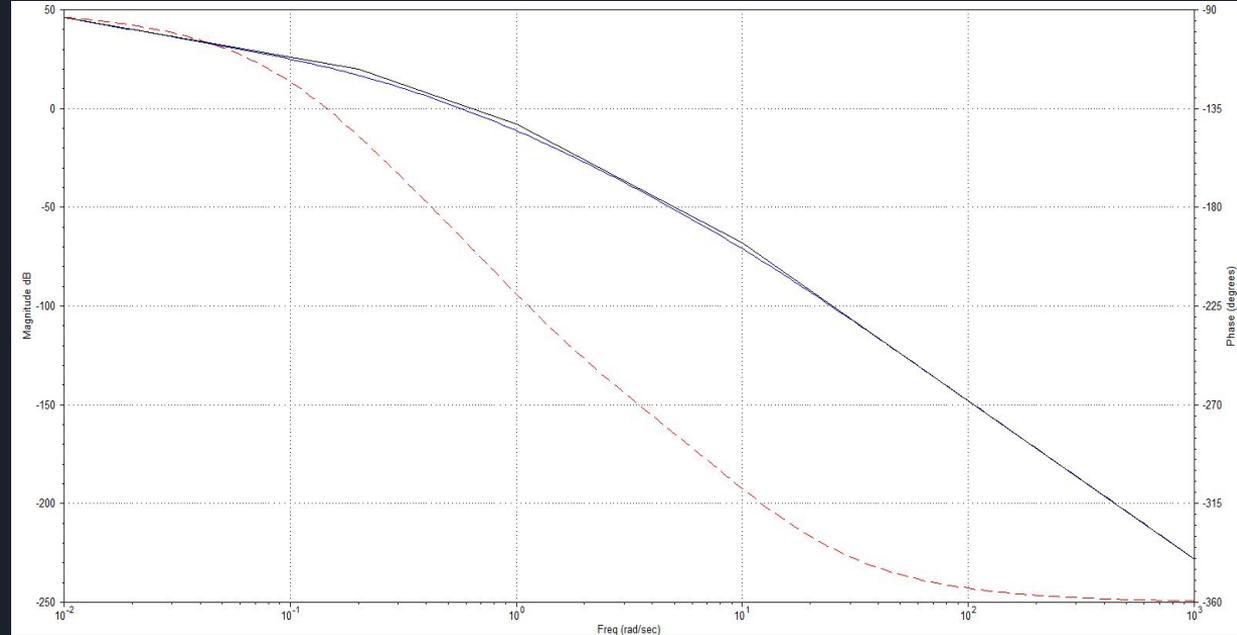
Ejercicio 4.1

BODE

$G_{ss} = 2$

Cambio de pendiente de
asíntotas en:

- $\omega = 0$
- $\omega = 0,2 \rightarrow \tau=5 \rightarrow T=10\pi$
- $\omega = 1 \rightarrow \tau=1 \rightarrow T=2\pi$
- $\omega = 10 \rightarrow \tau=0,1 \rightarrow T=20\pi$



```
CC>margin(g5)
```

```
At w= 0.423 r/s, Gain margin= 0.537 ( -5.41 dB)
```

```
At w= 0.572 r/s, Phase margin= -13.77 deg, Delay margin= -0.42 sec
```

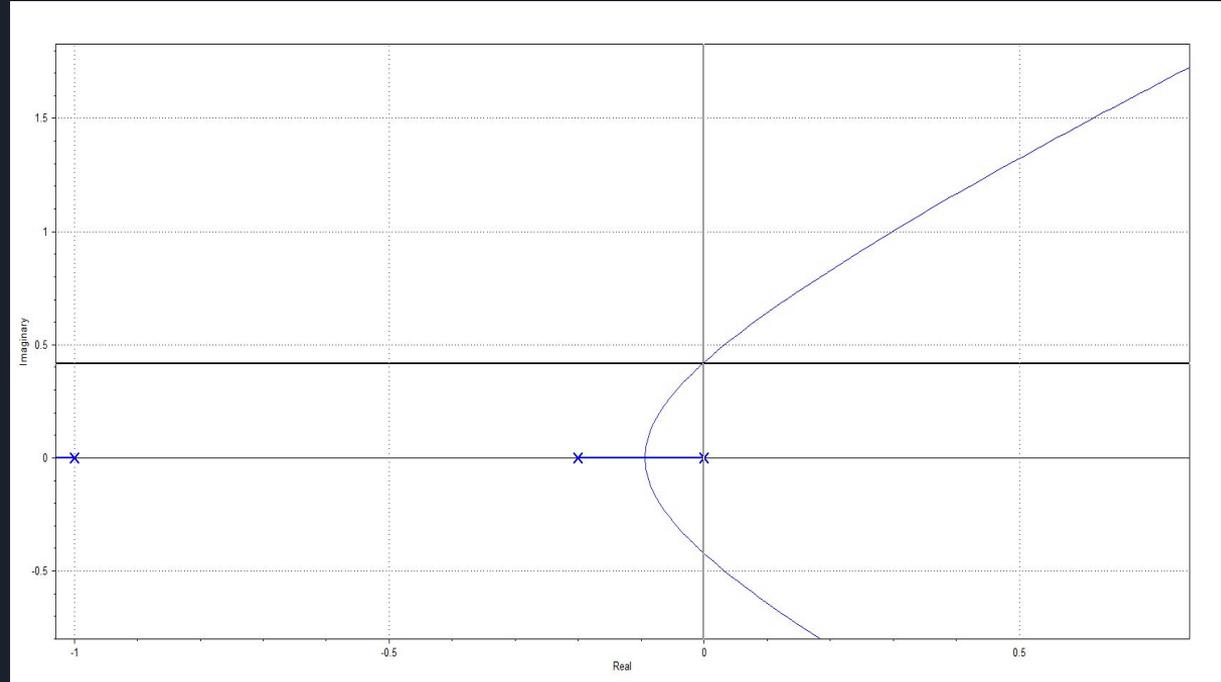
```
At w= 0.546 r/s, Mp= 4.65 (13.36 dB)
```

Lugar de raíces

$K_{cu} = 0.52$

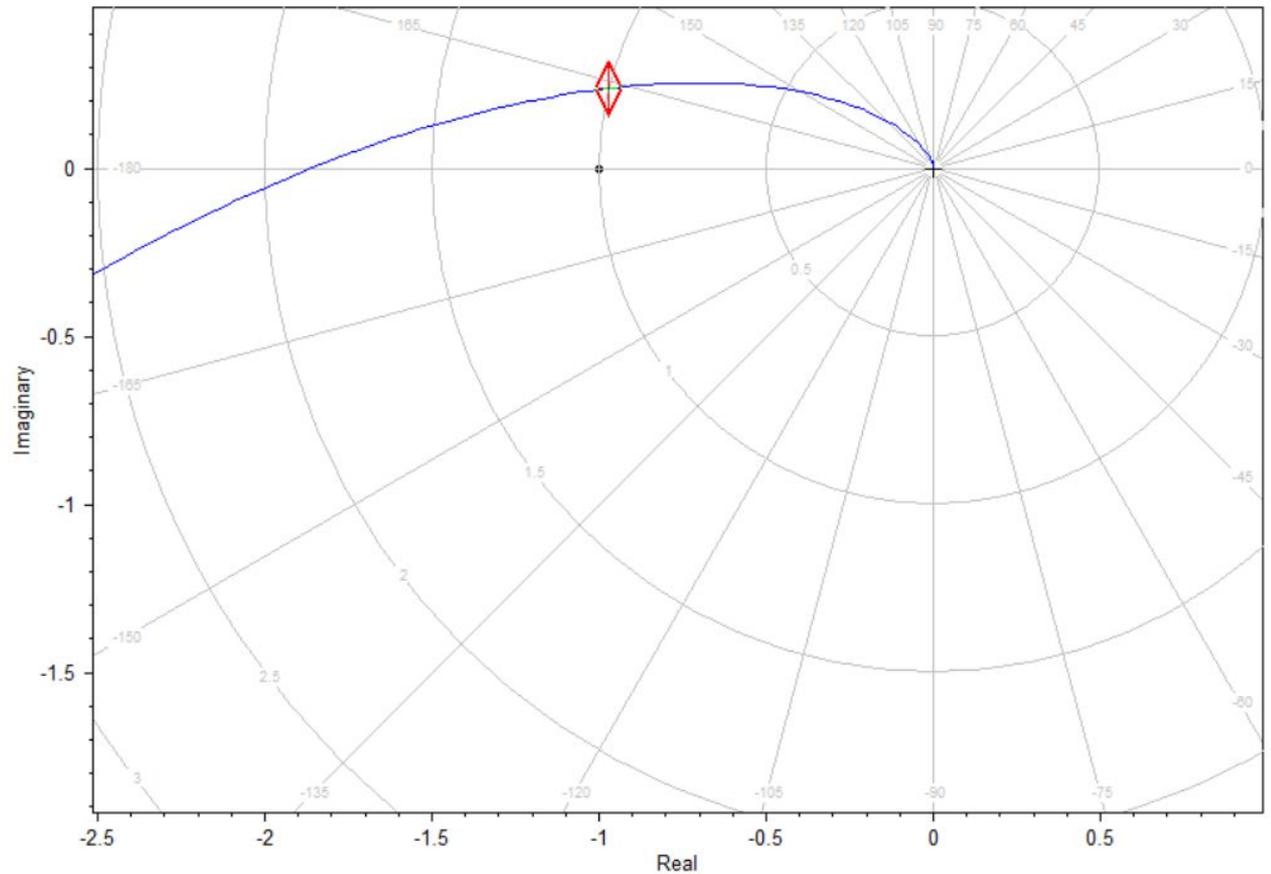
$\square u = 0.42$

$T_u = 14.96$



$s = -0.0004359 + 0.4167j$ (Mag= 0.4167, Zeta= 0.001046)
gain= $0.5215 - 0.004724j$ (Mag= 0.5215, Phase= -0.519 deg)

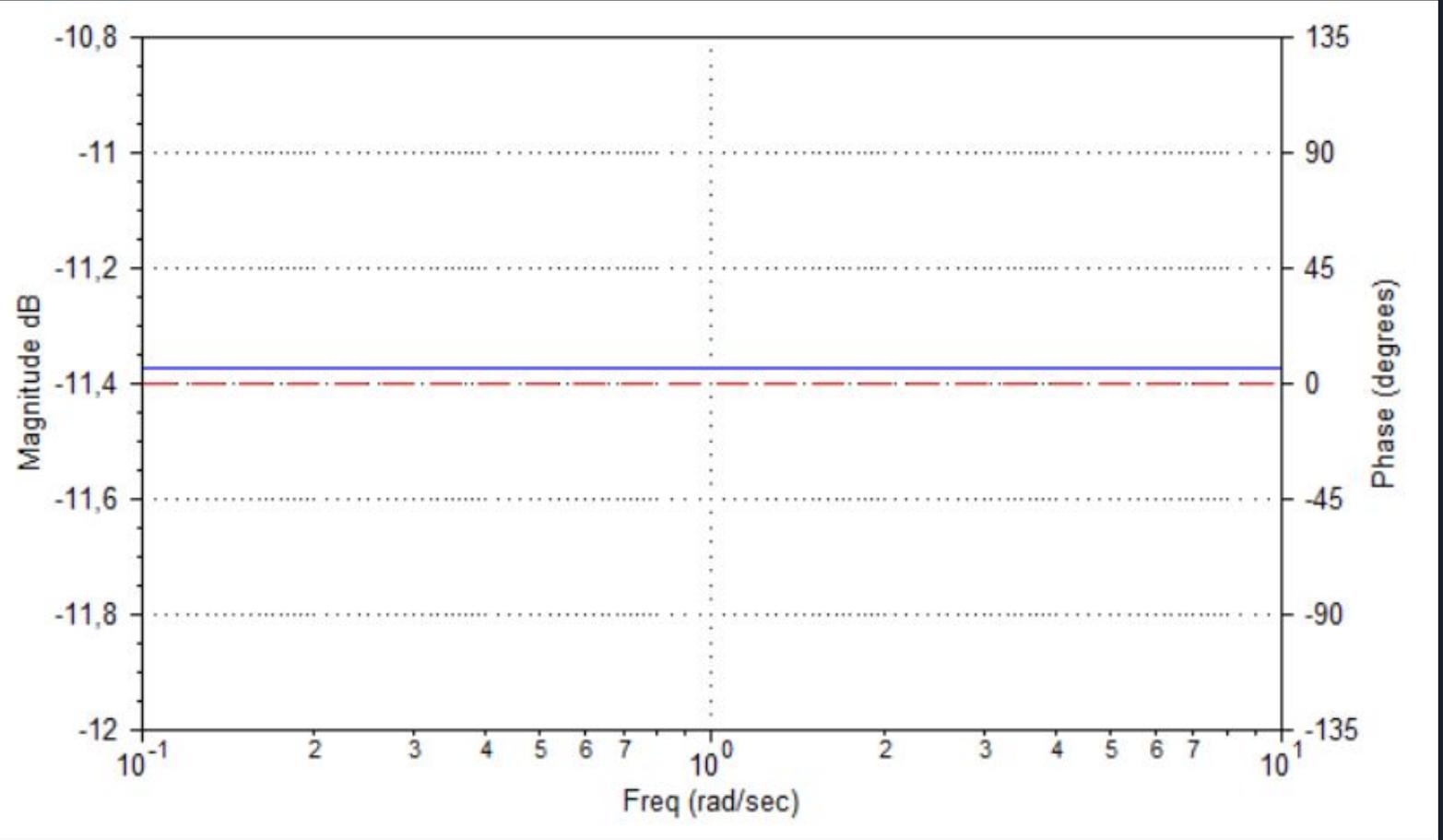
Nyquist



Freq= 0.5716 r/s, Real = -0.9729, Imag = 0.2379, Mag = 1.002 (0.01349 dB), Phase = -193.7 deg

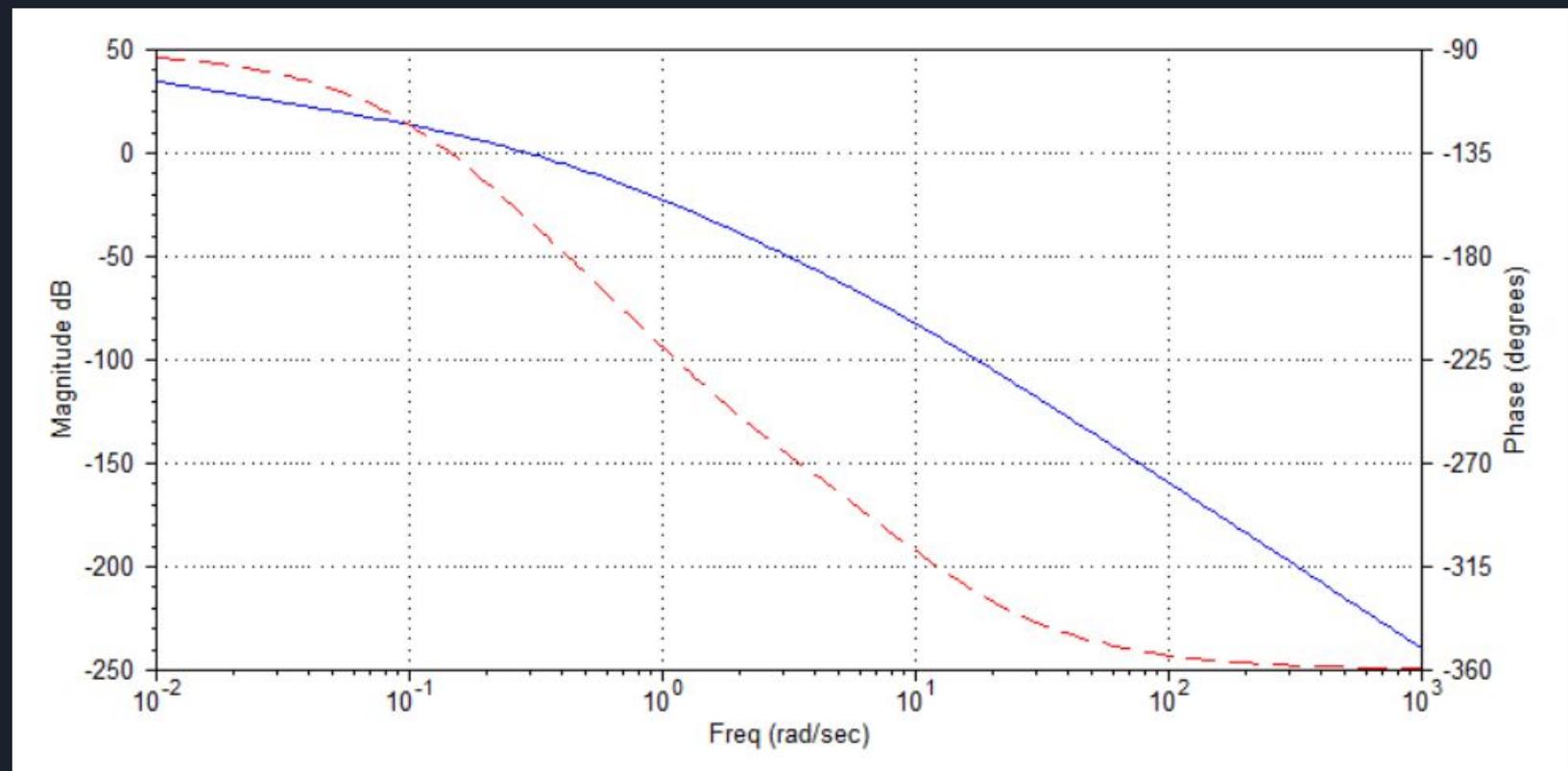


Gp
Bode





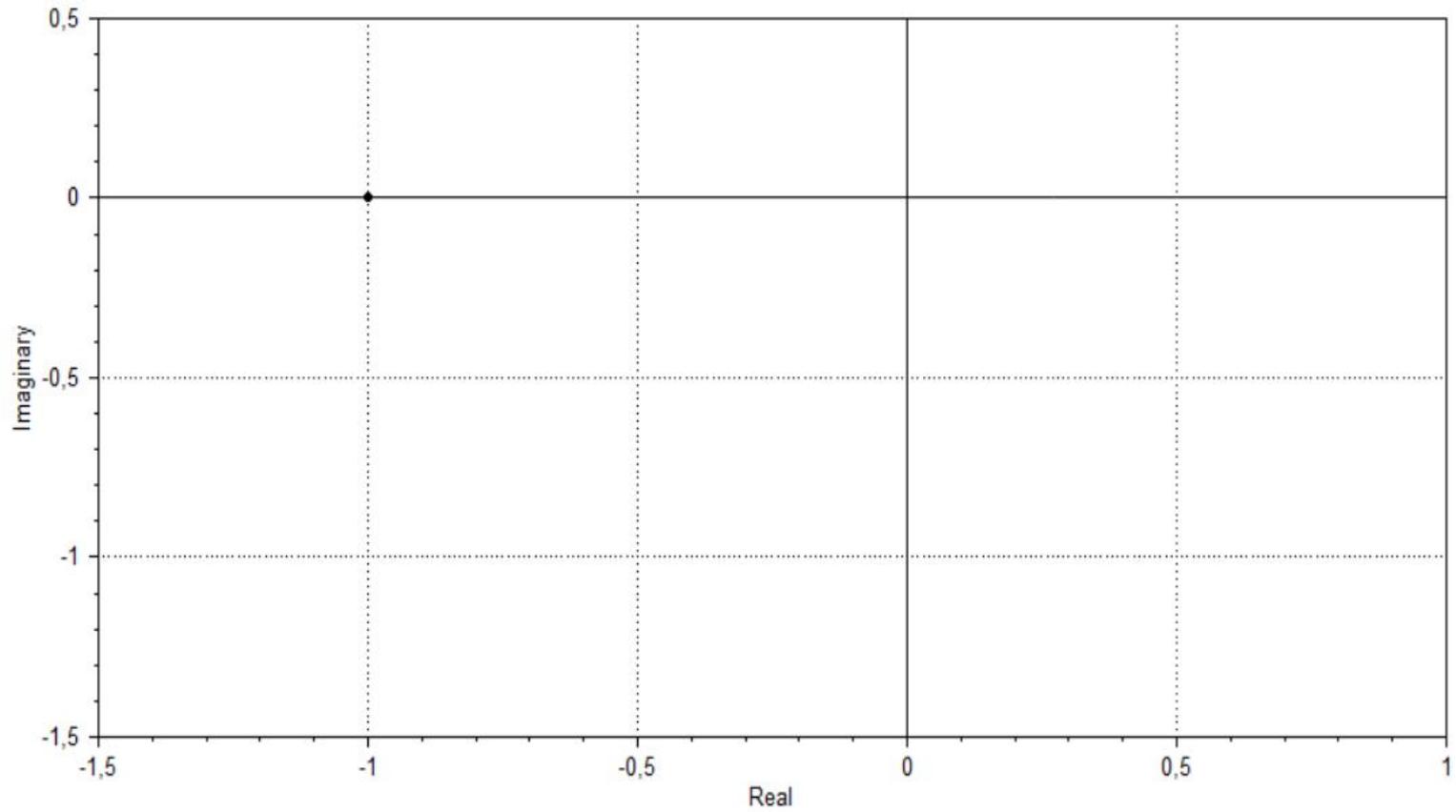
Gp*Go
Bode





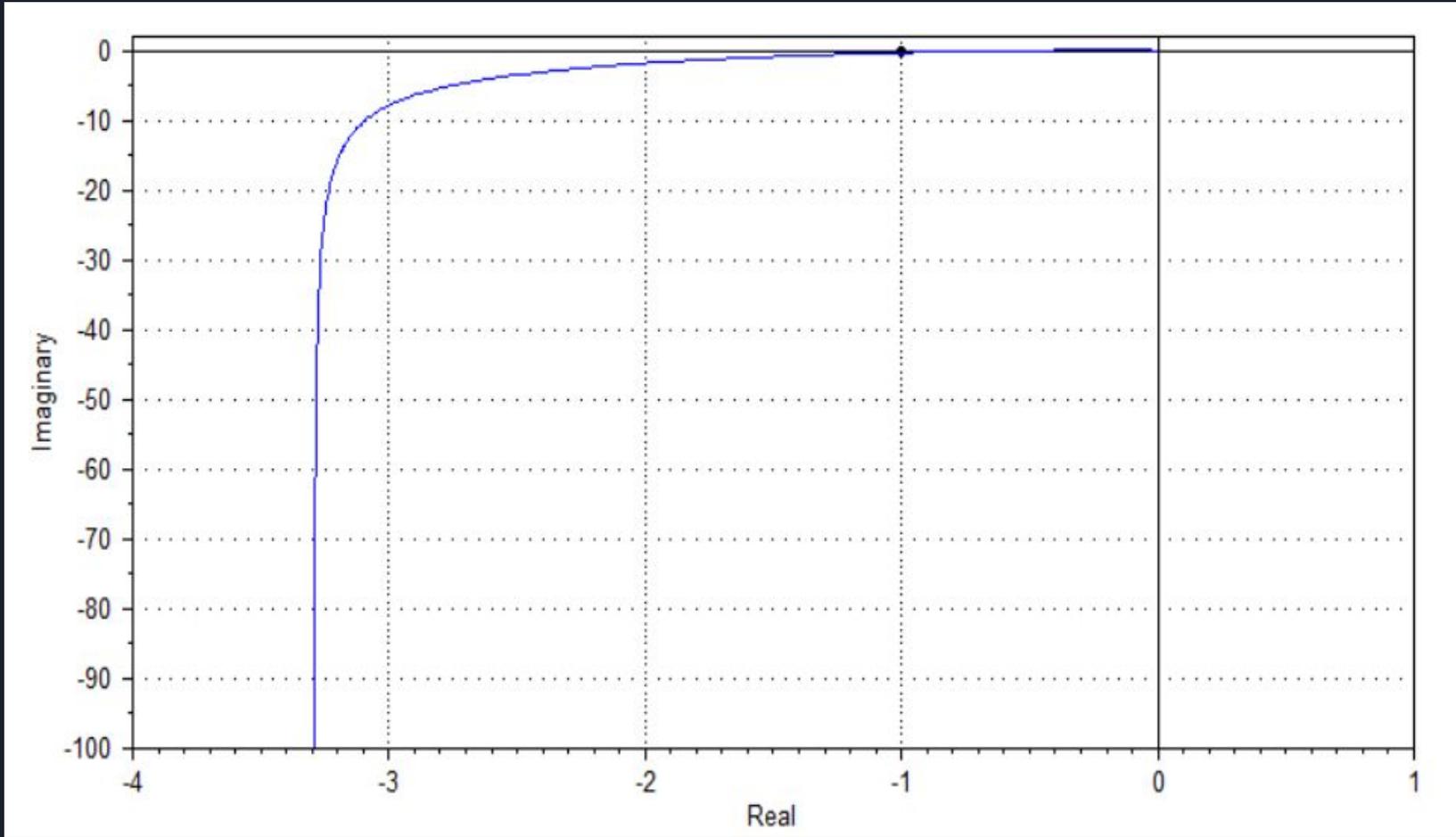
Gp

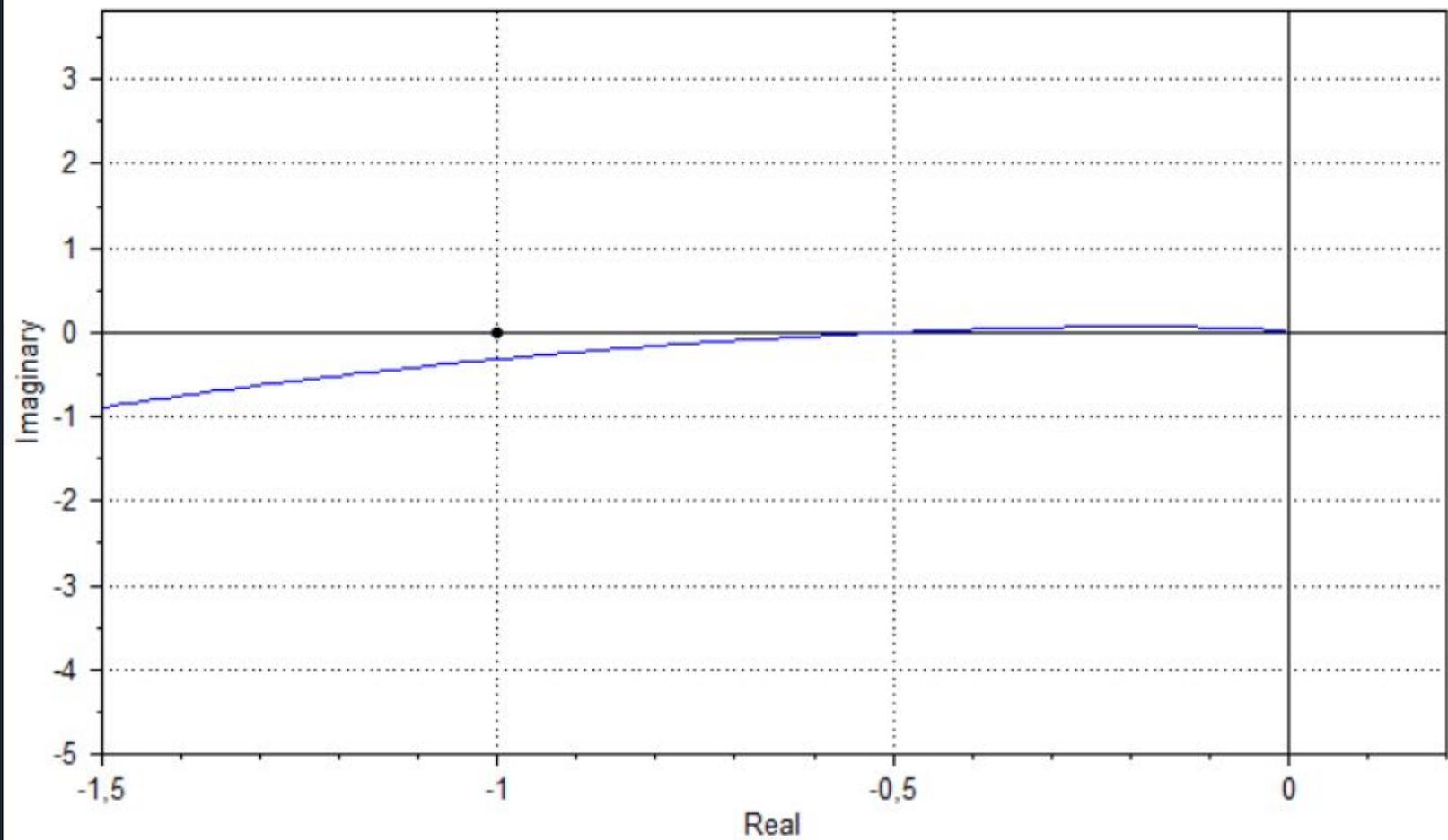
Nyquist





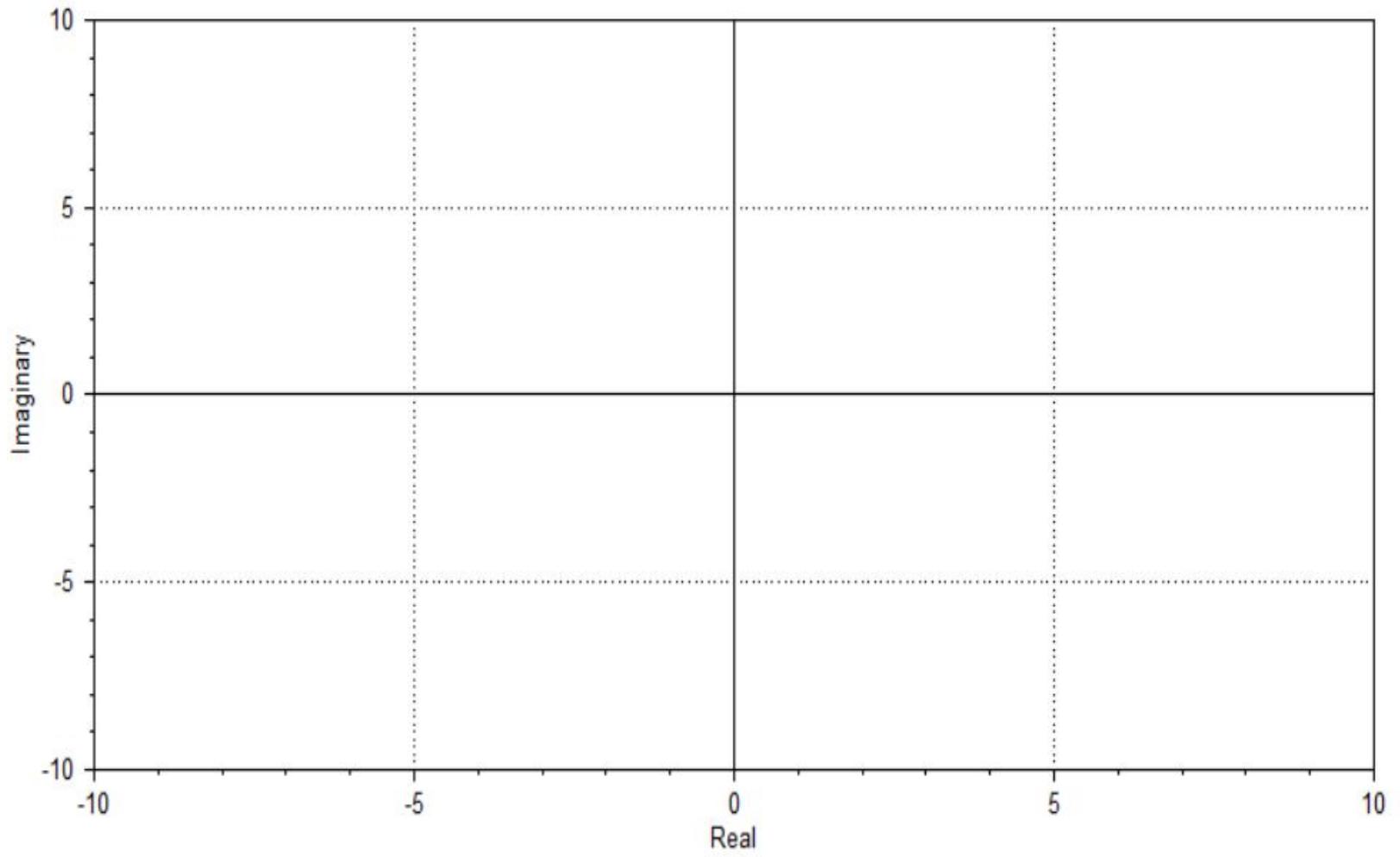
Gp*Go
Nyquist





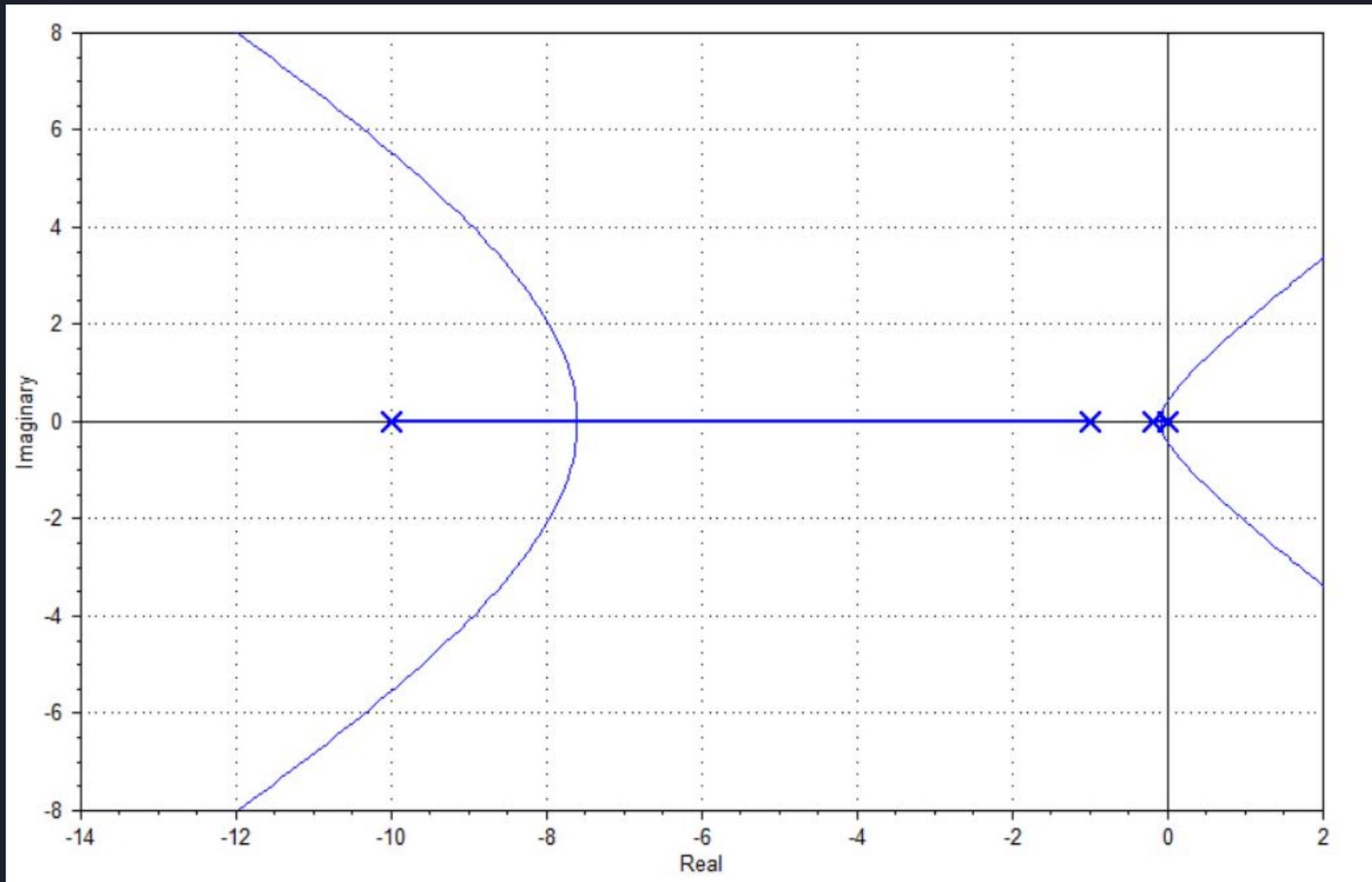


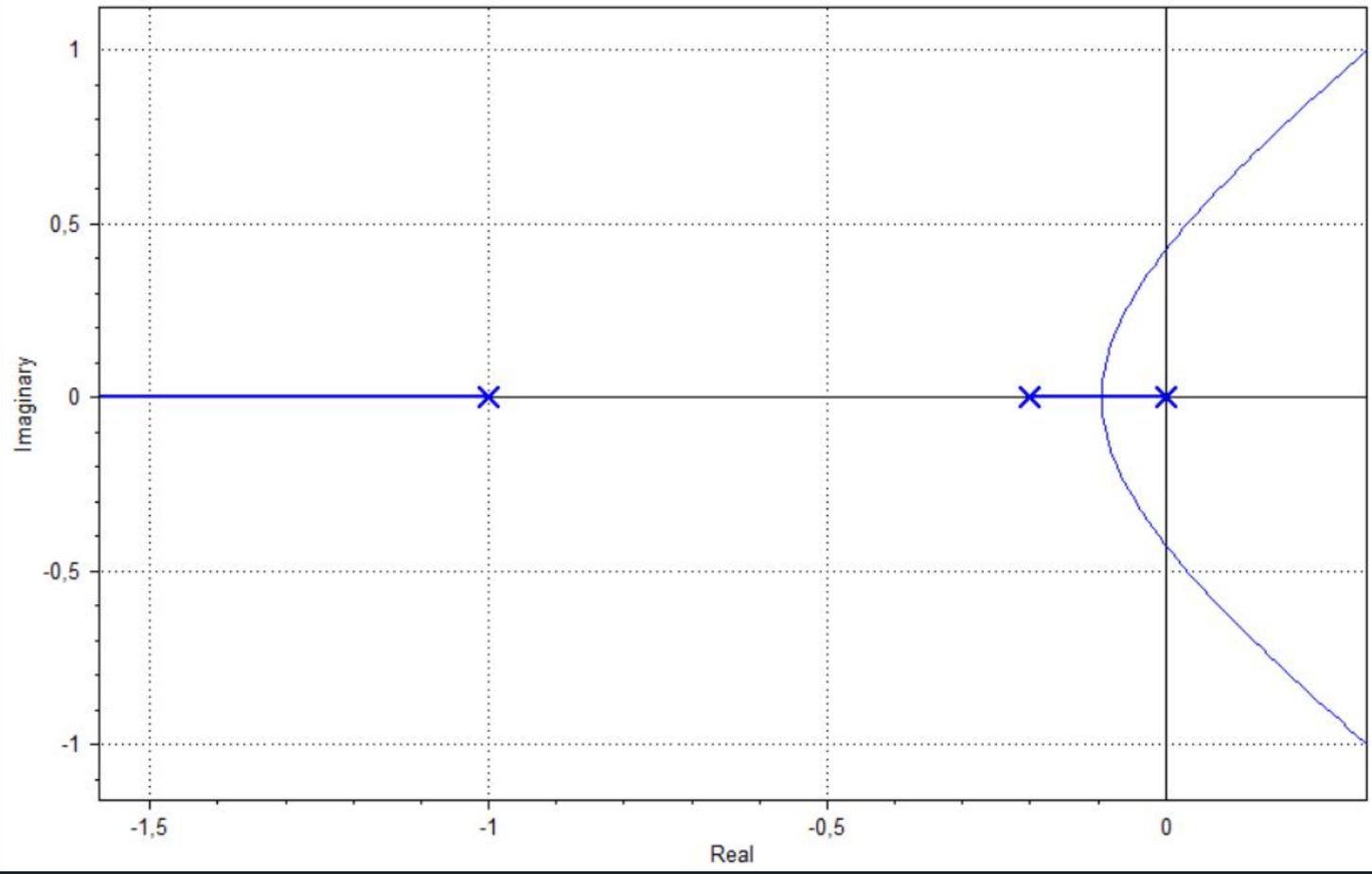
L.R
Gp





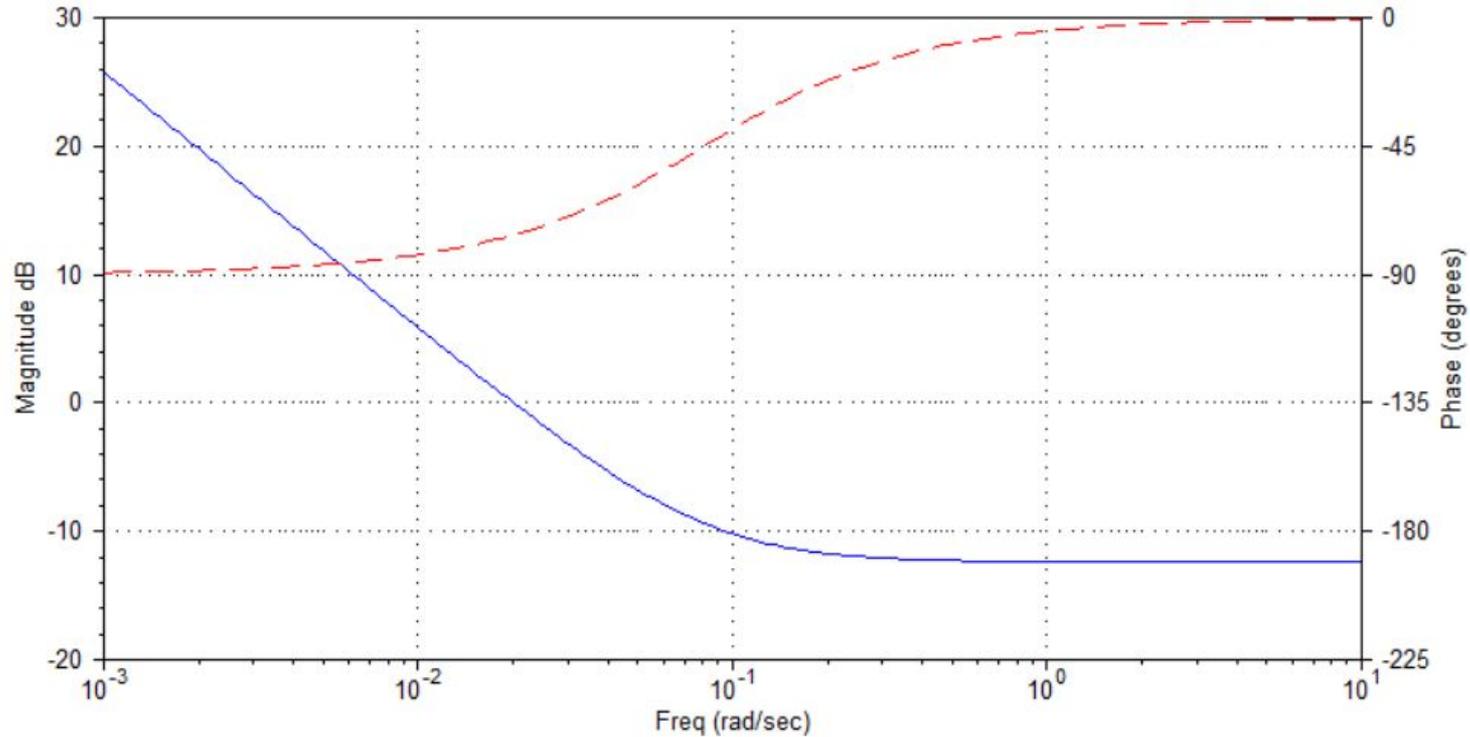
L.R
Gp*Go



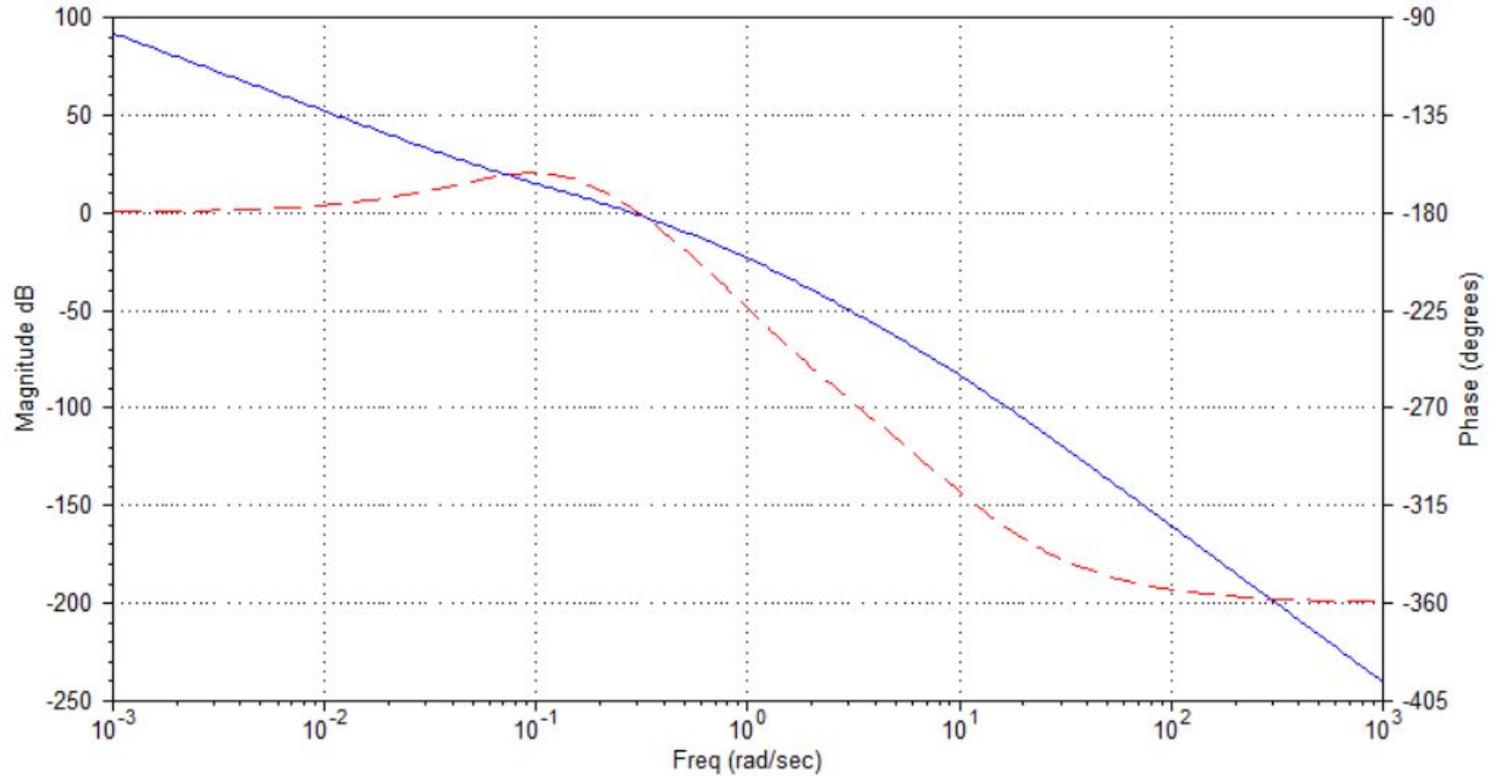


Control PI

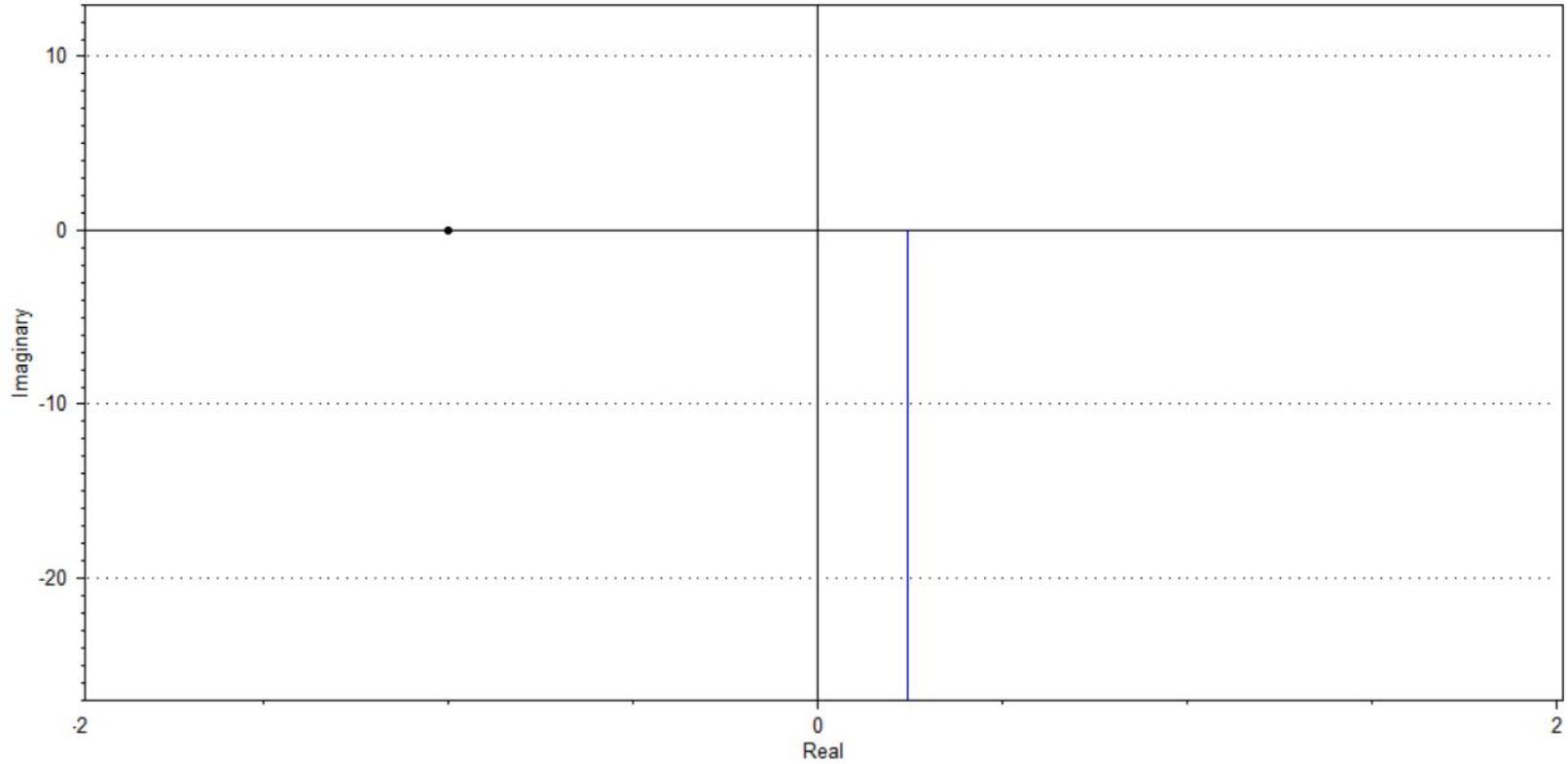
Bode Gpi



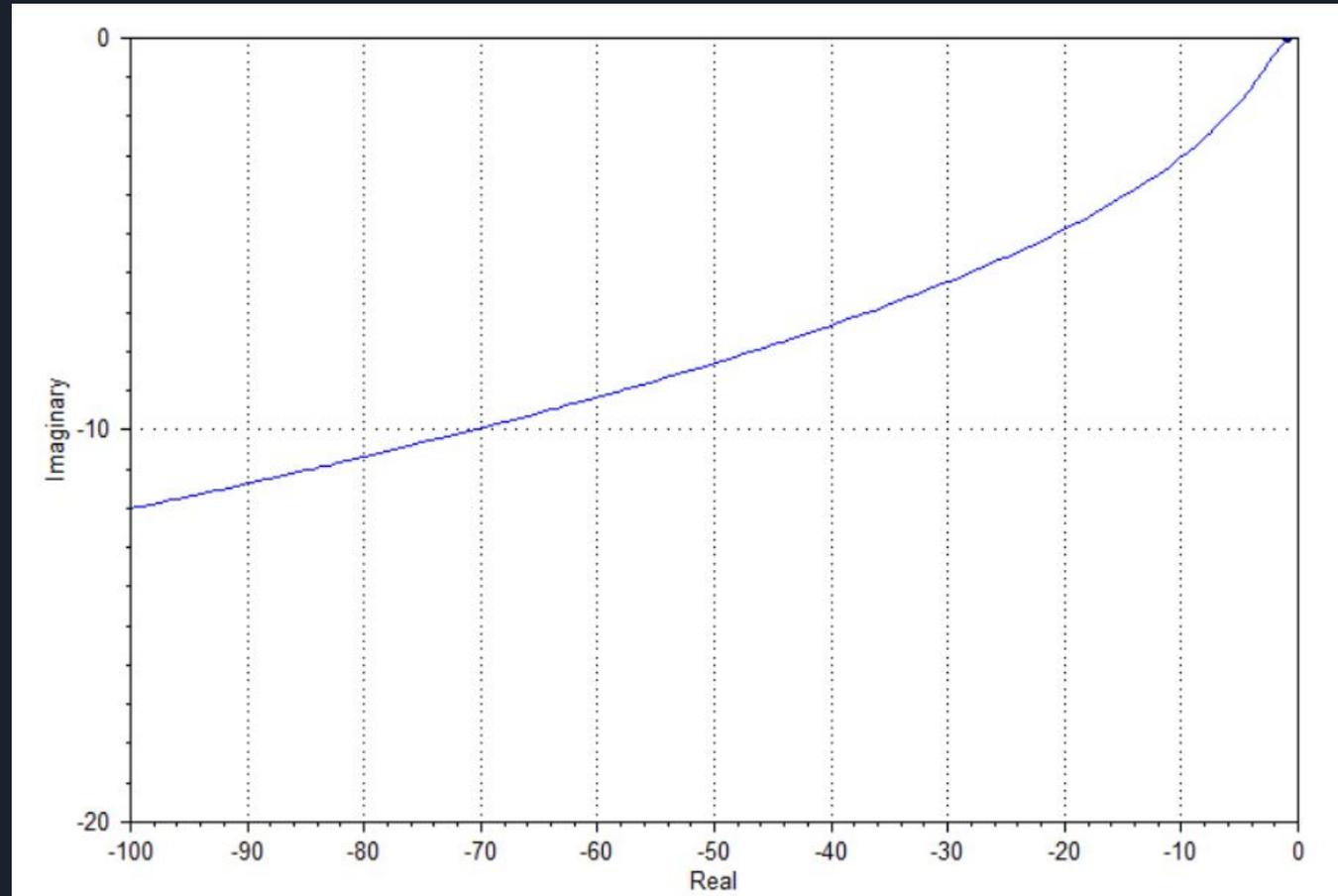
Bode $G_i * G$

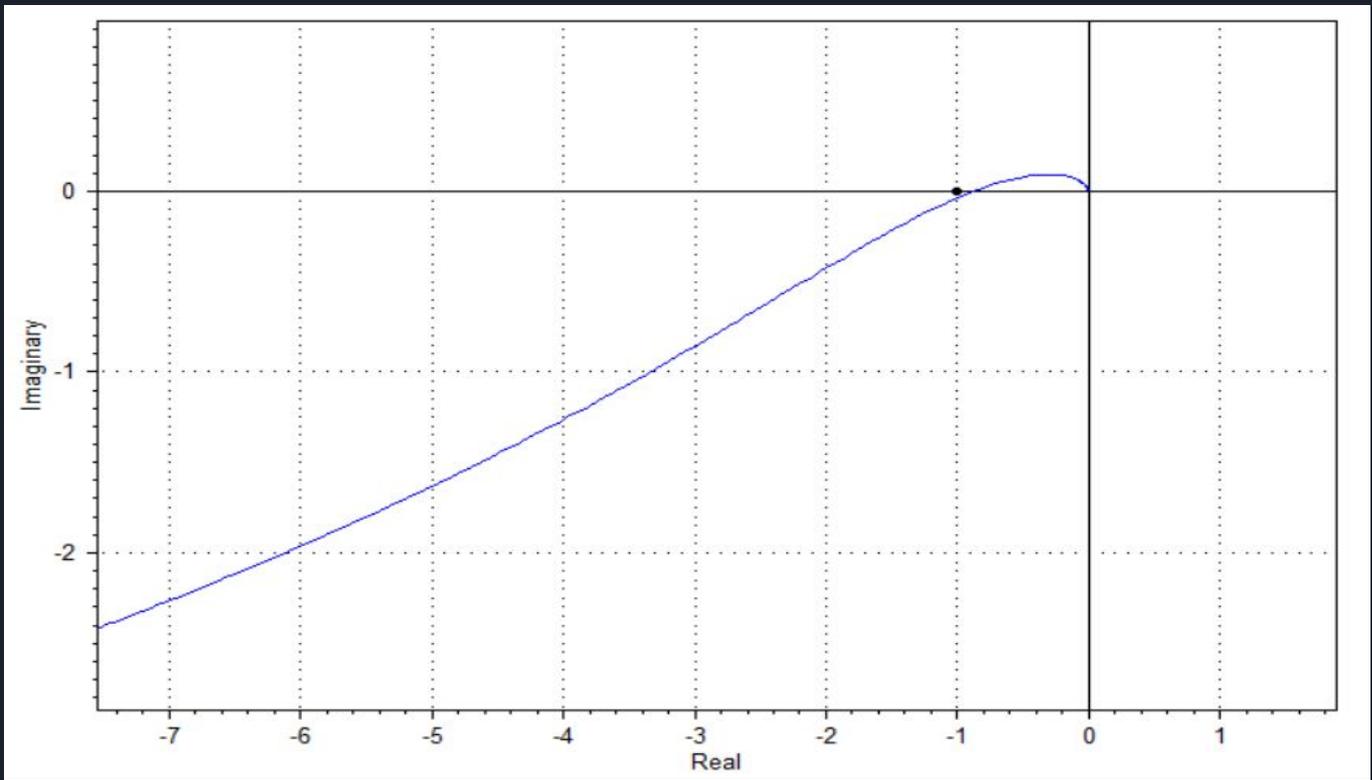


Nyquist Gpi

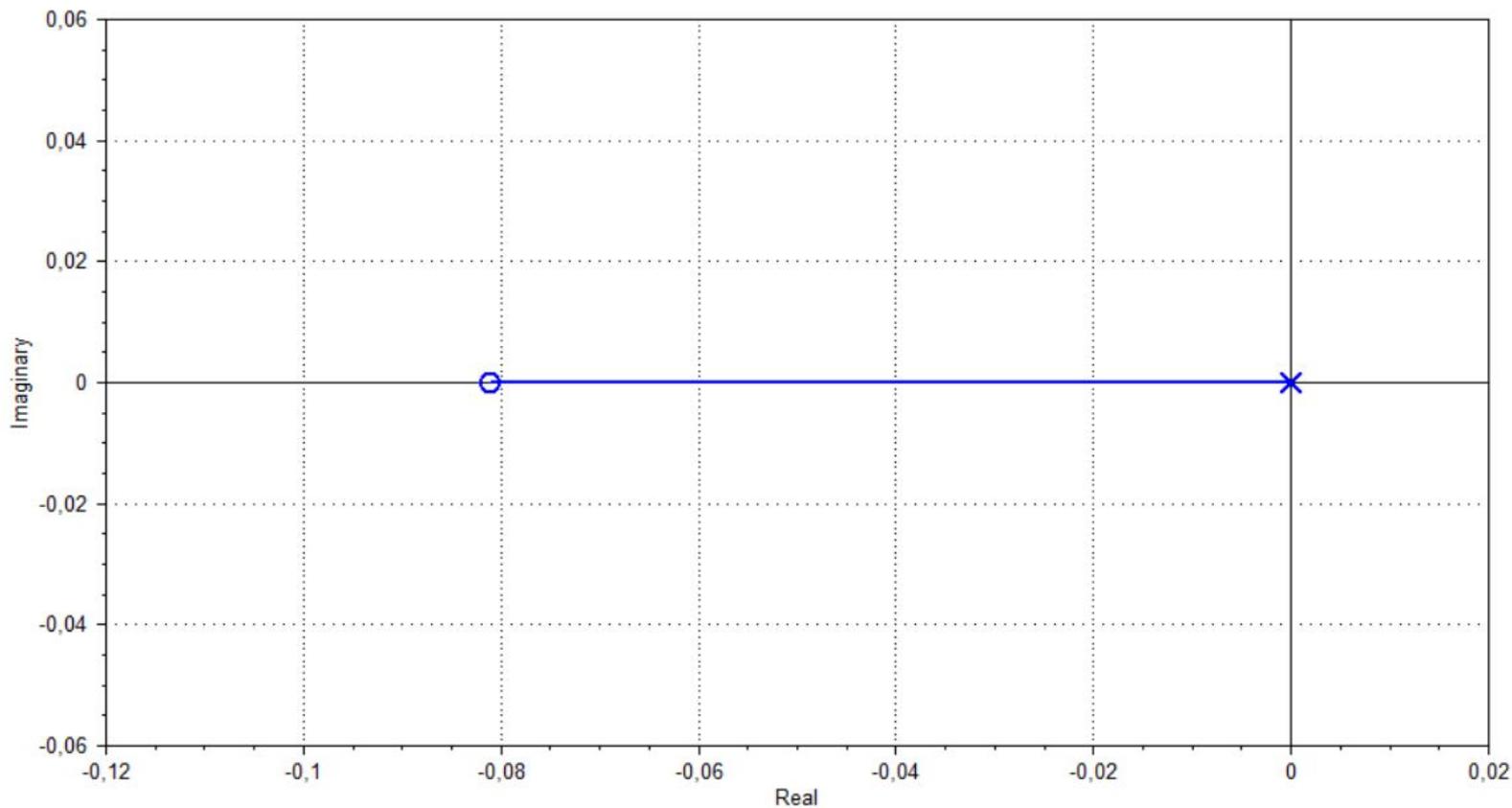


Nyquist $G_{pi} * G$

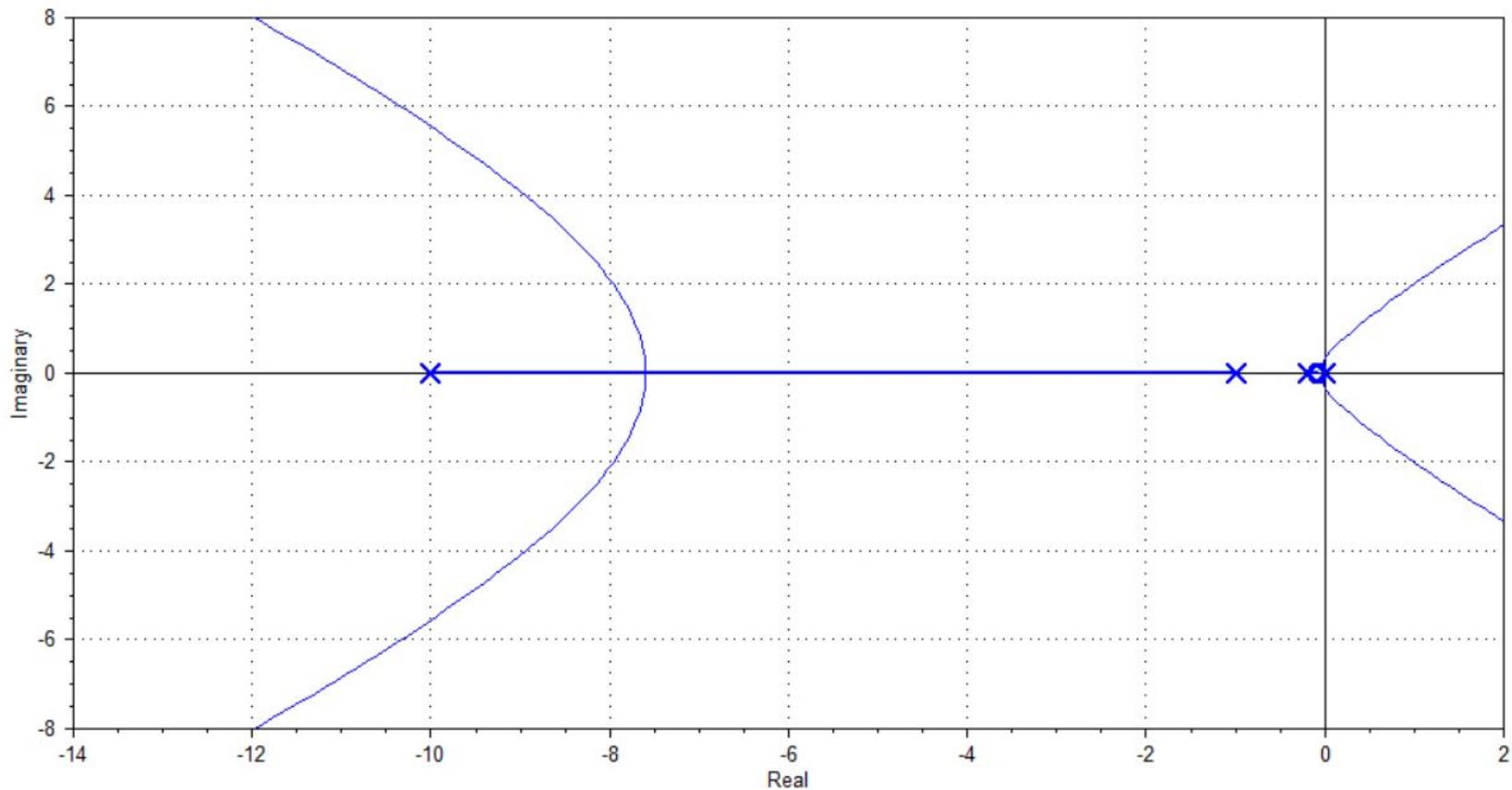


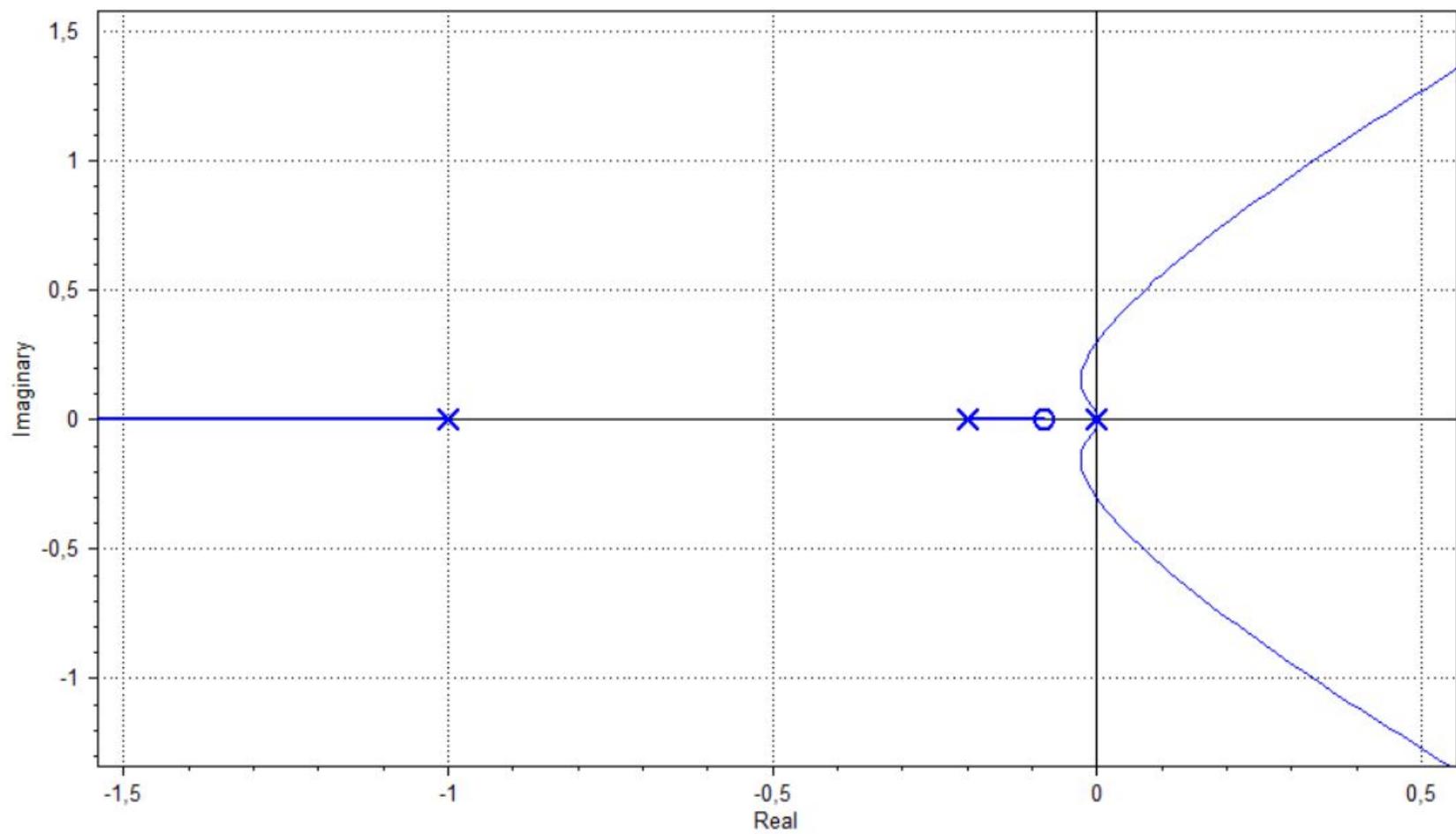


Lugar de raíces G_{pi}



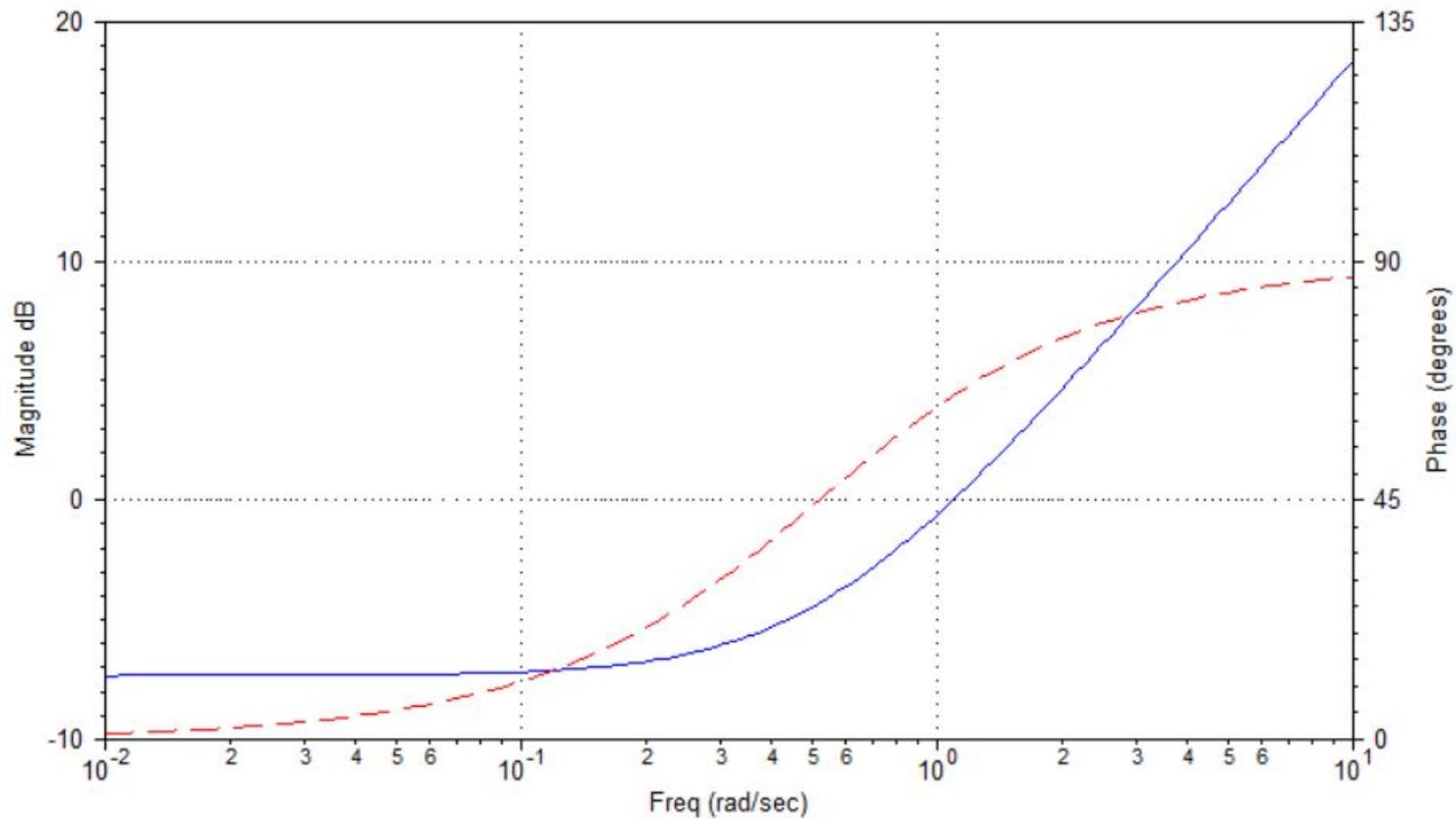
Lugar de raíces $Gp_i \cdot G$



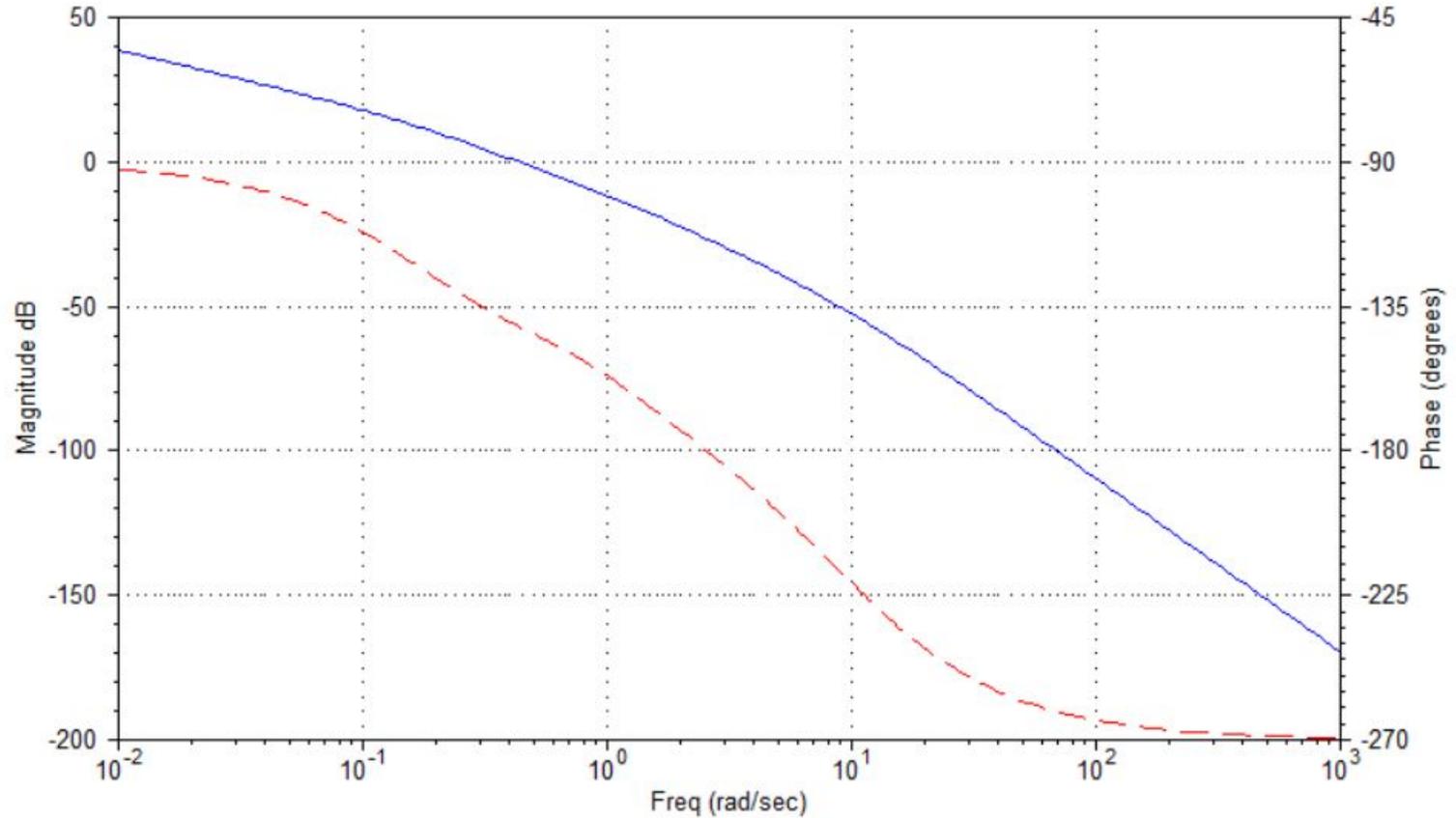


Control PD

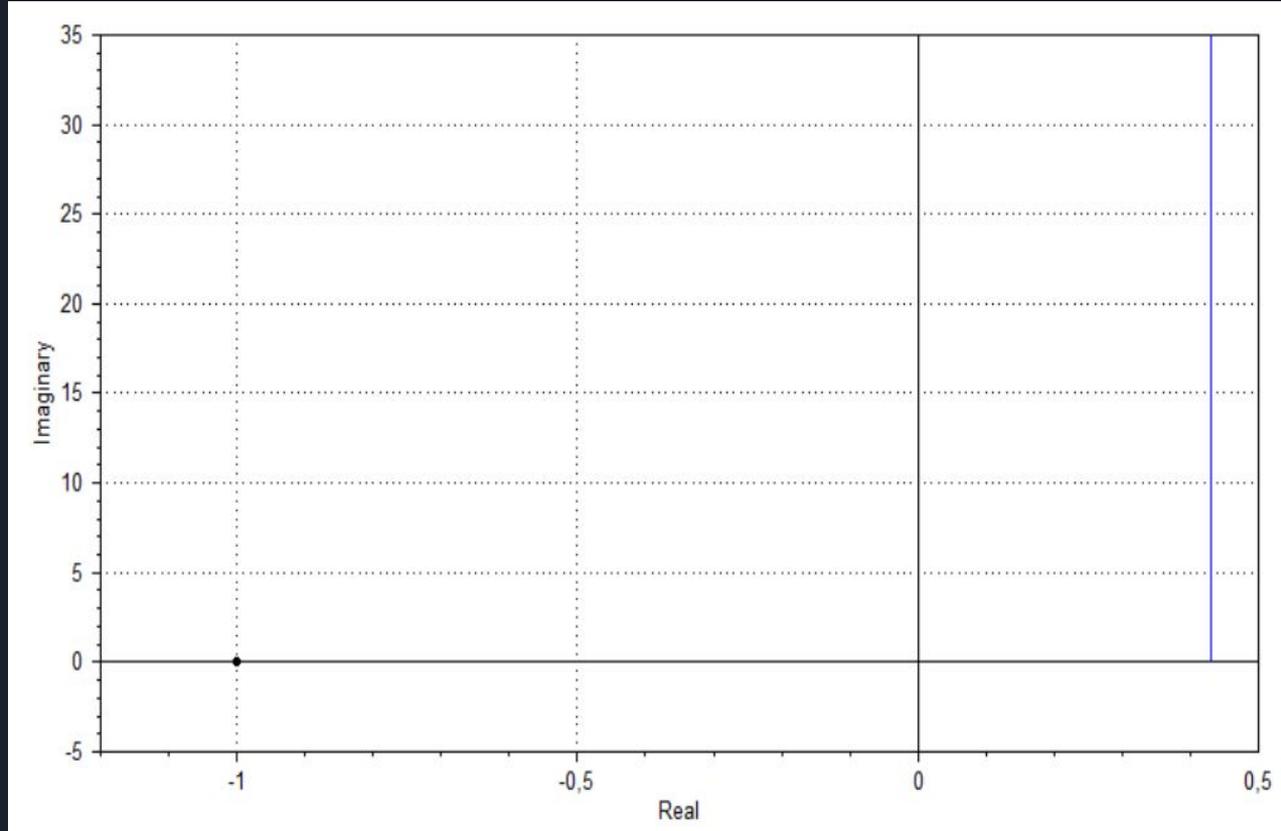
Bode Gpd



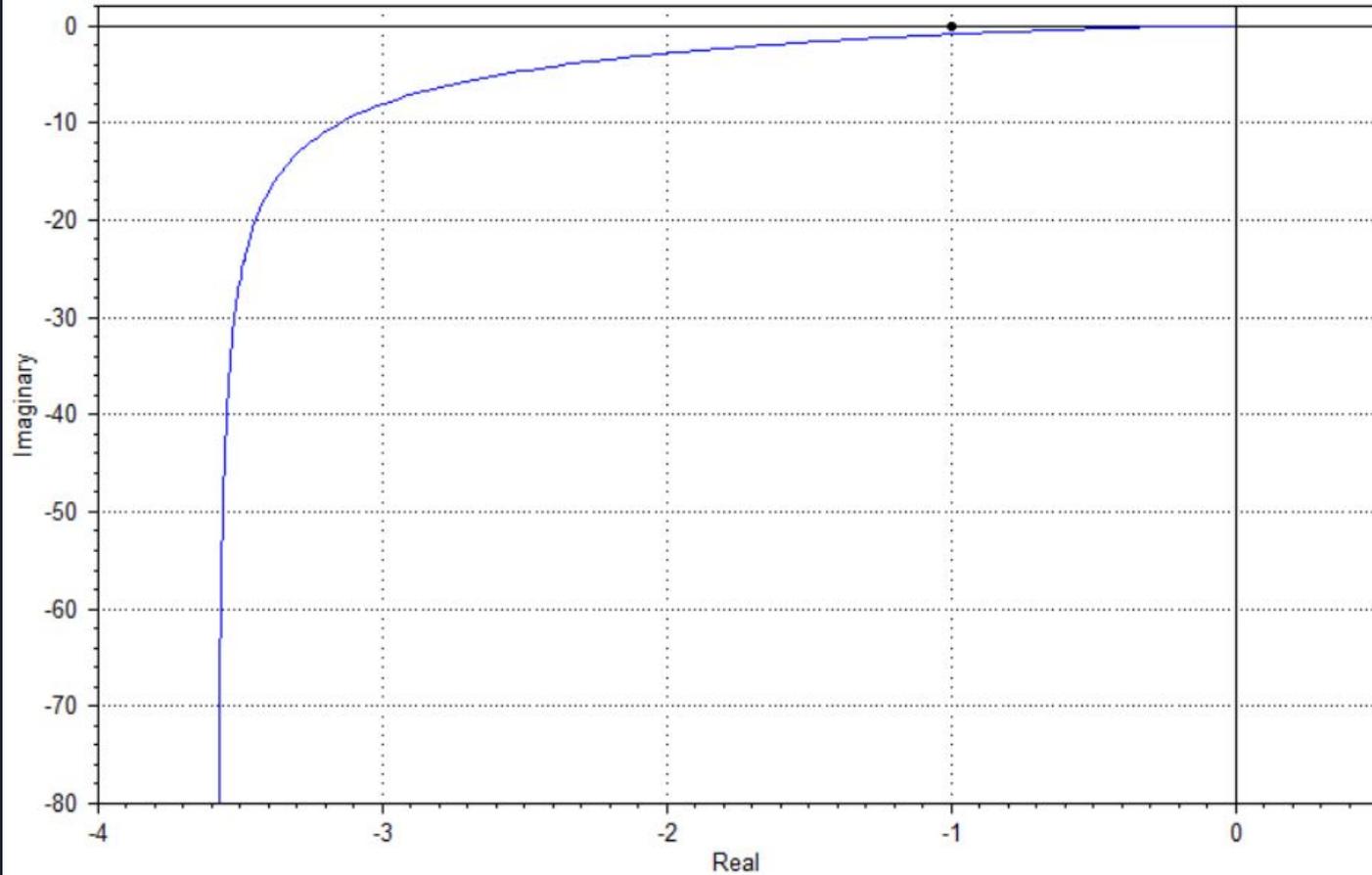
Bode Gpd*G

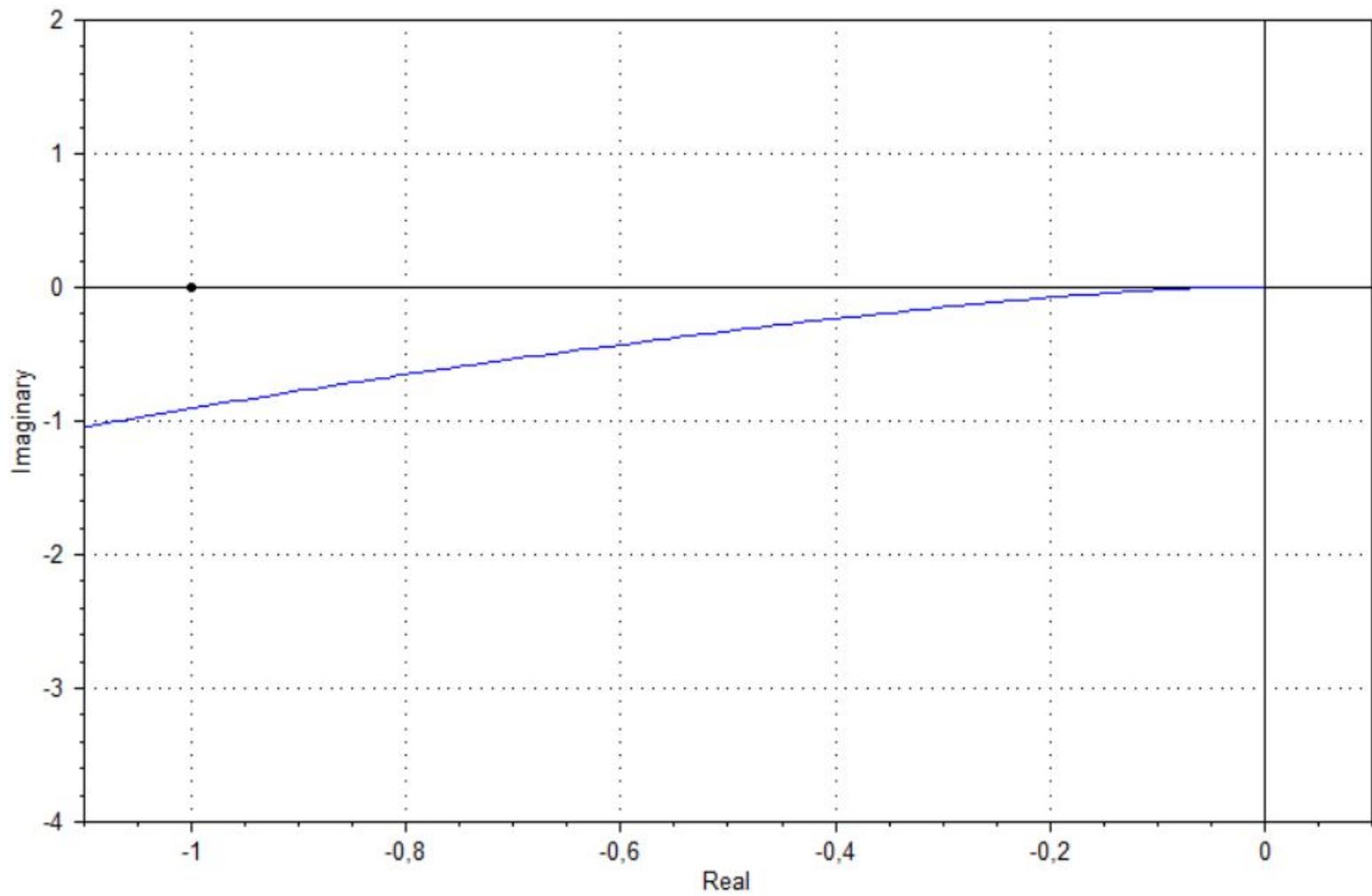


Nyquist Gpd

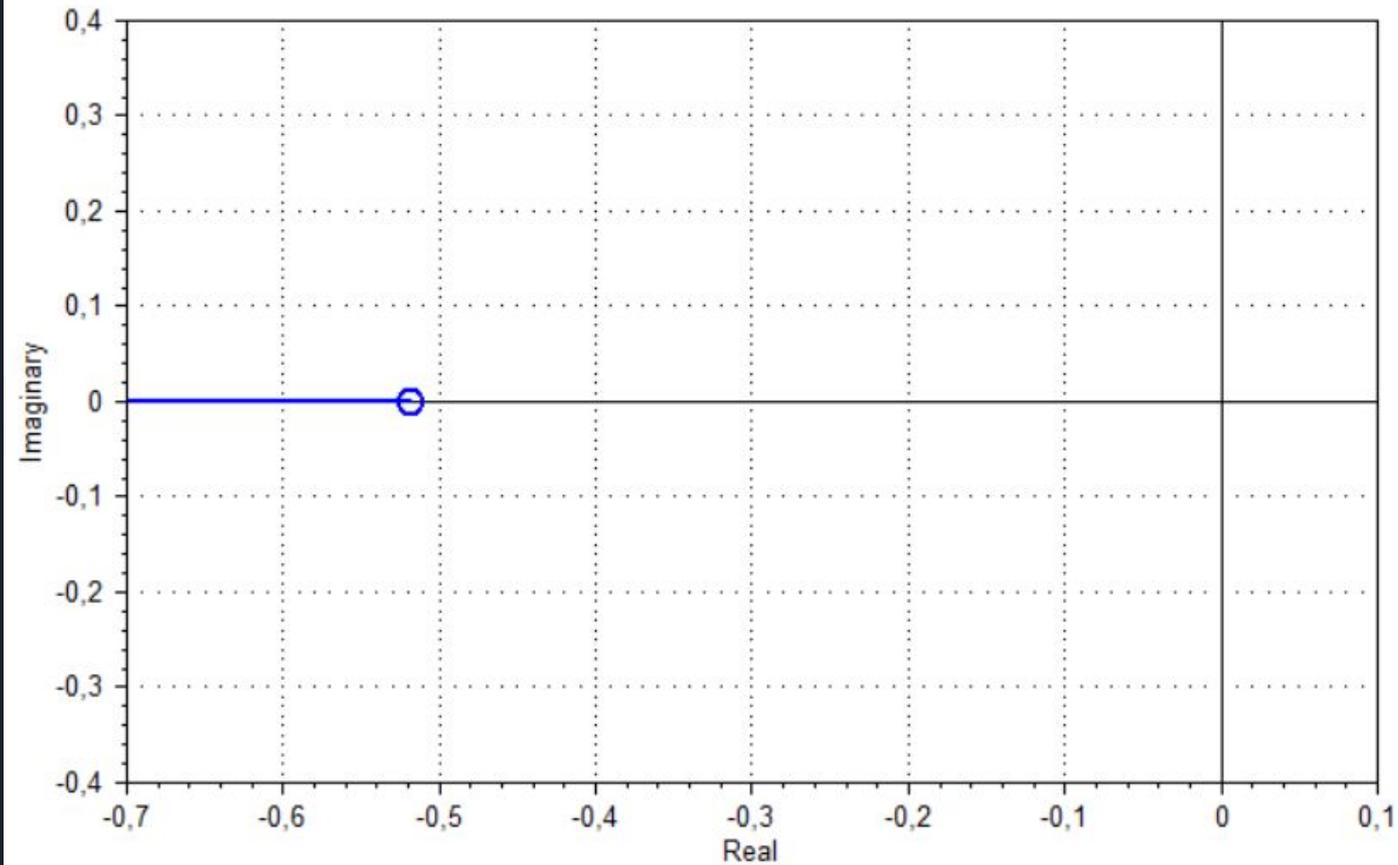


Nyquist $G_{pd} * G$

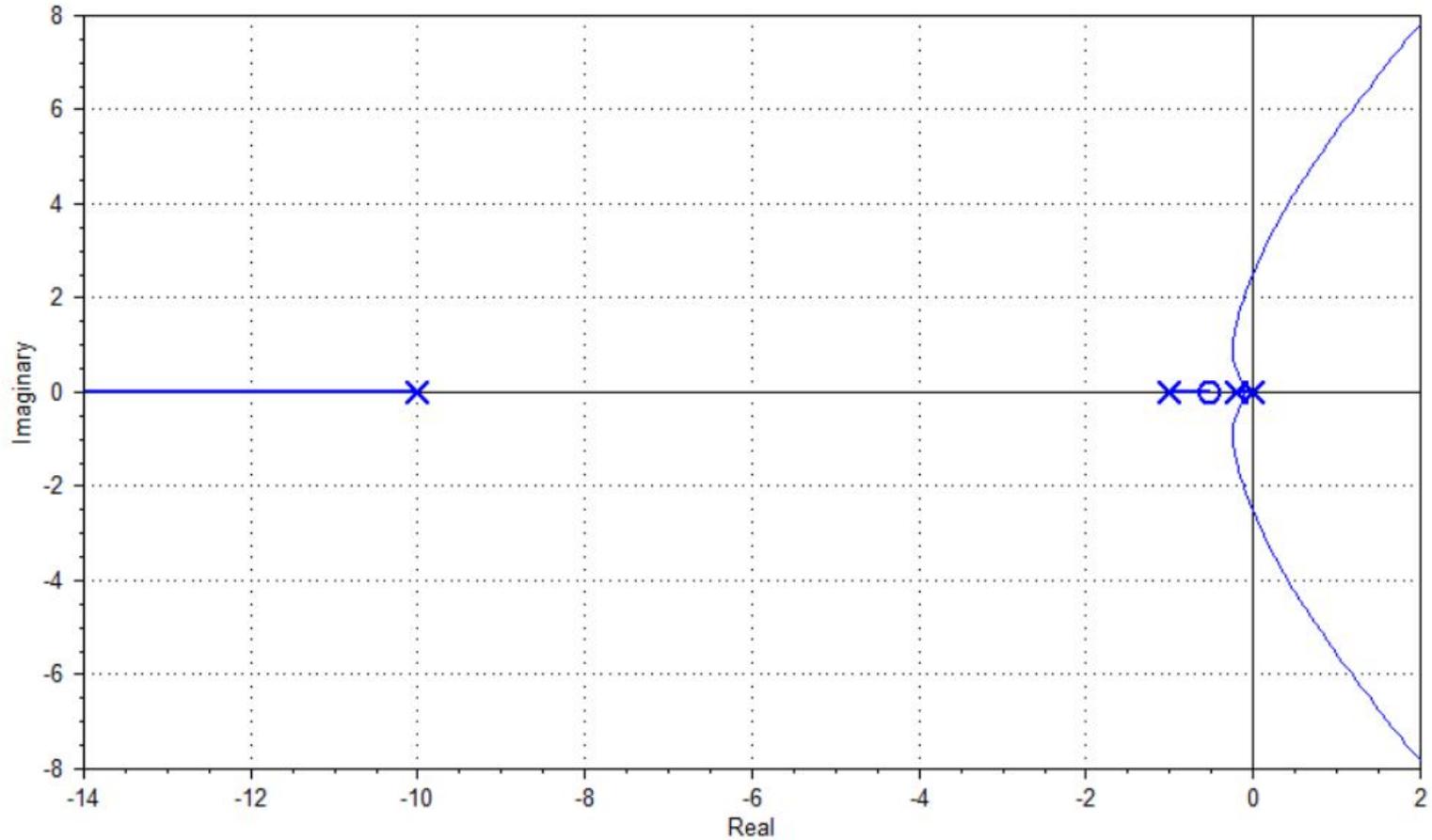


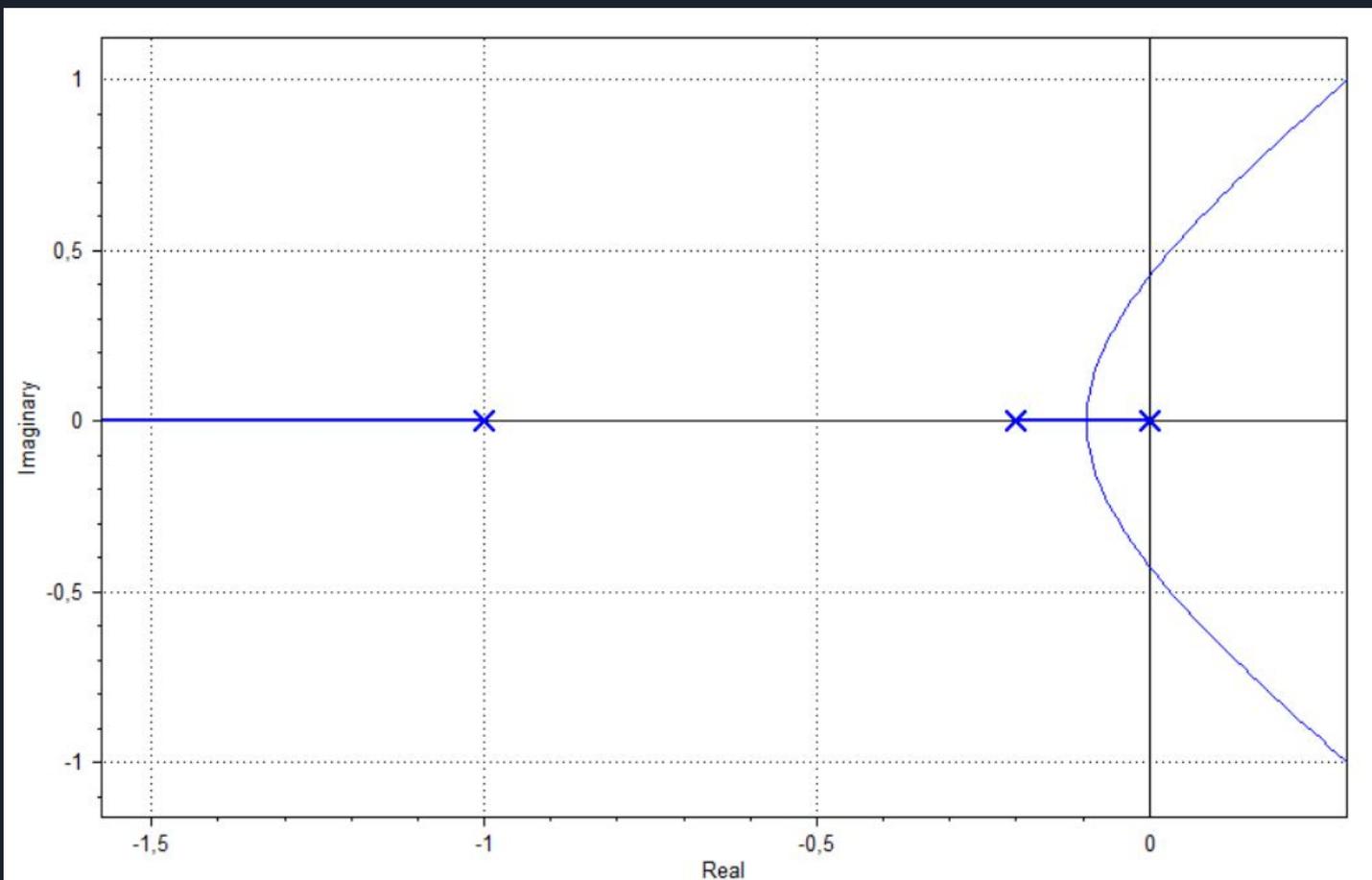


Lugar de raíces Gpd



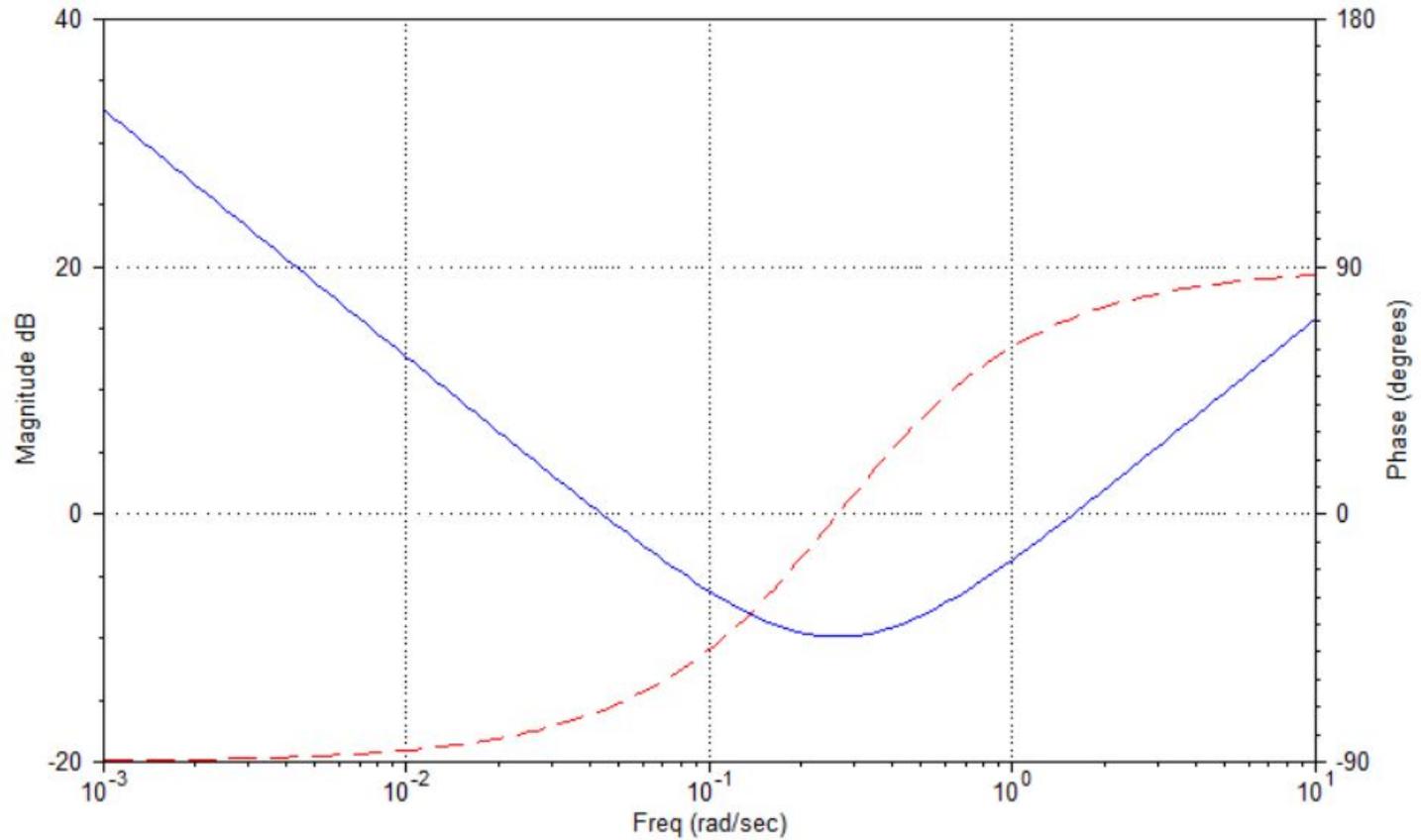
Lugar de raíces $Gp d^*G$



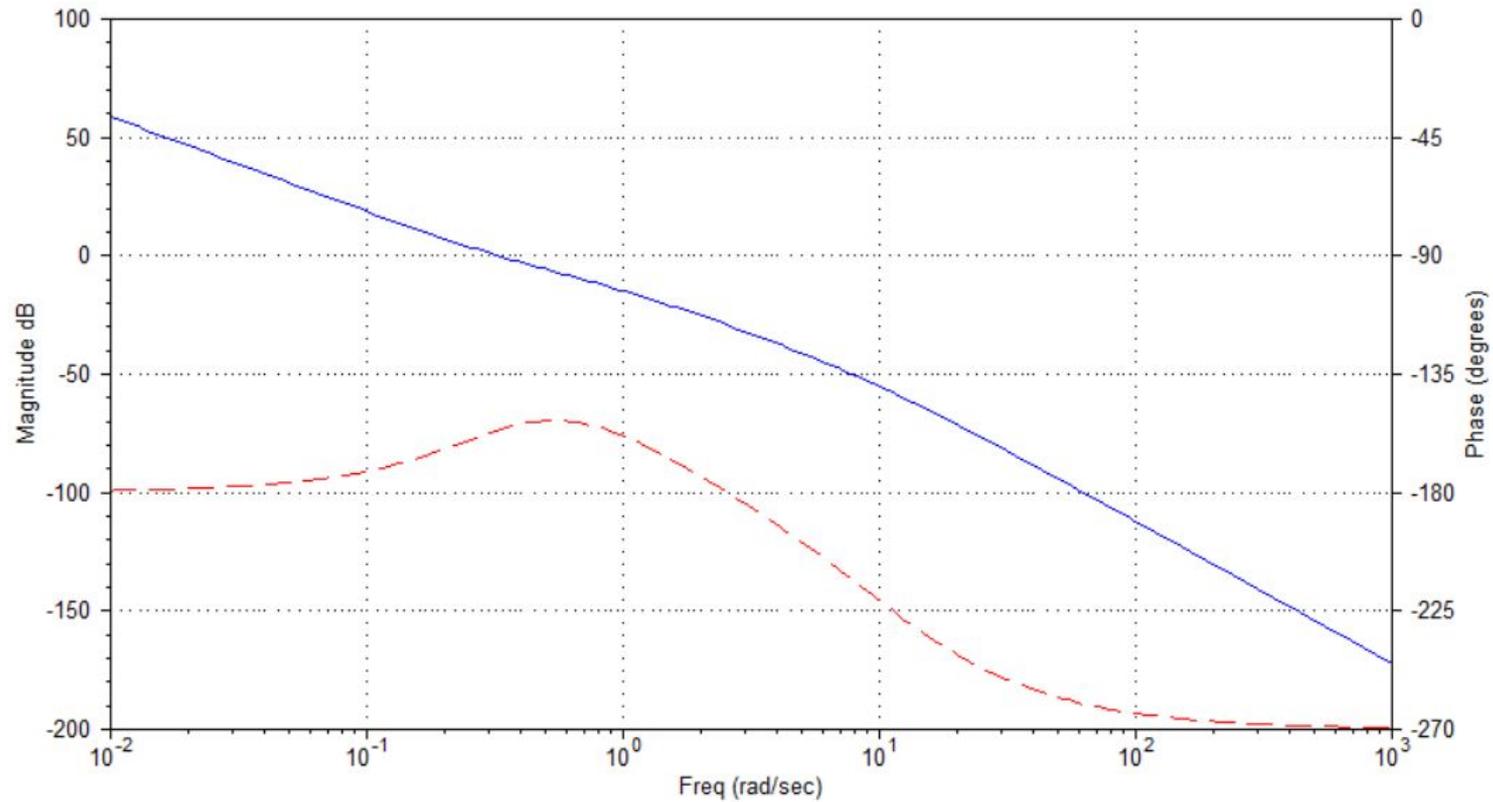


Control PID

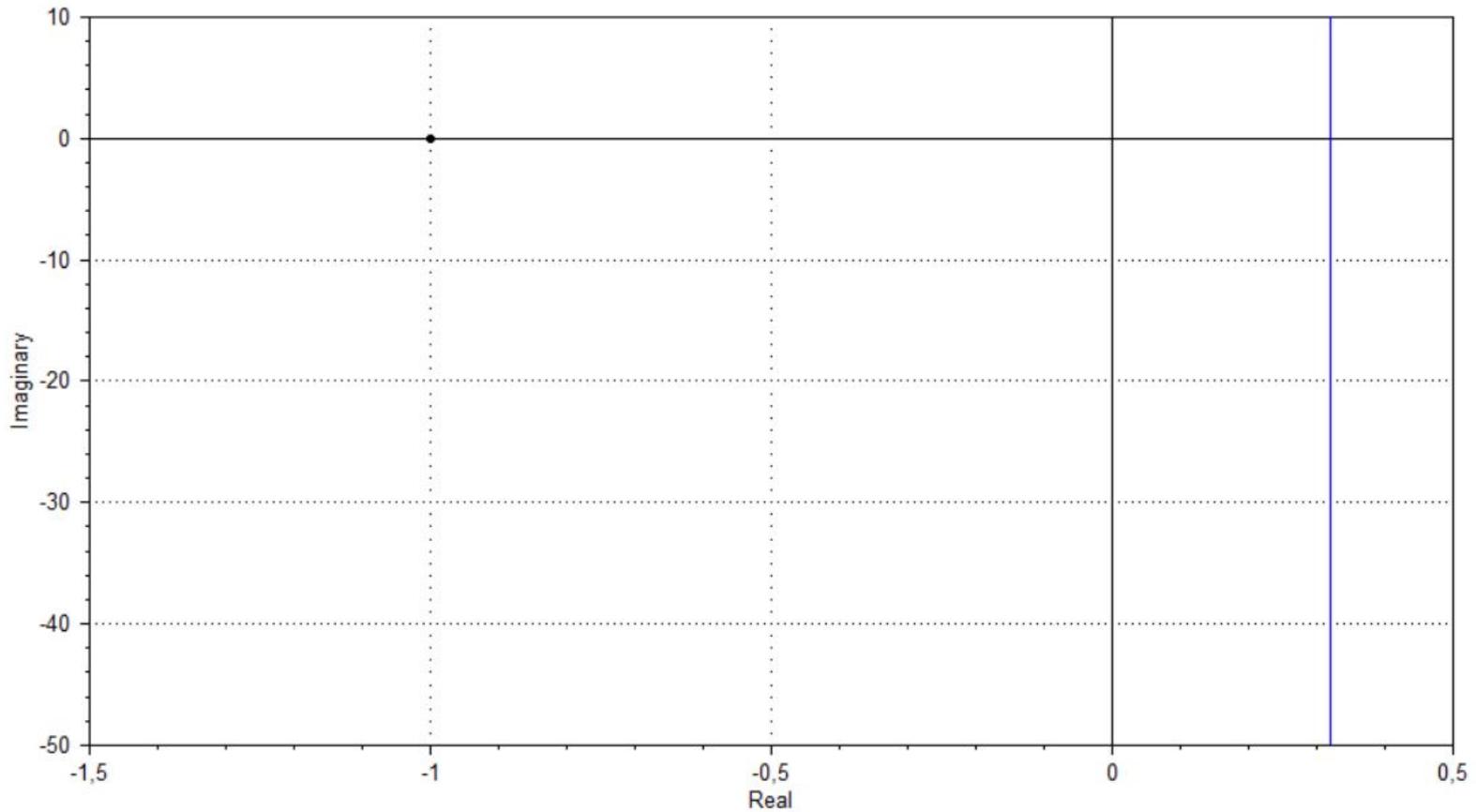
Bode Gpid



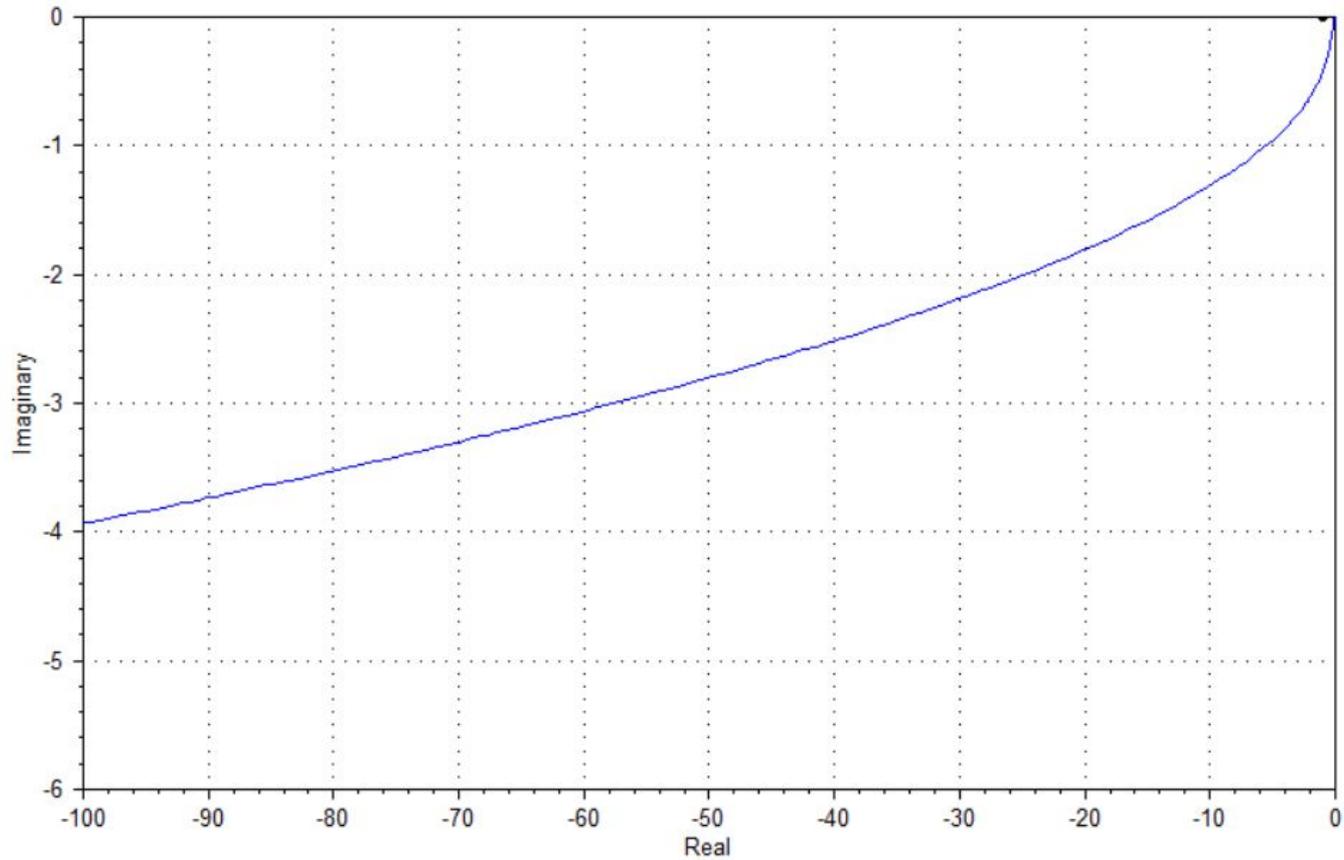
Bode Gpid*G

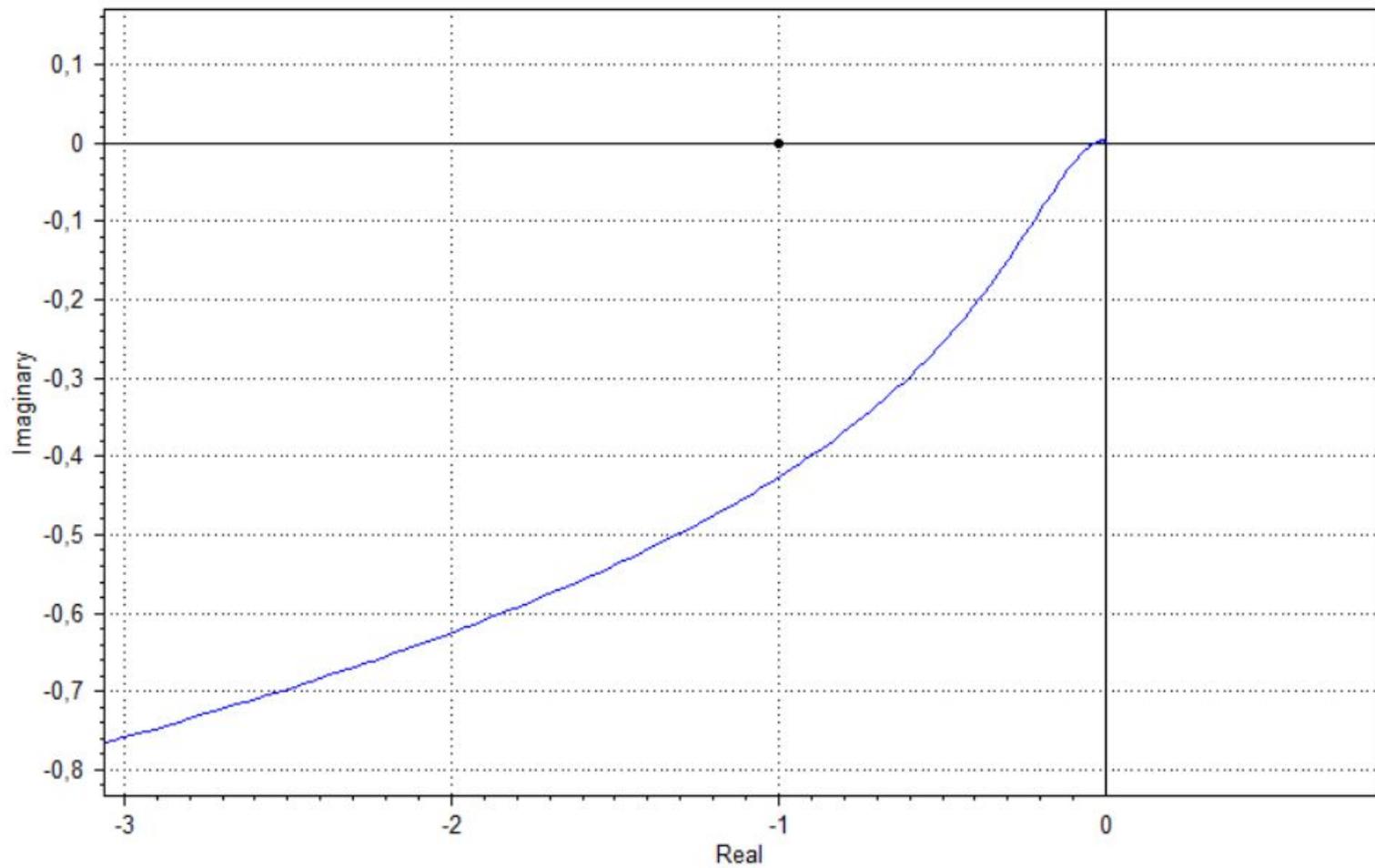


Nytquist Gpid

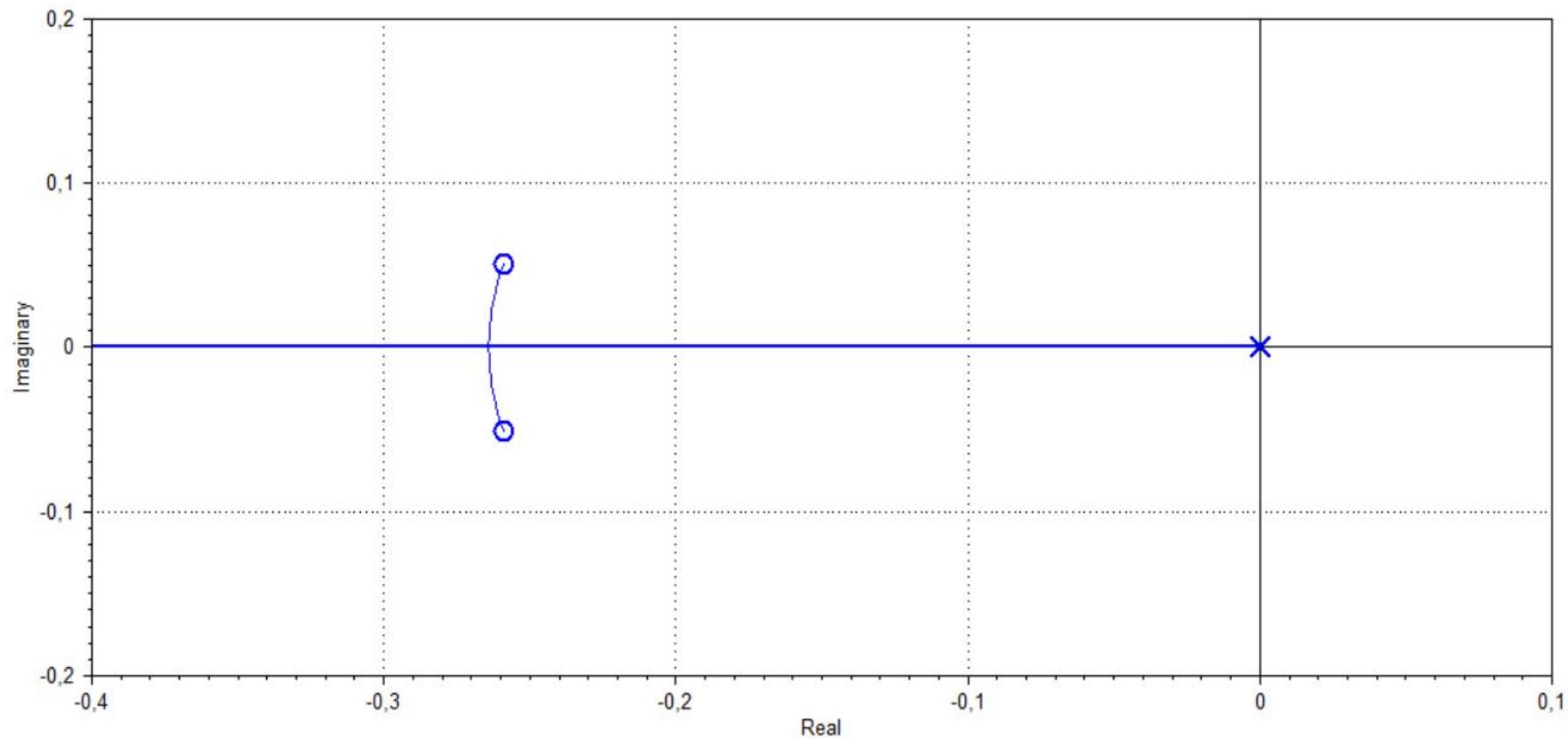


Nyquist $G_{pid} * G$

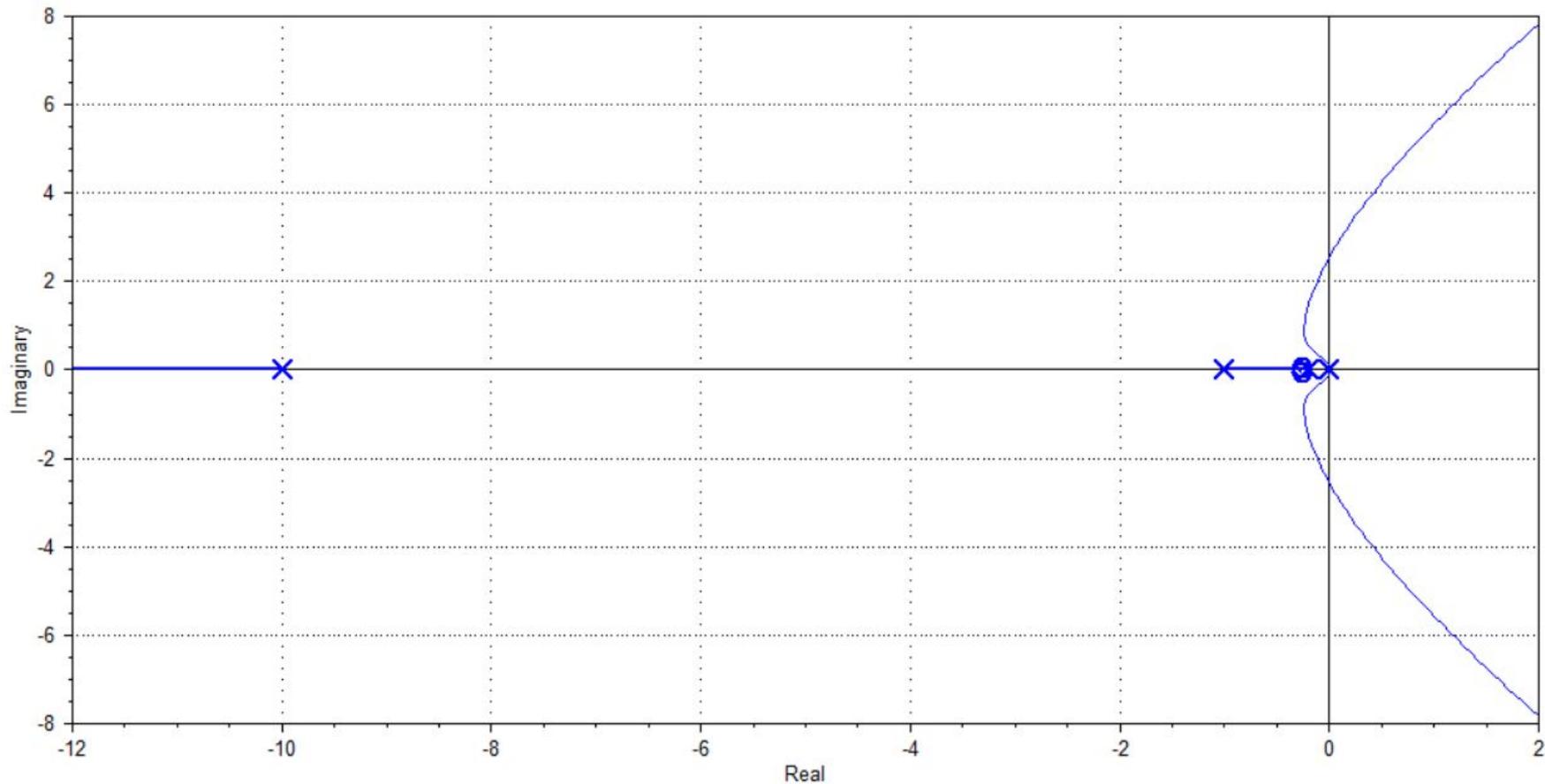


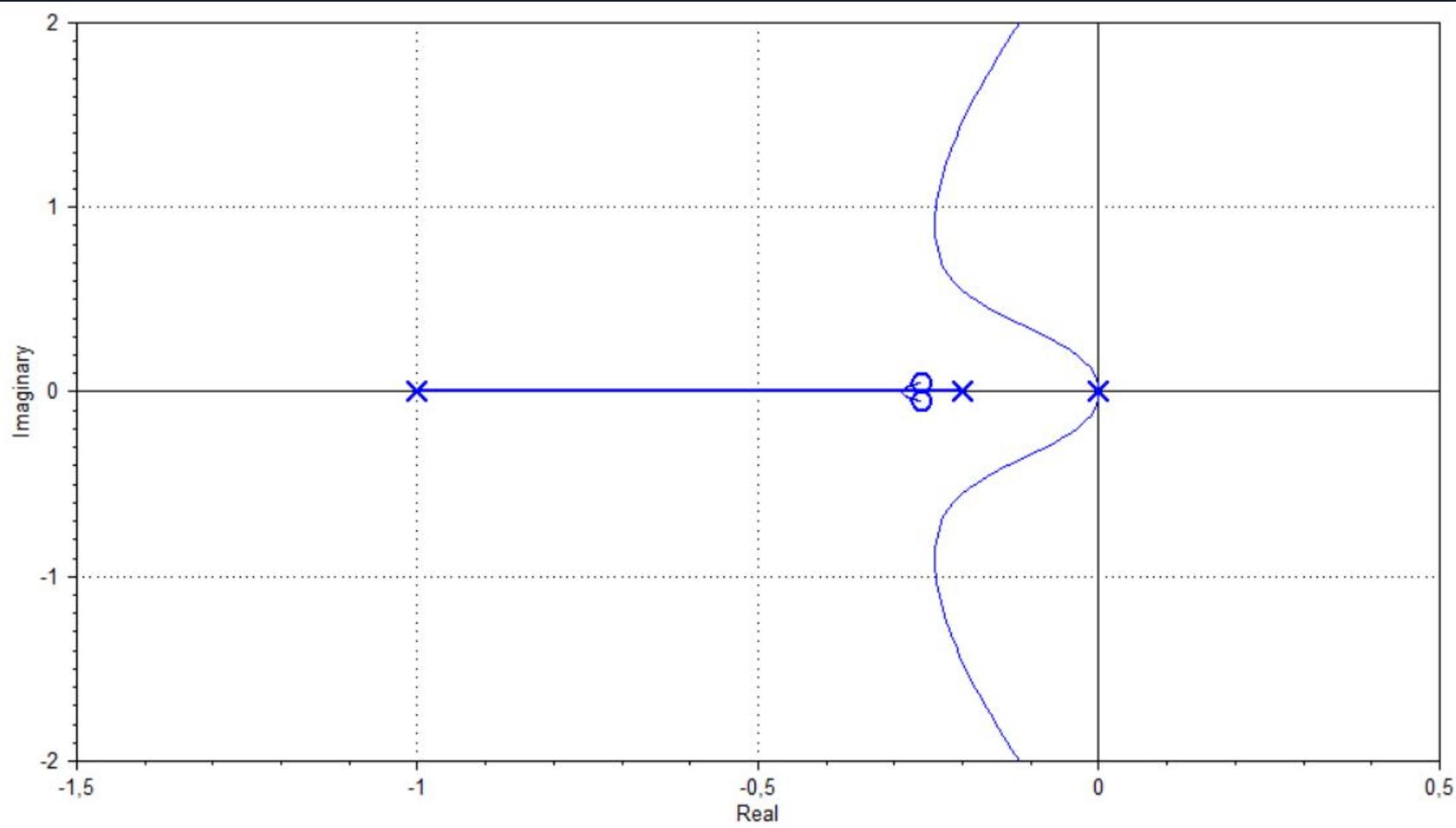


Lugar de raíces Gpid



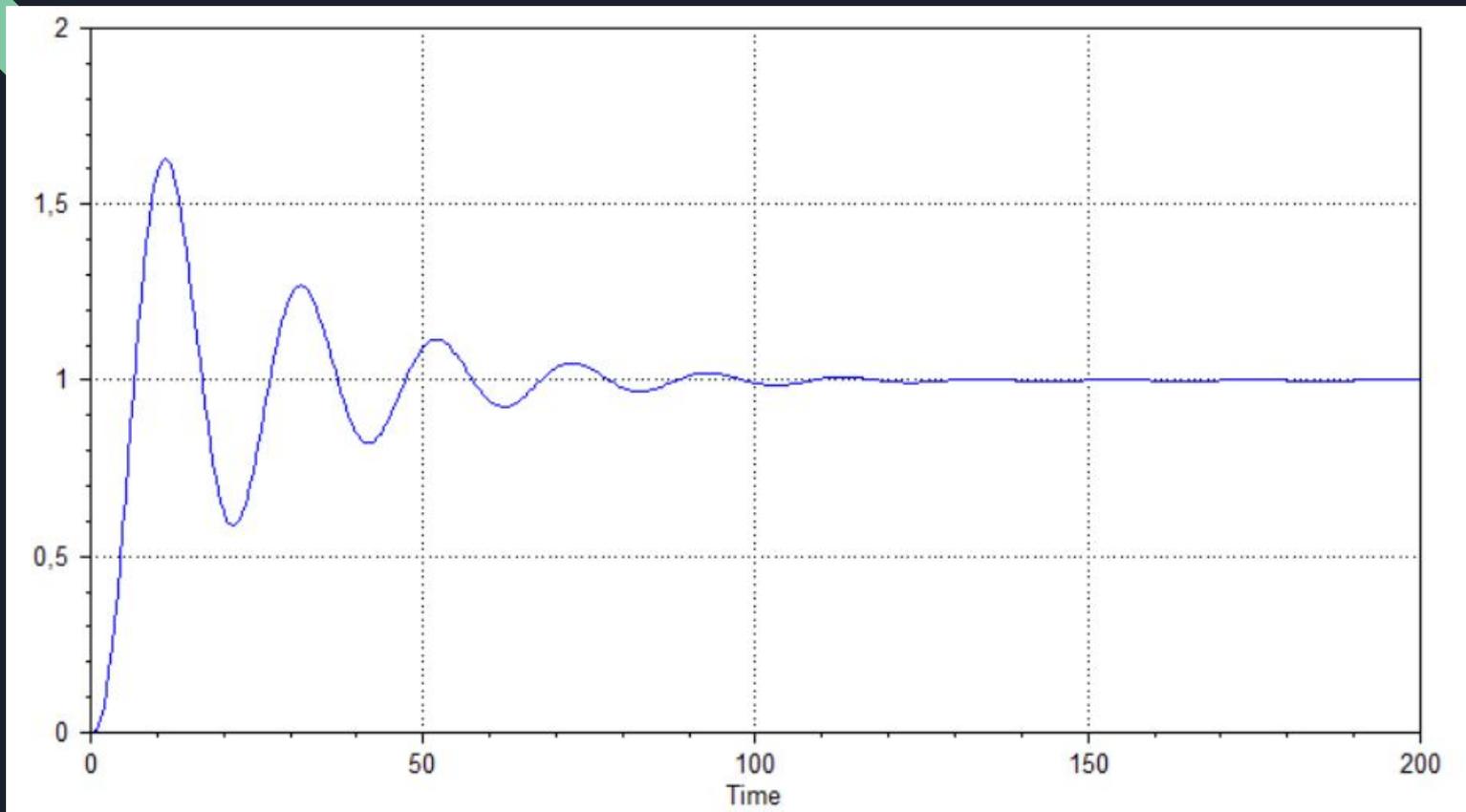
Lugar de raíces $G_{pid} * G$



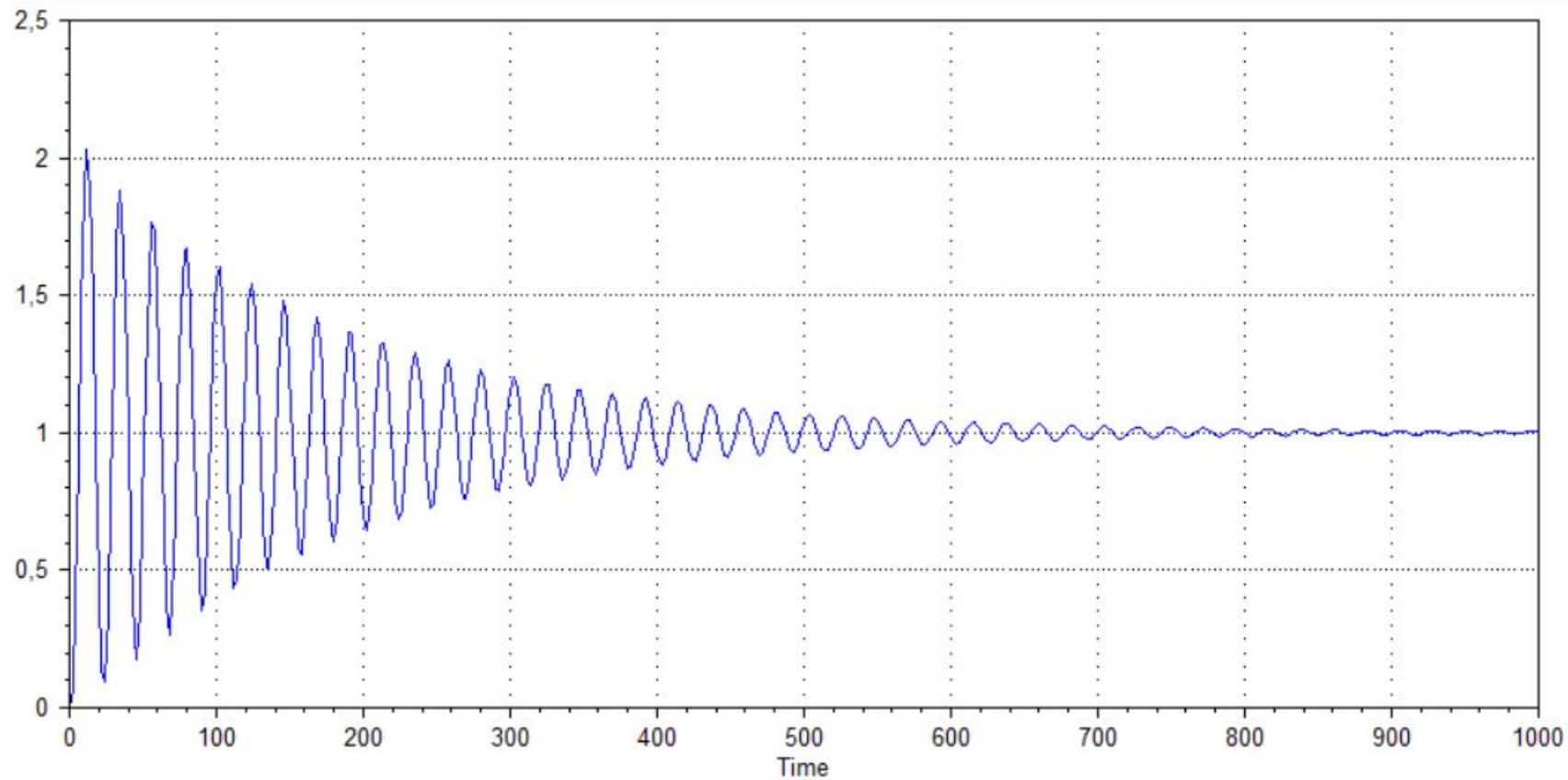


Punto 5

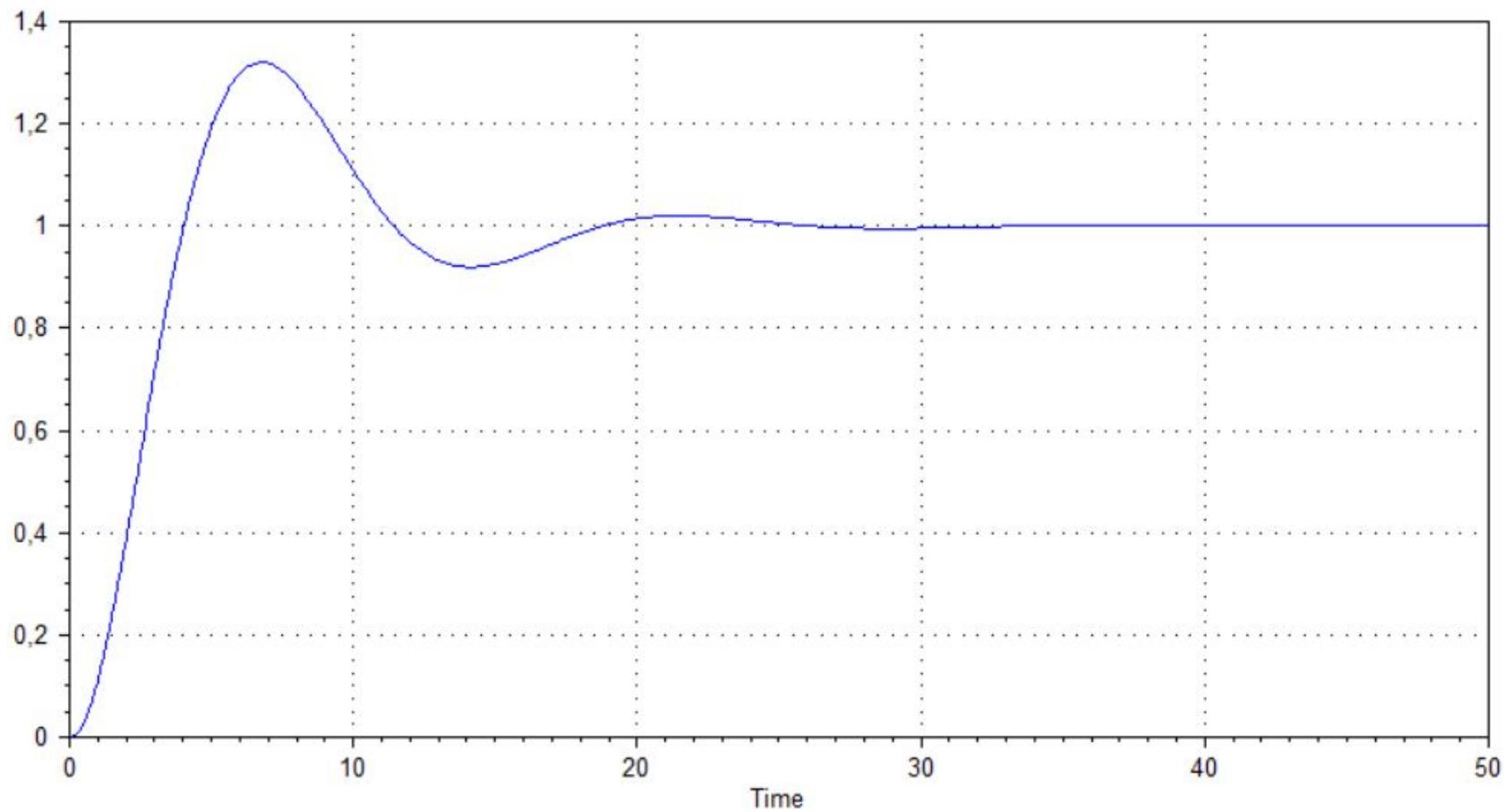
Lazo P



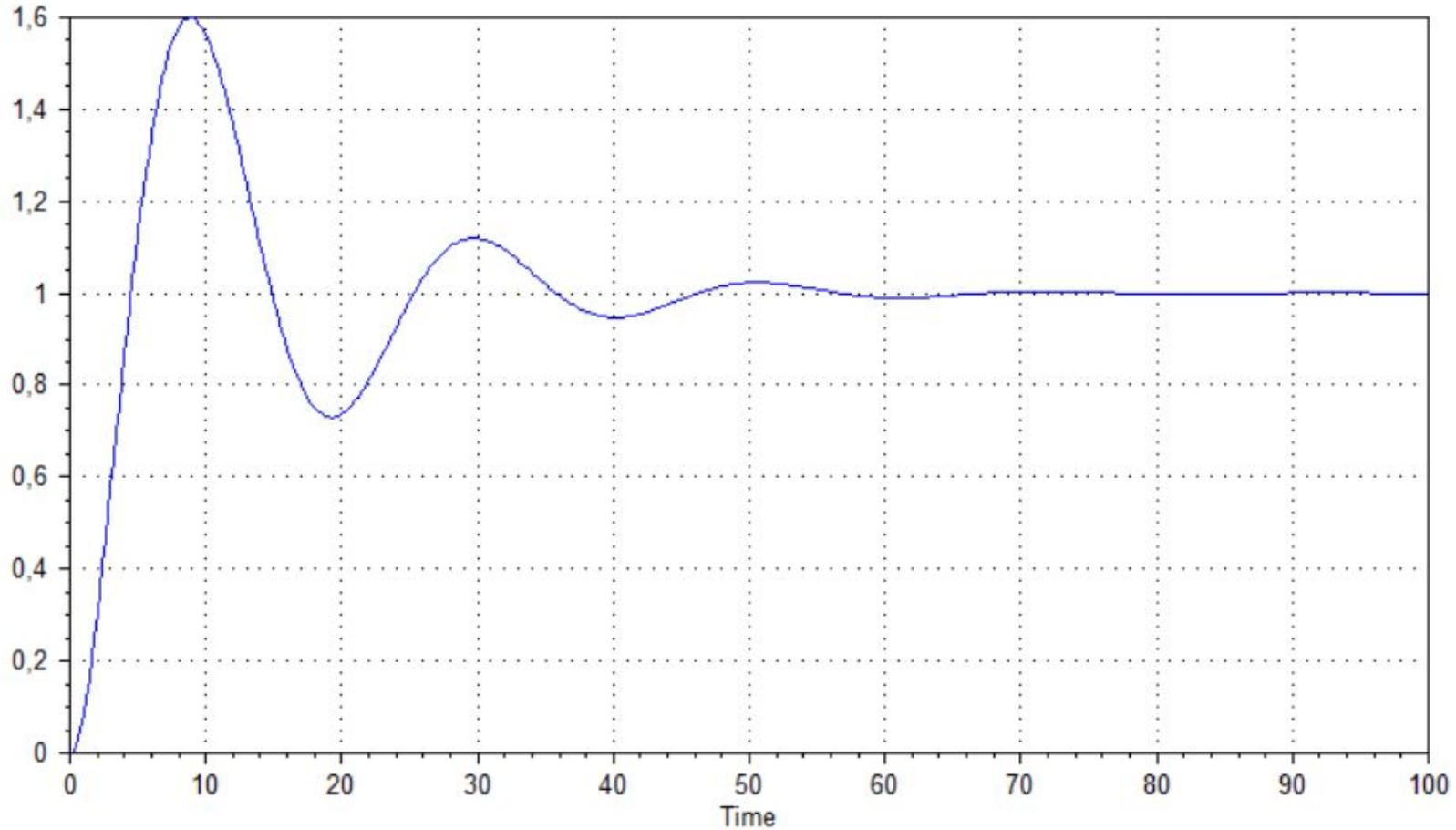
Lazo PI



Lazo PD

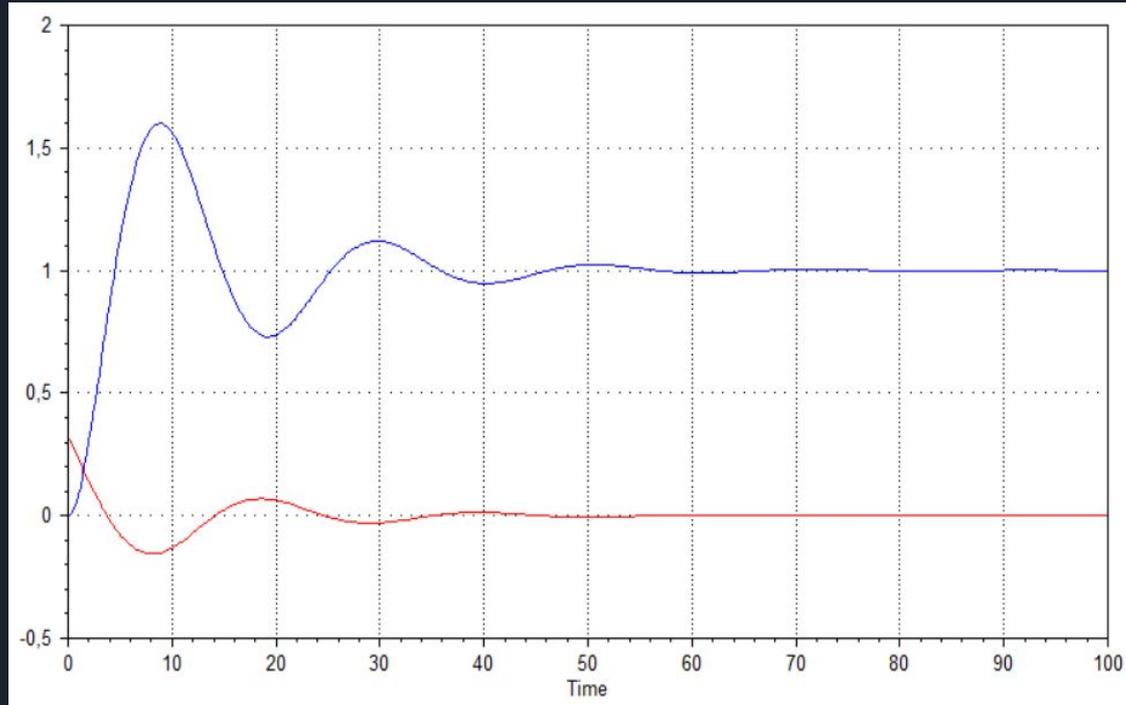


Lazo PID

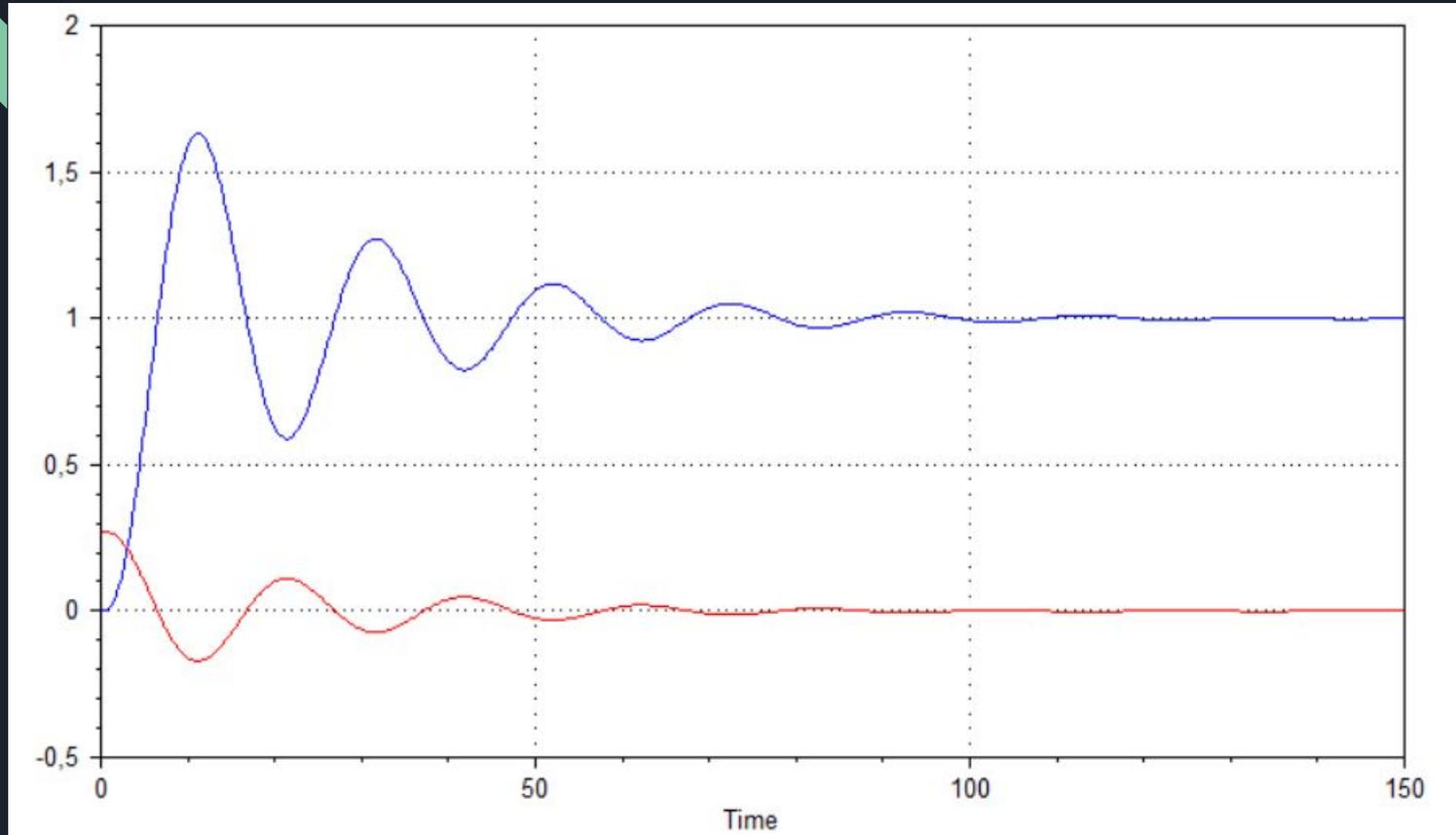


*Bonus track: Curva de la función y acción del controlador

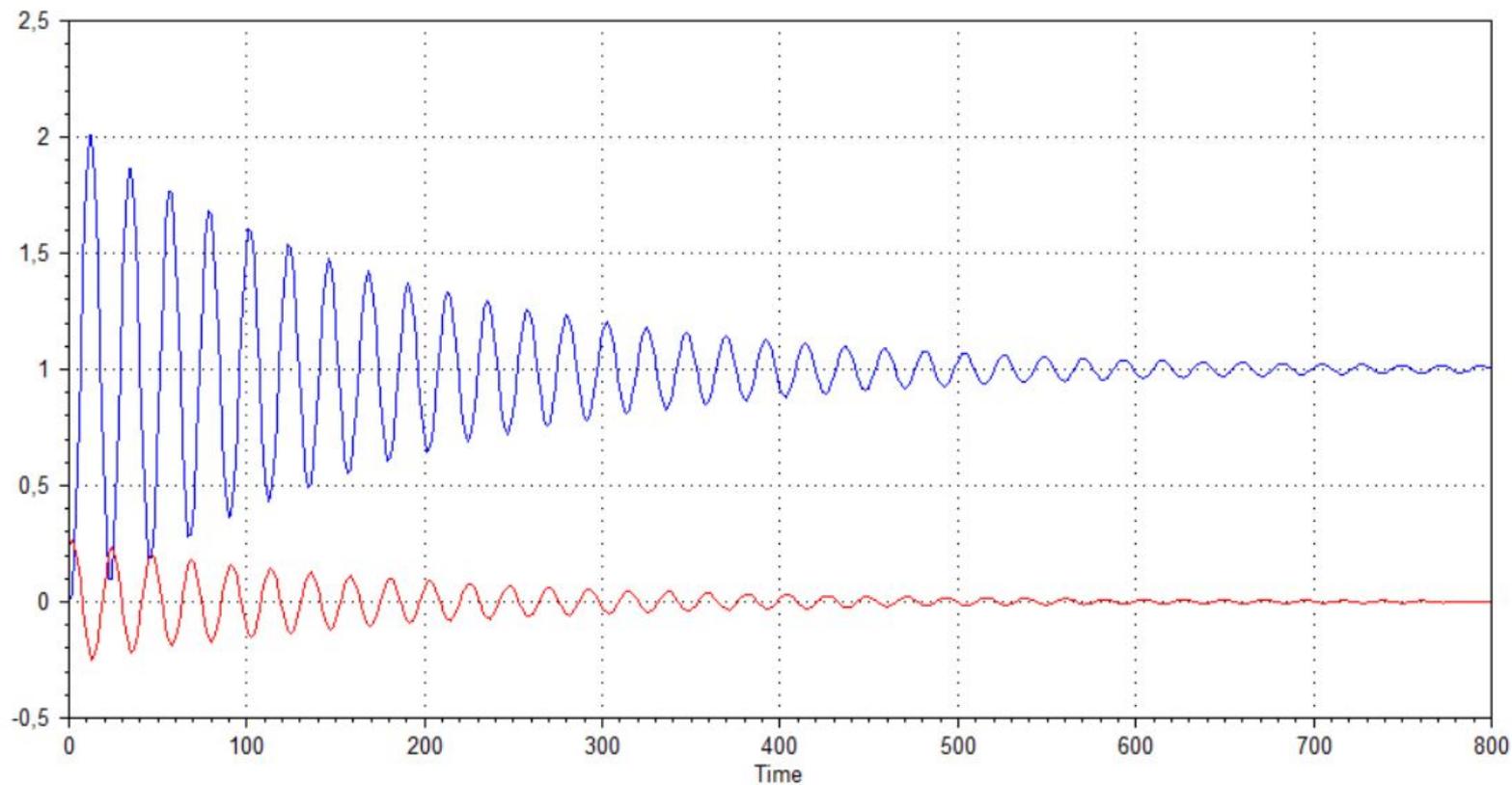
PID



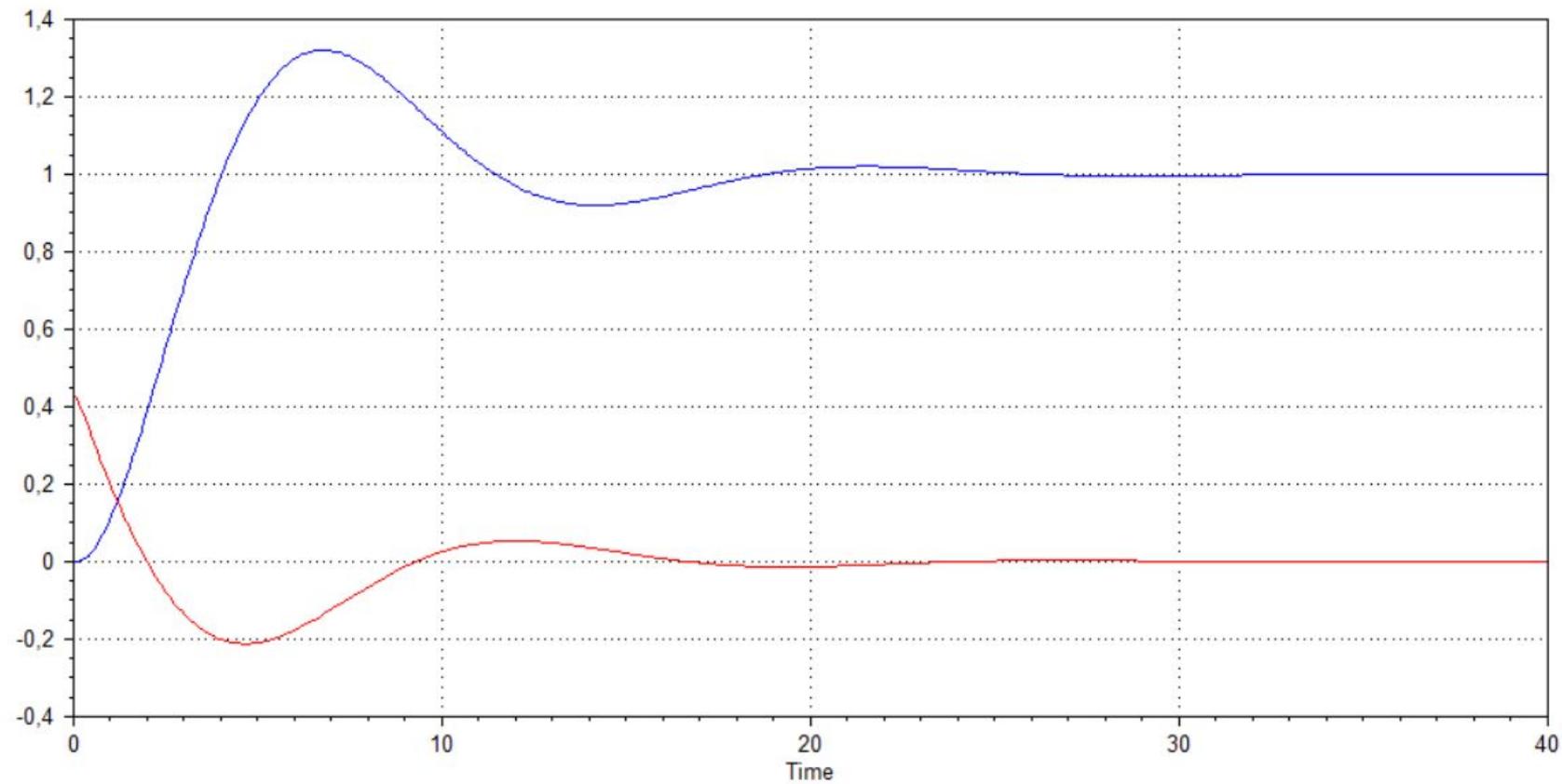
Control P



Control PI



Control PD



Muchas Gracias

