

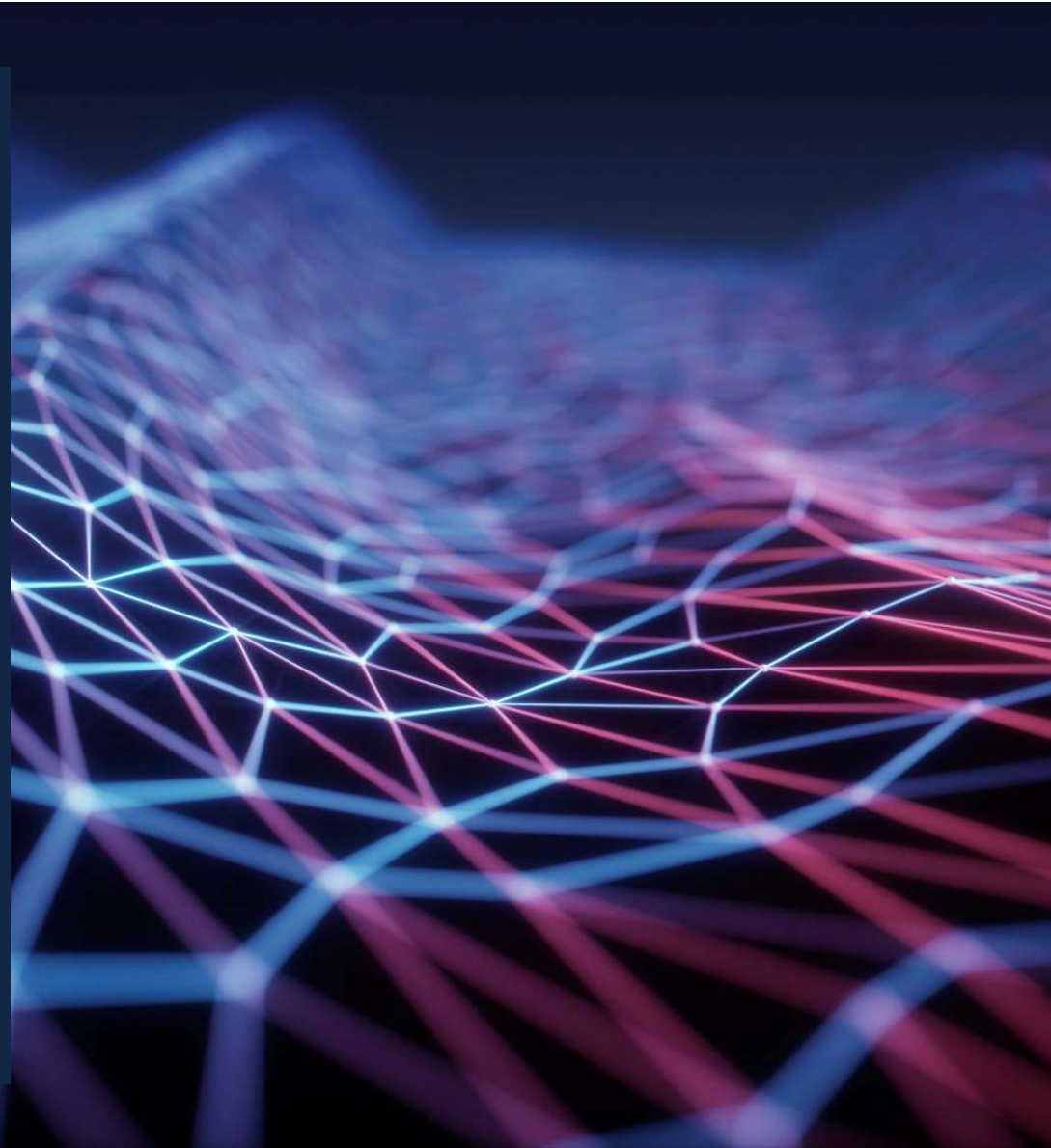


# SISTEMAS DE AUTOMATIZACIÓN Y CONTROL

TRABAJO INTEGRADOR – GRUPO N° 2

## INTEGRANTES:

- ARMANI, MATÍAS
- CALDERÓN, JOAQUÍN
- CASTEL, FRANCISCO
- DE MIGUEL, JUAN MARCOS
- MARTINEZ, MELANIE
- QUIROGA, JUAN IGNACIO
- RAYES, JULIÁN



## FUNCIÓN DE TRANSFERENCIA

$$G2 = \frac{2 * e^{-2s}}{((s) * (s + 1) * (3s + 1))}$$

$$H2 = 1$$

## CON Y SIN TIEMPO MUERTO

CON

$$G2 = \frac{2 * e^{-2s}}{((s) * (s + 1) * (3s + 1))}$$

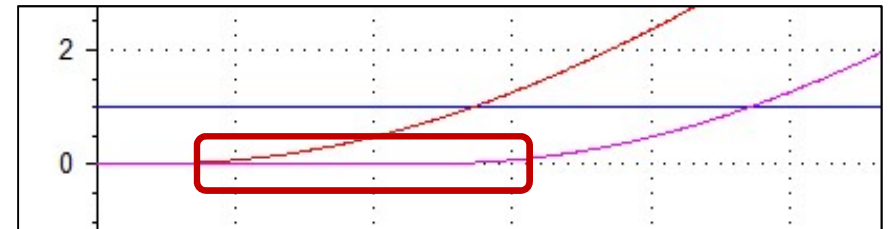
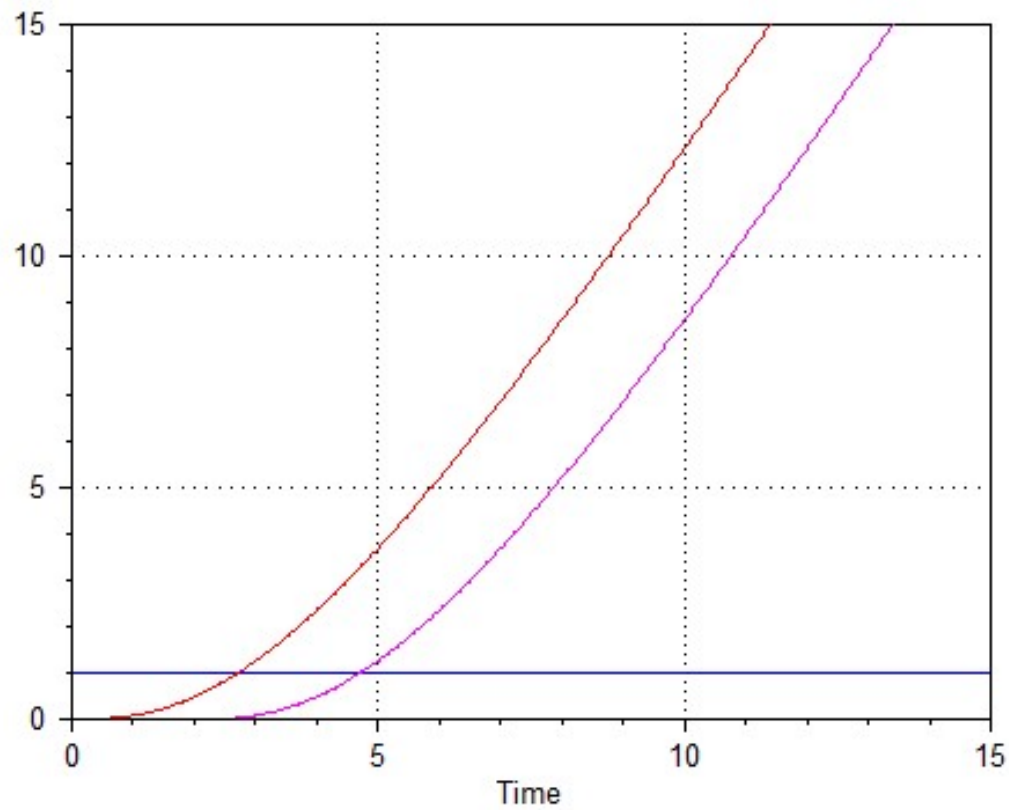
SIN

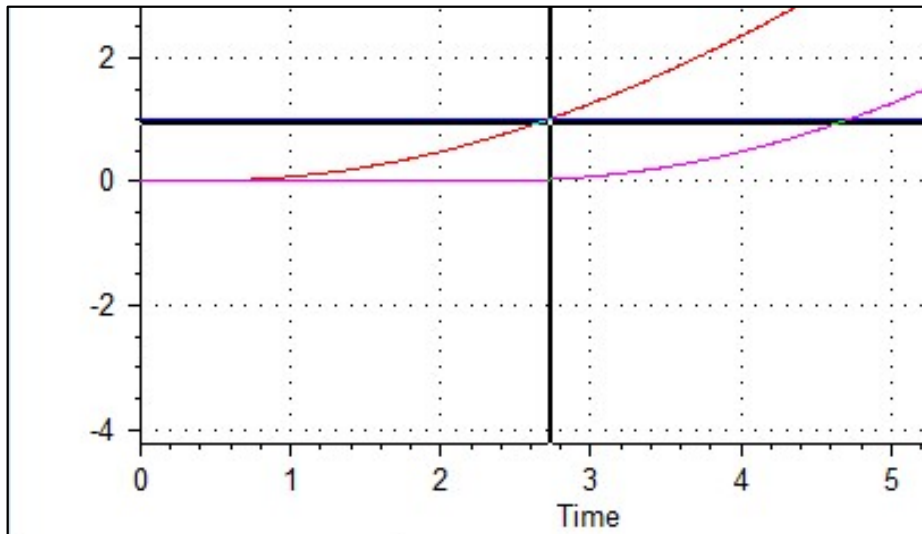
$$G2 = \frac{2}{((s) * (s + 1) * (3s + 1))}$$

# EJERCICIO 1

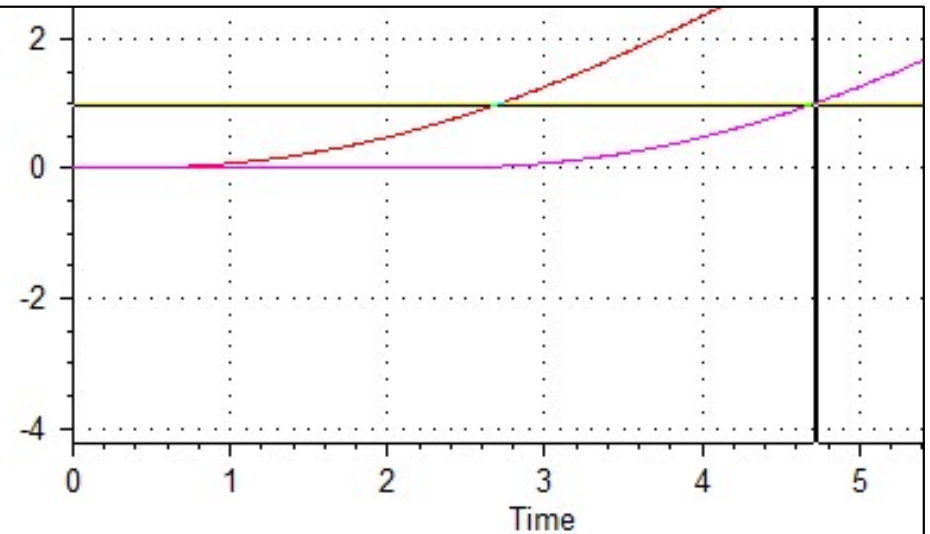


# RESPUESTA ANTE ESCALÓN UNITARIO





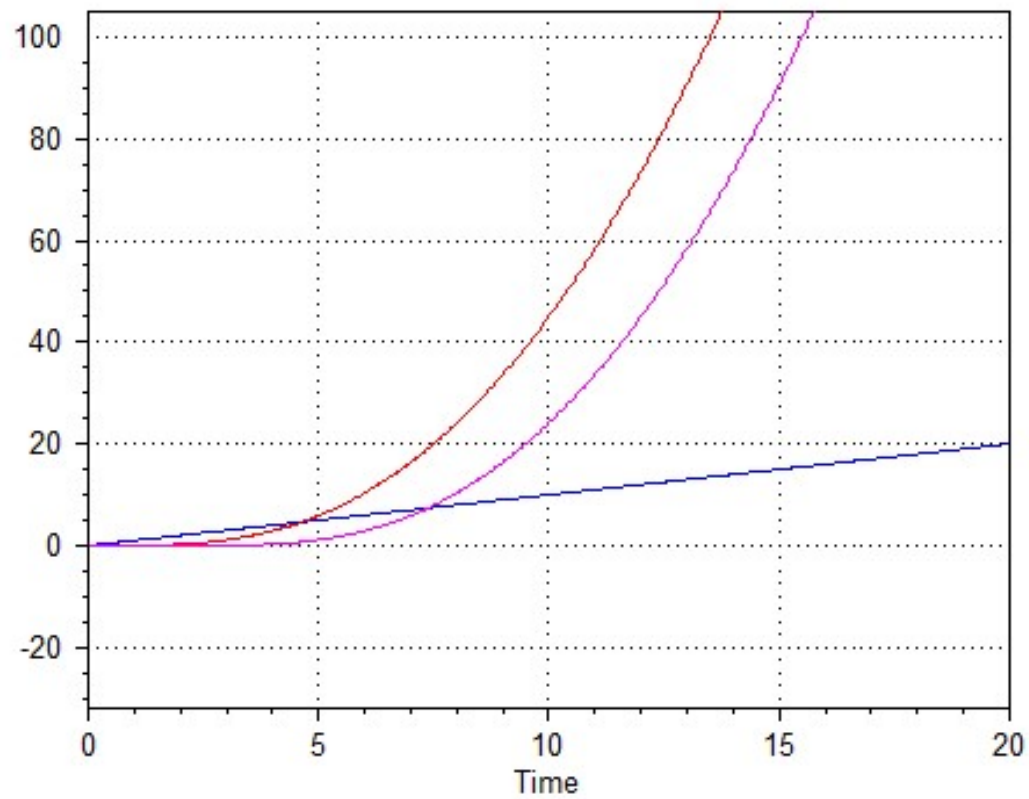
Time = 2,736, Real = 0,9333



Time = 4,73, Real = 0,97

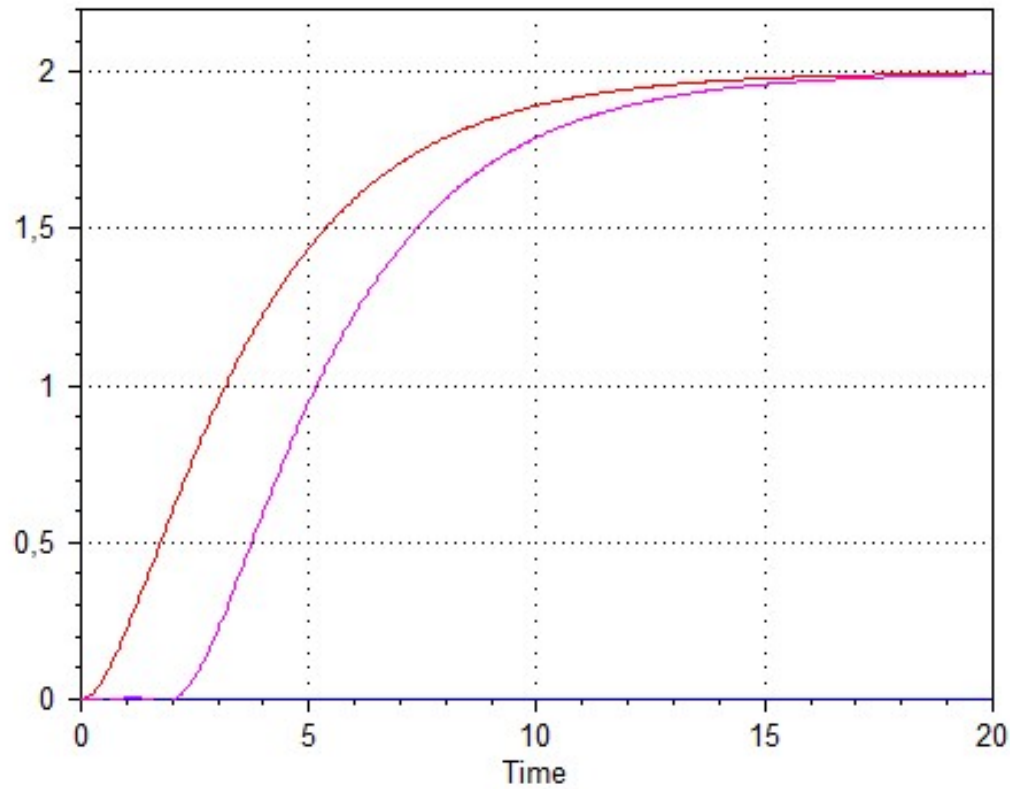
$$t = 4,73s - 2,73s = 2s$$

## RESPUESTA ANTE RAMPA UNITARIA

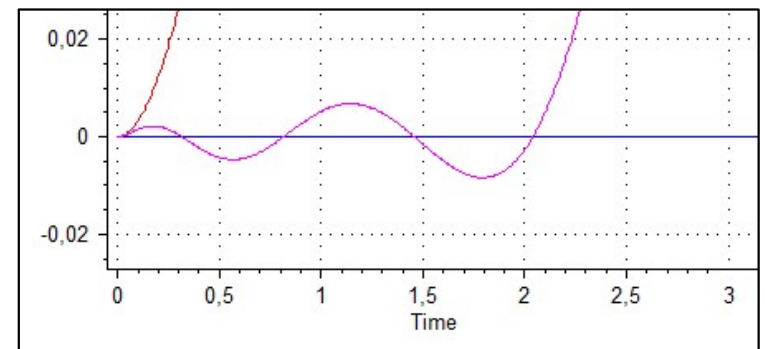




# RESPUESTA ANTE IMPULSO UNITARIO

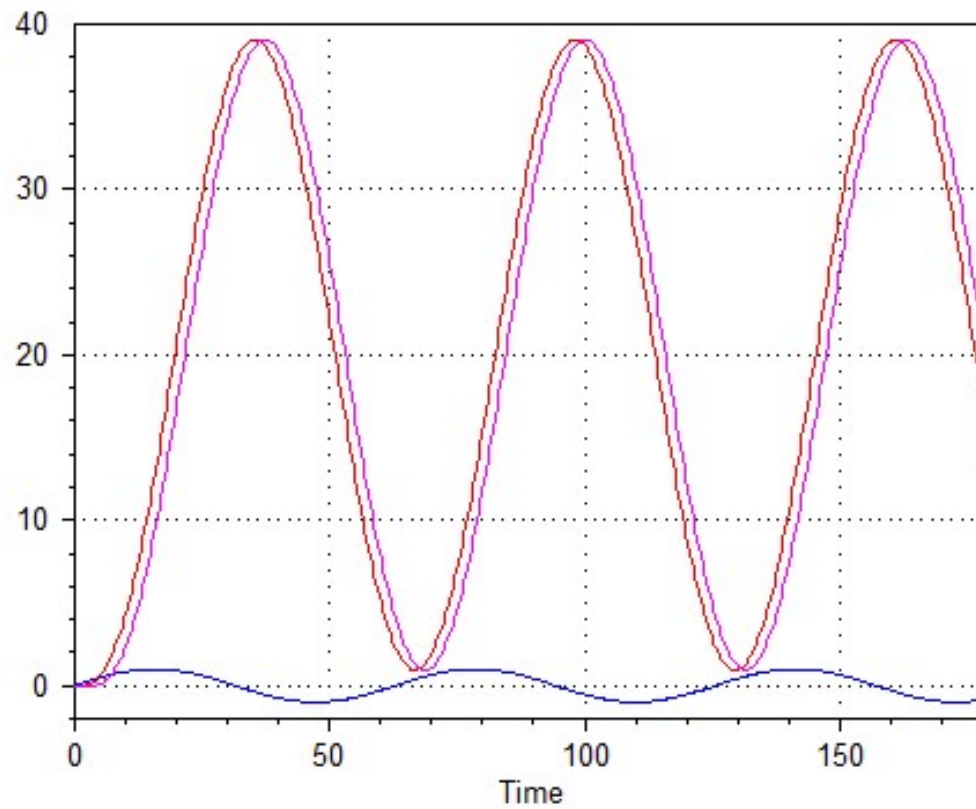


*Aproximación de Pade*



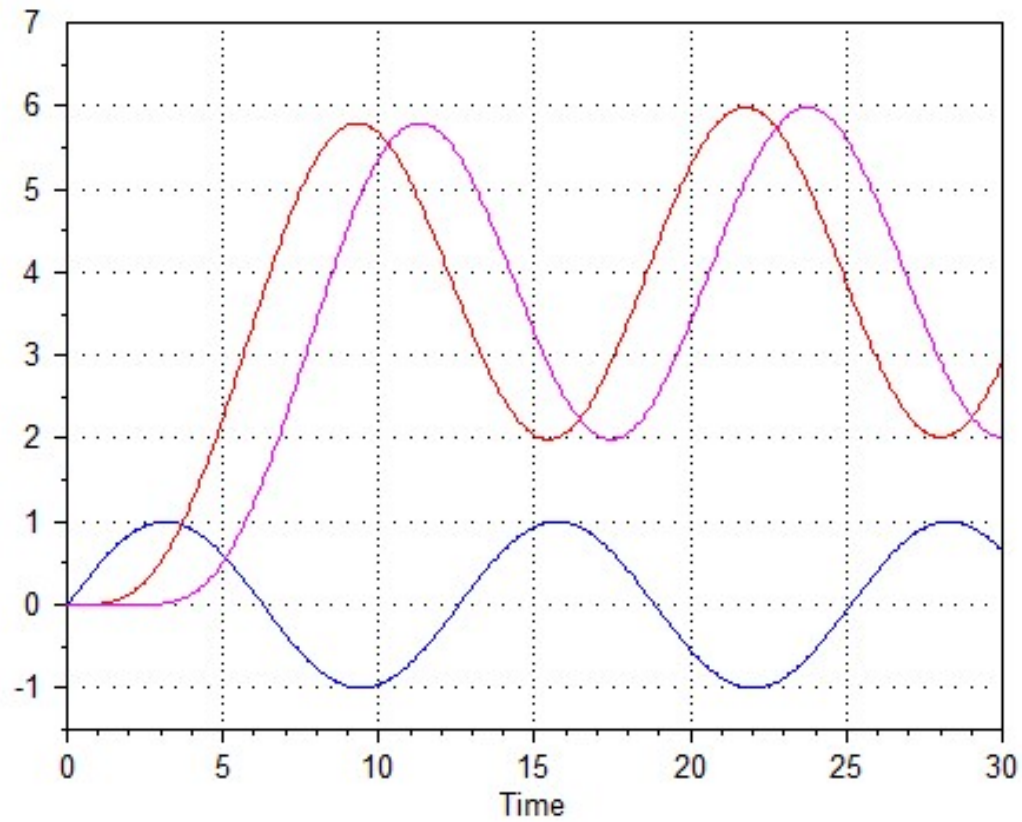
## RESPUESTA ANTE ENTRADA SENOIDAL

$$\omega = 0,1$$



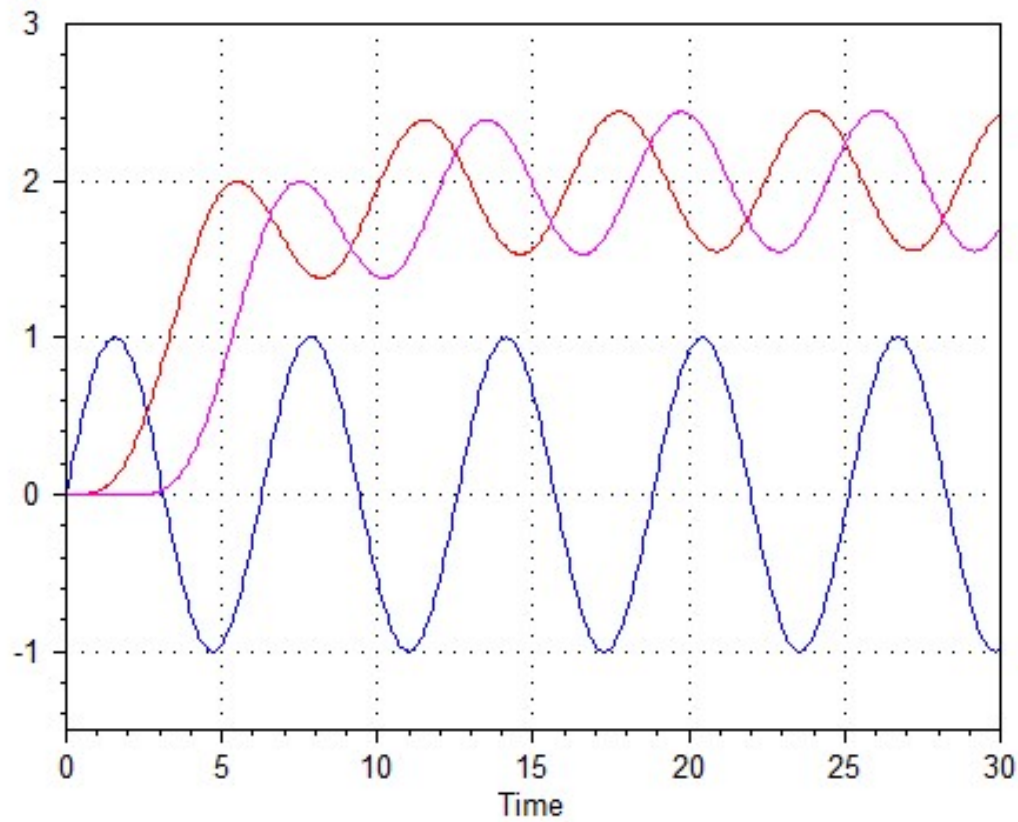
## RESPUESTA ANTE ENTRADA SENOIDAL

$$\omega = 0,5$$



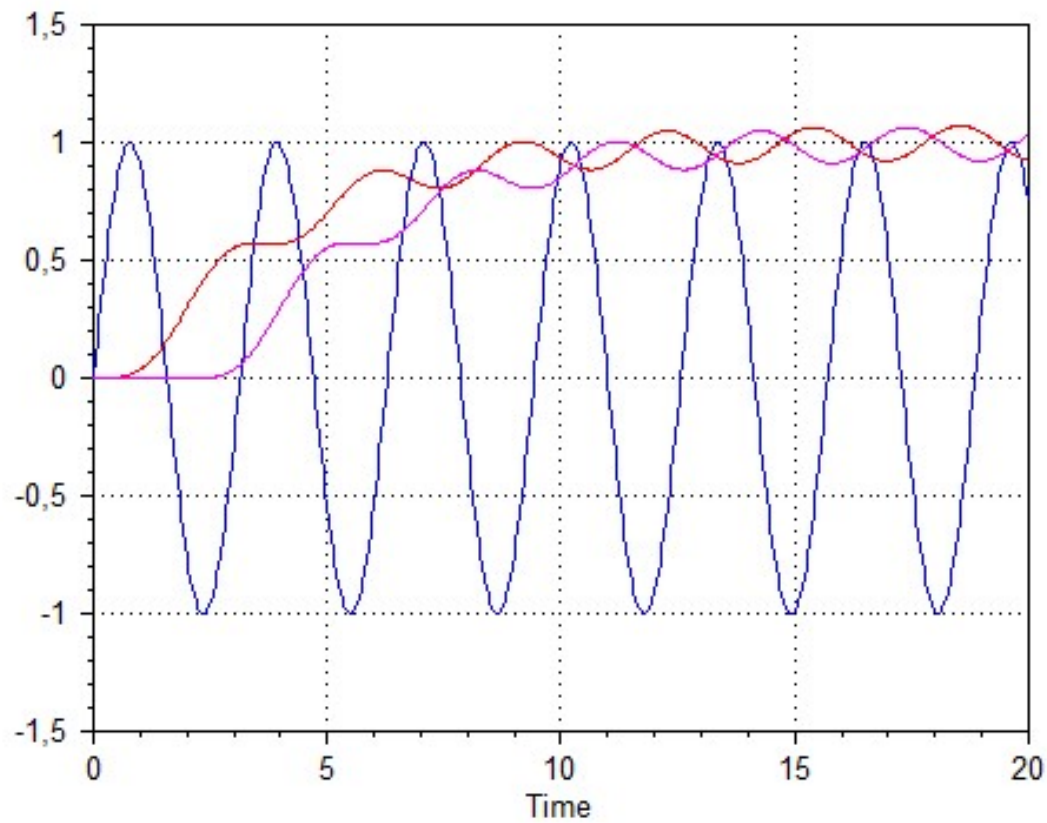
## RESPUESTA ANTE ENTRADA SENOIDAL

$$\omega = 1$$



## RESPUESTA ANTE ENTRADA SENOIDAL

$$\omega = 2$$

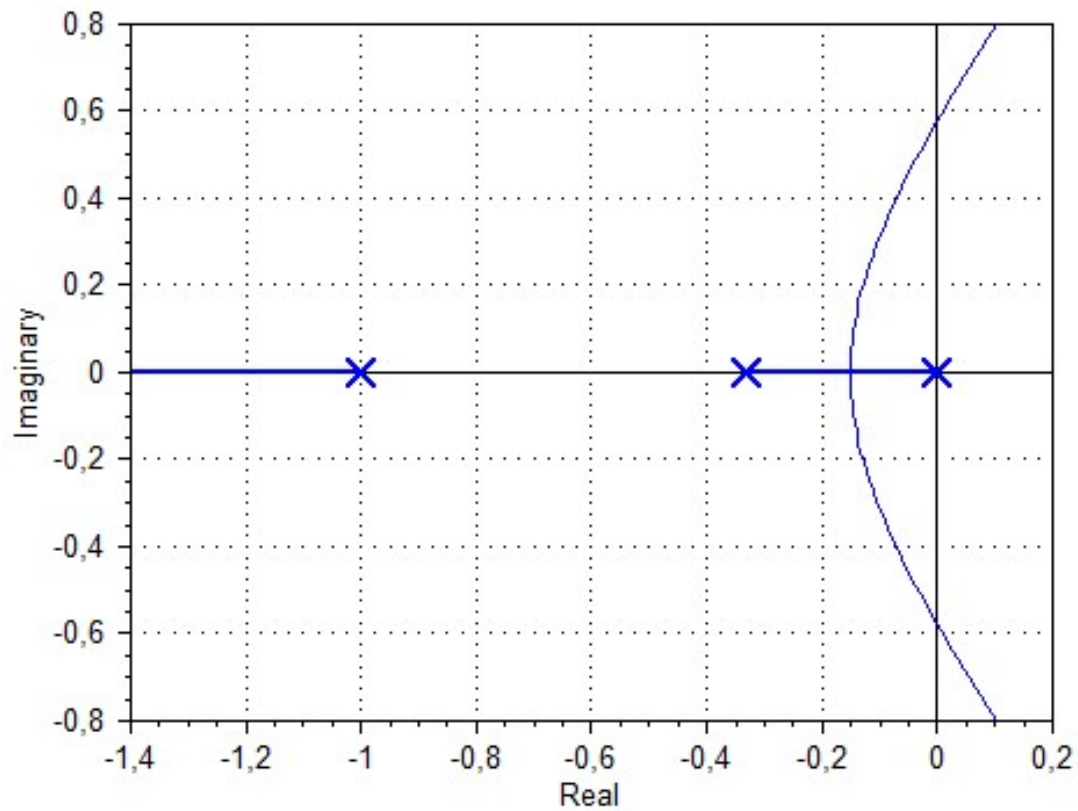


# EJERCICIO 2

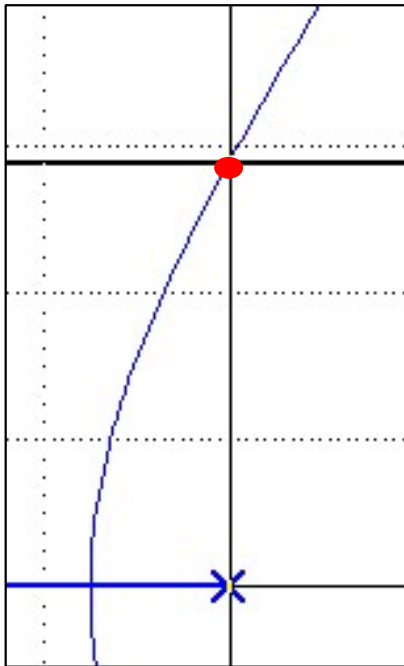
The background of the slide is a photograph of a server room. The lighting is predominantly blue, creating a cool, technological atmosphere. In the foreground, a dark blue rectangular box is centered, containing the text 'EJERCICIO 2' in white, bold, sans-serif font. The server racks in the background are slightly out of focus, with some lights glowing, suggesting a busy data center environment.

# LUGAR DE RAÍCES SIN TIEMPO MUERTO

$$G2 = \frac{2}{(s) * (s + 1) * (3s + 1)}$$



## DETERMINACIÓN DE KCU Y TU



$s = 0,002504 + 0,5763j$  (Mag= 0,5763, Zeta= -0,004345)  
gain= 0,6668 -0,006794j (Mag= 0,6669, Phase= -0,5837 deg)

$$K_{cu} = 0,6668$$

$$\omega_u = 0,5763 \frac{rad}{s}$$

$$T_u = 10,908s$$



## DETERMINACIÓN DE KCU Y TU

```
CC>margin(g)
```

```
At w= 0,577 r/s, Gain margin= 0,667 ( -3,52 dB)
```

```
At w= 0,702 r/s, Phase margin= -9,67 deg, Delay margin= -0,24 sec
```

```
At w= 0,68 r/s, Mp= 6,6 (16,39 dB)
```

# MÉTODO DE ROUTH

*Función de transferencia a Lazo Abierto:*  $G = \frac{Kc * 2}{(s)(s + 1)(3s + 1)}$

*Función de transferencia a Lazo Cerrado:*  $\frac{G}{1 + GH}$

*Ecuación Característica:*  $1 + GH = 0$        $1 + \frac{Kc * 2}{(s)(s + 1)(3s + 1)} = \frac{3s^3 + 4s^2 + s + 2Kc}{s(s + 1)(3s + 1)}$

$$3s^3 + 4s^2 + s + 2Kc = 0$$

## MÉTODO DE ROUTH

$$3s^3 + 4s^2 + s + 2Kc = 0$$

Arreglo de Routh:

$$\begin{array}{r|l|l} s^3 & 3 & 1 \\ s^2 & 4 & 2Kc \\ s & 1 - \frac{3}{2}Kc & 0 \\ s^0 & 2Kc & 0 \end{array}$$

Condición de estabilidad:  $1 - \frac{3}{2}Kc \geq 0$

$$K_{cu} = \frac{2}{3} \simeq 0,6667$$

## MÉTODO DE ROUTH

$$3s^3 + 4s^2 + s + \frac{4}{3} = 0$$

$$s_1, s_2, s_3 = -\frac{4}{3}; \frac{\sqrt{3}}{3}j; -\frac{\sqrt{3}}{3}j$$

$$\omega_u = \frac{\sqrt{3}}{3} \simeq 0,577 \frac{rad}{s} \Rightarrow Tu \simeq 10,882s$$

## MÉTODO DE SUSTITUCIÓN DIRECTA

$$3s^3 + 4s^2 + s + 2Kc = 0 \quad \Rightarrow \quad 3(j\omega)^3 + 4(j\omega)^2 + (j\omega) + 2Kc = 0$$

$$3j^3\omega_u^3 + 4j^2\omega_u^2 + j\omega_u + 2Kc$$

$$-3j\omega_u^3 - 4\omega_u^2 + j\omega_u + 2Kc$$

$$[-4\omega_u^2 + 2Kc] + j[-3\omega_u^3 + \omega_u] = 0 + j0$$

$$-4\omega_u^2 + 2Kc = 0$$

$$-3\omega_u^3 + \omega_u = 0$$

$$\omega_u[-3\omega_u^2 + 1] = 0$$

$$\omega_u = \frac{\sqrt{3}}{3} \quad Kc = \frac{2}{3}$$

$$K_{cu} = \frac{2}{3} \simeq 0,6668$$

$$\omega_u = \frac{\sqrt{3}}{3} \simeq 0,577 \frac{rad}{s} \Rightarrow Tu \simeq 10,882s$$

## AJUSTES ÓPTIMOS DE ZIEGLER Y NICHOLS

$$\text{Para } K_{cu} = \frac{2}{3} ; T_u = 10,882$$

Tipo de Controlador	Kc	Ti (s)	Td (s)
P	$1/3 \approx 0,333$	-	-
P+I	$10/33 \approx 0,303$	9,068	-
P+I+D	$20/51 \approx 0,392$	5,441	1,360

## CONCLUSIONES

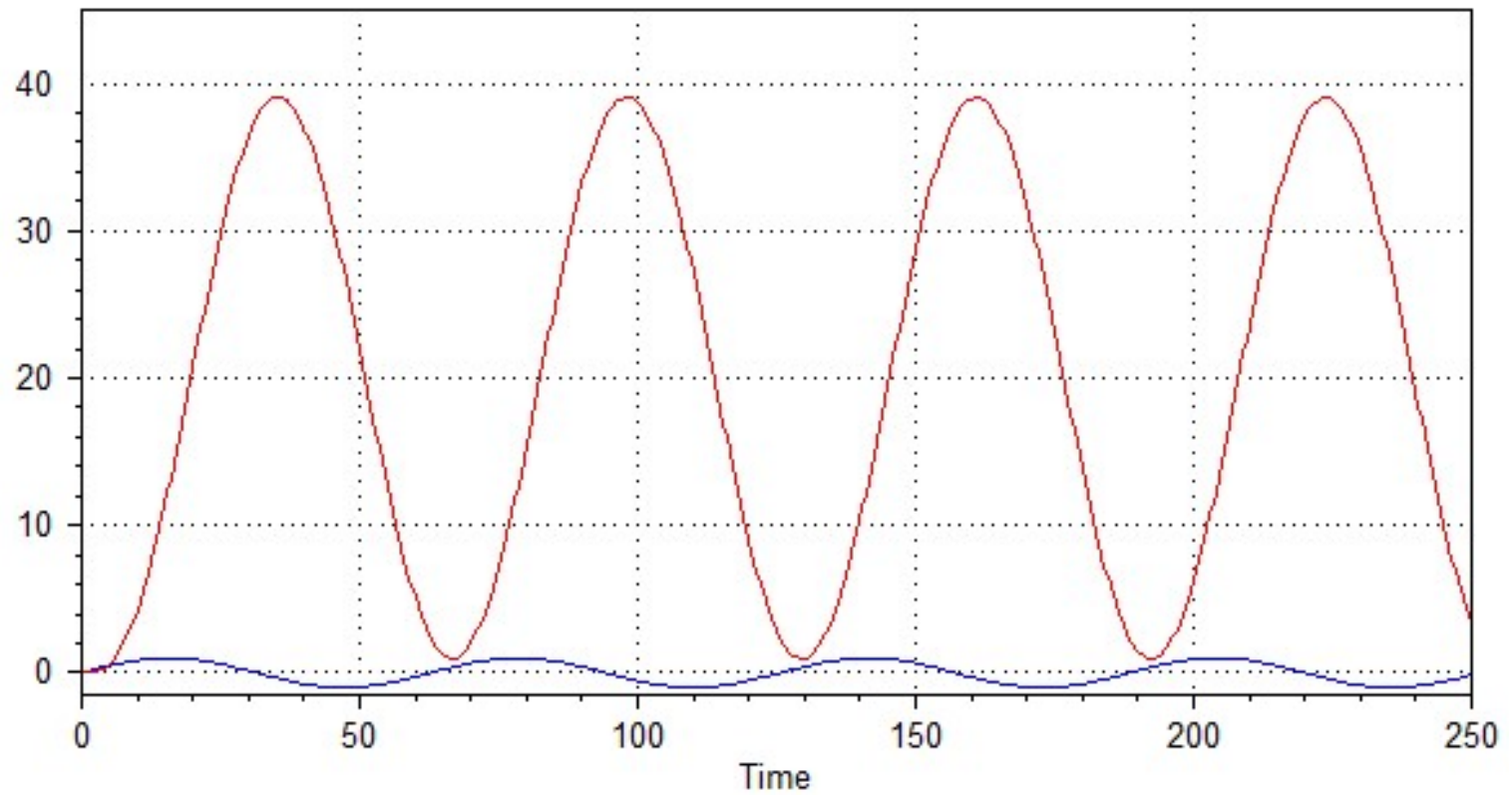
- Go es inestable naturalmente, por lo que surge la necesidad de que al agregar un controlador P al lazo,  $K_c$  sea menor a  $2/3$  para lograr la estabilidad.
- Con  $K_c = 2/3$  se obtiene una frecuencia angular última de  $0,577$  rad/s y por ende un periodo de oscilación de  $10,882$ s

# EJERCICIO 3

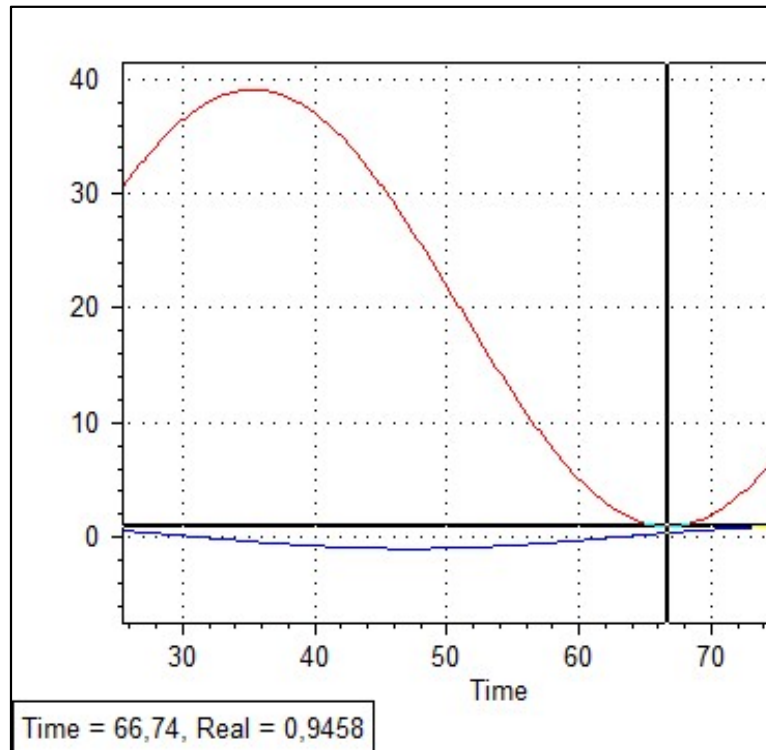
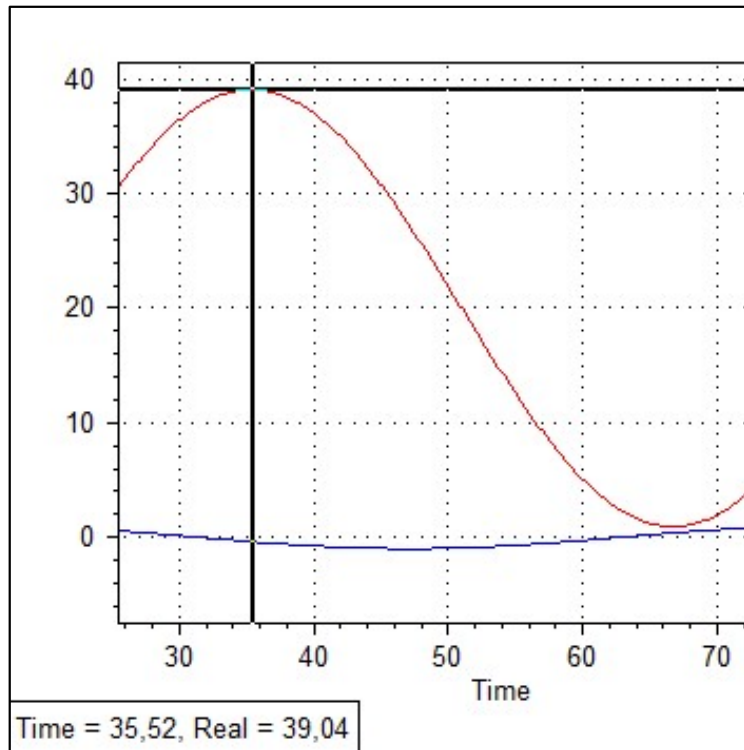
The background of the slide is a photograph of a server room. The lighting is predominantly blue, creating a cool, technological atmosphere. In the foreground, a dark blue rectangular box is centered, containing the text 'EJERCICIO 3' in white, bold, sans-serif font. The server racks in the background are slightly out of focus, with some lights glowing, suggesting an active data center environment.



FRECUENCIA ANGULAR = 0,1 RAD/S ▶▶▶ T=62,832 S



## AMPLITUD PARA FRECUENCIA ANGULAR = 0,1 RAD/S



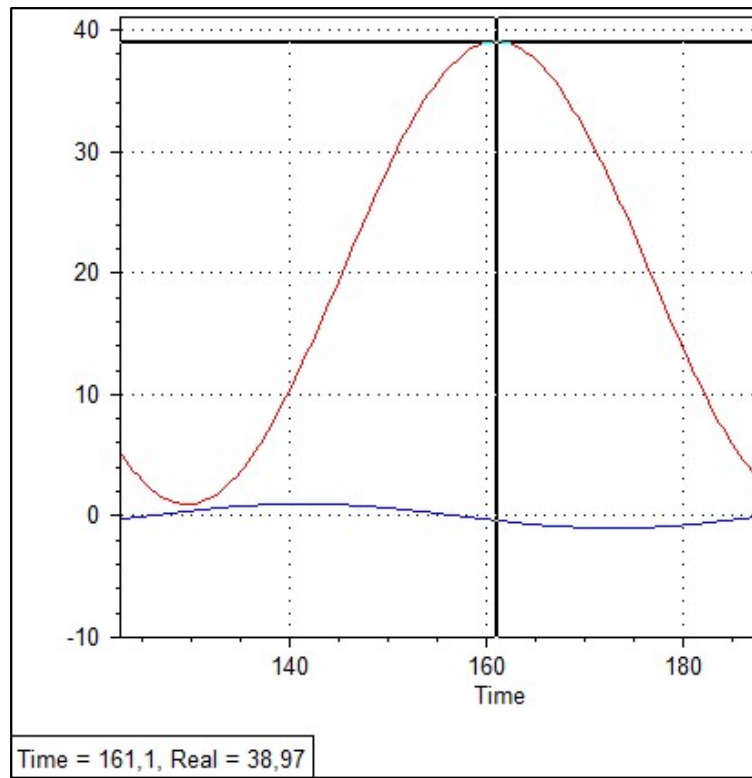
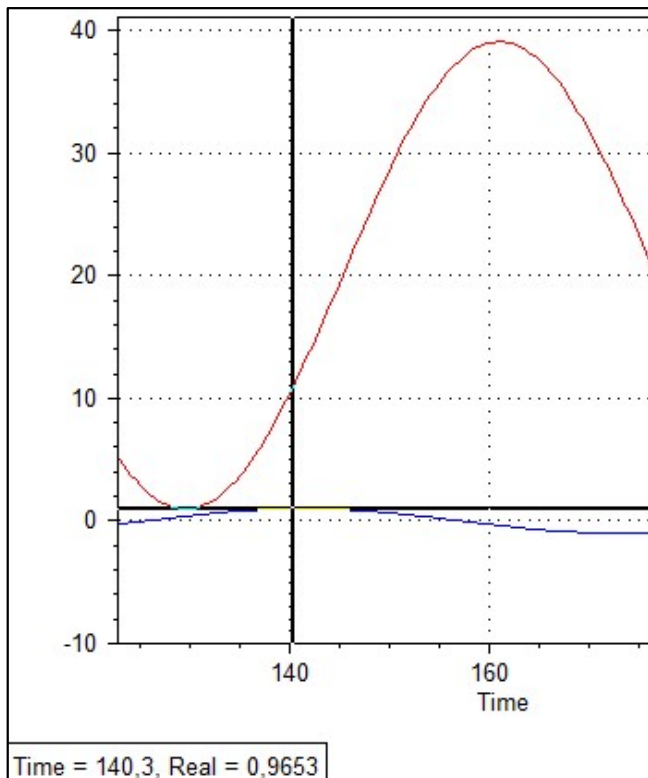
$$V_{pp} = 39,04 - 0,9458$$

$$V_{pp} = 38,0942$$

$$A = 19,0471$$

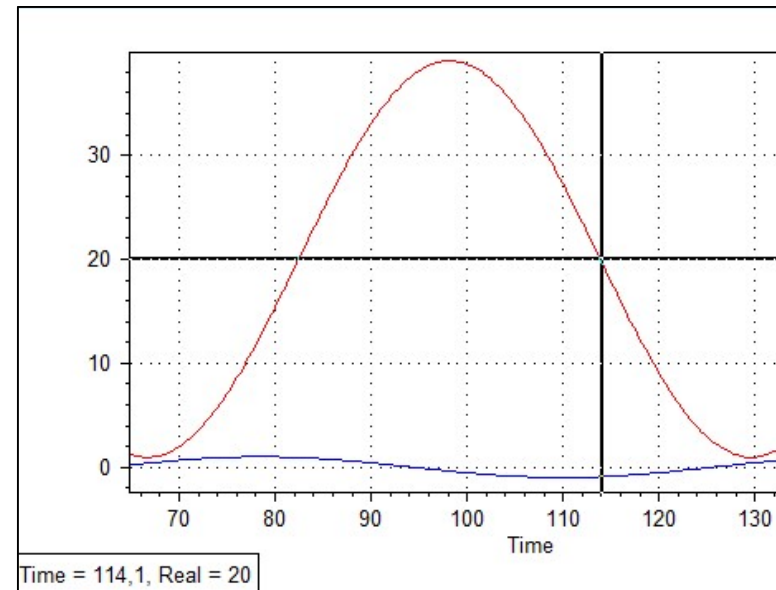
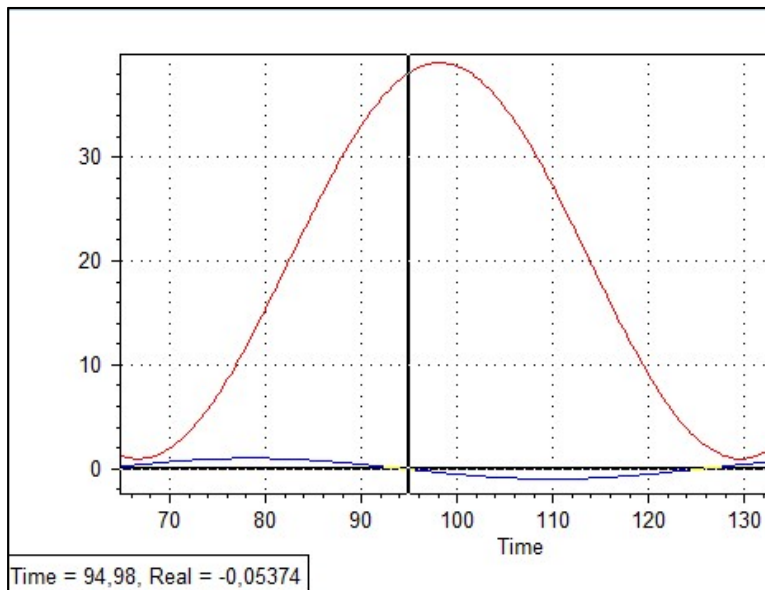
$$RA = 19,0471$$

## DEFASAJE PARA FRECUENCIA ANGULAR = 0,1 RAD/S



**Desfase temporal**  
 **$161,1s - 140,3s = 20,8s$**   
 **$62,832s \rightarrow 360^\circ$**   
 **$20,8s \rightarrow \phi$**   
 **$\phi = 119,17^\circ$**

## DESFAJAJE PARA FRECUENCIA ANGULAR = 0,1 RAD/S



***Desfase temporal***

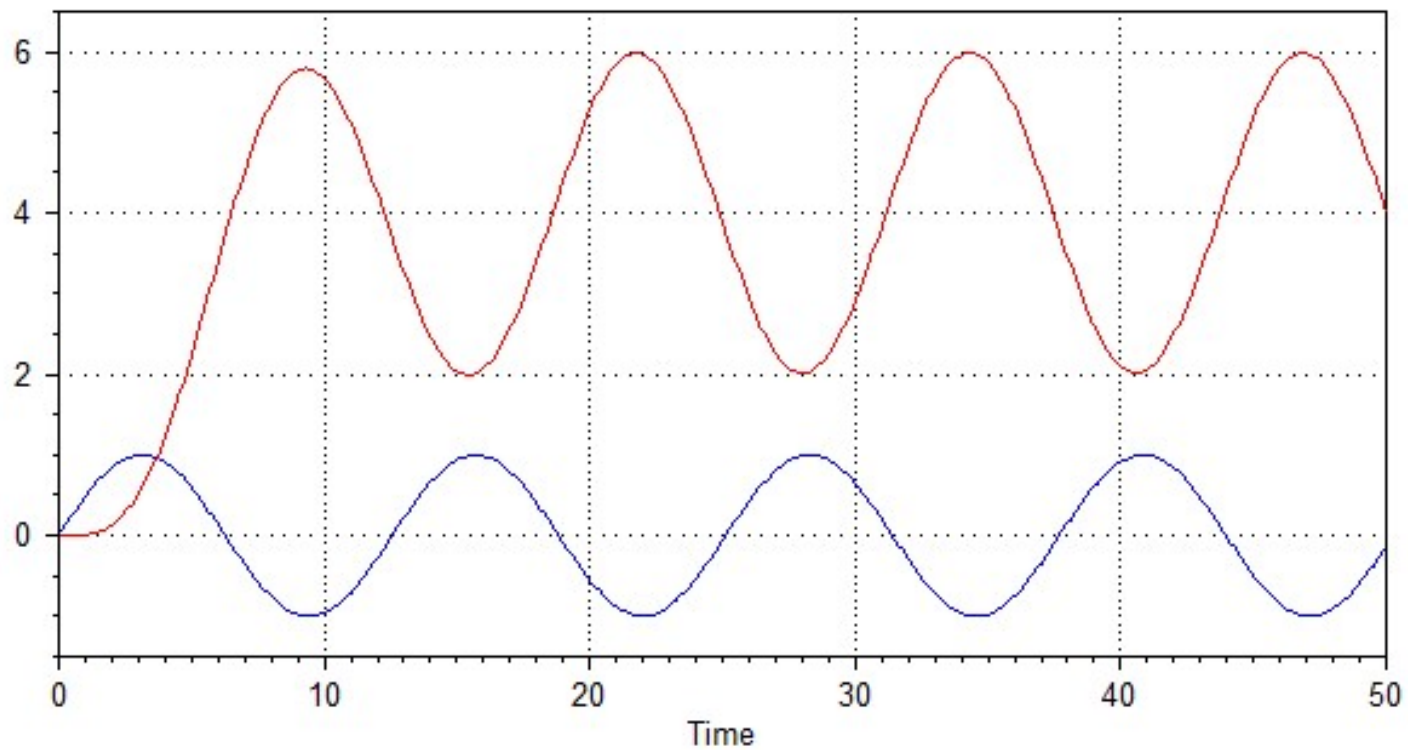
$$114,1s - 94,98s = 19,12s$$

$$62,832s \rightarrow 360^\circ$$

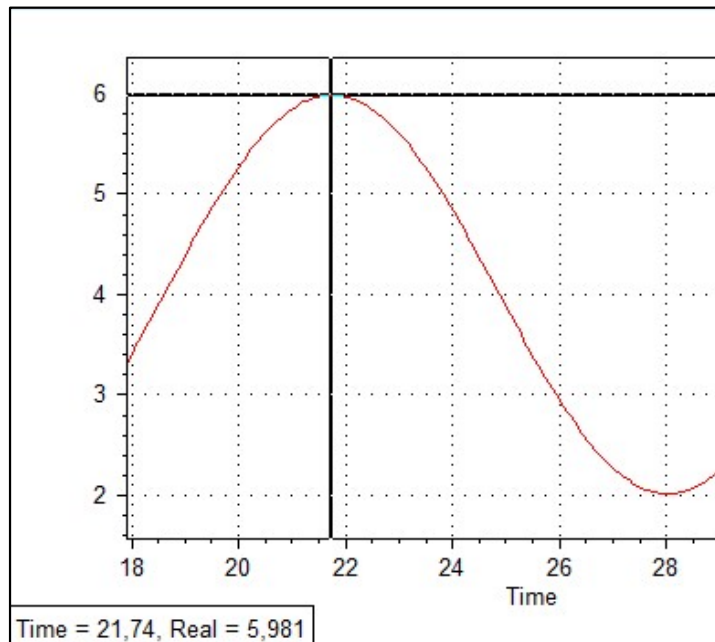
$$19,12s \rightarrow \phi$$

$$\phi = 109,55^\circ$$

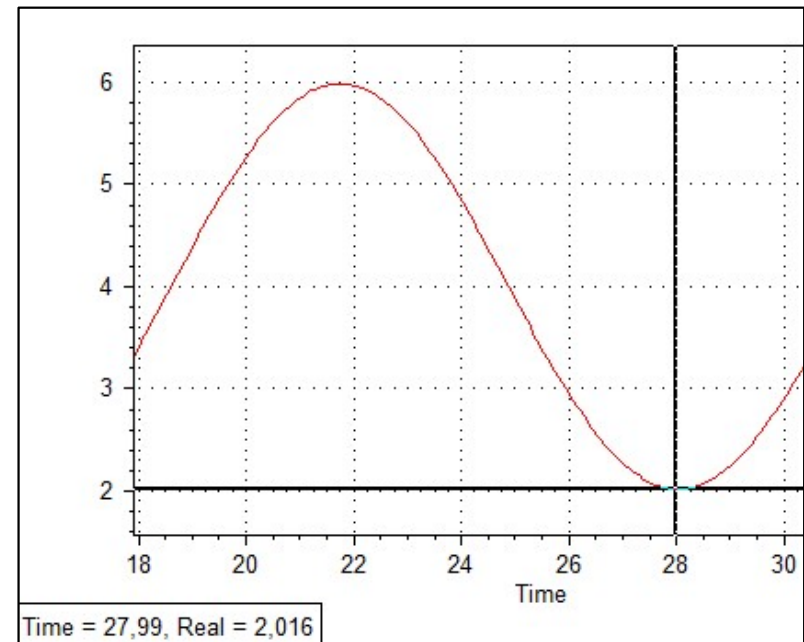
FRECUENCIA ANGULAR = 0,5 RAD/S ▶▶▶ T=12,566 S



# AMPLITUD PARA FRECUENCIA ANGULAR = 0,5 RAD/S



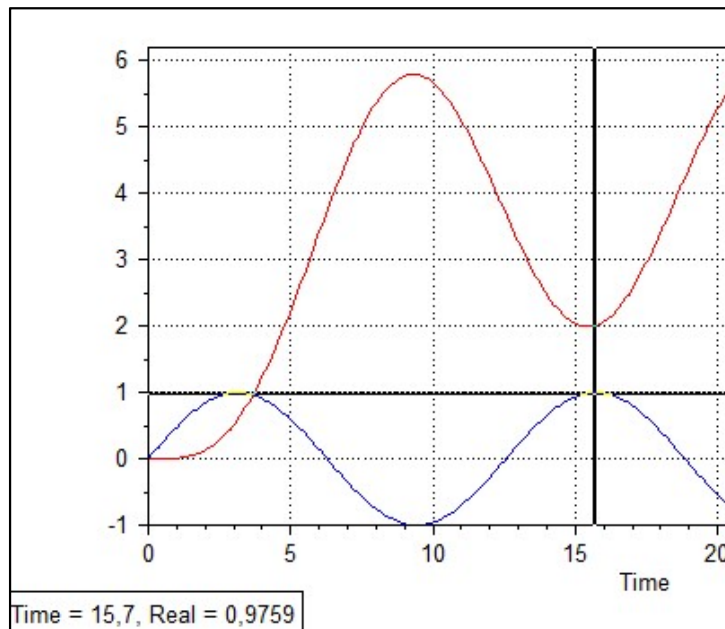
$$V_{pp} = 5,981 - 2,016$$



$$V_{pp} = 3,965$$

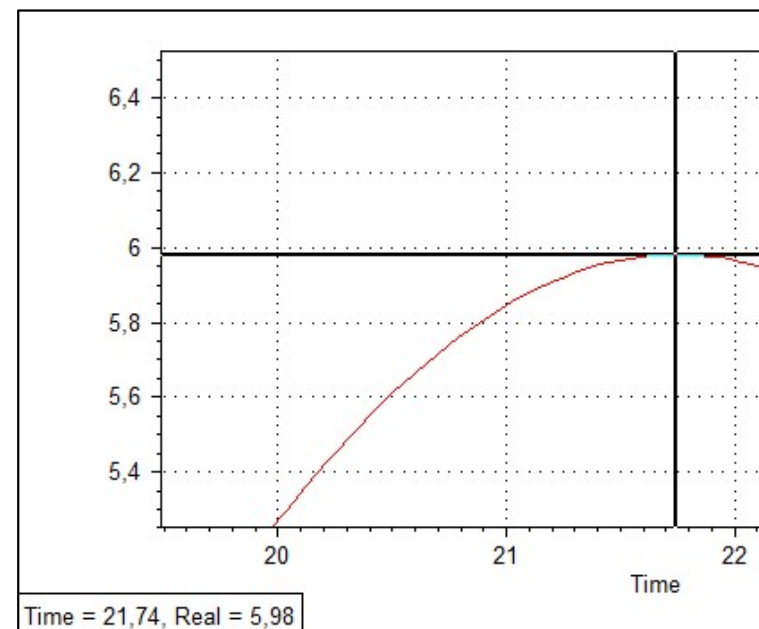
$$A = 1,9825$$

## DESFAJAJE PARA FRECUENCIA ANGULAR = 0,5 RAD/S



***Desfase temporal***

$$21,74s - 15,7s = 6,04s$$

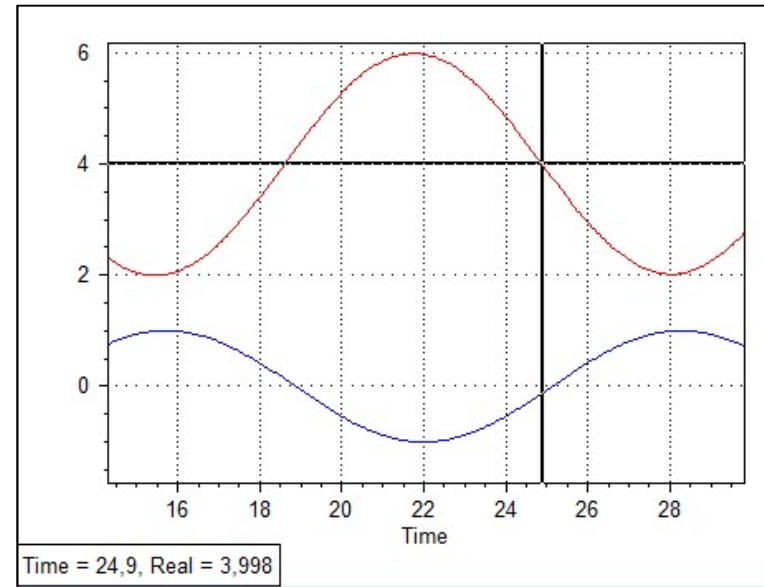
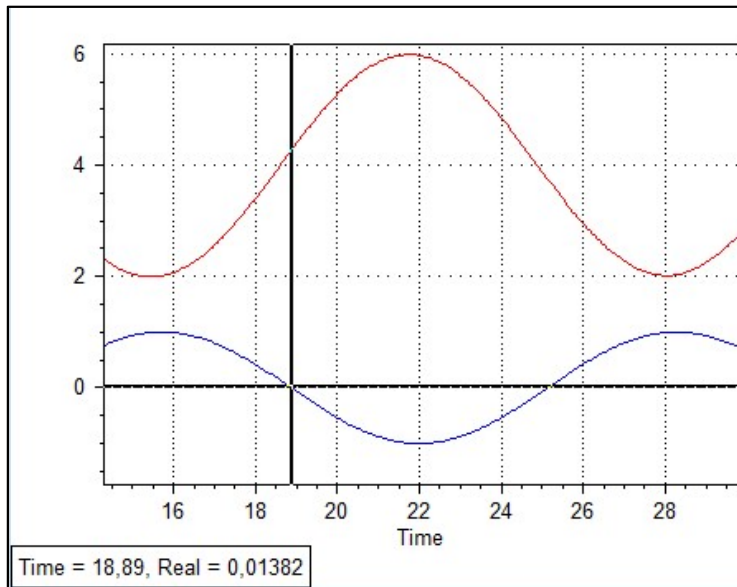


$$12,566s \rightarrow 360^\circ$$

$$6,04s \rightarrow \phi$$

$$\phi = 173,04^\circ$$

## DEFASAJE PARA FRECUENCIA ANGULAR = 0,5 RAD/S



***Desfase temporal***

$$24,9s - 18,89s = 6,01s$$

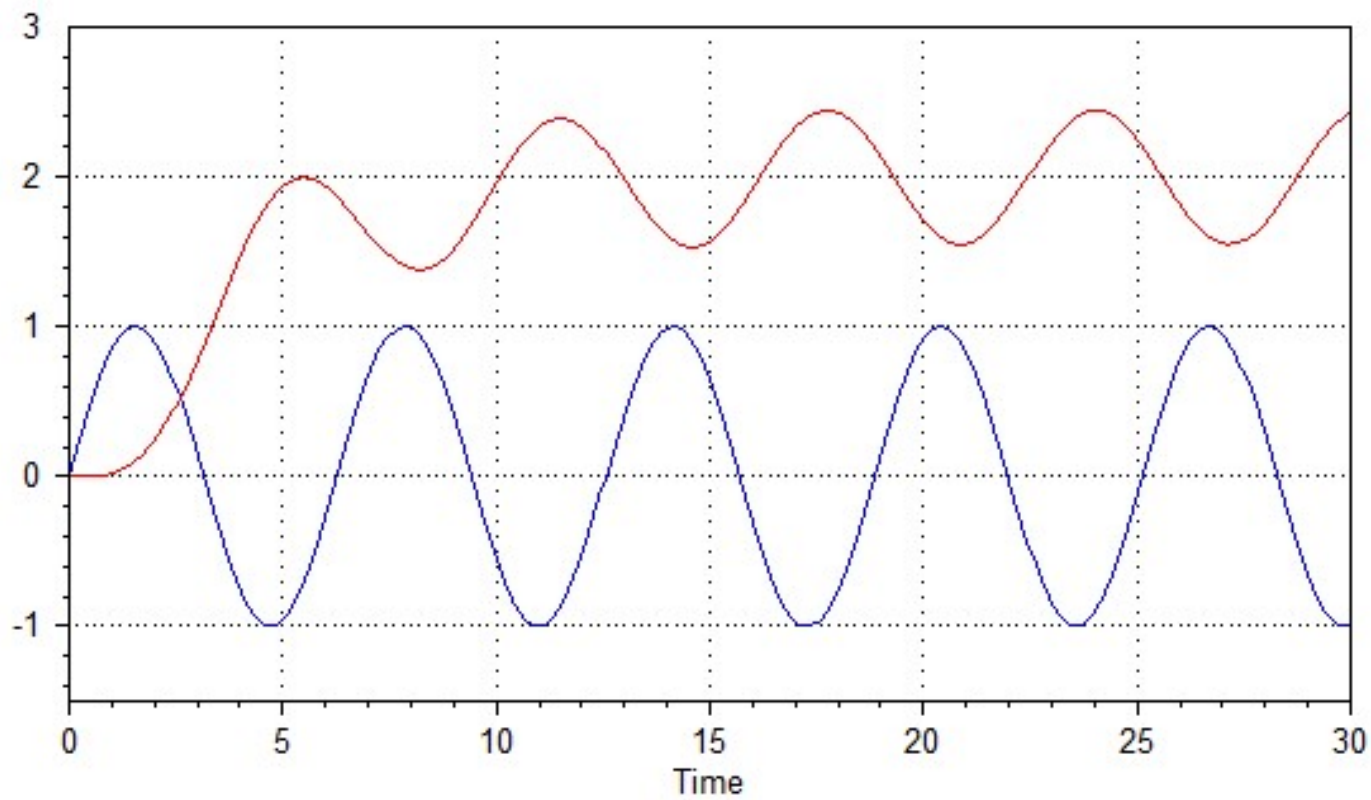
$$12,566s \rightarrow 360^\circ$$

$$6,01s \rightarrow \phi$$

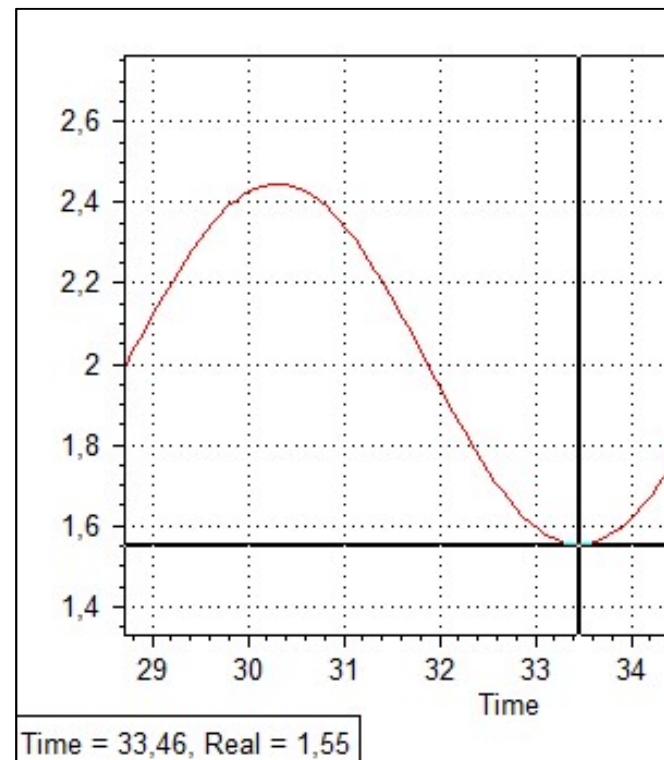
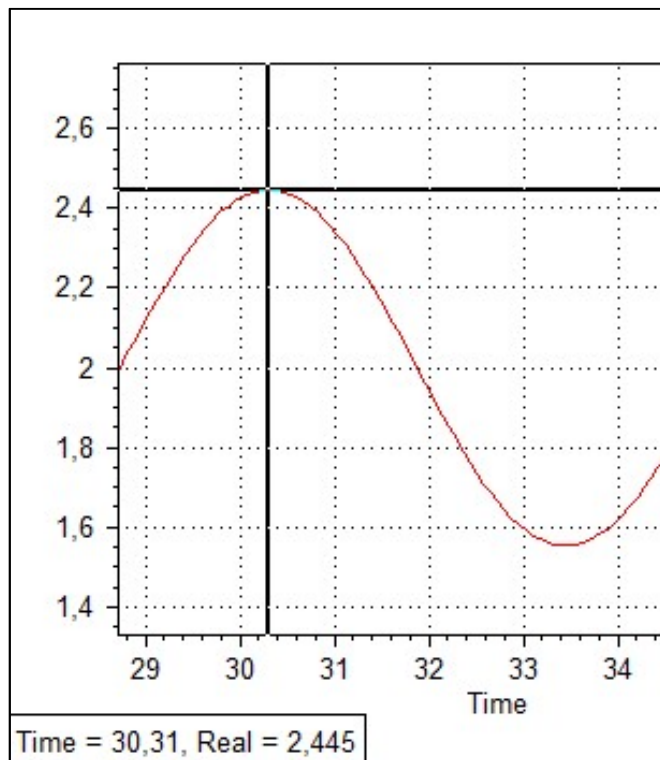
$$\phi = 172,18^\circ$$



FRECUENCIA ANGULAR = 1 RAD/S ▶▶▶ T= 6,283 S



## AMPLITUD PARA FRECUENCIA ANGULAR = 1 RAD/S

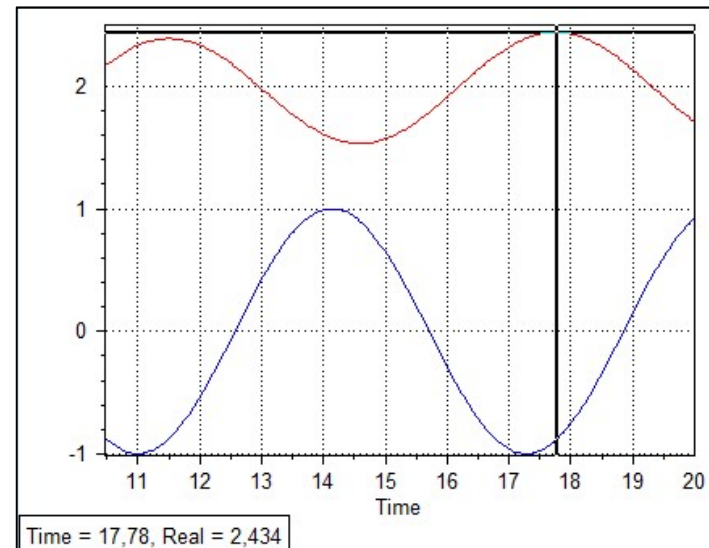
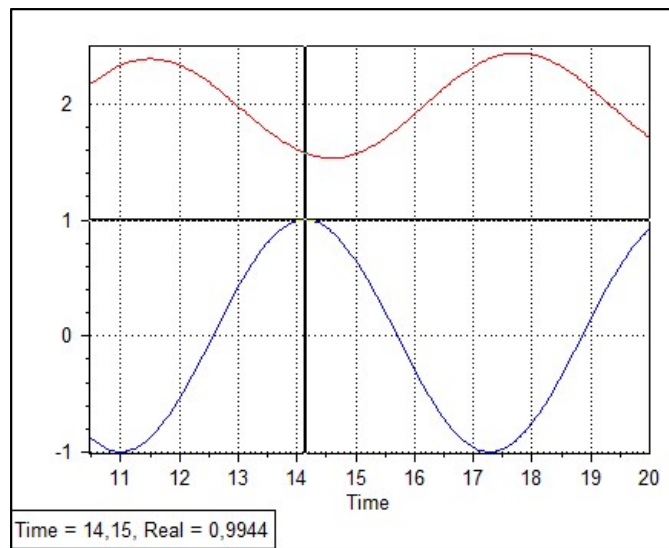


$$V_{pp} = 2,445 - 1,55$$

$$V_{pp} = 0,895$$

$$A = 0,4475$$

## DESFAJAJE PARA FRECUENCIA ANGULAR = 1 RAD/S



***Desfase temporal***

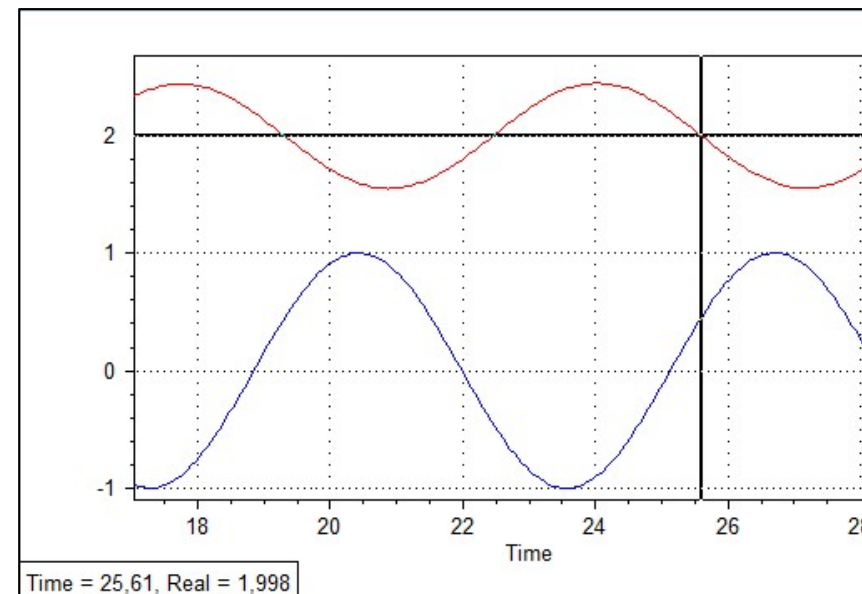
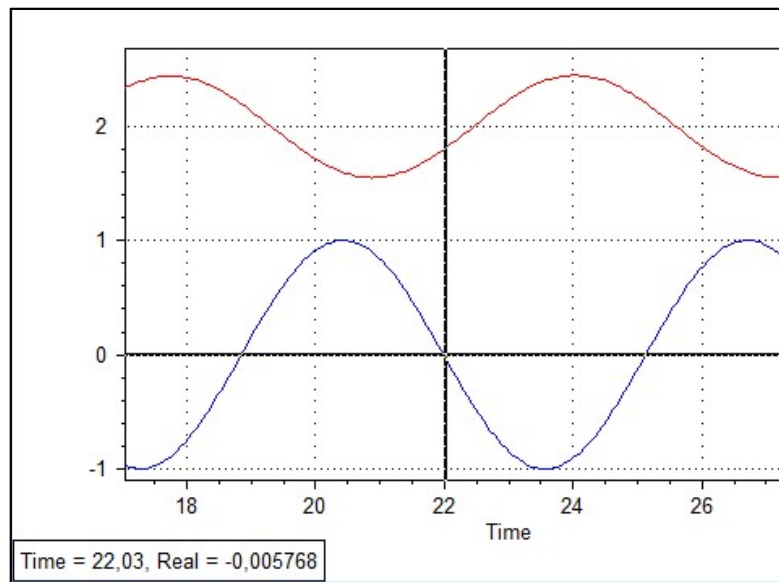
$$17,78s - 14,15s = 3,63s$$

$$6,283s \rightarrow 360^\circ$$

$$3,63s \rightarrow \phi$$

$$\phi = 207,99^\circ$$

## DESFAJAJE PARA FRECUENCIA ANGULAR = 1 RAD/S



***Desfase temporal***

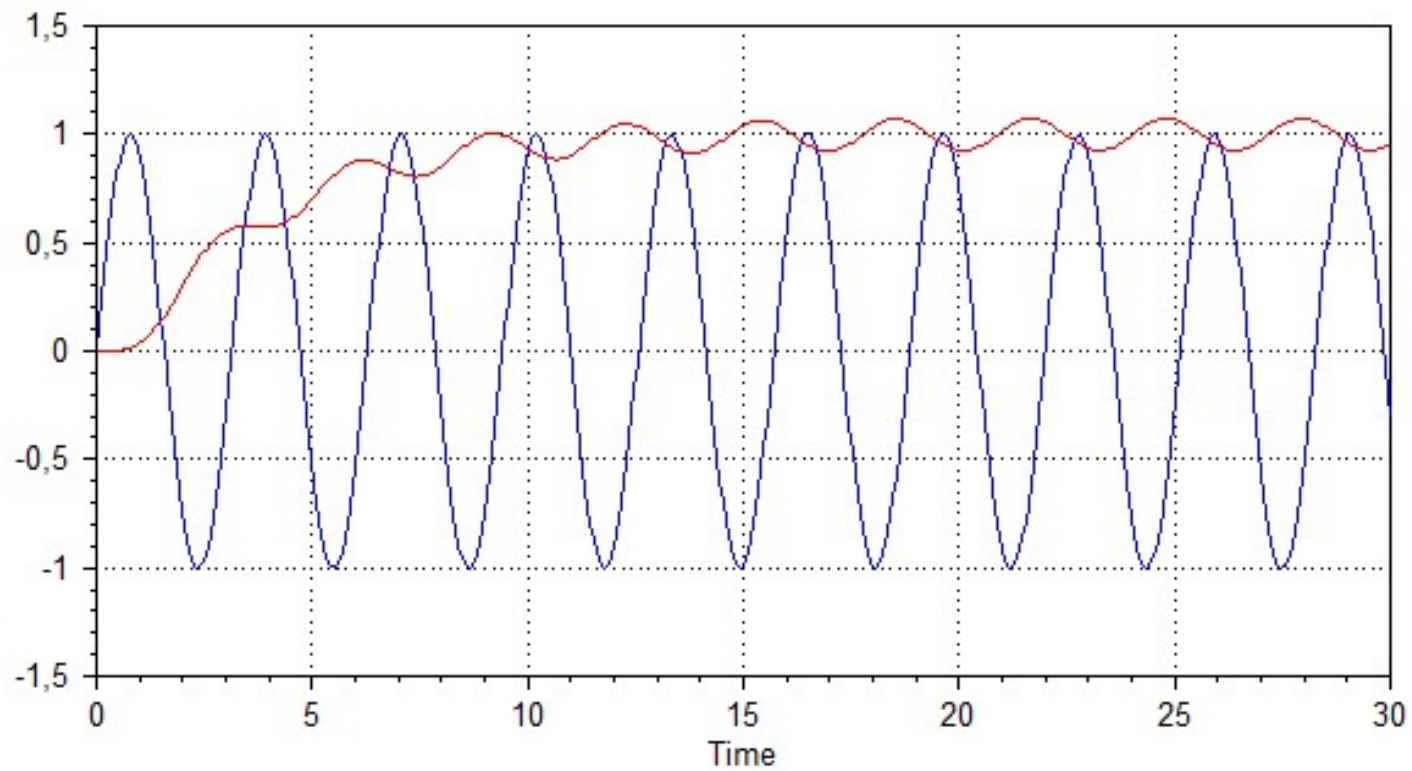
$$25,61s - 22,03s = 3,58s$$

$$6,283s \rightarrow 360^\circ$$

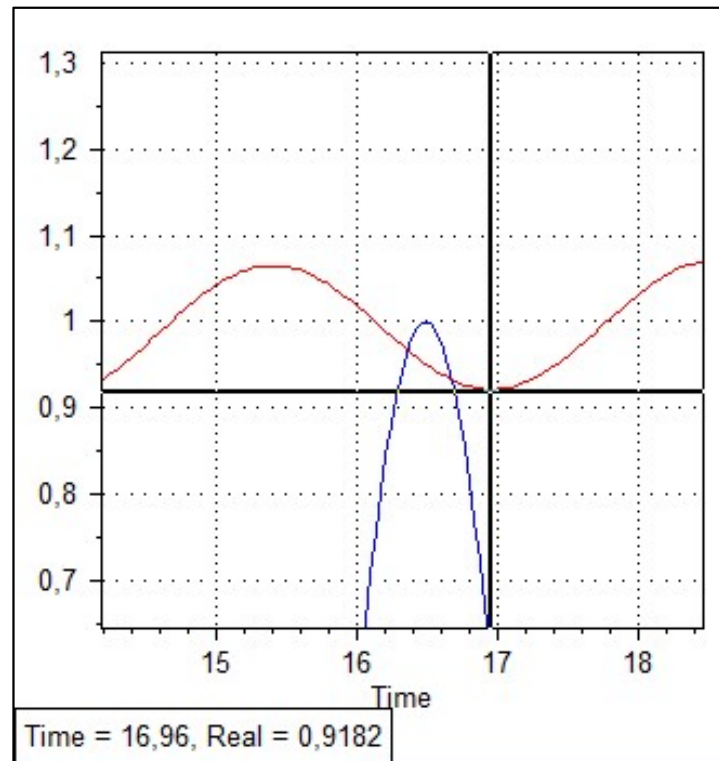
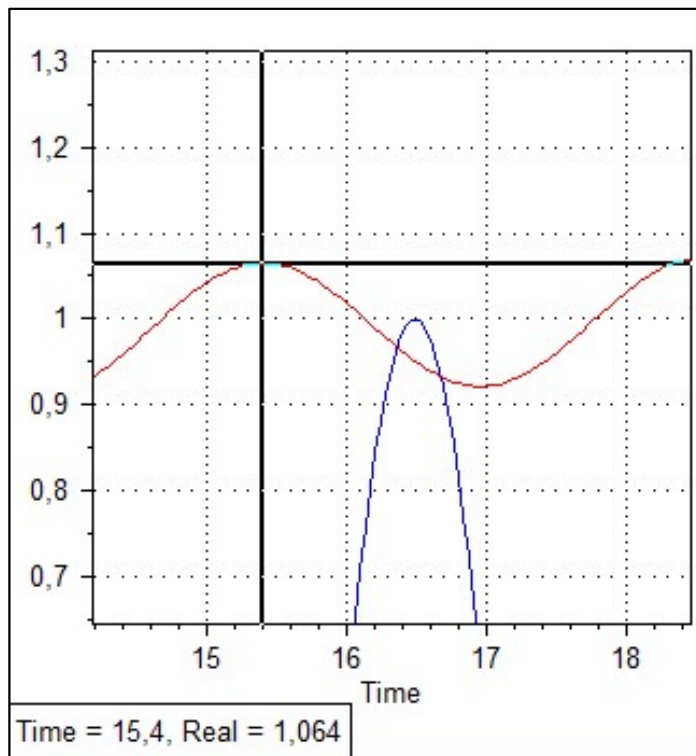
$$3,58s \rightarrow \phi$$

$$\phi = 205,12^\circ$$

FRECUENCIA ANGULAR = 2 RAD/S ▶▶▶ T= 3,142 S



## AMPLITUD PARA FRECUENCIA ANGULAR = 2 RAD/S

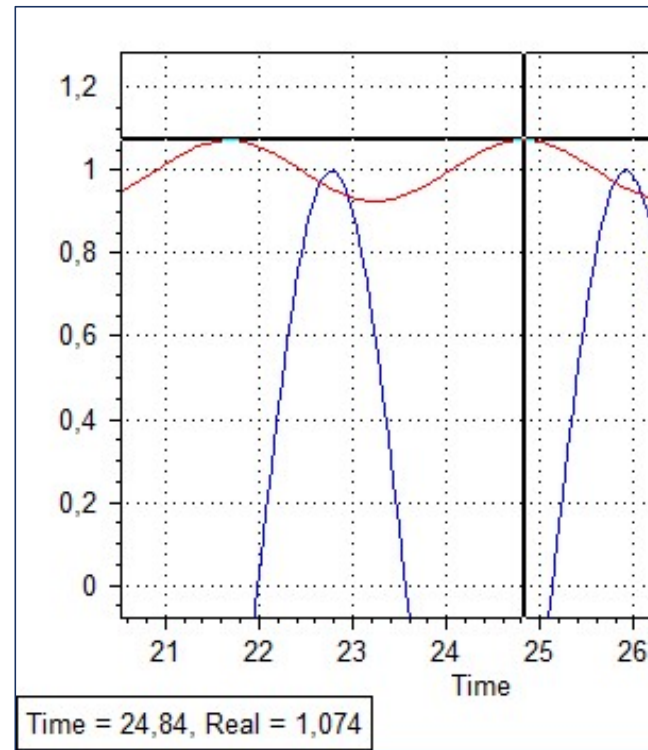
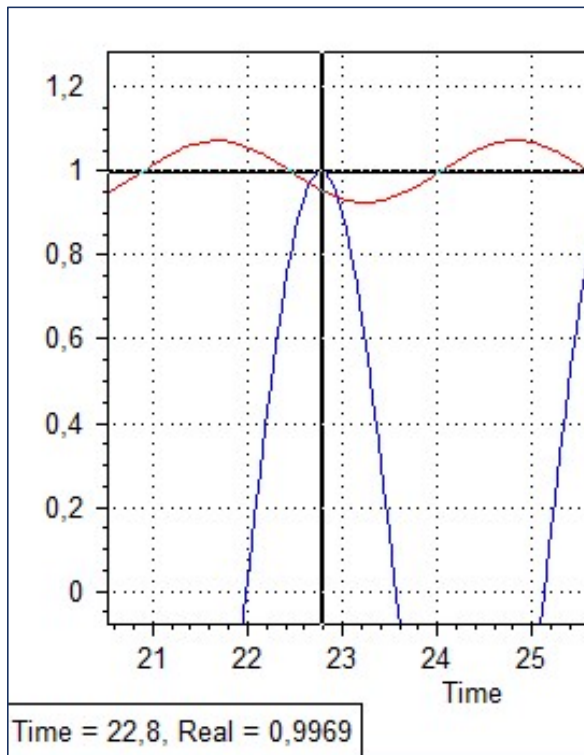


$$V_{pp} = 1,064 - 0,9182$$

$$V_{pp} = 38,0942$$

$$A = 0,1458$$

## DESFAJAJE PARA FRECUENCIA ANGULAR = 2 RAD/S



*Desfase temporal*

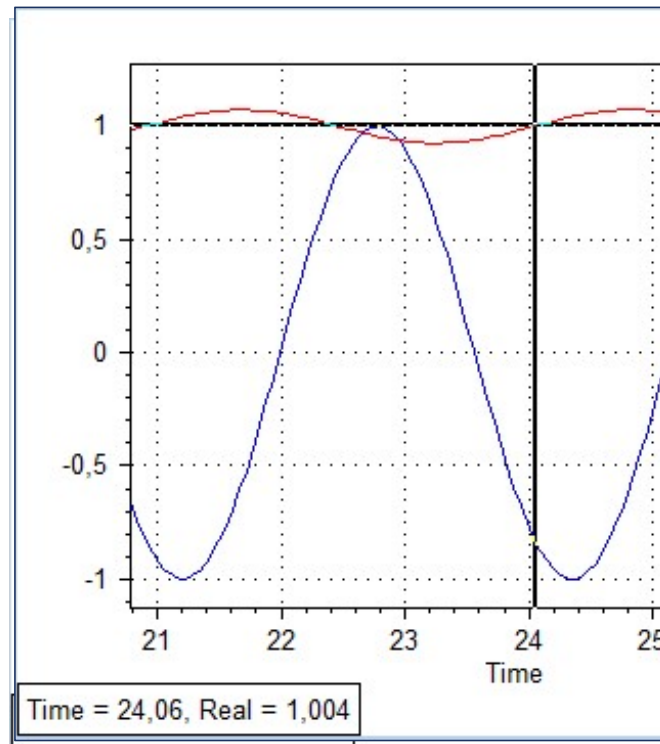
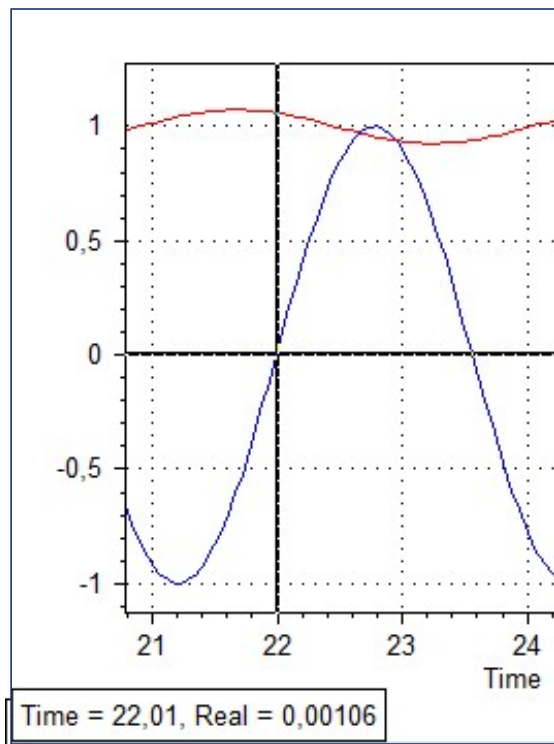
$$24,84s - 22,8s = 2,04s$$

$$3,142s \rightarrow 360^\circ$$

$$2,04s \rightarrow \phi$$

$$\phi = 233,74^\circ$$

## DESFAJAJE PARA FRECUENCIA ANGULAR = 2 RAD/S



*Desfase temporal*

$$24,06s - 22,01s = 2,05s$$

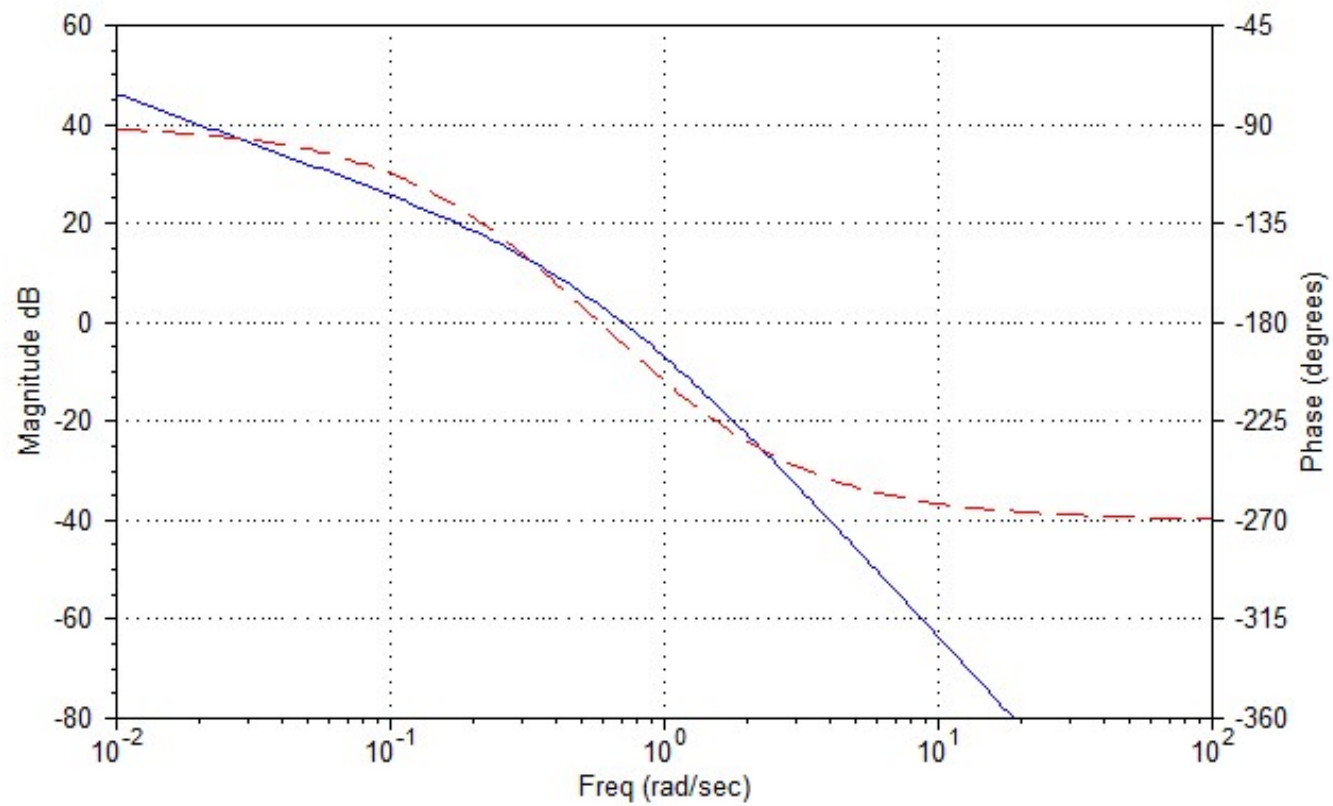
$$3,142s \rightarrow 360^\circ$$

$$2,05s \rightarrow \phi$$

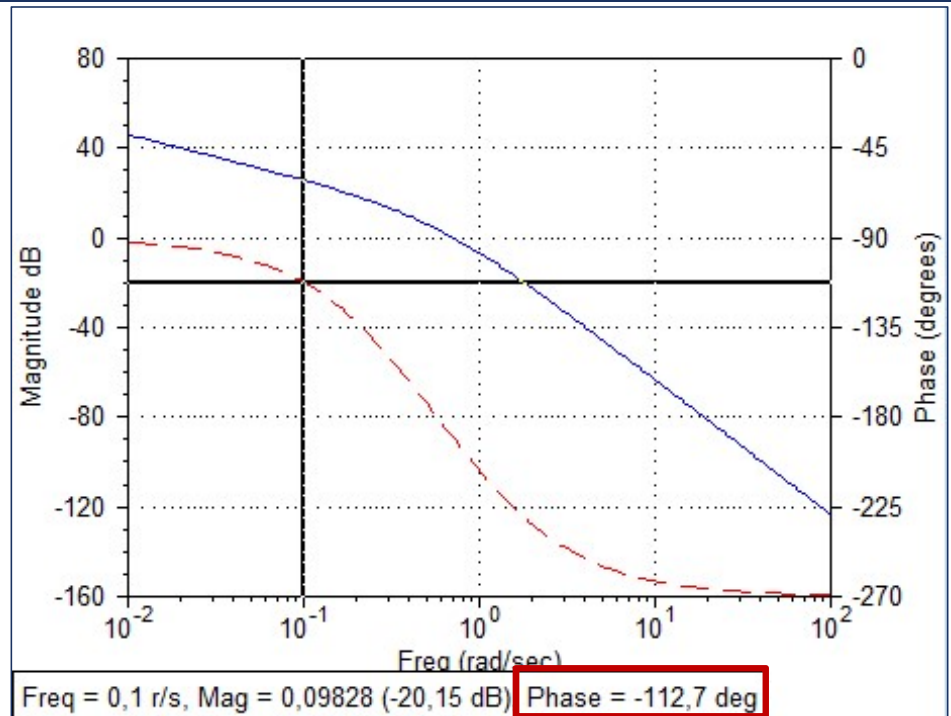
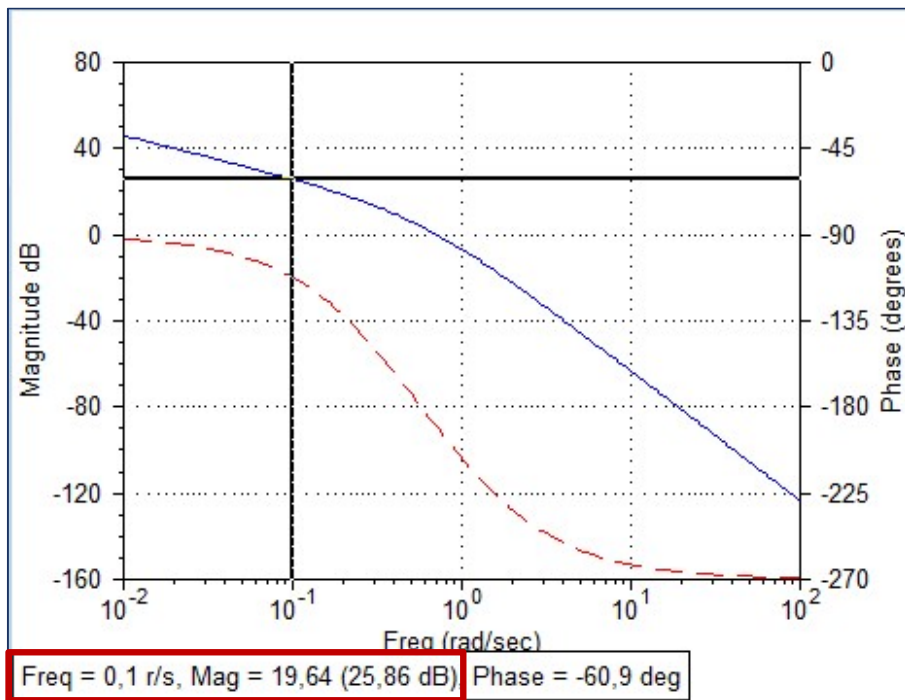
$$\phi = 234,88^\circ$$



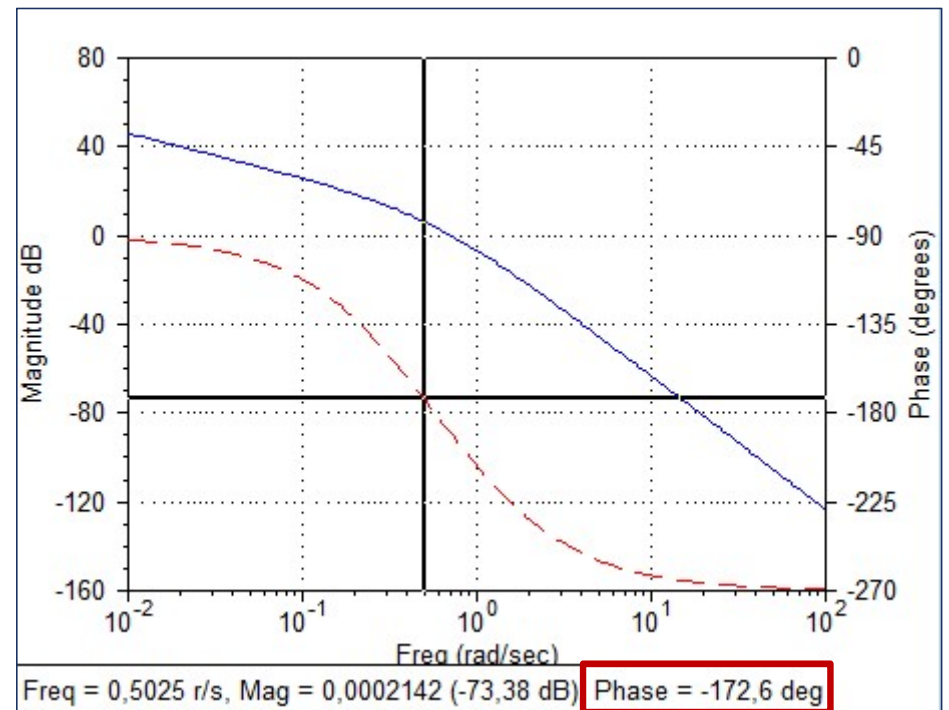
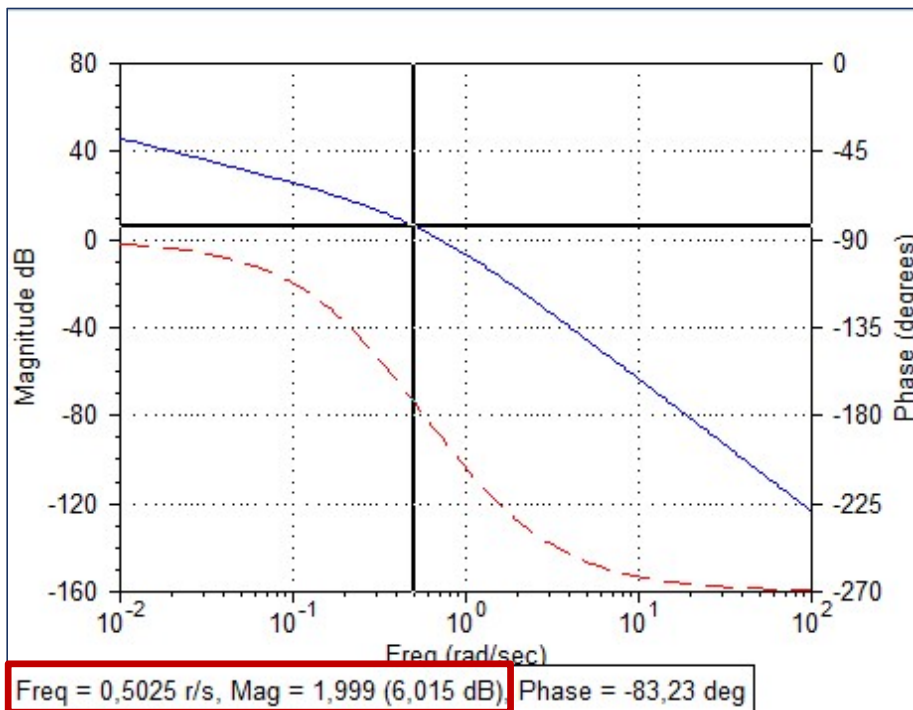
# DIAGRAMA DE BODE



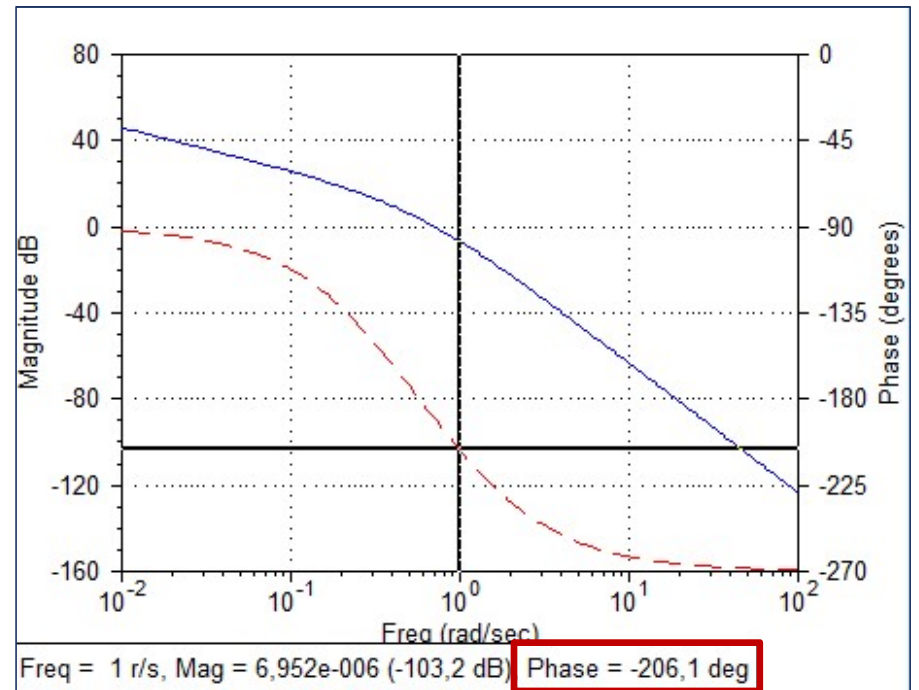
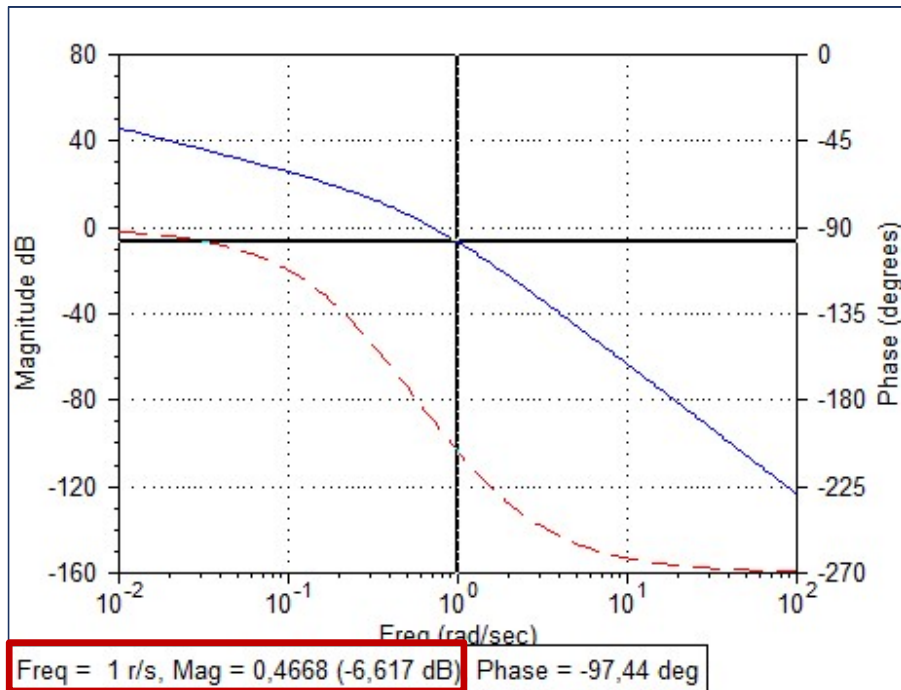
W=0,1 RAD/S



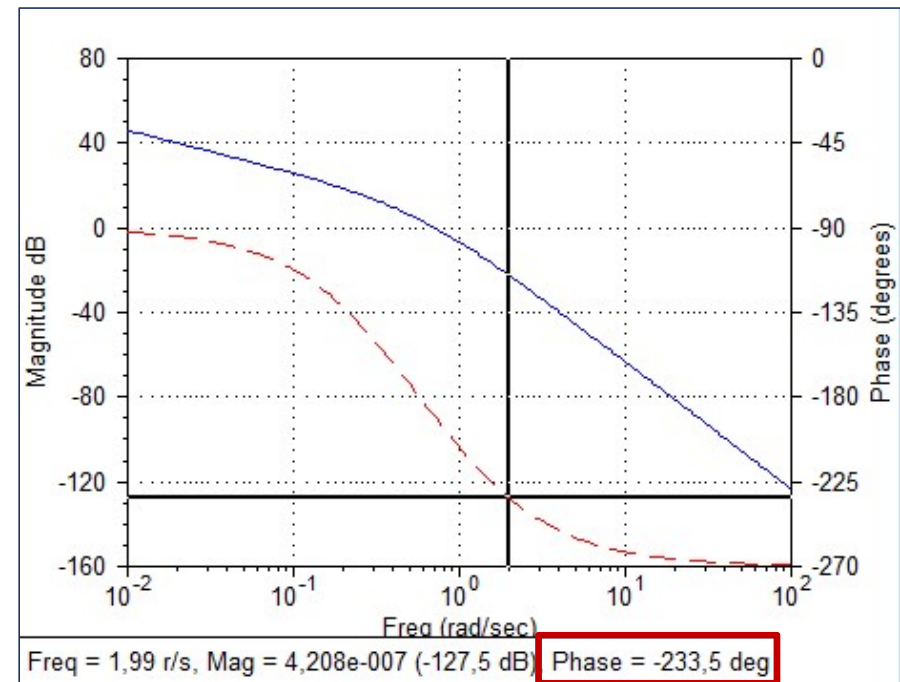
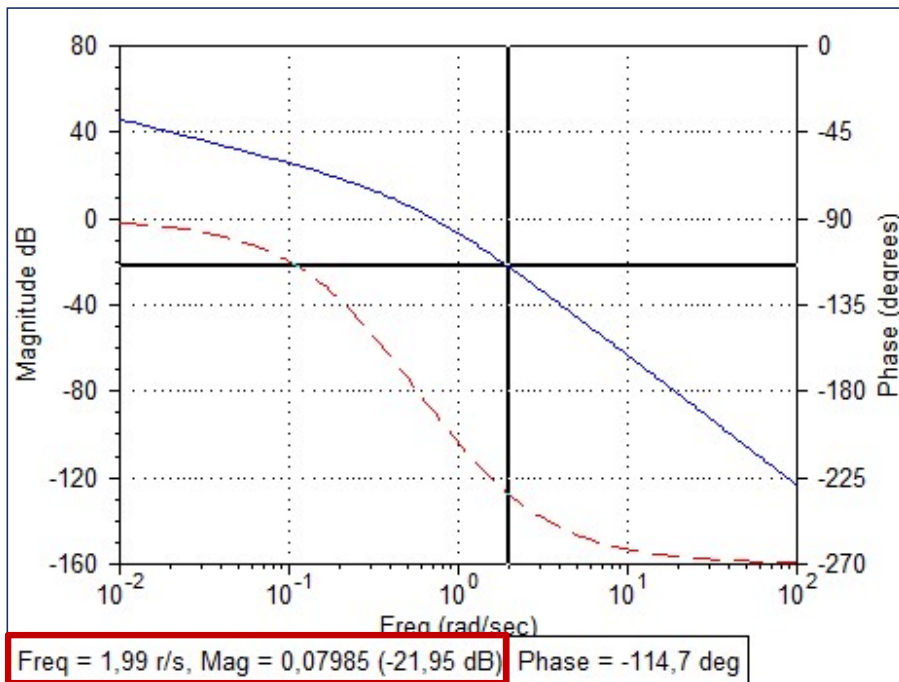
$\omega = 0,5 \text{ RAD/S}$



# W=1 RAD/S

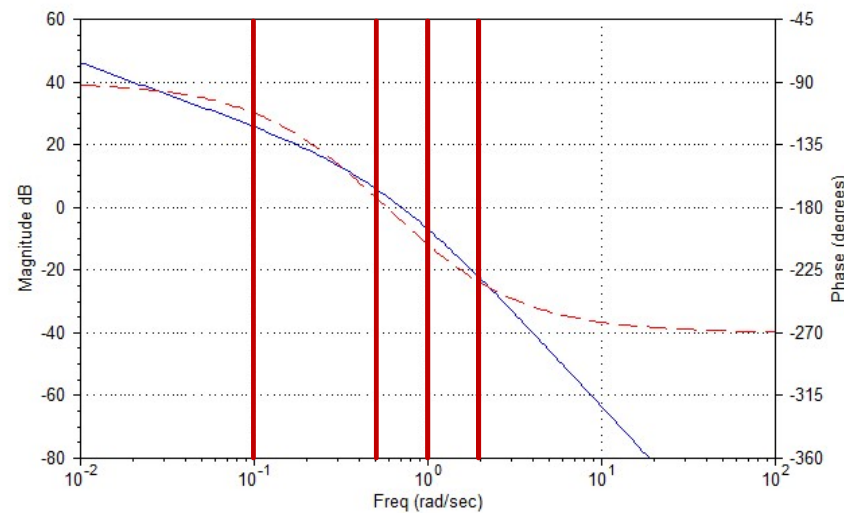


# W=2 RAD/S



## CONCLUSIONES

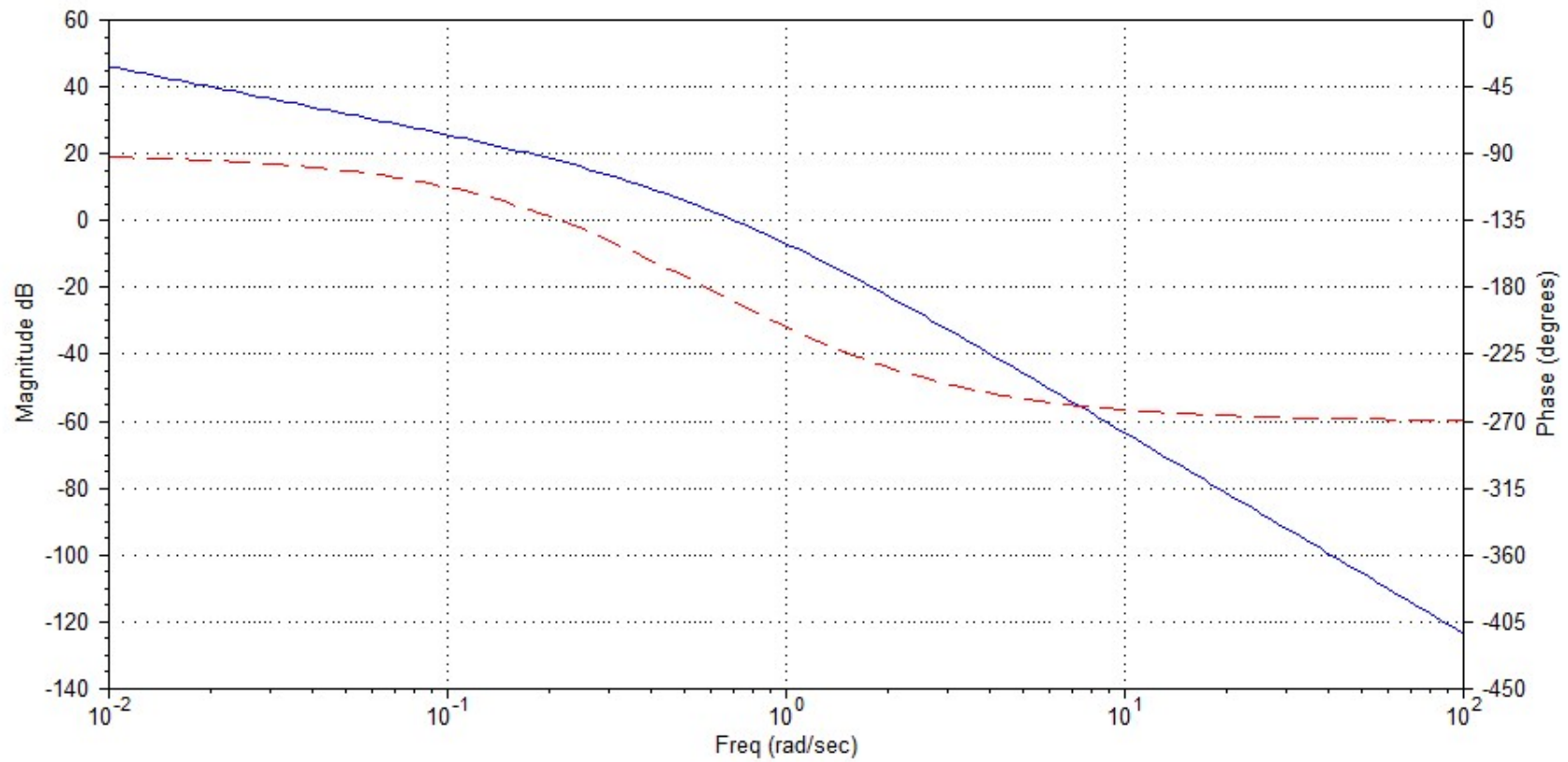
- Se corroboró la medida sobre las amplitudes y los desfases de la respuesta a la entrada senoidal que corresponde a cada frecuencia angular con los valores expuestos en el diagrama de Bode.
- Se pudo corroborar también con medidas que, al aumentar la frecuencia angular, disminuye la relación de amplitud y aumenta el desfase. Esto pudo ratificarse luego en el diagrama de Bode.





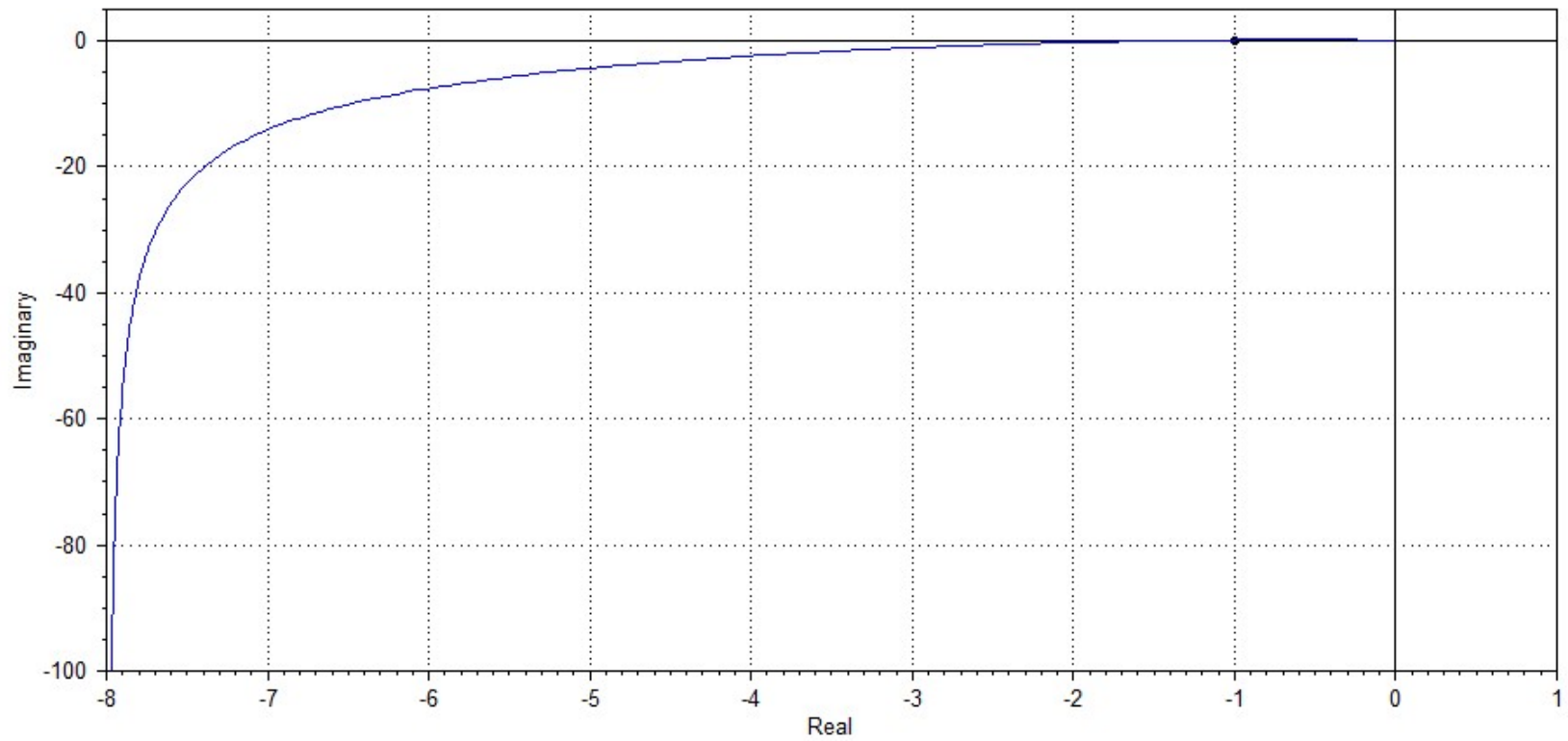
# EJERCICIO 4

# BODE

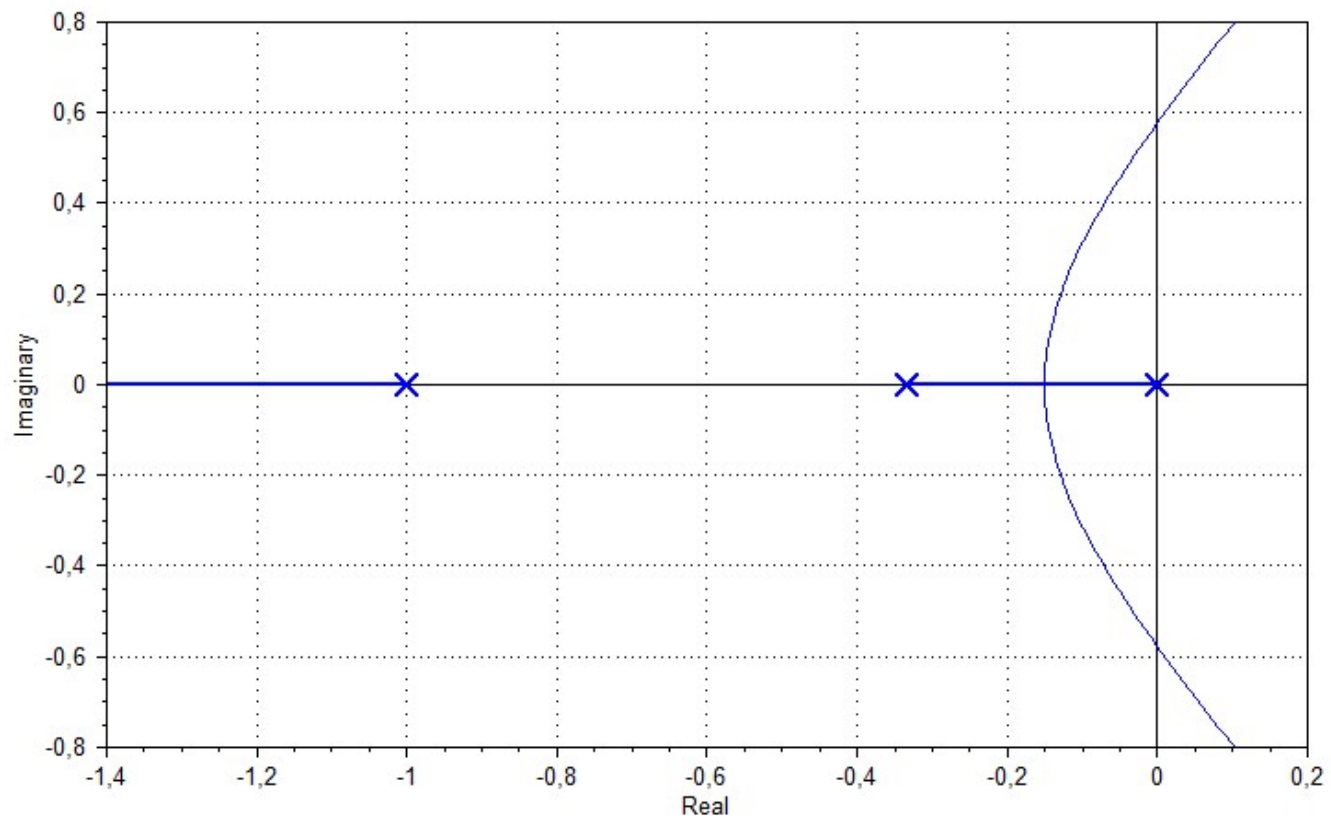




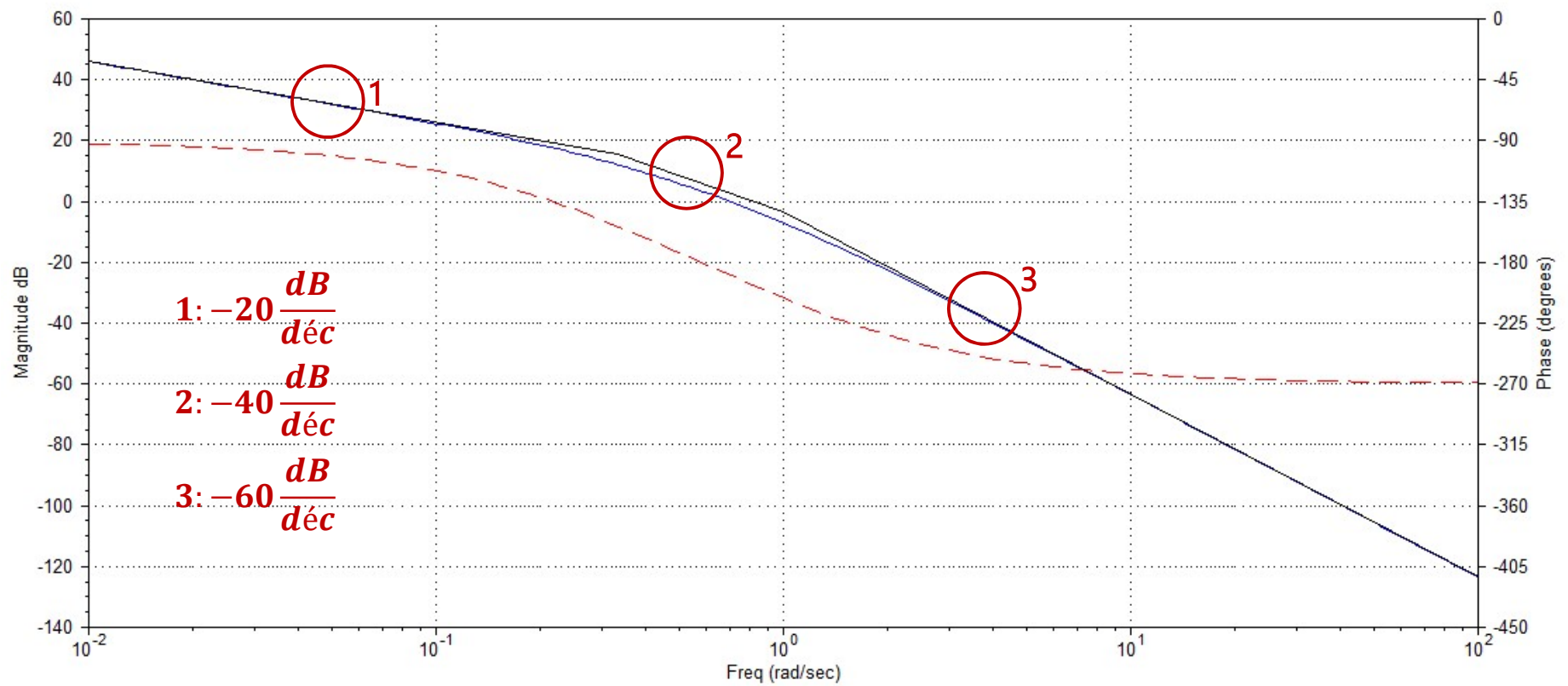
# NYQUIST



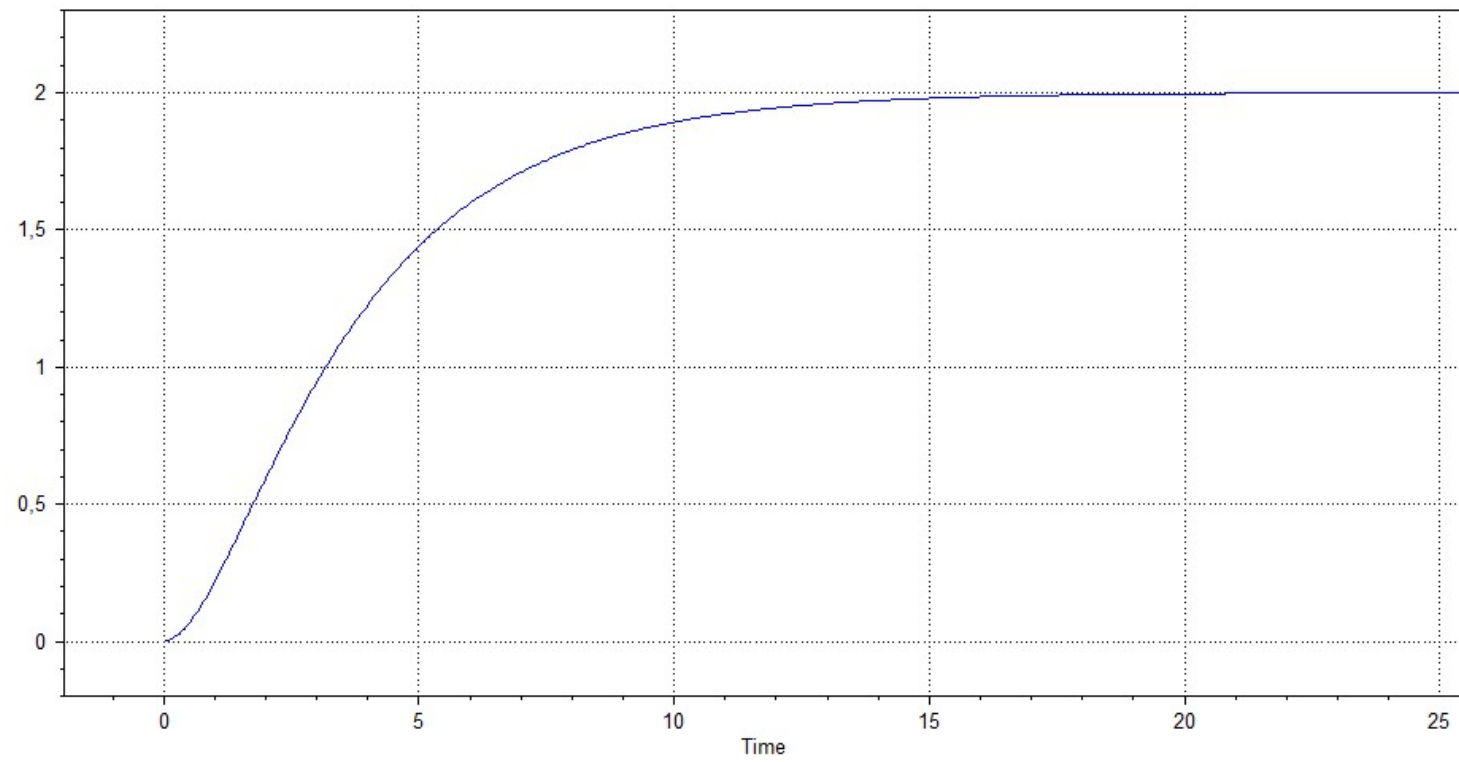
# LUGAR DE RAÍCES



# BODE: ASÍNTOTAS

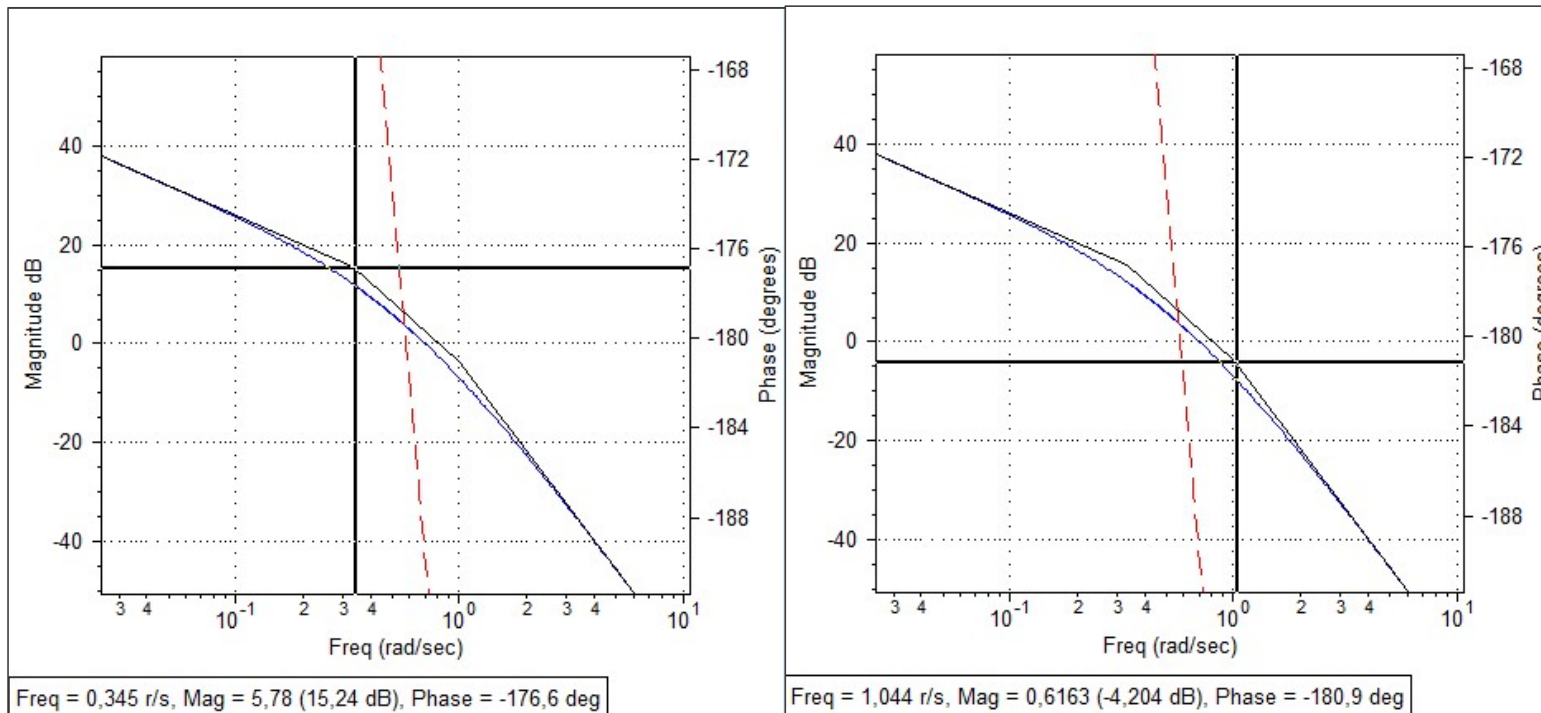


TIME: GSS=2



# BODE: CONSTANTES DE TIEMPO

$$G2 = \frac{2}{(s) * (s + 1) * (3s + 1)}$$



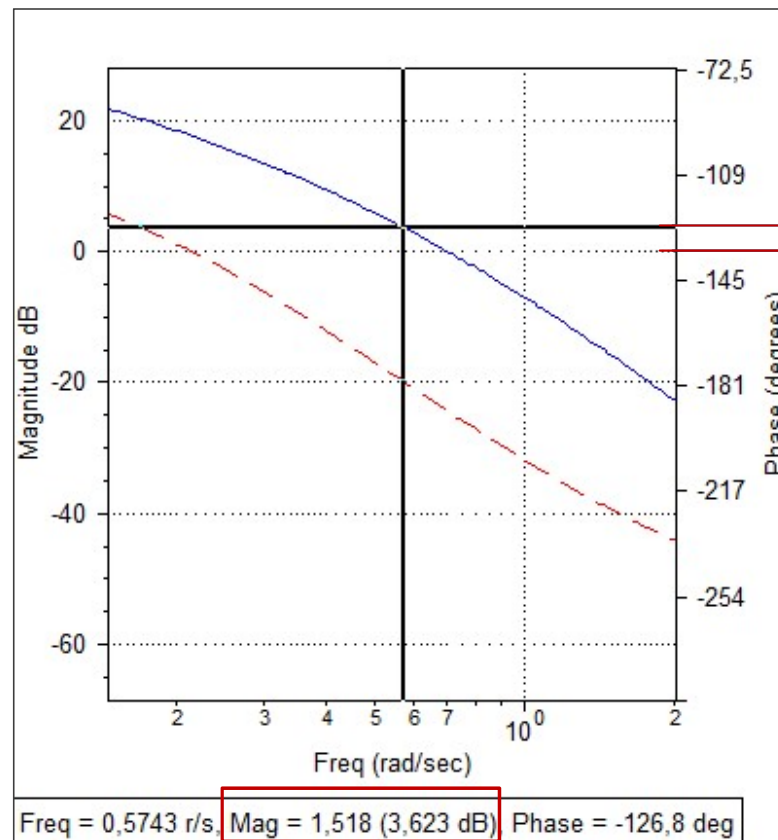
$$\tau_1 = \frac{1}{\omega_1} = \frac{1}{0,345s^{-1}} =$$

$$\tau_1 = 2,898s \approx 3s$$

$$\tau_2 = \frac{1}{\omega_2} = \frac{1}{1s^{-1}} =$$

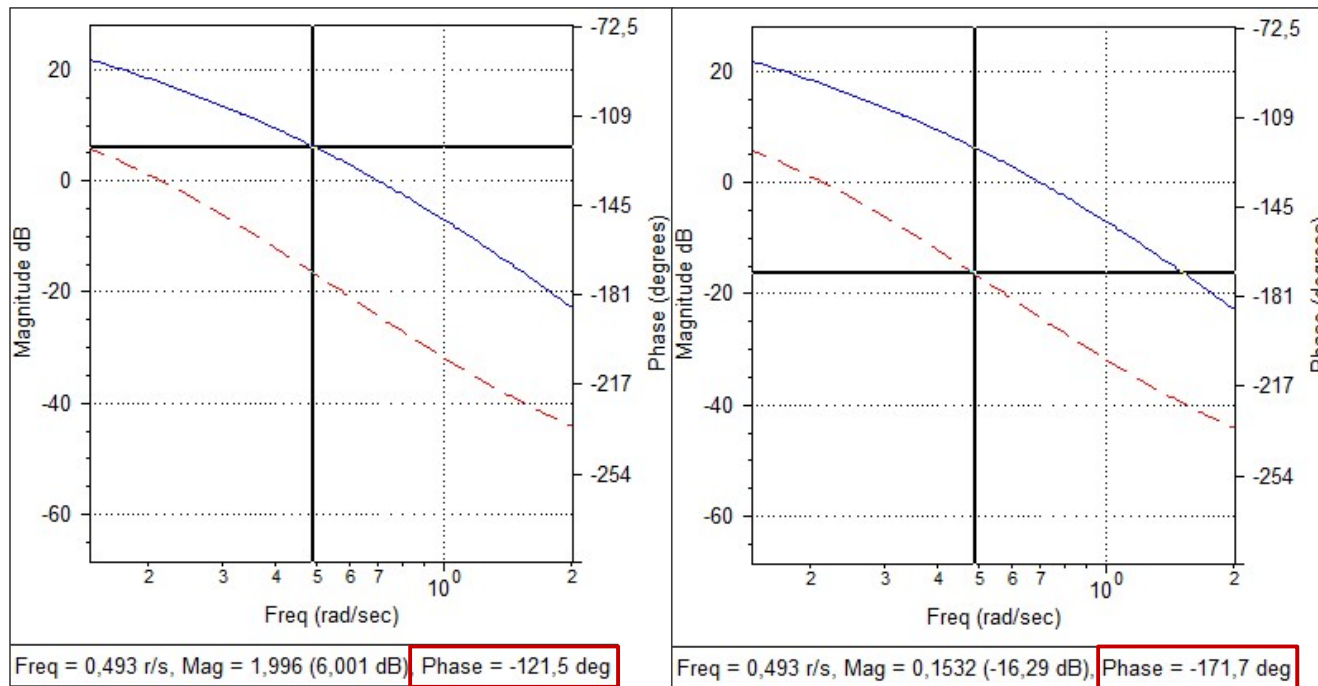
$$\tau_1 = 1s$$

# BODE: MARGEN DE GANANCIA



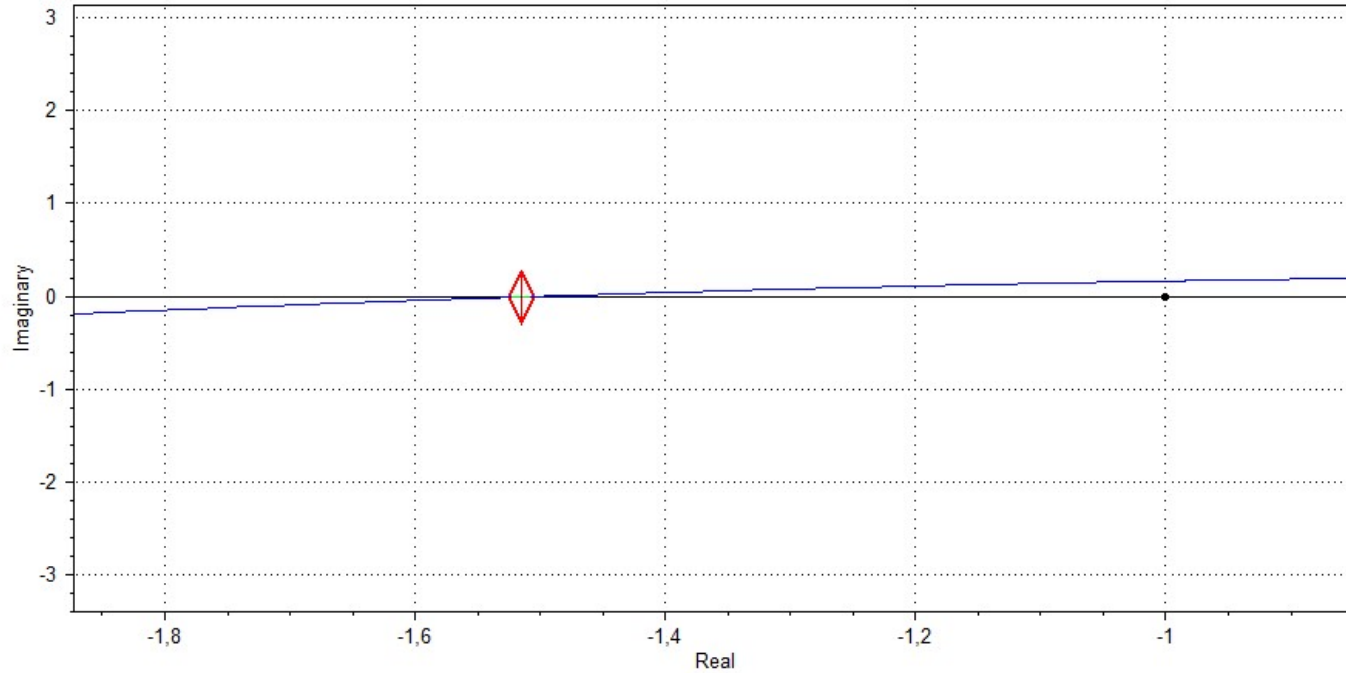
$$K_{cu} = \frac{1}{1,518} \approx 0,66 \approx \frac{2}{3}$$

# BODE: MARGEN DE FASE



$$-180^\circ - (-171,7^\circ) = -8,3^\circ$$

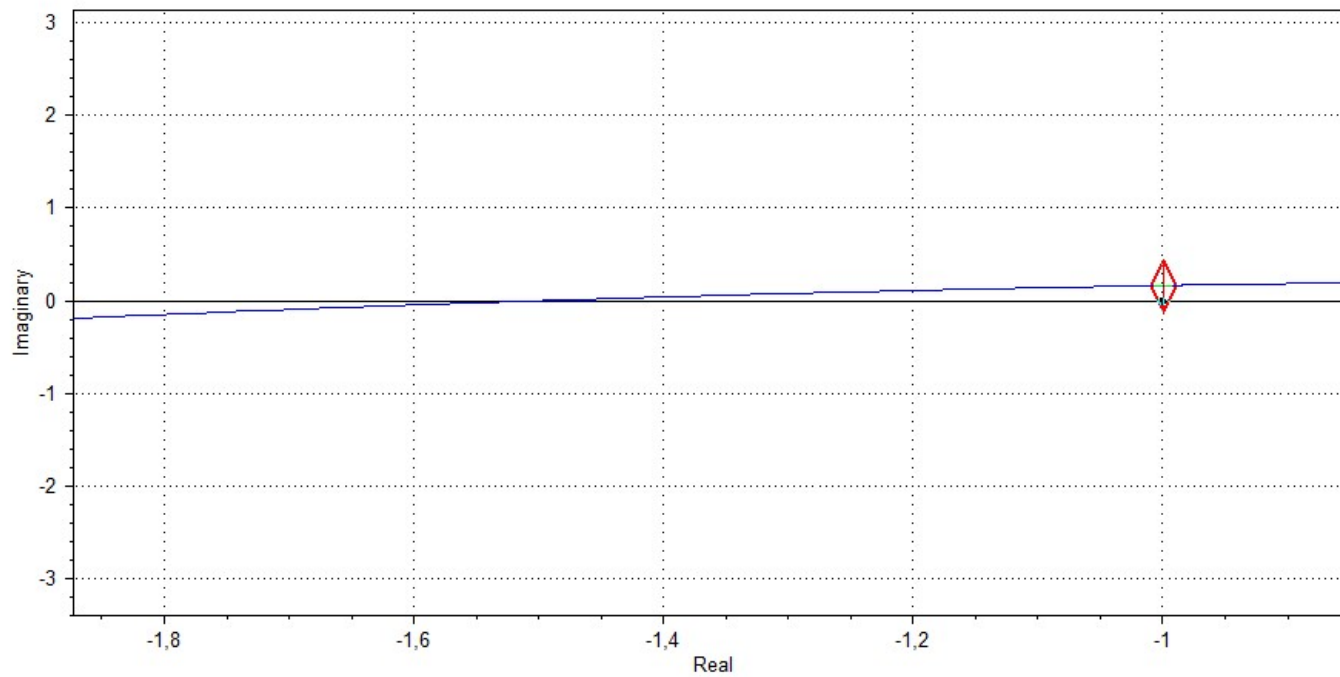
NYQUIST: MARGEN DE GANANCIA =  $-20\text{LOG}(1,5) =$   
 $=20\text{LOG}(1/1,5) = 20\text{LOG}(0,667) = -3,52 \text{ dB}$



Freq= 0,5745 r/s, Real = -1,515, Imag = -0,006536, Mag = 1,515 (3,608 dB), Phase = -179,8 deg

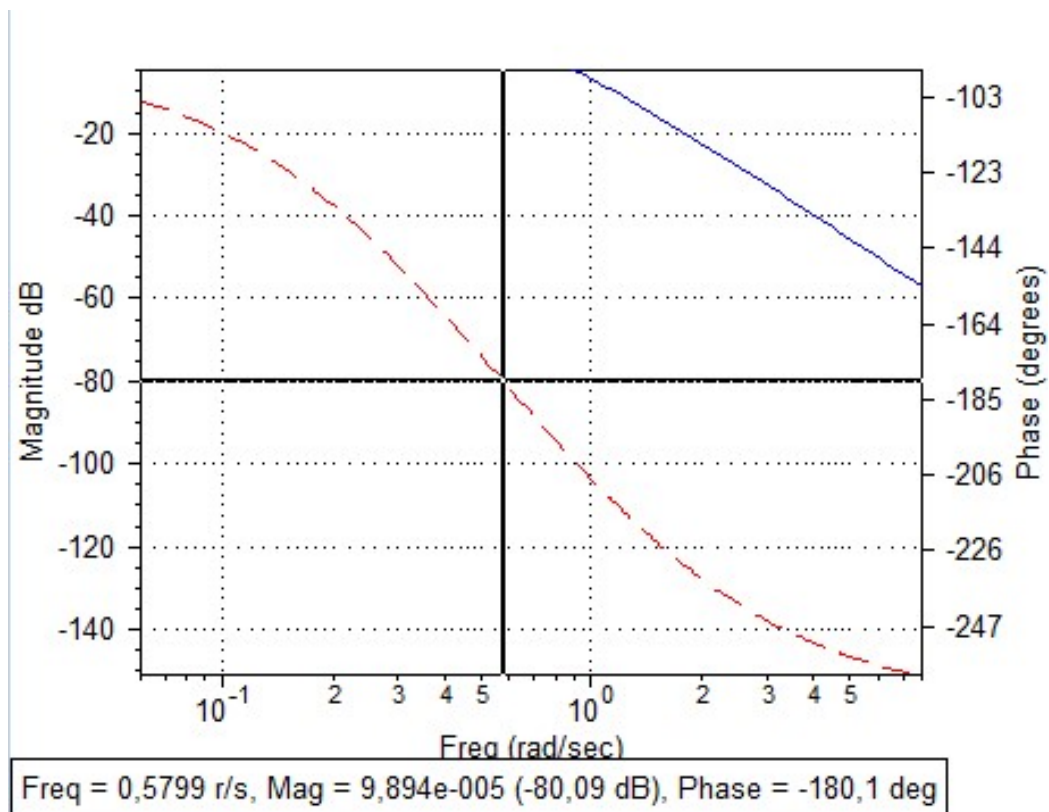


NYQUIST: MARGEN DE FASE =  $-189,4^\circ - (-180^\circ) = -9,4^\circ$

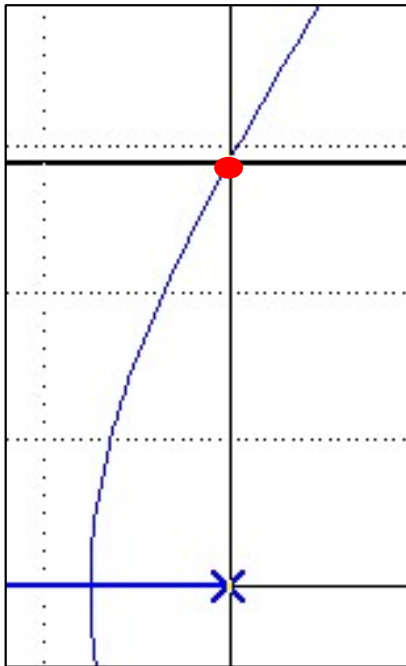


Freq= 0,6978 r/s, Real = -0,9995, Imag = 0,165, Mag = 1,013 (0,1124 dB), Phase = -189,4 deg

## BODE: DETERMINACIÓN DE WU (A 180° WU=0,579)



## LUGAR DE RAÍCES: DETERMINACIÓN DE KCU Y TU



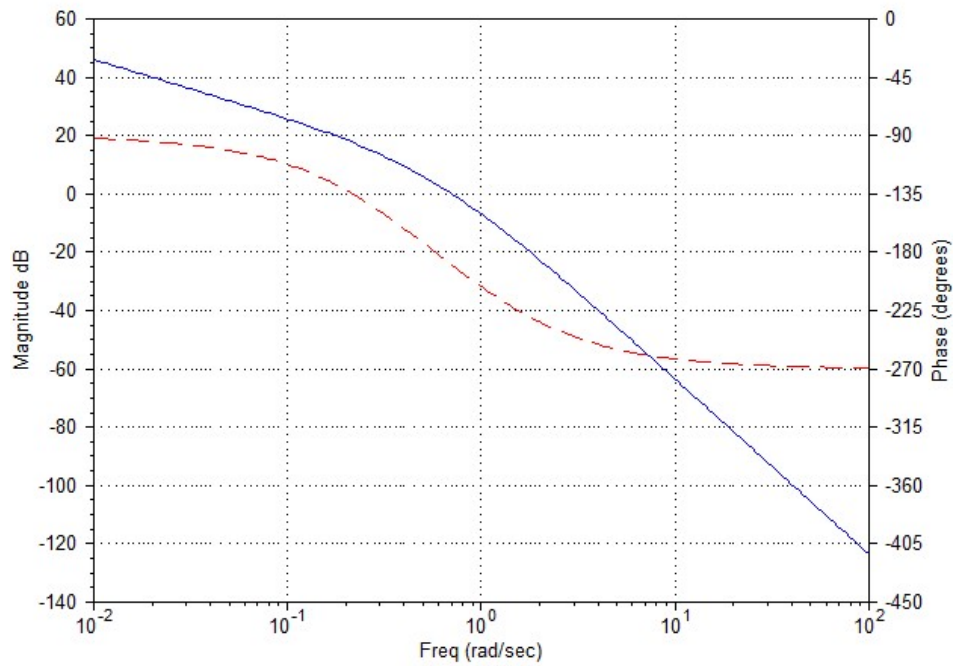
$s = 0,002504 + 0,5763j$  (Mag= 0,5763, Zeta= -0,004345)  
gain=  $0,6668 - 0,006794j$  (Mag= 0,6669, Phase= -0,5837 deg)

$$K_{cu} = 0,6668$$

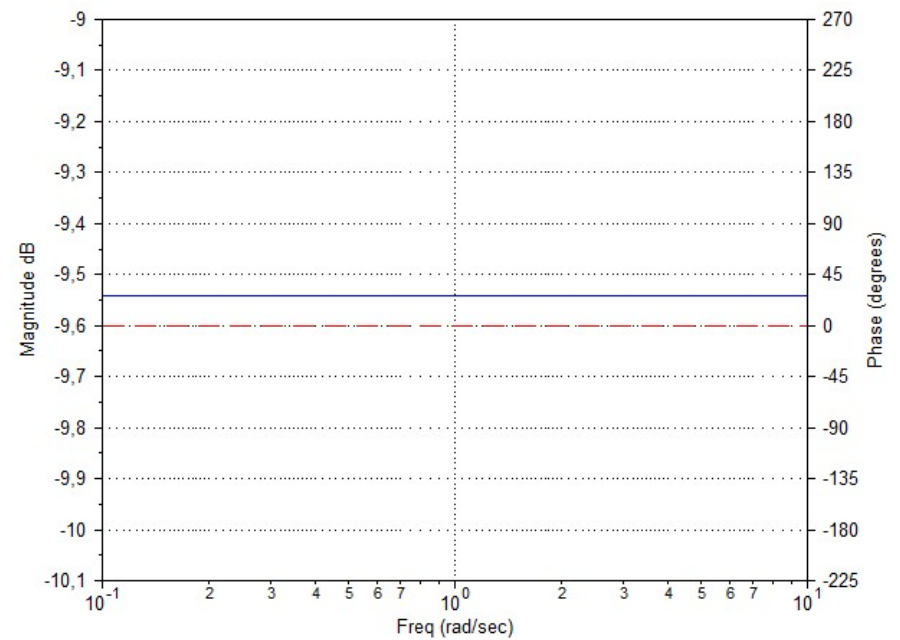
$$\omega_u = 0,5763 \frac{rad}{s}$$

$$T_u = 10,908s$$

# PARA UN CONTROLADOR SÓLO P: BODE

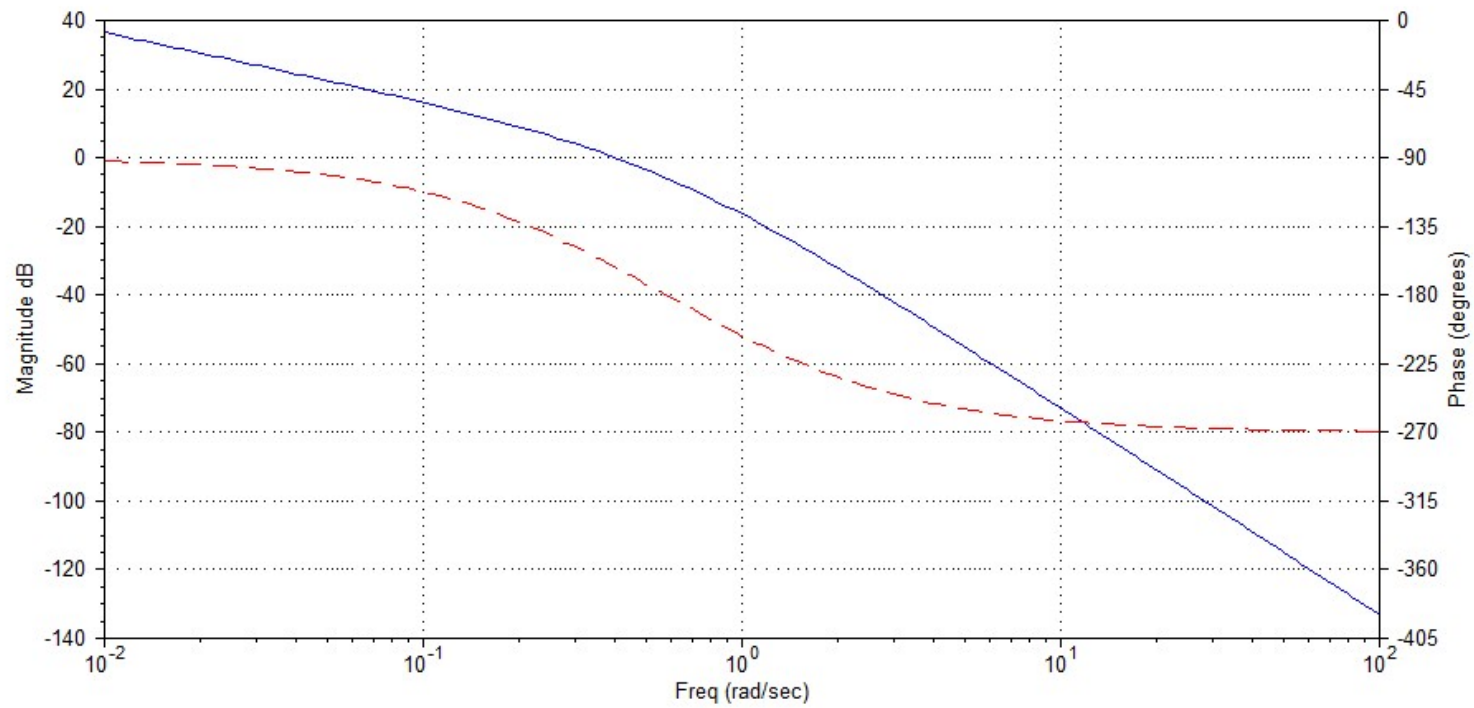


**Go**



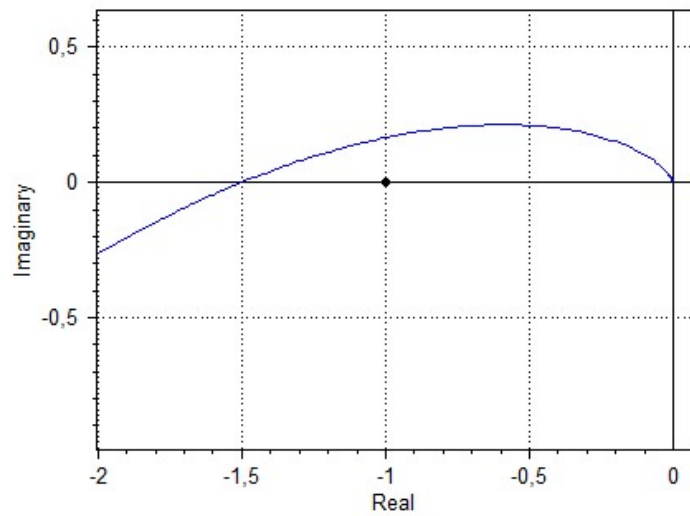
**Gc**

# PARA UN CONTROLADOR SÓLO P: BODE

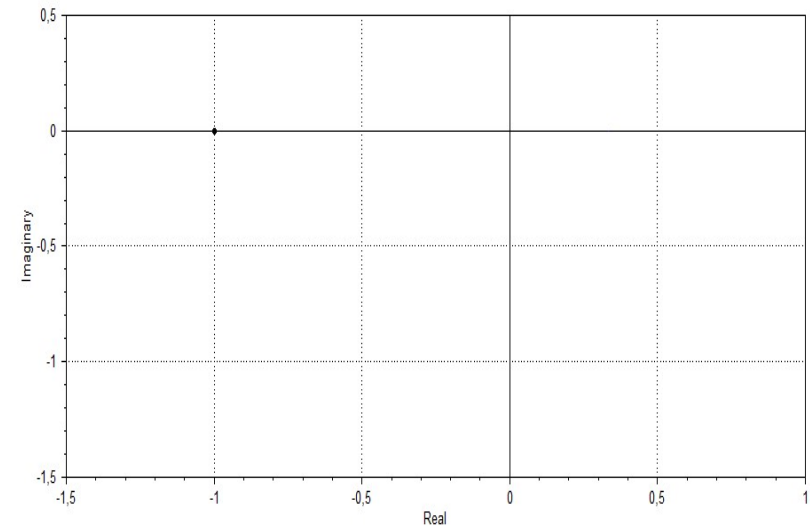


**Go\*Gc**

# PARA UN CONTROLADOR SÓLO P: NYQUIST

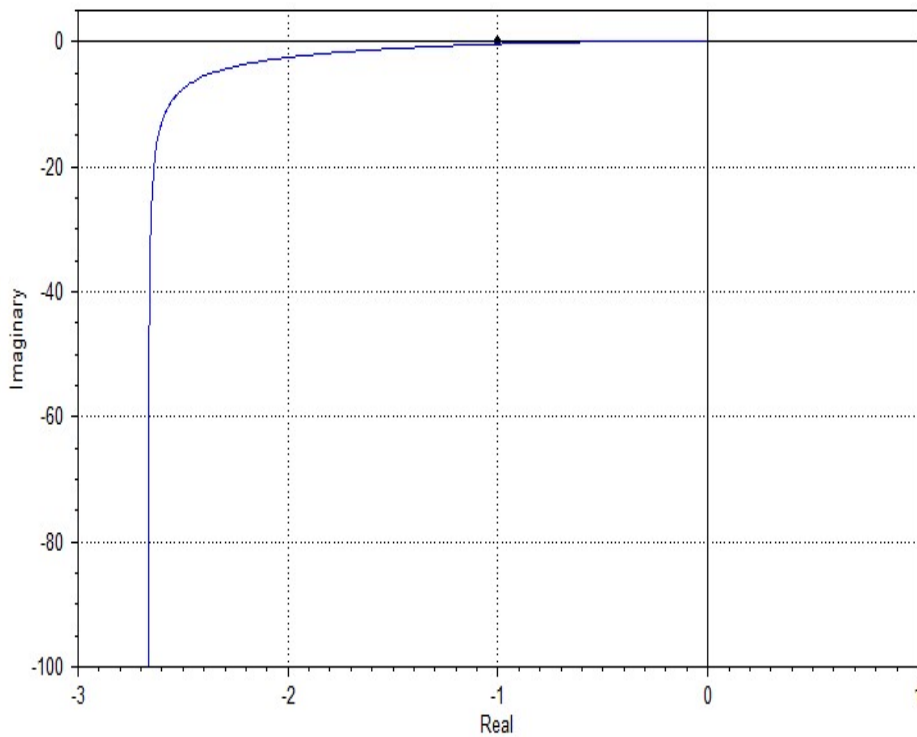


**Go**

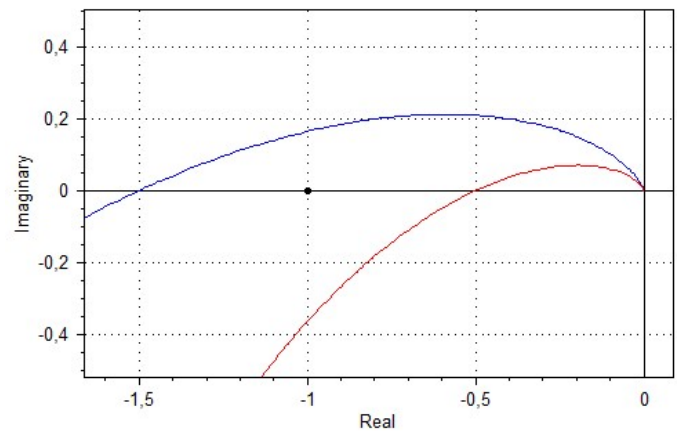
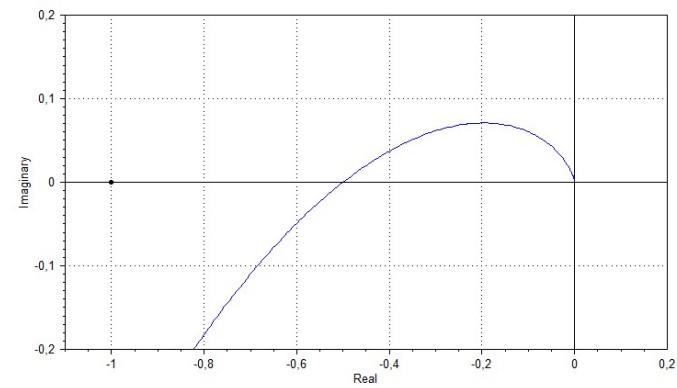


**Gc**

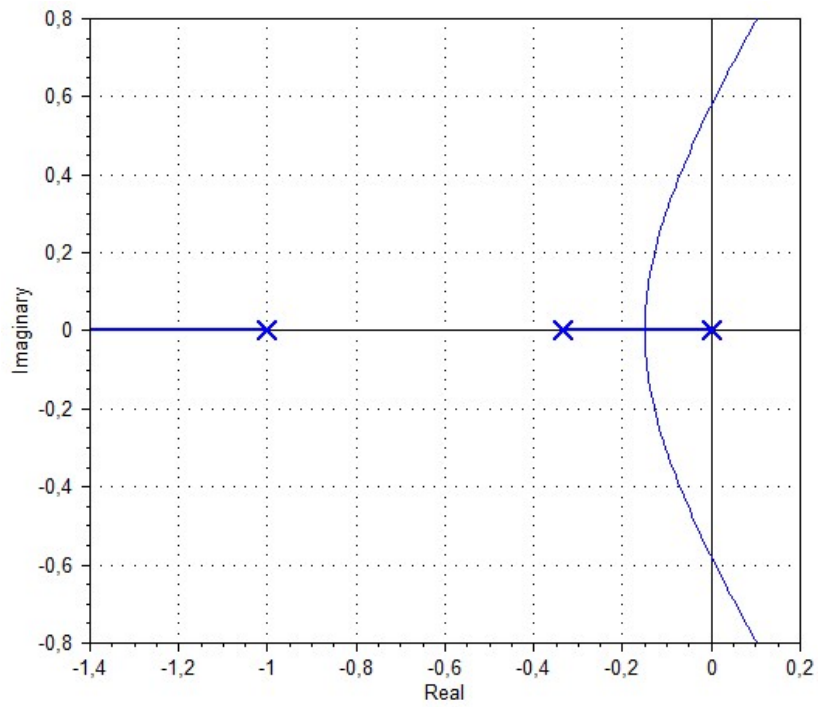
# PARA UN CONTROLADOR SÓLO P (CON AJUSTE ÓPTIMO): NYQUIST



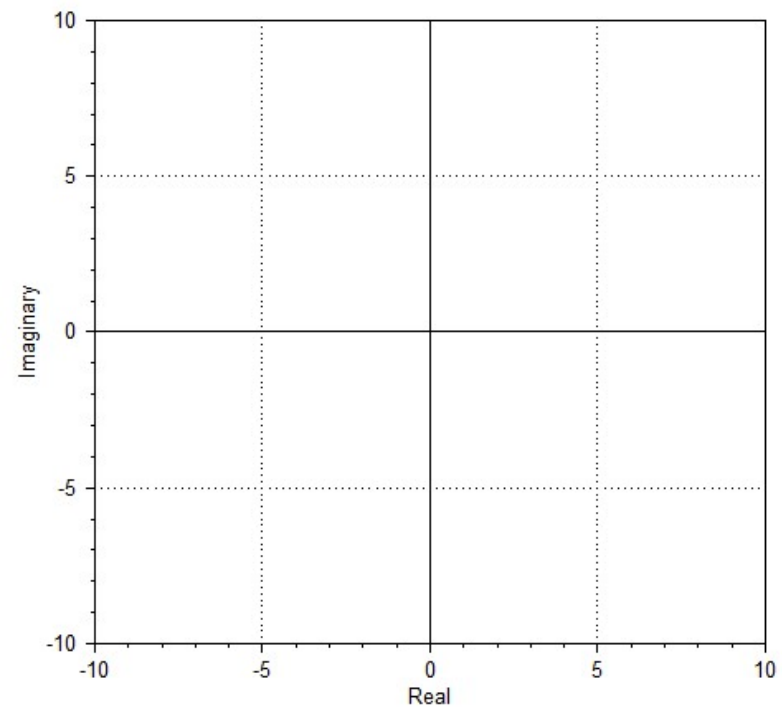
$G_o^*G_c$



# PARA UN CONTROLADOR SÓLO P: LUGAR DE RAÍCES



Go

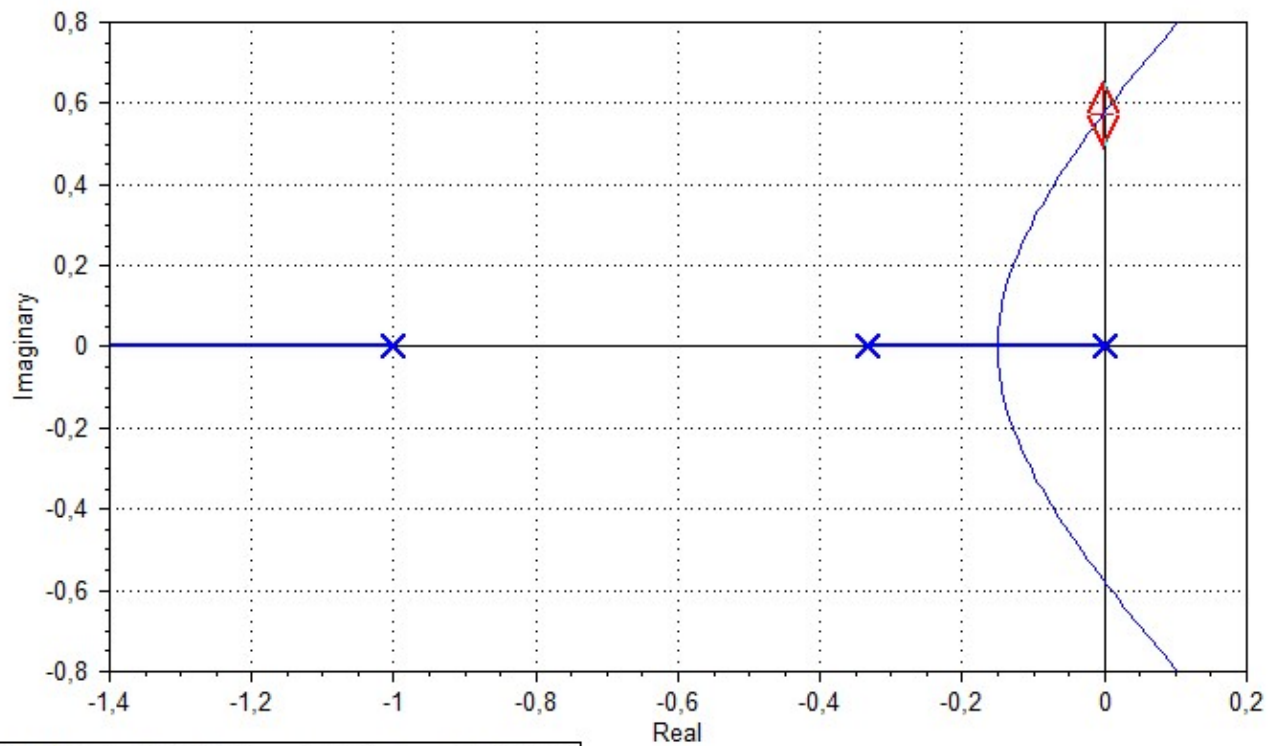


Gc



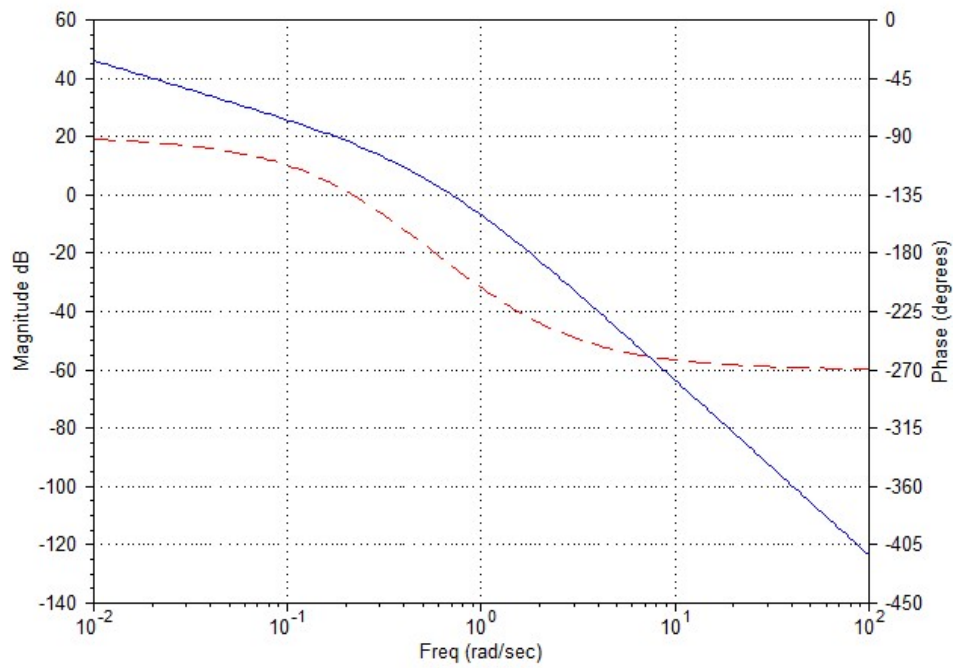
# PARA UN CONTROLADOR SÓLO P: LUGAR DE RAÍCES

$G_o * G_c$

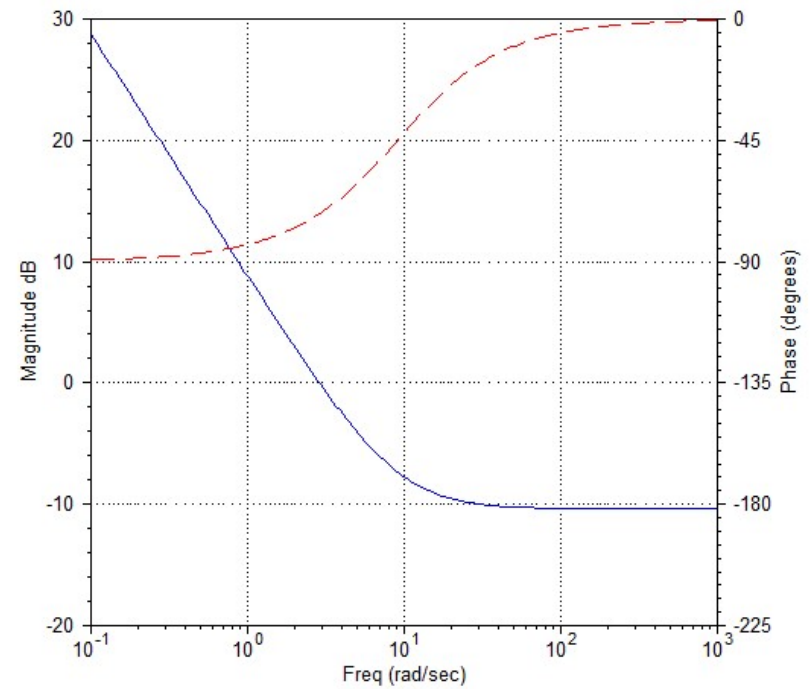


$s = -0,0009859 + 0,5751j$  (Mag= 0,5751, Zeta= 0,001714)  
gain= 1,981 + 0j (Mag= 1,981, Phase= 0 deg)

# PARA UN CONTROLADOR P+I : BODE



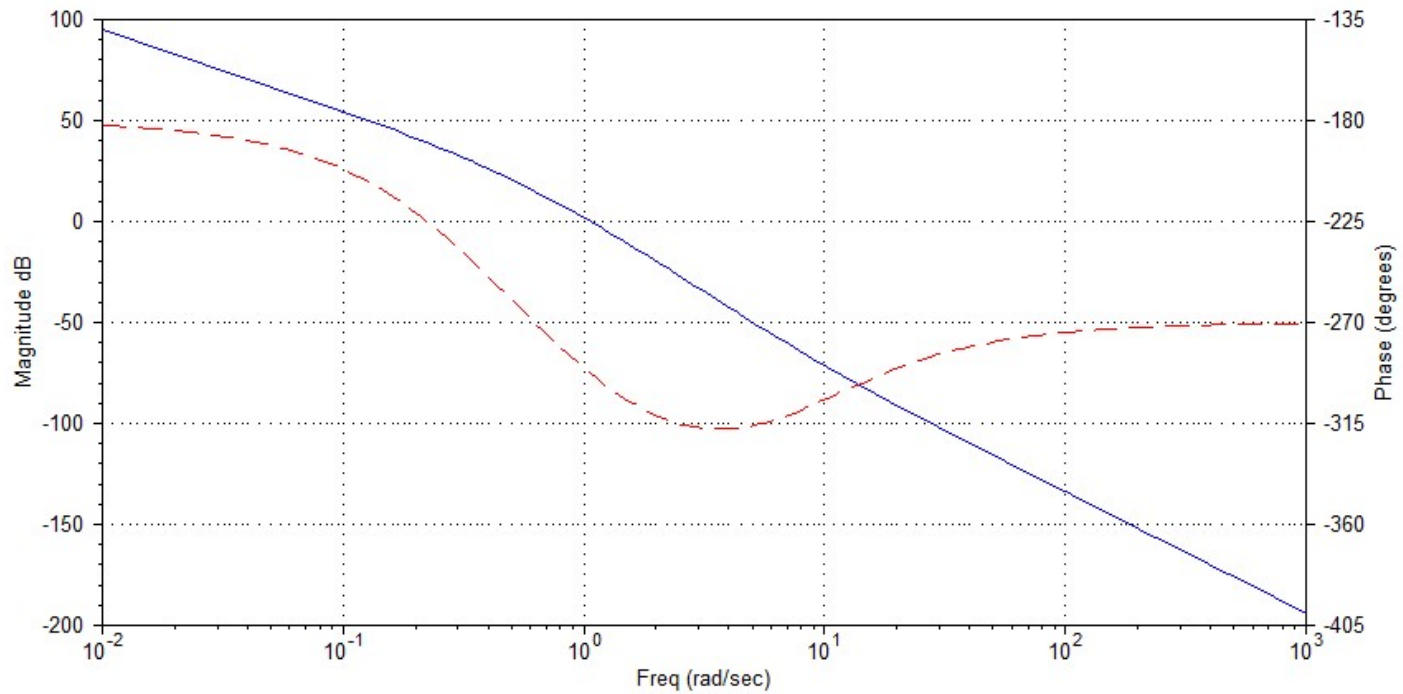
**Go**



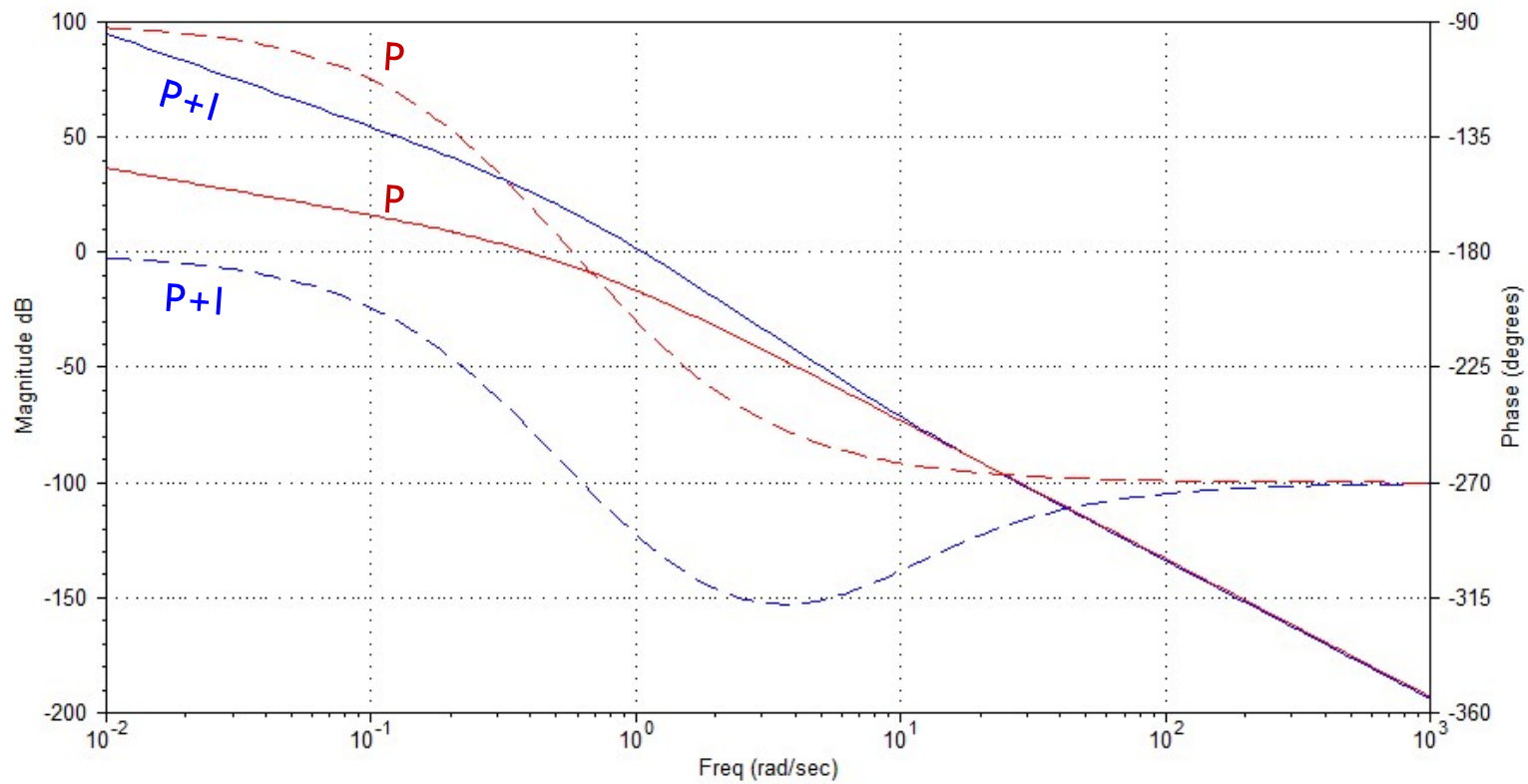
**Gc**

# PARA UN CONTROLADOR P+I : BODE

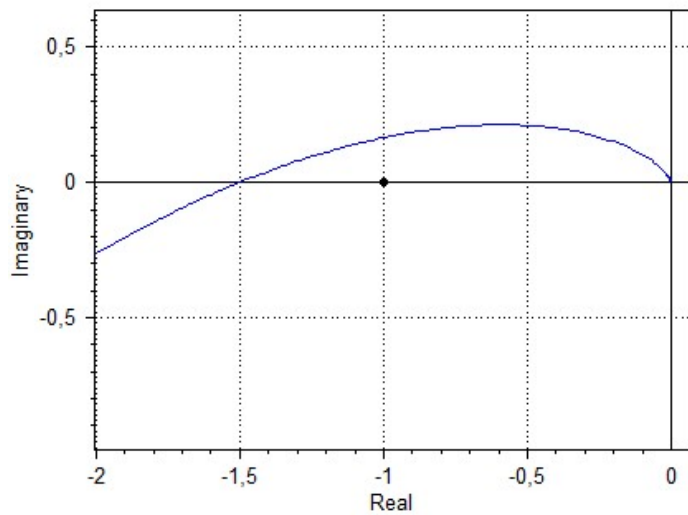
$G_o * G_c$



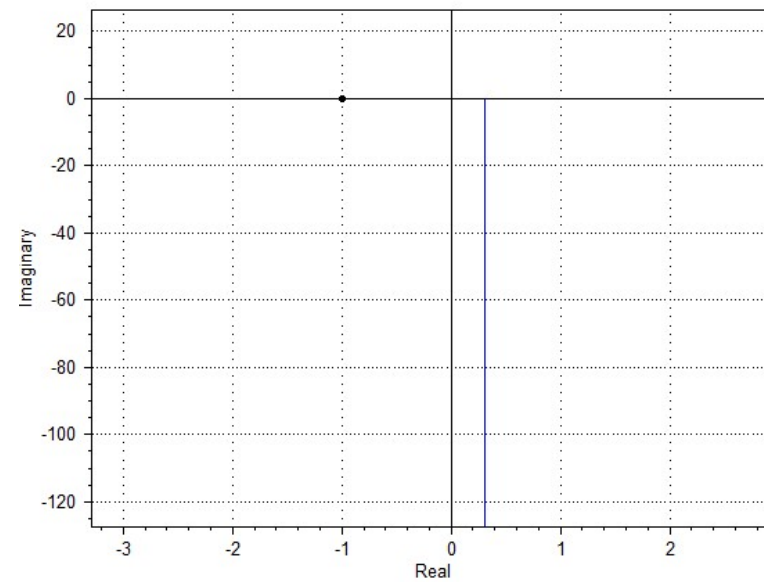
# PARA UN CONTROLADOR P+I : BODE (SUPERPUESTO CON P)



## PARA UN CONTROLADOR P+I : NYQUIST

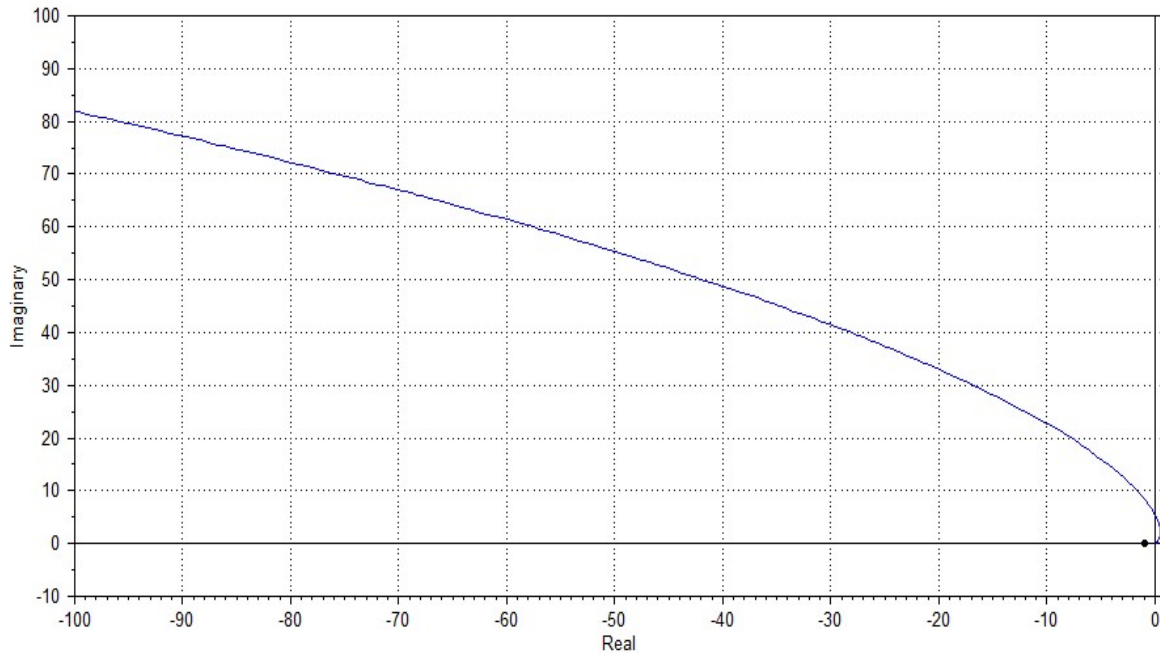


**Go**

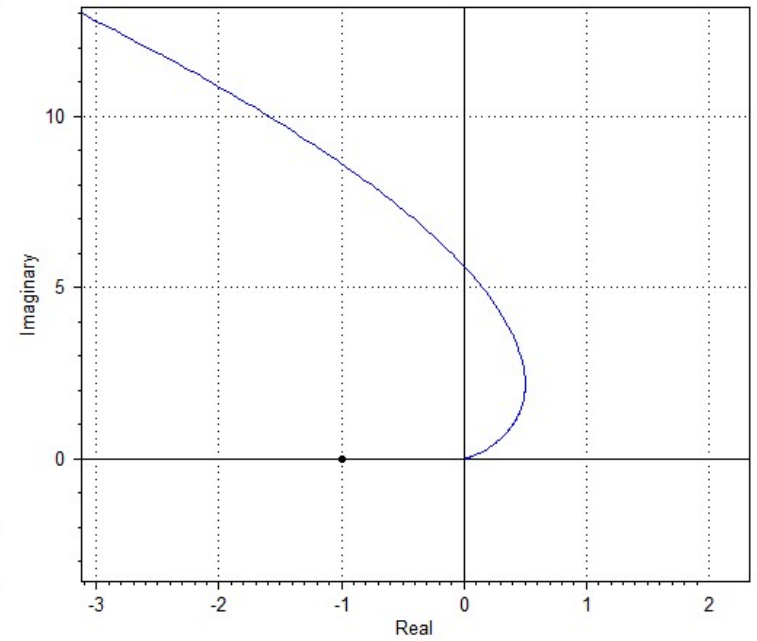


**Gc**

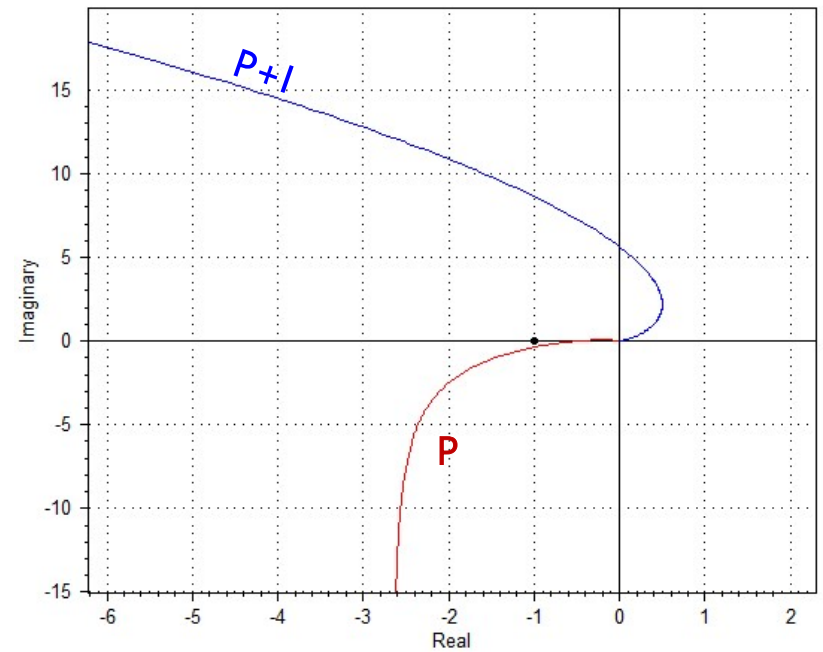
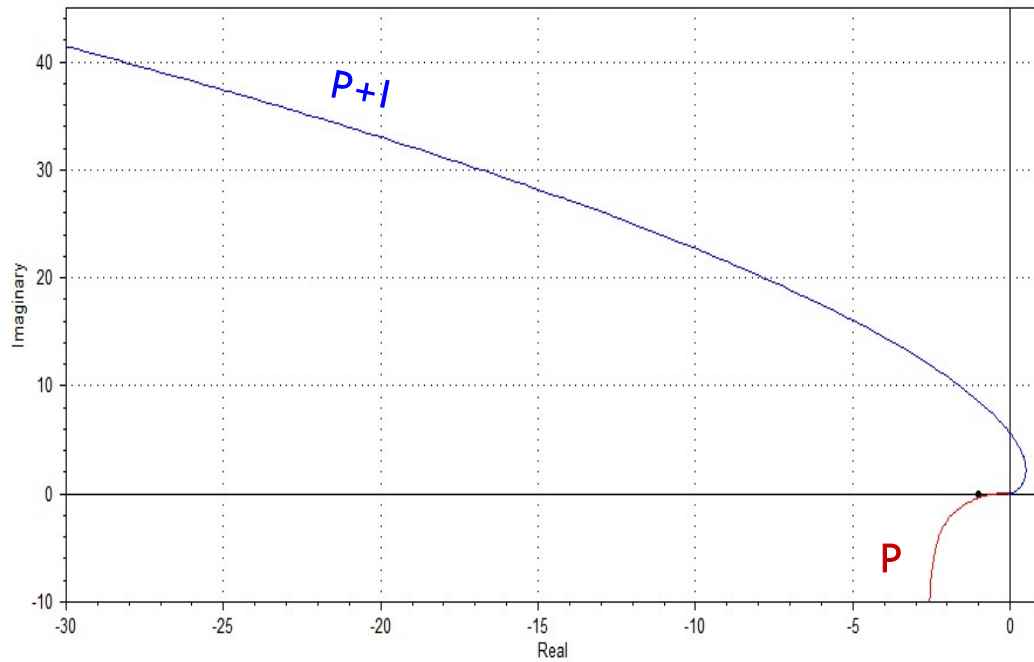
# PARA UN CONTROLADOR P+I : NYQUIST



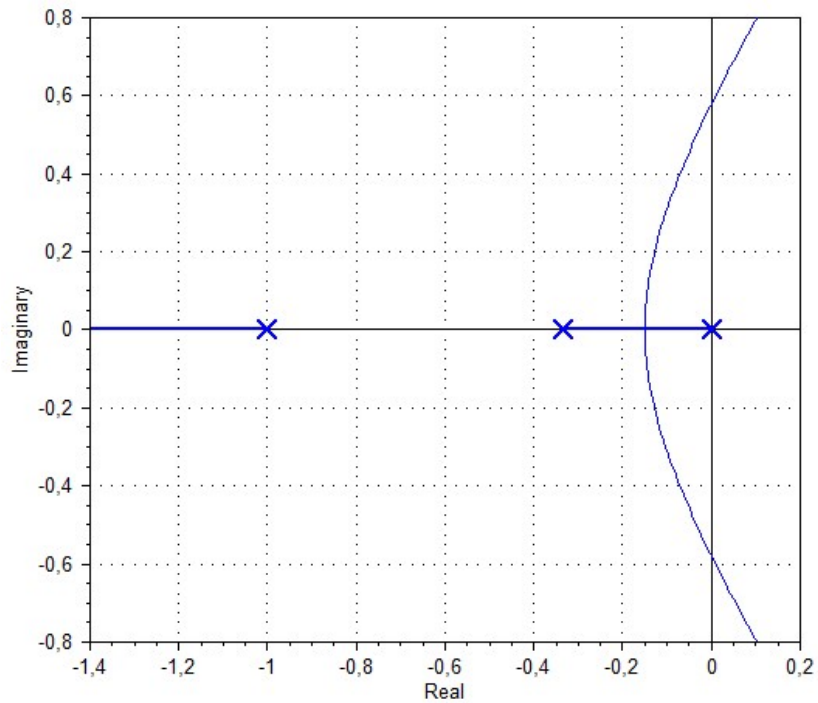
$G_o * G_c$



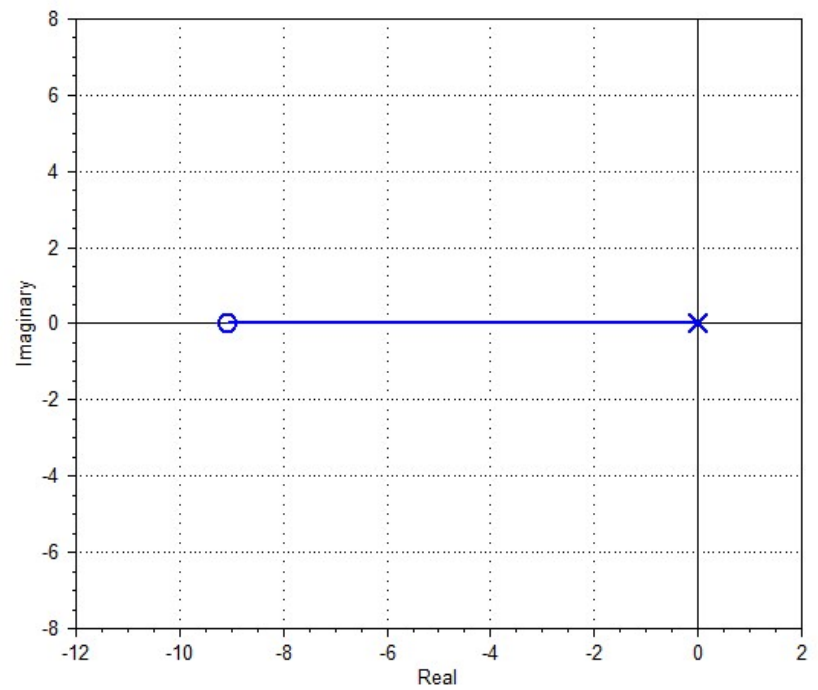
# PARA UN CONTROLADOR P+I : NYQUIST ( SUPERPUESTO CON P )



# PARA UN CONTROLADOR P+I: LUGAR DE RAÍCES



Go

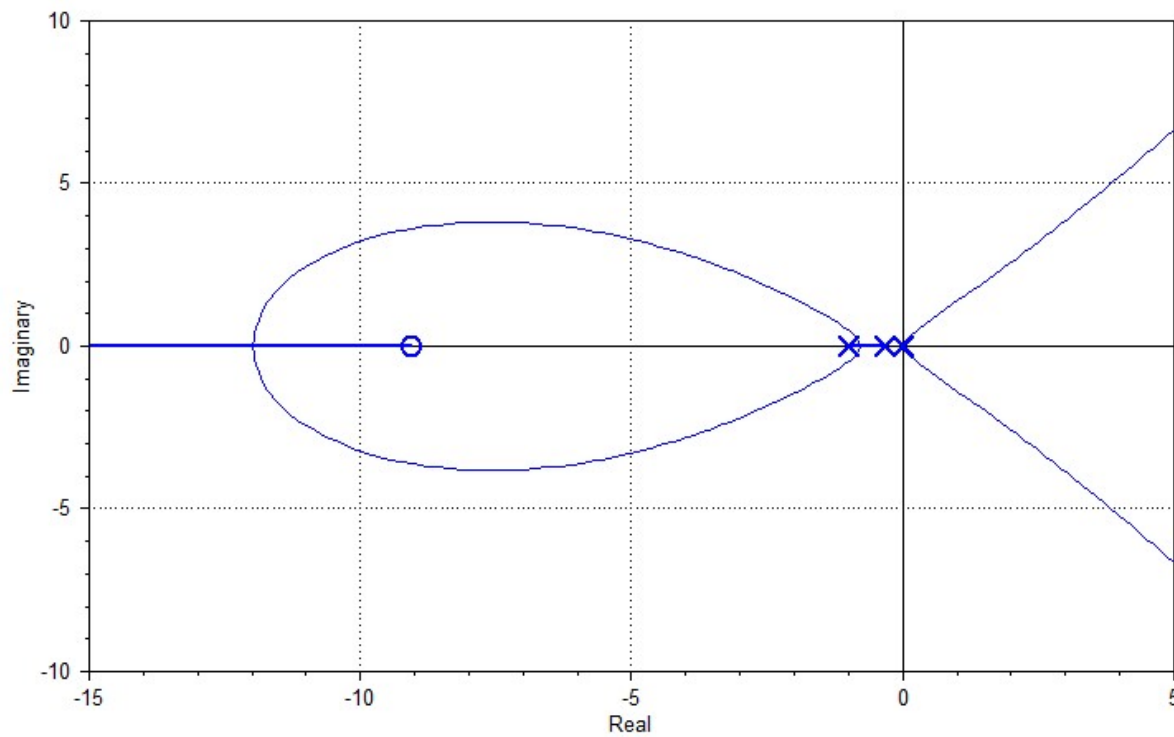


Gc

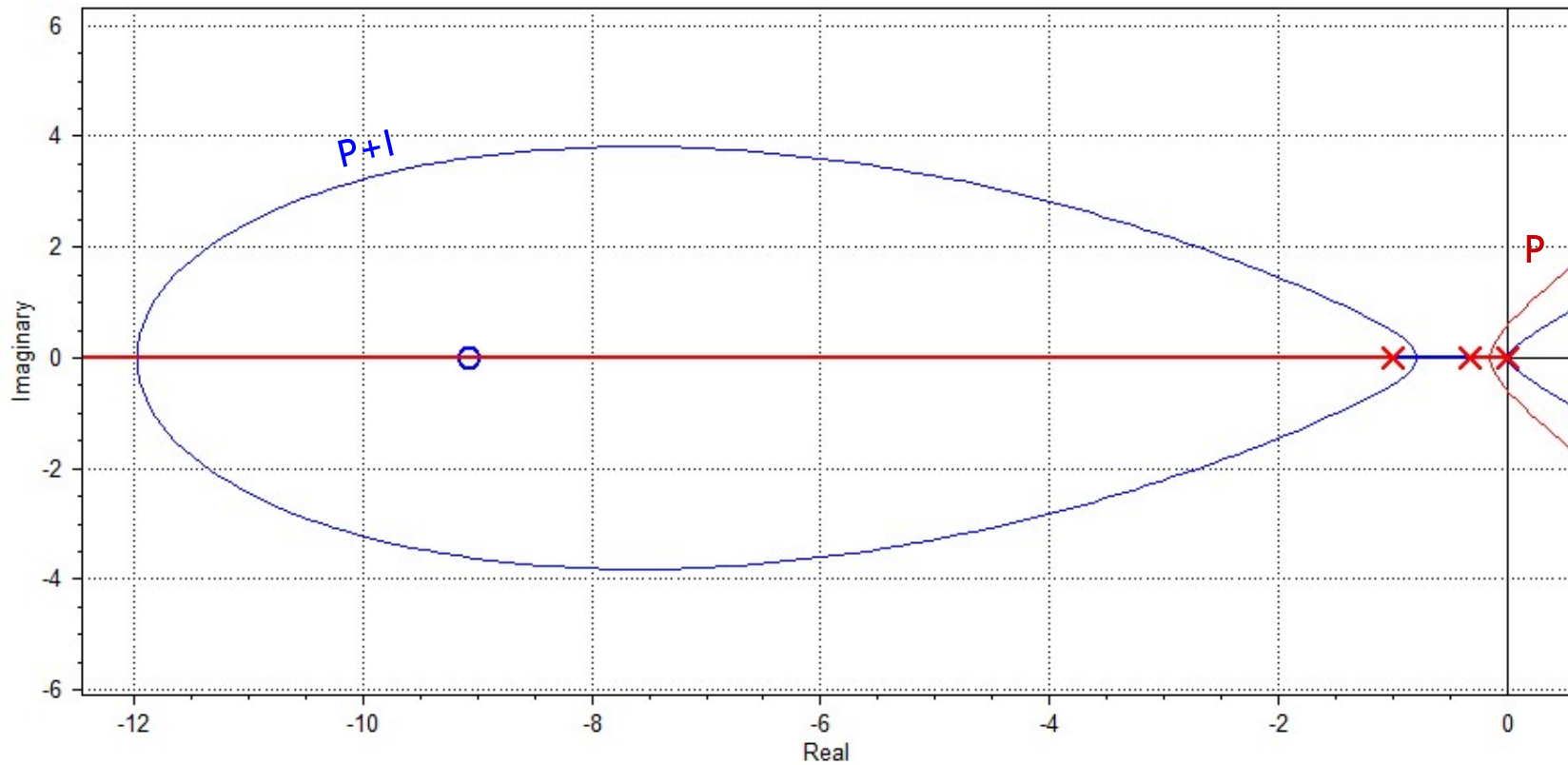


## PARA UN CONTROLADOR P+I: LUGAR DE RAÍCES

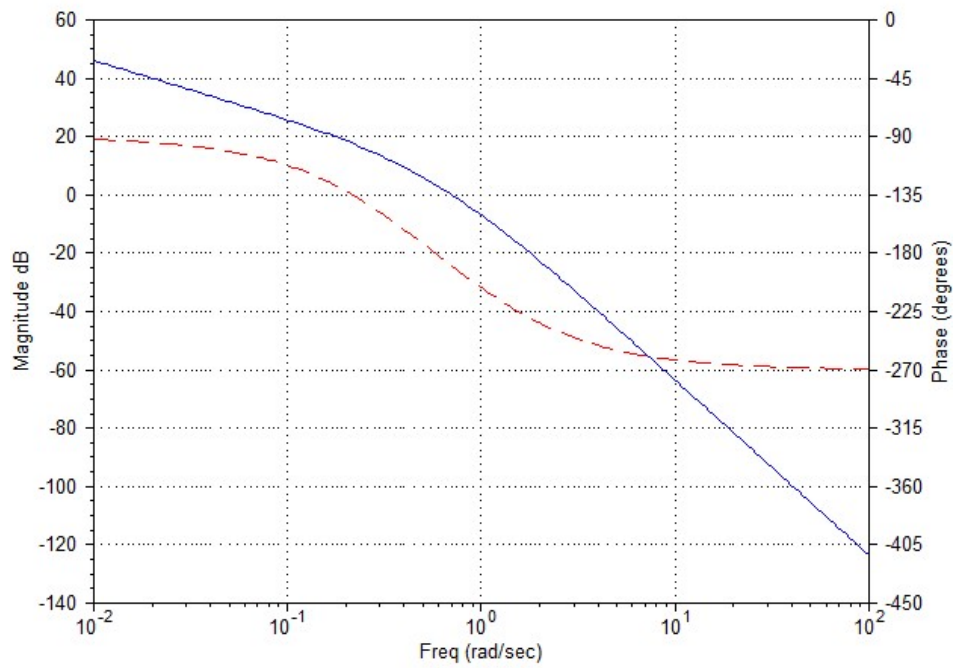
$G_o * G_c$



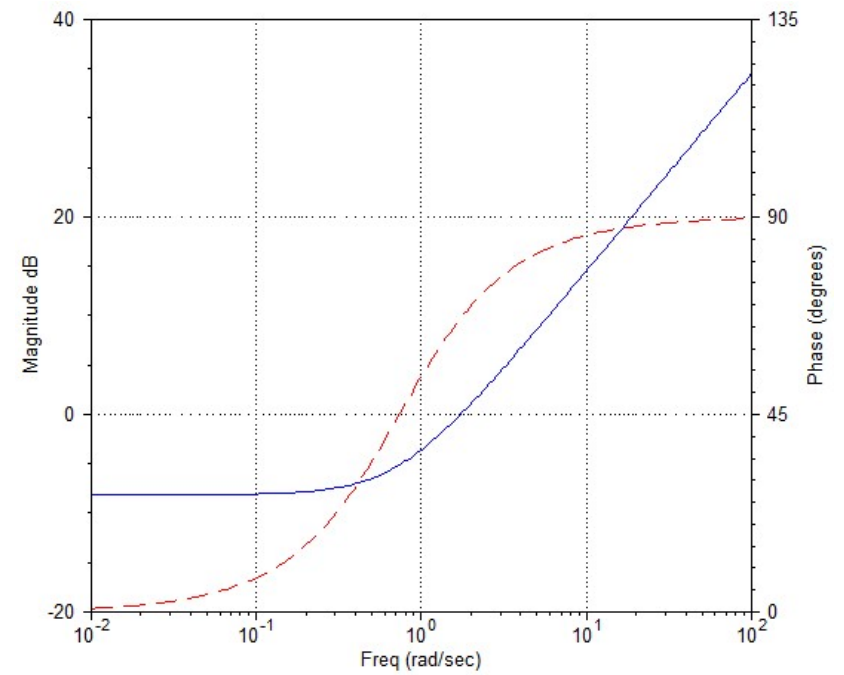
# PARA UN CONTROLADOR P+I: LUGAR DE RAÍCES (SUPERPUESTO CON P)



# PARA UN CONTROLADOR P+D : BODE

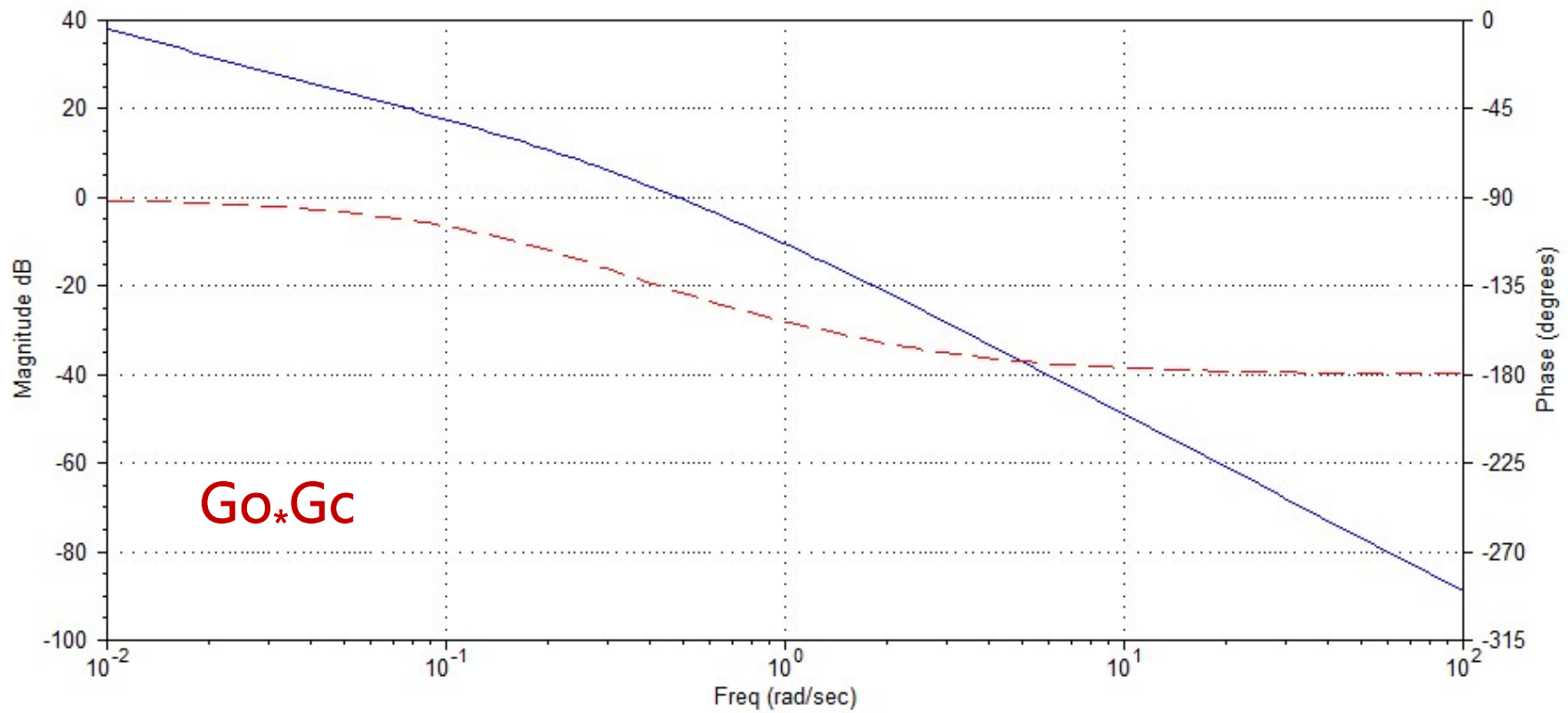


Go

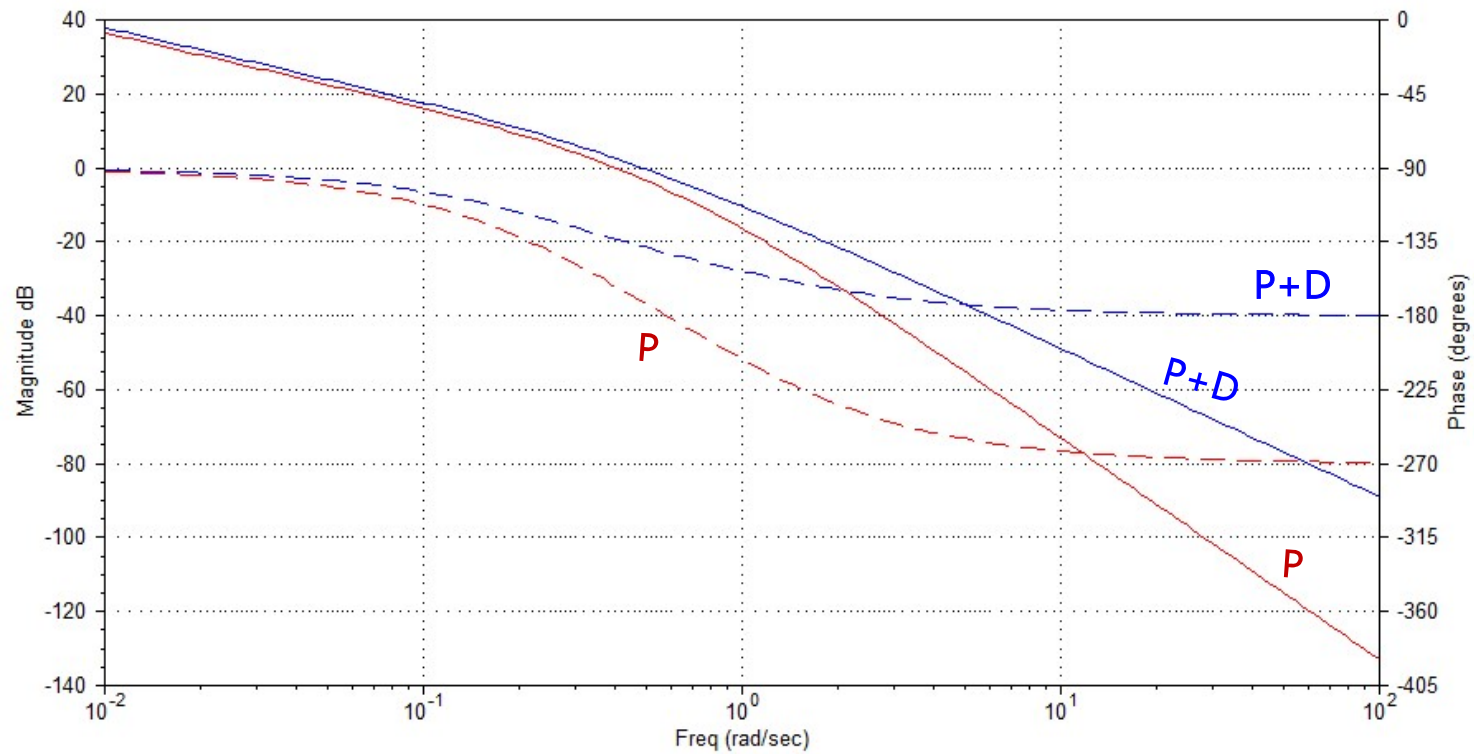


Gc

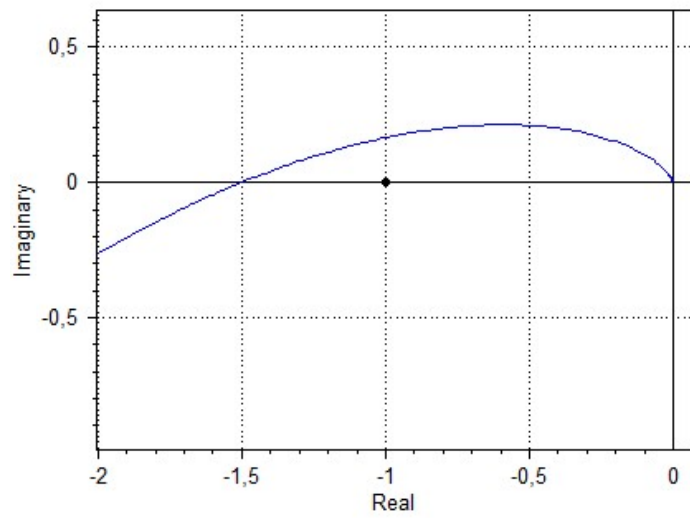
## PARA UN CONTROLADOR P+D : BODE



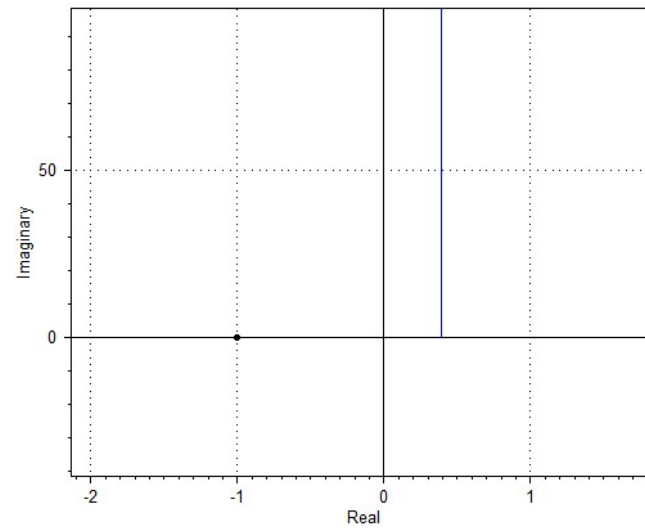
# PARA UN CONTROLADOR P+D : BODE (SUPERPUESTO CON P)



# PARA UN CONTROLADOR P+D : NYQUIST

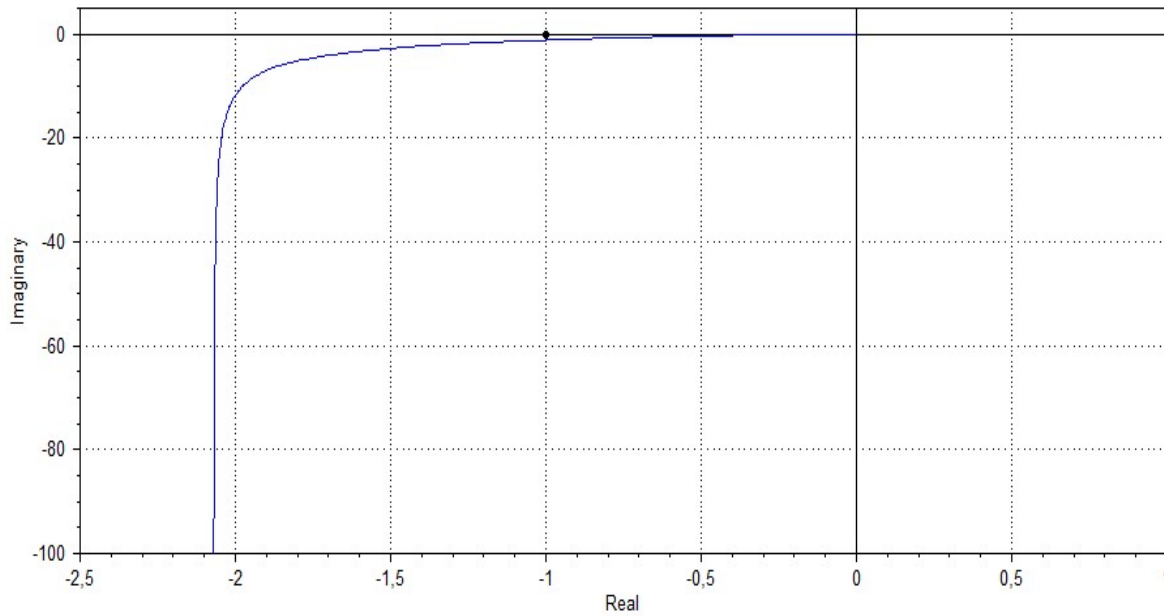


**Go**

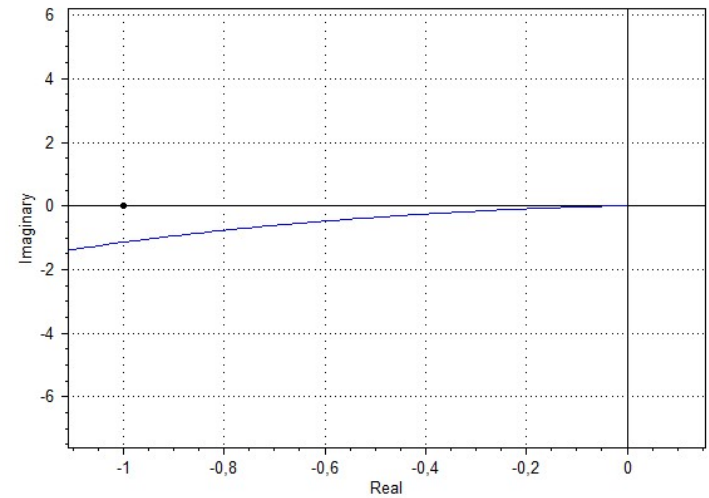


**Gc**

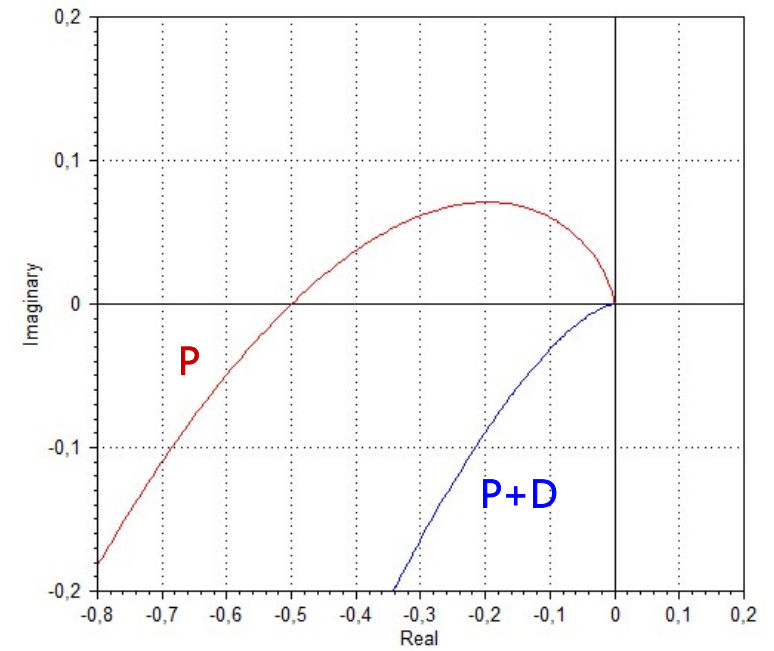
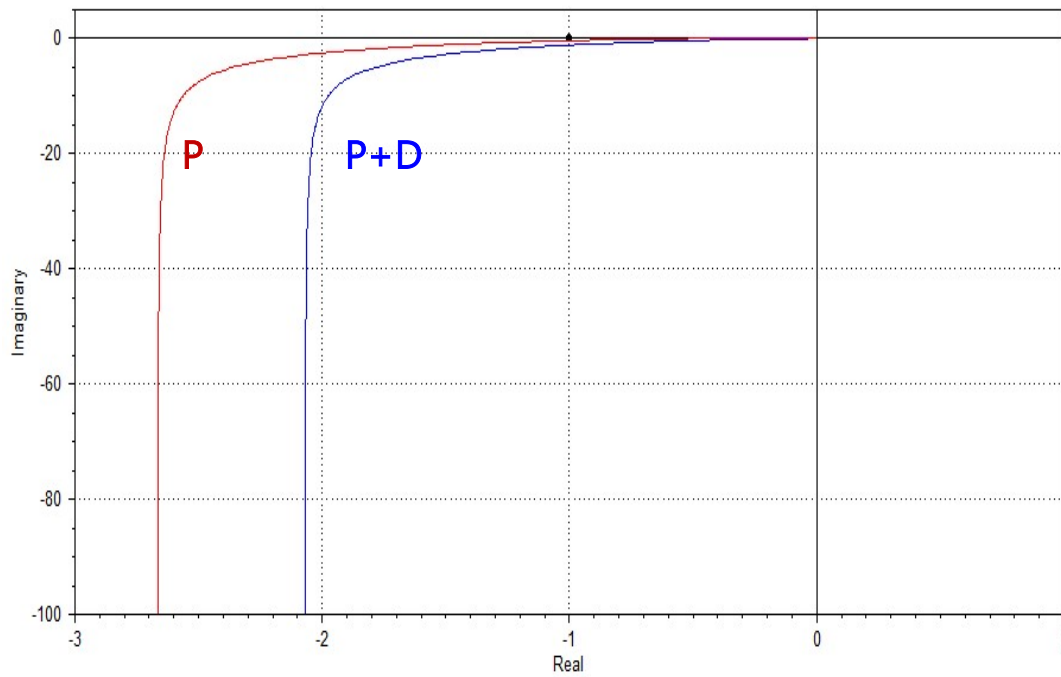
# PARA UN CONTROLADOR P+D : NYQUIST



$G_o * G_c$

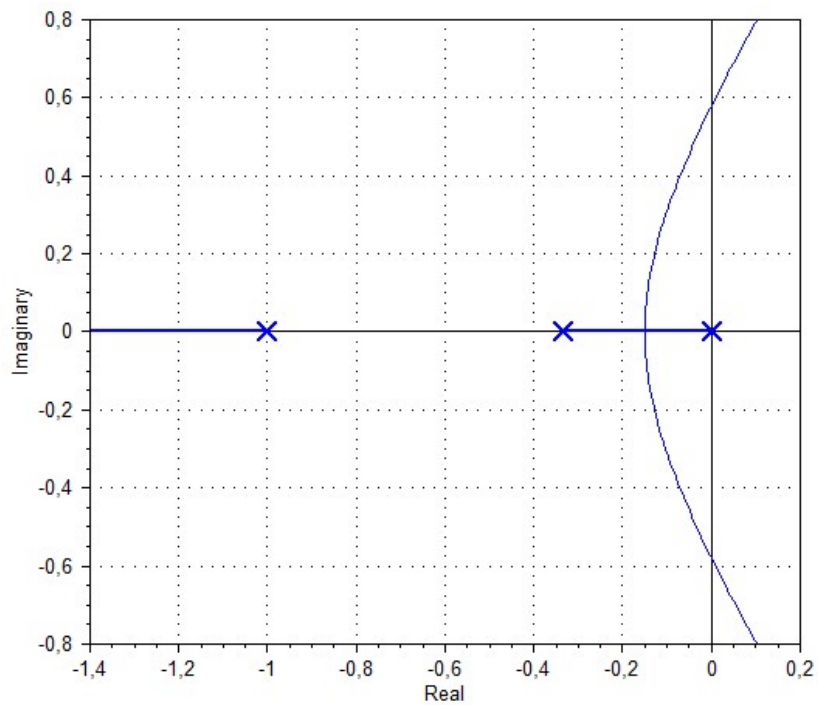


# PARA UN CONTROLADOR P+D : NYQUIST ( SUPERPUESTO CON P)

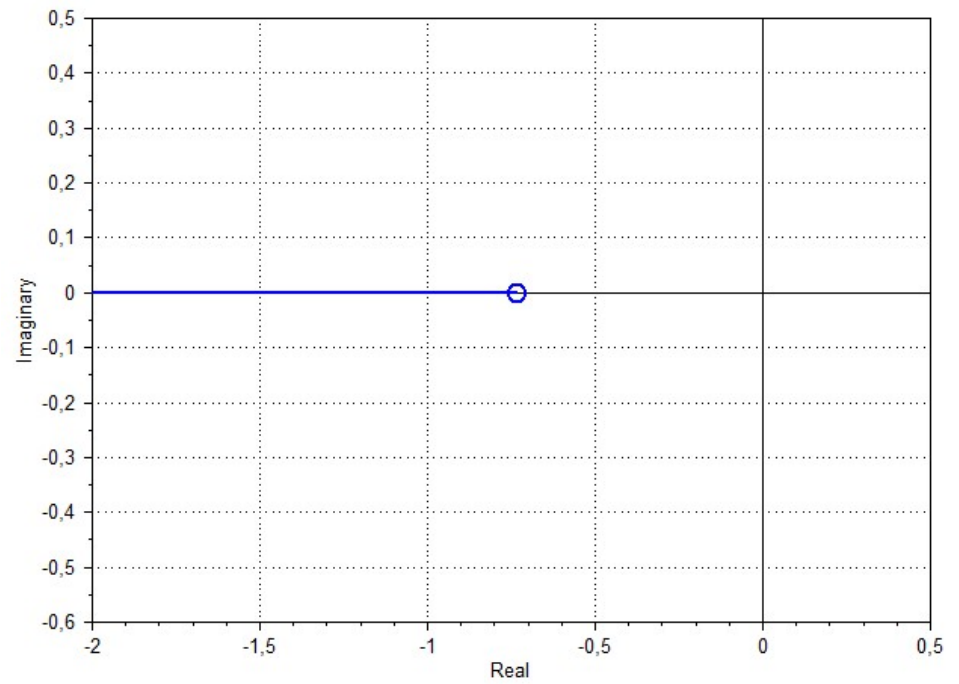




# PARA UN CONTROLADOR P+D: LUGAR DE RAÍCES



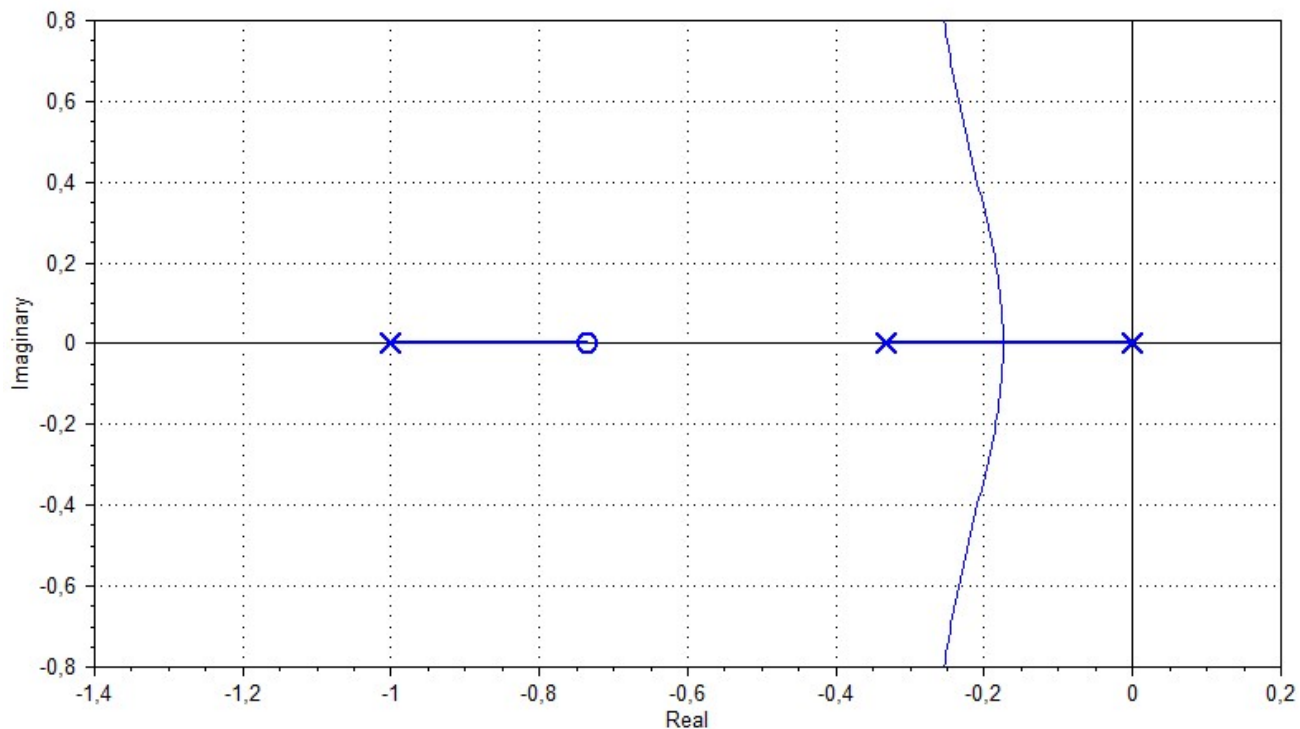
Go



Gc

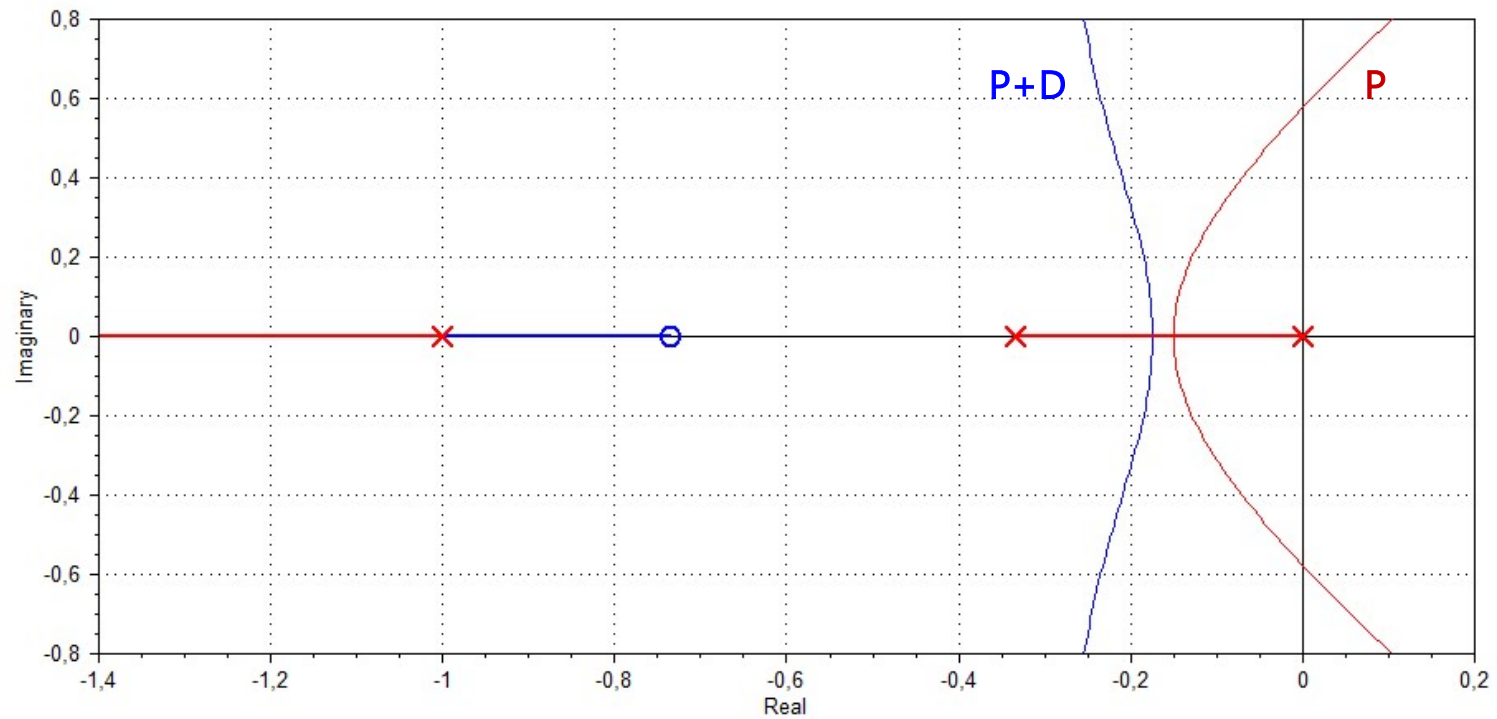
## PARA UN CONTROLADOR P+D: LUGAR DE RAÍCES

$G_o * G_c$

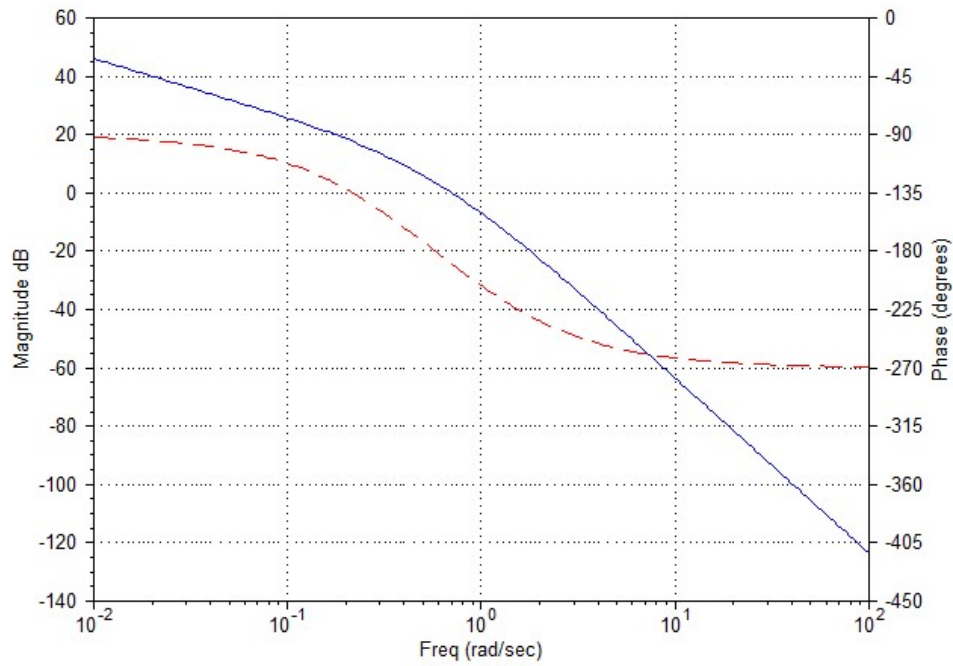


Podemos observar que gracias al cero introducido por acción derivativa, el sistema se comporta como uno de segundo orden

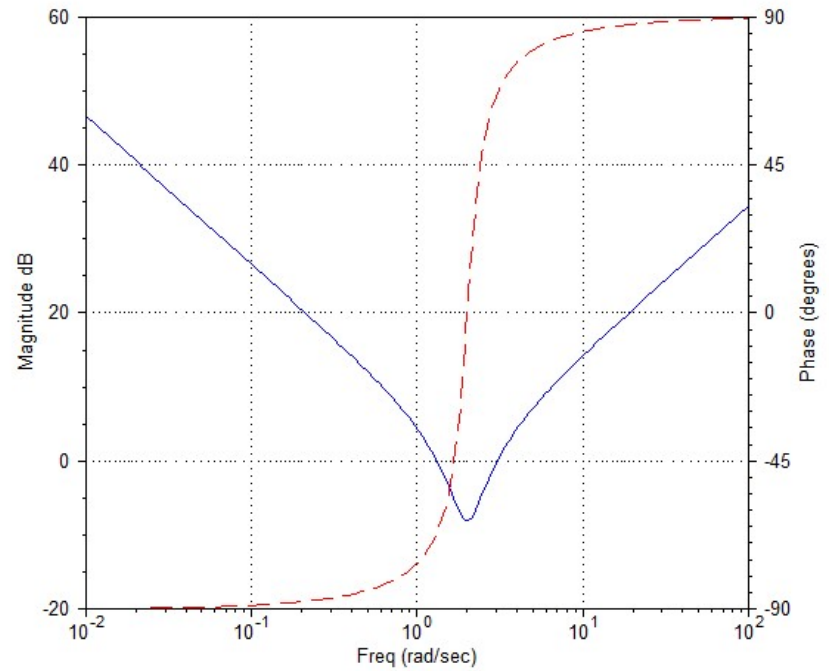
# PARA UN CONTROLADOR P+D: LUGAR DE RAÍCES (SUPERPUESTO CON P)



# PARA UN CONTROLADOR P+I+D : BODE



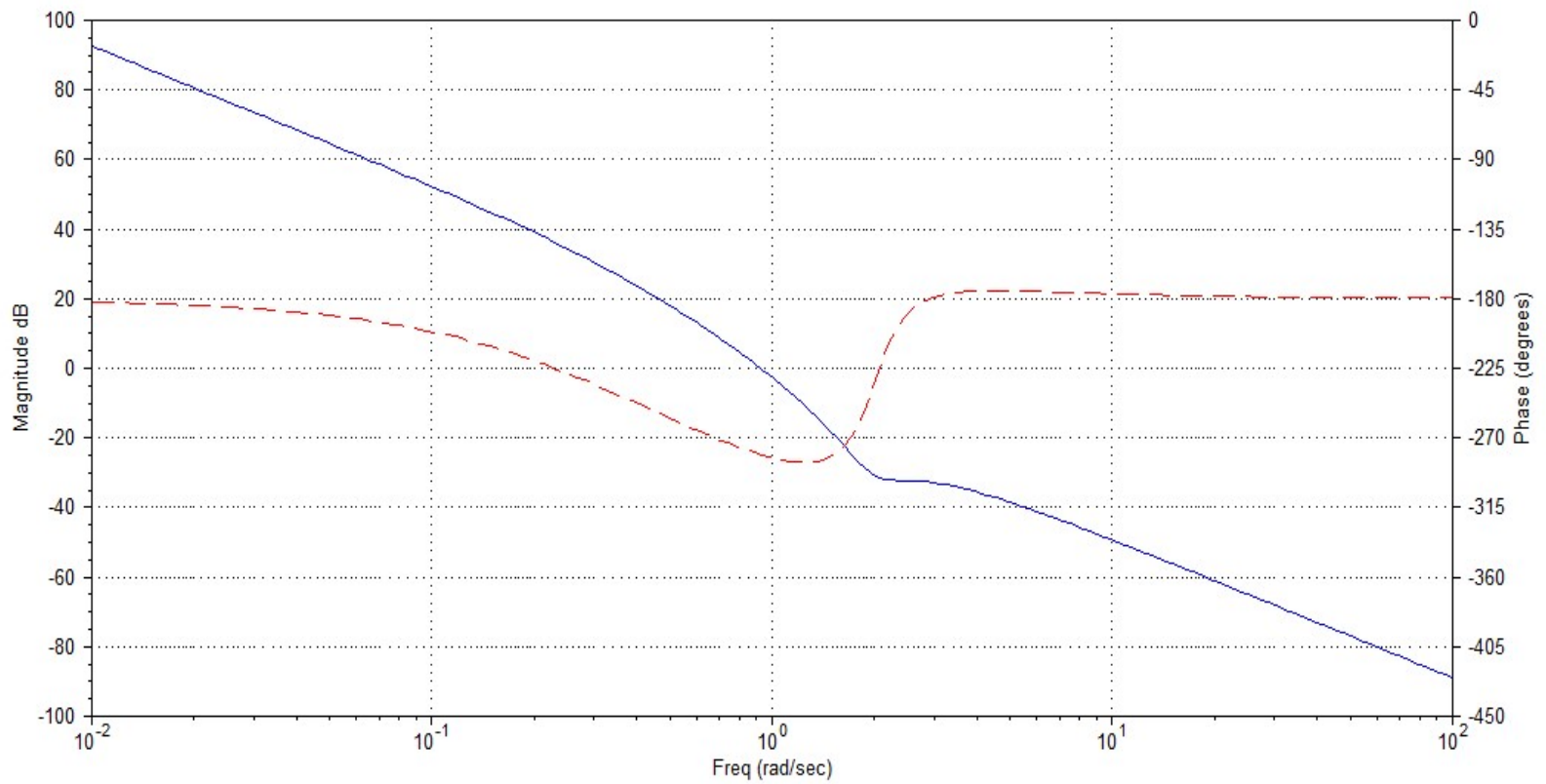
**Go**



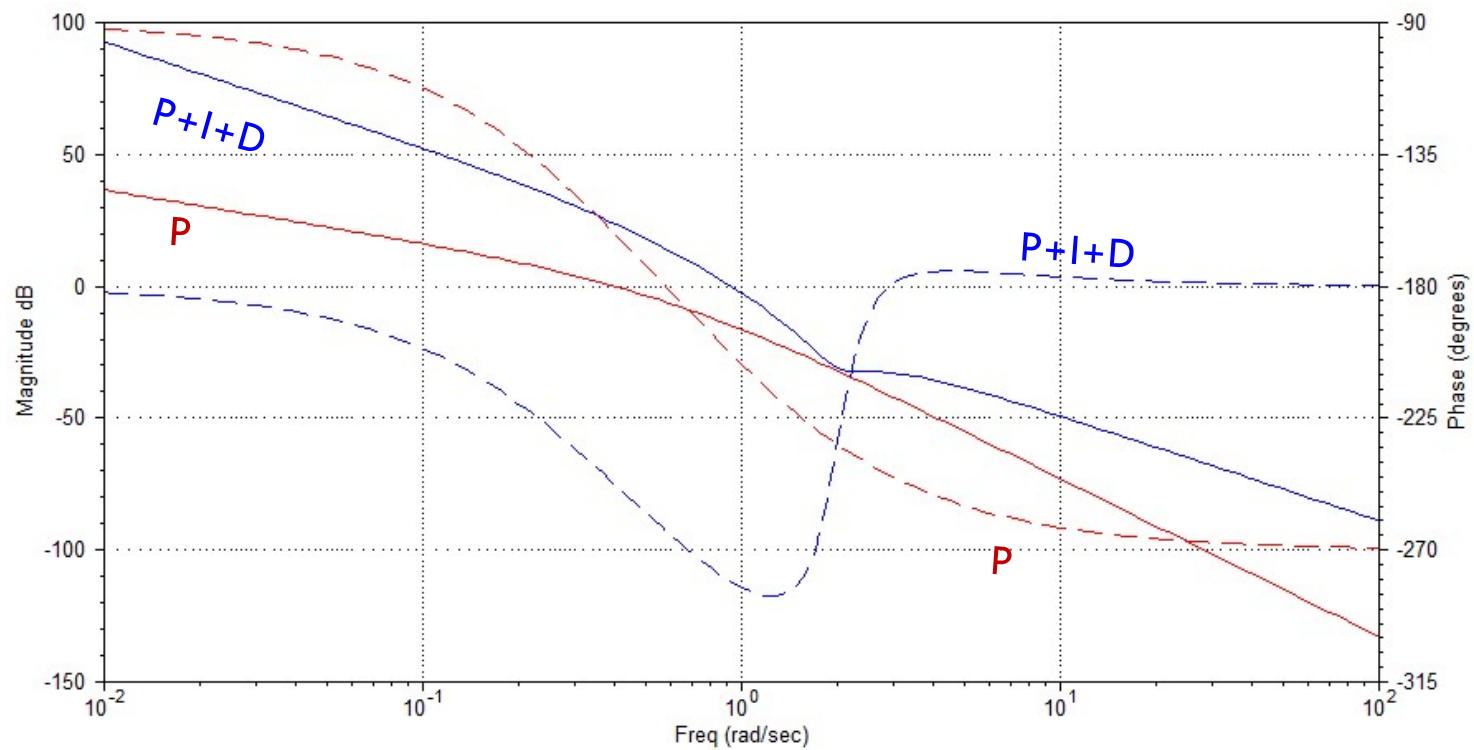
**Gc**

# PARA UN CONTROLADOR P+I+D : BODE

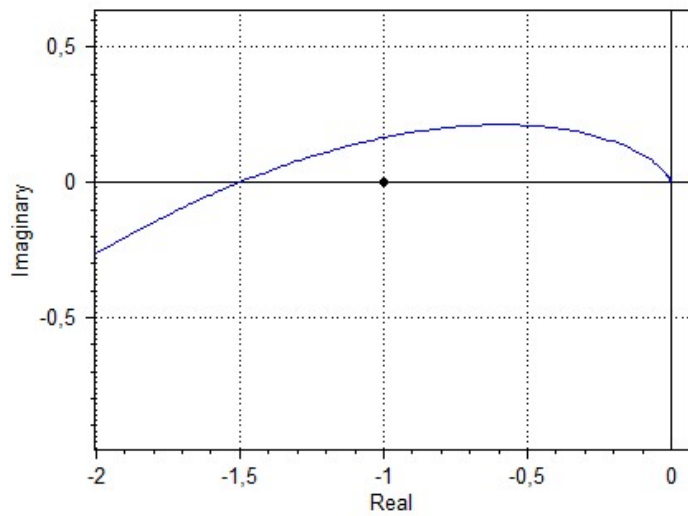
$G_o * G_c$



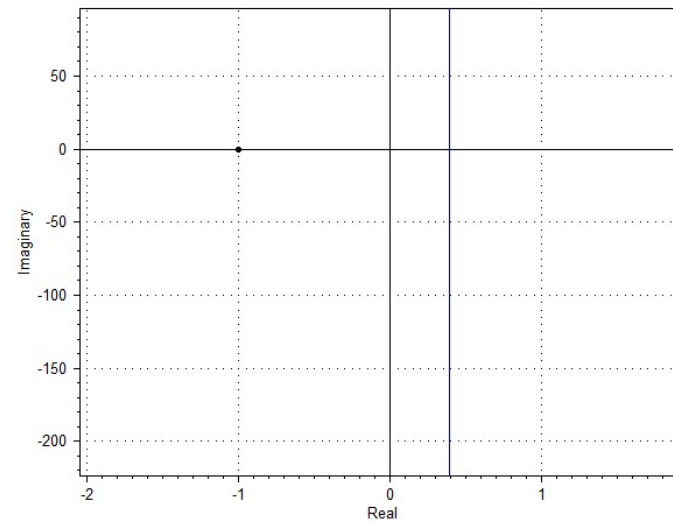
# PARA UN CONTROLADOR P+I+D : BODE (SUPERPUESTO CON P)



# PARA UN CONTROLADOR P+I+D : NYQUIST

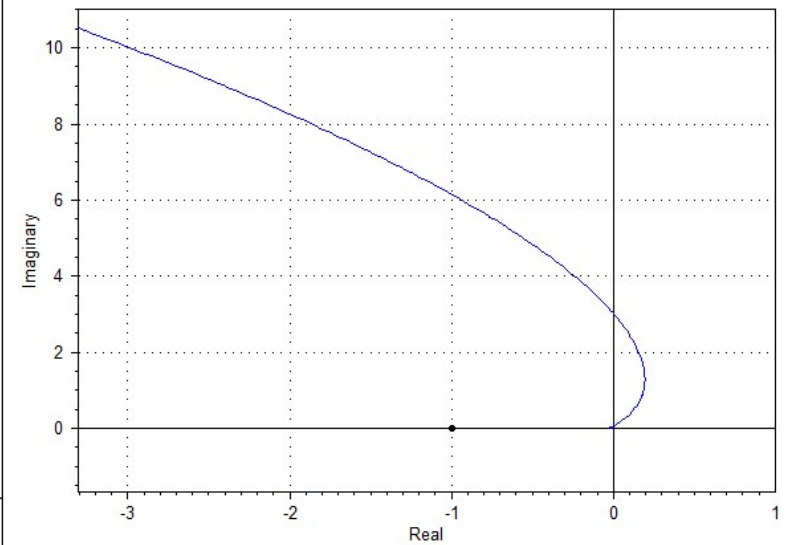
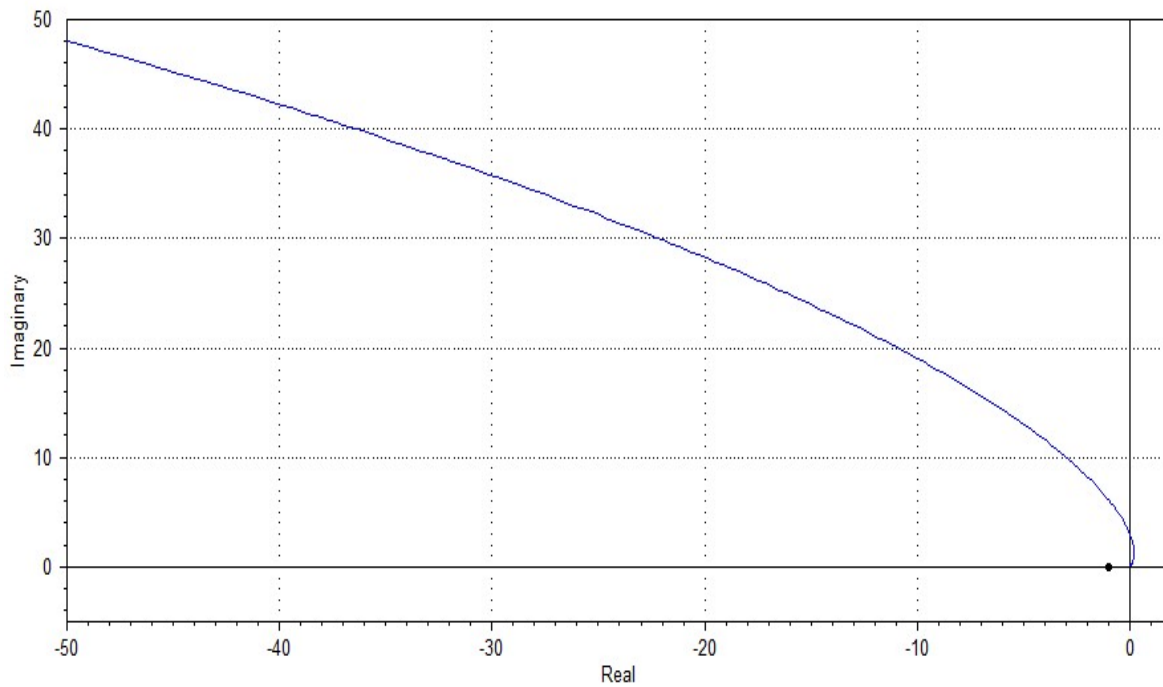


**Go**



**Gc**

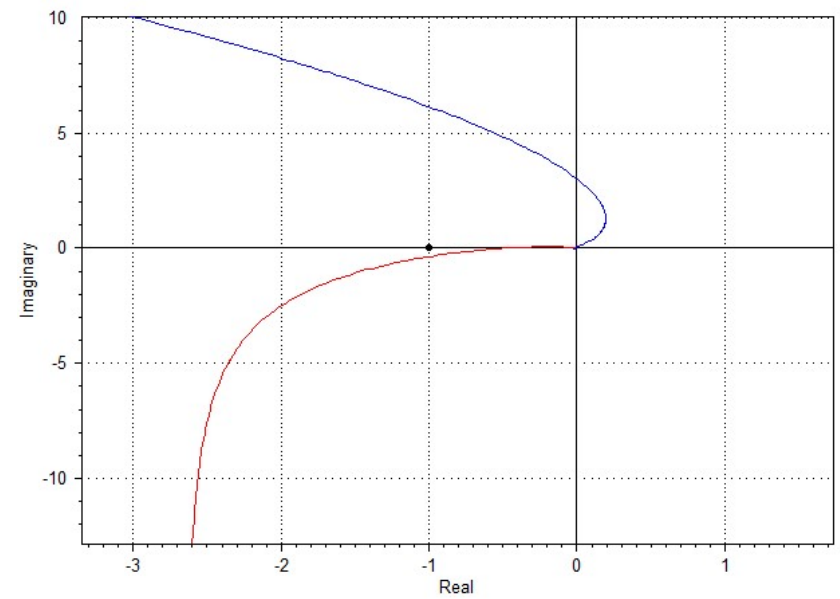
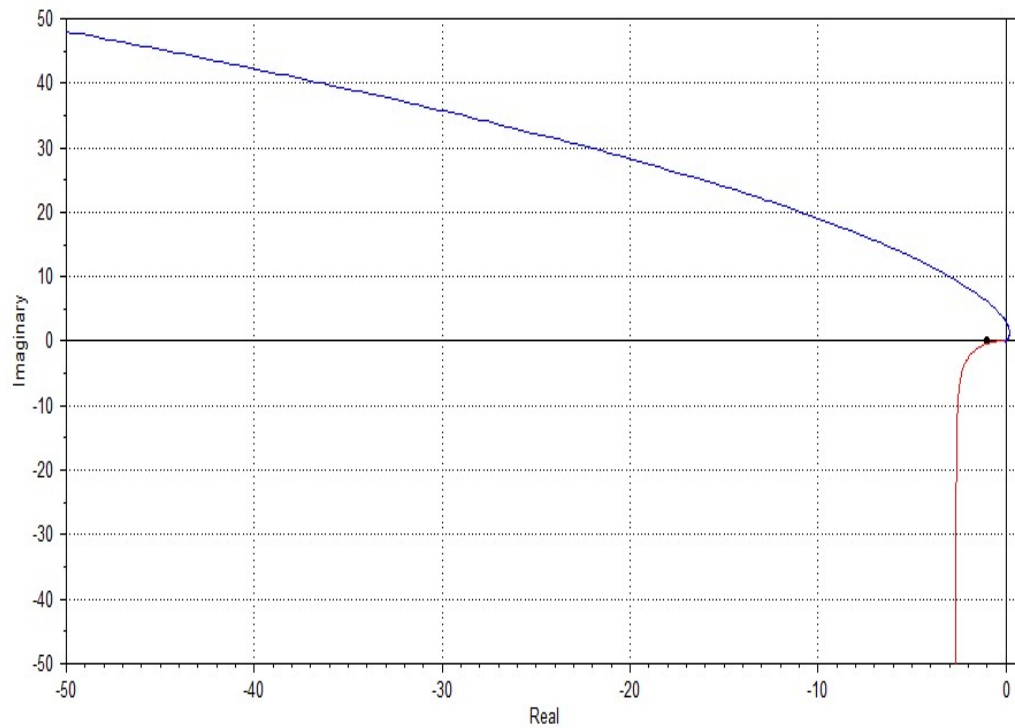
# PARA UN CONTROLADOR P+I+D : NYQUIST



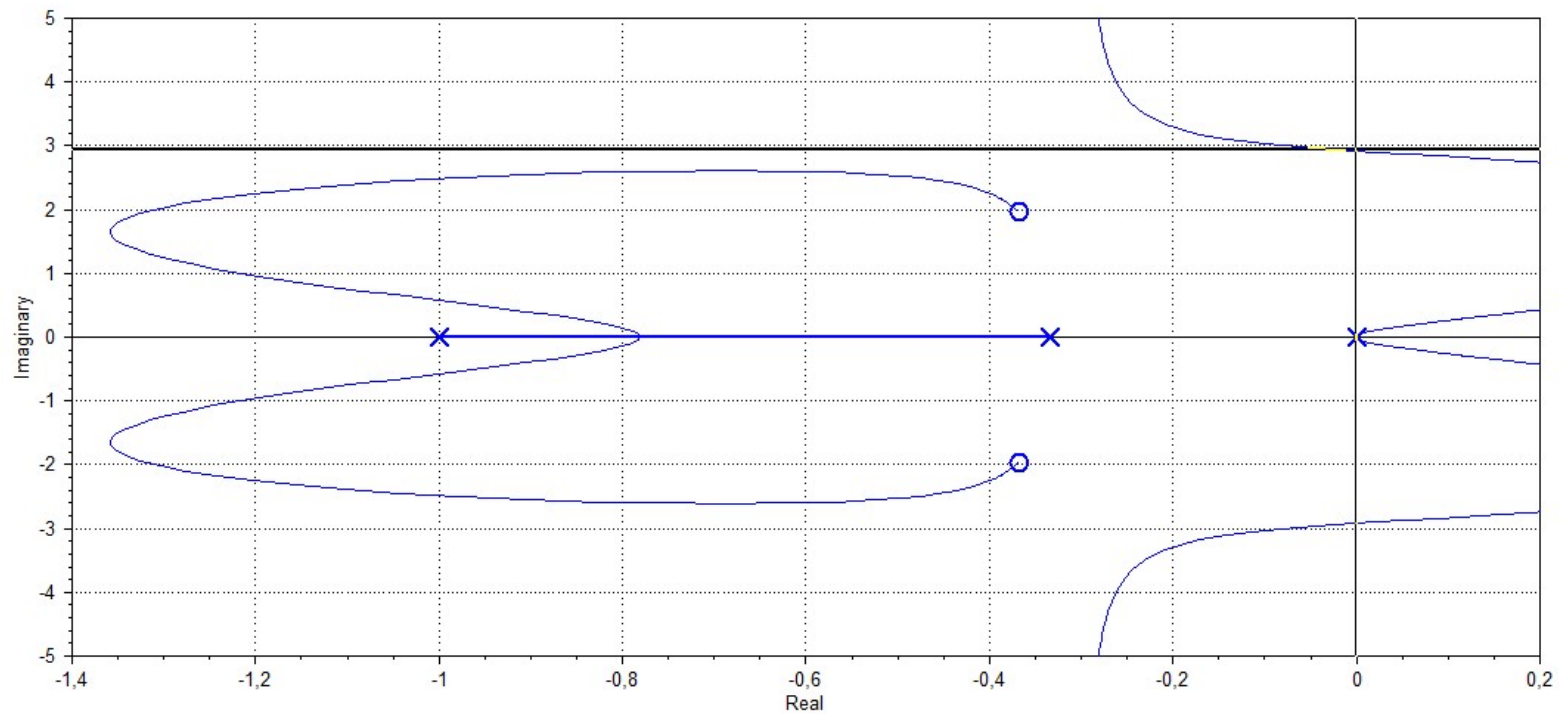
**Go\*Gc**



# PARA UN CONTROLADOR P+I+D : NYQUIST (SUPERPUESTO CON P)

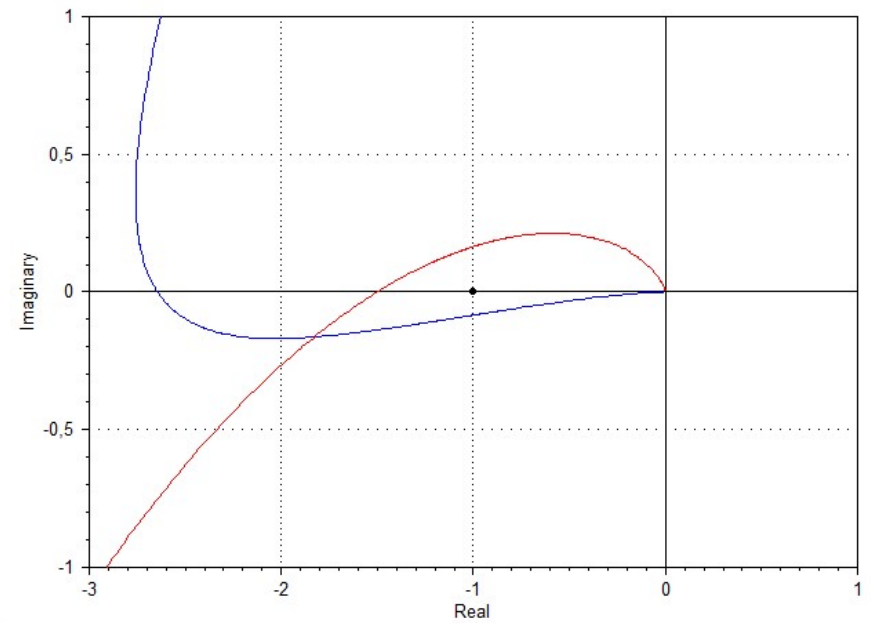
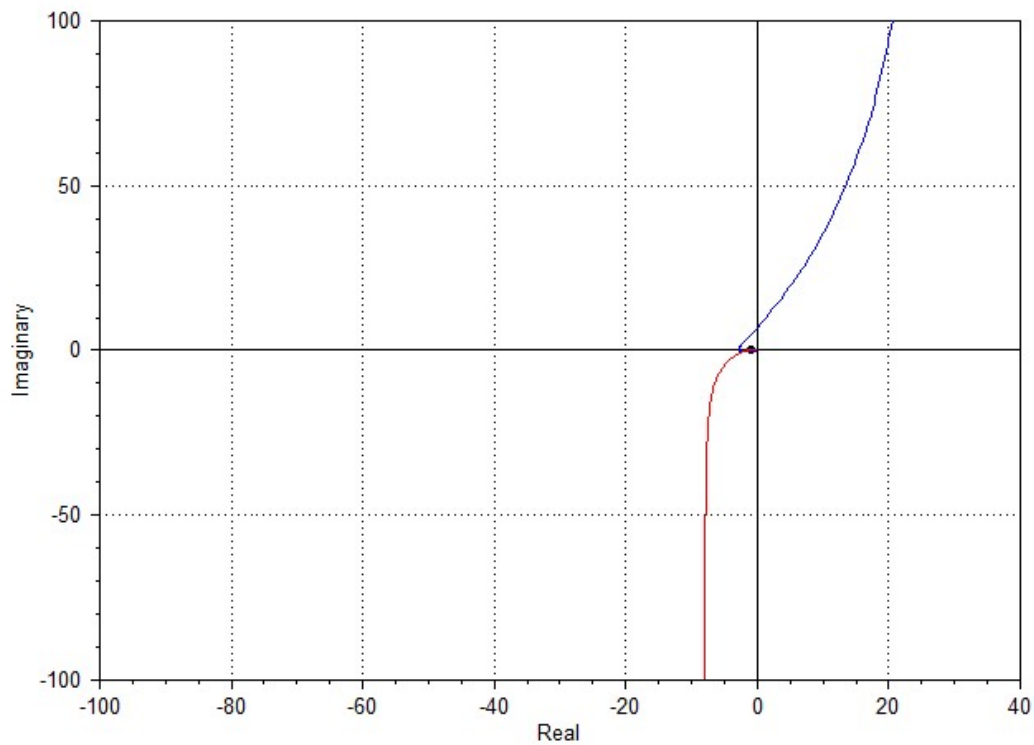


# PARA UN CONTROLADOR P+I+D: LUGAR DE RAÍCES

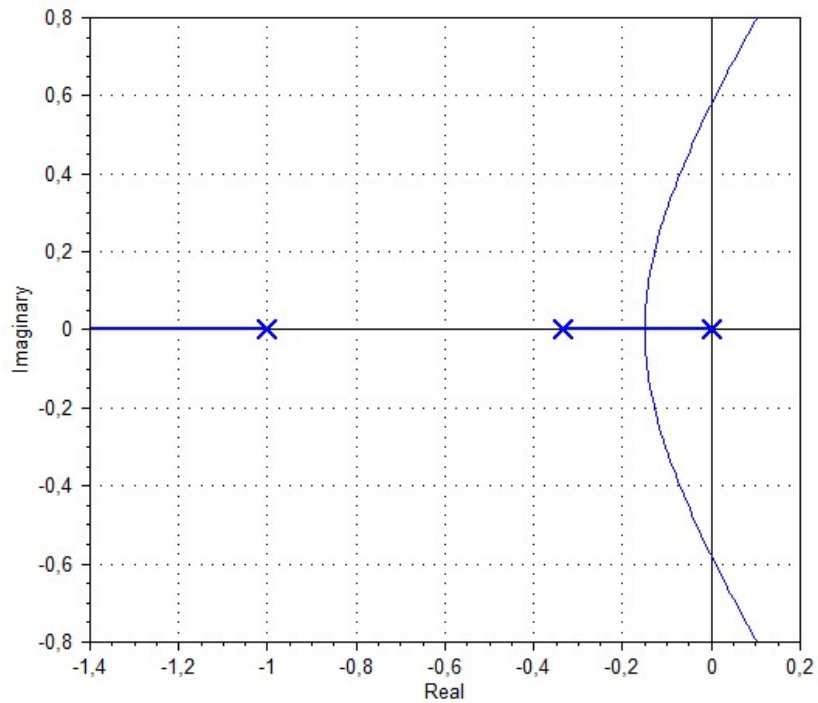


$s = 0,000603 + 2,94j$  (Mag= 2,94, Zeta= -0,0002051)  
gain= 43,61 -0,222j (Mag= 43,61, Phase= -0,2917 deg)

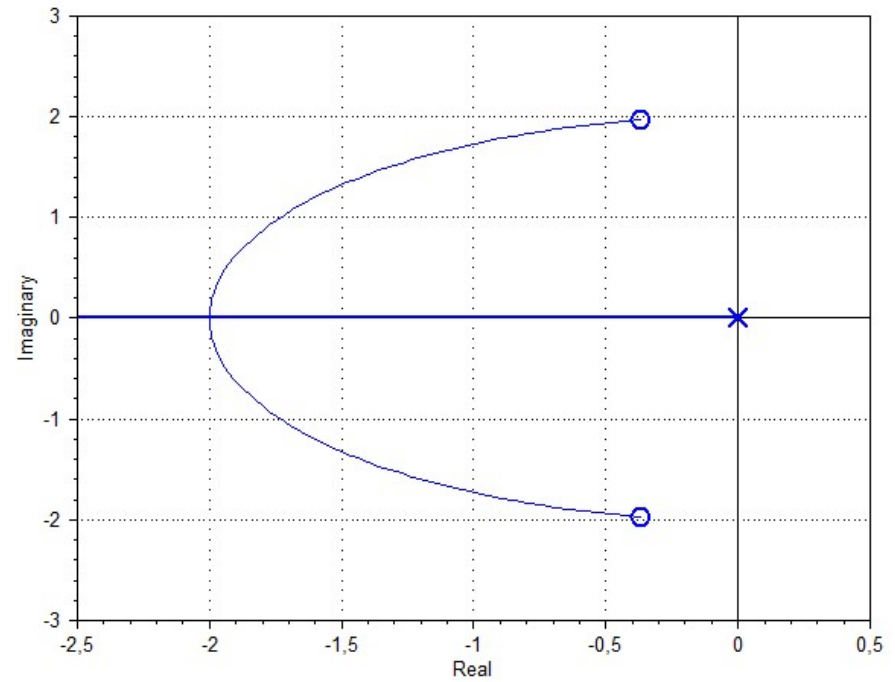
# PARA UN CONTROLADOR P+I+D : NYQUIST (ESTABILIZADO Y SUPERPUESTO CON P)



# PARA UN CONTROLADOR P+I+D: LUGAR DE RAÍCES



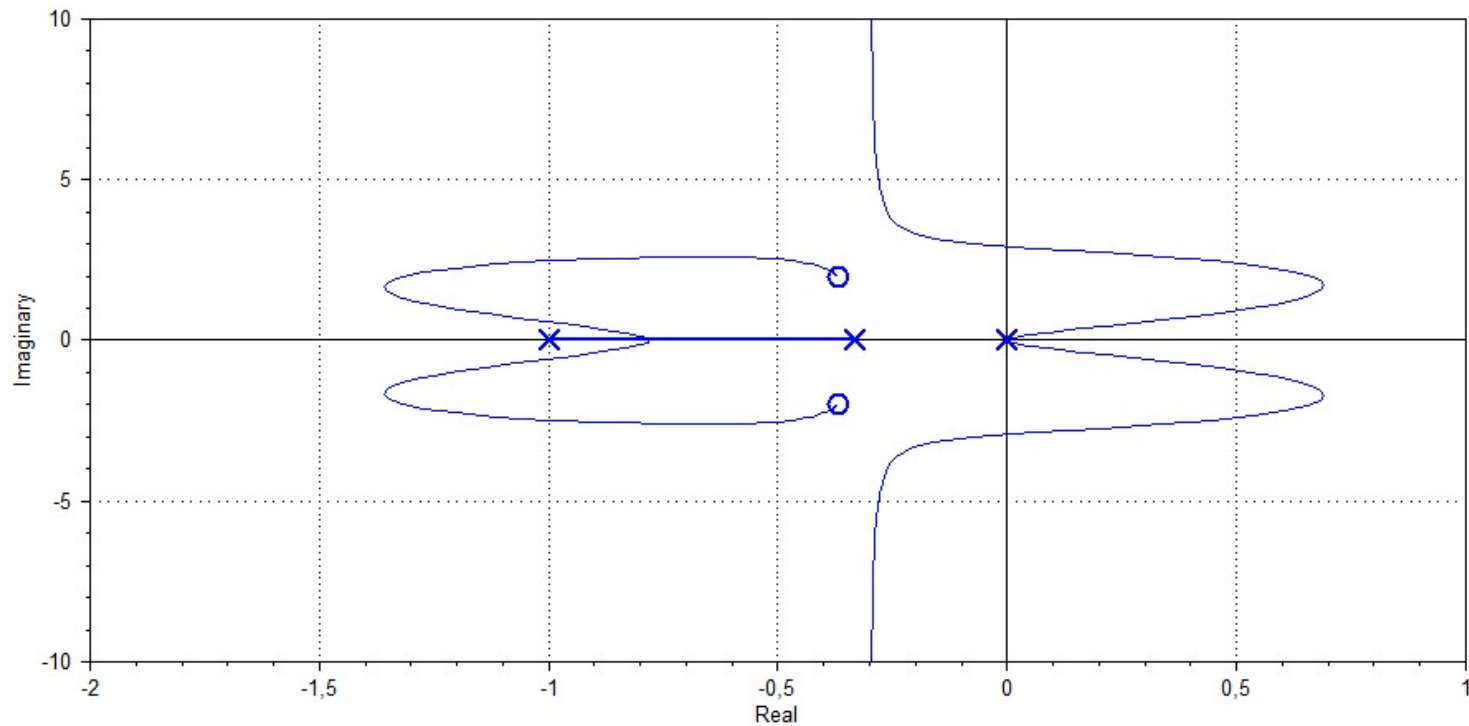
$G_o$



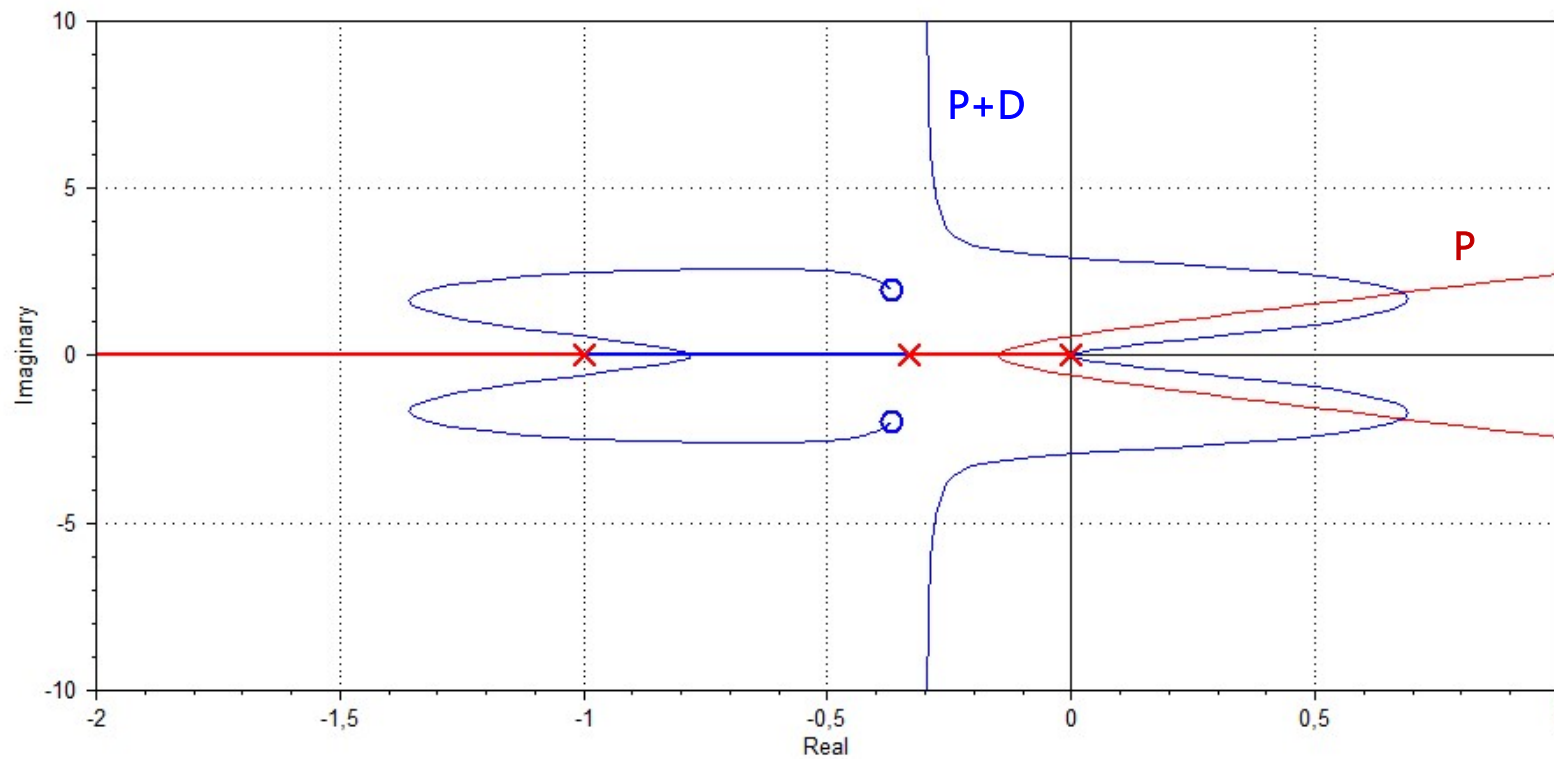
$G_c$

# PARA UN CONTROLADOR P+I+D: LUGAR DE RAÍCES

$G_o * G_c$



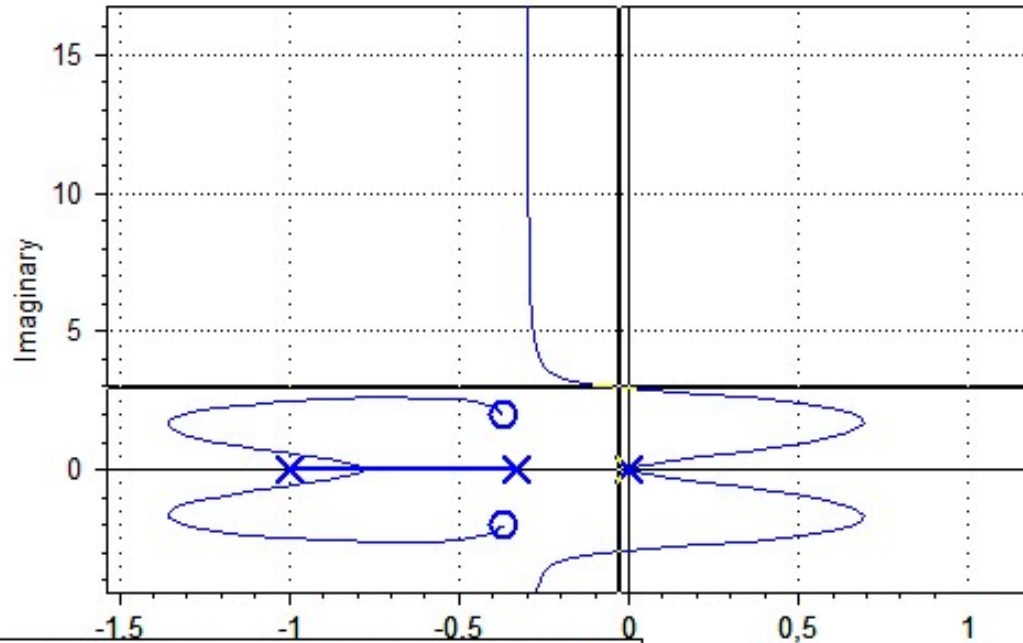
# PARA UN CONTROLADOR P+I+D: LUGAR DE RAÍCES (SUPERPUESTO CON P)



$$K_c \geq 43,6$$

$$K_c \leq \frac{2}{3}$$

AL SUPERAR EL K PARA QUE SEA ESTABLE, W COMIENZA A AUMENTAR, HACIENDO LA RESPUESTA MÁS OSCILATORIA



s= -0,02589 +2,956j (Mag= 2,956, Zeta= 0,008756)  
gain= 44 -0,1213j (Mag= 44, Phase= -0,158 deg)

*El hecho de incluir una gran ganancia, hace que la respuesta sea más rápida*

## CONCLUSIONES

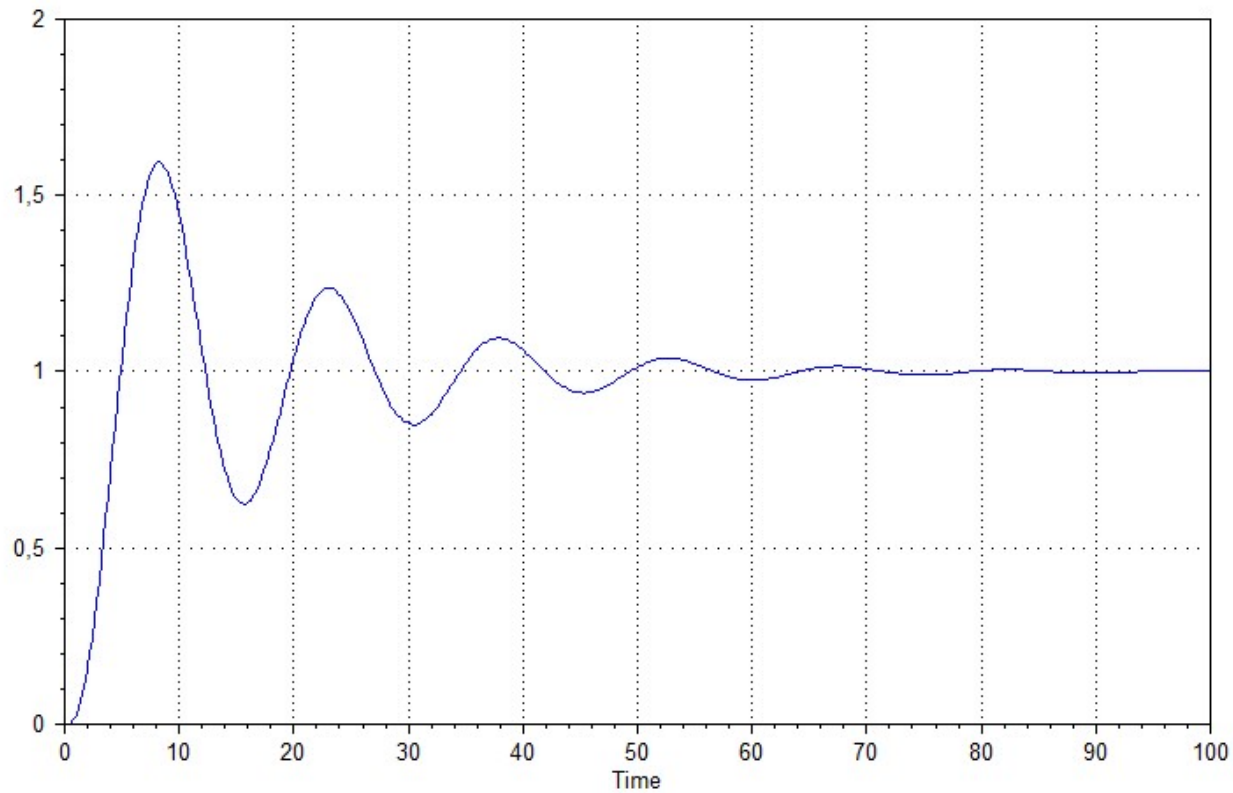
- Existen posibilidades de estabilidad mediante ajuste únicamente para control P, P+D, P+I+D.
- En el control P+I+D se obtiene una particularidad que obliga a que  $K_c$  sea mayor o igual que cierto valor, caso opuesto al convencional en el cual se tiene un límite superior.
- P+D es siempre estable. Su ganancia última es en teoría infinita.
- P es estable hasta  $K_{cu}$ , teniendo una respuesta lenta y no podemos corregir esto por la limitación de ganancia.
- En P+I+D sólo se puede aumentar la ganancia. Tiene un límite inferior, y podremos aumentar el tiempo de respuesta mediante ganancia sólo hasta donde el lugar de raíces tiende a la paralela vertical. Luego la velocidad de respuesta no aumentará y todo aumento de ganancia se traducirá en aumento de frecuencia.



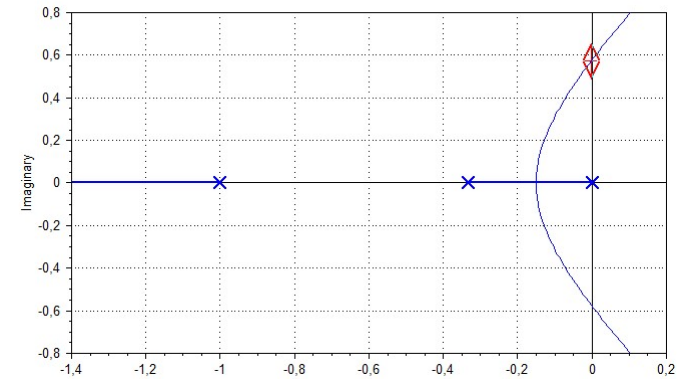
# EJERCICIO 5

The background of the slide is a photograph of a server room. The lighting is predominantly blue, creating a cool, technological atmosphere. In the foreground, a dark blue rectangular box is centered, containing the text 'EJERCICIO 5' in white, bold, sans-serif font. The server racks in the background are slightly out of focus, showing rows of lights and components. The overall composition is clean and modern.

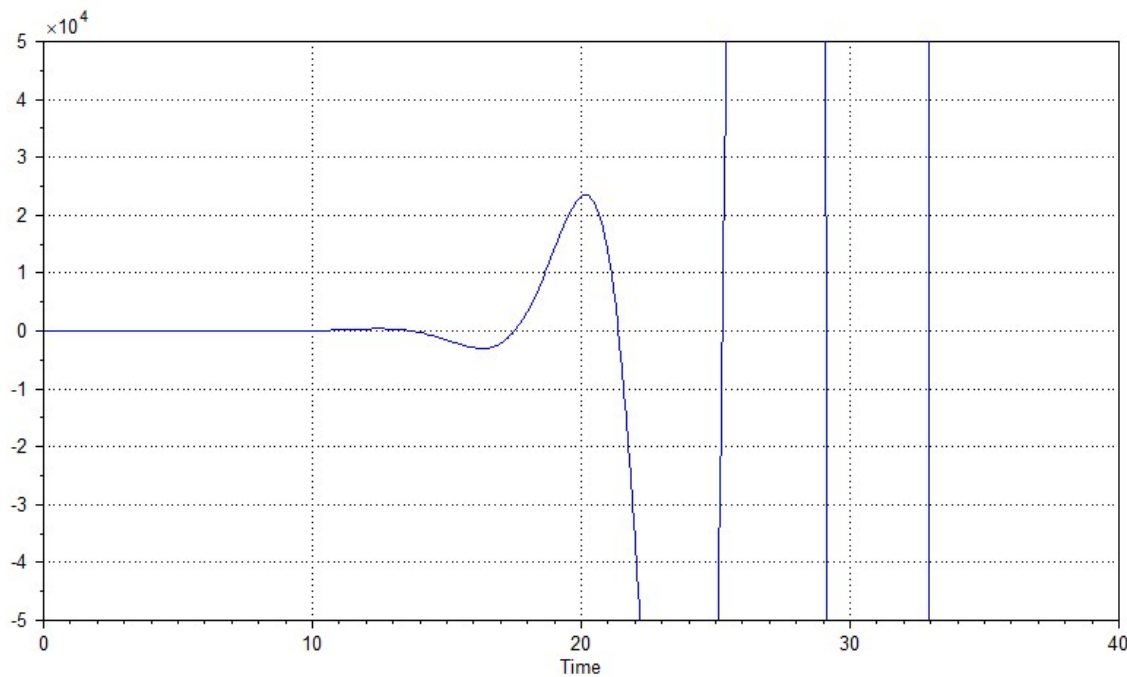
# RESPUESTA TEMPORAL A LAZO CERRADO CON CONTROLADOR P



$$G = \frac{G_o * K_c}{1 + G_o * K_c}$$



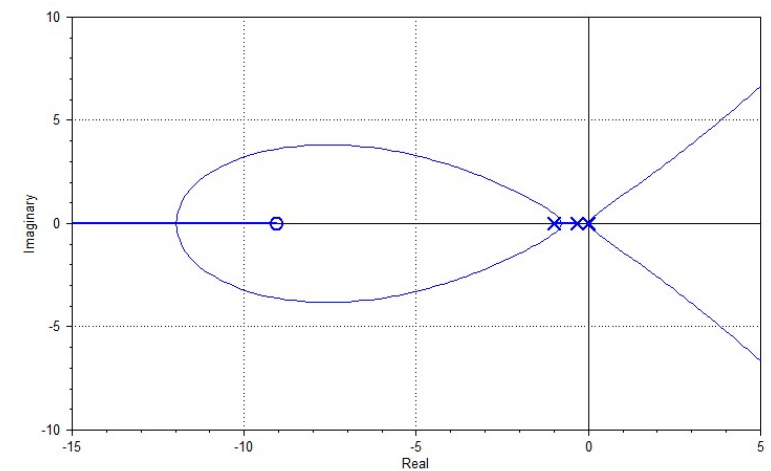
# RESPUESTA TEMPORAL A LAZO CERRADO CON CONTROLADOR P+I



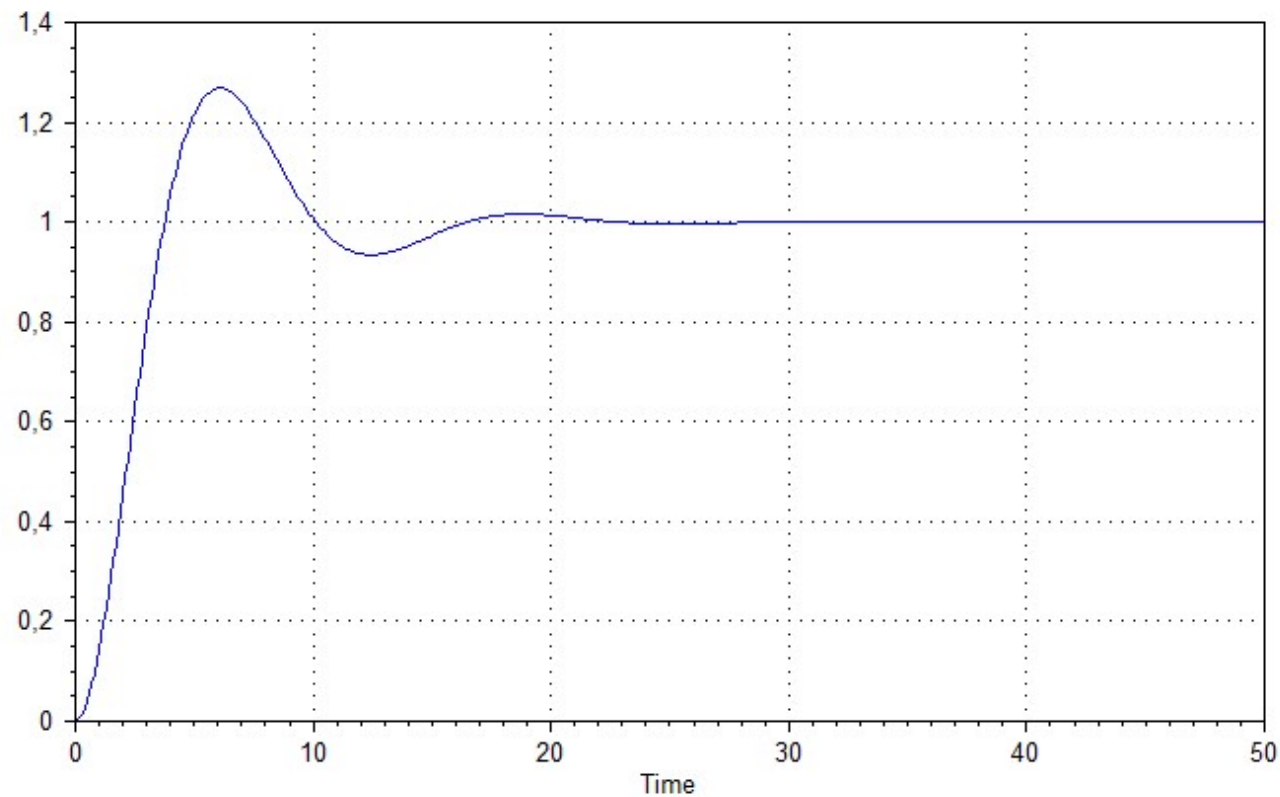
*No tiene posibilidades de estabilidad*

$$G = \frac{G_o * G_{PI}}{1 + G_o * G_{PI}}$$

$$G_{PI} = K_c \left( 1 + \frac{T_I}{s} \right)$$

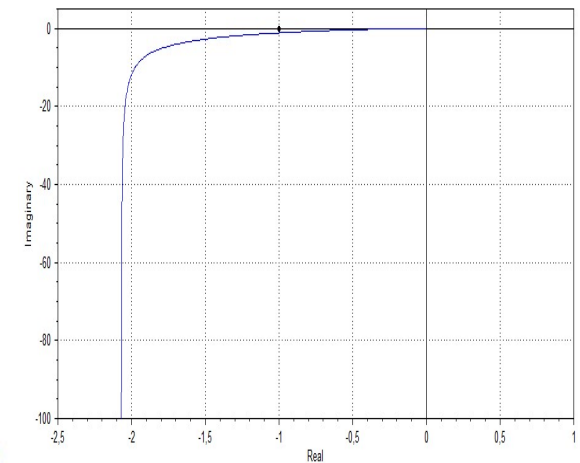


# RESPUESTA TEMPORAL A LAZO CERRADO CON CONTROLADOR P+D

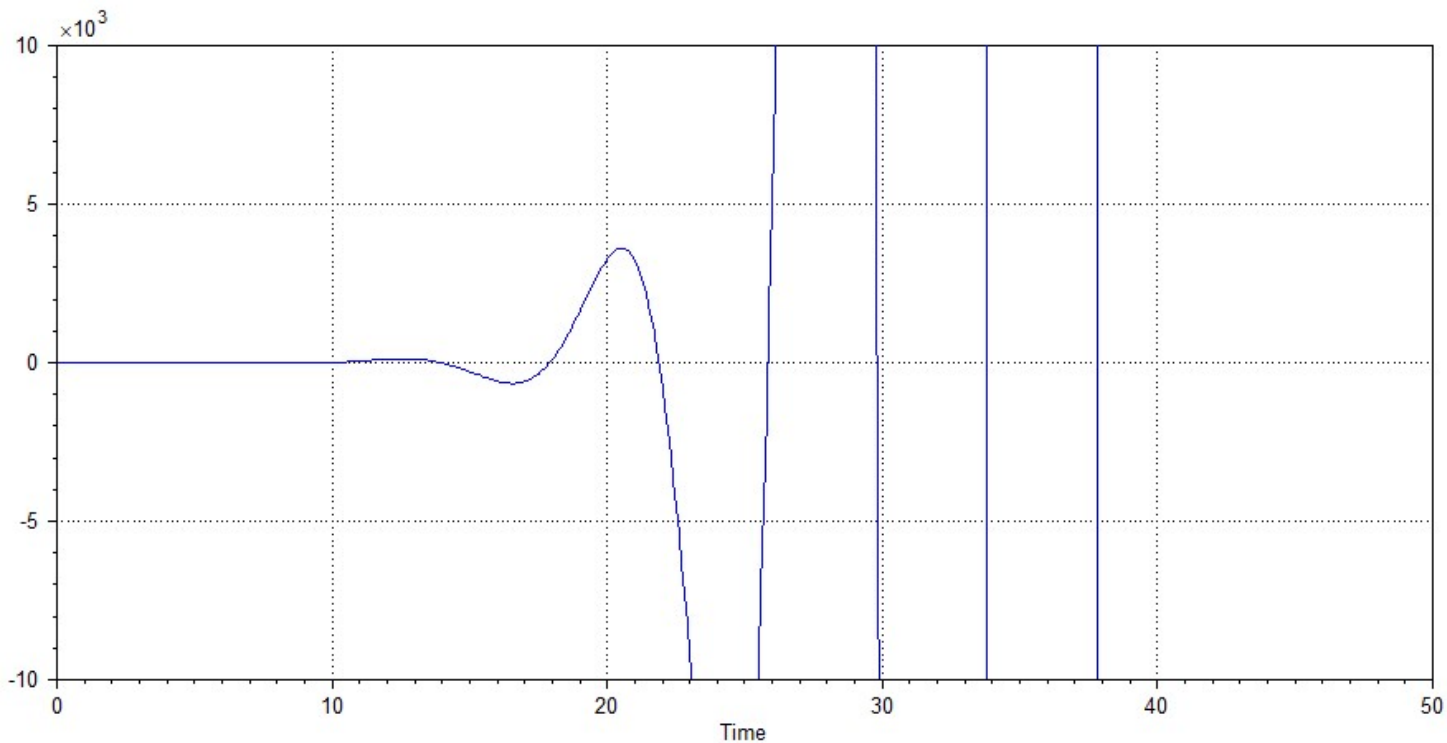


$$G = \frac{G_o * G_{PD}}{1 + G_o * G_{PD}}$$

$$G_{PD} = K_c(1 + T_D S)$$



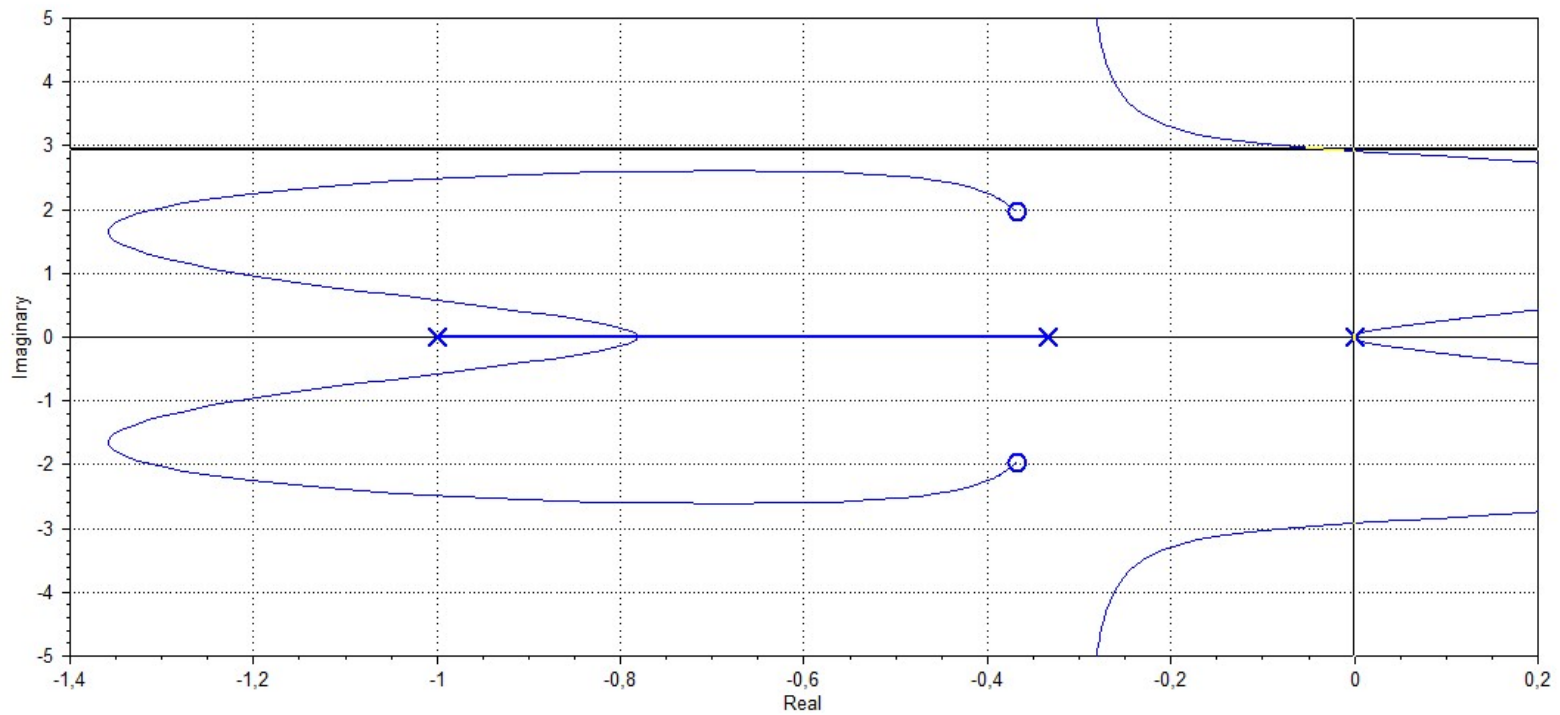
## RESPUESTA TEMPORAL A LAZO CERRADO CON CONTROLADOR P+I+D



$$G = \frac{G_o * G_{PID}}{1 + G_o * G_{PID}}$$

$$G_{PI} = K_c \left( 1 + \frac{T_I}{S} + T_D S \right)$$

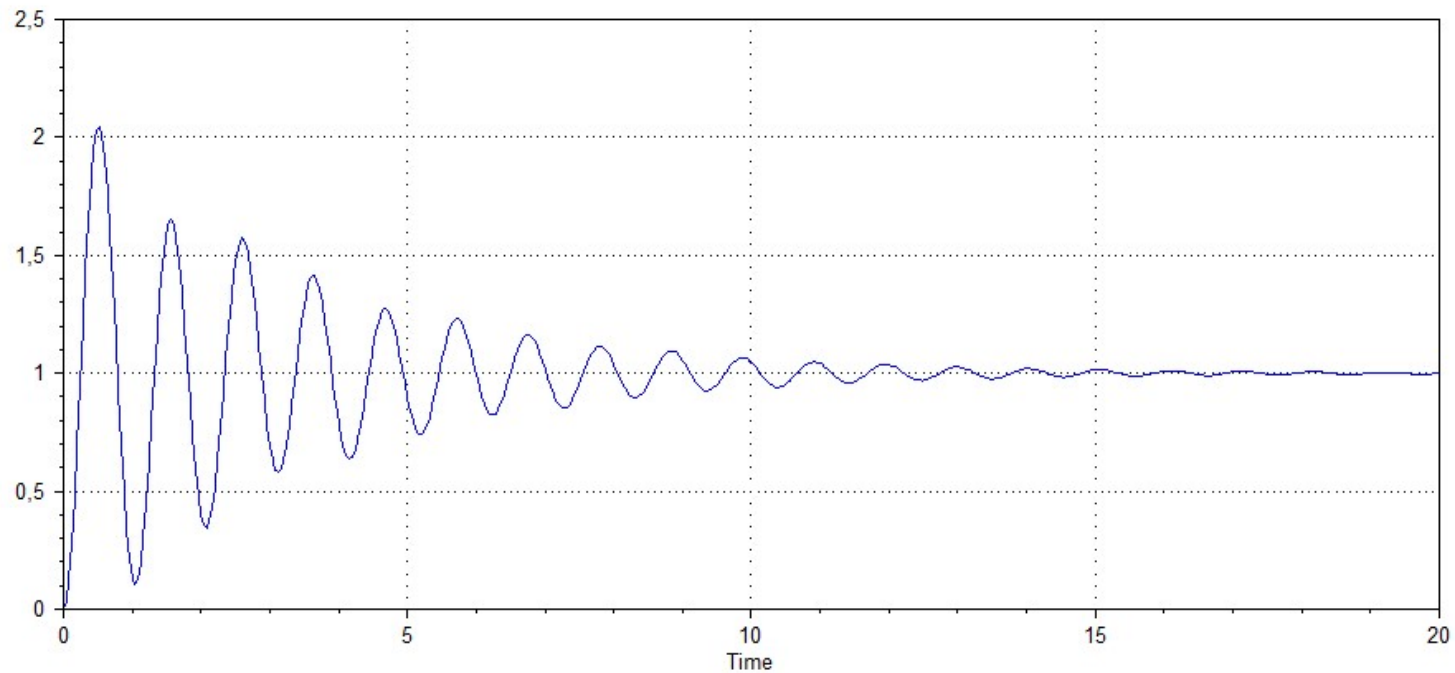
# PARA UN CONTROLADOR P+I+D: LUGAR DE RAÍCES



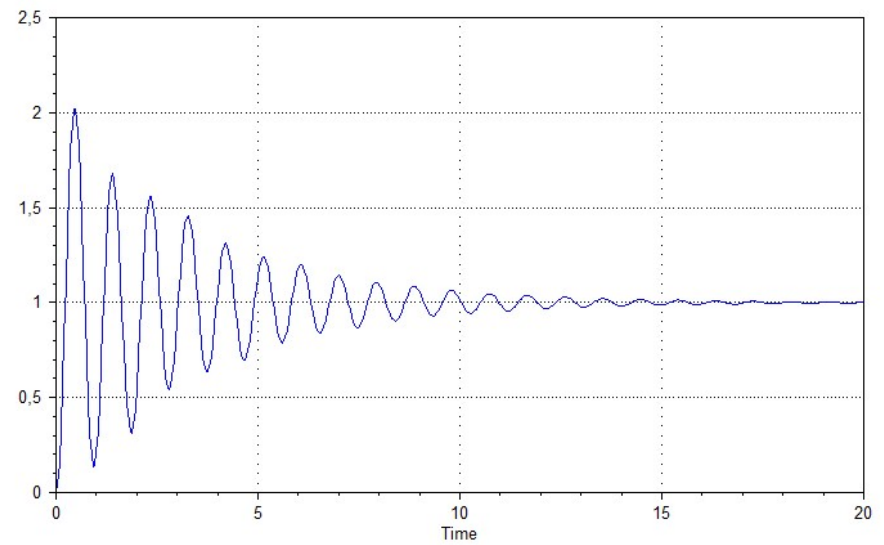
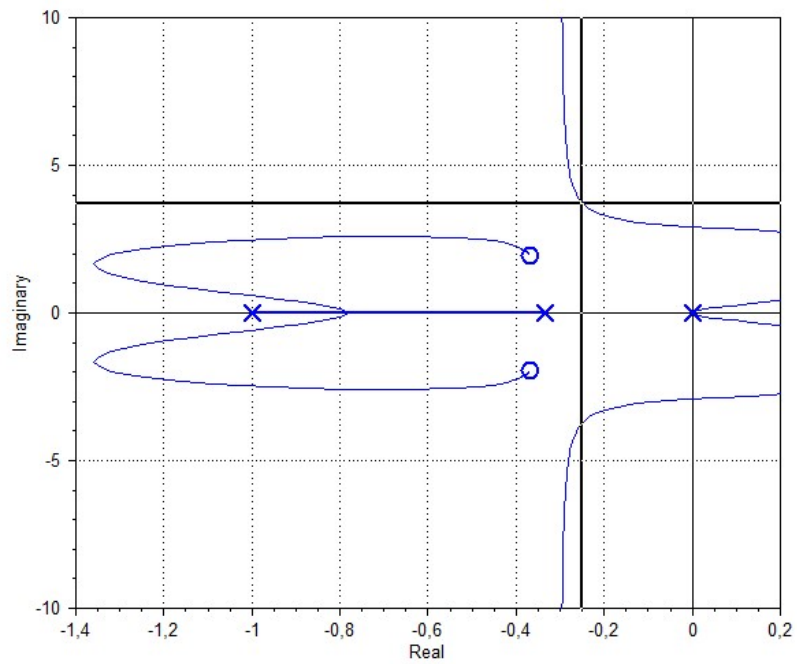
$s = 0,000603 + 2,94j$  (Mag= 2,94, Zeta= -0,0002051)  
gain= 43,61 -0,222j (Mag= 43,61, Phase= -0,2917 deg)

## RESPUESTA TEMPORAL A LAZO CERRADO CON CONTROLADOR P+I+D (ESTABILIZADO CON $K_C=45$ )

*Llega al estado estable aprox. en 20s*



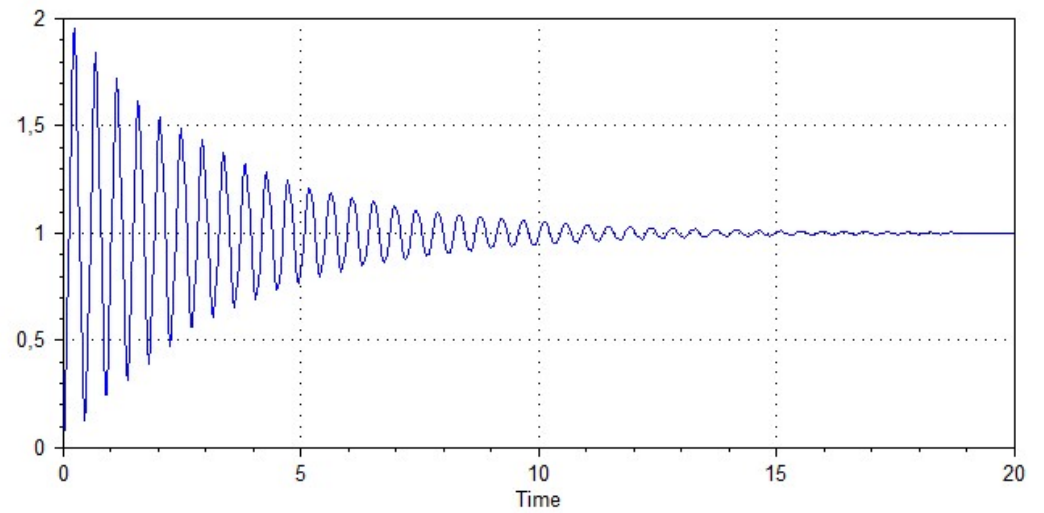
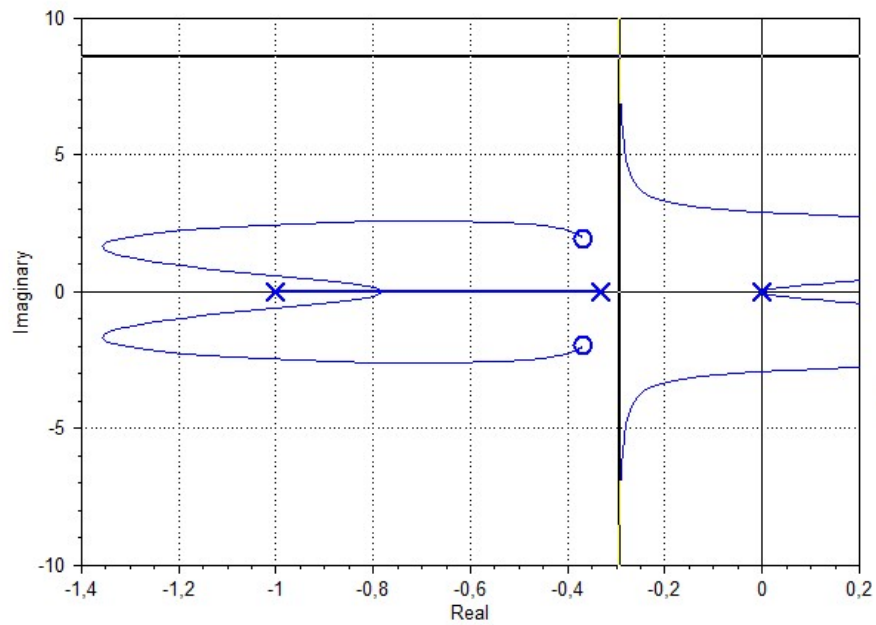
# PARA KC=55



$s = -0,2505 + 3,704j$  (Mag= 3,712, Zeta= 0,06748)  
gain= 54,93 + 0,05524j (Mag= 54,93, Phase= 0,05761 deg)

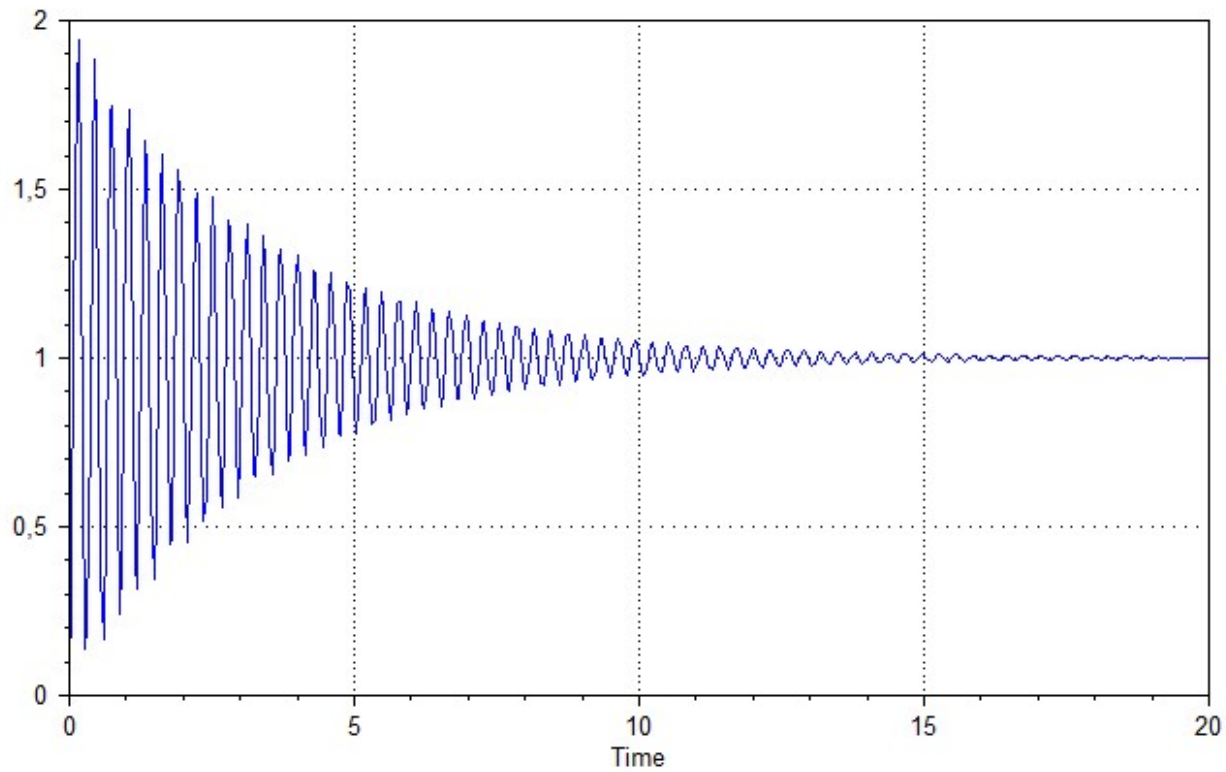


# PARA KC=220



$s = -0,2928 + 8,595j$  (Mag= 8,6, Zeta= 0,03405)  
 $gain = 220,2 - 0,07328j$  (Mag= 220,2, Phase= -0,01907 deg)

PARA  $KC=500$ , SÓLO SE REGISTRA AUMENTO DE FRECUENCIA DENTRO DE LA MISMA ENVOLVENTE



## CONCLUSIONES

- Con los ajustes correspondientes extraíbles del lugar de raíces, podemos obtener respuestas estables en todos los casos excepto en el de control P+I ya que siempre es inestable
- El control P+D añade un cero al numerador, cancelando un cero del denominador y llevándolo a un comportamiento de segundo orden, siempre estable
- El control P+I+D añade dos ceros al numerador y un cero al denominador, haciendo que a partir de cierto punto, el sistema se comporte como si fuera de segundo orden
- En este último, la ganancia debe superar cierto valor. Al hacerlo, podemos observar que al pasar  $K_c$  de 45, a 55 y a 220, se observan cambios en la envolvente de las oscilaciones, y a partir del valor de 220 que es donde se ve una paralela vertical en el lugar de raíces, aumentar la ganancia no hará que cambie la envolvente, sino que dentro de la misma envolvente aumentará mucho la frecuencia, empeorando el ruido.
- No hay error de offset debido al integrador puro de la función de transferencia, que aporta acción integral independientemente del tipo de controlador

The background features a complex network of glowing lines in shades of blue and red, creating a sense of depth and connectivity. The lines are interconnected, forming a mesh-like structure that recedes into the distance. The overall aesthetic is futuristic and technological.

¡GRACIAS POR SU  
ATENCIÓN!