Controladores Lead/Lag

Técnicas de Resposta em Frequência

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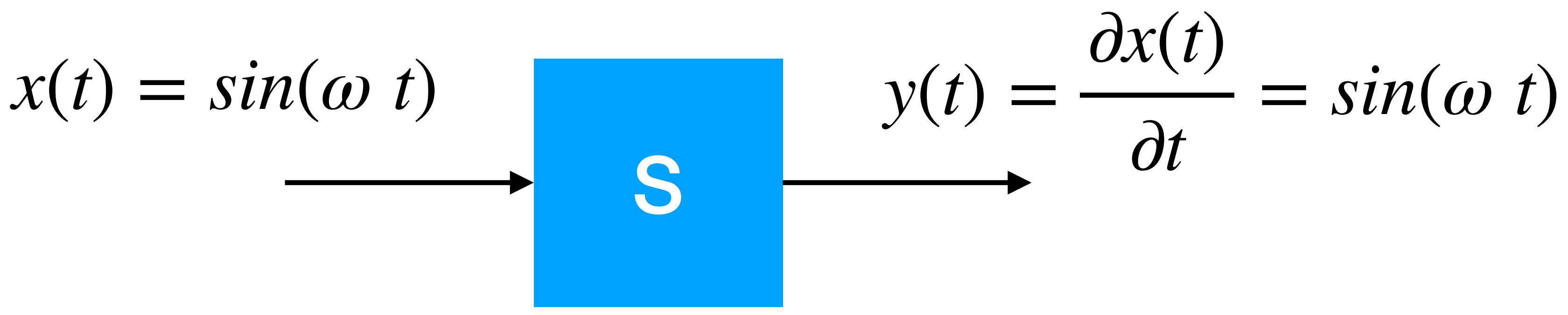
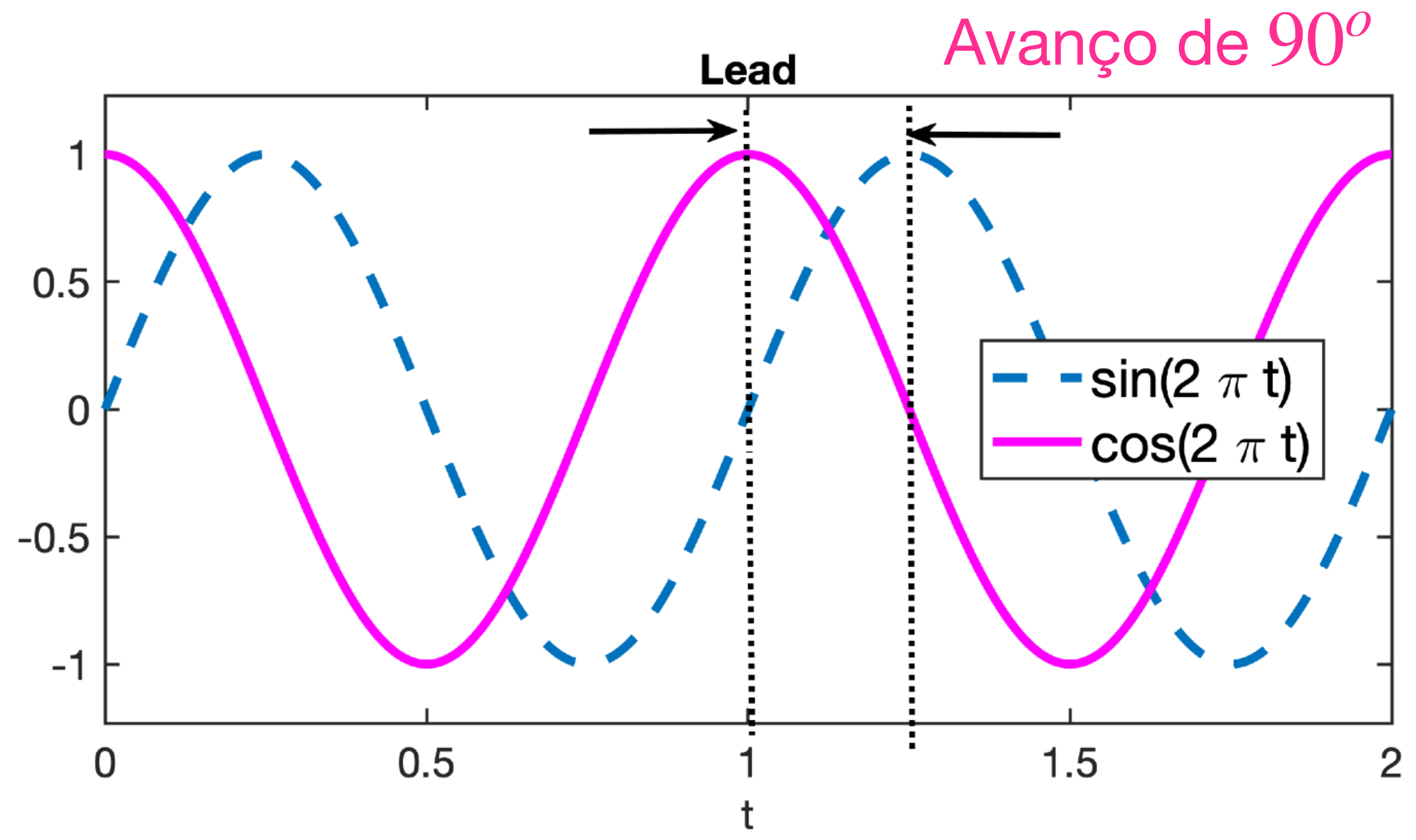
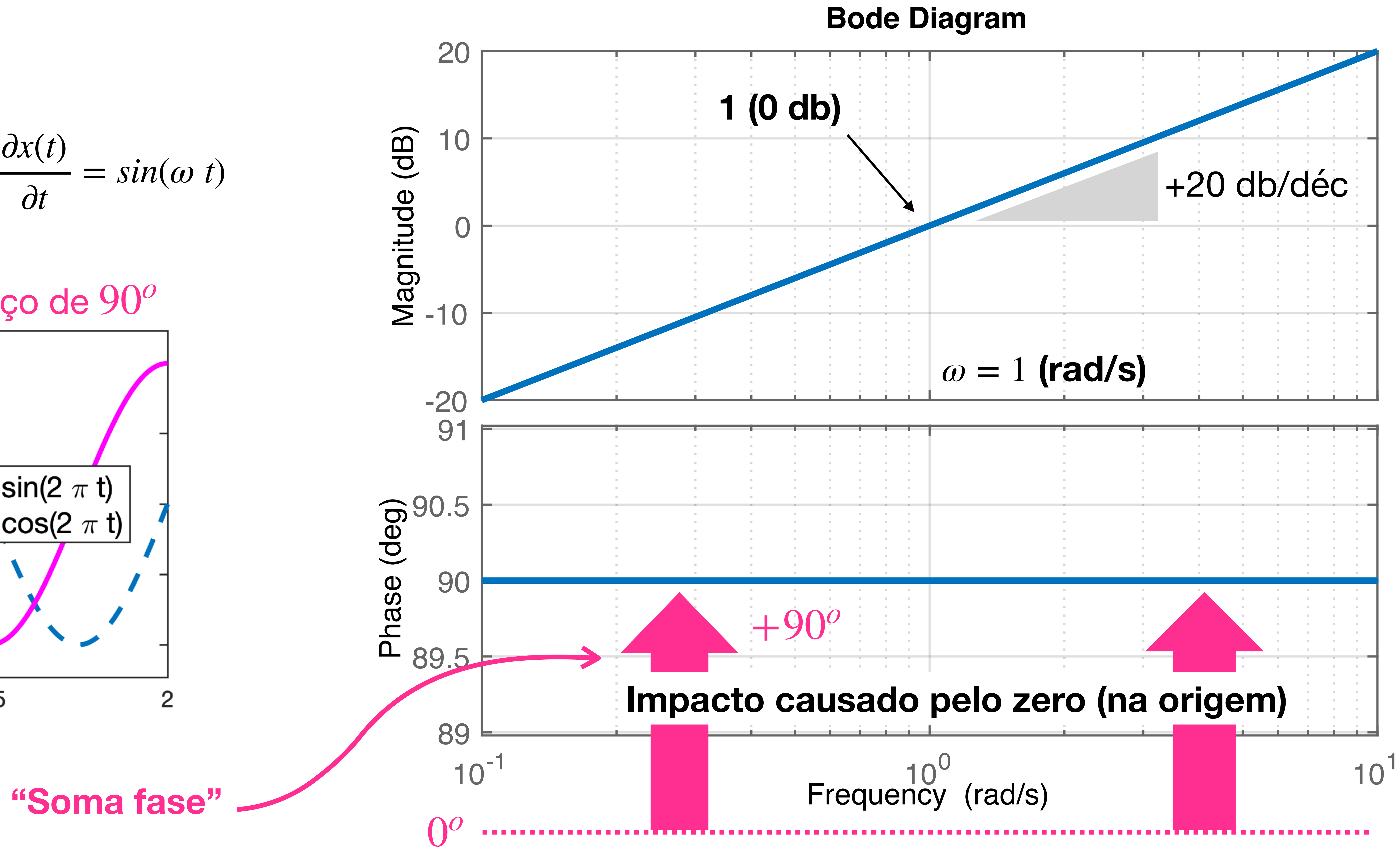
Controlador Lead (Avanço de Fase)

- Fatos:

Derivativo Puro: $C(s) = K \cdot s$








```
>> figure; ezplot('sin(2*pi*t)', [0 2])
>> hold on; ezplot('cos(2*pi*t)', [0 2])
>> title('Lead')
>> legend('sin(2 \pi t)','cos(2 \pi t)')
```

Controlador Lead (Avanço de Fase)

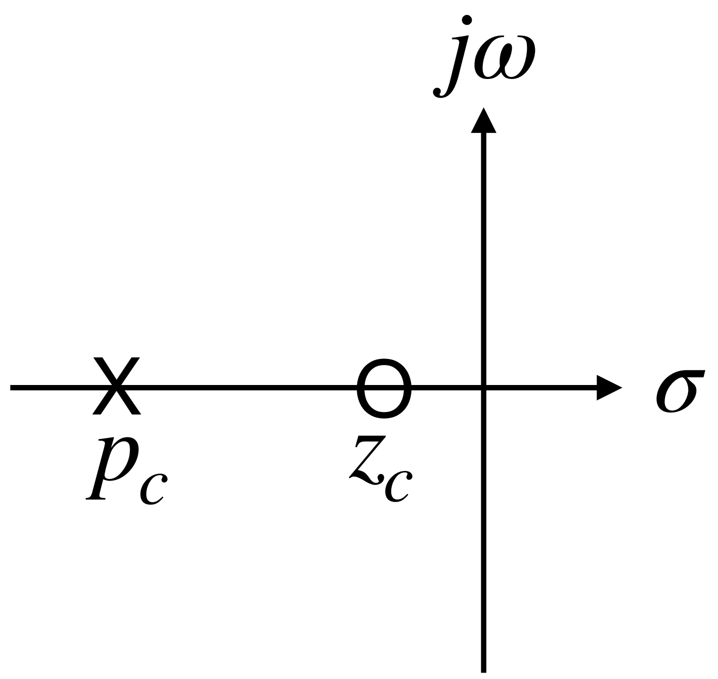
- Base teórica:

Controlador: $$C(s) = \overbrace{\left(\frac{\omega_p}{\omega_z}\right)}^{K} \cdot \frac{(s+\omega_z)}{(s+\omega_p)}$$

$\omega_p / \omega_z \rightarrow$ **1 (0 db)**

Zero $\Rightarrow$ próximo da origem (do plano-s)

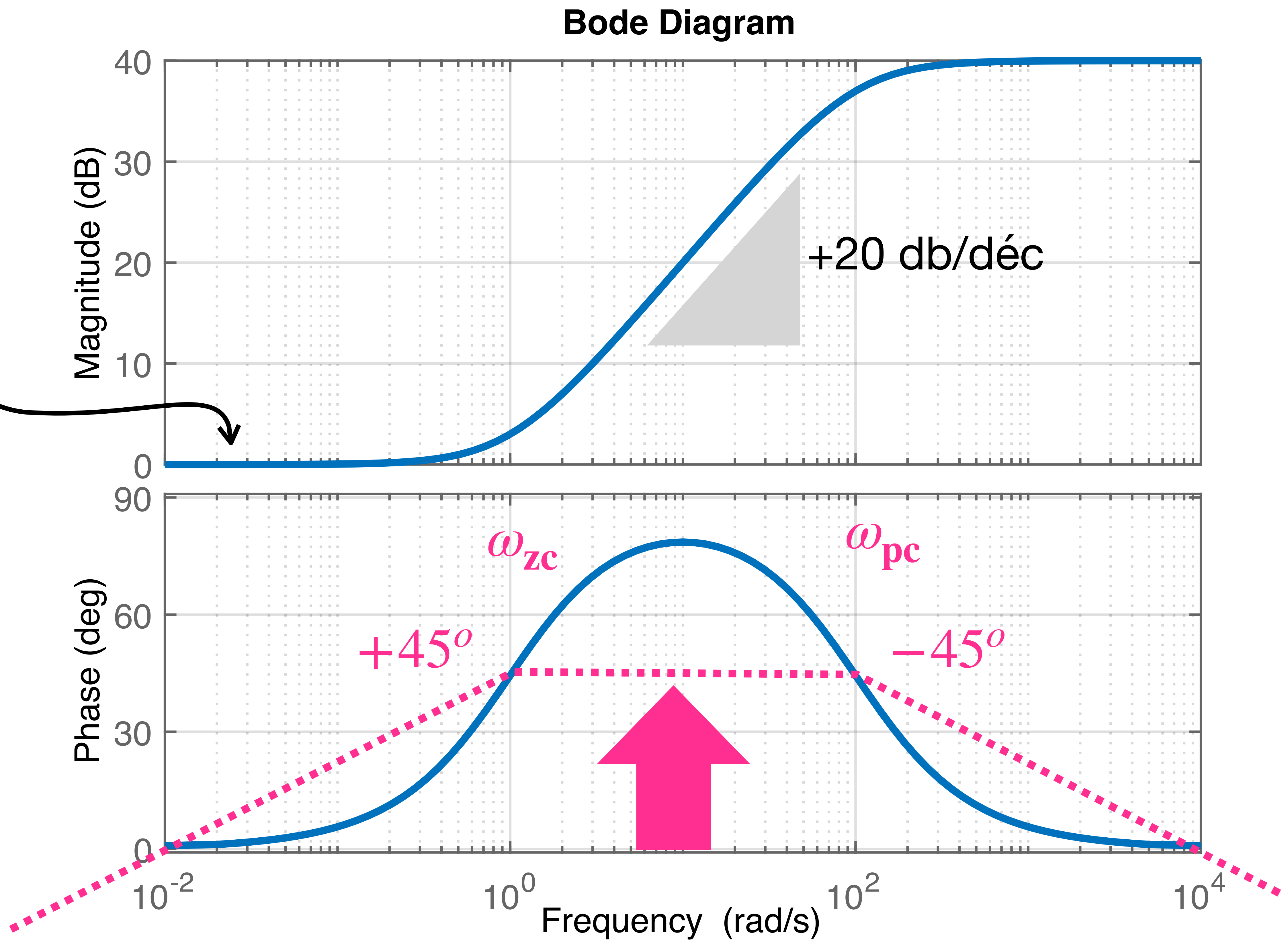
e $\omega_z < \omega_p$




```
>> G_lead=tf(100*[1 1],[1 100]);
>> zpk(G_lead)
ans =

  100 (s+1)
  ---------
   (s+100)

Continuous-time zero/pole/gain model.
>> figure; bode(G_lead)
```

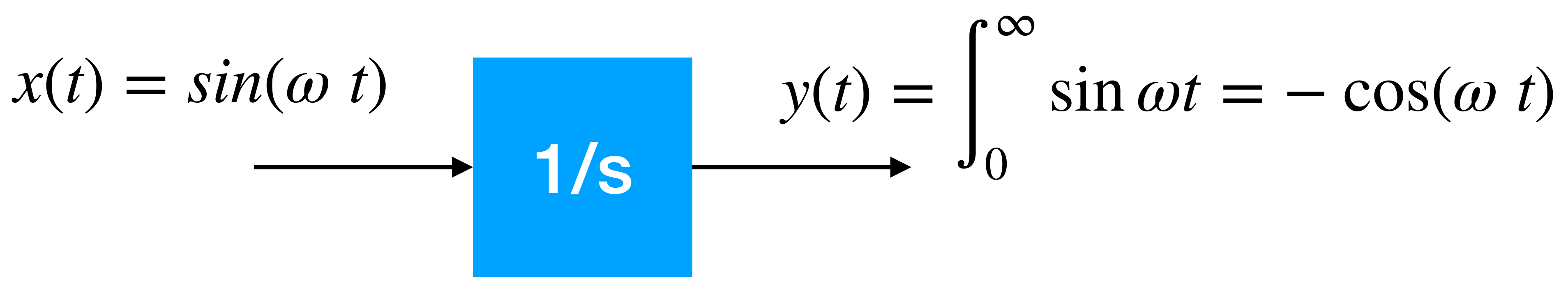


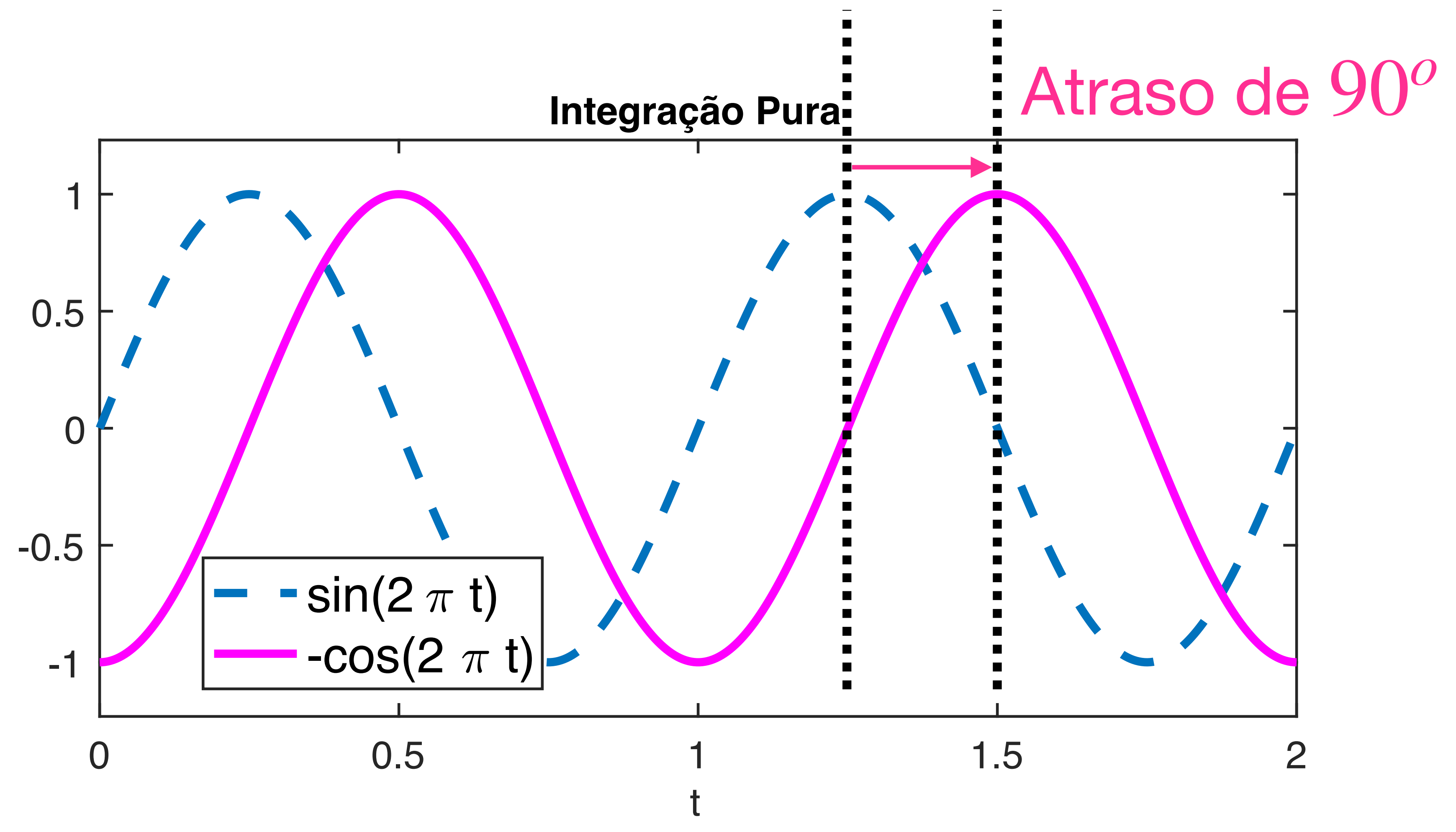
Vantagens:
- **aumenta margem de fase,** $\Phi_m \Rightarrow \propto \% OS, \zeta \downarrow$ **;**
- $\downarrow t_r$, $\downarrow t_s$
- **Faixa alta de frequências...**

Controlador Lag (Atraso de Fase)

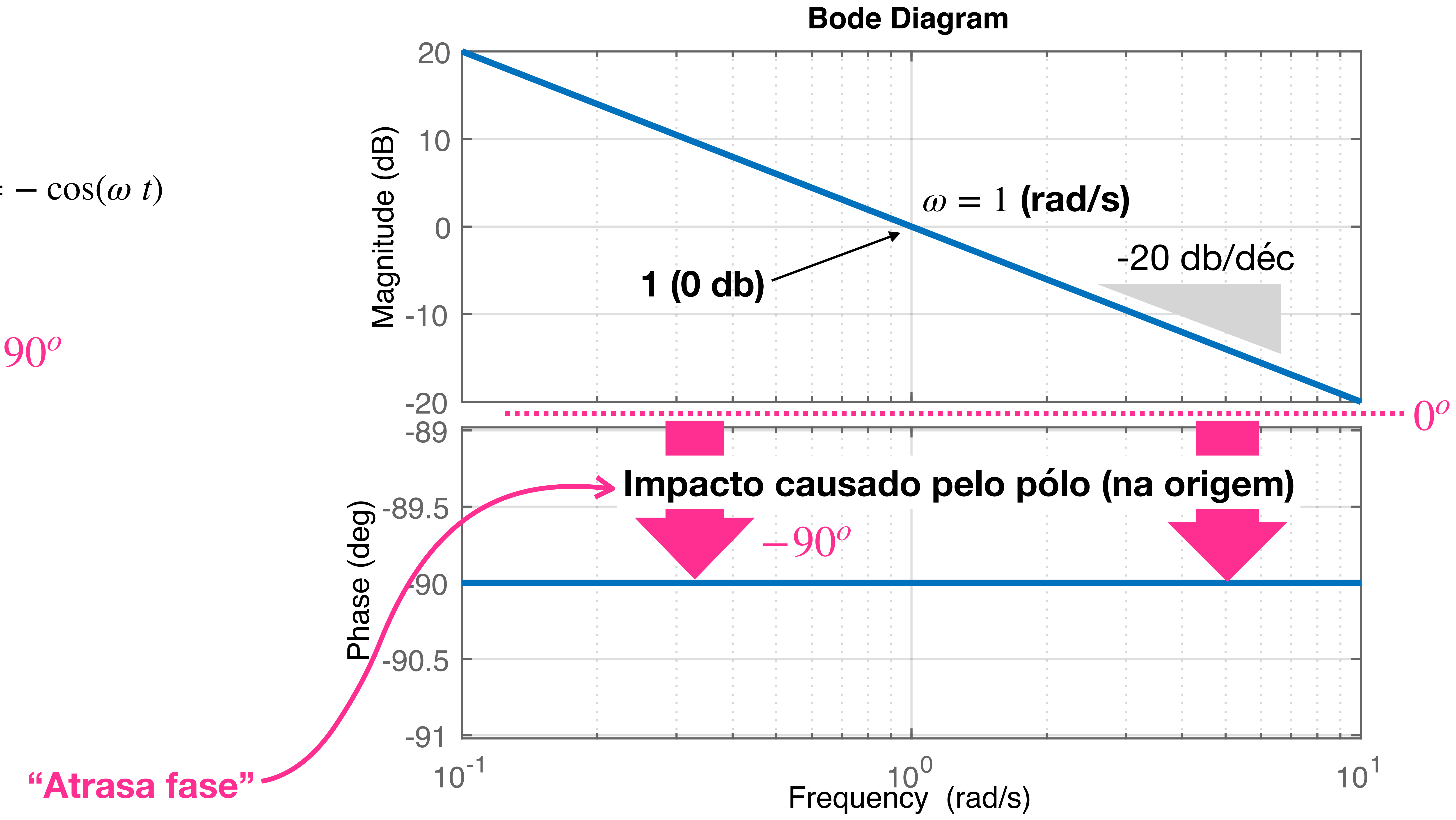
- Fatos:

Integrador Puro: $C(s) = K \cdot \frac{1}{s}$






```
>> figure; ezplot('sin(2*pi*t)', [0 2])
>> hold on; ezplot('-cos(2*pi*t)', [0 2])
>> title('Integração Pura');
>> legend('sin(2 \pi t)','-cos(2 \pi t)')
```



Controlador Lag (Atraso de Fase)

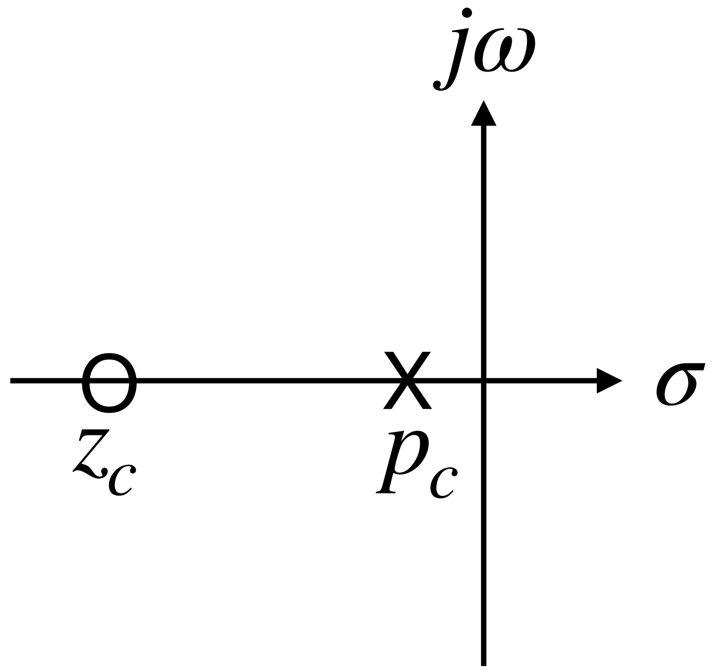
- Base teórica:

Controlador: $C(s) = \overbrace{\left(\frac{\omega_p}{\omega_z}\right)}^{K} \cdot \frac{(s+\omega_z)}{(s+\omega_p)}$

$\frac{\omega_p}{\omega_z} \rightarrow$ **1 (0 db)**

Pólo $\Rightarrow$ próximo da origem (do plano-s)

e $\omega_p < \omega_z$



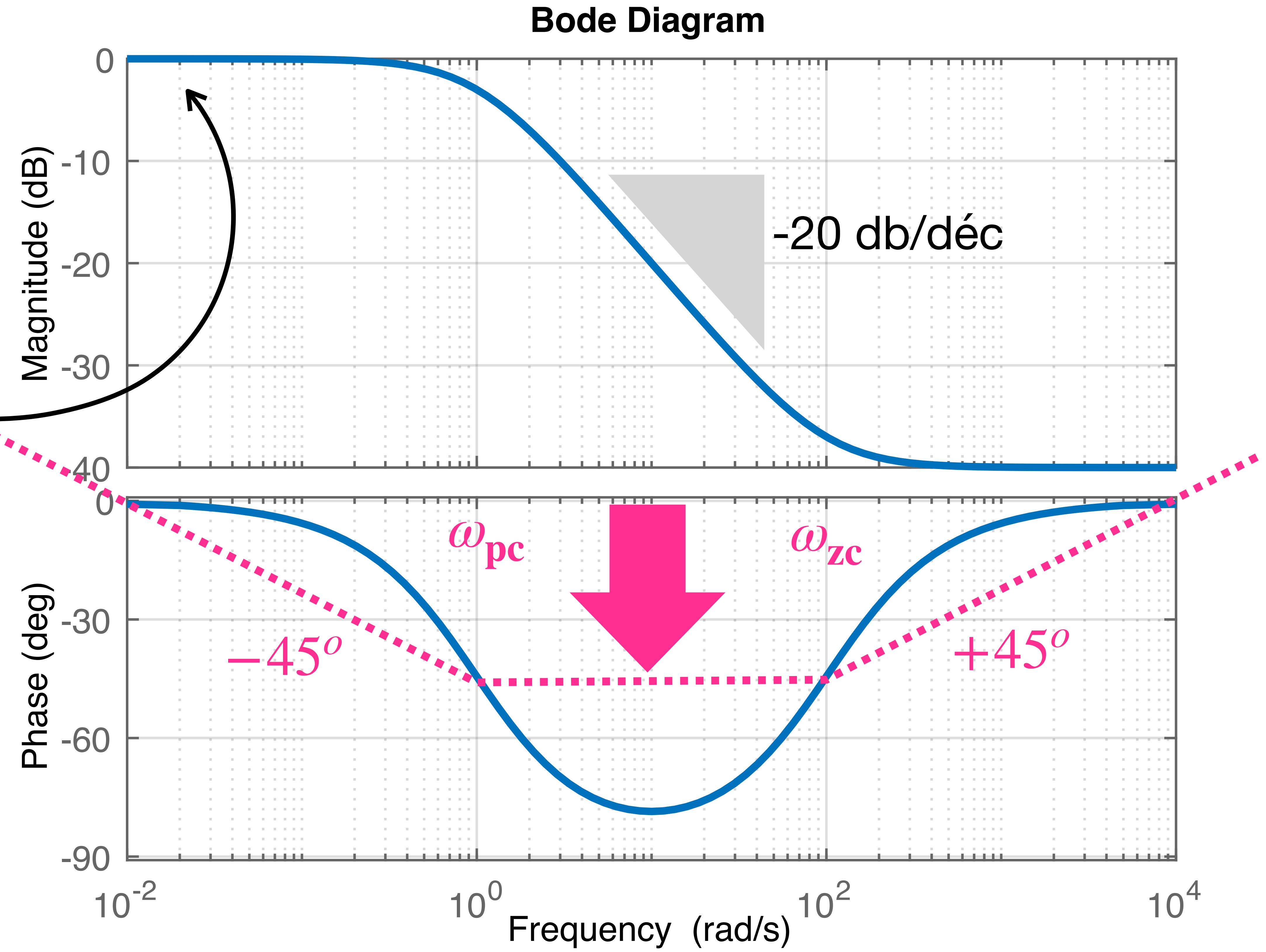

```
>> G_lag=tf((1/100)*[1 100],[1 1]);
>> zpk(G_lag)

ans =

  0.01 (s+100)
  ------------
     (s+1)

Continuous-time zero/pole/gain model.

>> figure; bode(G_lag)
```



Vantagens:
- **Melhora resposta do Lead:** $e(\infty)\downarrow$ **;**
- **Mas diminui margem de fase,** $\Phi_M \downarrow$ **;**
- **a relação:** $\frac{\textbf{zero}}{\textbf{pólo}} \propto K_p, K_v, K_a$ **;**
- **Faixa baixa de frequências…**

Controlador Lead-Lag

- Efeito

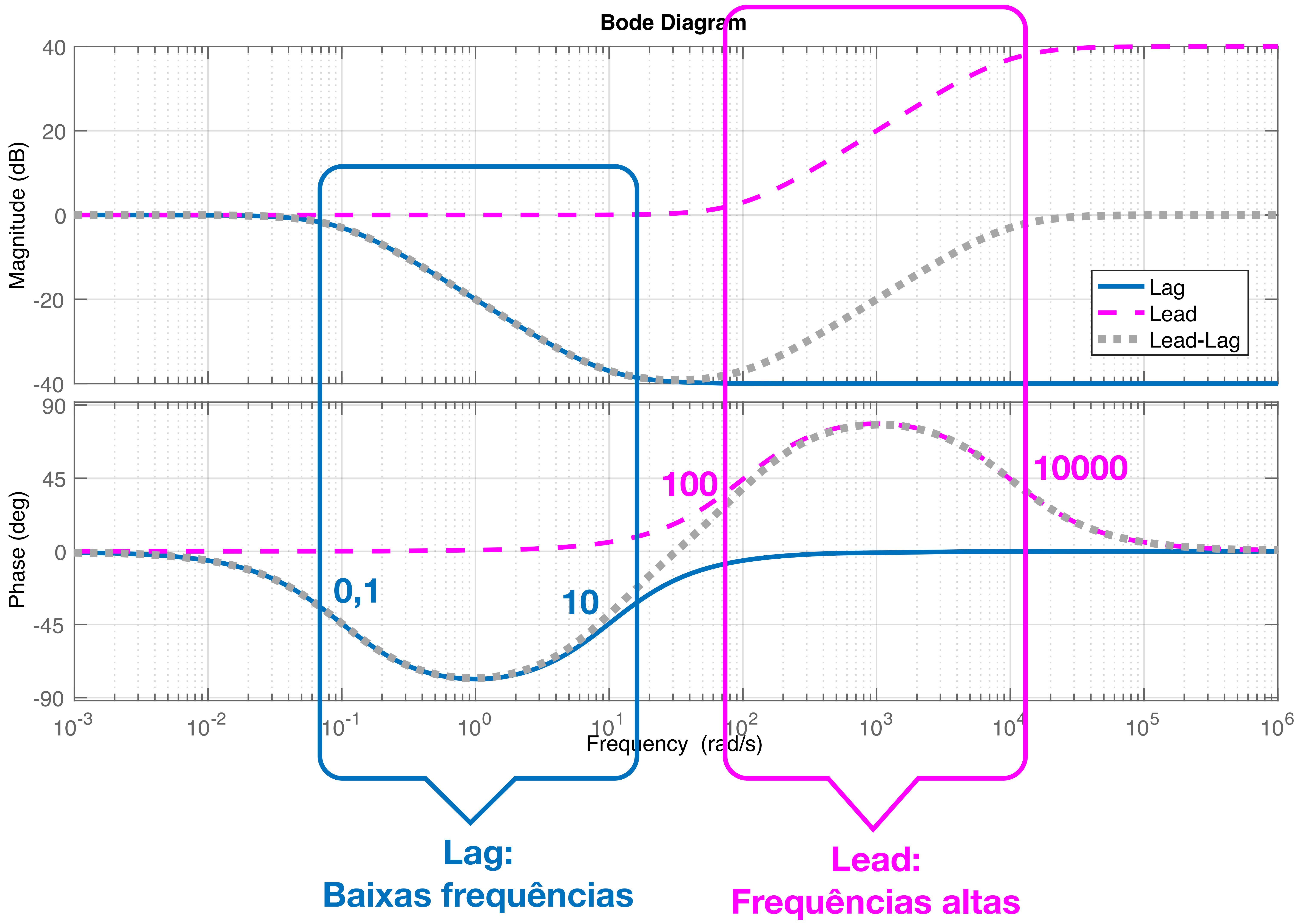
```
>> G_lag=tf((0.1/10)*[1 10],[1 0.1]);
>> zpk(G_lag)

  0.01 (s+10)
  -----------
    (s+0.1)

>> G_lead=tf((10000/100)*[1 100],[1 10000])
>> zpk(G_lead)

  100 (s+100)
  -----------
   (s+1e04)

>> C=G_lag*G_lead;
>> figure; bode(G_lag, G_lead, C)
>> legend('Lag', 'Lead', 'Lead-Lag')
>> grid
```



Controlador Lag (Atraso de Fase)

- Efeito:

Objetivos:

1. **Reduzir** $e(\infty) \downarrow$
2. **Aumentar** $\Phi_M \uparrow \Rightarrow$ **adequar** $\% OS$, t_s , ζ

Passos:

1) **Aumentar K;**
2) **Encontrar** Φ_M **(ou** P_M**)**
3) **Ajustar** p_C **e** z_c **para alcançar** Φ_m **desejado**
4) **Voltar a ajustar K para compensar alguma queda (variação) trazida pelo compensador.**

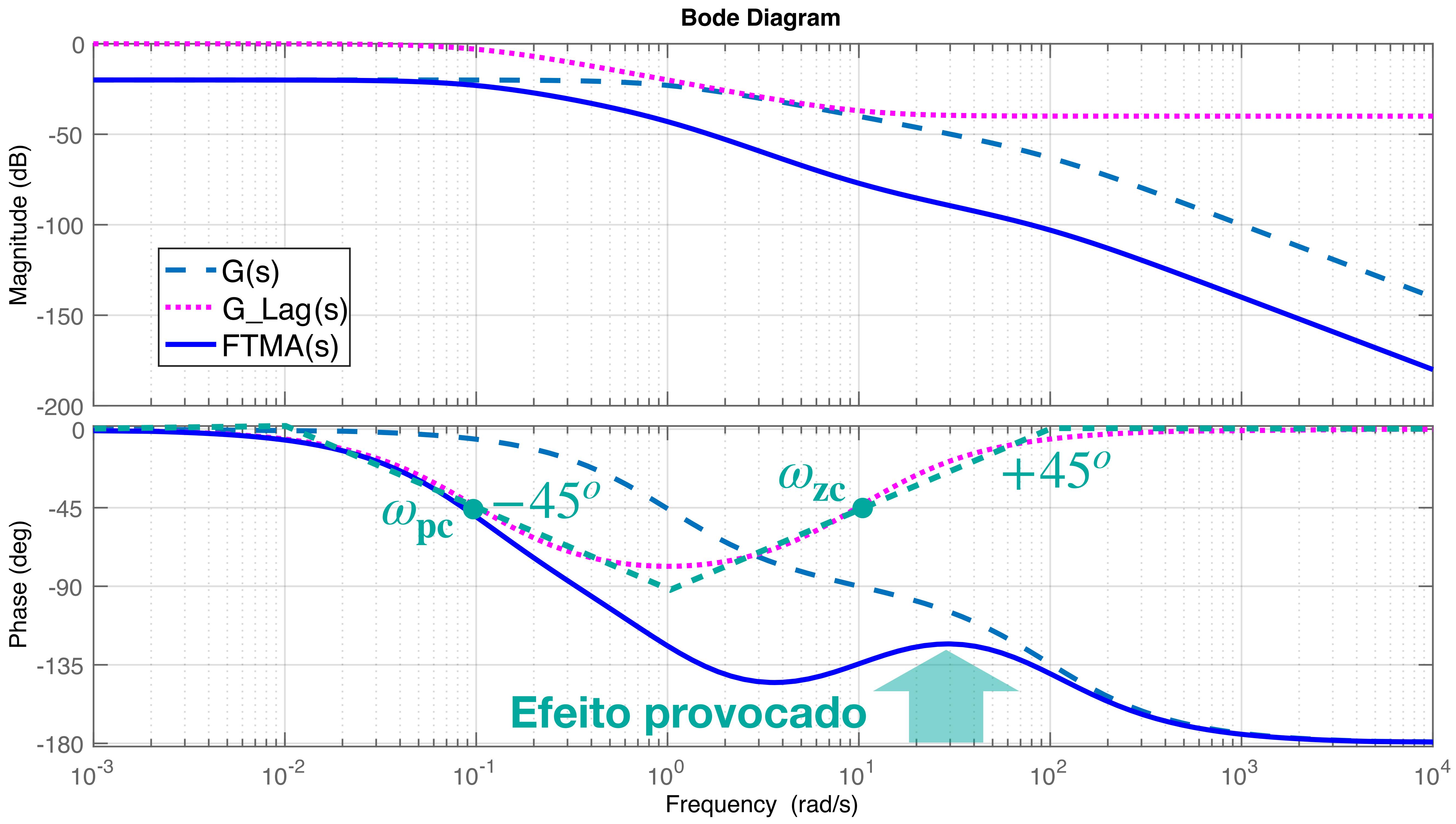
```
>> G=tf(10,poly([-1 -100]));
>> G_lag=tf((0.1/10)*[1 10],[1 0.1]);
>> ftma=G_lag*G;
>> figure; bode(G, G_lag, ftma)
>> zpk(G)

      10
  -------------
  (s+100) (s+1)

>> zpk(G_lag)

  0.01 (s+10)
  -----------
    (s+0.1)

>>
```



Região de interesse:

Reduz fase da planta, aumentando margem de fase, Φ_M