TEHNIČKO VELEUČILIŠTE U ZAGREBU
ZAGREB UNIVERSITY OF APPLIED SCIENCES
POLYTECHNICUM ZAGRABIENSE

Stručni prijediplomski studij Mehatronika

Upravljanje i regulacija

Sinteza standardnih regulacijskih sustava

dr. sc. tech. Toni Bjažić, prof. struč. stud.

Sadržaj

- Uvod
- Izbor strukture regulatora
- Podešavanje parametara regulatora
- Korekcija pojačanja regulatora i zahvati u grani referentne veličine
- Primjer sinteze kaskadnog regulacijskog sustava elektromotornog pogona
- Primjer sinteze sustava regulacije razine tekućine u spregnutim spremnicima

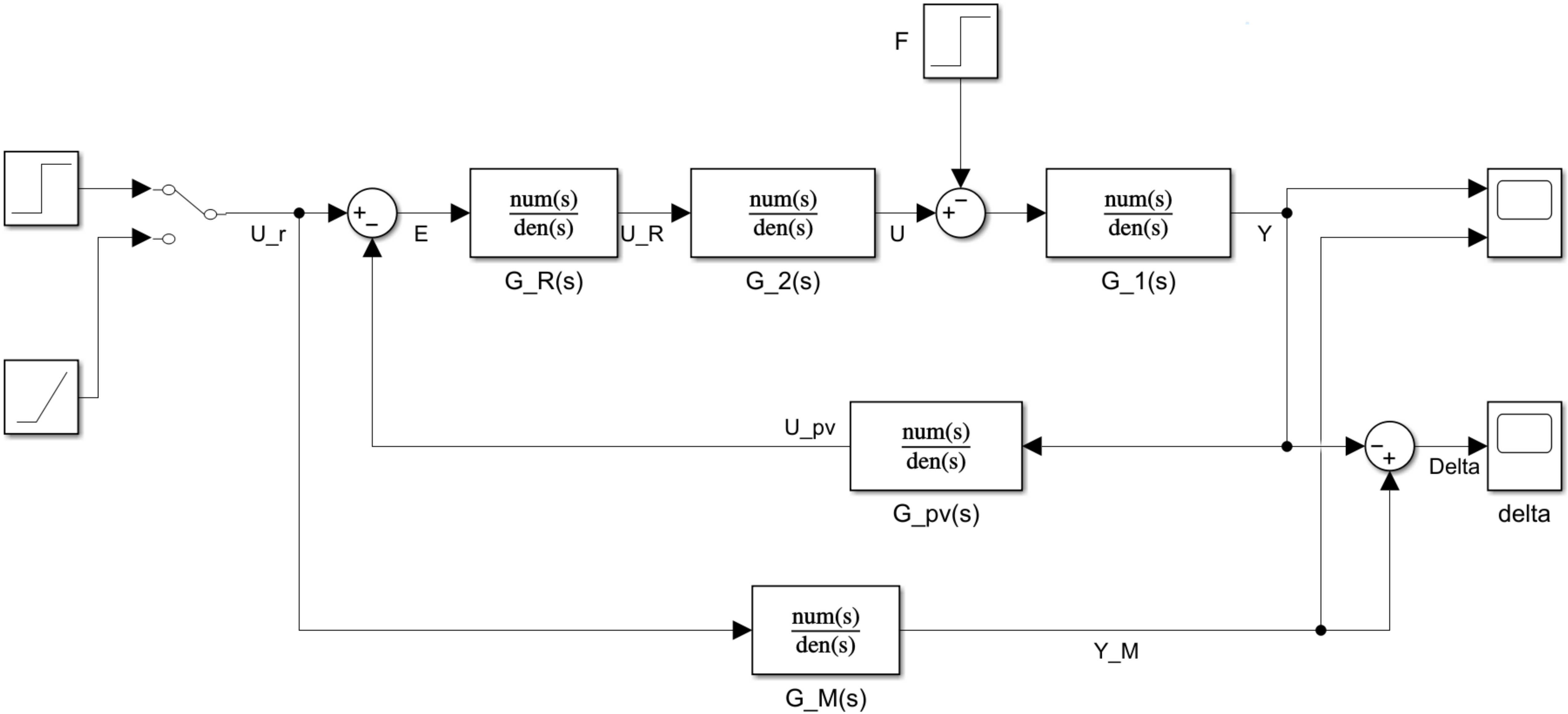
Uvod

- Sinteza sustava automatskog upravljanja podrazumijeva:
  - izbor strukture sustava i regulatora
  - parametara regulatora kojima se postižu zadani pokazatelji kvalitete upravljanja.
- Osnovni elementi sustava, izvršni element, pojačalo snage i mjerni elementi, biraju se prema tehničkim zahtjevima na sustav.
- Prijenosne funkcije i parametri osnovnih elemenata smatraju se poznatima i ne mogu se podešavati.
- Prijenosna funkcija i parametri regulatora obično se određuju prema:
  - zadanoj pogrešci u ustaljenom stanju i
  - zadanom nadvišenju odziva zatvorenog sustava.

Izbor strukture regulatora

- Zahtjevi na regulacijske sustave obično se svode na:
  - što bolju i bržu kompenzaciju poremećajne veličine i
  - što brži odziv u odnosu na referentnu veličinu, uz ograničeno maksimalno nadvišenje odziva i malu oscilatornost.
- Potpuna kompenzacija poremećajne veličine ili statička pogreška u odnosu na poremećajnu veličinu $\delta_{fs} = 0$ postiže se ukoliko prijenosna funkcija otvorenog kruga s regulatorom $G_{oR}(s)$ ima astatizam prvog ($r = 1$) ili drugog ($r = 2$) reda te ako se astatizam nalazi u regulatoru.
- Pri tome će i statička pogreška u odnosu na referentnu veličinu biti jednaka nuli ($\delta_{us} = 0$).
- Manja kinetička pogreška (δ_{uk}), bolja po iznosu kompenzacija poremećaja i što brži odziv u odnosu na referentnu veličinu postižu se uz što veći iznos koeficijenta pojačanja otvorenog kruga s regulatorom K_{oR}, nauštrb povećanja nadvišenja i oscilatornosti odziva.

Tipična struktura regulacijskog sustava



- Prijenosna funkcija objekta upravljanja $G_1(s)$ može biti:
  - statička (pojačanje s usporenjem prvog, drugog ili višeg reda) ili
  - astatička s astatizmom prvog ili drugog reda i/ili usporenjem prvog ili višeg reda
- Prijenosna funkcija pojačala snage i izvršnog uređaja $G_2(s)$ tipično se modelira kao prijenosna funkcija proporcionalnog elementa s usporenjem prvog ili rjeđe drugog reda.
- Prijenosna funkcija povratne veze $G_{pv}(s)$ tipično se modelira kao prijenosna funkcija proporcionalnog elementa s usporenjem prvog reda.

Sinteza regulacijskog sustava sa statičkim procesom

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{1 + T_1 s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

Sinteza regulacijskog sustava sa statičkim procesom

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{1 + T_1 s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

Sinteza regulacijskog sustava sa statičkim procesom

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{1 + T_1 s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{1 + T_1 s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

Sinteza regulacijskog sustava sa statičkim procesom

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{1 + T_1 s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{1 + T_1 s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

Sinteza regulacijskog sustava sa statičkim procesom

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{1 + T_1 s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{1 + T_1 s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

- Budući da proces nema astatizma ($r = 0$), nužno je izabrati regulator s integracijskim ponašanjem (astatizmom) da se dobije red astatizma otvorenog kruga s regulatorom $r = 1$.
- Ne izabire se samo I regulator, nego se dodaje i P komponenta radi ubrzanja odziva, smanjenja kinetičke pogreške i bolje kompenzacije poremećaja: PI regulator!

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- Uz postignut red astatizma $r = 1$ zadovoljeni su zahtjevi za potpunom kompenzacijom poremećajne veličine ($\delta_{fs} = 0$) te za statičkom pogreškom u odnosu na referentnu veličinu jednakoj nuli ($\delta_{us} = 0$).

Podešavanje parametara regulatora

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)} \qquad K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- U prijenosnoj funkciji otvorenog kruga s regulatorom $G_{oR}(s)$ nepoznati su parametri K_{oR} i T_I.
- Prvo se odabire integracijska vremenska konstanta regulatora T_I, pri čemu se u praksi koriste dva pristupa:
  - tehnički optimum ili kompenzacija najveće vremenske konstante: $T_I = T_1$
  - simetrični optimum: $T_1 > T_I > \max(T_2, T_{pv})$

Tehnički optimum

Tehnički optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da bude jednaka najvećoj vremenskoj konstanti sustava.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks t.

Tehnički optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da bude jednaka najvećoj vremenskoj konstanti sustava.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *t*.

$$T_{It} = T_1$$

Tehnički optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da bude jednaka najvećoj vremenskoj konstanti sustava.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *t*.

$$T_{It} = T_1$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1 + T_{It}s}{T_{It}s}$$

Tehnički optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da bude jednaka najvećoj vremenskoj konstanti sustava.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *t*.

$$T_{It} = T_1$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1 + T_{It}s}{T_{It}s}$$

$$G_{oRt}(s) = K_{oRt} \cdot \frac{\cancel{1 + T_{It}s}}{s\,\cancel{(1 + T_1 s)}\,(1 + T_2 s)\,(1 + T_{pv} s)}$$

Tehnički optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da bude jednaka najvećoj vremenskoj konstanti sustava.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *t*.

$$T_{It} = T_1$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1 + T_{It}s}{T_{It}s}$$

$$G_{oRt}(s) = K_{oRt} \cdot \frac{\cancel{1 + T_{It}s}}{s\left(\cancel{1 + T_1 s}\right)\left(1 + T_2 s\right)\left(1 + T_{pv} s\right)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s\left(1 + T_2 s\right)\left(1 + T_{pv} s\right)}$$

Tehnički optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da bude jednaka najvećoj vremenskoj konstanti sustava.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *t*.

$$T_{It} = T_1$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1 + T_{It}s}{T_{It}s}$$

$$G_{oRt}(s) = K_{oRt} \cdot \frac{\cancel{1 + T_{It}s}}{s\left(\cancel{1 + T_1 s}\right)\left(1 + T_2 s\right)\left(1 + T_{pv}s\right)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s\left(1 + T_2 s\right)\left(1 + T_{pv}s\right)}$$

$$K_{oRt} = \frac{K_{Rt} \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_{It}}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+T_2 s)(1+T_{pv} s)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+T_2 s)(1+T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRt}(s)$ nepoznat je samo koeficijent pojačanja K_{oRt}.
- Budući da je $K_{oRt} > 0$, ne utječe na fazno-frekvencijsku karakteristiku i može se nacrtati njena aproksimacija pravcima.
- Iz zadanog nadvišenja odziva σ_m računa se potrebno fazno osiguranje γ korištenjem empirijske relacije:

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRt}(s)$ nepoznat je samo koeficijent pojačanja K_{oRt}.
- Budući da je $K_{oRt} > 0$, ne utječe na fazno-frekvencijsku karakteristiku i može se nacrtati njena aproksimacija pravcima.
- Iz zadanog nadvišenja odziva σ_m računa se potrebno fazno osiguranje γ korištenjem empirijske relacije:

$$\sigma_m[\%] + \gamma[^\circ] \approx 60$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+T_2 s)(1+T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRt}(s)$ nepoznat je samo koeficijent pojačanja K_{oRt}.
- Budući da je $K_{oRt} > 0$, ne utječe na fazno-frekvencijsku karakteristiku i može se nacrtati njena aproksimacija pravcima.
- Iz zadanog nadvišenja odziva σ_m računa se potrebno fazno osiguranje γ korištenjem empirijske relacije:

$$\sigma_m[\%] + \gamma[^\circ] \approx 60$$

- Time je poznata i presječna frekvencija na kojoj se očitava fazno osiguranje:

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+T_2 s)(1+T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRt}(s)$ nepoznat je samo koeficijent pojačanja K_{oRt}.
- Budući da je $K_{oRt} > 0$, ne utječe na fazno-frekvencijsku karakteristiku i može se nacrtati njena aproksimacija pravcima.
- Iz zadanog nadvišenja odziva σ_m računa se potrebno fazno osiguranje γ korištenjem empirijske relacije:

$$\sigma_m[\%] + \gamma[°] \approx 60$$

- Time je poznata i presječna frekvencija na kojoj se očitava fazno osiguranje:

$$\gamma[°] = 180° + \varphi(\omega_c)$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+T_2 s)(1+T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRt}(s)$ nepoznat je samo koeficijent pojačanja K_{oRt}.
- Budući da je $K_{oRt} > 0$, ne utječe na fazno-frekvencijsku karakteristiku i može se nacrtati njena aproksimacija pravcima.
- Iz zadanog nadvišenja odziva σ_m računa se potrebno fazno osiguranje γ korištenjem empirijske relacije:

$$\sigma_m\,[\%] + \gamma\,[^\circ] \approx 60$$

- Time je poznata i presječna frekvencija na kojoj se očitava fazno osiguranje:

$$\gamma\,[^\circ] = 180^\circ + \varphi(\omega_c)$$

- Vrijeme prvog maksimuma procjenjuje se iz presječne frekvencije:

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+T_2 s)(1+T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRt}(s)$ nepoznat je samo koeficijent pojačanja K_{oRt}.
- Budući da je $K_{oRt} > 0$, ne utječe na fazno-frekvencijsku karakteristiku i može se nacrtati njena aproksimacija pravcima.
- Iz zadanog nadvišenja odziva σ_m računa se potrebno fazno osiguranje γ korištenjem empirijske relacije:

$$\sigma_m[\%] + \gamma[^\circ] \approx 60$$

- Time je poznata i presječna frekvencija na kojoj se očitava fazno osiguranje:

$$\gamma[^\circ] = 180^\circ + \varphi(\omega_c)$$

- Vrijeme prvog maksimuma procjenjuje se iz presječne frekvencije:

$$t_m \approx \frac{3}{\omega_c}$$

- Pristupa se crtanju amplitudno-frekvencijske karakteristike.
- I dalje je nepoznat K_{oRt}, ali poznata je presječna frekvencija ω_c i sve lomne frekvencije i nagibi karakteristike u pojedinim područjima određenim lomnim frekvencijama.
- Ucrtava se prvi pravac kroz presječnu frekvenciju ω_c i nakon toga ostatak karakteristike.
- Zatim se očitava dobiveni K_{oRt} na nagibu -1 ili njegovom produžetku do točke u kojoj amplitudna karakteristika siječe od 0 dB.

- Pristupa se crtanju amplitudno-frekvencijske karakteristike.
- I dalje je nepoznat K_{oRt}, ali poznata je presječna frekvencija ω_c i sve lomne frekvencije i nagibi karakteristike u pojedinim područjima određenim lomnim frekvencijama.
- Ucrtava se prvi pravac kroz presječnu frekvenciju ω_c i nakon toga ostatak karakteristike.
- Zatim se očitava dobiveni K_{oRt} na nagibu -1 ili njegovom produžetku do točke u kojoj amplitudna karakteristika siječe od 0 dB.

- Konačno, koeficijent pojačanja regulatora K_{Rt} računa se prema:

- Pristupa se crtanju amplitudno-frekvencijske karakteristike.
- I dalje je nepoznat K_{oRt}, ali poznata je presječna frekvencija ω_c i sve lomne frekvencije i nagibi karakteristike u pojedinim područjima određenim lomnim frekvencijama.
- Ucrtava se prvi pravac kroz presječnu frekvenciju ω_c i nakon toga ostatak karakteristike.
- Zatim se očitava dobiveni K_{oRt} na nagibu -1 ili njegovom produžetku do točke u kojoj amplitudna karakteristika siječe od 0 dB.

- Konačno, koeficijent pojačanja regulatora K_{Rt} računa se prema:

$$K_{Rt} = \frac{K_{oRt} \cdot T_{It}}{K_1 \cdot K_2 \cdot K_{pv}}$$

Korekcija pojačanja regulatora i zahvati u grani referentne veličine

Korekcija pojačanja regulatora i zahvati u grani referentne veličine

- Nakon izvođenja simulacije s izračunatim parametrima regulatora koeficijent pojačanja regulatora K_{Rt} može se dodatno korigirati kako bi se ostvarilo željeno maksimalno nadvišenje odziva σ_m.
- Pri tome se preporuča postaviti zadano nadvišenje pri projektiranju regulatora na nešto veću vrijednost od konačne željene vrijednosti kako bi se dobio veći koeficijent pojačanja, odnosno bolja kompenzacija poremećajne veličine.
- Primjer postavljanja inicijalnog zadanog nadvišenja s kojim se postiže kompromis između dobre kompenzacije poremećaja i male oscilatornosti odziva je σ_{mz} = 25%.
- Postavljanjem filtra prvog reda (PT_1) u granu referentne veličine i namještanjem vremenske konstante filtra može se nadvišenje spustiti na prihvatljivih 10% ili nižu vrijednost.
- Koeficijent pojačanja filtra može se postaviti na iznos K_{pv} kako bi se u bloku izvora reference izravno mogla namještati željena (referentna) vrijednost izlazne veličine.

Primjer 1

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

Primjer 1

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

Primjer 1

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$T_{It} = T_1 = 400 \text{ s}$$

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

Primjer 1

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$T_{It} = T_1 = 400 \text{ s}$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1+T_{It}s}{T_{It}s} = K_{Rt} \cdot \frac{1+400s}{400s}$$

Primjer 1

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$T_{It} = T_1 = 400 \text{ s}$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1+T_{It}s}{T_{It}s} = K_{Rt} \cdot \frac{1+400s}{400s}$$

$$G_{oRt}(s) = K_{Rt} \cdot \frac{\cancel{1+400s}}{400s} \cdot \frac{8}{\cancel{(1+400s)}(1+5s)(1+2s)}$$

Primjer 1

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$T_{It} = T_1 = 400 \text{ s}$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1+T_{It}s}{T_{It}s} = K_{Rt} \cdot \frac{1+400s}{400s}$$

$$G_{oRt}(s) = K_{Rt} \cdot \frac{\cancel{1+400s}}{400s} \cdot \frac{8}{\cancel{(1+400s)}(1+5s)(1+2s)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

Primjer 1

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$T_{It} = T_1 = 400 \text{ s}$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1+T_{It}s}{T_{It}s} = K_{Rt} \cdot \frac{1+400s}{400s}$$

$$G_{oRt}(s) = K_{Rt} \cdot \frac{\cancel{1+400s}}{400s} \cdot \frac{8}{\cancel{(1+400s)}(1+5s)(1+2s)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$K_{oRt} = \frac{K_{Rt} \cdot 8}{400} = \frac{K_{Rt}}{50}$$

Primjer 1

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$T_{It} = T_1 = 400 \text{ s}$$

$$G_{Rt}(s) = K_{Rt} \cdot \frac{1+T_{It}s}{T_{It}s} = K_{Rt} \cdot \frac{1+400s}{400s}$$

$$G_{oRt}(s) = K_{Rt} \cdot \frac{\cancel{1+400s}}{400s} \cdot \frac{8}{\cancel{(1+400s)}(1+5s)(1+2s)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$K_{oRt} = \frac{K_{Rt} \cdot 8}{400} = \frac{K_{Rt}}{50} \qquad K_{Rt} = 50 \cdot K_{oRt}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$G_{oRt}\left(s\right) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$0{,}1\omega_2 = 0{,}02\ \mathrm{rad/s}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$G_{oRt}\left(s\right) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$0{,}1\omega_2 = 0{,}02\ \mathrm{rad/s}$$

$$10\omega_2 = 2\ \mathrm{rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05\ \mathrm{rad/s}$$

$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$G_{oRt}\left(s\right) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

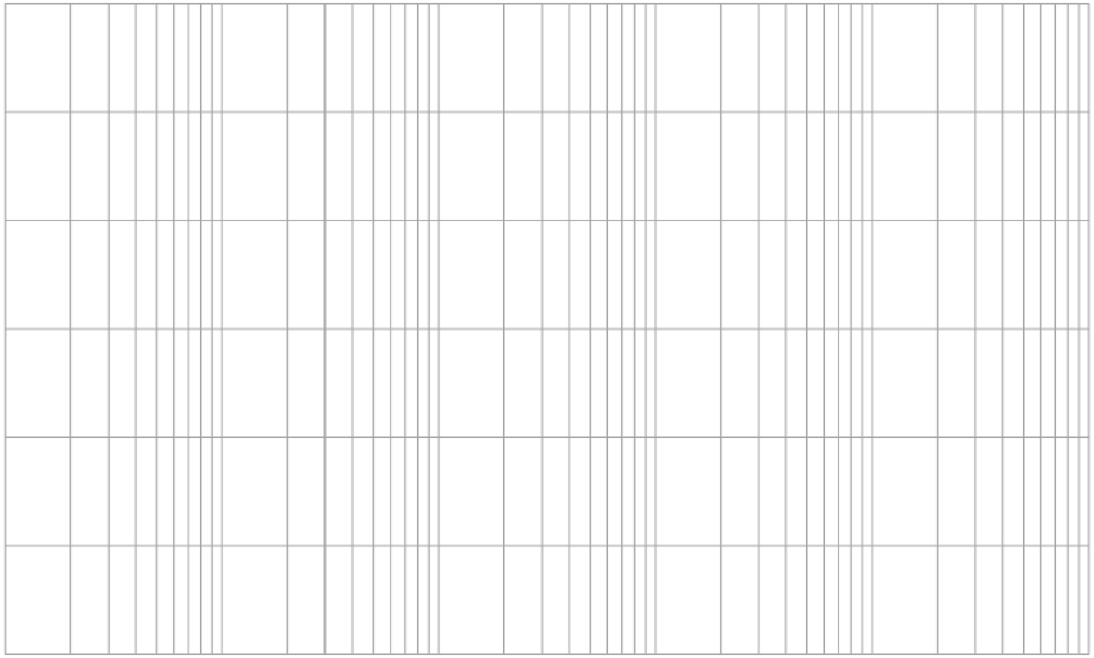
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

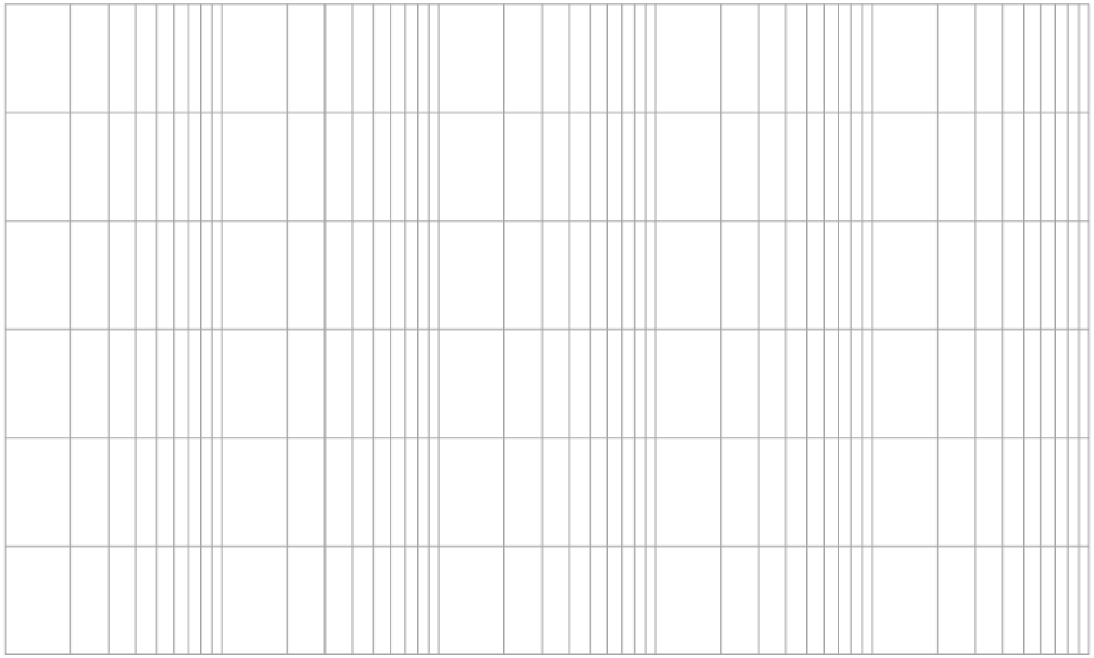
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

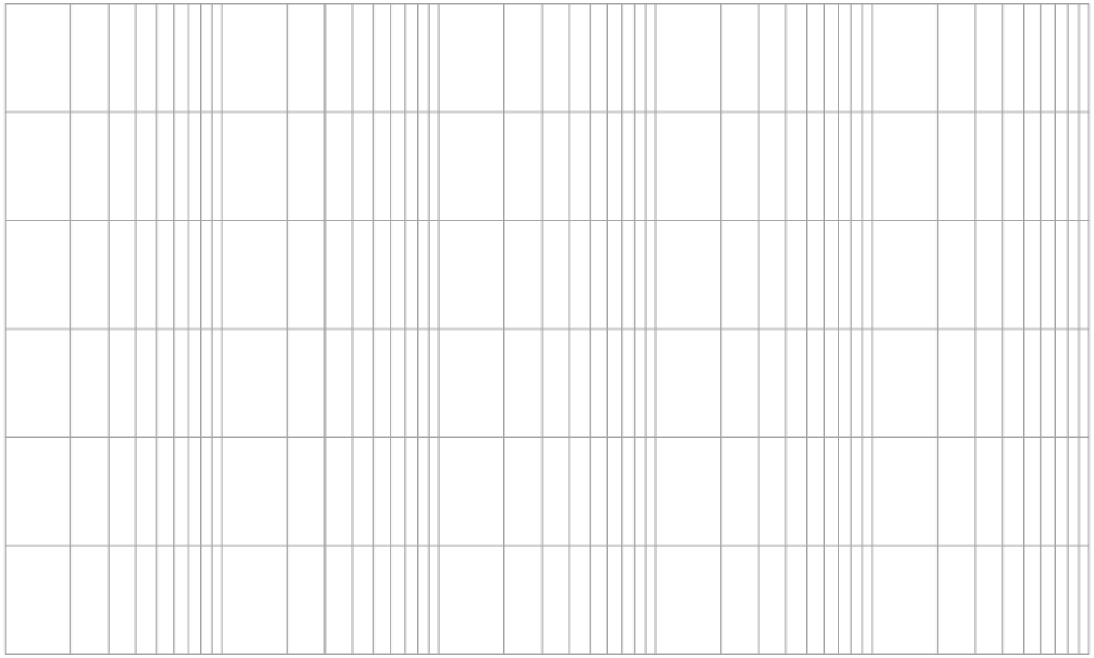
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

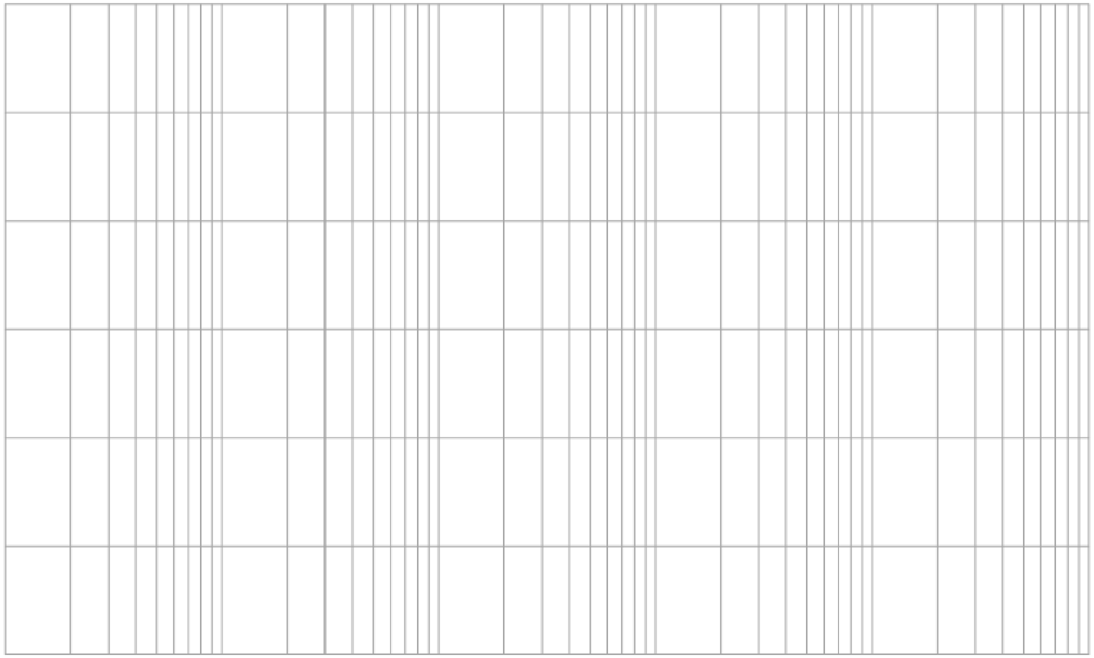
$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



ω [rad/s]



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

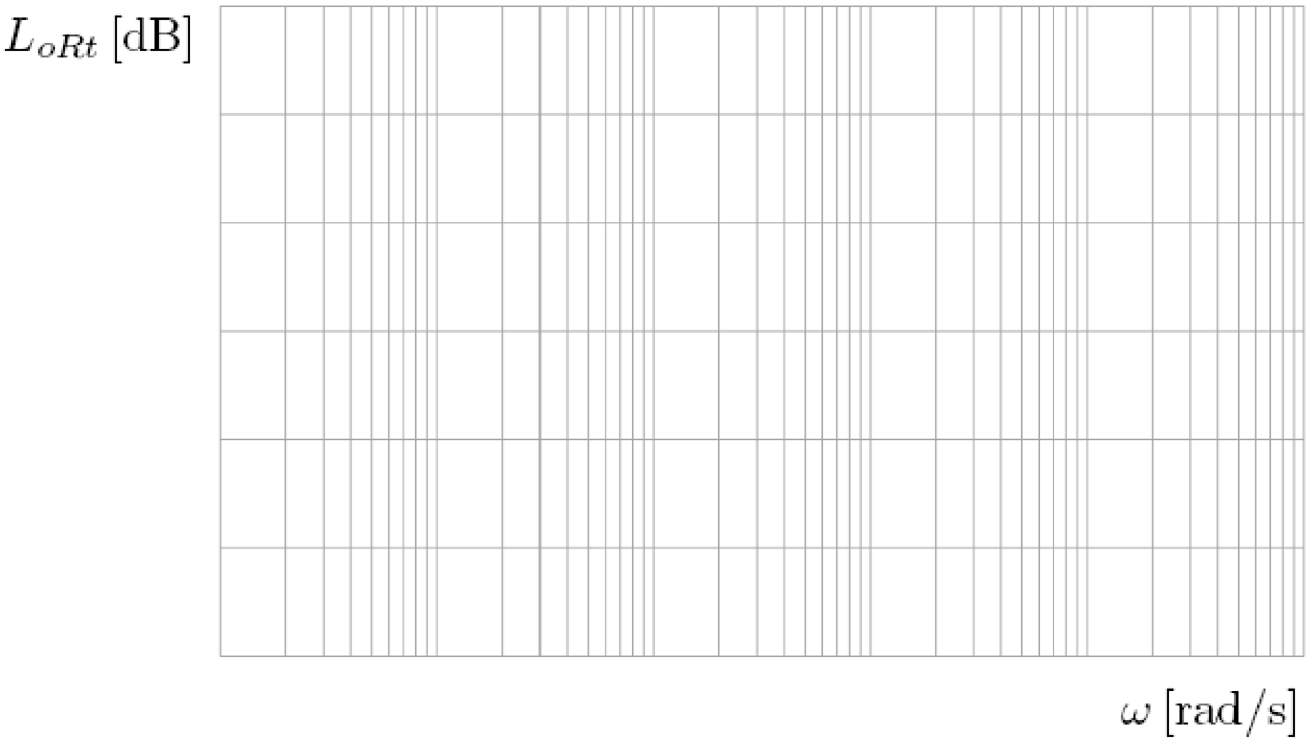
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

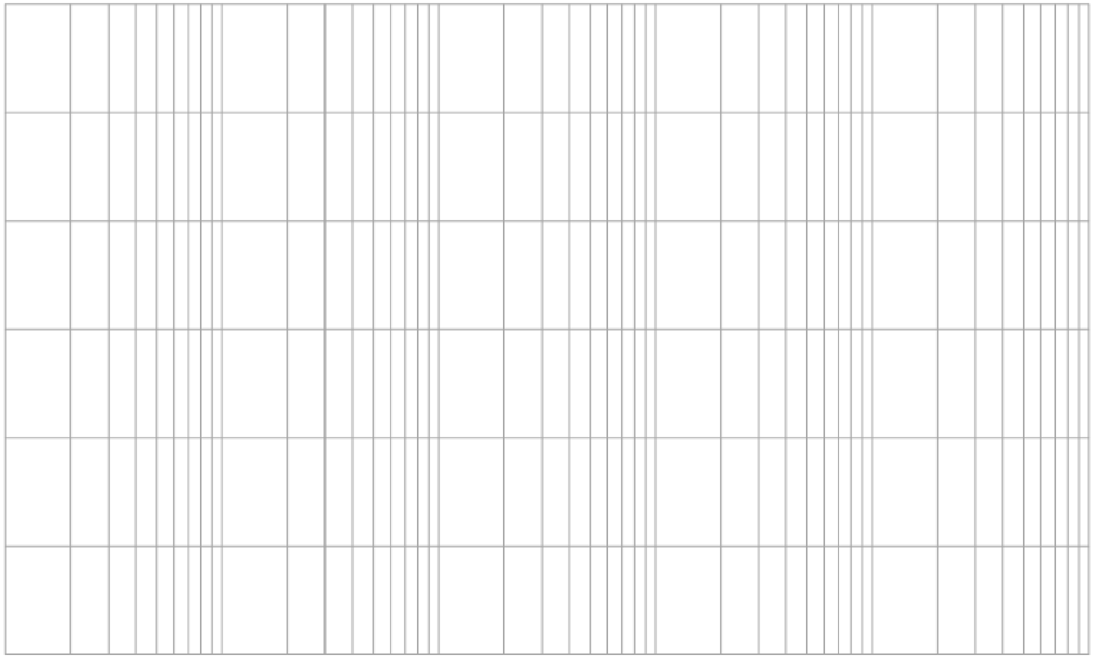
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

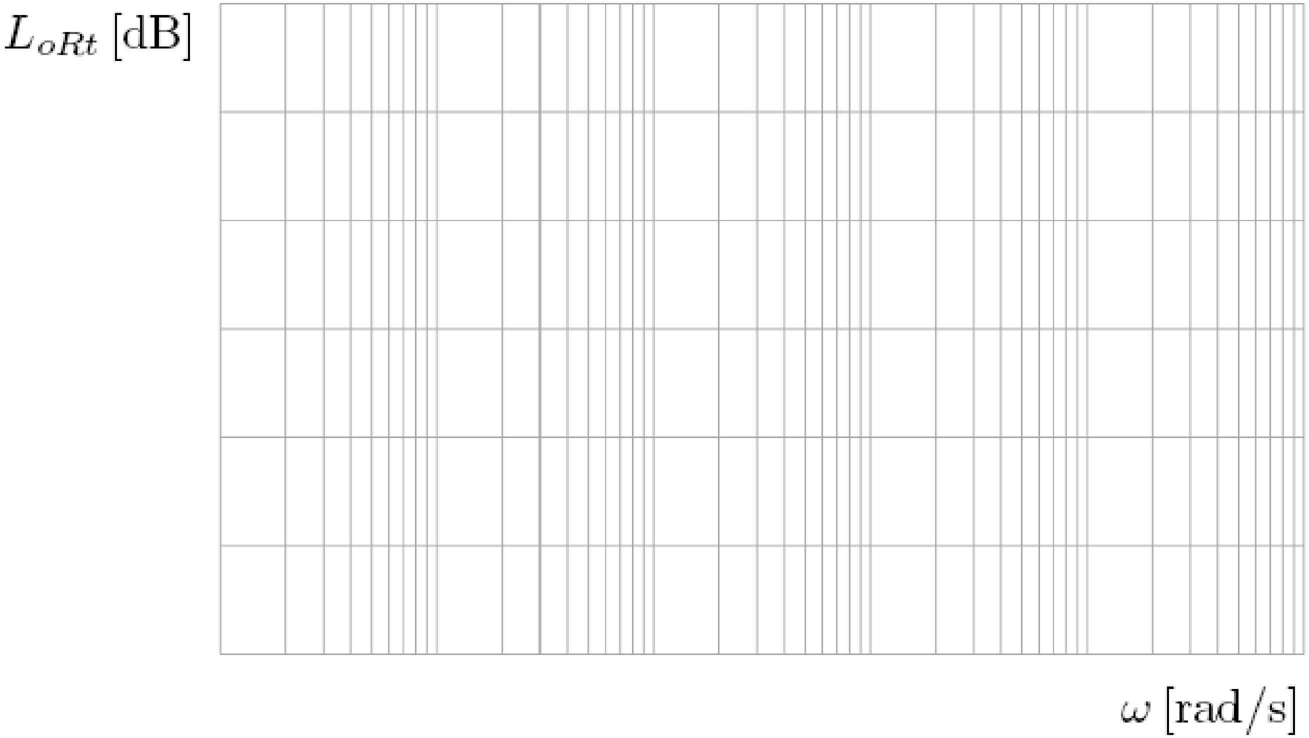
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

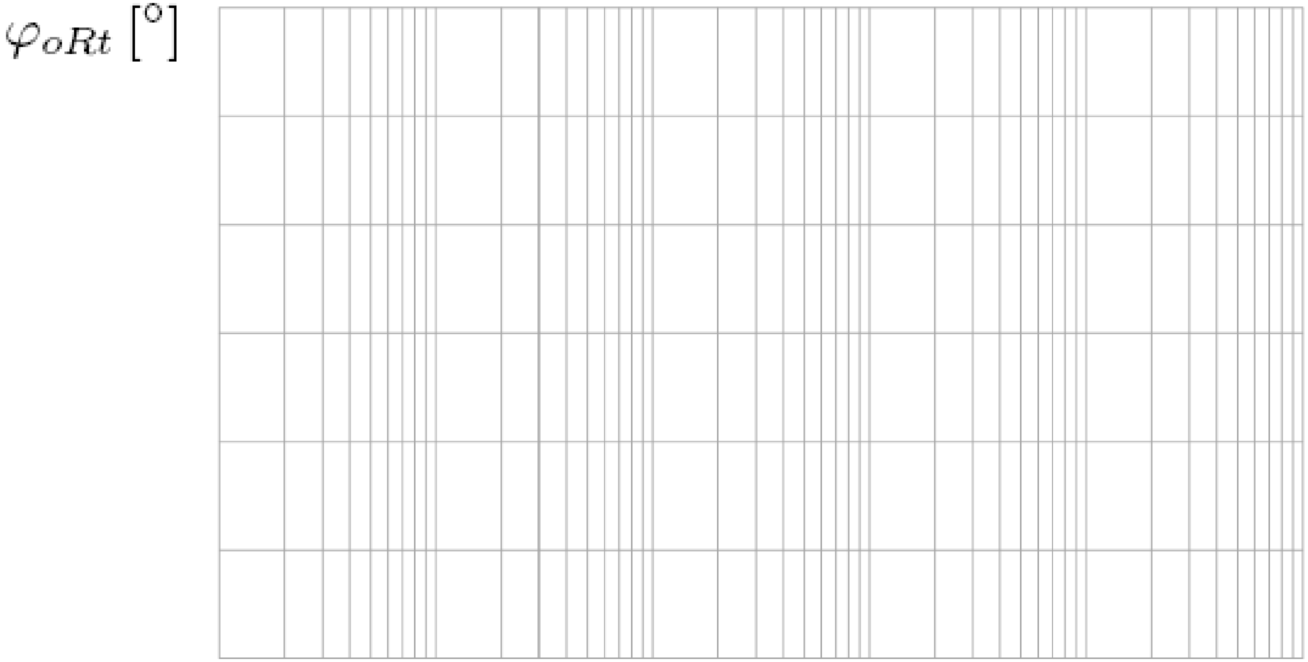
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

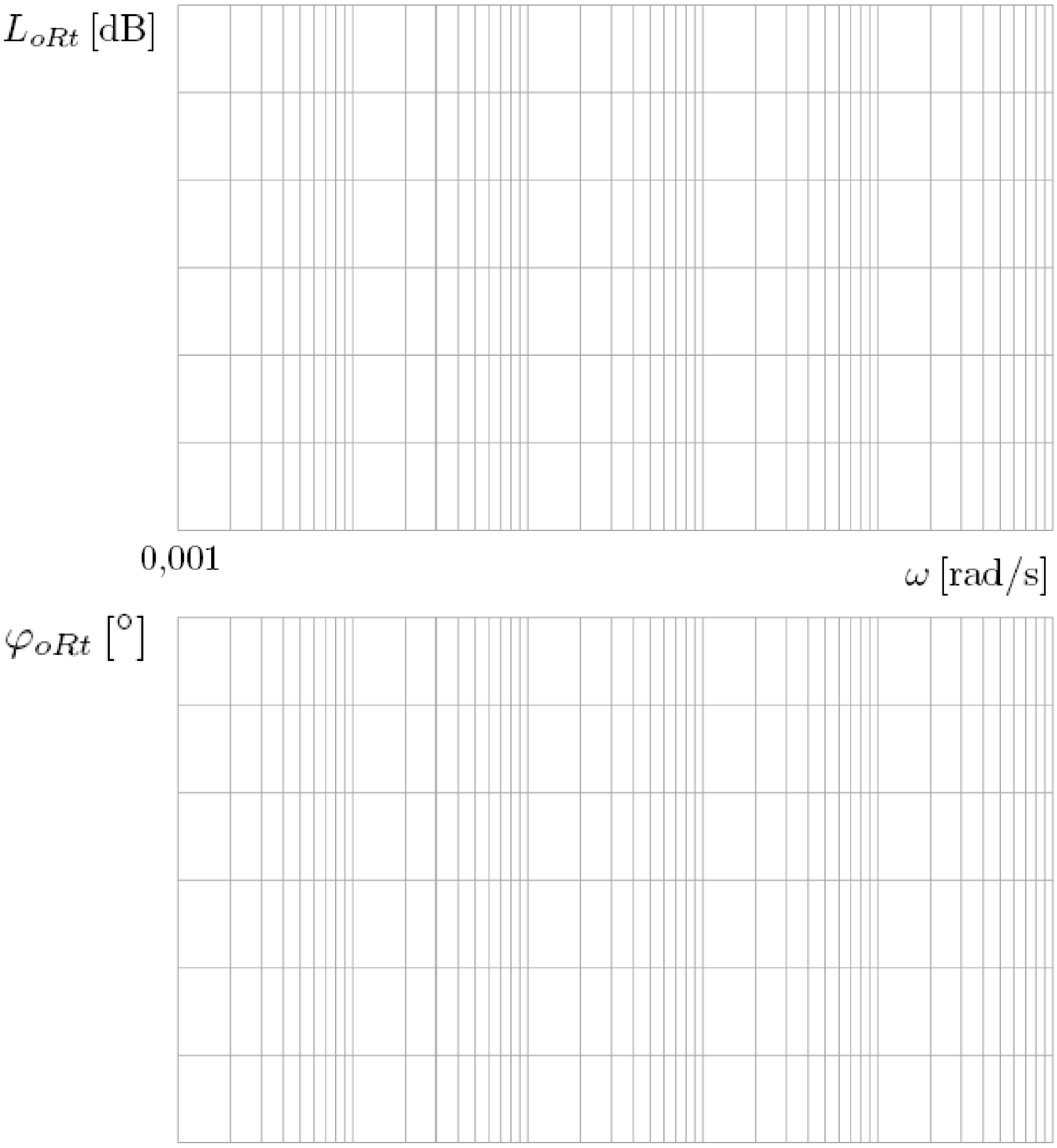
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

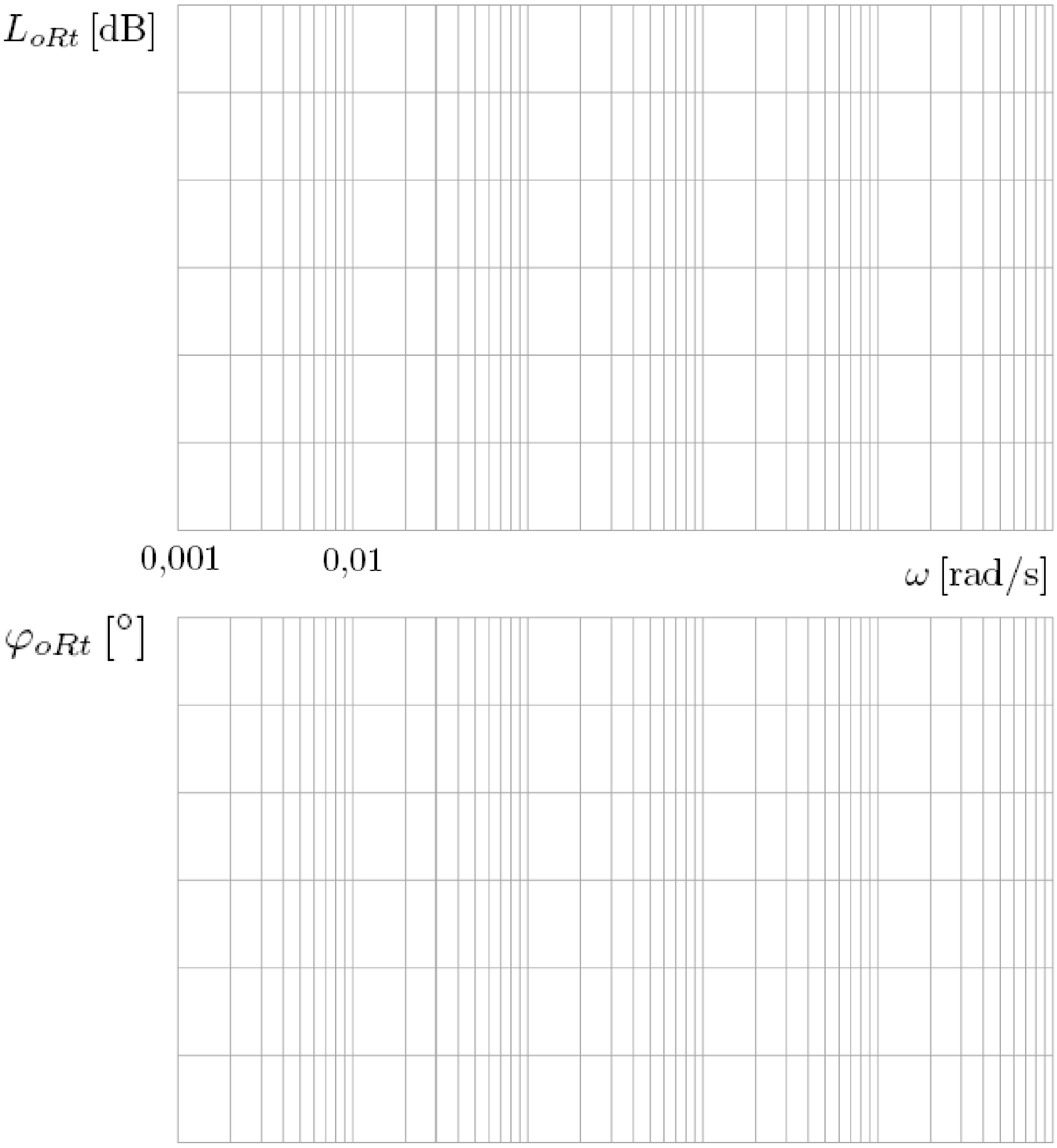
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

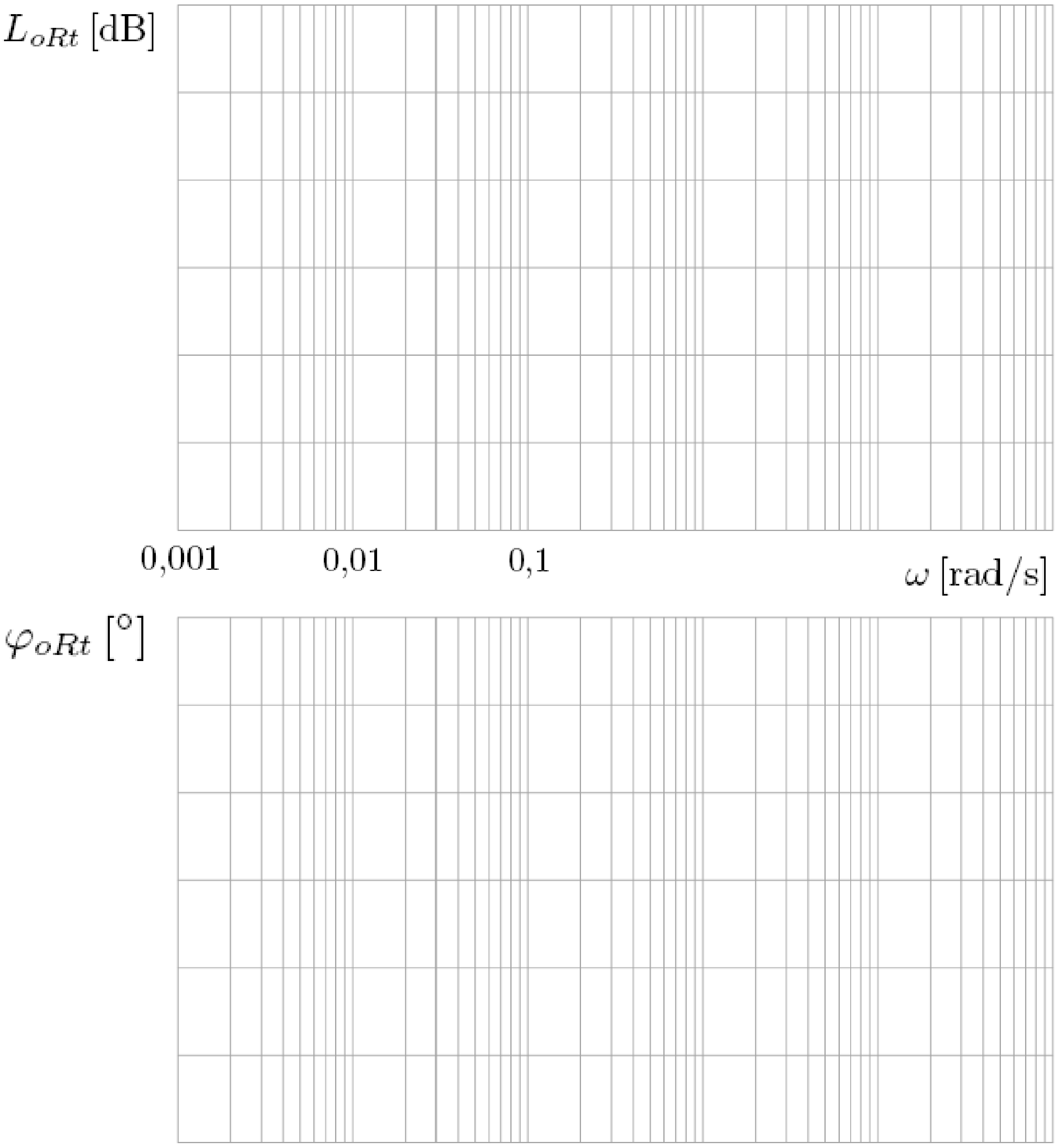
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

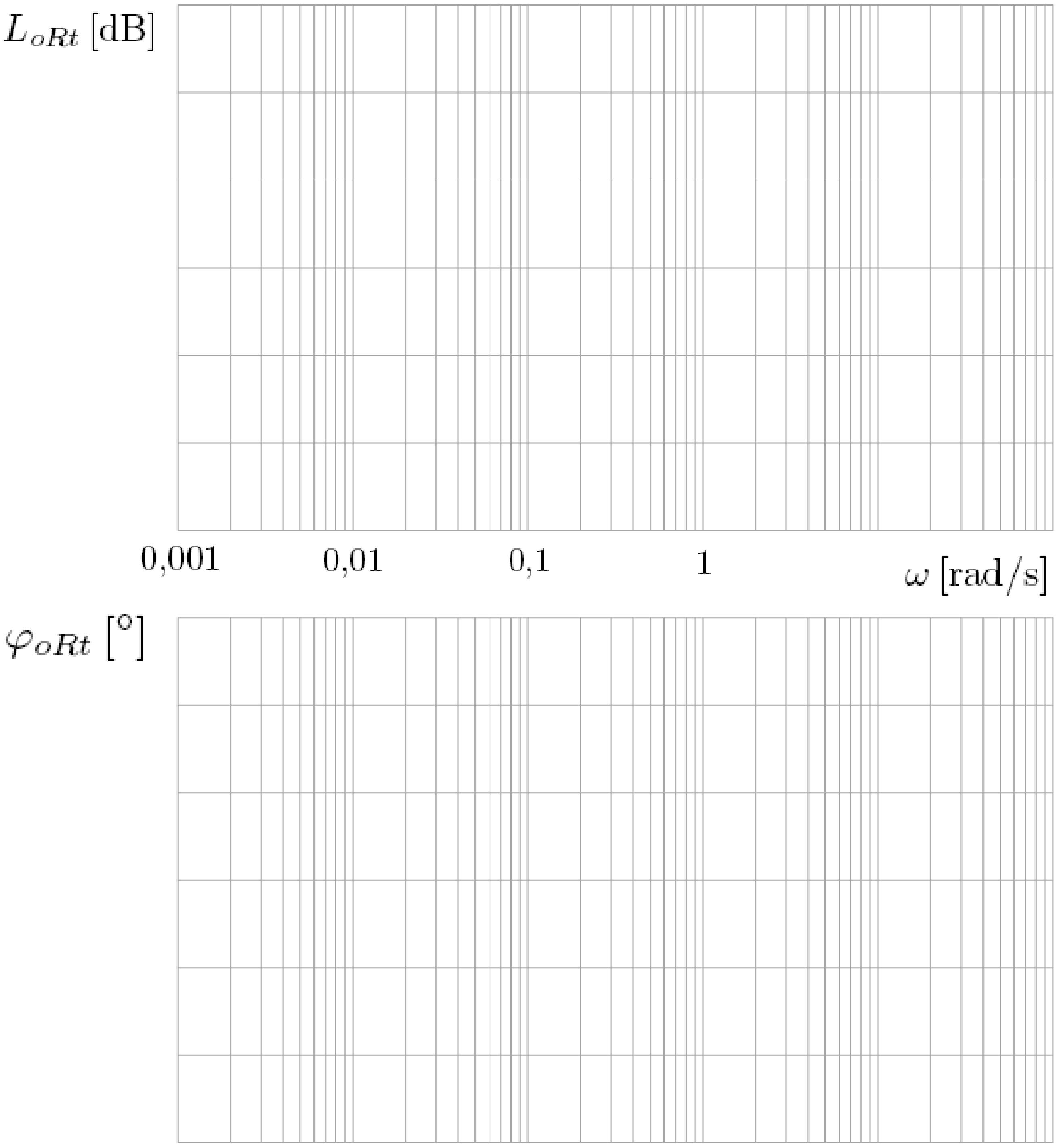
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

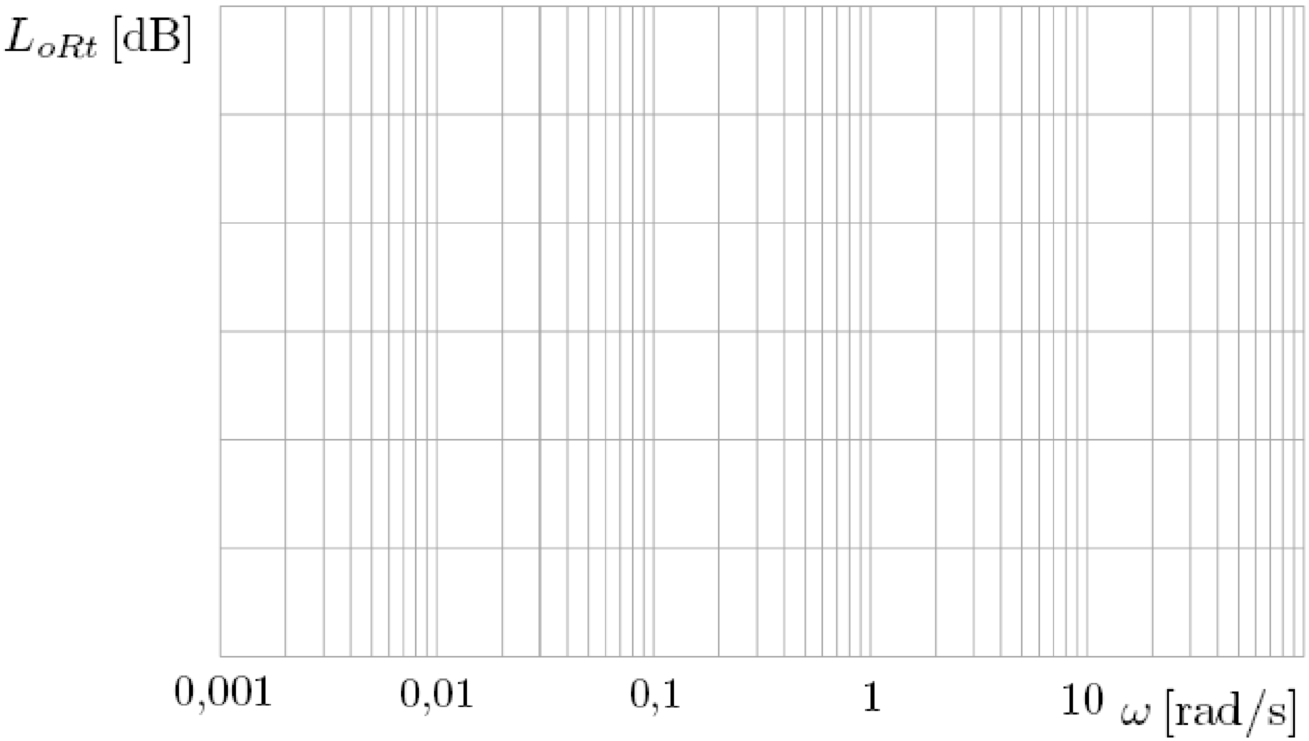
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

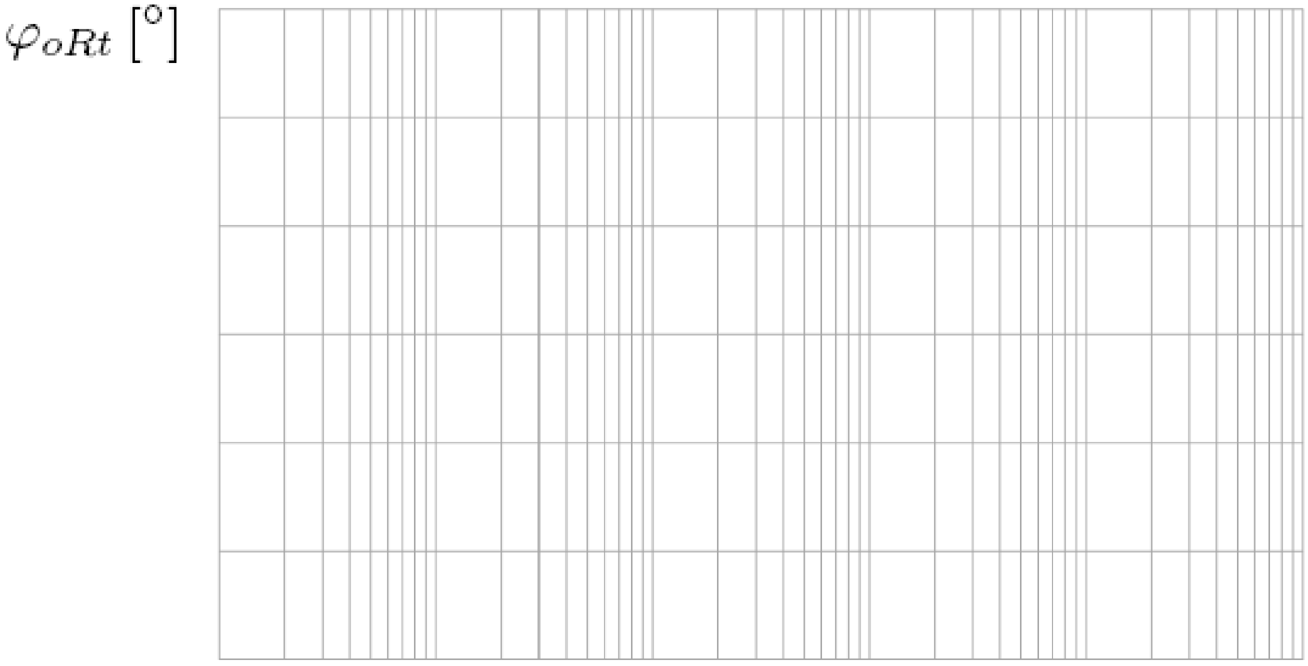
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

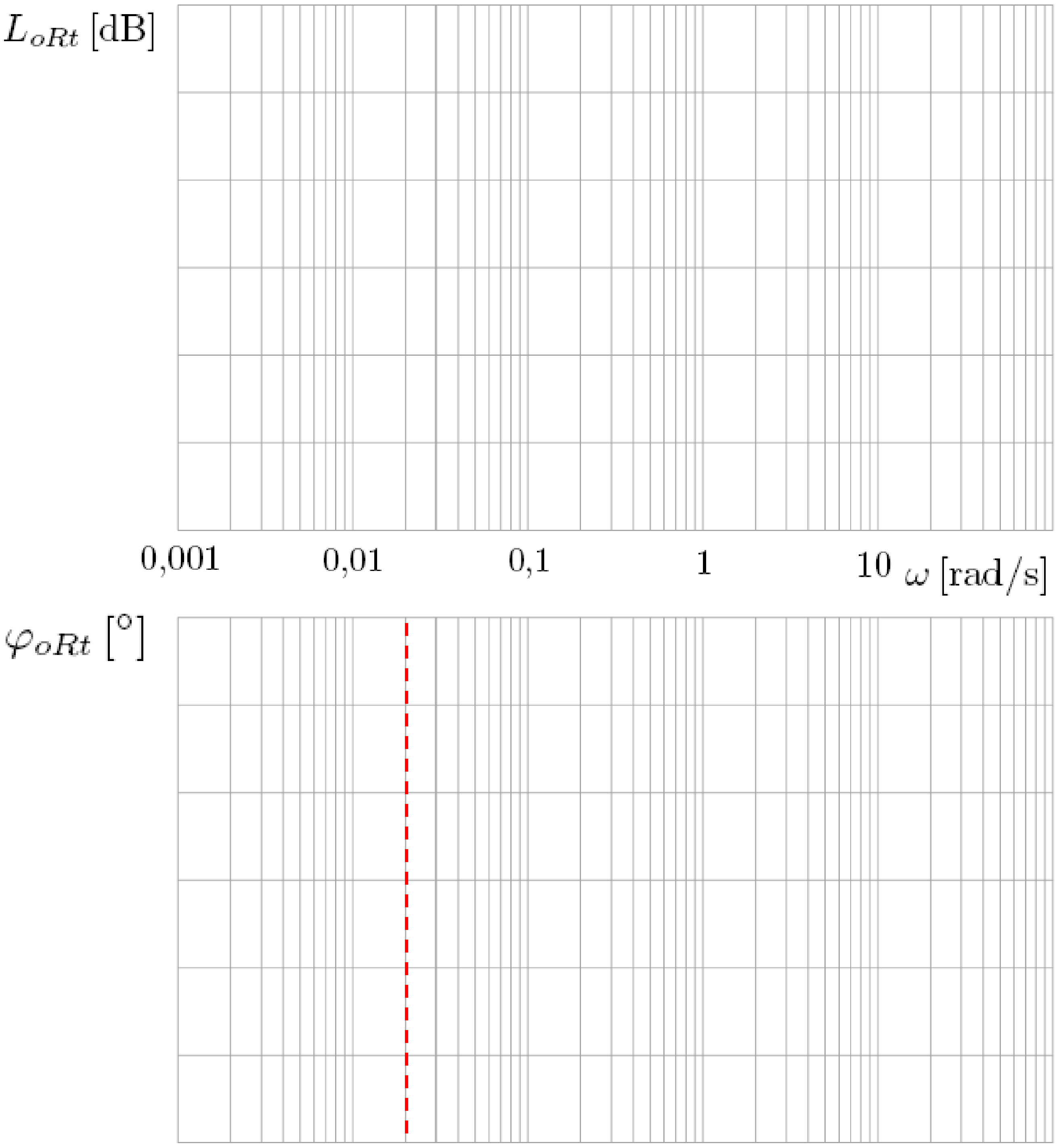
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

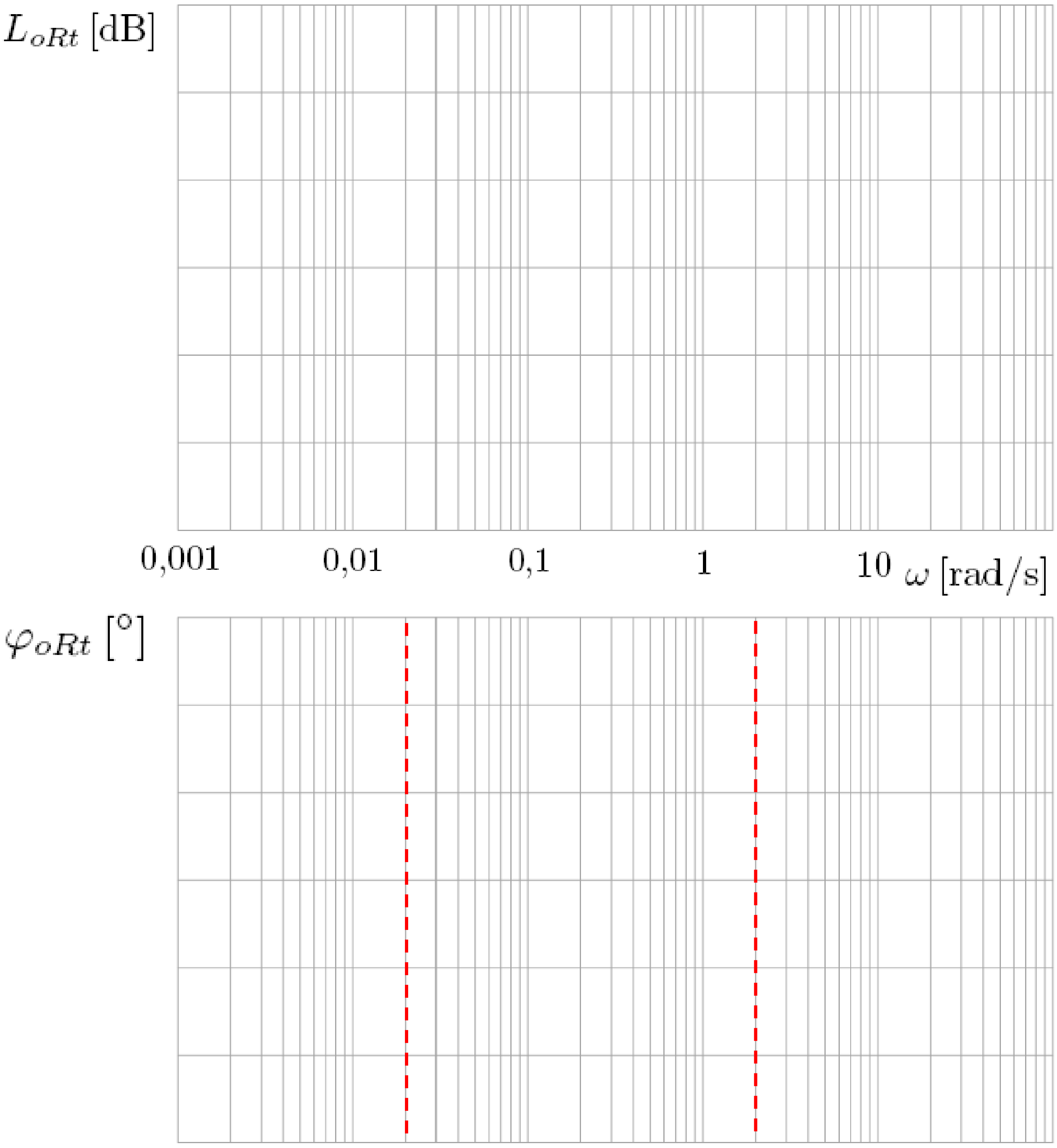
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

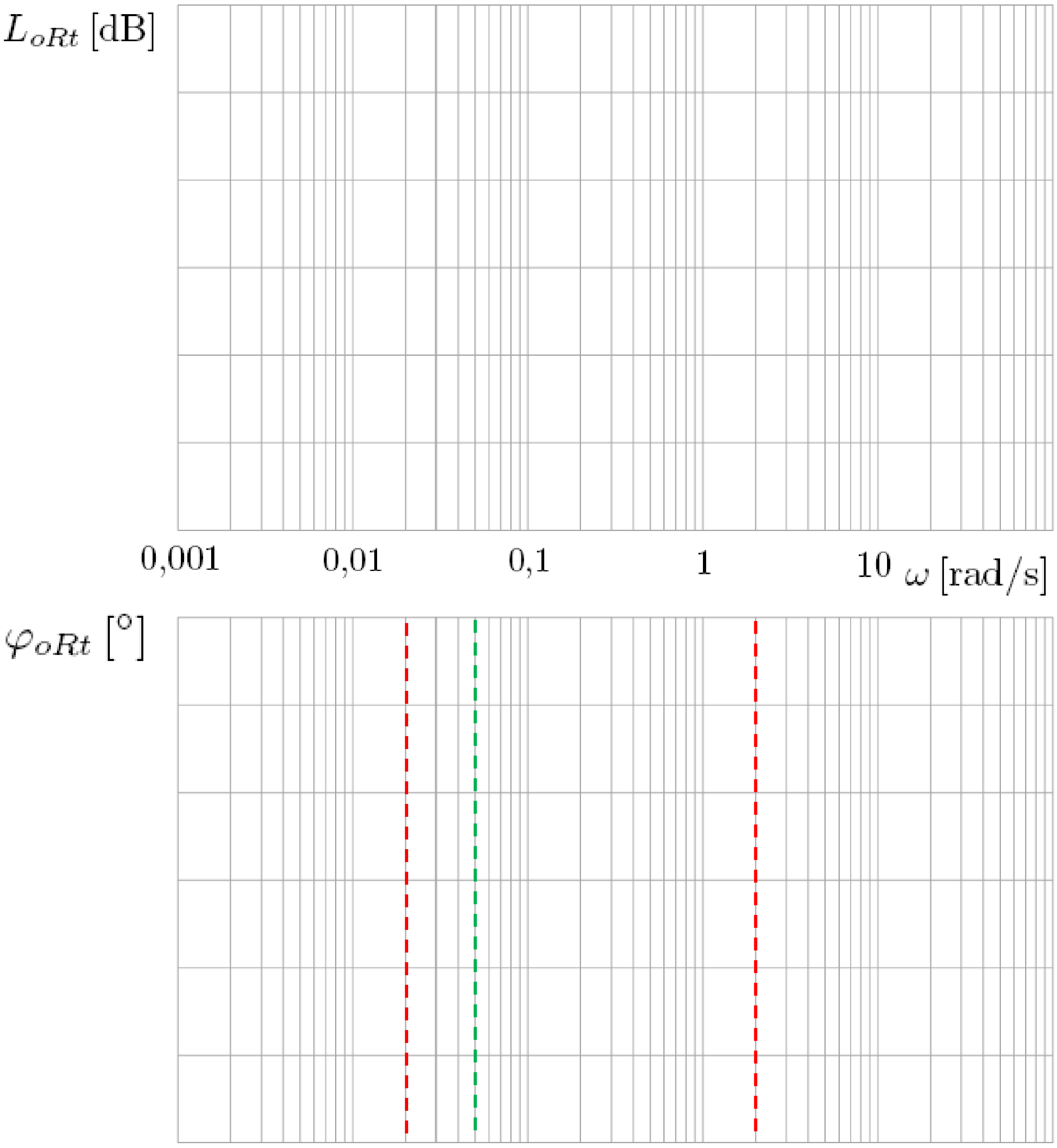
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

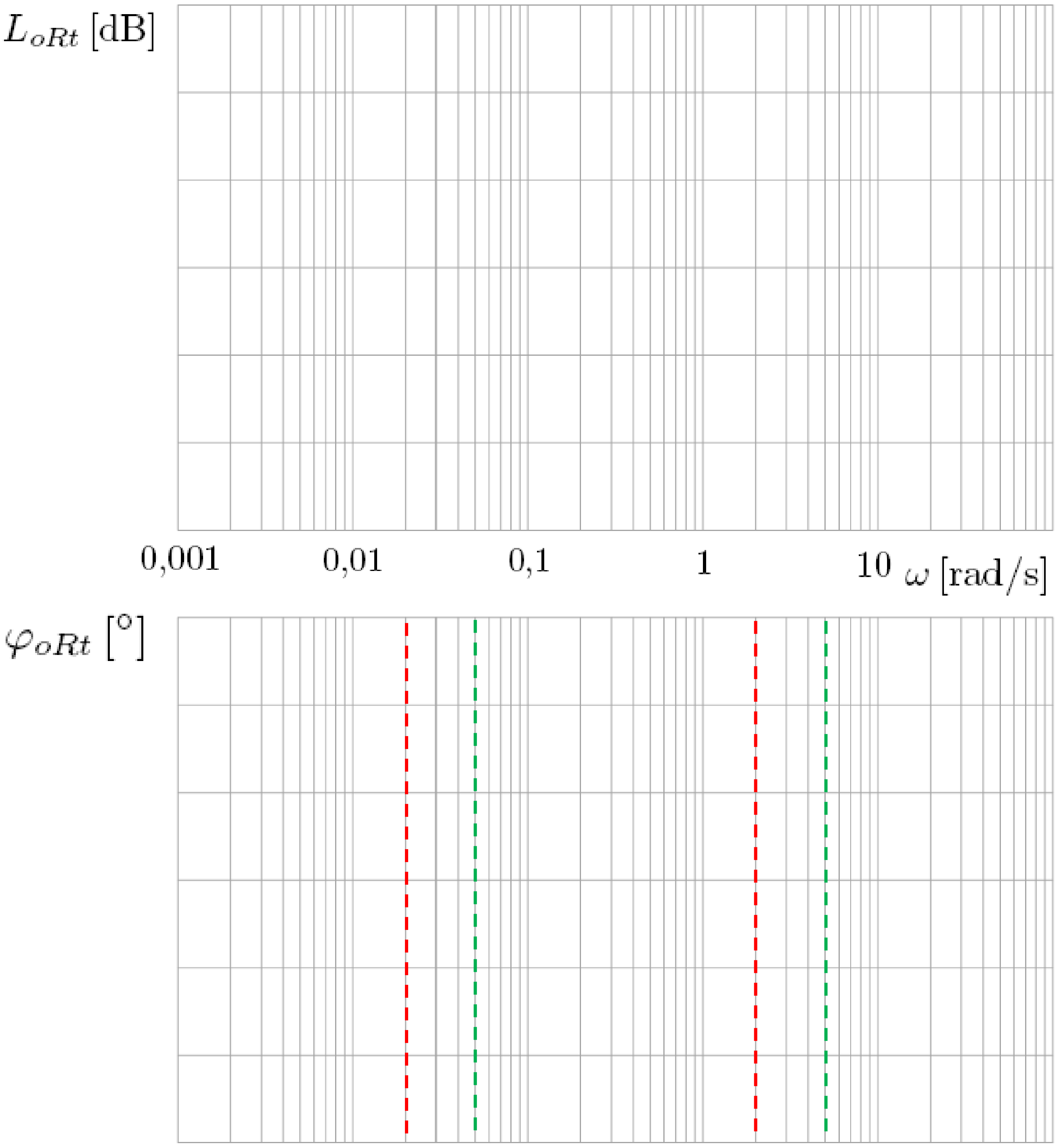
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

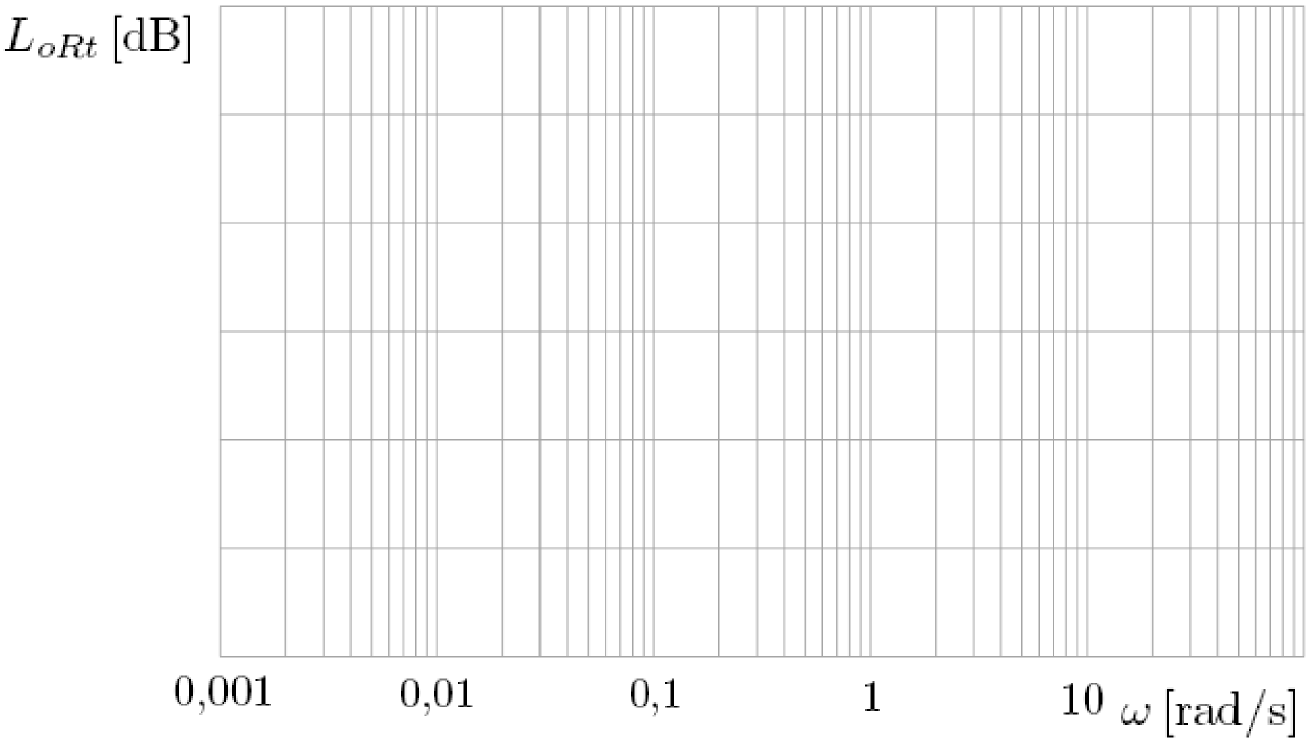
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

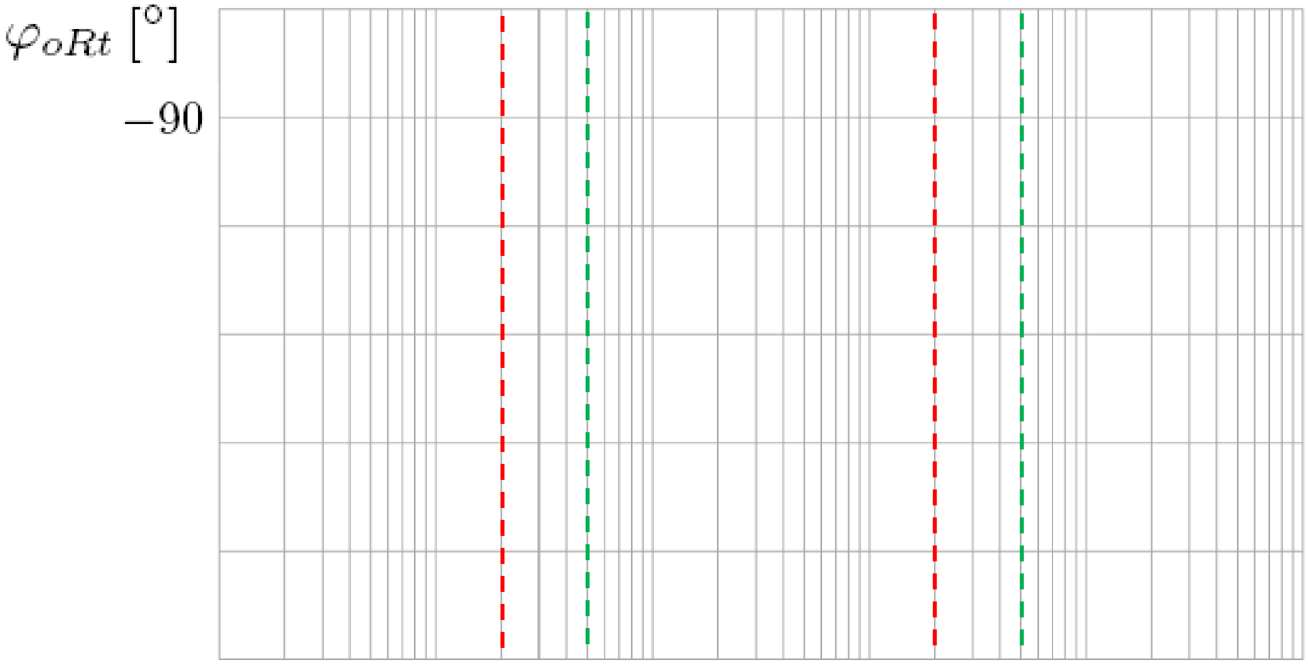
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

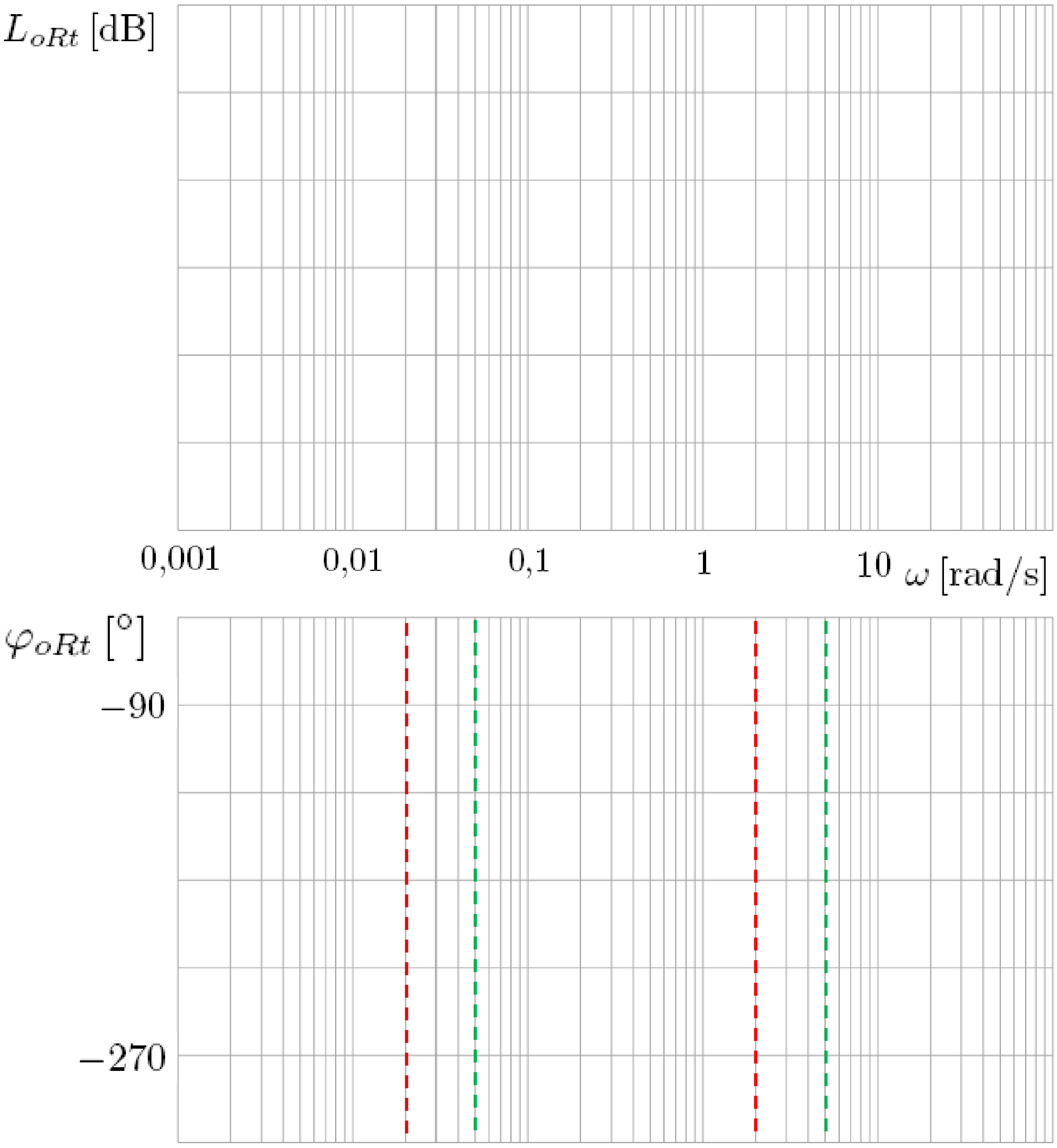
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

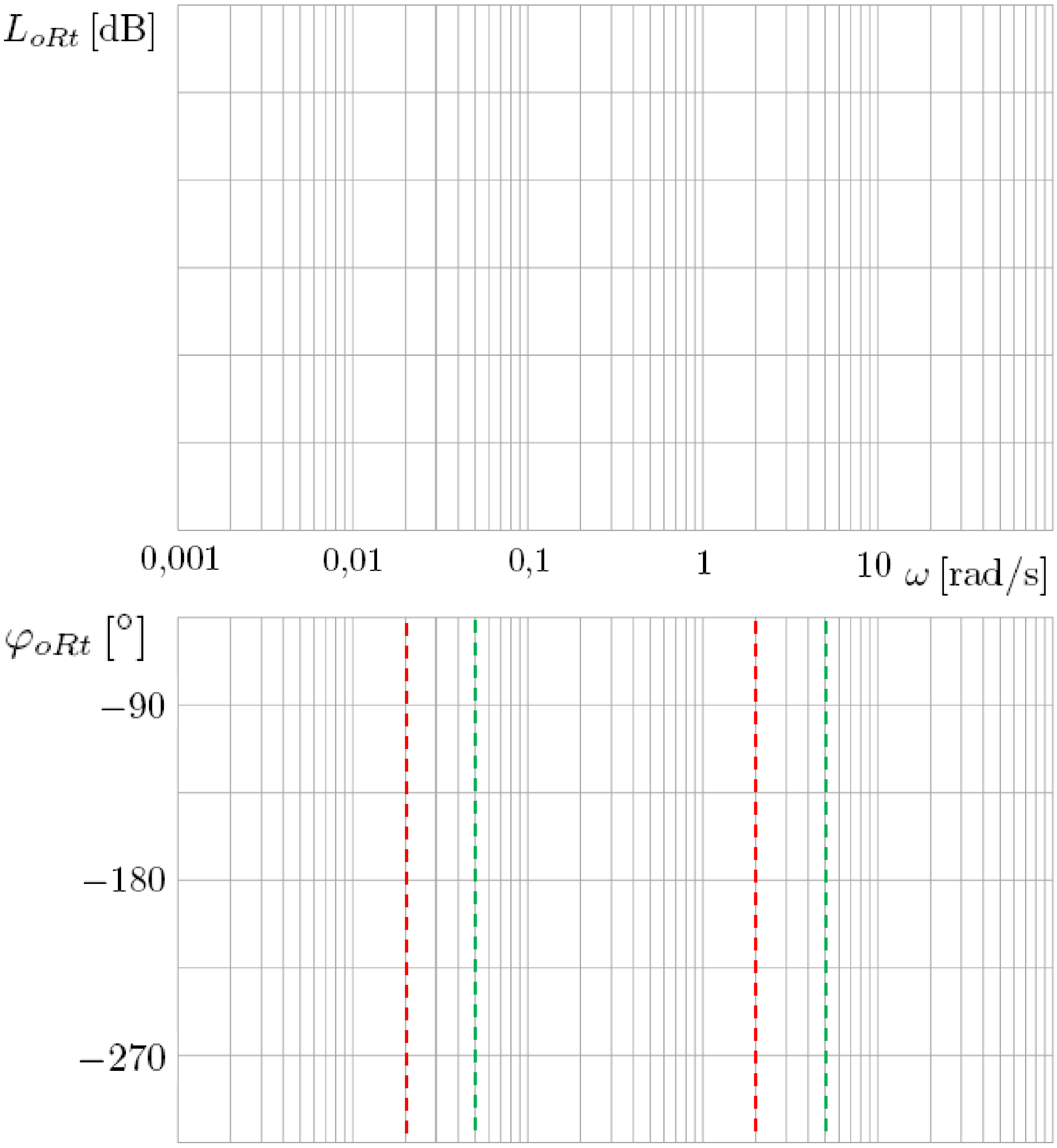
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

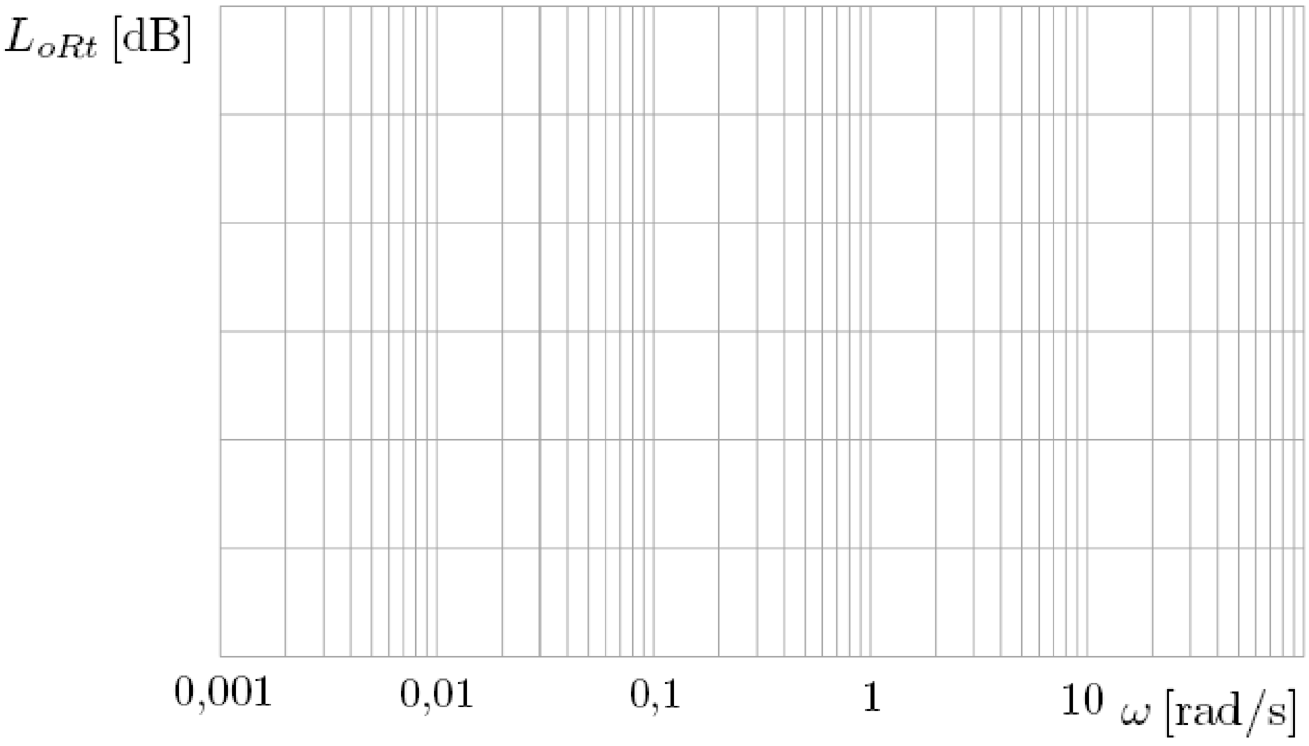
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

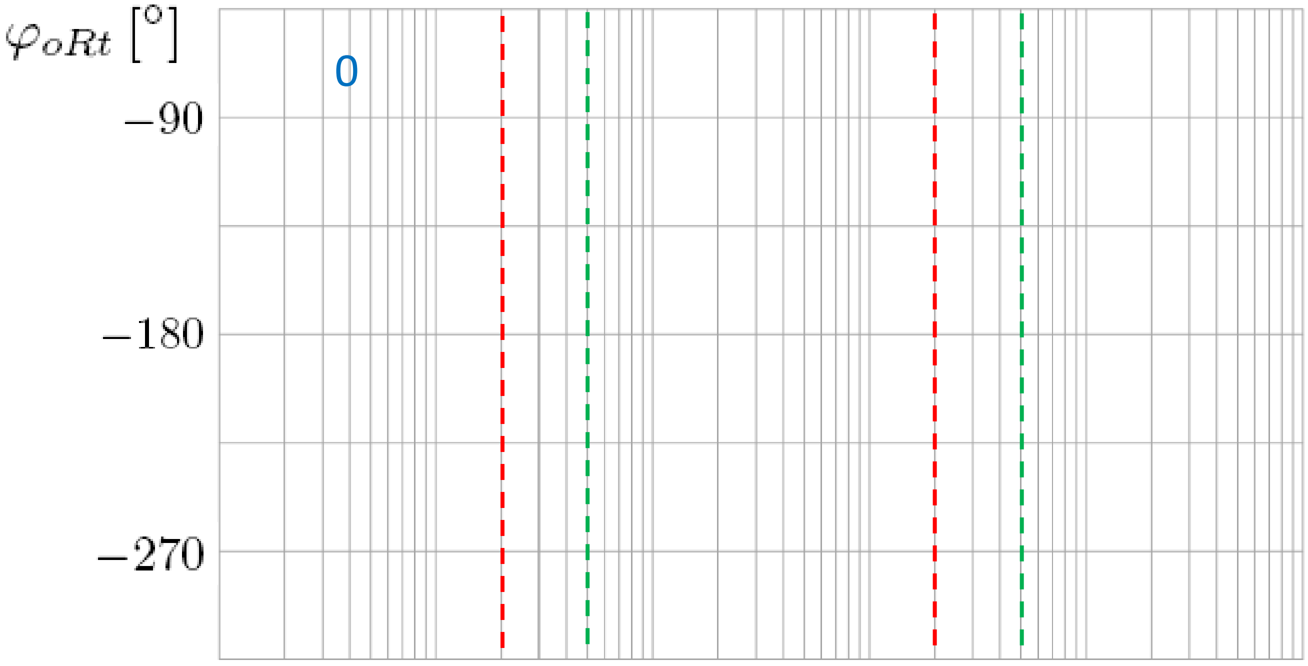
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

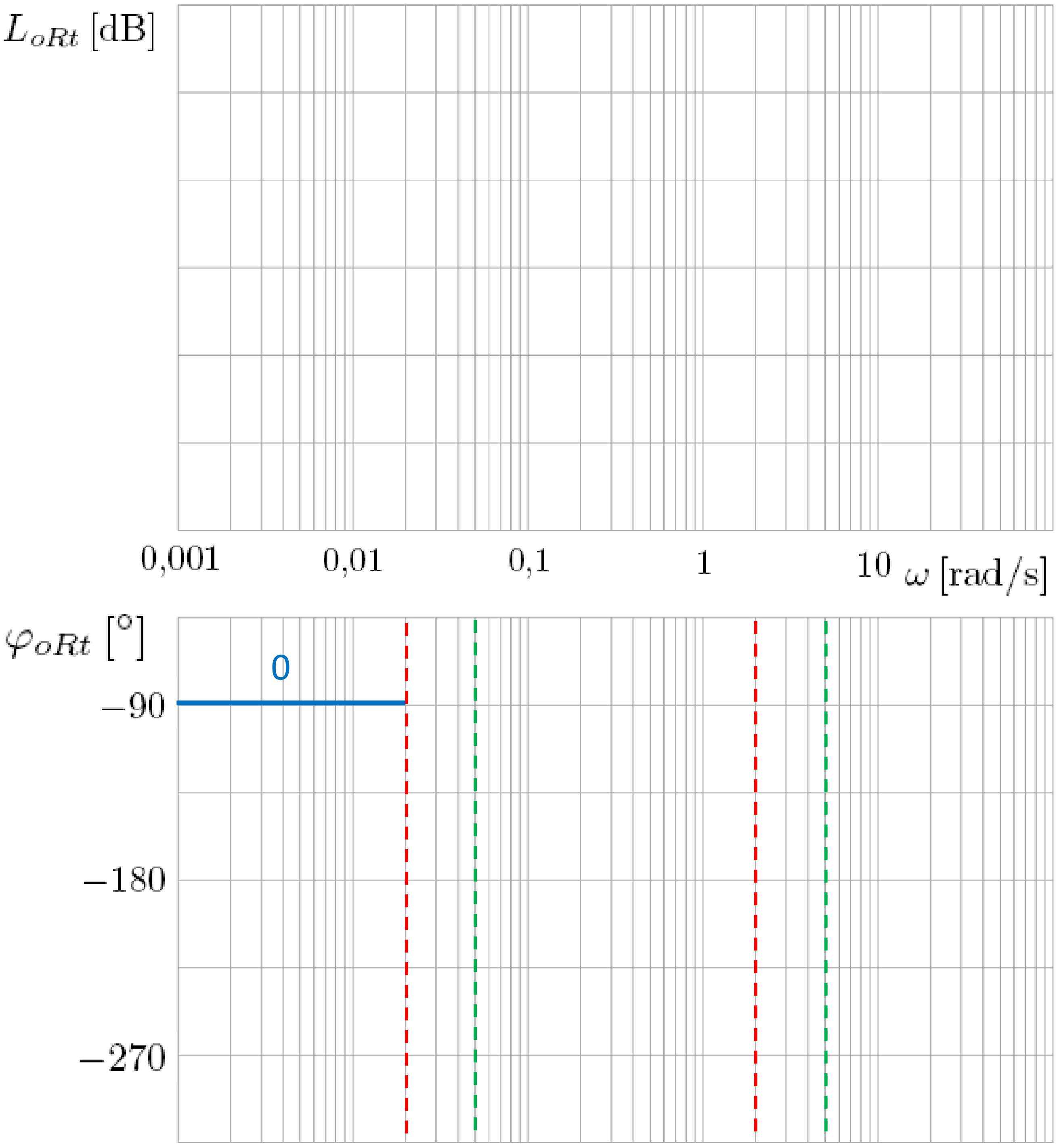
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

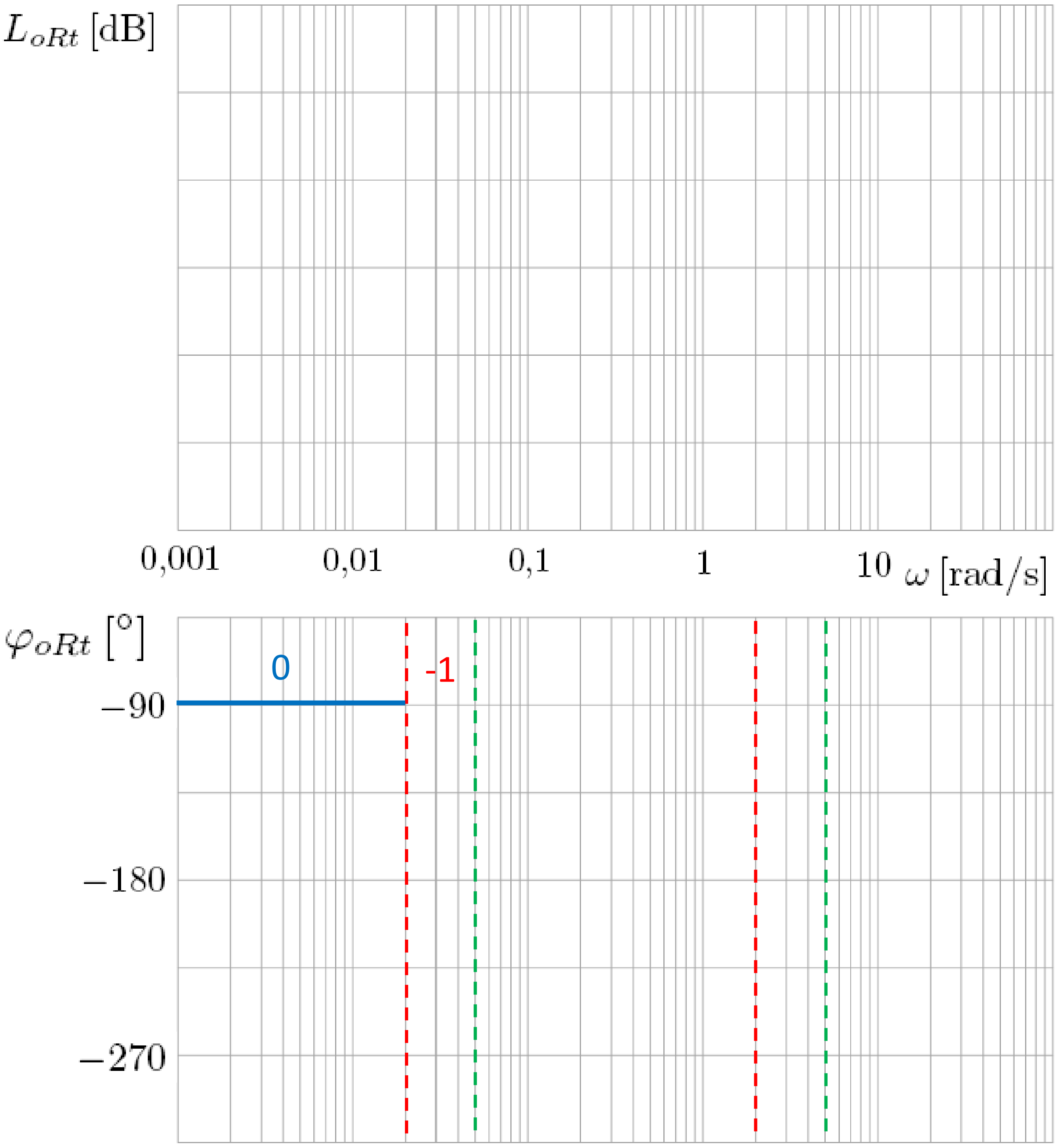
$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

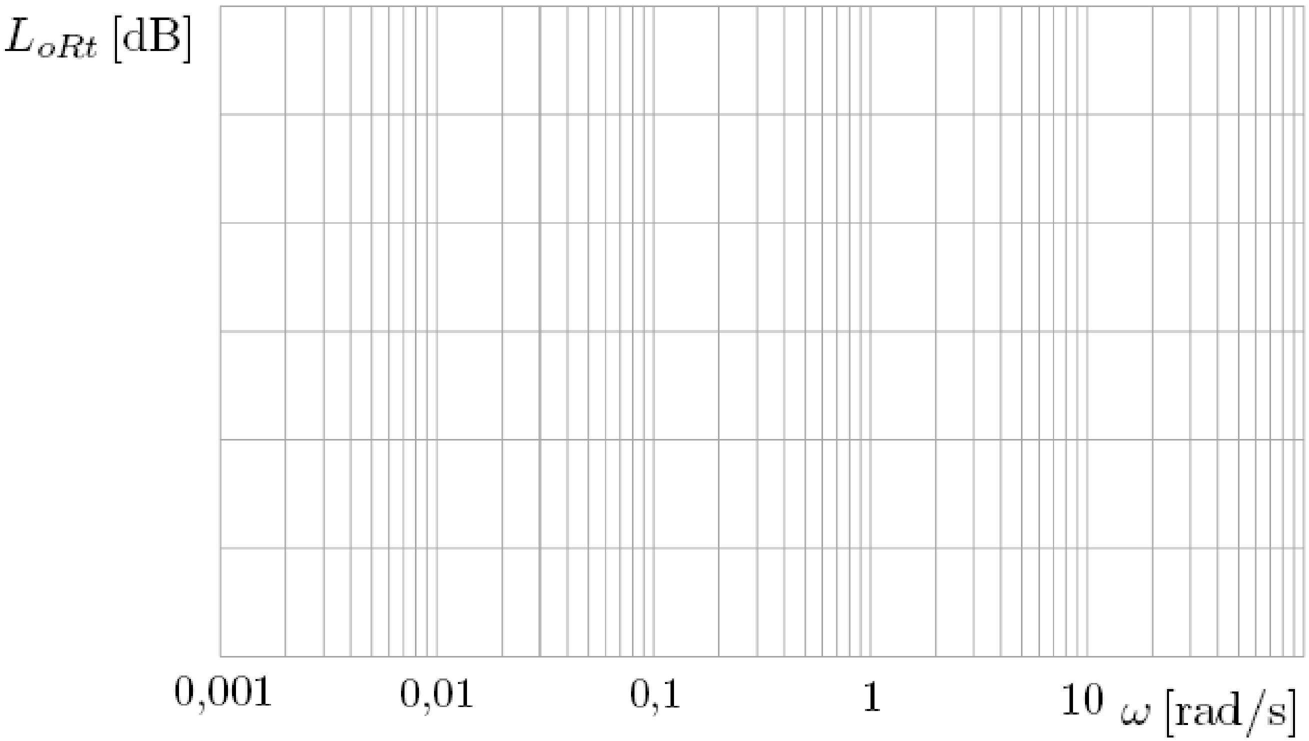
$$10\omega_{pv} = 5 \text{ rad/s}$$

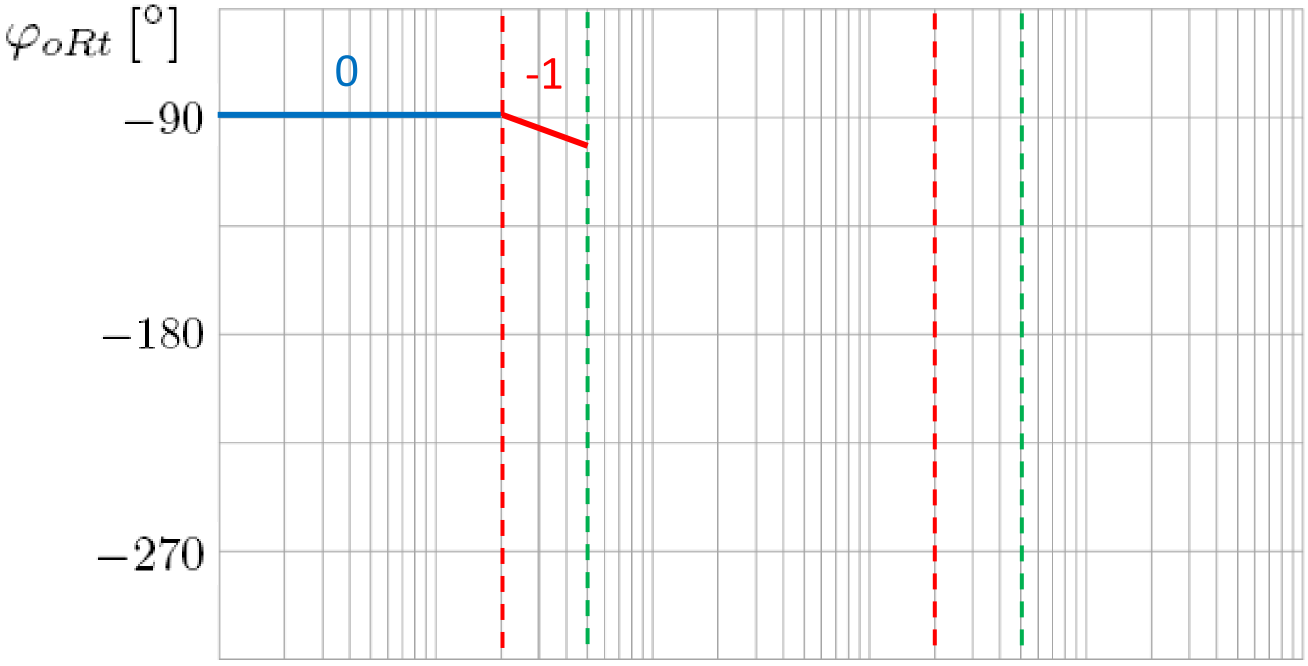


$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$



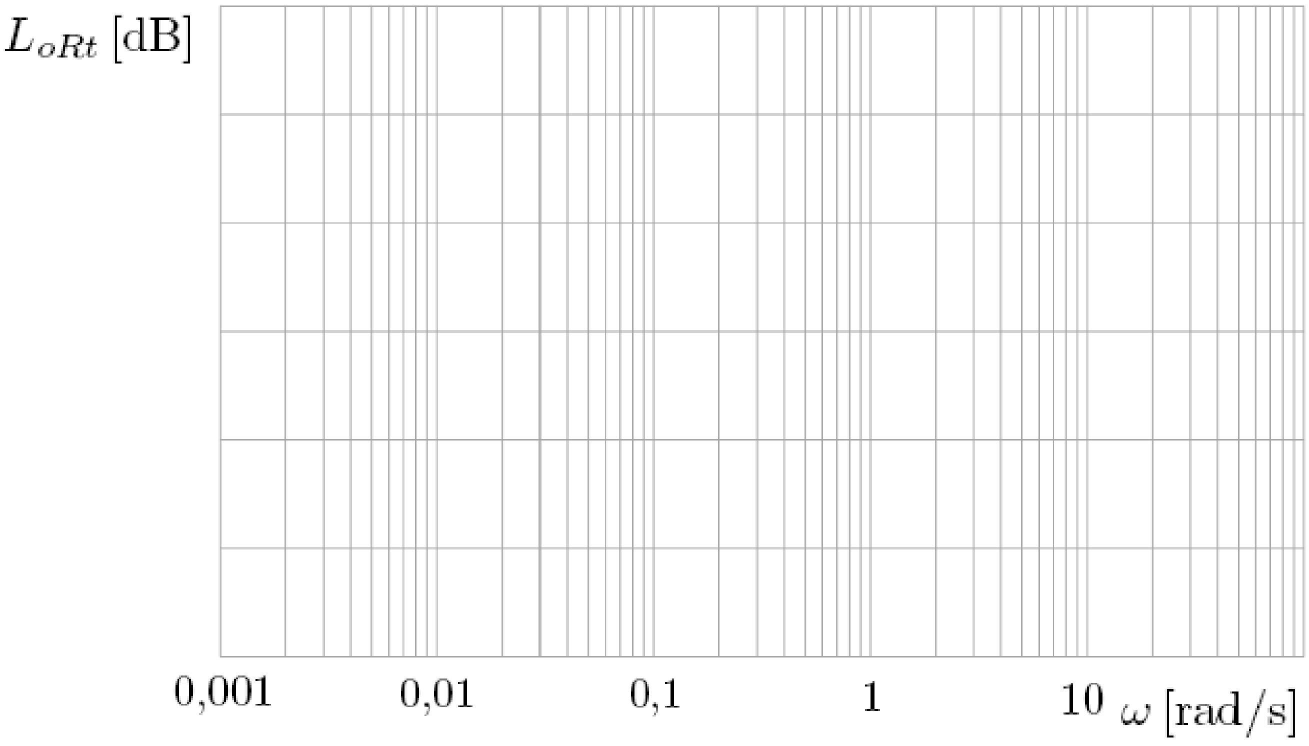


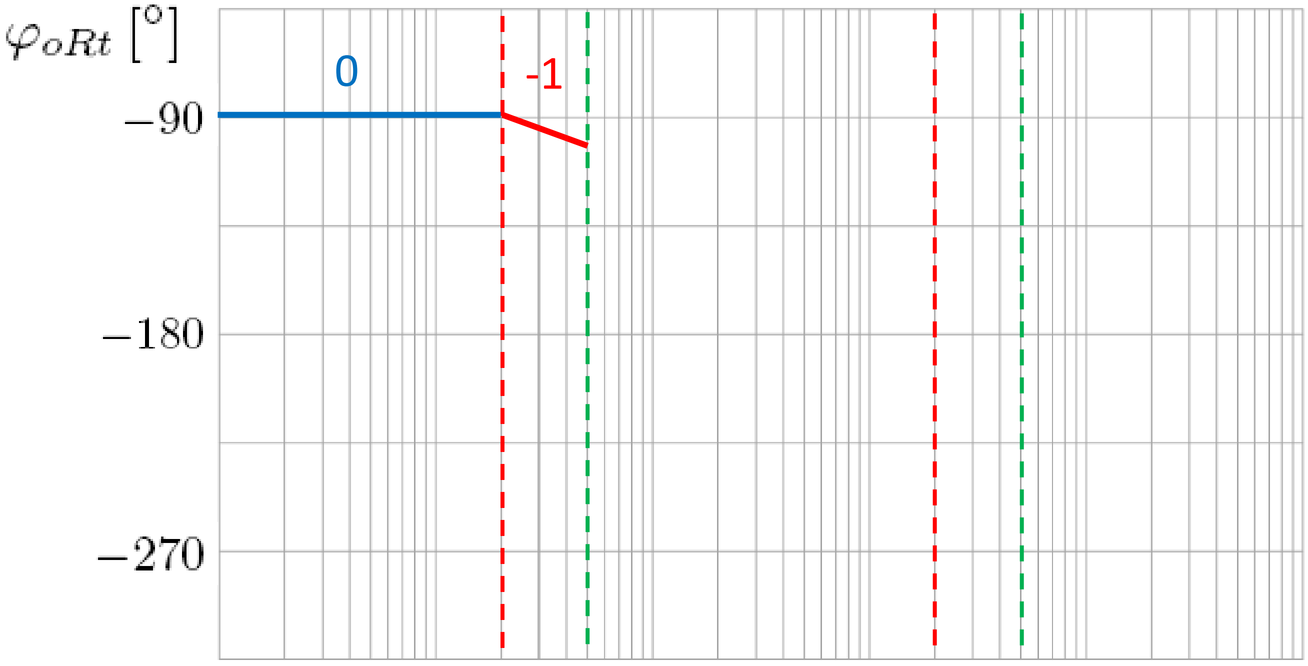
$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45 \log \frac{0{,}05}{0{,}02} = -107{,}9^\circ$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

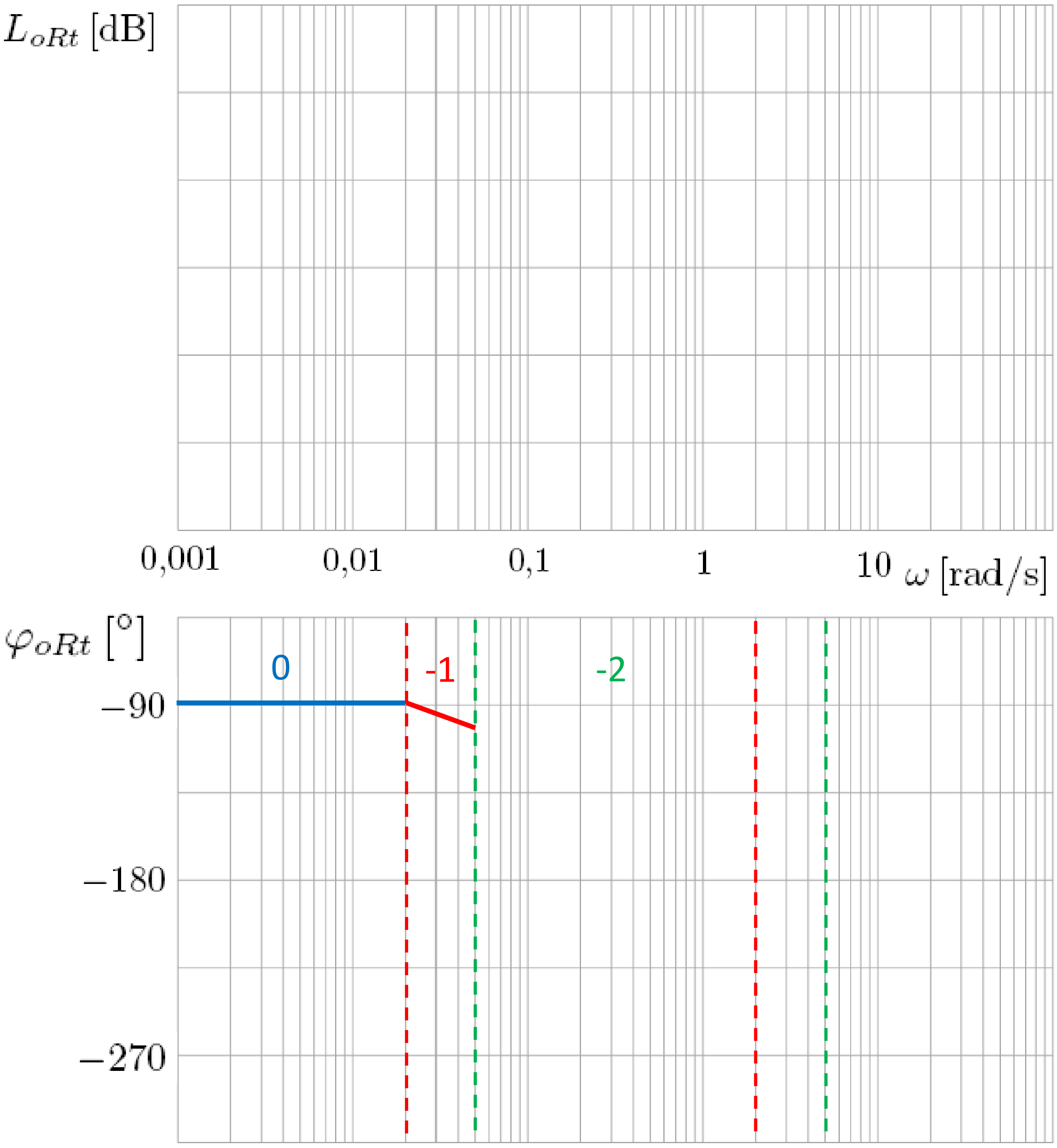
$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

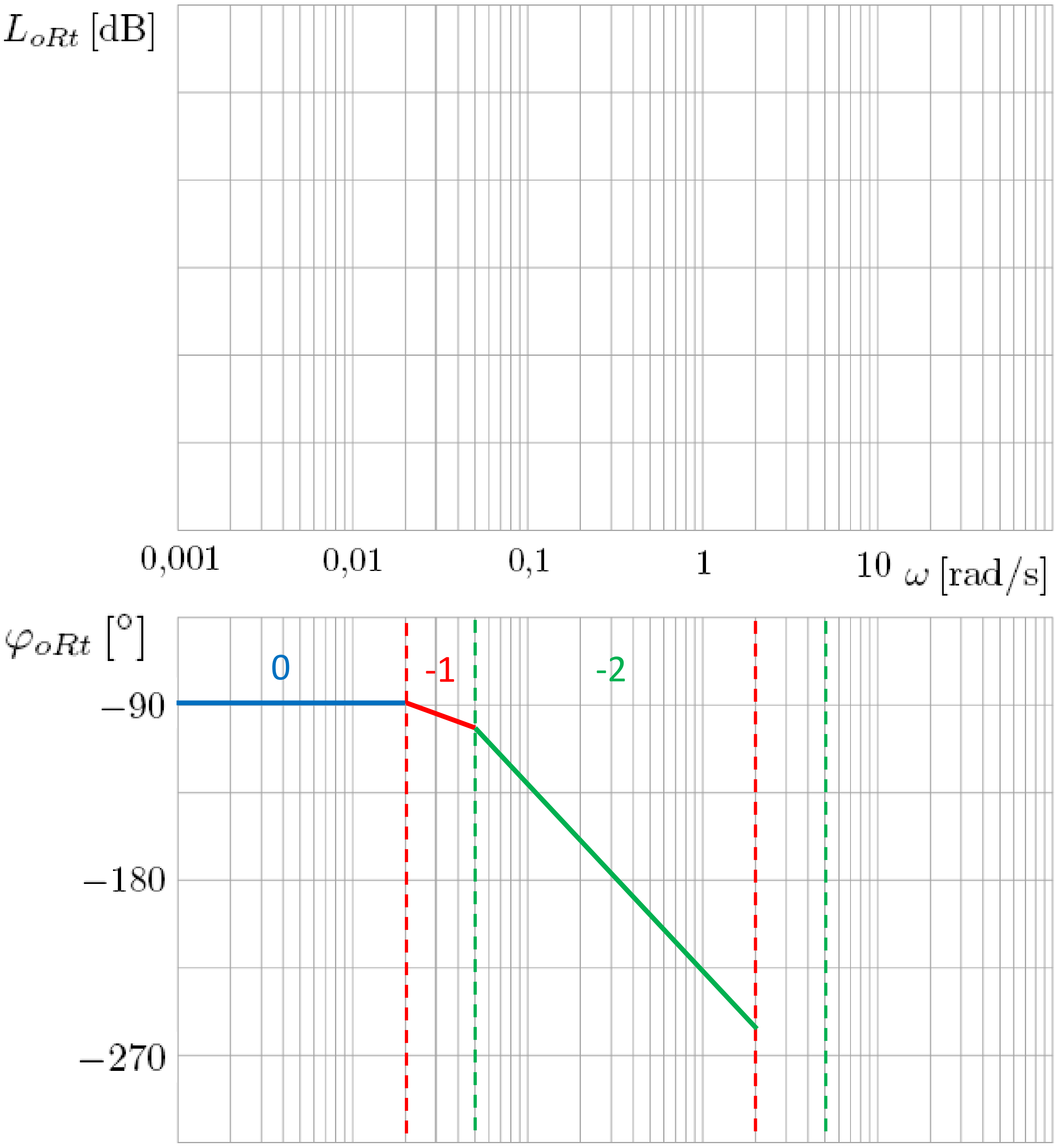


$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45 \log \frac{0{,}05}{0{,}02} = -107{,}9^\circ$$



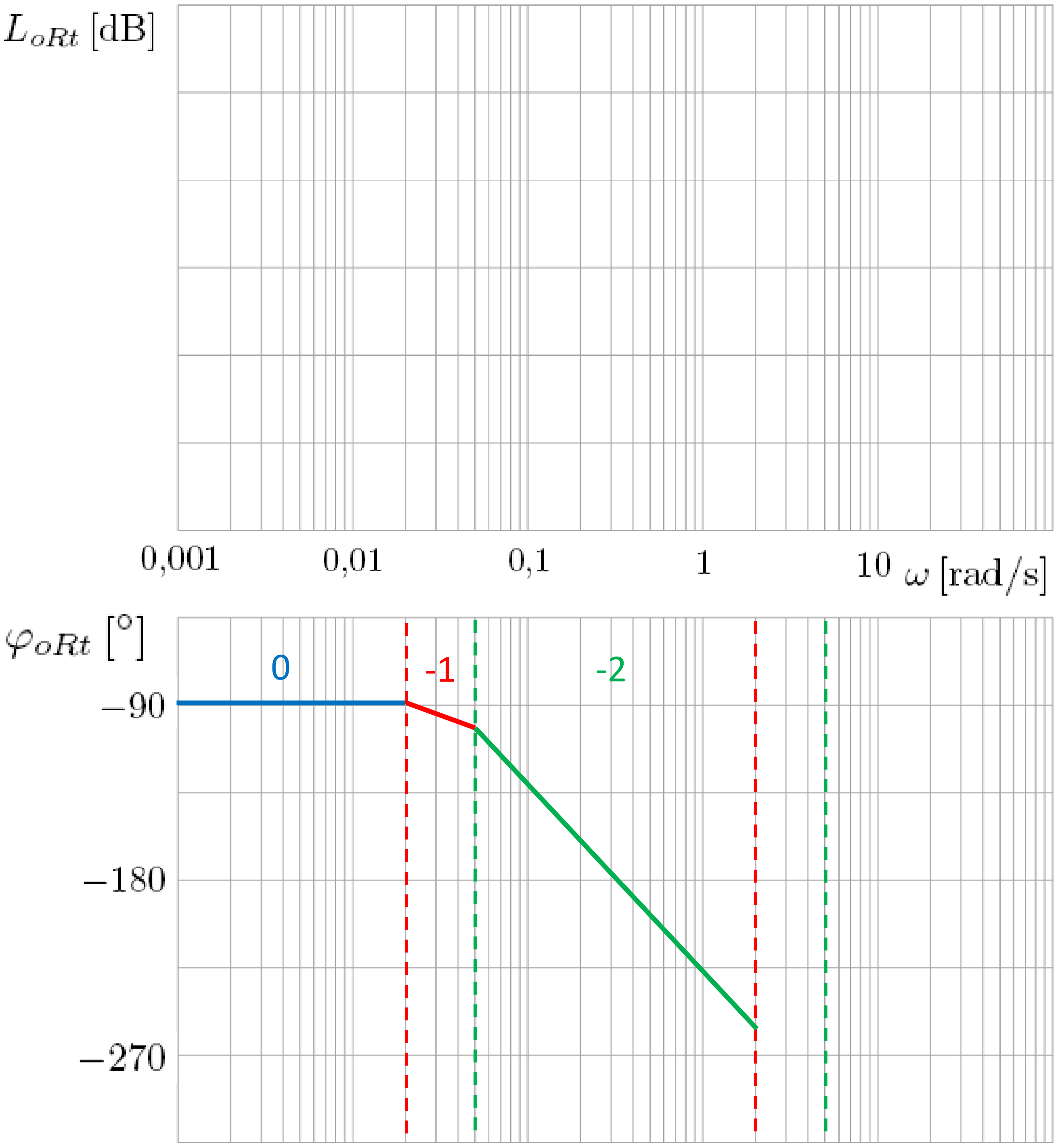
$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \text{rad/s}$$

$$0{,}1\omega_2 = 0{,}02\ \text{rad/s}$$

$$10\omega_2 = 2\ \text{rad/s}$$

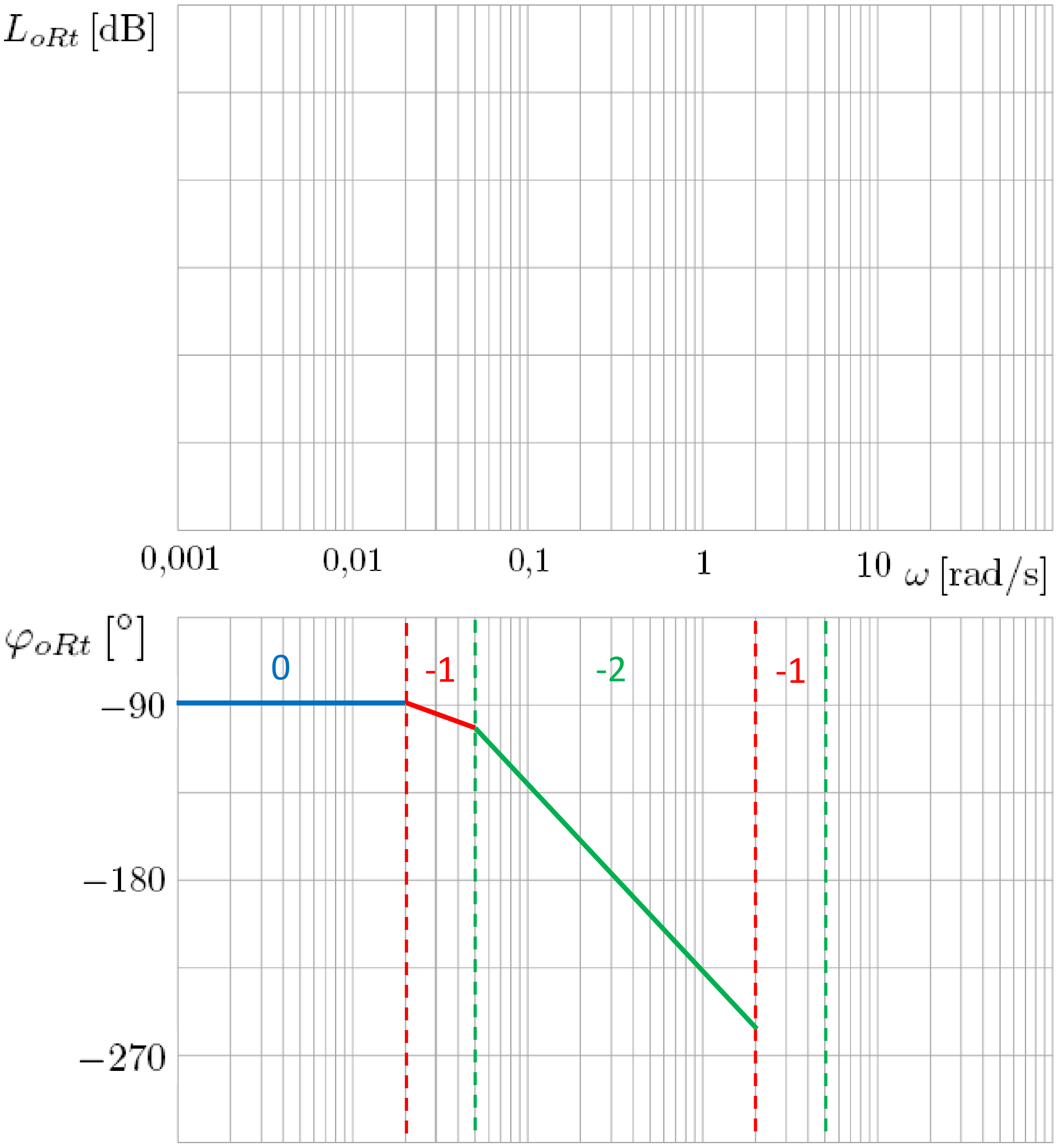
$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \text{rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05\ \text{rad/s}$$

$$10\omega_{pv} = 5\ \text{rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$



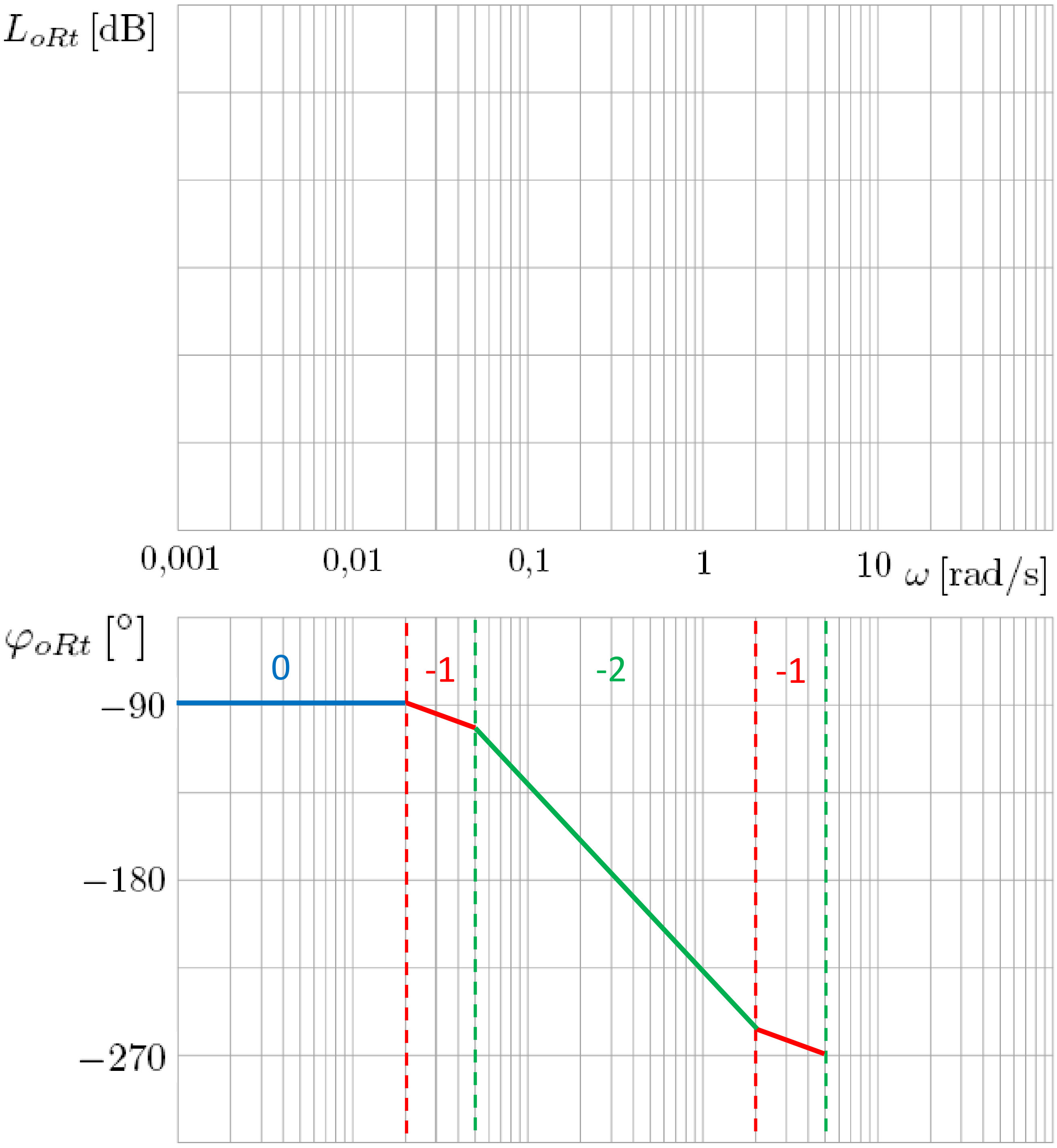
$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

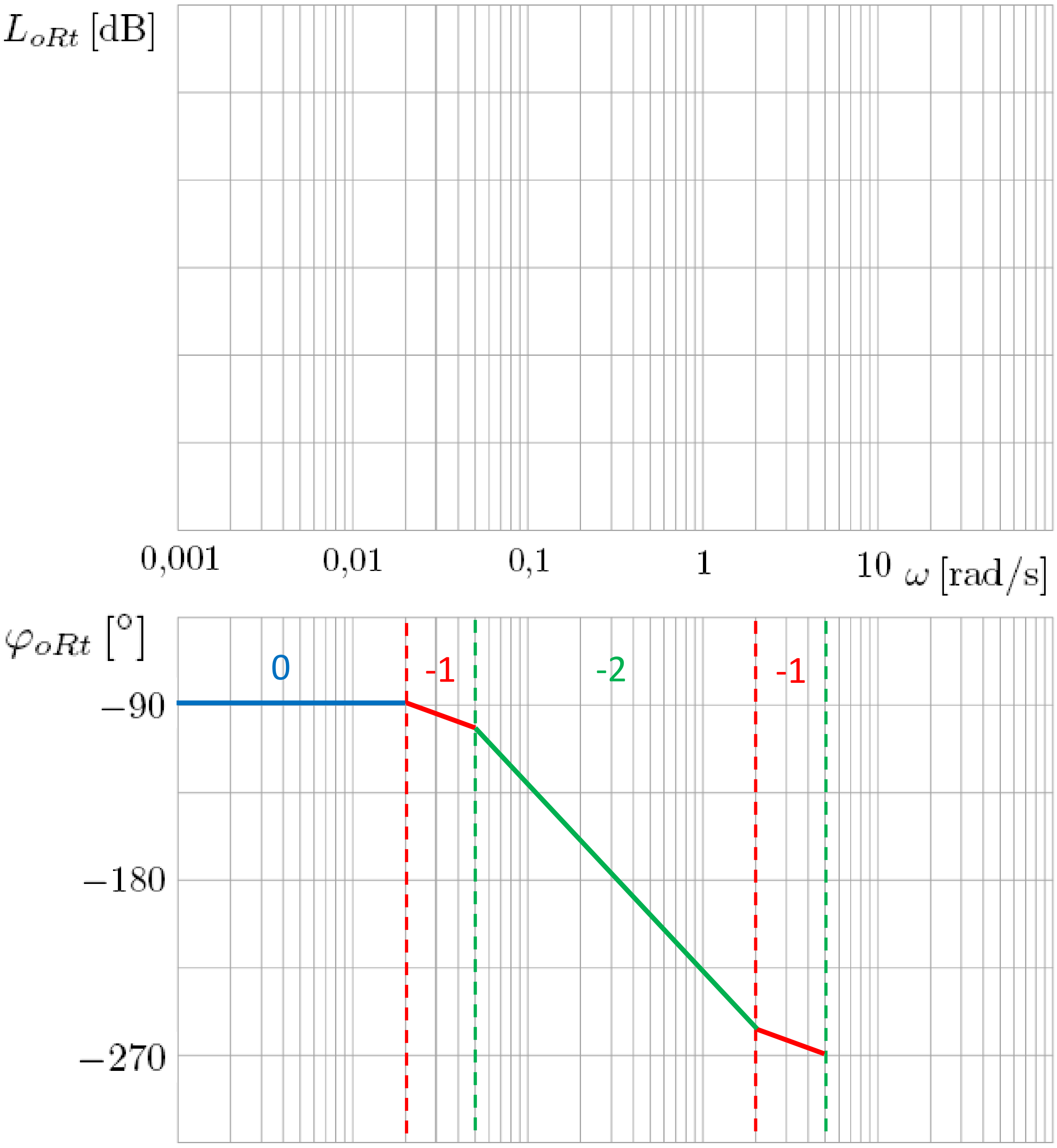
$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

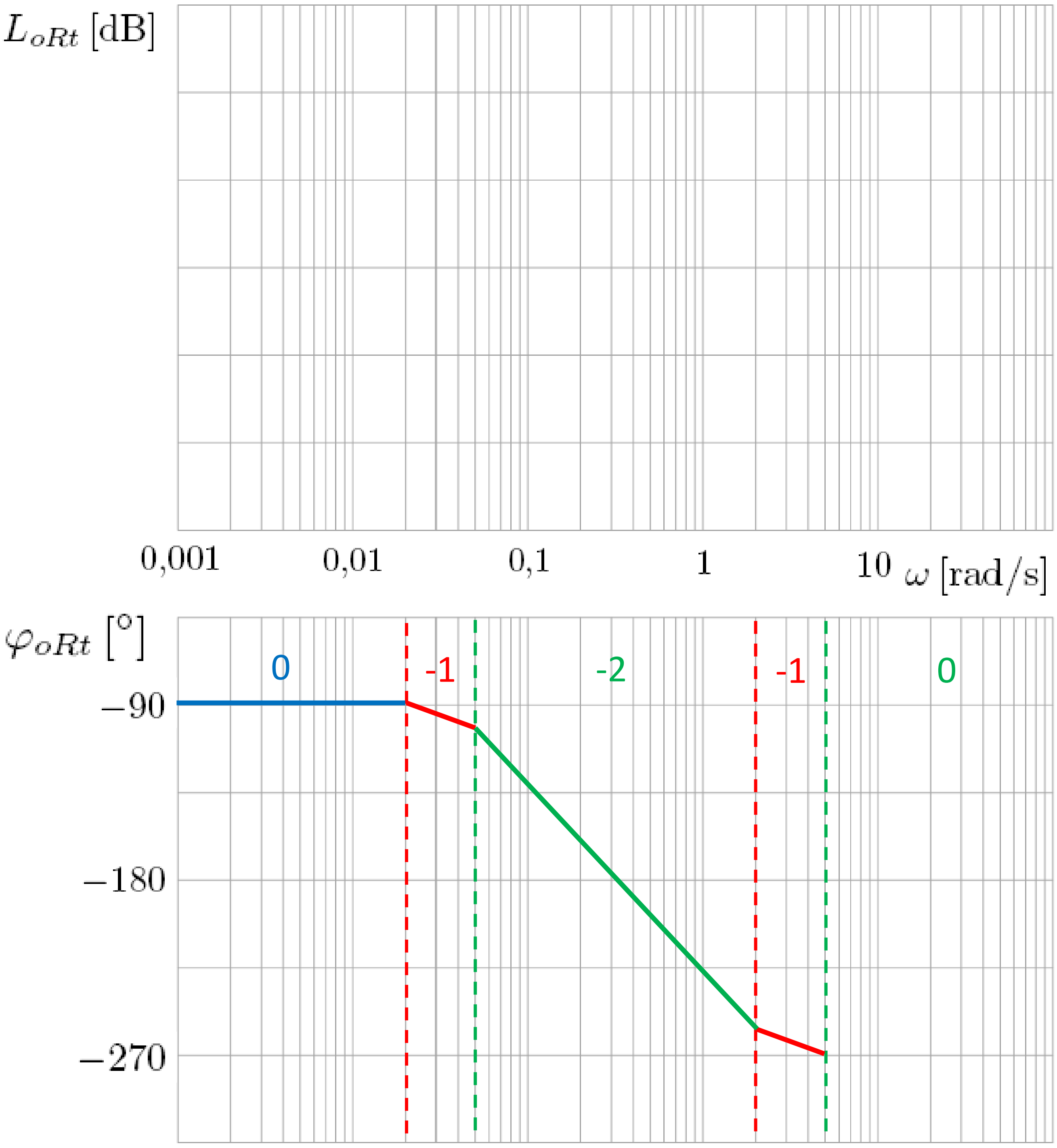
$$\omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s} \qquad 0{,}1\omega_2 = 0{,}02\ \mathrm{rad/s} \qquad 10\omega_2 = 2\ \mathrm{rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05\ \mathrm{rad/s} \qquad 10\omega_{pv} = 5\ \mathrm{rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

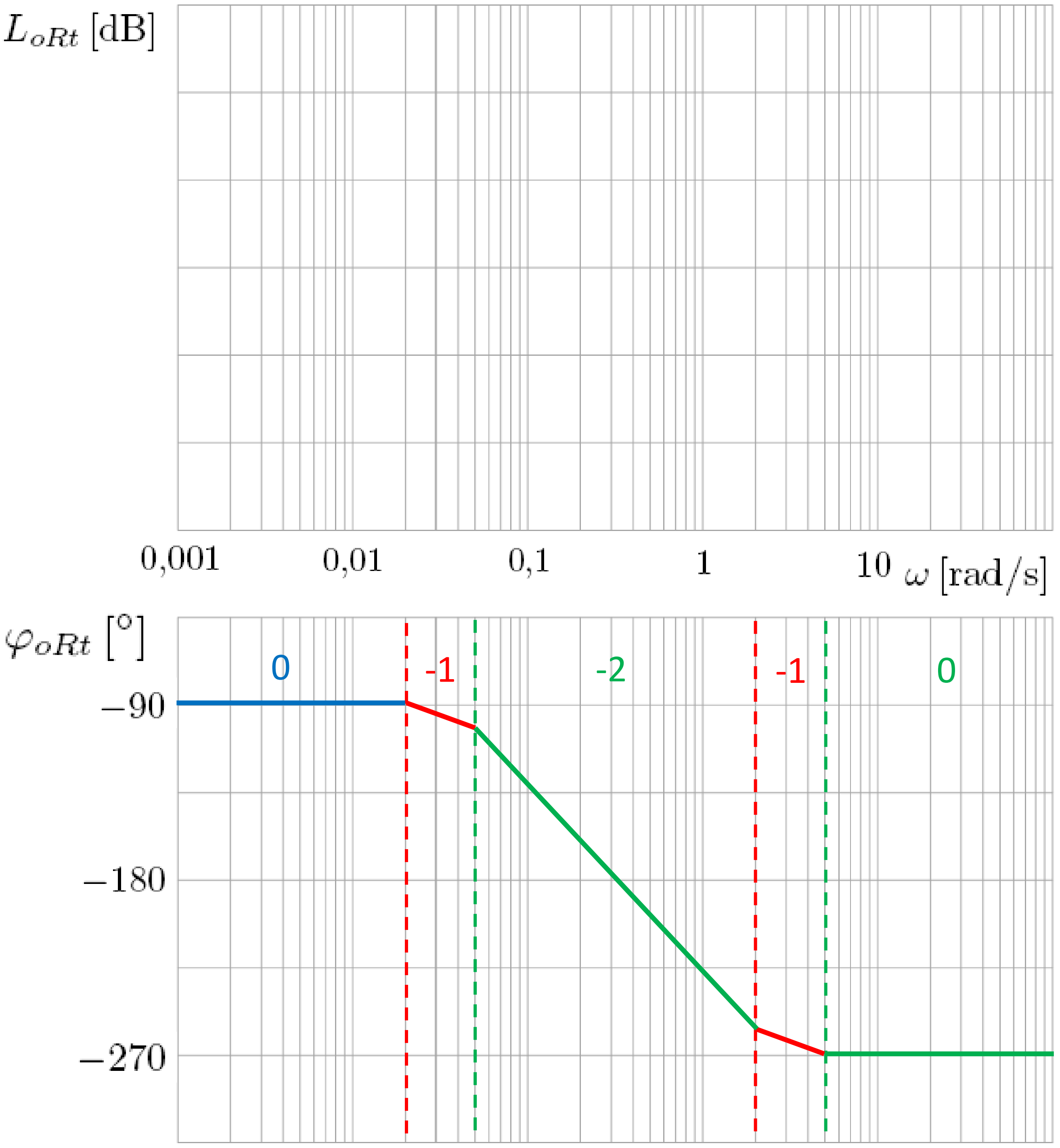
$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

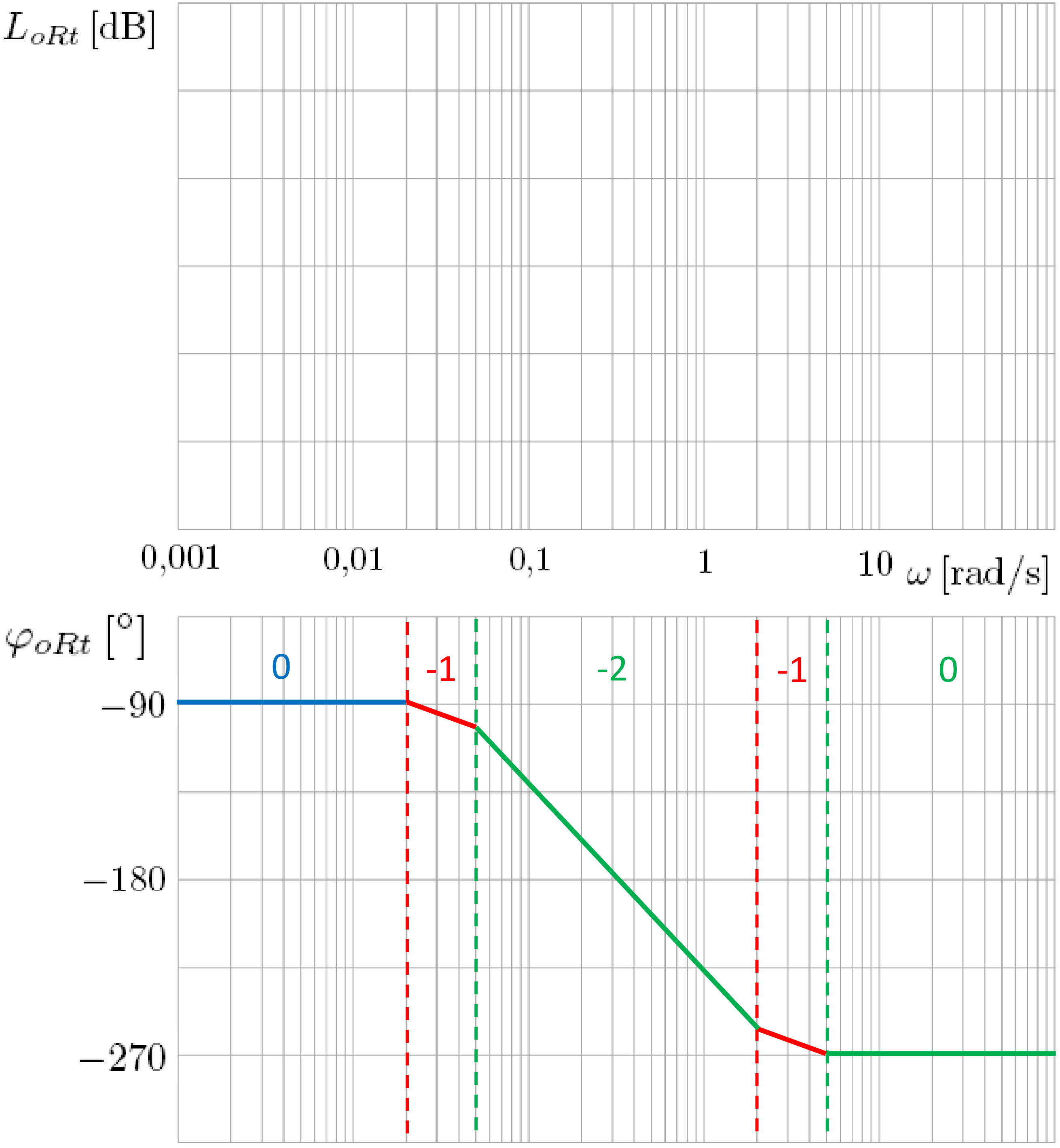
$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

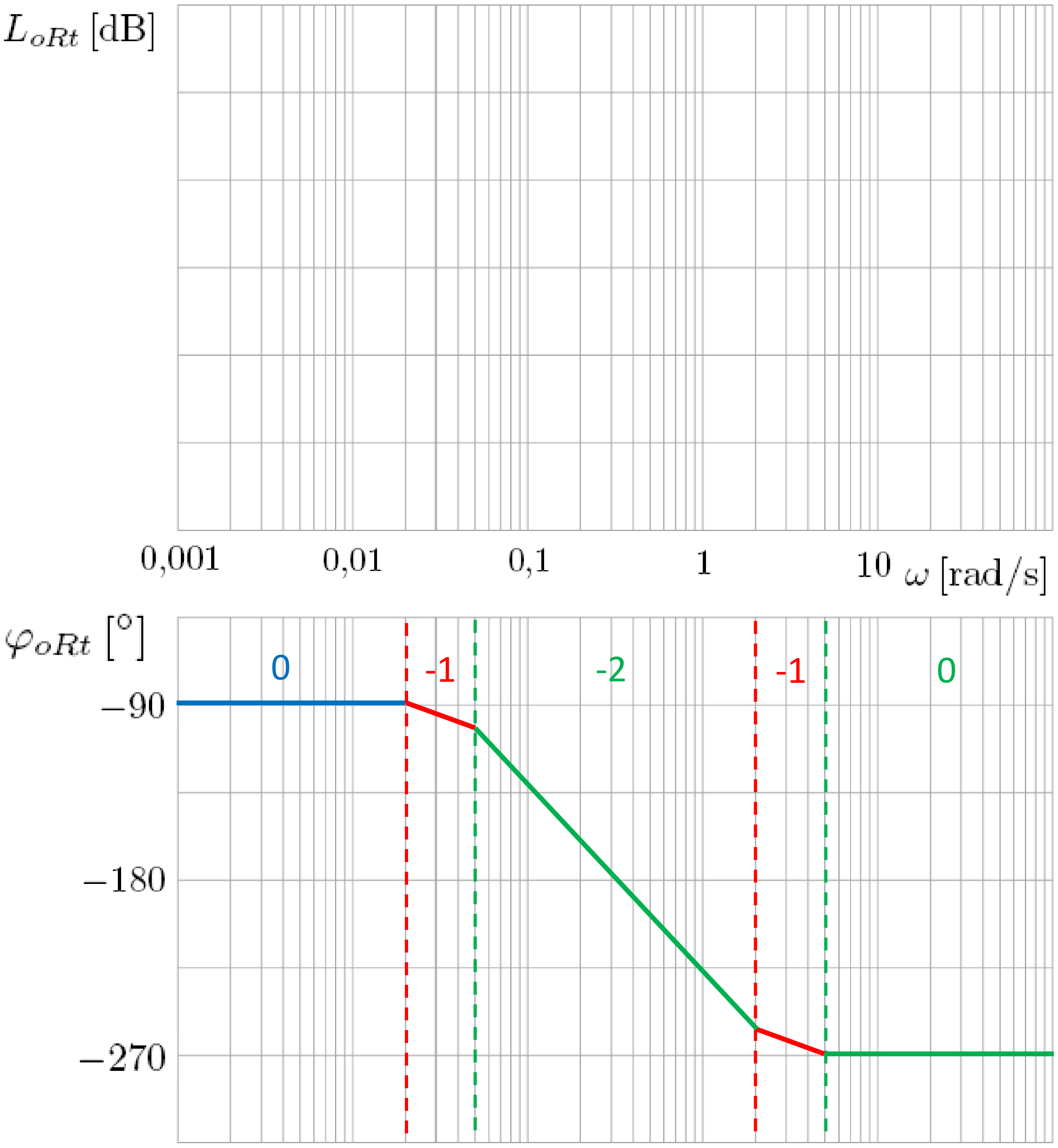
$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \text{rad/s} \qquad 0{,}1\omega_2 = 0{,}02\ \text{rad/s} \qquad 10\omega_2 = 2\ \text{rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \text{rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05\ \text{rad/s} \qquad 10\omega_{pv} = 5\ \text{rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

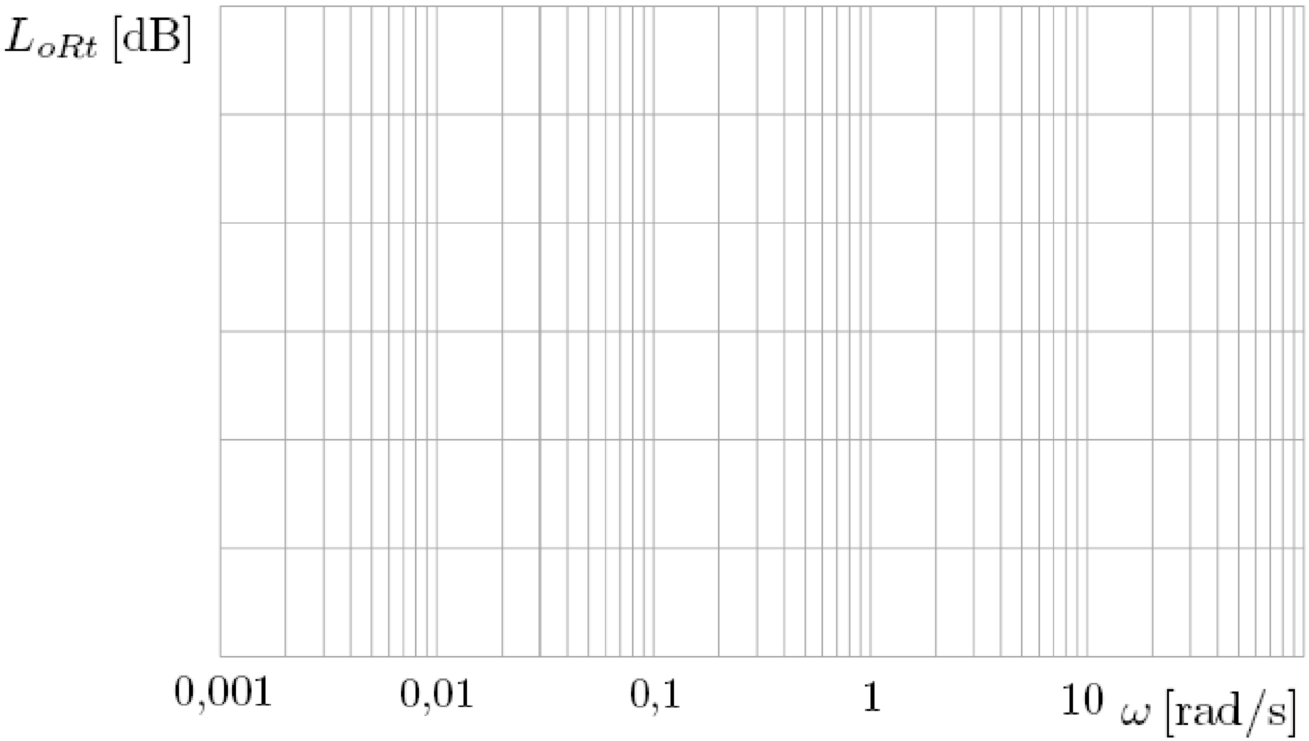
$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

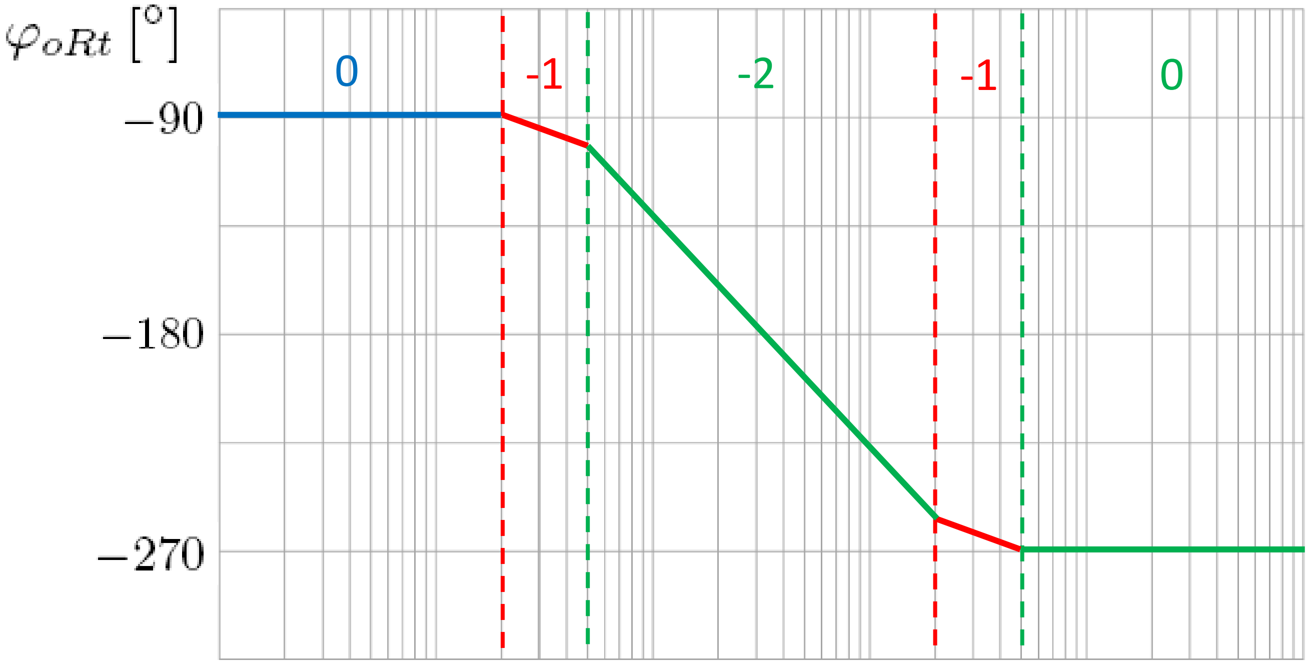
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

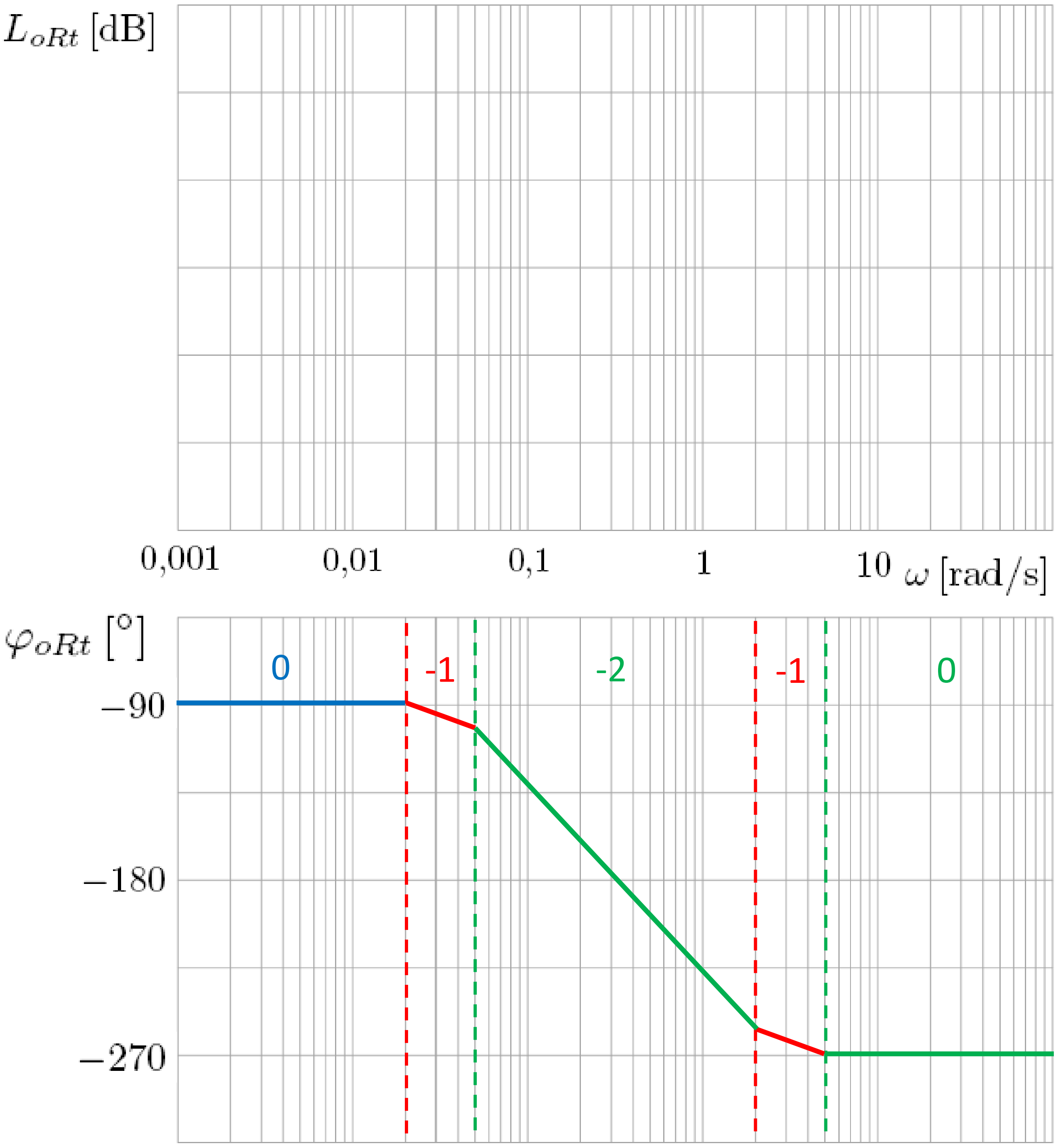
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

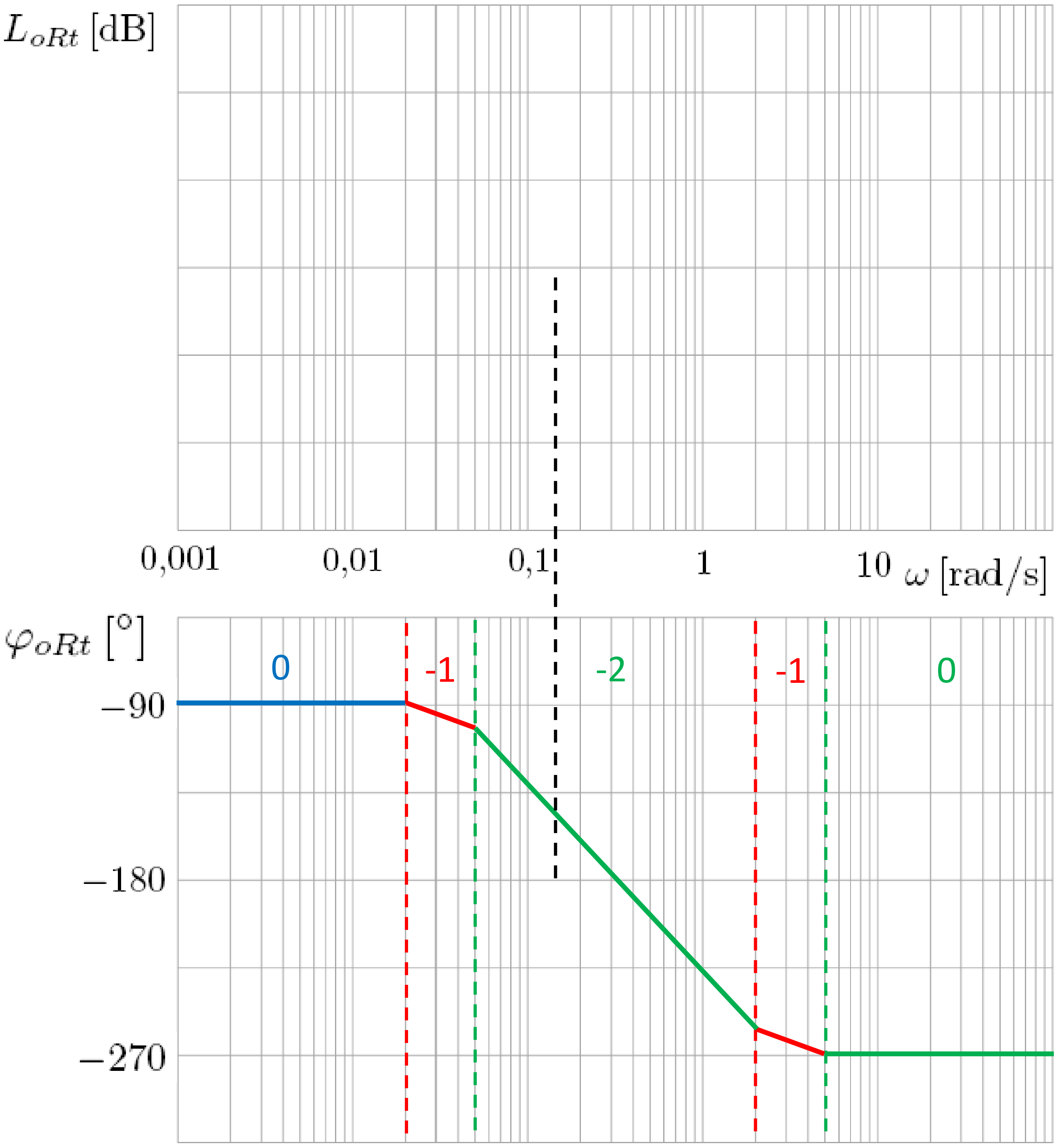
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

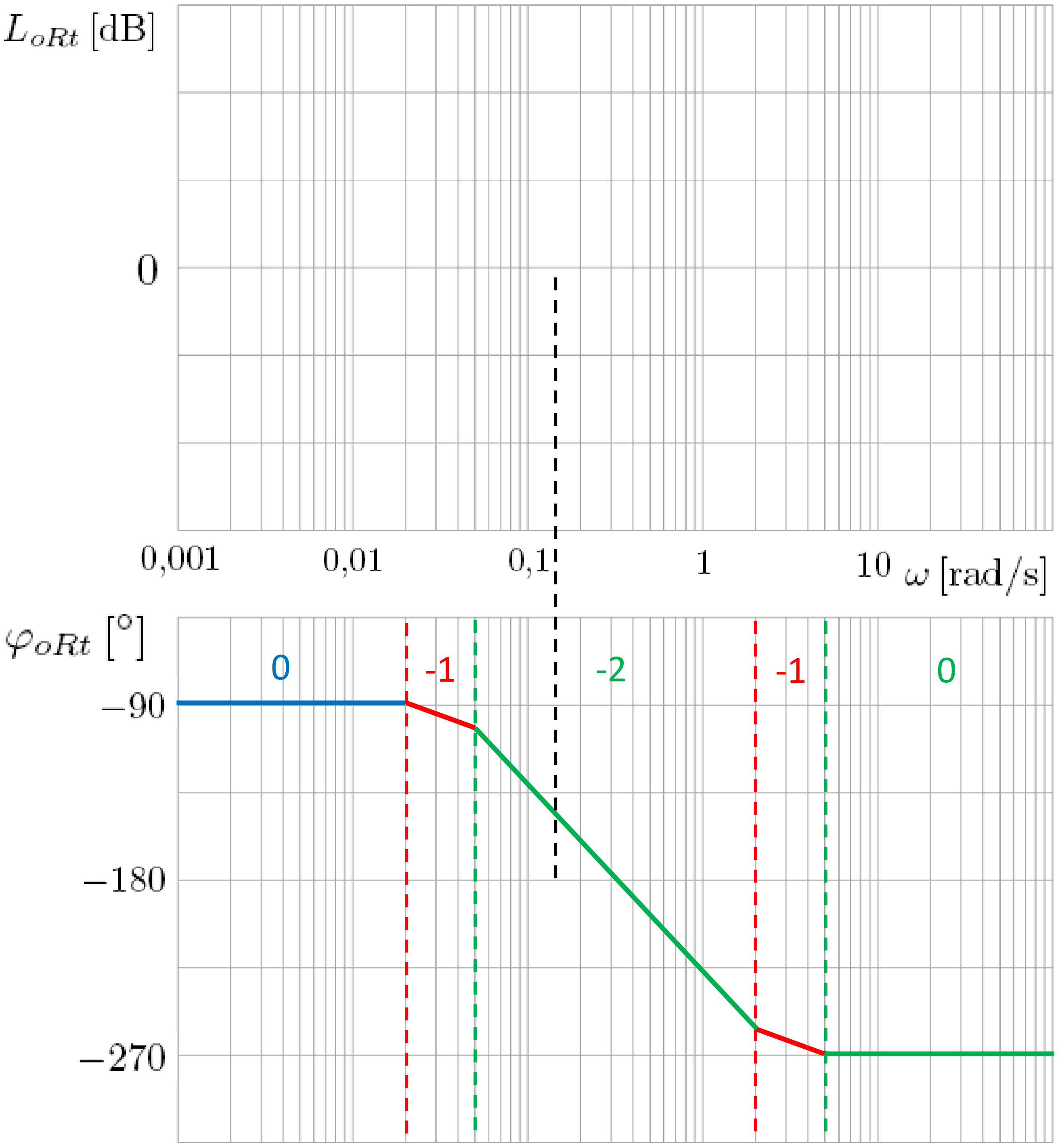
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

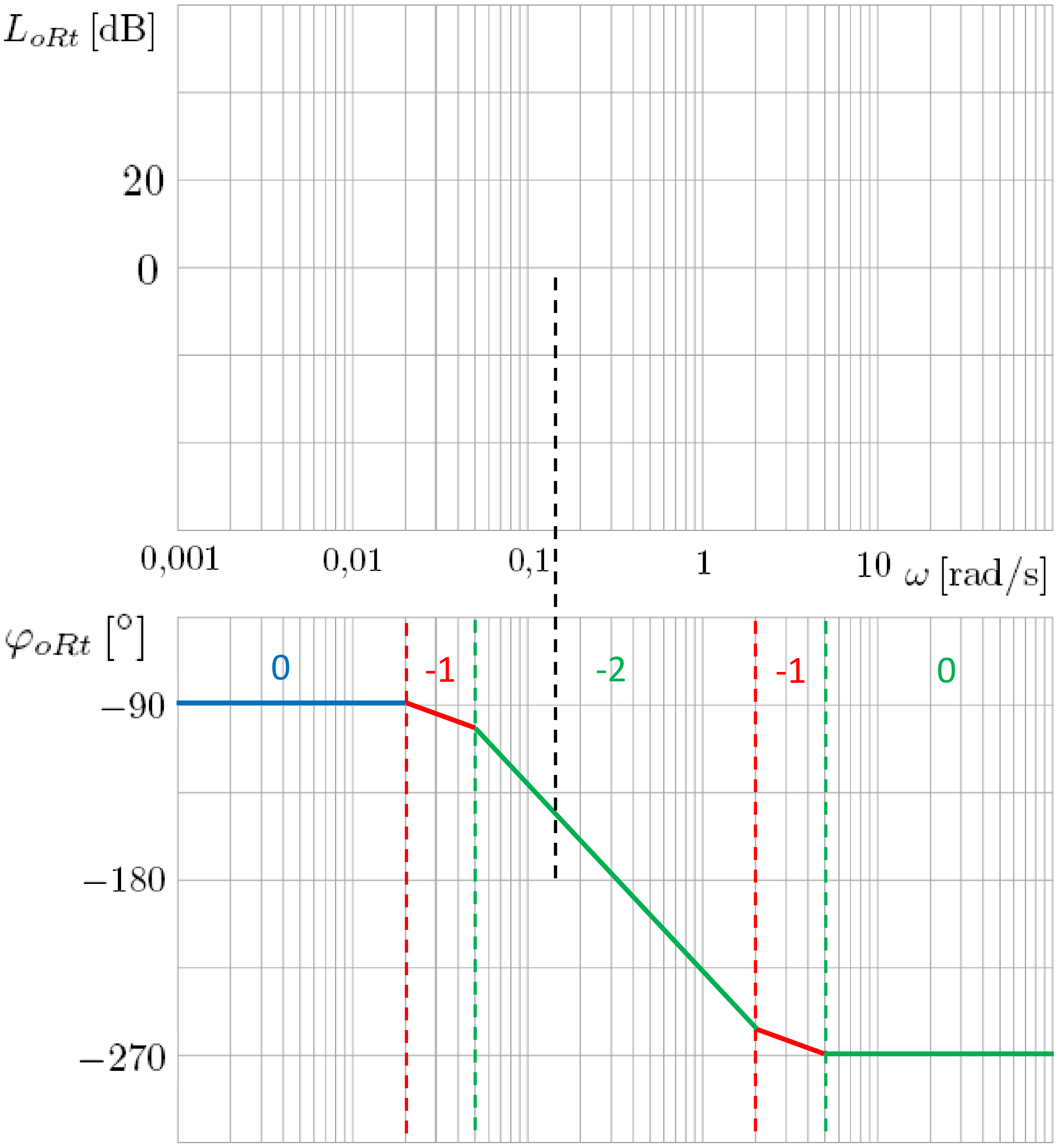
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

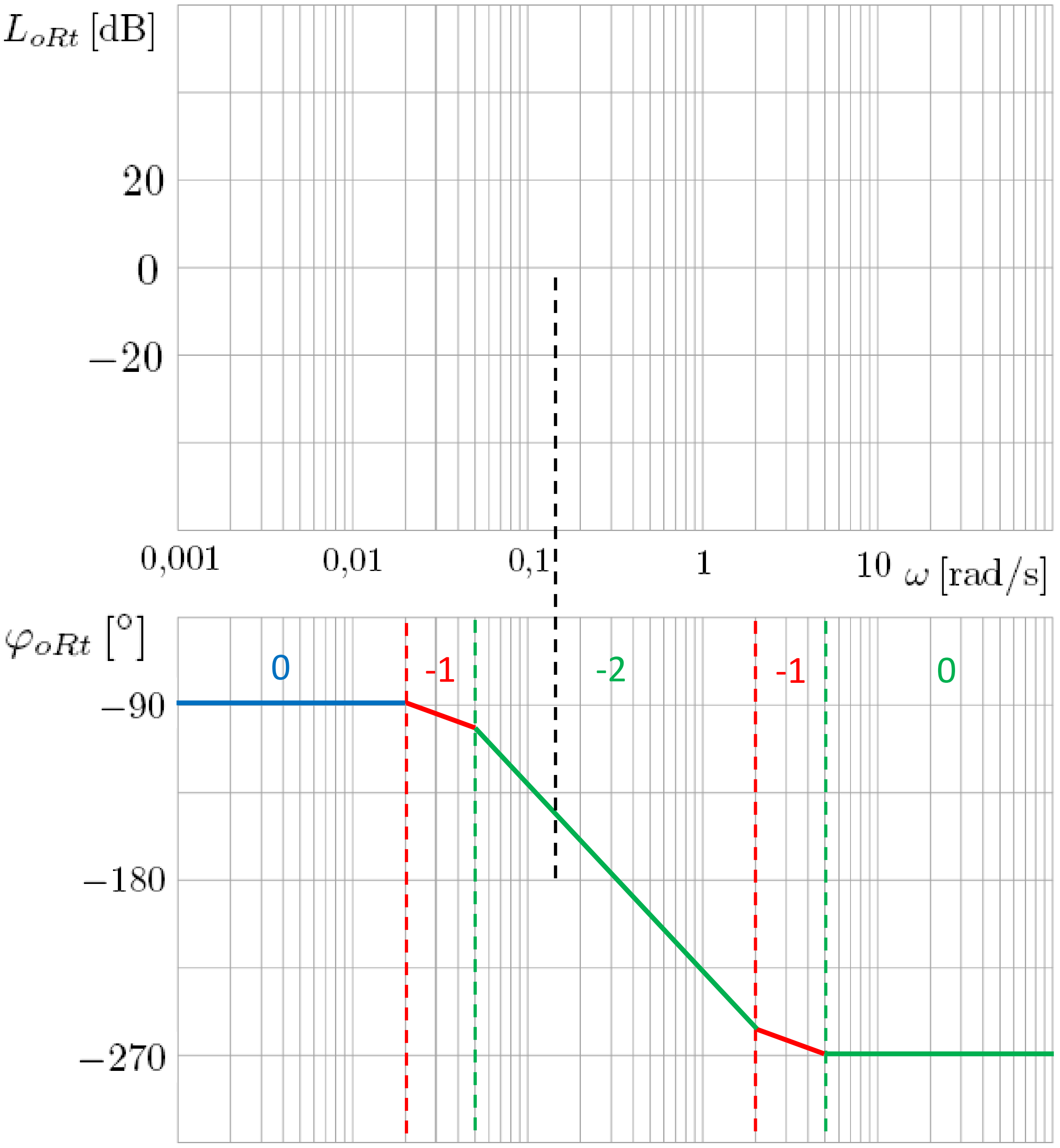
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

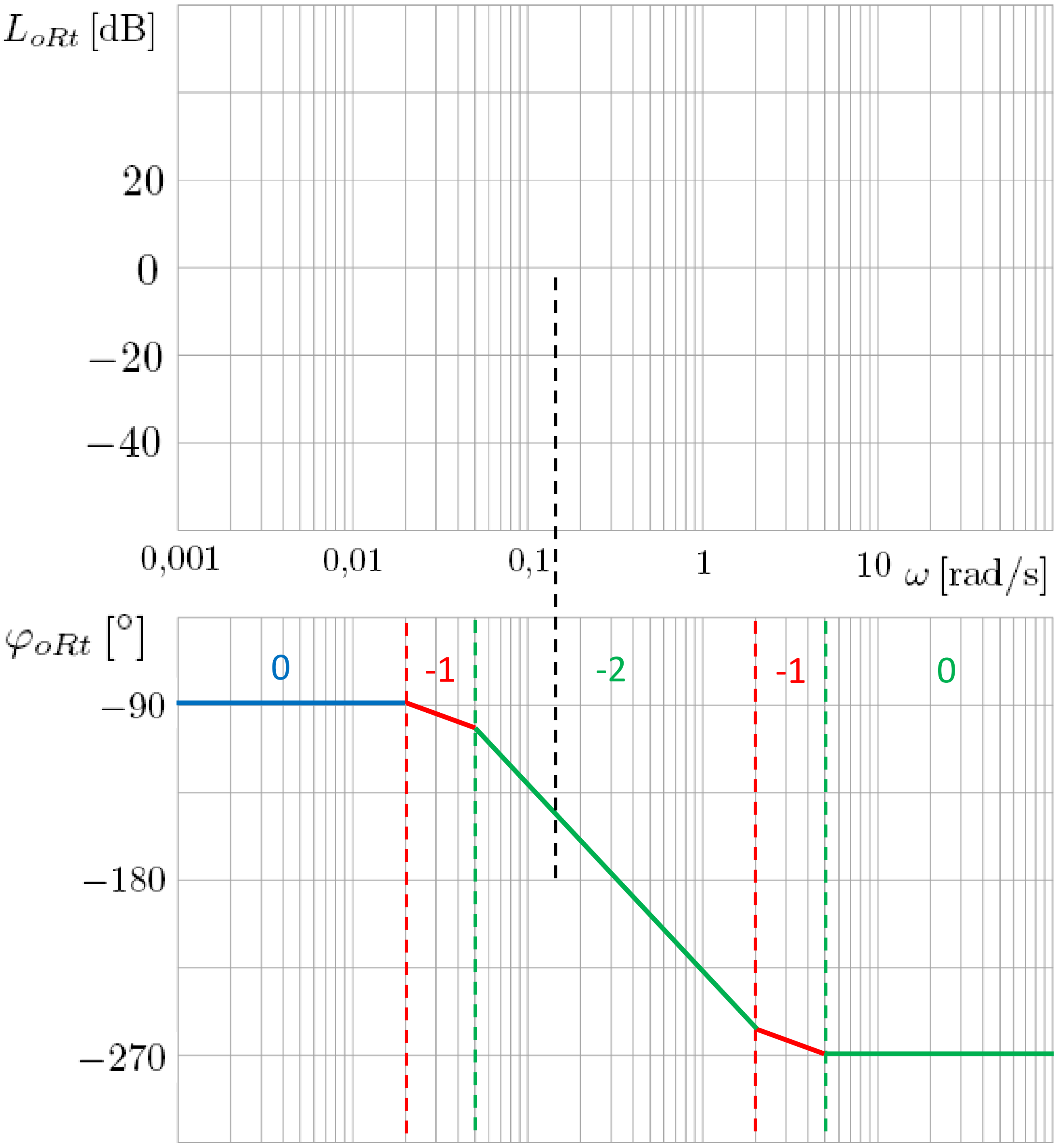
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

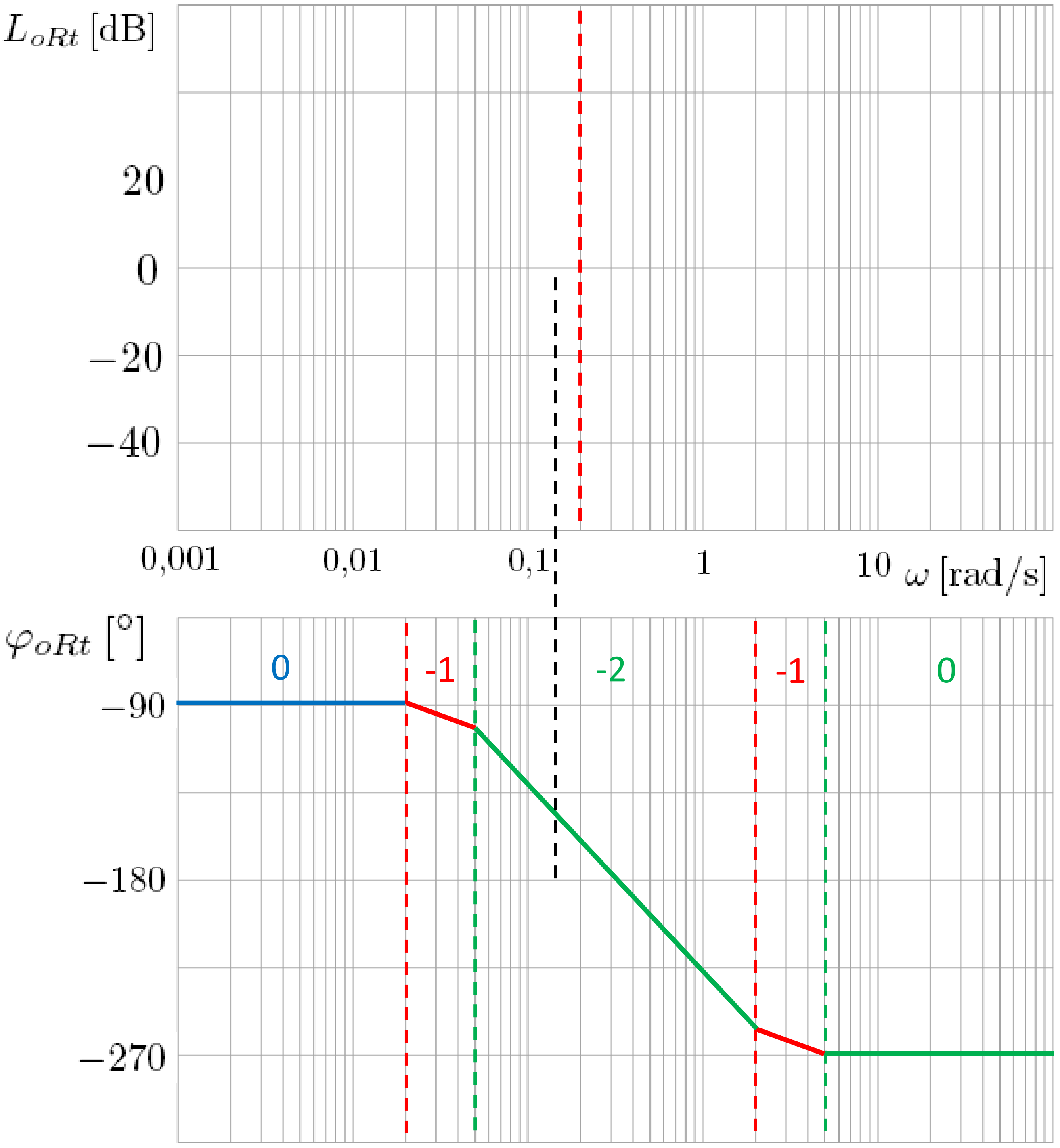
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$0{,}1\omega_2 = 0{,}02\ \mathrm{rad/s}$$

$$10\omega_2 = 2\ \mathrm{rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05\ \mathrm{rad/s}$$

$$10\omega_{pv} = 5\ \mathrm{rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

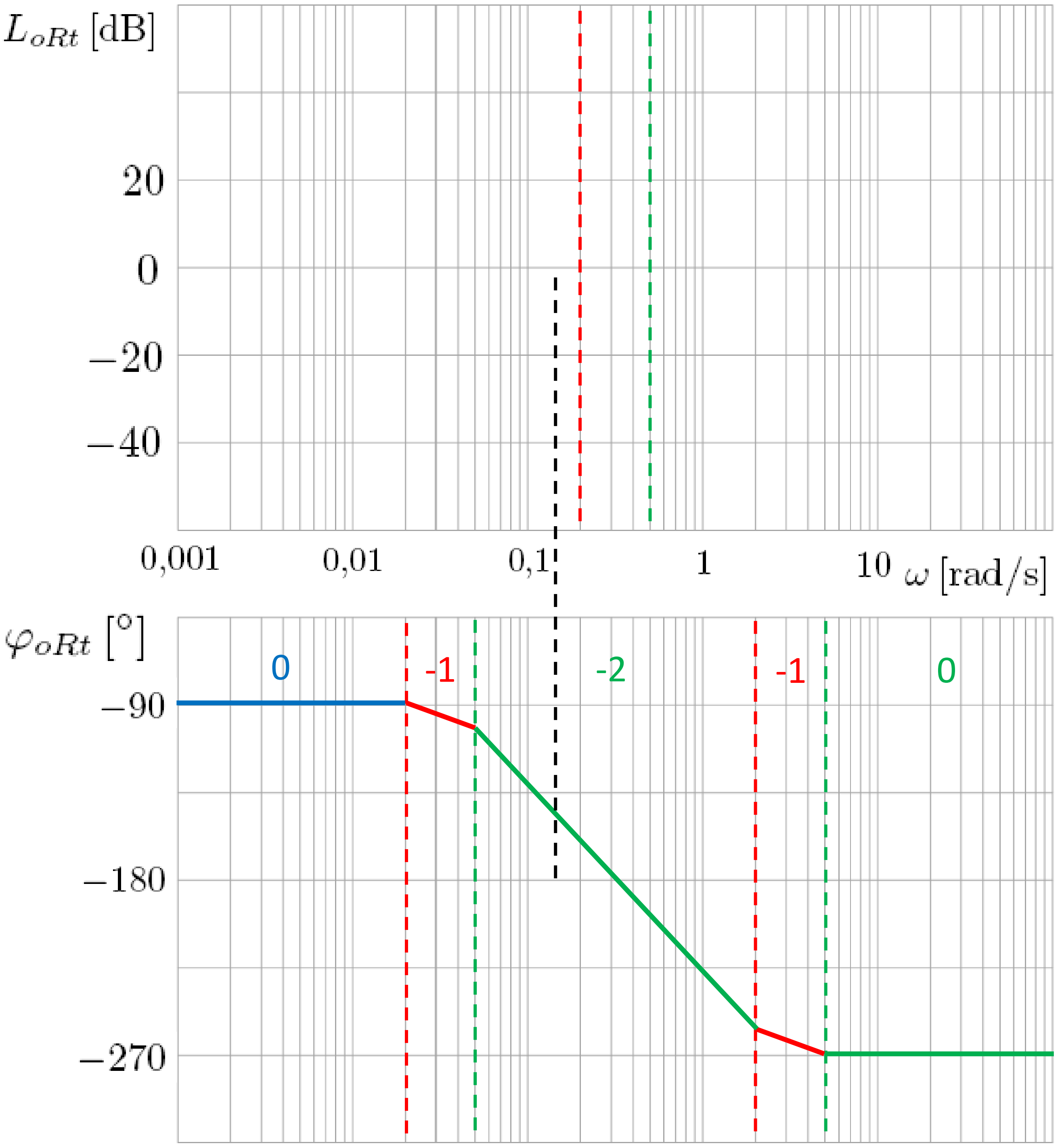
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129\ \mathrm{rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

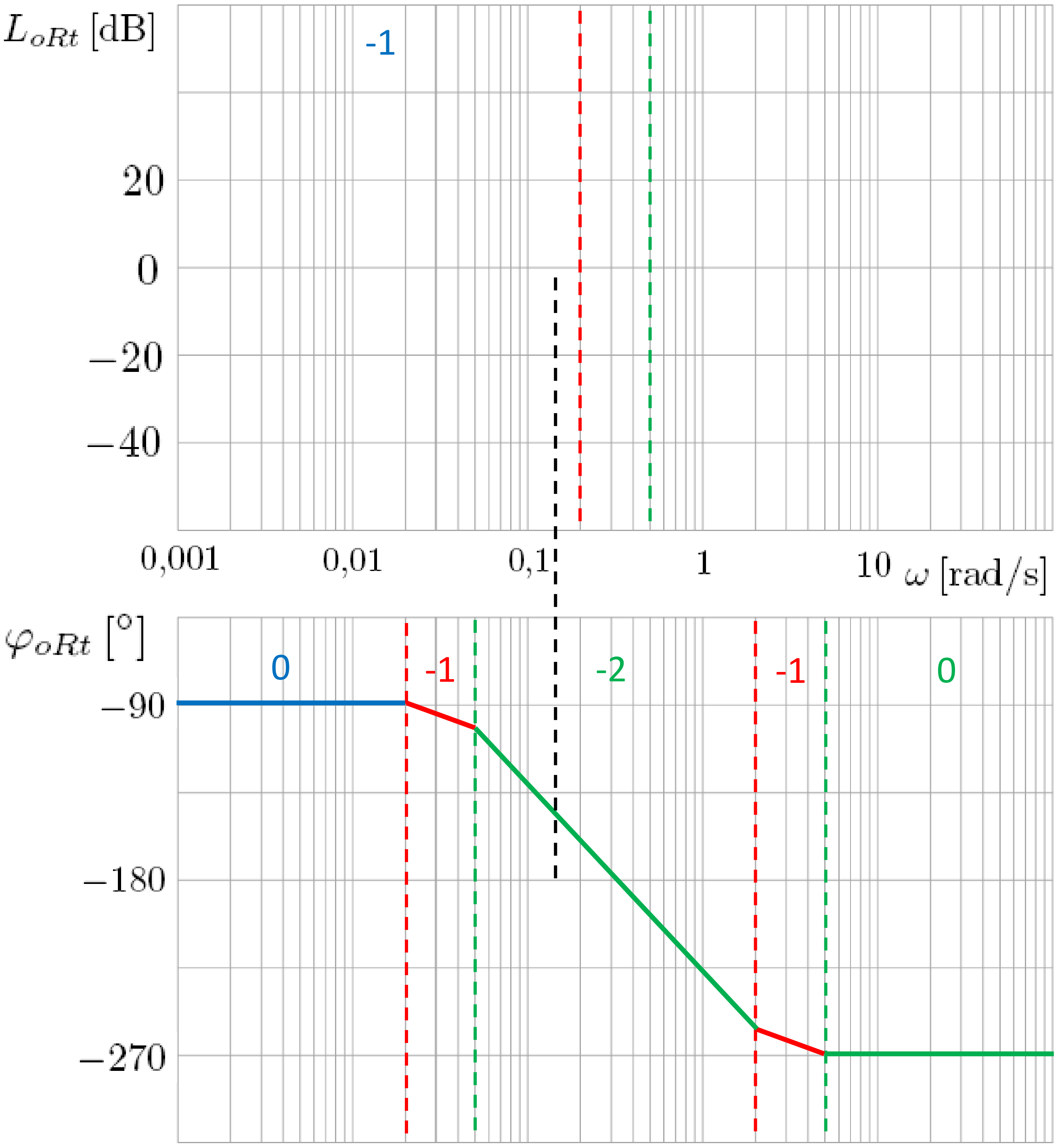
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

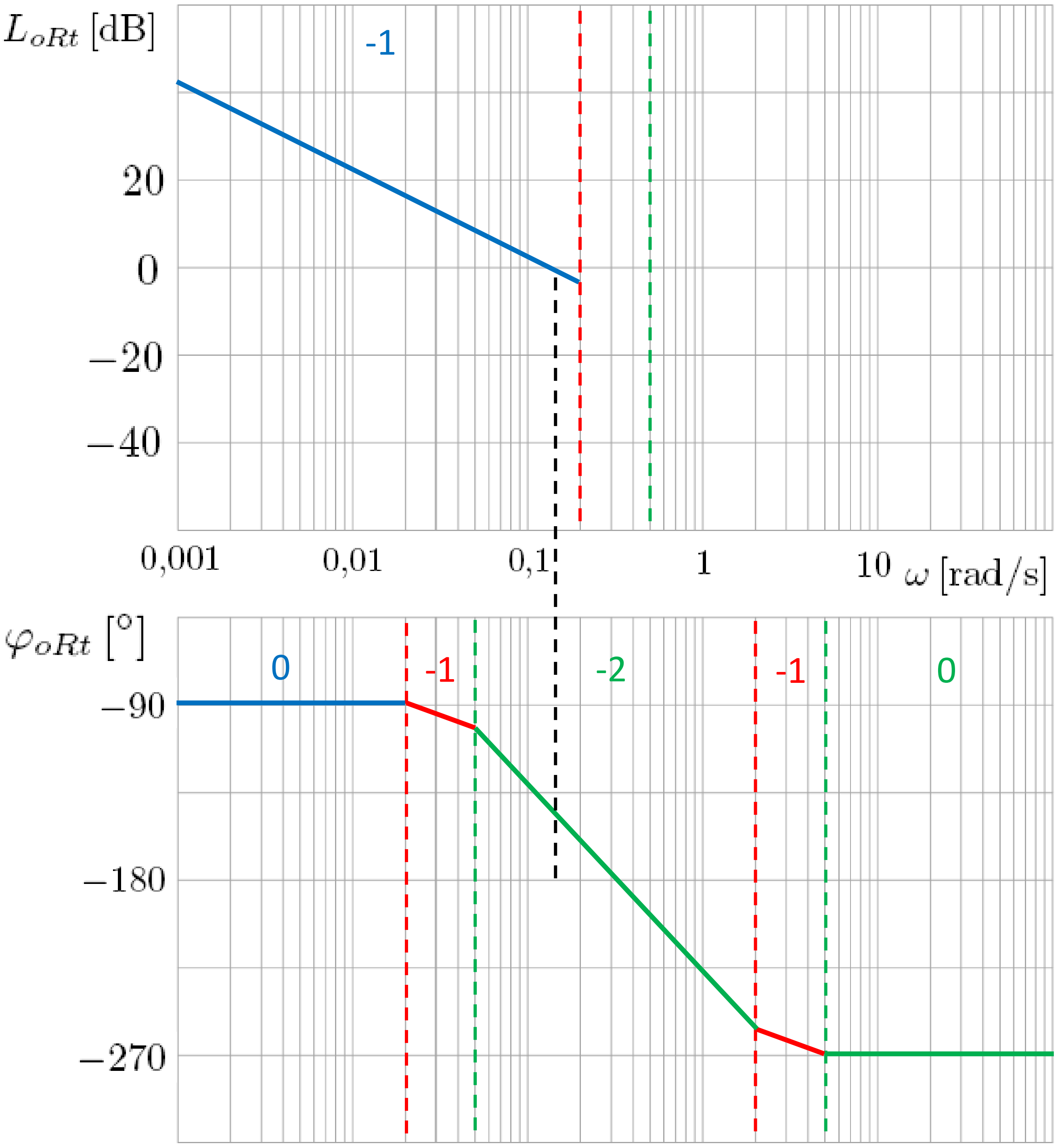
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

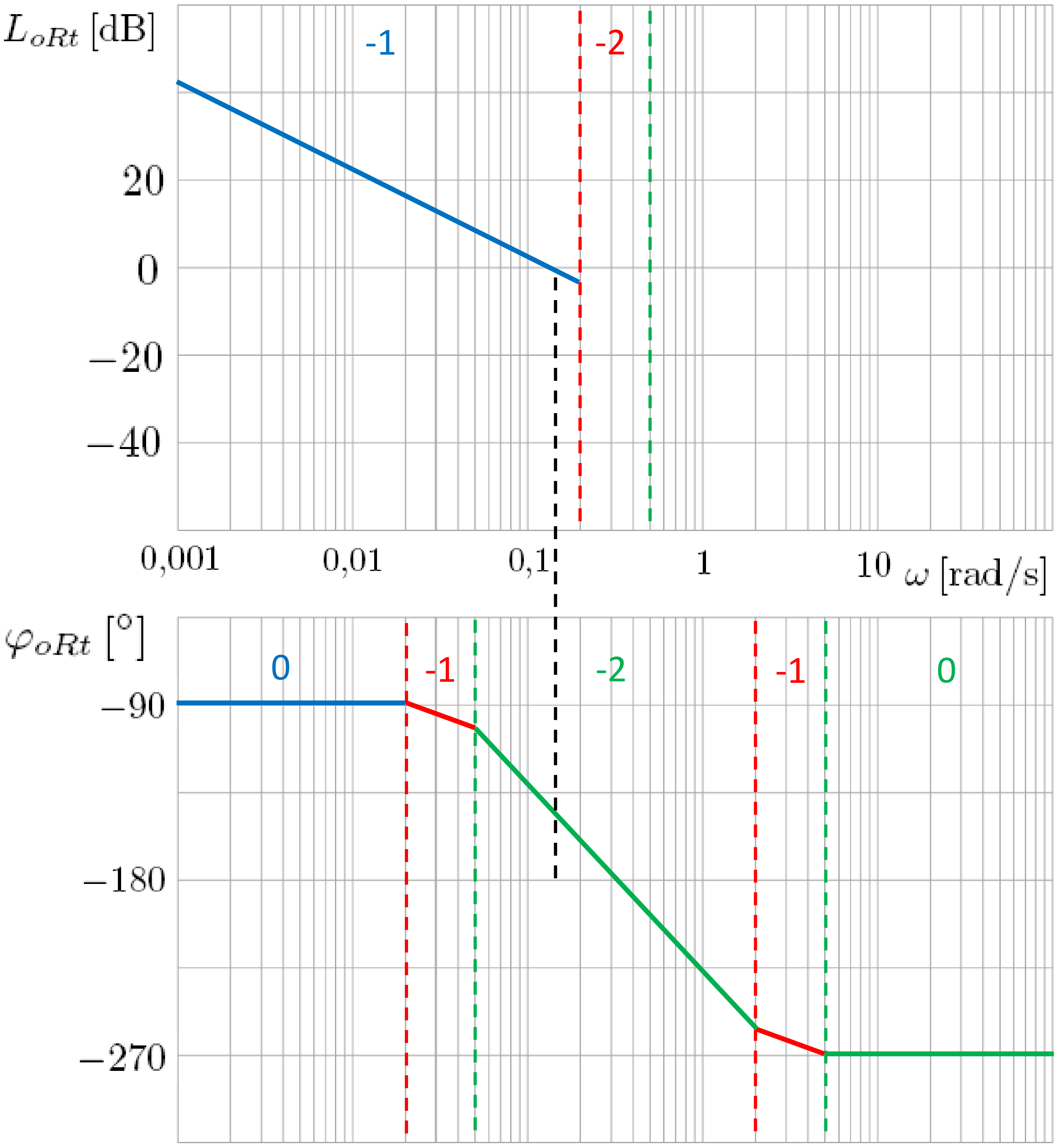
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

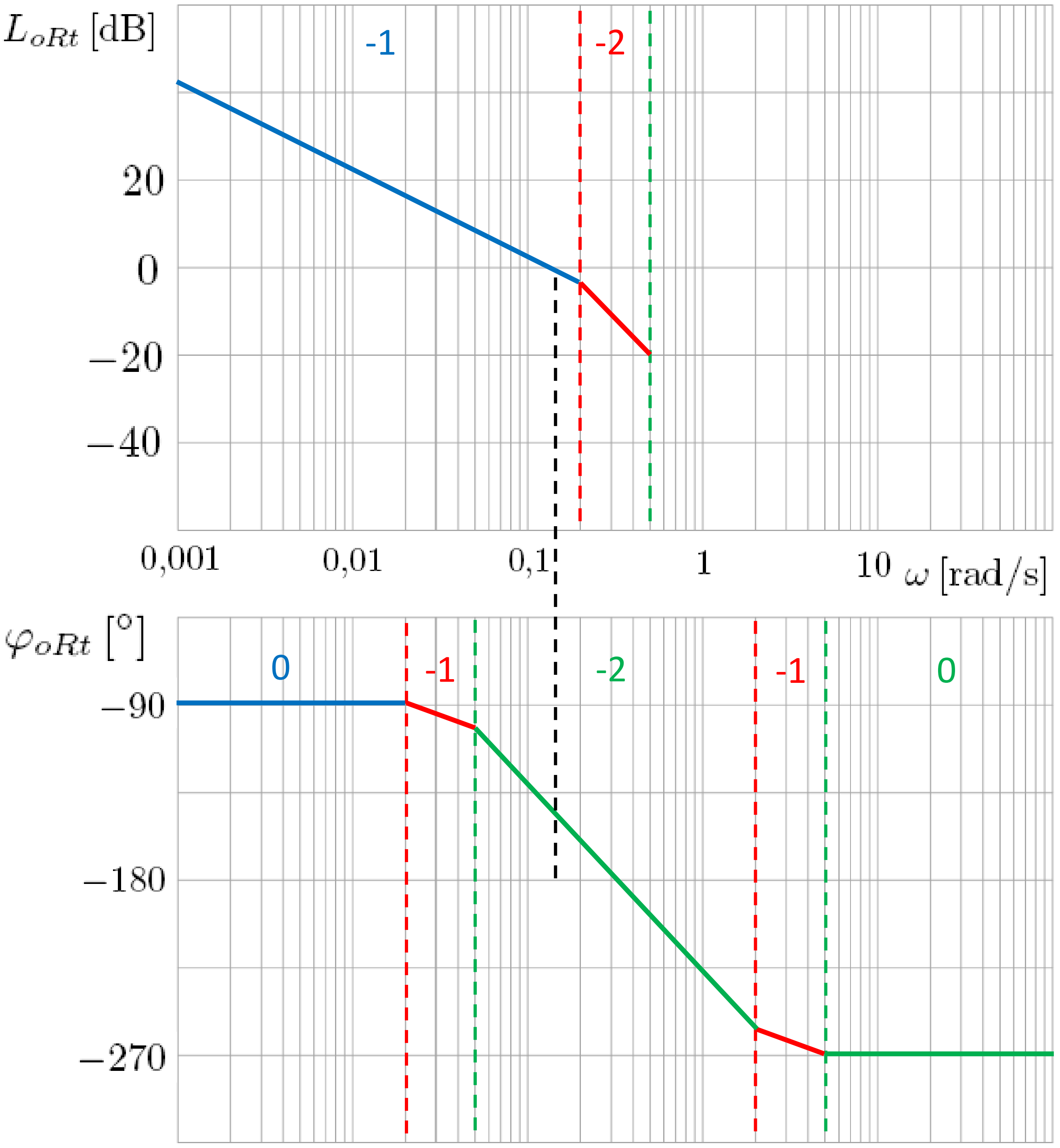
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

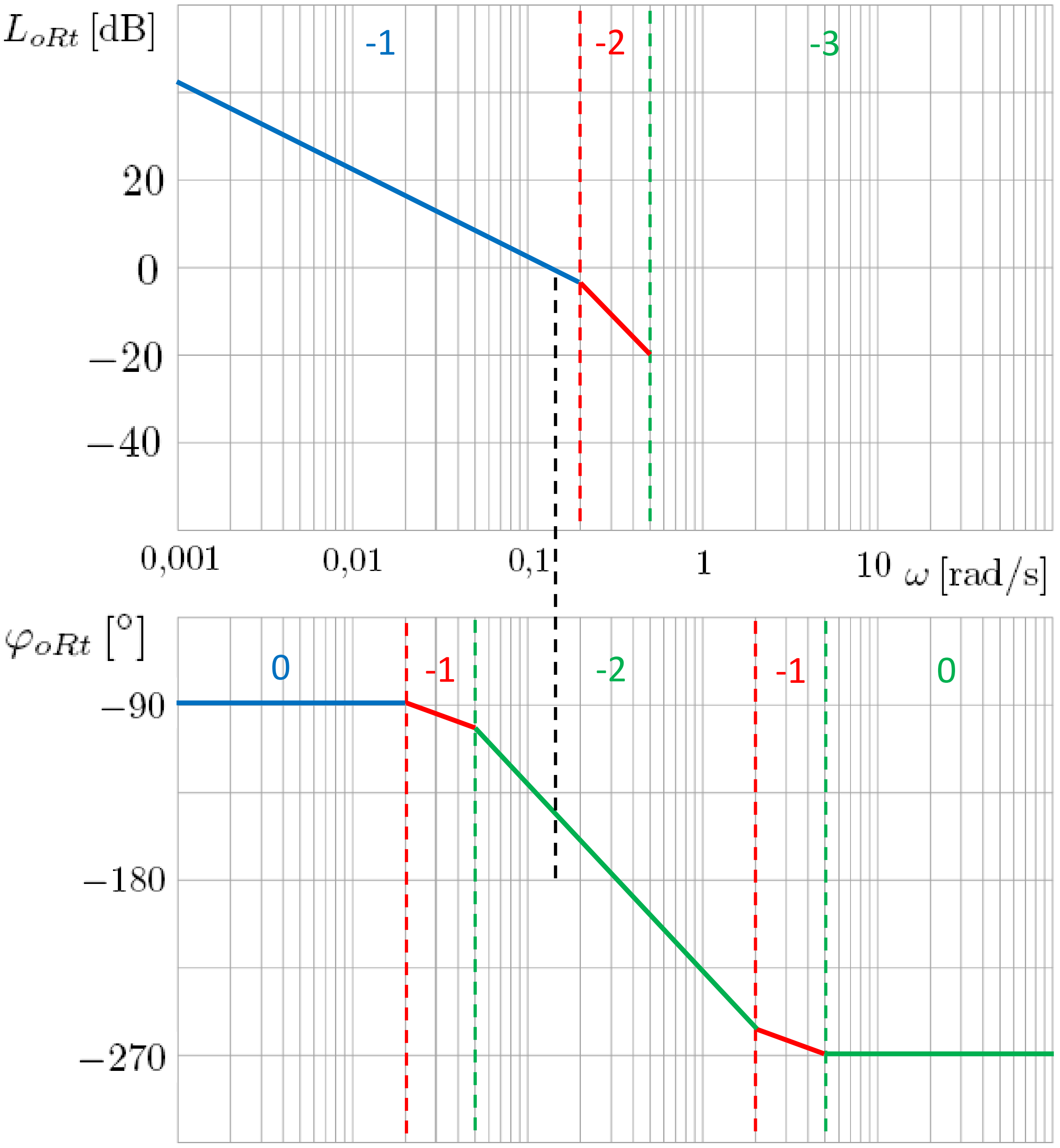
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \text{rad/s} \qquad 0{,}1\omega_2 = 0{,}02\ \text{rad/s} \qquad 10\omega_2 = 2\ \text{rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \text{rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05\ \text{rad/s} \qquad 10\omega_{pv} = 5\ \text{rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

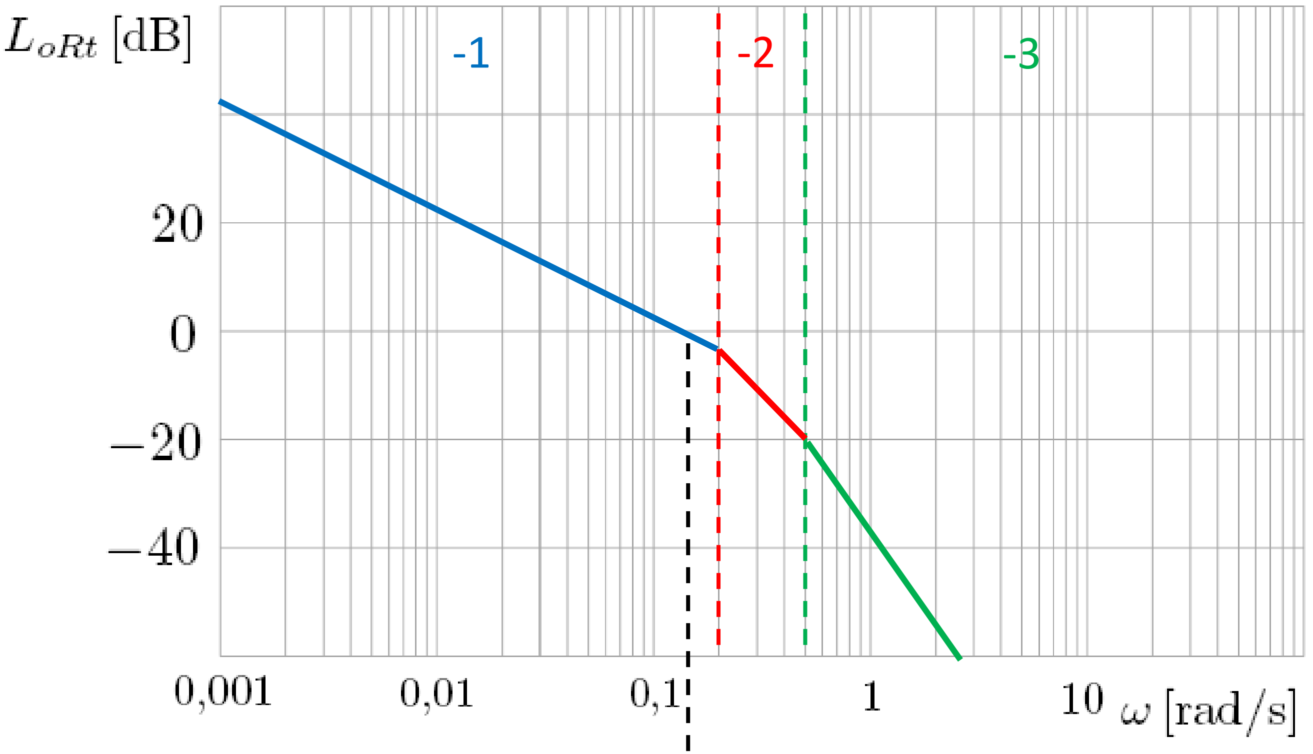
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

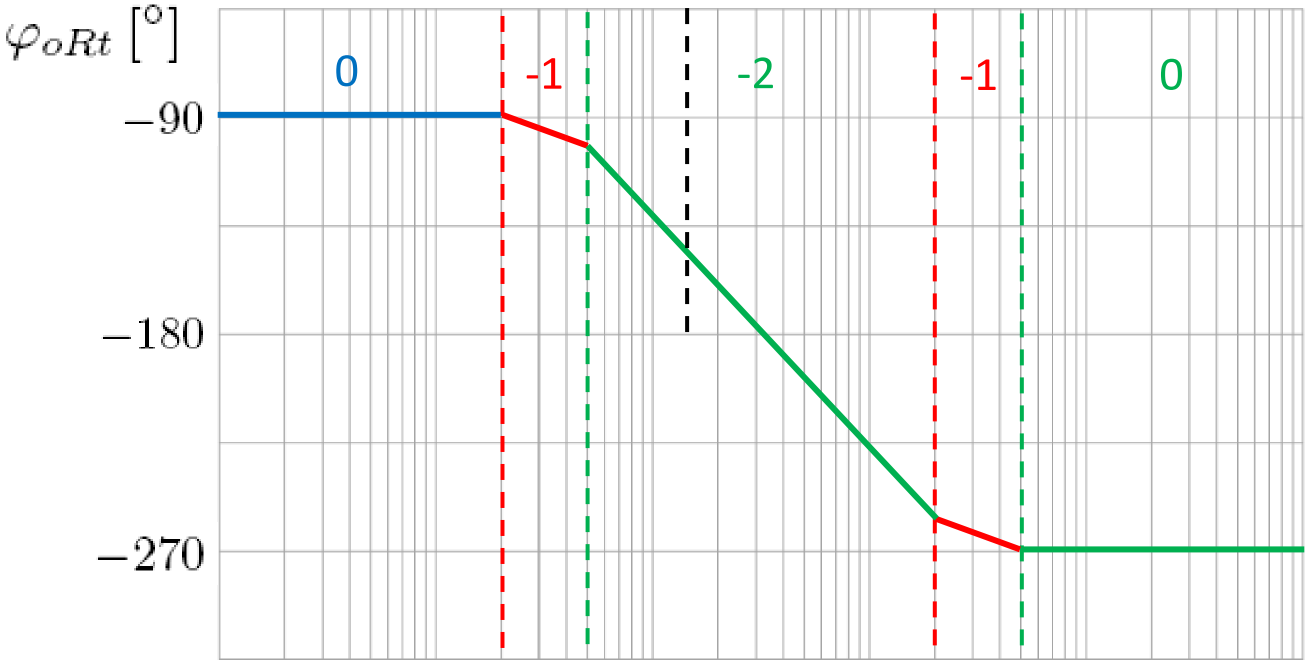
$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129\ \text{rad/s}$$





$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$0{,}1\omega_2 = 0{,}02\ \mathrm{rad/s}$$

$$10\omega_2 = 2\ \mathrm{rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05\ \mathrm{rad/s}$$

$$10\omega_{pv} = 5\ \mathrm{rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

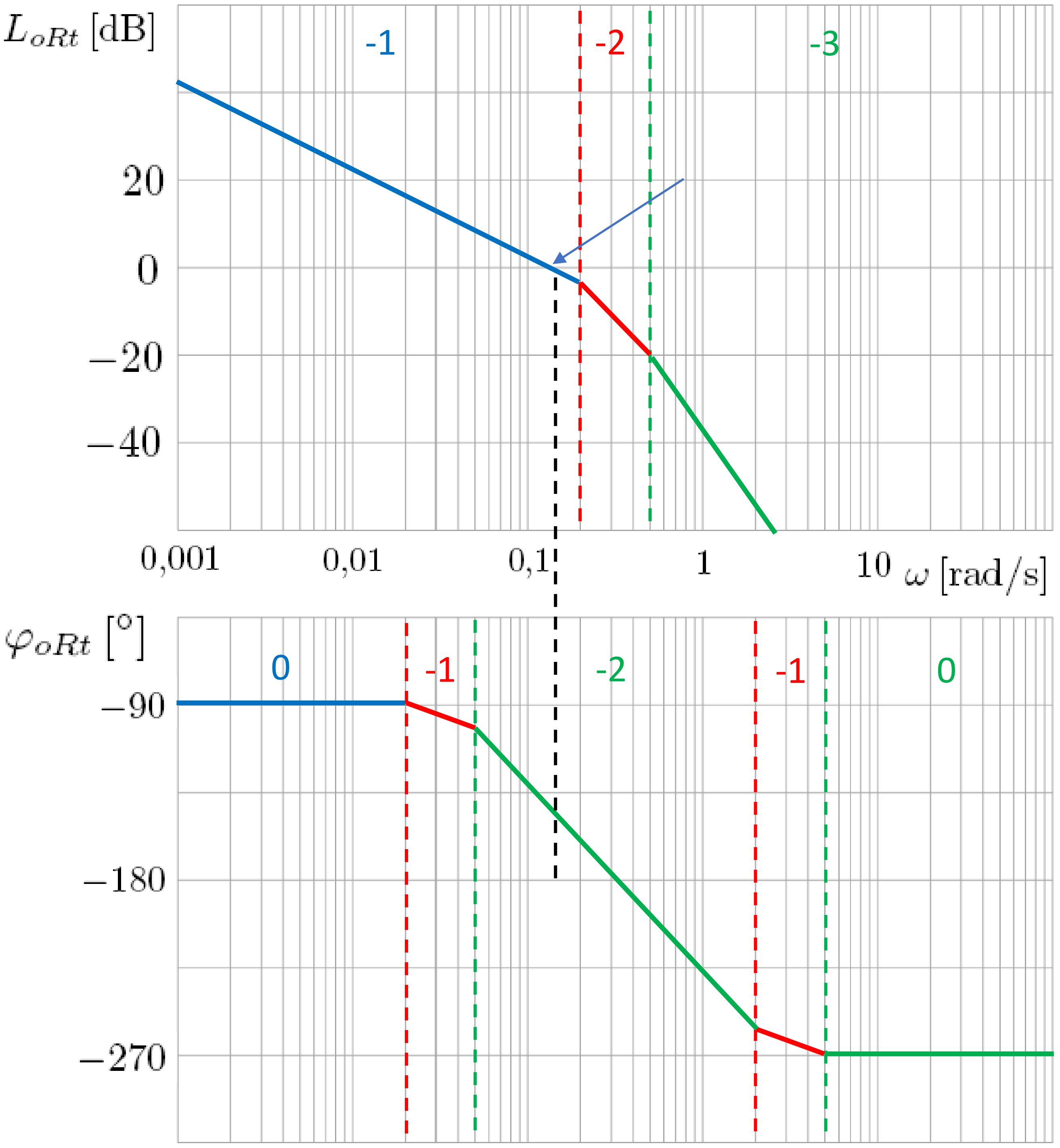
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129\ \mathrm{rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$0{,}1\omega_2 = 0{,}02 \text{ rad/s}$$

$$10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$0{,}1\omega_{pv} = 0{,}05 \text{ rad/s}$$

$$10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

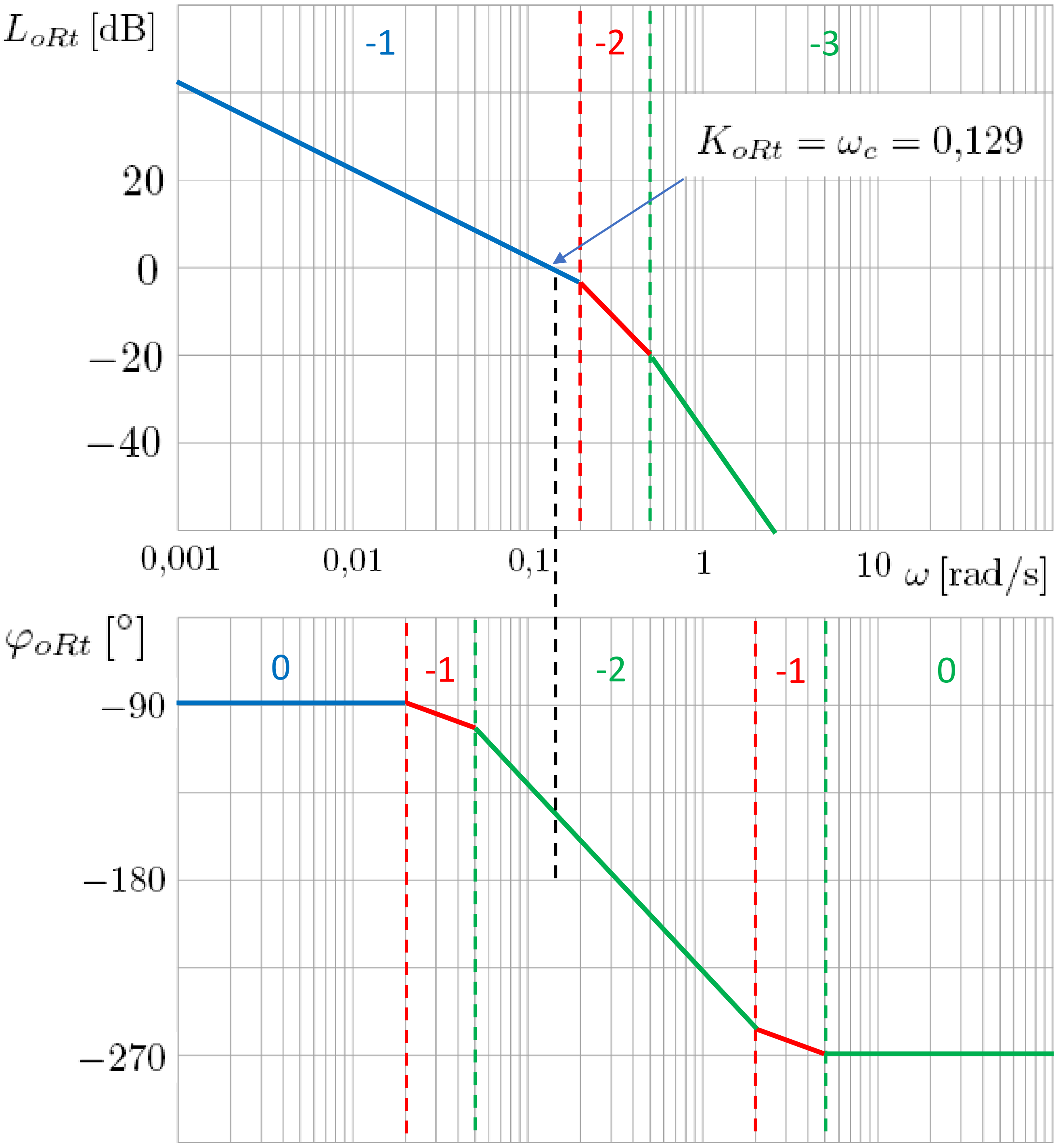
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



$$G_{oRt}(s) = \frac{K_{oRt}}{s(1+5s)(1+2s)}$$

$$\omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad 0{,}1\omega_2 = 0{,}02 \text{ rad/s} \qquad 10\omega_2 = 2 \text{ rad/s}$$

$$\omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s} \qquad 0{,}1\omega_{pv} = 0{,}05 \text{ rad/s} \qquad 10\omega_{pv} = 5 \text{ rad/s}$$

$$\varphi_{oRt}(0{,}05) = -90 - 45\log\frac{0{,}05}{0{,}02} = -107{,}9^\circ$$

$$\varphi_{oRt}(2) = -107{,}9 - 90\log\frac{2}{0{,}05} = -252{,}1^\circ$$

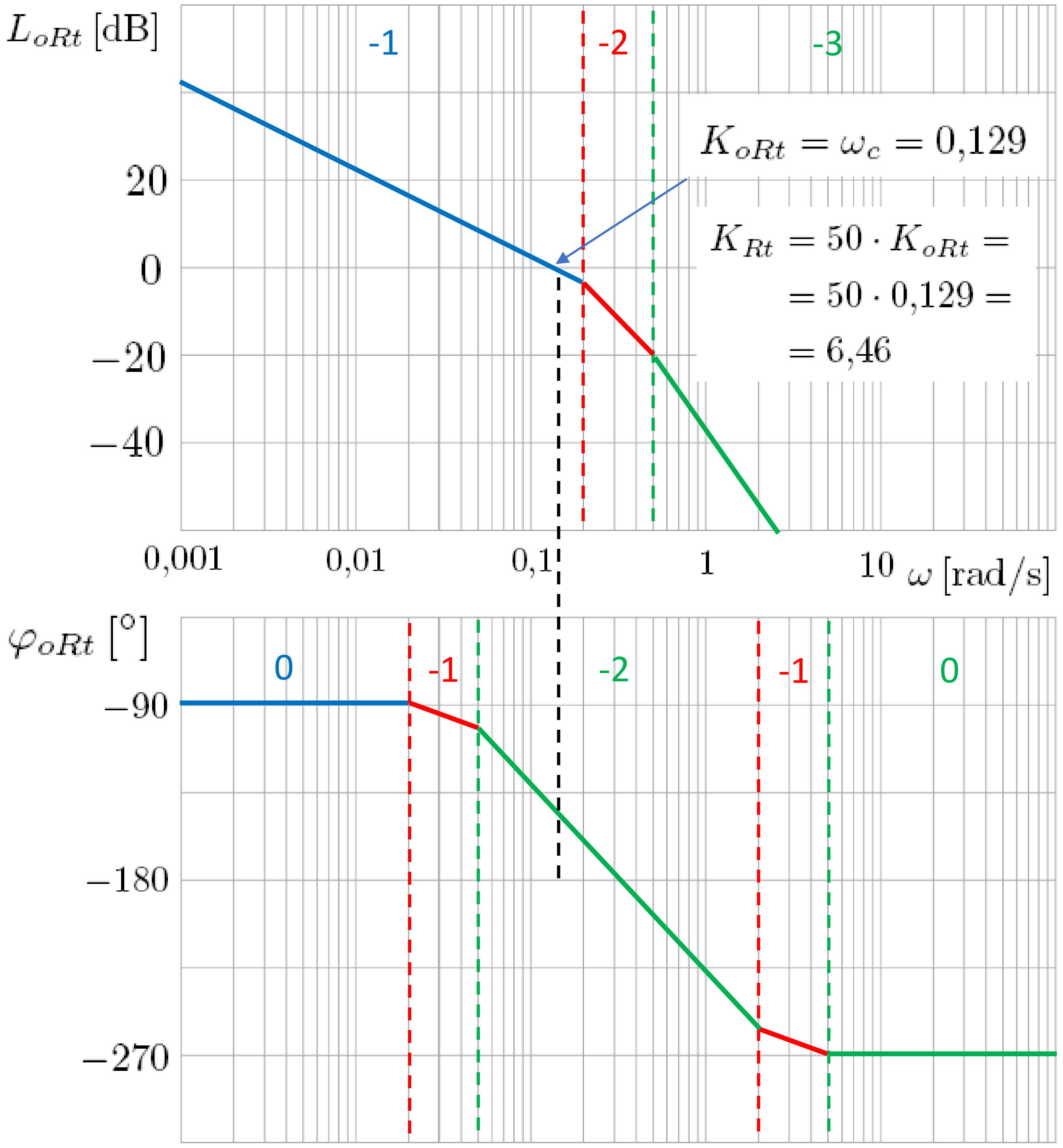
$$\varphi_{oRt}(5) = -252{,}1 - 45\log\frac{5}{2} = -270^\circ$$

$$\gamma = 60 - 25 = 35^\circ$$

$$\varphi_{oRt}(\omega_c) = -180 + 35 = -145^\circ$$

$$\varphi_{oRt}(\omega_c) = -107{,}9 - 90\log\frac{\omega_c}{0{,}05} = -145^\circ$$

$$\omega_c = 0{,}05 \cdot 10^{\frac{145-107{,}9}{90}} = 0{,}129 \text{ rad/s}$$



Simulacija i korekcija parametara

Simetrični optimum

Simetrični optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da vrijedi: $T_1 > T_{Is} > \max(T_2, T_{pv})$.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *s*.
- Simetrični optimum – postizanje simetrične frekvencijske karakteristike oko presječne frekvencije ω_{cs}.
- Nagib amplitudno-frekvencijske karakteristike oko ω_{cs} mora iznositi -1, tj. -20 dB/dek.
- Širina nagiba -1 oko ω_{cs} (parametar *a*) određuje iznos presječne frekvencije ω_{cs} i integracijske vremenske konstante regulatora T_{Is}.

Simetrični optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da vrijedi: $T_1 > T_{Is} > \max(T_2, T_{pv})$.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *s*.
- Simetrični optimum – postizanje simetrične frekvencijske karakteristike oko presječne frekvencije ω_{cs}.
- Nagib amplitudno-frekvencijske karakteristike oko ω_{cs} mora iznositi -1, tj. -20 dB/dek.
- Širina nagiba -1 oko ω_{cs} (parametar *a*) određuje iznos presječne frekvencije ω_{cs} i integracijske vremenske konstante regulatora T_{Is}.

$$\sigma_m\,[\%] + \gamma_{sa}\,[^\circ] \approx 70$$

Simetrični optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da vrijedi: $T_1 > T_{Is} > \max(T_2, T_{pv})$.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *s*.
- Simetrični optimum – postizanje simetrične frekvencijske karakteristike oko presječne frekvencije ω_{cs}.
- Nagib amplitudno-frekvencijske karakteristike oko ω_{cs} mora iznositi -1, tj. -20 dB/dek.
- Širina nagiba -1 oko ω_{cs} (parametar *a*) određuje iznos presječne frekvencije ω_{cs} i integracijske vremenske konstante regulatora T_{Is}.

$$\sigma_m\,[\%] + \gamma_{sa}\,[^\circ] \approx 70 \qquad a \approx \frac{\gamma_{sa}\,[^\circ]}{14}$$

Simetrični optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da vrijedi: $T_1 > T_{Is} > \max(T_2, T_{pv})$.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *s*.
- Simetrični optimum – postizanje simetrične frekvencijske karakteristike oko presječne frekvencije ω_{cs}.
- Nagib amplitudno-frekvencijske karakteristike oko ω_{cs} mora iznositi -1, tj. -20 dB/dek.
- Širina nagiba -1 oko ω_{cs} (parametar *a*) određuje iznos presječne frekvencije ω_{cs} i integracijske vremenske konstante regulatora T_{Is}.

$$\sigma_m\,[\%] + \gamma_{sa}\,[^\circ] \approx 70 \qquad a \approx \frac{\gamma_{sa}\,[^\circ]}{14} \qquad \omega_{cs} = \frac{\min\left(\omega_2, \omega_{pv}\right)}{a}$$

Simetrični optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da vrijedi: $T_1 > T_{Is} > \max(T_2, T_{pv})$.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *s*.
- Simetrični optimum – postizanje simetrične frekvencijske karakteristike oko presječne frekvencije ω_{cs}.
- Nagib amplitudno-frekvencijske karakteristike oko ω_{cs} mora iznositi -1, tj. -20 dB/dek.
- Širina nagiba -1 oko ω_{cs} (parametar *a*) određuje iznos presječne frekvencije ω_{cs} i integracijske vremenske konstante regulatora T_{Is}.

$$\sigma_m\,[\%] + \gamma_{sa}\,[^\circ] \approx 70 \qquad a \approx \frac{\gamma_{sa}\,[^\circ]}{14} \qquad \omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} \qquad \omega_{Is} = \frac{\omega_{cs}}{a}$$

Simetrični optimum

- Integracijska vremenska konstanta PI regulatora odabire se tako da vrijedi: $T_1 > T_{Is} > \max(T_2, T_{pv})$.
- Parametrima i prijenosnim funkcijama regulatora i otvorenog kruga s regulatorom dodaje se indeks *s*.
- Simetrični optimum – postizanje simetrične frekvencijske karakteristike oko presječne frekvencije ω_{cs}.
- Nagib amplitudno-frekvencijske karakteristike oko ω_{cs} mora iznositi -1, tj. -20 dB/dek.
- Širina nagiba -1 oko ω_{cs} (parametar *a*) određuje iznos presječne frekvencije ω_{cs} i integracijske vremenske konstante regulatora T_{Is}.

$$\sigma_m\,[\%] + \gamma_{sa}\,[°] \approx 70 \qquad a \approx \frac{\gamma_{sa}\,[°]}{14} \qquad \omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} \qquad \omega_{Is} = \frac{\omega_{cs}}{a} \qquad T_{Is} = \frac{1}{\omega_{Is}}$$

$$G_{Rs}(s) = K_{Rs} \cdot \frac{1 + T_{Is} s}{T_{Is} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{Rs}(s) = K_{Rs} \cdot \frac{1 + T_{Is}s}{T_{Is}s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oRs}(s) = G_{Rs}(s) \cdot G_p(s)$$

$$G_{Rs}(s) = K_{Rs} \cdot \frac{1 + T_{Is}s}{T_{Is}s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oRs}(s) = G_{Rs}(s) \cdot G_p(s)$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + T_{Is}s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{Rs}(s) = K_{Rs} \cdot \frac{1 + T_{Is}s}{T_{Is}s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oRs}(s) = G_{Rs}(s) \cdot G_p(s)$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + T_{Is}s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_{Is}}$$

$$G_{Rs}(s) = K_{Rs} \cdot \frac{1 + T_{Is}s}{T_{Is}s} \qquad G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oRs}(s) = G_{Rs}(s) \cdot G_p(s)$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + T_{Is}s}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_{Is}}$$

- Preostali nepoznati parametar K_{oRs} određuje se na sličan način kao i kod tehničkog optimuma, uz napomenu da se optimalni rezultati postižu ako se presječna frekvencija fino korigira tako da bude u vrhu zvona fazno-frekvencijske karakteristike, čime se postiže maksimalno fazno osiguranje, odnosno minimalno nadvišenje odziva zatvorenog regulacijskog sustava.

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 40\%$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}1}{2} = 0{,}05 \text{ rad/s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}1}{2} = 0{,}05 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}05} = 20 \text{ s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1 + 20s}{20s} \cdot \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}1}{2} = 0{,}05 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}05} = 20 \text{ s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+20s}{20s} \cdot \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}1}{2} = 0{,}05 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}05} = 20 \text{ s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+20s}{20s} \cdot \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot 8}{20} = 0{,}4K_{Rs}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}1}{2} = 0{,}05 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}05} = 20 \text{ s}$$

Primjer 2a

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1 + 20s}{20s} \cdot \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 20s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot 8}{20} = 0{,}4K_{Rs} \qquad K_{Rs} = \frac{1}{0{,}4}K_{oRs} = 2{,}5K_{oRs}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 40\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 30^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{30}{14} \approx 2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{2} = 0{,}1 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}1}{2} = 0{,}05 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}05} = 20 \text{ s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

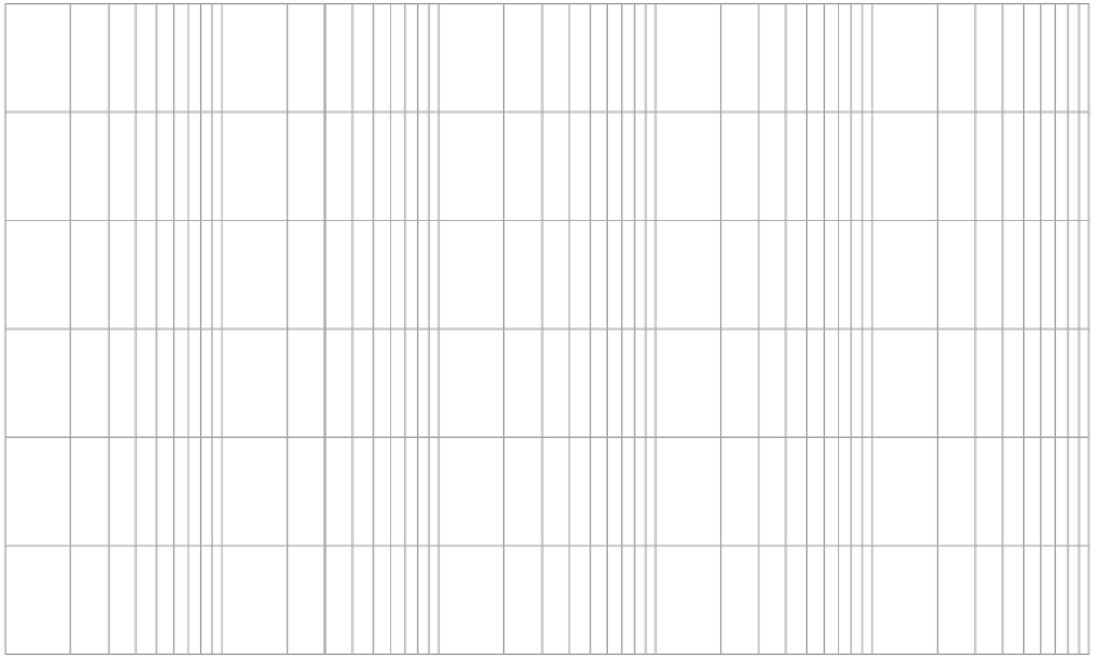
$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

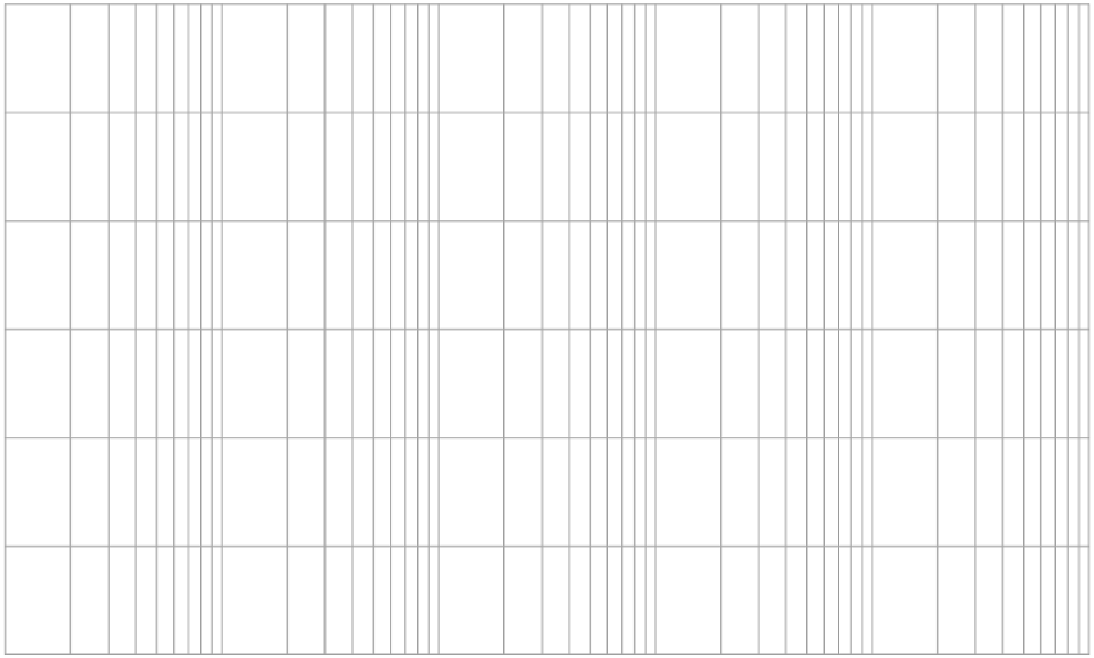
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

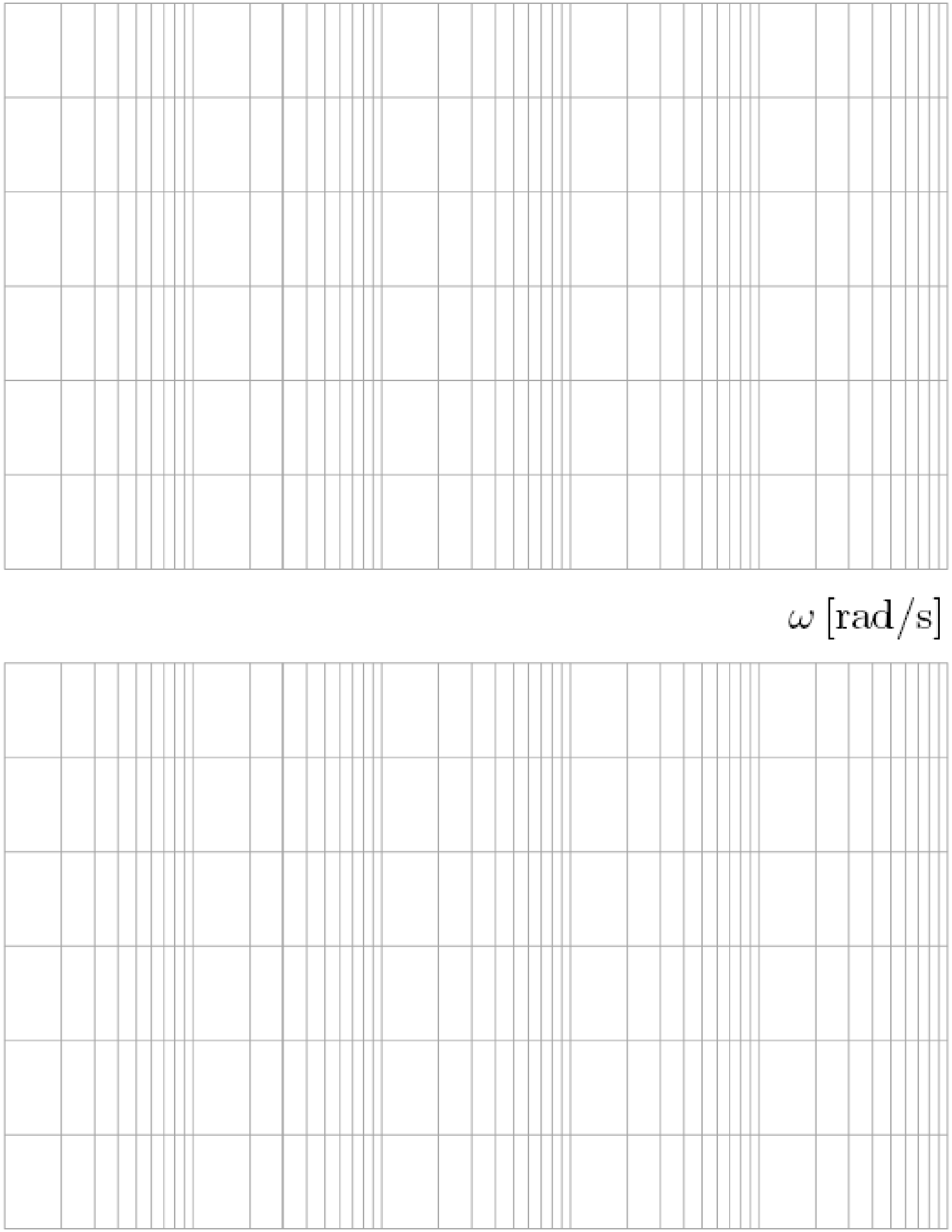




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



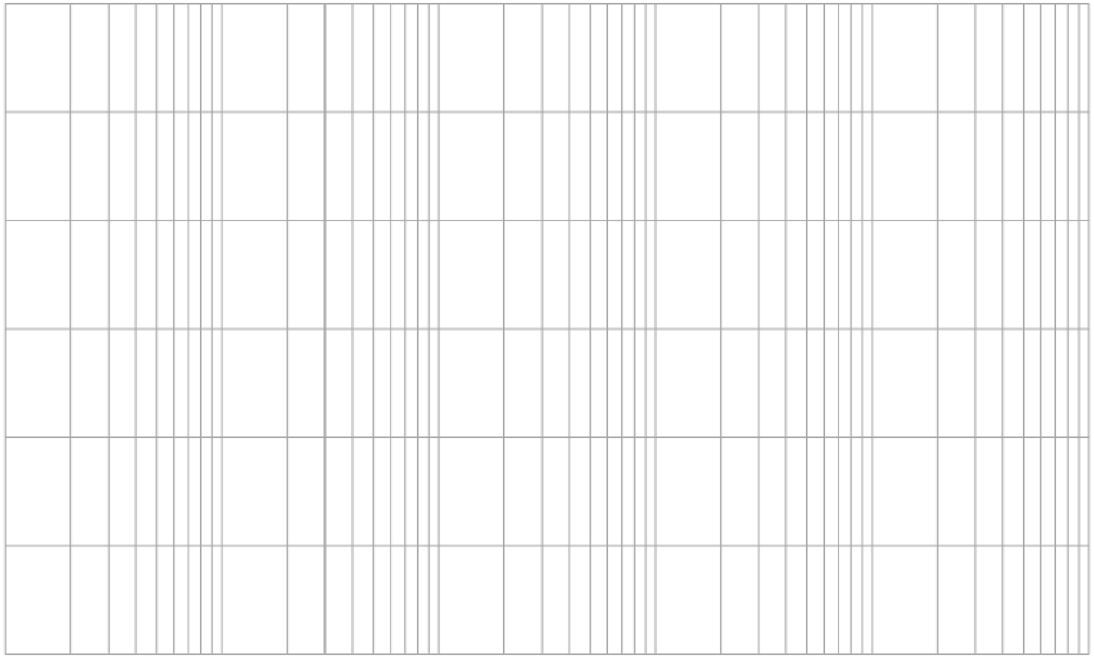
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

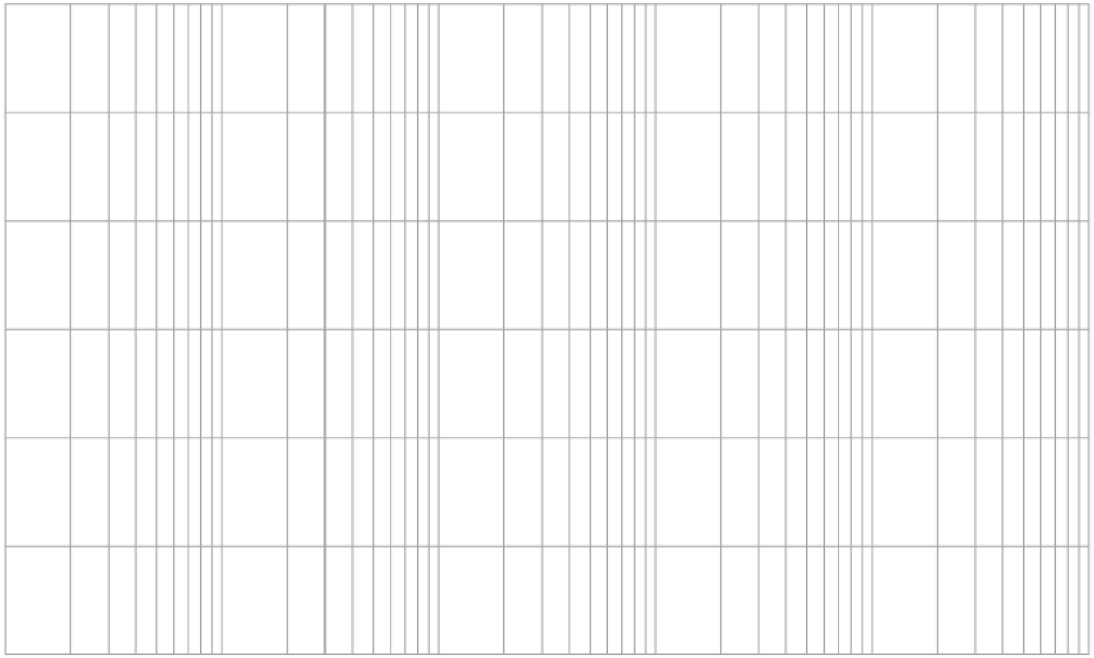
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$L_{oRs}(\omega)$

[dB]



ω [rad/s]



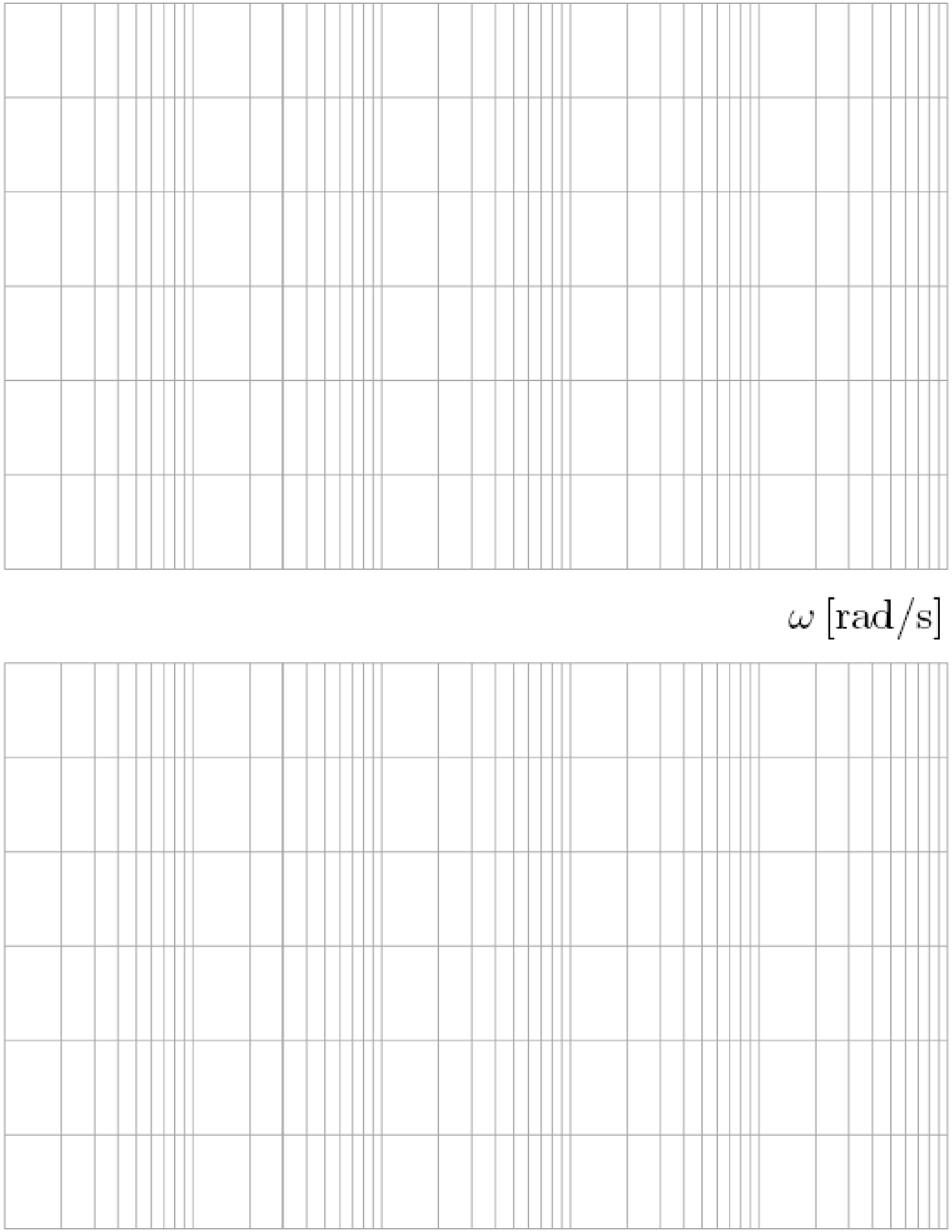
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$L_{oRs}(\omega)$ [dB]

$\varphi_{oRs}(\omega)$ [°]

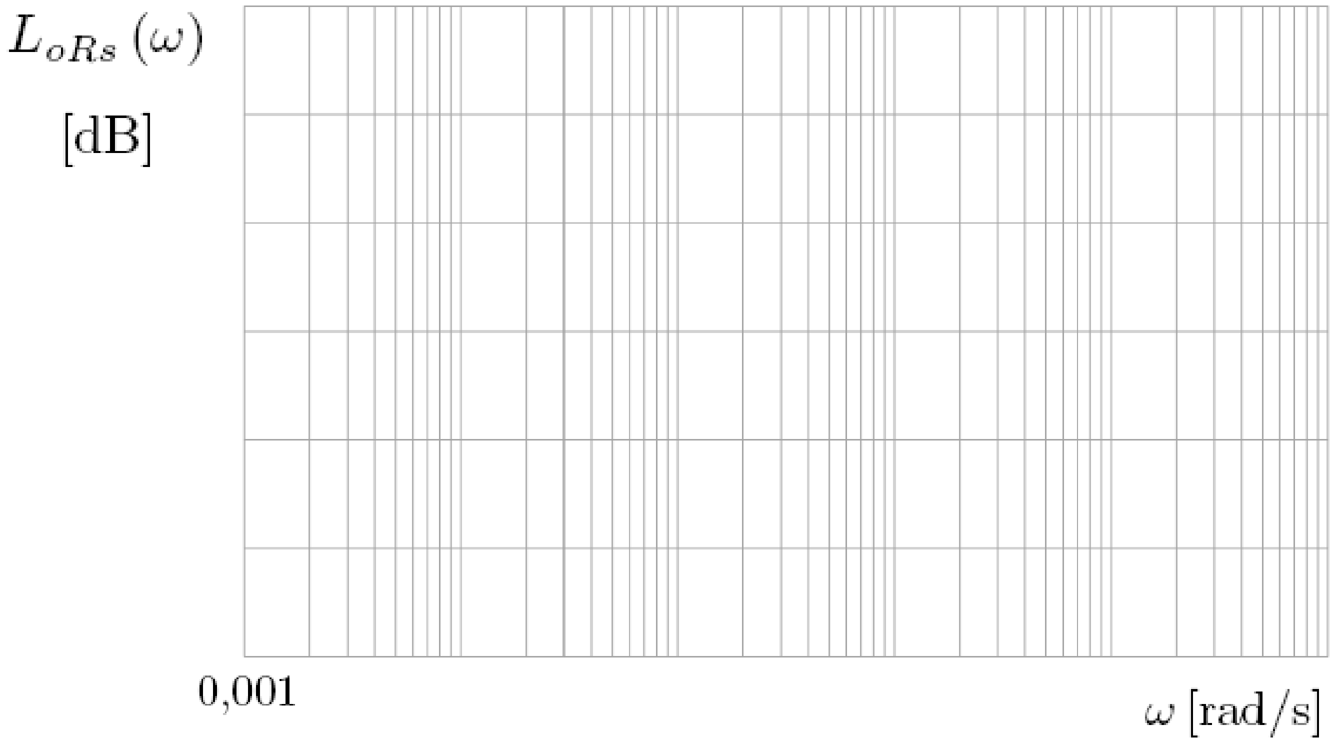


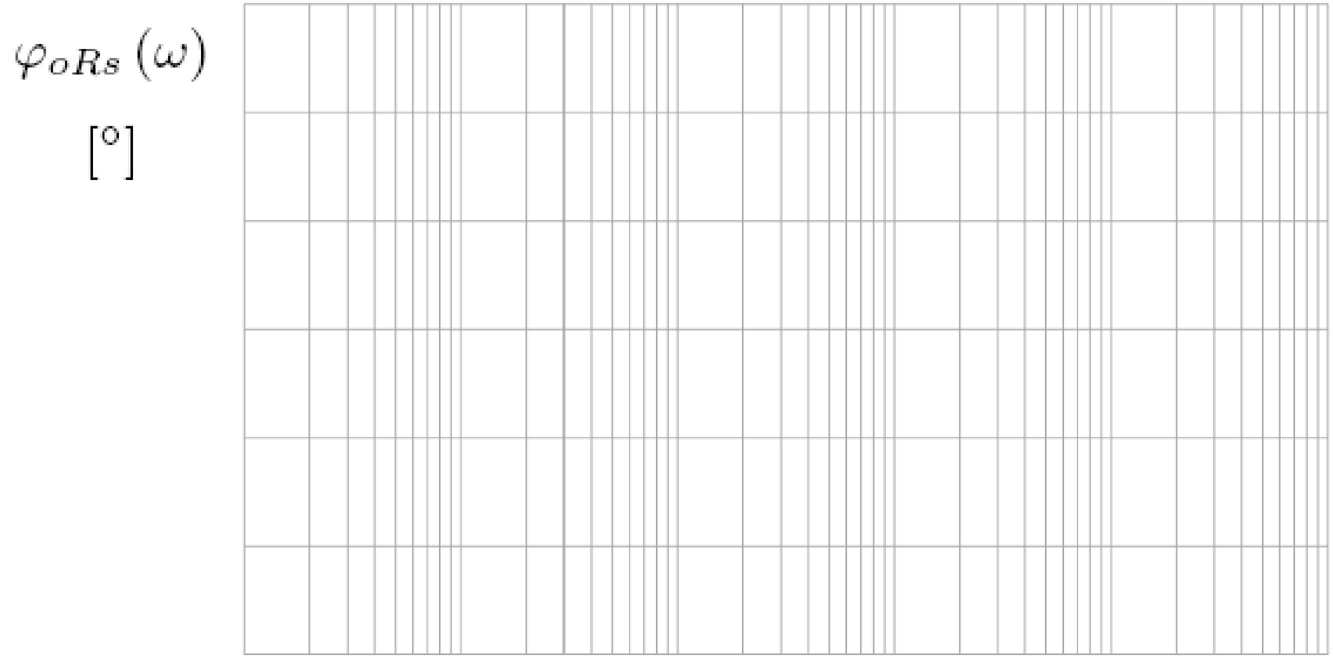
ω [rad/s]

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

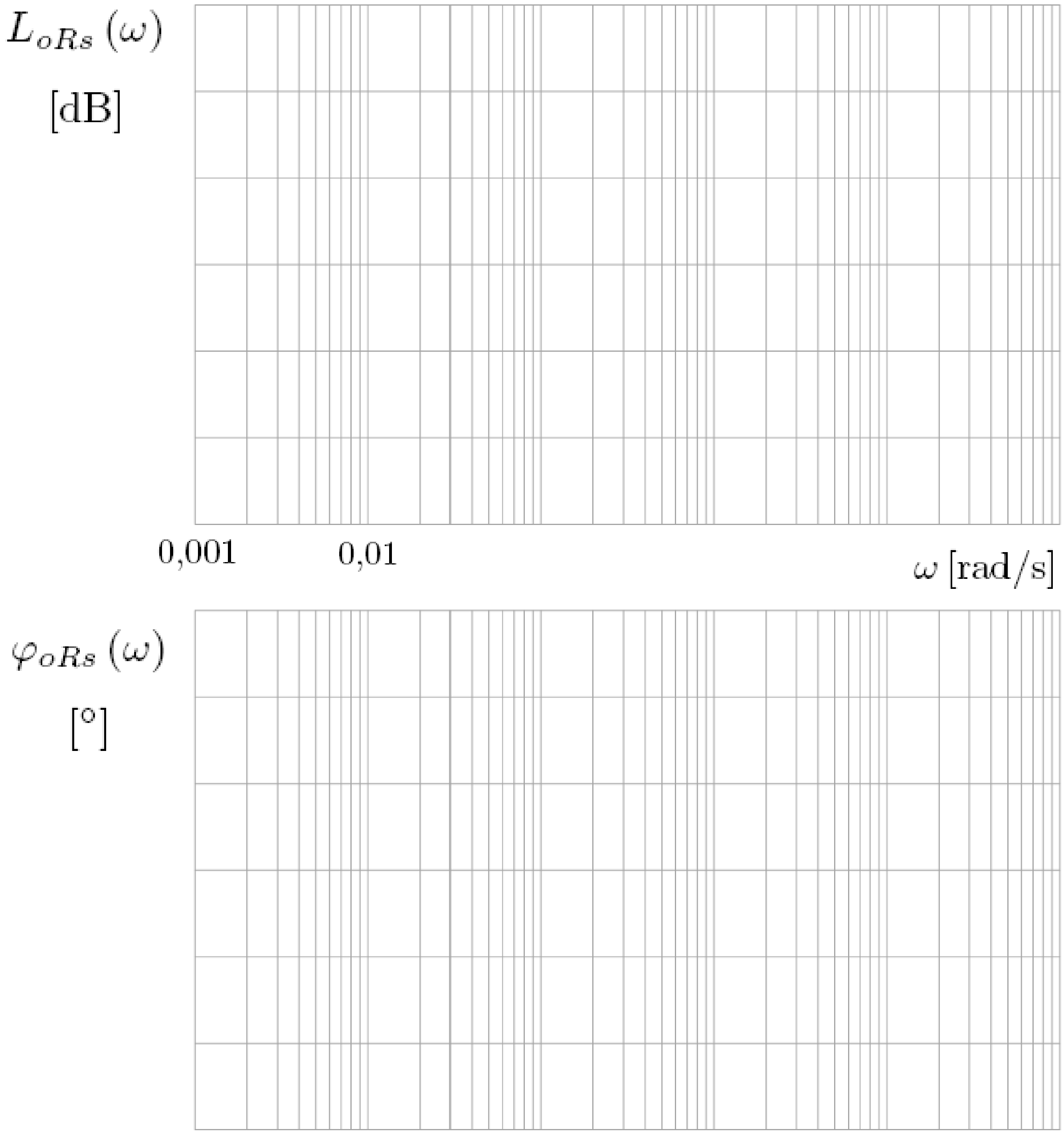




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

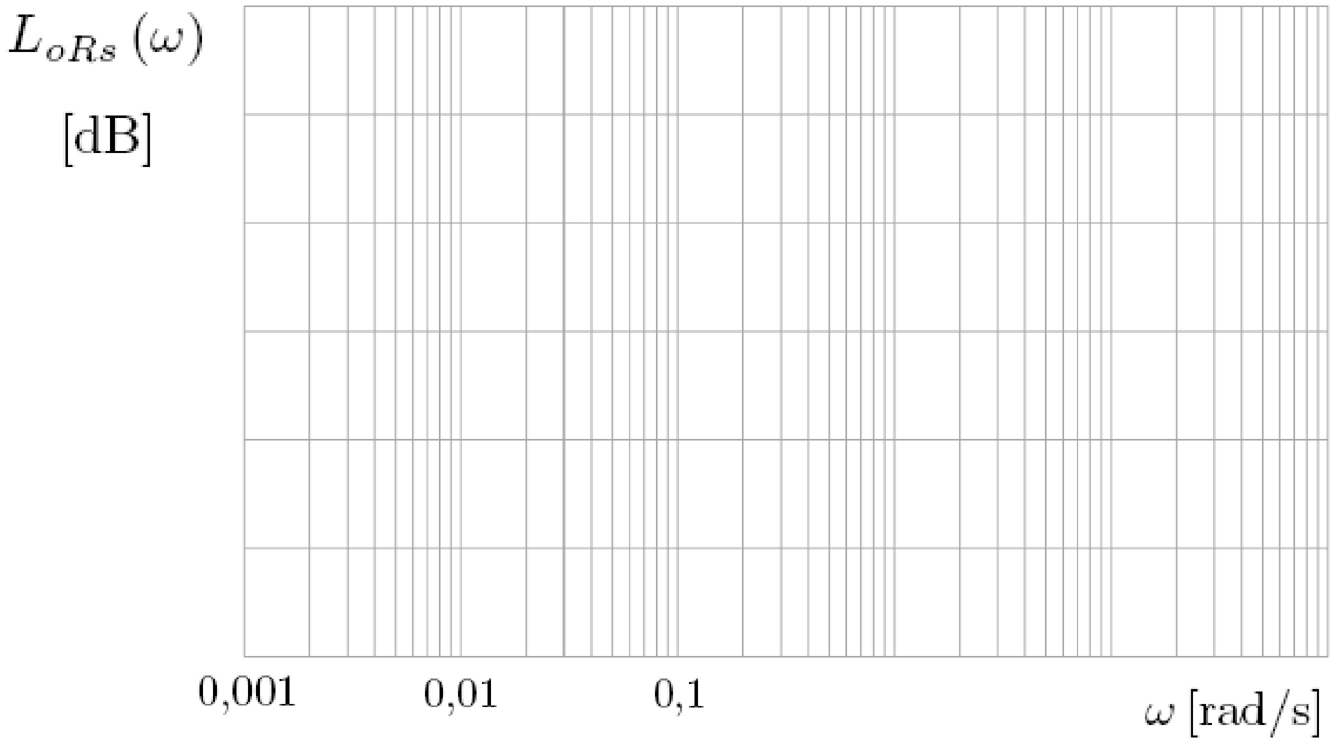
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

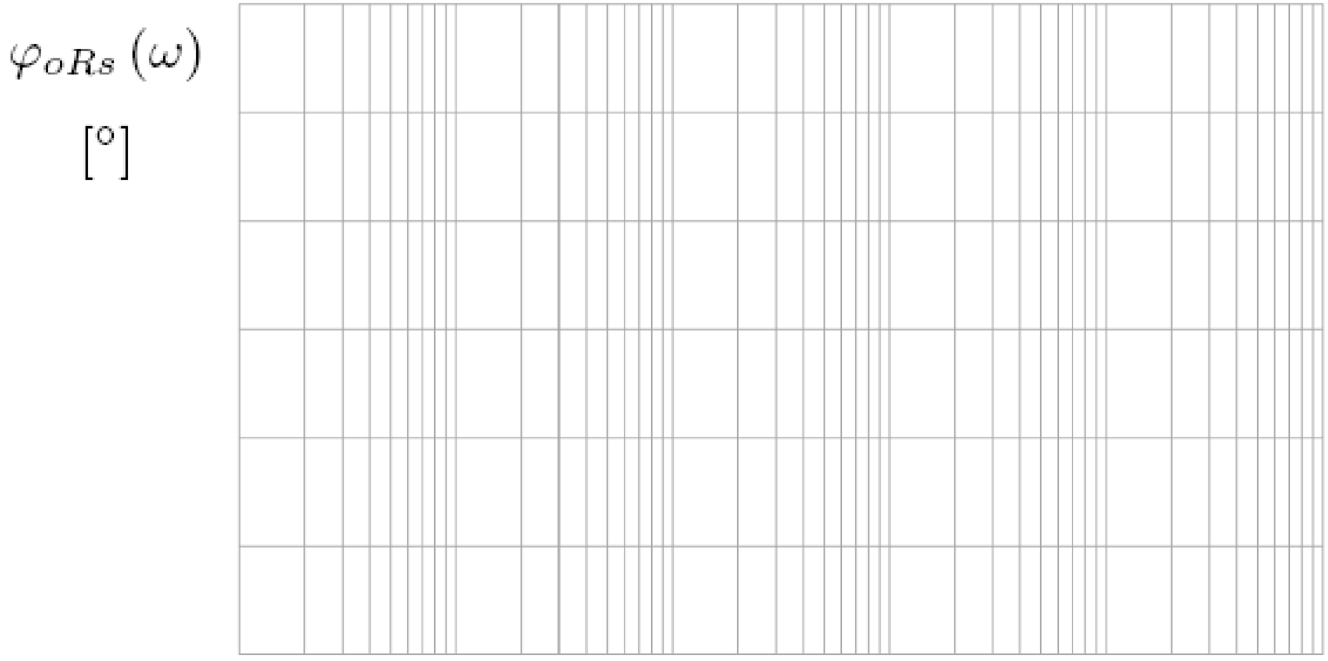


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

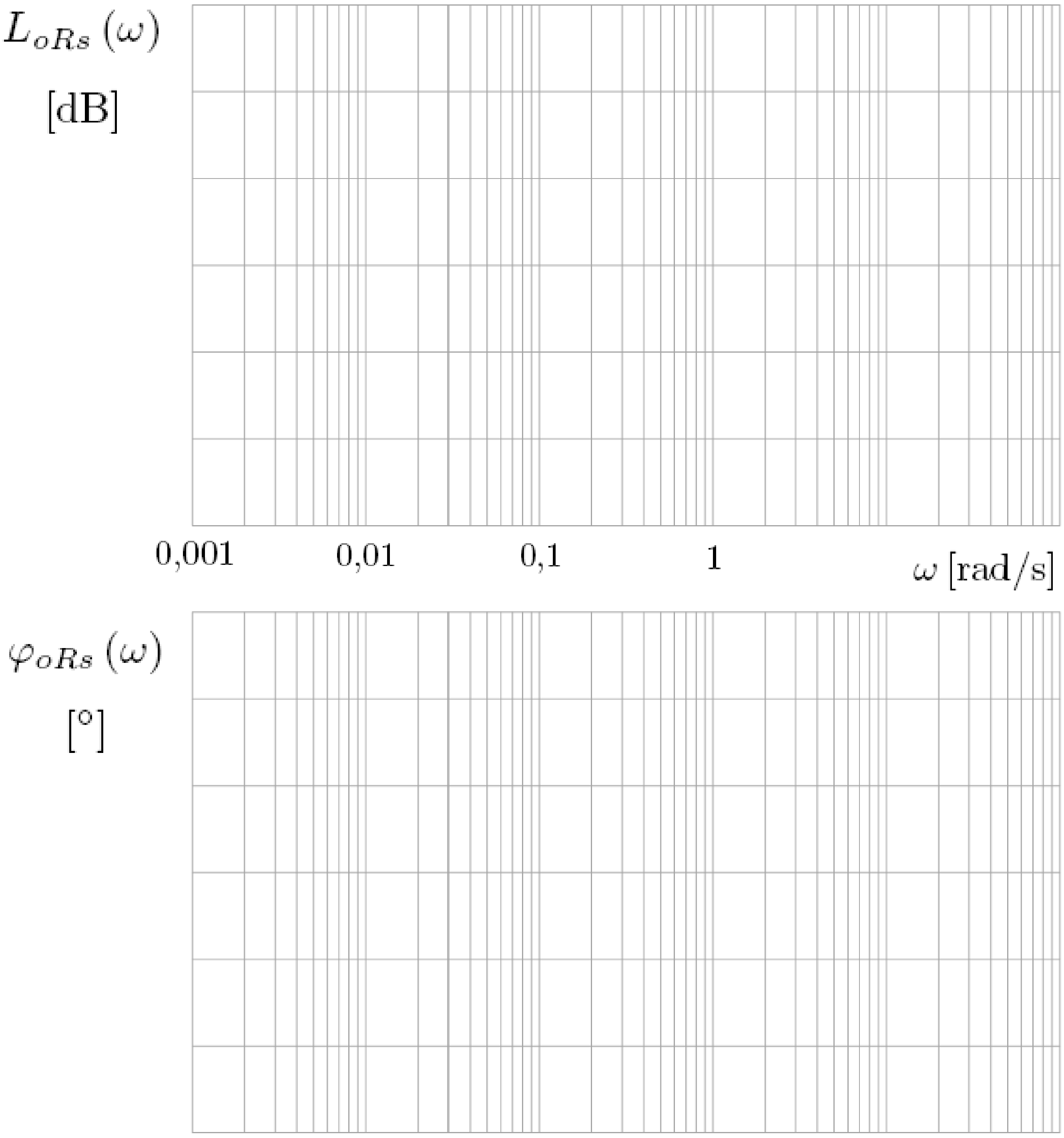




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

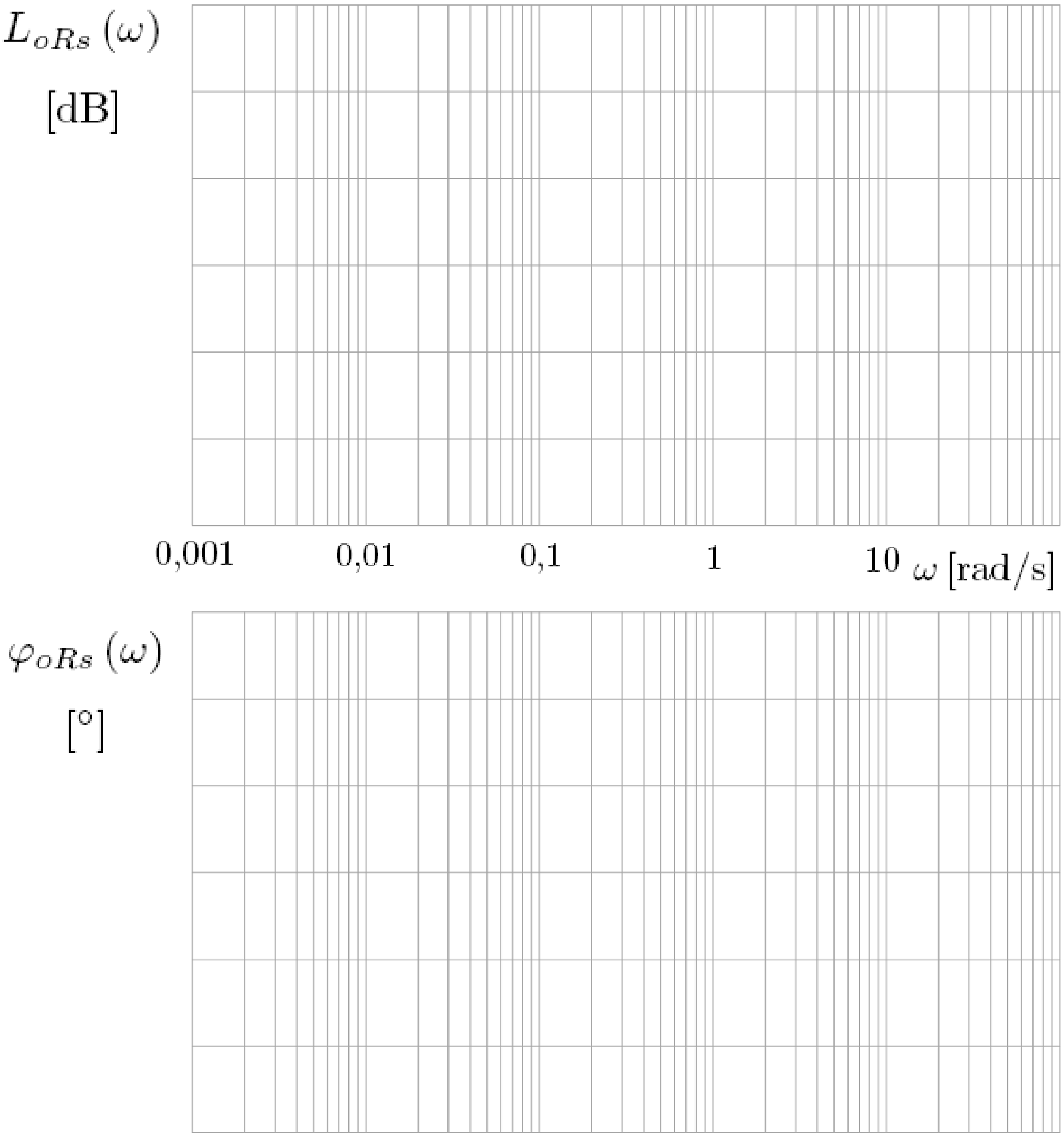
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

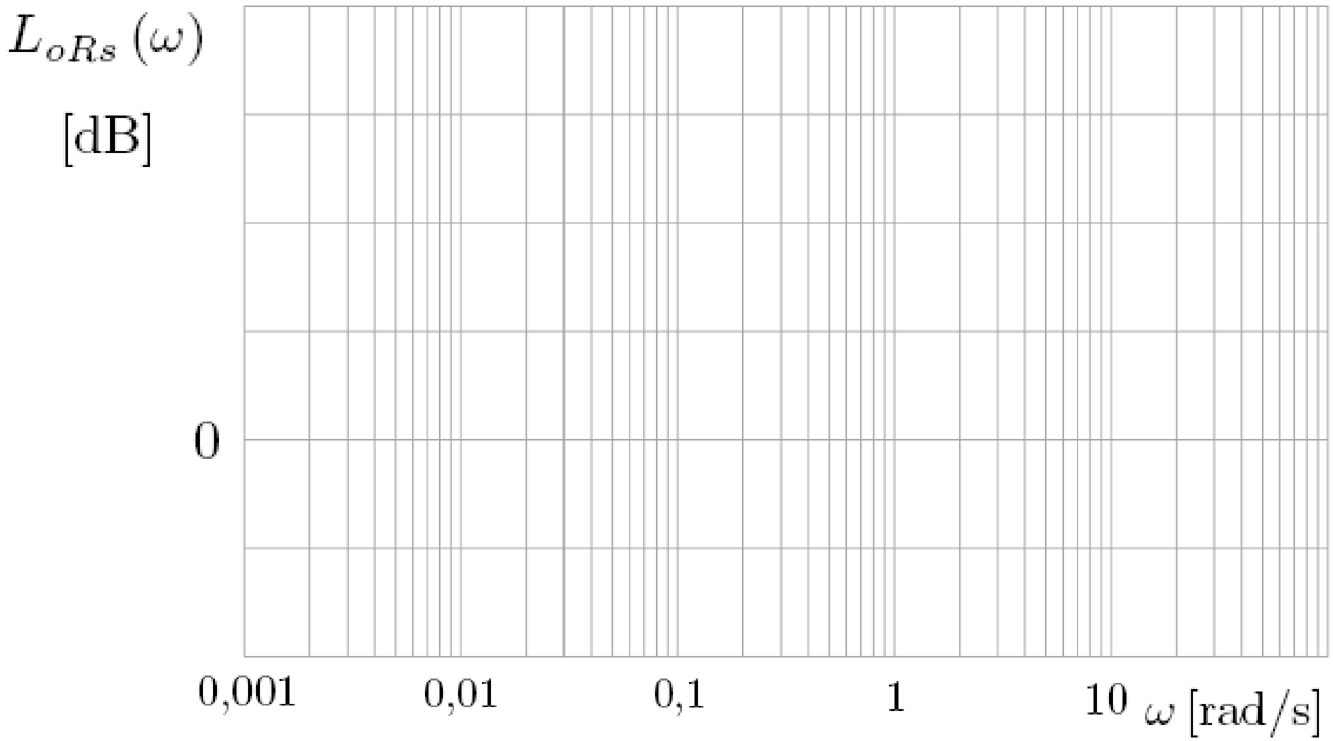
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

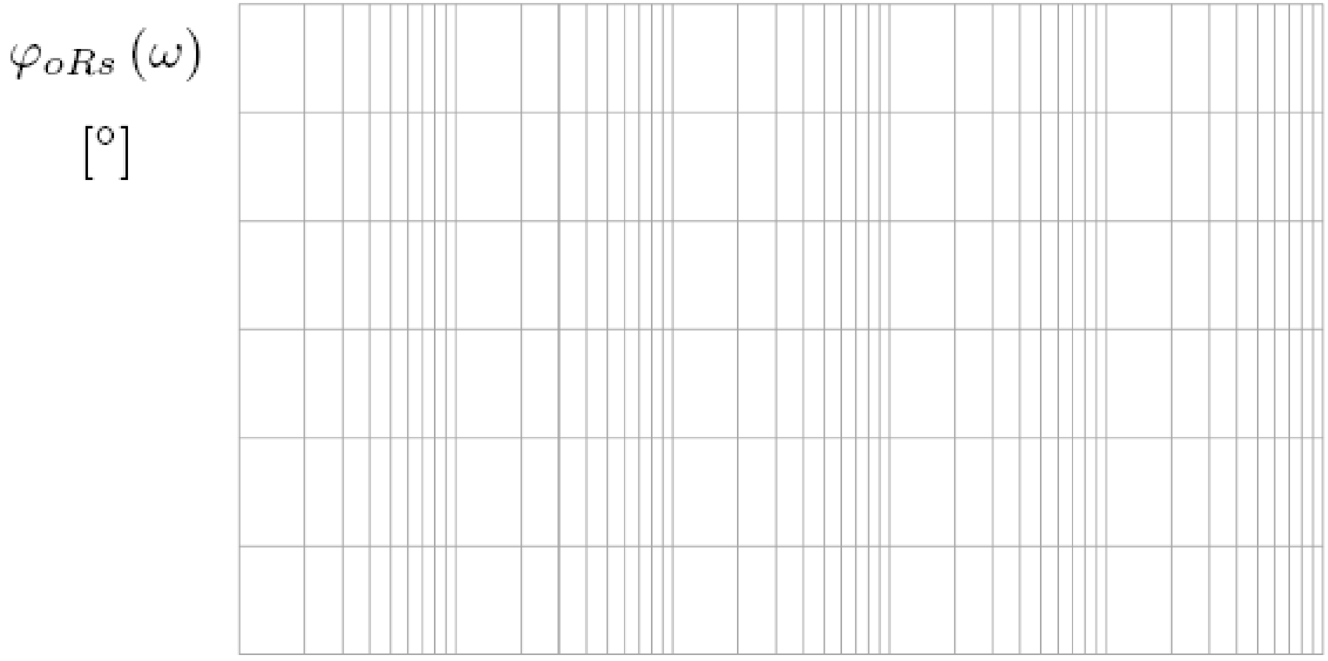


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

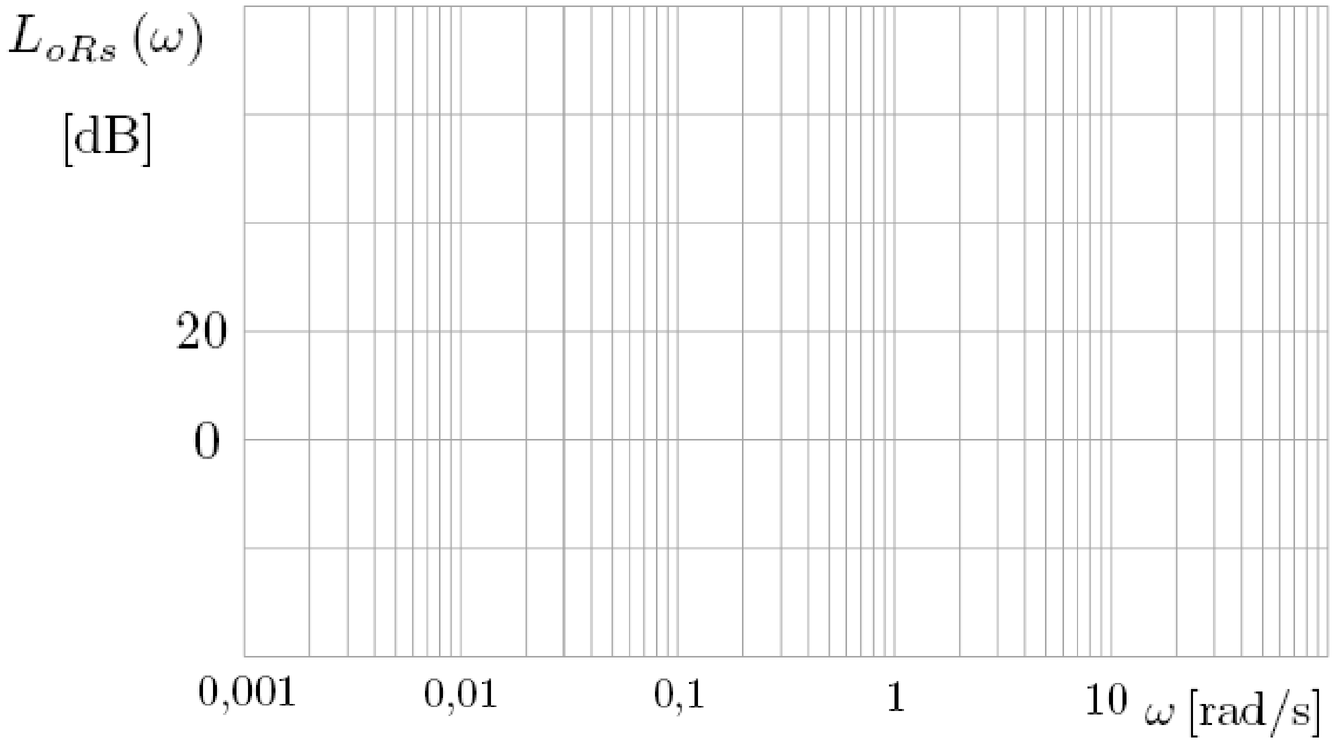


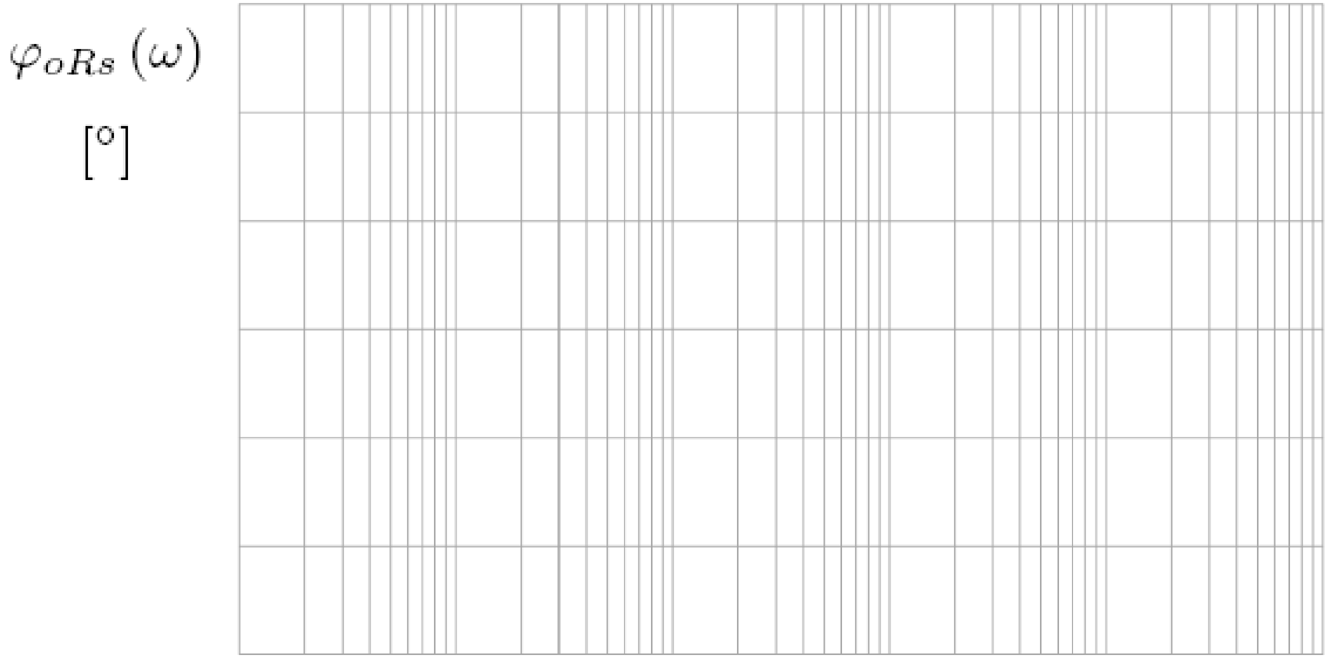


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

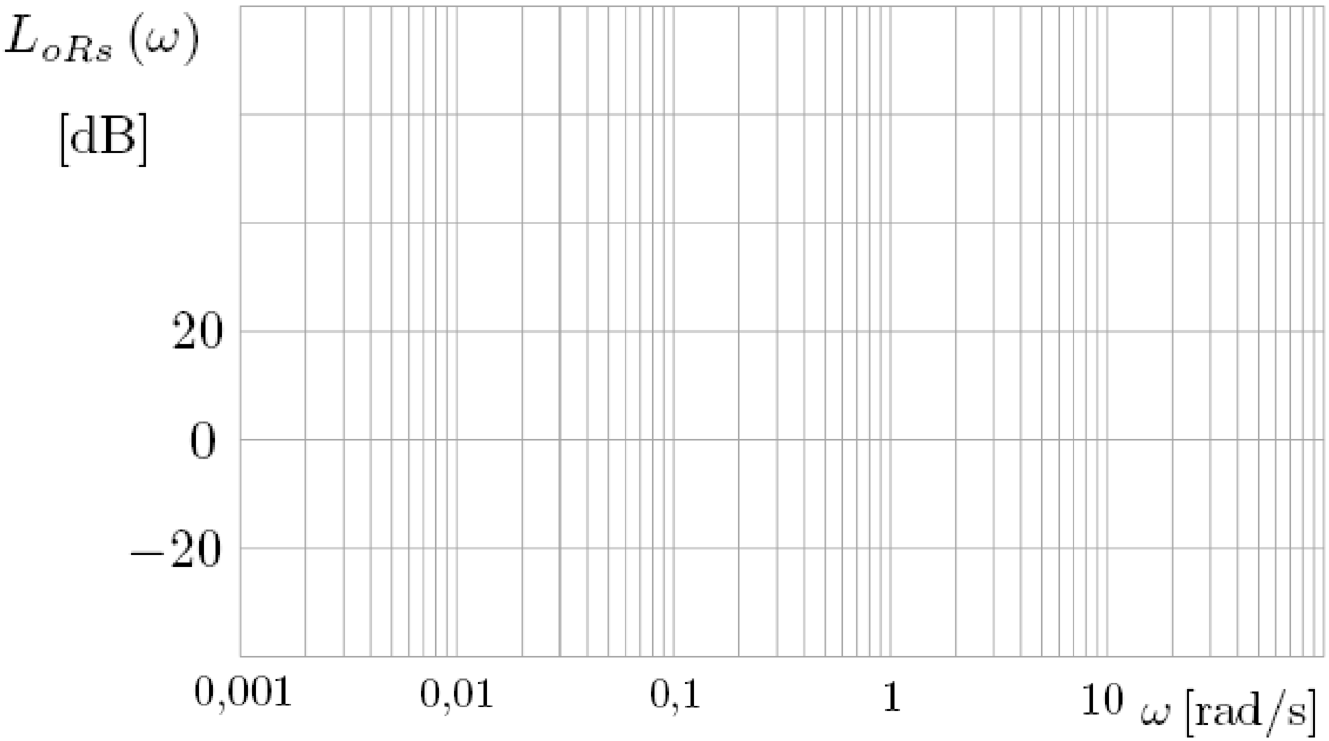


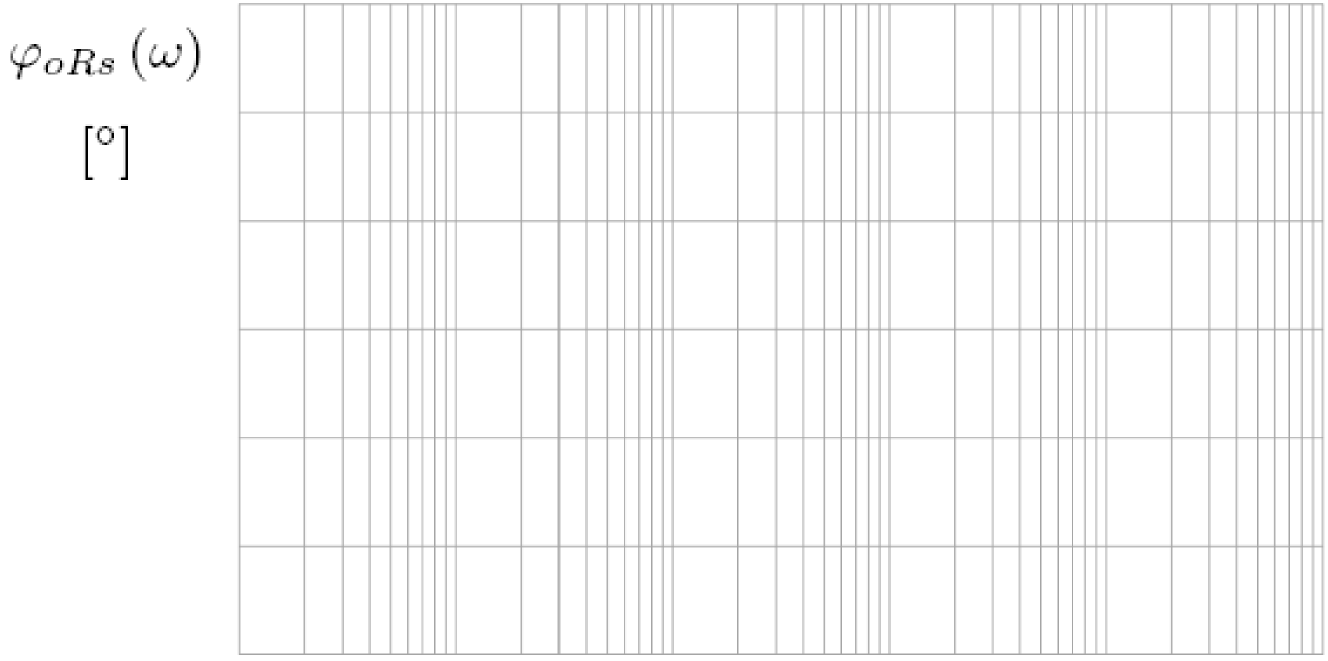


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

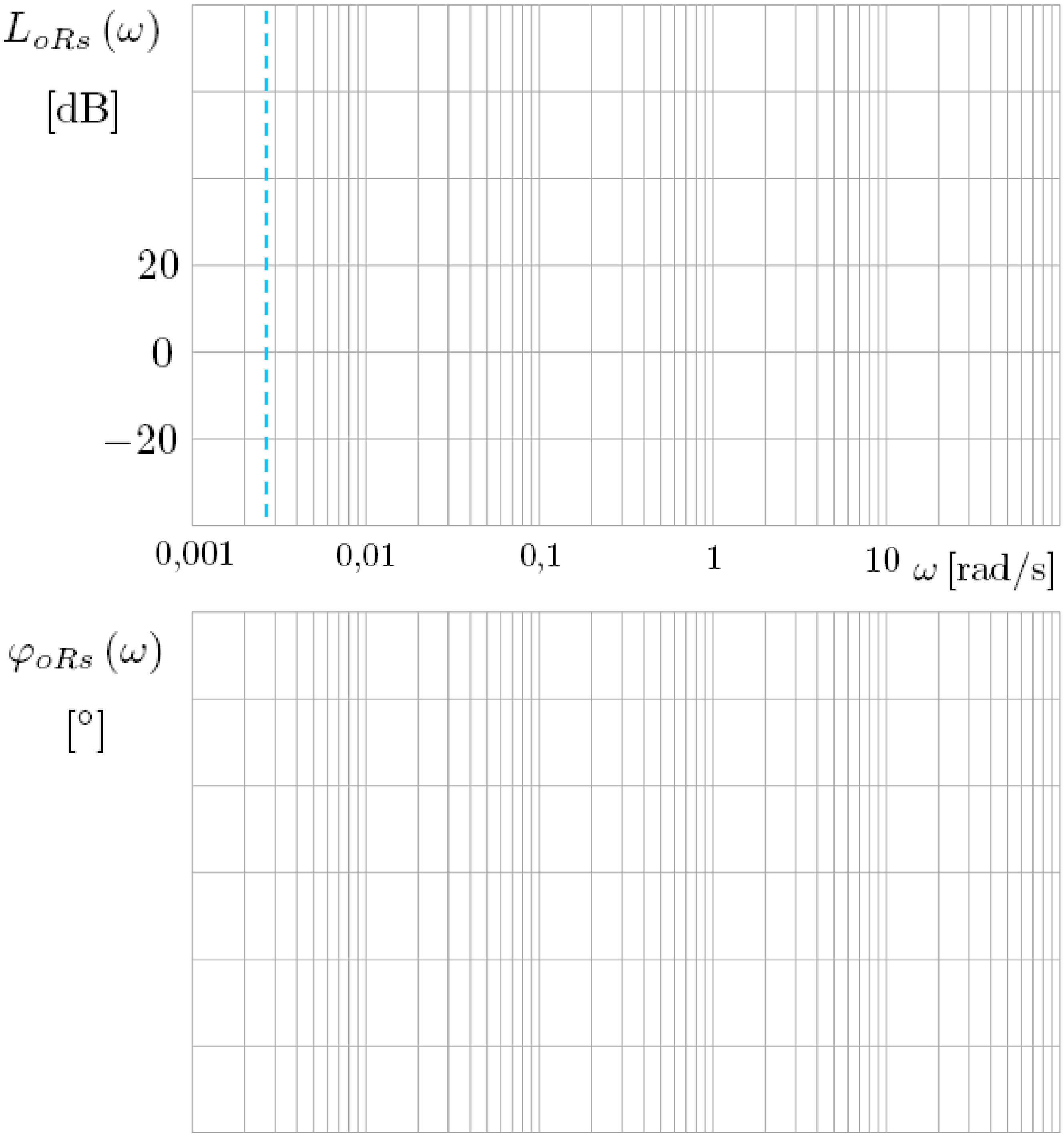




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

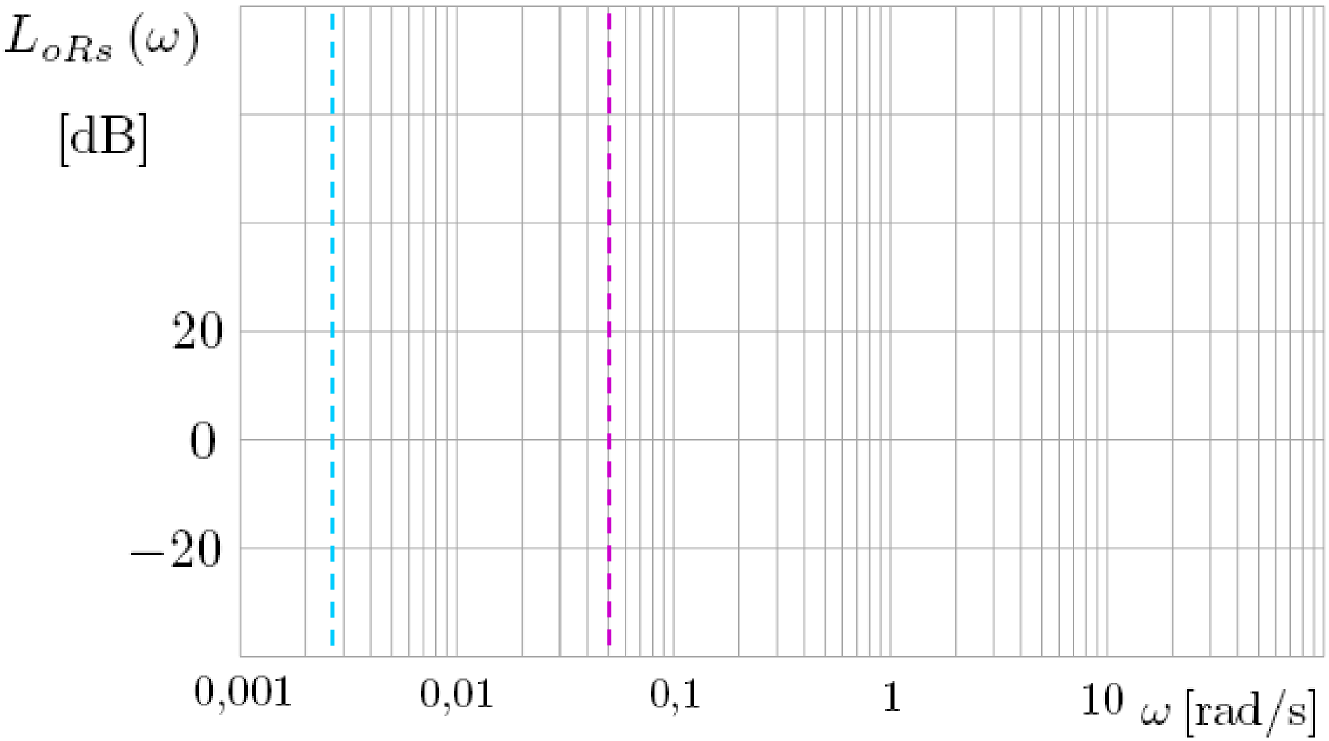
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

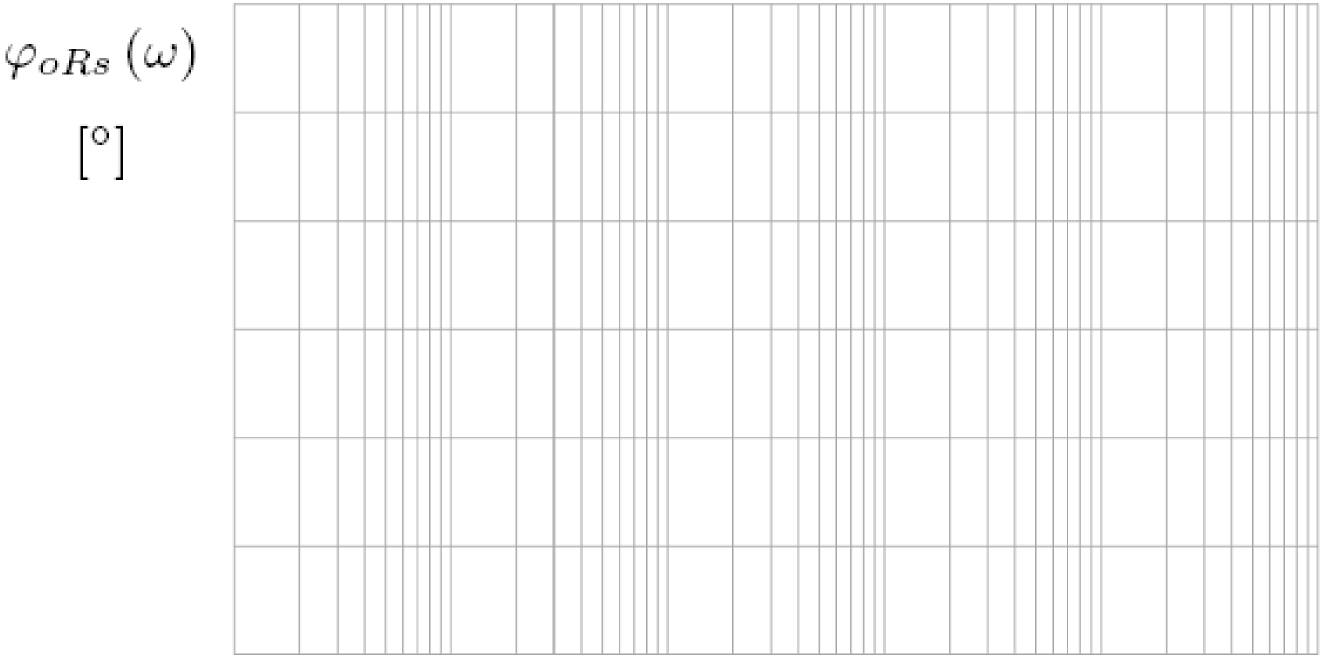


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

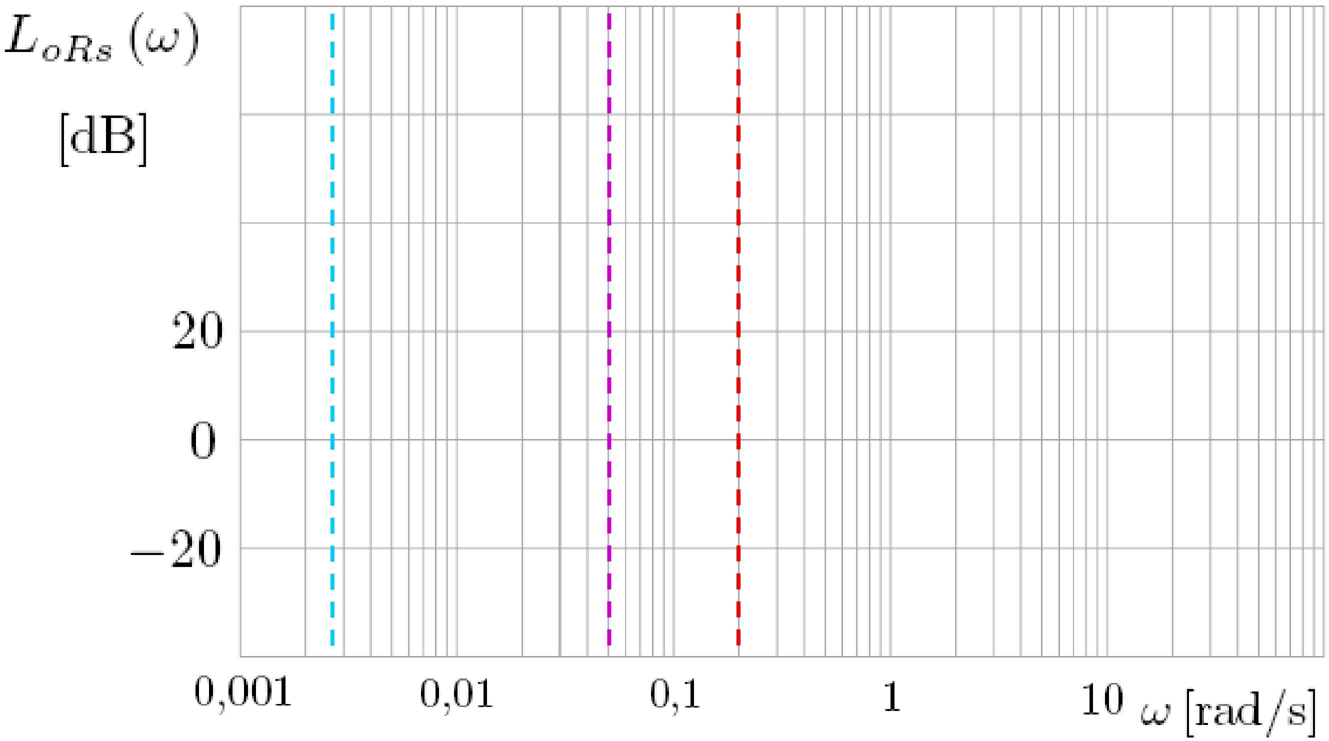


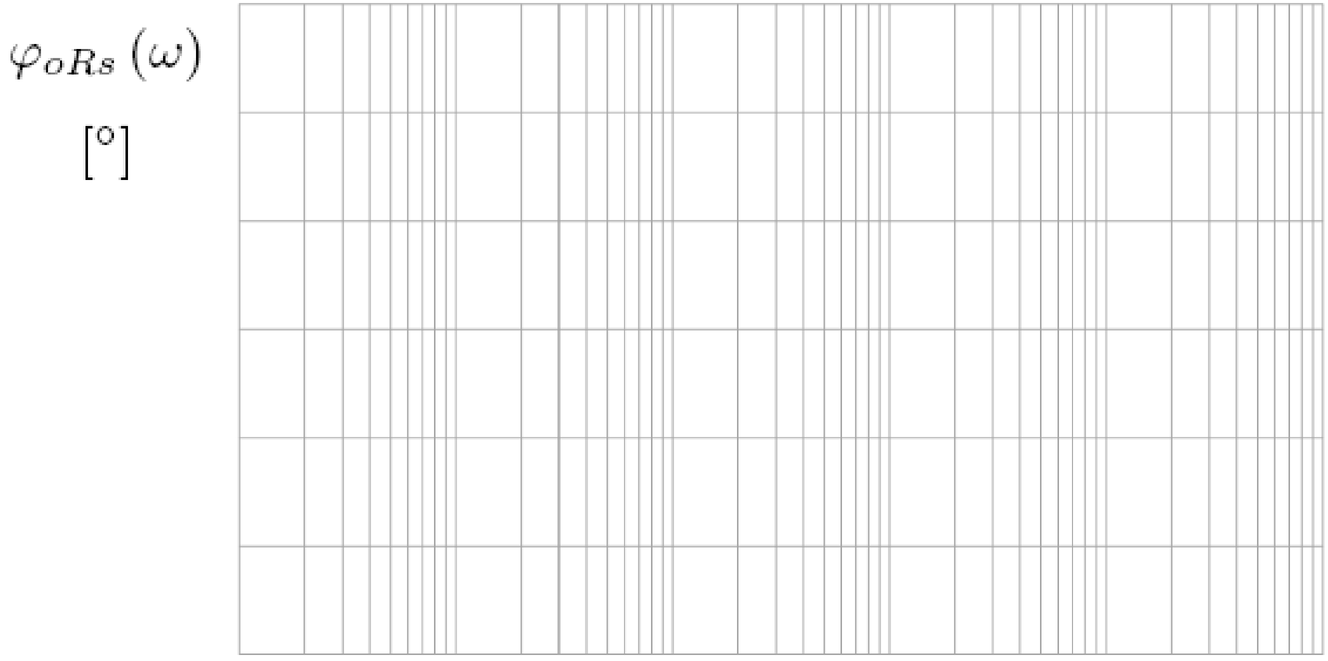


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

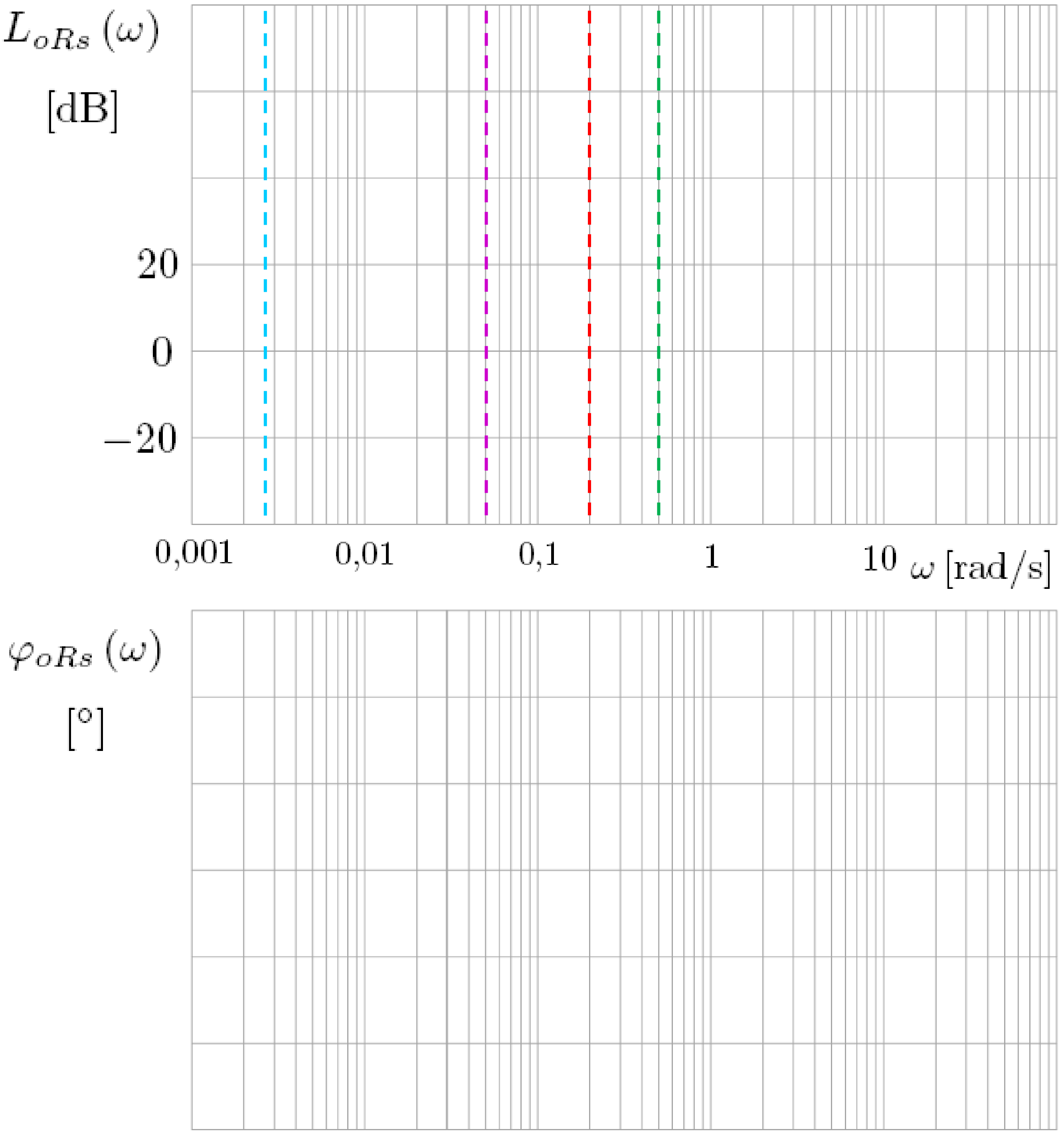




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

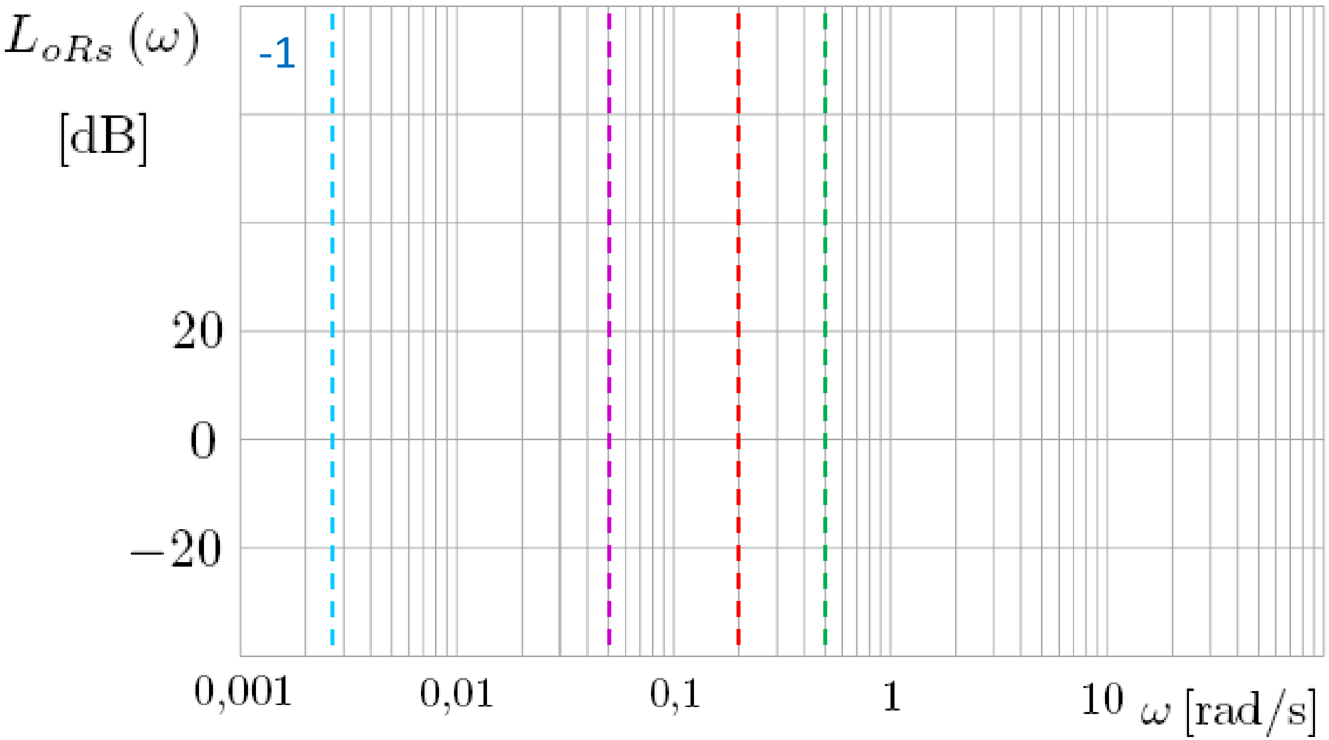
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

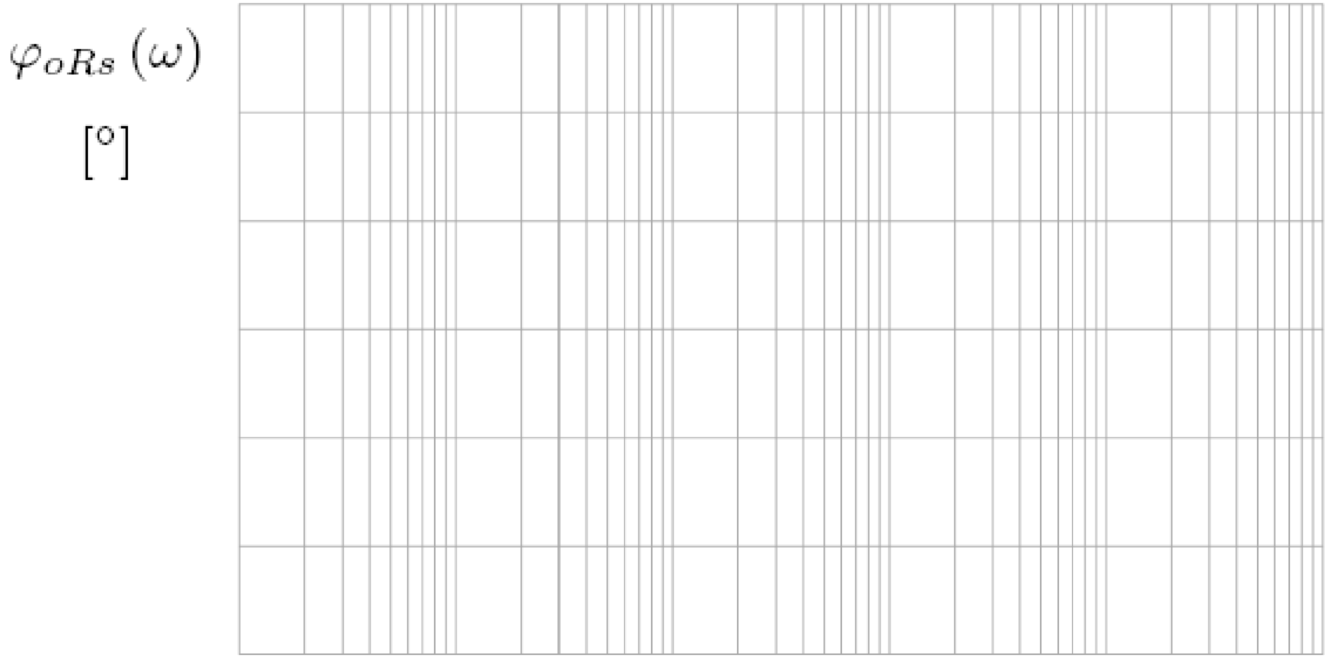


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

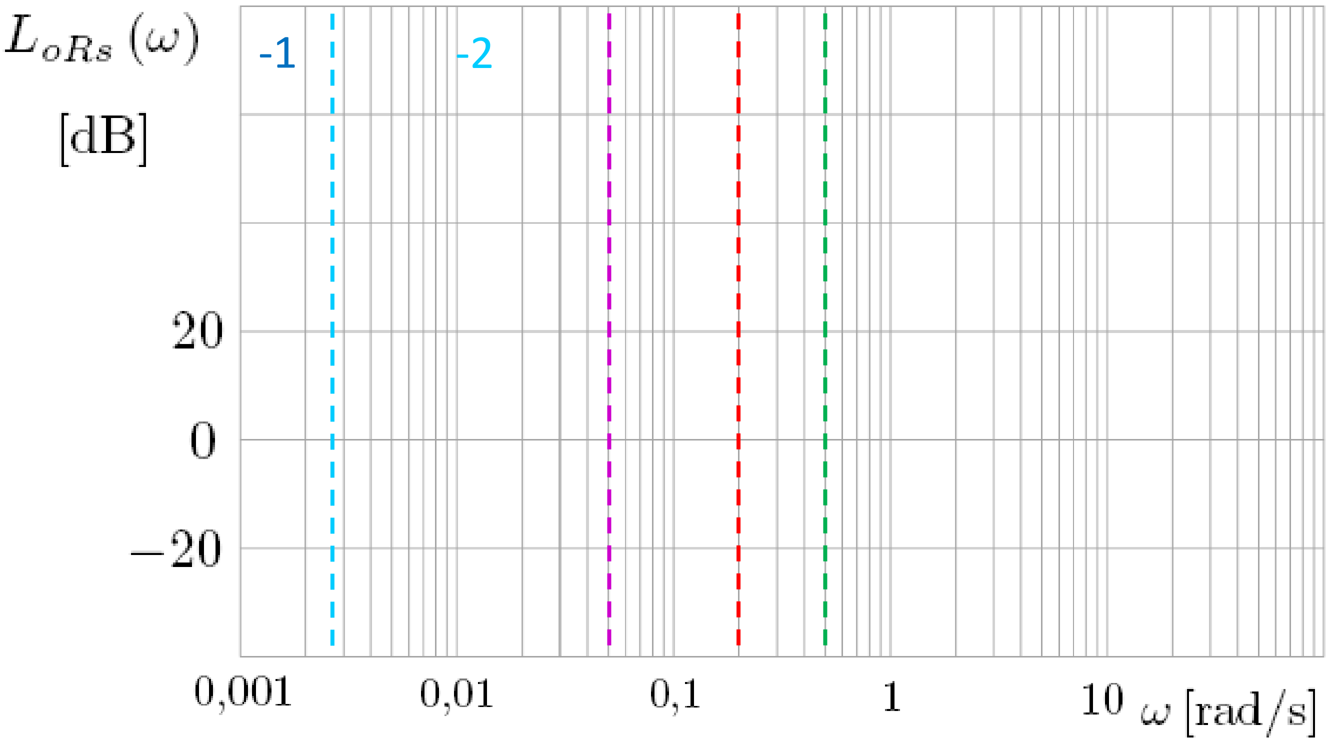


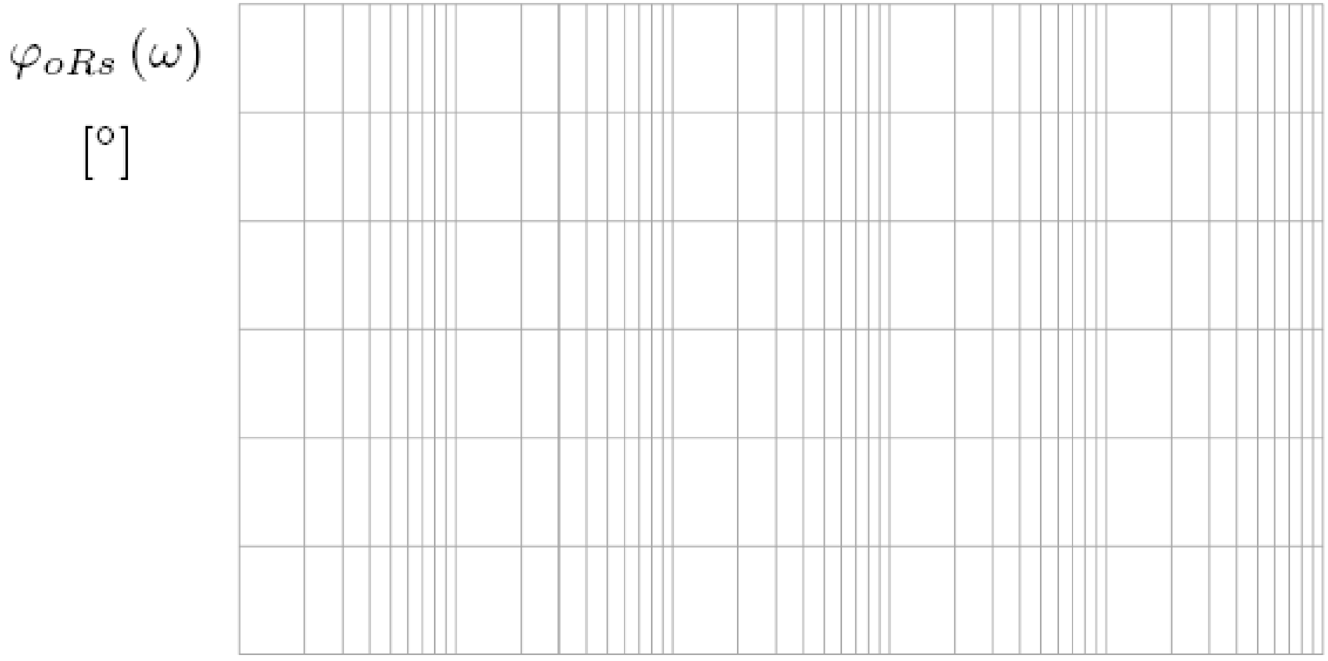


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

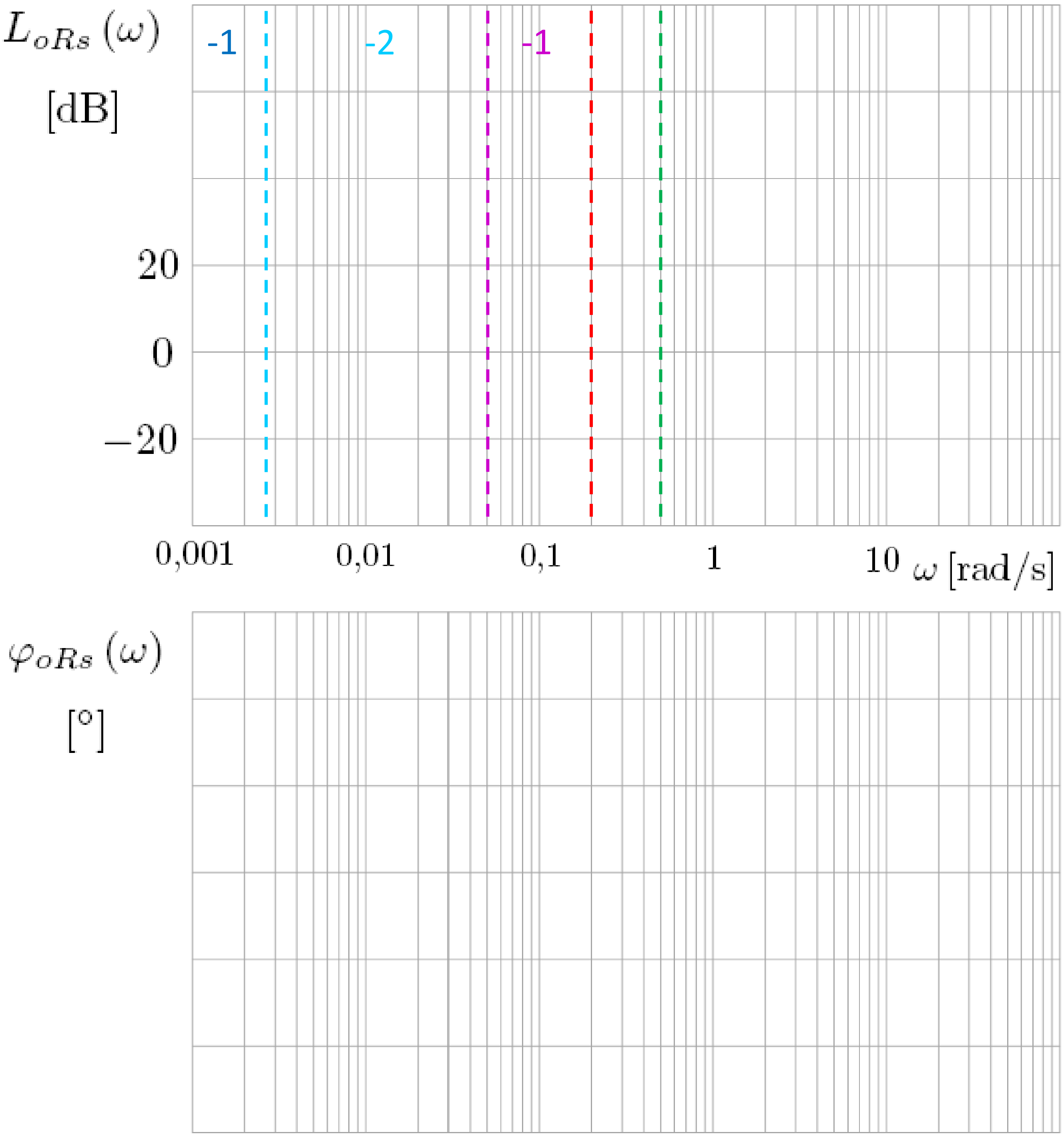




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

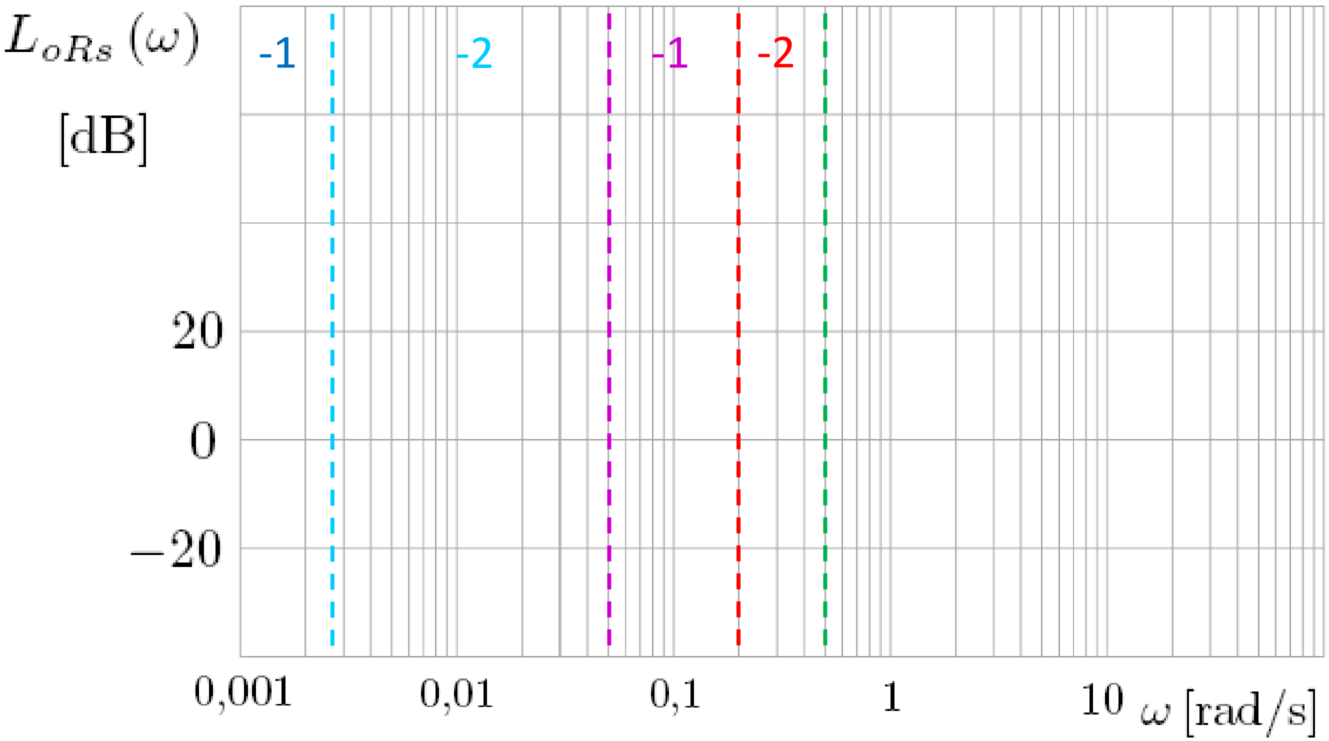
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

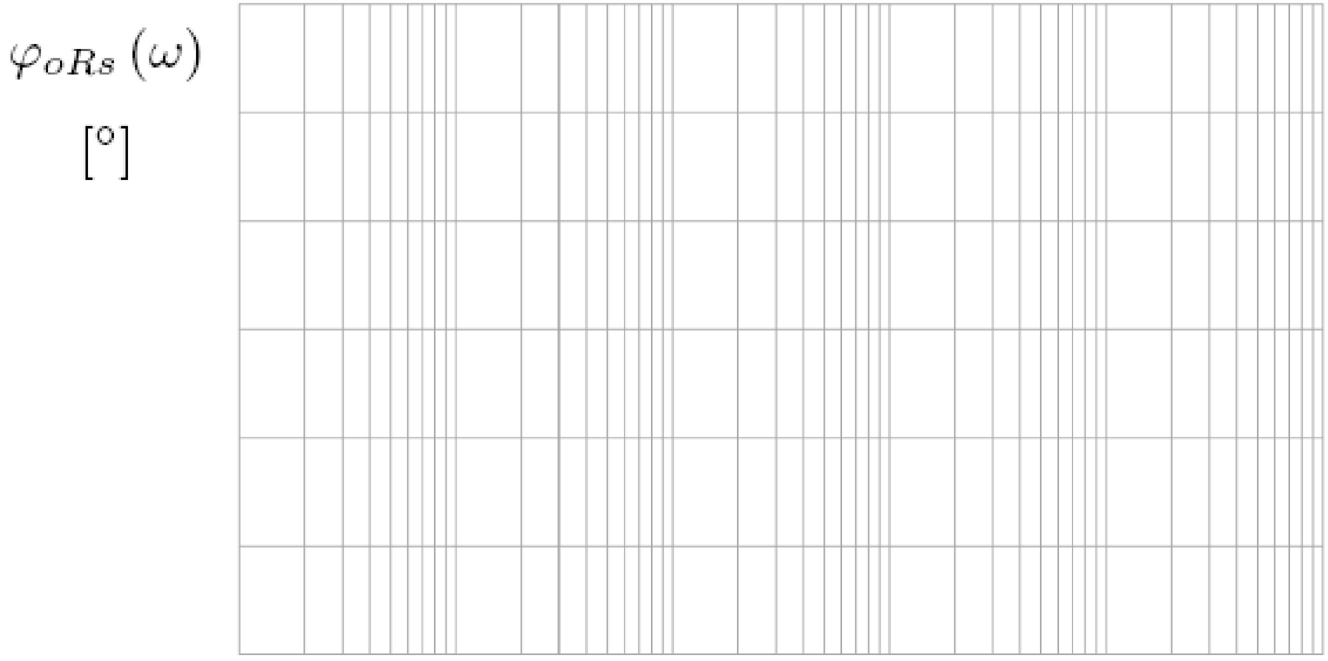


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

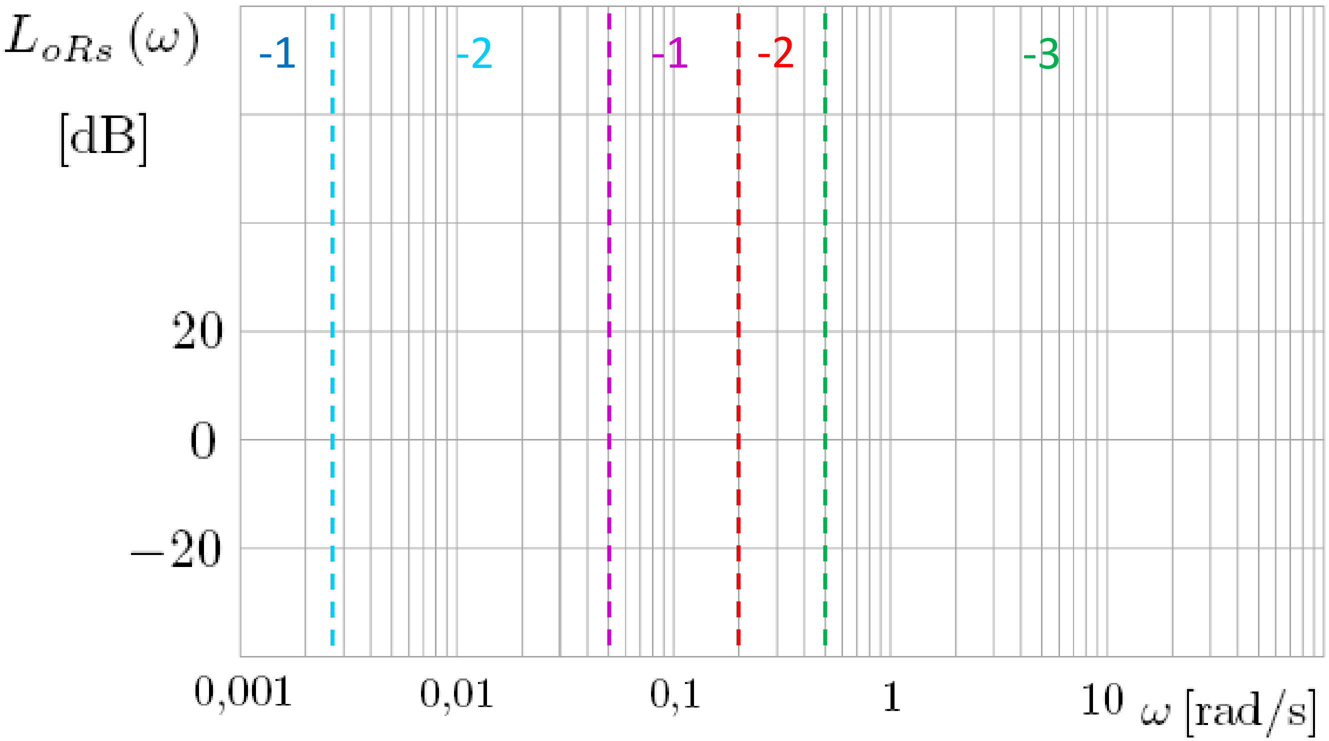


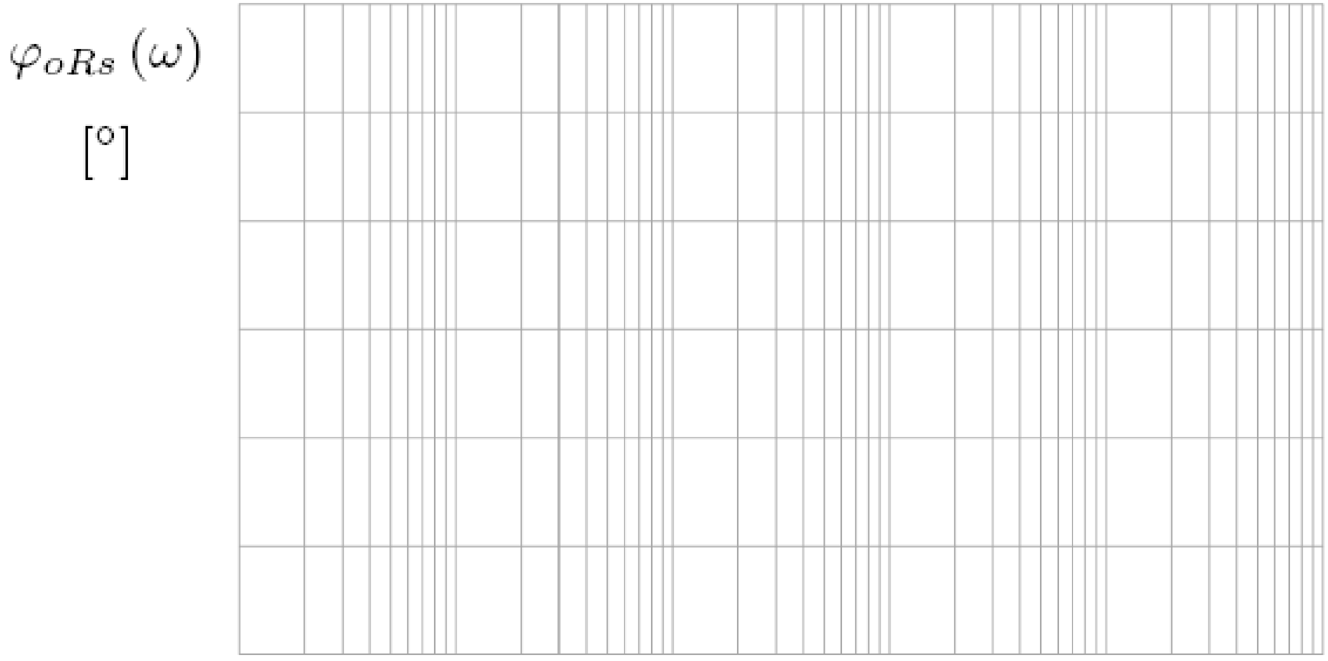


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



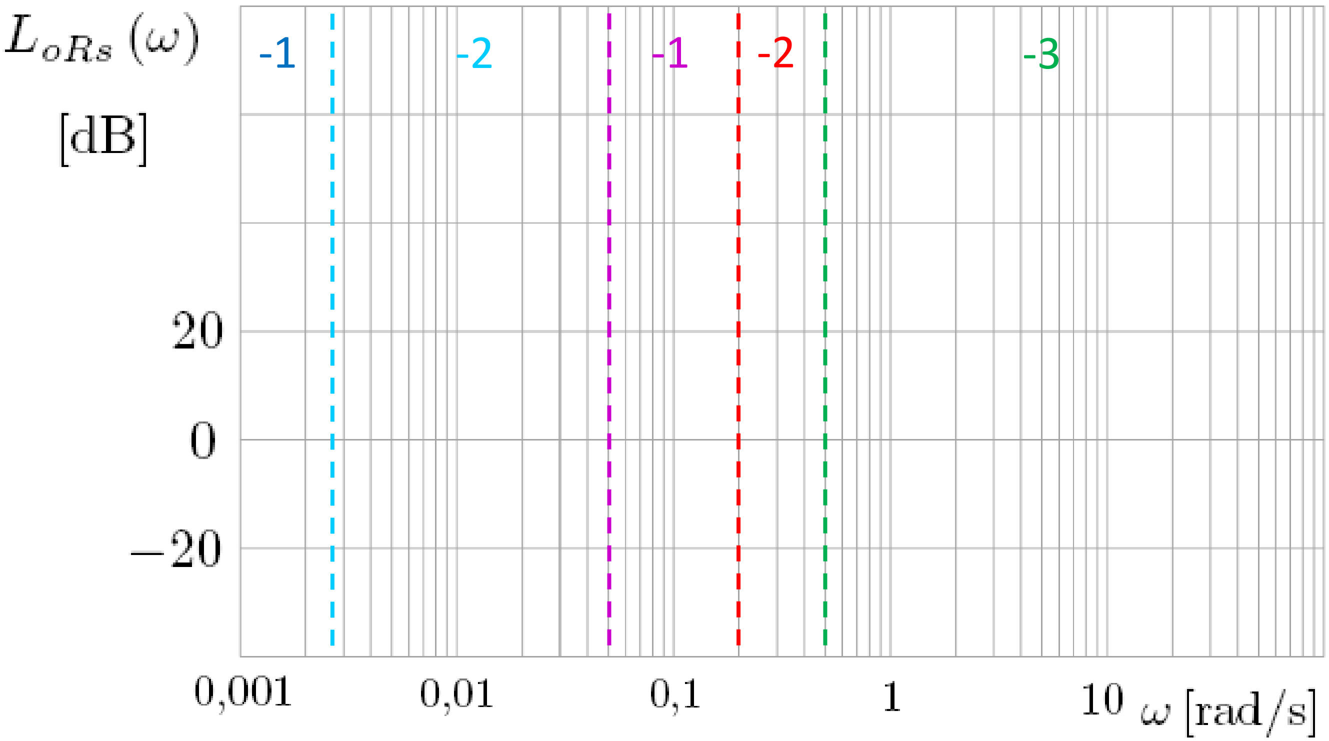


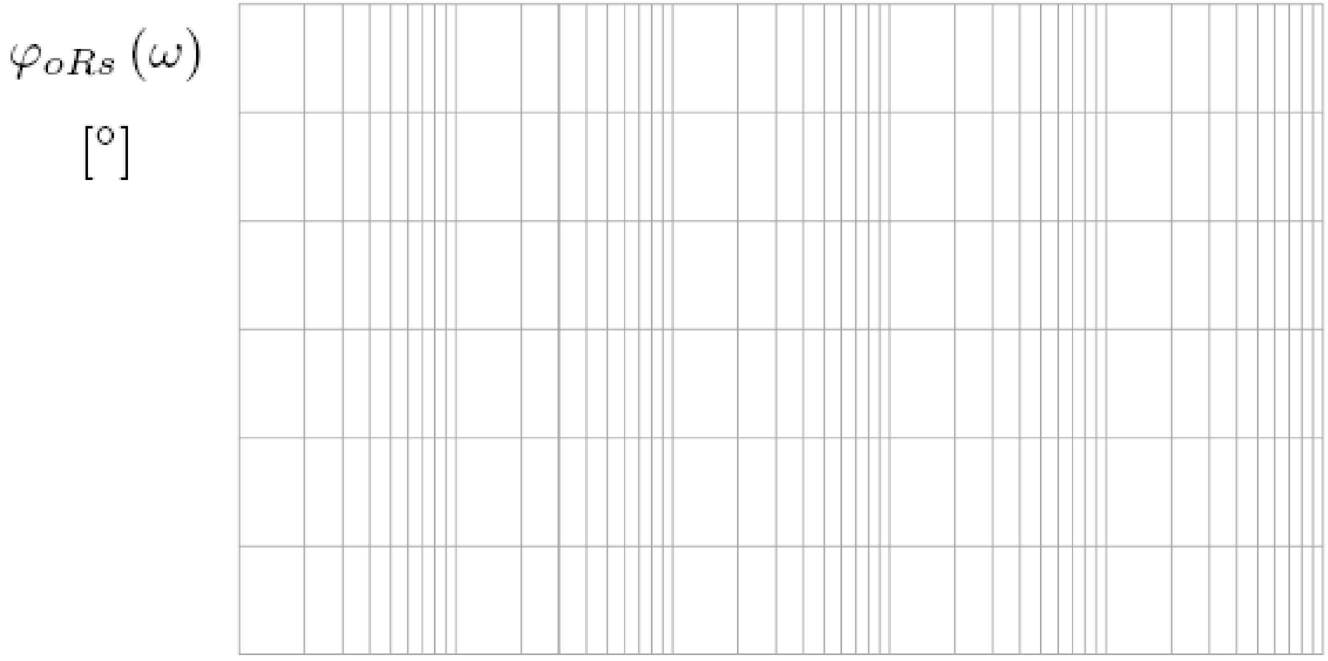
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s}$$



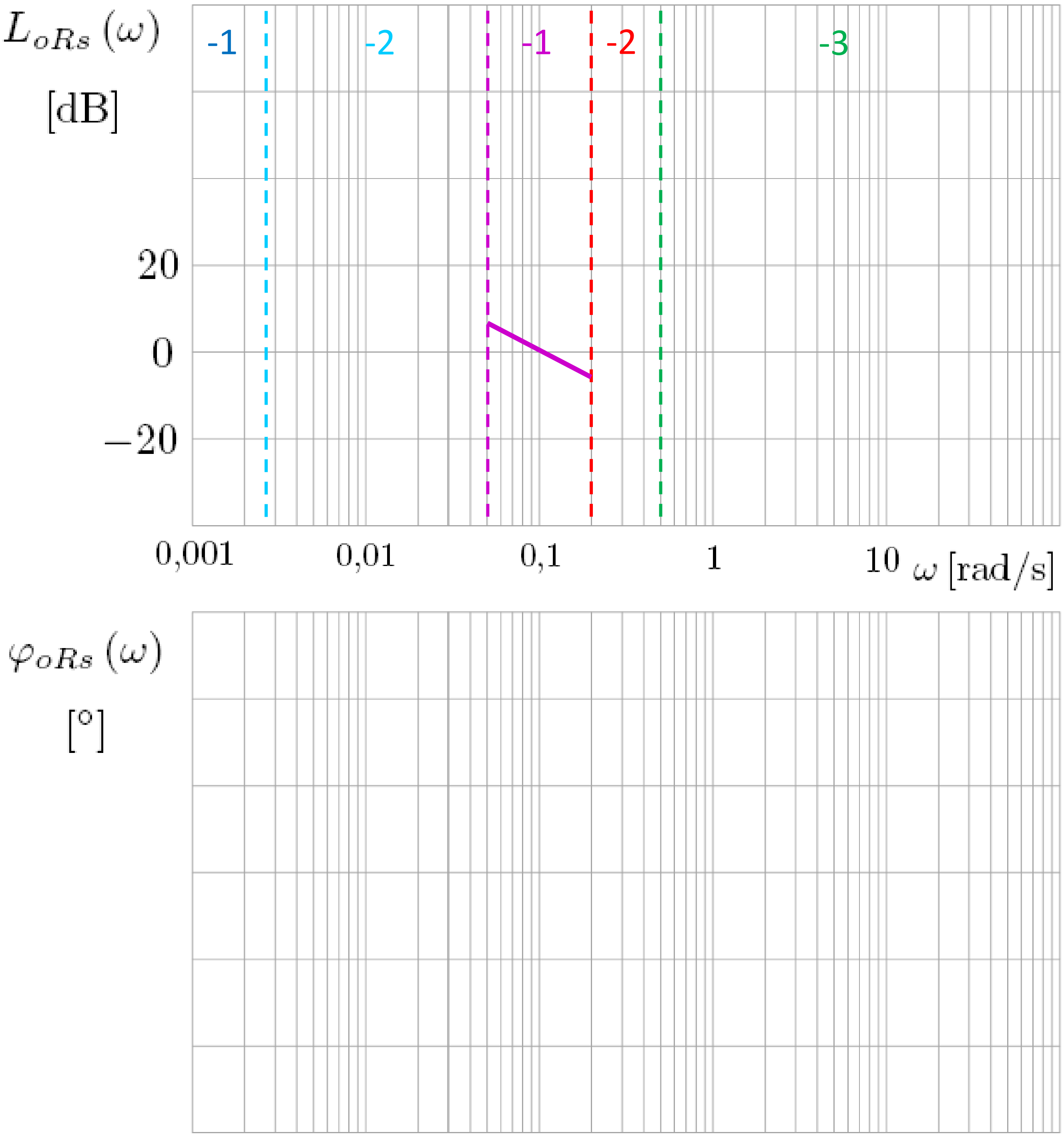


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s}$$

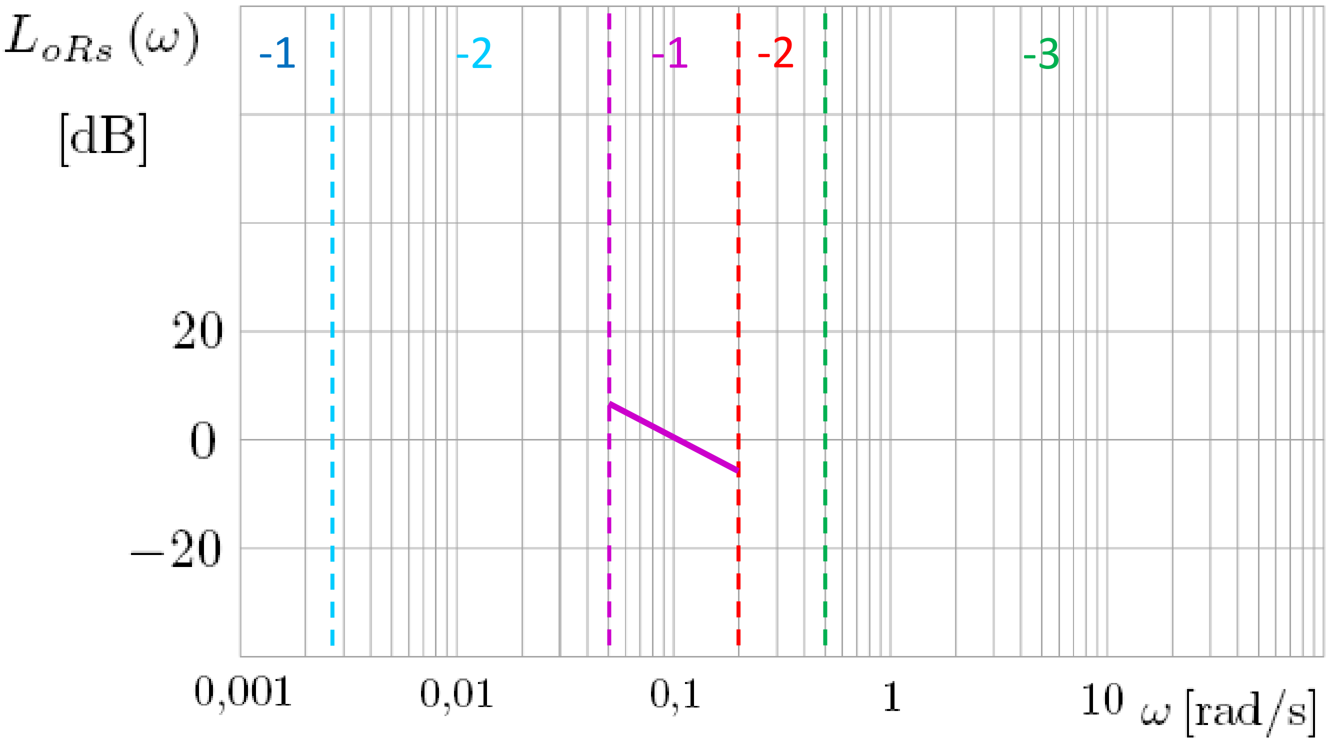


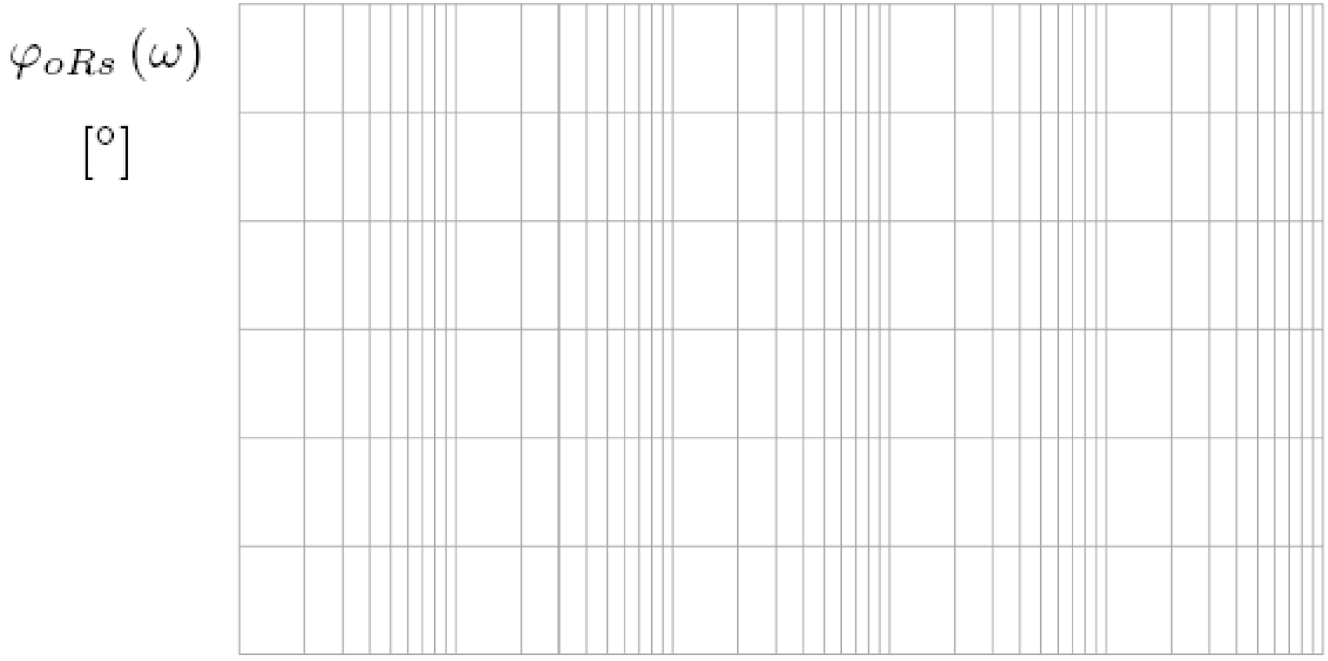
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$



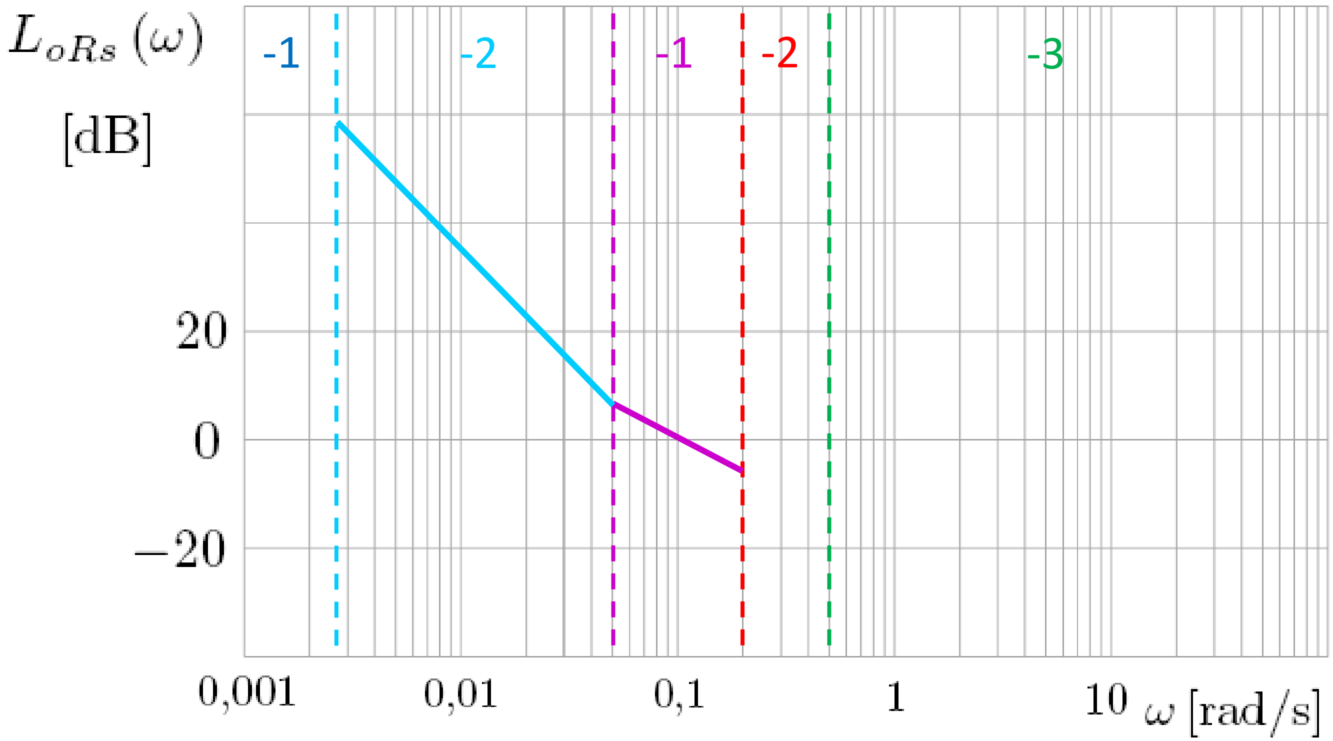


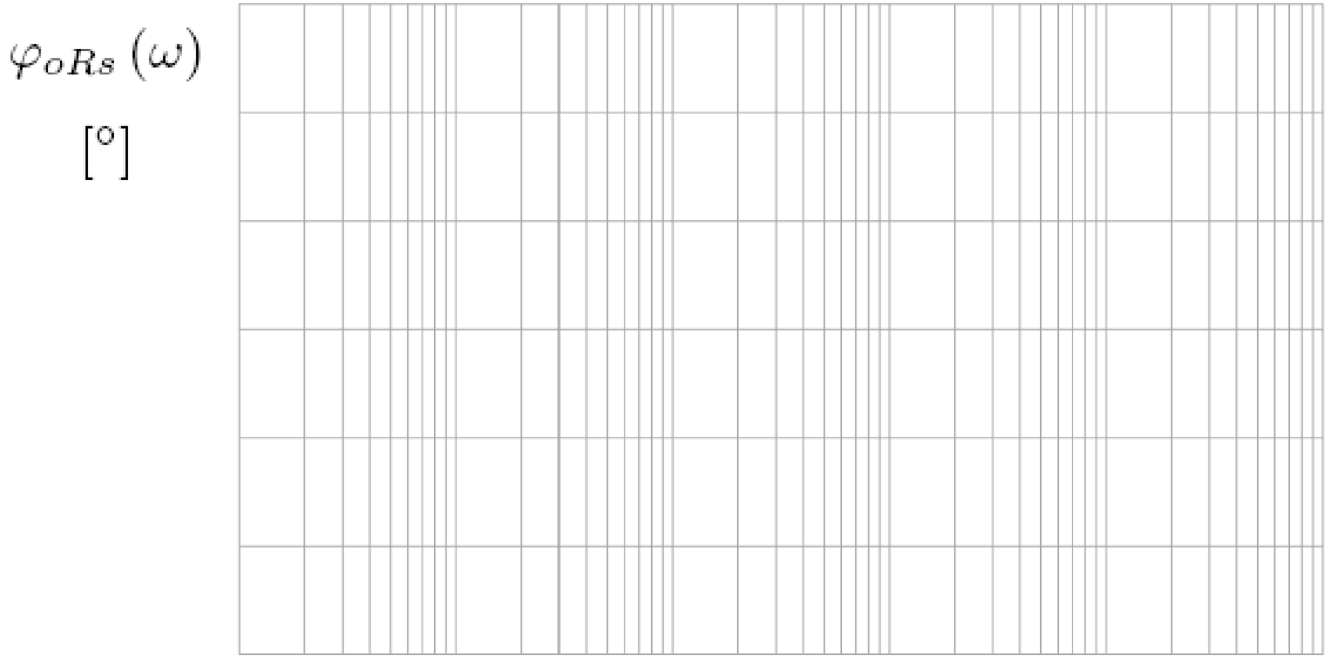
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$





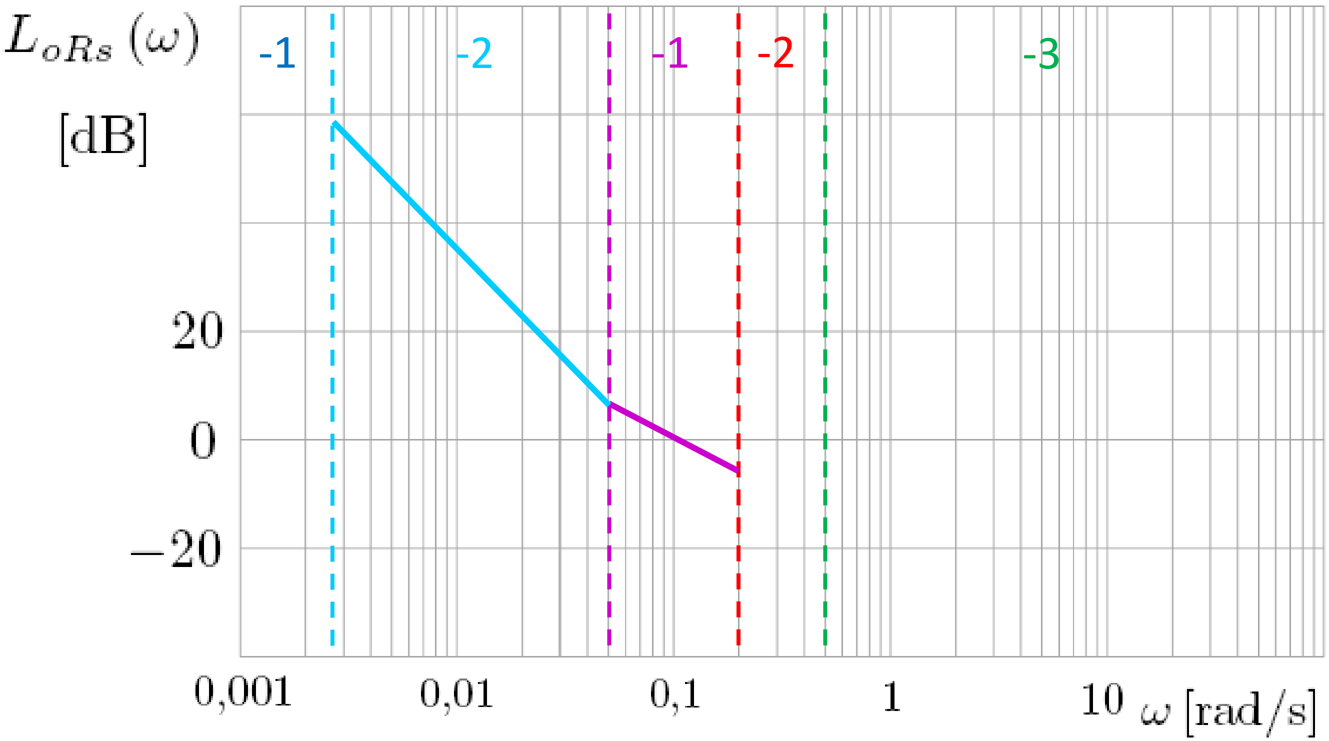
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

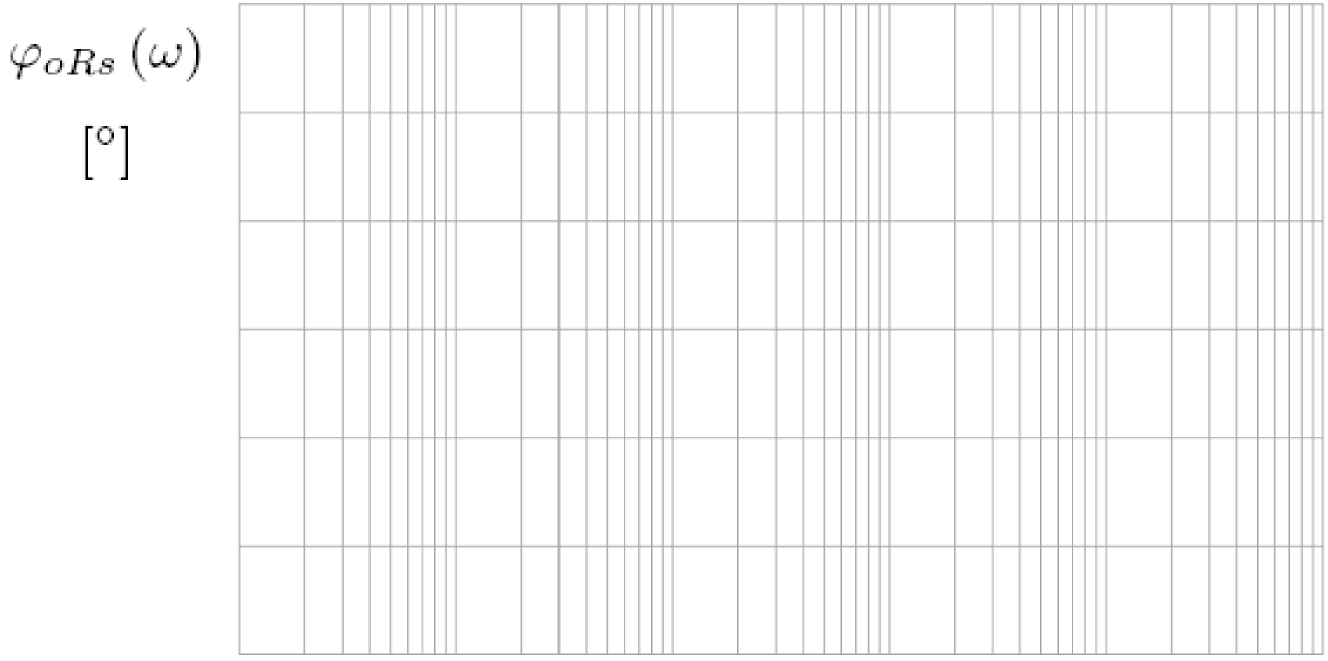
$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$





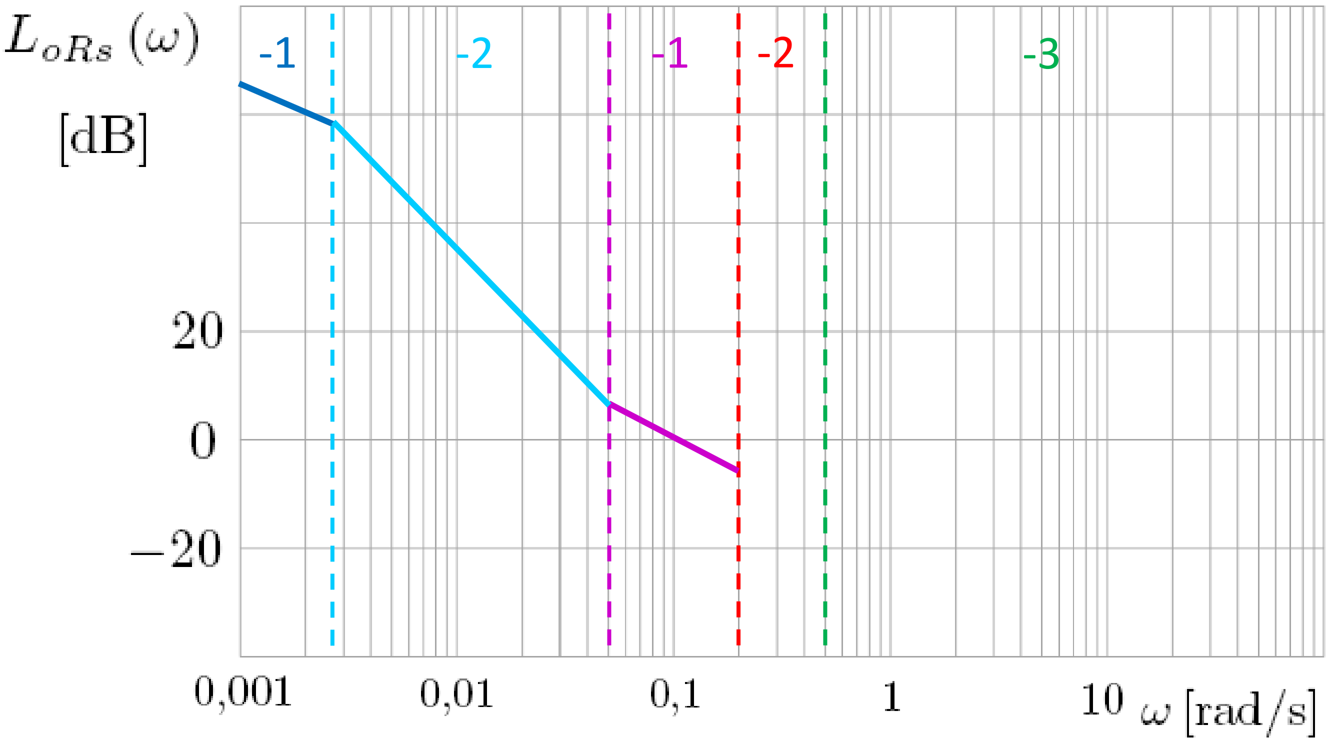
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

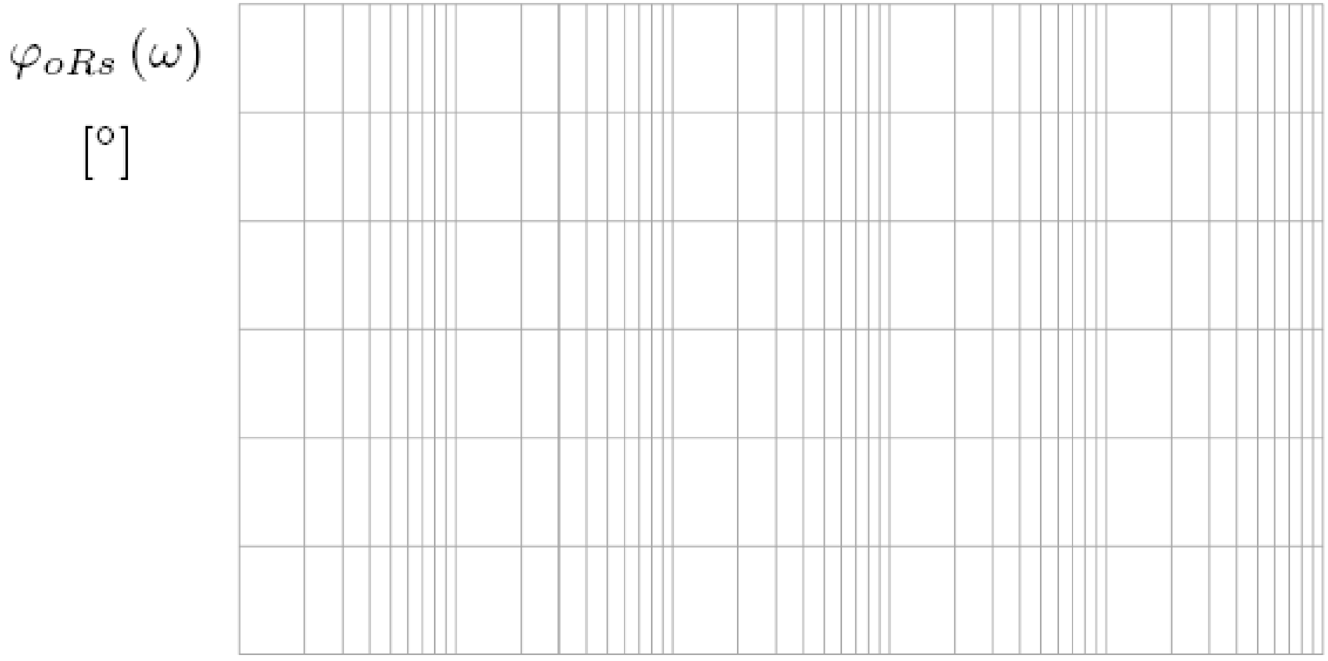
$$\omega_1 = \frac{1}{400} = 0{,}0025\ \text{rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2\ \text{rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05\ \text{rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5\ \text{rad/s}$$

$$\omega_{cs} = 0{,}1\ \text{rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6\ \text{dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1\ \text{dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

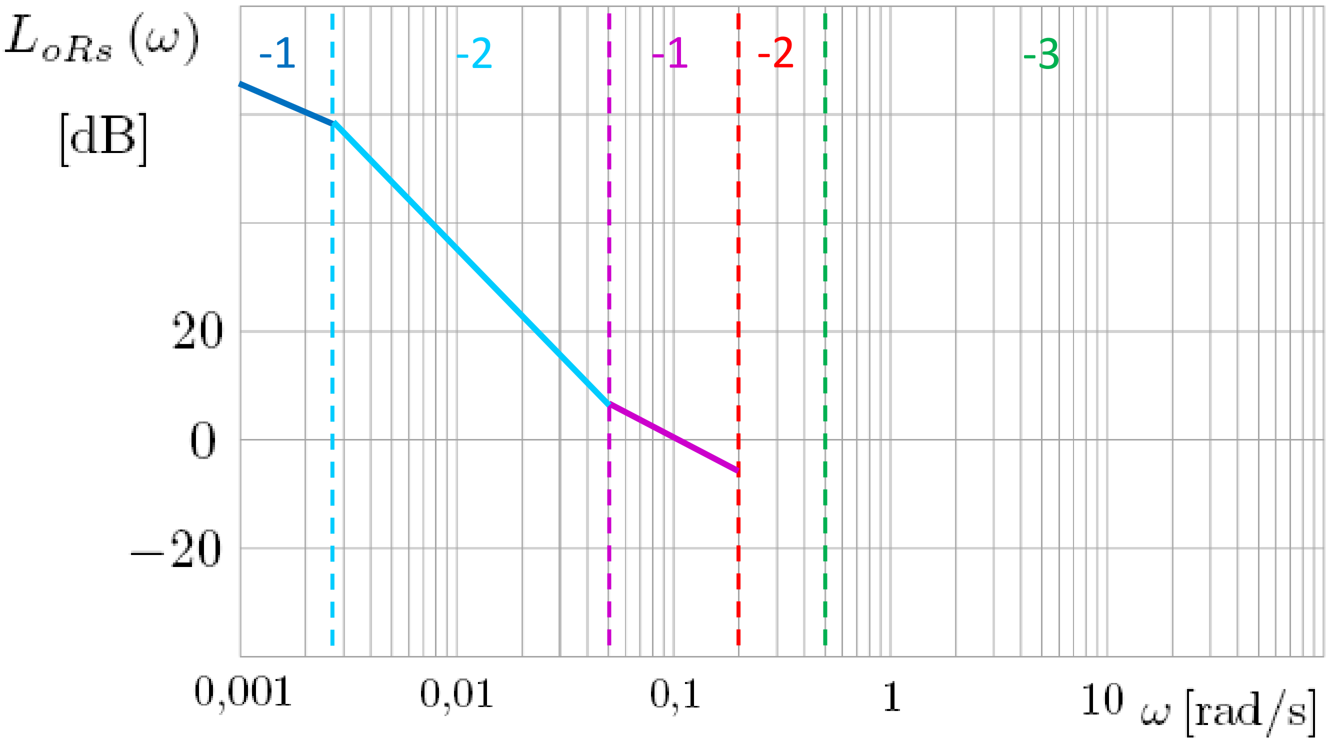
$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

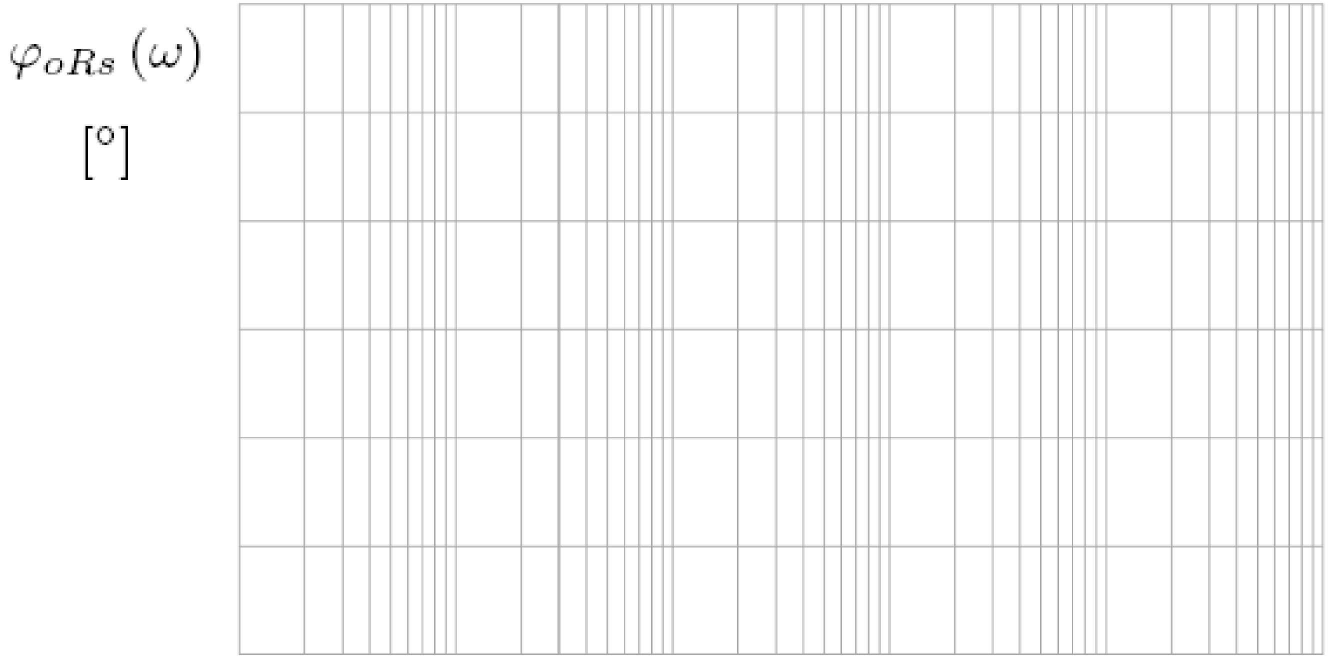
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

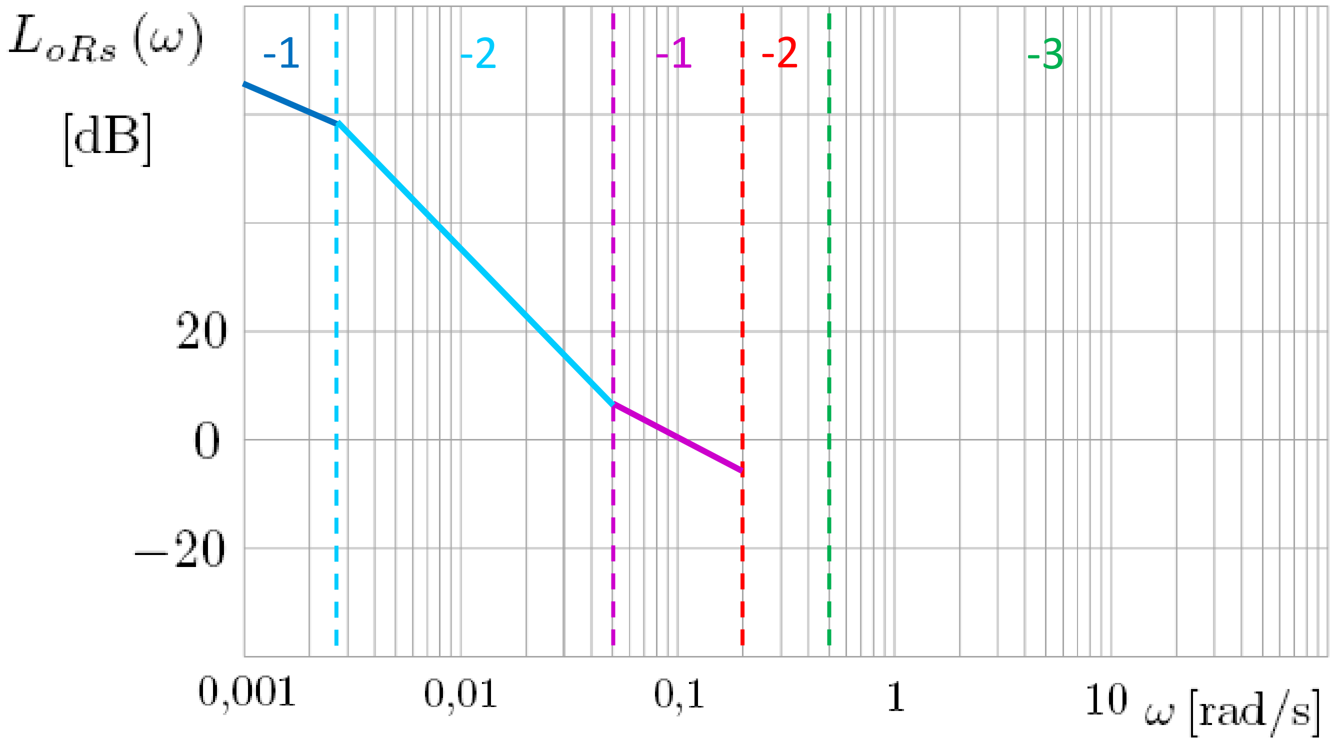
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

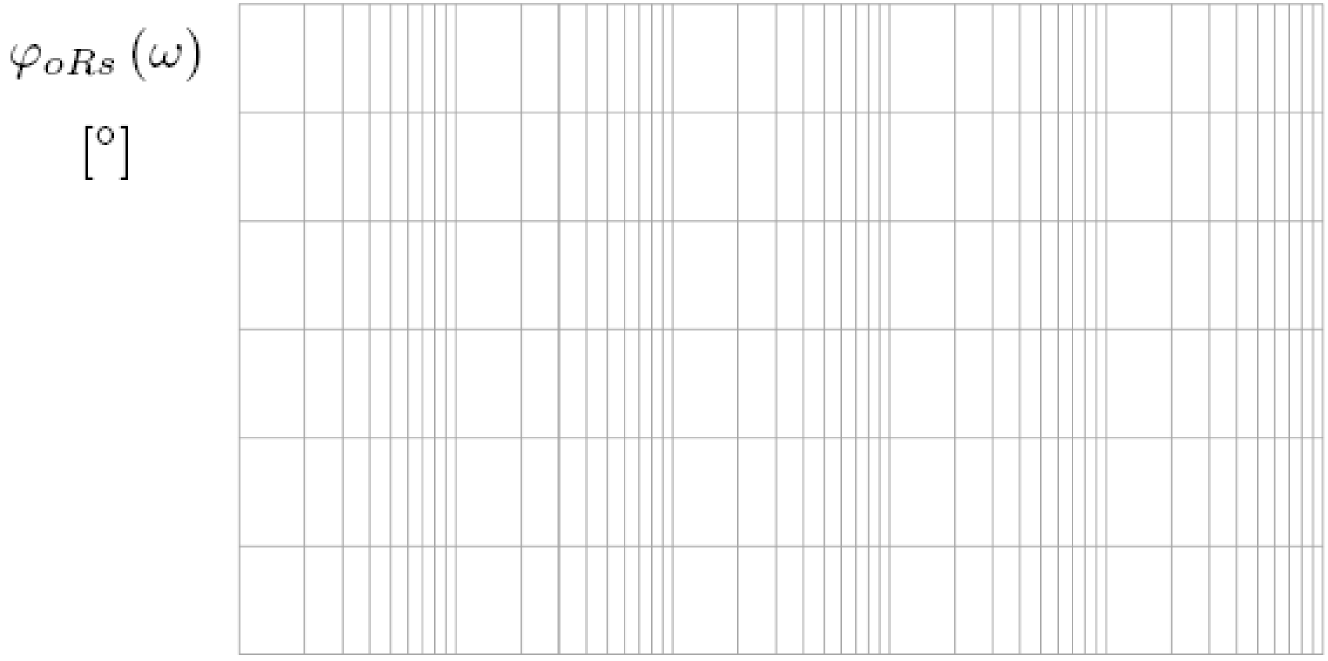
$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

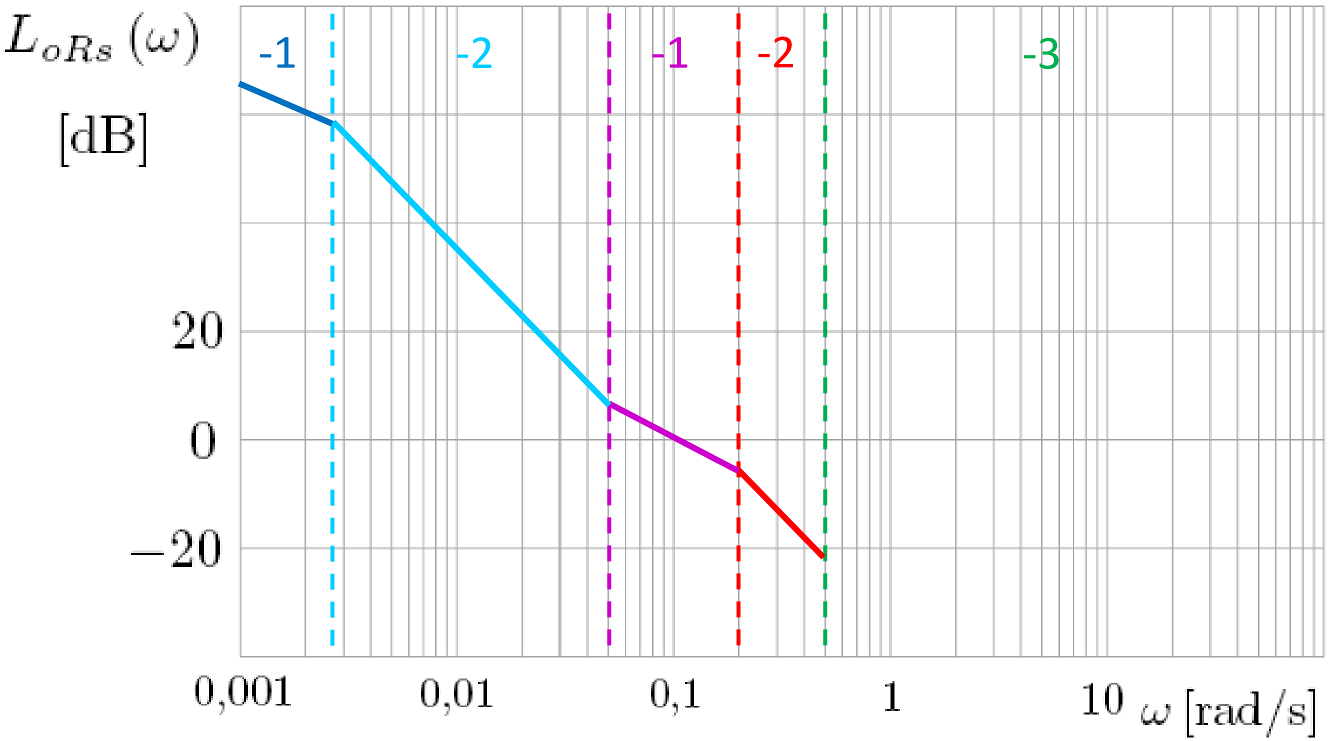
$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

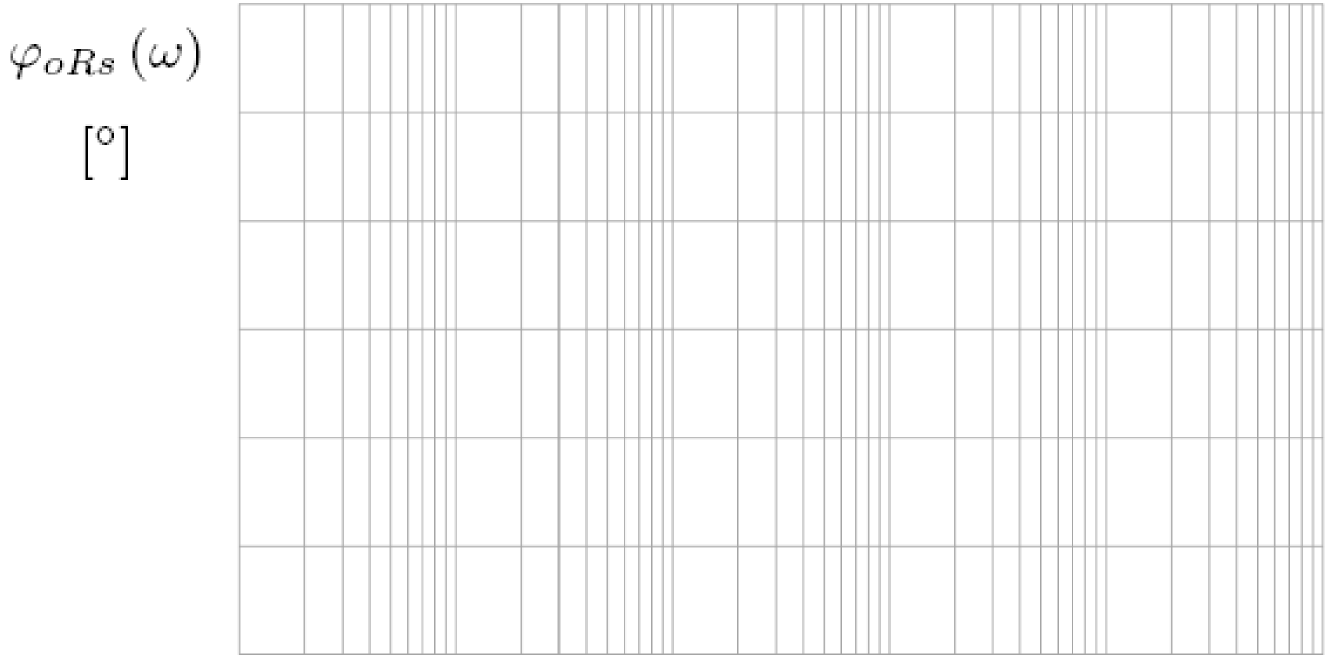
$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

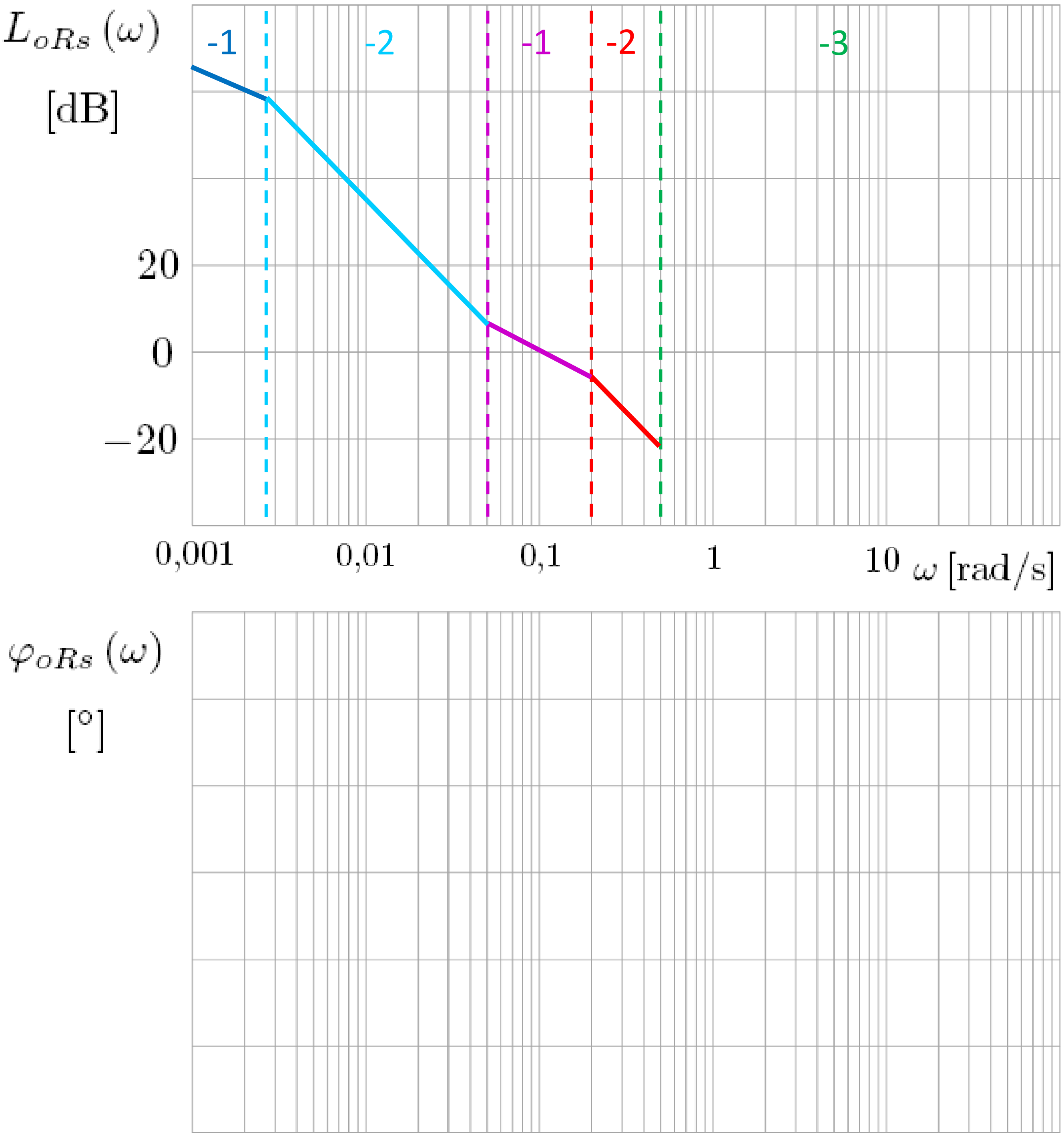
$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

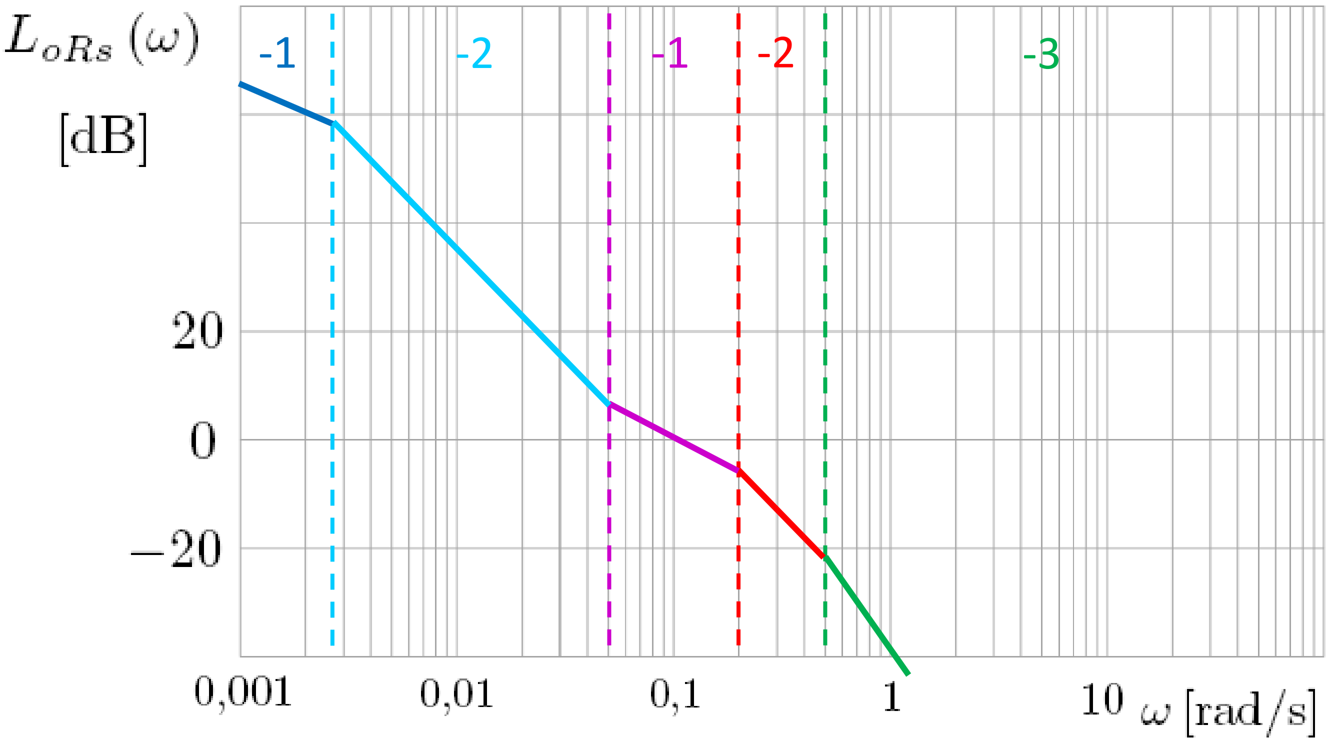
$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

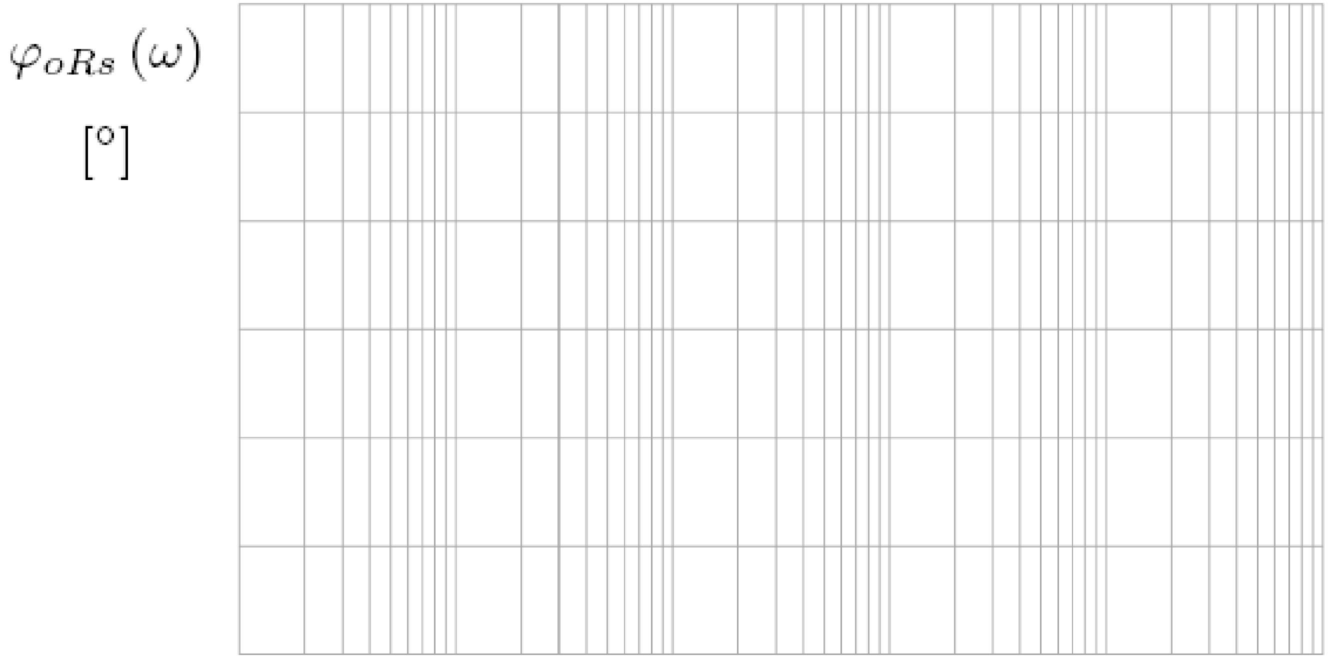
$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

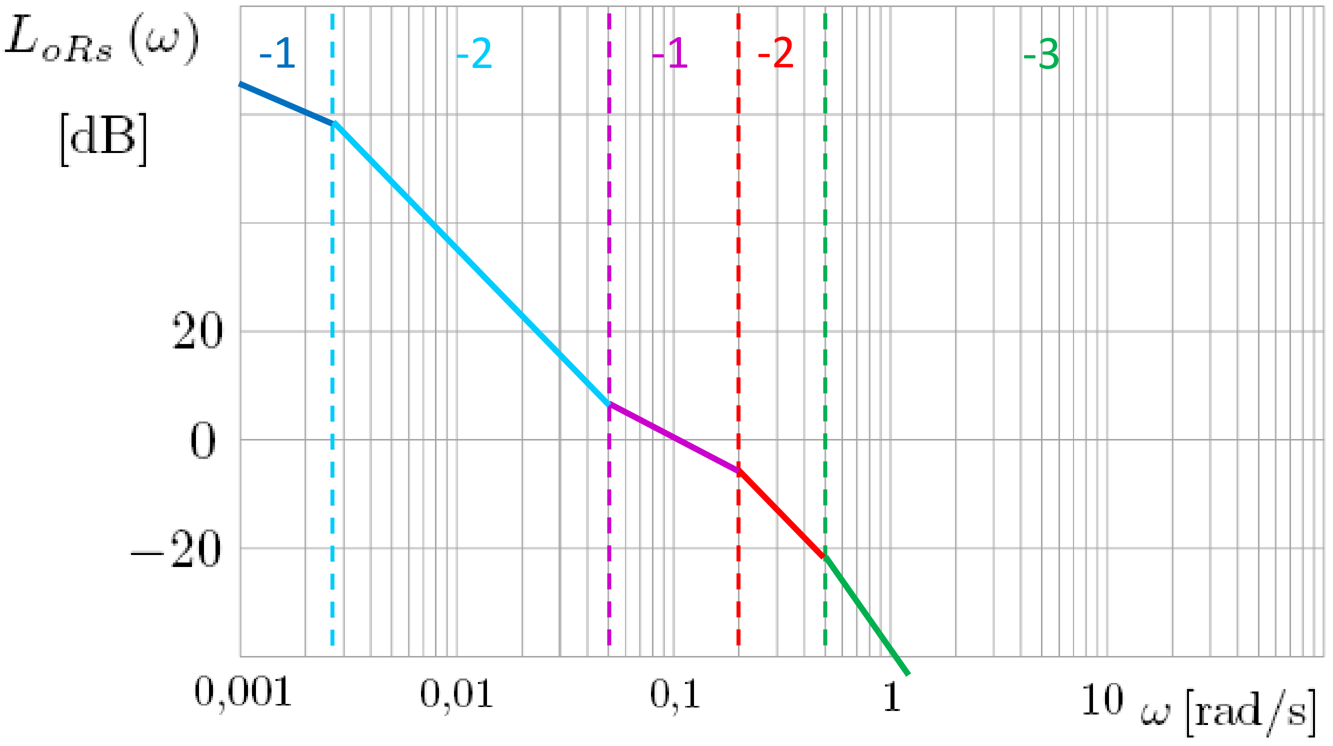
$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

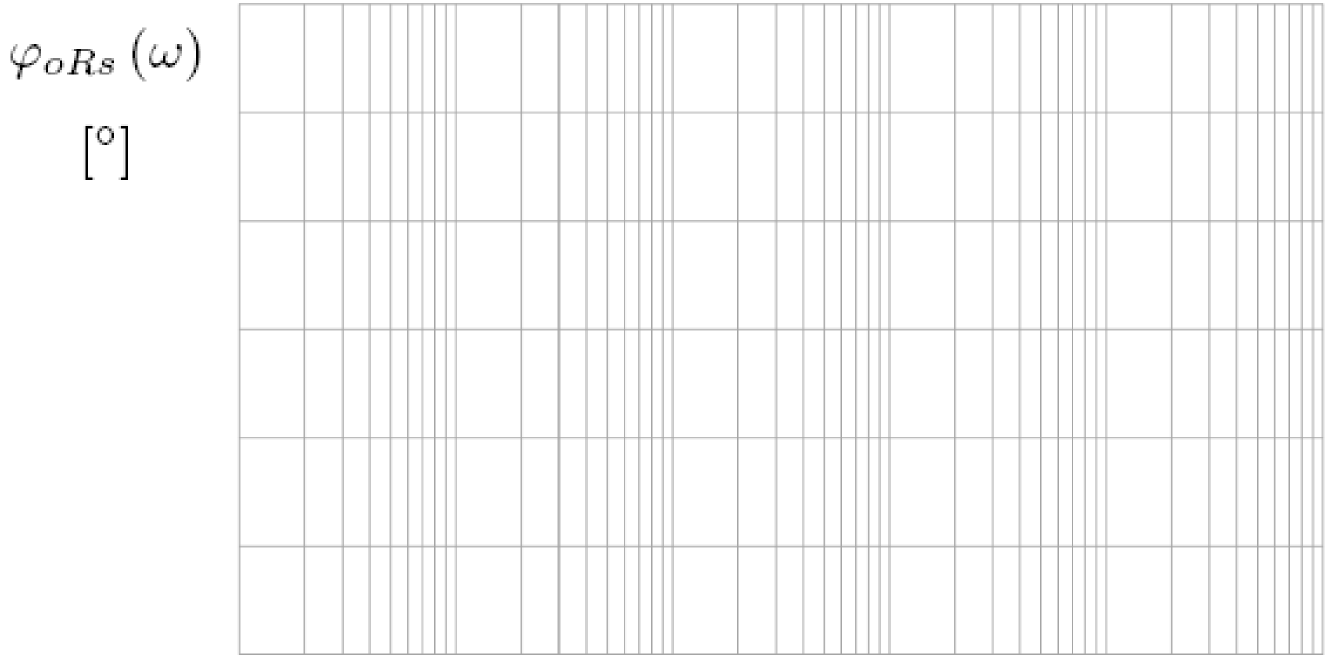
$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$

$$L_{oRs}(1) = -21{,}9 \text{ dB} - 60\log\frac{1}{0{,}5} = -40 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

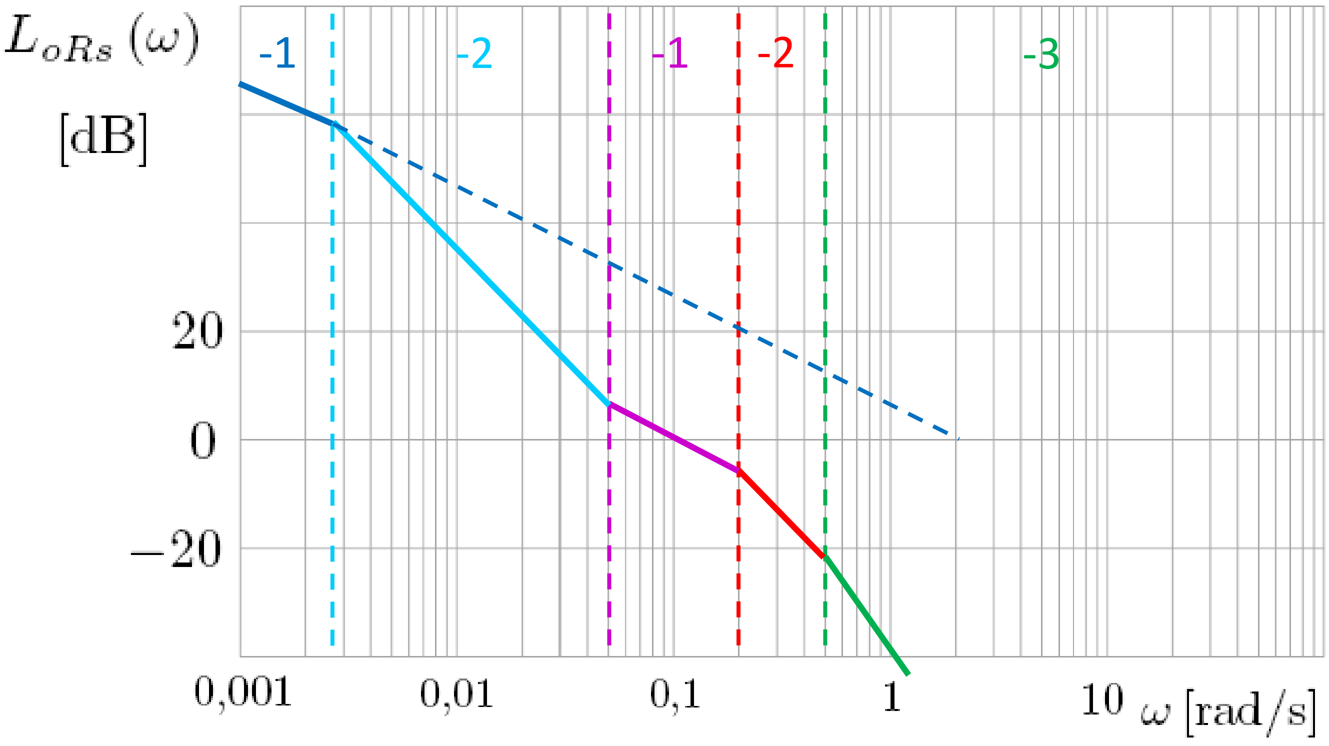
$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

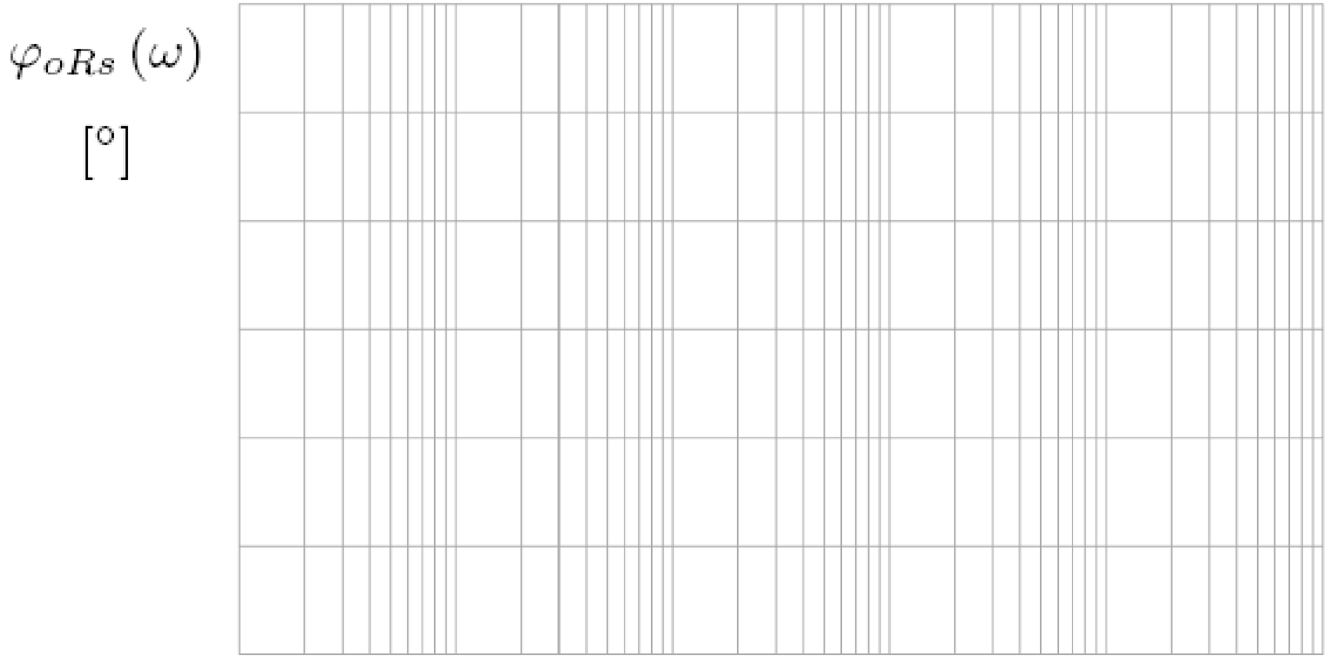
$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$

$$L_{oRs}(1) = -21{,}9 \text{ dB} - 60\log\frac{1}{0{,}5} = -40 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

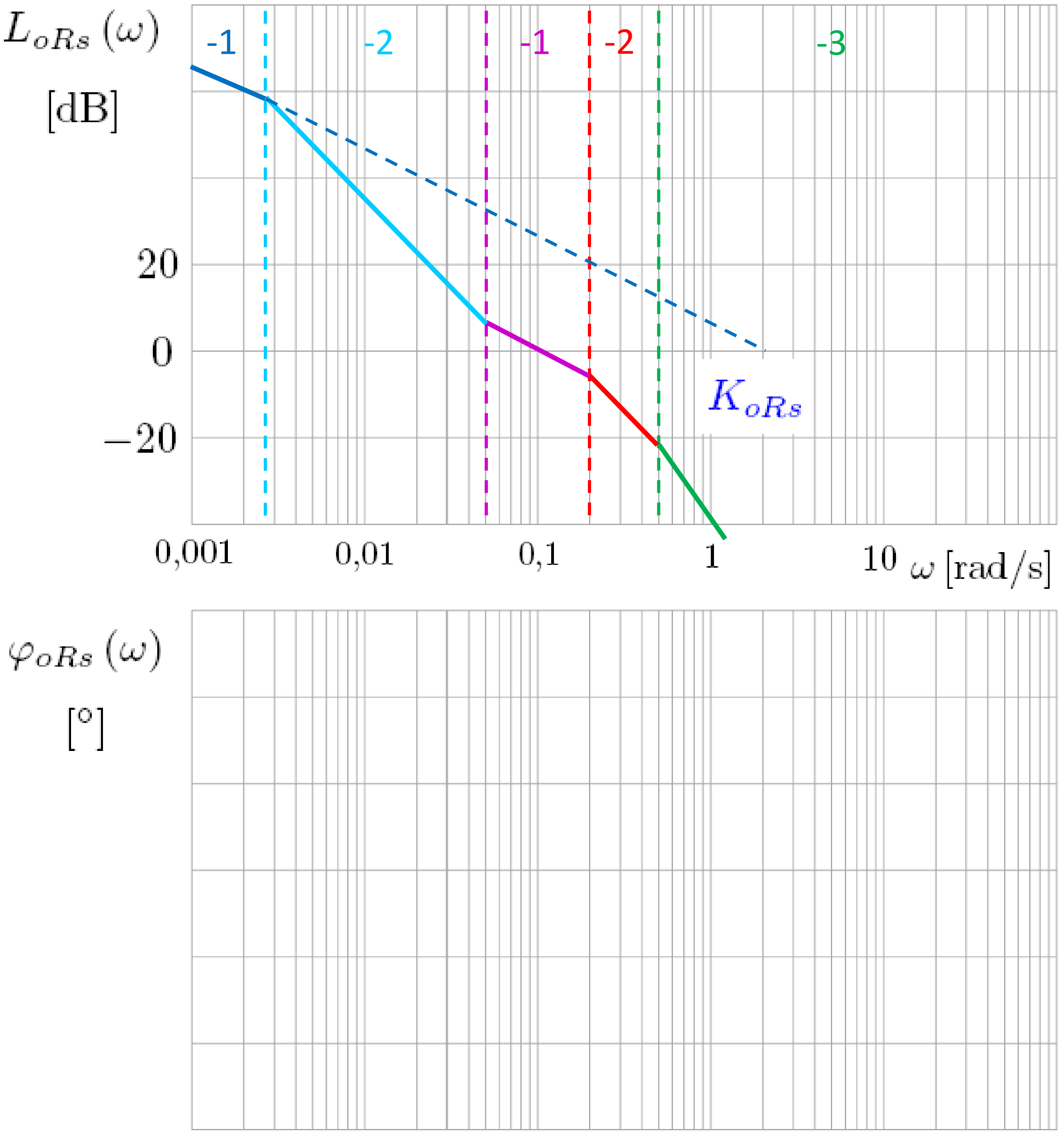
$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$

$$L_{oRs}(1) = -21{,}9 \text{ dB} - 60\log\frac{1}{0{,}5} = -40 \text{ dB}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

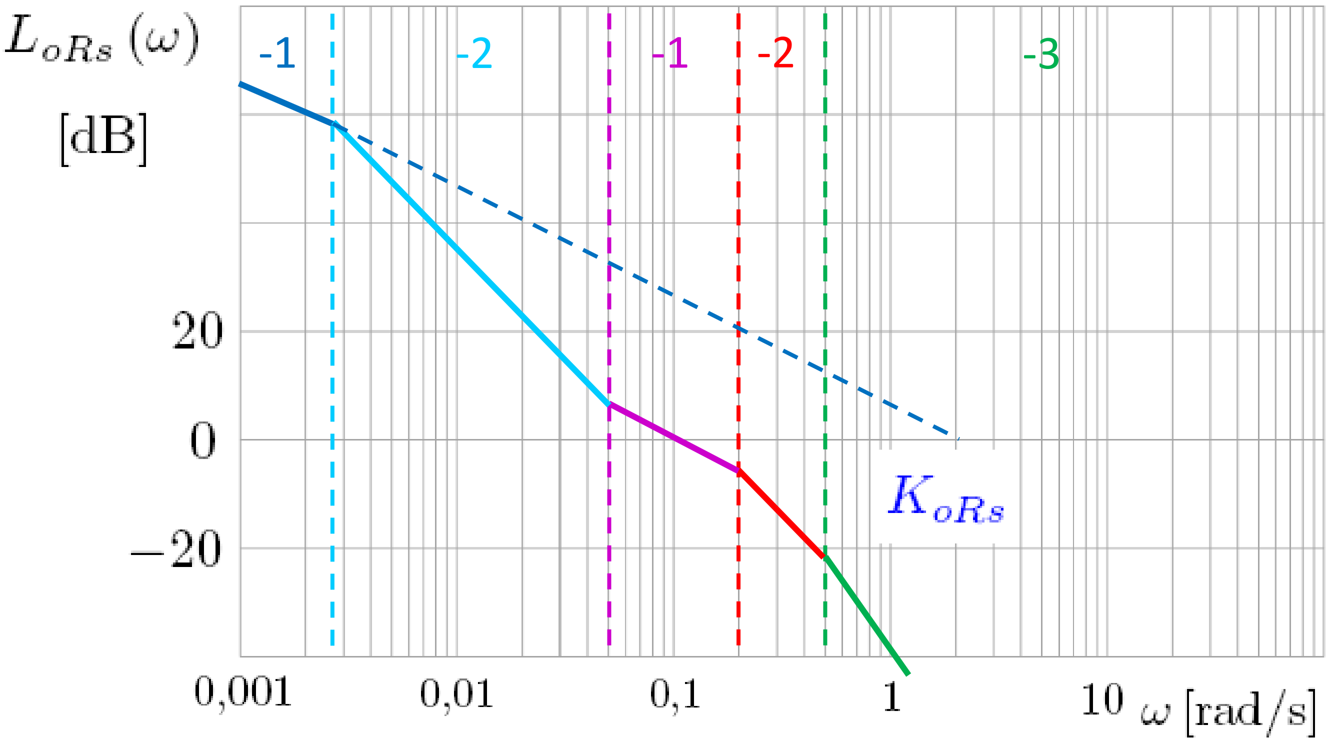
$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

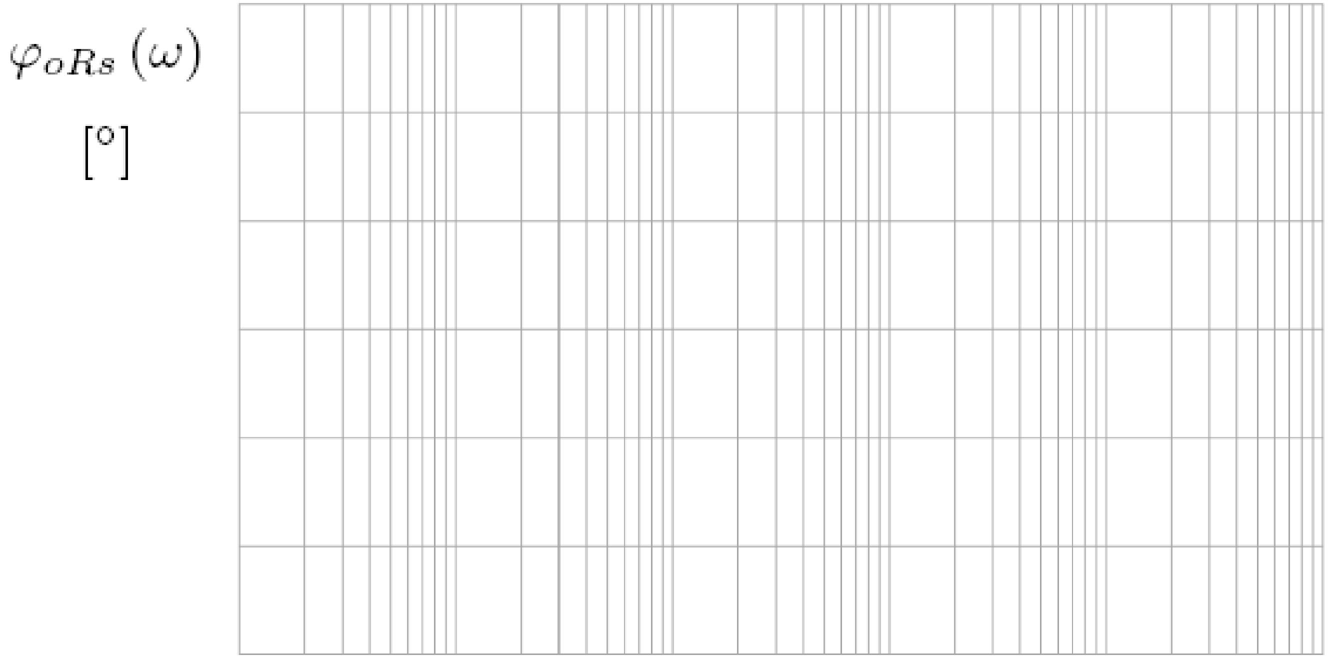
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$

$$L_{oRs}(1) = -21{,}9 \text{ dB} - 60\log\frac{1}{0{,}5} = -40 \text{ dB}$$

$$0 = 58{,}1 - 20\log\frac{K_{oRs}}{0{,}0025}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

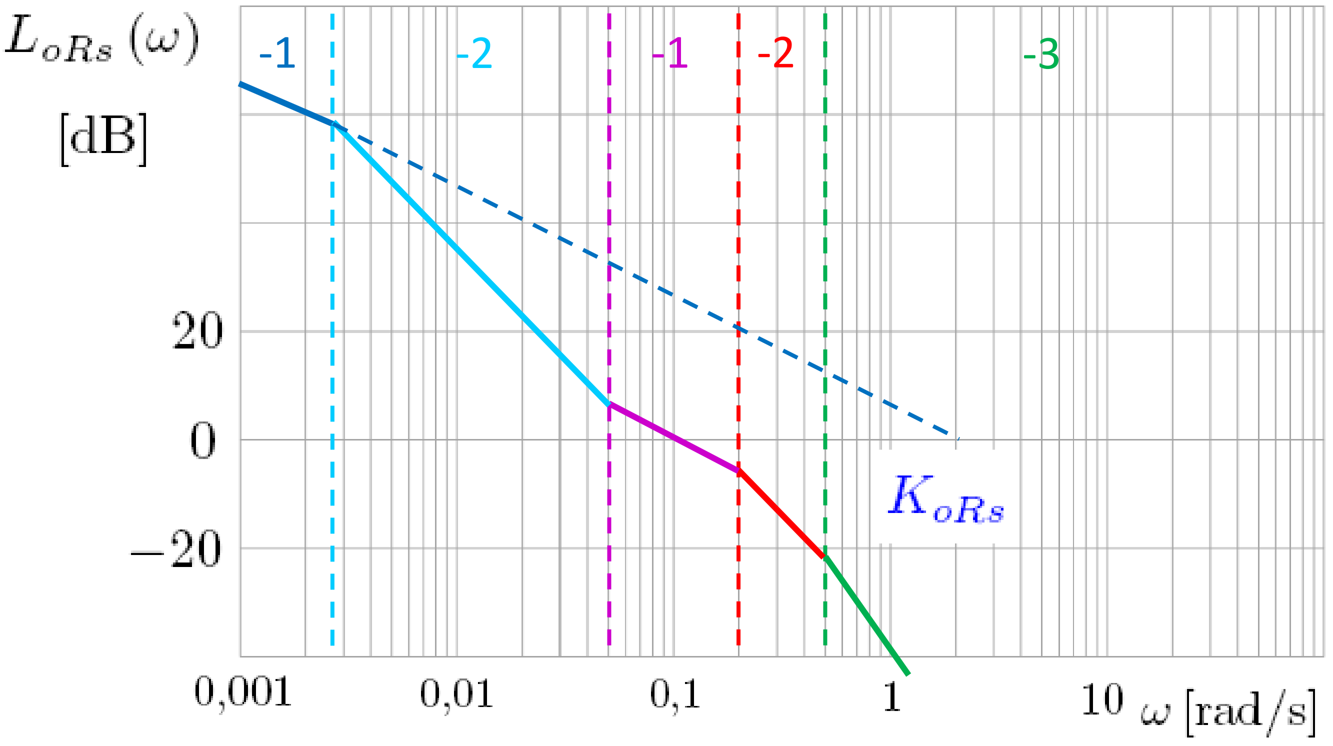
$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

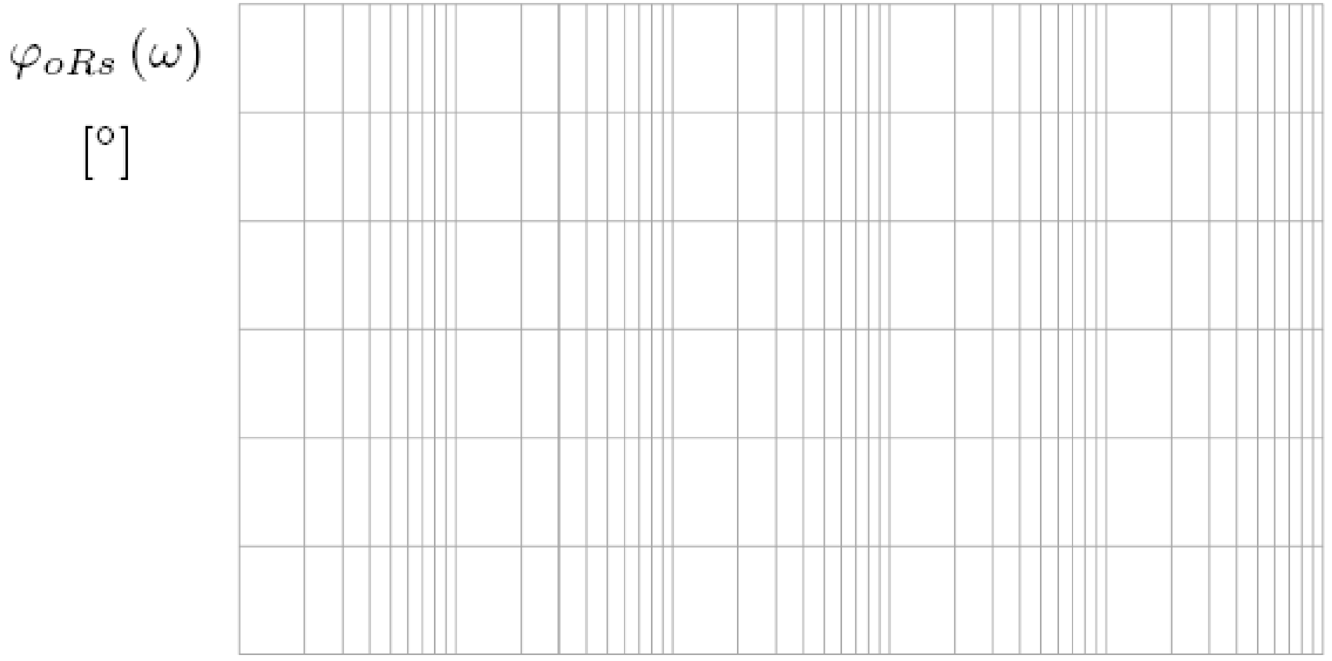
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$

$$L_{oRs}(1) = -21{,}9 \text{ dB} - 60\log\frac{1}{0{,}5} = -40 \text{ dB}$$

$$0 = 58{,}1 - 20\log\frac{K_{oRs}}{0{,}0025} \qquad K_{oRs} = 0{,}0025 \cdot 10^{\frac{58{,}1}{20}} = 2$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+20s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{20} = 0{,}05 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}1 \text{ rad/s} \qquad L_{oRs}(0{,}05) = -20\log\frac{0{,}05}{0{,}1} = 6 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 6 - 40\log\frac{0{,}0025}{0{,}05} = 58{,}1 \text{ dB}$$

$$L_{oRs}(0{,}001) = 58{,}1 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 66 \text{ dB}$$

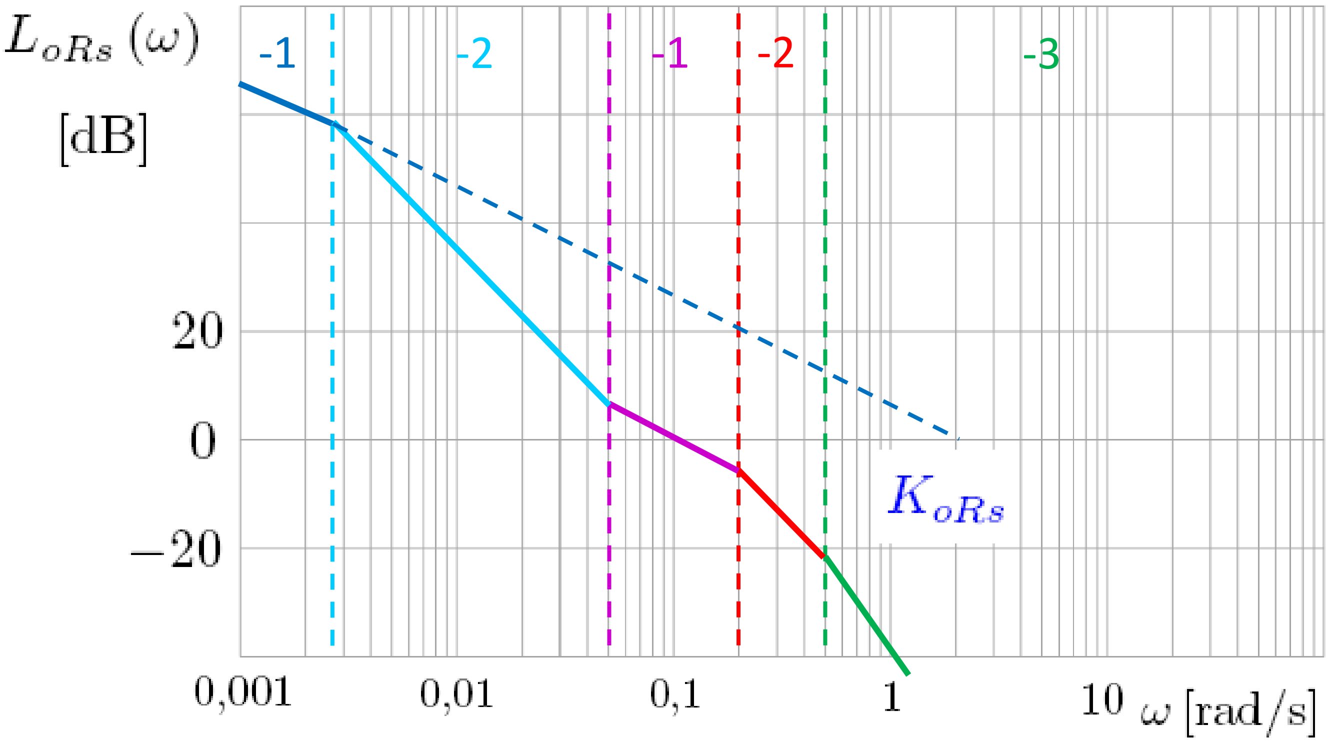
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}1} = -6 \text{ dB}$$

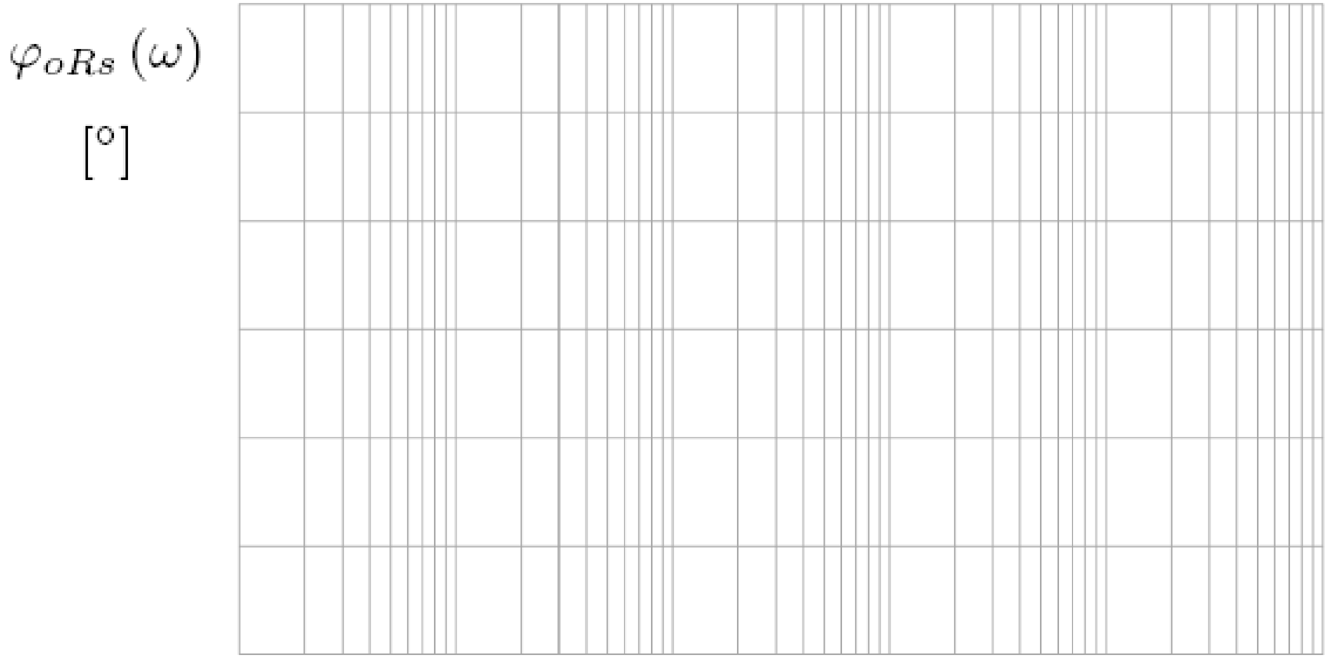
$$L_{oRs}(0{,}5) = -6 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -21{,}9 \text{ dB}$$

$$L_{oRs}(1) = -21{,}9 \text{ dB} - 60\log\frac{1}{0{,}5} = -40 \text{ dB}$$

$$0 = 58{,}1 - 20\log\frac{K_{oRs}}{0{,}0025} \qquad K_{oRs} = 0{,}0025 \cdot 10^{\frac{58{,}1}{20}} = 2$$

$$K_{Rs} = 2{,}5 K_{oRs} = 5$$





Simulacija i korekcija parametara

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 25\%$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}062}{3{,}2} \approx 0{,}02 \text{ rad/s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}062}{3{,}2} \approx 0{,}02 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}02} = 50 \text{ s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}062}{3{,}2} \approx 0{,}02 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}02} = 50 \text{ s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}062}{3{,}2} \approx 0{,}02 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}02} = 50 \text{ s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1+400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot 8}{50} = 0{,}16 K_{Rs}$$

$$G_p(s) = \frac{5}{1+400s} \cdot \frac{16}{1+5s} \cdot \frac{0{,}1}{1+2s}$$

$$G_p(s) = \frac{8}{(1+400s)(1+5s)(1+2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}062}{3{,}2} \approx 0{,}02 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}02} = 50 \text{ s}$$

Primjer 2b

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{5}{1 + 400s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1 + 50s}{50s} \cdot \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot 8}{50} = 0{,}16 K_{Rs} \qquad K_{Rs} = \frac{1}{0{,}16} K_{oRs} = 6{,}25 K_{oRs}$$

$$G_p(s) = \frac{5}{1 + 400s} \cdot \frac{16}{1 + 5s} \cdot \frac{0{,}1}{1 + 2s}$$

$$G_p(s) = \frac{8}{(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\sigma_{mz} = 25\% \qquad \gamma_{sa} \approx 70 - \sigma_{mz} = 45^\circ$$

$$a = \frac{\gamma_{sa}}{14} = \frac{45}{14} \approx 3{,}2$$

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{a} = \frac{0{,}2}{3{,}2} = 0{,}062 \text{ rad/s}$$

$$\omega_{Is} = \frac{\omega_{cs}}{a} = \frac{0{,}062}{3{,}2} \approx 0{,}02 \text{ rad/s}$$

$$T_{Is} = \frac{1}{\omega_{Is}} = \frac{1}{0{,}02} = 50 \text{ s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s}$$

$$G_{oRs}\left(s\right) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

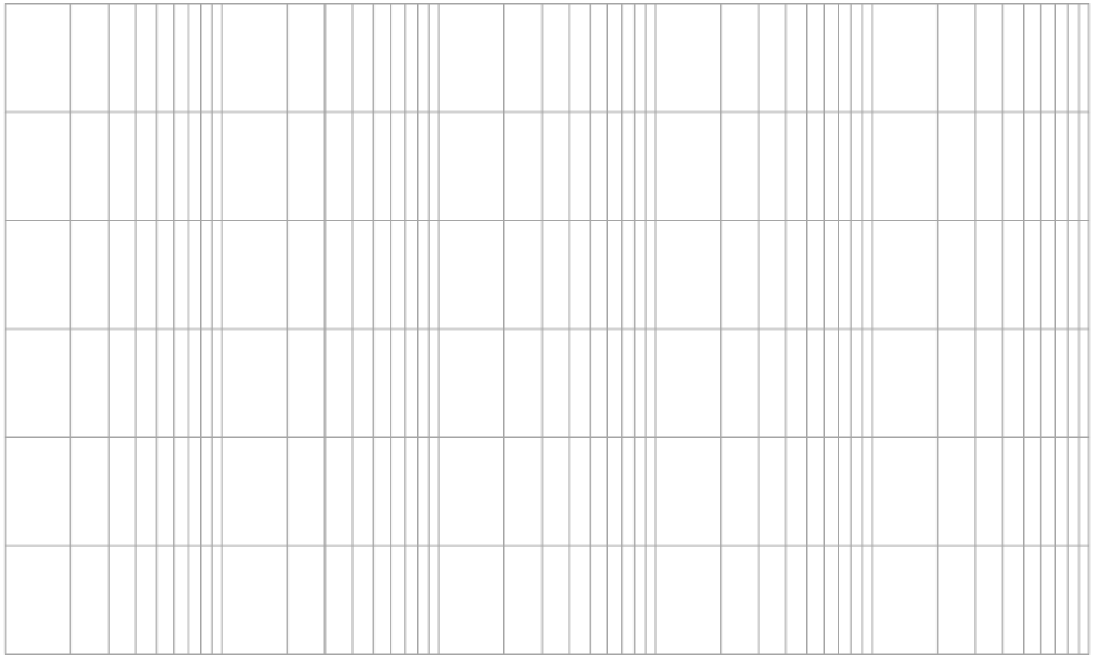
$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

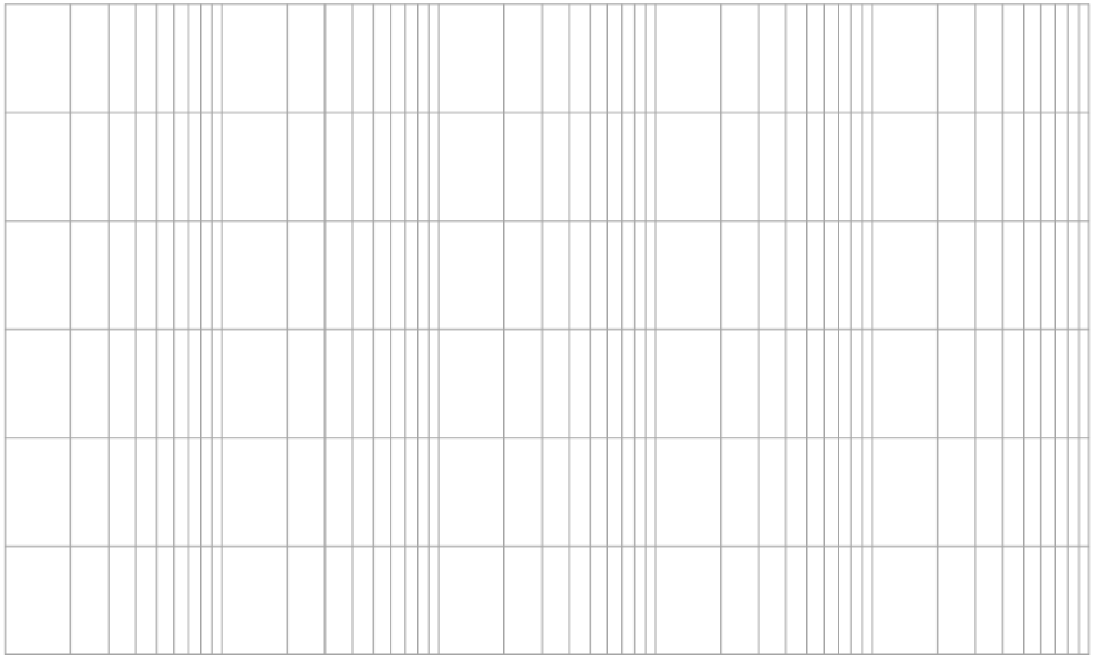
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

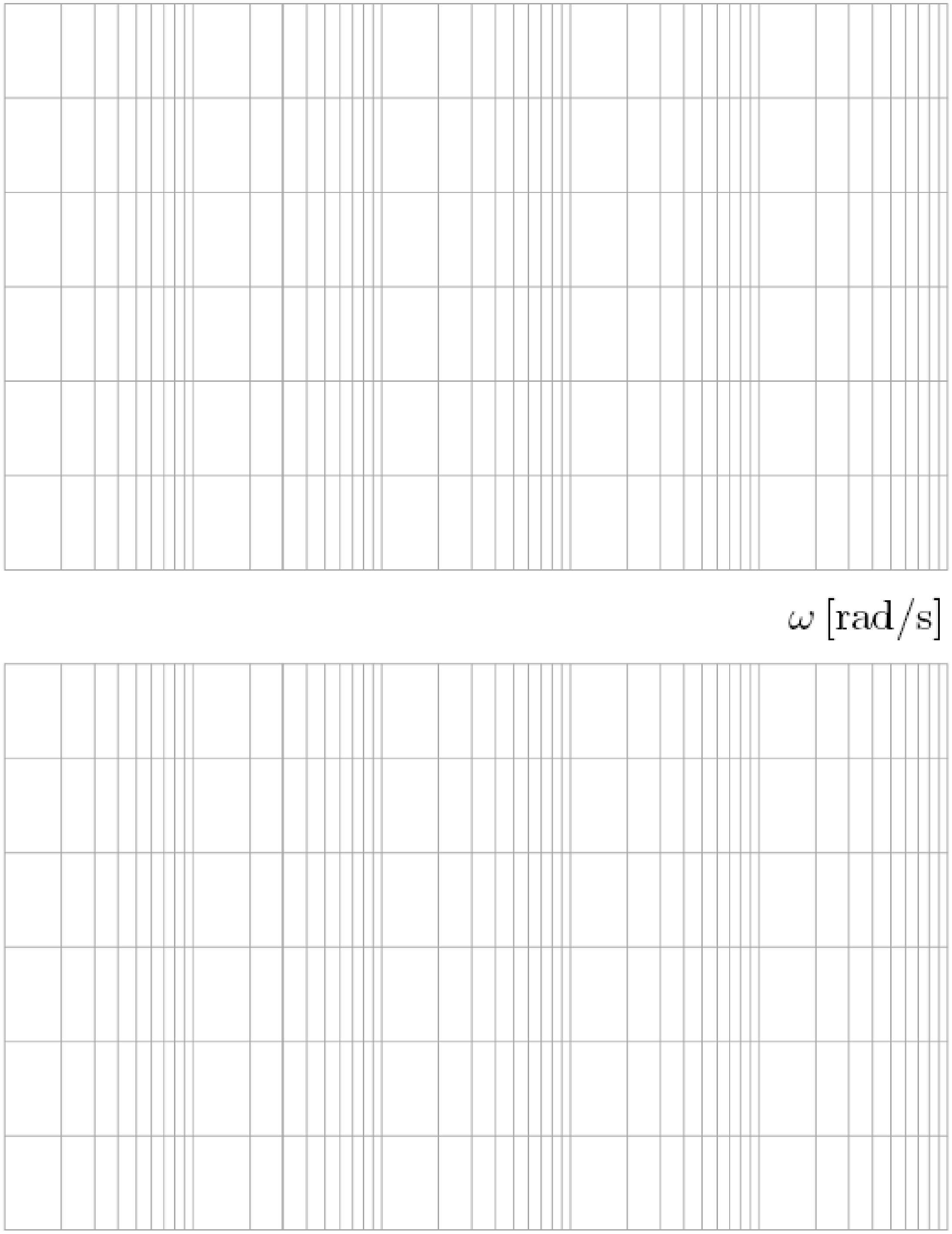




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

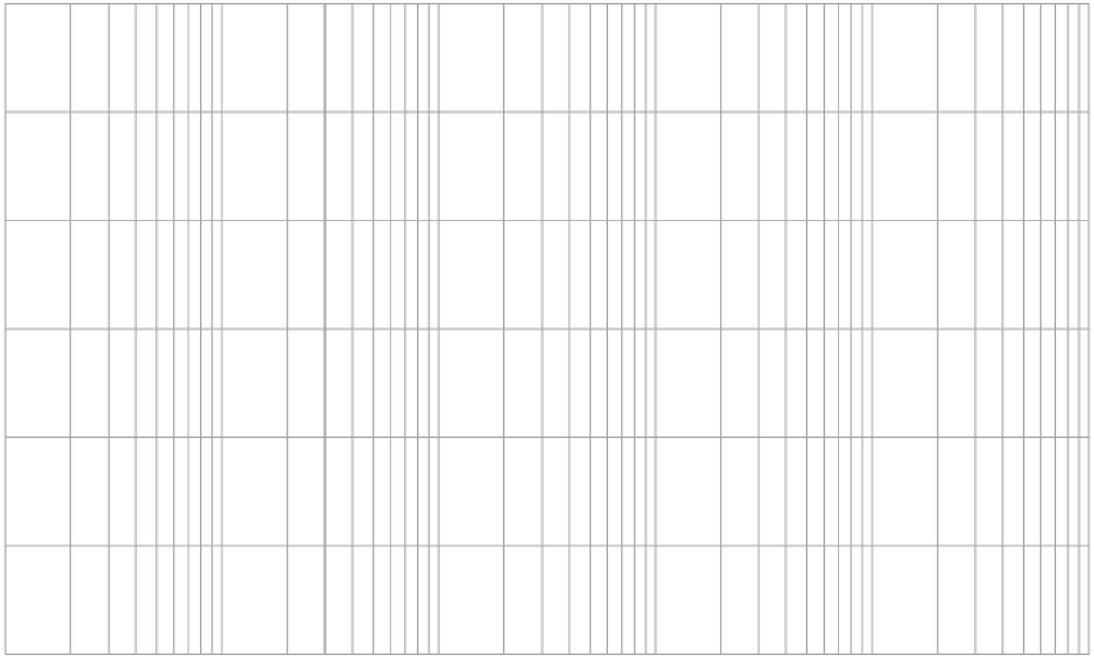
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

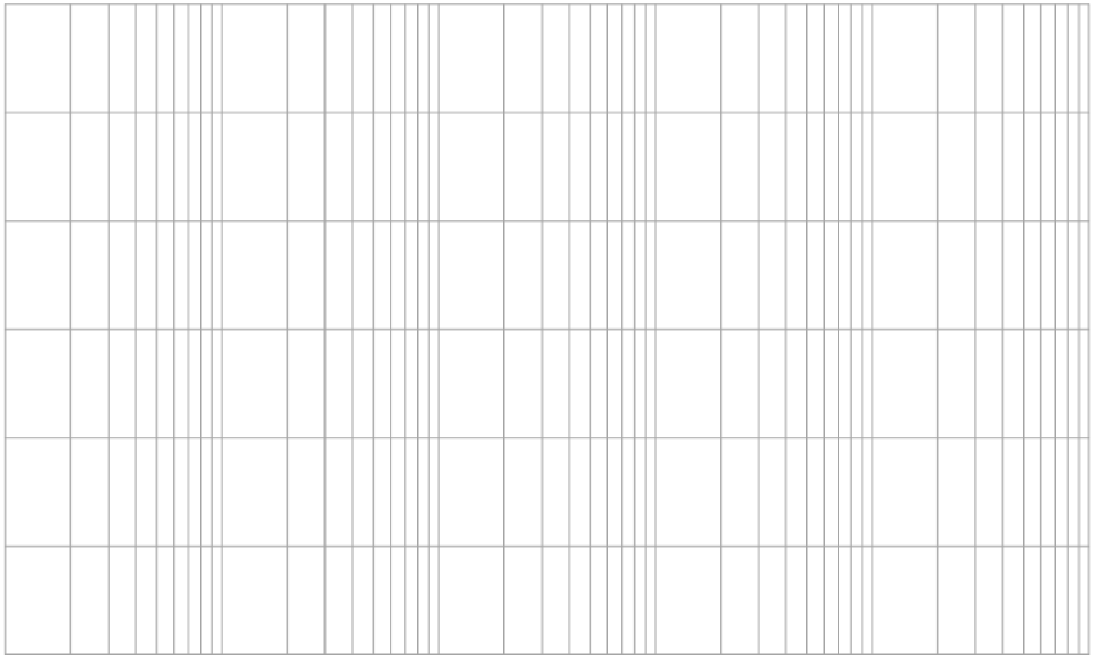


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$





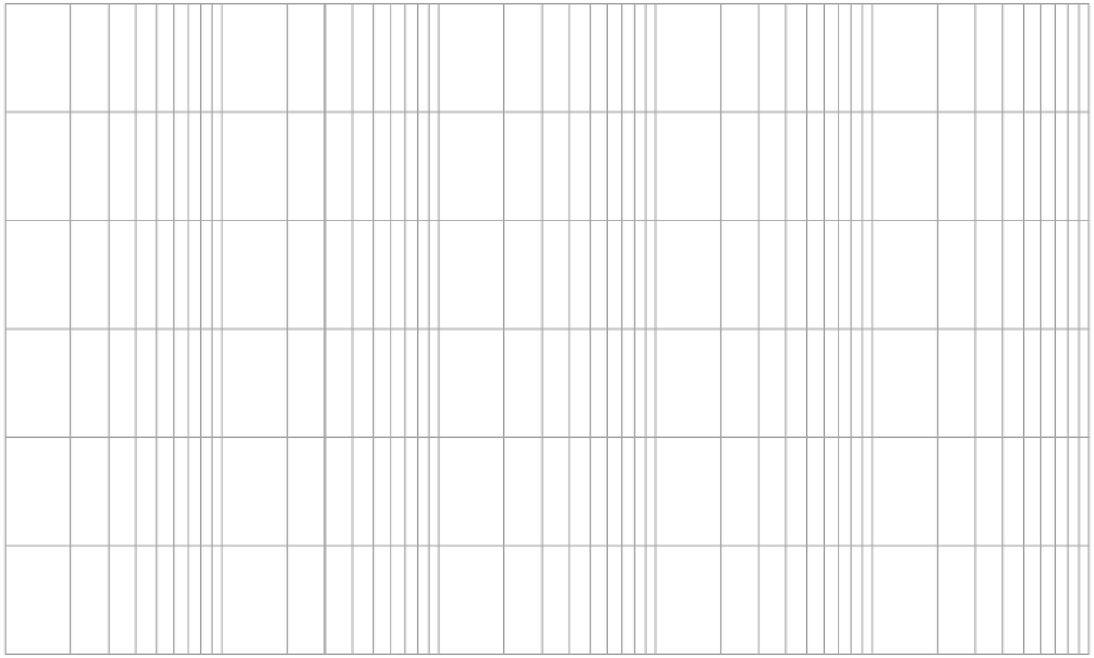
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$L_{oRs}(\omega)$

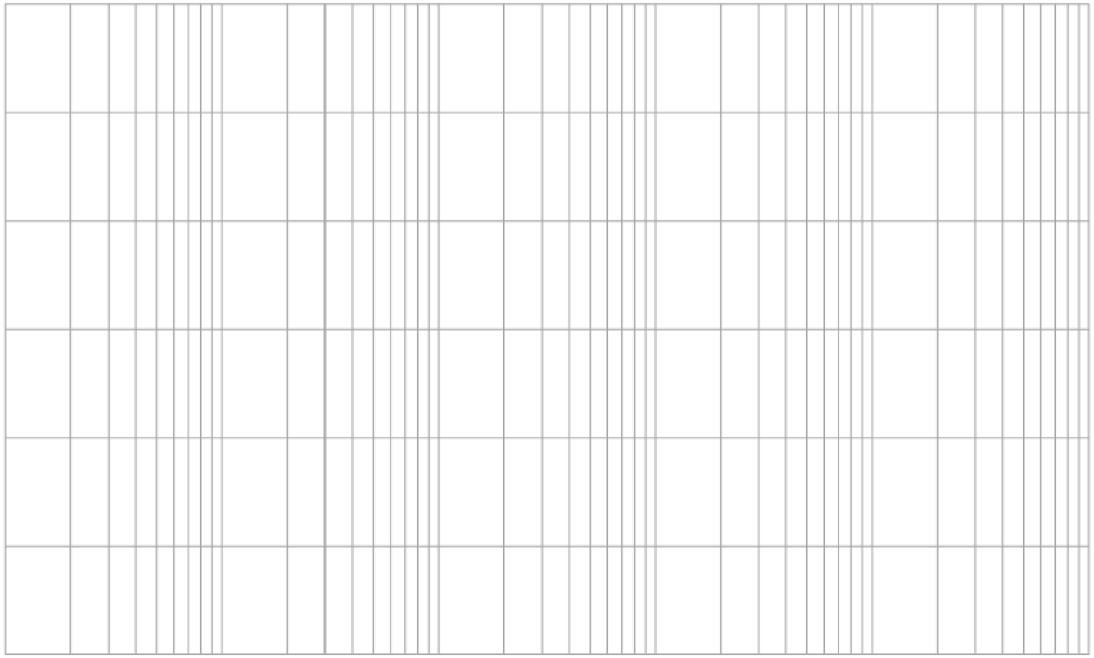
[dB]



ω [rad/s]

$\varphi_{oRs}(\omega)$

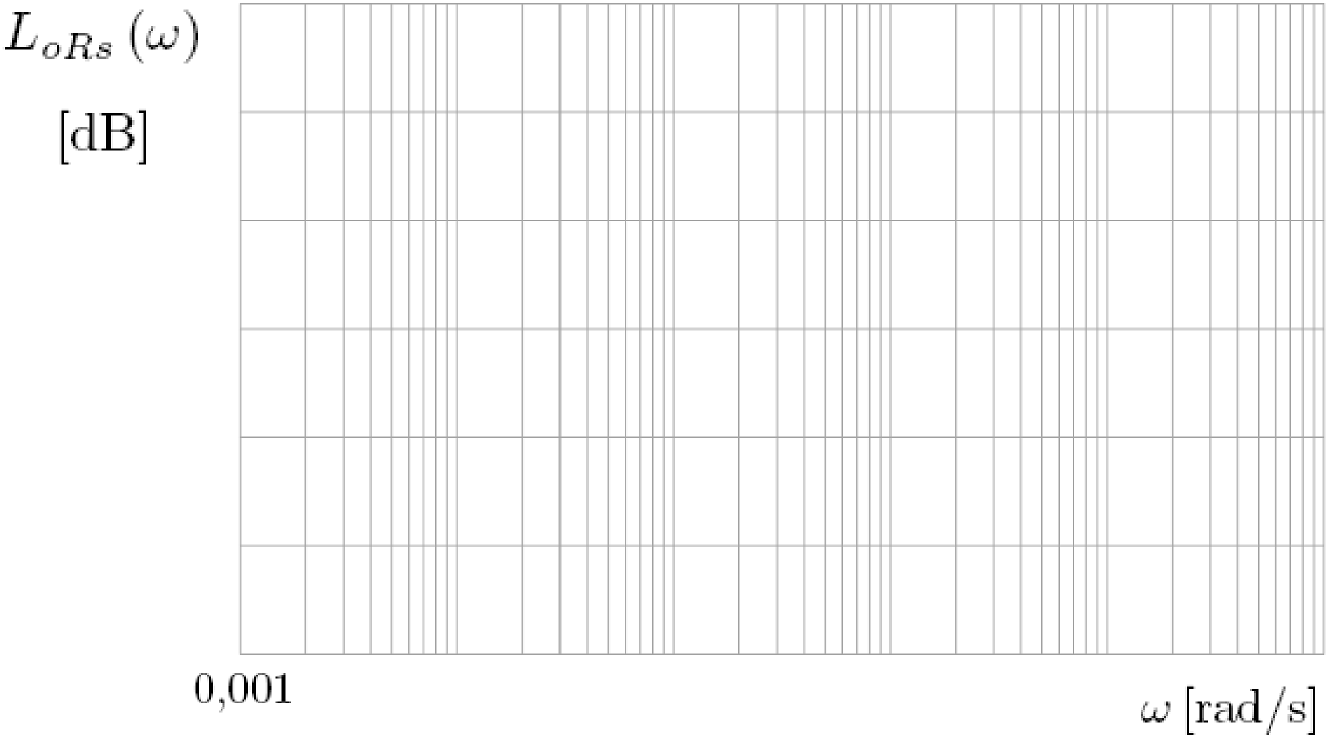
[°]

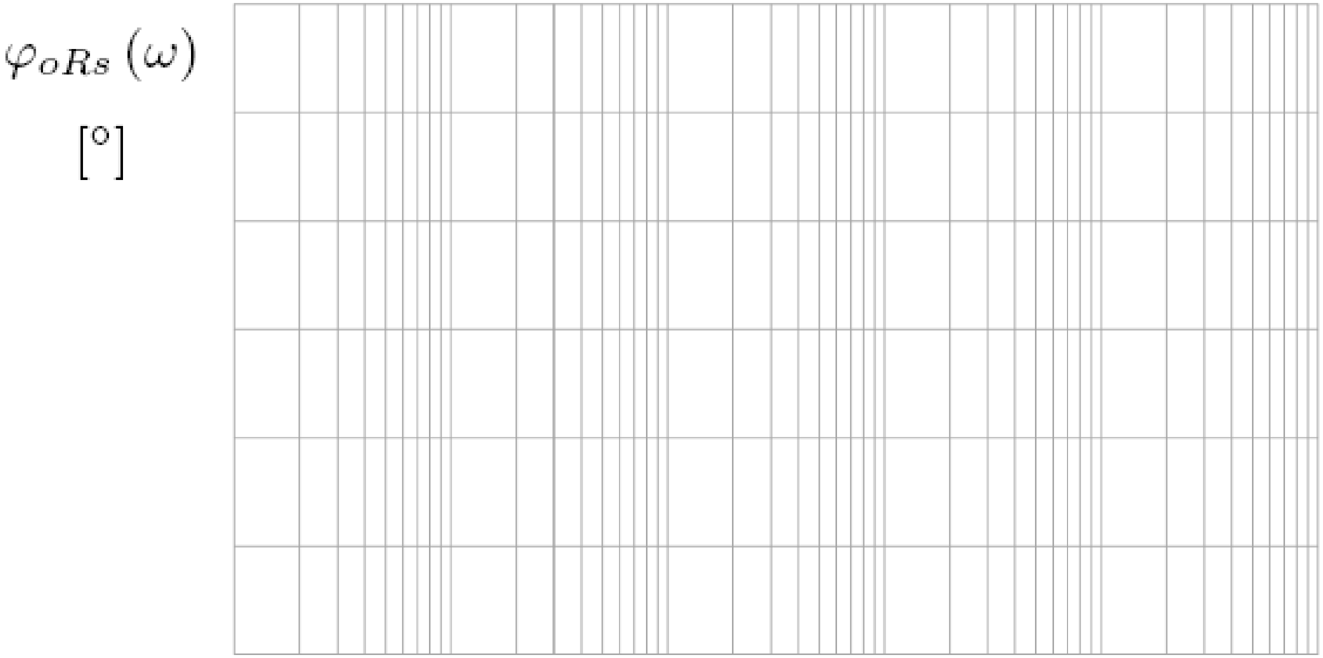


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

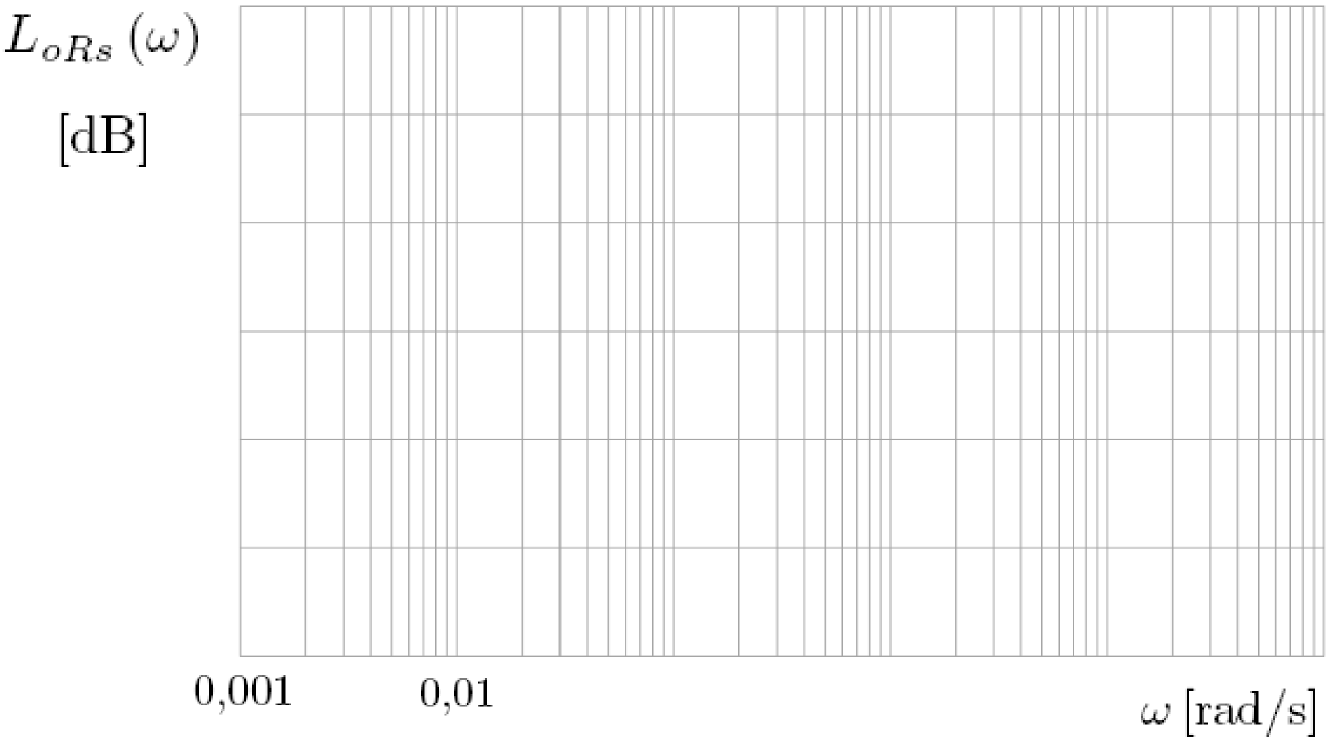


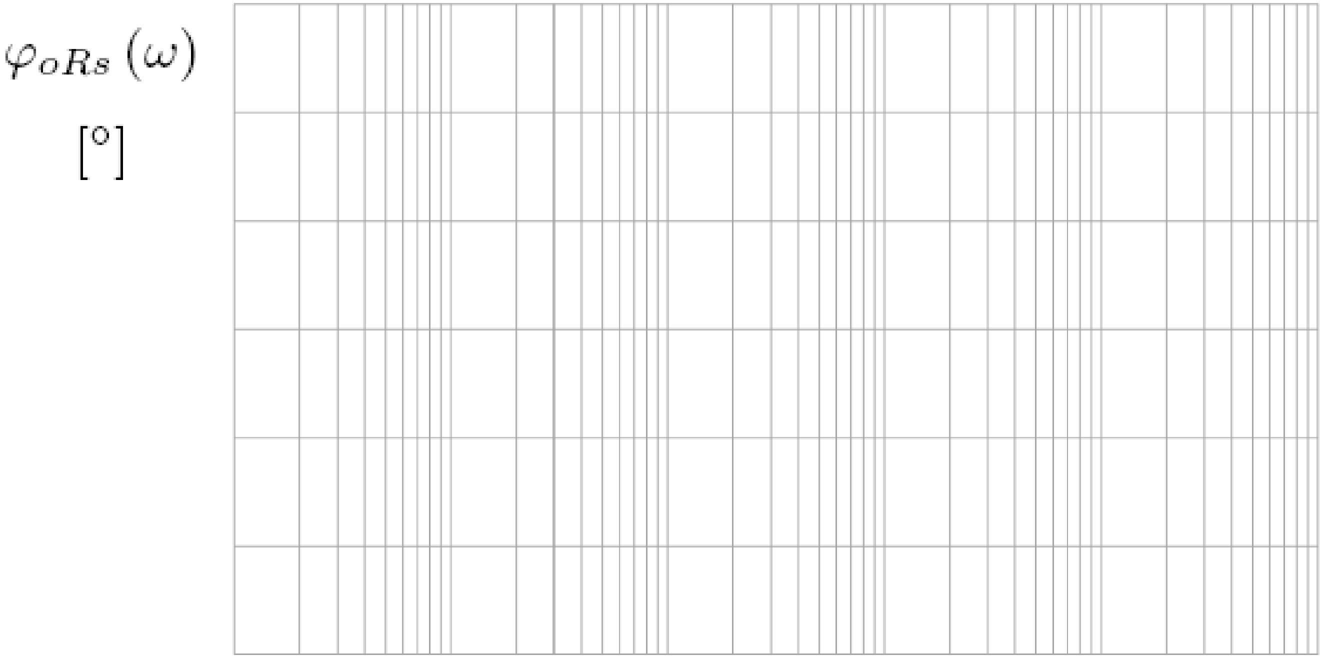


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

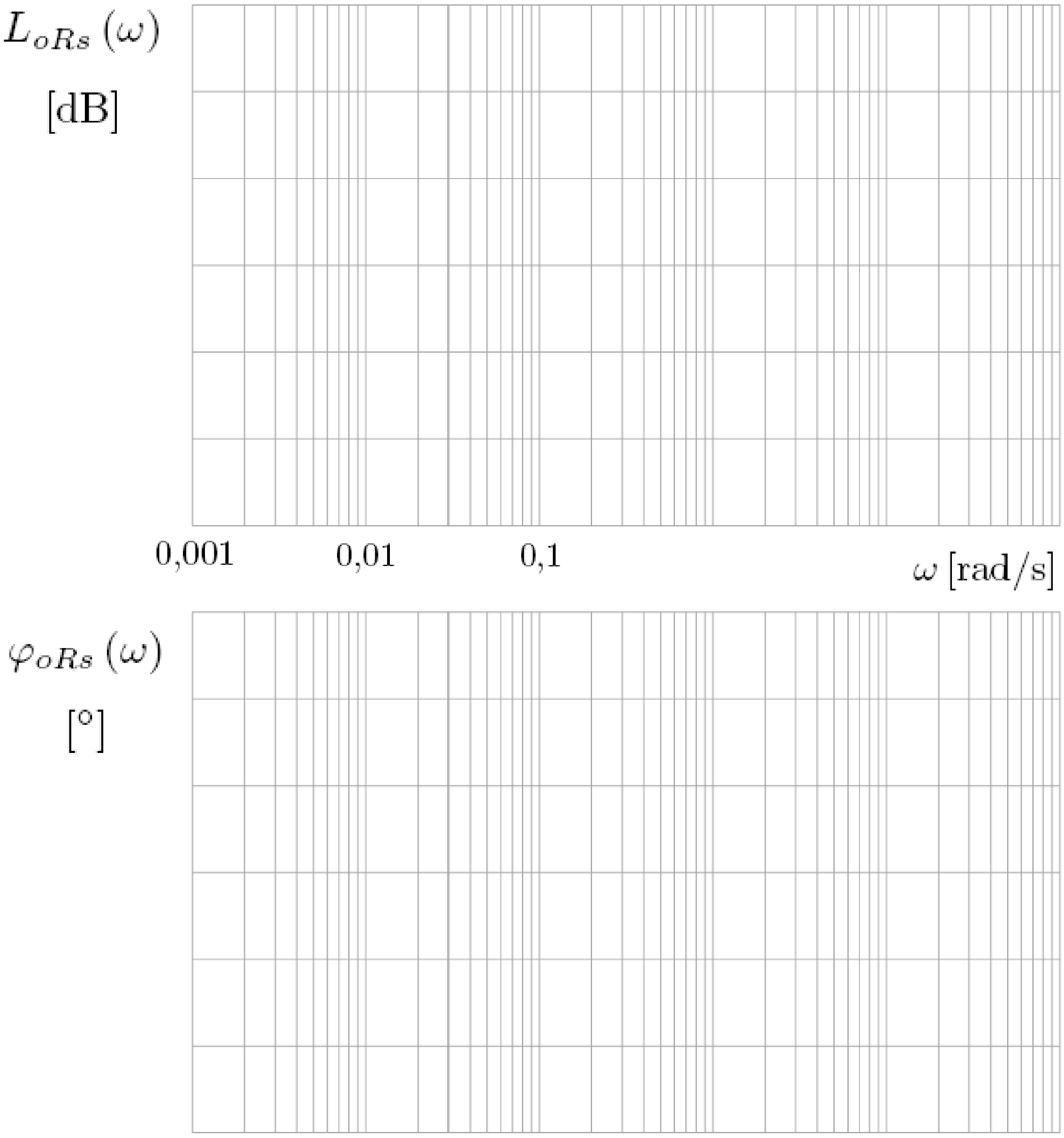




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

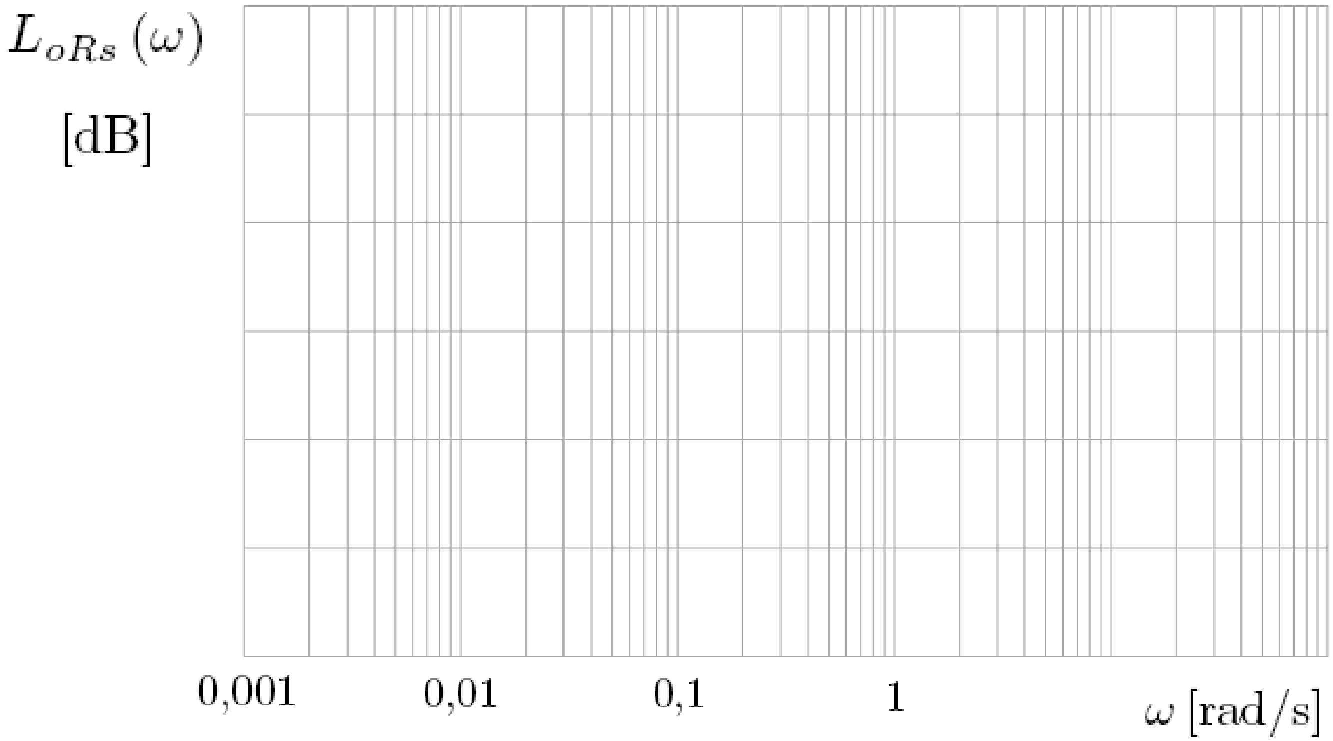
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

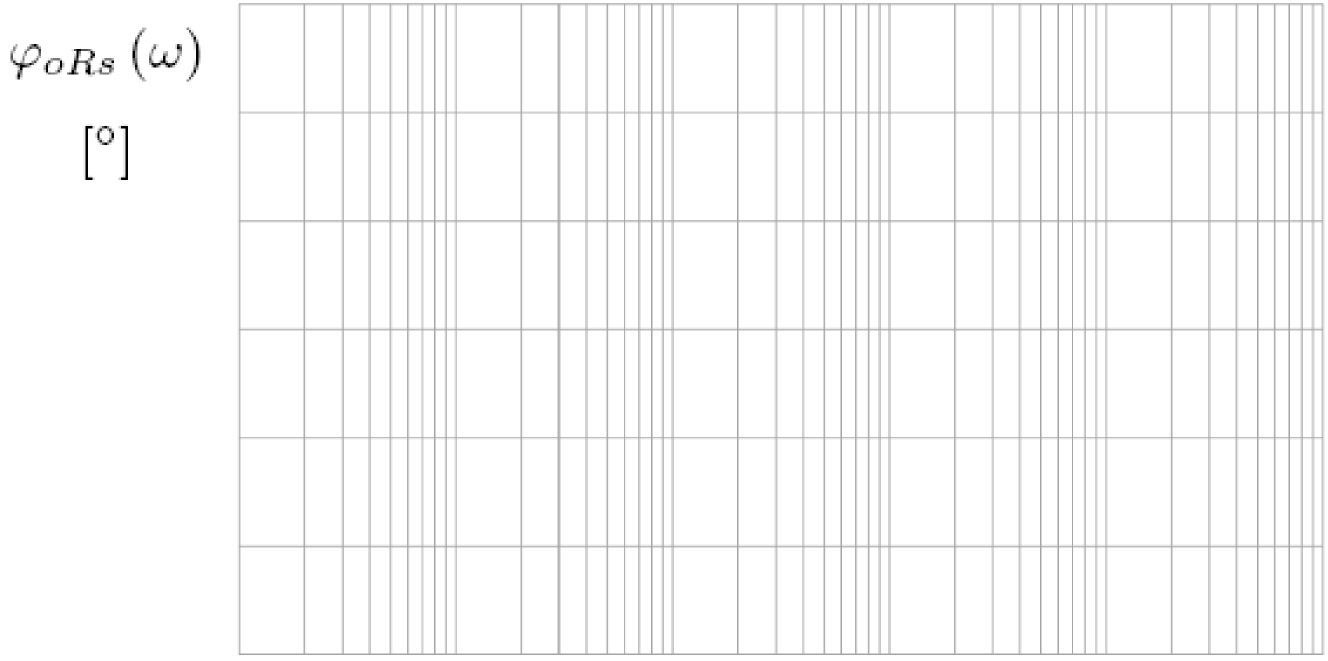


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

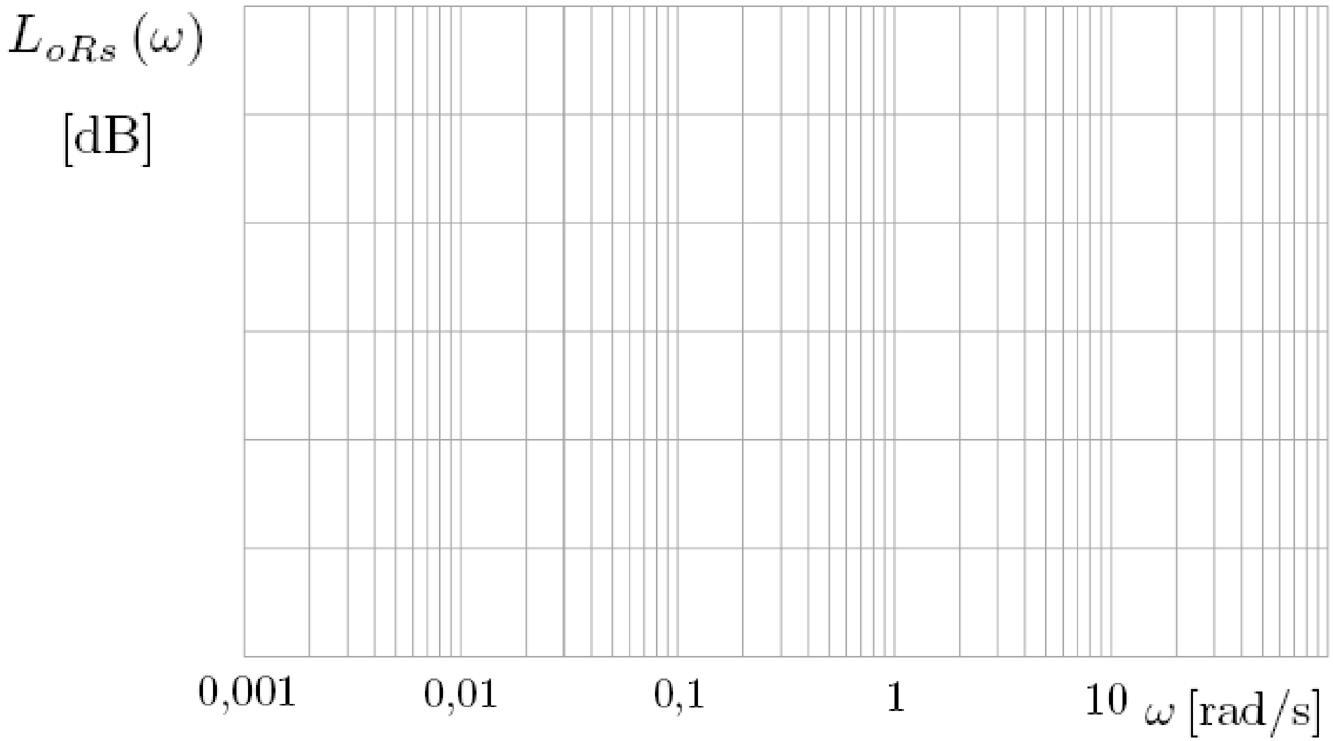


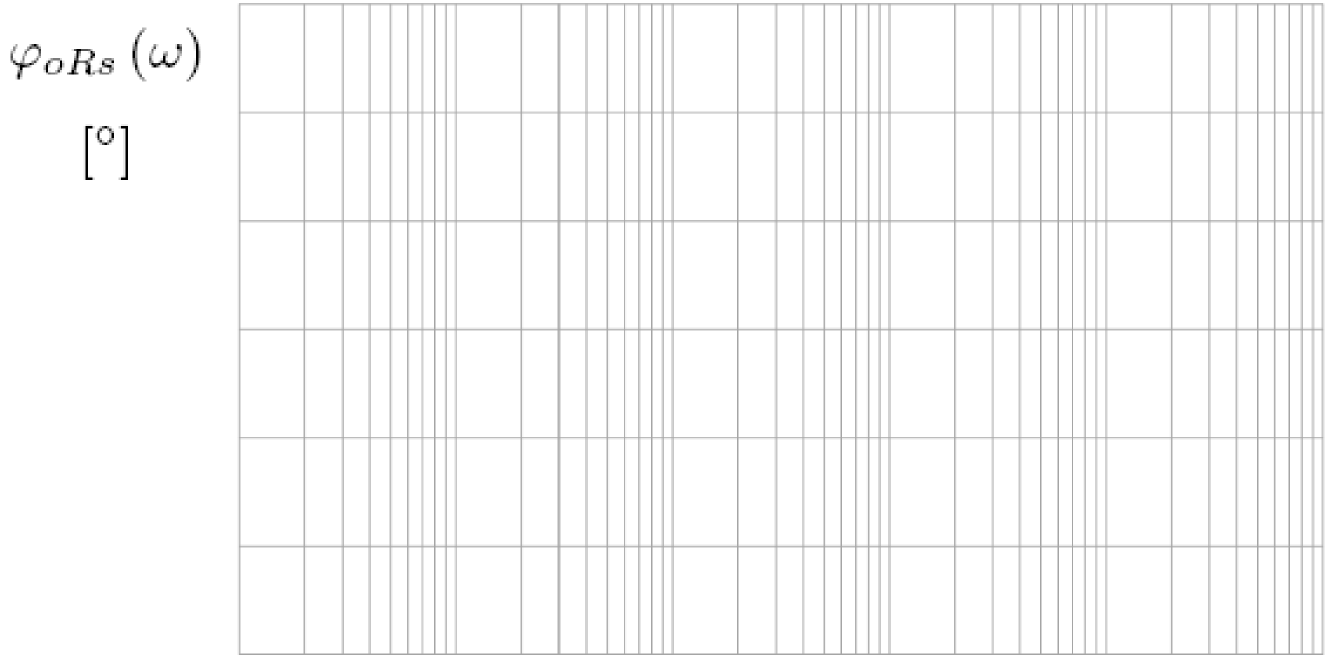


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

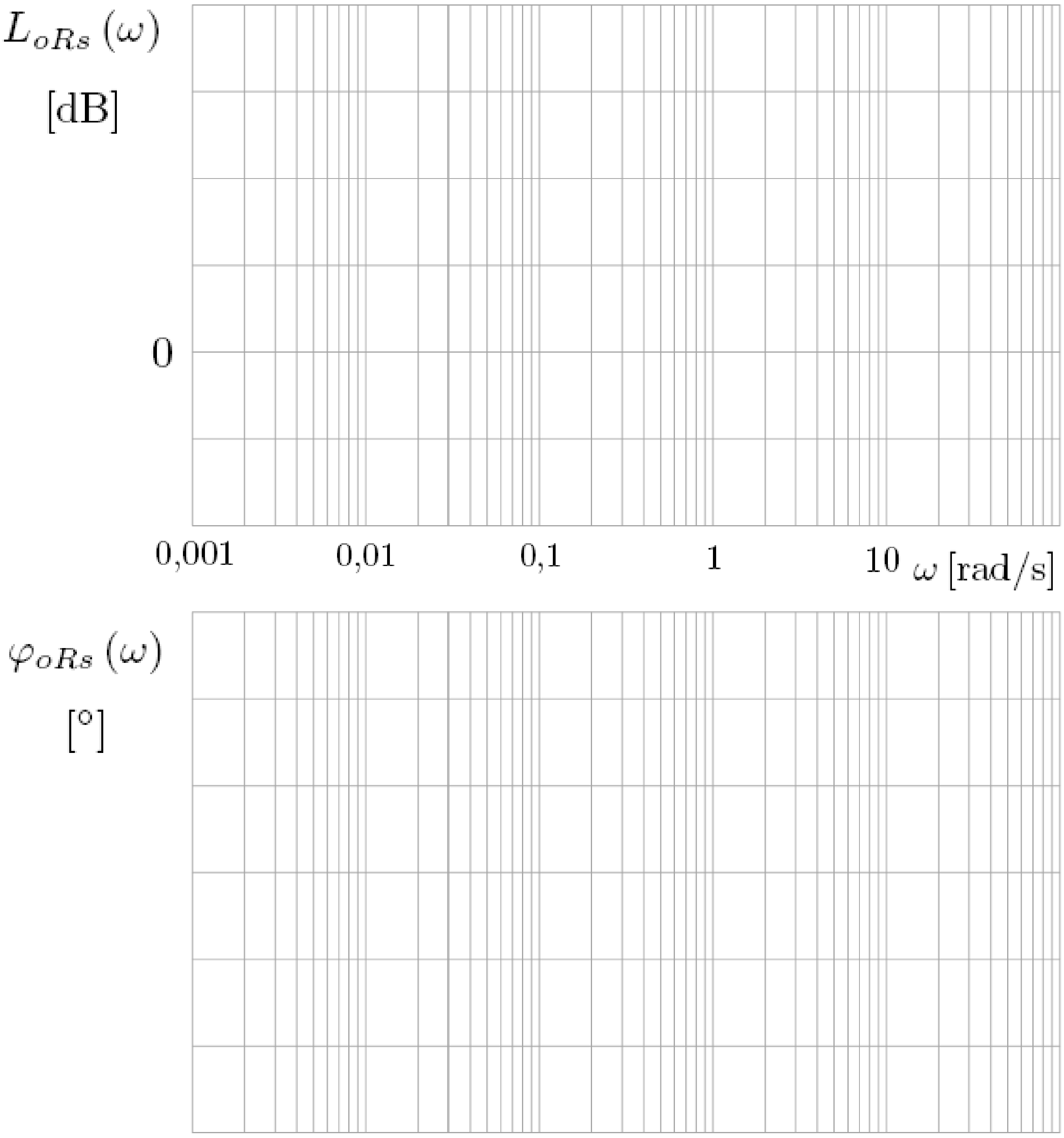




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

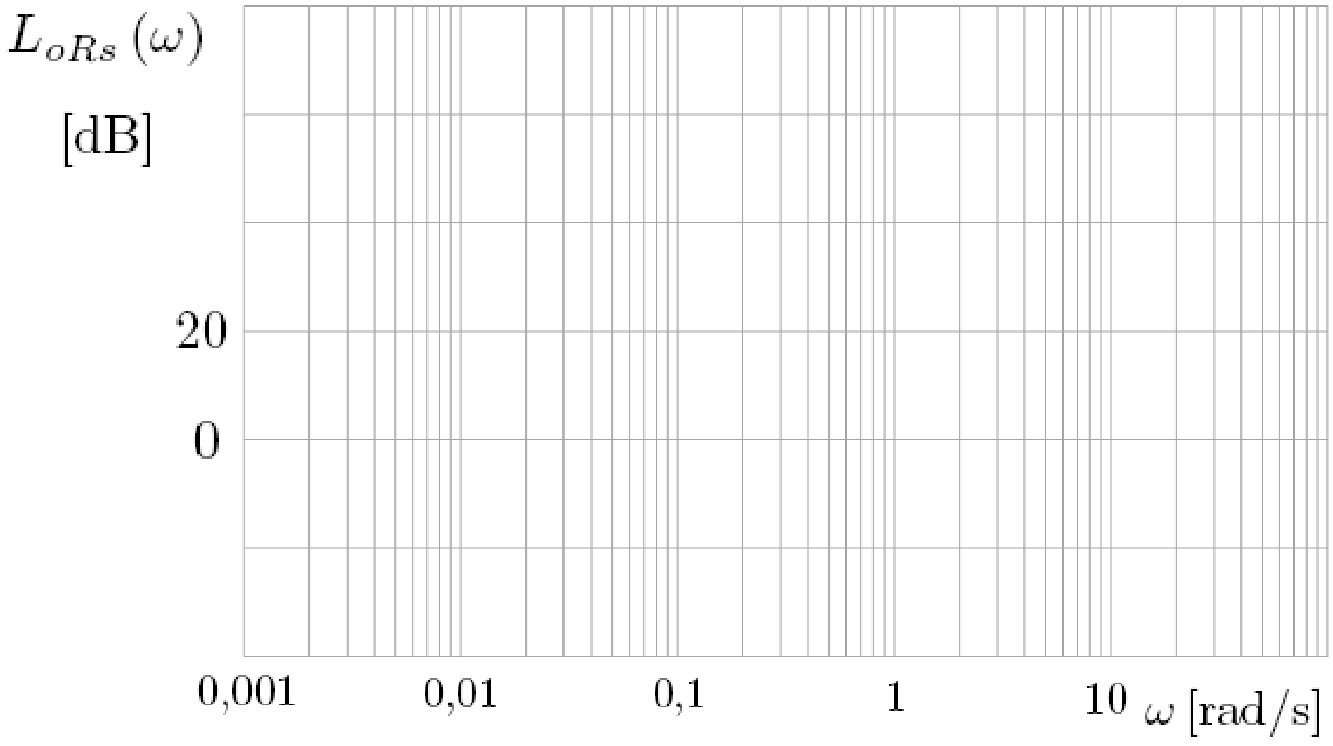
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

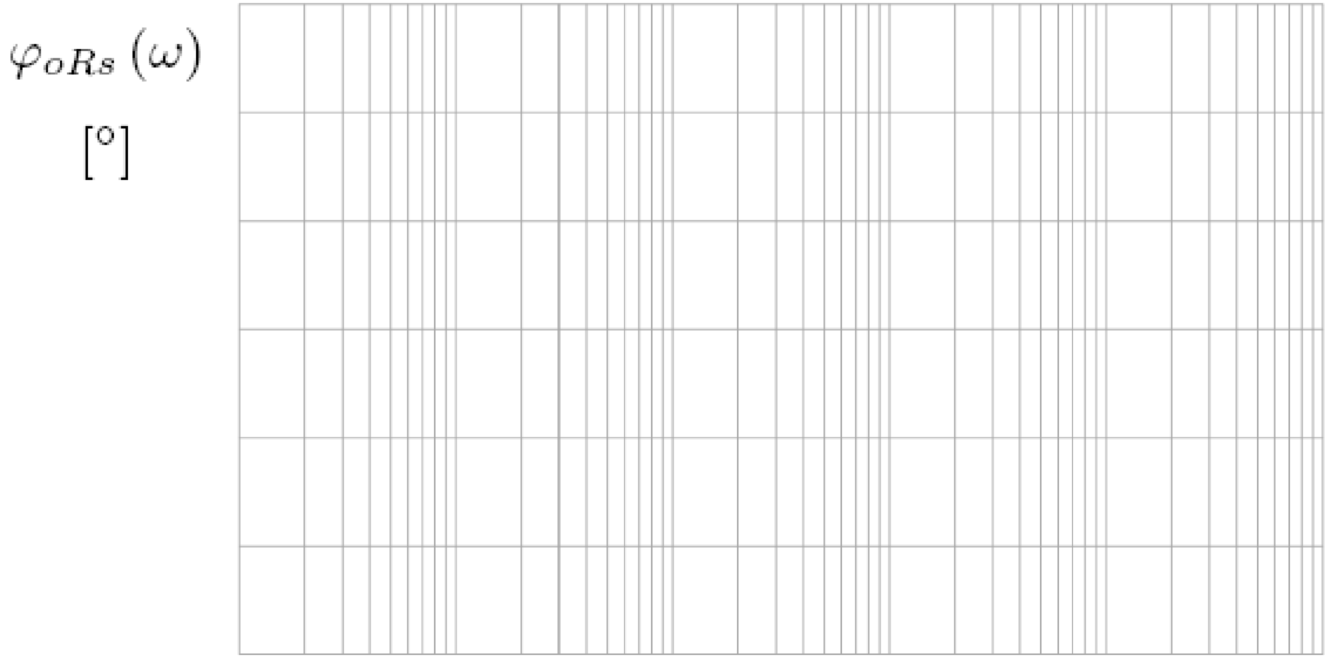


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

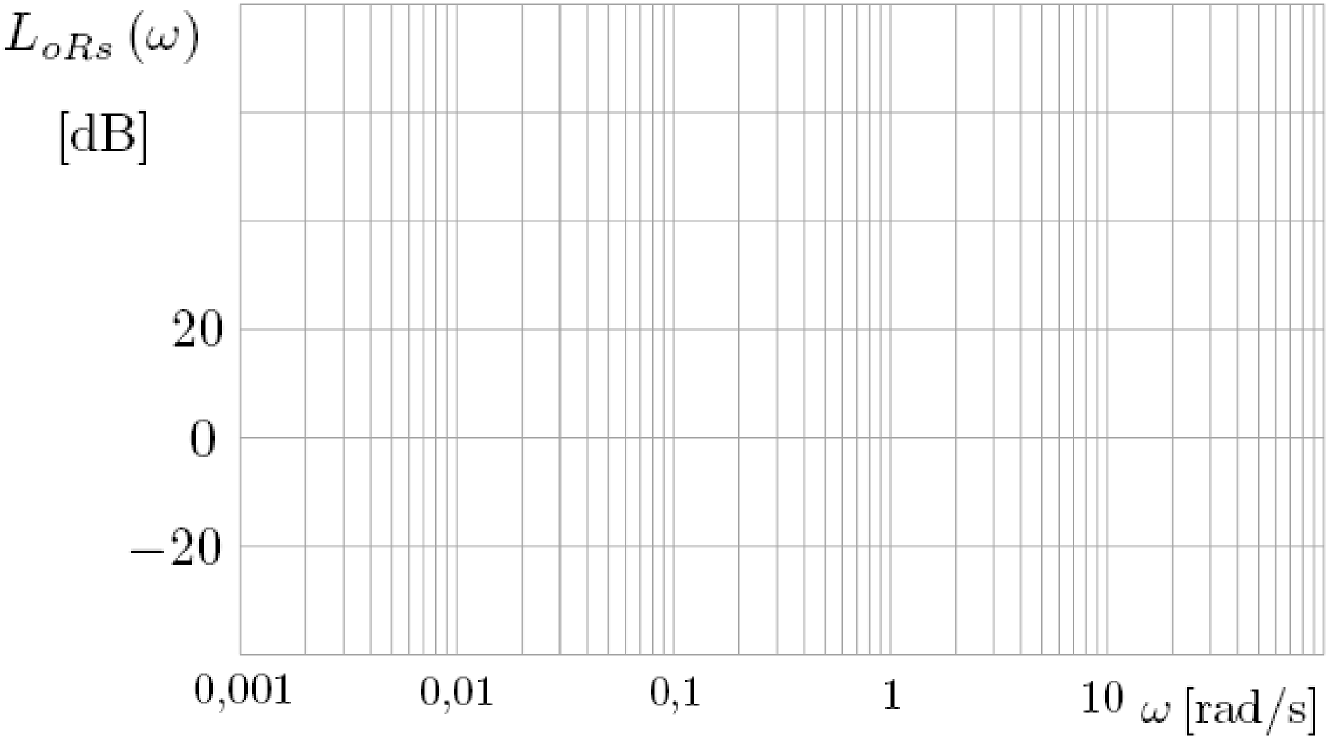


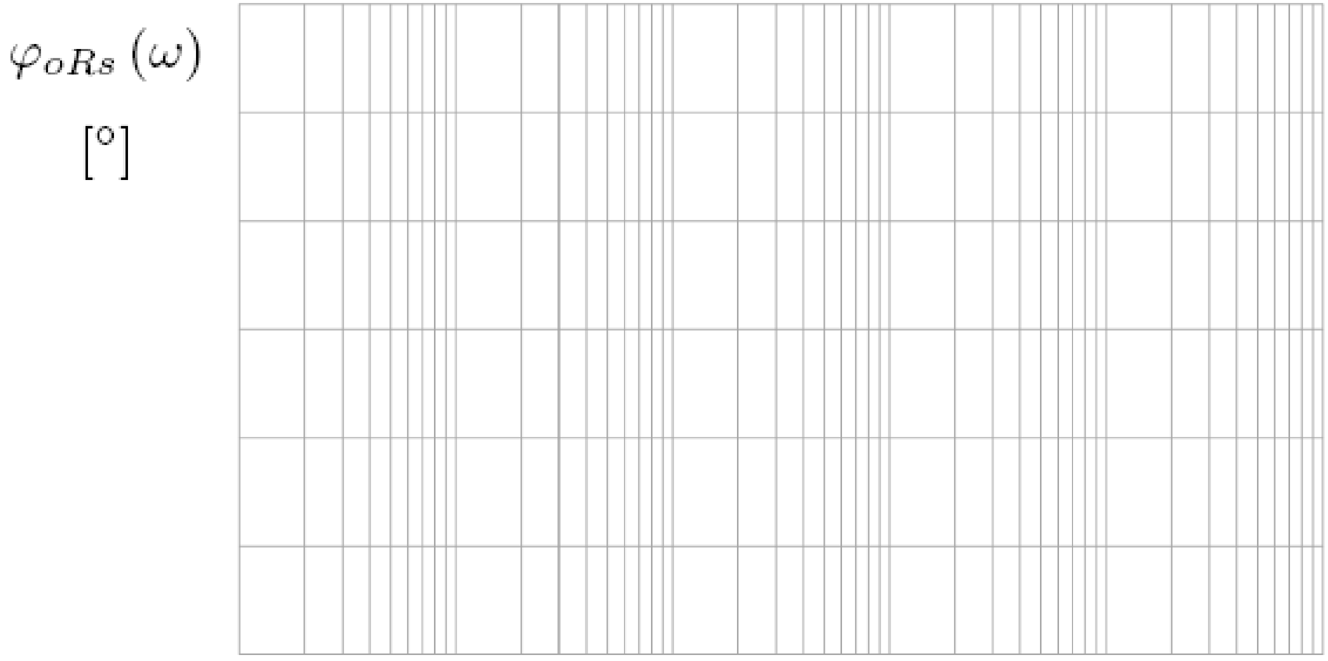


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

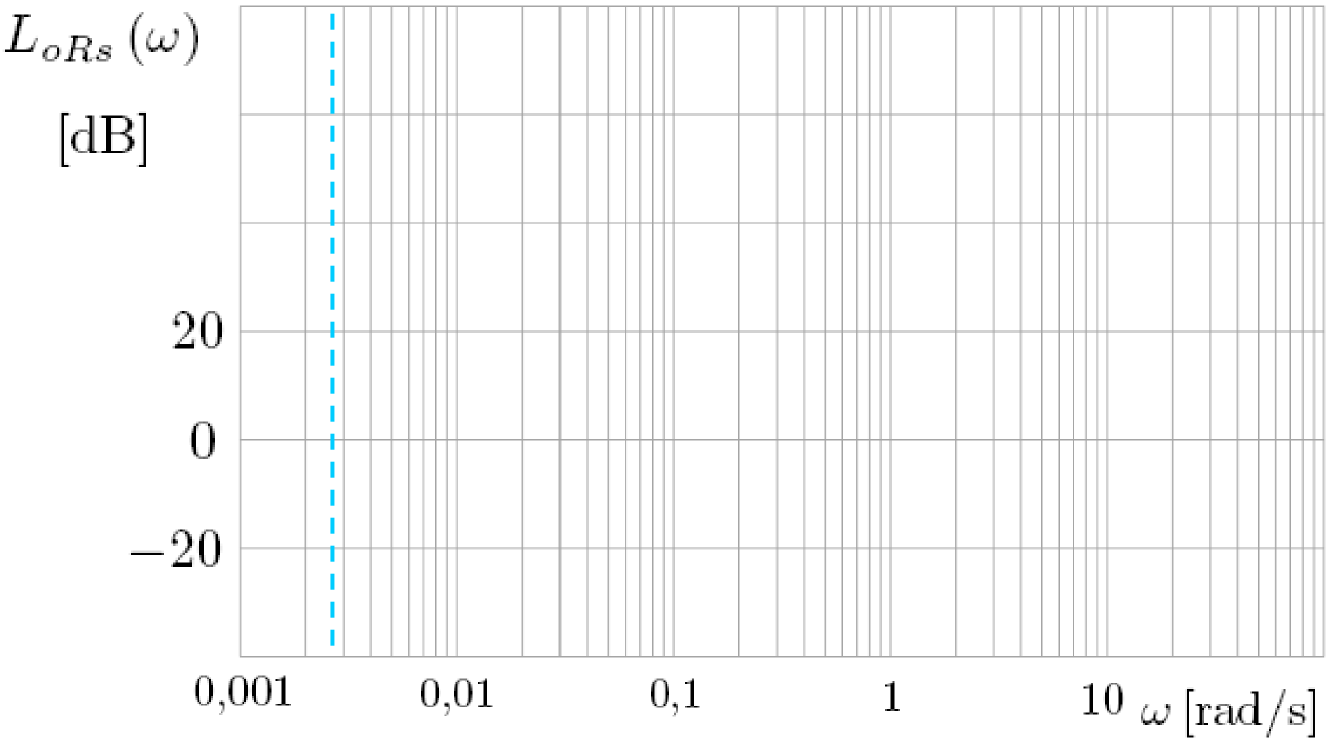


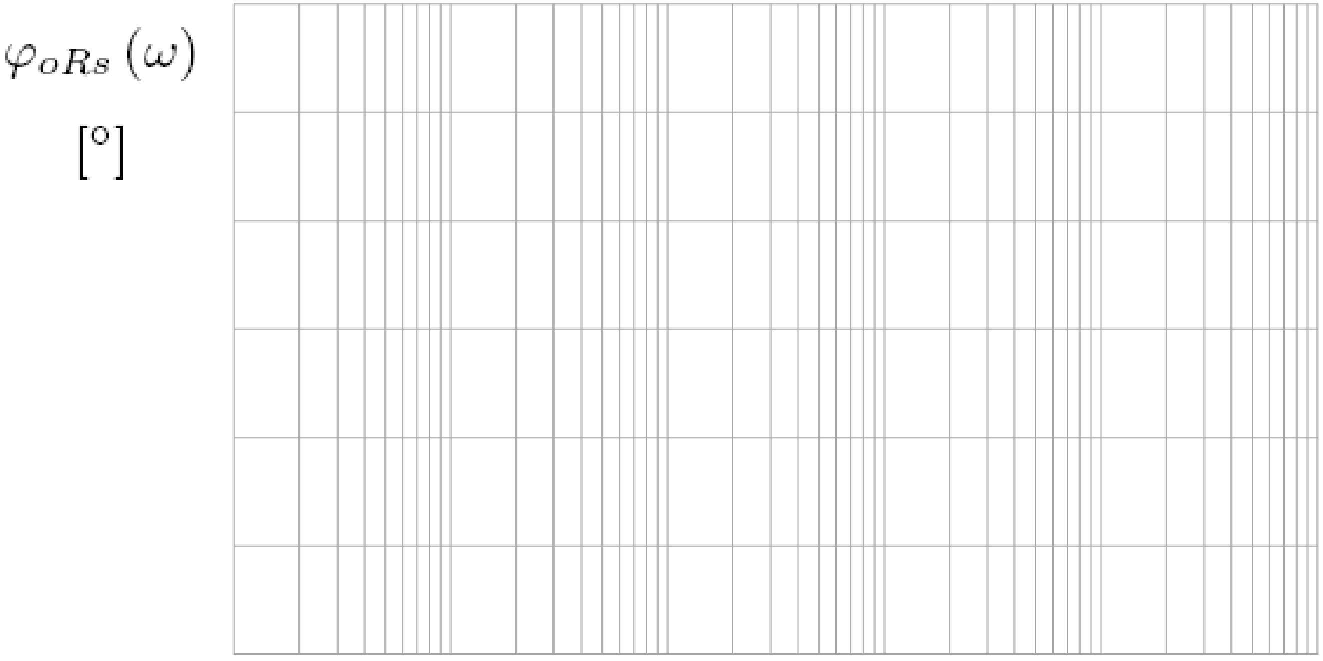


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

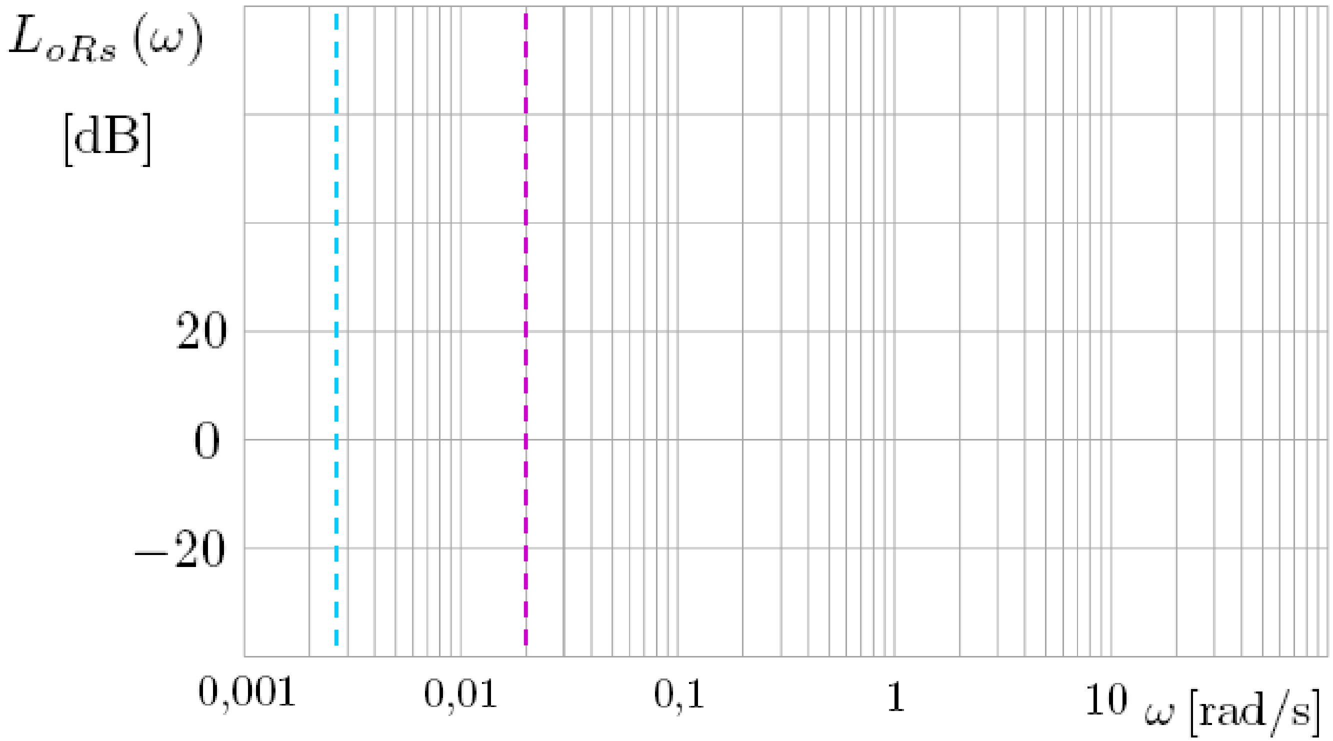


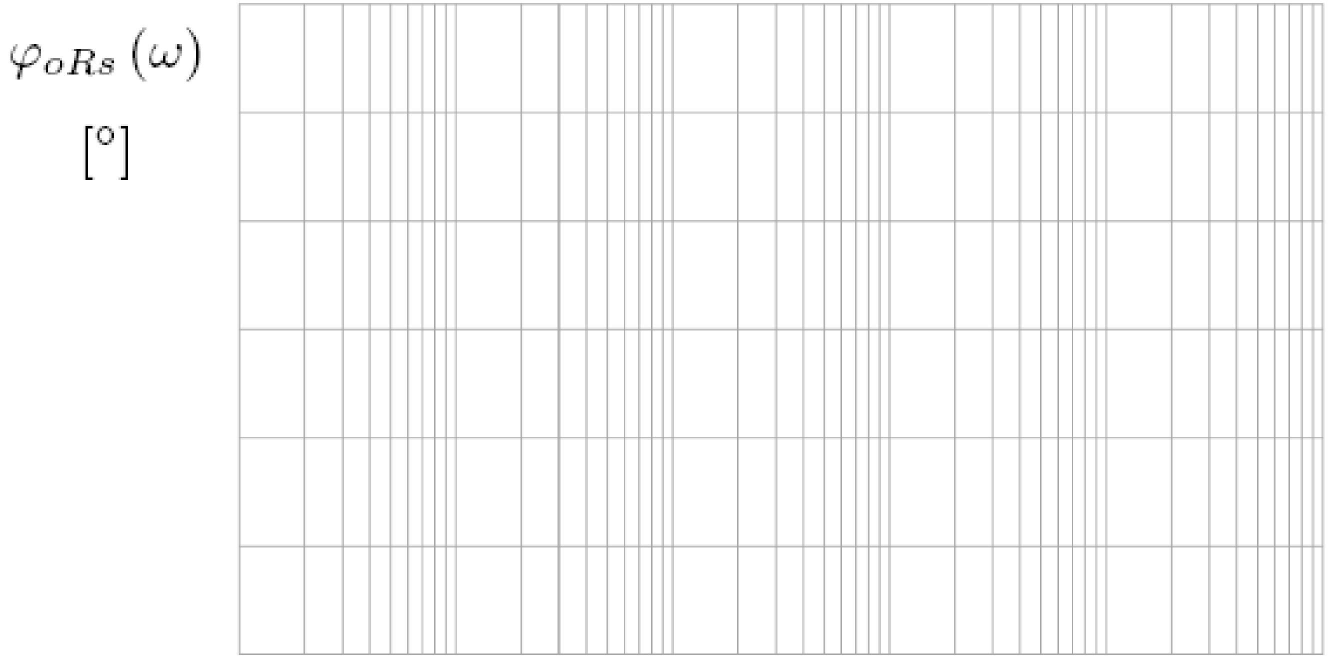


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

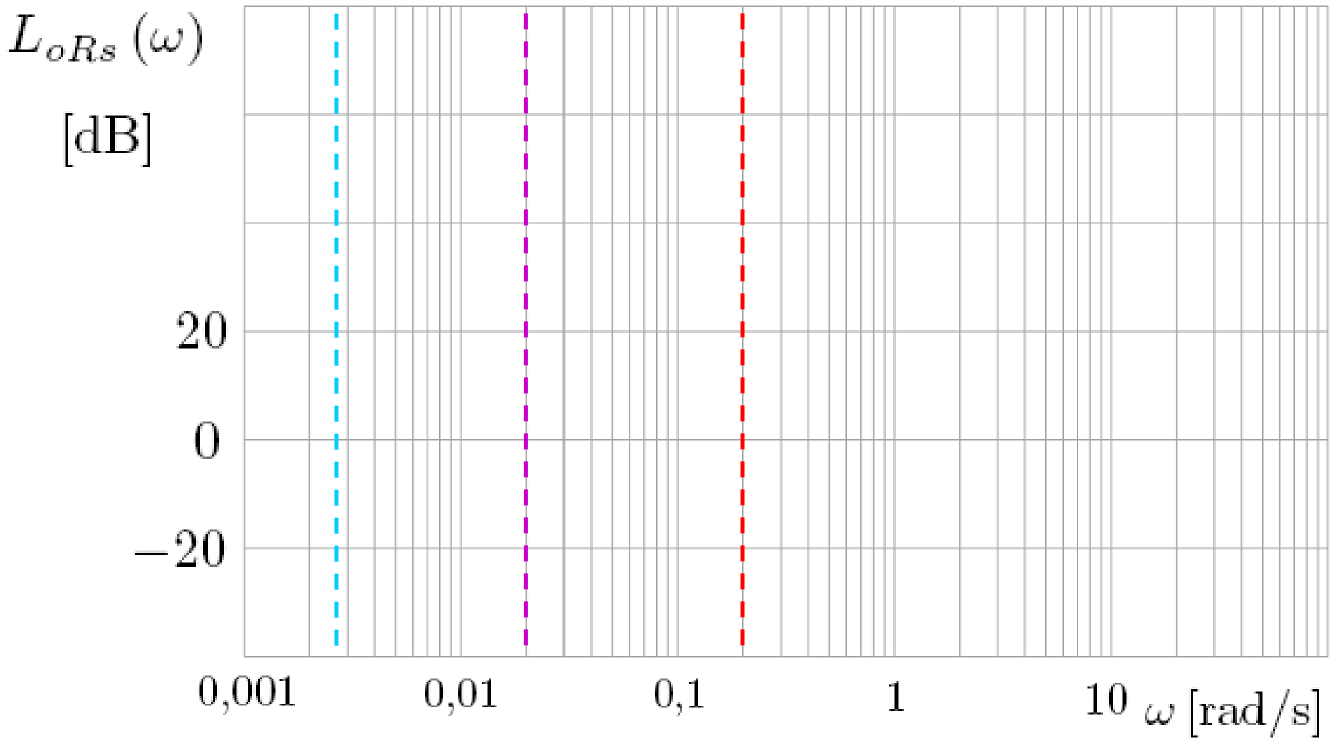


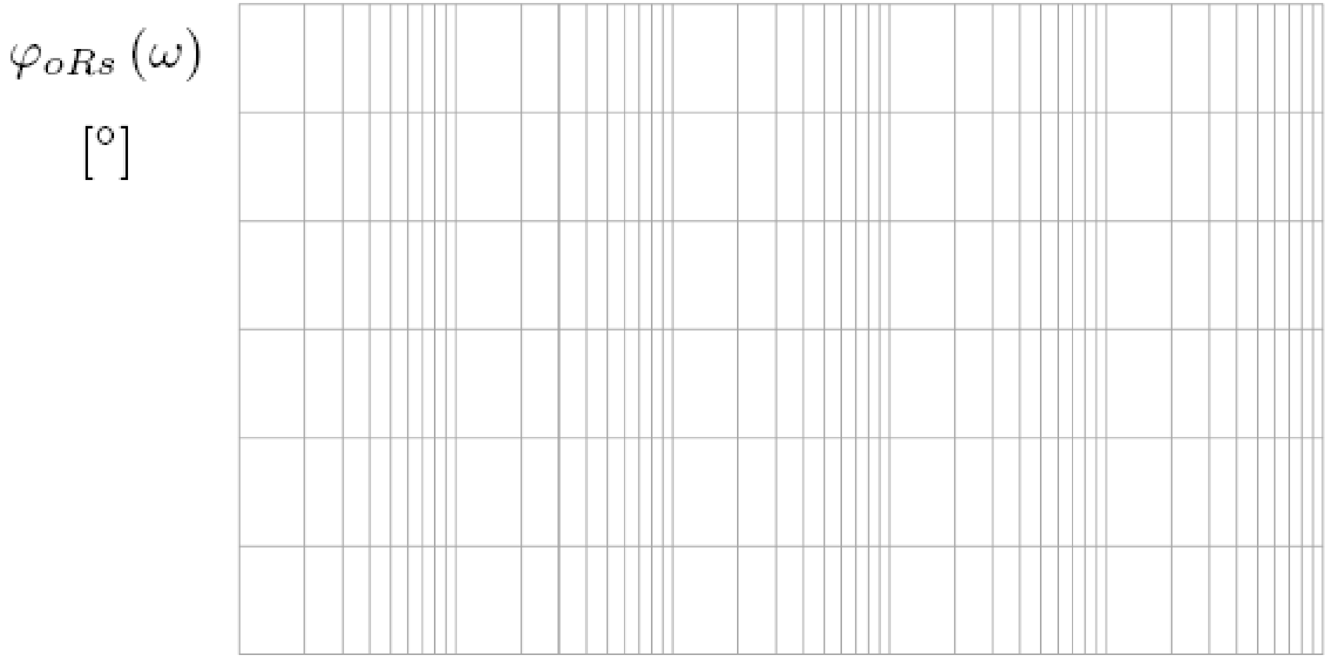


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

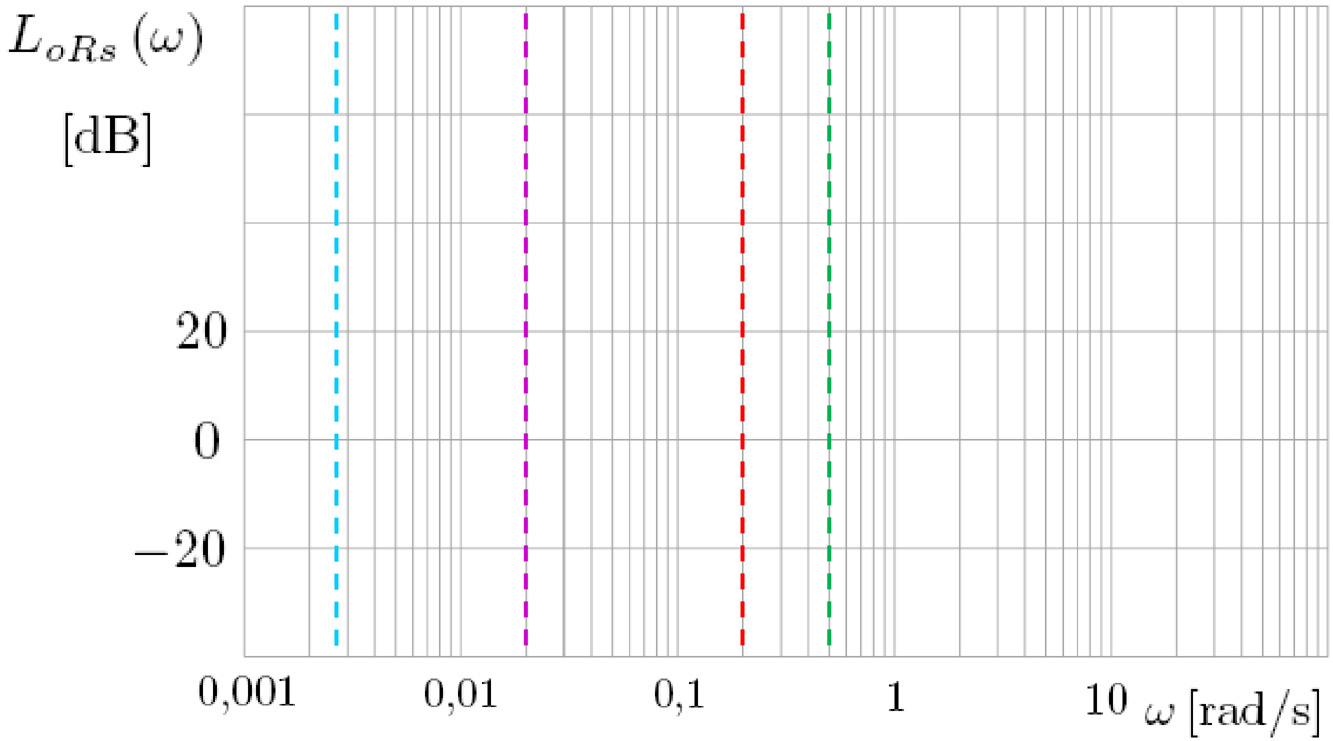


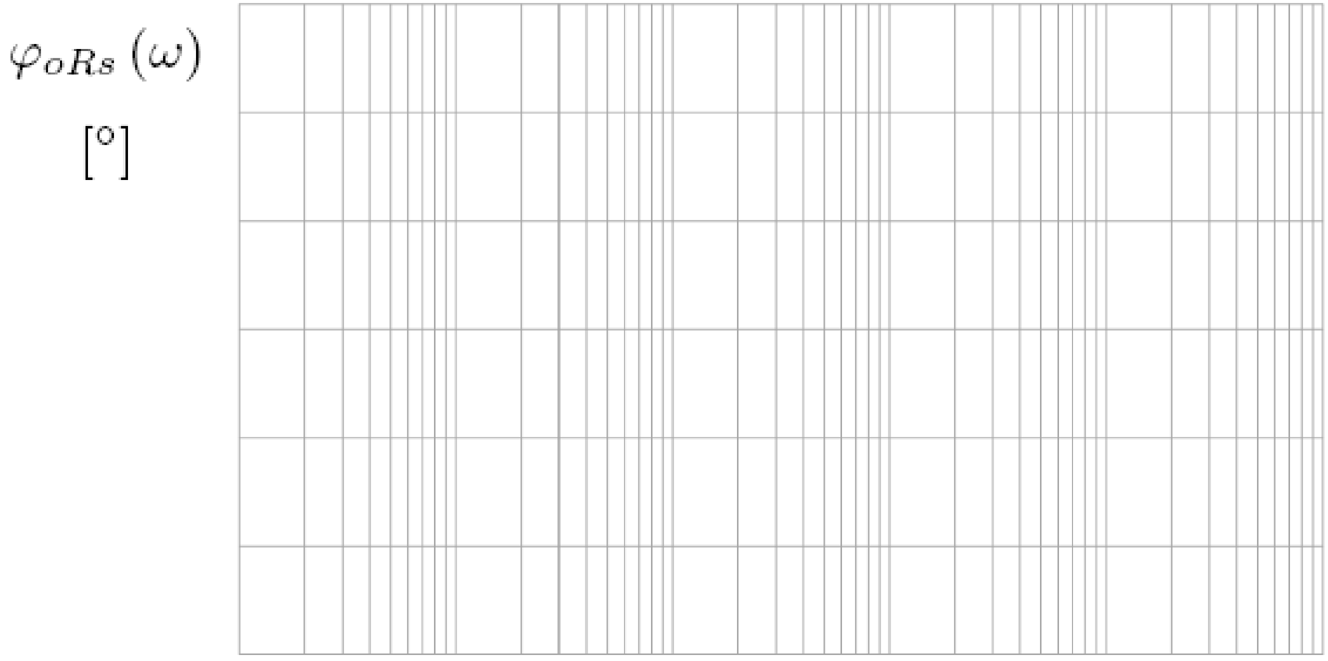


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

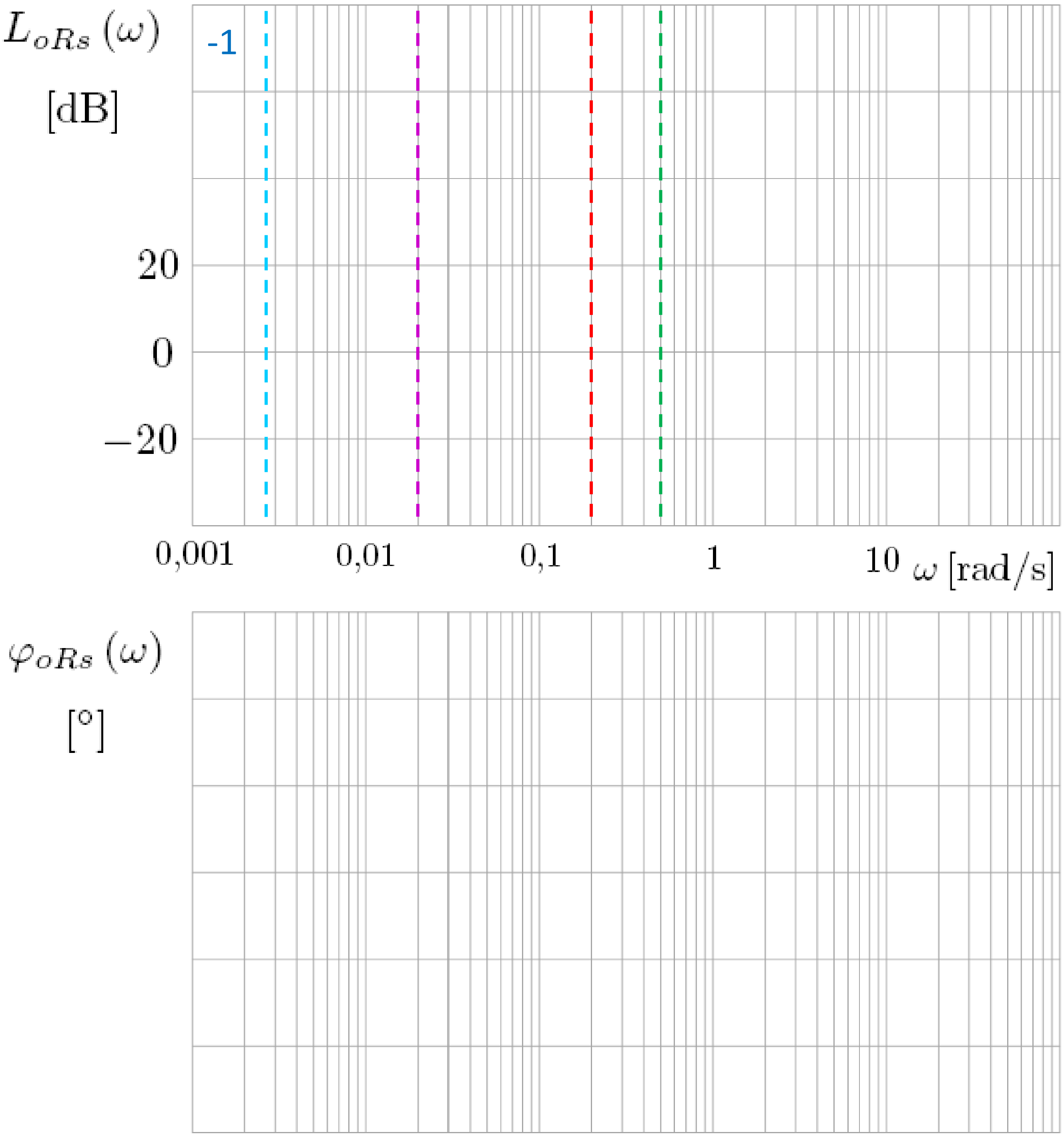




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

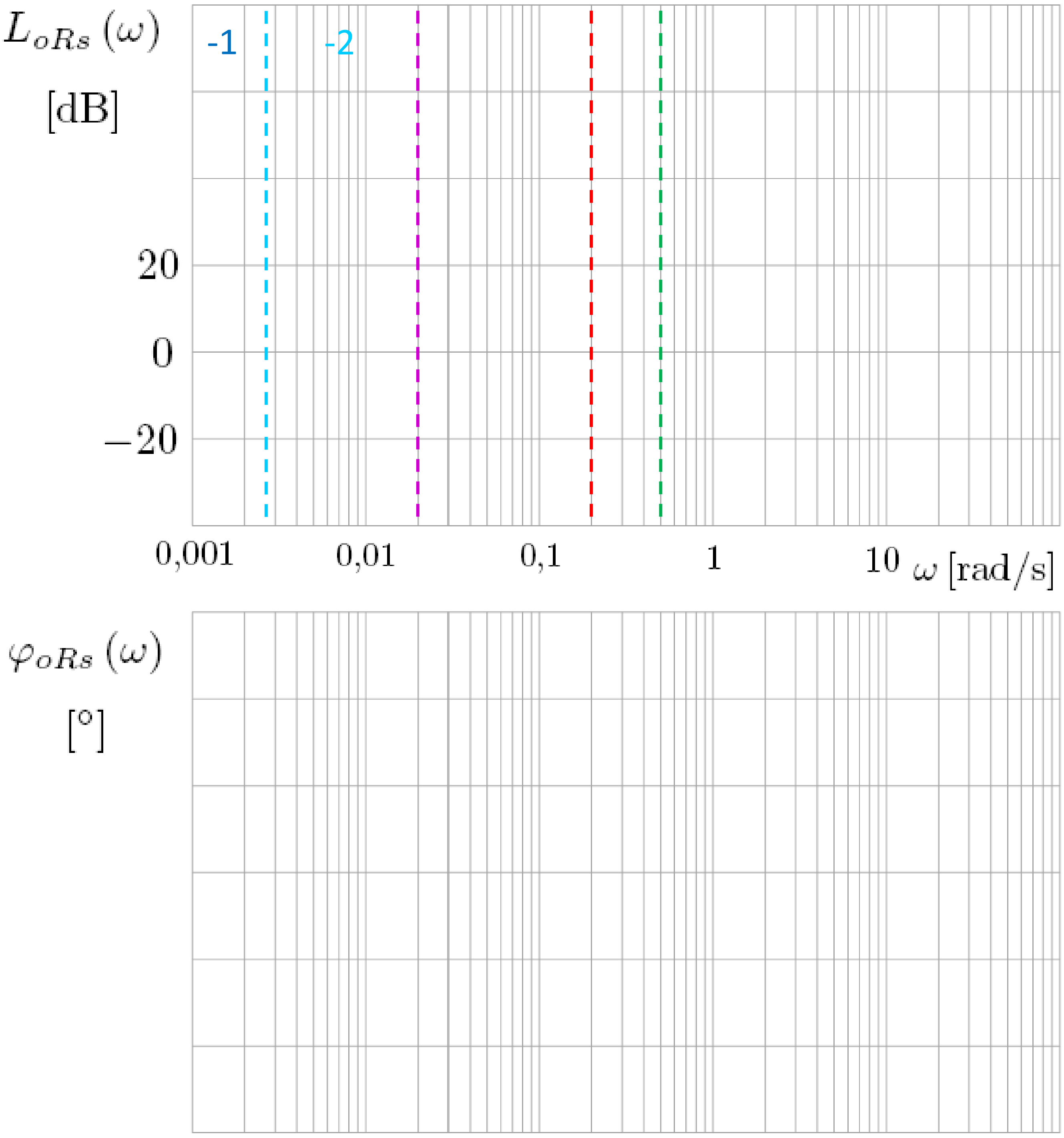
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

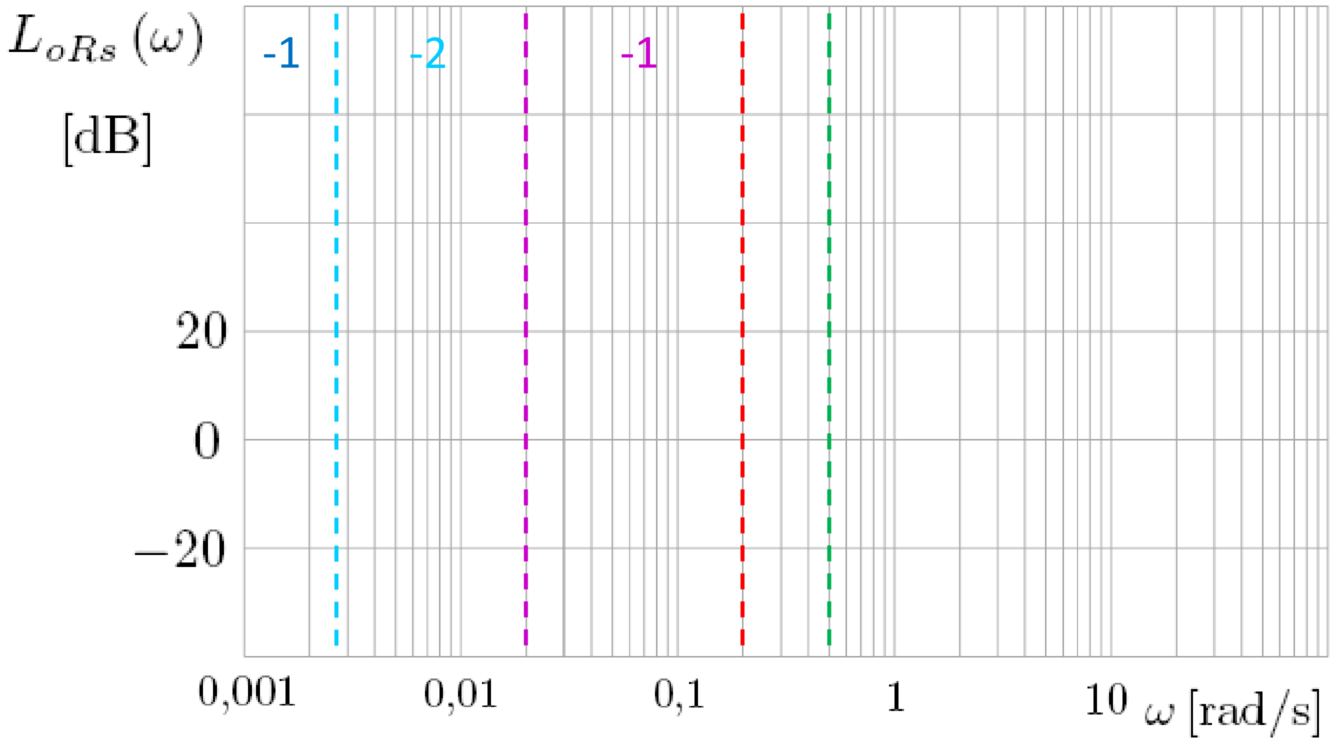
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

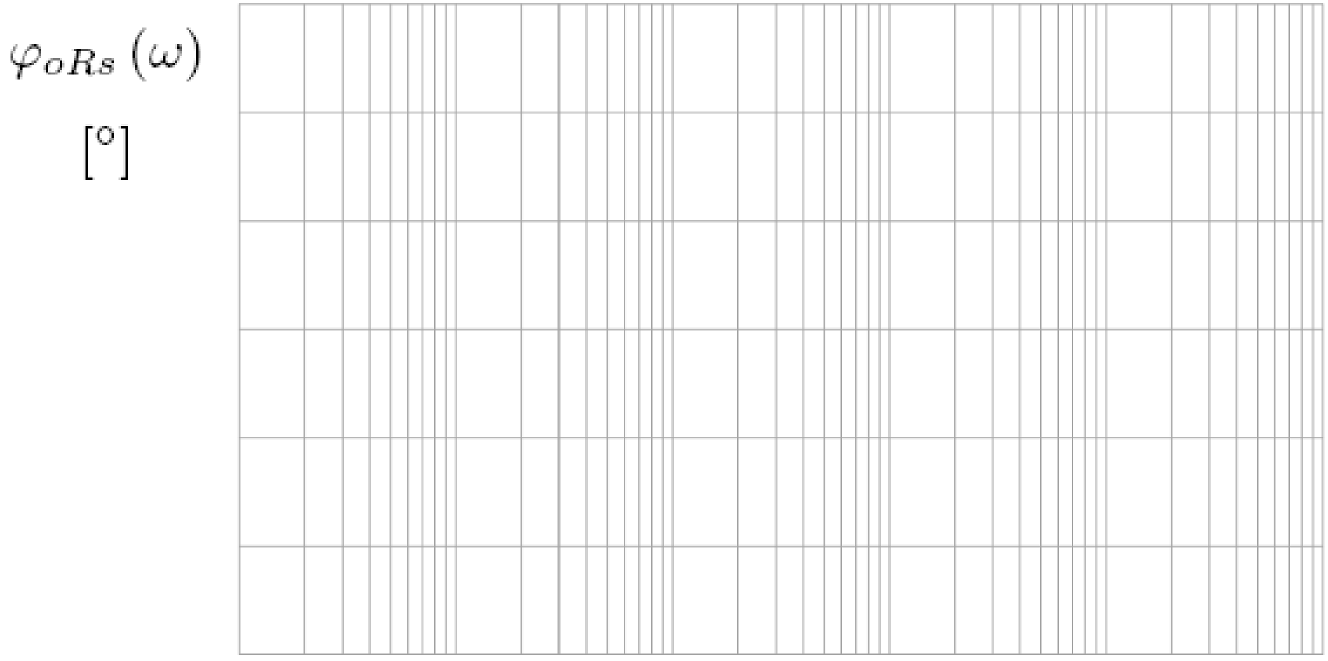


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

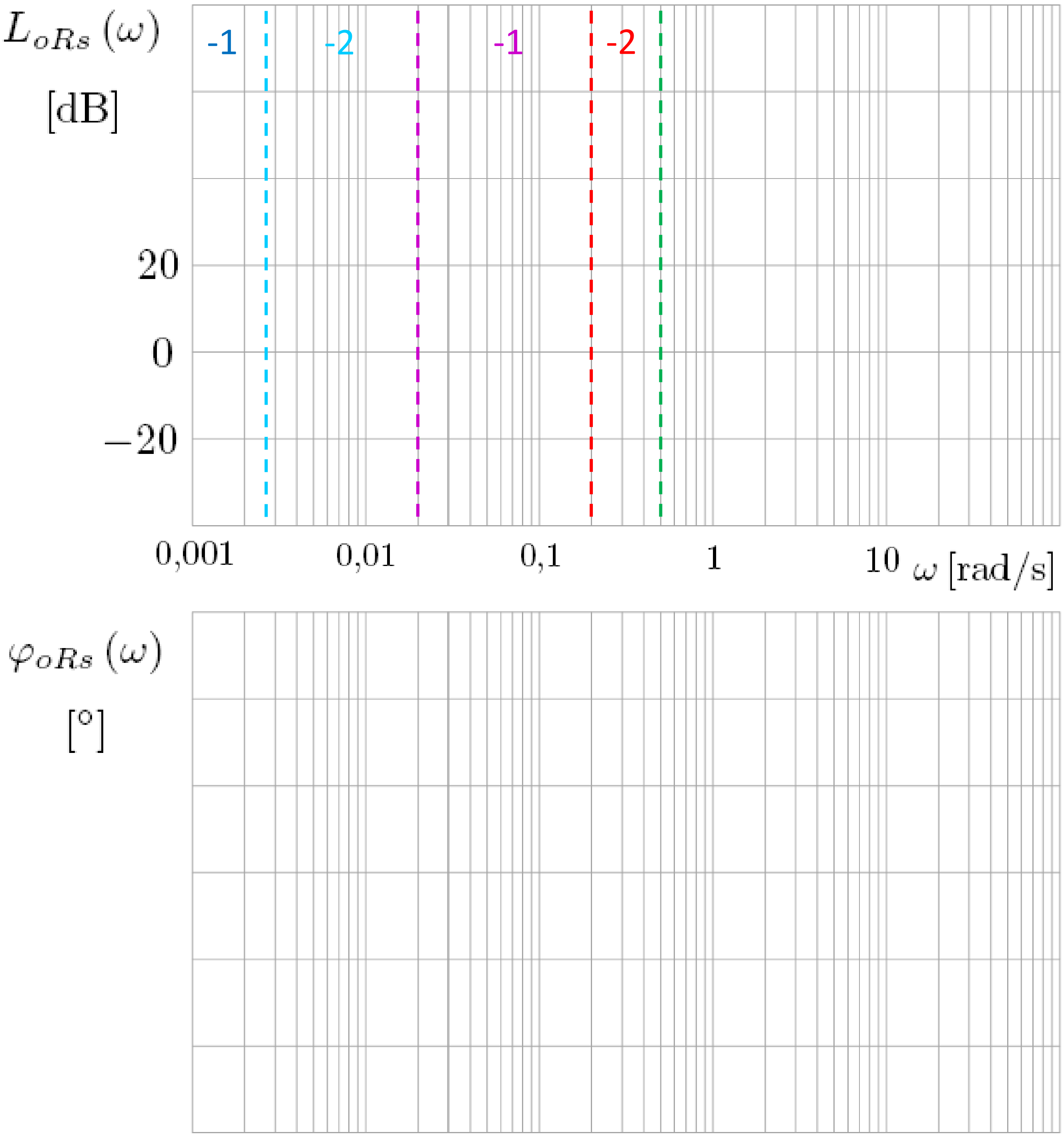




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

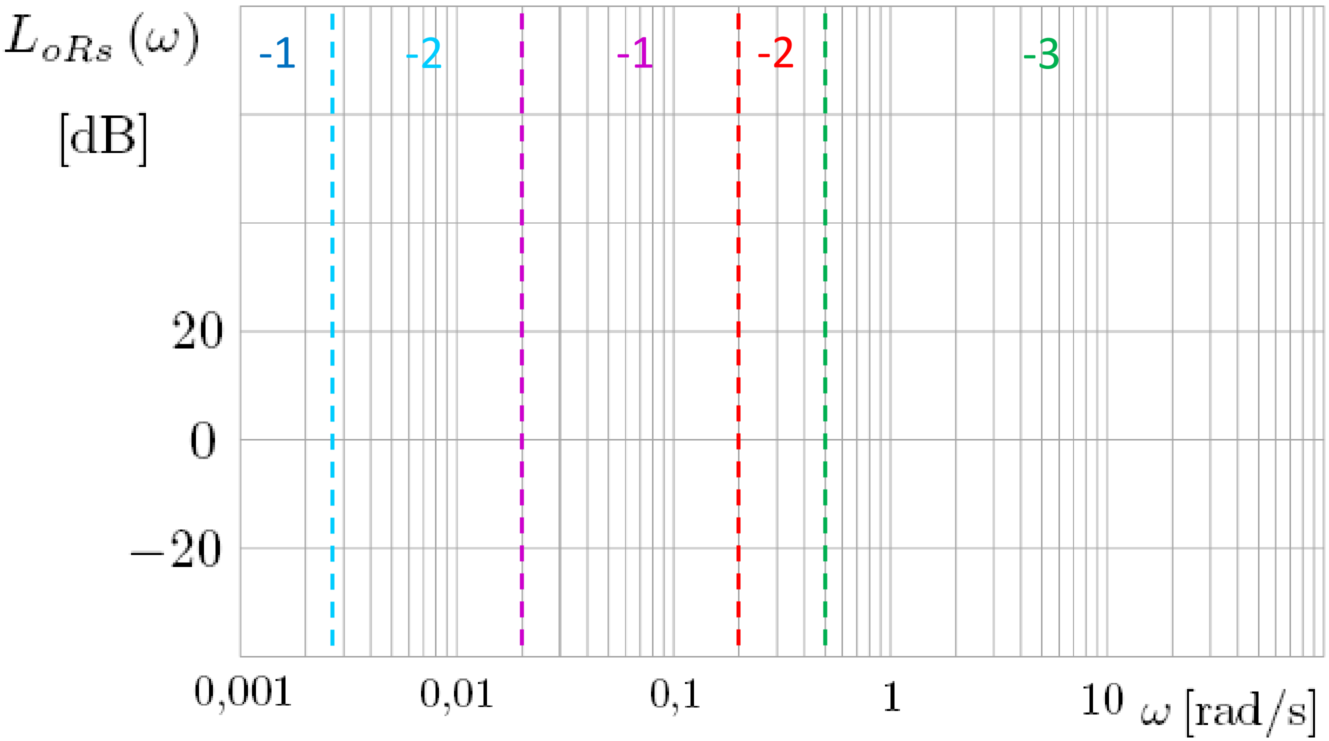
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

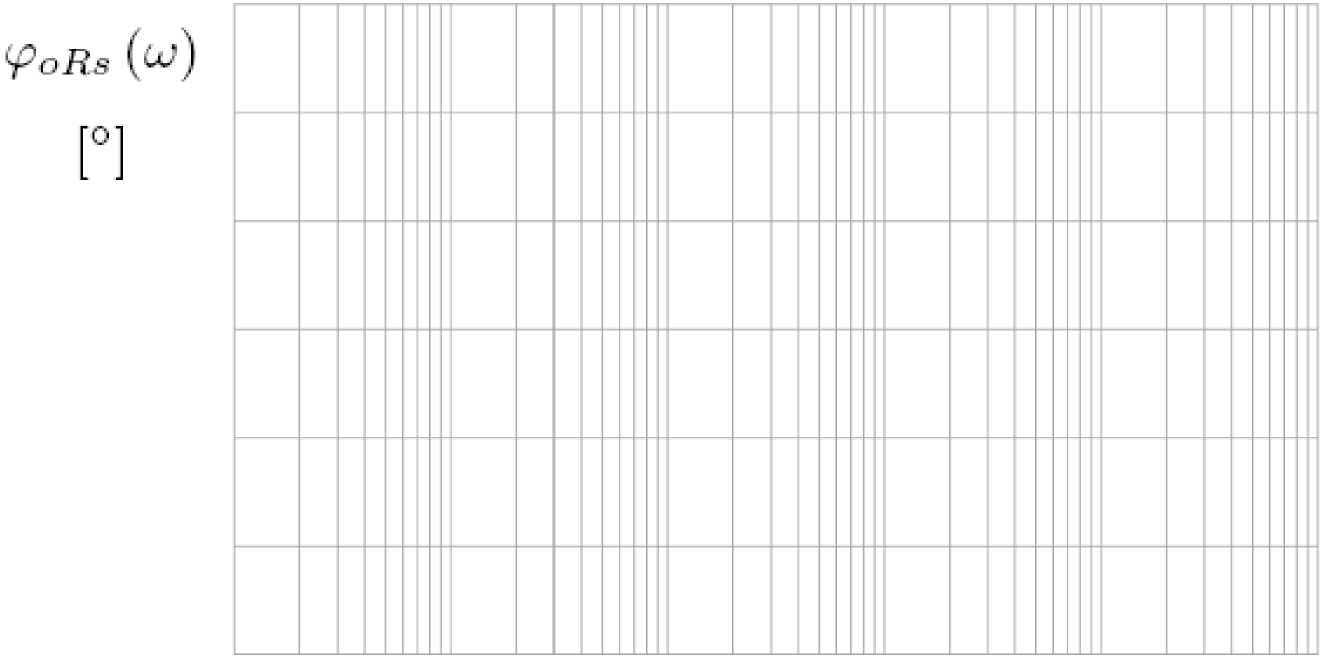


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025\ \mathrm{rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02\ \mathrm{rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$



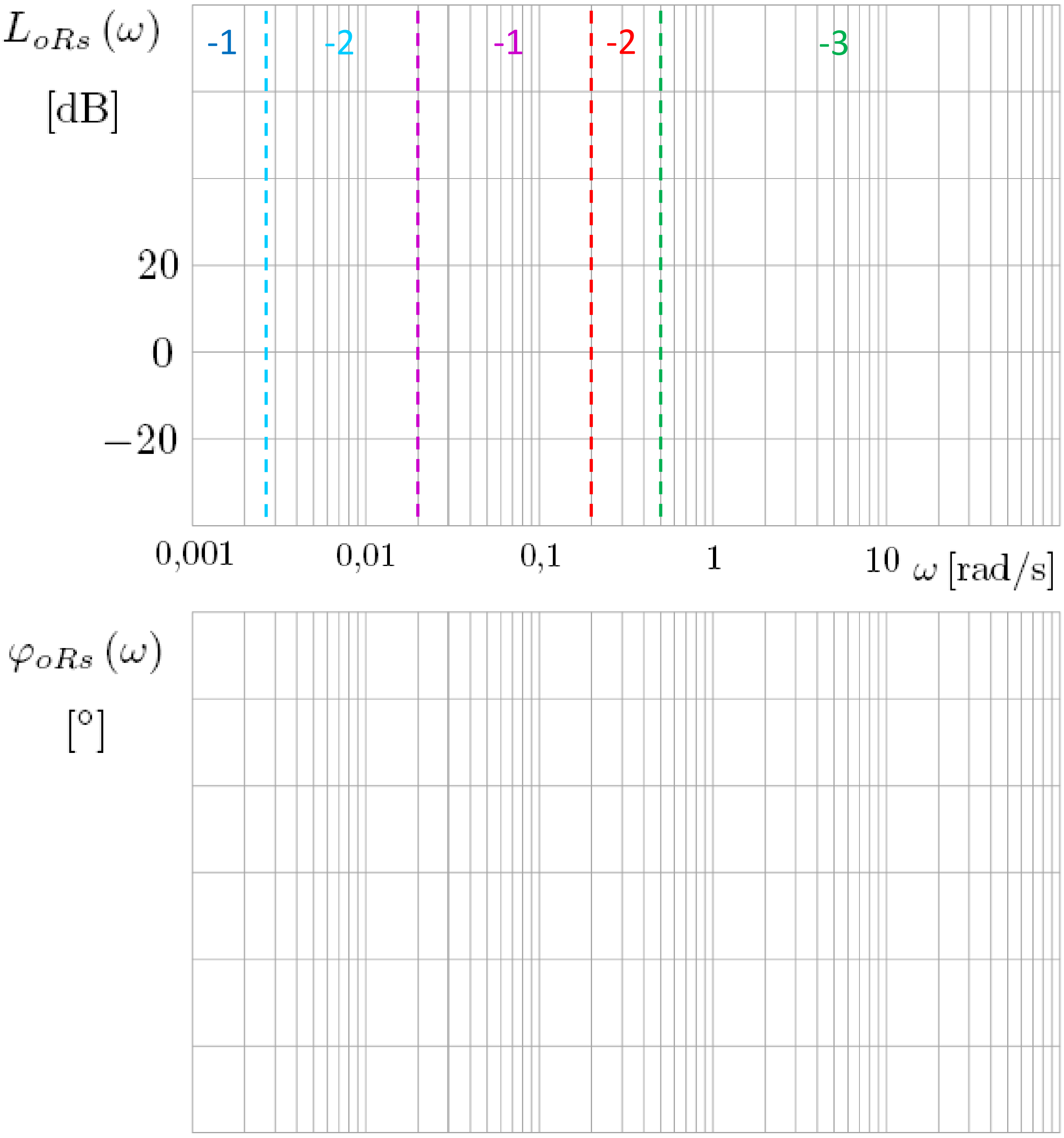


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s}$$

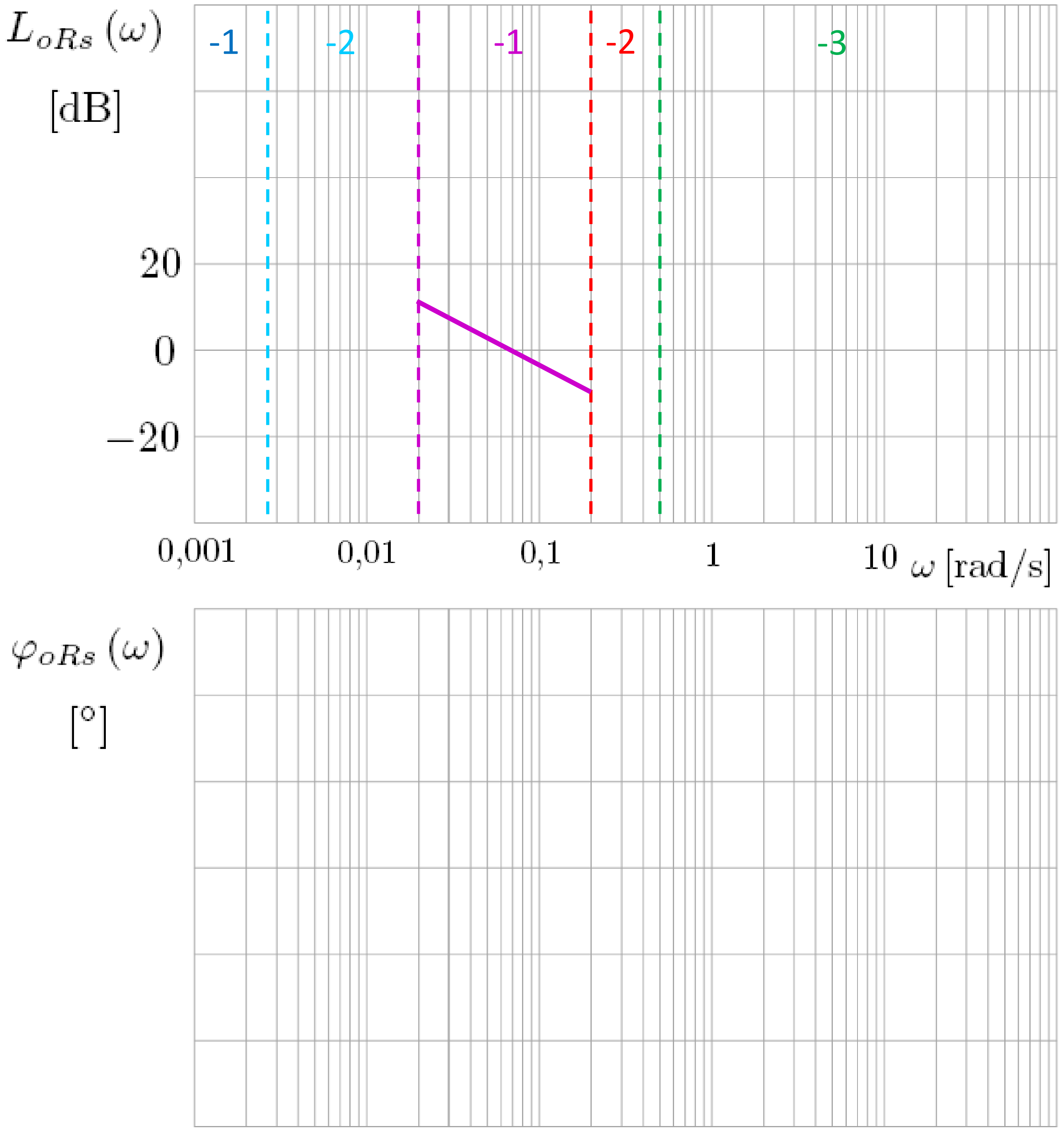


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s}$$

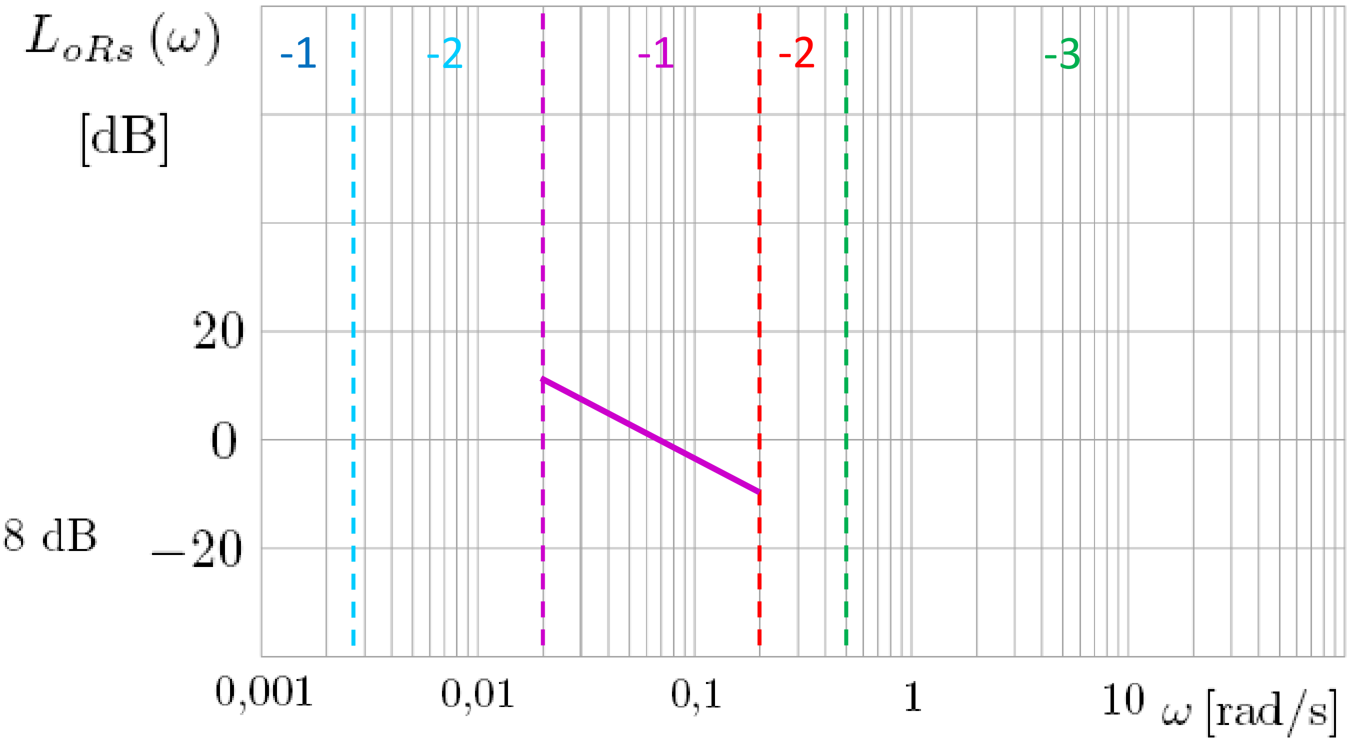


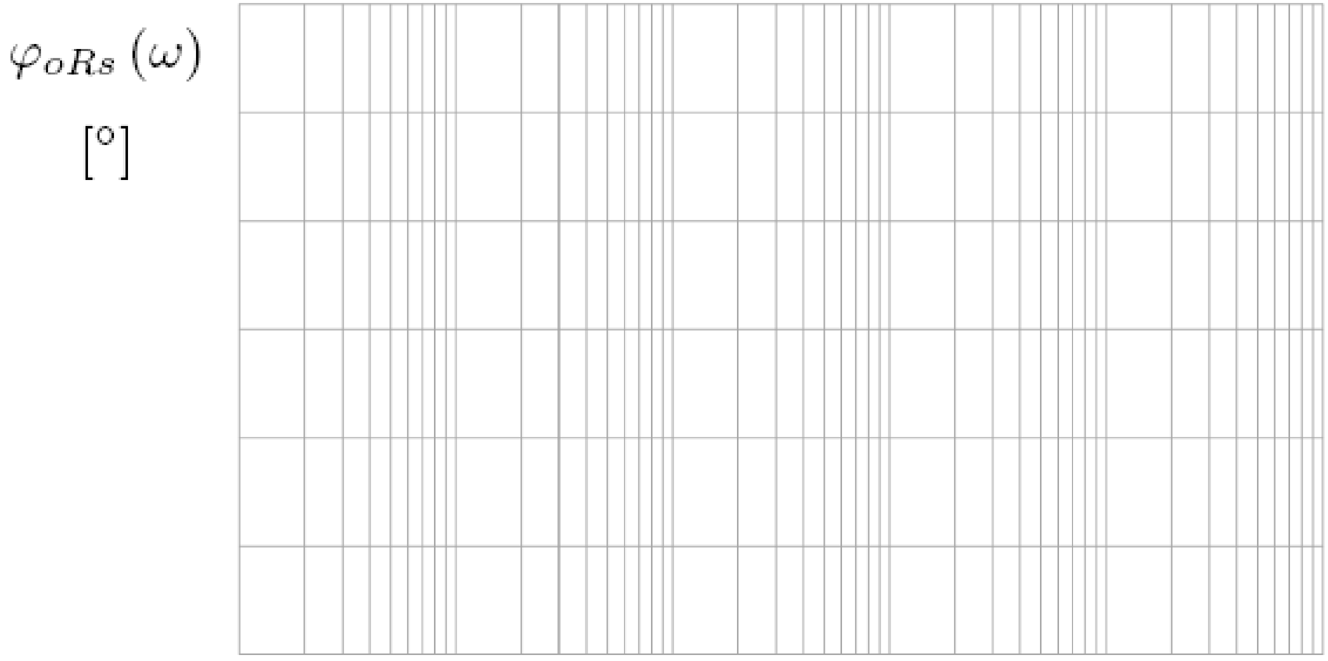
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$



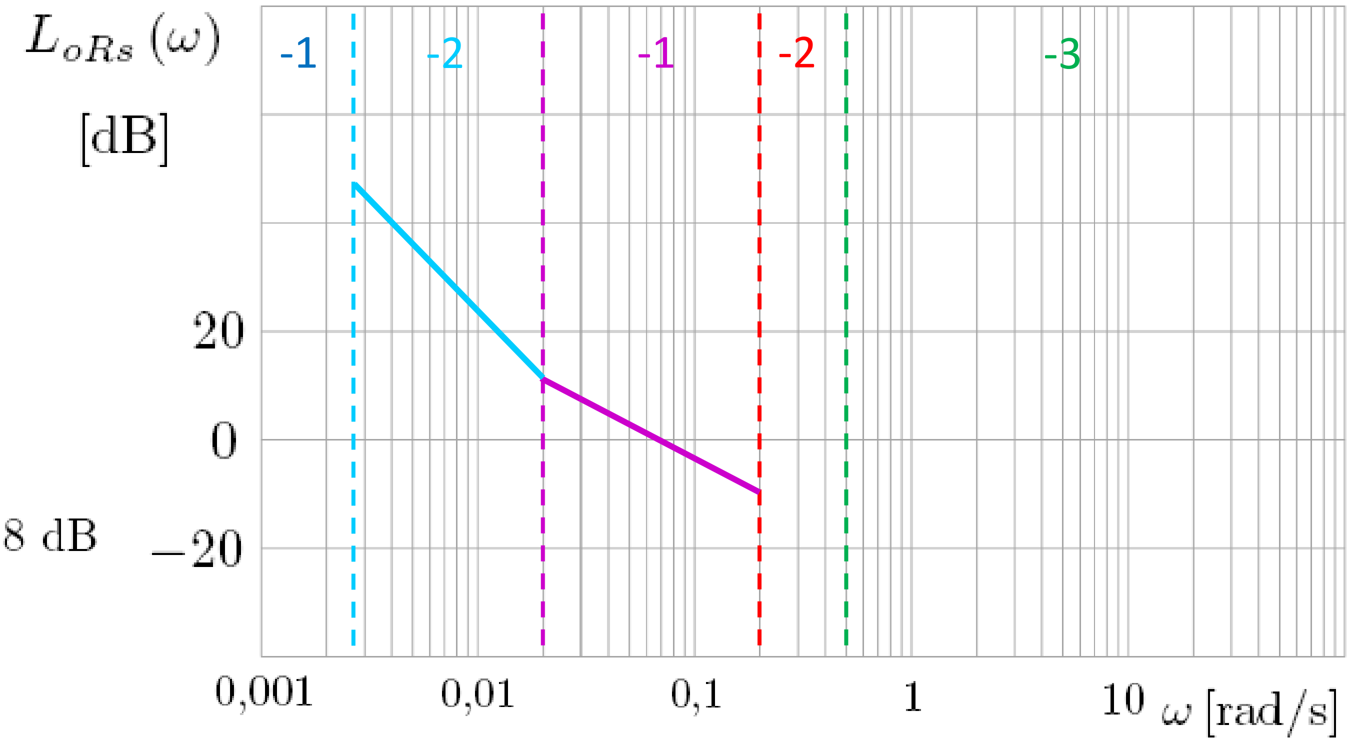


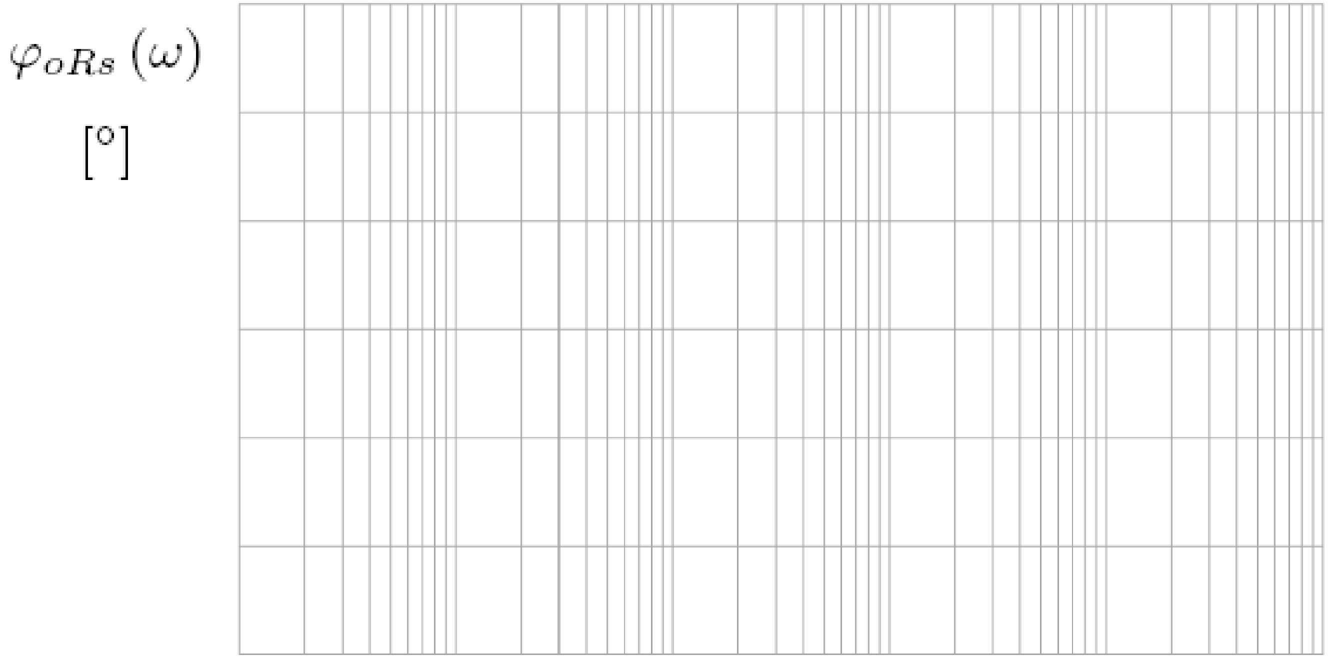
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$





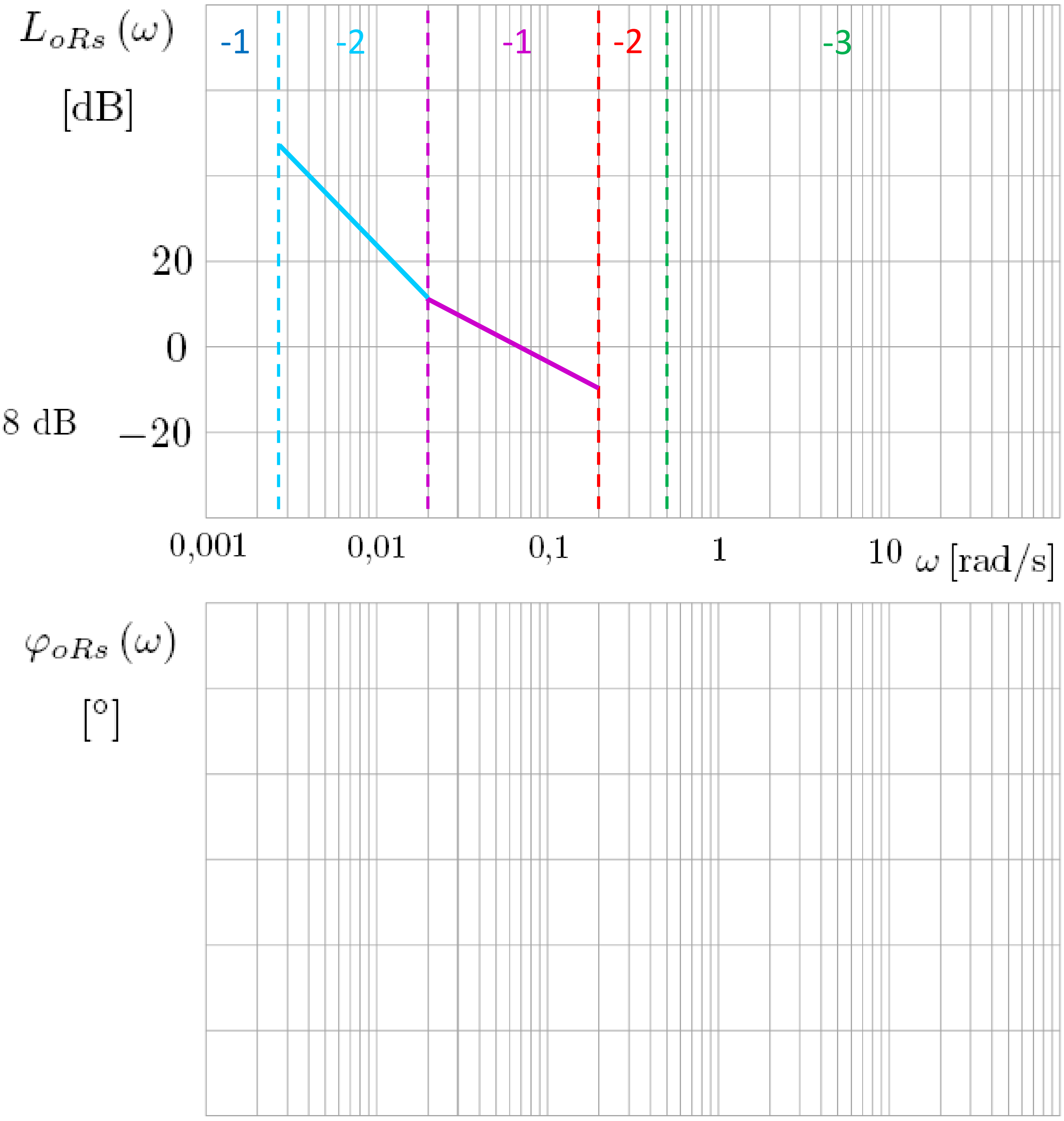
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$



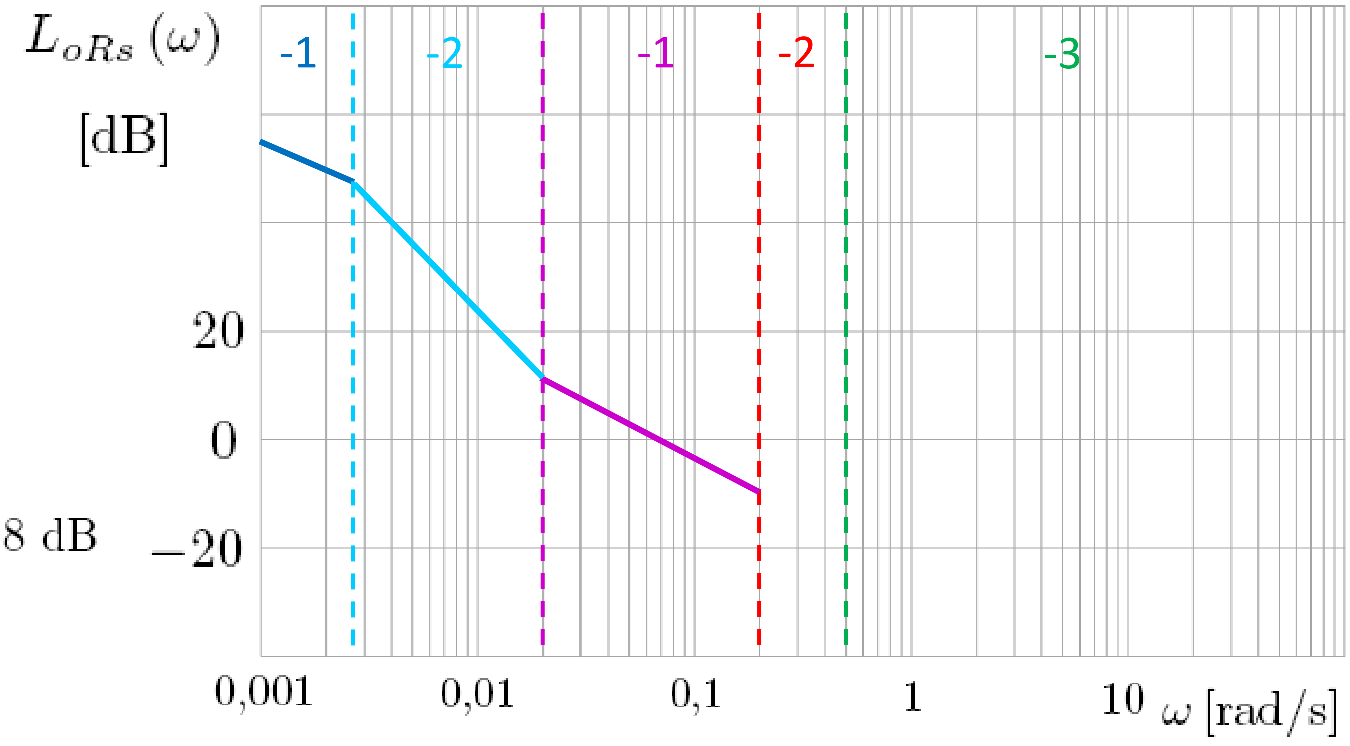
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

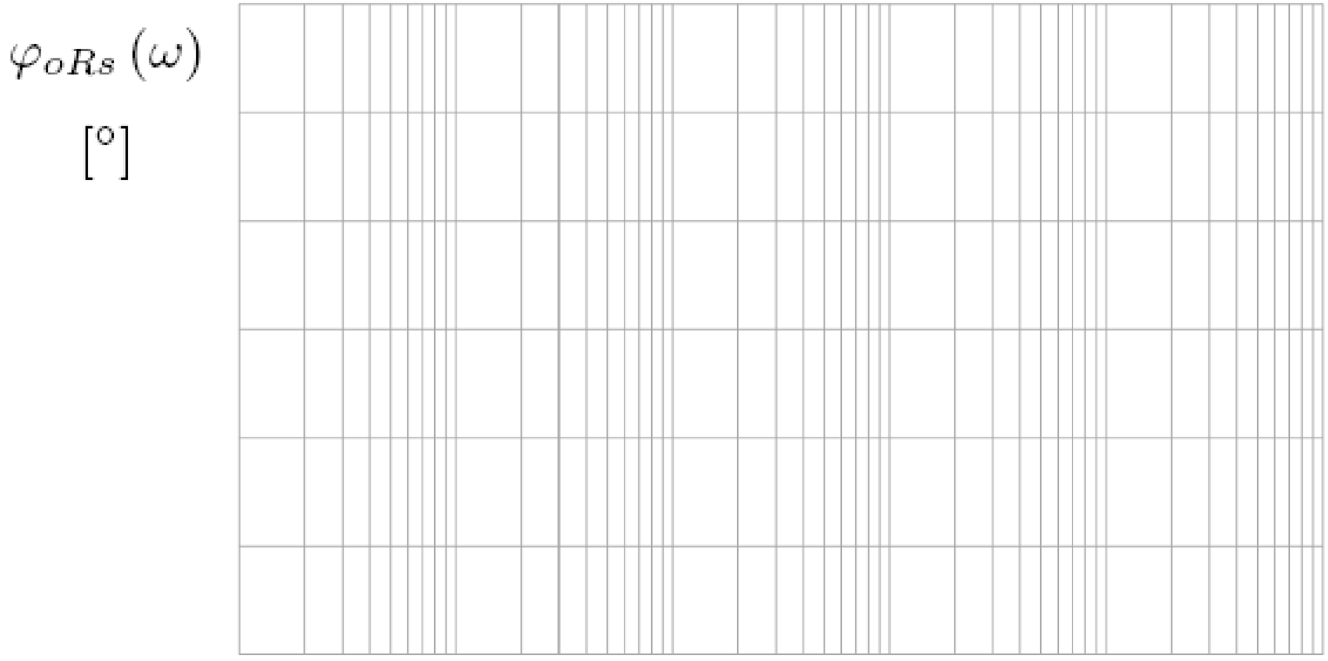
$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

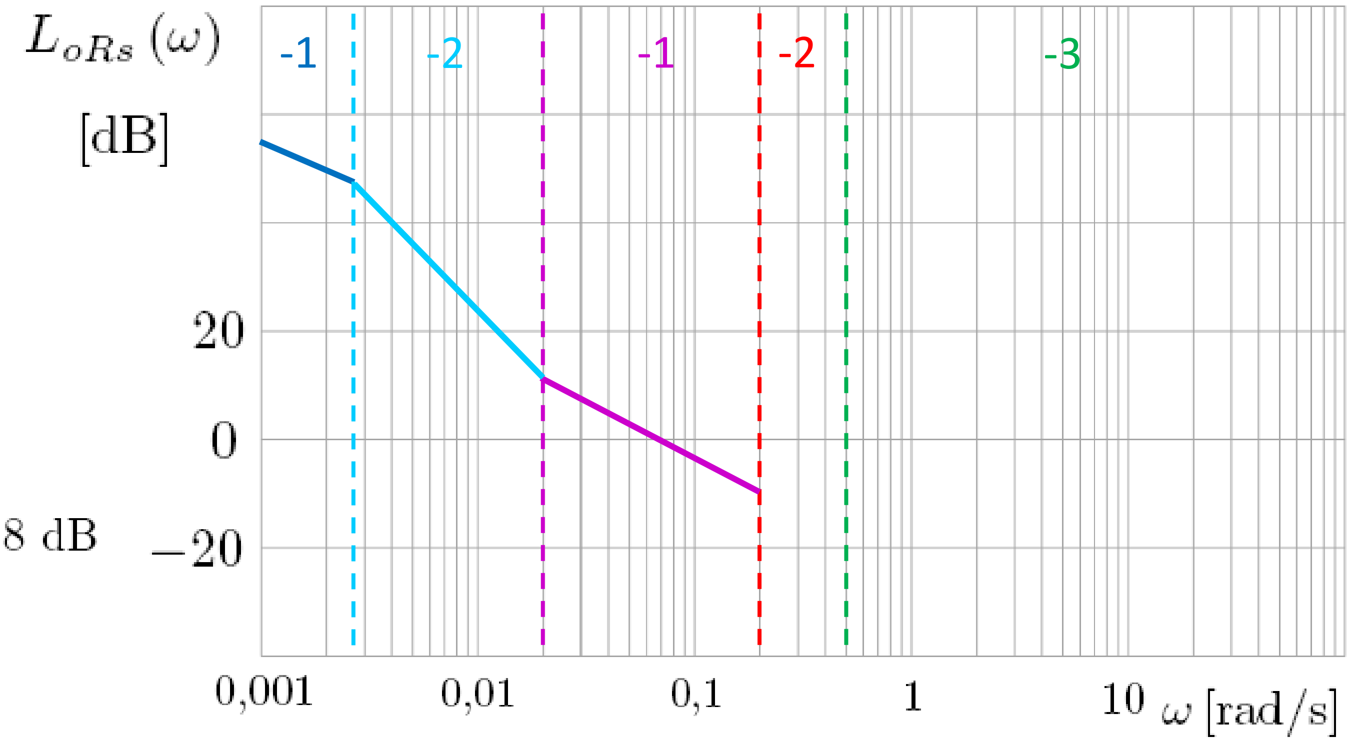
$$\omega_1 = \frac{1}{400} = 0{,}0025\ \mathrm{rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

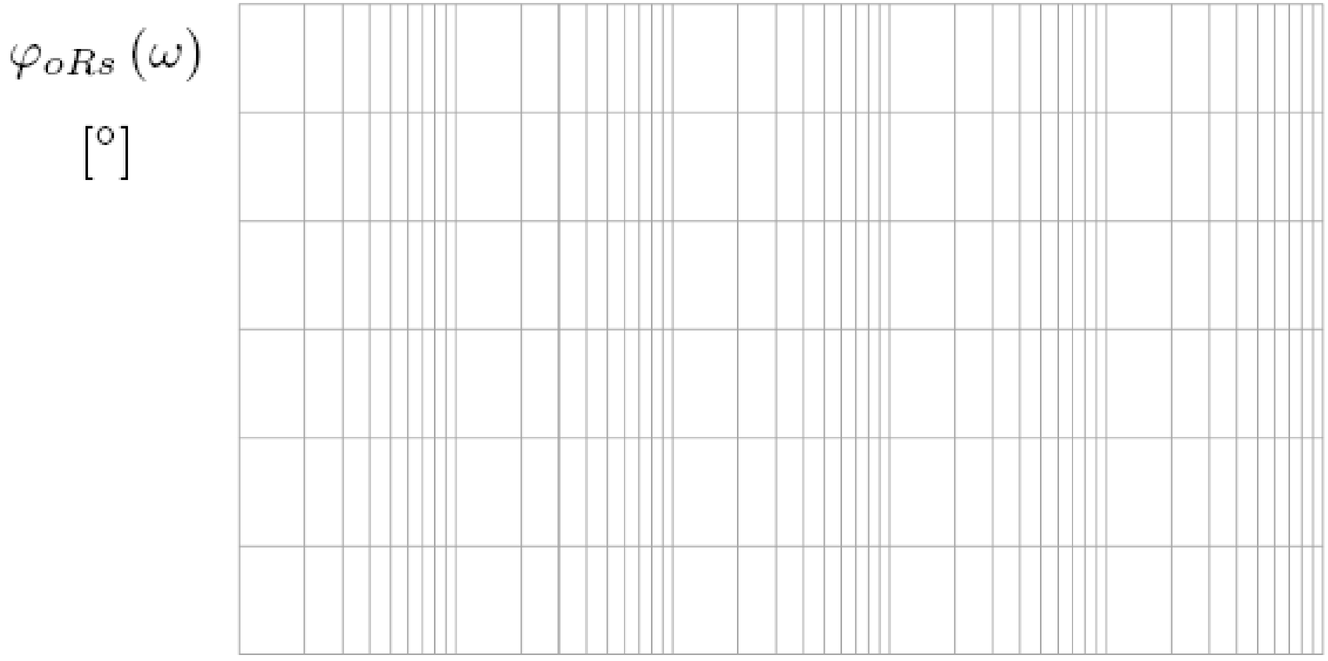
$$\omega_{Is} = \frac{1}{50} = 0{,}02\ \mathrm{rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$

$$\omega_{cs} = 0{,}062\ \mathrm{rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8\ \mathrm{dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8\ \mathrm{dB} - 40\log\frac{0{,}0025}{0{,}02} = 46\ \mathrm{dB}$$

$$L_{oRs}(0{,}001) = 46\ \mathrm{dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9\ \mathrm{dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

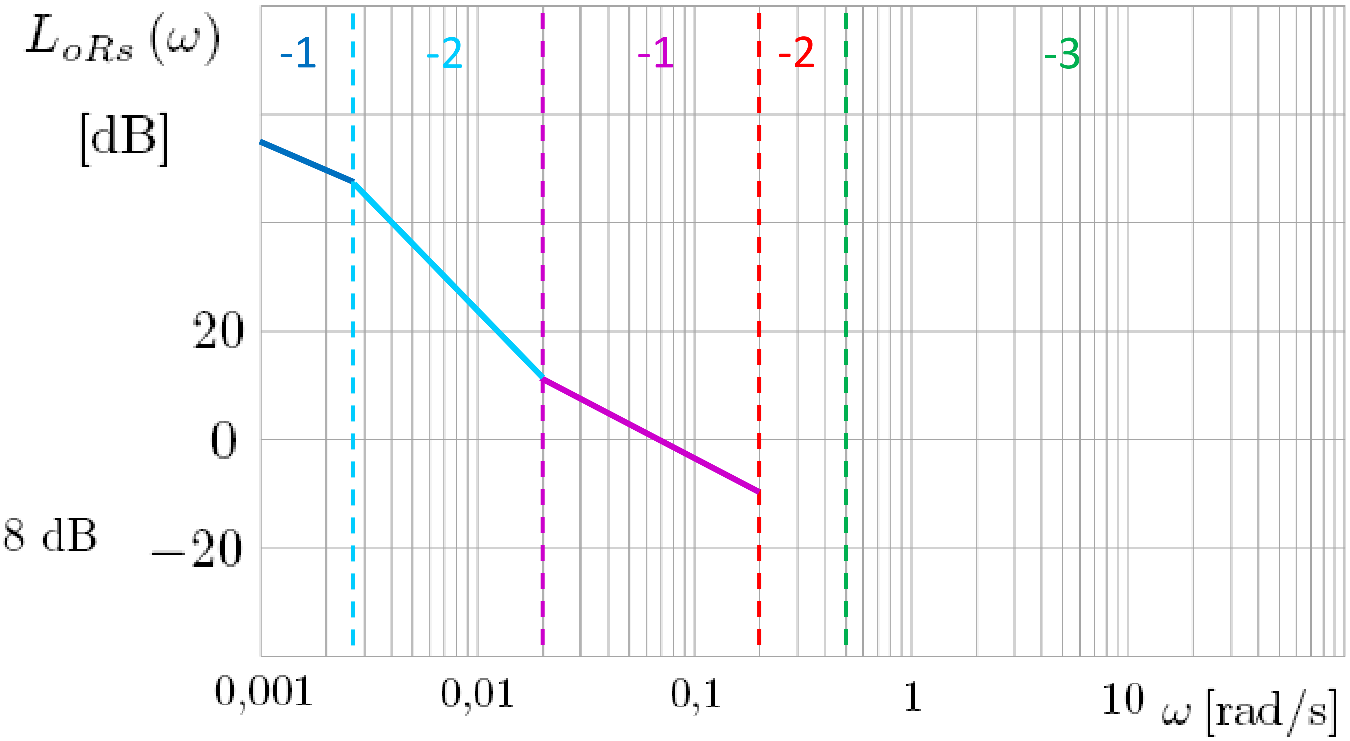
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

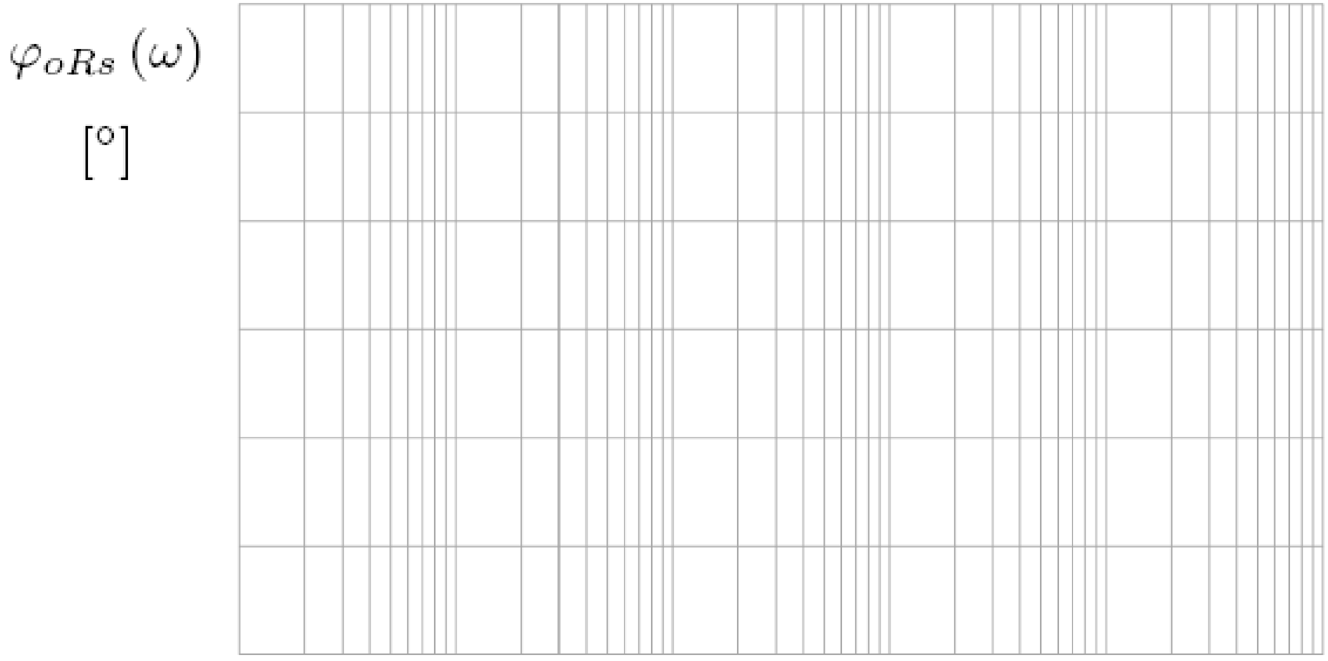
$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

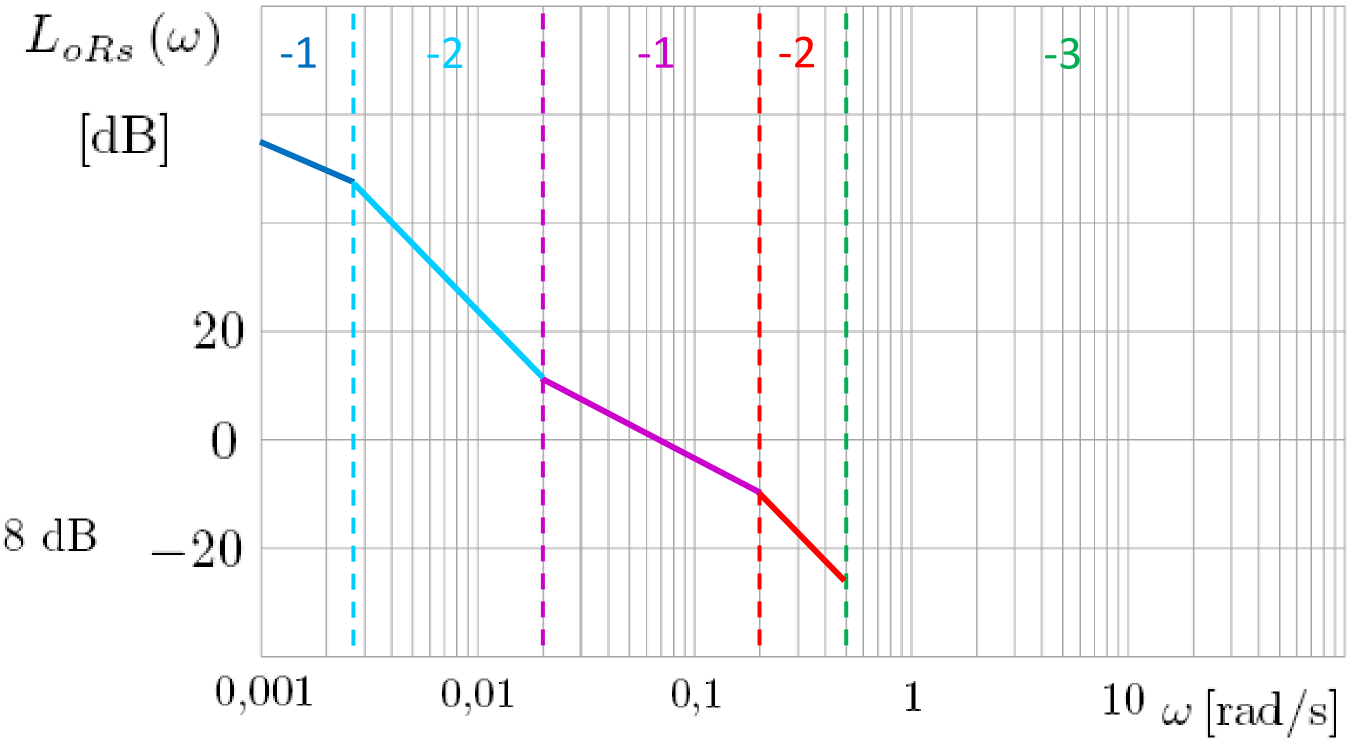
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

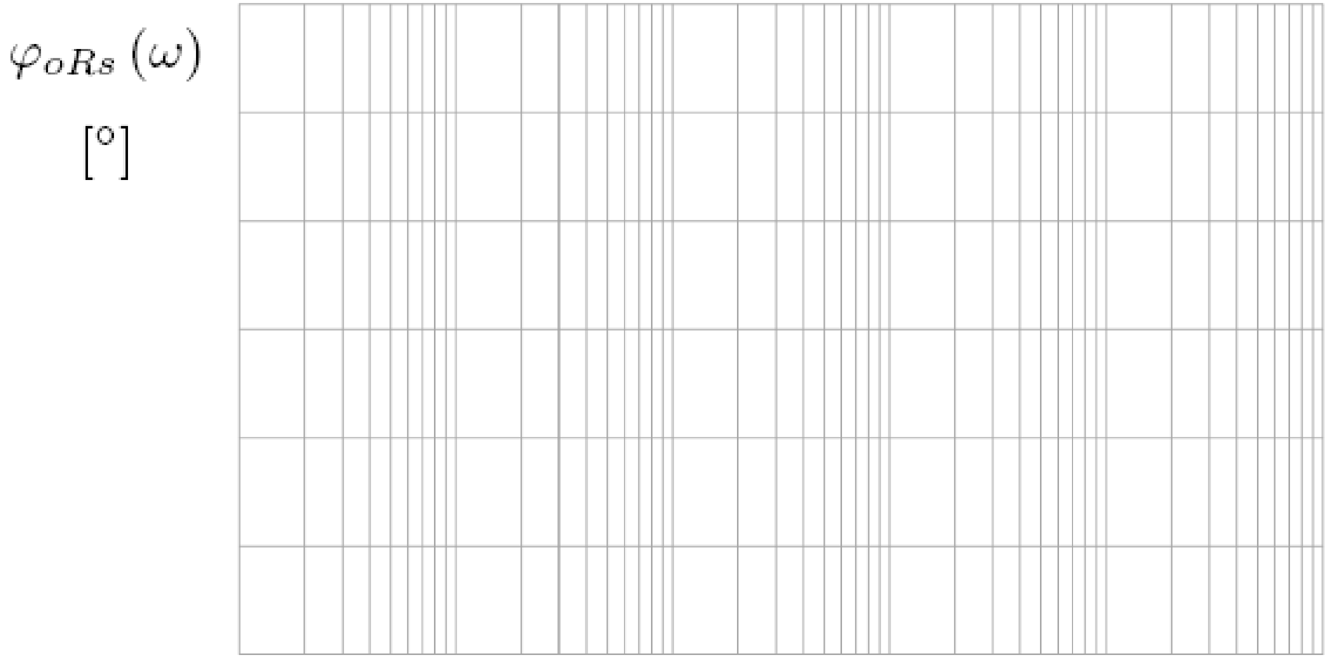
$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + 50s}{s(1 + 400s)(1 + 5s)(1 + 2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

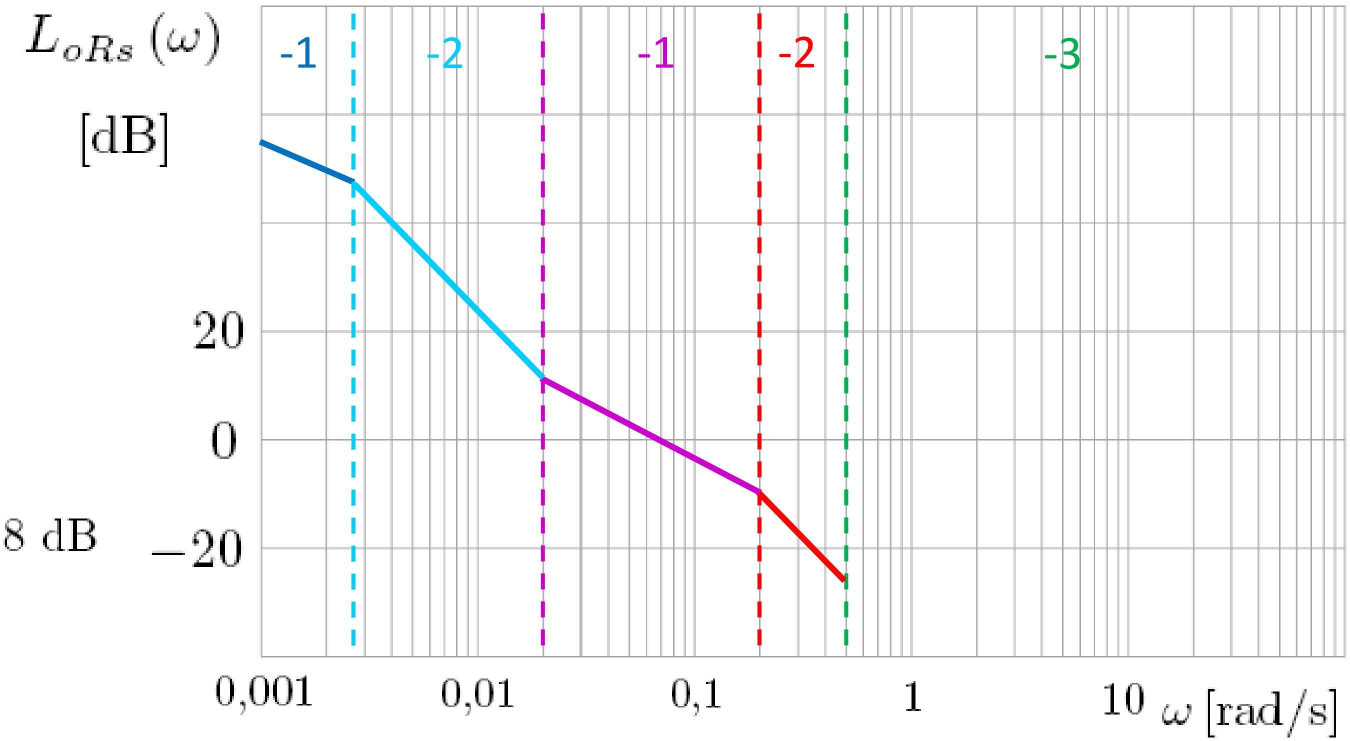
$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20 \log \frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

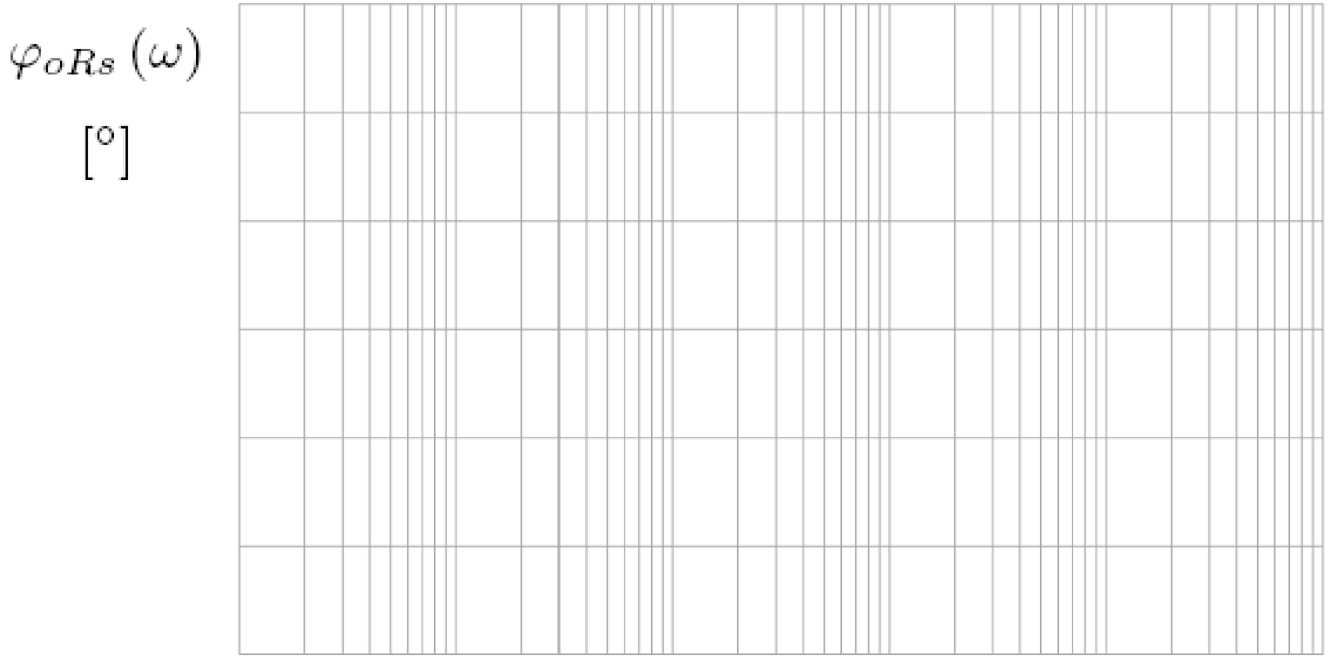
$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40 \log \frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20 \log \frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20 \log \frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}2 \text{ dB} - 40 \log \frac{0{,}5}{0{,}2} = -26{,}1 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025\ \mathrm{rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02\ \mathrm{rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$

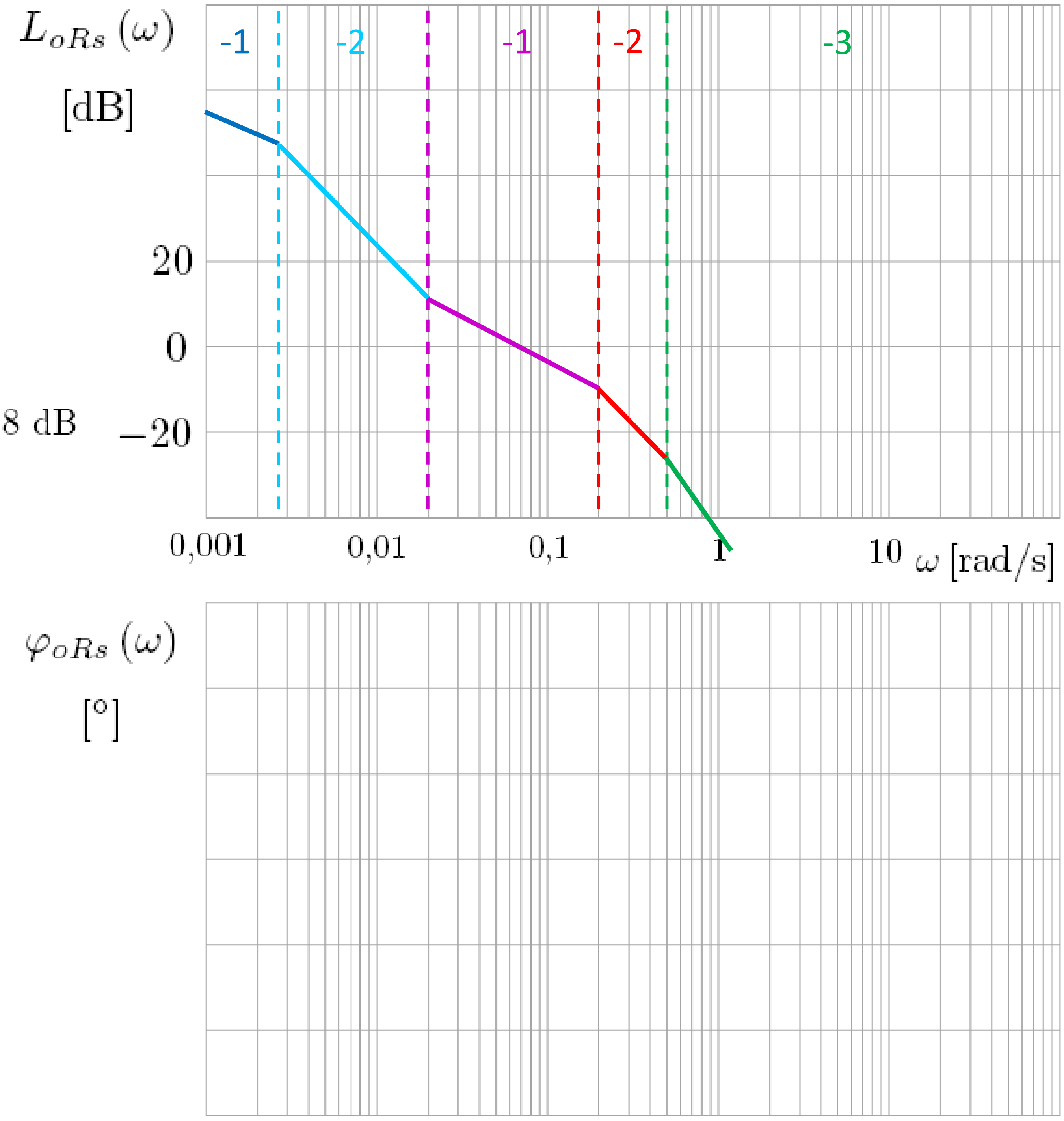
$$\omega_{cs} = 0{,}062\ \mathrm{rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8\ \mathrm{dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8\ \mathrm{dB} - 40\log\frac{0{,}0025}{0{,}02} = 46\ \mathrm{dB}$$

$$L_{oRs}(0{,}001) = 46\ \mathrm{dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9\ \mathrm{dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2\ \mathrm{dB}$$

$$L_{oRs}(0{,}5) = -10{,}2\ \mathrm{dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1\ \mathrm{dB}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

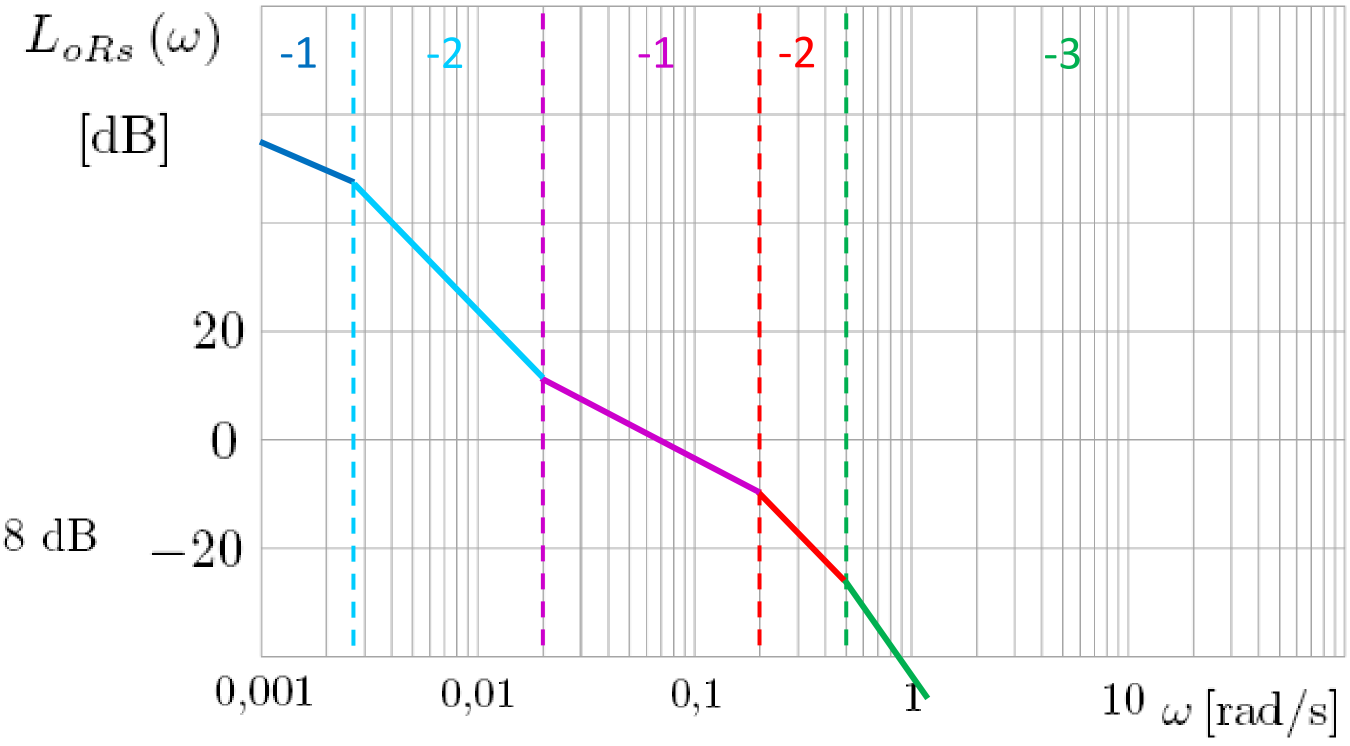
$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

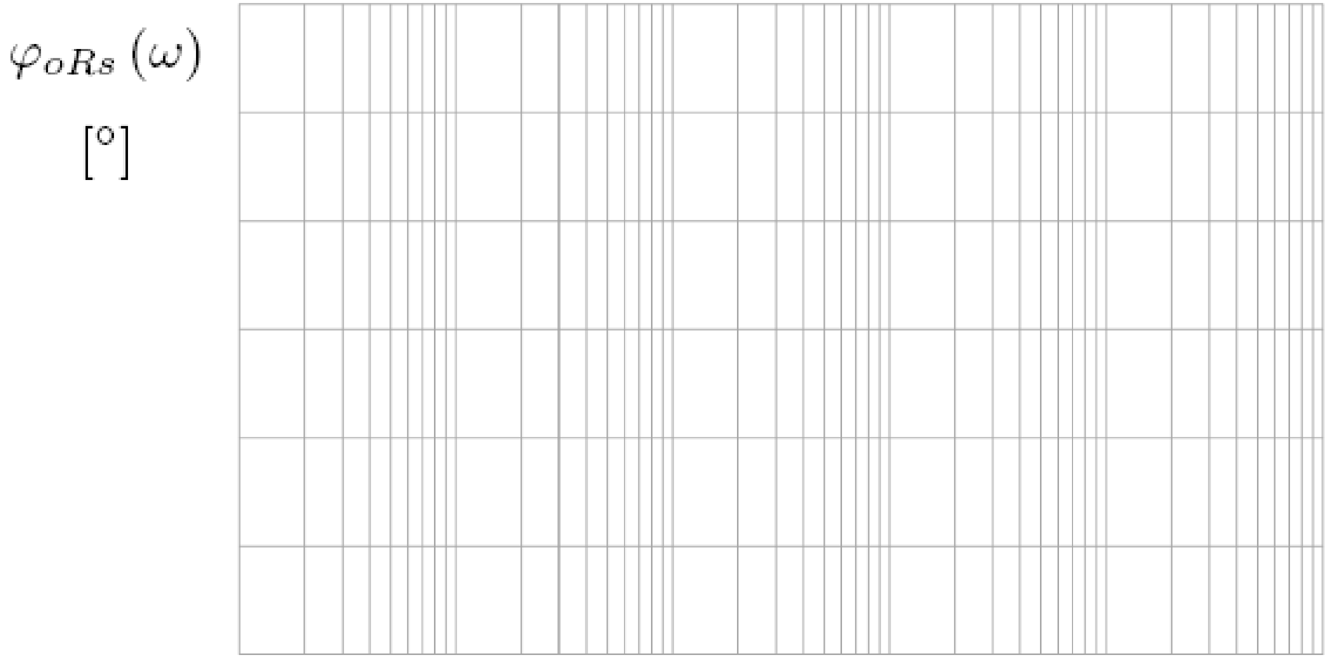
$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}2 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1 \text{ dB}$$

$$L_{oRs}(1) = -26{,}1 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}2 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

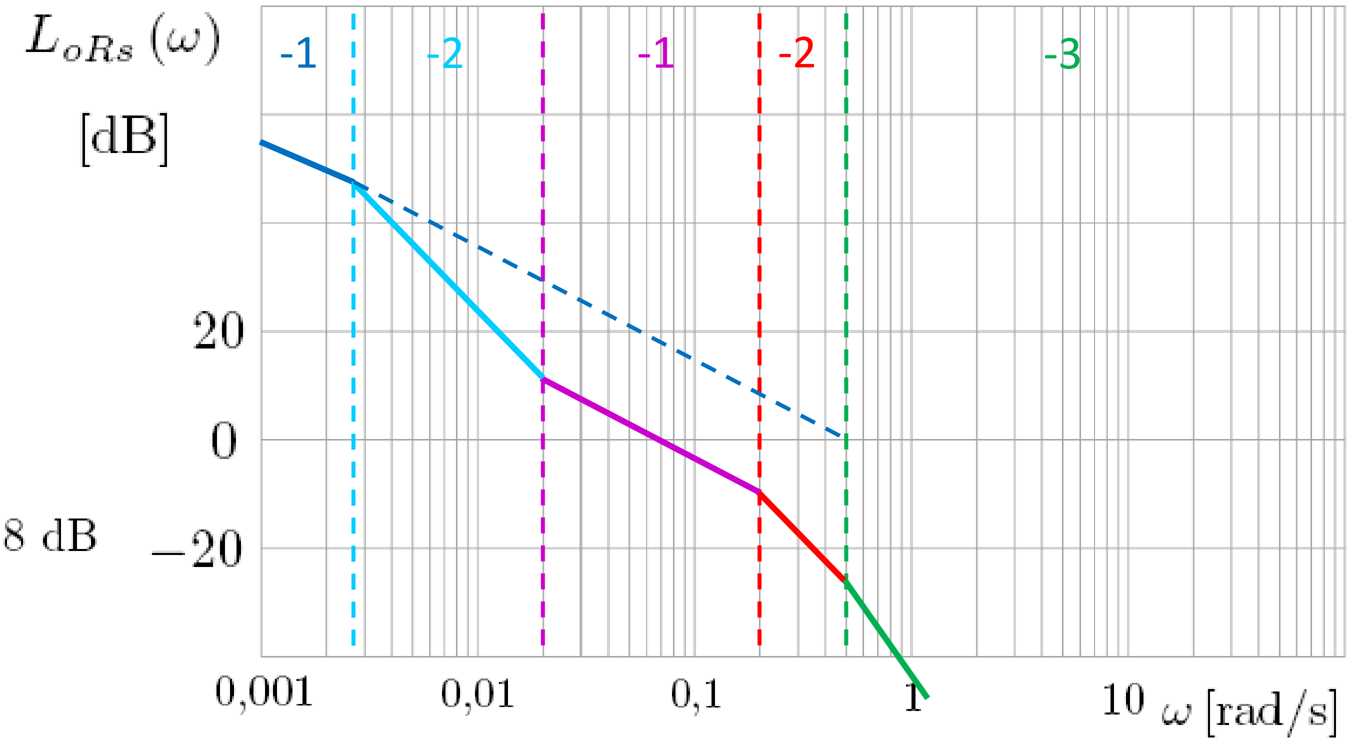
$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

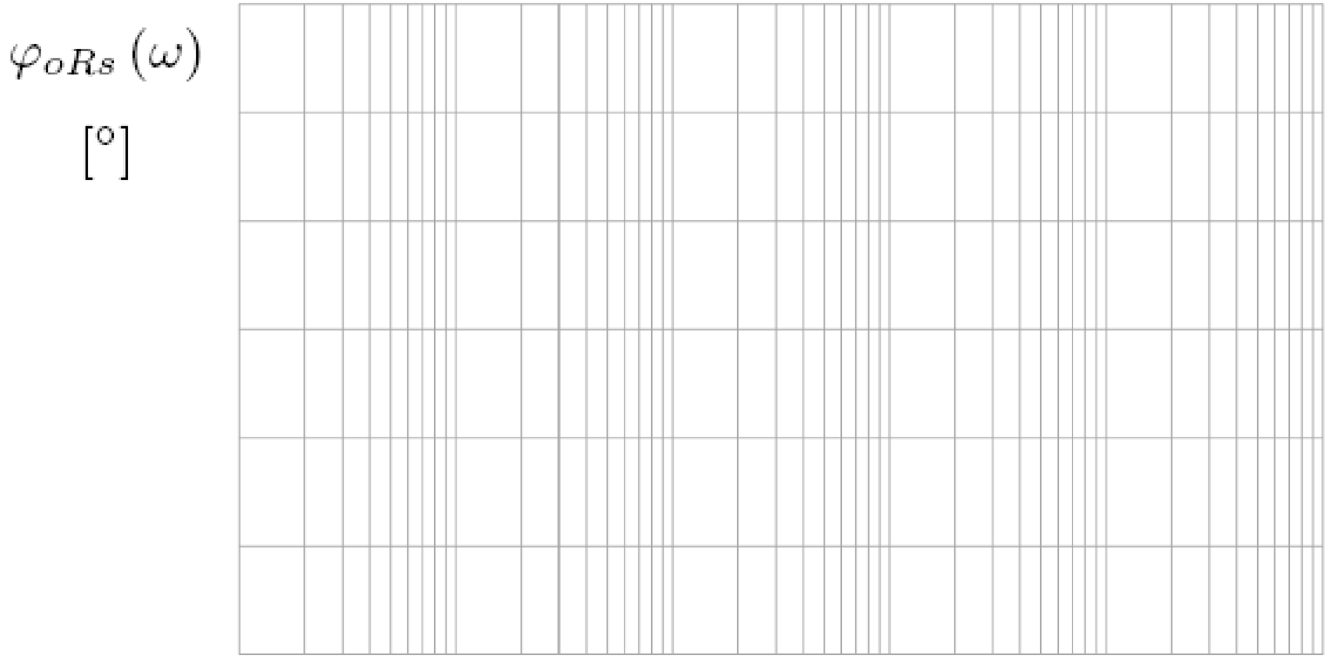
$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}2 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1 \text{ dB}$$

$$L_{oRs}(1) = -26{,}1 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}2 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

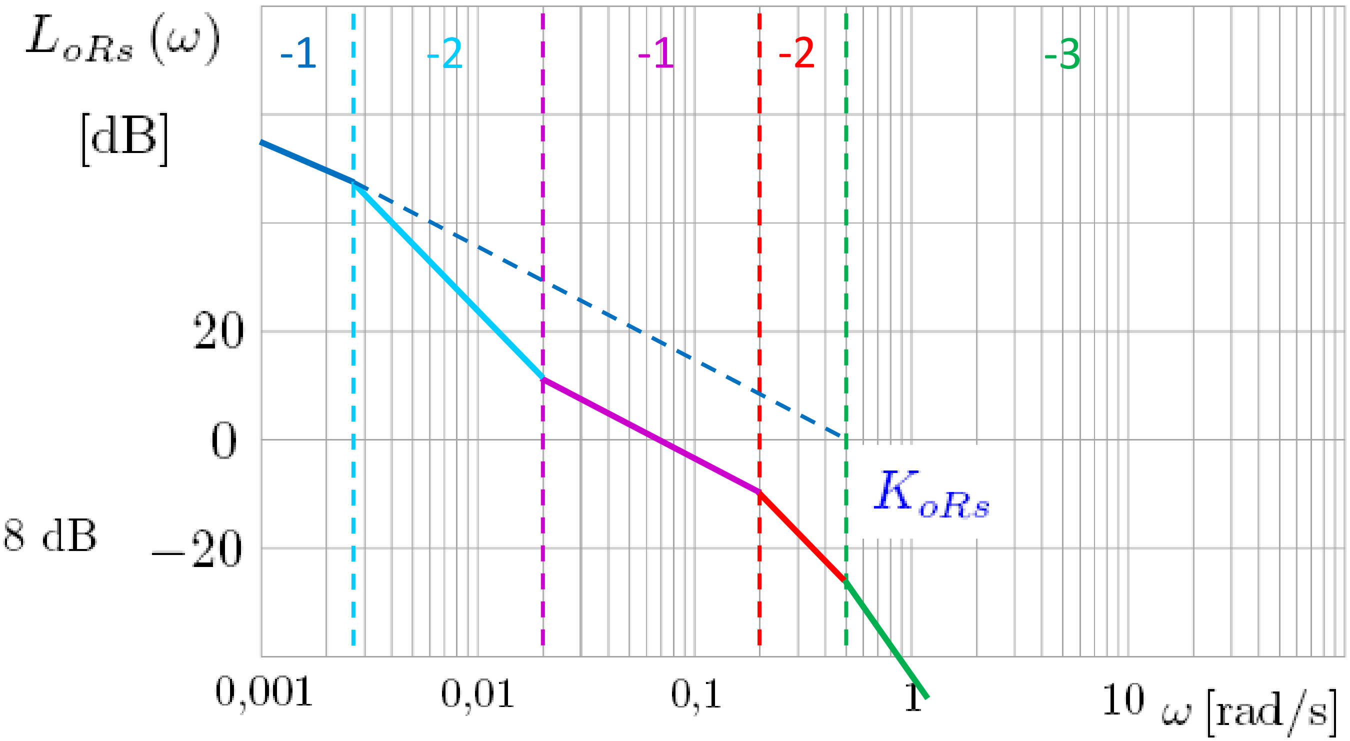
$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

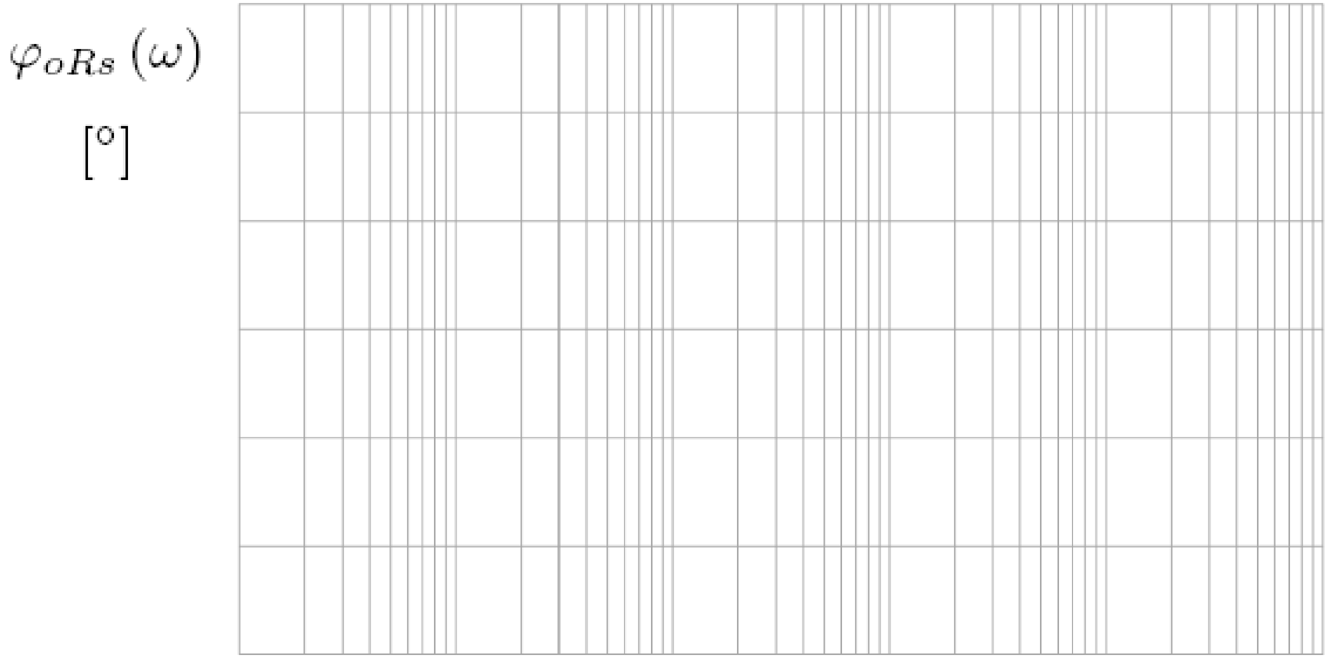
$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}2 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1 \text{ dB}$$

$$L_{oRs}(1) = -26{,}1 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}2 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025\ \mathrm{rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02\ \mathrm{rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$$

$$\omega_{cs} = 0{,}062\ \mathrm{rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8\ \mathrm{dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8\ \mathrm{dB} - 40\log\frac{0{,}0025}{0{,}02} = 46\ \mathrm{dB}$$

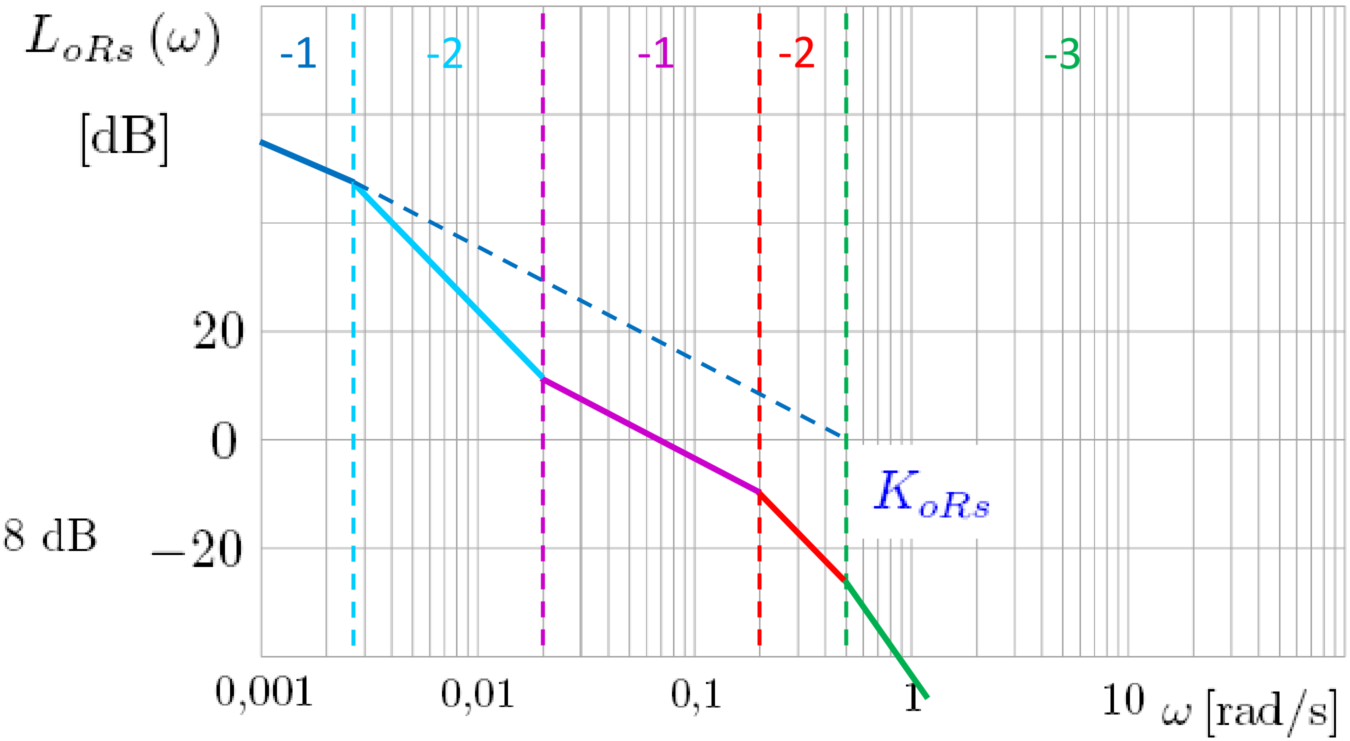
$$L_{oRs}(0{,}001) = 46\ \mathrm{dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9\ \mathrm{dB}$$

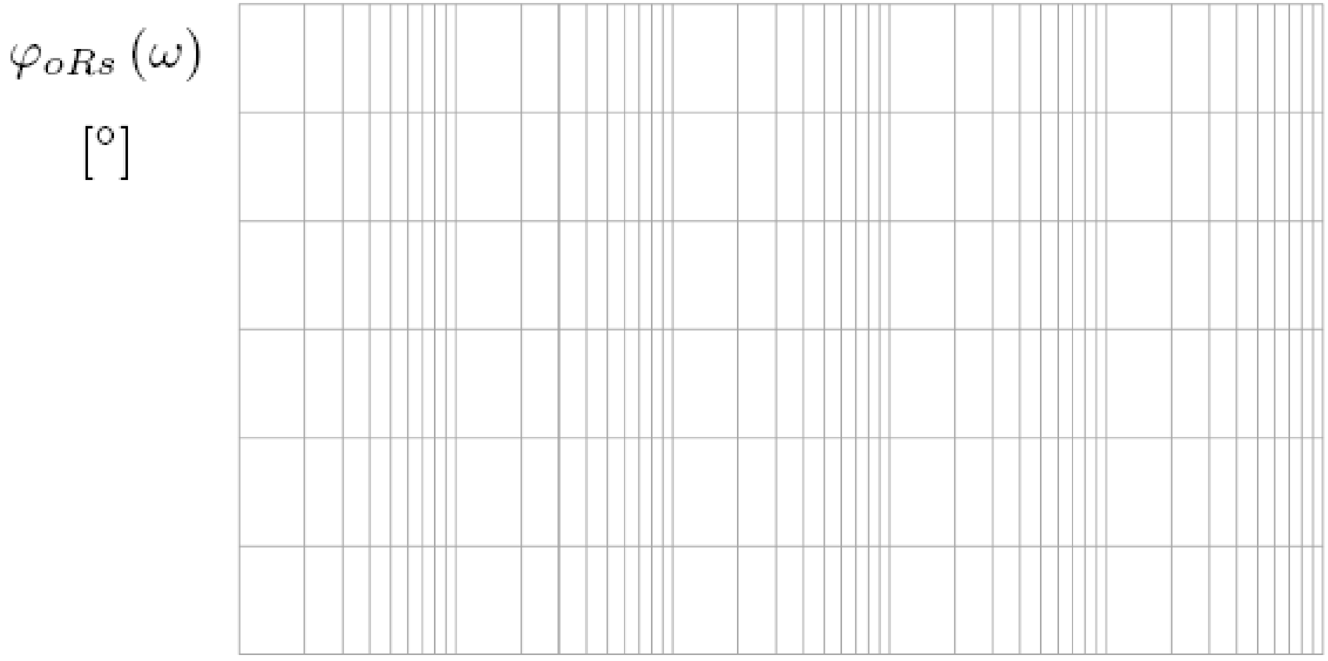
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2\ \mathrm{dB}$$

$$L_{oRs}(0{,}5) = -10{,}2\ \mathrm{dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1\ \mathrm{dB}$$

$$L_{oRs}(1) = -26{,}1\ \mathrm{dB} - 60\log\frac{1}{0{,}5} = -44{,}2\ \mathrm{dB}$$

$$0 = 46 - 20\log\frac{K_{oRs}}{0{,}0025}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

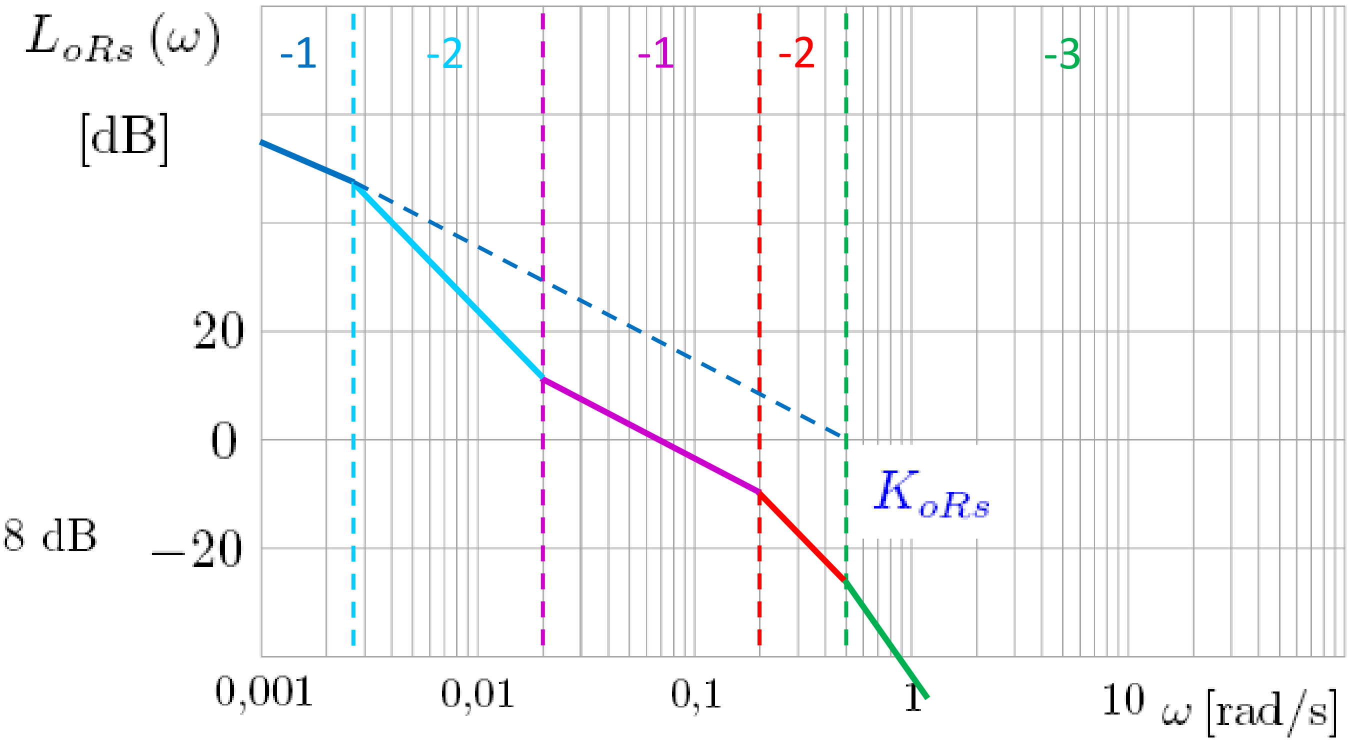
$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

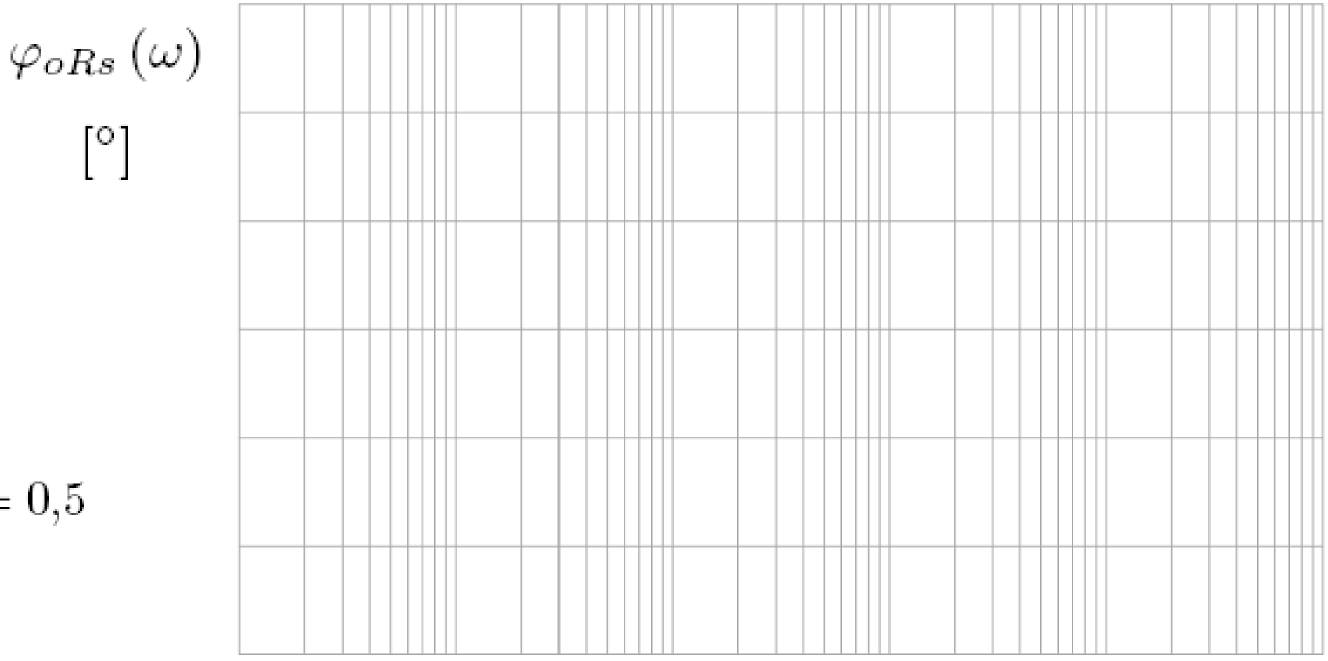
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}2 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1 \text{ dB}$$

$$L_{oRs}(1) = -26{,}1 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}2 \text{ dB}$$

$$0 = 46 - 20\log\frac{K_{oRs}}{0{,}0025} \qquad K_{oRs} = 0{,}0025 \cdot 10^{\frac{46}{20}} = 0{,}5$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s(1+400s)(1+5s)(1+2s)}$$

$$\omega_1 = \frac{1}{400} = 0{,}0025 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}062 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}062} = 9{,}8 \text{ dB}$$

$$L_{oRs}(0{,}0025) = 9{,}8 \text{ dB} - 40\log\frac{0{,}0025}{0{,}02} = 46 \text{ dB}$$

$$L_{oRs}(0{,}001) = 46 \text{ dB} - 20\log\frac{0{,}001}{0{,}0025} = 53{,}9 \text{ dB}$$

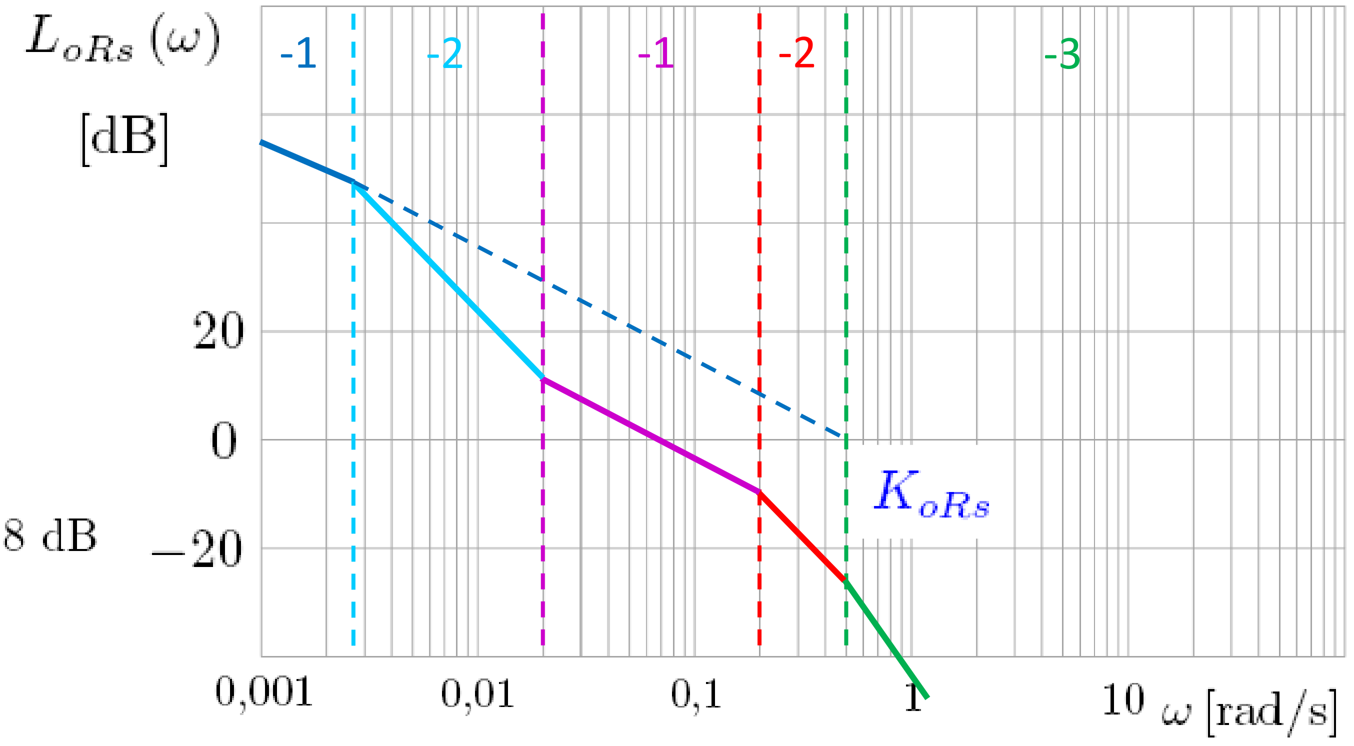
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}062} = -10{,}2 \text{ dB}$$

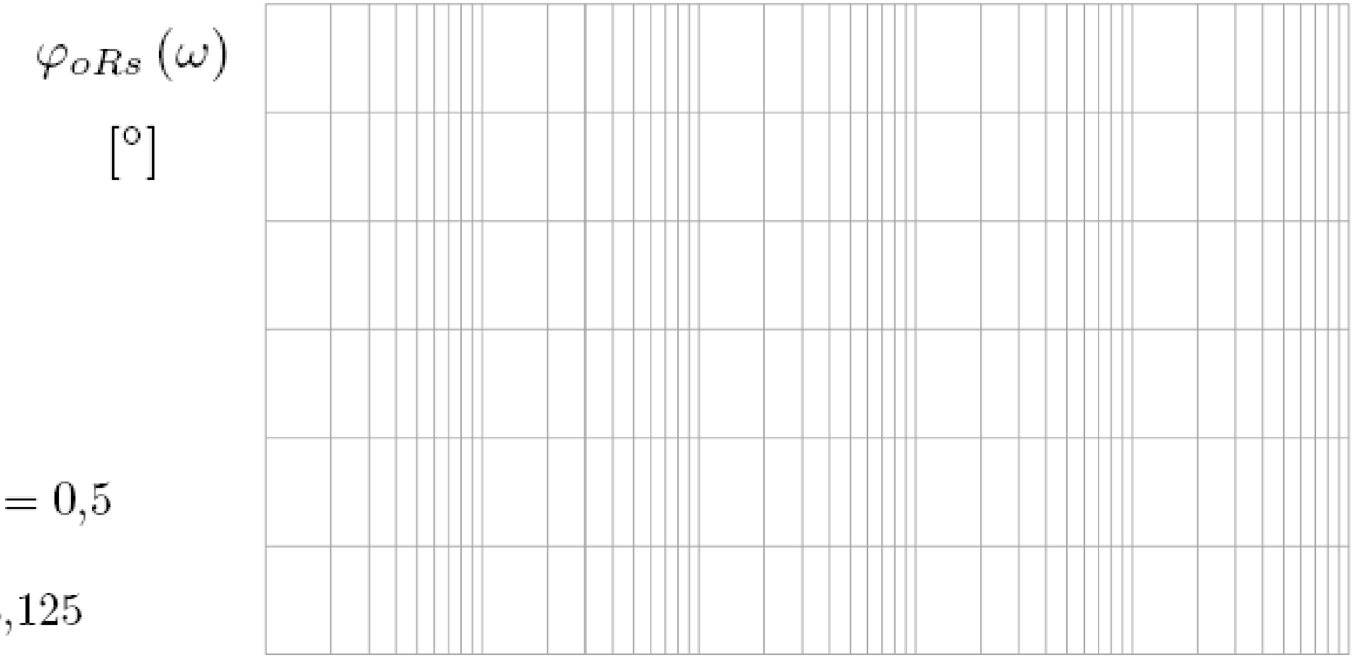
$$L_{oRs}(0{,}5) = -10{,}2 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26{,}1 \text{ dB}$$

$$L_{oRs}(1) = -26{,}1 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}2 \text{ dB}$$

$$0 = 46 - 20\log\frac{K_{oRs}}{0{,}0025} \qquad K_{oRs} = 0{,}0025 \cdot 10^{\frac{46}{20}} = 0{,}5$$

$$K_{Rs} = 6{,}25 K_{oRs} = 3{,}125$$





Simulacija i korekcija parametara

Preporuke za izbor vremenske konstante PI regulatora uz statički proces 3. reda

Preporuke za izbor vremenske konstante PI regulatora uz statički proces 3. reda

Pretpostavka: $T_1 > T_2 > T_{pv}$

Preporuke za izbor vremenske konstante PI regulatora uz statički proces 3. reda

Pretpostavka: $T_1 > T_2 > T_{pv}$

Ako je $\frac{T_1}{T_2} < 8$ koristiti tehnički optimum (TO): $T_{It} = T_1$

Preporuke za izbor vremenske konstante PI regulatora uz statički proces 3. reda

Pretpostavka: $T_1 > T_2 > T_{pv}$

Ako je $\frac{T_1}{T_2} < 8$ koristiti tehnički optimum (TO): $T_{It} = T_1$

Za $8 \leq \frac{T_1}{T_2} < 16$ koristiti simetrični optimum (SO) uz $a = 2$ $\left(a^2 = 4\right)$

Preporuke za izbor vremenske konstante PI regulatora uz statički proces 3. reda

Pretpostavka: $T_1 > T_2 > T_{pv}$

Ako je $\frac{T_1}{T_2} < 8$ koristiti tehnički optimum (TO): $T_{It} = T_1$

Za $8 \leq \frac{T_1}{T_2} < 16$ koristiti simetrični optimum (SO) uz $a = 2$ $\left(a^2 = 4\right)$

Za $16 \leq \frac{T_1}{T_2} < 100$ koristiti SO uz $a^2 = \sqrt{\frac{T_1}{T_2}}$, tj. $T_{Is} = \sqrt{T_1 \cdot T_2}$

Preporuke za izbor vremenske konstante PI regulatora uz statički proces 3. reda

Pretpostavka: $T_1 > T_2 > T_{pv}$

Ako je $\frac{T_1}{T_2} < 8$ koristiti tehnički optimum (TO): $T_{It} = T_1$

Za $8 \leq \frac{T_1}{T_2} < 16$ koristiti simetrični optimum (SO) uz $a = 2$ $\left(a^2 = 4\right)$

Za $16 \leq \frac{T_1}{T_2} < 100$ koristiti SO uz $a^2 = \sqrt{\frac{T_1}{T_2}}$, tj. $T_{Is} = \sqrt{T_1 \cdot T_2}$

Za $\frac{T_1}{T_2} \geq 100$ koristiti SO uz $a \approx 3{,}2$ $\left(a^2 = 10\right)$, tj. $T_{Is} = 10T_2$

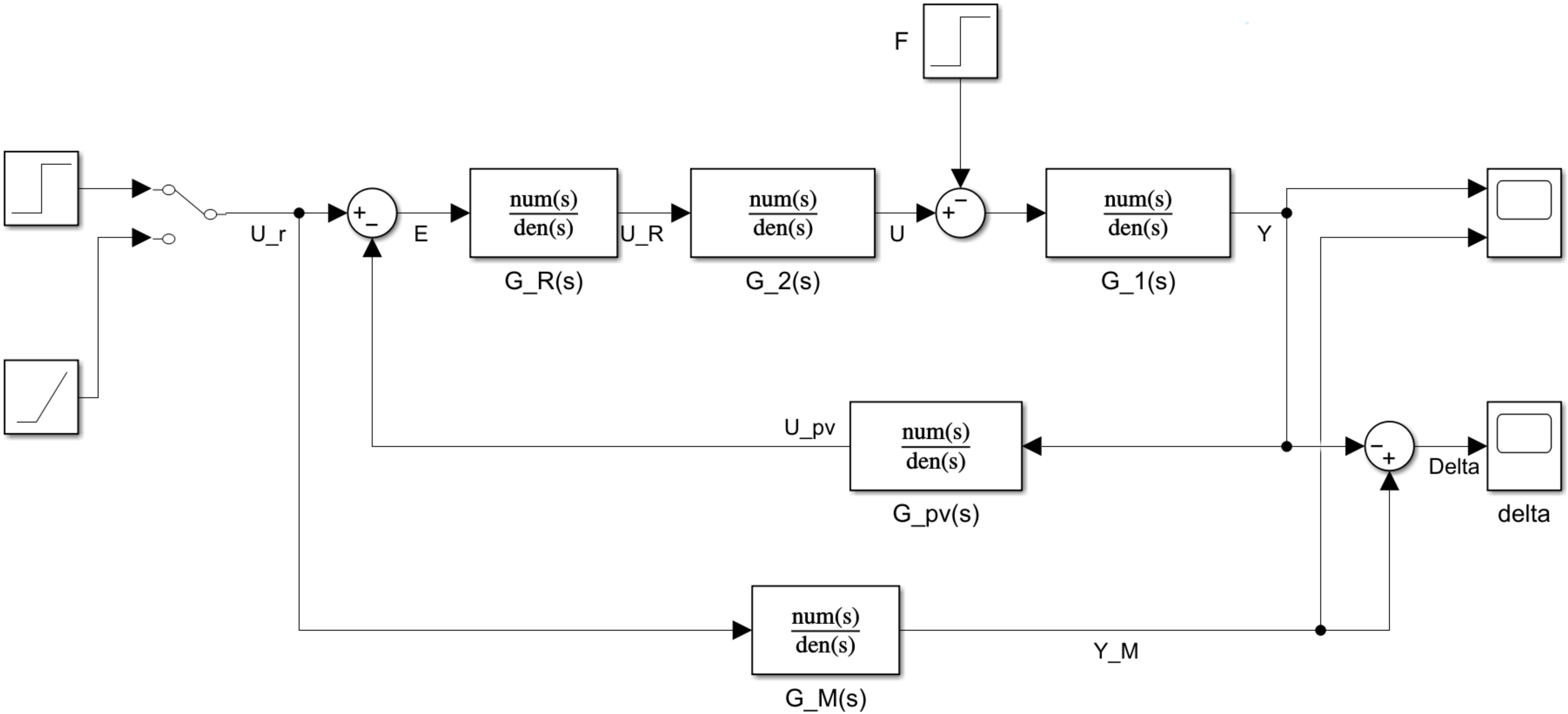
Zadaća

- Ponoviti sintezu za primjer uz podešavanje prema preporukama s prethodnog slajda!

BLDC primjer – laboratorijske vježbe

Sinteza regulacijskog sustava s astatičkim procesom 1. reda

Sinteza regulacijskog sustava s astatičkim procesom 1. reda



Sinteza regulacijskog sustava s astatičkim procesom 1. reda

Sinteza regulacijskog sustava s astatičkim procesom 1. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

Sinteza regulacijskog sustava s astatičkim procesom 1. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

Sinteza regulacijskog sustava s astatičkim procesom 1. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

Sinteza regulacijskog sustava s astatičkim procesom 1. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

Sinteza regulacijskog sustava s astatičkim procesom 1. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

- Budući da se astatizam ($r = 1$) nalazi u procesu, statička pogreška u odnosu na upravljačku veličinu δ_{us} bit će jednaka nuli čak i uz izbor čiste proporcionalne strukture regulatora.
- Međutim, da bi statička pogreška u odnosu na poremećajnu veličinu δ_{fs} bila jednaka nuli, astatizam se mora nalaziti u regulatoru!
- Stoga se izabire PI regulator: I dio zbog gornjeg zahtjeva za astatizmom u regulatoru, a P dio, kao i u slučaju statičkog procesa, radi ubrzanja odziva, smanjenja kinetičke pogreške i bolje kompenzacije poremećaja.

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s} \qquad G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s}$$

$$G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_I s}{T_I s} \qquad G_p(s) = \frac{K_1}{s} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_I s}{T_I s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s(1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- Uz postignut red astatizma $r = 2$ zadovoljeni su zahtjevi za potpunom kompenzacijom poremećajne veličine ($\delta_{fs} = 0$) te za statičkom pogreškom u odnosu na upravljačku (referentnu) veličinu jednakoj nuli ($\delta_{us} = 0$).

Podešavanje parametara regulatora

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

Podešavanje parametara regulatora

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)} \qquad K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- U prijenosnoj funkciji otvorenog kruga s regulatorom $G_{oR}(s)$ nepoznati su parametri K_{oR} i T_I.
- Prvo se odabire integracijska vremenska konstanta regulatora T_I.
- Budući da fazno-frekvencijska karakteristika već na niskim frekvencijama iznosi -180°, radi stabilizacije regulacijskog sustava potrebno je podići fazno-frekvencijsku karakteristiku iznad -180°.
- To se postiže tako da vrijedi: $T_I > \max(T_2, T_{pv})$
- Točan iznos T_I može se odrediti primjenom simetričnog optimuma kao kod statičkog procesa, a preporuka je odabrati:

Podešavanje parametara regulatora

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- U prijenosnoj funkciji otvorenog kruga s regulatorom $G_{oR}(s)$ nepoznati su parametri K_{oR} i T_I.
- Prvo se odabire integracijska vremenska konstanta regulatora T_I.
- Budući da fazno-frekvencijska karakteristika već na niskim frekvencijama iznosi -180°, radi stabilizacije regulacijskog sustava potrebno je podići fazno-frekvencijsku karakteristiku iznad -180°.
- To se postiže tako da vrijedi: $T_I > \max(T_2, T_{pv})$
- Točan iznos T_I može se odrediti primjenom simetričnog optimuma kao kod statičkog procesa, a preporuka je odabrati:

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{3{,}2}$$

Podešavanje parametara regulatora

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- U prijenosnoj funkciji otvorenog kruga s regulatorom $G_{oR}(s)$ nepoznati su parametri K_{oR} i T_I.
- Prvo se odabire integracijska vremenska konstanta regulatora T_I.
- Budući da fazno-frekvencijska karakteristika već na niskim frekvencijama iznosi -180°, radi stabilizacije regulacijskog sustava potrebno je podići fazno-frekvencijsku karakteristiku iznad -180°.
- To se postiže tako da vrijedi: $T_I > \max(T_2, T_{pv})$
- Točan iznos T_I može se odrediti primjenom simetričnog optimuma kao kod statičkog procesa, a preporuka je odabrati:

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{3{,}2} \qquad \omega_{Is} = \frac{\omega_{cs}}{3{,}2}$$

Podešavanje parametara regulatora

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_I s}{s^2 (1 + T_2 s)(1 + T_{pv} s)} \qquad K_{oR} = \frac{K_R \cdot K_1 \cdot K_2 \cdot K_{pv}}{T_I}$$

- U prijenosnoj funkciji otvorenog kruga s regulatorom $G_{oR}(s)$ nepoznati su parametri K_{oR} i T_I.
- Prvo se odabire integracijska vremenska konstanta regulatora T_I.
- Budući da fazno-frekvencijska karakteristika već na niskim frekvencijama iznosi -180°, radi stabilizacije regulacijskog sustava potrebno je podići fazno-frekvencijsku karakteristiku iznad -180°.
- To se postiže tako da vrijedi: $T_I > \max(T_2, T_{pv})$
- Točan iznos T_I može se odrediti primjenom simetričnog optimuma kao kod statičkog procesa, a preporuka je odabrati:

$$\omega_{cs} = \frac{\min(\omega_2, \omega_{pv})}{3{,}2} \qquad \omega_{Is} = \frac{\omega_{cs}}{3{,}2} \qquad T_{Is} = \frac{1}{\omega_{Is}} \approx 10 \cdot \max(T_2, T_{pv})$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + T_{Is}s}{s^2(1 + T_2 s)(1 + T_{pv}s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + T_{Is}s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRs}(s)$ nepoznat je samo koeficijent pojačanja K_{oRs}.
- Postupak određivanja pojačanja K_{oRs} sličan je kao i za statički proces:
  - kreće se s crtanjem amplitudno frekvencijske karakteristike oko presječne frekvencije
  - K_{oRs} se očitava na dijelu karakteristike do lomne frekvencije ω_{Is} (niske frekvencije) produljenjem tog dijela karakteristike do osi 0 dB i očitavanjem pripadne frekvencije koja je jednaka $\sqrt{K_{oRs}}$
- Koeficijent pojačanja regulatora K_{Rs} računa se prema:

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1 + T_{Is} s}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

- U prijenosnoj funkciji $G_{oRs}(s)$ nepoznat je samo koeficijent pojačanja K_{oRs}.
- Postupak određivanja pojačanja K_{oRs} sličan je kao i za statički proces:
  - kreće se s crtanjem amplitudno frekvencijske karakteristike oko presječne frekvencije
  - K_{oRs} se očitava na dijelu karakteristike do lomne frekvencije ω_{Is} (niske frekvencije) produljenjem tog dijela karakteristike do osi 0 dB i očitavanjem pripadne frekvencije koja je jednaka $\sqrt{K_{oRs}}$
- Koeficijent pojačanja regulatora K_{Rs} računa se prema:

$$K_{Rs} = \frac{K_{oRs} \cdot T_{Is}}{K_1 \cdot K_2 \cdot K_{pv}}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+T_{Is}s}{s^2(1+T_2 s)(1+T_{pv}s)}$$

- U prijenosnoj funkciji $G_{oRs}(s)$ nepoznat je samo koeficijent pojačanja K_{oRs}.
- Postupak određivanja pojačanja K_{oRs} sličan je kao i za statički proces:
  - kreće se s crtanjem amplitudno frekvencijske karakteristike oko presječne frekvencije
  - K_{oRs} se očitava na dijelu karakteristike do lomne frekvencije ω_{Is} (niske frekvencije) produljenjem tog dijela karakteristike do osi 0 dB i očitavanjem pripadne frekvencije koja je jednaka $\sqrt{K_{oRs}}$
- Koeficijent pojačanja regulatora K_{Rs} računa se prema:

$$K_{Rs} = \frac{K_{oRs} \cdot T_{Is}}{K_1 \cdot K_2 \cdot K_{pv}}$$

- Nakon toga se dodatno može povećati koeficijent pojačanja regulatora K_{Rs} radi bolje kompenzacije poremećaja i nakon toga obaviti zahvate u grani referentne veličine, kao i u dosadašnjim primjerima sa statičkim procesima.

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1 + 5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1 + 2s}$$

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$\omega_{cs} = \frac{\omega_2}{3{,}2} = \frac{0{,}2}{3{,}2} = 0{,}0625\ \mathrm{rad/s}$$

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$\omega_{cs} = \frac{\omega_2}{3{,}2} = \frac{0{,}2}{3{,}2} = 0{,}0625 \text{ rad/s}$$

$$T_{Is} = 10 \cdot \max(5, 2) = 10 \cdot 5 = 50 \text{ s}$$

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$\omega_{cs} = \frac{\omega_2}{3{,}2} = \frac{0{,}2}{3{,}2} = 0{,}0625 \text{ rad/s}$$

$$T_{Is} = 10 \cdot \max(5, 2) = 10 \cdot 5 = 50 \text{ s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{0{,}0125 \cdot 16 \cdot 0{,}1}{s(1+5s)(1+2s)}$$

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$\omega_{cs} = \frac{\omega_2}{3{,}2} = \frac{0{,}2}{3{,}2} = 0{,}0625 \text{ rad/s}$$

$$T_{Is} = 10 \cdot \max(5, 2) = 10 \cdot 5 = 50 \text{ s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{0{,}0125 \cdot 16 \cdot 0{,}1}{s(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$\omega_{cs} = \frac{\omega_2}{3{,}2} = \frac{0{,}2}{3{,}2} = 0{,}0625 \text{ rad/s}$$

$$T_{Is} = 10 \cdot \max(5, 2) = 10 \cdot 5 = 50 \text{ s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{0{,}0125 \cdot 16 \cdot 0{,}1}{s(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot 0{,}0125 \cdot 16 \cdot 0{,}1}{50} = 4 \cdot 10^{-4} \cdot K_{Rs}$$

Primjer 3

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{0{,}0125}{s}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{16}{1+5s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{0{,}1}{1+2s}$$

$$\omega_{cs} = \frac{\omega_2}{3{,}2} = \frac{0{,}2}{3{,}2} = 0{,}0625 \text{ rad/s}$$

$$T_{Is} = 10 \cdot \max(5,2) = 10 \cdot 5 = 50 \text{ s}$$

$$G_{oRs}(s) = K_{Rs} \cdot \frac{1+50s}{50s} \cdot \frac{0{,}0125 \cdot 16 \cdot 0{,}1}{s(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$K_{oRs} = \frac{K_{Rs} \cdot 0{,}0125 \cdot 16 \cdot 0{,}1}{50} = 4 \cdot 10^{-4} \cdot K_{Rs}$$

$$K_{Rs} = \frac{1}{4 \cdot 10^{-4}} \cdot K_{oRs} = 2500 \cdot K_{oRs}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

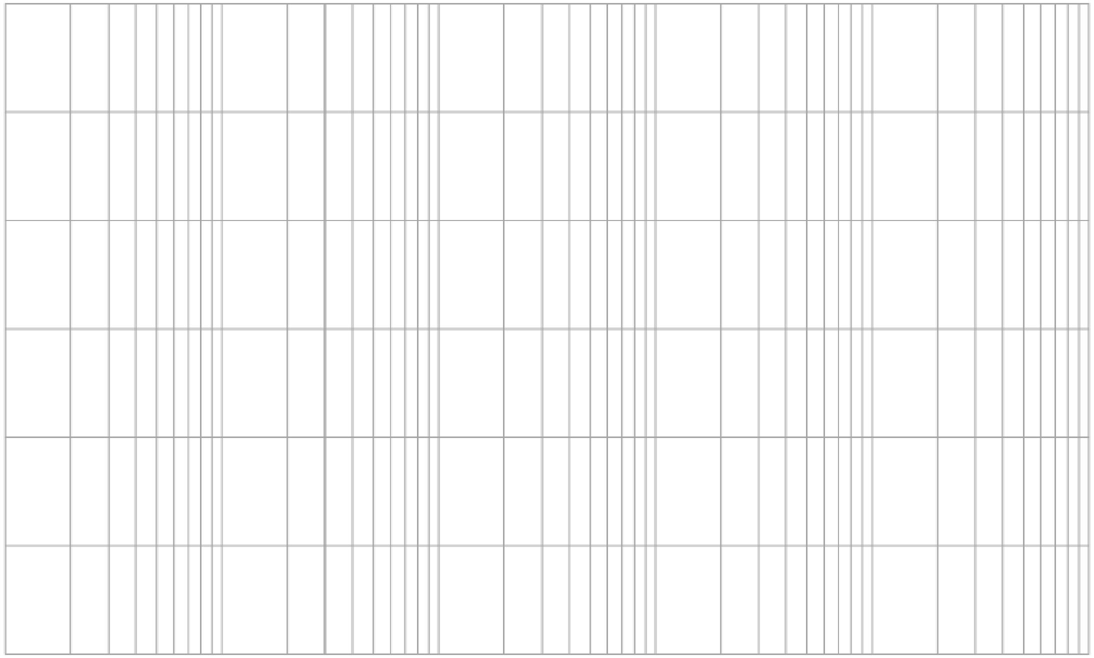
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$$

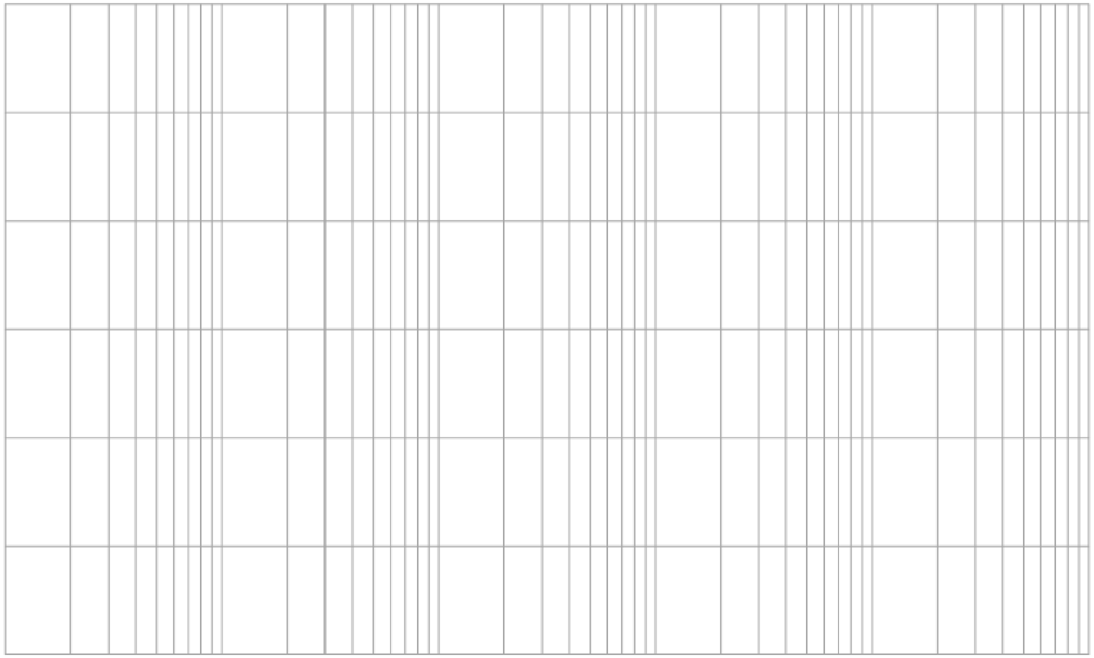
$$G_{oRs}\left(s\right) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

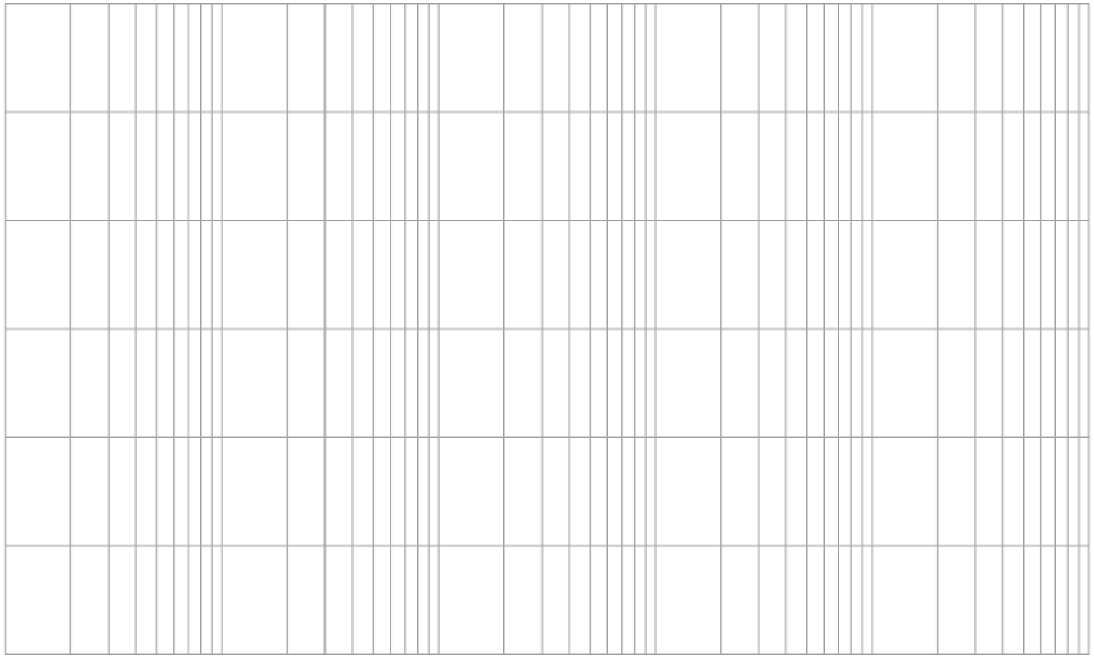
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



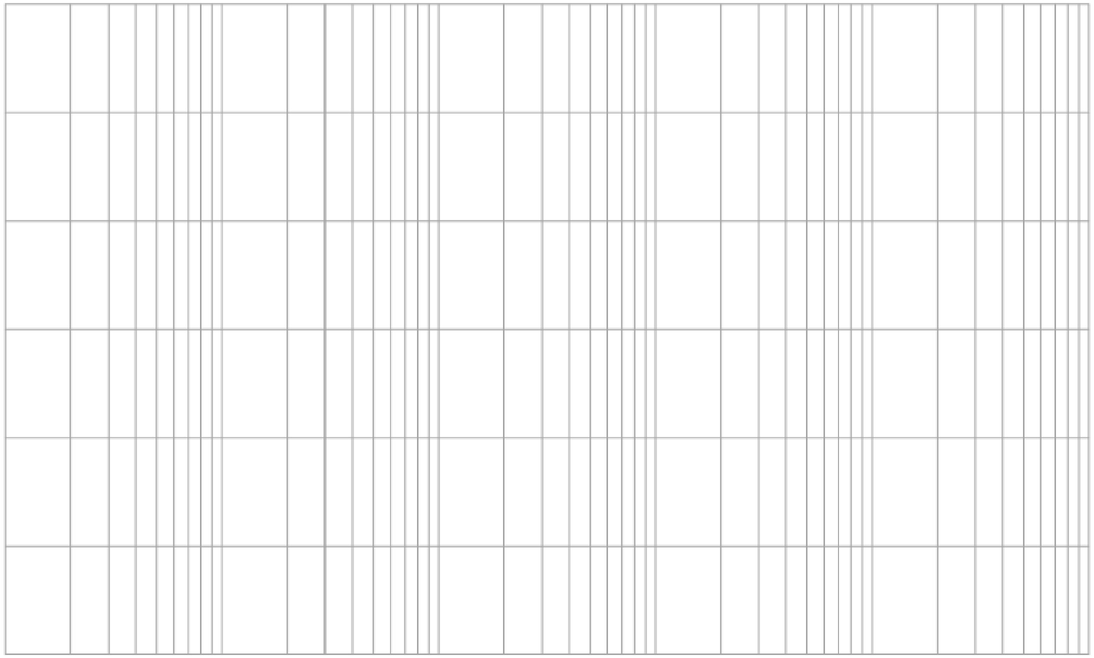


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



ω [rad/s]

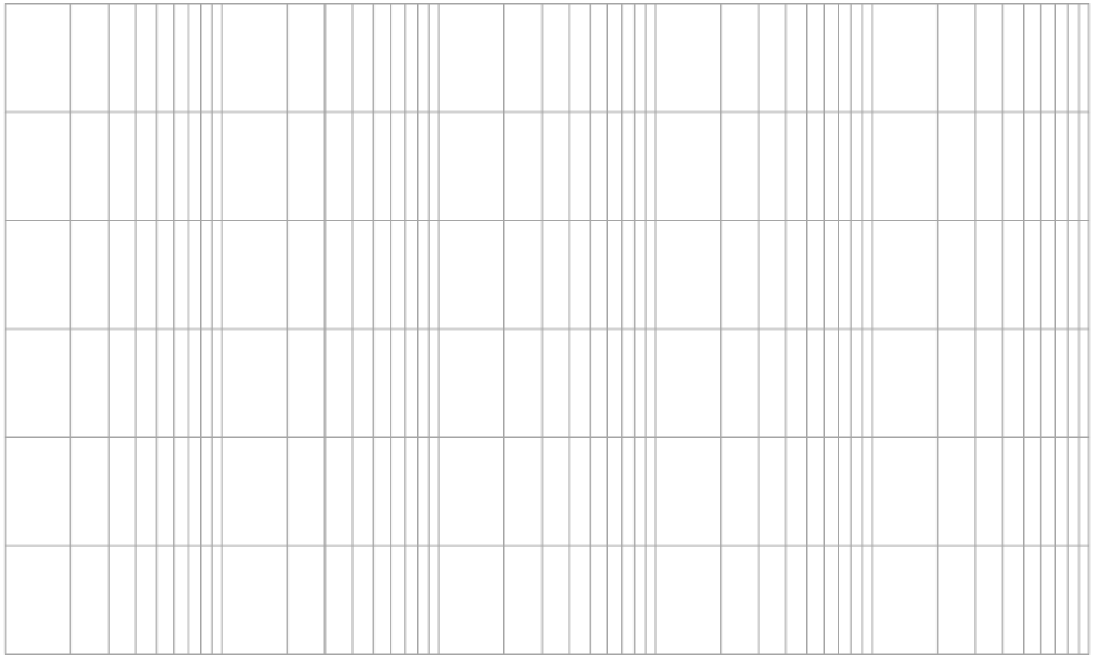


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

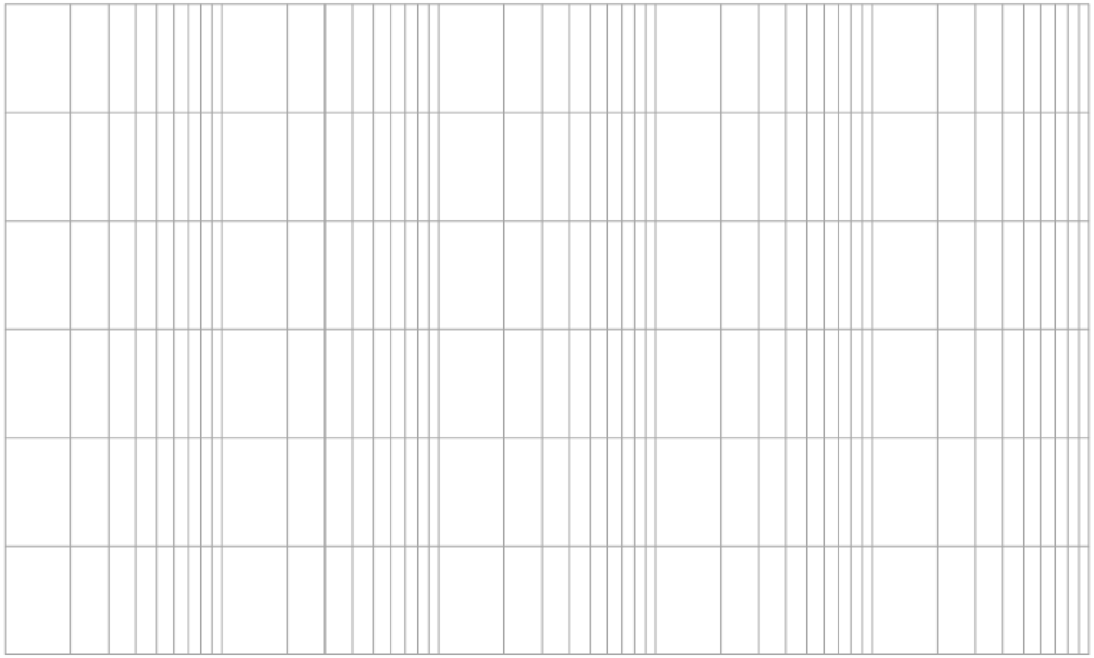
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$L_{oRs}(\omega)$

[dB]



ω [rad/s]

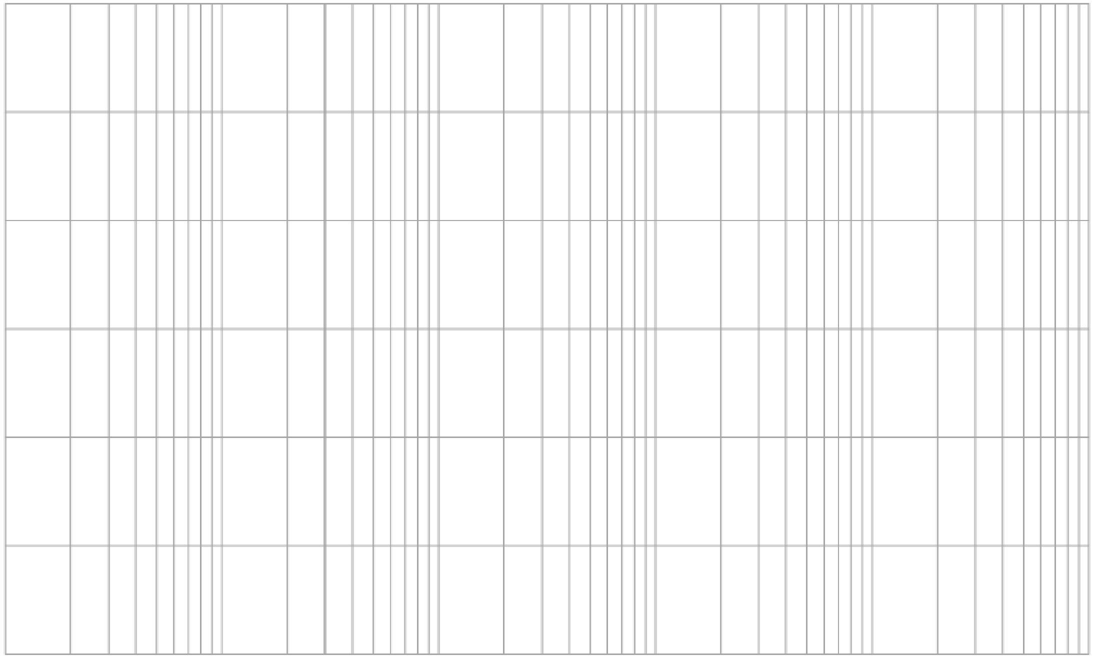


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$L_{oRs}(\omega)$

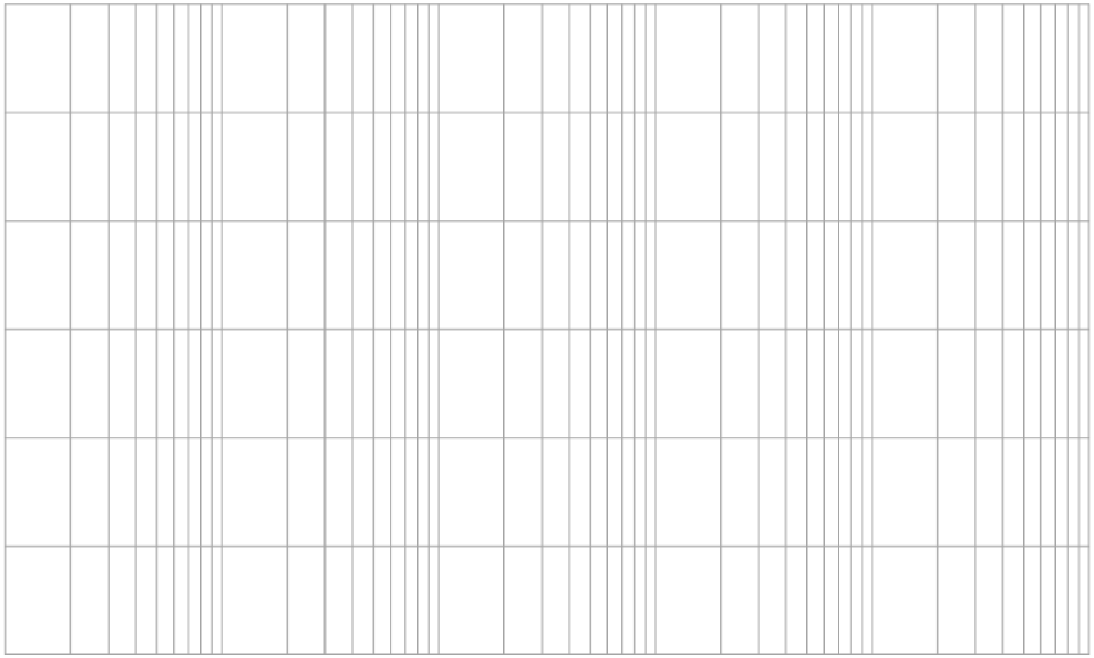
[dB]



ω [rad/s]

$\varphi_{oRs}(\omega)$

[°]

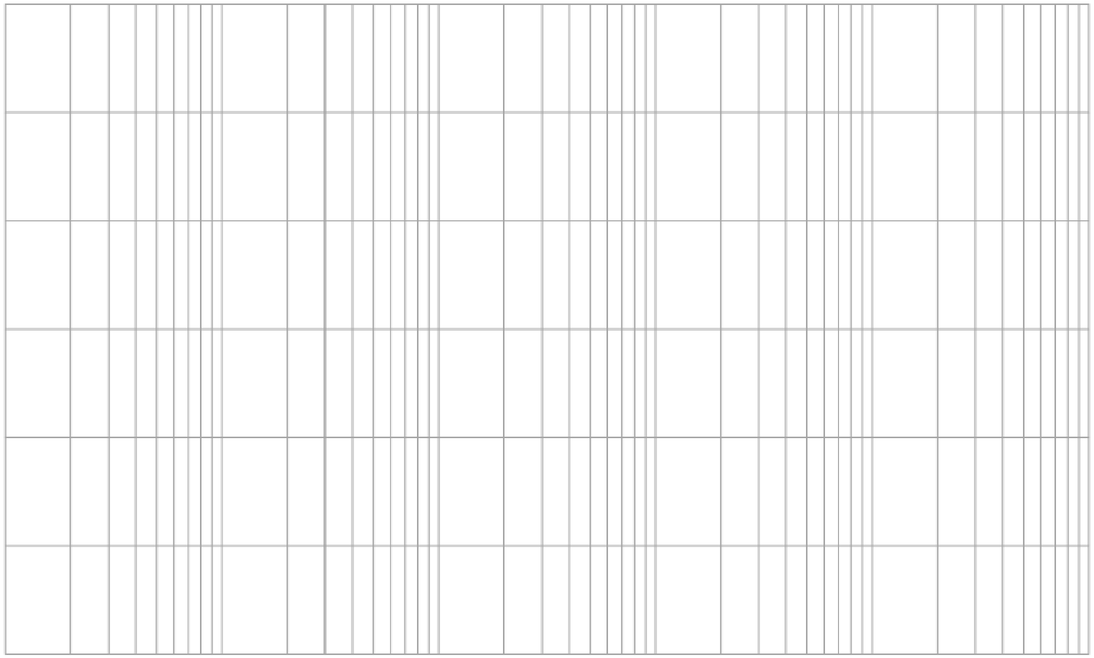


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$L_{oRs}(\omega)$

[dB]

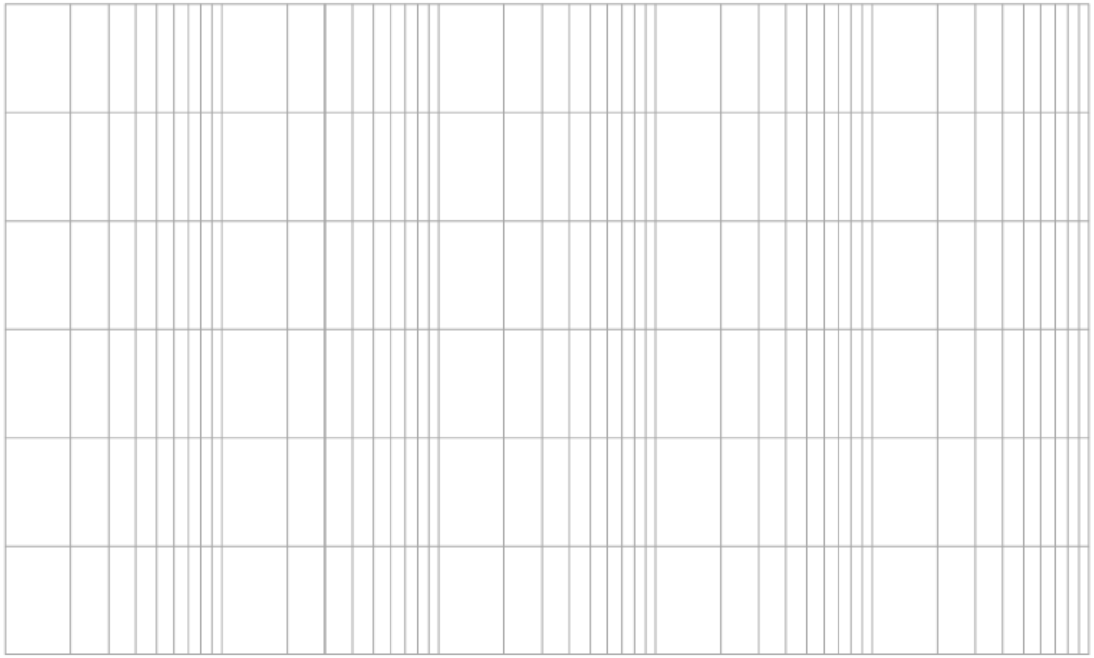


0,001

ω [rad/s]

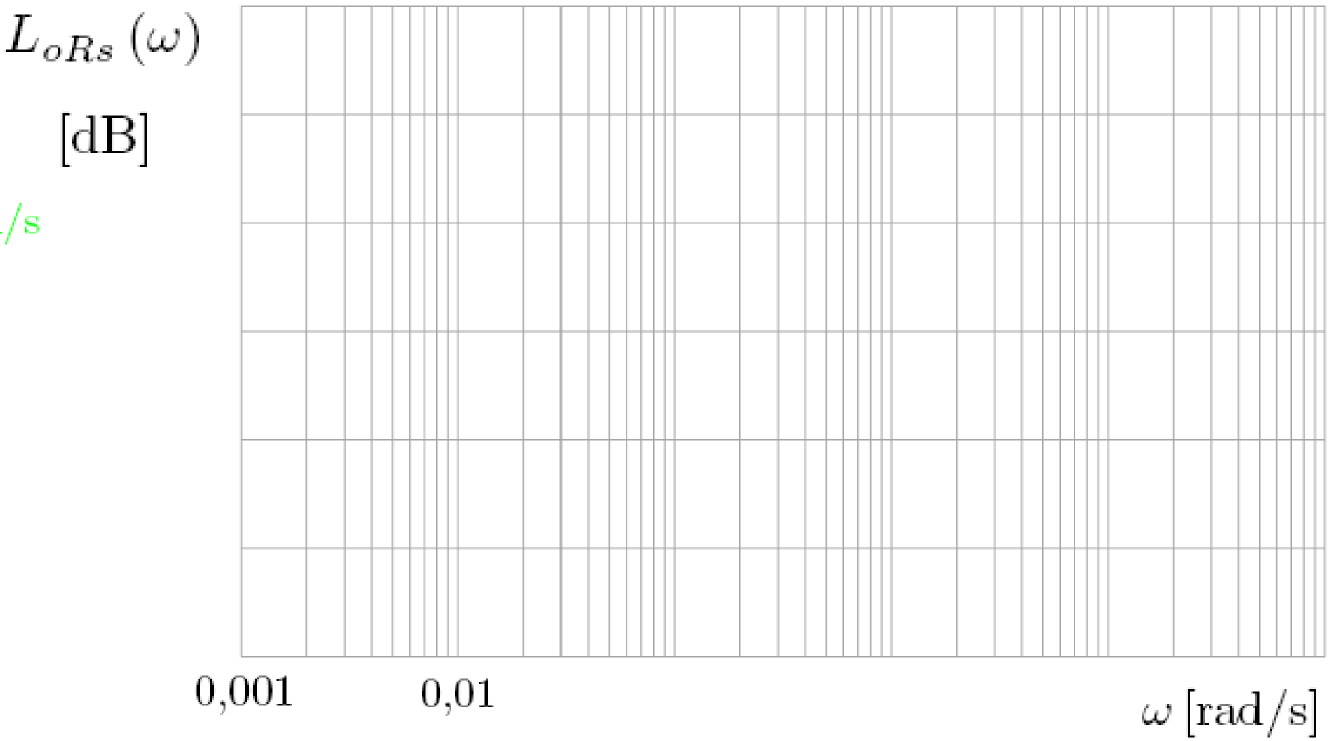
$\varphi_{oRs}(\omega)$

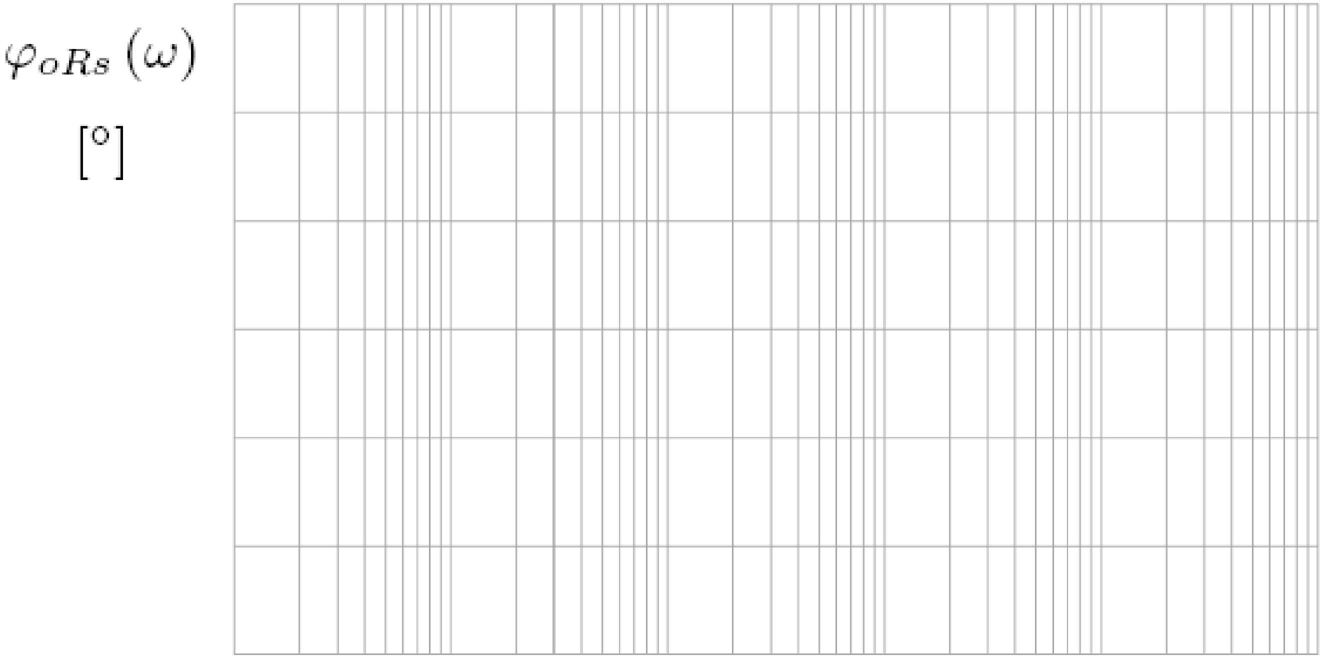
[°]



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

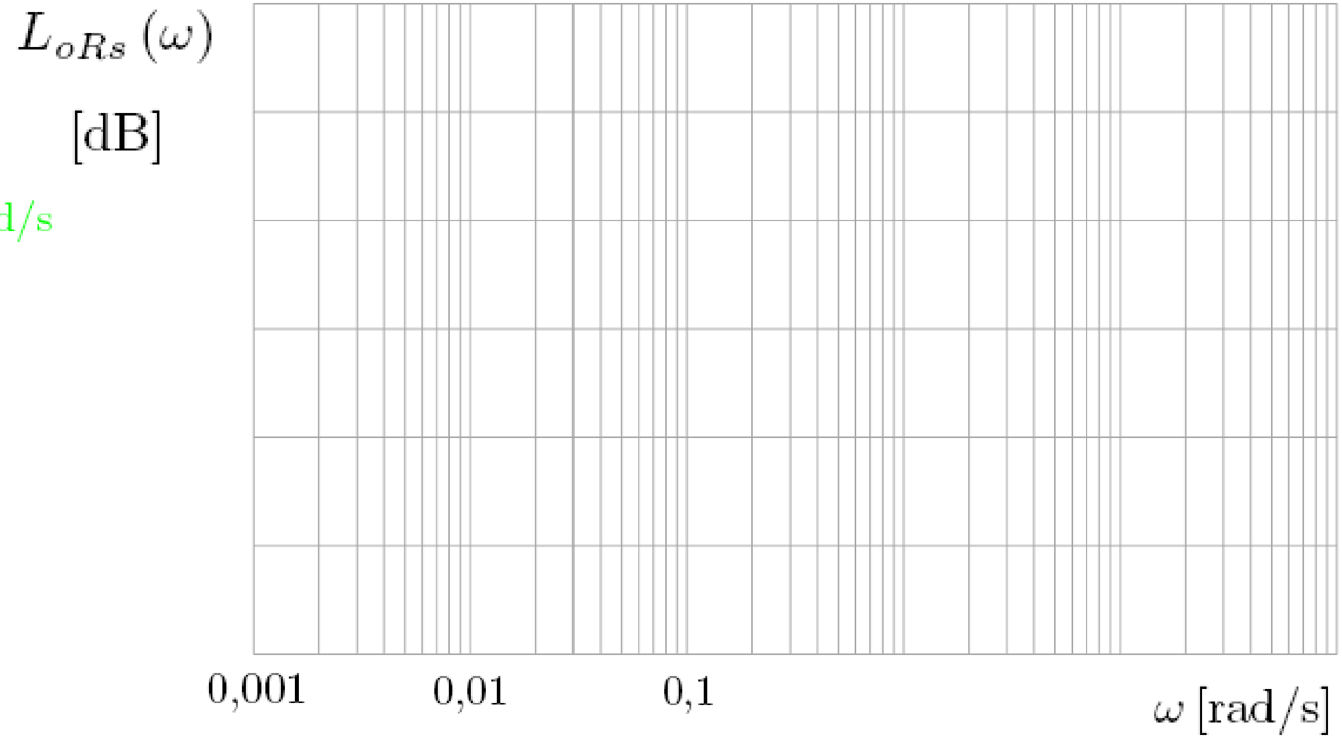
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

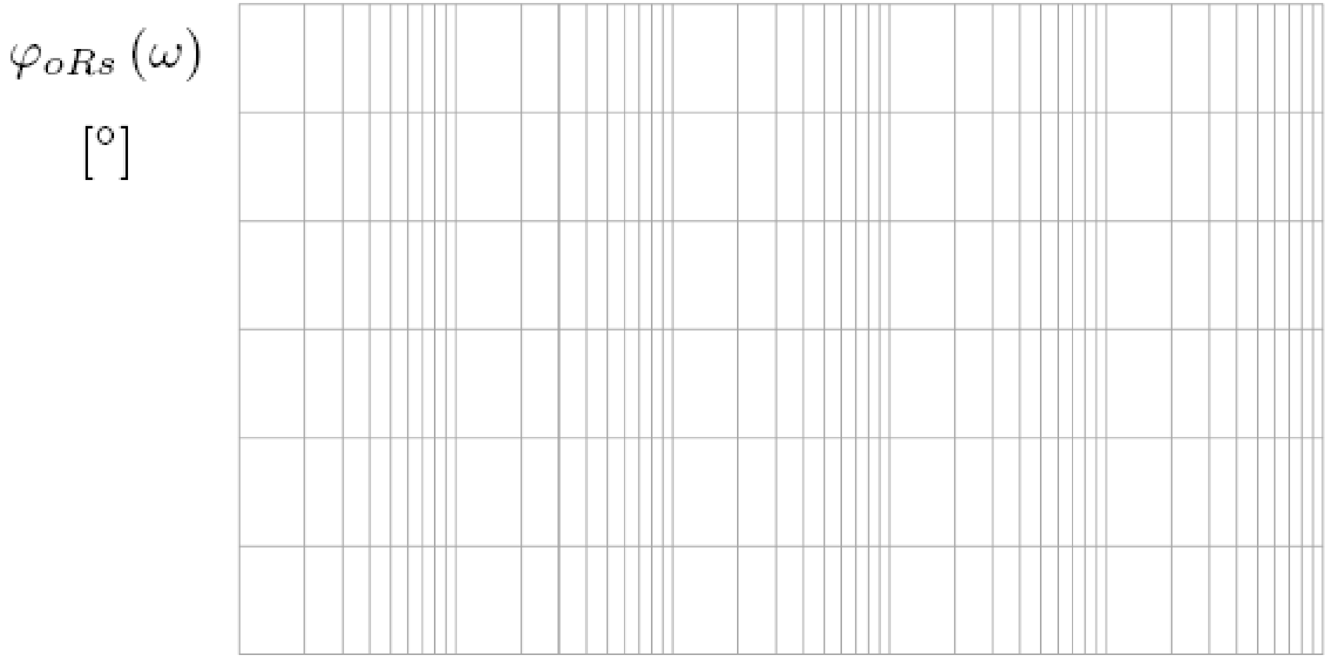




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

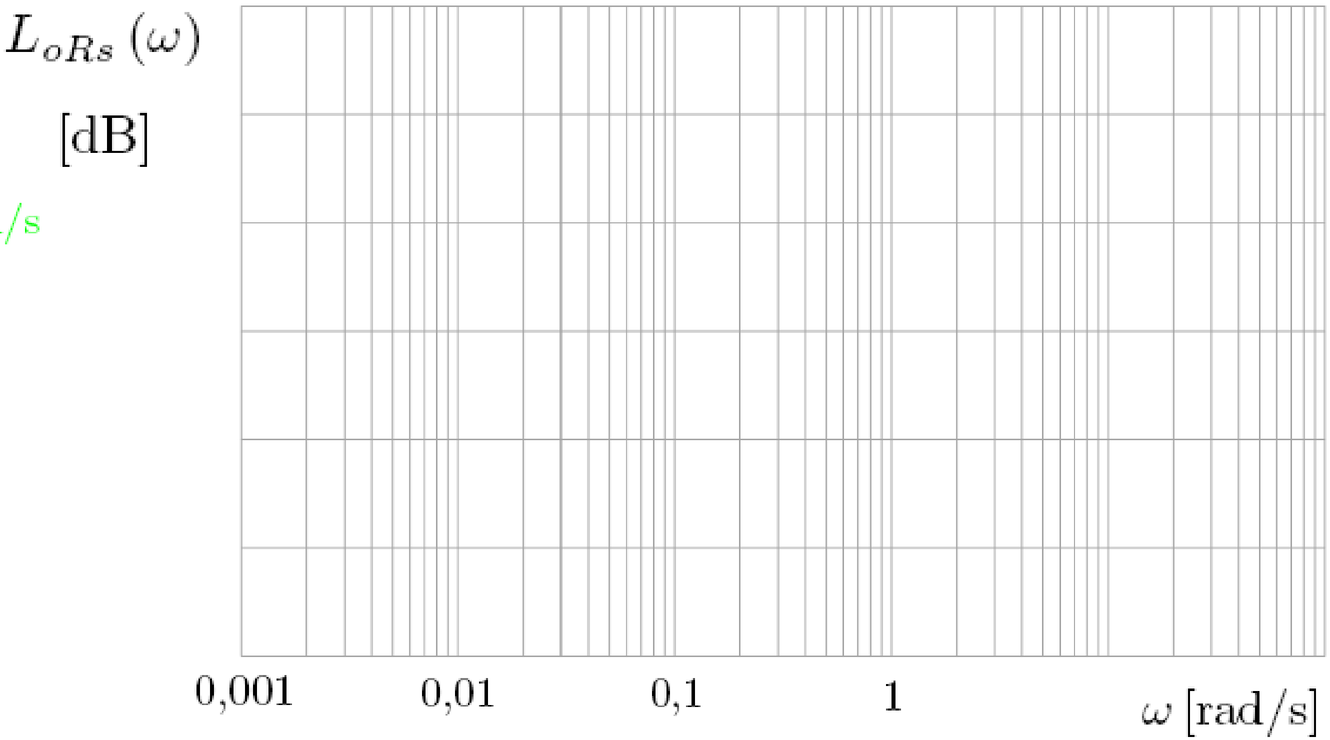
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

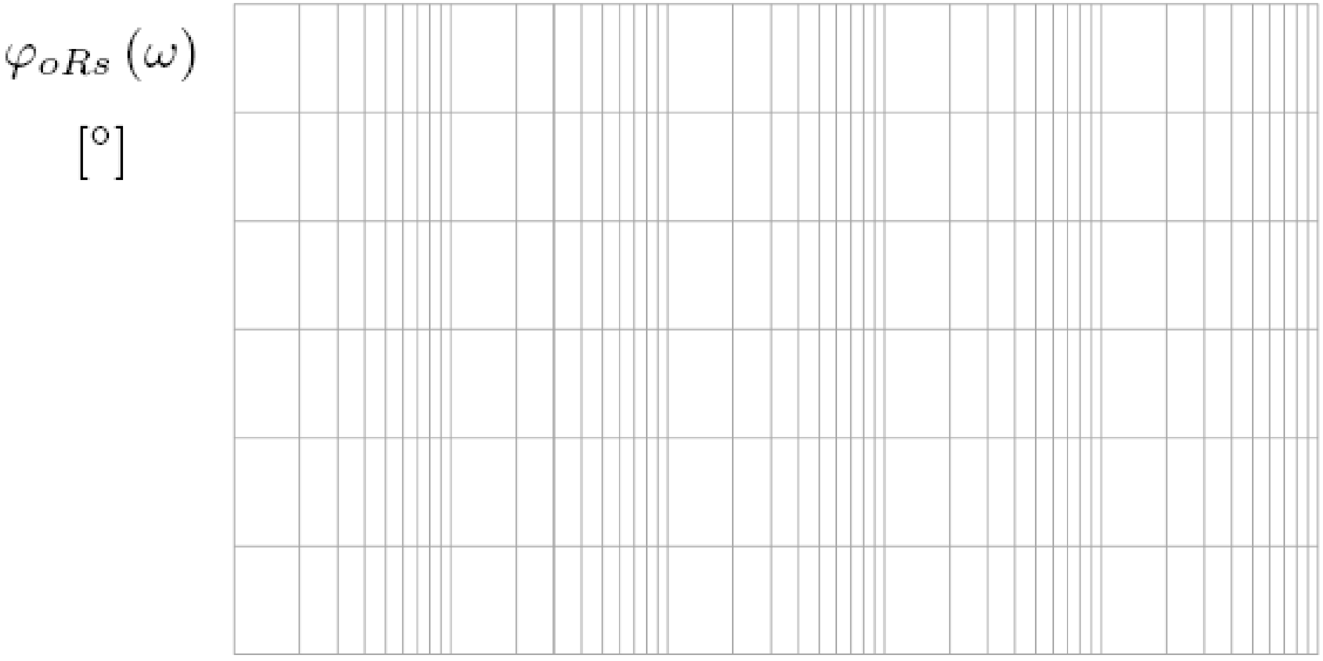




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

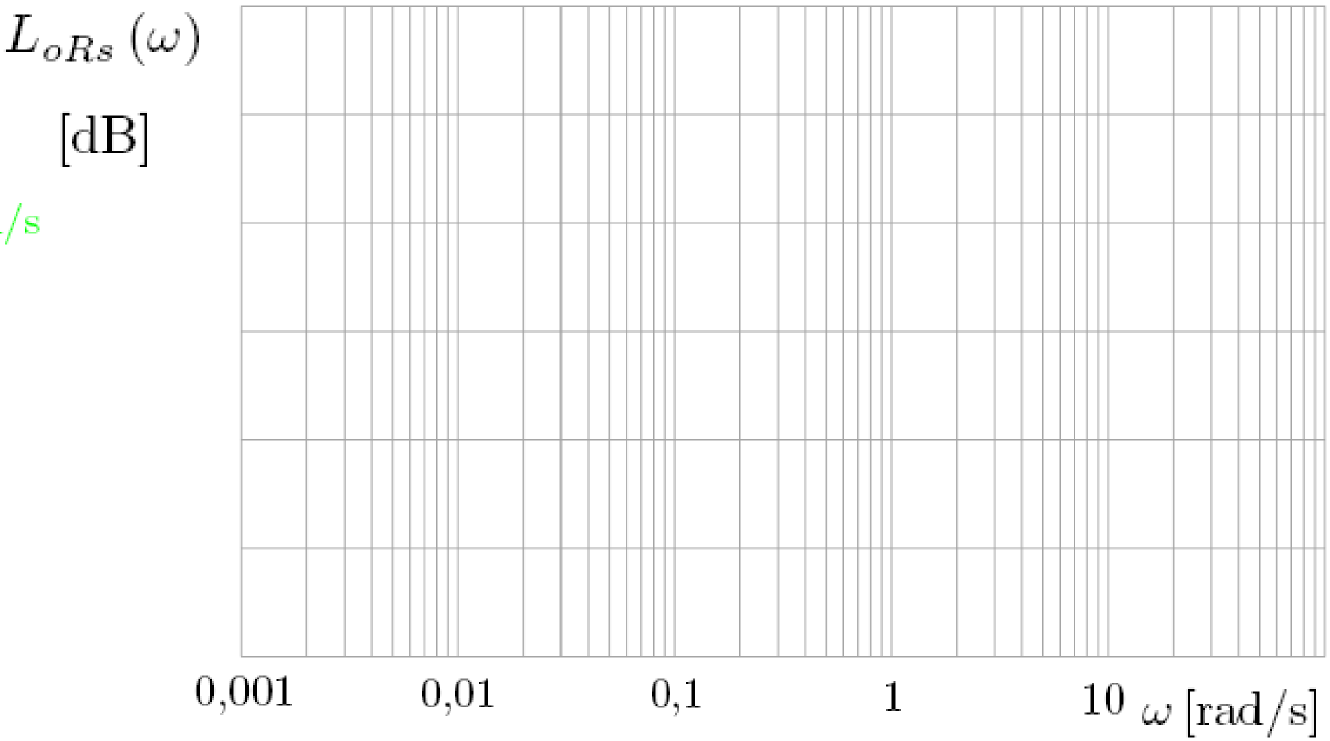
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

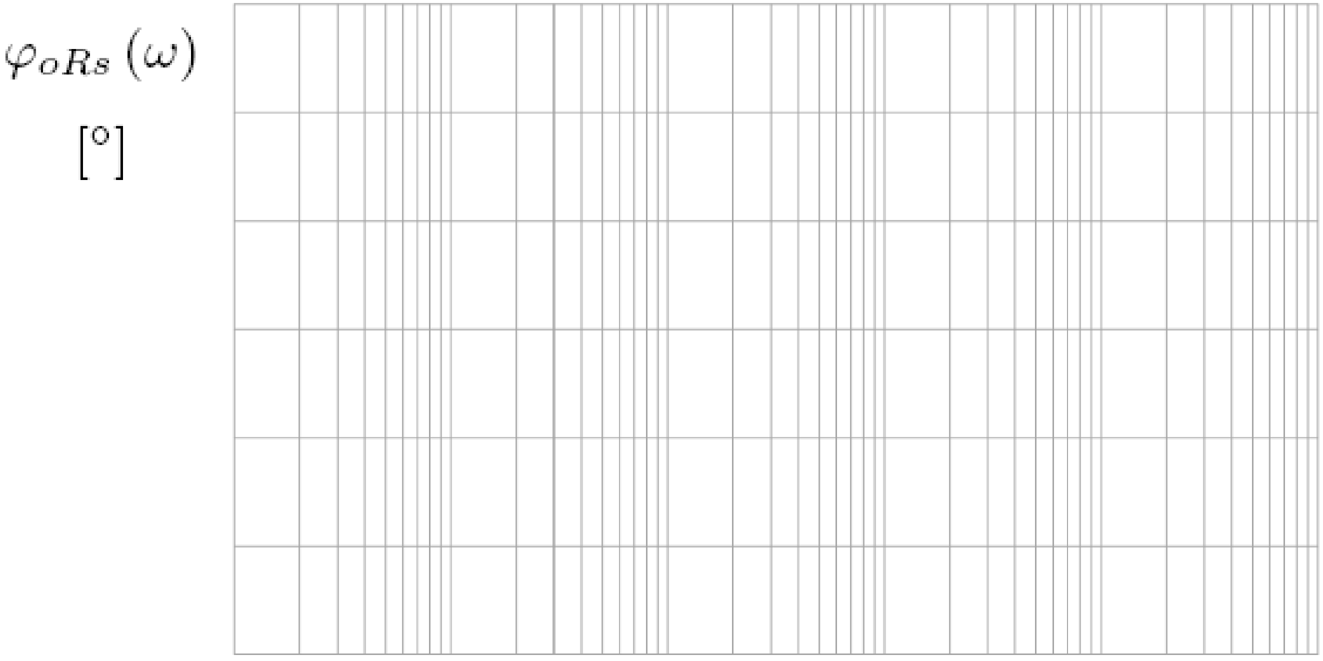




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

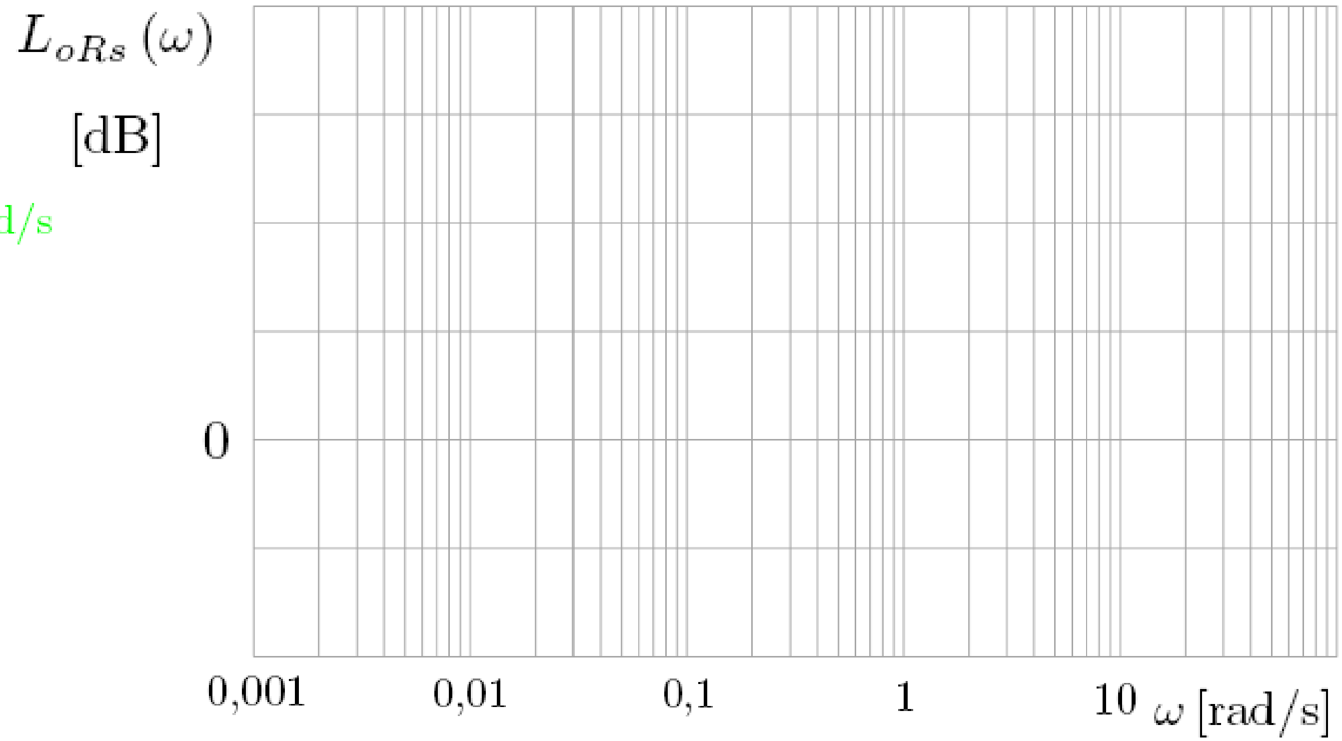
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

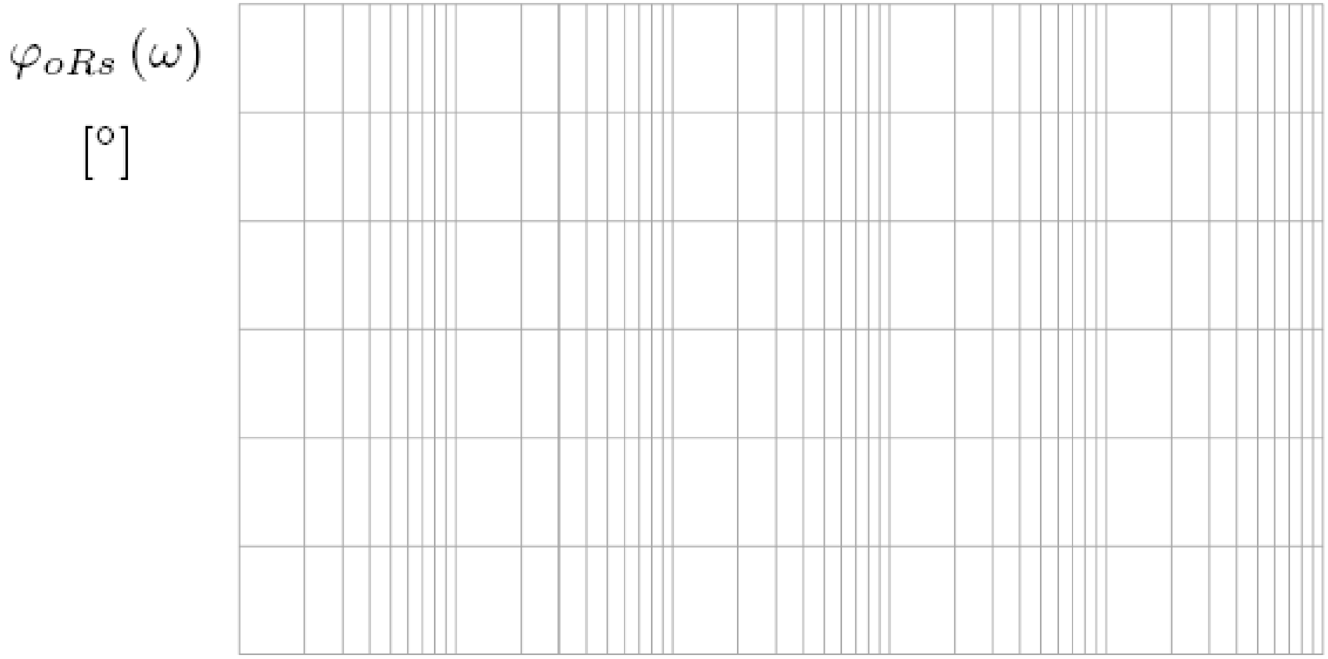




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

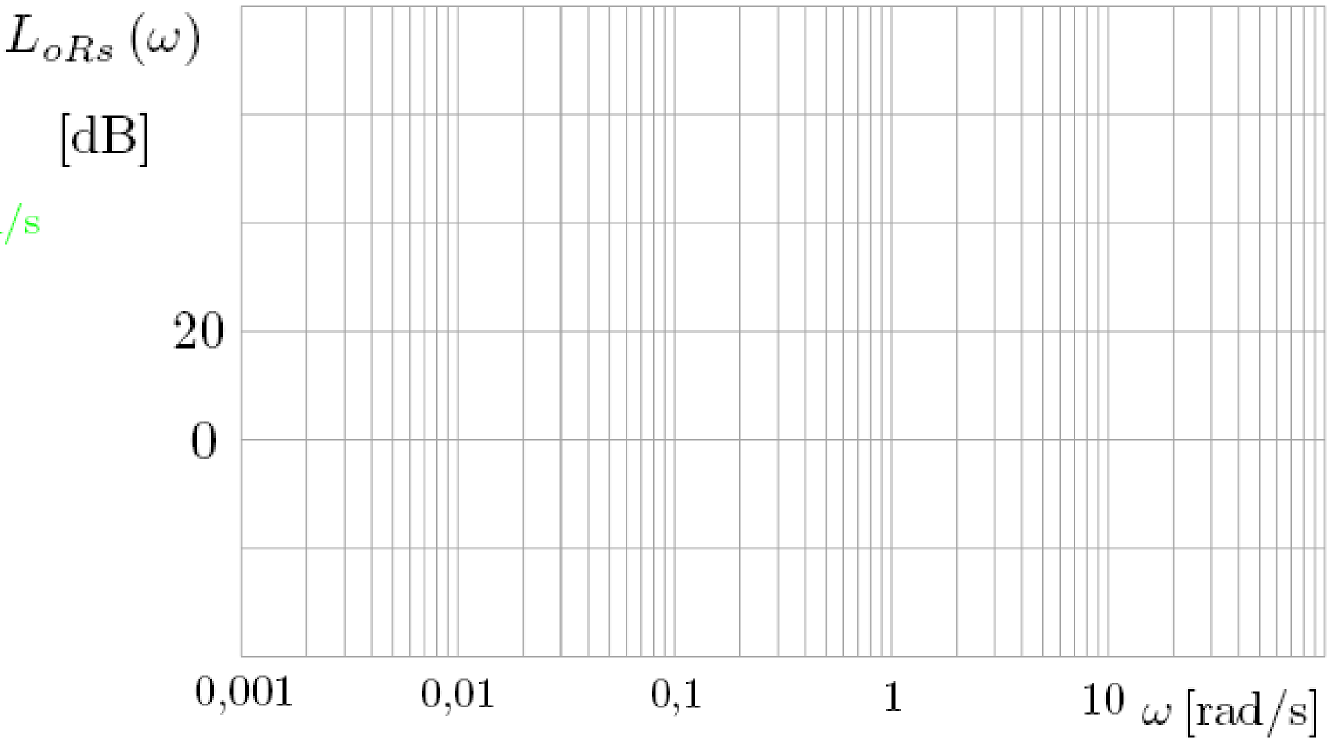
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

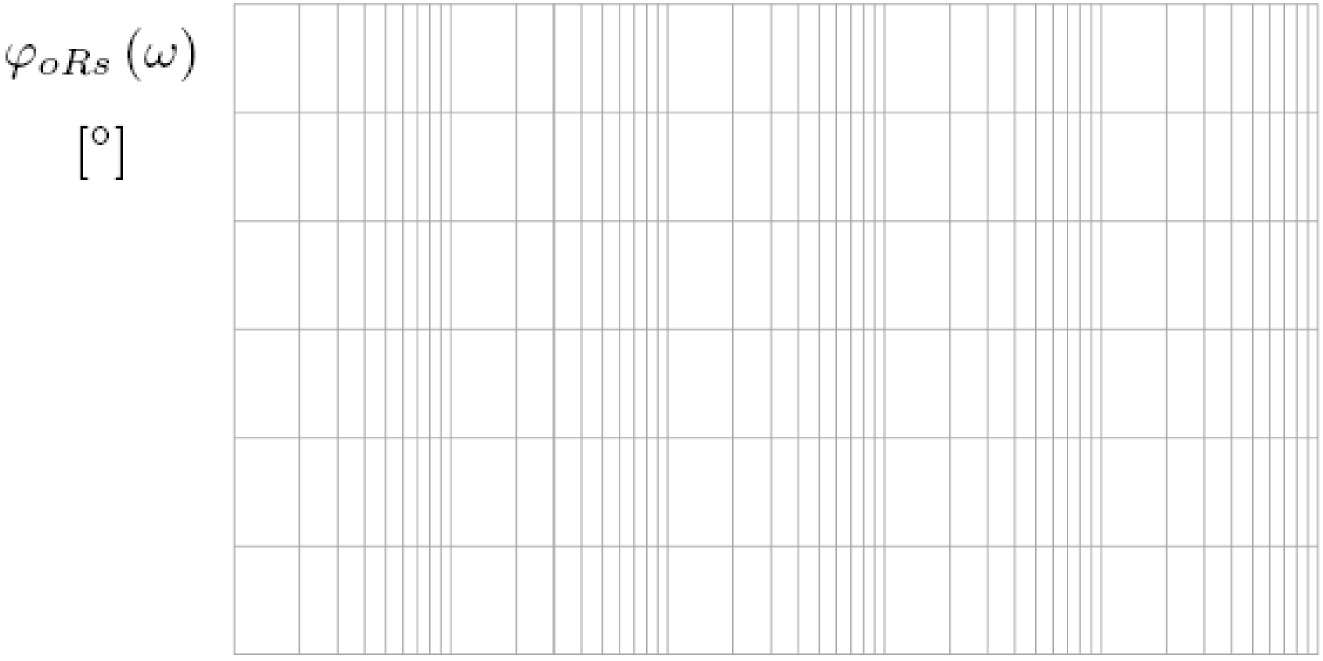




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

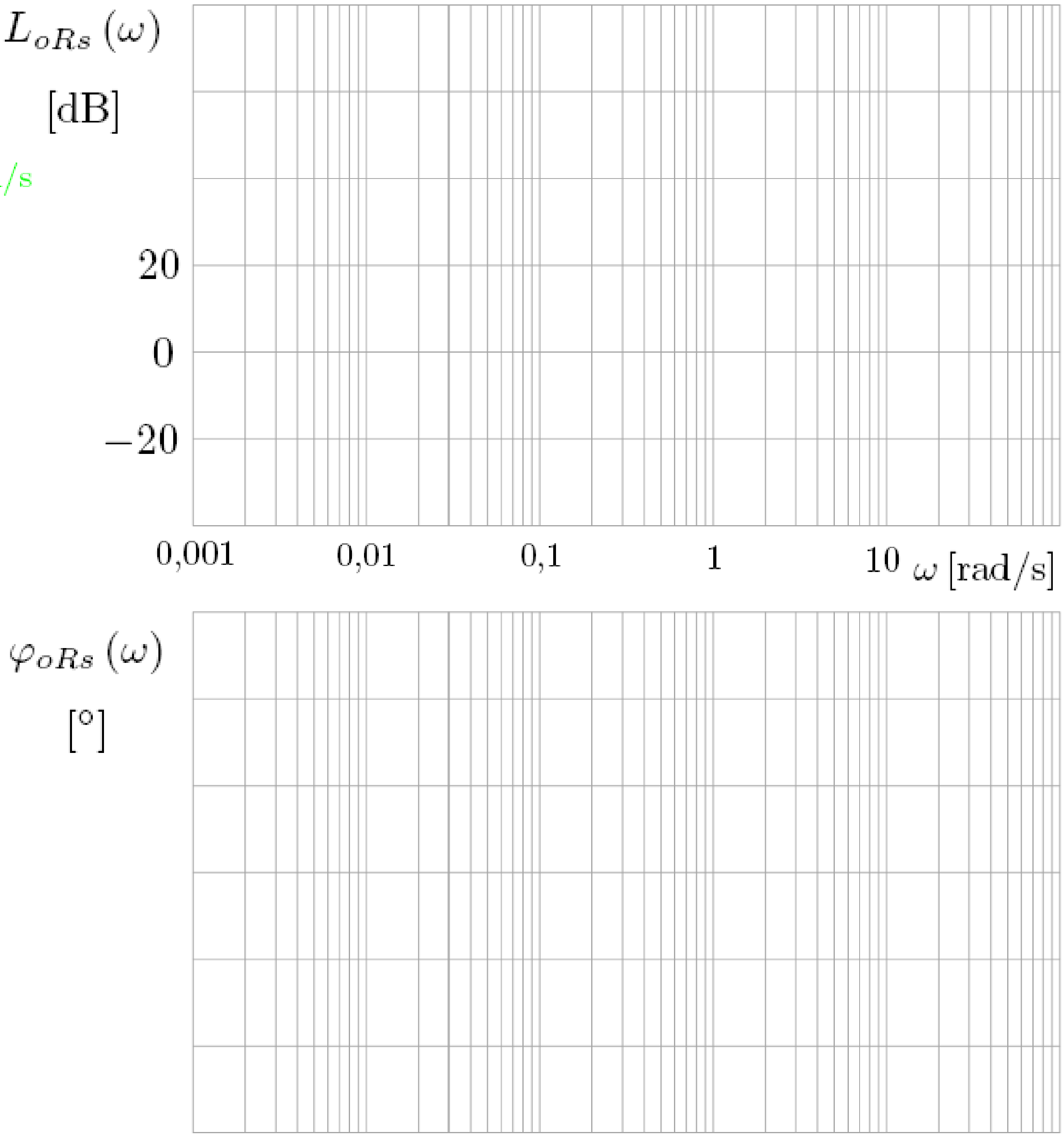
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$





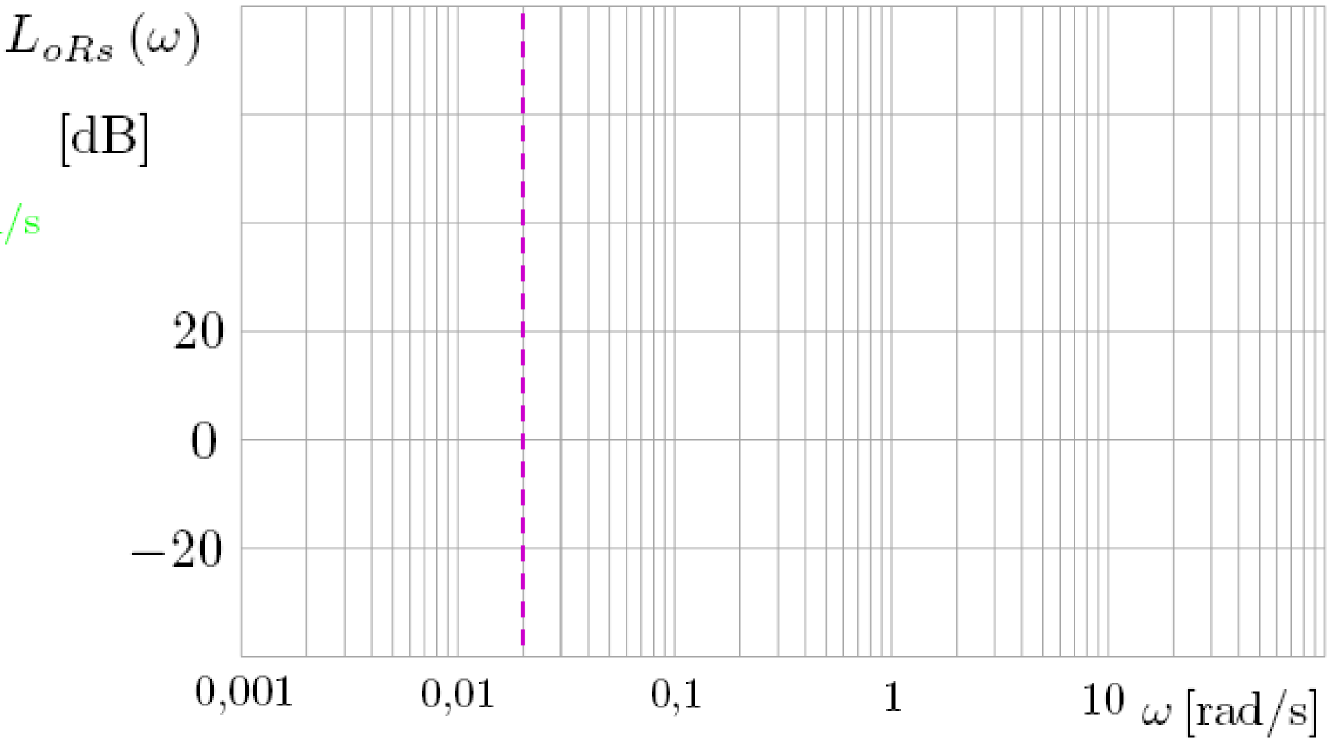
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

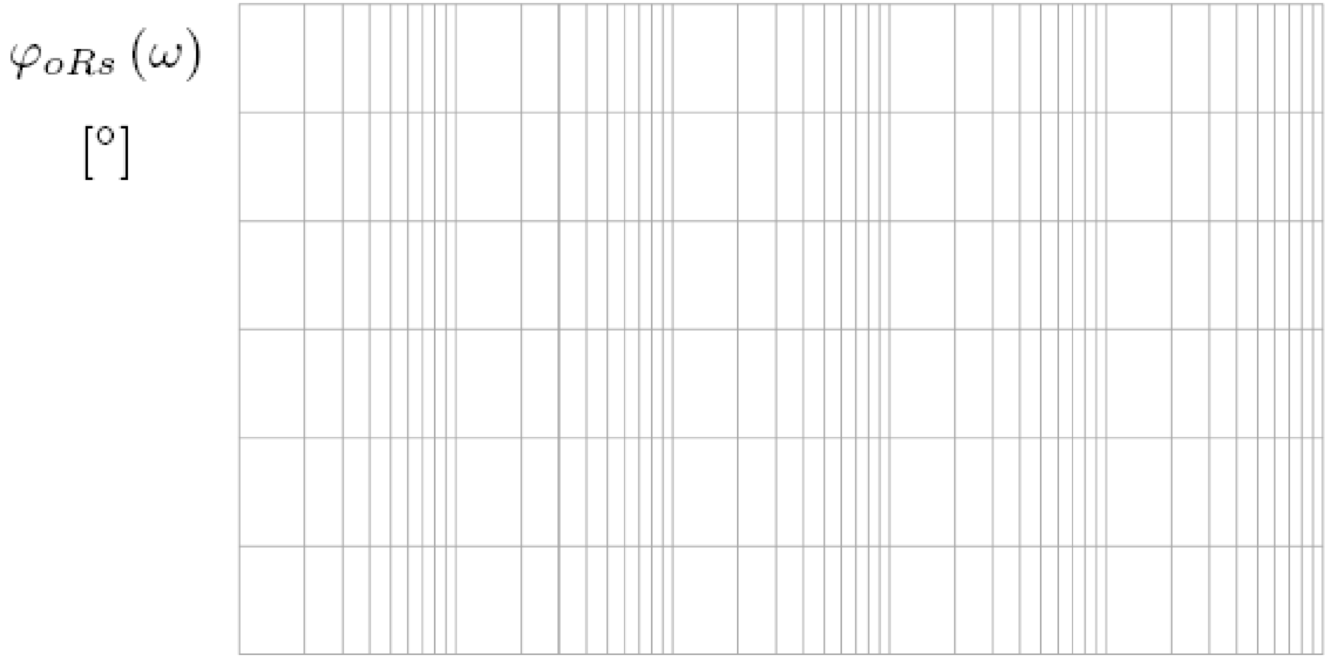
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

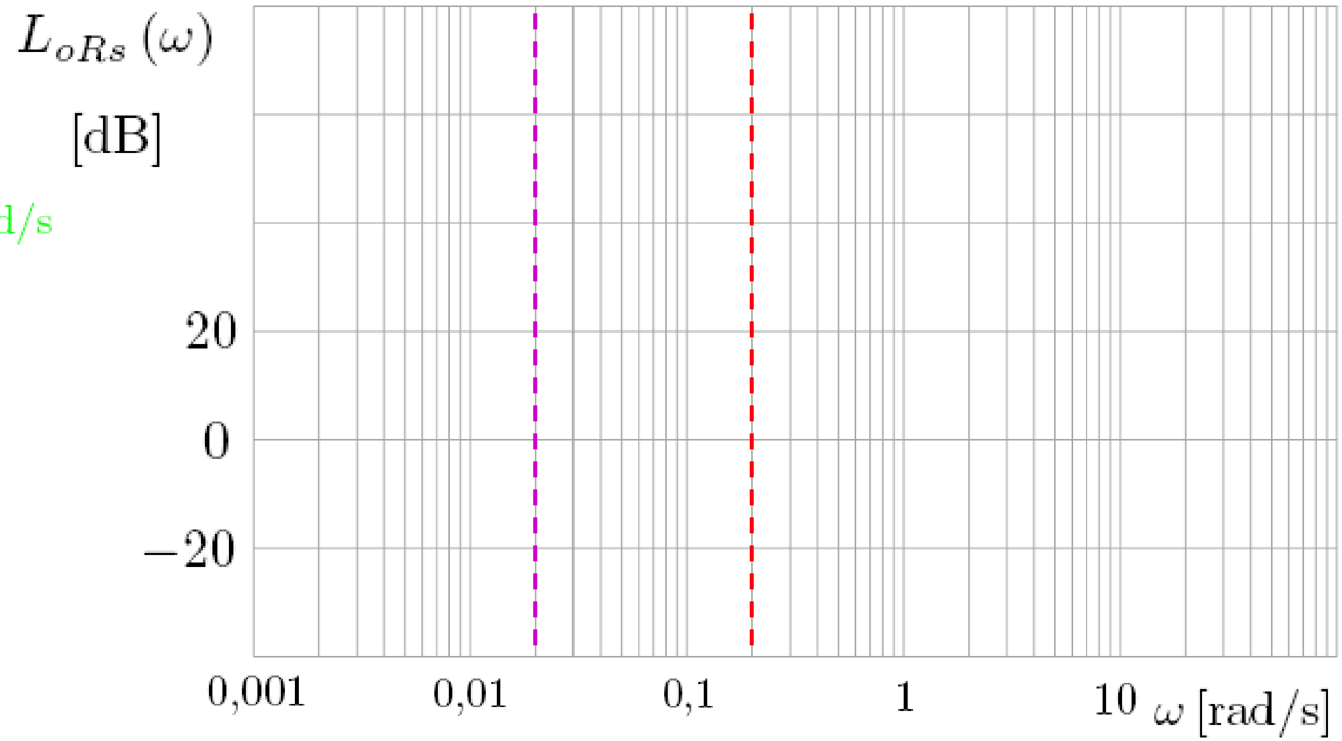
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

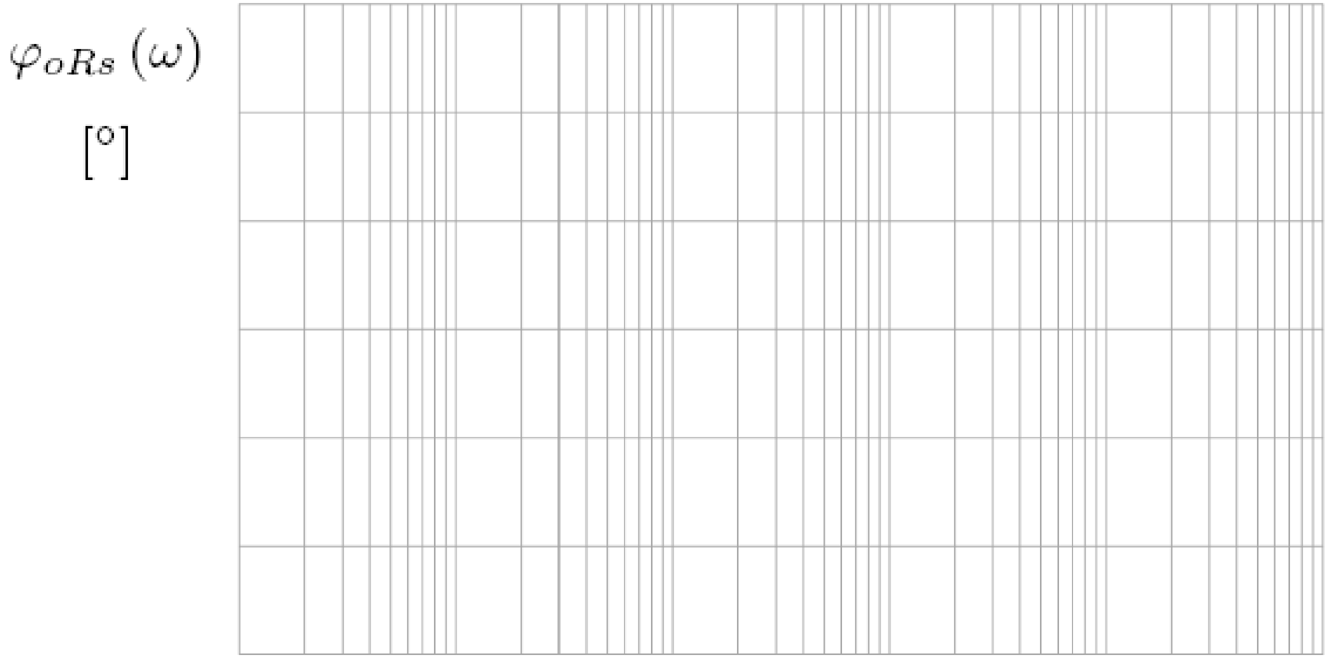




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

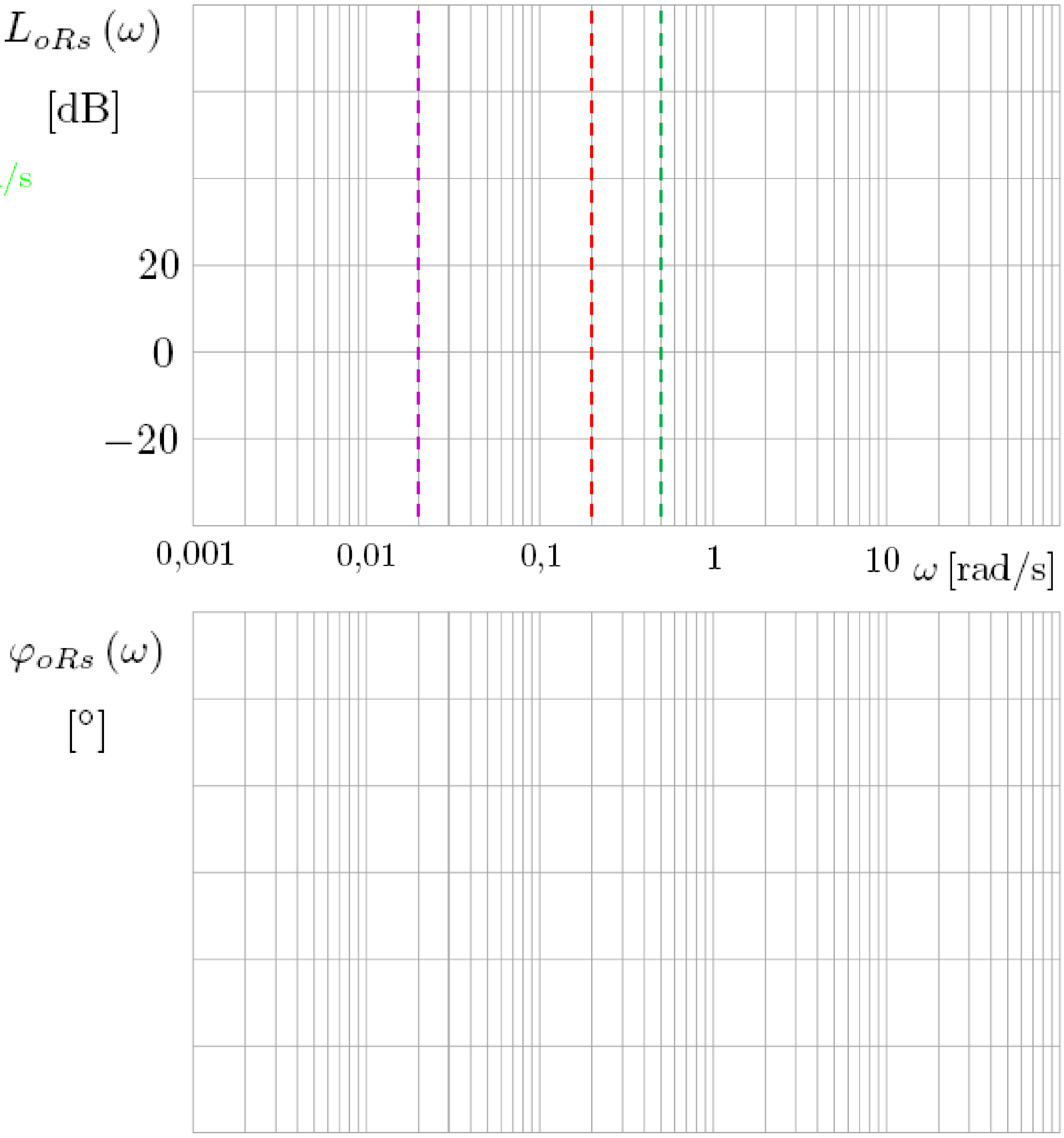
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$





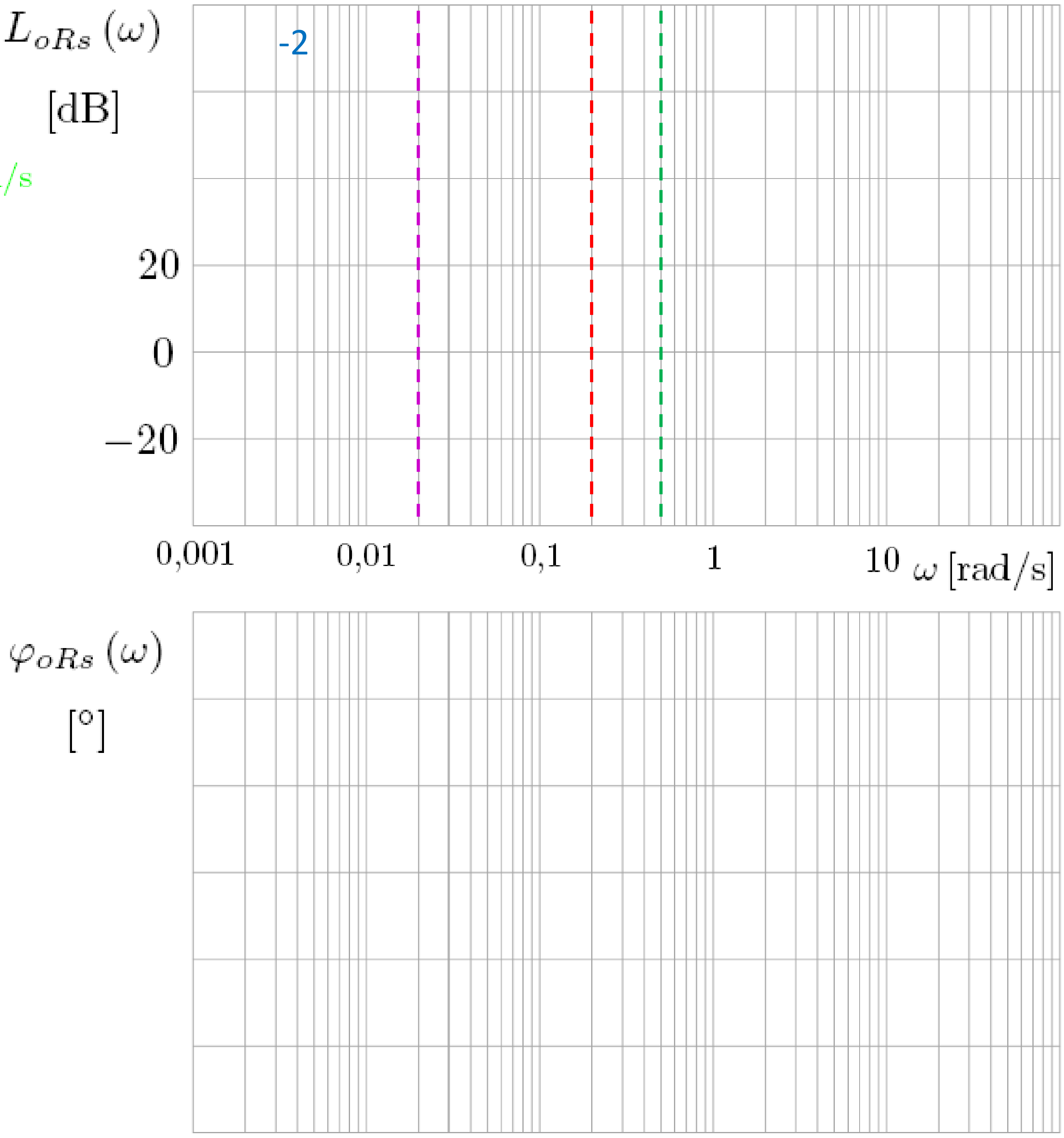
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \quad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \quad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



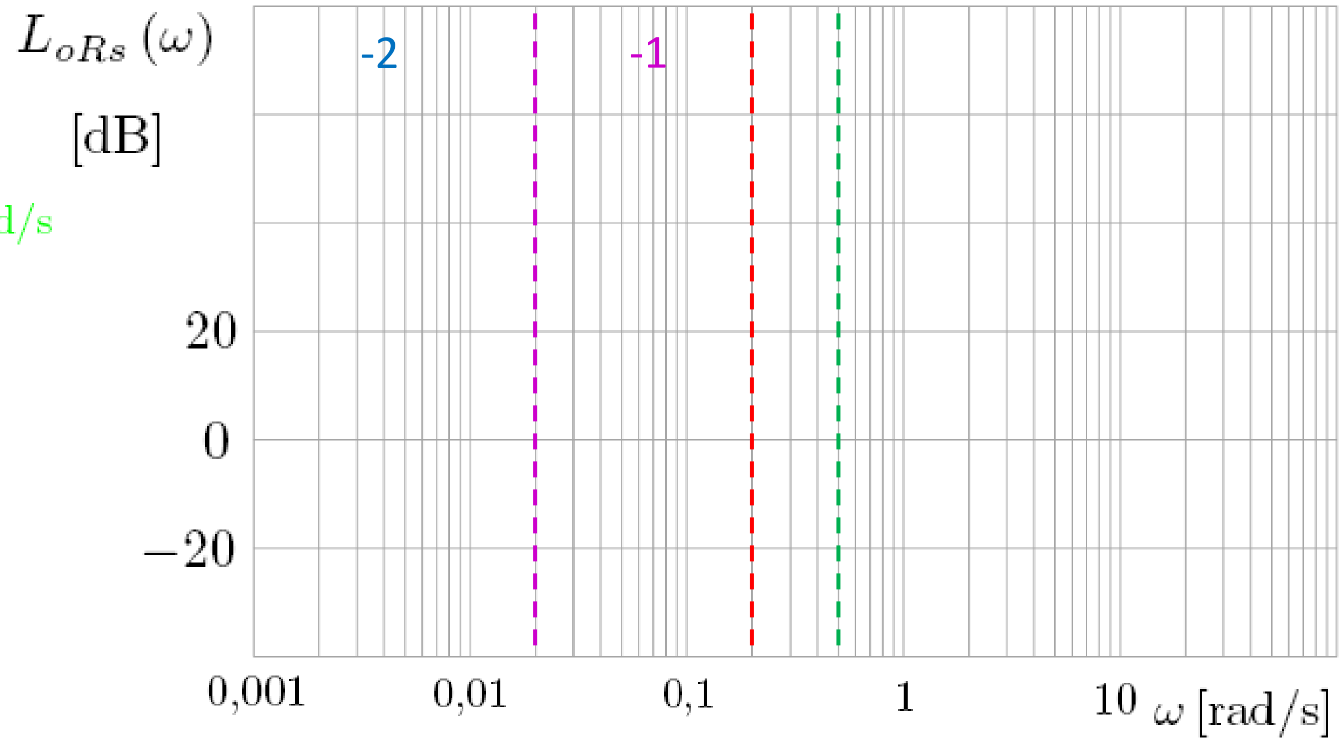
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

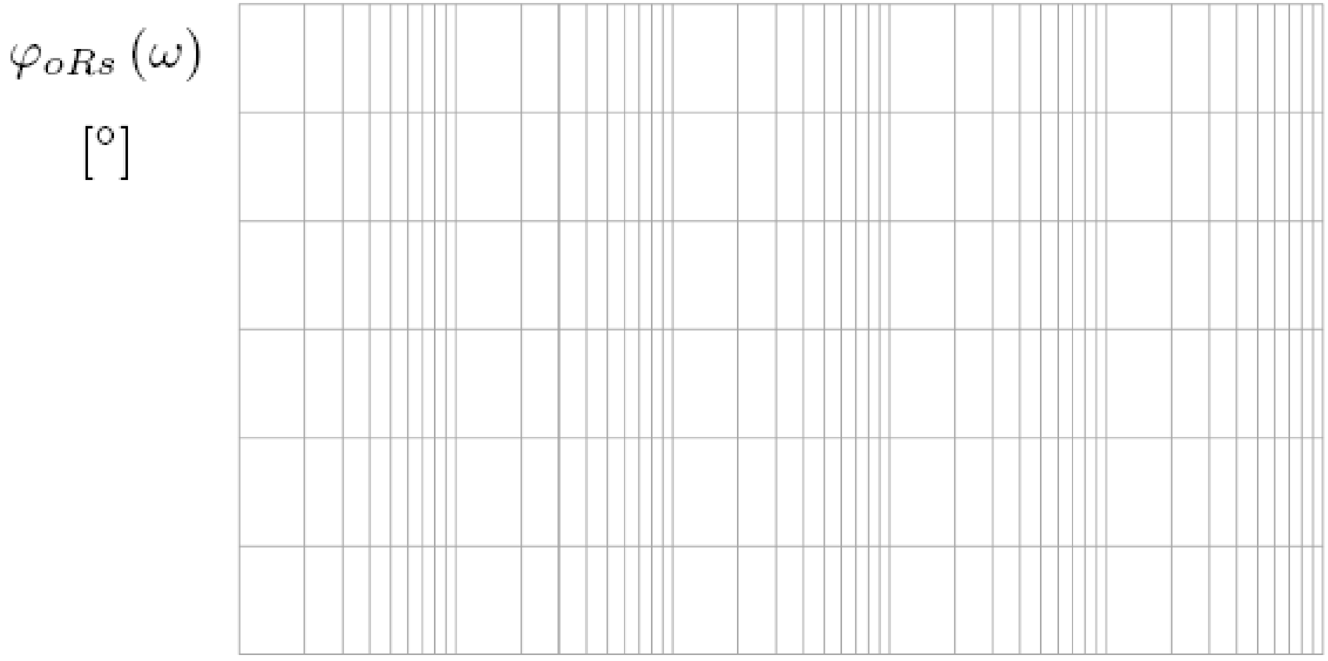
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \quad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \quad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

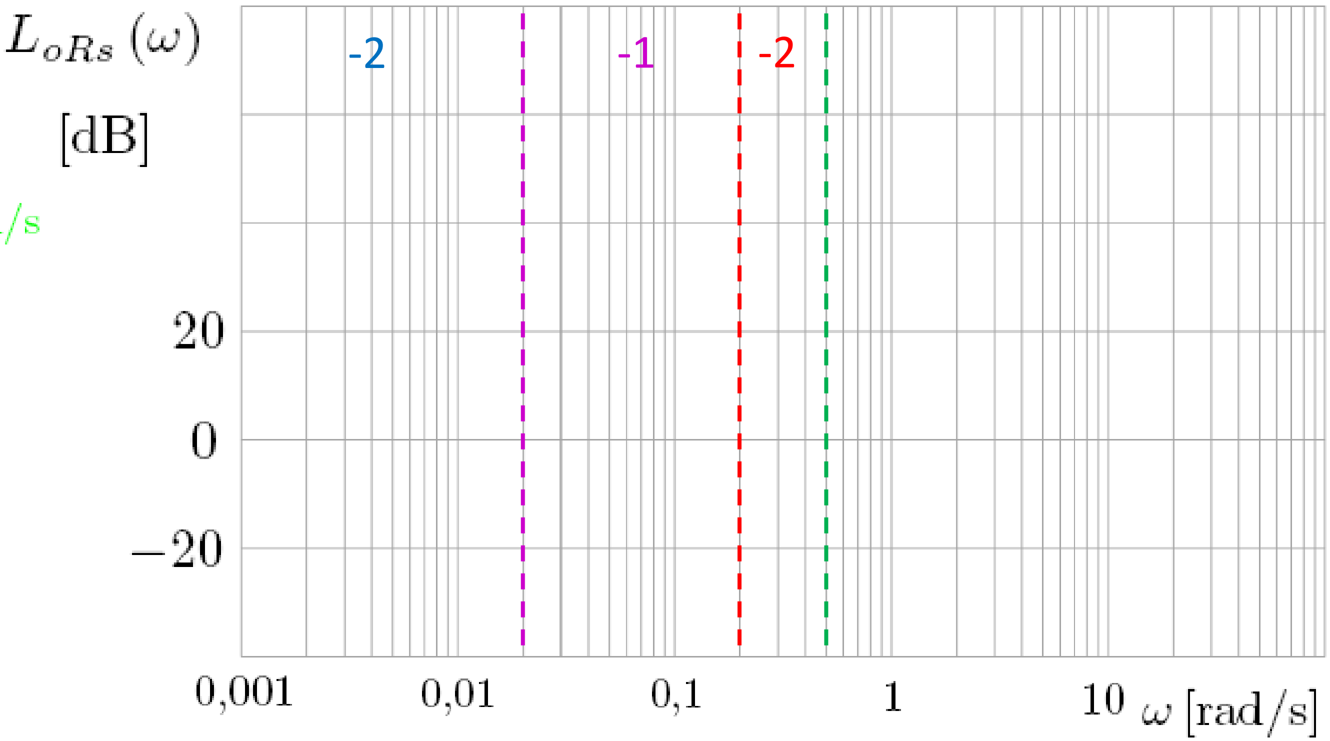
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \quad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \quad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

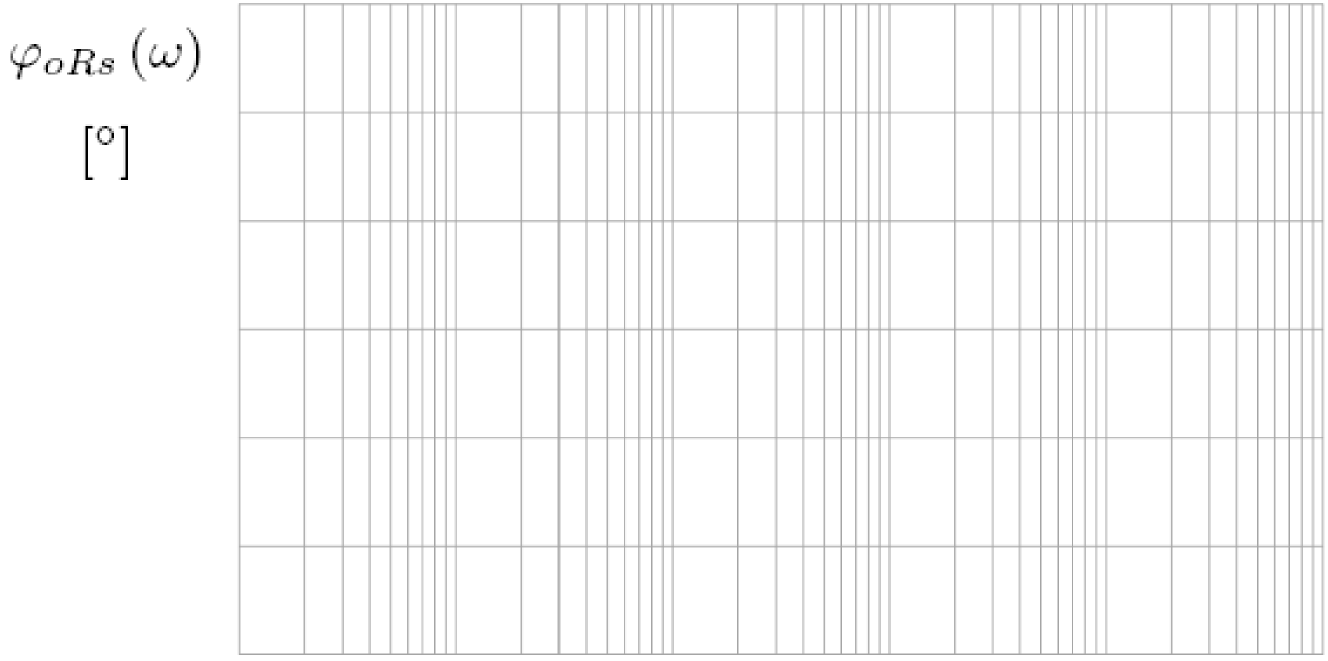




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

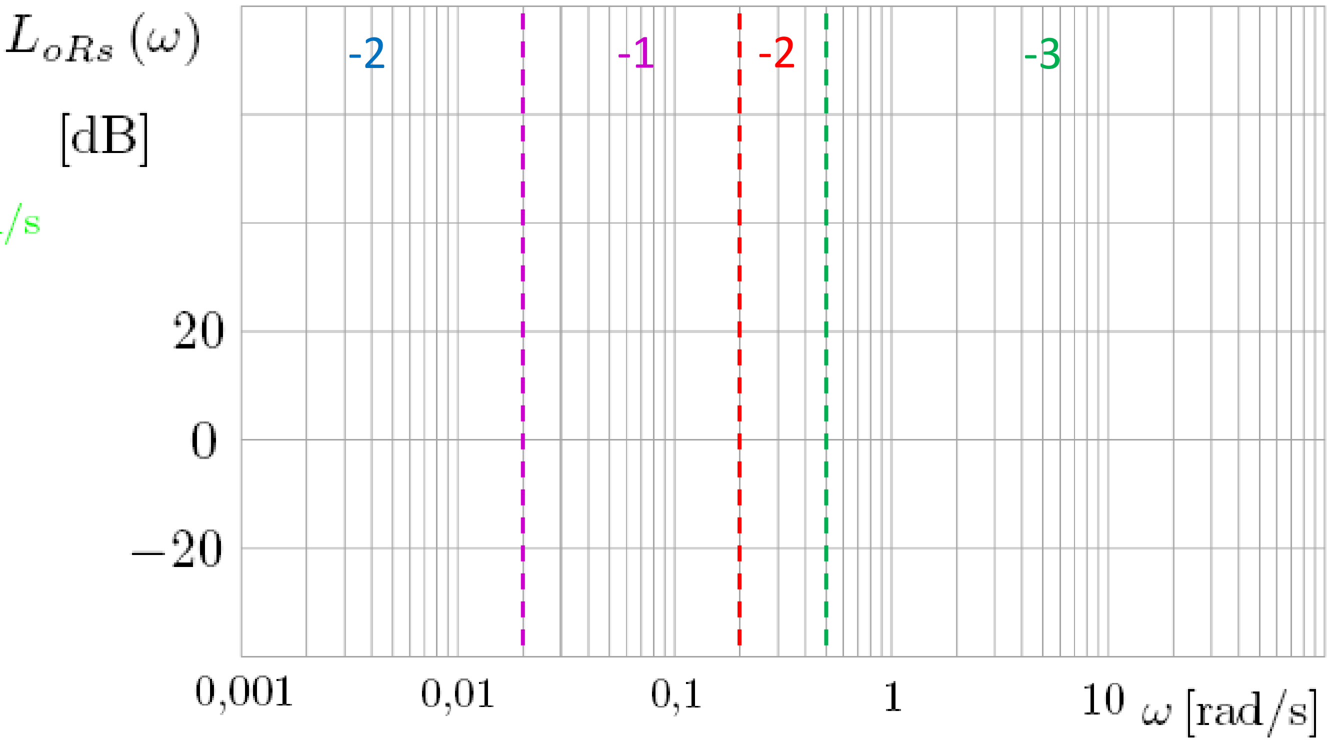
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \quad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \quad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

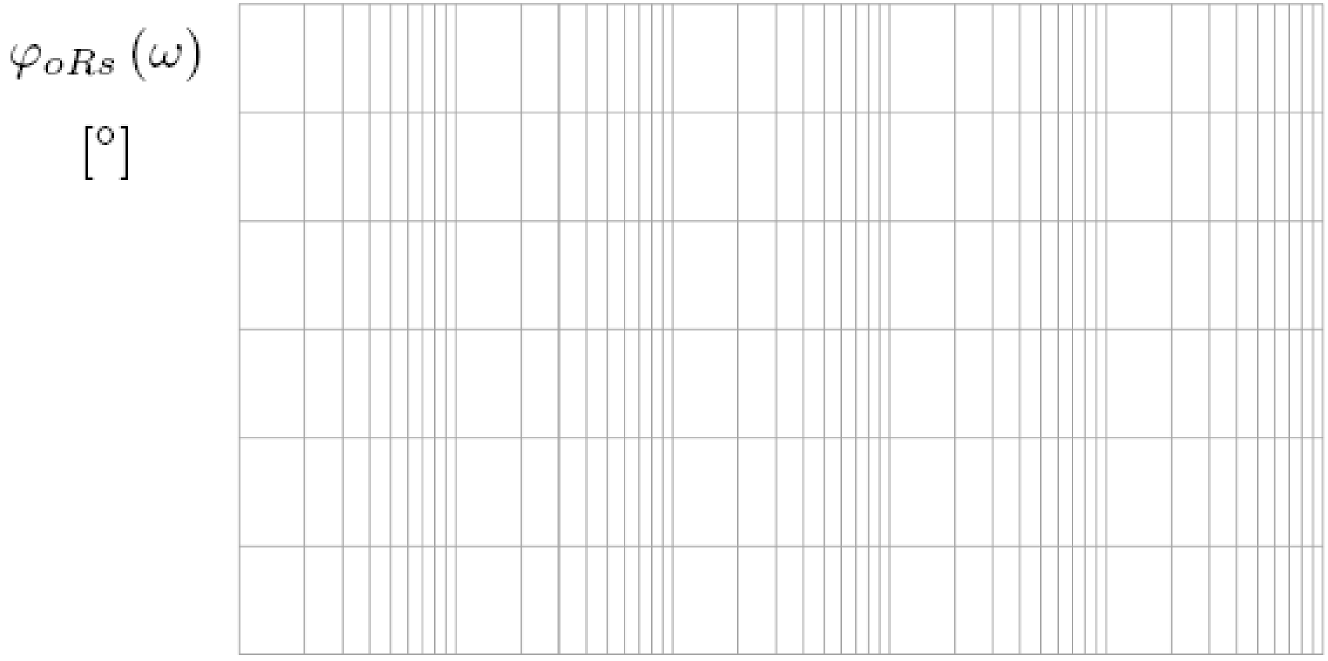




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$\omega_{Is} = \frac{1}{50} = 0{,}02\ \mathrm{rad/s}$ $\quad \omega_2 = \frac{1}{5} = 0{,}2\ \mathrm{rad/s}$ $\quad \omega_{pv} = \frac{1}{2} = 0{,}5\ \mathrm{rad/s}$

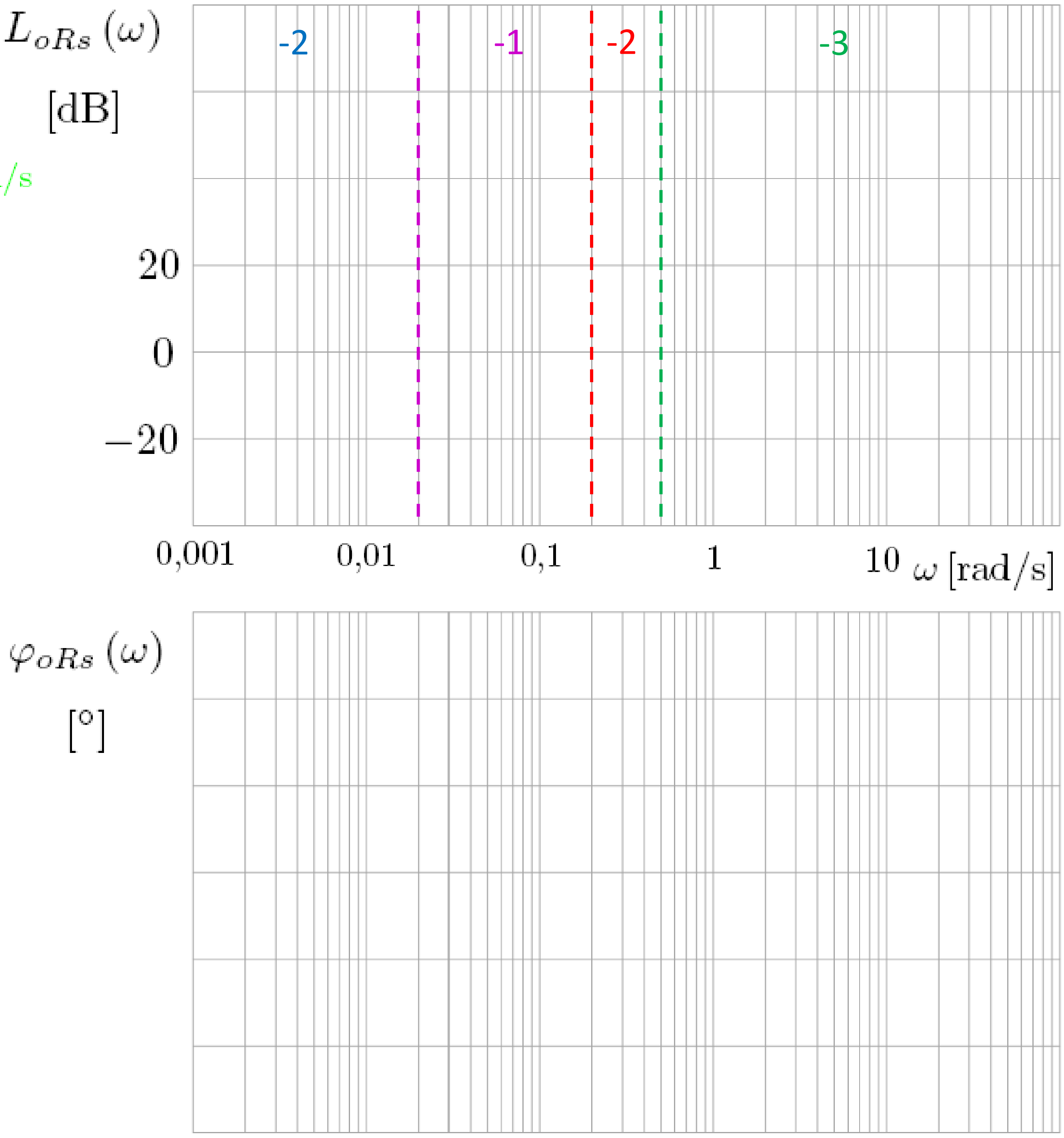




$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

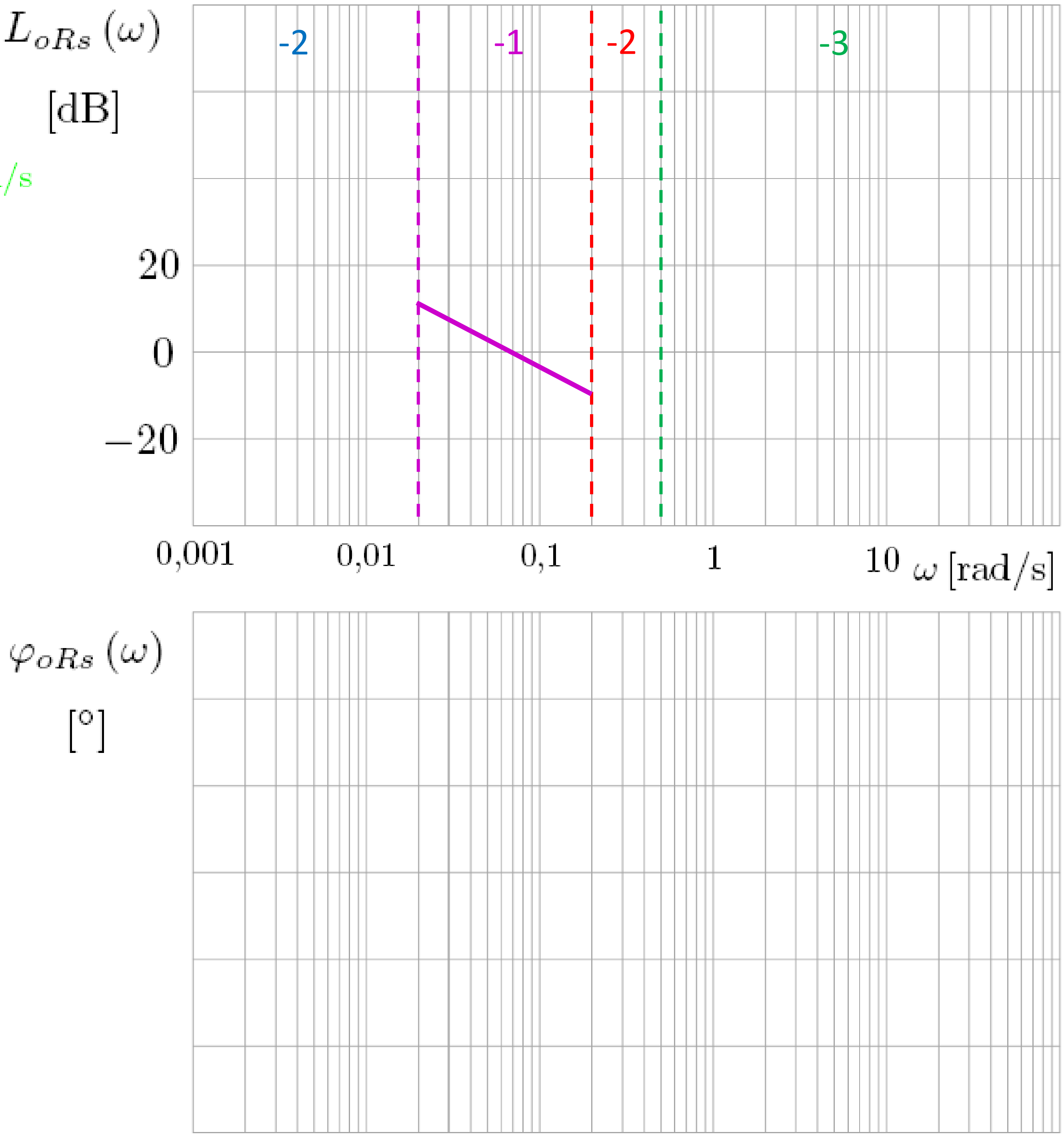
$$\omega_{cs} = 0{,}0625 \text{ rad/s}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

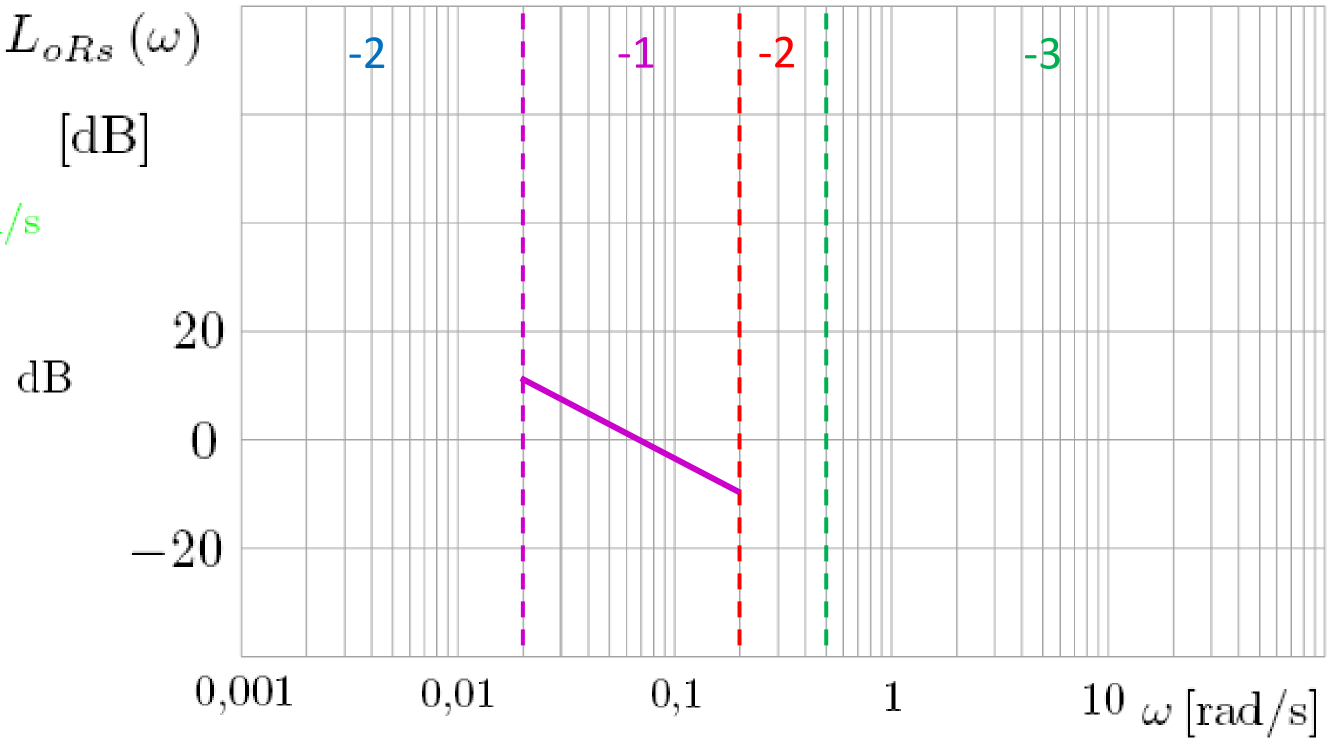
$$\omega_{cs} = 0{,}0625 \text{ rad/s}$$

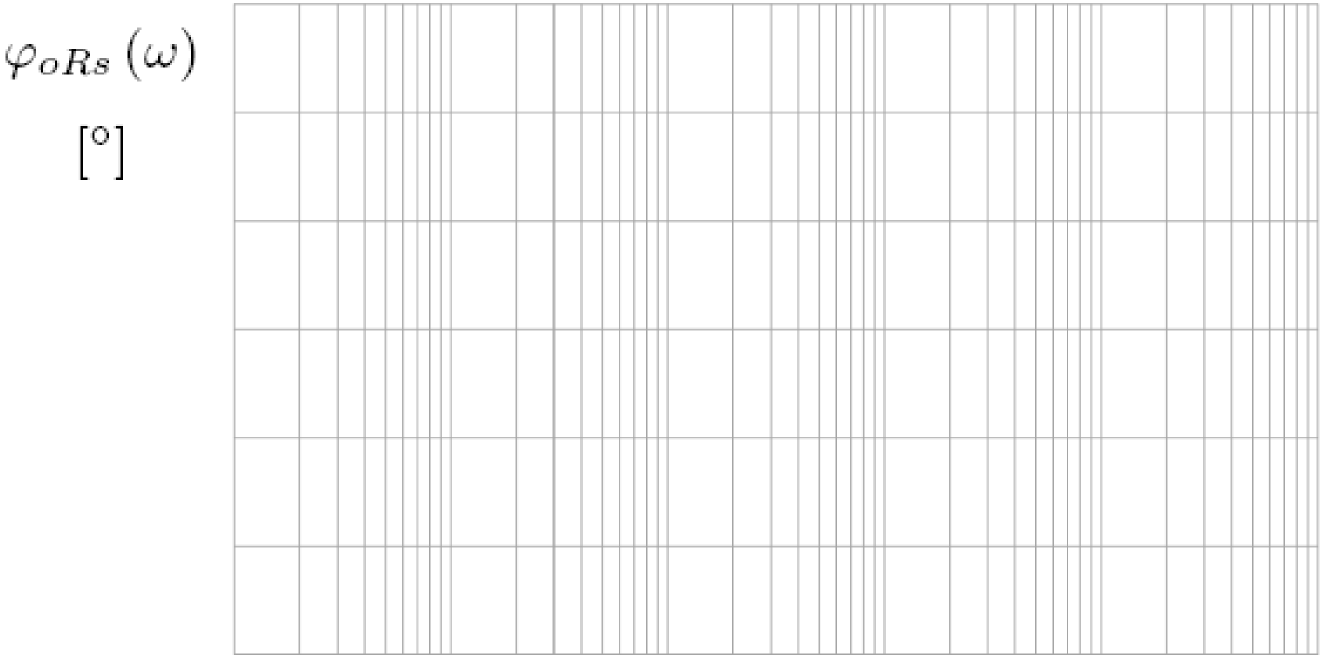


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

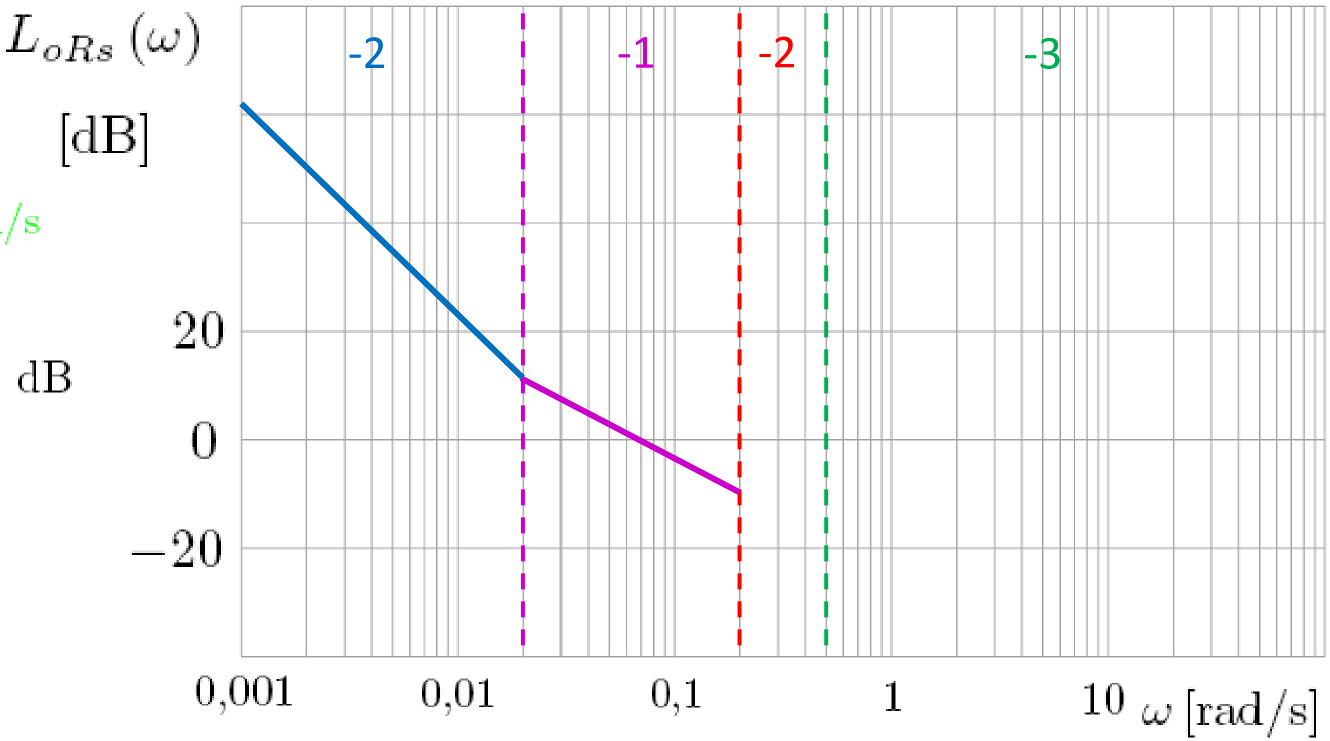


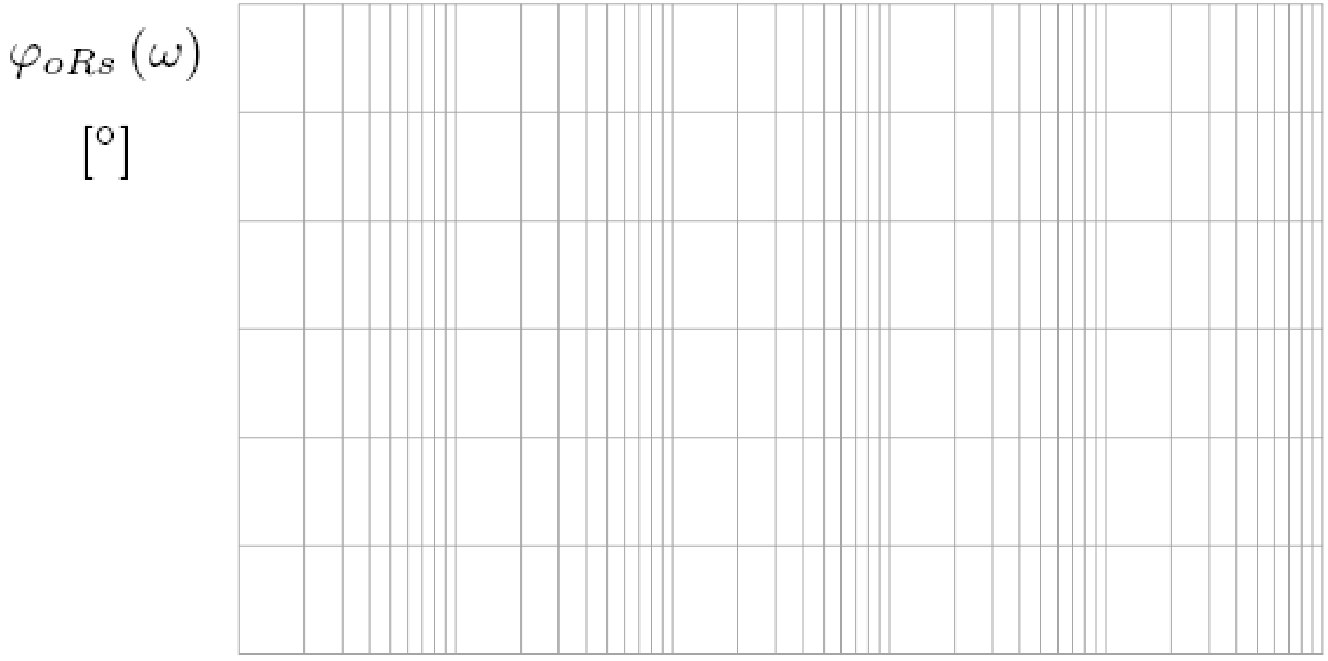


$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$



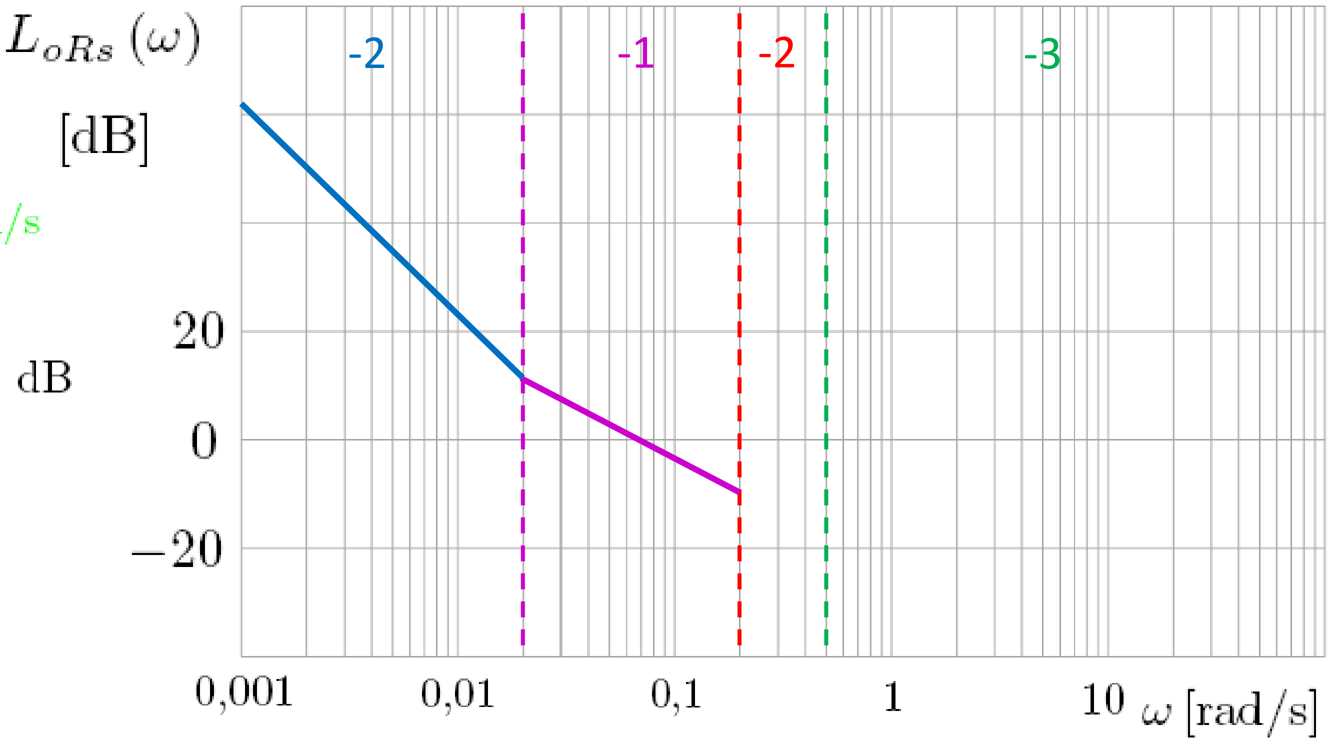


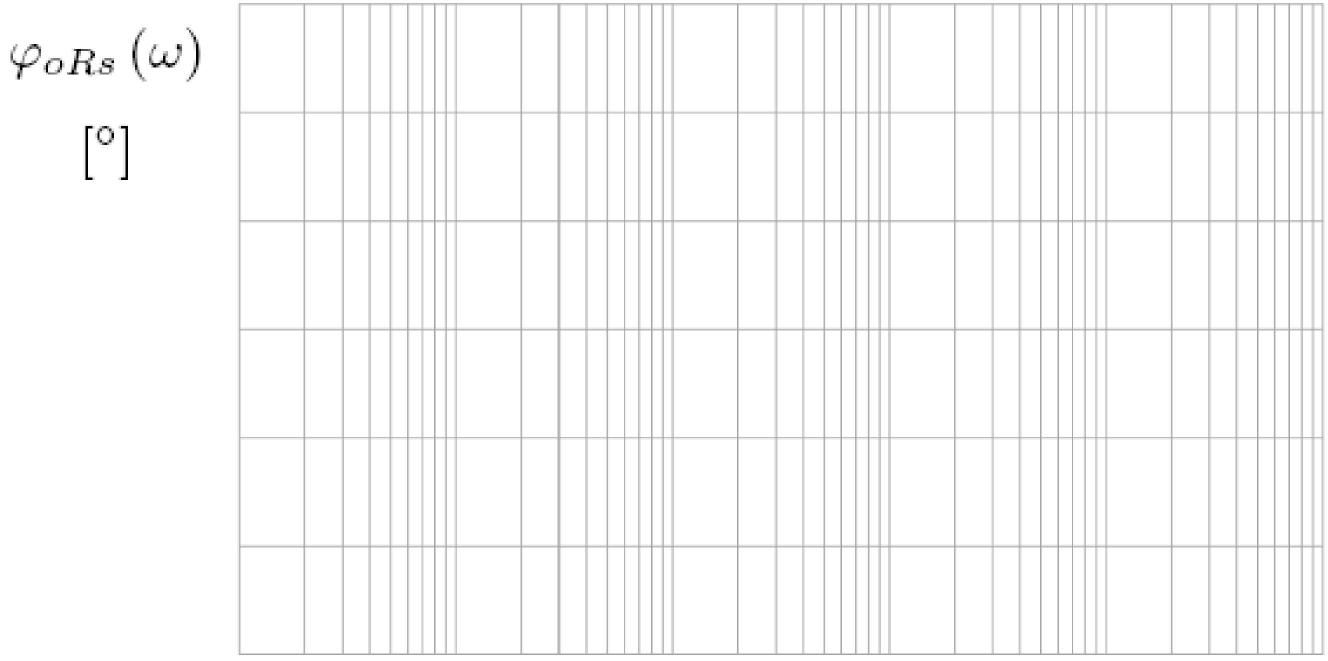
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$





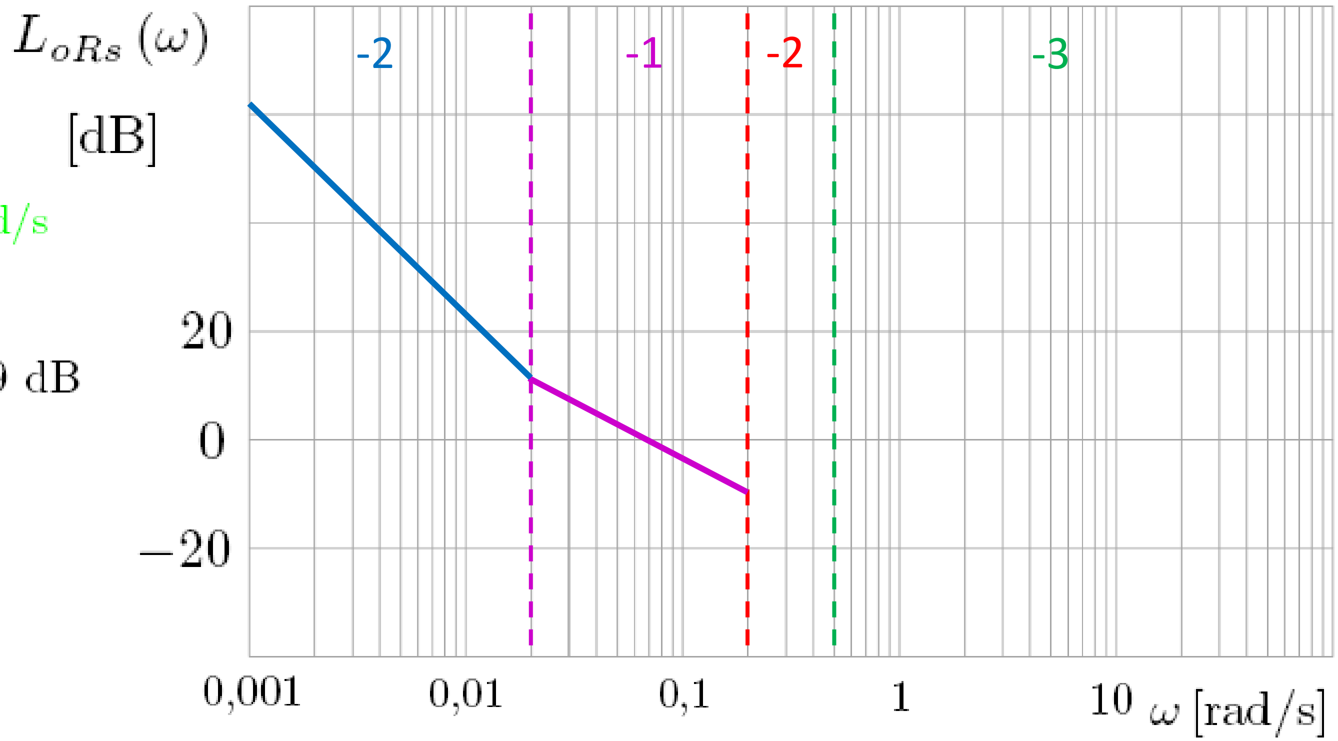
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

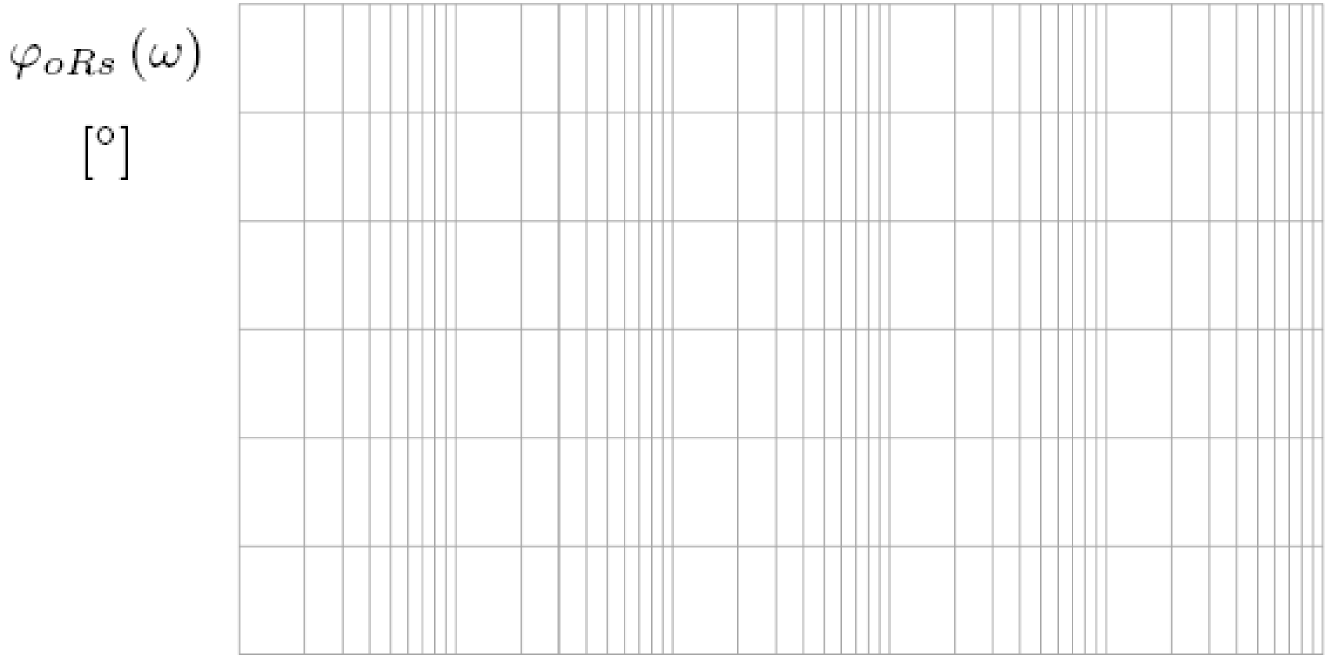
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$





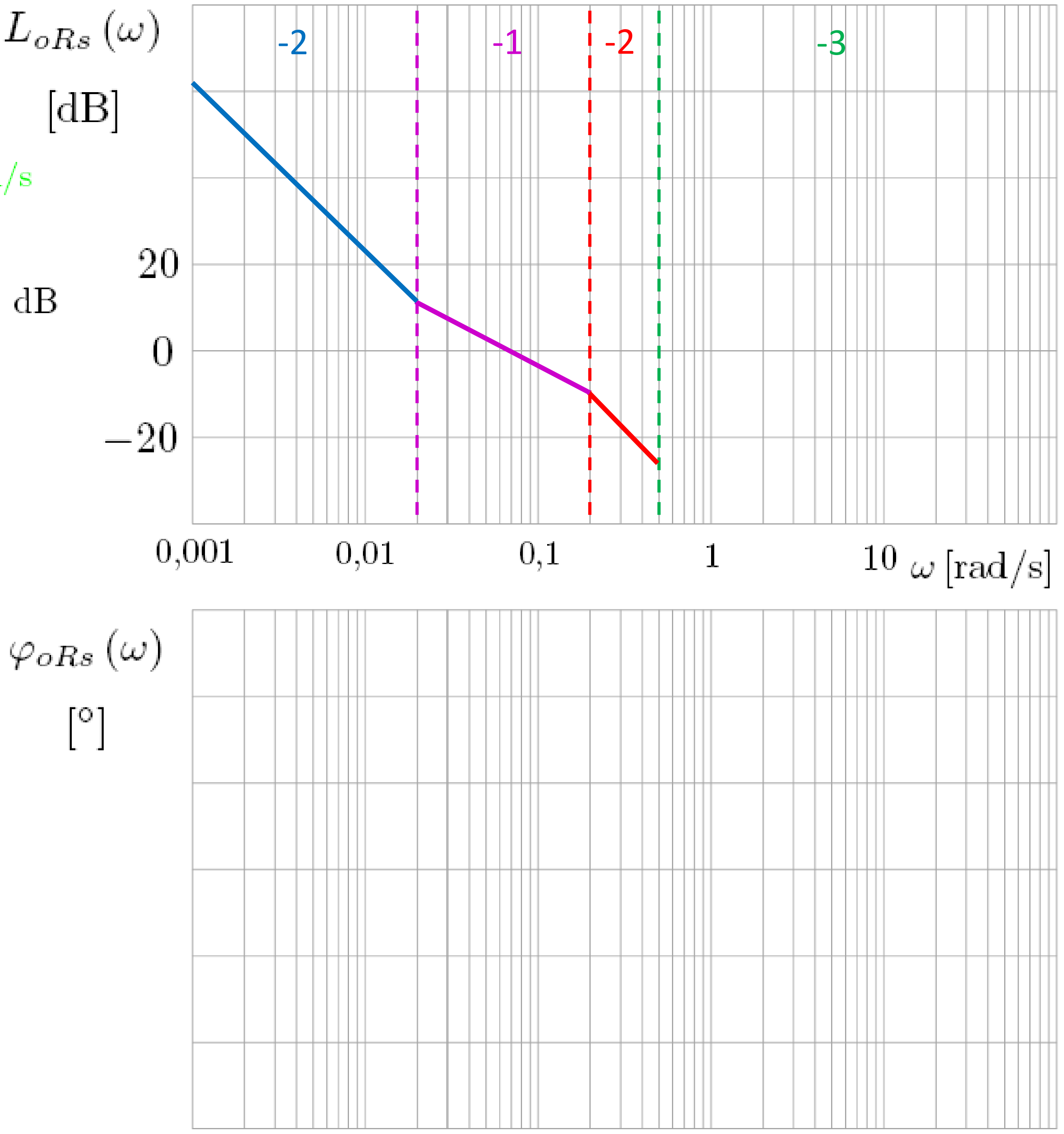
$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

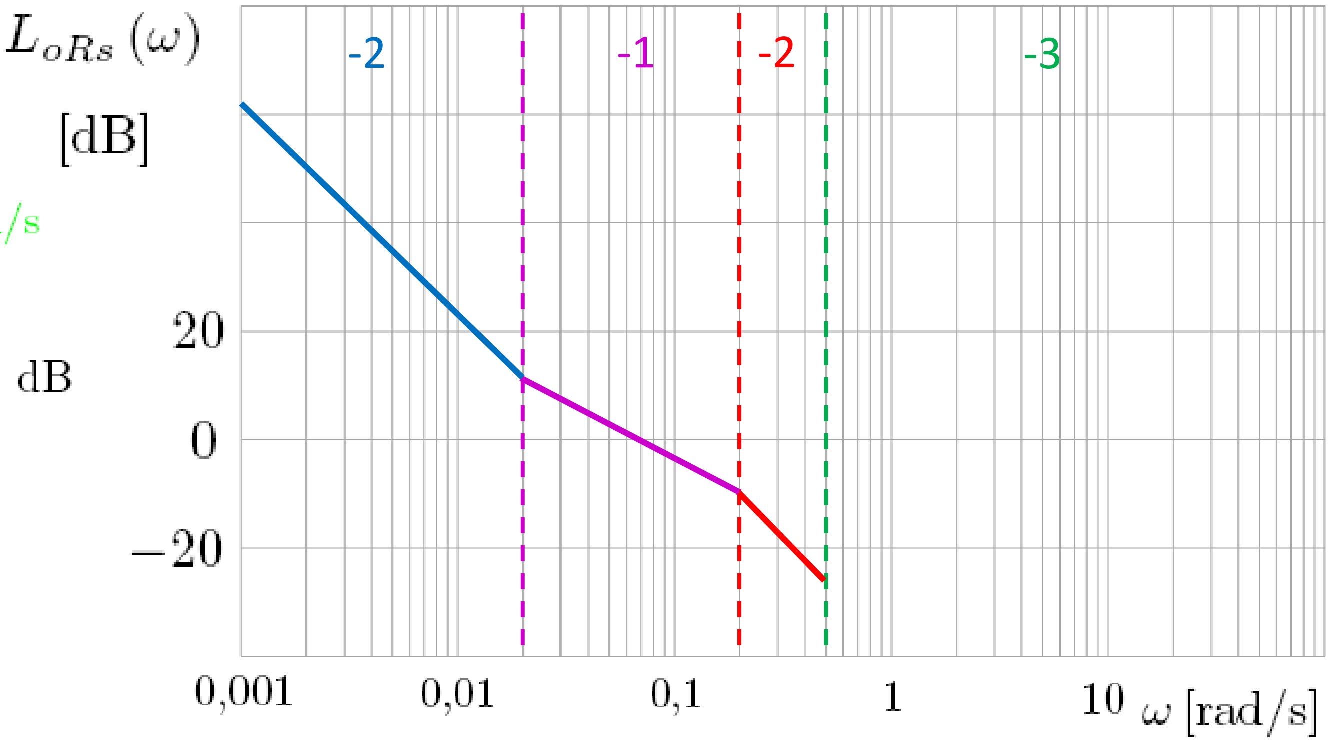
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

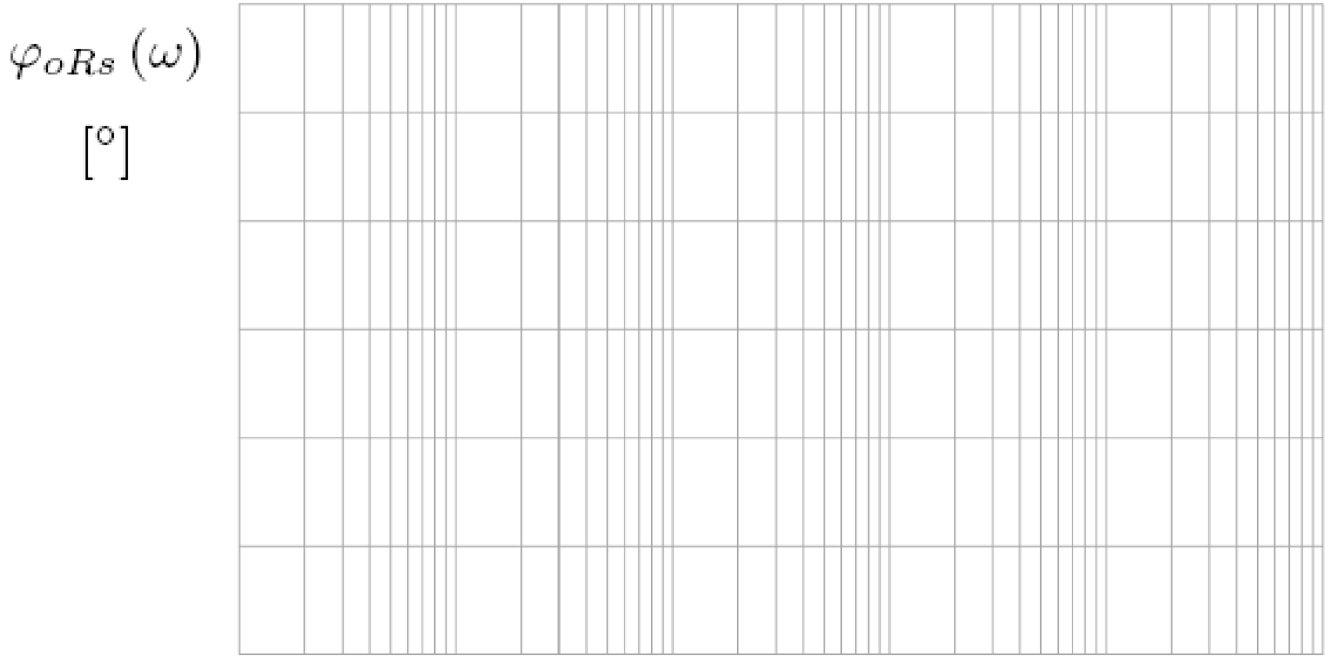
$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

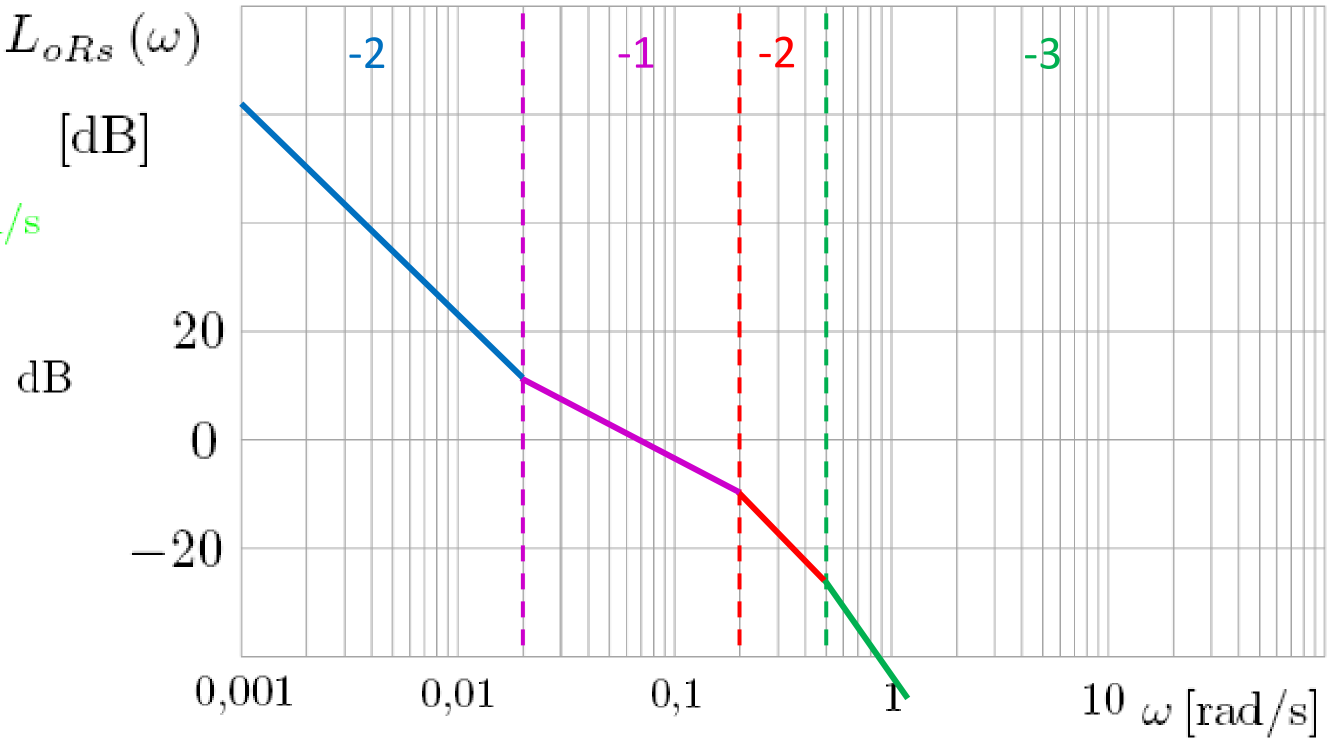
$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

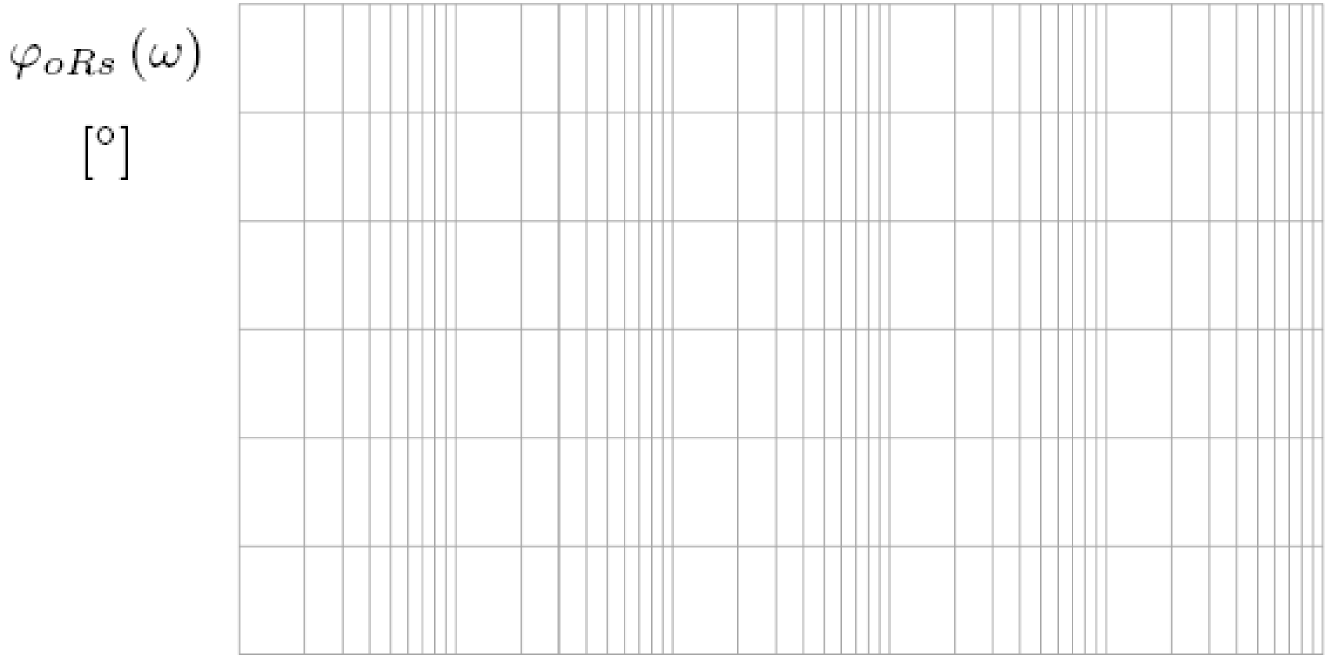
$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s}$ $\quad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s}$ $\quad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$

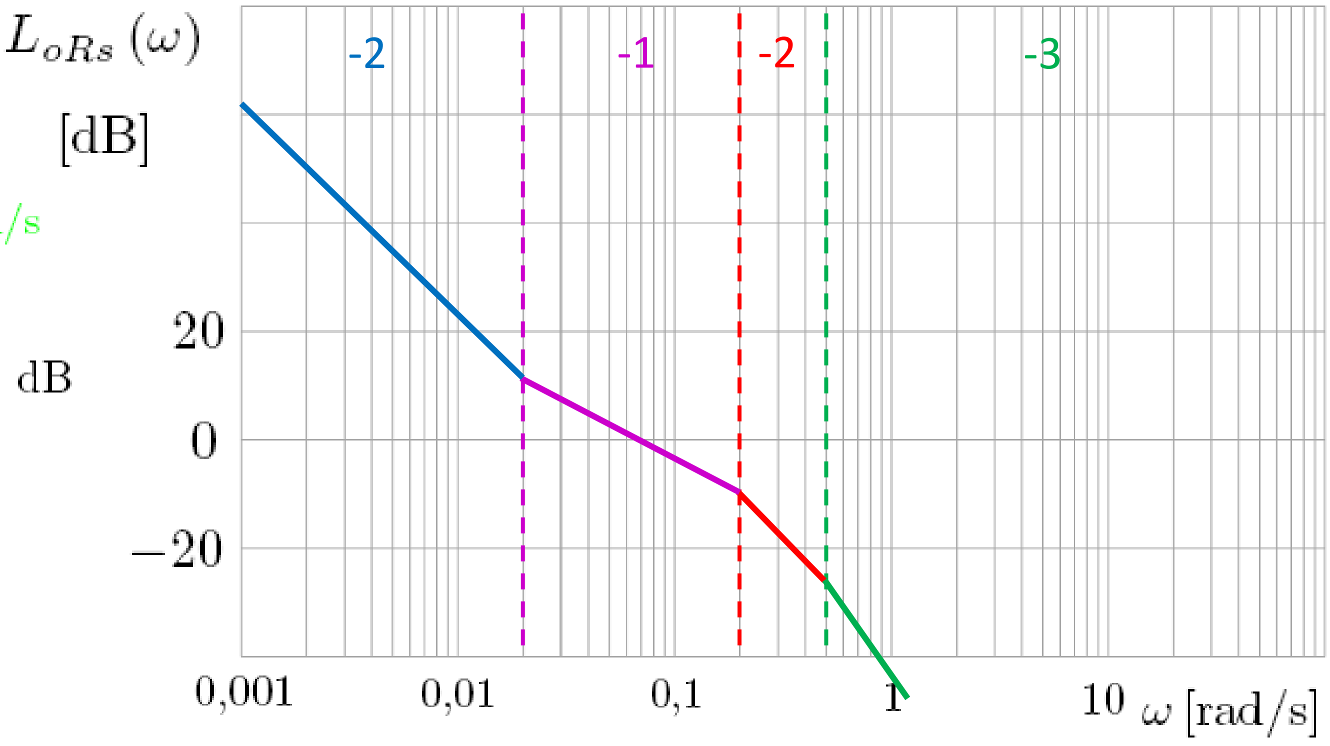
$\omega_{cs} = 0{,}0625 \text{ rad/s}$ $\quad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$

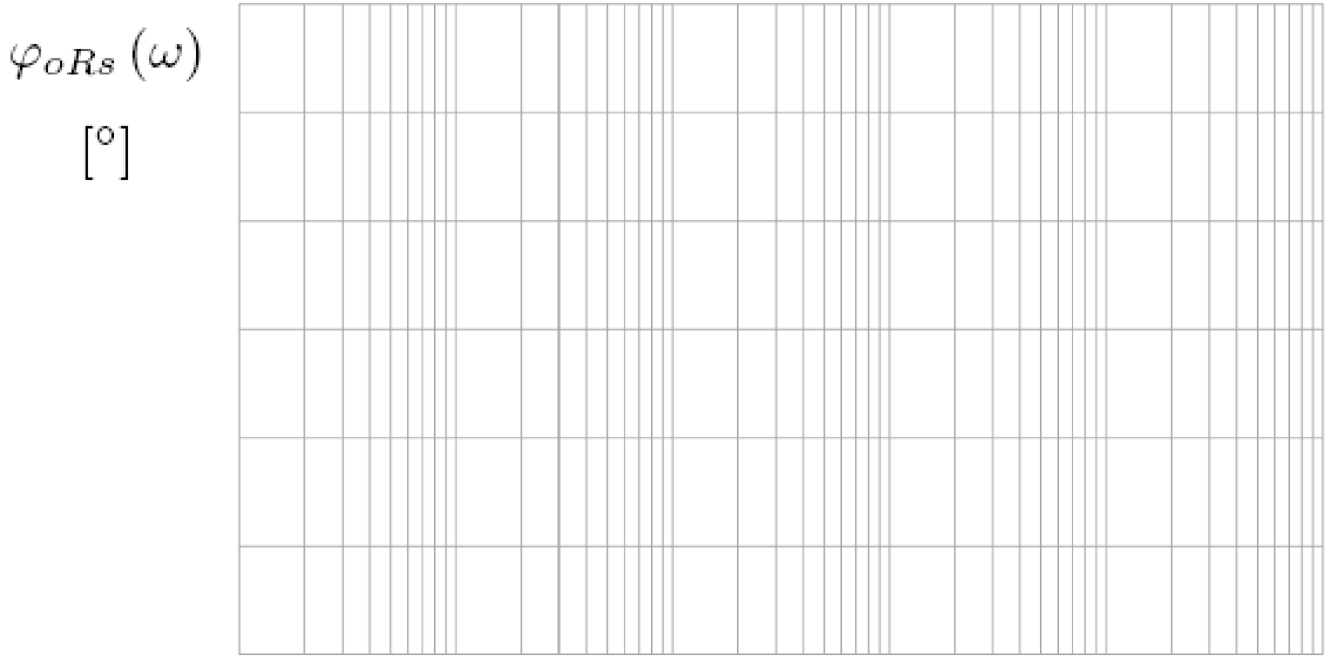
$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$

$$L_{oRs}(1) = -26 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}1 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

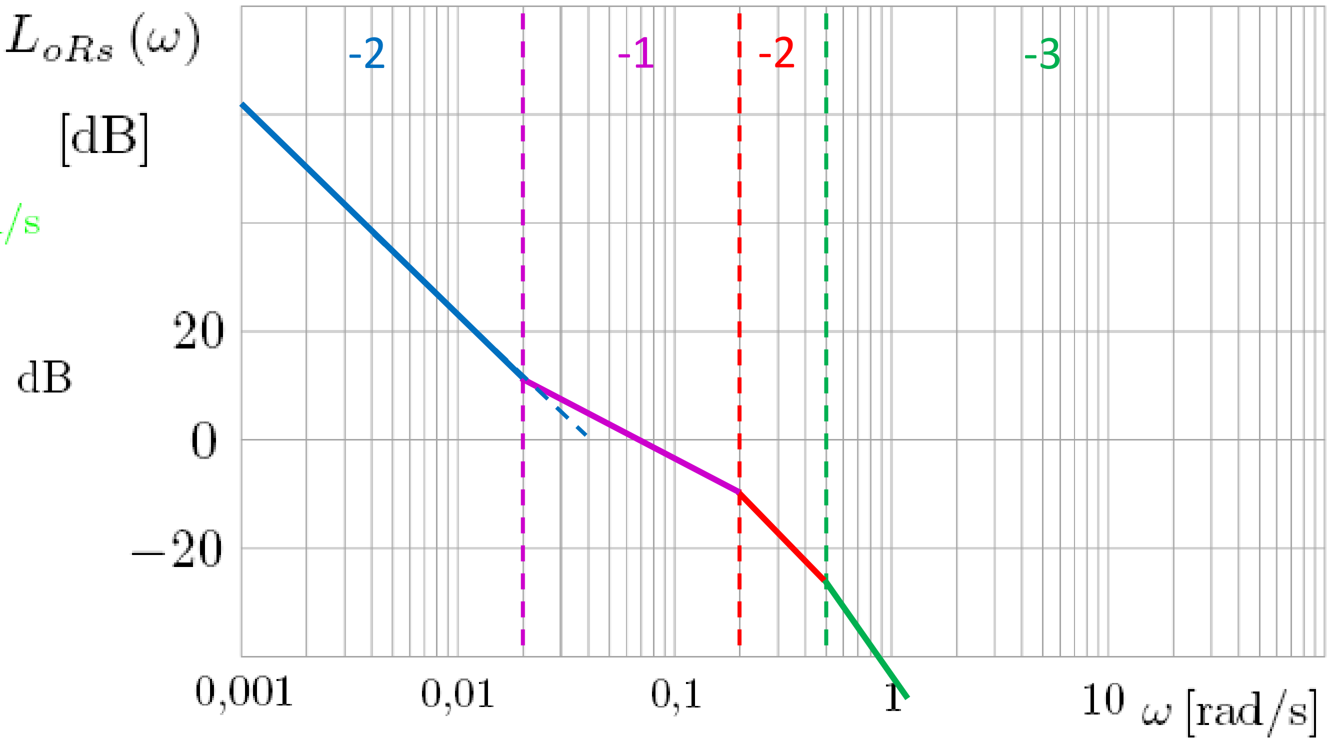
$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

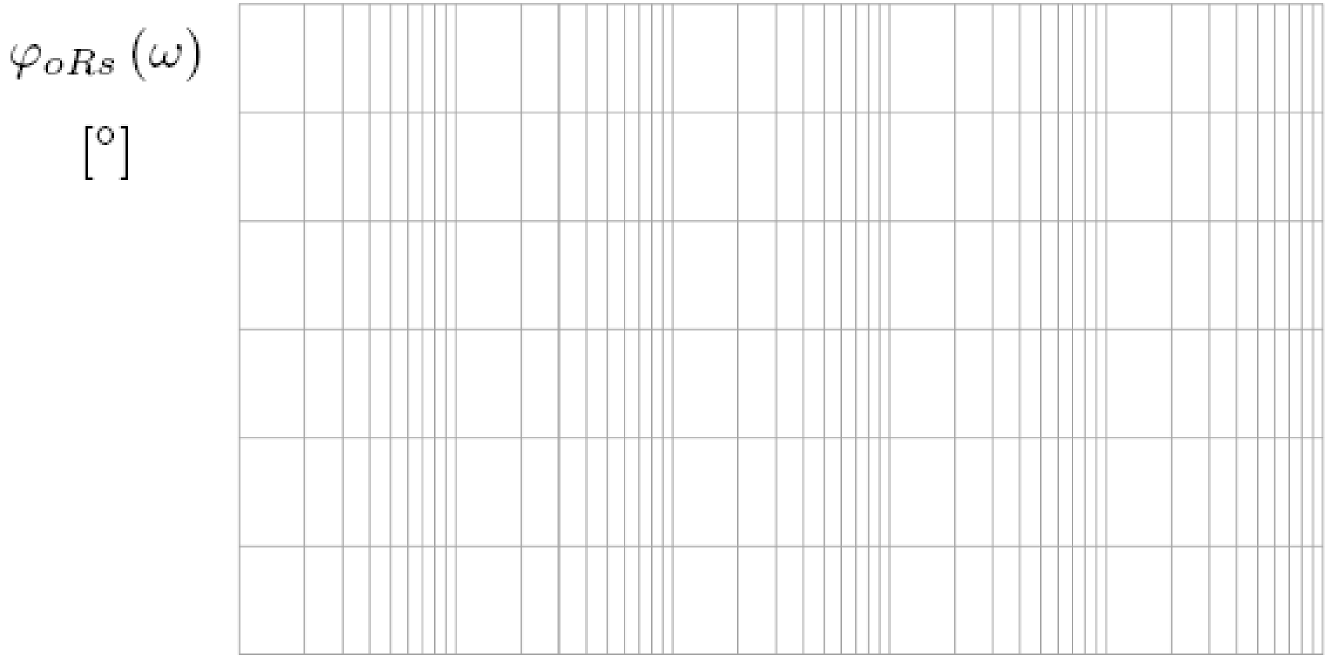
$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$

$$L_{oRs}(1) = -26 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}1 \text{ dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02\ \text{rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2\ \text{rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5\ \text{rad/s}$$

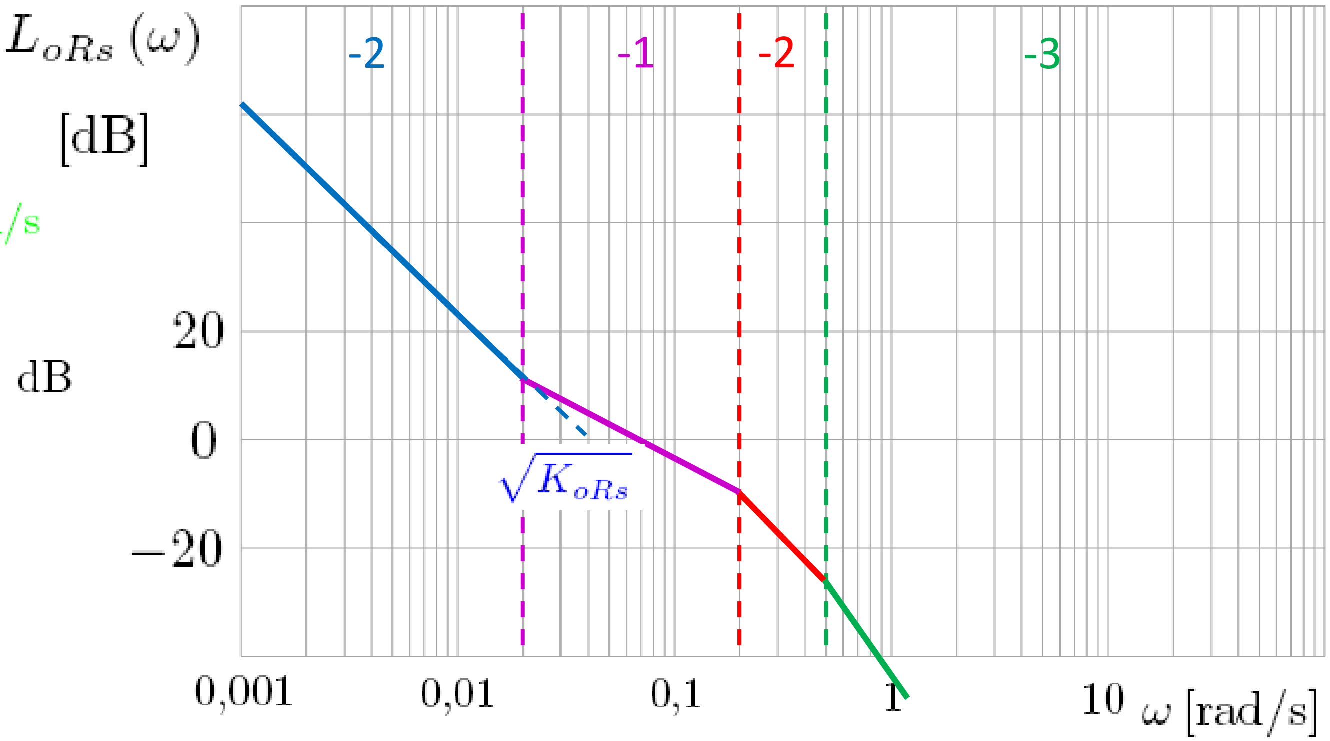
$$\omega_{cs} = 0{,}0625\ \text{rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9\ \text{dB}$$

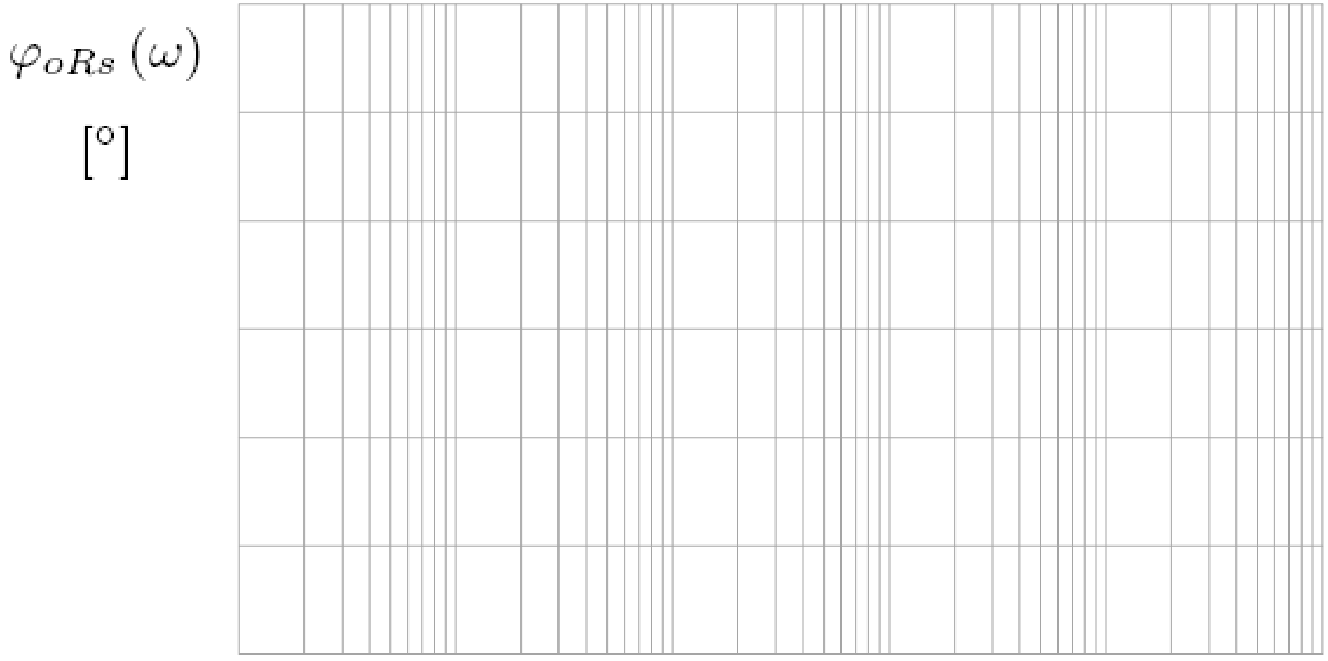
$$L_{oRs}(0{,}001) = 9{,}9\ \text{dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9\ \text{dB}$$

$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1\ \text{dB}$$

$$L_{oRs}(0{,}5) = -10{,}1\ \text{dB} - 40\log\frac{0{,}5}{0{,}2} = -26\ \text{dB}$$

$$L_{oRs}(1) = -26\ \text{dB} - 60\log\frac{1}{0{,}5} = -44{,}1\ \text{dB}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

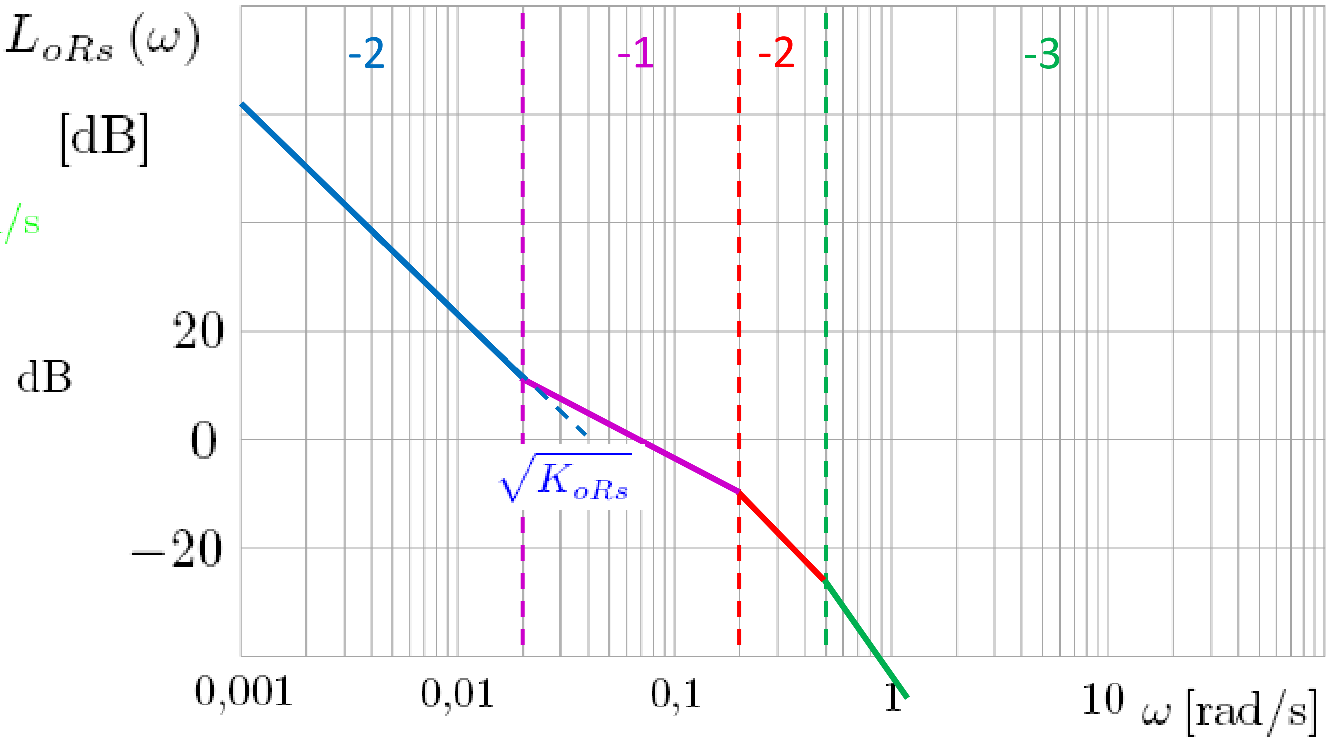
$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

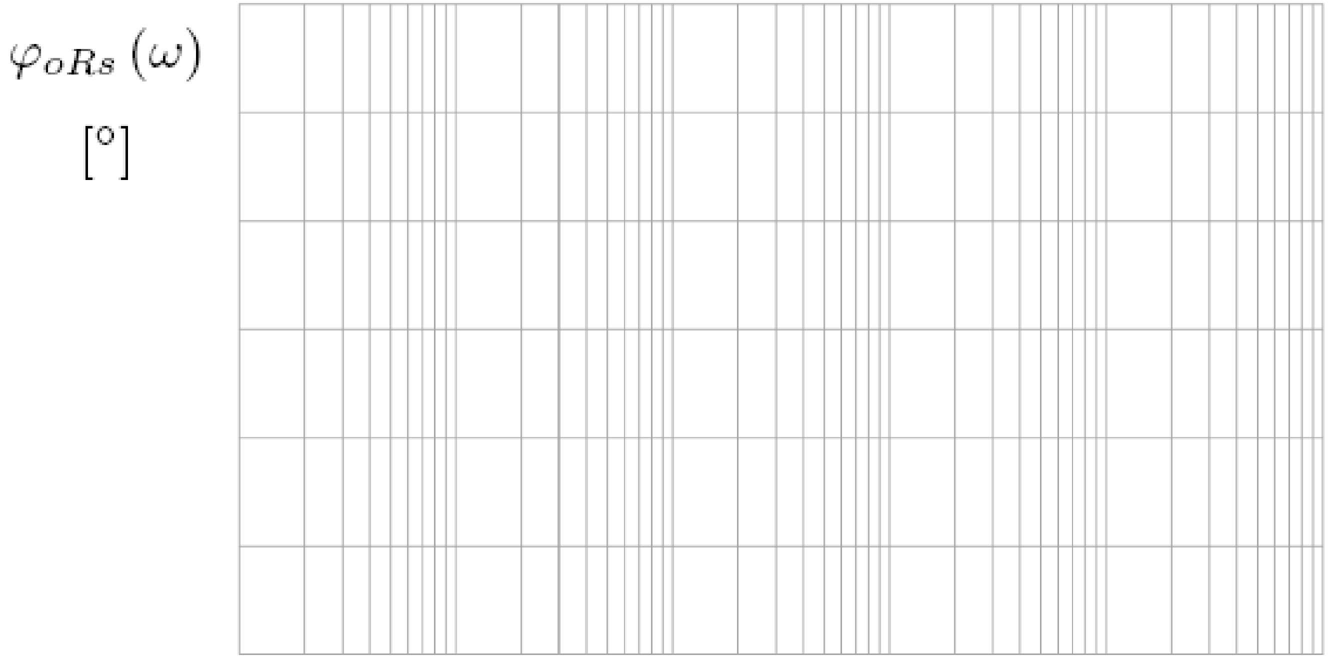
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$

$$L_{oRs}(1) = -26 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}1 \text{ dB}$$

$$0 = 9{,}9 - 40\log\frac{\sqrt{K_{oRs}}}{0{,}02}$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

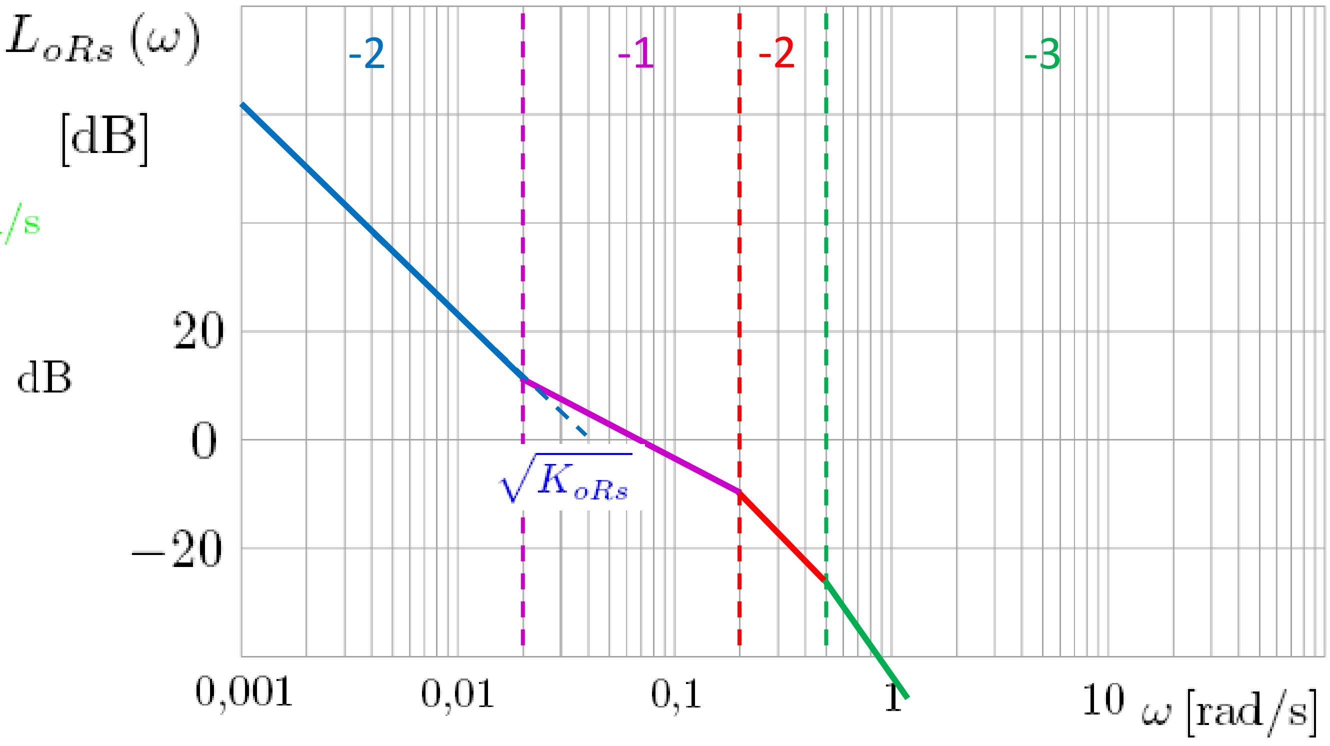
$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

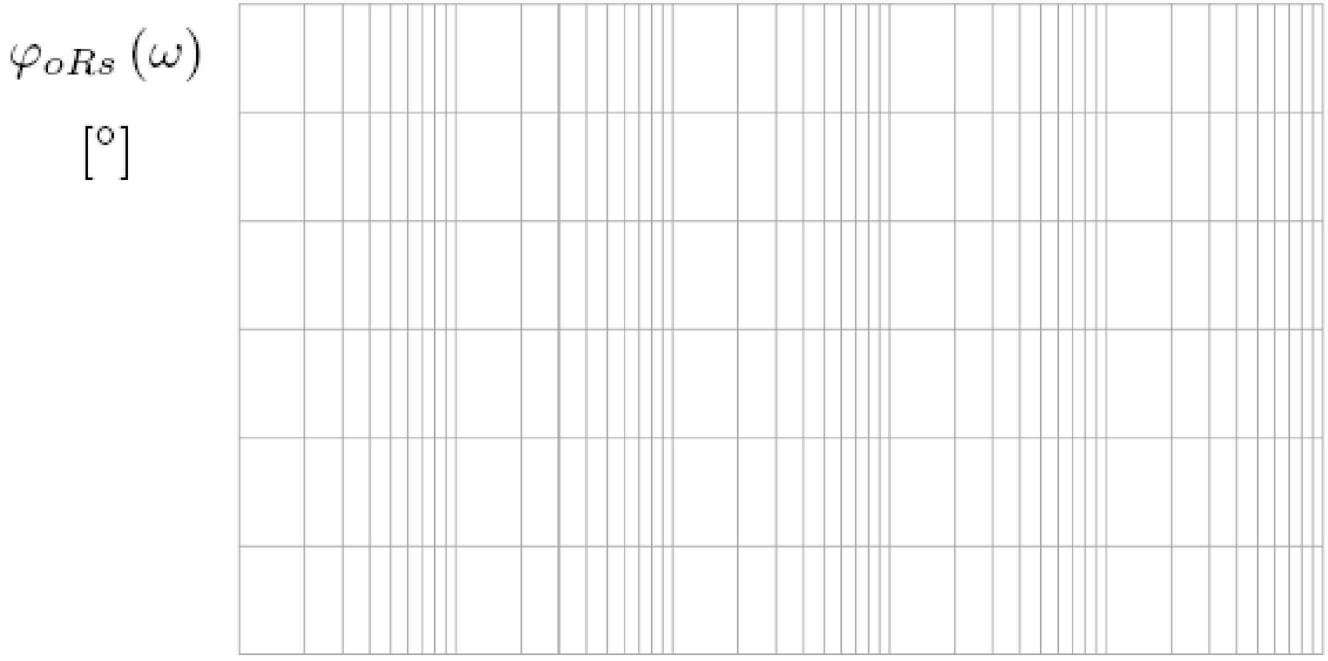
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$

$$L_{oRs}(1) = -26 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}1 \text{ dB}$$

$$0 = 9{,}9 - 40\log\frac{\sqrt{K_{oRs}}}{0{,}02} \qquad \sqrt{K_{oRs}} = 0{,}02 \cdot 10^{\frac{9{,}9}{40}} = 0{,}035$$





$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

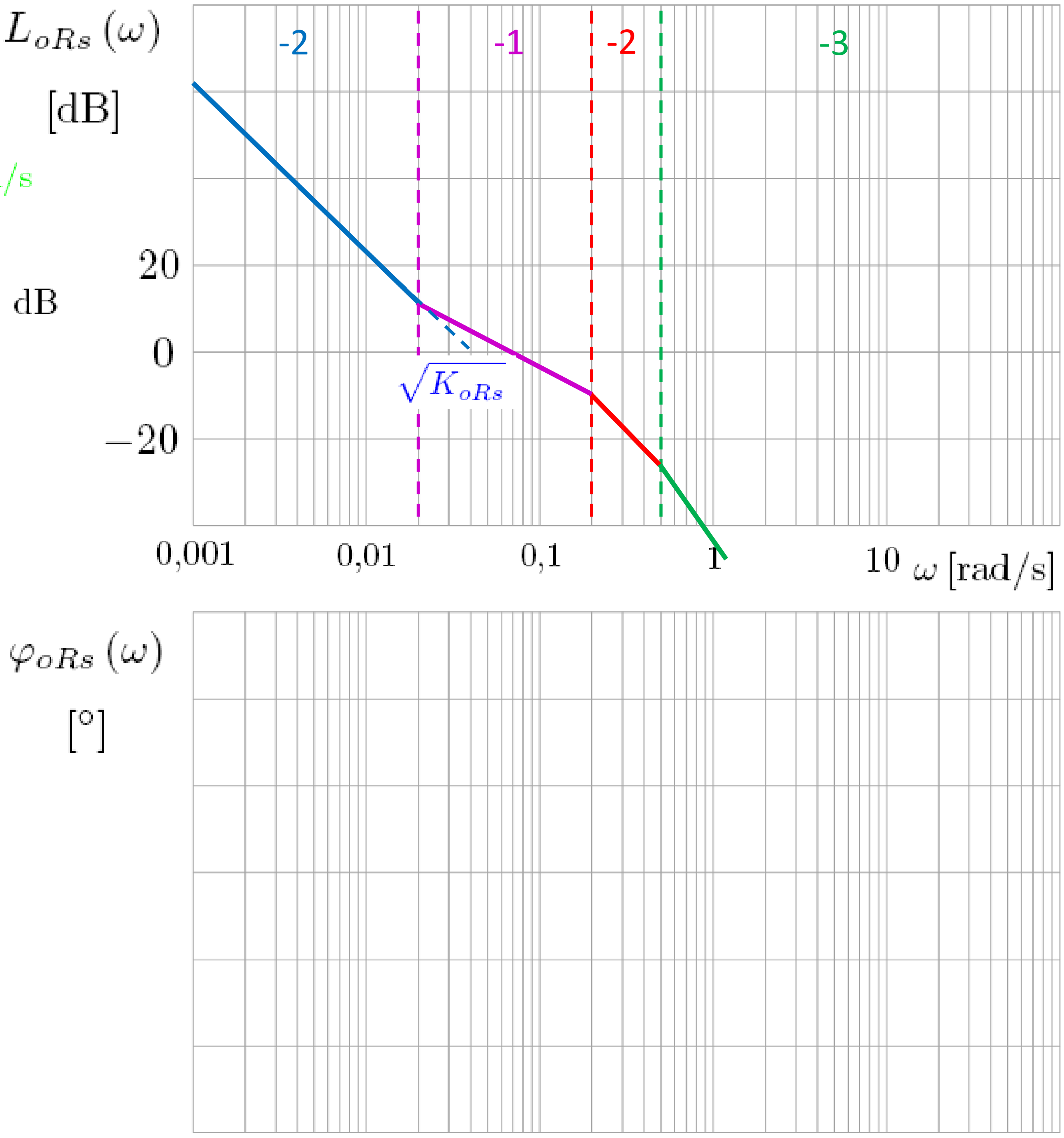
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$

$$L_{oRs}(1) = -26 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}1 \text{ dB}$$

$$0 = 9{,}9 - 40\log\frac{\sqrt{K_{oRs}}}{0{,}02} \qquad \sqrt{K_{oRs}} = 0{,}02 \cdot 10^{\frac{9{,}9}{40}} = 0{,}035$$

$$K_{oRs} = 0{,}035^2 = 0{,}00125$$



$$G_{oRs}(s) = K_{oRs} \cdot \frac{1+50s}{s^2(1+5s)(1+2s)}$$

$$\omega_{Is} = \frac{1}{50} = 0{,}02 \text{ rad/s} \qquad \omega_2 = \frac{1}{5} = 0{,}2 \text{ rad/s} \qquad \omega_{pv} = \frac{1}{2} = 0{,}5 \text{ rad/s}$$

$$\omega_{cs} = 0{,}0625 \text{ rad/s} \qquad L_{oRs}(0{,}02) = -20\log\frac{0{,}02}{0{,}0625} = 9{,}9 \text{ dB}$$

$$L_{oRs}(0{,}001) = 9{,}9 \text{ dB} - 40\log\frac{0{,}001}{0{,}02} = 61{,}9 \text{ dB}$$

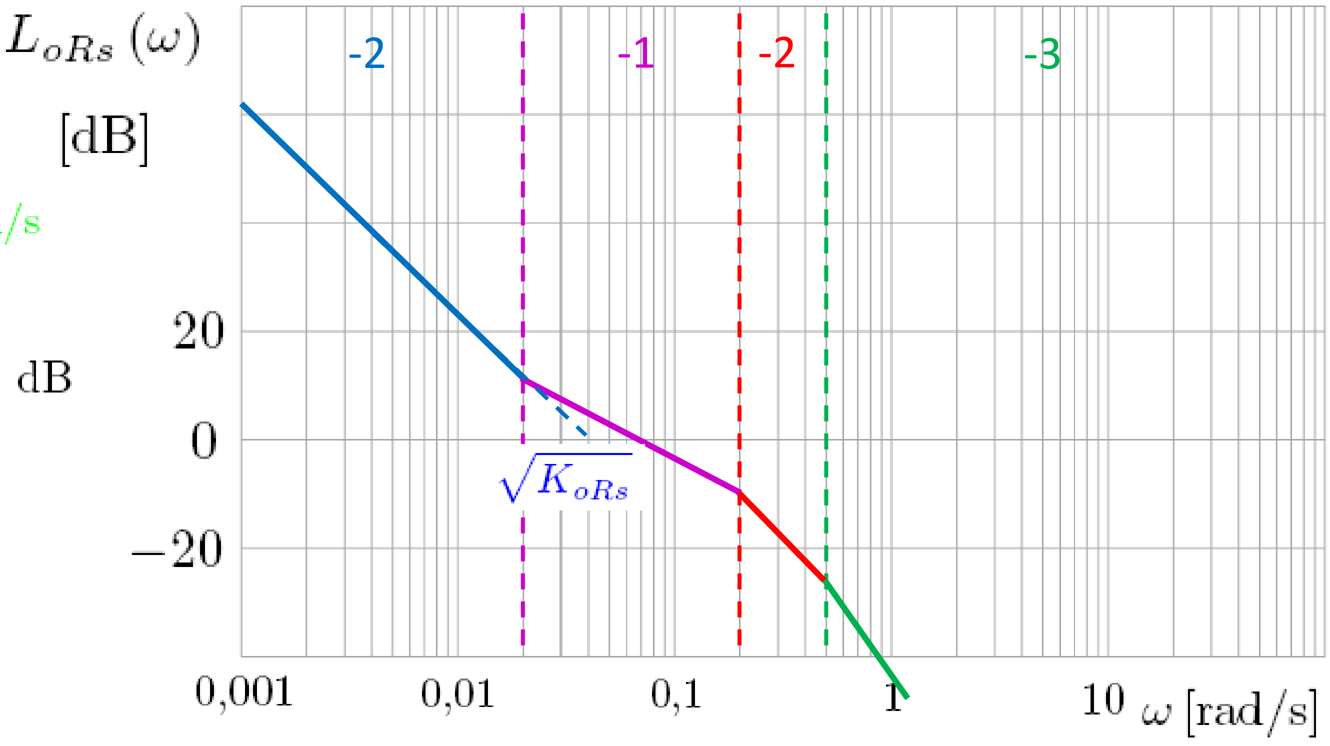
$$L_{oRs}(0{,}2) = -20\log\frac{0{,}2}{0{,}0625} = -10{,}1 \text{ dB}$$

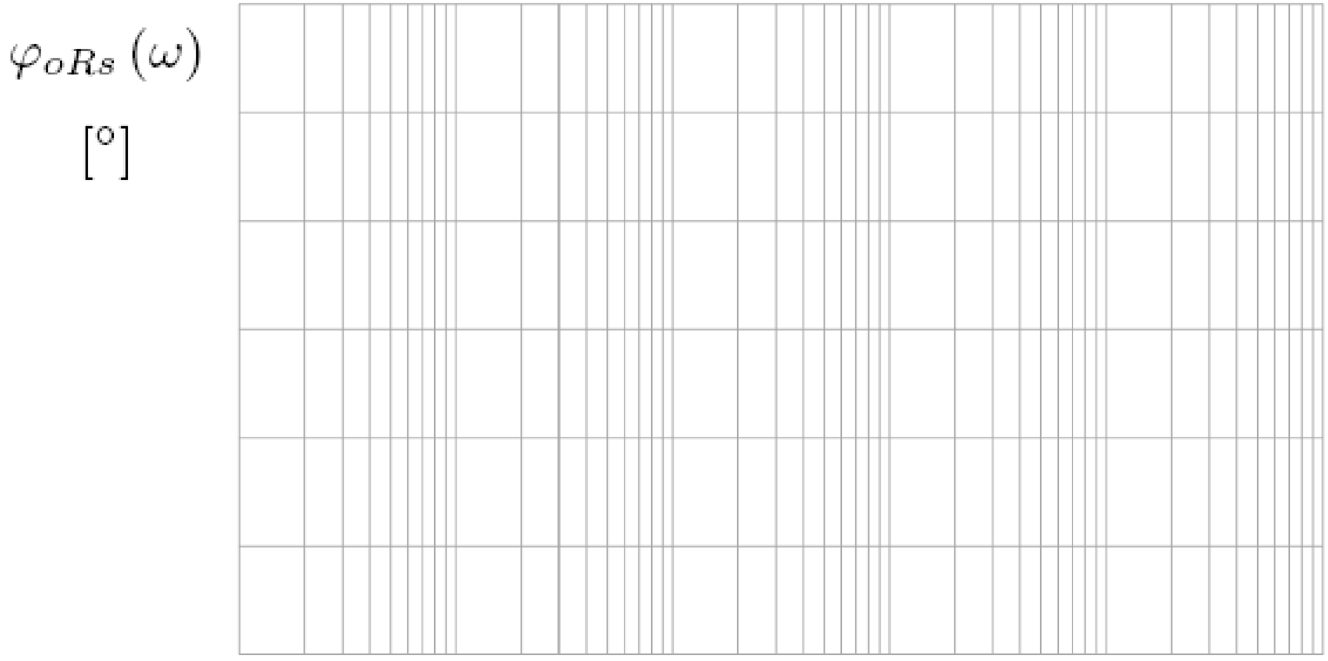
$$L_{oRs}(0{,}5) = -10{,}1 \text{ dB} - 40\log\frac{0{,}5}{0{,}2} = -26 \text{ dB}$$

$$L_{oRs}(1) = -26 \text{ dB} - 60\log\frac{1}{0{,}5} = -44{,}1 \text{ dB}$$

$$0 = 9{,}9 - 40\log\frac{\sqrt{K_{oRs}}}{0{,}02} \qquad \sqrt{K_{oRs}} = 0{,}02 \cdot 10^{\frac{9{,}9}{40}} = 0{,}035$$

$$K_{oRs} = 0{,}035^2 = 0{,}00125 \qquad K_{Rs} = 2500 K_{oRs} = 3{,}125$$

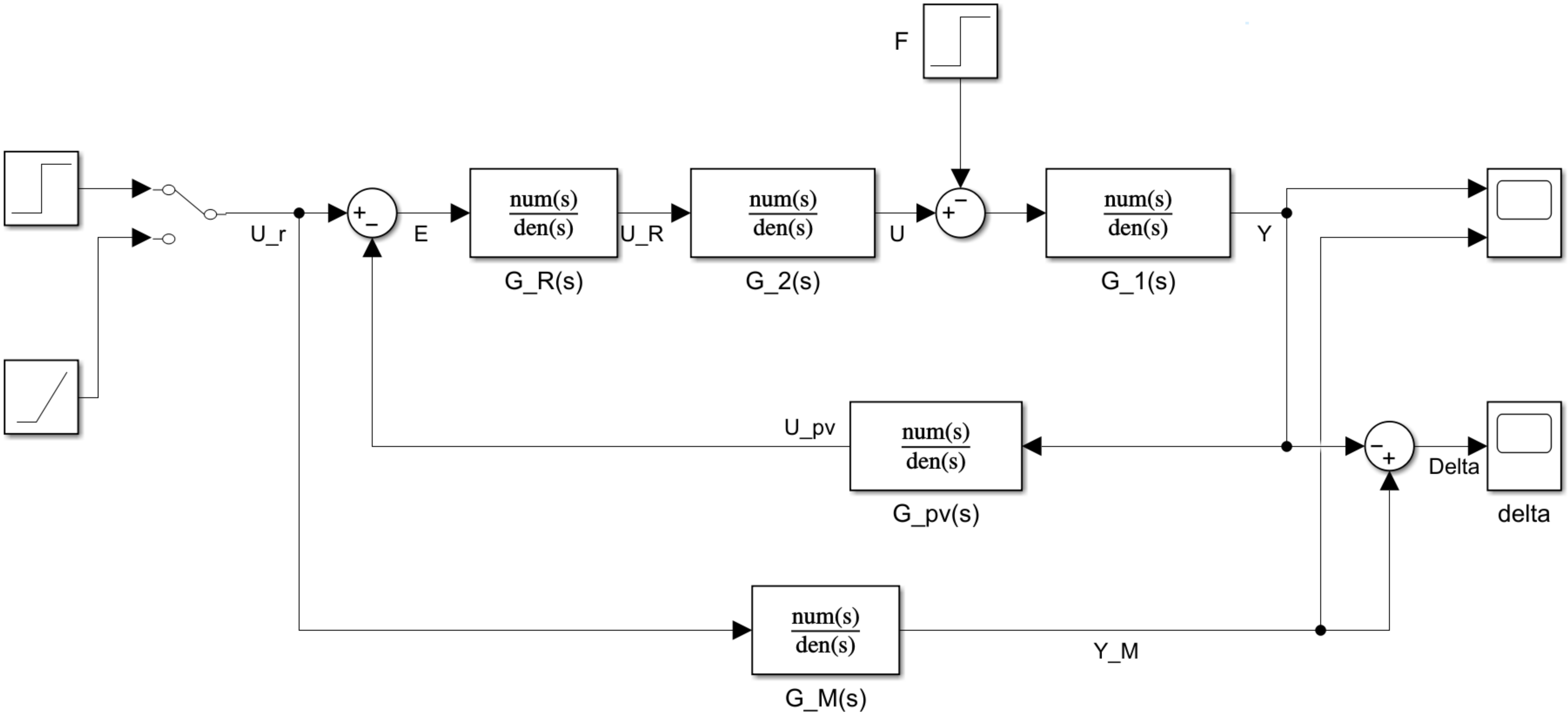




Simulacija i korekcija parametara

Sinteza regulacijskog sustava s astatičkim procesom 2. reda

Sinteza regulacijskog sustava s astatičkim procesom 2. reda



Sinteza regulacijskog sustava s astatičkim procesom 2. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s^2}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

Sinteza regulacijskog sustava s astatičkim procesom 2. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s^2}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

Sinteza regulacijskog sustava s astatičkim procesom 2. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s^2}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{s^2} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

Sinteza regulacijskog sustava s astatičkim procesom 2. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s^2}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{s^2} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

Sinteza regulacijskog sustava s astatičkim procesom 2. reda

$$G_1(s) = \frac{Y(s)}{U(s) - F(s)} = \frac{K_1}{s^2}$$

$$G_2(s) = \frac{U(s)}{U_R(s)} = \frac{K_2}{1 + T_2 s}$$

$$G_{pv}(s) = \frac{U_{pv}(s)}{Y(s)} = \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = G_1(s) \cdot G_2(s) \cdot G_{pv}(s)$$

$$G_p(s) = \frac{K_1}{s^2} \cdot \frac{K_2}{1 + T_2 s} \cdot \frac{K_{pv}}{1 + T_{pv} s}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

- Budući da se astatizam ($r = 2$) nalazi u procesu, statička pogreška u odnosu na upravljačku veličinu δ_{us} bit će (teoretski) jednaka nuli čak i uz izbor čiste proporcionalne strukture regulatora.
- Statička pogreška u odnosu na poremećajnu veličinu δ_{fs} neće biti jednaka nuli, jer bi se astatizam morao nalaziti u regulatoru.
- Međutim, s čistim P regulatorom, kao i s dodavanjem astatizma u regulator (I dio) onemogućili bi stabilizaciju sustava.

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

- Da bi podigli fazno-frekvencijsku karakteristiku iznad -180° regulator mora sadržavati derivacijsko djelovanje - DT_1 ili PDT_1 regulator s faznim prethođenjem:

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv} s)}$$

- Da bi podigli fazno-frekvencijsku karakteristiku iznad -180° regulator mora sadržavati derivacijsko djelovanje - DT_1 ili PDT_1 regulator s faznim prethođenjem:

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1+T_1 s}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1+T_D s}{1+T_1 s}, \quad T_D > T_1$$

DT_1 regulator

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D s}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D \cancel{s}}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^{\cancel{2}} (1 + T_2 s)(1 + T_{pv} s)}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D \cancel{s}}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^{\cancel{2}} (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = \frac{K_{oR}}{s (1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D \cancel{s}}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^{\cancel{2}} (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = \frac{K_{oR}}{s (1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = T_D \cdot K_1 \cdot K_2 \cdot K_{pv}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1+T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D \cancel{s}}{1+T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^{\cancel{2}}(1+T_2 s)(1+T_{pv} s)}$$

$$G_{oR}(s) = \frac{K_{oR}}{s(1+T_1 s)(1+T_2 s)(1+T_{pv} s)}$$

$$K_{oR} = T_D \cdot K_1 \cdot K_2 \cdot K_{pv}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \leq T_1 \leq 2 \cdot \max(T_2, T_{pv})$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D \cancel{s}}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^{\cancel{2}} (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = \frac{K_{oR}}{s (1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = T_D \cdot K_1 \cdot K_2 \cdot K_{pv}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \le T_1 \le 2 \cdot \max(T_2, T_{pv})$$

$$T_D = \frac{K_{oR}}{K_1 \cdot K_2 \cdot K_{pv}}$$

DT_1 regulator

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = \frac{T_D s}{1 + T_1 s}$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = \frac{T_D \cancel{s}}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^{\cancel{2}} (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = \frac{K_{oR}}{s(1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = T_D \cdot K_1 \cdot K_2 \cdot K_{pv}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \leq T_1 \leq 2 \cdot \max(T_2, T_{pv})$$

$$T_D = \frac{K_{oR}}{K_1 \cdot K_2 \cdot K_{pv}}$$

U praksi se najčešće može realizirati DT_1 regulator kod kojeg vrijedi:

$$2 \leq \frac{T_D}{T_1} \leq 10$$

PDT_1 regulator s faznim prethođenjem

PDT$_1$ regulator s faznim prethođenjem

$$G_p\left(s\right) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2\left(1 + T_2 s\right)\left(1 + T_{pv} s\right)}$$

PDT_1 regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_D s}{1 + T_1 s}, \quad T_D > T_1$$

PDT_1 regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_D s}{1 + T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

PDT$_1$ regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv}s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1+T_D s}{1+T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1+T_D s}{1+T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv}s)}$$

PDT$_1$ regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv}s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1+T_D s}{1+T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1+T_D s}{1+T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv}s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1+T_D s}{s^2(1+T_1 s)(1+T_2 s)(1+T_{pv}s)}$$

PDT$_1$ regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1+T_D s}{1+T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1+T_D s}{1+T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1+T_D s}{s^2(1+T_1 s)(1+T_2 s)(1+T_{pv} s)}$$

$$K_{oR} = K_R \cdot K_1 \cdot K_2 \cdot K_{pv}$$

PDT_1 regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \leq T_1 \leq 2 \cdot \max(T_2, T_{pv})$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_D s}{1 + T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_D s}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_D s}{s^2 (1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = K_R \cdot K_1 \cdot K_2 \cdot K_{pv}$$

PDT$_1$ regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_D s}{1 + T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_D s}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_D s}{s^2 (1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = K_R \cdot K_1 \cdot K_2 \cdot K_{pv}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \leq T_1 \leq 2 \cdot \max(T_2, T_{pv})$$

U praksi se najčešće može realizirati PDT$_1$ regulator kod kojeg vrijedi:

$$4 \leq \frac{T_D}{T_1} \leq 10$$

PDT$_1$ regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv}s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1+T_D s}{1+T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1+T_D s}{1+T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2(1+T_2 s)(1+T_{pv}s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1+T_D s}{s^2(1+T_1 s)(1+T_2 s)(1+T_{pv}s)}$$

$$K_{oR} = K_R \cdot K_1 \cdot K_2 \cdot K_{pv}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \leq T_1 \leq 2 \cdot \max(T_2, T_{pv})$$

U praksi se najčešće može realizirati PDT$_1$ regulator kod kojeg vrijedi:

$$4 \leq \frac{T_D}{T_1} \leq 10$$

Preporuka za izbor T_D kao kod procesa s astatizmom 1. reda:

$$T_D = 10 \cdot \max(T_1, T_2, T_{pv})$$

PDT$_1$ regulator s faznim prethođenjem

$$G_p(s) = \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_R(s) = \frac{U_R(s)}{U_r(s) - U_{pv}(s)} = K_R \cdot \frac{1 + T_D s}{1 + T_1 s}, \quad T_D > T_1$$

$$G_{oR}(s) = G_R(s) \cdot G_p(s)$$

$$G_{oR}(s) = K_R \cdot \frac{1 + T_D s}{1 + T_1 s} \cdot \frac{K_1 \cdot K_2 \cdot K_{pv}}{s^2 (1 + T_2 s)(1 + T_{pv} s)}$$

$$G_{oR}(s) = K_{oR} \cdot \frac{1 + T_D s}{s^2 (1 + T_1 s)(1 + T_2 s)(1 + T_{pv} s)}$$

$$K_{oR} = K_R \cdot K_1 \cdot K_2 \cdot K_{pv}$$

$$\frac{1}{2} \cdot \min(T_2, T_{pv}) \le T_1 \le 2 \cdot \max(T_2, T_{pv})$$

U praksi se najčešće može realizirati PDT$_1$ regulator kod kojeg vrijedi:

$$4 \le \frac{T_D}{T_1} \le 10$$

Preporuka za izbor T_D kao kod procesa s astatizmom 1. reda:

$$T_D = 10 \cdot \max(T_1, T_2, T_{pv})$$

$$K_R = \frac{K_{oR}}{K_1 \cdot K_2 \cdot K_{pv}}$$

Spregnuti spremnici