ESERCIZIO 1

(1.1) $A(s) = \left(- \dfrac{\dfrac{R_2}{1+R_2C_2s}}{R_3} \right) \left(-R_1C_1s \right) =$

$$= \frac{R_2 R_1 C_1 s}{R_3 (1+R_2C_2s)} = \frac{R_2}{R_3} \frac{R_1C_1s}{1+R_2C_2s}$$

$$A(f) = \frac{R_2}{R_3} \frac{j\, f/f_0}{1+j\, f/f_p}$$

$$f_0 = \frac{1}{2\pi R_1C_1} = 1.326 \text{ Hz}$$

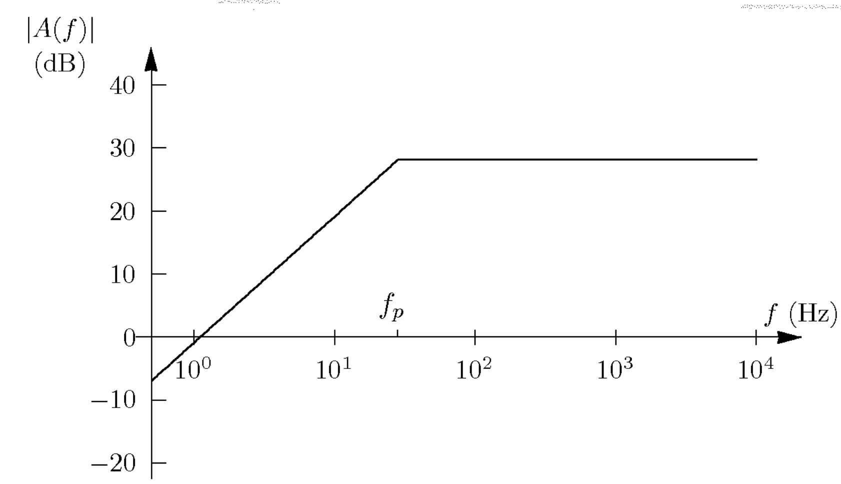
$$f_p = \frac{1}{2\pi R_2C_2} = 28.2 \text{ Hz}$$

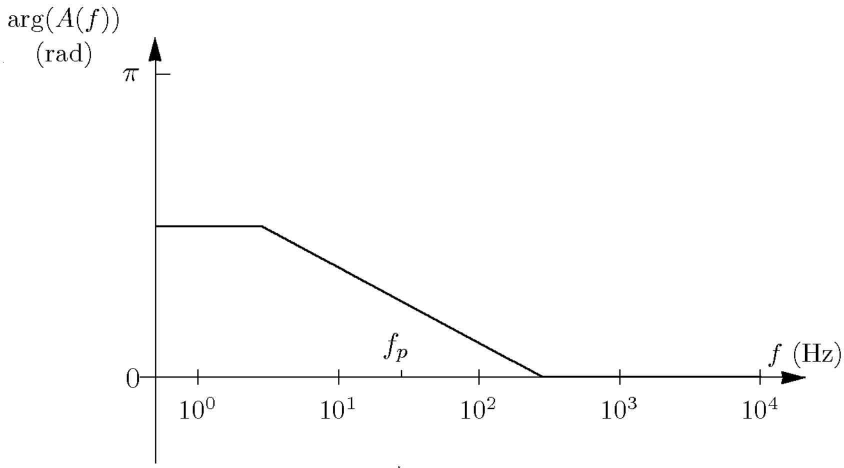
o, in modo equivalente,

$$A(f) = A_\infty \frac{j \dfrac{f}{f_p}}{1+j\, f/f_p}$$

con $A_\infty = \dfrac{R_1C_1}{R_3C_2} = 25.53$ (28.14 dB)

Diagrammi di Bode





1.2

$$A(f) = A_\infty \frac{j\, f/f_p}{1 + j\, f/f_p}$$

$$A_\infty \frac{f/f_p}{\sqrt{1 + f^2/f_p^2}} = 0.9\, A_\infty \Rightarrow \frac{f^2}{f_p^2} = 0.81 \left(1 + \frac{f^2}{f_p^2}\right)$$

$$\Rightarrow \frac{f^2}{f_p^2}\left(1 - 0.81\right) = 0.81 \Rightarrow f_1 = f_p \sqrt{\frac{0.81}{0.19}} = 58.26 \text{ Hz}$$

1.3

$$\varphi_2 = \frac{\pi}{2} - \operatorname{atan}\frac{1}{2} = 1.107 \text{ rad}$$

ESERCIZIO 2

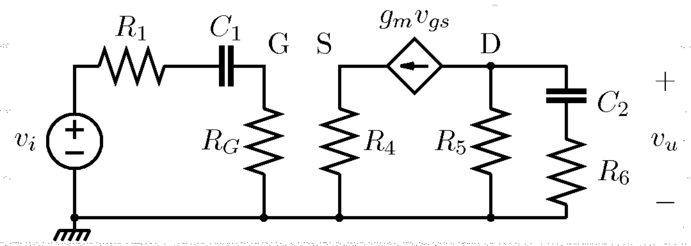
(2.1)
$$\begin{cases} V_{GS} = V^+ \dfrac{R_3}{R_2+R_3} - \left(V^+ - R_4 I_D\right) \\ I_D = \dfrac{k_p}{2}\left(V_{GS}-V_T\right)^2 \end{cases} \Rightarrow \quad \begin{aligned} V_{GS} &= -3\,V \\ I_D &= 3\,mA \end{aligned}$$

$$V_{DS} = R_5 I_D - \left(V^+ - R_4 I_D\right) = -\left[V^+ - (R_4+R_5) I_D\right] = -5.4\ V$$

ok saturazione

$$g_m = k_p \left(V_{GS}-V_T\right) = 3.43\ mS$$

(2.2) Circuito equivalente



$R_G = R_2 /\!/ R_3 = 61.6\ k\Omega$

Condensatori non interagenti

C_1: zero nell'origine + polo $\qquad f_{PC_1} = \dfrac{1}{2\pi C_1 (R_1+R_G)} = 2.54\ Hz$

C_2: polo + zero finito $\qquad f_{PC_2} = \dfrac{1}{2\pi C_2 (R_5+R_6)} = 1.48\ kHz$

Con C_1 chiuso e C_2 aperto $\quad \left(f_{PC_1} < f < f_{PC_2}\right)$:

$$A_1 = \frac{v_u}{v_i} = -\frac{g_m R_5}{1+g_m R_4}\,\frac{R_G}{R_G+R_1} = -1.319 \quad (2.41\ dB)$$

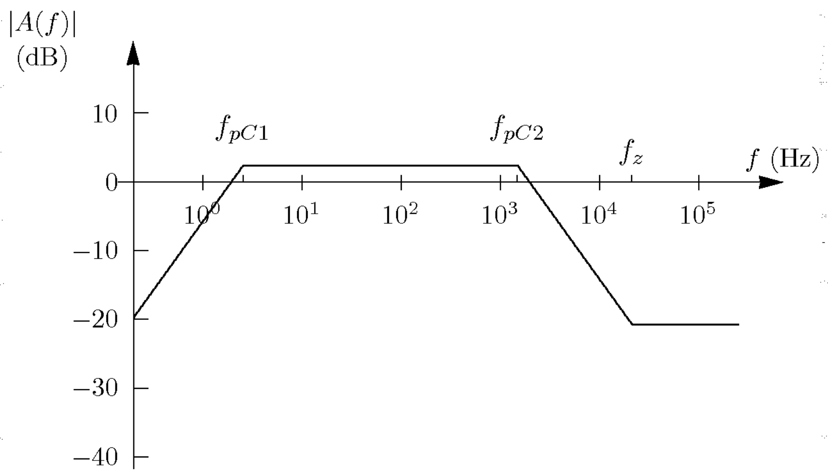
Con entrambi i condensatori chiusi $\left(f \gg f_{PC_1}, f_{PC_2}\right)$:

$$A_\infty = \frac{v_u}{v_i} = -\frac{g_m (R_5 /\!/ R_6)}{1+g_m R_4}\,\frac{R_G}{R_1+R_G} = -92.1\times 10^{-3} \quad (-20.7\ dB)$$

$$f_Z = f_{PC_2}\,\frac{A_1}{A_\infty} = 21.2\ kHz$$

$$A(f) = A_1 \frac{j\frac{f}{f_{pc1}}\left(1+j\frac{f}{f_z}\right)}{\left(1+j\frac{f}{f_{pc1}}\right)\left(1+j\frac{f}{f_{pc2}}\right)}$$

Diagramma di Bode

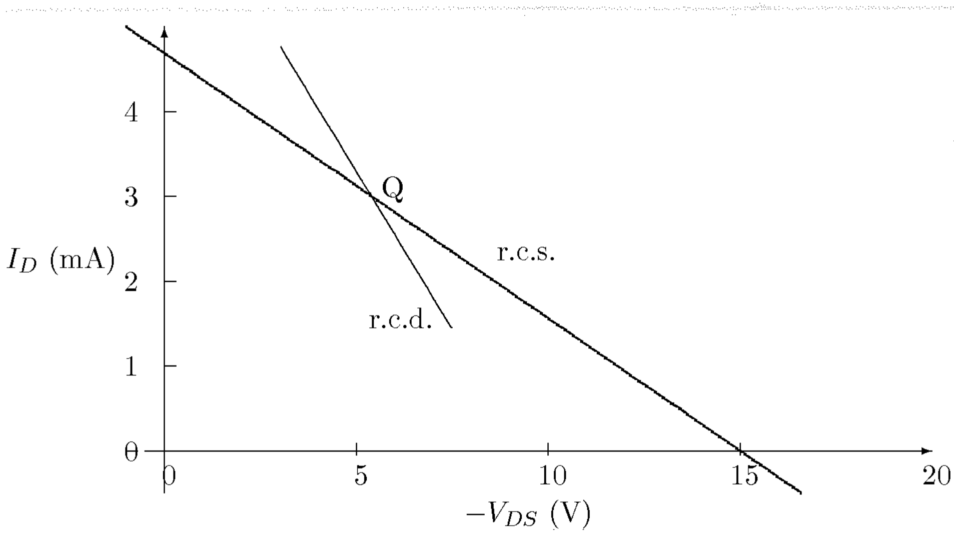


(2.3) $f_0 \gg f_z$ (C_1 e C_2 chiusi)

$v_{ds} = -\left[R_4 + (R_5 /\!/ R_6)\right] i_d$

Retta di carico statica: $V^+ = (R_4 + R_5)I_D - V_{DS}$.

La retta di carico dinamica passa per il punto di riposo ($I_D = 3\,\text{mA}, V_{DS} = -5.4$ V) e ha pendenza $\dfrac{-1}{R_4 + (R_5 /\!/ R_6)}$.



ESERCIZIO 3

(3.1)

$$V^+\frac{R_2}{R_1+R_2} - (R_1\|R_2)I_{B1} - V_{\gamma 1} - R_E(I_{C1}+I_{B1}) + V_{\gamma 2} - (R_3\|R_4)I_{B2} - V^+\frac{R_4}{R_3+R_4} = 0$$

trascurando i termini $(R_1\|R_2)I_{B1}$ e $(R_3\|R_4)I_{B2}$ e considerando $I_{B1} \ll I_{C1}$, si ottiene

$$I_{C1} = \frac{1}{R_E}\left(V^+\frac{R_2}{R_1+R_2} - V^+\frac{R_4}{R_3+R_4} - 2V_\gamma\right) = 2.2\ mA \simeq I_{C2}$$

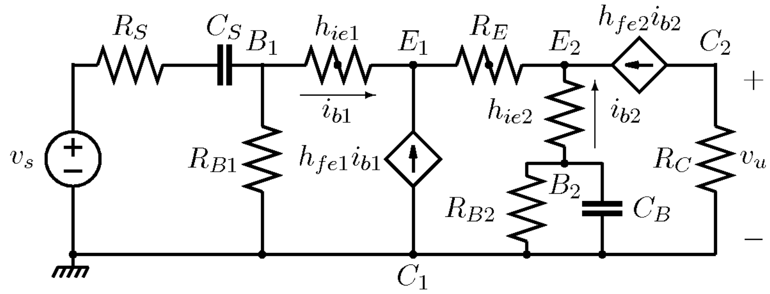
Detta $I_C = I_{C1} = I_{C2}$

$$V_{CE1} = V^+ - \left(V^+\frac{R_4}{R_3+R_4} + V_\gamma + R_E I_C\right) = 5{,}02\ V$$

$$V_{EC2} = V^+\frac{R_4}{R_3+R_4} + V_\gamma - R_C I_C = 3.08\ V \qquad (V_{CE2} = -3.08\ V)$$

$h_{fe1} = 270$ $h_{fe2} = 230$ $h_{ie1} = \frac{V_T}{I_C}h_{fe1} + r_{bb'1} = 3.89\ k\Omega$ $h_{ie2} = \frac{V_T}{I_C}h_{fe2} + r_{bb'2} = 2.92\ k\Omega$

(3.2) Circuito per le variazioni:



(coll. comune + base comune)

a centro banda entrambi i condensatori sono chiusi; in queste condizioni:

$v_u = -R_C h_{fe2} i_{b2}$ $\qquad (h_{fe1}+1)i_{b1} + (h_{fe2}+1)i_{b2} = 0 \quad (2)$

$$\underbrace{v_s\frac{R_{B1}}{R_{B1}+R_S} - (R_{B1}\|R_S)i_{b1}}_{*} - h_{ie1}i_{b1} - R_E(h_{fe1}+1)i_{b1} + h_{ie2}i_{b2} = 0 \quad (3)$$

* generatore equivalente di Thévenin

Ricavando i_{b1} dalla (2) e sostituendo nella (3) si trova infine

$$A_{CB} = \frac{R_{B1}}{R_{B1}+R_S} \frac{R_C h_{fe2}}{h_{ie2} + \frac{h_{fe2}+1}{h_{fe1}+1}\left[R_E(h_{fe1}+1) + h_{ie1} + (R_S /\!/ R_{B1})\right]} = 3.05 \quad (= 9.68\ dB)$$

$$f_{zCB} = \frac{1}{2\pi R_{B2} C_B} = 12.92\ Hz$$

$$R_S^o = R_S + \left\{R_{B1} /\!/ \left[h_{ie1} + \left(R_E + \frac{h_{ie2}+R_{B2}}{h_{fe2}+1}\right)(h_{fe1}+1)\right]\right\} = 9.84\ k\Omega$$

$$R_S^B = R_S + \left\{R_{B1} /\!/ \left[h_{ie1} + \left(R_E + \frac{h_{ie2}}{h_{fe2}+1}\right)(h_{fe1}+1)\right]\right\} = 9.83\ k\Omega$$

$$R_B^o = R_{B2} /\!/ \left[h_{ie2} + \left(R_E + \frac{h_{ie1}+R_{B1}}{h_{fe1}+1}\right)(h_{fe2}+1)\right] = 11.73\ \Omega$$

$$R_B^S = R_{B2} /\!/ \left\{h_{ie2} + \left[R_E + \frac{h_{ie1}+(R_{B1} /\!/ R_S)}{h_{fe1}+1}\right](h_{fe2}+1)\right\} = 11.71\ \Omega .$$

<u>Osservazione</u>: poiché $R_S^o \simeq R_S^B$ e $R_B^o \simeq R_B^S$, si ha <u>interazione debole</u> tra C_S e C_B

$$a_1 = C_S R_S^o + C_B R_B^o = 110.175\ ms$$
$$a_2 = C_S C_B R_S^o R_B^S = 1.153 \times 10^{-3}\ s^2$$

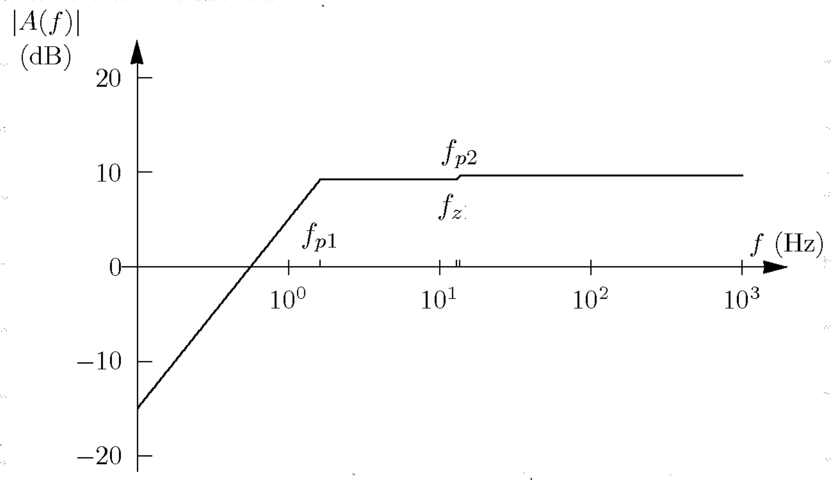
$$P(s) = 1 + a_1 s + a_2 s^2 \qquad s_{p1,2} = \begin{cases} -10.16\ rad/s \\ -85.4\ rad/s \end{cases}$$

$$f_{P1,2} = \begin{cases} 1.616\ Hz \\ 13.59\ Hz \end{cases}$$

Così

$$A(f) = A_{CB} \frac{f_{zCB} \, j \frac{f}{f_{P1}} \left(1 + j \frac{f}{f_{zCB}}\right)}{f_{P2} \left(1 + j \frac{f}{f_{P1}}\right)\left(1 + j \frac{f}{f_{P2}}\right)}$$

(3.3) Diagramma di Bode



(3.4) $P_{Al} = V^+\left(\frac{1}{R_1+R_2} + \frac{1}{R_3+R_4} + I_C\right) = 36{,}72 \text{ mW}$

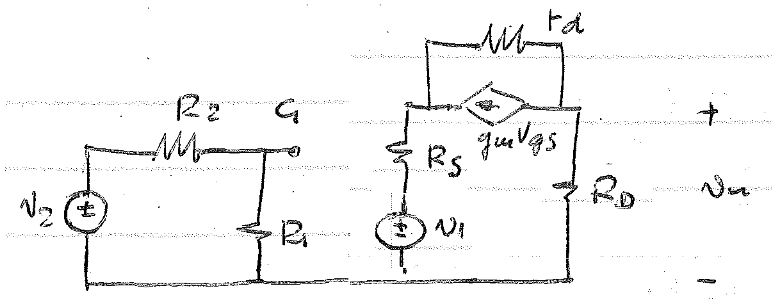
(trascurando le correnti di base rispetto a quelle nei partitori.)

ESERCIZIO 4

4.1

$A_2 = \left.\frac{v_u}{v_2}\right|_{v_1=0}$ è il guadagno di un amplificatore a source comune con resistenza sul source

$A_1 = \left.\frac{v_u}{v_1}\right|_{v_2=0}$ è il guadagno di un amplificatore a gate comune



$$A_1 = \frac{R_D g_m}{1 + g_m R_S} = 1.435$$

$$A_2 = \frac{-g_m R_D}{1 + g_m R_S} \frac{R_1}{R_1 + R_2} = -0.820$$

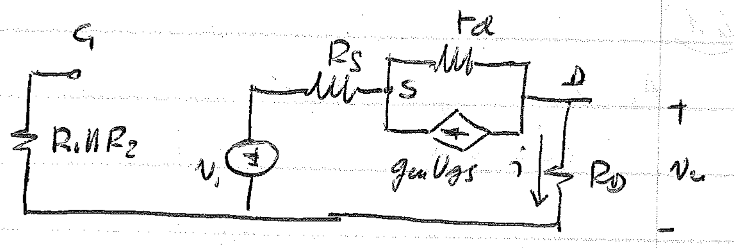
con $r_d \to \infty$

$$A_c = A_1 + A_2 = 0.615 \qquad A_d = \frac{A_1 - A_2}{2} = 1.127$$

$$\rho = \frac{A_d}{A_c} = 1.833 \quad (= 5.26\ dB)$$

(4.2) Considerando anche r_d, si ha:

per A_1:



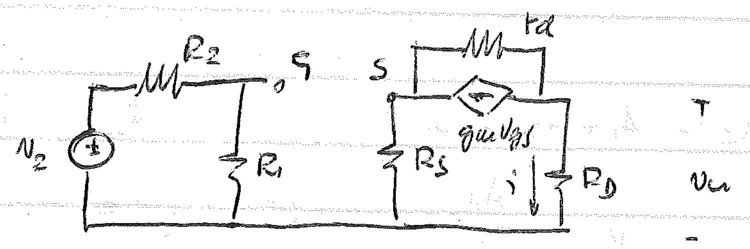
$$v_u = R_D\, i$$

$$v_1 - R_S i - r_d\,(i + g_m v_{gs}) - v_u = 0$$

$$v_{gs} = -(v_1 - R_S i)$$

$$\Rightarrow A_1 = \frac{v_u}{v_1} = \frac{R_D(1+g_m r_d)}{R_S + R_D + r_d(1+g_m R_S)} = 1.401$$

per A_2:



$$v_u = R_D\, i$$

$$v_{gs} = \frac{R_1}{R_1+R_2} v_2 + R_S i$$

$$i = -g_m v_{gs} \frac{r_d}{r_d + R_S + R_D}$$

$$\Rightarrow A_2 = \left.\frac{v_u}{v_2}\right|_{v_1=0} = -\frac{R_1}{R_1+R_2}\,\frac{g_m R_D r_d}{R_D + R_S + r_d(1+g_m R_S)} = -0.785$$

$$A_c = A_1 + A_2 = 0.616$$

$$A_d = \frac{A_1 - A_2}{2} = 1.093 \qquad \rho = \frac{A_d}{A_c} = 1.774 \quad (4.98\,dB)$$