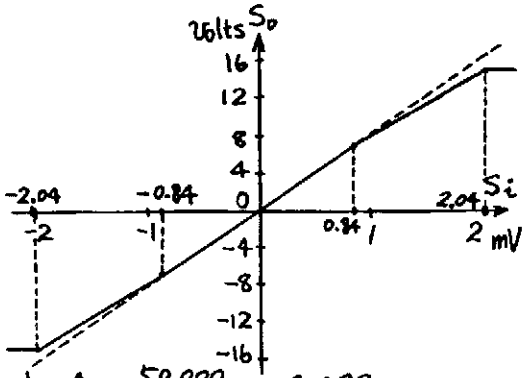
Homework Assignment No. 9 - Solutions

8.2

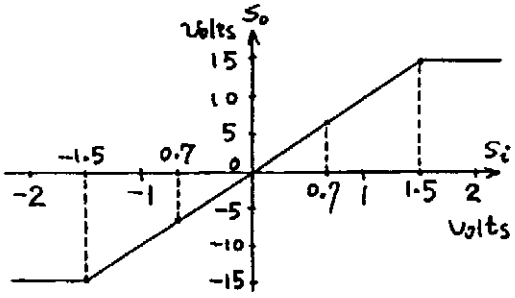
(a) $A_1 = \frac{a_1}{1+a_1 f} = \frac{50000}{1+5} = 8333$

$A_2 = \frac{20,000}{1+2} = 6667$



(b) $A_1 = \frac{50,000}{1+5000} = 9.998$

$A_2 = \frac{20,000}{1+2000} = 9.995$



8.6(a)

From (8.66)

$Z_{ia} = \frac{R_F Z_i}{R_F + Z_i} = \frac{100 \times 500}{600} = 83.3\ k\Omega$

From (8.68)

$Z_{oa} = Z_o \| R_F \| R_L$

$= 200 \| 100k \| 15K$

$\simeq 200\Omega$

From (8.70)

$T = \left(\frac{10^5 \times 15 \times 10^3}{10^5 \times 15 \times 10^3 + 200 \times 10^3 + 200 \times 15 \times 10^3}\right) \times 75,000 \times \frac{500}{600}$

$= 61,560$

Thus with feedback

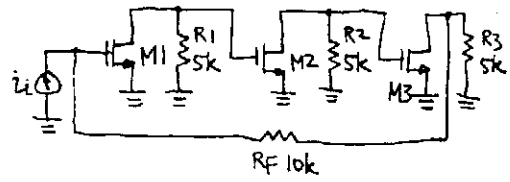
$Z_i = \frac{83.3k}{61,560} = 1.4\ \Omega$

$Z_o = \frac{200}{61,560} = 0.0032\ \Omega$

$A = \frac{1}{f}\frac{1}{1+\frac{1}{T}} = \frac{10k\Omega}{1+\frac{1}{61,560}}$

$= 99.998\ k\Omega$

8.7

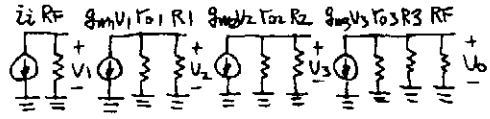


$g_m = \sqrt{2k'\frac{W}{L} I_D} = \sqrt{2 \times 60 \times 10^{-6} \times 100 \times 10^{-3}}$

$= 3.5 \times 10^{-3} A/V$

$r_{o1} = \frac{1}{\lambda I_D} = \frac{50}{10^{-3}} = 50\ k\Omega$

(a)



$a = \frac{v_o}{i_i}\Big|_{f=0} = R_F(-g_{m1})(r_{o1} \| R_1)(-g_{m2})(r_{o2} \| R_2)$

$(-g_{m3})(r_{o3} \| R_3 \| R_F)$

$= -g_{m1}^3 (r_{o1} \| R_1)^2 R_F (r_{o3} \| R_3 \| R_F)$

$= -(3.5 \times 10^{-3})^3 (50k \| 5k)^2 10k (50k \| 5k \| 10k)$

$= -2.76 \times 10^7\ \Omega$

$f = -\frac{i_{fb}}{v_o} = -\frac{1}{R_F} = -\frac{1}{10k\Omega}$

$af = 2.76 \times 10^3$

$\frac{v_o}{i_i} = \frac{a}{1+af} = \frac{-2.76 \times 10^7}{1+2.76 \times 10^3} = -10k\Omega$

$R_i = \frac{R_F}{1+af} = \frac{10k}{1+2.76 \times 10^3} = 16.4\ \Omega$

$R_o = \frac{r_{o3} \| R_3 \| R_F}{1+af} = \frac{50k \| 5k \| 10k}{1+2.76 \times 10^3} = 1.13\ \Omega$

(b)

$a = -2.76 \times 10^7 \frac{R_F \| R_S}{R_F} = -2.76 \times 10^7 \frac{10k \| 1k}{10k}$

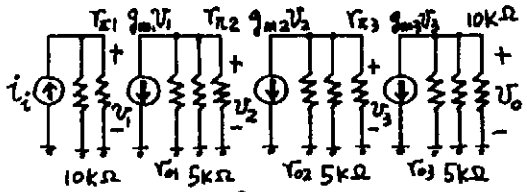
$= -2.51 \times 10^6\ \Omega$

$af = 251$

$R_o = \frac{r_{o3} \| R_3 \| R_F}{1+af} = \frac{50k \| 5k \| 10k}{1+251} = 12.4\ \Omega$

8.8

(a) Basic amplifier



$r_{\pi1}=r_{\pi2}=r_{\pi3}=\frac{\beta}{g_m}=5.2\,K\Omega$

$g_m=\frac{1}{26}U$, $r_o=50K\Omega$

$R_1=10k\|r_{\pi1}=\frac{5.2\times10}{15.2}=3.42\,k\Omega$

$R_2=r_{o1}\|5k\|r_{\pi2}=2.42K\Omega$

$R_3=r_{o2}\|5k\|r_{\pi3}=2.42\,k\Omega$

$R_4=r_{o3}\|5K\|10K=3.13\,K\Omega$

$\therefore \frac{v_o}{i_i}=-R_1g_{m1}R_2g_{m2}R_3g_{m3}R_4$

$=-3.42\frac{2420}{26}\frac{2420}{26}\frac{3130}{26}\,K\Omega$

$=-3.57\times10^9\,\Omega=a$

$f=-\frac{i_{fb}}{v_o}=-\frac{1}{10K\Omega}$

$\therefore$ overall $\frac{v_o}{i_i}=\frac{a}{1+af}=\frac{-3.57\times10^9}{1+3.57\times10^5}$

$=-10K\Omega$

loop gain $=af=3.57\times10^5$

$R_i=\frac{R_1}{1+af}=\frac{3420}{1+3.57\times10^5}=0.0096\Omega$

$R_o=\frac{R_4}{1+af}=\frac{3130}{1+3.57\times10^5}=0.0088\Omega$

(b)

New value of $R_1=3.42^K\|1^K=774\Omega$

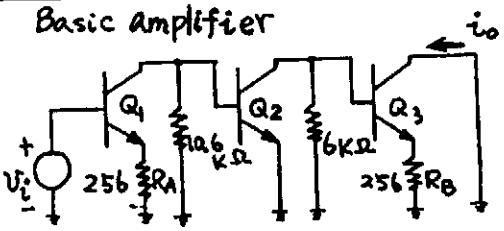
$\therefore a=-3.57\times10^9\frac{774}{3420}=-808\,M\Omega$

$\therefore af=808\times10^6\times10^{-4}=8.08\times10^4$

$R_o=\frac{R_4}{1+af}=\frac{3130}{1+8.08\times10^4}=0.0387\Omega$

8.11

Basic amplifier



$R_{E1}\|(R_F+R_{E2})=290\|2.19K=256\Omega$

$r_{\pi1}=\frac{\beta}{g_{m1}}=52\times120=6.24\,K\Omega$

$r_{o1}=80K\Omega$

$r_{\pi2}=\frac{26\times120}{0.77}=4.05\,K\Omega$

$r_{o2}=\frac{40}{0.77}=52\,K\Omega$

$r_{\pi3}=\frac{26\times120}{0.73}=4.27\,K\Omega$

$r_{o3}=\frac{40}{0.73}=54.8\,K\Omega$

In forward gain calculation, neglect r_{o1} and r_{o3}.

For the basic amplifier,

$\frac{i_o}{v_i}=\frac{g_{m1}}{1+g_{m1}R_A}R_1g_{m2}R_2\frac{g_{m3}}{1+g_{m3}R_B}$

$R_1=10.6K\|r_{\pi2}=2.93\,K\Omega$

$R_2=r_{o2}\|6K\|R_{i3}$

$R_{i3}=r_{\pi3}(1+g_{m3}R_B)$

$=4.27\left(1+\frac{0.73}{26}\times256\right)$

$=35\,K\Omega$

$\therefore R_2=52k\|6K\|35K=4.66\,K\Omega$

$\therefore \frac{i_o}{v_i}=\frac{1}{52}\frac{1}{1+\frac{256}{52}}2930\frac{0.77}{26}4660$

$\times\frac{0.73}{26}\frac{1}{8.19}$

$\therefore a=4.5\,A/V$

From (8.95)

$f=\frac{1}{\alpha_3}\frac{R_{E1}R_{E2}}{R_{E1}+R_{E2}+R_F}$

$=\frac{1}{0.99}\frac{290\times290}{290+290+1900}$

$=34.25\,\Omega$

$\therefore$ loop gain $=af=4.5\times34.25=154$

overall gain with feedback

$=\frac{a}{1+af}=\frac{4.5}{1+154}=\frac{4.5}{155}\,A/V$

$\therefore \frac{i_o}{v_s}=29\,mA/V$

For the basic amplifier

Input resistance

$r_{ia}=r_{\pi1}(1+g_{m1}R_A)$

$=6.24\left(1+\frac{256}{52}\right)=36.96\,k\Omega$

Output resistance

$r_{oa}=r_{o3}\left(1+g_{m3}R_B\frac{r_{\pi3}}{r_{\pi3}+R_{s3}}\right)$

$R_{s3}=r_{o2}\|6K=5.38\,K\Omega$

$\therefore r_{oa}=54.8\left(1+\frac{0.73}{26}256\frac{4.27}{4.27+5.38}\right)$

$=229\,K\Omega$

For the feedback amplifier

$R_i=r_{ia}(1+af)=36.96\times155=5.73\,M\Omega$

$R_o=r_{oa}(1+af)=229\times155=35.5\,M\Omega$