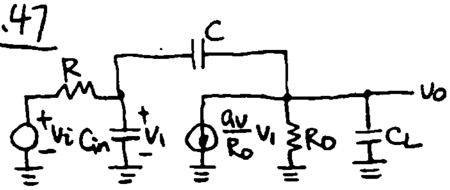
7.47



The zero value time constants

$C_{in}R = 0.2\times10^{-12}\times20\times10^{3} = 4\times10^{-9}\,s$

$C(R+R_o+\frac{a_v}{R_o}RR_o) = C(R+R_o+a_vR)$

$= C[(1+a_v)R+R_o]$

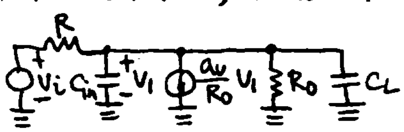
$= 50\times10^{-12}[(1+1000)20\times10^{3}+5\times10^{3}]$

$= 1\times10^{-3}\,s$

$C_LR_o = 0.5\times10^{-12}\times5\times10^{3} = 2.5\times10^{-9}\,s$

$P_1 = -\dfrac{1}{4\times10^{-9}+1\times10^{-3}+2.5\times10^{-9}} = -1\times10^{3}\,\text{rad/s}$

$1\times10^{-3}\,s \gg 4\times10^{-9}\,s,\ 2.5\times10^{-9}\,s$. C is shorted.



$(C_{in}+C)(R \| \frac{R_o}{a_v} \| R_o)$

$\approx (C_{in}+C)\dfrac{R_o}{a_v}$

$= (0.2+0.5)\times10^{-12}\dfrac{5\times10^{3}}{1000}$

$= 3.5\times10^{-12}\,s$

$P_2 = -\dfrac{1}{3.5\times10^{-12}} = -2.9\times10^{11}\,\text{rad/s}.$

Note that there is a zero at

$z = -\dfrac{a_v/R_o}{C} = -\dfrac{1000/5\times10^{3}}{50\times10^{-12}} = -4\times10^{9}\,\text{rad/s}$

It is between the two poles and confirmed by SPICE.

```
INTEGRATOR
VI   1   0   AC   1
R    1   2   20K
RO   3   4   5K
CIN  2   0   0.2P
C    2   3   50P
CL   3   0   0.5P
E    4   0   0    2    1000
.OPTIONS NOMOD
.AC DEC 5 10 100G
.PLOT AC VM(3)
.WIDTH OUT=80
.OPTIONS SPICE
.END

******  OPERATING POINT INFORMATION      TNOM=  27.000 TEMP=  27.000

+0:1       =  0.       0:2       =  0.       0:3       =  0.
+0:4       =  0.

******  AC ANALYSIS                      TNOM=  27.000 TEMP=  27.000
```

Plot axis (VM(3)): 1.000E-04, 1.000E-02, 1.000E+00, 1.000E+02, 1.000E+04

FREQ	VM(3)
1.000E+01	9.98E+02
1.584E+01	9.95E+02
2.511E+01	9.87E+02
3.981E+01	9.70E+02
6.309E+01	9.29E+02
1.000E+02	8.46E+02
1.584E+02	7.08E+02
2.511E+02	5.34E+02
3.981E+02	3.70E+02
6.309E+02	2.44E+02
1.000E+03	1.57E+02
1.584E+03	9.97E+01
2.511E+03	6.31E+01
3.981E+03	3.99E+01
6.309E+03	2.51E+01
1.000E+04	1.58E+01
1.584E+04	1.00E+01
2.511E+04	6.32E+00
3.981E+04	3.99E+00
6.309E+04	2.51E+00
1.000E+05	1.59E+00
1.584E+05	1.00E+00
2.511E+05	6.33E-01
3.981E+05	3.99E-01
6.309E+05	2.52E-01
1.000E+06	1.59E-01
1.584E+06	1.00E-01
2.511E+06	6.33E-02
3.981E+06	3.99E-02
6.309E+06	2.52E-02
1.000E+07	1.59E-02
1.584E+07	1.00E-02
2.511E+07	6.33E-03
3.981E+07	4.00E-03
6.309E+07	2.53E-03
1.000E+08	1.61E-03
1.584E+08	1.03E-03
2.511E+08	6.80E-04
3.981E+08	4.71E-04
6.309E+08	3.55E-04
1.000E+09	2.96E-04
1.584E+09	2.69E-04
2.511E+09	2.57E-04
3.981E+09	2.52E-04
6.309E+09	2.49E-04
1.000E+10	2.44E-04
1.584E+10	2.36E-04
2.511E+10	2.19E-04
3.981E+10	1.88E-04
6.309E+10	1.46E-04
1.000E+11	1.03E-04

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)

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

$$= 61{,}560$$

Thus with feedback

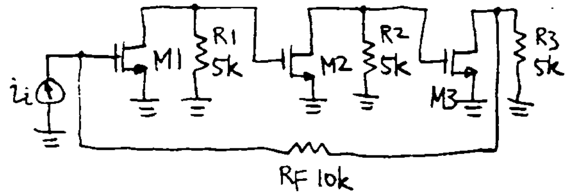
$$Z_i = \frac{83.3\text{K}}{61{,}560} = 1.4\ \Omega$$

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

$$A = \frac{1}{f}\,\frac{1}{1 + \frac{1}{T}} = \frac{100\text{k}\Omega}{1 + \frac{1}{61{,}560}}$$

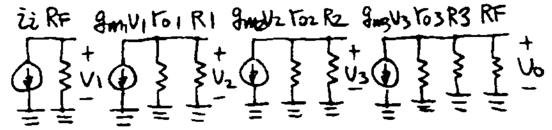
$$= 99.998\ \text{k}\Omega$$

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)



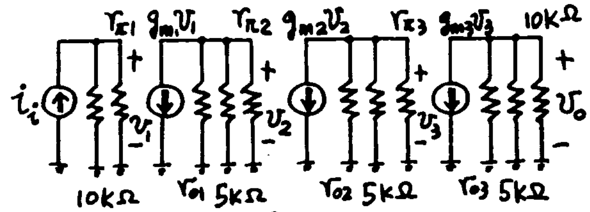
$$a = \frac{v_o}{i_i}\Big|_{f=0} = R_F(-g_{m1})(r_{o1}||R_1)(-g_{m2})(r_{o2}||R_2)$$
$$(-g_{m3})(r_{o3}||R_3||R_F)$$
$$= -g_{m1}^3(r_{o1}||R_1)^2 R_F(r_{o3}||R_3||R_F)$$
$$= -(3.5\times 10^{-3})^3(50k||5k)^2\,10k\,(50k||5k||10k)$$
$$= -2.76\times 10^7\,\Omega$$
$$f = -\frac{i_{fB}}{v_o} = -\frac{1}{R_F} = -\frac{1}{10k\Omega}$$
$$af = 2.76\times 10^3$$
$$\frac{v_o}{i_i} = \frac{a}{1+af} = \frac{-2.76\times 10^7}{1+2.76\times 10^3} = -10k\Omega$$
$$R_i = \frac{R_F}{1+af} = \frac{10k}{1+2.76\times 10^3} = 16.4\,\Omega$$
$$R_o = \frac{r_{o3}||R_3||R_F}{1+af} = \frac{50k||5k||10k}{1+2.76\times 10^3} = 1.13\,\Omega$$

(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



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

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

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

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

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

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

$\therefore \frac{v_o}{i_i} = -R_1 g_{m1} R_2 g_{m2} R_3 g_{m3} R_4$

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

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

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

$\therefore$ 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 $R_1 = 3.42^K \| 1^K = 774\,\Omega$

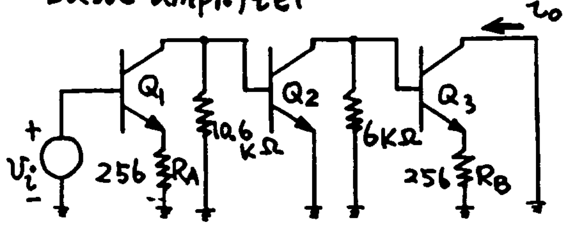
$\therefore a = -3.57\times10^9 \frac{774}{3420} = -808\,M\Omega$

$\therefore af = 808\times10^6 \times 10^{-4} = 8.08\times10^4$

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

8.11

Basic amplifier



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

$r_{\pi 1} = \frac{\beta}{g_{m1}} = 52 \times 120 = 6.24\ k\Omega$

$r_{o1} = 80 k\Omega$

$r_{\pi 2} = \frac{26 \times 120}{0.77} = 4.05\ k\Omega$

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

$r_{\pi 3} = \frac{26 \times 120}{0.73} = 4.27 k\Omega$

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

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

For the basic amplifier,

$$\frac{i_o}{v_i} = \frac{g_{m1}}{1 + g_{m1} R_A} R_1 g_{m2} R_2 \frac{g_{m3}}{1 + g_{m3} R_B}$$

$R_1 = 10.6K \| r_{\pi 2} = 2.93\ k\Omega$

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

$R_{i3} = r_{\pi 3}(1 + g_{m3} R_B)$

$= 4.27\left(1 + \frac{0.73}{26} \times 256\right)$

$= 35\ k\Omega$

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

$$\therefore \frac{i_o}{v_i} = \frac{1}{52} \frac{1}{1 + \frac{256}{52}} 2930 \frac{0.77}{26} 4660 \times \frac{0.73}{26} \frac{1}{8.19}$$

$\therefore a = 4.5\ A/V$

From (8.95)

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

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

$= 34.25\ \Omega$

$\therefore$ loop gain $= af = 4.5 \times 34.25 = 154$

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

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

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

Output resistance

$$r_{oa} = r_{o3}\left(1 + g_{m3} R_B \frac{r_{\pi 3}}{r_{\pi 3} + R_{S3}}\right)$$

$R_{S3} = r_{o2} \| 6K = 5.38\ k\Omega$

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

$= 229\ k\Omega$

For the feedback amplifier

$R_i = r_{ia}(1 + af) = 36.96 \times 155 = 5.73\ M\Omega$

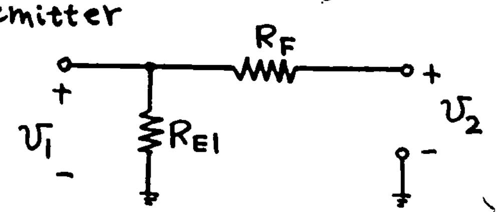
$R_o = r_{oa}(1 + af) = 229 \times 155 = 35.5\ M\Omega$

8.12

For the basic amplifier

$\frac{v_o}{v_i} = \frac{i_o}{v_i} R_B = 4.5 \times 256 = 1152$

where v_o is the voltage at Q_3 emitter



$$f = h_{12f} = \frac{v_1}{v_2} = \frac{R_{E1}}{R_{E1} + R_F}$$

$$= \frac{290}{290 + 1900} = 0.132$$