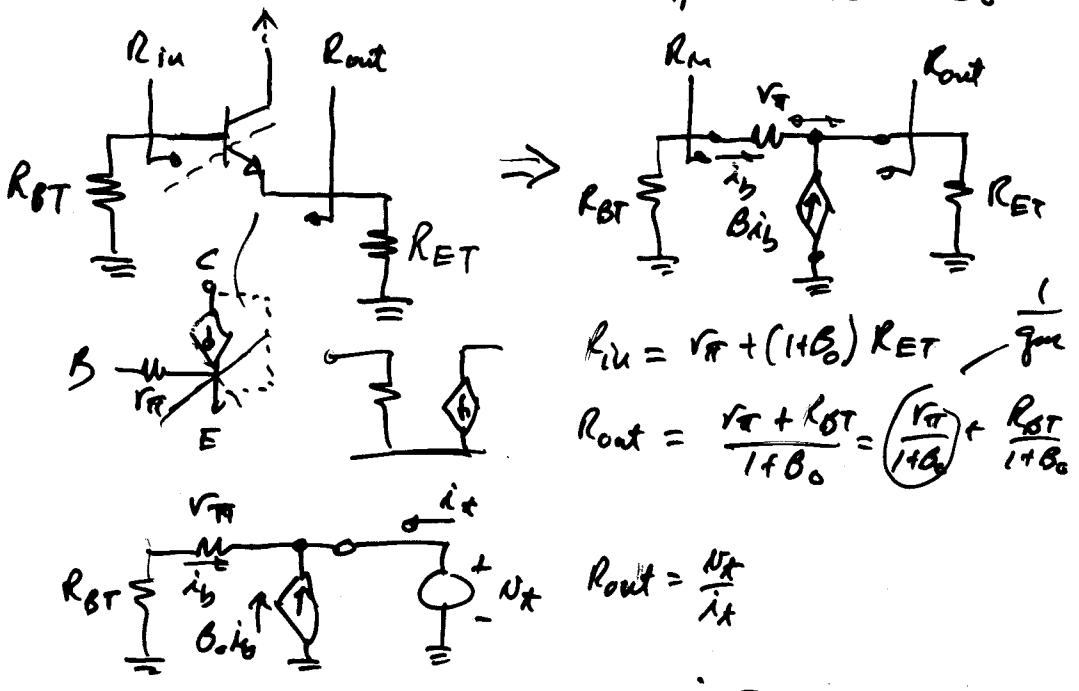
Comments on emitter follower output resistance:



$$R_{in} = r_\pi + (1+\beta_o) R_{ET} \qquad \frac{1}{g_m}$$

$$R_{out} = \frac{r_\pi + R_{BT}}{1+\beta_o} = \left(\frac{r_\pi}{1+\beta_o}\right) + \frac{R_{BT}}{1+\beta_o}$$

$$R_{out} = \frac{v_t}{i_t}$$

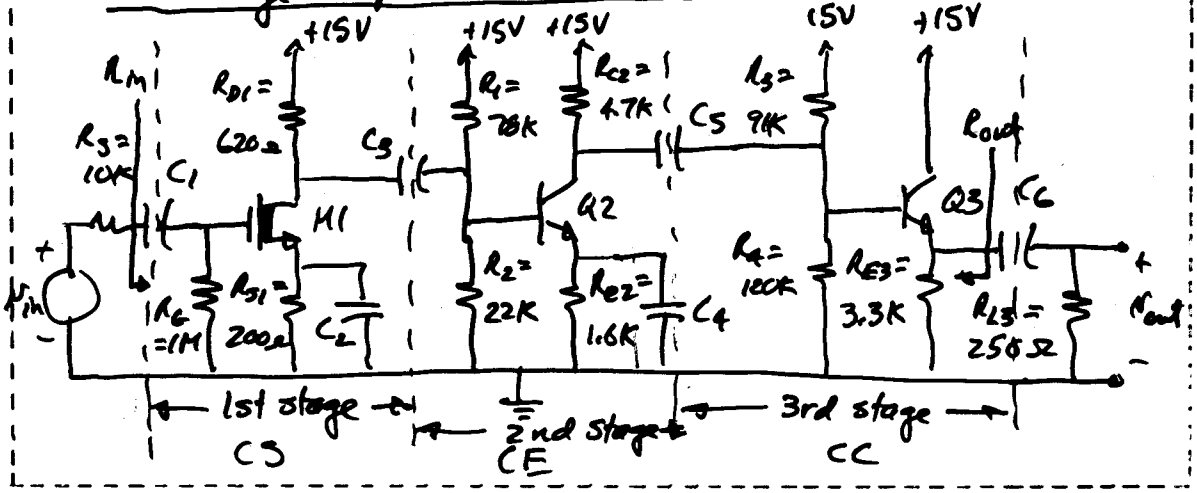
$$i_b(1+\beta_o) + i_t = 0 \rightarrow i_b = \frac{-i_t}{1+\beta_o} \qquad \frac{v_t}{i_t} = \frac{r_\pi + R_{BT}}{1+\beta_o}$$

$$i_b = \frac{-v_t}{r_\pi + R_{BT}}$$

CHAPTER 15 – MULTISTAGE AMPLIFIERS

- Multistage Amps
  - Darlington
  - Cascode
- Diff. amps

Multistage Amplifier Example



Transistor parameters:

M1: $K_n = 10 mA/V^2$, $V_{TN} = -2V$, $\lambda = 0.02 V^{-1}$

Q2: $\beta_0 = \beta_F = 150$, $V_A = 80V$ and $V_{BEQ} = 0.6V$

Q3: $\beta_0 = \beta_F = 80$, $V_A = 60V$ and $V_{BEQ} = 0.6V$

Q-point and s.s. model parameters:

M1: $I_{DS1} = 5mA$, $V_{DS1} = 10.9V \rightarrow g_{m1} = 10mS$ & $r_{o1} = 12.2k\Omega$

Q2: $I_{C2} = 1.57mA$, $V_{CE2} = 5.09V \rightarrow g_{m2} = 62.8mS$

$r_{\pi 2} = 2.39k\Omega$

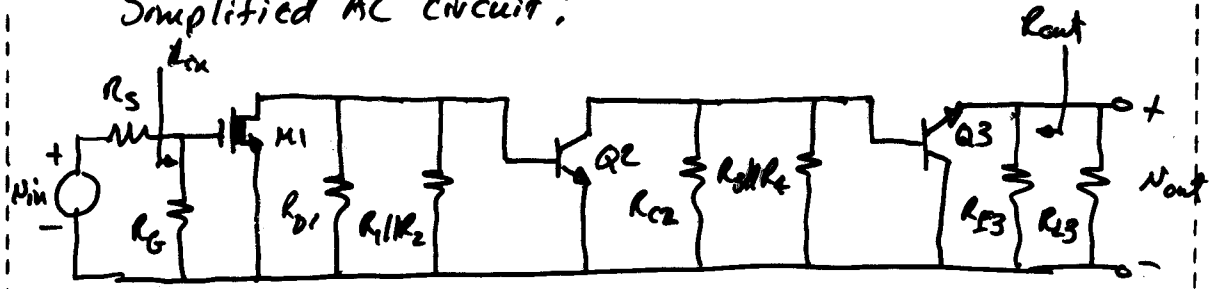
$r_{o2} = 54.2k\Omega$

Q3: $I_{C3} = 1.99mA$, $V_{CE3} = 8.3V \rightarrow g_{m3} = 79.6mS$

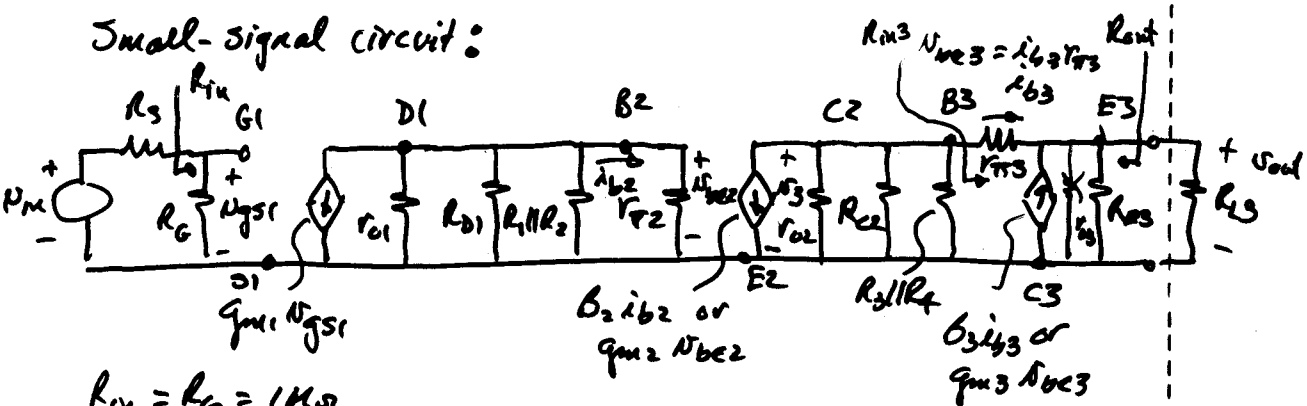
$r_{\pi 3} = 1K$

$r_{o3} = 34.1k\Omega$

Simplified AC circuit:



Small-signal circuit:



$R_{in} = R_G = 1M\Omega$

$$R_{out} = r_{o3} \| R_{E3} \| \left[\frac{r_{\pi 3} + r_{o2} \| R_{C2} \| R_3 \| R_4}{1 + \beta_3} \right]$$

$$\cong 3.3K \| \left[\frac{1K + 4.7K \| 51.75K \| 54.2K}{81} \right] = 60.4\Omega \geq \frac{1}{g_{m3}}$$

(r_{o2})

$$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{v_{be3}}\right)\left(\frac{v_{be3}}{v_3}\right)\left(\frac{v_3}{v_{be2}}\right)\left(\frac{v_{be2}}{v_{gs1}}\right)\left(\frac{v_{gs1}}{v_{in}}\right)$$

$$v_{out} = i_{b3}(1+\beta_3)\left[r_{o3} \| R_{E3} \| R_{L3}\right] \cong \frac{v_{be3}}{r_{\pi 3}}(1+\beta_3)(R_{E3} \| R_{L3}) = 18.82\ v/v$$

$\frac{v_{be3}}{v_3} = ?$

$$R_{in3} = r_{\pi 3} + (1+\beta_3)\, R_{E3} \| R_{L3}$$

$$i_{b3} = \frac{v_3}{R_{in3}} = \frac{v_{be3}}{r_{\pi 3}} \rightarrow \frac{v_{be3}}{v_3} = \frac{r_{\pi 3}}{R_{in3}}$$

$$\frac{v_{be3}}{v_3} = \frac{r_{\pi 3}}{R_{in3}} = \frac{1}{19.82}$$

$$\frac{v_3}{v_{be2}} = -g_{m2}\left(r_{o2} \| R_{C2} \| R_{in3} \| R_3 \| R_4\right) = -62.8(3.322) = -208.6\ \frac{V}{V}$$

$$\frac{v_{be2}}{v_{gs1}} = -g_{m1}\left(r_{o1} \| R_{D1} \| R_1 \| R_2 \| r_{\pi 2}\right) = -4.756\ v/v$$

$$\frac{v_{gs1}}{v_{in}} = \frac{R_G}{R_S + R_G} = \frac{1}{1.01}$$

$$\frac{v_{out}}{v_{in}} = 738.6\ v/v$$