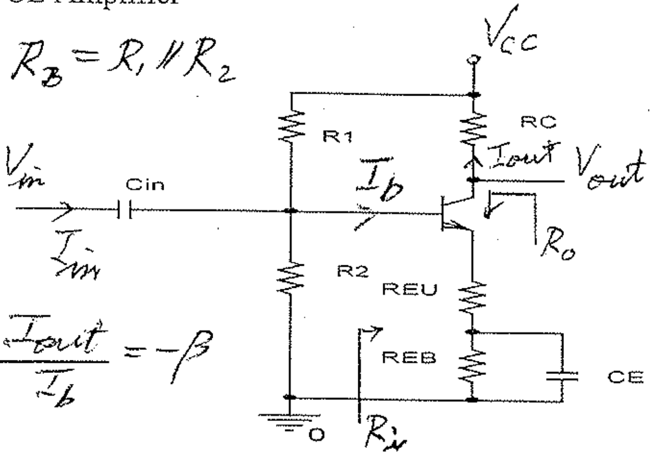
BJT Amplifier Configurations

CE Amplifier

$R_B = R_1 /\!/ R_2$



$\frac{I_{out}}{I_b} = -\beta$

Small-signal Analysis

$$A_I = \frac{I_{out}}{I_{in}} = -\beta \times \frac{R_B}{R_i + R_B}$$

$$R_o = \infty$$

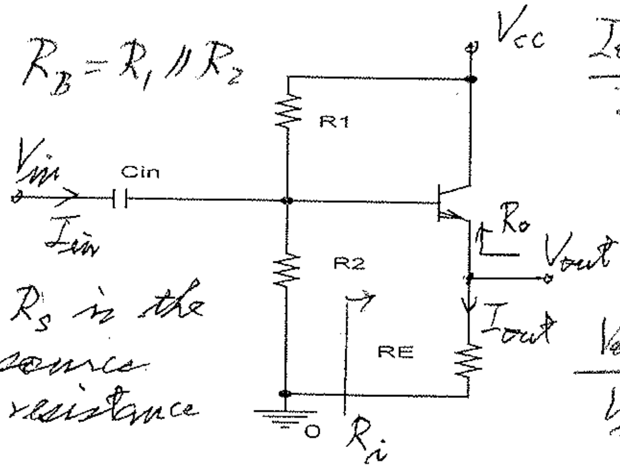
$$R_i = r_\pi + (1+\beta) R_{EU}$$

$$A_v = \frac{V_{out}}{V_{in}} = \begin{cases} -g_m R_c & (R_{EU} = 0) \\ -\frac{\beta R_C}{\beta R_{EU} + R_{EU} + r_\pi} & (R_{EU} \neq 0) \end{cases}$$

$A_v < 0$

CC Amplifier (Emitter follower)

$R_B = R_1 /\!/ R_2$



R_s is the ~~source~~ source resistance

$$\frac{I_{out}}{I_{in}} = A_I = (\beta + 1) \times \frac{R_B}{R_B + R_i}$$

$$R_o = \frac{(R_S /\!/ R_B) + r_\pi}{1+\beta} \simeq \frac{1}{g_m} \quad \left(\begin{matrix} R_S = 0 \\ \beta \gg 1 \end{matrix}\right)$$

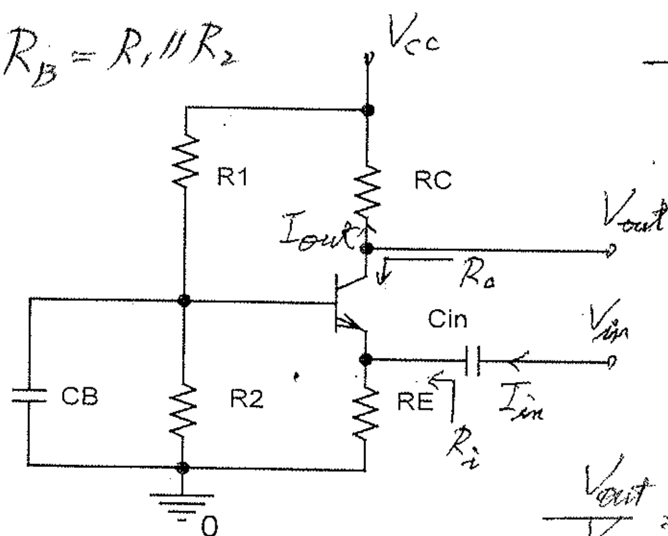
$$R_i = r_\pi + (1+\beta) R_E$$

$$\frac{V_{out}}{V_{in}} = A_V = \frac{g_m + \frac{1}{r_\pi}}{\frac{1}{R_E} + g_m + \frac{1}{r_\pi}}$$

If $g_m + \frac{1}{r_\pi} \gg \frac{1}{R_E}$, then $A_v \simeq 1$.

CB Amplifier

$R_B = R_1 /\!/ R_2$



With C_B $\quad A_I = \frac{I_{out}}{I_{in}}$

$$A_I = \frac{g_m}{\frac{1}{R_E} + \frac{1}{r_\pi} + g_m} \simeq 1 \text{ if } g_m \gg \frac{1}{R_E} + \frac{1}{r_\pi}$$

$$R_o = \infty$$

$$R_i = \frac{1}{\frac{1}{R_E} + \frac{1}{r_\pi} + g_m} \simeq \frac{1}{g_m} \text{ if } g_m \gg \frac{1}{R_E} + \frac{1}{r_\pi}$$

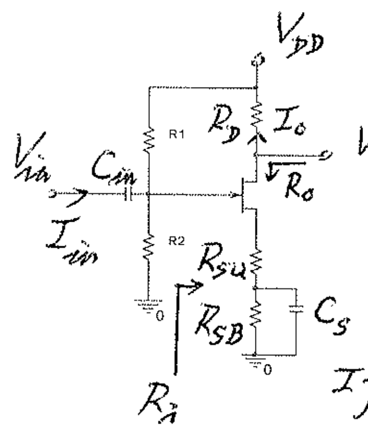
$$\frac{V_{out}}{V_{in}} = A_v = g_m R_c \quad (A_v > 0)$$

Without C_B $\quad A_I = g_m \times \frac{r_\pi}{r_\pi + R_B} \times R_i$ where $R_i = \frac{1}{\frac{1}{R_E} + \frac{1}{r_\pi + R_B} + \frac{g_m r_\pi}{r_\pi + R_B}}$

$R_o = \infty$, $A_v = g_m R_c \times \frac{r_\pi}{r_\pi + R_B}$

JFET Amplifier Configurations

Common Source Amplifier



$$A_V = \frac{V_o}{V_{in}} = -\frac{\mu R_D}{r_o + R_D + (1+\mu) R_{SU}} < 0$$

$$A_I = \frac{I_o}{I_{in}} = -\frac{\mu R_G}{r_o + R_D + (1+\mu) R_{SU}} < 0$$

$$R_i = \infty, \quad R_o = r_o + (1+\mu) R_{SU}$$

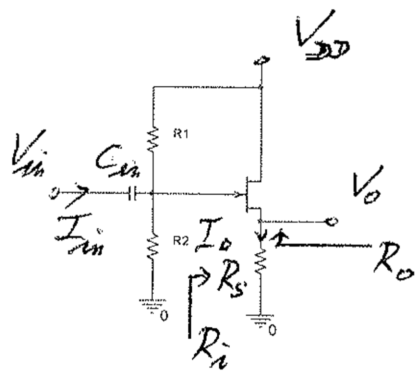
$$\text{If } r_o = \infty, \quad A_V = \frac{-g_m R_D}{1 + g_m R_{SU}}, \quad R_o = \infty$$

$$R_i = \infty, \quad A_I = -\frac{g_m R_G}{1 + g_m R_{SU}}$$

$$R_G = R_1 \parallel R_2$$

$$\mu = g_m r_o$$

Common Drain Amplifier (Source Follower)



$$A_V = \frac{V_o}{V_{in}} = \frac{g_m (r_o \parallel R_S)}{1 + g_m (r_o \parallel R_S)} > 0$$

$$A_I = \frac{I_o}{I_{in}} = A_V \times \frac{R_G}{R_S}$$

$$R_i = \infty, \quad R_o = \frac{r_o}{1 + g_m r_o} = \frac{r_o}{1+\mu}$$

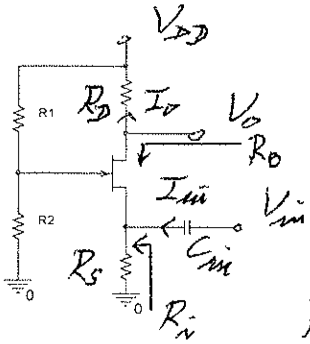
$$\text{If } r_o = \infty, \quad A_V = \frac{g_m R_S}{1 + g_m R_S}$$

$$A_I = \frac{g_m R_G}{1 + g_m R_S}, \quad R_i = \infty$$

$$R_o = \frac{1}{g_m}$$

JFET Amplifier Configurations

Common Gate Amplifier



$$A_V = \frac{V_o}{V_{in}} = \frac{(1+\mu)R_D}{R_D + r_o}$$

$$A_I = \frac{I_o}{I_{in}} = \frac{A_V}{R_D\left(\frac{1}{R_S} + \frac{1}{r_o} + g_m\right) - \frac{R_D}{r_o}A_V}$$

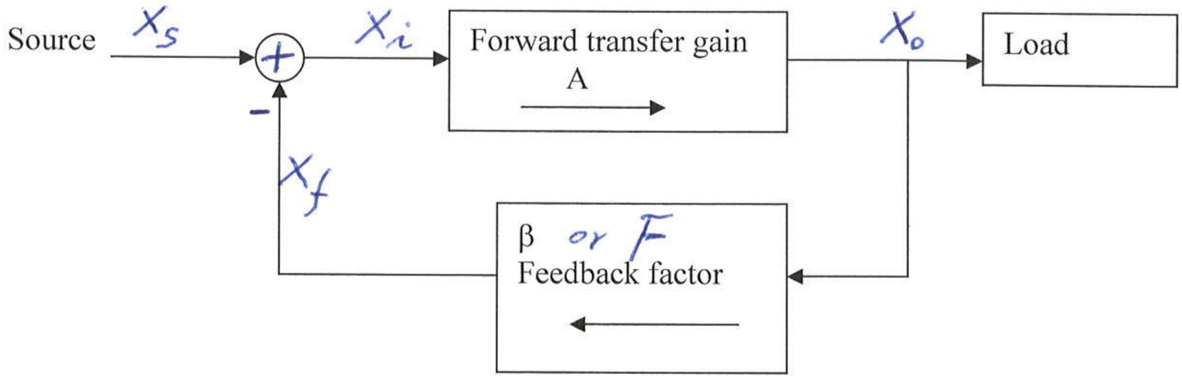
$$R_i = \frac{R_S r_o}{r_o + (1+\mu)R_S - A_V R_S}, \quad R_o = r_o$$

If $r_o = \infty$, $A_V = g_m R_D$

$$A_I = \frac{g_m R_S}{1 + g_m R_S}, \quad R_o = \infty$$

$$R_i = \frac{R_S}{1 + g_m R_S}$$

Method of analyzing a negative feedback amplifier



(i) Identify the (ac) feedback topology

Input mixing

Input is series (voltage) mixing if you can indicate (formulate) $V_i = V_s - V_f$ (KVL). $X_s = V_s$.

Input is shunt (current) mixing if you can indicate (formulate) $I_i = I_s - I_f$ (KCL) . $X_s = I_s$.

Output sampling

If $V_{out} = 0$ (Set $R_L = 0$), X_f (feedback signal) = 0. It is a voltage sampling at the output, $X_o = V_{out}$.

If $I_{out} = 0$ (Set $R_L = \infty$), X_f (feedback signal) = 0. It is a current sampling at the output, $X_o = I_{out}$.

Feedback factor = $F = X_f / X_o$. **Note that F should be independent of the load resistance.**

(ii) Obtain the ac equivalent circuit (A circuit) of the amplifier without feedback

1. Let dc supply voltage = 0 and connect all ground points together.

2. Delete the ground notation.

3. Remove the feedback signal from the output and redraw the input circuit.

Set $V_{out} = 0$ if it is a voltage sampling at the output (Short circuit the output node.).
Set $I_{out} = 0$ if it is a current sampling at the output (Open circuit the output loop.).

4. Remove the feedback signal to the input and redraw the output circuit. Indicate X_f on the output circuit (NOT the input circuit.)

Set $V_i = 0$ for current mixing.
Set $I_i = 0$ for voltage mixing.

(iii) Optional: Use a Thevenin's (Norton's) equivalent for the source if X_f is a voltage (current) variable.

(iv) Replace each active device by its small-signal model.

(v) Evaluate A , F (or β), input resistance and output resistance. $A = X_o / X_s$.

(vi) From A and F, determine the closed-loop (feedback) gain, input and output resistances of the original negative feedback amplifier.

$$A_f = \frac{A}{1+FA}, \quad D = 1 + FA, \quad R_{i,f} = D\,R_i \text{ (voltage mixing) or } \frac{R_i}{D} \text{ (current mixing)}$$

$$R_{o,f} = \lim_{\text{load resistance}=\infty} \frac{R_o}{D} \quad \text{for voltage sampling}$$

$$R_{o,f} = \lim_{\text{load resistance}=0} DR_o \quad \text{for current sampling}$$