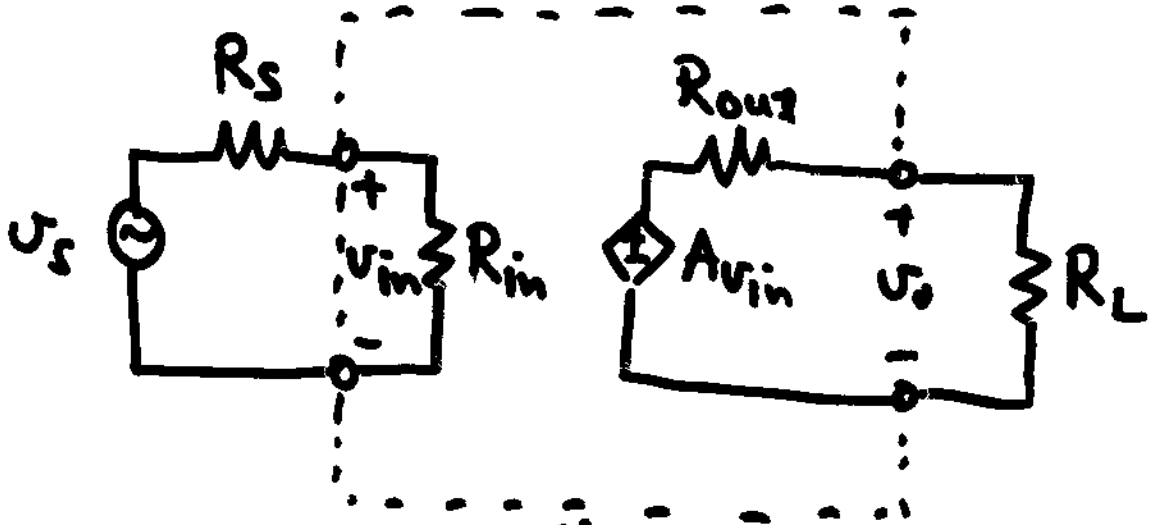
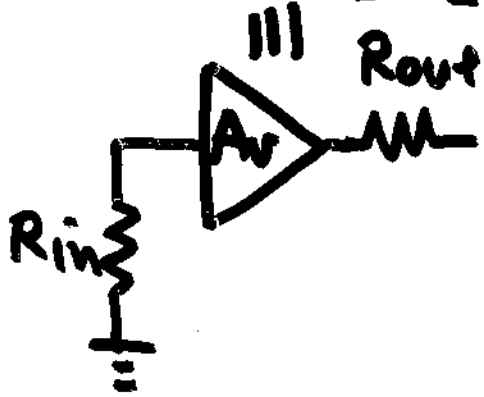
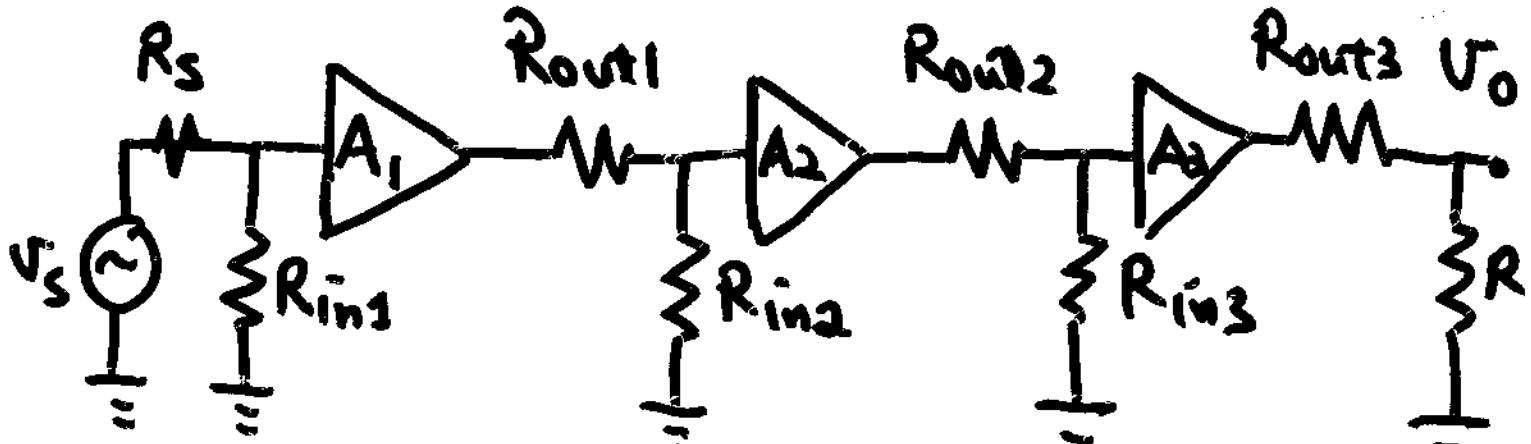
Multistage Amplifiers

Basic Amp:





Three-stage Amplifier



$$A_{v_s} = A_1 \cdot A_2 \cdot A_3 \cdot \frac{R_{in1}}{R_{in1}+R_s} \cdot \frac{R_{in2}}{R_{in2}+R_{out1}} \cdot \frac{R_{in3}}{R_{in3}+R_{out2}} \cdot \frac{R_L}{R_L+R_{o}}$$

$$A_{V_s} = \frac{V_o}{V_s}$$

$$= \frac{V_{in1}}{V_s} \cdot \frac{A_1 V_{in1}}{V_{in1}} \cdot \frac{V_{out1}}{A_1 V_{in1}} \cdot \frac{A_2 V_{out1}}{V_{out1}} \cdot \frac{V_{out2}}{A_2 V_{out1}} \cdot$$

$$\frac{A_3 V_{out2}}{V_{out_2}} \cdot \frac{V_o}{A_3 V_{out_2}}$$

$$= \frac{R_{in1}}{R_{in1}+R_s} \cdot A_1 \cdot \frac{R_{in2}}{R_{in2}+R_{out1}} \cdot A_2 \cdot$$

$$\frac{R_{in3}}{R_{in3}+R_{out2}} \cdot A_3 \cdot \frac{R_L}{R_L + R_{out3}}$$

$R_{in(overall)} = R_{in1}$

$R_{out(overall)} = R_{out3}$

$A_{V_s}(overall) = A_{VS1} \times A_{VS2} \times A_{VS3}$

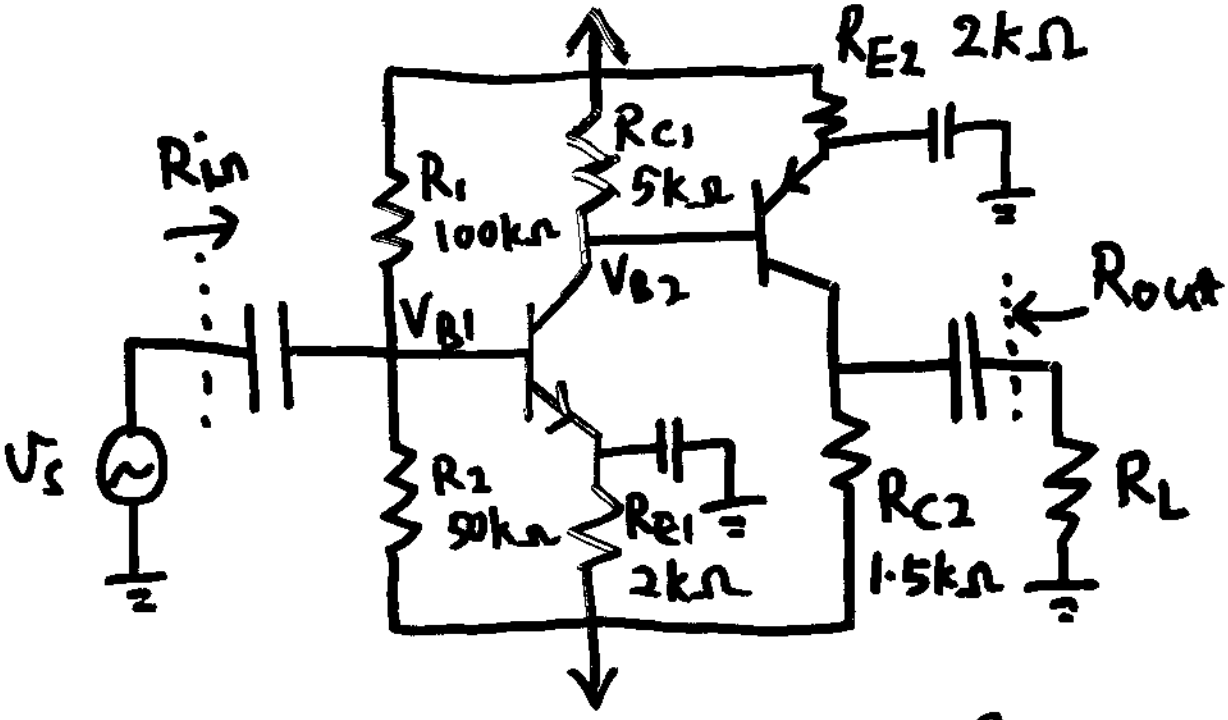
CASCADE

CE-CE Cascade Example

A_v ? [Huge : $-100 \cdot -100 = +10{,}000$]

R_{in} ? [few kΩ] [$r_{\pi 1} \| R_1 \| R_2$]

R_{out} ? [few kΩ] [$R_{C2} \| r_{O2}$]



$\beta = 100$

$V_A = \infty$

$$I_{B1} = \frac{V_{TH} - 0.7}{R_{TH} + (\beta+1)R_E}$$

$$= 11.2\mu A$$

$$I_{C1} = 1.12mA$$

$$I_{E1} = 1.13mA$$

$$r_{\pi 1} = \frac{.026V}{11.2\mu A}$$

$$= 2.32\,k\Omega$$

$$g_{m1} = \frac{1.12mA}{.026V}$$

$$= 43.1\,mA/V$$

KVL:

$$I_{E2} \cdot 2k\Omega + 0.7V + (I_{C1} - I_{B2})\,5k\Omega = 0$$

$$101\,I_{B2} \cdot 2k\Omega + 0.7V + (1.12mA - I_{B2})\,5k\Omega = 0$$

$$I_{B2} = 23.7\,\mu A$$

$$I_{C2} = 2.37\,mA$$

$$I_{E2} = 2.39\,mA$$

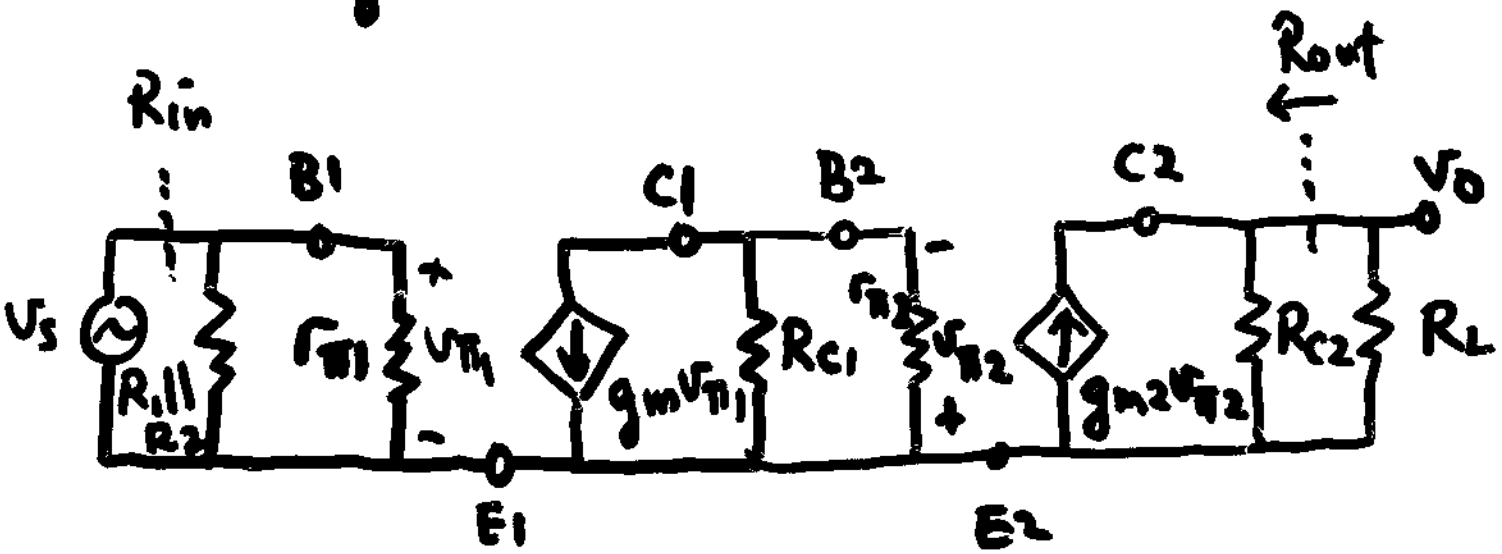
$$r_{\pi 2} = \frac{.026V}{23.7\mu A}$$

$$= 1.10\,k\Omega$$

$$g_{m2} = \frac{2.37mA}{.026V}$$

$$= 91.2\,mA/V$$

a.c. equivalent ckt



$$A_{V1} = \frac{V(B2)}{V_s} \quad , \quad A_{V2} = \frac{V_o}{V(B2)}$$

$$V(B2) = -g_{m1} V_s (R_{C1} \| r_{\pi 2})$$

$$A_{V1} = -g_{m1}(R_{C1} \| r_{\pi 2})$$

$$V_o = -g_{m2} V(B2) (R_{C2} \| R_L)$$

$$A_{V2} = -g_{m2} (R_{C2} \| R_L)$$

$$A_{Vs} = A_{V1} \cdot A_{V2} = g_{m1} \cdot g_{m2} (R_{C1} \| r_{\pi 2})(R_{C2} \| R_L)$$

$$= 43.1 \times 91.2 \times 0.90 \times 1.15$$

$$= 4068 \ V/V$$

$$R_{in} = 2.32 k\Omega \| 50 k\Omega \| 100 k\Omega = 2.17 k\Omega$$

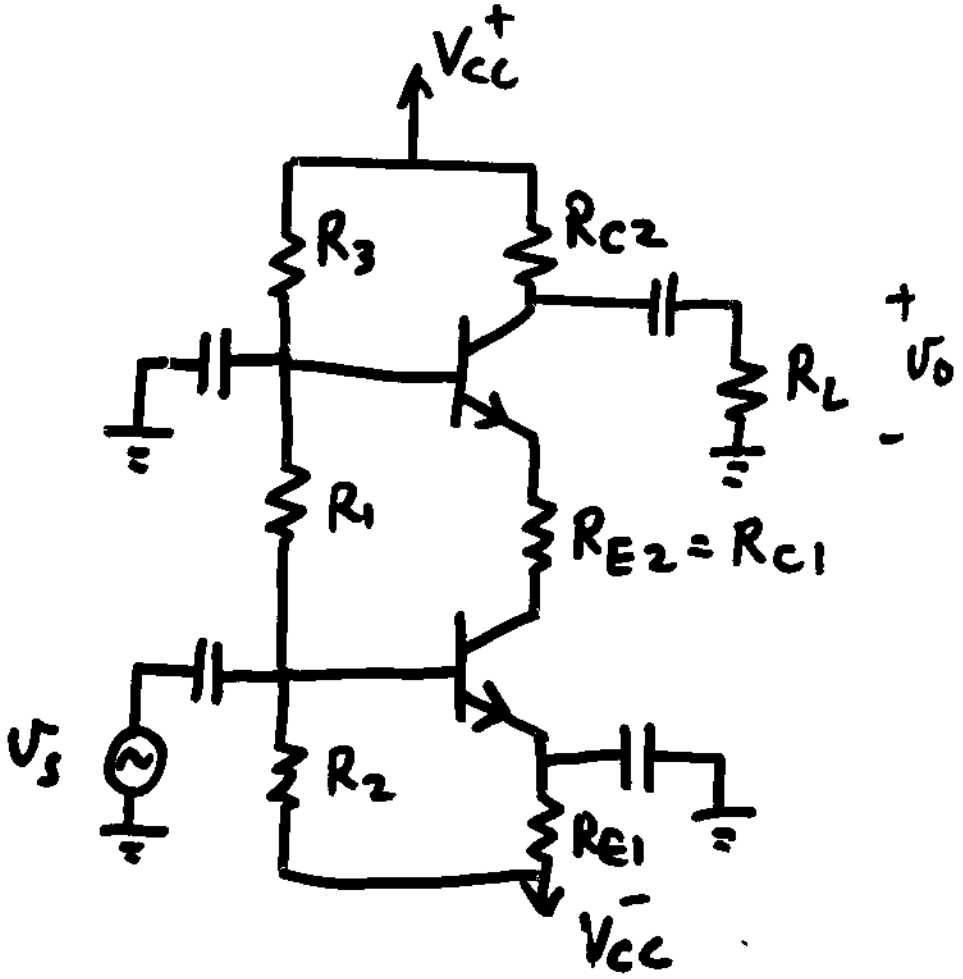
$$R_{out} = R_{C2} = 1.5 k\Omega$$

CASCODE Example : CE-CB

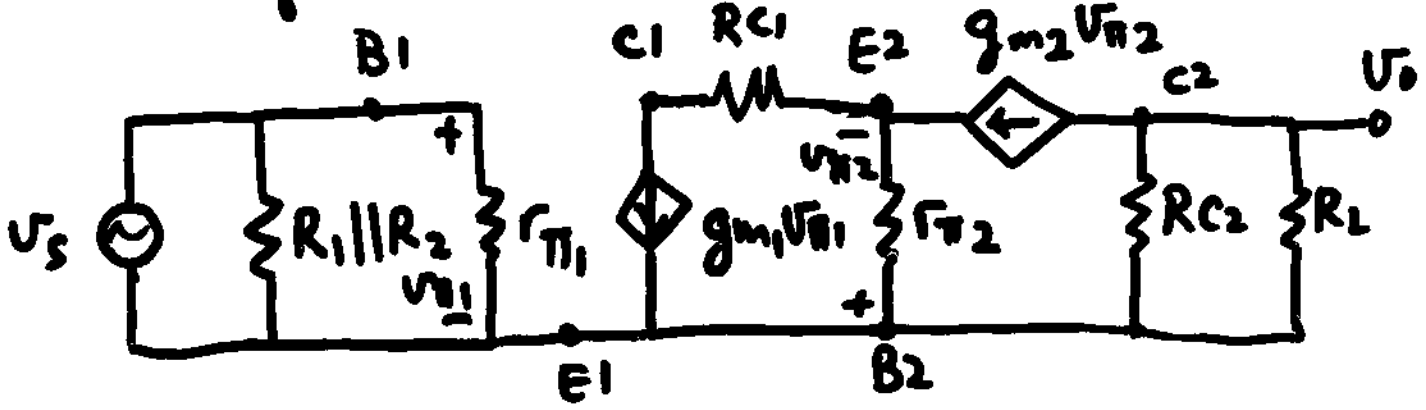
A_V (Huge: $-100 \cdot +100 = -10{,}000$)

R_{in} (few kΩ) $[r_{\pi 1} \| R_1 \| R_2]$

R_{out} (few kΩ) $[R_{C2}]$



a.c. equivalent ckt



$$g_{m1} v_{\pi 1} = g_{m2} v_{\pi 2} + \frac{v_{\pi 2}}{r_{\pi 2}}$$

$$v_{\pi 2} = g_{m1} v_{\pi 1} \Big/ \left(g_{m2} + \frac{1}{r_{\pi 2}} \right)$$

$$= g_{m1} v_{\pi 1} \frac{r_{\pi 2}}{\beta_2 + 1}$$

$$v_o = - g_{m2} g_{m1} v_{\pi 1} \frac{r_{\pi 2}}{\beta_2 + 1} (R_{C2} \| R_L)$$

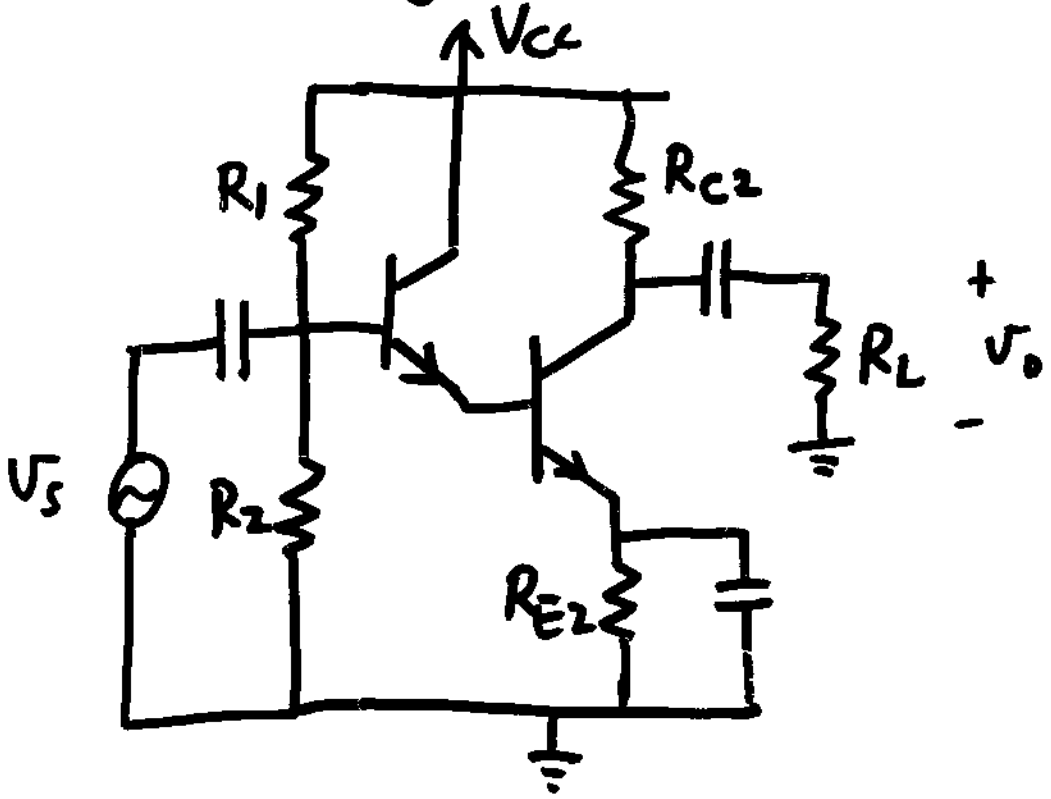
$$A_{vs} = - g_{m1} g_{m2} \frac{r_{\pi 2}}{\beta_2 + 1} (R_{C2} \| R_L)$$

$$\simeq - g_{m1} (R_{C2} \| R_L)$$

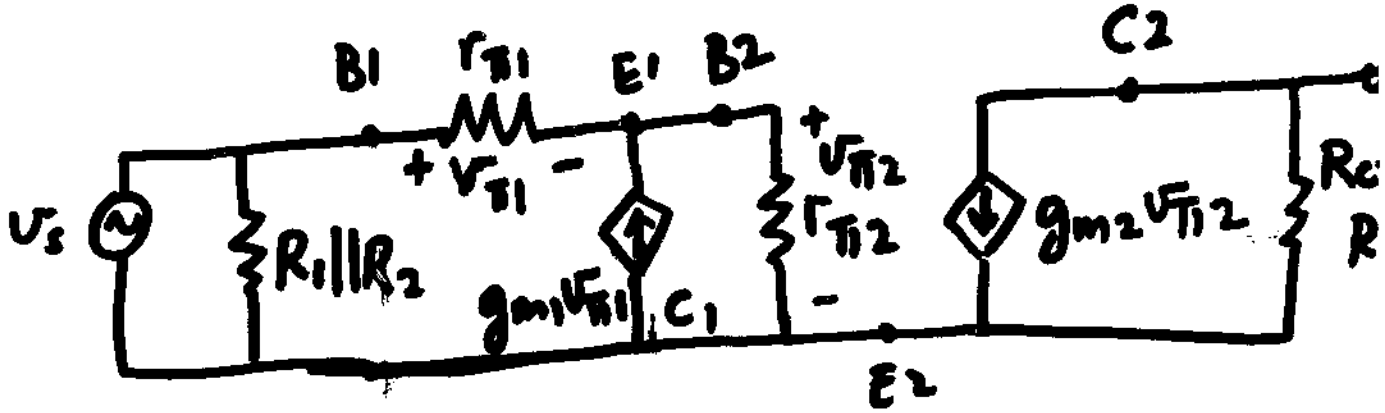
$$R_{in} = r_{\pi 1} \| R_1 \| R_2$$

$$R_{out} = R_{C2}$$

CC-CE Darlington



a.c. equivalent ckt



$$V_s = V_{\pi 1} + V_{\pi 2}$$

$$= V_{\pi 1} + \left(g_{m1} V_{\pi 1} + \frac{V_{\pi 1}}{r_{\pi 1}} \right) r_{\pi 2}$$

$$V_{\pi 2} = \left(g_{m1} V_{\pi 1} + \frac{V_{\pi 1}}{r_{\pi 1}} \right) r_{\pi 2}$$

$$A_{V_1} = \frac{V_{\pi 2}}{V_s} = \frac{(\beta_1 + 1) r_{\pi 2}}{r_{\pi 1} + (\beta_1 + 1) r_{\pi 2}}$$

$$V_o = -g_{m_2} V_{\pi 2} (R_{C2} \| R_L)$$

$$A_{V_2} = -g_{m_2} (R_{C2} \| R_L)$$

$$A_{V_S} = \frac{V_o}{V_s} = \frac{(\beta_1 + 1) r_{\pi 2}}{r_{\pi 1} + (\beta_1 + 1) r_{\pi 2}} \left[-g_{m_2} (R_{C2} \| R_L) \right]$$

$$R_{in}\ (\text{base } 1) = r_{\pi 1} + (\beta_1 + 1) r_{\pi 2}$$

HIGH IMPEDANCE