Analog & Digital Electronics

Course No: PH-218

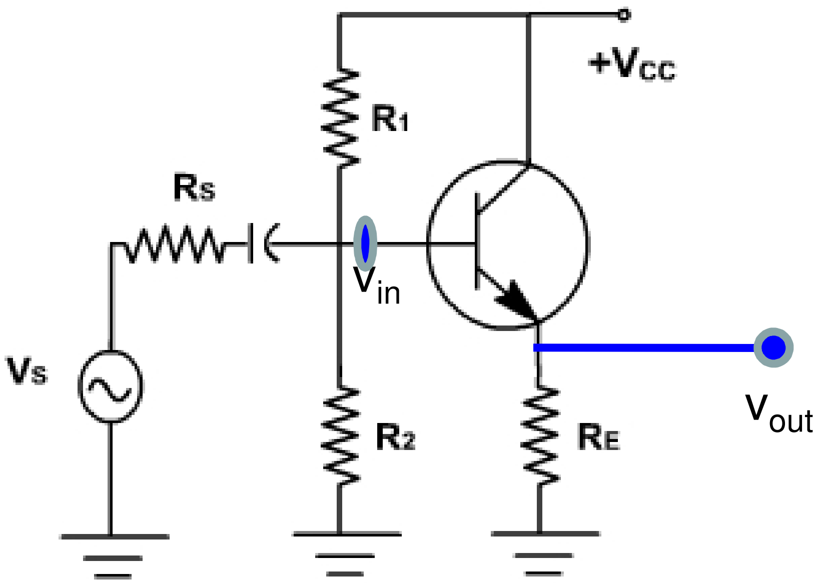
Lec-10: CC and CB BJT Amplifiers

Course Instructors:

❖ **Dr. A. P. VAJPEYI**

Department of Physics,
Indian Institute of Technology Guwahati, India

Common Collector Amplifier (Emitter Follower)



$$v_{out} = v_{in} - v_{BE}$$

If v_{in} is 2V, v_{out} = 1.3V
If v_{in} is 3V, v_{out} = 2.3V.

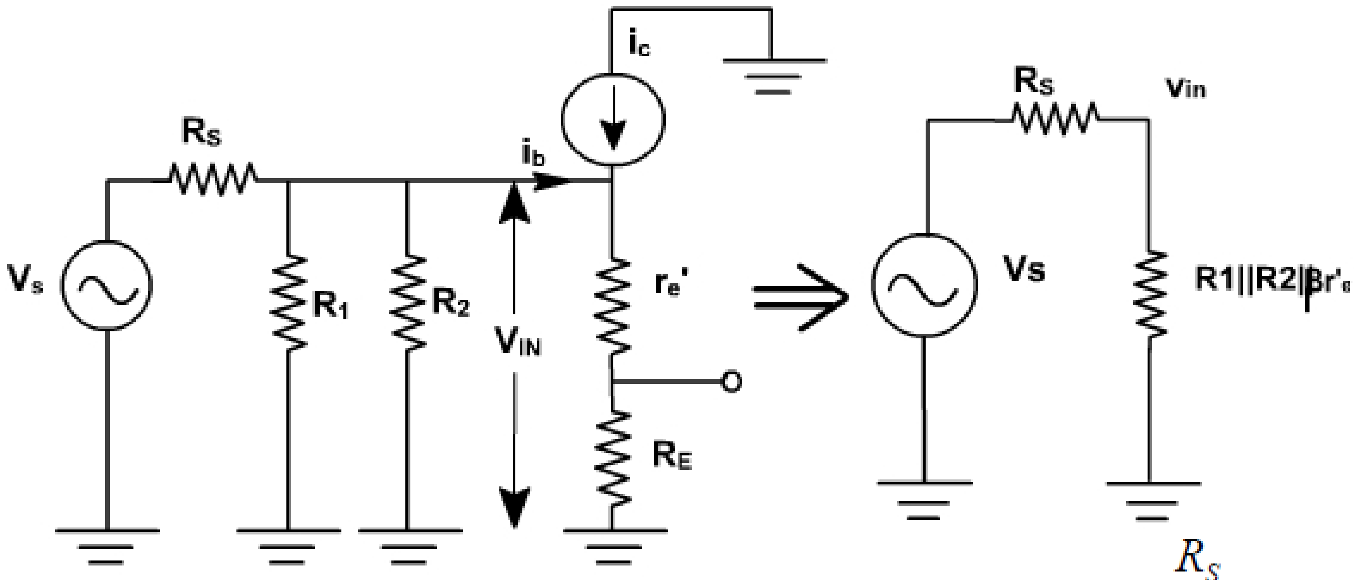
Since v_{out} follows exactly the v_{in} therefore, there is **no phase inversion** between input and output

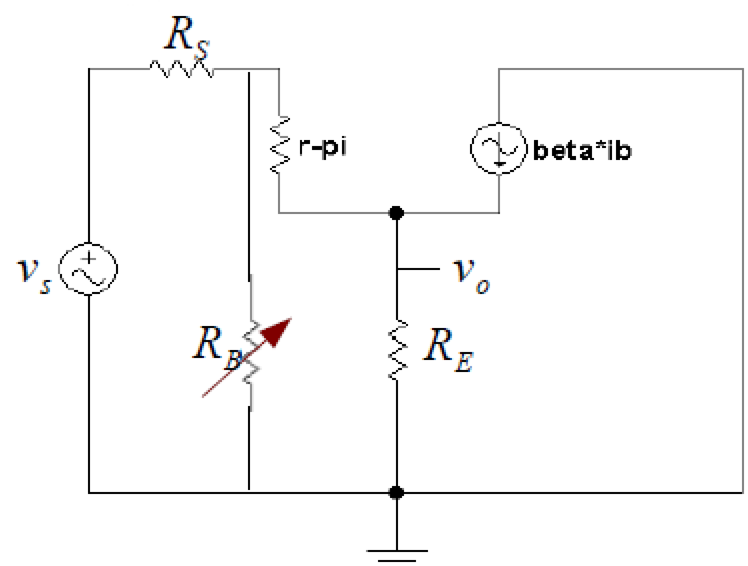
- **Since there is no resistance in collector circuit, therefore collector is ac grounded.**

- **A CC amplifier is like a heavily swamped CE amplifier with a collector resistor shorted and output taken across emitter resistor.**

- **The voltage gain of this amplifier is nearly one – the output "follows" the input - hence the name: emitter "follower.**

Common Collector Amplifier : Input Impedance





$$v_{in} = i_b r_\pi + i_E R_E$$

$$v_{in} = i_b(\beta+1)r_e' + (\beta+1)i_b R_E$$

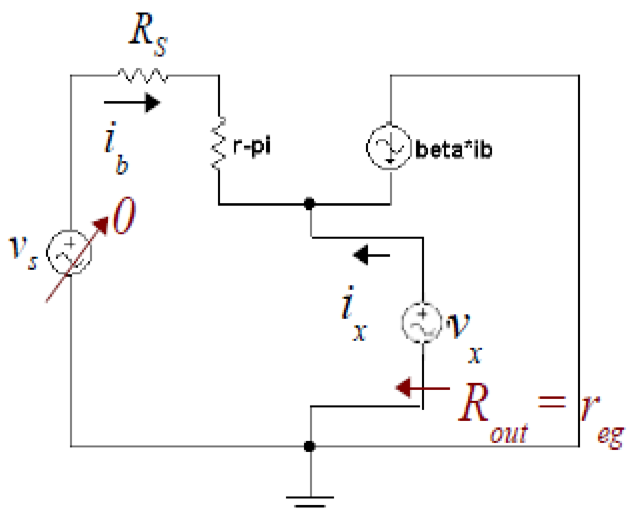
$$v_{in} = (r_e' + R_E)(\beta+1)i_b$$

$$Z_{in(base)} = \frac{v_{in}}{i_b} = \beta(r_e' + R_E)$$

$$Z_i = [R_1 \backslash\backslash R_2 \backslash\backslash \beta(R_E + r_e')]$$

Input Impedance is very large

Common Collector Amplifier : Output Impedance



$$R_B = 50k\,\Omega \gg R_S \Rightarrow R_B \| R_S \approx R_S$$

$$i_x = -i_b - \beta i_b = -(1+\beta) i_b \Rightarrow i_b = \frac{-i_x}{(1+\beta)}$$

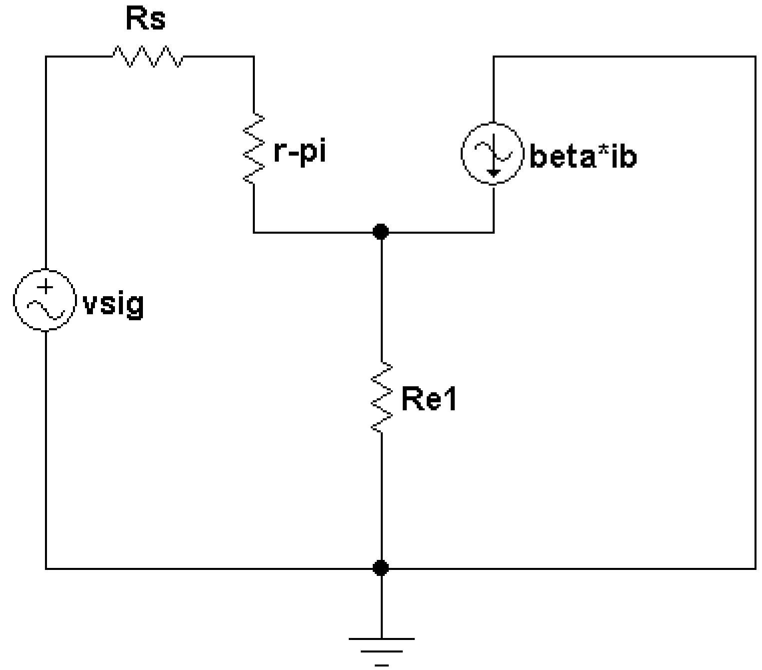
$$v_x = -i_b (R_S + r_\pi) = \frac{R_S + r_\pi}{1+\beta} i_x$$

$$R_{out} = \frac{v_x}{i_x} = \frac{R_S + r_\pi}{1+\beta} \approx \frac{r_\pi}{1+\beta} = r_e$$

$R_{out} = r_{eg}$ is the Thevenin resistance looking into the open-circuit emitter-to-ground output.

If a high impedance source is connected to low impedance amplifier then most of the signal is dropped across the internal impedance of the source. To avoid this problem common collector amplifier is used in between source and CE amplifier. It increases the input impedence of the CE amplifier without significant change in input voltage.

Common Collector Amplifier : Voltage gain



$$v_s = (R_s + r_\pi)i_b + i_e R_E$$

$$v_s = (R_s + r_\pi)i_b + (\beta+1)i_b R_E$$

$$i_b = \frac{v_s}{(R_s + r_\pi) + (\beta+1)R_E}$$

$$v_o = i_e R_E = (\beta+1)i_b R_E$$

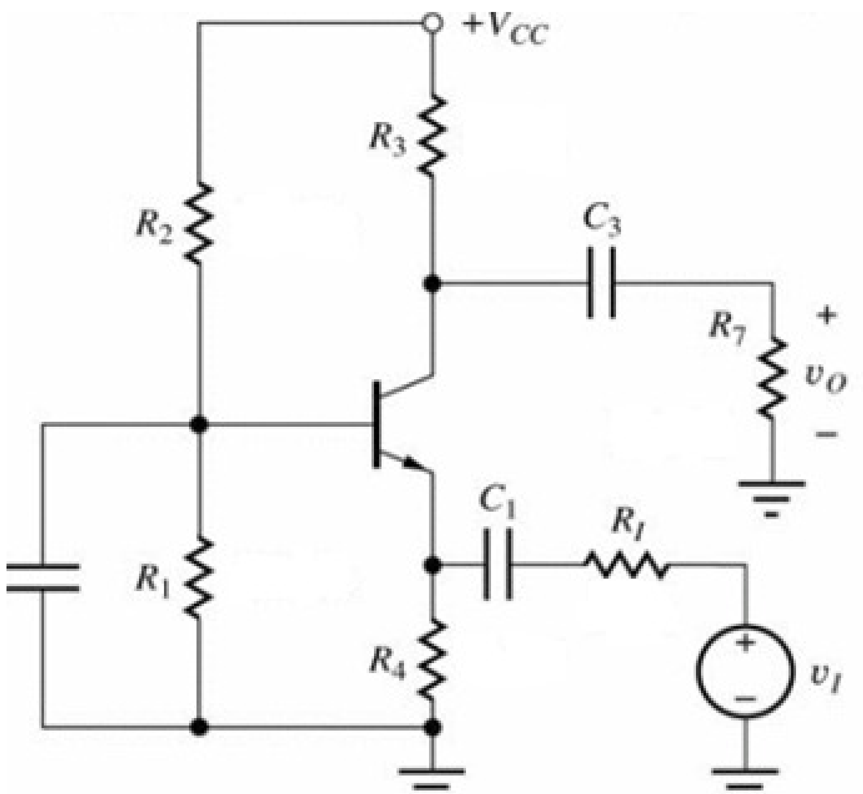
$$v_o = \frac{(\beta+1)R_E v_s}{(R_s + r_\pi) + (\beta+1)R_E}$$

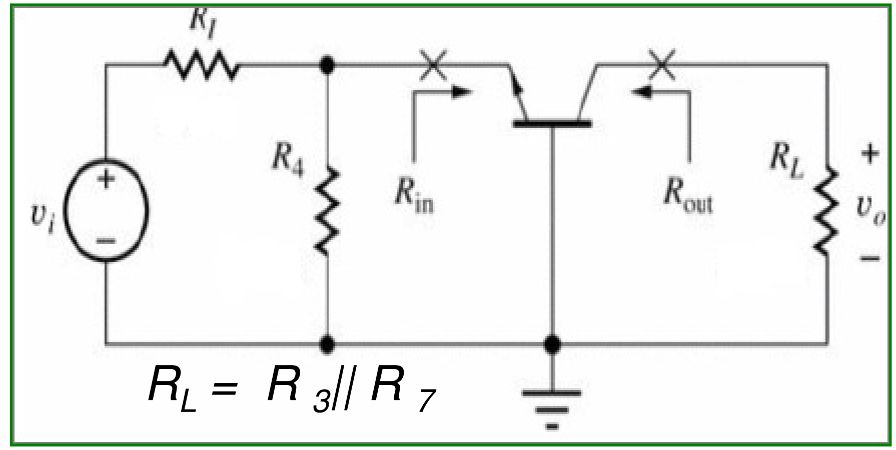
$$A_v = \frac{v_o}{v_s} = \frac{(\beta+1)R_E}{(R_s + r_\pi) + (\beta+1)R_E}$$

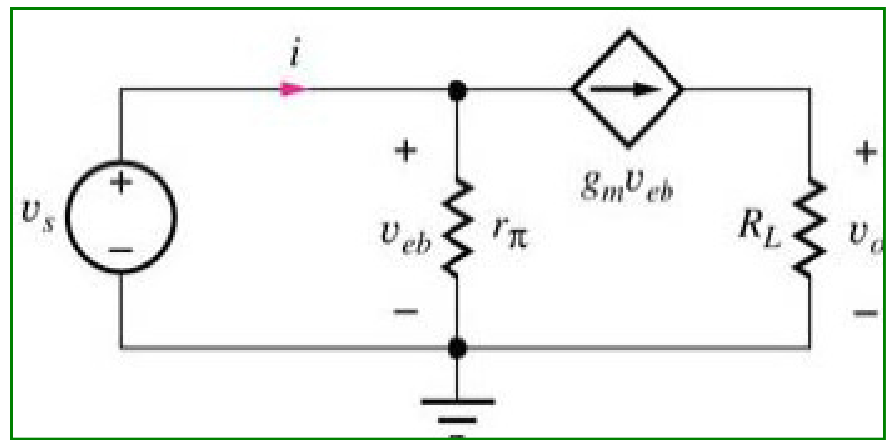
$$A_v = \frac{v_o}{v_s} = \frac{R_E}{\frac{(R_s + r_\pi)}{(\beta+1)} + R_E}$$

Since $\frac{(R_s + r_\pi)}{(\beta+1)} << R_E$ **Therefore, A_v=1**

Common Base Amplifier



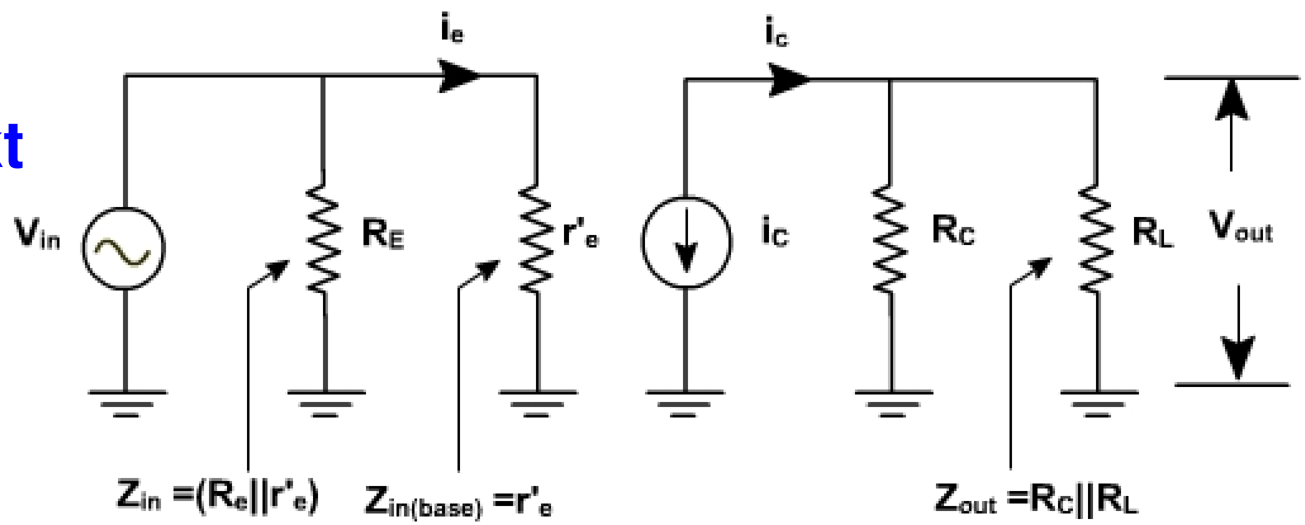




➢ **AC input signal is applied across emitter and the output signal is taken across the collector.**

Common Base Amplifier: Performance Parameters

AC Equivalent Ckt



Input Impedance: $Z_i = R_E \backslash\backslash r_e^{'}$ **Since** $r_e^{'} << R_E$ **Therefore** $Z_{in} = r_e^{'}$

Output Impedance: $Z_{out} = R_C \backslash\backslash R_L$

Voltage Gain: $A_v = \frac{v_{out}}{v_{in}} = \frac{i_c (R_C \backslash\backslash R_L)}{i_e r_e^{'}}$ $A_v = \frac{(R_C \backslash\backslash R_L)}{r_e^{'}}$

Input voltage and output voltage is in same phase

Summary of BJT Amplifier Performance Parameters

Characteristic	Common Base	Common Emitter	Common Collector
Input impedance	Low	Medium	High
Output impedance	Very High	High	Low
Phase Angle	0^o	180^o	0^o
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

➢The CB mode is generally only used in single stage amplifier circuits such as microphone pre-amplifier or RF radio amplifiers due to its very good high frequency response.

➢ The Emitter follower configuration is very useful for impedance matching applications because of the very high input impedance, in the region of hundreds of thousands of Ohms, and it has relatively low output impedance.

Multistage Amplifier: Gain Calculation

$$A_{vT} = A_{v1}A_{v2}A_{v3}\ldots$$

$$A_{iT} = A_{i1}A_{i2}A_{i3}\ldots$$

$$A_{pT} = A_{vT}A_{iT}$$

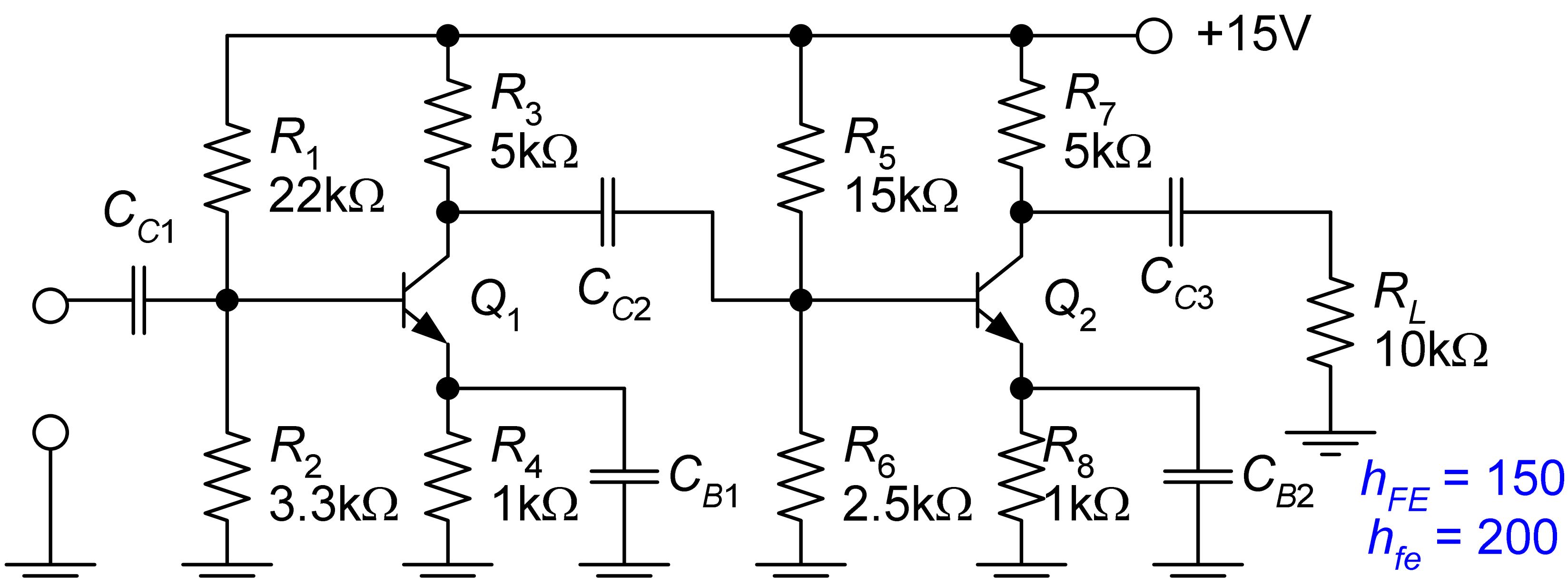
Procedure:

1. Do dc analysis
2. Find r'_e for each stage
3. Find r_C for each stage
4. Using r'_e and r_C to find A_v for each stage

Input impedance of next stage is the load of current stage.

(Z_{in} of next stage is R_L of current stage)

Determine A_v of the 1st stage, 2nd stage and overall voltage gain of the 2 stage amplifier. Assume that r'_e for the 1st stage is 19.8 Ω and r'_e for the 2nd stage is found to be 17.4 Ω. For the 2nd stage, h_{fe} is 200.



$$Z_{in(base)} = \left(h_{fe} + 1\right) r_e' = 201 \times 17.4 = 3.497\text{k}\Omega$$

$$Z_{in} = R_5 \parallel R_6 \parallel Z_{in(base)} = 1.329\text{k}\Omega$$

r_C for the 1st stage can be found as

$$r_C = R_3 \parallel Z_{in} = 5\text{k}\Omega \parallel 1.33\text{k}\Omega = 1.05\text{k}\Omega$$

$$A_v = -\frac{r_C}{r_e'} = -\frac{1.05\text{k}\Omega}{19.8\Omega} = -53.03$$

r_C for the 2nd stage can be found as

$$r_C = R_7 \parallel R_L = 3.33\text{k}\Omega$$

A_v for the 2nd stage is found as

$$A_v = -\frac{r_C}{r_e'} = -\frac{3.33\text{k}\Omega}{17.4\Omega} = -191.38$$

$$A_{vT} = A_{v1} A_{v2} = \left(-53.03\right)\left(-191.38\right) = 10.15 \times 10^3$$

Multistage Amplifier: Characteristics

Stage Number				Characteristics		
1	2	3	4	Rin	Rout	Voltage gain
CE	CE			Medium	Medium	High
CE	CC			Medium	Low	Medium
CC	CE			High	Medium	Medium
CC	CC			Very high	Very low	<1
CE	CE	CE		Medium	Medium	Extremely high
CE	CE	CC		Medium	Low	Very high
CE	CC	CE		Medium	Medium	Very high
CE	CC	CC		Medium	Very low	Medium
CC	CE	CE		High	Medium	Very high
CC	CE	CC		High	Low	Medium
CC	CC	CE		Very high	Medium	Medium
CC	CC	CC		Very high	Very low	<1
CC	CE	CE	CC	High	Low	Very high

Descriptor	Rin or Rout	Voltage gai
Low	less than a few hundred Ohms	
Medium	A few hundred to a few thousand Ohms	less than 50
High	a few thousand to a few ten thousand Ohms	50 to 500
Very high	many tens of thousands of Ohms	500 to 5000
Extremely high	Over one hundred thousand Ohms	Over 5,000