THE EMITTER FOLLOWER (COMMON COLLECTOR) AMPLIFIER

Assumptions: Small Signal, AC - Coupled, Single Power Supply

Standart Bias Circuit:

1. In this circuit $R_C$ is at AC ground at both ends. Therefore it can be eliminated.
2. The base bias can be represented by its Thevenin Equivalent ($R_B = \frac{R_{B1}}{R_{B2}}$)
Small Signal Equivalent Circuit:

\[ V_{\text{out}} = h_{fe} \Delta i_B + \Delta i_B + h_{ie} \Delta i_B - h_{oe} \frac{1}{R_E} \frac{1}{R_L} \]

\[ V_{\text{in}} = V_{\text{out}} + h_{ie} \Delta i_B \]
\[ \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{V_{\text{out}}}{V_{\text{out}} + h_{ie} \Delta I_B} = \frac{1}{1 + \frac{h_{ie} \Delta I_B}{V_{\text{out}}}} \]

\[ \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{1}{1 + \frac{h_{ie} \Delta I_B}{(h_{fe} \Delta I_B + \Delta I_B) (h_{oe}^{-1} // R_E // R_L)}} \]

\[ A_v = \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{1}{1 + \frac{h_{ie}}{(h_{fe} + 1) (h_{oe}^{-1} // R_E // R_L)}} \]

**Calculate** $A_{vo}$:

\[ A_{vo} = (A_v)_{R_L \to \infty} \quad \text{(by definition)} \]

$h_{oe}^{-1}$ is neglected compared to $R_E$

\[ A_{vo} = \frac{1}{1 + \frac{h_{ie}}{(h_{fe} + 1) R_E}} \]

\[ h_{ie} = h_{fe} \frac{kT}{q} \quad \text{if} \quad h_{fe} \gg 1 \]

\[ A_{vo} = \frac{1}{1 + \frac{h_{fe} \frac{kT}{q}}{h_{fe} R_E}} \approx \frac{1}{1 + \frac{kT}{R_E I_{CQ}}} \]

\[ R_E I_{CQ} \approx R_E I_{EQ} = \text{DC Bias on the } R_E \Rightarrow kT/q \ll R_E I_{EQ} \]

\[ A_{vo} \approx \frac{1}{1 + \text{small}} = 1 \]

This says there is no voltage amplification. However, this does not mean the Emitter Follower stage cannot be used as an amplifier. It actually provides power amplification of the signal. It is called "Buffer Amplifier" because one can connect it in between a small load resistance $R_L$ and a high output resistance amplifier stage to eliminate loading of the amplifier by the load while not changing the (voltage) amplitude.

("impedance matching" --not in the sense of max power transfer)
Then question is what is $R_{in} = $?

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{I_R + \Delta i_B} = \frac{1}{\frac{I_R}{V_{in}} + \frac{\Delta i_B}{V_{in}}} = \frac{1}{\frac{1}{R_B} + \frac{1}{V_{in}/\Delta i_B}}$$

$$R'_{in} = \frac{V_{in}}{\Delta i_B} \Rightarrow R_{in} = \frac{1}{\frac{1}{R_B} + \frac{1}{R_{in}}}$$

$$R'_{in} = \frac{V_{in}}{\Delta i_B} = \frac{h_{ie} \Delta i_B + (h_{fe} + 1) \Delta i_B}{\Delta i_B} \frac{(h_{oe}^{-1} || R_E || R_L)}{\Delta i_B}$$

$$R'_{in} = \frac{h_{ie} + (h_{fe} + 1) (h_{oe}^{-1} || R_E || R_L)}{1}$$

$h_{oe}$ is negligible $\therefore (R_{in})_{Emitter-Follower} \gg (R_{in})_{Common-Emitter}$

**PROOF:** $h_{ie} = h_{fe} \frac{kT}{q I_{CQ}}$

**If there is no load -- no $R_L$:**

$$R'_{in} = h_{fe} \frac{kT}{q I_{CQ}} + (h_{fe} + 1) R_E$$

$$R_E = \frac{V_{EQ}}{I_{EQ}} \quad and \quad I_{EQ} = I_{CQ}$$

$$R'_{in} = \frac{\left[h_{fe} \frac{kT}{q} + (h_{fe} + 1) V_{EQ}\right]}{I_{CQ}} \quad V_{EQ} > \frac{kT}{q}$$
What is $R_{\text{out}}$?

Use $(V_{\text{Test}}, I_{\text{Test}})$ method:

Neglect $h_{ce}^{-1}$, kill $V_s$, substitute $R_L$ with $(I_{\text{Test}}, V_{\text{Test}})$.

Then circuit becomes:

\[
V_{\text{Test}} = -\left[ (R_s \parallel R_B) + h_{ie} \right] \Delta i_B
\]
\[
I'_{\text{Test}} = -(\Delta i_B + h_{fe} \Delta i_B)
\]
\[
\frac{V_{\text{Test}}}{I'_{\text{Test}}} = -\left[\left(\frac{R_s}{\parallel R_B} + h_{\text{ie}}\right) \Delta i_B\right]
\]

\[
R_X = \frac{V_{\text{Test}}}{I'_{\text{Test}}} = \frac{(R_s \parallel R_B) + h_{\text{ie}}}{\left(1 + h_{\text{fe}}\right)}
\]

\(h_{\text{fe}}\) is large \(\Rightarrow\) \(R_X\) is small.

\[R_{\text{out}} = R_E \parallel R_X\]

Since \(R_X\) is small \(\Rightarrow\) \(R_{\text{out}}\) is small

**Conclusion:** \(R_{\text{out}}\) of Emitter Follower is small.

**Emitter Follower delivers:**

1. **Unity Gain Voltage Amplification**
2. **High** \(R_{\text{in}}\)
3. **Low** \(R_{\text{out}}\)

\(\therefore\) No voltage gain but there is "Power Gain".

Current Gain is as much as \((h_{\text{fe}} + 1)\)

(in reality less than this)

**Application:** Current Gain \(\leq (h_{\text{fe}} + 1)\) Power Gain \(\approx\) Current Gain