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

\[
v_{\text{in}} = i_b r_e + i_e R_E
\]

\[
v_{\text{in}} = i_b (\beta + 1) r_e + (\beta + 1) i_b R_E
\]

\[
v_{\text{in}} = (r_e + R_E) (\beta + 1) i_b
\]

\[
Z_{\text{in(base)}} = \frac{V_{\text{in}}}{i_b} = \beta (r_e + R_E)
\]

\[
Z_i = [R_1 \begin{array}{c} // \end{array} R_2 \begin{array}{c} // \end{array} \beta (R_E + r_e')]
\]

Input Impedance is very large
Common Collector Amplifier : Output Impedance

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 impedance of the CE amplifier without significant change in input voltage.
Common Collector Amplifier: Voltage gain

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

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

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

\[ v_o = i_e R_E = (\beta + 1)i_b R_E \]

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

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

Since \( \frac{(R_s + r_\pi)}{(\beta + 1)} \ll R_E \)

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:**
\[ Z_{in} = (R_e || r_e') \]
Since \( r_e' \ll R_E \)
Therefore
\[ Z_{in} = r_e' \]

**Output Impedance:**
\[ Z_{out} = R_C \parallel R_L \]

**Voltage Gain:**
\[ A_v = \frac{v_{out}}{v_{in}} = \frac{i_c (R_C \parallel R_L)}{i_e r_e'} \]
\[ A_v = \frac{(R_C \parallel R_L)}{r_e'} \]

Input voltage and output voltage is in same phase
Summary of BJT Amplifier Performance Parameters

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Common Base</th>
<th>Common Emitter</th>
<th>Common Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input impedance</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Output impedance</td>
<td>Very High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Phase Angle</td>
<td>0°</td>
<td>180°</td>
<td>0°</td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Current Gain</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Power Gain</td>
<td>Low</td>
<td>Very High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

- 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.

\((Z_{in} \text{ of next stage is } R_L \text{ of current stage})\)
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 $\Omega$ and $r_e'$ for the 2nd stage is found to be 17.4 $\Omega$. For the 2nd stage, $h_{fe}$ is 200.
$Z_{in(base)} = (h_{fe} + 1) r_e\' = 201 \times 17.4 = 3.497k\Omega$

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

$r_C$ for the 1\textsuperscript{st} stage can be found as

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

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

$r_C$ for the 2\textsuperscript{nd} stage can be found as

$r_C = R_7 \parallel R_L = 3.33k\Omega$

$A_v$ for the 2\textsuperscript{nd} stage is found as

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

$A_{vT} = A_{v1} A_{v2} = (-53.03)(-191.38) = 10.15 \times 10^3$
## Multistage Amplifier: Characteristics

<table>
<thead>
<tr>
<th>Stage Number</th>
<th>Characteristics</th>
<th>Voltage gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CE CE</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>2 CE CC</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>3 CC CE</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>4 CC CC</td>
<td>Very high</td>
<td>Very low</td>
</tr>
<tr>
<td>5 CE CE CC</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>6 CE CC CE</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>7 CE CC CC</td>
<td>Medium</td>
<td>Very low</td>
</tr>
<tr>
<td>8 CC CE CE</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>9 CC CC CC</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>10 CC CC CE</td>
<td>Very high</td>
<td>Medium</td>
</tr>
<tr>
<td>11 CC CC CC</td>
<td>Very high</td>
<td>Very low</td>
</tr>
<tr>
<td>12 CC CE CE</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very high</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Rin or Rout</th>
<th>Voltage gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>less than a few hundred Ohms</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>A few hundred to a few thousand Ohms</td>
<td>less than 50</td>
</tr>
<tr>
<td>High</td>
<td>a few thousand to a few ten thousand Ohms</td>
<td>50 to 500</td>
</tr>
<tr>
<td>Very high</td>
<td>many tens of thousands of Ohms</td>
<td>500 to 5000</td>
</tr>
<tr>
<td>Extremely high</td>
<td>Over one hundred thousand Ohms</td>
<td>Over 5,000</td>
</tr>
</tbody>
</table>