Section C5: Single-Stage BJT Amplifier Configurations

In the previous discussions, we’ve talked about modes, models and curves of the BJT. So… pretty cool, but so what? Actually, this background was necessary. What we really care about for these devices is what useful functions they can actually perform and, to achieve these useful functions, we have to have a clue how to get there!

Therefore... what we’re going to look at now is how to get signals in and out of a transistor in a manner that is of use to us. Recognizing that the transistor has highly nonlinear characteristics, we must use external dc sources to bias the transistor circuit to operate in the region of the characteristic curves where behaviors are approximately linear. Proper biasing of the transistor in the **linear region** of operation will allow us to apply a time-varying input signal to the input and get an **amplified**, **undistorted** signal at the output.

Large capacitors are used to provide **isolation** between ac and dc conditions. These capacitors effectively look like **open circuits** (infinite impedance) for dc conditions, while their impedance is close to zero (**short circuits**) at desired frequencies in ac operation. For now, we’re going to assume ideal caps (perfect opens at dc, perfect shorts at ac). *Don’t worry, we’ll get over it!*

**Note:** For consistency in our discussions, and to avoid confusion in small signal representations (coming), $v_{in}$ and $R_{in}$ (in your text’s figures) will be changed to $v_S$ and $R_S$ in the following figures. I’ve also lost the polarized cap notation since it’s not needed and may cause extra confusion. This is a deviation from your text – if it causes heartburn, let me know!

Depending on the choice of input, output and ground locations, as well as the placement of the capacitors, **four basic configurations** for the **single-stage BJT amplifier** may be defined and are illustrated in Figure 4.12 (modified as noted above.)
The configuration in Figure 4.12(a) is called the **common-emitter** amplifier because the emitter terminal is common to both the input and the output under ac conditions. This can be seen by considering the behavior of the **bypass capacitor** $C_E$.

- For **dc**, $C_E$ is an open circuit and $R_E$ can participate in the definition of the dc load line and Q-point.
- For **ac**, $C_E$ has essentially zero impedance. This shorts out (bypasses) $R_E$ for ac signals and ties the emitter directly to the negative terminal of $V_{EE}$. However, $V_{EE}$ is a dc source and looks like zero to ac, so the emitter is effectively tied to ground.

The other two capacitors in the common-emitter circuit, $C_B$ and $C_C$, are **ac coupling capacitors**. Their function in the circuit is **dc blocking** for the input and output signals – that is, they allow only ac signals to pass for the frequency range of interest and they do not affect the dc biasing.

The only difference between Figures 4.12(b) and 4.12(a) is that the bypass capacitor across $R_E$ has been removed. This circuit is identical to part (a) under dc conditions, but the emitter terminal is no longer grounded for ac operation. Although this configuration is often referred to as a **common-emitter with emitter resistor**, it has significant behavioral differences from the circuit in part (a) and will be identified as the **emitter-resistor** amplifier configuration in your text.
Note: Your text is not very consistent in the distinction between the common-emitter and emitter-resistor configurations, especially in later chapters. Be aware – if the text says common-emitter, but there is no emitter cap, it is an emitter-resistor!

- Two modified versions of Figure 4.12(c) are shown below. The dc operation of this circuit of the circuit on the left is still the same, but we’ll see that the circuit on the right only has $R_E$ as a dc resistance. Regardless, the ac operation is a completely different animal from the previous two circuits! The bypass capacitor, if used, is now across the collector resistor $R_C$, so the collector terminal will be grounded and common to both input and output for ac operation (in both circuits). Not surprisingly, this leads to the name **common-collector** for this circuit. Not as obvious, but still legitimate, is the other name for this configuration – the **emitter-follower**. The coupling capacitors, $C_B$ and $C_E$, provide dc isolation for the input (at the base) and the output (at the emitter) respectively.

- The last of the four basic single-stage BJT amplifiers is the **common-base** configuration of Figure 4.12(d). Once again, the dc operation is the same as all previous circuits, but now the bypass resistor is across the base. We’re going to talk about this more in the next chapter, but under ac conditions, the
resistors $R_1$ and $R_2$ are in parallel. This parallel combination is the base resistance, or $R_B$, which is shorted by $C_B$ (so that the base is at ground and is common to the input and output). The input is now applied to the emitter and coupled through capacitor $C_E$, while the output is taken at the collector and coupled through capacitor $C_C$.

**We’re going to be spending a whole chapter of your text and section of this course getting extremely familiar with these four configurations, but just as a preview of coming attractions:**

<table>
<thead>
<tr>
<th><strong>Configuration</strong></th>
<th><strong>Function</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>common-emitter</td>
<td>voltage amplification</td>
</tr>
<tr>
<td>emitter-resistor</td>
<td>voltage amplification</td>
</tr>
<tr>
<td>common-base</td>
<td>voltage amplification</td>
</tr>
<tr>
<td>common-collector</td>
<td>current amplification, power amplification, or impedance matching</td>
</tr>
<tr>
<td>(emitter-follower)</td>
<td></td>
</tr>
</tbody>
</table>

It looks a little squirrely for three of the four to be voltage amplifiers, but have no fear!! Each of these configurations has unique characteristics in terms of gain, impedance characteristics, and frequency response -- so they all have a right to exist.

Finally...

- although all the circuits above shown dc voltage sources (power supplies) connected to both the emitter and collector sides, either of these supplies could be set to zero (grounded), and
- pnp transistors are handled the same way, just switch the bias polarities.