
Chapter 5 review

1 - The DC Operating Point

- A transistor must be properly biased with a dc voltage in order to operate as a linear amplifier (without distortion in output ac voltage).

The nonlinear operation is when we have distortion in the output voltage $V_{ce}$ as shown:

(a) Linear operation: output has same shape as input except that it is inverted

(b) Nonlinear operation: output voltage limited (clipped) by cutoff

(c) Nonlinear operation: output voltage limited (clipped) by saturation
The operating point can be set on $I_C$ vs. $V_{CE}$ graph by calculating $I_B$, $I_C$, and $V_{CE}$ for the Q-point. They can be calculated depending on the values of $V_{CC}$, $V_{BB}$, $R_B$, and $R_C$.

For example: if $V_{in}$ is applied (see circuit below) cause $I_B$ to increase and decrease 100 µA ($ac$ base current $I_b$) above and below $I_{BQ}$.

\[ I_{BQ} = \frac{V_{BB} - 0.7 \, \text{V}}{R_B} = \frac{3.7 \, \text{V} - 0.7 \, \text{V}}{10 \, \text{k}\Omega} = 300 \, \mu\text{A} \]

\[ I_{CQ} = \beta_{DC} I_{BQ} = (100)(300 \, \mu\text{A}) = 30 \, \text{mA} \]

\[ V_{CEO} = V_{CC} - I_{CQ} R_C = 10 \, \text{V} - (30 \, \text{mA})(220 \, \Omega) = 3.4 \, \text{V} \]

## 2 – Voltage divider bias (most common biasing method for transistor)

In transistor circuits, it is more practical to use $V_{CC}$ as single bias source. For this purpose we use resistive voltage divider bias (as shown) to feed the transistor base with the voltage needed:

\[ V_B = \left( \frac{R_2}{R_1 + R_2} \right) V_{CC} \]

\[ V_C = V_{CC} - I_C R_C \]

\[ V_E = V_B - V_{DE} \]

\[ V_{CE} = V_C - V_E \]

\[ I_E = \frac{V_E}{R_E} \]

\[ I_C \approx I_E \]

\[ I_B = \frac{V_B}{\beta_{DC} R_E} = \frac{V_B}{R_{IN(BASE)}} \]

For stiff voltage divider ($R_{IN(base)} >> R_2$).
A more exact solution for circuit analysis is to Thevenize the input circuit (use thevenin equivalent).

Can be done by source transformation as shown:

Thevenin equivalent circuit

\[
R_{TH} = \frac{R_1R_2}{R_1 + R_2} \quad \text{\{(R_1||R_2)\}}
\]

\[
V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC}
\]

From KVL →

\[
V_{TH} = I_B R_{TH} + V_{BE} + I_E R_E
\]

Substituting \(I_E/\beta_{DC}\) for \(I_B\),

\[
V_{TH} = I_E (R_E + R_{TH}/\beta_{DC}) + V_{BE}
\]

\[
I_E = \frac{V_{TH} - V_{BE}}{R_E + R_{TH}/\beta_{DC}}
\]
Other four not very common biasing method exist for transistor

**EMITTER BIAS**

- $V_B = V_E + V_{BE}$
- $V_C = V_{CC} - I_C R_C$
- $V_E = V_{EE} + I_E R_E$
- $I_E = \frac{-V_{BE} - V_{BE}}{R_E}$
- $I_C = I_E$
- $I_B = \frac{V_B}{R_B}$

**COLLECTOR-FEEDBACK BIAS**

- $V_C = V_{CC} - I_C R_C$
- $V_B = V_{BE}$
- $V_E = 0 V$
- $I_C = \frac{V_{CC} - V_{BE}}{R_E}$
- $I_E = I_C$
- $I_B = \frac{V_C - V_{BE}}{R_B}$

**BASE BIAS**

- $V_B = V_{BE}$
- $V_C = V_{CC} - I_C R_C$
- $V_E = 0 V$
- $I_C = \beta_{DC} \left( \frac{V_{CC} - V_{BE}}{R_E} \right)$
- $I_E = I_C$
- $I_B = \frac{V_C - V_{BE}}{R_B}$

**EMITTER-FEEDBACK BIAS**

- $V_B = I_E R_E + V_{BE}$
- $V_C = V_{CC} - I_C R_C$
- $V_E = V_B - V_{BE}$
- $I_E = \frac{V_{CC} - V_{BE}}{R_E + R_B \beta_{DC}}$
- $I_C = I_E$
- $I_B = \frac{V_C - V_B}{R_B}$