Thévenin Emitter Circuit

The Thévenin equivalent circuit seen looking into the emitter is useful in calculating the response of common-collector stages. It consists of a voltage source $v_{e(oc)}$ in series with a resistor r_{ie} from the emitter node to signal ground. Fig. 1(a) shows the BJT symbol with a Thévenin source connected to the base. The resistor R_{tc} represents the external load resistance in series with the collector. With the emitter open circuited, we denote the emitter voltage by $v_{e(oc)}$. The voltage source in the Thévenin emitter circuit has this value. To solve for it, we use the simplified T model in Fig. 1(b).

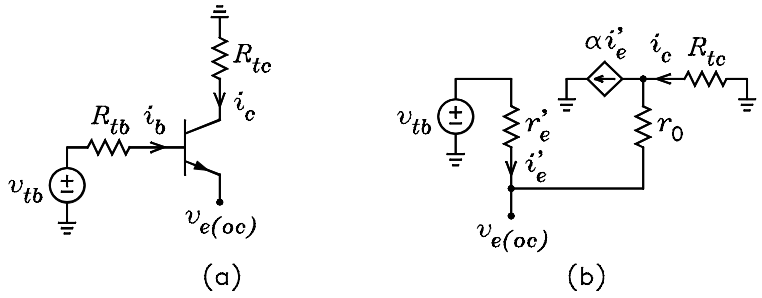

Figure 1: (a) BJT with Thévenin source connected to the base. (b) Simplified T model circuit for calculating $v_{e(oc)}$.

The current i'_e can be solved for by superposition of the sources v_{tb} and $\alpha i'_e$. It is given by

$$i'_e = \frac{v_{tb}}{r'_e + r_0 + R_{tc}} + \alpha i'_e \frac{R_{tc}}{r'_e + r_0 + R_{tc}} \tag{1}$$

This can be solved for i'_e to obtain

$$i'_e = \frac{v_{tb}}{r'_e + r_0 + (1-\alpha) R_{tc}} = \frac{v_{tb}}{r'_e + r_0 + R_{tc}/(1+\beta)} \tag{2}$$

The open-circuit emitter voltage is given by

$$v_{e(oc)} = v_{tb} - i'_e r'_e = v_{tb} \frac{r_0 + R_{tc}/(1+\beta)}{r'_e + r_0 + R_{tc}/(1+\beta)} \tag{3}$$

We next solve for the resistance seen looking into the emitter node. It can be solved for as the ratio of the open-circuit emitter voltage $v_{e(oc)}$ to the short-circuit emitter current. The circuit for calculating the short-circuit current is shown in Fig. 2(a). By superposition of i'_e and $\alpha i'_e$, we can write

$$\begin{aligned} i_{e(sc)} &= i'_e - \alpha i'_e \frac{R_{tc}}{r_0 + R_{tc}} = i'_e \frac{r_0 + (1-\alpha) R_{tc}}{r_0 + R_{tc}} \\ &= \frac{v_{tb}}{r'_e} \frac{r_0 + R_{tc}/(1+\beta)}{r_0 + R_{tc}} \end{aligned} \tag{4}$$

The resistance seen looking into the emitter is given by

$$r_{ie} = \frac{v_{e(oc)}}{i_{e(sc)}} = r'_e \frac{r_0 + R_{tc}}{r'_e + r_0 + R_{tc}/(1+\beta)} \tag{5}$$

The Thévenin equivalent circuit seen looking into the emitter is shown in Fig. 2(b).

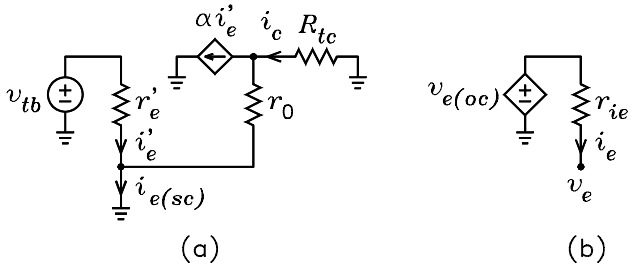

Figure 2: (a) Circuit for calculating $i_{e(sc)}$. (b) Thévenin emitter circuit.