Fig. 3. Transistor circuit that is supposed to function as a good voltage source, meaning that it should provide more or less fixed output voltage $V_{out}$ (measured across the load resistor $R_e$) irrespective of the value of the load resistance $R_2$. NOTE: $V_{out}$ as well as all other voltages are measured or applied with respect to the common ground.

According to the basic transistor properties, the base current must be extremely small compared to the collector and emitter currents, so that the amplification factor $\beta$ is: $\beta \equiv \frac{I_c}{I_B} \approx \frac{I_e}{I_B} \gg 1$ (typically $\beta \sim 10^3$).

$$I_B + I_c = I_e, \quad I_c \approx I_e$$

According to the voltage divider equation, base potential is: $V_B = \frac{R_2}{R_1+R_2} \cdot V_{in}$, where $V_{in} = 12V$ is the dc input voltage.

Then, $V_{out} = I_e \cdot R_e = \beta I_B \cdot R_e = \beta R_e \cdot \frac{V_B - V_{out}}{V_{be}}$, where $R_{be}$ is the resistance of the pn-junction biased forward which is very low ($R_{be}$ should be about $10-100$ $\Omega$).

Thus, by solving for $V_{out}$ in the equation above, we get:

$$V_{out} = \left( \frac{\beta \cdot \frac{R_e}{R_{be}}}{1 + \beta \cdot \frac{R_e}{R_{be}}} \right) \cdot V_B \sim V_B = \frac{R_2}{R_1+R_2} \cdot V_{in}$$  \hspace{1cm} (1)

This prefactor remains very close to 1, independently on $R_e$ value, because $\beta \gg 1$ and $R_{be} \gg 1$, which reduces loading effects.
Fig. 4. Transistor circuit that is supposed to function as a good current source, meaning that it should provide more or less fixed collector current (flowing through the load resistor $R_L$), irrespective of the value of the load resistance $R_L$. NOTE: $V_{out}$ as well as all other voltages are measured or applied with respect to the common ground.

Here, as always, the transistor is trying to maintain large $\beta$, and hence $I_c \approx I_e$. By definition, $I_e = \frac{V_e}{R_e}$.

At the same time (see prev. page), $I_e = \beta I_B = \beta, \frac{V_B - V_e}{R_e}$.

Hence, for $V_e$, we get: $V_e = \frac{\beta V_B R_e}{\beta R_e + R_e}$.

And for $I_e$, we get: $I_e = \frac{V_e}{R_e} = \frac{\beta V_B}{\beta R_e + R_e}$.

But $I_c \approx I_e = \frac{V_{in} - V_{out}}{R_L}$, and hence:

$$\frac{\beta}{R_e + \beta R_e} \frac{R_2}{R_1 + R_2} V_{in} = \frac{V_{in}}{R_L} - \frac{V_{out}}{R_L} \Rightarrow$$

$$V_{out} = V_{in} \left(1 - \frac{\beta R_2 R_L}{(R_1 + R_2)(R_e + \beta R_e)} \right)$$

and hence:

$$I_c = \frac{V_{in} - V_{out}}{R_L} = V_{in} \cdot \frac{\beta R_2}{(R_1 + R_2)(R_e + \beta R_e)} \approx V_{in} \cdot \frac{R_2}{(R_1 + R_2)R_L}$$

$$\beta R_e \gg R_e$$

which is independent of $R_L$. 