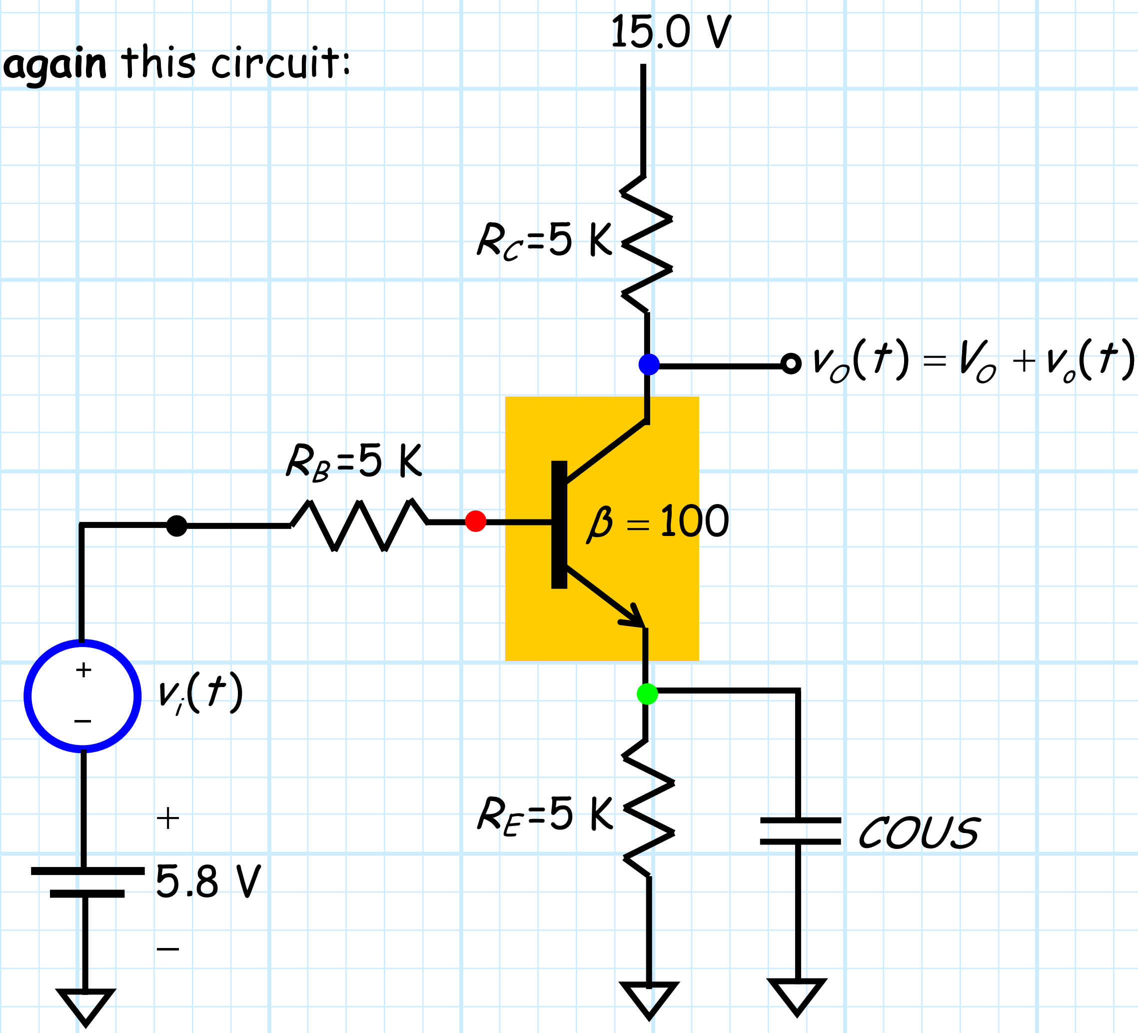
Example: Small-Signal Input and Output Resistances

Consider **again** this circuit:

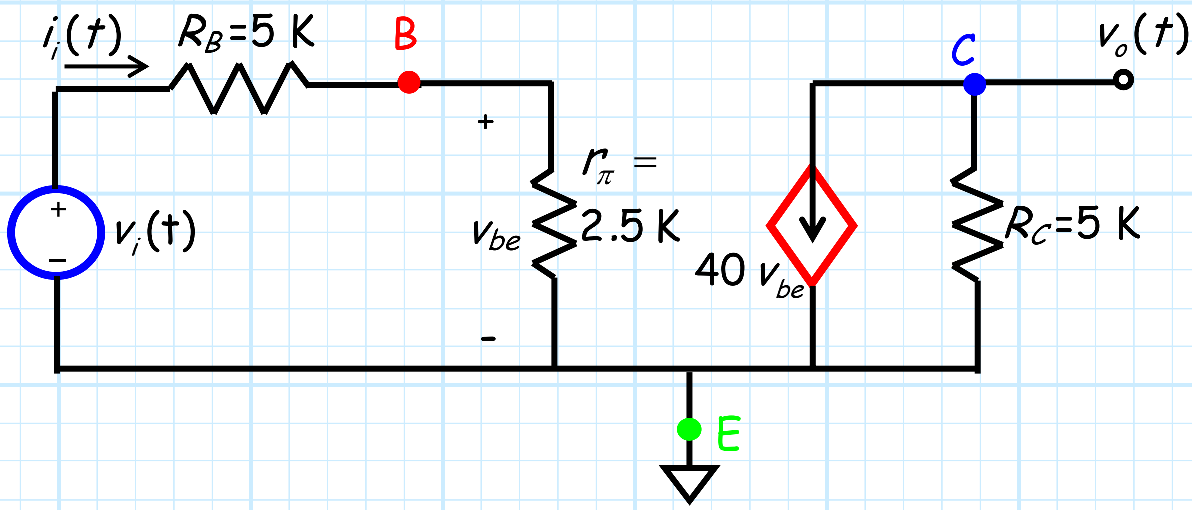


Recall we **earlier** determined the open-circuit **voltage gain** A_{vo} of this amplifier. But, recall also that voltage gain alone is **not** sufficient to **characterize** an amplifier—we likewise require the amplifier's input and output **resistances**!

Q: *But how do we **determine** the small-signal input and output resistances of this BJT amplifier?*

A: The same way we always have, only now we apply the procedures to the **small-signal circuit**.

Recall that **small-signal circuit** for this amplifier was determined to be:



The **input resistance** of an amplifier is defined as:

$$R_{in} = \frac{v_i}{i_i}$$

For this amplifier, it is evident that the **input current** is:

$$i_i = \frac{v_i}{R_B + r_\pi} = \frac{v_i}{5 + 2.5} = \frac{v_i}{7.5}$$

and thus the **input resistance** of this amplifier is:

$$R_{in} = \frac{v_i}{i_i} = 7.5 \text{ K}$$

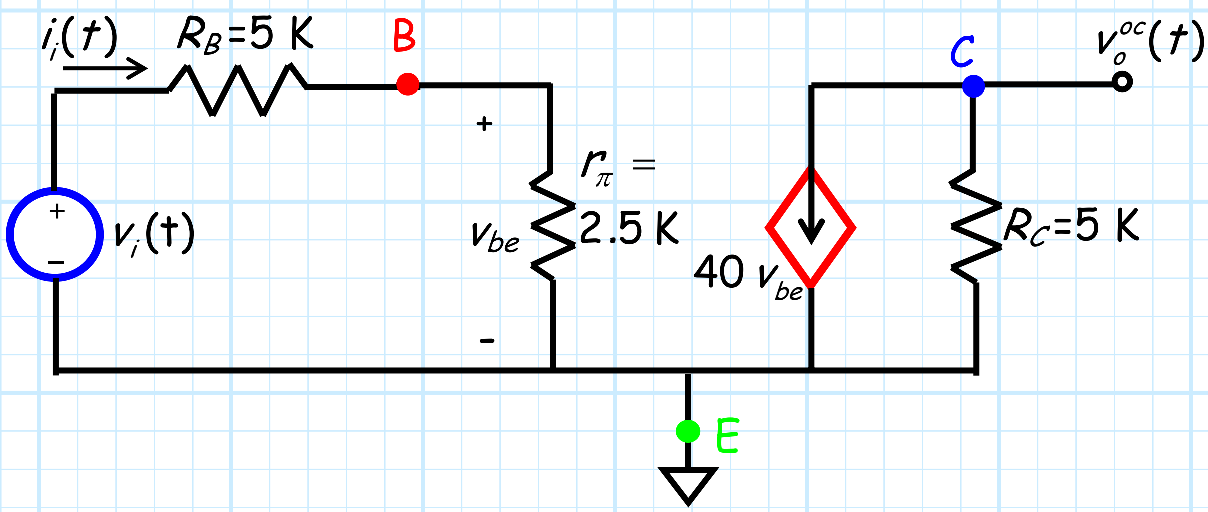
Now for the **output resistance**. Recall that determining the output resistance is much more **complex** than determining the input resistance.

The output resistance of an amplifier is the ratio of the amplifier's **open-circuit** output voltage and its **short-circuit** output current:

$$R_{out} = \frac{v_o^{oc}}{i_o^{sc}}$$

Again, we determine these values by analyzing the **small-signal** amplifier circuit.

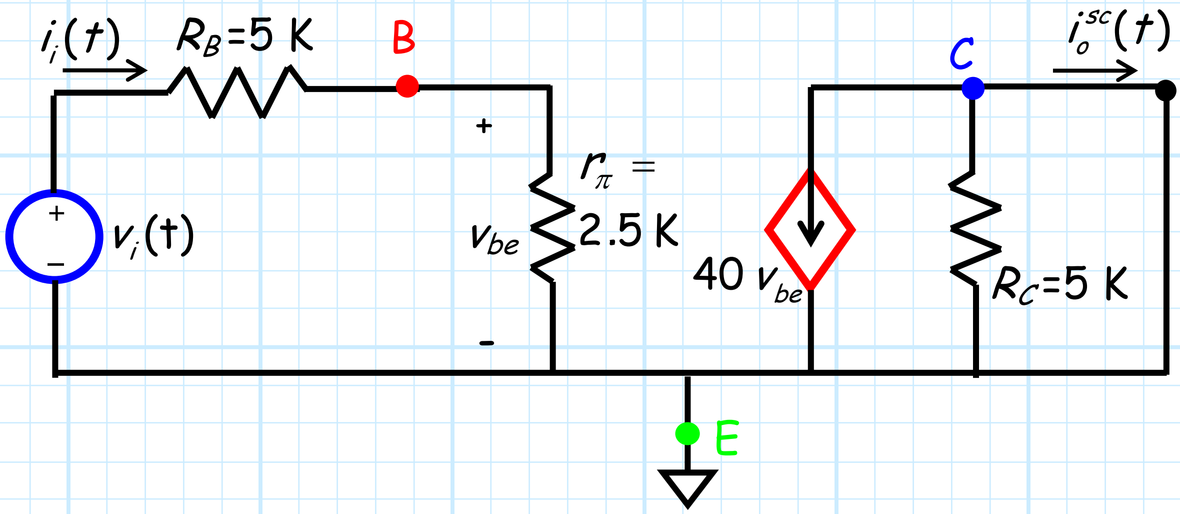
First, let's determine the open-circuit **output voltage**. This, of course, is the amplifier output voltage when the output terminal is **open-circuited**!



It is evident that the output voltage is simply the voltage across the **collector resistor** R_C:

$$v_o^{oc} = -\left(g_m v_{be}\right) R_C = -40\left(5\right) v_{be} = -200\, v_{be} \;\; \text{V}$$

Now, we must determine the short-circuit **output current** i_o^{sc}. This, of course, is the amplifier output current when the output terminal is **short-circuited**!



It is evident that the short-circuit output current is:

$$i_o^{sc} = -g_m v_{be} = -40\, v_{be} \;\; \text{mA}$$

and therefore the **output resistance** of this amplifier is:

$$R_{out} = \frac{v_o^{oc}}{i_o^{sc}} = \frac{-200\, v_{be} \;\; \text{V}}{-40\, v_{be} \;\; \text{mA}} = 5 \text{ K}\Omega$$

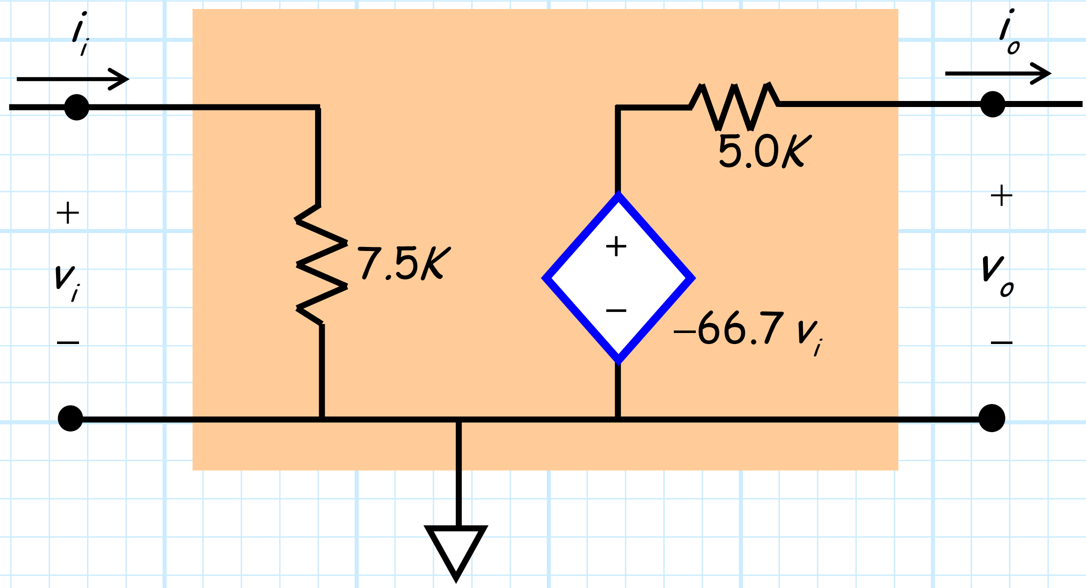
Now we know **all three** of the parameters required to characterize this amplifier!

$$A_{vo} = -66.7 \quad V/V$$

$$R_{in} = 7.5 \quad K\Omega$$

$$R_{out} = 5.0 \quad K\Omega$$

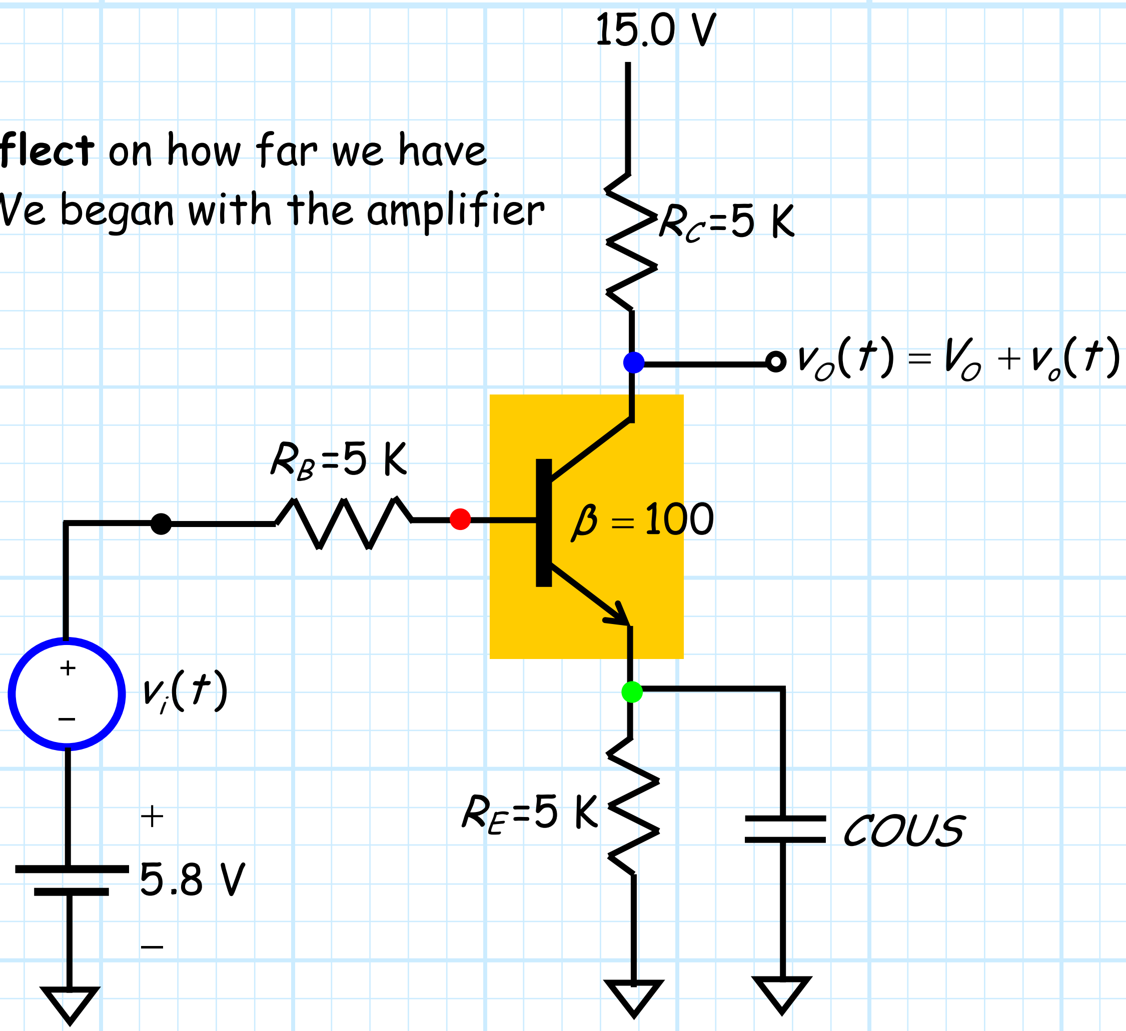
We can therefore write the **equivalent circuit model** for this amplifier:



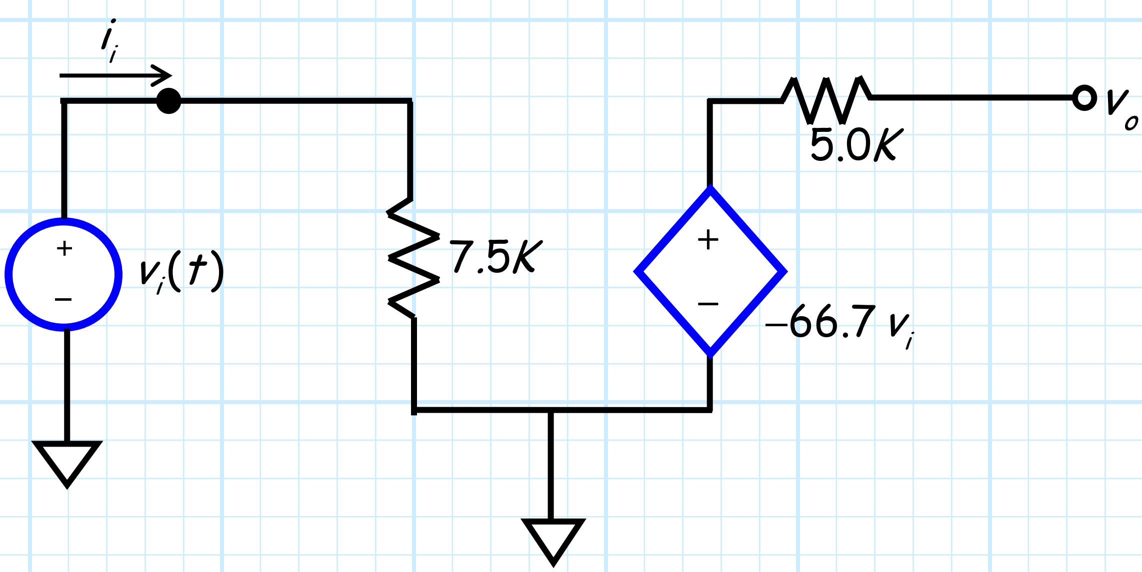
Note that the input resistance of this amplifier is **not** particularly large, and output resistance is **not** at all small.

→ This is **not** a particularly good voltage amplifier!

Now, **reflect** on how far we have come. We began with the amplifier circuit:



and now we have derived its **equivalent** small-signal circuit:



With respect to small signal input/output voltages and currents, these two circuits are **precisely** the same!