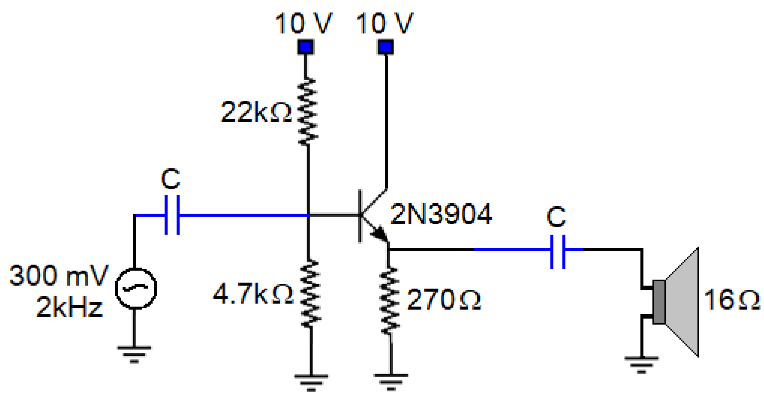
Electronics

Common collector amplifier

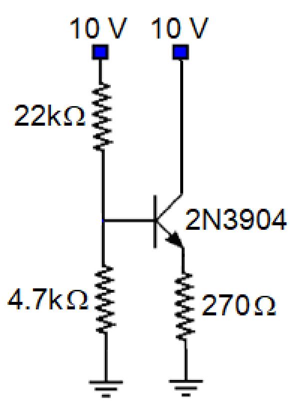
Problem 1.- An *emitter follower* is an amplifier that has a typical voltage gain of less than 1 that you can build with one transistor. Why would you want such a thing?

Solution: When you want to couple a high output impedance signal to a low impedance load the *emitter follower* gives you the solution.

Problem 2.- Assume the capacitors in the following circuit behave as short circuits at the signal frequency. Find
(a) The voltage gain of the amplifier
(b) The input impedance of the circuit and
(c) The gain in power obtained this way.



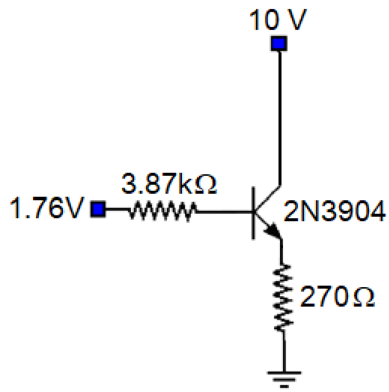
Solution: First we carry out the **DC analysis**. The capacitors behave like open circuits and so the equivalent circuit looks like this:



The base side of the transistor can be replaced by a Thevenin equivalent, where:

$$R_{Thevenin} = \frac{1}{\frac{1}{22k\Omega} + \frac{1}{4.7k\Omega}} = 3.87k\Omega \text{ and } V_{Thevenin} = 10V\left(\frac{4.7k\Omega}{22k\Omega + 4.7k\Omega}\right) = 1.76V$$

With these changes the equivalent circuit will be:



The equation for the voltage on the base side is:

$$1.76V = 3.87k\Omega I_B + 0.7V + 270\Omega I_E$$

But $I_E \approx \beta I_B$, so:

$$1.76V = 3.87k\Omega I_B + 0.7V + 270\Omega \beta I_B$$

$$I_B = \frac{1.76V - 0.7V}{3.87k\Omega + 270\Omega\beta}$$

We need the value of the current gain to find the base current. If we assume $\beta = 200$, which is the typical value according to the specs of this transistor, we get:

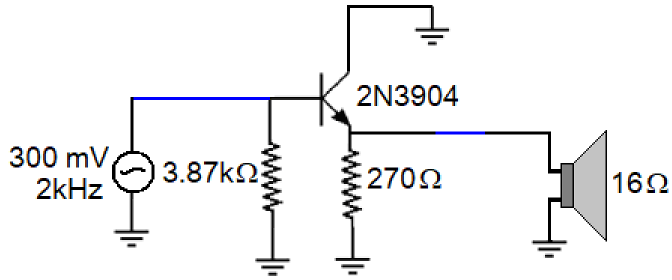
$$I_B = \frac{1.76V - 0.7V}{3.87k\Omega + 200 \times 270\Omega} = 18.3\mu A$$

The voltage collector emitter can be calculated now:

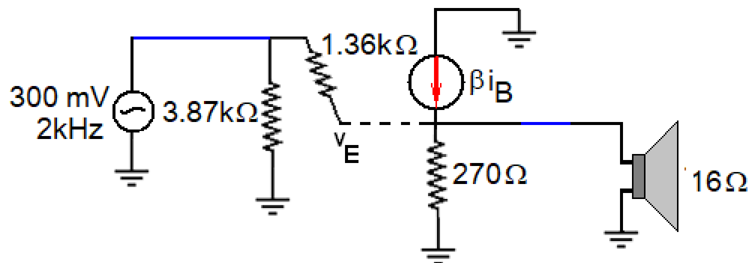
$$V_{CE} = 10V - 270\Omega I_E = 10V - 270\Omega(200 \times 18.3\mu A) = 9.0 \text{ V}$$

This is not the best operating point, but it is still in the active region.

Now, the **AC analysis.** Recall that the capacitors behave like short-circuits and all voltage DC sources are replaced by short circuits:

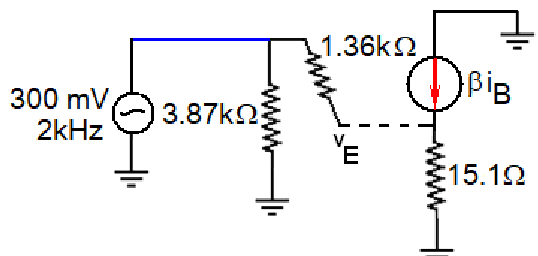


The transistor is replaced by a model where the base-emitter junction is a resistor of value $r_d = \frac{25mV}{I_B} = \frac{25mV}{18.3\mu A} = 1.36k\Omega$ and the collector–emitter is a current source of value $i_C = \beta i_B = 200 i_B$:



Notice that the load (the speaker) is in parallel with the 270-ohm resistor, so they give an equivalent of:

$R_{Equivalent} = \frac{1}{\frac{1}{270\Omega} + \frac{1}{16\Omega}} = 15.1\Omega$, so the simplified circuit looks as follows:



To calculate the voltage gain, notice that we can write an equation for the loop source-base-emitter-ground:

$$300mV = 1.36k\Omega i_B + 15.1\Omega i_E = 300mV = 1.36k\Omega i_B + 15.1\Omega(200 i_B)$$

$$\rightarrow i_B = \frac{300mV}{1.36k\Omega + 200 \times 15.1\Omega} = 68.5\mu A$$

So the load voltage is: $V_L = 15.1\Omega i_E = 15.1\Omega(200 \times 68.5\mu A) = 207mV$

As expected the gain in voltage is less than one: $A = \frac{207mV}{300mV} = \mathbf{0.69}$

To calculate the input impedance, notice that the 15.1 ohm resistor behaves like a resistor of value $r = \beta \times 15.1\Omega = 200 \times 15.1\Omega = 3{,}020\Omega$ from the point of view of the base. This resistor is in series with the 1.36kohm resistor, giving a value of 4.38kohm. And the combination is in parallel with the 3.87kohm resistor giving an input impedance of:

$$R = \frac{1}{\frac{1}{4.38k\Omega} + \frac{1}{3.87k\Omega}} = 2.05k\Omega$$

The load impedance is still 16 ohms and the gain in power is:

$$A_{power} = \frac{P_{load}}{P_{source}} = \frac{\frac{(207mV)^2}{16\Omega}}{\frac{(300mV)^2}{2.05k\Omega}} = \mathbf{61.1}$$