COMMON EMITTER AMPLIFIER

Transistors are used in amplifiers that amplify voltage and current. Our first amplifier is a voltage amplifier called a **common emitter amplifier** for which a change in input voltage ΔV_{in} leads to a change in output voltage ΔV_{out} linearly proportional to ΔV_{in},

$$\Delta V_{out} = A_v \Delta V_{in} \tag{4}$$

where A_v is a constant called the **voltage gain**.

The basic circuit

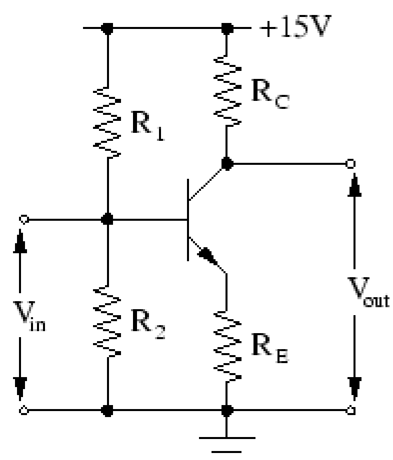

Figure 16: Common emitter amplifier.

Consider the circuit of Figure 16. The values of the resistors R_1, R_2, R_C, and R_E are chosen so that V_{out} is about 7.5 V (centered in the 0-15 V range) and V_{in} is about 0.6 V above the emitter, ensuring that a current always flows from the collector to the emitter, regardless of whether we are exciting the circuit. This is called the **quiescent state**, or the **DC operating point**, of the circuit.

If we apply a change in voltage ΔV_{in} to the input, this change is mirrored by the emitter. To see this, remember that the transistor is ``on'' and so the emitter voltage stays about 0.6 V below the base. We have $\Delta V_E = \Delta V_{in}$, leading to a change in the emitter current $\Delta i_E = \Delta V_{in}/R_E$. The collector and emitter currents are approximately equal, since $\beta \approx 100$, so we find

$$\Delta V_{out} \approx -\Delta i_E R_C = \frac{R_C}{R_E}\Delta V_{in} \qquad (5)$$

giving a voltage gain of

$$A_v = -\frac{R_C}{R_E}. \qquad (6)$$

The minus sign comes in, because an increase in current through R_C lowers the collector voltage.

β independent behavior

Note that the behavior of the circuit does not depend on the β value of the transistor. That is, we rely on the fact that the exponential dependence of i_C on V_{BE} ensures that the transistor can supply (more than) enough current to follow changes in the base voltage. An important design consideration is that we must not saturate the transistor.

Why not $R_E = 0$?

Equation 6 might inspire the question ``What happens if we remove the emitter resistor R_E? Do we get infinite gain?'' It turns out that we get maximal gain, but that the intrinsic dynamic resistance $r_e = \frac{dV_{BE}}{dI_E}$ of the emitter-base junction, looking at the base from the emitter, limits the gain to a finite value. Using the Ebers-Moll equation (Equation 3), we find

$$r_e = \frac{kT/e}{I_E} \approx \frac{kT/e}{I_C}. \tag{7}$$

At room temperature this gives something like $r_e \approx 25/I_C$ for I_C in mA and r_e in Ω. In fact, you measured a value of kT/e for your transistor in Section 3.1.

If $R_E = 0$, then the voltage gain becomes

$$A_v = -\frac{R_C}{r_e} \approx -\frac{I_C R_C}{kT/e} \tag{8}$$

which introduces two unwanted visitors - dependence on both temperature and collector current. The first leads to temperature instability, and the second leads to nonlinear gain. We avoid these problems by using a large enough emitter resistor R_E that the emitter voltage is insensitive to changes in the intrinsic emitter resistance r_e.

A refined circuit

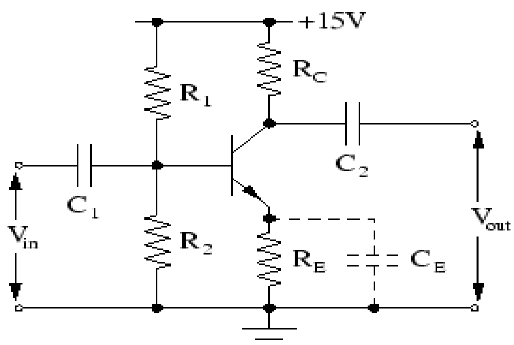

Figure 17: AC common emitter amplifier with capacitive coupling on the input and output.

The circuit of Figure 17 includes some refinements over that of Figure 16. If we only wish to amplify time dependent signals, we couple the input and output signals to the circuit with capacitors C_1 and C_2. This capacitive coupling removes DC components from the input and output that might interfere with the DC operating point of the amplifier. These coupling capacitors form high pass filters with the input and output impedances. Their values should be chosen so as to transmit signals of interest. The capacitor labeled C_E is chosen to bypass the emitter resistor at signal frequencies. You will investigate the effect this has on the gain. The bypass capacitor has no effect on the DC behavior of the circuit.

Source: http://webpages.ursinus.edu/lriley/ref/circuits/node4.html