Amplifiers

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1 Common Emitter Transistor Amplifier

The common emitter transistor amplifier has the input at the base. The emitter is grounded, that is connected to common. The output is taken at the collector. There is a resister R_C from the power supply V_{CC} to the collector. A modified feedback version has a second resistor R_E connected from the emitter to ground. See the schematic and feedback flow chart:

`http://stem2.org/je/common-emitter.pdf`

The following is based on notes taken at Chris Wilkson's circuit class in the cave on December 15, 2010. Some of the notation needs to be cleaned up a bit. For example a small v and a capitalised V sometimes represent the same variable.

The circuit operates at the far forward active region. The current gain is

$$A_i = \frac{i_{out}}{i_{in}} = \frac{i_C}{i_B} = \frac{i_E}{i_B} = \beta$$

β is approximately 100. Transconductance is defined as

$$g_m = \frac{\Delta I_{out}}{\Delta V_{in}},$$

or for small signal alternating current

$$g_m = \frac{i_{out}}{v_{in}}.$$

$$i_C = I_S e^{v_{BE}/v_{TH}},$$

where I_S is the reverse saturation current, and v_{TH} is the thermal voltage

$$v_{TH} = \frac{kT}{q}.$$

$k = 1.38 \times 10^{-23} J/K$ (Joules per Kelvin degree) is Boltzman's constant, T is the Kelvin temperature, and $q = 1.60 \times 10^{-19} C$ (Coulombs) is the charge of the electron. Charge carriers diffuse in semiconductors in order to reach thermal equilibrium according to the principles of statistical mechanics. At temperature $300K$ we have

$$v_{TH} = \frac{kT}{q} = 25.86mV.$$

We have

$$i_E = i_C + i_B.$$

$$v_{out} = V_{CC} - i_C R_C = V_{CC} - R_C I_s e^{V_{BE}/V_{TH}}.$$

Negative Feedback

A resister R_E is added to the circuit from the emitter to ground. We have

$$V_{out} = V_{CC} - R_C i_C$$

$$\approx V_{CC} - R_C i_E$$

$$= V_{CC} - R_C \frac{V_E}{R_E}$$

$$= V_{CC} - \frac{R_C}{R_E}(v_{in} - v_{BE}),$$

where v_{BE} is about $.6V$. We see from this last expression that the gain is

$$a_V = \frac{\Delta V_{out}}{\Delta V_{in}} = -\frac{R_C}{R_E}.$$

We have

$$R_C i_C \approx R_C i_E,$$

because

$$i_C = i_E \frac{\beta}{1+\beta},$$

where β is approximately 100. This comes from

$$i_C = \beta i_B$$

and

$$i_E = i_C + i_B.$$

So

$$i_E = i_C + \frac{i_C}{\beta} = i_C \frac{\beta + 1}{\beta}.$$

Or

$$i_C = i_E \frac{\beta}{\beta + 1}.$$

Also

$$i_C = I_S e^{V_{BE}/V_{TH}},$$

so

$$V_{BE} = V_{TH} \ln(i_C/I_S),$$

which is about $.6V$ in practice. This means that

$$\frac{V_{BE}}{V_{TH}} \approx \frac{.6}{25 \times 10^{-3}} = 24.$$

And so the ratio

$$\frac{i_C}{I_S} = 2.6 \times 10^{10},$$

is very large.

2 Homework

(1) **Make a list of the parts that you have.**
(2) **Create a Common Emitter Amplifier**

Use your split 12 volt ac transformer built into a plastic box. Use this box to connect to your regulated bridge rectifier. This rectifier is built with a LM7805 voltage regulater powered from the 28 volt or so ac transformer. A couple of resistors and a potentiometer are connected to the middle lead of the LM7805 so as to get a 15 volt regulated output. This 15 volts is the power source for the common emitter amplifier. Select resisters R_C and R_E so as to get a gain of about 6. Connect a resistor and potentiometer from V_{CC} to ground with the middle point conected to the base of the transistor. Vary the potentiometer to give various input voltages to the common emitter transistor, and record the output behavior of the amplifier.

3 Bibliography

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