EE321 Lab - week 9 - Emitter followers

8th September 2005

1 Purpose

The purpose of this experiment is to explore "emitter follower" type amplifiers, including class A, class B, and class AB.

2 Overview

So far, we have looked at classic designs for amplifiers with voltage gain. They have the disadvantage that they cannot provide much current to a load. Today, we explore a different kind of amplifier, that has close to unity voltage gain, but lots of current gain. They are called "follower" circuits. The configuration we will try is called an "emitter follower", because the output is taken from the emitter of a bipolar junction transistor.

We will look at the emitter follower in 4 forms:

A simple "Class-A" circuit with one transistor. It gets hot, even with no signal, and can put out moderate amounts of power.

A simple "Class-B", "complementary pair" circuit with two transistors, an NPN and a PNP. There is no quiescent current, so it runs cool, but with a signal it can get hot. It can put out large amounts of power with the appropriate devices. We will use the same power levels as before. It has a significant amount of "crossover" distortion. With a heavy load, it loads whatever you drive it with.

A modified version of the last one, using a "feedback pair" or "darlington" to enhance both transistors. This circuit has 4 transistors. 2 big ones, 2 small ones. The crossover distortion is the same, but it can supply more current, and loads the driver less.

Finally, we add one more transistor to fix the crossover distortion. We call this a "Class-AB" amplifier. We take the previous one, and add one transistor to allow a little bit of quiescent current. It is still low enough that it runs cool. This is similar to the circuit that most audio amplifiers, and many op-amps, use for their output stage.

3 Parts and equipment needed

- Power transistors: MJE15030 (NPN) and MJE15031 (PNP)
- Resistors: 1k (1), 100 ohm 3 watt (3) , 10k (3)
- Small transistors: 2N3904 (NPN) (2), 2N3906 (PNP)
- scope, signal generator, and HP power supplies on the bench
- pot 10K

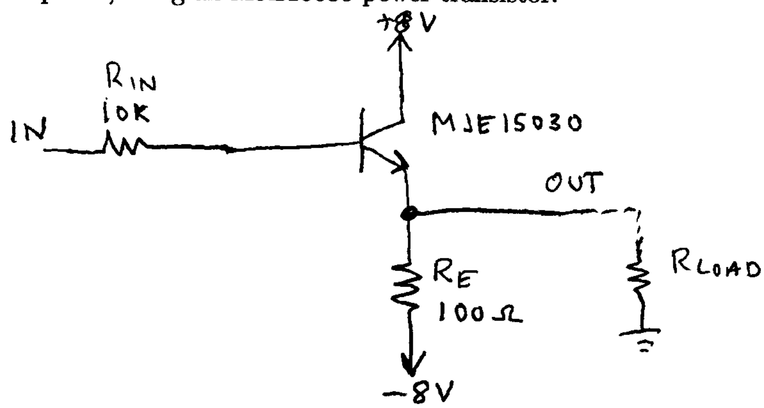
4 Procedure

4.1 Set up

1. Before beginning, check your equipment, set all controls to known states.
2. Set up two HP power supplies to provide + and - 8 volts. Set the current controls in the middle. Use your twisted 3-wire cable to connect power to your circuit.
3. Set the signal generator to about 1 KHz. Verify that the level can be turned up to about 20 volts p-p. Then turn it down to nearly zero.
4. Set the scope, both channels 1 and 2, to DC coupling, 2 volts per division, centered. It is probably a good idea to set the bandwidth to 20 MHz.

4.2 Simple one transistor emitter follower

Build this amplifier, using an MJE15030 power transistor.



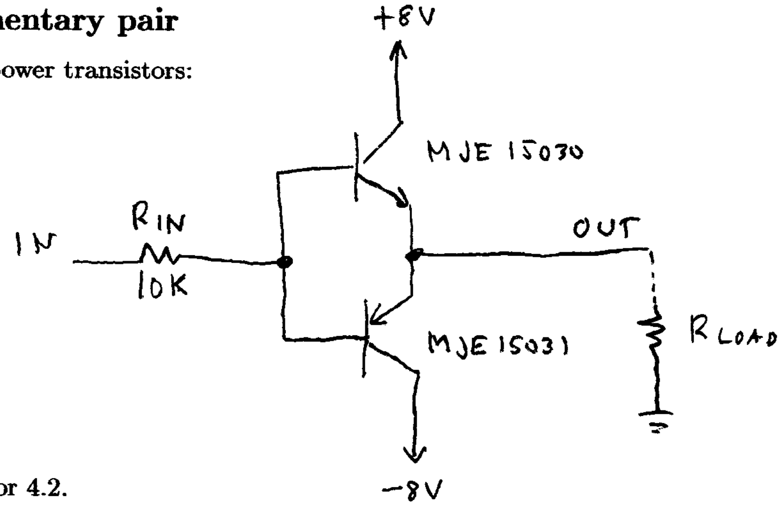
1. After checking the wiring, apply power and verify that the operating point is as expected, with the input grounded.
2. Connect the signal generator, and adjust the DC offset of the signal generator to center the output of the amplifier, compensating for the .6 volts base-to-emitter of the transistor.
3. Set the input level to abuot 10 volts p-p, or slightly below clipping and observe the waveform. Find the gain with an input amplitude of about 10 volts peak-to-peak, or slightly below clipping. It should look like a good sine wave. Take a picture.
4. Increase the amplitude and note the clipping voltage. Take a picture with it all the way up.
5. Repeat steps 3 and 4 for load resistors of 1K, 100 ohms and 50 ohms. Use 2 100 ohm 3 watt resistors in parallel for the 50 ohm load.
6. Do any parts get warm?

Fill in the chart:

Load	V_generator	V_base	V_out	voltage gain	Max out
infinity					
1K					
100 ohms					
50 ohms					

4.3 Class-B complementary pair

Build this circuit, using two power transistors:



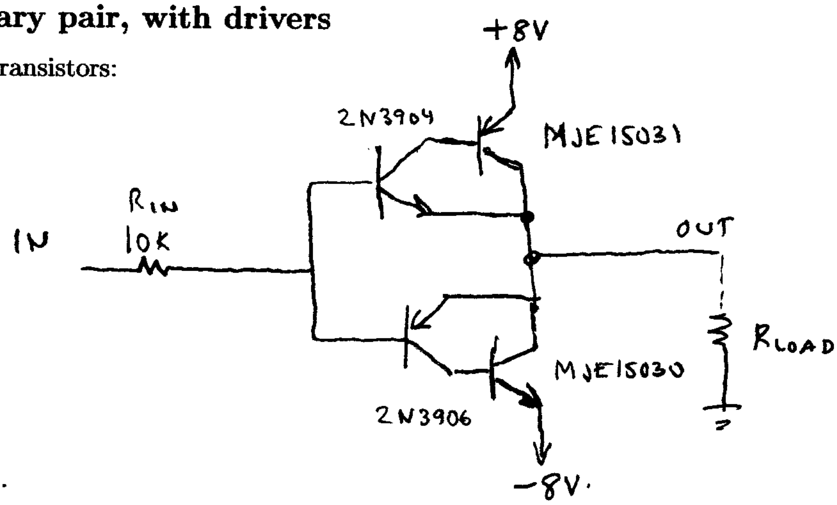
Repeat the tests you did for 4.2.

Fill in the chart:

Load	V_generator	V_base	V_out	voltage gain	Max out
infinity					
1K					
100 ohms					
50 ohms					

4.4 Class-B complementary pair, with drivers

Modify your circuit to add driver transistors:



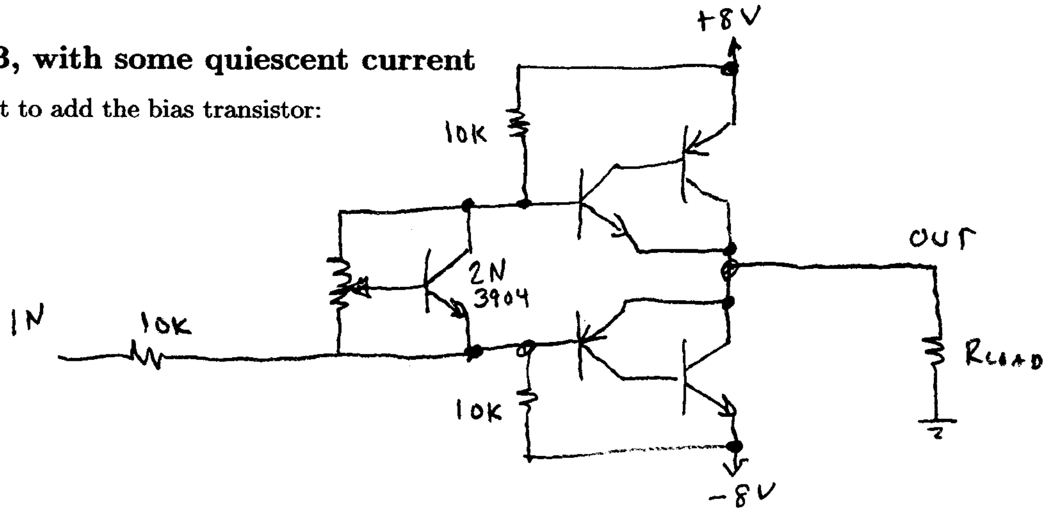
Repeat the tests you did for 4.2.

Fill in the chart:

Load	V_generator	V_base	V_out	voltage gain	Max out
infinity					
1K					
100 ohms					
50 ohms					

4.5 Class-AB, with some quiescent current

Modify your circuit to add the bias transistor:



Before applying power, set the pot so the base is connected to the collector of the bias transistor.

Leave the 50 ohm load connected. Apply a signal of about 2 volts p-p, and adjust the pot to just barely eliminate the crossover notch. get a picture.

Repeat the tests you did for 4.2.

Fill in the chart:

Load	V_generator	V_base	V_out	voltage gain	Max out
infinity					
1K					
100 ohms					
50 ohms					

5 Your report

5.1 Executive summary (on cover)

Show the 4 schematics, with the measurements with 50 ohm load only. Also indicate input and output impedance.

5.2 More detailed summary

Write a paragraph on what you learned, and point out any surprises. Does it do what you expect? Explain. Limit this section to one page.

5.3 Journal

Your report should include a journal of what you did, with enough detail that someone else can repeat your experiment, complete with mistakes. Remember that it will be read by a peer. Write it as you tell a peer what you did. The peer has the same skill as you, or maybe a little more.

5.4 Analysis

Based on the theory, calculate what all of the parameters you measured should be. Compare that to your measurements.

Also, calculate the input and output impedances. You can use how the amplitude varies with load, and a voltage divider model, to calculate it.

5.5 Simulation

Use a simulator to verify that it works as expected. Use the same levels as you did in the lab, producing the same waveforms as you saw in the lab. Run the simulator for one cycle of 1 KHz, with 20 steps per cycle. That's a run time of .001 seconds, and a step size of .00005 seconds. (.tran 0 .001 .00005)

In addition to the input and output waveforms, for the first one (class-A) and last one (class-AB) show current and instantaneous power waveforms, as follows:

Running at the highest undistorted output:

1. The emitter current in both power transistors — .plot tran IE(Q1) IE(Q2)
2. The current delivered by the power supply — .plot tran I(Vdd) I(Vss)
3. The instantaneous power delivered by the power supply — .plot tran P(Vdd) P(Vss)
4. The instantaneous power dissipated by the power transistors — .plot tran P(Q1) P(Q2)

Running at 20 volts p-p input (clipping)

1. The powers and currents from before
2. V_be of both transistors — .plot tran VBE(Q1) VBE(Q2)

In gnucap, you must set the scale for plotting. Do this by giving a pair of numbers after the probe name, for example "VBE(Q1)(-1,1)" . To keep the plots readable, only put two plots together, as indicated. If you are using an external plotting program, you don't need to set the range. Instead, use the ".print" command, then direct the output of the ".tran" command to a file, then use a program like gwave to view it.

This seems like a lot, but it shouldn't take long.

Use the following models:

.model mje15030 npn is=4e-11 bf=200 vaf=10
.model mje15031 pnp is=7e-11 bf=200 vaf=10
.model q2n3904 npn is=7f bf=300 vaf=70
.model q2n3906 pnp is=2f bf=200 vaf=20