Physics 117 Lab 4:Transistor properties and applications

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1. 4-1 Transistor Junctions are Diodes

1.1. Part A

The fist part of this laboratory was confirming a property that the junctions on a transistor act like a pair of diodes extending from the base to the collector and emitter, though in reality this is just a property and does not fully act like diodes. To accomplish observing this property we acquired a 2N3904 NPN transistor, then first we identified its leads using a DVM on the diode test function it has, we then ran connected the leads of the DVM to the base and then to the collector and emitter respectively and we got that the base to emitter had a a value of .703 Volts and the Base to collector had .682 Volts, and the reasons we are able to identify them this way is that the base to collector always has a higher voltage drop. A diagram of the property of diodes of the transistor can be seen in figure 1.

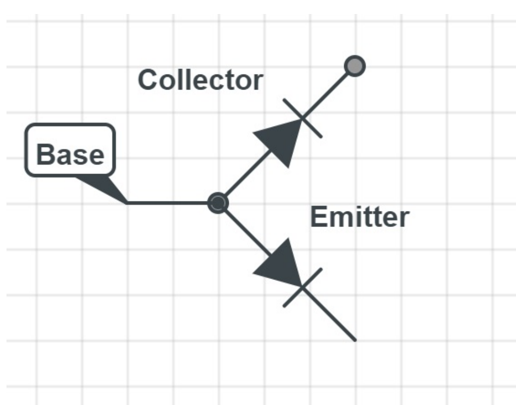

Figure 1: This simple schematic represents the Diode property of the transistor

2. Emitter Follower (4-2)

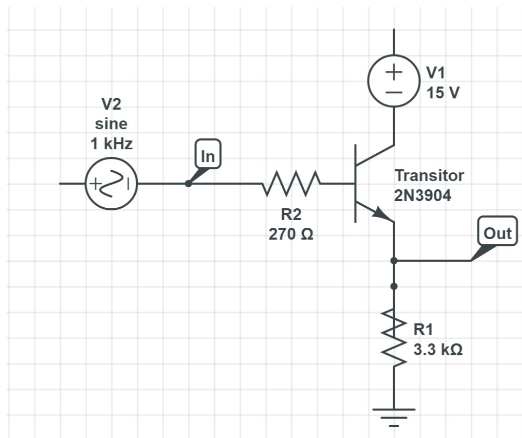

Figure 2: This Shows the circuit diagram for the Emitter Follower

2.1. Part B

The next section had us take a transistor and some resistors as well as our DC and waveform generators to construct the circuit shown in figure 2. This circuit is known as the emitter follower. The first test of the circuit had us drive a sinewave with no offset, and analyze the resulting waveform which we expect to be poor. The resultant waveform is shown in figure 3, what this waveform shows is the positive voltages going through the circuit and providing some voltage to the resistor; the base sends a voltage through a diode that supplies the voltage in the emitter, since it passes through the diode only positive voltages go through. We are asked to turn up the waveform amplitude and observe bumps that form, and explain why they form. The reason why is that the diode leading to the emitter has a breakdown voltage of 8 volts which we learned from a data sheet online; telling us that when the waveform has high enough voltage it leaks through the diode; which is why the bumps form, this can be seen in figure 5.

We are lastly asked what occurs when we replace ground with -15 volts and see what happens. In figure 5, we see a waveform that is fully formed. What happens is the diode loses its breakdown voltage because the -15 volts provides the breakdown allowing the full voltage from the base to pass through the emitter part of the circuit.

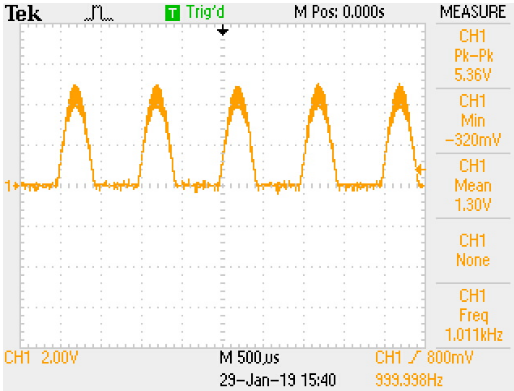

Figure 3: This is the waveform going through the emitter

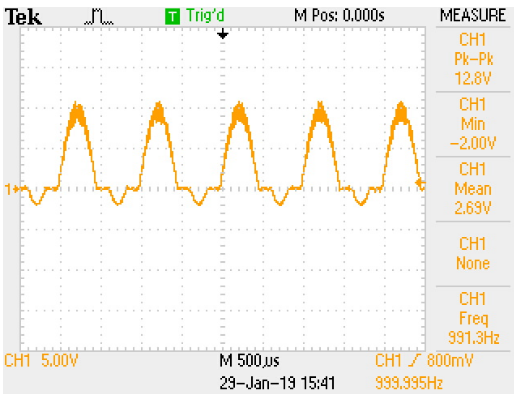

Figure 4: This Shows the waveform for emitter follower with bumps formed at high voltage

2.2. Part C

We are asked to measure V_{CE} and answer why it is not just two diode drops. The reason is that the collector does not drop over the base, rather the collector is collecting current to drive through the circuit, so its voltage does not drop against the first diode, the base then releases a voltage to the emitter which does face a diode, so V_{CE} does drop against 1 diode but not 2 because the voltage does not drop from collector to base.

3. input and Output Impedance of follower (4-3)

3.1. Part D

The next section had us observe the input and output impedance of the last circuit, to do this we use a capacitor and resistor shown in figure 6.

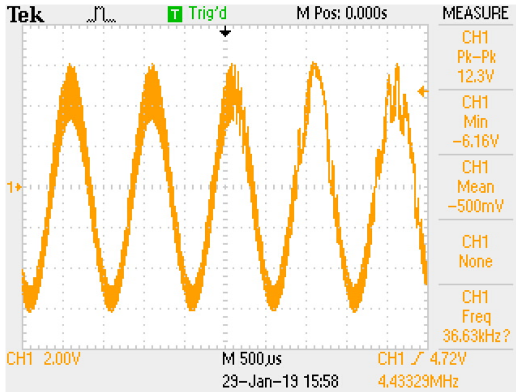

Figure 5: This Shows the waveform for emitter follower with a -15 Volt at the emitter point showing a full waveform

We are first asked to measure Z_{out} the output impedance of the followed, by connecting a $1k\Omega$ and seeing the drop in output signal amplitude; using less than a volt, and asked why we use a blocking capacitor. Firstly we used the capacitor to create a high pass filter to filter the offset in the thevenin resistor. Secondly to find the change in impedance we simply used the voltage divider and turned the transistor circuit into a thevinin equivalent circuit. To read the Z_{out} we simply added a $1k\Omega$ resisor and inputted a 1V in the original circuit and observed how it changed the voltage with the addition of the resistor. Simply using equations 1 and 2 we can calculate the output impedance which in our case was 86.9Ω after the voltage shifted from 1 Volt to .94 Volt. We can reduce equation 1 to equation 2 for easier data manipulation.

$$\frac{V_{out}}{V_{in}} = \frac{Z_{1k}}{Z_{out} + Z_{1k}} \qquad [1]$$

$$Z_{in} = \frac{V_{in} * Z_2}{V_{out}} - Z_2 \qquad [2]$$

To find the input impedance we use the same methodology of adding a resistor and observing how the voltages change, specifically we look at the 10k input resistor, what our result was that the initial voltage was 1 Volt the resultant was .86 Volts plugging the resistor into equation 2 we find that the input impedance was $244k\Omega$ which makes sense with what we would expect.

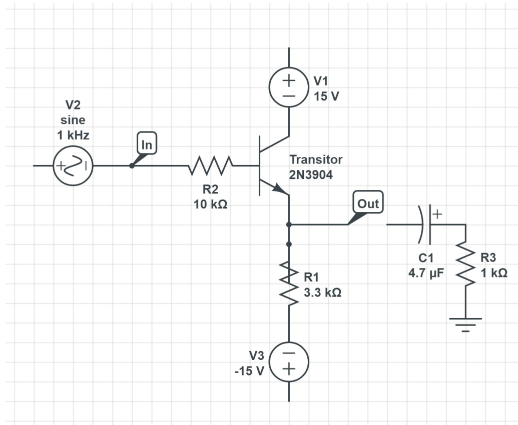

Figure 6: This figure shows the circuit diagram for the Input and Output impedance circuit

lastly since we know $Z_{in} and Z_{out}$ we are asked to find a value for β which we are able to do using equation 3 where R_E and R_B are given by $3.3k\Omega$ and $10k\Omega$ respectively. The resultant β we find is about 92.4, the beta for $Z_{out} = 116\Omega$ and $Z_{in} = 74\Omega$ all of these values fit the range of β that we want.

$$\frac{Z_{in}}{Z_{out}} = \beta^2(\frac{R_E}{R_B}) \qquad [3]$$

3.2. Part E

We are last asked to observe V_{CE} and observe that is large. When we measured it we got a value of 26 Volts which is large, the reason why it is large is that the voltage is being amplified.

4. Single-supply follower (4-4)

4.1. Part F

The next section had us create a Single supply Follower which can be seen in figure 7. We first had to investigate the clipping this circuit causes, we did this by generating large output swings which allowed us to an output of figure 8 where we saw the clipping the circuit causes.

4.2. Part G

The last part of this circuit was to measure V_{CE} and observe that it was large. We did that and got a value for $V_{CE} = 8.81Volts$ which is larger than the inputted voltage.

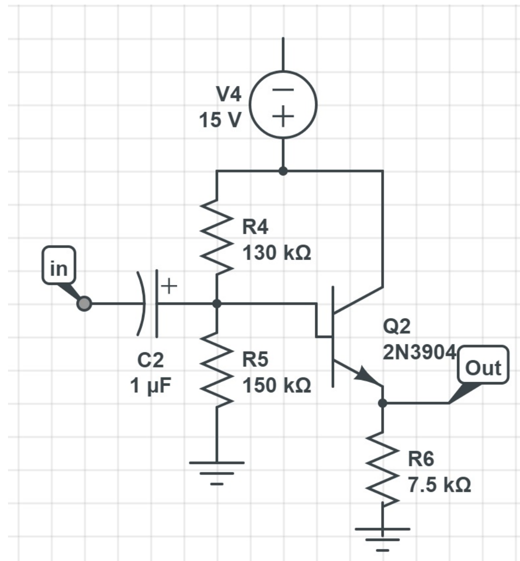

Figure 7: This shows the circuit diagram for a Single Supply Follower

5. Transistor Current Gain (4-5)

5.1. Part H

The next section had us create a Transistor Current Gain circuit which can be seen in figure 9. Specifically this circuit is simple, and is seeking to find β values for various resistors inputted into the circuit with a consistent current into the circuit. We are able to do this using equation 4 which simply shows that if we keep track of the base current we can find β.

$$I_C = \beta * I_B \qquad [4]$$

To collect the currents and measure I_B we simply use a 4.4 Volt always across the base since .6 is lost when you travel to the collector, and use the given resistance at the moment, which is a resistor of our choice and a 4.7 kΩ resistor, using Ohms law in equation 5 we are able to calculate the currents and then the beta following it.To find the collector current, since we are simply dropping against a 1kΩ resistor we always get a value of 15mA for the collector current. If the base only drops against the $4.7k\Omega$ we get .92mA for the base current, but when we vary the resistance we get different currents you can see the results in table 1. We get an average β at around 159.6 for the varying resistors.

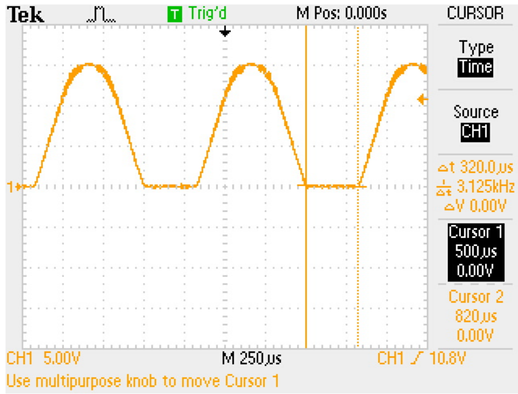

Figure 8: This shows the output of the single supply follower observing how the amplifier circuit adds clipping

Col1	Resistance	current	β
1	5 MOhm	.06 mA	250
2	1 MOHM	.72 mA	208
3	7.47 kOhm	9.4 mA	159
4	330 kOhm	2.27 mA	66
5	49.9 kOHM	13.1 MA	115

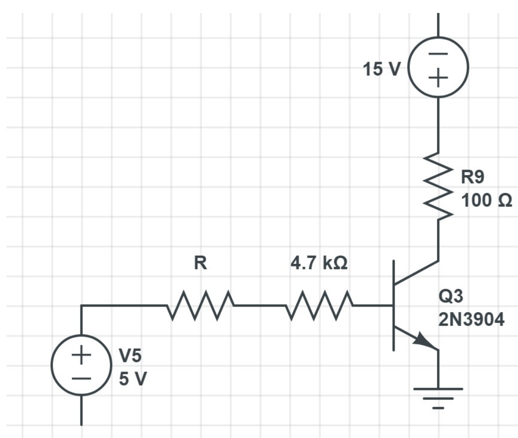

Figure 9: This shows the circuit diagram for the Transistor Current Gain.

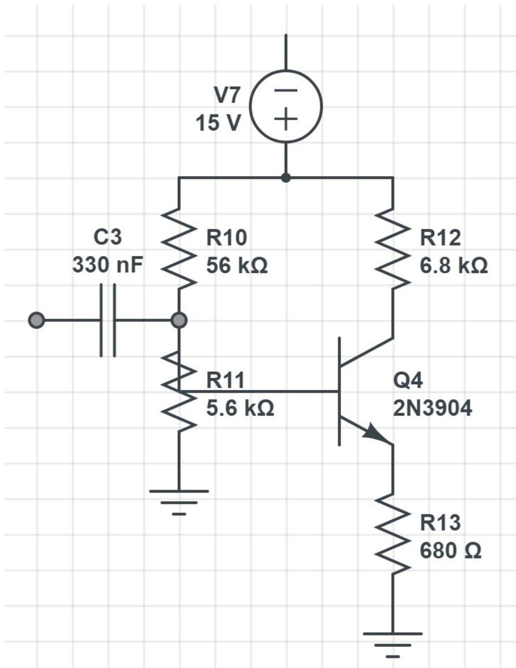

Figure 10: This shows the circuit diagram for the Common Emitter Amplifier.

6. Common Emitter Amplifier (4-7)

6.1. Part I

The next section had us create a common emitter amplifier seen in figure 10. We are asked what its voltage gain should be, in this case the voltage gain can be calculated from the ratio of resistances of the collector and emitter, $\frac{R_C}{R_E}$, so the values are 6800/680 which leads to a voltage multiplier of 10. Then we are asked if the Phase is inverted which it is, we can see this in figure 11. Then we are asked about the quiescent operating point which can be calculated in a variety of ways and is equal to the emitter voltage, in our case the quiescent point was at .642 Volts and the collectors quiescent point was 6.42 Volts. Then we are asked what the output impedance is. To calculate this we basically added a resistor to the collector circuit and measured the resultant voltage. To keep things simple we simply added a 6.8 $k\Omega$ resistor this cut the 6.42 volts in half to 3.21 volts meaning that the output impedance in the circuit is simply 6.8 $k\Omega$.

We are asked lastly about a couple of things, first what did we need to connect V_{out} to the collector instead of emitter for voltage gain. The reason why is that the biased voltage of the base is the same as the quiescent point of the emitter, so there would be no gain going from the emitter. You can see how the V_{out} is effected in equation 4.

$$Q\frac{R_C}{R_E} = 15 - V_{out} \qquad [4]$$

Lastly we are asked to quantitatively compare the output impedance of the amplifier to the input impedance of a speaker with 7.8 Ω resistance, the output impedance was 6.8 $k\Omega$, this leads to a ratio of 7.8/6800 which is equal to .001.

7. Emitter Follower Buffer (4-8)

We are asked to place another transistor, we specifically place the base of the second at the collector of the first transistor. We are asked if the overall amplifier gain effected by the 2nd transistor the answer is no, because their is no voltage drop. You can see the circuit in figure 12.

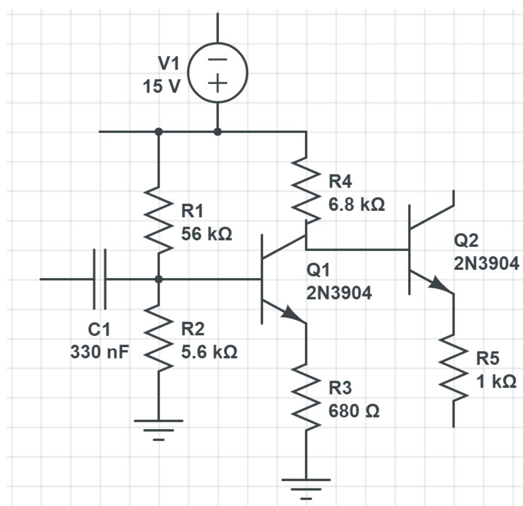

Figure 11: This shows the differentitor without the 2.2 $k\Omega$ resistor

7.1. Part H

We are asked to measure the input impedance of a speaker with our DMM, what we did is simply measure the resistance of the two leads out of the speaker, which gave us a value of 8.09 Ω.

7.2. Part I

We are asked to set our function generator to 5kHz, and then connect the speaker to the emitter follower buffer at various locations. First we do a basic check to see if the speaker worked which we confirmed. Then we are asked to hook up the speaker to the output of the amplifier which we could barely hear. The reason why is that the input impedance in so high that the voltage reaches the speaker but after effected greatly by the impedance in the system. We are lastly asked to put the speaker to the output of the emitter-follower relative to ground which provides us a large noise. The reason why this receives a amplified voltage from the first transistor which in a low impedance section of the second transistor providing us a large voltage in the speaker despite no voltage gain.