Experiment IX: AM Transistor Radio: The Transistor Amplifier Circuit

I. References

Horowitz and Hill, *The Art of Electronics*.
Diefenderfer and Holton, *Principles of Electronic Instrumentation*
The American Radio Relay League, *The ARRL Handbook*

II. Equipment

2 each ON Semi-Conductor MPSW45A Darlington Transistor
Digital Oscilloscope
Variable DC Power Supply
2 each 100 kΩ resistor
2 each 10 kΩ resistor
1 each 1 kΩ resistor
1 each 1 MΩ resistor
3 mini bread boards
4 each 0.1 μF capacitor
short insulated wires with ends stripped
BNC minigrabber scope probes
Crystal radio kit
Razor blades
Tape
Homemade speaker

III. Introduction

We have built a crystal radio, which is passive (has no power source) and is capable of only picking up very strong radio signals. We must use a crystal earpiece with very high impedance because we must keep the current in the circuit very low to prevent it from drawing too much power.

In Lab VIII, we examined some basic operating characteristics of a bipolar npn transistor. Transistors are commonly used to amplify signals. They can amplify current or voltage depending on how they are configured in a circuit. However, these circuits require a power supply.

In this lab, we will modify our radio to include a transistor amplifier circuit. We will feed the output signal from our crystal radio into the base of the transistor and examine the amplified signal. With our transistor amplifier, you will be able to run your iPod earbuds and hear a loud signal. The output will be strong enough to produce a faint sound even on your foam plate speaker.

IV. Transistor operation

For this lab, we will be using an On Semiconductor MPSW45A Darlington transistor. A Darlington transistor contains two transistors in a single package, providing greater amplification. As usual, you can find the transistor spec sheet by Googling.

As explained in Lab VIII, the base current and the collector current are related by

$$I_C = h_{FE}\, I_B$$

where h_{FE} for a Darlington transistor is much larger than for a conventional bipolar transistor. The plot below shows the relationship between the base and collector current. In the operating region of the transistor, the currents are nearly independent of the collector emitter voltage, but the collector current is very sensitive to small changes in the base current.

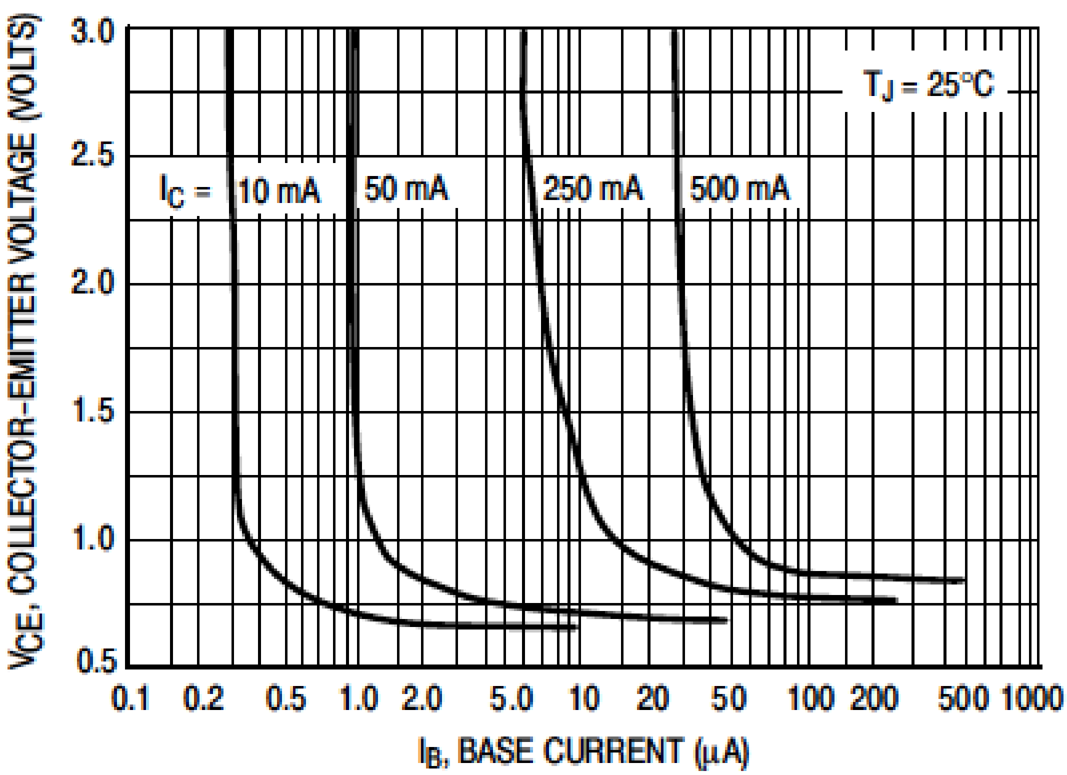

Fig. IX.1

V. Lab activity

PART A: BUILD A HIGH IMPEDANCE AMPLIFIER

Your foam plate has low impedance (measure it). Your crystal earpiece has high impedance. When designing an amplifier, it is important to take this into account. We will first use an amplifier for your crystal ear piece.

1. The circuit Fig. IX.2 has a high output impedance, and is well matched to your earpiece. Connect it up, using your crystal earpiece for the headphone. Have your instructor check it.

2. Using another breadboard, rebuild your crystal radio and listen to the signal. (Be careful! It will be loud! You probably do not need to stick it in your ear.)

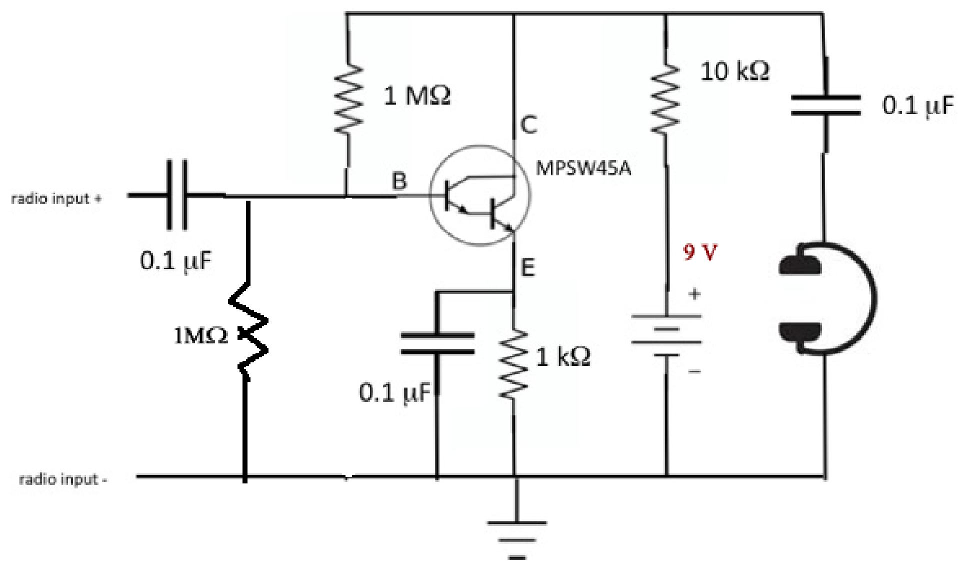

Fig. IX.2 Audio amplifier with high output impedance.

PART B: BUILD A LOW IMPEDANCE TRANSISTOR AMPLIFIER

For your foam plate speaker, we will use the circuit shown in Fig. IX.3. We input the signal through a voltage divider consisting of two 100 kΩ resistors. Remember that transistors consist of pn junctions and need a certain minimum base voltage to turn on.

By inputting the signal through a voltage divider, we push the voltage at the base up to ensure that the transistor doesn't turn off when the output drops to zero. We also put a 10 kΩ resistor at the input because, believe it or not, the signal from your crystal radio is too high, and we do not want distortion (signal clipping) in the output.

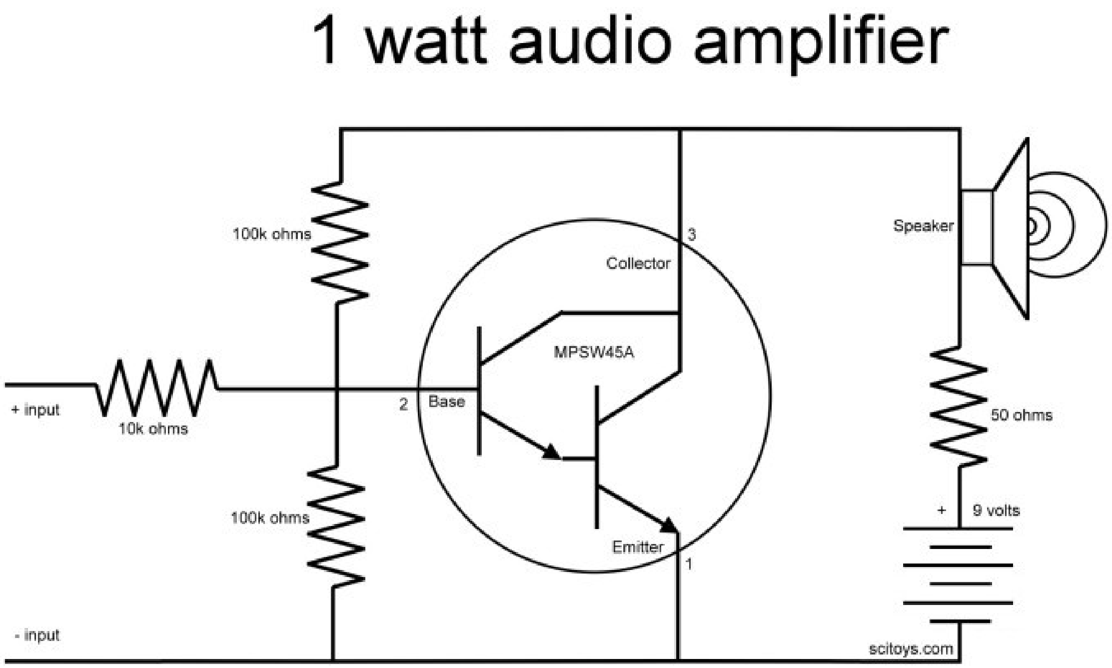

Fig. IX.3 Audio amplifier with low output impedance.

The "load" consists of a variable resistor (in the figure it is set to 50 Ω, but treat it as a variable resistor) for volume control, and to increase the life of the transistor and a speaker. Due to the voltage drop across the load, the voltage drop from the collector to the emitter will not equal the full voltage supplied.

Because the Collector current is so much larger than the base current, the current through the voltage divider and the base can be neglected and the collector and emitter current can be taken to be equal.

1. Connect up the amplifier circuit shown in Fig. IX.3. Use the resistor box to supply the 50 Ω. Connect your function generator to the input and display the output on CH1 of your scope. Use your DC power to bias the transistor (shown as a 9 V battery in Fig. IX.3). Slowly increase the voltage from 0 until the current drawn is around 0.1 A, or until you hear the tone in your earbud or speaker.

2. Apply a small signal (between 250mV and 500mV) with the function generator. This will simulate the audio signal from your crystal radio which produces a few hundred mV. You can decrease the amplitude of the function generator by pulling out on the amplitude knob. **Apply a DC offset of around +1 V to the**

signal (measure the mean value of the applied voltage signal to check!). (Remember that your audio signal will be rectified, and will therefore have a voltage offset.) Fine tune the DC power supplied to the transistor, and the DC offset voltage on the input signal, to get a good audible tone in your earbuds or speaker. Measure the voltage across the load (variable) resistor and display it on CH2. (Note that you will need to use your instrumentation amplifier if you hook up the circuit in the configuration shown.) Adjust the voltage per division and position offset so both traces are shown on your screen, and take a screenshot.

3. Record the peak to peak voltage on both channels and the offset voltage on both channels, for 4 values of the resistance from 30-90 Ω (be careful not to burn out the transistor). Calculate the voltage gain of the circuit.

4. Measure the collector current I_C, and the base current I_B for 4 values of the resistance from 30-90 Ω. (Hint, current I_B will be small, so it is most easily measured by measuring the voltage drop across the input 10k ohm resistor.) Calculate the current gain of the circuit.

5. Push the knob on your function generator in, and slowly increase the voltage. What happens to the signal as the voltage gets larger?

PART C: CONNECT YOUR RADIO

1. Reassemble your crystal radio on a small breadboard, hook it to an antenna and tune it to a strong station. You can listen with your crystal earpiece or look at the FFT to tune the radio.

2. Measure the signal across the load (the earpiece). Record the offset voltage and the peak to peak amplitude of the signal. Take a screenshot.

3. Now connect the crystal radio to your amplifier circuit. **Remove** the crystal earpiece and use two long wire jumpers to connect the output of your crystal radio to the inputs of you amplifier circuit. Keep the resistor box and either your iPod earbuds or your foam plate speaker as the output load of the amplifier. Once you have done this, ask your instructor to inspect the circuit. Apply voltage from the DC power supply until the current reaches 0.1 A. (Note: If you use your earbuds, start at a high resistance on the box and gradually decrease the resistance to avoid overheating your earbuds.) Alternatively, slowly increase the voltage from 0 and listen for an audible radio station in your earbud – it should show up around 2 – 3 Volts.

4. Record what you observe. Measure the peak to peak voltage and the voltage offset across the load (the resistor and the speaker). Take a screenshot. Use the

FFT mode (5.0 MS/s) to tune the radio and find an audible signal. Note that the tuner is much more selective now and you have to hunt carefully for a station.

5. Listen to the radio with your earbuds attached to the output of the circuit. This amplifier provides the impedance match required to drive the low-impedance earbuds.