Christopher Sonntag

University Physics 2, Lab Section L006

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Transistors and Amplification

"The single most important function in electronics can be expressed in one word: *amplification.*" (Jones 1995) Amplification occurs when a signal's power is increased in magnitude. This is important to many electronic instruments in daily use, beginning with electromagnetic relays in 1835, used to create powerful long-distance telegraph communications beginning from a simple tap of a transmitter, to the invention of the transistor in the early 1950s jumpstarting a revolution in the electronics industry.

The transistor, an electrical component which can be used to amplify a signal, is a semiconducting device with three terminals which can connect to a circuit. The output of a transistor can be much higher than its input, which is of great use, with one clear example being in the amplification of audio. In fact, one of the earliest applications was the *transistor radio*, among other devices such as calculators and early computers, which quickly became the most popular consumer electronic device in history, as transistors began the effective replacement of vacuum tube components in electronics in America.

The ability of a circuit to amplify a signal, usually in a ratio between the output and input, is *gain.* The type of transistor used in this demonstration is a *bipolar* transistor, which has terminals labeled B, C, and E (for base, collector, and emitter) and for small signals has a relatively low gain. Voltage or current applied between the *collector* and *base*, two of the terminals, changes the flow between the *base* and the *emitter*. (Jones 1995) The transistor draws power from the collector, which is then regulated by the input signal at the base before finally flowing out of the emitter as an amplified signal.

For the small amplifier demonstrated, an MPSW45A Darlington transistor is used. This is essentially a two-in-one transistor which connects together so that the amplified input signal is amplified again by the second transistor. (Jones 1995) The gain from this setup equals the two individual gains multiplied together. This allows for a relatively high output from a low input. According to datasheets available online, the Darlington transistor in question needs .7 volts across both of the B-E junctions inside it, meaning at least 1.4 V is required to turn it on. (Field) This means that if the input signal is low, the transistor essentially turns off, like a switch, and no sound is produced. To keep this from happening, a constant voltage is applied that is higher than the 1.4 V.

For best results in an audio amplifier, the voltage across the transistor should be somewhere in the middle of the power source's range of voltages, so that both positive and negative swings in the signal are accurately reflected in the final sound. Using a voltage divider (two resistors connected to the positive and negative side of a battery—when they meet, if they have the same resistivity, the voltage is halved), the output of the amplifier is at 4.5 volts without any sort of input signal. To keep too much current from flowing through, the resistors must have high values (two 100,000 Ω resistors are used), which will also keep them from getting too hot, which makes the battery last longer.

A 10,000 Ω resistor at the base of the transistor keeps the input signal from being too strong, which could cause distortion. A 50 Ω resistor helps to prevent the transistor from burning out, as without it, the circuit draws about 2 watts of power, while the transistor can only handle about 1 watt of power before heating up too much. ("Semiconducting Technical Data; One-Watt NPN Darlington Transistors") This also acts as a damper on the volume of the speaker.

Also needed are a small speaker to produce sound (1/4 A, 8Ω in this demonstration) and a 9-volt battery and clip to provide current. (Field) The input of the amplifier comes in through the 10,000 Ω resistor, so some sort of electrical device is needed to push a signal through. This can come from any sort of device, which originally in my experiment was to be a crystal radio set. However, I believe the instructions for the crystal radio set were likely incorrect (as were the instructions for the amplifier itself originally) or the radio was simply unable to pick up any stations, and so a bit of improvisation had to be used.

A set of headphones was cannibalized for its 1/8" jack and wires. When cut, there were four wires—two copper-colored, one red, and one blue—that were covered in enamel and had to be soldered to create useful connections. As the signal for headphones is stereo, the pair of colored wires were soldered together to form a sort of "mono" signal while the copper wires was soldered together to form a single ground. This was soldered to the 10,000 Ω resistor, while the 1/8" jack allows an input from a variety of devices such as phones and iPods. Unfortunately, with this set up, the impedance (in a DC circuit, this is the same as resistance to a changing current) of the output and input will likely not match. This creates interference and power loss as part of the signal is "reflected back."

Finally, with all of the components connected according to Figure 1 (attached schematic), the circuit path is closed and the one-watt transistor can easily amplify a signal. While the actual amplification of this design is fairly low, using a few more transistors (such as on an integrated circuit chip) with a few capacitors and extra resistors would help to ramp up the signal even further.

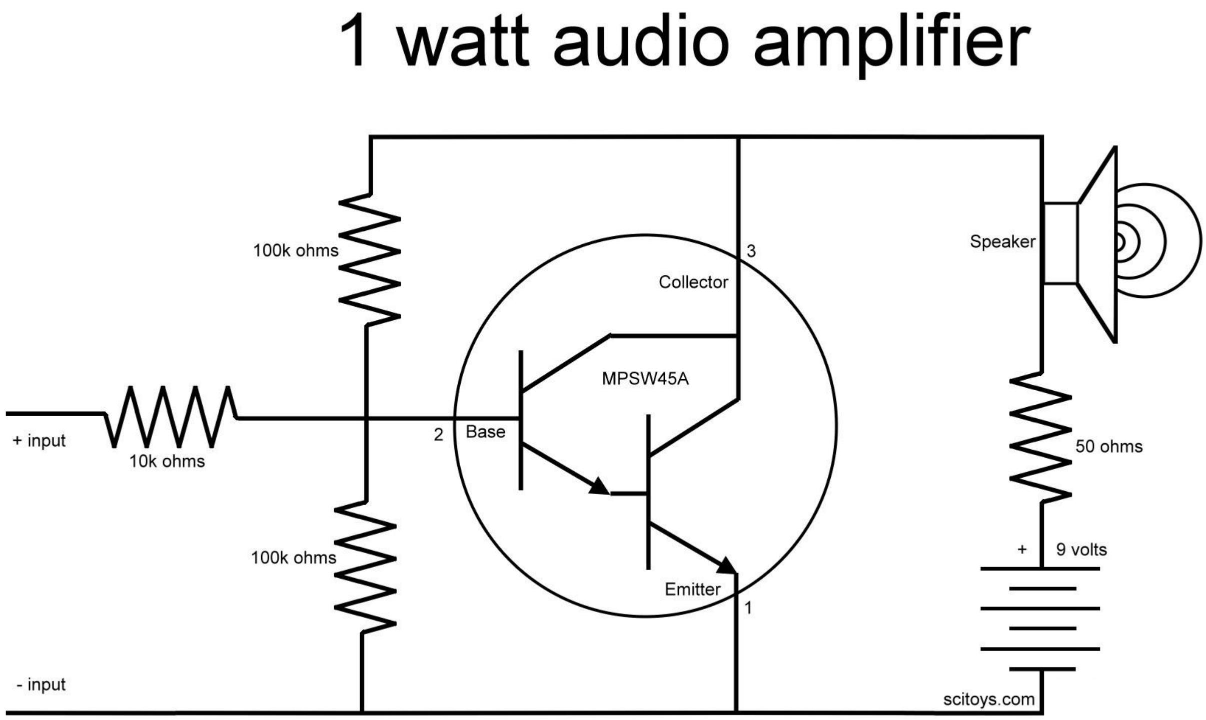

Figure 1

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