Speaker Lab: Homemade Hi-fidelity Speakers

Lab Plan
The purpose of this lab is to provide useful application of electromagnetic theory in the area of homemade hi-fidelity speakers. The student will discover how to assemble a simple speaker as well as how speakers operate in terms of electromagnetic theory. Applications of this lab can be extended into the realm of commercial speaker production. Upon completion of this lab the student will understand the process of audio generation and manipulation by:

1. Outputting a signal from an audio source (i.e. CD/DVD).
2. Receiving a signal for audio filtering.
3. Hearing the outputted signal from the speakers.

Design Decisions
The hardware design decisions for this lab come from the work of Mr. Jose Pino (http://www.josepino.com/other_projects/?homemade-hifi-speaker_jpc) who stressed cost and functionality. Mr. Jose Pino is a hobbyist engineer who was willing to allow his design to be utilized for educational purposes. We made use of the design to create a lab instruction set that will challenge students to experiment and discover better designs or a completely new design of their own.

Parts Choice
1. TRS Output Cable: We are going to utilize a TRS output cable so the speaker can receive the input signal without having to solder the copper wire to it. The exposed wire can simply be wrapped this cable.

2. Mono / Stereo Audio Plug: We used this during development of the demo unit to decide whether we wanted to use a mono or stereo source. We concluded that because we are creating a single speaker we will incorporate only the Mono audio plug.
3. Neodymium Magnets: They provided the most powerful magnetic field to price ratio that can produce a very high quality of audio outputted to the foam plate.

4. 38 Gauge Copper Wire: We will utilize 38 gauge copper wire instead of the recommended 30 gauge copper wire simply because of availability. This however creates additional resistance and requires extra windings around the magnet. The speakers will still operate correctly but can be improved by using 30 gauge copper wire.

5. Foam Plate: As recommended from the website, we will use a foam plate for the building process because it provides the best vibration vs. rigidity ratio and therefore gives the best audio performance as well.
Lab Write-up

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Introduction:
Disclaimer: Actual hardware creation process created by Jose Pino (www.josepino.com)
This instruction set is created to show how applied electromagnetism works, in this case, the building of a homemade hi-fidelity speaker.

Procedure:

1. Have your protective goggles on for safety purposes.

2. Visit http://josepino.com/other_projects/?homemade-hifi-speaker.jpc and follow the online instruction to create the speakers. You should have all the hardware you need available. There is also a YouTube video on the same page that is very useful in giving a general overview for the build process.
   
   Note: We have provided an audio source cable. Just wrap the exposed copper wire from the speaker around the audio source cable (no need to solder but make sure the enamel is removed from the contact points of the copper wire). Also, don’t use quick drying glue or ones that will adhere permanently so that you can easily make changes to the speakers like the changes you’ll need to do to answer the questions below.

3. Once you’re done building the speaker, use your ammeter to measure the resistance of the coil and test it out by plugging in the provided audio cable to an audio source (cell phone, mp3 player, computer audio port and play an audio file or Pandora, etc). Make sure you have the volume on your audio source set pretty high to make sure there’s enough current flowing through the copper wire.

4. Read the “electromagnetism at work” section below to help with answering the questions below.

5. Answer the questions below.
6. Come up with your own improvements to increase the quality of the speakers (last question below).

**Electromagnetism at work**

The main electromagnetic theory at work when it comes to the creation of speakers is Faraday’s Law:

\[ E = -\frac{d\Phi_B}{dt} \]

where,

- \( E \) is the *electromotive force* (EMF) in volts
- \( \Phi_B \) is the *magnetic flux* through the circuit (in webers).

In the early 1800’s, Michael Faraday discovered that a magnetic field is created when a current is applied to a coil of wire. One of the applications of this theory is in the creation of speakers. As you can see while building the speaker, the current from the audio source goes through the coiled copper wire and generates a magnetic field. This magnetic field interacts with the magnetic field of the magnets to generate a mechanical force that vibrates the foam plate. When the foam plate vibrates, air particles carry the vibration through the air and vibrate the eardrums in our ears which give us the audio we hear. The audio source generated is a sin wave with different frequency tones that give the audio its distinctiveness. Since the audio signal is in the form of a sin wave, the current continuously varies in order to create the force that vibrates the foam plate.

**Questions**

1. Why is a copper wire used instead of other materials such as silver?
   
   Copper is used because it has a low electrical resistance that it is easy for the current to flow through it. Also, copper wire can be easily shaped to make a coil.

2. Why do we use foam plate instead of paper or plastic? Try using different types of cone material and see how the quality of the audio generated is affected.
   
   Between the 3 plates, the foam plate provides the best balance between flexibility and reverberation qualities. The paper plate is too rigid and the plastic plate gives off too much feedback.

3. We use the range of 7-8 ohms of wire to create the speaker. Why do you think this value is set? Try researching speaker circuit impedance matching online. Hint: try reading about Thevenin equivalent circuits.
   
   We use impedance matching to create a Thevenin equivalent circuit that will generate the maximum current through the resistance. The reason for the set resistance value is so that industry wide, electronic companies can create circuits that will generate the appropriate current that will work across different products (use different speakers for the same
receiver). Otherwise the audio outputted by the speaker will have distortion or low amplitude caused by too much or too little current.

4. What would happen if you increased the number of magnets that is used on the speakers? This increases the magnetic field which should increase the amplitude of the speaker.

5. Based on the previous questions, come up with an equation relating number of turns (N), length of the coil (L), and the current through the coil to the magnetic field. Also include $\mu_0$ which is permeability of free space as being proportional to B. Example:

$$B = \frac{\mu_0 \cdot A}{c}$$

Solution: $B = \frac{\mu_0 \cdot N \cdot I}{L}$

6. Come up with an improved design using simple materials to improve the speaker. Also make use of electromagnet theory to increase its performance (increasing number of turns of the coil, changing the size of the vibrating plate, etc). You should post your improvements on the online blog and get input on what changes can further improve your design.