Reconstructing Speakers

And

Speaker Boxes

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Introduction

My Motivation:

When choosing my project for the semester, I had originally considered building a set of speakers, but it was just a passing idea until the day I found out that my roommate had spent over a thousand dollars on his sub-woofer alone. That was all the motivation I needed.

My Goal:

To construct a comparable sub-woofer for under $50.

What I Did:

I managed to get a pair of drivers from my other roommate for free. Although completely and utterly busted, they ended up being repairable. After fixing them up, I ran some tests on them to find all of the parameters of the drivers and then used an audio program to pinpoint what type and size of box I should use to enclose my drivers for best performance. Lastly, I needed to construct a crossover, so that I could leave the higher frequencies to mid-range and tweeter speakers and leave only the lower frequencies to my box. In the end, I spent under $25.

Repairing the Drivers

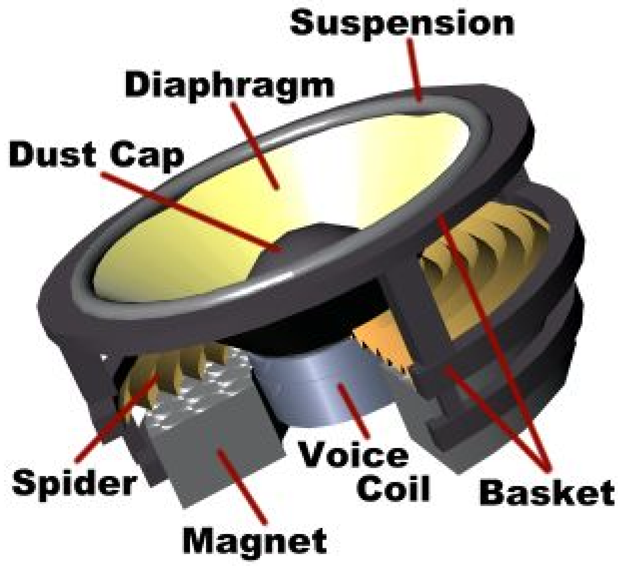
The drivers that I had available to me were a set of 12" drivers which were originally meant to be used in a single box with a midrange and a tweeter. The mid-range and tweeter drivers were in good working condition (more about those later) but the woofers were completely destroyed. The foam surround was so deteriorated that it was no longer connected to the outside.

As can be seen in this picture, the foam surround is the darker area around the edge of the cone. In the drivers I was given, you could see straight through to the other side of the driver.

This is a bad thing for several reasons. First of all, it hinders the speaker's ability to create lower frequencies because the box is not completely enclosed. In order for the driver to accurately make a low frequency the distance from the front of the cone to the back of the cone should be no less than a half wavelength of the frequency you're trying to make. Obviously, if the surround is completely destroyed, this provides a shortcut for the air to pass through, making the distance form the front of the cone to the back of the cone very small, and so lower frequencies would not be created very well. Also, a driver working in this condition would be about as useful in creating sound as if a person were to shake their hand back and forth in midair. Doing this would still push the air, but having gaps around the side allows the air to move around the driver, and not actually get pushed by it.

Another dead giveaway that these drivers were not in good condition was that with one of them, you should shake it and hear the wires from the voice coil shaking around inside. This added another level of complexity to fixing these speakers: I had to reconstruct the voice coil.

These speakers were old…. I mean really old. I don't know if it was just because they were Yamaha speakers of if it was because of really bad technology, but when I disconnected the cone from the spider, I found that the wire used to wind the voice coil was in really, really bad shape. I did some online research and found that for the past 8 years or so, most speaker manufacturers had agreed that the best wire for winding a voice coil was a flat wire. The wire in my drivers was not flat, and they were destroyed. My only option was to rewind



them myself……by hand.

Anybody who's reading this with the intention of rebuilding their own speakers should take warning that winding a voice coil by hand is both a mentally and physically straining experience. The time you spend winding 2 voice coils by hand may be better spent working a job to earn money for a set of drivers with decent voice coils. However, my end product was at least half a billion times better than what I started with, so I was happy.

Finding replacement foam surrounds can also be a hassle. Most speaker repair shops will not sell you the $1.50 foam replacement parts in hopes that you will pay them $30 to fix it for you. I didn't have $30 to spend, so I was forced to drive 45 minutes to a speaker shop who understood my plight. I picked up my new surrounds and was on my way to fixing up the drivers.

After reattaching the spider to the cone and soldering the voice coil leads back on, I was ready to attach the surrounds. The first step was to glue the surround to the cone first, and then after that dries, glue the other end of the surround to the basket. I was told by my friendly speaker shop salesman that Elmer’s Glue works perfectly well, so that’s what I used and t held up nicely. I had heard of people having problems when reattaching surrounds because they didn’t line the cone up properly and the voice coil would scrape against the magnet. To avoid this, I hooked my drivers up to a 9 volt battery so that the cone was extended enough for me to apply the glue and then remove the battery and let the surround settle in the glue naturally.

After the glue settled, I was ready for a test. Up to this point, I had no idea if all of my work would have been in vain. I hooked my revamped speakers up to a signal generator and….. it worked! I was thrilled. No scrapping of the voice coil against the magnet, and I suppose I must have wound the voice coil well because there was no distortion at all and the response seemed good.

Testing the Drivers

Now it was time for some tests. Using a signal generator I downloaded online and running the output of that to my speaker, I was able to conduct some tests. I used a digital multimeter and scanned through the frequencies and was able to find the impedance peak (Zmax), which is where the free air resonance (Fs) is of the speaker. A low resonant frequency is desired for a woofer, and my free air resonance was at 28 Hz, which isn’t amazing, but it beats the heck out of a lot of speakers. I also measured the DC impedance (Re) by just hooking the driver up to the multimeter. Here are some equations:

r0=Zmax/Re

Z’=Sqrt[r0]*Re

Next I found the frequencies (F1 and F2) where the impedance dropped from Zmax to Z’.

The next step was to calculate the driver’s Q’s.

Qms=Fs*Sqrt[r0]/(F2-F1)

Qes=Qms/(r0-1)

Qts=Qes*Qms/(Qes+Qms)

Then, it was time to put the driver in a box of known volume (Vt) and do some other calculations. I found the new resonance frequency (Fct). You can then calculate all of the values above, but with the test box.

Qmct=Fct*Sqrt[r0]/(F2-F1)

Qect=Qmct/(r0-1)

Vas=Vt((Fct*Qect)/(Fs*Qes)-1)

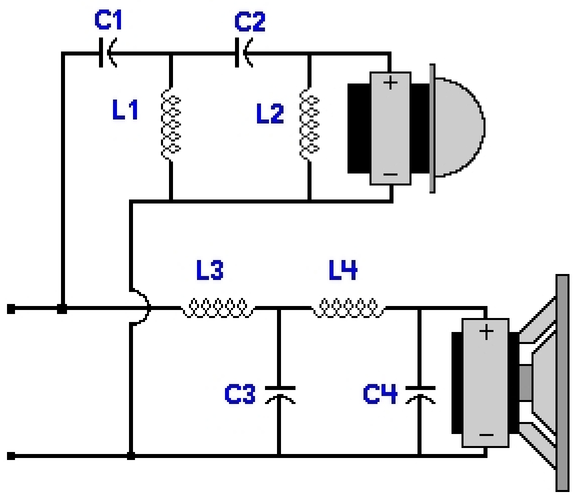
This gives you values for Fs, Qms, Qes, Qts, Vas which can be imputed into an audio program (I used Bass Box Pro provided generously by Professor Steven Errede).

The program took in all the information I had and recommended a box size which would provide the best bass response. I then went to the thrift store; most of them have a good selection of really bad speakers. And I picked out a box which fit the specifications given to me by the program. The program also gave me a bunch of response graphs and informative specifications.

When all was said and done, I had a box with a 3 decibel cutoff frequency (F3db) of 35 Hz. Compare that to my roommate's cutoff of 20 Hz…. Not too bad, definitely not worth the price difference.

The Crossover

There's a whole mess of different crossover styles, some better than others. Most of them cause some phase shift, which can disrupt your listening, so I decided to go with a 4^{th} order crossover which has a 360 degree phase shift which is simply 0. The only problem with 4th order crossovers is that they involve 4 different components for each speaker and so usually cost a bit more, but I built it myself, so the only price for me was the cost of the components. The Bass Box Pro program provided me with a recommended crossover cutoff of 700 Hz. With the impedance (Re) and desired cutoff frequency (f) I was able to calculate the components I needed.



$C1 = 0.0844/(R_H f)$

$C2 = 0.1688/(R_H f)$

$C3 = 0.2533/(R_L f)$

$C4 = 0.0563/(R_L f)$

$L1 = 0.1000 R_H/f$

$L2 = 0.4501 R_H/f$

$L3 = 0.3000 R_L/f$

$L4 = 0.1500 R_L/f$

It’s pretty impossible to find components with that exact of a value, so I had to use some summing techniques to combine different components and try to get as close as I could.

Summary

In the end, I am left with a good sub-woofer. Play mine back to back against my roommate's and you can't really tell the difference at all. I would highly recommend to anyone that if you want a decent sounding speaker, and you don't want to spend a lot of money, you should try t o build it yourself. It doesn't cost a lot of money to do, and the end result is highly rewarding. Not only did I learn a whole lot about speaker technology while doing this project, but I had a lot of fun as well. To be honest, before this project, I had no idea what a voice coil was, and now I can build one (need and patience willing).

Here are the final specs on my speaker:

Zmax=58 ohms

Fs=28 Hz

Xmax=16.5 mm

Qts=.44

Vas=2.61 cu. Ft.

F3db=35 Hz

Qms=4.028

Qes=.564

References

1. Introduction to Loudspeaker Design, John L. Murphey. True Audio. 1998

2. http://ccs.exl.info/calc_cr.html Accessed April 20th, no author