MT1

Designed by
Matt Willett

Contents

Concept

Design

A HiFi system that is suitable for both mixing and home entertainment while also being aesthetically pleasing. This system will be both suitable for high SPL's and extended low frequency response while focusing on a well-finished, unique enclosure.

The Box

Enclosure Design

Acrylic Speaker Cabinets [1]

Bubinga wood [2]

My initial design is to use acrylic as a front face of the cabinet so that the inside of the box is viewable. This also requires having nice wood for the rest of the box so the inside isn't plain OSB or just painted black. The material that I hope to use is Bubinga wood[1]. This material has a semi consistent density of 50-60 lb/ft^3 [2] whereas MDF has the average density of about 38 lb/ft^3 [3]. This high box density will increase the strength of a larger box as well as increase its rigidity allowing for a thinner box (if needed for budget issues) that won't flex from internal air compression due to high SPL's.[4]

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[1] "Ed Roman Guitars," http://www.edroman.com/customshop/wood/bubinga.htm

[2] "West Wind Hardwork inc," http://www.westwindhardwood.com/price_hardwoods_a-b.php

[3] "Freeman Manufacturing and Supply Company," http://www.freemansupply.com/MDFMediumDensityFi.htm

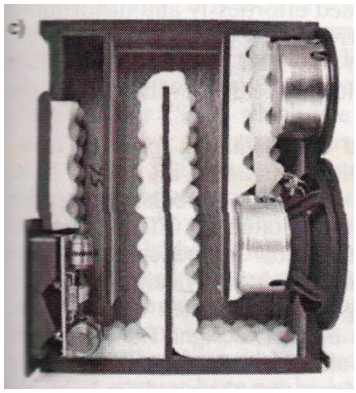
[4] John L. Murphy, *Introduction to Loudspeaker Design,* 86

Box Size

Material costs for the wood (stated later) is the main factor on the overall size of the cabinets. There is an unlimited amount of room to work with and transportation will not be an issue. This allows the system to more easily reach an f_3 of 20 Hz (lower range of human hearing) with a response time of less then 100 ms (reasonable HiFi speaker transient response) due to the physics of a larger box than a smaller ported one, which would also cause transient response issues [5].

Internal Box Design

Reaching an f_3 of 20 Hz is difficult without acoustical help. A 20 Hz signal is approximately 56 ft long. If I wanted to use the box resonance to increase a 20 Hz output, the box would have to be 14 ft (a quarter wavelength) in some direction from surface to surface. This is unreasonable even with an unlimited space for the box. The solution to this problem is the use of a transmission line or TL. This internal box design uses a labyrinth to essentially make a tube within the box itself[6]. Making it a quarter wavelength of the target frequency and having it open on the face of the box can allow a 20 Hz waveform to travel through the labyrinth and come out 90 degrees in phase with the driver. This essentially creates a second driver, that will add 6dB to a small bandwidth around 20 Hz. This will not create phasing issues because once the wave reaches the vent it is producing most of the output. And because the line



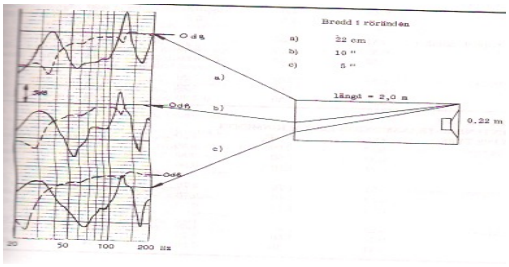
Internal TL [7]

[5] Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* ch. 11

[6] Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* 79, Figure 3.9 c

is operating over several octaves with the drive unit, cone excursion is reduced, providing higher SPL's and lower distortion levels [7].

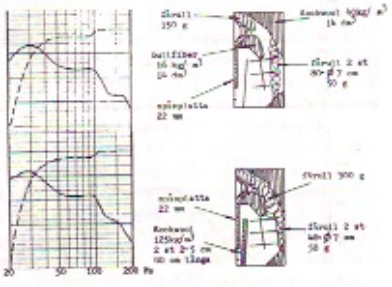
Acoustical Dampening



TL Tapering Response Chart [9]

Stopping all unwanted frequencies from passing through the transmission line is the next issue. The use of special foam that has the same consistency of fiberglass and is designed to only absorb certain frequencies is ideal. But it comes down to where and how you insulate the TL and the shape of the TL. The chart shows different ratios of tapering and the frequency response (solid line) that occurs due to the volume change. It seems as though a tapering ratio of 4.4:1 (graph c of the Tapering Response Chart) has the most useful frequency response of the port (the solid line) [8]. And to dampen the band from ~65 Hz to ~160 Hz is where creative dampening comes into play.

Dampening these frequencies is no science and comes down to a trained ear and trial and error. Vance Dickason's book, *"Loudspeaker Design Cookbook"* [9] gives some good examples of his techniques. Different densities of foam in different areas of the line absorb sound in different ways. This graph is a general guideline to the starting point of MT1's dampening. Doing this right will absorb the unwanted higher frequencies before reaching the opening of the TL, stopping unwanted phasing issues in the higher end.



TL Dampening Chart [10]

[7] Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* ch. 3.4.1
[8] Vance Dickason, *Loudspeaker Design Cookbook,* 101, Figure 4.16
[9] Vance Dickason, *Loudspeaker Design Cookbook,* 97, Figure 4.4

Making it HiFi

Transmission Response

As far as transient response time goes, a 20 Hz wave only takes around 12.5 ms to travel 14 ft which keeps the transient response still shorter than the desired 100 ms. And with the box being open, box compression is not a factor also keeping the transient response low [10]. All aspects of the box design will lead to a short transient response. The only other factor is the driver's transient response, which will be kept relatively low due to well-chosen purchases.

Speaker Sensitivity

The sensitivity of the speakers is important in relevance to how loud I listen to my music. My normal listening levels when I am doing homework tends to be around 65 dB. When I want to pay attention to the music I tend to listen around 75 to 80 dB. And when I am mixing, composing, or watching films I tend to listen around 85 dB, 97 dB c weighted. I listen to a wide variety of music from classical to rock and roll, so 10 dB headroom will be appropriate so the max SPL needed is around 110 dB. These types of SPL's will either lead me to choosing a high sensitivity speaker and saving money with a low wattage amp or a less likely choice of a low sensitivity speaker with a high wattage amp.

X-Over

Cross over points will be at 100 Hz, 1k Hz, and 5k Hz. These points were chosen because they divide the drivers into their flattest frequency regions.

[10] Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* ch. 11.1.1

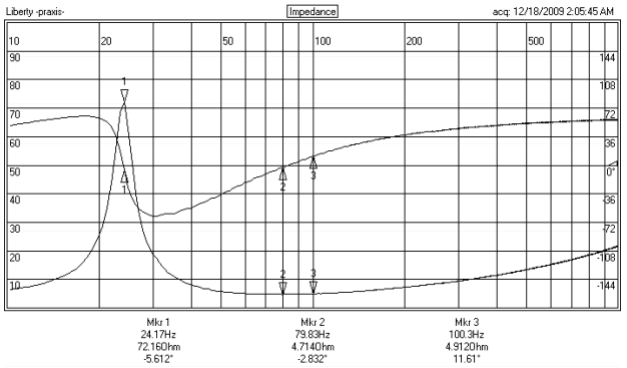
Realization

Subwoofer

12" TC Sound - Epic 12" DVC
$169.00

Parameter	12" Epic	Description
Qts	0.39	Total Q
Qes	0.415	Electrical Q
Qms	7.8	Mechanical Q
Fs	24	Hertz, Free Air Resonance
Res	3.66	Ohms, DC resistance
Ls	3.2	H, series inductance
Lp	2.9	H, lossy series inductance
Rp	4.2	Ohms, loss across Lp
Dia	250	m meters, effective
Vas	91	liters, air volume equivalent
mms	163	grams, effective mass
cms	269	um/N, compliance
bl	14.8	T*m, motor strength
SplSens	86.6	dBSPL max @1W absorbed

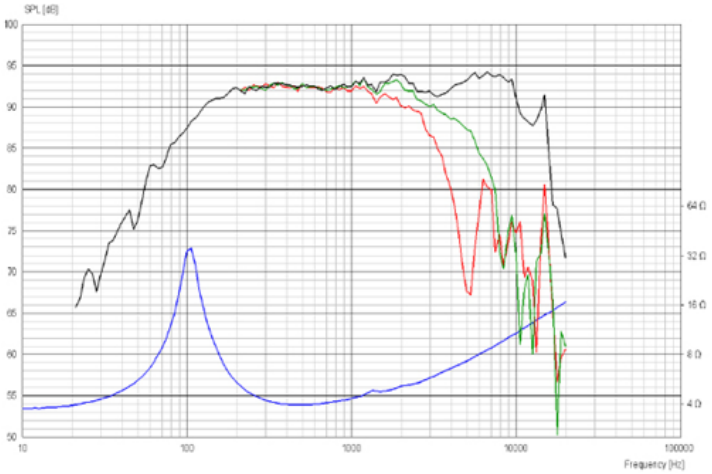
Parameter	12" Epic	Description
Geometric Stroke	18.1	Millimeters, (voice coil - gap) / 2
70% BL	22.9	Millimeters, BL is 0.7 original value (one way)
Xmech	32.7	Mechanical displacement limit (one way)
Long Term Power	500	Watts
Program Power	2000	Watts, short term peak power limit

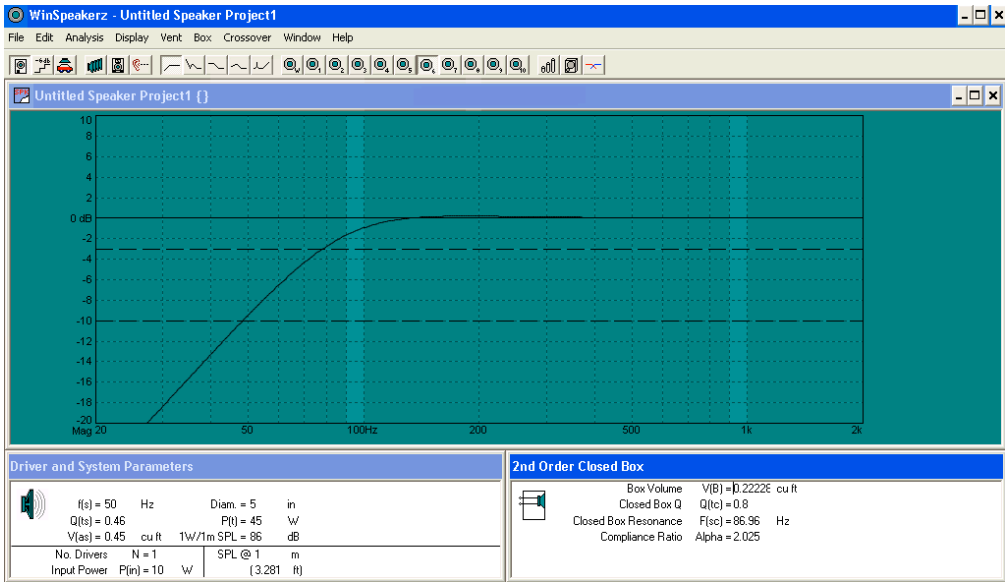


This Sub is a very big bang for your buck. It has a surprisingly fast Qts so the transmission response will be kept short, it will have no problem handling a transmission line at 20 Hz because it has an fs of 15 Hz, and mechanical excursion wont be an issue at high SPL's due to it having an xmax of 32.7mm. Now although this speaker doesn't have a frequency response sheet with it, it is almost unnecessary because it's only going from 15 to 100 Hz and is mostly just an LFO. The Woofer is were the low frequency accuracy will be at if not in the Sub Woofer.

Woofer

Scanspeak 15M/4624G Discovery
$71.20 each

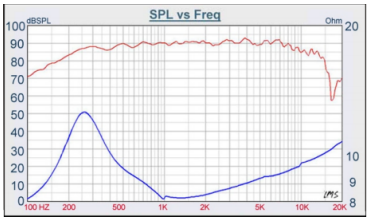




This woofer is very suitable for my x-over point at 100 Hz and 1k Hz. Its relatively flat response only wavers ~ ± 6 dB, which is ideal for my design goal and it will handle a slower smother -6 dB per octave upper roll off with ease. A small box volume of .22 ft^3 is very suitable for my design and will give the speaker a natural roll off at 100 Hz.

Mid Range

3" TB Speakers - 75-1558SE
$131.20

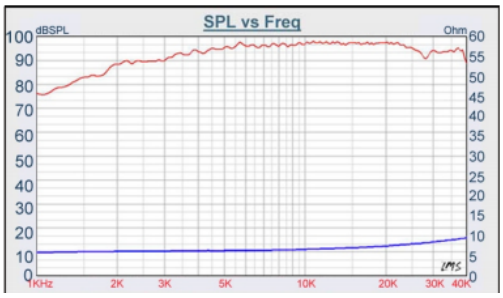


DIAPHRAGM MTL	Fabric
SURROUND MTL	N/A
NOMINAL IMPEDANCE	8 Ω
DCR IMPEDANCE	6.5 Ω
SENSITIVITY 1W/1M	90 dB
FREQUENCY RESPONSE	260Hz-8K Hz
FREE AIR RESONANCE	260 Hz
VOICE COIL DIAMETER	75.5 mm
AIR GAP HEIGHT	6 mm
RATED POWER INPUT	25 W
MAXIMUM POWER INPUT	200 W
FORCE FACTOR, BL	N/A
MAGNET WEIGHT (oz)	Neodymium
MOVING MASS	N/A
FERROFLUID ENHANCED	Yes
SUSPENSION COMPLIANCE	N/A
EFFECTIVE PISTON AREA	N/A
Levc	0.012 mH
Zo	12.3 ohm
Xmax	1.45mm
Vas	N/A
Qts	N/A
Qms	N/A
Qes	N/A

This driver also has a relatively flat frequency response that only wavers about 3 dB from 1k to 5k. This Driver has a nice roll off at around 7k, which will help drop out the frequencies with the x-over point at 5k. This Driver also has a nicer power rating compared to the other drivers so there will be no worry about over loading it. It has a sensitivity of 90 dB that is about 4 dB higher then the other drivers, but this can be solved with a simple pad. This speaker is ideal because it is self enclosed so no dampening will be needed inside the box.

Tweeter

TB Speakers - RT-1516SA
$183.70



DIAPHRAGM MTL	Alum
SURROUND MTL	N/A
NOMINAL IMPEDANCE	8 Ω
DCR IMPEDANCE	N/A
SENSITIVITY 1W/1M	95 dB
FREQUENCY RESPONSE	2KHz-40 K Hz
FREE AIR RESONANCE	N/A
VOICE COIL DIAMETER	8 mm
AIR GAP HEIGHT	2 mm
RATED POWER INPUT	8 W
MAXIMUM POWER INPUT	80 W
FORCE FACTOR, BL	N/A
MAGNET WEIGHT (oz)	Neodymium
MOVING MASS	N/A
FERROFLUID ENHANCED	NO
SUSPENSION COMPLIANCE	N/A
EFFECTIVE PISTON AREA	N/A
Levc	N/A
Zo	N/A
Xmax	N/A
Vas	N/A
Qts	N/A
Qms	N/A
Qes	N/A

This tweeter looks ideal for my design goals. The only issue looks is the rated power input relative to the other drivers, this will involve some Voltage padding. The response from this driver seems to be very good, and from hearing this tweeter before, it sounds fantastic.

Power

Plate amps that have a variable x-over point will power the subwoofers. A home receiver will power the other drivers. The goal is to make the system have a sensitivity of 92 dB. Total wattage for the receiver needs to be 80 W to power all 6 speakers per channel without any issue. This will allow an SPL limit of ~110 dB.

Budget

Drivers - $1000

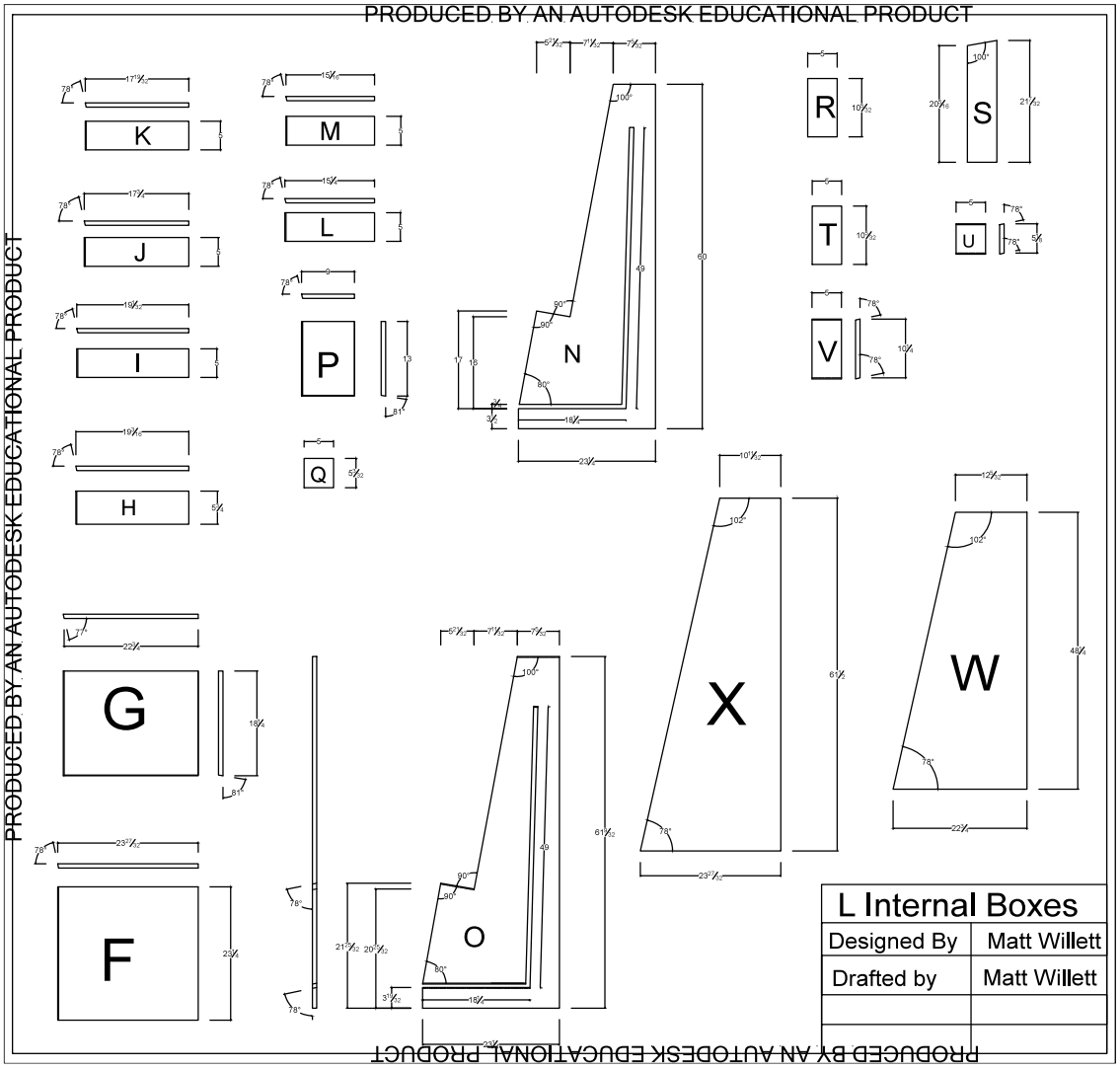
Cabinet - $500

Plate Amplifiers - $500

Passive X-Overs - $150

Total - $2150

Any other amplifiers will be purchased at a later date.



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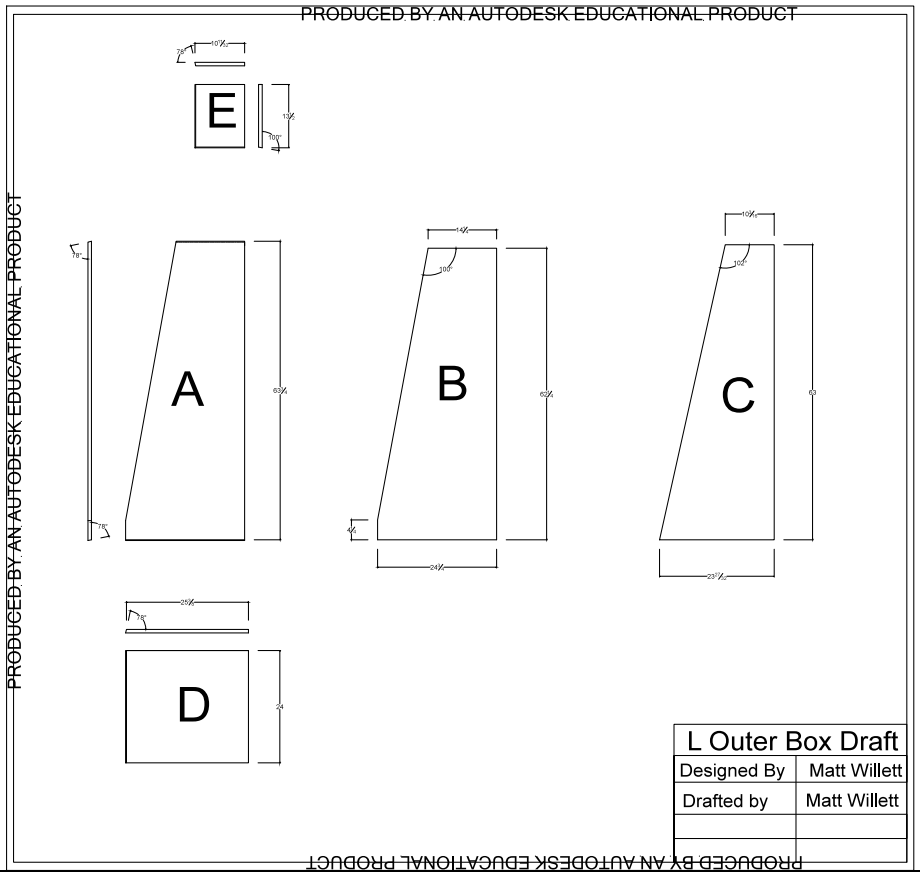
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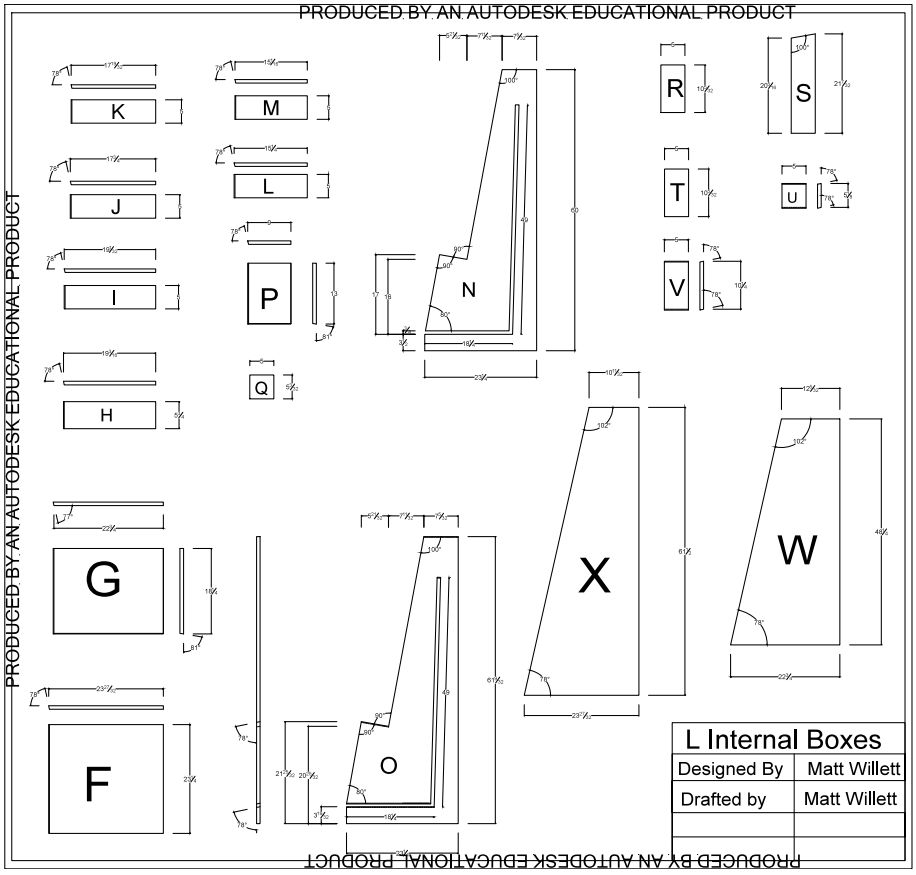

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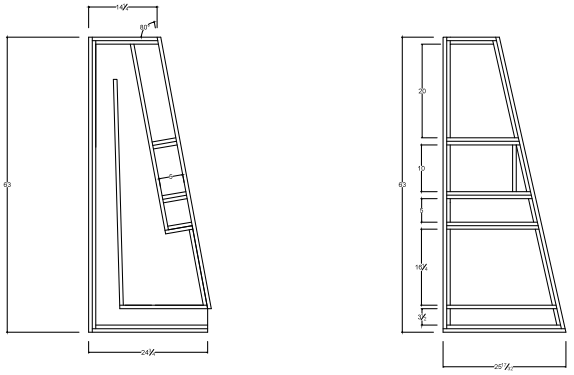

R internal design	
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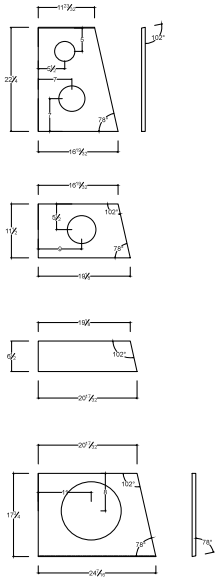

R Baffels	
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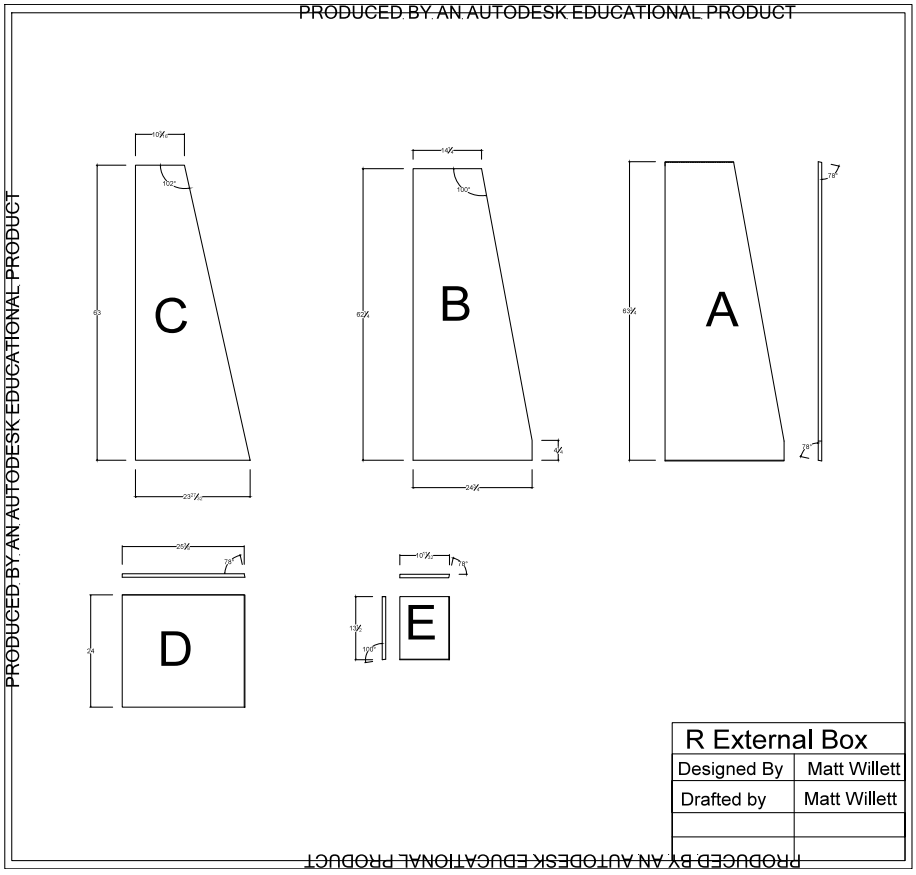

R External Box	
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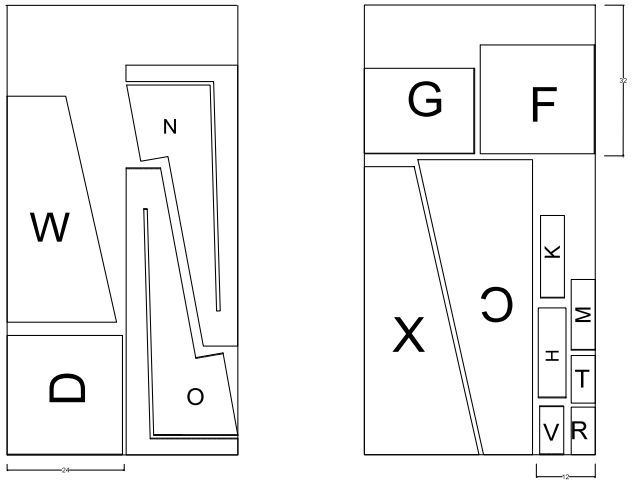

MDF C.S. Right	
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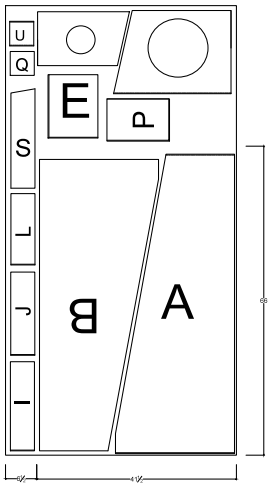
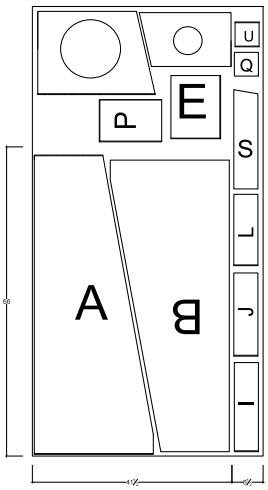
Left Speaker



Right Speaker



Nicer Wood C.S.	
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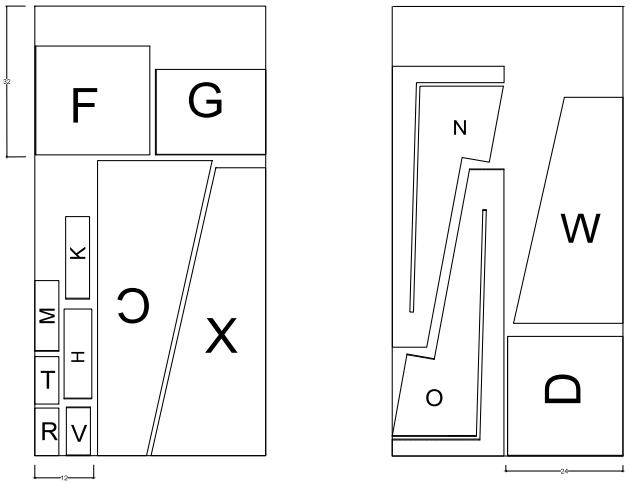

MDF C.S. Left	
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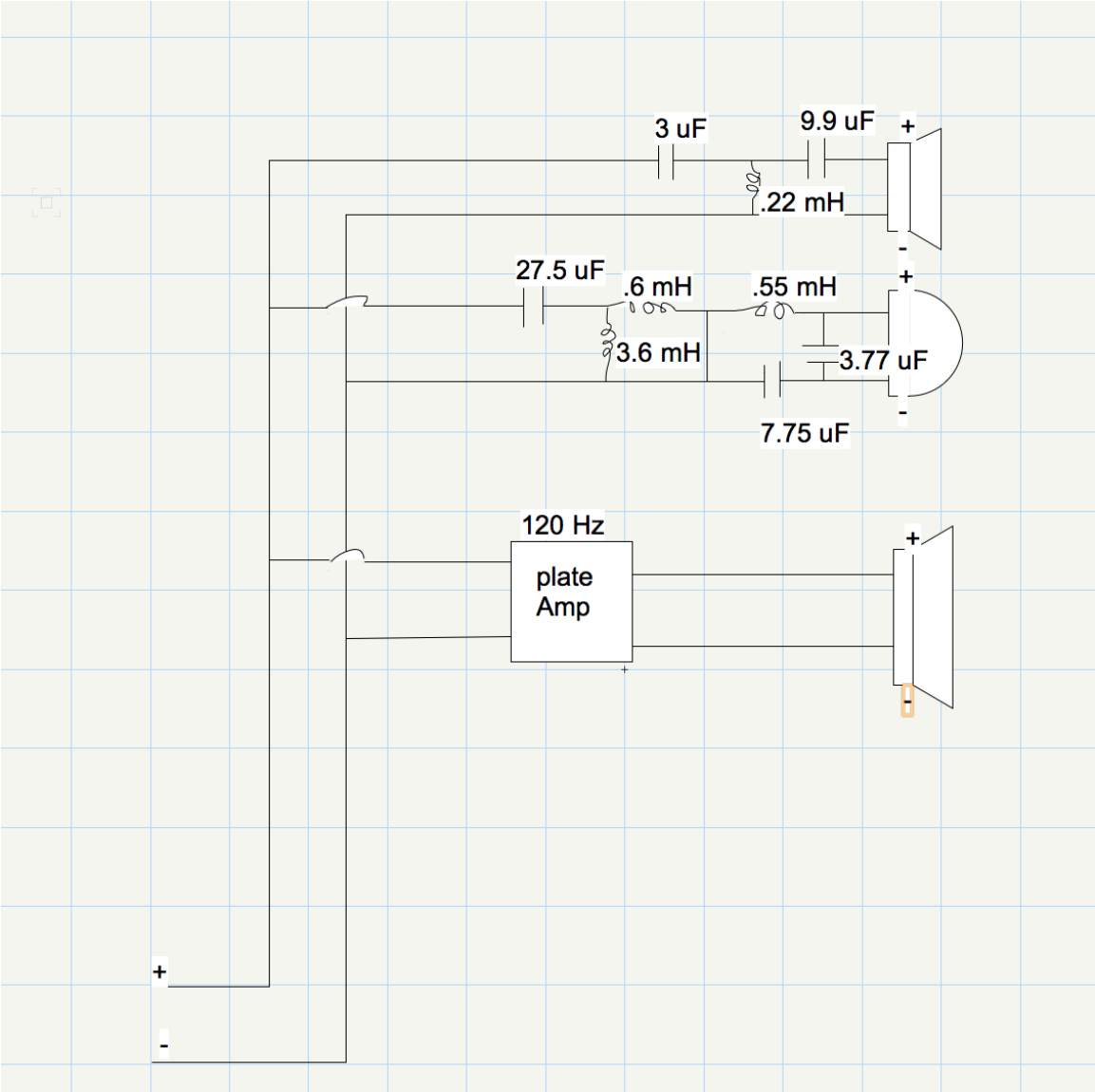
Cross Over


3 uF
9.9 uF
+
.22 mH
-
27.5 uF
.6 mH
.55 mH
+
3.6 mH
3.77 uF
-
7.75 uF
120 Hz
plate
Amp
+
-
+
-

Bibliography

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2- "West Wind Hardwork inc," http://www.westwindhardwood.com/price_hardwoods_a-b.php
3- "Freeman Manufacturing and Supply Company,"
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4- John L. Murphy, *Introduction to Loudspeaker Design,* 86
5- Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* ch. 11
6- Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* 79, Figure 3.9 c
7- Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* ch. 3.4.1
8- Vance Dickason, *Loudspeaker Design Cookbook,* 101, Figure 4.16
9- Vance Dickason, *Loudspeaker Design Cookbook,* 97, Figure 4.4
10 -Philip Newell and Keither Holland, *Loudspeakers for music recording and reproduction,* ch. 11.1.1