AH-8 Revealers

Studio Monitors

Design and Research

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FA 4740 Transducer Theory

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Functional Description

Listening Environment and Purpose

These monitors will be used as hi-fidelity mixing monitors, and more of listening back monitors as compared to listening forward speakers.¹ The monitor will be used to recreate the sound as close to the original acoustic source as possible, and not taking into account what the end consumer uses for their speakers. The goal is to have a set of monitors that do not add anything to the sound, revealing inaccuracies, poor mixing, and other defects in the content played through them, hence the name “revealers”. The content that will be played through the monitors will mostly be music being mixed, and editing equipment demonstration, instrument playthrough and music videos in post production. For frequency bandwidth, a 45 Hz to 20Khz is a good starting range to shoot for as it covers most of the audible frequency ranges in music. The extent of video work would most likely be for instrument play through, music videos, and gear demonstrations on YouTube and other video sharing websites. These speakers will most likely live in an apartment or house with small rooms. These rooms will be in the author’s “home studio” setup with a computer, guitars, and other studio equipment.

The current room in which the studio resides is 11’ long, 10’ wide, and 8’ high, with a small entrance that’s 2’ deep and a window sill that is also 2’ deep. The wall behind the listening position has a queen sized bed mattress propped against the wall,

¹David Moulton, Total Recording. (United States, KIQ Productions, 2000), 313
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with several guitar cases on top of that. The wall in front of the mix position has Auralex Wedgies pads placed directly behind the monitors on the wall. There is also a large, thick comforter blanket draped over a closet that is opposite the window wall. The current monitors that are in use are Yamaha HS8 monitors that are placed on a desk, with Auralex MoPAD Monitor Isolation Pads underneath them. The desk is very close to the wall, the speakers are about 3” to 5” away from the wall, and they are aimed inwards at the listening position.

**Mounting**

Ideally, the monitors will have dedicated stands for them. From preliminary desired enclosure volume calculations, these speakers will be too big to be on the desk. They will most likely still be close to the wall for added bass frequency response. When placed near a wall, or boundary, the radiating low frequencies reflect off that boundary. When the loudspeaker is placed in front of wall behind the listen position, half space spatial loading\(^2\), the boundary can increase the bass response up to 3 dB above the mid band response.\(^3\)

**Noise Floor of Listening Environment**

The current apartment is away from the main highway, and nicely secluded in the woods. It is very quiet, with the occasional loud souped up truck whizzing by. The walls


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are fairly good at keeping the neighbors’ sounds out. It is hard to say what the listening environment will be after graduation. Expected graduation is in the spring of 2019, and however long in between before moving out, hopefully to Los Angeles. It is assumed that city life will have a higher noise floor compared to living in the woods.

Visual Aesthetics

These monitors will look as good as they sound. As far as size and weight, they will be as big as they need to accommodate for the desired bass frequency response. The speakers will reside in a single location so they do not need to be ultra-portable. The cabinets will be painted a matte Ferrari red with black drivers and detailing.

For material choice, an inner layer of MDF will be used for an inner shell, with a Baltic Birch outer shell. These materials were chosen after a lecture on January 24, 2018, and also seeing Baltic Birch reappear in other cabinets⁴. Since the wood is going to be painted over, the grain and finish does not to need to be the highest quality, so a face grade of BB/CP will suffice⁵. These monitors will not have protective grills over the woofers or tweeters. The edges along the depth will be rounded off to help with edge diffraction.

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**SPL Output**

According to Bob Katz\(^6\), Philip Newell and Keith Holland\(^7\), a good level of mixing is 85 dB SPL. These monitors should be capable of producing at least 100 dB SPL for occasional high level listening, but not for extended periods. Several SPL readings were taken with the Galaxy Audio CM - 130 Check Mate SPL meter during various tasks that require mixing or listening. In the a studio in the Walker Arts and Humanities building, a level of 70 to 72 dBA was measured while editing a guitar demonstration video for YouTube. During the drive home, the music level in the car was 85 dBA and this is the normal listening level. The car's heater was also on near full blast. Once home, the author played electric guitar with an effects modeling device, into an USB audio interface that outputs into the the Yamaha HS8s. The level recorded was 80 to 82.5 dBA. When mixing a song, the level was at 79 to 81 dBA. When reviewing a mastering session, the level used was at around 79 to 82.5 dBA. While casually watching videos on YouTube on the same computer through the same monitors, the level was at 60 to 71 dBA. Later that night

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while in the bedroom watching Netflix on a tv, the level was at 45 to 60 dBA.

Subjective description of sound quality

These monitors will be judged by the “AES Subjective Eval Standards”\(^8\) and using definitions and terms from this journal. These monitors should have even spectral uniformity, little to no colorations from the cabinet, and good left-center-right localization. As these monitors will be used in music mixing, a good depth of field will be needed, as well as a high dynamic range. The speakers will be able to handle drastic changes in loudness. Since the chances are very high that the music being mixed will be high gain, rock and roll/heavy metal music, the transient responses should be excellent with the ability to reproduce the punchiness of the music, a transparent and open sound, no

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distortion coming from the cabinets, and great image separations. These speakers will have a good spectral uniformity, that is, the perception of appropriate modification of the spectrum of the diffuse reverberation. When the sound is dispersed into the room, it will be evenly dispersed, and not a bass-heavy reverberant sound. A high priority of these to have minimal coloration of the sound due to the enclosure itself. If the timbre of instruments is altered, that means it has been colored. Some recreational listening speakers may want slight coloration to make them enjoyable to listen to, but for purposes of listening back speakers, they need to be colorless. For creating stereo mixes, left–center–right image localization is crucial for having the center sounds localize to the center of the speakers. Localization of left- and right-intended sources will be excellent, and on axis center localization will also be good as well. As these are intended for near-field mixing, off-axis listening not critical in the design. Image separation also comes into play with the stereo effect. These speakers will produce a clear and defined sound sources, even when the sources are in a group. These speakers will sound open, or transparent. The speakers together will produce sounds that are clearly localized, but not to any particular speaker. This leads into the depth localization, being able to give the perception of sources “in front” or “behind” one another. The listener should be able to hear performers from the front to the rear of the sound stages.
Prioritization

For mixing purposes, SPL and bass frequency will have priority over over size.\(^9\)

Technical Specifications

Technical Goals

The following section will start to assign technical values to the previously stated design goals. Real numbers and data will start to appear after research and computer aided design tests.

Size & Shape

The shape of these speakers will be a sealed box. The box will be made “dissonant” as explained by David Moulton.\(^10\)\(^11\) The ratio of depth:width:height will be 1:1.414:2.245. These are dissonant ratios in musical terms, as in root:augmented 4th:major 9th. The goal is to make the distances between each parallel face a different distance to minimize resonances within the enclosure. With a depth of 9.25”, this yields

\(^10\) David Moulton, *Total Recording*. (United States, KIQ Productions, 2000), 216

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a width of 13.0795” and a height of 20.7663”. The frequency of these lengths can be found using the formula of wavelength = the speed of sound divided by frequency, giving the frequency of 1465.95 Hz, 1037.13 Hz and 652.981 Hz, respectively. These frequencies are still in dissonant intervals, allowing for minimal standing waves to occur. These internal dimensions yield an internal volume of 1.453 cubic feet.

The construction will be an interior of MDF board, and an exterior of baltic birch plywood, and will make for a hefty speaker. MDF is a sturdy material, easy to shape. It is fairly inexpensive and easy to come by. The BB/CP grade of baltic birch will allow for a good quality of structure, as well as good faces to apply paint to. When paired with the MDF Interior, it creates a thicker, variable density cabinet. The different layers will absorb sound at different levels, allowing for fewer resonances to leave the enclosure.3

The dimensions of the current studio monitors, Yamaha HS8, measure a height of 15 3/8th" by a width of 9 13/16th" by a depth of 11 15/16th". These are the external dimensions as well, so the internal volume has smaller dimensions. As shown, the speakers designed will be larger than the Yamahas, and will probably utilize an 8” woofer, like the HS8. The speakers will also be not be ported, as the HS8 are. The larger box volume will accommodate for lower frequency extension. These will be able to fit in a normal sized car or truck, stands included. As these will be near-field monitors, they should easily translate to any sized room, as long as the distance between the speakers and listener are maintained.
Visual Aesthetics

As previously mentioned, the boxes will be painted a deep Ferrari red, in a matte finish. This will be eye catching, and also a reflection of personality of the designer. The top and bottom boards will be painted black, while the front, back and side panels will still be the Matte Ferrari red.

These speakers will not need a grill for protection, aside from any domes or grills that come with the tweeter drivers. The edges that run along the depth of the box will be rounded off, as this is to improve the diffraction off the corners, increasing the high frequency decay time.\(^\text{12}\)

SPL

As discussed earlier, the average listening levels are around 85 dB SPL. This falls in very nicely with the K-System of monitoring established by Bob Katz\(^\text{6}\). The K-System is a way of trying to standardize monitoring levels for consistency across all studios. K-20 for film and audiophile mixing, for high dynamic range. K-14 for standard music mixing, and K-12 for broadcast. For the K-14 system, listening at 0 on a VU Meter is actually 85 dB, which is -14 dB full scale. For K-20, -6 on a VU meter is -20 db full scale. For these reasons, these speakers will be calibrated for the K-14 and K-20 system.


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For the speaker sensitivity, the woofer should be as close to 90 dB, 2.83volts at 1 meter. Most drivers do not go above 90 dB for sensitivity\textsuperscript{13}, a driver high as possible will yield good results.

**Frequency Response**

As these speakers will be used for mixing music, they will need to be able to clearly reproduce a broad frequency band, to represent each instrument of a group. As shown by the graphic courtesy of iZotope\textsuperscript{14}, the music frequency range spans from almost 20 hz to almost 20 khz.

\[\text{Hz 20} \quad 40 \quad 60 \quad 100 \quad 200 \quad 400 \quad 600 \quad 1K \quad 2K \quad 4K \quad 6K \quad 10K \quad 16K \quad 20K\]

\[\text{VOCALS} \quad \text{PERCUSSION} \quad \text{FETTED}\]

\[\text{Standard Grand Piano}\]

\[\text{Sub Bass} \quad \text{Bass} \quad \text{Warmth} \quad \text{Midrange} \quad \text{Presence} \quad \text{Bright} \quad \text{High Mids} \quad \text{Air} \quad \text{High Fresh}\]

\[\text{Hz 20} \quad 40 \quad 60 \quad 100 \quad 200 \quad 400 \quad 600 \quad 1K \quad 2K \quad 4K \quad 6K \quad 10K \quad 16K \quad 20K\]


\[\text{https://www.youtube.com/watch?v=j77VKw9Kx6U}\]

\[\text{iZotope’s Facebook’s page, accessed January 27th, 2018.} \]

\[\text{https://www.facebook.com/izotopeinc/photos/pb.62061695626.-2207520000.1464354680./1015687971930627/?type=1&theater}\]

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Because of this, these speakers should function between 45 Hz and 20 kHz, +/- 2dB. This range will include the thump of bass guitars and kick drums, to the highs of cymbals and be able to articulate the “air” that the high frequencies generate in a mix. In personal experimentation using a standard DAW, parametric equalizer and several commercial stereo recordings, it was found that placing a 12 dB/octave high pass filter at the \( F_3 \) of the enclosure, in this case 45 Hz. It was found that the sound of the music did not drastically change. Only a moderate change in the way the music filled the room, but not the timbre of the song. This idea was reinforced during lecture, when the same process was recreated on high quality stereo files.\(^\text{15}\) According to John Murphy, a studio monitoring system should have a cutoff frequency of 30 Hz, but a full range system should go down to 100 Hz.\(^\text{16}\) Because of this, a goal of a 45 Hz roll off frequency is a good compromise.

**Coloration, Time Response**

The coloration of the loudspeakers should be kept at the very minimum. These speakers will not be ported, but will gain a little low end extension from the boundary effect. They will be mounted on stands, close to a wall behind them to help with bass frequencies. The height will have the tweeters at ear level when sitting in the mixing chair, approximately 3’ 8” high.

\(^{15}\) Josh Loar. FA 4740, Michigan Technological University. February 14 & 16, 2018. Lecture

\(^{16}\) John L Murphy. *Introduction to Loudspeaker Design*. (Andersonville, TN: True Audio®, 2014), 44

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Cabinet Design

The cabinets will be constructed using two materials. MDF will be used for an internal box, and sandwiched together with a Baltic Birch Plywood on the outside. Both boards will have a thickness of \( \frac{3}{4} \)". Having two layers of material will add weight, but will reduce vibrations and resonances from leaving the insides of the box. The initial design had box joints for the side and top panels. After several hours of practice making the joints, it has been determined that the internal MDF and outer plywood boxes will be joined using rabbet joints. The shop does not have a miter gauge that allows for proper clamping to a jig, and no jig made for constructed precise box joints. The time and materials required to make a proper sled and jig would be almost equal to constructing the enclosure itself. Therefore for the use of box joints have been deemed inefficient. The author has prepared for the construction a full semester in advance seeking training in the Michigan Technological scene shop. The author has taken it upon himself to practice.
their craft to an acceptable level to achieve the desired speaker design.

Based on this design, this width will have the baffle step frequency centered at 282.79 Hertz. This is based on the equation \( F_3 = \frac{4560}{W_b} \) where \( W_b \) is the width of the front baffle in inches.\(^{17}\) The internal volume for this design is 1.453 cubic feet. The previously stated internal dimensions will be rounded to the nearest quarter of an inch for ease of measuring and construction. The internal dimensions are 9.25" deep, 13.25" wide, and 20.75" high. After the ¾" thick MDF board and plywood, the overall depth is 12.25", the width is 16.25" and the height is 24".

The faces will be sealed together without the use of a vent. The chosen box volume has a low resonant frequency and provides good frequency roll off with the chosen driver shown in the next section, so the enclosure does not require a port for further bass extension.

The listening axis will be centered between the woofer and tweeter. This axis is located in between the two drivers so that each one is equal distance from it. This will

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\(^{17}\) Martin J. King, “Simple Sizing of the Components in a Baffle Step Correction Circuit” (February 2nd, 2004), 3

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allow the time alignment to give a reference point that stays the same as the listening
position moves toward or away from the speaker\textsuperscript{18}.

To minimize ripple effect, drivers will be placed different distances from each
drive. The placement between the
woofer and tweeter will be within
a half wavelength of the
crossover frequency.\textsuperscript{19} This will
keep phase issues to a minimum
in the frequency range at the
crossover frequency.

**Driver Selection**

The following section describes the process of selecting a woofer and tweeter for
the monitors. Woofers were judged based on calculations made in Winspeakerz,
specifications, and price. Tweeters were judged on frequency response, as well as
material of dome, sensitivity, and price. The volume for the calculations used was 1.453
cubic feet. The information was taken from Madisoundspeakerstore.com and the
manufacturer's websites.

\textsuperscript{18} Chris Plummer. “Loudspeaker Alignment Axis” (February 20, 2018). 1

\textsuperscript{19} John L Murphy. *Introduction to Loudspeaker Design*. (Andersonville, TN: True Audio\textsuperscript{R}®, 2014), 81,111
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The Satori WO24P-4 is a 9.5 inch woofer made with a paper cone. As shown in the Winspeakerz plot, the low end roll off is fairly gradual. This speaker retail at $198.00. Although initial thoughts were to use an 8" woofer, the extra diameters allows for a slightly lower response, and a low box Q. There are other woofers with more desirable low frequency roll off, box Q and system resonance, so that is why this woofer was not chosen.
Next is the ScanSpeak Revelator 8” woofer. In an 1.453 cubic foot enclosure, this woofer has a gradual roll off that starts around 200 Hz. The Satori has later roll off, but this speaker has a much lower box Q with a similar system resonance. This speaker retails at $337.20. The increase price compared to the chosen driver does not show an increased performance, in the size box that has been chosen, so it was not picked.
The third speaker in line is the Eton 8-412/C8/32 HEX Symphony II 8” woofer. The low frequency roll off is gradual and starts around 80 Hz. The system resonance is 46 Hz, which is in line with the previous two woofers, but has a higher box Q of .7434. This driver retails for $201.50. This has good specs, but a slightly lower suspension compliance compared to the chosen woofer. This also has a slightly steeper roll off, and goes below -14 dB at 20 hz.
Audax HM210C0 8” Carbon Fiber Woofer

The Audax HM210C0 is an 8” woofer with a carbon fiber cone. This speaker has great frequency roll off, with a decent Q and system resonance. What is concerning is confliction specifications with in the website and their specification sheets, and their spec sheet has typos and errors with the numbers. Also, the frame would be a challenge to route a cavity for in the front baffle to make it sit flush with the wood. This woofer retails at $139.55.

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Finally, we end on the woofer of choice: the ScanSpeak Classic 21W/8555-10 8" woofer. Of all the woofers, this has the lowest system resonance, closed box Q and has the least roll off to -14 dB at 20 Hz. It has a hard paper cone for rigidity and sensitivity. This speaker retails at $218.90, which is less that the Revelator, and in these conditions, performs better. The compliance is fairly high at 1.98 mm/N, giving it good stiffness to handle the low bass frequencies.
The first tweeter under examination is the Eton 26HD3. It is 25mm a magnesium ceramic tweeter. The graphs they offer are not the most detailed, so it is questionable how accurate they are. The specs list a working range of 2 kHz to 25 kHz. Their description claims “rich detail” and excellent 3D staging. This tweeter retails at $139.70.
Next is the ScanSpeak Illuminator D3004/6600 AirCirc. They supplied a much more detailed frequency response graph, and it is easier to trust. It appears to have a fairly flat response from 1 kHz to 12 kHz with a little bump beginning at 12 kHz. Part of the construction allows for good dispersion for a 1” tweeter, allowing for decent off-axis response. While a wide coverage range is not the goal of these speakers, it is a nice addition to have good off-axis response in the listening position. This tweeter retails at $193.70.
Sticking with ScanSpeak, the next tweeter is the Revelator D2905/9900-00. It is a textile dome like the previous model, and is also a 1” dome. The response graph has a slight hump, and reaches out passed 25 kHz. This actually has a higher resonant frequency compared to the Illuminator, and also about the same sensitivity. This tweeter retails at $235.60. The chosen tweeter has a flatter response and also costs less.
ScanSpeak Illuminator D3004/6040-00 Beryllium Dome Tweeter

Going back to the ScanSpeak Illuminator series, next is the D3004/6040-00 Beryllium Dome Tweeter. This tweeter has a good frequency range, but is large hump starting at 700 Hz. This tweeter has a higher resonant frequency of 750 Hz, compared to the previous Illuminator model which had a resonant frequency of 450 Hz. The beryllium supposedly provides great stiffness and high damping. This tweeter has the highest price of the selection at $269.00. The steepness of the frequency response was a large factor as to why this tweeter was not chosen.
ScanSpeak Illuminator R3004/6620-00 1” Tweeter

The last tweeter in this list and the tweeter that will be selected for this monitor is the ScanSpeak Illuminator R3004/6620-00. It is a 1” textile dome, a phase plug and like the rest of the Illuminator line, it has their proprietary AirCirc Magnet system which optimize airflow in the magnet. It has a rubber surround for added diffraction, and excellent off-axis response. The on-axis response is nearly flat from 1 kHz to 30 kHz. This tweeter retails at $247.70. This tweeter has the flattest response of the other four

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choices, a resonant frequency of 540 Hz, which is lower the desired crossover point with the woofer of 1000 Hz.

**Driver Details**

The ScanSpeak Classic woofer has a power rating of 100 watts at 8 ohms and the Illuminator tweeter is rated for 90 watts at 4 ohms. Using a power amp with 150 watts, the following equation can be used to calculate the max SPL of the woofer:

\[
Max\ SPL = 87\ dB + 10 \times \log_{10}(\frac{150\ watts}{1}) = 108.76\ dB
\]

Where 87 dB is the sensitivity (2.83v/1m) of the woofer at 8 ohms.

The same equation can be used for the tweeter, with the amp giving 300 watts of power:

\[
Max\ SPL = 90.4\ dB + 10 \times \log_{10}(\frac{300\ watts}{2}) = 112.16\ dB
\]

Where 90.4 dB is the sensitivity (2.83v/1m) of the tweeter at 4 ohms.
ScanSpeak 21w/8555-10 Specifications

KEY FEATURES:
- Patented Symmetrical Drive Motor Design SD-1
- Low-Lois Linear suspension
- Low Damping SGR Rubber Surround

T-S Parameters
- Resonance frequency [fs] 20 Hz
- Mechanical Q factor [Qms] 4.50
- Electrical Q factor [Qes] 0.33
- Total Q factor [Qts] 0.31
- Force factor [Bl] 8.2 Tm
- Mechanical resistance [Rms] 0.89 kg/s
- Moving mass [Mms] 32 g
- Compliance [Cms] 1.95 mm/N
- Effective diaphragm diameter [D] 16.7 mm
- Effective piston area [Sd] 220 cm²
- Equivalent volume [Ves] 134 l
- Sensitivity (2.83V/1m) 87 dB
- Ratio Bl/Vre 3.50 N/m/V
- Ratio fs/Qts 65 Hz

Electrical Data
- Nominal impedance [Zn] 8 Ω
- Minimum impedance [Zmin] 6.4 Ω
- Maximum impedance [Zo] 80.5 Ω
- DC resistance [Re] 5.3 Ω
- Voice coil inductance [Lc] 0.4 mm

Power Handling
- 100h RMS noise test (IEC 17.1) 100 W
- Long-term max power (IEC 17.3) 160 W

Voice Coil & Magnet Data
- Voice coil diameter 42 mm
- Voice coil height 19 mm
- Voice coil layers 2
- Height of gap 6 mm
- Linear excursion ± 6.5 mm
- Max mech. excursion ± 12 mm
- Unit weight 2.2 kg

Notes:
IEC specs. refer to IEC 60268-5 third edition. All Scan-Speak products are Rok! compliant. Data are subject to change without notice. Datasheet updated: January 22, 2016.

ScanSpeak Illuminator R3004/6620-00 1" Specifications

KEY FEATURES:
- 1" Ring Dome Diaphragm
- Patented Symmetrical Drive (SD-2) motor
- Diffraction Damping Rubber Front

T-S Parameters
- Resonance frequency [fs] 520 Hz
- Mechanical Q factor [Qms] 3.27
- Electrical Q factor [Qes] 0.56
- Total Q factor [Qts] 0.48
- Force factor [Bl] 2.3 Tm
- Mechanical resistance [Rms] 0.30 kg/s
- Moving mass [Mms] 0.3 g
- Suspension compliance [Cms] 0.31 mm/N
- Effective diaphragm diameter [D] 27 mm
- Effective piston area [Sd] 5.6 cm²
- Equivalent volume [Ves] 0.01 l
- Sensitivity (2.83V/1m) 90.4 dB
- Ratio Bl/Vre 1.33 N/m/V
- Ratio fs/Qts 1994 Hz

Electrical Data
- Nominal impedance [Zn] 4 Ω
- Minimum impedance [Zmin] 3.9 Ω
- Maximum impedance [Zo] 26.3 Ω
- DC resistance [Re] 3 Ω
- Voice coil inductance [Lc] 0.03 mH

Power Handling
- 100h RMS noise test (IEC 17.1)* 90 W
- Long-term max power (IEC 17.3)* 150 W

*Filter: 2, order HP Butterworth, 2.5 kHz

Voice Coil and Magnet Data
- Voice coil diameter 26 mm
- Voice coil height 2.1 mm
- Voice coil layers 2
- Height of gap 2.5 mm
- Linear excursion ± 0.2 mm
- Max mech. excursion ± 1.6 mm
- Unit weight 0.3 kg

Notes:
IEC specs. refer to IEC 60268-5 third edition. All Scan-Speak products are Rok! compliant. Data are subject to change without notice. Datasheet updated: February 22, 2011.

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Crossover Design

According to the manufacturers frequency response specification sheets, starting the crossover frequency will be at 1000 Hz. This is a frequency that both drivers have a flat response at, and have enough range extending beyond this point, allowing the frequencies under the pass band to be attenuated evenly. The crossover type will be a 4th order Linkwitz-Riley curve. This crossover will allow for a moderate roll off, the out-of-band frequencies will be lowered considerably and is usually inconsequential. Because this crossover is made with cascading two Butterworth 12dB/octave filters together, the on-axis amplitude response is flat because each section of the crossover is rotated 180 degrees, they sum to unity and remain in phase. The crossover will be active using a MiniDSP 2x4 DSP and two Behringer iNuke 1000 power amplifiers.

The goal is to achieve a frequency response of +/- 1.5 dB in each pass band to ensure a smooth crossover region.

System Tuning

Initial Measurements

The following section shows the process of tuning the loudspeakers. The tests are performed in a large theatre room, with high ceilings and large distances between walls.

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The speaker is placed on a stand that is approximately 8 feet off the ground. This allows the speaker to act as it would in free space. The reflections off the floor and minimal in this setup. An Earthworks 5761G is placed 20 inches away from the speakers, centered between the two drivers. It is connected to an Apogee Duet, plugged into an Apple Mac Mini, and the software used to produce the sweeping sine waves and make measurements is FuzzMeasure and Meyer Sound’s Smaart.

Adjustments to correct the results are made in the MiniDSP 2x4 DSP using it’s proprietary plugin software: 2x4 Advanced. Below are the initial measurement of the speakers, with no equalization, internal damping, and 48dB/octave crossover slope that is the default slope in the MiniDSP, and not the desired slope.
The above frequency response was taken with no internal dampening material added, no time alignment between drivers and no level adjustments between high and low frequency channels on the amplifier. It is fairly flat, the F3 is around the target frequency, and the Q is close to the desired roll off.

As one might expect, the waterfall plot shows a fair amount of internal resonance occurring. Proper dampening material placed inside as well as time aligning the drivers will correct this.
Final Performance Documentation

Frequency Response

Integrated Frequency Response

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Harmonic Distortion

Horizontal Off-axis Response - To the left on the speaker

AH-8 Speaker Design and Research
Horizontal Off-Axis Response - To the right of the speaker

Step Response

AH-8 Speaker Design and Research
Integrated Step Response

Impulse Response

AH-8 Speaker Design and Research
Tweeter Performance

Frequency Response

Harmonic Distortion

AH-8 Speaker Design and Research
Step Response

Impulse Response

AH-8 Speaker Design and Research
Woofer Performance

Frequency Response

Harmonic Distortion

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