The SSA Evil Component Set Passive Crossover Design

Designed by Mike Edgar

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The following White Paper addresses the design goals, construction and measurement of the SSA Evil component set passive crossover. Portions of this White Paper may be omitted by SSA for proprietary reasons.

The primary goal of this design is to provide the car and home audio listener with a passive crossover that sounds appealing, measures reasonably flat in amplitude response and presents a manageable impedance load. Design simplicity, low parts count and thrifty construction were not of primary concern. This crossover is not simple, cheap or small. This would be considered a premium design and the final price point may reflect that. The crossover is completely encased in epoxy resin to eliminate vibration and moisture induced failure. The crossover utilizes gold plated 5-way binding posts for all input/output connections that will accept up to 12 Awg wire. Metalized Polypropylene capacitors are used as bypass to Electrolytic capacitors in all applications, with at least 30% of the total value for series high-pass circuits and 10% of total value in all shunt applications. The woofer series inductors are 18 Awg perfect lay designs that yield low series resistance and 20 Awg are used in the high pass shunt and equalization circuits. Non-inductive audio grade wire wound resistors are used throughout. The inductors are oriented for maximum induction isolation.

Regarding the drivers, the 6.5” Evil mid-woofer will be addressed first. Designs and features of this driver will not be addressed in detail here as they are available on the SSA website. What will be addressed are the driver acoustic and electrical measurements. Figures 1 and 2 display the mid-woofer on and off-axis 1-meter response and Figure 3 displays the impedance. All measurements were taken using Dayton Audio’s Omni Mic V2 and DATS driver measurement system. A 40” x 20” ¾” MDF test baffle was constructed and lined with 3/8” open cell dampening material.

Figure 1 Mid-woofer response 1-meter on-axis

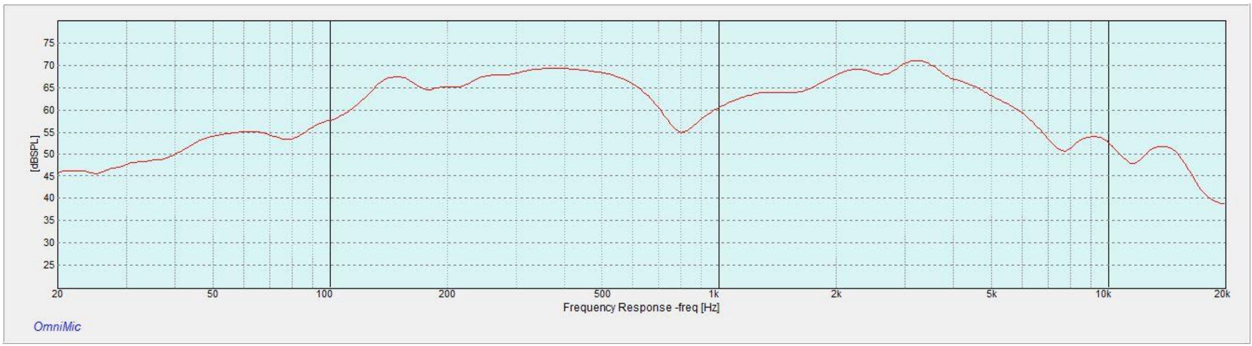


Figure 2 Mid-woofer response 1-meter off-axis

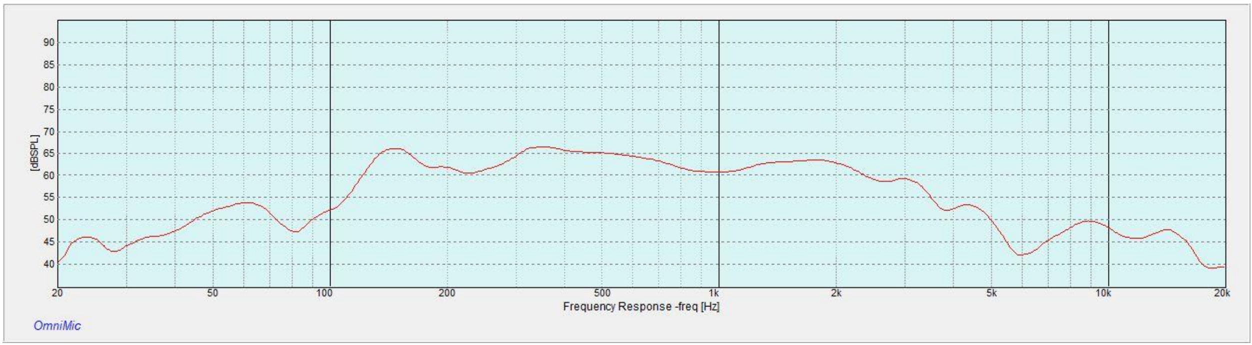
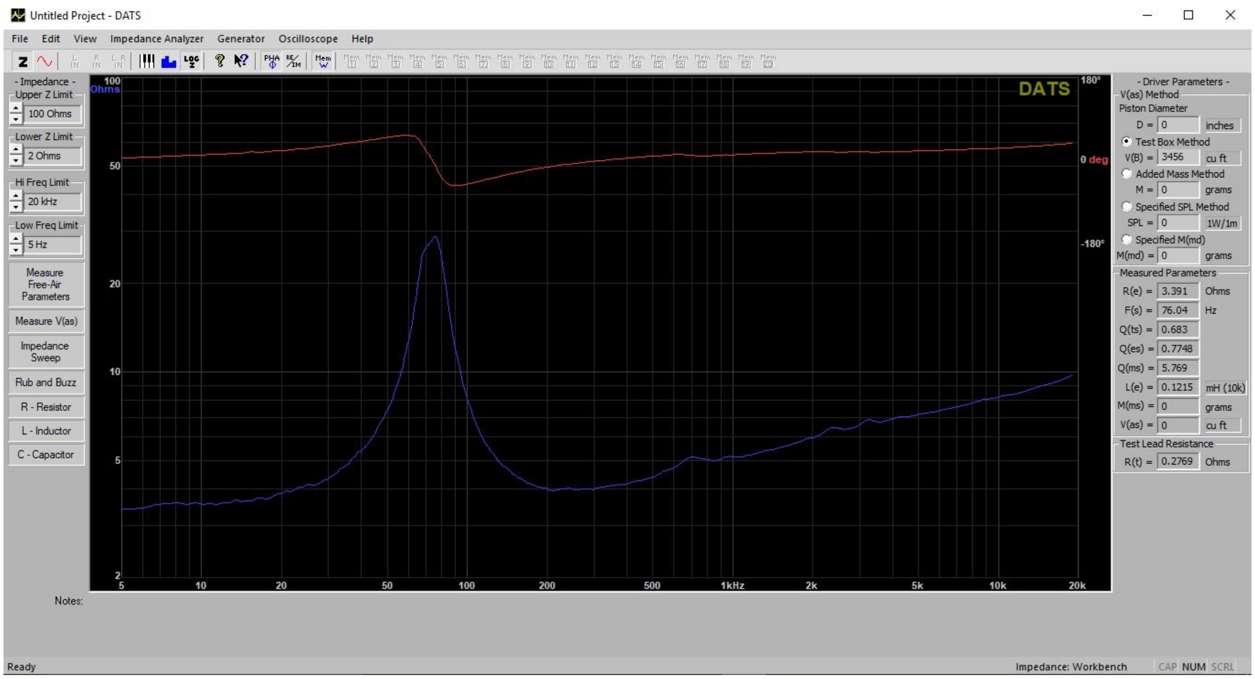


Figure 3 Mid-woofer impedance



At first assessment, there are some issues that will need to be addressed with the mid-woofer response. Most notably the two visible response peaks at roughly 2.3Khz and 3.2KHz (Figures 1 and 2). These are likely results of the stiff carbon-fiber cone resonant modes which are not uncommon with this type of cone design. Corresponding impedance peaks can be seen in Figure 3. I spent an extended period of time listening to the mid-woofer by itself both full-range and with low-pass filtering. These two peaks in response gave vocals a very edgy and rough sound, undesirable in my opinion. The other noticeable dip in response around 700hz was, in my best guess, caused by cone geometry and the phase plug. I note my guess because off-axis response (Figure 2) shows this dip almost completely goes away. Additionally, I didn't notice anything audible with this dip so I am not worried about it. This is normally the case with driver response, small peaks are noticeable to the ear where larger dips are not. There isn't anything else noteworthy in the response. Impedance behaves quite normal and the driver has low inductance which is probably a result of the motor design. Next, the tweeter measurements.

The SSA Evil tweeter measurements are below in Figures 4 and 5. The only items of note are a small dip around 2.5Khz and a slight lift on-axis around 10Khz, but this will be easily addressed with the crossover. The tweeter is more efficient than the woofer and will require some sort of attenuation and/or equalization to sum with flat amplitude response.

Figure 4 Tweeter Response 1-meter on-axis

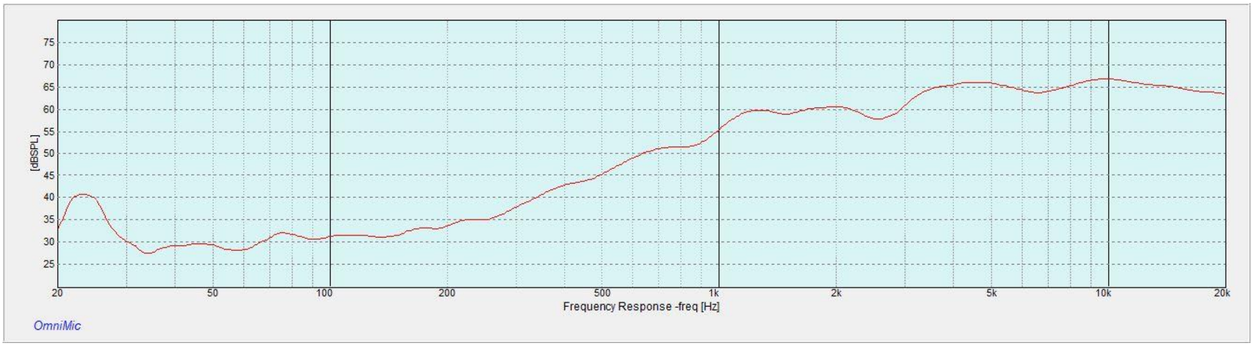
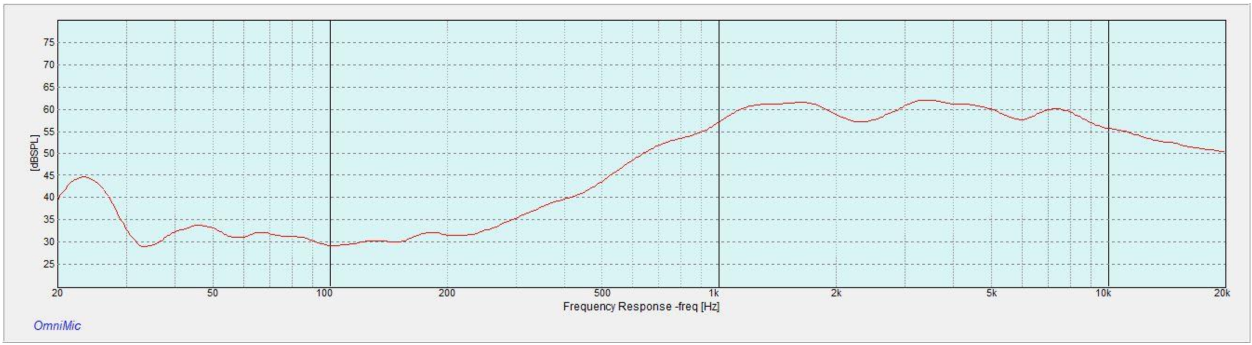


Figure 5 Tweeter Response 45 degrees off-axis



While the mid-woofer does have some response anomalies, the tweeter has a decently flat response that with the right passive crossover design should yield decently flat amplitude response. The crossover design will be discussed in detail below.

The first area of the crossover covers the mid-woofer. The two peaks at 2.3Khz and 3.2Khz must be addressed in order to provide adequate sound quality. There are two basic ways to deal with these peaks. Normally, you use notch filters to eliminate the response ripple or a crossover that has a low and steep enough cutoff that the peaks will not show up in the summed response. Initially I tried 4th order acoustic slopes (2nd order electrical slopes) with a notch filter centered at the first peak of 2.3Khz. This did eliminate the peak but it played havoc with impedance (dropping to under 2 ohms around 2.1Khz). It also added 3 additional components to the design, to include an inductor. The second peak was low enough in amplitude that it didn't appear in the summed response. I tried roughly 10 different designs with the 4th order filter but was never completely happy with the sound and impedance.

I decided to try a steeper filter centered around 2Khz. With 4th order electrical filters and roughly 6th order acoustic slope, the woofer achieved a smooth roll-off that would end up integrating quite well with the tweeter. This eliminated the components of the notch filter and made the impedance much more benign. The design was change roughly 10 more times, each with extended listening sessions and objective measuring until the results were acceptable. A Zobel network was added in the final design even though the woofer has low inductance. It did help smooth the ripple in the crossover region by roughly 1 db.

Moving on to the tweeter filter, design was much easier. Even though the slopes are asymmetric, a 3rd order electrical filter was implemented that gave a roughly 4th order acoustic roll-off on the tweeter. Roughly 2.5 db off attenuation was added to the tweeter to bring the overall response in line with the mid-woofer. Figures 6 and 7 below illustrate the summed system response.

Figure 6 System Response 1-meter on-axis

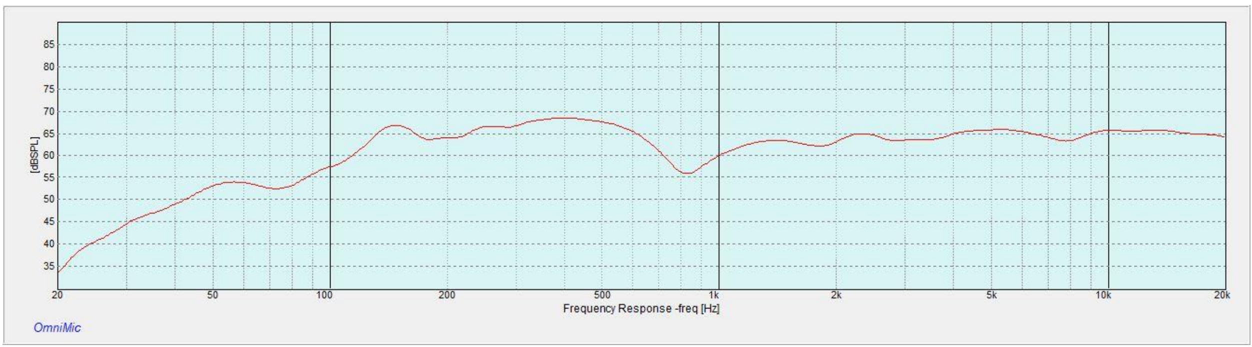
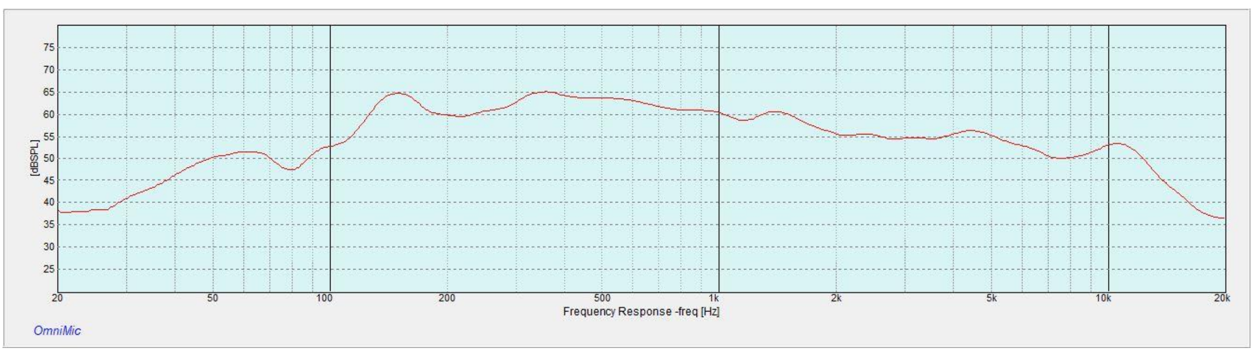


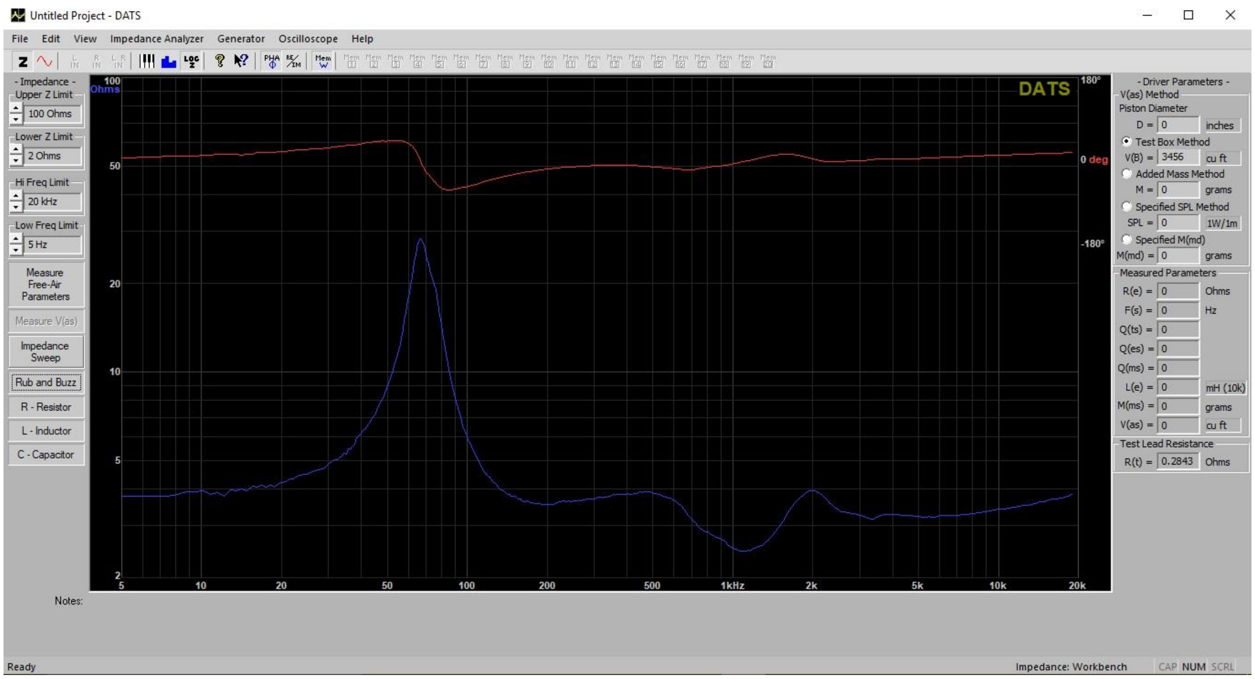
Figure 7 System Response 1-meter 45 degrees off-axis



Of particular note is the on-axis response from 1Khz to 20Khz. Overall ripple is roughly +/- 2.5db over that entire range, especially through the crossover region. The Butterworth slopes summed almost perfect with proper polarity configuration between the two drivers. This wasn't an easy task with the mid-woofer response anomalies, but after roughly 20 design changes it was accomplished with acceptable results. The off-axis response shows the dip around 700hz disappear and a small dip above 2Khz appear that isn't noticeable to the ears. Additionally, the dip at 7.5Khz isn't noticeable either. The off-axis response should prove acceptable in the automotive environment.

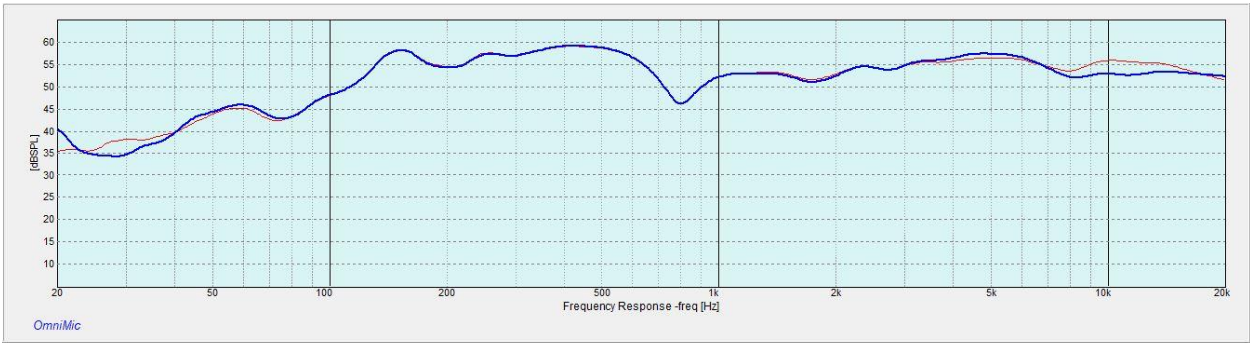
Figure 8 illustrates the overall system impedance. The large peak around 70Hz is due to the mid-woofer Free-Air resonance, this will vary depending on the enclosure resonance of the mid-woofer. The lowest dip of roughly 2.6 ohms happens below the crossover point and is primarily due to all the shunt capacitance in the woofer circuit. The rest of the impedance isn't noteworthy, containing a slight bump in the crossover region and a slight inductive rise due to the tweeter. Most amplification should be able to comfortably drive this component set with ease. Overall impedance would be an average of about 3.5 ohms.

Figure 8 System Impedance



The final summed amplitude response is flat in nature. While this may be considered an ideal alignment, some may feel that this gives the overall sound a "bright" character. Most of this will stem from the response above 10Khz. In the mobile environment, where the tweeters may be listened off-axis or equalization is easily achieved, this would be a non-issue. However, if these speakers were used as home audio monitors the sound could become fatiguing over time and may require modification for some listeners. I designed an equalization filter that would be added in place of the tweeter attenuation circuit for home audio use. Figure 9 below shows the summed response.

Figure 9 Summed Response 1-meter on-axis with tweeter equalization



The red line of Figure 9 is the original system response and the blue line represents the change caused by the tweeter equalization. To my ears, the equalized response sounds preferable on-axis. If any type of equalization or DSP is available in the home audio environment, this circuit would not be needed. Since this circuit omits the original design's tweeter attenuation circuit, it could not be "added on" to the original crossover and would require a separate overall crossover. SSA audio may address this as a possible option.

In summary, the SSA Evil Component passive crossover met the design goals of appealing and non-fatiguing sound, reasonably flat amplitude response and a manageable impedance load. The parts selection has little compromise and the overall design would be considered "high-end". The epoxy resin potting compound will ensure years of durability in any environment. Extensive measurements were completed and extended listening sessions were accomplished during development. I have well over 100 hours of time in development of these crossovers. I hope you will enjoy listening to them, it was an enjoyable project to complete.

- *Mike Edgar*