



Introduction

This guide documents the use of the Shiva-X in a Passive Radiator Design. This guide is meant to help the builder choose the appropriate parts and achieve predictable results.

Why a Passive Radiator?

Passive Radiators are a great choice when using the Shiva because they allow for smaller boxes without the potential noise issues of a port. A driver with the output potential of the Shiva-X requires very large diameter ports. If you size a port too small, it chuffs and makes noise (not the noise you want) as you increase output.

In an ideal world, the port would only make the noise over the range of frequencies you designed it for (centered around the tuning frequency). In real life, ports create noises as air flows across the surfaces at high speed. At high velocities the turbulence creates a chuffing noise. You also get compression of the port output as the turbulence increases. What worked well at low output, no longer is working the same at higher output levels.

Passive Radiators help us get around some of these limitations. A Passive Radiator uses a moving surface (cone) with a weight attached to tune the cabinet. By choosing the right Passive Radiator, and adding the right weight, you can easily tune a small cabinet low without the concerns of a long port. Also, we can size the Passive Radiator appropriately so that it is capable of delivering the full output when the Shiva-X is at full output. As a side benefit, the Passive Radiator requires very little cabinet volume to function. Compare that to a large diameter port that is 30" long and you quickly see that Passive Radiators have a lot going for them.

But wait a minute! Why not just use the Shiva-X sealed? There is nothing wrong with using the Shiva-X in a sealed design but the Passive Radiators or a ported design allows for more output when designed correctly. How much? It depends on what you're comparing but in general, down near the tuning frequency of the design, you can achieve about twice the output of a single sealed Shiva-X. All designs have their tradeoffs. A sealed design is simple, has no requirements for special filters (subsonic filter) and will function in a smaller cabinet (with less bandwidth). The choice is yours as the builder. For home theater

applications or in a large room, where every bit of output is needed and your trying to minimize the footprint of the subwoofer, a Passive Radiator design can make a lot of sense.

Ok... I'm convinced. Where do we start?

First, you have to have a design goal. When we start a design we typically load the parameters of the driver into a modeling program. This allows us to change variables like box size, tuning frequency, electrical filters and power and observe how changes affect the output of the subwoofer. A modeling program allows us to view the Frequency Response of the system, and it gives us a snapshot of the expected results from a given design. I'm not going to go into detail on how to model a system. There is a lot of complexity in designing systems and many different modeling packages. For the sake of simplicity, I'll model the system I'm describing in this technical guide and if you follow these guidelines, you will get the results shown.

Ok... most people want small subwoofers with LOTS of output. Unfortunately, we are playing with the laws of physics so there is only so small that the device can be and still provide good low frequency extension. Contrary to the marketing departments of most subwoofer companies, there is no free lunch. Small subs require some type of sacrifice to make them small and that sacrifice is either bandwidth, and/or cost. I've chosen a starting point with the Shiva-X that allows for a manageable box size (18"W, 21" H, 21" D) while allowing good extension with a reasonable sized (and priced) amplifier.

Design Guidelines

Box Design: 18" Wide, 21" Tall, 21" Deep (outside dimensions). The Shiva-X & PR-15s are flush mounted. Internal volume is just over 3.1 cubic feet and $\frac{3}{4}$ " MDF (or Baltic birch) can be used for all panels.

Amplifier Choice: This system is designed around two amplifiers that are easily available on the market, have the necessary power, and are cost effective tools for the application. There are a multitude of amplifiers that can work in this application but describing them is beyond the scope of this documentation.

Subwoofers have unique signal processing requirements that are rarely featured on traditional amplifiers. The first and foremost among them is a subsonic filter. A subsonic filter is an electronic filter that cuts off the output of the amplifier below a certain frequency (high-pass filter). Ported and passive radiator designs NEED a subsonic filter otherwise you risk damaging the system. The other filter that is commonly used on a subwoofer is the low-pass filter. Usually, this is a variable 2nd-order filter. Many home theater processors or receivers have a low-pass filter function that would allow you to theoretically bypass using one on the amplifier.

Amplifier #1: BASH 500W Amplifier Available from Parts Express (We sometimes stock this model). Parts Express Part Number: 300-752 Approx cost: \$229

This amplifier requires some modification to work in this application to set the subsonic filter correctly and add some low frequency boost. We use the 18.7Hz F3 & Q = 1.3 in this application (R17 = 15K, R18 = 100K). This gives the system 3dB of boost in the low 20Hz range. Parts Express offers a data sheet showing how to replace two resistors on the signal processing board. In stock form, the filter is set very high and is unsuitable for the application.

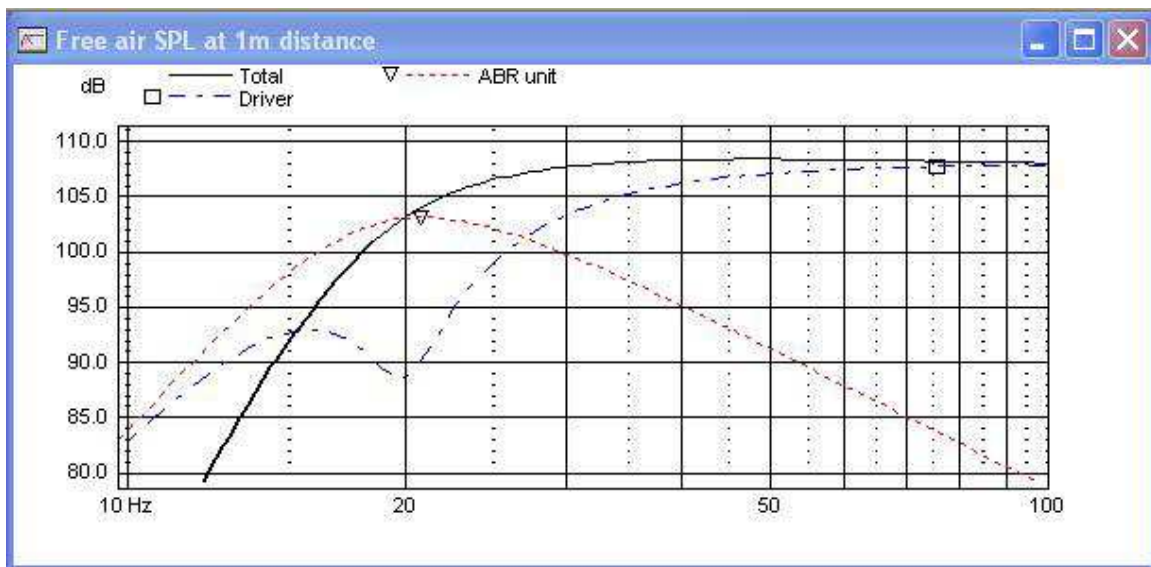
<http://www.parts-express.com/pdf/300-752.pdf>

We only recommend this amp if you are comfortable working with PCBs and soldering. If that doesn't describe your skills, we highly recommend using Amplifier #2.

Amplifier #2: Parts Express HPSA500 Part Number: 300-806 Approx Cost: \$325

This amplifier has the benefit of not needing any modifications to work properly in this application. The standard subsonic filter is low enough to be suitable and the single band PEQ filter can be used for the boost required. This also gives the user some flexibility in adding the amount of boost that fits their unique room situation (smaller rooms require less boost).

Bandwidth: As shown:

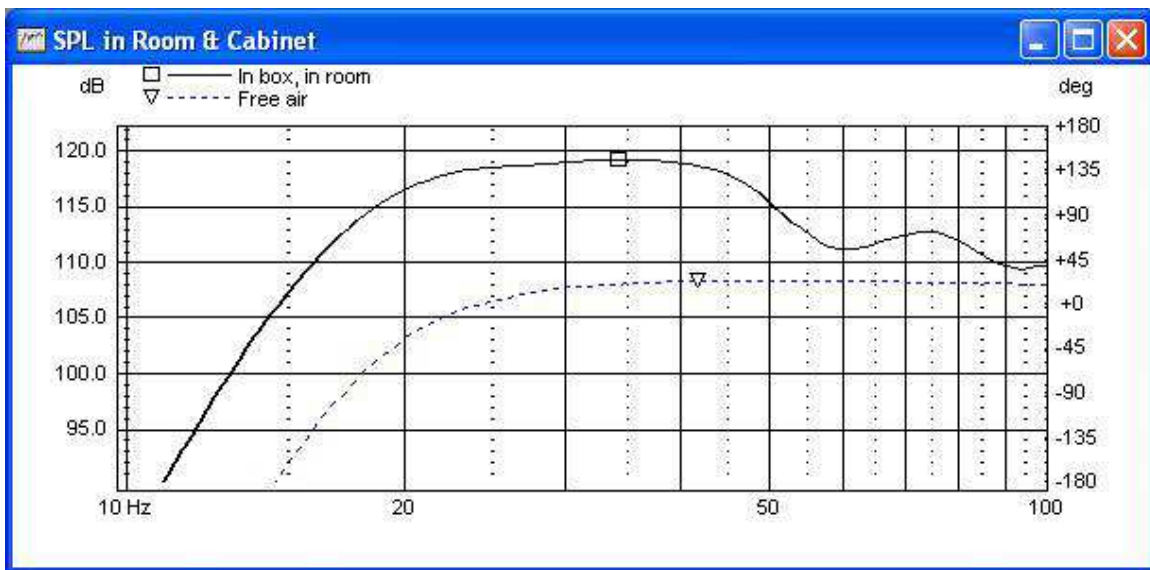


This chart shows the frequency response of the system measured in "free air". That is a fancy way of saying that the device was measured without the benefit of boundary gain you would see in a room or a real acoustic environment. It is a starting point so we can estimate

what kind of bandwidth the device is going to achieve in-room, which is really what we are after.

You will notice, that the design shows the output starting to drop at around 40Hz, and by 20Hz, we are down about 6dB. This is a common theme with most of the subwoofers we design. We allow the output to drop when looking at the "free-air" measurement because we know that in-room, the response will be boosted by room/boundary gain. If you design the system to be flat in free-air, it ends up with a large hump in the response in the first octave. Some people may like that artificially boosted bass hump, but that is another topic.

Here is a ROUGH estimate of what we will get in-room. Notice I emphasize ROUGH. The room really dominates the output of these devices down under 200-300Hz. It is not uncommon to have large 10-15dB humps or nulls in an in-room frequency response measurement. Once again, that is a topic for another discussion but I'm a big advocate of using room measurements and equalization to optimize a subwoofer installation. Doing so can have dramatic results.

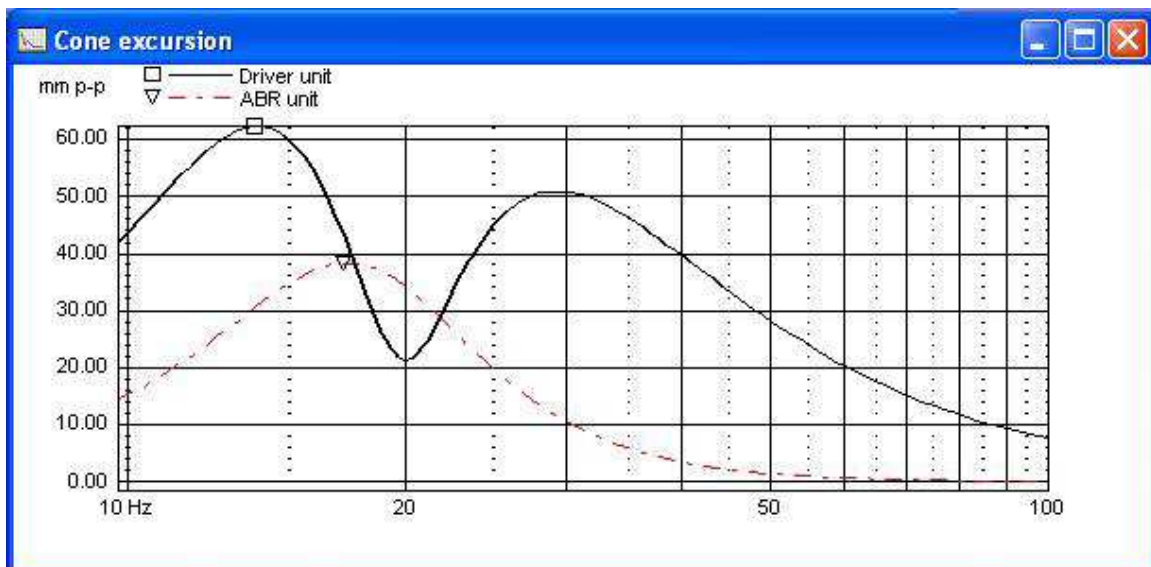
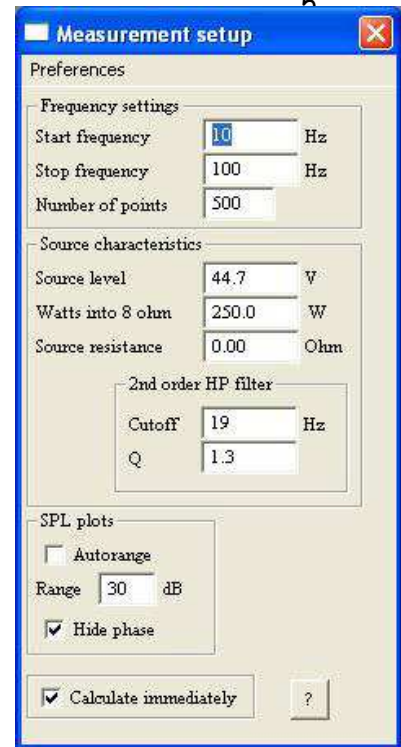


The modeling software makes some generalizations about the response. You will notice that we have a large hump from about 18-20Hz to 50Hz. That is mainly due to the pressure vessel gain of our imaginary room. I've disabled some of the room simulation tools to make the response resemble something smooth. Also keep in mind that most subwoofers are crossed over at 40-80Hz via a Low-Pass electrical filter. That is not shown in this response but the result of that will to further make the response look like a hump. Really, subwoofers are 1st/2nd octave devices (20Hz-80Hz) so that is expected.

The settings on the subsonic filter should give roughly a 17-19Hz cut-off. Most of these filters are not exact. Part tolerances can change the corner frequency +/- a couple hertz. Our filter settings are show @ 19Hz with a $Q = 1.3$ as described in the amplifier section.

Notice that the "Watts into 8 Ohm" setting is at 250W. For our purposes, this models the output of the subwoofer @ 500W because we are using a nominal 4-ohm subwoofer. We are modeling the device at the theoretical full-output of the amplifier because we want to be sure the subwoofer can handle it. Which brings us to our next topic.

The cone excursion graph shows our driver & Passive Radiator excursion at the above power (500W). Unfortunately, things are not as simple as this would leave us to believe. In the real world, subwoofers don't remain linear as you apply more power. The voice coil heats and the resistance of the coil increases causing power compression. Also, the suspension tightens near maximum excursion and the output is limited some by this mechanical limitation. Another factor to consider is that the advertised power rating of our amplifiers are sometimes a little optimistic. None of those imperfections are shown in our model but we keep them in mind. Here we are just trying to show that our driver isn't being driven into a situation where we will damage the driver. The Shiva-X has an x_{max} of around 26-27mm one-way. X_{max} is NOT the total excursion of the driver. X_{max} is just the point where the motor strength has fallen by 30%. Our real limitation is caused by the mechanical limits of the driver or the x_{mech} . For the Shiva-X, that is around 35mm one-way.



Our excursion graph is showing peak-peak (both forward and reward excursion combined) numbers so even at full power it looks like our system is well below the point at which we will cause damage via beating the driver to death (mechanical damage). The red dotted line is the excursion curve of the passive radiators. The PR-15 has a mechanical limit around 35-38mm on-way so our Passive Radiators are WELL within their design limits as shown in the above graph. Note that all of the non-linear factors we talked about earlier tend to decrease the total excursion capability of the driver. If the amplifier is truly limited to 500W, there is no way to mechanically damage the driver in this situation. One factor to consider though, most amplifiers will have a peak-output power that they can supply in short burst that may allow them to mechanically bottom the driver even though their power ratings are lower. Our design is conservative enough and the Shiva-X is durable enough that this should not pose an issue in this application.

Here are the box details for all the above simulations.

The screenshot shows the 'ABR box' software window with the following settings:

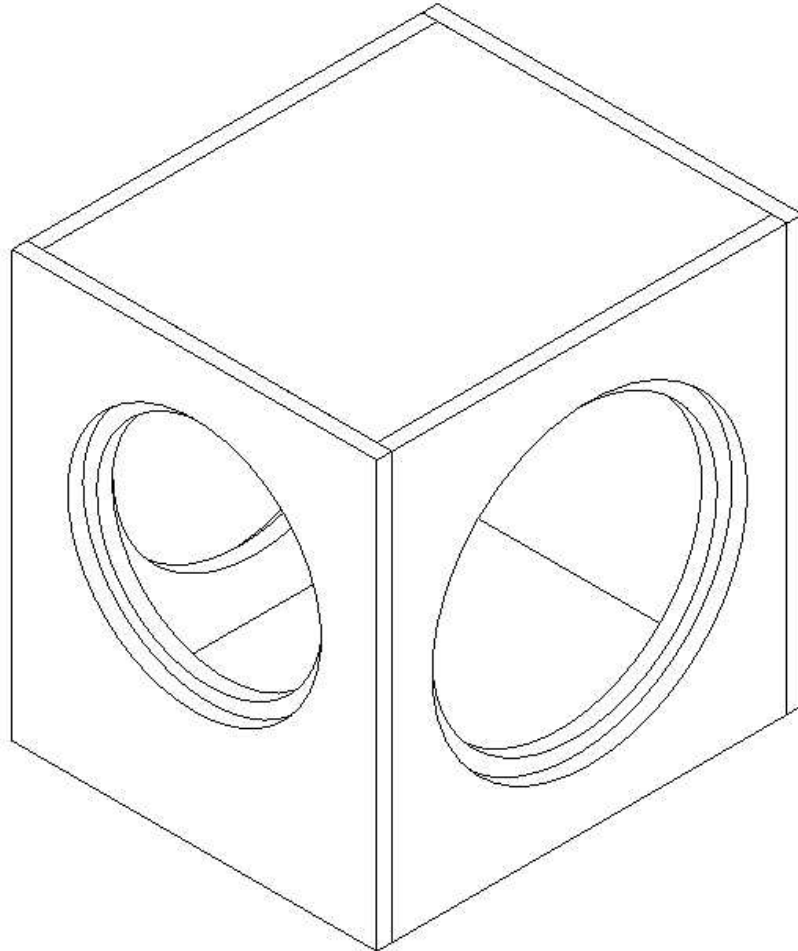
Box		ABR parameters	
Volume	87.0 l	Vap	245.0 l
Q1	12.0	Sd	791.0 cm ²
Qa	30.0	Qmp	6.0
Fill	0 %	Mmp	1500.0 g
# ABR units	2	Fp	7.8 Hz
<input type="checkbox"/> ?	<input checked="" type="checkbox"/> Simulate non lin.	Xsus	60.0 mm
		Fb	20.1 Hz

Our Box volume is 87 liters (just over 3 cubic feet), the other things we notice from this menu is that there is 0% fill (no polyfill used), and that our Passive Radiators are loaded with 1500g of mass (the passive has a starting mass of 200g). That is 13 washers from the mass kit loaded on each passive radiator to tune the cabinet to 20.1Hz.

Box Design

Here are some simple drawings of this proposed box. Building a subwoofer is about as easy as it gets. If you can build a box, with a couple holes, you can build a subwoofer. If you failed shop class, you may want to look for someone with the tools and ability to assemble a simple box. Most cabinet shops can easily build this subwoofer for a fairly reasonable price

and match the finish of your other furniture. This is one case where a custom designed piece of furniture may actually be less expensive. The details left out of this drawing are the feet and finish options (and plate amp cut-out). Those factors can be addressed in a number of ways. Use your imagination and/or design something that fits your décor. Grills may be fabricated or not.



Isometric View

You notice the front is for mounting the Shiva-X, which is a 12" driver. The side holes are slightly larger for the 15" Passive Radiators. The drawings for the dimensions of all parts of this cabinet design are available on our web site. **Double check all dimensions before cutting wood.** That old saying measure twice, cut once always applies. You may download the box dimensions and drawings at this link:

FAQ

Can I change the box design?

Sure... but it changes all the other variables. The important factors are the **internal volume**, and the fact that you can still fit all the parts on the enclosure. You have to be careful with the two passive radiators. The mass kits attach via a bolt on the rear and they need to have enough clearance so that they don't hit each other on the inside under full excursion. Keep the width to 18" and you won't have a problem. If you narrow it down to 16" you may not have a problem at low output, but could get some clanking from the bolts hitting at maximum output.

Can I use just one PR-15?

Yes, you can! A single PR-15 will function just fine. You run the passive harder, and it may bottom at full clip. If you have a smaller room, or just a tighter budget there is nothing wrong with using a single PR-15 for the build. One factor to consider is that the passive radiators when mounted opposing each other cancel some cabinet vibration so there are advantages to using two Passive Radiators other than output. The other factor to consider is that you need to change the amount of mass added to the design in order to get the right tuning frequency. For the above design you would use SIX mass washers on the one Passive to get roughly the same tuning frequency.

What if I want to use a different box volume?

Different box is a different design. You have to remodel the entire design to make sure you are getting good results. With the right equalization, the Shiva-X can be used in as small as 2.5 cubic feet with a single PR-15. You trade-off output down low the smaller the box. We are unable to support users with different CAD drawings and models for every possible box size. We have our standard and if you choose to use something other than that, you're responsible for figuring out all the details.

Can I add braces?

Yes you can! They will take up a little cabinet volume but a couple shelf braces may help with cabinet vibration and it won't throw off the design much. Feel free to get creative.

Can I use a different amp?

Sure... but you have to replicate the subsonic filter somehow. If you use a higher power amp, you will have the ability to damage the driver at maximum output.

Will it stomp subwoofer "XYZ" from company "ABC"?

Probably.... There are obviously a lot of variables. Some companies are doing a pretty good job with subwoofer design and others less so. All of us have to obey the same laws of physics so not matter what the marketing department has to say, there is only so much of an advantage you can get over another competitor

Legal Stuff

Life Support/Mission Critical Applications:

Exodus Audio products are not fault-tolerant and are not designed, manufactured, or intended for use or resale in hazardous environments requiring fail-safe performance, such as in the normal operation of nuclear facilities, aircraft navigation, communication systems, direct life support machines, heart defibrillators, or weapon systems in which the failure of our product could lead directly to death, personal injury or severe physical or environmental damage.

Certifications:

This product is designed to the highest standards and in accordance with all Exodus Audio internal processes. However, this product does not carry any certification relating to safety, standards compliance, or applicability for use in given situations. No certification is expressed or implied. Use of this product is entirely at the user's risk and responsibility.

Responsibility of Use:

Exodus Audio in no way is responsible for the use of this product. The product is capable of causing medical damage and loss of hearing under extreme use. The customer is solely responsible for proper use and common sense application of the product. Hearing damage is a real threat to exposure to high SPL sound levels. Act accordingly.

Subwoofer Power Ratings:

Power ratings on transducers are just guidelines for use. They are not guarantees of the fitness of a transducer to withstand a given power input. Why? Well, the actual power that can be safely handled by a subwoofer depends upon several variables, including the enclosure design, test signal or program material, amplifier details and ambient temperture.

Subwoofers by nature are inefficient devices. Most subwoofers are around 1-3% efficient, meaning that for every 100W of power delivered to the transducer, only 1-3W is actually converted into acoustical output. What happens to the other 97-99%? It is given off as

heat and dissipated to the environment, primarily (> 95% of it) through convective heat loss as air passes over the voice coil & former.

Obviously, the movement of the coil & former is critical to the device being able to dissipate heat. Consequently, if you run a 1K test tone into the driver at high power under continuous conditions in a small sealed & stuffed box, it is easy to thermally damage a driver. If you use a 20Hz test-tone in free-air, the same driver may be able to withstand the same power indefinitely. For these reasons power ratings are just guidelines. Ultimately the user must understand the conditions under which the driver is going to be used and plan for an appropriate amount of power for the application. This is the same design paradigm that manufacturers use. Note: Highly equalized systems quickly reach thermal limits. Careful design is required under heavy equalization especially with test-tones. Music or movies are typically 1/8th power. Test tones present a MUCH higher thermal load on transducers. Be careful testing drivers with test tones in high SPL conditions.

It is often best to be conservative with amplifier power. If you under-power the system you will clip the amplifier at the limits of output. That will MOST LIKELY not damage the transducer. Overpowering the transducer can quickly damage the device before the user has a chance to adjust the system levels. Also, amplifiers are capable of power output that exceeds their specifications under short duration transients. These short transients can be enough to damage the system if you are running it under full power conditions. The user is ultimately responsible for operating the transducer within its limitations.

So what is a consumer to do? We recommend building a subwoofer like you would a bridge. No responsible engineer would build a bridge to operate at its limit. You don't design a bridge to support EXACTLY the weight that it will carry under use. You design a bridge so that it can EXCEED not only the worst-case load, but typically you would design it to have capacity beyond its maximum expected load. While a subwoofer isn't a bridge and it's failure wouldn't be as catastrophic, it is a very good idea to build the system such that it has MUCH higher capacity than your highest output need. Only through good design and common-sense use will you prevent damaging the system. Since output levels required depend upon the room, program material, user preference etc... It is beyond the scope of this document to determine output needs.

Limited Warranty:

Exodus Audio warrants its products to be free of defects in material and workmanship for a period of 1 year from date of purchase. Exodus Audio and/or its designated representatives shall have all final determination about the validity of a warranty claim.

This warranty shall not apply to any product that has been subject to misuse, neglect, accident or abnormal conditions of operation. Improper installation is not covered under warranty.

This warranty is limited to Exodus Audio equipment only. It does not extend to any other equipment or product connected to or operated in conjunction with this product. We are not responsible for any damage to other equipment or product arising from the use of this product.

Exodus Audio's obligation under this warranty is limited to repairing or replacing or refunding the original purchase price (exclusive of shipping charges), at Exodus Audio's option, any product returned within 1 year of purchase date, provided that Exodus Audio determines the unit is defective and has been used in compliance with the terms of this warranty.

Subwoofer Returns – While we do not guarantee the suitability of a specific speaker to a specific application we provide a period of 30 days from the date of invoice in which the customer may return the product.

All refunds require at least 14 working days for processing. This does not include holidays or weekends. Do not contact customer service unless your return has taken longer than 21 working days from the date of it's arrival at DIYCable. The following conditions apply to full refunds:

- The speaker must be in the new condition. This **includes no mounting marks or scratches, no solder on the connectors, no sealing caulk, dirt, sawdust, or other debris.** Speakers showing mounting marks or other indications of use will be evaluated and a restocking fee, deducted from the refund amount. In extreme cases, no refund or credit may be offered. Our intention is not to offend or punish people returning product. The bottom line is that if we cannot resell the product as new, we cannot offer you a full refund. If we have to sell the product as b-stock or determine that it doesn't meet our standards for resale even as a b-stock product, the customer will not receive a refund.
- Product must be returned in all original cartons, outer shipping cartons, and boxes. This packaging includes all internal plastic bags or printed manuals. The product must be in NEW condition returned in ORIGINAL packaging.
- Package the product to protect it from damage in route to DIYCable. Insure the package for the value of the product. In the event the returned package is damaged in route to DIYCable due to insufficient packaging, the customer is responsible to file the claim with the shipper.

Damaged Product

Speaker Defects occur even in the most expensive of speakers from the most respected companies. Contact DIYCable immediately if you suspect you have received a defective product. Products that have obvious defects will be replaced at our cost or we will arrange for a credit based upon the customer's preference.

There are times when a customer may suspect a defect that is not obvious. Unless there is an obvious defect (broken part, missing components etc.) we reserve the right to inspect and test the transducer to confirm that it is in fact defective. Often, a mounting problem, or a system problem can appear like a defective transducer (clipping, popping or rubbing caused by obstruction hitting the cone or suspension components). If there is some doubt concerning the integrity of the product, we encourage the consumer to work with our technical support to troubleshoot the problem, avoiding costly shipping and replacement of parts that may not be defective. ***Customers are ultimately responsible*** for troubleshooting the problem. Our technical support will do the best they can to help but we are at a decided disadvantage by being at a remote location. Email and phone calls are not as effective as having the product in your hands to test. In the end, the customer is ***SOLELY*** responsible for system problems related to the use of the transducer or any damage caused to the system.

Parts returned will be tested for rub/buzz and T/S parameters to verify the integrity of the transducer. If the transducer is determined to be non-defective, the product will be treated as a returned new part with the same conditions outlined above in the Subwoofer Returns section, including restocking fees for cosmetic damage, non-payment of shipping charges and requirements for all original packaging.

All returned products require at least 14 working days for processing!

DAMAGED MERCHANDISE RETURNS

Contact Exodus Audio within 5 days of receipt. Carriers will not permit claims after 5 days. We will file a Damage Inspection Claim, which results in a carrier follow-up to inspect your package. Retain all boxes, labels, and packing materials until the claim has been approved. We will proceed with a replacement shipment once the carrier notifies us of claim approval. Note: Truck freight shipment damage must be reported directly to freight carrier.

All Returns should be shipped pre-paid to:

Exodus Audio
175 South Bay View Ave. Unit 23
Port Angeles, WA 98362
360-452-9373