SHIVA VENTED BOX APPLICATIONS

A technical paper related to the Shiva Subwoofer and the FP Series vent kits

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1 General Driver Description

Shiva is a subwoofer driver from Adire Audio. Shiva features a very long throw, low distortion design tailored to high SPL applications. For more information about Shiva, please see the Shiva White Paper.

2 General Application Notes

2.1 Power Amplifier Selection

At first glance, Shiva would seem to indicate a need for a 600W amplifier, since that's the power rating of the driver. However, this is not the case. Very good results can be achieved with Shiva running from as little as 40W per channel. Even smaller amplifiers (10WPC) can result in a musically satisfying experience. It really depends upon your tastes and the capabilities of the loudspeakers paired with Shiva.

The 600W rating of Shiva is just that: a maximum power rating. This is the peak amount of power that can be dissipated in Shiva over the long term. Realize that this level of power would yield an in-room output in the 120 dB SPL range; this level is well beyond the typical continuous home listening environment.

However, assuming a source peak-to-average ratio of 25 dB (such as is typical for modern music, FM broadcasts, and most soundtracks), listening at normal levels (80 dB SPL) would require peaks of 95 dB SPL. This peak level requires 17.5 dBW, or 56.2W of amplifier power. As such, most home receivers capable of 100W per channel performance will be quite suitable for use with Shiva.

We do realize that such listening levels (80 dB SPL nominal) are not for everyone. Some individuals will listen to Shiva at higher levels. The 600W rating is intended to allow for those who enjoy musical peaks up to and beyond 120 dB SPL in-room.

As with all acoustic transducers, we strongly recommend that you exercise good judgement when listening to your loudspeakers. High power/high SPL capable drivers such as Shiva can cause permanent hearing damage and actual hearing loss, if abused. Prolonged exposure to levels in excess of 110 dB can cause partial or full deafness. Be kind to your ears!

2.2 Mounting

Many low-Fs drivers cannot be mounted in a downfiring (or horizontal) configuration; they must be oriented vertically, with the cone/basket perpendicular to the floor. To achieve a very low Fs in other subwoofer systems, the moving mass of the system is made quite high, while the stiffness of the suspension is made low. These two changes work to create a system which will suffer excessive cone offset when mounted so that gravity will pull the cone out, away from the normal "rest" position.

Because Shiva has an Fs of 21 Hz, the moving mass is not substantially more than competitive subwoofers. However, the surround is considerably stiffer. This results in Shiva being rated for horizontal mounting. In fact, given the T/S parameters, one can calculate the effective loss in Xmax that will occur due to the offset of the cone from the force of gravity:

Basically, one looks at the mass of the cone (118.3 grams, in the case of Shiva), and the mechanical deflection, Cms (0.47 mm/N, as measured by DUMAX). The acceleration of gravity (what's pulling the cone down, or up) is 9.8 m/s^2.

Now, a Newton (the N in Cms' units) is in units of kg * m / s^2, or kilogram meter/second squared. So, multiply the mass of the cone by the force applied (gravity) by the mechanical deflection:

mass * force * deflection = 0.1183 kg * 9.8 m/s^2 * 0.47 mm/N

= 1.1593 kg * m / s^2 * 0.47 mm / (kg * m / s^2)

Note that there's a kg * m / s^2 term in the numerator and the denominator. Cancel the units out, and you're left with 0.545 mm. Thus when Shiva is mounted horizontally, one will end up with an Xmax of 14.355mm one way (in the direction of gravity), and 15.44mm in the opposite way. As a comparison, several other high-end 12" subwoofer drivers will exhibit up to 1mm of offset; considering these units typically start with 2+mm less Xmax than Shiva, the result is a considerable drop in usable swept volume.

2.3 General Alignment Notes

Shiva was designed to be a very versatile subwoofer driver, allowing numerous different acceptable bass alignments, depending on the characteristics desired of the system. In describing these enclosures and tunings, the following will be calculated for each alignment so that the responses can be compared:

- Box volume. The net internal volume, without any stuffing. Stuffed boxes can be from 10% to 25% smaller, based upon bandwidth of the signal and the stuffing density.
- Fb, the resonant frequency of the system. This is the nominal tuning frequency of the enclosure.
- Anechoic F3, the half power point of the system, in full space, referenced to the peak output.
- Anechoic F8, the apparent half volume point of the system, in full space, referenced to the peak output.
- Anechoic >105 dB SPL, the frequency above which the system is capable of greater than 105 dB SPL in full space.
- In Room F3, the predicted half-power point of the system, referenced to the peak output, when corner loaded in a $50m^3$ room (4m x 5.5m by 2.3m).
- In Room F8, the predicted apparent half volume point of the system, referenced to the peak output, when corner loaded in a $50m^3$ room (4m x 5.5m by 2.3m).
- In Room > 105 dB SPL, the frequency above which the system is capable of greater than 105 dB SPL, when corner loaded in a $50m^3$ room (4m x 5.5m by 2.3m).

Note that the frequencies are referenced to the peak output of the system, not the nominal output. Thus, increasing any peak in the output frequency response, e.g. increasing the Q of a sealed box, can result in a higher actual F3, not a lower F3. We choose to use this reference (peak versus nominal) because for higher Q systems, the nominal output is not achieved until several hundred Hertz (>200 Hz). We believe this is not applicable to subwoofers. As such, the F3 should be referenced to the highest value below 100 Hz.

When placed in a room, effective bass output increases considerably due to room loading. Thus 105 dB SPL is selected as a "reference" level representing a very loud signal. This is also the typical maximum SPL level required by several home theater specifications (notably THX).

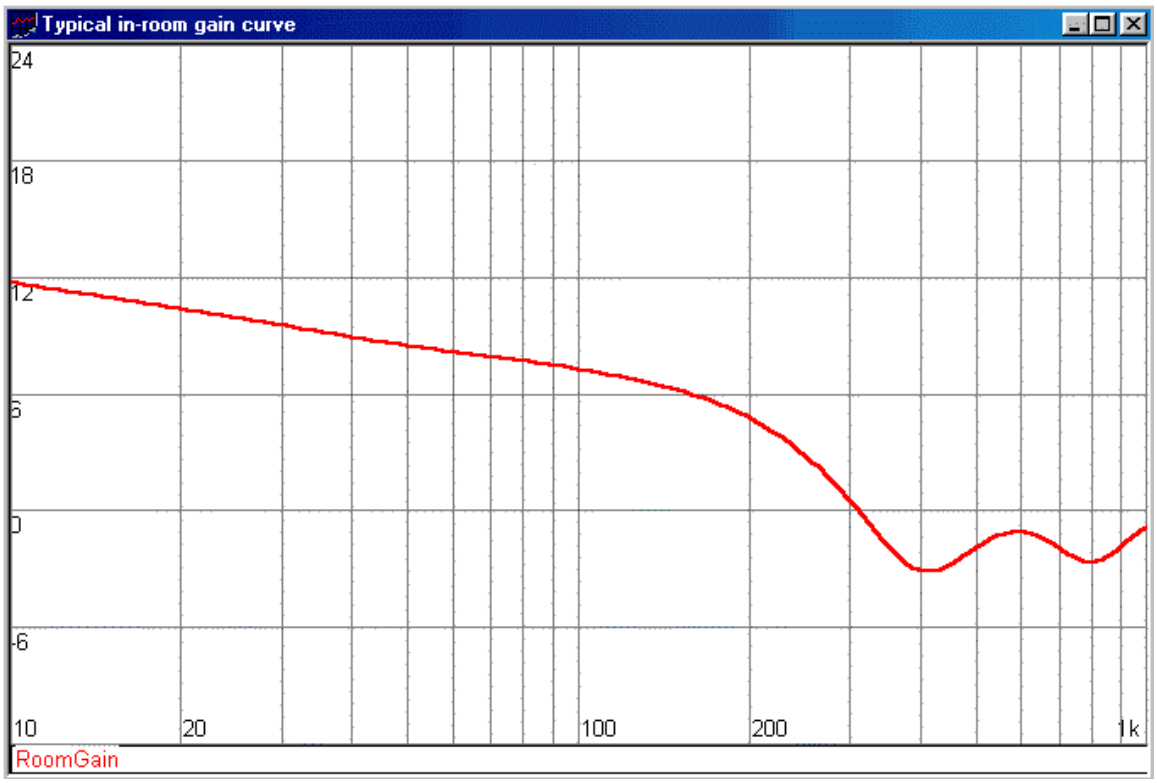
2.4 Room Gain

The room has a tremendous effect on the low-frequency performance of any loudspeaker system. This effect is generically referred to as room gain, although it is actually composed of two parts: boundary gain and pressure-vessel gain.

Boundary gain arises from the driver operating not in free space but in a constrained space. That is, the driver is typically referred to as operating in 4π space free air, but ½π space in-room. Each boundary cuts the total "space" in half. Thus the floor boundary cuts the space to 2π, the side wall cuts the space to π, and the rear wall finishes reducing the space to ½π (also referred to as eighth space).

Pressure vessel gain comes from the fact that, below a certain frequency, the room no longer supports standing waves; that is, the room is too small to contain a full wavelength. Contrary to legend, this does NOT mean the room cannot "reproduce" such waves! Rather, it means that the room is completely and uniformly pressurized by the input signal (we can't call it a wave, since it's not a full wave). This results in a gain in acoustic pressures in the room that grows as the frequency decreases (more gain for lower frequencies). Note that this effect is the primary reason one can get tremendous bass levels within a car; the gain starts at a very high frequency, thanks to the small size of the pressure vessel (car interior).

We model and use both of these effects when determining the typical in-room performance of a system. Our models are based upon application of accepted physical principles, as well as confirmation with empirical measurements in several different rooms. The curve we use for estimating room gain is:

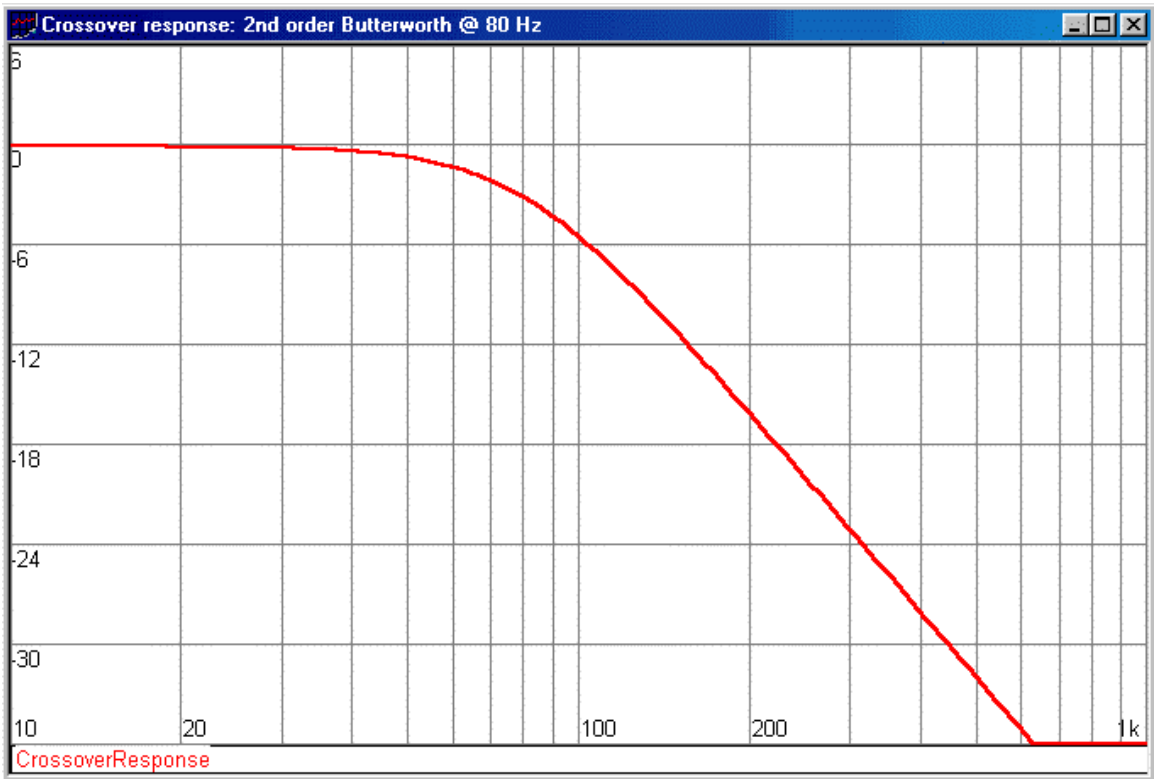


As you can see, such a room and placement within the room can provide 10 dB of gain at 20 Hz. In addition, the total gain starts well above the typical crossover point (above 300 Hz).

2.5 Crossover Effects

The crossover plays a major effect in the total bandwidth of the system as well. In fact, the crossover not only limits the overall high-end bandwidth extension, but can also significantly impact the peak output of the system (for crossovers with a Q less than or equal to 0.707).

We choose to use a standard LFE crossover for modeling. This crossover is nominally a second order low-pass design, with a corner frequency of 80 Hz, and a Q of 0.707 (second order Butterworth at 80 Hz). The effective response of such a filter is:



As you can see, the response of the crossover is never above 0 dB; in fact, above 20 Hz, the crossover is actually reducing the output of the nominal system. It is because of this effect that one needs to consider the crossover when designing a subwoofer system.

3 Alignment Comparisons

Because of the mid-value EBP (~55), Shiva is a natural driver for use in vented boxes. Additionally, the lower Vas, as compared to other 12" subwoofers on the market, allows use of less-intrusive box sizes.

Vented alignments offer many advantages when compared to sealed enclosures, including lower cone motion around tuning, reduced distortion around tuning, increased power handling around tuning, extended bandwidth, and other effects.

However, there is one significant drawback to vented systems; namely, driver unloading below tuning. At frequencies lower than roughly 1/3rd octave below the tuning frequency (Fb), the box completely "unloads" the driver. The vent is operating 180° out of phase with the driver. The net effect is that bass response rapidly drops, and so does power handling. Driver excursion greatly increases below Fb. For this reason, many suggest using a high pass or "rumble" filter with a vented design.

Using the DUMAX T/S parameters for Shiva as given in section 1.3, the following vented boxes are recommended:

Parameter	Adire Alignment	SBB4	EBS
Box Volume	85 liters	95 liters	142.5 liters
Fb	20 Hz	22.2 Hz	18.1 Hz
Vent Dimensions	FP-3: 8 3/8" center	FP-4: 12" center	FP-4: 12" center
Anechoic F3	24.4 Hz	23.0 Hz	17.8 Hz
Anechoic F8	17.8 Hz	18.3 Hz	14.5 Hz
Anechoic >105 dB SPL	17.8 Hz	18.8 Hz	16.3 Hz
In Room F3	22.4 Hz	21.8 Hz	16.3 Hz
In Room F8	16.3 Hz	17.3 Hz	13.7 Hz
In Room >105 dB SPL	14.5 Hz	15.4 Hz	13.7 Hz

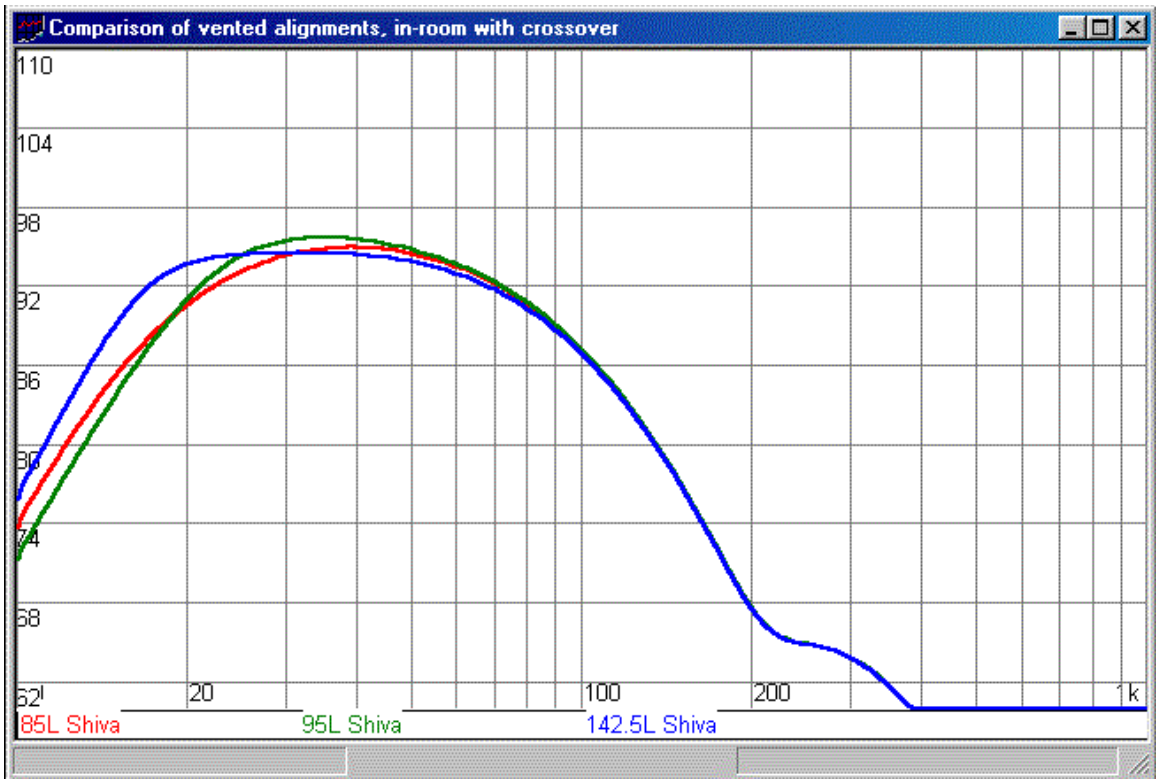
NOTE: The vent dimensions list the recommended flared port vent kit and the length of the center tube, to reach the desired tuning frequency. To use a straight pipe, add 5" length to the listed center length.

The Adire Alignment provides very good bass extension in a small box. The F8 in both cases is well below 20 Hz, while SPL crosses 105 dB at 17.8 Hz anechoic, and 14.5 Hz in-room. This alignment promises very good bass extension and very good SPL capability, in a 3 cubic foot net box.

The SBB4 is the standard SBB4 alignment. It attempts to maximize flat response, down to the lowest frequency possible. As such, it has the fastest fall-off rate of all three systems. This is seen by the ratio of F3/F8 for anechoic or in-room responses. The SBB4 does offer flatter response, while still providing F8s below 20 Hz, and more than 105 dB SPL out over the standard audible (20 Hz and up) range.

The EBS alignment is the deep-bass champion, thanks to its largest box. All other things being equal, a larger box will yield more efficiency (SPL out for power in), more bass extension, or some of both. In this case, we chose to maximize bass extension with the 18.1 Hz tuning. The result is a system with F8s in the low teens anechoic or in-room. Additionally, maximum SPL output is very high, with more than 105 dB SPL on tap from 13.7 Hz and up, in-room. If the box size (5 cubic feet, net) is acceptable, the EBS alignment should be seriously considered.

The following graph displays the typical in-room (corner-loaded) response of each system, when driven through the above-defined room-gain and crossover curves. Delivered power is 1W into a nominal 4Ω load ($2V_{RMS}$ drive level). The Adire Alignment box is shown in red. The SBB4 box is shown in green. The EBS box is shown in blue.



As can be seen, the EBS alignment is clearly the bass extension champion. Response is essentially flat from crossover to 16 Hz, with little peaking or "bowing" in the response. Additionally, the EBS has a major advantage in terms of SPL output down in the sub-20 Hz range. If the size of the box can be tolerated, or organ music is the reproduction goal, this is the recommended alignment.

The SBB4 alignment is as one would expect: designing for flat anechoic response will result in a peak in the in-room response. Here we see the peak clearly at ~35 Hz. Response above that follows the crossover, while response below falls off faster than the other systems. This is the tradeoff for extended anechoic bandwidth: faster roll-off below tuning. However, this response is still very attractive. In fact, this response is near-ideal for most home theater applications. The system can reach to below 20 Hz effectively, and the extra energy in the 30-40 Hz range adds a good amount of punch to the audio.

The Adire Alignment is an interesting option. It provides a response that's flatter than the SBB4, and has a slightly lower F3 in-room, as well as additional sub-20 Hz output. Additionally, its response is flatter than the SBB4, as measured between 20 Hz and 80 Hz. Overall, the Adire Alignment is a good compromise alignment for systems designed for both home theater and music. While the Adire Alignment does not have the extra midbass punch of the SBB4, which can be exciting for home theater reproduction, the flatter and more extended response is very welcome in high end audio applications.

4 Designs

Following are cabinet designs for the three shown alignments. For all designs, we use the following "assembly" layout:

1. Front and back panels are completely outset
2. Top and bottom are inset with respect to the front and back, and outset with respect to the sides
3. Sides are completely inset

All cabinets assume the use of ¾" thick stock. Use of different thickness stock will require a change in the external dimensions of the cabinet. Note that the internal dimensions are the critical values; changes in stock thickness must be accounted for in the final external dimensions.

Input cup/terminal locations are not shown. It is left to the final end-user to determine the best location for these components, as your final physical installation will be the guiding rule here.

All cabinets are designed assuming no polyfill is used. Polyfill can result in the cabinet appearing larger than it really is; however, the additional polyfill may decrease the effective Q of the system, resulting in a final alignment different from that shown here. As such, use polyfill with caution when building PR systems. Measurement systems are highly recommended for experimenting with polyfill.

All three cabinets are downfiring driver and vent. This is because the Shiva driver actually has more linear excursion when downfiring. Thus this orientation will actually result in the maximum linear output for the system, at any SPL level.

4.1 85L Vented Shiva Box

The 85 liter Vented Shiva box is the Adire Alignment. The vent is our FP-3 flared vent kit, with a center tube length of 8 3/8", for a final tuning of 20 Hz. This alignment yields a good compromise between bandwidth and midbass punch, which makes it ideal for combined home theater/audio reproduction needs.

4.1.1 Cut Lists

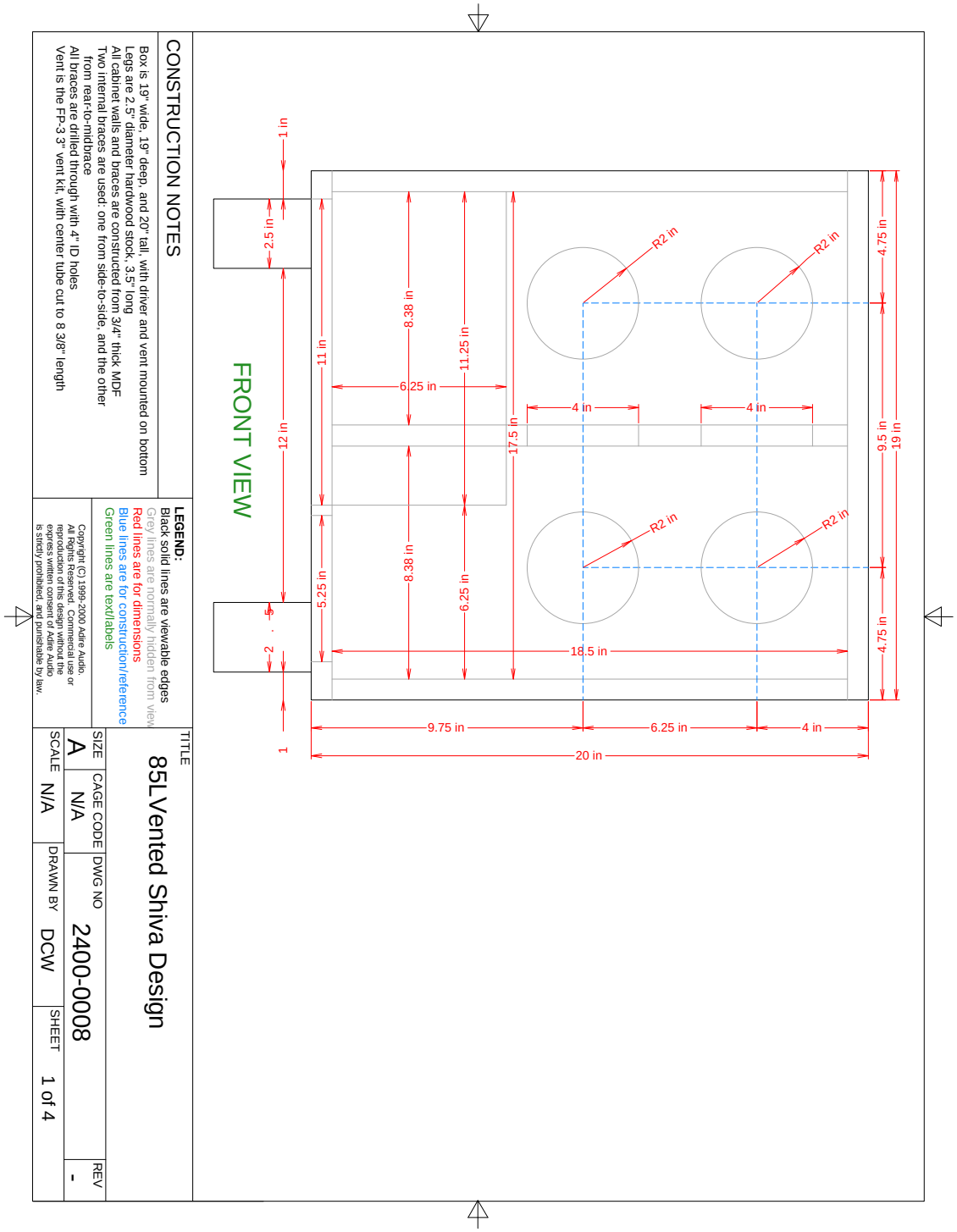
4.1.1.1 Panel cuts

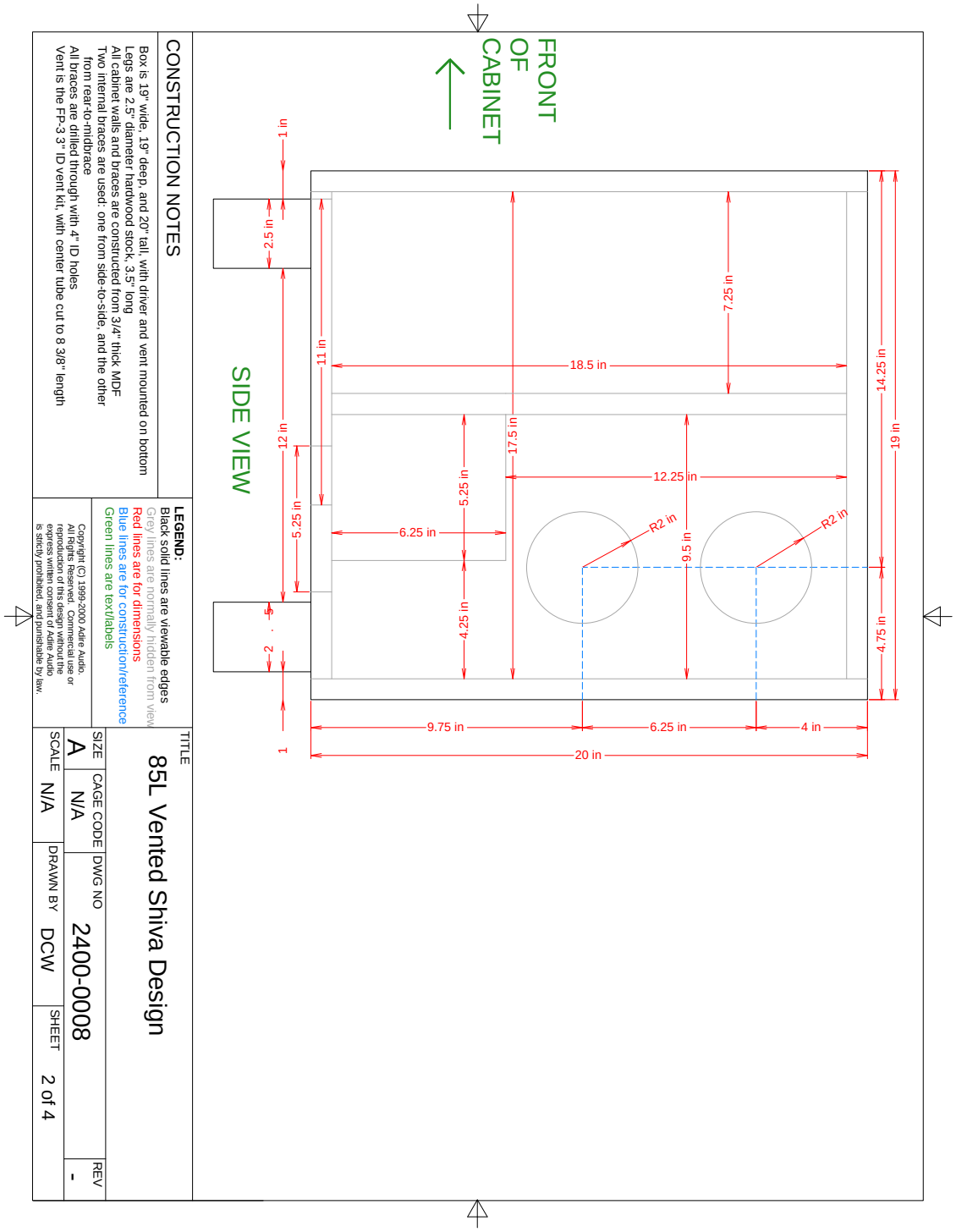
QTY	SIZE	USE
2	19" x 20"	Front and back panels
2	19" x 17.5"	Top and bottom panels
3	18.5 x 17.5"	Side panels, midbrace
1	18.5" x 9.5"	Rear brace

4.1.1.2 Hole/baffle cuts

QTY	SIZE	USE
1	11" diameter	Driver mounting; cut in bottom panel
1	5.75" diameter	Flared vent kit opening; cut in bottom panel
1	11.25" x 6.25"	Driver clearance; cut in midbrace
1	5.25" x 6.25"	Driver clearance; cut in rear brace
6	4" diameter	Internal air flow; four in midbrace, two in rear brace

4.1.2 Drawings





CONSTRUCTION NOTES

Box is 19" wide, 19" deep, and 20" tall, with driver and vent mounted on bottom
Legs are 2.5" diameter hardwood stock, 3.5" long
All cabinet walls and braces are constructed from 3/4" thick MDF
Two internal braces are used: one from side-to-side, and the other from rear-to-midbrace
All braces are drilled through with 4" ID holes
Vent is the FP-3 3" ID vent kit, with center tube cut to 8 3/8" length

LEGEND:
Black solid lines are viewable edges
Grey lines are normally hidden from view
Red lines are for dimensions
Blue lines are for construction/reference
Green lines are text/labels

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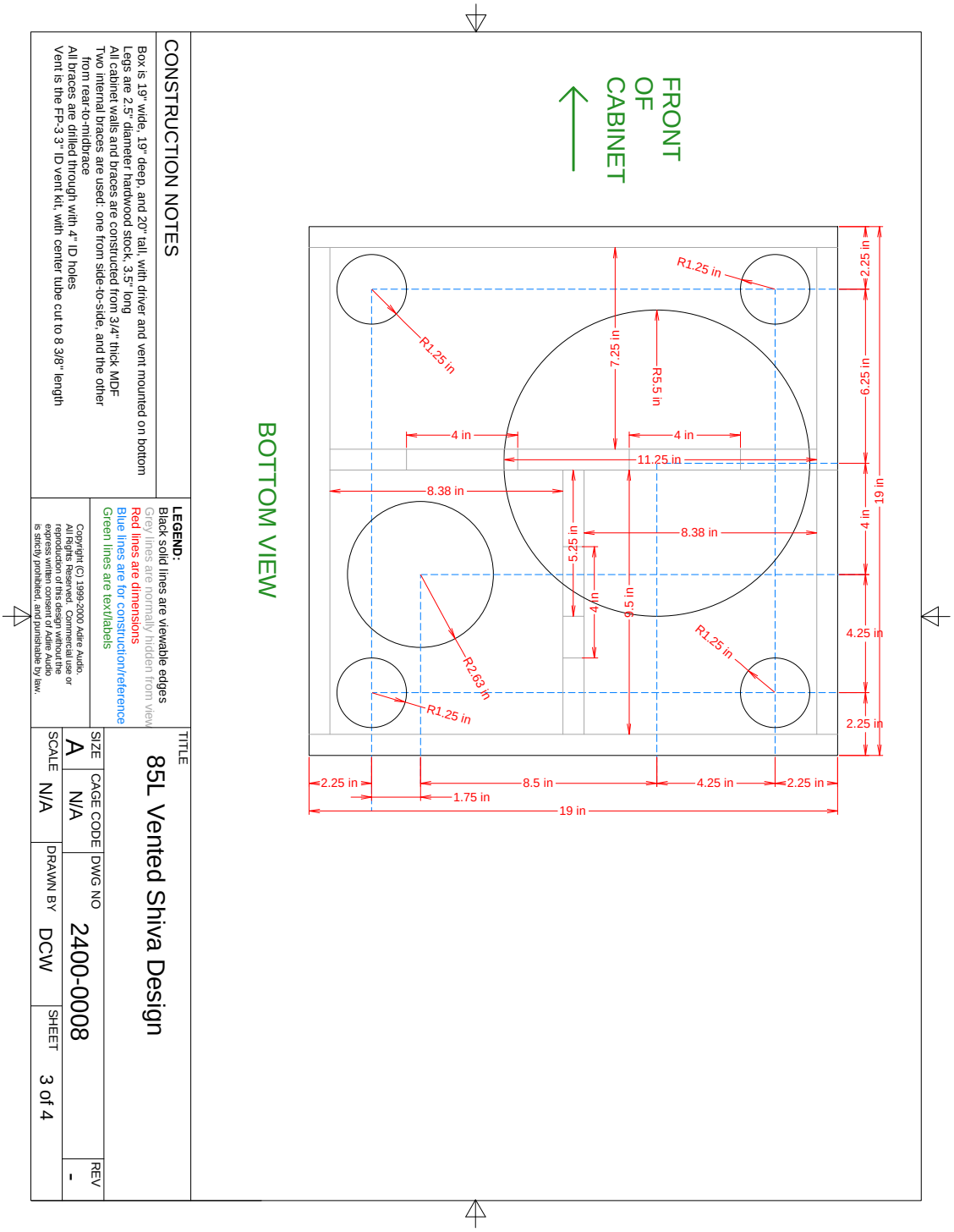

CONSTRUCTION NOTES

Box is 19" wide, 19" deep, and 20" tall, with driver and vent mounted on bottom
Legs are 2.5" diameter hardwood stock, 3.5" long
All cabinet walls and braces are constructed from 3/4" thick MDF
Two internal braces are used: one from side-to-side, and the other from rear-to-midbrace
All braces are drilled through with 4" ID holes
Vent is the FP-3 3" ID vent kit, with center tube cut to 8 3/8" length

LEGEND:
Black solid lines are viewable edges
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Green lines are text/labels

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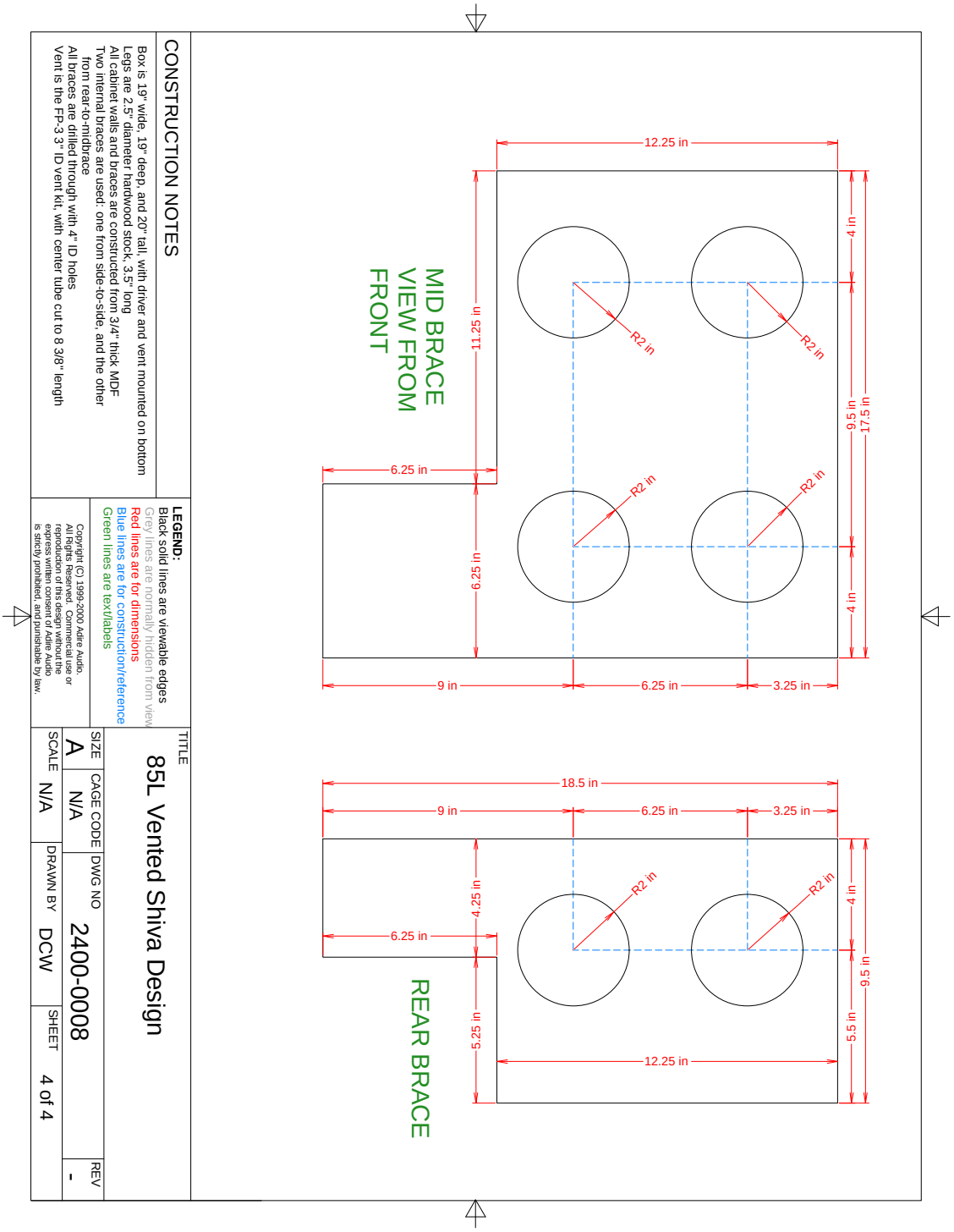

CONSTRUCTION NOTES

Box is 19" wide, 19" deep, and 20" tall, with driver and vent mounted on bottom
Legs are 2.5" diameter hardwood stock, 3.5" long
All cabinet walls and braces are constructed from 3/4" thick MDF
Two internal braces are used: one from side-to-side, and the other from rear-to-midbrace
All braces are drilled through with 4" ID holes
Vent is the FP-3 3" ID vent kit, with center tube cut to 8 3/8" length

LEGEND:
Black solid lines are viewable edges
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TITLE: 85L Vented Shiva Design

4.2 95L Vented Shiva Box

The 95 liter Vented Shiva box is the SBB4 alignment. The vent is our FP-4 flared vent kit, with a full-length 12" center tube, for a final tuning of 22.2 Hz. This alignment provides extra in-room midbass punch, which is well suited for home theater applications.

4.2.1 Cut Lists

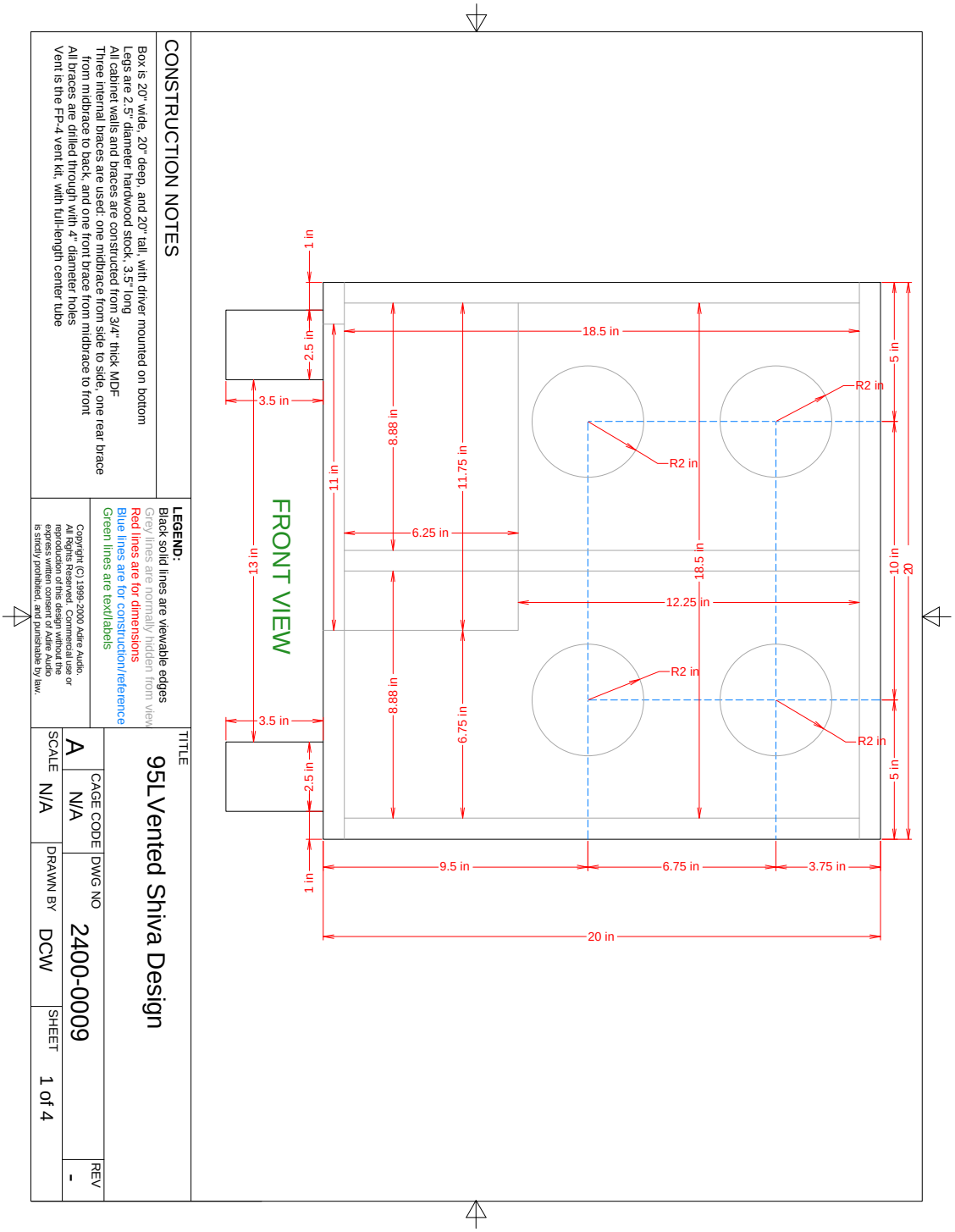
4.2.1.1 Panel cuts

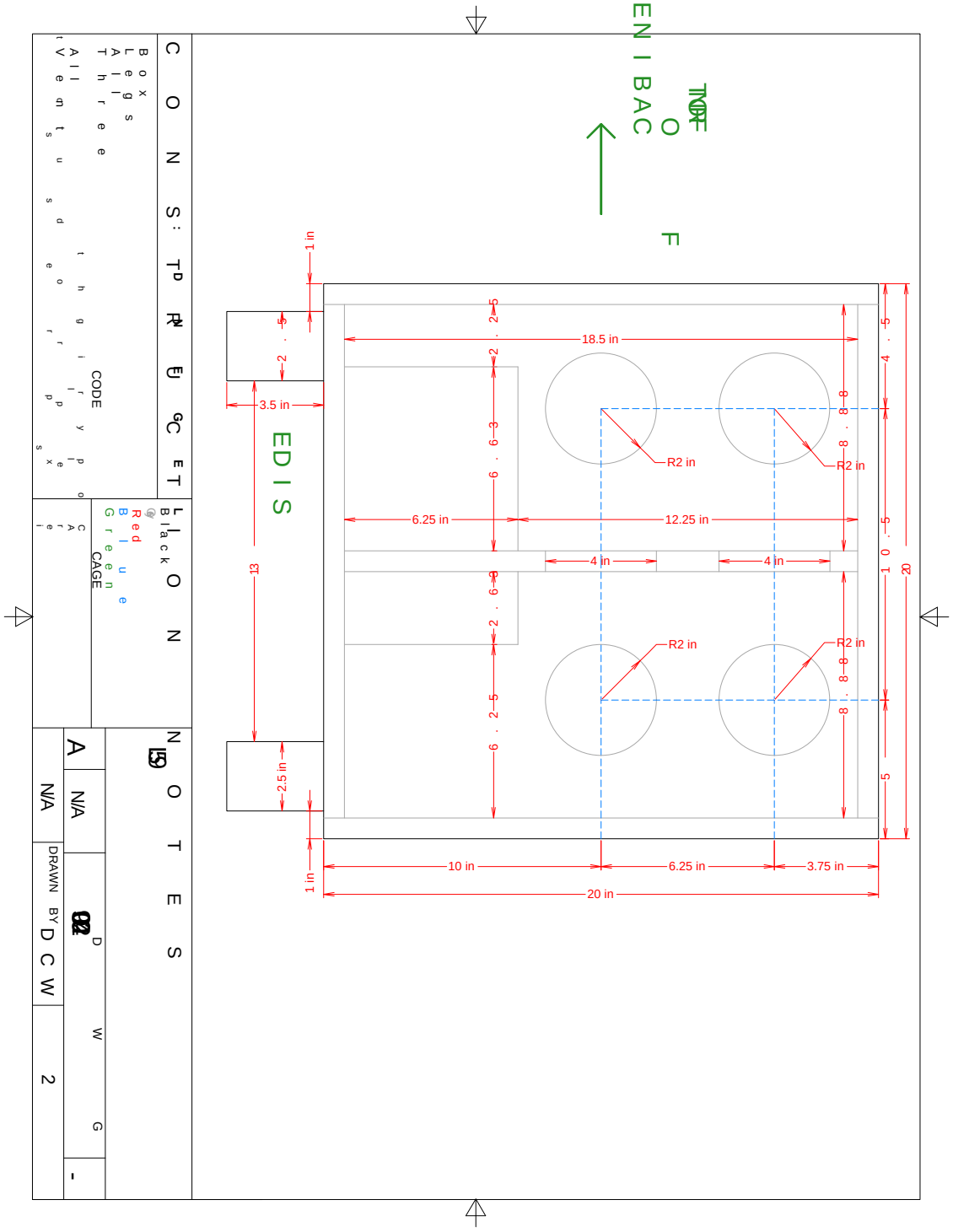
QTY	SIZE	USE
2	20" x 20"	Front and back panels
2	20" x 18.5"	Top and bottom panels
3	18.5" x 18.5"	Side panels, midbrace
2	18.5" x 8.875"	Front and rear brace

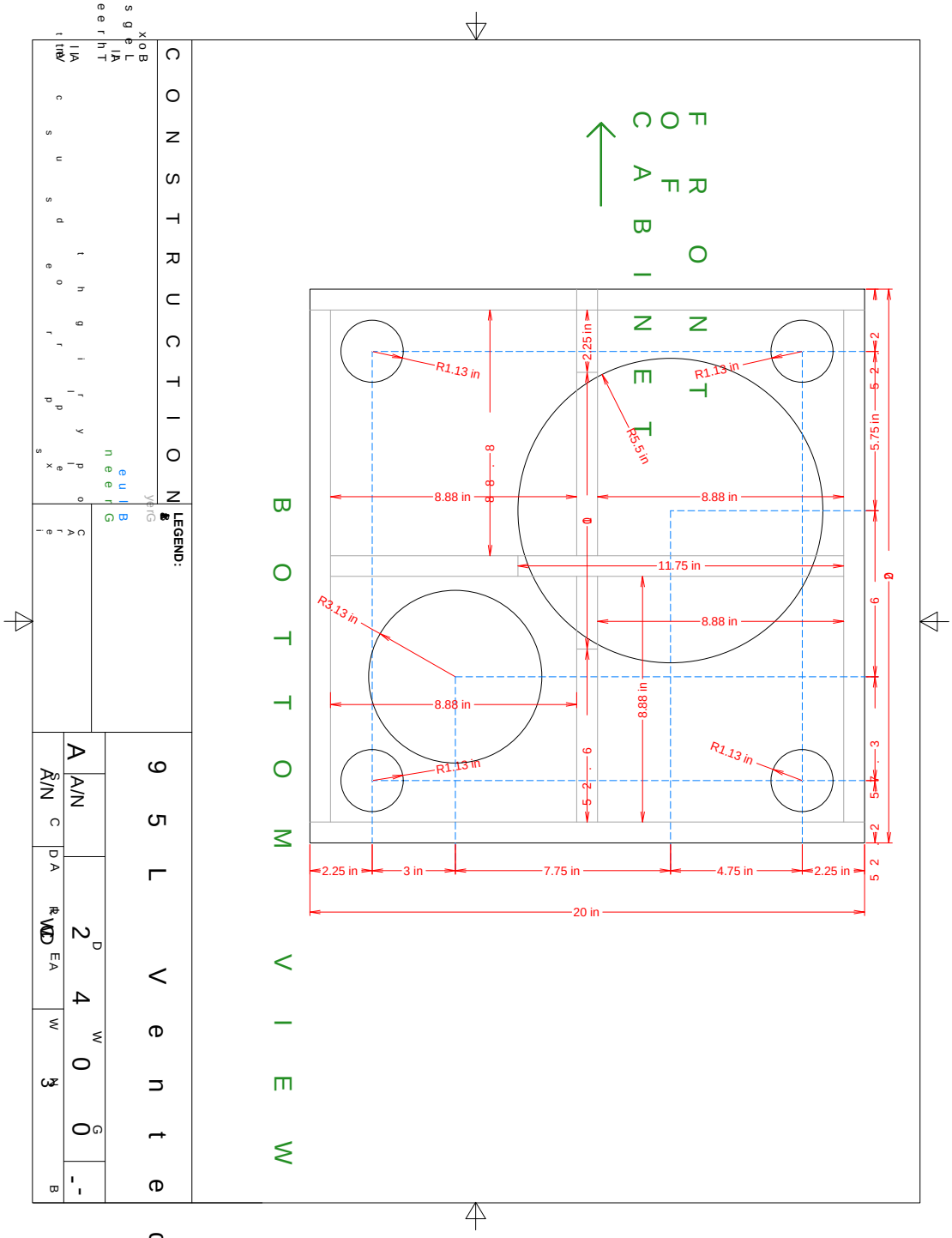
4.2.1.2 Hole/baffle cuts

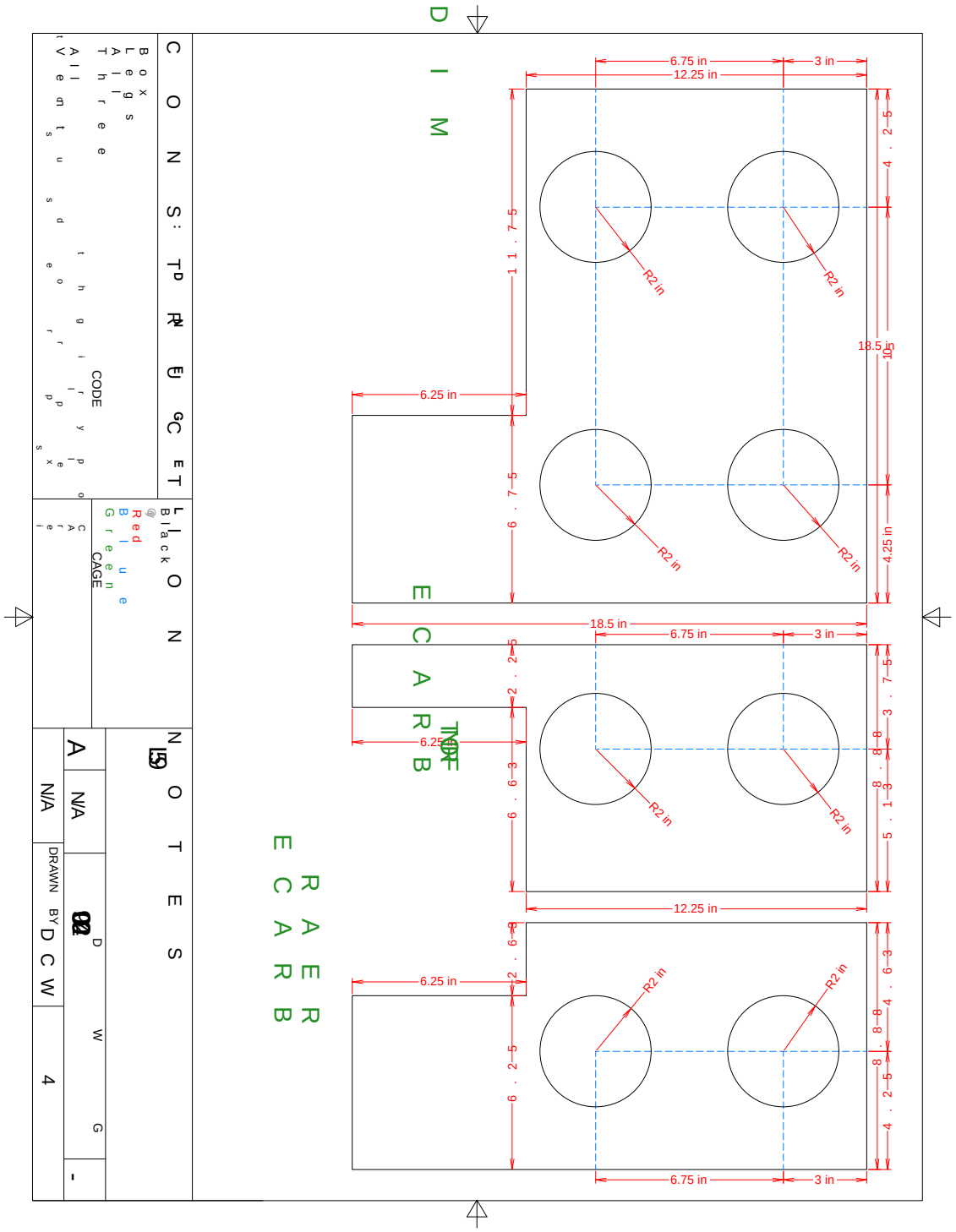
QTY	SIZE	USE
1	11" diameter	Driver mounting; cut in bottom panel
1	6.75" diameter	Flared vent kit opening; but in bottom panel
8	4" diameter	Internal air flow; four in midbrace, two each in front and rear brace
1	11" x 6.25"	Driver clearance cutout in midbrace
1	6.25" x 6.625"	Driver clearance cutout in front brace
1	6.25" x 2.625"	Driver clearance cutout in rear brace

4.2.2 Drawings









4.3 142.5L Vented Shiva Box

The 142.5 liter PR Shiva box is the EBS alignment. The vent is our FP-4 flared vent kit, with a full-length 12" center tube, for a final tuning of 18.1 Hz. This box, while physically the largest of the three designs shown in this paper, yields the lowest frequency extension, as well as the widest and flattest in-room response. If the size of the cabinet (5 cubic foot net) can be tolerated, the EBS will reward you with maximum SPL and bass extension. The EBS is the ideal subwoofer for organ and very demanding home theater applications.

4.3.1 Cut Lists

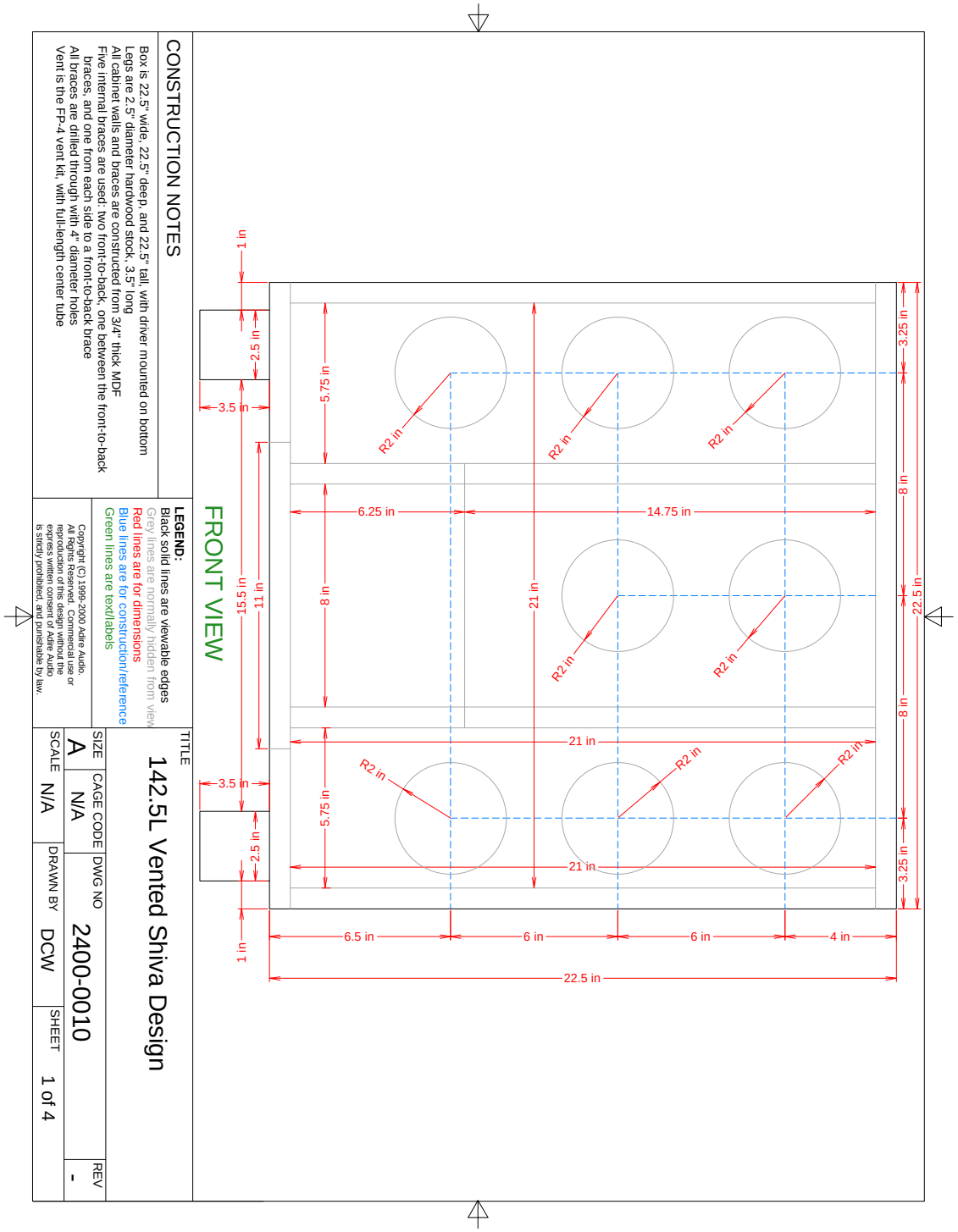
4.3.1.1 Panel cuts

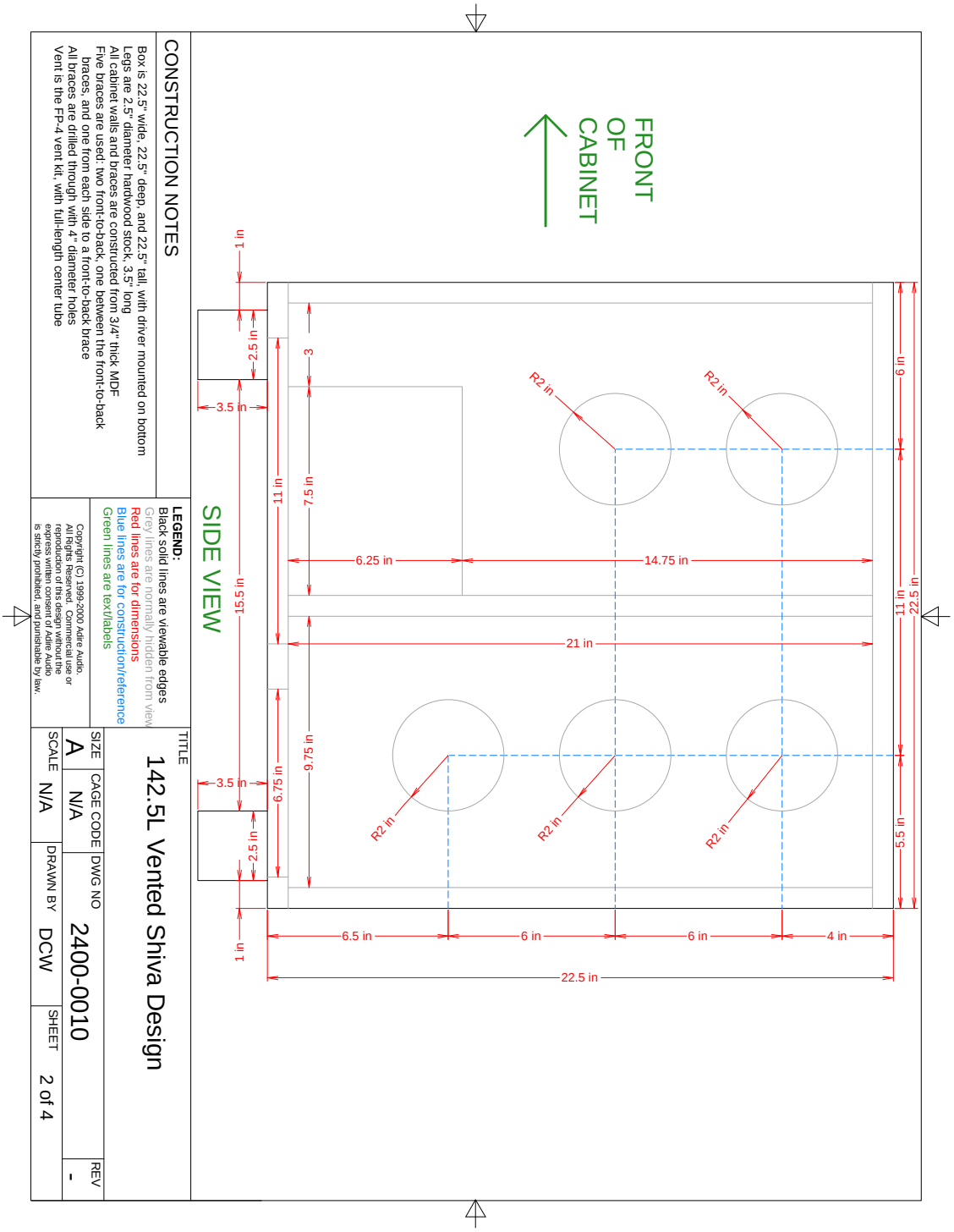
QTY	SIZE	USE
2	22.5" x 22.5"	Front and back panels
2	22.5" x 21"	Top and bottom panels
4	21" x 21"	Side panels, front-to-back braces
2	21" x 5.75"	Side to front-to-back-brace braces
1	14.75" x 8"	Mid brace

4.3.1.2 Hole/baffle cuts

QTY	SIZE	USE
1	11" diameter	Driver mounting; cut in bottom panel
1	6.75" diameter	Vent hole; cut in bottom panel
18	4" diameter	Internal air flow; five in each front-to-back brace, three in each side brace, two in mid brace
2	7.5" x 6.25"	Driver clearance; one in each front-to-back brace

4.3.2 Drawings





CONSTRUCTION NOTES

Box is 22.5" wide, 22.5" deep, and 22.5" tall, with driver mounted on bottom
Legs are 2.5" diameter hardwood stock, 3.5" long
All cabinet walls and braces are constructed from 3/4" thick MDF
Five braces are used: two front-to-back, one between the front-to-back braces, and one from each side to a front-to-back brace
All braces are drilled through with 4" diameter holes
Vent is the FP-4 vent kit, with full-length center tube

LEGEND:
Black solid lines are viewable edges
Grey lines are normally hidden from view
Red lines are for dimensions
Blue lines are for construction/reference
Green lines are text/labels

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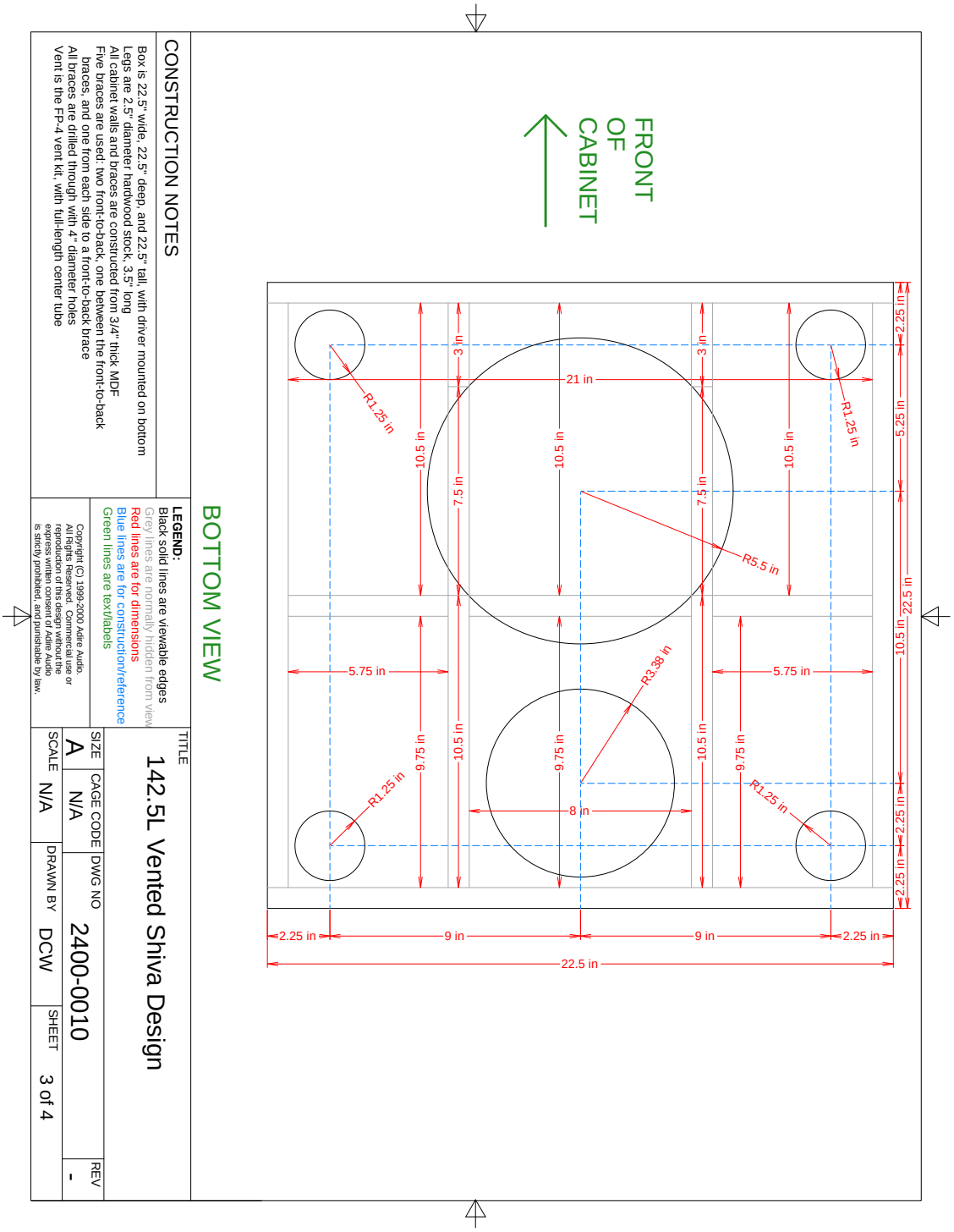

CONSTRUCTION NOTES

Box is 22.5" wide, 22.5" deep, and 22.5" tall, with driver mounted on bottom
Legs are 2.5" diameter hardwood stock, 3.5" long
All cabinet walls and braces are constructed from 3/4" thick MDF
Five braces are used: two front-to-back, one between the front-to-back braces, and one from each side to a front-to-back brace
All braces are drilled through with 4" diameter holes
Vent is the FP-4 vent kit, with full-length center tube

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