New DIY ER18 MTM Floor Standing Speaker

Mass-Loaded Transmission Line cabinet

There is a new DIY design that bears a very strong family resemblance to both the Salk SongTower and its big brother the Salk HT2-TL. The woofer and tweeter choice and the crossover design of this DIY speaker is the work of Dennis Murphy who designed many of the Salk products including the SongTower and the HT2-TL. Paul Kittinger designed the mass-loaded transmission line (MLTL) cabinet for this new speaker, using the same method as he used for those two very successful Salk models.

The obvious differences between this new design and the Salk speakers are the drivers and the DIY cabinet. The woofer is a relatively new one from SEAS, the ER18RNX http://www.madisound.com/catalog/product_info.php?products_id=8181. It is an 18 cm (7") woofer with a paper cone doped with reed fibers. The Salk SongTower originally used the smaller SEAS CA15RLY (5½") coated paper cone woofer, and now uses the SEAS ER15RLY, also with a reed/paper cone. The Salk HT2-TL uses the much more expensive SEAS W18 (7") magnesium alloy cone woofer. Although the ER18 woofer costs a bit more than the smaller ER15, it's about half the price of the W18. With larger woofers than in the SongTower, this MTM design should produce deeper bass, almost as deep as in the HT2-TL.

Dennis Murphy designed two versions of this speaker using the same woofers and cabinet, allowing builders a choice between two different tweeters. One is the excellent Dayton RS28F-4 silk dome tweeter, and the other is the Fountek NeoCD3-v2 ribbon tweeter. More about the tweeters appears below.

The ER18 woofer cone material, reed (bamboo?) fibers mixed into paper pulp, is said to make a stiffer cone material than with paper alone, but not as stiff as metal cones. The result is a driver somewhere between the smooth sound of paper and the more detailed sound of metal. I can easily imagine the SEAS engineers testing the sound from cones made with various amounts of reed fiber added to the paper before they came up with a successful formula. There are other woofers around with paper cones doped with other manmade fibers like glass, Kevlar, or carbon fibers, but I don't like most of them. Although I haven't heard them all, most seem to suffer from prominent resonances that make them sound wrong to my ears. This doped paper design from SEAS seems to be a better application of an idea that always was attractive in theory but seemed to rarely work well in practice.

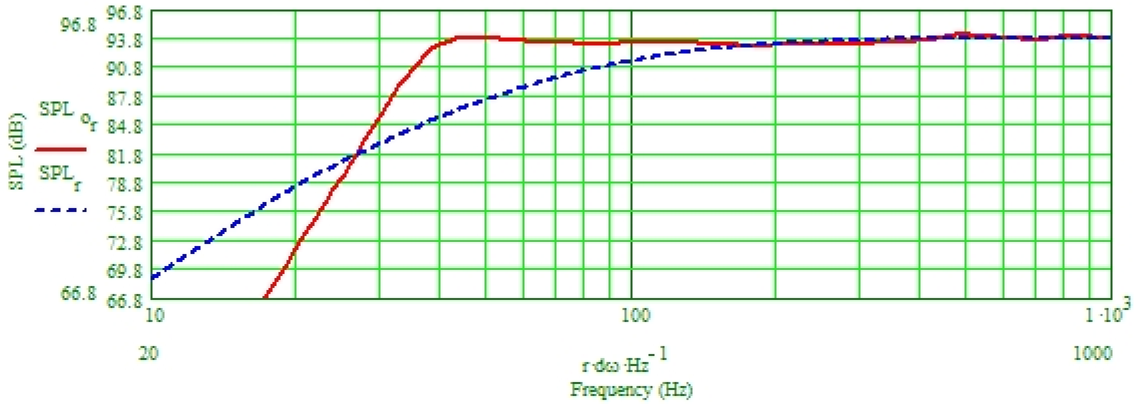
Seas developed the ER18 to be a long-throw high-fidelity woofer. Along with the reed/paper cone, it comes with well designed moving parts that contribute to a smooth, extended frequency response. The magnet/voice coil assembly includes a bumped back plate, and a long and light weight copper-clad aluminum voice coil that allows extreme coil excursion with low distortion. A copper anti-distortion ring below the T-shaped pole piece further reduces non-linear and modulation distortion. The basket is extremely stiff and stable, made from die-cast aluminum alloy, which keeps the components in better alignment than stamped steel. With all these features, the ER18 promises to deliver deep bass and detailed midrange with a smooth overall frequency response combined with low distortion. It very well might be better than the quite good woofers in the SongTower, and almost as good as the excellent ones in the HT2-TL.

Please note – the following designs are for personal or amateur use only. Any attempt to market or commercialize these plans for profit by anyone other than the designers will be subject to legal action.

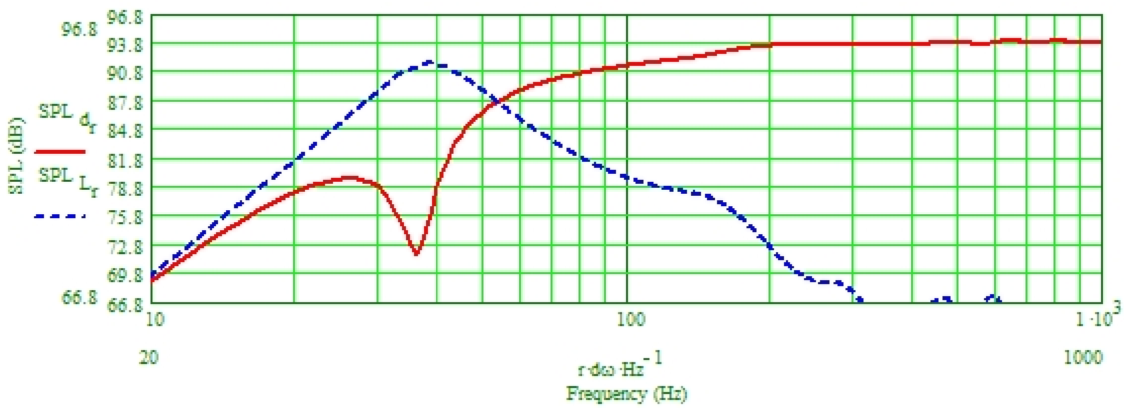
Cabinet Design (by Paul Kittinger)

Paul Kittinger came up with a quarter wave-tuned ported tower, also known as a mass loaded quarter wave transmission line. He modeled the bass response using software developed by Martin J. King. Paul used the Thiele/Small parameters measured by John Krutke (Zaph Audio) for the ER18RNX (Q_{ts} = 0.35, V_{as} = 26.3 L, and F_s = 39.1 Hz) instead of the somewhat different values provided by the manufacturer.

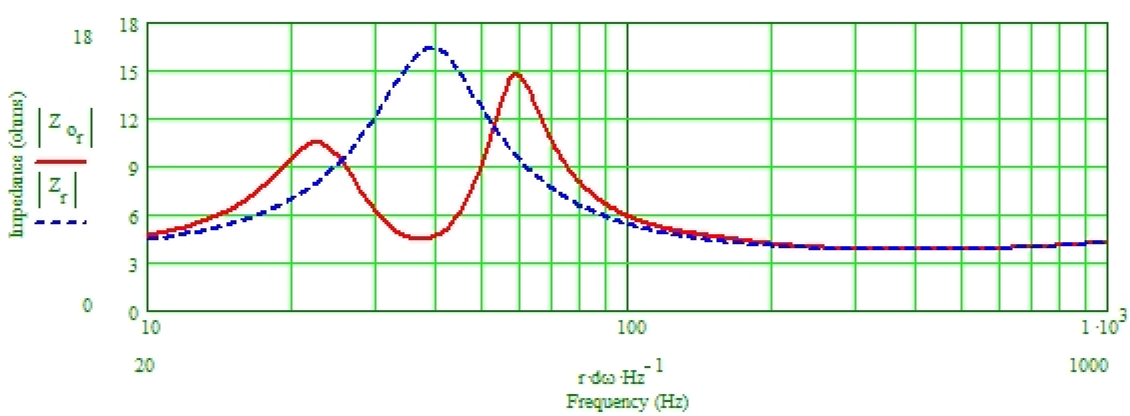
Paul's cabinet has internal dimensions 7½" wide × 12" deep × 43" tall. The port tube is 3" diameter × 2¾" long, centered 3" above the internal cabinet floor. The cabinet is stuffed with 17-18 ounces of polyester fiberfill confined to the upper 22" of the interior. With two ER18 woofers, it is predicted to have a F_3 of 35 Hz and can produce useful sound as low as 31 Hz. The predicted overall bass response is shown in the graph below (solid red line).



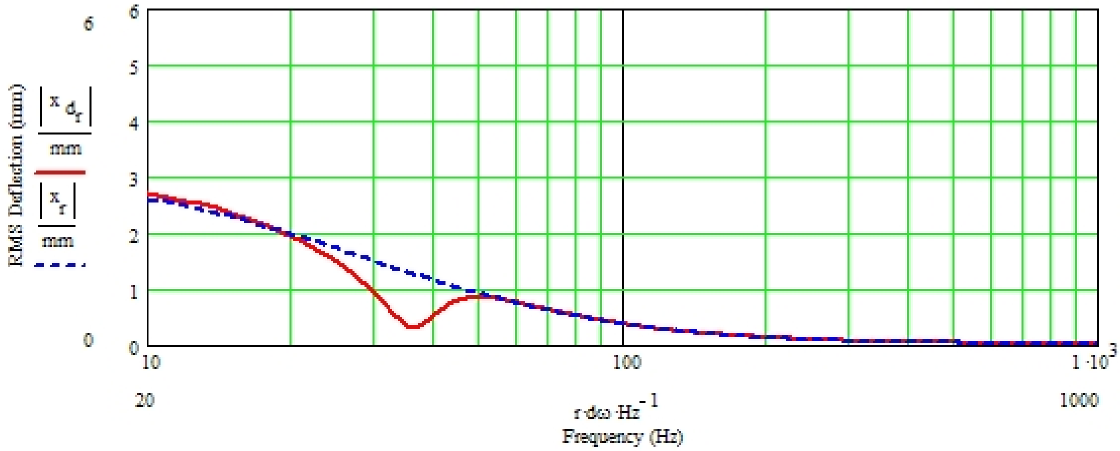
The 2[nd] graph shows the predicted bass response for the two woofers (solid red line) and the port (dashed blue line).



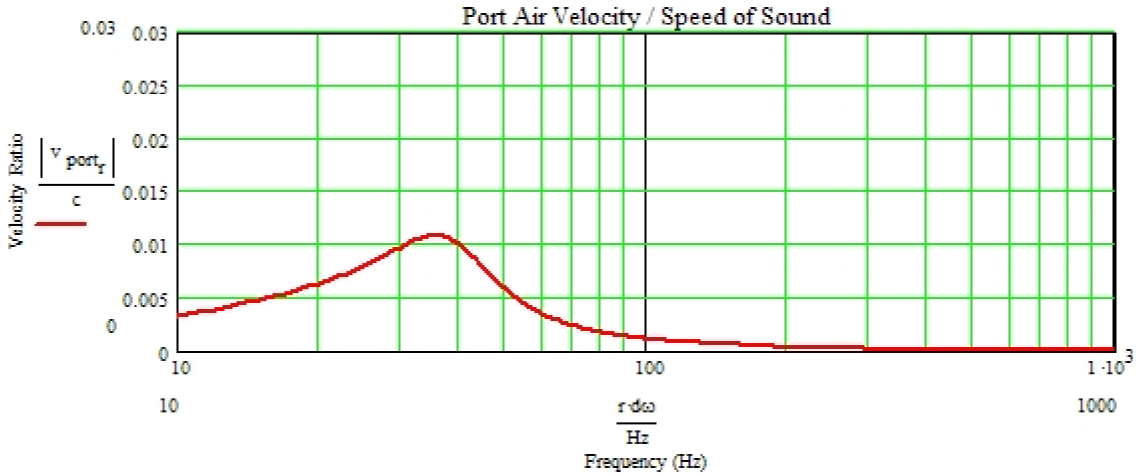
The 3[rd] graph shows the predicted system impedance (solid red line). The tuning frequency of the cabinet, about 37 or 38 Hz, is indicated by the trough between the two red peaks. It is easy to also see that this speaker's impedance goes as low as 4 ohms, but not any lower.



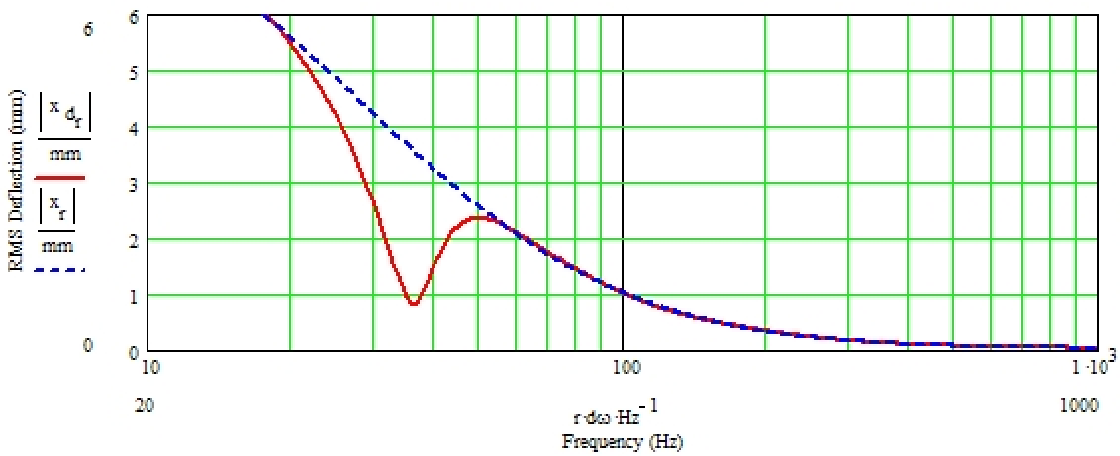
At 2.83 volts (2.1 watts at 4 ohms) input, the drivers' predicted excursion is <3 mm (solid red line):



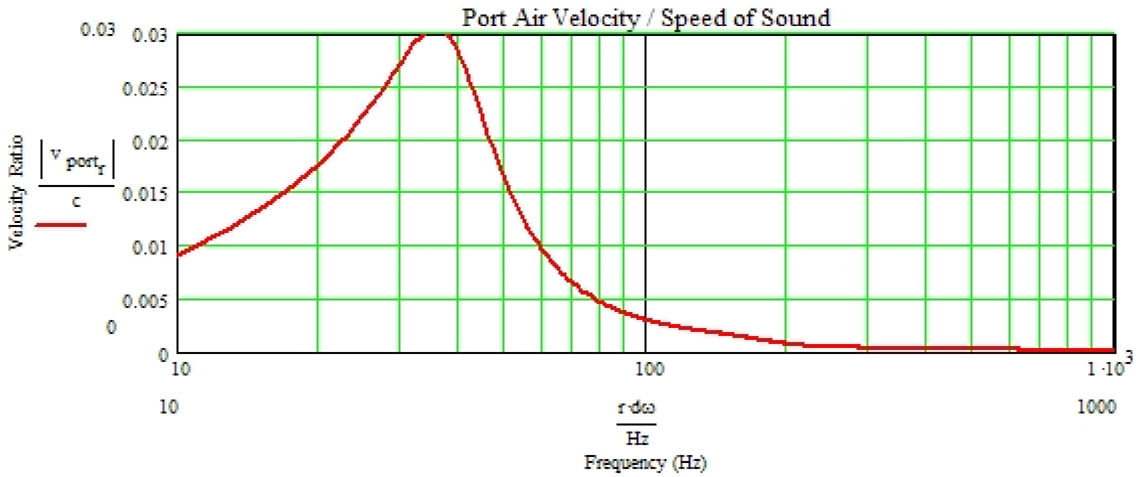
At this same input level of 2.83 volts, the predicted port air velocity is just over 1% the speed of sound with a 3" diameter non-flared port:



At 8 volts (16.8 watts), the woofers reach their maximum excursion (X_{max}) of 6 mm at 18 Hz (solid red line), but at all higher frequencies they move <6 mm:



At this same elevated input, the port's air velocity should be just over 3% the speed of sound, and the system should generate about 103 dB. With a rear mounted port, there should be no audible port noise:



Cabinet Details

Below is a table showing (on the left) internal and external cabinet dimensions, assuming you use ¾" thick sheet goods. On the right, is a suggested cut list. I have assumed the braces will be mounted in ¼" deep dados cut into the sides. You could instead cut 6 pieces the same size as the top and bottom (7½" × 12"), and butt-mount them between the sides, or use biscuits if you have a biscuit cutter.

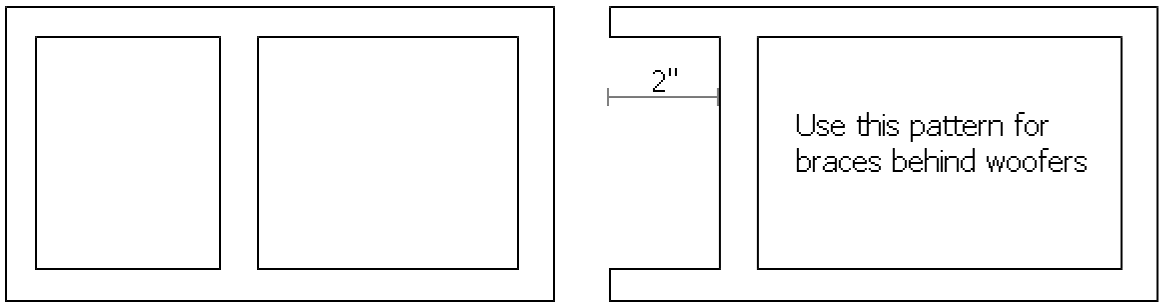
Cabinet Dimensions	Width	Depth	Height
Internal	7½"	12"	43"
External (¾" MDF)	9"	13½"	44½"

¾" MDF	#	Length	Width
Sides	2	44½"	12"
Top & Bottom	2	7½"	12"
Braces (dadoed)	4	8"	12"
Front & Back	2	44½"	9"
Outer Front Baffle	1	22"	9"
Shadow Piece	1	12¾"	8¼"
Base	1	17"	11"

	Flange Diameter			**Flange Depth**		**Thru Hole Diameter**		
	mm	inch	inch	mm	Inch	mm	inch	inch
Fountek tweeter	110	4.33	4⅜	5	0.197	61×87	2.40×3.43	2⅜×3 $^{7}/_{16}$
Dayton tweeter	104.5	4.11	4⅛	3.4	0.134	73.2	2.88	2⅞
Seas woofer	176	6.93	6 $^{15}/_{16}$	5.2	0.205	145.2	5.72	5¾

- Mount the center of the tweeter 10" below the interior cabinet ceiling, or 10¾" (if ¾" MDF is used) below the external top edge.
- Mount the tweeter's center ¾" away from the vertical center on the front baffle. Mirror image the off-set tweeters in a pair of speakers.
- Center the woofers vertically, as close as possible above and below the tweeter.
- Flush mount all drivers. See the above table for flange diameters and depths.
- The cut list includes an optional Outer Front Baffle that is approximately 22" × 9". In the diagram, it is shown in pale red. Glue this piece to the upper part of the cabinet front. If each of these pieces are ¾" thick, the part of the front baffle supporting the drivers will be 1½" thick. This piece may have rounded edges to decrease edge diffraction.

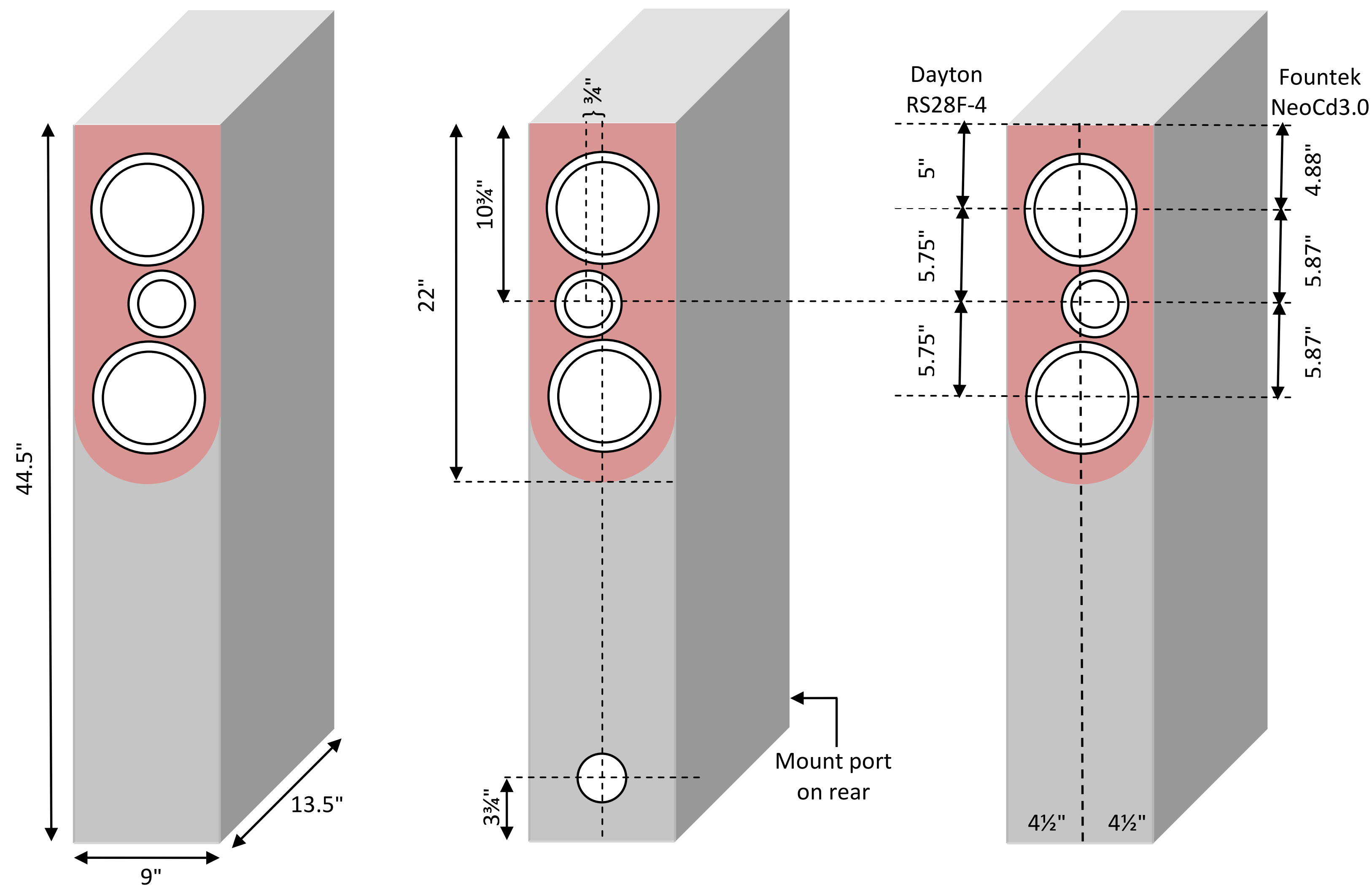
- Mount the 3" internal diameter port tube on the back of the cabinet, horizontally centered, with its center 3" above the cabinet floor, or 3¾" above the external bottom edge. The port's length, if not flared, is 2¾" long. If flared on one end, make it 3¼" long. If flared on both ends make it 3¾" long.
- Cut out window panes in the 4 internal braces (made from ¾" MDF) so they do not impede the air flow inside the cabinet. The center bar should be asymmetrically placed, not centered. These braces should be 8" × 12" if dado mounted, or 7½" × 12" if butt mounted. For the two braces that go behind the woofers, use the pattern on the right.



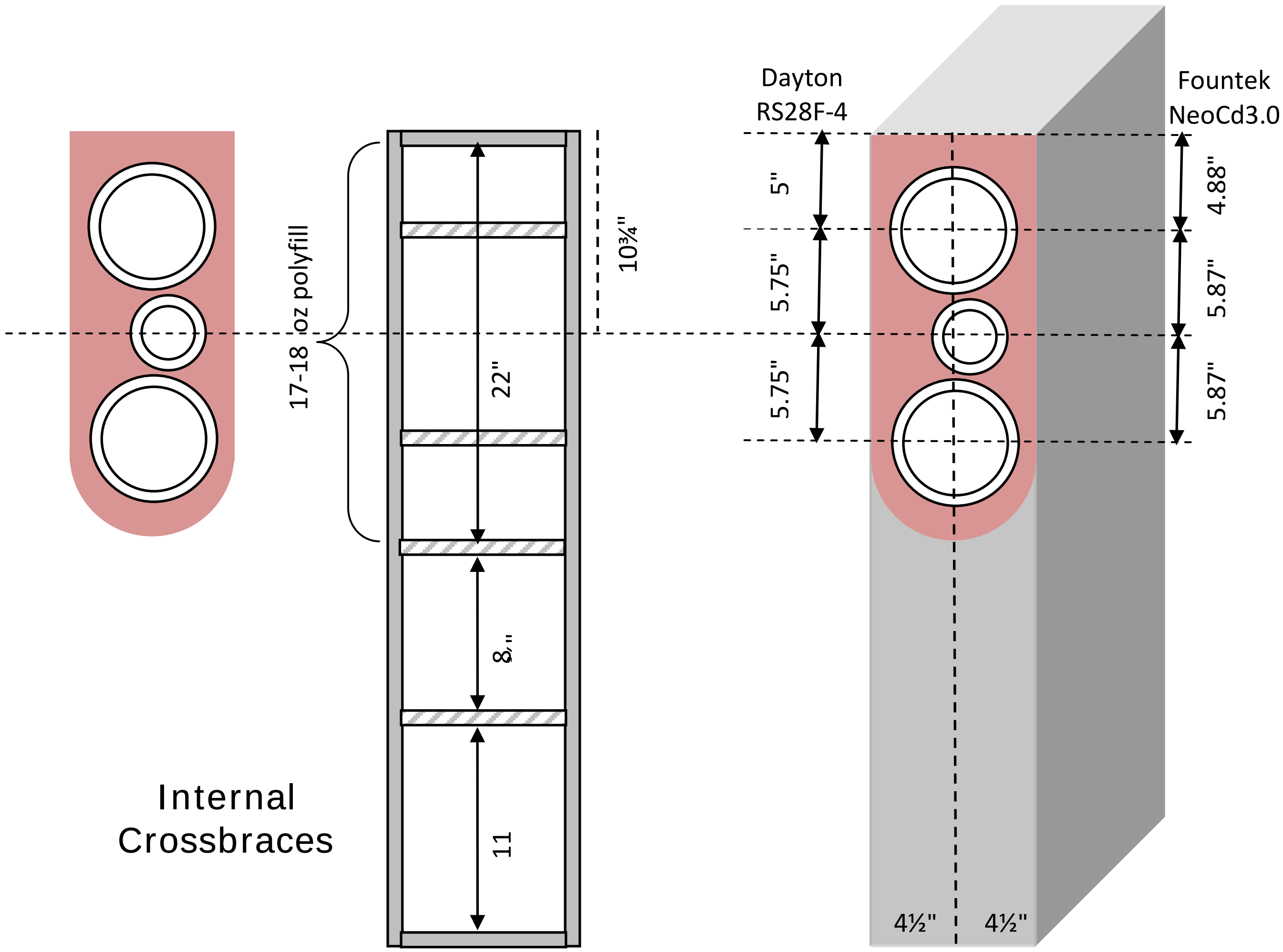
- Distribute these 4 internal braces unevenly along the height of the cabinet:
  1. Behind the upper woofer
  2. Behind the lower woofer
  3. With its top surface 22" below the interior cabinet ceiling (it will support the fiberfill)
  4. 8⅜" below the stuffing support brace (11⅛" above the interior floor).

  Space the braces along the height of the cabinet so that distances between them are not even multiples of each other, such as 4" and 8". Instead, try to make these distances multiples of the square root of 2 (roughly 1.4).
- Fill the upper 22" of the inside of the cabinet (from the top of the cabinet to 3rd brace) with 17-18 oz. polyester fiberfill, evenly distributed, for a stuffing density of about 1 lb/ft³. Paul said to use polyester or acousta-stuf. Generic polyester fiberfill (pillow stuffing) is cheaper and widely available where sewing or craft supplies are sold. Acousta-stuf is more expensive (1 lb bag for $10.80 at Parts Express). Do not use other materials like fiberglass. Paul does not mention using any inner cabinet wall lining. It isn't needed or desired for this design.

All the above details are important to this MLTL cabinet design. Change any of these details and you risk losing the outstanding bass performance of the design. People who've built typical vented bass reflex cabinets may be used to the idea that the dimensions can change so long as the internal cabinet volume does not, or that the port can be relocated with little effect on the bass response. In a MLTL design you cannot do this – it is not a typical bass reflex design. The length of the cabinet as well as the placement of the drivers and port produces a targeted quarter-wave resonance that reinforces the low frequency response. Paul has varied all these features to optimize the overall bass response, the shape of the roll-off curve, and the bass extension.



44.5"
9"
13.5"
¾"
10¾"
22"
3¾"
Mount port
on rear
Dayton
RS28F-4
5"
5.75"
5.75"
Fountek
NeoCd3.0
4.88"
5.87"
5.87"
4½"
4½"



17-18 oz polyfill
22"
10¾"
8
11
Internal Crossbraces
Dayton RS28F-4
Fountek NeoCd3.0
5"
5.75"
5.75"
4.88"
5.87"
5.87"
4½"
4½"

Crossover Designs (by Dennis Murphy)

Dennis Murphy designed two versions of this speaker, allowing a choice between two different tweeters. Both designs have two ER18 woofers and the same cabinet, but one uses a dome tweeter and the other a ribbon tweeter. For each tweeter there is a different crossover designed specifically for it. Note that the woofers and cabinet are identical for each design, but the woofer crossover sections of each design are also different. Schematic diagrams and parts lists for both designs are included below. The crossovers assume these details:

- Two SEAS ER18RNX woofers per cabinet, and one tweeter per cabinet:

  Dayton RS28F-4 silk dome tweeter (total parts cost **$551** as of August 2010)

  Fountek NeoCD3-v2 ribbon tweeter (total parts cost **$630**)

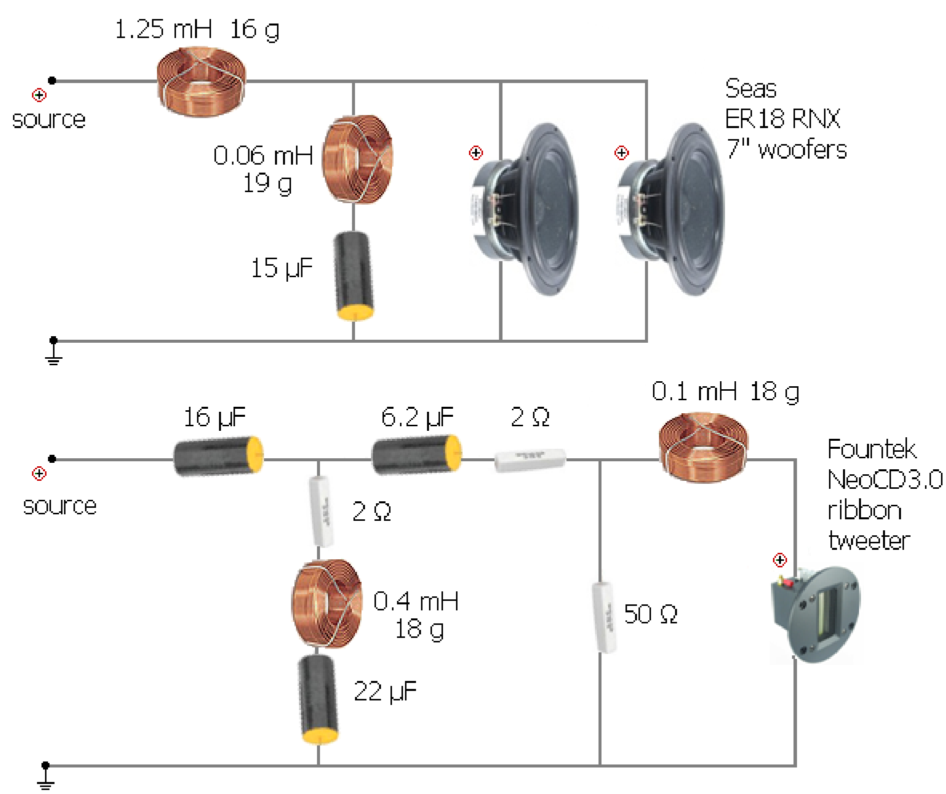
- Follow all details of crossover schematic diagram. It is OK if the crossover components you purchase vary by ±10% from the specified values in the diagram.
- Use the driver locations on front baffle as described above in the cabinet details. Make sure the front baffle outside width is 9". All drivers are meant to be flush-mounted.

Some of the parts on the list, such as binding posts and cabinet spiked feet are my own personal choices. Feel free to change those if you wish, as they will have no direct effect on speaker performance. I priced the various parts (as of August 2010) with info from:

Parts Express (PE) http://www.parts-express.com/home.cfm?raid=1&rak=parts_express
Madisound (Mad) http://www.madisound.com/index.php.

If you can get any of these parts at a better price from other vendors, feel free to do so.

ER18 MTM with Fountek NeoCd3.0 Ribbon Tweeter



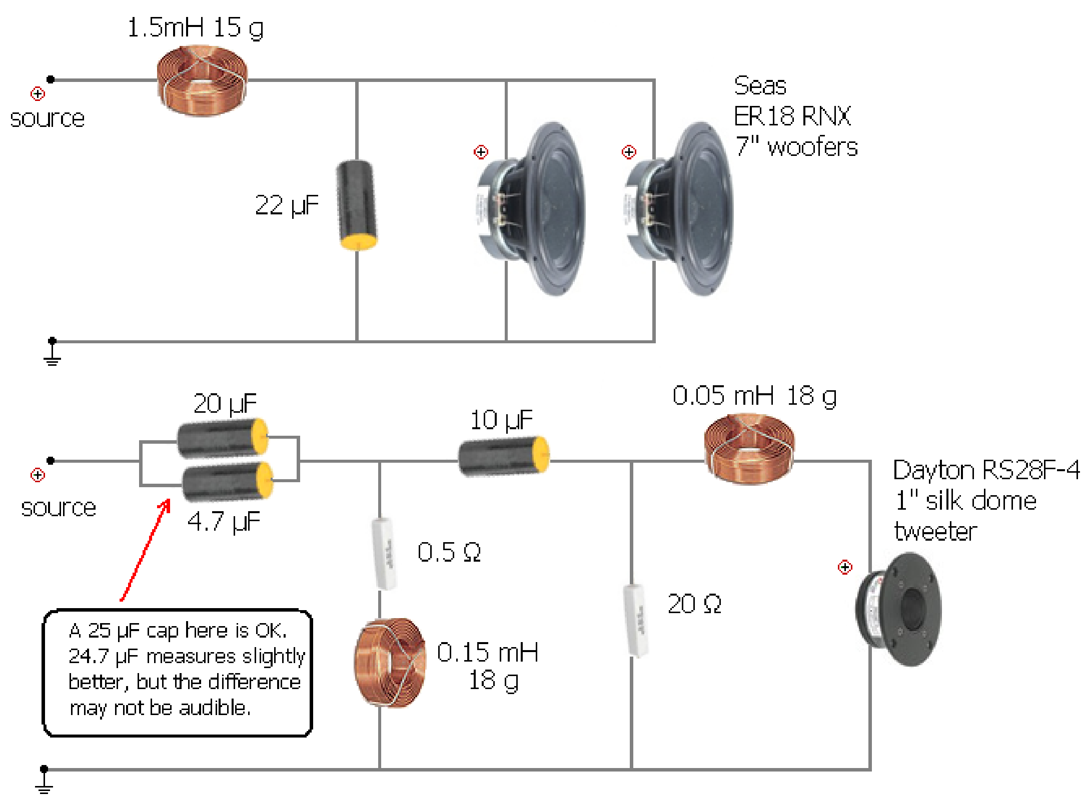
Parts: ER18 MTM with Fountek NeoCd3.0 Ribbon Tweeter

Part	Vendor	Part #	#	$ Each	$ Total
Seas ER18RNX woofer	Mad	H1456	4	81.40	$325.60
Fountek NeoCd3.0M	Mad	NeoCd3.0M-BLK	2	81.80	$163.60
Binding post	Mad	BG-POSTB	2	3.20	$6.40
Binding post	Mad	BG-POSTR	2	3.20	$6.40
Port tube 3" ID × 4½" L no flare	PE	260-404	2	2.09	$4.18
Dayton DSS3-G Gold 1⅜" Spikes (4)	PE	240-676	2	9.94	$19.88
1.25 mH 16 g Sidewinder 0.38Ω	Mad	SW1.25	2	13.15	$26.30
0.10 mH 19 g air core 0.1Ω unwind wire to 0.06 mH	Mad	.1MHL	2	3.40	$6.80
0.1 mH 18 g Jantzen 0.13Ω	PE	255-202	2	3.52	$7.04
0.4 mH 18 g Jantzen 0.29Ω	PE	255-224	2	5.40	$10.80
6.2 µF capacitor (Dayton)	PE	027-427	2	2.68	$5.36
15 µF capacitor (Dayton)	PE	027-432	2	5.49	$10.98
16 µF capacitor (Bennic)	Mad	BP16	2	6.30	$12.60
22 µF capacitor (Solen)	Mad	CP22	2	7.90	$15.80
25 Ω resistor	PE	004-25	4	0.98	$3.92
2 Ω resistor	PE	004-2	4	0.98	$3.92
Total					**$629.58**

Note:

- A **0.06 mH inductor** was not available. I unwound wire from a 0.1 mH inductor until it measured 0.06 mH. In my hands, unwinding XX coils of (inches of) wire was enough. I cut off the excess wire and sanded off the clear enamel insulation from the new end.
- I could not find a **50 Ω resistor**. I used two 25 Ω resistors wired in series with each other.

ER18 MTM with Dayton RS28F-4 1" Dome Tweeter



Parts   ER18 MTM with Dayton RS28F-4 1" Dome Tweeter

Part		**Part #**	**#**	**$ Each**	**$ Total**
Seas ER18RNX woofer	Mad	H1456	4	81.40	$325.60
Dayton RS28F-4 Silk Dome	PE	275-140	2	49.75	$99.50
Binding post	Mad	BG-POSTB	2	3.20	$6.40
Binding post	Mad	BG-POSTR	2	3.20	$6.40
Port tube 3" ID × 4½" L no flare	PE	260-404	2	2.09	$4.18
Dayton DSS3-G Gold 1⅜" Spikes (4)	PE	240-676	2	9.94	$19.88
1.5 mH 15 g air core 0.38Ω	PE	255-426	2	16.58	$33.16
0.05 mH 18 g air core 0.09Ω	PE	255-200	2	2.93	$5.86
0.15 mH 18 g air core 0.16Ω	PE	255-206	2	3.91	$7.82
25 µF capacitor (Dayton)	PE	027-438	2	6.59	$13.18
22 µF capacitor (Solen)	Mad	CP22	2	7.90	$15.80
10 µF capacitor (Dayton)	PE	027-428	2	4.12	$8.24
20 Ω resistor	PE	004-20	2	1.25	$2.50
0.51 Ω resistor	PE	004-.51	2	1.25	$2.50
Total					**$551.02**

Note:

- **24.7 µF capacitor** – 20 µF and 4.7 µF capacitors, wired in parallel with each other, behave the same as one capacitor with a value of 24.7 µF. A single 25 µF capacitor can be substituted. Dennis said 24.7 µF looked slightly better in his computer simulation, but he doubts if 25 µF will be audibly different that 24.7 µF.
- The **0.5 Ω resistor** in the tweeter circuit is real. I tried, without success, to find a smaller gauge 0.15 mH inductor coil whose extra DC resistance could allow me to eliminate the 0.5 Ω resistor.

Richard Swerdlow