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More Box, Less Sawdust

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How to build the biggest box from any rectangle of MDF.

When it comes to subwoofers, it's usually true that bigger boxes mean deeper bass. When a friend asked me to build a powered sub for his garage, I wondered what was the biggest box I could make from a half-sheet of MDF (medium-density fiberboard). I was able to come up with a design that used every square inch of the half-sheet, except for the sawdust.

Even more surprising, I found that it's possible to design a box from any size rectangle of wood that uses every square inch of material and gives the largest possible box (**Fig. 1**).

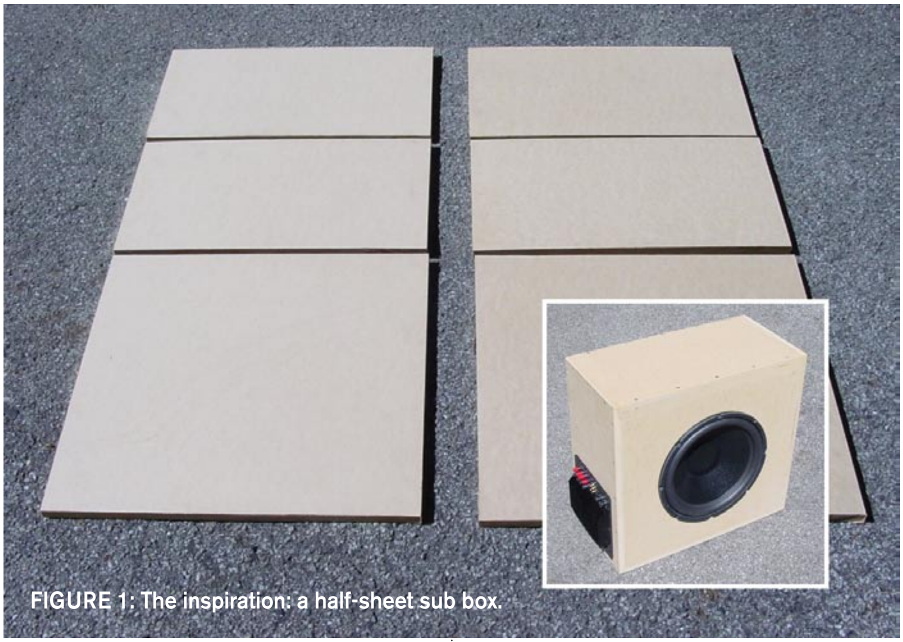

FIGURE 1: The inspiration: a half-sheet sub box.

THE DESIGN PROCEDURE

Figure 2 shows the three types of cutting patterns I will consider. Which cutting pattern is best depends on the length-to-width ratio of the rectangle of wood you're starting with. In general, the type-A cutting pattern is best for near-square panels, the type-C cutting pattern is best for long and thin panels, and the type-B pattern is best for in-between panels. You can choose to use a sub-optimum cutting pattern if you prefer the finished box dimensions that it provides, but at the price of reduced box volume. This will become clearer with some examples.

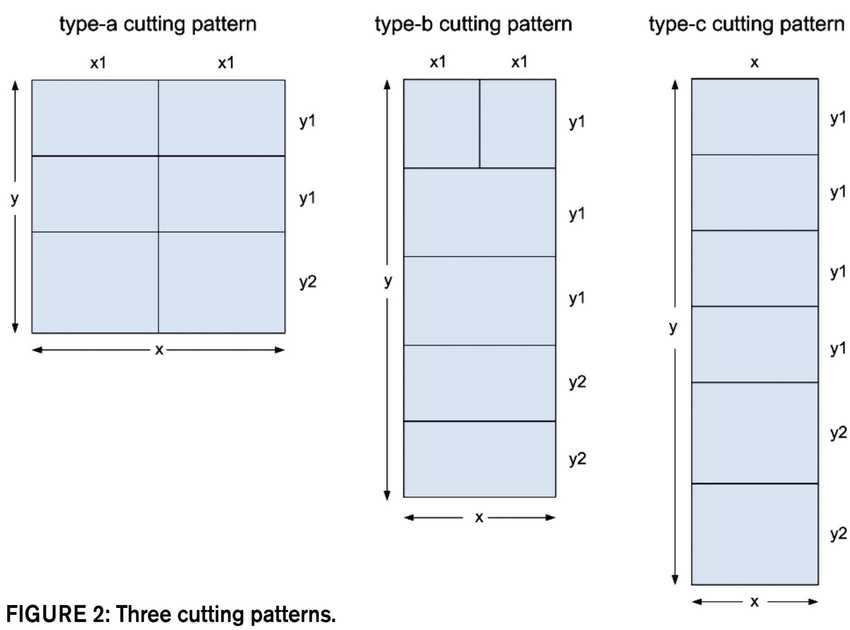

FIGURE 2: Three cutting patterns.

For each of the three cutting patterns, x represents the short dimension and y represents the long dimension of the original panel. The values

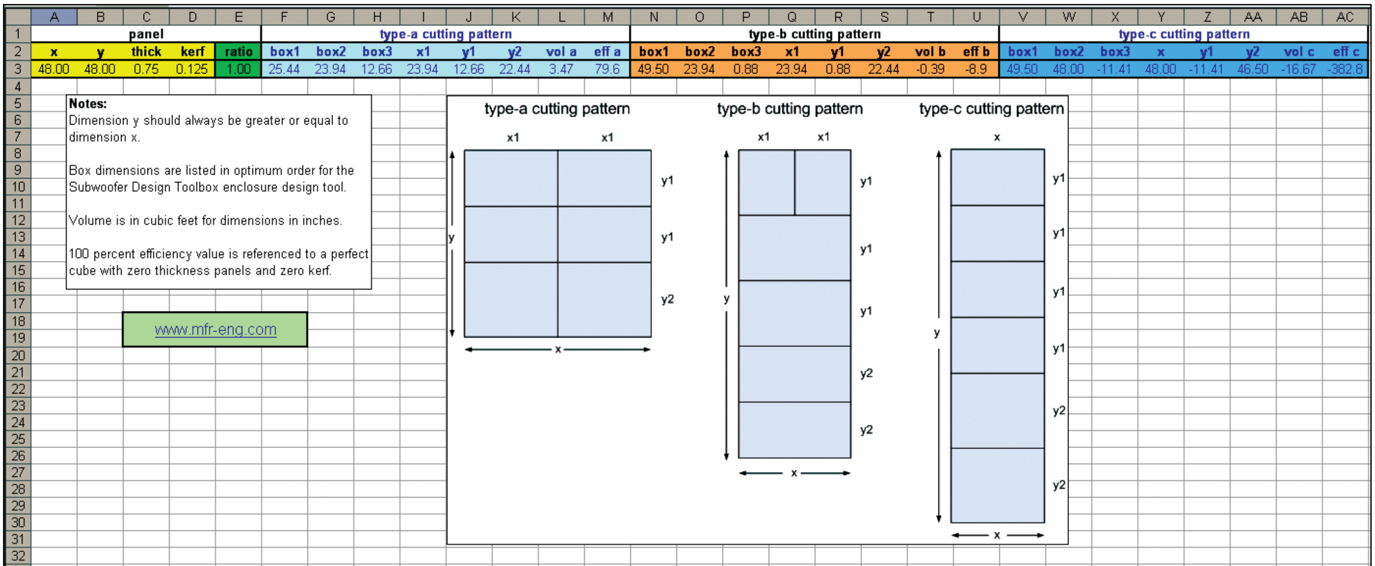

FIGURE 3: Spreadsheet view for 48″ × 48″ panel.

x1, y1, and y2 represent finished dimensions of the six cut pieces used to construct the box.

Determining these values is complicated by needing to consider the thickness of the wood, and also the kerf of the saw blade (the material lost to the cut width, i.e., the sawdust). The formulas would have been much simpler with zero thickness panels and zero kerf!

I've produced an Excel spreadsheet to perform the calculations. You can download it at www.mfr-eng.com/box_panels.xls.

Figure 3 shows the spreadsheet. For this example, I entered the half-sheet dimensions of 48″ × 48″, with a thickness of ¾″ and a ⅛″ kerf. To use the spreadsheet, enter your own values in the first four columns, and the spreadsheet will calculate the rest. If you're interested in the actual formulas, you can see them by clicking on the appropriate boxes in the spreadsheet.

The spreadsheet calculates the length-to-width ratio (in this case 1.00). This number provides guidance for the best cutting pattern type. The spreadsheet also calculates the following values for each of the three cutting patterns.

Referring to the spreadsheet in **Fig. 3**, the type-A cutting pattern provides a box volume of 3.47ft^3 and a volume efficiency of 79.6%. The type-B and type-C cutting patterns show negative values for volume, which means that they aren't useful for this square panel. Negative volume values result for a cutting pattern when the calculated dimensions of any of the sides drops near or below zero. This happens with the type-C cutting pattern when the length-to-width ratio is too low, and there isn't enough residual length to support the y1 dimensions, given that the y2 dimension is approximately equal to x.

Looking at the values for x1, y1, and y2 for the type-A cutting pattern, you can see that the value of x1 is ¹⁄₁₆″ less than half the width x of the original panel. That makes perfect sense because I specified that the kerf is ⅛″. If you add up the two y1 values plus y2, you see that you are ¼″ less than the original panel length y. This also makes sense because you have two ⅛″ kerfs to accommodate.

Figure 4 shows how the pieces fit together to form the box. This view is from the Subwoofer Design Toolbox software. You don't need the Toolbox software to make use of the spreadsheet, but it makes it easier to envision how the box is constructed. To learn more about the Subwoofer Design Toolbox, visit www.mfr-eng.com.

WHICH CUTTING PATTERN TO USE

Which cutting pattern to use for the half-sheet example was clear—only type-A provided a useful result. For larger length-to-width ratios of wood, the other cutting patterns may be better. **Figure 5** shows the spreadsheet results for a range of length-to-width ratios from one to eight. The x and y values in the spreadsheet were chosen to provide a uniform panel area of

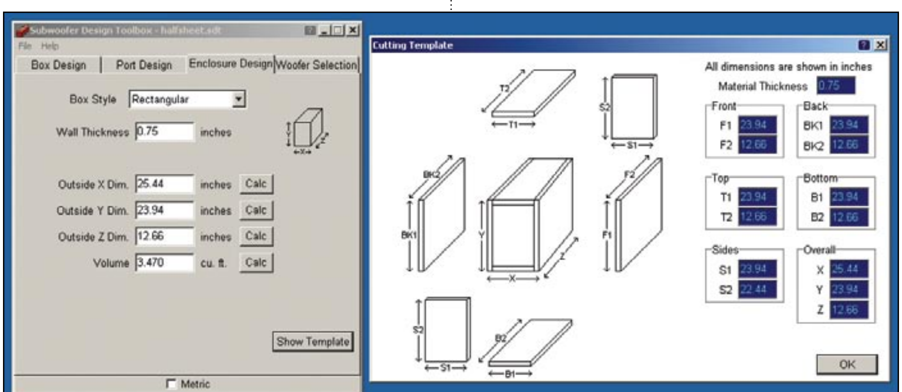

FIGURE 4: How the pieces fit together to form the box.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	panel					type-a cutting pattern							
2	x	y	thick	kerf	ratio	box1	box2	box3	x1	y1	y2	vol a	eff a
3	33.94	33.94	0.75	0.125	1.00	18.41	16.91	9.14	16.91	9.14	15.41	1.15	74.8
4	30.36	37.95	0.75	0.125	1.25	16.62	15.12	12.04	15.12	12.04	13.62	1.26	81.5
5	27.71	41.57	0.75	0.125	1.50	15.29	13.79	14.51	13.79	14.51	12.29	1.28	82.9
6	24.00	48.00	0.75	0.125	2.00	13.44	11.94	18.66	11.94	18.66	10.44	1.24	80.3
7	21.47	53.66	0.75	0.125	2.50	12.17	10.67	22.12	10.67	22.12	9.17	1.17	75.9
8	19.60	58.79	0.75	0.125	3.00	11.24	9.74	25.15	9.74	25.15	8.24	1.10	71.3
9	18.14	63.50	0.75	0.125	3.50	10.51	9.01	27.87	9.01	27.87	7.51	1.03	67.0
10	16.97	67.88	0.75	0.125	4.00	9.92	8.42	30.35	8.42	30.35	6.92	0.97	63.2
11	16.00	72.00	0.75	0.125	4.50	9.44	7.94	32.66	7.94	32.66	6.44	0.92	59.8
12	15.18	75.89	0.75	0.125	5.00	9.03	7.53	34.81	7.53	34.81	6.03	0.87	56.8
13	14.47	79.60	0.75	0.125	5.50	8.67	7.17	36.84	7.17	36.84	5.67	0.83	54.1
14	13.86	83.14	0.75	0.125	6.00	8.37	6.87	38.76	6.87	38.76	5.37	0.79	51.6
15	12.83	89.80	0.75	0.125	7.00	7.85	6.35	42.35	6.35	42.35	4.85	0.73	47.3
16	12.00	96.00	0.75	0.125	8.00	7.44	5.94	45.65	5.94	45.65	4.44	0.67	43.7

	N	O	P	Q	R	S	T	U
1	type-b cutting pattern							
2	box1	box2	box3	x1	y1	y2	vol b	eff b
3	35.44	16.91	0.88	16.91	0.88	15.41	-0.19	-12.3
4	31.86	15.12	3.40	15.12	3.40	13.62	0.46	29.6
5	29.21	13.79	5.49	13.79	5.49	12.29	0.79	51.1
6	25.50	11.94	8.87	11.94	8.87	10.44	1.07	69.4
7	22.97	10.67	11.61	10.67	11.61	9.17	1.15	74.8
8	21.10	9.74	13.94	9.74	13.94	8.24	1.16	75.5
9	19.64	9.01	15.99	9.01	15.99	7.51	1.14	74.2
10	18.47	8.42	17.85	8.42	17.85	6.92	1.11	72.2
11	17.50	7.94	19.54	7.94	19.54	6.44	1.08	69.8
12	16.68	7.53	21.11	7.53	21.11	6.03	1.04	67.4
13	15.97	7.17	22.58	7.17	22.58	5.67	1.00	65.1
14	15.36	6.87	23.97	6.87	23.97	5.37	0.97	62.8
15	14.33	6.35	26.53	6.35	26.53	4.85	0.90	58.6
16	13.50	5.94	28.87	5.94	28.87	4.44	0.84	54.8

	V	W	X	Y	Z	AA	AB	AC
1	type-c cutting pattern							
2	box1	box2	box3	x	y1	y2	vol c	eff c
3	35.44	33.94	-7.89	33.94	-7.89	32.44	-5.98	-388.7
4	31.86	30.36	-5.10	30.36	-5.10	28.86	-3.34	-217.3
5	29.21	27.71	-2.87	27.71	-2.87	26.21	-1.84	-119.3
6	25.50	24.00	0.59	24.00	0.59	22.50	-0.28	-18.4
7	22.97	21.47	3.28	21.47	3.28	19.97	0.44	28.6
8	21.10	19.60	5.49	19.60	5.49	18.10	0.82	53.2
9	19.64	18.14	7.40	18.14	7.40	16.64	1.03	66.9
10	18.47	16.97	9.08	16.97	9.08	15.47	1.15	74.8
11	17.50	16.00	10.59	16.00	10.59	14.50	1.22	79.3
12	16.68	15.18	11.98	15.18	11.98	13.68	1.26	81.8
13	15.97	14.47	13.26	14.47	13.26	12.97	1.28	83.0
14	15.36	13.86	14.45	13.86	14.45	12.36	1.28	83.3
15	14.33	12.83	16.63	12.83	16.63	11.33	1.27	82.6
16	13.50	12.00	18.59	12.00	18.59	10.50	1.25	81.0

FIGURE 5: Spreadsheet view for a range of length-to-width ratios.

8.0ft^3, to provide a level playing field for this comparison.

The highest efficiency values are highlighted in the chart. As the length-to-width ratio of the panel increases, the best cutting pattern (from the standpoint of highest box volume) shifts from type-A to type-B to type-C. To help decide what's the best cutting pattern to use, here are a few rules of thumb to consider:

- For length-to-width ratios below 2.5, the type-A cutting pattern produces the highest box volumes.
- For length-to-width ratios of 2.5 to 4.0, the type-B cutting pattern produces the highest box volumes.
- For length-to-width ratios above 4.0, the type-C cutting pattern produces the highest box volumes.

For subwoofers (in which the sound wavelengths are much longer than any panel dimension), the shape of the box has little importance from a performance standpoint—all that matters is box volume. But you may prefer the dimensions of one of the sub-optimum cutting patterns for appearance or for a better fit in your chosen location.

For full-range designs, the box shape is important, and the shape that maximizes volume (a perfect cube) is not at all desirable from an internal resonance standpoint. For full-range designs, the alternate cutting patterns may provide a superior compromise between volume and shape.

Table 1 spreadsheet calculated values

VALUE	MEANING
box1 box2 box3	Outside dimensions of the finished box. The dimensions are listed in the optimum order for the Subwoofer Design Toolbox enclosure design tool.
x1 y1 y2	Finished dimensions of the six cut pieces used to construct the box.
vol	Internal volume of the finished box. In cubic feet for dimensions in inches. (Change 12^3 to 10^6 in the volume formulas if you prefer metric units of mm and liters.)
eff	Volume efficiency (percent). Indicator of how much box volume you're getting for the amount of wood. The 100% efficiency value is referenced to a perfect cube having the same amount of wood, with zero thickness panels and zero kerf.

A FEW TIPS

Check the actual dimensions of the wood panel before using the spreadsheet. The panel may be slightly smaller or thinner than the nominal dimensions. If the edges of the panel are banged up or not square, give yourself some margin by specifying a slightly smaller panel size in the spreadsheet.

One of the advantages of these three cutting patterns is that many of the dimensions are shared among multiple pieces. This allows you to set up the fence of your tablesaw to perform the same ripping operation multiple times without moving the fence. This saves time and provides better-fitting sides, because small errors are common to multiple pieces and often cancel out.

When building a pair of boxes from a large panel, you have two ways to cut the panel in half before using the spreadsheet to design the cutting pattern for each box. This gives you more options to choose from. For example, you could cut a 4′ × 8′ sheet of MDF to provide two 4⅛ × 4⅛ panels or two 2′ × 8′ panels. The first method would favor a type-A cutting pattern, and the second would favor a type-B or type-C cutting pattern.

Bracing is important in subwoofer boxes to reduce unwanted panel vibrations. You can often cut bracing strips from scraps of MDF or other materials on hand. If you need to cut braces from the large rectangular panel that you're starting with, cut them off the side that leaves you with the best residual rectangle for the box design. aX