Stereo Subs for the Swans M1

A pair of 1ft³ sealed boxes with 8″ Scan-Speak drivers extends the response of these excellent mini-monitors, cleanly and powerfully down to 30Hz (typical in-room –3dB frequency).

PHOTO 1: Swans M1.

By Dennis Colin

In *SB* 3/99 I assembled from a kit and reviewed a pair of Swans M1 speakers (**Photo 1**), a vented system with a 5″ mid/bass and ribbon tweeter. I thought then, and do now, that the sonic reproduction is at least as naturally lifelike as that from any other speaker I've heard. They are remarkable in their absence of audible coloration. Reproduction of live-miked voice and bells is uncannily like the live sound. Resolution, image focus, and spatial envelopment are excellent.

The subwoofers described here were designed as a stereo pair, each to be placed directly under the M1, also serving to elevate the tweeter to a typical seated listener's ear height (39″). However, these subs should integrate well (similarly placed) with just about any high-quality small speaker.

BACKGROUND

In my upstairs lab, a 2000ft³ room with 40° wall/ceiling slopes, I'd been using the Swans speakers (positioned as shown in **Photo 2, Fig. 1**) driven by an H.H. Scott 222D 20W per channel tube amp. The very nice sound lacked only two things: deep bass and high power. I took care of the latter by designing and building "Mad Katy," a 125W per channel stereo tube amp (**Photo 3**).

PHOTO 2: Lab/listening room.

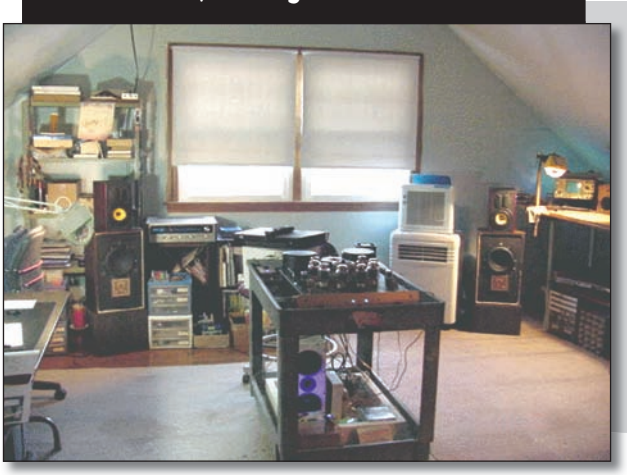


PHOTO 3: "Mad Katy" 125W per channel stereo amp.

FIGURE 1: Speaker locations in 2000ft³ listening room.

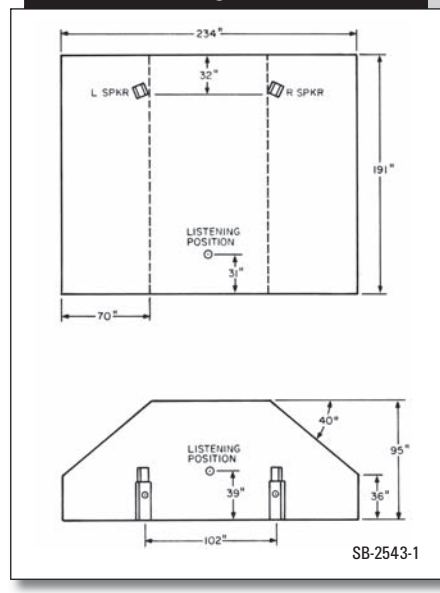
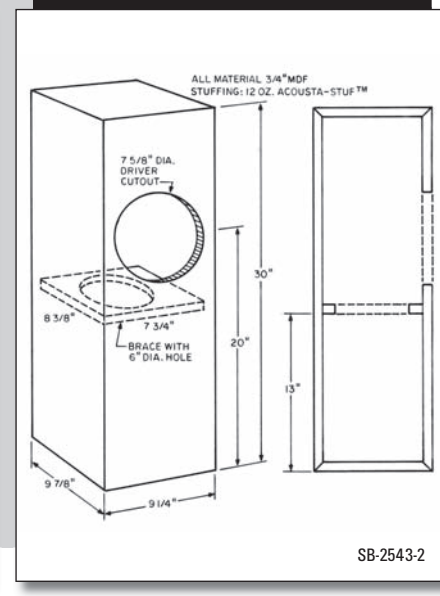


FIGURE 2: Enclosure detail.



THE SUBS

Each Swans M1 was sitting on an old "Advent/2" cabinet, which rested on a 9″ high box, the two elevating the M1 30″ off the floor; tweeter height = 39″ (**Photo 4**). The Advent cabinet, 21½″ × 13″ × 9″, has an internal volume of 1.0ft³.

I installed an 8″ Scan-Speak 21W/8555-00 in each cabinet (sealed) and measured f_{box} = 44.8Hz, Q = 0.72, f_{-3dB} = 44Hz. These are close to calculated values, taking into account the adiabatic-to-isothermal effective volume increase produced by the 12 oz. of Acousta-stuf™.

While the subs shown in **Photos 2** and **4** use the Advent cabinets, I recommend the enclosure specified in **Fig. 2** if you're building from scratch. Flush-mounting the woofer is not necessary, because the 210Hz crossover frequency has a wavelength of 64″.

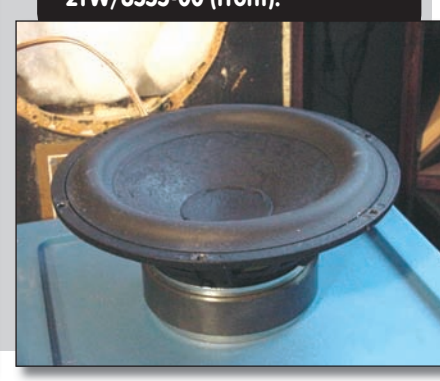
PHOTO 4: M1 and sub.

DRIVERS

These woofers (**Photos 5, 6**) are of very high quality, and unique (for an 8″ driver) in having an f_s of 20Hz. Q_{ts} = 0.31, V_{as} = 136 liters = 4.80ft³, DCR = 5.5Ω, and maximum linear excursion is ±6.5mm (about ½″ p-p). And they *are* linear: in free space, I drove the pair to ½″ p-p excursion at 20Hz, then held them next to my ears like giant headphones. The sensation of clean, ultra-deep bass was incredible!

The enclosure of **Fig. 1** has an internal volume of 1.055ft³, compared with 1.00ft³ in my Advent cabinets. With the same 12 oz. of Acousta-stuf™, the **Fig. 2** cabinet should produce a Q of 0.707, and f_{box} = f_{-3dB} = 43.8Hz.

PHOTO 5: Scan-Speak 21W/8555-00 (front).



DRIVER PLACEMENT

I made some room response measurements from my listening position, 31″ from the back wall, 39″ above the floor, 11′ from each speaker (**Fig. 1**). In the old Advent cabinets I use, the woofer is only 8″ center to cabinet top, so I could have the woofer (center) 8″ off the floor. This did not give the smoothest bass; it was better with some more elevation up to about 20″.

For curiosity, I tried the woofer in the room corner, 8″ off the floor (and about 8″ from the walls). This distance is ¼ wavelength at 423Hz, so this should be the lowest frequency dip from ½ wave reflections. Therefore, all room modes much below 423Hz should be fully stimulated. But this corner placement produced a large peak around 30-50Hz (I could enjoy that, but don't want it), followed by a very ragged response.

I returned the speaker to the location shown in **Fig. 1**. The woofer is 32″ from the front wall and 66″ from the (36″ high) side wall, 54″ from the 40° wall/ceiling slope.

In this position I obtained a smooth bass response with the woofer elevated 16″-24″ off the floor, hence the 20″ woofer height in **Fig. 1**. This elevation is also good for integration with the M1 mid/bass driver: center-to-center spacing is only 12¼″, which at the 210Hz crossover frequency is 0.19 wavelength, or 68°. The crossover is 2nd order; with the woofer electrical polarity inverted and the M1 positive, the two acoustic outputs are in-phase at the CO frequency, on a horizontal axis. The maximum summed acoustic reduction due to the 12¼″ driver spacing occurs on the vertical axis, but this is only –1.6dB, so the total integrated output is not significantly reduced.

FIGURE 3: Crossover schematic.

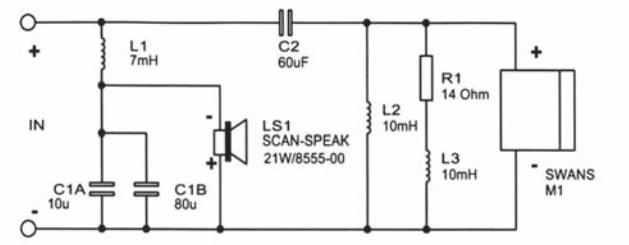


FIGURE 4: Crossover drive signals.

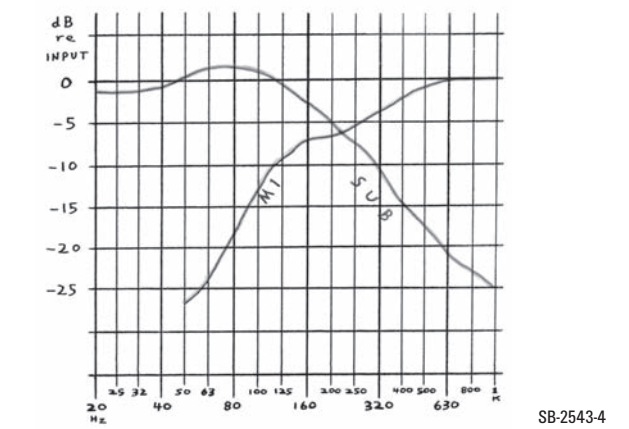
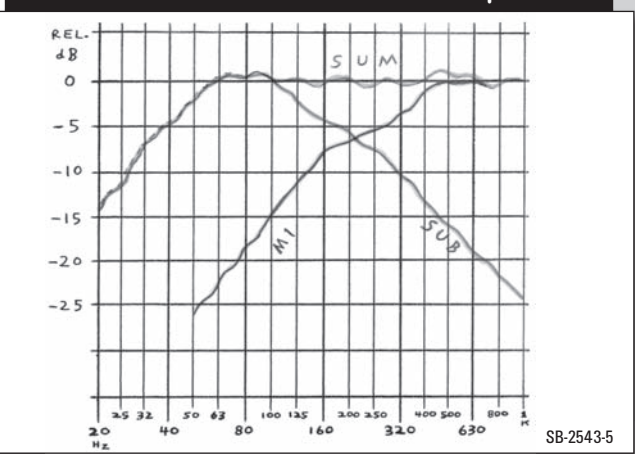


FIGURE 5: Crossover: nearfield acoustic outputs.



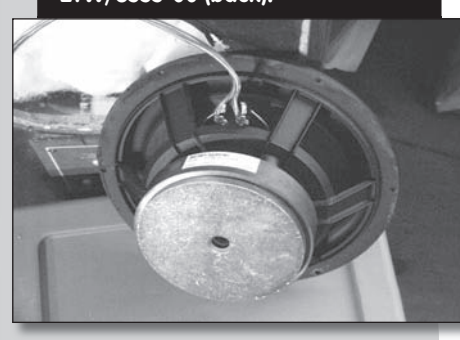
CROSSOVER

The crossover (CO), shown in **Fig. 3** and **Photo 7**, is 2nd order; CO frequency is 210Hz (acoustic), 220Hz (electrical). **Figure 4** shows the electrical responses; **Fig. 5** shows the acoustic responses (mike 1″ away from the cabinets, 5″ below the M1 mid/bass driver center).

The function of R1 and L3 is as follows: The M1 impedance has a peak at 85Hz (upper vented system peak); for a short span above 85Hz the impedance is capacitive. This reacts with L2, increasing its effective impedance. Without R1 and L3, this increased the M1 drive level below the CO frequency, particularly around 120Hz, where the rolloff was only –4dB. R1 and L3 lower the impedance below about 220Hz, thus functioning as a Zobel network. They also cancel some of the M1's capacitive reactance in the region above 85Hz. The rolloff at 120Hz (**Fig. 4**) is now –9dB, which is adequate to prevent overdriving the M1 mid/bass driver on powerful upper-bass fundamentals.

Note the Scan-Speak woofer polarity inversion, which is necessary to cancel that of the 2nd order network at the CO frequency.

PHOTO 6: Scan-Speak 21W/8555-00 (back).



CROSSOVER DESIGN

A 2nd order CO consists of a 2nd order lowpass filter (LPF) and a 2nd order highpass filter (HPF). The following analysis of the LPF also applies to the HPF:

PHOTO 7: Crossover.

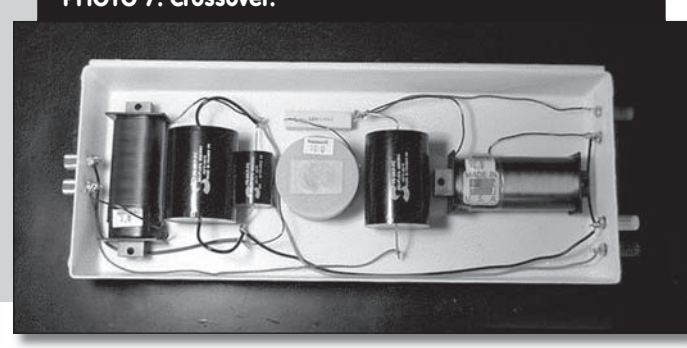


FIGURE 6: 1/3 octave smoothed in-room response, Swans M1 and sub.

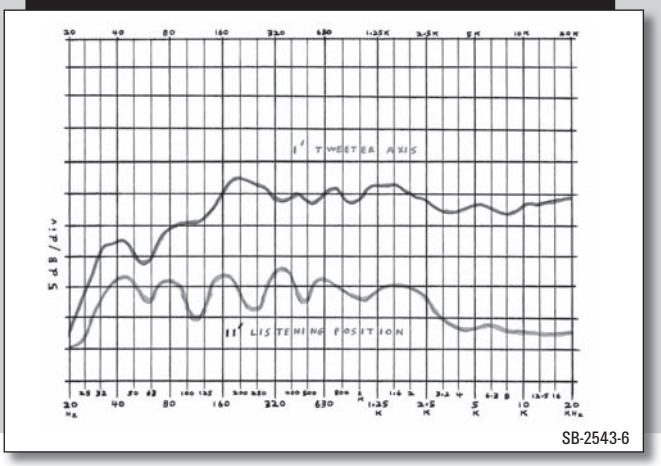


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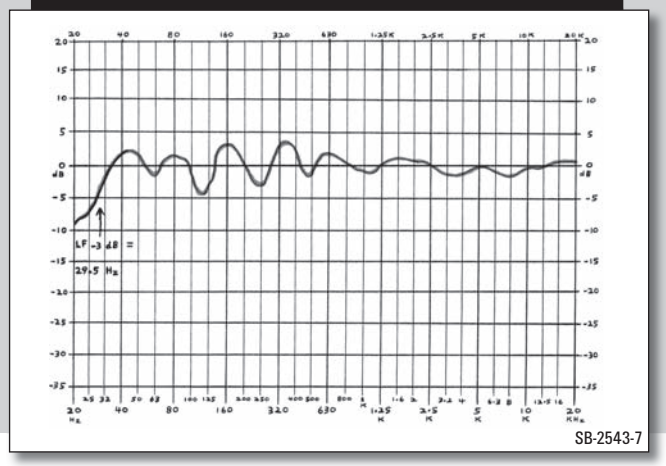
FIGURE 7: 1/3 octave smoothed in-room response, Swans M1 and sub, composite: < 2kHz = 11′ listening position; > 2kHz = 1′ tweeter axis.



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The woofer load "sees" L1 in series (to the input), and C1 in parallel, forming a 2nd order LPF. The so-called cutoff frequency is $1/2\pi\sqrt{L,C}$; at this frequency (fo) the reactances of L1 and C1 are equal, and called the characteristic impedance Zo = $\sqrt{L1/C1}$. The ratio of the load resistance (if the load is resistive) to Zo is the filter's Q. The filter's voltage gain at fo is numerically equal to Q.

Because (ideally) each driver's output should be rolled off by 6dB (its input voltage reduced to half) at fo, so that with no phase shift the two drivers will combine to unity gain, the Q should be 0.5. So as a starting point (which will likely need adjustment), select inductor and cap values to have a reactance that's twice the driver's impedance at the CO frequency.

LISTENING POSITION MEASUREMENTS

The lower curve in **Fig. 6** is the response at the listening position (31″ from the back wall, 39″ high, 11′ from the speakers). The mike responds, of course, to both direct and reverberant sounds, and this room is fairly live. Thus the rolloff above 2kHz is from narrowing tweeter dispersion (mostly only vertical with the excellent M1 ribbon tweeter) and decreasing room reflectivity.

Figure 7 is a composite; below 2kHz is the listening position response; above 2kHz is the response 1′ from the tweeter, on axis. The rationale for this is as follows: At the lower frequencies, the ear has less discrimination both directionally and temporally within short delay intervals; thus spectral judgments tend to integrate direct and short-term reverberant (typical of listening rooms) sounds. But at the higher frequencies, spectral judgments tend to largely favor the first-arrival (direct) sounds.

So the composite response of **Fig. 7** is at least a crude approximation of the perceived in-room spectral balance. To my ears, and as a testament to Igor Levitsky, designer of the M1, the sound is very natural, spectrally balanced, and uncolored.

MAXIMUM BASS OUTPUT

From 20–40Hz, I drove the subwoofers to a level where I estimated 3% THD (noticeable, but not objectionable, low-order distortion), and noted the cone excursion and drive voltage. At 20 and 30Hz, these were 0.5″ p-p and 11.7V RMS; at 40Hz they were 0.6″ p-p and 14.0V RMS.

With both stereo subs driven in phase, the SPL at the listening position was approximately 106dB at 40Hz, 103dB at 30Hz, and 96dB at 20Hz. Scan-Speak data states ±6.5mm (0.51″ p-p) maximum linear excursion, which agrees with these tests. Maximum (not linear) excursion is stated as ±12mm (0.94″ p-p), which provides 5dB peak headroom (albeit with significant distortion) above the maximum linear SPL figures I estimated.

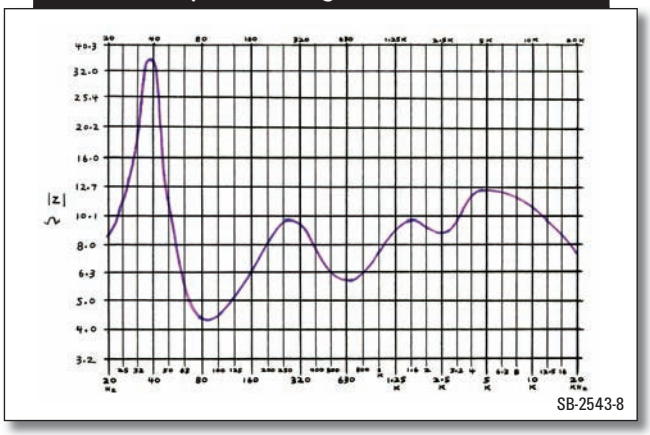
TABLE 1

Subwoofer Parts List (excluding cabinets)
Quantity: 1 each per channel
Source: Madisound

CO Schematic reference	Description	Part no.	cost
	8″ woofer, Scan-Speak	21W/8555-00	$162
C1A	Solen "fast cap," 80µF	CP80	17.75
C1B	Solen "fast cap," 10µF	CP10	3.80
C2	Solen "fast cap," 60µF	CP60	14.20
L1	Steel Laminate Inductor, 7.0mH	SL 7.0	14.05
L2	Steel Laminate Inductor, 10.0mH	SL 10.0	16.20
L3	Iron core bobbin inductor, 10.0mH	10.0 L8	10.00
R1	wire-wound resistor, 14Ω, 15W	15R14	0.40
	Terminal cup	D-cups	3.15

Total per channel	$241.55
Stereo pair	$483.10
Swans M1 kit, pair	$449.50
Swans M1 assembled, pair	$899.00

FIGURE 8: Impedance magnitude.



I think that clean 30Hz production at 103dB SPL in a 2000ft³ room from a pair of 8″ woofers "speaks" very well for these Scan-Speak drivers. Expensive at $162 each, but worth it.

SPEAKER PLACEMENT

The (sub) woofer center is 20″ off the floor; this distance is ¼ wavelength at 169Hz. At this frequency the reflection path (woofer to floor back to woofer) is ½ wavelength, whose phase cancellation produces the infamous "floor dip." But if you place the woofer twice this distance (40″) from the front wall, this reflection path will be a whole wavelength, returning in-phase, thus producing a reinforcement. This can largely cancel the floor dip.

In my setup (**Fig. 1**) the woofers are 32″ from the front wall, but this is because of space constraints in this crowded lab/listening room. Apparently the 32″ distance is good enough, because the bass response at the listening position (**Figs. 6, 7**) is relatively smooth (for a room response, that is). **Figure 8** shows the impedance magnitude.

BIGGER BROTHER

For more bass power, you could use the Scan-Speak 25W/8565-01, a 10″ woofer with the same motor structure as the 8″ unit. In a 2.0ft³ sealed box with 16 oz. of Acousta-stuf™, approximate parameters are f_{-3dB}, Q = 0.71. Maximum linear deep-bass output will be about 3.5dB greater than with the 8″ driver. Suggested sealed box dimensions are 12½″ square × 30″.

CONCLUSION

With the addition of these stereo integrated subs (making the M1 part of a floor-standing three-way system), excellent transparency and resolution are maintained with high power handling and deep bass extension. The system can handle the full output of the "Mad Katy" amp (155W per channel at clipping) without obvious distortion. Peak SPL in this 2000ft³ room is about 106dB; maximum average SPL with typical music waveforms is about 95dB; and with typical LF room gain, the LF –3dB rolloff point is about 30Hz. *aX*

Sources

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