HSU RESEARCH SW10
STEREO SUBWOOFER SYSTEM

Dick Olsher

Bass-reflex subwoofer using a 10" long-throw woofer. Crossover: passive, 12dB/octave low-pass, connected between the main amp outputs and the subwoofer amp inputs; an 18dB/octave network is available for an additional $50. Frequency response (free-field): ±1dB from 20Hz up, rolling off to -3dB at the crossover point. Sensitivity (measured in-room): 87dB/W/m. Maximum power output: excursion-limited to 116dB at 1m from 17Hz up. Amplifier requirements: 40-300Wpc and at least 50k ohm input impedance. Finish: black knit cloth over the cylindrical enclosure, with a walnut-veneered top plate; oak and rosewood finished top plates are available for an additional $100. Dimensions: 14.5" diameter by 29" H. Weight: 25 lbs each. Warranty: 5 years against manufacturing defects. Price: $750/pair, including 12dB/octave passive crossover and a free CD. Approximate number of dealers: 1 (factory-direct, with a 30-day money-back guarantee). Manufacturer: Hsu Research, 20013 Rainbow Way, Cerritos, CA 90701. Tel./Fax: (310) 924-7550.

A subwoofer's basic assignment is to realistically reproduce music's bottom octave from 20 to 40Hz. Only a few musical instruments dip below 40Hz: the piano, harp, organ, bass tuba, and, of course, Lewis Lipnick's favorite instrument: the contrabassoon. However, the piano and organ are different matters. To reproduce these instruments with all of their fundamentals intact, and to flesh out their hall reverb signature, requires a loudspeaker that can generate an in-room response flat to at least 20Hz.

Unfortunately, Mother Nature isn't so kind when it comes to bass reproduction. As far as bass efficiency is concerned, bigger is better. All else being equal, an 18" woofer is considerably more sensitive (by about 5dB) than a 10" because of the increased radiation resistance afforded the larger diaphragm by the air load. But there's no free lunch; a large woofer requires a big, rigid cabinet, which costs a lot of money to make. The end result is usually a large, expensive box with no wife acceptance factor, and whose integration with the main speakers is left as an "exercise for the student."

Then there are the creative marketeers, who have no compunction in advertising as a "subwoofer" a woofer system with a -3dB point at 32, or even 38Hz. I've learned to take published "subwoofer" specs with a large grain of salt. Worst of all are those designs that send a 6.5" woofer to do a man's job. With a small-signal bass response that may be extended to 30Hz or so, these gutless wonders are foisted on the public as true subwoofers. Yet because of their poor coupling to the air at low frequencies, they must be pushed exceptionally hard to generate realistic sound pressure levels in the deep bass. For every additional octave of bass coverage, the cone's linear excursion capability must quadruple. With a small woofer, you begin to look at distortion-free excursion requirements in excess of 1", and thus enter the realm of the impractical.

Enter the Hsu Research SW10. It isn't very heavy, nor is it particularly large—certainly no larger than many floor-standing two-way designs. But within certain operational limits (to be delineated later), the SW10 delivers reasonably clean bass, and plenty of it, flat to a true 20Hz.

The SW10 is the brainchild of Dr. Poh Ser Hsu (pronounced "Ssoo"), who grew up in Singapore and came to the US to study at MIT. Although his degrees are in civil engineering, electronics research took up a lot of his time and resulted, for example, in a patent for a high-speed switching semiconductor. His love for audio apparently started at age five, when he became fascinated by the wild cone excursions of the family's loudspeaker. He has been collecting vintage audio gear for much of his life, which gives him a closer—in my opinion an essential—technical link to prior art.

Hsu Research was born as Definitive Research about a year ago, but opted for the name change to avoid legal hassles with Definitive Technology.

TECHNOLOGY

The SW10's level of performance is all the more impressive in view of its modest price. This is no accident, but the direct result of some very clever engineering concerning tubes and paper. First, there's the cylindrical enclosure. Made of recycled paper, the tubular enclosure is said to provide excellent damping and unparalleled rigidity without using thick, heavy wood panels. This fully accounts for the enclosure's low weight and low cost.

That a tube is superior to a box in terms of resisting radial pressure was nicely elucidated by Peter Mitchell in the March 1991 issue of *Stereophile*, where he illustrated the principle using analogies that included an egg, a submarine, and spaceships. He went on to describe the laminated-paper tubes used at construction sites as forms for casting concrete into cylindrical columns. (These are available commercially from Sonotube and possibly other vendors.) Each tube consists of approximately 100 layers of hard paper glued together, forming a cylinder wall about 0.5" thick.

Dr. Hsu uses such a tube, 14" in diameter and 29" tall, as the speaker enclosure. The tube is capped at each end with MDF endpieces and stands upright atop four metal feet (actually long bolts).[1] A 10" long-throw woofer and a 23"-long bass-reflex vent (also a paper tube, 3.25" in diameter) are hidden from view by being attached to the bottom end cap, which serves as the primary baffle. Because the feet raise the baffle about 2.5" off the floor, the woofer's acoustic output is, in effect, slot-loaded. This helps roll off high-frequency information and harmonic distortion products. Again, the simple expedient of locating the woofer out of sight pays dividends.

The woofer sports a 2", four-layer voice-coil and a paper cone. The surround and spider allow a linear excursion capability of ±10mm (±0.39"). Hsu Research boasts that this woofer's excursion exceeds that of the legendary JBL 18" subwoofer. Of course, an 18" cone normally doesn't need the excursion of a 10"; the bottom line is the system's actual sensitivity.

The SW10's impedance magnitude, as seen by the bass amp, is shown in fig.1. The measurements for both channels show pretty much identical tunings for both channels. The main peak reaches 133 ohms at 27Hz, while a couple of wrinkles between 120Hz and 250Hz reveal enclosure and/or pipe resonances, these well above the unit's intended passband. The cabinet is tuned for a resonant

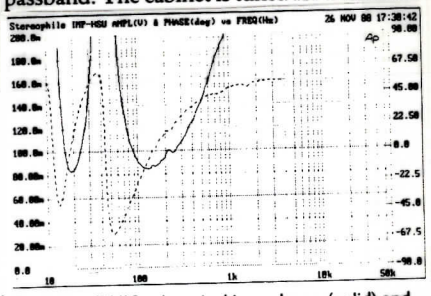

Fig.1 Hsu SW10, electrical impedance (solid) and phase (dashed) (2 ohms/vertical div.).

frequency of 19Hz, as evidenced by the 8.4 ohm impedance minimum there. The woofer is well-damped at this resonant frequency. Remember that there's an inverse relationship between electrical and mechanical impedances. A low electrical impedance implies more of a mechanical resistance. Try putting your finger (gently, please) against the cone surround during an impedance measurement and you'll see the electrical impedance drop—there's now less of a back EMF generated by the voice-coil.

At 19Hz, when the woofer's excursion is at minimum, the vent output is at maximum. The woofer works hardest just above the resonant frequency at 25–30Hz, and in the subsonic region, say below 16Hz. As with any bass-reflex design, the SW10 is subject to overload below the system cutoff frequency; the instruction manual states that with vinyl playback, a subsonic filter is necessary to prevent subsonic garbage from overloading the woofers.

A passive 12dB/octave low-pass filter network with a 40Hz crossover frequency is standard. An 18dB/octave network is avail-

1 These feet have been made stronger in current production. —JA

able as an option for an additional $50, as are other crossover frequencies between 40 and 100Hz. A level control is now standard with either the 12 or 18dB networks. The Hsu crossover's unique feature is its speaker to line-level matching. The network is connected between the outputs of the main stereo amp and the inputs to the subwoofer or bass amp. Thus, the subwoofer amp is driven with a filtered line-level signal. Subwoofer level control may be accomplished with either the network's volume pot or the bass amp's input control (if it has one). I could have done with an additional foot of cable on the bass amp side of the network module. Also, I have to note that the quality of the cable and RCA jacks is strictly economy class.

What about that bass amp? Well, that's the customer's responsibility. Hsu Research recommends a 40–300Wpc amp with at least a 50k ohm input impedance. However, if you're into pipe-organ music, I recommend at least a 100W amp. Because the SW10 is such an easy load, an exotic amp is definitely not required. Even an old Japanese receiver optimized to drive an 8-ohm test-bench resistor would do well in this application.

An important point to note about the SW10 system is that it is strictly augmentive in nature. It extends the bass response of the loudspeaker system, but does *not* relieve the main speakers of the deep bass load. The main speakers continue to reproduce the full music signal. The SW10 thus passes over one of the potential attendant virtues of adding a subwoofer: the relief of stress and congestion for the main speakers. For many this may prove to be a crucial consideration, as the effortless character of a full-range system is due in great measure to delegating the midrange and bass regions to separate drivers.

Agh! My samples were provided with spring-loaded speaker connectors. I absolutely, positively *hate* these. If there's a worse speaker terminal, I'm not aware of it. Why should this be tolerated on an audiophile product? Solid-core wire is especially difficult to attach securely to such terminals, and dressing the cable away from the SW10's woofer surface often resulted in breaking one of the connections. Now that I've gotten all this off my chest, I can tell you the good news: According to Dr. Hsu, current production is outfitted with gold-plated 5-way binding posts.

A word of caution: It's tempting to move the SW10 about by grabbing the top and bottom end caps. *Don't!* The woofer occupies most of the bottom face of the enclosure—you're likely to ram a finger through the woofer cone. Nor do I recommend that you use the vent as a handle; that maneuver could separate it from the baffle.

Setup

After having tried the SW10 with several dynamic loads, I settled on the Signet SL260 two-way (reviewed in Vol.16 No.1) for long-term listening tests. First of all, I like the Signets. And at $450/pair, they represent an affordable main speaker and an excellent sonic value. Like all minimonitors, they're deficient in the deep bass, and as such are representative of the genre: *ie*, a product in search of bass augmentation. Finally, the SW10 is only moderately sensitive at about 87dB (1W/1m). Therefore, it can only be easily mated with speakers of equal or lower sensitivity. The Signets are a very close match sensitivity-wise; I was able to use the SW10s with the network volume control wide open.

The Signets were located in the Reference Room atop 20" Chicago Speaker Stand stands. I'm not a fan of hiding subwoofers behind sofas or relegating them to corners. In my experience, the integration of a subwoofer into an existing system is made much easier by locating the sub adjacent to the main speakers. I was tempted to park the Signets on top of the SW10—that's exactly how the system was set up at the 1992 Winter CES. In the end, I decided not to do that; I'll tell you why.

After all of the previous discussion about the merits of cylindrical enclosures, I may have left the impression that the SW10's enclosure is perfection incarnate. Well, it isn't. The weak spots are the end caps. The woofer beats on the bottom cap as on a drum. The vibrational energy flexes the paper tube longitudinally, and is also transmitted to the top cap. A tube readily resists radial pressure, but is much less effective along its long axis. With a 25Hz sinewave input, the SW10 tube was alive to the touch. But that was nothing compared to the top cap, which vibrated so much that a nut driver I'd left on top of the enclosure started to dance in rhythm to the signal. It felt as if the whole enclosure was readying itself for launch. Spiked, carpet-piercing feet would have helped to transfer energy to the concrete pad below. The SW10's current feet are not spiked, however, and thus are ineffective in "grounding" the enclosure.

I ended up using two bass amps during the listening tests. The Electrocompaniet AW250 handled the load until it went up in a puff of smoke, after which an antique Ampzilla took over without a hitch.

Sound

One of the most difficult tasks in adopting a subwoofer into one's audio system is maintaining family harmony—*ie*, avoiding sonic pollution in previously unpolluted areas. All too often, a subwoofer can thicken and obscure mid and upper bass textures, and sometimes even reduce lower-mid transparency by injecting slowly decaying resonances into the reproduction. In other words, the core of the music can sometimes sound a whole lot worse *with* the sub.

In the case of the SW10, I can confidently report that there was no lower-midrange breakthrough or coloration. The intelligent choice of crossover frequency (40Hz), together with a smooth woofer upper range, combined to do the trick. If anything, the feel for the recorded hall was consistently better.

With the SW10s, the Signets' entire bass floor was transformed. Wow! For the first time, the pipe organ backing Gary Karr (*Adagio d'Albinoni*, King K33Y 236) was resolved with authority and conviction. I turned off the bass amp, and the bottom dropped out of the soundstage.

For such a large instrument, the double bass actually produces little volume in the deep bass. Its harmonic spectrum, however, is very strong around 100–160Hz; because of this, the double bass makes for an excellent midbass test. With the Signets coupled to the SW10s, midbass detail was reasonably tight. Textures were a bit heavier than the real thing, so that last measure of control was lacking. There was also a deficiency in the upper bass, around 200Hz, where I could have used more heft and body—but this really isn't the SW10's fault. The better the bass response of the main speakers, the easier it becomes to integrate a subwoofer into the system. It would be unfair to ask a sub to fix a problem in the upper bass that is clearly the Signet's responsibility.

There was enough deep, pretty clean bass that reproduction of the king of deep bass—pipe-organ fundamentals—was convincing in authority and impact. The close encounter with the Ruffati pipe organ in Davies Symphony Hall (Telarc CD-80097), with Michael Murray at the helm, was especially awesome, with gut-shaking 20Hz bass at 3:45 into track 11. Ditto for Saint-Saëns's Organ Symphony (the Edo de Waart performance on Philips 412 619-2). Hsu Research provides this "Test CD" with the SW10 so that the purchaser can immediately explore the deepest bass on record. The 20 seconds starting at 9:00 in track 2 contain bass information at 16Hz—a true subwoofer test.

At around 20Hz, the bass-reflex vent pumps out a huge amount of air. Turning the enclosure on its side and putting your face in line of sight with the vent is like sticking your head in a fan. At one point, one of the sub channels started spitting out bits of pink fluff. I was startled at first, until I realized that some of the internal stuffing was being agitated and forced out of the vent. Unfortunately, the vent is too small to handle so large an air flow without turbulence. This manifested itself as a sound of rushing air when there was a goodly dose of 20Hz information in the music signal. Though partly masked by the music, enough noise got through to detract from the organ fundamentals' purity of tone. Flaring the end of the vent pipe might help smooth the air flow

and reduce this annoying noise.

During analog playback, the SW10 exhibited an incredible amount of cone pumping due to subsonic garbage. It was as if an alien creature was about to burst out of the woofer. Inserting Pawel Acoustics' Subsonic Filter (distributed by Ensemble USA) into the chain instantly cured the cone pumping. The Pawel filter is a good-sounding unit; I just wish it didn't start rolling off the bass at 25Hz. Those 5Hz from 25 to 20Hz aren't easy to come by in the first place.

A somewhat unexpected benefit from the addition of the subs was that the Signets' treble appeared less pronounced than before. This is a perceptual consequence of the human auditory system: A treble peak is much more audible when a speaker is bass-shy. Discovered back in the '50s by the BBC loudspeaker research team, this phenomenon has important applications for loudspeaker design. It argues that, for any loudspeaker with restricted low-frequency extension, an inherently dull tonal balance, rolling off the treble gradually, is a better prescription for a natural-sounding treble than a rising or a peaky high end.

One aspect of the Signets' performance that did not change after the addition of the SW10s was their dynamic range (in the midrange). For example, the Beethoven Ninth (Chesky CD66) sounded as congested during loud passages as it did via the Signets alone. The sense of orchestral foundation was greatly improved, but the feeling of dynamic power and freedom from strain typical of good full-range loudspeakers never materialized. Although I expected as much on the basis of the SW10's augmentive bass role, I was disappointed enough with the system's inability to soar like an eagle that I was moved to try a quick and simple fix—relieving the Signets of some of the bass signal.

I put together a 200μF cap consisting of a 100μF electrolytic cap in parallel with two 50μF metalized polypropylene caps. This network is nothing more than a first-order high-pass filter. One such large cap was inserted in series with the woofer voice-coil of each Signet '260 by placing it between the main amplifier's hot output and the Signet's positive terminal. This done, not only did I feel that the system integrated better, with more upper-bass body, but dynamics improved as well. Listening again to the Beethoven revealed a system that was now much more at ease during loud passages. The music ebbed and flowed with much less strain than before. The drum solo on track 3 of *Stereophile*'s Test CD 2 came through with greater conviction, with a heightened impression of bass punch and speed. I've heard track 13 on Test CD 2 (Elgar's *Dream of Gerontius*, Part 1) through the Signets many times. Now, for the first time, the *Dream* came alive. The system projected a convincing orchestral foundation *together* with satisfying dynamics.

Measurements

I measured the frequency response of both subwoofer channels in-room at 18″ and found that even under these non-anechoic (*ie*, real-world) conditions, the SW10's response was flat within 2dB from 40 to 20Hz. There was also a tight match between channels, typically to within 1dB. The output between 40Hz and 80Hz fell off at the rate of 12dB/octave. The only problem here was that this particular crossover module was said to be an 18dB/octave unit. Hsu Research had sent me two modules: a 12dB and an 18dB. They measured similarly.

JA measured the responses of both woofer and port in the nearfield under two conditions: no low-pass crossover filter, and with the 40Hz, 18dB/octave filter. Fig.2 shows the responses without the crossover: the overdamped woofer actually covers a wide, flat passband, from 50Hz to 650Hz, above which its output becomes affected by breakup behavior. As might be expected from such a long, narrow tube, the port's output is affected by what are presumably "organ-pipe" resonances at and above 250Hz. As can be seen from the plots taken with the filter in circuit (fig.3), however, these are well above the SW10's passband.

The SW10 could be pushed fairly loud before compression and serious distortion set in. Measured close, if not quite in the nearfield (the mike capsule was 12″ from the center of the woofer), the SW10 was comfortable at sound pressure levels up to about 108dB. The measurements shown in fig.4 are for one channel at two drive voltages, the second voltage being double the first. As the drive voltage is doubled under conditions of linear operation, the speaker's spl should increase by 6dB. That is exactly what happens, at around 40Hz. Note, however, that the spacing between the two response curves narrows; at around 25Hz, the increase in output is only 4dB. The harder the cone is driven at subsonic frequencies—that is, the larger its excursion—the greater the nonlinearity and the attendant harmonic distortion. In practice, then, the SW10's comfort zone is below its excursion limit, though real music rarely has as much content at these low frequencies as it does higher up, where the SW10 has greater dynamic range.

Summary

Within its operational limits, the Hsu Research SW10 delivers relatively clean, extended bass flat to 20Hz. Because the SW10 does not relieve the main speakers of the bass load, it fails to provide one of the traditional benefits of subwoofing, namely improved midrange dynamics in the combined system. Although I obtained good results by using a series capacitor to roll off the bass input to the Signets, such an expedient cannot and should not be expected to give similar results with many other loudspeakers.

Even so, the improved bass extension, enhanced feeling for the hall, and resultant orchestral foundation brought about by the SW10 significantly increased my enjoyment of the Signet SL260s. I can't imagine being able to fully enjoy any minimonitor solo while my sonic memories of the Hsu Research subwoofer are still fresh.

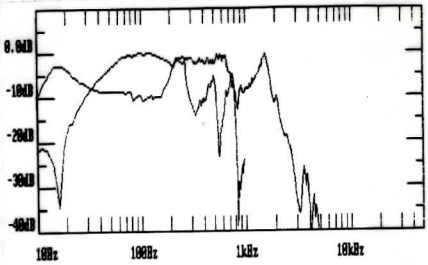

Fig.2 Hsu SW10, full-range nearfield responses of woofer and port without low-pass filter in circuit.

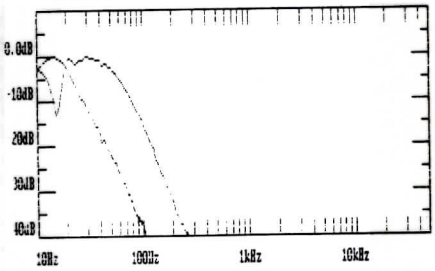

Fig.3 Hsu SW10, nearfield responses of woofer and port with 40Hz, 18dB/octave low-pass filter in circuit.

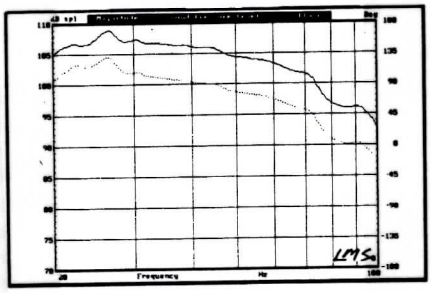

Fig.4 Hsu SW10, frequency response at 12″ at two drive voltages separated by 6dB. Note that the measured level difference drops from 6dB to 4dB below 30Hz, implying signal compression at the higher level.

The SW10 can be confidently matched to any speaker system of moderate sensitivity. It offers a budget-priced but sonically honest introduction to the octaves that time forgot: the deepest reaches of the sonic spectrum. I guarantee you this much: once you hear good, clean bass, you'll be hooked for life. Highly recommended.