Vented Enclosures

The gospel according to Thiele & Small

Much of the early information on the design of vented loudspeaker systems ignored certain vital parameters. This new article presents, in a readable and practical form, up-to-date thinking on the subject — much of it pioneered in Australia by Neville Thiele and Richard Small.

By DAVID B. WEEMS*

A decade ago the bass-reflex speaker was an endangered species. During the last few years, however, it has made a spectacular comeback, and is now a respected competitor of acoustic suspension systems.

The arrival of acoustic suspension speakers in the 1950s was an important milestone in loudspeaker development. Reversing the traditional practice of putting a stiffly suspended speaker in a large cabinet to achieve good low-bass response, the acoustic- or air-suspension system used a driver with an ultra-compliant suspension mounted in a small enclosure.

A vented loudspeaker system. The ducted port can be seen in the bottom right hand corner, below the woofer.

The timing was fortuitous. Stereo, just around the corner, would put a premium on space-saving speakers. When demonstrations proved that the little acoustic-suspension speakers could outperform many larger systems, the era of the compact speaker system had begun.

Though the closed box beat the reflex competition on several counts, there was a single overriding reason why many manufacturers converted their production to sealed systems: the reflex was just too complex and unpredictable. Leading engineers argued about how to tune the system and how big to make the box.

G. A. Briggs, the late English authority, once compared reflex enclosures to heads of lettuce, saying that one rule, "the bigger the better," applied to both. Later he added the qualifier, "within reason." "Like lettuce," he said, "loudspeaker enclosures can get so big they go to seed."

In the 1950s, "within reason" was about the only guide available. Hobbyists built enclosures to dimensions obtained from charts that scaled box volumes according to advertised speaker diameter and ignored all other parameters. Thoughtful experimenters, suspicious of such reliance on cone size alone, wished for a more precise guide. So it wasn't surprising that the audio world greeted the acoustic-suspension speaker with enthusiasm – and almost abandoned the reflex.

The surrender to the closed box was not quite total, though. James F. Novak, now Vice President of Engineering at Jensen Laboratories, made an analysis of enclosures for high-compliance speakers in 1959 that reiterated some of the virtues of the reflex. He claimed that high-compliance drivers in properly designed vented boxes reduced distortion and extended bandwidth.

Novak described an ideal reflex system consisting of a driver with relatively high magnetic damping in a box that had an air compliance lower than that of the driver's equivalent suspension compliance. He specified the relatively low Q (amplitude of the peak at resonance) of 0.3 to 0.4 for the driver. Novak's speaker/box compliance ratio was 1.44. (The compliance of an air volume for a given driver varies directly with the volume of the air and inversely with the square of the driver's effective piston area.)

Novak's work introduced a new principle to vented speaker design, the optimum volume concept. His compliance ratio brought precision to the drivers in the specified range of Q. With drivers outside that range, particularly those with higher Qs, the results remained unpredictable.

A. N. Thiele, an Australian electrical engineer, saw Novak's paper and noticed that Novak's mechanical equivalent circuit for the reflex had the same general form as an electrical high-pass filter. Applying filter theory to reflex design, Thiele found that he could predict characteristics such as cut-off frequency, optimum enclosure tuning, and the shape of the response curve near cut-off.

In 1962 he published a definitive paper in an Australian journal that laid the foundation for a new approach to vented loudspeakers. He included data for 28 different designs, or alignments.

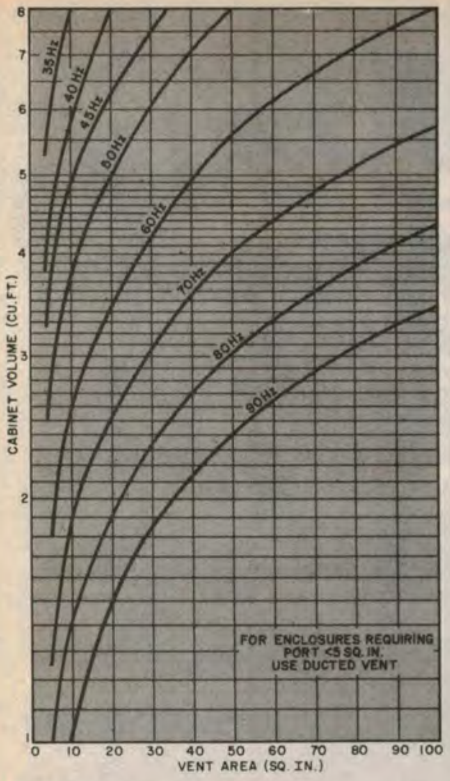


Fig. 1: Design chart to be employed for enclosures with a simple vent (see text for explanation).

Although his work was largely ignored in the United States, after about 10 years it was "discovered."

Thiele's analysis was expanded by Richard Small, an American engineer who subsequently emigrated to Australia; it was then put to practical use by Ray Newman, Senior Systems Engineer at Electro-Voice; D. B. Keele, Jr, now Senior Transducer Engineer at JBL; Pat Snyder of Speakerlab, and others.

Woofers and resonators.

To fully appreciate Thiele's contribution, you must compare the present state of the art to that of just a few years ago. Vented speaker systems have been in use for about 50 years, but that half-century has been filled with widespread misconceptions and even superstitions about how such speakers work. During that time there was no mystery about the performance of Helmholtz resonators themselves.

Helmholtz, studying the resonance behaviour of air volumes in the mid-19th century, showed that any enclosed air volume that is vented will have a single natural frequency of resonance determined by the volume of the enclosed air and the area of the vent. Specifically, it is the mass of air in the port coupled to the compliance of the air in the enclosure that produces the resonance. As the vent is made smaller, the air directly in the vent reaches a higher velocity and forces air in front and back of the opening to move with it. The increased moving mass lowers the frequency of resonance.

To tune a small volume of air to a very low frequency, a simple vent must be small in area. Alternatively, a duct can be coupled to the vent to trap an even larger mass of vibrating air, reducing the frequency of resonance still further or allowing a larger vent for a given resonant frequency.

Dimensions of vents and ducts (made from cardboard tubing obtainable from stationery or business supply stores) for tuning various enclosure volumes are given in Figs. 1 and 2 (the latter developed by Novak).

When a driver is installed in a ported box, the cone action alternately compresses and expands the enclosed air. Near the tuned frequency of the enclosure, the air "piston" in the port moves in phase with the driver cone, damping the movement of the cone rather heavily and making it appear to stand still at resonance.

This damping, which offers some relief from the prodigious cone excursions that occur at low frequencies, is what attracted experimenters to vented designs in the first place. But too often their speakers exhibited a low-frequency hump that gave the reflex the derisive nickname "boom box."

In 1969, while researching an article for "Popular Electronics," I asked engineers at several major companies for advice to hobbyists on how to design and tune a vented speaker. One group suggested that the box be tuned to the frequency of the driver's free air resonance, a traditional practice.

A few advocated putting the box resonance above the driver resonance because such tuning produced a flatter impedance curve in the usable band. (Instead of the familiar double-humped curve, with the humps approximately equal in amplitude, this produced a large hump at a very low frequency and a minor hump at the upper resonance.)

Still others contended that the box should be tuned below the driver's free air resonance so that the port could control distortion at the lowest frequencies.

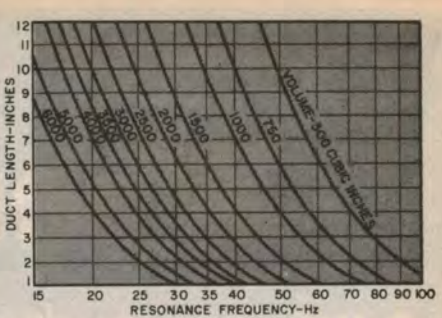
Thiele's answer to the tuning question, interestingly, gives a clue as to why engineers from different companies offered such sharply conflicting advice in 1969. It's all a matter of driver Q. If Q lies in the range specified by Novak, the box should be tuned to the driver resonant frequency; higher Q demands a tuning below resonance and lower Q a tuning above. To see the details of how this works we'll have to look at Thiele's alignment chart. This, as rewritten by Keele, appears in Table I. Definitions are given in Table II.

Let's examine the data for alignment #5, a fourth order Butterworth (maximally flat) alignment. A good starting point is the value for QT, 0.383. This is the total Q of the speaker in the system, including internal amplifier resistance and resistance added by the speaker cable. For amplifiers with high damping factors, and with adequate speaker cables, QT can be considered to equal that of the driver alone. So for alignment #5 a speaker with a Q of about 0.38 would be ideal. Notice that this fits within the range specified by Novak.

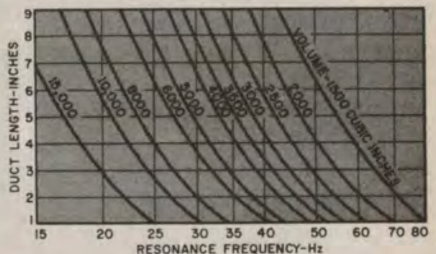
Next we look for VB, box volume. The table specifies the ratio of box volume to speaker compliance volume (VAS) as 0.7072. A designer would either obtain the value of VAS from the manufacturer of the driver or he would measure it himself. Then he would multiply VAS by 0.7072 to get the theoretically correct box volume. In the real world no reflex enclosure is perfect so this volume must be enlarged.

When Small applied Thiele's original data to typical vented enclosures, he found that he had to add about 30% to the theoretically correct volume to get the low-frequency performance predicted by the data.

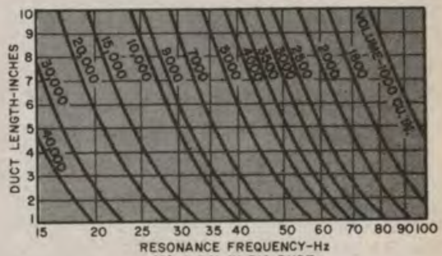
In Thiele's original paper, the box volume ratio was not included in the table; instead a speaker/box compliance ratio was stated. A speaker/box compliance ratio would give the same value



(A) 2-IN. DIA DUCT



(B) 3-IN. DIA DUCT



(C) 4-3/4 IN. DIA DUCT

Fig. 2: Design charts for cardboard tube ducted enclosures. Tubing diameters given are inside measurements; duct length is measured from the front of the cabinet baffle board.

TABLE I—THIELE ALIGNMENT DATA AS REWRITTEN BY KEELE

Alignment details			Box design				Aux. circuit	
No.	Type	Ripple (dB)	f_3/f_S	f_B/f_S	V_B/V_{AS}	Q_T	Peak Lift (dB)	f_{PK}/f_S
1	QB_3	—	2.68	2.000	0.0954	0.180	—	—
2	QB_3	—	2.28	1.730	0.1337	0.209	—	—
3	QB_3	—	1.77	1.420	0.2242	0.259	—	—
4	QB_3	—	1.45	1.230	0.3390	0.303	—	—
5	B_4	—	1.000	1.000	0.7072	0.383	—	—
6	C_4	—	0.867	0.927	0.9479	0.415	—	—
7	C_4	0.13	0.729	0.829	1.372	0.466	—	—
8	C_4	0.25	0.641	0.757	1.790	0.518	—	—
9	C_4	0.55	0.600	0.716	2.062	0.557	—	—
9.5	C_4	1.52	0.520	0.638	2.60	0.625	—	—
—	—	—	—	—	—	—	—	—
15	B_6	—	1.000	1.000	0.366	0.299	+6.0	1.07

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as a VAS/VB ratio, the inverse of the ratio shown in Table I. For alignment #5 that would be 1/0.7072 or 1.414. If that figure looks familiar it is almost exactly the ratio specified by Novak as optimum.

Moving to other aspects of box design, the f3/fs ratio is 1.000. That shows that the system's bass response will be 3dB down at the frequency of the driver's free-air resonance. The fB/fs ratio is also 1.000, so the box should be tuned to the free air resonance of the driver.

Now look at alignments #1–#4, for speakers with higher magnetic damping (lower Q). In #4, for example, a driver with a Q just slightly lower than that of #5 has a VB/VAS ratio that is less than half that of #5. Thus if you had two drivers that were identical except for Q, the one with the Q of 0.303 could be put into a box less than half the volume of that required by the driver with the Q of 0.383. But the other data for #4 show that the speaker with the lower Q will have its low-frequency cut-off moved up to 1.45 fs when the box is properly tuned to 1.23fs.

On the other hand, speakers with higher Q's fit into the alignments beyond #5 and demand larger boxes, larger at least in the acoustical sense – in relation to the driver's equivalent air compliance. These boxes should be tuned to frequencies below the driver's resonant frequency.

The reason for this kind of tuning is shown in Fig. 3. High-Q speakers have smaller magnets which give less control on the moving system at resonance. Coupled with a resonator these speakers may be subject to peaking before cut-off, but if they are matched to a box tuned too low, the combination of a box that rolls off the bass response and a driver that peaks can produce a flat response down to cut-off.

Some of the Chebychev alignments extend the low-frequency cut-off to well below the driver resonance, but at the expense of some ripple in the passband. And if the Q is higher than about 0.7, distortion is greater.

Many engineers consider alignment #5 a good choice. Although this alignment will normally require a driver with a Q of approximately 0.38, it can be used with drivers of lower Q – with a sacrifice in system efficiency – if a resistance is put in series with the driver. The added resistance raises the QT to 0.383, and the design is executed as if the driver had been designed with a Q of 0.383.

To summarise the Thiele alignment data and make some comparisons, a driver with a very low Q can have an optimum box volume that is small compared to the driver's equivalent air volume compliance. This doesn't necessarily mean small boxes because low-Q speakers typically have a high compliance. Table III shows this correlation clearly.

A system composed of a low-Q speaker in an optimum box volume should be tuned to a frequency above that of the driver's free-air resonance and it will cut off above that frequency. While this may seem to limit the low-frequency range of these speakers, note that speakers with low Qs also usually have low resonant frequencies.

A high-Q speaker needs a box volume that is large compared to its equivalent compliance air volume, but this box will be tuned below the speaker's free-air resonance. Again, high-Q speakers typically have lower compliance and higher resonance frequencies, so the box volume that is acoustically large for them may seem rather moderate to the beholder.

These relationships may explain why engineers who worked with different kinds of drivers in the 1950s and 1960s offered such divergent advice on box design and tuning. Each school of thought was working on a single aspect of a larger problem. Thiele put it all together and developed a general theory of vented loudspeaker systems.

The Thiele data can be used in various ways. One obvious application is to design a box to match an existing driver. But it can just as easily show how to design a driver to fit a certain box size. The designer can compute an ideal cone mass, magnet size, voice-coil resistance, and other specifications for a driver that will work well in such a box. Or, knowing the specifications of this driver, he can calculate the performance of the driver in various boxes.

Although the Thiele alignments show optimum values, systems based on them may have box volumes other than those indicated by the table. Proper use of the data can let the designer predict system performance by computer, instead of by guesswork and trial and error.

As mentioned earlier, Thiele's original publication provided 28 different alignments. Table I shows 11: Thiele's first 9, an additional one labelled "9.5" by Keele, and an example of an electronically assisted design in #15. The table shown here was revised by Keele to make it more useful for designing a box to fit a driver rather than designing a driver to match a specific box volume.

Here is a concrete example of how to

TABLE II—DEFINITIONS OR SYMBOLS USED IN THIELE DATA

Symbol	Definition
B	Butterworth—alignments with flat response down to cutoff.
C	Chebychev—alignments with some degree of ripple in response.
QB	Quasi-Butterworth alignments.
f_S	Frequency of driver's free-air resonance.
Q_{TS} or Q	Q of driver at f_S.
Q_T	Total Q of the driver in the system at f_S. With modern amplifiers of low internal resistance, and a high damping factor, Q_T will be approximately the same as Q_{TS} unless speaker cable is excessively long or of inadequate gauge.
V_{AS}	Equivalent air compliance of driver. The volume of air that offers a compliance to the driver that is equal to the compliance of the driver's suspension.
V_B	Volume of air in box.
f_3	Cutoff frequency, response down 3 dB from mid-band level.
f_B	Frequency of box resonance, determined by internal volume of air and vent characteristics.
f_{PK}	Frequency of peak lift produced by auxiliary equalizer.

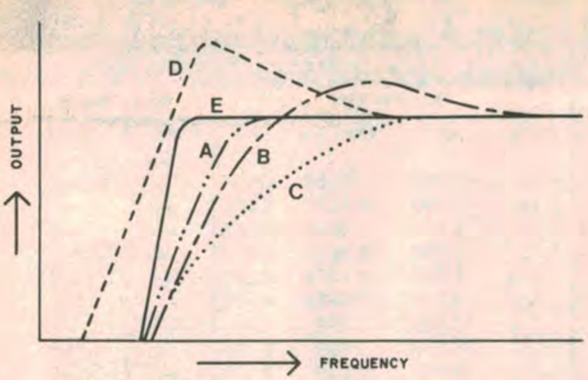

Fig. 3: Characteristic response curves for various reflex systems: (A) Fourth-order Butterworth; (B) reflex box with f_B too high; (C) reflex box with f_B too low, similar to system before equalisation; (D) equaliser output to complement B_6 speaker; (E) response of system that combines detuned box (C) with equaliser (D). If driver Q is 0.383, (A) represents optimum tuning for alignment No. five. If box is tuned too high for this driver, response has a hump; if too low, bass is weak. Speaker with lower Q might require higher tuning to avoid weak bass; higher-Q driver requires lower tuning for flat response. Comparisons assume drivers are identical except for differences in magnet strength—or Q.

use the Thiele data. Let's assume a woofer with the following specifications: fs = 40Hz, Q = 0.41, VAS = 5 cu ft. The box should be tuned to 0.927fs, or 37Hz. This system will have a cut-off frequency of 0.867fs, or about 35Hz. If the value for the driver's Q had fallen between the values indicated in the table for adjacent alignments, the designer would interpolate to get correct box volume, resonance, and cut-off frequency.

Equalised alignments.

The first 9 alignments, and Keele's 9.5 alignment, consist of simple speaker/box combinations driven by a typical power amplifier. Thiele's complete listing shows systems with significant bumps or dips in the response curves that must be corrected by auxiliary electronic equilisation. Some of these alignments are of little more than academic interest.

For example, one group requires a great amount of bass boost at frequencies below the box resonance. Such systems would show excessive cone motion, a potential problem for all unfiltered vented speakers but one that extra boost below resonance would surely aggravate.

Unloading occurs because below resonance the air in the vent moves as if in series with the cone, and out of phase with it. Now hardly at all restrained, the cone can be driven into distortion or even damaged by low-frequency noise or pulses.

Many amplifiers and receivers have low-frequency filters, effective at infrasonic frequencies, but many listeners mistakenly fail to use them because they don't want to impair their system's frequency response. With vented speakers a correctly designed filter will give the effect of more bass, not less, because the bass is firm and undistorted.

Cone surging can also be eliminated by choosing Thiele's 15th alignment. It offers a double dividend: a bass boost gives extended bandwidth in a small box and a cut-off of infrasonic noise. Alignments #15 and #4 use drivers of about the same Q and boxes close to the same size. But check the two systems for bass range. The assisted system gives response down to the free-air resonance of the driver instead of cutting off at 1.45fs as does #4. A driver with a free-air resonance of 35Hz would cut-off at about 51Hz in alignment #4; alignment #15 with electronic assist extends its response to 35Hz.

Keele has greatly expanded Thiele's data to include a wider range of drivers. His method is roughly this: design a system according to one of the first 9 alignments, then lower fB by a half octave to produce a drooping low-frequency response. By adding a second-order high-pass filter with a Q of 2 and a 6dB boost at 1.07fb, we can flatten the response and reduce the cut-off point to fs.

Keele suggests that any driver with a resonance and a Q so placed that the ratio fs/Q falls between 80 and 160Hz is suitable for this alignment. The alignment works with relatively high-resonance, high-Q drivers as well as with low-resonance, low-Q drivers.

An appropriate driver in this sixth-order Butterworth alignment (all vented systems are at least fourth-order) should give a cut-off at 25 to 50Hz. To use Keele's method, the designer chooses a box volume that is approximately equal to $4.1Q^2$VAS, then tunes that box to 0.3fs/Q. These same relationships hold in the data shown in Table I. Where the table shows only a single Q value, the Keele technique can be applied to any driver with a suitable ratio of resonance to Q.

Considering the advantages of the B_6 alignment, it would be helpful if manufacturers would include tunable, 6dB boost circuits in their amplifiers. An owner of a typical fourth-order Butterworth system could convert to sixth-order assisted operation by adding a longer tuning duct to the enclosure and switching in the boost that gives the proper response.

For the present, if you want to experiment with equalised alignments you will have to build your own equaliser. Pat Snyder of Speakerlab has designed an equaliser to be inserted into the tape-monitor circuit of almost any amplifier or receiver. As originally designed, his circuit offers a variable degree of boost — from 0dB up to about 10dB. You can adjust the frequency of the boost by choosing two matched capacitors for each channel.

TABLE III—THIELE/SMALL PARAMETERS FOR SEVERAL TYPICAL DRIVERS

Brand	Model	Advertised diameter (in.)	f_S (Hz)	Q_{TS}	V_{AS} (cu ft)	V_{AS} (liters)
Electro-Voice	SP12C	12	45	0.67	5.9	165
	SP15C	15	40	0.45	9.9	280
JBL (Prof. Series)	2145	12	30	0.51	5.5	155
	2135 (Ext. range)	15	40	0.25	10.5	300
	2231 (Low Freq. driver)	15	16	0.21	26.0	735
Speakerlab	1204A	12	16.1	0.176	17.9	500
	W1508S	15	18.8	0.239	31.9	900

Vents and "vent substitutes."

A small box can be tuned to a low frequency by a small simple vent, but a port can be too small for good performance. A small vent radiates just as much power as a larger one but causes air to move through it at higher velocity. If the velocity is great enough it will cause whistling and hissing and possibly even distortion. A box with a small vent can be tuned to the same frequency by enlarging the vent and adding a duct behind it.

In some small enclosures where a very low box resonance is necessary, the duct can occupy so much volume that the

Vented Loudspeakers ctd. . .

enclosure must be enlarged to accommodate the duct.

Such systems can be tuned to the proper frequency by use of a "drone cone," or passive radiator. This "vent substitute" is a suspended cone, essentially a speaker without a motor. The drone can be tuned by adjusting its mass; the greater the mass, the lower its frequency of resonance. Because a vent substitute is solid and far denser than a gas, such as the air in a duct, the passive radiator requires hardly any more space than the panel area it occupies.

Early systems of this type usually had drones equal in diameter to that of the woofer, but current practice makes the drone's effective cone area about twice that of the woofer. An enlarged passive radiator piston can more easily provide the volume velocity necessary to effectively load the woofer.

Driver parameters.

Some people have objected that normal production variations in drivers preclude such precise calculations in box design. This has been answered in studies by Keele and Snyder.

One driver parameter that is difficult for manufacturers to control precisely is compliance. In fact, in some kinds of suspension systems, the compliance changes with temperature or humidity. Fortunately, compliance variations are usually cancelled by compensating changes in other parameters.

For example, if the compliance of a driver is reduced, the frequency of resonance will be raised, but the Q is also raised to a similar degree. Thus, the ratio of resonance to Q, a really important factor, is hardly affected. If the mass of the moving system is constant and the magnetic field around the voice coil unimpaired, the speaker will perform according to design specifications.

Finally we come to another aspect of the bass-reflex problem that has often plagued hobbyists, the information dam. Several years ago I wrote to a company and asked for specifications on its woofers. The reply suggested that I rely on the reputation of the brand rather than upon specifications!

In the past there was an excuse for such reticence, in the unreliability of acoustical measurements made under differing conditions. In fact, most measurements were useful only to experienced engineers who could interpret them correctly.

But most of the required measurements for Thiele data can be made by tests that are fairly simple and easily reproducible. There is no longer any reason for the attitude shown in the letter mentioned above. Several companies now offer complete Thiele data for their speakers. Table III shows some representative drivers with a summary of the Thiele data for each.

While the closed-box loudspeaker – which Small has shown to be analogous to a second-order filter network – still offers the ultimate in design simplicity, its overwhelming advantage has been reduced by the Thiele approach to vented-system design. It looks as if the bass reflex, having fallen into virtual oblivion, has been reborn, Phoenix-like, from its own ashes.

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FORUM

Conducted by Neville Williams

THE KEY TO BETTER BASS? TURN THE CLOCK BACK THIRTY YEARS!

A reply to a query in our May issue about poor bass response (P.M., Altona, Vic, page 122) prompted a letter from a NSW reader, who felt that he had encountered a similar problem with entirely different equipment. His letter raises a number of questions about bass response in general — an evergreen subject in the world of hifi.

Before taking up these matters, however, we should mention another letter from R.B. of Belgrave Heights, Victoria, who reacted quite differently to our reply to P.M. In fact, he didn't like it at all and felt that we had been haughty, unhelpful and a few other things into the bargain.

And he didn't like our rather flippant put-down of loudness controls, which he obviously considers to be a worthwhile inclusion in a modern amplifier.

In retrospect, I agree that the reply could have been better phrased – less concerned with defence of the 40-40 amplifier, and more analytical of the reader's stated problem.

In fact, the 40-40 scarcely needs defending, as one of the notably successful designs in the realm of do-it-yourself hifi. It certainly does not suffer any intrinsic lack of bass response and, with full bass boost in operation, would be a potential thunder machine. Hence our question about whether P.M. had checked it in any way by instruments or by comparison.

If subsequent checking did, indeed, reveal a fault, then rectifying that fault should overcome the problem. On the other hand, if the amplifier was shown to be normal, with normal bass boost available, then the trouble must surely be elsewhere.

There could be a problem with the pickup but it would more likely have to do with the loudspeaker system. It might even be that the stereo pair are operating out of phase, in which case reversing the connections to either loudspeaker might effect a noticeable improvement.

It may have been helpful to P.M. had we added a paragraph to this effect. Point taken, R.B.!

As for loudness controls, one can start an argument at any time in hifi circles by merely mentioning the term. If one elects to compensate for the classical Fletcher-Munson curves – and this is part of the argument – then at least it should be done accurately. This would involve some method of assessing the sound pressure level at the listening situation in order to determine how the loudness control should operate.

Much more commonly, the loudness function ends up as a fairly arbitrary preset bass and (sometimes) treble boost, which the listener switches in when he feels so inclined, and which is switched out again when he happens to remember. In these circumstances, it really isn't surprising that a loudness control is so frequently dismissed as a "gimmick".

More than this I need not say here. Leo Simpson has already said it in "Audio Talk" in the July '79 issue.

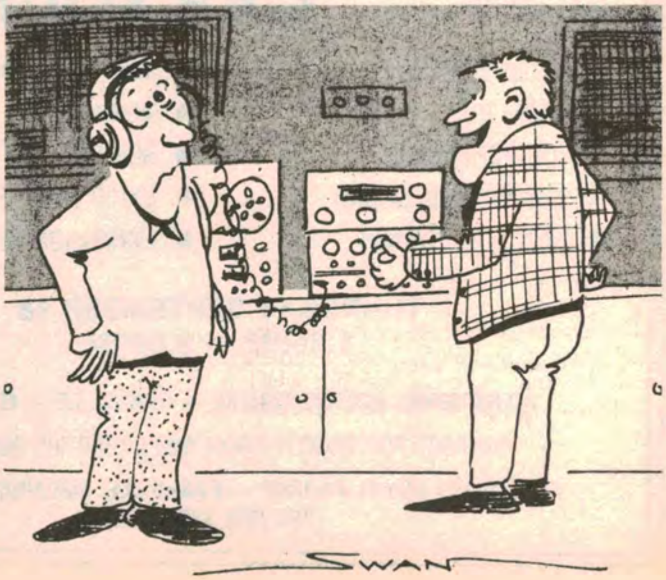
In fact, we did not debate the matter too seriously when planning the original 25+25 and 40+40 watt amplifiers. We were responding to approaches from electronic parts dealers who sensed a need – at that time – for a couple of basic, high-performance amplifiers, which would be no more costly and no more difficult to build than strictly necessary. Whatever they might say now, their plea at the time was "no frills".

In 1980 it might be quite different and, for compelling commercial reasons, Leo Simpson might have to abandon his pride and eat his words – lumps and all!

However, to take up the original theme, R.B. of Turramurra, NSW, writes as follows (the identical initials are a coincidence):

Dear Sir

The comments of P.M. (Altona, Vic) concerning the lack of bass in a Playmaster 40+40 amplifier were of interest to me because of a similar experience. However, I suspect he will find his trouble in the speaker boxes rather than in the amplifier.



"But for really solid bass, there's no substitute for a pair of top quality phones and a hundred watt amplifier!" (Adapted from "Audio" magazine)

I should explain that I have a strong interest in pipe organ music and in Bach in particular. My equipment is conventional – a 45 watts/channel commercial receiver/amplifier and a pair of commercial three-way speakers, with a good quality turntable and magnetic cartridge.

To say this set-up, worth about $800, was disappointing for pipe organ music would be very much an understatement. I tolerated the situation until Ron de Jong's article on a super bass filter appeared in your February 1980 issue. I made up the filter using only the components for position 4, cutting off at 100Hz. (I cannot imagine any use for the other three positions). This done, I returned to service a Playmaster 136 amplifier to drive the central bass speakers.

There was an immediate and distinct improvement but an even better result was obtained by abandoning the filter altogether. Instead, I fed the signal from the existing speakers and was content with the bass boost and treble cut available on the amplifier itself. In my case, the outstanding success of the final result lay in the use of a pair of Rola 12UX hifi speakers some 30 or so years old.

R.B. goes on to emphasise the high flux density in the air gap of these classic hifi speakers, and their resulting sensitivity, concluding that modern drivers lack the ability to produce equivalent bass at low listening levels on the domestic scene. He then continues:

It is all very well to talk about amplifiers with 45 watts/channel ouput. In the home, we are much more interested in levels up to 1W per channel. In my set-up that gives a sound pressure level reading, six metres away from the speakers, of 85dB on the fast A scale of a sound level meter (pressure). If anyone wants more noise than this, they are welcome to it – and my ears are nearly 70 years old!

This is the nub of the argument because, at voltage input levels equivalent to one watt (2.83V into 8 ohms) modern ceramic magnet speakers are apparently just too insensitive to produce a reasonable level of bass air pressure, hence the absence of bass response.

Not everyone will be fortunate enough to possess a pair of 30-year-old speakers, as I do, but you may be able to make some alternative suggestions.

It is fortuitous that, elsewhere in this issue, you will find an authorative article on driver and enclosure design, which will help shed light on matters raised by R.B.

In the heydey of the Rola 12UX, and contemporary models by Goodmans, Wharfedale and others, most systems were mono and most hifi enthusiasts managed to find a spot in the listening room for a single large enclosure; or maybe a closet door or wall or fireplace in which a big driver could be mounted.

As R.B. observes, all those heavy duty speakers were very sensitive and could make a lot of noise with the 10 to 30 watts of drive that was commonly available from contemporary valve amplifiers.

But the sensitivity had another significant implication: electrical damping on the cone movement was very high and it was often difficult to judge where the cone resonance was by simply listening as you ran over the range with an audio generator.

How far down the bass response extended still depended on the acoustic laws of baffling but, with a smooth (if tapering) response, a firmly suspended cone and sensitivity to spare, those classical old drivers were amenable to generous bass boost.

Given a spare wall, a fireplace, Briggs-style sand-filled baffle, or a big enough enclosure, the speakers worked fine by the standards of the period. According to R.B., they still work fine by the standards of 1980!

THEN CAME STEREO . . .

As pointed out in the article by David Weems, elsewhere in this issue, the arrival of stereo spelt the end of the big driver/big enclosure approach and the search began for smaller enclosures which would still produce a satisfying bass response.

This search had a fairly unfortunate beginning, when the major loudspeaker manufacturers tried simply to reduce the size of the enclosures around their otherwise conventional drivers. They fiddled with filling materials, internal baffles, vents, ports, acoustic filters, and so on – ending up with only partial solutions.

It was left to those mentioned in Weems' article, plus the odd unsung pioneer, to rationalise what was going on. Out of all this came the modern sealed "acoustic suspension" enclosure and the modern vented system.

Without repeating the contents of Weems' article, it turns out that practical drivers for both types of enclosure end up with a lower acoustic efficiency than the classical hifi drivers of the 12UX variety. Indeed, the more a system is scaled down, in a search for compactness, the lower the driver efficiency is likely to be. It will need more electrical power to produce a given sound level.

Fortunately this is not, in itself, too much of a problem, nowadays. One can get up to 100 watts from a solid-state amplifier with no more hassle than once went into winning 25 watts from valves. And a 12dB increase in power level is sufficient to offset that kind of loss in driver sensitivity.

Superficially, R.B. of Turramurra is in error when he implies that lower driver sensitivity has something to do with bass

FORUM: Better Bass — continued

response at low listening levels. A properly designed modern system will have a flat response down to some stated corner frequency (-3dB) and this response will be evident from low listening levels through to the upper limit of power handling.

At the heart of the matter – and of R.B's problem – lies the question: "What is the corner frequency of any given system?" Forget the superlatives and the glamour settings in which somebody's loudspeaker system is depicted. How far down does the bass response really go?

In fact, it is quite interesting to look at the response curves published by overseas reviewers for dozens of widely publicised loudspeaker systems. In a surprising number, the response is on its way down at 50Hz!

THE KIND OF MUSIC

For many listeners, whose interest centres on vocal, instrumental and orchestral recordings, a system of this nature can be quite satisfactory, particularly if it is agreeably compact and capable of being played at loud room volume.

It is organ buffs like R.B. who listen for – and miss – those 32ft pedals. It is they who are likely to be disappointed in otherwise acceptable modern systems – just as they might have been disappointed, in other days, in anything less than a fireplace enclosure, a corner horn or a huge sand-filled baffle.

Nor is bass boost the answer to an organ buff's deprivation, with a modern over-compact system. One can nudge up the response around the corner frequency by a few dB but any attempt to recover response in the "cut-off" region is likely to find the amplifier running out of power, and/or the driver(s) running out of travel.

If one is going to demand sustained response around 35-40Hz, one has to shop for a system which has been designed to this sort of specification. And, having found it, there is every chance that it will turn out to be larger and more expensive than you had hoped.

Maybe as much or more for a pair of speakers than R.B. quoted for his entire system!

It was to help out in this area that we published Ron de Jong's article on the Super Bass Filter in the February 1980 issue. As R.B. rightly concluded, the basic intention was to reinforce the sound level below 100Hz and particularly in the region below 50Hz, where the average enclosure system tends to roll off.

To complete the job, one needs a powerful amplifier, preferably comparable with the total power rating of the existing stereo system.

One also needs an appropriately rated woofer mounted in a way which will allow it to propagate adequately frequencies in the region of 30-40Hz.

A favourite trick of hifi specialists overseas is to mount a downward facing 15in or 18in woofer in a heavy box, styled to look like a period or oriental chest. It rests innocently in a convenient spot, supporting ornaments of coffee cups, without anybody being immediately conscious of where the deep rumbles are coming from!

R.B. was able to get away with a relatively modest super bass amplifier because of the high acoustic efficiency of his Rola 12UX speakers. But I'm not convinced that he experienced the full and originally intended benefit of the system.

Unless the 12UX's were unusually well baffled, their effective acoustic output at 30Hz would be way below that at 60Hz and above. That could still make the big pipes sound impressive but their loudness would be coming more from their partials than from the foundational 32ft tone.

What supports this reservation is his further statement that the system sounds even better with the super bass filter switched right out of circuit. That "even better" can only mean that he is responding also to frequencies well above 100Hz. In effect, R.B. is saying: I like a lot of weight in the pedals and maybe the left hand – from 200Hz down!

That would not be at all unusual for a pipe organ fan, particularly one who is apparently discreet in his use of the volume control.

CAUSE TO THINK

Be that as it may, R.B's statements hit me at a time when I had just got through commenting on the smoothness of the bass in the Technics SX-7700G organ, reviewed in our June issue. No enclosure; just three speakers on the fascia board and good, fundamental sounding pedals.

Talking the matter over with engineer Nick Kay of Etone, the local speaker manufacturer, Nick suggested that the explanation would probably be in the use of sensitive, highly damped drivers, with possibly some shaping in the amplifier curve to flatten the overall response.

I'm currently thinking about that one, because one of the things it's difficult to fit into an organ console is an adequate enclosure!

And that leads us to some "wouldn't-it-be-funny-if" speculation flowing from R.B's letter:

Wouldn't it be funny if an attractive proposition for good bass turned out to be one of Etone's highly-damped big-magnet woofers, mounted in a semi-open cabinet and driven by a husky bass-compensated solid-state amplifier?