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No. 19 DECEMBER 1995

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KIT *NEWS*

NEW MAPLIN CATALOGUE

The new Sept '95 - Aug '96 Maplin catalogue is now available. It is the biggest ever, containing over 1000pages, and has several new sections. Of most interest will be the new Hi-Fi, TV & Video section, which includes several new drive units, two loudspeaker kits, new interconnect cables and more.

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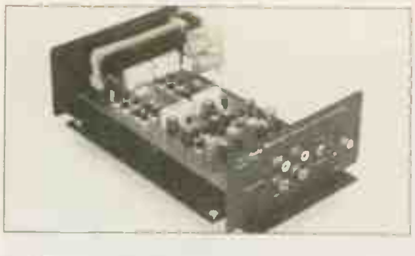

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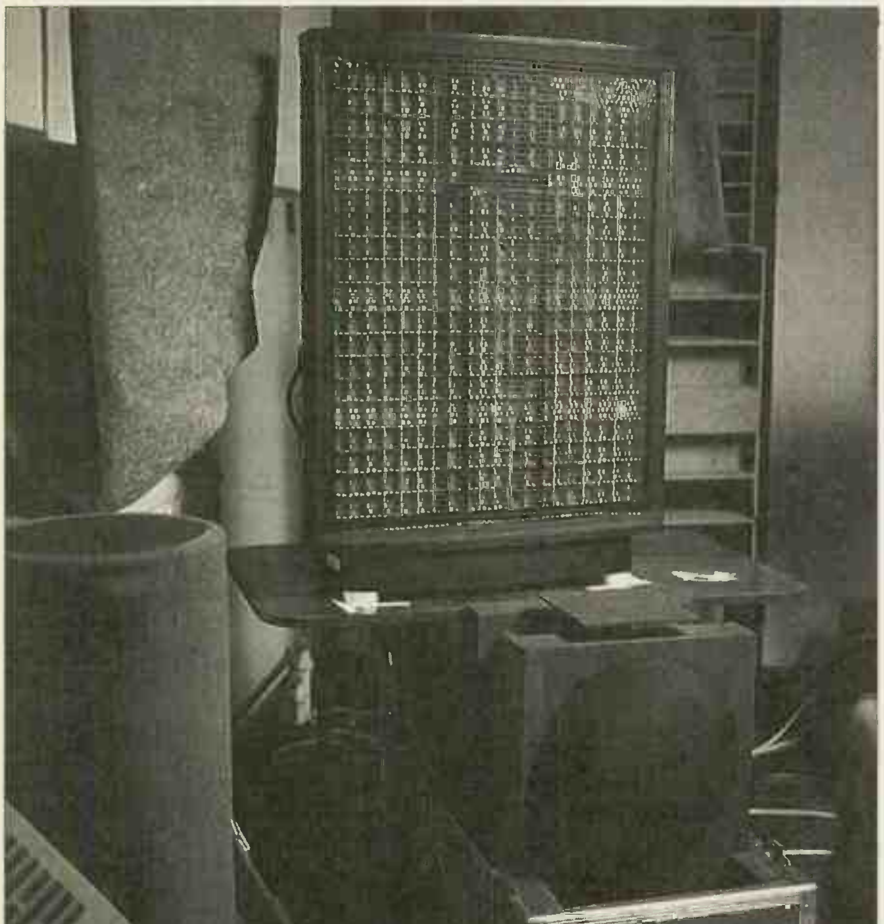
A SUBWOOFER FOR QUAD

Prodded by yet another reader's request, Noel Keywood describes his adaption of the Celestion SL-6000 dipole subwoofer to match the Quad ESL-63 electrostatic loudspeaker.



A Celestion and Quad setup used by Polygram Records - similar to our own, but using Celestion's crossover. Note the stripped down Quads.

Q I am a relatively new reader of 'World'. However, I have purchased some back copies from the 1991 era, including Issue No.1.

It is clear from the 1991 issues that a combination of the Quad ESL-63 and Celestion SL6000 was one for which you personally had a great affinity. The most interesting articles and correspondence in the March, September and November 1991 issues are illuminating as to the potential of the SL6000 and convinced me that they would be worth enduring some pain in setting up in a listening room.

Theoretically speaking, the benefits of avoiding boxes for any speaker has to be a majorly positive factor in the quality of reproduction. The two speakers can apparently independently give outstanding mid and treble quality and transparency (ESL) and bass depth (SL6000) unapproached by boxed subs. You do however point out eloquently in the November 1991 issue that there is a dropout zone between the two units (100Hz to 270Hz). You opined that you would be marketing a dedicated surface mounted electronic crossover to get over this problem.

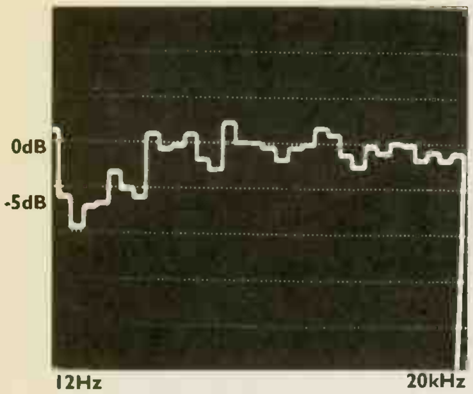
My system comprises Micromega Stage 1, Michell Argo/Hera, Quad 606/II and Celestion Ditton 44s, with my own constructed external crossovers (Solen caps & RATA inductors).

I have the following questions, to which I would be grateful for your answers:

Did you progress with the design and marketing of the crossover? Are there any other articles from past issues that comment on the above pairing? You write currently that you use modified ESL-63s in your listening tests. What modifications have you made? What differences in sound quality would I experience between ELS and ESL-63 speakers? Do you have any articles/reviews on the Gradient sub for Quad ELS?

Jonathan Ling
Blackheath,
London.

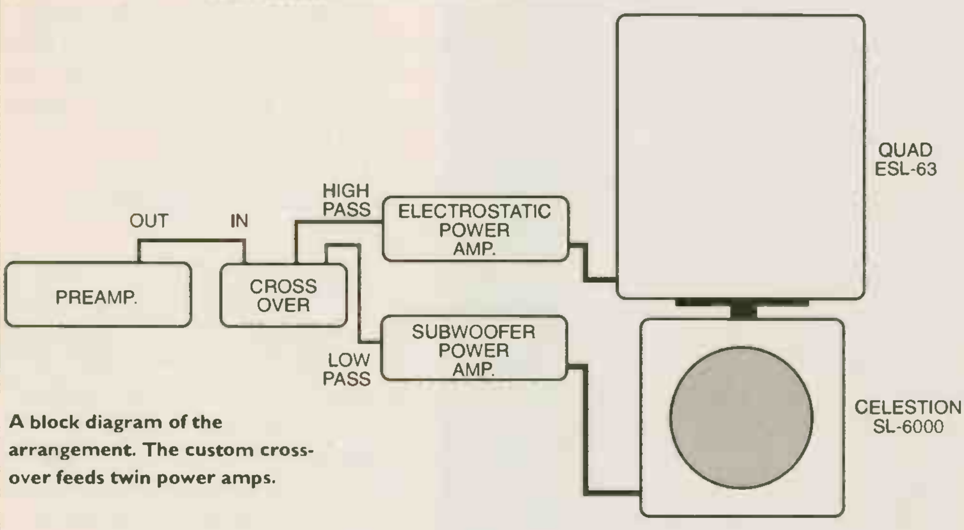
Since you want to "endure pain" I'm sure we can oblige! This project is painful, expensive, and frustrating in its obscure complexities. Anyone that makes it past the finishing post will reap rich rewards. What it gives you, I've confirmed by measurement, is a loudspeaker that runs from 5Hz smoothly up to 20kHz.



Frequency response of the Quad and Celestion together reaches down below the 12Hz of this analysis.

Better still, it isn't a barrenly theoretical achievement. The combination is truly awesome to hear; it really does offer a sound that is quite extraordinary, not just a different type of squeak.

We're talking about getting the best from the Quad ESL-63 electrostatic which, as enthusiasts will know, has one of the smoothest and most natural presentations of any loudspeaker, plus unmatched imaging. The subwoofer adds much needed bass, in this case including sub-bass down to the seismic movement zone. Furthermore, I carefully ensured bass signals were not handled by the Quad, allowing it to go louder without strain. The whole caboodle is larger than life in every sense.



A block diagram of the arrangement. The custom cross-over feeds twin power amps.

Although the circuit published here took months of acoustics measurements and listening tests to develop (carried out back in 1991), some practical difficulties remain. This project fell by the wayside originally when Celestion stopped making the SL6000 open dipole subwoofers. They were heavy and cumbersome (barely liftable), had a poor electronic crossover/EQ box and were expensive, so commercial success was eluded. In my view they are an interesting idea with loads of potential, but Celestion's iteration was compromised, if fantastic in basic performance.

Anyone wanting to assemble this hybrid all-dipole / no-box system will either have to find a pair of second hand SL-6000s or build their own equivalent. Since a simple bass dipole comprises a bass unit on a baffle, it isn't difficult, but experiment will be needed to tailor my crossover circuit to it. I believe there's enough information here to get you acquainted with the problems and the advantages of bass dipoles, a very rare and peculiar form of subwoofer with great strengths.

Electrostatics and open-dipole bass units definitely have a future in our view. Although the subwoofer (low pass) section of my crossover is very specifically tailored for the Celestions, it could be modified for an open baffle subwoofer. However, this is entirely down to the home constructor.

To tackle this project you will need some knowledge of electronics and, probably, Don Lancaster's Active Filter Cookbook (contact Modern Book Co., Praed St., Paddington, London W2. Tel: 0171-402-9176). The bass section (low pass) of the crossover has a lot of equalisation built in, so test equipment to measure frequency response is essential - not expensive these days.

Bought new this set up is costly. But there are a lot of Quad owners around who already have half of it. And there are enough Quads about for them to be available second-hand too. Although the bass section will need experimenting with, there are hours of fun here, plus a potentially great end result. All that's needed are a pair of hefty bass drivers if you build your own bass baffles - nothing too expensive. So overall cost depends very much upon circumstance. I shouldn't forget to point out that Celestion designed the SL-6000s to go with their SL600 monitors. Similarly, the bass section here could be used with dynamic speakers other than Quad's.

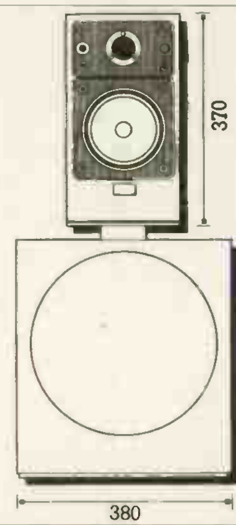
I found satisfaction in running a loudspeaker that achieved so much without a cabinet in sight. This radical proposition offers an appropriately different result, one that showed me just how many preconceptions characterise speaker design. Endless research has been carried out on enclosures of all sorts; that enclosures aren't necessary never gets consideration. It's quite an important realisation, one with some interesting commercial implications too. What if the Japanese developed and commercialised a speaker with no cabinet, using just a rigid plastic front instead? It would devastate the speaker market. I strongly suspect that the equalised dipole (open baffle) loudspeaker, with development, could be turned into a commercially viable loudspeaker. The open-dipole subwoofer is a most peculiar beast. I know of very few manufacturers who've ever built or considered building such a speaker - and most that have walked away in the end! All credit to Celestion for trying. Here's a simple description of the operating principle and main features.

In principle the open dipole is just a bass driver mounted on a small baffle. There is no cabinet whatsoever. Below a frequency where the front-to-back distance of the driver, around the baffle

CELESTION SL-6000 DIPOLE SUBWOOFER

Specifications

Type:	Double dipole low frequency array.
Drive units:	Two 12" dia. long throw ultra linear units.
Sensitivity:	Matched to SL600, adjustment available.
Dimensions:	Height (inc. SL600) 825 mm Height to stand top 455 mm Depth 536 mm Width 380 mm Base 310 x 380 mm
Weight:	Unpacked 76lbs 34.5kg Packed 86lbs 39kg



(twice baffle radius, or baffle diameter) is half the wavelength of the signal reproduced, cancellation between the forward and rear radiation (they are out of phase) starts to occur, causing output to drop by -6dB per octave. Since to hit 40Hz, the lower limit of most box speakers, would mean building a baffle 28ft in diameter, it's not surprising that most people opt for a closed box.

An alternative is to use a small baffle and apply compensatory +6dB/octave gain in the amplifier, to cancel out the acoustic cancellation. That's what Celestion did with the SL-6000, albeit using twin drivers and some unspecified (but patented) modification to improve performance.

The potential benefits of this system are fascinating. There's no tuned cabinet to impose its own sound and lower frequency limit. So bass output is even and reaches down low. In fact, the lower limit is set by the free air resonance of the driver. The SL-6000 did, as I've already explained, actually go down *too* low - to 5Hz! The only other unit to get close is the big REL Stadium subwoofer, by the way. So open dipole subwoofers are effective in this respect, ignoring other matters such as power handling, cone travel, etc.

The SL-6000 subwoofers came with their own crossover and equalisation box, which I found unsatisfactory. It was necessary to re-equalise the SL-6000 subwoofers to overcome certain problems; my crossover replaces Celestion's. It's rather unusual, being a fourth-order section 'tuned' to meet various criteria, but it is reasonably simple electronically.

I investigated three main areas for this project:

1) SUBWOOFER-TO-QUAD MATCHING

2) OPEN BAFFLE SUBWOOFER EQUALISATION

3) OPEN BAFFLE SUBWOOFER ROOM ALIGNMENT.

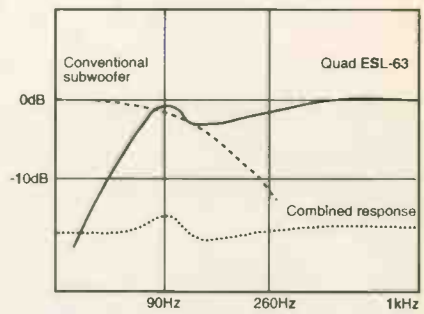
---

1) MATCHING

Quad ESL-63

The Quad ESL-63 and the first ESL (57) have light bass because cancellation of forward radiation against backward radiation starts to occur at 260Hz, a frequency determined by the smallest panel dimension of 66cms (width). The rate of roll off depends upon positioning within a room, least loss occuring when placed on the floor and against a side wall, both of which can be thought of as panel extensions. On stands, however, the Quad's roll off in the bass is marked. There is some lift at around 90Hz where resonance of the driver/dust cover film occurs. This augments what is otherwise a lean sound, adding a little extra weight.

I've drawn the ESL-63's low frequency response in outline (see diagram). It is a classic electrostatic response, by the way, not peculiar to the Quads. You can see from this that it is impossible to perfectly integrate a subwoofer. There'll always be lumpy bass and a very obvious mismatch between bass unit and Quad - that's one major reason why commercial subwoofers never blend in with ESL-63s. I tackled this problem by designing a second-order high pass filter with a little response peaking. This equalises the Quad's response, making it flat. The filter also acts to remove low bass which in turn improves the ESL-63's power handling. It keeps the internal audio step-up transformer away from core saturation, a mechanism Quad use to limit low frequency power to the speaker. The effect of the filter is, as the response shows, to give the ESL-63 a flat frequency response down to 180Hz or so, below which a -12dB/octave attenuation of low frequencies comes into play.



Quad ESL63 low frequency response and conventional subwoofer response (dotted line). They are impossible to combine perfectly.

Rolling off the Quad at 180Hz prevents it from trying to handle low bass, which is a good thing. However, male vocals contain strong energy down to 80Hz, So any subwoofer used will, on occasion, have to handle vocal information - a potential problem. The Celestions did occasionally add a little colouration to deep male vocals. One way of minimising this effect is to use a subwoofer drive unit that is inherently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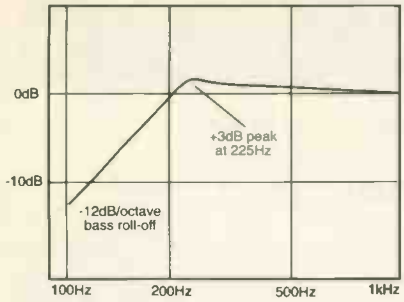


HIGH PASS FILTER & EQUALISATION FOR ESL-63

less coloured, always bearing in mind that the cone must be heavy if it is to have the low free air resonance needed for open-baffle working.

In the overall scheme of things, I didn't feel that occasional "chestiness" was anything more than a minor blemish in this set-up. But I've always accepted that the SL-6000s were far from perfect and needed development. Their prime role here is to demonstrate and confirm the merits of the open baffle dipole subwoofer.

Celestion SL-6000

Matching the Celestions to the Quads was even more problematical. Talking about colouration, Celestion would surely point out that the SL-6000s were not designed to work up to 180Hz, so what could I expect? Like most subwoofers, their own low pass crossover limits them to 100Hz, a sensible upper limit where true bass gives way to low-midrange, but not one that suits the ESL-63s, for reasons explained. This was less of a concern to me, however, than the complex matter of subjective "speed". Necessarily, to obtain a low free air resonance, the SL-6000s have heavy cones. I believe they were designed as guitar speakers, with heavy paper cones, a long throw and high power handling. Matching them in to the gossamer film of an electrostatic seemed as likely to work as perpetual motion.

Initially, I reasoned that these speakers could best be controlled by the use of motional feedback. Hah! That was false confidence. It took little more than a busy Saturday to find that a simple set-up is inherently unstable and liable to violent antics. Motional feedback senses cone movement and applies correction in a similar fashion to negative feedback. I wound a sensing coil onto the exposed front of an SL-6000's driver voice coil former to derive a motion related signal.

This experiment was instructive, as well as dramatic. Instability was caused, Graham Bank of Celestion told me, by lack of a position reference. The result was an enormous crack from the cone as it attempted to leave the chassis on music peaks. Each time it did this the connecting braids carrying the signal from frame to voice coil broke, even though they were long enough to cope with the movement. It appeared they fractured under the enormous acceleration involved. Both Graham Bank at Celestion and Paul Mills at Tannoy have worked on motional feedback and between them convinced me that there were some deep seated difficulties in its application, explaining Philips' rapid withdrawal from the field back in the Seventies.

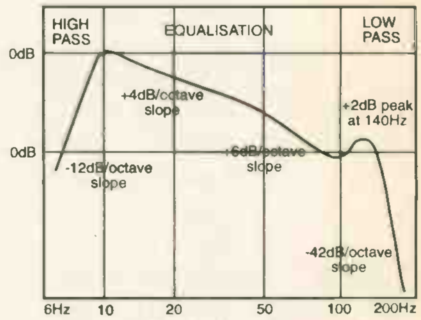
I noted then, in a demonstration at their headquarters in Eindhoven, Holland, that motional feedback gave the sort of fast, tight and even bass most enthusiasts dream about. That's just what I heard too from my own basic version: fantastic bass quality, provided I kept volume down, otherwise, the driver instantly destroyed itself!

However, my interest was, literally, academic. Analysing the (output) cone velocity signal against electrical input I found, not unexpectedly, that a lot of correction was being applied above 100Hz.

2) SUBWOOFER EQUALISATION

Similar correction could be applied passively by the use of equalisation in the low pass crossover network feeding the subwoofer and this is the reason for the peculiarly sharp response peaking above 100Hz you can see in the low-pass subwoofer feed. It injects high frequency energy (as far as bass frequencies go, that is) into the driver to add subjective "speed". Bear in mind that you don't hear this peak as such, because the drive unit cannot accurately reproduce it. It simply injects a little more energy where it is needed and is adjusted subjectively. I found +2dB or so about right for the Celestion drive units, but others may need more or less, according to their abilities.

Another "speed" injection came from cutting out really low sub-bass frequencies. They contain a lot of energy and decay slowly in the room. This



CELESTION SL-6000 EQUALISATION & FILTERING

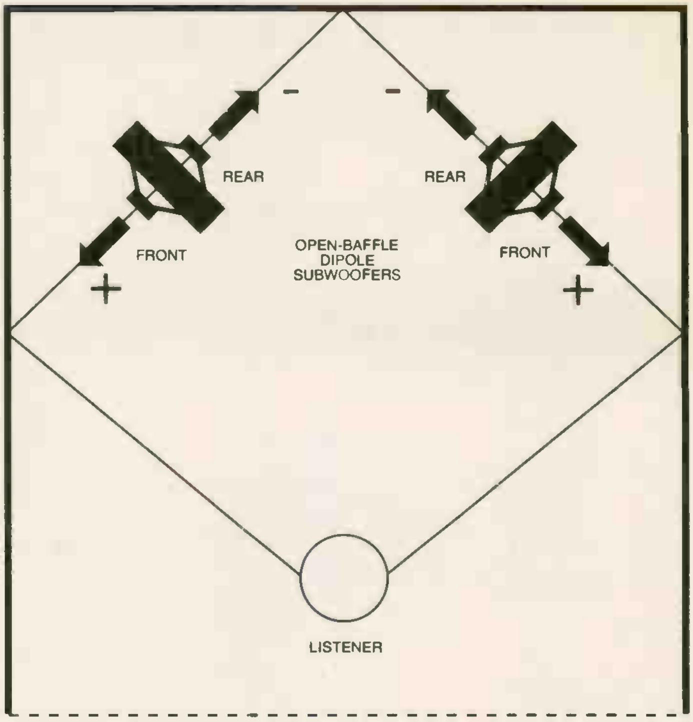
serves to give an impressive amount of physical presence to sound, but subjectively it weighs it down with lingering room boom. Believe it or not, the Celestion's go too low with the crossover supplied, which has no useful lower limit. My crossover applies tailored bass correction, with less emphasis on lower frequencies (i.e. around 40Hz), which compensates for room gain. It also incorporates a second-order (-12dB/octave) high pass filter at 10Hz to prevent record warps in particular overworking the system.

What you have to bear in mind is that the woofer cones are acoustically undamped and will flap around like crazy if given a chance. The high pass filter acts to limit cone excursion, necessary with this sort of sub-woofer. I managed to get adequately high sound pressure levels out of the SL-6000s though, although they will bottom if pushed too hard when strong subsonics are present.

Bass quality from these speakers varied considerably according to the power amplifier used to drive them; the SL-6000s were quite obviously a severe load. Trying to steady them by hand whilst working was impossible. They draw and reproduce quite staggering amounts of bass energy, shuddering in use, even though heavy and spiked to the floor. This vividly demonstrates just how much acoustic energy an open dipole subwoofer dissipates, although much of it is lost through cancellation.

The 120Hz peak equalisation applied to the SL-6000s is unique to them.

Experimenters interested in this subject could use any large bass unit on an open baffle, or two in parallel to handle the power, and tune out the peak. Just bear in mind that the drivers must be big enough to move a lot of air. A fair amount of experiment will probably be necessary to get the bass sounding right, but a delight of the system is that it's amenable to tweaking. There's no driver/cabinet interaction to contend with, an overriding influence upon the sound of conventional cabinet loudspeakers. This makes the open-dipole subwoofer something of an experimenter's dream, but by now you may well be realising that they also have their problems and peculiarities - and in this section I haven't even talked about the need to tune them into a room. That's even more fun!

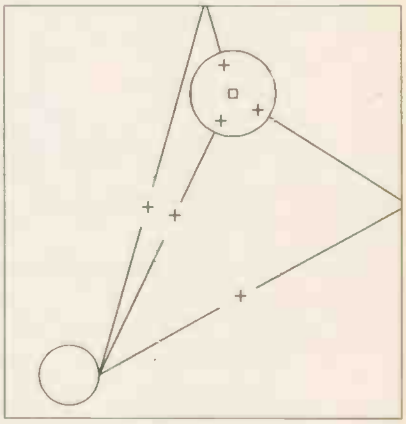


Within all the rooms in which we have used the Celestion SL-6000 subwoofers, best results were achieved with this orientation. We believe the rear wave reverses in phase and cancels at the opposing loudspeaker. While the front wave is heard by the listener the cancellation zones suppress diagonal room modes.

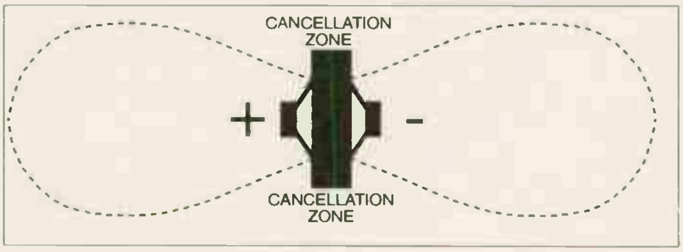
3) ROOM ALIGNMENT

There's one other big, big consideration which rarely gets talked about: tuning into the room. This is a peculiar process unique to the open baffle when it is used to deliver bass. It must be positioned and aligned correctly if it is to produce smooth bass, otherwise it will boom. In the few dipole speakers we have come across, including the Quad ESL-63, this subject is not even raised, let alone discussed, possibly because it is difficult to understand and resolve at a practical level.

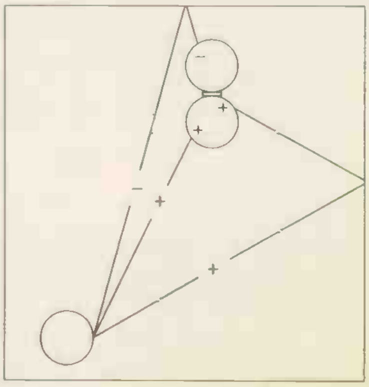
Celestion decided to run room analyses on a computer for their customers to solve the problem. We tried to reach an empirical understanding with our SL-6000s, finding only that in all the rooms in which we tried them they had to face outward for best results. The same should apply to Quads, by the way; they should give smoothest bass when facing outward, although I've never tried this. I suspect part of the reason why Quads give peculiar bass is because they are a non-optimally aligned dipole, facing inward to fire high frequencies toward a listener. Experimenters can, of course, easily move an open baffle for best results. Just bear in mind that this is a necessary part of running a dipole bass unit.



A conventional monopole generates additive reflections off all walls. Their strength and phase depends upon speaker position. The result is unpredictable emphasis.

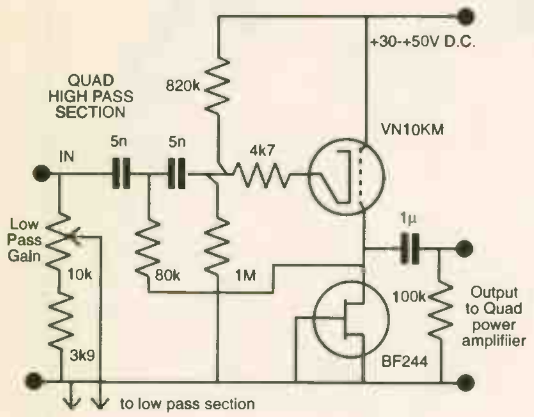


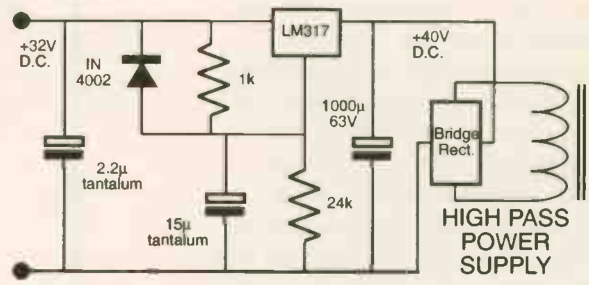
A dipole radiates sound equally from front and rare, but 180 degrees out of phase. Where front and rare wave meet they cancel. This produces a 'dead' zone either side of the speaker. Both Quad and Celestion loudspeakers exhibit this characteristic.

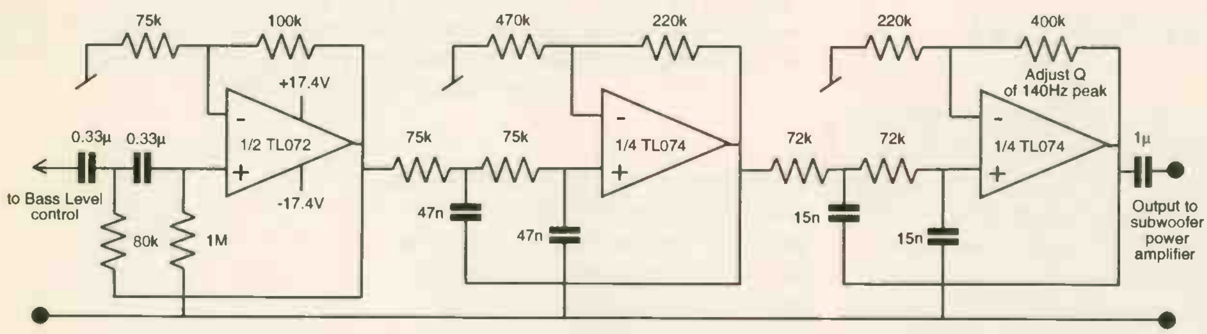


A dipole can provide negative reflections and, properly arranged, this can be used to give a more balanced overall result in a reflective field like a room.

CROSSOVER CIRCUITS

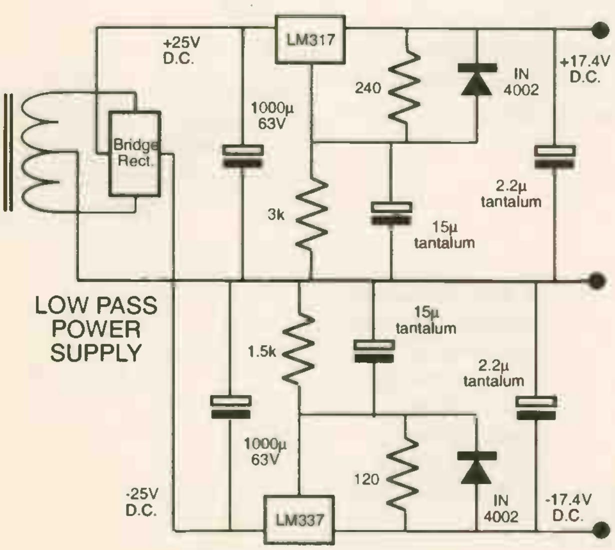






HIGH PASS (20Hz) LOW PASS & L.F. EQ LOW PASS & 140Hz PEAK

CELESTION SUBWOOFER LOW PASS SECTION



LOW PASS POWER SUPPLY

Because of the amount of filtering involved here, and the fact that a high level of transparency is not required for heavy bass cones, I used a set of TL072/4 silicon chips for the low pass section.

The circuit is a pretty straightforward arrangement with a second-order high-pass at 10Hz, followed by two cascaded second-order sections that combine to give equalisation and a fast, fourth-order, low-pass roll-off at 150Hz that can be tweaked to yield that vital 140Hz peak. Our diagram and spectrum analysis clearly show what this circuit provides.

Basically, an open baffle needs +6dB /octave bass lift to correct acoustic cancellation. However, room gain due to resonances, usually around the 40Hz-70Hz, must be taken into account, or over-heavy bass results I found. This is a benefit, because low frequency gain can be lessened. It needs to be kept in check if power handling is to be acceptable, and that's why I also included a second-order high pass filter.

I'd suggest you don't get too involved in the filter electronics, as so many engineers do. It is not necessary to use Butterworth responses, for example, in the face of massive imperfections elsewhere. This whole speaker is in fact a struggle to understand and tame various acoustic phenomena of some magnitude; pedantic electronic details are a distraction.

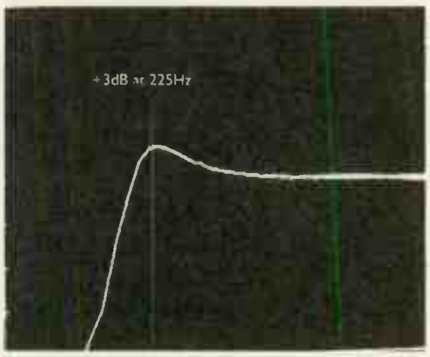
The bass low pass section feeds a power amplifier that in turn drives the SL-6000 subwoofers (or equivalent). This needs to be able to deliver a good 100watts. There are plenty of solid-state amps available second-hand for this purpose, or you could buy an NAD power amp new. They are very good value.

Remember that an open-baffle dipole subwoofer can produce enough bass to shake a building - but cones and power amps are put under severe strain if asked to do so.

In the next DIY Supplement we hope to have our own replacement for the SL6000s up and running, as well as a circuit board for active the crossover ●

Our thanks to Hi-Fi Experience Tel: 0171 580 3535, for the loan of Quad ESL-63s featured in the front cover photograph (ours don't look so smart without their grilles etc.)

QUAD HIGH PASS SECTION



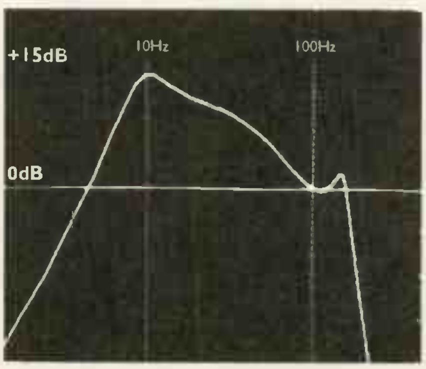
Most filters these days are, knocked up around a silicon chip. It's a fast and easy way of doing things, but not necessarily a satisfactory one. Cheap chips invariably have a sonic signature, something I wanted to avoid in the critical high pass section feeding the Quad. There are innumerable ways of designing such a circuit, but my notional ideal was to use just one high quality amplifying device.

I found that a remarkably high transconductance MOSFET, the VN10KM, offered what I wanted. This thing is a bit of a wonder for audio work, even if it is a pig to use, being almost 'naturally' unstable because of the gain available; a grid stopper must always be used if it is not to oscillate.

In the configuration used here as an active filter, the circuit has an overall gain of one, minimal noise, a very high overload ceiling and negligible distortion at all frequencies and levels. It also has a high input impedance and a reasonably low output impedance, able to drive down to a 4k7Ω load with 1000pF in parallel. I measured a 124dB dynamic range. Quad enthusiasts can rest assured that this device is as transparent as one might hope, unlike chip-based filters.

Frequency response can be seen in our explanatory diagram and as an analysis from our spectrum analyser. A -12dB/octave high pass attenuation characteristic serves to prevent bass reaching the Quad, whilst the gentle lift that reaches +3dB maximum at 225Hz equalises the Quad's natural roll-off, giving it a fuller, richer and more balanced sound.

CELESTION LOW PASS SECTION



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Circuits, Valves & Basic Technical Information

SOUND PRACTICES

BOXMODEL

Dominic Baker tests Robert Bullock's computer program for loudspeaker design.

There is little to choose between most computer aided box design packages for loudspeakers. All use the tried and trusted Thiele-Small driver parameters and equations that predict the response of a driver in a given box. Some offer a more user friendly interface and better graphics, but all of them should give you the same results, if used with care.

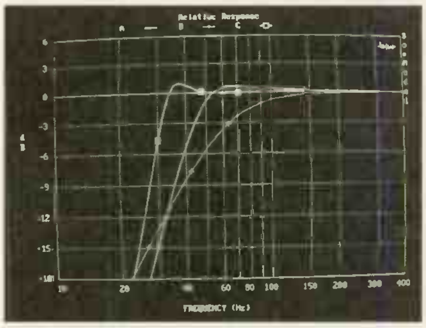
So, you may ask "why another review of a loudspeaker CAD package?" Well the reasons are two-fold. The package covered here, BoxModel, written by Bob Bullock, is one of the most comprehensive I've come across at a reasonable price. It includes many extra facilities, such as being able to model active equalisation, but more of these later.

Also, there is another version of BoxModel, TL BoxModel, for transmission line loudspeaker box design, which we intend to review in the next DIY Supplement. The package reviewed here is an ideal grounding.

First things first: what's BoxModel like to use? Well, once you've used one of these packages, they're easy to pick up; I quickly had a response up and running on screen. Straight away, though, I found one little annoyance. To clear the drop down menus and move on to another section (i.e. once you have selected a driver to use and want to go on to decide whether to use a vented or sealed cabinet) you use the ESC key. Not a problem in itself, but if you touch the ESC key once to much, the program quits. Normally most packages prompt with 'are you sure. . . Y/N', which prevents such unintentional shut downs.

Apart from this inconvenience though, BoxModel is simple enough to use and has a good, logically laid out tree structure of menus. The instructions for BoxModel are all enclosed in README files on the program disk, so you'll need a printer to make a hard copy. The HOWTO file gives four examples of complete system optimisations, each in 10 steps, which is extremely useful for first time users.

Now on to those features that make BoxModel one of the best at the price. It comes complete with specs. for 1074 drive units which have been pre-programmed in, including drivers from Audax, ScanSpeak, KEF, Focal, etc. This is great, saving a lot of monotonous data entry. When you have decided exactly which driver you want to use though, it is well worth checking the Thiele-Small parameters. Errors on manufacturer's data sheets are fairly common. For those with reasonable maths skills and something like Bullock's own book, Bullock on Boxes, the parameters can be cross checked through the Thiele-Small equations.



Typical low frequency response curves.

Once you have selected the driver you want, it is a very quick process to get to a predicted response. For example, tell BoxModel that you want to use a single driver in a closed box with no equalisation, set the losses (default parameters are given in the HOWTO file) set input power, select Align (a useful command which optimises the cabinet for you to give the flattest response) and plot the response. The screen will show the predicted response for the data you have supplied.

But, along the way you are given many more options which make BoxModel more comprehensive than most at this price level. Rather than using just a single driver, it is possible to model a pair of bass drivers wired in series or parallel and in a normal (vented or sealed) enclosure or isobaric type.

As well as sealed or vented boxes, it is also possible to model passive radiators (ABRs). You can also simulate 1st, 2nd or 3rd order active equalisation, something that is rarely used in domestic audio, but may be of interest to more ambitious experimenters.

BoxModel allows you to toggle between the Imperial system still in use in the U.S. and the European Metric system.

The losses within a vented system can be entered individually, QL - Leakage losses, QA - absorption from cabinet damping, and QP - port losses, which is really something for more advanced designs and designers. Normally, because QA and QP are low enough to be deemed insignificant (assuming that the port can vent freely and cabinet damping is thin), most packages rely on a 'typical' overall loss figure of 0.7 which gives accurate enough results. Here, default values for each of the losses in a vented system are given which yield this 'typical' value.

There are a few other facilities that BoxModel offers, such as modelling of a high pass warp filter, but most are going to be of little practical relevance to the home constructor.

BoxModel offers an affordable and comprehensive package that the user can learn and grow with. Some of the simpler packages around, although adequate, are easily surpassed when you get more experienced and adventurous. BoxModel should serve you through a wide range of designs at all levels, and as such is fine value.

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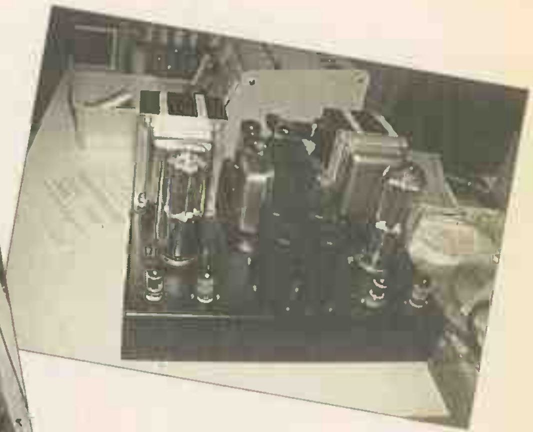
THE 1ST EGHAM AUDIO FAIR

visited by Noel and Dominic - who describes the event.

Held at Egham Youth & Community Centre on the 1st October and arranged by Graham Tricker of GT Audio, the Egham Audio Fair was an event worth attending, especially if you're into valves and vintage audio. I got a fantastic looking Nitrogen filled analogue voltage meter, reading up to 500V for a project I'm working on and a handful of vintage books, one on radio techniques by Scroggie, who was a great Wireless World writer in the 1950s, and a valve data book complied by A. M. Ball, all at bargain prices.

Here are some of the other interesting items we spotted.

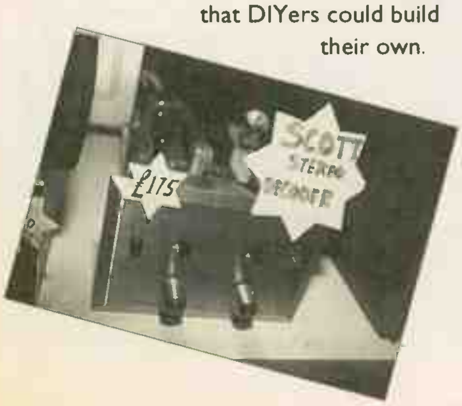
▶ Based on the Audionote Ongaku circuit, this home built single-ended 211 amplifier using Audionote transformers attracted a crowd. No one dared ask the price though!



▲ If you want to re-create a vintage circuit, Audio Fairs like this are the place for original components. Here's a box of unused and original transformers including those from Parmeko, offered by Sussex Surplus. And below a selection of original valves, including GEC KT66s, Mullard GZ32s and the increasingly scarce GZ34s. ▼

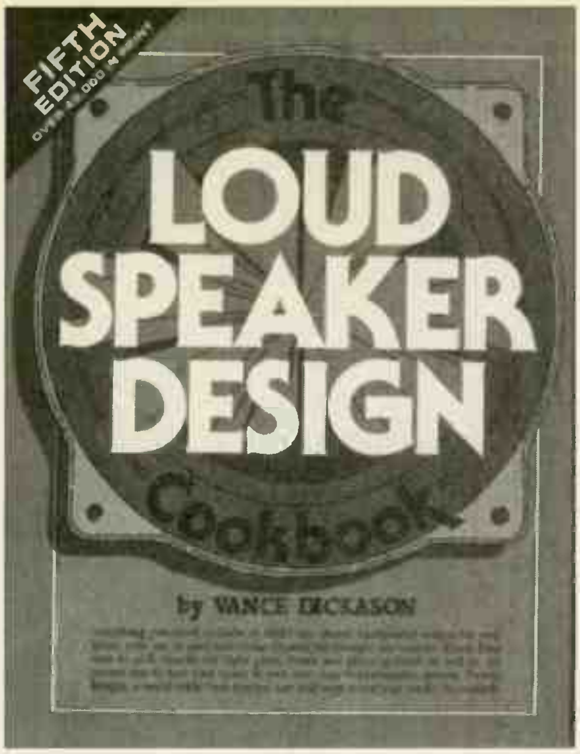
▼ A mixture of old and new here. This amplifier was home designed with modern transformers and components, but uses vintage PX25s in fixed-bias, single-ended working. This must be one of very few amplifiers in use using these extremely rare, but gorgeous looking PX25s.

▲ A Mullard 5-10, probably built in the 60s. Mullard published their designs (we sell the re-printed book today) so many transformer manufacturers of the time wound to Mullard's specification so that DIYers could build their own.



◀ Scott's stereo decoder is regarded by many as one of the best vintage designs around. This Type 335 decoder in absolutely superb condition was going for £175.

▶ Even if you can't afford a complete amplifier using these rare and sought after valves, for between £5 and £15 you could take home one mounted to a wooden plinth. And don't worry, the valves used for these ornaments have all served their useful electronic life span ●



THE LOUDSPEAKER DESIGN COOKBOOK

5th Edition, by Vance Dickason

Reviewed by Dominic Baker

The Loudspeaker Design Cookbook has long been popular amongst DIY loudspeaker builders. It is written, like many American publications, in a chatty style that is easy to understand and digest, and is certainly better geared towards readers who actually want to build something, unlike more theoretical publications.

The new 5th edition, reviewed here, includes two new chapters, on Home Theatre and Car Audio Sound. These are as well covered as any I've seen, especially on Home Theatre which carries some very useful information for those that are interested.

We are more interested in the main body of The Loudspeaker Design Cookbook though, which covers a wide range of loudspeaker design and construction problems. The introductory chapter covers the basic drive unit and how it works. Unfortunately, for beginners to completely understand this short chapter they will need to be familiar with principles of electricity and magnetism - an A-level physics text book should give you the grounding needed. However, a lot of this first chapter will be irrelevant to practical DIYers; for example, fringe field effects for different pole geometries and different shorted-turn configurations, which are more to do with driver design than loudspeaker system design.

The next three chapters concentrate on the classic areas of sealed, vented and passive radiator systems, giving tables for various alignments. If you have the basic Thiele-Small data provided by the driver manufacturer, it is relatively straight forward to plug the figures into these design tables. Even if you don't have the Thiele-Smalls for a driver, a chapter later on is dedicated to measurement techniques used to extract them.

It always surprises me to see such attention devoted to Passive Radiator systems, since there are few commercial designs and only a handful of ABRs available to the home constructor. It seems especially odd when transmission lines (far more interesting as a design and popular amongst commercial manufacturers and home constructors alike) are skated over in four pages and some of the rarer, but more intriguing concepts such as isobaric, horn and open baffle are nowhere to be found. I suspect this is because the mathematical treatment of passive radiators is very similar to that of vented systems, so it is easy to generate such information.

Nowadays there are some very cheap computer packages that will model your design for you, saving you lengthy maths and use of tables, as well as being faster and more flexible. "What if I don't have a computer?" I hear you say. Well, if you simply want to optimise your driver to a cabinet, the book Bullock on Boxes is a better bet. But if you want to design your own crossover too, this is where The Loudspeaker Design Cookbook has the edge.

Chapter 7 deals comprehensively with passive crossover theory. This will give the hobbyist a good insight into how to manipulate crossovers to give the effect they desire. But beware! Without some form of test equipment this is not a simple task. It is hard to know where to aim if you don't know where you're starting from, and all too often subjective tests can be misleading due to amplifier/loudspeaker interaction and lack of prior experience.

The Loudspeaker Design Cookbook covers many aspects of loudspeaker design and construction and as such is a valuable reference book to have on your shelves. For more involved design work though, aiming towards a practical design, I feel that home constructors would be advised to take a look at some of the more dedicated works around or some of the superb CAD packages available.

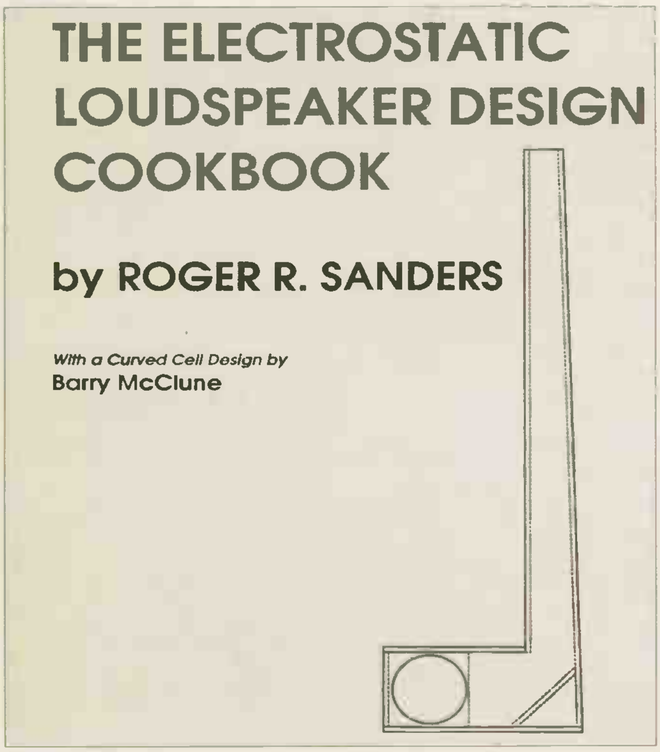
Bullock on Boxes is a better read if you want to design your own cabinet, and practical circuits for active crossovers can be found in far more useful depth in The Active Filter Cookbook. And Liberty's IMP test system is simple, cheap and the measurements it's capable of generating will get you far closer to your ideal loudspeaker than any number of books.

However, the Loudspeaker Design Cookbook will give you a good insight into what is involved in designing a loudspeaker, and if carefully digested will guide the reader towards selecting good drive units that will match the system you intend to build, which can be half the battle ●

by Roger R. Sanders.

THE ELECTROSTATIC LOUDSPEAKER DESIGN COOKBOOK

Reviewed by Noel Keywood



Of all the obscure and wacky things to do, building your own electrostatic loudspeaker must be one of the most far out. Electrostatics represent the outer limits of hi-fi, although they've always been revered for their promise of near perfect reproduction. It's a promise rather than a reality though, which simply serves to keep ever-hopefuls trying (I've started building one too). For that ardent band of experimenters, mostly American it seems, here's yet more help on what sort of Clingfilm to use (sorry, Du Pont Mylar type S), how many kilovolts are needed to polarise it (10kVs is adequate, 20 will have you cookin' - literally), and what sort of transformer will give you a 50:1 step-up so you can swing the polarising potential far enough to get some acoustic action - or a blinding flashover.

This is one of the world's most obscure and arcane hobbies; it is also one of the most complex - and a little dangerous too. The audio drive, when stepped up to a few kVs, as it must be, has enough punch to kill, even if the polarising potential doesn't.

I have to admire a book like this, for the subject is a notoriously difficult one. All through, author Roger R. Sanders, whilst chivying the reader on, discusses all the compromises that have to be considered. With a background that, he claims, includes working on "thousands" of 'speakers for customers of the ESL Clearinghouse (his own U.S. enterprise, it seems) it's obvious he has broad experience of the practical problems.

This Cookbook attempts to provide a comprehensive grounding in electronics theory, but skates through the entire field at an alarming pace. It does the same for conventional subwoofers, which appear in this book because the author is firmly of the conclusion that they must be used with electrostatics. I tend to agree. Happily, the rapid fire nature of these chapters is balanced by the rare value of the book's core content.

And this is where the Cookbook scores. Down-to-earth practical in a way that only American authors can be - but which others should take more note of (especially Brits) - this book tells you in "screw this to that, and glue that to the other" terms just how to build an electrostatic loudspeaker. It's 100% a hands-on enthusiasts book, rather than a theoretical tome, which means just about anybody will get the drift of the discussion.

Brits may run into supply problems with raw materials, but you can always contact the author by writing or phoning him at the ESL Clearinghouse in Oregon (USA), since he bravely provides contact details in the book. I could find no mention of all-American wonders like Uncle Elmer's Hickory Glue, but you are asked to find Du Pont Mylar, Lincaine, Glyptol, Krazy Glue and Hot Stuff. I started to smile when I saw that you also need Popsicle Sticks - getting those could be embarrassing.

It's rare to find so much practical information and experience in one book. I was fascinated to see confirmation of something I have discovered by measurement, that open-panel ESL response falls off below 280Hz (according to panel size) then peaks back up at 90Hz. The author suggests use of equalisation as one solution to this problem, which was my conclusion, as I explain in our DIY Supplement this month. The need for subwoofering is also discussed, because of the extreme difficulties of making electrostatics that will work at low frequencies.

I was disappointed to see absolutely no round-up of electrostatic theory at all; one chapter hidden away at the end of the book would have been better than none. But the author does say specifically that his book is theory and maths free, so the omission is intentional.

The Electrostatic Loudspeaker Design Cookbook has to be great value for anyone interested in building such a loudspeaker. It contains an enormous amount of information for the enthusiast and is as easy to read as could be possible. Since much information is just about unavailable elsewhere it's excellent value. A wacky book, but a must ●

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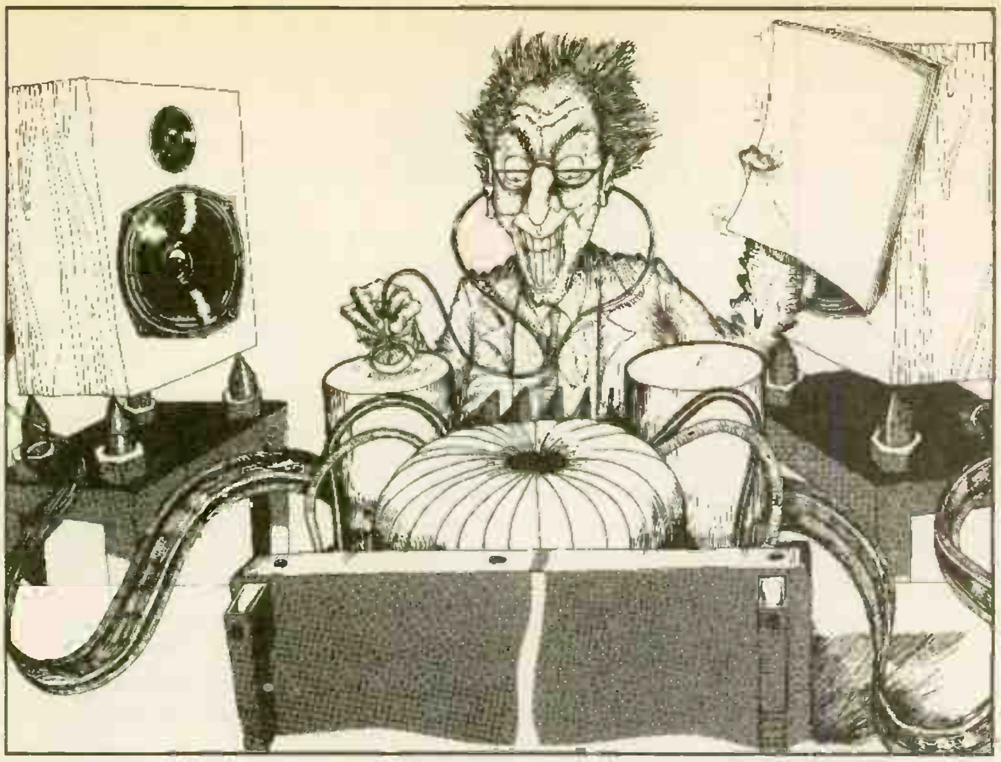


D.I.Y. Letters

TRAPPED

For anyone thinking about building the open back HDA-driver DIY (KLS6) speaker from Hi Fi World, here's some tweaking advice. The 3inch mid-driver has got a resonance frequency of 220Hz and the 100µF high pass filter is not working as it should. Around the resonant frequency the filter function is virtually zero: I have measured 1 volt in and 1 volt out .

To get around this problem you should construct a LCR trap centred around 200-250Hz. It consists of a 4mH inductor, 100µF capacitor and a 5.6Ω resistor across the terminals of the mid-driver to give you a 6Ω +/- 1Ω impedance from 100Hz to 600Hz, instead of 37Ω at the resonance frequency without the trap. You should also lower the value of the high-pass capacitor to around 68µF(47µF+20µF Solen polypropylene) to get the -3 point centred at 400Hz, as the 100µF did without the LCR trap. With this little tweak the filter function will work as planned and the driver will withstand probably twice or three times the power it did before, with less distortion as a result.

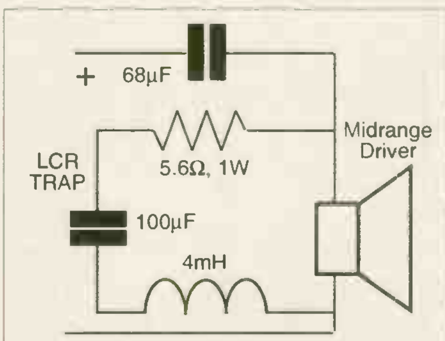
For anyone thinking about building this speaker, but can't afford the superb but terribly expensive Audax piezo tweeter, you can substitute a ribbon tweeter (Tonigen or ACR Fostex makes good ribbons for around £50). This is the closest you can get to the piezo driver. Don't put a dome tweeter in it's place because they don't even come close! A third order T-filter consisting of a series 2.2µF / 0.15mH to ground / series 6µF, centred at 6kHz should do the trick. You also have to bring the ribbon down about -3 dB to match the midrange and bass. This is the solution for a budget HDA open-back speaker if you can't stand the huge cost of the Audax tweeter.

Keep up the good work.
Per Karlsson
DSS-Audio,
Borlange, Sweden.

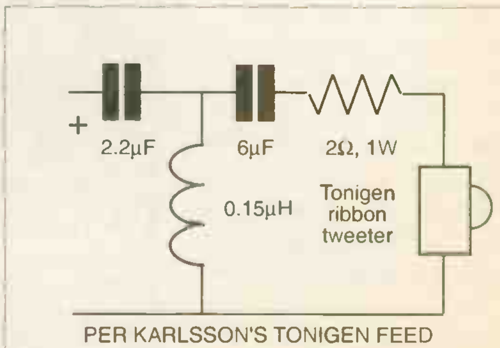
One of the things we look for in all of our kit designs is high sensitivity. We use modern, light cone materials - carbon fibre and High Definition Aerogel, and simple crossovers so that as much of the power at the 'speaker terminals as possible is turned into sound. The 100µF capacitor is there as a safety precaution, acting as a D.C blocker, rather than as a actually acting as a filter.

The output from the midrange driver, being on an open baffle, self cancels and rolls off where the dimensions of the baffle allow the wave from the front of the cone to cancel with the rear. This happens around 400Hz. The 100µF capacitor is to prevent this midrange driver being overdriven by subsonics, such as record warps from LP where there is no LF filter.

However, your use of an LCR trap is useful. It adds more components to the signal path, which we try to avoid, but as you suggest power handling will be improved and impedance smoothed. This difference in approach to 'speaker design is common, for example Epos prefer minimalist crossovers at the cost of some response flatness, and KEF take an opposite



PER KARLSSON'S LCR TRAP



PER KARLSSON'S TONIGEN FEED

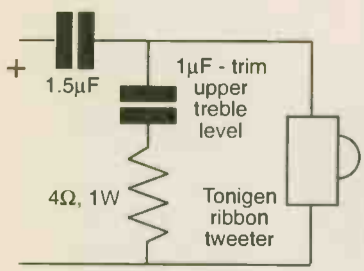
▶▶

view, creating a super smooth response using a complex crossover network at the cost of some sensitivity.

On the subject of KLS6 we have made a few subtle tweaks recently which may be of interest to builders. I was keen to exploit the clarity of the HD-3P tweeter, but without making it too obvious, as the Tonigen in the old Heybrook Sextets could be. However, it has been suggested that they are a little too soft in the treble, and, like the Tonigen, once you get used its super-clean and fast character, you want more. We have tweaked our pair by reducing the series resistor R2 from 3.3Ω to 2.2Ω.

Another thing we noticed was that KLS6 could become a little thick and full in the upper bass in smaller rooms. The midrange and bass overlap deliberately, the lower midrange cancelling in the far field to give a flat response. Closer to the speakers this overlap causes a lift around 400Hz. To counter this and give a dryer, better balance sound, we have increased C3 from 50µF to 120µF. These tweaks have already been implemented for anyone who has ordered the KLS6 kit. DB

We have not tested and validated Per Karlsson's notch filter, but it is pretty standard and should work. However, a third-order high pass for the Tonigen is unnecessary and is unlikely to give a net flat resonse. A simple 1.5µF series capacitor combines with the tweeter's innate frequency response characteristic (which is not flat) to give a sharp roll-in curve and a ruler flat pass band from 6kHz to 21kHz - see circuit. This is a tested and validated circuit. NK



HI-FI WORLD'S TONIGEN FEED

VALVES & TRANSISTORS

Observing the growing interest in valve audio amplifiers and comments about them sounding more natural than transistor amplifiers, we have started a project to compare the two.

Although many interesting subjective comments and technical discussions have been printed in various magazines, it has been difficult to access literature in scientific journals. Could you or any of your readers point us to any past or recent literature on this subject?

M J Ruttar
Y N Tsakiris,
Edinburgh

I searched through my reference books but could find no useful sientific comparison between valves and solid-state devices. In many electronics books which were published during the transition from vacuum to crystal, superficial comparisons were made to assist engineers in understanding the new fangled three-legged dvices, but that is as far as it seems to go. I think yours may be the first real comparison on audio grounds.

Although valves and transistors (bipolar and FETs) do much the same job in an amplifier circuit

Letter of

HOOKED ON DIY HI-FI

I recently purchased your magazine at a speciality book store and found it to be possibly the best Hi-Fi magazine I have ever encountered, because of the inclusion of construction and electronic theory related articles. Earlier this year, I designed and built a pair of 6V6 push-pull tube amplifiers, and this hooked me on their warm sound. I am writing to request your technical advice on the following matter. I have purchased a pair of high quality output transformers with the following specifications; 4300ohm, centre tapped ultra linear primaries, and 4/8/16 ohm secondaries.

These transformers have a power rating of 60W. At our local surplus store I bought a power transformer with two 408-0-408V secondaries at 232mA each. I am planning to construct a single chassis stereo amplifier with these components using 6550 output tubes and a power rating of 40-60 watts per channel. I have enclosed the best design that I could come up with and am wondering if you could comment on it and tell me ways to improve it, or if you find it unacceptable, please provide me with a better design using the same basic components (output tubes, power and output transformers).

The preamp section of my amp is using a separate (on same chassis) 300Vdc regulated power supply featuring another surplus transformer. I am planning to use this for both sides of the amplifier for all tubes but the output tubes. Your advice on these matters would be greatly appreciated. I would also like your opinion on the Chinese made 6550 output tubes, as these are all I can afford for the time being, but do you think it would be worth the expense to retube with Tung-sol, GE or GEC output tubes when possible? I am 16, and have taught myself everything I know about electronics, therefore your advice is very important to me. Keep up the great work with your magazine and I eagerly await the issue with your response to my questions in it.

Max Holubitsky
Edmonton,
Alta. Canada.

It is not realistic to design an amplifier "from a distance" like this, because there are so many variables. For example, you say your output transformers are "high quality", but what is their phase shift at 20kHz? Is this phase shift caused by leakage inductance or interwinding capacitance, or both? Also, the HT voltage provided by your mains *and look similar on paper they are very different in the physics of their operation. Also, a typical valve amplifier is different in it's topology to a typical transistor amp. This must also affect the sound quality of each. It is possible to build valve and transistor amplifiers which have very similar measured performances but which sound completely different. This leads me to think that there must be other more subtle differences which elude standard tests, or our interpretation of them.*

I think you are going to have to search through the reference books on each type and draw your own conclusions, but here are some areas which aren't usually covered.

It would be useful to start at the most basic level and analyse the fundamental differences between valves and solid-state devices. In a valve any particular electron (strictly speaking the electron's wave function) travels through free space, influenced only by the electric fields caused by the various electrodes in its path. The control grid's field holds back a proportion of the total electrons emitted by the cathode, a change in the grid voltage changes it's field and thereby varies the total amount of electrons reaching the anode and hence the anode current.

The velocity of an electron by the time it reaches the anode after bering accelerated by the anode's field is truly mind boggling. For example, in a valve with a fairly typical anode voltage of 450V the electrons will hit the anode at approximately 12 million metres per second (28million m.p.h. - no wonder it gets hot!). The electrons which make it past the grid are the same ones which, a tiny fraction of a second later, appear at the anode and cause the signal in the load.

In a solid - state device the electrons have a very hard time of it. They have to fight their way through millions of random fields caused by the atoms in the substrate material. Solid-state (and that includes wire) electrons move at only a fraction of a metre per second, crashing and bouncing all the way, rather like a Christmas shopping trip on Oxford Street. It is not the actual electrons which carry the signal but the influence of one electron on it's neighbours, the message gets carried as a Chinese Whisper" only with less corruption of the signal (?).

In a bipolar transistor the flow of electrons is impeded by the base junction. Forward biasing the junction allows electrons to pass. Similarly, in an enhancement mode FET the gate has to be forward biased to allow the electrons through. Junction FETs, which were gate first type available, are normally reverse biased like valves. No bias on the gate allows the full saturation current to flow; reverse biasing reduces the current.

Comparisons were made between JFETs and pentode valves in the early texts because their characteristic curves look similar. That is, the current through the device is dependant more or less solely on the grid/gate voltage, but their method of operation is very different indeed, we we have seen.

Another point is that the current densities in valve and solid-state devices are completely different. In a valve a small current (milliamps rather than amps) flows ▶▶

The Month

transformer may not tally up with the operating conditions of the valve/ output transformer combination.

I suggest you seek out old valve manufacturer's data books and any other source of information you can for a circuit which is close to what you are after. The Groove Tubes "Tube Amp Book" has loads of commercial amplifier circuits in it, and companies like Angela Instruments have circuits of many of the more obscure amps, as well as those for Conrad Johnson and Audio Research etc. By studying other amplifiers you will get a feel for the different possible topologies used and can experiment to find which suits your ear.

Regulated supplies are a good idea but commercial constraints usually restrict their use to the more exotic amplifiers. You may want to experiment with regulating the output valve screen grid supplies as well; improved clarity and bass definition usually results.

We have had experience with the Chinese KT88 valve(which is similar to the 6550) and found it to give good power output and sound quality, but you should get them from a reputable supplier, such as Billington or P.M. Components, in case of problems. Svetlana have released the 6550B-3 just recently and they will be worth a look at. The Tung-Sol 6550 is supposed to be the best of it's type, only beaten by the G.E.C. KT88. Both of these are extremely rare and expensive. There are some G.E.s and RCAs around, but they are pricey. Of course, the extended life and reliability, together with improved sound quality, may justify the price for you. AG

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through a comparatively large area, while in any form of transistor the currents are much larger but the area through which that current flows is very much smaller. In other words, valves operate at low current densities while transistors operate at high current densities. Whether this, or the resultant magnetic fields generated (which could cause hysteresis distortion if the transistor has a ferromagnetic body) have any effect on the operation of the device is open to question.

At the macro level the topology of typical valve and transistor amplifiers bear very little similarity to each other. This is due in part to the nonexistence of a "PNP" valve. Early transistor amplifiers relied heavily on the germanium PNP transistor because NPN types were difficult to make before silicon appeared. These amplifiers looked quite like the valve amplifiers of the time, but offered very poor performance compared to valves. Cheapness and small size were the main driving force behind the popularity of transistor amps (and they still are).

Nearly all modern transistor amplifiers use what is known as the Lin topology (see the circuit to our solid-state monoblocks for an example), having a long tailed pair input stage, a single-ended voltage amplifier and a push-pull emitter follower buffer output stage all enclosed in a feedback loop. Both NPN and PNP transistors are needed for the Linn type of amplifier.

Maybe because valve designers only have one polarity of valve to play with they seem to have shown a little more creativeness and there are all sorts of different possible configurations, although most commercially available amps seem to be developed from one of two generic types, the Mul 5.20 or the GEC 50W.

One fundamental difference between push-pull valve amplifiers and their solid-state counterparts is the output stage. Valve amplifiers use two identical devices and their outputs are summed in the output transformer (except OTL amplifiers, which still use identical devices but no transformer). The transistor amplifier uses two different but complementary devices and their signals are summed at the output node.

Distortion, frequency response and most of the standard tests applied to amplifiers have not so far explained the perceived differences in sound quality between different amplifier types. I hope that by detailed analysis your study may bring you closer to understanding the hows and whys of amplifier sound quality and that my observations may help. A.G.

A QUALITY BUILD

Please find enclosed photographs of the super sounding KLS3 loudspeakers. I enjoyed building them. I found the construction basically straight forward. As you can see from the photographs they are not like the house that Jack built! I have been building speakers for 27years - from KEF etc. I have also built the KLS4s (see photos), again straight forward.

I would appreciate your comments on the finished products. My kit consists of Arcam 5 CD player with DacMagic 1, Audiolab 8000C preamplifier and two 8000P power amplifiers, Yamaha KX580 cassette deck and Sony STS-311 tuner. I am using good quality interconnects and Cable Talk 3. Listening room size 18' long x 12' wide x 8' high.

P. McCartney
Nottingham.

You've certainly made a super job of the cabinets, every bit as good as any commercial design. Perhaps you could make us a few pairs? I'm glad you found the cabinets easy, but with 27years of experience you will have become quite a master at this by now. For less experienced readers it is useful to know that any good timber merchant is capable of preparing the wood panels to a close tolerance. Once glued together only a little light sanding should be necessary to give a smooth finish.

As for your system, it seems very nicely balanced. I suspect that you would hear a worthwhile improvement by upgrading you front end though, perhaps updating your CD player to Arcam 6 status which can be carried out for £150, would be the most economical. Contact Arcam on 01223 861550. DB

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THE HI-FI LAW OF DIMINISHING RETURNS

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