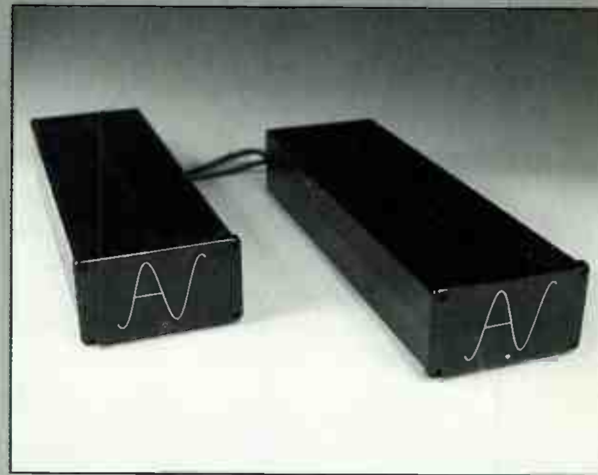
# Hi-Fi WORLD SUPPLEMENT

FEBRUARY 1993



## AN ADVANCED CD CONVERTOR KIT TESTED

## GOOD TOOLS FOR THE HOBBYIST

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## DESIGNING LOUDSPEAKERS on a home computer

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## KIT SUPPLIERS

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# D.I.Y. Supplement

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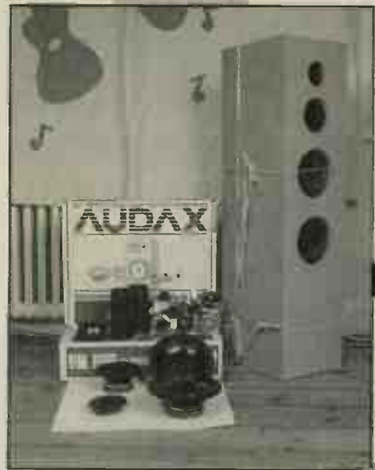
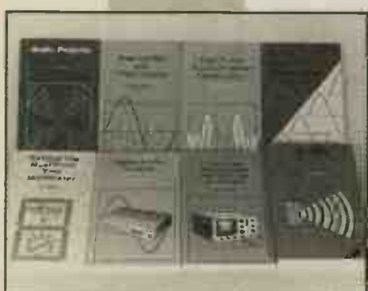
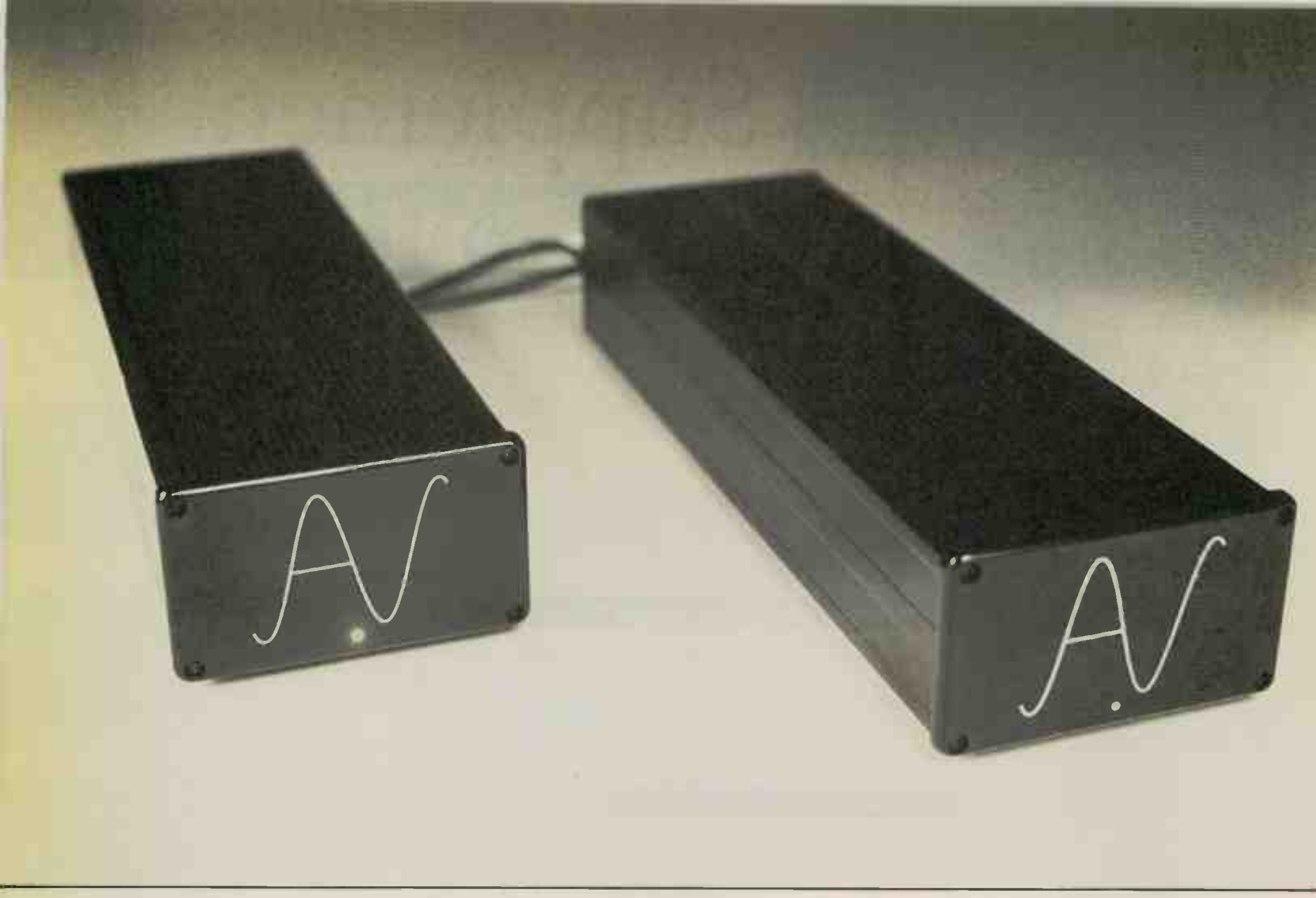








# AUDIO SYNTHESIS KIT CONVERTOR

**An advanced digital-to-analogue convertor kit is available from Audio Synthesis.**

**Noel Keywood and Dominic Baker check out a built version to see how well it performs.**

Audio Synthesis started trading in 1987 following Ben Duncan's Hi-Fi News series "Supertuning CD". Ben Duncan is still the man within Audio Synthesis who is responsible for all the designs, but the sales and marketing are now a separate operation.

Audio Synthesis have a large range of kit and ready built audiophile projects. All of the kits are intended to be state-of-the-art high quality items and as such most are quite complicated. The range includes two DACs which can have an Arcam master clock system and an optical input added if required, plus a passive volume control using a 31 position stepped attenuator and a professional modular preamplifier, all to extend the scope of the project.

Of all the kits this one, the DSM-M with Burr-Brown chips is one of the most difficult to make. I have done a lot of silver soldering over the years and possess an expensive and very good temperature controllable iron. However, it would take me a lot of time and care to build this kit to a professional standard. I don't want to put people off at an early stage, but unless you are very competent at soldering it would be better to buy this in built form.

It was suggested by Audio Synthesis that the kit should take a competent builder around 10hrs to finish. This means that it could be built in a week, spending a couple of hours a night on it. The DAC comes in two separate parts, the power supply and the digital/analogue audio circuitry. The power supply will be quite straight forward to build with little chance of mistake. The DAC itself is a different matter. The circuit board is double sided and the chips have a lot of legs on them to solder down. Errors may occur but the main problem for most people will be the fine and accurate soldering required. It requires some experience, both with soldering in general and with the handling of a lightweight, 15W iron with a fine tip. This is a job for the dextrous, those who have a good eye and a steady hand. The iron must be applied quickly and precisely; any delay will overheat a component and may well destroy it - especially the expensive silicon chips.

The components supplied with the kit are of high quality, most being special and expensive selected audiophile grade. Externally the DAC is also well finished, housed in two long, slim, black aluminium extrusions with highly polished front panels. The sockets on the rear are the massively engineered WBT phono's which are expensive.

## SOUND QUALITY

After numerous 'soft' sounding DACs, as I'd loosely call them, the Audio Synthesis came as an interesting and not unwelcome contrast. Here's a convertor that really delineates and resolves, one that isn't scared to jolt your senses, one that'll give you a quick jab between the eyeballs, followed by a fast left hook lower down. Then it'll be speeding on, not hanging around awaiting the outcome.

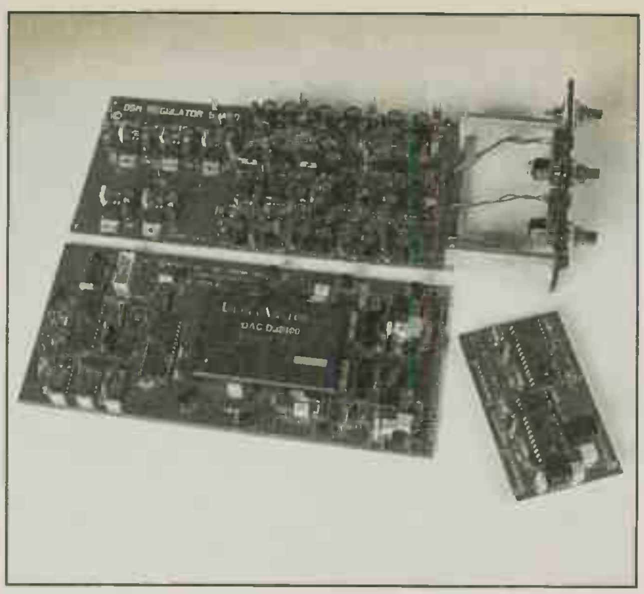
I'm beginning to like DACs like this, even though I continue to have sneaking reservations about them too. We seem to agree on this magazine that DPA Digital (ex-Deltec) DACs are distinguished by their larger-than-life sound, one that doesn't necessarily go down too well with someone who's just come home from a hard day at the office and wants to relax in front of the stereo, listening to something tranquil and soothing. A DPA DAC seems to make any and every performance jump out from the loudspeakers. It's like coming home to Round 2.

The Audio Synthesis does likewise, but perhaps with just a little more restraint and finesse. As such, it's an edge-of-the-seat design; you'll always remember why you bought it; this isn't a shy and retiring product that'll meld into the background and lull your senses into possibly believing CD can sound a little like LP. No indeed - this convertor is all about contrasts, power and rich textual changes too. It really does sort out the complex strands of a performance remarkably well and present instruments in their full glory, showing clearly that other convertors commonly offer pale representations by comparison.

I believe I heard the characteristics of special capacitors and possibly other special audiophile components in this DAC; it has qualities that I am beginning to recognise as attributable to specific specialised audio components. It's the dryness of the sound, the sense of deep insight and the general lacking of smearing and softening that indicates such speciality. The tight bass with its incredibly fast and controlled pace is another give away.

I have to say that I'm very impressed with this DAC. It really does offer a a superbly clean sound, full of life and vigour, right across the audio band. Only at high frequencies do my ears sense just a little too much energy, just the hint of an occasional rasp that presents more a small threat than a withering assault ●

**Audio Synthesis**
**99 Lapwing Lane**
**Manchester M20 0UT**
**Tel: 061 434 0126**



◀ **Although the convertor is very sophisticated, most of the processing is carried out by silicon chips. Building the convertor is a matter of placing these chips and support components onto pre-drilled and marked circuit boards.**

## MEASURED PERFORMANCE

For a kit, the Audio Synthesis DSM-M digital to analogue convertor (DAC) is an advanced piece of audio technology. It is a two-box convertor, one housing the DAC and one the outboard power supply. The DAC itself uses Burr Brown's Co-Linear PCM63K chips, as used by Creek for example. They are 20-bit, single channel chips, so two are needed for stereo. The K suffix indicates that they are the highest quality version of the PCM63.

The circuit board is of high quality, as are the components. Precision Holco resistors, Elna audio capacitors, silver wiring and WBT phono sockets are all used. Components of this quality are rare at the price level, so is the excellent standard of finish. The price is low for the technology used.

The frequency response of the DSM-M is a slightly dished one, as can be seen by the plot below. Either side of 1kHz the response gradually rises. The rise at the frequency extremes, although only a fraction of a decibel, will have a small effect upon the character of the sound. I would expect the Audio Synthesis to have a powerful bass performance and a slightly bright treble (but see Noel's notes on sound quality)

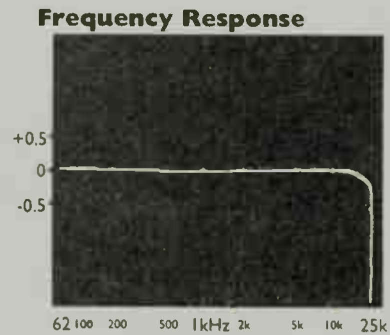
The plot taken with an input of 1kHz at -30dB shows very little harmonic distortion. The first harmonic of any size being the fourth, and even this is relatively low. The DSM-M has good channel separation and a low noise figure, plus a dynamic range figure of 113dB, which is something that Audio Synthesis can be proud of.

Output was measured at 2.13V for both of the channels, which is about average, so no incompatibility problems should arise. Overall, the DSM-M measured very well and our only concern would be that the hobbyist will not be able to check his work in the same way as we can. Fortunately, for £35 Audio Synthesis will do these kind of measurements for you and additionally correct any mistakes made during construction.

## TEST RESULTS

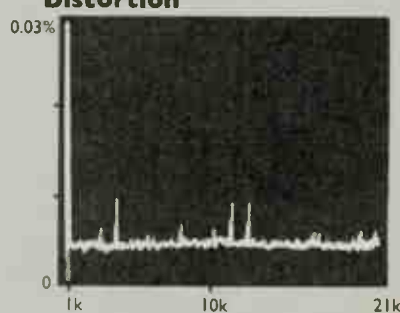
| | | |
|---|---|---|
| Frequency response (-1dB) | 3Hz-21kHz | |
| Distortion | | |
| -6dB | 0.006 | 0.002 |
| -30dB | 0.017 | 0.024 |
| -60dB | 0.56 | 0.50 |
| -90 29.9 | 29.6 | |
| -90dB dithered | 2.74 | 4.44 |
| Separation | left | right |
| 1kHz | -109 | -119 |
| 10kHz | -102 | -99 |
| Noise | -105dB | |
| with emphasis | -104dB | |
| Dynamic range | 113dB | |
| Output | 2.13V | |

**Frequency Response**




Flat frequency response.

**Distortion**

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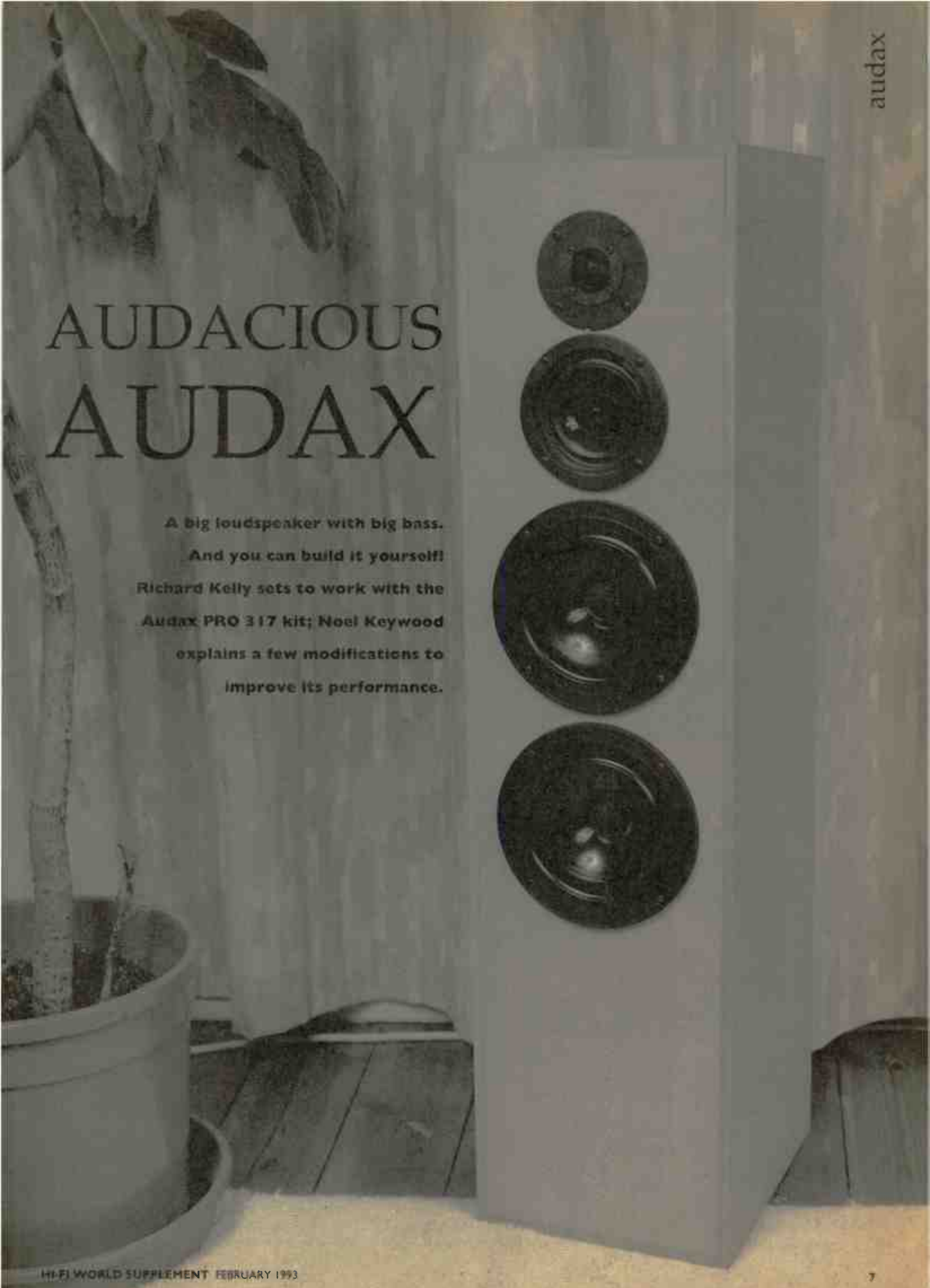
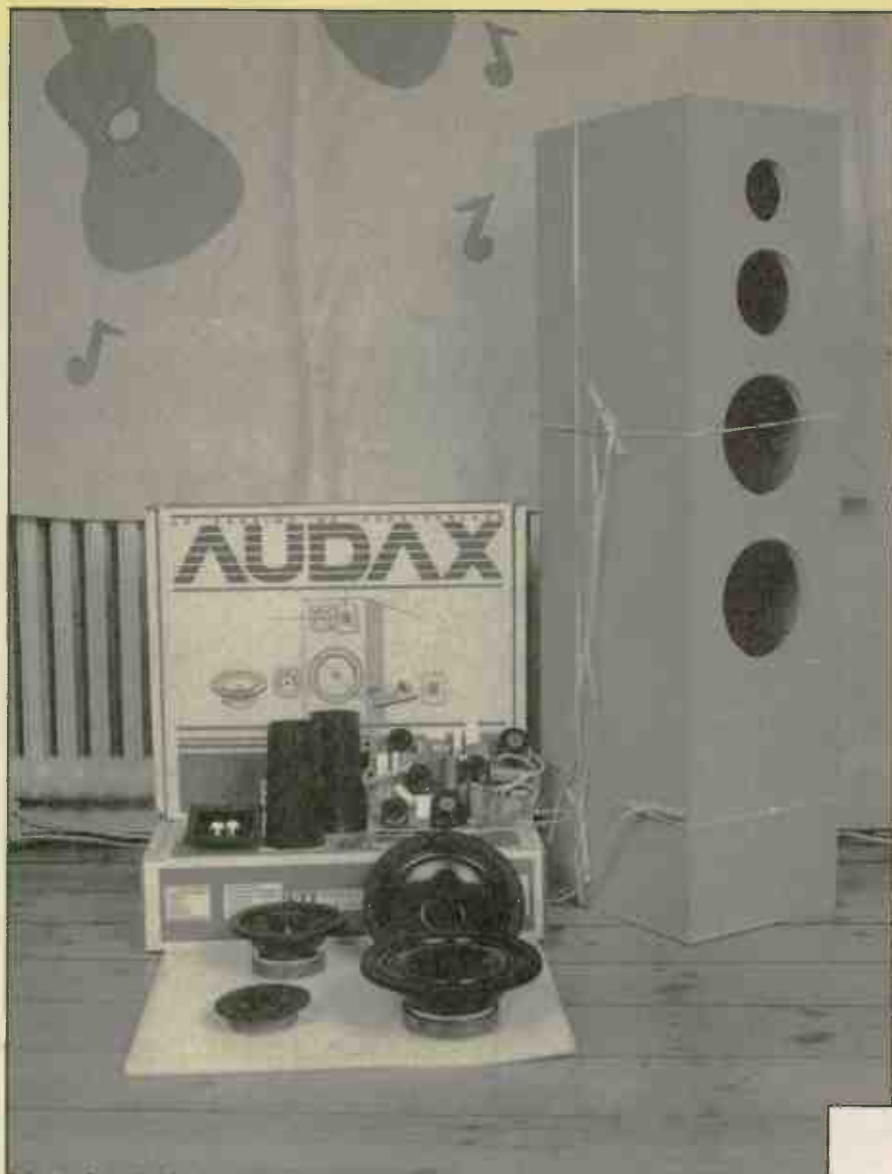


# AUDACIOUS AUDAX

**A big loudspeaker with big bass. And you can build it yourself! Richard Kelly sets to work with the Audax PRO 317 kit; Noel Keywood explains a few modifications to improve its performance.**




The cabinet of the Audax PRO317, glued together, with drive units and crossover.

Audax, together with a few others, believe that one of the few potentially prosperous areas of hi-fi in today's financial climate is that of DIY. The lure of pounds off a comparable product in the ready-made market, along with a chance of polishing up your carpentry and electrical skills and keeping yourself out the pub, is going to prove irresistible to the nouveau broke . . . or so they hope.

Enter the Audax PRO 317, a three-way system employing four drivers: two identical BMH bass drivers complemented by a MDH 302 mid range and a TWH105 tweeter. Audax tell me they believe this model is the one most likely to suit British criteria: highest performance for lowest cost! They have a further nine models to choose from, including a rather attractive satellite/sub-woofer system - which I look forward to building in the near future. It will sell for, I quote, "a fair bit less than the PRO 317". Thanks to the Forex markets, the '317 sells for £449 in the UK for a flat-pack cabinet, the drivers and crossover, but confident carpenters can buy the kit less the cabinet for £359.

How it all goes together is quite straightforward, but I'm afraid the instructions were a little vague and not entirely satisfactory. However, I mentioned this to Peter Denning, who represents the French company over on this side of the channel, and he assures me that this actual kit is a pre-production run and all the little oversights will have been ironed out once the product is fully launched.

Firstly, you take the side and top panels, which have a chamfered 45 degree edge, and glue them together to make an oblong box with no top or bottom. Whilst this is drying, it is all held together by tying the lengths of very strong flat sisal tape around the perimeter and using the little blocks of wood also supplied. In effect, this is a tourniquet, holding it all together very tightly.

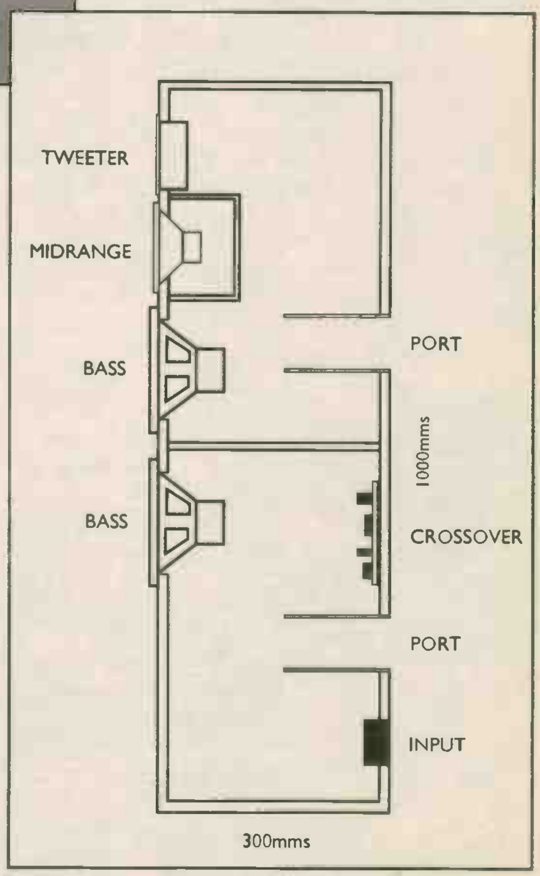
It couldn't be simpler - just remember to use a flat working surface to keep all your faces true. After you have gently tapped all the corners square, clean off the excess PVA adhesive with a damp cloth and the speaker is ready for the second stage.

Take the front baffle and glue this into position; the rebating is accurate enough to ensure a smooth fit, so no worries here, then leave it with wads of magazines or other weighty material to hold it firmly down whilst it dries.

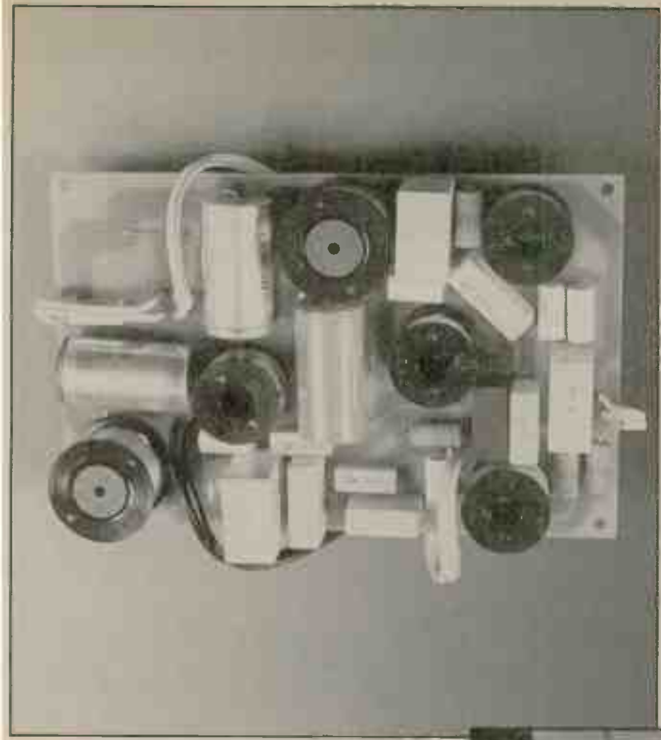
Strangely, the instructions made no mention of mounting the crossover, so pondering for a while, I realised that I'd better mount it at this point in the build routine, while I could st ll get my hands, screwdriver and so on into the cabinet. Using the length of the wires from the crossover as a guide, I decided to place it on the internal horizontal dividing board between the two bass chambers*. I used 1cm of foam from the drivers' packaging under the crossover as a vibration absorbing base and screwed the assembly down gently so the foam was just in compression at all four corners.

The instructions should have pointed out that you need to drill a hole by the front baffle to allow the wires to run from the upper chamber down to the lower one, to reach the input terminals and the bottom bass driver.

This task completed, it was time to fix the mid-range chamber, consisting of three blocks which I had previously glued together to make the U-section which is to be glued to the back of the front baffle. Again, there was no mention of drilling holes for the wire! Do this before fitting,




Cutaway drawing of the PRO 317. Each bass unit is loaded by its own vented chamber; the midrange has a sealed chamber. Our choice of crossover position was behind the lower bass unit, as shown.



**The crossover comes built. As the picture shows, it contains a large number of components. See the schematic diagram further on to identify components.**

it's much easier than trying to do it when you've completed your cabinet.

Measure up the inside of the cab. to determine where the dividers should go and then glue into place. The bass-chamber board will of course try to fall over due to the weight of the crossover, so this will have to be propped into position until the glue does its stuff. Not the best way, this. I'd rather see a rebated groove it could slot into; this would be much stronger and would ease construction. When the glue has gone off you can glue the back panel into its rebated place making sure that you've got the input terminals on the bottom. Be careful, here! Get this wrong and you're stuffed; the only way to take the cab apart is by delicate application of a club mallet.

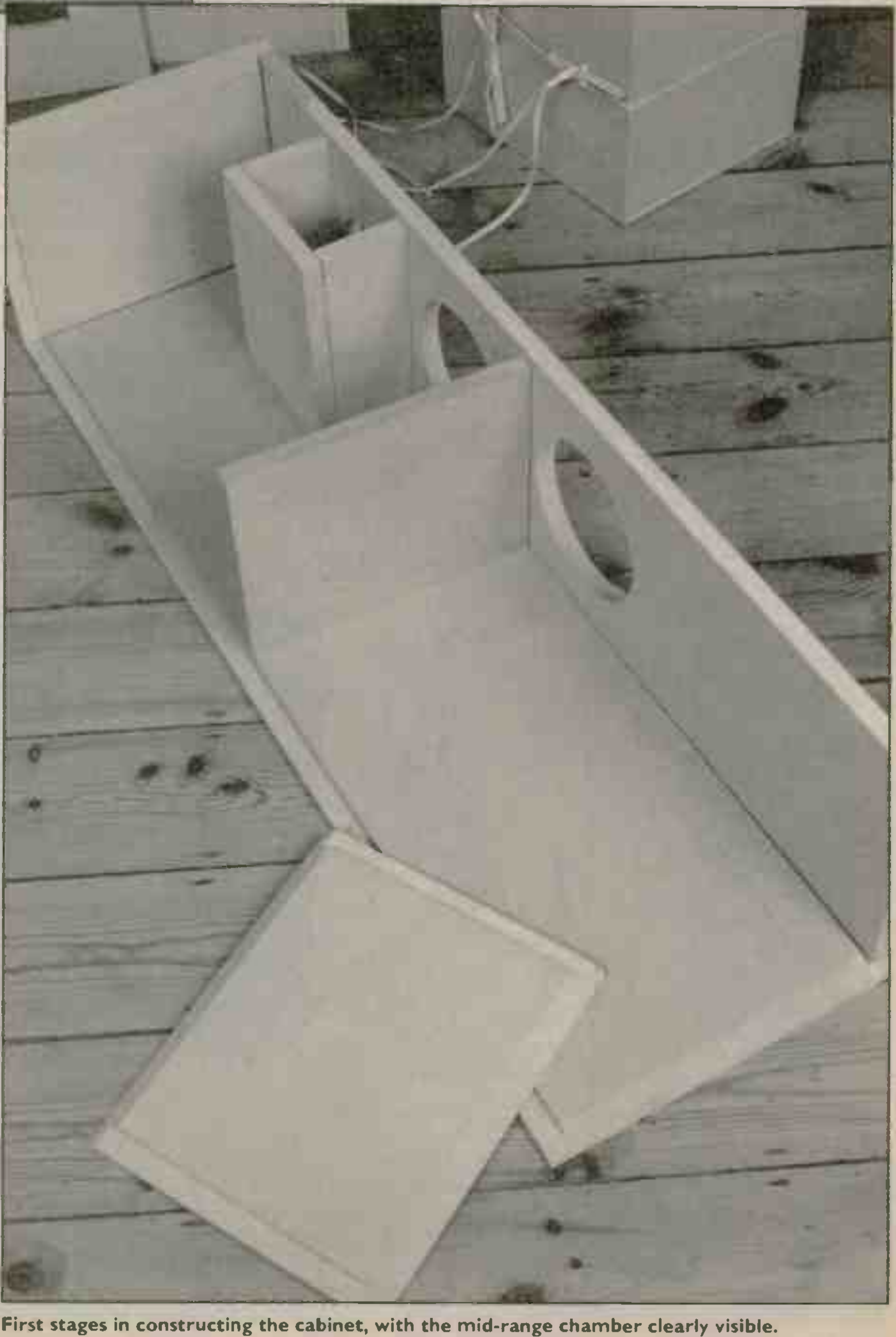
Finish is such a personal thing. I can live with polished or lacquered MDF, others can't. But whatever finish you want, now is the time to do it. Sand all edges, fill any cracks with plastic wood and indulge in your wildest fantasies. Just get the wife's permission beforehand: flocked wall paper matching your local Tandoori house may stretch your domestic status to new horizons.

Clean out the inside of the chambers and fill them with equal amounts of BAF wadding, keeping a small amount back for the mid-range chambers. Just pull the appropriate wires through their holes and solder to the drivers prior to screwing them down. Fitting the units couldn't have been easier. Drill pilot holes (1/16th inch is fine for the screws provided) drop in and tighten down. No gaskets were supplied with the kit, so I guess current practice is not to bother with them, relying on smooth metal castings and flat, smooth MDF to form an airtight joint. Is this minimalism reaching new heights or am I just emerging from the Dark Ages?.

Did I say things couldn't be easier? Huh! When it came to fixing the tweeter I found that it wouldn't fit because the little lugs on the back to which you solder the leads interfered with the edge of the mounting hole. The solution is to cut out some little lug-holes. But don't use the cranial type as you'll need these later on for listening tests. All that's left is to connect up the input block and screw it into place and lastly push the two tubes supplied into the rear ports. Arrrgh! Yeah - they didn't fit! The last job - and another niggle. Twenty minutes with sand paper had them opened up enough - and that's it!

All in all it's not a bad kit. After a bit of sorting out it was easy enough. With patience, you will have an end product which, due to its good woodworking, is quite a handsome speaker. Even unfinished, naked, my girlfriend said she'd give it house room. I mean the speaker was naked.

* NK says: If the crossover board is mounted here it is very difficult to remove for experimentation. I found the alternative position we used, on the inside of the rear panel, behind the lower bass unit, to be preferable, even if some of the wires to the drive units need lengthening ●



**First stages in constructing the cabinet, with the mid-range chamber clearly visible.**

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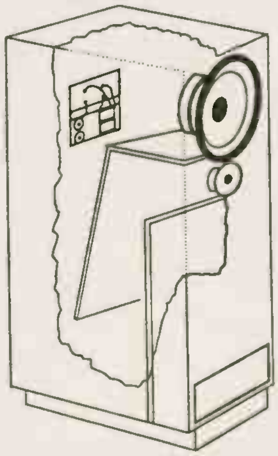

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# AUDAX UNDER ANALYSIS by Noel Keywood

Tracing through the circuit of the crossover was enough to show me just how different this kit is to the IPL S2 we reviewed some months ago. The IPL was simple but effective; it used a straightforward crossover and a couple of good drive units to get flat frequency response and a balanced sound.

The Audax, by way of contrast, has one of the most complex crossovers I have encountered for a long time, so complex that it comes ready assembled, which is a bit of a shame. Some of the fun of building a speaker lies in crossover wiring and tuning; it allows the hobbyist to experiment with the sound and perhaps find a way to make it better, or at least alter it to be more in keeping with personal tastes. This option is more difficult to exploit when the crossover comes without a circuit diagram, without notes on fine tuning and looks like it has been designed by a shareholder in RS Components. That of the PRO 317 possesses no fewer than 30 components, which kept me puzzling for a good hour as I traced the tracks this way and that, through banks of coils and capacitors in an electrical equivalent of Hampton Court Maze.

**BEFORE**

**Frequency Response**


**Strongly raised bass with good downward extension to 30Hz (-6dB), plus raised treble characterise the PRO 317 in standard form**

The outcome can be seen, simplified, in the circuit diagram. Many of the capacitors are paralleled in practice, to improve transient performance. I've represented them by one capacitor, so it looks simpler than the real life unit. The bass section uses two drive units acting in parallel, both of which have their own reflex chambers. Using two bass drivers improves power handling; this speaker should be good for very high volumes. I certainly found it relaxed-sounding when driven hard by a pair of Audiolab monoblock power amplifiers.

Although there are two ports, they share the same task of extending bass output. Measurement showed output from each extended from 25Hz up to 80Hz, covering deep bass. Both drivers work up to 300Hz, above which the mid-range unit starts to come into play. The bass leg of the crossover is a normal second-order low pass filter, rolling off frequencies above 300Hz at -12dB/octave, our measurements show. This is quite a high frequency, meaning the twin bass units have to handle the lower frequencies of the human voice - an exacting task. Their synthetic cones didn't quack, but there was some boxiness with powerful vocals, a characteristic of the speaker that cannot be eradicated.

What a lot of people want from a loudspeaker, they say, is heavy bass. Well, this speaker has got oodles of heavy bass. Frequency response measurement showed that it goes right down to 30Hz (-6dB) in a large room - which is low - and that bass output is raised, relative to the mid-band in particular. In use I found the speaker was obviously bass heavy, putting more power into fundamentals than really exists. This makes for a really big, deep rumbly sound that fills a room with window shaking frequencies. The drivers sounded well-damped though, playing a bass tune well and reproducing drums cleanly, with a good tight thwack. The tuning mods. I produced to improve the PRO 317 act to bring up the mid-range, lessening bass emphasis. This made the bass end seem to knit in better to the rest of a performance, but the '317 remains a bass-strong loudspeaker.

So these speakers go very low, play a bass tune well and sound quite fast and controlled. However, because in standard form their bass output is emphasised, bass lines dominate. Worse, because the mid-band is so depressed, singers move back in the mix and seem to exist only to accompany the bass, rather than vice-versa. It's not a balance or presentation I go for or would describe as being accurate, but if you like giving your cranium a regular shaking, these speakers will oblige. Frequency response measurement clearly showed why the PRO 317 sounds the way it does, hence the tuning mods to make it more accurate.

The crossover, with drive units connected, was analysed and measured in detail before being assembled into the cabinet, to get a feel of what the designer was out to achieve. A good poke around in this part of a kit can say a lot about the seriousness or otherwise of the whole. In this case, there's no doubt that Audax have put a lot into the crossover, literally in terms of the number of components used, but also in going to the length of using bypass capacitors everywhere. What a pity though, that pre-building discourages experiment. This may well be intentional, since when errors occur in a kit, it is usually in wiring.

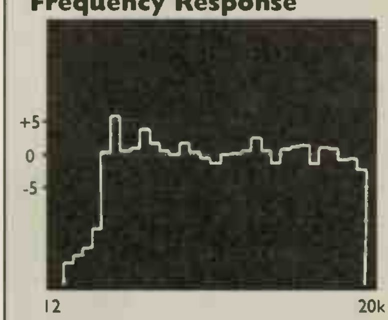
Much of the complexity of the crossover lies in the band-pass filtering feeding the mid-range unit. It works from 300Hz up to 3kHz, with steep third-order roll-off rates (-18dB/octave) being used to prevent bass and treble signals (i.e. below 300Hz and above 3kHz) getting into the unit. But in spite of the complexity, this is the area where the speaker needed a bit of fine tuning, since output to the mid-range needs to be increased in order to reduce or eliminate the somewhat depressed mid-band it possesses. Frequency response measurement revealed this problem and in use it was clearly audible, I found. Tracey Chapman sang from the back of the stage, with a pinched, nasal voice that sounded reedy, for example. Good imaging and a strong sense of clarity helped put her out into the open, freed from muddle or colouration, and this I felt helped the Audax speakers to stay fairly firmly on the right side of acceptability, even in standard form.

Whilst output from the mid-range unit is depressed, that from the treble unit is quite strong, in spite of an attenuating resistor of 3ohms being used. The speaker doesn't sound overly bright, but it has clean and clear treble, with a hint of sharpness and spitch accompanying sibilance, probably due to a peak at 3kHz. Output is strong up to 8kHz, after which it falls away to become about -5dB down at 20kHz.

The measured frequency response of this speaker perfectly accords with its perceived sound quality. It has raised bass that goes low, right down to 25Hz. Stringed instruments rarely go lower than 40Hz; double bass gets down to 31Hz and organ to 16Hz on its biggest pipes. The Audax reproduced them all without any reticence. However, I did recognise from my own experiments with subwoofers the over-large sound that results from bass fundamentals that are artificially made stronger than the harmonics. Few speakers get to offer such a balance, because it takes a big cabinet with big drive units. Although initially impressive, I find this balance a little too larger-than-life; strong bass lines become so strong they over- ▶

**AFTER**

**Frequency Response**




**Bringing the mid-range up and the treble down flattens the frequency response curve, as well as improving efficiency. The mods described result in the flat frequency response shown here.**

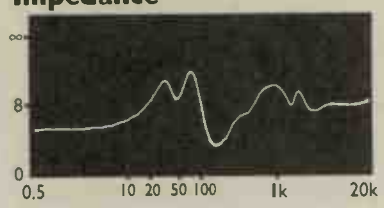
whelm everything, sending vocalists to the back of the stage. Because of this, the speakers are best used in a large room and kept away (3ft minimum) from walls and corners.

Bass quality was very good, which provided some compensation for excessive level. The speakers sound clear, powerful and dynamic; they're great at punching out Heavy Rock music. There was plenty of detail to be heard, but the mid-band is recessed, which pushes vocalists backward in the mix. I wouldn't choose these speakers for their subtlety or truthfulness, but for excitement they score highly.

Overall impedance was low at 6ohms, with a drop to 3ohms minimum at 140Hz. The speaker draws current, utilising the potential of modern solid state amplifiers well, but it is not the easiest of loads. Rapid impedance swings indicate strong reactance around 100Hz, which some amplifiers don't like. Sensitivity was high at 89dB sound pressure level for one nominal watt (2.8V) of input, partly due to low impedance. As a result, plenty of volume will be available from even a 60watt amplifier.

I'd guess that Audax have aimed this speaker at the Rock music enthusiast who wants a big, butch sound possessing plenty of wallop. I liked the lack of colouration and good sense of clarity that was available, but had reservations about the speaker's somewhat artificial tonal balance and its disjointedness. It just goes to show that complexity in loudspeakers doesn't necessarily equate with accuracy. However, the PRO 317 is designed in Germany and is almost certainly tailored for European tastes, which universally seems to mean raised bass and treble to get plenty of boom and ting, vocalists being consigned to the bathroom at the end of the hall. Quite what Europeans - the ones on the other side of La Manche that is - have against vocalists, and quite why they prefer Bactrian loudspeaker response curves is one of those arcane mysteries sent to tease us. For pernickety Brits and all others who appreciate accuracy, smoothness and cohesiveness, I set about the PRO 317s with an FFT, soldering iron and a determination to steamroller the response curve flat. As is so often the case, it didn't prove difficult and the exercise showed just how amenable the loudspeaker is to being tweaked ●

**Impedance**




**The PRO 317 has a low nominal impedance of 6ohms, with a minium of 3ohms occuring at 150Hz, as the dip in the analysis shows. This will result in high peak currents flowing, so a powerful amplifier that can handle low loads is needed.**

## TWEAKING THE PRO 317

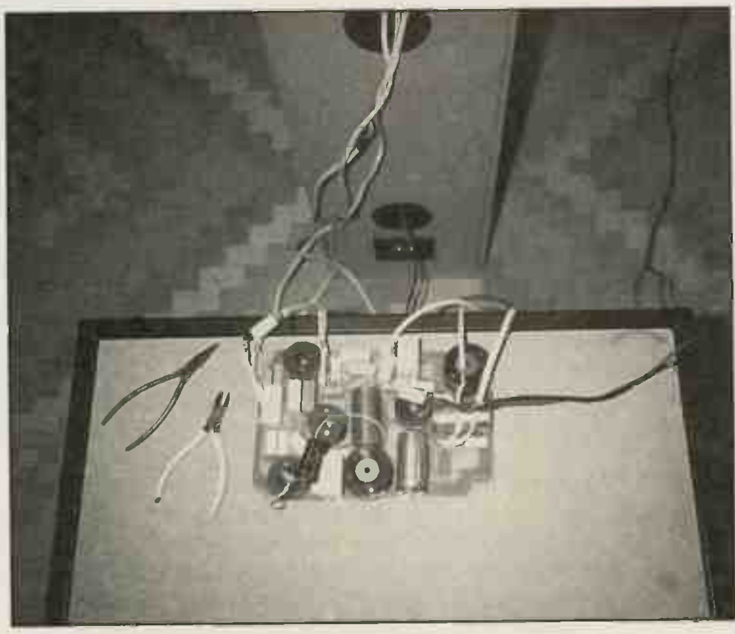
After listening to the Audax PRO 317, the nature of its measured frequency response came as no surprise. Our third-octave analysis (Fig 1) clearly shows a depressed mid-band, down by about -4dB, which is a lot. There's also very strong bass, which goes down low to around 30Hz (-6dB) in a large room.

Ideally, the mid-band needs to be brought up, to improve overall efficiency, rather than attempting to bring bass and treble down to meet it. However, what can be done to improve matters depends upon the crossover. I decided against a complete redesign, since this would result in a project possibly too complex for many people. In this circumstance, some compromise is inevitable, although the PRO 317 did prove to be quite easy to improve significantly.

What you have to bear in mind with any passive network like this one is that very complex interactions exist, so altering a component can do more than than simply change signal level; it will change impedance, matching and, therefore, frequency response and damping too. Having said that, what is clearly obvious to the Fast Fourier Transform spectrum analyser I use for speedy and accurate analysis isn't necessarily so obvious to the ear in terms of an immediately perceivable difference. Yet it might significantly alter the underlying character of the loudspeaker and whether in the long term one would come to like it or loathe it.

This is where the individual experimenter can score. Whereas, I suspect, development engineers are pushed for time and have to make hasty choices of component value (or they use computers running inadequate programs) the hobbyist has time to spend experimenting and listening to the outcome. I combine measurement with listening, usually finding that the best end result is a flat frequency response loudspeaker that can be fine tuned to individual satisfaction, according to taste and circumstance as usual. You may like to adopt my recommendations, which will give you, technically, a more correct design than the one brewed up by Audax, but I suggest you'll find experimentation both interesting and satisfying.

Perhaps I should mention quickly, for the sake of engineers reading this and wondering, that crossover electrical responses are viewed in real time and at high resolution and accuracy using pseudo-random noise produced by, and measured by, a Hewlett Packard 3561A FFT spectrum analyser. This allows the full impact of component changes to be seen throughout the audio band. The acoustic frequency response is gathered by using pink noise and third-octave analysis, by the usual methods, using a B&K 2230 precision integrating sound level meter and the HP3561A. The response is the averaged forward response of three positions: on axis of mid and tweeter, and between them.



**When tweaking the crossover, extend the leads to the drive units, running them in through either reflex port. Then the crossover can be worked on whilst it is out of the cabinet, so that listening tests don't require full reassembly.**

**Bass**


The second order low pass section feeding the two bass/midrange drivers rolls off bass at -12dB/octave above 300Hz. The hump at 160Hz puts a bass peak in the response curve and enhances the apparent 'speed' of the bass.

**Middle**


The band pass section feeding the midrange unit works from 300Hz up to 3kHz, with steep roll-off rates of -18dB/octave from third-order sections. This is the standard curve, before modification. The small dip at 1.6kHz is produced by a damped compensatory notch filter placed across the driver (L2, C4&5, R2).

**Treble**


The high pass filter feeding the treble unit is a third-order section giving a roll-off rate of -18dB/octave below 3kHz. Increasing R5 alters load resistance and response shape slightly, but for the better.

**Tweaking**


This analysis shows before and after curves of the bandpass section feeding the midrange unit. The modifications raise output in the 1kHz - 2kHz region, as required, but reduce output above 2kHz more quickly, eliminating an overlap peak with the tweeter. Audax have used a notch filter to reduce the peaking in this section, but further reduction can usefully be applied for a smoother sound by reducing R 2 to 3.3Ω.

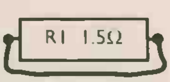
## CROSSOVER CHARACTERISTICS

## THE MODIFICATIONS

Like all good modifications, those needed by the PRO317 consist mainly of removing components. Less is more.

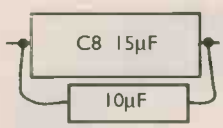
1) Midrange output can be brought up by around +1.5dB overall by shorting out the 1.5Ω series resistor (R1) in the midrange section of the crossover. This is a green wirewound component and it can be replaced by a shorting link. This brightens the sound and pushes singers forward, making vocals sound more balanced in relation to the rest of a performance

2) Midrange output can be increased further over a narrow band from 1kHz-




2kHz, as it needs to be, by removing the 47Ω damping resistor across the coil L5. This enhances midband detailing.

3) Excessive energy in the crossover region between midrange and treble unit results in an 'overlap' peak in output at 3kHz. This can be eliminated by increasing C8, a 15μF capacitor, to 25μF (63V working). This moves the upper roll-off frequency down by a small amount, but it is critical in removing the overlap peak. Either connect 10μF across the existing 15μF component or remove the latter altogether and replace it with a 25μF item. For best quality, use a 'dry' capacitor, ideally polypropylene, but polycarbonate or polyester will do. Non polarised electrolytics will dull and smudge the treble; they are not recommended. This mod. cuts out a sharp spitch that affected vocals in particular.




4) Bring tweeter output down by around 2dB by increasing the 2.7Ω series resistor (R5) up to to 9.7Ω (maximum). Reduce back down to 7.7Ω if you think the speaker then sounds too dull or warm, according to taste. Lowering the value brightens treble subjectively.

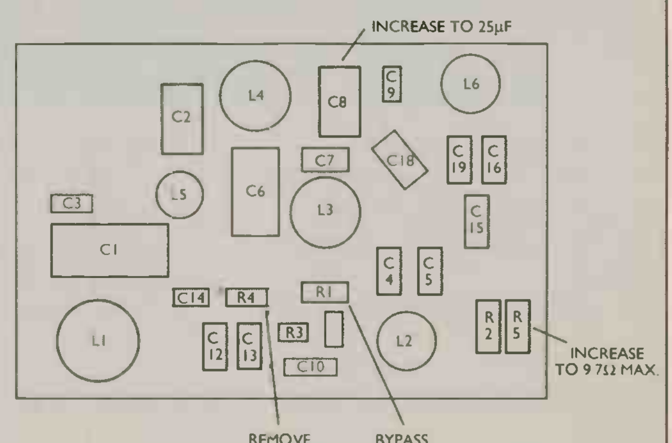
The flat frequency response seen in our second 'post-tweaked' analysis was made with 9.7Ω in place. It results in easy, almost reticent treble. Although going down to to 8.7 or 7.7Ω brightens the speaker up slightly, it also adds a little sharpness. However, many might prefer such a balance, I suspect.

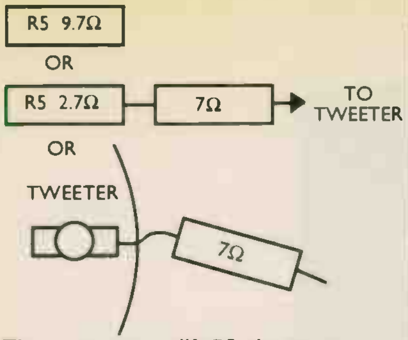
Note that the resistance value quoted is the total resistance. You can either replace the green wirewound component (R5) with 9.7Ω or your preference, or you can simply wire 5-7Ω in series with it. Use 5W wirewound resistors; they are usually wound on or in a heatproof ceramic former.

This set of mods will result in a frequency response similar to that shown in our analysis, within the usual limits of component variation. Bass apart, the final trace is very flat by loudspeaker standards, since ▶▶

Component layout of the crossover board with our own component identifications to make location easier. The items needing modification are arrowed. The diagram is a guide only; it is not to scale. ▶

## SCHEMATIC DIAGRAM






**Three ways to modify R5, the tweeter resistor. Replace with a 9.7ohm resistor (top), or add a 6.8ohm resistor in series with the 2.7ohm fitted onto the crossover board (middle), or alternatively add the same resistor to the tweeter (bottom).**

the vertical scale here is a high resolution 5dB/division which magnifies response variations (manufacturers always use 10dB/division to make their products look relatively flat).

Interestingly, there is a narrow +2dB peak at 1.6kHz and a -1dB dip to the right of it at 2.5kHz. Both can be tuned out and perfectionists might like to have a go. The peak can be lowered by reducing R2 from 3.9Ω to 3.3Ω. This is a damping resistor in a 1.6kHz parallel acceptor circuit, comprising capacitor C4/C5 and coil L2 placed across the midrange unit.

The dip can be closed up by decreasing the value of C8 a little, from 25µF down to 22µF or so. This will appear to brighten the sound a little, but it will also detract from smoothness and integration; a balance must be struck. I suggest you play it by ear with these last mods. They are both subtle in their impact, but worth making. You'll probably have a hard time deciding what's right, even when differences can be heard.

Sound quality when modified sounds altogether more acceptable. The PRO 317s lose none of their dynamism for being 'flattened' in frequency response terms, but they sound far more even and balanced. These are punchy sounding loudspeakers with thunderous bass, no matter what you do to them. A better sense of integration comes about after the mods, although bass remains prominent, if not overpowering. Bringing the mid-band up puts singers strongly centre stage, right at the heart of a performance, as they are meant to be. Quite why Audax had suppressed the mid-band of this speaker so much I do not understand. Modified, it retains its basic character, but sounds more natural.

There's no doubt in my mind that the PRO 317 competes very effectively with expensive floor standers costing up to £1000 or more. Admittedly, this isn't difficult, because a lot of £1000 loudspeakers aren't so impressive in any case, but the big Audax is. It has a large sound, commensurate with its physical size, and it will deliver huge volume levels without sounding strained - an advantage of loudspeakers with many drive units sharing the power and radiating it. I'd say it was better suited to Rock than Classical, unless bass output is brought down, in the manner described, to get a very high degree of smoothness and integration.

For £449 the Audax PRO 317 is a lot of loudspeaker. It's extremely good value and it responds well to modification, making available a range of presentations for those who are willing to experiment. As always though, the instructions are poor or, in our case, non-existent. I hope that the importers will be able to address this problem.

## How To Do It

The easiest and quickest way to change component values on a crossover and listen to the outcome is to remove it from the cabinet altogether and use extended connecting wires to the drive units. This is made easy with the PRO 317 by its twin reflex ports, through which all the wires can be led. Solder connections - don't wrap or twist them together - and use electrical tape to prevent shorting.

Buy a range of components (see our component suppliers list), because this will save time and frustration, and remember to get two of everything, since there are two crossovers! Thankfully, components are inexpensive. A soldering iron is needed, plus good quality electrical solder (not plumber's solder, nor a gas heated iron, nor 'plastic solder'!). You'll need wire cutters and strippers and I always use snipe nosed or jewellers' pliers to hold components whilst soldering. Use solid wire for the links on the circuit board and multistrand speaker wire for connection of the crossover board to the drive units.

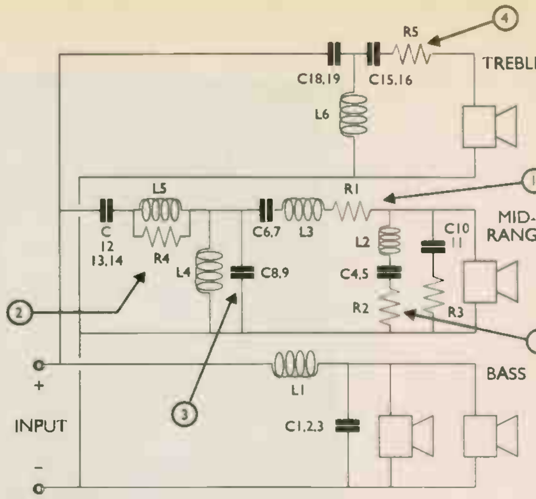
Be very careful about polarity of the drive units. Check and double check that the drivers are not connected the wrong way around, or the speaker will sound vague and phasey (but you won't cause damage). Note that the tweeter has its phase reversed as standard, positive (red) going to earth (ground) on the circuit board.

## Bass Level

There's no easy and theoretically correct way of attenuating the bass from this loudspeaker. I suspect that most people wouldn't want to do so in any case; big speakers are usually bought in the belief that they'll deliver big bass - and the PRO 317s do.

For those who might want a little less, the only easy way of reducing bass is to wire resistors in series with each drive unit. A value of 2Ω in series causes a -1dB drop in output from each driver. Experiment with values of 1Ω-3Ω in series and use at least 10watt rated wirewound resistors.

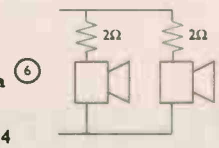
In basic theory series resistors upset the termination of the filter, altering its response characteristic, and they destroy electrical damping. However, electrical damping by the amplifier is compromised in any case by the resistance of the series coil (0.5Ω) and both acoustic and magnetic damping of the drive unit, which are more influential, remain unaffected. Because of this, using series resistors isn't so bad in practice. Tests showed that the filter altered its response little with 2Ω in series, so my advice is to give it a go if you'd like to get an even flatter frequency response, especially if the speakers are to be used close to a rear wall ●




**The circuit diagram of the PRO 317 crossover.**
**1) Short out R1 (1.5Ω) with a link**
**2) Disconnect and remove R4 (47Ω)**
**3) Increase C8 to 25µF**
**4) Increase R5 to 9.7Ω maximum**

**FURTHER TWEAKS**
**5) For even smoother sound, free of small 3kHz peak, drop R3 from 3.9Ω down to 3.3Ω.**

**6) To reduce bass output, wire 2Ω 10W (minimum) resistors in series with each bass unit**




**MAIN COMPONENT VALUES**

| | |
|---|---|
| **CAPACITORS** | |
| C1 | 47µ |
| C2 | 47µ |
| C4 | 3.3µ |
| C6 | 68µ |
| C8 | 15µ |
| C10 | 3.3µ |
| C12 | 29µ(25+4.7) |
| C15 | 15µ |
| C18 | 4.7µ |
| **RESISTORS** | |
| R1 | 1.5Ω |
| R2 | 3.9Ω |
| R3 | 15Ω |
| R4 | 47Ω |
| R5 | 2.7Ω |

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# Designing a Loudspeaker

**So you want to design your own loudspeakers? Simple, accurate methods don't exist. Manufacturers use trial and error, coupled with experience - and often get it wrong! Or they design by computer. The same design programmes are now being tailored for home computers. We test MACSPEAKERZ, a programme for the Apple Macintosh.**

Designing loudspeakers is not as simple as many people believe, at least, not if you hope to produce something that equals or surpasses commercial products. However, 'speakers have the great advantage of possessing few basic components and being of apparent simplicity. Home built designs invariably work first time. Experimental tuning, done on a suck-it-and-see basis, is often enough to get respectable results.

But what if you want to do the job properly? How do you go about competently designing your own loudspeakers?. One relatively new way is to use a Computer Aided Design (CAD) package. These are powerful computer programs that basically handle the complicated maths for you and visually display the predicted results of your design before you take saw to wood.

We decided to assess the MacSpeakerz 2.52 loudspeaker design package from True Image Audio, California. This package uses the Thiele-Small equations for its calculations which are regarded by the industry as amongst the most accurate loudspeaker models currently available.

A query about the impedance plot of the excellent HL-P3 loudspeakers reviewed in this issue revealed that Alan Shaw, their designer, had a lot of experience with many of these CAD packages. In addition, Harbeth has a large selection of Bruel & Kjaer measuring equipment and test jigs for accurately specifying drive unit parameters. This enables them to evaluate such a package in a comprehensive manner - which is exactly what we asked them to do.

### HARBETH SAYS -

There can be few penniless students who haven't knocked up a pair of speakers. This review of the MacSpeakerz design package is the result of imagining that I am an impoverished student, rather than a professional manufacturer considering such a program for his bread and butter. As you will have gathered from the name, it runs only on the Apple Macintosh. My experience is mainly with fast (486) IBM PC compatibles, so one of our graduate engineers who uses the Macintosh LC, put the package to the test.

The program is supplied on a floppy disk, which is simplicity itself to load up and run. The program divides the screen into three primary areas under a title line. The graphic area, which is where all the curves are displayed, is scaled from 10Hz to 1kHz and a fine graticule in light blue is displayed on the white background, so it is easy to read off frequency responses. Beneath the graphical area is a box entitled "Driver and Subsystem Parameters" which holds primary data on the drive unit to be examined. Finally, there is the "Box Parameters" block, which as you might expect, holds the data concerning the enclosure being designed.

A good test of software user friendliness is the ability to fire-up and run the program without having to read the manual, which is what I did. From the command line selecting: File-Open Driver throws up a screen of pre-loaded drive units from a wide range of manufacturers, many of whom are unknown in this country (the program is American). Picking out familiar names like KEF, Polydax (known in Europe as Audax) and Scan-Speak inspires confidence, which turned out to be unjustified. Readers may be aware that Harbeth manufacture the BBC designed LS3/5A, so the KEF B110 which is used in this design, seemed a good starting place.

Moving into the KEF drivers library and clicking on the B110 picks out the key driver parameters - Fs, Qts and Vas and highlights these in the Driver and Subsystem Parameter box. The full parameter list can be accessed using the Edit-Edit Driver command which pulls up the Driver Editor. For this particular model it shows that many of the parameters are not present. For example, the DC resistance (Rc) is specified at 0Ω! Also the piston area is zero!. This was a disappointing start.

The B110 is a well known unit, data for it is easily obtained and, worst of all, the absence of this primary data makes accurate modelling an impossibility.

Defining a theoretical box is simple.

The Edit-Edit Subsystem command allows you to create a box, define a vent if desired and then it will calculate the box resonant frequency, vent length etc. Once the subsystem or driver/box has been created, all that remains is to run Analysis-Calculate Response which draws a graph of the systems sound pressure level (SPL) versus frequency (i.e. its frequency response).

The impedance response is also calculated, but for this particular example produced a zero impedance plot across the band, which clearly is incorrect. Returning to the Driver Editor and overwriting the DC resistance of 0Ω with a sensible figure - say 5Ω - and then re-running the analysis produced a straight line from 10Hz to 1kHz on the 5Ω line.

All sealed box systems have a peak in their resonant curve, so there was still something wrong with the drive unit model. More careful examination revealed that the parameters Qes and Qms were not specified, nor was the BL product which defines the strength of the magnet. Thus, as supplied, the B110 model had neither a magnet nor a voice coil!.

Unfortunately, I did not have a KEF data sheet handy for the B110 but if I had it would have been possible to fill in the missing data and produce a full set of results. However, an incomplete definition of a drive unit will render MacSpeakerz incapable of anything other than the most crude system approximation, which is disappointing. The hobbyist could do as well or perhaps better with a design table such as the excellent "The Loudspeaker Design Cookbook" by Vance Dickason and forego the pretty graphics.

I pulled up the KEF B139 which had a fuller set of parameters and created a similar box. Another frustration - it seems strange that there is not the ability to switch between the old fashioned imperial units of cubic feet that the Americans still persist in using and the metric system which we have used in Europe for many years. This makes mandatory conversion of cubic feet into litres and vice-versa annoyingly painful when the program could do it so easily.

The B139 looked more promising because the screen memory displayed a predicted system response, an impedance curve and excursion prediction. Excursion limiting is a more and more important consideration for loudspeakers as modem amplifiers are capable of such high powers and digital program material encourages enthusiasts to "turn up the wick". Predicting an excursion limit shows how loud a driver can be pushed before running out of steam.

A quick peek into the Driver Editor shows why this model works and the B110 didn't. Ninteen of the twenty-two parameters describing the drive unit had been completed, from free air resonance right the way down to the flux density and voice coil inductance. No wonder the system was incapable of plotting a frequency response.

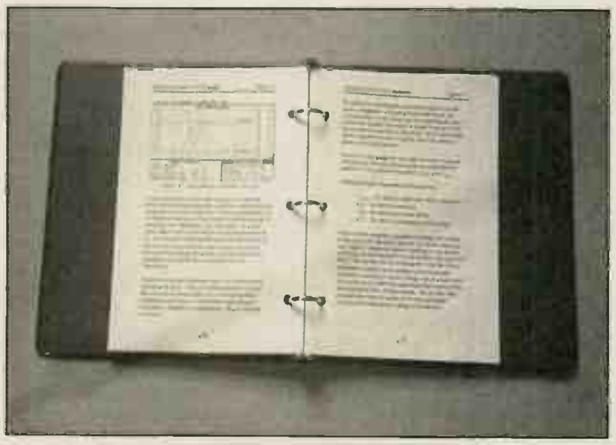
My enthusiasm for MacSpeakerz excellent graphical display is offset by the use of just 5 primary colours when all the various traces are plotted. Each re-calculation fills the screen with over-plotted curves, so the ability to clear the screen on demand is very welcome. Re-calculation after adjusting a system parameter - say the size of the box - takes about 6 seconds which is very fast and encourages the user to play around with all manner of parameters. This is where CAD really scores over calculator and design table.

As we have already seen - and it is true of all computer systems - garbage in, garbage out. I will return to the tricky question of from where one obtains reliable drive unit characteristics later, but now let's look at editing the B139 driver data. The moving mass is specified as 43.5g and the free air resonance (Fs) as 25Hz. Considering a mass suspended on the end of a spring and set into motion, we could expect an oscillation eventually decaying to nothing. Altering either the stiffness of the spring or the mass (or indeed both together) will change the resonant frequency which can be expressed as -

$$F = \frac{1}{2\pi\sqrt{CxM}}$$

where C = compliance and M = mass.

What happens when we edit the B139 to change its mass to say 100g? Unfortunately, this is where the limitations of MacSpeakerz started to show up. Increasing the mass of the B139 to 100g did not seem to make any difference to the resonant frequency. In fact, if one parameter is changed the program does not re-calculate the other figures that would be affected by that change. So it is down to calculator work and lengthy equations to define the new values corresponding to, in this case, the increase in the moving mass.



**A substantial manual with graphs, formulae and theory, is supplied.**

This limited interaction between the driver parameters demands the use of basic data of very high accuracy if meaningful predictions of system performance is to be obtained. From my experience, manufacturer's data sheets are generally non-representitive of carefully measured drivers, because there are so many variables which must be accounted for including temperature, power level, stimulus method, not to mention the accuracy of the measurement equipment itself.

## Thiele and Small

Turning to the back of the extremely well prepared manual, there is a section on driver measurement which is based on the techniques developed by Thiele and Small in the 1960s and 70s. This method allows extraction of the "fundamental driver parameters" from a simple jig, comprising the driver under test, a stable signal generator and an inexpensive digital voltmeter. There has been very little contribution to the science of loudspeakers since Thiele-Small developed their electro-mechanical model for drive units.

The MacSpeakerz driver parameter measurement section jumps in at the deep end and omits the critical method for measuring what is known as the BL product (in other words, the magnetic field) and for estimating the moving mass. Without this explanation, the novice could end up with some apparently correct but wildly erroneous data for electrical Q (Qes) and mechanical Q (Qms) and therefore total driver Q (Qts).

My experience is that tiny errors of a few percent when measuring a drive unit can have a dramatic effect on the resulting data, due to the many squaring functions in the maths. This explains why manufacturers, let alone enthusiasts, have so much difficulty in characterising their drivers. Reviewing the driver parameter section encouraged me to dig out the old Thiele-Small papers which 20+ years on are a joy to read. Thiele's equation number 101 states Vas (the volume of air equivalent to the drivers compliance) as

$$V_{AS} = V_T\left[\left(\frac{fcb \times Qesb}{fs \times Qes}\right) - 1\right]$$

where fcb and Qesb relate to the resonant frequency of the driver and its electrical Q in the test box. In the MacSpeakerz manual this equation appears to have been incorrectly printed as

$$V_{AS} = V_T\,\frac{f_{CT}\,Q_{ECT}}{f_S\,Q_{ES}}$$

which is going to give a dramatically different estimation of driver Vas.

MacSpeakerz also has a crossover calculator which draws a simple schematic diagram of the drive units and electrical components. In common with the theoretical tables, this assumes a straight tweeter and woofer resistance which sadly doesn't reflect real drivers.

It also ignores the fact that what is important is the acoustic roll off in the crossover region which is a combination of the drivers natural roll off and the electrical circuit. This could mislead a constructor into designing a third order Butterworth crossover which, when combined with the driver's roll off would give a much sharper response fall requiring a totally different system consideration.

Real drivers do not behave like resistors or have flat responses in their roll off/roll up regions. MacSpeakerz's crossover calculator is interesting but simplistic.

Other interesting features of MacSpeakerz are a box calculator which automatically multiplies height, width and depth to calculate the box volume. A vent calculation program which allows up to four port tubes to be fitted to the box predicts a vent length to hold a given Fb constant. I didn't check these calculations but as Thiele-Small point out in their articles, there may be some variation between the theoretical port length/ diameter and the practical solution.

In conclusion, having spent a reasonable amount of time with MacSpeakerz, I am very impressed with its on screen presentation. For the serious hobbyist who wants to develop a feel for the inter-relationship of drive units/system parameters and cabinet design, this program is good value. However it relies too heavily on skills which the hobbyist will not have, when offering an understanding of the complex electro-mechanical interrelationship between parameters. In the hands of the novice it will almost certainly produce highly erroneous results.

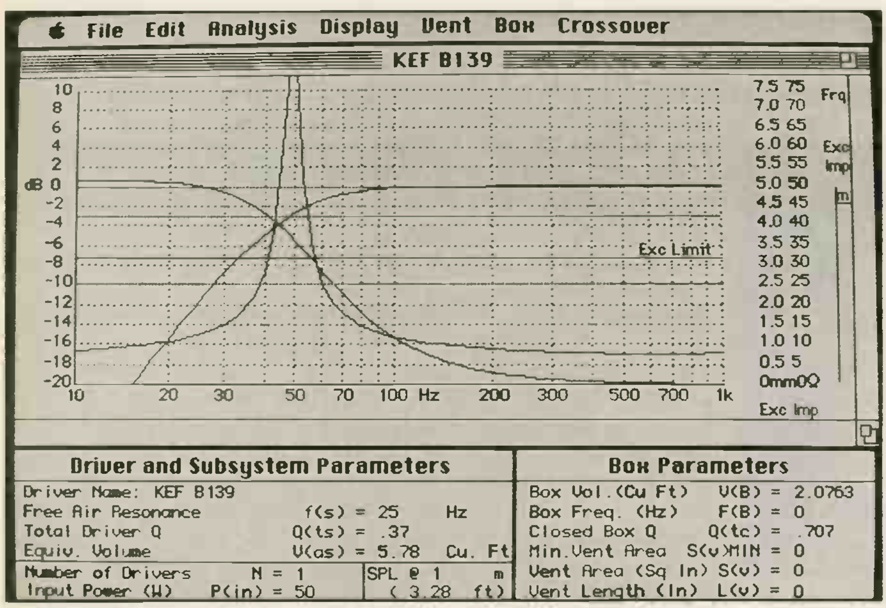
I would like to see future versions automatically cross-checking the driver parameters so that the system would automatically adjust, for example, Fs after the user played with the moving mass. Within these constraints, MacSpeakerz can be recommended with caution.

I strongly recommend serious hobbyists investing in the Audio Engineering Society's (AES) "Anthologies of Loudspeakers" which conveniently pull together all the pioneering work from the 1950's to date. The two anthologies make indispensable reading for £38. The pair are available from the AES Ltd, Lent Rise Road, Burnham, Slough. (cheque with order)

Alan Shaw
Managing Director and Designer of Harbeth Loudspeakers.

## DOMINIC SAYS -

MacSpeakerz requires the user to perform calculations using Thiele-Small equations - not a simple task. Potential users need to have some mathematical ability to cope with this.




**MacSpeakerz offers very good screen graphics, plus on-screen lists of parameters.**

It also attempts to be a practical loudspeaker designer. In practice the design that is finalised on the screen will at best be a rough starting model. Once this starting point has been constructed you can evaluate the practical modifications necessary to refine the design. MacSpeakerz can be used again to view the general direction of the modifications required. For example, if the loudspeaker doesn't have enough bass, the package will show whether you need to increase or decrease the box volume or vent area to increase it.

I was a little disappointed that MacSpeakerz could not design the perfect loudspeaker without hassle. But after seeing a few packages myself and conversing with Alan Shaw, I realise the constraints that the mathematical theory available has on such programs. All that can be expected is an approximate starting point, from which experimentation on a trial and error basis should produce a satisfactory finished product, with the guidance the package can provide.

True Image Audio are due to update the MacSpeakerz package to version 3.0 which will include bandpass enclosure analysis. Version 3.0 will hopefully also have the capability of working entirely in metric units, which should make it easier to use and interpret. MacSpeakerz 3.0 will be released in the first quarter of 1993.

The Loudspeaker Design Cookbook recommended by Alan Shaw is available from I.P.L. Acoustics (tel: 0373 823333) at a price of around £24.

## NOEL SAYS -

I've had a long talk with KEF about all this; here's their wisdom on the subject.

MacSpeakerz is based upon Thiele-Small 'small signal' equations. The problem is that it uses drive unit parameters that are difficult for manufacturers to derive - and effectively impossible for amateurs.

Whilst the equations are widely acknowledged as accurate for design purposes, the real problem lies in getting accurate parameters to enter into them. Alan Shaw notes that this American package apparently offers a look-up list of parameters, but that the list is incomplete, as it is likely to be for drivers not made in the States.

However, Dr Richard Small (the Small part of Thiele-Small) works at KEF and the company long ago derived these parameters for their drive units, which are available to kit builders. So MacSpeakerz should give a useful result if the Thiele-Small parameters that KEF can supply with their drive units are entered in. KEF confirmed, however, that these parameters are very difficult to measure and compile and that a small error leads to a bigger error in the predicted result.

To recap: you can use MacSpeakerz with drive units for which all 22 Thiele-Small parameters are available, meaning at present KEF drive units.

Out of interest, Don Keele (JBL, Electrovoice) has rearranged the Thiele-Small equations into a simpler and more practicable form. It may well be that a computer design program using his data is more amenable to hobbyist useage ●

Our version of MacSpeakerz was priced at $249. The new version may be repriced.

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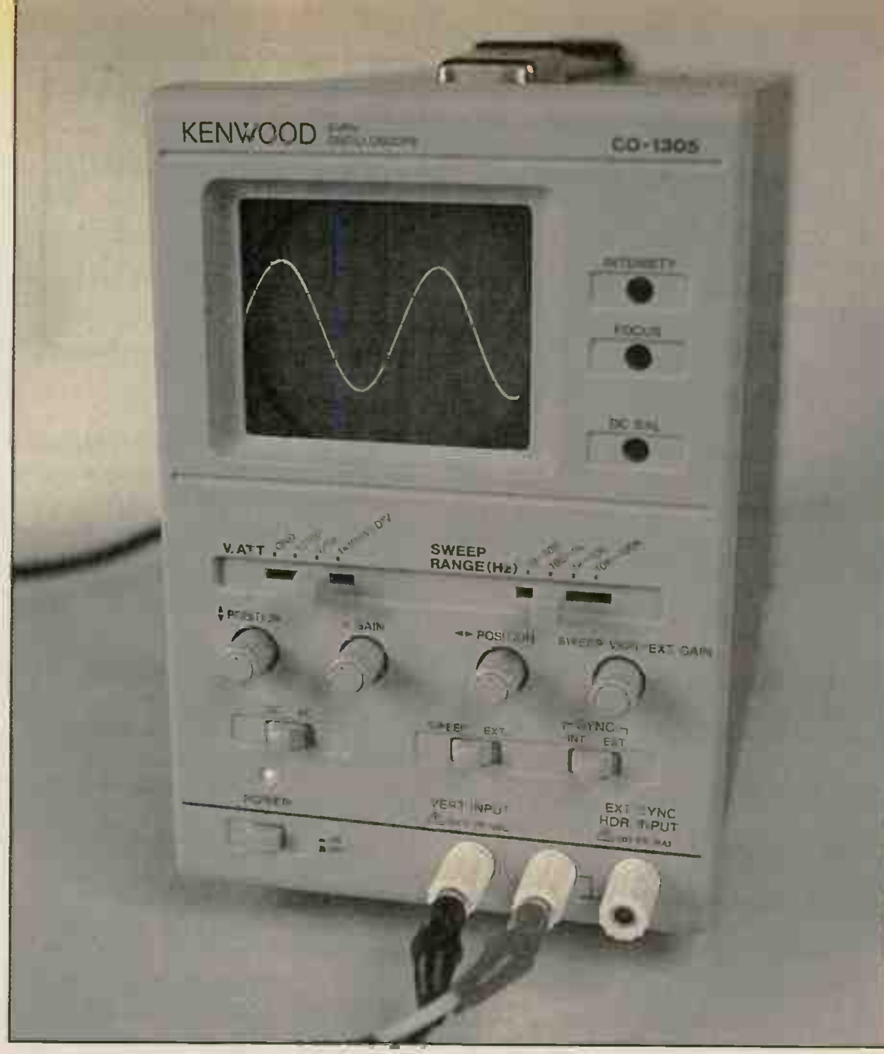
An oscilloscope is a wonderfully informative way of seeing electrical signals. A little experience - and for beginners a small reference book as well - soon makes for correct interpretation of its pictures. Then the 'scope becomes an invaluable piece of test equipment - which is why every electronics workshop has one.

But most hobbyists don't - mainly because of price. Oscilloscopes, like a TV (with which they have much in common) possess a cathode ray tube (CRT) and the high voltage power supplies needed to drive it. As a result, they are expensive and traditionally have been the domain of professionals. To meet their requirements, manufacturers have tended to add all sorts of weird and wonderful features, but few are really necessary for basic audio work.

What the hobbyist needs is a simple, inexpensive design with just the one or two features that are especially useful for audio. That's what we'll consider here: what's really needed for basic audio work and how to use a 'scope. But a simple explanation of how oscilloscopes work should make their application more understandable.




# USING AN OSCILLOSCOPE

**Noel Keywood explains how to use a piece of test equipment vital for the hobbyist.**

### HOW IT WORKS

The tube in a 'scope produces an electron beam. When this hits the phosphor coating on the front face, it produces a spot of green light or, with long persistence phosphors that continue to glow after the spot has passed, blue (Fig 1).

The electron beam has negligible mass so it can follow a fast changing electrical signal accurately - which is the 'scopes great strength. It can easily trace out a signal that is changing one million times a second and show it on the screen. To do this, the beam is continuously deflected across the screen, from left to right, by a timebase generator within the 'scope (Fig 2). When it reaches far right, it is made to jump back to the start at far left almost instantaneously, to execute another sweep across the screen. Timebase speed is user adjustable, often from zero, where the spot stands still, up to 10µS (ten millionths of a second) or faster to get from one side of the screen to the other. At slow speeds the spot can be seen moving; at high speeds it forms a bright line across the screen.

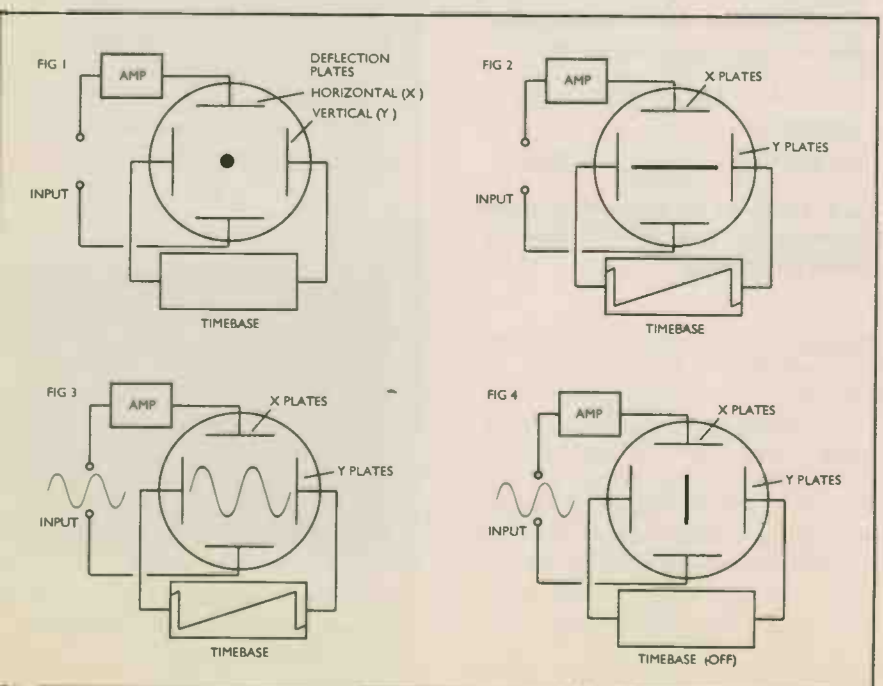



**Fig 1 - With no signal applied, only a spot is produced.**

**Fig 2 - The spot is deflected horizontally by a repetitive ramp voltage developed by the timebase.**

**Fig 3 - When a signal is applied it deflects the spot vertically as well, tracing out a representation of the signal.**

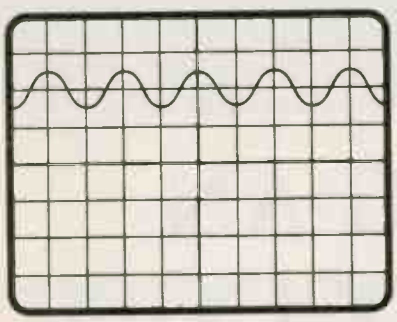
**Fig 4 - Without the timebase, the input signal produces a vertical trace.**

Any signal under investigation is applied to an amplifier within the scope that deflects the spot vertically (Fig 3). In this way, as the spot moves across the screen it is also moved up or down, tracing out a visible pattern. The pattern in fact shows what the audio signal is doing, amplitude wise, over the duration of the sweep. With real audio signals, such as music, speech or noise, the pattern changes rapidly and randomly. With repetitive test signals, like sine waves or square waves, the wave can be 'frozen' on the screen by synchronisation of the timebase to the incoming waveform, enabling it to be seen clearly.

To recap, the spot is continuously driven horizontally (i.e. X axis) across the screen by an internal timebase whose speed can be adjusted by the user. The signal being measured is applied to the input terminals and, via internal amplifiers, it drives the spot vertically (i.e. Y axis). This results in a trace across the screen that is a representation of the waveform.

## USES

What use is a 'scope? The main use is depiction and identification of a signal. Hook it up to a circuit and you can see in an instant what is happening. Both DC

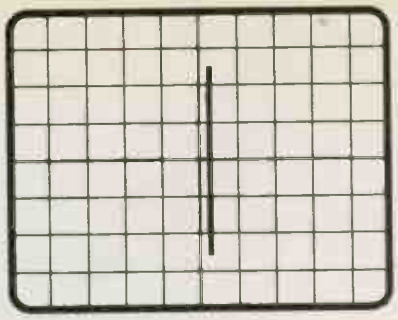


I V AC SUPERIMPOSED ON 2V DC
VERT. SCALE: I V/DIV

**Fig 5 - A IV peak-to-peak sine wave on a DC level of 2V will produce this trace when the 'scope is DC coupled.**

conditions and imposed AC signals are shown (Fig 5). If an AC voltmeter is used to measure audio test signals, a 'scope hooked up to its signal output terminals will show the state of the signal, whether it is distorted, noisy, intermittent or whatever (Fig 6). It will also warn whether the meter is reading a test signal or a spurious signal, like hum (Fig 7). In practice this type of confirmation is vitally important, since it prevents misinterpretations being made. That's why every electronics workshop has to have a 'scope of some sort.

In addition to providing a visual representation of a signal, the 'scope can also be used to make various measurements. Signal level is the most obvious, determined by the height of the trace on the screen (Fig 8). Because the electron beam will accurately follow a sudden pulse, the potential to record a short term musical peak exists, something most meters cannot do. However, the eye may have difficulty following the quickly

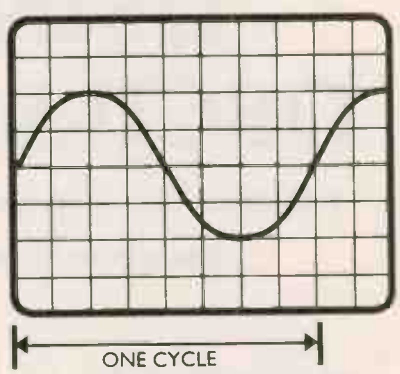


SIGNAL: 5V PEAK-TO-PEAK
VERT. SCALE: I V/DIV

**Fig 8 - AC signal level can be measured with the timebase off. This is a good way of seeing and measuring transients.**

changing display unless it repeats regularly or the phosphors are made to glow longer by turning up brightness or using a long persistence display. For audio work, a long persistence display is useful for seeing sudden music peaks and very low frequencies that are slowly traced out on screen. Trouble is, they're expensive, adding a hundred pounds or so to the price - but this is still cheaper than using any form of memory. Alternatively, switching the timebase off, to give a vertical line can be useful (Fig 8).

Many other measurements can be made. Frequency can be assessed by the number of complete cycles of a wave at any set timebase speed (Fig 9). Phase and frequency can be shown by a curious display known as a Lissajous figure, obtainable only with an instrument




HOR. SCALE: 0.1mS/DIVISION SWEEP
ONE CYCLE = 0.8mS

$$\text{FREQUENCY} = \frac{1000\text{mS}}{0.8\text{mS}} = 1250\text{Hz}$$

**Fig 9 - Frequency can be measured against the screen scale if the timebase is set to a known sweep speed.**

possessing an X input (Fig 10). Guidance on interpretation of the patterns is necessary, since they can get complex.

An oscilloscope is vital for electronic design work, since it will clearly show whether DC working voltages are correct and whether an AC test signal is getting through, or whether instability is occuring. It's dangerous to read an AC meter without having a scope hooked up, since it may not be reading what you'd expect. You might think it's reading a test signal, when in fact the circuit isn't working and

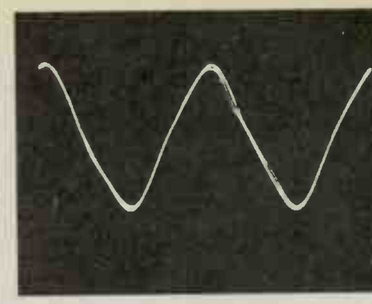


**Fig 6 - Here's a distorted sinewave. It shows bass distortion due to head saturation (magnetic overload) at 0VU, 40Hz. Third harmonic at 7% produces a triangulated waveform. A 'scope can be used to set record levels.**

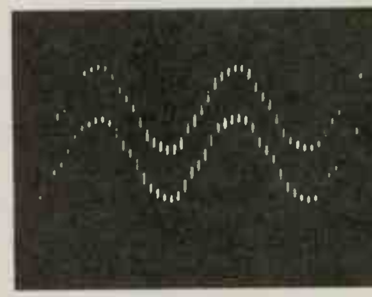


**Fig 7 - A 1kHz test tone imposed upon hum. Without a 'scope, the presence of hum wouldn't be detected, so an AC meter would give an incorrect reading of the test tone voltage.**

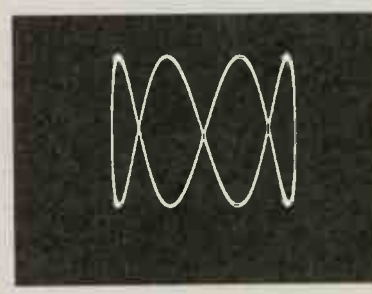


**Fig 10 -Lissajous figures can show phase and frequency, but they tend to spin around if exact multiples aren't being measured. Here's a 4:1 difference in frequency between two signals; it produces four peaks.**

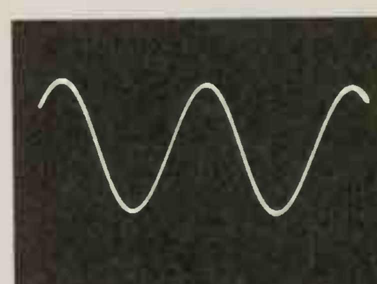


**Fig 11 - A pure sinewave test signal. It is a pure signal of just one frequency; there are no harmonics.**

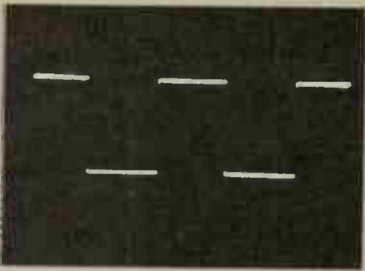


Fig 12 - A square wave contains a fundamental signal, plus numerous harmonics. If their amplitude and phase are not maintained by a circuit, the symmetry is upset.

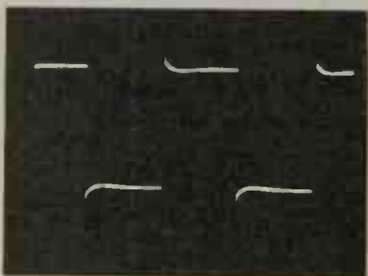


Fig 13 The square wave of Fig 12 gets modified to this shape when passed through a tone control stage set to 'flat', showing treble lift and phase shift.

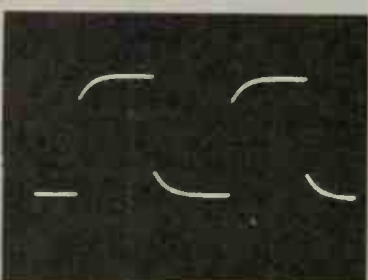


Fig 14 - Treble cut rounds off the leading edges of a square wave.

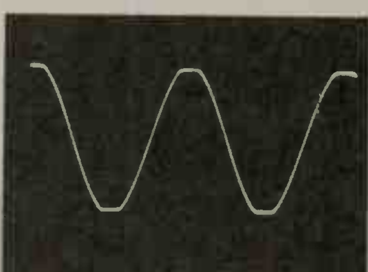


Fig 15 - Output overload of an amplifier produces clipping of sine wave test tone peaks.

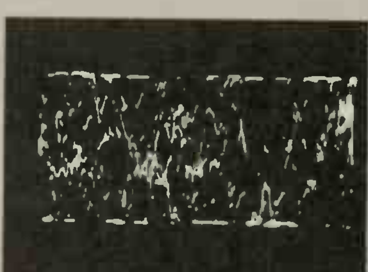


Fig 16 - Output overload again, but with the multiple tones of real music. Peak clipping can be seen as strong horizontal lines.

it's actually reading a signal generated by instability.

For audio analysis, a scope is best used in conjunction with a sine wave (Fig 11) signal generator and, preferably, an AC millivoltmeter. Sine wave generators invariably generate square waves (Fig 12) too, which are especially useful, since their shape is changed by phase and frequency response errors (Figs13 & 14). Sinewave signals or music can also be used to see whether, or at what level, an amplifier is overloading. This is useful both on the test bench and in a hi-fi system, to ensure overload distortion isn't present in the sound.

These are just some of the many uses for a 'scope. It is an invaluable tool for serious hobbyists and, these days, not an expensive one.

## FACILITIES

By common convention, the calibrated grid in front of the tube that allows voltage and frequency measurements to be made has eight vertical divisions and ten horizontal divisions, as the screen drawings show. Scope specs are usually referred to these divisions.

### Vertical (Y) amplifier

Vertical sensitivity is quoted as the voltage needed to deflect the spot over one division. Note that this is in effect a DC voltage. At a setting of 1V/div, for example, for an AC sine wave to occupy one division it would have to have a peak-to-peak voltage of 1V. This would give it a peak voltage half as large (i.e. 0.5V) and an RMS voltage x0.707 peak, or 353mV - the reading an AC millivoltmeter would give.

For audio work, high sensitivity (1-10mV/division) is useful if a millivoltmeter is not being used. Maximum input should be 250V rms/350V peak minimum to withstand full mains voltage, which may be applied by accident. Beware of this; blowing up input stages is easily done and can be expensive.

Bandwidth of the Y amplifier should be at least DC-1MHz (-3dB), a spec. easily met these days.

### Timebase

These days the timebase is specified in time taken for the spot to traverse one division. To show 1Hz (one cycle per second) over 5 divisions (half the screen width), each division must equal 1/5 sec, or 200mS, therefore a sweep speed of 200mS/division (0.2s/div) must be available.

At the other end of the frequency scale, if one cycle at 1MHz was to be resolved over 5 divisions of screen width, then sweep speed would need to be 0.2µS (two tenths of a microsecond)/div. Modern scopes usually manage to reach this speed, even though for audio it is high, since there's usually little need to resolve much above 100kHz.

### Horizontal (X) amplifier

A horizontal input effectively replaces the role of the timebase. It's main use is for the creation of Lissajous figures and, these days, an X input with amplifier is becoming common. On dual beam scopes, one input amplifier is switched to work as an X amp. since only one beam is needed. An X input without an amplifier is likely to be insensitive and will likely need an external amp. if a weak signal (less than 1V) is to be applied for X drive.

Timebase expansion is also provided by an X amplifier, but this is now commonly not used to provide gain after the X input terminals, as it once was.

### Synchronisation

This is vital if the signal is not drift across the screen, because the timebase is running at a rate slightly different to that of the signal under test. For audio work, however, TV line and frame sync are not needed. Internal sync is always provided; external sync can be useful for locking signals drifting in frequency.

### Dual beams

All but the most inexpensive scopes these days have 'dual beams', or 'two channels'. In fact, they use single beam tubes with an electronic switching unit that chops the trace so it shows two waveforms on screen. To avoid confusion and possible accusations of misrepresentation, 'two channels' is the cautious term most commonly adopted for this arrangement, for it is possible but rare to get tubes with two beams, making for a true dual-beam scope.

Two channels are useful for making comparisons, often of output versus input to highlight distortion. Note that although a 'scope will show distortions, it cannot measure them. In chop mode, twin channel scopes can also show phase shift, which is more convenient than using Lissajous figures.

### General beam controls

People commonly become confused when no trace appears on a 'scope. Auto trace-locate helps, as does auto free-run. Failing this, vertical and horizontal position controls have to be twiddled to bring the trace onto the screen and the time base switched to zero or 'free run'. Brightness must be turned up as well.

### Z-axis modulation

This allows beam brightness to be modulated to insert time markers, for example, to indicate frequency. A 'Y' channel output for a frequency counter can be a useful alternative ●

See pp96, 97 of the magazine for an oscilloscope, ideal for audio work and easy for the hobbyist to use.

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Audionote supply a range of very high quality and very expensive audiophile components including valve output transformers.

Superior Sound Audio
25 Montefiore Road
Hove
Sussex
0273 206327
Valves galore, everything from complete amplifiers built to order, to output transformers.

Sowter Transformers
E.A.Sowter Ltd
PO Box 36
Ipswich IP1 2EL
0473 219390/252794
Output and mains transformers for GEC KT88 circuits. They can also make any other transformer to order.

Audio Synthesis
99 Lapwing Lane
Manchester M20 0UT
061 434 0126
Audio Synthesis have a range of very high performance DACs and pre-amplifiers. They are all built using high grade audiophile components of which they stock a range for the home constructor.

Bandor Loudspeakers
Design & Development Studio
11 Penfold Cottages
Penfold Lane
Holmer Green
Bucks HP15 6XR
Manufacturers of their own range of metal cone loudspeaker drive units.

Cirkit
Park Lane
Broxbourne
Herts EN10 7NQ
Sales: 0992-444111/ enquiries 441306/ Orders 440779/fax 464457
General components suppliers, but specialise in radio parts, modules and electronics kits, including Velleman kits.

# GOOD

**Selected by**

*To make any of the kits in this supplement a certain number of tools will be required. Many people will already have an adequate selection of tools to complete the job, but for those who don't or are not sure wether or not theirs are up to the job I have selected a few that we would recommend. All of the following are available from Electromail, whose address is given at the end of the article.*

*Electromail are a subsidiary of RS Components. RS have been supplying the industry with tools, components etc. for more years than I've been alive. They are not the cheapest, but they pride themselves in stocking only the better lines of tools and thus the longest lasting. You can buy a pair of cheap snips from a shop for around*


**SOLDERING IRON**
660-264 £32.88
**IRON STAND**
660-646 £6.98

A good iron is essential when using silver solder for audio work. This particular iron feels solid and is very comfortable to hold due to the foam ring around the handle.

Silver solder requires a slightly higher temperature to melt, making power and recovery time important. The Weller iron here is a 60w version; it can handle silver solder and can produce the kind of power needed for the soldering banana plugs onto thick loudspeaker cable.

The recovery time is also very good. This is the time that the iron takes to get up to temperature again. Cheap, low power irons can often take 30 secs or so to heat up the solder to melting point, following the previous job.

The iron can be fitted with a range of different bits from 1.6mm to 6.4mm screwdriver tips. Additionally each bit is supplied in four different versions, which set the temperature at the tip. Temperatures are 315, 370, 430 and 480 degrees centigrade. For general silver soldering I always use 370 centigrade. This seems to give a fast melt time, but it isn't so hot that it burns the flux out of the solder, which would help produce a 'dry' joint.

The iron stand is useful if you wish to save burning your work surface, hands and anything else that could come into contact with the iron. It also has a foam pad which should be kept damp so that you can clean the iron regularly to ensure that the solder on the bit is clean and fresh.

**SOLDER SUCKER**
547-391 £9.41

The solder sucker works like a miniature spring loaded bicycle pump. It has to be primed first: all the air is squeezed out as the piston is pushed down against the spring. When the release button is pressed the plunger shoots up, sucking solder through the nozzle.

To remove excess solder from an object or joint, you will first need to melt the solder with an iron. Then whilst still holding the iron in place, use the nozzle of the solder sucker to remove the molten solder. The nozzle itself is made from P.T.F.E., which has a higher melting point than the solder. Eventually this nozzle will wear down, but replacements are only about £1.50.


**PRECISION SCREWDRIVERS**
619-503 £19.64

These are miniature screwdrivers suitable for constructing or dismantling electronic products. They are also good for fine tuning Cermet trimmers. Being a long reach variety is useful, as you will quickly realize when you try and get to that little screw in the bottom left hand corner under the main circuit board. Four flat blade and three Philips™/crosspoint screwdrivers are provided and colour coded for quick identification. They are packed in a vinyl wallet which is sectionalized to keep them tidy.

**ALLEN™ KEYS**
Metric 663-34 £6.65
Imperial 663-358 £6.65

Allen™ keys or Hex drivers are used a great deal for the mounting of loud-speaker drive units on a baffle and in kit electronics. Thus a good set of keys is required and these Allen™ keys are the original and best available. There are two sets, one imperial and one metric, both comprising nine hex drivers. The imperial set has sizes from 5/64in to 3/8in and the metric from 1.5mm to 10mm.

# TOOLS

**Dominic Baker**

*£2.50, but after cutting through 10 pieces of thick wire they will already have started to go blunt. The extra cost of the following tools will ensure they are still working well in several years time.*

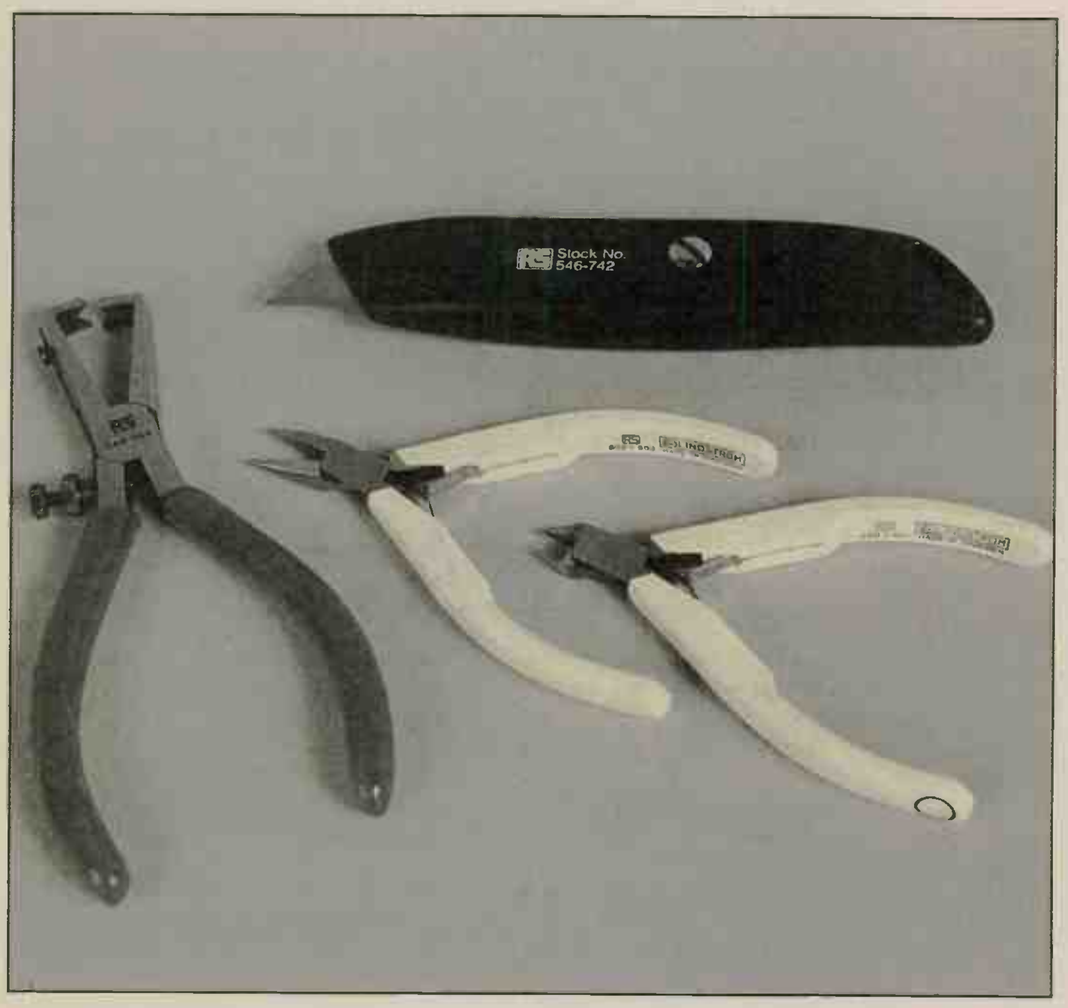
*All of these tools have been selected and used by us. They will make the job at hand fast and easy, as well as neat and accurate.*

*The tools are listed followed by the stock No. and price from Electromail.*

### TRIMMING KNIFE

546-742 £3.02

A good safe knife is a necessity when building any kit, be it loudspeaker or D/A convertor. This trimming knife has a retractable blade for safety and a large solid handle to help prevent accidents. It can be used for cutting veneers, heatshrink and those other things that people will inevitably use it for that I refuse to mention in print. This is a sharp knife and care must be exercised at all times: never cut towards yourself or your fingers.




### CLOSE CUT SNIPS

609-821 £23.46

These particular snips are made for R.S. by F.E. Lindstrom of Sweden. The specification includes drop forged steel frames, box jointed for long term reliability and stability with repeated jaw closure. They have a small jaw size to allow intricate work to be carried out, but the strength is not compromised due to the well engineered design and high grade steel used.

They are ideal for clipping flush the legs of components soldered to a circuit board, or for cutting small gauge wire. They cut quickly and neatly, with no hacking or chewing needed, giving work a professional finish. Also, when used with the F.E. Lindstrom pliers below they can be used to strip solid-core cable without damaging the core.

### WIRE STRIPPERS

544-544 £12.58

You would have to pay a lot to get a good wire stripper - most damage the metal core in one way or another. This is only recommended for large gauge stranded cable such as QED 79 strand or the flying leads on a power transformer. On smaller, solid-core cable they will leave a cutting mark and a score along the wire as they slice the insulation, which is drawn off. This small cut weakens the wire making it prone to breaking when twisting or bending (Noel says: you can you use a soldering iron to melt insulation without damaging the wire).

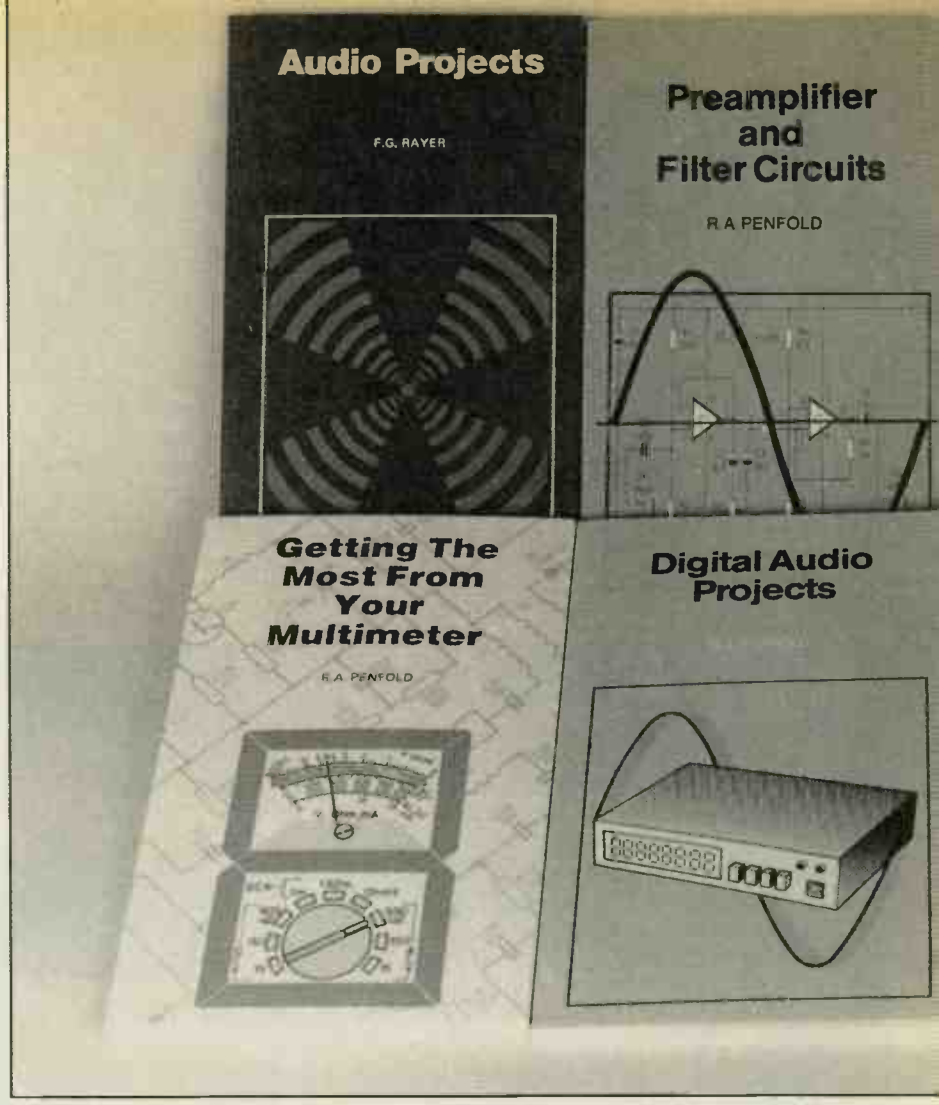
### SNIPE NOSE PLIERS

609-809 £18.22

Again supplied to RS by F.E. Lindstrom, these are miniature pliers with flat jaws. Due to the contour of the jaws, which end in a small point, they are excellent as forming-pliers and at retrieving dropped resistors from awkward places.

They are also particularly useful for stripping some types of small gauge solid core wire. This is done by gently squeezing the insulation so that it splits and can be peeled back. It may then be trimmed with the snips detailed above. The small piece of wire that was squeezed by the pliers may be then cut off leaving a complete and unmarked bare core.

Electromail
PO Box 33
Corby
Northants
NN17 9EL
0536 204555




# BABANI

**Practical books for the DIY enthusiast are difficult to find . . .**

The Bernard Babani range of books are aimed at the novice who has little or no knowledge of electronics. They contain mainly basic introductory information which is normally backed up by easy-to-understand diagrams.

Overall, these books provide the beginner with some basic information which he or she can can apply to simple practical examples. They are not the 'be-all and end-all'. For example if you build one of the suggested circuits from the 'High Power Audio Amplifier Construction' book, don't expect it to give your audiophile quality amp a run for its money. It may however, be a good basis on which to add progressively upgraded circuits, learning how to design in the process.

## Audio
F. A. Wilson

F.A. Wilson has a penchant for theory, supported by basic equations, some of which he works through in practical examples. When discussing horn theory - in useful detail I should add - he says "we cannot have too much practice in finding out for ourselves what formula have to tell" (p153). It is an approach that sets the tone of this book. 'Audio' is for students and those not afraid of a bit of maths and basic theory, who want to get a good basic understanding of the subject, without having to wade through technical tomes.

The book starts right back at basics with The Sound Wave, with plenty of detail upon its nature and what resonance is. Sound pressure and the effects of an obstacle in the path of a sound wave are two areas interestingly covered.

The next few chapters go through Hearing and The Things we Hear, and Room Acoustics. The latter, for example, jumps straight into 'Units of sound absorption', or Sabins, followed by Reverb Time, but never talks about practical room problems or treatments. That's the nature of the book. It offers a useful quick precis of basic theory, but with little in the way of practical example. Bibliographical ›eferences are not given either, which is a y. I would like to have seen the origin of horn equations, for example.

book that ranges so wide inevitably s some simplicities. Of loudspeaker ncy response he says: "the ear is ...2-3dB (variation) is hardly le" - p135, but contentious 's are a part of audio (with small

l, Mr Wilson tackles his thought, diligence and gusto, mprehensive if abbreviated k. In fact, I have bought of his for their basic theory . Audio will be excellent se who need or feed on 't for hobbyists, those looking guidance or for simple planations. £3.95

## Digital Audio Projects
R. A. Penfold

As with most of the Bernard Babani Books this one starts with the basics. The first half of the book makes sure the reader understands most of the simple terminology and concepts of Digital electronics. It begins with the difference between digital and analogue quantities and goes on through to A/D convertors and a simple explanation of Pulse Width Modulation (PWM).

The second half of the book concerns itself with two digital projects. The first is a digital storage adapter for an oscilloscope. It enables the wave on the screen to be stored in a memory until it is recalled at a later date. The second project is a delay line circuit and the reader is shown how to use it as an echo unit. Both of these projects are reasonably simple and will provide the essential practical experience needed to clarify the theory.
£2.95

## Audio Amplifier Construction
R. A. Penfold

This book is divided into two basic sections, pre and power amplifiers. The first half details microphone, tape, guitar, and RIAA circuits and construction. Also basic principles of equalisation and buffer amps are covered, which are important to understand.

The circuits given are fairly standard and will be easy to build, since in addition to a circuit diagram a component layout schematic is provided, together with the track disposition on a piece of stripboard. As I have mentioned before, these circuits are not really intended to be audiophile quality. However they will work and you never really understand the theory until you try to put it into practice.

The second part of the book lists practical power amplifiers in ascending order of output. Circuits and construction details are given for 0.8W, 2W, 6W and 18W (bridge) amplifiers based on IC's,


# BOOKS

**the inexpensive Bernard Babani range is an exception.**

which makes life easy, even if it does shield the constructor from the nitty gritty of power amp design. However, the more powerful circuits for 32W and 100W amplifiers use discrete MOSFET's, assuming a better knowledge of electronics, heatsinking and various other associated concerns on behalf of the experimenter.

This is a practical book, aimed at those who want to build, rather than study lengthy theory. It should provide hours of absorbing work for those with the dedication and enthusiasm to follow projects through. All the circuits have been built and work, but beware that the bigger projects do require some knowledge and experience. £3.95

## How to Use Oscilloscopes and Other Test Equipment

R. A. Penfold

How an oscilloscope works and what to buy are among the early chapters. Disappointingly, although there are many screen diagrams, comprising simple line drawings, there is little else to add variety or depth to the illustrative matter. For example, it is common to show input and output test waveforms expected from a specific depicted circuit, but this book has none. Most books on this interesting subject have many good illustrations to support the text. For example, Scroggie in the Radio and Electronic Laboratory Handbook gives twenty nine Lissajous figures and Easterling in Using an Oscilloscope gives six. Penfold offers two, with no scope connection diagrams, something I found disappointing.

Chapter 2, titled 'In Use', gets to grips with using the oscilloscope and understanding the waveforms that appear. However it doesn't have much detail on useful measurements for audio equipment and the text tends to waffle somewhat, but the information provided in the most part is helpful, if not well honed for its task. At the price, serious criticism seems a bit churlish, but all the same, with a bit more thought and effort, this book could have been a lot more useful than it is. £3.50

Other titles from the Bernard Babani range of books that we think will be of interest to DIY constructors are pictured above. Below we give a brief description of their contents, along with prices.

## Getting The Most From Your Multimeter

R. A. Penfold

This book covers how to choose a multimeter and then how to use it to test components and complete circuits. Unfortunately the choosing chapter seems to consider features more important than accuracy, which it fails to mention. The testing is mainly concerned with whether something works or not, rather than finding the fault, which seems a little unhelpful. £2.95

## Audio Projects

F. G. Rayer

Audio Projects is basically the practical version of Audio. It offers practical circuits for pre and power amplifiers as well as tone controls. It is quite concise, which is refreshing after the waffle of some of the other titles. £2.50

## Preamplifier and Filter Circuits

R. A. Penfold

The subjects covered by this book include; Feedback, RIAA, Tone controls etc. These are all fairly important principles and Mr Penfold has described them well, enough to give the DIY constructor an insight into the problems that designers will face. £3.95

## High Power Audio Amplifier Construction

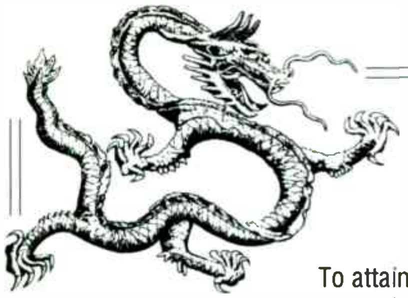
R. A. Penfold

High power audio amplifier construction starts with a chapter on problems such as loudspeaker matching. This is only brief and doesn't really deal with the problems in any depth. The high power circuits include a discrete MOSFET design complete with details on heatsinks, power supply and construction. £3.95 ●

Available by mail order from:

The Modern Book Co.
19-21 Praed Street
London W2 1NP

Tel: 071 402 9176
Fax: 071 724 5736



# Golden Dragon

Precision Audio Tubes

To attain a premium tube, sonic quality must be designed in from the start. As with any fine audio component, vacuum tube design is both an art and a science. With the closing of the legendary tube manufacturers it seemed that the magic combination would be forever lost.

Fortunately, a group of British audiophiles and engineers have worked diligently with the Shuguang and Beijing tube factories in China to create tubes of the highest sound quality and reliability. No aspect of design or performance has been neglected. Countless prototypes were auditioned in the creation of custom audio tubes that rival the finest ever made. The results of these efforts are now available as Golden Dragon precision audio tubes.

**Please enquire for any tube types not listed. We have an inventory of over 2,500 different types in stock.**

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| 211 | £28.50 | £59.00 | £118.00 |
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| EL34/6CA7 | £18.50 | £37.00 | £74.00 |
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|---|---|---|---|
| EL84/6BQ5 | £8.50 | £17.00 | £34.00 |
| E84L/7189A | £12.50 | £25.00 | £50.00 |
| KT66 | £25.00 | £50.00 | £100.00 |
| KT88 | £49.50 | £99.00 | £198.00 |
| *KT88 SUPER | £59.00 | £118.00 | £236.00 |
| 6L6GC | £18.50 | £37.00 | £74.00 |
| 6550A | £39.50 | £79.00 | £158.00 |

*Denotes New Design or New Type

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24 Hour Answerphone Service

**Golden Dragon Select Tubes.** A new range of tubes specially sourced from other factories, aged, tested and carefully selected to Golden Dragon standards and available in matched pairs and quads at no extra charge.

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**We also have available ceramic valve sockets and holders for the entire Golden Dragon range.**
**For further details please contact:**

**P.M. COMPONENTS LTD., Springhead Enterprise Park, Springhead Road, Gravesend, Kent DA11 8HD, England**
**Tel: 0474 560521. Telex: 966371 TOS-PM-GM, Fax: 0474 333762**

The Golden Dragon range is available from the following list of specialist International distributers who provide an afficient distribution service to meet the growing worldwide demand for Golden Dragon Tubes

## GOLDEN DRAGON DISTRIBUTERS

**AUDIO TRADE GMBH**
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4330 Mulheim/Ruhr
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Tel: 49 208 44646

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**KINGSLEY COMPANY**
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**MOTRON**
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Norway
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**KIMMO SALMINEN**
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33540 Tampere
Finland

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Indonesia
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**J & W Bryant**
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