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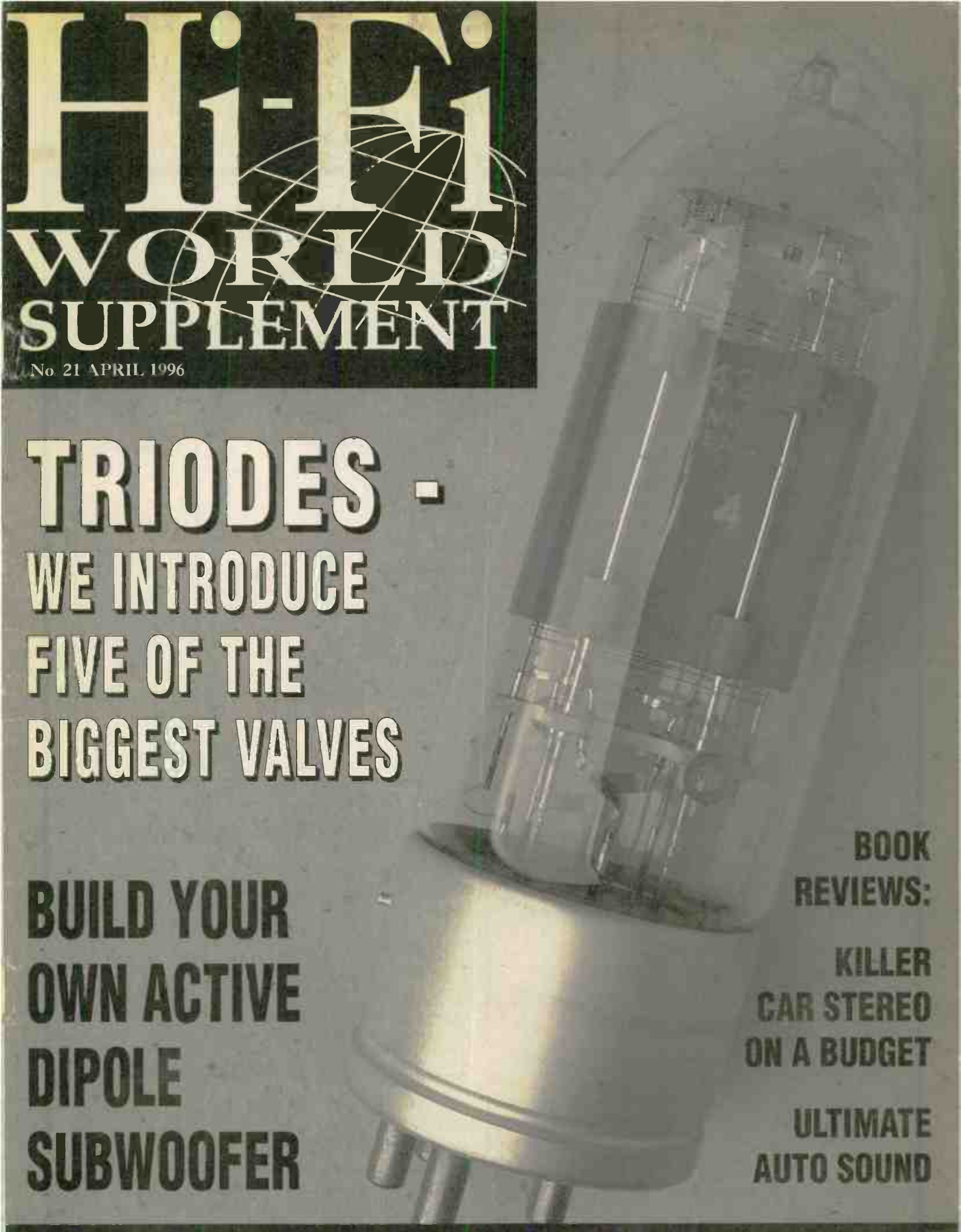

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AN ACTIVE DIPOLE SUBWOOFER

Dominic Baker describes the design of a subwoofer for Quad's ESL-63 electrostatics

A flurry of correspondence followed our dipole subwoofer project in the December '94 DIY Supplement. We gave details of a unique active crossover that married Quad electrostatics to Celestion's SL6000 dipole subwoofer. But the Celestions are no longer available, so you wanted to know how you could build your own.

We set about designing a system that could be built around modern drive units available today. First we had to find a large, high power driver capable of surviving the huge power required in a dipole subwoofer system. Beyma and Precision Devices sprang to mind, both known for their superb high power bass drivers. But they are expensive too, so much so that it would put the system out of reach for many enthusiasts.

This quickly brought our sights to bear on our final target. To keep cost down, a single driver needed to be found to replace the twin-driver Celestion system. A good cost saving could be made straight away, although some output level (volume) is sacrificed. With only one driver per channel rather than a pair, the system is not quite as powerful, but this is not a problem in a medium size living room, where a smaller, simpler system is more appropriate.

We also needed to find a driver with high sensitivity, because dipole subwoofers absorb a lot of power. There would be little point keeping the system simple if powerful and costly amplification was needed. Problem is, higher sensitivity drivers have lighter cones and a higher resonant frequency, which limits bass depth, so there's a trade off here.

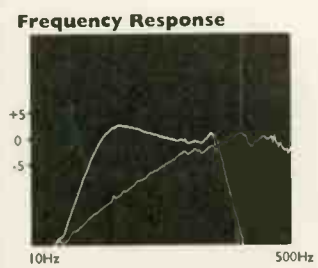
We had to find the best compromise available. Audax's PR330M0, a 13" driver from their professional range, seemed to fit the bill nicely. Sensitivity is massive at 98dB, comparable to the 12" Beyma drive unit which was one of the highest sensitivity drivers I know. But with a slightly larger cone the Audax looked better able to shift air in volume. And the resonant frequency on paper was a low 28Hz; I couldn't find anything of similar sensitivity that could rival this low figure.

Best of all, the Audax driver was considerably more affordable than anything comparable. This looked to be a super driver, so without further delay a set was ordered and experimentation began. Here's how we developed our dipole subwoofer system for you.

TECHNICAL DESCRIPTION

The Dipole Subwoofer

Our dipole subwoofer is effectively a drive unit working in free space, although in practice it is mounted on a compact baffle. There is no cabinet to 'hold in' the energy from the rear of the cone, so the sound pattern behind the dipole is identical to that in front, but out-of-phase. This energy from the rear cancels the front resulting in a 6dB/octave roll-off. Because our practical baffle is small, bass rolls off from around 200Hz down,.



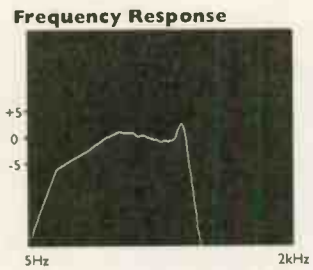
Electronic equalisation lifts the driver's output by 6dB/octave

To counter this bass roll-off, it is necessary to electronically equalise the response with a +6dB lift. If the driver's response on the open baffle falls by 6dB/octave, and you add-in a +6dB/octave lift electronically the net result should be a flat response. You can see the near field response of the equalised driver in the plot above, along with the unequalised response.

The Drive Units

Because we wanted to produce, for the DIY enthusiast, a more affordable speaker than Celestion's SL6000 system we chose a very high quality heavy duty bass driver, a 13" Audax unit. Celestion use two 12" drivers per channel in a double-dipole arrangement, each pair push-pulling together. We chose to use a single, but slightly larger cone to keep cost down. This means that our system works in medium size listening rooms typical in the UK, for larger rooms the drivers could be doubled up.

The PR330M0 bass driver used is from Audax's professional range. It is very powerful, with a high sensitivity of 98dB. Because a +6dB/octave lift is applied electronically to counter the losses of the open dipole, caused by cancellation, a lot of power is needed. Use of a sensitive driver like the PR330MO makes the system suitable for a wider range of amplifiers, although you should still be looking for at least 100watts. The only downside of using a lighter and more sensitive driver is its higher resonant frequency, which limits downward extension.



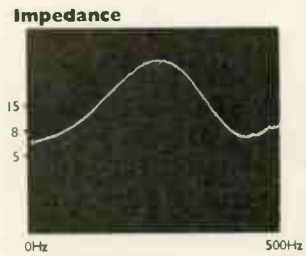
The original crossover for the Celestion SL6000s with our subwoofer. We limited bass extension to improve performance and power handling.

The Crossover

Our crossover was designed to smoothly integrate Quad's ESL-63 electrostatic loudspeakers with Celestion's SL6000 dipole subwoofer. Because we wanted to offer a more affordable, simpler system for DIYers, a few changes had to be made to the electronics.

When we first fired up the system with the original crossover the results were as I'd hoped: wonderfully deep, clear and extended bass. But really deep bass at high levels on a recording could bottom out the cones, causing distortion. Here there were two problems. Firstly, the single cone was having to work too hard to reproduce the lowest bass, running out of excursion. Secondly, driving the bass unit below its resonant frequency increases distortion.

The solution was to limit lower bass electronically. The original crossover filtered out low bass below around 20Hz to prevent cone flap and 'speed-up' the sound. Measuring the impedance curve of the PR330M0 it was found that the resonant frequency was around 26Hz. By changing the values of C1 and C2 on the original circuit from 0.33µF to 0.1µF, the lower limit was raised from 20Hz to 30Hz, or just above the resonant frequency. The reduction in cone excursion at lower frequencies improved power handling greatly, allowing high levels to be reproduced in a medium size listening room. Bass was also cleaner and faster still, the cone no longer being forced to operate below its resonant frequency.

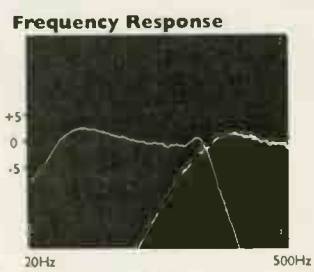


The peak in the impedance plot indicates that the resonant frequency of the driver is 26Hz.

The original crossover had a peak centred around 140Hz. This again added useful speed and upper bass kick in the SL6000 system, compensating for losses in Celestion's bass driver.

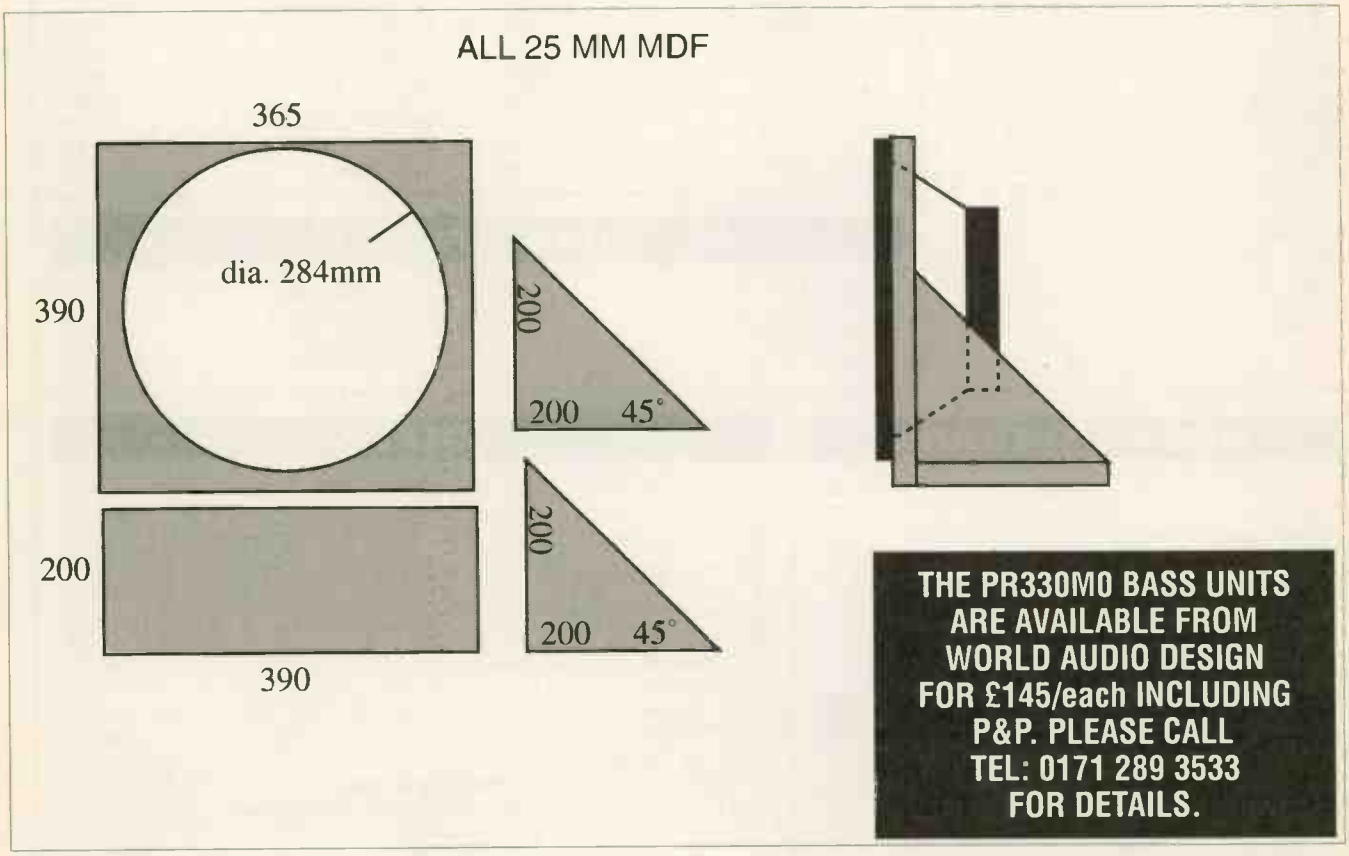
The high-pass section of the crossover was designed specifically for the Quads, the 3dB lift at 225Hz equalising their natural roll-off. If you are interested in building the dipole subwoofer system but aren't using Quads, the 3dB lift could be removed for better compatibility with normal box loudspeakers.

However, this will depend on which loudspeakers you have. For example, some small loudspeakers may also need this peak, but KEF's Reference loudspeakers have a natural lift here, so a cut would be more suitable. I measured the response with Harbeth's Compact 7s which are quite flat in the bass and the lift can be clearly seen. Although the results were very favourable, the thickening in the lower midrange was audible. Here a flat filter would work better.



Our subwoofer with Harbeth's HL Compact 7s.

BUILDING THE BAFFLES



THE PR330M0 BASS UNITS ARE AVAILABLE FROM WORLD AUDIO DESIGN FOR £145/each INCLUDING P&P. PLEASE CALL TEL: 0171 289 3533 FOR DETAILS.

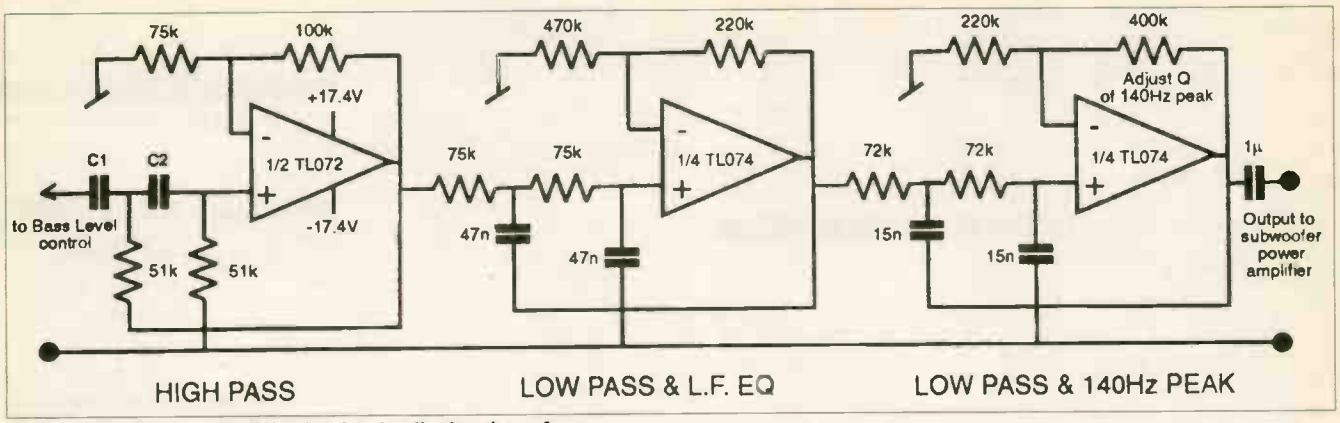
A dipole subwoofer is probably the simplest form of loudspeaker you could ever build. We have provided plans for a suitable arrangement, but being just a drive unit on a baffle, there is a good degree of freedom. There are a few guidelines to follow which will help ensure that you get the best performance possible.

One of the most important is to make sure that the drivers are securely and rigidly fixed to the baffle. That 6dB of bass boost means that the driver will be working quite hard, with large excursions. There is a lot of energy being generated by the driver, which will cause the baffle to vibrate. I used 25mm MDF and this seemed to do the job well, with strong M6 fixing bolts holding the driver.

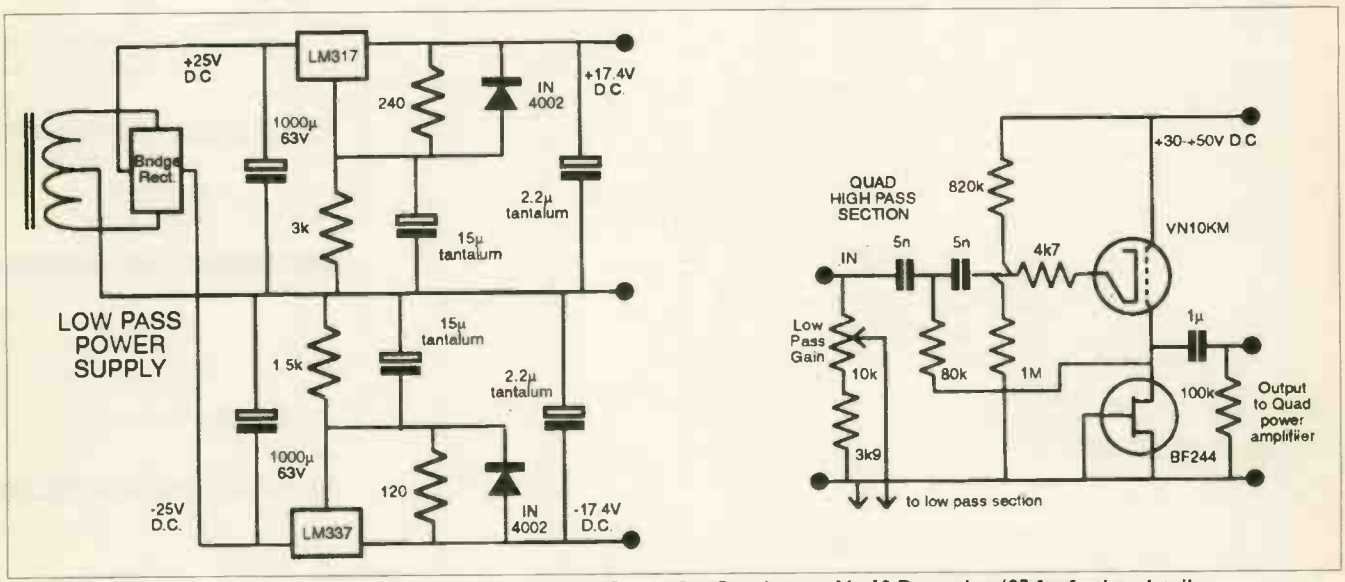
Once the driver is bolted to your baffle the whole structure will shake with every bass note. Luckily, using 25mm MDF and a heavy bass driver makes the subwoofers quite heavy, and once spiked and seated firmly on the floor they become rigid. If you can't use spikes, it may be worthwhile weighting the baffles down. You could use bricks in a compartment beneath the driver.

Again to keep any vibration, which introduces distortion or colouration, to a minimum, the baffle itself should be kept reasonably small. For a given thickness of MDF, a smaller baffle will resonate less. For this reason keep the baffle around the PR330M0 bass unit as small as possible whilst leaving enough wood around the driver cut-out to keep the baffle strong; around 30mm all round should be enough.

If you follow these guidelines, you shouldn't go too far wrong. If you are unsure, follow our plans. You can either get a local carpenter to build the baffle for you, or have the wood cut to size by a timber merchant. If you build them yourself, it is best to use glue (Evostick Resin 'W' is best) and strong wood screws to make sure the baffles are strong.



The low pass filter and equalisation for the dipole subwoofer.



A suitable power supply and the active high pass section for the Quads. See Supplement No.19 December '95 for further details.

SOUND QUALITY

Immediately apparent with a dipole system is the complete lack of boxy colourations. Bass can sound a little light in colour (definitely not power) until you get used to it, with no thickening of tone normally caused by a cabinet. Bass certainly couldn't be termed 'dry' though. In fact it was surprisingly full and warm with the double bass introduction to Lou Reed's 'Walk on the Wild Side', clearly revealing the rich harmonic structure and resonances of the instrument's wooden body.

The other great difference between a dipole bass system like this, and just about every other box loudspeaker, although Castle's Howards get close, is its ability to follow a bass line, clearly enunciating each note. As a bass guitar moves up and down its own musical scale these subwoofers capture every change in pitch cleanly, playing all notes with equal force.

A criticism often levelled at box systems is their tendency to 'one note' bass lines. This occurs when driver and box are tuned to a particular frequency. With a dipole the driver can span its range free from interaction with a box. Eddie Reader's album benefited most here. Where the bass normally sounds overblown and forced, the cones working so hard to capture low subsonics that all above is lost, the dipole system gave a radically better performance. Bass was cleaner, faster and tighter, but best of all upper bass took on a new lease of life; it was able to describe the tune being played. I'd never realised that there were so many notes there to be uncovered. Normally there's a wash of bass with little definition around individual notes.

Compared to Celestion's SL6000 system, which used two drivers for each side, our system did lack ultimate extension. It went as deep as any large 3-way floorstander, deeper than the Spendor SP9/1s reviewed in the main issue this month, but the SL6000 just doesn't seem to stop going. Remember though that the SL6000 cost around £1800 just before it went out of production and whilst its heavy twin-cones possessed downward extension, they did not display high sensitivity.