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FREE D.I.Y. SUPPLEMENT No. 25
### Golden Dragon

#### RETAIL PRICE LIST

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<tr>
<th>Golden Dragon Pre-Amplifier Tubes</th>
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<tr>
<td>12AT7A/811C/EC81</td>
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<td>243 OCTAL</td>
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### Special Quality Golden Dragon Pre-Amplifier Tubes

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<td>E88CC-01 Gold Pins Low Microphony Low Noise</td>
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<tr>
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<tr>
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<tr>
<td>(300B etc.)</td>
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<td>Damping Can (pre amp)</td>
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<tr>
<td>Power Valve Retainer (EL34 etc.)</td>
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<td>6550A Special</td>
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#### Golden Dragon Triodes

- 274B: £14.50 each
- 350B: £29.95 pair
- EL156 Octal: £75.00 pair
- EL34 Super: £25.00 pair
- EL34M: £25.00 pair

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- GZ34: TEONEX 5.50 6L6GC TEONEX 4.50 6189W GE 5.95
- GZ37: NEC 5.50 6SN7GT TEONEX 4.50 6201 GE 6.50
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D.I.Y. Supplement

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Edited by John Borwick and containing chapters from some of the industry's leading experts, this is one of the most complete reference works we've come across.

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Here's where you can write in to tell us about your own unique designs and ideas as well as ask for help along your way to DIY hi-fi bliss.

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KIT-BUILDING. There are numerous kits around nowadays. They all require skill/experience to build satisfactorily and, in the case of valve equipment, safely. Some designs are good, others... well, let’s just say their designers' would benefit from a sojourn on that celebrated desert island with only Terman and Langford-Smith for company! Whichever kit you choose, though, it will benefit from a professional build. We will build it, de-slug it and give you a set of Final Test figures from your sample.

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AUDIO LABORATORIES (LEEDS)
THE NEW POWERS THAT BE
Svetlana Electron Devices of Huntsville, Alabama, have just introduced four new power triodes intended specifically for use in high quality amplifiers. Like the 845 and 211A, these new Svetlanas have direct-heated, thoriated tungsten filaments, but come with massive graphite anodes. Rated at 125w, there's power on tap even in single-ended operation.

Four amplification factors are offered for circuit design flexibility, with the SV572-3, for example, claimed to give a clean sound without feedback, while a pair of SV572-160s can produce 300w output in Class B.

BACK TO THE FUTURE
PM Components are taking a trip down memory lane with their new Retro range of valves, recreations of original designs from companies like GEC and Marconi. Thus far two valves have been produced, the KT88-R and KT66-R, both using the same materials in their construction as the originals and built to the same standard. For prices and more information contact:

PM Components
Unit B3
Springhead Enterprise Park,
Gravesend,
Kent DA11 8HD
Tel: 01474 560521

AUDIOPHILE GO ALUMINIUM
Audiocom are now able to supply 450v aluminium capacitors from Panasonic. These have a large ripple current capacity and can be used in valve amp power supplies and the like. Audiocom are also offering 10% off prices of OSCON capacitors and high purity silver wire during November, and any order over £25 will include a free metre of silver solder.

Audiocom
2 Swallowtree Gardens,
Saundersfoot,
Pembrokeshire SA69 9DE
Tel: 01834 814036

CHELMER'S LION
Chelmer Valve Company can now supply a version of the KT88 which is a close copy of GEC's Gold Lion valve. The valves are manufactured in Europe and come in matched pairs with individual test reports at £60 a set.

SJS TRANSFORMATION
Extending their existing range of valve amplifier output transformers, SJS Electroacoustics are now producing four new single-ended transformers designed for maximum bandwidth with interleaving and split bobbins. For those who like transformers in their pre- as well as power amps, there are also new arrivals on the interstage and pre-amp output transformer scene, SJS claiming a bandwidth of 120kHz for both types. For the final aesthetic touch, black, chrome and brass finished caps are available.

SIMPLE SWITCHERS
If you'd like to follow Linn down the road to high efficiency switch-mode power supplies, then Farnell might have what you're looking for. They now stock the new £7.50 LM2825 from National Semiconductor, which contains a complete 1A switching regulator on a single chip - all you need to add for a 5v or 3.3v output is a 7-40v input. Also available is a variety of regulators from Melcher's IMR6 range, concentrating mainly on 5v and 12v supplies with prices starting at £28.69.

MORE SVETLANA GOLD
Watford Valves have started importing the latest Svetlana EL34 and 6550C Gold power valves. The latter benefits from a new tri-plate anode, precise grid/screen alignment and gold-plating on the grid itself. There is also a free matching service on both valves throughout October.

Chelmer Valve Company
130 New London Road,
Chelemsford,
Essex. CM2 0RG.
Tel: 01245 355296

Farnell Electronic Services
Edinburgh Way,
Harlow,
Essex CM20 2DF
Tel: 01279 626777

Watford Valves
3 Ryall Close,
Bricket Wood,
St. Albans,
Herts. AL2 3TS.
Tel: 01923 893270

Svetlana Electron Devices
8200 South Memorial Parkway,
Huntsville, AL 35802
Tel: (205) 882 1344
Fax: (205) 880 8077

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130 New London Road,
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More SVETLANA GOLD

SJS Electroacoustics
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Harlow,
Essex CM20 2DF
Tel: 01279 626777
This is a very readable, black and white document that contains a detailed description of the features and specifications of a high-quality audio amplifier kit. The text highlights the kit's features, such as its wide frequency response, low distortion, and high-quality components. It also mentions the kit's ease of assembly and the availability of additional options, such as a stereo LED power meter and a versatile passive front end. The document provides a comprehensive overview of the kit's design, construction, and performance, making it a valuable resource for audiophiles and DIY enthusiasts.
Noel Keywood investigates the restoration of the Quad FM1 valve tuner.

I've seen boxes of unloved Quad FM1s tuners sitting under trestle tables, to clear for around £10 apiece. Why does a lovely valve tuner like this so commonly inhabit the lowlier regions of a vintage swap-meet? A Leak Troughline these days goes for £50 minimum - and often a lot more. There is a reason Quads remain ignored of course, but it isn't related to performance.

The big drawback with the Quad FM1 is that it is powered from the Quad II valve power amplifiers (yes, both of them), via the preamplifier. It is also switched by the Quad II preamplifier. So an FM1 is the most inert tuner going if you don't happen to own an entire Quad 22/11 set up. Peter Walker, founder of Quad, showed some ingenuity with his first integrated system arrangement (he did beat B&O), but he didn't do much for second hand prices.

Unbelievably, to split the load, the Quad 22 preamp and the FM1 draw L.T. for their heaters (6.3V) from one power amp, and H.T. (330V) from the other power amp. The mains connection to the preamplifier exists only so that the whole shooting match can be switched on by the volume control. In those days - the late 1950s - power amps were hidden away, leaving a set up as compact as any today, and certainly more elegant, but difficult to switch on without a complex arrangement like this.

For me, the volume control mounted power switch and illuminated Quad legend were distinguishing features of Quad pre/powers, not to mention the delightfully solid cast fascias. I was going to say they don't build 'em like it today, but they do.

Both Mission and Linn acknowledge the example of Quad in this respect, and both use complex castings that cost a fortune to tool up. Trouble is, neither really exploit the styling benefits casting provides, certainly not in the way Quad did with the FM1, sculpting wonderful curves, bevels and ledges, difficult to achieve by any other method. Linn and Mission castings are too planar to clearly advertise their uniqueness and - woe! - they are painted black.

So that's the glory of the FM1: it's beautiful to look at and to use, one of a kind, but a mite difficult to get going. What do you expect for a tenner? There's definitely leeway here for many evenings entertainment, restoring an
FM1, so as usual let me first pour a little cold water on the idea.

Building a power supply for the FM1 gets it up and running as an independent unit. This is a simple enough task for anyone conversant with electronics, but dangerous if you don’t know how. The FM1 needs 330V H.T. (High Tension). The good news is that a complete supply will cost just £20 or so.

The other big problem with old tuners is alignment. This is quite likely to be awry and tuner realignment is not an easy task. If a simple RF generator is used it requires skill and experience. A poorly aligned tuner will distort, be insensitive and suffer interference. But I have more good news: Quad offer an alignment service that costs £40.

Ageing valve units like this - and the FM1 is now 40 years old - usually have a lot of resistors and capacitors that need replacing, since old components drift in value over the years and fail. The few decent condition FM1s I’ve encountered to date worked in a fashion, but not properly. However, armed with a circuit diagram and a good electronic multimeter it isn’t difficult to repair a tuner like this, if you have a little electrical knowledge. Fail, and you have either lost £20 or so, or you can ask Quad to bail you out, since they still service and repair the FM1.

I need to point out that this article is a guide to getting the FM1 going, identifying the main problems. You must have some electronic knowledge to be able to tackle such a project. This is not a subject for beginners and this article is not meant for those with scant knowledge.
CIRCUIT DESCRIPTION

Here is Quad's circuit description:

"A broad band fixed tuned transformer couples the low impedance aerial to a RF pentode (6BH6) the output of which is transformer coupled to a low noise triode (one half of 12AT7) mixer stage.

The local oscillator (other half of 12AT7) is fully temperature compensated and provides an output 10.7MHz above the signal frequency. It is capacitively coupled to the mixer grid.

Both the mixer grid and local oscillator circuits are ganged and permeability tuned by special low loss cores driven from the spindle via a precision worm drive mechanism.

The resultant 10.7MHz IF signal at the mixer anode is transformer coupled to the automatic gain controlled first IF stage (6BJ6). A combination of critical and over coupled circuits and a single tuned circuit in the second IF stage (6BH6) together with a close control of the Q of these circuits ensures a wide passband with a steep cut-off outside the band.

The second IF anode tuned circuit is coupled via a short time constant CR circuit to the limiter valve (6BH6), the anode of which contains a transformer with a capacitively centre tapped secondary winding feeding two diodes (6AL5) in a phase discriminator circuit. Again, the coupling and Q are chosen to give low distortion in the audio output.

The audio signal is fed via a two position switch either, in the unmarked mono position, to the appropriate de-emphasis network and DC blocking condenser, or in the red spot position, to the output cable when an uncorrected signal is needed for feeding into a stereo decoder.

The DC component at the discriminator output whose magnitude is proportional to the amount of mistune and of polarity dependent upon the direction of mistune, is fed to a cathode coupled phase inverter stage (12AX7) which contains a miniature neon in each anode. Slight mistuning extinguishes one neon, showing the direction of mistune, while even illumination of both indicates correct tuning. In addition, this stage provides Automatic Frequency Control, one section of the double triode acting as a reactance valve across the local oscillator tuning coil."

CHECKING WITH A MULTIMETER

Quad quote the H.T. as "between 250V and 350V". However, the nominal is 330V, the exact value being determined by mains supply volts and component tolerances, etc. The tuner consumes 27mA. The heaters consume 1.5A, and there's a 0.3A lamp, making for 1.8A total L.T. consumption, at 6.3V. These values must be checked with a multimeter.

The valves V1 (6BH6), V3 (6BJ6) have around 170V on the anodes, and V4 (6BH6) has 157V. Around 0.75V-1V should exist on the cathodes. The mixer/oscillator, V2 runs at lower voltages and the limiter, V5, works in saturation mode. It has no grid bias, so the cathode is connected to ground, and it has just 35V on the anode. All the main voltages are marked on our circuit.

Ken Bunting, who has been with Quad servicing their products since 1970, told me that all the resistors in the high voltage lines tend to go high; one of ours had drifted from 82kΩ up to 103kΩ over the years, for example. They inspect and replace these first. The old capacitors, he told me, might look a little rough by modern standards, but they were more likely to be acceptable. In 'our' FM1, a tidy unit supplied by Graham Tricker I should point out, all the capacitors had been replaced, but not the resistors. In spite of the resistors being generally high, and the voltages a little low, it worked well. However, it was obvious to me from distortion figures, frequency response and the way it tuned into and out of stations that alignment of our FM1 was out, and the de-emphasis needed tweaking. So, be aware that just checking all DC voltages with a meter is not enough.

Ken Bunting, who has been with Quad servicing their products since 1970, checked and re-aligned our FM1 for optimum performance.

QUAD FM1 TEST RESULTS

<table>
<thead>
<tr>
<th>Distortion</th>
<th>Frequency Response</th>
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<td>Test Tone</td>
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<tr>
<td>500k</td>
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<tr>
<td>2kHz</td>
<td>3kHz</td>
</tr>
<tr>
<td>5kHz</td>
<td>10kHz</td>
</tr>
</tbody>
</table>

- Frequency response: 14Hz-16kHz, 54dB
- Stereo separation: mono
- Distortion (50% mod.): 1.3%
- Hiss (CCIR): -81dB
- Signal for minimum hiss: 2mV
- Selectivity (at 0.4MHz): 54dB
- Sensitivity: 4µV

Ken Bunting, who has been with Quad servicing their products since 1970, checked and re-aligned our FM1 for optimum performance.
Long known as specialists in rare tube brands, Billington Export provides a line of premium-grade valves to fill the increasing demand for hard-to-find tubes! Billington Gold features specially tested valves selected for long life, low microphony and low noise. Versions with gold plated pins are available. Billington Gold brand comes from a variety of countries around the world. We have carefully chosen the best manufacturer for each type, with an emphasis on the highest audio quality and product reliability. We stock one million valves including: Brimar, GE USA, GEC UK, Mazda, Mullard, RCA, Russian/Sovtek/Svetlan, Sylvania, Tesla, Thermionic, Tungsram and other rare brands, as well as sockets and CRTs.

**Special Offers**

- 5Y3WGTA Sylvania: 2.93
- 6AS7G Russian: 2.99
- 6AU6WC Sylvania: 1.20
- 6AUBA RCA/Sylvania: 0.75
- 6BE6 Brimar/ECG Philips: 1.20
- 6CM7 RCA: 2.70
- 6SN7GT Russian: 3.30
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DE-EMPHASIS & DECODING

Demodulation from a 10.7MHz IF (Intermediate Frequency) signal to audio takes place in V6, which is a shunt-loaded Foster Seeley discriminator. So the audio signal (mono) passes through few components on its way to the output socket, ignoring for a moment the need for a stereo decoder.

Our circuit shows an early mono FM1 with an internal de-emphasis network. Later stereo compatible units have a two-position switch that, moved to the Red position, switches out de-emphasis to give a raw feed for a stereo decoder. This must be used to feed either Quad’s own original decoder or the modern design such as the 1310 based design Graham Tricker can supply. De-emphasis is then applied later, within the decoder. Quad told me that C32 between the discriminator cathodes should be reduced to 15pF or so (from 47pF) when feeding a decoder direct, in order to strengthen the 19kHz pilot tone.

I should explain here that in order to lessen the audibility of hiss an FM signal is pre-emphasised above 2kHz (i.e. has treble lift) by the broadcaster to increase treble energy. The signal is then de-emphasised (i.e. has reciprocal treble fall) after demodulation in the receiver to give a net flat response. This technique is used in mono and stereo FM transmissions alike.

The Zenith GE stereo system, introduced in the late 1950s and used today, possesses a 19kHz pilot tone and a 38kHz suppressed sub-carrier, modulated with the stereo information. De-emphasis would ruin this composite signal, so it is applied after stereo decoding. So a stereo decoder always takes a raw audio feed, lacking de-emphasis.

For mono listening the stereo decoder can be ignored, but then the capacitors C33 (DC blocking) and C34, and resistors R20 and R21 must all be correct value. De-emphasis is carried out by R20,21 and, believe it or not, the output load (100k) all in parallel, in conjunction with C34, to give nominally 48µS de-emphasis time constant (the UK uses 50µS). Incorrect values here upset audio frequency response, as will any stereo pre-amplifier input impedance other than 100kΩ! So you must pay special attention to these component values and to the item an FM1 feeds if it is to sound right when delivering mono audio direct out.

Because I wanted to assess the basic tuner and not get too involved in the stereo decoder at this time - a whole subject in itself - I chose to set up, use and measure the FM1 in mono (dual-channel). Feeding an Audiolab 8000S preamplifier I found putting 47kΩ in series with the output and increasing C34 to 1250pF gave a flat response to 1kHz (there’s no mpx filter to limit treble extension), shown in our spectrum analysis.

A Leak Troughline suffers none of this interfacing trouble, having a buffered output. And it is self powered of course, so now you know why the FM1 comes cheap nowadays. Audio output from our FM1, without decoder, measured 600mV at 100% modulation (i.e. full output).

Most FM1s are fitted with a piggy-back Quad stereo decoder, which is solid-state, using old germanium type transistors like OC44s (which some people insist sound better than modern silicons). By and large, early decoders give somewhat mediocre results, and Quad’s has a complex power supply arrangement, which is why I’ve not concentrated on it here. My apologies if this is a slur on Quad’s first decoder. I suggest the use of a modern stand-alone decoder such as Graham Tricker’s.

I visited Quad to get our FM1 aligned. Ken Bunting confirmed that it was in fair working order, but it could be improved by resistor replacement. He had some other interesting observations to make.

The neon tune indicators have ‘popeye’ lenses on them and, also, they produce RF interference that causes spurious whistling when tuning into and out of stations. Since the original popeye types are not now available Quad choose to fit a small circuit board carrying LEDs that do the same job, but better.

Many chip-based stereo decoders have been brewed up over the years for the FM1. National Semiconductor publish a circuit in their Audio Handbook that uses a LM1800 chip. Quad have most parts for the FM1, but not the front panel. The gold bands normally corrode, making the FM1 look tatty after a time. Graham told us that “ours” (his in fact!) was the best sample he’d ever seen, and Quad agreed. Realignment showed that the IFs were too peaked. Ken flattened the passband and ensured the demodulator was fine.

This work optimises selectivity, minimises distortion and, very importantly, gives and optimum tune point. Where the tune indicators had appeared not to work properly, after alignment they did. Having built quite a few valve receivers myself in the past I knew not to bother assessing the FM1 until it had been aligned properly.

The Quad FM1 is simple enough inside to make servicing and renovation fairly straightforward. Quad themselves and specialists like GT Audio can help here if you’re unsure what to do.

Tracking across Band II (88-108MHz) cannot be made perfect. Quad ensure the tuner is station accurate at the bottom end of the band (Radio 2/3/4) but admit it may be up to 1MHz out at the top end, around Radio 1, for example. Also, component position in the RF head (the metal box into which the tuning shaft goes) affects tracking so if any component is disturbed or replaced here - and it is likely that some resistors will need to be - then tracking needs to be reset.

You might have gathered there’s a bit too all this. Sadly, there seem to be few books available now on this subject, especially referring to valve tuners. Just bear in mind, if you are looking for a book on the subject, that a tuner like the FM1 is configured much like any superheterodyne receiver, AM or FM, right up to its demodulator.
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THE POWER SUPPLY

Very conveniently, 330V happens to be the peak value of 240V rms. This means that a mains 1:1 transformer can be used, since with a bridge rectifier, electrolytic smoothing capacitor and low current drain of 27mA we can expect 330V to be achieved almost exactly - and it was. Even more conveniently Maplin have just the right transformer. It delivers 240V AC at 100mA, plus 6.3V at 1.5A.

Whilst we need a little more than the rated LT current, it’s an extra 2VA from a 34VA transformer, and since we are 8VA short from full drain on the HT I’d not expect core heating. In practice this was the case; the transformer ran cool and the LT didn’t droop, giving 6.3V at 1.8A, with 240V AC in. Maplin identify this part as Valve Transformer XP27E, priced at £12.99, on p991 of their Sept-Aug 96 catalogue. I bought one from Maplin’s Hammersmith branch in West London one Saturday morning.

Under measurement, frequency response was flat, our de-emphasis values giving a little +0.5dB lift at 8kHz. Mono noise figures are always much better than stereo, but the FM1 was still very good, giving -81dB hiss no less - better than most solid-state tuners. Mono -50dB sensitivity was a healthy 4µV and quieting so good that the FM1 will, in mono, should work well even with a poor aerial. Selectivity was a bit lop sided on ours, giving a mediocre 48dB rejection to stations +0.4MHz away, but a healthy 60dB to stations -0.4MHz away.

In listening tests I was not surprised to find the FM1 lacked the hardness of tone, flatness of imaging and treble glare that can afflict solid-state designs. It wasn’t as sweet and deeply atmospheric as our Trouline, that’s for sure, and I have to say that I did have to wrestle it into action with a lot of fiddling to ensure the de-emphasis components matched the preamplifier load. Since this was done with the aid of a stereo generator and spectrum analyser, to ensure a flat frequency response, the investment here was not inconsiderable. There’s a good case for letting Quad’s excellent service department sort out this sort of thing. You will have to pay of course, but their charges are reasonable.

Both Classic FM and Radio 3 transmissions lacked hiss, hardly surprising considering the unit’s fabulous -81dB noise figure. To eliminate hum completely power supply smoothing must be very good. The FM1 also has its own internal smoothing capacitor, C38, which needs to be checked.

Lacking inter-station muting, and working from a large outdoor aerial, the FM1 picked up many “ghost” stations. These were distant transmitters in fact, solid-state tuners experiencing the same effect with muting out (mono mode). The difficulty here was tuning into the proper station in the absence of a signal strength meter. I listened for hiss and crackles; local transmissions are always quieter (stronger signal). The FM1 also produces images above and below a wanted signal, something modern tuners avoid, but the tune indicator indicates an off-tune condition to them.

With good solid bass and clean, well differentiated treble free from solid-state grain and rasp (excellent tuners like NAD’s 412 excepted) I felt the Quad FM1 more than justified its £30 or so basic outlay. It pulled in myriads of stations, proving very sensitive, and it separated most satisfactorily. However, to be realistic, getting it running properly wasn’t without its problems, making this a project for engineers with a bit of time on their hands. The FM1 is an elegant looking tuner though, and it’s lovely to use as well. I hope to be able to tackle the stereo decoder problem in future.

---

Our thanks to:

GT Audio, tel: 01895 833099
Quad, Tel: 01480 52561
Classique Sounds,
Tel: 0116 283 5821
Prompted by a reader’s letter, Dominic Baker produces a theoretical design for a passive open baffle loudspeaker.

DEar Hi-Fi World,

I am a regular purchaser and reader of Hi-Fi World (every issue so far) with a particular interest in DIY articles and ideas.

Your recent article describing an open baffle sub-woofer is of interest to me, as I wish to build something a bit similar. Some time ago now I bought a pair of Audax HM17020 aerogel bass midrange units from you, with which I have been experimenting. I now plan to use four of these units per channel mounted in vertical array on an open baffle, to cover the frequency range up to about 400Hz in an active loudspeaker design which I am working on.

This will use a Linkwitz type active filter (fourth order Butterworth). The actual crossover frequency is 420Hz. The baffle width would be similar to your sub-woofer design, so I am assuming that the cancellation roll-off effect would set in from below 200Hz, at -6dB per octave, again as in your design.

I wonder if you could help me with three questions. With the units wired in series/parallel (to maintain the same, 8 ohm nominal input impedance as for a single driver), what gain in efficiency could I expect from the quadrupling of total-radiating area? Would it be approximately +6dB, or more? (The more the better, as far as I am concerned)

Related to that, and given sensible usage with predominantly classical and jazz programme, what is the maximum electronic boost (again in dB) that it would be prudent to apply at low frequencies to the four driver array? I had in mind somewhere between +6dB and +12dB, which would extend the flat response down to about 70Hz or 50Hz, respectively, assuming roll-off at -6dB/octave from 200Hz.

I would be happy to incorporate a ‘bottom end’ filter to roll off the input signal more sharply below the driver resonance frequency, in order to reduce displacement and distortion at very low frequencies.

Lastly, can you suggest a circuit which would be compatible with the Linkwitz filter circuit, and would achieve the required bass boost? I ask because I have to hand a circuit and equations - Linkwitz again - for step boost of +12dB per octave with variable turnover frequencies, but not for +6dB per octave boost.

Perhaps I should just add that I plan to use the four Audax units in conjunction with a Lowther Vogt DMSa(f) wideband mid/ treble driver, loaded by a short, tractrix profile midrange horn, above 420Hz. Hence the interest in high efficiency, and the attraction of this specific multi-driver configuration below 420Hz, as the effective moving mass would be comparable to that of the Lowther unit, with a better chance of achieving seamless integration. I am more concerned with optimising the midrange and lower treble performance than with extracting very deep bass.

Brian Wadsworth

You’re about to open up a large can of worms here, one that’ll require a lot of experimentation to get the best performance. Using four drivers, two in parallel then the pair in series gives the same impedance as a single unit, which as you say keeps things at a nominal 8Ω. Because you have four times the cone area though, you will see an increase of 6dB output.

That’s the easy bit. You’re going to run into phase problems though, where the distance between the drivers is close to the half wavelength of sound you are using them at. This will more than likely cause a lumpy, phasey lower midrange response, something to be avoided if you want a coherent sound. Also, applying +6dB/octave bass lift to a 6” driver, even though there are four of them, is going to push them close to their limits. Basically, I think you’re going to struggle with this arrangement, and that’s before we even consider the electronics.

For this reason, I’d like to suggest a slightly different approach, one that’ll be a lot simpler to build. The bass of an open baffle relies on serious cone area and high power units capable of really shifting air; I’d use a pair of the 13in. professional Audax
PR330M0 bass drivers for each channel as part of a three-way system on a 450mm wide open baffle. These, in parallel, will draw more current from your amplifier (use a good solid state amplifier and it'll still be able to drive them easily enough though) increasing apparent sensitivity by 3dB. It does this by halving impedance and doubling the amount of current drawn, but a dipole is inefficient anyway, so even if you went the active route you'd need a powerful amplifier. Doubling the cone area by using two per channel adds another 3dB.

This 6dB on top of its 98dB sensitivity gives you a massive 104dB to play with. Why? With this much sensitivity you can afford to implement the 6dB/octave rise towards low frequencies with a passive circuit, making this system much simpler. Use a series inductor to apply 6dB/octave cut above 60Hz. The effect will be a response that rises at 6dB/octave from 350Hz down to 60Hz, countered by the 6dB/octave roll off of an open baffle.

This combined response should be flat from 350Hz down to 60Hz, with a -6dB (bass cut-off) point of 30Hz. Above 350Hz the response will continue to fall at 6dB/octave under the effect of the inductor.

You could then use your HM170Z0 drivers for midrange, one per channel, with a simple series inductor to flatten the response and give a 1st order roll-off characteristic. Around 1mH should be about right, but if you want a slightly softer

The original frequency response of the HM170Z0 driver rises with frequency. This can be simply corrected with a series inductor. Mounted on the open baffle, the lower response will roll-off due to cancellation.

With bass and midrange on an open baffle you can see that the 1st order roll-offs will combine well to give a smooth (predicted) response. The 6dB/octave rise through the bass is cancelled out by the 6dB/octave roll-off caused by cancellation around the baffle, resulting in a flat response. The TW025M1 soft dome tweeter needs just a single capacitor forming a 1st order crossover to get a smooth response, so this could be a good choice for the top end.
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BECAUSE THE RESPONSE OF THE HDA MIDRANGE DRIVER WILL ALSO BE ROLLING OFF AT 6dB/OCTAVE DUE TO CANCELLATION AROUND THE BAFFLE, IT SHOULD MATCH WELL WITH THE BASS END. THIS IS ONLY A SUGGESTION, AND AS I HAVE NOT BUILT ONE I CAN'T GUARANTEE IT WILL WORK. BUT THERE'S DEFINITELY POTENTIAL, AND IT SHOULD PRODUCE AN EXCELLENT SOUND BEING SO SIMPLE; NO CABINET AND ONLY SIMPLE 1ST ORDER CROSSOVERS. DB

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Predominant comments about K5881 are that it's 'difficult' to build because it does not use a circuit board, that it is of surprisingly high build and finish quality for a kit, and that it has a fast sound with plenty of treble and bass. I've always thought of it as a "bouncy sounding" amplifier, that is, fast, detailed and with lively bass.

What were we going to change? I've opposed moving to circuit boards for simplicity of build. I am not at all certain that the sort of person who needs to build by numbers should be tampering with a valve amplifier like this. K5881 isn't a toy; it has 450V on the H.T. line and we actively discourage people from buying it if they have no experience. Furthermore, hard wiring is better in terms of sound quality and easy for a constructor to modify. When we do a real budget amp. then we will use a circuit board, but the chassis work will also be far less costly than K5881's welded 16 gauge steel affair.

We decided instead to hone K5881's sound quality by making it smoother, more neutral and more valve like. In my original re-working of the Mullard 5.20 I discarded ultra-linear operation in the output stage, finding that it wasn't especially linear at all. We have the benefit here of using a fast computing distortion analyser that shows harmonic structure and how it changes with level. My whole basic approach to amplifier design is to optimise open-loop (i.e. no feedback) linearity, then close the loop, using feedback only to tiddle up final results. Feedback skews an amplifier's transfer characteristic and ultra-linear working commits this sin.

A well designed amplifier should offer at least reasonable results without feedback. You might not be surprised to learn that transistor amplifiers are unable to meet this criterion, whilst a highly optimised design like our 300B needs no feedback at all. Like 300B, I ensured good linearity with K5881 by running it at a high 450V H.T. and using relatively high impedance output transformers. Under these conditions ultra-linear gave worse results than simply running the screen grids a few volts below the H.T. line. Some advocate running the screens from half H.T. but this only reduces output power and increases distortion.

Most valve amps run from low 350V H.T. lines so cheap electrolytic capacitors can be used, these items being a major cost in any valve amplifier. K5881 was never meant to be a cheap amplifier though. We use a massive 5H choke in the power supply in conjunction with a special twin 50uF+50uF / 500V electrolytic in classic π filter arrangement. In my view this arrangement incorporates the best of choke-input and capacitor-input power supply arrangements, being effectively a compromise between the two. It pulses the mains transformer less than a pure capacitor input type (which all transistor amps use and which the EC are threatening to ban), whilst offering excellent smoothing and regulation. It avoids the hum fields, mechanical buzz and voltage drop of a choke input filter too.

In my original circuit the EF86 input stage was strapped to run in triode mode. We decided that, in light of experience, the Shunt Regulated Push-Pull stage based around the 7025 double-triode (high performance ECC83) valve would be a good upgrade for the front-end. The Japanese swear by SRPP and, with this valve, I must say it gives superb results. This front-end change has eliminated the bright and treble we were getting with the EF86, bringing a smooth neutrality to K5881.

After finding, from our 300B, that lowering feedback increases the sense of air and space around images on the sound stage, as well as lessening that dry, clinical presentation that is the bane of transistor amps., I decided also to reduce feedback, in so far as this might be possible within the limitations of using output tetrodes. That's why I again spent a lot of time ensuring K5881 was as linear as possible without feedback applied. Feedback was introduced only to maintain bandwidth, set to -1dB at 22kHz. For this I found just 18dB was needed, a reduction of around 8dB from the previous design. Sensitivity has increased to 75mV for full output (20W) whilst distortion remains around 0.1% at full output. The sensitivity is so high, a preamp is not needed, just a volume control.

As expected, lowering feedback opened out the sound and made it more...
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valve like in terms of spaciousness and ease of presentation. This last property is difficult to describe. Some people call it liquidity, a not inappropriate term. Music flows more easily and naturally; it sounds less 'clinical' or 'forced'.

Overall, the amplifier has changed considerably in its sound. It has swung from being distinctive to neutral, which is what I wanted to achieve. There's a better sense of insight than before, plus greater openness and clarity. Curiously, the amplifier's actual sound has subsided so much it isn't really easy to describe, but I'm happy with that. At heart this is a very linear amplifier, with output transformers so good there is no slewing or ringing at high frequencies, a problem that affects too many of today's thermionic "me-too" copies. K5881 remains a first rate valve amplifier design suitable for knowledgeable enthusiasts.

K5881 MkII Sound Quality
I souled out to start K588I off with Marvin Gaye's What's Going On? My tapping feet told me this inherently warm, rhythmic recording was having little trouble making it to our KLS 3 loudspeaker intact. 'Right On' had nimble bass guitar joining with sweet percussion to move the music along. Imaging was stable and detailed, the zither that appears at stage right on this song placed clearly in the soundstage, the feeling of space around it adding to the realism of the performance. Vocals were smooth, flowing naturally with the melody and possessing realistic body and substance. Triangles, drums, bass guitar and vocals knitted together in 'Inner City Blues (Make Me Wanna Holler)', emphasising K5881's smooth, organic delivery.

Musicality and emotional communicativeness featured high on the sonic menu with Rimsky-Korsakov's Scherazade. Strings were smooth, as was the flow of the music, clearly painting a picture of Sinbad sailing across the sea. A nicely proportioned soundstage gave the various sections of the orchestra plenty of elbow room, increasing the sense of involvement with its openness. Raising the tempo in the fourth movement proved K5881 no dynamic slouch, crescendo building impressively on crashing cymbals, powerful snare drums and thunderous tympani.

More heavily processed music punched cleanly out of KLS 3. Upper bass caught leading edges of drum machine notes well and gave synthesisers their full measure of pungency. A valve warmth to the bottom end played a part in giving bass lines weight and an easy foot-tapping quality. K5881's transparency also helped make whatever was coming through it comprehensible, an ability appreciated on thick Rock mixes, where insight stopped the music becoming confused. Jon Marks
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Finding a reference book that covers all areas of loudspeaker performance, from design and manufacture to the acoustic interaction within a room, ain’t easy. It’s even harder to find one that’s up to date and thorough. That’s the problem editor John Borwick has tried to address with the Loudspeaker and Headphone Handbook, enlisting the help of top industry experts along the way.

Before I go any further, a word of warning. The Loudspeaker and Headphone Handbook is not a gentle read on loudspeakers. It is more of a technical manual, many of the sections launching into quite complex maths of at least ‘A’ level standard (integration and differentiation). Enthusiasts without the maths to understand the equations shouldn’t be put off though, the chapters all provide plenty of easily digestible reading material.

The Loudspeaker and Headphone Handbook starts with the ubiquitous ‘Principles of Sound Radiation’, this chapter written by R. D. Ford, a lecturer from Salford University’s Applied Acoustics department. It’s a fairly standard introduction, describing the way sound waves are generated, their dispersion patterns and how they are specified in terms of level.

Next up, Stanley Kelly provides one of the most comprehensive introductions to drive unit mechanisms I’ve seen. It’s a little dated in places “for domestic loudspeaker systems... a frequency response of 100Hz to around 7kHz with, possibly, a small tweeter unit added to accommodate the high frequencies”. But he does go on to explore various cone materials, profiles, surrounds and diaphragms in useful detail. Most of the chapter, as expected, covers the moving coil driver, but there is also a section on ribbons.

At the beginning of Kelly’s chapter is a section on the lonophane driver, which works by causing an ionic discharge to occur in sympathy with the audio signal. This is done at the bottom of a horn, the gas discharge causing a wave to travel down the horn, producing sound from no moving parts. Unfortunately the lonophane’s discharge was Ozone (O3) which is poisonous (try getting one of these past current safety standards). It is a small section, but the only one I’ve seen on the lonophane.

Peter Baxandall takes over next to cover the electrostatic loudspeaker. It is mainly a theoretical look at the principles behind electrostatic operation, suitable materials and their constraints, rather than a practical guide to building one like Wagner’s Electrostatic Loudspeaker Design and Construction. It doesn’t so much tell you what materials to look for and how to construct an electrostatic, as give you the maths and theory to research the thing for yourself. It was also good to see that the two practical descriptions of commercial electrostatics are of Quad’s 57 and 63 models - what else?

The world of the crossover is explored, mathematically, by Laurie Fincham, ex Chief Engineer at KEF, now hidden somewhere deep in the Harman empire over in L.A. This is one of the least accessible chapters for the amateur, launching into the maths almost straight away. The Loudspeaker Design Cookbook would be a better bet if this is your area of interest.

Loudspeaker enclosures, as described by Celestion’s Graham Bank and Julian Wright, seems almost lightweight by comparison. Brief descriptions of all the various enclosure types are followed by some useful practical considerations, such as cabinet material, damping and bracing.

The following chapters expand into public address, studio monitoring, measurement and subjective evaluation, to complete a very broad look at the loudspeaker. The chapter on headphones contains useful descriptions of the human ear and the book concludes with standards and definitions, which really are more a commercial consideration than being any particular use to the enthusiast.

In the Loudspeaker and Headphone Handbook, a valiant attempt has been made to cover all aspects of sound radiation. As such, there is little else available today that betters it. Individual areas of loudspeakers are covered in more depth in specialised texts, Robert Bullock’s Bullock on Boxes springs to mind in the case of loudspeaker enclosures. But as a single reference work, no engineer or keen enthusiast should be without a copy.

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TWEAKING THE UPGRADE BUG

I have the following system: Micromega Drive 1 and DAC on sorbothane CD feet, Mission Cyrus II and PSX, Mission 751 speakers and Partington Dreadnought stands. Cables are 0.5m Siltech HF6 between CD and DAC, 0.5m Insert Audio Status 3.4 interconnect and Audioquest Indigo speaker cable.

I am thinking of upgrading the speaker crossovers (I am experiencing some sibilance) and would be grateful for your opinion. Would it be worth making up external crossovers? What are the benefits? I would like to upgrade the internal wiring as well.

I want to upgrade the PSX and amplifier either by Russ Andrews’ mods, or what about going for a valve kit bearing in mind the speakers? What kit would you suggest, i.e. World Audio, Audio Innovations, Audio Note, and how do you feel about upgrading the parts to Black Gates, etc., or would I be better off going for a transistor pre and power like Audiolab or Naim. I do intend to upgrade the Drive 1 to Drive 3 status at some point.

Lee Duckett
Wimbledon, London.

Upgrading the components in your Missions should bring about a worthwhile improvement, if a little care and consideration are taken in doing so. First of all, I’d start by removing the original crossover in its entirety. Build your new upgraded crossover completely separately - that way, if anything doesn’t quite work, you have a chance to revert back to the original.

You will need to measure the DC resistance as well the inductance of the coils used in your 751s. I’ve heard very good things about the CFAC Copper Foil Air Core inductors advertised in the American magazine Speaker Builder, so these may well be worth investigating. They’re available through The Parts Connection, Tel: 001 800 769 0747.

For the capacitors I’d use Solen polypropylenes (available from Falcon Acoustics, Tel: 01508 578272), which strike a fine balance between performance and price. If you really want the ultimate, try Hovland’s Musicaps, available from SJS Electroacoustics, Tel: 01706 823025. These are smoother, more detailed and open, but you pay for it.

Internal wiring should be at least Ortofon SPK100, perhaps Chord Co. Rumour, if you’re using the CFACs and Hovlands so that you capitalise on the improvements. Use a good quality silver loaded solder which not only makes a better electrical join, but is stronger mechanically too. Keeping the whole caboodle out of the boxes and close to the amplifier does have its advantages sonically, as long as you don’t mind putting up with two sets of cables lying on the floor.

Upgrading the components in your amplifier is a different matter. You will need to have considerable electronic experience before taking on this task. The Cyrus II with PSX is a fine sounding amplifier, very clean and detailed along with plenty of power. I’d leave it as is, trading it in against a new Cyrus III. To this you could add a Cyrus power amplifier, biasing your system which I feel will bring a far greater improvement than tweaking your existing Cyrus II. DB

BRIDGING IT

Here is an idea that might be of interest to anybody experimenting with Motional Feedback.

To avoid the complication of a second voice coil and make it possible to use any loudspeaker, why not make the loudspeaker part of a balanced Wheatstone Bridge. The voltage across C-D will be proportional to the signal generated by the motor effect of the speaker. If R1=R2 the system will be only 50% efficient. A 95% efficiency will be achieved by making a 20:1 bridge as shown.

To balance the bridge: replace the power signal with a few volts D.C. across A-B and adjust R1 until there is zero volts across C-D.

Theoretically, a small inductance should be put in series with R3 to compensate the loudspeaker inductance. However, the inductance would be so small that it could probably be ignored.

I must point out that I have not tried out this idea, not having any test equipment.

R. Turner
Chalfont St Giles, Bucks.

Mr Turners suggestion for a motional feedback system uses a Wheatstone bridge to providing a sensing signal without the need for a second voice coil.

Looks OK to us. But bear in mind that a transformer introduces serious phase shift at the edges of its passband, which reduces the available feedback.
frequency, motional feedback that can be going positive, or positive would be going negative. This will set the stability limits and determine the amount of feedback that can be applied.

In practice the amount of shift will depend upon such an item, one could have purchased a dozen valves and still had some change left over! The fact remains that the output transformer is still, and always will be, the weakest link in any amplifier in which it is used.

While I do not profess to be an electronics expert or a 'Golden-Eared' hi-fi buff, I derive great pleasure from building various valve amplifiers (this being one of them) and exploring ways in which they can be improved. Most of the tests which I was able to conduct on this amplifier do confirm the findings of the designer - flat from near DC to over 15kHz, and still some more.

The output transformer can be seen to be the weakest link in an amplifier's signal path. It is the interface between the output stage and the loudspeaker load, made necessary because there are very few valves which can operate into a low impedance load like a loudspeaker voice coil. The 6080 with its 100 ohm anode impedance barely works into a simple 8 ohm load, even if paralleled valves are used. Because of the thermionic nature of valves, relatively high voltages and impedances are needed for successful operation and good linearity, and this is where the output transformer comes in.

It's like a gearbox between the output valves and the speaker. In the same way, a car engine works at low torque and high rpm, so the gearbox steps the torque up and lowers the rpm to effectively transfer power and propel the vehicle. Running the valves into a low impedance without a transformer is like trying to pull away in 5th gear. If the impedance problem can be overcome by using either a large number of valves in parallel and/or using very high current valves (which is like increasing the capacity of the engine), there is still a problem in that the two halves of the output stage operate in totally different modes, one as an anode follower, the other as a cathode follower.

This results in a totally different gain for the two halves, and the generation of large quantities of distortion. This imbalance is far worse than the differences between NPN and PNP devices or FETs. They are nearly always operated as unity gain followers, and as their transconductance is so...
much greater than that of any valve, the differences are mostly swamped by local feedback. In the OTL amplifier, however, these differences are laid bare. The article mentions that 40dB of feedback has been applied; that is, the gain has been reduced by 100 times. But the distortion of the amplifier at 25W, its rated output, is still 0.4%. Multiply this figure by the 100 times feedback factor to see what the distortion was before feedback and of course you get 40%!

The most ingenious solutions to this problem are generally attributed to Julius Futterman. He used local negative feedback around the phase splitter stage to decrease the gain to the anode follower half of the output stage, and later changed to local positive feedback to increase the gain to the cathode follower half. Check out the Futterman circuits, you could modify your amplifier to work as such and the performance would be much better.

Another improvement would be either to parallel up a lot more 6080s (say 10 pairs per channel) or go to 6C33CBs, or triode or pentode connected PL519s, which would be the cheapest option. The later versions of the Futterman amplifiers used 6L6s which are big TV valves like the PL519, only a lot rarer. You could end up with an excellent amplifier if you went over to the Futterman topology and threw money at the output stage, but you may also wind up spending more and getting worse performance than, say, a pair of push-pull 845s and wideband output transformer. Additionally, the 845s would be Class A and wouldn’t vapourize your speakers if something went wrong with one of them. There have been a few commercial OTL amplifiers such as the Futterman, and there are the Croft OTLs, but the cons seem to outweigh the pros and they are still quite rare beasts.

In bi-filar windings the two wires are wound together and so have excellent inductive coupling due to their proximity, the only downside being a large capacitance between the windings. This can be used to positive effect if the phase of the signal on the two is the same, but if the two halves of a push-pull primary (with 180 deg phase difference between the two valves’ anodes) were wound in a bi-filar manner, the capacitance between them would be detrimental, causing the load impedance to decrease at high frequencies.

The MacIntosh amplifiers use a very elegant output stage with a bi-filar wound transformer. The cathode of one valve is coupled to the anode of its partner by bi-filar winding. This works because on each of the valves there is a 180 degree phase shift between its anode and its cathode, so one’s cathode is coupled to the other’s anode, they are back in phase again. There is, however, a large DC potential between them. The output transformers for the solid state SE amplifier are bi-filar wound, and in a lot of my driver and output transformers I use bi-filar and even tri-filar up to penta-filar windings depending on the application.

The transformers in switch mode PSUs often use bi- and tri-filar windings, or even Litz wire, which has many strands all insulated from
each other to reduce the skin effect. When I first started building valve amps, I used to wind my output transformers with a hand drill and stripped down mains transformers! Grain oriented silicon steel (the most common type is called Mn) laminations are quite easy to get hold of if you ask around, and you can make bobbins from thick card. The wire is available from catalogues like Maplin and Electromail, and these companies even offer mains transformer kits which could be adapted to make an output transformer, although the iron is of quite poor quality.

Nickel iron such as Radiometal or Permalloy, which is used in the best transformers, is very expensive and comes in various grades of permeability and hysteresis loss. The core for a small 15W push-pull output transformer, for example, would cost in the region of £70, but offer superior sound and performance if the winding technique is up to the mark. Even higher performance can be obtained with custom-dimensioned C cores, then you could use exotic materials inside like teflon. . . The sky's the limit. AG

NO MOTION AT THE BBC

Your item on motional feedback in speakers (Supplement No. 23) was very interesting. An article with the ruffled some feathers in the Philips camp. Motional feedback to control an electro-mechanical transducer was patented in 1938 by Western Electric in respect of a moving coil disc cutting head. The principle has been applied to modern stereo heads and offers some points of interest.

The Ortofon head shown uses two feedback coils, wound in phase opposition and placed within opposite polarity magnetic gaps, hence the motionally derived output is summed whilst any coupling from the drive coil's field is cancelled.

The resonance frequency (which would normally be placed at the top of the working range to ensure stiffness control) is placed at the logarithmic centre, e.g. 2 kHz. No mechanical damping is used. The effect of varying degrees of feedback is shown, yielding an optimally flat response after which phase shifts in the upper region begin to cause a peak, which if increased would lead to instability. The difference in the f.r. response between the two graphs is due to an integrating circuit in the feedback amplifier which allows greater control at low frequencies. Whilst not directly transferable to a loudspeaker system the above may suggest avenues of research.

S. Davies Aylesbury.

Motional Feedback offers an avenue of escape from the straight-jacket that embraces current loudspeaker design. Most of today's domestically acceptable models are modelled, to a useful degree of accuracy, as networks of masses and compliances (i.e. reactive mechanical elements), with of course the odd resistor thrown in. Thiele-Small equations, which computers gobble up, manipulate these parameters with such speed and accuracy that industry has become completely wired into the idea of designing a loudspeaker's bass section by this method. We use it - and boy does it work.

Trouble is, you become locked into certain immovable trade-offs and ways of thought. That's why 'speakers are so alike these days. Innovation has gone out of the window, to be replaced by convenience and design efficiency. Plus a catalogue of standard trade-offs: for example, increase cone mass to decrease LF resonance to get deeper bass, and you lose sensitivity. It's impossible to use small boxes for deep bass unless the system is made very insensitive. And small drivers in small boxes distort badly.

Motional feedback overcomes these limitations. Most importantly, it can be made to suppress or eliminate the basic box resonance problem that currently sets the low frequency limit and behaviour around that point (i.e. bass quality). So we could hardly agree with Dudley Harwood's observations. Not only can motional feedback reduce the considerable distortions generated by small bass drivers in particular (20% second harmonic, 5% third), it can also provide optimal and adjustable damping. It is quite fundamentally different from what faces us today and also quite radical in what it can achieve. It just cannot be compared with a passive box system, since it overcomes its constraining parameters.

All this is not academic either. Those who have heard Motional Feedback working are struck by the tightness and impact of the bass it can produce. And if the industry is ever to get more or better bass from a small, domestically acceptable box this is one of the only routes available.

Why is motional feedback so rare? We are not entirely sure. We do suspect however that it raises all sorts of marketing and R&D problems for companies that, although thoroughly prosaic, still conspire to keep M.F. off the market. Philips, for example, built their power amps. into their speakers. It seems perfectly sensible, but the sort of buyer knowledgeable enough to choose such a system is likely to want a choice.

We are interested in seeing Motional Feedback brought to market in sensible form. This is likely to be provoked by open discussion, so a wider understanding of its problems and benefits takes place. NK

![Ortofon's motional feedback moving coil disc cutting head](image-url)
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**SOCKETS ETC**

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**MATCHING CHARGES**

| POST & PACKING (UK) | £3.00 |
| TOTAL EXC VAT | £ |
| VAT @ 17.5% (UK/EEC ONLY) | £ |
| TOTAL TO PAY | £ |

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ADDRESS: 
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