HI-FI WORLD

Hi-Fi WORLD

NO.44 APRIL 1999 SUPPLEMENT

SECOND ELEVEN

KLS11 gold-dome loudspeaker part 2

ABSOLUTELY VALVE

Tesla and Valve Art 300B triodes

BOOK REVIEW:

Radio Designer's Handbook, 4th Ed. by Fritz Langford-Smith

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D.I.Y. Supplement

Contents

KIT NEWS 5

Your chance to catch up with the goings-on in the cut and thrust world of DIY audio.

KLS11 PART 2 7

This month we explain the process of optimising our latest gold-dome loudspeaker kit.

JAMMING RADIO 13

Guido Tent of Philips Semiconductors in Eindhoven explains how to minimise Radio-Frequency Interference in your DIY hi-fi.

TAKING STEPS 19

Our experts give this Rothwell stepped attenuator kit the once over and deliver their verdict.

VALVE VERSIONS 21

Jon Marks examines 300B triodes from manufacturers Tesla and Valve Art.

BOOK REVIEWS: RADIO DESIGNER'S HANDBOOK 23

by Fritz Langford-Smith.

DIY LETTERS 25

Experiencing difficulties in the soldering-iron department? Let our resident men in white coats sort out your techno-problems.

KIT NEWS

ALL CHOKED UP

Word received from Audio-Links, the specialist component suppliers, is that they have acquired the sole UK distribution of the new M-Cap Fusion air-core inductors.

Considerable care is taken in the manufacture of these devices: for example, the 99.99% pure Oxygen-Free Copper is heat treated to remove the torsional stresses set up during the winding process. When completed, the winding is bonded to both itself and the spool, the intention being that the coil behaves as a single mass.

As a result of these techniques, it is claimed that the inductors have zero microphony, improved clarity and tone.

Audio-Links are offering values of M-Cap Fusions between .1mH and 12mH with a tolerance of 1%.

Audio-Links
7 Fairmont Crescent,
Scunthorpe,
North Lincolnshire
DN16 1EL
Tel: 01724 870432

CAPS IN THE AIR

A welcome new face in the field of component manufacture is Ampohm (Capacitors) Ltd of Launceston, Cornwall. Ampohm have been around for many years but have recently expanded their range to cover the audio market with a selection of high-quality paper and foil capacitors.

The Ampohm caps feature a robust double-layer paper and gel dielectric between the foil 'plates' and voltage ratings of 630V are readily achievable.

Although primarily a wholesale manufacturer, Ampohm welcomes enquiries for short-run jobs from smaller buyers, so there might be a golden opportunity for some of our readers to get the original value decouplers back into some vintage gear for a start. Subject to a reasonable quantity being ordered (around 50+), Ampohm hope to be able

to offer considerable savings over similar products currently on the market.

Our own KEL34 upgrade kit, to be launched in a forthcoming Supplement, will feature Ampohm .47uF capacitors.

Sales Office
Ampohm (Capacitors) Limited,
Tudor House,
Redhill Lane,
Worcester
WR5 2JL
Tel: 01905 763188
www.ampohm.co.uk

COME INTO THE PARLOUR

Well-known valve manufacturers Svetlana have set up a handy armchair tour of their St. Petersburg factory on the Internet. Surfers now have the opportunity to view a series of photographs of the Svetlana plant showing the fascinating processes by which bits of glass, nickel and so on are turned into audiophile delights.

To take this cyber-stroll through one of the world's surviving valve factories, find www.svetlana.com and click on 'What's new'.

TURNING THE TABLES

Some of our readers may have tried contacting Audio Note for spares and service for Systemdek turntables. To clarify this matter, Audio Note wish it to be known that their stocks of parts are intended for their own manufacturing purposes and that they can not offer service for any Systemdeks.

We understand that the company formerly known as Systemdek themselves still offer some spares for their earlier models, and can be contacted on tel: 01292 311511.

CLUBS ARE TRUMPS

Good news for fans of Radford hi-fi equipment; with the permission of the Estate of the late Arthur Radford, there is to be an Arthur Radford Appreciation Society. The stated purpose of the Society is to "enable users of Radford equipment around the world to communicate and exchange ideas, tips and experiences."

If you would like to be one of the first members of the Society, please send a stamped addressed envelope to:

Philip Parkinson
Windermere House,
Cleadon Village,
Tyne and Wear
SR6 7QQ
Tel: 0191 478 3840
Email: Pparkin352@aol.com

KLS11 LOUDSPEAKER - PART 2 -

In our February issue we published plans for KLS11, a high-quality, three-way loudspeaker. This month Noel Keywood concludes by explaining how to tune-up and tweak the final design.

It was back in the February 1999 DIY Supplement that we printed the first section of this two-part feature on our latest loudspeaker based around a relatively new bass unit from Audax, the PR240ZO. This driver possesses a High Definition Aerogel cone which is light but stiff as well as being consistent in its properties. Audax have designed this unit to work in a reasonably compact, reflex-loaded cabinet. Since it has a large, 10in. (240mm) HDA cone, the PR240ZO can move a lot of air and develop strong, low-distortion bass. It also operates smoothly up to and beyond 1kHz before suffering cone break-up. This allowed us to match it up to Audax's HM100ZO midrange unit, which is built around an HDA cone too. Because they use the same cone material, subjectively these units can be married together seamlessly.

The HM100ZO's extended high-frequency response runs to 6kHz where it meets up with the unique Audax HD3P

piezo-electric, gold-dome tweeter. This tweeter uses piezo-electric forces to flex a gas-filled, gold-coated dome in order to produce sound.

This system demands the use of a step-up transformer to match what is a capacitive load to amplifiers, which are low-voltage, current-delivery systems designed for low-impedance voice coils. It is more complex and expensive than conventional tweeters but gives better results.

This is how KLS11 was conceived - it is a quality three-way with powerful bass and a midrange driver that ensures vocals in particular are handled with a fidelity not achieved by simpler two-way designs. Using three drivers also avoids placing the crossover in the area where the ear is most sensitive, and reduces the phase and transient anomolies that can arise in that region in a two-way design. This makes the loudspeaker more difficult to design, more expensive and more complex. That's why I said in Part 1 that KLS11 is not ideal for beginners, although in truth it is the design rather than the assembly which is difficult. KLS11 uses technologies not commonly available in commercial loudspeakers because, after the margins needed for retail sale have been added, the end product would simply be too expensive to attract interest.

OPTIMISING KLS11

The first article in February outlined the loudspeaker's basic construction, giving its cabinet volume, dimensions and crossover circuit. In this second part I will reveal the final tuning and tweaks.

TREBLE LEVEL

The HD3P functions smoothly up to 20kHz without loss of level. This is fine in well-furnished rooms, especially with side walls that either absorb (because of curtains, for example) or diffract (from an uneven surface like a bookcase). However, in a room with hard, reflective walls, or with a bright sounding CD player, this can give a treble-heavy sound. The best solution is to roll down the upper response gently by placing a 4700pF (4N7) capacitor directly across the tweeter, as illustrated in the circuit diagram. The frequency response analysis (Fig 1) shows tweeter performance without this capacitor in the upper trace. With the capacitor, treble output falls progressively up to 20kHz, where it is -2dB down. This is just enough to soften out treble without making the 'speaker sound dull.

PORT TUNING

The PR240ZO bass unit runs down to 50Hz (-3dB) before the port starts to curtail its output. The port is an anti-resonant system that works against the bass driver, reducing its output to zero at port resonance, which is 35Hz (the port frequency) in this design. The port takes over from the bass unit, radiating from 55Hz downward. The near-field analysis (Fig 2) shows what happens here, with

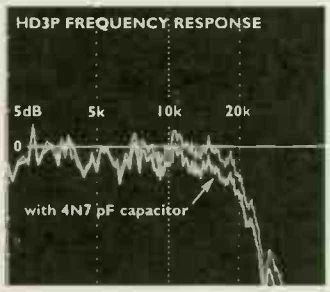
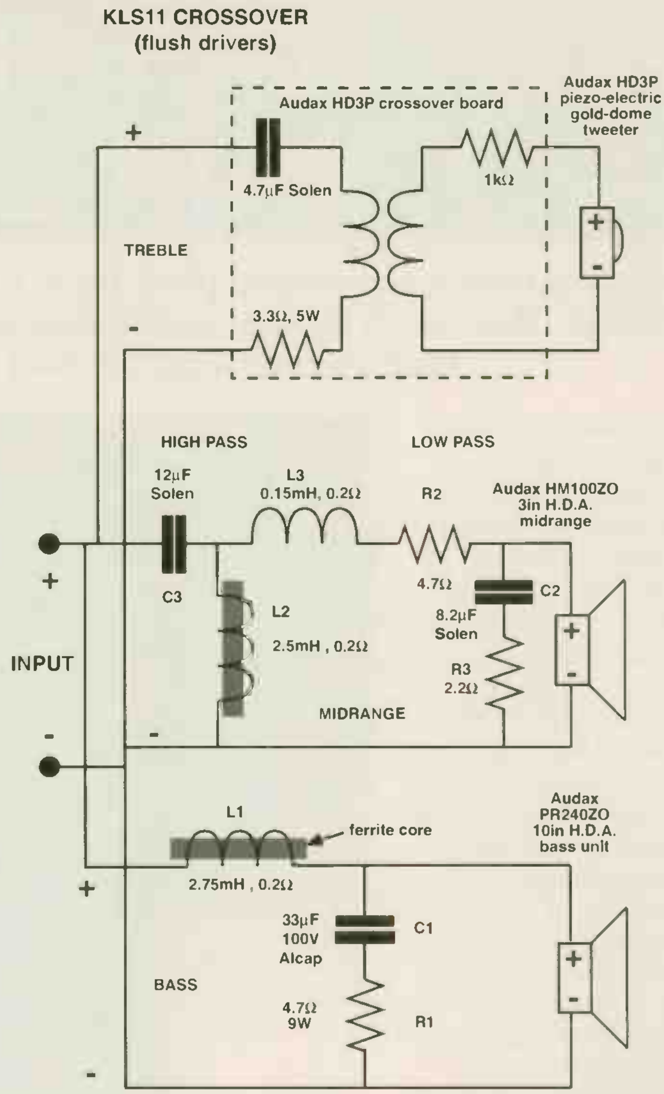


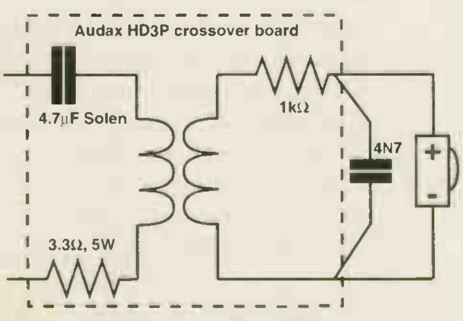
Fig 1 - This high-frequency response analysis, from 2kHz to 52kHz, shows how connecting a 4N7 (4700pF) capacitor across the HD3P produces a treble drop of -2dB at 20kHz.



port output extending down to 20Hz (-3dB), below which it rolls off rapidly.

The port is another area of this design which is open to adjustment - it can be tuned by changing its length. At 100mm long it gives a 35Hz tune frequency. Extending the tube to 150mm takes this frequency down to 30Hz, and it is in this region that the port exerts the most influence and damping upon the bass unit. Lengthening the tube as far as it will go (250mm) lowers the port frequency to 26Hz but increases tube noise, whilst removing the port altogether (the 25mm cabinet wall acts as a short port) raises the operating frequency to 45Hz.

These extremes, shown in Fig 3, will give different bass qualities. The long option gives deeper but muggier bass in most rooms, whilst the short port gives bouncy, obvious bass. I suggest using a two-part extensible port tube and tuning to 35Hz/100mm to begin with and then down to 30Hz/150mm after a month of the bass unit running in, since resonant frequency drops a little. All of this is fairly uncritical subjectively. The changes in bass quality from 35Hz to 30Hz are minimal, but become more obvious if you try the extremes of port length/frequency. Quite where to tune a port seems to be open to opinion. I prefer to tune for maximum port influence, which means with symmetrical side peaks in the impedance curve. This exerts most damping upon the bass driver and gives the lowest overall impedance, thereby drawing most bass power



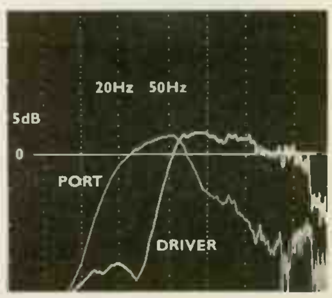


Fig 2 - This near-field response analysis of the PR240ZO bass driver and port clearly shows the operating range of each. As the port starts to resonate it acts against the driver, causing output to drop rapidly below 55Hz. Below this frequency the port radiates, extending bass response down to 20Hz.

An extensible tube makes port tuning simple.

from an amplifier. The upshot is usually tight, fast bass since the low air mass of the port is doing the job of radiating. It is best to experiment, however. Other factors, like your listening room, also come into play, so what I find generally to be the case at HFW may not equate with your experiences.

Gary Hollands chooses to tune for maximum bass power handling, which is roughly analogous to best bass damping, which can be achieved in KLS11 with the 35Hz tune frequency. There are hours of interesting experiment in all this of course. But be aware that a bass reflex enclosure should not be over-damped internally. The rear wall behind the bass unit will send a reflection back through

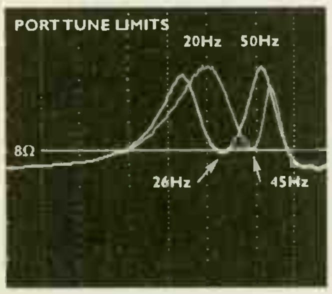


Fig 3 - This analysis shows port tuning limits. Extended fully to 250mm the port reaches its lower limit of 26Hz. Removed altogether, so the cabinet wall acts as a short port, resonance rises to 45Hz. Experimenting with port length tunes between these limits, the optimum being 35Hz/100mm.

the bass cone unless a double-layer or roll of carpet felt is glued directly behind the PR240ZO. Otherwise, reflex cabinets usually sound best when unlined or lightly lined. Over-lining the walls or stuffing with long-haired wool can make reflex bass sound dull and ponderous. If there is a boxy or wooden coloration, then cabinet side-wall bracing will probably provide a cure.

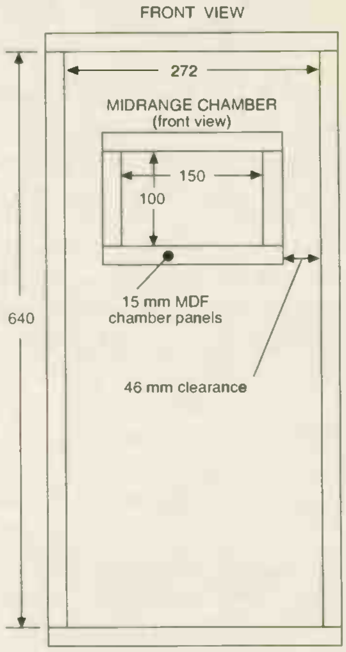
CABINET DESIGN

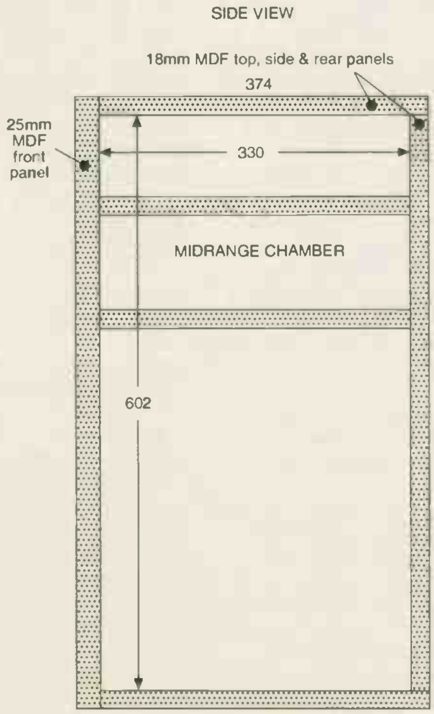
KLS11's midrange chamber was dimensioned to be 188mm wide externally, which in a cabinet 272mm wide gives 42mm clearance either side. By using 15mm MDF this increases to 46mm, shown at right. This must not be reduced by the use of thicker wood or carpet-felt lining. If it is, the upper chamber may become acoustically divorced from the lower chamber by resistive ports. I had not foreseen this possibility in the design process.

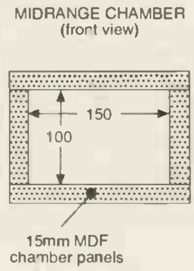
The midrange chamber could take many forms, including an open-ended tube exhausting through the rear of the loudspeaker. This eliminates the rear cabinet-wall reflection and gives a more open sound. It is best to line the tube with long-haired wool to minimise rear output.

Since the midrange unit works down to 800Hz, the distance from the rear of the cone to the front is well over half a wavelength so cancellation will not occur. If you decide on this approach, stout plastic tube from a plumber's merchant or even clay drainage pipes could be used. The tubes must be fixed to the front panel and will almost certainly need to be let into a routed circular groove and glued. At the other end it will require gluing once more to form an airtight seal. The bass unit can be moved downward to accommodate this tube, but the tweeter cannot be moved upward. Its spatial relationship with the midrange is crucial to maintaining phase coherence between these drivers. Which brings me to another feature of KLS11.

The original crossover worked for drive units mounted directly onto the front panel or flush in routed grooves; it was a compromise to suit both, since not everyone owns a router. However, these handy tools are not uncommon nowadays, so we tweaked the crossover slight-







Time Waits For Saga of the Audio Note

While we all wait for the brave new world of DVD, with its many proposed (imagined??!) benefits to sound quality, Audio Note is introducing a highly innovative and unusual addition to existing digital converter technology.

The question is, will the one times oversampled D to A converter with no digital filter make a further contribution to 96kHz/24Bit technology or extend the life of the existing 16Bit system??

A brief technical discussion follows below.

Digital Audio recording consists of measuring (sampling) the ampliture of the audio waveform at regular intervals and storing the measurement results in the form of binary data.

A digital to analogue converter generates an output which bears a direct relation to the digital data it is presented with, and hopefully if all goes well we retrieve the original analogue signal.

The sampling rate is the rate at which measurements are made and the resolution is the accuracy of these measurements. The greater the sampling rate, and the greater the resolution (number of "Bits") the closer we theoretically get to the original, and infinite amounts of each would result in a perfect recording, this has been the limiting factor sofar, because more resolution and higher sampling rate means more information which in turn requires greater storage space and thus greater cost.

The engineers who originally specified CD decided upon 44.1kHz sampling rate and 16 Bits (65536 discrete levels) of resolution were aiming at good recording time on the disc combined with acceptable cost within the technology available at the time (1982/83). This just about gets us to the generally accepted 20kHz upper hearing limit and gives acceptable dynamic range and distortion, but only just.

Due to the limited sampling rate of 44.1kHz the actual bandwidth of the system is limited to a theoretical maximum of 22.05kHz (half the sampling rate). If a digitally recorded signal is played back above the high frequency limit there is a lot of signal related noise which is generally considered to be undesirable. In fact, if you observe a 16Bit 44.1kHz encoded signal which has been directly converted by a D to A converter without filtering it looks a real mess. The current wisdom is to use a digital filter which interpolates the 16Bit/44.1kHz signal to a higher sampling rate and to a seemingly higher resolution. Commonly the interpolation is 8 times oversampling (to 352.8 kHz) and to 18 or 20 Bits of resolution, no information is added, the filter mathematically joins the "dots". Then after the interpolated signal has been converted to analogue an analogue filter is used to put the final polish on the signal.
As the theoretical maximum frequency limit is 22.05kHz and the required bandwidth is 20kHz the digital filter has to cut off very very quickly. In fact the popularity of the digital filter today is entirely due to the impossibility of designing an analogue filter which can roll off so fast, and without phase distortion and time related problems. The digital filter uses a mathematical function called a sinc function which gives the required "brickwall" roll-off and with no theoretical phase distortion. The sinc function is an impulse which starts at time Zero and ripples off infinitely into the future, and the past!! Of course this is impossible in reality and the filter uses a part of the function and feeds the data into one end. Even though the filter only uses a small part of the sinc function it must still be large enough to be effective at filtering and this means that it is usually several milliseconds long, regardless of the duration of the signal itself.

At Audio Note we have long pondered the question of how much damage the signal suffers at the hands of this filter function and the unavoidable time smearing it introduces. To give you an example, if an impulse lasting only one sample is fed into a digital filter, it gets smeared out into a ringing signal several milliseconds long, hardly supporting claims of accurate reproduction, or as we say here at Audio Note; time waits for no-one, not even the "perfect" digital medium. Time displacement is the greatest cause of audible anomalies in audio reproduction and always has been.

Whilst we are not alone in questioning the effects of the sinc function and the digital filtering universally used in all CD-players and D to A converters, we are the only manufacturer unconventional enough to have grasped the nettle properly and removed the digital filter altogether, in an attempt to answer the central question; "how else do you establish with any accuracy exactly what the digital filter actually does to the signal and is there an alternative method of filtering that would preserve the signal better??"

After much trial and error we found a way of removing the digital filter and incorporating a carefully designed analogue filter after the D to A conversion. Needless to say, this goes so completely against the grain of all current opinion because a lot of the spurious signals above 20kHz are still present in the output of the converter after the analogue filtering. The filter is a 3rd order design with a silver wired inductor and silver capacitors and is so designed to slowly attenuate the higher harmonics in a natural way, preserving as much of the musical waveform as possible, each filter is dynamically matched to within 0.5dB of its partner in the other channel across the full frequency spectrum, to achieve best possible channel balance.

Rather than use an off the shelf voltage regulator chip for the low voltage digital and analogue power supplies for the DAC we designed a unique discrete shunt regulator circuit, and use only the finest components throughout. In fact the DAC 5 power supplies take up more than 2/3rds of the substantial chassis. After the signal leaves the filter it is passed to a valve output stage, similar to that used in the M5 pre-amplifier, and is transformer coupled to the output, allowing both balanced and single-ended operation.

So how does the Direct Line DAC 5 converter with no digital filter and one-times oversampled D to A converter sound??
Let me first give you some background to what I believe matters in music reproduction and how I have arrived at the evaluation criteria we use at Audio Note.

It is no great secret that ever since Digital Audio was introduced in 1983, I have seriously questioned the validity of the claims that the technology would deliver the "Perfect Sound Forever" that launched the technology, I, and many others with me, found analog reproduction far more "real", satisfying and authentic, not to mention less fatiguing.

The main criterion I have always used when evaluating any hifi system or component is that when playing different pieces of software (whether LP or CD) the better system or component is the one that individualises the sound from each record the most, or in other words makes you sense each recording as a different and individual musical "event".

This evaluation system is based on a fundamental analysis of recording in all its forms that concludes that all we really know about recordings, is that they must sound different from each other, the conclusion is based on the indisputable fact that each piece of software was done at a different time in a different location, with different microphones, cables, mixers, tape recorders and they were recorded by different people to any other recording, furthermore the software was manufactured by different cutting and pressing machinery at different plants and as a result must have an individual character or "signature" uniquely its own.

I call this method of differentiation "Comparison by Contrast" and with this tool in hand (or should I say ear??) I have spent many years searching out the "better", more accurate (you will notice that the term used is more accurate, not accurate in its absolute sense, because total accuracy does not exist in recording or music reproduction, it is an unachievable goal, that will never be a reality, no matter how much the marketing men of the hifi industry would like you to believe it is) audio components and technologies in a largely selfish quest to improve the reproduction of my own record collection.

I made this pursuit my livelyhood in 1977, when I left my career as a broker with a large multinational shipping company.

Back to the main subject, by the criteria outlined above, CD fails miserably compared against even quite cheap analog component hifi, and I have always thought that this failing was inherent in the medium itself, i.e. the fact that the musical signal is broken down into little "bits", with poor resolution at low levels, which is after all the entrypoint of the musical signal (it is often forgotten that music starts from silence, not from somewhere up the amplitude scale, the assumption is often made that what we hear at the beginning of a note is what was recorded and the words "I hear more detail" assumes that we somehow know what is supposed to be there, which we certainly do not, what the reviewer should perhaps say is I hear more contrast!) it never seems to occur to anyone that the starting parts of the musical note might be missing.
The quiet background of the digital medium should therefore allow the best possible low level detail, but it does not, low level acoustic information like hall ambience is almost completely lost on most digital recordings (it is a little better on good analog recordings transferred to CD, indicating that the digital recording process is at least

No One or the DAC 5 D/A Converter.

partly to blame). modern recording techniques do not help, as multi miking, digital mixing and other technical gadgets used in the studio. "help" the recording engineers do their job speedily and within budget, a far cry from the simplicity, dedication and time that went into every recording made from the early acoustically recorded 78's to the earliest LP's) and this real acoustic information is replaced by a varyingly degree of hard and bright electronic echo, which makes most CD listening fatiguing, unless of course the system used tailors the high frequencies to suit, creating a "listenability" that comes at the price of severe loss of information at high frequencies, which may be preferable. but does nothing for the idea of a wide band system or signal, nor does it improve the listener's ability to distinguish between the great and the merely good performance or interpretation.

While I owned Audio Innovations (sold out 1991) I spent years in denial and despite all the arguments in favour of the commercial considerations of what my company required I heard nothing from CD that encouraged much enthusiasm and since I prize my longterm cred bility more than just making money and as long as my favourite music was available on LP either new or second hand. I had no need for CD until the early 1990's when a lot of interesting material (mainly historical piano recordings previously unavailable) suddenly appeared on CD-only releases.

I had already spent a lot of time looking at the subject of digital to analog conversion. without achieving any really substantial sonic improvements against the better converters already available. my approach was to conformist, as it turned out, as it accepted too much of the existing dogma and therefore too closely followed the already beaten track.

In 1990 I decided to test the use of an interface transformer between the converter chip and the analog filter, primarily in the belief that a better interface between the D-A converter chips output should yield sonic improvements but also because I felt that separating the digital and analog circuits ground planes ought to yield some improvements.

Early experiments showed promise. but the matching impedance and associated analogue filter configuration were more critical than first assumed, after two years later we finally got it right and Audio Note launched it's first digital product, the DAC3 D-to-A converter with patents awarded in the UK, the USA. Germany, Australia and elsewhere.

Since then we have progressed with greatly refined components quality (DAC3 Signature), even more high quality components plus a power supply with a valve rectifier (the DAC4), and finally the best output stage and ultimate component quality (the DAC4 Signature). and whilst all of these measures achieved even better sound quality than the original DAC3 offered. the improved versions did nothing to dent the original product's price/quality relationship to competing converters, after 6 years on the market it is no mean achievement for a digital product to stay at the top of the performance spectrum in its price range in a market where model life generally is measured in months rather than years.
The more I studied the fundamental equations that all digital theory is based on, the more convinced I became that the sinc functions used in the digital filtering must have a far more damaging effect on the signal, than is generally accepted (or even considered).

The basis for my idea is that there has to be a price to pay in all attempts to improve, "correct" or manipulate the signal, regardless whether it is done in the digital or the analog domain. and I have always thought that the digital filters with their oversampling, reclocking. noise shaping, jitter reduction and whatever else are no different in their fundamental properties to the corrective feedback systems employed in the analog domain. in that they also try to "stop" or reverse time. so their deteriorating effect on the sound must be similar.

In early 1995 work started on the no digital filter - 1 x oversampling D to A converter and when Andy Grove joined me in 1996. his contribution to the idea was a first prototype within weeks of joining, a great credit to his talent and ability.

Although the first version had a fair bit of the sampling frequency breaking through, even with this interference it was obvious to everyone that the sound had something fundamentally "right", it was freer, had more presence, immediacy. delicacy and contrast than any digital product I had ever heard. there was obviously more good information in the digital data stream than previously thought, and it was clear that this converter had very serious sonic potential, so we persevered getting the interface transformer and filtering right, and here we are. nearly three years later introducing the finished product. the DAC5 Direct Line D/A Processor with 1 x oversampling and no digital filtering, reclocking, noise shaping. jitter reduction or other such signal correction or manupulation.

Having listened to the final version of the DAC5 with its no-oversampling D to A conversion for nearly a year, I can say for the first time since my earliest experience with digital audio in late 1983 that digital has more to offer than I had ever imagined. because for the first time there is genuine contrasting quality between recordings with the DAC5, a fact which combined with an incredible sense of hall ambience, where instruments have greater presence, solidity and texture and a far more defined spatial position (provided this is what how it was recorded). An orchestra now has an organic quality where the musicians appear more like real people actually playing in real space, rather than as cardboard images in a sound deadened studio. the reproduction of stringed instruments has the sound and feel of real wood rather than the usual artificial and plasticky presentation of digital.

It may sound absurd, but the greatest beneficiaries of this vast improvement in the sound of my CD's are my big collection of historical recordings of piano music, the distinct differences in style, touch, tempo. tone and sound of each of the great pianists from Sergei Rachmaninov to Joseph Lhevinne, and from Simon Barere to David Saperton is a true revelation, which has greatly contributed to my appreciation of the interpretative skill, dedication and pure musicianship of these great artists.

When all is said and done. however and despite the DAC 5's great and almost analog qualities I still find my AN-TT Three Reference turntable with AN-1s/AN-Vz arm and IoGold cartridge excels with the best recordings. but at least now it is a contest between the two formats rather than a race between a Ferrari and a man wearing a pair of worn shoes!

The DAC 5 uses the Analog Devices AD1862NJ chip with as little in the signal path between it and the input chip as possible, the analog filtering has been done in such a way that the carrier frequency is inaudible, although it will show up on the oscilloscope in abundance (another example of the hard to grash reality of measuring and its correlation to sonic reality)! We have experimented extensively with different filter configurations to find the one that passes an amount of breakthrough that does not disturb the ear without affecting the quality of sound more than necessary.

The DAC 5 has facility for 96KHz DVD technology, as well as the conventional 44.1 and 48KHz. it has high B C-core output transformers, with a 600Ohm balanced output using a professional Lemo connector (we can provide the silver cables with the Lemo plug for this) as well as a standard unbalanced RCA output.

There will be no patent applications or copy rights filed on this revolutionary idea. because that would limit its wider use by other manufacturers, to the detriment of the reproduction of music, instead we are offering a small technical paper on the technology to anyone who wants to test the idea, and this includes any of our competitors, all we ask is that you remember who thought of it first.

The DAC 5 is not cheap at £ 18,500.00. its component. power supply and transformer quality is far too expensive and elaborate for that. but go and give it a listen anyway. even if it is out of your price range, because the improvement it represents is nothing short of a digital revolution and you can rest assured that we shall move this advance in technology down in price as quickly as possible, so after 6 years most of our DAC-range (from the DAC3 upwards) will be upgraded to 1 x oversampling and 96KHz technology. to take us through at least another 6 years. which is in line with our stated aim to do our homework thoroughly and properly and only release products that have longevity built in.

Peter Qvortrup
01.09.1998.

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ly to optimise phase coherence between the HM100ZO and HD3P when they are set into routed grooves (3mm deep for the HD3P and 5mm deep for the HM100ZO). The revised crossover is shown with the 4.7uF Solen in the HD3P crossover board reduced to 3.3uF. The 0.22mH low-pass inductor (L3) is reduced to 0.15mH and a damping resistor of 2.2ohms is placed in series with high-pass shunt capacitor C2. This small adjustment makes little difference to sound quality quite frankly, but we measure phase - a critical parameter - to high resolution using an FFT and never pass up an opportunity to tighten it up as far as possible. Whilst one little improvement may not make much difference, many improvements can accumulate to yield an audibly better result, so we decided not to let this opportunity pass us by.

CONCLUSION

With this project we have covered all essential design information, but have not provided much in the way of mechanical build information such as crossover wiring, component positioning in the cabinet and such like. We have assumed a level of knowledge capable of answering such questions. We prefer to build hard-wired crossovers (no printed circuit boards) in plastic boxes that lie on the floor outside the cabinet. Alternatively, you can fix this box to the rear wall of the cabinet externally - possibly the most convenient arrangement - or place it internally as in commercial loudspeakers. KLS11 is an advanced design for constructors with some experience. With a little enthusiastic woodwork and tweaking it will provide superb sound quality.

MEASURED PERFORMANCE

The frequency response of this loudspeaker is shown in Fig 4, measured using pink noise and third-octave analysis. It runs from 50Hz up to 20kHz within +/-3dB limits. The response holds over a good vertical range but not above the tweeter's axis. The ideal listening position is on the axis of the midrange unit.

Sensitivity is a respectable 88dB of sound pressure level for one nominal watt (2.84V) of input. Since overall impedance, measured using pink noise, was 9.5ohms, in truth the loudspeaker draws a bit less than a true watt for this output. With three drive units and high sensitivity, KLS11 will go loud even with low-power amplifiers (40watts' output or thereabouts) and will accept the full output of high-power amplifiers, going very loud. That said, it is not a party machine and 100watts per channel will be more than enough.

Like most of our loudspeakers we engineer for high sensitivity. This equates to high quality in the motors of the drivers plus lightweight cones. Audax drive units will accept a lot of power but power-handling capacity is no arbiter of quality in loudspeakers. in fact, it's the reverse in some ways - the less (true) power a loudspeaker needs to go loud, the more efficient it is and this correlates well with good sound quality. This can depend on cone material - thin, untreated pulp cones are efficient but sound awful.

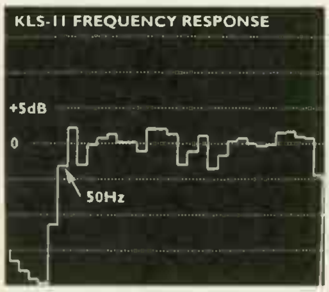

Fig 4 - The frequency response of KLS11 extends from 50Hz to 20kHz within +/-3dB.

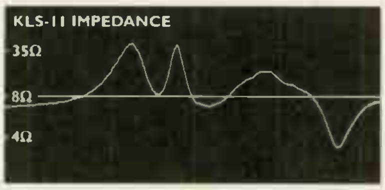

Fig 5 - Impedance was set to around 8ohms and measured out at 9.5ohms overall on a pink noise measurement signal.

KLS11 PARTS LIST (per loudspeaker)

Drivers

Bass

Audax PR240ZO 240mm (10in.) High Definition Aerogel cone, cast chassis bass unit

Midrange

Audax HM100ZO 100mm (4in.) High Definition Aerogel cone, cast chassis

Treble

Audax HD3P piezo-electric, gold-dome tweeter

Crossover for flush drivers only

L1	2.75mH, 0.2Ω DCR, 1.25mm wire ferrite cored
L2	2.5mH, 0.2Ω DCR, 1.25mm wire ferrite cored
L3	0.15mH, 0.11Ω DCR, 1mm wire ferrite core
C1	33μF, Alcap (100V)
C2	4.7μF, Solen (400V)
C3	12μF Solen (400V)
R1	4.7Ω resistor, 9W
R2	3.3Ω resistor, 5W
R3	2.2Ω resistor, 5W

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SUPERIOR SUPPLY DECOUPLING

Guido Tent, EMC engineer with Philips Semiconductors at Eindhoven, explains how to reduce digital circuitry's Radio-Frequency emissions and their affects on hi-fi equipment.

As I am still an enthusiastic valve audio designer, I was happily surprised to read Jon Marks' article in July 1998. He describes how Radio-Frequency Interference (or RF emission) can influence hi-fi equipment's sound, and how screening can affect this RFI. However, screening is only one strategy in the battle against RFI. In this article I would like to point out some other issues that need attention when designing for low RFI.

For the moment I will restrict my comments to the most important aspects of circuit and PCB layout. However I would like to mention some 'obvious' aspects first:

1) Never use a higher bandwidth than strictly necessary. Whenever possible reduce currents and their frequency content (by adding local low-pass filtering).

2) Keep loops as small as possible.

3) Consider that attached wires like mains, antenna, loudspeaker and S/PDIF create the biggest loops and need little current to emit heavily.

4) If available, choose suface-mount components for ICs.

BASIC DECOUPLING

Now let's look at supply decoupling. In figure 1, a sub-circuit consisting of two ICs is depicted. Their respective decoupling capacitors are placed close by, as we learned from most textbooks. In figure 2 the RF equivalent circuit is given.

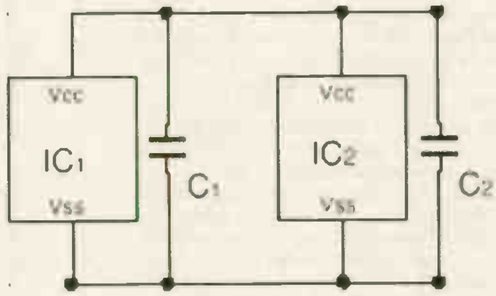

Figure 1: Regular supply decoupling.

The traces interconnecting the supply and reference of the ICs are replaced by inductances. These are weakly coupled as they might be on a double-layer board with a ground plane (coupling about 0.8). As such both fluxes compensate partly. Due to this, an average inductance of 2nH per cm (sorry, no inches here) can be assigned to the traces. As an example, average values are given in the figure. Normal DIL packages lead to such values.

Now we can distinguish two current loops. The smallest, with C1 inside, is intended to short the RF current of IC1. The bigger is hidden, and seldom considered. The supply lines and the capacitor C2, assigned to IC2, create this loop.

The impedances jwL and 1/(jwC) will be complex conjugate for a certain frequency f. With L=44nH and C=100nF we find f=2.4MHz. At this frequency the supply loop will resonate. As there are no or very small resistive elements in the LC network, a quality-factor of 100 can be expected. As such resonant currents 100 times bigger than generated inside the IC supply will result. These currents do run in bigger loops than intended! In an average application up to 10 ICs might be present. This might end in up to 100 loops, as all ICs have their own decoupling capacitor. All those loops will resonate at different frequencies over a huge range. These resonance frequencies are defined by the physical structure of the PCB, and as such will all differ.

The given frequencies are no exceptions. In a multi-bit D/A convertor clocked at 11.2896MHz, a spectrum starting at a few hundred kHz up to at least 200MHz can be found. Single-bit convertors are even worse as they operate at higher internal clock frequencies.

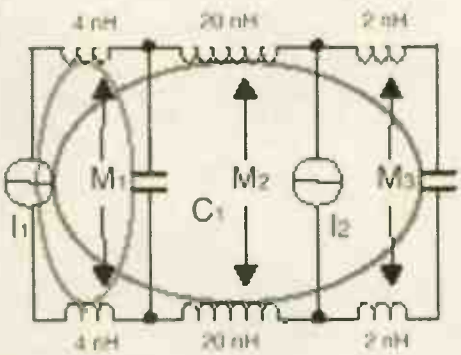

Figure 2: Equivalent RF-circuit.

BETTER DECOUPLING

Figure 3 shows a suggestion to improve decoupling. At first inductances L1 and L2 (>1uH) are placed in every supply line of the digital ICs before they are connected to the power supply line(s). As such the impedance towards the supply is dominated by L. The chance of a resonance still appears, but the frequency will be far lower than the aforementioned 2.4MHz. As long as we use RF chokes as inductances, no damping of the circuit appears.

When lossy ferrite beads are applied, some damping is added as well. This can be seen when we consider the equivalent circuit of a bead, given in figure 4. Ferrite

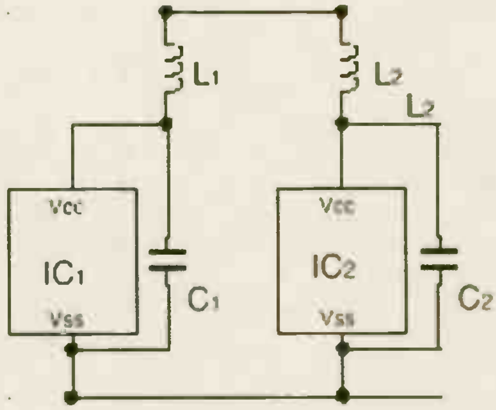

Figure 3: Improved supply decoupling.

has dissipative properties, represented by a resistor R. As such the Q of the decoupling circuit lowers significantly; resonances are well damped. For DC the bead behaves as a straight wire, so no voltage drop appears in the supply line. However, when the circuit consumes only a few mA, a resistor can be applied as well, as this only gives a small voltage drop. A minimum value of 100ohms is advisable.

Suitable beads are available from Philips, Murata and many others. Data books in general clearly state the properties like impedance versus frequency and maximum DC current. Again a minimum impedance of 100ohms at 100MHz can be taken as a rule of thumb. The final choice mainly depends on the frequencies that appear in your circuit. Consider a resistance 20 times the highest clock frequency as a minimum value.

The inductances should be placed nearby the IC, but their routing is far less critical than the decoupling capacitor placement and routing, as pointed out below.

DECOUPLING CAPACITOR ROUTING

The usual way capacitors C are connected to the reference is illustrated in figure 1. Usually when a ground plane is available they are connected by placement only; the ground is everywhere you might say.

Minimising the loop area is most important, but another aspect needs to be taken into account. As can be seen in figure 2, inductances have to be assigned to the ground plane. As the decoupling currents run through these inductances, they generate RF voltages - U=L(dI/dt) - across the plane. These will appear in series with the functional signals crossing this part of the plane. This means functional disturbance might appear on the PCB.

As a direct consequence the RF emission of the whole PCB increases as well as the RF voltage driving the attached cables.

THE BETTER WAY

The solution is in the connection and routing of the capacitor. The safest way is to place every decoupling capacitor as close as possible to the Vss (ground) pin(s) of the IC(s). As such only the smallest part of the ground plane will carry the decoupling current. Care should then be taken with respect to the routing of this capacitor to the Vcc (power) pin of the IC. Figure 5 shows how to do that in an effective manner.

As an illustration, the layout of silicon chips (die, bondwires and leadframe) has been shown in grey. This route as shown can be considered the optimum, the current describing the smallest loop.

When we add the third dimension, height, it becomes clear why an IC socket is not favourable - the loop height will increase, and as such its area.

MORE SUPPLY PINS

If an IC has more supply pins, every pin should be connected following the same strategy.

MORE GROUND PINS

If an IC has more then one ground pin, for example an analogue and a digital ground, all of them should be connected directly to the first ground layer on the PCB.

ON-CHIP DECOUPLING

Some latest-generation ICs have a decoupling capacitor integrated on their silicon. In this case no external capacitors should be used. As the external capacitor has lower impedance, the current again will run in the external capacitor loop. The supply pin(s) of ICs with on-chip decoupling capacitors should be connected directly with a ferrite bead. As such the decoupling strategy does not change although the position of the capacitor does.

DECOUPLING CAPACITOR QUALITY

Very often two capacitors are connected in parallel; 100nF ceramic and 4.7uF electrolytic, for example. This habit has an historic origin. In the early years electrolytics had poor RF characteristics and a smaller ceramic or foil cap, with good RF behaviour, was placed in parallel. Figure 6 shows the equivalent of an electrolytic.

Modern electrolytics are far better RF performers. Their construction is such that the series inductance is very low (both films are terminated at the same side). They have very low impedance over up to four decades in frequency, enough to say goodbye to the additional ceramic capacitor. It saves money and space as well and eliminates the risk of yet another resonance.

When selecting an electrolytic, the series inductance relative to the inductance of the total supply loop the cap is in needs to be taken into account. In figure 6 this loop can be seen. The total inductance of the supply loop (for a DIL28 package for example) is about 12nH. The ESL of the capacitor is relatively small compared to this value; it does not make sense to look for 2nH as

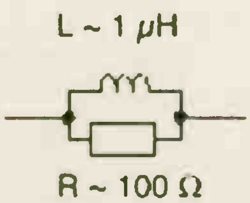

Figure 4: Typical RF-equivalent of lossy ferrite bead.

the loop itself dominates!

I have had good experience with electrolytics of Philips' series 179, Os-Con SC/SA series and Black Gate FK types, but many other electrolytics might meet your requirements as well.

OTHER CURRENT LOOPS

Until now we have only considered supply loops. As ICs need to interface, more loops appear once we interconnect ICs. As some I/O buffers or 'ordinary' inverters can drive up to tenths of a mA and we only need a few to drive the next stage, a series resistor in the output is often added. Values of 47ohms (or even more if functionally acceptable) are applicable.

Care should be taken that the minimum required signal-slope be retained (as is necessary for example to maintain jitter specifications and/or susceptibility levels). Signal slope is the ratio of rise of voltage versus time needed. For example, 0V to 5V in 5ns gives 1V/ns. An induced voltage of 1mV then gives 1ps jitter. The higher the slope, the smaller the chance on induced jitter, but the higher the peak currents. A trade-off needs to be found.

If we add series resistors, a circuit similar to the one illustrated in figure 7 appears. As an example two ICs are taken. In series with their inputs and outputs resistors are inserted. Now restricted areas around each IC appear. I call these 'impedance zones' as they are only crossed by impedances (>100ohms). The only direct interconnect is via the ground-plane. As Kirchoff's law (sum of currents in and out of an IC is zero) still applies, we have full control over the RF current through the ground connection(s) of the IC. (One exception here, which has to do with parasitic current, will be described later).

COMPONENT PLACEMENT

Most circuits consist of a bunch of components. They are drawn as such, but it is not wise to put them on the PCB the same way. As an example take a digital-to-analogue convertor (DAC). This is a project that I am privately involved in; it's a three-year development already, with three friends.

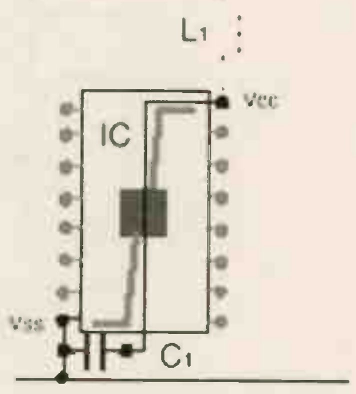

Figure 5: Proper way to r oute the decoupling capacitor.

A DAC typically consists of an input receiver (IR) to recover clock and data, and a digital filter (DF) to achieve filtering in the digital domain. Furthermore there are two digital to analogue convertor chips (DACs) that finally create an analogue signal out of the digital. Analogue low-pass filtering (LPF) follows. The analogue output stage consists of a simple anode-follower tube, but is not considered here.

After extensive listening tests and measurements we found that the jitter of the recovered clock signal (from the input receiver) as well as the jitter at the outputs of the digital input receiver did not meet our requirements. As a result, we added a phase-locked loop (PLL) controlling a voltage-controlled crystal oscillator (VCXO). On top of that we added re-clocking of all signals that enter the DA chips, in order to remove the internally-generated jitter of the digital filter. The phase comparator (PC) is built from discrete logic, as we did not find comparators good enough.

The PCB is separated into two areas: digital and analogue. The analogue part consists of the PLL loop filter (LPF) and gain element (GAIN) and the input (control) terminal of the VCXO. Therefore the VCXO is placed so that it crosses the border. The same holds for the LPF filter, filtering the output of the phase comparator; it has a digital input and an analogue output. The rest of the circuit covers the digital part.

The Burr-Brown PCM63 D-to-A - chip's silicon is well laid out. After examining the pins and their functions, a straight line could be drawn through the chip, separating analogue from digital. Luckily the supply is separated as well.

The placement of these chips becomes obvious and unique, as shown in figure 8. The route the signal takes dictates the placement of all other chips. The phase comparator is planted in a corner, as it is a circuit with a lot of logic (six ICs). If it were in the middle their voltage build-up in the ground plane could disturb others more. Finally all signals crossing from analogue to digital (drawn in grey) do so with a series impedance of 100ohms or more.

LAYERS

With modern clock speeds at least a double-layer board should be used in order to meet European emission limits and to maintain signal integrity. We can assign one of these layers as a ground plane. This layer will be the closest to the ICs (component side) and act as an electrical screen as well. For high frequencies (practice shows >200MHz) the die of the IC starts acting as an electrical monopole. Reduction of this type of emission was shown to be useful

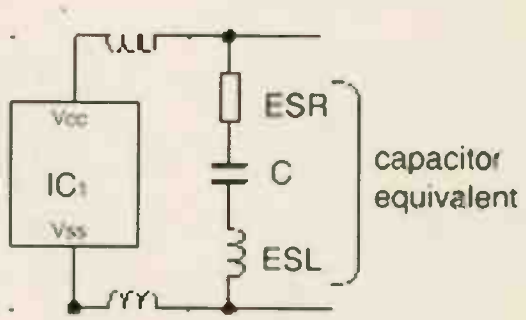

Figure 6: Decoupling capacitor equivalent circuit.

in Jon Marks' article.

With the described decoupling philosophy, signals interacting between ICs will always run through the ground plane, regardless of the transaction (high to low or low to high), as the supply lines are transparent for RF currents. Seeing as this is the case, neat transmission lines can be made between the ground and the signal. Due to the use of series resistors and inductances, lots of bridges appear, effectively reducing the number of vias (a via interconnects signals from different layers) usually necessary.

Supply lines can be routed last. Inductances have been added so the RF current through these lines is heavily reduced; their routing has become non-critical as they only carry DC. Never use a power plane. It is not necessary as DC supply currents only need small traces. A power plane may start to resonate with the ground plane and as such act as a dipole antenna!

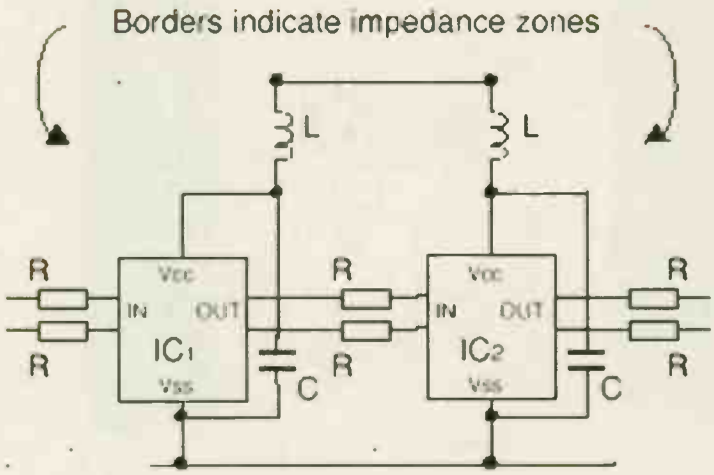

Figure 7: ICs interfacing.

KEEP THE GROUND PLANE CLOSED

One final word to finish. Very often the ground plane is intersected by a slit between the analogue and digital part of the PCB. The two planes are then connected beneath the A/D or D/A convertor chip or, even worse, at the supply lines' entry to the PCB. With the planes separated, signal currents that cross the intersection are forced to return via the ground plane and as such need to describe a huge loop around the intersection. This leads to high emission and a greater chance of inter-system pollution.

Recently a friend followed the measures described in this article on a commercially-available A/D convertor from a well-known manufacturer. The improvements resulted in a decrease in emissions of over 30dB! By taking appropriate measures we can fully control amplitude, frequency content and domain of the currents on the PCB. These currents through the plane are known and will not interfere. We can now keep the plane closed and profit from all the advantages this brings.

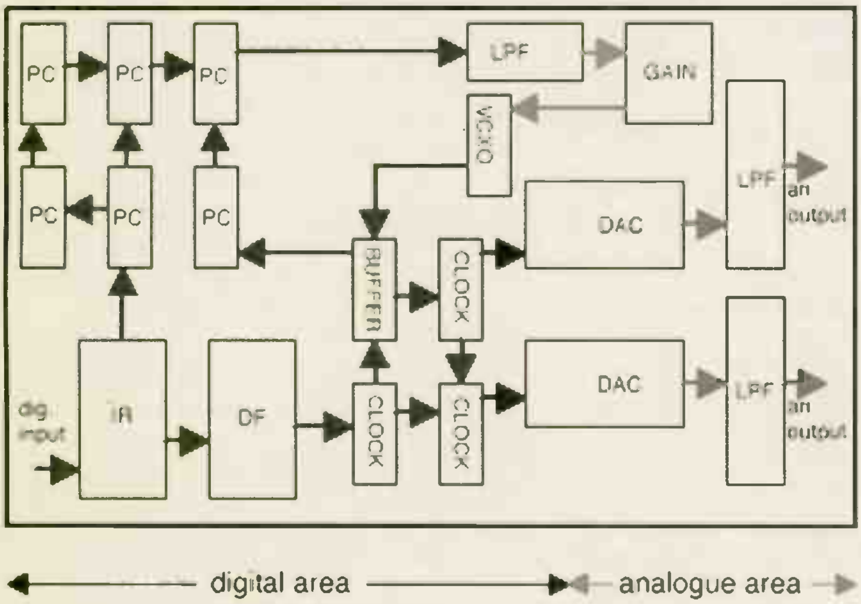

Figure 8: PCB floorplan of digital-to-analogue convertor PCB.

THE LINK TO TUBE AMPLIFIERS

The philosophy described above can be applied to tube amps as well. Replace ICs with gain stages (a triode for example), ferrite beads could be read as filter chokes or resistors (1kohm for instance) and the local decoupling capacitor is present as the high-voltage decoupling capacitor already in use. Series resistance in signal lines is often present as the output impedance of gain stages is in the range of a few kilohms. This means the reference or ground of the circuit carries only DC.

The loop of rectifier and first capacitor carries higher (100Hz) currents though. The ground path of this loop will never be part of the ground plane, as can be seen in commercial amplifiers! That ground wiring should not be shared; the ground should be taken from the negative pole of the last supply capacitor (eg, the output of a pi-filter) and fed into the circuit, starting with the output stage.

Guido Tent has generously offered to help readers with further enquiries. He can be reached on e-mail at:
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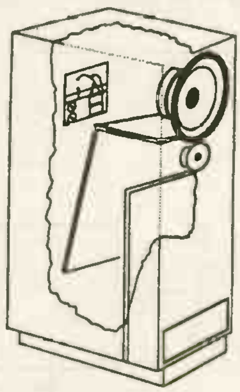

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"POT" IS FOR POTENTIAL

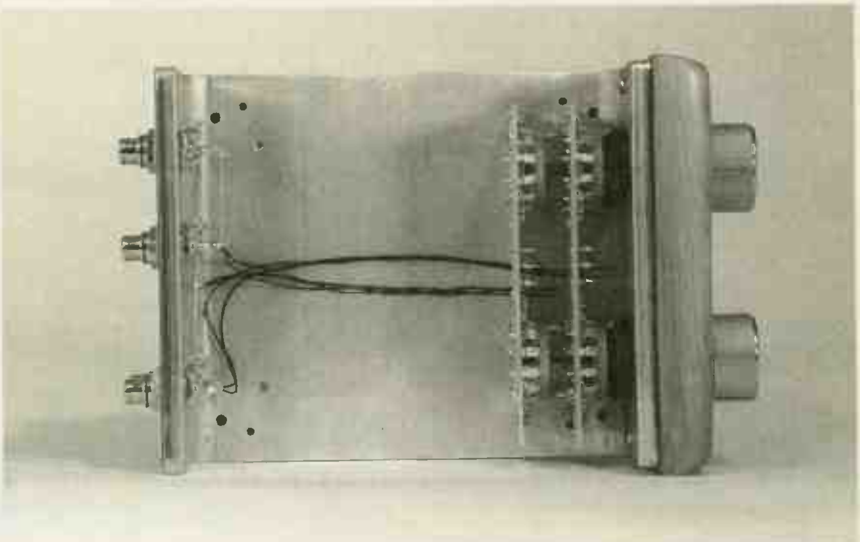
Jon Marks comes over all passive with Rothwell Electronics' DIY stepped attenuator.

What's in a passive pot? Well, the common or garden variety consists of plenty of air inside a case only otherwise populated by a source switch and the all-important volume potentiometer. Differing slightly from the norm is Creek's OBH-12, where the above are joined by remote control of volume and source selection. But if you want to venture away from the standard, infinitely variable devices with their carbon tracks and oft-associated channel matching problems, you need to turn to a stepped attenuator. Trouble is, when it comes to DIY and you don't fancy building your own design from scratch, where do you start?

One company offering a solution is Rothwell Electronics (tel: 01204 654 614). Unlike some of the more esoteric home-build attenuators (such as those from Audio Synthesis) Rothwell's is constructed around inexpensive switches and 1% metal-film resistors. While the four wafers onto which the resistors are soldered may be limited to 12 positions each, a combination of coarse and fine controls gives a total of no less than 132 steps.

Tying the left and right pairs of wafers together are two PCBs and it is these which unfortunately restrict the number of amps to which the Rothwell can be directly fitted. Unlike most controls, the Rothwell uses two knobs side by side, which makes squeezing it onto the front panel of most would-be tweak subjects nigh on impossible. Therefore our review sample was installed in a solid aluminium and steel case (which provides screening to reduce hum pick-up). Creek's OBH-12 was wheeled in as a benchmark in a system where the source was a modified Pioneer DV-505 DVD player and power amplification Musical Fidelity's cylindrical X-A200 monoblocs. Magneplanar SMGa panels did loudspeaker duty.

Slotting the Creek into a position usually occupied by a battery-powered DPA 50S I discoverd a softer, more rounded sound which was generally smoother and slower. There was that familiar slightly loose bass accompanying the attractively glare-free treble and midrange. CDs such as Tori Amos' Boys For Pele and Jimi Hendrix's re-mastered Electric Ladyland remained enjoyable and involving; they just gave the impression that a veil had been laid over the music.



Inside the metal case housing the review sample are the four wafers and two PCBs which form the Rothwell kit.

When the Rothwell was inserted into the circuit that veil was lifted. It might not have had the clarity of the DPA, but then the 50S's pot on its own costs two or three times as much as the Rothwell kit's £79 (fully assembled). The benefits of the tight channel-matching and discrete resistors were much more sharply focused imaging (especially on dense mixes like 'Yoga' from Bjork's Homogenic album) and abundant extra detail and control. This was most obvious in the lower octaves, where the wooliness of the OBH-12 was replaced by a taut, punchy drive that speeded up the bass-heavy tracks on the Drum 'n' Bass fest of Asian Dub Foundation's Rafi's Revenge.

One small fly in the ointment affected the treble. Although the OBH-12 has a touch of sibilance compared with the Rothwell, its overall tonal balance is very even. The Rothwell, on the other hand, has a slight brightness in the upper registers which is not down just to superior resolution. Budget metal-films have a reputation for being a bit 'enthusiastic' at the top-end, and so it was here, although a warmish cable like The Chord Company's Chrysalis nudged the Rothwell back on course.

If you can give the Rothwell a comfortable home in a metal case it makes a lot of sense as a passive pot. As was the case with the basic 12-step version we featured in December 1998's supplement, it has a crisp bass, imaging precision and soundstage spaciousness which the majority of carbon-track pots can't match●

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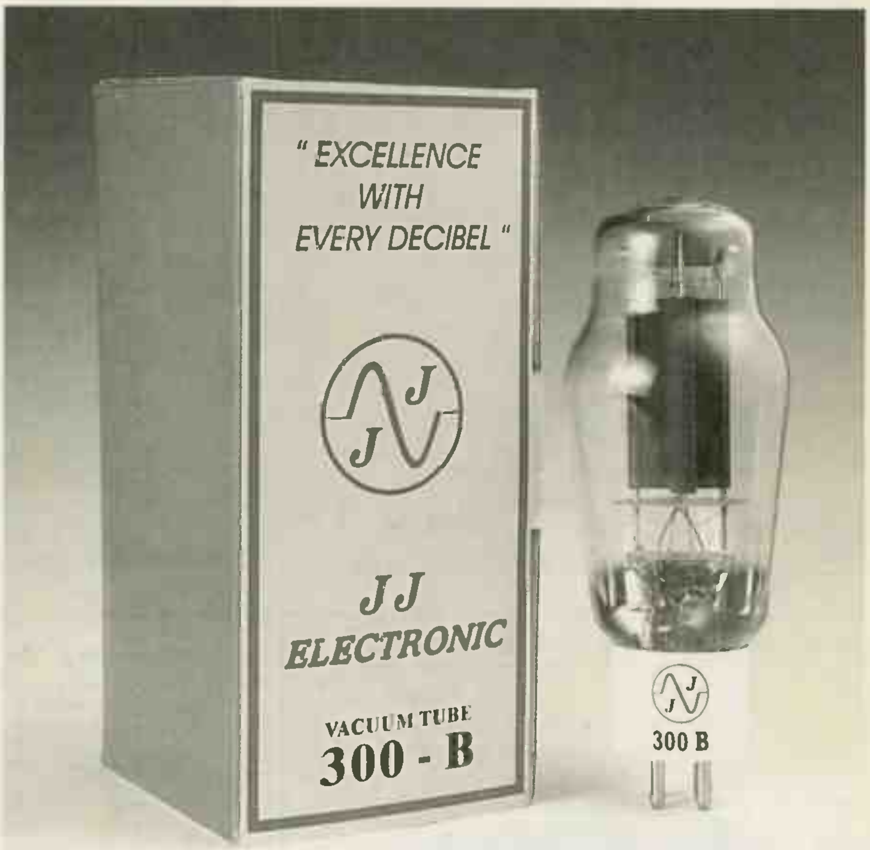
TAKING THE TUBE

Jon Marks auditions two flavours of the world-famous 300B from Tesla and Valve Art.

As DIYers who have been stricken with chronic tweaking addiction will know, every component soldered into a piece of equipment has its own characteristic sound. This goes beyond passive parts such as resistors, capacitors and volume potentiometers, extending to active ones too - yes, even valves and transistors possess sonic signatures.

Solid-state designers searching for a clean, fast presentation often look to trannies built for use in video systems because of their massive bandwidths. Their thermionic counterparts frequently opt for the 300B power triode, one of the most linear amplifying devices ever created, whether the topology is single-ended or push-pull. The question is, whose 300B should you invest in (these valves don't grow on trees, you might say!) This month, we've lined up 300Bs from Chinese manufacturer Valve Art and Tesla of the Slovak Republic.



Both sets of tubes were plugged into our own World Audio 300B push-pull amplifier partnered with a Canary 601 Mk2 pre-amp. Loudspeakers were our KLS9s, the source a Teac P-30 and Pink Triangle Da Capo DAC with 24-20 filter.

The Valve Art 300Bs have been resident in the listening room for a while now, during which time all at HFW have become accustomed to their sound.

Compared to solid-state amplification, these 300Bs offer a much smoother, more natural sound. The harmonics of string instruments are also a lot more realistic.

Soundstaging and vocals are two more 300B strengths, the Chinese bottles managing a life-like acoustic and singing devoid of the hardness which afflicts most transistorised amps.

The VA300Bs aren't perfect, however. They can be rather microphonic and their tonal balance isn't the most even - bass is slightly loose and emphasised and the treble isn't the purest around; it can be bright, too.

Switching to the Tesla 300Bs, I was in for quite a shock. Tonally, these takes on the classic were far better balanced tonally - the upper registers were cleaner and less 'fizzy'. Bass was faster and meatier as well, Heaven 17's Penthouse And Pavement gaining in speed and impact.

If you hanker for image precision and soundstaging of the 'warehouse' variety, the Teslas are well worth consideration. With Opus 3's Opera Pearls HDCD compilation running through them, they filled the room with the orchestra and performers.

Microphony is less of a problem with the Teslas than many large power valves. One thing you immediately notice about them when you heft a set is the fact that their glass envelopes are thicker than most. Give them a tap and you'll find they ring less as a result.

Of the two 300Bs, the Tesla is superior all-round to the Valve Art. Price-wise, there isn't that much between them - the going-rate for two VA 300Bs is about £130; Watford Valves (tel: 01923 893270) are hoping to offer the Tesla 300Bs at a similar price, although a final figure has yet to be confirmed●

In June's Supplement, we will be reviewing 300BS from Western Electric and Svetlana.

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VACUUM STATE ELECTRONICS

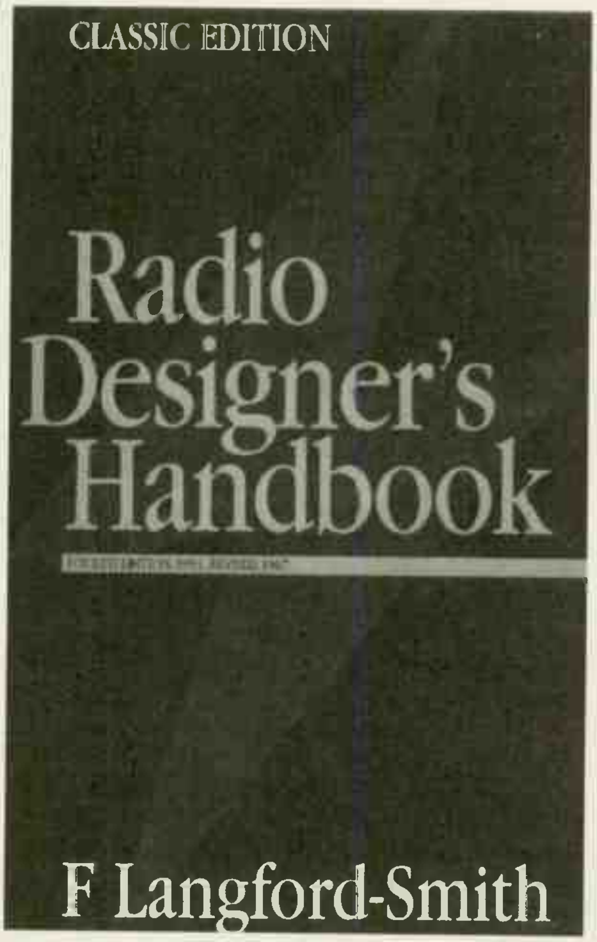
RADIO DESIGNER'S HANDBOOK, FOURTH EDITION

By Fritz Langford-Smith

Reviewed by Noel Keywood.

The Radio Designer's Handbook has almost legendary status as a definitive guide to valve amplifier engineering. It has been out of print for a long time now, so until this new reprinting by Newnes (Butterworth-Heinemann), copies could only be found second-hand at bookshops and audio fairs; prices ranged from £15-£30, according to condition. We have two copies and I considered reprinting the book myself because of demand and because of its excellence. But at 1500 pages, forming a tome 7cms. thick, it was going to be costly and with an order quantity of 200, a substantial retail price of £50 would have barely justified costs: we dropped the idea.

At £35 in hardback form from Newnes, this reprint is a bargain. That Newnes had the book reprinted and bound in India doubtless helps, since we had difficulty finding UK binders even prepared to quote for such a thick book.



First published in 1934 by "the Wireless Press for Amalgamated Wireless Valve Company Pty" (it says in my 1960 fifth impression) of 47 York Street, Sydney, the Radio Designer's Handbook enjoyed success in its earlier incarnations it seems. Of the fourth impression "over 280000 have been sold around the world" we are told by editor F. Langford-Smith. As well as contributing to the book, he commissioned and checked the works of many other expert authors to produce, in his own words, "a comprehensive and self-explanatory reference handbook for all those with an interest in radio receivers and audio amplifiers".

My fascination with the book is that it seems to have at least a small chapter or two on absolutely every theory, phenomenon or technique ever used in this field. It says more about audio transformer design than I have encountered elsewhere and there are chapters on inductors, inductance, transformers and calculations about same.

Inductors have always been a difficult subject and, whilst there is plenty of theory to be found, most wound components do not work as intended unless they are built properly. This is a mechanical process, taking into account the core used, the spacing, aspect ratio and disposition of the windings and sections used, plus various other factors. Practical matters such as this are difficult to cope with nowadays because much of the information is being lost as such skills are becoming progressively less important and published information is going out of print. That is why the reprinting of a reference work like this is quite important.

Of course, if you want to design a valve amplifier then this is the premiere reference book - there is little missing and few additions one could wish for. Again, on top of all the equations and graphs needed to establish working points, there is plenty of practical advice such as screening techniques, how to avoid inductive hum pick-up, the problems and their solutions in DC heaters, hum buckers and a whole variety of other arcane facts.

Budding designers will doubtless be interested in discussions of various famous circuit topologies, such as the McIntosh and Quad output stages, with a circuit of the McIntosh included.

The radio side of things includes FM techniques, communications receivers, detectors and RF theory, including aerials. Again, this is comprehensive, although perhaps this side of the book has less application nowadays with digital radio arriving.

There is plenty of power-supply theory, including obscurities like choke-input PSUs. If ever you come across a reference to a forgotten design technique, this book is likely to have something on it, plus references to research papers. Trouble is, most are very old and not easily obtained these days. The interest in audio is emphasised by chapters on reproduction from records (LPs), microphones and loudspeakers.

With 38 chapters in all there is so much in this book it would be difficult to read it cover to cover. The authors include lots of design equations and there are chapters on algebra, vectors, the Fourier Transform and various other technical data. In times before computers, graphs and charts were used to derive useful design data and there are plenty of these in the Radio Designer's Handbook. At this level it is a practical and down-to-earth design manual, albeit for those with some mathematical ability and technical knowledge. With so much valuable basic theory, this is a great book to have in any design lab, and it is obligatory for those wanting to understand valve amplifiers●

RADIO DESIGNER'S HANDBOOK 4TH ED. BY FRITZ LANGFORD-SMITH

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DIY Letters

IN AND ON RESPONSE

I was pleased to see you have once again used the Audax HM100ZO in your KLS11 loudspeaker. I designed and constructed my own three-way floorstander using this superb driver at about the same time as you introduced it in the KLS6, so I was very interested to see it employed in your latest offering.

I am intrigued by the way you have applied the acoustic design and the crossover. I use a design package called Speaker Pro 6.0 by CS Software and home-made test equipment to measure results. I have always found measured results broadly agree with the programme's predictions and require only minor fine tuning to get the best results.

A minor discussion point is the KLS11 midrange chamber. You say the critical chamber volume is 3 to 5litres. According to my programme the optimum volume is 2.07litres. This gives a small 1dB peak before roll-off at 250Hz. Using a 5litre chamber has no effect above your roll-off at 800Hz, so I assume you are only employing this volume to utilise the full chamber length and thus reduce rear reflections.

My design uses a 164mm-deep damped enclosure. The damping material is a special laminated foam used in professional acoustic engineering. The side and rear walls have a laminate construction with 4mm cell-foam backing, 1mm perforated bituminous layer and 15mm graduated-density, open-cell foam. This has a flat profile rather than the usual egg-carton one. The top and bottom use 5mm open-cell foam.

I arrived at this chamber size and damping material after many hours of listening to experiments with sealed chambers and open-back (as per KLS6), long-haired wool, carpet felt, Deflex, etc. What I found confirms your recommendations not to overstuff and to leave the chamber closest to the driver open. That's why I chose to line the internal walls only and not use wool as damping material. Another reason I opted for acoustic foam was that it enabled the side walls to be profiled in a 10in. taper and a full-radius curve around the rear wall to help reduce standing waves.

Audax's driver parameters (like those of the HM100ZO above) can sometimes change without notice.

The main point of this correspondence is that I cannot get your crossover to work in theory. I entered your crossover and the Audax Thiele-Small parameters into the Speaker Pro. The 12uF capacitor gives a huge 10dB drop-off slope from 6kHz down to 500Hz. Change to 25uF and it's flat. Also a 0.33mH series inductor gives a flatter top end that yields a -3dB point at 6kHz.

If I had the parts I would be seriously tempted to rewire my 'speakers and take a measurement. I am not saying computer design packages are perfect but I have never known my programme to be so far out. Am I missing something?

Mike Barr
mike_barr@thermoking.com

The electrical response does not reflect the loudspeaker's acoustic response. The latter can only be assessed by acoustic measurement using a highly-accurate microphone. We use a Bruel & Kjaer, which validates the measuring mic used by our designer, who relies on a LEAP measurement system.

Be aware that Audax's published Thiele-Small parameters are often out of date and incorrect as a result. In our experience, Audax have sometimes changed driver parameters without posting up the new data. We measure these parameters rather than designing from Audax's information. NK

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REGULATORY BODY

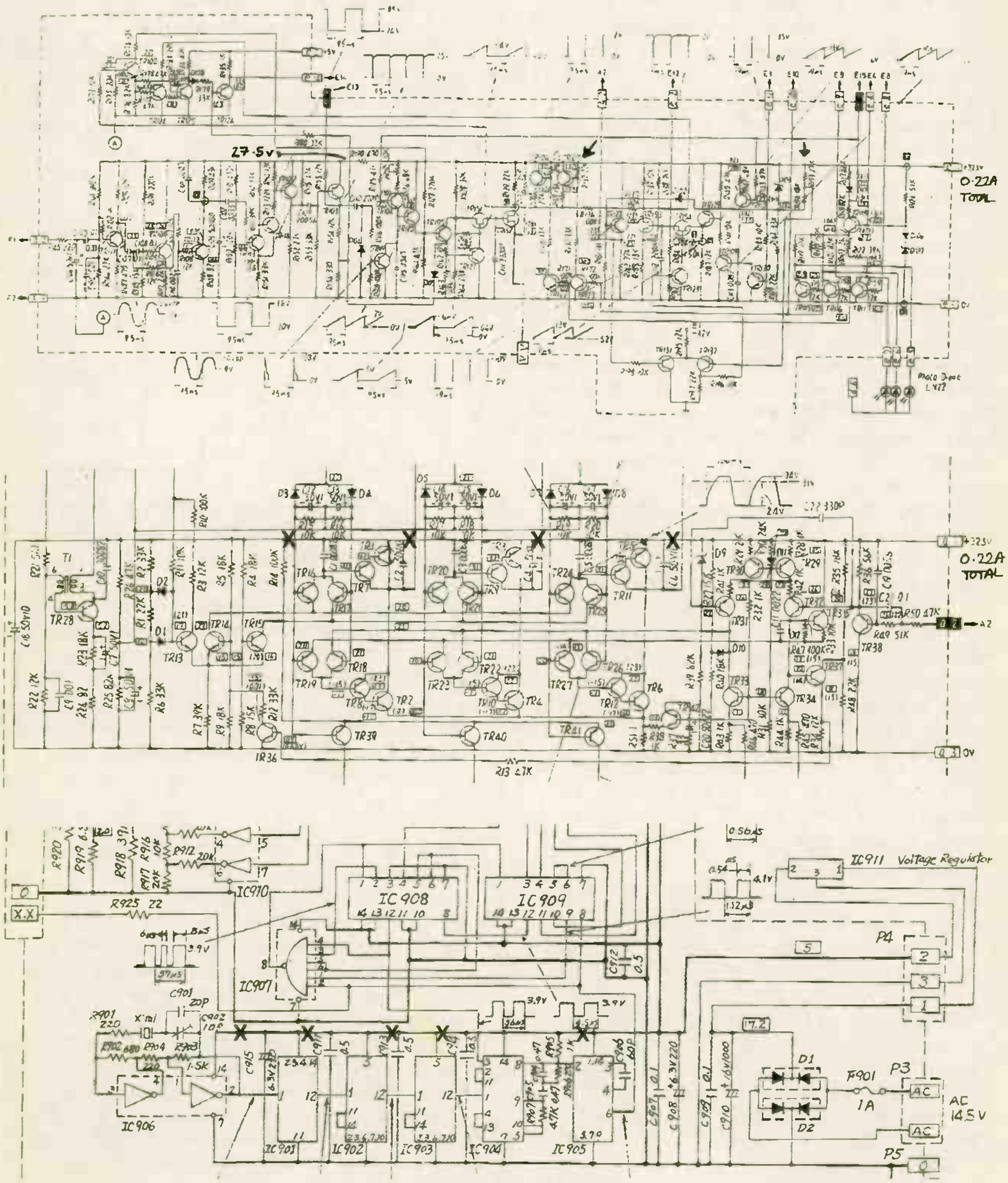
I have a Technics SP-10 in its BBC version, with the BBC power supply. Is the mod described in HFW appropriate to the BBC power supply? I seem to remember it's about adding regulation. Could you remind me of the details of this mod so I can try it?

Andy Evans
arts.psychology@cwcom.net

The modifications published in November and December 1997 were, in fact, only appropriate for the BBC version of the SP-10 MkII, the 'P' suffix. The 'A' suffix type is wholly different electronically in that it uses a host of ICs rather than the P's predominantly discrete circuitry.

We've had a number of requests to re-publish this information, so here it is again. One modification I'd like to see is independent battery PSUs for analogue and digital sections. If anyone tries this, please let us know. JM

These are the regulator modifications for Technics' SP-10 MkIIP direct-drive turntable.



PAY ATTENUATION, PLEASE

Richard White goes in to bat against a strong side of DIY-ers on the subject of stepped attenuators.

It is always gratifying to find reader interest has been stimulated by a feature we've printed, and the stepped-attenuator recipe from the December supplement has obviously given many of you food for thought. In view of this continuing interest, we print here some extracts from representative specimens of the queries and improvements you've made, with a side serving of comments and Awful Warnings to boot.

From Daniel Ross: (d.j.ross@uclan.ac.uk)

In view of the continuing discussion on ways to improve stepped attenuators and balance controls, I have modified the design of the attenuator in the December 1998 DIY Supplement. The modification is very simple - break the link to the stepped attenuator from the signal input by removing R12 and soldering it across the signal in and signal out points. I don't listen to music at very loud levels so R12 was never used. The rest of the resistors then act like a balanced pot to lift from ground.

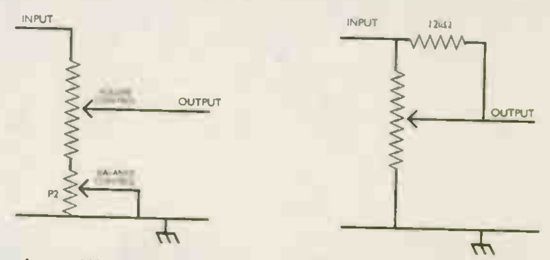
This arrangement was suggested by D.W. Richards in February 1999 as a balance pot. Incidentally I used 0.25watt metal films as they were less bulky and soldered very neatly in between the 'legs' of the wafer.

Trying the idea with a pot on the tail of the potential divider and a higher value resistor for R12 gave promising results. I had originally replaced the Alps 20kohm pot in my Naim 42 pre-amp. The increase in sound quality with the DIY attenuator was mind-boggling.

The metal film resistors used sounded bright, as was indicated in the article, but with only one resistor in the signal path the brightness disappeared. Extra subtleties were revealed and the bass became very tight and fast.

What Mr Richards was suggesting (Feb issue letters) was the arrangement illustrated in fig 1, where an additional resistance is put into the earthward tail. As I mentioned then, this approach needs caution, and the extra resistance should not be more than, say, twice the value of the main pot. It is important to note that the proper place for this resistance is OUT of the circuit - in other words, most of the time it is simply by-passed to earth by the wiper.

If I have interpreted your letter correctly and the arrangement in fig 2 is what you have in mind, I'm not at all sure about this. The important feature of most attenuators is that they present a relatively constant load to the preceding stage. It is asking for trouble to effectively short the output of an amplifying stage as a means of regulating the volume. In a well-designed pre-amp, the value of the volume or balance pot will have been chosen to give the optimum load to the preceding stage. This load is supposed to be fairly constant regardless of the proportion of the signal being taken off by the next stage; the output



device will always 'see', say, a 100kohm load. In practise it never works quite like this but the intention is sound.

Vary the load parameters by too much and amplitude distortion will start to occur as the device finds its 'headroom' more and more limited. Feedback taken from the area will also tend to be proportional to the attenuator setting, rather than the device output, which could lead to harmonic distortion varying with the load.

If I have misunderstood what you intend, I apologize but I pen the advice as others may stumble into the same mire even if you've side-stepped it! RMW

From Dennis Buttigieg:

(Dennis.Buttigieg@yes.optus.com.au)

I'd love to make a stepped attenuator for my old Sansui A80 amp (which I want to keep and improve since it was my very first amp). However, having had a look inside I notice that the pot has four pins, not three as with your attenuator.

Are the four pins on my pot just signal in and ground as well as signal out and ground? Are the pots with three pins just sharing the same grounding for signal in and signal out? Can I branch out another grounding terminal from the original one to accommodate the four-pin configuration?

One other question. Do you have any tips on how I can work out which pin is which on my amp's pot since I don't have a circuit diagram for it?

I do not in the least recommend trying to modify an amplifier unless:
a) you have the circuit diagram, or
b) the thing is blindingly obvious .

Without a sketch, it is difficult and dangerous to hazard a guess; for example, is your fourth terminal a tapping on the main track or a second wiper for some purpose like a loudness control? Step 1 in this case is to get a circuit diagram if you can, and if you can't, leave it for the moment.

As I have intimated in some of the answers, there are many more considerations to circuit design than can appear at first glance and, especially with an integrated, it is easily possible to do more harm than good by modifications. If you happen to find a junk-shop 20-quidder, that may be the place to start. RMW

John Caswell writes:

I built several stepped attenuators some years ago using surplus 30-way Painton Type 72 rotary switches, which have the advantage of make-before-break wipers and silver-stud contacts. I used discrete 1% metal-film resistors and removed the switch detent mechanism to provide a smoothish rotation like the stud-quadrant faders for TV broadcasting.

I purchased these switches for approx £10 each on the surplus market, but they are currently available (new of course) from Farnell in Leeds (0113 263 6311) at a cost of approximately £110 for silver or £120 for gold contacts plus VAT. I calculated the 30 resistor values for a 10kohm log pot in 2dB steps, but of course these would be very easy to scale up or down.

The results far exceeded my expectations - I still use them and they are as noise-free today as they were when built. Matching is naturally quite good!

Sussex Surplus have some 24-position, two-gang rotary switches at prices from under £10, so for the keen tryer-outer, this may be the most economical route. Our original article was naturally budget-motivated but there's no harm in puttin' on the style a bit, although a solder-sinner or fuddle-fingers might wreck some impressively expensive switches without a bit of practice ("Here's one I ruined earlier...") RMW

A DESIGN FOR DEPTH

I have home-made 'speakers built to a design taken from V. Capel's little Maplin's book, An Introduction To Loudspeaker And Enclosure Design. The Kappellmeisters (as they're called) are very similar to transmission lines. They have long, folded tubes, the cross-sectional area of which is the same as the driver's cone area. Stiffening the enclosure are concrete fillets. A ceramic-tile finish reflects the sound around bends in the 8ft. tube to a vent.

The result is a pair of very heavy 'speakers which don't require a physics degree to build and sound pleasantly natural. The designer suggests that the bass may need "boosting", and indeed it does right at the bottom-end. This is my problem.

I have a Mordaunt-Short T2000 subwoofer (for multi-media, I know, but I got it cheap) which, even when used in a very subtle way, colours the sound - it makes the bass rounded and warm but isn't the crisp, direct sound I've got used to over the last year. I know the sound I want and I can hear it on some of my more bassy CDs when I turn up my hi-fi to Friday-night-neighbour-annoying levels.

So what do I do? Buy more expensive drivers (I've already got some 6in. Audax kevlar drivers from Maplin)? Should I bi-amp my woofer and tweeter, or buy a new subwoofer?

J.B. Minns
jo@fish66.freeserve.com

For really shifting air at low frequencies, you can't beat a large-diameter driver like Audax's HM210ZO.

Bi-amping is a mandatory first step as this in itself should yield faster, more satisfying bass. Depending on what the crossover slopes are (12dB/octave to enable the DR66 to be used), going further would involve an active crossover.

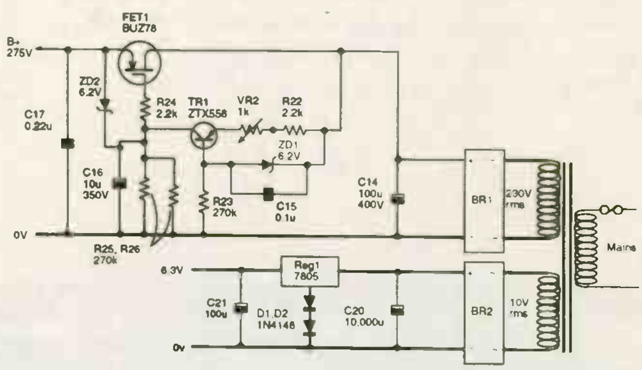
If you still crave more bass, a subwoofer is the answer. The drivers inside the M-S and the 6in. Audaxes are unlikely to hit the spot as the first are probably too cheap to provide the speed and clout you're after and the second are too small. Audax do manufacture larger woofers which we sell, and Wilmslow can supply suitable drivers from other companies.

Transmission-line subs would go nice and deep, but they wouldn't exactly be domestically inconspicuous! Ported cabinets are more compact, but some bass-heads remain unconvinced by their sound, finding it imprecise and lacking in a grunt. JM

KEEPING TRIM

I have completed your kits and must say that, returning to hi-fi after some years' lay-off, I find the sound very impressive. However, I have one query about the set-up of the KLPP1 phono stage. There is a trimmer, VR2, on the power supply which I assume is to control the level of ripple in the power-supply circuit. How is this set - it is not spelled out in the kit instructions?

Donald Campbell
BELLEROPHON@email.msn.com



The output voltage of KLPP1's regulator can be set via VR2 with a multi-meter.

The purpose of trimmer VR2 is to set the correct HT voltage (275V) for KLPP1's circuitry. Due to variations in the mains supply, this sort of adjustment is necessary. You'll need a small, flat-head screwdriver and a multi-meter on its highest DC voltage setting to carry this out. The MM's black probe should be in contact with KLPP1's earthing post, while the red one should touch the HT line at the junction of R12 and R18.

First, with the valves in place turn on the pre-amp without it being hooked up to the rest of your system. Let it warm up for five minutes. Then simply adjust VR2 until you have a reading of 275V on the meter. NL

BETTERING BASS

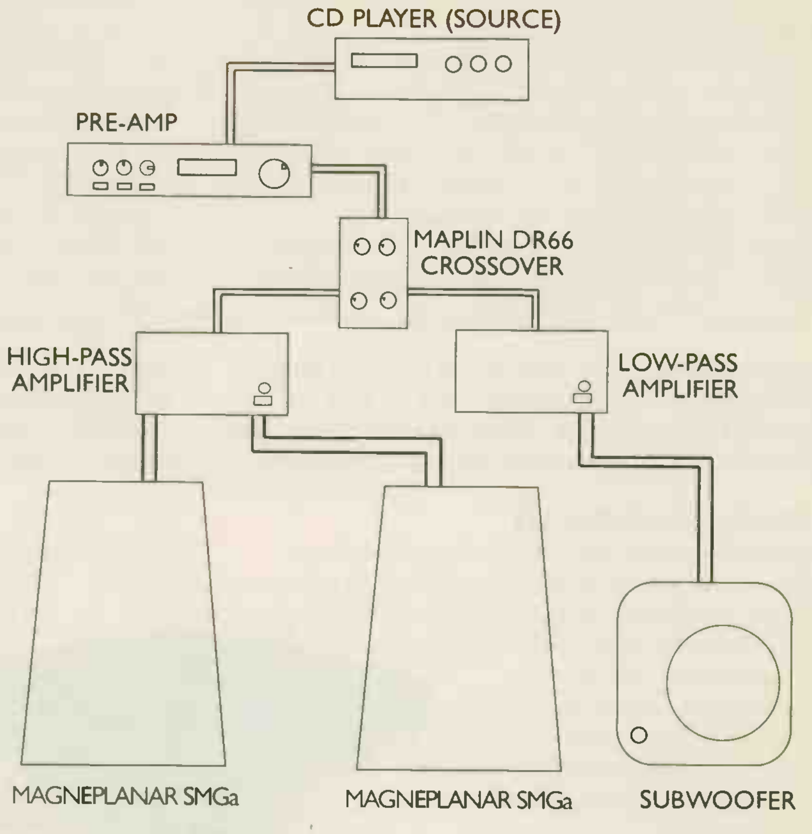
My system revolves around a Roksan ROK DP1 CD transport and ROK DA1 convertor working into a John Linsley Hood SA kit amplifier from Wilmslow/Hart via home-made silver interconnects from Maplin. This drives a pair of Magneplanar SMGa loudspeakers.

I had a pair of Morel 10in. bass drivers doing nothing so I asked Wilmslow Audio to design me a coupled-cavity subwoofer to roll in at about 50Hz-60Hz where the Maggies roll off. This they did and I now have it made and working. It goes down to about 20Hz!

The only other component in the sub apart from the drive units is an air-cored inductor for each channel. Because of the low frequencies involved, these have a resistance of some 10ohms and, when in circuit, give a total resistance across the terminals of the sub of some 15ohms. This is compared to the 4ohms of the Maggies.

The sub is wired from the 'speaker terminals on the amp in series with the Maggies. I was wondering if it would be of benefit to connect the sub to its own amplifier to compensate for the difference in resistance. The overall quality of sound is exemplary but the sub doesn't seem to have had quite the impact I was hoping for. Your advice would be much appreciated.

Alan Parkinson
Merseyside.



To make your system work, you'll need to wire it up as in the diagram above.

The brutal reality of subwoofers is that passive ones are more likely to sound bad than good. Amplifiers have a very tough time keeping a grip on woofer cones when faced by large inductors - an active crossover would give much better results.

As you seem to be a Maplin fan, check out their DR66 active crossover which we featured in the November 1998 issue. This may not be intended specifically for use with subwoofers, but its low-pass point can be set at 50Hz and varied upwards. Maplin's other sub crossovers have fixed roll-off points, making them relatively inflexible.

Unfortunately, as the kit amplifier lacks Pre Out sockets, connecting up the sub will take a little lateral thinking. To ensure that the sub's level changes in line with the Maggies' you need a 'master' volume control. The ideal candidate would be an active pre-amp which will drive the DR66 without difficulty (see diagram). This obviously involves extra expense but the improvements will be worth it. If you keep the cables between amp and sub short, you should find the bass becomes much, much tighter and faster. JM

Supplement Advertiser's Index

AUDIO LINKS	4	FALCON DIY	20	SOWTER TRANSFORMERS	18
AUDIO LINKS	22	HOWARD DAWSON	22	TECHNICAL & GENERAL	18
AUDIO NOTE	10,11			VACUUM STATE ELECTRONICS	22
BILLINGTON EXPORT	20	IPL ACOUSTICS	18	WALTHER ELECTRONICS	14
		LANGREX	6	WATFORD VALVES	4
BK ELECTRONICS	14	MARTON MUSIC	20	WIRE & INSTALLATION	24
COLORMOR	6	ORIGIN LIVE	24		
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