AFFORDABLE, HIGH PERFORMANCE 35W INTEGRATED VALVE AMPLIFIER

DESIGNING A TOP CLASS HEADPHONE AMPLIFIER

FREE D.I.Y. SUPPLEMENT No. 18
THE HI-FI LAW OF DIMINISHING RETURNS
Ask a Hi-Fi dealer to upgrade your system, and he'll sell you ever more expensive bits of hardware, giving you a constantly changing sound, new solutions producing more problems which can only be solved with more expensive equipment. The harder you try, the more it costs and the less satisfying the results. This is the well known Hi-Fi law of diminishing returns. We have an alternative:

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Why buy new equipment when it makes more sense to realise the full potential of your existing equipment. Don't replace it, upgrade it; it's cheaper. Most equipment can be transformed by us for the cost of a dozen CDs. Magic? No - logic! To find out how we do it, ask for our 1994/95 Catalogue; it provides discussion, analysis and a definitive resource of audiophile components and advice on the art of recreating music 'in the home.'

Russ Andrews
Audiophile Catalogue
Includes:
- CD Players, Preamplifiers, Disc
- Preamplifiers, Power Amplifiers
- Loudspeakers
- Kimber Kable
- Upgrading Services and Guides
- Audiophile Kits and Components
- Accessories
- Reviews

1994/95 CATALOGUE

Russ Andrews
Edge Bank House, Skelsmergh, Kendal
Westmorland. LA8 9AS
England
Tel: 01539 823247
Fax: 01539 823317

To receive your copy of our 1994/95 catalogue just mail, phone or fax the address above.
Contents

KIT NEWS
All the latest developments from the world of Hi-Fi kits and components.

K6L6 35W INTEGRATED VALVE AMPLIFIER
Another unique design from the World Audio Design stable. This one's a high performance integrated with an output of 35 watts and a price under £300.

HEADPHONE AMPLIFIERS
Looking to get the best sound from your headphones? We take a look at what goes into the design of a high quality headphone amplifier.

A TOP QUALITY FINISH FOR YOUR CABINETS
We show you how to get a professional finish on your DIY loudspeaker cabinets, be it glossy paint or real wood veneer.

BOOK REVIEWS

70 YEARS OF RADIO TUBES AND VALVES
A historical look at the birth of the vacuum tube and the people and companies associated with it up to the present day.

BULLOCK ON BOXES
Everything you need to know about designing vented and sealed loudspeaker enclosures. An ideal book for those without a computer, since it shows how to tackle the maths.

DIY LETTERS
Our team of experts set about answering your DIY hi-fi design queries. Write to us for practical advice and help with your DIY projects.
Billington Gold
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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.

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<tr>
<th>BILLINGTON GOLD</th>
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<tr>
<td>2A3 15.50</td>
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<td>12AX7 5.25</td>
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<td>811A 12.00</td>
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<td>845 33.00</td>
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<td>6B4G 27.00</td>
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<td>6CG7 Yugoslavainian</td>
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<tr>
<td>6X4W RaytheonUSA</td>
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<tr>
<td>Jumbo 4-Pin for 211, 845 etc</td>
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<tr>
<td>Jumbo 4-Pin, Gold Plated, for 211</td>
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<td>UX4 for 2A3, 300B, 811A, etc.</td>
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<td>UX4 Large Locking Type for 300B</td>
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<tr>
<td>B5 UK</td>
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<td>UX5 McMurdo UK for 807</td>
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<td>B7A for 6C33CB</td>
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<td>B7G McMurdo UK, chassis, skirted</td>
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<td>813 Ceramic</td>
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<td>Octal McMurdo UK</td>
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<td>Octal PCB, nylon</td>
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<tr>
<td>Octal PCB, foreign</td>
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<tr>
<td>B94A for ECC83, EL34, EF86, etc, suitable for pre-amps:</td>
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<tr>
<td>- Ceramic, skirted, chassis, screening can,</td>
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<td>- Russian</td>
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<tr>
<td>- PCB, gold pins</td>
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<td>B9D Magnovan, chassis, for PL519</td>
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We supply sockets for all valves listed in this advertisement

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<tr>
<th>TOPCAPS</th>
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<tr>
<td>For 2C34, 807, etc</td>
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<tr>
<td>For 12E1, 5B-254M PL519</td>
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<tr>
<th>MATCHED TESTING</th>
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<tr>
<td>£2.00 Per Valve</td>
<td>(£4.00 per pair)</td>
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All items in stock at time of going to press. Prices in GB Pounds and subject to fluctuation: please check before placing your order.

We stock over 3000 valve types and 400 types of CRT. Please ask for our free 50 page catalogue of valves and/or our CRT catalogue.

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World Radio History
TOP AUDIO ANALYSER FROM KENWOOD

Kenwood have announced a new audio analyser, the VA2230. Priced at £4800 it isn’t cheap, but it combines several instruments into one to reduce the amount of equipment and test leads normally found on a test bench (anyone who’s seen our test bench with over twenty measuring instruments and miles of cabling will understand the benefits of this). The VA2230 Audio Analyser combines an audio generator (5Hz-100kHz), AC/DC electronic voltmeter, wattmeter, distortion meter, frequency counter and signal-to-noise meter. It can also be linked to a PC for computer controlled analysis and there is optional software for frequency response graphs etc. All in all, it looks an impressive piece of kit, and we hope to bring you a short test in one of our future supplements.

Trio-Kenwood UK
Kenwood House,
Dwight Road,
Watford,
Herts. WD1 8EB
Tel 01923 816444

PM COMPONENTS

PM components are continuing to expand their range of modern-manufacture vacuum tubes. New this month is the EL34M. Produced using an original Mullard EL34 as a reference when designing the component parts, PM Components hope to have faithfully reproduced this classic British valve to the highest standard. Price is £25/pair.

There is also a new EL34 Super, priced at £25/pair. It is a more rugged EL34 for longer life span. Features include a bottom getter for cooler running and higher current operation, and it is made using a lower temperature process to reduce ionization in manufacture. This, combined with a high vacuum, should make the EL34 Super a very efficient valve.

NEW TRANSFORMERS AND CABLES

Audio - Links are pleased to announce that they are now able to offer a custom transformer winding service to customers. Audio - Links can wind transformers for original designs such as the Mullard 5-20 and Western Electric WE-91, as well as helping with custom designs for your own project. They can also take the failed transformer from your vintage valve amplifier, analyse it and wind a modern, high performance replacement to give it a new lease of life. Call for a quote.

Also new is a kit version of Audio - Links’ “The Green” interconnect. Using silver plated OFC copper wire insulated with PTFE, The Green usually retails for £75. In kit form, including silver loaded solder, it is available for £50, a worthwhile saving for anyone equipped with a good soldering iron and a keen eye.

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

SPECIAL OFFER SINGLE-ENDED HEADPHONE AMP

A special offer to Hi-Fi World readers. Hart electronics are reducing the price of their Chiara single-ended headphone amplifier and associated Adante power supply from £198.53 to £184.92 in kit form for any orders placed before Christmas. It is also available fully built and tested for £284.74.

Hart Electronic Kits
Penylan Mill,
Oswestry. SY10 9AF
Tel 01691 652894

NEW CATALOGUE FROM PV

PV Tubes have just produced a new catalogue, containing a listing of all of the valves they stock as well as other components for audio, including a range of capacitors. This 50page catalogue is available for 50p, which should be sent with a large SAE to:

PV Tubes
104 Abbey Street,
Accrington,
Lancs. BB5 1EE
Tel 01254 236521

NOVEMBER 1995
FED UP WITH TRYING TO FIND THOSE ELUSIVE VALVE DATA BOOKS.?? SO WERE WE.!!!!
THE SIMPLE FACT IS THEY DON'T EXIST ANYMORE.
THAT'S WHY WE PRINTED OUR OWN
NOT ONLY THAT WE DECIDED TO TAKE IT A STAGE FURTHER, AND INCLUDED SCHEMATIC DIAGRAMS OF AMPLIFIERS FROM 3 WATTS TO 500 WATTS, PUSH PULL TO SINGLE ENDED. POWER SUPPLIES FROM 150 VOLT TO 1500 VOLTS STABILISED. ALL THE DATA YOU NEED IS IN THIS BOOK
THIS BOOK IS INVALUABLE FOR THOSE INTERESTED IN THE DESIGN AND BUILDING OF VALVE AMPLIFIERS.

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Introducing The Parts Connection's first complete DIY kit: the Assemblage DAC-1 Digital Processor.

It comes in a small package (24cm x 5cm x 18cm chassis), but packs a big punch and a very musical sound. Designed for the rookie or first time kit builder, the only tools required are a pencil tip soldering iron, a screw driver, a wrench, a pair of electronics pliers, and a wire stripper or hobby knife. With only 21 solder joints and a handful of nuts and bolts, this kit goes together in one evening (typically about an hour). It's as easy as connecting the dots.

The parts quality is top notch. The board comes assembled and tested, implementing the Burr Brown 1702 DAC, a Crystal 8412 input receiver, an NPC 5813 digital filter, Analog Device's AD844 and 847 op amps and a custom potted toroidal power transformer.

At $449 US, the Assemblage DAC-1 offers an outstanding value in digital conversion and comes with a Satisfaction Guarantee (return it within 30 days of purchase for a full refund) and an Assembly Guarantee (if you can't get it running, we will!). We challenge you to find a DAC anywhere near this price with better measured performance, component quality, and most importantly, sound quality. Call us for more specific information on the performance or construction features.

To order the DAC-1 kit or to order The Parts Connection 1994 Catalog (for £3), full of a lot of other exciting stuff (including a $10 US discount coupon good on your first order over $100 US), send us your request and mailing address - or call with credit card information.

THE PARTS CONNECTION
A DIVISION OF SONY FRONTIERS INC
Toll Free Order Line 1-800-769-0747 (U.S. & Canada only)

2790 Brighton Road, Oakville, Ontario, Canada L6H 5T4
Telephone 0101-905-829-5858 Facsimile 0101-905-829-5388

Connect the dots.
K6L6 VALVE AMPLIFIER

by Noel Keywood

This amplifier was conceived in direct response to your requests for an inexpensive design. But we failed - to make it cheap, that is! A cheap cheapy means performance compromise, which contradicts the basic thrust of high fidelity, a pursuit of perfection. So here's a 35watt per channel integrated valve amplifier that as a kit costs £295, but as an amplifier is quite specialised.

Our basic design brief demanded the use of inexpensive valves of course. The tried and trusted 6L6 was our preference. This is a beam tetrode, designed by RCA for audio use. It delivers good power and excellent audio performance, but costs little, so replacement after a few years carries no fear. Russia and China manufacture them today in quantity, so availability is not a problem either.

To match a good range of modern commercial speakers, including ones of mediocre sensitivity, power output needed to be 30watts or more, we felt. Pure Class A was out, because at this power the amplifier would stream heat and transformer costs would rise if we were to meet our usual criterion of cool-ish running in the tropics (our kits are popular in Singapore, Hong Kong and Malaysia). So the new K6L6 amplifier is a Class A/B push-pull design running substantially in Class A. Although nominally rated at 35watts, this is conservative. It hits 40watts at a few percent distortion.

A moderate amount of feedback has been used to keep output impedance low, again to ensure good speaker matching. Also, as usual we’ve optimised performance at around 6Ω, giving good power transfer and low distortion to a large majority of 8Ω loudspeakers. In the mid-band, distortion hovers around 0.02%; this is a low distortion amplifier.

There’s no point in making a budget power amp, 'cos then the preamp will hike the overall system cost, so K6L6 had to be integrated, with input selector and volume control. This amplifier has a lot of gain, so it has a high input sensitivity of 220mV - low enough to match any signal source. Anyone wanting to use a record deck will need to add an external phono stage.

A lot of the cost of a valve amplifier - any amplifier in fact - lies in the casework and transformers. All the same, we didn't consider offering an unpunched chassis for the sake of cheapness. We expect our kits to have a professional finish, not look like battered...
Cocoa tins. A lot of cost saving lies in a new form of chassis construction devised for K6L6 that’s simple to manufacture, yet strong, safe and neat in appearance. It’s a two-part “clamshell” design that dispenses with welded & buffed corners. Most of the circuit is built onto a printed circuit board with component positions printed on, to simplify assembly.

The chassis comes powder coated for durability and longevity; powder coat is baked on in an oven, dispelling moisture, so it survives better in humid climes than plating or paint. As always, we have used heavy 16 gauge steel, and the chassis comes screen-printed front and rear, so it looks and feels professional. The bottom section ensures high voltages cannot be touched, but bear in mind that the output valves run hot enough to cause a burn, so young children and pets shouldn’t be allowed close.

The ever important power supply uses a toroidal transformer for cool, efficient running and low external hum field. This feeds a bridge rectifier built from fast diodes, which give cleaner switching free from sharp transition glitches. The bridge feeds a reservoir capacitor of 500μF, comprising stacked 1000μF units to give 800V working, fitted with bleed/balancing resistors. This gives such a quiet H.T. line that hum and noise come mainly from the input valves, because of the large amount of gain that follows them. To get hum right down to negligible levels we found it essential to use a d.c. supply to the input valve heaters.

We took note of a new ruling by the E.C. against the use of 4mm loudspeaker plugs, because they can be inserted into European mains outlets. It would be more sensible if others used the British shuttered 13A socket, because children can’t poke wire, metal knitting needles or heaven knows what else into them, but since rewiring Europe would probably be more expensive than German reunification, it’s hi-fi amps and ‘speakers that must change.

We’ve opted to use XLR ‘speaker connectors, female on the amp so the output terminals cannot be touched. They’re not dangerous, swinging just 20V or so, but because amps of 100W or more must in future have protected outputs (E.C. rules again) we thought we’d fall in line. The ‘speaker cable must have a sheathed male plug at the amplifier end. Ideally, a female XLR plug should be used at the other end, but I suspect most U.K. DIYers will use 4mm plugs, because all speakers are so equipped.

Talking of safety, do remember that anything over about 100V is potentially lethal. K6L6, like any valve amp, runs at a very high 500V and is potentially hazardous during the final testing stage (it meets BS415 safety requirements). If you do not know about safety precautions or are at all uncertain of your abilities, then we do not recommend you build it - it’s as simple as that! Get someone experienced and knowledgeable to build it or at least test it. Electricians are a good bet, as is your local TV repair man. Speak to them first to agree costs though, since building will take 8-12 hours, testing 1 hour or so, but fault finding and rectification unspecified hours!

K6L6 THEORY OF OPERATION
by designer, Andy Grove.

The K6L6 circuit is straightforward, similar to the ubiquitous Mullard 5.20, but with some refinements to improve performance.

The input valve, V1, is a 6AU6 low noise R.F. pentode. It is configured as a high gain, single-ended amplifier stage with R5 as its anode load and R7/C3 as part of the H.F. compensation to maintain feedback stability. The input grid (g1) is connected via a grid stopper R2 (to prevent parasitic instability). VR1 is the volume control with R1 as a precautionary measure to ground g1 in case VR1’s wiper contact fails. The screen grid (g2) is supplied by R6 with C2 to bypass any audio signal to the

![Diagram](image1)

BAILEY CIRCUIT (Wireless World, Sept. 1962)
Fig. 1

![Diagram](image2)

GROVE CIRCUIT (Hi-Fi World, Nov.1995)
Fig. 2
cathode. R4 is the cathode bias resistor and C1/R3 are LF feedback compensation components.

The second stage and phase splitter (V2) is an ECF80 triode pentode valve with the pentode section (V2a) direct-coupled to V1's anode, at approximately 95V D.C. under quiescent conditions. The triode section's (V2b) input grid (g1) is connected to V1's anode via R8 but all audio signals are bypassed to ground by C4, effectively holding it at around 95V D.C. V2a's and V2b's cathodes are connected together and to ground by R13 and R14 which define V2's total cathode currents. V2b's anode load is R9 with R10 and R11 in series to give the correct load for V2a for accurate A.C. balance. R12 supplies V2a's screen grid (g2) and C5 A.C. couples to the common cathode connection.

Capacitors C6 and C7 block D.C. and couple the audio signal via grid stoppers R17 and R20 to the grids of the 6L6 beam tetrode output valves, V3 and V4. Resistors R15 and R16 hold the grids to ground at D.C. Resistors R18 and R19 are V4 and V3's cathode bias resistors which are bypassed by C8 and C9 with regard to A.C. ZD1 (2) causes a voltage drop of 2x68V from the main H.T. line for safe operation of the screen grids of V3 and V4, and R21 is a common stopper resistor to prevent parasitic oscillation. The anodes of V3 and V4 are connected to the output transformer and feedback is taken from the secondary via R22, R23 and C10, which are compensation components.

The power supply uses a capacitor input filter and R24, C12, R25 and C11 lower the voltage from the raw supply and filter it further for the low level stages.

The heater supply is a normal 6.3V A.C., except for the input valves, which are fed D.C. to minimise hum.

There are some unusual features in this amplifier which need some extra explanation. Firstly the phase splitter circuit is somewhat unconventional but bears some similarity to the Radford type designed by Dr. A.R. Bailey. It uses a triode-pentode valve for improved electrical performance, in place of the Mullard 5.20's double-triode. The problem with the conventional double-triode phase-splitter is it's high input capacitance caused by the Miller effect. This causes H.F. loading on the input valve and reduces bandwidth, making it very difficult to use appreciable amounts of negative feedback without instability due to the phase shifts incurred. A pentode has a very low input capacitance and high gain due to the shielding effect of the screen grid. This means that the loading on the input valve is greatly reduced, increasing bandwidth and decreasing troublesome phase shifts.

In the original Bailey/Radford circuit a pentode replaces the first triode of the Mullard type cathode-coupled phase-splitter, but it's capabilities are not fully exploited. Fig 1 shows the Bailey circuit. Here the screen bypass capacitor C1 is connected to ground. This means that the drive voltage for the triode section (which appears at the common cathode
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AMERICAN TYPES

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|                    | 128BY7A GE                             |
|                    | 6146B GE                               |
|                    | 6550A GE                               |
|                    | 7027A GE                               |
|                    | 7581A SYL                              |

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connection) causes not only feedback into g2 but also increases the input capacitance, because g2 is grounded to A.C. but g1 is not.

To overcome these drawbacks I have connected the capacitor to the cathode connection (see Fig 2). This means that g2 and the cathodes now have the same A.C. voltage on them. This removes the unwanted feedback mechanism, increasing gain, but it also reduces the capacitance between the input g1 and g2, widening bandwidth and reducing phase shifts. This allows substantial feedback to be applied without instability, even with highly capacitive loads like electrostatic speakers.

Feedback was tried at various levels, both for measured performance and audio quality. It was found that, in this design, greater feedback at high frequencies, as long as good stability and square-wave performance could be maintained, gave a cleaner and sweeter quality. This could be due to the decrease in distortion and better transient response. The special LF feedback networks gave a cleaner and faster bass quality.

The H.F. compensation networks R7/C3 and R23/C10/R22 are quite ordinary, but the L.F. compensation is somewhat unusual. At medium to high audio frequencies the reactance of C1 is negligible so the feedback is determined by R3. As the frequency decreases the reactance of C1 increases, increasing the feedback at L.F. but maintaining stability. This gives the amplifier excellent control over the speaker at low bass frequencies and reduces bass distortion. A.G.
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WORLD AUDIO DESIGN K6L6 INTEGRATED

oscillation with some particular samples of a valve. For safety we use them, but home constructors may like to experiment with their removal.

The are some common and recurrent build difficulties. Any channel that 'motorboats' (low frequency instability that produces a very loud drone) has its feedback the wrong way around. Reverse the feedback connection on the output transformer secondary. When checking remember that the amplifier is stable without feedback and should not motorboat in this state, although it will have excessive gain and seem to have hum and noise until feedback is connected.

Poor soldering and wire layout are not uncommon too, we find. Keep all high level signal lines in the output stages away from input lines to prevent mutual induction and possible instability. All input lines on this amp must be kept away from mains and heaters; they are unusually sensitive, being of high impedance, and must be screened. Beware of running cables alongside each other or in looms - they may interact.

Watch out for dry joints when soldering, another common problem. A joint might appear made, but in fact it will 'dry' and be making poor or no contact, because of movement whilst the solder was cooling. Inspection, continuity testing and pulling at wires have to be used to spot this mistake. Finally, electrolytic capacitors must be inserted the right way around and their polarity marking correctly identified. Usually, can is negative, black end positive and negative is the pole identified on the side. NK

SOUND QUALITY

K6L6 is a high feedback design, and shows all the hallmarks of this in its sound quality. The sound stage is tightly defined and well ordered, images sounding clean and free of grain. Where K6L6 scores is in clarity and detail. It has all of the openness through the midrange and sweetness of treble that any good valve design should be capable of.

Bass is tight and powerful, unstuttered by strong dynamics, shown well by the powerful bass guitar on Soundgarden’s 'The Day I Tried to Live'. The notes really punched out, underpinning the track with a firm foundation. K6L6 copes with awkward loads well too, an advantage of feedback, driving a wide variety of loudspeakers and always producing stable and tuneful bass.

Where K6L6 shows its best colours though, is with female vocals and strings, where its dry and analytical nature urges detail to the fore. The Cranberries’ Dolores really shone on ‘Daffodil Lament’, vocals clear and forward pushing out into the room. Valves just can’t be matched.

DB

K6L6 PARTS LIST

<table>
<thead>
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<th>RESISTORS</th>
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<td>1M, 0.5W</td>
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<tr>
<td>R2</td>
<td>1k, 0.5W</td>
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<tr>
<td>R3</td>
<td>10, 0.5W</td>
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<tr>
<td>R4</td>
<td>1k, 0.5W</td>
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<tr>
<td>R5</td>
<td>100k, 0.5W</td>
</tr>
<tr>
<td>R6</td>
<td>270k, 0.5W</td>
</tr>
<tr>
<td>R7</td>
<td>10k 0.5W</td>
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<tr>
<td>R8</td>
<td>1M, 0.5W</td>
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<tr>
<td>R9</td>
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<td>R10</td>
<td>47k, 1W</td>
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<td>R11</td>
<td>3.3k, 0.5W</td>
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<td>6k8, 1W</td>
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<td>R15, 16</td>
<td>470k, 0.5W</td>
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<tr>
<td>R17</td>
<td>3.3k, 0.5W</td>
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<tr>
<td>R18, 19</td>
<td>560, 7W</td>
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<td>3.3k, 0.5W</td>
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<td>R21, 22</td>
<td>100, 0.5W</td>
</tr>
<tr>
<td>R23</td>
<td>750, 0.5W</td>
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<tr>
<td>R24</td>
<td>10k, 1W</td>
</tr>
<tr>
<td>R25</td>
<td>100k, 1W</td>
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<td>Power supply</td>
<td></td>
</tr>
<tr>
<td>R26, 27</td>
<td>68k, 1W</td>
</tr>
<tr>
<td>R28</td>
<td>2Ω, 1W</td>
</tr>
<tr>
<td>R29</td>
<td>100Ω, 1W</td>
</tr>
<tr>
<td>VR1</td>
<td>250k, dual, log.</td>
</tr>
<tr>
<td>Cin (D.C. block)</td>
<td>50n/63V</td>
</tr>
<tr>
<td>C1</td>
<td>2200μ, 10V</td>
</tr>
</tbody>
</table>

| C2        | 0.22μ, 400V |
| C3        | 220p, 630V  |
| C4        | 0.22μ, 400V |
| C5        | 6.8, 250V   |
| C6, 7     | 1μ, 400V    |
| C8, 9     | 470μ/63V    |
| C10       | 4.7n, 63V   |
| C11, 12   | 68μ, 450V   |
| C13, 14   | 1000μ, 400V |
| C15       | 10,000μ, 15V|
| C16       | 0.22n, 250V |

2 x ZD1 zener diode, 68V,5W
H.T. Bridge Diodes 4 x BYV96E
Heater Bridge IA, 50V
V1 6AU6
V2 ECF80
V3,4 6L6GC
L1 toroidal output transformers
L2 toroidal mains transformer

K6L6 SPECIFICATION

Class A/B, push-pull stereo power amplifier using 6L6GC output valves.

Power 35W/ch.
Distortion 0.02%
Separation 60dB
Noise (CCIR) -103dB
Sensitivity 220mV

FOR FURTHER INFORMATION ON K6L6 AND ORDERING DETAILS, PLEASE SEE PAGE 82 IN THE MAIN ISSUE.
If you are generally interested in the subject of valve amplifier design, without the usual preconceived notions of what is "good" amplifier design and technology (the traditional view, which has tended to regard them as "unreliable" and all that), you will find there is a lot of valuable information here, in the form of parametric data, diagrams for amplifiers and speakers, reviews of new and old, in other words the subject that nobody else has spoken of, which, along with the well known theory, will teach them how to reinforce the bass of their normal amplifiers. You can buy SOUNDSiaz the US $50 price list (and then at the same time the UK "Sound" publication, which is the only one of the two to carry the full list of the Manufacturer's World of Valve Amplifiers). These components include mostly especially suited items like ceramic signal capacitors, gold plated tuning diodes, paper in oil aluminium signal capacitors, coser & silver foil signal capacitors, Black Gem phosphor mylar capacitors, silver foil capacitors, paper in oil foil signal capacitors, silver foil signal capacitors, which are pretty staggering in quality. The second reason is that we are preparing a range of very small price paper in oil signal capacitors, we will be offering our own 99.99% pure replacements in old and new valve amplifiers alike (and even in the solid state). And essential for DIY projects in line with our initial premise, which is to make in a valve amplifier, then you really should try. Our recommendations are: We also have a main transformers high for the WESI power transformers, as our "circuit pack" transformers, from which we can buy our single-ended output transformers with 30000 microfarad output, will make a very nice replica of the classic amplifier sound. We also use it to make a very nice replica of the classic amplifier sound. We have also made the circuit packs for making transformers, which we are selling at a very reasonable price, and we can say that we are in possession of any kind of diode, transistor or valve which makes sense, as well as a host of other signal capacitors, which are pretty staggering in quality, and we have to say this myself (as I am the only one who have seen the value of the single-ended stage). The increasing interest in our output transformers, as well as the part in technical competition, our products are designed to be used in our products are designed to be used in high end audio equipment, and we have a lot of other equipment which has to give up much more for a lot of more for a lot more. We are not the only people who have been worrying about this, and we are interested in the subject of valve amplifier design, without the usual preconceived notions of what is "good" amplifier design and technology (the traditional view, which has tended to regard them as "unreliable" and all that), you will find there is a lot of valuable information here, in the form of parametric data, diagrams for amplifiers and speakers, reviews of new and old, in other words the subject that nobody else has spoken of, which, along with the well known theory, will teach them how to reinforce the bass of their normal amplifiers. You can buy SOUNDSiaz the US $50 price list (and then at the same time the UK "Sound" publication, which is the only one of the two to carry the full list of the Manufacturer's World of Valve Amplifiers). These components include mostly especially suited items like ceramic signal capacitors, gold plated tuning diodes, paper in oil aluminium signal capacitors, coser & silver foil signal capacitors, Black Gem phosphor mylar capacitors, silver foil capacitors, paper in oil foil signal capacitors, silver foil signal capacitors, which are pretty staggering in quality. The second reason is that we are preparing a range of very small price paper in oil signal capacitors, we will be offering our own 99.99% pure replacements in old and new valve amplifiers alike (and even in the solid state). And essential for DIY projects in line with our initial premise, which is to make in a valve amplifier, then you really should try. Our recommendations are: We also have a main transformers high for the WESI power transformers, as our "circuit pack" transformers, from which we can buy our single-ended output transformers with 30000 microfarad output, will make a very nice replica of the classic amplifier sound. We also use it to make a very nice replica of the classic amplifier sound. We have also made the circuit packs for making transformers, which we are selling at a very reasonable price, and we can say that we are in possession of any kind of diode, transistor or valve which makes sense, as well as a host of other signal capacitors, which are pretty staggering in quality, and we have to say this myself (as I am the only one who have...
WE DO NOT SEE SLOT 4300A's, nor do they carry the same premium price, please consider the following, unless you absolutely insist on having or having to have them in your set, do not consider original 300B's. If it is in most cases far better to invest the same or more, i.e. in upgrading the front panel finishes of the amplifier, as for instance, like better output transformers, better signal caps or resistors in the line, valves were out, but better quality components such as Aquadyn. A + very sound improvement is in terms of an overall sound compromise, you can change some outdated capacitors and, for the relatively high price of an entire set of these high quality transformers. We believe, however, that it is not very exciting when a good-quality stereophonic cartridge. We believe, however, that it is not very exciting when a good-quality stereophonic cartridge. We believe, however, that it is not very exciting when a good-quality stereophonic cartridge. We believe, however, that it is not very exciting when a good-quality stereophonic cartridge.
A lot of you loved Richard Brice's Class A headphone amplifier. Here are some interesting follow-on suggestions, given consideration by designer Andy Grove.

**HEADPHONE AMPLIFIER COMPATIBILITY**

I was fascinated to discover Richard Brice's design for a Class A single-ended headphone amplifier in your DIY Supplement. About 18 months ago I came up with a very similar design for my own set of Jecklin Float Model 2s (the 'phones photographed in the article). In my case I used just two transistors per channel, and a common emitter gain stage and emitter follower (TIP121) driver, and no op-amps. Power was supplied via 78 series regulators and the thing sounded pretty good as far as I could tell. A bit light in the bass department perhaps, probably due to 100uF output caps rather than 220uF as specified by Mr Brice.

One thing that intrigued me was the lack of mention of compatibility with different types of 'phones. I believe the Floats have a relatively high impedance (approx. 200Ω) making them an easy load for the single transistor. I wonder how the circuit would cope with low impedance 'phones, say 8-16 ohms. Any comments?

Out of interest, I have recently been playing with an op-amp that seems well suited to exacting audio applications, the OP27. This is a reasonably low noise, highish slew rate device that performs well in voltage gain stages in power amps as well as the active part of RIAA preamps. In fact, it may well get incorporated into a Mk2 version of my headphone amplifier.

Peter Withers
Pershore,
Worcestershire.

Unfortunately the headphone amplifier as it stands will not satisfactorily drive low impedance headphones, due to the fact that the quiescent bias current in the output transistor and supply voltage are optimised for high impedance types.

For 100mW into 200Ω, 4.5Vrms (6.3Vpeak) and 22.5mA rms (32mA peak) is needed. The supply voltage is 15V and the quiescent current is around 50 mA, so no problems.

For 100mW into 8Ω 0.9Vrms (1.26Vpeak) and 113mA rms (160mA peak) is needed, with the standard circuit the quiescent current is just too low and asymmetrical clipping will result even at reduced levels.

To optimise for low impedance headphones, reduce the supply voltages to +/-5V and change the 15Ω emitter resistor to 8.2Ω, this will increase the quiescent current while keeping the transistor's dissipation sensible. The 220µF output coupling capacitor will have to be increased to 4700µF as well. Also, the biasing resistors may have to be modified slightly to get maximum power from the available supply voltage. Alternatively, use the Direct Coupled circuit with +/-5V rails and a 15Ω emitter resistor for even better results, the transistor will now need a small heatsink (10 deg. C/Watt) though. Either circuit should then perform satisfactorily with headphones of 8Ω to 16Ω.

The OP27 is widely used in professional audio equipment such as mixing desks, mic preamps and so on. There are, however, some real hot-rodded op-amps, designed specifically for audio, such as the AD743 and AD797 from Analogue Devices. Burr Brown and Linear Technology also make audio types so check with them as well, but be prepared to pay premium rates for these specialist chips. Whether the 2N3055 will be as sought after as a Western Electric 300B we'll just have to wait and see! AG

**AN AMP FOR YOUR EARS**

After building the headphone amplifier I can honestly say it has elevated the sound quality of my headphone listening to a level I would not believe possible from such a modest pair of 'phones. I would actively encourage anyone else who uses headphones to build this circuit and then try different op-amps and gain stages until they find a combination that suits them.
Having built this design and listened to it for a considerable time I would like to pass on some hints and modifications that your readers may be interested in.

Firstly, the choice of components. All resistors in the amplifier I have built are 1% metal film types, these are good quality but inexpensive and so do not add to the cost. The decoupling and output coupling capacitors are all low-ESR electrolytics, as intended for use in switch mode power supplies, and again are easily available at modest cost. The coupling/d.c. blocking capacitor between the output of the op-amp and the base of the transistor has been through this position and, after some listening, started with a 1 pF tantalum capacitor in several iterations in my amplifier. I changed it to a 1 pF metallised polyester film. The tantalum capacitor had a more relaxed sound whilst the film type had a sharper, but maybe harsher quality.

After more some listening I felt that the low frequency response was rolling off too early, and since the 1 pF capacitor, in conjunction with the impedance presented by the base of the transistor, is the primary reason for this early roll-off I changed the 1 pF capacitor for a 100 pF tantalum. This resulted in an even more extended bass response and the effect was very noticeable! I have now settled for a 100 pF tantalum in this position and the bass extension is now superb. Your readers would be advised to experiment with this value to find a response that suits their own headphones.

My headphone amplifier was built on a p.c.b. of my own design using a stand-off resistor. Since there is now d.c. present on the input of the op-amp, a d.c. blocking capacitor will have to be added. Comparing the sound quality of the two will prove very interesting! See enclosed diagram for details.

The only other area for experimentation is in the choice of op-amp, but to experiment in any detail a dual mono p.c.b layout will be required as there are no other high quality, audio grade op-amps available in a dual package.

Andrew Weeks
Sevenoaks,
Kent.

ANDY GROVE SAYS:
Your modified circuit is interesting, although I think you made an error in your calculations for the biassing network at the op-amp input. The op-amp has loop feedback which sets its gain at 11. The required voltage at the transistor's emitter is 7.5V, the base-emitter voltage drop is inside the feedback loop and will be corrected for by the feedback. Therefore we need 7.5/11=0.68V at the op-amp input. I have added some values to your circuit to supply this. I have also taken another step and sketched a fully DC coupled amp which eliminates the input and output coupling capacitors, replacing them with one in the feedback path which provides 100% feedback at DC, keeping the output at 0V. This circuit however requires full +/- split supplies for both the op-amp and the output transistor. The latter may require a heatsink unless the supply voltage is reduced from the original +/-15V. It may be worth trying a high grade stereo op-amp, the LM833. Why not split the two channels and use two separate supplies and high quality op-amps? You can even cascade the voltage regulators, i.e. regulate to +/-15V then regulate again to +/-12V this allows the regulator supplying the audio circuit to work from a fairly clean supply to start with, reducing ripple and noise. Keep experimenting! AG.
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Building your own loudspeakers is great fun; it gives tremendous pride of ownership. We've noticed that constructors like to pay attention to choosing and applying a good finish, but this isn't so easy, so here's some guidance with help from industry experts.

Nowadays, the most common material for loudspeaker cabinet manufacturing is MDF (medium density fibreboard). This is a very workable material, being easy to saw and sand, and not prone to warping. It has good acoustic properties too, making it near-ideal. This article concentrates on MDF and how to finish cabinets made from it.

**INITIAL TREATMENT OF MDF**

So you've built up your cabinets and they're reasonably square and neat. Make sure there are no overlapping edges or depressions where screws or panel pins have been used, filler can be used to rectify this. MDF is a very workable material, so I'd suggest a rough grade sandpaper, say 80 grade, and a wood block to ensure that you are sanding the surface flat.

Once the cabinets are in a reasonable state, with smooth edges and surfaces, sand with 150 grade paper and then more carefully with 280 grade paper to get rid of surface defects. A quick wipe down with a lightly dampened cloth will then help remove any fine surface dust which would otherwise show up in the applied finish.

**PRIMER/SEALER**

Once the cabinets have been prepared, a primer coat can be applied. It is always better to apply two or more light coats, sanding them smooth in-between, than one thick gloopy coat full of lumps and dribs.

Primer serves two purposes, it seals the wood, especially the end grain which would otherwise soak up the top coat, giving an uneven finish. It also provides a good base for the top coat to ensure that you get a smooth, even finish.

Once the primer coat has dried, sand it very gently with 400 grade paper to remove the surface dust and grit that will have dried on. This will gently key the surface and prepare it for the finish coat.

**TOP COAT**

The finish coat can either be painted on with a brush, rolled on with a roller, or sprayed on.

A paint brush will leave lines but is quick and easy, and if carefully done can look superb. A roller gets around the 'hand painted' look and can give the top coat an interesting pattern that will look quite professional. You can check what kind of pattern you will get from different rollers on a spare piece of MDF.

Spraying potentially gives the finest finish. I say potentially, because in the wrong hands it can be a disaster. You need a clean environment, plenty of space and mountains of patience. Spray in fine coats, don't try and completely cover a surface in one go. I find that spraying on to vertical panels works best. Don't spray downwards onto a surface; drips of paint from the nozzle have an annoying tendency to drip onto the wet paint just as you finish.

**GLOSS OR PIANO FINISHES**

These follow essentially the same procedure as above, but remember, at each stage any imperfection will show up that much more. So, if the bare MDF is uneven, or you leave a bit of grit in the primer coat, it's going to be seen. It takes a great deal of work to get gloss finishes perfect and it is well worth at
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<thead>
<tr>
<th>Kit</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board</td>
<td>£215</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>£290</td>
<td>370</td>
<td>460</td>
</tr>
</tbody>
</table>

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least one practice run on a spare piece of MDF first.

From the primer stage onwards, it is important to have the cleanest possible atmosphere for a good finish. If you have a garage, it is worth building a simple plastic tent, so wind can't blow grit, leaves, grass cuttings and what have you, onto the cabinets. The high gloss finish is achieved by applying a good quality clear lacquer, which is then hand finished with a burnishing cream. This kind of finish takes a lot of work, but when carefully done is among the most professional.

PRE-VENEERED BOARD
One of the easiest ways to get a real wood veneer on your cabinets is to use pre-veneered MDF. This is MDF with a machine applied veneer, so it is just about perfectly flat and needs very little further sanding or finishing before a varnish or polish can be applied. Pre-veneered MDF is more expensive though. An 8x4ft sheet of plain 25mm MDF costs around £40, whereas pre-veneered board ranges from £85 for Ash and Oak for example, to around £95 for more exotic woods such as Cherry and Maple.

The drawback is that the edges are bare MDF. Fortunately, there is a simple and very effective solution used by many top loudspeaker manufacturers, including KEF on their Reference Series. Radius all of the edges where there is bare MDF, as shown in the diagram below. This can be done with a plane to remove the bulk of the material, and then sanded smooth, 150 grade followed by 280 grade, followed by 400 grade.

The bare edges then need to be stained to match the veneer in colour. This finish will be more successful with dark wood finishes or Black Ash finishes, because it is a lot easier to achieve a good colour match. These bare edges will be very porous, so you will need to keep applying the stain until it dries to leave an even top colour.

From here onwards finishing is relatively easy. Seal the cabinets with a coat of sanding sealer and then finely sand smooth using 400 grade paper. Several coats of light varnish or polish should give you a super finish.

Three easy steps to finishing the ends of pre-veneered MDF. Radius the corners and then stain them to match the veneer. With darker finishes a very good colour match is possible, and once the whole cabinets have been varnished the effect is very professional.

Recommended paints etc. by Foxell & James

<table>
<thead>
<tr>
<th>Paint Type</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-cat Lacquer Paints</td>
<td></td>
</tr>
<tr>
<td>981 Clear Basecoat</td>
<td>£4.61/ltr</td>
</tr>
<tr>
<td>(won't affect tone of top coat colour)</td>
<td></td>
</tr>
<tr>
<td>Coloured top coats</td>
<td>£5.38/ltr (black)</td>
</tr>
<tr>
<td>Aerosol Spray Paints</td>
<td></td>
</tr>
<tr>
<td>Plasticote colours</td>
<td>£5.30/500ml</td>
</tr>
<tr>
<td>Plasticote Clear Acrylic</td>
<td>£5.30/500ml</td>
</tr>
<tr>
<td>Sanding Sealer</td>
<td></td>
</tr>
<tr>
<td>Mylands 2000 Shellac Basecoat</td>
<td>£5.99/ltr</td>
</tr>
<tr>
<td>Varnish</td>
<td></td>
</tr>
<tr>
<td>Mylands No.8</td>
<td>£8.06/ltr</td>
</tr>
<tr>
<td>Matt</td>
<td>£7.17/ltr</td>
</tr>
<tr>
<td>Semi</td>
<td>£6.46/ltr</td>
</tr>
<tr>
<td>Gloss</td>
<td></td>
</tr>
<tr>
<td>Wax Polish</td>
<td></td>
</tr>
<tr>
<td>Mylands (various types)</td>
<td>£3.27/450ml</td>
</tr>
<tr>
<td>Lacquers</td>
<td></td>
</tr>
<tr>
<td>Use clear Pre-cat Lacquer</td>
<td></td>
</tr>
<tr>
<td>or Mylands Gloss varnish</td>
<td></td>
</tr>
<tr>
<td>Burnishing Cream</td>
<td></td>
</tr>
<tr>
<td>Mylands Glossoid</td>
<td>£2.35/500ml</td>
</tr>
<tr>
<td>Wood Filler</td>
<td></td>
</tr>
<tr>
<td>Mylands Nitrofilla</td>
<td>£14/4kg</td>
</tr>
</tbody>
</table>

Prices are not inclusive of VAT.

Foxell & James stock the paints etc. mentioned above recommended by Moss and Co. timber merchants. This is just a small selection of what they can offer. Give them a call and they will be able to supply exactly what you need for a professional finish.

Our thanks also go to the following for their help with this article:

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70 Years of Radio Tubes and Valves by John W. Stokes.

Reviewed by Andy Grovè.

Here is a historical survey of valve evolution. Author John W. Stokes starts at the very beginning with Edison's original discovery of the unidirectional current flow from a heated filament and how this discovery led Fleming to the first commercial detector diodes. De Forest's addition of a grid to the diode to form the “Audion” (triode) and the first commercial Audions are covered next. These, first two chapters are a brief history of the discovery of the valve as we know it. There are quotes from the inventors and pictures of the original prototypes and early commercial versions, which were basically modified light bulbs! The reader is led forward in time to WW1 and the valves and respective numbering systems used by the armed forces at that time.

The valves start to become a little more recognisable with the introduction of the British R valve (French derived) and similar types. American valve development after WW1 is next with the politics behind the formation of RCA as well as the other giants AT&T, Western Electric and ITT, and their valves. The early independent American companies are introduced in a separate chapter, a lot of these were either absorbed by the giants or just faded away. There are names like Moorhead, Myers, Schickerling and so on, probably familiar to valve collectors but totally new to me.

Screen grid valves (tetrodes) are next on the historical trail. Most of the manufacturers of this type of valve are European, with familiar names like Mullard and Philips, because the tetrode was invented by Schottky while working for Siemens of Germany. Unusual double-ended RF tetrodes are described as well. Chapter 7 introduces valves intended for use on AC mains, where previous valves needed a battery supply for the filaments. Next is the pentode, designed by Philips to overcome the problems associated with tetrodes, together with pictures and details of the very first types. However, the tetrode underwent further development and beam tetrodes such as the 6L6 (RCA) and KT66 (GEC) are described in the following chapter.

Multiple filament valves which led to multi-element valves are covered in Chapter 10. Chapter 11 returns us to the diode with a short description of the developments which took place in detectors.

The radio theme is continued into the next chapter, all about frequency changers for heterodyne receivers. These valves had multiple grids, hexodes, heptodes and octodes, the type numbers will be recognisable to vintage radio collectors.

The author, having detailed the basic valve types, continues his survey in the next few chapters with the development of the different basing and bulb arrangements. Metal tubes come first and then the familiar Octal base. All-glass envelopes, which aided mass production, come next together with the politics surrounding their introduction. Chapter 15 describes a variety of power rectifier valves and their evolution to Tungar and Mercury vapour types as well as the later indirectly heated rectifiers such as the GZ34.

Chapter 21 returns the reader to the American independent companies, but this time the names are more familiar, Sylvania and Tung-Sol for example. Then the Australian and Canadian manufacturers are followed by a return to large British companies like Ediswan (Mazda), Marconi and Brimar. The smaller, independent British companies are in the following section: Ekco, Cossor, Hivac, Lissen and so on, all familiar to British set owners. Some more unusual manufacturers are also described. Following this is a chapter dedicated to Philips and their valves.

Valve development in the USA after WW2 is the subject of the penultimate chapter, also covering the American manufacturers’ attempts at cheapening valve production by manufacturing in Chile and Brazil. The final chapter is about valve collecting as a hobby.

This chronological look at valve evolution up to just after the Second World War has many monochrome pictures showing some really unusual valves, packaging and vintage advertisements. It is also interesting to read how now-familiar brand names came about, as well as the manufacturers that didn't make it in such a big way but were important historically. This book seems to be aimed at set owners and valve collectors more than hi-fi enthusiasts, but if you are interested in valve history it's for you.
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Bullock on Boxes is a collection of articles printed in Speaker Builder from 1980 onwards by author Bob Bullock. Although a professor of Applied Mathematics at Miami University, Bob Bullock’s explanations of vented and closed box systems are written in an informative, down to earth style with the emphasis on practicality.

But who will this book interest? Nowadays a lot of the basic box design for a loudspeaker is done on a PC. Simple box modelling packages are cheap and easy to use, giving fast and accurate results. But if you don’t have a PC, it doesn’t mean you can’t design your own loudspeaker cabinets. All manufacturers give Thiele-Small parameters with their drive units these days, and applying these with a few simple formulae will give you all of the design information you need, it just takes a little longer.

Bullock on Boxes gives you these equations and shows exactly how to manipulate them for the design you want. There are even design examples, textbook style, which clearly show how to manipulate the maths, calculate the data you need and interpret it.

The first chapter gives the reader a grounding in Thiele-Small parameters, without getting into heavy maths; ideal for the keen amateur who doesn’t need to plough through lengthy equations. A useful part of this first chapter is the description of Thiele’s work in determining a specific vented speaker system alignment for a given driver. This basically shows you what kind of bass response you get from a driver with a given Qts, which varies from 0.2 to around 0.65 for quality drivers. With a Qts of 0.38 it is possible to tune for a Butterworth 4th order alignment (B4), which gives the flattest response possible in the pass band. With a Qts above 0.38 the response will show some ripple before it rolls off (these are normally better suited to sealed enclosures where a flatter response is possible). Below 0.38 bass rolls early which would give light bass. This is useful stuff, showing that to get good bass and a flat response, the right driver parameters must be matched to the right type of cabinet alignment.

In the next article, Bullock describes in detail a method and the equipment needed to measure the Thiele-Small parameters for yourself. The method is fairly standard, and similar procedures can be found in The Loudspeaker Design Cookbook, amongst others. For most readers it will not be necessary to make these measurements, nearly all manufacturers supply a full set of Thiele-Smalls for their drivers nowadays. In Chapter 3 Bullock takes the vented box a stage further. There is a lot of useful practical advice here, well worth knowing before you buy your drivers. For example, he draws attention to the fact that the higher Q drivers need a larger cabinet volume for a given bass response than low Q drivers. So if you are aiming to design a compact enclosure with good bass, Qts should be low.

In places Bullock makes valid points, but they are not necessarily important in practical designs. He suggests that if you arrive at a given volume for a loudspeaker cabinet, the volume that the driver, port, bracing and so on take up should be allowed for. In practice this tends to be a very small percentage of the total volume, and leakage and absorption losses will further complicate things.

In other areas the author is very practical though, describing his method for making a removable baffle for experimentation. He goes on to describe a process of fine tuning, and which parameter; box volume, port size, etc. to vary to get the effect you want.

These first three chapters give the home constructor just about everything they need to competently design and tune their own loudspeaker cabinets. Chapter 4 goes on further to discuss alternative alignments and how they can be used to get specific response shapes. This is really for those with a perverse quest for knowledge, and isn’t necessary for DIYers just looking to design a good loudspeaker for themselves. It is useful information, but goes further than most will need.

The remainder of the articles, with the exception of Chapter 9 which discusses 6th order alignments (more for the boffins), concerns Boxresponse and Boxmodel, computer aided design packages that do a lot of the maths for you. But I suspect that this book will be of more interest to readers without access to a PC.

Last of all, Chapter 10 contains updates and correspondence from Speaker Builder readers, where many questions are raised and answered by Bullock, for example: how to apply Thiele-Small parameters when two drivers are used in the same box. All in all, Bullock on Boxes is a very comprehensive, readable and practical guide to all aspects of vented and sealed cabinet design, a must for enthusiast loudspeaker builders.
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DIY DAC KIT?
Congratulations and thanks for the feature on preamp valves in the DIY section of the April issue. It was very clearly written and pitched exactly at the right level for a reader like myself, who has built three of the World Design kits by following the ‘recipe’ but who seeks a bit of real ‘understanding’ of what the components are doing. I expect that you will produce a similar piece on power valves soon, and I for one will look forward to reading it.

One thing that interested me about your feature was that, despite your initial mild reproof of your friend’s approach of ‘just plugging in and listening’, your final comments about each of the valves were concerned with their sonic qualities. But how else could these be ascertained except by taking your friend’s advice?

I would be tempted to get out my soldering iron again if you could produce a DAC kit, because then I could claim to have built everything from front end through pre and power amps to speakers. But I note your (actually NK’s) reservations about the cost savings in digital circuit assembly. So if that is not on the stocks, what about a circuit for a single channel with variable components and headphone output, so that we could all ‘plug in and listen’ and also fiddle around with the component values to try and get a deeper understanding of the influence of each on the sound.

In any event, thanks again and keep up the high standard. It’s a real pleasure to read HW each month.

Don Dougall
East Nemphlar, Lanark.

Feature on power valves?
Now that’s a good idea, one so obvious we hadn’t thought of it!

Digital convertors work at up to 30MHz and can be very difficult things to design, especially in their mechanical layout. Philips Labs at Eindhoven, Holland, are quick to complain that their DAC chips often didn’t work properly in commercial products because of board layout problems arising from unsatisfactory design. If manufacturers can’t get it right, we’re doubtful that DIYers without test equipment can manage, making us reluctant to feature such things.

Ironically, the very fact that layout is such a problem has spurred chip makers to produce “evaluation boards” (examples of how you should do it), which DIYers can buy. Crystal evaluation boards are available from Electromail, for example. These demonstrate that even the electronics alone are not cheap.

We have tentatively discussed designing a valve one-bit convetsor, but the development costs and problems are too much for us at present. NK

BUILDING A LOWTHER SPEAKER
A few weeks ago I ordered two drive units from Lowther, their PM7s.

As I have no experience with Lowther, and can’t find tests in the leading Hi-Fi press, except in the latest issue of Hi-Fi World in form of the Thomas Tranducers Brio, my imagination ranges from very positive to scepticism. The idea is as follows. There were (I don’t know if they still exist) a few models in the past, all big (large) transmission line or horn loaded TP, Acoustic, Audiovector etc. that used Lowther drivers.

As I have no idea about the size and proportions, can you describe those models? Or if there are some drawings or tests from some Hi-Fi mags that can be of help before I decide which plan to purchase for building. So please describe for me the sound of each kit enclosure for Lowther drivers and if you can draw some connection with the new Bicor range.

I know it is a lot to request from you, but if I choose the wrong model to build, it’s financial and musical disappointment for me.

Marjan Vacev
Skopje, FYR Macedonia

If you contact Lowther on Tel: 0181 300 9166, they have a large range of cabinet drawings available to suit your drivers. If you let them know what kind of thing you’re after, what size your listening room is etc. they will be able to supply suitable plans for around £25. DB
IMPROVING K588I

I want to make some notes to improve the design of your K588I amplifier.

1) The supply of the EF86 input valve should be stabilised with three 68V/1.3W zener diodes. This not only improves the dynamic response of the amplifier, it helps also to solve another problem: if the amplifier is turned on, the potential on the grids of the ECC83s will rise up to 450volts (or more) until the tubes are warmed-up. In the original Mullard design this problem never existed, because the GZ34 rectifier valve delayed the plate voltage until the other valves are warmed-up.

2) Every electrolytic capacitor should be bypassed with a small polypropylene or polyester capacitor (rule of thumb: 1 percent of the capacity of the electrolytic). This improves not only the treble response, it also improves the quality of the "room reproduction" (paper-in-oil capacitors may work also for this, but I never tried.)

3) The power supply capacitors C12 - C15 should only be high quality types with screw terminals used. This will not only perform better (lower ESR), it will also last for many years.

4) If an output transformer with 4 and 16 ohms secondary taps is used, you can connect the 4 ohm tap to ground and use the 0 and 16 ohm taps for cathode feedback of the output valves. This not only improves control on the bottom end, it also improves coupling between the primary and the secondary of the output transformer. This will result in better submission of the resonant peak of the output transformer and greater bandwidth of the whole amplifier.

5) UL Taps should be offered as an option. The problem here is that 43% taps do not always work best. For example, the first commercial amplifier with ultra linear feedback (as described in Jean Hiraga's "Initiation aux Amplis a Tubes") invented by Hafler and Keroes used 18.5% UL taps for an output stage with two 6L6s very similar to the K588I. In my experience it works best if both UL taps and cathode feedback used together.

Karl Stephan
Frankfurt, Germany.

Many vintage amplifiers were built to a standard only found in the very best of modern day equipment. As you say, for the non-enthusiast, the expense of buying and restoring an old Leak or Marantz amplifier may come to a substantial amount of money and most would, at a basic practical level, be better off with a solid-state integrated. The restored vintage amplifier, however, is likely to outperform anything in the same price range, and then there is the pride of ownership commonly lacking in today's characterless products.

Regarding your comments on the K588I amplifier, I am afraid to say that you overestimate the capabilities of zener diodes, especially high voltage types (avalanche operation). A quick look at the specification for the 1.3W 68V zener you mention reveals it has a slope resistance of around 130ohms, so three in series would add up to 390 ohms.

DIY CD CONVERTOR

I have just finished the construction of a DAC using a Crystal CDB4328 evaluation board supplied by RS Components referred to in your June DIY supplement. I have recorded some notes that may be of interest to anyone who intends using the board as the basis for a DAC.

1. Obtain the application notes for the CS4328 chip from RS as it gives some valuable information that is not included with the evaluation board.

2. Before working on the board, observe the precautions for avoiding static discharge by making sure that you and any tools that you use are connected to earth. I use simple croc clip pads attached to my metal watch strap, soldering iron etc the other end of which is connected via a resistor to earth.

3. The board requires two power supplies analogue +/-15V and digital +5V. I chose to use two mains transformers (supplied via a lamp mains filter) for this, one toroidal O-9-0-9v for the analogue supply and a small 6V PCB mounted one for the digital supply. The board already has filtering and regulation for the analogue supply and only requires a rectifier and smoothing capacitors to be included in your circuit. For the digital supply a +5V supply can easily be constructed using a 7805 regulator. (You can also wire across from the analogue supply patch area, if you wish)

4. I used a black slimline case from RS to house the unit, they're are quite expensive but give a professional look to your project and exactly match the width and finish of some commercial hi-fi. I had to remove the binding posts from the board so that it would fit in the case. I suggest that you keep these in place during initial testing and then solder all connections later.

5. Jumper configuration caused some problems, but eventually I arrived at these settings: JP1 can be left as is, it only affects the on-board LED error display. JP2 should be set to 0. DIF1 (next to JP2) should be set to 1 (away from CS4328) and DIF0 to 0 (towards
expensive 300B project. Bypassing electrolytic capacitors is considered good practice in some circles and bad in others. It seems that bypassing can cause a change in the tonal colour of the amplifier when going from one frequency extreme to the other and for those who want absolute tonal consistency this is not acceptable. I find it is best to use a single very high quality unit, except possibly in the main power supply. In my personal projects, where commercial cost constraints don’t exist, I use only Black Gate (available from AudioNote) and BHC ALS20 electrolytic capacitors. The super high quality screw-terminal cans types you mention (such as BHC ALS20 or Philips-grade one) are better than the smaller axial types but are much larger and much more expensive, precluding their use in a budget design.

The K5881 amplifier is ideal for experimentation and owners may wish to try bypassing their electrolytics and assess the sound. Use 630V or 1000V rated units on the H.T. lines, available from Maplin. In fact, it would be possible to replace the smaller value electrolytics with polypropylenes from their range (if you can find room!). Expect a more open sound but, depending on which type of capacitor is used, also an increase in overall brightness and possibly aggressive treble.

The problem with using the impedance taps of an output transformer for cathode feedback is that they may not be symmetrically coupled to the primary. In most transformers they won’t be. This could lead to asymmetrical operation of the output valves at high frequencies, causing distortion and/or instability.

Also, using the taps in the manner you suggest only allows you to use 16 ohm speakers for fully balanced operation. Some amplifiers use this type of local feedback, such as the Quad II and MacIntosh amplifiers. Here though, the output transformers were specially designed with cathode feedback in mind. The MacIntosh used a unity coupled transformer with a bifilar winding, injecting 50% of the primary voltage into the cathodes. Some modern day American super-amps use linearising cathode feedback in the output stage, but with no global feedback.

Similar difficulties arise with Ultra Linear taps. The transformer needs to be designed around them because the taps must be very tightly coupled to the primary to avoid instability and H.F. distortion. This makes the transformer much more expensive, and as you say the commonly quoted 43% taps (which I believe came into being in the application notes for the KT66 and EL34 valves) are not always ideal. The optimum ratio must be calculated first, and then...
Regulated power supplies, super components, cathode feedback and Ultra Linear taps would make K5881 into a different, possibly better, but definitely more expensive amplifier. The basic kit can be used as it is or as a platform on which to try these and other modifications at minimum expense. A.G.

This sort of debate raises an important basic consideration of design outlook. My experience strongly suggests that elegant simplicity gives the best results. With K5881 I quite deliberately simplified and honed the circuit during development; a lot of components in the original circuit ended up on the floor.

Simple inspection of this sort of circuit doesn't reveal much, which might disappoint you and arouse a desire to bolt on goodies. You can, of course, do so and certain mods, mainly component substitution, do yield improvement. But most of the ideas you suggest are likely to be unnecessary and possibly retrogressive.

Most commercial valve amps operate with a 400V H.T. line, set purely by the 450V limit of electrolytic capacitors and the steep rise in cost of using stacked series caps. if this limit is to be exceeded. K5881 runs with a special 500V power supply electrolytic, which gives a 460V line. The output valves see a higher load impedance in consequence and operate more linearly. The output transformers were load matched using an FFT to give optimum performance at all frequencies (not just one spot frequency) giving optimal power transfer into a 6Ω nominal load (8Ω tap). Distortion falls at higher load values, giving unusually linear behaviour, helped by very high quality output transformers. Speaker matching is therefore excellent (the 4Ω tap is optimised to 2Ω and there's even a 16Ω tap). You talk about applying more feedback, but in truth it doesn't need it. Ultra-linear taps were tried and abandoned. This form of feedback skewed the transfer characteristic, modulating the distortion pattern to make third harmonic dominant at higher outputs. My findings were in line with Peter Walker's (Quad) and D.T.N. Williamson's observations on Hafler and Keroes claims (Amplifiers & Superlatives, J.A.E.S., Vol 2, No2, April 1954: "With up to 30% of the winding common to screen and anode the reduction in distortion is greater than the reduction in gain. This "something for nothing" is small however and can be lost or reversed if there is any appreciable unbalance". "Departure from ideal (in the output transformer) may mean that at high frequencies the circuit is not all it would appear and the effective sense of the coupling may be reversed, producing oscillation. "Even with transformers of the same nominal specification, wide variations in performance at high frequencies may occur owing to minor variations in the quality and thickness of insulants and in the positioning of windings". "The possibility of pitfalls is greatest in the output transformer and increases rapidly with the number of windings when all these must be close coupled". See our diagram (3) and explanation from the AES paper.

Hafler & Keroes 1951 claims for originality were refuted by Quad, by the way, who stated that a similar technique had appeared in Wireless World, April/May 1947 and that the Quad II amplifier contained a better variant, cathode coupled feedback. As it stands, because of the design approach adopted, K5881 produces just 0.02% pure second harmonic at 1W/1kHz and this rises smoothly but slowly as output power increases, a very benign characteristic. It's better as it is.

Feedback is an attempt to make a silk purse from a sow's ear. Where it exists in audio, by definition the basic circuit is not, at a most fundamental level, adequate for its purpose, the reproduction of music. If it is, then why are we trying to make it better using feedback? N.K.
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**RECTIFIERS**

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| **SOCKETS ETC**
| B9A (Chassis or PCB) | 1.60 | |
| B9A (Ch or PCB) Gold | 3.00 | |
| Octal (Ch or PCB)    | 1.80 | |
| 4 Pin (For 2A3, 300B) | 3.30 | |
| 4 Pin Jumbo (For 211 Etc.) | 11.00 | |
| 4 Pin Jumbo Gold (For 211 Etc.) | 15.00 | |
| 5 Pin (For 807)      | 3.00 | |
| 7 Pin (For 6C33C-B)  | 4.50 | |
| Screening Can (For ECC83 Etc.) | 2.00 | |
| Anode Conneeter (For 807 Etc.) | 1.50 | |
| Anode Conneeter (For PL519 Etc.) | 1.60 | |
| **MATCHING CHARGES** | £ | |
| POST & PACKING (UK) | £3.00 | |
| TOTAL EXC VAT | £ | |
| VAT @ 17.5% (UK/EEC ONLY) | £ | |
| TOTAL TO PAY | £ | |

Please make cheques payable to: 'CHELMER VALVE COMPANY' or pay by ACCESS/MASTERCARD/VISA Please give details: [Signature] [Exp. Date] Name: [Address]: [Post Code]:

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