Valve Final Amp (2)

Part 2: printed circuit boards and construction

Design by Bob Stuurman

This final amp is easy to build. The stereo version essentially consists of two amplifier boards, a power supply board for the high voltage and negative grid voltage, two output transformers and a power transformer. We have designed two printed circuit boards for building the final amp, but it can also be constructed in the 'old-fashioned' manner using solder turrets.

The chassis is made of aluminium and consists of two parts: an open-ended U-shaped channel section and a flat plate resting on top of the channel section. The channel section is fitted upside down, with the output transformers on top and the power transformer underneath. The combined weight of the transformers alone is more than eight kilos, and using a channel section gives the chassis adequate stiffness.

The rear wall of the channel section is aligned with the rear edge of the plate. All of the connectors are mounted on the rear wall, along with the master volume control. An IEC appliance socket with integrated filter, switch and fuse holder is used to keep the 230-VAC wiring to a minimum. There is no need for a pilot lamp, since the valves glow nicely when the amplifier is on.

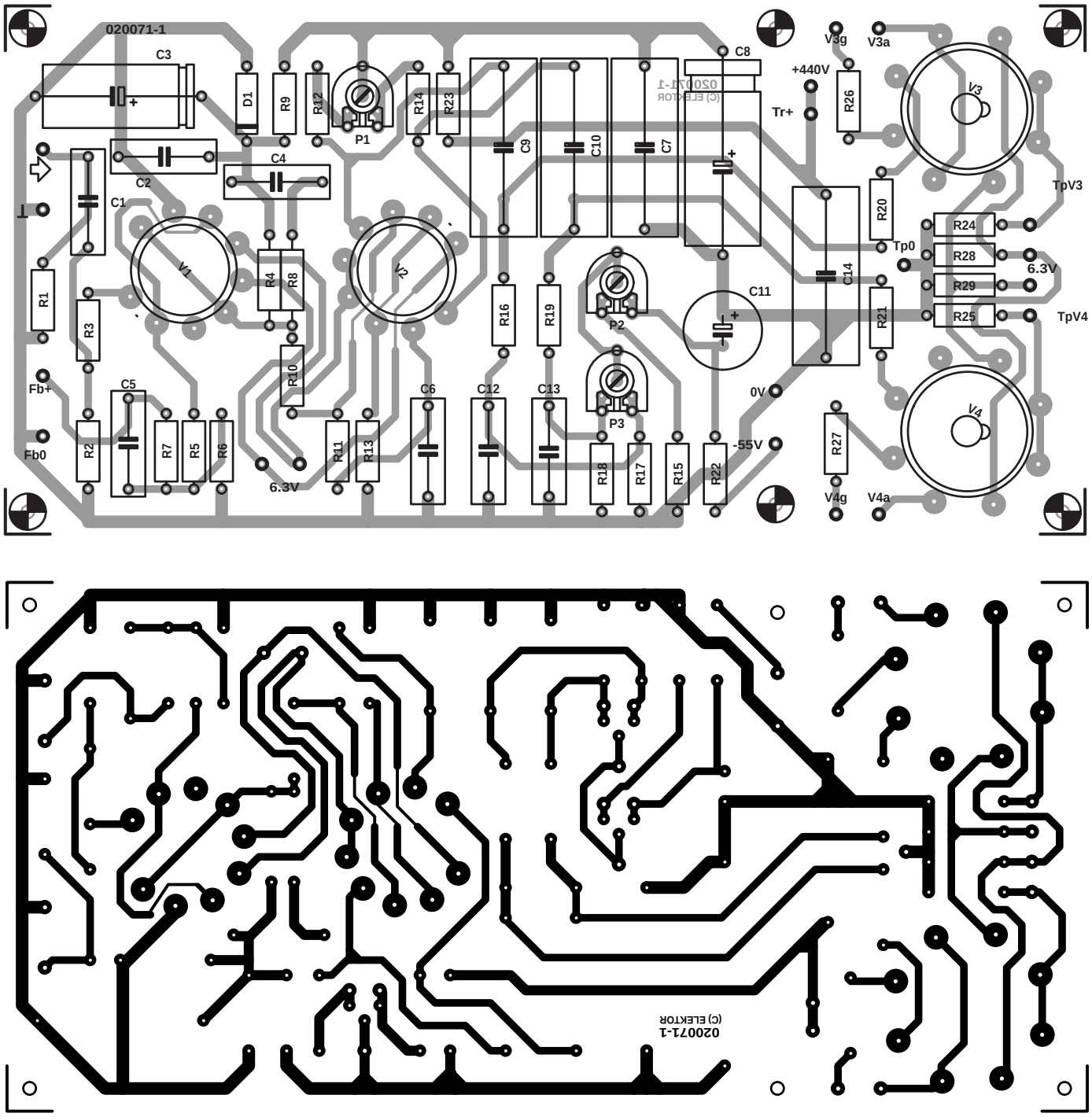


Figure 1. Copper layout and component layout of the printed circuit board for one amplifier channel.

Safety precautions

Hazardous voltages are present in this amplifier. The electrolytic capacitors in the power supply have a large capacity, so it takes quite a while for the high voltage to drop to a safe level after the amplifier is switched off. For this reason, you should connect two 230-V 15-watt incandescent lamp bulbs in series across the high voltage while the amplifier is being tested. As soon as the mains voltage is switched off, they will discharge the electrolytic capacitors in a few seconds, and they will have practically no effect on the operation of the amplifier.

Amplifier construction

The copper track and component layouts of the amplifier printed circuit board are shown in **Figure 1**. The only component that is not included on the board is the output transformer. The circuit board is single-sided, and using the artwork shown here (and available from our website) some of you will be able to make it themselves. However, the board it is also available ready-made from Readers Services (order number **020071-1**). Two of these boards will be needed for a stereo version of the amplifier.

All connections to the circuit boards are

COMPONENTS LIST

Amplifier (one channel)

Resistors:

All fixed resistors: metal film, Beyschlag type MBE0414 or BC Components type PR-02, dim. 4x12 mm.

R1,R2,R11 = 1MΩ
R3 = 4kΩ7
R4,R17,R18 = 47kΩ
R5 = 390Ω
R6,R22,R28,R29 = 100Ω
R7 (LS = 8Ω) = 3kΩ3
R7 (LS = 4Ω) = 2kΩ2
R8 = 27kΩ
R9 = 100kΩ
R10,R26,R27,R30 = 1kΩ
R12,R14 = 150kΩ
R13 = 82k
R15 = 15kΩ
R16,R19 = 390kΩ
R20,R21 = 2kΩ2
R23 = 10kΩ
R24,R25 = 10Ω
P1 = 50kΩ preset
P2 = 10 k preset
P3 = 20 k preset
(All presets: Bourns type 3386P)

Capacitors:

All film capacitors: Wima type MKS4, unless indicated otherwise.

C1 = 470nF 100V, lead pitch 15mm
C2 = 100nF 400 V, lead pitch 15mm
C3 = 10µF 350V or 450V, axial, dim. 12x25 mm
C4 = 100pF 630V, polypropylene, dim. 5x11 mm
C5 (for LS 8Ω) = 680pF 630V, polypropylene, dim. 5.5x15 mm
C5 (for LS 4Ω) = 1000pF 630V, polypropylene, dim. 5.5x15 mm
C6,C12,C13 = 220nF 250V, lead pitch 15mm
C7,C14 = 470nF 630V, lead pitch 27.5 mm
C8 = 10µF 450V, axial, dim. 15x30 mm
C9,C10 = 100nF 630V, lead pitch 22.5 mm
C11 = 470µF 63V, radial, dim. 12.5x25 mm

Semiconductors:

D1 = 200 V 1.3 W zener diode

Valves:

V1 = EF86 (US: 6267)
V2 = ECC83 (US: 12AX7)
V3,V4 = EL34 (US: 6CA7), matched

Miscellaneous:

2 noval (9-way) valve sockets, ceramic
2 octal (8-way) valve sockets, ceramic
Tr1 = output transformer, Lundahl type LL1620 P-P
PCB, order code **020071-1** (see Readers Services page)

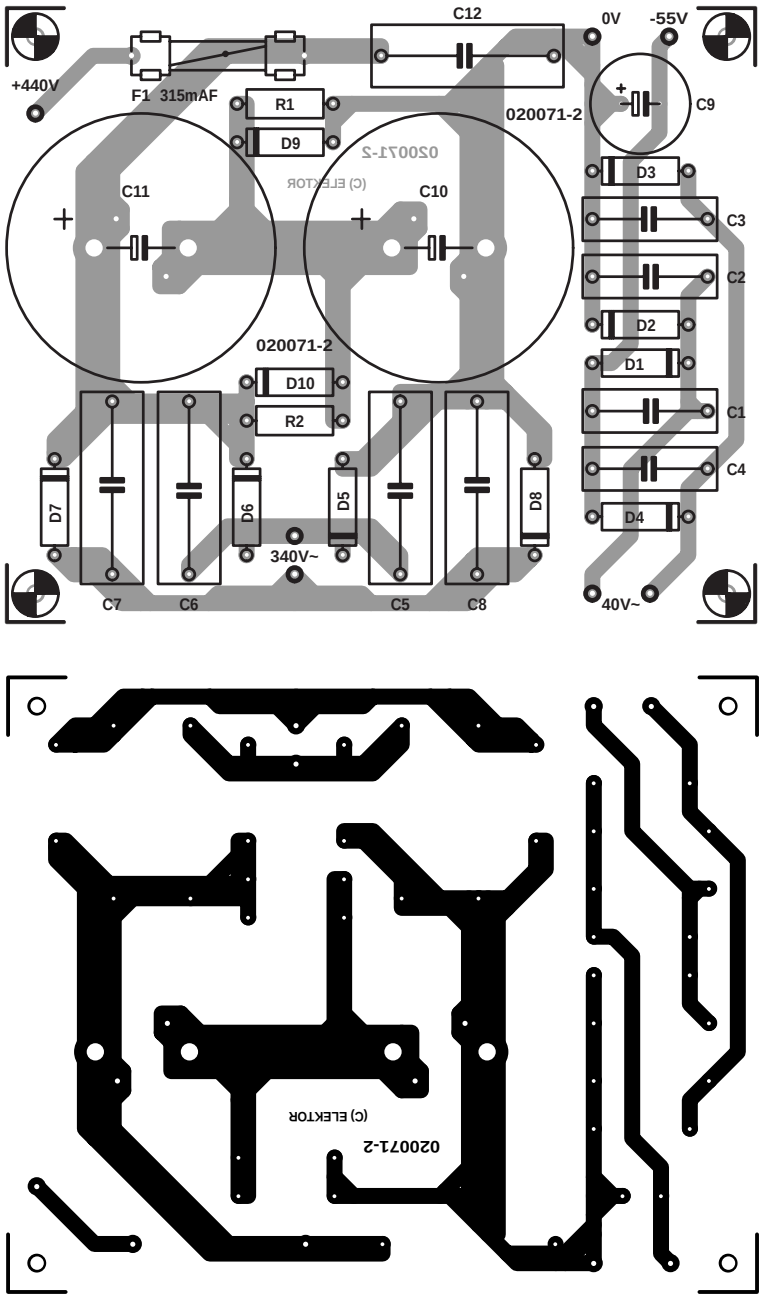


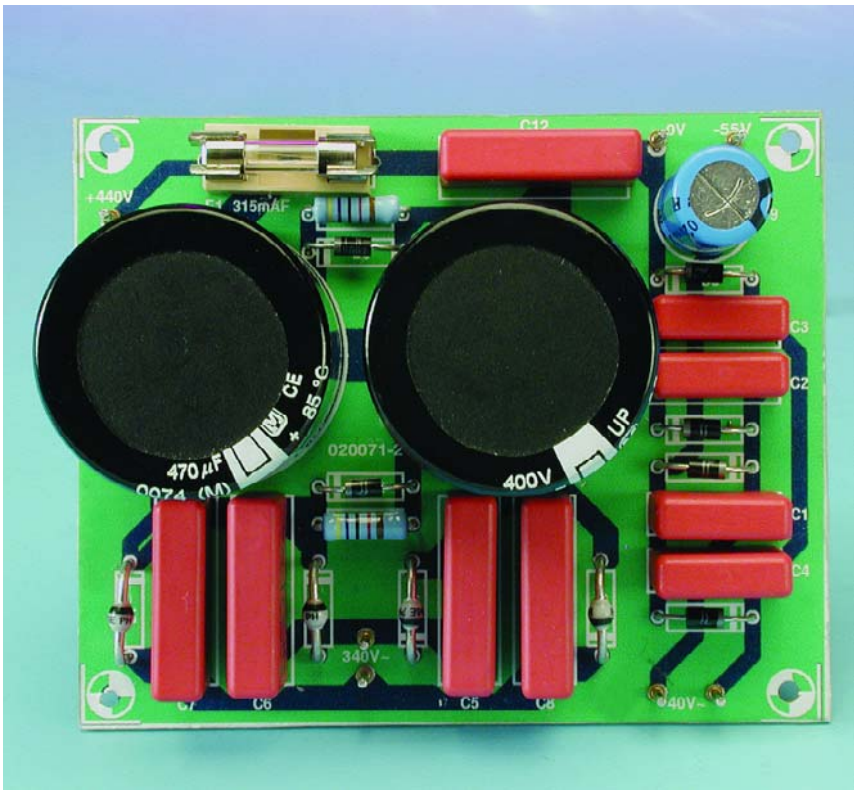
Figure 2. Copper layout and component layout of the printed circuit board for the power supply.

made using solder posts with a diameter of 1.3 mm and matching connectors. Noval valve sockets are used for V1 and V2. These sockets are available in plastic and ceramic versions; the circuit board has been designed for the ceramic version.

Ceramic octal sockets are used for V3 and V4, the EL34s. They have solder tabs with a width of 2 mm and a thickness of 0.5 mm. In order to allow the sockets to be fitted flat against the circuit board, the drilled holes for the solder tabs must be widened somewhat by (mis)using a circuit board drill as a routing bit.

The circuit board has six mounting holes, which allow it to be firmly attached to the base plate. This provides extra support for the portion holding the output valves.

If you stick to the parts shown in the components list, building the printed circuit board is a breeze; everything fits perfectly. The PR-02 resistors from BC Components (formerly Philips) are 1% types and have four colour-coding bands.



Since it can be difficult to read their values from these bands, it's a good idea to always check them with an ohmmeter.

The valve sockets are soldered to the copper side of the circuit board. In order to align the individual contacts properly while soldering them in place, you should insert the valves in the sockets. When fitting the octal sockets, be careful to orient the notches properly. The sockets will 'fit' in all possible orientations, and it's next to impossible to remove a socket once it's been soldered in place.

The single-sided printed circuit board for the power supply (**Figure 2**) is available from Readers Services under order number **020071-2**. Here again, 1.3-mm solder posts with matching connectors are used. Building the power supply board is so simple that we don't need to say anything about it, except to remind you to watch the polarity of the diodes and electrolytic capacitors.

Building the amplifier

The dimensions of the chassis plate and channel section are shown at the lower left of the wiring diagram (**Figure 3**). The channel section is made from a piece of aluminium sheet 370 mm long and 290 mm wide, with its long edges folded to form a U-shaped channel with 80-mm walls.

The convenient feature of this chassis is that the channel section and plate can be prepared separately. However, some of the holes must be made in both the channel section and the plate, which requires the two parts to be temporarily bolted together. For this purpose, you can drill holes for 2-mm screws inside the outlines of the transformer covers.

For the next stage, you will need paper templates, preferably made from tracing paper. The templates for the amplifier boards and the power supply board can be made by simply copying the component layouts, since they show the dimensions of the circuit boards and the locations of the mounting holes. For the output transformers and their covers, you will have to make a drawing showing the outside dimensions (of the cover) and the locations of the drilled holes. The template for the power transformer consists of a circle and its centre point. Make templates for

COMPONENTS LIST

Power supply

Resistors:

R1,R2 = 47kΩ (Beyschlag type MBE0414 or BC Components type PR-02, dim. 4x12 mm)

Capacitors:

C1-C4 = 100nF 400V, lead pitch 15 mm
C5-C8 = 100 n/1000 V, lead pitch 22.5 mm
C9 = 470µF 63V, radial, lead pitch 5 mm, dim. 12.5x25 mm
C10,C11 = 470µF 400V, radial, lead pitch 10 mm (e.g., Roederstein series EYS)
C12 = 100nF 630V, lead pitch 22.5 mm

Semiconductors:

D1-D4,D9,D10 = 1N4007
D5-D8 = BYW96E

Miscellaneous:

Fuse, 315 mA (fast) with PCB mount holder
Mains transformer, secondaries 340V at 0.7A, 6.3V at 6.8A and 40V at 0.1A (Amplimo # 7N607)
PCB, order code **020071-2**

Miscellaneous parts

IEC mains appliance socket with integral filter, switch and fuse holder, fuse 1.5A(T) (time lag)
2 NTC-resistors, 5 Ω 5 W (Amplimo or Conrad Electronics)
Audio potentiometer, 100kΩ stereo, logarithmic law (e.g., Alps type RK-27112) with knob
2 cinch sockets, chassis mount (isolated)
2 binding posts, red (isolated)
2 binding posts, black (isolated)
Terminal block strip
Covers for output transformers

SUGGESTED SUPPLIERS

Lundahl transformers

Lundahl Transformers AB, Tibeliusgatan 7, SE-761 50 Norrtälje, SWEDEN. Tel. +46 176 139 30, Fax +46 176 139 35.
Distributor overview at www.lundahl.se

Valves and valve sockets

Chelmer Valve Co. (www.chelmervalve.com),
Conrad Electronics (www.int.conradcom.de),
Amplimo (www.amplimo.nl)

PR-02 resistors

Farnell (www.farnell.co.uk),
C-I Electronics (www.dil.nl)

MKS capacitors

Farnell (www.farnell.co.uk),
C-I Electronics (www.dil.nl),
Conrad Electronics (www.int.conradcom.de)

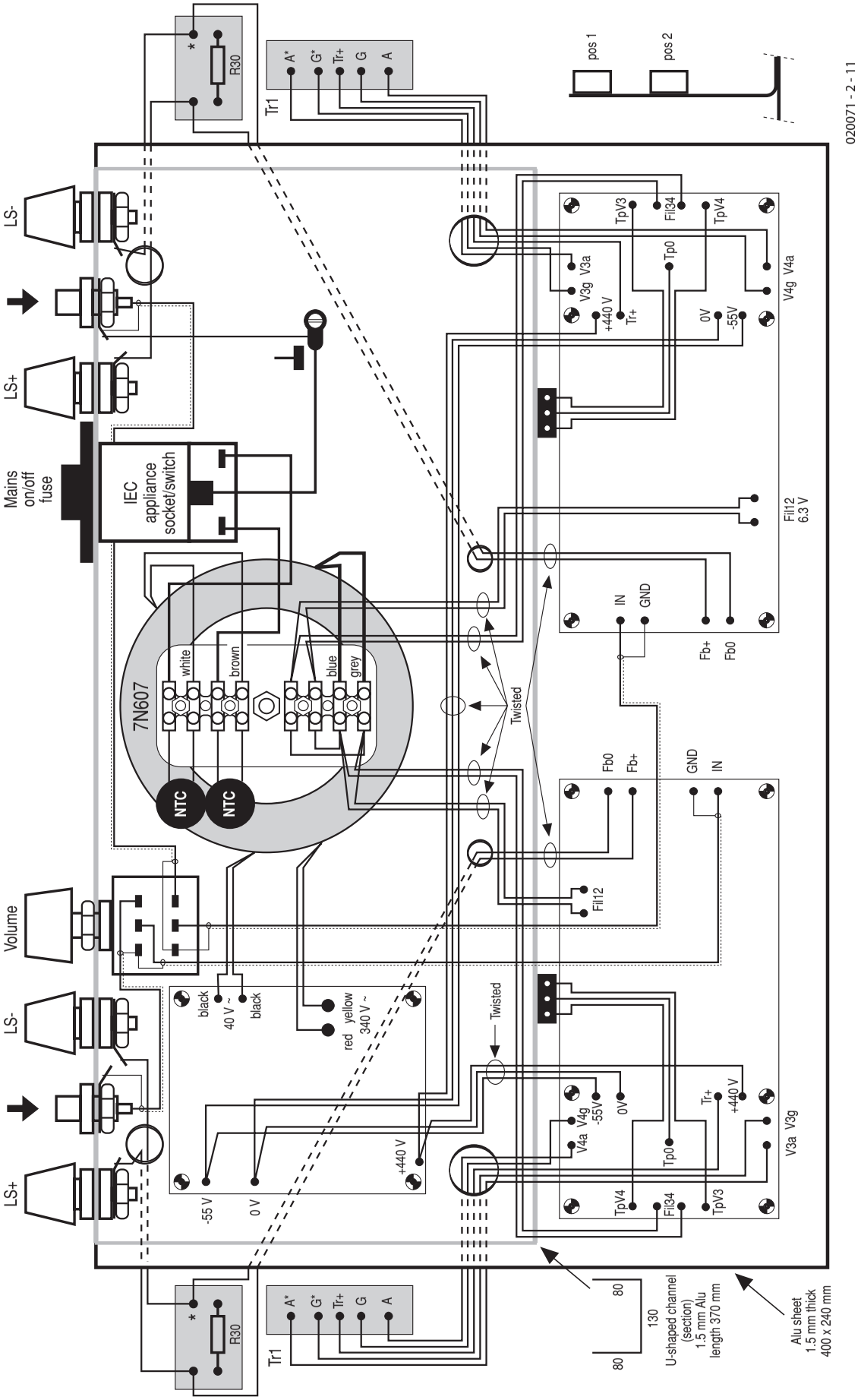


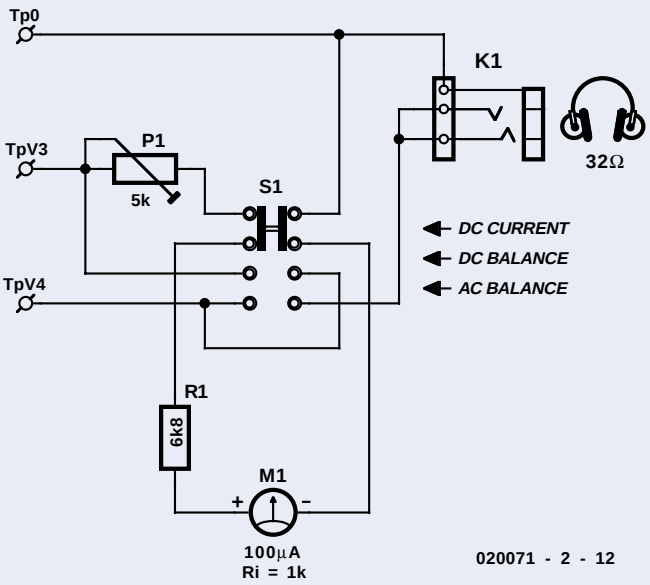
Figure 3. Sample wiring diagram and mechanical layout (bottom view) for a stereo amplifier.

Alignment

An 8-Ω or 4-Ω load, as appropriate, must be connected to the loudspeaker output of the amplifier during alignment and whenever measurements are being made on the amplifier. Several power resistors attached to a heat sink can be used for this purpose. If the amplifier is not loaded, arcing can occur in the output transformer, possibly resulting in a defective transformer.

The output valves are not self-biasing, since a negative grid voltage is used instead of cathode bias resistors. Consequently, they should preferably be purchased as matched pairs.

The following items must be aligned in the order listed: DC current, DC balance and AC balance. The characteristics of the valves change as they age, so it is advisable to check the settings every two weeks at first, and after that every two months. The current through the output valves fluctuates somewhat, which makes it difficult to use a digital voltmeter to make the adjustments. An analogue moving-coil meter is much easier to use for this purpose. Since the adjustments need to be made repeatedly, an alignment aid is a handy accessory. For this purpose, a pair of three-way female headers (one for each amplifier board) can be fitted in convenient locations using double-sided adhesive strips. The middle contact is connected to Tp0, and the outer contacts are connected to TpV3 and TpV4, respectively. The alignment aid can then be connected using a length of cable with a 3-way circuit-board header.



The current flowing through each EL34 should be 50 mA (combined anode and screen-grid currents). This yields a power dissipation of around 22 W for each valve. At this level of current, the voltage across the cathode resistor of each valve will be 0.5 V.

The circuit diagram of the alignment aid is shown next to this box. It also has to be aligned before it can be used. To do so, connect a DC voltage of 0.5 V to terminals Tp0 and TpV3 of the alignment aid and set S1 to the topmost position ('DC current'). Then adjust P1 until the meter shows a value of 50 (read mA for µA).

When S1 is in the 'DC balance' position, the circuit measures the voltage between TpV3 and TpV4. If the currents through the two valves are equal, the meter reading will be 0. The nice feature of this circuit is that it has higher sensitivity for this adjustment, since the only series resistance is provided by R1.

When S1 is in the 'AC balance' position, TpV3 and TpV4 are tied together and connected to a headphone plugged into K1. The alignment signal can be heard using the headphone.

Adjusting the DC current and DC balance

On each amplifier board, first set P1 and P3 to their midrange positions and rotate P2 fully counter-clockwise, so that the negative grid voltage has its maximum negative value. Connect the alignment aid with its switch set to 'DC current,' and then switch on the power. Wait a few minutes, and then adjust P2 for a meter reading of 40 mA. Next, change S1 to the middle position ('DC balance') and adjust P3 to obtain a meter reading as close as possible to 0. After the amplifier has warmed up for ten minutes, you can increase the DC current to 50 mA and tweak the DC balance as necessary.

Adjusting the AC balance

The AC balance of an amplifier is usually adjusted using a distortion meter. Mr Byrith has devised a method to allow this be done using an audible signal. Set the switch to the 'AC balance' position and connect a sine-wave signal to the input of the amplifier (1 kHz / 100 mVrms). While listening to this signal with the headphones, rotate P1 until the 1-kHz tone is as weak as possible. You will also hear mains hum and harmonics of the sine-wave signal, and the loudness of the signal will fluctuate, but it is certainly possible to find a setting where the 1-kHz tone is at a minimum. The signals on the cathodes have opposite phases, and when they are in balance they have equal amplitudes. Clever thinking!

Square-wave alignment

Capacitor C5 in the feedback loop corrects the phase lag. If its value is a bit too small, the corners of a square-wave signal will be rounded off, and if its value is a bit too large, the corners will have overshoots. You need to have access to a square-wave generator and an oscilloscope if you want to check and/or adjust the square-wave response.

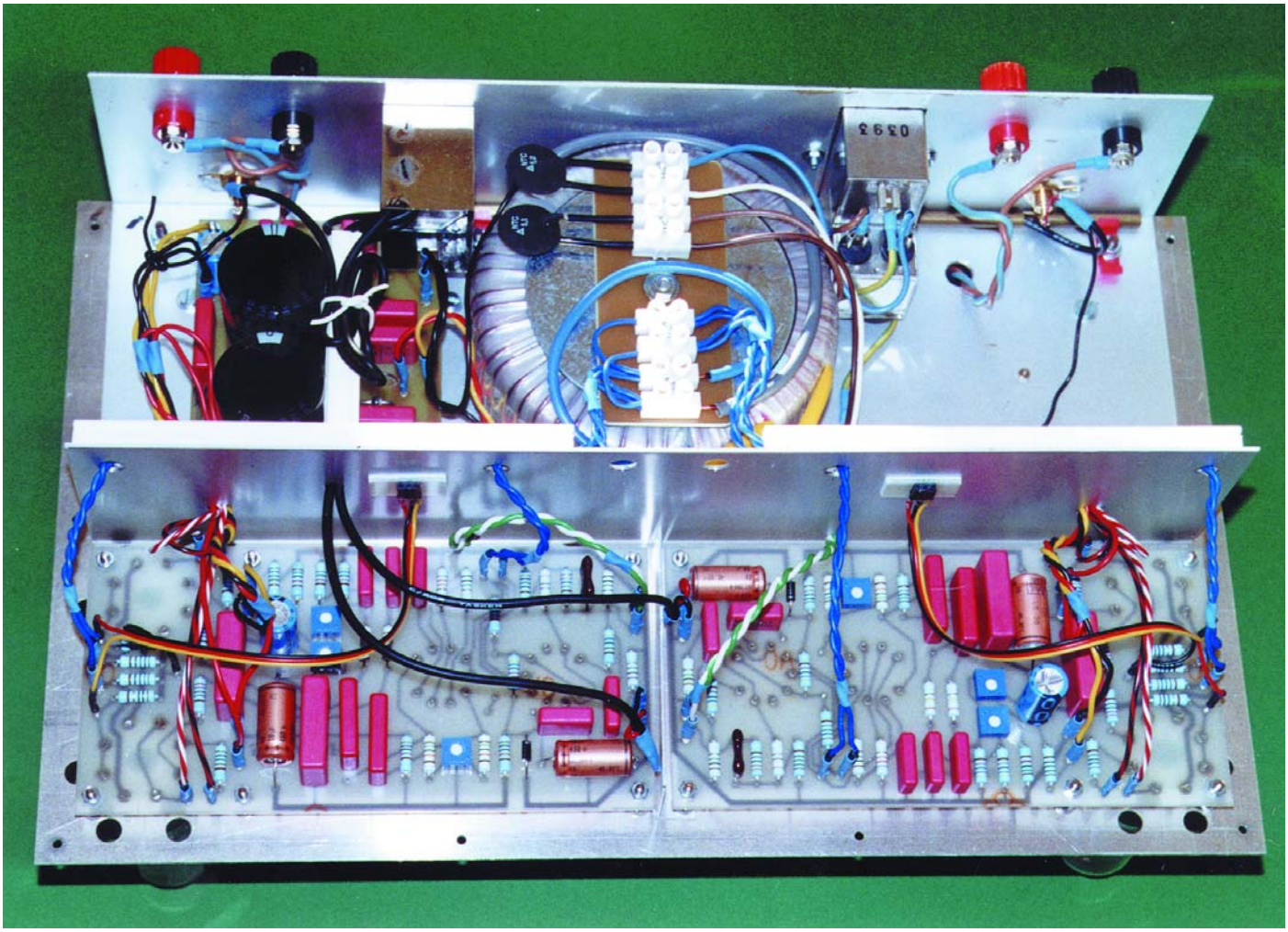


Figure 4. Bottom view of the fully assembled amplifier.

the IEC appliance socket and the Alps volume control as well.

Tape the templates to the chassis plate such that the amplifier boards are spaced 13 mm from the front and side edges (this clearance is required for the supporting strips in the case). The fixing nuts for the transformer covers must fit inside the channel section. Align the C cores with each other, and position the power transformer in the middle of the channel section.

Now you can centre-punch and drill all of the holes. For each output transformer, two holes are needed to allow the wiring to pass through the chassis. If they are drilled within the outline of the cover, they will be hidden when the assembly is finished.

Drill six holes with a diameter of 8 mm around the openings for the output valves to allow cooling air to flow past the EL34s, since they become rather hot.

Run the wiring for the filament supply in a length of small cable duct stuck to the inside of the front wall of the channel section ('pos 1' in the detail at the lower right of the wiring diagram). Make feedthrough openings at the positions of the filament connections on the circuit boards.

Run the wiring for 0 V, –55 V and +440 V in a second small cable duct located at 'pos 2'.

Attach the amplifier boards to the chassis plate using 10-mm standoffs. Adjust the separation between the boards and the plate using shim washers so that the sockets for the output valves are firmly pressed against the top plate. Fit the power supply board using standoffs as well.

Fit an aluminium screening plate between the amplifier boards, and use a sheet-metal enclosure to screen the Alps volume control.

Testing

As long as the amplifier boards are not yet fitted, everything is easily accessible. In order to test the amplifier boards, it's convenient to first assemble the power supply portion. Fit the power transformer and the power supply circuit board to the channel section, along with the IEC appliance socket. Install a 1.5-A slow-blow fuse. In our amplifier, we fitted two four-way connector strips to a piece of epoxy board using countersunk 3-mm screws, and then secured this board to the fitting screw for the power transformer using an extra nut. The lower set of terminals (as shown in **Figure 3**) is for the filament wiring.

Practically all of the wiring, except the heavy leads for the loudspeaker terminals, consists of 0.5-mm^2 flexible hookup wire with various colours of insulation. Three such wires can be easily fitted into a connector strip terminal.

The four upper connector-strip terminals are used to connect the primary leads of the power trans-

former to the IEC appliance socket. An NTC resistor is placed in series with each lead, in order to reduce the switch-on surge. They are not absolutely necessary, but they are a simple and effective way to achieve a 'soft' switch-on.

Once the wiring interconnecting the IEC appliance socket, mains transformer and power supply board is finished, you can begin testing by checking the power supply by itself. First connect the two 230-V/15-W incandescent lamps in series between the +440 V and 0 V terminals, and then switch on the power. If the lamps light up brightly, you can then (carefully!) check the high voltage and negative grid voltage.

After switching off the power, connect the loose amplifier boards to the power supply and output transformers. Before applying the high voltage, first check that the filaments of the valves light up. With the EF86, you can see this by looking in from the top, although it is a bit tricky. Next, switch off the power and remove the output valves, and then connect the high voltage leads. Switch on the power and allow the EF86s and ECC83s to warm up, and then check the voltages on these valves. Small variations from the nominal values are possible, but a major deviation means that there is probably an incorrect resistor value somewhere.

If everything is OK, switch off the power and plug in the output valves. Now you can perform a preliminary alignment of the amplifier (see the 'Alignment' box). After this, you can fit the amplifier circuit boards in the enclosure and route the rest of the wiring.

Finishing

Such a nice amplifier naturally deserves an attractive wooden case. We made our case from lengths of 9-mm multiplex board, after finishing off the openings in the chassis plate and channel section. There are two rectangular openings in the back of the case for the connectors and volume control. Our case is finished with veneer, but it would naturally also be possible to build a case using solid wood. Self-adhesive feet are fitted below the channel section.

Even without a case, the amplifier sits quite stably on the walls of the aluminium channel section. If strips of wood are taped onto the transformer covers, the completed amplifier, with the valves installed, can also be placed upside down on top of a table. This makes it easy to access all of the circuitry, and it is also convenient for fitting a wooden case.

The bottom of the case can be closed with an aluminium plate if desired. If you use such a plate, be sure to earth it, and drill openings for cooling airflow.

It's a good idea to switch on all the other equipment in your audio system before switching on the final amp, in order to avoid a switch-on 'thump'.

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