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LOUDSPEAKER TEST JIG

Use your PC's sound card to measure loudspeaker performance, inductors, capacitors and complex impedances. With this Jig and appropriate software, measuring and tweaking crossovers, cabinets and speakers is easy.

When designing or building loudspeakers, you need a good microphone and test setup and the ability to measure the impedance of the loudspeaker driver and crossover parts. You can do this at home with our *Loudspeaker Test Jig*, without breaking the bank.

It is an interface to your PC, allowing you to measure complex impedances, which is important when building crossovers. This is one job where even the best multimeter doesn't help, as impedance is frequency dependent, with real and imaginary components. The *Test Jig* also connects to a microphone for analysing loudspeakers.

Fig.1 is the impedance and phase plot of a 12-inch (305mm) driver, a PA bass-mid with a resonant frequency of 60Hz. The dotted phase line goes through an inflection at this frequency, from about +55° degrees to -55°.

It is possible to make this sort of plot using an oscilloscope and graph paper, but your PC and sound card can make this sort of measurement in seconds with our *Test Jig*. Eric Wallin is credited with originating the basic concept of the 'Wallin Jig', shown in Fig.2. It is the de facto standard for PC-based speaker testing.

It uses the left output channel of the sound card output to drive a signal through a reference resistor and the device under test (DUT). The left input channel measures the voltage across both the reference and DUT, while the right input channel measures the voltage across the DUT alone.

For a complete test setup, you need:

- A PC or Mac with a sound card
- Test software. We recommend 'Room EQ Wizard' (REW, Windows/Mac) or the old but good 'Speaker Workshop' (Windows only). Both are available for free.
- A measurement microphone
- The *Loudspeaker Test Jig*, which includes:
  - An audio power amplifier of a few watts
  - A microphone preamplifier
  - A reference resistor of a few watts capacity that is 'calibrated'
  - A switching arrangement

It is also very useful to have:

- A monitor output for the audio input to the *Test Jig*, allowing both monitoring and regular use of the sound card when not testing
- An oscilloscope to monitor the microphone signal on the front panel

Two handy features this design provides are floating power for the *Test Jig* to avoid earth-loop-induced hum and switchable gain on the input and microphone to allow for 'near field' and 'far field' tests.

Features and Specifications

- Measures loudspeaker driver frequency and phase responses
- Measures loudspeaker relative SPL (absolute SPL possible with external calibration sources)
- Time alignment of loudspeaker drivers in combination with an oscilloscope
- Measures the impedance of loudspeakers, crossover networks
- Measures the value of capacitors, inductors (μH to mH range) and resistors
- Incorporates a microphone preamplifier and small power amp
- Frequency range: 10Hz to 20kHz (depending on your sound card)
- Power output; about 5W peak into 8Ω (not continuous due to power supply limitations)
- Amplifier gain: switchable between +14dB and +34dB
- Common-mode rejection ratio (CMRR): >60dB on prototype (20Hz to 20kHz)
- THD+N: <0.01% across the audio range
- 50/100Hz hum: more than 100dB below full-scale
- Microphone phantom power: 48V, selectable via header on PCB
- Power supply: 15V AC @ 1.2A from a plugpack (no mains wiring)

Software support

The software does the heavy lifting in this design. The most current program that can be used is 'Room EQ Wizard' (REW), currently in development and available at: **www.roomeqwizard.com** – we tested V5.20.13. For Mac users, this is a good option. We'll focus on this program as it is the most actively supported.

A surprising but excellent option for Windows users is 'Speaker Workshop', which has been around for over 20 years. It is dedicated to designing and building loudspeakers and, among other things, can measure Thiele-Small parameters accurately and simply.

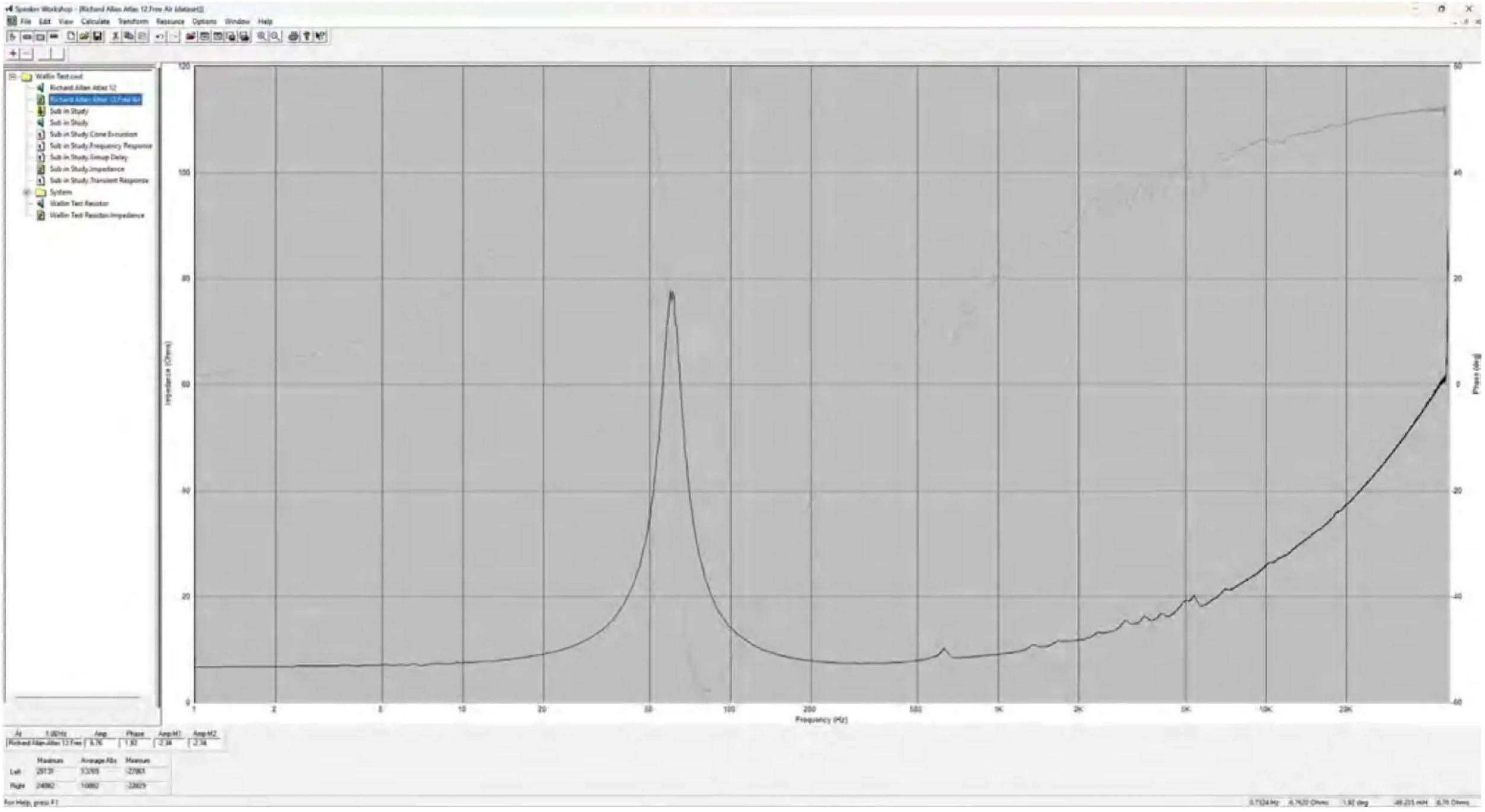


Fig.1: the magnitude and phase of the impedance of a loudspeaker bass driver in free air. You can see the high impedance peak close to 80Ω at 60Hz and the rapid change in phase around there.

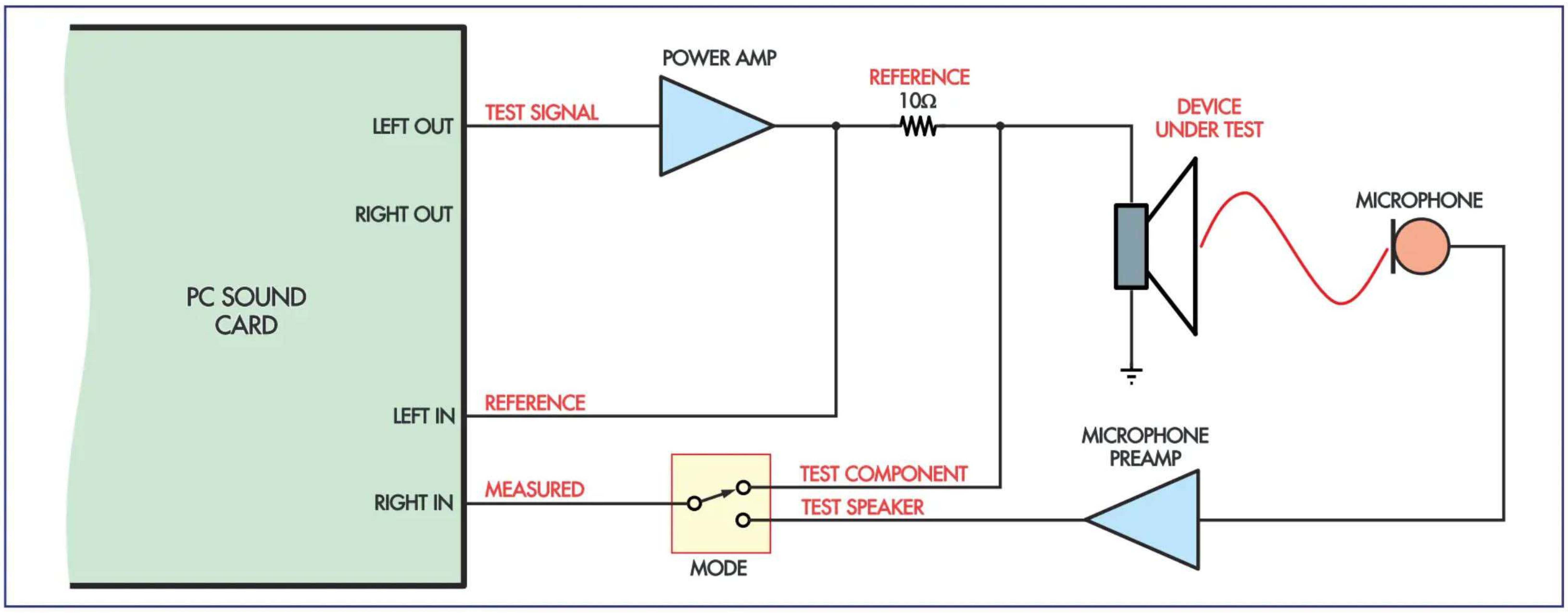


Fig.2: the basic arrangement for measuring impedance. Conventionally, the power amplifier and microphone preamplifier are standalone devices, wired to the 'Wallin Jig'. Our new design incorporates everything you need into one, handy, compact unit.

Sadly, it hasn't been upgraded since about 2001. Even though it gives a warning message on startup, this remains a brilliant tool and is worth checking out. The last version is V1.06 and is available from the download page at: **www.claudionegro.com**

These programs perform measurements in slightly different ways but ultimately deliver similar results. REW uses a swept sinewave to make measurements, while Speaker Workshop uses a noise pulse. Both programs perform Fourier transforms and compare the reference to the measured signals to calculate either the speaker frequency response or the impedance of the DUT.

Our *Loudspeaker Test Jig* provides the amplification and switching to allow these programs to work. We have kept it as simple as practical. It would be possible to add more switching for attenuators and reference resistors, but as we will show in the 'how to use this' article, they would be gilding the lily and make it harder to use than necessary. You could easily add more switching externally if you wish.

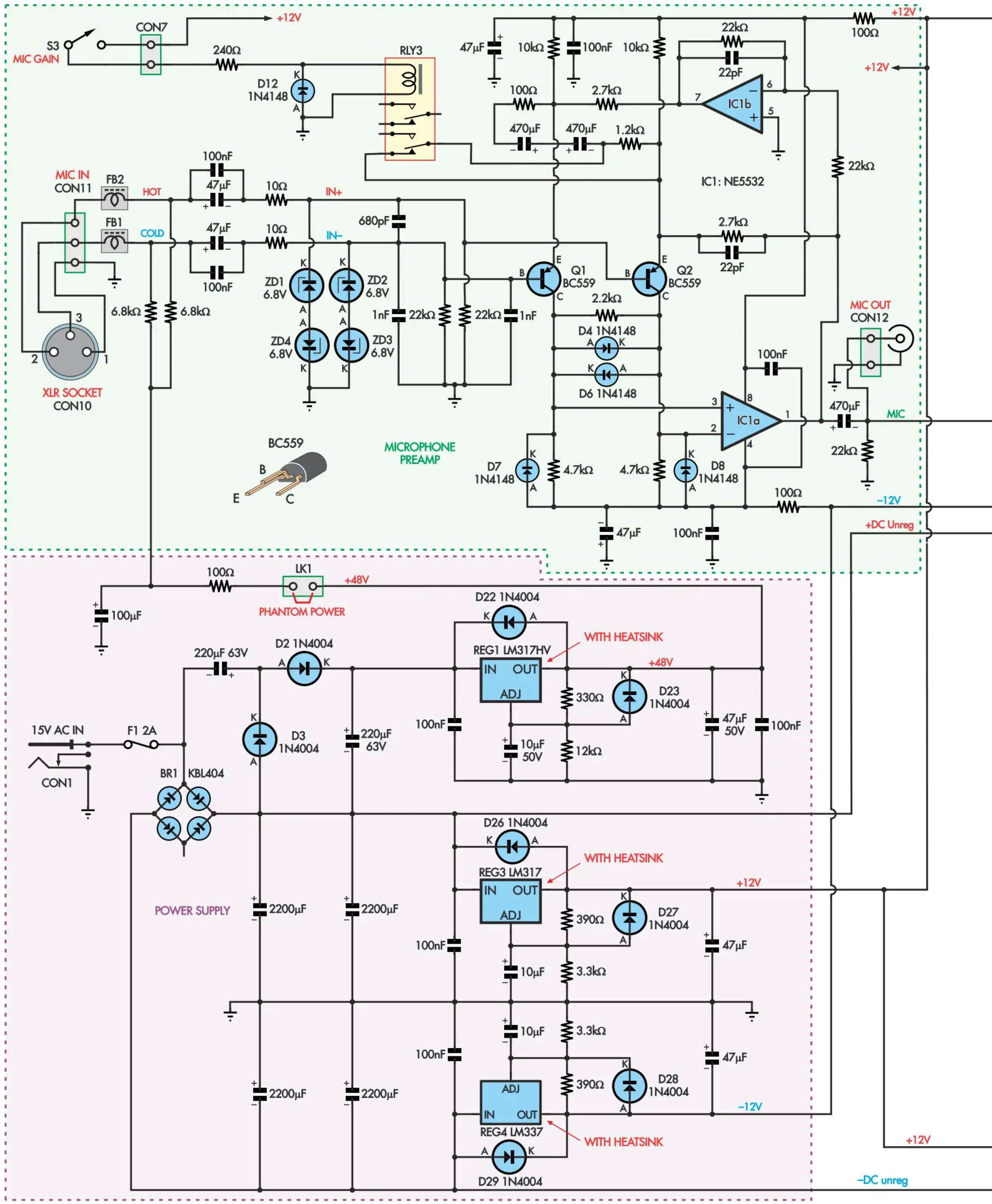
Microphone selection

As for the microphone, you need a measurement microphone. The Shure SM58 has a shaped frequency response and is unsuitable for this job. At the low end, you can buy a Behringer ECM8000 for about £30 or a Dayton Audio EMM6 with calibration data for about £80. Alternatively, it is easy to build an excellent measurement mic very cheaply indeed, which will be the subject of an upcoming project.

Circuit description

The full circuit is shown in Fig.3, and it has five main sections: the power amplifier, microphone preamplifier, input buffer, switching and power supply, shown as shaded areas.

While some of these sections connect to each other, besides the power supply, they primarily operate as independent blocks. The power amplifier is used to drive the loudspeaker being tested, while the microphone preamplifier picks up the radiated sound and converts it to a signal that can be analysed. The input buffer allows the



Loudspeaker Test Jig

sound card's outputs to be monitored while one is fed to the power amplifier.

The switching section determines whether the output of the mic preamp or sense input is fed to the computer sound card's inputs. It also provides switchable attenuation for the sense input and switchable gain for the amplifier.

Power amplifier

We don't need a substantial power amplifier; the LM1875 IC is commonly available and requires minimal parts to work. It needs to be able to drive a loudspeaker at a modest volume and be tolerant of abuse, which can happen with this sort of equipment. You would never short the amplifier, would you?

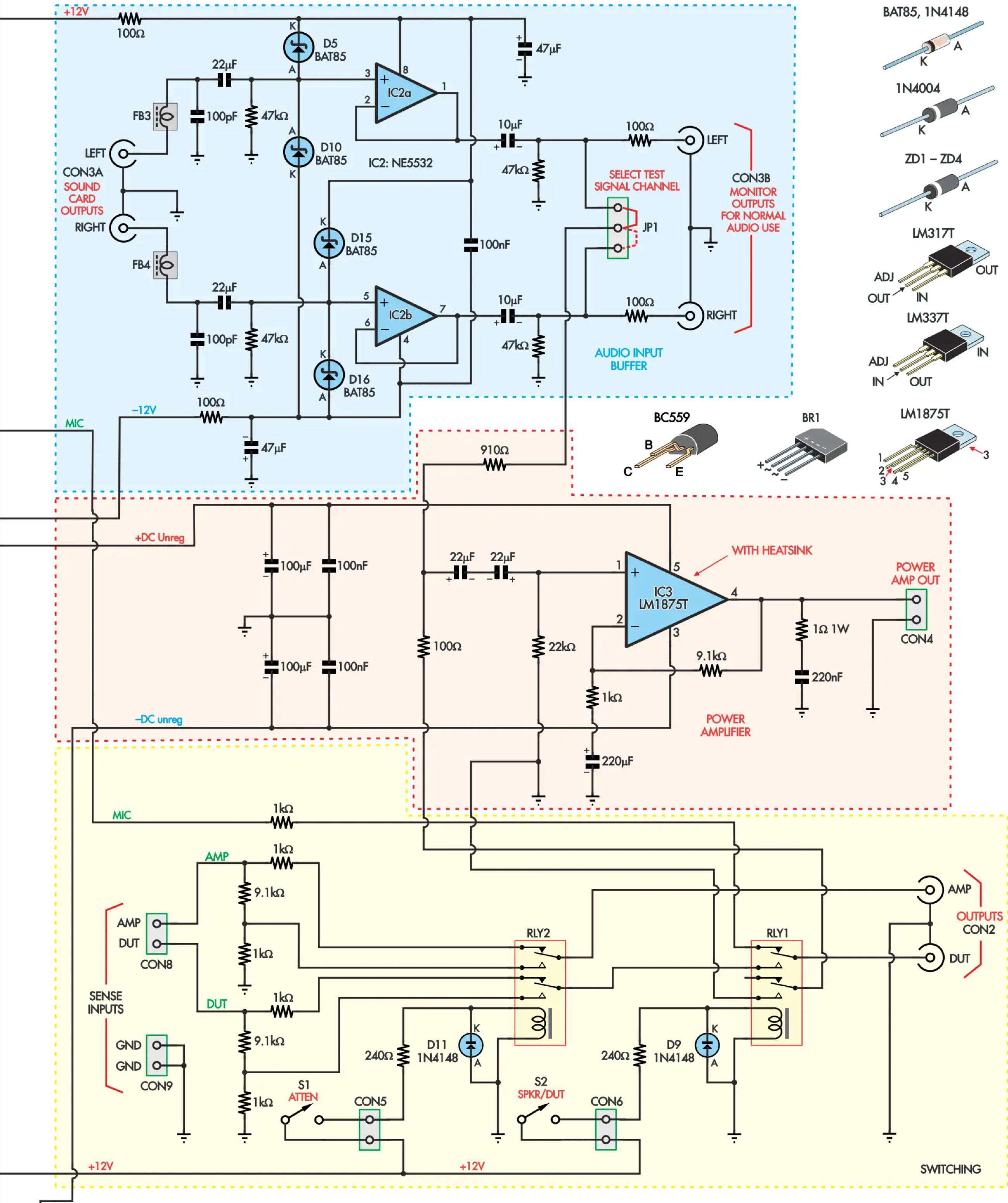


Fig.3: the complete circuit diagram of the Test Jig with shaded boxes showing the separate sections. The Power Amplifier drives a loudspeaker while the Microphone Preamplifier picks up the resulting sound and amplifies it to send it to the sound card. The Speaker Measurement section is essentially a buffer, while the Switching section lets you perform various tests without disconnecting and reconnecting many leads.

We run it from dual half-wave rectified 15V AC to get positive and negative rails of about ±20V from the 15V AC plugpack. This is cheeky, but we only need a couple of watts at most. Note that only half the diodes in bridge rectifier BR1 are used since we don't have a centre-tapped transformer (few plugpacks have a centre tap as it requires a 3-pin connector).

This power amplifier will provide sufficient output to allow you to wire your speaker to the output binding posts to perform listening tests as you develop it. We have set the gain to about 10 (set by the ratios of the 9.1kΩ and 1kΩ resistors), which is low but enough for our purposes.

Parts List – Loudspeaker Test Jig

1 double-sided PCB coded 04106231, 99.5 × 189.5mm
1 Hammond 220×103×53mm black aluminium instrument case **[element14 9287892, Mouser 546-1455N2201BK, Digi-Key HM1732-ND]**
1 15V AC plugpack (rated at least 1.2A) **[Jaycar MP3021]**
3 2A 5V DC coil DPDT PCB-mounting telecom relays (RLY1-RLY3) **[Altronics S4128B]**
4 5mm-long, 2mm inner diameter ferrite beads (FB1-FB4)
2 PCB-mounting M205 fuse clips (F1)
1 2.1mm or 2.5mm inner diameter PCB-mounting DC barrel socket, to suit plugpack (CON1)
1 stereo right-angle PCB-mounting RCA socket, above/below (CON2) **[Altronics P0210]**
1 dual stereo vertical PCB-mounting RCA socket (CON3) **[Altronics P0214]**
7 2-way 2.54mm right-angle polarised headers with matching plugs (CON4-CON9, CON12) **[Altronics P5512 + P5472 + P5470A × 2]**
1 3-way 2.54mm right-angle polarised header with matching plug (CON11) **[Altronics P5513 + P5473 + P5470A × 2]**
1 2-pin header with jumper shunt (LK1)
1 3-pin header with jumper shunt (JP1)
2 8-pin DIL sockets (**optional**; for IC1 and IC2)
2 dual panel-mount red/black binding posts with banana sockets **[Altronics P9257A]**
3 SPDT solder tail panel-mount toggle switches with locking mechanism **[Altronics S1311]**
1 panel-mount 3-pin XLR socket for microphone (CON10) **[Altronics P0903]**

Hardware and wire
1 2A 250V M205 fast-blow fuse (F1)
1 84×24×28mm low-profile PCB-mounting heatsink **[Altronics H0668]**
3 16×22mm TO-220 PCB-mounting heatsinks **[Altronics H0650]**
5 TO-220 insulating kits (washers + bushes) **[Altronics H7210, set of four]**
1 M3 × 25mm panhead machine screw
6 M3 × 16mm panhead machine screws
6 M3 shakeproof washers
6 M3 flat washers
4 M3 hex nuts
2 fibre or Nylon washer, 3mm inner diameter **[Jaycar HP0148]**
2 4G × 12mm countersunk head machine screws **[Bunnings 2420062]**
1 150mm length of 3-wire jumper cable
1 300mm length of green light-duty hookup wire
1 1m length of light-duty figure-8 twin lead or ribbon cable
1 200mm length of 3mm diameter black heatshrink tubing

Semiconductors
2 NE5532 dual low-noise op amps, DIP-8 (IC1, IC2)
1 LM1875T 20W audio amplifier, TO-220-5 (IC3) **[Jaycar ZL3755]**
1 LM317HV high-voltage adjustable linear regulator, TO-220 (REG1) **[Altronics Z0545]**
1 LM317 adjustable positive linear regulator, TO-220 (REG3)
1 LM337 adj. negative linear regulator, TO-220 (REG4)
2 BC559 100mA 30V PNP transistors, TO-92 (Q1, Q2)
4 6.8V 1W zener diodes (ZD1-ZD4)
1 400V 4A SIL bridge rectifier (BR1) **[eg, KBL404; Altronics Z0076A]**
8 1N4004 400V 1A diodes (D2, D3, D22, D23, D26-D29)
7 1N4148 75V 200mA signal diodes (D4, D6-D9, D11, D12)
4 BAT85 30V 200mA schottky diodes (D5, D10, D15, D16)

Capacitors
4 2200µF 25V low-ESR radial electro, 7.5mm pitch **[Altronics R6204; Jaycar RE6330]**
3 470µF 25V radial electrolytic, 5mm pitch **[Altronics R5164; Jaycar RE6326]**
2 220µF 63V radial electrolytic, 5mm pitch **[Altronics R5148; Jaycar RE6348]**
1 220µF 16V radial electrolytic, 3.5mm pitch **[Altronics R5143; Jaycar RE6312]**
3 100µF 50V radial electrolytic, 5mm pitch **[Altronics R6127; Jaycar RE6346]**
9 47µF 50V low-ESR radial electrolytic, 3.5mm pitch **[Altronics R6107; Jaycar RE6344]**
2 22µF 50V low-ESR radial electrolytic, 2.5mm pitch **[Altronics R6077; Jaycar RE6342]**
2 22µF 50V non-polarised radial electrolytic, 3.5mm pitch **[Altronics R6570A; Jaycar RY6816]**
5 10µF 50V low-ESR radial electrolytic, 2.5mm pitch **[Altronics R6067; Jaycar RE6075]**
1 220nF 63V MKT polyester
12 100nF 63V MKT polyester
2 1nF 63V MKT polyester
1 680pF 50V NP0/C0G or YSP radial ceramic
2 100pF 50V NP0/C0G or SL radial ceramic
2 22pF 50V NP0/C0G radial ceramic

Resistors *(all ¼W 1% axial unless otherwise stated)*
4 47kΩ
6 22kΩ
1 12kΩ
2 10kΩ
3 9.1kΩ
2 6.8kΩ 0.5W or 0.6W 1%
2 4.7kΩ
2 3.3kΩ
2 2.7kΩ
1 2.2kΩ
1 1.2kΩ
6 1kΩ
1 910Ω
2 390Ω
1 330Ω
3 240Ω
9 100Ω
2 10Ω
1 10Ω 5W 5% non-inductive **[Altronics R0323; Jaycar RR3250]**
1 1Ω 1W 5%

The signal is AC-coupled to IC3's input via a pair of back-to-back 22µF electrolytic capacitors to remove any DC bias. The output goes straight to CON4, which is wired to a pair of binding posts. The 1Ω/220nF Zobel network ensures stability.

We mount the LM1875 on a heatsink to ensure that the IC has adequate cooling if you do extended testing. This heatsink is available from Altronics, but if you can't find that, a folded piece of aluminium would work just fine.

Interestingly, the Altronics heatsink we bought had one hole in the middle, but their specification has two holes, and our design accommodates that. If yours only comes with one hole as well, you will need to drill a 3mm hole 10mm to the left of the centre.

Microphone preamp

This basic design is pretty standard across the audio industry. It includes a tweak by Douglas Self, described in his books, whereby the input transistors are included in the operational amplifier feedback loop. This significantly reduces the resulting distortion.

The microphone preamplifier is simply an AC-coupled balanced amplifier with switchable gain. If you switch off the phantom power, this becomes a simple balanced input. That is handy to remember if you want to probe a circuit using the *Loudspeaker Test Jig*.

RF is filtered out of the input signals by series ferrite beads and an RC low-pass filter comprising 10Ω resistors and 680pF and 1nF capacitors. 48V phantom power, if selected, is applied via 6.8kΩ resistors, with a 1kΩ/100µF low-pass filter before them to remove any supply noise. Pairs of back-to-back zener diodes protect the rest of the circuitry from any voltage spikes that might be picked up.

The two balanced signals are then fed to the bases of PNP transistors Q1 and Q2, which are within the feedback loop of low-noise op amps IC1a and IC1b, providing the amplification as follows.

Pins 2 and 3 of IC1a must be at essentially the same voltage, enforced by negative feedback from this op amp. The current through transistors Q1 and Q2 will be essentially the same, and within the tolerance of transistor matching, their emitter voltages will be the same.

From a DC perspective, the output will be close to 0V as IC1b inverts the signal from IC1a, creating differential feedback to the transistors. The transistor bases are AC-coupled to the input and DC-biased to ground, so their emitters will be pulled up to about 0.6V by the 10kΩ emitter resistors and the 2.7kΩ op amp feedback resistors.

Q1 and Q2 will each pass about 1mA, which will primarily flow through the 4.7kΩ collector resistors, resulting in pins 2 and 3 of IC1a being about 4V above the negative rail.

The AC input is a differential voltage between the bases of Q1 and Q2. The emitters of Q1 and Q2 are the feedback point, via the 2.7kΩ resistors. As the input is differential, the 100Ω resistor (and 1.2kΩ if the contacts of relay RLY3 are not shorting it out) see the total differential voltage; the midpoint of these can be seen as a 'virtual zero point'.

So the gain is defined by the 2.7kΩ feedback resistors with the parallel combination of half of (100Ω + 1.2kΩ) and (10kΩ + 10kΩ) forming the voltage divider for gain.

Gain is controlled by the 2.7kΩ resistors in series with the NE5532 outputs, combined with the 10kΩ resistors to the positive rail and the 1.2kΩ and 100Ω resistors. A 20dB gain step is implemented by switching RLY3 across the 1.2kΩ resistor.

The gain on the low setting can be calculated as:

$$1 + (2.7k\Omega \div (10k\Omega \parallel [(1.2k\Omega + 100\Omega) \div 2]))$$
$$= 1 + (2700\Omega \div 610\Omega)$$
$$= 5.42 \text{ times gain } (+14.7dB)$$

On the high setting, it is:

$$1 + (2.7k\Omega \div (10k\Omega \parallel [100\Omega \div 2]))$$
$$= 1 + (2700\Omega \div 49.8\Omega)$$
$$= 55.2 \text{ times gain } (+34.8dB)$$

The input buffer

The *Loudspeaker Test Jig* includes a simple op-amp-based buffer to ensure that your sound card output is presented with a high impedance, while also providing a monitor output to drive an amplifier or other equipment. You can even use this output to drive an active crossover for testing active speakers.

The input includes protection against RF noise with ferrite beads and 100pF capacitors to ground, while schottky clamp diodes protect the op amp from voltage spikes on the input.

The signals are AC-coupled to the op amp inputs via 22µF non-polarised capacitors with 47kΩ DC bias resistors, forming a high-pass filter with a -3dB point of 0.15Hz. So there will be no detectable roll-off at 20Hz. The outputs are also AC-coupled and have 100Ω series resistors for stability and safety.

A jumper on JP1 can feed either the left or right channel to the input of the power amplifier.

Switching section

This section does two main things in the *Loudspeaker Test Jig*. It switches one of the sound card's input channels between the output of the microphone preamplifier and a 'DUT Sense' input. It also allows you to select a gain of 1× or 0.1× for both the 'DUT Sense' signal and 'Amp Out Sense' signal.

When 'DUT Sense' is selected as the signal source, the power amplifier gain is automatically cut from 10× to 1× by switching in a 910Ω/100Ω resistive attenuator in its input signal path. This is so that when testing components a signal of only a few hundred millivolts is applied to them. That allows you to measure the impedance of tweeters without over-driving them.

Despite this, if you are testing tweeter responses, always put a 20-100µF capacitor in series with the tweeter to avoid over-driving it at low frequencies.

When testing loudspeaker frequency responses, though, you need more volume. Therefore, with the 10× gain provided in the amplifier, it delivers a couple of volts RMS (depending on where you set your sound card volume). This will be loud enough to get good frequency response plots.

Power supply

The power supply for the *Loudspeaker Test Jig* is minimalist to keep cost,

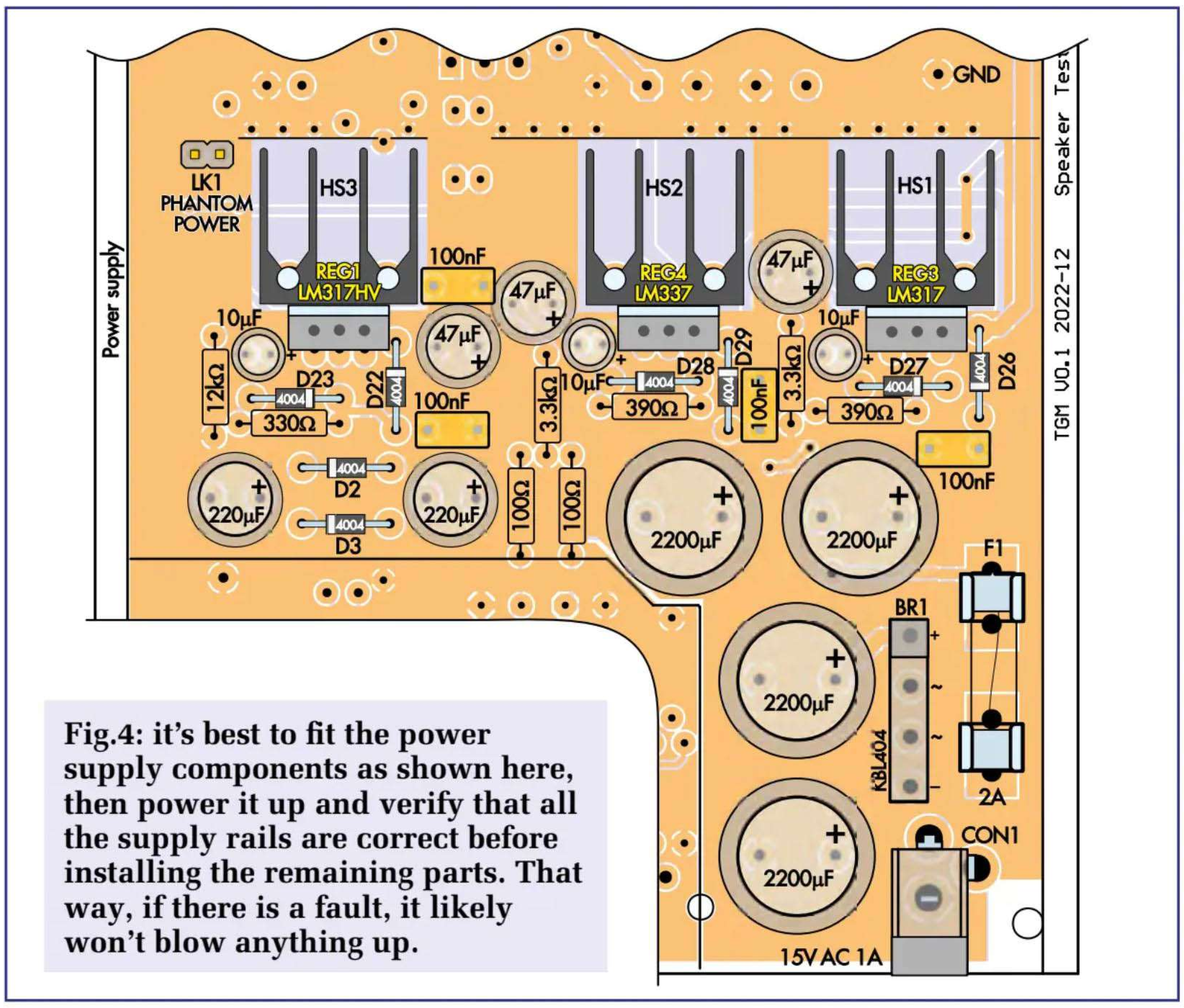


Fig.4: it's best to fit the power supply components as shown here, then power it up and verify that all the supply rails are correct before installing the remaining parts. That way, if there is a fault, it likely won't blow anything up.

Photo 1: an exterior view of the completed front panel assembly. Dymo labels will help you to remember what each switch and terminal does down the track!

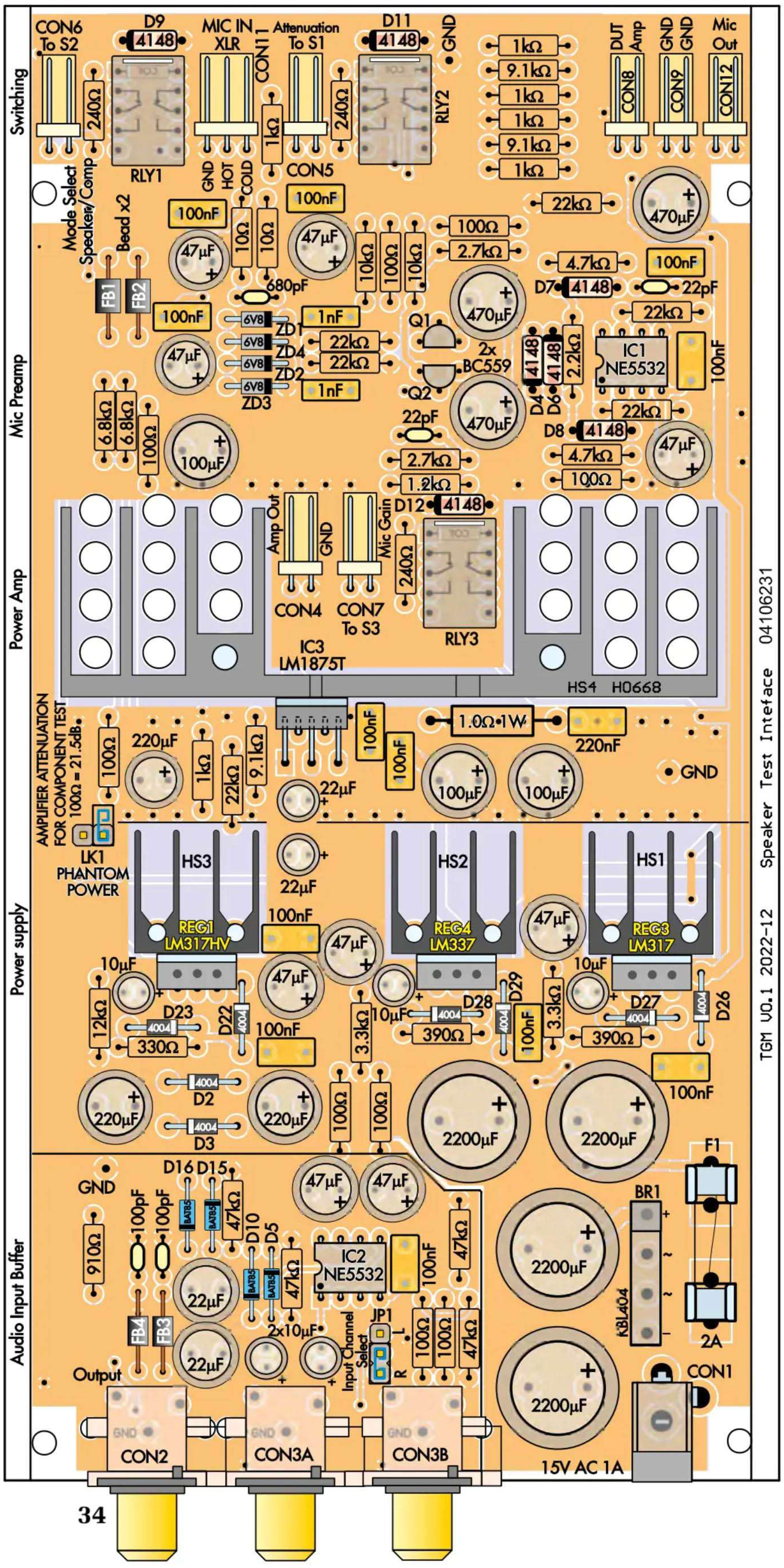


Fig.5: once you've tested the power supply, you can fit all the components as shown here. Ensure all the TO-220 devices are insulated from their heatsinks and watch the polarity of the ICs, diodes and electrolytic capacitors. Two of the 22μF electrolytics are non-polarised types (near the lower-left corner), so no polarity markings are shown.

complexity and size down. We use a single 15V AC plugpack to power the unit. As mentioned earlier, dual half-wave rectification via BR1 provides the split rails to drive the power amplifier. This avoids the need for any fancy voltage inverting IC or the use of a single-rail topology for the whole *Test Jig*.

It does mean that our supply rails are 50Hz half-wave rectified, with resultant ripple challenges. So we have doubled down on the filter capacitors and used two 2200μF capacitors per rail, which in a standard application, would be overkill. In this case, a couple of pounds worth of extra capacitors saves on using a dual-winding transformer.

With 4400μF per rail, there will only be a couple of volts ripple on the rails during higher-power tests.

The small-signal circuitry needs clean power, so we have added LM317/337 regulators generating regulated rails at nominally ±12V. These are textbook circuits.

Generating the 48V phantom power rail for the measurement microphone is a little more interesting. We use a voltage doubler circuit that steals energy from the positive unfiltered rail via diode D3 charging the 220μF capacitor at its cathode on negative voltage swings at the plugpack tip, then dumping its charge into the other 220μF capacitor via D2 on positive swings.

The second 220μF capacitor 'sits on top of' the main unfiltered rail, resulting in close to 70V DC at the cathode of D2 when it is unloaded. This is dropped to 48V by an LM317HV adjustable regulator. You could use a normal LM317, provided you never short its output to ground. In typical operation, its output goes via a 1kΩ resistor, so there is no chance of that happening in daily use.

The current drawn from the 48V rail is never more than 14mA, so the 220μF capacitors are more than sufficient to keep ripple below 1V.

We placed heatsinks on all regulators, but didn't notice them getting that warm. If you want to save a little expense, you might get away without using them.

Construction

Construction is fairly easy, although, for designs like this, we like to load the power supply section first and check the voltage rails. Once that checks out, you can power it down and fit all the remaining parts with the confidence that a power supply fault won't fry them at switch-on!

The *Loudspeaker Test Jig* is built on a 99.5 × 189.5mm double-sided PCB coded 04106231, available from the *PE PCB Service*.

To build the power supply section, fit all the resistors and diodes in that section, as shown in Fig.4. Be careful with the orientation of the diodes as they vary. Follow with the MKT and electrolytic capacitors in this section (watching the polarity of the electrolytics), then the rectifier, fuse holder and connectors. Install a 2A fuse.

Finally, attach the regulators to the heatsinks with a TO-220 insulator kit on each. Don't tighten the screws until you have inserted the regulators with their heatsinks into the PCB. Then you can solder the heatsink mounting pins along with the regulator pins.

Testing the power supply

Plug in the 15V AC plugpack and check the unregulated rails by measuring the voltages on pins 3 and 5 of the LM1875 IC relative to GND (there is a GND test point at upper left in the Audio Input Buffer section). These voltages ought to be 18-24V DC. If they measure low, check the AC voltage and verify that the bridge rectifier has been installed the right way around. Also check the capacitor orientations.

Assuming that's OK, measure the ±12V rails at pin 2 of the LM317 (REG3) and pin 3 of the LM337 (REG4). These ought to be within 1V. If not, verify that the regulators are in the right spots, the correct resistors have been used and the diodes are oriented properly. There should always be 1.25V between the ADJ and OUT pins of the LM3X7s.

Next, check that the 48V rail is within 3V (ie, 45-51V). This is accessible on pin 2 of the LM317HV. If it is off, verify that the input voltage on its pin 3 is well above 48V. Also check the resistor values around this regulator and that the capacitors and diodes are the right way around.

Finishing off the PCB

Now that we know the power supply is working, remove power and fit all the remaining parts, as shown in Fig.5. As usual, start with the lower-profile components by mounting the resistors, diodes, relays, NE5532 ICs and right-angle headers first. Then move on to the larger parts, including the capacitors and RCA sockets.

As with the regulators, loosely attach the LM1875 to the large heatsink and use an insulating kit. Insert the IC into its pads and solder the heatsink to the board. The solder pins will require some effort to get hot enough, but they do work (it is not screwed to the PCB). Once it is held in place securely, tighten up the IC mounting screw and solder its leads.

Note that there are two bipolar (non-polarised) electrolytic capacitors right next to CON2, as we don't know if an input will have a DC offset. They have polarity marks on the PCB, but

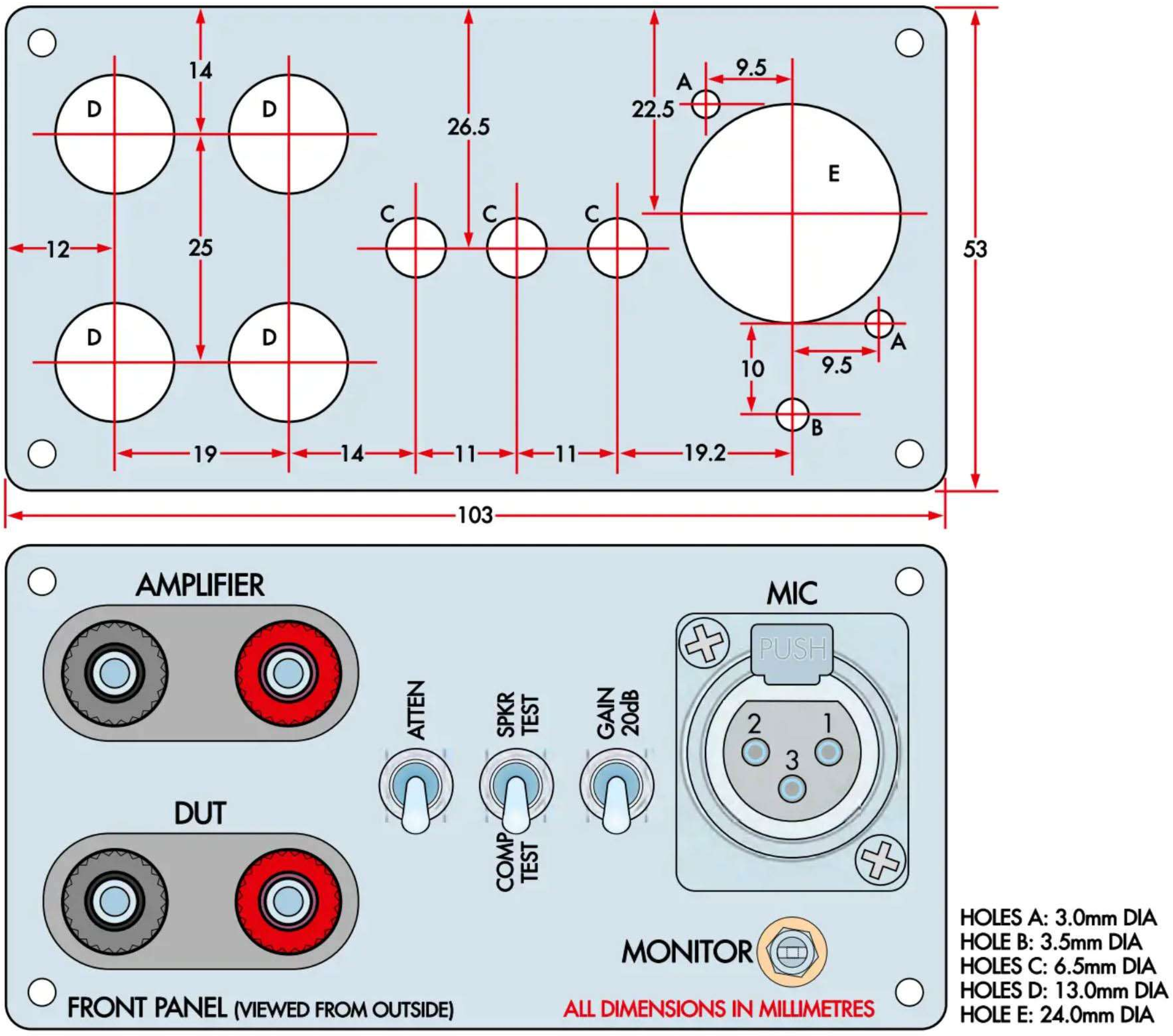


Fig.6: drill the front panel supplied with the recommended case as shown here, making sure the pre-drilled countersunk screw holes face outwards.

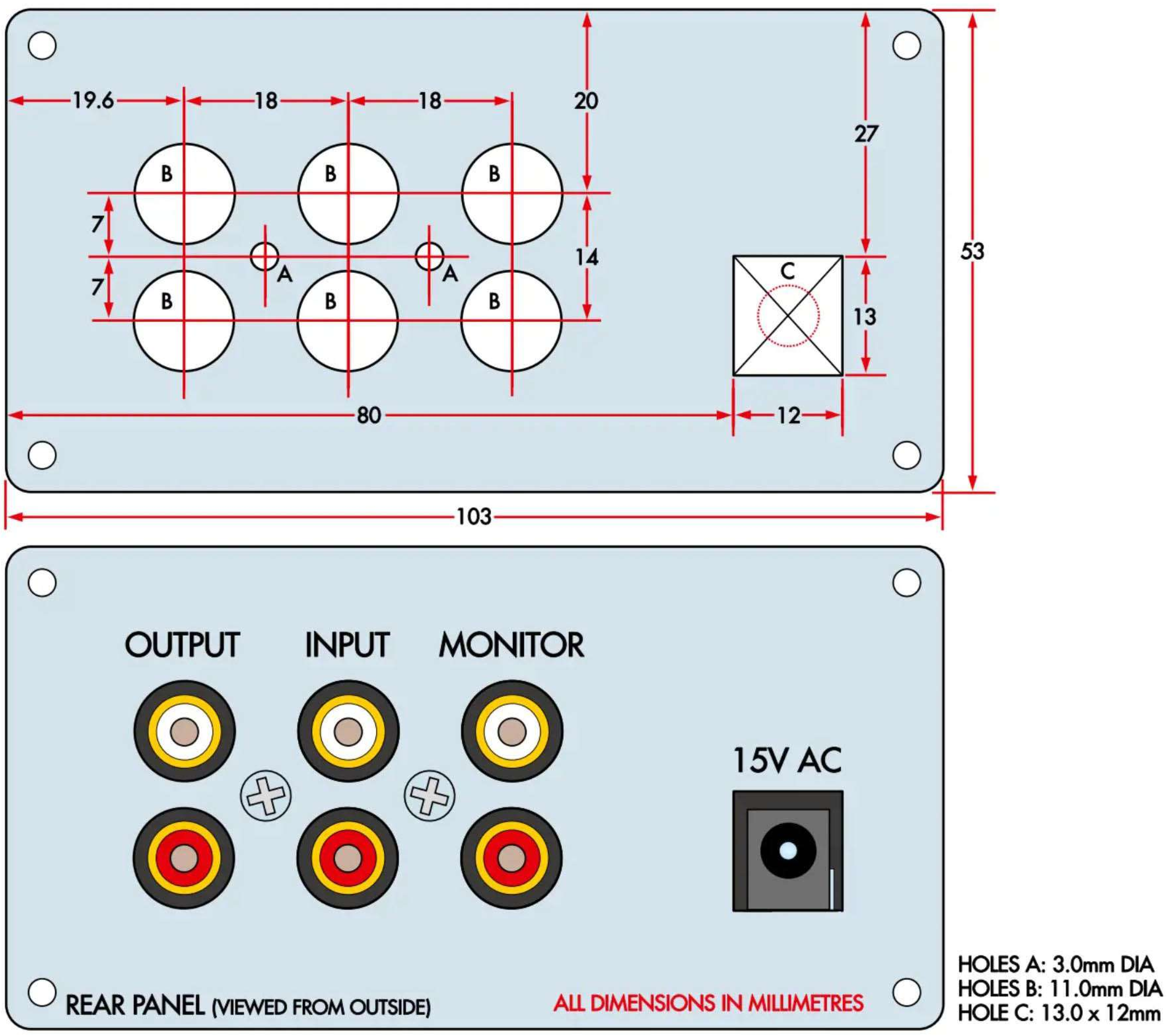


Fig.7: drill the rear panel as shown here, again paying attention to which side has the holes countersunk. For the rectangular hole, you can drill an 11mm hole and then file the corners out. Otherwise, you can drill out the dotted hole marked in red which only leaves enough room for the plug sleeve.

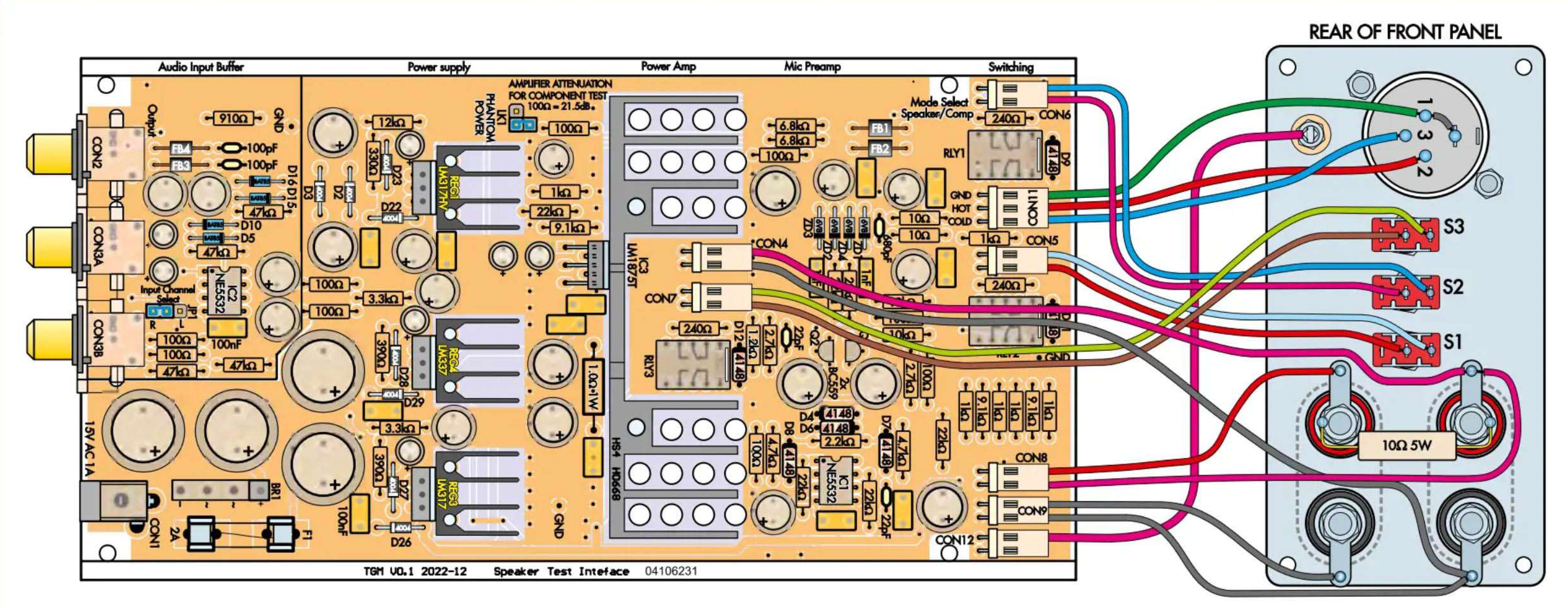


Fig.8: use this diagram and Photos to wire up the front panel. By using polarised header plugs, the whole assembly can be disconnected from the main board, making assembly and disassembly easier.

you can ignore them as the parts are not polarised.

The two 47μF capacitors all the way on the left side of the Mic Preamp section can operate with 48V DC phantom power applied, so we must use at a minimum 50V-rated electrolytic devices and orient them with their longer positive lead to the right as shown. If you will never use phantom power, you could instead use polarised electrolytics with a much lower voltage rating.

With the PCB assembled, we can move on to wiring it up so it can go in the case.

Case preparation

The PCB slides into the second slot up from the bottom in the recommended extruded aluminium case. Use the provided drilling drawings, Figs.6 and 7, to cut the required holes in the front and rear panels. Once prepared, they fit perfectly, allowing you to secure the board using 4G screws through the rear panel into the RCA sockets.

Our recommended case is very tidy, but it is not the cheapest. If you want a more cost-effective solution, any case over about 220mm wide, 130mm deep and more than 60mm high will work. You could consider using plastic instrument cases like Altronics H0476 or H0482; however, you will need to adapt Figs.6 and 7 to fit the differently-sized panels.

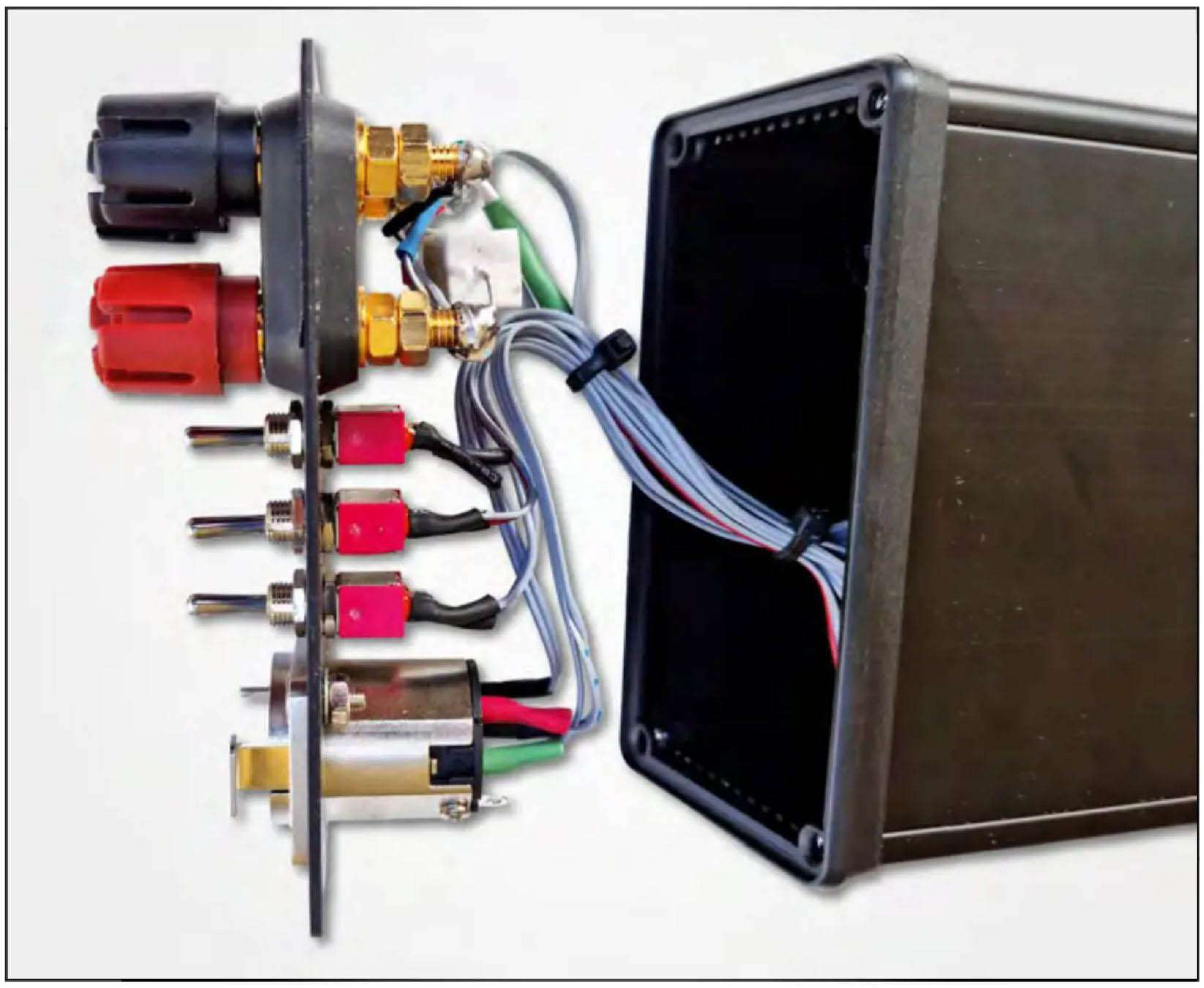
The PCB can be secured via spacers and screws through the provided mounting holes if you are not using the recommended case.

Mark and drill the front and rear panels. Be careful to choose the right side of the panel, as the pre-drilled screw holes are countersunk on the outside. All the holes have been kept circular for easy construction, except the power connector hole, which will require a little filing.

If you choose one of the larger ABS plastic cases, you could spread things out a bit and run flying leads from the power, input and output connectors to the rear panel. However, since the front panel connectors are all wired, you could still mount the PCB right up against the rear panel to avoid extra wiring.

We labelled our panel using Dymo stickers, as shown in Photo 1. We printed labels in small text on 10mm-wide tape and used tweezers to place the labels on the panel. Most of the switches are self-explanatory, but our experience is that we will have forgotten what does what in a year or two. So labelling is a good idea and makes the box look better.

Photo 2: heatshrink tubing and cable ties keep the front panel wiring manageable. Note the 10Ω reference resistor soldered across the binding post terminals.



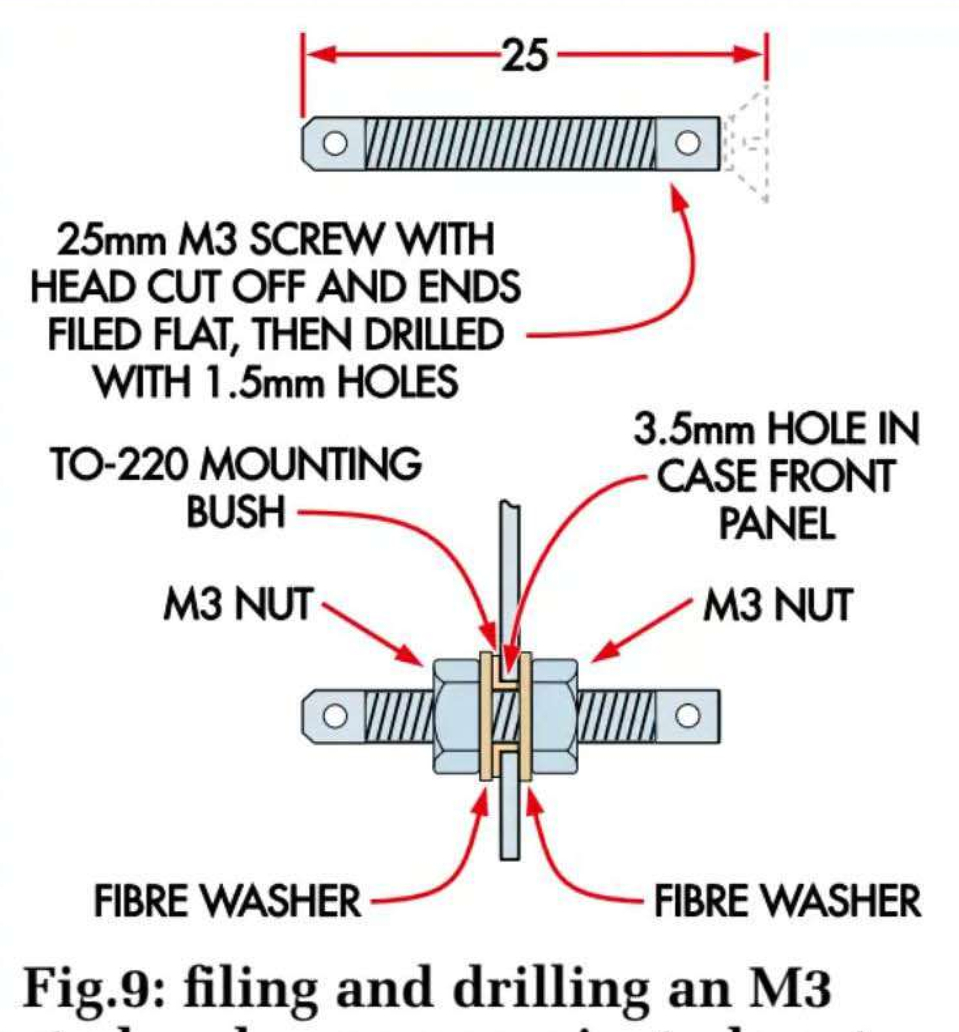
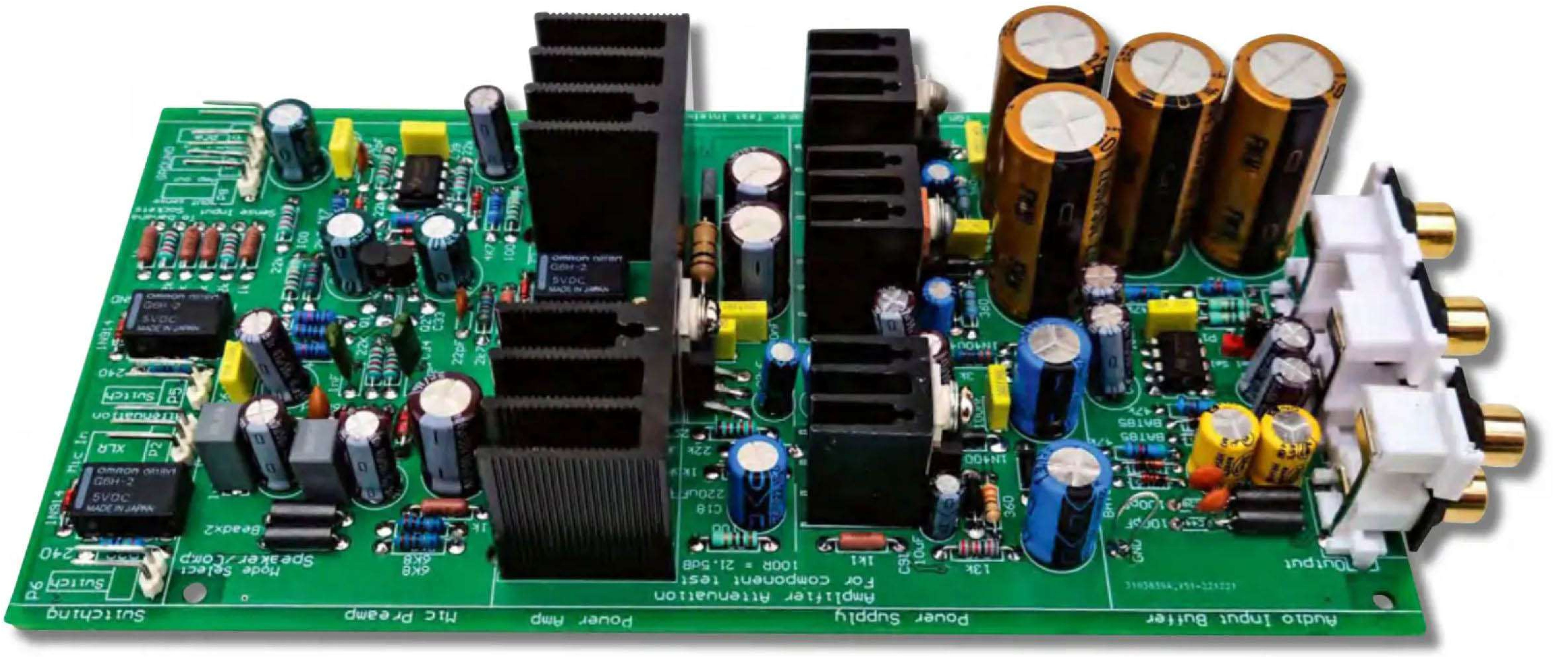


Fig.9: filing and drilling an M3 stud makes a convenient place to attach a test probe. However, you could devise your own scheme if you prefer; a loop of tinned copper wire would be sufficient.



The assembled PCB, ready to be wired up to the front panel via eight right-angle polarised headers. That makes plugging and unplugging easier when it is mounted in the instrument case.

With the case panels prepared, mount the front panel hardware. We used dual binding posts for the speaker connections, although you could save a little money by using captive-head binding posts. Whatever you choose, make sure they can act as both binding posts and banana sockets, as that is really handy in use.

After mounting the binding posts, follow with the three switches, then the XLR microphone socket. Watch your selection, as some XLR connectors are pretty deep and the mounting hole locations vary.

The last 'fiddly bit' is the microphone monitor output. We had very little space and wanted a test output for hooking an oscilloscope probe, similar to the calibration post on many oscilloscopes. We made ours from a 25mm M3 screw by cutting the head off with a hacksaw, filing each end flat, then drilling a 1.5mm hole through the flat parts using a PCB drill. That worked a treat, as shown.

Fig.9 shows the details. We soldered to this using plenty of flux. It is used for measuring the time alignment of speaker drivers.

Wiring it up

Cabling for the *Loudspeaker Test Jig* is made easy by using plugs on the end of the leads connected to the front panel, as shown in Fig.8. You need to make up the following flying leads, all using wires stripped from ribbon cable or light-duty figure-8, except the ground lead:

- **Four 150mm-long leads with two wires for:**
  - The Mic output monitor post (CON3)
  - The Output Attenuation switch (CON5)
  - The Mode switch (CON6)
  - The sense wires for the Amp Output and DUT (CON8)
- **One lead from medium-duty hookup wire for the ground connection (CON9).**
- **Two 200mm-long leads with two wires for:**
  - The amplifier output (CON4). Ideally, use two lengths of light-duty hookup wire.
  - The Mic Gain switch (CON7)
- **One 150mm-long lead with three wires for the Microphone input (CON2).**

Label these at the plug end so you will know what header they plug onto later. Also make sure you mark pin 1 on each lead; we used pieces of leftover heatshrink to mark pin 1. You could use a marker pen, but be aware that the marking could become less distinct with time and handling.

Wire up the board to the front panel connectors and controls, as shown in Fig.8. The best way to do this is:

- Solder the CON9 ground wires to the black pins on the banana sockets/binding posts. Jumper across them at the banana socket to 'double up' the ground wiring.
- Measure your 10W reference resistor with the best precision you can. Mark the reading on the resistor, so you don't forget the resistance. Securely bend the leads around the red posts of the 'Amp' and 'DUT' headers and solder them.
- Solder pin 1 of CON4 to the red terminal of the AMP banana socket. Pin 2 goes to ground.
- Solder pin 1 of CON8 to the red terminal of the DUT banana socket and pin 2 to the red terminal of the AMP banana socket.
- Solder the CON5 wires across the top two pins of the Atten switch on the front panel.
- Solder the CON6 wires across the top two pins of the Mode switch on the front panel.
- Solder the CON7 wires across the top two pins of the Mic Gain switch on the front panel.

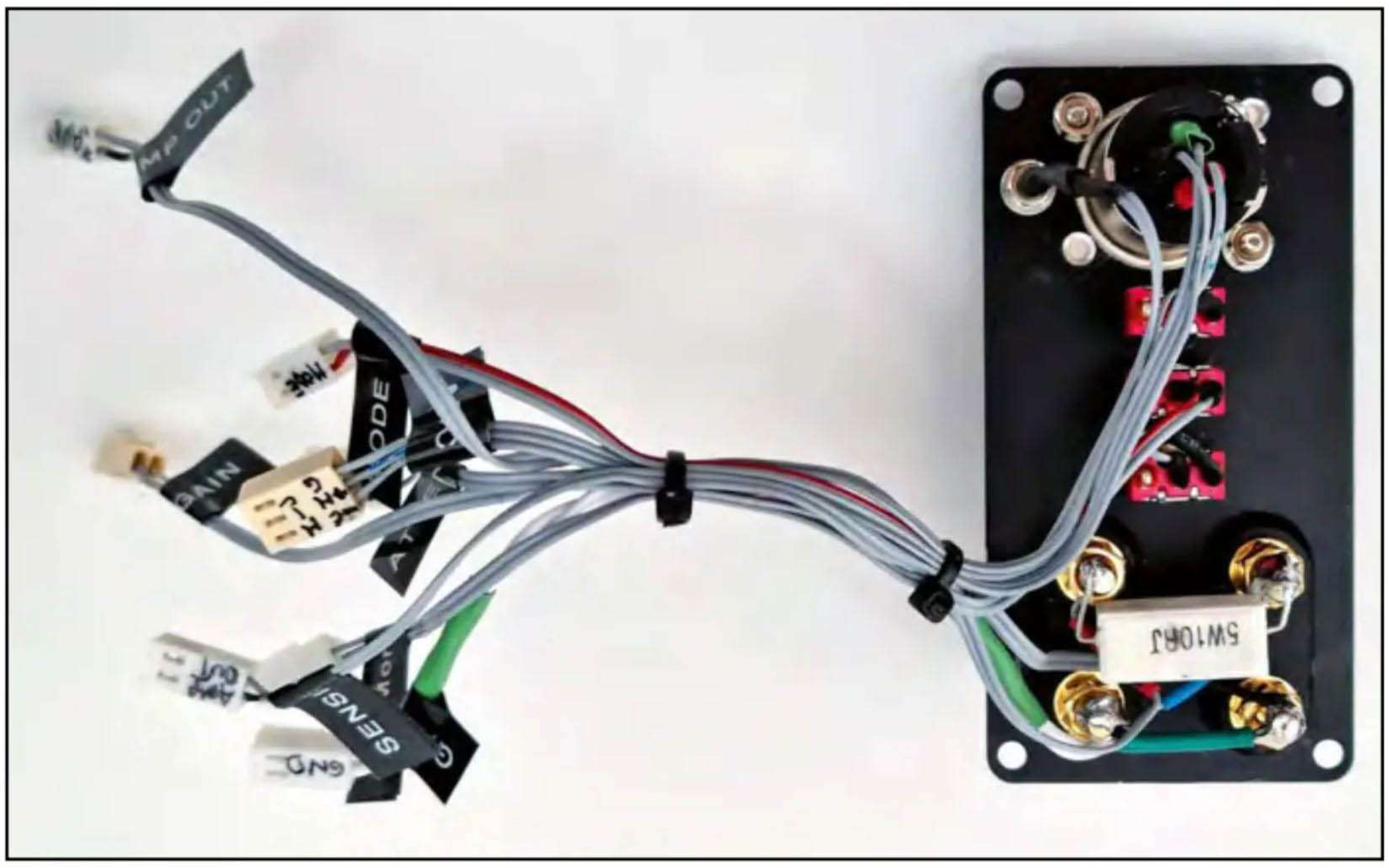


Photo 3: label the plugs and wire so that you don't get them mixed up when plugging them into the PCB headers. This photo also shows more clearly how the reference resistor is connected.

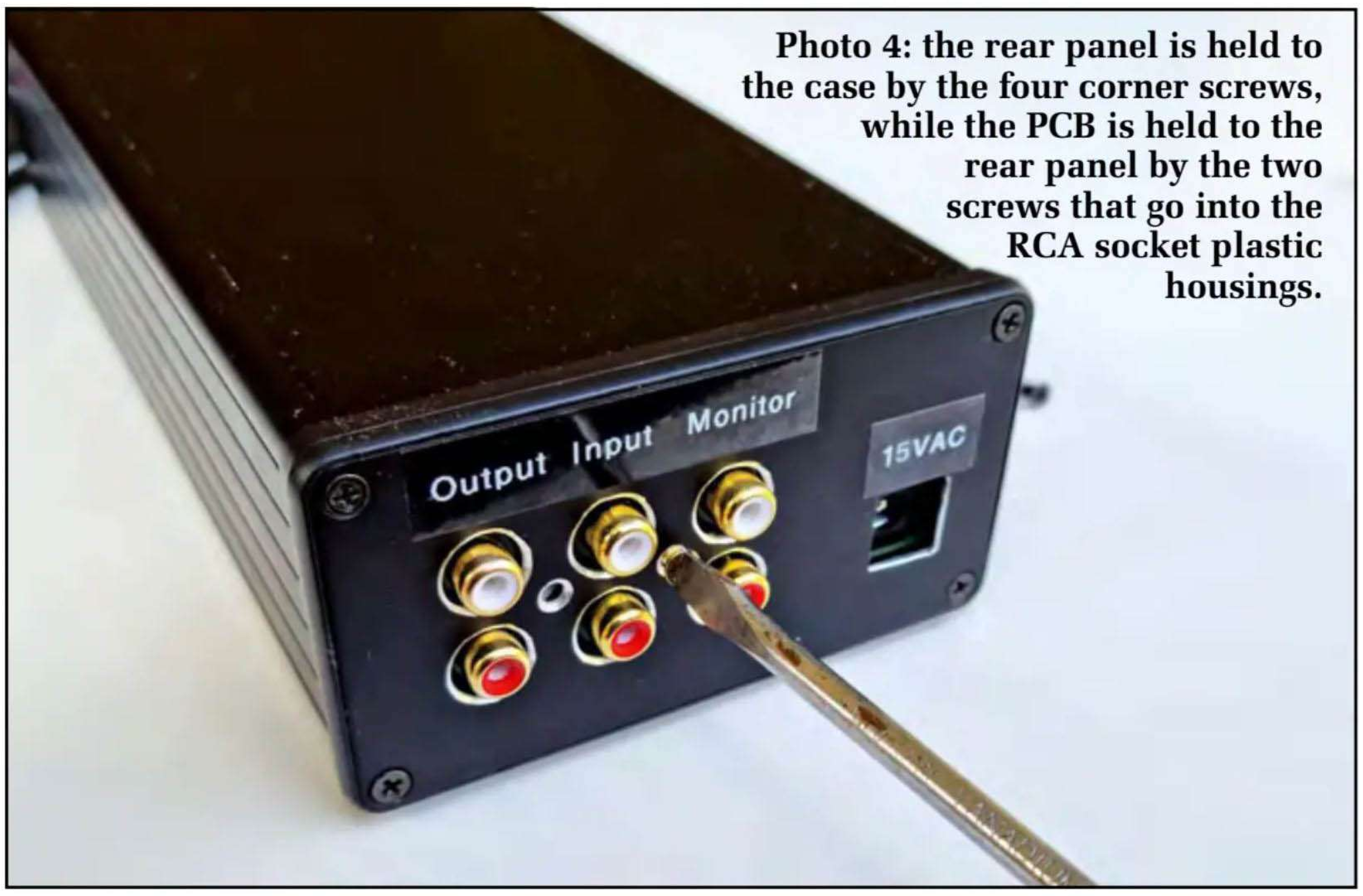


Photo 4: the rear panel is held to the case by the four corner screws, while the PCB is held to the rear panel by the two screws that go into the RCA socket plastic housings.

- Solder pin 1 of CON3 to the Mic Monitor post. Fold the ground wire back and insulate it.
- Solder pin 1 of CON2 to the ground pin of your XLR, pin 2 to hot (+) and pin 3 to cold (–).

These should all now plug in neatly to the PCB. Use a couple of tie wraps/cable ties to secure the wiring after checking that it all works. You are now ready to test it properly!

Once wired up, the front panel will look something like Photos 2 and 3.

Assembly to the rear panel just involves sliding the board into the case and using two 4G screws to secure the RCA connectors to the rear panel, as shown in Photo 4.

Operational testing

It's best to plug the front panel into the PCB before inserting the PCB into the case for testing, as you can't probe the test points on the PCB once it is in the case. When you've verified it's all working correctly, you can slide the PCB in and then attach the front panel.

Set the jumper for the input you expect to use for testing on JP1. Without this, the power amp will not get a signal, although most programs seem to drive both outputs with the test signal.

Apply a signal to the input (CON3a left and right) of 200mV RMS at about 1kHz. A buffered version of this signal should appear at CON3b. Toggle each switch and check that you hear the relays click. If not, check that you have used the correct relays and that the diodes are the right way around.

Set the 'Speaker/Comp' switch to Speaker. Monitor the Amp Out at pin 1 of CON4 and check that you see an amplified version of the input signal at about 2V RMS. Switch the 'Speaker/Comp' switch at CON6 and check that the output is attenuated in the 'Comp' position. This should be close to the amplitude of your test signal (about 200mV RMS).

Next, ensure you have the phantom power enabled by putting a shorting block on LK1 and check that you have 48V ±3V on the hot and cold pins of CON2. Plug in your test microphone and check for a signal on pin 1 of CON3 and your Mic test point on the front panel. If you have trouble, check that:

- There is about 10.3V across the 10kΩ resistors connected to the emitters of Q1 and Q2 (both above and to the left of Q1).
- There is about 3.7V across the 4.7kΩ resistors at the collectors of Q1 and Q2 (next to D7 and D8), and that these voltages are the same.
- Pin 1 of IC2 is close to 0V.

If any of these are wildly off, verify the component values and orientations in these areas; check for short circuits and that you have used the right transistors.

Testing, calibration and usage

With the unit now assembled and working, the next step will be to install the software, set it up and verify that it's working as expected. As the 'REW' software is not tied to this hardware, we have those instructions in a small separate article starting on page 40.

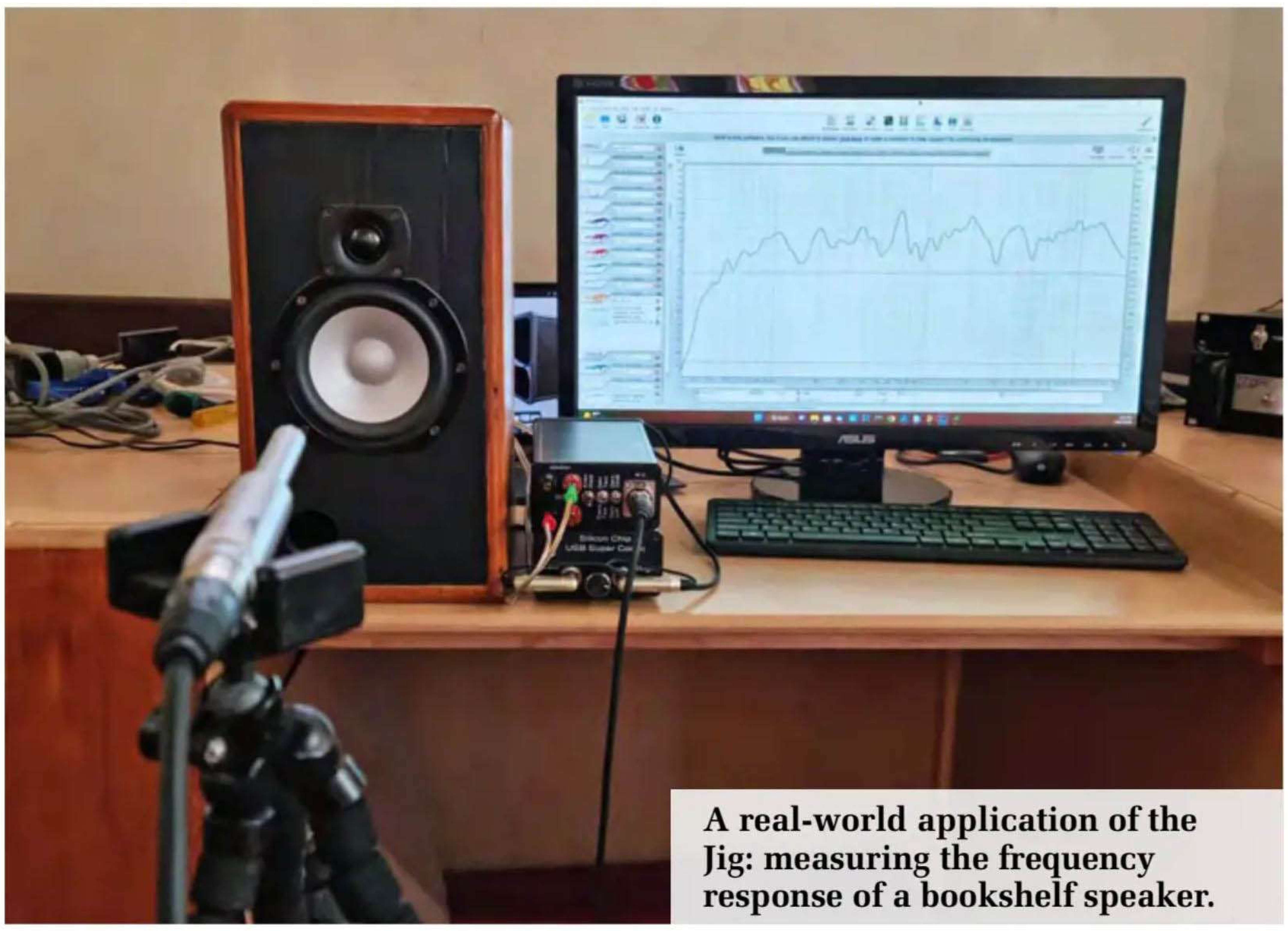
You will need a computer with a reasonably good sound card that has stereo analogue inputs and outputs to hook up to the *Loudspeaker Test Jig*. If your computer lacks those, consider building our very high-quality external *USB SuperCodec*, described in the September to November 2021 issues.

That unit is capable of simultaneous 192kHz, 24-bit recording and playback and has a rated THD figure of just 0.0001% (-120dB) and a THD+N figure of 0.0005% (-106dB) for playback and 0.00063% (-105dB) for recording. You don't need a sound card with such high quality for speaker testing, but it certainly doesn't hurt!

Whatever sound card you use, go into your operating system's settings and ensure it is the active device for recording and playback. In recent versions of Windows, you can do that by right-clicking the speaker icon in the screen's lower right-hand corner and selecting 'Open Sound settings'.

If your sound card's sockets are 3.5mm jack sockets, you can use 3.5mm jack plug to twin RCA plug cables to connect them to the Input and Output sockets on the Loudspeaker Testing Jig. If the sound card has RCA sockets, like the SuperCodec, use twin RCA to RCA leads instead. Then, connect the Monitor outputs to your amplifier inputs with a twin RCA to RCA lead.

When ready, turn to page 40 for the final testing procedure.



A real-world application of the Jig: measuring the frequency response of a bookshelf speaker.