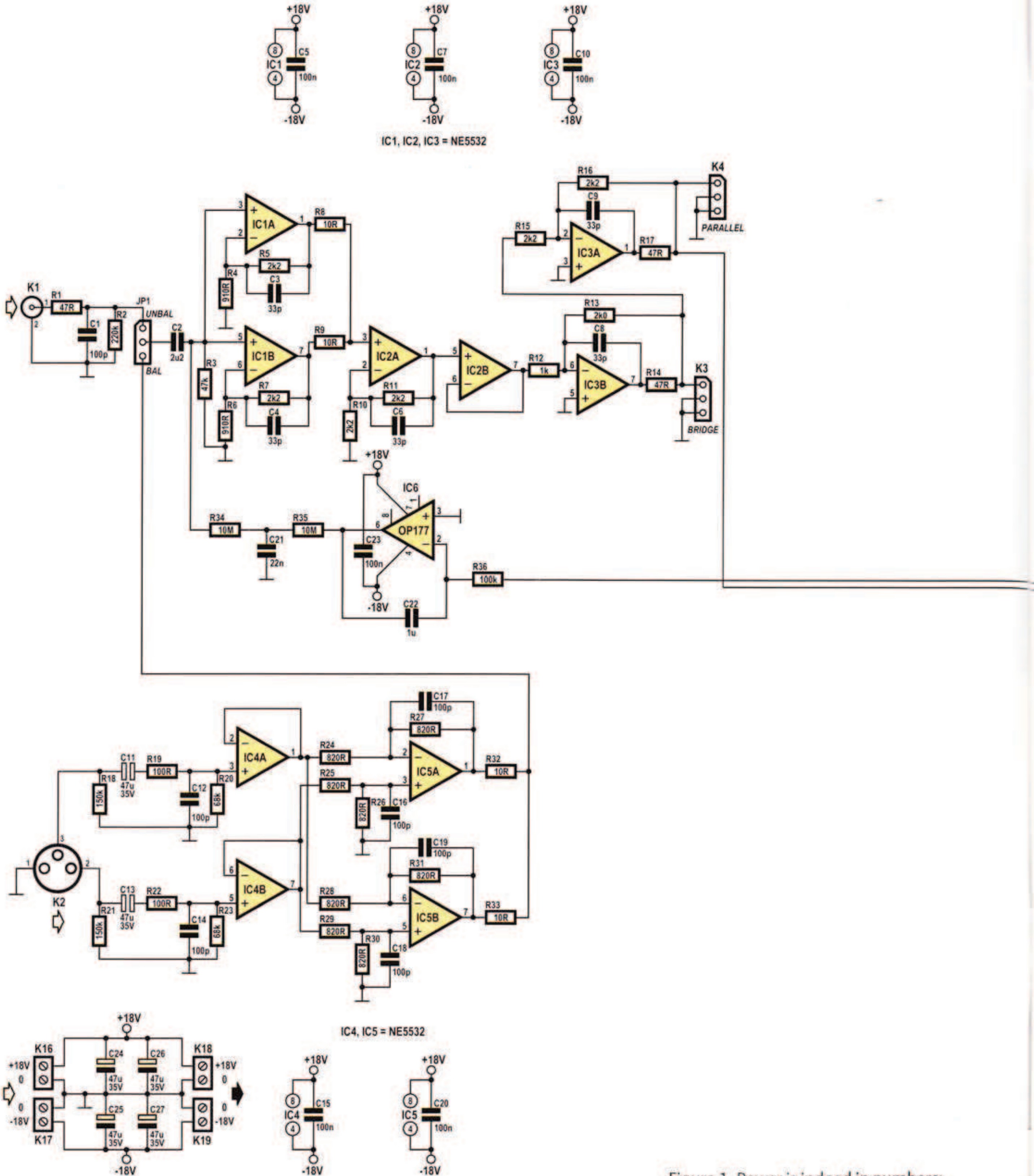
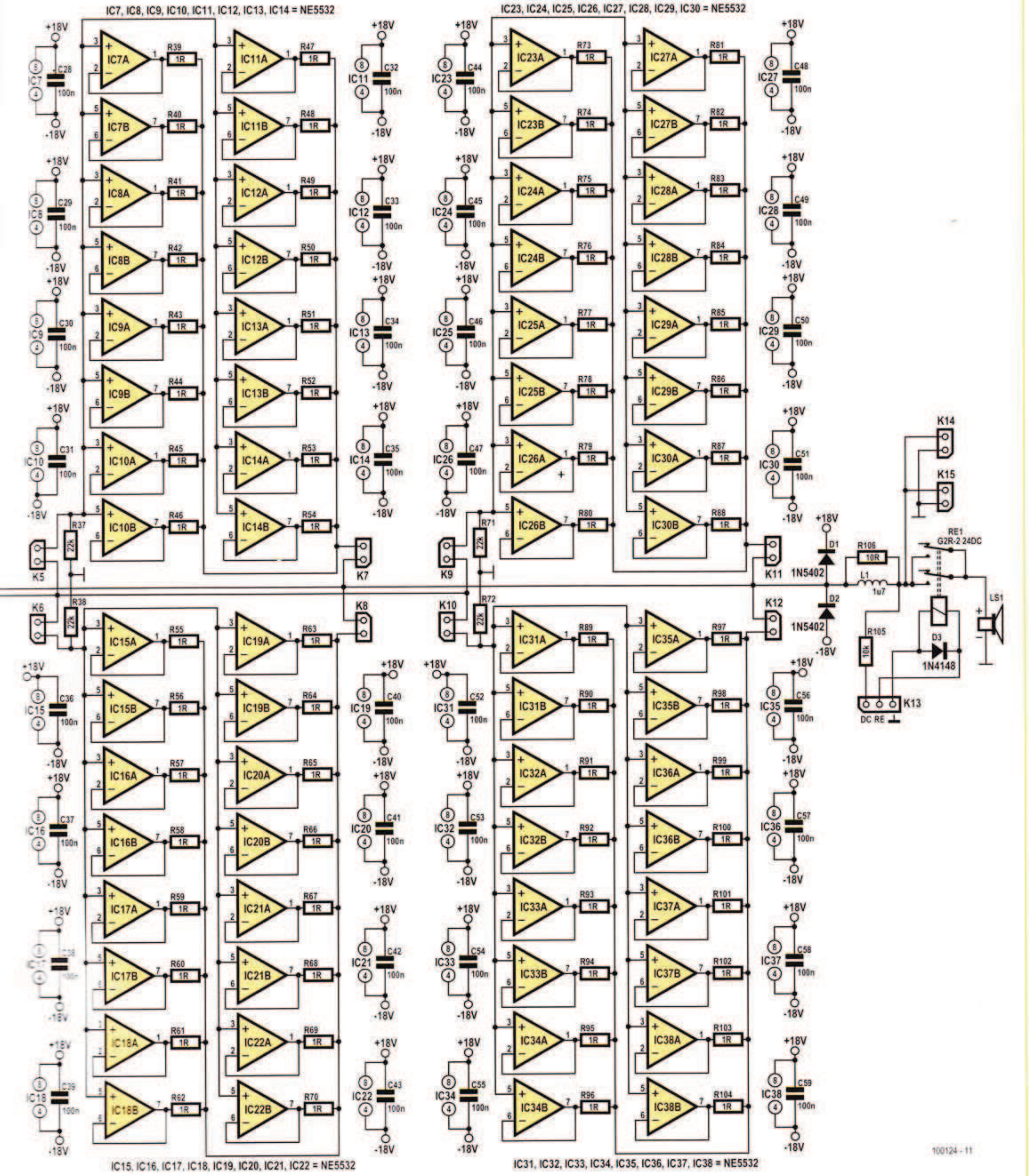


Figure 1. Power is indeed in numbers: circuit diagram of the basic NE5532 audio amplifier (one channel shown).


IC7, IC8, IC9, IC10, IC11, IC12, IC13, IC14 = NE5532
IC23, IC24, IC25, IC26, IC27, IC28, IC29, IC30 = NE5532
IC15, IC16, IC17, IC18, IC19, IC20, IC21, IC22 = NE5532
IC31, IC32, IC33, IC34, IC35, IC36, IC37, IC38 = NE5532
+18V
-18V
100n
1R
22k
K5
K6
K7
K8
K9
K10
K11
K12
K13
K14
K15
RE1
G2R-2 24DC
R106
10R
L1
1u7
D1
1N5402
D2
1N5402
R105
10k
D3
1N4148
LS1
DC RE
100124 - 11

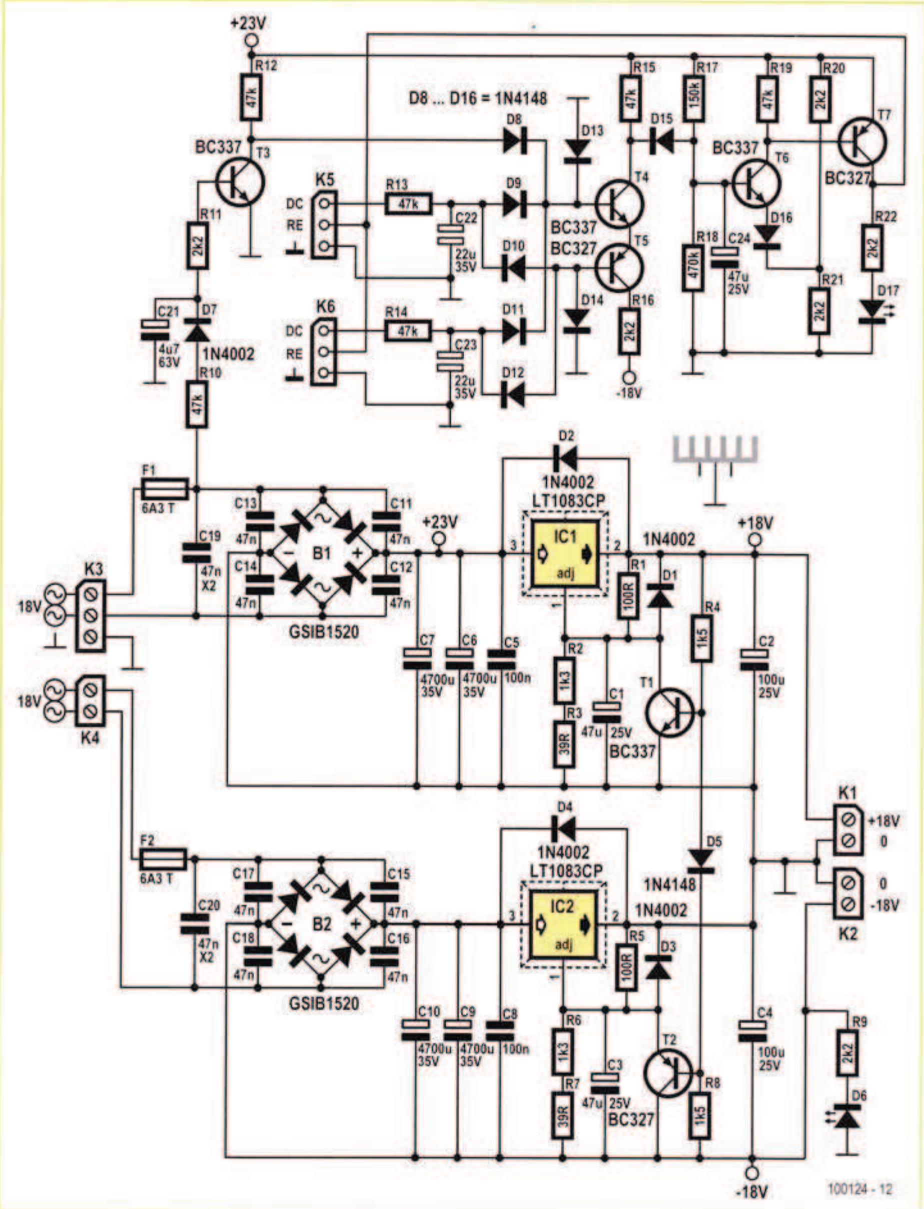


Figure 2. The symmetrical power supply is dimensioned for the 2x15-watt, 8 ohm basic version of the amplifier.

completely distortion-free, and the THD would be significant.

The first stage (IC1A, IC1B) gives +10.7 dB of gain; the two outputs are combined by R8, R9 to give a 3 dB noise advantage, as in the balanced amplifier. The second stage IC2A gives +6 dB of gain. The gain is less to maximise negative feedback because the signal level is now higher. IC2B is a unity-gain buffer which prevents the 1 kΩ input impedance of final gain stage IC3B from loading the output of IC2A and causing distortion. IC2B is less vulnerable to loading because it has maximal negative-feedback. IC3B gives the final +6 dB of gain; it is used in shunt-feedback mode to avoid the common-mode distortion which would otherwise result from the high signal levels here. It has a 'zero-impedance' output, with HF feedback via C8 but LF feedback via R13, so crosstalk is kept to a minimum while maintaining stability with load capacitance. The output at K3 is phase-inverted and can be used for bridging.

IC3A is a unity-gain inverting stage which corrects the signal phase. The output is also of the 'zero-impedance' type.

The power amplifier

The power amplifier consists of thirty-two 5532 dual opamps (i.e. 64 opamp sections) working as voltage-followers, with their outputs joined by 1 Ω current-sharing resistors. These combining resistors are outside the 5532 negative-feedback loops, and you might wonder what effect they will have on the output impedance of the amplifier. A low output impedance is always a good thing, but not because of the so-called 'damping factor' which is largely meaningless as the speaker coil resistance always dominates the circuit resistance. 'Damping factor' is defined as load impedance divided by output impedance; we have 64 times 1 Ω resistors in parallel, giving an overall output impedance of 0.0156 Ω. This gives a theoretical damping factor of 8 / 0.0156 = 512, very good by any standards. The wiring to the loudspeaker sockets will have more resistance than this!

The output opamps may be directly soldered into the board to save cost and give better conduction of heat from the opamp package to the copper tracks. However, on the prototype built in the Elektor labs, high quality sockets were used. Having a lot of opamps in parallel could make fault-finding difficult — if there is one bad opamp out of 32 then you are likely to have to do a lot of unsoldering (or IC unplugging) to find it. The opamp array is therefore split up into four sections of eight opamps, which are joined together by jumpers K5–K12, so on average you would only need to unsolder (or pull out) four opamps to find a defective one. In my many years of experience with it the 5532 has proven a very reliable opamp, and I think such failures will be very rare indeed. There is an output choke L1 for stability into capacitive loads, and catching diodes D1–D2 to prevent damage from voltage transients when current-limiting into reactive loads.

The output relay and its control

The output mute relay RE1 protects the loudspeakers against a DC offset fault and gives a slow-on, fast-off action so no transients are passed to the loudspeakers at power-up or power-down. The relay is controlled from the power supply board. With reference to **Figure 2**, at power-up R17 charges C24 slowly to give a turn-on delay. In operation C21 is charged and

T3 is on; when the AC power is removed C21 discharges rapidly, T3 turns off, and D8 turns on T4–T5, which discharge C24 and cause the output relay contacts to be opened immediately. Even a brief AC power interruption gives the full turn-on delay.

Normally T4 and T5 are off and D15 non-conducting, but if a DC offset fault applies either a positive or negative voltage via R13 or R14, T4–T5 turn on and the relays are opened at once to protect the loudspeakers.

Power supply

Again referring to the circuit diagram of the power supply unit in Figure 2, the ±18 V symmetrical supply is regulated by two type LT1083 TO3-P positive regulators. When a 5532 sees one supply rail disappear, this opamp can get into an abnormal state in which it draws excessive current. This could obviously be catastrophic with this design, so the PSU incorporates a mutual-shutdown facility which shuts off each supply rail if the other has collapsed due to short-circuiting or any other cause. If the positive rail collapses, T2 turns on and disables the negative supply. If the negative rail collapses, T1 turns on and disables the positive supply.

Cost

This project uses quite a lot of 5532s; 37 in each channel, but that does not mean the cost is excessive. In Great Britain, 5532s can be had from Rapid [1] for 24 p each at 100-off (Rapid are prepared to deal with anyone who has a credit card) This means that the cost of all the opamps would be about £18.00.

To be continued

Next month's closing instalment will cover approaches to constructing the amplifier on circuit boards, some performance figures obtained from our high-end test equipment, and an outline of challenges to those of you wishing to modify the amplifier for higher output powers and/or lower output impedance. Meanwhile this month's *E-Labs Inside* section has a page or so on issues with electrolytic capacitors encountered while the first prototype of the amplifier was tested.

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Internet Link

1. www.rapidonline.com