Constructional Project

SIMPLE AUDIO CIRCUITS

Part 3 – Power Supplies, Loudspeakers, Crossover Networks and Filters

RAYMOND HAIGH

A selection of "pic-n-mix" low-cost audio circuits – from preamplifier to speaker!

If a modest output from one of the smaller power amplifiers (May '02) is all that is required, dry batteries represent a suitable power supply. However, when the output is expected to exceed the half-watt level for sustained periods, a mains power unit is more appropriate. Savings in the cost of batteries will quickly cover expenditure on components.

Compromises, inherent in the design of loudspeakers, give rise to limitations which are normally overcome by the use of two or more units and a crossover.

Power supplies, loudspeakers and associated networks are the topics to be covered this month.

SUPPLY REGULATION

A simple mains power supply comprising a full-wave rectifier and capacitor input filter will deliver an off-load voltage of around 1·4 times the transformer secondary voltage.

With a secondary rated at 12V a.c., the off-load d.c. output voltage will, therefore, be almost 17V. If the power supply output is close to the maximum safe operating voltage of the amplifier i.c., there is a danger that, under no-signal conditions, the device will be ruined.

When fully loaded, the d.c. output voltage will fall to around 14V with an adequately rated transformer; lower when the transformer specification has been skimped. Voltage will, therefore, be low at the very moments when the power amplifier is being called upon to deliver a high output.

These voltage variations are a cause of distortion and impair the performance of the power amplifier. Moreover, when high-gain preamplifiers or radio tuners are fed from the same supply, the variations can also result in instability, even when substantial decoupling is provided.

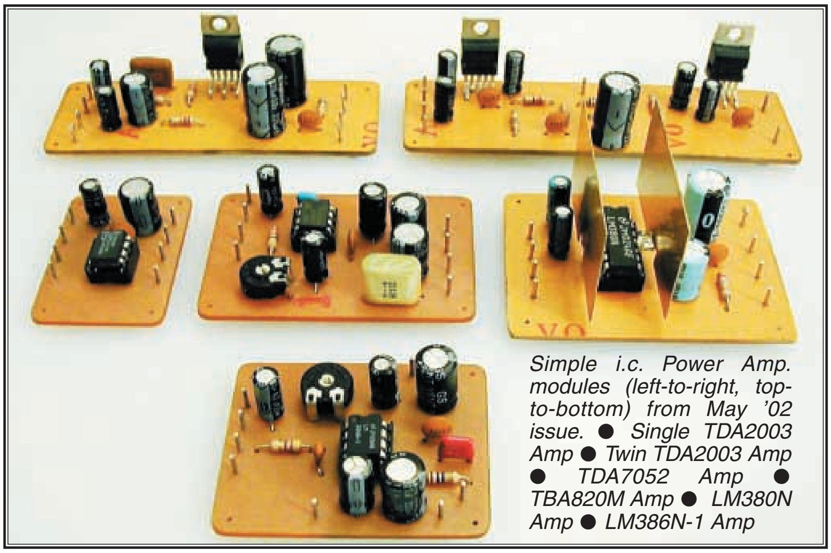
POWER SUPPLY

These problems can be avoided by regulating the output of the power supply, and a versatile circuit, which can be adapted for single or stereo pairs of any of the amplifiers described in Part 1 (May '02), is given in Fig.1. The mains voltage is stepped down by transformer T1, and a full-wave bridge rectifier arrangement, D1 to D4, produces the d.c. output. Reservoir capacitor C5 reduces supply ripple.

Voltage regulators IC1 and IC2 virtually eliminate any voltage swings caused by load variations. The regulators also remove any residual 100Hz ripple on the supply voltage rails and permit the use of a lower value reservoir capacitor (C5). Low level electrical noise, extending into the r.f. spectrum, is present in the output of the i.c.s, and bypass capacitors, C6, C7, C8 and C9, shunt this to the 0V rail.

The voltages required by amplifiers, preamplifiers and auxiliary equipment are often different, and provision is made for two regulated outputs. Alternatively, each output can supply a separate channel of a stereo system in order to double the current rating.

The switching action of the rectifier diodes (D1 to D4) modulates any r.f. (radio frequencies) present in the mains input. This modulated r.f. can be picked up by radio receivers connected to the supply and it manifests itself as a 100Hz hum which only appears when a station is tuned in. Capacitors C1 to C4, connected across the diodes, suppress this interference, which is known as modulation hum. If radio tuners are to be powered from this circuit, these capacitors must be fitted.



Simple i.c. Power Amp. modules (left-to-right, top-to-bottom) from May '02 issue. ● Single TDA2003 Amp ● Twin TDA2003 Amp ● TDA7052 Amp ● TBA820M Amp ● LM380N Amp ● LM386N-1 Amp

COMPONENT RATINGS

Fuse

It is good practice to protect the equipment with an internal fuse of the lowest possible rating. Because of the nature of the load, this should be of the anti-surge or slow-blow type, and a component rated at one amp (1A) would be suitable for power supplies serving the amplifiers described in this series of articles.

Transformer

The rectified d.c. voltage across the reservoir capacitor (C5) must be at least 3V more than the regulator output when maximum current is being drawn from the supply. Further, the maximum input voltage to the regulator i.c., which is usually 35V for devices with a 2A rating, *must not* be exceeded. It is also desirable for the voltage drop across it to be no more than 10V or so, or power dissipation within the chip will be increased and more elaborate heatsinking will be required.

These requirements can best be met if the mains transformer secondary voltage is 3V more than the regulated d.c. output.

To determine the required current rating of the secondary winding, add together the demands of the amplifiers and ancillary equipment to be connected to the power supply, and increase this by at least 25 per cent to allow for the reactive load presented by the reservoir capacitor (C5). The current requirements of the power amplifiers were given in Part 1. For convenience, they are repeated here in Table 2.

Manufacturers usually indicate the current delivering capacity of their mains transformers by quoting a ***VA*** rating. This is, of course, the secondary output voltage multiplied by the maximum current which the transformer can supply.

In Europe, mains transformers often have two 115V primary windings and two identical secondary windings. The primary windings must be series or parallel connected to suit the local supply voltage, and the secondary connected to deliver the desired output. Parallel connecting the secondary will, of course, double the current available. *Connect the windings in phase or the transformer will be short circuited.*

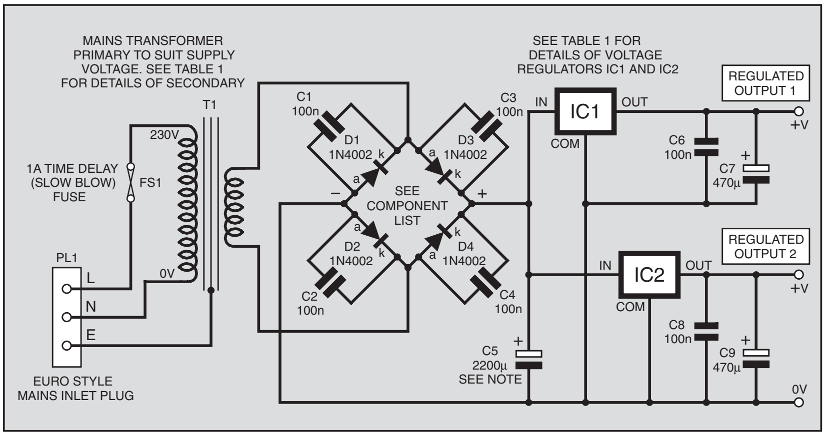


Fig.1. Circuit diagram for a Dual Output Regulated Power Supply.

Table 1: Component Ratings

Regulated Output V d.c.	*Transformer Sec. V r.m.s.*	*Regulator I.C. (1A max output)*	*C5 Working Voltage*
6	9	L7806	25
9	12	L7809	25
12	15	L7812	35
15	18	L7815	35

NOTES:

(1) To determine the transformer current rating, add together the current demands of pre and power amplifiers and any ancillary equipment, then increase the total by at least 25% to allow for the reactive load presented by C5.

(2) A bridge-connected pair of TDA2003 i.c.s with a 4 ohm load will draw 1·7A from a 15V supply and the **ratings of the rectifiers, regulator and reservoir capacitor must be increased**. Use 1N5401 rectifiers, an L78S15 regulator and a 4700μF capacitor for C5 (35V working).

(3) For two, bridge-connected pairs of TDA2003 i.c.s in a stereo combination, fit a 10000μF (or two 4700μF) 35V reservoir capacitor, two L78S15 regulators, (one for each stereo channel) and use P600D rectifiers.

Rectifiers

With a capacitor input filter, the rectifiers (D1 to D4) must have a p.i.v. (peak inverse voltage) rating at least three times the secondary voltage of the mains transformer. Their current rating should be at least 50 per cent greater than the maximum load on the power supply.

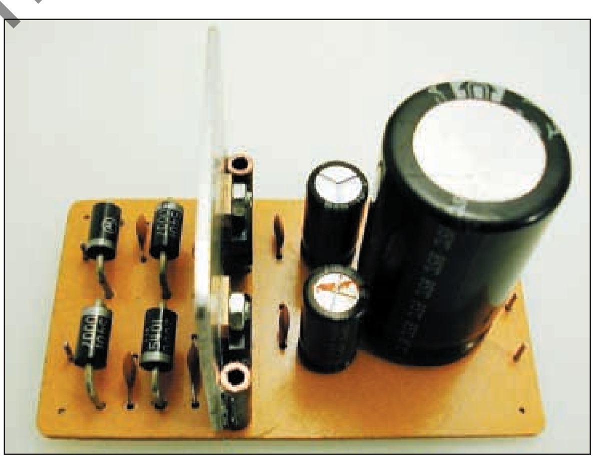
Reservoir Capacitor

The value of the reservoir capacitor, in microfarads (μF), should be at least 2500 times the maximum load current in amps when the supply is regulated, and double this value when unregulated. The working voltage should be at least double the secondary voltage of the mains transformer.

Regulators

The current rating of the voltage regulators (IC1 and IC2) must, of course, be equal to or greater than the maximum current demand on the power supply. The maximum input voltage rating (usually 30V to 35V) must be at least 1·5 times the secondary voltage of the mains transformer.

Regulator i.c.s are available in a range of output voltages suitable for the audio amplifiers (May'02) and preamplifiers (June'02) described in this series. Maximum current ratings are 5A for 12V and 3A for 15V units, but chips rated at more than 2A can be difficult to obtain. When the current demand exceeds 2A; e.g. when two, bridge-connected, pairs of TDA2003 audio power amplifier modules are used in a stereo combination, fit a 2A regulator to each output of the power supply and use one for each stereo channel.



Completed power supply board.

Table 2: Power Amplifier Current Requirements

Power Amp I.C.	*Speaker Imp Ohms*	*Supply volts V d.c.*	*Current drain A*	*Power output W*
LM386N-1	4	6	0·13	0·32
LM386N-1	8	9	0·12	0·56
TDA7052	4	6	0·42	0·78
TDA7052	8	9	0·39	1
TBA820M	4	9	0·23	0·98
TBA820M	8	12	0·17	1·1
LM380N	4	12	0·23	1·12
LM380N	8	15	0·19	1·32
TDA2003	4	15	0·5	3·92
TDA2003	8	15	0·27	2·1
TDA2003 x 2	4	15	1·7	12·5
TDA2003 x 2	8	15	0·96	8·2

Current drain and power output measured just before the onset of clipping.

Suppressor Capacitors

The working voltage of capacitors C1 to C4, connected across the rectifier diodes, should be at least four times the secondary voltage of the mains transformer. Bypass capacitors C6, C7, C8 and C9, should have a working voltage at least 1·5 times the transformer secondary voltage to protect them in the event of regulator failure.

DUAL OUTPUT REGULATED POWER SUPPLY

COMPONENTS

POWER SUPPLY

Capacitors
C1 to C4 — 100n ceramic, 100V (4 off)
C5 — 2200µ radial elect. (see Table 1)
C6, C8 — 100n ceramic, 50V (2 off)
C7, C9 — 470µ radial elect. 50V (2 off)

See SHOP TALK page

Semiconductors
D1 to D4 — 1N4002 rect. diode for 1A max. output (4 off)
1N5401 rect. diode for 3A max. output (4 off)
P60D rect. diode for 4A max. output, limited by regulators (4 off)
IC1, IC2 — 78 series for 1A; 78S series for 2A maximum output. See Table 1 (2 off)

Miscellaneous
T1 — mains transformer – see text and Table 1
FS1 — 1A 20mm slow-blow fuse to suit holder
PL1 — Euro fused mains inlet, chassis mounting, plug with line socket

Printed circuit board available from the EPE PCB Service, code 356 (PSU); metal case, size and type to choice; multistrand connecting wire; mains cable; aluminium sheet or proprietary heatsink and heatsink compound; solder pins; nuts, bolts and washers; stand-off pillars (4 off); solder etc.

Approx. Cost Guidance Only **£20** ***excluding case***

CONSTRUCTION

Any readers who have no experience of building or commissioning mains-powered equipment are reminded that the voltages involved can kill! Anyone who feels unsure of his or her ability to complete a project of this kind MUST seek help and guidance from an experienced constructor.

The small components are assembled on the printed circuit board (p.c.b.) as illustrated in Fig.2, together with a full-size copper foil master and the interwiring to off-board components. This board is available from the *EPE PCB Service*, code 356.

Commence construction by first soldering in position on the p.c.b. the rectifier diodes and non-electrolytic capacitors. This can be

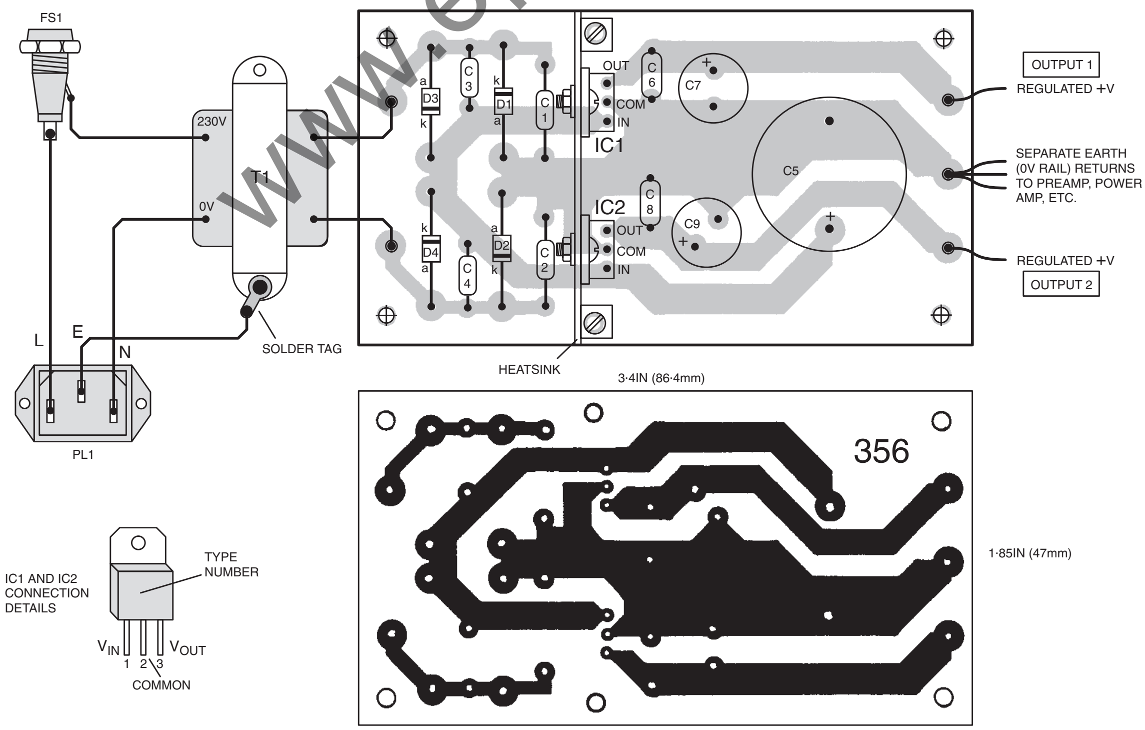


Fig.2. Power Supply printed circuit board, full-size copper master and suggested mains transformer and separate panel fuseholder interwiring. The 16 s.w.g. aluminium heatsink measures 45mm x 45mm.

followed by the larger electrolytic types and the voltage regulators IC1 and IC2. Finally, you will need to bolt a heatsink to the regulators and details of choosing a suitable heatsink will be given shortly. Solder pins, inserted at the lead-out points, simplify the task of off-board wiring.

Diodes D1 to D4, the reservoir capacitor, C5, and the regulators, IC1 and IC2, have to be chosen to suit the voltage and current to be delivered by the power supply. The requirements are summarised in Table 1 and the associated notes. Details of the modest current needs of the various preamplifiers were given in Part 2 of the series, and the current demands of the power amplifiers are scheduled in Table 2.

Dimensions and fixing arrangements for mains transformers vary and this heavy component should be mounted directly into or on the *metal* equipment case bottom or chassis panel. A Euro-style mains inlet plug, with a built-in fuseholder for FS1, is strongly recommended. You can, of course, use a separate panel-mounting fuseholder if you wish, see Fig.2.

Mains Earth should be connected to any metal case and to the core and cladding of the transformer. (A solder tag bolted under one of the mains transformer mounting lugs makes a good earthing point for the mains Earth lead.)

Interwiring details to off-board components are also shown in Fig.2. Leads connecting the mains transformer to the inlet plug and the p.c.b., and any mains switch wiring, should be tightly twisted to minimise external fields. Keep the transformer at least 150mm (6in.) away from signal input wiring.

Toroidal transformers have a smaller external field than units with conventional cores. They are the component of choice when the equipment is particularly compact and/or high gain preamplifiers are used.

HEATSINKING

Unless the current drain is to be very low (say 20mA or less), the regulator i.c.s must be bolted to a heatsink. The 45mm × 45mm sheet of 16s.w.g. aluminium shown on the drawing (Fig.2) is sufficient for current drains up to 1A when the voltage drop across the regulators is not too extreme.

For larger current loads it is suggested that the heatsink be extended and bolted to the metal case or chassis of the unit to ensure adequate heat transfer. Failure to properly dissipate heat from the regulators will result in the devices shutting down.

COMMISSIONING

Once construction has been completed, check the p.c.b. for poor soldered joints and bridged tracks. Check the orientation of electrolytic capacitors, diodes and regulators.

Make sure that the primary windings of the mains transformer are connected to suit the local supply voltage, and that the secondary windings are connected, in phase, to deliver the correct voltage to the power supply p.c.b. It is a good idea to connect the transformer to the mains and check the secondary voltage with a test meter before linking it to the p.c.b. **Extra care must be taken when carrying out this last task**.

Check the voltage across the reservoir capacitor C5, and that the voltages delivered by regulators (IC1 and IC2) are correct before using the supply to power any equipment.

LOUDSPEAKERS

Loudspeaker (speaker) designers have to make compromises. Sensitivity, good transient and good high frequency response call for a lightweight cone and speech coil assembly. Power handling and an extended low frequency response require a large, strong (and heavy) cone and coil.

For good sensitivity, the magnetic field cutting the voice coil must be intense. Unfortunately, this increases the impedance at the cone's resonant frequency. However, this impedance rise can be controlled by the speaker enclosure, and a powerful magnet is always preferable.

The reproduction of low frequencies involves large cone excursions and the suspension must be highly compliant. High compliance also lowers the cone's resonant frequency, and this extends the speaker's low frequency response. However, the need to maintain control of the position of the voice coil in the magnet gap imposes limits on how free the suspension can be.

Cone movement for a given sound output reduces with increasing speaker size but, as we have seen, greater diaphragm mass impairs transient and high-frequency response.

HORSES FOR COURSES

To avoid performance being excessively degraded by these conflicting requirements, domestic "hi-fi" systems usually combine two or more speakers, each being designed to reproduce part of the audio frequency spectrum.

The low frequency unit, or ***bass*** speaker, has a comparatively heavy cone and voice coil with a highly compliant suspension. Clever designers have managed to obtain reasonable results with small speakers, but an extended low frequency response and good power handling are more easy to achieve with speakers of 200mm (8in.) or more in diameter.

Mid-range units are sometimes provided when the low frequency speaker is large (300mm to 450mm or 12in. to 18in. diameter). As one would expect, cones are lighter, the compliance is often stiffer, and the chassis can form a sealed enclosure.

High-frequency units, or *"tweeters"*, have a very small diaphragm, which is commonly dome shaped to improve sound dispersal. Units of this kind always have sealed backs.

Whilst moving coil tweeters are the preferred option for hi-fi applications, horn-loaded piezoelectric units are often fitted in the high power speaker systems used by musicians. The impedance of these devices rises, and their power consumption falls almost to zero, as the applied frequency is lowered. They do not, therefore, require a "crossover unit", and are easy to connect into multiple speaker systems.

COMMUNICATIONS

Loudspeakers intended primarily for speech reproduction in communications equipment have to perform well over a restricted frequency range, usually around 300Hz to 3000Hz.

Inexpensive speakers of the type manufactured for portable receivers are better suited for this purpose, and, if space is available, a 102mm (4in.) diameter unit is to be preferred. Clarity will be impaired if low frequencies are allowed to excite the cone of a speaker of this kind, and measures to prevent this were discussed in Part 1 (May '02).

IMPEDANCE

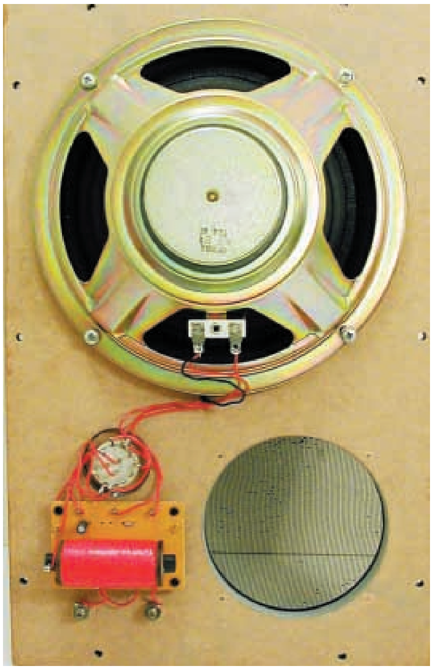
Speech coil impedance is usually measured at around 400Hz. At this frequency, the inductance of the coil has a minimal effect, and its impedance is only one or two ohms more than its d.c. resistance. As frequency rises, the inductance of the speech coil has a growing impact and impedance mounts steadily.

The movement of the speech coil in the magnetic field induces in it a voltage which opposes the signal voltage. At the cone's resonant frequency, very little energy is needed to sustain it in motion, and it vibrates readily, over larger distances, for a comparatively small power input.

These larger cone excursions generate a greater opposing voltage, or back-e.m.f., and speech coil impedance, at resonance, increases by as much as a factor of ten over its nominal value. The more powerful the magnetic field, the more dramatic the rise in impedance.

Impedance peaking at cone resonance (between 30Hz and 100Hz for low frequency speakers), and the gradual rise in impedance with increasing frequency, makes the response of the speaker non-linear. (The power which can be fed to a speaker system falls as its impedance rises). Fortunately, the former can be tamed by good enclosure design, and the latter can be overcome by the use of filter networks and the addition of a tweeter.

Care must always be taken to ensure that the rated impedance of a speaker system is not too low for the power amplifier. Too low an impedance will cause excessive dissipation in the output transistors and, if there is no overload protection circuitry, the power amplifier will be ruined.



Safe supply voltage and speaker impedance combinations for the various i.c. power amplifiers were given in Part 1. They are summarised here in Table 2.

CROSSOVERS

When two or more speakers are used to improve performance, arrangements must be made to allocate the audio spectrum between them.

The resistance presented by capacitors to the flow of alternating current decreases as frequency rises. With inductors, resistance increases with rising frequency. This frequency-dependant opposition to current flow is known as *reactance*.

Capacitors and inductors can be combined in simple networks which utilise this phenomenon to allocate frequency bands to different speakers. Circuits and design data are given in Fig.3 and inductor and capacitor values for common speaker impedances, and a range of crossover frequencies, are set out in Table 3. The reactances of standard value capacitors, at various audio frequencies, were tabulated in Part Two.

FILTER ORDERS

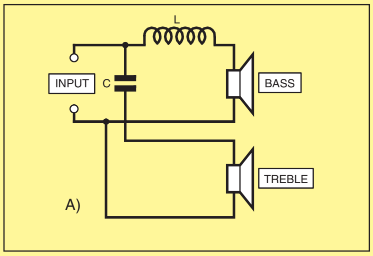
The simple "first order" filters shown in Fig.3a and Fig.3d are perfectly suitable for domestic systems rated at up to 15W.

Low frequency roll-off above the crossover frequency is 6dB per octave and this may not be sufficient to protect some tweeters when higher powered amplifiers are used. In these cases, the second order filters, shown in Fig.3b and Fig.3e, which produce a 12dB roll-off, are safer options.

Table 3: Crossover Network Inductor and Capacitor Values

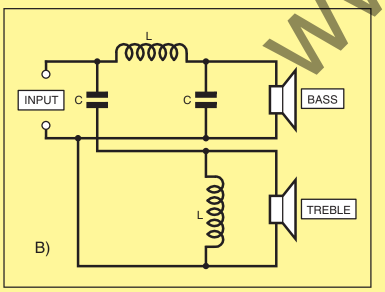
Crossover frequency Hertz		***500***	***1000***	***1500***	***2000***	***2500***	***3000***	***3500***	***4000***	***4500***
4 ohm Speaker	L	1·3	0·63	0·42	0·32	0·25	0·21	0·18	0·16	0·14
1st Order Filter	C	80	40	26	20	16	13	11	10	8
4 ohm Speaker	L	1·8	0·9	0·6	0·5	0·35	0·3	0·25	0·22	0·2
2nd Order Filter	C	56	28	18	14	11	9	8	7	6
8 ohm Speaker	L	2·6	1·26	0·84	0·64	0·5	0·42	0·36	0·32	0·28
1st Order Filter	C	40	20	13	10	8	6·5	5·5	5	4
8 ohm Speaker	L	3·6	1·8	1·2	1	0·7	0·6	0·5	0·44	0·4
2nd Order Filter	C	28	14	9	7	6	4·5	4	3·5	3

Inductance values, L, are given in mH (millihenries).
Capacitor values, C, are given in μF (microfarads).
See text for guidance on rounding figures up or down to nearest standard value.



FIRST ORDER NETWORK
TWO SPEAKER SYSTEM

Make reactance of inductor, L, and capacitor, C, at the crossover frequency, equal to the rated speaker impedance.

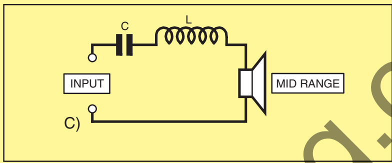


SECOND ORDER NETWORK
TWO SPEAKER SYSTEM

(1) Calculate inductor and capacitor values, as for the first order network.

(2) Divide the capacitor values by 1·4 and multiply the inductor values by 1·4 to obtain the correct values for the second order two speaker network.

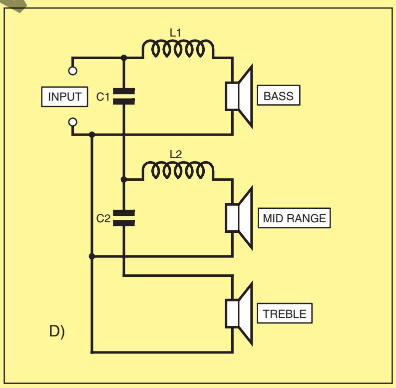
Inductors, L, are identical.
Capacitors, C, are identical.



FIRST ORDER NETWORK
MID-PASS ARRANGEMENT

Make the reactance of inductor, L, and capacitor, C, at the centre frequency of the pass band, equal to the rated speaker impedance.

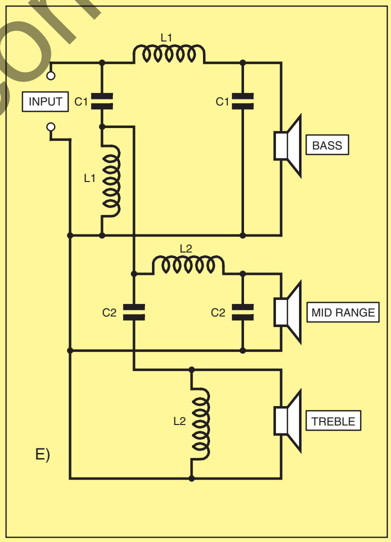
Assume a band centre frequency of 1000Hz when the circuit is being used as a band-pass filter for speech frequencies.



FIRST ORDER NETWORK
THREE SPEAKER SYSTEM

(1) Make inductor, L1, and capacitor, C1, reactances, at the bass/mid-range cross-over frequency, equal to the rated speaker impedance.

(2) Make inductor, L2, and capacitor, C2, reactances, at the mid-range/-treble cross-over frequency, equal to the rated speaker impedance.



SECOND ORDER NETWORK
THREE SPEAKER SYSTEM

(1) Calculate inductor and capacitor values as for the first order three speaker network.

(2) Divide the capacitor values by 1·4 and multiply the inductor values by 1·4 to obtain the correct values for the second order three speaker network.

Fig.3. Circuit and design data for loudspeaker crossover networks. Inductor and capacitor values for common speaker impedances and crossover frequencies are given in Table 3.

Components with the same reference numbers have identical values – i.e. L1 and L2 are two inductors of the same value; C1 and C2 are capacitors of the same value.

CROSSOVER FREQUENCY

With two-speaker systems the crossover frequency is usually between 1kHz and 4·5kHz, and the tweeter manufacturer's recommendations should be followed. If the unit is of uncertain origin, adopt a crossover frequency of around 2·5kHz: this will normally be satisfactory.

When the bass speaker is large (12 inches diameter or more), a crossover at 1kHz or even lower can produce a more even frequency response. Suitable tweeters tend to be rather costly, but an inexpensive alternative will be described later.

THREE SPEAKERS

Another way of ensuring a more even response when a large bass speaker is used is to install a third, mid-range unit. Suitable circuits are given in Fig.3d and Fig.3e.

The bass/mid-range crossover point is usually around 500Hz with open chassis mid-range speakers, and 1000Hz with sealed back units. The mid-range/treble crossover is generally between 4·5kHz and 6kHz. Again, the recommendations of the speaker manufacturer should be followed.

PHASING

Parallel connected bass speakers must be wired in phase to avoid cancellation of the lower audio frequencies. Use a 1·5V dry cell to test for phasing on unmarked speakers by noting the battery positive connection for the outward movement of the cone.

Crossover networks introduce phase shift, but, as frequency increases, phasing becomes less important. Readers can try reversing the connections to mid-range units. However, unless they have a very refined ear, they are not likely to detect any difference.

CROSSOVER COMPONENTS

Inductors

Inductors for home-made crossovers have to be hand wound. The amount of wire, and the resistive losses, can be greatly reduced by winding the coils on short lengths of ferrite aerial rod. Core saturation problems should not arise at the power levels encountered in domestic installations.

Bobbin construction is illustrated in Fig.4. Winding details for the inductor values likely to be encountered are given in Table 4.

The wire should be wound on evenly, and masking tape, applied over each layer, will make the task a little easier. Constructors who have difficulty producing neat windings should increase the diameter of the bobbin ends for the larger inductance coils.

Capacitors

The bipolar electrolytic capacitors used in crossover networks are available in a limited range of values. Capacitors of this kind can be formed by connecting two ordinary electrolytics back-to-back, and this makes possible the production of non-standard values. The details are given in Fig.5. Capacitors rated at 50V working will be suitable for all of the power amplifiers described in Part 1.

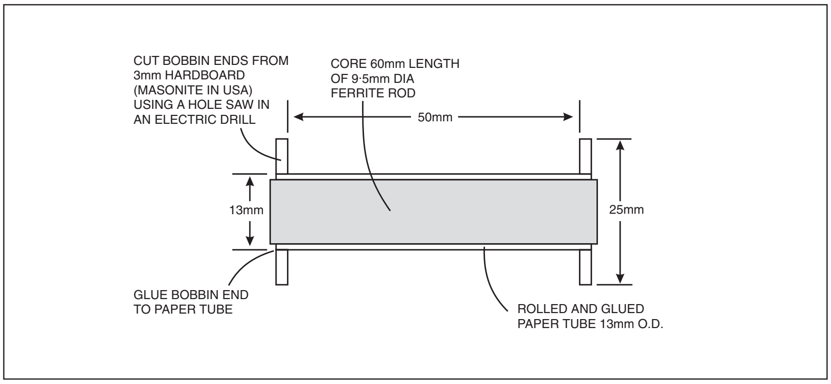


Fig.4. Inductor bobbin construction details.

Table 4: Inductance of Ferrite-cored Coils

Induct mH	0·1	0·2	0·3	0·4	0·5	0·75	1	1·5	2	2·5	3	3·5
No. of turns	45	60	75	90	100	125	150	175	200	225	250	275

Use 20 s.w.g. (19 a.w.g.) enamelled copper wire for coils up to 2mH.
Use 22 s.w.g. (21 a.w.g.) enamelled copper wire for 2·5mH to 3·5mH coils.
See illustration for details of bobbin and core.

The performance of electrolytic capacitors can become uncertain at high audio frequencies, and the best crossover networks use components with a paper, polyester or polypropylene dielectric.

Tolerances

Variations in the composition of ferrite rod will affect the tabulated inductor values shown in Table 4 by plus or minus 10 per cent or so. Bipolar electrolytics, whether purchased or homemade, have a tolerance, at best, of plus or minus 20 per cent.

Fortunately, loudspeaker crossover networks are very forgiving, and component spreads even greater than this produce no audible difference. When calculated values are being rounded up or down, it is prudent to err on the high side with inductors and on the low side with capacitors.

BANDPASS FILTERS

Mention has already been made of the desirability of restricting the audio bandwidth of speakers used primarily for speech communication. An inductor and capacitor can be combined to produce a bandpass effect, and a typical circuit is given in Fig.3c.

As a starting point, select the inductor and capacitor values for a centre frequency of 1000Hz (1kHz). If a more severe attenuation of frequencies below 300Hz and above 3000Hz (3kHz) is required, reduce the capacitor and increase the inductor value. When using this network with earphones, connect both earpieces in parallel to produce an impedance of 16 ohms, and perform the calculations on this basis.

Although extremely simple, this measure will greatly improve the clarity of speech, especially when signals are overlaid by received or generated noise within the amplifiers.

CROSSOVER UNIT

The circuit diagram for an inexpensive 8ohm Crossover/Filter unit suitable for a multi-purpose workshop speaker is shown

FORMULAE FOR THE REACTANCE OF INDUCTORS AND CAPACITORS

$$X_L = 0{\cdot}00628\ f\ L \text{ ohms}$$

$$X_C = \frac{159000 \text{ ohms}}{f\ c}$$

where
f is in Hertz
L is in millihenries (mH)
and C is in microfarads (μF)

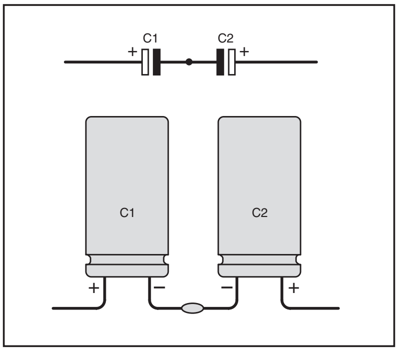


Fig.5. Creating a bipolar electrolytic from two capacitors.

FORMULAE FOR COMBINING CAPACITORS

Two capacitors in series:

$$Cx = \frac{C1 \times C2}{C1 + C2}$$

Capacitors in parallel:

$$Cx = C1 + C2 + C3 \ldots\ldots$$

The working voltage of each capacitor should be at least 1·5 times the peak-to-peak signal voltage developed across the loudspeaker at maximum input.

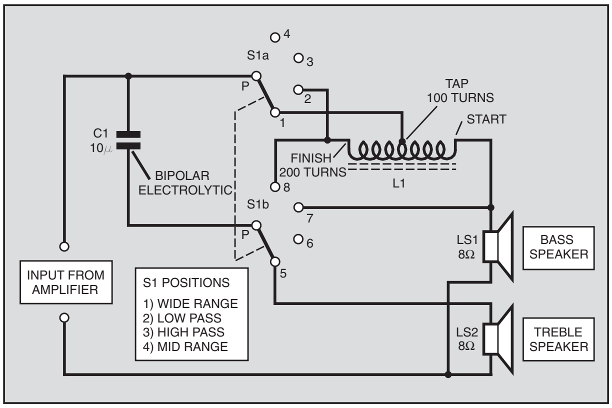
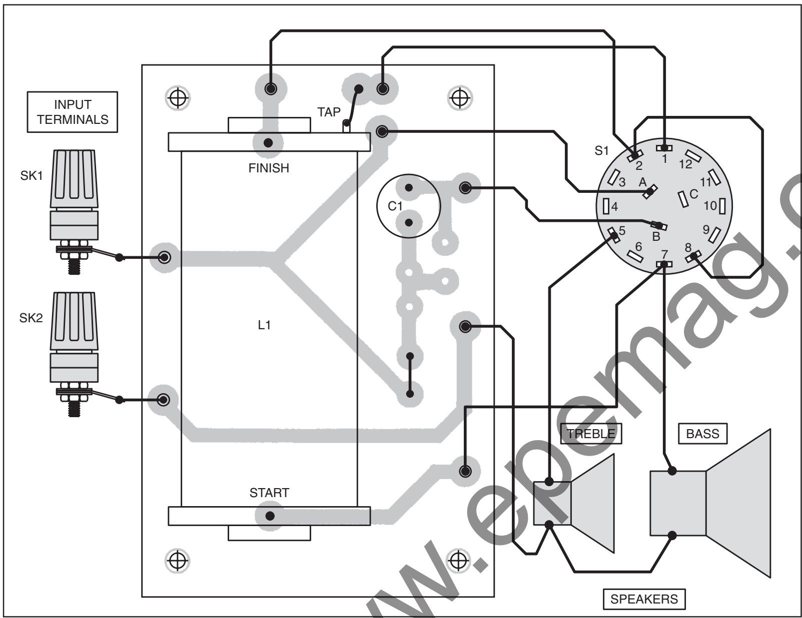
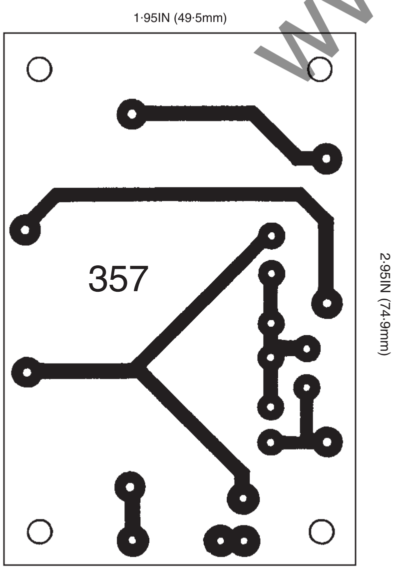
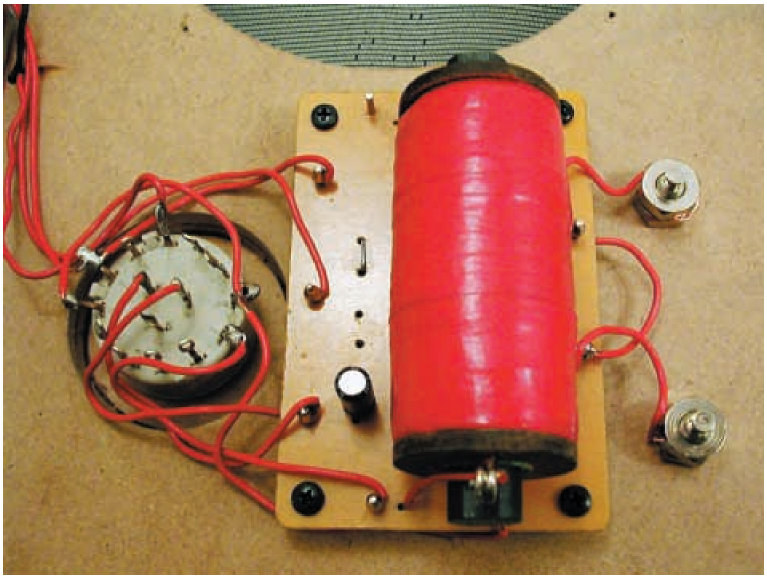


Fig.6. Circuit diagram for the Loudspeaker Crossover/Audio Filter.







COMPONENTS

CROSSOVER/AUDIO FILTER

Capacitors

C1 10µ bipolar radial elect. 50V (Alternatively, two 22µ standard elect. connected back-to-back – see text and Fig.5)

Inductor

See SHOP TALK page

L1 9·5mm (3/8in.) dia. ferrite rod, length 63mm (2½in.); card, hardboard and glue for bobbin. Enamelled copper wire: Crossover only – 100 turns 20 s.w.g. (19 a.w.g.). Crossover and Filter – 200 turns 22 s.w.g. (21 a.w.g.). See Fig.4 and text

Miscellaneous

S1 3-pole 4-way rotary switch (only two poles used)

SK1, SK2 4mm screw terminal post/socket (2 off)

Printed circuit board available from the *EPE PCB Service*, code 357 (Crossover/Filter); multistrand and connecting wire; plastic control knob; speaker terminals; solder pins; solder etc.

Approx. Cost Guidance Only **£9** *excluding speakers*

Fig.7. Crossover/Audio Filter printed circuit board component layout, interwiring to off-board components and full-size copper foil master. The completed crossover is shown in the above photograph.

in Fig.6. The first order filter serves as a basic crossover when the speaker is being used for testing or listening to "hi-fi" equipment.

Switching out the Treble speaker and connecting the inductor in series with the Bass speaker gives a low-pass (top cut) effect. Connecting the capacitor in series with the speaker provides a high-pass (bass cut) arrangement. With the inductor and capacitor in series with the speaker, response to speech frequencies is emphasised, making the unit suitable for use with a communications receiver or for surveillance work.

Rotary switch S1 selects the required function, and the inductor is tapped to provide appropriate values for the crossover and speech filter.

CONSTRUCTION

Construction of the Crossover/Filter Unit is based on a small single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 357.

The topside component layout, full-size copper foil master and off-board wiring details are illustrated in Fig.7. Again, solder pins at the lead-out points will simplify off-board wiring. The p.c.b. makes provision for series and parallel combinations of capacitors, and a wire link must be inserted if capacitor C1 is a single, bipolar electrolytic.

Constructors interested only in "hi-fi" applications can ignore the switching arrangements and simply connect a 100-turn (0·5mH) inductor and the capacitor as shown in Fig.3a.

Next Month: The final part will deal with speaker enclosures and include a low-cost, high-performance design which incorporates this month's Crossover/Filter unit.

The construction of a simple and inexpensive oscillator and resonance detector, which can be used to match any speaker to an enclosure and optimise performance, will also be described.

Low Frequency Oscillator for loudspeaker resonance checking.

SHOP TALK
with David Barrington

Infra-Red Autoswitch

As the *Infra-Red Autoswitch* project is mains powered, all the components have been specially selected to fit directly on the small printed circuit board (p.c.b.). If alternative, non-board mounting components, such as the mains transformer and relay, are used you ***must*** take extra care when building and testing this unit. In this case, it is very important that the p.c.b. and any off-board parts be mounted in its case ***before*** testing and that a separate *battery* supply is used for checking its operation, prior to mains connection.

The special Sharp IS471F infra-red sensor/detector came from **RS Components** and carries the order code 564-396. They also supplied the p.c.b. mounting, short-circuit proof, mains transformer with twin 9V 0·027A (0·5VA total) secondaries, code 310-1263. These components can be ordered from any *bona-fide* RS stockists, including some of our advertisers. You can order direct (*credit card only*) on ☎ ***01536 444079*** or on the web at **rswww.com**. A post and handling charge will be made.

The 12V d.c. low-profile relay, with 12A 250V a.c. rated single-pole changeover contacts, used in the model was purchased from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapid electronics.co.uk***), code 60-4630. We understand that RS (see above) also stock a similar relay, code 198-6933.

The specified low-profile case came from **CPC** (*credit card only*), ☎ ***08701 202530***, code EN55028. A post and packing charge is made on all orders under £30. The Autoswitch printed circuit board is available from the *EPE PCB Service*, code 358 (see page 539).

Teach-In 2002 – Lab 9

Once again, it's only the sensor and semiconductor devices called for in this month's *Teach-In 2002 Lab Work* that will give some readers sourcing grief. Starting with the Nemoto NAP-7AU gas sensor/compensator pair, these were obtained from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code FM87U and are sold as a pair.

We have found two listings for the precision low off-set op.amp type OP177 and it can be ordered from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 82-0092, or **RS Components** (☎ ***01536 444079*** or on the web at ***rswww.com***), code 127-2868. Expect to pay a handling and postage charge.

If readers experience any difficulty in finding a local source for the 4093 quad 2-input NAND Schmitt trigger (Rapid 83-0420) and the ADC0804 8-bit analogue-to-digital chip (Maplin QQ00A or RS 411-674) they should contact the above mentioned companies. The relevant code numbers are shown in brackets.

The Linear Technology LTC1062CN8 5th order switched capacitor low-pass filter i.c., used in the *Anti-aliasing Filter (Lab 9.5)*, appears to be listed only by RS (see above), code 633-880.

EPE Stylopic

A couple of items proved hard to find when tracking down parts for the *EPE StyloPIC* project. The National Semiconductor LM13600 transconductance amplifier i.c. and the SGS-Thompson L272 dual power op.amp i.c. only appear to be listed by **RS**, codes 304-453 and 635-167 respectively. You can order them direct from RS (credit card only) on ☎ ***01536 444079*** or on the web at ***rswww.com***. A post and handling charge will be levied.

The above company supplied the Texas TLC7524CN 8-bit digital-to-analogue converter chip, code 650-087. It is also currently listed by **Rapid** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 82-0764, but double check it is the 16-pin device being supplied.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-20 microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). It is the 20MHz version you require. The software is available on a 3·5in. PC-compatible disk (*EPE* Disk 5) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 539). It is also available *Free* from the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pub/PIC/StyloPIC**.

The printed circuit board/keyboard is available from the *EPE PCB Service*, code 359 (see page 539).

Simple Audio Circuits – 3

Most of our components advertisers should be able to supply all the parts needed to construct the circuits in this month's instalment of the *Simple Audio Circuits*. A suitable Bulgin fused Euro-style mains inlet, chassis mounting, plug (code MK18U or FT37S) together with an insulation, rear tag, protective cover (code JK67X) and line socket (UL16S) is listed by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***). They also list the 6A 200V P600D rectifier diode for one version of the Power Supply Unit, code UK60Q.

If problems are experienced in obtaining a ferrite rod for the Crossover unit, we understand, from the author, that one is obtainable from **JAB, PO Box 5774, Birmingham, B44 8PJ** (*mail order only*), and **J. Birkett** (☎ ***01522 520767***). You will need to cut the rod down to size (take care, it is brittle!). These two firms can also supply 50g (2oz) reels of enamelled copper wire for the Crossover.

The two printed circuit boards are available from the *EPE PCB Service*, codes 356 (PSU) and 357 (Crossover) – see page 539.

Rotary Combination Lock

Probably the most expensive item when purchasing components for the *Rotary Combination Lock* project is likely to be the heavy-duty power solenoid. The one in the model cost about £15 and came from **RS** (☎ ***01536 444079*** or ***rswww.com***) and is their 12V d.c. standard pull action, spring return type, code 250-1303. They also supplied the Omron 12V d.c. ultra-min., p.c.b. mounting relay, code 369-359.

The two printed circuit boards are available from the *EPE PCB Service*, code 260 (Lock) and 361 (Interface).

PLEASE TAKE NOTE

L.E.D. Sequencer (Ingenuity Unlimited) *June '02*
Page 406. To prevent the i.c. outputs (IC2, IC3) from adversely affecting each other, 1N4148 signal diodes should be inserted between each i.c. pin and the respective l.e.d. The anode on the pin and cathode on the l.e.d.

World Lamp *June '02*
Where it is said that VR1 should be turned clockwise, this should read anti-clockwise, and where anti-clockwise, clockwise.

Toolkit TK3
Updated files for V1.2 are now on our FTP site. Only files Disk 1 and Disk 3 are affected.