SIMPLE AUDIO CIRCUITS

Part 2 – Preamplifiers, Tone Controls and Filters

RAYMOND HAIGH

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

ALTHOUGH the power amplifiers described last month have a respectable amount of gain, some signals may be too weak to produce an adequate loudspeaker output without additional amplification. They can also be further weakened by an excessive mismatch between signal source and amplifier. Tone controls are usually required when music is being reproduced, and restricting the bandwidth will clarify speech signals, especially under noisy conditions.

These three issues: preamplification, impedance matching and tailoring the frequency response, are covered in this article.

TRANSISTOR AMPLIFIERS

Impedances

The impedances presented by the input and output ports of transistor amplifier stages are extremely variable. Load and bias resistors exert a major influence, as do the gain of the transistor and its emitter current. Negative feedback can either raise or lower impedance and, to further confuse the issue, the load connected across one port influences the impedance presented by the other.

The impedance figures quoted are, therefore, intended as no more than *a guide* when selecting the best circuit for a particular application.

Biasing

Transistor amplifier stages are usually biased so that the output (collector or emitter; drain or source) rests at half the supply voltage under no-signal conditions. This enables the stage to deliver the greatest possible signal swing; i.e. the highest output, before the onset of clipping.

Transistor gain (h_{fe}), and supply voltage, affect the biasing. However, over a wide range of h_{fe} values (at least 200 to 600), and supply voltages from +9V to +12V, the circuits described here will deliver a low distortion output that is more than sufficient to fully drive the power amplifiers described last month.

Experimenters who require the stages to have the highest possible signal-handling capability for a given supply voltage may have to adjust the bias resistors. Guidance on this is given later.

Cascading

The various preamplifiers, tone controls and filters can be combined to suit individual requirements. Blocking capacitors have been provided at the inputs and outputs, and the units can be used safely with any equipment.

Cascading makes one of these capacitors redundant. Similarly, when they are connected to the power amp described last month, the output blocking capacitor can be omitted (C1 on the power amplifier p.c.b. duplicates this component).

Decoupling

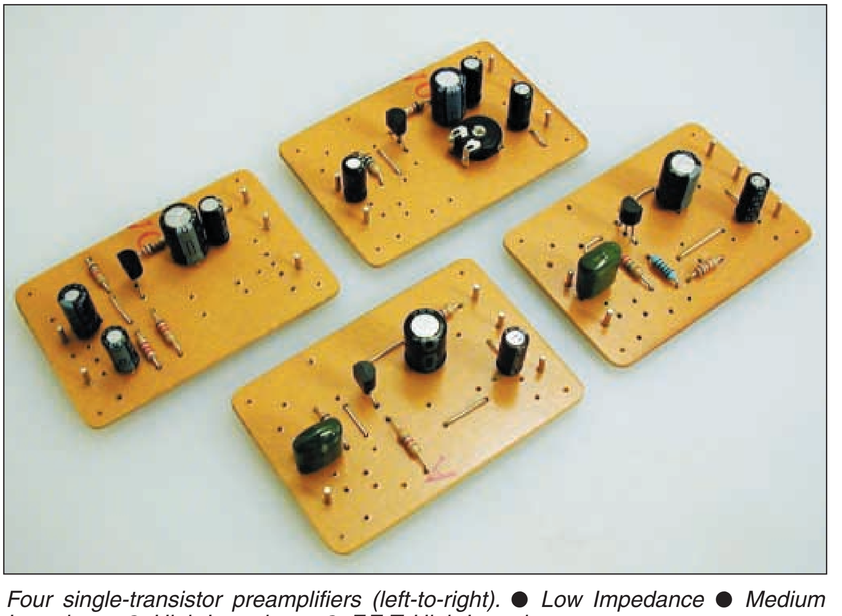
All of the preamplifier circuits are decoupled from the power supply by a resistor and capacitor. Failure to include these components will almost certainly result in motor boating (low frequency instability).

The main cause of this instability is the wide swing in power amplifier current drain: even with small units this can range from 10mA to 150mA. These signal-induced current swings cause variations in the voltage of dry batteries or badly regulated mains power supplies. When high gain preamplifiers share the same supply rail, the resulting feedback causes low-frequency oscillation.

If problems are encountered, increase the value of the decoupling resistor, or capacitor, or both, by a factor of ten. A capacitor of 2000μF or more, connected across a dry battery power supply, will also help to eliminate instability at high volume levels.

R.F. Interference

The single transistor preamplifiers described here have an extended high



Four single-transistor preamplifiers (left-to-right). ● Low Impedance ● Medium Impedance ● High Impedance ● F.E.T. High Impedance.

frequency response, and problems with r.f. interference may be encountered. Connecting a low value ceramic capacitor between the input (emitter or base) and the 0V rail will cure the problem, and the accompanying printed circuit board (p.c.b.) makes provision for this.

SINGLE TRANSISTOR CIRCUITS

In many cases, all that is required is the additional gain and/or impedance matching afforded by a single transistor stage. Four circuits will now be considered.

Low Input Impedance Preamplifier

It is convenient, with simple intercom units, to make the speaker double up as a microphone. Voice coil impedance and output are very low: a few ohms and less than 1mV at a close speaking distance. Transformers are often used to increase the impedance and voltage of this signal source, but a transistor can be made to do the job just as well.

The "grounded base" stage illustrated in Fig.1 has an input impedance of around 50 ohms, an output impedance roughly equal to the collector load resistance (R2) of 10 kilohms, and a voltage gain of around 100. Although more commonly encountered at the front-end of a radio receiver, this configuration is suitable for matching low source impedances to the power amplifier and, at the same time, providing a useful amount of voltage gain.

In the circuit diagram for the Low Input Impedance Preamplifier shown in Fig.1, C1 is a d.c. blocking capacitor, R1 and R2 are the input and output load resistors, and resistors R3 and R4 bias the transistor. The base (b) is grounded at audio frequencies by capacitor C3.

Supply line decoupling is effected by C4 and R5, and C2 is the output coupling and d.c. blocking capacitor.

CIRCUIT BOARD

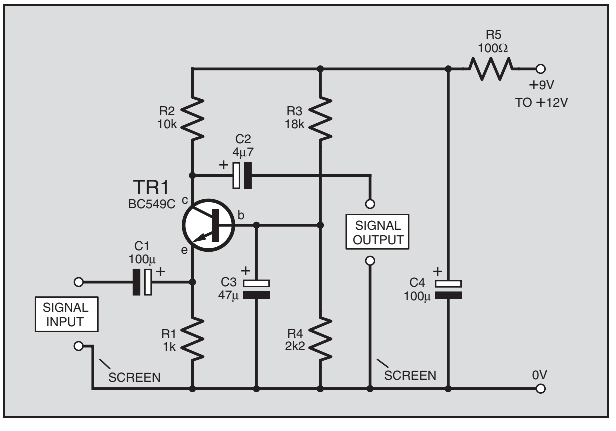
The printed circuit board component layout, wiring details and full-size copper foil master pattern are shown in Fig.2. This board is available from the *EPE PCB Service*, code 349 (Single Trans.).

Before commencing assembly, check the component, construction and interconnection notes at the end of the article.

VARIATIONS

Readers wishing to operate the stage from lower supply voltages should check the voltage on the collector (c) of transistor TR1 under no-signal conditions. If it is much more than half the supply voltage, reduce the value of resistor R3 to increase the bias current. With 3V on the supply rail, R3 will need reducing to around 6·8 kilohms and, with a 6V supply, its value will be in the region of 12k.

Because of its very low input impedance, the circuit of Fig.1 is not prone to capacitative hum pick up, and the input lead can be

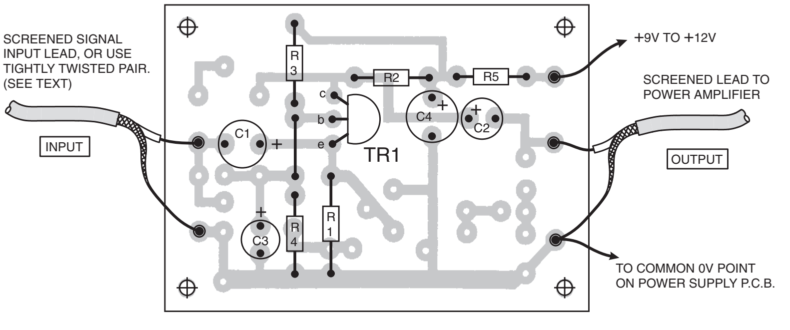


VOLTAGE GAIN 100 OVER AN h_{fe} SPREAD OF 110 TO 600.
CURRENT DRAIN AT 9V SUPPLY 0·75mA.

Fig.1. Circuit diagram for the single-transistor Low Input Impedance Preamplifier.

LOW INPUT IMPEDANCE PREAMPLIFIER

Low Input Impedance Preamplifier components mounted on the "single" p.c.b.



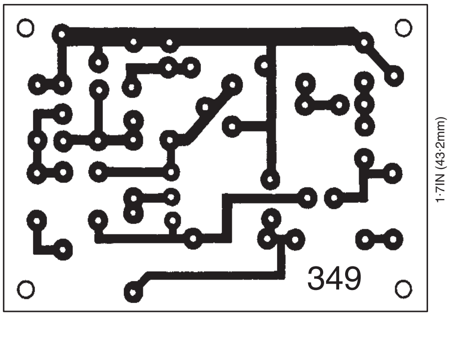


Fig.2. Printed circuit board component layout, wiring and full-size copper foil master pattern for the Low Input Impedance Preamplifier.

COMPONENTS

LOW INPUT IMPEDANCE

Resistors

R1	1k	See
R2	10k	SHOP
R3	18k (see text)	TALK
R4	2k2	page
R5	100Ω	

All 0·25W 5% carbon film

Capacitors

C1, C4	100µ radial elect. 25V (2 off)
C2	4µ7 radial elect. 25V
C3	47µ radial elect. 25V

Semiconductors

TR1	BC549C *npn* transistor (or similar – see text)

Miscellaneous

Printed circuit board available from the *EPE PCB Service*, code 349 (Single Trans); audio screened cable; multistrand connecting wire; input and output sockets, type to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£7**

tightly twisted flex rather than screened cable. If r.f. interference problems are encountered, connect a 100nF capacitor between the emitter (e) of TR1 and the 0V rail: provision is made for this on the p.c.b.

Combining this low impedance circuit (Fig.1) with the LM386N-1 or the TBA820M power amplifiers (fully described in Part 1, last month) will produce a decent intercom unit, but more amplification is needed for surveillance purposes. Cascading the grounded base stage with the medium impedance preamplifier described next (Fig.3) is one possible answer.

Medium Input Impedance Preamplifier

The input impedance of the single transistor, common emitter preamplifier illustrated in Fig.3 is approximately 1500 ohms (1·5k), and the output impedance roughly equal to the value of the load resistor, R2; i.e. 4700 ohms (4·7k).

Base bias resistor R1 is connected to transistor TR1 collector (c) rather than the supply rail. The resulting d.c. negative feedback makes the biasing more immune to transistor gain spreads and variations in supply voltage.

Preset potentiometer VR1 acts as the emitter bias resistor. Connecting capacitor C2 to the slider (moving contact) enables part of it to be left un-bypassed. This introduces varying levels of negative feedback and, with the specified transistor, the gain of the stage can be set between 10 and 160 times to suit different applications.

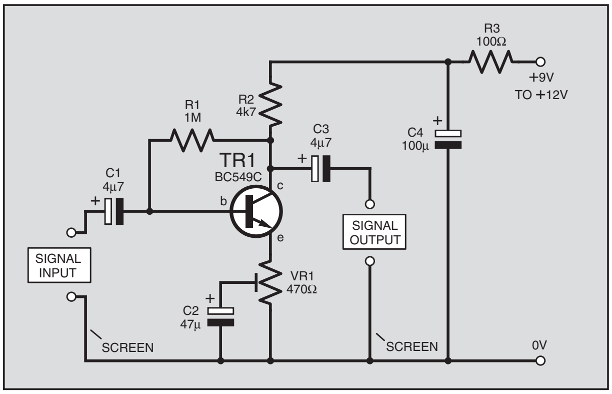
Comment has already been made about supply rail decouplers, R3 and C4, and blocking capacitors, C1 and C3.

CIRCUIT BOARD

The printed circuit board component layout, wiring details and full-size copper foil master pattern are shown in Fig.4. This board is available from the *EPE PCB Service*, code 349 (Single Trans.).

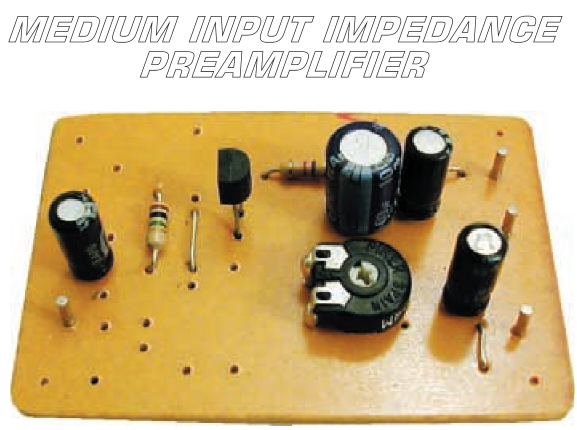
Before undertaking assembly work, see the component, construction and interconnection details at the end of the article.

Provision is made for connecting an r.f. bypass capacitor across the input. A 1nF or 10nF ceramic component should be adequate if problems arise.



VOLTAGE GAIN WITH VR1 SLIDER AT 0V RAIL, 8 TO 10 OVER AN h_{fe} SPREAD OF 110 TO 600.
VOLTAGE GAIN WITH SLIDER AT TR1 EMITTER, 80 TO 600 OVER AN h_{fe} SPREAD OF 110 TO 600.
CURRENT DRAIN AT 9V SUPPLY: 1·25mA.

Fig.3. Circuit diagram for the Medium Input Impedance Preamplifier.



Medium Input Impedance preamplifier components mounted on the "single" p.c.b.

COMPONENTS

MEDIUM INPUT IMPEDANCE

See SHOP TALK page

Resistors
R1 1M
R2 4k7
R3 100Ω
All 0·25W 5% carbon film

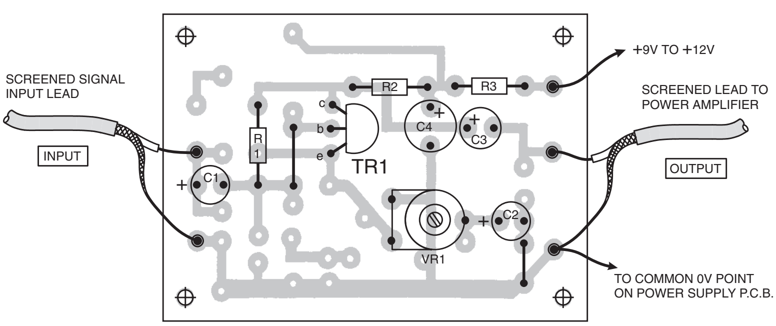
Potentiometers
VR1 470Ω enclosed carbon preset

Capacitors
C1, C3 4μ7 radial elect. 25V (2 off)
C2 47μ radial elect. 25V
C4 100μ radial elect. 25V

Semiconductors
TR1 BC549C *npn* transistor (or similar – see text)

Miscellaneous
Printed circuit board available from the *EPE PCB Service*, code 349 (Single Trans); audio screened cable; multi-strand connecting wire; input and output sockets, type and size to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£7**



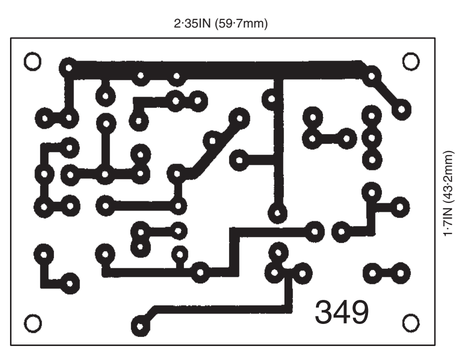


Fig.4. Medium Input Impedance Preamplifier printed circuit board component layout, wiring and full-size copper foil master.

High Input Impedance Preamplifier

Crystal microphones and ceramic gramophone pick-ups (there are still a few in use) require an amplifier with a high input impedance, and a stage of this kind is useful when the damping on a signal source has to be kept low.

Configuring a bipolar transistor in the emitter-follower (common collector) mode results in a high input and low output impedance, and a typical High Input Impedance Preamplifier circuit diagram is shown in Fig.5. The input impedance is roughly equal to the gain of the transistor (h_{fe}) multiplied by the value of the emitter load resistor R2.

This is, however, limited by the bias resistor R1, and the output load, which shunts the emitter resistor. Nevertheless, a high gain transistor will still produce an input impedance of about 100 kilohms.

Often the low output impedance is the sought after feature, either for matching purposes or for avoiding high-frequency losses and hum pick-up when long screened cables have to be used. Output impedance is directly related to the impedance presented by the signal source, and is usually in the region of 1000 ohms. The voltage gain of the circuit is a little less than unity.

CIRCUIT BOARD

The printed circuit board component layout, wiring details and full-size copper foil master pattern for the High Input Impedance Preamplifier are shown in Fig.6. This board is the same one used for all the single transistor preamplifiers, and is available from the *EPE PCB Service*, code 349 (Single Trans.). See the component, construction and interconnection notes at the end of the article.

High input impedance makes the stage very vulnerable to hum pick up. Careful attention must, therefore, be paid to screening the input leads and, possibly, the entire unit.

VARIATIONS

It is possible to obtain higher input impedances with a bipolar transistor by applying positive feedback from the emitter to the base bias network. This involves an extra pair of resistors and a capacitor, and an alternative solution, if very high input impedances are required, is to use a field effect transistor (f.e.t.); a device which tends to introduce less noise at audio frequencies.

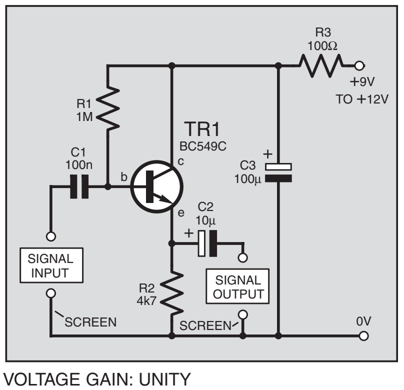
USING A F.E.T.

A circuit diagram for a F.E.T. High Input Impedance Preamplifier is given in Fig.7. The gate resistor R1 is tapped down to the source resistors R2/R3 in order to improve biasing and, hence, signal handling. By this means the f.e.t. develops its gate bias across R2, and R3 drops an additional 3V or so to fix the voltage on the source at around half the supply voltage.

Connecting the gate resistor R1 in this way applies a proportion of the in-phase output signal to its lower end, and the resulting positive feedback, or "bootstrapping", increases its effective resistance, and the input impedance of the circuit, to around 6 megohms (6M).

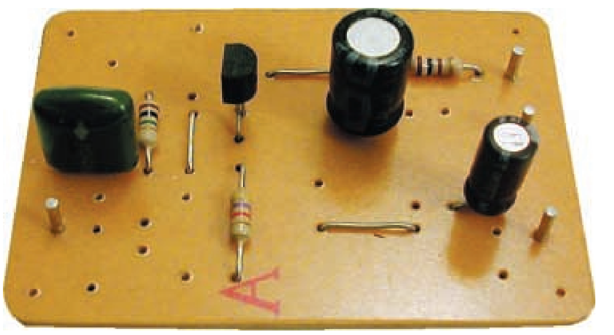
Output impedance is independent of signal source impedance. It is governed by the transconductance (gain) of the device, and is usually of the order of 500 ohms.

HIGH INPUT IMPEDANCE PREAMPLIFIER



VOLTAGE GAIN: UNITY
CURRENT DRAIN AT 9V SUPPLY: 1·25mA.

Fig.5. High Input Impedance Preamplifier circuit diagram.



High Input Impedance Preamplfier circuit board.

COMPONENTS

HIGH INPUT IMPEDANCE

Resistors
R1 1M
R2 4k7
R3 100Ω
All 0·25W 5% carbon film

See SHOP TALK page

Capacitors
C1 100n polyester
C2 10µ radial elect. 25V
C3 100µ radial elect. 25V

Semiconductors
TR1 BC549C *npn* transistor (or similar – see text)

Miscellaneous
Printed circuit board available from the *EPE PCB Service*, code 349 (Single Trans); audio screened cable; multi-strand connecting wire; input and output sockets, type to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£7**

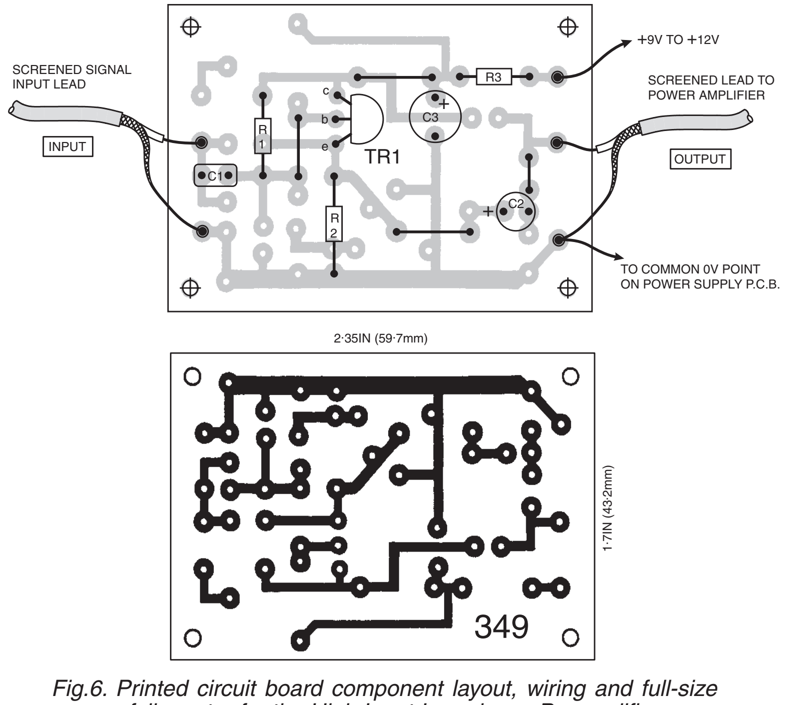


Fig.6. Printed circuit board component layout, wiring and full-size copper foil master for the High Input Impedance Preamplifier.

This is the circuit of choice when a high impedance source has to be connected to a long screened cable; e.g., a capacitor or crystal microphone. However, f.e.t. characteristics vary widely, and readers wishing to use the circuit of Fig.7 should be prepared to adjust the value of resistor R3, over the range of 1500 to 4700 ohms, especially when low supply voltages are used, in order to optimise signal handling capability.

CIRCUIT BOARD

Details of the printed circuit board component layout, wiring and copper foil master pattern are given in Fig.8. The board is the single transistor version and is available from the *EPE PCB Service*, code 349 (Single Trans).

Before assembly, check the component, construction and interconnection details at the end of the article.

LOW-NOISE PREAMPLIFIER

Amplifiers introduce unwanted noise and, as gain increases, more care has to be taken to prevent the noise becoming too intrusive. The noise generated by a bipolar transistor can be reduced by operating it at a low collector current, typically between 10μA and 50μA. This technique has been adopted for the first stage of the directly-coupled, two transistor, Low-Noise Preamplifier shown in Fig.9.

Overall gain is stabilised by negative feedback applied via preset VR2. With the value shown, gain is approximately 300. If a 47k potentiometer is used instead, gain will be reduced to around 150, and it can be taken down to 70 or so with a 22k component.

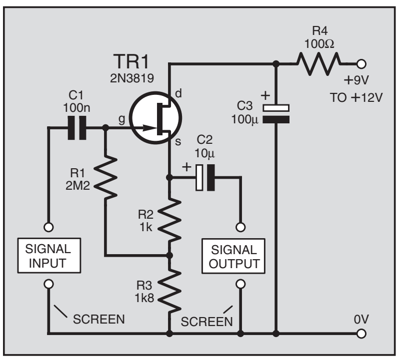
Rotating the slider (moving contact) of preset VR2 causes it to be progressively bypassed by capacitor C6, increasing the negative feedback, and reducing gain, at high frequencies. This feature is useful for reducing noise and for correcting the recording characteristic of long playing records. It is usual to incorporate more complicated *RC* networks in the VR2 position for the latter purpose but, unless the listener has a very refined ear, there will be little or no discernible difference.

Operating conditions are stabilised by d.c. negative feedback applied via resistor R5. This, together with the high value collector load, R3, fixes the collector current of transistor TR1 at around 50μA with a 12V supply.

Input impedance is around 50k, but the optimum signal source resistance for lowest noise is between 5k and 10k. This has influenced the value of the input potentiometer, VR1.

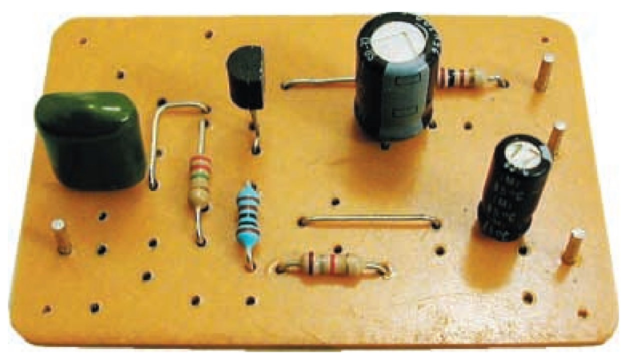
The purpose of the remaining components will be evident from earlier circuit descriptions. However, because of the

F.E.T. HIGH INPUT IMPEDANCE PREAMPLIFIER

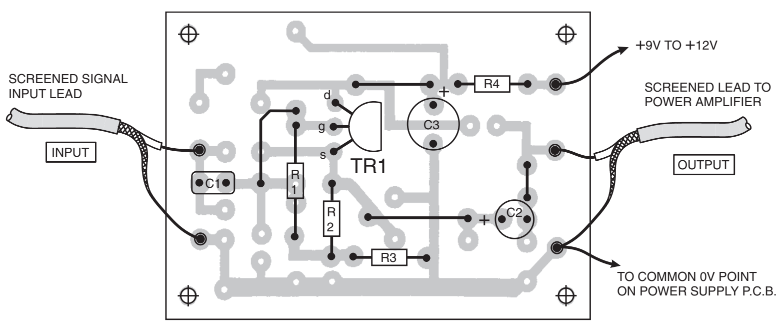


VOLTAGE GAIN: UNITY
CURRENT DRAIN AT 9V SUPPLY: 1·75mA.

Fig.7. Alternative circuit diagram for a High Input Impedance Preamplifier using a field effect transistor (f.e.t.).



F.E.T. High Input Impedance Preamplifier p.c.b.



2·35IN (59·7mm)

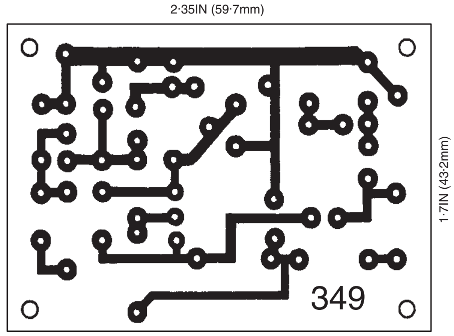


Fig.8. Printed circuit board component layout, wiring and full-size copper foil master for the F.E.T. High Input Impedance Preamplifier.

COMPONENTS

HIGH INPUT IMPEDANCE (F.E.T.)

Resistors

R1	2M2
R2	1k
R3	1k8 (see text)
R4	100Ω

All 0·25W 5% carbon film

See SHOP TALK page

Capacitors

C1	100n polyester
C2	10μ radial elect. 25V
C3	100μ radial elect. 25V

Semiconductors

TR1	2N3819 *n*-channel field effect transistor (f.e.t.)

Miscellaneous

Printed circuit board available from the *EPE PCB Service*, code 349 (Single Trans); audio screened cable; multi-strand connecting wire; input and output sockets, type to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£7**

higher gain, the supply line decoupling capacitor C7 has been increased in value to ensure stability.

CIRCUIT BOARD

The printed circuit board component layout, wiring details and full-size copper foil master pattern for the Low-Noise Preamplifier are shown in Fig.10. This board is available from the *EPE PCB Service*, code 350 (Dual Trans.).

See the general construction, component and interconnection guide-lines on the last page.

VARIATIONS

Some readers may wish to use this circuit with electret microphones which contain an internal line-powered f.e.t. amplifier. The load for this remote device is provided by resistor R1, and the supply voltage is reduced to around 4·5V, which is optimum for most microphones of this kind, by resistor R2. Decoupling is by means of capacitor C1.

These components (R1, R2 and C2) should only be fitted if an electret microphone is used, as the circuit maintains a

COMPONENTS

LOW-NOISE PREAMPLIFIER

See SHOP TALK page

Resistors

R1*	1k
R2*	10k
R3, R5	220k (low-noise metal film preferred) (2 off)
R4	270Ω
R6	6k8
R7	560Ω
R8	100Ω

All 0·25W 5% carbon film, except R3 and R5.
*Only required if electret mic. used

Potentiometers

VR1	10k enclosed carbon preset
VR2	100k enclosed carbon preset

Capacitors

C1*, C4	100µ radial elect. 25V (2 off)
C2	4µ7 radial elect. 25V
C3	100n polyester
C5, C8	10µ radial elect. 25V (2 off)
C6	10n polyester
C7	1000µ radial elect. 25V

*Only required if electret mic. used

Semiconductors

TR1, TR2	BC549C *npn* transistor (or similar – see text) (2 off)

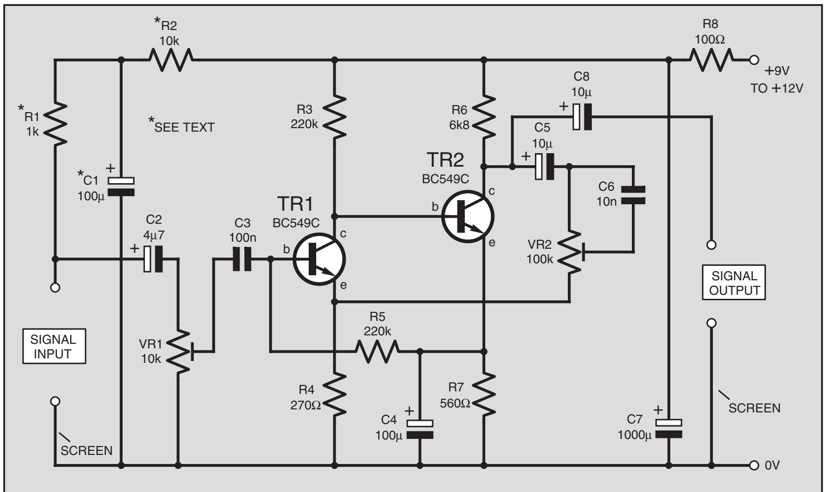
Miscellaneous

Printed circuit board available from the *EPE PCB Service*, code 350 (Dual Trans); audio screened cable; multistrand connecting wire; input and output sockets, type to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£8** ***excluding microphone***

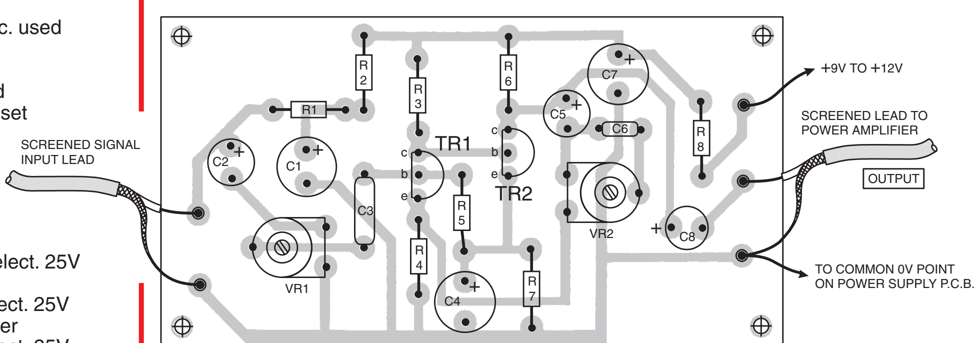
LOW-NOISE PREAMPLIFIER

Completed p.c.b. for the Low-Noise Preamplifier.



VOLTAGE GAIN 300 OVER h_{fe} SPREAD OF 450 TO 600. CURRENT DRAIN AT 9V SUPPLY: 1mA.

Fig.9. Circuit diagram for the Low-Noise Preamplifier. Components marked with an asterisk are only needed if an electret microphone is used. Increase the value of R2 to 18k with 12V supplies.



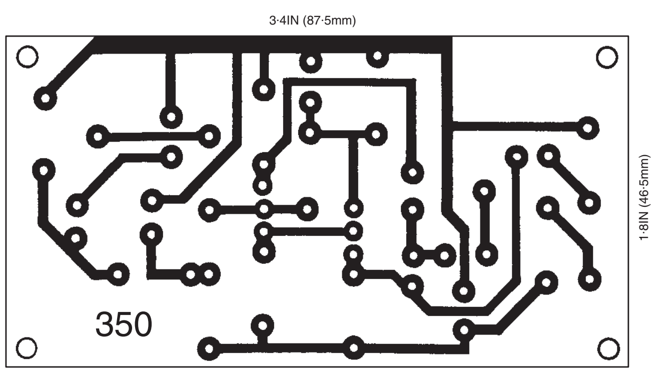


Fig.10. Printed circuit board component layout, wiring and full-size copper foil master for the Low-Noise Two-Transistor Preamplifier.

d.c. voltage on the input which could disturb the action of some signal sources.

This circuit, and variations of it, form the basis of the front-ends of most high quality preamplifiers. With the component values shown, 3·3mV r.m.s. input will produce a 1V output before the onset of clipping.

The noise introduced by the amplifier is about the same, or a little less, than that generated by the single transistor amplifier set for a gain of 150. The noise level could be further reduced by using low-noise, metal film resistors for R3 and R5.

FREQUENCY RESPONSE

Although inductors are sometimes used for "tailoring" the frequency response, the key components in networks which modify audio frequency response are normally capacitors.

The resistance presented by a capacitor to the flow of alternating current (a.c.) decreases as frequency rises. This frequency dependant resistance is known as *reactance*.

Capacitors combined with resistors form frequency dependant potential dividers which can be used to tailor the response.

These *RC* networks can, of course, only attenuate signals. So called "bass boost" is obtained by reducing the response of the system to the higher audio frequencies.

Table 1 lists the reactances of a range of standard capacitor values, at spot frequencies, across the audio spectrum. Referring to it, an 0·1μF (100nF) capacitor presents a resistance of 5300 ohms at a frequency of 300Hz. This rises to 32000 ohms at 50Hz and falls to 320 ohms at 5kHz.

Fitting a blocking capacitor of this value to an amplifier with an input impedance of 5000 ohms will result in signal levels at 300Hz being halved. (Capacitor and input impedance act as a potential divider). This attenuation will increase as the frequency is lowered, and reduce as frequency is raised, at a rate of 6dB per octave.

Fitting low value d.c. blocking capacitors to one or more stages will, therefore, roll-off the low frequency response. Capacitors connected from signal lines to ground; e.g. across the tracks of volume controls, will progressively attenuate high frequencies. Although simple, these measures can make a significant improvement in clarity and signal-to-noise ratio.

Refer to Table 1 when selecting a capacitor to give the desired roll-off with a particular input impedance, then refine its value by trial and error.

FEEDBACK NETWORKS

Capacitors are used to make gain-reducing negative feedback networks frequency dependant; for example, capacitor C6 in the two-transistor Low-Noise Preamplifier shown in Fig.9.

Reducing the emitter bypass capacitor C2, in the single transistor preamplifier shown in Fig.3, to 4·7μF, will progressively increase feedback, and reduce gain, as frequency lowers. This is another simple, but effective, way of securing low frequency roll-off.

TONE CONTROLS

Some means of continuously varying the frequency response is desirable when music is being reproduced, and a suitable Tone Control circuit diagram is given in

Table 1: Reactance, in Ohms, of standard value capacitors at stated audio frequencies

Cap. μF	50 Hz	100 Hz	200 Hz	300 Hz	400 Hz	500 Hz	1 kHZ	2 kHz	3 kHz	4 kHz	5 kHz	10 kHz	20 kHz
1000	3Ω2	1Ω6	0Ω8	0Ω5	–	–	–	–	–	–	–	–	–
470	6Ω8	3Ω4	1Ω7	1Ω1	–	–	–	–	–	–	–	–	–
100	32	16	8	5	4	3Ω2	1Ω6	–	–	–	–	–	–
47	68	34	17	11	8Ω5	6Ω8	3Ω4	1Ω7	1Ω1	–	–	–	–
10	320	160	80	53	40	32	16	8	5Ω3	4	3Ω2	1Ω6	–
4·7	680	340	170	110	85	68	34	17	11	8Ω5	6Ω8	3Ω4	1Ω7
1	3k2	1k6	800	530	400	320	160	80	53	40	32	16	8
0·47	6k8	3k4	1k7	1k1	850	680	340	170	110	85	68	34	17
0·1	32k	16k	8k	5k3	4k	3k2	1k6	800	530	400	320	160	80
0·047	68k	34k	17k	11k	8k5	6k8	3k4	1k7	1k1	850	680	340	170
0·01	320k	160k	80k	53k	40k	32k	16k	8k	5k3	4k	3k2	1k6	800
0·0047	680k	340k	170k	110k	85k	68k	34k	17k	11k	8k5	6k8	3k4	1k7

Reactance values rounded off

Fig.11. This is the medium impedance transistor preamplifier illustrated in Fig.3 with negative feedback applied, via a frequency dependant network, from transistor TR1 collector to base. First published by P J Baxandall in 1952, the circuit has since been used, with minor variations, in most high quality preamplifiers.

Potentiometers VR1 (Bass), and VR2 (Treble), control the impact of capacitors C1, C2 and C3 on the feedback network. Resistors R2 and R3 minimise interaction between the controls, and the circuit affords 15dB of "boost" or cut at 100Hz and 10kHz.

CIRCUIT BOARD

The printed circuit board component layout, wiring details and full-size copper foil master pattern are shown in Fig.12. This board is available from the *EPE PCB Service*, code 351 (Tone).

Before undertaking any assembly work, see the general component, construction and interconnection notes at the end of the article.

IN-CIRCUIT

When circuits are cascaded, the Tone Control unit should always be the last in the chain; i.e. the one connected to the power amplifier. Most high quality preamplifiers consist of the two transistor circuit illustrated in Fig.9 followed by this Tone Control circuit.

BANDPASS FILTERS

Reducing bandwidth to around 300Hz to 3kHz greatly improves the clarity of speech signals, and the practice is adopted by telephone companies around the world. Limiting the frequency response in this way significantly improves the signal-to-noise ratio. This is particularly desirable with sensitive radio equipment and surveillance systems, where the high level of amplification needed for the weakest signals brings with it a good deal of background and equipment generated noise.

For best results, roll-off beyond the pass band should be fairly steep: the 6dB per octave afforded by a single *RC* combination is not sufficient.

The Bandpass Filter circuit diagram shown in Fig.13 cascades three high-pass (low frequency cut) sections between transistors TR1 and TR2, and three low-pass (high frequency cut) sections between TR2 and TR3. By this means, a roll-off of 18dB per octave is achieved above and below the desired frequency range.

Filter networks of this kind need to be fed from a comparatively low impedance, and feed into a high impedance. The emitter follower stages, TR2 and TR3, are thus eminently suitable, and amplifiers of this kind have already been discussed. The input stage, transistor TR1, overcomes signal losses, or, with the slider of VR1 at TR1 emitter (e), ensures an overall circuit gain of around 25.

Emitter to base feedback around TR2 and TR3, via the *RC* networks, improves the action of the filters. Component values have been selected to start the roll-off just within the pass band, and the response falls steeply below 300Hz and above 3kHz.

Two capacitors have to be combined to produce a difficult-to-obtain value. To avoid confusion they are shown separately on the circuit diagram as C8 and C9.

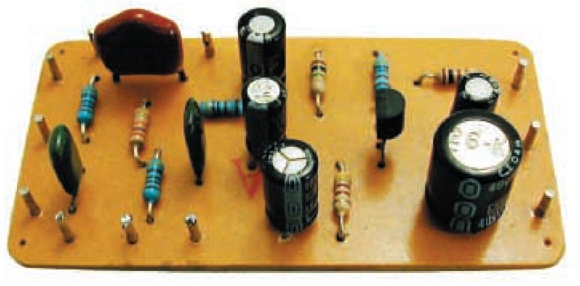
CIRCUIT BOARD

Details of the printed circuit board component layout, wiring and copper foil master are given in Fig.14. The Bandpass Filter board is also available from the *EPE PCB Service*, code 352 (Filter).

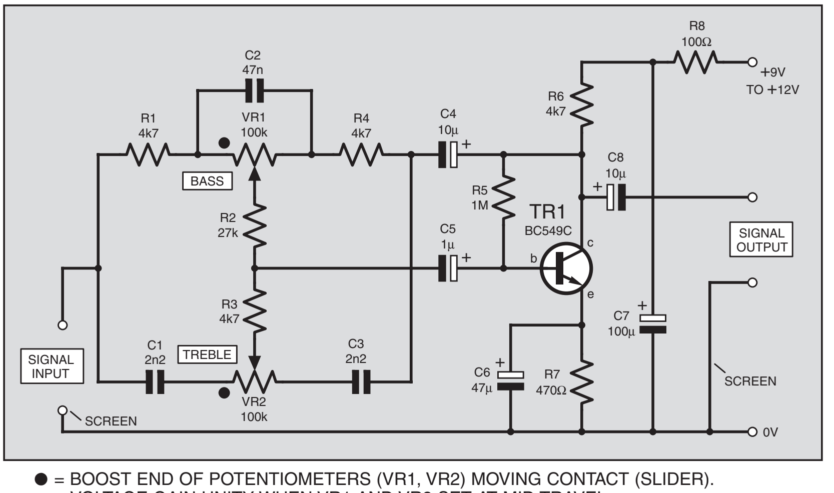
See component, construction and interconnection notes before commencing building.

Bandpass Filter (top) and Tone Control p.c.b.s.

TONE CONTROL



Tone Control printed circuit board.



● = BOOST END OF POTENTIOMETERS (VR1, VR2) MOVING CONTACT (SLIDER).
VOLTAGE GAIN UNITY WHEN VR1 AND VR2 SET AT MID TRAVEL.
BOOST AND CUT ±15dB AT 100Hz AND 10kHz.
CURRENT DRAIN AT 9V SUPPLY: 1·25mA.

Fig.11. Circuit diagram for the Tone Control (bass, treble boost and cut).

COMPONENTS

TONE CONTROL

Resistors
R1, R3, R4, R6 — 4k7 (4 off)
R2 — 27k
R5 — 1M
R7 — 470Ω
R8 — 100Ω
All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers
VR1, VR2 — 100k min. rotary carbon, linear (2 off)

Capacitors
C1, C3 — 2n2 polyester (2 off)
C2 — 47n polyester
C4, C8 — 10µ radial elect. 25V (2 off)
C5 — 1µ radial elect. 25V
C6 — 47µ radial elect. 25V
C7 — 100µ radial elect. 25V

Semiconductors
TR1 — BC549C *npn* transistor (or similar – see text)

Miscellaneous
Printed circuit board available from the *EPE PCB Service*, code 351 (Tone); metal case (optional), size and type to choice – see text; audio screened cable; multistrand connecting wire; input and output sockets, type to choice; solder pins; solder etc.

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

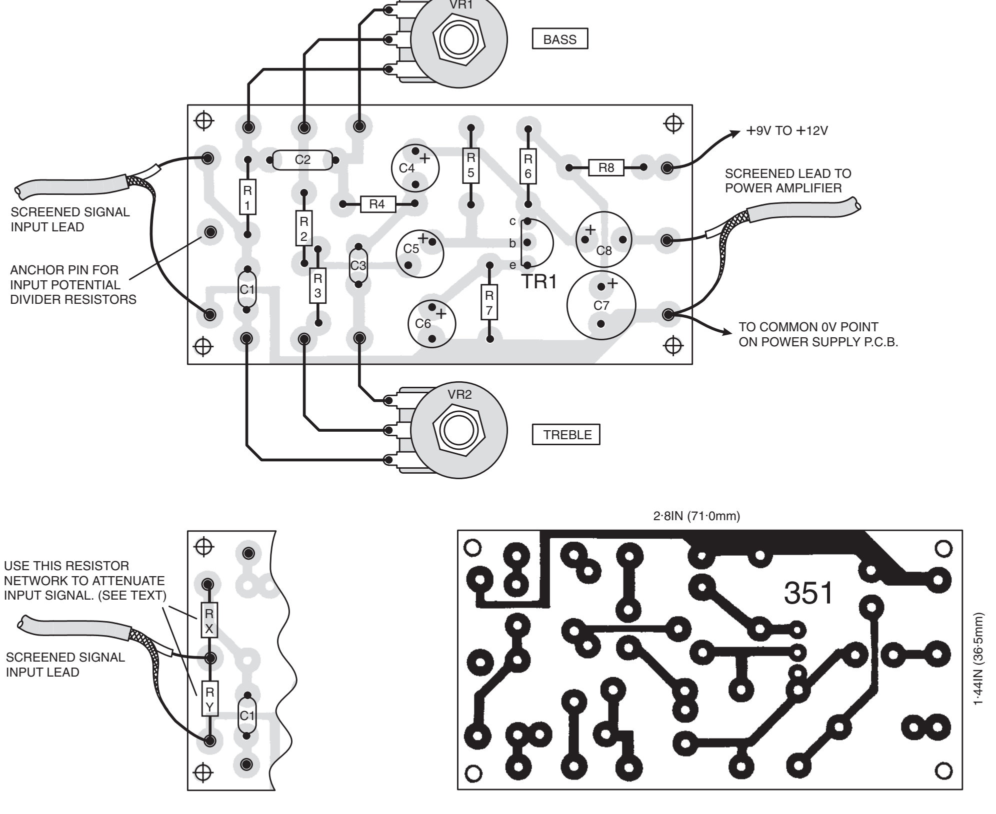
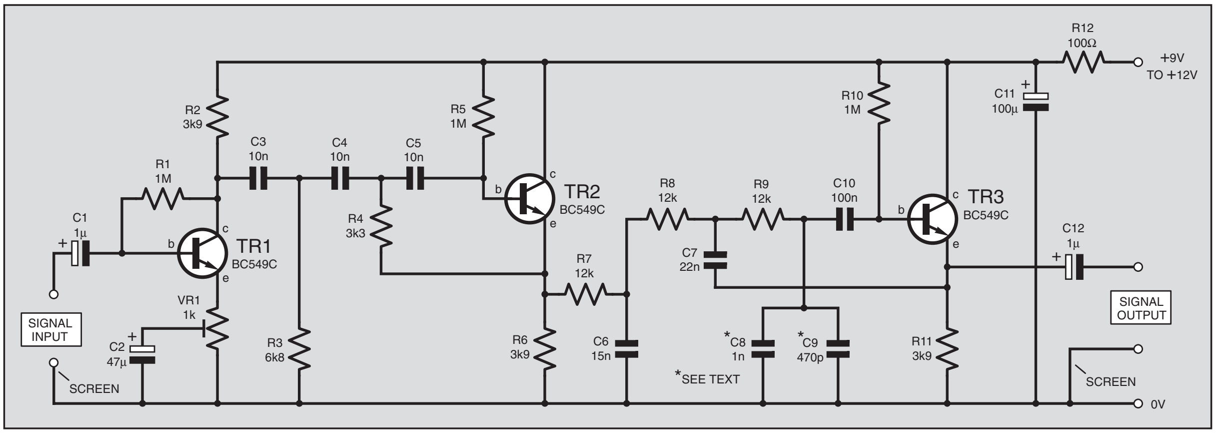


Fig.12. Tone Control printed circuit board component layout, interwiring and full-size copper foil master. The tape and CD player signal input attenuation resistors (see text) are shown in the inset diagram (left).

SPEECH FREQUENCIES (300Hz TO 3kHz) BANDPASS FILTER



VOLTAGE GAIN WITH PASSBAND, UNITY WITH VR1 SLIDER AT 0V RAIL; 25 WITH SLIDER AT TR1 EMITTER END.
ROLL-OFF 18dB PER OCTAVE BELOW 30Hz AND ABOVE 3kHz. CURRENT DRAIN AT 9V SUPPLY: 4mA.

Fig.13. Circuit diagram for the Bandpass Filter for speech frequencies (300Hz - 3kHz).

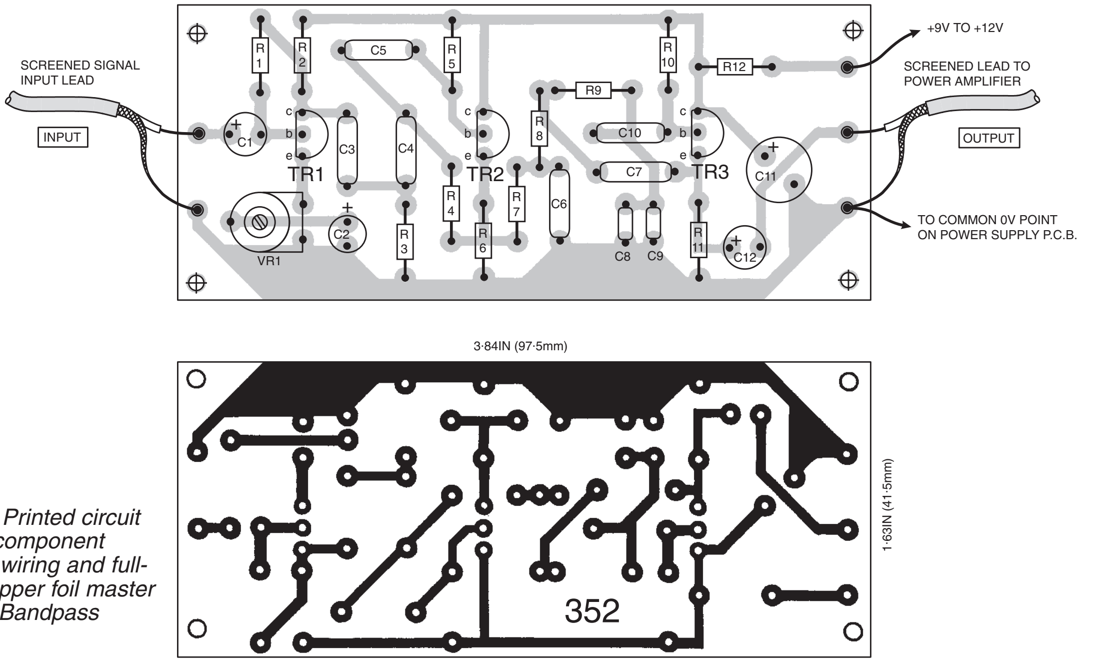
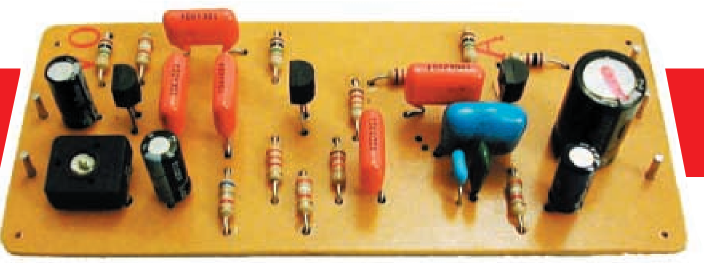


Fig.14. Printed circuit board component layout, wiring and full-size copper foil master for the Bandpass Filter.



Bandpass Filter printed circuit board.

COMPONENTS

BANDPASS FILTER

Resistors
R1, R5, R10 1M (3 off)
R2, R6, R11 3k9 (3 off)
R3 6k8
R4 3k3
R7 to R9 12k 1% metal film (3 off)
R12 100Ω
All 0·25W 5% carbon film, except R7 to R9

Potentiometers
VR1 1k carbon preset

Capacitors
C1, C12 1µ radial elect. 25V (2 off)
C2 47µ radial elect. 25V
C3 to C5 10n polyester (5% or better) (3 off)
C6 15n polyester
C7 22n polyester
C8* 1n polyester
C9* 470p ceramic
C10 100n polyester
C11 100µ radial elect. 25V
*Combined (parallel) to give 1n5

Semiconductors
TR1 to TR3 BC549C *npn* transistor (or similar – see text) (3 off)

See SHOP TALK page

Miscellaneous
Printed circuit board available from the *EPE PCB Service*, code 352 (Filter); audio screened cable; multistrand connecting wire; input and output sockets, type to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£9**

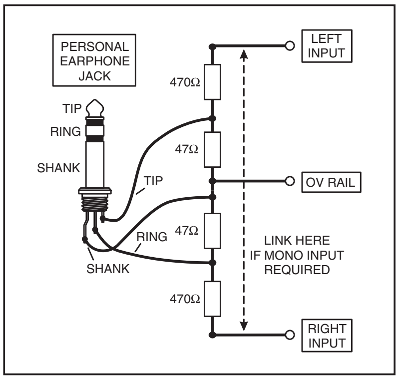


Fig.15. Method of connecting a "Walkman" tape or CD player.

SUMMARY

Operational amplifiers (op.amps) are more commonly used in filters of this kind but, when the need is simply for a unity gain buffer with a high input and low output impedance, the ubiquitous bipolar transistor can be made to serve our purpose just as well.

SIGNAL SOURCES

Radio Receivers

The output from the detector or f.m. discriminator in a superhet radio receiver should fully load the power amplifiers described last month. After the usual filtering, the signal can be fed directly to the power amplifier, or via the Tone Control unit shown in Fig.11 and Fig.12.

Microphones

The single transistor preamplifiers shown in Fig.1 to Fig.8 will provide appropriate matching and sufficient gain for dynamic (moving coil), electret and crystal microphones when they are used for intercom purposes. (A circuit for line-powering electret microphones can be taken from Fig.9). The common emitter circuit given in Fig.3 should be used with moving coil units as these present an impedance of around 600 ohms.

When electret or dynamic microphones are deployed for surveillance or "sound capturing" purposes, the two transistor circuit of Fig.9 will ensure a good degree of sensitivity. Electret microphones have an extended low frequency response. If this proves troublesome, reduce the value of the d.c. blocking capacitor C2. Try 47nF (0·047µF) as a starting point.

Gramophone Pick-ups

The low output of moving-coil pick-ups necessitates the use of the two transistor preamplifier detailed in Fig.9. Omit preset VR1 and feed the signal to the base of transistor TR1 via capacitor C3. Low output ceramic pick-ups should be connected via a 1M (megohm) or 2M2 series resistor to preserve low frequency response.

The F.E.T. Preamplifier circuit illustrated in Fig.7 is more suitable for high output ceramic and crystal pick-ups.

Personal Tape and CD Players

An arrangement for extracting the signal from personal cassette players and headphone radios is given in Fig.15. The 47 ohm resistors substitute for the 32 ohm earpieces, and the 470 ohm resistors attenuate the signal.

Preamplification is not required, but readers may wish to use the Tone Control unit to process the signal. Provision is accordingly made, on the Tone Control p.c.b. illustrated in Fig.12, for a signal attenuating network; resistors Rx and Ry.

STEREO

The chosen system must, of course, be duplicated if stereo operation is required. Tone and Volume controls are usually ganged, and an additional potentiometer is provided to balance the gain of the two channels.

With the simple circuit arrangement shown in Fig.16, the Balance potentiometer is connected across the ganged Volume controls at the inputs to the two power amplifiers (VR1 on the power amplifier circuit diagrams).

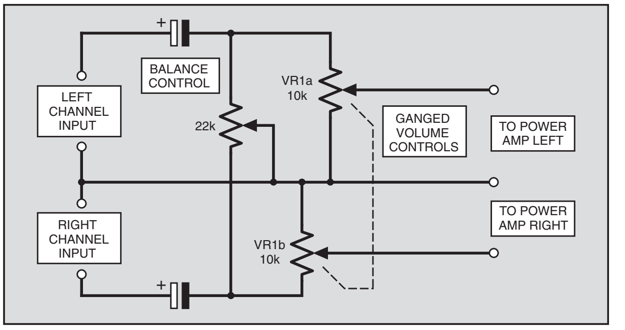


Fig.16. Circuit arrangement for a stereo Balance control.

COMPONENTS

All of the components, for this part of the series, are readily available from a variety of sources. Transistor types are not critical and almost any small-signal *npn* device will function in the circuits.

A low-noise, high gain transistor will, however, ensure the best performance, and the base connections for some alternative types are given in Fig.17. With European transistors, the suffix "C" indicates the highest gain grouping.

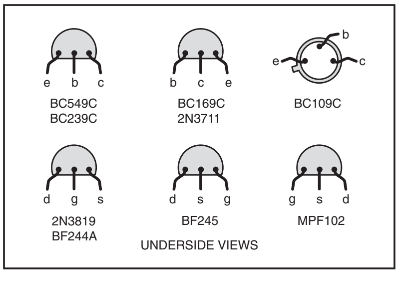


Fig.17. Base connections for suitable transistors and f.e.t.s.

If possible, use transistors with an h_{fe} of at least 450 for the input stage of the Low-Noise Preamplifier and for the various emitter follower stages (where high input impedance depends on the use of a high gain device).

CONSTRUCTION

All the preamplifiers covered in this part are assembled on printed circuit boards and construction is reasonably straightforward. Solder pins, inserted at the lead-out points, will simplify any off-board wiring. Remember to earth the metal bodies of rotary potentiometers and to use screened audio (mic.) cable for the leads to tone and volume controls to minimise hum pick-up.

The single transistor preamplifiers all use the same p.c.b. and wire links are required. If units are cascaded, and coupling capacitors deleted, remember to install wire links to maintain the signal path.

It may help to start construction by first placing and soldering in position the various wire links on the chosen preamplifier p.c.b. This should be followed by the lead-off solder pins, and then the smallest components (resistors) working up to the largest, electrolytic capacitors and presets. Finally, the lead-off wires (including the screened cables) should be attached to the p.c.b.

On completion, check the orientation of electrolytic capacitors and transistors, and examine the board for poor connections and bridged tracks, before connecting the power supply. The approximate current drains are included with the circuit diagrams.

INTERCONNECTIONS

Overall voltage gain can be in excess of 2000, and care must be taken to avoid hum pick-up and instability.

Hum pick-up is of two kinds, capacitative and inductive. High impedance circuits are prone to the former, and low impedance to the latter. Housing the pre- and power amplifiers in a metal case will do much to minimise these problems.

If hum increases when a finger is brought near to the preamplifier, the pick-up is capacitative. It can usually be cured by providing an earthed metal screen around the input wiring or even the entire preamplifier board.

All mains and a.c. power leads within the metal case of the unit must be tightly twisted to minimise external fields, and the mains transformer should be sited at least 150mm (6in) from the input circuitry. Tightly twist power amplifier output leads, and keep them as far away as possible from preamplifier inputs. Keep all leads as short as possible.

Run a separate negative power supply connection from *each* of the p.c.b.s to a common 0V point on the power supply board, or to the negative battery terminal. ***Do not*** connect one circuit board via another to supply negative, or rely upon screened cable braiding or a metal case to provide this connection. Make only one connection to any metal case, close to the negative terminal on the power supply p.c.b.

If all of the above measures have been adopted and hum problems still persist, try disconnecting, one by one, the screens of the audio cables, *at one end only*. Reorientating the mains transformer can also effect a cure.

Next Month: Mains power supplies, loudspeakers and signal filtering will be discussed.