The materials and works contained within EPE Online — which are made available by Wimborne Publishing Ltd and TechBites Interactive Inc — are copyrighted.

TechBites Interactive Inc and Wimborne Publishing Ltd have used their best efforts in preparing these materials and works. However, TechBites Interactive Inc and Wimborne Publishing Ltd make no warranties of any kind, expressed or implied, with regard to the documentation or data contained herein, and specifically disclaim, without limitation, any implied warranties of merchantability and fitness for a particular purpose.

Because of possible variances in the quality and condition of materials and workmanship used by readers, EPE Online, its publishers and agents disclaim any responsibility for the safe and proper functioning of reader-constructed projects based on or from information published in these materials and works.

In no event shall TechBites Interactive Inc or Wimborne Publishing Ltd be responsible or liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or any other damages in connection with or arising out of furnishing, performance, or use of these materials and works.

READERS’ TECHNICAL ENQUIRIES

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years’ old. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it. A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured; these can be supplied by advertisers in our publication Practical Everyday Electronics. Our website is located at www.epemag.com

We advise readers to check that all parts are still available before commencing any project.

To order your copy for only $18.95 for 12 issues go to www.epemag.com
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.

**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\textsubscript{e}), and supply voltage, affect the biasing. However, over a wide range of h\textsubscript{e} 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 2000\mu\text{F} 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 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 capacitive hum pick up, and the input lead can be connected to 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 capacitive hum pick up, and the input lead can be
tightly twisted flex rather than screened cable. If r.f. interference problems are
countered, 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 resis-
tor, 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 capaci-
tor 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 transis-
tor, 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 inter-
connection 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 ade-
quate if problems arise.

---

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

---

**Medium Input Impedance Preamplifier components**

Mounted on the “single” p.c.b.

**Fig.4. Medium Input Impedance Preamplifier printed circuit board**

---

**Components**

**Resistors**
- R1 1M
- R2 4k7
- R3 100Ω
- All 0.25W 5% carbon film

**Potentiometers**
- VR1 470Ω enclosed carbon
  preset

**Capacitors**
- C1, C3 47µF radial elect. 25V
  (2 off)
- C2 47µF radial elect. 25V
- C4 100µF 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
**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 (hfe) multiplied by the value of the impedance is roughly equal to the gain of the circuit.

A typical High Input Impedance Preamplifier in a high input and low output impedance, and emitter-follower (common collector) mode results in an extra pair of resistors and a capacitor, which tends to introduce less noise at audio frequencies.

### 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.

---

**Fig.5. High Input Impedance Preamplifier circuit diagram.**

**COMPONENTS**

**HIGH INPUT IMPEDANCE**

<table>
<thead>
<tr>
<th>Resistors</th>
<th>See TALK page</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>1M</td>
</tr>
<tr>
<td>R2</td>
<td>4k7</td>
</tr>
<tr>
<td>R3</td>
<td>100Ω</td>
</tr>
<tr>
<td>All 0.25W 5% carbon film</td>
<td></td>
</tr>
</tbody>
</table>

**Capacitors**

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

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

COMPONENTS

<table>
<thead>
<tr>
<th>HIGH INPUT IMPEDANCE (F.E.T.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resistors</strong></td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>R2</td>
</tr>
<tr>
<td>R3</td>
</tr>
<tr>
<td>R4</td>
</tr>
<tr>
<td>All 0.25W 5% carbon film</td>
</tr>
<tr>
<td><strong>Capacitors</strong></td>
</tr>
<tr>
<td>C1</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>C3</td>
</tr>
<tr>
<td><strong>Semiconductors</strong></td>
</tr>
<tr>
<td>TR1</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
</tr>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>

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 Pre Amplifier 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 guidelines on the last page.

VARIATIONS

Some readers may wish to use this circuit with electret microphones which contain an internal line-powered FET 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

![Completed p.c.b. for the Low-Noise Preamplifier.](image)

VOLTAGE GAIN 30dB OVER hfe 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.

![Printed circuit board component layout, wiring and full-size copper foil master for the Low-Noise Two-Transistor Preamplifier.](image)

LOW-NOISE PREAMPLIFIER

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1*</td>
<td>1k</td>
<td></td>
</tr>
<tr>
<td>R2*</td>
<td>10k</td>
<td></td>
</tr>
<tr>
<td>R3, R5</td>
<td>220k</td>
<td>low-noise metal film</td>
</tr>
<tr>
<td>R4</td>
<td>270k</td>
<td></td>
</tr>
<tr>
<td>R6</td>
<td>6k8</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td>560k</td>
<td></td>
</tr>
<tr>
<td>R8</td>
<td>1000k</td>
<td></td>
</tr>
<tr>
<td>All 0-25W 5% carbon film, except R3 and R5. *Only required if electret mic. used</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potentiometers</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>VR1</td>
<td>10k</td>
<td>enclosed, carbon preset</td>
</tr>
<tr>
<td>VR2</td>
<td>100k</td>
<td>enclosed, carbon preset</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capacitors</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1*</td>
<td>100uF</td>
<td>radial elect. 25V</td>
</tr>
<tr>
<td>C2</td>
<td>4u7</td>
<td>radial elect. 25V</td>
</tr>
<tr>
<td>C3</td>
<td>100n</td>
<td>polyester</td>
</tr>
<tr>
<td>C5, C8</td>
<td>10u</td>
<td>radial elect. 25V</td>
</tr>
<tr>
<td>C6</td>
<td>10n</td>
<td>polyester</td>
</tr>
<tr>
<td>C7</td>
<td>1000u</td>
<td>radial elect. 25V</td>
</tr>
</tbody>
</table>

*Only required if electret mic. used

<table>
<thead>
<tr>
<th>Semiconductors</th>
<th>Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR1, TR2</td>
<td>BC549C</td>
<td>npn transistor</td>
</tr>
</tbody>
</table>

(or similar – see text) (2 off)

Approx. Cost: £8

Guidance Only

Excluding microphone

Everyday Practical Electronics, June 2002
d.c. voltage on the input which could disturb the action of some signal sources. The circuit, and variations of it, form the basis of the front-ends of most high quality preamplifiers. With the component values shown, 3-nmV 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 dependent resistance is known as reactance.

Capacitors combined with resistors form frequency dependent 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 bleed 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.

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 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 shown 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.

These networks of this kind need to be fed from a comparatively low impedance, and fed 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 pattern are shown in Fig.12. The Bandpass Filter board is also available from the EPE PCB Service, code 352 (Filter).

See component, construction and interconnection notes before commencing building.

---

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

<table>
<thead>
<tr>
<th>Cap. μF</th>
<th>50 Hz</th>
<th>100 Hz</th>
<th>200 Hz</th>
<th>300 Hz</th>
<th>400 Hz</th>
<th>500 Hz</th>
<th>1 kHz</th>
<th>2 kHz</th>
<th>3 kHz</th>
<th>4 kHz</th>
<th>5 kHz</th>
<th>10 kHz</th>
<th>20 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>302</td>
<td>102</td>
<td>028</td>
<td>025</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>470</td>
<td>602</td>
<td>302</td>
<td>127</td>
<td>121</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>32</td>
<td>16</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>302</td>
<td>102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>68</td>
<td>34</td>
<td>17</td>
<td>11</td>
<td>85</td>
<td>638</td>
<td>302</td>
<td>127</td>
<td>121</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>320</td>
<td>160</td>
<td>80</td>
<td>53</td>
<td>40</td>
<td>32</td>
<td>16</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>302</td>
<td>102</td>
<td>638</td>
</tr>
<tr>
<td>4-7</td>
<td>680</td>
<td>340</td>
<td>170</td>
<td>110</td>
<td>85</td>
<td>68</td>
<td>34</td>
<td>17</td>
<td>11</td>
<td>8</td>
<td>85</td>
<td>638</td>
<td>302</td>
</tr>
<tr>
<td>1</td>
<td>3k2</td>
<td>1.6k</td>
<td>800</td>
<td>530</td>
<td>400</td>
<td>320</td>
<td>160</td>
<td>80</td>
<td>53</td>
<td>40</td>
<td>320</td>
<td>160</td>
<td>8</td>
</tr>
<tr>
<td>0-47</td>
<td>6k8</td>
<td>3k4</td>
<td>1k7</td>
<td>1k1</td>
<td>850</td>
<td>680</td>
<td>340</td>
<td>170</td>
<td>110</td>
<td>85</td>
<td>68</td>
<td>34</td>
<td>17</td>
</tr>
<tr>
<td>0-1</td>
<td>32k</td>
<td>16k</td>
<td>8k5</td>
<td>5k3</td>
<td>4k3</td>
<td>1k6</td>
<td>800</td>
<td>340</td>
<td>170</td>
<td>680</td>
<td>340</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>0-047</td>
<td>68k</td>
<td>34k</td>
<td>17k</td>
<td>11k</td>
<td>8k5</td>
<td>6k8</td>
<td>3k4</td>
<td>1k7</td>
<td>1k1</td>
<td>850</td>
<td>680</td>
<td>340</td>
<td></td>
</tr>
<tr>
<td>0-0047</td>
<td>680k</td>
<td>340k</td>
<td>170k</td>
<td>110k</td>
<td>85k</td>
<td>68k</td>
<td>34k</td>
<td>17k</td>
<td>11k</td>
<td>8k5</td>
<td>6k8</td>
<td>3k4</td>
<td></td>
</tr>
</tbody>
</table>

Reactance values rounded off.

---

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

Everyday Practical Electronics, June 2002
**TONE CONTROL**

- **Resistors**
  - R1, R3, R4, R6 4k7 (4 off)
  - R2 27k
  - R5 1M
  - R7 470Ω
  - R8 100Ω
  - All 0.25W 5% carbon film

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

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

- **££9 excluding case**

---

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

*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).*
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

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
- C12: 1µ radial elect. 25V

Potentiometers
- VR1: 1k carbon preset

SCR CAPS

Semiconductors
- TR1 to TR3: BC549C npn transistor

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. 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.

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.

Everyday Practical Electronics, June 2002

426
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).

**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 vacuum 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 group.

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 the basic 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, capacitive 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 capacitive. 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.

---

<table>
<thead>
<tr>
<th>Fig.15. Method of connecting a &quot;Walkman&quot; tape or CD player.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig.16. Circuit arrangement for a stereo Balance control.</td>
</tr>
</tbody>
</table>

---

**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 is 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.)

**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 is 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.)

**Operational amplifiers (op.amps)**

Operational amplifiers (op.amps) are suitable for use as gain devices. For a signal attenuating network, resistors Rx and Ry.

**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 vacuum 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 group.

**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, capacitive 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 capacitive. 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.

---

**Everyday Practical Electronics, June 2002**