Amplifier Add-on Kit X40A

X40A Instruction manual

PHILIPS

Amplifier Add-on Kit X40A

Instruction Manual

Published by Radionic Products Ltd.,
a member of the ESL BRISTOL Group.

Third impression: 1972

Printed and bound in Great Britain by
St. Stephen's Bristol Press, Filton, Bristol.

Batteries

Note: No batteries are supplied with the kit. Any 9-volt battery of reasonably large capacity will do, but EverReady PP4, PP7 or PP9 (or equivalents) are recommended as these have press-studs which will fit the battery leads provided in the kit.

Spares

Spares price list is available free on application to Radionic Products Limited, ESL BRISTOL, St. Lawrence House, 29/31 Broad Street, Bristol. BS1 2HF

Contents

	page nos.
Introduction	4
Descriptions and functions of components	5
Amplifier circuits:	
1. The basic amplifier	8
2. A baby alarm	12
3. An inter-com system	14
4. A record player	16
5. An improved amplifier	18
Power Amplifiers	22
Appendix A—List of contents of kit	28
Appendix B—Resistor colour code	29

Introduction

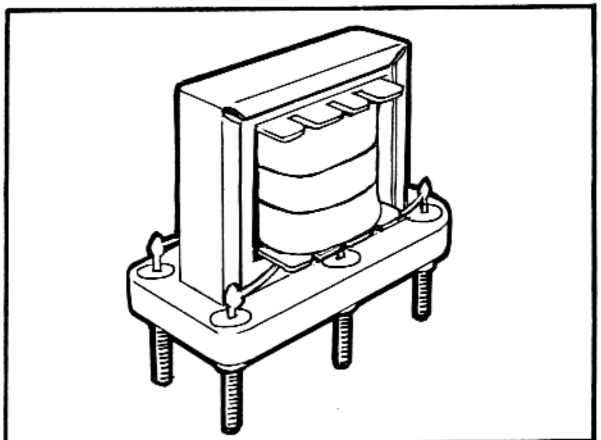
This kit is intended for use in conjunction with the X40 Kit. It extends the range of the X40 Kit by supplying an Audio Frequency Amplifier which does away with the necessity for earphones and enables the use of a loudspeaker instead. The A.F. amplifier has many more uses than just as part of a receiver. Some of these uses you will find out more about in this manual.

Before starting to build, read the section entitled 'Descriptions and functions of components' and physically identify each component in the kit. This section has only those components in it which were not used in the X40 Kit and so are unfamiliar to you.

Descriptions and functions of components

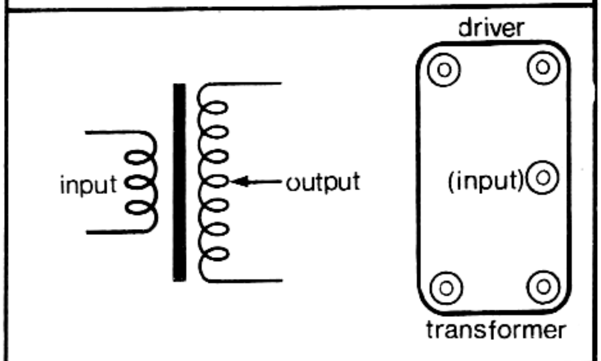
Transformer

A transformer is made from two coils that are placed close to, but insulated from, each other, so there is no actual electrical connection between them. An alternating current passed through one coil (called the primary) will *induce* an alternating current of the same frequency to flow in the other coil (called the secondary). Furthermore, depending on the number of turns in the primary compared with those in the secondary, a larger, the same, or a smaller current than that passed through the primary can be induced in the secondary coil.



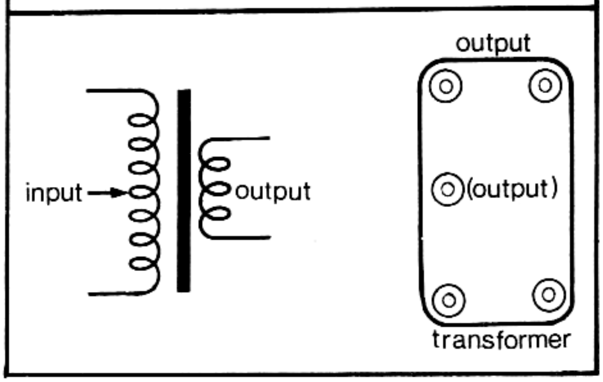
Driver Transformer

This transformer has an iron core and a tapping on the secondary coil. It can be identified by the yellow band around the outside of the coils.



Output Transformer

This transformer has an iron core and a tapping on the primary coil. It can be identified by the blue band around the outside of the coils.

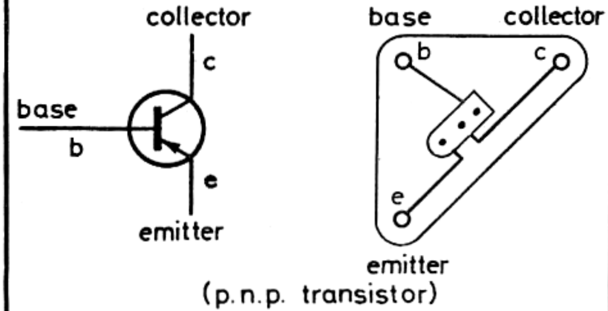


Note

Ensure that the transformers are placed in the circuit the right way round. Each transformer base has six pins of which only five are used. On the input side of the driver transformer only two of the three pins are used. There is no soldered connection to the centre pin on the input side. Similarly, for the output transformer only two of the three pins on the 'output to loudspeaker' side are used, and there is no soldered connection to the centre pin on that side.

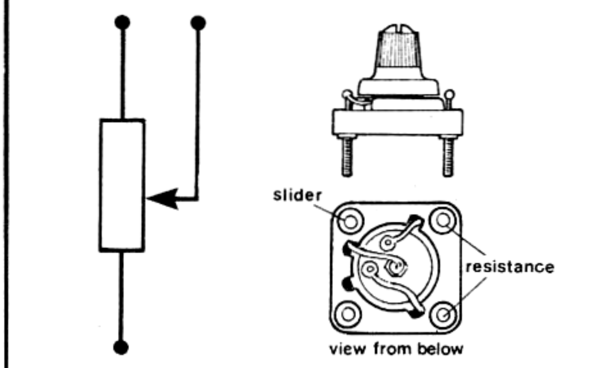
PNP Transistor

These transistors differ from the ones used in your X40 kit, which were NPN transistors. You should take care when connecting them, that the emitter is connected to the *positive* line and the collector is connected to the *negative* line. To help you to recognise the PNP transistors, the mounting has been marked with red dye.



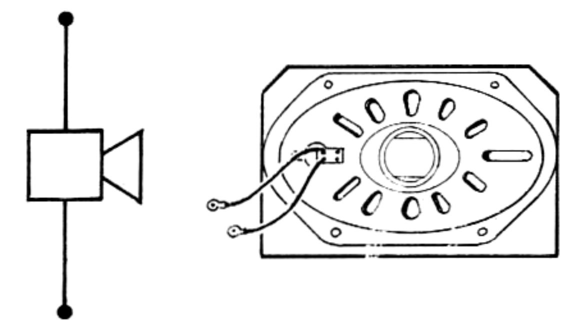
Potentiometer

The potentiometer is a variable resistor, the value of which is altered by rotating the knob on the top. With full movement, the resistance varies from 0 to 5.6 kΩ. It is used in this kit as a volume and a tone control.



Loudspeaker

The loudspeaker works on similar principles to the earphone, in that it converts varying electric currents into sound waves. The difference is that it is a larger device suitable to the much more powerful output from the A.F. amplifier, enabling the sound waves to be heard from a distance.



Interconnecting leads

These are included in the kit to enable the connections to be made from the X40 board to the X40A board when making the receivers.

Brass sockets

These are included to make easier and more positive the switching arrangement between the radio and gram. in circuit 5. They are inserted at the points marked X, Y and Z on the printed circuit board diagram.

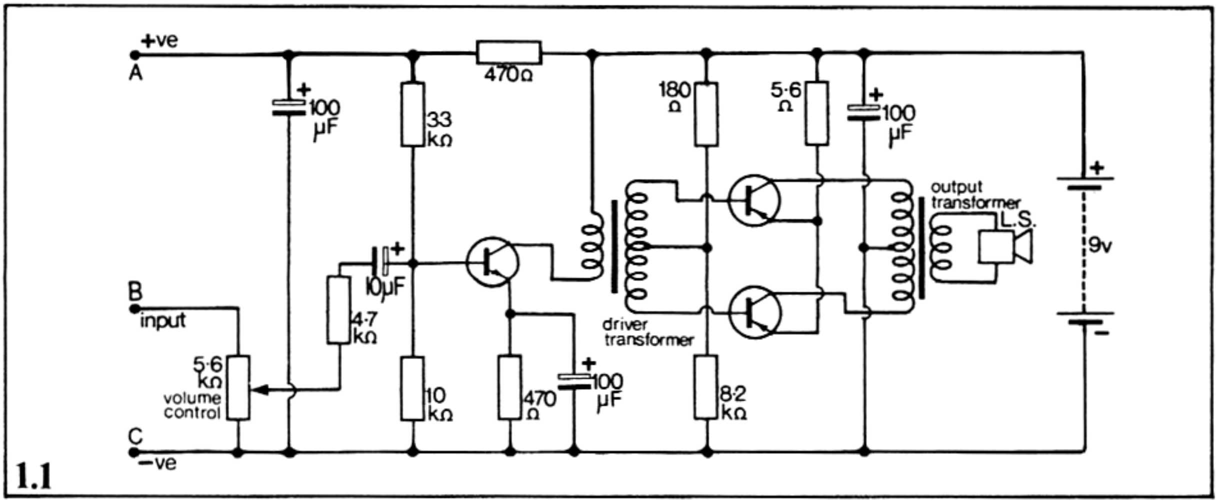
Amplifier circuits

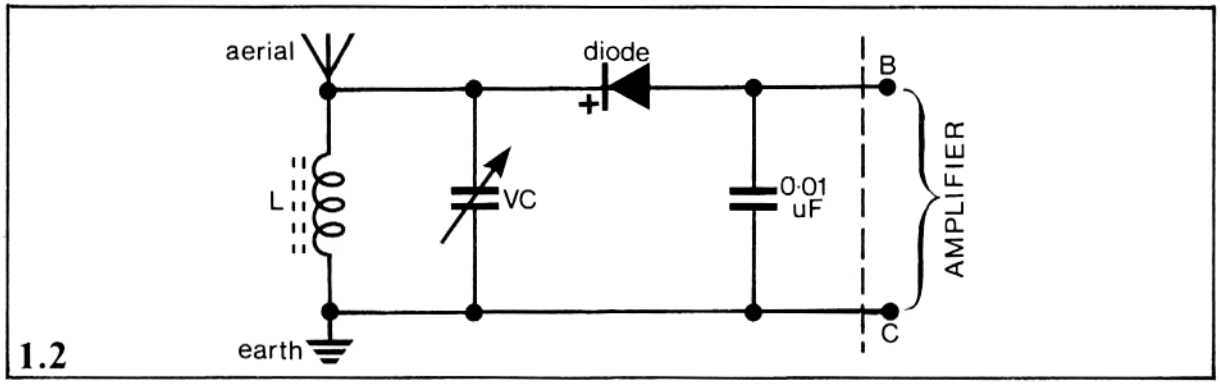
1. The basic amplifier

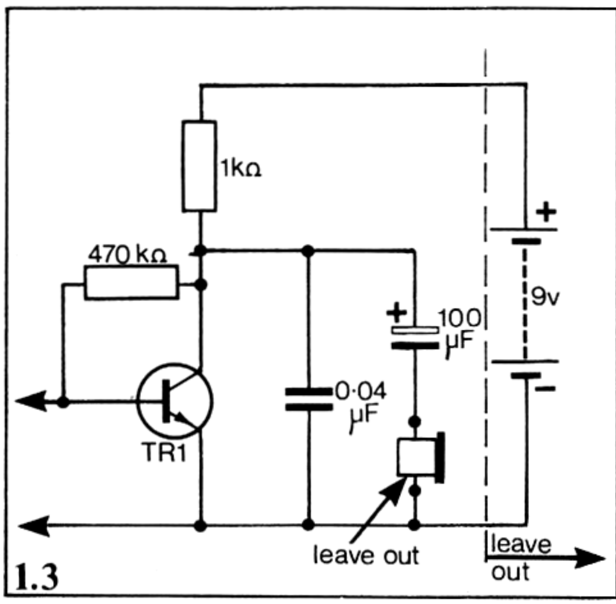
The circuit shown in diagram 1.1 is of an efficient, well-tried 250 M.W. 'push-pull' amplifier. It can be used in conjunction with the X40 kit to convert to loudspeaker operation the receivers shown in experiments 26, 27, 28, 29 and 30.

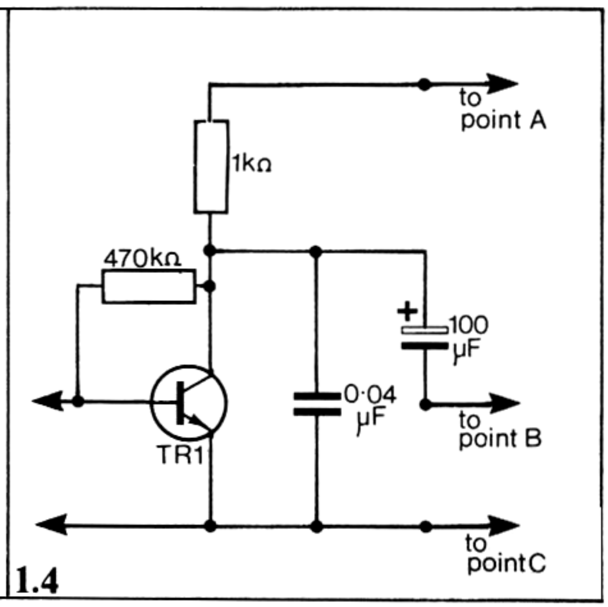
This can be accomplished with the receiver shown in experiment 26 by leaving out the earphone and connecting points B and C on the amplifier to the points on the receiver so freed, as shown in diagram 1.2.

The amplifier can be joined to the receivers shown in the remaining experiments, again by omitting the earphone and connecting the freed ends to points B and C on the amplifier. These experiments included a battery in the circuit. This battery can be omitted if the amplifier is joined to the receivers as shown in diagrams 1.3 and 1.4.


+ve
A
100 µF
470Ω
33 kΩ
180 Ω
5·6 Ω
100 µF
output transformer
L.S.
9v
B
input
10µF
4·7 kΩ
5·6 kΩ volume control
10 kΩ
470 Ω
100 µF
driver transformer
8·2 kΩ
C
−ve
1.1


aerial
diode
B
L
VC
0·01 uF
AMPLIFIER
earth
C
1.2


1kΩ
470 kΩ
100 µF
9v
0·04 µF
TR1
leave out
leave out
1.3


to point A
1kΩ
470kΩ
100 µF
0·04 µF
TR1
to point B
to pointC
1.4

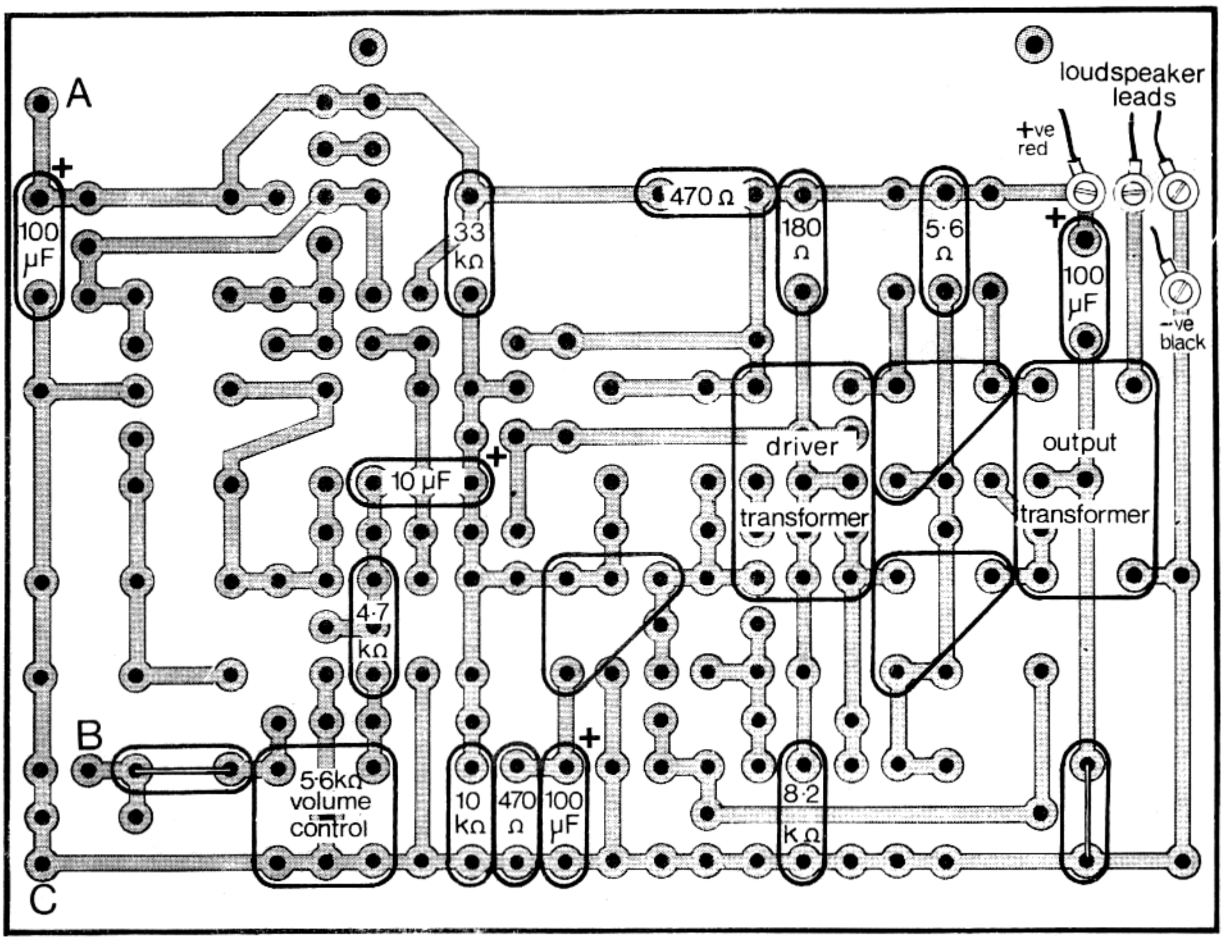
The following points, concerning the A.F. Amplifier you can build with this kit, may be of interest.

(*a*) In 'quiescent' conditions, that is, when there is no signal input to the amplifier, the current drain on the battery should normally be between 6 and 8 milliamps.

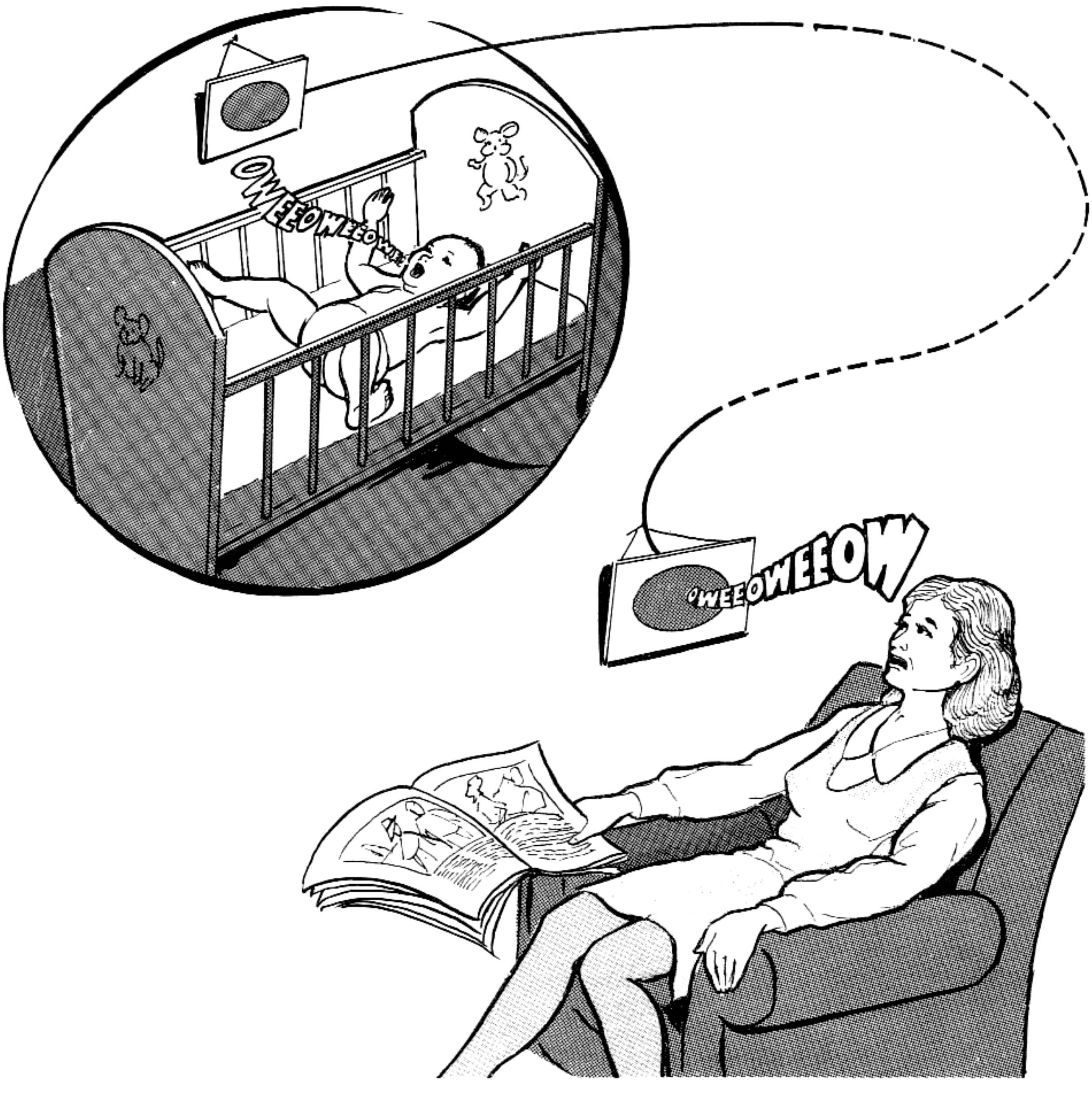
(*b*) When there is a signal input and the amplifier is working at full volume, the current drain on the battery should normally be between 15 and 25 milliamps.

(*c*) The 4·7 k Ω resistor between the volume control and the 10 μF capacitor may be reduced in value, or even shorted out altogether, if you should need an increased maximum volume or if you should need to use the 4·7 k Ω resistor somewhere else.

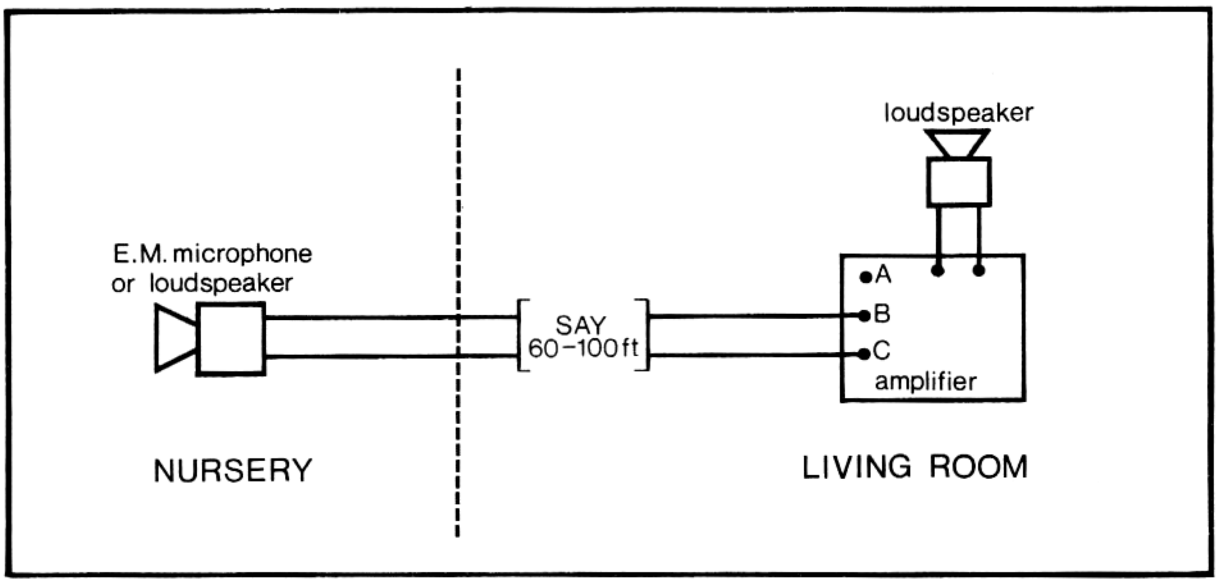
(*d*) To switch the amplifier on and off you should connect, or disconnect, the battery leads. To prevent the possibility of damage to any of the components in the amplifier, however, due to initial surge current, you should always turn the volume control to its minimum setting before disconnecting the battery and ensure that it is still at this setting before re-connecting the battery.


A
B
C
100 μF
33 kΩ
470 Ω
180 Ω
5·6 Ω
100 μF
loudspeaker leads
+ve red
−ve black
10 μF
4·7 kΩ
driver transformer
output transformer
5·6kΩ volume control
10 kΩ
470 Ω
100 μF
8·2 kΩ

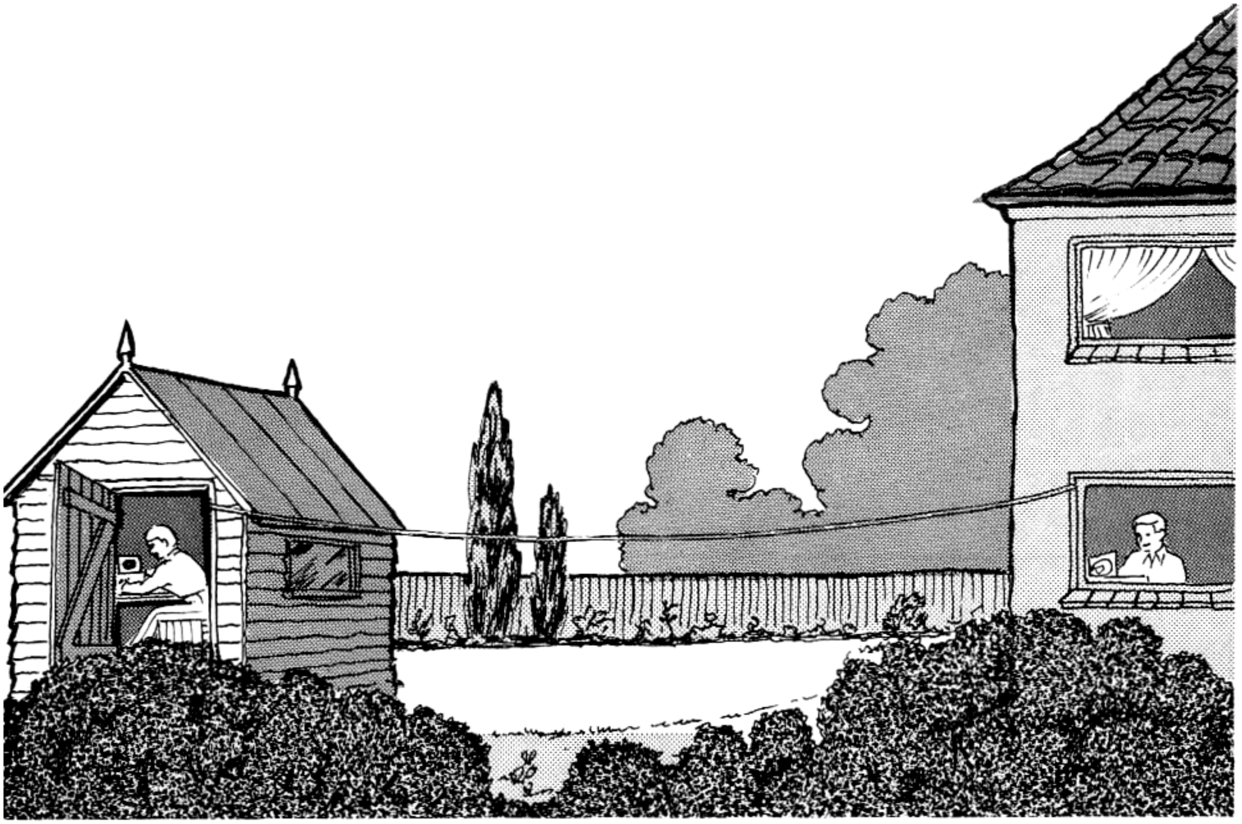
2. A baby alarm



The amplifier can form the basis of an efficient 'baby alarm' system. A sound-sensing device is required, however, and this, preferably, may be an electro-magnetic (low-impedance) microphone or almost any loudspeaker. In addition one needs enough twin bell-wire or thin flex to stretch from the nursery to the living room (e.g. 60–100 feet). Connect one pair of ends of the twin flex to Points B and C of the amplifier in the living room (see diagram opposite). Run the length of flex up to the nursery and connect the second loudspeaker (or other sound-sensing device, such as a microphone) to the other pair of ends. Place the sound-sensing device within a few feet of the cot and any unusual sounds will readily be heard in the living room. Initially the volume control should be turned up to maximum. A little experimentation may be required for the best results. **Warning: Ensure that none of the wiring is within reach of the baby.**


E.M. microphone
or loudspeaker
SAY
60–100 ft
loudspeaker
A
B
C
amplifier
NURSERY
LIVING ROOM

3. An inter·com system



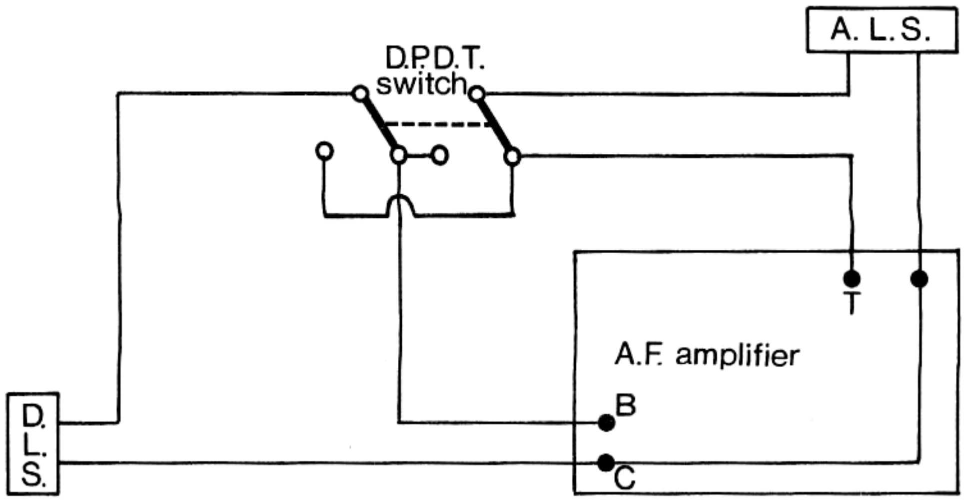
An efficient inter-com system can be made with the basic amplifier. It is similar to the baby alarm system described previously, but the 'sound sensing device' must be a loudspeaker and switching arrangements must be made so that the roles of the two loudspeakers may be interchanged from sound sensing to sound reproduction as required. For the best results, however, you must speak clearly and loudly, close to the speaker when transmitting.

To make the inter-com system, you will need to purchase (or otherwise acquire) an extra loudspeaker to the one supplied in the kit and a double-pole double-throw (DPDT) switch.

The wiring arrangement can be seen in diagrams 3.1 and 3.2. One side of both the distant loudspeaker (D.L.S.) and the amplifier loudspeaker (A.L.S.) is connected to negative. The positive side is thus the only side that passes through the DPDT switch.

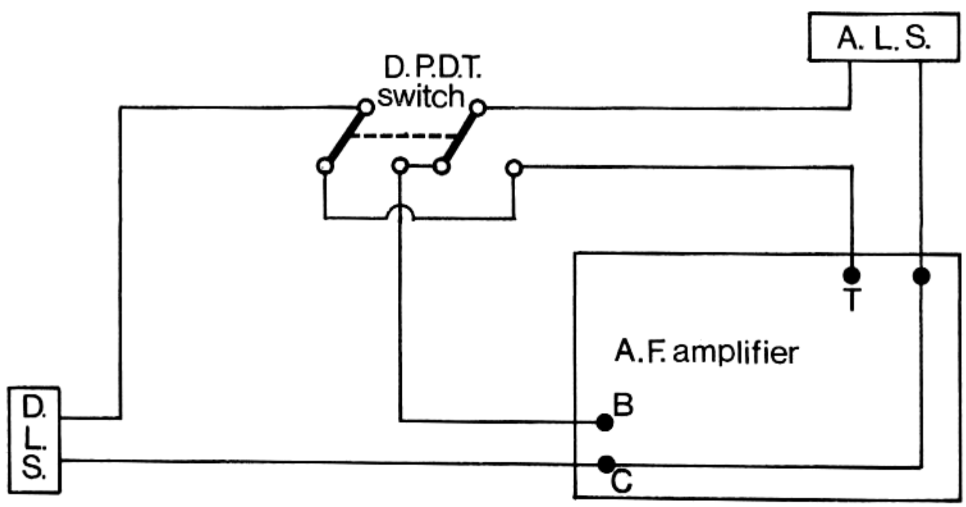
With the switch in the position shown in diagram 3.1 the positive side of the distant loudspeaker is connected via the switch to the amplifier input at point B. The output on the positive side from the output transformer is passed to the amplifier loudspeaker again via the switch. Thus, anyone speaking into the distant loudspeaker will be heard from the amplifier loudspeaker.

When the switch is moved to the alternative position, the original connections are broken and new connections are made which reverse the roles of the loudspeakers. Now, when anyone speaks into the amplifier loudspeaker, he will be heard from the distant loudspeaker.



Position 1. D.L.S. speaks to A.L.S.

3.1



Position 2. A.L.S. speaks to D. L. S.

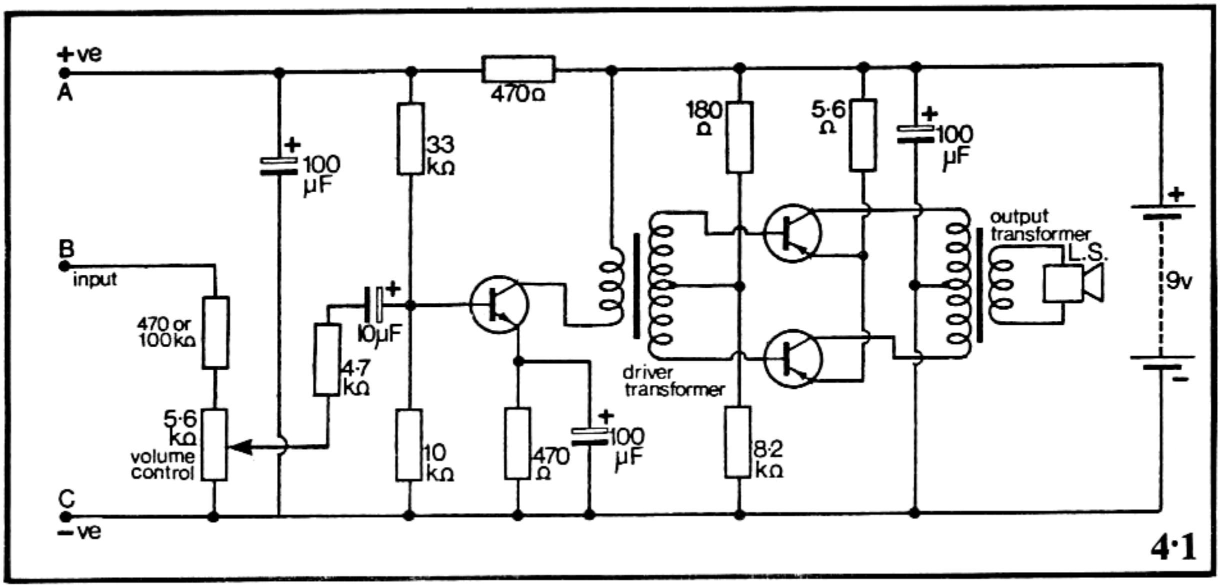
3.2

4. A record player

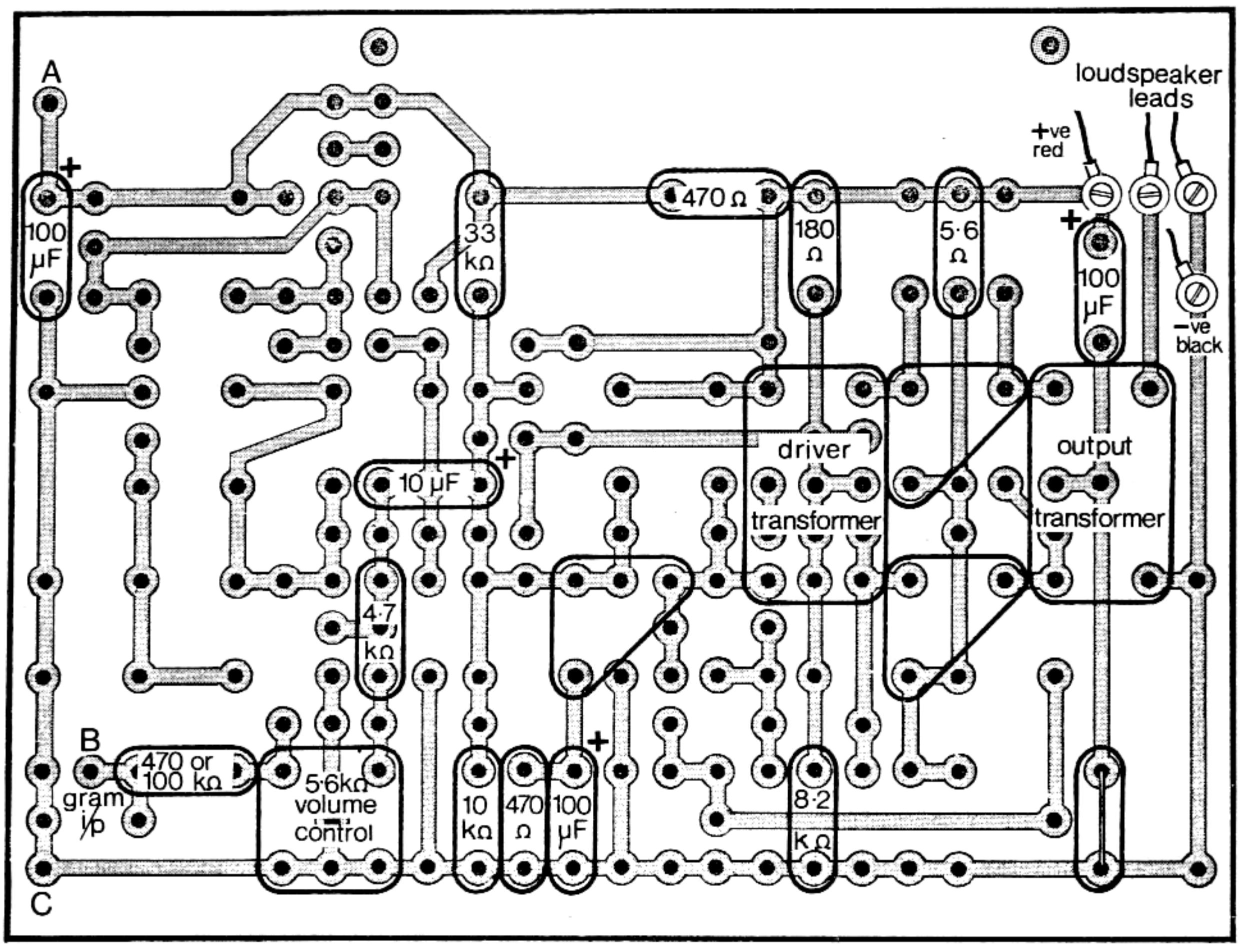
To use the basic amplifier as a record player, a gramophone turntable and pick-up are required. One lead from the pick-up should be connected to point B and one lead to point C on the amplifier.

The resistor shown between point B and the volume control improves the quality of the reproduced sound, but reduces its volume. For this reason, alternative values (470 and 100 kΩ) are shown. Each resistor should be tried in turn and also shorting out the resistor altogether, so the best method to suit your requirements can be adopted.

Remember that the result required may change with the situation. With the circuit shown, the volume should be adequate for normal living room reception. So if records are being played solely for the pleasure of listening, the accent should be on the quality of the sound. However, if records are required for dancing at a party, for instance, then volume can become more important than the quality of the sound. The maximum volume possible can be increased further by changing the 4·7 kΩ resistor in series with the 10 μF capacitor for a 1 kΩ resistor or, if necessary, by shorting out this resistor altogether.


+ve
A
470Ω
180 Ω
5·6 Ω
100 µF
33 kΩ
B
input
470 or 100kΩ
10µF
4·7 kΩ
5·6 kΩ volume control
10 kΩ
470 Ω
8·2 kΩ
driver transformer
output transformer
L.S.
9v
C
−ve

4·1


A
loudspeaker leads
+ve red
100 µF
470 Ω
33 kΩ
180 Ω
5·6 Ω
−ve black
driver transformer
output transformer
10 µF
4·7 kΩ
B
470 or 100 kΩ
gram i/p
5·6kΩ volume control
10 kΩ
470 Ω
8·2 kΩ
C

5. An improved amplifier

An Impedance Matching Stage

The amplification from the record player can be increased considerably by adding a further stage to the basic amplifier circuit, as shown in diagram 5.1. The transistor is connected in the 'common collector' mode to match in the high impedance of the pick-up from the gramophone. The new points to which the pick-up leads from the gramophone should be connected are also shown.

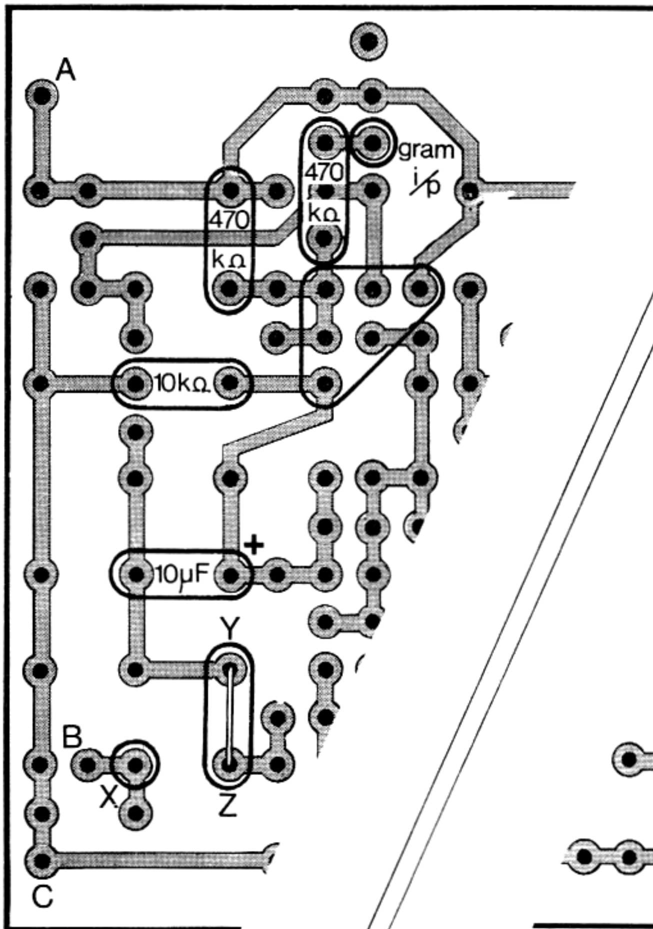
A Tone Control

Diagram 5.2 shows how an additional 5·6 kΩ potentiometer together with a 0·1 μF capacitor can be used in a tone control arrangement. This can be used to good effect to improve the quality of the sound when the amplifier is being used to make a radio as well as when it is in the record player configuration.

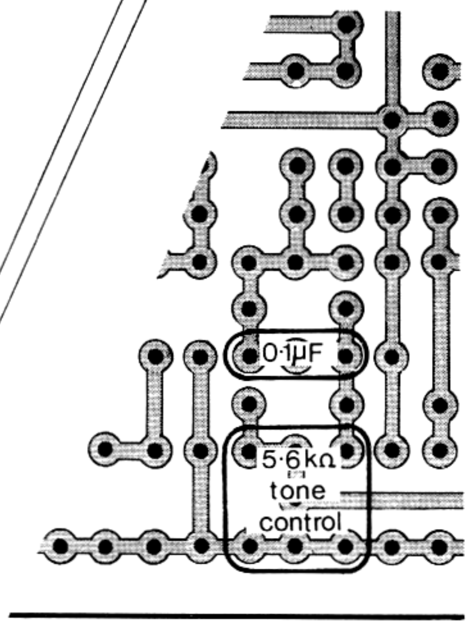
Radio/Gram. Switch

Diagram 5.3 shows how a switch link can be used to change from radio to record player at will, when the pre-amplifier has been installed. The three brass sockets in the kit are used here, at points X, Y and Z to facilitate switching and to help to make a more positive contact.

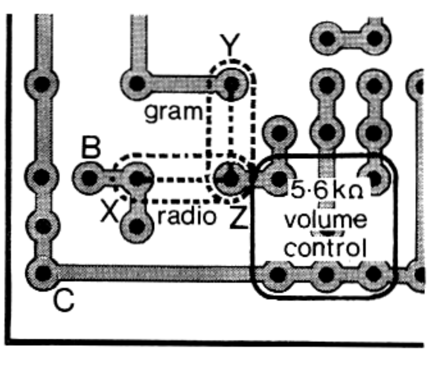
The theoretical and circuit board diagrams for the complete amplifier with all the improvements added are shown on pages 20 and 21.


A
470
kΩ
470
kΩ
gram
i/p
10kΩ
+
10μF
Y
Z
B
X
C

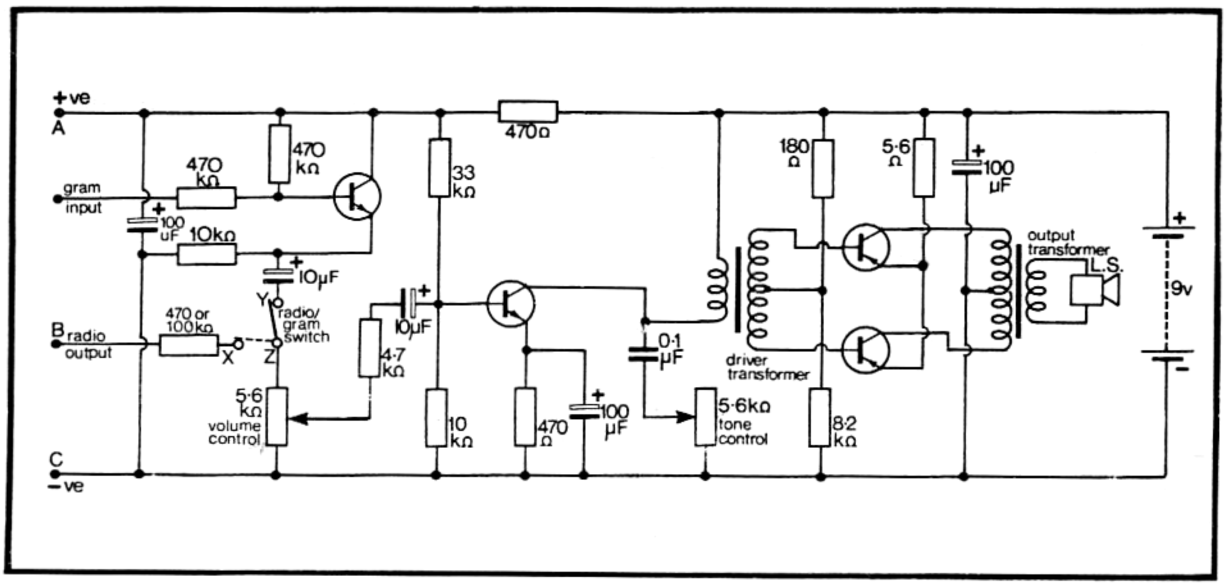
5.1

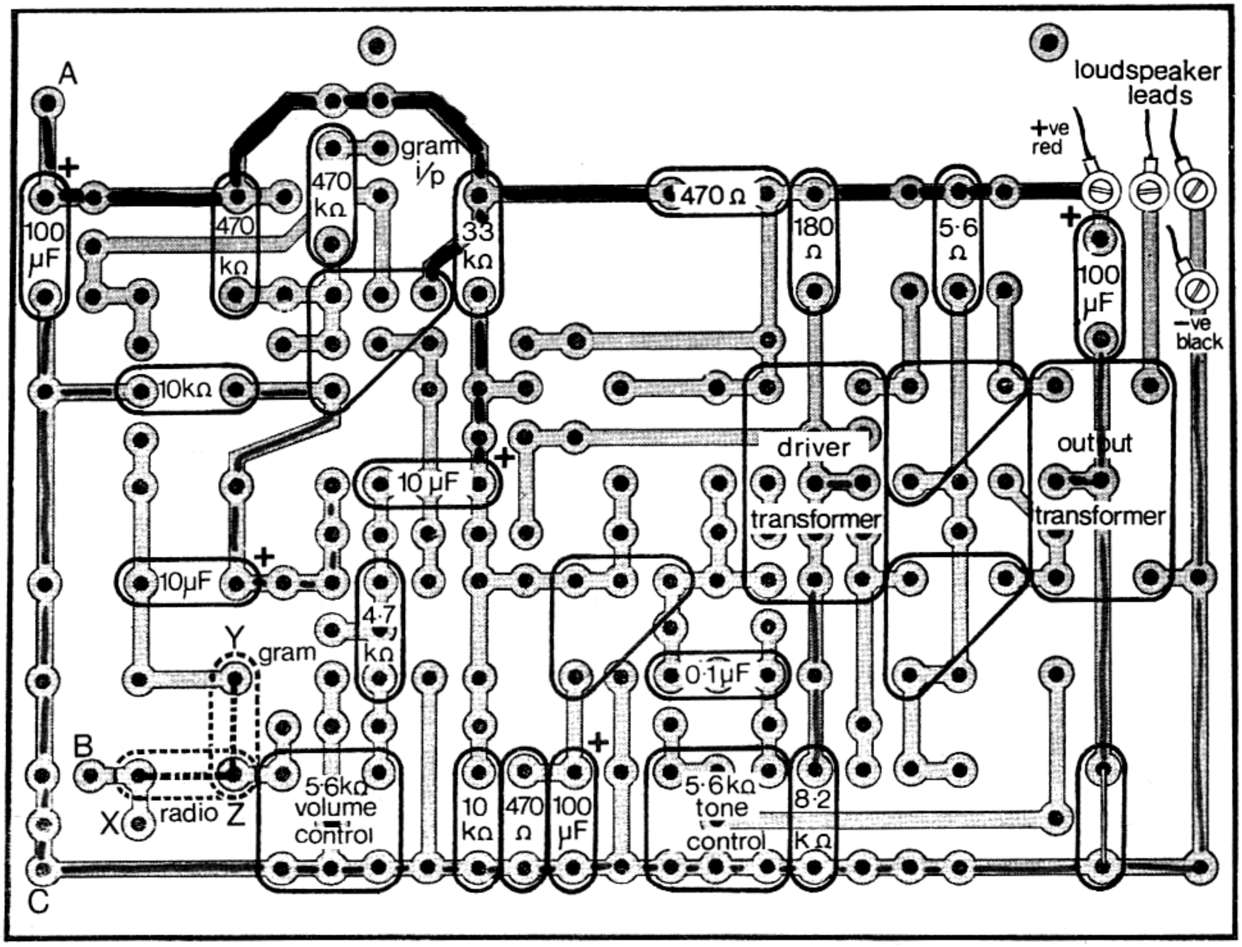

0·1μF
5·6kΩ
tone
control

5.2


Y
gram
B
X
radio
Z
5·6kΩ
volume
control
C

5.3

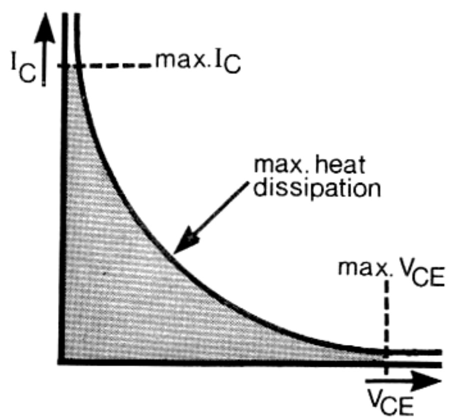

+ve
A
gram input
470 kΩ
470 kΩ
100 uF
10kΩ
10μF
B radio output
470 or 100kΩ
X
Y
Z
radio/ gram switch
5·6 kΩ volume control
C
−ve
33 kΩ
470Ω
10μF
4·7 kΩ
10 kΩ
470 Ω
100 μF
0·1 μF
5·6kΩ tone control
driver transformer
180 Ω
8·2 kΩ
5·6 Ω
100 μF
output transformer
L.S.
9v


A
loudspeaker
leads
+ve
red
−ve
black
100
μF
470
kΩ
470
kΩ
gram
i/p
33
kΩ
470 Ω
180
Ω
5·6
Ω
100
μF
10kΩ
driver
transformer
output
transformer
10 μF
10μF
4·7
kΩ
0·1μF
Y
gram
B
X
radio
Z
5·6kΩ
volume
control
10
kΩ
470
Ω
100
μF
5·6kΩ
tone
control
8·2
kΩ
C

Power amplifiers

The amplifying ability of a transistor was discussed briefly in Experiment 3 of the X40 kit. It was shown there, that if a 9 volt battery is being used and the transistor is biased so that when there is no input signal, the collector voltage is $4\frac{1}{2}$ volts, then however much the input signal is varied, the collector voltage cannot alter by more than $4\frac{1}{2}$ volts positive or $4\frac{1}{2}$ volts negative.

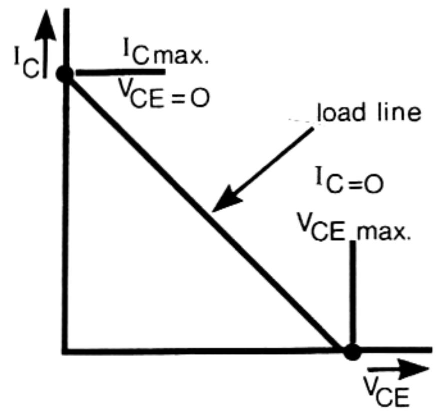
There are also physical limitations to the maximum power available from any particular transistor. These limitations are very important in power amplifier design because the transistors are worked over a very much greater part of their operating range. The maximum power obtainable from a transistor without damage depends on three factors. These are, the absolute maximum voltage and the absolute maximum current that the transistor can handle, and the maximum amount of power that the transistor can dissipate in the form of heat. The third factor is very important because if the transistor is worked so that it produces more heat than it can dissipate it will be destroyed. If a graph is drawn using the collector current, I_C for one axis and the collector-emitter junction voltage for the other axis, a curve showing the maximum heat dissipation for the transistor can be plotted as shown in diagram 1. The transistor must never be allowed to work outside the shaded area on the graph or damage will result.



1

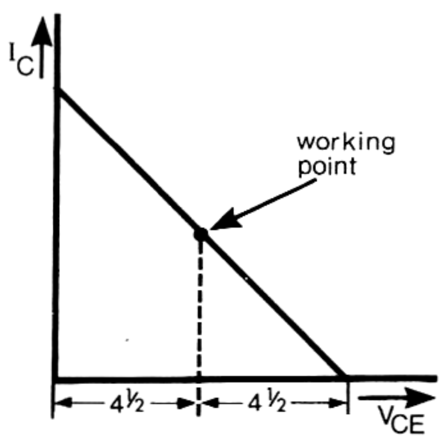
When the collector current, I_C, is zero, the collector-emitter junction voltage, V_{CE}, is at a maximum. When V_{CE} is zero, however, I_C is at a maximum. When I_C is at zero, the transistor is said to be 'cut-off'. When I_C is at a maximum, the transistor is said to be 'saturated'.

If these two points are plotted on a I_C–V_{CE} graph, a line can be drawn between them as shown in diagram 2. This line is known as the 'Load Line'.



2

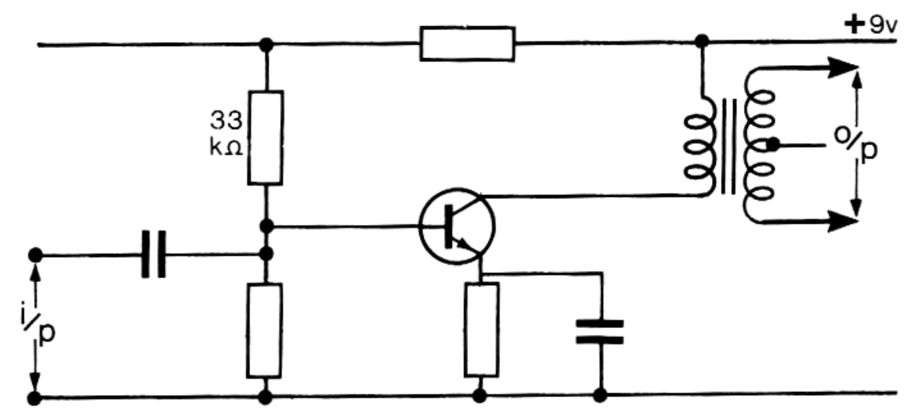
The selected point on the load line about which the transistor is biased to operate is called the 'Working Point'. In Experiment 3 of the X40 kit, the transistor base was biased so that V_{CE} could swing $4\frac{1}{2}$ volts either side of the working point. That is, the working point was half-way along the load line, as shown in diagram 3.



3

When the working point is midway along the load line, the amplifier is called a Class A Amplifier.

The driver transistor in the A.F. amplifier you can build with this kit, shown in diagram 4 below, is acting as a Class A Amplifier. The 33 k Ω resistor acts to bias the base of the transistor and the load is the driver transformer from which the amplified signal is passed to the next amplification stage.



4

Assuming that the transistor has linear characteristics and that the output voltage and current, V_{CE} and I_C, swing between zero and maximum, the maximum power output Po will be half the product of the working point voltage and current. That is,

$$P_o \ max = \frac{V_{CE}}{\sqrt{2}} \times \frac{I_C}{\sqrt{2}} = \frac{V_{CE} \cdot I_C}{2}$$

At the same time, the supply power, Ps, is $V_{CE} \times I_C$.

So the maximum theoretical efficiency of a Class A amplifier is:

$$\eta = \frac{\text{output power into the load}}{\text{Power from the supply}} = \frac{P_o}{P_s}$$

$$= \frac{V_{CE} \cdot I_C/2}{V_{CE} \cdot I_C} \times 100$$

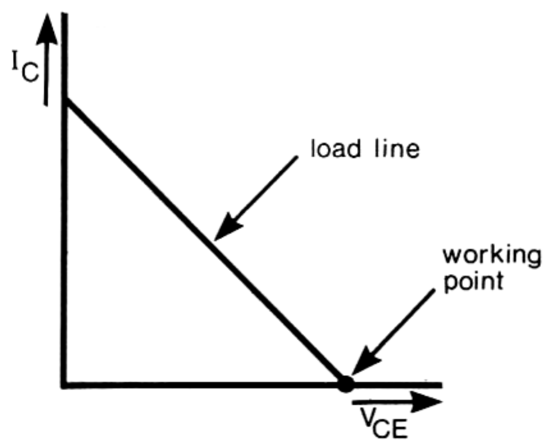
$$\eta = 50\%$$

Due to several factors, including the non-linearity of the transistor characteristics at the extremes of their range, the practical efficiency of a Class A amplifier is nearly half the theoretical efficiency. Thus the practical efficiency of a Class A amplifier is approximately 25%.

In practice, the Class A amplifier is both simple and cheap to run, providing the power output requirements are relatively low. This class of amplifier, therefore, is very often used for small portable radios. As the power requirements increase, however, the Class A amplifier becomes less economical. Because the working point is set halfway along the load line, there is a current drain on the batteries even when there is no signal input to the transistor. Also, as the power requirements increase, so an increasingly high-power transformer is required, which makes the amplifier increasingly expensive to produce.

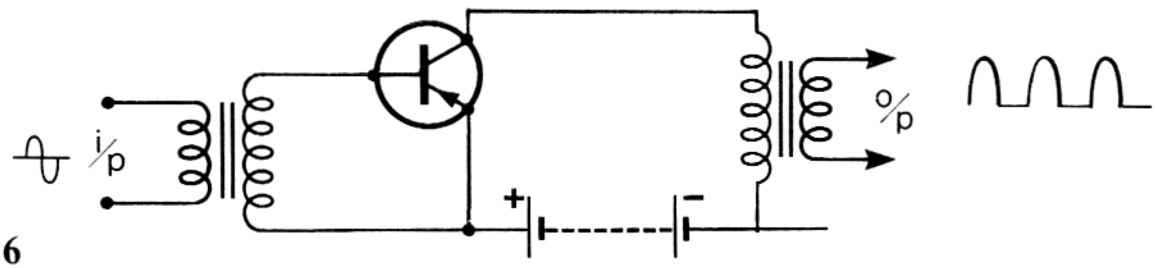
Another logical point at which to establish the working point, is at one end of the load line where $I_C = 0$ and V_{CE} is a maximum as shown in diagram 5. At least at this point there would be no current flowing under 'no-signal' conditions which would make the supply batteries last longer.

When the working point of the transistor is established on the load line at $I_C = 0$, the amplifier is known as a Class B amplifier.



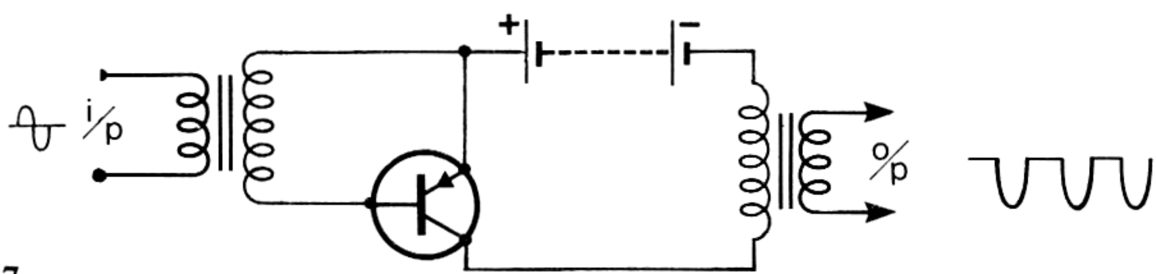
5

On the face of it, the major disadvantage of this system, is that only one half of the input signal is amplified, the other half being cut-off as shown in diagram 6.



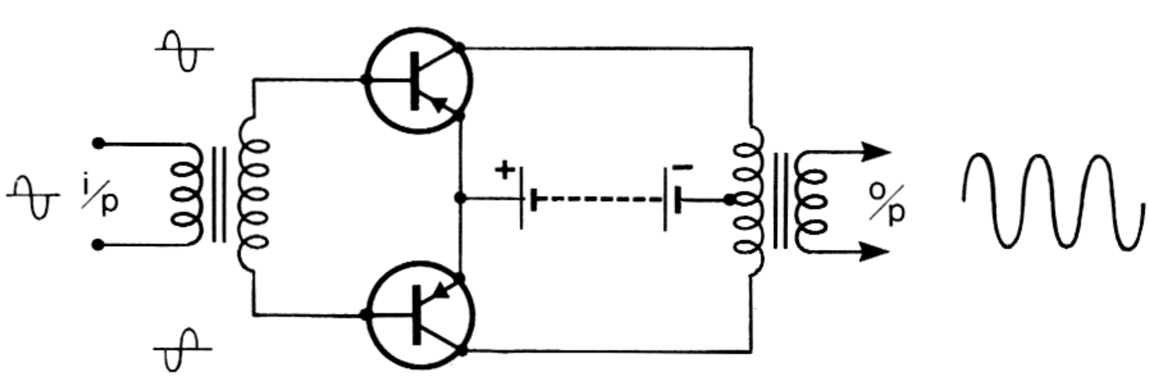
6

To get over this difficulty, another transistor can be used to amplify the other half of the input signal as shown in diagram 7.



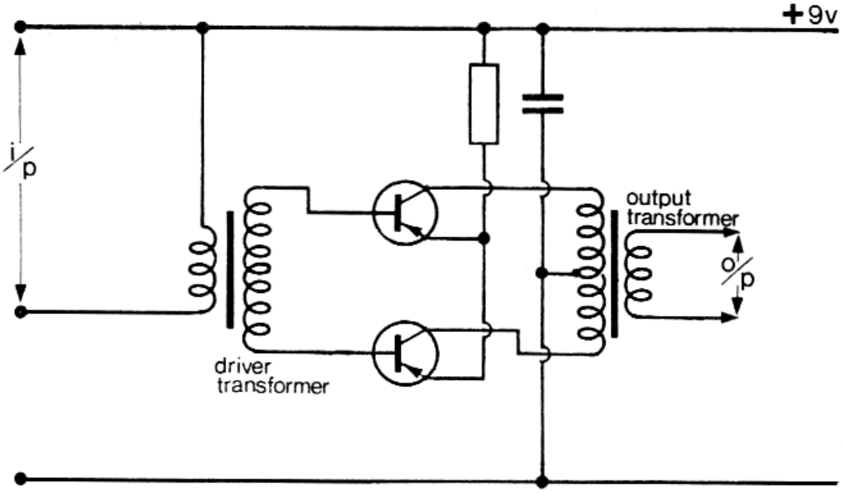
7

Now of course, the output from each of the transistors has to be combined so that the final output is an amplified replica of the input signal. This is done by using a centre-tapped transformer as shown in diagram 8.



8

When two transistors are used together in Class B amplification in the form shown in diagram 8, the amplifier is known as a 'Push-pull amplifier with Class B bias'. This is the type of amplification that is used in the last stage of the AF amplifier that you can build with this kit. The part of the amplifier which employs Class B push-pull amplification is shown in diagram 9.



9

The maximum theoretical power output, Po, from this type of circuit is the product of the r.m.s. values of the maximum output voltage and current V_{CE} and I_C.

Then,

$$\text{Po max} = \frac{V_{CE}\ \text{max}}{\sqrt{2}} \times \frac{I_C\ \text{max}}{\sqrt{2}} = \frac{V_{CE} \cdot I_C\ \text{max}}{2}$$

Also, the power supplied, Ps, will be:

$$\text{Ps} = \text{Vs} \times \text{average current.}$$

$$= \text{Vs} \times \text{Is}/\pi$$

In this case,

$$\text{Vs} = V_{CE} \quad \text{and} \quad \text{Is} = \tfrac{1}{2} I_C\ \text{max}.$$

So

$$\text{Ps} = V_{CE} \times \tfrac{1}{2} I_C\ \text{max}/\pi.$$

And the theoretical efficiency Po/Ps becomes:

$$= \frac{V_{CE} \cdot I_C\ \text{max}}{2} \times \frac{1}{V_{CE}} \times \frac{\pi}{I_C\ \text{max}} \times \frac{1}{2} \times 100$$

$$= \frac{\pi}{4} \times 100$$

$$= 78{\cdot}5\%.$$

In practice, it is possible to obtain an amplifier efficiency of 70 to 75% which is approximately double that obtainable with a Class A amplifier. Furthermore, there is no battery drain under 'no-signal' conditions, making the Class B amplifier more economical to run. Additionally, a higher effective power output is obtainable compared with the Class A amplifier with considerably less distortion. The major disadvantage of the Class B push-pull amplifier is that two transistors and two transformers are necessary which makes the Class B amplifier more expensive to produce. Also, the two transformers make the amplifier more bulky.

In general, Class A amplifiers are used when the output power requirements are low, whilst Class B amplification is used for medium and high output power purposes.

Appendix A:

Amplifier Add·on Kit X40A

List of Contents

Item	Quantity
Instruction manual	1
Fundamentals of Electricity	1
Printed circuit board	1
Transistors PNP	2
Driver transformer	1
Output transformer	1
Loudspeaker mounted on baffle	1
Potentiometers 5·6 k Ω	2
Resistors:—	
470 k Ω (yellow, mauve, yellow-silver)	2
33 k Ω (orange, orange, orange-silver)	1
10 k Ω (brown, black, orange-silver)	2
8.2 k Ω (grey, red, red-silver)	1
180 Ω (brown, grey, brown-silver)	1
5·6 Ω (green, blue, gold-silver)	1
Capacitors:—	
100 μF	2
10 μF	1
0·1 μF	1
Interconnecting leads 6″	3
Switch link	1
6BA Brass sockets	3
Screws, Nuts, Washers } packet	1

Appendix B:

Resistor colour code

The value of a fixed resistor is normally indicated by a colour code in which:

0 = Black	4 = Yellow	8 = Grey
1 = Brown	5 = Green	9 = White
2 = Red	6 = Blue	
3 = Orange	7 = Mauve	

Three colours, generally in the form of colour bands, denote the value in *ohms*. The first two indicate the digits and the third the number of noughts which follow them.

Thus: Brown, Grey, Brown,– 180 ohms.
Green, Blue, Red = 5600 ohms
= 5·6 k Ω (kilohms).
Brown, Black, Green = 1,000,000 ohms
= 1 megohm.

In addition Gold or Silver are sometimes used in the third colour position as 'Dividers' when the value of the resistor is less than that denoted by the first two digits. Gold means divide by 10 and Silver divide by 100.

Thus: Green, Blue, Gold = 56/10 = 5·6 ohms.
Orange, Orange, Silver = 33/100
= 0·33 ohms.

A fourth band at the other end of the body shows the tolerance in the indicated value of the resistor. Thus:

No fourth band = ± 20% tolerance
Silver band = ± 10% tolerance
Gold band = ± 5% tolerance