

AMATEUR ELECTRONICS BASIC PRINCIPLES AE CIRCUITS
TEN CIRCUIT-BOARDS
DIAGRAM EXAMPLES
J. SOELBERG


# AMATEUR ELECTRONICS 

by
Jan Soelberg

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Ing. Jan Soelberg

## Preface

The first edition of Amateur Electronics was published in 1970.

The book was published in the hope that those who are interested in applied electronics, and young people studying this subject in their spare time, a considerable number altogether, can acquire a wider technical knowledge.

Amateur Electronics was the first programmed technical book.

This combined build-and-learn method has proved to give good study results of $50 \%$ in many cases, whereas other forms of self-study rarely exceed a $10 \%$ satisfactory result.

The author
J. Soelberg


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How to study this book
The contents are divided into four main sections:
a. Basic book comprising theory explanations and practical examples. The basic section pages are marked $G$ followed by the subject number.
b. The supplementary section containing information on such matters as colour codes, mathematics, etc. These pages are marked T followed by a subject number.
c. The feed-back list, marked with an F.
d. The diagram section containing many interesting circuits, some from JOSTY KIT, some AE-circuits with accompanying circuit boards, and others including many "borrowed circuits" found in electronic magazines published all over Europe.

The basic and supplementary sections are programmed. After each task a number of questions are put in which you have the choice of between two and six answers .
Having solved a problem and chosen the answer, refer then to the feed-back list. A bookmark is invaluable when doing this. The feed-back list is numbered in succession like the basic section. See if the answer chosen is correct, and if it is, continue to the next task or question. If you are good at answering these questions, try solving the last problem in the following group until you get stuck - then start reading the text.
If you have chosen the wrong answer, the feed-back list will tell you what is wrong, together with an explanation. When you feel that you thoroughly understand each task, continue to the next group - if not, it is advisable to re-read it.

This system of study has proved to be the most effective. It entails, of course, that you do not "cheat yơurself" but really try to solve each problem without looking at the feed-back list until you have decided on an answer.

To demonstrate the system, these instructions are programmed. Test yourself here!

Question 1
What is meant by programming a book?
It is illustrated with drawings
It includes questions with a feed-back list
A $\square$
It includes a programme statement
B $\square$
It is compiled with the easy work first and the difficult work at the end
D $\square$

Refer now to the feed-back list below:
A. It is, of course, important to have drawings illustrating the text, but the essential thing in a programmed technical book is the questions put and the answers in the feed-back list. When solving a problem, this system shows if anything is wrong, states the correct answer in a "different" way and tells what to do next. Proceed to Question 2.
B. Correct. The feed-back list is a check on the solving of the problems, and this shows that the subject is understood completely. Proceed to Question 2.
C. Wrong. You have been misled by the word itself. Programming means you have a feed-back list at your disposal, and this is not just a list of answers. A list of answers gives you the correct solution only while a feed-back list gives both answer and an explanation of the solution in another way. It also gives the next step to take. Proceed to Question 2.
D. It is correct that a technical book usually starts off with the easier subjects and ends with the hard ones, but this does not mean it is programmed. The feed-back list is the essential thing here because you are told about your progress, the solution is reached in another way, and finally it states the next step to be taken. Proceed to Question 2.

Question 2
What is the niost important purpose of a feed-back list?

| To state the correct answer | A $\square$ |
| :--- | :--- |
| To see if an answer is wrong | B |
| To explain correct and incorrect answers, |  |
| to give another possible solution | C |
| To state the following problem to be solved | D |

Feed-back, Question 2
A. To state the correct answer only is insufficient. To thoroughly check the ability to understand a subject an explanation is necessary and as far as possible to see what has been misunderstood and finally the next step to be taken. Your out-dated idea of a list of answers won't help here. We hope that you now see our aim proceed with the book proper.
B. A short statement telling you whether a correct or incorrect answer given is not sufficient. The feed-back list must explain the correct solution in another way and attempt to tell you where you have gone wrong. The list should also tell you your next step. We think you should get started on the book now.
C. Correct. All three points are included in the idea of programming. You now know how to set about the job and we wish you happy studying.
D. It is essential that the feed-back list states the problems to be solved, but it is of greater importance to include an explanation of the answers. Both explanation and the correct solution as well as an indication of what is wrong is the idea behind this book. All three points must be included in a good feed-back list. We feel sure you now understand how to utilize this book and we wish you happy reading.


## THE ATOM Fig. 1.1

Everything consists of particles called atoms. This is a Greek word meaning 'indivisible". The Greek philosopher, Democritus, who was born about 400 B.C., concluded that there was a limit to the splitting of all matter, the remaining particles being indivisible.

In the Middle Ages his theories were opposed, while today they hold good to a certain extent in that the atom is no longer regarded as a round particle that cannot be split - on the contrary.

An atomic nucleus is composed of protons (positively charged) and neutrons (no charge), and constitutes practically all the mass of the atom. (Its charge equals the atomic number, its diameter is from $10-13$ to $10-12 \mathrm{~cm}$.)

Surrounding the nucleus is a cloud of electrons (negatively charged) the diameter of this cloud being approx. $10-10 \mathrm{~m}$. The figure above shows the He (helium) atomic structure having two protons, two neutrons, and two electrons.

The electrons in the electron cloud are not in an equally stable position. The electron cloud around the nucleus is divided into layers (shells) rather like those of an onion. There can be up to eight electrons in each shell, and when these are in position the shell is round and smooth. A deficit or a surplus in the amount of electrons results in an uneven surface and reduced stability.

A strip of metal is normally electrically neutral. The structure of metal is such that there is one or more electrons to each atom, the former being unstable (free to move) within the metal.

CONDUCTOR
Fig. 1.2


If we connect a wire to a substance, a battery or current, having a deficit of electrons, the unstable loose electrons in the wire will flow to the substance and fill in the vacant spaces. If the other end of the wire is connected to a substance having a surplus of electrons, the electrons will flow from the substance into the vacant positions. This movement of charged electrons is in fact a flow of current.

The electrons travel from surplus (-) to deficit (+) while some of us remembering the early days of electricity still say that the current flows in the opposite direction, i.e. from positive to negative.

Question 1.
The atomic nucleus is composed of

| Electrons | A $\square$ |
| :--- | :--- |
| Protons | B $\square$ |
| Others | C $\square$ |

Question 2.
Which direction does an electron travel in this wire?

| - | To the right <br> To the left | A $\square$ |
| :--- | :--- | :--- |
|  | B $\square$ |  |

See feed-back list after answering each question.

## G2 SEMICONDUCTORS I

Semi-conductors in practice are not really semi-conductors. Semi-conductors are substances that conduct very poorly. This poor conductivity is due to the electrons being confined to a path (orbit) around the atom, unlike the unstable electrons in metals.

However, when we mix small amounts of certain substances in a semi-conductor material we improve its conductivity. This matter must be explained further as it forms the basis of all semi-conductor theory.

To attain the maximum effect when introducing these foreign matters, the semi-conductor substance must be in mono-crystallic form.

We are all familiar with crystals in the form of salt and precious stones. Metals also consist of crystals, but they are microscopic and uneven in appearance. If a semi-conductor were of this structure, it would affect the uniformity of the electron shells in two adjacent crystals, and many of the free electrons are able to conduct the current.

Fig. 2.1


A two-dimensional view of a germanium or a silicon crystal is shown in the drawing. The characteristic feature of these crystals is that each atom has four electrons in its outer shell and they all bind the crystal together bymeansof pairs of electrons forming the bond.

The binding electrons belong to several atoms, each atom appearing to be surrounded by eight electrons. Trie layer is complete and all the electrons are stable and no charging movement can take place - the crystal is thus a poor conductor.

If some of the atoms are replaced by others, e.g. As (arsenic) or B (boron) that have five and three electrons, respectively, in the outer shell, the picture changes.

Fig. 2.1 shows $\operatorname{Si}$ (silicon) mixed with As. You will notice an electron in the crystal that is not bound to a particular atom. It is unstable and is free to move as in ordinary metal. A semi-conductor material with too many electrons is called an 'N substance".

Fig. 2.2


This drawing shows a section of Si with boron added. An electron is missing so an adjacent electron can jump from its original position over to the vacant space, which is called a hole. A new hole is thus formed, and as an electron is still missing, a hole is regarded as a positive charge. This neans that a positive charge goes in the opposite direction of the displaced electron. This is how current travels in a P-substance, the name we give to a crystal with vacant holes.

We now reach the important conclusion:

A free electron cannot persist in a P-doped material and a hole cannct persist in an N-doped material, at least not for any length of time. (The mean value of the persistence time is termed recombination time.)

Question 1.
Why is the conductivity of pure silicon poor while that of impure silicon is excellent?

Because all the electrons in pure silicon are stable while impurities form unstable electrons or holes:

A $\square$
Because the impurities are unstable and thus conduct electricity:

B $\square$
Question 2.
Why do electrons not exist freely in a P-substance for any length of time?

Because they are attracted by N -substance Because they recombine with a hole
Because there is no room for them
$\mathrm{C} \square$

When generating electricity we separate the electrons from the atoms to which they were attached and keep them together at a point where they cannot return. By means of conductors (wires) we can lead them to any desired position and utilize them for a certain purpose. This is the principle in all equipment driven by electricity. This separation can be carried out with the aid of batteries, power supply, solar cells etc.

## CURRENT

siom betigder ab clectuoner inta ing fian an
Current means that electrons are transferred from one position to another. The amount of current depends on the amount of electrons per second.Current is measured in amperes and a current of 1 amp . means that $6 \times 1018$ electrons pass through a conductor every second.

## VOLTAGE

Voltage is a measurement of surplus or deficiency in electrons, i.e. a sort of electron pressure. If we compress air in a vessel, it will leak out af any holes until the pressure inside and outside the vessel is equal. This also applies to electrons that are assembled at the pole of a battery.

## BATTERIES

When connecting a wire to the battery, the current runs in the direction of greater number of electrons to smaller, even if the voltage drops from +6 to +3 volts. Keep in mind, however, that the current we normally speak of flows from + to -, whereas electrons flow from - to + .

## SERIES CONNECTIONS

When connecting batteries in series, that is the positive pole of one being connected to a negative pole of another, the total voltage is equal to the sum of the battery voltages. This is seen in torches, transistor receivers etc., where several batteries are connected in series to obtain the total voltage required.

Fig. 3.1 Three batteries connected in series


## PARALLEL CONNECTIONS

The drawing below shows the parallel connection of batteries. This gives no more voltage, but in this case the amount of available current is three times greater.

Fig. 3.2 Three batteries connected in parallel


Question 1
If a current of $6 \times 1019$ electrons per second flows in a wire, what is the amperage? See section T1 (powers) if necessary. 1 amp
$A \square$ 6 amps B $\square$ 10 amps $\mathrm{C} \square$

Question 2
How great a current expressed in milliamps is represented by $6 \times 1015$ per sec.? See sect. T1 (maths) if necessary.

$$
\begin{aligned}
& 0.6 \mathrm{~mA} \\
& 1.0 \mathrm{~mA} \\
& 60 \mathrm{~mA}
\end{aligned}
$$

A $\square$
B $\square$
$\mathrm{C} \square$
Question 3
Which way do the electrons run in this drawing?
Fig. 3.3


| Both towards 0 | A |
| :--- | :--- |
| From -7 to 10 | B |
| Away from 0 | C |
| From 10 to -7 | D |

Question 4
Three batteries each 450 V are connected in series. What is the total voltage expressed in kV ? See sect. T 1 (maths) if necessary.

| 1.35 kV | A |
| :--- | :--- |
| 4.50 kV | B |
| 0.135 kV | $\mathrm{C} \square$ |
| 0.45 kV | D |

Question 5
How many mA can we get out of two parallel connected batteries each giving 0.1 A, that in turn are parallel connected to a battery giving 2 A ? Batteries have equal voltages. See sect. T1 (maths) if necessary.

$$
2100 \mathrm{~mA}
$$

1200 mA
B $\square$
2200 mA
$\mathrm{C} \square$
12000 mA


PITH BALLS


PITH BALLS

The balls repel each other

The balls attract each other

## CAPACITORS

A very old experiment in connexion with electricity is that with two pith balls suspended and insulated. If both balls are charged with the same sort of electricity the balls will repel each other, while they attract each other if they are charged with different sorts of electricity.

A capacitor comprises two metal plates separated by an insulating material. If a negative charge is applied to one of them, and a corresponding negative charge removed from the other, the capacitor plates will be differently charged. The two charges attract each other in the same way as the pith balls. They remain in this state until the plates are connected with a wire. Then the surplus electrons flow through the wire to fill the vacant holes.

If a charge (current) is applied to a capacitor via an ammeter we notice a momentary rush of current until the capacitor is charged. This important characteristic is dealt with later under the subject of alternating current.

We can carry out a little experiment using a lamp, a capacitor and a switch. When connected, the lamp lights and goes out after a short time because the capacitor is charged. On switching to position 2, the capacitor is decharged via the lamp and is lit momentarily. We see then that a current flows to and from the capacitor, but not through it.

Fig. 4.3


The capacitance of a capacitor is expressed in Farads and indicates the size of charge it can accumulate.

The capacitance depends on:

1. Size of plates
(Large plate $=$ great capacitance)
2. Distance between plates
3. Insulating material
(Great distance $=$ small capacitance)
(Suitable material = great capacitance

Question 1.
Is the capacitance of a freely suspended key

| Great | ? | A $\square$ |
| :--- | :--- | :--- |
| Small | $?$ | B |
| Medium | $?$ | C |

1. Capacitors can be series or parallel connected.

Two parallel connected capacitors of equal size can be compared with one in which the plate area is doubled.

Parallel connections can be calculated according to the following equation:

$$
C_{x}=C_{1}+C_{2}+C_{3}
$$

$$
\mathrm{Cx}=\mathrm{C}_{1}+\mathrm{C}_{2}+\mathrm{C}_{3}+\ldots
$$

Fig. 5.1

2. Two series connected capacitors of equal size can be compared with one in which the plate distance is doubled, the capacitance thus being reduced by a half. Series connections can be calculated according to the following equation:

$$
\frac{1}{\mathrm{Cx}}=\frac{1}{\mathrm{C}_{1}}+\frac{1}{\mathrm{C}_{2}}+\frac{1}{\mathrm{C}_{3}} \ldots \quad \text { Fig. } 5.2
$$



Concerning problems with fractions and powers, see sect. T1.

## Question 1

Two capacitors of $0.5 \mu \mathrm{~F}$ are connected in parallel. What is the resulting capacitance?

| $1 \mu \mathrm{~F}$ | $\mathrm{~A} \otimes$ |
| :--- | :--- |
| $0.25 \mu \mathrm{~F}$ | $\mathrm{~B} \square$ |
| $50 \mu \mathrm{~F}$ | $\mathrm{C} \square$ |

Question 2
The smallest capacitors at your disposal are 1 nF . How can these be combined to give the value 333 pF ?

By soldering two together in parallel
By connecting three in series
A $\square$
By connecting two in parallel and one in series
B $\square$
$\mathrm{C} \square$

Question 3.
What is the total capacitance of two parallel connected capacitors that are marked brown, black, orange?

| 50 nF | A |
| :--- | :--- |
| 2 nF | B |
| 20 nF | C |
| 5 nF | $\mathrm{D} \square$ |

Question 4.
Three capacitors each marked brown, green, red are connected in series. What is the capacitance?

| 1.5 nF | $\mathrm{A} \square$ |
| :--- | :--- |
| 500 pF | $\mathrm{B} \square$ |
| 5 nF | $\mathrm{C} \square$ |
| 4.5 nF | $\mathrm{D} \square$ |

Generally speaking the following types of capacitors are available:

Polyester
Ceramic
Oil
Trimming
Variable
Electrolytic
Tantalum
Capacitive (varactor)diodes
In this connexion, obsolete types are paper and mica capacitors.

Polyester capacitors comprise two thin layers of polyester and two layers of metal foil which are insulated by the polyester. Due to their size, the metal often has to be vaporised onto the polyester. These capacitors are potted and colour coded, the capacitances being between 10 nF and $2 \mu \mathrm{~F}$.

The ceramic (pin-up) capacitors consist of an insulating ceramic tube that is silver plated on the inner and outer surfaces. The connecting wires are led out and the whole tube is cast in an insulating polyester cement and colour coded. Capacitances 1 pF to 10 nF .

Oil capacitors are generally used in high voltage equipment as oil (and paper) has good insulating properties.

The trimming and variable capacitors comprise two sets of sliding plates, air being the insulator. Capacitance between 1 and 1000 pF .

The electrolytic capacitors are the commonest type to attain maximum capacitances, normally between $10 \mu \mathrm{~F}$ and 10 mF , the capacitance being chemically converted. Electrolytic capacitors are polarised, and polarity must therefore be observed.

As an effective illustration of wrong connections, try connecting an a.c. supply via an electrolytic capacitor of approx $100 \mu \mathrm{~F} / 35 \mathrm{~V}$. Use a safety shield as some capacitors can "explode". The current supply should give 30 V a.c. and approx. 3 amps , short-circuit proof.

The tantalum capacitor is a relatively new type in which a higher capacitance can be attained in relation to size compared with an electrolytic capacitor. As the tantalum capacitor has a very low loss, it is especially suited for use in timer circuits and similar applications in which the charging time must be constant during a long period.

The tantalum capacitor is polarised in the same way as an electrolytic capacitor, so polarity must be observed.

Question 1
How is the value of a capacitor expressed? In Volts
m
B $\square$
Farads
C $\square$
Amps
D $\square$

## Question 2

A paper capacitor $30,000 \mathrm{pF}$ is connected in parallel with a mica capacitor of 2 nF - what is the total capacitance?

| $0.032 \mu \mathrm{~F}$ | A |
| :--- | :--- |
| $16,000 \mathrm{pF}$ | B |
| 1.9 nF | $\mathrm{C} \square$ |
| $23 \mu \mathrm{~F}$ | $\mathrm{D} \square$ |

Question 3
How many layers can a polyester capacitor have?

## Question 4

Find the cotour codes of the following capacitors:
$3.3 \mathrm{nF}, 270 \mathrm{pF}, 47 \mathrm{pF}, 10 \mathrm{pF}, 8.2 \mathrm{nF}, 3.9 \mathrm{nF}, 390 \mathrm{pF}$ by memorising the colour code in section T2. Check them and fill in A, B or C according to the number of correct answers.

0-3 correct
4-5 correct B $\square$
6-7 correct
Question 5
Why are oil capacitors hardly ever used in electronic equipment?

Too expensive A A
Too big
Voltage too high
$\mathrm{C} \square$
Equipment must
be oil-dipped
$\mathrm{D} \square$
Question 6
A trimming capacitor of 3 to 30 pF is parallel connected with a capacitor that is marked brown, red, brown. What is the resulting capacitance?

| $2.8-23 \mathrm{pF}$ | $\mathrm{A} \square$ |
| :--- | :--- |
| $213-240 \mathrm{pF}$ | $\mathrm{B} \square$ |
| $123-150 \mathrm{pF}$ | $\mathrm{C} \square$ |

Question 7
In which diagram is the capacitor placed correctly?
Diagram A
Diagram B B $\square$


## ELECTRO-MAGNETISM

In 1820, H.C. Oersted discovered that a magnet could be made by means of an electric current. Later it was discovered that a current could be made by means of a magnet moving in relation to a coil. This is called induction. All powerful generators i.e. dynamos, are based on the induction principle.

Fig. 7.1


When a magnetic field in a coil varies, a voltage is induced in the coil. This also happens when the current in the coil creates a magnetic field.

When we pass a current through a coil, the magnetic field thus created will induce another voltage in the coil in the opposite direction. The current does not rise immediately in the same way as when we close a switch.
If the current is reduced (by regulating a resistor or a transistor) the variation in the magnetic field will induce a voltage that endeavours to maintain the current.

Fig. 7.2


The figure above shows this. Lamp 2 lights later than lamp 1 when the contact is closed while it remains lit a little longer when turning off the switch to Pos. 2. The latter is harder to see than the delay when switching on. The purpose of the resistors is to maintain equal brightness of the lamps and to limit the current.

## COILS

A coil is a length of wire wound round some object. Coils vary greatly, from a single winding round a pencil to huge ones the size of a table with thousands of windings. The diagrams specify the types of coil to be used.

The electric value of a coil is expressed in "Henry". We often see $\mu \mathrm{H}$ and mH as Henry alone represents a high value. A coil blocks high frequencies.
The resistance of a coil to a.c. is termed $Z_{L}=$ a.c. impedance. This a.c. resistance is calculated as follows:

$$
\mathrm{Z}_{\mathrm{L}}=\omega \cdot \mathrm{L}=2 \pi \cdot \mathrm{f} \cdot \mathrm{~L}
$$

$\omega$ is the angular frequency which again is $2 \times \pi(3.14) \cdot \mathrm{f}$.
$L$ is the coil value in Henry.
Remember that a coil often has a considerable self-induction.

Question 1.
Is electricity produced when a magnet is in a coil?

| Yes | A $\square$ |
| :--- | :--- |
| No | B |

Question 2.
In the diagram we see that lamp 2 is still on when the switch is changes to position 2. Why does it go out later?

Because
it is blown
A $\square$
it lights only when there is a magnetic field in the coil
it lights only when there is a change in current the coil is not big enough

Fig. 7.3


Question 3.
What is the a.c. resistance of a coil that is $1 \mu \mathrm{H}$ and the frequency 1000 Hz ?
6.28 Mohm
A $\square$
6.28 kohm
B $\square$

Question 4.
What is the impedance of the same coil but with a frequency of $1,000,000 \mathrm{~Hz}=1 \mathrm{MHz}$ ?
6.28 ohm
A $\square$
6.28 Mohm
B $\square$

Resistors are "electronic brakes" placed in a circuit to limit the current.

If the voltage across the resistor is high, it will force many electrons - high current - through the resistor.

If, on the other hand, the voltage is low, a low current is forced through a high resistance.

This is expressed in Ohm's Law as follows:
$\mathrm{E}=\mathrm{R} \cdot \mathrm{I}$
where $\mathrm{E}=$ voltage, $\mathrm{R}=$ resistance, and $\mathrm{I}=$ current.
The value of a resistor is expressed in ohms or $\Omega$.

Fig. 8.1


Ohm's Law is used to determine the values of $I, E$ or $R$ when two of the values are known as shown below.

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}} \text { or } \mathrm{I}=\frac{\mathrm{E}}{\mathrm{R}}
$$

Both these equations are found by simple fractional arithmetic.
To understand and to apply Ohm's Law is absolutely necessary to be able to proceed in this book.

Types of resistors
This sub-section deals with resistors of all shapes and sizes. Formerly all resistors were wound with constantan wire, but now carbon resistors are mainly used. This is because the method of applying a layer of carbon has been improved.

Standard carbon resistors are available from $1 / 8$ watt to 1 watt. As the carbon film cannot withstand high temperatures, it is still necessary to use wire-wound resistors for outputs exceeding 1 W . These may be encapsulated in glass.

The usual types of resistors are normally accurate under various physical conditions. Special types are resistance-dependent which is not desired in standard resistors.

These special qualities can be seen under NTC resistors. This type of resistor has an ohmic value that decreases when the temperature rises. NTC mean Negative Temperature Coefficient. These resistors are used for regulating and measuring purposes. See the signs in sect. T3 concerning the symbol explanations.

PTC resistors are also available, these being the opposite of NTC, i.e. rising temperature, increasing resistance $=$ Positive Temperature Coefficient.

Another special type of resistor in the VDR, i.e. Voltage Dependent Resistor. Its ohmic value falls when the voltage across it exceeds a certain level. A VDR resistor can be used to protect a series transistor such as in a transistor ignition unit.

LDR resistors are made of germanium, LDR meaning Light Dependent Resistor. More light, less resistance. LDR resistors are used for light measuring, for instance, in kit No. AT 30 supplied by Josty Kit.

The LDR resistor should not be confused with a solar-cell. The solar-cell produces a voltage while the LDR resistor merely varies its resistance.

Potentiometers and trimming potentiometers are variable resistors. The resistance can be varied by a sliding contact or
a knob. A potentiometer is, in fact, a voltage divider in which the ratio between resistances can be varied.

Signal voltage is applied to the potentiometer across the two outer terminals, one of which is connected to earth (frame). The output voltage is taken from the middle point to frame. The signal conductor is led to the middle point.


Fig. 8.2


Question 1.
When we have a resistor of 10 ohms and wish to apply a current of 0.1 amp through it, what voltage is required?
0.1 V
A $\square$
1.0 V
B $\square$
100 V
C $\square$

Question 2.
What is the current in a resistor of 0.1 ohm and the voltage across it is 10 V ?

| 1 A | $\mathrm{~A} \square$ |
| :--- | :--- |
| 0.1 A | $\mathrm{~B} \square$ |
| 100 A | $\mathrm{C} \square$ |

Question 3.
What is the voltage of a pick-up when it sends $10 \mu \mathrm{~A}$ through a resistor of 47 kohm?

| 0.044 V | A |
| :--- | :--- |
| 470 mV | B |
| 210 mV | C |

Question 4.
We require a voltage drop of 1.2 V across a resistor through which there is a current of 1 mA - find the correct resistor.
1.2 kohm

A $\square$
820 ohm
B
120 ohm
C口
8.2 kohm

D ロ
Question 5.
Is wire used in resistors because it is out-dated or because the wires can withstand a higher temperature?
Old type
A $\square$
Higher temp.
B $\square$

Question 6.
What can be measured by means of an LDR resistor?

| Pressure | A $\square$ |
| :--- | :--- |
| Temperature | B $\square$ |
| Light | C $\square$ |

## RESISTOR COMBINATIONS

Resistors can be connected either in series or in parallel. In series, each resistor contributes its resistance to the total resistance, the calculation of resistors connected in seres thus being:
$R_{x}=R_{1}+R_{2}+R_{3} \ldots$ etc.
Resistors in parallel are calculated as follows:

$$
\frac{1}{R x}=\frac{1}{R_{1}}+\frac{1}{R_{2}}+\frac{1}{R_{3}}+\ldots
$$



It is easier to remember when thinking of each resistor in parallel conducting its share of electrons. The amount of electrons passing through a parallel connection is always greater than through each individual resistor connected this way. The total resistance is thus always less than the smallest resistor.
What we actually add together is the opposite of resistance, called conductivity and is expressed:

$$
\gamma \cdot \frac{1}{\mathrm{R}}
$$



## VOLTAGE DIVIDER

It is often necessary to reduce a voltage or to divide it into certain proportions, so we use a voltage divider.
A voltage divider is in fact two resistors connected in series. Voltage is applied across these two resistors. One pole of the voltage source is called neutral and is often connected to chassis. If the negative pole is connected to neutral we use the expression neutral and positive (or vice versa, neutral and negative) about the voltage source.
If the common conductor of the voltage divider is connected to chassis or common, the voltage is zero. We apply a positive voltage at the top of the voltage divider. On the way from positive via the two resistors the voltage consequently drops from positive to negative. If the two resistors are identical, the voltage drop is equal across each resistor, and the voltage from neutral to the connecting point of the resistors is half the total voltage. As a large resistor is a heavy "electronic brake", most of the voltage drop occurs here. This means then that the voltage is proportional to the resistor value, so Ohm's Law does not have to be applied. Let us take a simple example. We wish to reduce a voltage of 11 V to 1 V .

Fig. 9.4


In practice this means that $\frac{10}{11}$ of the total resistance value of the voltage divider must exceed R1. We could, for instance, use a 10 kohm resistor as R1 and a 1 kohm resistor as R2. The total resistance of these is 11 kohm, 11 being across R1 and $1 / 11$ across R2. The voltage is divided by 10. Do not think, however, that this can be applied in cases of higher currents such as lamps, radios, tape recorders etc. Only very limited currents can be taken from the voltage divider if the output voltage is to correspond to calculations.
An easy rule to remember is that the voltage divider current (cross current) must be at least ten times greater than the current consumed. Any error is then reduced to $10 \%$ only. Why is this? Let us lcok at Fig. 9.5 in which the output of 1 V is connected to a source of consumption that is 1 mA at 1 V. According to Ohm's Law, this corresponds to 1 kohm, but remember that R 2 also represents 1 kohm. We get a parallel connection of $1 \mathrm{kohm} / / 1 \mathrm{kohm}$ which is 500 ohms.


According to this ( 10 kohm to 500 ohm ) the voltage is now only $1 / 2 \mathrm{~V}$ ( $50 \%$ error). From this we see that a voltage divider must be used with caution. The ratio is calculated as follows:

$$
\frac{E \text { in }}{E \text { out }}=\frac{R_{1} R_{2}}{R 2}
$$

which in cases where 10 is exceeded corresponds to:

$$
\frac{\mathrm{E} \text { in }}{\mathrm{E} \text { out }}=\frac{\mathrm{R} 1}{\mathrm{R} 2}
$$

Using zener diodes, the voltage divider is suitable for higher currents. See Section G12 - Power Packs, and the last part of Section G17.

Question 1.
Two resistors are connected in series, one being 5.6 kohm, and the other 12 kohm . What is the total resistance?

| 3.9 kohm | A |
| :--- | :--- |
| 17.6 kohm | B |

Question 2.
Two resistors each of 100 ohms are connected in parallel. What is the total resistance?

| 50 ohm | A $\square$ |
| :--- | :--- |
| 200 ohm | B $\square$ |

Question 3.
What is the current through two parallel connected resistors when the voltage across them is 10 V and they are each 22 kohm?

| 2.2 A | A $\square$ |
| :--- | :--- |
| 0.9 mA | $\mathrm{~B} \square$ |
| 0.009 A | $\mathrm{C} \square$ |

Question 4.
Two resistors are connected in parallel and 4.5 V is applied.
These resistors are 1 kohm and 1.5 kohm . What is the current?

18 mA
A $\square$
1.8 mA

B
6.8 mA

Question 5.
Our supply voltage is 7.5 V and we need 3 V with the possibility of a $10 \mu \mathrm{~A}$ current. Which resistors are required?

R1 R2
47 kohm
33 kohm
A $\square$
470 kohm
330 kohm
B $\square$
Question 6.
The ratio between R2 and R1 in a voltage divider is 1:4. The input voltage is 10 V . What is the output voltage?

| 2 V | $\mathrm{~A} \square$ |
| :--- | :--- |
| 2.5 V | $\mathrm{~B} \square$ |

Question 7.
We wish to divide a voltage in the proportion $1: 10$. The voltage is unknown, but we do know that the input resistance to the next stage is 50 kohm . Which resistors are required?

R1
R2
470 kohm
47 kohm
47 kohm

47 kohm
A $\square$
4.7 kohm

5 kohm

B $\square$
C $\square$

## POWER/OUTPUT

When electrons are held back in a resistor, heat (frictional heat) is created in the same way as in the brakes of a car. This heat (power) is expressed in watts - W. The formular $\mathrm{W}=\mathrm{E} . \mathrm{x}$ I expresses the heat that is formed when many electrons pass through a resistor at high pressure (E x I).
If an electronic component is exposed to a greater power than it is designed for it will '"blow".
We see that power is expressed by the symbols E and I which are included in Ohm's Law and can be combined in the formulas, e.g.

$$
W=E \times \frac{E}{R}=\frac{E 2}{R}
$$

In this way we can find the wattage or power when we know the resistor and the voltage across it, a useful thing to remember when calculating the output wattage of a power amplifier. The voltage E can be measured via a 3.2 ohm resistor, for instance, applying the formula above.

By combining Ohm's Law and the power formula we can see the 12 resulting equations as follows:


Fig. 10.1

The symbols in the centre represent the values we wish to know, and out from each there are three ways of expressing them, in all 12 expressions of $E, I, R$ and $W$.

## 2uestion 1.

Ve wish to measure the output of an amplifier. We cannot measure across a loudspeaker as the impedance varies with frequency. Instead we use a 3.3 ohm resistor - the neighbours will love you. Across this resistor the amplifier can produce a voltage of 15 V ac , without our being able to hear or an oscilloscope show any form of distortion. We then apply the equation in the circle of symbols:
$\mathrm{W}=\frac{\mathrm{E} 2}{\mathrm{R}}$
What is the output?

| 7 W | A $\square$ |
| :--- | :--- |
| 70 W | B |
| 10 W | C |

## G11 ALTERNATING CURRENT/AC VOLTAGE

A current that varies between positive and negative values is called alternating current. All other types of current, including pulsating currents, are called direct currents. Alternating current is produced at power stations by means of huge dynamos, but d.c. can also be produced from a.c. via electronic conversion (dc/ac converters).

Fig. 11.1


In Denmark the sinusoidal ac voltage varies from +310 V to -310 V . This is because the ac voltage is expressed in effective value (root mean square value - RMS) i.e. the value necessary to accomplish the same as a direct current. This is illustrated in the system of co-ordinates above right. The peaks can be filled in the valleys, the RMS value being 220 V.

In sinusoidal ac voltages, the peak value equals 1.4 x effective value (RMS) ( $\sqrt{ } 2 \mathrm{x}$ effective value) which is most important to bear in mind when calculating power supplies, these charging the capacitors to peak value. This is why the dc voltage output exceeds the ac input of a non-stabilised rectifier component. Ac behaves like dc in conjunction with ordinary resistors, but when capacitors and coils are included in a circuit, "special rules" apply. This is mentioned in Section G12. The number of times ac voltage oscillates from positive to negative is called the frequency, which in Europe is mostly 50 Hz . Taken over a long period this frequency, 50 Hz , is very accurate and is used for controlling clocks, record players etc. Hz means Hertz expressed thus:

## amount of oscillation <br> second

It makes no difference whether the oscillations are acoustic, electric or mechanical. In the field of electronics frequencies from 0 Hz til Giga ( $1000,000,000 \mathrm{~Hz}$ ) are used.

Audible range
Ultrasonic range
Long wave
Medium wave
Short wave
TV-channels 2-4 (VHF)
FM radio
TV-channels 5-12 (VHF)
TV-channels 21-48 (UHF)
Radar
Microwave (ovens)
Infrared radiation
Light
$16-20.000 \mathrm{~Hz}$ $20 \mathrm{kHz}-60 \mathrm{kHz}$ $150 \mathrm{kHz}-350 \mathrm{kHz}$ $500 \mathrm{kHz}-2000 \mathrm{kHz}$ $2 \mathrm{M} \mathrm{Hz}-50 \mathrm{M} \mathrm{Hz}$ $50 \mathrm{M} \mathrm{Hz}-70 \mathrm{M} \mathrm{Hz}$ 86.5 MHz - 108 MHz $200 \mathrm{MHz}-400 \mathrm{MHz}$ $450 \mathrm{MHz}-750 \mathrm{MHz}$
$1 \mathrm{GHz}-10 \mathrm{GHz}$
$>16 \mathrm{GHz}$
$>10 \mathrm{GHz}$
$>100 \mathrm{GHz}$

Besides the sinusoidal voltages we also encounter saw-tooth voltages, as well as square and triangular voltages, these being employed for control and measuring purposes in electronics. The name indicates the wave-form.

Question 1.
Why is a voltage greater after rectifying and filtering?
Because the rectifier amplifies
Because the maximum value of the
incoming AC voltage is attained $\quad$ A $\square$ B $\quad \$$

## TRANSFORMER

In coils we know that a current gradually increases in a self-induction because it sends a current of almost equal size in the opposite direction. If the coil is given an extra winding, it will send a current round in its winding. This is a transformer. On applying an AC voltage a counter voltage is induced, in the other coil, too.


Primary Secondary


The first coil is called the primary windings and the other the secondary windings. The resulting voltage is proportional to the number of windings and is expressed as follows:

$$
\frac{\text { Primary voltage }}{\text { Number of primary windings }}=\frac{\text { Secondary voltage }}{\text { Number of secondary windings }}
$$

or

$$
\frac{\mathrm{Ep}}{\mathrm{Vp}}=\frac{\mathrm{Es}}{\mathrm{Vs}}
$$

The output voltage of a transformer is usually 10-20\% higher than that rated due to inner loss. The test voltage from a transformer is in fact only present when it is loaded with its nominal current.

Half - wave rectifier


Fig. 12.1

Graetz rectifier


## RECTIFIERS

The theoretical functions of a rectifier are specified under "semi-conductors". At this point we must remember that a rectifier is a kind of valve that allows a current to pass in one direction only. In this way a positive current can pass in the direction of the diode while a negative current is stopped. Normally a combination of four diodes is used in rectifying AC voltages, (Graetz bridge) so as to avoid "dropping" one of the AC half-cycles. This connection leads all the negative half-cycles from both of the transformer leads to minus; and all positive half-cycles to plus as shown in the drawing.

Wave form before and after half - wave rectification with filter capacitor.

Fig. 12.2

50 Hz


$\stackrel{1}{T}$


The figure below shows how by a single rectifier the pulsating dc voltage is smoothed out with a capacitor.

Wave form before and after full - wave bridge rectification with filter capacitor.

Fig. 12.3
(on

A double rectifier doubles the frequency of the pulsating dc voltage and also doubles transformer utilisation. Furthermore, the value of the electrolytic capacitor can be reduced by a half for smoothing out purposes. As rectifiers are comparatively small while the electrolytic capacitors are large, a bridge-coupling can be used with advantage.

Fig. 12.4


## CAPACITOR

To remove the pulsation from the rectifier, a large capacitor is connected, normally exceeding 1000 uF , from plus to minus in the rectifier connection. The capacitor is charged to peak value which is 1.4 times RMS value. The output voltage is thus greater than the AC RMS voltage applied. The voltage across the electrolytic capacitor is:

$$
\mathrm{E}_{\mathrm{C}}=\mathrm{E}_{\mathrm{AC}} \times \sqrt{2}
$$

A rectifier of this type is usually satisfactory for most purposes, but if ripple is to be avoided completely, the DC voltage must be transistor-stabilised.
See section NT 315.

## ELECTRONIC SMOOTHING

Every rectifier unit comprising a transformer and rectifier with charging condenser will produce dc voltage having a superimposed ripple voltage. In most cases this ripple voltage is of no consequence. If such a current supply is used for an output amplifier correctly designed, the negative feedback of the amplifier partially suppresses the ripple.

Here is an example:
The remaining ripple has been measured at 1 volt. If the amplifier were not inserted the hum of 1 volt would go direct to the loudspeaker which would be very unpleasant to hear. Fortunately, the negative feedback factor of an amplifier is often about 10,000 , the hum being reduced to $100 \mu \mathrm{~V}$ from 1 V .

Unstabilised voltage with ripple.


Stabilised voltage without ripple.


Fig. 12.5

If the equipment connected to the power supply has no negative feedback, the power supply must be stabilised electronically. This is comparatively simple. Bridge-coupled rectification and smoothing out with a capacitor is first carried out. The output voltage is then reduced so that the ripple peaks are completely removed - see Fig. 12.5. If the stage reducing the output voltage is free of inherent noise the output voltage will be "pure". In its simplest form, the stabilising stage comprises a resistor and a zener diode only, whereas the more sophisticated designs include integrated circuits and transistors. This is described in Section G17, and practical applications Nos. NT 10 and NT 300.

Question 1.
We are to use a transformer with a primary voltage of 220 V and 10,000 windings. The secondary coil has 500 windings. What is the voltage after rectifying with a Graetz-bridge and filtering via a capacitor?

| 155 V | A $\square$ |
| :--- | :--- |
| 15.5 V | B |
| 11 V | $\mathrm{C} \square$ |

## ALTERNATING CURRENT: COILS AND CAPACITORS

## CAPACITOR IMPEDANCE

In a previous section concerning capacitors we see that there is a momentary current impulse when the capacitor is connected to a battery. An AC voltage comprising many impulses results in the flow of AC current through the capacitor.
We can regard the capacitor as a kind of resistor shown as follows:

Fig. 13.1

$\mathrm{Zc}=\frac{1}{2 \pi \times \mathrm{fxC}}$
f: frequency in Hz
C: capacitor size in Farads

From this we see directly that if a frequency is high or the capacitor is big, a high current flows through which corresponds to a low resistance.

This is not a resistance proper, however, so it is called impedance and expressed as the symbol $\mathrm{Z}_{\mathrm{C}}$. The "c" means that we are dealing with capacitors. In most cases we can assume that impedance is an ohmic resistance and can apply Ohm's Law.

Fig. 13.2


## COIL IMPEDANCE

The coil current does not react immediately to any change in voltage, and in the case of AC voltage it consumes a lower current than at DC. A special AC resistance, impedance $Z_{L}$ is shown here:

$$
\mathrm{Z}_{\mathrm{L}}=2 \pi \mathrm{fL}
$$

where f is the frequency in Hz , L the coil size in Henry (self-induction).

It is worth noting that the capacitor impedance drops with increasing frequencies.

We see from this formula that the impedance drops with decreasing frequencies and decreasing self-induction.

Question 1.
At a given frequency of 1 kHz a capacitor must have an impedance of 1 kohm. What size capacitor is required?

$$
Z_{C}=\frac{1}{2 \pi \times f \times c} \quad \text { or Converted to } C=\frac{1}{2 \pi \times f \times Z_{c}}
$$

| 150 nF | $\mathrm{A} \square$ |
| :--- | :--- |
| 15 nF | $\mathrm{B} \square$ |
| 1 uF | $\mathrm{C} \square$ |

## TUNED CIRCUITS

Let us take a closer look at cases where coils and capacitors cannot be regarded as ordinary resistors.
This applies when a coil and a capacitor are connected either in parallel or in series.

Fig. 14.1


On applying an ac voltage with a certain frequency, there is a resonance in the system. The electrons move to and fro like waves in a swimming-pool.Each impulse produces a wave, but heavy waves will be produced only when the impulses have the right frequency to produce a wave.

This can be compared with a swing. When the swing is pushed lightly it moves to and fro and then stops. When the swing is pushed at the right moment it can be kept going without much effort. If pushed at the wrong moment it comes to a standstill. When our resonant circuit is excited at the correct frequency - resonant frequency - it acts in a certain manner, but we can normally count on the impedances even with a slightly different frequency.

The resonant frequency is expressed:

$$
f_{\text {res }}=\frac{159,000}{\sqrt{L \times C}} \quad(n F, m H, H z)
$$

In all connections at resonant frequency we have an input impedance corresponding to the resistance $R$ in a voltage divider.

## CONNECTION IN SERIES

The resistance in a series resonant circuit is very low at resonance, but we can normally depend on the impedance of individual components when the frequency is far from resonance. The voltage divider will at resonant frequency give a very low signal, while it is high at other frequencies.


Fig. 14.2

Example: $\mathrm{R}=10$ kohm $\quad \mathrm{Z}_{\mathrm{res}}=10$ ohm $\quad \mathrm{E}_{\mathrm{in}}=10 \mathrm{~V}$

## PARALLEL CONNECTIONS

Far from the resonance we may have, for instance, $\mathrm{Z}_{\mathrm{c}}=1$ kohm, $\mathrm{Z}_{\mathrm{L}}=100$ ohm producing $\mathrm{E}_{\mathrm{out}}=1 \mathrm{~V}$.


Fig. 14.3

At resonant frequency the parallel circuit has a very high impedance allowing the passage of full signal, while all other frequencies are damped.

Example: R $=10$ kohm $Z_{\text {res }}=100$ kohm $E_{\text {in }}=10 \mathrm{~V}$

At resonance we have $\mathrm{E}_{\text {out }}=$

$$
\frac{100 \times 10 \mathrm{v}}{110}=9 \mathrm{v}
$$

Far from the resonance we can have the same data as above, thus:

$$
E_{\text {out }}=\frac{100 \mathrm{Ohm}}{10 \mathrm{kohm}} \times 10 \mathrm{~V}=0.1 \mathrm{~V}
$$

All calculations are rough as the question of phase angle is not dealt with.

Question 1.
Work out the resonant frequency of a crystal receiver with a ferrite rod having a self-inductance of 0.1 mH , and a capacitor of 100 pF .

Is the receiver for?
Medium wave, approx. 1 MHz
Long wave, approx. 150 kHz

## MEASURING

The universal meter is the one mainly used in electronics, and other types are not mentioned here. It measures current, voltage, and resistance.
It consists of a moving coil instrument having good sensitivity, $20 \mathrm{KOhm} / \mathrm{Volt}$, and a selector switch with various resistances to produce the different ranges. A battery is used in the circuit for measuring ohmic resistance. At full scale deflection the current and voltage are always equal in the moving coil instrument. This is determined by the inner resistance according to Ohm's Law which is applied in the following calculations.


Fig. 15.1

## CURRENT MEASURING

When measuring current, some of the current is led past the instrument via a shunt. It is necessary to know the resistance and sensitivity of the instrument to calculate the shunt. If the sensitivity is e.g. $20 \mathrm{kohm} / \mathrm{V}$ and the inner resistance 100 ohm , the voltage across the instrument at full deviation is calculated as follows:

## Inner resistance sensitivity

at full scale deflection, or as follows:

$$
\frac{100 \mathrm{Ohm}}{20.000 \mathrm{Ohm} / \mathrm{V}}=\mathrm{Ei}=5 \mathrm{mV}
$$

The current can then be determined by means of Ohm's Law:

$$
I_{i}=\frac{E}{R}=\frac{5 \mathrm{mV}}{100 \mathrm{Ohm}}=50 \mu \mathrm{~A}
$$

If the instrument is to measure $1 \mathrm{~mA}, 950$ uA must run through the shunt so that the instrument has full scale deflection and no more.
As there is 5 mV across the shunt (and the parallel connected meter) and we know that the current must be 950 uA, we can apply Ohm's Law:

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{5 \mathrm{mV}}{950 \mu \mathrm{~A}}=5.26 \mathrm{Ohm}
$$

Fig. 15.2


## VOLTAGE MEASURING

When measuring voltages, some of the voltage is dropped across a series resistor - see G9 potentiometers. At full scale deflection according to calculations, there is 5 nV across the instrument used for measuring current. We also know that the current through the instrument at full scale deflection is 50 uA , and since the current is the same in the whole circuit, we have only to know the voltage across the resistor to be able to calculate it by applying Ohm's Law.

If we are to measure 1 volt at full scale deflection and there is 5 mV across the meter, there must be 995 mV across the series resistor, Ohm's Law:

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{995 \mathrm{mV}}{50 \mu \mathrm{~A}}=19.9 \mathrm{kohm}
$$

As most meters have a $2 \%$ accuracy, it is sufficient to use a 20 kohm resistor in this case. When measuring the current we counted on a 5.26 ohm resistor - a 5 ohm resistor would be suitable.


Fig. 15.3

## 2ESISTANCE MEASURING

When measuring resistance, the current in a circuit containing the unknown resistor is measured. When using the ohmmeter, short-circuit the connecting pins and adjust the trimming potentiometer to zero ohms. Connect the unknown resistor, and read the value on the special scale.


## UNIVERSAL METER, KEW 7

This inexpensive and internationally famed little instrument is sufficient in range and data to satisfy the needs of most amateurs, and used properly it is also suitable for professional purposes. Any shortcomings of the KEW 7 are made up for by its low price and compactness ( $2 \times 5 \times 7 \mathrm{~cm}$ ) as well as the easy and exact readings.
Its disadvantage lies in the low degree of sensitivity which exposes the object to be measured to a relatively high load. This does not mean that the KEW 7 can cause damage, only that it gives reading errors if used incorrectly. The sensitivity is 1 kohm/volt, i.e. 20 times lower than that of professional instruments of 20 kohm/volt.
The fact that it is very simple in design makes it easier to explain its functions.


## OHM MEASURING

Insert the test pins at the points marked $\Omega$ (red) and at D.C. $\Omega$ (black). Short-circuit the test pins and the little potentiometer at the side of the instrument must be adjusted to zero ohms. In this position all resistors between 100 ohm and 50 kohm can be tested with reasonable accuracy. Resistors above 100 kohm do not register, but it is possible 'judge"' resistors between 25 and 100 KOhm .
Remember that it is not possible to measure resistors fitted in a circuit as other components can cause indication errors. As the ohmmeter has a built-in battery, it is possible to see whether larger capacitors are faulty. As an example, connect a $1000 \mu \mathrm{~F}$ electrolytic capacitor across the measuring pins. The needle shows a high reading and then returns to zero. The capacitor is short-circuited and is charged and consequently there is a deflection. With a small capacitor e.g. 1 $\mu \mathrm{F}$ the charging current surge is very low.

## CURRENT MEASURING

The KEW 7 has only one current range, but this is well chosen at 150 mA . Insert the test pins at D.C. $\Omega$ and at " 150 $\mathrm{mA}^{\prime \prime}$ - black in D.C. $\Omega$ - and red in 150 mA .
It is not possible to measure ac current on the KEW 7 even though it is tempting to insert the black pin at AC instead of D.C. $\Omega$. Those who work on amplifiers prefer the range 1.5 or 3 amps , but this is easily overcome by fitting an outer shunt directly across the instrument testing pins. For 1.5 A the shunt must be 0.20 ohm and for 3A 0.10 ohm .

## VOLTAGE MEASURING

The KEW 7 can measure both ac and dc voltages in the ranges 15,250 and up to 1000 V .
Insert the pins at $\mathrm{DC} \Omega$ - (black) and the required range when measuring dc voltages. When measuring ac voltages, insert the black pin at AC instead of DC $\Omega-$. Special care should be taken when using the 15 V range as the inner resistance of the instrument is 15 kohm . If there is 15 kohm in the circuit to be measured the indication error can be up to $50 \%$. If the resistance to be measured is in the $1-2$ kohm region, the error is rarely greater than $10 \%$ which is acceptable. If the 15 V range is too low and 30 V is more suitable, a 15 kohm resistor can be connected in series with the red test lead, remembering to multiply the scale readings by two, of course.

| SPECIFICATIONS : |  |
| :--- | :--- |
| DC Voltages | $0-15-250-1000$ volts $(1000 \Omega / \mathrm{V})$ |
| AC Voltages | $0-15-250-1000$ volts $(1000 \Omega / \mathrm{V})$ |
| DC Current | $0-150$ milliamperes |
| Resistance | $0-100 \mathrm{~K} \Omega$ |
| Size | $57 \times 93 \times 30 \mathrm{~mm}$ |
| Net Weight | 108 g |



## KEW 7 DIAGRAM

The best way to understand the diagram is to concentrate on one range at a time. Let us take the voltage range DC, 15,250 or 1000 V .
The voltage must pass through one of the dropping resistors, $750 \mathrm{kohm}, 250 \mathrm{kohm}$ or 14.65 kohm . In any case, the voltage is reduced via the dropping resistors, so that the voltage across the parallel connections in the meter, a 270 ohm resistor, a 1.8 ohm resistor and series connected resistor gives approx. 100 mV . If one of the test pins is taken from DC to AC, the ac voltage has only to be converted to dc voltage by means of the two diodes. The diodes also act as a satisfactory means of protection against momentary incorrect connections.

When measuring current, it flows through the 1.8 ohm resistor giving a voltage drop of approx. 300 mV .200 mV are thus lost in the 330 and 270 ohm resistors, this being the greatest fault of an otherwise excellent meter.

Finally, resistance is measured via a little battery in series with the 100 ohm resistor and the unknown resistance that sends a weak current to the instrument. Depending on the adjustment of the potentiometer, resistance values between 100 ohm and 100 kohm can be measured.
Special types of meters are mentioned elsewhere. See under Item MI 10 showing power supply meter.

Question 1.
A meter is often classed by kohm/V. What other factors are necessary to calculate the inner resistance?

| Current | A $\square$ |
| :--- | :--- |
| Sensitivity | B $\square$ |
| None | C $\square$ |
| Voltage | D $\square$ |
| Full scale deflection | E |

Question 2.
What is the current that runs in a shunt at range 100 mA , when the instrument in question is $1 \mathrm{kohm} / \mathrm{V}$ and has full scale deflection at $100 \mu \mathrm{~A}$ ?

| 10 mA | A $\square$ |
| :--- | :--- |
| 999 mA | $\mathrm{~B} \square$ |
| 99.9 mA | $\mathrm{C} \square$ |

Question 3.
Determine the size of the shunt in this instrument. Find voltage across shunt (and instrument) proportionately

$$
\frac{1 \mathrm{~mA}}{1 \mathrm{~V}}=\frac{100 \mathrm{uA}}{X \mathrm{~V}} \quad X V=? \mathrm{mV}
$$

Knowing the current from Question 2, apply Ohm's Law.
What is the resistance?

| 9 Ohm | A $\square$ |
| :--- | :--- |
| 10 Ohm | B |
| 1 Ohm | $\mathrm{C} \square$ |

Question 4.
We now use the same meter for measuring 100 V . Question 3 tells us the voltage across the meter, from which we can calculate the resistance. Determine the series resistors in the following:

| 1 kohm | A $\square$ |
| :--- | :--- |
| 1 MOhm | B $\square$ |
| 100 KOhm | C $\square$ |

## Question 5.

Work out the component values. We must be able to switch from 10 V and 100 V full-scale voltage. The meter is rated 1 kohm/V and full scale deflection at 1 mA

Which combination is correct?

| R1 | R2 |  |
| :--- | ---: | ---: |
| 9 KOhm | 99 KOhm | A |
| 9 KOhm | 990 KOhm | B |



Semiconductors II
All semiconductor components consist of a chip of semiconductive material (germanium, silicon etc.) as the active part. All semiconductor substances are of the $N$ or $P$ type, and here we shall see what happens when N and P substances are in contact with each other.

## DIODES

There is a P-N junction in diodes. When connected as shown below, some of the electrons in the N-layer pass to the positive pole and holes in the P-layer into the negative. No new electrons or holes can be formed in the crystal, and vhen the excess electrons in the N -layer are no longer oresent, the current stops. This also happens in the P-layer noles. The junction is thus blocked.


Fig. 16.1

If the battery is reversed, there will be more electrons in the N-layer and more holes in the P-layer. Some af the electrons are forced over to the P-layer, filling out the holes. The holes are forced into the N-layer in the same way, joining the electrons there. Holes and electrons which recombine disrupt each other, allowing more from the battery. A current is established and the junction conducts.

The junction blocks when positive is connected to N and negative to $P$, while it conducts when positive is connected to $P$ and negative to $N$. To understand the function of a transistor, it is important to grasp this.

## TYPES OF DIODES AND THEIR USE

Besides tunnel diodes, 4-layer diodes, gunn diodes and laser-maser diodes, we today use silicon diodes, germanium diodes, capacitive diodes, zener diodes, Diacs, Triacs and SCR's. The first four types are used for special purposes and do not fall within the scope of this book. Silicon diodes are used mainly for rectifying and in certain cases for gates and relay coil protection etc.
Silicon diodes have extremely good blocking properties and when conducting, the resistance is slight. This is why the silicone diode is well suited as a rectifier of high currents and voltages. A special feature of the silicon diode is that current does not run through it until voltage in the forward direction exceeds $0.6-0.8 \mathrm{~V}$. This value is temperature dependent in that the voltage is 0.7 V at $20^{\circ} \mathrm{C}$. At increasing temperature the voltage drops linearily to approx. 0.6 V at $100^{\circ} \mathrm{C}$, and the silicon diode can withstand temperatures up to approx. $150^{\circ} \mathrm{C}$.
Silicon diodes are often coupled together in a common housing - bridge couplings etc.

Germanium diodes are in certain respects superior to silicon diodes for instance when rectifying high frequencies and where low voltage is essential. The forward voltage of a germanium diode is between 0.1 and 0.2 V . This is important when rectifying a weak ac voltage to a measuring instrument. Silicon diodes are quite unsuitable for this purpose. Germanium diodes can withstand only low currents, approx. 50 mA where silicone diodes can handle up to several hundred amps.

Capacitive (varactor) diodes are silicon diodes with voltage dependent capacitance. When voltage (approx. 2-30 V) is applied to a capacitive diode in the direction of blocking the capacitance varies within a certain range (approx. $15-2$ pF ) and there is practically no current. Capacitive diodes are used for tuning special TV/FM bands both in transmitters and receivers.

Gallium-arsenide diodes or light emitting diodes as they are sometimes called are silicon diodes incorporating special crystals that emit light when a current passes in the direction of conductivity. The light emitting diode must be series connected with a suitable resistor from supply source for protection purposes. It has a 'light voltage" of approx. 1 V and the consumption is about 20 mA . It is not as effective as a filament lamp, but its life is practically unlimited. The response time is very short - approx $1 \mu \mathrm{~s}$. This means that it can be employed together with a photo cell for e.g. light-ray intercom systems. Light emitting diodes are also used in digital displays.

Zener diodes are made of silicon and have the ability at a certain voltage of conducting a heavy current. They are thus well suited as stabilising components in constant voltage power supply units. In the reversed position, a Zener diode conducts 0.7 V like an ordinary silicon diode. Zener diodes are today available rated from 2 to 200 V .
The following circiut shows how zener diodes are used to stabilise voltage.


Fig. 16.2

A 9.1 V zener diode is used - input voltage 12 V and output voltage 9.1 V representing an ordinary voltage divider in which a zener diode is used instead of a resistor ( $\mathrm{R}_{2}$ - see Section G9). The zener diode chosen can withstand 100 mA , this being the maximum output current. The voltage drop across R1 is the input voltage minus the output voltage, in this example: $\mathrm{E}_{\mathrm{RI}}=\mathrm{E}_{\text {in }}-\mathrm{E}_{\mathrm{out}}=(12.0$ $-9.1 \mathrm{~V})=2.9 \mathrm{~V}$.

The current through R1 is 100 mA as it also flows to the zener diode. This being a series connection in which the current is the same throughout, we apply Ohm's Law and find:

$$
\mathrm{R} 1=\frac{\mathrm{E}_{\mathrm{R} 1}}{\mathrm{Iz}}=\frac{2.9 \mathrm{~V}}{100 \mathrm{~mA}}=29 \mathrm{Ohm} 27 \mathrm{Ohm} \text { standard }
$$

The R1 power consumption is:

$$
\mathrm{W}_{\mathrm{R} 1}=\mathrm{E}_{\mathrm{R} 1} \cdot \mathrm{I}_{\mathrm{z}}=2.9 \mathrm{~V} \cdot 100 \mathrm{~mA}=290 \mathrm{~mW}
$$

A $1 / 4 \mathrm{~W}$ resistor would be slightly under-rated.
When the consumption is between 0 and 100 mA , the current is divided between the zener diode and the source of consumption. Drawing 75 mA from the circuit, 25 mA runs to the zener diode, but up to 100 mA the voltage is stable. If the input voltage fluctuates slightly the output voltage remains stable, but if it jumps by several volts, R1 must be rated according to the highest voltage across it. At an input voltage of 15 V in the example here, the voltage across R 1 would be $5.9 \mathrm{~V}-\mathrm{R} 1$ must be rated at 59 ohms.

A diac is a double-trigger diode for controlling triacs. A diac resembles a neon indicator electrically speaking in that they both have a high resistance when the voltage is lower than firing voltage. At firing voltage a heavy current is limited by a dropping resistor. Diac firing voltage is around 30 V as opposed to a neon indicator voltage of 90 V .

A triac is controlled by a diac, and as the triac is ac regulated, the diac must operate at both positive and negative voltages. The diac is the only ac diode.
$A n S C R$ is an ordinary silicon diode that does not conduct current until there is a positive voltage in the region af 100 mV on the gate. The SCR continues to conduct until the current through the diode itself is zero. Even if the voltage across the SCR rises once more, it does not conduct until a control pulse is received again. The SCR conducts only at one half ac cycle (forward direction).

The triac in principle resembles two back-to-back coupled SCR's. Standard triacs must be triggered with positive
voltages in the '"positive conduction direction" and negative in the "negative conduction direction". Triacs of this description are said to trigger in two quadrants. Triacs that can be controlled with positive and negative pulses in both directions of transition trigger in four quadrants. These triacs are TTL compatible, i.e. in logic integrated circuits that only produce positive or zero (high or low) output voltages, can control ac voltage with dc voltage on the gate of the triac.

## TRANSISTORS

A transistor consists of three layers, e.g. one $P$, one $N$, and one $P$. The two outer layers are always separated from each other by a very thin one.
One of the P-layers is the emitter, the other the collector, while the N -layer is base.


The PNP-transistor must be connected with emitter to plus and collector to minus. No current can flow until the base is connected as there are no electrons supplied. When base is connected to minus (via a resistor) it receives electrons, thus attracting holes from the emitter.

Now this is important
It takes time for a hole to find an electron and in this time it travels around. The hole has a chance to penetrate via the NP-junction to the collector which does not block the holes, but only the electrons from the base region.

As the base layer is very thin, the chances of holes passing through are great, because for each electron combining with a hole in the base there are perhaps 100 or 200 holes moving on in vain to the collector. A current flows through the transistor, causing a current amplification as the low basic current brings about a greater emitter/collector cur-
rent. The ratio between the higher collector current and the lower base current is called current gain $\beta$.
Mathematically expressed:

$$
\beta=\frac{I_{c}}{I_{b}}
$$

where $I_{c}$ is the collector current and $I_{b}$ the base current and $\beta$ is current gain

In an NPN-transistor the layers are reversed and the emitter must be corrected to minus and collector to plus.
Here we send holes to the base. They attract electrons from the emitter, and most of these electrons not finding a hole continue travelling to the collector.
The current-gain $\beta$ is calculated in the same manner as with PNP-transistors.

These symbols are essential to know, and are used in the following sections without further explanation.

Basic transistor couplings
A standard transistor can be connected in three different ways:

COMMON EMITTER COMMON COLLECTOR COMMON BASE EMITTER-FOLLOWER


Fig. 16.4


Fig. 16.5


Fig. 16.6

Common-emitter couplings are often used for gain purposes in the LF range, utilising all the transistor gain which in many cases is several hundred times. There must be feedback however, so that the frequency response is linear
and the distortion low (rarely exceeds 10). The input impedance is between 1 and 10 kohm . The output signal is phase displaced $180^{\circ}$ in relation to the input signal.
Common collector couplings or emitter follower has a gain factor approx. 1. This coupling gives in itself optimal feedback and the input impedance is almost equal to the emitter resistance times the transistor gain (up to several Mohm). The output impedance is equal to emitter resistance divided by the transistor gain. There is no phase rotation.
Common base couplings are used mainly in high-frequency amplifier circuits at frequencies above 50 MHz . In this way, the transistor has excellent HF isolation and good linearity, the former being essential to prevent undesired oscillator emission, and the latter is necessary to suppress undesired stations.

## TYPES OF TRANSISTORS AND THEIR USE

The first transistors produced were of the germanium type. They are the simplest type to manufacture and were marketed for about 15 years until the beginning of the 1960's when improved technical and chemical skill resulted in the silicon transistor.
Silicon transistors were a great improvement on the earlier
 types and are more easily manufactured to meet the requirements of higher frequencies and greater outputs.
When the author of this book purchased the first transistor from Philips, Type OC 70, in 1956 the price was about 15 times higher than the price today of a better transistor, for instance Type BC 107 metal-enclosed. To this must be added the price index which has trebled in the meantime.
We see then that the germanium transistor cannot compete with the silicon type except in certain applications.
Germanium transistors like germanium diodes have a baseemitter voltage of $0.1-0.2 \mathrm{~V}$. This is one of the reasons why we still see this out-dated transistor type used in battery-driven (in cars 12 V ) amplifiers. They are used in complementary output stages in which a low base-emitter voltage is required to give maximum output voltage. You have probably come across the transistor types AC 187-188 and AD 161-162. The maximum output at 12 V and 4 ohm speakers is $2.5 \mathrm{~W}(15 \mathrm{~V} \sim 4 \mathrm{~W})$. The crystal of a germanium transistor can withstand up to approx. $60^{\circ} \mathrm{C}$ temperature only.

Silicon transistors are those most widely known and used today. Mass production techniques and other improvements have made them very competitive both in quality and price compared with both thermionic valves and germanium transistors. Where the gain factor of germanium transistors is only 1 at 1 MHz , that of silicon transistors is the same at $100-500 \mathrm{MHz}$, and it is possible to produce them with this gain at $1-3 \mathrm{GHz}(1 \mathrm{GHz}=1000 \mathrm{MHz})$.
At the same time inherent noise is low and linearity good. This means that an amplifier incorporating silicon transistors has a lower hiss and distortion level. Silicon power transistors are also available, e.g. the 2N3055 with its collector power loss of 115 W is famous. In 1972 the Motorola company produced a direct complementary type called MJ2955, 115 W . A new technique called epi-base has enabled low prices.
However, it is possible that this "new" transistor is already outdated because the new plastic types are even cheaper to produce, the metal housing being relatively high in cost.
Remember that silicon transistors do not conduct a current until the base-emitter voltage exceeds 0.7 V . They can also present some difficulties due to the fact that they start oscillating at 10 MHz or more because of the gain at high frequencies. Silicon transistors can withstand crystal temperatures of almost $200^{\circ} \mathrm{C}$.

## FIELD EFFECT TRANSISTORS

There are two types of field effect transistors - junction FET's and MESA FET's. The former are just as robust as silicon transistors but do not exceed frequencies above 10 MHz while the MESA-FET operates in the GHz range. MESA-FET's present certain difficulties because they blow easily due to the high input impedance and static electricity. MESA-FET's are obtainable, however, incorporating protective diodes which increases their reliability.
The FET can be regarded as a variable resistor in which the resistance between the terminals drain/source varies greatly with low voltage changes between gate and source. The FET conducts current at zero gate voltage and does not start blocking until $1-5 \mathrm{~V}$ is reached. If it is required to use the FET in the on/off range, a negative voltage must be available or the source voltage increased to 2 or 3 V .

If the FET is to be used for amplification purposes it is usually sufficient to have zero voltage at gate so that the FET has a linear operation.
The FET greatly resembles a thermionic valve electrically speaking because it does not conduct gate current. The noise level is higher than in ordinary transistors, and the output power is comparatively low.


Fig. 16.7

Unijunction transistors are a kind of dual transistor suitable for triggering, oscillating or switching purposes. They are not employed linearily in amplifier circuits, the function being as follows:
When a certain voltage applied at the emitter is reached, a current flows from B2 (base 2) to B1 (base 1). A very weak emitter current is sufficient to trigger the UTT (approx. 1 $2 \mu \mathrm{~A}$ ). The maximum current between B2 and B1 is 100 mA . Emitter triggering voltage is somewhat dependent on temperature.

## COOLING

When working with outputs exceeding 1 W , the question of cooling arises, so in concluding this section on transistors and their use, mention should be made of the problems in connexion with cooling.
What is meant by 'Junction to case'?
When studying the various data lists issued by manufacturers of semiconductor components we often encounter the term Tje or junction to case. The better power transistors show a value of approx. $1^{\circ} \mathrm{C} / \mathrm{W}$, this referring to heat conduction from crystal to case. A transistor can normally withstand an operating temperature of the crystal of $175^{\circ}$ C , and the heat conduction to case is useful information, telling us the outer case temperature at a given output.

The case temperature is as follows:

$$
\mathrm{T}_{\mathbf{C}}=\mathrm{T}_{\mathrm{J}}-\mathrm{T}_{\mathrm{Jc}} \times \mathrm{W}
$$

If $\mathrm{T}_{\mathrm{J}}$ is stated as $175^{\circ} \mathrm{C}, \mathrm{T}_{\mathrm{JC}}$ as $1.0^{\circ} \mathrm{C} / \mathrm{W}$, and the output at 100 W , the case temperature permitted is:

$$
\begin{aligned}
& \mathrm{T}_{\mathrm{C}}=175^{\circ} \mathrm{C}-1.0^{\circ} \mathrm{C} / \mathrm{W} \times 100 \mathrm{~W} \\
& \mathrm{~T}_{\mathrm{C}}=75^{\circ} \mathrm{C}
\end{aligned}
$$

If the ambient temperature $\mathrm{T}_{\mathrm{O}}$ is $25^{\circ} \mathrm{C}$, we can find the remaining temperature tolerance $\mathrm{T}_{\mathrm{X}}$ :

$$
\mathrm{T}_{\mathrm{X}}=\mathrm{T}_{\mathrm{C}}-\mathrm{T}_{\mathrm{O}} ; \mathrm{T}_{\mathrm{X}}=75^{\circ} \mathrm{C}-25^{\circ}=50^{\circ} \mathrm{C}
$$

The 100 W heat must now be conducted away so that the temperature drop from the transistor via air and heat-sink does not exceed $50^{\circ} \mathrm{C}$. TTK. The heat-sink cooling ability is expressed in the same manner as in transistors $T_{K}$.

$$
\begin{aligned}
& \mathrm{T}_{\mathrm{K}}=\frac{\mathrm{T}_{\mathrm{TK}}}{\mathrm{~W}} \text { and in the example given: } \\
& \mathrm{T}_{\mathrm{K}}={\frac{50^{\circ} \mathrm{C}}{100 \mathrm{~W}}=\frac{1}{2}^{\circ} \mathrm{C} / \mathrm{W}}^{\mathrm{o}}
\end{aligned}
$$

A cooling surface of $1 / 2^{\circ} \mathrm{C} / \mathrm{W}$ is quite considerable when considering the fact that the space between transistor and heat sink with mica and compound is usually reckoned at $0.2-0.3^{\circ} \mathrm{C} / \mathrm{W}$.
If only two transistors were used in this example the required heat sink level would be $1^{\circ} \mathrm{C} / \mathrm{W}$. It would seem that water-cooling is called for here! Try working it out.
When designing output stages using heat-sinks, it is normally necessary to know either the power to be conducted in a given heat-sink, or the size of the heat-sink required at a given power.
Firstly the output:

$$
\mathrm{W}=\frac{\mathrm{T}_{\mathrm{J}}-\mathrm{T}_{\mathrm{o}}}{\mathrm{~T}_{\mathrm{JC}}+\mathrm{T}_{\mathrm{GK}}+\mathrm{T}_{\mathrm{k}}}
$$

where $\mathrm{T}_{\mathrm{J}} \quad$ is the temperature of the crystal (max. $175^{\circ} \mathrm{C}$ )
$\mathrm{T}_{\mathrm{O}}$ is ambient temperature (between 25 and $50^{\circ}$ C)

TJc is junction to case heat transmission ( ${ }^{\circ} \mathrm{C} / \mathrm{W}$, for a TO3 case normally $1.2^{\circ} \mathrm{C} / \mathrm{W}$ and plastic approx. $\left.2^{\circ} \mathrm{C} / \mathrm{W}\right)$
$\mathrm{T}_{\mathrm{GK}}$ is heat transmission from transistor case through the air, mica plate and compound. In normal designs the air is 0.3 and mica plate 0.7 . An improvement of $0.2-0.3$ is attained by applying compound on both sides.
$\mathrm{T}_{\mathrm{K}}$ is the heat-sink ability to transfer the heat to the air. This value depends on heat-sink size and shape, and is between 100 and 0.3.

To assess the heat conduction ability of a heat-sink, the following formula can be applied:

$$
\mathrm{T}_{\mathrm{K}}=\frac{\mathrm{T}_{\mathrm{J}}-\mathrm{T}_{\mathrm{JC}} \times \mathrm{W}-\mathrm{T}_{\mathrm{GK}} \times \mathrm{W}-\mathrm{To}_{\mathrm{o}}}{\mathrm{~W}}
$$

All thes $\in$ values are known and are mentioned under power calculations.

Question 1.
If a diode is connected plus/minus in the direction of the arrow, can the current flow?

| Yes | A $\square$ |
| :--- | :--- |
| No | B $\square$ |

Question 2.
What is Beta - $\beta$ ?
The number of times the collector current is greater than base current
The number of times the collector current is smaller than base current

B $\square$

## DC CIRCUIT

Dc coupled circuits indicate that a d.c. current is used in certain components.
A capacitor is never d.c. coupled.
D.C. circuits are used mainly for determining the bias currents and voltages of a transistor - also called working point.

We have used capacitors at input and output to couple the individual stages together for ac purposes.
To be able to amplify, a transistor must be able to draw more or less current through a loudspeaker or a resistor, thereby varying the voltage across the load.

Fig. 17.1


The easiest lay-out consists of a transistor and two resistors. We have chosen a 4.5 V battery and a current of 0.5 mA . This keeps the noise of a small transistor at a minimum.

When the input signal changes the base current, the collector current varies more due to the current gain of the transistor. The collector current passes through $\mathrm{R}_{\mathrm{C}}$, and the changes in current caused by the transistor results in voltage changes across the load resistor $\mathrm{R}_{\mathrm{C}}$ - Ohm's Law.

To attain the greatest variation up to plus and down to minus, a collector bias voltage of half battery voltage, i.e. 2.25 $V$ is chosen.

At this stage we can already calculate the collector resistance:

$$
\mathrm{R}=\frac{2.25 \mathrm{~V}}{0.5 \mathrm{~mA}}=4.7 \mathrm{KOhm}=\mathrm{Rc}
$$

To find the necessary base current we must know the current gain according to specifications. $\beta=100$ in the transistor used, Type BC 170.

We can find the base current because it must be 100 times smaller than the collector current to get a gain from base to collector:

$$
I_{b}=\frac{I_{c}}{B}=\frac{0.5 \mathrm{~mA}}{100}=5 \mu \mathrm{~A}
$$

We also know that the diode section from base to emitter conducts, and that a forward placed diode has a Zener voltage of 0.7 volt, so the voltage across $R_{b}$ is:

$$
\mathrm{E}_{6}=\mathrm{E}-0.7 \mathrm{~V}=3.8 \mathrm{~V}
$$

Applying the two results above, we can determine $R_{b}$ :

$$
\mathrm{R}_{\mathrm{b}}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{3 \times 8 \mathrm{~V}}{5 \mu \mathrm{~A}}=680 \mathrm{KOhm}
$$



Fig. 17.2

Another possibility is to connect $\mathrm{R}_{\mathrm{b}}$ to collector. Part of the signal thus returns reacting on the incoming signal.
This gives a more uniform gain across a wider frequency range, low distortion better temperature stability, and less sensitivity to varying current gain in transistors.
The gain is reduced, however.
Using once more a 4.5 V battery and a collector current of 0.5 mA , the rule of half collector voltage is known and we can find $\mathrm{R}_{\mathrm{c}}$.

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{2.25 \mathrm{~V}}{0.5 \mathrm{~mA}}=4,7 \mathrm{KOhm}=\mathrm{Rc}
$$

We must now find the base resistance. The current gain is 100.

As opposed to the previous example, $\mathrm{R}_{\mathrm{b}}$ is connected to collector voltage, 2.25 V , so the voltage across $\mathrm{R}_{\mathrm{b}}$ is equal to $2.25 \mathrm{~V}-0.7 \mathrm{~V}=1.55 \mathrm{~V}$.
$\mathrm{R}_{\mathrm{b}}$ is thus:

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{1.55 \mathrm{~V}}{5 \mu \mathrm{~A}}=330 \mathrm{KOhm}=\mathrm{R}_{\mathrm{b}}
$$

The 5 uA is found by dividing the collector current by the current gain.

Fig. 17.3


In our third example, the bias voltages are almost independent of the current gain of the transistor, this being a great advantage.
Again with a battery voltage of 4.5 V and the collector current 0.5 mA , we must choose the voltage across $\mathrm{Re}_{\mathrm{e}}$. This is normally $10-30 \%$ of battery voltage. The resistor stabilizes the transistor against temperature variations. The voltage 0.5 V has been chosen.
We now have plus-minus 2 volts available collector swing. The collector voltage is thus 2.5 V .
We then proceed to the collector resistance:

$$
\mathrm{Rc}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{2.0 \mathrm{~V}}{0.5 \mathrm{~mA}}=3.9 \mathrm{KOhm}
$$

Notice here, as elsewhere, that we do not give the exact value, but the nearest standard value (rating).
Then the emitter resistance:

$$
\mathrm{Re}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{0.5 \mathrm{~V}}{0.5 \mathrm{~mA}}=1 \mathrm{KOhm}
$$

We must now determine both base resistances, and to ensure that the voltage at their common point is not affected by the transistor temperature variations we set this current 10 times greater than the necessary base current, this being 5 $\mu \mathrm{A}$ because the current gain is a 100 times, and the collector current 0.5 mA .
The base current must then be 10 times greater, i.e. 50 uA. We must then know the base voltage of the transistor to find the voltage across both base resistors.

There is 0.7 V from base to emitter, and from emitter to 0 we have chosen a voltage of 0.5 V - together the base voltage is $1.2 \mathrm{~V}(0.7+0.5 \mathrm{~V})$.
The voltage across $\mathrm{R}_{\mathrm{b} 2}$ is 1.2 V and the current $5 \mu \mathrm{~A}$ :

$$
\mathrm{Rb} 2=\frac{\mathrm{E}}{\mathrm{I}}=\frac{1.2 \mathrm{~V}}{50 \mu \mathrm{~A}}=22 \mathrm{KOhm}
$$

The voltage across $R_{b 1}$ is of course the battery voltage minus that across $\mathrm{R}_{\mathrm{b} 2}, 4.5 \mathrm{~V}$ minus 1.2 V . E across $R_{b 2}=$ 3.3 V . The resistance $\mathrm{R}_{\mathrm{b} 1}$ can now be found, $1=50 \mu \mathrm{~A}$.

$$
R b 1=\frac{E}{I}=\frac{3.3 V}{50 \mu \mathrm{~A}}=68 \mathrm{kohm}
$$

The capacitors in input and output connect the adjoining stages without interfering with the d.c. calculations. They only transfer a.c. voltage - see section on a.c. connections.

See practical applications AE 2


Our fourth example shows how two transistors can be dc-coupled. The current 1.5 mA in T 1 is fixed and the battery voltage 4.5 V . We then "hope for" an input impedance of 15 kohm , to match a B \& O pick-up, for example.

The emitter resistor to T1 can be determined when we have chosen the voltage across it. We choose 1.5 V because the transistor in front must have a base voltage of at least 0.7 V . Here it is higher.

At this voltage and the given current we find $R_{e 1}$ :

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}} \quad \frac{1.5 \mathrm{~V}}{1.5 \mathrm{~mA}}=1 \mathrm{KOhm}=\operatorname{Re} 1
$$

The collector of transistor $\mathrm{T}_{1}$ can now only drop to 1.5 V and rise to 4.5 V , so we choose a collector voltage of 3 V . There is thus 1.5 V bias voltage across the collector resistor:

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{1.5 \mathrm{~V}}{1.5 \mathrm{~mA}}=1 \mathrm{KOhm}=\mathrm{Rc} 1
$$

The current in T2 is chosen 10 times greater than the necessary control current for T1. This is done to be independent of the tolerances of the transistor parameters and to get good temperature stability in the same way as in Example 3 in which the current was set at 10 times greater in the resistors $\mathrm{R}_{\mathrm{b} 1}$ and $\mathrm{R}_{\mathrm{b} 2}$. Having a current gain of 100, and a collector current of 1.5 mA , the necessary control current for T1 is 15 uA . The current in T2 is chosen 10 times greater, i.e. 150 uA.
The base voltage of T1 is equal to T 1 emitter voltage plus base/emitter voltage, ( 0.7 V ).

This voltage is also equal to the collector voltage of T2 being directly coupled, so the voltage across $\mathrm{R}_{\mathrm{b} 1}$ is the battery voltage minus 2.2 V , i.e. 2.3 V .
$\mathrm{R}_{\mathrm{b} 1}$ is calculated as follows:

$$
\mathrm{R}=\frac{\mathrm{E}}{\mathrm{I}}=\frac{2.3 \mathrm{~V}}{150 \mu \mathrm{~A}}=15 \mathrm{kohm}=\mathrm{R}_{\mathrm{b} 1}
$$

$\mathrm{Re}_{2}$ must now be found. It is a known fact that the input impedance of the transistor is roughly equal to the current gain multiplied by the emitter resistance. We require an input impedance of 15 kohm and a current gain of 100 , the emitter resistor is:

$$
\mathrm{R}_{\mathrm{e}}=\frac{\mathrm{Zin}}{ß}=\frac{15 \mathrm{KOhm}}{100}=150 \mathrm{Ohm}=\mathrm{R}_{\mathrm{e} 2}
$$

Finally, $\mathrm{Rb}_{2}$ must be determined, and the voltage across $\mathrm{Re}_{2}$ must be found.

$$
\mathrm{E}_{\mathrm{e}}=\mathrm{I} \times \mathrm{R}=150 \mu \mathrm{~A} \times 150 \mathrm{Ohm}=0.02 \mathrm{~V}
$$

$$
\mathrm{Eb} 2=0.7 \mathrm{~V}+0.02=0.72 \mathrm{~V}
$$

Voltage across $\mathrm{R}_{\mathrm{b} 2}=\mathrm{E}_{\mathrm{e} 1}-\mathrm{E}_{\mathrm{b} 2}=1.50 \mathrm{~V}-0.72 \mathrm{~V}=0.8 \mathrm{~V}$.

Resistor $\mathrm{R}_{\mathrm{b} 2}$ can be worked out:

$$
\begin{aligned}
& I_{R 2}=\frac{I_{T}}{\beta}=\frac{150 \mu \mathrm{~A}}{100}=1.5 \mathrm{uA} \\
& R=\frac{E}{I}=\frac{0.8 \mathrm{~V}}{1.5 \mu \mathrm{~A}}=470 \mathrm{KOhm}
\end{aligned}
$$

See practical applications AE 1

Fig 17.5


All the resistances have now been found. The feedback here is quite considerable, but it can be avoided to a certain extent by means of capacitors, a.c. circuits mentioned in the following section.

Our fifth example shows how a complementary output stage can be made for direct connection to loudspeakers. These are the specifications:

Loudspeaker 3.2 Ohm
Transistor BC $170,50 \mathrm{~mA}, 20 \mathrm{~V}, 100 \mathrm{~mW}, \beta=100$.
Transistor MEO412, $50 \mathrm{~mA}, 20 \mathrm{~V}, 100 \mathrm{~mW}, \beta=100$.
We start by describing its function.
T1 and T2 are complementary transistors, one of which, BC 170 activates the loudspeaker in the positive half-cycle, while the other MEO412 activates it in the negative half-cycle. This system is called PUSH-PULL, and this type of output amplifier gives maximum utilisation and power using the minimum of transistors.

T3 is a control transistor that activates the bases of T1 and T2 output transistors.

As transistors are not linear, they must be fed with base bias so that the current used is great enough to make them reach a linear range of their characteristics. The current necessary for this is called no-load current. If the T1 and T2 bases were directly combined there would be no no-load current but there would be CROSS-OVER distortion, particularly evident at low volume.

T1 and T2 receive base bias from R2 and $\cap$ which also adds to temperature stabilisation. If R2 is too high it can result in both output transistors conducting simultaneously which of course produces a short circuit.
R1 is the collector resistor for T3. T3 gets its base bias from the common point between T1 and T2, giving effective temperature stability.
We now calculate this stage with the known data:
The voltage at the common point between T1 and T2 can vary between 2.25 V and 4.5 V and down to 0 V . There is a peak voltage, ac 2.25 V . Normally we measure the RMS
value (root mean square). Divided by $\sqrt{ } 2$ this gives a maximum RMS ac voltage of 1.6 V .
An emitter resistor for T3 is often inserted - 20-100 ohm - and in bigger output stages emitter resistors for T1 and T2 between 0.3 and 1 ohm .
By applying Ohm's Law we can determine the maximum output power.

$$
\mathrm{W}=\frac{\mathrm{E}^{2}}{\mathrm{R}}=\frac{1.6^{2}}{3.2}=0.8 \mathrm{Watt}
$$

This. however. is more than the transistors can withstand. If each of them is loaded by 200 mW , working alternately in each half cycle we see the following, corresponding to 100 mW continuous.
At 200 mW using a 3.2 ohm loudspeaker, the collector current will be:
$I^{2}=\frac{W}{R}=I=\sqrt{\frac{W}{R}}=\sqrt{\frac{0.2 \mathrm{~W}}{3.2 \mathrm{Ohm}}}=0.25 \mathrm{~A}=250 \mathrm{~mA}$

This current is acceptable because each transistor is loaded only during one half cycle. We can now proceed to find the necessary base current, the gain being 100.

$$
\mathrm{Ib}=\frac{\mathrm{I}_{\mathrm{c}}}{ß}=\frac{250 \mathrm{~mA}}{100}=2.5 \mathrm{~mA}
$$

As T3 and R1 +R 5 together form a voltage divider (like $\mathrm{Rb}_{1}$ and Rb2 in the third example) we choose for the same reason a current three times higher for R1 and T3 i.e. 8 mA . If the output voltage from the divider is 2.25 V , and the base-emitter voltage 0.7 V , the base-collector voltage is 1.55 V. - See diagram.

Now that we know both current and voltage, we can find the resistance:

$$
\mathrm{R} 1=\frac{\mathrm{E}}{\mathrm{I}} \quad \frac{1.55 \mathrm{~V}}{8 \mathrm{~mA}}=180 \mathrm{Ohm}
$$

We then proceed to R2. The conducting or forward biased diode D drops 0.7 V , so there is 0.5 V left for R 2 . This resistor must be accurate to avoid an excess no-load current in the transistor stage.

$$
\mathrm{R} 2=\frac{\mathrm{E}}{\mathrm{I}}=\frac{0.5 \mathrm{~V}}{8 \mathrm{~mA}}=68 \mathrm{Ohm}
$$

The transistor T3 will be carrying a current of 8 mA . The base current must be correct so that the voltage across is correct. If the current gain is 100, the necessary base current is 80 uA . We have a stabilised voltage divider in R3 and R4. To stabilise, the current in this voltage divider should be 10 times greater than the necessary control current to $\mathrm{T} 3-0.8 \mathrm{~mA}$.
The voltage from base to 0 (common) is 0.7 V , so R 4 can be determined:

$$
\mathrm{R} 4=\frac{\mathrm{E}}{\mathrm{I}}=\frac{0.7 \mathrm{~V}}{0.8 \mathrm{~mA}}=820 \mathrm{Ohm}
$$

We then find the resistance of R3:

$$
\begin{aligned}
& \mathrm{E}_{\mathrm{R} 3}=\mathrm{E} \text { out }-\mathrm{E}_{\mathrm{b} 3}=2.25 \mathrm{~V}-0.7 \mathrm{~V}=1.55 \mathrm{~V} \\
& \mathrm{R} 3=\frac{\mathrm{E}}{\mathrm{I}}=\frac{1.55 \mathrm{~V}}{0.8 \mathrm{~mA}}=2,2 \mathrm{KOhm}
\end{aligned}
$$

The output capacitor is $320 \mathrm{uF} / 6.4 \mathrm{~V}$, and the input capacitor $6.4 \mathrm{uF} / 25 \mathrm{~V}$. The base resistance of T 1 is for feed-back reasons split equally and de-coupled by a capacitor.

The capacitor C4 is inserted to prevent oscillation. C4 is 100 pF. In worst conditions this circuit can oscillate up to 100 MHz without the capacitor. This is a good example of oscillation suppression. It is, of course, not audible but indirectly the low frequency signal is distorted or can give a hissing sound.

Up to the present we have only spoken of dc amplifiers, but a circuit that is just as important to know is the stabilised power pack.
There are many kinds of power packs, but we will here describe a "series regulator" with an overcurrent limiter (short-circuit protection). We have chosen this layout with care because it gives the greatest advantages at low cost. The principle is applied in JOSTY KIT's power pack No. NT 315.

The diagram can be divided into four functions:

1. Power supply, transformer, D1 and C1
2. Series regulator, T1, T2, R1, R2, R3 and C3
3. Reference and fault current regulator, T3, R6, R7 and C2.
4. Overcurrent limiter, T4, R4, R5 and C4
5. Of these four combined units we have already described the power pack including transformer, rectifier bridge, and filter capacitor.
6. The series regulator comprises T1 and T2 in the wellknown Darlington coupling. T1 is a power transistor 10 200 W , and T2 is a "small signal type", 100 mW to 10 W , and is inserted purely to regulate the current. Applying the Darlington method of connecting transistors, there is a total current gain of $\beta_{\mathrm{T} 1} \times \beta \mathrm{T} 2$. As an example, $20 \times$ $100=2000$, with a regulating current of 2000 mA in this case we only need a base current of 1 mA .
R1 and R2 are base resistors for the Darlington coupling, these resistors having to supply at least 1 mA as stated above, also when the output voltage is almost equal to the input voltage. Selecting a difference of 2 V we get a resistance of $\mathrm{R} 1+\mathrm{R} 2=1 \mathrm{~mA}=2 \mathrm{kohm}$. R1 and R2 is thenchosen at 1 kohmeach.C3 short-circuits the remaining ripple from R1 preventing it from spreading to T2 and T1 and the output. The only function R3 has is to prevent possible leakage current from T1 influencing the output voltage.
7. The reference regulator measures the output voltage at T3 base. The reference voltage is at the emitter base voltage of T3. The well-known 0.7 V is so stable that regulating from zero to full load is within $10 \%$ ( $0-2200$ mA ) which is sufficient in most cases. In other words, if the output voltage is too high T3 "steals" some of the
base current which T 2 would require to conduct output current.
8. By means of the base emitter junction, T4 measures the voltage across R4, and when it exceeds 0.7 V the transistor conducts the base current that T2 should have had to supply output voltage. If R4 is chosen to ensure 0.7 V across it at 1 Amp , the value can be calculated by applying Ohm's Law.

$$
\mathrm{R}=\frac{0.7 \mathrm{~V}}{1 \text { Ampere }}=\underline{0.7 \mathrm{Ohm}}
$$

From this we see that by a simple calculation we can determine the short-circuit current. For instance, $100 \mathrm{~mA}=$ 7 ohm ( 6.8 ohm ). Try other examples.
R5 and C4 are included because the circuit would otherwise start oscillating at a high frequency during short-circuiting. Oscillation at full load means instant damage.

This power-pack circuit is suitable for all transformers between 0 and 30 V using the following components: R1 = $1 \mathrm{KOhm}, \mathrm{R} 2=1 \mathrm{KOhm}, \mathrm{R} 3=100 \mathrm{Ohm}, \mathrm{R} 4$ - see text, $0.3-$ 100 Ohm (current regulation), $\mathrm{R} 5=1 \mathrm{KOhm}, \mathrm{R} 6=100 \mathrm{Ohm}$, $\mathrm{R} 7=10 \mathrm{KOhm}, \mathrm{C} 1=1000$ or $2000 \mu \mathrm{~F} / 40 \mathrm{~V}, \mathrm{C} 2=100$ $\mu \mathrm{F} / 40 \mathrm{~V}, \mathrm{C} 3=100 \mu \mathrm{~F} / 40 \mathrm{~V}, \mathrm{C} 4=100 \mathrm{pf}-1 \mathrm{nF}$.
$\mathrm{T} 1=2 \mathrm{~N} 3055$, MJE 3055 , BD 165 or similar power transistor.


T2, T3 and T4 = BC 171, BC 107, BC 341 or similar NPN small signal or medium power transistor. D1 = B40 C 2200 or lower B40 C 600 depending on the current required. The former is for 2200 mA and the latter for 600 mA .

Question 1.
Apply the rules in the first example to find the following: Current gain 75 , collector current required 0.5 mA , supply• voltage 6 V . Which are the correct $R_{c}$ and $R_{b}$ values?

| $\mathrm{R}_{\mathrm{c}}$ | $\mathrm{R}_{\mathrm{b}}$ |  |
| :--- | :--- | :--- |
| 12 KOhm | 680 KOhm | $\mathrm{A} \square$ |
| 5.6 KOhm | 820 KOhm | $\mathrm{B} \square$ |
| 5.6 KOhm | 680 KOhm | $\mathrm{C} \square$ |
| 12 KOhm | 1.5 KOhm | $\mathrm{D} \square$ |

Question 2.
We must now calculate a transistor stage as in the third example. The supply voltage is 3 V , the required collector current 1 mA , and we apply 0.7 V across the emitter resistor, $\beta=100$ in T1. Which combination of resistors is the best?

| $\mathrm{Re}_{\mathrm{e}}$ | $\mathrm{R}_{\mathrm{c}}$ | $\mathrm{R}_{\mathrm{b} 1}$ | $\mathrm{R}_{\mathrm{b}}$ |  |
| :--- | :--- | :--- | :--- | :--- |
| 680 Ohm | 1.2 KOhm | 6.8 KOhm | 22 KOhm | $\mathrm{A} \square$ |
| 680 Ohm | 1.2 KOhm | 15 KOhm | 15 KOhm | $\mathrm{B} \square$ |
| 1.2 KOhm | 2.2 KOhm | 15 KOhm | 15 KOhm | $\mathrm{C} \square$ |
| 680 Ohm | 2.2 KOhm | 6.8 KOhm | 22 KOhm | $\mathrm{D} \square$ |

## Question 3.

Try calculating a complementary output stage as example 5, but at 15 V instead of 4.5 V . Use more powerful transistors such as:

T1, BD $165,10 \mathrm{~W}, \beta=50,1.5 \mathrm{~A}, 40 \mathrm{~V}, \mathrm{NPN}$
T2, BD 166, $10 \mathrm{~W}, \beta=50,1.5 \mathrm{~A}, 40 \mathrm{~V}, \mathrm{PNP}$
T3, BC 171, $300 \mathrm{~mW}, ~ \beta=100,100 \mathrm{~mA}, 40 \mathrm{~V}, \mathrm{NPN}$.

What output do you get, and what resistors are to be used?

| W | R1 1 and R5 | R2 | R3 |  |
| :--- | :--- | :--- | :--- | :--- |
| 2 | $680+680 \mathrm{Ohm}$ | 100 Ohm | 10 KOhm 1 KOhm | A $\square$ |
| 6 | $68+68 \mathrm{Ohm}$ | 10 Ohm | 1 KOhm 100 Ohm | B $\square$ |

## AC CIRCUIT

An ac coupled circuit transfers alternating current, but blocks direct current. There are only two components having this ability - capacitors and transformers.
Transformers are employed mainly on HF (high frequency) as distortion is difficult to avoid on LF (low frequency). The HF capacitor circuits are shown in a later section.
These days capacitors are nearly always used in ac circuits in the LF-range. The amplification of a transistor stage is confined to a signal via base-emitter. The diagram on the right shows the signal in a circuit.
The signal enters base, passes base-emitter and R4 and leaves through (0) common. Base-emitter and R4 form a voltage divider. The bigger R4 is, the greater the signal here instead of in the base-emitter. This reduces the signal.
To avoid this, a capacitor is inserted from emitter to common, rendering the emitter "cold", i.e. the emitter is ac-connected to common.
The capacitor should be as big as possible, but dimensions and price tend to reduce it to a minimum.
The impedance of a capacitor is lowest at high frequencies, so it's the bass that gives the difficulties.
In practice, the human ear cannot distinguish a volume difference less than 3 dB .3 dB is half the signal, so the impedance of the capacitor need only equal that of the resistor it is across. Two identical resistors in parallel give half the ohmic value. If the resistance is 1 kohm , the impedance of the capacitor must be 1 kohm at lowest frequency $(20 \mathrm{~Hz})$.

$$
C=\frac{1}{2 \times \pi \times f \times Z_{c}} \quad \frac{1}{6.28 \times 20 \times 1000}=8 \times 10^{-6}=8 u F
$$

we choose 12.5 uF 25 V
The by-pass capacitor C1 must have a low impedance compared with the input impedance.
The input impedance is determined by R1 and R2 in parallel, and this in parallel with the actual transistor input impedance. Including the by-pass capacitor, this is usually approx. 1 kohm , and without it is R4 times the current gain.

With C2 we get:
$\mathrm{Z}_{\mathrm{i}}=1 \mathrm{KOhm}$
all in parallel:

$$
\begin{aligned}
& \frac{1}{\mathrm{R}}=\frac{1}{10 \mathrm{kOhm}}+\frac{1}{27 \mathrm{kOhm}}+\frac{1}{1 \mathrm{kohm}}=\frac{1}{900 \mathrm{ohm}} \\
& \mathrm{R}=900 \mathrm{Ohm}
\end{aligned}
$$

$\mathrm{Z}_{\mathrm{c}}=900 \mathrm{Ohm}$ at 20 Hz gives again 8 uF and we use $12.5 \mathrm{uF} / 25 \mathrm{~V}$
Without C2 we get: $\mathrm{Z}_{\mathrm{i}}=1 \mathrm{KOhm} \times 100=100 \mathrm{KOhm}$
We chose $4 \mathrm{uF} / 10 \mathrm{~V}$.


Fig. 18.1

## TRANSFORMER CIRCUITS

Formerly one saw one or two transformers in the low-frequency amplifiers of small Japanese radios. This was to achieve maximum amplification, impedance matching and efficiency with a minimum amount of transistors. There is more work involved in producing transformers than transistors, so with the ever-increasing wage costs even in Japan, Hong Kong*, Korea, China, and other countries of the East, it is obvious that labour costs must be cut.

* 400 mill. dollars electronic equipment exported in 1972.

Microphone


Good quality transformers are, however, still widely used in the production of microphones. All hum can be out-balanced by means of a balanced transformer and a screened twin-lead cable. See Fig.18.2.

Question 1.
The emitter resistance ( 300 ohms ) of a transistor must be by-passed down to a frequency of 40 Hz . Which is the correct capacitor size?

| 13 uF | A $\square$ |
| :--- | :--- |
| 25 uF | B $\square$ |
| 250 uF | C $\square$ |
| 125 uF | D $\square$ |

The subject of filters belongs to ac circuits. Their purpose is to suppress certain frequencies in relation to others. The basic circuit is a frequency-dependent voltage divider. Filters of this description are often called RC-filters.


Fig. 19.1

See practical applications AE 9

## TREBLE BOOST

In Fig. 19.1 we see that all the high frequencies are allowed to pass, but is a bad conductor of the low ones. The cut-off frequency is that in which half of the signal passes, i.e. the capacitor impedance is equal to the resistance. In practice this means that when a capacitor is a good conductor of high frequencies, they pass unhindered. Lower frequencies have difficulty in passing due to the high resistance of the capacitor
The values of components are determined by selecting R-resistor and calculating C-capacitor.
The resistor value must be at least 10 times lower than input impedance of the circuit or amplifier concerned. If the input impedance of the amplifier is 100 kohm the R -value must be 10 kohm . As the capacitor of the cross-over frequency selected must have the same impedance for 3 dB suppression, we can calculate as follows: $\mathrm{f}=10 \mathrm{kHz}$

$$
\begin{aligned}
& \mathrm{C}=\frac{1}{2 \pi \times \mathrm{f} \times 2 \mathrm{c}} \quad \mathrm{C}=\frac{1}{2 \times 3.14 \times 10^{4} \times 104}=1.5 \mathrm{nF} \\
& \text { TREBLE SUPPRESSION }
\end{aligned}
$$

Fig. 19.2 shows how the treble is suppressed.
In practice this circuit allows the high frequencies to "run" through the capacitor to common (chassis short-circuit)
while the medium and bass frequencies "run" direct to the amplifier. The reason for not leading the medium and bass via the capacitor is that its resistance is high in this range.
Like the previous example, the capacitor is calculated and the resistor selected, remembering that $R$ resistance must be $1 / 10$ amplifier impedance. Applying the same principles we see that the component values are 1.5 nF and 10 kohm at f $=10 \mathrm{kHz}$.

Fig. 19.2


## TREBLE BOOST (20 dB)

The treble can be boosted by following Fig. 19.3. The function is the same as in Fig. 19.1 , but the boost is fixed at 20 dB which is equal to ten times. If you are not acquainted with the relation between the value decibel ( dB ) and amplification, see Section T4 1.
In practice the principle shown in Fig. 19.3 is that the resistors R1 and R2 suppress the signal path by $10(20 \mathrm{~dB})$ which means that the output is 100 mV when the input is 1000 mV .
The capacitor $C$ breaks the voltage dividing ratio of the high frequencies sending them around the resistor R1. The output voltage is thus increased at high frequencies and we boost the treble after suppressing the whole frequency range by means of R1 and R2.
In the following examples as in previous ones, we select a resistor for the filter output 10 times lower than the input impedance of the amplifier. We have chosen R2 at 10 kohm. To establish the voltage dividing ratio 10:1 we have R1 at


Fig. 19.3

100 KOhm (11:1). The capacitor $C$ size is calculated according to the resistor shunting the high frequencies, in this case R1 $=100 \mathrm{kohm}$. At the same cross-over frequency as in Fig. 19.1, $f=10 \mathrm{kHz}$ we see:

$$
\begin{aligned}
& C=\frac{1}{2 \pi \times f \times \mathrm{Z} c} \\
& C=\frac{1}{2 \times 3.14 \times 10^{4} \times 10^{4}}
\end{aligned}
$$

recalling that $Z_{c}=R 1 \quad 100 \mathrm{kohm}=10^{5} \mathrm{Ohm}$

$$
\mathrm{C}=150 \mathrm{pF}
$$

## TREBLE SUPPRESSION

Fig. 19.4 shows how the treble frequency is suppressed. The voltage divider R1 + R2 lowers the signal by ten, and the treble is further suppressed because the capacitor $C$ leads the treble to common (chassis).
When calculating, R1 and R2 are selected according to the required ratio ( 10 times) and the input impedance of the circuit concerned. The capacitor $C$ must be equal to the impedance of $\mathrm{R} 2\left(\mathrm{R} 2=\mathrm{Z}_{\mathrm{c}}\right)$ according to the cross-over frequency required which is usually between 2 and 15 kHz . At 10 kHz and $\mathrm{R} 1=100 \mathrm{KOhm}$ and $\mathrm{R} 2=10 \mathrm{KOhm}, \mathrm{C}$ becomes $=1.5 \mathrm{nF}$.


The treble suppression filter is often known under the term "stylus filter" for use on the old type of gramophone records, the range being $3-7.5 \mathrm{kHz}$.

## BASS BOOST

You have probably come across radio enthusiasts who have built an amplifier only to find when connecting a record player that the reproduction is "scratchy". The author has often been faced with this question, anyway.
This filter to lower the signal level and to boost the bass can reduce the scratchy sound. The reason why the pick-up signal sounds scratchy is that discs are recorded at 20 dB suppressed bass and 20 dB boosted treble to solve noise

Fig. 19.5

problems. When reproducing the sound, the lacking bass is restored by a bass boost filter 20 dB , and the treble is lowered thus eliminating stylus noise. Our bass boost filter does not lower the treble which is necessary when playing records, but we have designed a combined filter, the AE10 which is according to CCIR standards. See under AE10 further on in this book.
We must not forget the bass boost filter calculations after all this talk about records. Select the R2 value according to the amplifier input impedance, which in Fig. 19.5 is 10 kohm. Then the R1 is at voltage divider ratio 100 kohm. The capacitor $C$ can now be calculated according to the required bass boost frequency, e.g. 150 Hz .

$$
\begin{aligned}
& \mathrm{C}=\frac{1}{2 \pi \times \mathrm{f} \times \mathrm{Zc}} \quad \mathrm{Zc}=\mathrm{R} 2 \\
& \mathrm{C}=\frac{1}{2 \pi \times \mathrm{f} \times \mathrm{Zc}} \approx 100 \mathrm{nF}
\end{aligned}
$$

Test yourself here by calculating with a different frequency.


Fig. 19.6


## BASS SUPPRESSION

If bass reproduction is too pronounced or there is record player rumble, the filter shown in Fig. 19.6 can be used. Via R1 and R2, this filter suppresses the total signal by 20
dB , and the bass is suppressed further because the capacitor $C$ selected allows only the passage of medium and treble frequencies unhindered.
The capacitor $C$ is calculated according to R1, and using the same resistors as the previous examples we get:

$$
\begin{aligned}
& \mathrm{C}=\frac{1}{2 \pi \times \mathrm{f} \mathrm{\times Zc}} \quad \mathrm{Zc}=\mathrm{R} 1 \\
& \mathrm{C}=\frac{1}{6.28 \times 300 \times 10^{5}} \approx 10 \mathrm{nF}
\end{aligned}
$$

Fig. 19.7


## FILTER CHAINS

As shown in Fig. 19.7 several filters can combined in a circuit (single filters shown in Figs. 19.1 and 19.2) so that cut-off characteristics become "sharper". Each filter gives -6 dB per octave which means that every time the frequency is halved or doubled the change is 6 dB (twice or half). On adding an extra filter to the chain, the suppression or boost is improved by 6 dB per octave. The three filters shown give 18 dB . Read Section T4.1 on the subject of dB if necessary.

## COMBINED TREBLE CONTROL

The design in Fig. 19.8 shows how the treble can be varied as required. When the potentiometer arm is in the upper position, all treble frequencies passing C1 are shunted around R1. This is a treble boost. In the lower position of


Fig. 19.8
the potentiometer arm, all treble frequencies passing R1 are led to common (chassis). This is treble suppression. $\mathrm{Z}_{\mathrm{C} 1}$ is equal to R 1 and $\mathrm{Z}_{\mathrm{C}}$ is equal to R 2 . The potentiometer is approx. $10 \times \mathrm{R} 1$ and R2, R1 and R2 being selected according to amplifier impedance. That is, R2 is ten times less than $\mathrm{Z}_{\mathrm{in}}$, and $\mathrm{R} 1=10 \times \mathrm{R} 2 . \mathrm{R} 3$ is inserted only if treble and bass controls are to be combined, i.e. dependent on each other. The rating must be based on experiments, but is usually in the region of R 2 value.
Let us take an example: Treble control to be based on an amplifier input impedance of 100 kohm. We can now determine R2 and R1 as the amplifier input impedance is $100 \mathrm{kohm}, \mathrm{R} 2$ is $1 / 10$ of 100 kohm , that is $R 2=10 \mathrm{kohm}$. As the voltage divider ratio normally chosen is $10, \mathrm{R} 1=10$ $\times \mathrm{R} 2=100 \mathrm{KOhm}$.
The potentiometer must be well-dimensioned compared to R1 and R2 to achieve power control so this is also fixed at $10 \times \mathrm{R} 1+\mathrm{R} 2$. The nearest standard rating is $1 \mathrm{Mohm}(1 \mathrm{M}$ $=1000 \mathrm{k}=10^{6}$ ).

We now come to the capacitor calculations. This combined version is easily adapted to our non-variable examples. Let us assume that the potentiometer is turned right down to C2. The treble frequencies must now run through the total potentiometer resistance of 1 Mohm, leaving little signal. The C2 function is now at maximum, so we can assume that the circuit comprises only R1 and R2 and C2 across, i.e. as in Fig. 19.4. As we have used the same components in Example 19.8 as in 19.4, we have the same capacitor of $1.5 n F$, and we choose the same crossover frequency (10 kHz ).
We now turn the potentiometer up to the point where C2 no longer functions, and C1 is in fact in parallel with R1.
'The crossover frequency is 10 kHz , and as R 1 is ten times greater than R2, C1 is reduced to $1 / 10$, i.e. 150 pF .
Consequently:

$$
\begin{aligned}
\mathrm{C} 1 & =\frac{1}{2 \pi \times \mathrm{f} \times \mathrm{Zc}} \\
\mathrm{C} 1 & =\frac{1}{2 \times 3.14 \times 10^{4} \times 10^{4}} \\
\mathrm{C} 1 & \approx 150 \mathrm{pF}
\end{aligned}
$$

Try calculating a different treble control.

Fig. 19.9


COMBINED BASS CONTROL
Fig. 19.9 shows a combined bass control and is actually a combination of Figs. 19.5 and 19.6, this being effected by a 1 Mohm potentiometer.
We choose the same connection impedance as in the treble control circuit which makes a direct combination of bass and treble easier. The control range of the bass is selected at 100 Hz .
Using the same resistors and potentiometers as those in treble control (R1 $=100 \mathrm{KOhm}, \mathrm{R} 2=10 \mathrm{KOhm}, \mathrm{P}=1$ Mohm) we calculate C3 according to R1 resistance and C4
according to R2. The reason for this choice is that Fig. 19.9 corresponds to bass boost in Fig. 19.5 when the potentiometer is in the top position, and to bass suppression in Fig. 19.6 when the potentiometer is right down.
Calculatin C3:

$$
\mathrm{C} 3=\frac{1}{2 \pi \times \mathrm{fx} \mathrm{R1}}
$$

$$
\mathrm{C} 3=\frac{1}{2 \times 3,14 \times 100 \times 10^{5}}
$$

$$
C 3 \approx 15 \mathrm{nF}
$$

and C4 is as follows:

$$
\left(\mathrm{Z}_{\mathrm{C} 4}=\mathrm{R} 2\right)
$$

$$
\mathrm{C} 4=\frac{1}{2 \pi \times \mathrm{f} \times \mathrm{R} 2}
$$

$$
\mathrm{C} 4=\frac{1}{2 \times 3,14 \times 100 \times 10^{4}}
$$

$$
C 4 \approx 150 \mathrm{nF}
$$

## COMBINED BASS/TREBLE CONTROL

Combining Figs. 19.8 and 19.9 shown in Fig. 19.10 we get a joint bass and treble control. The resistors $R 1$ and R 2 are common to $\mathrm{C} 1+\mathrm{C} 2$ and $\mathrm{C} 3+\mathrm{C} 4$.
The resistor $R 3$ reduces the influence of treble control on bass control. The greater the resistance the smaller the influence, but unfortunately in this case the efficiency of the treble control is affected. We have then a compromise. Connection to P1 "arm" instead of P2 "arm" could be direct, but this would weaken the bass control. R3 could also be split up into two equal resistors, taking a lead from the middle of P1 and P2, giving equal control of bass and treble.

Fig. 19.10


The whole circuit suppresses the signal by 20 dB which nearly always entails the use of a following amplifier stage. Fig. 17.3 can also be applied.
Instead of going through all the calculations once more we can use the following mathematical formula:
$\mathrm{R} 2=\mathrm{Z}$ in/10
R1 = R2. 10
$\mathrm{P} 1=\mathrm{P} 2=10 \cdot(\mathrm{R} 1+\mathrm{R} 2)$
$\mathrm{Z}_{\mathrm{C} 1}=\mathrm{R1}$ at $\mathrm{f}_{\mathrm{u}}$
$\mathrm{Z}_{\mathrm{C}}$ 2 $=\mathrm{R} 2$ at $\mathrm{f}_{\mathrm{u}}$
$\mathrm{Z}_{\mathrm{C}} 3=\mathrm{R} 1$ at $\mathrm{f}_{1}$
$\mathrm{Z}_{\mathrm{C}} 4=\mathrm{R} 2$ at $\mathrm{f}_{1}$
$\mathrm{f}_{\mathrm{I}} \quad=\quad$ lower limit frequency (selected between approx. 100 Hz and 500 Hz )
$\mathrm{F}_{\mathbf{u}}=$ upper limit frequency (selected between approx. 2000 Hz and 10 kHz )

From this you can calculate a combined bass and treble control.

## PHASE DISPLACEMENT

Up to now we have said the impedance of a capacitor can be compared with a resistor at a certain frequency, but this is not all of it. Another factor to be taken into consideration

The projection of a circle forms a sine wave when the paper strip (projection) moves in the direction of $R$.

as far as voltage and current is concerned is phase displacement.
Fig. 19.11 shows a revolving circle projected upon a plane moving in the direction of $R$ (a strip of paper) and thus forming a sine wave. On adding another circle revolving at the same speed but on a different plane, we see a corresponding wave that is displaced in relation to the first one. The difference between them is called phase displacement. This can be expressed simply as the angular difference between the projection point of the first and second circle. The paper strip in the illustration shows a phase displacement of $90^{\circ}$, while $180^{\circ}$ would show exactly opposite waves, and if they represent two equal voltages they cancel each other.
If the phase displacement is zero the waves coincide.
With regard to voltage, the function of a transistor (common emitter coupling) is such that a positive change at base causes a negative change at collector. This characteristic is utilised for feedback purposes in that more or less of the negative output signal is sent back to input where it cancels (feedback) some of the positive input signal.
If in a special circuit the phase can be turned another $180^{\circ}$ for a certain frequency, the signal thus changing polarity due to the $180^{\circ}$ difference, being led back to input, the input signal will have positive feedback and not negative feedback.

If the positive feedback factor exceeds 1 , the circuit starts oscillating and is in fact a tone generator as shown in Fig. G 19.12.

Fig 19.12


A capacitor displaces the phase by $90^{\circ}$. R1/C1, R2/C2 and $\mathrm{RC} / \mathrm{C} 3$ form a 3-phase filter, as shown in Fig. 19.1. As the filters are affected by the adjacent resistors, the phase displacement of each filter is limited to approx. $60^{\circ}$. The three filters combined give $180^{\circ}$, and together with the transistor giving $180^{\circ}$, the result is $360^{\circ}$ which causes oscillation of the circuit if the transistor has enough gain to make up for the loss in the three RC combinations. The oscillation frequency depends on:

$$
F=\frac{0.07}{R \times C}
$$

Fig. 19.13

Wien bridge


## WIEN BRIDGE

A Wien bridge is actually a combination of a treble suppressor (C2) and a treble boost (C1) - see Fig. 19.13.

The components are based on one basic frequency at which the phase displacement is $0^{\circ}$. By means of two transistors a signal can be phase displaced $360^{\circ}=0^{\circ}$ which means that an oscillator can be made using a Wien bridge. This circuit is particularly suited as a tone generator because the frequency can be adjusted by using an ordinary stereo potentiometer (R1 and R2).
The crossover frequency is

$$
F=0.2:(R \times C)
$$

See AE7 for complete diagrams

## DOUBLE T-NETWORK

A double T-network can be used to filter out certain frequencies. It consists of three resistors and three capacitors. It damps effectively at a certain frequency, allowing other frequencies to pass.


Fig. 19.14
Double T-connection

Data: $\mathrm{R} 1=\mathrm{R} 2=\mathrm{Z}_{\mathrm{C} 1}=\mathrm{Z}_{\mathrm{C}}$ at the required frequency, and $R 3=2 R 1=Z_{C 3}$.
In practice this means that R3 is half R1 or R2, and C3 is twice C1 or C2.
It can be difficult to get this circuit to function as the component values must match one another exactly, and the input impedance of the following stage must be high.

Fig. 19.15


## PRESENCE FILTER

The circuit shown in Fig. 19.15 allows adjustment of the intermediate tone range. With a double T-connection inserted in the negative feedback path of the transistor, some of the heavy feedback can be removed from the middle tone range.
The forward gain factor is 1 and the presence gain is adjustable between 0 and +12 dB . The filter is rated at $4-5$ kHz .
The presence filter can be connected on either side of the tone control for adjusting the middle tone range.

## TONE CONTROL WITH AMPLIFICATION

This circuit also originates from ITT Schaltbeispiele 1972 see Fig. 19.16.
The transistor BC 173 B compensates the loss in the tone control, and BC 171 B raises the input level from tuner or tape (approx. 100 mV ) about ten times so that the output signal around 1 V is fed to an output amplifier.
Notice in the frequency curves that the upper and lower curves do not converge due to the mutual influence of the bass and treble controls. This influence would be more pronounced without the presence of the 1 kohm resistor.


Tone Control

Question 1.
Which tones does a capacitor couple the better?

| Bass | A $\square$ |
| :--- | :--- |
| Treble | B $\square$ |

Question 2.
Does a capacitor block the treble in circuit Fig. A or B?

Fig. $A$


Fig.B


Fig. A
Fig. B

Question 3.
We will now design a filter for bass boosting, amplification 10. First of all the whole signal level is lowered in the ratio of 10 , and then the bass is boosted, but not the medium and treble tones, to the initial: $\left(Z_{c}=R\right) R=10 \mathrm{kohm}$.

What is the required value of C to boost the bass from 160 Hz ?

| 680 nF | A $\square$ |
| :--- | :--- |
| 100 nF | B |
| 1000 nF | C |

Question 4
We wish to make an RC-oscillator of 530 Hz ,
A current of 1 mA must be fed to collector $(\beta=100)$ giving a base current of 10 uA .
With a battery voltage of $4.5 \mathrm{~V}, 0.5 \mathrm{~V}$ across the emitter resistor, and 2 V across the transistor, we find that there is 2 V across the collector resistor.
$\mathrm{R}_{\mathrm{C}}=\mathrm{E} 1=2 \mathrm{~V} 1 \mathrm{~mA}=2 \mathrm{KOhm}$
$\mathrm{RE}_{\mathrm{E}}=\mathrm{E} 1=0.5 \mathrm{~V} 1 \mathrm{~mA}=470 \mathrm{Ohm}$
There is 3.3 V from plus to base.
For stabilising purposes we choose a current in the base voltage divider 10 times greater than base current, i.e. 0.1 mA
This gives the following two resistors:
$\mathrm{R}_{\mathrm{B} 1}=\mathrm{E} 13.3 \mathrm{~V} 0.1 \mathrm{~mA}=33 \mathrm{KOhm}$
$\mathrm{R}_{\mathrm{B} 2}=\mathrm{E} 11.2 \mathrm{~V} 0.1 \mathrm{~mA}=12 \mathrm{KOhm}$
To attain the correct frequency, the other resistors in the RC-circuit must be approx. 10 kohm , as $\mathrm{R}_{\mathrm{B} 1}$ and $\mathrm{R}_{\mathrm{B} 2}$ in parallel.
' Which capacitor is required to get a frequency of 530 Hz ?

| 1 nF | A $\square$ |
| :---: | :---: |
| 15 nF | B $\quad$ |
| 1.5 nF | C |

## Question 5

We wish to remove a rumble frequency in a record player. The rumble frequency is 30 Hz , and R1, R2 must be 10 KOhm (and R3 $=5 \mathrm{KOhm}$ ).
Which capacitors must be used?

```
220 nF and 470 nF
470 nF and 1 }\mu\textrm{F
```

* Unpleasant rumbling noise that can be heard when playing records. The noise occurs in the motor, and its mechanical connection with the turntable and is sensed by the pick-up.


## ACOUSTIC COMPONENTS

Acoustic components convert mechanical oscillations to electrical ones and vice versa, the most important of these being microphones, loudspeakers, and pick-ups.
When we throw a stone into water we see that waves are formed on the surface. The same thing happens when we hear a sound. Sound waves (pressure waves) spread, and on hitting an object, the latter moves in step with the waves. The lighter the object the greater the deflection.

## MICROPHONES

A microphone converts sound to electricity. It can consist of a light diaphragm and a small coil that moves with the sound wave within a magnetic field. Voltages are induced and fed to an amplifier and a loudspeaker.

Microphones vary according to functions and characteristics, and they vary in price. Good microphones are normally of the dynamic type, while professionals use condenser microphones with variable characteristics.

Fig. 20.1 Condenser microphone


## CONDENSER MICROPHONES

The principle of condenser microphones is shown in Fig. 20.1

This type of microphone has the best frequency range, $20-20,000 \mathrm{~Hz}$, and a tolerance of $\pm 1 \mathrm{~dB}$ is not unusual.

A condenser microphone entails a polarising voltage of $100-400 \mathrm{~V}$ between plates. When the electrostatic field is
changed, the voltage across the plates varies also. Field variations occur through acoustic effect on the extremely thin diaphragm. The output voltage is usually in the region of $1-10 \mathrm{mV}$. As this type of microphone has a high impedance, it must be connected to a field-effect transistor amplifier (input impedance at least 100 Mohm ) placed in close vicinity of the cap ( $1-5 \mathrm{~cm}$ ).

This makes a condenser microphone an expensive business. The sensitivity characteristics can be changed from spherical to kidney shape via the polarising voltage.

Carbon microphone

Fig. 20.2


## CARBON MICROPHONES

Fig. 20.2 is a diagram of a carbon microphone. The carbon granules are loosely filled in a synthetic housing behind which is a metal cap. When the nickel or carbon diaphragm is activated acoustically, pressure variations which are followed by the diagram are transmitted to the granules. As the degree of packing alters, so does the electrical resistance of the device, and the current variations correspond to the original sound waves. The output voltage is from 500-1000 mV , which is enough for headphones without amplification. The frequency response is between approx. 400 and 2000 Hz with resonances around $\pm 10 \mathrm{~dB}$, i.e. 'telephone'' sound.

If the carbon microphone is to be used for transmitter modulation, for instance, there must be a bias current of approx. 10 mA .


## DYNAMIC MICROPHONES

The dynamic microphone is in construction very similar to its counterpart the loudspeaker - see Fig. 20.3.

A small coil is attached to an extremely thin diaphragm, the coil being placed in a magnetic field comprising a round permanent magnet core. The output voltage of a hi-fi dynamic microphone is $0.5-2.0 \mathrm{mV}$ max.

Fig. 20.4


## CRYSTAL MICROPHONES

The crystal microphone utilises the piezo-electrical properties of certain crystals in which mechanical stress due to sound waves is converted proportionally into electrical output which is approx. $1-10 \mathrm{mV}$ max. The sound quality is not very impressive, the frequency response being $200-3000 \mathrm{~Hz}( \pm 3 \mathrm{~dB})$ in typical types.

## PICK-UPS

Pick-ups convert the mechanical vibrations of a record groove into electrical impulses that are amplified. Among these are the crystal, ceramic, dynamic and photo-electric
types, the last two reproducing high-quality sound. The pick-up consists usually of a diamond stylus attached to a needle that activates a crystal or a magnet, whereas the photo-electric type functions differently.

Dynamic pick - up

stylus unit

Fig. 20.5

## ELECTRO-DYNAMIC PICK-UPS

Electro-dynamic pick-ups are those most widely used today due to their quality. Fig. 20.5 shows how a standard dynamic pick-up functions. In front of a permanent nagnetic armature with coil is a small ferrous cross-shaped art that when activated induces a voltage of approx. 2-8 IV max. at 1000 Hz .

Connection impedance of pick-ups in this group is between 2 and 50 kohms.

Quality is dependent on price, the expensive ones costing about ten times more than the cheapest. Some countries in the Far East, however, produce pick-ups at about a third of the European and American top prices for the same high quality. The frequency response of a good pick-up is $20-20,000 \mathrm{~Hz} \pm 3 \mathrm{~dB}$.

## CRYSTAL PICK-UPS

The piezo-electrical property of the crystal used here makes use of mechanical activation which is converted into electrical output that is max. $500-1000 \mathrm{mV}$ across 470 kohm impedance. A lower impedance reduces the voltage.

Fig. 20.6


The life of a crystal is limited to about two years because of the gradual drying-up process which causes a drop in voltage.

The frequency response is poorer and the distortion higher in a crystal pick-up compared with the dynamic type.

The ceramic pick-up (cartridge) is in principle similar to the crystal type while the quality and output voltage can be compared with the dynamic type (as well as the price).

Fig. 20.7


## OPTICAL PICK-UPS

One of the most exciting innovations in the field of pick-ups in recent years is the optical pick-up. By means of a light, or rather a light-emitting diode, an electrical output is created via a photo-transistor, a photo-resistor or a photo-cell.

As a photo-transistor easily produces a relatively high output voltage, this means up to 1000 mV without distortion and frequency linearity problems.

The high output voltage also means a lower noise level from an amplifier at 1000 mV compared with 5 mV sensitivity.


Fig. 20.8

## TAPE HEADS

Tape heads convert the weak magnetic recordings on tape to electrical output. See Fig. 20.8. The core of the head is of a permeable ferrous metal and shaped like an almost closed "U", the remaining gap being only 1-10 millionth part of a meter. The coil wound round the core usually has an impedance of 200 ohms. The output voltage is approx. $0.5-3 \mathrm{mV}$ max. at 1000 Hz .

Most tape heads produced earlier were of iron, but today they are superseded by improved tape heads in a glass/ferrite combination.

## LOUDSPEAKERS

A loudspeaker transforms electrical impulses into mechanical vibrations, i.e. sound. It consists of a diaphragm and a moving coil within a magnetic field, that is activated when a current passes through it.

If the diaphragm is large it can follow only at low frequencies, for instance up to 1000 Hz , but is nevertheless necessary for the bass reproduction.

A small thin diaphragm reproduces the high frequencies, an example of which is the Dome type that reaches $25,000 \mathrm{~Hz}$.

A complete set of speakers should reproduce from 20 to $20,000 \mathrm{~Hz}$. Several speakers must be employed, often three to cover bass, medium and treble tones. A cross-over unit (filter) is necessary to distribute the signal correctly among the speakers.


Fig. 20.9

One type of loudspeaker is based on the electrostatic principle and is similar in fact to the condenser microphone principle, but instead of receiving a voltage from it, a voltage is fed to it.

It is necessary to transform the voltage up to 8000 V which is one of the reasons why these loudspeakers are so expensive and uncompetitive.

## CROSS-OVER UNITS

As all tones are not reproduced with the same power in a loudspeaker, more than one speaker is used (often 3) where a speaker takes over the work another speaker cannot do. It is futile to connect three suitable speakers in parallel as there would be a waste of power in the two not functioning.


Fig. 20.12

We must use a cross-over unit (network) that sends the bass, medium and treble tones to their respective loudspeakers.

The figure shows how this is done.
The bass tones easily pass a small coil L1 that is big enough to block the medium and treble tones. The treble tones are quick enough to pass the small capacitor C1 that blocks the medium and bass tones.

Finally the medium tone is connected to a coil and capacitor in series, allowing only the medium frequencies to pass.

A reasonably good Hi -fi effect can also be obtained with only two speakers. The function is practically the same apart from the bass speaker covering the medium range, too.

The following components can be used, but experimenting is recommended to achieve the right sound.

B-loudspeaker: AD 1256/W4
M-loudspeaker: AD 5060/W4
D-loudspeaker: AD 0160/T4
$\mathrm{L} 1=6.4 \mathrm{mH}, 100$ turns 1 mm Cu wound on 10 mm dia.
$\mathrm{L} 2=1.2 \mathrm{mH}, 25$ turns 1 mm Cu wound on 10 mm dia.
C1 $=20 \mu \mathrm{~F}$, bi-polar
$\mathrm{C} 2=60 \mu \mathrm{~F}$, bi-polar
Cross-over frequencies approx. 500 and 2000 Hz .

An open speaker connot reproduce bass frequencies because overpressure at the front and underpressure behind causes a short - circuit.


Fig. 20.13

## LOUDSPEAKER DESIGNS

The loudspeaker cabinet is just as important as the loudspeaker. Only the correct cabinet gives the right sound. It is impossible to calculate the correct dimensions of a cabinet to produce the best sound under all conditions, so compromises must be found.

We can make a good speaker system by using two or three loudspeakers and a cross-over network, a large cabinet with a volume of at least 50 litres, and a good rockwool lining. The bigger the cabinet, the better the bass reproduction. An open speaker cannot reproduce bass frequencies because the low tones short-circuit themselves. If a loudspeaker were fitted on an infinitely great board it would produce the ideal sound.

To explain further why the bass frequencies short-circuit themselves, we see that when the bass speaker moves forwards there is overpressure at the front and underpressure behind. The overpressure extends to the edge of the speaker and equalises the underpressure at the rear. This means that the pressure wave does not move forward but short-circuits the bass range.

At high frequencies, the distance between waves is less and the pressure wave cannot spread around the speaker before the next one commences. By extending the edge of a speaker the tone must travel farther, reaching the rear perhaps when the speaker moves in the opposite direction. Overpressure meets overpressure without any undesired effect.

We can find the length of sound waves knowing the speed of sound and the frequency in question. The lowest audible frequency is 20 Hz , thus:

$$
\text { Frequency } \begin{aligned}
f & =\frac{300}{\text { wave length } \lambda} \\
f & =\frac{300}{\lambda} \text { therefore } \\
\lambda & =\frac{300}{f} \text { and in our example: } \\
\lambda & =\frac{300 \text { metres }}{20 \mathrm{~Hz}}=15 \text { metres }
\end{aligned}
$$

This distance indicates that from one overpressure to the next. As the phase difference of a speaker from front to rear is $180^{\circ}$, we must ensure that the speaker edge is $\lambda / 2$ metres away so that the distance to be covered by the lowest tone gives $180^{\circ}$ phase displacement to equalise the $180^{\circ}$ phase difference of the speaker.

As the sound extends to the upper and lower edges, the radius need only be $\lambda / 4$, or as shown in the calculations, 3.75 m.

Fig.20.14

Bass reflex cabinet


## BASS REFLEX CABINETS

Theoretically, the sound should cover a distance of 7.5 m , but this is unrealistic, of course. In practice, the cabinet is provided with a port or possibly a built-in labyrinth. This is

Measuring to determine the resonance frequency of a loudspeaker using a tone generator, a voltmeter, and a linear amplifier.
$R=4-16$ ohm


Fig. 20.15
called a bass-reflex cabinet. The port is often designed as a sloping box to ensure that the bass resonance covers a wider frequency range.

This type of loudspeaker system has been widely used for many years. The frequency response and efficiency are good, but the size presents a problem. A bass speaker having a lower cut-off frequency of 20 Hz is used in a reflex cabinet, and the cabinet must meet these requirements to resonate at 20 Hz . The best procedure is by experimenting, the resonant frequency being measured by means of a tone generator, an amplifier and an AC voltmeter according to the diagram above.

The amplifier and tone generator must, of course, be linear down to 15 Hz . At resonant frequencies of the cabinet or speaker the voltage decreases across R1. If the cabinet and speaker resonate at the same frequency, they will equalise each other and the base frequency range will become linear.

If the speaker resonant frequency is stated by the manufacturer, the resonant frequency of the cabinet is easily ascertained, it being the other frequency. If the speaker in the cabinet has a frequency of 40 Hz and the voltage-drop reading on the $A C$-voltmeter shows e.g. 40 and 80 Hz , the resonance of the cabinet is 80 Hz , and it must either be bigger, or it must be provided with a labyrinth or a port with box.

The reason for the voltage decrease across R1 is that the speaker has a higher impedance during resonance. This gives less voltage across R1.

A popular speaker system is the pressure chamber type, that even in small dimensions gives a fairly good bass response (used in bookshelves etc.). A pressure chamber speaker is designed with a special flexible diaphragm. The cabinet is
airtight, the enclosed air acting as a spring on the diaphragm. Together with a suitable filling of mineral wool etc. it gives quite good results. Even the smallest cabinets can produce excellent sound, but they cannot be compared with the reflex cabinet systems. The efficiency of a pressure chamber speaker is approx. $1-3 \%$ whereas a reflex cabinet system is in the region of $10-50 \%$. If a speaker having $1 \%$ efficiency is to reproduce a symphony orchestra naturally it would require 4000 W . In a normal room 400 W is enough at $1 \%$ efficiency. However, we can employ a $25 \%$ efficiency speaker with a 16 W output to achieve the same result, i.e. a fair reproduction of a symphony orchestra.

High quality speakers in a bass reflex system (e.g. Lansing) have an efficiency degree up to $30 \%$.

## HORN SYSTEMS

In horn systems the acoustical principle used in organ pipes is applied.

Dependent on its length, a pipe has a resonance frequency. If it is closed at one end the air compression vibrates heavily while the movement is practically negligible here, while at the other (open) end the compression is low and the movement great. If the speaker is placed at the closed end and has the same resonance frequency as the pipe, the diaphragm movement is braked by the resonance, resulting in a level frequency response of the bass.

There is considerable movement at the other end of the pipe at times, and if the edge of the open end is flared, the resonance frequency is spread over a wider range giving a rich bass tone. Efficiency approx. 50\%, depending on the speaker and enclosure.

It is difficult to design horn cabinets for very low frequencies ( 20 Hz ) because this theoretically entails a cabinet length of 16 metres and an aperture diameter of 4 metres!

An example of the horn speaker system:

Fig. 20.16
Example of a horn cabinet using a Philips speaker type AD 9710 M

$75 \times 40 \times 30 \mathrm{CM}$

The dimensions should be experimented with, the measurements here are for guidance only.

Question 1.
A man fires a cannon shot in the middle of a roundabout. At the four roads leading north, east, south, and west from the roundabout are a car, a large sheet of cardboard, a plate of sheet steel $1 / 8^{\prime \prime}$ thick, and sheet of aluminium foil. All four things are of the same size and all face north/south lengthwise. What moves most? The possibilities stated are in the order of less movement and are named by the four points of the compass.

NSEW
A $\square$
SNEW
B $\square$
WENS
WESN
$\mathrm{C} \square$
EWNS
D $\square$
E ロ

## Question 2.

Why is a dynamic microphone not fitted with a magnet on the diaphragm and the coil stationary?

| The coil is bigger than the magnet | A $\square$ |
| :--- | :--- |
| The coil is lighter than the magnet | B $\square$ |
| The coil has several windings | C $\square$ |
| It may have | D $\square$ |

Question 3.
What sets the limits in the frequency range of a microphone?

| A limited diaphragm | A $\square$ |
| :--- | :--- |
| The weight of the coil | B $\square$ |
| The magnet power | C $\square$ |
| The size of the coil | D |

Question 4.
Why does a single loudspeaker not reproduce all the frequencies?

| Not practical | A $\square$ |
| :--- | :--- |
| It would be too large | B |
| Low frequencies require large diaphragm <br> and the high a small one | $\mathrm{C} \square$ |
| So that factories can produce <br> more loudspeakers <br> Low frequencies must have more <br> power than high frequencies | $\mathrm{D} \square$ |
| 吅 |  |

Question 5.
Why is there an essential difference in the quality of pick-ups?

$$
\begin{array}{ll}
\begin{array}{l}
\text { Due to the method itself (the properties } \\
\text { of the crystal as against induction or } \\
\text { light variations). }
\end{array} & \text { A } \square \\
\text { A good crystal pick-up would be too } \\
\text { expensive }
\end{array} \begin{aligned}
& \text { The stylus of crystal pick-up is sturdier } \\
& \text { than that of dynamic or photo-electric }
\end{aligned} \quad \text { C } \square ~ \$
$$

## Question 6.

Why does the bass range give rise to difficulties in designing cabinets?

| The tone wavelength must be equal to |
| :--- |
| the distance from front to rear of |
| speaker, and the bass wave is |
| longest |
| There must be more space for the bass <br> sound waves <br> The sound of a bass tone is richer and <br> requires more space to sound correct |

Question 7.
Why are three different speakers often used in a cabinet?

| To get a greater power | A $\square$ |
| :--- | :--- |
| To extend the frequency range | B |

Question 8.
Which tones are reproduced by a Dome tweeter?

| High | A $\square$ |
| :--- | :--- |
| Low | B |

Question 9.
Is a coil in series with a bass loudspeaker used for

| To cut the treble | A |
| :--- | :--- |
| To feed the bass frequencies |  |
| to the bass speaker | B |



## FREQUENCIES AND WAVE LENGTHS

An antenna receives the radio waves transmitted from a radio station. For best results the antenna must be tuned to the transmission frequency.


Radio waves are electric (and magnetic) waves, that spread at the speed of light like rings in water (speed 3.108 m (the first wave movement in one second), $3 \times 10^{8} \mathrm{~m}=300,000$ km.

Dividing this distance by the number of waves, we get the single wave length:

$$
\lambda=\frac{300,000,000}{\mathrm{f}}(\mathrm{~m})
$$

f being the frequency and $\lambda$ (lambda) the wave length.
The formula is simplified by using $\mathrm{MHz} \lambda(\mathrm{m})=$

$$
\lambda=\frac{300}{\mathrm{f}(\mathrm{MHz})}(\mathrm{m})
$$

In a parallel oscillatory circuit the capacitor and coil are designed for a certain frequency. If the capacitor is folded out in rods as shown in the figure, we still have an oscillatory circuit sensitive to outer electric oscillations. The



Fig. 21.1 resonance frequency is given by the length of the rods, each rod being $1 / 4 \lambda$ long. This is a dipole antenna.

In medium and long waves, we must use earth as one of the poles and a few metres of wire as the other due to the size of the antenna.


TRANSMITTER $\longrightarrow$

## ANTENNA CONSTRUCTIONS

The main element of an antenna is the dipole. By adding a reflector and a director the sensitivity is greater (TV antennae).

The reflector is placed behind the dipole and reflects the signal while the director in front attracts it.

The reflector is behind the dipole to reflect the signal, while the director pulls in - see Fig. 21.2.

For good reception, definite distances and lengths must be used. The reflector must be fitted $1 / 8 \lambda$ behind the dipole, and must be $5 \%$ longer.

The first director must be $1 / 8 \lambda$ in front of the dipole and $5 \%$ shorter.

The distances and lengths of the following reflectors must decrease $5 \%$ successively.

The reflector and the first director give double response.
Every fourth director gives double response.
The greater the gain of an antenna, the more directional it becomes, and consequently the mounting becomes more critical.

Question 1.
What length is required in a $1 / 4$ wave antenna to receive Luxembourg on short wave (approx. 6 MHz )?

50 metres
A $\square$
12.5 metres

B $\square$
Question 2.
Calculate a dipole for 100 MHz . With a $1 / 2$ wave on the whole dipole, what is the total length of both $1 / 4$ wave rods?
1.5 metres

A $\square$
3 metres
B $\square$

## AM AND FM MODULATION

Radio waves are rapid electrical oscillations - high frequency. A "pure" radio wave without speech or music is called a carrier wave. The wave is necessary to carry a signal farther than it can be heard.

A pure radio wave is an "empty" station "saying" nothing. To transmit a signal, the form of a carrier wave must be varied, these variations being measured in the receiver. These variations in the carrier wave, also called modulation, can be heard as a signal from the transmitter.

A carrier wave can be modulated in different ways. Radio receivers are made to receive the two types we call AM and FM.

AM is an abbreviation of amplitude modulation, that is the high frequency varies in strength (amplitude) in step with the signal being modulated - see figures below.

FM - modulated carrier wave


Fig. 22.1

AM - modulated carrier wave


FM means frequency modulation, the high frequency varying in step with the signal, but the amplitude remains constant. The advantage gained by FM is the absence of sensitivity to noise, which is always generated as an AM modulation. On the other hand, FM transmitters occupy a wider frequency-band.

Nearly all ordinary radio stations with long, medium, and short wave bands to 30 MHz are AM modulated, while FM is used above 30 MHz . TV transmitters employ AM for the picture and FM for sound.

Those amateurs who wish to acquire a wider knowledge of this subject and other types of modulation are advised to contact their local amateur radio organisations.

Question 1.
When operating the scale of a radio a "dead" low-noise point is found, what is missing?

Carrier wave
A $\square$
Modulation
Question 2.
Why is FM better than AM?

## Less noise

Wider range
A $\square$
B

## A TRANSMITTER HAS TWO FUNCTIONS

A: To produce a high-frequency carrier wave to be broadcast (HF)

B: To modulate this carrier wave (HF) with low-frequency (LF).

Besides this there are certain demands to be met with regard to output power, frequency stability, degree of modulation, and the avoidance of undesired oscillations.

The output power must preferably be high enough to reach remote receivers.

The frequency, the point at which a station is to be found on the scale, must be extremely stable so that constant fine adjustments are unnecessary. It is also essential that the frequency of the transmitting station does not drift so much that inadvertent interference with other stations (perhaps of vital importance) does not occur.

Degree of modulation tells us something of the excitation level of a transmitter in the same way as a tape-recorder which must not exceed a certain recording level to avoid distortion.

Undesired oscillations is another important question to be considered, as a station can also transmit so-called harmonic oscillations that result in distortion, doubling and trebling the frequency, and so on. This means then that a walkie-talkie on 27 MHz , for instance, can cause interference on Channel 2 TV at 54 MHz .

## BLOCK DIAGRAM OF A SIMPLE AM-TRANSMITTER

Fig. 23.1 shows a diagram of an AM-transmitter for telephonic or telegraphic purposes.

A Oscillator to produce transmitting frequency (carrier wave)


Fig. 2

B Buffer to amplify the carrier signal
C Output amplifier to obtain sufficient output power
D Modulator to control the output power in step with microphone signal

E Power supply sending sufficient power to output stage and ensuring good stability so that the oscillator maintains its frequency.

Apart from the microphone modulator, the transmitter can be fitted with an ordinary telegraph key to switch the oscillator on or off..

## THE OSCILLATOR

To be approved by the Post and Telegraph Authorities (GPO) the oscillator in a transmitter must be crystal-controlled to ensure frequency stability, this being the only economical way to stabilise a transmitter. Other requirements must be met by radio amateurs who in their transmitters often have both crystal and LC oscillator controls.


To illustrate the function of a small AM-transmitter we have included a complete circuit shown in Fig. 23.2. At first sight it seems rather complicated, so try concentrating on one section at a time comparing it with the block diagram.

This transmitter is designed for 27 MHz . If you decide to build one of these we hasten to say that it might present certain difficulties in operation as considerable experience is necessary when working on high-frequency equipment. All wires must be as short as possible and the chassis must shield effectively. The transistor BC 172 serves as an oscillator, and is operated dc-wise like an LF (low-frequency) stage. The emitter resistance must be calculated after determining the current, in this case 6 mA . About half the battery voltage must be across transistor and coil, and the rest is across the emitter resistor, i.e. 6 V each with a 12 V battery. We now calculate the emitter resistance:

$$
R=\frac{E}{I}=\frac{6 \text { Volt }}{6 \mathrm{~mA}}=1 \mathrm{kohm}
$$

If the transistor current gain is 60 , the base current is:

$$
I_{b}=\frac{I c}{B}=\frac{6 \mathrm{~mA}}{60}=100 \mu \mathrm{~A}
$$

We choose a cross-current in the base resistances 10 times greater to ensure good temperature stability, this giving 1 mA .

We know that approx. half the battery voltage 6 V is across the emitter resistor, so the base voltage must be $6 \mathrm{~V}+0.7 \mathrm{~V}$ $=6.7 \mathrm{~V}$. As an approximation we can say that the base resistors share the battery voltage equally. $2 \times 6 \mathrm{~V}=12 \mathrm{~V}$. With 1 mA through the resistors we get:

$$
\mathrm{Rb}=\frac{\mathrm{E}_{\mathrm{B}}}{\mathrm{I}}=\frac{6 \mathrm{Volt}}{1 \mathrm{~mA}}=5.6 \mathrm{kohm}
$$

The oscillator now functions correctly dc-wise, and we want it to oscillate at 27 MHz . The tuned circuit is incorporated in the collector, and the frequency is determined according to the formula in section G14.

$$
\mathrm{fMHz}=\frac{159 \times 10^{-6}}{\sqrt{\mathrm{~L} \times \mathrm{c}}}
$$

and the quantities inserted are $\mathrm{pF}, \mu \mathrm{H}$ and MHz .
We must also calculate the coil as a function of dimensions and amount of turns. With a single layer open coil the following formula applies:

$$
\mathrm{L}_{\mathrm{H}}=\mathrm{n} \times \frac{10^{-2} \times \mathrm{D}}{\frac{\mathrm{~L}}{\mathrm{D}}+0.43}
$$

$\mathrm{L}_{\mathrm{H}}$ is the self-induction of the coil expressed in Henry, $\mathrm{n}=$ number of turns, $\mathrm{D}=$ coil diameter, and $\mathrm{L}=$ length of coil.


Fig 23.3

For 27 MHz we have found that $10-12$ turns 1 mm wire wound tightly and a trimming capacitor of $3-30 \mathrm{pF}$ are suitable. Final adjustments can be made by means of a coil core.

The collector circuit does not oscillate by itself so positive feedback must be employed. This is done by means of a separate winding with two turns. (10-20\% of the amount of collector turns). In this coil a current is induced (with a phase angle that gives positive feedback) and this current is amplified over and over again until the transistor is saturated. Then no current is induced in the feedback coil and the transistor is de-saturated, and the whole process is then repeated.

If the crystal is inserted as shown in Fig. 23.2, the transmitting frequency will be stable and coil and trimmer capacitance is merely adjusted to maximum output voltage.

## DIODE VOLTMETER

To find maximum adjustment of oscillator voltage, a diode voltmeter is necessary, see Fig. 23.4. It is effective and easily operated.

When a high-frequency voltage passes through the 47 pF capacitor, it is rectified by the diodes and filtered to a dc voltage by the 1 kohm resistor and 100 nF capacitor. The trimming potentiometer is adjusted to the required deflection on the scale. An ordinary inexpensive moving-coil meter serves the purpose.


## POWER STAGE

To prevent influencing the oscillator frequency when connecting an antenna direct, a buffer stage must be inserted. If the output power required does not exceed approx. 1 W , the buffer stage serves as an output stage, otherwise higher rated transistors must be used with corresponding couplings. Our combined buffer and output stage amplifies the oscillator output of approx. 50 mW up to $0.5-1 \mathrm{~W}$.

As the output stage is in Class C, in which only the most positive part of the high frequency is transferred, the output must be connected to antenna via a so-called $\pi$-unit which converts these peaks to sine-waves. The two trimming capacitors in the $\pi$-unit can be regarded as series connected across the coil with 10-12 turns, the calculations as for the oscillator coil.

The impedance coil with the 100 turns at the output transistor collector has been inserted to conduct dc and modulation voltages to the collector, but to block the high frequencies so that these are transferred to the antenna only. Emitter resistance of 27 ohm must be adjusted to obtain maximum output at lowest current consumption. Fig. 23.5 shows an excellent dummy antenna for use when trimming the transmitter. It consists of an ordinary filament lamp 6V - 50 mA , and a capacitor inserted between antenna outlet and chassis. When operating, the oscillator always has a slight transfer to output stage which is enough to cause the lamp to light weakly. The whole transmitter from oscillator to $\pi$-unit can now be trimmed, and if it functions correctly there is enough power to blow the lamp.


Fig. 23.5

Probe for output stage adjustment

The $\pi$-unit not only acts as a filter but it also has an impedance matching function. A transistor impedance of several hundred ohms is converted to 30-90 ohms, i.e. antenna impedance.

Final trimming is best carried out with antenna connected, and a receiver with an S-meter at one's disposal. The transmitter can then be adjusted to max. deflection of the meter.

Fig. 23.6


## MODULATOR

The modulator consists of a standard LF-amplifier such as the JOSTY KIT type AF20. This small output amplifier is connected to a modulation transformer - see Fig. 23.2 once more.

When the modulator operates, the secondary in series with plus and the output transistor, simply adds its positive half-cycles to the supply voltage and vice versa. If the transformer gives 12 V ac, the voltage to the transistor varies from zero to 24 V , and the output voltage on the antenna is as shown in Fig. 23.6.

## FM-TRANSMITTER

Fig. 23.7 shows an oscillator designed for frequencies exceeding 50 MHz . A BC172 transistor can be employed and the circuit is straightforward. At frequencies above 50 MHz , the transistor has a suitable phase displacement from collector to emitter to enable oscillation. As regards high
frequencies the transistor base is not active due to the shorting effect of the two 10 nF capacitors. On the other hand, low frequencies up to several kHz modulate the transistor base, utilising all the transistor gain in the LF range. This means that this oscillator can AM-modulate at base. If this circuit is used at 100 MHz FM , the results are excellent due to the FM-modulated oscillator.


Fig. 23.7

When AM-modulating in this way, the working point of the transistor is shifted and the inner capacitances changed, thus influencing the total tuning capacitance and consequently the frequency. See JOSTY KIT HF65 in the practical application section of this book.

If an FM-modulation of a VHF-oscillator only is required, we can look at the circuit in Fig. 23.8.

The oscillator itself functions in the same way as in Fig. 23.7, but the modulation is carried out with a capacitive diode. By changing the voltage across this diode up to 1 V as shown, the capacitance at the tuning coil varies and consequently the frequency - and only the frequency.

Further information concerning transmitters is issued by amateur radio organisations.


Fig. 23.8

Question 1.
What does a transmitter produce?

| LF | A $\square$ |
| :--- | :--- |
| HF | B $\square$ |
| Modulation | C $\square$ |

## RECEIVERS

A receiver has the following functions:

1. To amplify the extremely weak antenna signal
2. To convert the non-audible high-frequency signal to low-frequency
3. To amplify the low-frequency signal to audible level via loudspeakers or headphones.

To enable you to become thoroughly conversant with the function of receivers we now explain step by step the principle of an ordinary type of receiver.


Fig. 24.1

DIODE DETECTOR
Fig. 24.1 shows a diagram of a diode detector which has taken the place of the illustrious crystal set for beginners. The diode detector is an AM-receiver, and the circuit AE3 is designed for a special AM-band, i.e. medium wave.

Fig. 24.2


The tuned circuit L1 and C2 fixes the receiver frequency, C2 being adjustable to the required station. In general terms, this circuit is a blocking device. All transmitter carrier waves that do not have the same frequencies as the resonance of the circuit are led either through the capacitor or the coil to chassis. The modulated carrier-wave is illustrated in Fig. 24.2 by all the fine lines. The carrierwave falls and rises in amplitude (strength) in step with the modulation tone. C1 conducts the antenna signal from the antenna to detector and tuned circuit.

Fig. 24.3

The detector in our modern crystal set comprises a germanium diode, e.g. AA119, and a capacitor C3. The diode removes half the carrier-wave and modulation - see Fig. 24.3. The capacitor is rated to short-circuit the carrier-wave which is a high frequency, while the low-frequency modulation is not affected by C3, as the frequency is so low and the capacitor impedance high. The low frequency signal can thus slip through to the headphones without obstacles. After C3, the signal is as shown in Fig. 24.4, the amplitude being exaggerated slightly for illustration purposes. The diode detector is a straightforward design, but it needs a powerful antenna even to receive local stations. The weak signal of the diode detector can be amplified, however, but this affects its separation of


Fig. 24.4
stations. In the "good old days" an antenna amplifier was used on crystal sets to increase the signal to a level where a diode detector rectifies better. This receiver had many faults, for instance, difficult tuning.


## REGENERATIVE RECEIVERS

The diagram Fig. 24.5 shows a so-called regenerative receiver. The amplified signal from the antenna goes back to base via a tapping on the coil. This does not overload the circuit and gives greater selectivity.

HF current enters the transistor, and from emitter some is fed back to the tuned circuit and thus to base. The transistor works by itself and gives a powerful amplification. The selectivity is also improved. The right station runs through the circuit several times before it is damped while the wrong stations are damped immediately. The feedback must not be too strong as the circuit can act as an oscillator.

The feedback can, on purpose, be raised to such a high level that it causes oscillation, and a special form of modulation ( $\mathrm{SSB}=$ Single Side Band) can be received on amateur radio wave lengths.

Detection (rectification) also takes place in the transistor, so the LF can be taken direct from collector to the headphones.


## SUPERHET RECEIVERS

The full name of this type of receiver is the superheterodyne receiver, the block diagram. Fig. 24.6 showing its function principle.

The high frequency stage (HF) amplifies the received signal, and by means of a simple tuned circuit at input, undesired stations are suppressed.

The oscillator (OSC) in a tone generator with a frequency above or below the input signal.

The mixer (MIX) is non-linear and mixes the oscillator signal and received signal. This non-linear mixing process always gives two new frequencies, i.e. the sum of and the difference between oscillator frequency and received frequency, respectively. Non-linear mixture is in fact a "distortion mixing" just like a false note. The mixer output frequency is always the same irrespective of the station received.

The intermediate frequency amplifier (IF) is a tuned amplifier that has the special characteristic of amplifying only a narrow frequency band, i.e. that received from the mixing unit. For practical reasons, a standard frequency is used in all radios, AM 455 kHz , and $F M 10.7 \mathrm{MHz}$ (with minor exceptions).

Let us now take an example:

| Oscillator frequency: | 1500 kHz |
| :--- | ---: |
| Intermediate frequency: | 455 kHz |

The receiver frequency is both the sum of and the difference between 1500 and 455 kHz .

$$
\begin{aligned}
& \mathrm{R} 1: 1500+455=1955 \mathrm{kHz} \\
& \mathrm{R} 2: 1500-455=1045 \mathrm{kHz}
\end{aligned}
$$

These two frequencies would be received at equal level if the receiver frequency were not tuned in the HF stage. As these two frequencies are relatively far apart it is an easy matter with the aid of a tuned circuit as in the diode receiver, to eliminate one of them. The suppressed receiver frequency is let through at low level in the cheaper types of radios, however. The difference in strength between the station proper and the false one (image) is called image selectivity and is expressed in dB .

The detector is similar to the diode receiver detector and usually comprises one diode and one capacitor.

The low frequency stage has only to amplify the weak radio signal to loudspeaker level, as mentioned in Section G17.

We will now take an AM-receiver to pieces and describe each stage or unit separately, and then assemble it once more.

Fig. 24.7


## HF-AMPLIFIER

The HF circuit amplifies HF from antenna and the inserted tuned circuits choose the range of the required station.

Actually, the circuit shown in Fig. 24.7 is well-suited for antenna amplification purposes, its function being to amplify a single tuned frequency. The capacitor and coil at input form a tuned circuit. The coil is often wound directly on a ferrite rod which in itself is an antenna, no other antenna being required. In theory, a ferrite rod could also be used for TV and FM bands, but as the ferrite granules are not sufficiently fine to eliminate the eddy current loss, the ferrite rod can only be used up to approx. 5 MHz .

As the transistor is a heavy load on the input circuit, it is necessary to match the input circuit to attain good selectivity. Normally there is a tapping or a separate $10-20 \%$ winding on the primary side.

The transistor works on the common emitter principle, amplifying from base to collector. Resistances are calculated as in ordinary LF-circuits in which half battery voltage is across an emitter resistor which is by-passed to a capacitor to fully utilise the gain. In the output circuit, as in input circuit, the coil and the capacitor must be adjusted to receiver frequency. If the tuning is to be adjustable, the two tuned circuits must track.

The intermediate frequency amplifier greatly resembles the HF-amplifier shown in Fig. 24.7 except that the input and output circuits are permanently tuned to 455 kHz or 10.7 MHz . In AM, 455 kHz intermediate frequency circuits, two of these MF amplifiers are used.

In FM 10.7 MHz IF amplifier circuits, three or four are used. Also, the circuit just before the detector has an extra limiting function, i.e. to chop off the top and bottom of the signal so that frequency variations only are received. This is very practical since signal strength variations and noise are in fact an AM modulation which should be suppressed.


Fig. G 24.8

## OSCILLATOR AND MIXER

The mixer receives two signals - from the HF circuit and the oscillator. The IF is led via the first IF transformer in collector. The terminal AVC is for automatic volume control.

The circuit shown in Fig. 24.8 is a combined oscillator and mixer, this often also serving as an HF-stage by connecting the tuned circuit to transistor base as seen in Fig. 24.7. The HF-signal is amplified in the transistor. At the same time there is positive feedback of the signal from collector to emitter via the two small separate windings. Correct oscillator frequency is achieved by providing the oscillator coil with an extra winding which combined with a variable capacitor constitutes a tuned circuit.

The input signal is mixed with the oscillator frequency, and only the received signal which mixed with the oscillator frequency is equal to 455 kHz is amplified by the IF amplifier.

This combined oscillator, mixer, and HF-stage is calculated dc-wise like an LF-stage in which the emitter voltage is half the battery voltage.

Fig. 24.9


## AM-DETECTORS

Two different types of detector are used in AM and FM. All AM detectors can be simple diodes or transistors. A diode detector is shown here. The LF signal is produced in the same way as in a diode receiver by rectifying and filtering the IF signal and led out to the right as in Fig. 24.9 In addition to this there is a dc voltage across C2 that is proportionate to the average IF signal strength, i.e. transmission signal strength. This dc voltage can be used for automatic volume control (AVC) as it is fed back to the mixer resulting in less amplification. This means that a powerful station is amplified less and a weak station more,
sounding more or less equal in volume. By applying a meter at C2, the deflection shows us the strength of the station. S-meters are used for walkie-talkies.


## FM-DETECTORS

The FM detector is more complicated - let us see how it functions. The detector illustrated here is the Foster-Seeley type. At a certain frequency (resonant frequency of the tuned circuit) there is no voltage on the terminals. Frequencies above or below give positive or negative voltages. (S-curve).

As the FM signal frequency varies according to the transmitted signal, the terminals change to positive or negative as does the LF signal.

It also has a mean voltage depending on how accurately the itation is tuned on the scale. If it is accurate, the negative and positive signals are equal. If the medium frequency of the station is displaced in relation to the detector, it will lean to one side.

This function can also be used in automatic frequency control (AFC). If the capacitor C4 is charged by the mean terminal voltage, we can control a pair of varactor diodes in tuning. Inaccurate tuning will be rectified via a voltage across C4. Varactor diode tuning is relatively simple.


Fig. 24.11

## MECHANICAL IF FILTERS

To improve the selectivity of a receiver, we can either use several IF transformers or insert special filters, three of which we mention here.

The mechanical filter is based on the principle of a metal rod vibrating at medium frequency in the same way as a water pipe emits a tone when struck. A short rod gives the IF unit a tone. A magnetic rod is fitted with a coil at each end, one of which is connected to the IF signal and the metal rod starts vibrating at IF. When the other end vibrates in its coil a signal induction occurs that is the same as the original IF signal. As the rod has a limited frequency interval only a small part of the frequency range gets through.

## CRYSTAL FILTERS

The crystal filter is also based on mechanical vibrations, the quartz crystal vibrating in the IF unit. The crystal is placed between two plates, and at a very limited frequency interval, the impedance between the plates is very low. The interval, in fact, is too narrow, but the difference in resonance between the two crystals enables a frequencyband to pass. We thus get a sharply defined frequency range.


Fig. 24.13


## CERAMIC FILTERS

The ceramic filter, not to be confused with a crystal filter, is gaining ground in competing with the other types due to its high quality and low price. The operating principle is the same as the crystal filter, but the ceramic filter is wider in range and is more suitable for the MF.

## CAPACITIVE (VARACTOR) DIODE TUNING

The variable tuning of HF circuit and oscillator includes nowadays varactor diodes. When a varactor diode is fitted and biased in the direction of blocking, it acts as a small capacitor. By varying the blocking voltage, the capacitive value is changed. By means of a potentiometer, the HF circuit and oscillator can be tuned simultaneously. The advantage of a varactor diode is mainly that it is smaller and much lighter than a variable capacitor. Varactor diodes do not use power.

## COMPLETE MEDIUM WAVE RECEIVER

The diagram Fig. 24.14 is from Mullard, a British company of the Philips group, and shows a medium wave receiver incorporating three transistors. This receiver is a combination of the three units mentioned earlier, i.e. combined mixer, HF-amplifier, and oscillator - intermediate frequency (IF) amplifier - AM detector. The detector diodes are biased to give a good automatic volume control (AVC) of the first IF stage. Note the resistor to base current here. The AVC is used to prevent high level receiver signal from overdriving the IF unit which can result in distortion.


This receiver is comparatively easy to build as many different Japanese complete coil units are available these days.

Question 1.
If a transmitter sends a signal that varies in amplitude and frequency, is it?

| AM | A $\square$ |
| :--- | :--- |
| FM | B $\square$ |
| FM + AM | C $\square$ |

Question 2.
On which points are superheterodyne receivers superior compared with other types?

Price
A $\square$
Quality of sound Selectivity
Amplification (sensitivity)
Simplicity (amount of components)
Operation

Question 3.
Is intermediate frequency
variable?
A $\square$
permanent?
B $\square$

Question 4.
Is intermediate frequency determined by
The mixer
A $\square$
HF-circuit
B $\square$
Question 5.
Which components can be used to determine the frequencies in a receiver?

Ceramic filters
A $\square$
Resistors
B $\square$

Fig. 25.1


## MONO

In mono sound reproducers there is a loudspeaker system and one amplifier. The sound comes from one place only and the listener feels no perspective or third dimension in sound. The difference in sound waves registered by the ear is converted to a sense of direction in the brain.

Fig. 25.2


Loudspeaker B
Loudspeaker A

STEREO
When recording a sound to reproduce a degree of spaciousness, two microphones must be employed representing the two ears. The recording keeps both channels separated as far as possible.

The signal is recorded on a disc or a tape where the channels are kept separate. Reproduction requires two combined monaural systems. Technically speaking, this means that the reproduction system must be doubled to achieve stereo. However, we do not use two of everything. To simplify the operation of stereo, the amplifier and control panel are combined in one. A stereo potentiometer is a double one electrically, but it is combined mechanically.


Fig. 25.3

QUADRO
In the latest stereo technique, four channels are used. There are four tracks on the recording tape for the four channels, and there are four channel amplifiers, speakers and microphones.

This might seem to be a sales "gimmick", but the four channel system does add something to stereo because the human ear not only registers left and right but also front and rear sounds. We never look in the wrong direction when we hear a plane in the sky, for instance.

## IATRIX PRINCIPLE

There are several ways of achieving a four-channel stereophonic or quadrophonic sound, the simplest being, of course, to devote each of four tape recorder tracks to four separate channels. But how is this to be applied to gramophone records or FM-radios?

A number of possibilities have emerged from radio equipment manufacturers showing that there is a tendency away from the ideal four-channeltape recorder reproduction. It appears that various versions of the matrix system have gained ground. An American by the name of David Haffler has patented a system in which a unit and two extra

speakers are added to existing stereo equipment - see Fig. 25.4. To understand this system we must consider the possible influences on the output amplifier when, for instance, $A$ is positive and $B$ negative - there would be a voltage drop at $A+B$ across speaker $C$. A being positive and $B$ negative, the voltage across speaker $C$ is $A-B$. We show in schematic form all the possible output voltages to all speakers.

AMPLIFIER

| A | B | A | B | C | D |
| ---: | ---: | ---: | :---: | ---: | ---: |
| +1 | -1 | +1.5 | -1.5 | +2 | 0 |
| +1 | +1 | +0.7 | +0.7 | 0 | +2 |
| -1 | +1 | -1.5 | +1.5 | +2 | 0 |
| -1 | -1 | -0.7 | -0.7 | 0 | +2 |

By inserting a variable shunt resistor across speaker $D$, and a series resistor in speaker $C$, these constants can be modified, this being the "secret formula" of individual manufacturers.

Parts list (all resistors 2 W )
by 4 ohm by 8 ohm by 16 ohm

| R1 | 4.7 | Ohm |  | Ohm | 15 Ohm |
| :---: | :---: | :---: | :---: | :---: | :---: |
| R2 | 8.2 | Ohm | 15 | Ohm | 33 Ohm |
| R3 | 15 | Ohm | 33 | Ohm | 68 Ohm |
| R4 | 33 | Ohm | 68 | Ohm | 120 Ohm |
| R5 | 0.3 | Ohm | 0.3 | Ohm | 1 Ohm |
| R6 | 0.3 | Ohm |  | Ohm | 1 Ohm |
| R7 | 0.3 | Ohm | 1 | Ohm | 2.2 Ohm |
| R8 | 1 | Ohm | 2.2 | Ohm | 4.7 Ohm |
| R9 | 1 | Ohm | 2.2 | Ohm | 4.7 Ohm |
| R10 | 1 | Ohm | 2.2 | Ohm | 4.7 Ohm |
| R11 | 1 | Ohm | 2.2 | Ohm | 4.7 Ohm |

Fig. 25.5 shows a matrix unit inserted between a stereo amplifier and four output amplifiers to avoid undesired impedance changes in output amplifiers.

The "pre-amplifier method" has the added advantage of varying the constants by simply changing a few small resistors.

SANSUI in Japan have patented a system of phase displacement and a slight tremulous effect on both rear speakers.

In general terms, the matrix system means a reduction in channel separation to max. 10 dB , compared perhaps with 40 dB tape recorder level ( $10 \mathrm{~dB}=3 \mathrm{x}, 40 \mathrm{~dB}=10 \mathrm{x}$ ).

The American company "Victor" have developed a gramophone record (disc) with a pilot tone, a system used in radio stereo, but instead of converting one channel to two channels, two channels are converted to four channels.

Finally we would mention that a two-channel or four-channel stereo system is of no use unless the quality is hi-fi, and unless the system is correctly installed. A good example of this can be heard at some discotheques where the loudspeakers are placed so badly that the stereo effect leaves much to be desired.


Question 1.
How many output amplifiers are necessary to obtain stereophonic reproduction?


Question 2.
Would you use two balance knobs in a four-channel stereo system, and two or four volume controls?
$\begin{array}{ll}2 \text { balance knobs } & \text { A } \\ 4 \text { volume controls } & \text { B }\end{array}$
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## OSCILLOSCOPES

An oscilloscope is an instrument that shows a curve representing the wave-form of an alternating voltage as a function of time, the main component being the cathode ray tube.


## CATHODE RAY TUBES

The cathode ray tube consists of a filament (f) and a cathode that when heated emits a narrow beam of electrons, as well as a number of grids that can vary the strength and focus (sharpness) of the electron beam, deflection plates and an anode.

The cathode ray tube is under vacuum, and when plus is applied to the anode, and minus to the cathode, the slectrons flow from the cathode to the anode. The grids mnsure a narrow beam of electrons. When the beam strikes the fluorescent screen it can be seen as an illuminated spot. The electrons flow from the screen to the anode. By varying the negative control grid (g1) the strength of the electron beam is varied. Too much negative grid stops the electrons completely. Applying voltage to g2, that acts like a magnifying glass on light, the focus or sharpness is adjusted.

The deflection plates in the cathode tube guide the path of the screen spot. There are two vertical and two horizontal plates placed at right angles to each other. A positive voltage applied to a plate attracts the beam and vice versa. The spot on the screen can be moved to any point in this manner. Let us now compare with the block diagram.


Fig. 26.2

## AMPLIFIERS

A potentiometer is placed at each input to adjust the level. Then there is an amplifier that raises the low measuring voltages from a few mV to approx. 300 V , this being the required deflection plate voltage to deflect the beam.

The Y-amplifier in the oscilloscope raises the very weak voltages to control voltage level. The amplifier is often either double or differential so that the operating temperature does not affect the ray position. The X-amplifier, keeping the ray horizontal, is usually coupled with a saw-tooth generator.

A saw-tooth generator gives a voltage that increases to a certain level and then drops to zero immediately. When the generator is applied to the X-plates, the spot on the screen moves evenly from left to right, and then jumps back and repeats this. No signal at $y$-input is seen as a line on the screen. When a signal is applied the electron beam moves up and down. We thus get a wave-form that can be analysed as the signal at input.

The saw-tooth voltage rise period can be adjusted oscillations up to 12 MHz can be seen without the use of a sampling oscilloscope.

Question 1.
What is the function of an oscilloscope?
To show a wave-form as a function of time
A $\square$ To measure current
To show a picture

Question 2.
Which point in the cathode-ray tube emits electrons?

| The grid | A $\square$ |
| :--- | :--- |
| The anode | B $\square$ |
| The cathode | C $\square$ |

Question 3.
What happens when the vertical side of the saw-tooth generator is not perpendicular?

A circle appears
A $\square$
A part of the wave-form returns to itself, because the fly-back trace becomes visible

B

As this subject is a very wide one we will only deal with the main principles here - there is much technical literature available.
The cathode ray tube is the heart of a television receiver. It contains an electron gun of the same type as described under the oscilloscope, but it has no deflection plates. The deflection of the beam is carried out by means of electro-magnets assembled in a so-called deflection coil found at the neck of the tube.

TV-transmitters send the following to receivers:

1. Black/white (image) level
2. Line synchronising
3. Frame synchronising
4. Sound
5. Colour information

Fig. 27.1


The signal transmitted is picked up by the antenna and sent to the tuner. The tuner chooses the required channel. It is then amplified in the IF amplifier. Part of the signal is fed to the sound IF amplifier where it is FM detected, amplified and sent to the loudspeaker.

The other part of the IF signal is detected according to the AM method by means of a single diode, resulting in an LF signal containing the image signal.

The low frequency signal sent to the picture tube includes line, frame and black/white signals, also called video signals.

A special circuit separates the line and frame synchronising pulses and leads the signal to the deflection coils. 25 frames a second are formed, each comprising 625 lines.

As the cathode tube operates at high voltage, the TV receiver has a high voltage generator that supplies 16,000 to 25,000 volts. The generator is operated by the line output circuits. The simpler functions of a TV receiver can be seen in the block diagram. Besides the 'blocks" there are circuits for image stabilising etc.

The high tone always heard on TV is 15.625 Hz which together with a 50 Hz tone controls the 625 lines.

Question 1.
What does an oscilloscope tube contain that is not found in a TV tube?

```
Grids
Deflection plates
A \(\square\)
Cathode
B \(\square\)
C ロ
```

Question 2.
What does not have to be transmitted to obtain a correct TV image?

| Line synchronising | A $\square$ |
| :--- | :--- |
| Sound | B $\square$ |
| Black/white image | C $\square$ |

Question 3.
Which frequencies are separated in a TV receiver?

| 4000 Hz | A |
| :--- | :--- |
| 625 Hz | B |
| 50 Hz | C |

## TAPE RECORDERS

The principle of a tape recorder is the conversion of electrical current to magnetism on a tape.

## TAPE

On being played the magnetism of the tape induces an electric signal, see Fig.28.1.

Tape recorders have redording and playback heads, i.e. electromagnets containing a thin gap, approx. $5 \mu \mathrm{~m}$.

The tape is plastic, coated with ferromagnetic powder. The use of chrome dioxide improves the noise/signal ratio by $2-6 \mathrm{~dB}$ and has the same magnetic qualities.

## RECORDING

When recording, an electric signal forms a magnetic signal in the electromagnet. When the tape passes the gap some of the magnetic flux affects the magnetic coating of the tape.

## PLAY-BACK

When playing, the varying magnetic field in the tape passes the gap in the playback head. Part of this field enters the electromagnet inducing a signal in the coil. This is then amplified to loudspeaker level.

## FUNCTION

The motor or motors play an important part in conveying the tape in either direction and via a capstan to attain a steady tape speed. Various devices are used to ensure a taut tape.

A constant operating speed is essential as the slightest variation ruins the sound reproduction. This phenomenum is called "wow' and is expressed percentually, and later in

this section we explain how wow is measured. Before recording, the tape must be erased by passing the erasing head on the tape recorder. It is principally the same as a recording head. A high frequency is applied to it to attain uniformity in magnet direction. The erasing head is situated in front of the other head and is normally switched on automatically. Besides the required signal, a bias signal is also sent to the recording head. The bias has a high frequency, and helps to increase the quality (cuts distortion). A new system is to have a special bias head that is fitted opposite to the recording head, the bias field crossing the signal field thus improving the cut-off frequency and cutting distortion. The system is called "crossfield" the upper cut-off frequency being 1.5 times higher by comparison. The Japanese firm AKAI has patented this method and the Norwegian company Tandberg manufacture same under licence in Scandinavia, see Fig.28.1.

The playing and recording heads are often combined. When they are separate there is the possibility of monitoring the quality during recording. There are many recording tricks such as multiplay, echo, reverberation, etc.

## CONTROL PANEL

The control panel can be quite complicated covering such things as amplifier regulation, tape wind control, switch between record and play and tape speed.

## TRACKS

Tape recorders can be single or double track - in some cases there are four tracks.

In double track tape recorders, half the tape width is used for recording. By reversing the tape (still with the ferrous side facing the heads) the other half can be used.

The four-track systems halves this width again. Tracks 1 and 3 are played one way and tracks 2 and 4 the other. This gives double playing time, but there is a greater risk of noise. Two tracks at a time are played in stereo recordings, which also necessitates double-heads.

A new technique employs the whole tape width for four-channel recordings giving an extended stereo effect.

## MAINTENANCE

Tape recorders must be cleaned regularly, mechanically and electrically.

The mechanical cleaning includes wiping the recording head surfaces with ether and cotton wool and the electrical cleaning is done by means of an induction coil. It creates a powerful alternating magnetic field to remove accumulated magnetism. It must be moved around the recording heads and slowly removed to a distance of about two or three metres and then switched off.

Wow is measured in the following way: A hum signal from a plug outlet is connected to the tape recorder input via two capacitors 5 nF . The hum signal is played on the recorder, this being fed into one side of a meter. Flutter is caused by rapid speed variations, while wow is due to slow variations.

Again we get a signal from a plug outlet and feed it into the other side of the meter. It must be a frequency meter or tachometer type. The voltage read is proportional to the wow.

If the wow is low, which is the case in most tape recorders, an ordinary ac meter can be employed - the amount of deflections per second being measured. One deflection per second should be the maximum.

Question 1.
What is tape made of?

| Aluminium foil | A $\square$ |
| :--- | :--- |
| Colour coated plastic | B $\square$ |
| Plastic coated with ferromagnetic powder | C |
| Steel | D $\square$ |
| Paper | E $\square$ |

Question 2.
Which features are better in 4-track systems compared with double track?

| Distortion | A $\square$ |
| :--- | :--- |
| Noise | B $\square$ |
| Wow | C |
| Playing time | D $\square$ |

Question 3.
How much of the tape is used in a stereo recording on a double track recorder?

| full tape width | A $\square$ |
| :--- | :--- |
| half tape width | B $\square$ |
| third tape width | C $\square$ |
| quarter tape width | D |

## FITTING

It is important when working with electronics to acquire practical skill. If you fully understand the functions of an amplifier, for instance, and the correct use of components, it is a great pity if it proves faulty because of bad soldering or bad connections.

Most soldering these days is done on printed wiring boards, i.e. a printed circuit on an insulating board consisting of copper strip connections to the individual components and holding them in position. The position of components is fixed and the necessary holes in the board are provided for fitting.


Fig. 29.1

Printed wiring board

## PRINTED CIRCUITS

Making your own printed wiring (circuit) boards is both interesting and instructive, but patience is required in preparation, placing components and drawing the board.

## MASKING METHOD

By following these simple rules, anyone can make a PWB from a piece of surplus board, see Fig. 29.1.

Scrub the copper side of the board with scouring powder until the copper is bright. Apply a layer of self-adhesive plastic (self-adhesive vinyl decorating film) suitable on the copper and smooth out any air blisters. Draw the diagram on the plastic layer using carbon paper if necessary. Using a very sharp knife or razor blade, cut out strips around the conductors or component connections. After removing these thin strips, dip the board in a bath of $50 \%$ ferrochloride ( Fe Cl 3 ) etching solution. When heated to $60-100^{\circ} \mathrm{C}$ the process takes about five or ten minutes. Avoid touching the ferrochloride or splashing on clothes as it is a strong etchant. When the etching process is completed, rinse the board under a water tap and remove the remaining layer of plastic and the circuit board is ready for use after drilling the necessary holes.

Fig. 29.1a


Component correctly fitted

## PAINTING METHOD

Special masking paint for PWB's is available in many places. The paint is applied on the copper side on areas that are to conduct (wiring) between components. Dip the circuit board in a $30-50^{\circ} \mathrm{C}$ ferrochloride etching solution, rinse, and drill holes and it is ready for fitting components. The painting method is easy, but it is difficult to get results as good as the professional circuit boards.

## PHOTO-RESIST METHOD

The leading photo film manufacters make a light-sensitive varnish that can be used on the copper side of PWB's. This enables one to make circuit boards in the same way as contact prints are made by photographers.

First of all, draw the whole circuit board as required, then mask the board with drawing ink or a special masking tape which is black, completely opaque, very flexible and made specially for the purpose (soldering lands and complete integrated circuit combinations are also available). This work is usually done in a size that is double or four times that of the actual print size, and then reduced to required size in the form of a negative film. A positive print is then made and placed on a PWB with photographic emulsion. it is then exposed to ultraviolet light for approx. 10 minutes.

A sun-ray lamp can be used for this purpose at a distance of one meter from the PWB. The wiring pattern is now hardened, leaving only the developing process using the recommended developing liquid according to the emulsion used. Finally there is the ferrochloride etching process as described earlier, and the result is a professional product.

A fully automatic silk-screen process is used when the amount of PWB's required exceeds about a hundred.

## CUTTING PWB's

The fibre-glass printed wiring board must be cut with a sircular saw or a fretsaw - shears and cutting machines can also be used, of course. This Pertinax PWB is a crude-oil product and becomes very soft when heated to $60-100^{\circ} \mathrm{C}$ when it is easily cut without cracking. High-speed drills are best for drilling circuit boards, preferably at high speeds from 10-40,000 r.p.m.

Follow these simple rules when fitting components on a printed wiring board. (PWB). Bend the component leads so that they fit the holes in the PWB. Place components on the non-copper side as close to the PWB as possible. Cut the leads from 2 to 5 mm on either side of board and solder.

Use a hot, well filed, clean and tinned soldering iron. Make sure that the iron is in contact with the copper strip on the PWB and the component lead, and use 2-5 mm tin solder. Do not remove the soldering iron until the solder flows on the PWB like water on a sponge. This takes about 3 or 5 seconds using a $20-50 \mathrm{~W}$ iron. Use special electronic solder containing flux and not other types.

Soldering tin MULTICORE and FLUITIN are recommended.

CAUTION - Do not use flux fluid, soldering paste and the like as they can cause damage that cannot be repaired. If you require practice, use an old PWB and wire until you master the technique.

## MECHANICAL FITTING

The mechanical fitting of electronic equipment is just as important as the electrical. This is not just to maintain the quality but it is also a necessity for good functioning. Don't build a bird's nest in a cigar box when the design is already planned, such as a kit.

Note the following points when assembling amplifiers, meters etc.

1. Always use a sturdy metal chassis, 2-3 mm aluminium, for instance.
2. Always place pre-amplifiers as far away as possible from transformers, power-packs, switches and their leads to avoid hum. If necessary use a shield, preferably magnetic materials such as steel.
3. Fit the individual units by using 3 mm screws and nuts in all holes not forgetting spacers of $6-8 \mathrm{~mm}$ (metal tubing).
4. Remember only one connection from individual circuits to common, and only one common point in the middle of the chassis. Use a screw and several soldering lugs.
5. Always use heavy wiring from a power unit to an output amplifier and not ordinary wire.
6. Use screened wiring from input terminals to the first amplifier stage and connect one end of screen only to common on the chassis.
7. Insert the necessary RC-filter in the plus wire between the individual amplifier stages.
8. Ensure effective cooling of output transistors.
9. Always keep leads as short as possible.
10. Insert fuses wherever possible to avoid fire risk.
11. Insulate and screen all live parts to protect meddlesome onlookers.

## COMPUTERS AND DATA PROCESSING

Computers are the biggest electronic devices ever produced. A medium sized computer contains between 50,000 and 100,000 transistors, even more diodes and a corresponding number of resistors and capacitors.

The equipment as a whole is extremely complicated, but a closer look reveals a series of simple circuits repeated over and over again.

## FLIP-FLOPS

The most important circuit is that called a bi-stable multivibrator or a flip-flop. The unit comprises two transistors that work symmetrically in two states - T1 conducts a current while T2 blocks a current or vice versa.

When T1 conducts a current the collector voltage is approx. 0.4 V which is not sufficient to supply base current to T2 as at least 0.5 V is necessary. When T2 receives no base current, there is no collector current either, and the collector voltage is high. T1 base can then conduct current and the circuit is stable. The opposite state is stable too as the circuit is symmetrical.

Fig. 30.1


By applying a negative impulse to the base that conducts current, it stops conducting for a moment and the collector voltage rises. The other transistor then receives base current, and the collector current causes collector voltage to drop, blocking the base current to the first transistor. This then is the opposite state. Due to the two diodes as shown in the diagram, each negative impulse reverses the state, hence the name flip-flop (to and fro). The capacitor is used to speed up the regenerative switching action and to control same.

As a great amount of flip-flops are used in calculating machines, counters, and other digital equipment, groups of them are integrated in small 14 and 16 pin plastic units. As the integration can also incorporate numerous semiconductors, it increases functional stability tremendously.

Circuits 7473 and 7474 both include a double set of flip-flops.

IC 7490 incorporates four flip-flops and some gates that can be coupled for decade counters (10-counters).


Fig. 30.2

See practical applications AE 4 and 5.

## ASTABLE MULTIVIBRATORS

This is a tone generator that produces a square wave. We can regard it as a combination of two monostable circuits in which the impulses are sent from one to the other via the capacitors.

The resistors try to make the transistors conduct full current, but the tendency of the T1 collector to drop in voltage is transferred to base of T2 so that it conducts less current. The rising collector voltage in T2 causes T1 to conduct full current thus cutting-off T2. This state is partially stable as R2 keeps T2 base current-free. C1 is charged by R3 and voltage starts to appear at T2 base. The transistors switch over, but the state is still not stable as C2 is now charged. Oscillation occurs at a frequency determined by:
$f=\frac{0.7}{R \times C} \quad \begin{aligned} & R \text { being base resistance and } C \text { the transfer or coup- } \\ & \text { ling capacitor }\end{aligned}$
The resistors must be rated so that the base current is sufficient to bring the collector to zero. In theory R2 $=\beta \mathrm{x}$ R1 but rate $20-30 \%$ lower to be on the safe side. R1 depends on collector current and supply voltage. The capacitor is finally calculated according to the required frequency.

We choose the collector current. The collector current must give a voltage drop equal to supply voltage at this current. There must be sufficient current to base to give correct collector current. This is determined by the total resistance in base line. If the current gain is 100 and the supply voltage 4.5 V , and the required collector current 0.4 mA we get:
$\mathrm{Rc}=\frac{4.5 \mathrm{~V}}{0.4 \mathrm{~mA}}=11 \mathrm{kohm} ;($ choose 10 kohm$)$
Necessary base current $\frac{0.4 \mathrm{~mA}}{100}=4 \mu \mathrm{~A}$
The total resistance in base line:

$$
\mathrm{R}_{\mathrm{b}}=\frac{4.5 \mathrm{~V}-0,7 \mathrm{~V}}{4 \mu \mathrm{~A}}=\frac{3.8 \mathrm{~V}}{4 \mu \mathrm{~A}}=\text { approx. } 1 \mathrm{Mohm}
$$

We choose 1 Mohm as the nearest standard value, always remembering to choose a lower standard value unless the nearest higher one is very close. For instance, 660 kohm required, choose 680 kohm - 630 kohm required, choose 560 kohm, etc.


Fig. 30.3

See practical application AE 6

## MONOSTABLE MULTIVIBRATOR

If one of the base resistors in a flip-flop is connected to plus instead of to the other collector, we get a monostable multivibrator. The circuit is stable with T1 conducting and T2 blocked, as T2 gets base current via R2. C1 can suppress T1 base temporarily. This occurs when we trigger the circuit via D. A negative impulse steals the base current and collector voltage drops.

C1 transfers the voltage drop preventing base current to T1. This state with T1 blocked and T2 conducting lasts until R2 has charged C1. T1 then conducts base current once more, collector voltage drops and blocks T2.

The result is then that a negative impulse switches the circuit at a time that is determined by the C2 charging period: $t=R \times C \times 0.7$. R2 must supply sufficient base current to exceed 0.4 V on T 1 collector. There must be ample ratings. R1 and R3 must give base current to T2. We see that the collector currents must be chosen first. We thus have base current as collector current divided by current gain (plus $20-30 \%$ extra). When the supply voltage is given, we can calculate the resistances. A wave form of any shape will be converted to square wave form having a clearly defined height and width.

## SCHMITT-TRIGGER

A Schmitt-trigger converts all analogous signals to digital signals. When the input voltage of a Schmitt-trigger reaches a certain level a triggering action takes place at output. The output voltage does not return to its original value until the input voltage level falls below the certain level mentioned.

The difference between these two input levels is termed "'hysteresis".

The left transistor is blocked and the right one conducts at low input voltage, so the output voltage is thus equal to the voltage divider output between the collector and emitter resistances, 1 kohm and 100 ohm, in this case approx. 1.1 V.

When the input voltage rises to a level above the voltage across the emitter resistor plus the left transistor base/emitter voltage, it starts conducting. The collector voltage then falls to a point where no base voltage/current reaches the right transistor. The output voltage now jumps to almost the same level as supply voltage. When the right transistor stops conducting, the current in the common emitter resistor decreases, and consequently there is a voltage decrease across the emitter resistor.

If the input voltage is equal to the voltage across the emitter resistor, the Schmitt-trigger is activated quickly, because only the left transistor base/emitter voltage has to be overcome. The input is thus more sensitive.

Fig. 30.4

Schmitt - trigger


The Schmitt-trigger output can also control another NPN-transistor via a resistor of 1 to 10 kohm.

## COUPLED LOGIC CIRCUITS

With four flip-flop circuits we can make a digital counter that can count to 16 . The two states of the flip-flop 1 and 0 enable us to obtain 16 different combinations in four circuits. The diagram shows that both collectors in each circuit are led out one of them marked 0 and the other 1 , the state of the circuit being determined by the most positive lead.

We can split the combination with the help of diode sets so that a transistor conducts current only when there is a certain combination at outlets. The diodes are coupled in such a way that it is only when all diodes receive positive blocking voltage that the transistor conducts current, otherwise the base current would flow through the base resistor to the negative voltage diode. The figure shows an example, a diode gate with three outlets from three flip-flop circuits - 8 possibilities in all. They are activated by the combinations 111, 010, and 001. With a combination of diode gates, flip-flops and monostable multivibrators, the impulses can be directed to certain points in a device for adding or subtracting and the whole process can be remote controlled by means of punched cards or tapes. The


Fig. 30.5

Flip - flop

impulses can also be magnetically stored in small ferrite rings for later use. These are the basic principles of a computer, also called a Central Processing Unit (CPU).

The development of integrated circuits has increased enormously and their applications too, of course. Mass-production has now led to a great decrease in prices. Special literature on this subject is mentioned elsewhere.

For home use, impulse circuits can be for timing, digital instruments, remote control and electronic music boxes.


## TIPS ON CALCULATION

If you can count apples and divide a cake, you are already way ahead in the art of arithmetic and mathematics. We know, of course, that you remember what you were taught at school, we only want to make sure that you don't place the decimal point incorrectly and ruin a set of expensive transistors!

If you have two apples and buy three more, you have five, of course. The total resistance of resistors connected in series is simple addition, too. $10 \mathrm{kohm}, 15 \mathrm{kohm}$, and 22 kohm give 47 kohm.

If you have two large plumcakes to be divided equally among five persons, what does each one get (apart from a stomach ache)? Two divided by five is $2 / 5=0.4$ cake.

Here we work with decimals.
Let us now put pieces of a cake together. 30 people have $1 / 8$ cake - how many cakes in all?

X cakes $=30 \times 1 / 8$
$\mathrm{X}=30 / 8=36 / 8=33 / 4$ cakes
Now we want to assemble a wedding cake that is three times as high as the others using the same pieces of cake mentioned above.
$3 \times$ cakes $=30 \times 1 / 8$
$3 X=30 / 8$
$\mathrm{X}=30 /(3 \times 8)=10 / 8=5 / 4=11 / 4$ wedding cakes

We see here the most important rule concerning fractions:
WHEN INTERCHANGING FIGURES ACROSS AN EQUA-
TION MARK DO IT DIAGONALLY TION MARK DO IT DIAGONALLY
or in other words, if the figure is above the fraction line on one side, it can be placed below the fraction line on the other.

Remembering the rule when dividing by fractions, multiply the opposite, e.g.
$\frac{2 \times 3 \times 2}{2 \times 2 \times 2}=\frac{3 \mathrm{~A} \times 4}{8} \quad 3 \mathrm{~A} \times 4 \times(2 \times 2 \times 2)=2 \times 3 \times 2 \times 8$
$12 \mathrm{~A} \times 8=12 \times 8 \quad 12 \mathrm{~A} \times 12 \times \frac{8}{8} \quad 12 \mathrm{~A}=12 \quad \mathrm{~A}=\frac{12}{12}=1$ and we have worked out the value of $A$

We can add to fractions if they have a common denominator, but how do we add $1 / 4$ cake and $1 / 8$ cake? The bigger piece $-1 / 4-$ must be cut into two halves, i.e. two $1 / 8$ cake. We now have three pieces of $1 / 8$, altogether $3 / 8$. Another example $-1 / 3$ and $1 / 4$ cake. This time it is not enough to cut one of the pieces - we must cut them both. $1 / 3$ cake is cut into four pieces giving twelfths. The $1 / 4$ cake is cut into three pieces, i.e. three twelfths. We have in all then $7 / 12$ of a cake.

We must find a common denominator when dealing with different fractions
$\mathrm{x}=\frac{1}{3}+\frac{3}{2}$
$\mathrm{x}=\frac{2 \times 1}{2 \times 3}+\frac{3 \times 3}{3 \times 2} \quad$ (we muliply by $\frac{2}{2}$ and $\frac{3}{3}$ )
$x=\frac{2}{6}+\frac{9}{6} \quad$ (we get the same denominator)
$x=\frac{11}{6}=1 \frac{5}{6} \quad$ (we can work out the answer)

Do not think that all figures are simple in the subject of electronics. There are values in which there are many noughts before or after the decimal point, so instead of using figures we use a certain letter to indicate the amount of noughts. The letter is combined with the basic unit.

## NOMENCLATURE

We see examples in our daily life, for instance at the greengrocer's. We buy potatoes in a bag marked 2500 g . This can be abbreviated to $2.5 \mathrm{~kg}(21 / 2 \mathrm{~kg})$ because 1000 g $=1 \mathrm{~kg}$. A "' k ' means a thousand times the unit concerned. The other letters used are:

$$
\begin{array}{cl}
\frac{1}{1,000,000,000,000} & =10-12=1 \mathrm{p} \text { called pico } \\
\frac{1}{1,000,000,000} & =10-9=1 \mathrm{n} \quad \text { called nano } \\
\frac{1}{1,000,000} & =10-6=1 \mu \quad \text { called micro } \\
\frac{1}{1,000} & =10-3=1 \mathrm{~m} \quad \text { called milli } \\
1 & =100=(\text { the power of } 0 \text { defined thus }) \\
1,000 & =10^{3}=1 \mathrm{k} \\
1,000,000 & =10^{6}=1 \mathrm{M}
\end{array}
$$

## POWERS

$10^{-12}$ (negative power). The use of powers saves calculation and writing work.

We can simplify the expression by subtraction or addition because we can multiply two tens raised to a power by adding the powers.

The following case can be reduced to give an example - try writing it fully and see how many noughts are required.

$$
\mathrm{x}=\frac{10^{-15} \times 2 \times 10^{-3}}{10^{-8} \times 10^{3} \times 10^{12}} \quad, \frac{\text { numerator }}{\text { denominator }}
$$

Above the fraction line:

$$
\begin{aligned}
& 10^{15} \times 2 \times 10^{-3}= \\
& 10^{15} 3 \times 2= \\
& 10^{12} \times 2
\end{aligned}
$$

below the fraction line:

$$
\begin{aligned}
& 10^{-8} \times 10^{3} \times 10^{12}= \\
& 10^{12}+3-8= \\
& 10^{7}
\end{aligned}
$$

Then the equation:

$$
\mathrm{x}=\frac{10^{12} \times 2}{10^{7}}
$$

This is a tricky equation, but we can transfer the power from numerator to denominator or vice versa by changing the sign in front

$$
x=\frac{10^{12} \times 2}{1}=2 \times 10^{5}=200,000=200 \mathrm{k}
$$

Remember!
WHEN A FIGURE IS CHANGED FROM DENOMINATOR TO NUMERATOR OR VICE VERSA, AND THERE ARE NO REMAINING FIGURES, THE RESULT IS ONE AND NOT NOUGHT.

It is impossible to divide by 0 .

Get started on the questions and increase your self-confidence. The first ones are easy, but they become harder as you go along.

Question 1.

$$
\frac{1}{4}+\frac{1}{4}=?
$$

| $\frac{1}{8}$ | A $\square$ |
| :--- | :--- |
| $\frac{1}{4}$ | B $\square$ |
| $\frac{1}{2}$ | C $\boxtimes$ |

Question 2.

$$
\frac{1}{4}+\frac{1}{8}=?
$$

$$
\frac{2}{8}
$$

$$
\mathrm{A} \square
$$

$$
\frac{3}{8}
$$

$$
\mathrm{B} \square
$$

$$
\frac{4}{4}
$$

Question 3.

$$
\frac{3}{4}+\frac{4}{16}=?
$$

$$
\frac{16}{4}
$$

Question 4.

$$
A+\frac{A}{2}+\frac{A}{6}=
$$

$\frac{10 \mathrm{~A}}{6} \quad \mathrm{~A} \square$

Question 5.

$$
\begin{aligned}
\mathrm{x}=\frac{1}{\mathrm{~A}}+\frac{1}{14 \mathrm{~A}}+\frac{1}{7 \mathrm{~A}}+\frac{11}{14 \mathrm{~A}} & x & =\frac{2}{\mathrm{~A}} & \mathrm{~A} \square \\
& x & =\frac{A}{2} & \mathrm{~B} \square
\end{aligned}
$$

Question 6.
We can also include the constant $\pi$ in the formula, the value of $\pi$ being 3.14. We insert values for $f$ and $Z$ e.g. $f=100 \mathrm{~Hz}$ and $Z=1$ Mohm.

C can be found: $C=2 \pi \times f \times Z$

$$
\frac{1}{2 \times \mathrm{fxZc}}
$$

Which is the correct capacitor?

| 15 nf | A $\square$ |
| :--- | :--- |
| 1.5 nF | B $\square$ |
| 6.28 nF | C $\square$ |

## COLOUR CODES

Colour coding is a good way of marking components. Both manufacturers and consumers find it advantageous. The colours can be seen from all angles while numbers are often hidden from view. Even if some of the paint peels off a colour code, we can nearly always determine the value of a component. All the normal wattages of resistors (1/10-2 W) are colour coded. The same applies to ceramic and polystyrene capacitors. Different types of other capacitors in the range $10 \mathrm{pF}-1 \mathrm{uF}$ as well as all electrolytic capacitors are marked with figures, however.

Colour codes are coloured bands around a component, and up to five colours are used on each. First of all we must find the significant figures of the bands. If a wire is led out at both ends (always applies to resistors) the colours are placed at one end and we begin with the outer band. In capacitors the leads are often at the bottom. We start numbering from the top. (the other way round with NTC resistors).

The bands have the following significance. The three first one indicate ohms or pF . The fourth tells us the tolerance (manufacturer's guarantee for the accuracy limits). The fifth (on capacitors only) gives temperature information. The first three code bands are used both on capacitors and resistors except the values x 0.1 and 0.01 . There are different codes for tolerances except 1 and 2 which are brown and red respectively. Temperature coefficients apply only to capacitors.

Colour 1st band 2nd band 3rd band 4th band

| BLACK | 0 | 0 | $\times 1$ |
| :--- | :--- | :--- | :--- |
| BROWN 1 | 1 | $\times 10$ |  |
| RED | 2 | 2 | $\times 100$ |
| ORANGE 3 | 3 | $\times 1,000$ |  |
| YELLOW 4 | 4 | $\times 10,000$ |  |
| GREEN 5 | 5 | $\times 100,000$ |  |
| BLUE | 6 | 6 | $\times 1.000,000$ |
| VIOLET 7 | 7 |  |  |
| GREY | 8 | 8 |  |
| WHITE 9 | 9 |  |  |
| SILVER |  |  | $\times 0.000,000$ |
| GOLD |  |  | $10 \%$ |
| NO BAND |  |  | $5 \%$ |



Not all values are obtainable, only the so-called international standards in the same way as the colour code is international. The standard values are based on the principle that there is a $20 \%$ difference between a certain value and the next higher one. Starting off, for instance with 1 ohm, the standard values are as follows: $1 \mathrm{ohm}, 1.2$ ohm, 1.5 ohm, 1.8 ohm, 2.2 ohm, $2.7 \mathrm{ohm}, 3.3 \mathrm{ohm}, 3.9 \mathrm{ohm}, 4.7$ ohm, $5.6 \mathrm{ohm}, 6.8 \mathrm{ohm}, 8.2 \mathrm{ohm}$, and 10 ohm . This list of values is called the E12 series. The same applies in the next groups $10-100$ and $100-1000$ and so on. A 25 ohm resistor is not available, the nearest being 22 ohm and 27 ohm. Colour coded capacitors have the same standard values as resistors.
A couple of examples to explain the system. We have a resistor marked yellow, violet, red and silver. This gives 4,7 , 00 , and 10 - that is, 4700 ohm $/ 10 \%$. A capacitor is marked
 blue, grey, orange, white, and black. The values are 6,8 , $000,10 \%$ and temperature classification we won't worry about here. The capacitor then is $68,000 \mathrm{pF} / 10 \%$ or 68 $\mathrm{nF} / 10 \%$.

## DROP-SHAPED TANTALUM CAPACITORS

A special colour code applies to drop-shaped tantalum capacitors.
This type of capacitor is being used to an increasing extent
 in modern electronic circuits, so we include the special IEC and DIN 40820 standards concerned.


A closer look at the drawing of the drop-shaped tantalum capacitor shows that the first and second bands indicate the first and second values of the capacitor. The spot, besides indicating the polarity, shows the 10 -power by which the two first values must be multiplied to obtain the capacitor values in $u F$.
The first two bands/digits indicate the normal colour code from black, brown, red etc. to white, from 0 to 9 , whereas the multiplicator spot shows the following:

| Black | x 1 |
| :--- | :--- |
| Brown | x 10 |
| Grey | x 0.01 |
| White | x 0.1 |

Special marking indicating rated voltages of the capacitors apply, starting with the colour nearest the pins:

| White | 3 V |
| :--- | :--- |
| Yellow | 6.3 V |
| Black | 10 V |
| Green | 16 V |
| Blue | 20 V |
| Grey | 25 V |
| Pink | 35 V |

As the drop-shaped tantalum capacitor must be correctly polarised in relation to positive and negative, it is provided with a spot on one of the sides.
This spot also indicates the multiplication factor (10th power).
When holding the spot of the capacitor towards you, the pins pointing downwards, the RIGHT pin is the POSITIVE polarity.

Question 1.
What is the data of a resistor with brown, black, red and gold bands?

| 100 ohm $/ 5 \%$ | A |
| :--- | :--- |
| 1000 ohm $/ 10 \%$ | B |
| 1 kohm $/ 5 \%$ | C |
| 10 kohm $/ 10 \%$ | D |
| 10 kohm $/ 5 \%$ | E |

Question 2.
What is the data of a resistor with orange, white, orange and silver bands?

| 390 ohm $/ 10 \%$ | A $\square$ |
| :--- | :--- |
| 37 kohm $/ 10 \%$ | B $\square$ |
| 3.1 kohm $/ 10 \%$ | C $\square$ |
| 31 kohm $/ 10 \%$ | D $\square$ |
| 39 kohm $/ 10 \%$ | E $\square$ |
| 3.9 kohm $/ 10 \%$ | F |

Question 3.
What is the data of a resistor with gold, yellow, violet and yellow bands?

| 4.7 ohm $/ 4 \%$ | A |
| :--- | :--- |
| $47 \mathrm{kohm} / 20 \%$ | B |
| 470 kohm $/ 5 \%$ | C |
| 4.7 kohm $/ 20 \%$ | D |

Question 4.
\& capacitor has the colours green, blue, brown, white and slack. Ignoring the temperature code, what are the values?

| $560 \mathrm{pF} / 10 \%$ | A |
| :--- | :--- |
| $650 \mathrm{pF} / 10 \%$ | $\mathrm{~B} \square$ |
| $560 \mathrm{nF} / 10 \%$ | $\mathrm{C} \square$ |
| $560 \mathrm{uF} / 10 \%$ | $\mathrm{D} \square$ |
| $560 \mathrm{~F} / 10 \%$ | $\mathrm{E} \square$ |
| $6500 \mathrm{pF} / 10 \%$ | $\mathrm{~F} \square$ |

Question 5.
Which is the correct value of a capacitor marked orange, red and black?

| $33 \mathrm{pF} / 50 \%$ | $\mathrm{~A} \square$ |
| :--- | :--- |
| $33 \mathrm{pF} / 20 \%$ | $\mathrm{~B} \square$ |
| $32 \mathrm{pF} / 20 \%$ | $\mathrm{C} \square$ |
| $3300 \mathrm{pF} / 20 \%$ | $\mathrm{D} \square$ |



## FUSE

This sign is like a resistor but with a through line and a dot in the middle. The value is often stated above it. In the component list a fuse is often denoted " S " plus a number.


## RESISTOR

The letter R and following number


## POTENTIOMETER

The letter P and following number. Often shown as a resistor with an arrow pointing inwards.

## VDR-RESISTOR

The letter R and following number. VDR means Voltage Dependent Resistor and is shown with a black diagonal half.


## LDR-RESISTOR

The letter R and following number. LDR means Light Dependent Resistor and is shown as an ordinary resistor plus an arrow at each end.


## NTC/PTC-RESISTOR

The letter R and following number. NTC and PTC mean negative and positive temperature coefficients, respectively, and are temperature dependent. Shown as an ordinary resistor but with a double diagonal arrow added. P or N is usually written but when omitted means NTC in most cases.


## TRIMMING POTENTIOMETER

The letter P with following number. A trimming potentiometer is shown as an ordinary resistor with a diagonal trimming line.

## CAPACITOR

The letter C with following number. A capacitor is shown as two thick parallel lines at right angles to the leads. This sign is used for the following capacitor types: ceramic, polyester, oil, paper, rolled, pin-up and metal-paper.


TRIMMING CAPACITOR
The letter C with following number. Shown as an ordinary capacitor with diagonal trimming line.


## VARIABLE CAPACITOR

The letter C with following number. Shown as an ordinary capacitor with diagonal arrow.

## CAPACITIVE (VARACTOR) DIODE

The letter D with following number. Shown as a combination of a capacitor and a diode. Belongs to the semiconductor component group, but is used as a tuning capacitor.


## ELECTROLYTIC CAPACITOR

The letter C with following number. Shown as an ordinary capacitor but with one thick line unfilled. This line indicates the plus. None of the other types of capacitor is polarised.


## OPEN (AIR) COIL

The letter L with following number. Shown as a series of windings.

## COIL WITH IRON CORE

The letter L with following number. Shown as a coil with a parallel line along the round part of the coil. If a trimming line is shown, it is a variable coil.
Moving coils are not standard.


## PNP-TRANSISTOR

The letter T with following number. Shown as a circle with vertical base line and diagonal collector and emitter leads. PNP-transistors with minus to collector, the arrow enters the transistor at emitter.


## NPN-TRANSISTOR

The letter T with following number. Shown in the same way as an PNP-transistor except that the arrow is reversed and there is plus to collector.

## UNI-JUNCTION TRANSISTOR

The letter T with following number. Shown as an ordinary transistor but with connections shown at right angles.


## FIELD EFFECT TRANSISTORS

The letter T with following number. An FET is drawn like a UJT but the emitter E is now a $\mathrm{G}=$ gate.

MOST
The letter T with following number. A transistor with three base lines, i.e. drain, bulk and source. The input is called a gate.


## DUAL GATE MOST

The letter T with following number. This is the same as MOST except there is an extra gate. This transistor has the qualities of a valve heptode plus the excellent power features of a transistor.


## INTEGRATED CIRCUIT

The letter IC with following number. The triangular arrow indicates the direction of amplification. An integrated circuit can include 14 terminals or more.


## DIODE

The letter D with following number. Shown as an arrow at the lead with right angular blocking line. The current flows positive in direction of arrow only.

## ZENER DIODE

The letter D with following number. Shown as diode above with an extra stroke on the blocking line.


## CONTROLLED RECTIFIER, SCR (THYRISTOR)

The letter D with following number. Shown as a diode with a diagonal stroke from blocking line. This indicates the control gate.


## DIAC

The letter D with following number. Shown as two combined opposite diodes in a circle.


TRIAC
The letter D with following number. Shown as a DIAC with control gate added. TRIACS often have built-in DIACS.


AMPEREMETER
The letter $M$ with following number. Shown as a ring surrounding an " A ".


VOLTMETER
The letter M with following number. Shown as a ring surrounding a "V".


## WIRING

All wire connections shown as lines. When wires cross each other without connection, one of the lines is broken, while connected wires are shown with a dot.


## EARTH CONNECTION

Vertical line with three diminishing horizontal lines. Symbol G.


COMMON (CHASSIS) CONNECTION
Vertical line with a thicker horizontal line at bottom.


LOUDSPEAKER
Symbol with following number. Shown as a conical figure on a rectangular base.


## HEADPHONES

Symbol.

## MICROPHONE

The letter M with following number. Shown as a circle and tangent vertical line.

## PICK-UP

Symbol PU with following number. Shown as a circle with right angular stroke through the circle.


## RELAY

The symbol RE with following number. Shown as a rectangular figure with lines twice as thick as a resistor. The contacts are also shown, and are always in the no-load position, the make contact indicated by an open arrow and the break contact by a filled arrow.


## LAMPS

Symbol GL with following number. A diagonal cross in a circle.

BATTERY
The letter B with following number. Shown as alternate long and short strokes at right angles to the lead. The short stroke indicates plus if not otherwise stated.

## SLIDING SWITCH



The letter O with following number. Shown as dots with the connections established and leads.


ROTARY SWITCH
The letter O with following number. Shown as dots and arrow indicating position.


## ANTENNA

The symbol ANT with following number. AM antenna is shown as a vertical line with a "brush" on top. FM antenna or dipole shown as two thick angular lines.

## Feedback G1

1. A. No - you probably meant well, but we expressly said the atom nucleus, not the atom.
B. Yes, but it also contains neutrons which you probably know. Try Question 2.
C. This is the right answer. The atom nucleus contains both protons and neutrons. Proceed to Question 2.
2. A. Quite correct. Electrons travel from surplus (-) to deficit (+). Proceed to next text or the last question of G2 if you feel confident.
B. No, the electrons travel from surplus (-) to deficit $(+)$. Continue with text G2.

Feedback G2

1. A. Correctly answered. Stationary electrons cannot move while the loose electrons or spaces (holes) can. Proceed to Question 2.
B. It is not the impurity that moves. In pure silicon there is a separation of atoms and electrons. The atom has eight electrons in the outer shell which makes a very stable bond. The impurities make room for electrons or enter the surplus electron holes. Try Question 2.
2. A. This is not correct - generally speaking. There are holes or lacking electrons in P material. An electron that travels finds a hole after a time and "disappears", Wee will return to this subject later.
B. Correct. Electrons travel for a time before finding a hole and then it is no longer free. Read on about current and voltage. We will return to the subject of semiconductors later.
C. No, there isn't enough space. There are many spaces or holes that the electrons find. When this happens the electron is no longer free. Proceed to next subject concerning current and voltage.

Feedback G3

1. A. No, $10^{19}$ is not the same as $10^{18}-$ it is ten times greater. $6 \times 10^{19}$ is ten times greater than $6 \times 10^{18}$ and the current is thus 10 amps. Try Question 2.
B. 1 A is $6 \times 10^{18}$ electrons per second. However, $6 \times 10^{19}$ is ten times greater. At $6 \times 10^{18}$ the current is 1 A . It must then be 10 A at $6 \times 10^{19}$ electrons per second.
C. Correct. If you feel conversant with the nomenclature, i.e. the relationship between powers and symbols (letters) proceed to Question 3 or start Question 2.
2. A. Starting point $1 \mathrm{~A}=6 \times 10^{18}$ electrons per sec., 6 x 1015 has three noughts less than 1018 . We have a current that is a 1000 times less than 1 A . The current is thus $6 \times 1015=1 \mathrm{~mA}$. Try Question 3.
B. This is correct. The subject of powers isn't so hard, is it! Try Question 3.
C. Not good at all. As $6 \times 1018$ is equal to $1 \mathrm{~A}, 6 \times$ 1015 must be equal to 1 with the decimal point placed correctly. As $6 \times 1015$ is a 1000 times less, the corresponding current must be a 1000 times less, i.e. 1 mA . If you understand this completely, proceed to Question 3 or study the section on powers, T1.
3. A. The current flows from a higher voltage to a lower one. From 10 V it goes to 0 , and then to -7 V . The electrons that travel the other way travel from -7 to +10 V. Proceed to Question 4.
B. Correct. The voltage drops in the order $10 / 0 /-7 \mathrm{~V}$ and the current flows from 10 to -7 V . We asked about the direction of the electrons which is opposite. You answered correctly because the flow of electrons is from -7 to +10 V . Try Question 4.
C. If all the electrons flowed from o, a positive voltage would occur which is wrong. The flow of current is

- always from higher to lower voltage, that is from +10 V to -7 V . However, we asked about the direction of electrons which is opposite that of current. This means that the flow of electrons is from -7 to +10 V. Proceed to Question 4.
D. The current goes from 10 V to -7 V . The electron flow runs the other way, that is from -7 to +10 V . Proceed to Question 4.

4. A. $3 \times 450 \mathrm{~V}$ is 1350 V . To convert to kV divide by 1000 and the result is 1.35 kV . This is correct so proceed to Question 5.
B. When connecting batteries in series, the voltage is the sum of the separate battery voltages. This also applies here. The total voltage is $3 \times 450 \mathrm{~V}=1350 \mathrm{~V}$. Your answer was wrong, yet the decimal point was placed correctly. 1000 V is 1 kV which means that 1.35 kV is the same as 1350 V. Proceed to next question.
C. You have found the correct figure but the decimal point is placed incorrectly. $3 \times 450 \mathrm{~V}=1350 \mathrm{~V}$ and a 1000 V is the same as 1 kV , i.e. $1350 \mathrm{~V}=1.3 \mathrm{kV}$. Try Question 5.
D. You have converted 450 V direct to kV . When connecting voltages in series, each separate voltage must be added, so we get 1350 V , or 1.35 kV . Try the next question.
5. A. Something is wrong here. Perhaps you have forgotten that two batteries connected in parallel 100 mA each give 200 mA . Together with another parallel connected battery, the total current is 2200 mA or 2.2 A . Proceed to the section on capacitors, G4.
B. Perhaps you were guessing. When connecting in parallel, the currents must be added together, i.e. $2000 \mathrm{~mA}+100 \mathrm{~mA}+100 \mathrm{~mA}=2200 \mathrm{~mA}$ or 2.2 A . Proceed to the section on capacitors, G4.
C. You have found the correct answer. Try the last question in the next group or start with the text.
D. When connecting in parallel, the batteries give a higher current. The total current we can obtain is the sum of the individual batteries: $2000 \mathrm{~mA}+100 \mathrm{~mA}$ $+100 \mathrm{~mA}=2200 \mathrm{~mA}$ or 2.2 A. Proceed to next group.
6. A. The distance from all the surrounding things is great, and a key is usually small. Both give a low capacitance. Before proceeding to the next group, read the last four lines of the text.
B. Correct. Size, distance and air that insulates indicate a low capacitance. Proceed to G5.
C. Neither size nor distance should make us think that the capacitance is high. Proceed to the section on capacitors, G5.

## Feedback G5

1. A. Yes, quite correct. Proceed to Question 3.
B. Wrong answer. Perhaps you calculated with series connections. When capacitors are parallel connected, the capacitances are added, i.e. $0.5 \mu \mathrm{~F}+0.5 \mu \mathrm{~F}=1$ $\mu \mathrm{F}$. Try Question 2.
C. Wrong. The capacitance is not 10 times greater when connecting parallel, as the individual capacitances must be added, i.e. $0.5 \mu \mathrm{~F}+0.5 \mu \mathrm{~F}=1 \mu \mathrm{~F}$. Proceed to Question 2.
2. A. Wrong. When parallel connecting capacitors, the individual values must be added. In series connection we see:

$$
\frac{1}{\mathrm{C} 333}=\frac{1}{\mathrm{C} 1}=\frac{1}{\mathrm{C} 2}+\frac{1}{\mathrm{C} 3}
$$

As the resulting capacitance is 333 pF we then have $\frac{1}{333}=\frac{1}{3 \mathrm{C}}$ as $\mathrm{C} 1=1 \mathrm{nF}$, and three are used. Proceed to Question 3.
B. Quite correct. Continue to Question 3.
C. Wrong answer. See answer A above before proceeding to Question 3.
3. A. You must have misread the colour code, or have you studied it at all? The capacitors have the values: 1,0 , $10^{3}=10,000 \mathrm{pF}=10 \mathrm{nF}$. A parallel connection of the capacitors gives the total 20 nF . You have reckoned a series connection - try Question 2.
3. B. The method you have chosen is correct but you started off with an incorrect capacitor value. Orange is x 1000 , and brown-black 10. The capacitor is $10,000 \mathrm{pF}$ or 10 nF . A parallel connection gives 20 $n F$. Proceed to next question.
C. Answer correct - proceed to Question 2.
D. You have reckoned on a series connection but found the correct value of each capacitor. Parallel connection of capacitors means the addition of all values. We thus get 20 nF . Proceed to Question 2.
4. A. Perhaps you guessed the value of each capacitor. They are correct, but series connection gives a capacitor that is smaller than each of those used. Applying the formula for series connections we get a capacitance of $0.5 \mathrm{nF}=500 \mathrm{pF}$. Read the next section concerning various types of capacitors.
B. Quite correct, read on about the various capacitors, G6.
C. You have a wrong capacitor value or you have confused pF and nF . Otherwise the answer is correct, so proceed to the next section concerning various capacitors, G6.
D. Perhaps you thought it was a parallel connection. Three identical capacitors in series gives a total value equal to $1 / 3$ of each. Proceed to capacitor types, G6.

## Feedback G6

1. A. Not correct. Voltage is expressed in volts while the unit used for capacitors is FARAD. Have you read the section on capacitors thoroughly? If not, study it and proceed to Question 2.
B. M alone stands for a meter. Formerly the unit used in capacitors was cm which corresponded roughly to 1 pF . Today the unit is FARAD - proceed to next question.
C. Correct answer - proceed to next question.
D. Ampere is the unit expressing current. The capacitor unit is FARAD. Have you read the section on capacitors, G4? Proceed to Question 2.
2. A. This is difficult. The $30,000 \mathrm{pF}$ must first be converted to 30 nF . The parallel connection gives the sum of both capacitors - this is 32 nF . You can see already that the answer is correct. 32 nF is equal to 0.032 uF , the factor 1000 being the difference - Try Question 3.
B. Don't divide by 2 when the capacitor values are added. The result is $32,000 \mathrm{pF}$, or 32 nF , which again is 0.032 uF . Go on to Question 3.
C. 1.9 nF is the capacitance we get when connecting in series. In parallel connections the individual capacitances must be added. The answer is 0.032 uF . Try the next question.
D. You have changed the figures round. The answer is $32 \mathrm{nF} .30,000 \mathrm{pF}$ is equal to 30 nF .2 nF must be added and we get 32 nF or 0.032 uF . Try the next question.
3. A. Perhaps we haven't explained the principles of a capacitor sufficiently well. You will find it under Item 3. There must be two layers of metal foil and two layers of insulation - four layers in all. If the metal is vaporised onto the insulation only two layers are visible. The layers are in the form of long strips rolled together in a block. Proceed to Question 4.
B. If the metal is vaporised on to the insulation, you are right, but in many cases the metal foil is separate, i.e. four layers. Proceed to Question 4.
C. You have reckoned on separate metal foil in which case there are four layers. If the metal is steamed on to the insulation, there are only two layers. Proceed to Question 4.
D. Eight layers are too many. Perhaps you think that there is insulation on both sides of the metal foil, but this is not correct. A capacitor has four layers, metal and insulation alternately. Some capacitors have insulation vaporised onto the metal, so there are only two layers we can separate. Try Question 4.
4. A. Not good enough. You had better study the section on colour codes before trying Question 5.
B. Not bad. If you think you can manage, try Question 5 or re-read the colour code section T2. You will soon learn the colour code when you start on the AE assemblies.
C. Excellent - proceed to Question 5. You know the colour code well.
5. A. It is correct that they are expensive, which is why they should be avoided. Furthermore, they are rather big, another disadvantage. Oil capacitors are designed for high voltages, and are rarely made for less than 10,000 V. Proceed to Question 6.
B. The size is important. Smaller and cheaper capacitors are available. The ability of oil capacitors to withstand high voltages is rarely called for in electronics.
C. Oil capacitors can withstand high voltages, but smaller and cheaper ones suitable for most electronic applications are available. Proceed to Question 6.
D. This is fortunately not the case. Oil capacitors are big and expensive. Use them only in cases of high voltages. Proceed to Question 6.
6. A. You have based your answer on a series connection, but you have found the right capacitor value. The capacitance must be added in parallel connections, the result being $123-150 \mathrm{pF}$. Proceed to Question 7.
B. You have found a wrong capacitor value, but the answer is otherwise correct. The capacitor value is not 210 pF but 120 pF , which in parallel gives a capacitance of $123-150 \mathrm{pF}$. Proceed to Question 7.
C. Quite correct - go on to Question 7.
7. A. The black part of the capacitor is minus, while the other part is plus. In other words it is reversed. Proceed to next section on electromagnetism, G7.
B. Correctly placed. The black square is minus, and the white plus. Continue to the next section on electromagnetism, G7.

## Feedback G7

1. A. Incorrect. Current is only induced when the magnet moves. When it is stationary nothing happens. Try Question 2.
B. Correct. The magnet must move to produce electricity. Proceed to next question.
2. A. This is hardly likely - only in cases where extremely big coils are used. Counter electromotive force is induced only while the field is exposed to a current change. The current always seeks towards neutral, but the coil ensures a counter effect on any current variation. There is a state of equilibrium in which the current variations are sufficient to hold the prevailing current. When the current approaches zero, the lamp goes out. If the coil were of infinite size the lamp would light infinitely. Proceed to next question.
B. The magnetic field in itself does not keep the lamp lit, but a varying magnetic field can, and does when the current is broken. When the magnetic field has expired, the lamp goes out. Proceed to next question.
C. Yes, when the current reaches zero, it no longer varies. This is due to the limited size of the coil. A coil of infinite size would keep the lamp lit infinitely. A smaller coil means less current. Answer D is the correct one, so study it before answering next question.
D. Yes, it is the coil that maintains the current. The current falls quickly to zero in a small coil, while a big coil extends the period. The limited size of the coil will result in the lamp eventually going out, no matter how big the coil is. Proceed to next question.
3. A. Quite correct. You can see that the coil at this frequency conducts almost as well as a wire. Proceed to Question 4.
B. Not completely correct. There is an error in the power calculations. See Answer A above before proceeding to Question 4.
4. A. Yes, the coil has a resistance of 6.28 ohm . When the frequency increases, the resistance (impedance) increases proportionately. If the frequency had been 1 GHz (Giga - see Sect. T1, Nomenclature) the impedance would be 6.28 kohm . Proceed to G8.
B. Wrong. A small coil does not have such a high resistance at normal frequencies. See Answer A above before proceeding to the section concerning Ohm's Law.

Feedback G8

1. A. Too low. Ohm's Law $\mathrm{E}=\mathrm{R} \times \mathrm{I}$ gives $\mathrm{E}=10$ ohm x $0.1 \mathrm{~A}=1.0 \mathrm{~V}$. Try Question 2.
B. Correct. Proceed to Question 2.
C. We must find the voltage by applying Ohm's Law. E $=\mathrm{R} \times \mathrm{I}, \mathrm{E}=10 \mathrm{ohm} \times 0.1 \mathrm{~A}=1.0 \mathrm{~V}$. Answer Question 2.
2. A. No, do not multiply but divide. $E=R \times I$ gives $I=\frac{E}{R}=$ $\frac{10 \mathrm{~V}}{0.1 \mathrm{ohm}}=100 \mathrm{~A}$. Try Question 3.
B. You are on the wrong track. Apply Ohm's Law: $\mathrm{E}=$ $\mathrm{R} \times \mathrm{I}$. We exclude I when finding the current: $1=$ 100 A. Proceed to Question 3.
C. Correct. Try Question 3.
3. A. Apart from one nought, the answer is correct. 10 uA $=10 \times 10^{-6} \mathrm{~A}, 47 \mathrm{kohm}=47 \times 10^{3} \mathrm{ohm} . \mathrm{E}=\mathrm{R} \times 1$ $810 \times 10^{-6} \times 47 \times 10^{3} \mathrm{~V}=470 \times 10^{3} \mathrm{~V}=470 \mathrm{mV}$. 0.047 V is equal to 47 mV . Proceed to Question 4.
B. Quite correct. Now answer Question 4.
C. The formula is calculated incorrectly. The voltage is found by $\mathrm{E}=\mathrm{R} \times \mathrm{I}=10 \mathrm{uA} \times 47 \mathrm{kohm}=470 \mathrm{mV}$. You have divided the current by resistance. Try Question 4.
4. A. The resistance is found by $R=\frac{E}{I}$ and your answer is correct. If you are conversant with the subject of resistors, go direct to the next section or start reading the text.
B. The formula is applied incorrectly as you have divided the current by the voltage. It must be other way round. $R=1.2$ kohm. Proceed to next section.
C. There's a nought wrong somewhere. 1.2 divided by 1 is 1.2 but $1 \mathrm{~mA}=10^{-3} \mathrm{~A}$, so we must divide by $10^{-3}$ or multiply by $10^{3}$. $\mathrm{R}=1200$ ohm $=1.2$ kohm. Go on to next section.
D. Incorrect. Apply the formula $R=\frac{E}{I}$

See the answer under C.
5. A. Yes, this is correct. Formerly only wire wound resistors were used, but the answer B is also correct. Read it before proceeding to next question.
B. This is correct. Wire wound resistors cast in glass are nearly always used for high outputs. Proceed to next question.
6. A. Wrong. Light is measured by means of an LDR resistor. Pressure is measured by a STRAIN GAUGE. Proceed to next section on outputs.
B. Not quite correct. Temperatures are measured by an NTC resistor while an LDR resistor can measure light. Proceed to section G10 on outputs.
C. Quite correct. Proceed to section G10 on power and try the last question to see if it is necessary to study further.

## Feedback G9

1. A. You thought it was a parallel connection. In series, the resistances must be added, thus the result is 17.6 kohm. Proceed to Question 2.
B. Correct. It wasn't difficult, was it? Proceed to Question 2.
2. A. Quite correct. Go ahead with Question 3.
B. You are still on Question 1 because you thought it was a series connection. It is a parallel connection, however, and when two resistances are equal in parallel, the total resistance is half, i.e. 50 ohm. Proceed to Question 3.
3. A. Your calculations are wrong. The first thing to remember is that the two resistors must be in parallel when the total resistance is 11 kohm . Perhaps you misunderstood and worked out the current in one of the resistors, which is wrong, of course. Question 2 in Section G8 tells us that the current is found by $1=\frac{E}{R}$ the correct result being $\mathrm{I}=0.9 \mathrm{~mA}$. Notice that it is kohm! Proceed to Question 4.
B. Correct. Go on to G10 on power.
C. There's a fault in the power (Ohm's Law). $0.009 \mathrm{~A}=$ 9 mA and the result is 0.9 mA . Otherwise it was quite good - proceed to next question.
4. A. It is not a series, but a parallel connection. The resistance is thus 667 ohm and not 2.5 kohm . There's a wrong nought too, but it is not so important. When the resistance is 667 ohm and the voltage 4.5 V the current is 6.8 mA . Proceed to Question 5 .
B. 1.8 mA would have been correct in a series connection, but a parallel connection gives a resistance of 667 ohm, and a current of 6.8 mA . Try Question 5.
C. Well done! Proceed to Question 5.
5. A. Start by choosing the cross current first. It must be 10 times greater than $10 \mathrm{uA}=100 \mathrm{uA}=0.1 \mathrm{~mA}$. To get a voltage of 3 V the current must pass a 30 kohm resistor As this is not standard we choose 27 kohm or 33 kohm. Calculations correct, try Question 6.
B. You have forgotten that the cross current must be ten times greater than the maximum output current. Otherwise correct as the resistances must be divided by 10 to 47 kohm and 33 kohm. Proceed now to Question 6.
6. A. You have thought well and found the right answer, 4 $+1=5$ of which we take one part. Proceed to Question 7.
B. You fell into the trap. As one of the resistances must be four times greater than the other, the total resistance must be five times. The voltage ratio is thus $1: 5$, the result being 2 V . Proceed to Question 7.
7. A. As the input resistance is 50 kohm , the voltage divider resistance must be 10 times less, i.e. 5 kohm. As this is not a standard value, we use a 4.7 kohm . To divide into the ratio 1:10 the resistance ratio must be 1:9. Theoretically, R1 must be 42.3 kohm, but this is not standard, so we choose between the two nearest 39 kohm and 47 kohm , and prefer the latter. Proceed to the section on power G10.
B. The correct choice. Did you notice that the resistance ratio is $1: 9$, but that the standard values force us into this choice? You do now, anyway. Go on to next section, G10.
C. You have worked it out correctly, but 5 kohm is not a standard value. We are forced to use 4.7 kohm even though we get the ratio $1: 11$ instead of $1: 10$. Read section G10.

## Feedback G10

1. A. We think you really made an effort to answer the question correctly, but there's a nought wrong somewhere. Have another try, the right answer being 70 W. Proceed to section G11.
B. Quite correct. Go ahead with the next section on alternating current, G 11.
C. Not correct. Perhaps there's a mistake in the power calculation. E 2 is not equal to $15+15$, but $15 \times 15$ which is 225 . Dividing by 3.3 we get 70 W . Proceed to next section on alternating current, G11. If you feel a bit uncertain about powers, read Section T1 which is easily understood, in fact it's a piece of cake!

## Feedback G11

1. A. Completely wrong. A rectifier does not amplify, but converts alternating current to direct current. The reason for the voltage rise is that the capacitor is charged up to maximum value. This peak value is $\sqrt{ } 2$ times greater, and explains the higher voltage. Proceed to next text.
B. Quite correct - perhaps you knew beforehand. It might be a good idea to skip the next part and get on with the questions.

## Feedback G12

1. A. No, you're mistaken. The ratio between primary and secondary is much lower. 10,000 windings as against 500 gives a ratio of $20: 1$. This means that the output voltage of the transformer is 20 times less than 220 V , i.e. 11 V . After rectification and filtering we get a dc voltage that is $\sqrt{2}$ greater. $\sqrt{2}$ is 1.41 which multiplied by 11 V gives approx. 15.5 V. Proceed to next section.
B. Quite correct. You can proceed to the next section on capacitors and coils in ac circuits.
C. Not quite correct, but you are on the right track. The transformer reduces 220 V to 11 V , of course, but due to rectifying and filtering - also called smoothing out - we get a voltage that is $\sqrt{2}$ greater. $\sqrt{2}=$ $1.41 \times 11 \mathrm{~V}$ gives approx. 15.5 V . Go ahead to next section, but remember that an ac voltage rectified and smoothed out gives a value $\sqrt{2}$ greater.

## Feedback G13

1. A. Quite right. You probably don't need more practice in calculating capacitor values so proceed to next section, G14.
B. Not quite correct. The figure is correct but a nought is missing. It might be a good idea to study the section on powers, T1 before starting on G14.
C. Not correct. We had better run through the calculations once more, applying the formula:

$$
\mathrm{Z}_{\mathrm{C}}=\frac{1}{2 \pi \times \mathrm{f} \times \mathrm{C}}, \quad \text { giving } \quad \mathrm{C}=\frac{1}{2 \pi \times \mathrm{f} \times \mathrm{Zc}}
$$

When substituting we get:

$$
\begin{aligned}
& C=\frac{1}{6.28 \times 10^{3} \times 10^{3}} \\
& C_{n F}=\frac{10^{9}}{6.28 \times 10^{6}} \quad C=150 \mathrm{nF}
\end{aligned}
$$

## Feedback G14

1. A. This is not correct as the answer is 1.59 MHz which is medium-wave. We arrive at 1.59 MHz by taking the square root of 0.1 mH times 0.1 nF which is $0.1=$ $1 / 10$ and we divide by $1 / 10$ by multiplying the opposite. This means that 159,000 must be multiplied by $10=1.59 \mathrm{MHz}$. Proceed to G15, measuring, a different subject altogether.
B. Quite correct. No guessing we hope - if so see answer above under A. Proceed to G15.
C. Wrong. If the text does not explain sufficiently, see the answer under A before going on to the next section.

## Feedback G15

1. A. Wrong. The current is already known. What we want to know is the value full scale deflection. As we know the current that flows through the instrument we can work out the inner resistance as we also know the voltage. We must also know the value at full scale deflection. Proceed to Question 2.
B. Something wrong. We wish to know the full scale deflection value. Proceed to Question 2.
C. It is necessary to know this value at full scale deflection. Try the next question.
D. No, the voltage is known. What we want to know is the value at full scale deflection. Proceed to next question.
E. Quite correct.
2. A. Wrong answer. The only thing that interests us is that the instrument is to conduct 100 mA , and at full scale deflection 100 uA . This means that apart from the 100 uA or 0.1 mA , all the other current flows through the shunt, in all 99.9 mA . Next question.
B. Definitely wrong. In the question we said that the current here was 100 mA , so we cannot get almost ten times as much through the shunt. Correct answer A above.
C. Correct, so no further comment is necessary. Proceed to next question on shunt sizes.
3. A. No, not correct. The voltage across the meter is 100 mV . We know that there must be full scale deflection at 100 mA , and 99.9 mA through the shunt, so we also know the voltage and current, and calculate the shunt through Ohm's Law. A meter accuracy of more than $1 \%$ is rare, so we can round off the 99.9 mA to 100 mA .
$R s=E / I ; R s=\frac{100 \mathrm{mV}}{100 \mathrm{~mA}}=1 \mathrm{Ohm}$.
Proceed to next question.
B. Incorrect. Perhaps there is a power fault. See answer A above and go on to next question.
C. Quite correct. Proceed to Question 4.
4. A. Wrong answer, sorry to say. Perhaps a factor of 1000 has been forgotten, anyway this is how it should be done. Question 3 tells us that the voltage across the meter at full scale deflection is 100 mV . As we are to measure 100 V , the series resistance must be a 1000 times higher than the inner resistance because the voltage to be measured is a 1000 times higher. The inner resistance is known from Question 2, i.e. 1 kohm, based on the instrument type $1 \mathrm{~mA} / 1 \mathrm{~V}$. As the resistance must be a 1000 times higher than 1 kohm we get a resistance of 1 Mohm. Proceed to Question 5.
B. Correct - you have understood the essential facts. Proceed to Question 5.
C. The correct answer is 1 Mohm. If you do not wish to try again, you'll find the calculations under A above, and then go on to Question 5.
5. A. You have found the correct resistors, so proceed to next section G16.
B. Not correct. The resistor 9 kohm is correctly calculated, but the 990 kohm one is wrong. It must be 99 kohm. Both resistances are found as follows: We know that there is 1 V across the instrument at 1 kohm. If the voltage to be measured is 10 V , there must be 9 V across the resistor. 1 V and 1 kohm give a current of 1 mA .1 mA through a resistor with 9 V across gives an ohmic value of 9 kohm . At 100 V , there is 99 V across the other resistor and conse-
quently 99 kohm, or 100 kohm roughly speaking. The 9 kohm resistance, can for instance, be in the form of a 8.2 kohm and a 820 ohm resistor connected in series. Proceed to next section, G16.

Feedback G16

1. A. Correct - try Question 2.
B. Yes, there is a current. Plus is conducted in the direction of the arrow. Go on to Question 2.
2. A. Yes, you know what is meant by Beta. Proceed to next question or text as explained.
B. No, this reduces the current. The idea of a transistor is to extract a higher current from collector than is applied at base. Study the signs T3 and proceed to G17.

Feedback G17

1. A. You have forgotten that there is half supply voltage at collector. All the voltage is across $R_{c}$ instead. As it must be halved, the resistance must be halved, i.e. 6 kohm. We use a standard resistor 5.6 kohm. $\mathrm{R}_{\mathrm{b}}$ is correctly worked out. Try Question 2.
B. This is a good answer, but remember that when rounding off downwards in a collector resistance, the same also applies to the base resistance, i.e. 680 kohm. There is no audible difference between the two circuits. Proceed to Question 2 or direct to Question 3.
C. Quite correct. Go ahead with Question 2, or if you feel confident, Question 3.
D. Your suggestion is not impossible, but the collector current is 0.25 mA instead of 0.5 mA . All the supply voltage is across $R_{c}$ instead of half of it. $R_{b}$ is also wrong or you have estimated that the $R_{b}$ value must be twice current gain times $R_{c}$. Remember the rule of half supply voltage and try Question 2.
2. A. You are right as far as $R_{e}$ and $R_{c}$ are concerned, but you have forgotten the voltage drop of 0.7 V from base to emitter. Correct this mistake and proceed to Question 3.
B. Quite correct - go ahead with Question 3.
C. There are two serious mistakes here. First of all there must be half supply voltage at collector. With $\mathrm{R}_{\mathrm{c}}=$ 2.2 KOhm , the voltage across the resistor drops, leaving none for the transistor to work on. The correct answer is half value $\mathrm{R}_{\mathrm{c}}=1.2 \mathrm{KOhm}$, and $\mathrm{R}_{\mathrm{b} 1}$ $=\mathrm{R}_{\mathrm{b} 2}=15 \mathrm{KOhm}$. Try Question 3 .
D. You don't seem to like Ohm's Law. Re must be 680 Ohm and not 1.2 KOhm. The same fault occurs in $R_{c}$ that must be $1.2 \mathrm{KOhm} . \mathrm{R}_{\mathrm{b} 1}$ and $\mathrm{R}_{\mathrm{b} 2}=15 \mathrm{KOhm}$. Try and make a better job of Question 3.
3. A. Incorrect. Try studying Example 5 in Sect. G17 and compare with the correct resistances in Answer B.
The following data may help: The 6 W power through a 4 ohm loudspeaker corresponds to approx. 1.2 A. The base current is 50 times less, 20 mA , but is raised to 60 mA cross current. T3 is calculated at 0.6 mA base current, but is increased 10 times to 6 mA .
B. Quite correct. 6 W is the absolute maximum that can be drawn from a $12-15 \mathrm{~V}$ car battery. The resistor values are comparatively low, and the output and input capacitors should be $1,000 \mu \mathrm{~F} / 16 \mathrm{~V}, 100$ $\mu \mathrm{F} / 16 \mathrm{~V}$, and the Bootstrap capacitor $100 \mu \mathrm{~F} / 16 \mathrm{~V}$. Don't forget C4 at 100 pF to avoid oscillation.
Feedback G18
4. A. Correct answer - proceed to section G19, filters.
B. You have forgotten a factor of 2. Let's hope you haven't made a mistake in the normal 20 Hz . Do not use a higher capacitor value than necessary. When a loudspeaker cannot reproduce lower frequencies than 40 Hz , there is no reason to rate the components down to 20 Hz . You seem to be conversant with 10 powers. In practice we employ a 12.5 uF capacitor as 13 uF is not standard. Continue to section G19.
C. You must have made a mistake in the tenth powers, as well as a wrong 2. The correct result is 13 or 12.5 $u F$. Proceed to section on filters.
D. There is a power error here. The correct answer is 13 or 12.5 uF. Watch out for it another time. Proceed to section on filters, G19.

Feedback G19

1. A. No, this is not correct. Perhaps our description under capacitors needs further explanation. When we change the amount of electrons in the capacitor plates, the current (amount of electrons per second) will be higher at greater speed. This means that higher frequencies are transferred easily. On to the next question.
B. Quite correct. Try the next question.
2. A. No - in the first question we see that the treble conducts well in the capacitor. This means that the treble even increases because it is led round the resistor. Answer Question 3.
B. Good answer. The capacitor conducts the treble to common - conducts the high frequencies. We hear the medium and bass frequencies via an amplifier. Common is always the lower conductor. Proceed to Question 3.
3. A. Incorrect - not even the figures are right. Try again but remember that $\pi=3.14$.
B. Correct. Try making a printed wiring board and you can hear that the bass becomes more powerful. Proceed then to Question 4.
C. Not completely correct - there's a figure dropped somewhere. The answer is 100 nF . Proceed to Question 4.
4. A. No, the capacitor must be 15 nF . You have made an error. 'Try once more remembering that the resistance is 10 kohm and the frequency 530 Hz .
B. Quite correct - proceed to Question 5.
C. No, the figure is right but the decimal point is placed incorrectly. Find the fault. The capacitor value should be 15 nF . Proceed to next question.
5. A. Incorrect. You must find the capacitor the impedance of which at 30 Hz must be equal to $\mathrm{R} 1=\mathrm{R} 2=$ 10 kohm - this gives us 470 nF . R3 is 5 kohm and the capacitor twice the value: 1 uF . Run through this question once more and start on the next section.
B. Correct and fully understood. Take the last question in the next section if you feel confident enough.

## Feedback G20

1 A. Wrong answer. First of all it is the light things that move, but the size of the surface facing the sound source also come into consideration. Draw a sketch and try again. The things are placed incorrectlu. Lengthwise they go north/south and the broad side faces east/west. Make a sketch including the pressure waves.
C. This is correct. East/west broad side facing the centre, north/south lengthwise. West is lighter than east, but even though south is light than north, a car has a certain breadth which is considerable compared with $1 / 8$. Solve the next problem.
D. Almost correct. Even though the steel sheet is lighter than the car, there is only $1 / 8$ for the pressure wave to meet compared with the breadth of a car. Answer Question 2.
E. You are probaly on the right track, but what does aluminium foil weigh compared to cardboard? Proceed to Question 2.
2. A. Incorrect. It is not the size, but the weight that matters here and a magnet usually weighs more than a coil. Proceed to Question 3.
B. Correct. The light coil moves more than the heavy magnet. On to Question 3.
C. You are guessing. It is the weight that matters and the light coil moves more than the magnet. Proceed to Question 3.
D. It is theoretically possible, but in practice the device is less sensitive because a coil is usually lighter than a magnet. It is good that you are not bound by the traditional way of thinking. Go ahead with the next problem.
3. A. Right answer if you are thinking of the low frequencies, wrong if thinking of high. The limits of a diaphragm should be as wide as possible in relation to the sound wave. This gives a lower limit of the frequency. If you have thought of $B$ as the right answer too, you have a good knowledge of sound wave effects. Answer next question.
B. Correct concerning the upper frequency limit - solve the next problem.
C. The influence of the magnet is equal at all frequencies. It is the weight of the diaphragm and coil that restrains the microphone at high frequencies. Next question.
D. Wrong. It is the weight and not the size that matters. A heavy weight cannot keep up with the high frequencies. Proceed to Question 4.
4. A. Wrong. On the contrary, it is the contrast between the requirements of a good distance between front and rear sides and the movement of big volumes of air, and the requirements at high frequencies of a small, light diaphragm, that renders it impossible for a single loudspeaker to cover the whole range - if possible it would be ideal. Try Question 5.
B. No. A large loudspeaker is necessary for the low frequencies while a small one covers the high frequencies. Proceed to Question 5.
C. Correct. There must be plenty of room around the diaphragm at low frequencies, a large quantity of air being displaced. A small and light diaphragm is required at high frequencies to keep pace. Try Question 5.
D. Manufacturers are not that calculating. It is a technical question, a large diaphragm being necessary to reproduce the low frequencies, and a small, light one for the high. Proceed to Question 5.
E. It is correct that the output is normally not high at high frequencies, while it automatically regulates itself. The requirements of bass and treble tones cannot be met in a single loudspeaker. The deep tones demand a large diaphragm. The tweeter, on the other hand, must have a small, light diaphragm to keep pace with the high frequencies. Both these requirements cannot be met in a single speaker. Continue to Question 5.
5. A. Partly correct because crystal and ceramic pick-ups are difficult to make linear. And then there is the question of distortion. The problem is easier solved in dynamic and photo-electric pick-ups. The main difference is that a crystal pick-up requires a rather rigid stylus assembly. The high frequencies (rapid
vibrations) cannot be registered by the stylus unless the pressure is increased, and this, of course, wears the record. Try Question 6, loudspeakers.
B. There's some truth in this as it cannot be mass-produced, but has to be adjusted by hand after a strict selection of materials. The quality will never reach that of a dynamic or photo-electric pick-up, however. The connection between stylus and crystal is rather rigid, and the finer shades of tone (expecially the high frequencies) are not reproduced. Another disadvantage is the risk of jumping grooves. The two other types of pick-up require little movement pressure. Proceed to Question 6.
C. Correct. As the stylus in the pick-up is rigid, greater pressure is required to move it. High frequencies and high amplitudes cause distortion. This does not occur in dynamic and photo-electric pick-ups. Proceed to Question 6.
6. A. Correct. The cabinet must be spacious or fitted with features such as a labyrinth. Solve the next problem.
B. More length, not space is required. The distance from the rear of the speaker to the aperture through which the rear side sound is emitted must be considerable. This can only be achieved by devious sound routes in the cabinet. Go on to Question 7.
C. An intuitive answer. The explanation is more down to earth as it is the long bass sound wave that creates problems. If the distance from the rear of the speaker to the open is not sufficient, the bass sound short-circuits itself. A correctly made cabinet avoids this as the distance from front to rear is extended artificially, i.e. a labyrinth etc. Proceed to next question.
7. A. No, if a greater output is required several identical speakers must be employed. Three speakers are used, each of which covers a certain frequency range. The ranges overlap one another to cover the complete range. Proceed to Question 8.
B. Quite correct - try Question 8.
8. A. Correct. A dome tweeter can reproduce up to 25,000
Hz . On to Question 9 .
B. Wrong. It is the dome tweeter that reproduces frequencies up to $25,000 \mathrm{~Hz}$.
9. A. Quite correct as the high frequencies cannot easily flow through a coil. Try the last question in the next section or start with the text if you feel unsure.
B. A coil conducts the bass, but blocks the treble. Try the last question in the following section or read the text if you are not completely confident.

Feedback G21

1. A. Not correct. We arrive at the 50 m by dividing the radio wave propagation speed 6 MHz (speed 300,000 $\mathrm{km} / \mathrm{sec}$.). If we require a quarter wave antenna, we divide by 4 arriving at 12.5 m . Proceed to next question.
B. Quite correct. The Luxembourg frequency is a little higher, approx. 6.2 MHz , so the antenna must be shorter, approx. 12 m . Try Question 2.
2. A. Quite correct - hope you did not guess! If you did, read answer B before proceeding to G22.
B. No, we arrive at 3 m when we divide the radio wave propagation speed $300,000 \mathrm{~km} / \mathrm{sec}$. ( $3 \times 108 \mathrm{~m} / \mathrm{sec}$.) by 100 MHz . This is 3 metres. Including both dipoles we get $2 \times 1 / 4 \times 3 \mathrm{~m}=1.5 \mathrm{~m}$. Proceed to section G22.

Feedback G22

1. A. There's a slight misunderstanding here. The carrier wave conveys the signal to the receiver. It is the modulation, consisting of music and speech, that is missing. Proceed to Question 2.
B. Correct. The unmodulated carrier wave suppresses the noise. Answer next question.
2. A. Quite correct. Motors, refrigerators, fluorescent lighting causes AM noise but not FM noise, thus the noiseless reception. Continue with the text or G23, transmitters.
B. Not according to the text. AM has the bigger radius. FM frequency is higher, the waves resembling those of light - more directional. Try G23, next section.

## Feedback G23

1. A. No, the transmitter itself produces HF , the radio station producing LF signal as a transmission. Read the section on receivers.
B. This answer is right. Go ahead with G24, receivers, and get good marks in electronics.
C. To a certain extent. The modulation is produced at the transmitter, while it produces HF. Proceed to section on receivers, G24.

## Feedback G24

1. A. Yes, it is AM, but as the frequency varies too, there is both AM and FM. Try next question.
B. Yes, it is FM, but as the amplitude varies too, it is both AM and FM. Try next question.
C. Have a go at Question 2, your answer is correct.
2. A. No, a super is the most expensive receiver due to the amount of components. See F.
B. Yes. See F.
C. We can choose the selectivity in the IF-amplifier ourselves. All other receivers have poor selectivity, at least if they can be tuned. See F.
D. Yes, the amplification limit depends on the noise in space and that of the input components and nothing else. In other types, the method sets its own limits. See F.
E. No, there are many components in a super. See F.
F. Partly. There is only one control, the tuner, but this advantage applies to other receivers. If you have from $1-3$ correct answers, re-read this section, while 4 correct answers means that you can proceed to the next section. 5 correct answers is excellent while 6 means that you can manage the following problems.
3. A. Definitely not. Let us explain it another way. The intermediate frequency is fixed to avoid tuning in several circuits. It is impossible to find an accurate point with five tracking variable capacitors. Try the next question.
B. Yes, otherwise an accurate intermediate frequency could not be attained. Answer next question No. 4.
4. A. Correct. The mixer together with the oscillator signal determine the desired signal, the intermediate frequency. Try the next question.
B. No, the medium frequency is formed by the oscillator in the mixer. Question 5.
5. A. Correct. The new ceramic filter is one of the best frequency-determining components for the IF unit. Try the last question in the following section.
B. No, a resistor does not determine a frequency, only a current. Read the last part of the section, receivers, once more and you will understand the answer A.

Feedback G25

1. A. One output amplifier is not enough - we must have two. They can be combined in the same cabinet, of course. Proceed to next question.
B. This is correct - only one would mean mono. Answer Question 2.
2. A. The Danish humorist, Robert Storm Petersen once said, 'It is difficult to predict, especially about the future!" and in this year of 1973, the four-channel stereophonic (quadrophonic) sound has only just started. In our opinion, a four-directional potentiometer will be developed that enables adjustment up and down, right and left. Proceed to G26, the oscilloscope.
B. See answer A above.

## Feedback G26

1. A. Quite correct, so go on to Question 2. If you guessed, you are a good guesser!
B. Current can be measured by means of an oscilloscope, but its main purpose is to show ac wave-forms. Try the next question.
C. A picture is usually shown on a TV receiver. An oscilloscope can show pictures but its main object is to show wave-forms as a function of time. Answer next question.
2. A. Wrong answer. The grid blocks the electrons with a control voltage. The "hot" cathode emits a mass of electrons. Proceed to next question.
B. No, not understood corectly. The anode is connected to plus, i.e. a deficit of electrons. It is the heated cathode that emits electrons when voltage is applied. Go on to Question 3.
C. Completely correct. It is the cathode that emits electrons. Proceed to next question.
3. A. Only correct if the saw-tooth generator does not produce saw-tooth voltage but sine-waves, and these are sent to input at the same frequency. If the flank is not vertical we see the trace return. Answer the next question.
B. Correct. This is especially the case in cheap oscilloscopes containing a poor quality saw-tooth generator. Go on to the last question in the following section or read the text if of interest or your knowledge of same is limited.

## Feedback G27

1. A. No, there's a misunderstanding somewhere. The grid controls the light intensity. A cathode tube in an oscilloscope has electrically controlled deflection plates. This is not so in a TV set. A deflection coil at the neck is used instead. Proceed to Question 2.
B. Correct answer, so go on to Question 2.
C. A cathode emits electrons that rush towards the screen giving light. The cathode is necessary for both TV-tube and cathode ray tube. A TV set has no deflection plates, but has instead a deflection coil placed at the neck of the tube.
2. A. The question was what does not have to be transmitted - perhaps you didn't think of this. Line synchronisation is necessary to position the TV picture, whereas the sound is not necessary. Proceed to Question 3.
B. Correct. The sound is not necessary to produce the picture. Solve the next problem.
C. It is indeed very important to include the black/ white level otherwise either black or white only appear. Only the sound is not necessary in the video control. Proceed to No. 3.
3. A. No. Have you read the text or are you guessing? 50 Hz is separated in the TV set to give a start impulse for each new half-frame. Proceed to the next text.
B. Quite correct. 50 Hz and $15,625 \mathrm{~Hz}$ are separated to give the 625 lines. 50 Hz is the start impulse for each new half-frame. Continue with the next text.
C. Quite correct. The 50 Hz give the start impulse for each new half-frame. Proceed either to last question in the following or read the text.

Feedback G28

1. A. This is wrong because ferromagnetic powdered plastic that is magnetised by the tape-head is used. Only a small portion of the tape is of aluminium, that is the end strip that automatically stops the recorder. Answer next question No. 2.
B. The tape is made of plastic in a brown colour. A layer of ferromagnetic powder is on the tape for magnetising and reproduction purposes. Try Question 2.
C. Correct. It is a layer of ferromagnetic powder - pure iron would rust. Try Question 2.
D. A steel band would be suitable magnetically speaking, but it would be exposed to rust and besides it is too stiff. Recording tape is of plastic with a ferromagnetic coating - this is a form of rust and cannot rust further. If you understand this question, proceed to No. 2.
E. Wrong. Paper is not suitable at all. Read the answer B above and continue with the next question.
2. One correct answer is not satisfactory, and neither are two. Three correct answers not bad, while four is perfect. Proceed to Question 3.
A. Distortion depends on tape quality and tape-head quality, but not on the width of the track.
B. No, a narrower track can result in a less uniform signal with flat spots in reproduction. Dust especially can cause more noise on four-track recorders than those with a double track.
C. The same. Wow arises from the motor and its mechanical connections to the tape.
D. This gives double playing time, both in mono and stereo.

After checking the number of correct answers, proceed to Question 3.
3. A. Correct. Stereo signal necessitates two tracks, when the whole width of the tape is used. Continue now to Section G29, fitting.
B. No, half the width of a double track tape is a single track. Two tracks are necessary in stereo, so the whole width is used. Proceed now to G29.
C. $1 / 3$ tape width cannot be registered on normal recorders. See answer $B$ above and then on to G29, fitting.
D. You thought of 4-track and double track recorders, but you forgot that two tracks are necessary for stereo. If both tracks occupy the whole width, there is only space for stereo signals (two tracks).

## Feedback T1

1. A. No, think of the cake again. It is divided into four equal pieces of $1 / 4$. 2 pieces $=2 / 4$ which is $1 / 2$ cake. Try the next question.
B. No, this is just as wrong as saying that one apple placed beside another is still one apple. $1 / 4+1 / 4=$ $2 / 4$ which is $1 / 2$. Go on to next question.
C. Yes, of course. Proceed to next question.
2. A. No, $1 / 4$ can be divided into two, each of which is $1 / 8$. Added to the other part $1 / 8$, we get $3 / 8$. Try Question 3.
B. Correct - go ahead with Question 3.
C. No $-4 / 4$ is the same as one whole, but $1 / 8+1 / 4=$ $3 / 8$ because the quarter ( $1 / 4$ ) can be divided into 2/8. Try Question 3.
3. A. The figures above and below the line must be multiplied. Don't think that the 4 in both places gives 4 as a result. The answer is $16 / 16=1$. Proceed to next question.
B. This is correct, but not completed. It must be reduced to $1.16 / 16=1$. Try the next question.
C. Quite correct. Go on to Question 5.
4. A. Yes, it's correct. Try Question 5 which is more difficult.
B. Not correct. Let us run through it once more. A/6 is correct. A/2 must be converted to sixths. $1 / 2$ is divided into $3 / 6$, so $A / 2$ is equal to $3 \mathrm{~A} / 6$. We must also convert A into sixths. If a cake is divided into six, we get six equal pieces. Therefore, A is equal to $6 \mathrm{~A} / 6$, and now we can add:

$$
\frac{6 \mathrm{~A}}{6}+\frac{3 \mathrm{~A}}{6}+\frac{1 \mathrm{~A}}{6}=\frac{10 \mathrm{~A}}{6}
$$

and this can be reduced to $\frac{5 \mathrm{~A}}{3}$ or $12 / 3 \mathrm{~A}$. Proceed to Question 5.
5. A. Quite correct. Have a go at the last question.
B. Not correct. The answer is $\frac{2}{A}$. Try Question 6.
6. A. By substituting we arrive at:

$$
C=\frac{1}{6,28 \times 10^{2} \times 10^{6}}
$$

converted to $\mathrm{nF}, \mathrm{C}_{\mathrm{nF}}=\frac{10^{9}}{6.28 \times 10^{8}}=1.5 \mathrm{nF}$

The answer is in Farads which is a large unit. We can express it in $\mathrm{nF}, 109$ times smaller when multiplying by $10^{9}$. $1 / 6$ cake expressed in sixtieths is $10 / 60$.
B. Correct - you are good at mathematics.
C. No, you have forgotten to divide 10 by 6.28 which gives 1.5. See answer $A$ above if necessary. We hope this little test has helped you.

Feedback T2

1. A. You have the numbers 1 and 0 , but the red colour at third place means that 10 must be multiplied by 100 and not that 1.0 must have two noughts. The answer then is 1 kohm, $5 \%$. The gold for $5 \%$ you found. Try the next question 2.
B. 1000 ohm is correct. 1 and 0 plus two noughts gives 1000 ohm $=1$ kohm. The tolerance is wrong, however. Gold indicates a $5 \%$ resistor and not $10 \%$. Otherwise quite good. Answer the next question.
C. This is the right answer. You were not confused by the unit kohm. The gold band $5 \%$ is also correct. Try Question 3 or 2 if you're not really sure.
D. One nought too many. Brown $=1$, black $=0$, i.e. 10 . The third ring, the red one, gives a factor of 100 , that is two more noughts. In all 1000 ohm $=1$ kohm. Perhaps your finger slipped when looking up the gold band. Gold is $5 \%$. A silver band is $10 \%$. See if Question 2 is easier.
E. Brown and black give 10 , but the red band is the factor 100 only, so the resistor is 1000 ohm $=1$ kohm. The $5 \%$ tolerance is correct. Try Question 2.
2. A. The figures 3 and 9 are correct. but orange as third band gives three noughts, i.e. $39,000 \mathrm{Ohm}=39$ KOhm.There's a trap in Question 3, try it.
B. The white band has caused trouble. White is 9 , but you have found the correct number of noughts. Be careful when answering Question 3, and there are no typographical errors in the colour code.
C. Not too good. You have mistaken the white value which is 9 and not 1 . If you had looked at the list of standard values you would have seen at once that something was wrong. The amount of noughts is also wrong. Orange as the third band gives 3 noughts, and orange and white as the two first ones give 39, totalling $39,000 \mathrm{Ohm}=39 \mathrm{KOhm}$. Try Question 4 and 5 first, hen return to Question 3. This gives more practice in the use of the colour code.
D. Having the correct amount of noughts (3) the white value is wrong. White is not 1 but 9 . Don't try to remember the colour code by heart at first. Look it up every time and then you will remember most of it. Proceed to Question 3, but be careful of the trap - it's not a printing error.
E. Correct. Orange gives 3, white 9 and orange in 3rd position 3 noughts. $39,000 \mathrm{Ohm}=39 \mathrm{KOhm}$. Proceed to Question 3.
F. The figures are correct, but there must be 3 noughts and not 2. $39,000 \mathrm{Ohm}=39 \mathrm{KOhm}$ Console yourself with the fact that anyone can make this mistake. Answer Question 3.
3. A. You have regarded the gold colour to be a factor placed in front of the figure. The question is correctly worded. We have merely turned the resistor the other way round, starting at the end. It can be difficult at times to distinguish between first and last bands. Gold can never be the first band but often the last. We then get 47 and four noughts: 470,000 $\mathrm{Ohm} / 5 \%=470 \mathrm{KOhm} / 5 \%$. That entailed a bit of detective work. Answer Question 4 which is straightforward.
B. You have answered very systematically. First 0.1 x $47 \mathrm{Ohm}=4.7 \mathrm{Ohm}$. Then the four noughts giving $47,000 \mathrm{Ohm}=47 \mathrm{KOhm}$, and finally blank $=20 \%$. The resistor has been turned round the wrong way,
however, perhaps because it is difficult to see where to start. The gold band should have put you on the right track. It can never be the first one, so the resistor must face the wrong way. We now get 47 and four noughts $=470,000 \mathrm{ohm}=470 \mathrm{kohm}$. Gold gives $5 \%$. Proceed to Question 4, which is a normal one.
C. Well done, if you didn't guess! You were not confused by starting at the wrong end of the resistor, and you soon discovered that the gold band can only have third or fourth place. The question was then reduced to the normal colour code task. Skip the next question and go on to No. 5.
D. This appears to be guesswork. You simply ignored the gold band, found the correct figure, and guessed the amount of noughts. The solution is that the resistor has been turned the wrong way round. It is often difficult to find the first band, but we must remember that the gold ring can never be the first, but often the last. The answer then is 47 with four noughts and $5 \%$. That is $470 \mathrm{kohm} / 5 \%$. Try Question 4 , a normal one
4. A. Green gives 5, blue 6, and brown a single nought. Altogether 560 with the unit pF. White is $10 \%$ and the last one we forget. Correct answer so on to Question 5.
B. Green and blue must be reversed, that is 560 pF and not 650 pF . The noughts were correct. Proceed to Question 5.
C. The figure 560 is correct but it must be pF and not nF . The result is always in pF. Try Question 5.
D. The figure 560 is correct, but the unit is wrong always use pF . Later you can convert to $u F$ or nF , e.g. $1,500,000 \mathrm{pF}=1.5 \mathrm{uF}$. Continue to Question 5.
E. The unit $F$ is never employed. What an enormous capacitor you have decided on! Even the biggest capacitors of the electrolytic type are always given a number, and usually do not exceed $25,000 \mathrm{uF}=$ 0.025 F . Use the unit pF when applying the colour coded capacitors. The answer is 560 pF . Proceed to Question 5.
F. You have mixed up the figures. The answer is 56 and a nought, i.e. 560 pF . Try Question 5.
5. A. You have read direct: orange $=3$, red $=2$, black $=x 1$. This gives 32 pF . You have assumed that we found the tolerance: First of all you will recall that 32 pF is not a standard value, so something is wrong. Split the orange band into two and the result is 33 . There should be five bands, however. One possibility is to take three orange bands first and get 33 pF , and then red gives $2 \%$ and the black one the temperature information. This could be regarded as correct based on the question text but it is not included in the possible answers. Another possibility is to split the red band into two thus getting $3.3 \mathrm{nF} / 2 \%$. This is not mentioned either. On the other hand, the black band can be split, giving $20 \%$ and temperature. The result is then a capacitor of $3.3 \mathrm{nF} / 20 \%$. We can always see the difference between a wide and a narrow band. In this case the orange band is wide, the red narrow, and the black wide again, and this is the correct solution. Continue reading the rest of the book.
B. You decided to split the orange band into two, giving 3.3 nF which is correct. The black band must also be split resulting in a $20 \%$ tolerance. If you wish to know all the possibilities here, read the answer $A$ above, or depend on us and continue reading the book.
C. Orange gives three, red two, and the black is split up giving $x 1$ and $20 \%$. This makes only four bands, and 32 is not standard. By splitting the orange band into two we get a standard value of 33 and red gives two noughts, 3300 pF . The black band being split gives $20 \%$ and band five. All the possibilities involved are explained above under the answer $A$, otherwise continue reading the book.
D. This is the only possibility that fits. Both the orange and the black rings are split into two, i.e. orange, orange, red, black, black. To look at the capacitor we see only orange, red and black. $3.3 \mathrm{nF} / 20 \%$ is not the only possibility when the colours only are stated. The answer $A$ above gives all the possibilities. Read it if you like, and continue reading the rest of the book.

## PRACTICAL APPLICATIONS

In this part of the book we endeavour to widen your knowledge of the practical side of electronics.
A printed wiring board AE accompanies this book.
The first 10 circuits in this book are based on this wiring board.
If you do not have the necessary components, we supply complete sets for each circuit.
We regret that we are unable to offer you any guarantee, as the price of this book does not include such service. Each circuit has been thoroughly tested, however, and you can start without any hesitation.
The AE printed wiring board shows how to place individual components.
The AE circuits can be separated and employed as required. All the circuits are based on the basic theories explained in this book.

Use a 4.5 V battery for these AE circuits, or the stabilised power supply unit NT 315.


AE 1 (AE 1 means Amateur Electronics, Circuit 1) is the first in a series of small, simple designs to help you get started in gaining practical experience.

AE 1 is a small output amplifier of 100 mW . The output, though not high, is sufficient for testing purposes, small intercommunication systems or radios. The amplification is approx. 2 only, so a pre-amplifier must be used, i.e. AE 2. This small output amplifier has a good impedance transfer ratio, however, in that a loudspeaker impedance down to 3.2 ohms can be used. The input impedance is approx. 1 kohm. Loudspeakers are connected between common (0) and OUT at capacitor C3. The voltage is 4.5 V . Input signal is connected between C 1 (IN) and 0 . The capacitor C 4 is inserted to avoid inherent oscillation at 100 MHz .

The calculations can be found in Sections G17 and G18.
The following components can be used:
$\mathrm{R} 1 \mathrm{~A}=1$ kohm, $\mathrm{R} 2=560$ ohm, R3 $=15 \mathrm{kohm}, \mathrm{R} 4=6.8$ $\mathrm{kohm}, \mathrm{R} 5=560 \mathrm{ohm}, \mathrm{C} 1=6.8 \mathrm{uF} / 40 \mathrm{~V}, \mathrm{C} 2=47 \mathrm{uF} / 10 \mathrm{~V}$, $\mathrm{C} 3=330 \mathrm{uF} / 10 \mathrm{~V}, \mathrm{C} 4=100 \mathrm{pF}, \mathrm{T} 1$ and $\mathrm{T} 3=\mathrm{BC} 172$ or BC 107/108/109. T2 is a transistor of the type MEO 412 or BC 177. D1 is a silicon diode e.g. 1N4140 or BA 100.


AE 2 is a pre-amplifier having an amplification ratio of approx 1:50. It is necessary to connect to AE 1 to obtain sufficient output power for an intercommunication system.

Connections for an intercom are from OUT on AE 2 to IN on AE 1. Supply voltage to be connected in parallel. On connecting a loudspeaker to the input, the speak side is established. Any switch can be used for the speak/listen positions. Supply voltage 4.5 V .

The calculations can be found under G17
The following components are used in AE 2:
$\mathrm{R} 1=47 \mathrm{Ohm}, \mathrm{R} 2=270 \mathrm{Ohm}, \mathrm{R} 3=47 \mathrm{Ohm}, \mathrm{R} 4=270 \mathrm{Ohm}$, $\mathrm{R} 5=2.7 \mathrm{KOhm}, \mathrm{R} 6=12 \mathrm{KOhm}, \mathrm{C} 1$ and $\mathrm{C} 3=6.8 \mathrm{uF} / 40 \mathrm{~V}$, $\mathrm{C} 2=330 \mathrm{uF} / 10 \mathrm{~V} \mathrm{~T} 1$ and $\mathrm{T} 2=\mathrm{BC} 172$ or BC 107/108/109.


Amplifiers AE 1 and AE2 coupled with a switch so that it can be used as an intercom.


Volume control connection


Diagram shows the interconnection of AE 1 and AE 2 to which a microphone or radio can be connected.


AE 3 is a diode receiver. Compared with the low number of components used in the design, this is a powerful receiver, but it rarely receives more than one station. In connexion with AE 2 and AE 1, it makes an excellent little radio. Even without an antenna, it receives transmissions of moderate strength provided the transmitter is not too distant.

The calculations can be found under G24.
The following components are recommended:
$\mathrm{R} 1=22 \mathrm{KOhm}, \mathrm{C} 1=2.2 \mathrm{nF}, \mathrm{C} 2=500 \mathrm{pF}$ variable capacitor, D1 = AA 143, the coil L1 being a ferrite rod with 30 turns of multistrand wire.AE 3 is connected with out to input of AE 2 and common to common (0 to 0). Antenna connection at ANT.


AE 4 is a flasher that can be used for Christmas tree lighting, electric train models etc. The voltage required is 4.5 to 6 V . The AE 4 has a loudspeaker option.

This output function is explained in AE 5
The function of the flashing unit is described under G30, Fig. 30.2, together with calculations.

Components:
$\mathrm{R} 1=100 \mathrm{Ohm}, \mathrm{R} 2$ and $\mathrm{R} 3=2.7 \mathrm{KOhm}, \mathrm{C} 1$ and $\mathrm{C} 2=100$ uF/2.5 V, GL is a flashlight bulb of $6 \mathrm{~V} / 50 \mathrm{~mA}, \mathrm{~T} 1$ and T2 $=$ BC 172 or BC $107 / 108 / 109$.


AE 5 is a slightly different version of AE 4. We use much smaller capacitors and there is no lamp. This kit can be used as a testing generator. A powerful tone is emitted that is fed either to an AE 1 output amplifier or direct to a loudspeaker. An amusing experiment is to connect AE 5 to S on AE 4 with plus, when AE 4 will activate AE 5 in step with the lamp, so that a tone sounds intermittently - try it! The output from AE 5 terminal S is coupled via AE 1 to the speaker.

The necessary calculations can be found under G30 astable vibrator. Fig. 30.2.

The supply voltage is 4.5 V .
Necessary components:
$\mathrm{R} 1=1 \mathrm{KOhm}, \mathrm{R} 2=33 \mathrm{KOhm}, \mathrm{R} 3=33 \mathrm{KOhm}, \mathrm{R} 4=1 \mathrm{KOhm}$, C 1 to $\mathrm{C} 3=47 \mathrm{nF}, \mathrm{T} 1$ and T 2 are BC 172 or BC 107/108/109.


AE 6 is a monostable multivibrator which on being triggered remains in the position for a period of time and then switches back.

The astable multivibrator AE 5 plus is connected to $S$ here. Start by short-circuiting IN and plus, and the AE 5 emits a tone, the length of which depends on $C_{X} \cdot C_{X}=400 \mu \mathrm{~F}$ gives a 10 sec . tone, the length being proportional to $\mathrm{C}_{\mathrm{x}}$.

This unit can be used for door-bells when the tone from AE 5 is connected direct to AE 1. The pushbutton at the door short-circuits in and plus producing a tone independent of how long the button is pressed.

Components:
$\mathrm{R} 1=1 \mathrm{KOhm}, \mathrm{R} 2=27 \mathrm{KOhm}, \mathrm{R} 3=27 \mathrm{KOhm}, \mathrm{R} 4=1 \mathrm{KOhm}$, R5 $=100 \mathrm{KOhm}, \mathrm{T} 1$ and $\mathrm{T} 2=\mathrm{BC} 172$ or $\mathrm{BC} 107 / 108 / 109$, $\mathrm{C} 1=68 \mathrm{nF}, \mathrm{C}_{\mathrm{x}}=47 \mathrm{uF} / 10 \mathrm{~V}$.

Supply voltage: 4.5 V.


The AE 7 is an RC generator that produces a practically sinusoidal tone. It can feed AE 1. The RC generator can be used as a signal source when measuring output power and for testing purposes.

Supply voltage 4.5 V . The theoretical basis can be seen under G19, filters.

Components:
C 2 to $\mathrm{C} 4=10 \mathrm{nF}, \mathrm{R} 1=15 \mathrm{KOhm}, \mathrm{R} 2=15 \mathrm{KOhm}, \mathrm{R} 3=33$ $\mathrm{KOhm}, \mathrm{R} 4=10 \mathrm{KOhm}, \mathrm{R} 5=220 \mathrm{KOhm}, \mathrm{R} 6=18 \mathrm{Ohm}, \mathrm{T} 1=$ BC 173 or $\mathrm{BC} 109, \mathrm{C} 1=47 \mathrm{uF} / 10 \mathrm{~V}$


The AE 8 is a filter that can be installed in connection with tape-recorders, amplifiers etc. to give a bass boost of 15 to 20 dB . The filter theory can be found under Sect. G19, filters.

The following components are used:
$\mathrm{R} 1=18 \mathrm{KOhm}, \mathrm{R} 2=1.8 \mathrm{KOhm}, \mathrm{C} 1=220 \mathrm{nF}$.


AE 9 is a filter for treble boosting purposes. The theory is explained in the section on filters G19.

Components:
$\mathrm{R} 1=18 \mathrm{KOhm}, \mathrm{R} 2=1.8 \mathrm{KOhm}, \mathrm{C} 1=4.7 \mathrm{nF}$


The AE 10 CCIR-filter is extremely suitable for inserting in a circuit behind a crystal pick-up. The filter boosts the bass and suppresses the treble, so that gramophone records sound more true in reproduction. This filter is actually designed for use in the amplifier Kit AF 20 obtainable from JOSTY KIT. The basic theory can be seen in the section on filters, G19. The CCIR-filter is designed for a bass boost at 500 Hz and a treble cut at $2,150 \mathrm{~Hz}$. AE 1, AE 2 and AE 10 can also be used as a small record player amplifier.

Components:
$\mathrm{R} 1=18 \mathrm{KOhm}, \mathrm{R} 2=1.8 \mathrm{KOhm}, \mathrm{C} 1=220 \mathrm{nF}, \mathrm{C} 2=47 \mathrm{nF}$.


The AF 20 is a classic example of a simple, cheap and quite effective little amplifier for the beginner.
More advanced designers use it as a headphone amplifier. It comprises two stages. A pre-amplifier including a transistor T1 and the output unit employing transistors T2, T3 and T4. The calculations which are very simple, can be seen in the basic book.
The output stage is fed back via R 6 where the intermediate voltage is adjusted. C 3 is employed for anti - oscillation purposes. Normally, the regwired signal is fed to input 1 and the common connection to 2 . A small aluminium plate should form the chassis, the assembly screws being connected to 2 .
AF 20 can also be used as a radio amplifier, for crystal sets or record player with built-in pre-amplifier and equaliser. If a crystal pick-up is used, there is no equaliser in which case an equalising filter must be inserted. See AE 10.
The equalising filter boosts the bass and reduces the treble according to international standards. The low frequencies occupy more space than the high in the recording, so the former is filtered and then boosted to give a truer reproduction. Some of the noise due to the stylus running in the groove is removed in the high-frequency range.

Technical data

| Voltage | 12 V |
| :--- | ---: |
| Current, max. | 450 mA |
| Loudspeaker | 3.2 Ohm |
| Sensitivity | 50 mV |
| Input impedance | 5 KOhm |



PARTS LIST
R1
R2
R3
R4
R5
R6 potentiometer
R7
R8
R9
R10
R11
R12

2,7 KOhm 150 Ohm 470 Ohm 130 Ohm 220 Ohm 200 KOhm 8,2 KOhm $4,7 \mathrm{KOhm}$ 47 KOhm 8,2 KOhm $1,8 \mathrm{KOhm}$ 15 KOhm

C1
C2
C3
C4
C5
C6
C7
D1
T1
T2
T3-T4 AC 187/88-01
1N4148
BC 173
BC 173
BC 173
BC 173
$22 \mathrm{uF} / 25 \mathrm{~V}$ $6.8 \mathrm{uF} / 25-40 \mathrm{~V}$ 4.7 nF
-40 V
$6.8 \mathrm{uF} / 25-40 \mathrm{~V}$ $1000 \mathrm{uF} / 10-16 \mathrm{~V}$
$68 \mathrm{uF} / 63 \mathrm{~V}$
100 pF $1000 \mathrm{uF} / 10-16 \mathrm{~V}$
$68 \mathrm{uF} / 63 \mathrm{~V}$
100 pF


The AF 30 is an all-round pre-amplifier for low-impedance pick-ups such as B \& O, Shure and Ortofon.
The pre-amplifier is dc coupled direct from T1 collector to T 2 base, and filtering via C 2 and C 6 that reduces the treble and raises the bass frequencies within $\pm 1 \mathrm{~dB}$ in relation to CCIR standards. R1 and C5 together form a filter to remove any resonant frequencies above 100 MHz . R4 and C4 is a simple RC-filter to eliminate 'motor-boating', a strange throbbing sound that can occur under certain conditions of the amplifier.
The AF 30 is a balanced amplifier dc-wise, as the T1 base voltage is from T2 emitter, and T2 base voltage comes from T1 collector. R2 is thus collector resistor for T1 and base resistor for T2.
R8 and R10 are emitter resistors ensuring negative-feedback for ideal frequency response. R11 and R12 constitute a simple voltage divider that cuts down voltage to T1 base via R7 that is inserted to limit the current to T1, and to avoid excessive attenuation to common. If not used, the resistance to common would be via R12 which is 10 kohm , as opposed to R 7 which is 150 kohm.

Technical data

Voltage
Current
Frequency response
Amplification factor
Signal to noise ratio
Input impedance Output impedance
$20-30 \mathrm{~V}$
1 mA
$20-20,000 \mathrm{~Hz}, \mathrm{CCIR} \pm 1 \mathrm{~dB}$ 10 - nominal input impedance 56 dB
15 kohm (2-50KOhm)
50 KOhm


PARTS LIST

| R1 | 100 Ohm |
| :--- | ---: |
| R2 | 680 KOhm |
| R4 | 22 KOhm |
| R5 | 100 KOhm |
| R6 | 1 MOhm |
| R7 | 150 KOhm |
| R8 | 4.7 KOhm |
| R9 | 6.8 KOhm |
| R10 | 1.5 KOhm |
| R11 | 27 KOhm |
| R12 | 10 KOhm |



C1
C2
C3
C4
C5
C6
C7
T1
T2
330 nF 47 nF 100 nF $22 \mathrm{uF} / 25 \mathrm{~V}$ 100 pF 10 nF $47 \mathrm{uF} / 10 \mathrm{~V}$ BC 173 BC 173


## Description

The AF 310 is a universal output amplifier that can be used on 12 or 30 volts. At 12 V the output is 4 W , and at 30 V , 10 W.

## Mechanical Design

The AF 310 is based on a fibre-glass wiring board having a 5 mm aluminium plate as a heat sink. This enables the conduction of heat to a main heat sink, a chassis or other cooling surface. The wiring board including components and heat sink measures only $5 \times 10 \times 2 \mathrm{~cm}$, and seven edge connectors are placed along one side. The aluminium heat sink and edge connectors are employed to ensure easy fitting and replacement of the unit, as experience shows that this is the cause of many faults.

## Diagram

As the diagram shows, the amplifier design is quite conventional in which the negative feedback is led out via connectors. The output section includes robust overdimensioned output transistors Type 40312 (RCA). The driver stage comprises two phase-splitting transistors of the types BC 171 and MEO 412. The no-signal voltage is determined by a BC 172 while BC 171 is a series transistor - the pre-amplifier transistor is a MEO 412. The whole circuit is dc coupled which ensures minimum distortion. In cases of centre-tapped current supply, the output electrolytic capacitor can be omitted and the loudspeaker connected dc-wise.

## Adjustments

When the supply voltage has been determined and $\mathrm{Ra}, \mathrm{Rb}$ and Rc fitted (see parts list) the trimming potentiometer on the wiring board can be adjusted so that no-signal voltage is exactly half that of supply voltage. This gives maximum output of the amplifier.


Voltage
Current consumption
Frequency range plus/minus 1 dB Output

12 or 30 V
0.3 or 1.0 A
$20-20,000 \mathrm{~Hz}$ 3-10 W

| PARTS LIST |  | C1 |
| :---: | :---: | :---: |
|  |  | C2 |
| R1 | 100 Ohm | C3 |
| R2 | 100 Ohm | C4 |
| R3 | 10 Ohm | C5 |
| R4 | 2.7 KOhm |  |
| R5 | 15 KOhm | T1 |
| R6 | 100 KOhm | T2 |
| R7 | 47 KOhm | T3 |
| R8 | 27 KOhm | T4 |
| R9 | 5.6 KOhm | T5 |
| $\mathrm{Ra}]$ | 6.8 KOhm | T6 |
| Rb at 12 V | 3.3 KOhm | T7 |
| Rc | 18 Ohm |  |
| $\mathrm{Ra}]$ | 15 KOhm |  |
| Rb at 30 V | 10 KOhm |  |
| Rc | 18 Ohm |  |

1 nF
1 nF
100 pF
$6.8 \mathrm{uF} / 24-40 \mathrm{~V}$
$6.8 \mathrm{uF} / 25-40 \mathrm{~V}$

40312
40312
BC 171
BC 172
EO 412 or BC 251
B 171
EO 412 or BC 251




The AT 5 is an electronic relay. When connected to a battery, T1 conducts current because this transistor receives base current via R2. The T1 collector voltage increases and a base current goes to T2 giving a collector current that is equal to base current times the amplification factor.
If the load at 5 and 6 is a lamp, it will light. The lamp should not exceed 1.2 W (limited by T2).
When 1 and 2 are short-circuited the lamp goes out as there is no base current in T1.
It is not necessary to short-circuit 1 and 2 direct as a photo-resistor can be inserted that has a lower resistance with increasing light.
AT 5 can also be used as a flash-unit because the lamp and the photo-resistor placed close to each othe form a feedback circuit. The flashing frequency deper. Is on the distance between lamp and bulb.
The accompanying parts list gives the possibility of connecting to various voltage sources.


The circuit shows minus to common (chassis). If there is plus to common, reverse all connections shown.


## PARTS LIST

For 6 V minus to chassis

| R1 | 150 Ohm |
| :--- | :--- |
| R2 | 47 KOhm |
| R3 | 47 KOhm |
| R4 | 150 Ohm |


| T1 | AC 128 | T1 | AC 128 |
| :--- | :--- | :--- | :--- |
| T2 | AC 127 | T2 | AC 127 |

$$
\text { AC } 127
$$

T2
For 12 V minus chassis
R1
R2
R3
R4
560 Ohm
47 KOhm 82 KOhm 560 Ohm

AC 128
AC 127
For 12 V plus to chassis
R1
R2
R3
R4
560 Ohm
47 KOhm
82 KOhm
560 Ohm
AC 127
AC 128


The AT 30 is an automatic control of professional standard that is supplied in large quantities for industrial purposes.
The circuit is designed to operate on light, temperature, humidity etc. provided the necessary transducers are employed.
A photo-resistor is used for measuring light, a temperature dependent resistor for measuring temperatures (thermistor or NTC-resistor) and two stripped wires for measuring humidity. The diagram shows a voltage stabilisor comprising R3, R2, R1 and D1.
The trimming potentiometer R1 enables exact sensitivity adjustments.
T1 is a dc-coupled pre-amplifier that activates T2 and T3 together forming a Schmitt trigger that at a certain voltage activates a relay.
D2 is a protective diode that prevents any damage to T3 due to inductive voltages from the relay, and C1 is a slow-down capacitor to prevent undesired rapid switching.

Technical data

| Voltage | 18 V dc |
| :--- | ---: |
| Current | 50 mA |
| Switching | 500 mS |
| Sensitivity | $10 / 00$ change of resistance |
|  |  |
| between 3 and 4 |  |

L : Light source
F : Photo-resistor
K : Bell
X : Person breaking light beam


PARTS LIST
C1
$6.8 u \mathrm{~F} / 25-40 \mathrm{~V}$
R1 potentiometer 4.7 KOhm

R2
R3
R4
R5
R6
R7
 47 KOhm
47 KOhm T1
10 KOhm T2
39 Ohm T3

1N4148
1N4148
BC 109
BC 107
BC 107


The AT 50 is designed for regulating lighting, heating or motor speeds with ac connection.
The AT 50 consists of a DIAC that feeds current to the control gate of a TRIAC when the voltage of a charged capacitor C1 reaches a certain level. When a current passes this gate, there is a full flow of current through the TRIAC until the voltage changes polarity which in Denmark occurs a 100 times a second. When the capacitor is charged synchronously with the alternating current the firing voltage occurs within a single cycle and the TRIAC is triggered at a speed of 1 usec. At the mid-point of the "intensity-potentiometer" we get 100 halved voltage peaks and this gives a flashing frequency of 100 Hz , which cannot be registered by the human eye.
However, when a TRIAC switches current at a speed of 1 MHz , it functions as a transmitter on long, medium and short waves, which limits the possibilities of this fantastic little unit. By comparison, mechanically speaking, one thinks of the huge variable resistors and transformers used in theatres, etc.

Despite the noise drawback, the use of TRIACS is not forbidden in Denmark. The law, however, sets limits to radiated noise. The noise can be suppressed by a filter, but efficiency is lowered and suppression is rather poor.

Technical data

| Regulating | 6 A |
| :--- | ---: |
| Voltage | 220 V |
| Noise frequency | 1 MHz |



AT 50


PARTS LIST

| R1 | 3.3 KOhm |
| :--- | ---: |
| R2 | 15 KOhm |
| R3 | 470 KOhm |
|  |  |
| C1 | 47 nF |
| C2 | 47 nF |

D1 Diac 40583 or replacement type
T1 Triac 40664 or replacement type


This TRIAC circuit can handle up to 15 amps . despite its compactness.

It functions in the same manner as AT 50.
Technical data

Operating voltage
Adjustable current AT 55
Adjustable current AT 56
Load AT 55 (continuous running) Load AT 56 (continuous running)

220 V
max. 6 Amp $\max .15$ Amp
$\max .1300 \mathrm{~W}$
$\max .2200 \mathrm{~W}$


PARTS LIST:

| R1 | 12 Ohm |
| ---: | ---: |
| C1 | 100 nF 250 Volt |
| P1 | 470 Ohm |
| T1 | AT 55 Q 4006 T |
| T1 | AT 56 Q 4010 T |

## WARNING

We strongly recommend to build the AT 55-56 into a box as the circuit and many components carry mains voltage and may be dangerous to touch.

If the AT 55-56 is to work continuously on max. load. It is essential to mount a heat sink (cooling plate) to the triac.


The AT 60 makes it possible to synchronise light with music in an inexpensive way. This unit has the advantage over other equipment in following music exactly without time delaying accessories such as lamps and photo-resistors.
The unit is designed for direct connection to a loudspeaker outlet with a 5 ohm resistor inserted, and to 220 V ac in series with the light source.

A special feature is that the AT 60 can be adjusted to minimum zero-light without switching off the lamp, thus ensuring long lamp life.
If you do not wish to over-load the loudspeaker outlet this corresponds to an extra speaker - a small 3 W amplifier AF 20 can be inserted as a buffer amplifier.
The AT 60 diagram shows how the transformer insulates the dangerously high 220 V power, transfers the music voltage that is rectified, charging C1. Via R4 and R5 the incoming pulsating ac voltage is synchronised so that T1, a uni-junction transistor, connects the lamp at the end of each cycle, the lamp being barely lit. The music signal voltage is then rectified via D1, charging C1 quicker, the lamp lighting at an earlier point in each cycle, and thus burning brighter.
D2 is a zener diode that maintains the voltage across T1 at a low, non-damaging level.

## Technical data

| Voltage | 220 V ac |
| :--- | ---: |
| Output | 600 W |
| Control wattage | 1 W |
| Synchronising speed | 20 ms, provided the lamp used |
|  | can follow the frequency |



## PARTS LIST

| R1 | $4,7 \mathrm{KOhm}$ |  |  |
| :--- | ---: | :--- | ---: |
| R2 | 100 Ohm |  |  |
| R3 | 100 Ohm |  |  |
| R4 | 15 KOhm | D1 | 1N4148 |
| R5 | 470 KOhm | D2 | ZPD 15 |
|  |  | D3 | 1N 4005 |
| C1 | 47 nF | D4 | 1N 4005 |
| C2 | 100 nF | D5 | 1N 4005 |
|  |  | D6 | 1N 4005 |

2N 4870, 2N 4871
2N 4443 TR 3.2 Ohm/18 KOhmTransformator


The AT 65 is a light organ with frequency separation for bass, medium and treble frequencies. The circuit is slightly different from the AT 60. The AT 60 converts music variations to light variations, while the AT 65 "merely" switches on or off according to the level. The lamp voltage can be adjusted in the AT 65 so that the lamp is barely lit which means longer lamp life.
The AT 65 is fed with approx. 2 W either from an amplifier or a tape recorder. Remember to insert a 4 ohm resistor (minimum) in one of the loudspeaker leads to the AT 65.

Application
Max. operating voltage
Max. wattage per unit
Max wattage in all, AT 65
Necessary input
Adjustment of lamp bias

3-channel light shows 250 V
600 W
1800 W
1 W
0-220 V


## PARTS LIST

R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
3,9 KOhm
5,6 KOhm
39 KOhm
15 KOhm
15 KOhm
15 KOhm
$3,3 \mathrm{KOhm}$
$3,3 \mathrm{KOhm}$
3,3 KOhm
470 KOhm adjustable
470 KOhm adjustable
470 KOhm adjustable

| C1 | $6,8 \mathrm{nF} / 125$ Volt |  |  |
| :--- | :---: | :---: | :---: |
| C2 | $8,2 \mathrm{nF} / 125$ Volt |  |  |
| C3 | $10 \mathrm{nF} / 125$ Volt |  |  |
| C4 | $68 \mathrm{nF} / 125$ Volt | D1 | Diac |
| C5 | $47 \mathrm{nF} / 125$ Volt | D2 | Diac |
| C6 | $47 \mathrm{nF} / 125$ Volt | D3 | Diac |
| C7 | $47 \mathrm{nF} / 125$ Volt |  |  |
| C8 | $47 \mathrm{nF} / 125$ Volt | T1 | Triac |
| C9 | $47 \mathrm{nF} / 125$ Volt | T2 | Triac |
| C10 | $47 \mathrm{nF} / 125$ Volt | T3 | Triac |



The GP 310 is the basic circuit board which combined with two AF 310 output amplifiers and an NT 310 power pack makes a complete stereo amplifier, $2 \times 6 \mathrm{~W}$ with dc coupled loudspeakers. As the AF 310 is universal in application, it can also be used as a dc amplifier. The reproduction quality is high also at low frequencies. The basic wiring board is provided with input terminal bushings, switches and potentiometers.

The controls from left to right are:
Volume potentiometer, balance potentiometer, rumble filter, stereo-mono switch, bass potentiometer, treble potentiometer, and input selector that has positions for tape recorder, radio and record player.
The pre-amplifier is for a dynamic pick-up.
If a crystal pick-up is to be used, R1 and R2 in the pre-amplifier input must be reversed. If the signal is still too strong, R1 can be replaced by a resistor 1 kohm instead of the 4.7 kohm resistor.
To avoid hum, the main circuit board must be mounted on a sturdy metal chassis.
Power pack needed, an NT 310 and a double transformer. Fuses, power switch and pilot lamp included on the NT 310 circuit board.

## Technical data

Supply voltage $+15 \mathrm{~V}, 0,-15 \mathrm{~V}$ (centre-tapped 30 V supply) Current consumption

2 A
Output power, sine wave
Frequency range, plus minus 1.5 dB
Harmonic distortion max.
Loudspeaker connection
$2 \times 6 \mathrm{~W}$
$40-20,000 \mathrm{~Hz}$
$1 \%$
4 Ohm


TONE CONTROL


## PARTS LIST

| R1 | $A$ and $B$ | 4.7 | KOhm | C1 | $A$ and $B$ | 6.8 | uF/25-40 V |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| R2 | $A$ and $B$ | 47 | KOhm | C2 | $A$ and $B$ | 6.8 | uF/25-40 V |
| R3 | $A$ and $B$ | 150 | KOhm | C3 | $A$ and $B$ | 6.8 | uF/25-40 V |
| R4 | $A$ and $B$ | 68 | KOhm | C4 | $A$ and $B$ | 22 | uF/25 V |
| R5 | $A$ and $B$ | 68 | KOhm | C5 | $A$ and $B$ | 6. 8 | uF/25-40 V |
| R6 | $A$ and $B$ | 680 | Ohm | C6 | $A$ and $B$ | 6.8 | uF/25-40 V |
| R7 | $A$ and $B$ | 470 | KOhm | C7 | $A$ and $B$ | 6.8 | uF/25-40 V |
| R8 | $A$ and $B$ | 22 | KOhm | C8 | $A$ and B | 6.8 | uF/25-40V |
| R9 | $A$ and $B$ | 4.7 | KOhm | C9 | $A$ and $B$ | 6.8 | uF/25-40 V |
| R10 | $A$ and $B$ | 470 | Ohm | C10 | B | 100 | $u F / 16 \mathrm{~V}$ |
| R11 | $A$ and $B$ | 22 | KOhm | C11 | $A$ and $B$ | 220 | uF/16 V |
| R12 | $A$ and $B$ | 22 | KOhm | C12 | A | 220 | uF/16 V |
| R13 | $A$ and $B$ | 12 | KOhm | C13 | A | 470 | uF/16 V |
| R14 | $A$ and $B$ | 47 | KOhm | C14 | $A$ and $B$ | 4.7 | nF |
| R15 | $A$ and $B$ | 68 | KOhm | C15 | $A$ and $B$ | 15 | nF |
| R16 | A | 470 | Ohm | C16 | $A$ and B | 4.7 | nF |
| R17 | $A$ and $B$ | 2.2 | KOhm | C17 | $A$ and B | 4.7 | nF |
| R18 | $A$ and $B$ | 4.7 | KOhm | C18 | $A$ and $B$ | 15 | nF |
| R19 | $A$ and $B$ | 22 | Ohm | C19 | $A$ and B | 15 | nF |
| R20 | $A$ and $B$ | 1 | KOhm | C20 | $A$ and $B$ | 47 | nF |
| R21 | $A$ and $B$ | 1 | KOhm | T1 | $A$ and B |  | BC 172 |
| R22 | $A$ and $B$ | 100 | Ohm | T2 | $A$ and $B$ |  | BC 172 |
| R23 | $A$ and $B$ | 100 | Ohm | T3 | $A$ and B |  | BC 172 |
| R24 | $A$ and $B$ | 47 | KOhm |  |  |  |  |
| R25 | $A$ and $B$ | 47 | KOhm |  |  |  |  |
| R26 | A | 470 | Ohm |  |  |  |  |
| R27 | A | 150 | Ohm |  |  |  |  |

FREQUENCY RESPONSE OF COMPLETE AMPLIFIER:

FREQUENCY RESPONSE
OF PRE-AMPLIFIER DYNAMIC PICK-UP



OUTPUT AMPLIFIER



The GU 330 can be inserted between any electronic instrument and a conventional amplifier for orchestral purposes.
The tremolo unit slightly raises the amplification and gives a heavy vibration according to a potentiometer adjustment from 2 (slow) to 10 Hz (quick). The GU 330 is normally inserted between amplifier input and the musical instrument, and even high input signals up to 300 mV are not distorted. As any amplifier is extremely hum (ripple) sensitive at input, it is essential to enclose the GU 330 in a metal box, and equally important to connect the enclosure to negative on the tremolo unit.
The GU 330 is designed specially for battery operation (low power consumption).
The GU 330 circuit includes a slow-acting astable multivibrator combined with PNP-transistors T1 and T2. The field-effect transistor T3 is triggered in step with the multivibrator impulses to C6, that again varies the activation of the amplification transistor T 4 emitter. The transistor amplification rises and falls in step with the astable vibrator. As the astable multivibrator emits a square-shaped wave, it cannot be directly coupled to a low-frequency amplifier. Two RC components have therefore been inserted to convert the square-wave voltages to a combination of sine and triangular voltages.

The input signal is led to the amplification transistor T 4 via R19 and C7. It must be mentioned at this point that R19, together with the output resistance of the instrument concerned determines the amplification of the stage. As most musical instruments have a low output impedance, this alone would decide the impedance if R19 were not inserted. This would mean an amplification difference between 1 and 100 depending on the instrument.
The GU 330 output signal is via C8.
The intensity control of this tremolo unit is effected by inserting a 47 kohm potentiometer across C9. This ensures a range from full vibrato in output signal to very slight vibrato.
The potentiometer acts as variable resistor, i.e. only centre and one side has to be connected.

Technical data:
Operating voltage 9-30 V dc
Power consumption at 9 V 4 mA
Tremulo frequency
$2-10 \mathrm{~Hz}$


PARTS LIST:

| R1 | 1 | KOhm | 1/4 Watt |
| :---: | :---: | :---: | :---: |
| R2 | 33 | KOhm | 1/4 Watt |
| R3 | 33 | KOhm | 1/4 Watt |
| R4 | 33 | KOhm | 1/4 Watt |
| R5 | 15 | KOhm | 1/4 Watt |
| R6 | 33 | KOhm | 1/4 Watt |
| R7 | 33 | KOhm | 1/4 Watt |
| R8 | 12 | KOhm | 1/4 Watt |
| R9 | 3,9 | KOhm | 1/4 Watt |
| R10 | 12 | KOhm | 1/4 Watt |
| R11 | 68 | KOhm | 1/4 Watt |
| R12 | 12 | KOhm | 1/4 Watt |
| R13 | 4,7 | KOhm | 1/4 Watt |
| R14 | 180 | KOhm | 1/4 Watt |
| R15 | 10 | KOhm | 1/4 Watt |
| R16 | 3,9 | KOhm | 1/4 Watt |
| R17 | 10 | KOhm | 1/4 Watt |
| R18 | 5,6 | KOhm | 1/4 Watt |
| R19 | 56 | KOhm | 1/4 Watt |
| C1 | 2,2 | uF | 35 Volt |
| C2 | 2,2 | uF | 35 Volt |
| C3 | 1 | uF | 35 Volt |
| C4 | 1 | uF | 35 Volt |
| C5 | 220 | uF | 16 Volt |
| C6 | 10 | uF | 25 Volt |
| C7 | 10 | uF | 25 Volt |
| C8 | 10 | uF | 25 Volt |
| C9 | 10 | uF | 25 Volt |


| '1 | ME 0412 |
| ---: | :--- |
| '2 | ME 0412 |
| T3 | 2N4302 |
| T4 | BC 173 |
| D1 | ZPD 7.5 |



The HF 61 is a crystal set based on the original principles. The JOSTY KIT includes all the parts necessary to become a "real radio amateur".
The HF 61 Kit is efficient and easily assembled by amateurs.
Rough tuning is carried out by adding or reducing the windings on a ferrite rod. On finding the correct number of windings the rod can be placed on a cardboard cylinder and moved to the correct tuning position. In the Copenhagen region, 50 windings give an excellent result, the long-wave reception being quite powerful.
Fine adjustments are carried out on C2.
A suitable antenna is a metre long wire connected to a water-pipe, gas-pipe or metal railing.
The HF 61 can for good results be connected to a small amplifier, e.g. AF 20.


## PARTS LIST

| C1 | 4.7 nF |
| :--- | :--- |
| C2 | 300 pF adjustable |
| R1 | 10 KOhm |
| D1 | AA 143 |
| L1 | Ferrite rod with 50 turns <br> multistrand wire |



The HF 75 is a super-regenerative receiver for frequencies between 25 and 200 MHz . With only one transistor, this receiver is extremely sensitive.
The principle of a super-regenerative receiver is as follows: By means of a transistor and a tuned circuit, the stage oscillates in exactly same manner as a transmitter oscillator with a frequency of, for instance, 100 MHz . With the aid of another tuned circuit, the oscillator is activated at approx. 50 kHz as well. This frequency is called the quench frequency.
The quench frequency does not form a sine wave like the oscillator frequency, but is saw-tooth shaped.
The main oscillator is made increasingly unstable by means of the rising quench voltage and eventually starts oscillating. Just prior to the start of oscillations, the tuned circuit is extremely sensitive to outer influence, and the signal received is greatly amplified.
Every time the oscillator reaches the oscillation limit, the signal strength is registered and this information is fed into an LF amplifier.

Technical data

Supply voltage
Supply current
Reception range
Reception principle
Radio output voltage
High impedance ear-plug output voltage Super-regenerative 50 mV 50 mV


PARTS LIST

R1
R2
R3
R4 R5
R6


C2
C3
C4
C65
C6
C7
C8
T1

| $2.2 \mathrm{Kohm} \chi$ | L1 |
| :---: | :---: |
| $5.6 \mathrm{K@hm} X$ | L2 |
| 5.6 K®hm $\times$ | L3 |
| 2.7 K@hm | L4 |
| 220 (1) hm |  |
| $1 \mathrm{~K} \oplus \mathrm{hm}$ / |  |

20 pF variable capacitor 20 pF variable capacitor $47 \mathrm{nF} / 125 \mathrm{~V}$ $470 \mathrm{pF} / 125 \mathrm{~V} \times$ $47 \mathrm{nF} / 125 \mathrm{~V}$ $22 \mathrm{nF} / 125 \mathrm{~V}$ $10 \mathrm{uF} / 25 \mathrm{~V}$ 10 uF/25 V

2-10 turns, wire 5 mm diam 2 turns, wire 5 mm diam 0.68 uH turns 1 A choke 4 cm stripped wire

BF 125, BF 199


Technical data

Operating voltage Power consumption Tuning range Aerial impedance Sensitivity - 3 dB limit Sensitivity IHF standard I.F. rejection AM suppression 12-55 V DC 22 mA
87-104 MHz
75 Ohm 5.0 uV 10 uV 100 dB

Image rejection 55 dB

Spurious response fo $-1 / 2 \mathrm{fm}$
Harmonic distortion ( $\mathrm{f} 40 \mathrm{KHz} / 1 \mathrm{KHz}$ )
22 dB Output voltage $10 \mathrm{KOhm} / \Delta \mathrm{f} 75 \mathrm{KHz}$ 60 dB 1.5\% 1.5 V


## PARTS LIST:

| R1 | 68 | KOhm | DI | ZPD 12 |
| :--- | :--- | :--- | :--- | :--- |
| R2 | 68 | KOhm |  |  |
| R3 | 560 | Ohm | D1 | ZPD 12 |
| R4 | 10 | KOhm | D2 | BB142 |
| R5 | 10 | KOhm | D3 | BB142 |
| R6 | 1.8 | KOhm |  |  |
| R7 | 47 | KOhm | T1 | BC 173 |
| R8 | 5.6 | KOhm | T2 | BC 173 |
| R9 | 5.6 | KOhm |  |  |
| R10 | 820 | Ohm | IC1 | SO 42 P |
| R11 | 470 | KOhm | IC2 | TBA 120 S |
| R12 | 15 | KOhm |  |  |
| R13 | 39 | KOhm | L1 | 0024A-23L (MITSUMI) |
| R14 | 220 | KOhm 2 | 0024B-23L (MITSUMI) |  |
| R15 | 100 | Ohm |  |  |
| R16 | 330 | Ohm | F1 | SFE 10.7 MA (MURATA) |


| C1 | $2.2 \mathrm{uF} / 35 \mathrm{~V}$ |
| :--- | :--- |
| C 2 | $10 \mathrm{uF} / 25 \mathrm{~V}$ |
| C 3 | $1 \mathrm{uF} / 35 \mathrm{~V}$ |
| C 4 | 22 nF |
| C 5 | 22 nF |
| C 6 | 22 nF |
| C 7 a | 10 nF |
| C7b | 470 pF |
| C 8 | 10 nF |
| C 9 | 10 nF |
| C 10 | 1 nF |
| C11 | 1 nF |
| C 12 | 100 pF |
| C 13 | 100 pF |
| C 14 | 27 pF |
| C 15 | 10 pF |
| C 16 | 10 pF |
| C 17 | 10 pF |
| C18 | $2-20 \mathrm{pF}$ |
| C19 | $2-20 \mathrm{pF}$ |



Technical data

Operating voltage
Power consumption
Tuning range
Areial impedance
Sensitivity - 3 dB limit
Sensitivity - IHF standard
Medium frequency attenuation
AM suppression
Image selectivity
Spurious response
Harmonic distortion ( f $40 \mathrm{KHz} / 1 \mathrm{KHz}$ )
Output voltage ( $10 \mathrm{kohm} / \mathrm{f} 75 \mathrm{KHz}$ )

12-55 V DC
22-25 mA
$87-104 \mathrm{MHz}$
75 and 300 Ohm
0.6 uV
1.8 uV

60 dB
55 dB
60 dB
100 dB
2\%
1.5 V

parts list

R 1820 Ohm 1/4 Watt R 2270 Ohm 1/4 Watt R 339 KOhm 1/4 Watt R $4 \quad 1$ KOhm 1/4 Watt R 5 3.9 KOhm 1/4 Watt R 6180 KOhm 1/4 Watt R 7 4.7 KOhm 1/4 Watt R 8 4.7 KOhm 1/4 Watt R 9 4.7 KOhm 1/4 Watt R 102.2 KOhm 1/4 Watt R 11330 Ohm 1/4 Watt R 12330 Ohm 1/4 Watt R 13 3.3 KOhm $1 / 4$ Watt R 14390 Ohm 1/4 Watt R 15100 Ohm 1/4 Watt R 16120 Ohm 1/4 Watt R 17100 KOhm 1/4 Watt R 18820 Ohm 1/4 Watt

| C 1 | 10 uF | 25 V |
| :--- | :---: | ---: |
| C 2 | 220 uF | 16 V |
| C 3 | 2.2 uF | 35 V |
| C 4 | 1 uF | 35 V |
| C 5 | 22 nF |  |
| C 6 | 22 nF |  |
| C 7 | 1 nF |  |
| C 8 | 47 nF |  |
| C 9 | 1 nF |  |
| C 10 | 47 nF |  |
| C 11a | 10 nF |  |
| C 11 b | 470 pF |  |
| C 12 | 47 nF |  |

[^0]

Technical data

Operating voltage
Power consumption
Harmonic distortion
Channel separation at 1 KHz
LED-current (stereo lamp max. 100 mA )
Stereo signal at full separation
Amplification factor

12-55 V DC
45 mA
0.3\%

40-45 dB
35 mA
125 mV
1

Automatic switching mono/stereo Direct adoption to HF 310 and HF 325



The HF 395 is an antenna amplifier of modern design. It includes a silicon epitaxial transistor with a very low feedback capacitance and low phase displacement even at high frequencies.
Together with a very advanced high frequency circuit board, a high frequency resistor and other high quality components gives excellent gain from a simple circuit as well as low noise level. The HF 395 can be used in connexion with:

> Long-wave receivers Medium-wave receivers
> Short-wave receivers
> Walkie-talkies
> TV channels 2-12
> FM band
> Radio telephone up to 175 MHz

As no coils are employed in the HF 395, it only has to be assembled and correctly connected to a receiver and an antenna, and trimmed to the right frequency. If the HF 395 is to be used to pep up the signal in older FM-receivers, it is advisable to replace the capacitor $C 1$ with a 10 pF type instead of the 470 pF one shown. This is because old type receivers are normally equipped with inferior AM-suppression and it is here that the HF 395 does wonders. The amplification of low frequencies is suppressed by this modification, but it is usually not necessary in most modern receivers.

If the HF 395 is to be used for AM-bands (LW, MW and SW) a wire only a few metres in length is required, and connected to soldering lug 4 (input).
An immediate improvement is attained, and even poor receivers pull in otherwise weak stations and ensure pleasant listening.
The HF 395 has also been tried on various types of radio-telephones, e.g. AP and ITT 8, Both types showed a marked improvement in reception at signals below 1 uV , and the limiter stages functioned earlier.
Tests were carried out in the field and at the JOSTY laboratory. A Marconi signal testing generator was used for sensitivity tests, as well as a Bradley HF-voltmeter and a Radiometer modulation meter.

Technical data

Connection voltage
Current consumption
Voltage gain at 20 MHz min.
Voltage gain at 100 MHz min.
Voltage gain at 225 MHz min.
Noise level
Input impedance
Input impedance
$\ln F=10000{ }^{\circ}$



## PARTS LIST

|  |  | C1 | 470 pF |
| :--- | ---: | ---: | ---: |
| R1 | 22 KOhm | C2 | 470 pF |
| R2 | 100 KOhm | C3 | 1 nF |
| R3 | 18 KOhm |  |  |
| R4 | $1,2 \mathrm{KOhm}$ | T1 | BF 125 or BF 199 |



The NT 10 is an effective little all-round power-pack with 6 soldering lugs at the output rendering many various possibilities. The following shows five combinations with explanations and drawings.

Fig. 1 When connecting ZPD 9.1 between a and $c$ (remember that the mark on the zener diode must face towards a) we have a stabilised power pack with an output voltage of 9 V between 3 and 1 , suitable for use with transistor radios or tape recorders with an output of 500 mW . Also suitable for all circuits having a high and varying current consumption.

Fig. 2 This NT 10 circuit is suitable for pre-amplifiers, antenna amplifiers and other applications having a low but constant current consumption. In connection with the antenna amplifier HF 380 or HF 385, 9 V is fed to the amplifier between c and b while the amplified antenna signal to radio or TV is taken from points 1 and 2.

Fig. 3 This circuit is used when a lower zener stabilised voltage than 9.1 V is required, a resistor being inserted between $a$ and $b$, and a zener diode from $b$ to $c$. The zener stabilised voltage is taken at points 1 to 2. R is e.g. $100 \mathrm{ohm}, \mathrm{z}=7.5 \mathrm{~V}$.

Fig. 4 In this case the voltage between 1 and 2 is stabilised by means of a transistor, a zener diode and a resistor. The component values depend on the zener diode voltage that must not exceed $9.1 \mathrm{~V} . \mathrm{R} 1=10$ ohm, for instance, and $R=270$ ohm.

Fig. 5 In this circuit the two resistors form a voltage divider in which the voltage is taken from points 1 and 2. By using a trimming potentiometer as one resistor, we get a variable voltage supply 0-9 V. Note, however, that only equipment with a low current consumption can be connected as the regulation and stability of the output voltage would otherwise be affected.
Trimming potentiometer $=470 \mathrm{ohm}$.
The NT 10 is a good universal and compact power pack with many possibilities.


Fig. 1


Fig. 2


Fig. 4


Fig. 3


Fig. 5

Operating voltage
Output voltage, stabilised
Output voltage, unstabilised
Output peak current
Ripple voltage at 100 mA

240 V AC
9 V at 100 mA
12 V at 10 mA
150 mA
less than 1 mV

PARTS LIST:

R1
R2
C1
C2
C3
S1
VT
ZPD 9.1
282


The NT 300 is a highly stable laboratory power pack incorporating an electronic cut-off device and an integrated circuit.
Any type of $15-30 \mathrm{~V}, 100 \mathrm{~mA}-3 \mathrm{~A}$ transformer can be used.
The integrated circuit includes a differential amplifier and stable voltage reference. As the integrated circuit cannot supply higher currents than approx. 50 mA , a power stage is added.
The output voltage is adjustable from approx. 2 V to transformer rms voltage.
The current is adjustable from 10 mA to max. transformer current.

Technical data
Input voltage
Output voltage
Continuous load dissipation
Current limit adjustment
Max. output current
Ripple voltage rms at 1 A
Voltage stability at 0-1 A load
Output voltage temperature drift
$9-30 \mathrm{~V} \mathrm{ac}$
$2-30 \mathrm{~V} \mathrm{dc}$
50 W
$10-2200 \mathrm{~mA}$
5 A
1 mV
50 mV
$10^{-4} \mathrm{~V} / \mathrm{OC}$


PARTS LIST

| R1 | 10 Ohm | C3 | $4,7 \mathrm{nF}$ |
| :---: | :---: | :---: | :---: |
| R2 | 220 Ohm | C4 | 1 nF |
| R 3 | 820 Ohm | C5 | 2200uF 50/63 V |
| R4 | 390 Ohm | C6 | 68 uF/64 V |
| R5 | 1 KOhm | C7 | 2.2 nF |
| R6 | 100 Ohm |  |  |
| R7A | 680 Ohm | T1 | 40312 |
| R7B | 390 Ohm | T2 | 2N3055 |
| R8 | 0,3 Ohm |  |  |
| R9 | 470 Ohm | IC | 723/123 |
| R10 | 4,7 KOhm |  |  |
| R11 | 470 Ohm | D1 | B 40 C 2200 |
|  |  | D2 | 1 N 4005 |
| C1 | 1 nF | D3 | 1N 4005 |
| C2 | 1 nF |  |  |

The NT 305 is an electronic voltage converter designed to be inserted between a 12 V or 15 V storage battery and equipment for voltages $6,7.5$ or 9 V , at a maximum current of 1 Arms or 1.8 A peak.
The principle diagram of the NT 305 is the same as that of the NT 315 apart from a few minor differences:
Instead of a bridge-coupled rectifier at input, there is a series rectifier diode to prevent the current from the voltage converter output from returning via T1. Reverse current of this description can cause noise in the equipment, or even worse, affect the stability of the transistor.
Instead of a potentiometer for voltage regulation via transistor T3, a number of fixed resistors is used. It is not necessary to have a voltmeter at hand to adjust the required voltage - all that is required is a soldered connection at the terminals marked with the required voltage.
The power transistor T1, together with T2, form a Darlington pair for the series regulation of output voltage and current. The T3 registers the output voltage through its base, compares with its own base/emitter constant voltage of 0.7 V , and sends a fault-current signal to the Darlington pair.
T4 is a current limiting transistor that at output currents exceeding 1.8 A , reduces the voltage to zero, thus protecting the series transistors.
When the voltage across R 4 exceeds 0.7 V as a result of overcurrent, the T4 starts conducting and consequently prevents T 2 and $\mathrm{T}^{1}$ from conducting.

Technical data:

Input voltage
Output voltage
Output current
Output voltage regulation
$12-15 \mathrm{dc}$
$6,7.5$ or 9 V dc
$1 \mathrm{~A} / 1.8$ Apeak
$10 \%$ from zero to full load

## PARTS LIST

R1 470 Ohm
R2 470 Ohm
R3 100 Ohm
R4 0.47 Ohm
R5 470 Ohm
R6 15 k Ohm
R7 390 Ohm
R8 330 Ohm
R9 $1,2 \mathrm{k} \mathrm{Ohm}$
C1 $220 \mathrm{uF} / 16 \mathrm{~V}$
C2 $220 \mathrm{uF} / 16 \mathrm{~V}$
C3 47uF/ 40 V
C4 $1 \mathrm{nF} / 125 \mathrm{~V}$
D1 1N4005
T1 BD 165
T2 BC 171
T3 BC 171
T4 BC 171

application



The NT 310 is a power pack especially designed for the output amplifier GP 310. This is a double power pack with a built-in power switch, neon lamp and fuses for both the 220 V side and the low-voltage side.
The power pack is provided with two well dimensioned electrolytic capacitors to remove crosstalk and hum.

## Technical data

Transformer input
240 V AC
Transformer output $15 \mathrm{~V}-0-15 \mathrm{~V}$ ac ( 30 V centre-tapped)

Input voltage
Output voltage Current
Ripple voltage at 1 A dc Transformer (not included)

220 V ac
$+18 \mathrm{~V}, 0,-18 \mathrm{~V} \mathrm{dc}$
2 A
0.5 V ac

NT 310

## PARTS LIST

| R1 | 150 KOhm |
| :--- | ---: |
| D1 | IN 4005 |
| D2 | IN 4005 |
| D3 | IN 4005 |
| D4 | IN 4005 |


| C1 | $4700 \mathrm{uF} / 16-18 \mathrm{~V}$ |
| :--- | :--- |
| C 2 | $4700 \mathrm{uF} / 16-18 \mathrm{~V}$ |

S1 fuse holder
S2 fuse holder
S3 fuse holder
S1 fuse 250 mA slow
S2 fuse 2 A quick
S3 fuse 2 A quick
GL Neon lamp 110 V

TR 1 T 301 transformer
Combination of NT 310, GP 310 and AF 310 for complete stereo amplifier



## Application

The NT 315 is suitable for use with cassette recorders or walkie-talkies.
The power pack is both stabilised and provided with an electronic overcurrent protection.
The transistor pair T1 and T2 are of the Darlington type, controlled by T3. A zener diode is normally inserted in this transistor emitter to obtain an accurate voltage reference. If a long-term stability of $5-10 \%$ is sufficient it is enough with the built-in reference in the T3 base-emitter ( 0.7 V ). R6 limits the voltage adjustment making the variation in R7 more linear. T4 together with R4 and R5 constitute the electronic safety measure.
J4 prevents self-oscillation in the electronic section. C2 rotects against a voltage impulse in reverse direction. If aductive currents and large relays etc. are to be taken into account, an extra safety measure is to insert a diode from minus to plus at the output.

Technical data

Input voltage
Output voltage
Voltage drop at 0-0.5 A
and output voltage $5-12 \mathrm{~V}$
Current
Short-circuit current, approx.
Ripple voltage at 250 mA approx.

240 V AC 4.5-20 V DC
$10 \%$
$0-500 \mathrm{~mA}$
600 mA
10 mV


PARTS LIST:
C1
C2
C3
R1
R2
R3
R4
R5
R6
R7
D1

|  | C1 | $1000 \mathrm{uF} / 16 \mathrm{Volt}$ |
| :---: | :---: | ---: |
|  | C2 | $100 \mathrm{uF} / 35-40 \mathrm{~V}$ |
|  | C3 | $100 \mathrm{uF} / 35-40 \mathrm{~V}$ |
| 1 KOhm | C4 | 4.7 nF |
| 1 KOhm | T1 | 40312 |
| 270 Ohm | T2 | BC 171 |
| $1 \mathrm{Ohm} / 2 \mathrm{~W}$ | T3 | BC 171 |
| 1 KOhm | T4 | BC 171 |
| $3,3 \mathrm{KOhm}$ |  |  |
| 470 Ohm |  |  |
| B40C600 |  |  |



ASTABLE MULTIVIBRATOR WITH IC
This astable multivibrator is based in the inexpensive uA 710 or MIC 710. Due to high amplification and cut-off frequency, the multivibrator operates at basic frequencies up to 5 MHz .
Together with R1 and R2, the capacitor C1 determines the oscillator frequency.
Output voltage is between 2 and 4 V and is symmetrical around the zero line.


## AMPLIFIER WITH HIGH INPUT IMPEDANCE

At all high-frequency measurements it is important to have a low input capacitance and high input impedance. This diagram shows that an input impedance exceeding 100 Mohm can be attained, and an input capacitance less than 0.25 pF , depending on the circuit board and leads used The field effect transistor is the 2 N 4416 type made by National Semiconductor.


SQUARE/TRIANGLE WAVE GENERATOR
This multivibrator circuit is especially suited for low-frequency testing. Square or triangle wave form depends on the adjustment of the potentiometer.
Transistor AC 125 or AC 126 can be used.


## LOW NOISE LEVEL PRE-AMPLIFIER

When using a field effect transistor in a pre-amplifier the noise level can be kept low. This circuit shows a combination of FET and PNP transistors.
Negative feedback is fed from the BC 312 output to the FET transistor source.
There is not complete negative feedback as a capacitor is inserted at source, giving a gain of approx. 100.
The input impedance is 1 Mohm . This can be increased by using a higher gate resistor.
The frequency response of this pre-amplifier is linear within $1 / 2 \mathrm{~dB}$ from $20-20,000 \mathrm{~Hz}$. Within -3 dB the frequency response is from 10 to $45,000 \mathrm{~Hz}$.
Supply voltage from 12 to 30 V .


## NOISE GENERATOR

This shows how it is possible with only a unijunction transistor and five other components to build a noise generator with a basic frequency of kHz .
Due to the wide band width a generator of this kind is suitable for HF testing from 500 kHz to 0.5 GHz .


## CRYSTAL OSCILLATOR WITH LOGIC CIRCUITS

A crystal oscillator is both simple and stable. Another advantage in using a crystal is that coils and capacitors are not required.
The circuit comprises three gates, e.g. the TTL series, 7400 being suitable.
The crystal is inserted in the negative feedback circuit of the two gates.
The circuit thus oscillates at the series resonance of the basic tone.
To avoid overloading the oscillator, and to attain a $50 \%$ on/off ratio an extra gate is used as a buffer.


## LIE DETECTOR

This is in fact a feeling-reaction tester, an instrument to ascertain how a person reacts to a certain question.
As a lie causes an emotional change, it is possible to detect the resulting variation in resistance levels.
Even when lying "for fun", the detector will function. Deflection values depend on the type of questions asked.
The input circuit is a bridge type, and the person being tested grips both electrodes thus forming one of the four bridge legs.
One of the other bridge legs is a fixed resistor of 68 kohm and the other is a potentiometer for adjusting the tester to zero before the questions are asked.
The sensitivity of the unit can be adjusted by means of a trimming resistor 1 Mohm .
The slightest change in resistance is amplified by the integrated circuit MIC 741.
A 1 mA instrument shows variations in resistance.
Copper tubing is suitable for making the electrodes. Power supply - three 9 V dry batteries.


SCR-THERMOSTAT

The firing point of a thyristor depends on the difference between the adjusted temperature and the actual temperature.
If the difference is great, $C$ is quickly charged and the thyristor triggers at an early point in the cycle, thus switching the oven on for long periods of the cycle.
If the ambient temperature approaches the set temperature, the NTC resistance drops and the thyristor is triggered later in the cycle, the oven then being on for shorter periods of the cycle.
If a higher wattage than that shown in the diagram (1000 W) is required, a higher rated thyristor (SCR) must be used. The circuit is connected direct to the mains, so it is important to insulate correctly. The potentiometer must have a plastic (insulated) shaft.


The AF 25 is a mixer containing three amplifying transisors. By using buffer amplifiers, the individual potentiometers are independent of one another.

Diagram: The AF 25 comprises two separate input stages with strong negative-feedback from emitter to base via resistors R 7 and R 4 , and capacitors C 3 and C 4 . A high input impedance is achieved by means of high ohm emitter-resistors R6 and R9. The input impedance is equal to emitter-resistance multiplied by current gain in the transistor which in this case gives an input impedance exceeding 1 Mohm.
To maintain a suitably low output impedance, T3 is coupled as an emitter follower. The output impedance here is approx. equal to the emitter-resistance divided by the transistor current gain, i.e. approx. 150 ohm.
Both pre-stages are dc coupled to the emitter follower, which gives good linearity without distortion.

## Technical data

| Voltage | 20 V dc |
| :--- | ---: |
| Current consumption | 2 mA |
| Amplification factor | 1 |
| Frequency response | $20 \mathrm{~Hz}-30 \mathrm{kHz} \pm 1 \mathrm{db}$ |
| Harmonic distortion | $\max 0.1 \%$ |
| Intermodulation | $\max .0 .5 \%$ |
| Output impedance | 150 Ohm |
| Input impedance | 1 MOhm |
| Output voltage | $\max .1 \mathrm{~V}$ |



PARTS LIST

| R1 | 270 KOhm | C1 | 100 nF | C3 $6.8 \mathrm{uF} / 25-40 \mathrm{~V}$ |  |
| :--- | :---: | :--- | :---: | ---: | :--- |
| R2 | 12 KOhm | C 2 | 100 nF | C 4 | $6.8 \mathrm{uF} / 25-40 \mathrm{~V}$ |
| R3 | 270 KOhm | R7 | 100 KOhm | C5 | $6.8 \mathrm{uF} / 25-40 \mathrm{~V}$ |
| R4 | 100 KOhm | R8 | 100 KOhm | T1 | BC 173 |
| R5 | 100 KOhm | R9 | 15 KOhm | T2 | BC 173 |
| R6 | 15 KOhm | R10 | 15 KOhm | T3 | BC 173 |



The AF 35 pre-amplifier can be used in connection with crystal microphones, high-impedance guitars and line output from tube circuits. It is also admirably suitable as an impedance converter when long cables are used. The use of high-impedance microphones etc. causes hum even with good quality screened cable exceeding 10 m in length. Besides the AF 35 amplification factor exceeding 1, this amplifier can reduce a 1 Mohm impedance to 300 ohm. At this low impedance good screened cable can have a length of 100 m without causing hum.
The AF 35 is an excellent example of a dc coupled double emitter follower, and here are some of the specifications.

Supply voltage 10 V . To achieve maximum voltage oscillation on T2 emitter, the no-signal voltage at T2 emitter must be half the supply voltage, i.e. 10 V . This is the peak voltage of the signal, and effective value is approx. 6 V .
R6 is set at 30 kohm , as the required output impedance of 300 ohm is roughly the emitter resistance divided by current gain.
10 V through resistor R 6 at 30 kohm is according to Ohm's Law (used in all these calculations) a current of 300 uA through the transistor collector-emitter. With a current qain of 100 , the base current is a 100 times less, i.e. 3 uA.

The current chosen in T 1 is 0.5 mA . The voltage across R 2 - a common collector-base resistor for T1 and T2 - is 9.3 V because the built-in zener voltage from emitter to base is 0.7 V and the voltage across R 6 is 10 V .

When applying Ohm's Law, 9.3 V and 500 uA give a resistance of 22 kohm . The base current from T2 also contributes to the current in R2, but this is negligible. R1 and R4 form a voltage divider that reduces the voltage to approx. 7 V at C2 plus. The voltage at T1 emitter is fixed at half the voltage from collector to common, that is approx. 5.3 V . This means a voltage drop of 1 volt across R3, not including the zener voltage from emitter to base.
As the collector current must be 0.5 mA , and the current gain around 80-100, the base current must be approx. 6 uA. 1 volt and 6 uA means that R3 must be 150 kohm. The voltage divider resistances are based on the cross current that must be at least five times base current.
The input impedance of the circuit is the current gain times the first transistor emitter resistance, i.e. approx. 2.2 Mohm. C2 is inserted for strong negative-feedback. The same applies to the resistor R5, giving an amplification factor of approx. 1, and an excellent frequency response.

Technical data
Voltage
Current
Frequency response
Signal to noise ratio
Harmonic distortion
Intermodulation
Input impedance
Output impedance
Load impedance
Output voltage
$2 \mathrm{~Hz}-100 \mathrm{kHz} \pm 0.5 \mathrm{~dB}$ 60 dB at 50 KOhmload
$0.05 \%$
$0.2 \%$ at $50 / 5000 \mathrm{~Hz}$
2 MOhm 300 Ohm
3 KOhm
6 V rms

AF35

## PARTS LIST

| R1 | 470 KOhm |
| :--- | ---: |
| R2 | 22 KOhm |
| R3 | 150 KOhm |
| R4 | 180 KOhm |
| R5 | 22 KOhm |
| R6 | 27 KOhm |
|  |  |
| C1 | 47 nF |
| C2 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |
| C3 | $22 \mathrm{uF} / 25 \mathrm{~V}$ |
|  |  |
| T1 | BC 173 or BC 172 |
| T2 | BC 173 or BC 172 |



NOT AVAILABLE AS KIT.


The AF 45 is a line amplifier for use in conjunction with an output amplifier, or to increase the signal level in mixers. This amplifier is based on the same theory as the AF 35, but here the output signal is taken across a collector resistor. T1 base voltage is from a stable voltage between R6 and R7.
C3 and R6 are the stabilising components, and C3 also acts as the T2 emitter bypass.
As R4 is 4.7 kohm, the input impedance is $100 \times 4.7$ $\mathrm{kohm}=0.5 \mathrm{Mohm}$. The amplifier must not be loaded with a higher input resistance than 50 kohm due to signal/noise ratio. When using special components (other resistors) the AF 45 can drive the 120 W AF 62/65 amplifier. These components are specified in the AF 65 description.

Technical data

Voltage
Current
Frequency response Signal to noise ratio Harmonic distortion Intermodulation
Output voltage

45 V
6 mA ( 25 mA using other resistors)
5 Hz to $40 \mathrm{kHz} \pm 0.1 \mathrm{~dB}$ 60 dB at 47 kohm input impedance
$0.1 \%$
$0.3 \%$
8 volts at 10 KOhm load

## PARTS LIST:

R1 270 KOhm
R2 6.8 KOhm
R3 47 KOhm
R4 4.7 KOhm
R5 150 KOhm
R6 390 Ohm
R7 1 KOhm
C1 220 nF
C2 $220 \mathrm{uF} / 16 \mathrm{~V}$
C3 $220 \mathrm{uF} / 16 \mathrm{~V}$
T1 BC 172


T2 BC 341



The AF 80 is a small 0.5 W integrated amplifier. It comprises the integrated circuit TAA 263 and two germanium transistors, AC 128 and AC 127.
The design is as compact as possible which makes it rather difficult to assemble..
The amplifier is dc-coupled from input to output. There are only two transfer electrolytic capacitors, C1 and C2 in parallel with C3. The last capacitors are parallel coupled to ensure a reasonable lower cut-off frequency, and compactness.
The integrated circuit gain is exceptionally high, and the amplifier can manage a dynamic pick-up direct and amplify a crystal set to such a degree that an antenna a few metres long gives good reception of the local transmitter. The output stage is complementary and the no-load current is stabilised by the diode D1. It has a forward voltage of 0.7 V. As this is too high, however, R3 and R4 are inserted as a voltage divider.

There is negative feedback via R5 and R6 and across the loudspeaker via R2, that also supplies base voltage to the output transistors. By fitting a capacitor from common point of R5 and R6 to chassis, the ac negative feedback is short-circuited, which increases the gain.
The common point between R5 and R6 cannot be connected direct to chassis as it affects the temperature stabilisation and the no-signal voltage level.

Technical data

| Voltage | $+4-6$ volt |
| :--- | ---: |
| Current | 200 mA max. |
| Power | 500 mW |
| Distortion | $10 \%$ |
| Frequency range | $100-14,000 \mathrm{~Hz} \pm 3 \mathrm{~dB}$ |



## PARTS LIST

R1
R2
R3
R4
R5
R6
C1 $\quad 6.8 \mathrm{uF} / 25-40 \mathrm{~V}$
C2 $\quad 100$ uF/16 Volt
C3
D1
TC
1N4148
T1
T2
1 KOhm
470 ohm
150 Ohm
68 Ohm 56 kOhm 56 kOhm 47 nF

TAA 263
AC 127
AC 128


Parts: $\mathrm{C} 1=100 \mathrm{nF} . \mathrm{C} 2=10 \mathrm{nF} . \mathrm{R} 1=6.8 \mathrm{kOhm} . \mathrm{R} 2=10 \mathrm{KOhm} . \mathrm{P} 1=4.7 \mathrm{KOhm}$. $\mathrm{P} 2=4.7 \mathrm{KOhm} . \mathrm{P} 3=22 \mathrm{KOhm}$.


Parts: $\mathrm{C} 1=10 \mathrm{nF} . \mathrm{C} 2=10 \mathrm{nF} . \mathrm{C} 3=6.8 \mathrm{uF} / 25 \mathrm{~V} . \mathrm{R} 1=6.8 \mathrm{KOhm} . \mathrm{P} 1=4.7 \mathrm{KOhm}$,


Parts: $\mathrm{Cl}=100 \mathrm{nF} . \mathrm{C} 2=100 \mathrm{nF}, \mathrm{C} 3=10 \mathrm{nF}, \mathrm{C} 4=10 \mathrm{nF} . \mathrm{C} 5=6.8 \mathrm{uF} / 25 \mathrm{~V}$. $\mathrm{R} 1=6.8 \mathrm{KOhm} . \mathrm{Pl}=4.7 \mathrm{KOhm} . \mathrm{D}=\mathrm{AA} 143$


NOT AVAILABLE AS KIT.
The AF 90 is on excellent tone control with built-in amplification. It is of the Baxendale type.
The signal is fed into a frequency determining tone unit.
On turning P1 to the left, the bass is boosted because the low frequency from R2 passes direct via R2 and is amplified by T1. On screwing the control to the right, the low frequencies have to pass a capacitor that acts as a high-impedance.
On turning P1 to the left the high frequencies pass the aigh-frequency conducting capacitor unhindered. Turning to the right gives a weak treble tone, as the high frequencies that penetrate T1 pass on to C3 and C2 which gives negative feedback of the treble.
This is just an indication of the complicated functions.
The T1 amplifier is typical - see transistor coupling, G18.
Technical data
Supply voltage
Current consumption
Amplification factor
Frequency response
Signal to noise ratio
Frequency variation
Cross-over frequencies
Harmonic distortion
Input impedance
Output impedance

18 V 2 mA<br>1<br>$20 \mathrm{~Hz}-20 \mathrm{kHz} \pm 1 \mathrm{~dB}$ 60 dB at 1 volt output voltage At $40 \mathrm{~Hz} \pm 20 \mathrm{~dB}$ At $20 \mathrm{kHz} \pm 20 \mathrm{~dB}$<br>Bass, 500 Hz<br>Treble, 1500 Hz<br>Less than 0.1\%<br>40 KOhm<br>180 Ohm



## PARTS LIST

R2
R3
R4
R5
R6
R7
R8
R9
C1
C2
C3
C4
C5
C6
T1
P1-2 2 potentiometers 100 KOhm lin.


NOT AVAILABLE AS KIT .

The AF 95 is a tone unit with built-in amplifier. The unit is provided with a considerable amount of filters having different functions.
The AF 95 input must be fed from an AF30, a tape recorder, or a tuner. The sensitivity is 100 mV at an output signal of 1 V . The Af 95 is based on two different amplifier stages, the first of which comprises two transistors T1 and T2, dc - coupled in the same manner as the AF 45 circuit. The second stage is an ac - coupled amplifier employing transistor T3.
The signal from T2 is taken via C7 to a tone control circuit, from where it comes out at C11, contimuing to T3 where it is amplifier from 100 mV to 1 V . The Leise filter consists of R4 and C3 forming an RV - connection. This damps the treble, but allows the medium and low frequencies to pass. BC and C 2 form a bass filter, only the medium frequency remaining, which is used for negative feedback of T1.

The Leise filter thus raises the bass and treble, while the medium frequency range is suppressed.
The presence filter lifts the tone level at 3000 Hz , this form of medium frequency lift being employed in Diana Ross recordings.
The rumble filter removes any unwanted low resonances caused by even high-quality record players. To utilise the presence-filter properly, it is necessary to connect AF 95 as shown in the diagram, but the volume level cannot be lowered completely. If this is required 2 and 3 must be short-circuited, but this spoils some of the presence effect. Stylus noise (scratch) filters can be inserted at 10, 7.5 and 5 kHz .

## Technical data

Operating voltage
Current consumption
Frequency response
Gain
Max. ac out
Distortion
Signal to noise ratio
Bass
Treble
Leise filter
Presence filter
10 kHz filter
Rumble filter
7.5 kHz filter
$10+7.5 \mathrm{kHz}$
Input impedance
Output impedance

24 V
approx. 10 mA
$10-25,000 \mathrm{~Hz} \pm 1 \mathrm{~dB}$
approx. 100
1.2 V
$0.05 \%$ at $1 \mathrm{kHz}, 1 \mathrm{~V}$
60 dB at 1 volt out $\pm 12 \mathrm{~dB}$ at 100 Hz
$\pm 12 \mathrm{~dB}$ at 15 kHz
$-20 \mathrm{~dB}$
$5 \mathrm{kHz}:+10 \mathrm{~dB}$
-3 dB at 10 kHz
-3 dB at 100 Hz
-3 dB at 7.5 kHz
-3 dB at 5 kHz
approx. 50 KOhm
approx. 5 KOhm
24-60V DC

100 Ohm
820 Ohm
1.5 k Ohm
1.8 k Ohm
470 Ohm
$24-30 \mathrm{~V}$
$30-40 \mathrm{~V}$
$40-50 \mathrm{~V}$
$40-50 \mathrm{~V}$

N
N
N

PARTS LIST： R1 10 KOm R1 10 KOhm 5.6 KOhm 5.6 KOhm
1 MOhm $\begin{array}{ll}\text { R6 } & 1 \mathrm{MOhm} \\ \text { R7 } & 8.2 \mathrm{KOhm} \\ \text { R8 } & 270 \mathrm{Ohm} \\ \text { R9 } & 330 \mathrm{Ohm} \\ \text { R10 } & 1 \mathrm{MOhm} \\ \text { R11 } & 56 \mathrm{KOhm} \\ \text { R12 } & 220 \mathrm{Ohm}\end{array}$



C14 47uF／10V $220 \mathrm{nF} / 250 \mathrm{~V}$
 むごニため
R1
R2
R3
R4
R6
R7
R8
R
R10
R11
R12

## NOT AVAILABLE AS KIT.



The AF 200 consists of the basic printed wiring board, transformer, rectifier and all the passive components for a stereo amplifier of 60 W sine. The individual amplifiers must be bought separately or the complete amplifier Kit AF 230, containing all the necessary parts right down to the last screw.
The diagram shows how the various plug-in wiring boards are connected.
The AF 201 consists of the printed wiring board and all the necessary components for a 30 W stereo amplifier. The plug-in circuit boards are not included here either, but the complete Kit $2 \times 30 \mathrm{~W}$ is available under the heading AF 230.

Technical data
Wattage
Voltage
Current
Frequency range
$2 \times 30 \mathrm{~W} / 2 \times 15 \mathrm{~W}$, both sine 220 V ac 2 amp max. at 220 V , AF 235 , 1 A $40-40.000 \mathrm{~Hz} \mathrm{~T} 2 \mathrm{~dB}$

## PARTS LIST:




NOT AVAILABLE AS KIT.
The AF 221 is a correction printed wiring board according to R1AA requirements. This filter lifts the bass and reduces the treble from a crystal pick-up.

The filter can be reversed for use as a line input, e.g. record players with equaliser and pre-amplifier. The filter is obtainable as a plug-in unit for the AF 200 amplifier.

Technical data

Amplification
Input impedance
$1 \times$ line, $0.3 \times \mathrm{PU}$
PU: 1 Mohm

| PARTS LIST | CB | 470 nF |  |
| :--- | ---: | ---: | ---: |
|  |  | CA | 470 nF |
| R1 | 1 kohm 1/4 Watt | C5 | $6.8 \mathrm{uF} / 25-40 \mathrm{~V}$ |
| R2 | 22 ohm | $1 / 4$ Watt | P1 |




NOT AVAILABLE AS KIT.

Voltage
Current
Amplification
Frequency response
Harmonic distortion
Intermodulation
Signal to noise ratio
$24-30$ V DC
10 mA
$\times 10$
$40-20.000 \mathrm{~Hz}$
0,1\%
0,1\%
56 dB min, typ. 60 dB


PARTS LIST:
R1 2.7 KOhm R9 $2.2 \mathrm{KOhm} \quad$ C4 $10 \mathrm{nF} / 250 \mathrm{~V}$ T1 $\quad$ BC 173
R2 270 Ohm R10 4.7 KOhm
C5 $6.8 \mathrm{uF} / 40 \mathrm{~V}$
T2 BC 173
R3 1.8 KOhm R11 47 KOhm
C6 $22 \mathrm{uF} / 25 \mathrm{~V}$
R4 330 Ohm R12 560 Ohm
C7 $\quad 100 \mathrm{nF} / 250 \mathrm{~V}$
R5 120 KOhm
C8 $6.8 \mathrm{uF} / 40 \mathrm{~V}$
R6 330 Ohm C1 $220 \mathrm{uF} / 35-40 \mathrm{~V}$ C9 220 pF
R7 3.3 KOhm C2 68nF/250V C10 22uF/25V
R8 3.3 KOhm C3 330nF/250V



NOT AVAILABLE AS KIT .
The AF 251 is a plug-in unit that fits into the AF 200 amplifier when it is used for dynamic pick-ups or microphones. The amplifier is dc-coupled.
T2 base receives bias from T1 emitter combined with negative feedback, this giving excellent temperature stabilisation and frequency response. The correction RIAA filter is from T1 collector to T2 emitter.
This circuit is designed for use with high-quality pick-ups.
The amplifier has a very low signal to noise ratio at an input load of $15-47$ kohms, but is also suitable for 4 ohm top quality pick-ups.
High pick-up signal levels to amplifier are attenuated at the AF 251 output.
In cases of small pick-up signals, R4 can be removed and R1 shorted.

Technical data

Voltage
Current
Amplification
Frequency response
Output voltage
Harmonic distortion
Intermodulation
Signal to noise ratio
$24-30 \mathrm{~V} \mathrm{dc}$ 5 mA
20 x at 15 kohm load
RIAA $\pm 1 \mathrm{~dB}$
2 V max.
$0.1 \%$
$0.1 \%$
56 dB , min, typical 60 dB


PARTS LIST:
R1 10 KOhm
R2 $5,6 \mathrm{KOhm}$
R3 22 KOhm
R4 150 KOhm
R5 39 KOhm
R6 3.9 KOhm
R7 270 Ohm
R8 2,7 KOhm
R9 150 Ohm
C1 $220 \mathrm{uF} / 35-40 \mathrm{~V}$
C2 $10 \mathrm{uF} / 25 \mathrm{~V}$
C3 $22 \mathrm{uF} / 25 \mathrm{~V}$
C4 $10 \mathrm{uF} / 25 \mathrm{~V}$
C5 $47 \mathrm{uF} / 10 \mathrm{~V}$
C6 $10 \mathrm{uF} / 25 \mathrm{~V}$
C7 $22 \mathrm{nF} / 250 \mathrm{~V}$
C8 $\cdot 100 \mathrm{nF} / 250 \mathrm{~V}$

R10 68 KOhm
T1 BC 173
R11 1 KOhm
R12 1,5 KOhm
R13 47 Ohm
R14 18 KOhm
R15 12 KOhm
T2 BC 173


The AF 305 is an intercom unit with the integrated circuit「AA 611. This circuit together with a single transistor can , ee combined to give a complete intercom or baby-sitter unit.
Also required are two loudspeakers and a battery or an NT 10 power pack. The circuit board for the AF 305 includes switches, so all that is necessary is to connect the speakers. A double-core cable is suitable for connectingpurposes.

Technical data
Supply voltage
9-12 V
Power consumption $10-100 \mathrm{~mA}$
Input sensitivity
Speakers (2)
2 mV
Distortion max. at 1 kHz and 100 mV
4 Ohm
Signal to noise ratio $3 \%$ 42 dB


| R1 | 27 Ohm | C 1 | $220 \mathrm{uF} / 16 \mathrm{~V}$ | C 10 | $2.2 \mathrm{uF} / 35 \mathrm{~V}$ |
| :--- | :--- | :--- | :--- | :--- | :--- |
| R2 | 4.7 Ohm | C 2 | $470 \mathrm{uF} / 16 \mathrm{~V}$ | C 11 | $2.2 \mathrm{uF} / 35 \mathrm{~V}$ |
| R3 | 220 Ohm | C 3 | $47 \mathrm{uF} / 35-40 \mathrm{~V}$ | C 12 | $470 \mathrm{pF} / 125 \mathrm{~V}$ |
| R4 | 10 KOhm | C 4 | $10 \mathrm{uF} / 25 \mathrm{~V}$ | T 1 | BC 173 |
| R5 | 22 Ohm | C 5 | $47 \mathrm{nF} / 250 \mathrm{~V}$ | IC | TAA 611 B |
| R6 | 5.6 KOhm | C 6 | $470 \mathrm{pF} / 125 \mathrm{~V}$ | KO |  |
| R7 | 10 KOhm | C 7 | $2,2 \mathrm{nF} / 125 \mathrm{~V}$ |  |  |
| R8 | 10 KOhm | C 8 | $470 \mathrm{pF} / 125 \mathrm{~V}$ |  |  |
| R9 | 1 M Ohm | C 9 | $10 \mathrm{uF} / 25 \mathrm{~V}$ |  |  |




NOT AVALLABLE AS KIT IN UK.

Technical data:

Supply voltage
Power consumption
Audio power Input sensitivity
Distortion at $1 \mathrm{~W} / 1 \mathrm{kHz}$

35-50 V DC
50-2.000 mA
40 W
0.775 V
$0.06 \%$


Loudspeaker 3,2-16 Ohm Bass -10dB

## PARTS LIST:

| R1 | 0.3 Ohm | R15 | 27 KOhm | T1 | MJE 3055 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| R2 | 0.3 Ohm | R16 | 56 KOhm | T2 | MJE 3055 |
| R3 | 470 Ohm | R17 | 100 Ohm | T3 | BC 171 |
| R4 | 1.8 KOhm | R18 | 10 KOhm | T4 | BD 517 |
| R5 | 1 KOhm | C1 | $1 \mathrm{nF} / 125 \mathrm{~V}$ | T5 | BD 518 |
| R6 | 2.2 KOhm | C2 | $470 \mathrm{pF} / 125 \mathrm{~V}$ | T6 | BC 341 |
| R7 | 100 Ohm | C3 | $2200 \mathrm{uF} / 35-40 \mathrm{~V}$ | 7 | MEO 412 |
| R8 | 1 KOhm | C4 | $47 \mathrm{uF} / 35-40 \mathrm{~V}$ |  |  |
| R9 | 33 KOhm | C5 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |  |  |
| R10 | 4.7 KOhm | C6 | $22 \mathrm{uF} / 35 \mathrm{~V}$ |  |  |
| R11 | 100 KOhm | C7 | $100 \mathrm{nF} / 250 \mathrm{~V}$ |  |  |
| R12 | 330 Ohm | C8 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |  |  |
| R13 | 4.7 KOhm | C9 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |  |  |




The AT 25 is an electronic timer for automobile windscreen wipers. The circuit is connected in series with the starting switch of the wiper motor.
The diagram shows that the AT 25 comprises a uni-junction transistor and a controlled rectifier. The uni-junction transistor does not conduct current until the emitter has a voltage of approx. 2 V in relation to B 1 .
The capacitor $C 1$ is charged via R1 and P1, and after a time the emitter reaches 2 V . The UJT then begins to conduct through all the electrodes until C1 is de-charged almost to zero, at which the UJT again switches into its non-conducting state. The voltage across R3 rises sharply at the moment of firing. This voltage causes a current to the gate of the controlled rectifier, thus conducting and acting as a relay contact. A current then goes to the wiper motor that starts and activates its own latching contact that keeps the wiper in action across the windscreen. While this contact keeps the wiper in action, it short-circuits the AT 25 which extinquishes the controlled rectifier as it receives no holding current. This state is maintained until the UJT sends a new impulse.

Technical data

| Current | 8 A |
| :--- | ---: |
| Voltage, max. | 15 V |
| Time delay | 3 to 60 secs. |


| R1 | $4,7 \mathrm{KOhm}$ |
| ---: | ---: |
| R2 | 100 Ohm |
| R3 | 100 Ohm |
| R4 | $1 \mathrm{Ohm} / 2 \mathrm{~W}$ |
| R5 | $1 \mathrm{Ohm} / 2 \mathrm{~W}$ |
| P1 | 100 kohm |
| C1 | $100 \mathrm{uF} / 16 \mathrm{Volt}$ |
| C2 | $10 \mathrm{uF} / 25$ Volt |

T1 2 N4870, 4871
SE $2 N 4441,4443$
Battery Contact


AT 25


## NOT AVAILABLE AS KIT.



The AT 70 is a timer for amateur photographers, and can be connected direct to 220 V ac and enlargers.

Diagram
The transistor T1 receives base voltage when the inserted capacitor is charged to 0.7 volt or higher. It then conducts collector current and the collector voltage is practically zero. R6 transfers the collector voltage to T2. As there is no voltage there is no base current and consequently no collector current, and the relay opens. By means of the potentiometer P1 via R4, the current to the capacitor can be adjusted and thus determine when the 0.7 V level is reached. At this time the relay drops out.
In normal condition the capacitor is charged and by pressing a button it is discharged, and the relay is closed until the capacitor is charged once more. The relay then opens again. The timing period can be altered by the use of various capacitors.

Technical data

| Voltage | 220 V ac |
| :--- | ---: |
| Current | 50 mA ac |
| Timing period | $0.1-60 \mathrm{secs}$ |



PARTS LIST

|  |  | P1 | 100 KOhm |
| :--- | :---: | ---: | ---: |
| R1 | 1.5 KOhm | C1 | $100 \mu \mathrm{~F} / 16 \mathrm{~V}$ |
| R2 | 1.5 KOhm | C2 | $22 \mu \mathrm{~F} / 25 \mathrm{~V}$ |
| R3 | $100 h m$ | T1 | BC 172 |
| R4 | 100 KOhm | T2 | BC 172 |
| R5 | 100 KOhm | Cx | $100 \mu \mathrm{~F} / 16 \mathrm{~V}$ |
| R6 | 1.5 KOhm | D1 | 1 N 4148 |
| R7 | 10 KOhm | D2 | BA 100 |
| R8 | 3.3 KOhm | D3 | ZPD 15 |



NOT AVAILABLE AS KIT.

The AT 345 is the electronic unit for a professional tachometer.
Any standard 1 mA moving-coil instrument can be used.
The round printed wiring board AT 345 is designed for the KTM 3.
The AT 345 must be connected to the car battery, plus to 1 and minus to 2 . The terminal 3 is connected to the low voltage lead between ignition coil and distributor. If in doubt, try both leads - use the one that registers. Don't use the high-voltage side. If your car is connected negative to frame, the instrument illumination must be connected to 4 and 5 as shown in the figure. If the car is connected plus to frame reverse the connections 4 and 5 .

For use as a frequency meter.
Besides the use of an AT 345 as a tachometer, it can also be employed as a frequency meter from 10 Hz to $10,000 \mathrm{~Hz}$. The frequency range can be changed by replacing the capacitor C2 with one having ten times greater or smaller value. C2 $=10 \mathrm{nF}$ gives the possibility of measuring frequencies up to $10,000 \mathrm{~Hz}, \mathrm{C} 2=100 \mathrm{nF} 1000 \mathrm{~Hz}$ and finally C2 $=1$ uF 100 Hz .

## Technical data

Voltage ( + or - to frame)12 VCurrentInstrument 8,000 or 10,000 (r.p.m.)20 mAMax. frequency (frequency meter)1 mA10 kHz
Accuracy min. ..... 2\%
Accuracy typ. ..... $0.5 \%$
Number of cylinders ..... 2-8


PARTS LIST

R1
R2
R3
R4
R5
R6
R7
120 Ohm
C1
$1,5 \mathrm{KOhm} \quad \mathrm{C} 2$
6,8 KOhm C3
27 KOhm
IC
3,3 KOhm
D1
22 KOhm
1 KOhm

22 uF/35 Volt $100 \mathrm{nF} / 250$ Volt $10 \mathrm{nF} / 250$ Volt SAK 110 ZPD 7.5


NOT AVAILABLE AS KIT.
Application
The GP 304 is a basic circuit board for a 4 W amplifier in which the outer components utilise some of the AF 310 powerful amplification for tone control purposes. The name "Jumbo" indicates that this circuit combined with the AF 310 is as strong as an elephant. The AF 310 is designed for 12 V . The Jumbo can be connected to headphone or radio terminal on a cassette recorder, record player, or radio unit, and gives ample volume and good reproduction with a 4 ohm speaker. The output is best with a 15 V supply from a fully charged 12 V accumulator, while three dry batteries $(3 \times 4.5 \mathrm{~V}=13.5 \mathrm{~V})$ also give a good result. The Jumbo is the best low-priced amplifier with tone control, incorporating good quality potentiometers and not trimming potentiometers, a sign of high grade equipment. An extra advantage is the trimming potentiometer provided with each circuit to control amplification.

Technical data
Supply voltage
Power consumption
Sensitivity 1 W min. (adjustable) max.
Frequency response Signal to noise ratio
Distortion at $1000 \mathrm{~Hz} / 4$ ohm

> 12 or 36 V 30 to 400 mA 100 mV
> 1000 mV
$50-20,000 \mathrm{~Hz}$

Bass/treble control 60 dB
$0.4 \%$
Speaker impedance
Output at 15 or $36 \mathrm{~V}, 10 \%$ dist.
$4-16 \mathrm{Ohm}$
4 or 10 W


| PARTS LIST: |  | C3 | 470nF/250V |
| :---: | :---: | :---: | :---: |
| R1 | 1 k Ohm | C4 | $470 \mathrm{nF} / 250 \mathrm{~V}$ |
| R2 | 22 Ohm | C5 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |
| R3 | 470 Ohm | P1 | 22 KOhm LOG |
| R4 | 100 Ohm | P2 | 2.2 KOhm LIN |
| C1 | 470 uF/35-40 V | P3 | 22 |
| C2 | 220 uF/35-40 V | P3 | 2.2 KOhm LIN |




NOT AVALLABLE AS KIT.
Two bridge coupled AF 310 amplifiers are used here. As the picture shows, the Marina is excellent for fitting in cars as this output amplifier has speaker and input sockets as well as potentiometers at the front - the voltage supply only is at the rear. The circuit board width matches a standard heat sink. The Marina is fitted with a noise suppressor filter at the supply terminals to eliminate ignition noise etc.

Technical data

Supply voltage
Power consumption Sensitivity at 1 W
Distortion at 1 W
Output at $10 \%$ distortion
Bass and treble control
Speaker impedance
$12-15 \mathrm{~V}$

PARTS LIST:

| R1 | 100 Ohm | C1 | 470uF/16V | P1 | 10 KOhmLIN |
| :---: | :---: | :---: | :---: | :---: | :---: |
| R2 | 100 Ohm | C2 | $100 \mathrm{nF} / 250 \mathrm{~V}$ | P2 | 100 KOhm LIN |
| R3 | 120 Ohm | C3 | 220uF/16V | P3 | 100 KOhm LIN |
| R4 | 1 k Ohm | C4 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ | T1 | BC 172 |
| R5 | 22 KOhm | C5 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ | T2 | BC 172 |
| R6 | 3.9 KOhm | C6 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ | 12 | BC 172 |
| R7 | 180 KOhm | C7 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |  |  |
| R8 | 10 KOhm | C8 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |  |  |
| R9 | 22 Ohm | C9 | $6.8 \mathrm{uF} / 40 \mathrm{~V}$ |  |  |
| R10 | 39 KOhm | C10 | 47nF /250V |  |  |
| R11 | 4.7 KOhm | C11 | $2,2 \mathrm{nF} / 125 \mathrm{~V}$ |  |  |
| R12 | 10 KOhm | C12 | $2,2 \mathrm{nF} / 125 \mathrm{~V}$ |  |  |
| R13 | 5.6 KOhm | C13 | 1000uF/16V |  |  |
| R14 | 1 KOhm |  |  |  |  |
| R15 | 10 KOhm |  |  |  |  |

Input 0.5 V



The HF 380 is an antenna amplifier without tuned circuits. It covers the whole TV and FM-band and walkie-talkie channels.
The amplification is approx. 10 dB . The use of inexpensive UHF transistors BF 125 has made this circuit possible. The transistor gain exceeds 100, which enables a powerful negative feedback to be used. The diagram shows the negative feedback of both transistors, T1 via R1 and C3, and T2 via R5 and C7.
S 2 is a filter to suppress feedback and self-oscillation from T2 to T1.
S3 leads dc voltage to the transistors and prevents C9 from shorting of the amplified high-frequency signal that is intended to be amplified through the HF 380.
The input and output impedances are critical - see the description concerning correct matching to antenna and receiver.
The removal of C3 gives approx. 10 dB improved amplification, but not without the risk of self-oscillation - lines on TV screen or radio hum. This has no harmful effect on the HF 380 or the receiver, however.

Technical data

Transistors
Frequency range
Amplification
Current consumption
Supply voltage
Antenna impedance

Two silicon transistors
$10-350 \mathrm{MHz}$ approx. 12 dB approx. 10 mA 9-12 V $70-75 \mathrm{Ohm}$

THE HF 380 MUST BE PLACED AT THE ANTENNA MAST!



NOT AVAILABLE AS KIT.

## Application

The MI 5 is a capacitor set with switches for the four capacitors on the wiring board. As the contacts do not trip one another there are many capacitive value possibilities. The MI 5 was originally designed as a range switch for the photo-timer AT 70, but is also equally suitable as a capacitor decade. When inserting resistors instead of capacitors the MI 5 can be employed as a resistor decade.

Max. current
Max. voltage
Max. load
Contact resistance $3-6 \times 10^{-3} \mathrm{Ohm}$
Capacitive values Cx
$25 u F-1000 u F$
Time delay in connection with AT 70


PARTS LIST
C 3
C 4
C 5
C 6
$22 \mathrm{uF} / 40 \mathrm{~V}$
$100 \mathrm{uF} / 16 \mathrm{~V}$
$220 \mathrm{uF} / 10 \mathrm{~V}$
$1000 \mathrm{uF} / 16 \mathrm{~V}$


The MI 60 is an astable multivibrator that emits a square shaped wave of approx. 1000 Hz .
This multivibrator can be used as a fault tracing instrument for HF and LF as the special wave contains so many overtones that they are audible when the MI 60 is conneced to the antenna input of an FM receiver. The function of a astable multivibrator is described in the basic section of this book.
When connected to an FM transmitter, e.g. the HF 65, the MI 60 acts as a jamming station (used in the cold war between East and West) and is, of course, forbidden in most countries.

Technical data
Voltage
Output voltage
Frequency
$1.5-9 \mathrm{~V} \mathrm{dc}$
2 mA at 9 V dc
1 V (peak to peak) at 1.5 V
1 kHz


PARTS LIST
R1 $\quad$ 4.7 KOhm - $1 / 8 \mathrm{~W}$
R2 $\quad 120 \mathrm{KOhm}-1 / 8 \mathrm{~W}$
R3 $120 \mathrm{KOhm}-1 / 8 \mathrm{~W}$

R4 $4.7 \mathrm{KOhm}-1 / 8 \mathrm{~W}$

| C 1 | 10 nF |
| :--- | :--- |
| C 2 | 10 nF |
| C 3 | 10 nF |

T1 BC 172 о. BC 173
T2 BC 172 о. BC 173



The MI 91 is a VU-meter kit comprising a 50 mA instrument, a trimming potentiometer and a diode. The kit can be used as an S-meter, drive monitor meter for an amplifier or wattmeter.

The MI 92 is a balance meter and is to be connected to both sets of loudspeaker terminals. Unbalanced adjustment causes the meter to show a deflection to the higher volume side.

|  | Connection impedance | $3.2-16 \mathrm{Ohm}$ |
| :--- | :--- | :--- |
|  | Connection wattage | $1-50 \mathrm{~W}$ |
| MI 92 | Unbalance power difference | $3-0-3 \mathrm{~W}$ |
|  | Pointer deflection | $1-0-1$ |
|  | Settling time to rms value | 2 secs. |
|  | Connection impedance |  |
| MI 91 | Connection wattage | $1-2-800 \mathrm{Ohm}$ |
|  | Suppression | Rms value |

344


VU meter

PARTS LIST for MI91:
R1 100 k Ohm Trim.
D1 AA 119
M 100 u

PARTS LIST for M192:
R1 $\quad 2.7 \mathrm{KOhm}$
R2 2.7 KOhm
R3 2.7 KOhm
R4 2.7 KOhm
C1 $22 \mathrm{uF} / 25 \mathrm{~V}$
C2 $22 \mathrm{uF} / 25 \mathrm{~V}$
D1 AA 143
D2 AA 143
M 200uA



Aplication
Transistors can be tested in many different ways. One can use an ohmmeter, a current measuring instrument designed for transistor testing, or an MI 302. The first method is difficult, the second demands an expensive measurement, while the third method is a reasonable compromise.
Transistors of the NPN or PNP types can be connected to measuring leads, with C to transistor collector, B to transisor base, and E to emitter.
f a transistor functions correctly and the connections are sorrect, the green lamp lights up. All other combinations of lights, for instance, red light, both lights on no light at all, indicates that the transistor is faulty.
Diodes can also be tested on the MI 302 by connecting the two alligator NPN clips C and E to the two leads of the diode. When measuring in the forward direction, both lamps light up, whereas no light appears when the leads are switched. When the lamps are on, it means that E is the cathode of the diode (the one with a mark) the other being the anode. Zener diodes are tested in the same way as diodes. When testing zener diodes the lamps often show a weak light in the blocking direction. The mark on the diode indicates the direction of blocking, i.e. the opposite case compared with ordinary diodes.


Triacs without Diacs are tested in the same way as transistors. The green lamp must light even when C and E are interchanged. Use the NPN alligator clips. $\mathrm{C}=$ anode, $\mathrm{B}=$ gate, and $\mathrm{E}=$ cathode. Do not let the terms anodes and cathodes confuse you. The pin symbols on SCR's are nearly always the same as those on ordinary transistors, that is, the anode is normally placed like a collector, etc.
Uni-junction transistors are tested by connecting the E-alligator clip from the PNP side to the UJT middle pin. The C-alligator clip is connected to the two other pins. The lamps should light when connecting both pins (singly connected) (B1 and B2).

Technical dates
Input voltage
220 V ac
Power consumption
2 W
Measuring voltage
12 V
Testing possibilities
Transistors, diodes, triacs, zener diodes, uni-junction transistors, SCR's

R1 470 Ohm TR1 MI 302
R2 470 Ohm GL1 indication lamps 6 Volt red
D1 1N4148 GL2 indication lamps 6 Volt green
D2 1N4148
D3 1N4148
D4 1N4148
D5 1N4148
D6 1N4148



This book is equally suitable for class tuition and self-study purposes. The basic idea of the AE book is that the reader answers questions by choosing from several possibilities (programmed).If a wrong answer is chosen, the feed-back list not only tells what is incorrect, but it also gives an explanation. Although not new, this system is effective and gives rapid results.

The enclosed circuit board (printed wiring) gives the reader an opportunity to put his knowledge into practice. Full instructions are given and the necessary components are available in smal plastic bags at modest prices, if not already at hand.

The reader can also get started on more advanced electronic equipment, as the book includes many circuits covering such items as amplifiers, measuring instruments, power packs, and automatic units, most of which are available in kit form.

Amateur Electronics is the book for both beginner and the more experienced amateur.


[^0]:    zener diode
    transistor
    integrated circuit
    integrated circuit
    ceramic filter
    ceramic filter
    orange coil
    zener diode
    transistor
    integrated circuit
    integrated circuit
    ceramic filter
    ceramic filter
    orange coil
    zener diode
    transistor
    integrated circuit
    integrated circuit
    ceramic filter
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    ceramic filter
    orange coil
    zener diode
    transistor
    integrated circuit
    integrated circuit
    ceramic filter
    ceramic filter
    orange coil
    zener diode
    transistor
    integrated circuit
    integrated circuit
    ceramic filter
    ceramic filter
    orange coil

