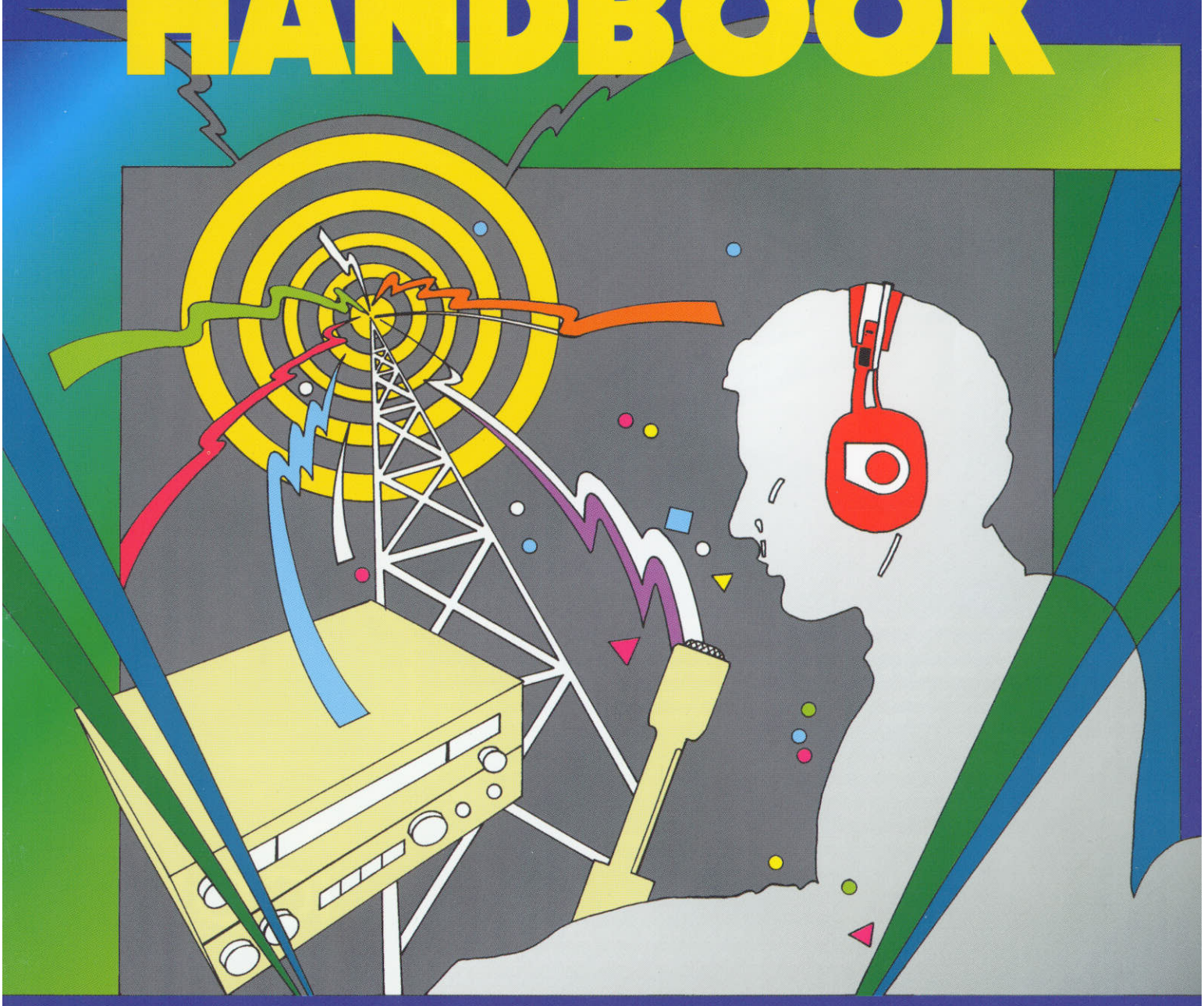
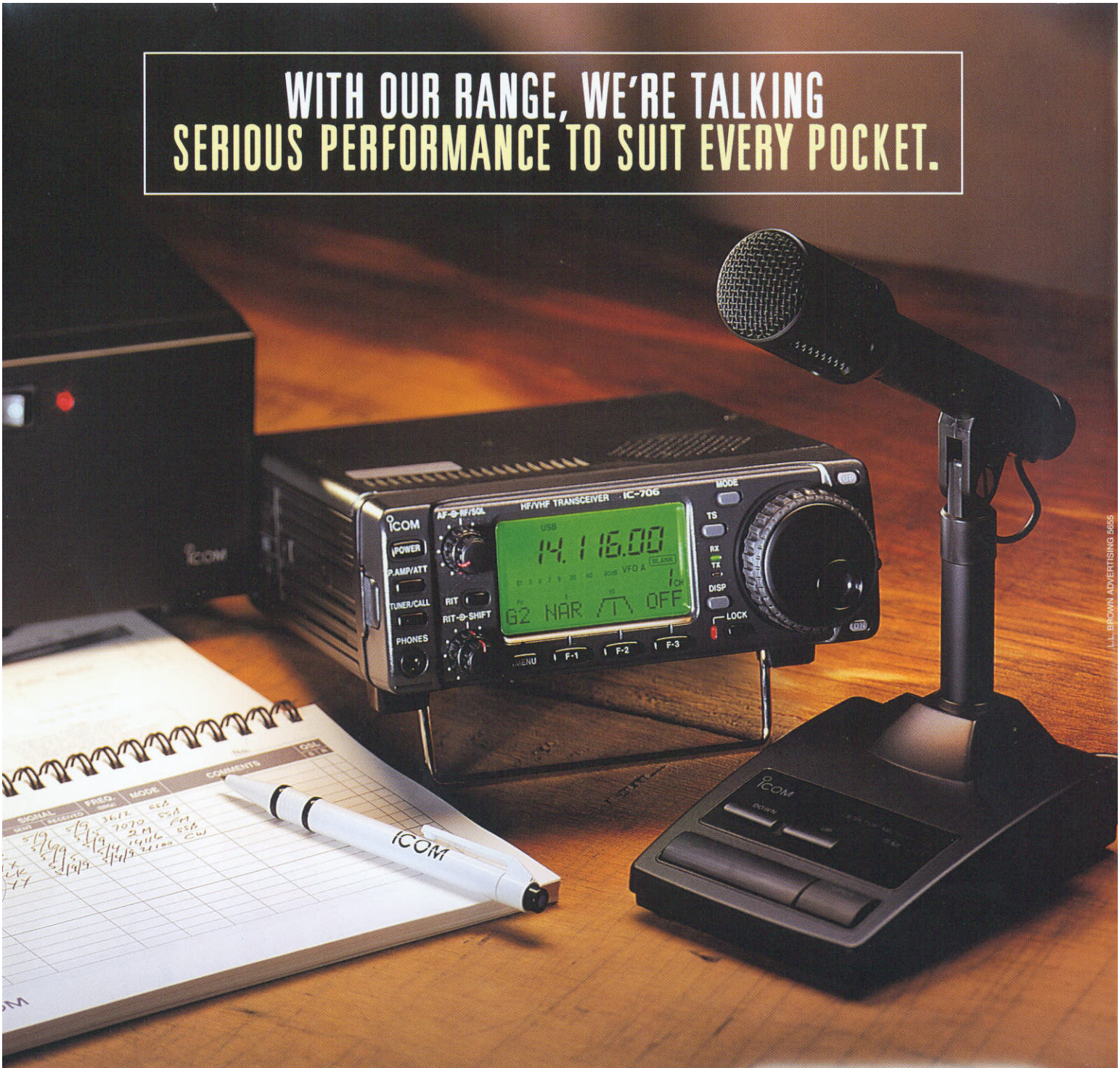
THE NOVICE OPERATORS THEORY HANDBOOK



GRAEME SCOTT VK2KE

Covers the entire Novice Theory Course
for Australian Amateur Operators

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The Novice Operators Theory Handbook

A practical study guide for those with little or no prior knowledge of Electronics.

By Graeme Scott VK2KE

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FOREWORD

This is the fourth edition of the Novice Operators Theory Handbook.

The book has been an overwhelming success as thousands of new operators have passed the exams and are now on the air. It was the first Novice theory book to be written and published in Australia.

It is hoped that few or no errors have crept-in, however if you should see any, we'd be grateful if you would convey them along with any suggestions to the author.

I'd like to acknowledge the help of the staff of Dick Smith Electronics. Their comments on the technical content and presentation of the material in the book have been invaluable.

This book is designed to give you the basic theory which you need to learn to pass the Exams.

It covers the theory in a simple way with copious diagrams to make your task of absorbing the information as easy as possible.

Graeme Scott, VK2KE

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INTRODUCTION

This handbook has been produced to help the person wishing to enter the hobby of Amateur Radio with a minimum of difficulty. Study for exams is not always the easiest thing to cope with in our busy lives, and so this handbook is designed to give you only the really essential information to help you gain a pass in the exams.

This will save you the hassle of poring through the extensive (and expensive) text books normally recommended for the theory study. The course as outlined in this handbook is very closely aligned with the published syllabus for the Novice Operator. You should obtain a copy of the Amateur Operators Brochures published by the Spectrum Management Agency. They give you all the relevant regulations regarding the operation of a station along with the syllabus and sample exam questions.

The Author recommends that you contact a local Radio Club and try to attend the meetings to get to know some other Hams in your vicinity.

You'd be surprised how helpful they can be in assisting you to get your licence and getting on air for the first time.

It's also a good idea to become a member of the Wireless Institute of Australia (WIA) as it offers you many services such as a monthly magazine, QSL card Bureau and advice.

Suggested Study Method:—Read each chapter in short sessions and attempt the questions at the back of the book. And then check your answers at the back of the book.

Amateur Radio — An Exciting Hobby

There are many wonderfully interesting facets to this hobby.

Once you have obtained your licence there is a very wide scope of activities in which you can become involved.

Here are some of them:—

- **MORSE CODE OPERATING**
- **DX-ING**
- **SLOW SCAN TV**
- **UHF TV**
- **UHF REPEATER**
- **VHF REPEATERS**
- **MOON BOUNCE**
- **FOX HUNTS**
- **MOBILING**
- **QSL-ING**
- **PORTABLE — FIELD DAYS**
- **CONTESTS**
- **RAG CHEWING**
- **BUILDING EQUIPMENT**
- **TELETYPE**
- **FACSIMILE**
- **COMPUTERS**
- **BUILDING ANTENNAS**
- **JAMBOREE OF THE AIR**
- **EXPERIMENTING**
- **PACKET RADIO**

The whole family can become involved and everyone can concentrate on the special interest area which appeals the most!

*Some of the above activities are not permitted for the Novice to use for transmitting, however, receiving can still be a valid activity until a higher licence is eventually obtained.

NOVICE OPERATOR PRIVILEGES:

The Novice has certain restricted operating conditions:

1. Type of emission

2. Transmitter power

3. Sub-band rights

1. EMISSIONS: You are only permitted to use Telephony (voice) and Telegraphy (morse)

2. POWER: You can use up to 30 watts PEP output with an ssb transmission and 10 watts output on morse.

3. SUB-BANDS: On the 80 metre band the frequencies available extend from 3.525 to 3.625 MHz.

15 Metres: 21.125 to 21.30 MHz	2 Metres: 144.692 – 145.208
10 Metres: 28.10 to 28.60 MHz	70cm: 433.000 – 435.000
2 Metres: 146 – 148 MHz (FM only)	70cm: 438.000 – 440.000

*morse transmissions are usually kept to the lower end of each band and voice signals to the upper end of each band.

chapter one

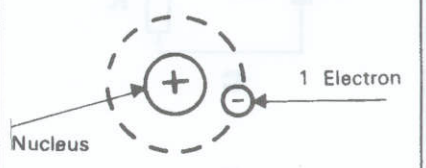
Electrical Laws and Circuits

ATOMS

To understand the basic concepts of electricity and electrical currents you need a simple understanding of Atoms. Figs 1.1 & 1.2 describe the structure of two atoms, Hydrogen and Copper. Atoms consist of a central Nucleus which contains Protons and Neutrons. Electrons orbit around the nucleus in a structure of "Rings"

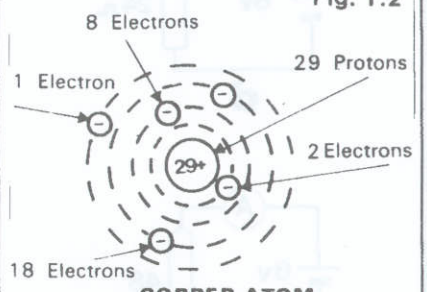
A stable atom is, in effect, a miniature "solar system" in equilibrium because electrons, which have a negative charge, are attracted to the positive charge of the protons, however an electron does not leave its orbit because of its relative mass and velocity. The neutrons have no charge and are said to be neutral.

Fig. 1.1



HYDROGEN ATOM

Fig. 1.2

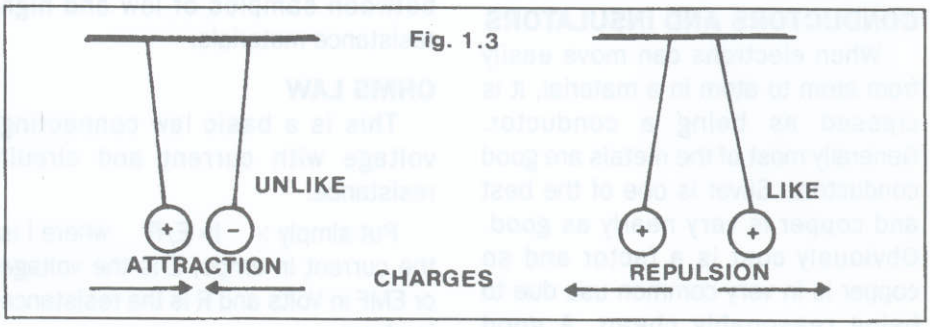


COPPER ATOM

CHARGES

Because there are two bodies in an atom having different polarities, we can apply the law of charges. - LIKE bodies (charges) REPEL and UNLIKE bodies (charges) ATTRACT. The electron and the proton are mutually attracted to each other but the orbital velocity of the electron maintains it in orbit. Fig 1.3 shows the law of Like and Unlike charges.

Fig. 1.3



THE COULOMB

This is the unit of charge. If a body has stored 6.3 X 10^{18} electrons, it is said to have a charge of one coulomb. This would be called a negatively charged body. Similarly, a positively charged body lacking the same number of electrons would have a charge of one coulomb.

If these bodies were brought near each other, they would show a strong attraction force because of their unlike charges.

IONS

An ion is an atom or group of atoms which is either deficient in some of its orbiting electrons or has some added to it over and above its normal complement. One which has lost an electron is known as a positive ion or "CAT-ION" as the charge on its nucleus exceeds the charge from its electrons and so it has a net positive charge . One which has gained electrons is thus a negative ion and is known as an "AN -ION"., it has a net negative charge as the charge on the electrons exceeds the charge on the nucleus in this case. If two electrodes made of different metals were immersed in a conductive solution called an electrolyte, one would eventually become quite corroded. This is because one electrode becomes a cathode and the other becomes an anode. By Ionic conduction through the electrolyte, the metal ions flow from one electrode to the other causing corrosion of one electrode and deposition onto the other. (this is the principle used on ships to save the brass propellors from being destroyed by ionic corrosion in the salt water.)

POTENTIAL DIFFERENCE

Two bodies have a potential difference if they possess different levels of charge. If we allowed them to touch each other, a current would flow between them until the charges were equalised. This current is a movement of electrons.

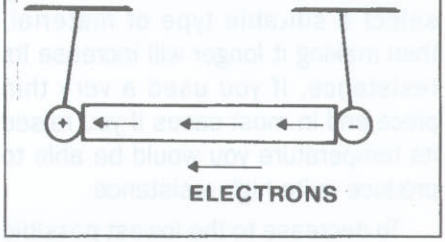
The symbol for potential difference is V or E. Often this is known as Electromotive Force (EMF) . The unit of emf or potential difference is the VOLT.

CURRENT

When electrons are in motion, we say that a current is flowing. Fig 1.4 shows a piece of solid material, namely copper. If we connect it between two bodies which have a potential difference then a current will flow through the copper. The electrons in the outer orbits of the copper atom are called free electrons and can easily be dislodged from their orbits thus becoming available for current flow. The unit of current is the ampere, usually abbreviated to amp.

Direct Current (DC) can be either varying, steady or pulsating . DC is a

Fig. 1.4



one-directional current, in other words it flows in one direction only. In electronic terms, electrons flow from negative to positive. (In "conventional current flow"- current flows from positive to negative.)

CONDUCTORS AND INSULATORS

When electrons can move easily from atom to atom in a material, it is classed as being a conductor. Generally most of the metals are good conductors. Silver is one of the best and copper is very nearly as good. Obviously cost is a factor and so copper is in very common use due to being reasonably cheap. A good conductor should allow a current to flow with minimum opposition (resistance).

Typical conductors include:-

platinum, silver, copper, aluminium, brass, gold, lead, nickel, steel, iron, zinc.

Poor conductors include:- carbon, tungsten and nichrome.

Insulators are materials which do not readily allow current to flow. This is because the electrons tend to stay in their orbits and are difficult to dislodge. Insulators are sometimes referred to as Dielectrics. (This is discussed in more detail in capacitors.) The best insulator will not allow any current to flow through it.

Typical insulators are:- ceramics, plastics, dry wood, rubber, glass, bakelite, mica, fibreglass, air, vacuum, oil, paper.

RESISTANCE

Resistance is the opposition to electrical current flow. The resistance of a material to current depends upon four factors:

1. type of material
2. length of the material
3. cross-sectional area
4. temperature

To increase the resistance of a conductor, you would need to firstly select a suitable type of material, then making it longer will increase its resistance. If you used a very thin piece and in most cases if you raised its temperature you would be able to produce quite high resistance.

To decrease to the lowest possible value, you would need to select a very high conductance material such as silver, then use a short length and one of high cross-sectional area (thick)and finally keep it as cool as possible. Fig 1.5 shows a comparison between samples of low and high resistance materials.

OHMS LAW

This is a basic law connecting voltage with current and circuit resistance.

Put simply :- I= E/R where I is the current in amps, E is the voltage or EMF in Volts and R is the resistance in ohms.

If you study the formula, when E is increased , the current will be increased and if the resistance is increased then the current will decrease. Put another way - the current is directly proportional to the voltage and inversely proportional to the resistance.

Fig 1.6 shows a simple circuit which demonstrates Ohms law. The 1.5 volt cell produces an emf which will cause a current of say, one amp to flow. The lamp will light and the ammeter will indicate the current. If we changed the wires in the circuit from copper to nichrome , then the lamp would light dimly because nichrome has more resistance than copper and less current would flow in the circuit . So we can conclude that the current in a circuit is dependant upon two factors - the voltage applied and the resistance in the circuit.

Let's look at a few examples of circuits containing resistors and having different voltages supplied. (refer to Fig 1.7 for these examples.)

We can use the formula to calculate the current in a circuit if we know the voltage applied and the resistance.

The equation to use is I=E/R. The value of the circuit resistance R can

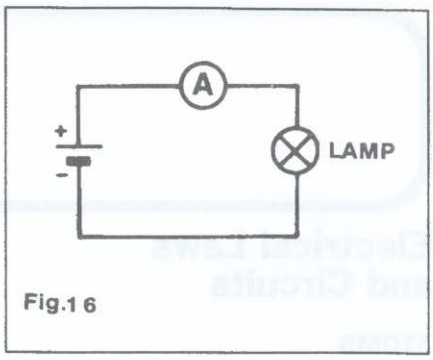


Fig.1 6

Fig. 1.7

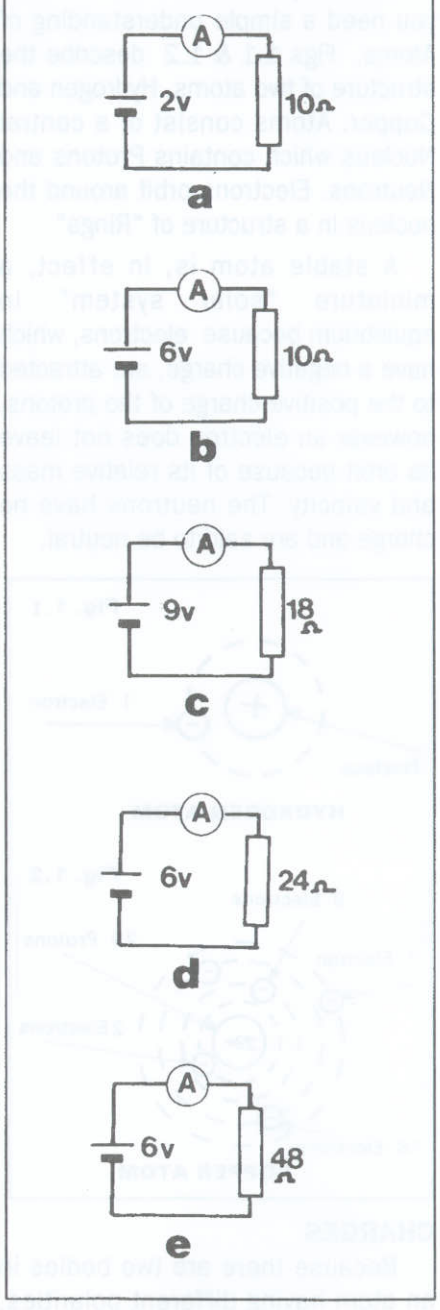
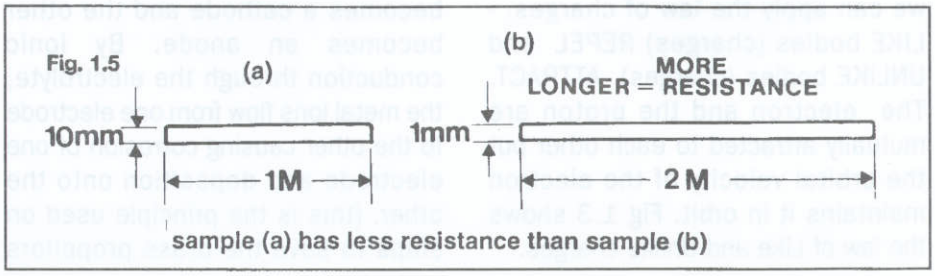


Fig. 1.5



sample (a) has less resistance than sample (b)

TABLE 1.1
Calculations for the circuits in figure 1.7

(a)	(b)	(c)	(d)	(e)
I = E / R	I = E / R	I = E / R	I = E / R	I = E /R
= 2 / 10	= 6 / 10	= 9 /18	= 6 / 24	= 6 / 48
= 0.2 amps (200mA)	= 0.6 amps (600mA)	= 0.5 amps (500 mA)	= 0.25 A (250mA)	= 1/ 8
				= 0.125 A (125 mA)

be calculated when E and I are both known. The equation to use is R=E/I. (fig. 1.9 shows 2 examples)

The formula can be transposed again to find the voltage applied to a circuit if the current and resistance are both known. - if I = E / R then E = I x R.

Fig 1.8 shows three circuits where the voltage can be calculated as both the resistance and the current are known.

RESISTORS

In electronics we use many resistances to achieve certain circuit functions.

Resistors have been highly developed and are split into three main categories:- wire wound, metal film and carbon types.

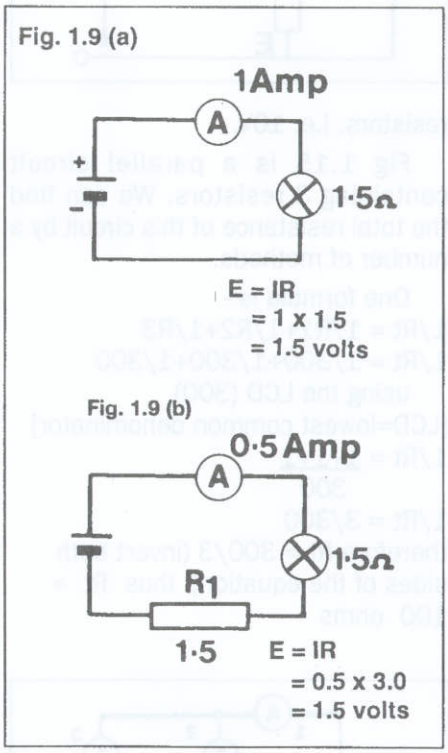
The wirewound types are usually made for high heat dissipation and the carbon and metal Film types are mainly used for low power applications.

Carbon types may be - carbon film or solid carbon.

Color Code

Most resistors are color-coded with color bands around them to make it easy to know their resistance value. This color code is internationally recognised and is used on other components for quick recognition of their value.

BLACK = 0 BROWN = 1 RED = 2 ORANGE = 3 YELLOW = 4 GREEN = 5 BLUE = 6 VIOLET = 7 GRAY = 8 WHITE = 9



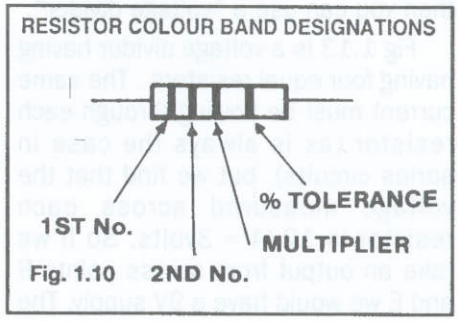


Fig. 1.10

* If you list the first letters of each color you can make up a short saying like this to help you remember the color code :- "Black Bull Ran Over Your Garden Blue Violets Gone West". Then all you have to recall is that it starts with zero and goes up to 9.

The first color band gives the first number of the value, the 2nd band gives the next number of the value , then the third band gives the multiplier.The fourth band gives the tolerance in percent. (see fig 1.10)

Tolerance.

Another factor relating to resistors is that they have tolerance - this means that after manufacture, they have a small 'spread' in actual values. So if you see a resistor with four color bands on it ,then the fourth band is to indicate the percent tolerance. A silver band denotes +/-10% and a gold band means +/- 5%. No color band indicates a +/- 20% tolerance.

Example 1. A resistor has these color bands:- Red, Yellow, Orange , Gold

Answer: red = 2, yellow = 4, orange = 3, gold = +/-5%, so this resistor would be 24k ohm with a tolerance of +/-5%. (K = kilo = x1000).

Example 2. yellow, red, green, silver.

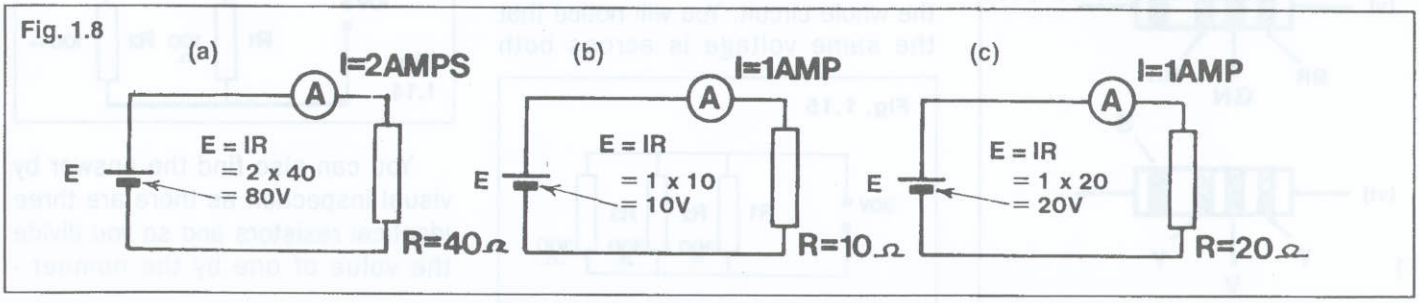
Ans. yellow = 4, red=2, green = 5, silver= +/-10%, so this resistor would have a value of 4.2 Megohms with a tolerance of +/-10%

Refer to Fig 1.11 for some examples of various resistors.

Power ratings

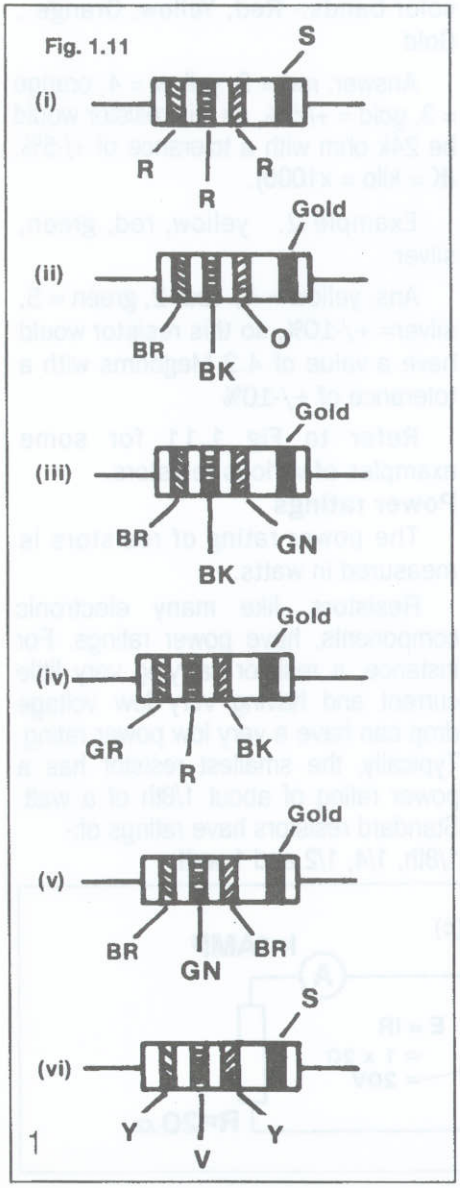
The power rating of resistors is measured in watts.

Resistors, like many electronic components, have power ratings. For instance, a resistor carrying very little current and having very low voltage drop can have a very low power rating. Typically, the smallest resistor has a power rating of about 1/8th of a watt. Standard resistors have ratings of:- 1/8th, 1/4, 1/2 and 1 watt.



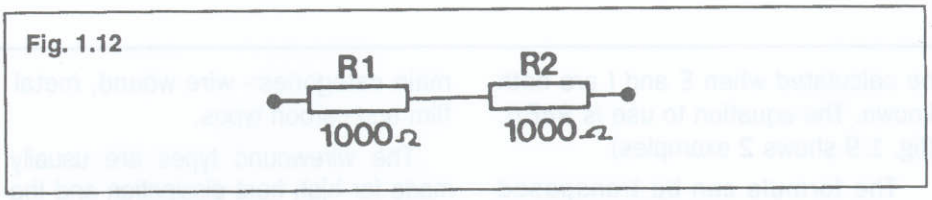
(Ratings up to 20 watts or more may be used in some circuits.)

Preferred values: Stock resistors made by the major manufacturers are to agreed international standards. This makes circuit design easier and stock-holding less complex . The "E12 series" has values including : 1.0, 1.2, 1.5,1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2 and decimal multiples of these, so you could have for example : a 5.6 ohm, a 5.6k or a 5.6 megohm resistor. When allowing for say the 10% tolerance if you had a resistor of 5.6k then its upper possible value is 5600+560 = 6160 ohms , then if you had a 6.8k resistor, its lowest possible value is 6800-680 = 6120 so you can see that the two values can overlap in the E12 series and this allows the choice of an exact value if it is critical for a certain circuit. You would have to measure a number of resistors in a batch to obtain a precise value, if the value was absolutely critical.



Resistor values for fig 1.11

(i) 2200ohms ±10%
(ii) 10k ohms ±5%
(iii) 1,000,000 ohms ±5%
(iv) 52 ohms ±5%
(v) 150 ohms ±5%
(vi) 470 k ohms ±10%



RESISTORS IN SERIES

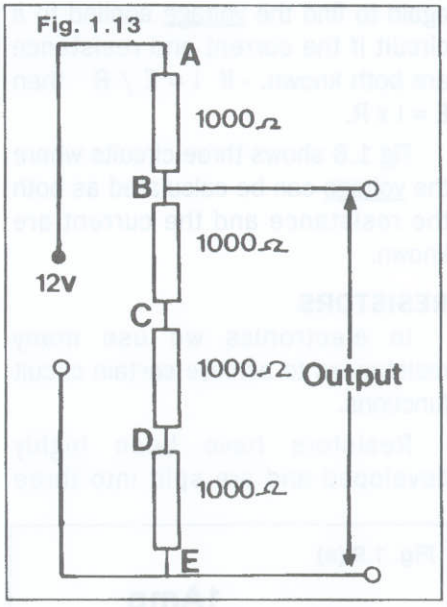
Fig 1.12 shows two resistors of 1000 ohms in series. The total resistance of the circuit can be found by a simple formula :-

Rtotal = R1 + R2
Rt = 1000 +1000
Rt = 2000ohms

Thus, in series circuits, the total resistance is found by simply adding all the values together.

One very useful application for resistors in series is that they can be used as voltage dividers. For example if you have a 12 volt supply and need a 9V supply for a piece of equipment, then you can use a "voltage divider".

Fig 1.13 is a voltage divider having having four equal resistors . The same current must be flowing through each resistor (as is always the case in series circuits), but we find that the voltage measured across each resistor is 12/4 = 3volts. So if we take an output from across points B and E we would have a 9V supply. The current we could draw would be limited by the power rating of the resistors but it would be a cheap way to obtain 9V from a 12V source.



RESISTORS IN PARALLEL

When two resistors R1 and R2 are connected in parallel (as shown in Fig 1.14.) each resistor draws its own current from the supply rails A and B. Ammeters A2 and A3 will indicate the current drawn by each resistor and A1 will indicate the total current drawn by the whole circuit. You will notice that the same voltage is across both resistors. i.e. 10V.

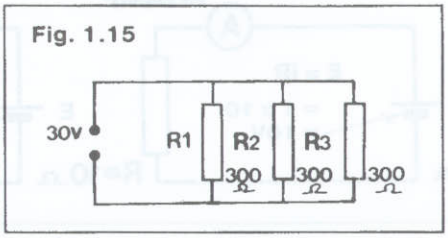


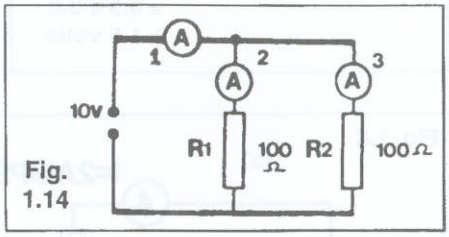
Fig 1.15 is a parallel circuit containing 3 resistors. We can find the total resistance of this circuit by a number of methods.

One formula is:-

1/Rt = 1/R1+1/R2+1/R3
1/Rt = 1/300+1/300+1/300
using the LCD (300)
[LCD=lowest common denominator]

$$1/Rt = \frac{1+1+1}{300}$$

1/Rt = 3/300
therefore Rt = 300/3 (invert both sides of the equation) thus Rt = 100 ohms



You can also find the answer by visual inspection as there are three identical resistors and so you divide the value of one by the number -

300/3 = 100 ohms.

*The total resistance of a parallel circuit is ALWAYS less than the lowest value resistor *

Another method can be used if only two resistors are in parallel - it is called the "product over sum" method:

e.g. a 50 ohm resistor in parallel with a 25 ohm one.

Rt = product /sum

$$Rt = \frac{50 \times 25}{50 + 25}$$

$$Rt = \frac{1250}{75}$$

Rt= 16.66 ohms

Variable resistors

We often need to have a variable resistor such as the volume control or tone control in a receiver. This takes the form of what we call a potentiometer (or Pot).

Pots can be of the carbon or wirewound type. Carbon pots are for low power applications such as volume,balance,tone controls etc. The wirewound types are for greater power dissipation and can be made to handle many watts of heat dissipation.

UNITS, MULTIPLES AND SUB-UNITS

In electronics it is often impractical to use quantities such as the amp, volt, ohm etc. To overcome this problem, sub and multiple units have been derived. For example,the signal at the antenna terminals of a receiver is commonly measured in millionths of a volt (microvolts.) The current in a circuit is often measured in thousandths of an amp (milliamps)

Table 1.2 outlines the units with their powers of ten, prefixes and symbols.These multiple and sub multiple units can be used with many values in electronics. For instance we can have a microfarad or a pico farad of capacitance and we can make inductances from microhenries up to Henries .

TABLE 1.2

MULTIPLE AND SUB MULTIPLE UNITS

FACTOR	POWER OF TEN	PREFIX	SYMBOL
1 000 000 000 000	10^{12}	Tera	T
1 000 000 000	10^{9}	**Giga**	G
1 000 000	10^{6}	**Mega**	M
1 000	10^{3}	**Kilo**	k
100	10^{2}	Hecto	H
10	10^{1}	Deca	Da
0.1	10^{-1}	Deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	**milli**	m
0.000 001	10^{-6}	**micro**	u
0.000 000 001	10^{-9}	**nano**	n
0.000 000 000 001	10^{-12}	**pico**	p
0.000 000 000 000 001	10^{-15}	femto	f
.000 000 000 000 000 001	10^{-18}	atto	a

* those in bold are the most common ones you will encounter in Radio.

SOURCES OF EMF

There are various ways in which a voltage (or EMF - Electromotive force) can be produced :-

1. simple cell - usually a zinc-carbon cell
2. lead acid cell
3. nickel cadmium cell
*4. the electromagnetic generator
5. solar cell (photovoltaic)
6. friction (electrostatics)
7. thermo couple (thermal)

These above sources are DC - (direct current) sources of voltage. *However, the electromagnetic generator can produce AC or DC.

(AC is alternating current). Alternating current flows in one direction for 1/2 cycle then reverses for the other 1/2 cycle.

CELLS

Cells can be categorised into two main categories:

a) primary b) secondary

Primary cells such as the common torch battery are zinc carbon or Alkaline and may not be recharged.

Secondary cells such as the nickel cadmium or the lead-acid may be recharged many times.

The state of charge of a lead-acid cell is measured by taking the Specific Gravity of the acid. This should be about 1.275 when fully charged and it drops to about 1.125 when discharged.

The main considerations when using batteries in electronic equipment are the load current and the voltage required. This will determine the size of the battery and whether primary or secondary type is the best for the application. (Of course size, cost and weight are other factors.)

BATTERIES

These are made up from a number of cells connected either in parallel or in series.

Table 1.3 gives a listing of a number of typical cells and their main characteristics. The capacity of batteries is usually quoted in ampere hours (Ah) or milliamp hours (mAh).

A commonly used lead-acid cell on the 8 hour discharge period has a 300 Ah capacity. It can provide higher currents for less than the 8 hours or lower currents for longer periods of course.Nickel cadmium or lead-acid types are most frequently used where large capacity is needed.These are available in sealed style for spill-free portable use. The electrolyte in these may be a gel rather than a liquid.

Table 1.3

Cell type	Class	Voltage
Zinc-Carbon	primary	1.5
lead-acid	secondary	2.2
nickel-cadmium	secondary	1.25
manganese-alkalyne	primary	1.5
mercury	primary or secondary	1.35

Figs 1.16 a-e give the basic construction of some cells.

CARE OF BATTERIES

When a lead acid battery is being charged it gives off hydrogen gas which can create an explosive atmosphere. Do NOT allow naked flames or sparks to come near a battery under charge or one just charged. The manufacturer's charging data should be followed carefully to avoid overheating of the battery during charging and to avoid shortening the battery's life. Charging is done by connecting the battery to a source of DC voltage of slightly higher voltage than that of the battery

The positive terminals are linked to each other and the negative terminals are also linked to each other. In theory the amp hours taken from the battery whilst under load must be replaced plus a small allowance (about 20-50%)for losses. Nickel cadmium batteries can also be recharged, however if they are of the sealed type, especially , the manufacturer's specifications must be closely followed to prevent any excess build up of gases inside the cells and possible explosion. (This precaution also applies to sealed lead acid types too.)

Nicad cells are charged by the constant current method whereas lead acid types are charged by the constant voltage method.

BATTERY CONNECTIONS

Various voltages can be obtained by connecting cells in different configurations.The most common configurations being series or parallel.

Fig 1.17a shows three 1.5v cells connected in series to provide an output of 4.5 v.

Fig 1.17b shows five 2.2 v cells connected in parallel to obtain an output of 2.2 v.

Series connections provide higher voltage but at the same current rating of one cell as the current is common to all cells in the string. Parallel connections provide the same voltage as for one cell but at a higher current than one cell could supply.

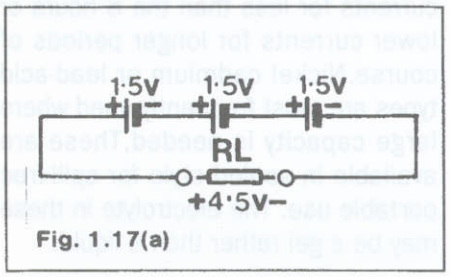


Fig. 1.17(a)

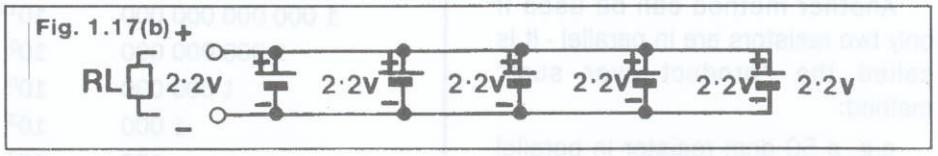
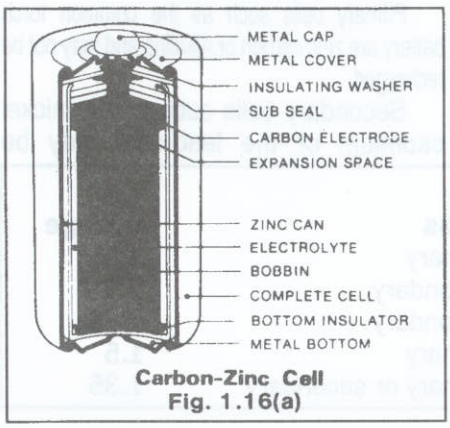


Fig. 1.17(b)

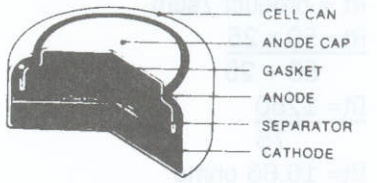
Two common applications for series connected cells are: the car battery where six 2.2 volt lead- acid cells are arranged to provide an output of about 13.8volts. The dry cell type 216 which has six 1.5V cells arranged in series to give a 9v output.

INTERNAL RESISTANCE OF VOLTAGE SOURCES

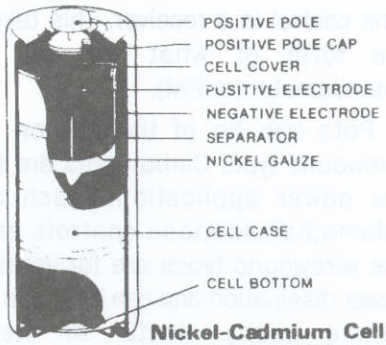
In Fig 1.18a we have a circuit with a 1.5v cell supplying current to a load resistor of 150 ohms. Ri is the internal resistance of the battery. The total resistance of the circuit is thus 150.1 ohms. The circuit current can be calculated by Ohms law and is about 10 mA. The voltage drop across the internal resistance is negligible so the load (R1) receives almost the full voltage of 1.5 v. Now in Fig 1.18b the cell is slightly discharged and its internal resistance has risen to 100 ohms. The total circuit resistance is now up to 250 ohms. The current will now be 6mA. Now the voltage drop across the Ri is quite significant at 0.6 v, so the load receives only 0.9v instead of the full 1.5 v. You can conclude from this that if the internal resistance of a voltage source such as a cell is high, the amount of load current which can be supplied is limited. Also the voltage output from the source will be less than its nominal value due to the internal losses caused by Ri.



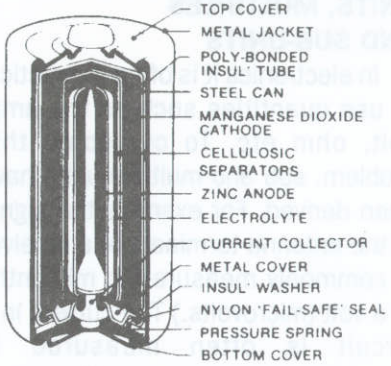
Carbon-Zinc Cell
Fig. 1.16(a)



Mercury Cell
Fig. 1.16(b)



Nickel-Cadmium Cell
Fig. 1.16(c)



Manganese – Alkaline Cell
Fig. 1.16(d)

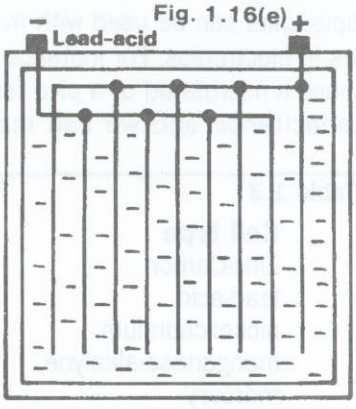


Fig. 1.16(e)

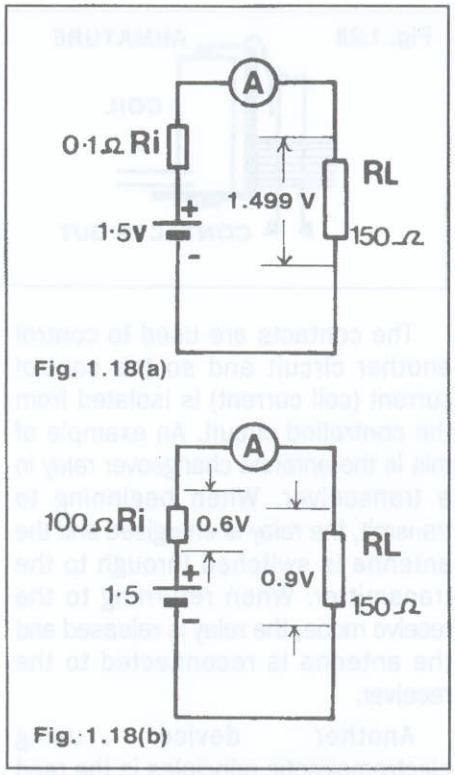


Fig. 1.18(a)

Fig.·1.18(b)

POWER IN A DC CIRCUIT

When a voltage source provides current for a load circuit such as in 1.19a and b, power is dissipated by the circuit. In simple terms,the load resistor becomes hot. Dissipation of heat means that power is being expended. If we were to increase the battery voltage ,the current would rise and more power would be dissipated. This means that there is a relationship between voltage, current and resistance in the circuit.

This can be expressed by a formula -

$P=E \times I$

where E is the applied voltage, P is the power dissipated and I is the circuit current.

Figs 1.20 a&b give examples of the power in a circuit. From this you can see that if the voltage is increased,the current increases and so the power dissipated rises too. It is important to realise that the resistor in Fig 1.20b must have a higher power rating than the one in fig 1.20a because it has to dissipate more heat.

There are two other equations for calculating the power in a DC circuit :

$P=I^2R$ and $P=E^2/R$. (Figs 1.21a & b give examples of these two equations.)

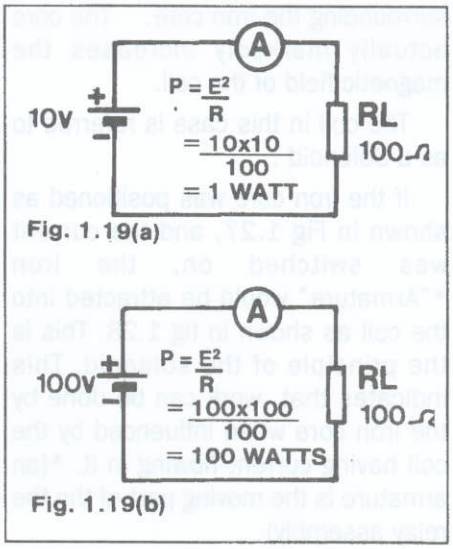


Fig. 1.19(a)

Fig. 1.19(b)

MAGNETS AND MAGNETIC FIELDS

Permanent magnets

Fig 1.22 shows the magnetic fields which could be seen if you placed magnets under a piece of glass or paper and sprinkled iron powder on top of the glass.

Fig 1.22a shows the field around a single magnet.

In fig 1.22b a force of attraction will be observed between the magnets when their unlike poles are brought together.

Fig 1.22c shows the field around two magnets with their like poles near each other. A force of repulsion will be observed by these magnets.

These magnets are permanent magnets and are made from an alloy called alnico which contains aluminium, cobalt, iron, copper and nickel.

Ferro ceramics - magnets are made from this material. It consists of very finely powdered iron mixed with binder substances and pressed under high pressure and temperature whilst exposed to a strong magnetic field. When cooled, the magnet retains its magnetism. These magnets are able to be moulded to almost any shape.

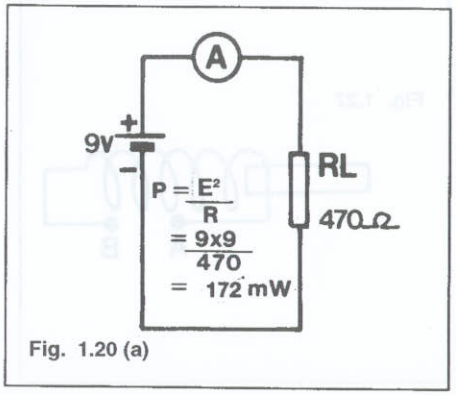


Fig. 1.20 (a)

Temporary magnets

Fig 1.23 shows a permanent magnet with a steel nail attached to it. The nail has become a temporary or induced magnet. Its head has

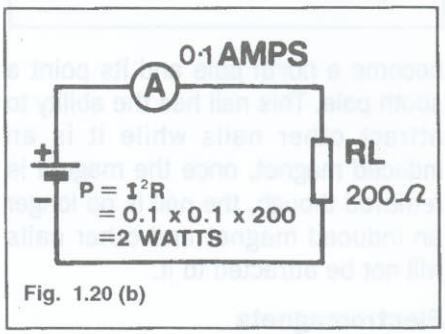


Fig. 1.20 (b)

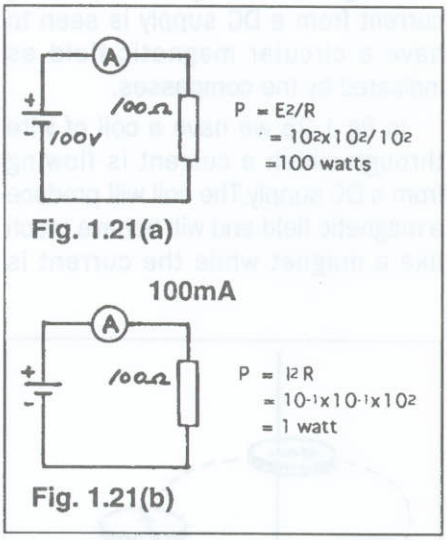


Fig. 1.21(a)

Fig. 1.21(b)

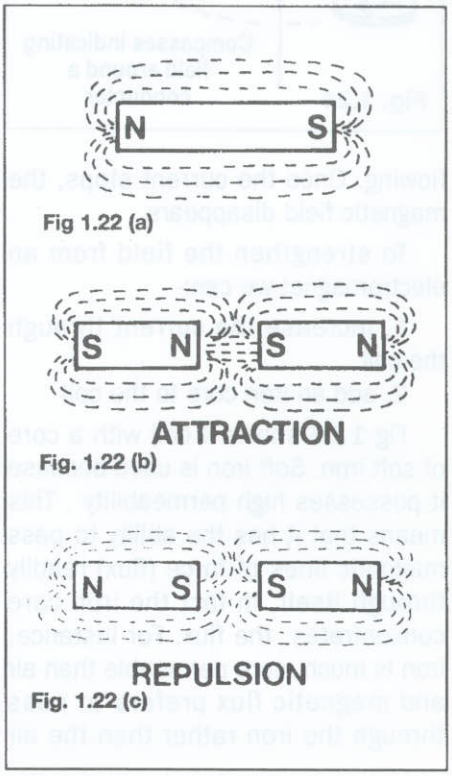


Fig 1.22 (a)

Fig. 1.22 (b)

Fig. 1.22 (c)

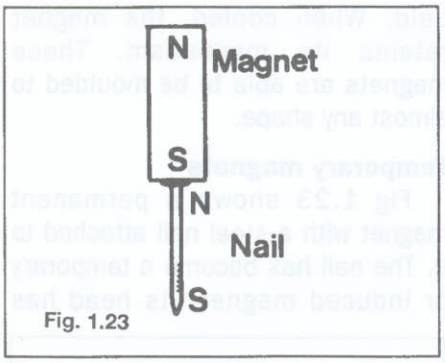


Fig. 1.23

become a north pole and its point a south pole. This nail has the ability to attract other nails while it is an induced magnet, once the magnet is removed though, the nail is no longer an induced magnet and other nails will not be attracted to it.

Electromagnets

In Fig 1.24 a single wire passing current from a DC supply is seen to have a circular magnetic field as indicated by the compasses.

In fig 1.25 we have a coil of wire through which a current is flowing from a DC supply.The coil will produce a magnetic field and will behave much like a magnet while the current is

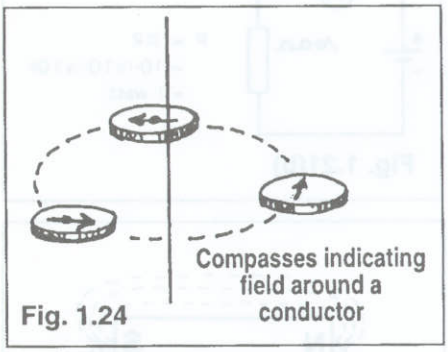


Fig. 1.24

flowing. Once the current stops, the magnetic field disappears.

To strengthen the field from an electromagnet we can:-

1. increase the current through the coil
2. add an iron core to the coil

Fig 1.26 shows a coil with a core of soft iron. Soft iron is used because it possesses high permeability . This means that it has the ability to pass magnetic lines of force (flux) readily through itself. In fact the iron core concentrates the flux. For instance, iron is much more permeable than air and magnetic flux prefers to pass through the iron rather than the air surrounding the iron core. The core actually markedly increases the magnetic field of the coil.

The coil in this case is referred to as a Solenoid .

If the iron core was positioned as shown in Fig 1.27, and the current was switched on, the iron *"Armature" would be attracted into the coil as shown in fig 1.28. This is the principle of the solenoid. This indicates that work can be done by the iron core when influenced by the coil having current flowing in it. *(an armature is the moving part of the the relay assembly)

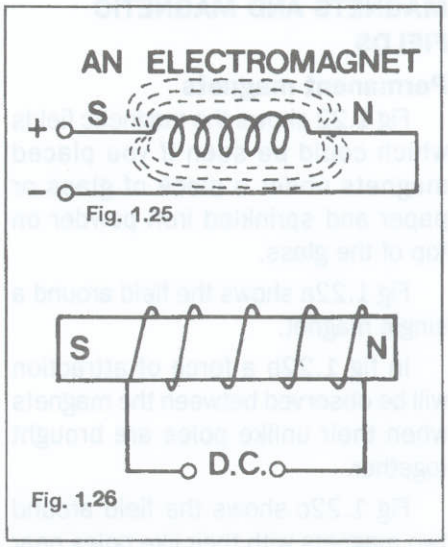


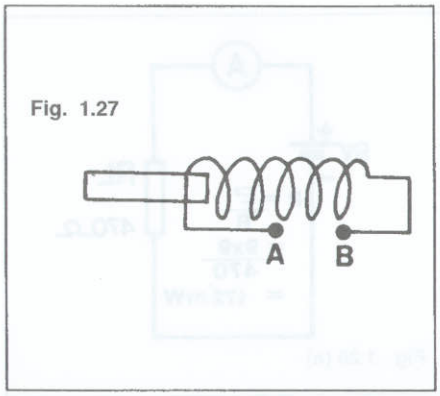
Fig. 1.26

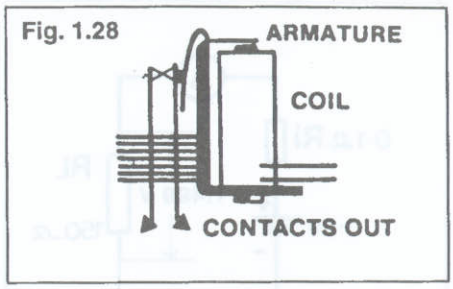
Relays

Referring to fig 1.28 :-

A solenoid can have sets of switch contacts coupled via an insulator to the moving armature.

When the coil is energised, the magnetic flux builds up in the iron core of the the coil and the armature is attracted to the top of the iron core in the coil and the contacts are thus activated.





The contacts are used to control another circuit and so the control current (coil current) is isolated from the controlled circuit. An example of this is the antenna changeover relay in a transceiver. When beginning to transmit, the relay is energised and the antenna is switched through to the transmitter. When returning to the receive mode, the relay is released and the antenna is reconnected to the receiver.

Another device using electromagnetic principles is the reed relay as shown in fig 1.29. It consists of a coil with a hollow centre . Inside the coil is the contact set which is sealed into a glass tube.

One of the contacts (the reed) is moveable and is made from magnetic material. When the coil is energised, the magnetic field attracts the reed and thus closes the contacts. Because the reed is contained in a vacuum, the contacts do not oxidise and so have very long life.

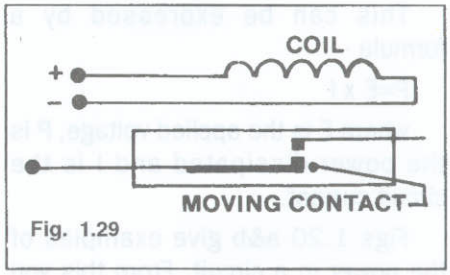
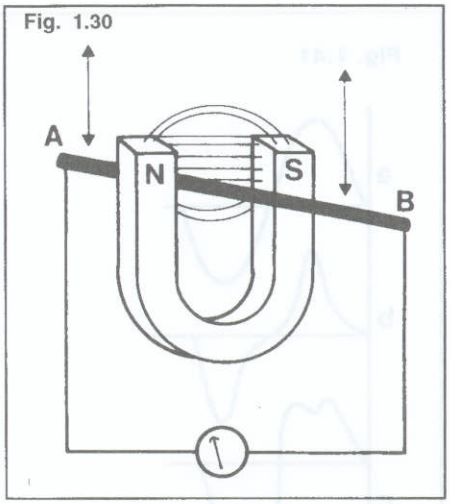


Fig. 1.29

ALTERNATING CURRENT (AC)

Referring to fig 1.30 we have a conductor A-B suspended in a magnetic field from a permanent magnet. If the conductor is moved in the direction of the arrows,that is up and down within the field, we would induce an Alternating EMF in the wire. This voltage could be measured by an AC voltmeter as shown in Fig 1.30. The conductor could be fixed and the magnet moved up and down instead but the same emf would be generated.



In fig 1.31 a single turn coil is pivoted on bearings so that it can be rotated within the magnetic field of a magnet. The ends of the coil are terminated at slip rings c and d, while brushes a and b bear onto the slip rings . If the coil is rotated in either direction, an AC voltage will be induced in it and this voltage will be picked up by the brushes. This is the principle of the AC generator or Alternator.

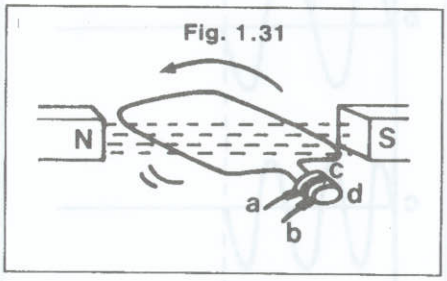
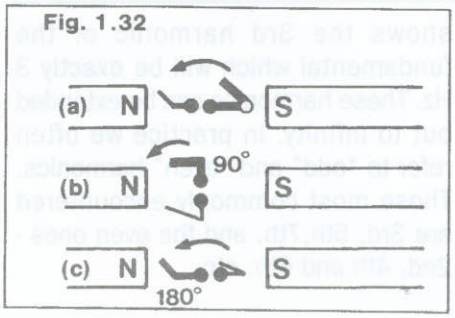
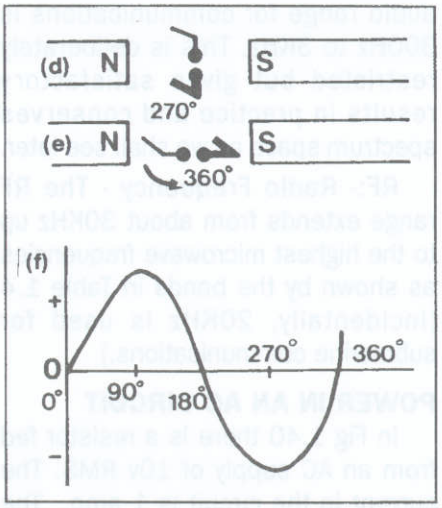
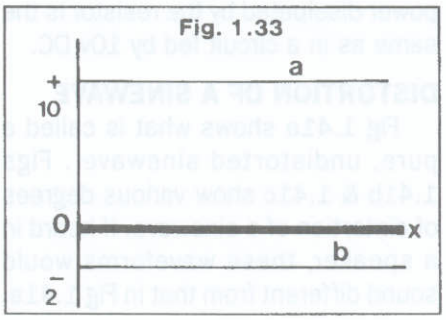


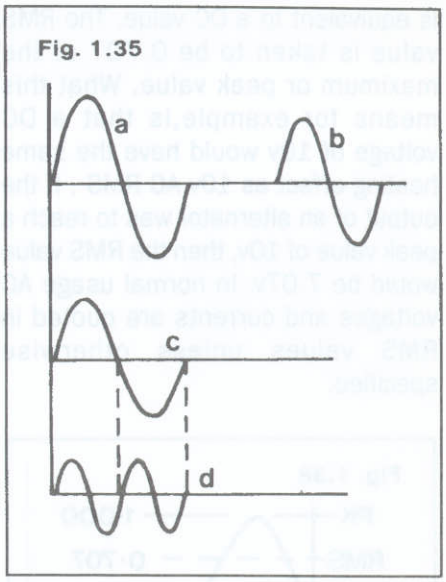
Fig 1.32 a-e shows the single turn alternator as it is rotated a full circle from 0 to 360 degrees in a counter clockwise direction. Fig 1.32f shows the output voltage from the alternator's slip rings during one revolution. The voltage rises to a maximum positive value at 90°,falls down to zero at 180°, then rises to the negative polarity maximum at 270° and then falls to zero again at 360° . This is known as one complete cycle or alternation.

Fig. 1.33 shows +10v and a -2v





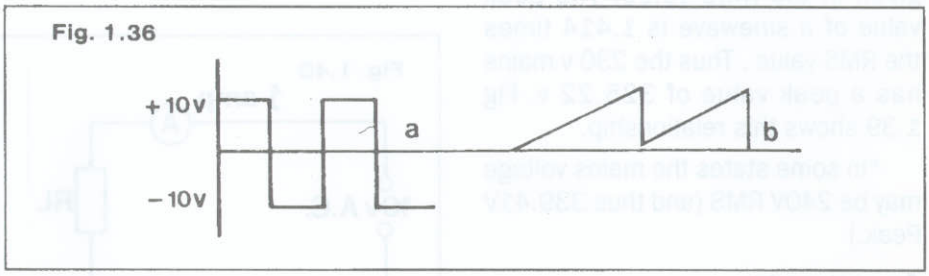




(d) is said to have twice the frequency of (c)

Other AC waveshapes

Fig 1.36a shows a square wave of 10v amplitude and Fig 1.36b shows a sawtooth wave



voltage as shown on a Cathode Ray Oscilloscope.

AC VOLTAGE TERMINOLOGY

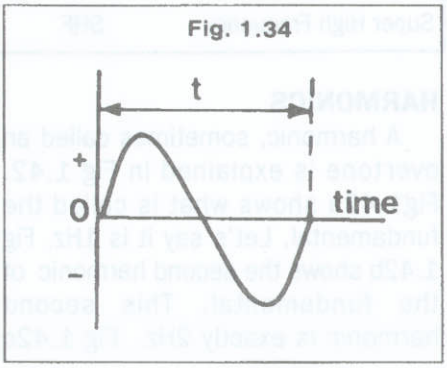
The distance (t) shown in Fig 1.34 can be called :-

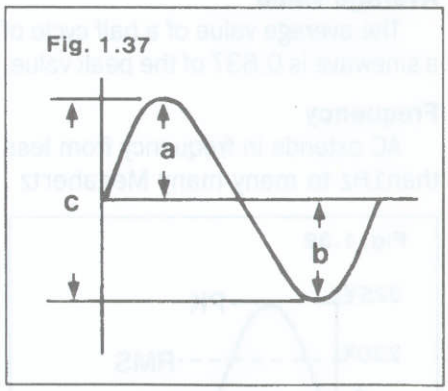
(a) the wavelength
(b) the period

The waveshape is known as a sine wave . If (t) was one second in time, the wave is said to have a frequency of one cycle per second or 1Hertz (1Hz)

Fig 1.35 shows various characteristics of sine waves -

(b) is said to have a lower amplitude than (a)





SINEWAVE VALUES

In Fig 1.37 the value ("a") represents what is called the positive peak value of the wave. Value ("b") represents the negative peak value. Value ("c") represents what is called the peak to peak value and of course this is twice the peak value.

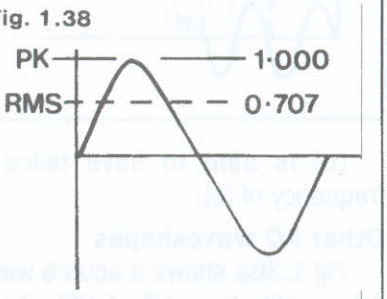
RMS value

The effective value is shown in Fig 1.38.

This is usually called RMS value. RMS means "Root Mean Square" and is that value of an AC sinewave which

is equivalent to a DC value. The RMS value is taken to be 0.707 of the maximum or peak value. What this means for example,is that a DC voltage of 10v would have the same heating effect as 10v AC RMS . If the output of an alternator was to reach a peak value of 10v, then the RMS value would be 7.07v. In normal usage AC voltages and currents are quoted in RMS values unless otherwise specified.

Fig. 1.38



For example the 230 v AC mains is given in the RMS value. The peak value of a sinewave is 1.414 times the RMS value . Thus the 230 v mains has a peak value of 325.22 v. Fig 1.39 shows this relationship.

*In some states the mains voltage may be 240V RMS (and thus 339.41V Peak.)

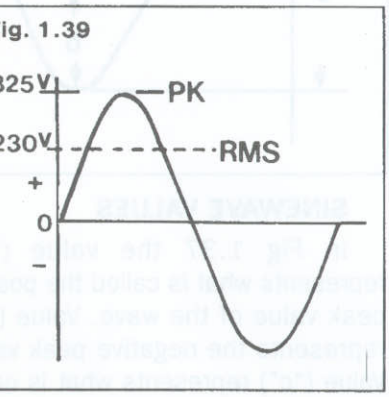
Average value

The average value of a half cycle of a sinewave is 0.637 of the peak value.

Frequency

AC extends in frequency from less than1Hz to many many Megahertz .

Fig. 1.39



There are two main ranges of AC, Audio Frequency (AF) and Radio Frequency (RF).

AF:- The audio frequency (AF) range is normally considered to be from 10 Hz to 20 KHz , (HiFi) however the audio range for communications is 300Hz to 3KHz. This is deliberately restricted but gives satisfactory results in practice and conserves spectrum space as we shall see later.

RF:- Radio Frequency - The RF range extends from about 30KHz up to the highest microwave frequencies as shown by the bands in Table 1.4 (Incidentally, 20KHz is used for submarine communications.)

POWER IN AN AC CIRCUIT

In Fig 1.40 there is a resistor fed from an AC supply of 10v RMS. The current in the circuit is 1 amp. The power dissipated by the resistor is the same as in a circuit fed by 10v DC.

DISTORTION OF A SINEWAVE

Fig 1.41a shows what is called a pure, undistorted sinewave . Figs 1.41b & 1.41c show various degrees of distortion of a sinewave. If heard in a speaker, these waveforms would sound different from that in Fig 1.41a.

Fig. 1.40

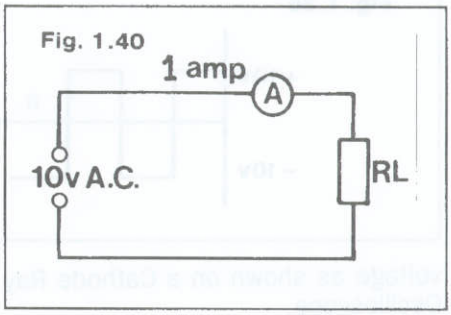


Fig. 1.41

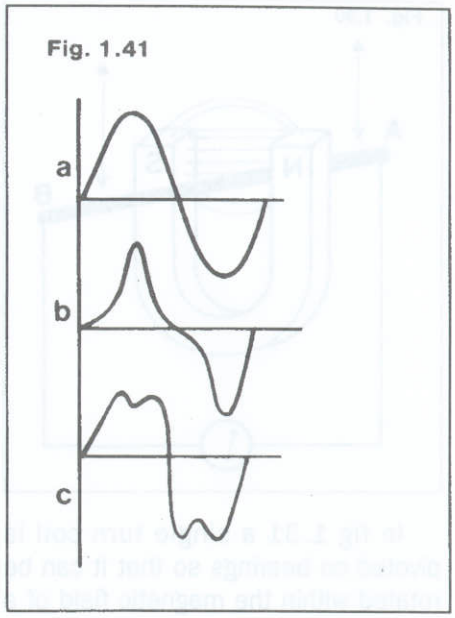


Fig. 1.42

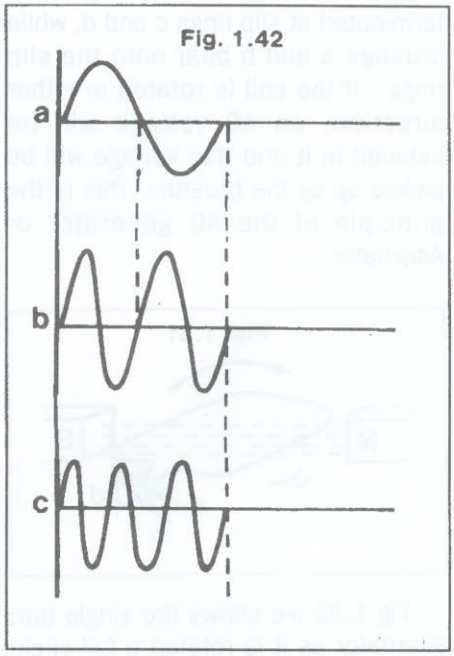
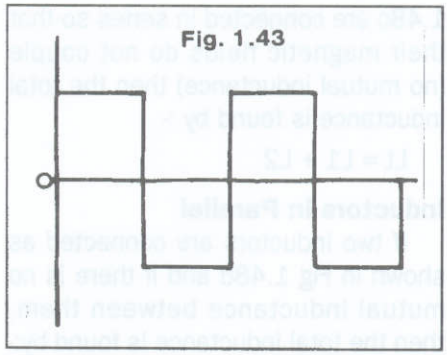


TABLE 1.4

Very Low Frequency	VLF	:below 30kHz
Low Frequency	LF	:30-300 kHz
Medium Frequency	MF	:300kHz - 3MHz
High Frequency	HF	:3-30 MHz
Very High Frequency	VHF	:30-300MHz
Ultra High Frequency	UHF	:300-3000MHz (0.3 - 3GHz)
Extra High Frequency	EHF	:3000-30000 MHz (3 - 30GHz)
Super High Frequency	SHF	:30000-300000 MHz (30 - 300GHz)

HARMONICS

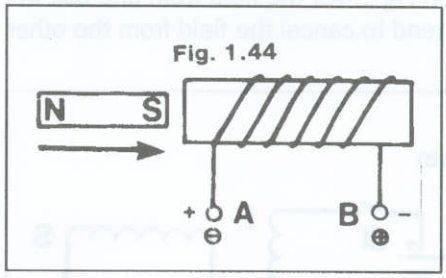
A harmonic, sometimes called an overtone is explained in Fig 1.42. Fig1.42a shows what is called the fundamental. Let's say it is 1Hz. Fig 1.42b shows the second harmonic of the fundamental. This second harmonic is exactly 2Hz. Fig 1.42c shows the 3rd harmonic of the fundamental which will be exactly 3 Hz. These harmonics can be extended out to infinity. In practice we often refer to "odd" and "even" harmonics. Those most commonly encountered are 3rd, 5th,7th, and the even ones - 2nd, 4th and 6th. etc.



The square wave shown in Fig 1.43 is the combination of many harmonics of the fundamental frequency. A square wave is made up from many harmonics combined together.

SKIN EFFECT

As the frequency is increased into the VHF range and above it is found that the RF currents tend to flow on the outside surface of the conductors. This is referred to as the skin effect. Often, conductors for RF at higher frequencies are silver plated and commonly are tubes rather than solid conductors because of the skin effect.



ELECTROMAGNETIC INDUCTION

Earlier we discussed the effect of a magnet being moved within a coil of wire. That is, an AC voltage was induced in the coil. If we moved the magnet rapidly into the coil only in one direction as shown in Fig 1.44, we would produce a momentary DC voltage across the coils terminals A-B.

Similarly, if we moved the magnet rapidly out of the coil only, we would produce a DC voltage of the reverse polarity -shown by the polarities within the circles. We could increase the induced voltage by increasing :-

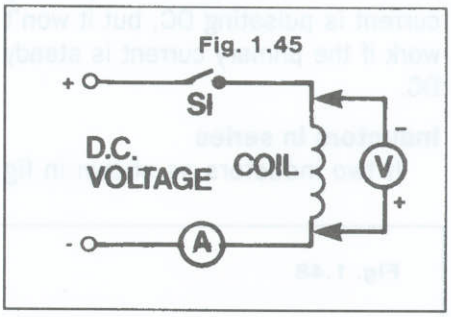
(a) the magnet's strength (b) the number of turns in the coil. (c) the velocity of motion of the magnet.

INDUCTANCE

This is the property of a conductor or coil where it will produce an induced emf across its ends when the current flowing through it changes in value.

Referring to fig 1.45, if we close the switch S1, then current will flow through the coil and a magnetic field will be established around the coil. Now if S1 is suddenly opened,the voltmeter will indicate a momentary pulse of voltage which will quickly disappear, Quite likely a spark will occur at the switch contacts as S1 opens. This indicates a dissipation of the energy stored in the coil's magnetic field.

If you were holding the voltmeter's leads with your hands, it's quite likely that you would receive an electric shock as many volts can be generated by a coil when the current through it is interrupted. This effect is known as self-induced emf or "back emf".The amount of voltage is determined by a number of factors:-



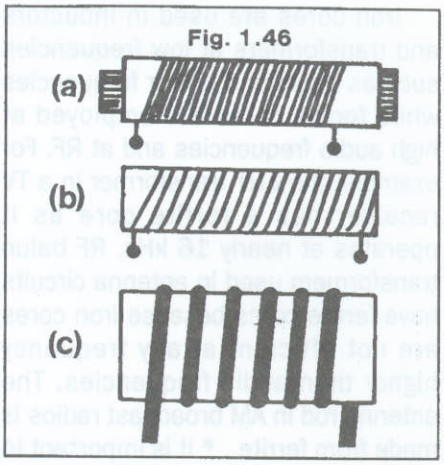
(a) the number of turns in the coil (b) the amount of current flowing (c) the rate of change of the current and (d) the type of core material inside the coil

A petrol engine's ignition system uses a principle similar to that shown in Fig 1.45 to produce many thousands of volts to fire the spark plugs.

Inductance of coils (or as they are often called- inductors) is affected by some physical factors:-

(a) the number of turns in the coil (b) the gauge of wire used in the coil (c) the length of the coil (d) the diameter of the coil (e) the core material of the coil.

In Fig 1.46a we have a coil which is small in diameter, is wound with fine wire and has an iron core. This coil will possess high inductance. Fig 1.46b is a similar coil not having an iron core. It will have less inductance because it only has an air core and it is wound over greater length -i.e. there



is more space between each turn.

The coil in Fig 1.46c will have the least inductance because it is wound on a larger diameter, it uses less turns, the turns are spaced well apart and the gauge of wire is much thicker.

Slug tuning

A core can be arranged inside a coil to be able to be moved in and out. This will give you the ability to change the inductance of the coil over a set range. The core in this case is called a "slug" and the coil is said to be slug-tuned.

Coils are sometimes referred to as chokes., RF chokes, solenoids or inductors.

UNITS OF INDUCTANCE

The unit of inductance is the HENRY. In circuit descriptions , it is usually abbreviated to H.

Large chokes for power supply filtering are measured in tens of henries and are wound with enamelled wire onto iron cores. Chokes used at RF are referred-to as RF Chokes (or RFC on circuits) and may range from a few millihenries (mH) down to a few microhenries (uH).RF chokes are either wound on a ferrite core or may be air-wound. On circuits, inductors or chokes are often referred to as L1, L2 or RFC1 RFC2 etc.

PERMEABILITY

Various materials have the ability to concentrate magnetic flux through themselves - this is known as permeability. Air has a permeability of 1, while iron or ferrite cores have greatly increased permeability above that of air. Ferrites are materials made from finely powdered iron and ceramic compounds.

Iron cores are used in inductors and transformers at low frequencies such as audio and power frequencies while ferrite cores are employed at high audio frequencies and at RF. For example, the EHT transformer in a TV receiver has a ferrite core as it operates at nearly 16 kHz. RF balun transformers used in antenna circuits have ferrite cores because iron cores are not efficient at any frequency higher than audio frequencies. The antenna rod in AM broadcast radios is made from ferrite . * It is important to know that ferrites are manufactured in many shapes and grades so the correct one must be used for specific applications such as AF, RF - HF, VHF or UHF circuits.

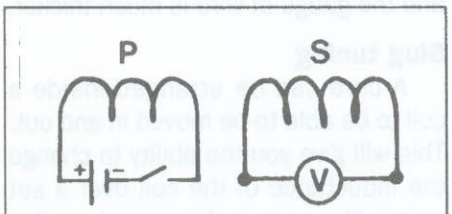


Fig. 1.47

MUTUAL INDUCTANCE & TRANSFORMERS

The principle of mutual inductance is used in transformers as shown diagrammatically by Fig 1.47.

If we close the switch S1, a magnetic field is created around coil "P". As this field expands, it induces a momentary voltage in coil "S" which can be read on the voltmeter. When steady state conditions are achieved in the circuit, i.e. the current has grown to its maximum value, the voltage in coil S will fall to zero. If we now open switch S1 the current in coil P will fall to zero and the magnetic field around P collapses . This change in the value of current will now induce a reverse-polarity voltage momentarily in coil S. These two coils are said to have mutual inductance as the field of one is strongly influencing the other. In other words, they are magnetically coupled.

If we add a highly permeable core to coils P & S we increase their mutual inductance and the voltages induced in coil S will be greater . This is shown in Fig 1.48a. Now if we orientate the two coils as shown in fig 1.48b so that they are at 90° to each other,we would find little or no voltage would be induced in coil S. The reason for this is that the mutual inductance between the coils is now zero. The two coils are now said to have very little (or no) magnetic coupling. i.e. very few shared lines of force.

Referring back to Fig 1.47, if the switch was left permanently closed, there would be no induced emf in coil S because the voltage in S is dependant upon the current in coil P constantly changing its value. If the current in P is constantly being changed, the magnetic field from P is varying and so an emf is induced in S. This is the principle of the transformer . i.e. a pulsating DC in the Primary coil - P is necessary to produce an emf in the secondary coil S.

So you can now see that a transformer will work if the primary current is pulsating DC, but it won't work if the primary current is steady DC.

Inductors in series

If two inductors as shown in fig 1.48c are connected in series so that their magnetic fields do not couple (no mutual inductance) then the total inductance is found by :-

Lt = L1 + L2

Inductors in Parallel

If two inductors are connected as shown in Fig 1.48d and if there is no mutual inductance between them, then the total inductance is found by:-

1/Lt = 1/L1 + 1/ L2...(etc)

e.g. two 20H inductors in parallel:

1/Lt = 1/20 + 1/20

1/Lt = 2/20

(now invert both sides of the equation)

therefore Lt = 20/2

Lt = 10H

Inductors series aiding :- If L1 and L2 are wired as shown by Fig 1.48e and their magnetic fields are linked together, the total inductance is increased.

Inductors series opposing:- However, if the coils are connected as in Fig 1.48f the field from one coil will tend to cancel the field from the other

Fig. 1.48

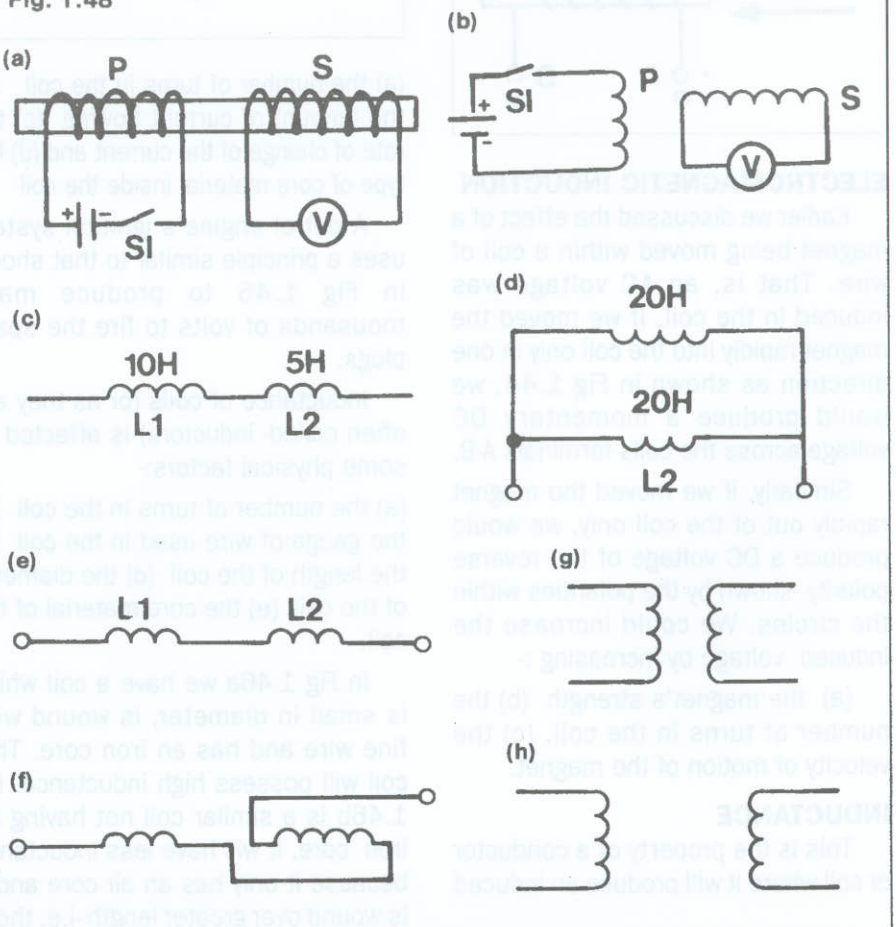
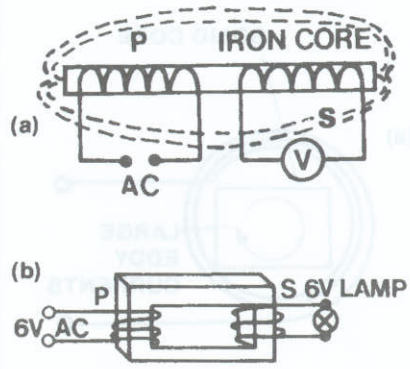


Fig. 1.49



and the overall (total) inductance will be decreased.

COUPLING

If two coils are arranged as in Fig 1.48g they would have high mutual inductance and are said to be "tightly or closely coupled". If they are placed well apart as in Fig 1.48h, then there is little mutual inductance and they are said to be "loosely coupled".

THE TRANSFORMER

If we apply an AC voltage to the primary winding "P" on the basic transformer shown in Fig 1.49a, we will find that there would be an AC voltage induced in the secondary winding "S".

We can improve the efficiency of the transformer by using a core type as shown in Fig 1.49b.

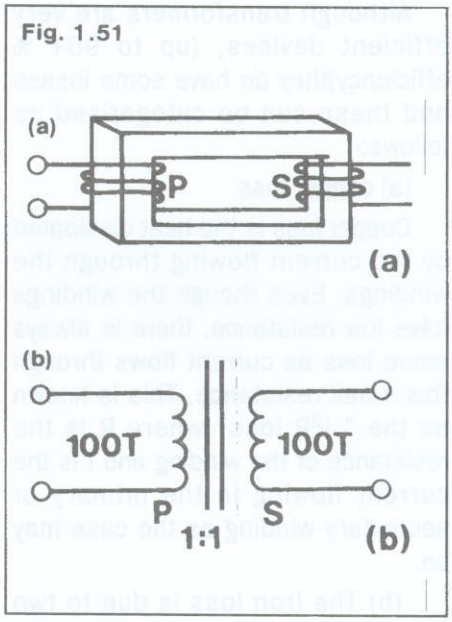
Let's assume that both windings P & S have 100 turns each. Then if we applied 6v AC to winding P then we would expect to obtain close to 6v AC from the secondary winding 'S' and the lamp will light up. The efficiency of the transformer at (b) would be very much greater than the one at (a) as it has much lower leakage of the magnetic flux from the better core.

In another transformer, (fig 1.50a) let's say we put 230 turns onto the primary winding P and 6 turns on the secondary winding S. This would be a voltage step-down transformer. If the transformer was turned around the other way as in Fig 1.50b , we could feed the 6v winding with 6v (as a primary now)and we would get 230 v from the other winding (which has become the secondary) so we have now used the transformer as a voltage step-up. You may have noticed that this transformer has a ratio of one turn per volt. This relationship can be shown by a simple equation :-

Np/Ns = Ep/Es where Np is the number of turns on the primary, Ns is the number of turns on the secondary, Ep is the primary voltage and Es is the secondary voltage.

Fig 1.51a shows a transformer with one primary and one secondary winding, Fig 1.51b is the way this transformer would be shown on most circuit diagrams. As this transformer has 100 turns on each winding it is known as a one-to-one (1:1) transformer.

Fig. 1.51



We have shown a 2:1 step down transformer in Fig 1.52. The primary winding has 200 turns and the secondary 100 turns. We can find the secondary voltage if we know the primary voltage Ep by using the equation :-

Np/Ns = Ep/Es

200/100 = 200/Es (Ep is 200v as shown on the diagram)

2/1 = 200/Es
2Es = 1x200
Es = 200/2
Es = 100 volts

If we use Ohms law, we can calculate the secondary current- 'Is' drawn by the load resistor R1:-

I=E/R
I=100/100
I=1 amp

Calculating the power, P = E x I

P=100x1 = 100 watts.

A transformer is looked upon as a very efficient device in most cases and has quite low losses. We can assume that the secondary power is about the same as the power being fed to the primary. If this is the case, the primary power will also be 100 watts. (or 100 volt-amps as we should say in AC circles.)

So here we have a situation where the primary power is 100 watts,and the voltage is 200 V, and on the secondary side we have 100v with one amp flowing through the resistor. How could we find the primary current ?

Fig. 1.50

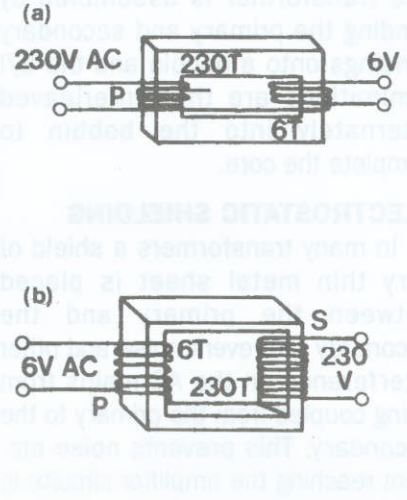
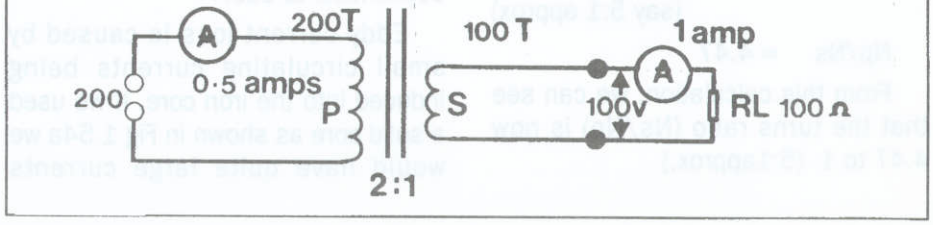


Fig. 1.52



Simple ! just use this equation :-

$$\frac{Ep}{Es} = \frac{Np}{Ns} = \frac{Is}{Ip}$$

leaving out the turns ratio part (Np/Ns) , we use the remainder of the equation -

thus $\frac{Ep}{Es} = \frac{Is}{Ip}$

$\frac{200}{100} = \frac{1}{Ip}$

$2 = \frac{1}{Ip}$

$Ip = {}^{1}/_{2}$

$Ip = 0.5$ amps

*It is important to remember that the current ratio Is/Ip is reversed in the equation as a transformer which is voltage step-up is at the same time a current step-down and vice versa.

IMPEDANCE TRANSFORMATION

Impedance is the total opposition to current flow offered by an AC circuit. Impedance may be made up from resistance, inductive reactance and capacitive reactance. (more about impedance shortly)

A transformer is able to transform impedances. Let's say that you want to connect a microphone with an impedance of 50Kohm to an amplifier which has an input impedance of 1Megohm as shown in Fig 1.53. There is a simple equation which relates the impedance ratio to the voltage ratio of a transformer. The turns ratio to give an impedance ratio of 50 k ohm to one Megohm can be calculated as follows:-

$$\frac{(Ns)^2}{(Np)} = \frac{Zs}{Zp}$$

(now take square root of both sides)

therefore ${}^{Ns}/_{Np} = \sqrt{Zs/Zp}$

(10^6 is the one megohm)

and $5x10^4$ is the 50kohm)

$Np/Ns = \sqrt{\frac{10^6}{5 \times 10^4}}$

$= \sqrt{\frac{10^2}{5}}$

$= \sqrt{20}$

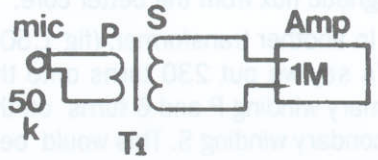
$= 4.47$

(say 5:1 approx)

$Np/Ns = 4.47$

From this calculation, we can see that the turns ratio (Ns/Np) is now 4.47 to 1 (5:1approx.)

Fig. 1.53



* So it takes a turns ratio of 5:1 to give an impedance ratio of 20:1

Put simply, the turns ratio squared equals the impedance ratio,

or put the other way, the impedance ratio equals the turns ratio squared.

If this impedance matching transformer was not used , then there would be losses and possible distortion in this amplifier setup.

TRANSFORMER LOSSES

Although transformers are very efficient devices, (up to 90+ % efficiency)they do have some losses and these can be categorised as follows:-

(a) copper loss

Copper loss is the heat dissipated by the current flowing through the windings. Even though the windings have low resistance, there is always some loss as current flows through this small resistance. This is known as the " I^2R loss" where R is the resistance of the winding and I is the current flowing in the primary or secondary winding as the case may be.

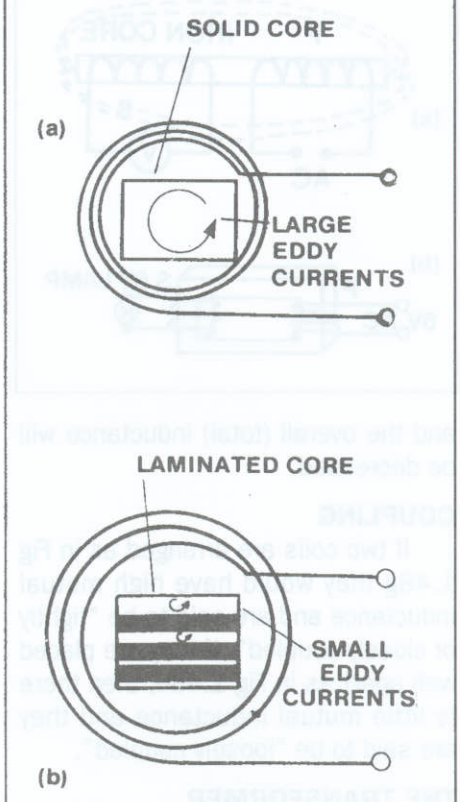
(b) The Iron loss is due to two factors :-

(i) the Hysteresis loss

the Hysteresis loss is caused by the iron having to be magnetised in one polarity on the positive half cycle of the AC wave and then it has to be reversed on the negative half cycle. This continual reversal of the flux direction has a heating effect upon the iron. The way to minimise this is to use the highest grade of iron that is economical to use.

Eddy current loss is caused by small circulating currents being induced into the iron core. If we used a solid core as shown in Fig 1.54a we would have quite large currents flowing in the core and it would become very hot and the losses would be high.

Fig. 1.54

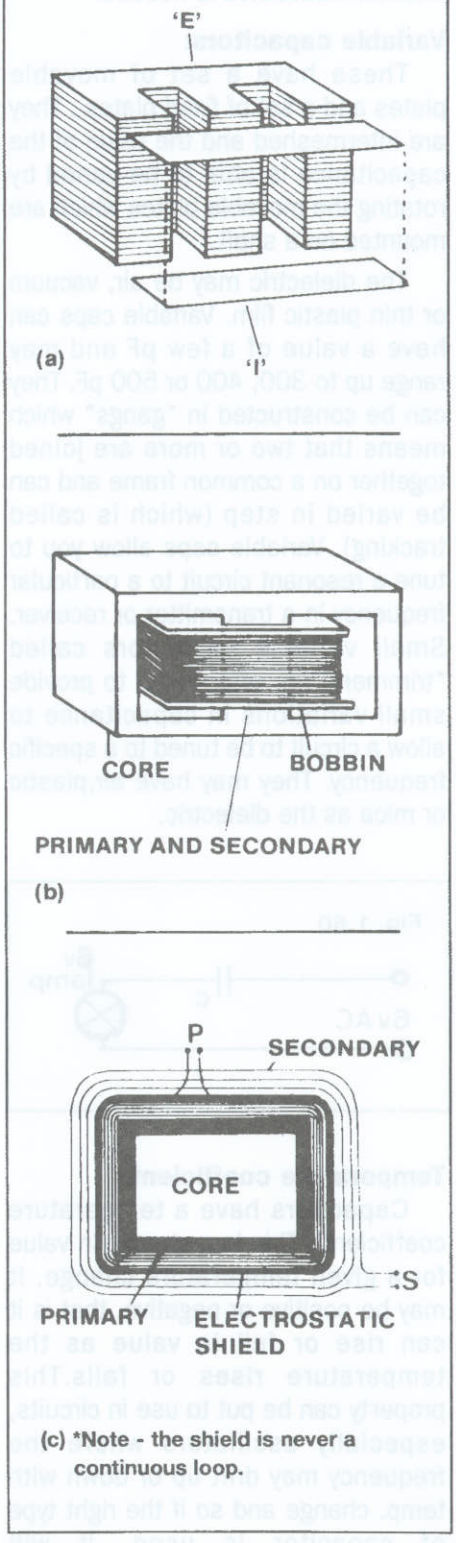


However if the core was made from many pieces of sheet iron (laminations) with insulating layers between them,then the eddy currents would be greatly reduced and the heat losses then become minimal. The insulation is usually a thin layer of oxide on the surface of the iron. Most transformers are made with a core of interleaved laminations in an "E- I" configuration as shown in Fig 1.55a. The transformer is assembled by winding the primary and secondary windings onto a bobbin and the E/I laminations are then interleaved alternately into the bobbin to complete the core.

ELECTROSTATIC SHIELDING

In many transformers a shield of very thin metal sheet is placed between the primary and the secondary to prevent noise and other interference on the AC mains from being coupled from the primary to the secondary. This prevents noise etc. from reaching the amplifier circuits in

Fig. 1.55



(c) *Note - the shield is never a continuous loop.

receivers and other equipment. This shield must be carefully installed in the transformer so that it doesn't form a complete loop as it would then form a shorted turn. A shorted turn would cause the transformer to overheat and burn out. Fig 1.55c shows how the shield is placed in between the windings. The electrostatic shield is usually earthed to provide a path to earth for the interference currents which are coupled to the shield by capacitive effects.

Most transformers now have a two-section bobbin which has a barrier strip between the primary and secondary so that there is almost no chance for the 240 v on the primary shorting across to the secondary.

Fig. 1.56

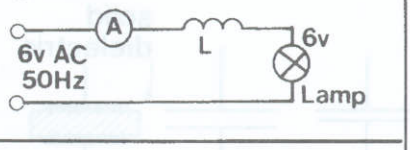
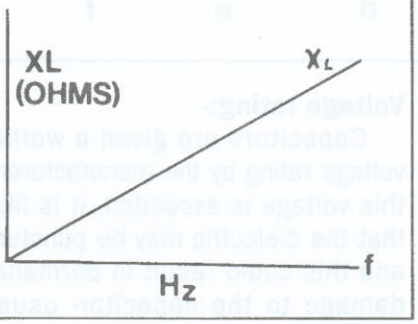


Fig. 1.57



INDUCTORS ON AC

In Fig 1.56 we have a lamp and a choke (L) connected in series to an AC supply. Let's assume that the lamp is currently lit-up. Now if we slowly increase the frequency from 50 Hz up to about 10KHz, the lamp brightness will steadily decrease and at some stage it will cease to light.

This is caused by the inductive reactance (the AC resistance) of the choke.

Inductive reactance is measured in Ohms and is found by this equation:-

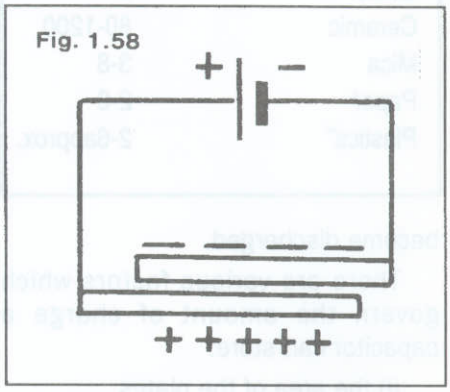
$XL = 2 \pi f L$ where f is the frequency in Hz and L is the inductance of the choke in Henries.

So, as frequency rises, the reactance XL rises and when frequency is reduced, XL decreases. The graph in Fig 1.57 shows how Inductive reactance (XL) varies with frequency.

CAPACITORS

Fig 1.58 shows a basic capacitor (they used to be called condensers) A capacitor is an electronic component which can store a charge. Looking at the capacitor in Fig 1.58, you will notice that there are two wires connected to a battery. The wires which form the plates of a capacitor have an air gap . One plate has a deficiency of electrons and the other has a surplus of electrons. We can therefore say that this capacitor is charged. If the battery was removed and a voltmeter connected to the plates it would read the voltage of the charge. However a capacitor of this size would not hold very much charge and the voltmeter would quickly discharge it. We could make this capacitor hold more charge by placing a greater voltage across it.

Fig. 1.58



The energy is stored in the capacitor in the form of an electrostatic field between the plates. This is analagous to the inductor which stores its energy in the form of a magnetic field. If we kept on increasing the voltage applied across the capacitor's plates, we would eventually reach a point where the air gap or insulation between the plates would break down and an arc discharge occur. The material between the plates is called the Dielectric and this is an insulating material. To store more charge for a given pair of plates, we could place some solid dielectric between the plates and this would increase the capacitance , thus allowing more charge to be stored.

* Plastic dielectrics include such materials as:- polyester, polycarbonate, & polystyrene.

Dielectric Loss

Most dielectrics are not totally perfect insulators and so very slight leakage currents occur through them and a charged capacitor will eventually

Fig. 1.59

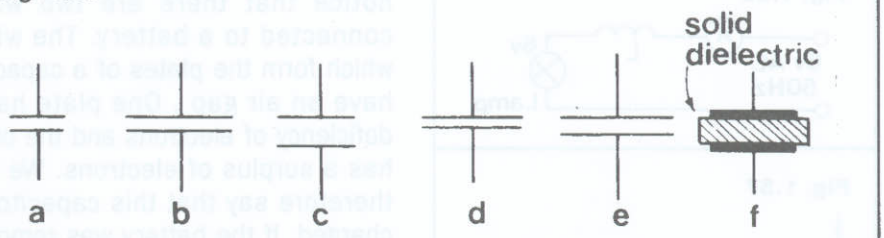


TABLE 1.5
Some Typical Dielectric Materials:-

DIELECTRIC	DIELECTRIC CONSTANT (K)
Air	1
Vacuum	1
Glass	8
Ceramic	80-1200
Mica	3-8
Paper	2-6
Plastics*	2-6approx.

become discharged.

There are various factors which govern the amount of charge a capacitor can store:

(i) the area of the plates

(ii) the spacing of the plates

(iii) the dielectric material

* the larger the plates, the greater the capacitance

* the smaller the gap between the plates,the greater the capacitance

Various dielectrics can be used and will increase the capacitance over that of air or vacuum. Dielectrics have what is called "Dielectric Constant" (K) Table 1.5 gives the values of K for some dielectrics.

Fig 1.59 illustrates the various factors governing the value of a capacitor (b) has larger plates than (a) and so it has more capacitance, (d) has the same size plates as (c) but they are spaced closer togther so it has more capacitance, (f) has a solid dielectric and so it has more capacitance than (e).

UNITS OF CAPACITANCE

The Farad is the basic unit of capacitance, however it is a very large value and it is more commonplace to encounter capacitors rated in microfarads, (uF), Nanofarads (nF), and picofarads (pF).

Voltage rating:-

Capacitors are given a working voltage rating by the manufacturer. If this voltage is exceeded, it is likely that the dielectric may be punctured and this could result in permanent damage to the capacitor- usually resulting in a short circuit.

Capacitor types:

The various types are categorised by their dielectric materials -

mica, ceramic, polyester, polycarbonate, polystyrene, electrolytic, tantalum.

Each type has its own special characteristics and the use you put them to should be carefully selected as some are fine in audio but no use at RF, so be guided by the manufacturers specifications or by constructional and other advice given in books and magazines.

Electrolytic and Tantalum capacitors

These types are used to obtain very large values of capacitance in small physical packages. Their values typically range from about 1 microfarad to many thousands of microfarads. (A one farad capacitor is available but with very low voltage rating.)

The dielectric in these capacitors is a very thin film of aluminium or tantalum oxide, (it's this very thin dielectric which makes high values possible in small packages.) Note that electrolytic capacitors are polarised and must be placed in the circuit correctly or they may explode !

Uses of capacitors:

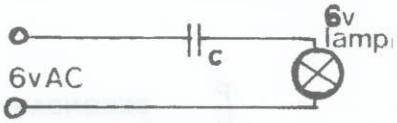
Each type has certain applications for which it is best suited. For instance, electrolytic and tantalums are most commonly used as power supply filters, emitter bypasses,decoupling and coupling in audio and low frequency circuits. Disc ceramic types are used mostly in RF circuits where small values and low internal inductance is needed.

Variable capacitors:

These have a set of movable plates and a set of fixed plates . They are intermeshed and the value of the capacitance is able to be varied by rotating the movable plates which are mounted on a shaft.

The dielectric may be air, vacuum or thin plastic film. Variable caps can have a value of a few pF and may range up to 300, 400 or 500 pF. They can be constructed in "gangs" which means that two or more are joined together on a common frame and can be varied in step (which is called tracking). Variable caps allow you to tune a resonant circuit to a particular frequency in a transmitter or receiver. Small variable capacitors called "trimmers' are often used to provide small variations in capacitance to allow a circuit to be tuned to a specific frequency. They may have air,plastic or mica as the dielectric.

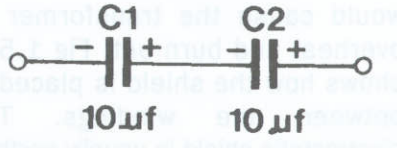
Fig. 1.60



Temperature coefficient

Capacitors have a temperature coefficient . This is a change in value for a given temperature change. It may be positive or negative, that is it can rise or fall in value as the temperature rises or falls.This property can be put to use in circuits, especially oscillators where the frequency may drift up or down with temp. change and so if the right type of capacitor is used, it will compensate for this drift and vary its

Fig.1.61



value , so preventing the oscillator from drifting.

Capacitors on AC.

If we connected the circuit of Fig 1.60 and could vary the frequency of the AC supply from about 50 Hz to say, 10KHz, we would find that as the frequency was raised, the lamp would glow brighter and brighter until it reached full brilliance. This is caused by the capacitor possessing - CAPACITIVE REACTANCE. This is the capacitor's AC resistance. The symbol for this is Xc. It is measured in ohms and can be calculated by this formula:-

$$Xc = \frac{1}{2\pi fC}$$

(where f is the frequency in Hz and C is the capacitance in farads).

If you study this equation, you will see that if the frequency rises, the Xc falls and if the frequency falls, the Xc rises.

Fig. 1.62

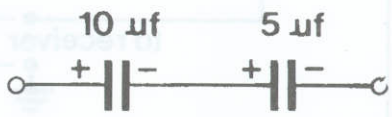
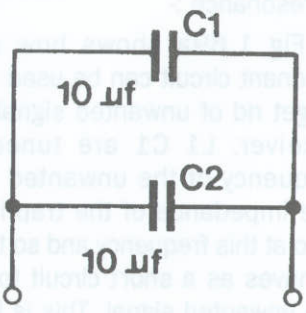


Fig. 1.63



Capacitors in series

Fig 1.61 shows two 10uF capacitors in series.

their total capacitance is found by using the equation:

$$\frac{1}{Ct} = \frac{1}{C1} + \frac{1}{C2} \text{ etc.}$$

thus: 1/Ct = 1/ 10 + 1/10
1/Ct = 2/10 (invert both sides of the equation)
Ct = 10/2
Ct = 5 uF

So the total capacitance is now only 5uF, however if both C1 and C2 were rated at 100v, this series combination would have a joint voltage rating of 200v ! So, if we applied 100v across this combination, there would be an equal division of the voltage and each capacitor would have 50v across it. However if the capacitors were of different value as shown in Fig 1.62, then the voltages appearing across them would NOT be equal.

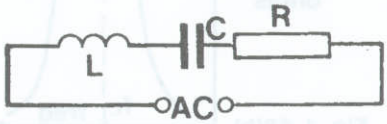
In fact, contrary to what you may at first think the smaller capacitor would have the greater voltage across it ! So care must be taken when connecting capacitors in series. Incidentally, the symbol for capacitors in circuits is usually - "C".

Capacitors in parallel

Two 10uF capacitors are connected in parallel as shown in Fig 1.63. The total capacitance can be found by using this equation:

Ct = C1 + C2 etc.
thus Ct = 10 + 10
Ct = 20 uF.

Fig. 1.64



In parallel, we can directly ADD the values, whereas in series we have to use the reciprocal equation.

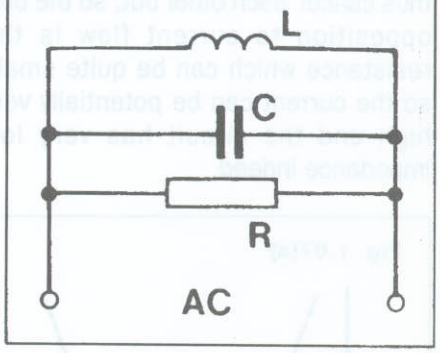
The good news is that in parallel, we increase the capacitance but hold the voltage rating of the lowest voltage capacitor in the circuit, while in a series circuit, we decrease the total capacitance but we get the benefit of increasing the overall voltage rating of the series string .

IMPEDANCE

This is the opposition to current flow offered by an AC circuit. Impedance is measured in ohms and the symbol for impedance is the letter - Z.

Fig 1.64 shows a series circuit containing an inductor, a capacitor and a resistor. This is often called an "R-L-C " circuit - resistance-inductance - capacitance.

Fig. 1.65



This circuit will offer an impedance to the AC supply which is the VECTORAL addition of the R, Xc and X_L of the circuit components. (In other words, you simply can't just add arithmetically the reactance of each as you can in a purely resistive circuit). For example, if the resistance was 1000 ohms, the Xc was 1000 ohms and X_L 1000 ohms, the impedance would not be 3000 ohms. (Xc is the capacitive reactance, X_L is the inductive reactance and R is the resistance).

The impedance is calculated this way:-

$Z = \sqrt{R^2 + X^2}$ [X being the difference between X_L and Xc]

Fig 1.65 shows a parallel R,L,C circuit . Its impedance is complex and once again the individual component reactances cannot just be added in the normal way that you can in DC circuits.

The impedance can be found by the equation - Z = E / It.

And It is found by :-

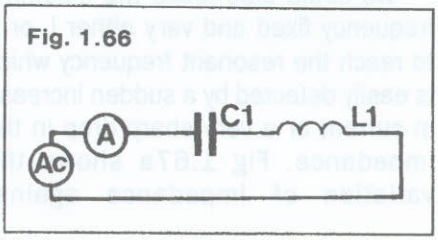
$It = \sqrt{Ir^2 + Ix^2}$.

RESONANT CIRCUITS

Resonant circuits can be either series or parallel and are used in many applications in receivers and transmitters.

(i) series Fig 1.66 shows a series L-C circuit. If the reactance of L and C are equal at a particular frequency, then the circuit is said to be resonant.

Fig. 1.66



In fact, at resonance, the two reactances are equal and opposite and thus cancel each other out, so the only opposition to current flow is the resistance which can be quite small, so the current can be potentially very high and the circuit has very low impedance indeed.

Fig. 1.67(a)

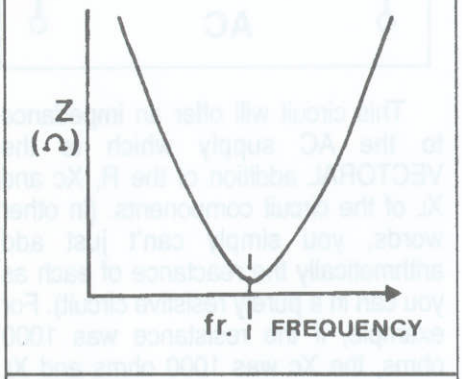
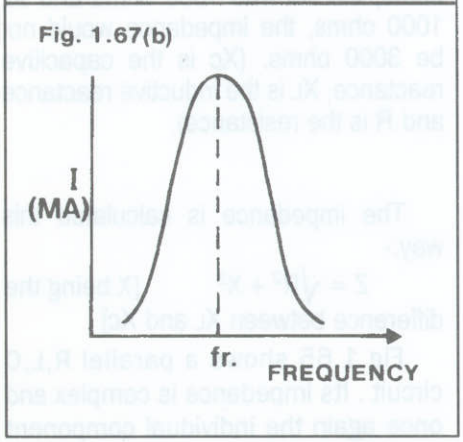


Fig. 1.67(b)



Resonance is a very useful property as it can be employed to single-out a particular frequency in transmitters, receivers and antennas. If the frequency fed to this circuit in Fig 1.66 were slowly increased from zero, the inductive reactance of L would steadily increase and at the same time the reactance of C would steadily fall. At one specific frequency they would be equal and this is the resonant frequency. It is calculated by :-

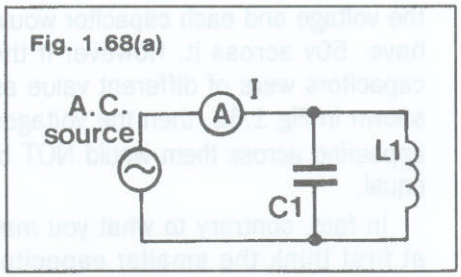
$$fr = 1/ 2\pi \sqrt{LC}.$$

(where L is the inductance in henries and C is the capacitance in farads).

We could also leave the incoming frequency fixed and vary either L or C to reach the resonant frequency which is easily detected by a sudden increase in current or a very sharp drop in the impedance. Fig 1.67a shows the variation of impedance against frequency of a series L-C circuit.

Notice that the impedance is minimum at resonance. Fig 1.67b shows the current rising as resonance is approached and how it falls as the frequency goes above resonance.

Fig. 1.68(a)



(ii) Parallel resonance

Fig 1.68a shows a parallel L-C circuit which is sometimes referred to as a "tank circuit." The resonant frequency once again depends upon the values of L in henries and the capacitance in farads. The same equation applies:-

$$fr = 1/ 2\pi \sqrt{LC}.$$

This equation applies to resonance in audio or RF circuits.

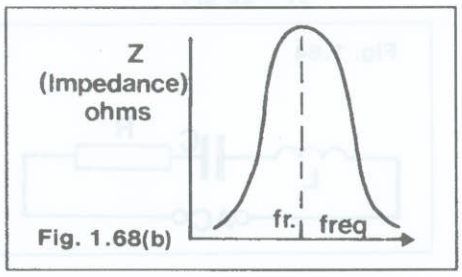


Fig. 1.68(b)

Fig. 1.68(c)

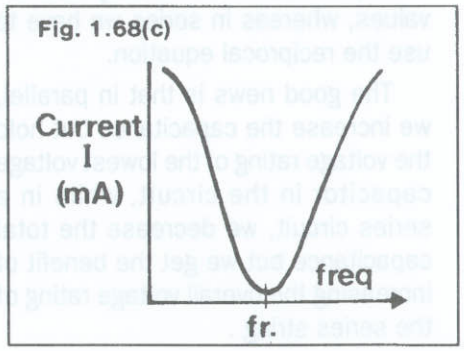


Fig 1.68b shows the relationship between impedance and frequency for the tank circuit. *Note carefully that the impedance is maximum at resonance which is opposite to the series circuit in Fig 1.67.

In Fig 1.68c we can see how the current dips to a minimum at resonance - this is opposite to the series circuit in Fig 1.67.

The behavior of the parallel resonant circuit is thus quite opposite to that of the series circuit, and each configuration has certain useful applications in radio as we shall see later. The AC source of signal in Figs 1.66 and 1.68a could be any device which produces an AC signal. This

Fig. 1.69(a)

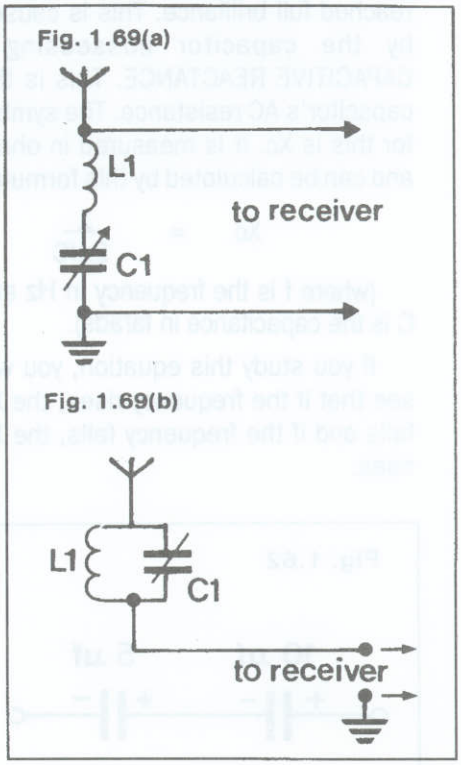


Fig. 1.69(b)

could be an oscillator, an antenna, a signal generator or a transmitter. Figs 1.69a and b show some applications of resonance :-

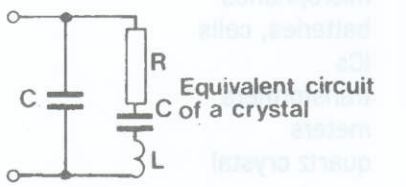
Fig 1.69a shows how a series resonant circuit can be used as a trap to get rid of unwanted signals from a receiver. L1 C1 are tuned to the frequency of the unwanted station . The impedance of the trap is almost zero at this frequency and so the circuit behaves as a short circuit to earth to the unwanted signal. This is known as an acceptor circuit.

A parallel resonant circuit is shown in Fig 1.69b . It is inserted into the cable from the antenna to the receiver and C1 is varied until the tank circuit is resonant at the unwanted signal's frequency. The impedance of this circuit is very high at resonance and so the unwanted signal is blocked from reaching the receiver. This is known as a rejector circuit and acts as a trap to only the unwanted signal.

If we wish to raise the resonant

frequency, we have to either reduce the value of the capacitor or the inductor. In receivers or transmitters, should we wish to have continuous tuning, either the inductor or the capacitor is made variable to make a range of frequencies (or a band) possible to be tuned.

Fig. 1.70



THE PIEZO ELECTRIC EFFECT

A piece of quartz crystal when given mechanical stress will be found to produce an electrical output across its faces. Similarly when an AC signal is applied across its faces it will produce mechanical vibrations.This is known as the Piezo-electric effect.

It is used in microphones, pickups, oscillators, receiver and transmitter filters and gas lighters to name a few applications. A quartz crystal is often used in oscillators to control the frequency. The crystal behaves as a highly selective tuned circuit and has a very high Q factor. A crystal has two resonances which are quite close in frequency. One is the series resonant mode the other is the parallel mode. Fig 1.70 shows the equivalent circuit of a crystal. (Crystals will be discussed in more detail in the section on transmitters.)

* Q Factor is a "quality factor" for tuned circuits and crystals. It relates reactance to resistance and if the reactance is high in relation to resistance, then the Q is high. Q = XL/ R or Xc/R.

DECIBELS

The decibel is used in radio to express power, voltage and current as ratios . Decibels are abbreviated to the symbol dB.

dBs use a logarithmic scale and can be calculated using these equations:-

Power gain/loss = 10 log p1/p2 where p1 is the output power and p2 is the input power. Referring to Fig 1.71a, there is an amplifier with a 50 watt output and an input of 5 watts. You can calculate the gain of the amplifier in dB by using the formula:-

dB gain = 10 log p1/p2
= 10 log 50/5
= 10 log 10 (log 10 is 1)
= 10 x 1
= 10 dB

so this amplifier has 10 dB of gain. If we only fed in 0.5 watts, the output would be 5 watts and the gain of course is still only 10 dB.

In Fig 1.71b we have an amplifier with an input of 0.5 watts and an output of 50 watts.Let's calculate its gain:-

dB gain = 10 log p1/p2
= 10 log 50/0.5
= 10 log 100
(log 100 = 2)
= 10 x 2
= 20dB.

So this amplifier has much more gain than the previous one.

We can use a table to obtain dB figures once we know the ratio of the output to input power. From the table you can see that a ratio of + 3dB is double the power.

Fig. 1.72

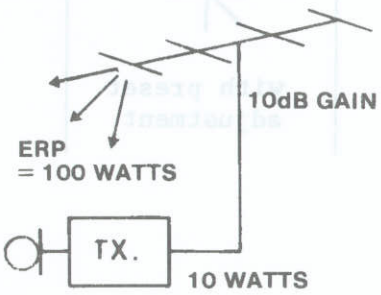


Fig. 1.71(a)

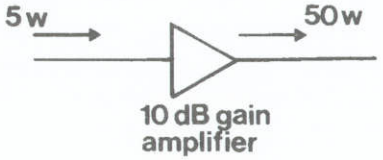
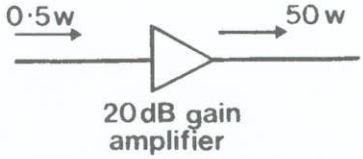


Fig. 1.71(b)



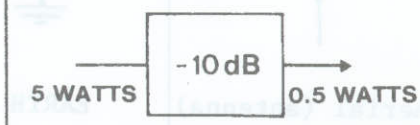
+3dB is double the power
+10dB is ten times the power
+20dB is a hundred times the power
+30dB is a thousand times the power
-3db is half the power

TABLE 1.6

RATIO	dB power gain
x 1,000 000	60
x 100 000	50
x 10 000	40
x 1000	30
x 100	20
x 10	10
x 2	3

Fig 1.72 illustrates a 10 watt transmitter feeding an aerial which has a gain of 10dB. The effective radiated power (ERP) is 10 x 10 = 100 watts. So an aerial with 10 dB gain gives a power gain of 10 times.

Fig. 1.73



ATTENUATORS

Fig 1.73 shows an attenuator which is reducing the power of a 5 watt signal down to 0.5 watts. This attenuator is said to have a loss of 10dB or a gain of -10dB.

dB loss = 10 log p2/p1
= 10 log 0.5 / 5
= 10 log 0.1
(log 0.1 = -1)
= 10 x -1
= -10 dB.

It is important to note that dB s are based on *logarithms. This is illustrated by the fact that if we double the output power of an amplifier from say 10 watts to 20 watts, this is an increase of only 3db. Incidentally, 3dB is the smallest increase in power that is detectable by the human ear.

dB gain = 10 log p1/p2
= 10 log 20/10
= 10 log 2
(log 2 =0.3)
= 10 x 0.3
= 3 dB.

*Logarithms are mathematical processes. A logarithm is the power to which a number must be raised to produce another given number. Refer to the chapter on maths for more information.

chapter two

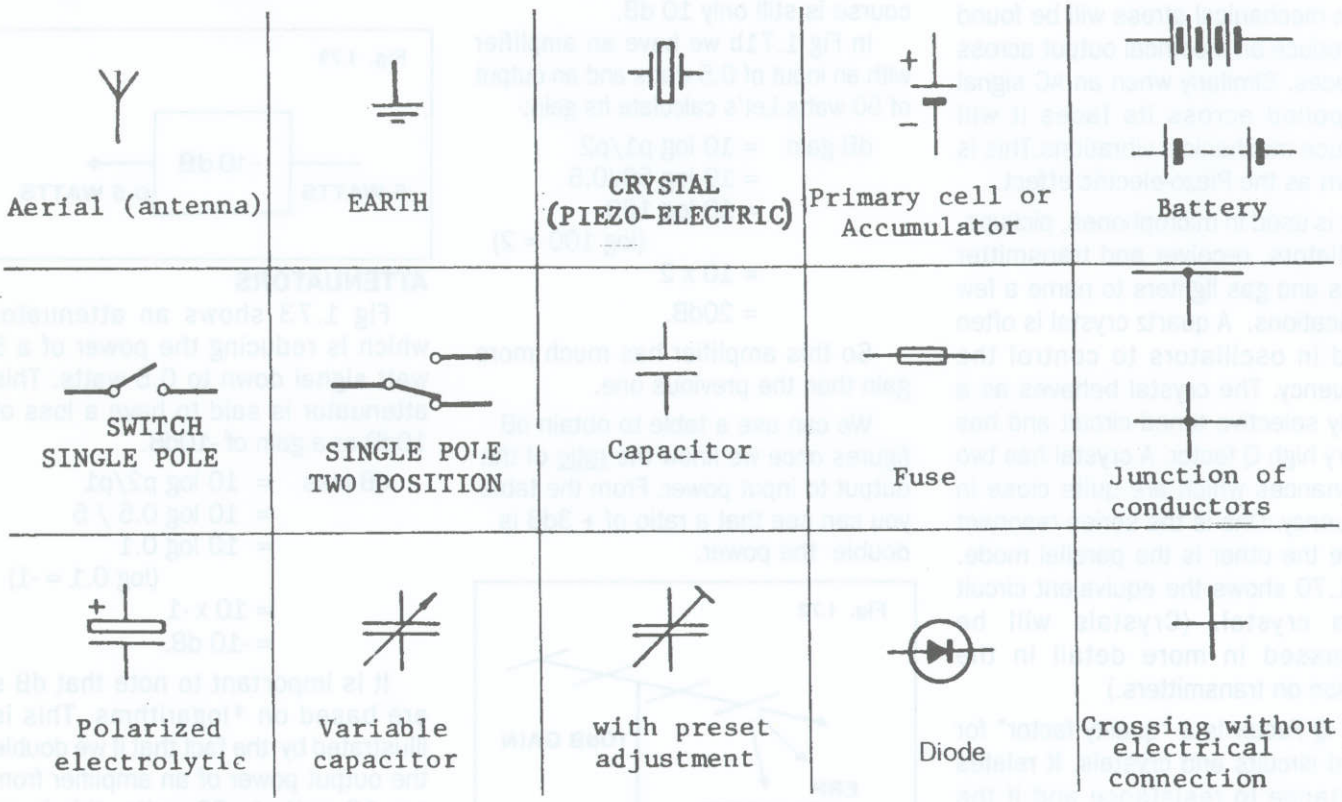
CIRCUIT SYMBOLS

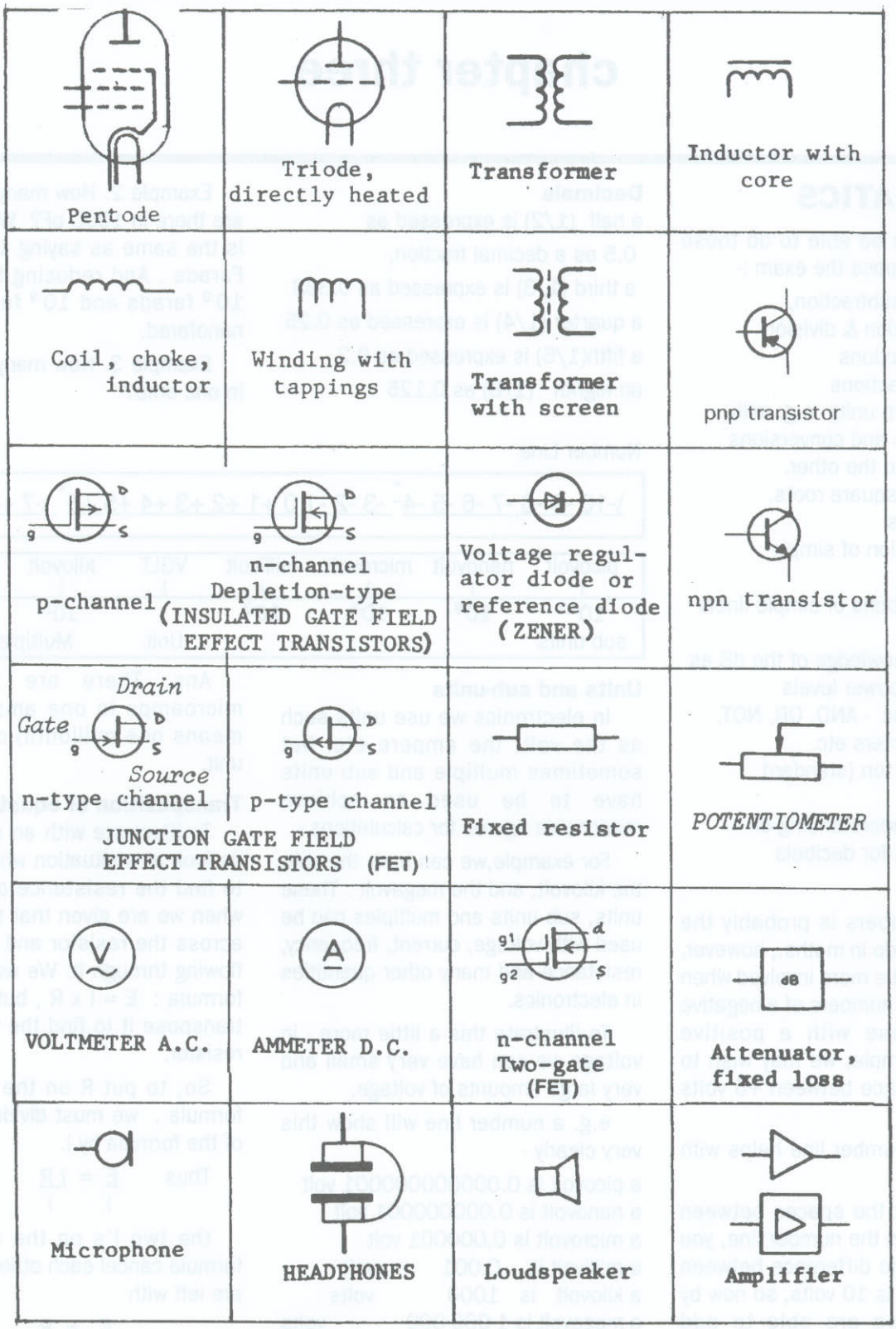
In Radio, we have a "graphic shorthand" using a set of circuit symbols which represent resistors, capacitors and many other components in an easily-recognised way. You need to learn most of these as they are essential information when discussing or examining the operation of a particular circuit which is made up from a combination of many different components.

Some exam questions will require you to be able to recognise component symbols -probably in a circuit diagram. Study the symbols shown in this book.

The main ones you will need to be fully conversant with include:-

Resistors
capacitors
inductors
diodes
vacuum tubes - triode, pentode
transistors -bipolar, FET
antennas
earth
speakers/ headphones
microphones
batteries, cells
ICs
transformers
meters
quartz crystal




Pentode
Triode, directly heated
Transformer
Inductor with core
Coil, choke, inductor
Winding with tappings
Transformer with screen
pnp transistor
p-channel
n-channel Depletion-type (INSULATED GATE FIELD EFFECT TRANSISTORS)
Voltage regulator diode or reference diode (ZENER)
npn transistor
Drain
Gate
Source
n-type channel
p-type channel
JUNCTION GATE FIELD EFFECT TRANSISTORS (FET)
Fixed resistor
POTENTIOMETER
VOLTMETER A.C.
AMMETER D.C.
n-channel Two-gate (FET)
dB
Attenuator, fixed loss
Microphone
HEADPHONES
Loudspeaker
Amplifier

chapter three

MATHEMATICS

You need to be able to do these calculations to pass the exam :-

- addition, subtraction,
- multiplication & division
- simple fractions decimal fractions
- units & sub units e.g. milli, mega , etc and conversions from one to the other.
- squaring, square roots,
- reciprocals
- transposition of simple equations
- interpretations of simple linear graphs
- the dB, knowledge of the dB as a ratio of power levels
- binary logic - AND, OR, NOT, NOR, Inverters etc.
- powers of ten (standard notation)
- a basic understanding of logarithms for decibels

Addition

Adding numbers is probably the easiest task to do in maths., however, it becomes a little more involved when we start to add numbers of a negative nature to those with a positive nature.For example, we may wish to find the difference between +6 volts and -4 volts.

Using the Number line helps with this :-

If you count the spaces between the asterisks on the number line, you can see that the difference between +6 and -4 volts is 10 volts, so now by this system we are able to add negative and positive numbers together quite easily.

Fractions

These are typical fractions which we commonly use:-

1/2 (a half) 1/3 (a third) 1/4 (a quarter) 1/5 (a fifth) 1/7 (a seventh) 1/8 (an eighth) 1/9 (a ninth) 1/10 (a tenth) - and so on.

Decimals

a half (1/2) is expressed as 0.5 as a decimal fraction,

a third (1/3) is expressed as 0.333

a quarter (1/4) is expressed as 0.25

a fifth(1/5) is expressed as 0.2

an eighth (1/8) as 0.125

Number Line

\-10 -9 -8 -7 -6 -5 -4* -3 -2 -1 0 +1 +2 +3 +4 +5 +6* +7 +8 +9 +10

picovolt	nanovolt	microvolt	millivolt	VOLT	kilovolt	megavolt
10^{-12}	10^{-9}	10^{-6}	10^{-3}		10^{3}	10^{6}
sub units				Unit	Multiple units	

Units and sub-units

In electronics we use units such as the volt, the ampere etc. but sometimes multiple and sub units have to be used to achieve reasonable figures for calculations -

For example,we can have the volt, the kilovolt, and the megavolt . These units, sub units and multiples can be used with voltage, current, frequency, resistance and many other quantities in electronics.

To illustrate this a little more - in voltage we can have very small and very large amounts of voltage.

e.g. a number line will show this very clearly -

a picovolt is 0.000000000001 volt
a nanovolt is 0.000000001 volt
a microvolt is 0.000001 volt
a millivolt is 0.001 volt
a kilovolt is 1000 volts
a megavolt is 1 000 000 volts

The volt is the basic unit in this case and the microvolt,nanovolt & picovolt are sub-units and the kilovolt and Megavolt are multiple units of the volt.

Conversion between units:

Example 1. How many volts are there in 1000 mV ? Well, since the millivolt is 1/1000 of a volt, 1000 mV is equal to one Volt.

Example 2. How many nanofarads are there in 1000 pF? Well, 1000 pF is the same as saying 1000 x 10^{-12} Farads . And reducing this we get 10^{-9} farads and 10^{-9} farads is one nanofarad.

Example 3. How many microamps in one amp?

Ans. There are 1000 000 microamps in one amp (as micro means one millionth) of the basic unit.

Transposition of equations:-

To illustrate with an example, let us look at a situation where we need to find the resistance of a resistor when we are given that there's 10 V across the resistor and 2 amps are flowing through it. We would use the formula : E = I x R , but we have to transpose it to find the value of the resistor.

So, to put R on the left of this formula , we must divide both sides of the formula by I.

Thus $\frac{E}{I} = \frac{I R}{I}$

the two I's on the right of the formula cancel each other out and we are left with

$$\frac{E}{I} = R$$

We can now write this formula this way - R = E / I

NOW we can calculate the value of the resistor - R = 10 / 2
=5 ohms

Some further examples using power calculations:-

To calculate the power consumed by a resistor, we need to know at least two

variables in these formulas:-

$P = \frac{E^2}{R}$; $P = I^2R$ or $P = E \times I$

Example 1. If we have measured 10V across a 25 ohm resistor, what is the power dissipated by the resistor?

We would use the formula:-

$P = E^2 / R$, so -

$P = 10 \times 10 / 25$

$P = 100 / 25$

$= 4$ watts

Example 2. If we measured 2 amps flowing through a 100 ohm resistor, what is the power being dissipated by the resistor?

We would use the formula:-

$P = I^2R$

$P = 2 \times 2 \times 100$

answer $P = 400$ watts.

Squaring and square roots:-

To square a number it simply means to multiply it by itself.

e.g

4 squared (4^2) means 4 x4 =16

2 squared (2^2) means 2 x2 = 4

3 squared (3^2) means 3 x3 = 9

a square root is the reverse of the above process-

*(a square root is the number, which when multiplied by itself gives the original number)

What is the SquareRoot of 16 ? This means - what number multiplied by itself gives 16.

You can see from the above squares that 4 x4 = 16

so 4 is the square root of 16

What is the square root of 64 ?

The answer is 8,

(Because 8x8 =64.)

What is the square root of 81?

The answer is 9. (Because 9x9=81)

Reciprocals:-

A reciprocal is the inverse of something. In other words if we had a fraction , (say 1/2)

Then if we took its reciprocal, it would be 2/1 or simply 2.

To take the reciprocal, we divide one by the number.

example 1:- the reciprocal of 2 is 1/2

example 2:- the reciprocal of 6 is 1/6

To add reciprocals as in parallel resistor connexions and series capacitor connexions , we must use the LCD (lowest common denominator).

Example 1 : we have three 2 ohm resistors in parallel, how do we find their total resistance ?

Ans. we add their reciprocals thus-

$1/R = 1/2 + 1/2 + 1/2$ and to solve this addition, we use the LCD . (in this case it's 2), so:-

$$1 = + \frac{1}{R} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$$

$$\frac{1}{R} = \frac{1 + 1 + 1}{2}$$

$$\frac{1}{R} = \frac{3}{2}$$

now we invert or take the reciprocal of each side of this formula and we get -

$$\frac{R}{1} = \frac{2}{3}$$

and we now get the answer of 0.66 ohms (as 2/3 = 0.66).

Example 2.

We have a circuit containing three parallel resistors of 2 ohms, 3 ohms and 4 ohms. Find the total resistance.

$1/R = 1/R1+1/R2+1/R3$

$1/R = 1/2 + 1/3 + 1/4$

(the LCD of 2, 3 and 4 is 12)

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4}$$

$$\frac{1}{R} = \frac{6 + 4 + 3}{12}$$

$$\frac{1}{R} = \frac{13}{12}$$

(now invert both sides)

$R = 12 / 13$ and

so $R = 0.923$ ohms

This may seem very involved but it's not really and with practice over a number of examples you will become quite conversant with the process.

chapter four

SEMICONDUCTORS

A semiconductor is neither a good conductor nor a good insulator, it falls into that gray zone of not being good at either. Typical semiconductors are carbon, silicon,and germanium.

The Semiconductor devices used in radio include -Diodes, transistors and ICs and are made from either silicon or germanium.

Germanium (Ge) was used in the early devices but has given way to silicon for most semiconductor components.

Very pure silicon (Si) is the first step in the manufacture of semiconductors but in its very pure state it is not much use to us yet. So we have to deliberately "dope" the Si with certain elements to obtain useful semiconductor materials.

Doping

The conductivity of Si can be greatly improved by adding a strictly controlled amount of impurity atoms, called dopants to the pure Silicon.

Fig 4.1a shows some Si to which 'donor' atoms have been added. This material now has an excess of electrons in its atomic structure and is called N -type silicon.

Current flow in N-type Silicon is by movement of electrons which exist in the crystal lattice structure of the Silicon. Electrons are known as the Majority current carriers in this material. (a few "holes" exist in this material and they are known as minority current carriers.)

Fig 4.1b shows Silicon to which has been added 'acceptor' atoms which leave the atomic lattice structure incomplete in terms of its normal complement of electrons. This incomplete structure possesses what are called "Holes". This is called P Type Silicon. The majority current carriers in P-type silicon are "holes" and there are a very few free electrons which become the minority current carriers. "Holes" are spaces where an electron could fit if given the opportunity.

Incidentally, the batteries in both above circuits could be reversed and the current flow would be the same but in the reverse direction.

Referring to Fig 4.2, we see a silicon junction diode where some N-type and some P-type silicon have been joined together to form a junction diode. Current will flow as the positive terminal of the battery is connected to the P-type material and this will send holes toward the junction of the P-type and N-type materials. (You can picture this by imagining one seat in a row in a theatre is vacant and if everyone moves up by one seat at a time, then this is similar to how a hole moves).The negative terminal of the battery is connected to the N-type silicon and this will force electrons in the N-type toward the junction. At the junction, electrons and holes will meet each other and recombine. That is, holes will be filled by the electrons. So a continuous current will be flowing in the circuit. In fact a great deal of current would flow, so much that the diode would be destroyed if there were not resistor R in the circuit to limit the current to safe levels. In this situation, the diode is said to be FORWARD-BIASED and is conducting.

Now looking at Fig 4.3, we have reversed the battery polarity. We now have the negative terminal of the battery connected to the P-type silicon. This will attract the holes

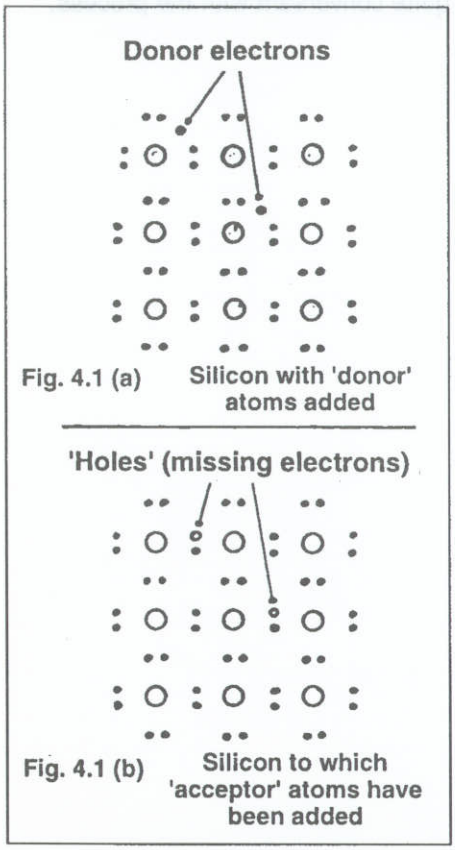
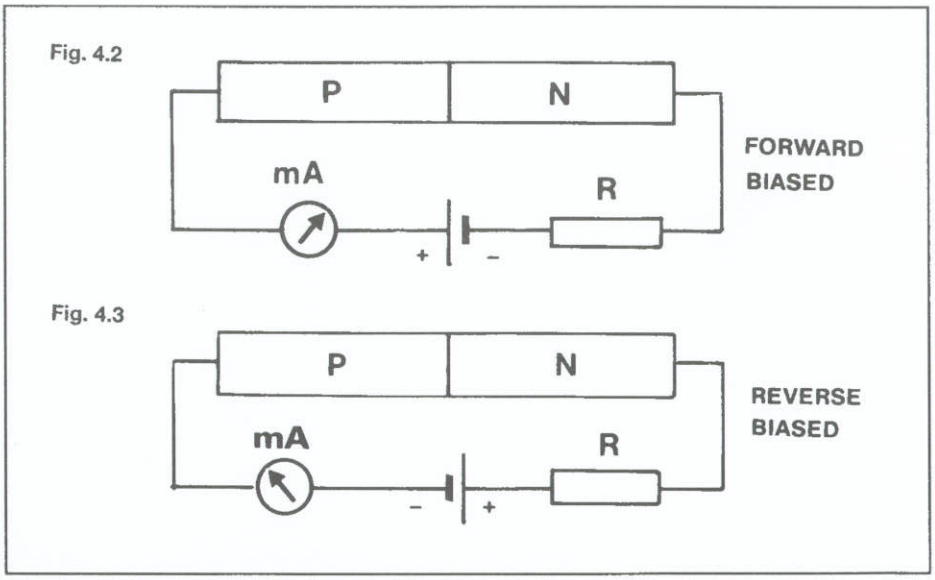
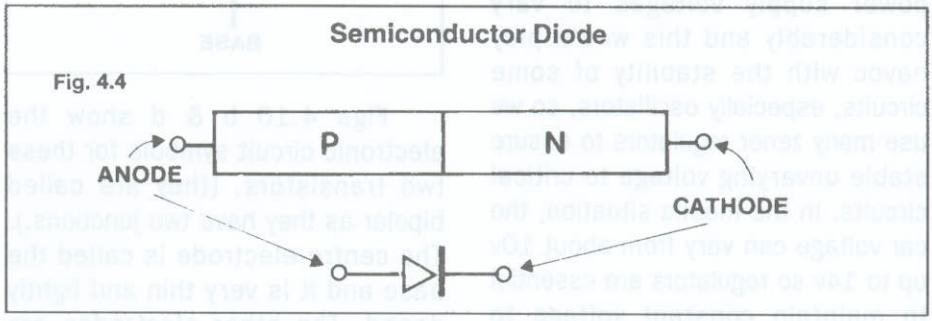


Fig. 4.1 (a) Silicon with 'donor' atoms added

Fig. 4.1 (b) Silicon to which 'acceptor' atoms have been added



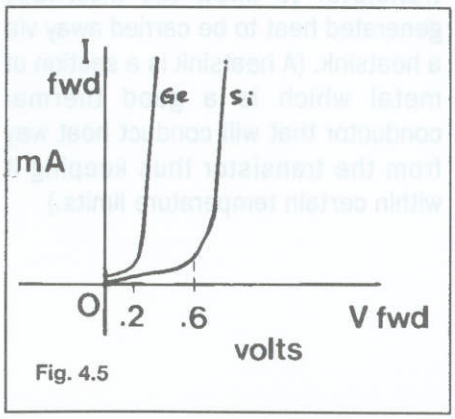
toward the negative terminal and away from the junction. The positive terminal of the battery is connected to the N-type silicon and this will attract the electrons away from the junction and toward the positive terminal of the battery. So we now have the majority current carriers in each side of the diode attracted away from the junction. This leaves it depleted of current carriers and we say that a depletion zone has been established at the junction. No current will flow through this diode. So it is said to be REVERSE-BIASED and is non-conducting.



(However, very minute reverse currents actually flow through the diode under these conditions as there are a few free electrons in the P-type and a few stray holes in the N-type silicon, so a very very small reverse leakage current flows.)

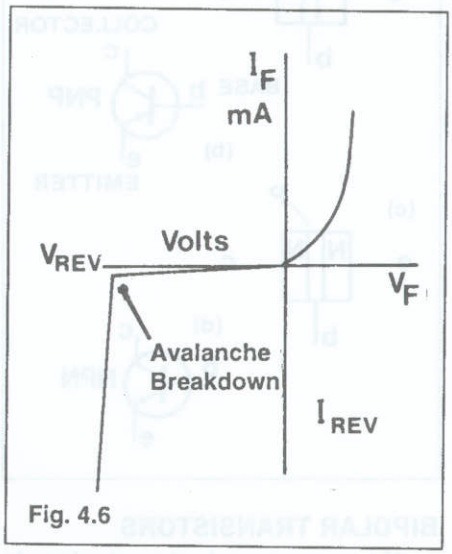
Fig 4.4 shows the diode symbol as compared to the basic junction diode construction. The N-type silicon is known as the cathode and the P-type is known as the anode.

Fig 4.5 shows the forward characteristics of both silicon and germanium diodes. As the voltage across each diode is slowly increased from zero, the current slowly rises and at a specific voltage, 0.2v (approx)for germanium, and 0.6v (approx). for silicon, there is a "knee" where the current increases markedly with little increase in voltage. These two voltages are known as the conduction points for silicon and germanium. - If you put a voltmeter across a conducting diode of either type, you would measure about 0.2 v or 0.6 v respectively.



Current ratings

Each diode type has a particular rating in terms of the forward current (maximum) which it can handle safely. For instance, if you had a one amp diode, you could not expect it to carry more than one amp without getting too hot and failing. If overheated, a diode will eventually fail and may go open circuit or short circuit. (These are two common fault conditions for diodes.)



Voltage ratings

Each diode is only capable of withstanding a certain reverse voltage maximum. If we exceed that voltage the diode will suddenly go into reverse breakdown and the level of current will lead to instant destruction of the diode.

Two typical diodes are the 1N914 and the 1N4148. Both of these diodes are called small signal types and can conduct 450 mAmps and have a reverse voltage maximum of 75V.

By comparison, a rectifier diode such as 1N4004 has a 1 amp rating and a reverse (PIV) rating of 400V. A Germanium diode such as an OA95 has a current rating of 50mA and a PIV of 90V.

[PIV means the Peak Inverse - or peak reverse voltage]

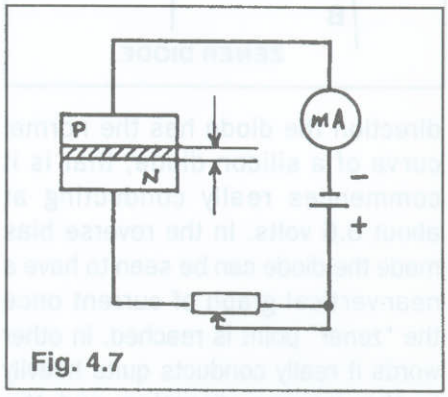


Fig 4.6 shows the reverse voltage situation for a diode. As the voltage is steadily increased, the current does not alter for quite a while, then suddenly avalanche breakdown occurs and the current increases at a spectacular rate. This aspect will be discussed in more detail later.

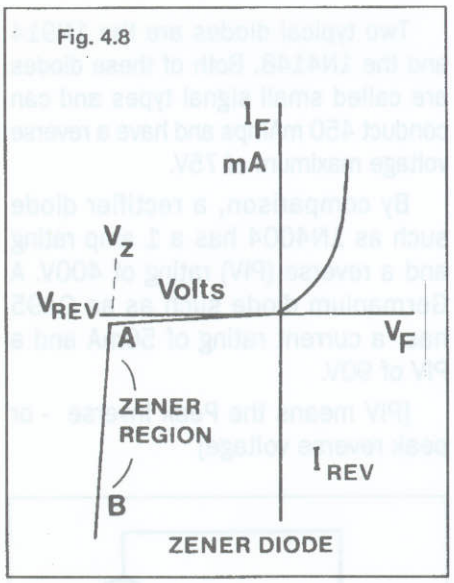
Diode capacitance

Fig 4.7 shows a diode in the reverse bias mode. The depletion zone is wide and in fact we have created a capacitor as there is a dielectric (the depletion zone) and two plates (the P & N type material). If we change the amount of reverse bias voltage, the depletion zone changes in width so we can adjust the thickness of the dielectric. This gives us the ability to use the diode as a small variable capacitor as we can alter its capacitance in this way using the reverse voltage applied as the control.

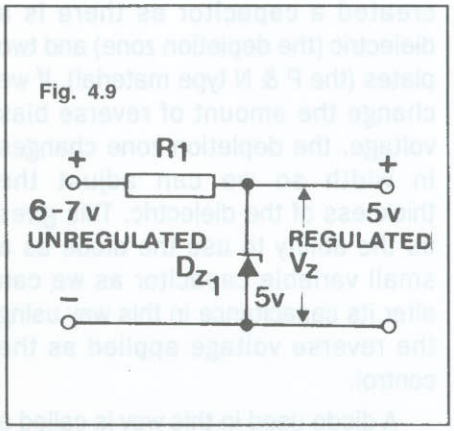
A diode used in this way is called a varicap diode. But it is important to note that all diodes have junction capacitance when in the reverse bias mode.

ZENER DIODES

Fig 4.8 shows the characteristics of a zener diode. In the forward



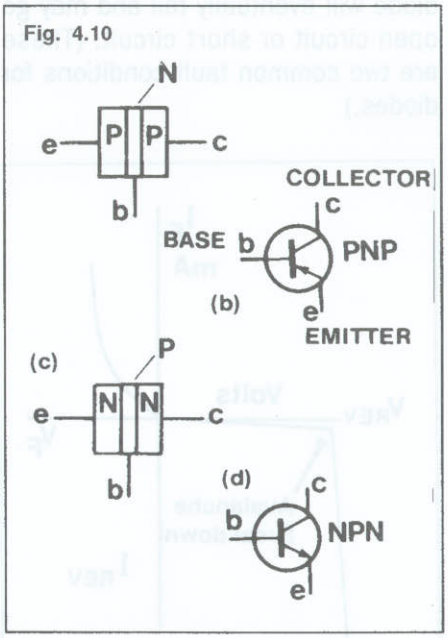
direction the diode has the normal curve of a silicon diode, that is it commences really conducting at about 0.6 volts. In the reverse bias mode the diode can be seen to have a near-vertical graph of current once the "zener" point is reached. In other words it really conducts quite heavily in the reverse direction and the voltage variation for a wide range of currents is quite small, so this characteristic is put to good use as a voltage regulator as we shall see. Incidentally, the zener diode is deliberately made with heavy doping so that it will conduct quite happily in the reverse bias mode when compared to a normal diode which is made to NOT conduct in the reverse bias mode at all.



In fig 4.9 shows a zener diode in a voltage regulator circuit.

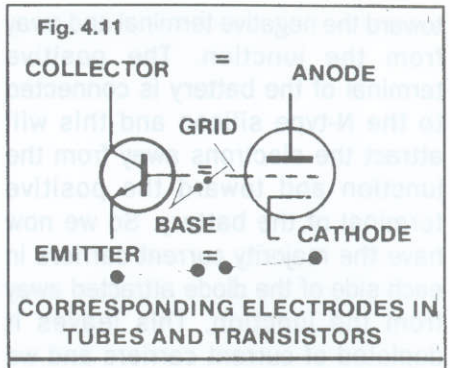
Let's say we've just bought a 5v zener diode. If we place it in this circuit, we could apply say 7 volts to the input of the circuit and the diode would immediately go into its reverse or zener mode of operation. We would now find that the diode would have exactly 5v across it and the series resistor R1 would have exactly the remainder (2v) across itself. If we should change the input voltage from 7 to 9 v then the diode would still have 5v across itself due to zener action and R1 would now have 4v across it. This is how the zener diode works as a voltage regulator.

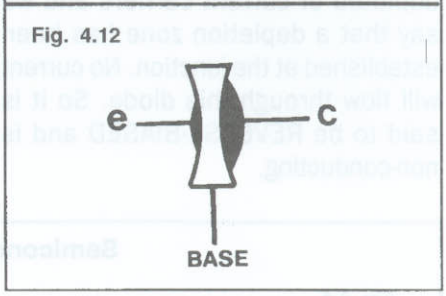
In electronics, we often need regulated voltages to ensure stability for oscillators etc. The mains voltage variations and load factors can cause power supply voltages to vary considerably and this would play havoc with the stability of some circuits, especially oscillators, so we use many zener regulators to ensure stable unvarying voltage to critical circuits. In the mobile situation, the car voltage can vary from about 10v up to 14v so regulators are essential to maintain constant voltage to certain receiver and transmitter circuits.



BIPOLAR TRANSISTORS

If a semiconductor device is constructed as shown in Fig 4.10a it would be called a PNP transistor. It has two P-N junctions and these are called the collector-base junction and the emitter-base junction. If we arranged the P-N junctions as in Fig 4.10c, we would have an NPN transistor.





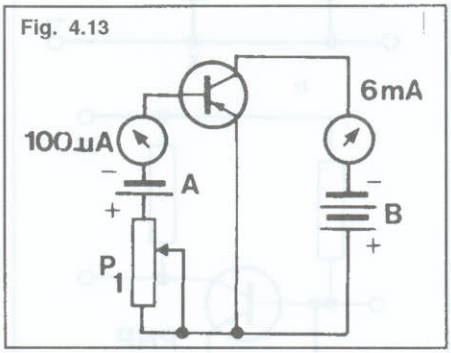
Figs 4.10 b & d show the electronic circuit symbols for these two transistors. (they are called bipolar as they have two junctions.). The centre electrode is called the base and it is very thin and lightly doped. The other electrodes are called the collector and the one with the arrow is called the emitter. If the arrow points away from the base it is an NPN transistor and if the other way, a PNP transistor. The base is the control electrode and is analagous to the grid in a valve or vacuum tube. The collector is analogous to the anode and the emitter to the cathode in vacuum tubes. Fig 4.11 illustrates the relationship between the valve and transistor electrodes.

Fig 4.12 shows the way in which some transistors are basically made. A substrate is doped to form the base and then the emitter and collector are diffused into the substrate. The collector is usually made larger and may be connected to the case of the transistor to allow the internally generated heat to be carried away via a heatsink. (A heatsink is a section of metal which is a good thermal conductor that will conduct heat way from the transistor thus keeping it within certain temperature limits.)

Transistor operation

fig 4.13 shows a transistor wired with a microammeter in the base circuit and a milliameter in the collector circuit. If we vary the current flowing in the base circuit by adjusting the pot P1, we will observe a change in collector current. Thus control of the output (or collector current) is made by varying the base current. You will note that the control current in this case is very small, in microamps

Fig. 4.13



whereas the collector (output) current is much larger, being measured in milliamps. So we have current gain in this configuration.

Current gain

Referring to fig 4.13 again, we can calculate the current gain (Beta) of this amplifier.

Beta = Ic/Ib (where Ic is the collector current and Ib is the base current) In this example, Ic = 6 mA and Ib = 100 microamps, so:-

Beta = Ic/Ib

$= 6 \times 10^{-3} / 10^{-4}$

$= 60$

(6mA = 6×10^{-3} and

100 microamps = 10^{-4})

Beta is 60 in this particular case, however Beta can range from below 10 and up to 400 or more for high gain types.

Large and small signal transistors

Small signal transistors are used in *low level stages and handle less than 1 watt whereas power transistors (large signal) can handle high power- into the order of tens or hundreds of watts.

(*low level stages are those operating below certain power or voltage gain levels)

THE TRANSISTOR AS AN AMPLIFIER

Fig 4.14 shows the circuit of a common emitter amplifier. R1 and R2 are used to provide a constant base current which is known as forward bias current. This sets the operating conditions for the amplifier. R3 is known as the load resistor. With no signal applied, the voltage between the collector and ground will be about 6 volts. Now if we connect a signal generator to the base, its signal will add and subtract to the bias voltage already on the base. Let's say that the base to emitter voltage is 0.6 volts and the signal causes the base voltage to vary from 0.61 to 0.59V. This is a peak to peak swing of 0.02 v (or 20mV). This changing base voltage causes the collector current to vary and as a consequence, the collector to ground voltage (the output voltage) will be found to vary also. The collector voltage is found to vary from +4 to +8 V. This is a peak to peak value of 4V; therefore the voltage gain of this single stage amplifier is 4 / 0.02 = 200.

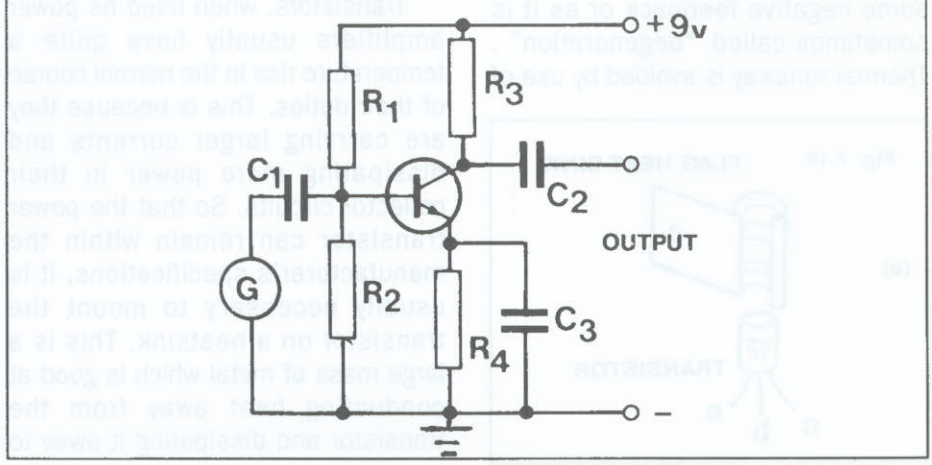
*Although we have illustrated the amplifying action of the transistor by considering a small change in the base voltage causing a large change in collector voltage, the transistor is really a current-activated device. In other words, a small change in base current causes a large change in collector current. So it is basically a current-amplifying device when compared with a vacuum tube (valve) which is a voltage-activated device. (Valves will be discussed later in this book.)

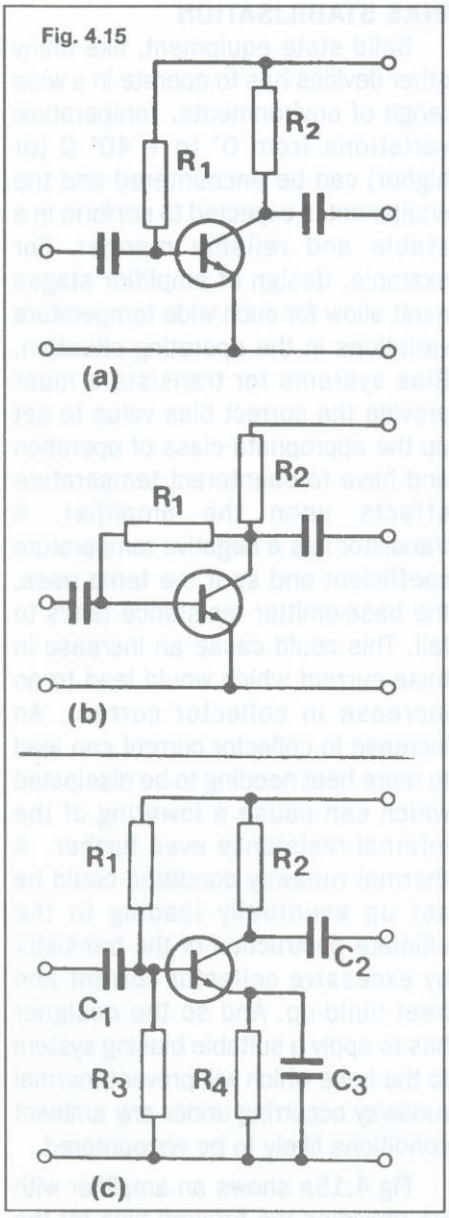
BIAS STABILISATION

Solid state equipment, like many other devices has to operate in a wide range of environments. Temperature variations from 0° to + 40° C (or higher) can be encountered and the equipment is expected to perform in a stable and reliable manner. For example, design of amplifier stages must allow for such wide temperature variations in the operating situation. Bias systems for transistors must provide the correct bias value to set up the appropriate class of operation and have to counteract temperature effects upon the amplifier. A transistor has a negative temperature coefficient and so if the temp rises, the base-emitter resistance tends to fall. This could cause an increase in base current which would lead to an increase in collector current. An increase in collector current can lead to more heat needing to be dissipated which can cause a lowering of the internal resistance even further. A thermal runaway condition could be set up eventually leading to the ultimate destruction of the transistor by excessive collector current and heat build-up. And so the designer has to apply a suitable biasing system to the base which will prevent thermal runaway occurring under any ambient conditions likely to be encountered.

Fig 4.15a shows an amplifier with R1 providing the forward bias for the base and R2 acting as the load resistor. In this particular circuit, the thermal stabilisation would be very poor and as the temperature rose, the base current would tend to rise and so the collector current would rise

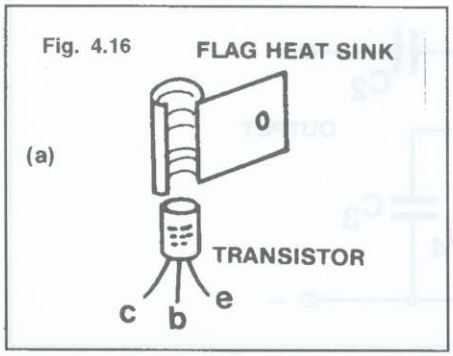
Fig. 4.14

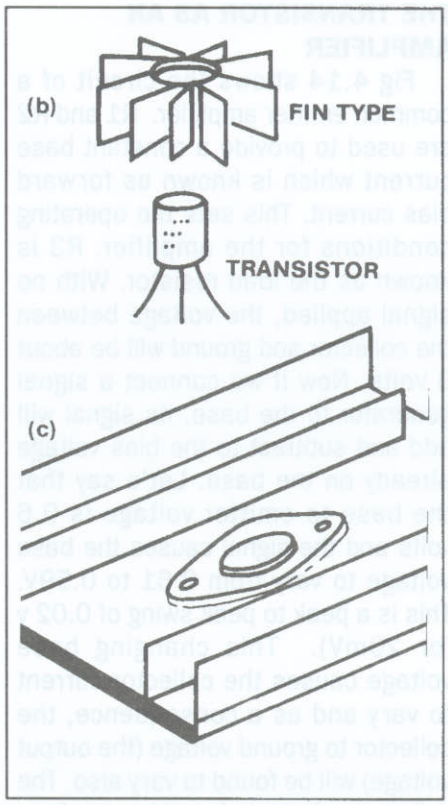




and the thermal runaway condition mentioned above would occur.

The circuits shown in Figs 4.15b & c indicate two methods by which the bias compensates for temperature changes and thus stabilises the amplifier.(b) shows that R1 has been connected to the collector rather than to the supply rail. This introduces some negative feedback or as it is sometimes called- "degeneration" . Thermal runaway is avoided by use of this circuit. (c) is a configuration called combination bias. R1 and R2 form a voltage divider which maintains a constant bias current for the base . R4 is used in the emitter circuit and it is designed to "swamp-out" any variations in base-emitter resistance by virtue of its resistance being higher than the internal base-emitter resistance. So any variations in the internal resistance of the transistor caused by temperature changes are rendered insignificant by R4 being much greater than the transistor's internal resistance. C3 is likely to be used in parallel with R4 to prevent any degeneration. (negative feedback). Incidentally, C3 is a large value capacitor in audio applications and a small value for RF circuits.





HEATSINKS

Transistors, when used as power amplifiers usually have quite a temperature rise in the normal course of their duties. This is because they are carrying larger currents and dissipating more power in their collector circuits. So that the power transistor can remain within the manufacturer's specifications, it is usually necessary to mount the transistor on a heatsink. This is a large mass of metal which is good at conducting heat away from the transistor and dissipating it away to the air. Various heatsinks are shown in Fig 4.16.

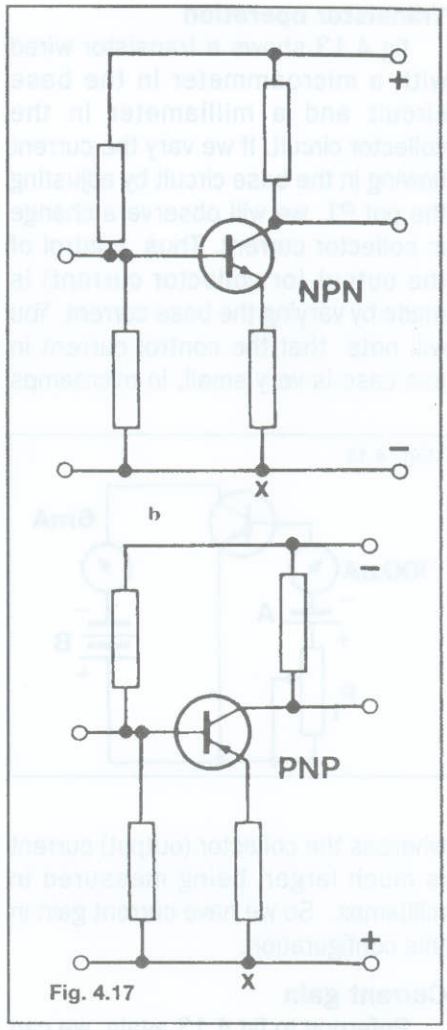


Fig 4.16a shows a simple "flag" type heatsink which can be slipped over the body of the transistor. Similarly at (b) the finned type can also be slipped over the transistor and gives more efficient cooling. The heatsink at (c) is for high power applications and the transistor is bolted to the flat part between the fins of the heatsink which is most commonly made from aluminium extrusions having many fins to effectively radiate the heat to the air. Usually the heatsink surface is treated with a matt black coating which gives off heat to the air most efficiently. Copper or brass heatsinks are satisfactory but may be more expensive and heavier than aluminium.

POLARITY OF SUPPLY VOLTAGE

Fig 4.17 shows the correct supply voltages for an NPN and a PNP transistor amplifier.*Note that the supply voltages are the opposite of each other. The point marked X on

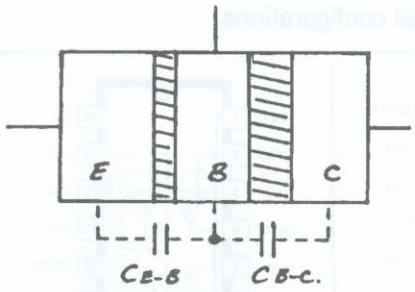
TABLE 4.1 - A COMPARISON BETWEEN VALVES AND TRANSISTORS

VALVES	BIPOLAR TRANSISTORS
larger	small and light
fragile	robust
requires a heater	no heater
has a warm-up time	has no warmup time
has high input impedance	has low input impedance
operates from high voltage*	operates from low voltage
usually needs a socket	usually direct-wired
prone to microphonics	not subject to microphonics
has a finite life	has unlimited life

*some tubes operate at 12v

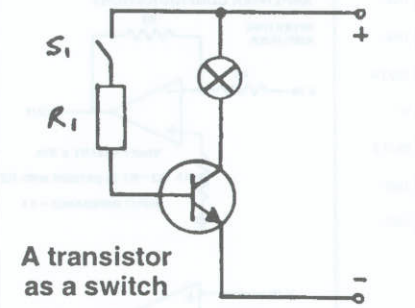
each circuit may be earthed but this is not always necessary.

Table 4.1 shows a very broad comparison between valves and transistors. Some of these comparisons may be arguable but they will serve to at least allow you to compare the valve with its solid state equivalents.



Inter-electrode capacitances in Bipolar transistors

Fig. 4.18



A transistor as a switch

Fig. 4.19

Inter-electrode capacitances:

*As the base is separated from the collector by a junction, thus there is capacitance between the two electrodes and this varies according to the amount of reverse bias. Similarly, there is capacitance between the base and the emitter as there is a junction here too which is varying depending upon the width of the depletion layer between them. (See fig 4.18)

THE TRANSISTOR AS A SWITCH

Fig 4.19 shows an NPN transistor configured in a switching application.

Once the switch S1 is closed, the base current commences to flow immediately and then at the same time the collector current also commences to flow through the load (a lamp in this case). By this means, the switch can be a very light duty device and the lamp could be a very high current load. The transistor becomes the switch handling the high load current. Once S1 is opened, the transistor ceases to conduct and the load no longer receives current. By this means, the transistor becomes a solid state switch and with suitable transistors, quite high currents can be switched with very light duty switches controlling the transistor. S1 could be replaced with a switching voltage waveform and so switching action can be quite sophisticated.

Fig. 4.20



a. N type channel junction FET.



b. P type channel junction FET



c. Insulated gate FET.



d. Dual gate IG-FET.

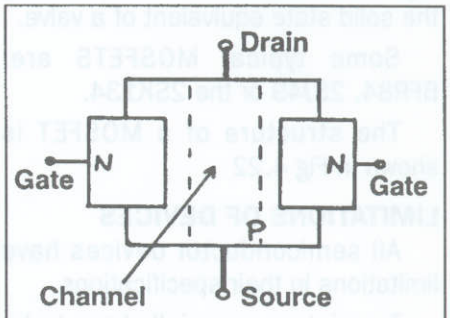


Fig. 4.21 P-Channel FET.

FIELD EFFECT TRANSISTORS - ("FETs")

The FET is a later development of the transistor and as distinct from the bipolar transistor , it gives a number of improved characteristics. The first type developed was the junction FET and later on came the MOSFET.

Fig 4.20 shows circuit symbols for some FETs. When compared to bipolar transistors, the Gate compares to the Base, the Source to the Emitter and the Drain to the Collector.

Some typical junction FETs are the 2N3819, MPF102 or the 2N5245 (as shown in the parts suppliers catalogs).

The structure of a junction FET is shown in Fig 4.21

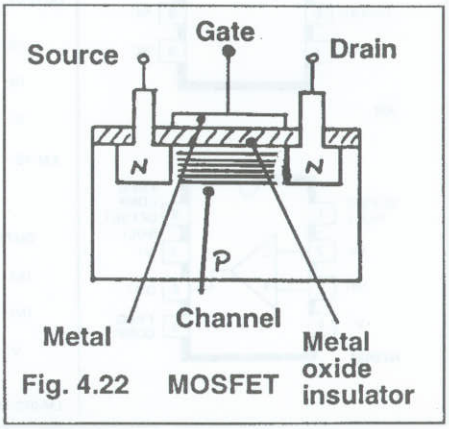


Fig. 4.22 MOSFET

MOS means "Metal Oxide Semiconductor". The metal oxide is the insulating material which completely isolates the gate from the rest of the transistor. A MOSFET is also known as an insulated gate transistor (or IGFET). As the gate is so well insulated, it gives the FET a very high input impedance thus providing the solid state equivalent of a valve.

Some typical MOSFETS are: BFR84, 2SJ49 or the 2SK134.

The structure of a MOSFET is shown in Fig 4.22

LIMITATIONS OF DEVICES

All semiconductor devices have limitations in their specifications.

Transistors especially have to be watched as they can be inappropriately used with either poor or disastrous results. When using a transistor in a circuit, you must decide if the application is for : - audio, RF- (HF, VHF or UHF), low power or high power. For instance a transistor designed for audio or HF will of course not operate usefully at VHF , so you need to consult the specifications carefully before you wire the device into your new circuit!

INTEGRATED CIRCUITS

Integrated circuits (or ICs) have been developed to the point where very complex circuits, amplifiers etc. can be packaged into one 'chip.' (a chip is the colloquial term for almost any solid state device, particularly Integrated circuits) Hundreds and even thousands of transistors are able to be encased into a single IC.

There are two major "families" of IC -

(i) linear (ii) digital.

Linear types include audio amplifiers and voltage regulators for example and the digital family includes micro processors and logic functions. The first types were known as RTL (Resistor-Transistor Logic) , then TTL was developed -meaning transistor-transistor logic and later followed CMOS (Complementary metal oxide semiconductor) . CMOS uses much less current than TTL chips and so circuit efficiency is much greater. TTL uses a supply rail of 5 volts and CMOS uses a supply range of 3 to 15 volts.

The advantages of ICs are that they are space and power saving. As well, they make printed circuit board layouts much simpler as many functions using a lot of components are now integrated onto one chip. A good example of this is the ZN414 IC which is almost a complete radio in one device.

Fig 4.23 shows some typical ICs and their circuit symbols and supply rail configurations.

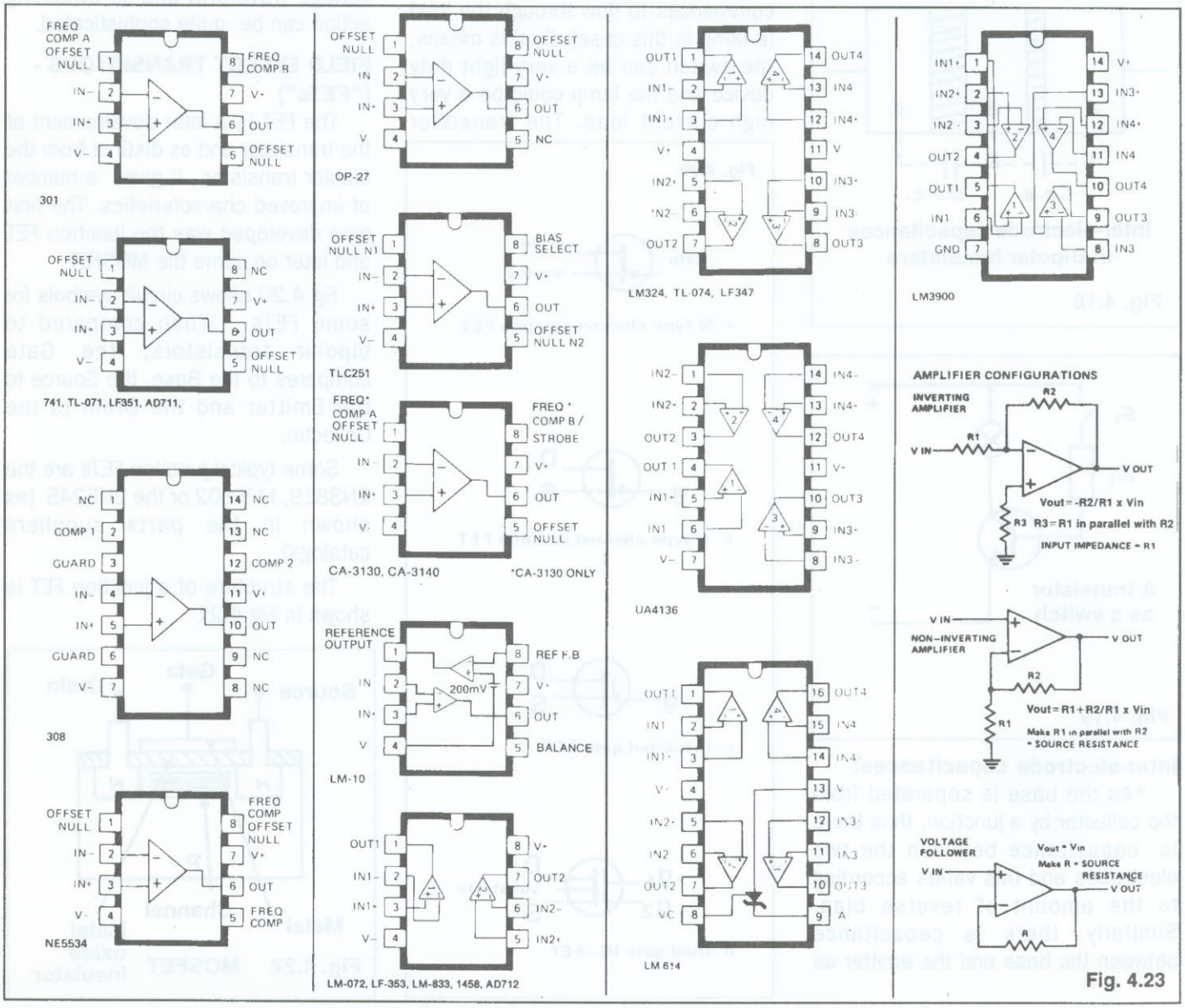


Fig. 4.23

chapter five

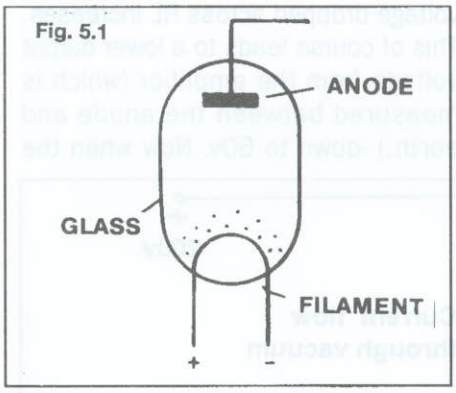
VACUUM TUBES
(Valves)

Even though valves have fallen out of common use in most equipment it is necessary to understand their operation as you may encounter them in :- Transmitters, Linear Amplifiers, Cathode Ray Oscilloscopes, and home made gear or older equipment.

The Vacuum Diode

The simplest valve is the diode - it simply has two electrodes : the anode and the cathode.

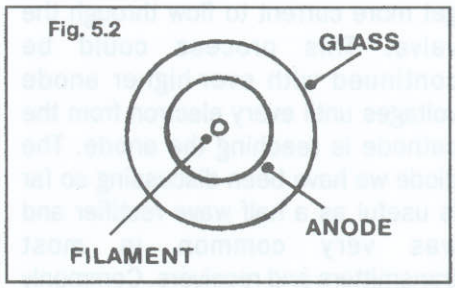
Referring to figure 5.1 you can see the basic construction of a diode valve.



The valve consists of an airtight compartment, usually made of glass or metal and containing two electrodes - the anode and the cathode. Then the air is evacuated from the envelope to leave a high vacuum inside. In early valves, the cathode was also the filament or heater. (The filament is like the one in a light globe and it is heated by passing current through it.)

Thermionic emission

The glowing filament being at or near red heat is so hot that it emits electrons from its surface. The electrons are effectively being 'boiled off'. So all around the filament (we'll call the filament the cathode from now on) there is a cloud of electrons which are negatively charged as you will recall from earlier in the book.

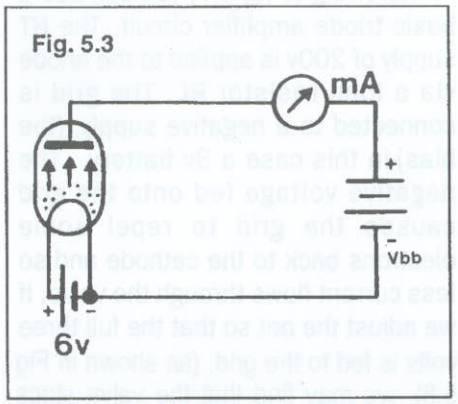


Often this cloud of electrons is called a "space charge". Now looking at fig 5.2, you will see that not far from the cathode another electrode is located so that it surrounds the cathode as it is cylindrical in shape. This electrode is called the ANODE.

Fig 5.3 shows the valve in a basic circuit where the cathode is directly heated by the 6v battery and the anode is connected to a 45 v battery.

The 6v battery is referred to as the low tension supply (LT) and the 45v battery is called the high tension supply (HT). As the anode is positive, it now has a strong attracting force for the electrons near the cathode and current starts to flow across the vacuum in the valve by electron movement.

Incidentally, valves similar to this have been used in mobile transmitters as they are very quick to heat up and become operational, so in the mobile transceiver, the final amplifier, which was a directly heated valve was not energised on receive. When the transmit button was pressed, the filament was energised and the transmitter quickly came up to full power. (This technique was used to save battery power.) Transistors have since rendered this technique redundant however.



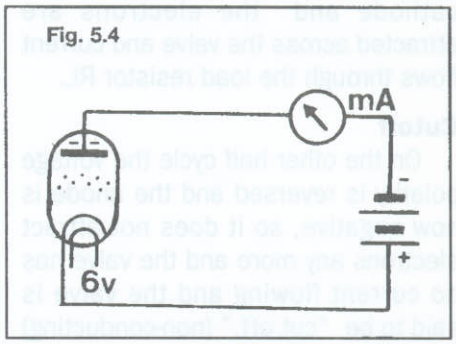
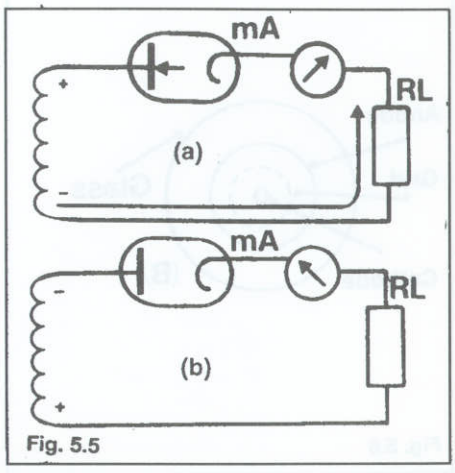


Fig 5.4 shows that this valve has an indirectly heated cathode. The configuration in this case has a coated cathode which is heated by the heater. These valves take a little longer to warm up as there is a short thermal delay while the heater heats up the cathode.

The cathode is coated with thorium which is mildly radioactive and has been found to emit copious electrons when heated. Now the heater and the cathode circuit can be isolated from each other electrically which is an advantage in many circuits.

Otherwise the valve still operates in much the same way as earlier.

Heater voltages for valves have been as low as 1.2 v and have been as high as 50 v. Some valves had



their heaters wired in a series string across the mains (110v in the USA and 250v in Aust). So for example, five valves with 50 v heaters could be wired across the 250 v mains.

Operation of the diode

The operation of the diode can be seen conveniently by studying the half wave rectifier circuit in fig 5.5.

When the transformer voltage has the polarity as shown in fig 5.5a the anode is positive with respect to the cathode and the electrons are attracted across the valve and current flows through the load resistor RL.

Cutoff

On the other half cycle the voltage polarity is reversed and the anode is now negative, so it does not attract electrons any more and the valve has no current flowing and the valve is said to be "cut off." (non-conducting) (fig 5.5b)

Saturation

If the valve is conducting fully, that is, all the electrons emitted by the cathode are being attracted to the anode, then it is said to be "saturated" . Thus 'cut off' and 'saturated' are the two extremes of state for a valve. Of course any value of current in between is possible too and more on this in a moment.

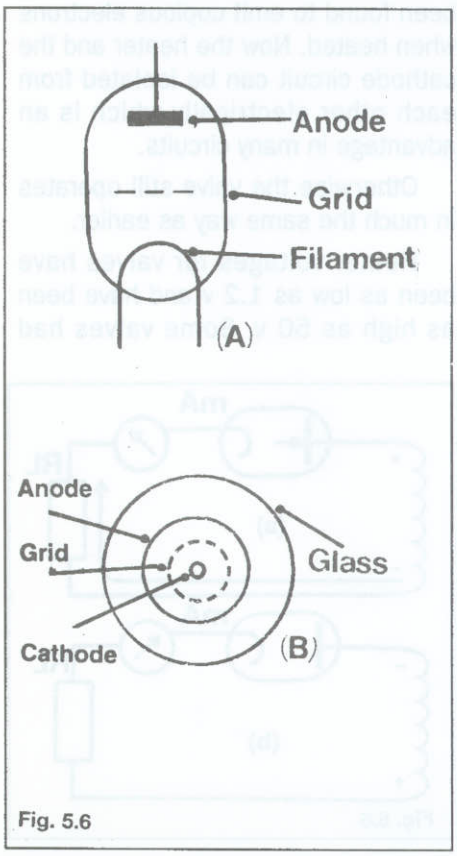


Fig. 5.6

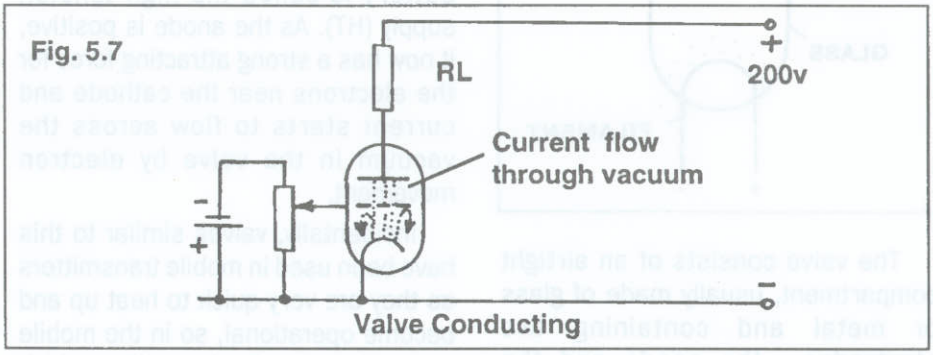
Conduction

We have now seen that the valve conducts only when the anode is positive and the cathode is negative. If we changed the anode voltage from 45 v to 90v then we would be able to get more current to flow through the valve. This process could be continued with ever-higher anode voltages until every electron from the cathode is reaching the anode. The diode we have been discussing so far is useful as a half wave rectifier and was very common in most transmitters and receivers. Commonly it was combined with another valve in the same envelope to give two diodes and a full wave rectifier was produced to give greater efficiency.

THE TRIODE

The only control of the current in a diode is by varying the anode voltage. In the triode as shown in fig 5.6a we have introduced a new electrode into the valve called the grid (or control grid).

The grid is a fine mesh of wires in a cylindrical shape between the cathode and the anode. So now we have three concentric (or coaxial) cylinders in the valve- cathode, grid and finally the anode.



Triode Operation

Referring to fig 5.7, you can see a basic triode amplifier circuit. The HT supply of 200v is applied to the anode via a load resistor RL. The grid is connected to a negative supply, (the bias)-in this case a 3v battery. The negative voltage fed onto the grid causes the grid to repel some electrons back to the cathode and so less current flows through the valve. If we adjust the pot so that the full three volts is fed to the grid, (as shown in Fig 5.8), we may find that the valve stops conducting altogether. Then if we adjust the pot so very little negative voltage reaches the grid the valve will conduct heavily, so by this means we can see that the current through the valve can be very conveniently controlled by the voltage (or Bias) which we feed to the grid.

AMPLIFICATION

Fig 5.9, shows a basic triode valve amplifier circuit.

A signal is applied to the grid in series with the bias supply of 3v. And now as shown in fig 5.9, the signal which has an amplitude of 2 v peak to peak is adding to and subtracting from the bias voltage and thus the grid voltage is varying up and down by 2 v P-P. This will cause the anode current to vary too. As the signal voltage on the positive half cycle subtracts from the bias supply, the effective bias on the grid is thus reduced to 3-1=2v and so the valve conducts more anode current and the voltage dropped across RL increases. This of course leads to a lower output voltage from the amplifier (which is measured between the anode and earth.) -down to 50v. Now when the signal voltage is on its negative half cycle, the signal voltage of 1v is added to the bias and the net grid voltage goes up to -4v (bias of 3v +1v=4v). Now the anode current is reduced as the grid is repelling more electrons back to the cathode . As the anode current is less, the voltage dropped across RL reduces and the output voltage rises to 150v.

So we have achieved amplification - with just 2v "swing" on the grid we are able to achieve 100v "swing" on the output voltage . This gives us a voltage gain of 100/2=50 .

This is the basic principle of amplification.

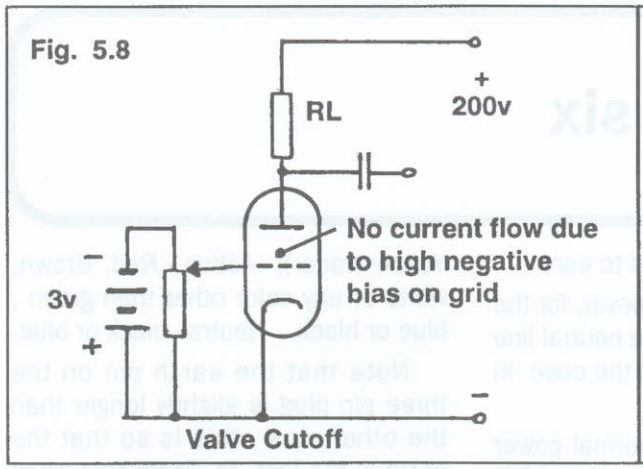


Fig. 5.8

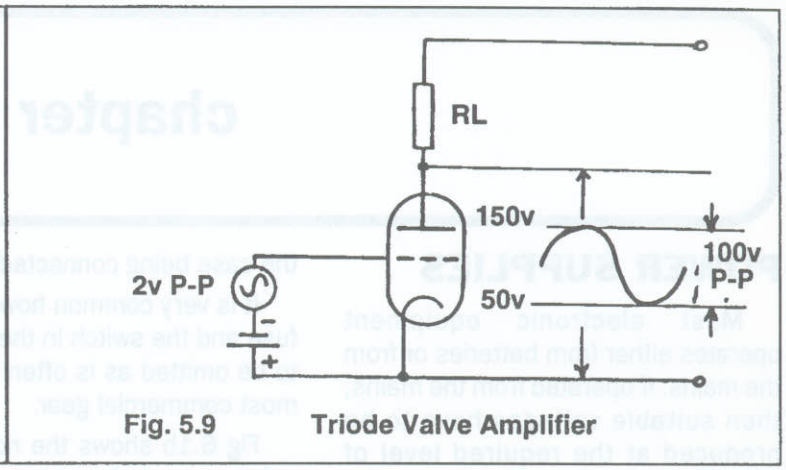


Fig. 5.9 Triode Valve Amplifier

The Pentode

The construction of the pentode valve is shown in fig 5.10.

The pentode is obviously a valve with many more elements - the heater, cathode, grid,screen grid, suppressor grid, anode. All of these are concentric, that is they are all cylindrical-one inside the other.

The grid is sometimes called the control or signal grid and is closest to the cathode, next is the screen grid which is fed from a positive voltage supply, the suppressor grid is next and it is usually earthed or connected internally to the cathode.

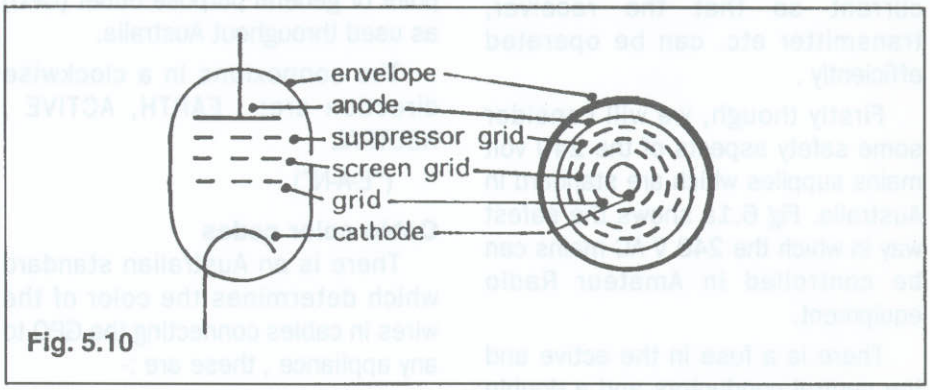


Fig. 5.10

Pentode Operation

The cathode is heated in the normal way, then the grid is connected to a bias supply to set the amount of standing current through the valve. (this is known as the quiescent condition) . The screen grid accelerates the electrons allowed through by the grid on their way to the anode. Then a very coarse mesh grid-(the suppressor) is placed between the screen and the anode so that any electrons bouncing back from the anode are repelled back to the anode by the negative or earth potential on the suppressor. Finally the majority of the electrons emitted by the cathode reach the anode to become anode current. (A small number of electrons are attracted to the screen and become screen current.) Incidentally, the screen reduces the capacitance between the anode and the grid.

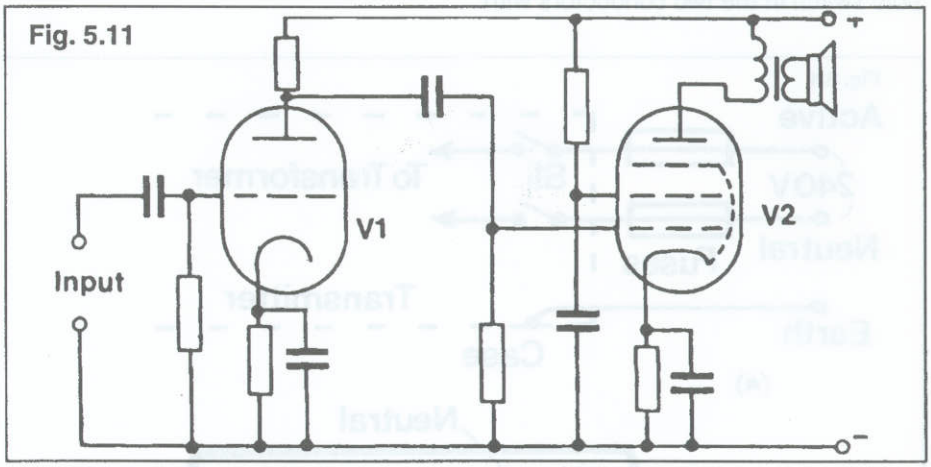


Fig. 5.11

As the pentode has much more voltage gain than the triode, it is possible to obtain much more amplification with a pentode .

Fig 5.11 shows a triode amplifier connected in 'cascade' to a pentode amplifier . The input signal is fed between the cathode and the grid and the output voltage of the triode is fed to the pentode grid.

The pentode then provides considerable further amplification. Instead of a load resistor, the pentode has a speaker transformer connected as its load. And the speaker is then connected to the transformer secondary.

chapter six

POWER SUPPLIES

Most electronic equipment operates either from batteries or from the mains. If operated from the mains, then suitable voltages have to be produced at the required level of current so that the receiver, transmitter etc. can be operated efficiently .

Firstly though, we will consider some safety aspects of the 240 volt mains supplies which are standard in Australia. Fig 6.1a shows the safest way in which the 240 V AC mains can be controlled in Amateur Radio equipment.

There is a fuse in the active and the neutral conductors and a double pole switch in the two conductors with the case being connected to earth.

It is very common however, for the fuse and the switch in the neutral line to be omitted as is often the case in most commercial gear.

Fig 6.1b shows the normal power point or general purpose outlet (GPO) as used throughout Australia.

The connexions in a clockwise direction are:- EARTH, ACTIVE , NEUTRAL

("E-A-N")

Cable color codes

There is an Australian standard which determines the color of the wires in cables connecting the GPO to any appliance , these are :-

Earth - Green (or Green with a Yellow tracer); Active - Red, Brown, white or any color other than green , blue or black. Neutral- black or blue.

Note that the earth pin on the three pin plug is slightly longer than the other pins , this is so that the earth is the last to disconnect when removing a plug from a GPO.

Fig 6.1c shows a fault condition where an internal fault has caused the active to come in contact with the case of a piece of equipment. As the fault is usually of a low resistance nature, a very high fault current will flow and the fuse will *'blow' thus disconnecting the active and rendering the equipment "safe" . A blown fuse will then indicate some fault has occurred and action is needed to rectify the fault. If the case was not earthed a serious shock hazard situation would exist as the fuse would not necessarily blow and anyone touching the metal case would receive a 240 volt shock which may be lethal. When building equipment using 240V AC mains, the metal case is earthed properly via the green/yellow conductor.

The fuse is designed to be the 'weakest link' in the chain so that if a fault current occurs, the fuse blows and disconnects the equipment. So it is obvious that you should use a fuse with the most suitable rating so that it blows under fault conditions.

*When the wire in a fuse is melted by a fault or excessive current,it is said to be 'blown'.

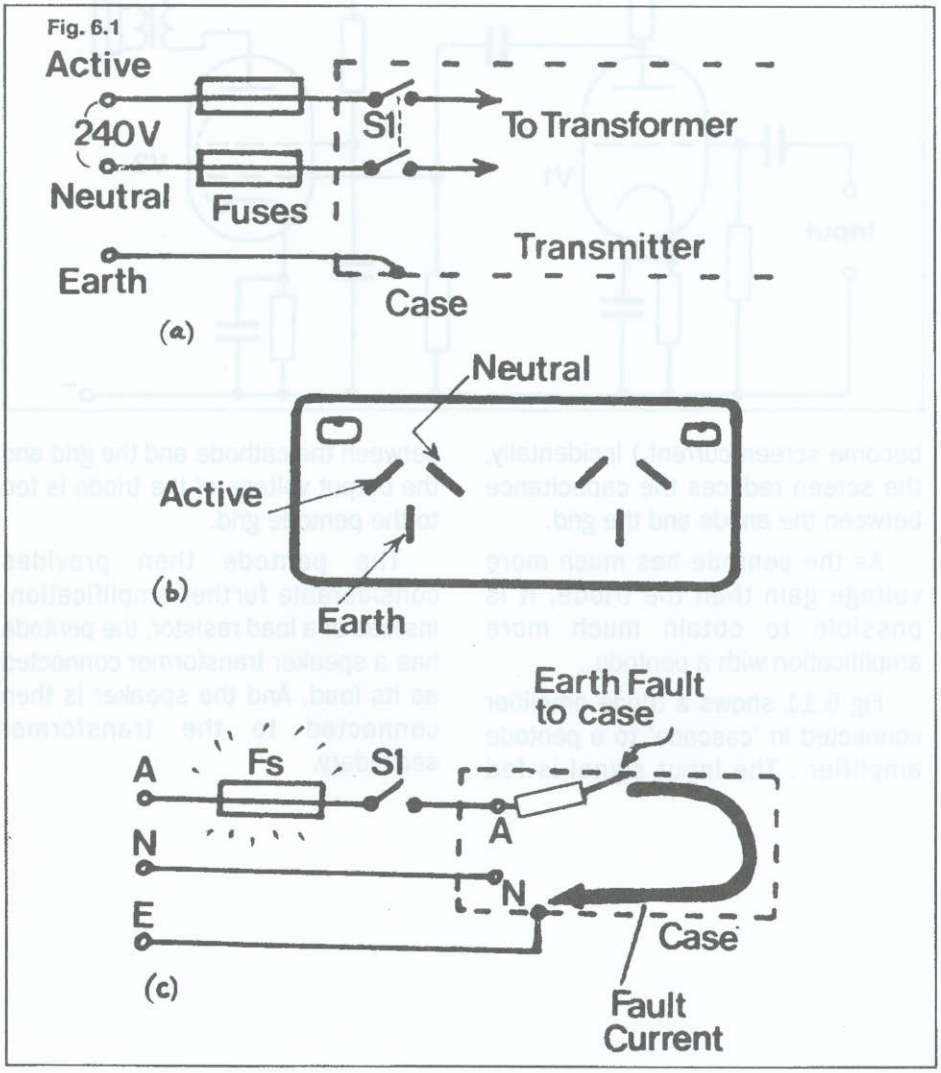
Live equipment

*It is a very dangerous practice to work on live equipment ! * Switch it off, make any adjustments and then reconnect the power.

It is good practice to fully insulate any terminals on switches, fuses etc, so that inadvertent contact with your body is impossible.

Fig 6.2 shows a typical input circuit of a power supply. Note that the fuse and switch must be in the active

Fig. 6.1



conductor - never in the neutral alone.

The active conductor is normally at 240 volts above earth and the neutral is always at or near earth potential. In some towns or suburbs the voltage may vary from about 190v to 260v and this can vary from hour to hour and day to day depending upon street loading etc.

The frequency of the mains voltage in Australia is 50 Hz.

Some overseas countries have different voltages, frequencies and color coding of their cables so be careful if you are using any foreign equipment, especially if is is non-standard or non-approved.

*Note that it is illegal to do any work on the permanent wiring in your workshop or house if you are not licenced by the power authority in your state.

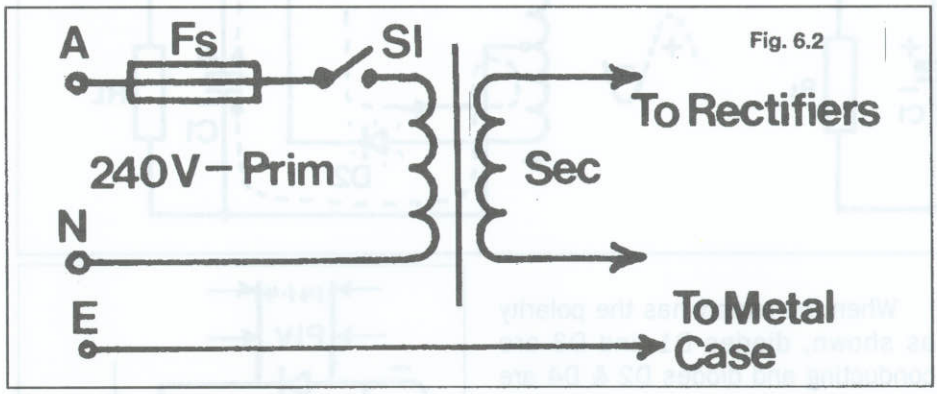


Fig. 6.2

Building a power supply

If you are building a power supply, the power rating of the load must be determined first so that transformers and components with adequate ratings are used.

For example, a transmitter for Novice use may have an RF power output of 30 watts, however it will consume more than 30 watts of DC power due to circuit inefficiencies.

Example:

A transformer for a valve transmitter power supply may have to provide these voltages:

300 volts at 200 mAmps=60 watts

6.3 V at 2 amps = 12.6 watts so the total power is 72.6 watts.

If 20% power loss occurs due to circuit inefficiencies, the total power from the transformer primary will increase to 87 watts, so a transformer with a rating of at least 100 watts (100VA)* is required to provide a safety margin. *(transformers are usually rated in volt/amps - VA, rather than watts as they operate on AC).

To find the primary current we use this formula- P= E x I and transpose it to find the current -

I= P/E I= 100/240 I= 0.42 amps

(Thus a suitable fuse for the primary would be rated at 1 amp to allow for switch-on surges).

RECTIFIERS

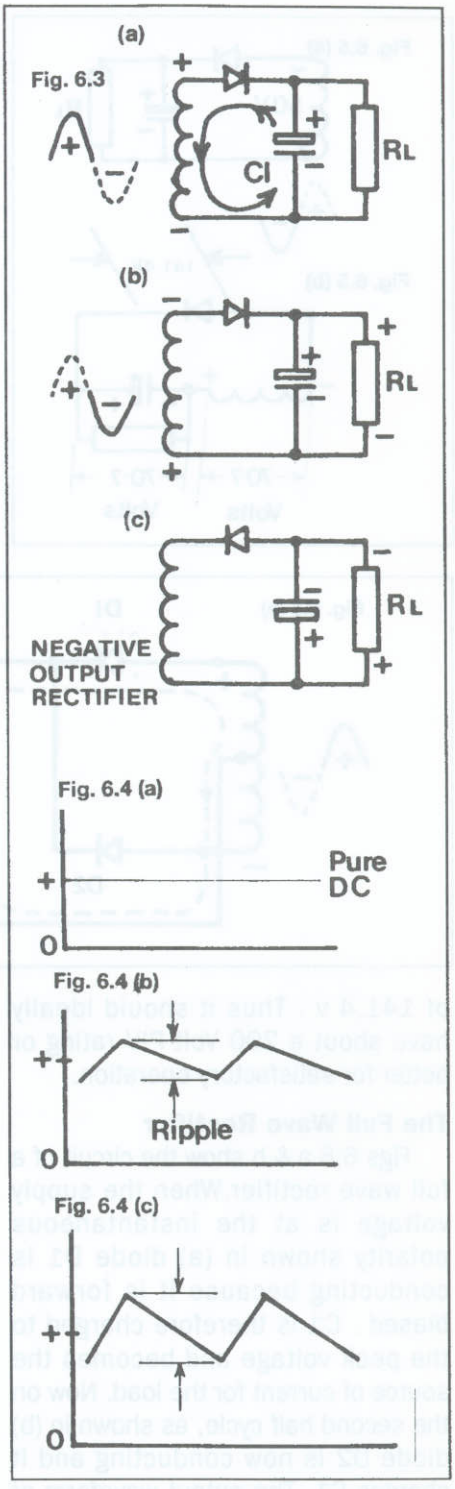
A half wave rectifier circuit is shown in Fig 6.3a. It requires only one diode and when the instantaneous polarity of the AC is as shown, the diode conducts and charges the capacitor C1 to the peak value of the secondary voltage. In fig 6.3b, the AC voltage has reversed its polarity and the diode is now cut off (or not conducting.) The capacitor acts as the supply for the load during this half cycle and partially discharges.

When the next positive half cycle arrives,the diode conducts again and recharges C1.Referring to Fig 6.4b, you can see that the DC voltage from this rectifier has a "ripple". Compare this with the pure DC voltage from a battery as shown in fig 6.4a.

If the load on this rectifier is increased , that is RL is decreased in value, then the increased load current will cause the voltage from C1 to fall to a lower value on the negative half cycle and so the ripple amplitude increases as shown in fig 6.4c.

Ratings of this rectifier circuit:-

(refer to fig 6.5a)



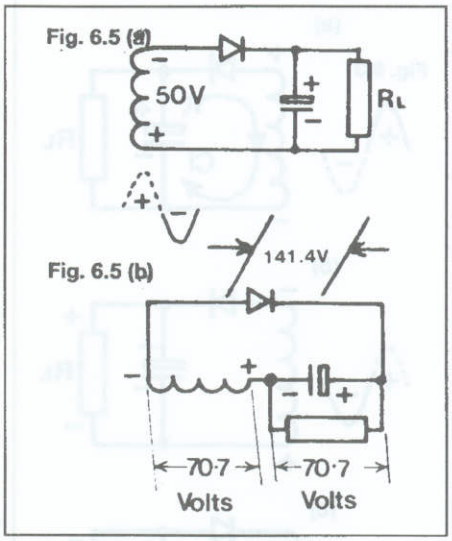
The peak inverse voltage of the diode in this circuit is twice the peak value of the applied voltage -

50 x 1.414 x 2

= 141.4 volts.

Fig 6.5b shows the circuit redrawn slightly, this illustrates the conditions when the voltage from the transformer has the instantaneous polarity as indicated. Also, C1 is charged to 70.7v which is the peak value of 50v RMS.

While the diode is cut off (no current flow) it has to withstand a PIV



approximately the same output voltage as the half wave rectifier, the fullwave circuit needs a 100V centre-tapped transformer winding.

Fig 6.8 shows that the PIV encountered in the full wave rectifier is similar to that in the half wave rectifier- i.e. twice the peak voltage is impressed across each diode when it is not conducting (2 x 70.7 = 141.4 V). For a one amp supply , each diode must have a one amp rating.

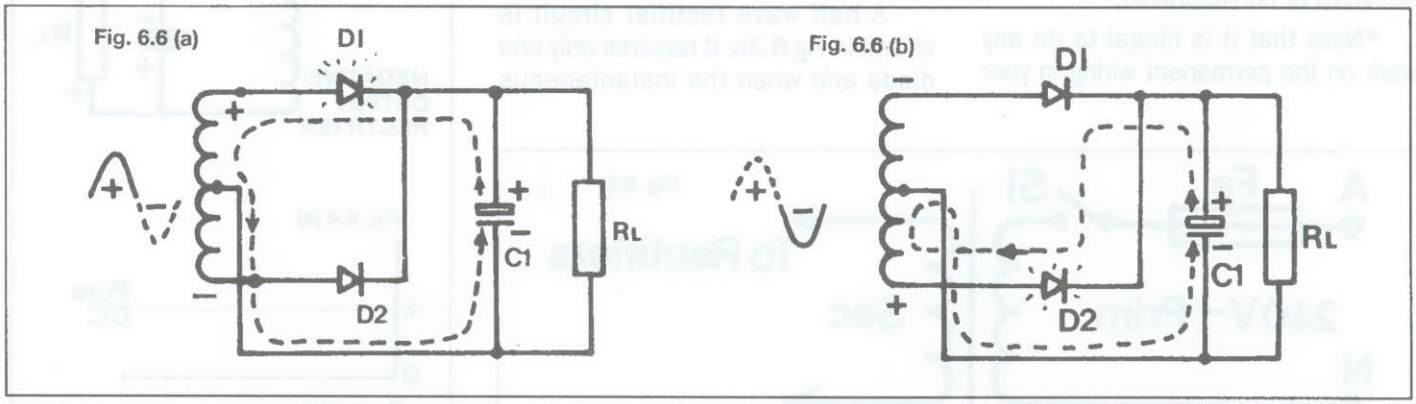
THE BRIDGE RECTIFIER

Fig 6.9a shows the circuit of a fullwave bridge rectifier. (all bridge rectifiers are full wave)

The bridge rectifier acts the same as the fullwave rectifier except that the PIV of its diodes has only to be half as they are in series .

FILTERING

The DC output of a rectifier has a great deal of "ripple" superimposed upon it and for many electronic applications the ripple needs to be filtered out, as smooth DC like that from a battery is required for acceptable operation. For example, an amplifier fed from unfiltered DC will have quite a lot of hum in its output.



of 141.4 v . Thus it should ideally have about a 200 Volt PIV rating or better for satisfactory operation.

The Full Wave Rectifier

Figs 6.6 a & b show the circuit of a full wave rectifier.When the supply voltage is at the instantaneous polarity shown in (a) diode D1 is conducting because it is forward biased . C1 is therefore charged to the peak voltage and becomes the source of current for the load. Now on the second half cycle, as shown in (b) diode D2 is now conducting and it charges C1. The output waveform of this circuit without C1 connected would be pulsating DC as shown by fig 6.7b.

For a comparison, Fig 6.7c shows the output of a half wave rectifier without the capacitor filter.

Note that the full wave rectifier's output (b) has twice the ripple frequency of a half wave rectifier . (d) shows the DC from the rectifier when a capacitor is used as a filter.

The full wave rectifier requires two diodes and a transformer with a centre-tapped winding. For

When the supply has the polarity as shown, diodes D1 and D3 are conducting and diodes D2 & D4 are not conducting. On the other half cycle, shown in fig 6.9b , D2 & D4 are now conducting while D1 & D3 are not. At all times, two of the four diodes are conducting while the other pair are not conducting, then the situation is reversed on the next half cycle.

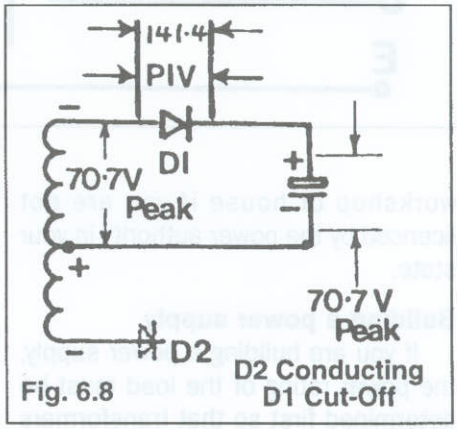
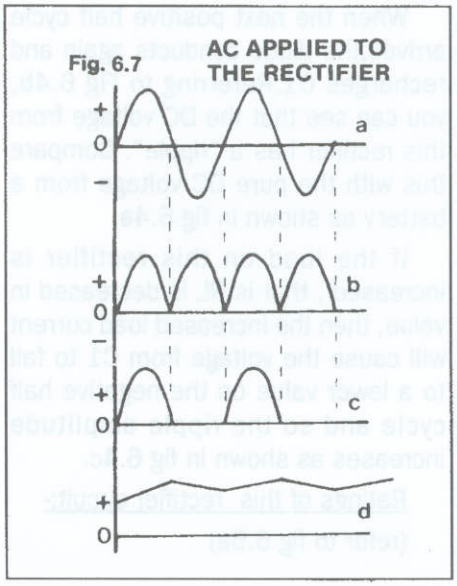


Fig. 6.8



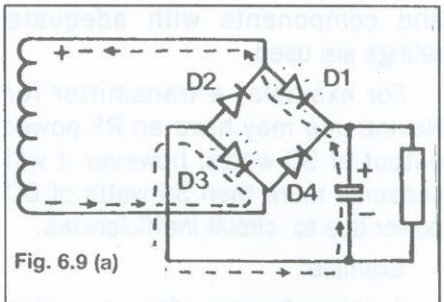


Fig. 6.9 (a)

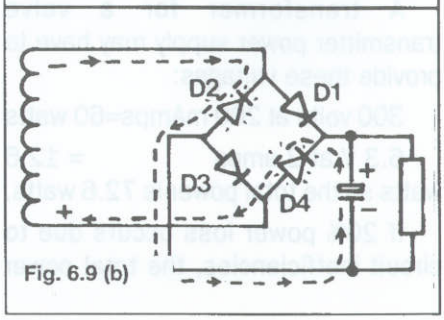


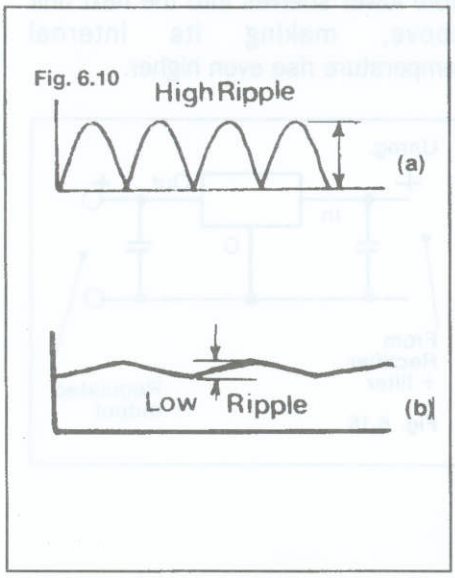
Fig. 6.9 (b)

Various filter circuits are used after the rectifier to remove the ripple and thus provide smooth DC.

Filter types:

(i) The simplest filter is the capacitor and its performance is shown in fig 6.10. The rectifier's output is shown at (a) and when a capacitor of suitable size is used as a filter, then the DC output is smoothed to that shown at (b).

(ii) the choke input filter



using a choke (L1) as shown in fig 6.11 will reduce the ripple even more.

For mains supplies, the choke is usually an iron-cored type with many turns of wire and possessing quite a few henries of inductance.

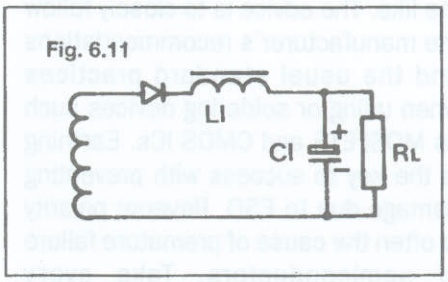
The action of the choke is to store energy in the form of a magnetic field on ripple peaks and to provide energy on ripple troughs. This has a very great smoothing action upon the DC.

And so the ripple amplitude is considerably reduced by the choke's action.

(iii) the "PI" filter (Fig 6.12)

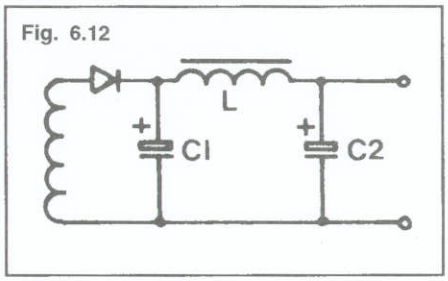
This circuit gets its name from its similarity to the greek letter Pi. Because the pi filter uses both capacitors and a choke, its filtering action is the best with a resultant low ripple amplitude.

TABLE 6.1 gives a comparison between applications and the size of filter capacitors needed to obtain low ripple.



Bleeder resistors

Fig 6.13 shows a high voltage supply with RL being the load . If the fuse should fail due to a fault or if the load is disconnected, then C1 would be left fully charged even if the power was disconnected. This would then be a major shock hazard as a charged high voltage capacitor can be lethal. The Bleeder resistor R1 is therefore connected across C1 so that if the above situation arises, then C1 would be quickly discharged to remove the danger. R1 's value is chosen so that



it is not much of an extra load on the rectifier but not so high that it takes too long to discharge C1. (a good compromise is for the capacitors to be discharged in about 10 seconds)

VOLTAGE REGULATION

The output voltage from a power supply can vary because of supply variations from the mains and because of load changes.

If the DC is varied (or unregulated) it can have a bad effect upon many circuits. And so voltage regulators have been developed to overcome this problem.

Gasfilled valves used to be used in this application but they are basically a high voltage device.

Zener Diodes are used to regulate voltage in low voltage supplies. *(see chapter 4 for zener diode operation)

Series regulators

These circuits combine the zener diode with a "series-Pass" transistor as shown in fig 6.14. They give the ability to regulate large currents with the use of a low power zener diode.

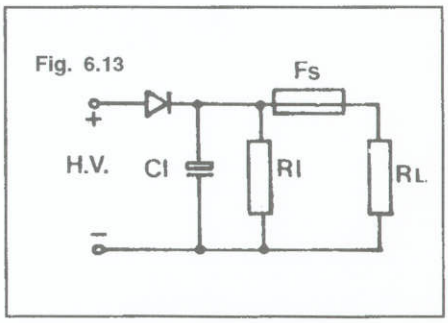
A later development following the series regulator is the IC regulator. (See Fig 6.15)

These are similar in outward appearance to a power transistor but they contain very sophisticated circuitry to regulate voltage under quite arduous conditions.

The IC regulator is commonly packaged in a three terminal case - hence their common name -"3 terminal regulator".

Table 6.2 lists some of a wide range of common IC three terminal regulators.

These regulators are virtually indestructible as they have overload and over-temperature protection integrated into the IC.



To operate these regulators in practice, they must have an input voltage at least 3 to 5 volts higher than their rated output voltage.

Most IC regulators have a fixed output voltage but some types are available which allow the output to be varied over a given range by use of a

TABLE 6.1

application	voltage / current	capacitor size
high voltage	200v @100 mA	tens of microfarads
linear amplifier	600v @ 200 mA	hundreds of microfarads
low voltage	12v @ 10 Amps	thousands of microfarads

* a good rule of thumb is to use at least 1000 uF per amp of load current.

control pot and some additional components.

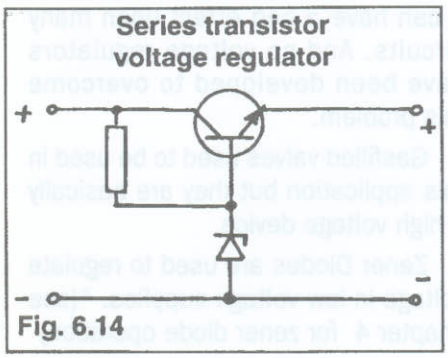


Fig. 6.14

TABLE 6.2

regulator type	current	voltage
LM 78L05CZ	100mA	5
LM7805	1 amp	5
LM7812	"	12
LM7815	"	15
LM350K	3amp	*

*(adjustable from 1.2 to 32 v)

Practical limitations

All semiconductor devices have limitations and the main one is over-voltage. If the voltage ratings of a device are exceeded, it is very likely that you will destroy it.

Another problem is ESD - electro static discharge. This can be caused by careless handling or static voltage build-up during electrical storms and the like. The advice is to closely follow the manufacturer's recommendations and the usual standard practices when using or soldering devices such as MOSFETS and CMOS ICs. Earthing is the key to success with preventing damage due to ESD. Reverse polarity is often the cause of premature failure of semiconductors. Take every precaution to avoid this happening or it could cost you very dearly. Only disconnect devices with the power off. Use of polarised plugs and sockets is a good code of practice.

Voltage Spikes

These are the nasty "glitches" (often referred to as Transients) that travel along power lines every so often to catch the unwary. Wherever possible, include spike suppression devices such as Metal Oxide Varistors (MOVs) in power supplies to prevent damage to sensitive devices.

Temperature

Solid state devices are made to operate up to given temperatures, so keep them cool by using adequate heat sinks and operating the equipment in the coolest places out of direct sunlight and not in confined spaces. Stacking gear on top of each other is not advisable as heat rises from lower shelves into the next unit above, making its internal temperature rise even higher.

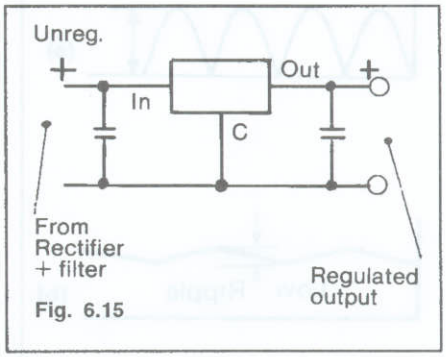


Fig. 6.15

chapter seven

OSCILLATOR AND AMPLIFIER PRINCIPLES

Oscillators are used in receivers and transmitters to generate given frequencies or ranges of frequencies. They may be fixed (one set frequency) or variable so that a range of frequencies can be covered.

The basic requirements for an oscillator are:- amplification and positive feedback.

Virtually any amplifier can be turned into an oscillator by providing feedback from its output back to its input circuit. In fact some amplifiers are prone to oscillating, especially when we don't want them to oscillate !

Fig 7.1 shows the block diagram of a simple oscillator.

Some of the amplifier's output is sampled, and taken via a phase shift network, then fed back to the input and the amplifier will then become an oscillator. Positive feedback means that the feedback signal is IN PHASE with the input signal such that it aids or boosts the input, and this gives a greater amplification. If there is sufficient gain and feedback, the amplifier will reliably oscillate every time it is switched on. Positive feedback gives more distortion but this is not usually a problem with oscillators.

(Negative feedback means that the feedback signal detracts or subtracts from the input signal and leads to reduced gain of the amplifier but the benefit is reduced distortion.)

Oscillators can operate at virtually any frequency - AF , and RF from LF right up to UHF and beyond.

Oscillators can produce many waveshapes but the most common one is sinewave.

The output of an oscillator is usually a continuous wave or a carrier.

A simple way to consider the concept of an oscillator is when a public address amplifier squeals- this is when the sound from the speaker is being picked up by the microphone and amplified again along with the voice of the person speaking. If enough of the amplifier's output reaches the microphone, it reinforces the signal from the microphone and the whole system's gain is so increased that oscillation results. Moving the microphone away from the nearest speaker or reducing the amplifier gain is usually enough to reduce the overall gain to the point where oscillation ceases and the sound becomes clear and pleasant to listen to again. Use of a highly directional microphone such as a cardioid type is another way to prevent feedback.

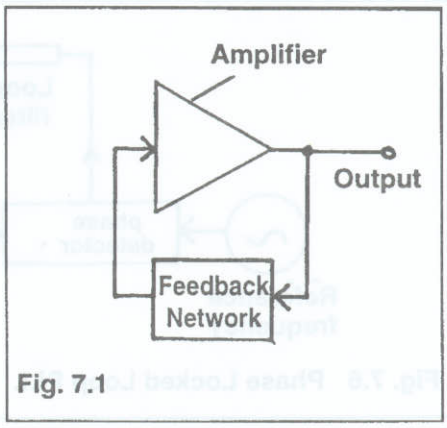


Fig. 7.1

VFOs.

Let us firstly consider variable frequency oscillators (VFOs).

The most common VFO circuits are the Hartley ond the Colpitts oscillators.

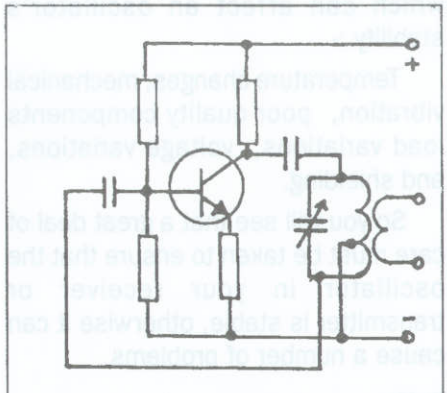


Fig. 7.2 Hartley Oscillator

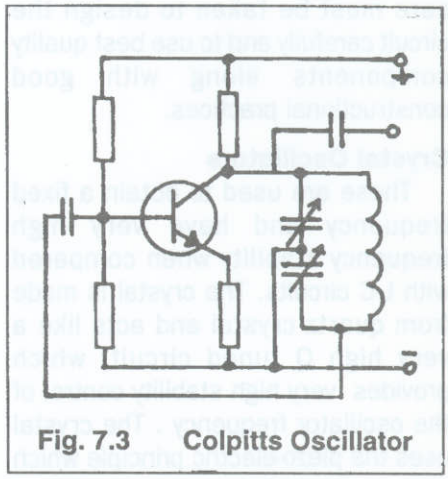


Fig. 7.3 Colpitts Oscillator

See figs 7.2 and 7.3 for the circuits of these two oscillators.

The frequency of the Hartley or the Colpitts oscillator can be varied by varying either the tuning capacitor or adjusting the coil's inductance by use of a movable slug. Both of these oscillators are known as L-C oscillators- this means that they have coils and capacitors in their circuits. There are also crystal and R-C oscillators as well. (R-C oscillators use resistors and capacitors instead of coils & capacitors)

The advantage of the VFO is that a range of frequencies can be obtained so that a receiver or transmitter can tune across a band of frequencies. However, great care has to be taken with the design of the circuits so that the oscillator covers just the range required and that the output is both stable in frequency and output amplitude.

The feedback in the Hartley oscillator is derived via the use of a tapped coil, whereas the feedback in the Colpitts oscillator is derived via the use of a tapped capacitor.The Hartley tends to have more harmonics in its output when compared with the Colpitts circuit.

The output frequency of the Hartley and Colpitts oscillator circuits is determined by the values of the

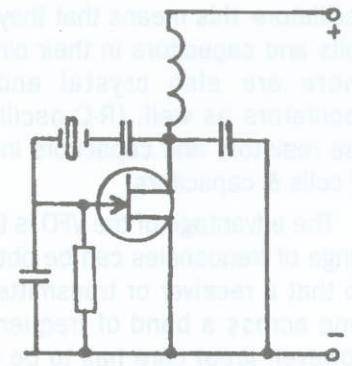
inductance and the capacitor - hence the term L-C oscillators. The frequency is calculated by the formula

$$F = \frac{1}{2\pi\sqrt{LC}}.$$

The frequency stability of the L-C oscillator can be very good but great care must be taken to design the circuit carefully and to use best quality components along with good constructional practices.

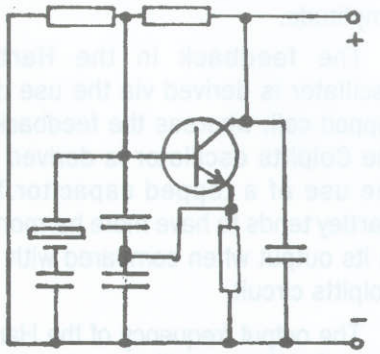
Crystal Oscillators

These are used to obtain a fixed frequency and have very high frequency stability when compared with L-C circuits. The crystal is made from quartz crystal and acts like a very high Q tuned circuit, which provides very high stability control of the oscillator frequency . The crystal uses the piezo-electric principle which means that when under electrical stress it will vibrate at its natural resonant frequency and this becomes the accurately controlled frequency of the oscillator. (it should be noted that there are many variations of crystal oscillator circuits as there are for L-C oscillators for special applications).



FET Crystal Oscillator

Fig. 7.4



Bipolar Crystal Oscillator

Fig. 7.5

Figs 7.4 and 7.5 show two typical crystal oscillator circuits.

Phase locked loops (PLLs)

A development which is finding many applications in radio is the PLL.

A block diagram of the PLL is shown in fig 7.6.

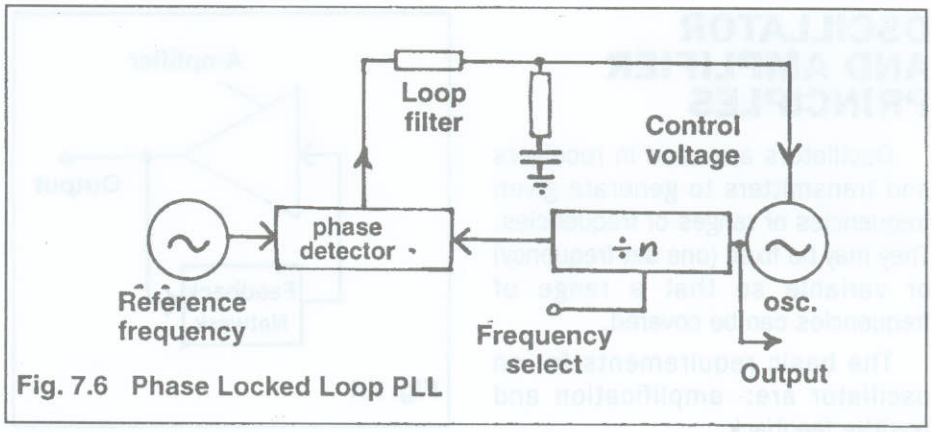


Fig. 7.6 Phase Locked Loop PLL

The PLL is used in most receivers and transmitters now. The circuit consists of a Voltage Controlled Oscillator (VCO) and a master crystal oscillator along with a phase comparator and a programmable divider. The principle is simply this - the VCO is set to a given frequency and if it tends to drift, the phase comparator detects the change and produces a correction signal which is used to pull the VCO back onto frequency. The ultimate frequency stability is determined by the master crystal oscillator and this is extremely stable. (hence the popularity of PLLs with designers.-and operators!) Plus of course they make very wide ranges of frequency control possible with the great stability of the master oscillator and so it is replacing the use of L-C or crystal oscillators.

OSCILLATOR STABILITY

There are a number of factors which can affect an oscillator's stability :-

Temperature changes, mechanical vibration, poor quality components load variations, voltage variations, and shielding.

So you will see that a great deal of care must be taken to ensure that the oscillator in your receiver or transmitter is stable, otherwise it can cause a number of problems.

Drift:

Frequency drift can cause your transmission to slowly move up or down a band and you could cause interference to other stations if you move onto their frequency, besides the problem of the receiving station having to constantly retune their receiver. Drift is caused by temperature variations in components as they warm up and slow voltage variations in the DC supply .

Chirp.

Chirp is caused by either voltage or load variations during keying of a morse transmitter. Chirp is evidenced by the oscillator moving frequency slightly as the load or voltage changes, and then returning to its correct frequency once the load or voltage is normal. The effect is to give a "chirpy" sound to the received signal which is not pleasant to copy.

Temperature changes can cause components to change their value. For example, as temperature rises, the copper wire in the coil expands and so the inductance changes slightly. This leads to a slight change in the resonant frequency of the tank circuit of the oscillator. Certain types of capacitor can be used to compensate for this effect - they are known as NPO types as they have a negative temperature coefficient which counteracts the change in the coil's inductance.

Vibration

Any mechanical vibration or movement can vary the frequency of an oscillator especially if it is not constructed with very well supported components, so good constructional practices help in oscillator immunity from vibration and mechanical shock problems. Components which can

move or which are susceptible to vibration can give a "microphonic" effect where the vibrations can be heard in the output signal as they are modulating it.

Component quality

It goes almost without saying that cheap components are false economy, so use the best you can get if you want an oscillator to be stable and reliable.

Load variations

Load variations can "pull" an oscillator off frequency so it needs to be isolated by the use of a buffer amplifier which places a constant load on the oscillator and keeps it from being affected by load variations occurring in other parts of the circuit.

Voltage changes

Voltage changes, either fast or slow can cause the oscillator to shift frequency so the usual cure is to use voltage regulators such as zener diodes or IC regulators to keep the voltage supply absolutely constant under all operating conditions.

Shielding- oscillators are often encapsulated in a metal can or shield enclosure to maintain a fairly constant temperature and to prevent stray leakage of signals to sensitive parts of the equipment.

FREQUENCY CONVERSION

Frequency conversion can be achieved by a process called "frequency multiplication". Also frequency translation (or heterodyning) can be used.

Frequency multiplication

Sometimes it is necessary to double or triple the frequency of an oscillator in a transmitter or receiver. Often, from the viewpoint of stability, it is better to generate a frequency at a relatively low frequency and then multiply it up via doublers or triplers.

Fig 7.7 shows the configuration of oscillator and multiplier to generate VHF signals for use in transmitters and receivers.

As an example, we may wish to generate a transmitter frequency of 146 MHz for use in the 2 metre band. The oscillator is set at 48.666 MHz in this case and the tripler multiplies the frequency to 146 MHz for the transmit frequency.

Another example is in a 2 metre receiver where the IF is 10.7 MHz and the receive frequency is 146.5 MHz. The local oscillator in the receiver will have to be set at 146.5-10.7 MHz = 135.8 MHz. So the oscillator could be crystal locked on 45.2666 MHz and a tripler would bring the frequency up to the required 135.8 MHz.

Via a chain of oscillator, amplifiers and multipliers, we may find we have a frequency of 72 Mhz in a transmitter circuit. And to reach the final transmit frequency in the 2 metre band of 144 MHz, we would need a doubler to double the 72 MHz to 144 MHz.

Requirements for frequency multipliers :-

1. an amplifier operated in class C (see amplifier classes later)

2. an over-driven (deliberately overloaded) amplifier

3. output circuit tuned to the required harmonic

As you can see, the frequency multiplier is a useful circuit to generate particular frequencies for use in transmitters as well as receivers.

Heterodyning

Heterodyning means "mixing". This is usually done in a non-linear circuit (known as a mixer) and when two input frequencies are fed into the circuit, new output frequencies known as the "sum" and the "difference" frequencies are produced. Fig 7.8 shows a typical heterodyning situation.

Heterodyning is used in both receivers and transmitters to produce a third (or output)frequency from two input frequencies.

For instance, if the input signals in the circuit in fig 7.8 were 9MHz and 5.5 MHz, the output of the mixer will be either 9+5.5= 14.5 MHz or

9-5.5=3.5MHz.

The required output is selected by using a tuned circuit to resonate at either 14.5 MHz (sum freqy) or 3.5 MHz.(difference freqy) The tuned circuit accepts only the desired output and rejects the other, so it can resonate at either the sum or the difference frequency.

At VHF, a mixer circuit might have one input of 146 MHz and another input of 135.3 MHz and so the desired output frequency in this case would be 10.7 MHz which is the difference frequency.

See fig 7.9.

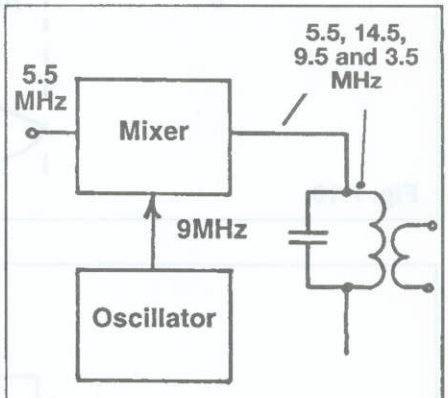


Fig. 7.8

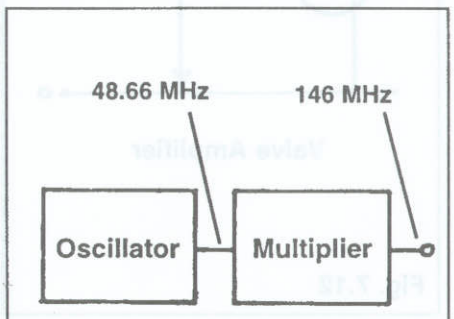


Fig. 7.7

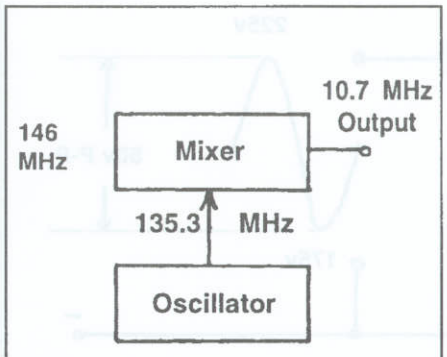


Fig. 7.9

AMPLIFICATION

Fig 7.10 shows the characteristic curve of an amplifier . We have used a valve amplifier in this case to illustrate some important points. The horizontal axis of the graph shows the grid bias

voltage applied to the amplifier and the vertical axis shows the anode current of the valve. An input signal is applied to the grid and it effectively "swings" the input voltage on the grid evenly either side of the bias point (5v) from -7v to -3v. The bias voltage in this case is set at -5v and this is the "resting" or "quiescent point" of the amplifier. When the signal is applied, it causes the effective bias voltage to be varied about the quiescent point. This allows the valve to conduct varying amounts of anode current - as the bias is effectively reduced to -3v the valve conducts more and when the grid signal is down to -7v, then the valve conducts much less due to the higher negative bias on the grid.

By looking at the output voltage, you can see that the output is larger (greater in amplitude) than the input signal and so we have achieved amplification.(refer to fig 7.11)

To explain amplification a little more - look at fig 7.10. The grid voltage is being 'swung' from -3 to -7v, so we have an input signal peak to peak value of 7-3 = 4v P-P. And as the anode current is being controlled by the bias voltage on the grid, of course the anode voltage is going to vary in sympathy (but 180° out of phase) with the grid signal. This is due to the voltage drop across the load resistor RL.If the anode current is changing from 1.5 mA to 2.5mA (the resting or operating point is 2.0mA) then there will be a voltage drop across the 50K ohm load resistor of 0.0015x50,000=75v and at 2.5 mA the voltage drop is 0.0025x50,000=125v.

Referring to fig 7.11, you can now see that the output voltage of the amplifier is the difference between the HT voltage and the voltage dropped across RL. For example 300-75 = 225v and 300-125 = 175v. So we have an output voltage swing of 225-175 = 50v.P-P

To calculate the voltage gain of this amplifier, we divide the P-P output voltage by the P-P input voltage, thus 50/4 = 12.5 . So this amplifier has a stage gain of 12.5 which is not remarkable by today's standards but it serves to illustrate that amplification is achieved by an input signal varying the current through the valve and the output voltage is the difference between the supply voltage (HT) and the voltage dropped across the load resistor.

Tabulation of the values in this amplifier (with an RL of 50K ohm) is shown in Table 7.1.

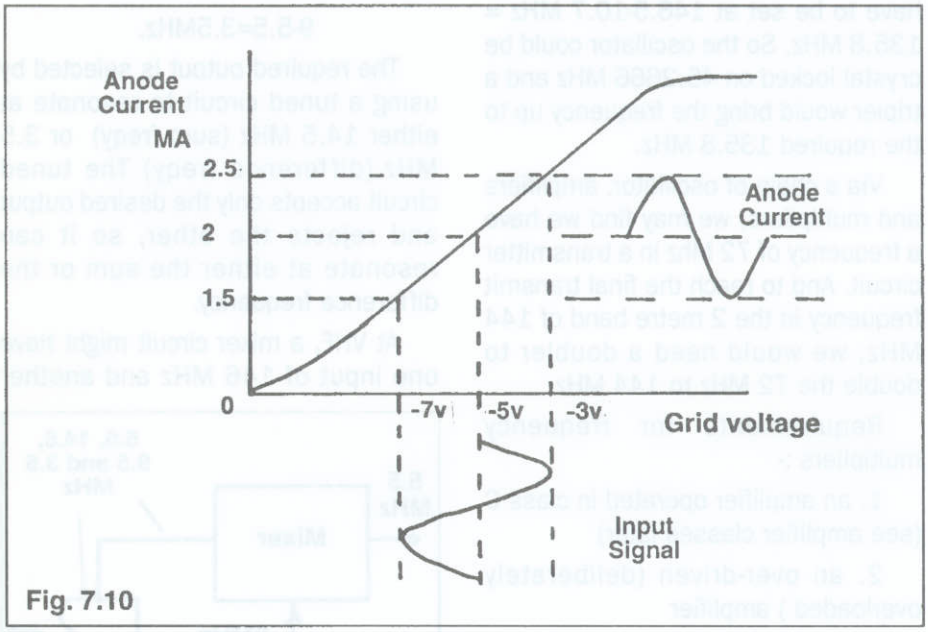


Fig. 7.10

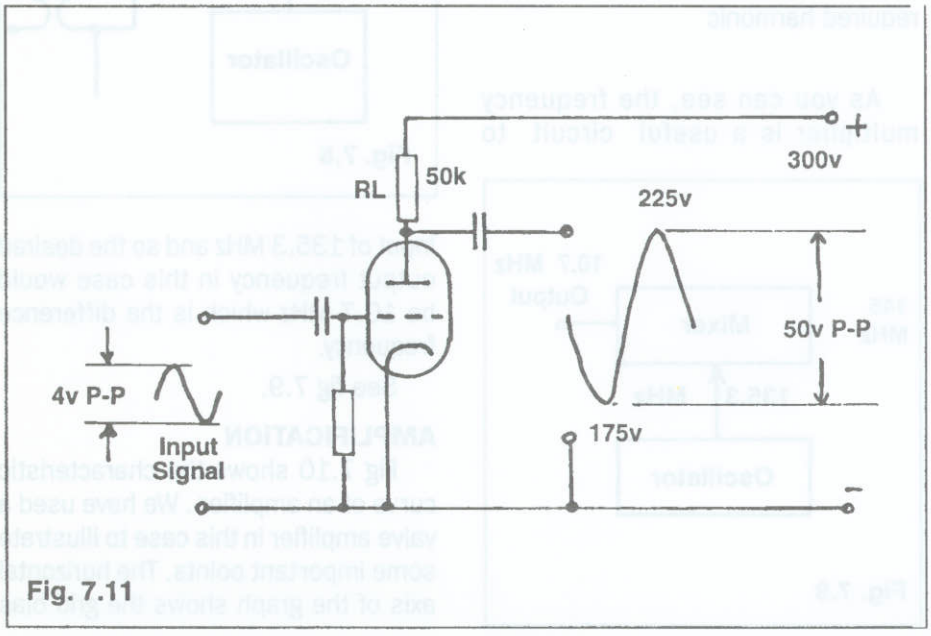


Fig. 7.11

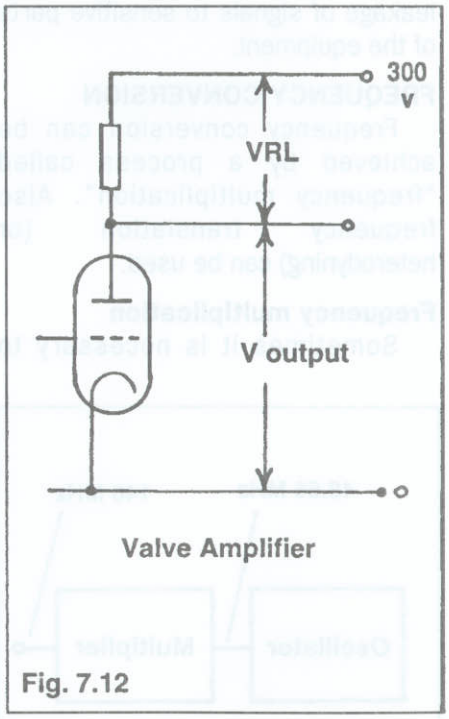


Fig. 7.12

TABLE 7.1

Vgrid	I Anode	VRL	V output
-3v	2.5 mA	125	175
-5v	2.0	100	200
-7v	1.5	75	225

HOW A TRANSISTOR AMPLIFIES

(Referring to fig 7.13)

First we need to bias the transistor to set the operating point in a similar way to the valve, only with the transistor, we use base current instead of grid voltage.

The operating point bias current in the case of this particular amplifier is 100uA. The input signal changes the bias current from 90 to 110 uA. So it changes the bias current 10uA either side of the operating bias. (20uA P-P).The collector current is thus varied

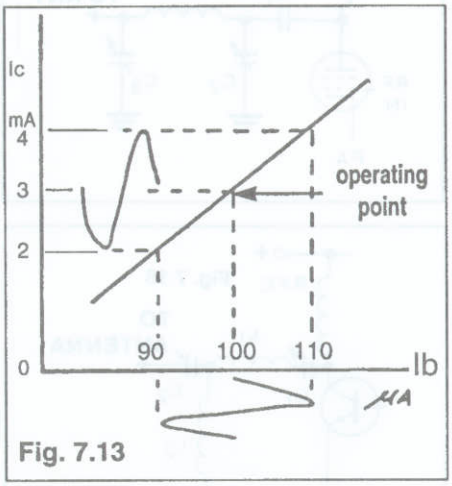


Fig. 7.13

1mA either side of the operating current of 3mA so we have a "swing" of 2 mA in output current caused by a 20uA "swing" in the input current !

Referring to fig 7.14, we have a Vcc supply to the collector of 9v and the load resistor is 1k ohm. When the collector current is 3mA , the voltage drop across RL is calculated by ohms law ,(E = I x R) thus:-.003x1000=3v and so the output voltage is 9 - 3 = 6v. When the collector current is 4mA,the voltage across RL rises to .004x1000=4v and the output voltage falls to 9-4=5v. When the input signal

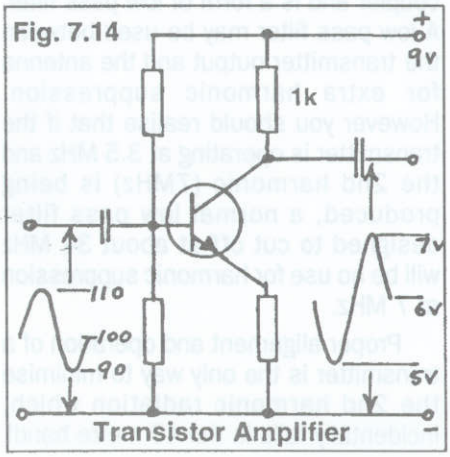


Fig. 7.14

causes the collector current to fall to 2mA, then the voltage across RL falls to .002 x 1000 = 2v. and so the output voltage rises to 9-2=7v. Thus we have a 'swing' of output voltage of 7-5 = 2v. This output voltage has been produced by a change in the base input current of only 20 uAmps !

Table 7.2 Shows the Amplifier's Voltages and Currents

Current Gain -

The current gain of the above amplifier circuit was 2mA/20uA = 100 (this is known as a Beta of 100). Beta is found by dividing the change in collector current by the change in base current.

TABLE 7.2

Base current	collector current	VRL	Voutput
90uA	2mA	2V	7v
100	3	3	6
110	4	4	5

CLASSES OF AMPLIFIER OPERATION

Amplifiers can be operated with various levels of bias and this leads to the ability to operate them in at least three distinct "classes" of operation.

These classes are : A, B & C.

Classes A,B & C apply equally to valve and transistor amplifiers.

There are also classes AB1 and AB2.

Table 7.3 shows the main differences between these classes of amplifier:

From this table you can see that the various classes of amplifier each have their particular applications. For example, an RF linear amplifier is usually operated in class A or AB whereas a final amplifier in an AM or FM transmitter is most likely to be a class C amplifier. A microphone amplifier or a hifi amplifier must be a class A amplifier for the lowest distortion and thus the best fidelity.

Class C amplifiers conduct current for much less than a full 360° of a cycle but as they are used in conjunction with a tuned circuit, they are able to amplify satisfactorily. The tuned circuit is maintained in oscillation by the amplifier and this is known as the "flywheel effect".

AMPLIFIER STABILITY AND PROBLEMS

Amplifiers can become unstable and possibly burst into oscillation unless certain precautions are taken. Some of the problems include:-

(a) Self oscillation, (b)parasitic oscillations and (c) harmonic generation.

(a) Self-oscillation

Fig 7.15 shows the block diagram of an amplifier (it could be either an RF or Audio application).

If the input and output frequencies are the same, in other words a "straight thru" amplifier, it can suffer the problem of having unwanted positive feedback due to circuit layout and if the feedback is sufficient, oscillations may occur.

An amplifier in a transmitter which has gone into oscillation ("taken off") is a problem which must be attended to as it can damage the transistor or valve and almost certainly will cause interference to other services.

TABLE 7.3

Class	level of bias	application	main characteristics	efficiency
A	biased to centre of linear part of operating curve	audio & hifi	very linear - low distortion	poor
AB_1	biased lower down the curve	audio & RF	not so linear slight distortion	higher
AB_2	biased even further down the curve	audio & RF	less linear more distortion	higher
B	biased to cutoff point	audio & RF	less linear greater distortion	higher
C	biased to twice cutoff point	RF only	very non-linear high distortion	highest

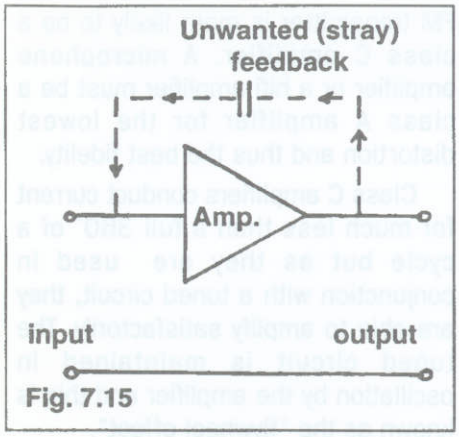


Fig. 7.15

The way in which it is controlled is to "neutralise" the circuit. This means that a deliberate amount of negative feedback is applied to the circuit to counteract any positive feedback which may be present.

Fig 7.16 shows the principle of neutralisation. As the frequency rises towards the higher end of the HF band and into the VHF range, neutralisation becomes more important as stray circuit feedback paths become more of a problem. If insufficient neutralisation is used, the amplifier will tend to oscillate and if too much neutralisation is used, the amplifier's efficiency will be too low.

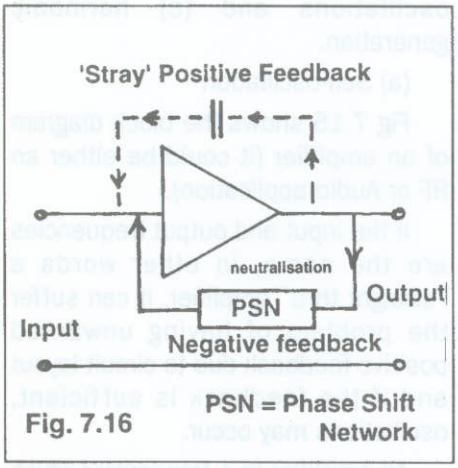


Fig. 7.16

(b) Parasitic oscillations

These are commonly referred to as 'Parasitics' and are caused by stray resonances in RF amplifier circuit layout . Each conductor has inductance and of course various stray capacitances exist in almost every circuit layout, so it is quite possible for an amplifier to have sufficient stray inductances and capacitances such that it can possess unwanted resonances. These parasitic resonances can lead to unwanted oscillations which are called parasitics. Parasitic oscillations can cause distortion, low efficiency and instability. They can be much lower or much higher than the current operating frequency of the amplifier. In an HF transmitter, they can extend up into the VHF or UHF range for instance.

To check for parasitics, an amplifier is connected to a dummy load and with suitable precautions, and with the drive removed , the input and output tuned circuits are "swept" throughout their normal tuning ranges. Under these conditions there should be no changes in current drawn by the amplifier and no RF output power should be measured .

The most common cures for parasitics are:-

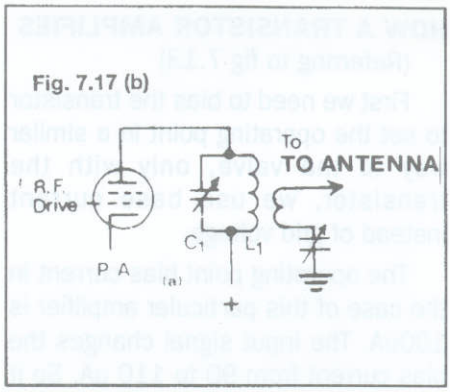
(i) to use a fairly high value resistor in series with the grid circuit

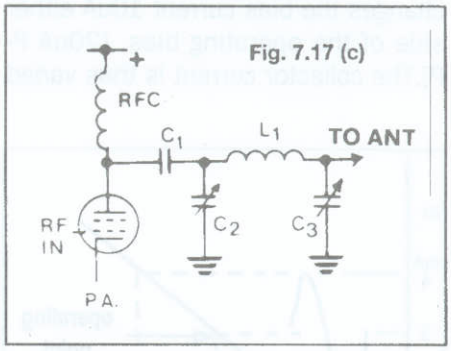
(ii) to wind an RF choke around a suitable resistor and insert this choke in series with the anode, or the the grid. In transistor amplifiers, in series with the base and or the collector circuit of the amplifier. This causes the losses to be high at the frequency of the parasitic and thus prevents the unwanted oscillation.

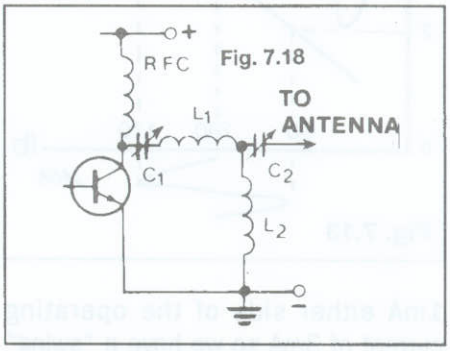
(c) Harmonics

Almost any transmitter will generate harmonics. For example, a transmitter operating on 3.5 MHz will radiate some RF at 7,10.5,14 and 17.5 MHz. etc. This corresponds to the second, third, fourth and fifth harmonics respectively.

The method of coupling between stages in a transmitter is a factor in the generation & radiation of harmonics.







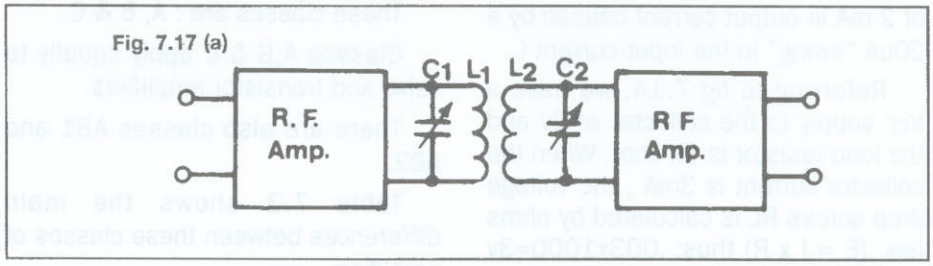


Fig 7.17a shows tuned coupling between stages .

The tuned circuits L1-C1 and L2-C2 are tuned to the operating frequency and will help to reject harmonics and thus prevent them from passing through transmitter stages. Fig 7.17b shows a valve power amplifier coupled to the antenna via a tuned link. This method of coupling also helps in preventing harmonic radiation.

Fig 7.17c shows a pi-tank output circuit. C1 blocks the DC from reaching the antenna circuit and C2-L1-C3 form the Pi-tank. DC is fed to the anode via an RF choke . The Pi tank gives high harmonic suppression and allows low impedance antennas to be easily matched to the power amplifier (PA) stage.

Fig 7.18 shows a transistor PA stage and its output coupling circuit which feeds the antenna.

This output circuit is known as a pi-coupler and is a form of low pass filter. A low pass filter may be used between the transmitter output and the antenna for extra harmonic suppression. However you should realise that if the transmitter is operating at 3.5 MHz and the 2nd harmonic (7MHz) is being produced, a normal low pass filter designed to cut off at about 34 MHz will be no use for harmonic suppression at 7 MHz.

Proper alignment and operation of a transmitter is the only way to minimise the 2nd harmonic radiation which, incidentally falls in the 40 metre band!

chapter eight

TRANSMITTERS

Morse code transmitters are the simplest in the whole spectrum of transmitters.

Morse code emissions take up the least radio spectrum space so they have a number of advantages over other modes of emission.

The ability of morse code to penetrate through under most adverse conditions is the reason why many amateurs still use morse as their main form of communication.

Morse (commonly referred-to as "CW" - from continuous wave) has many applications all these years after Samuel Morse invented the code. Morse is used on repeaters as identification. It is used to identify navigational beacons for ships and aircraft . Computers are capable of sending and receiving morse transmissions via a transceiver.

The carrier is keyed on and off by one of a number of methods to provide interrupted continuous wave (ICW) which is made up of the morse characters in the transmission.

The wave emitted is shown in fig 8.1b . (This is the morse character "G".)

The wave shown is the ideal form of keying which would be free of key clicks. (More on this later).

Fig 8.2 shows morse keying of a "hard" nature which would generate key clicks.

The oscillator would be supplied from a well-regulated DC power supply to ensure the signal is stable and does not drift. The power supply for the buffer, driver and PA are carefully isolated from each other to prevent interaction from occurring via the common supply voltage rails.

(This is called "decoupling")

Fig. 8.1 (a)

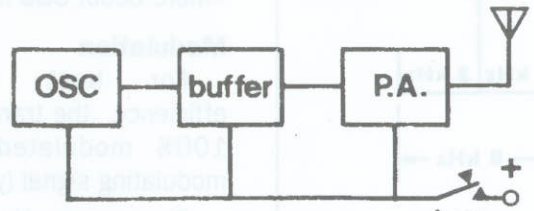


Fig. 8.1 (b)



Fig 8.1a shows the block diagram of the stages in a very basic morse transmitter.

The oscillator generates the carrier or continuous wave, the buffer amplifier isolates the oscillator from the later stages, the PA (power amplifier) stage amplifies the RF carrier to feed the antenna. (Another stage may be inserted between the buffer and the PA stage and this would be known as the driver. It lifts the power level of the carrier to provide a suitable input drive signal for the PA.)

Fig. 8.2



Keying methods

A very common form of keying is the "blocked base" method.

Basically this consists of a means by which an amplifier is biased off when the key is up and allowed to amplify when the key is down.

It is not normally good practice to key the oscillator or the buffer from the point of view of good, stable emissions, so a later stage is usually keyed.

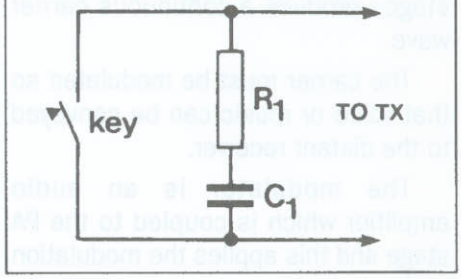
This is usually an intermediate amplifier or the driver stage.

Keying problems

(i) Key clicks. These are one of the worst problems with morse transmitters. These are usually cured by using a key click filter. Fig 8.3 shows the circuit of a key click filter

The key click filter 'shapes' the attack and decay times of the keying waveform so that the transmitter is turned an and off more gently in order that sharp switching transients are avoided. It uses the principle of a time constant delay to slow down the keying waveform slightly to achieve click-free emissions.

Fig. 8.3



(ii) "chirp"

This is caused by the oscillator being affected by the keying of the transmitter. Voltage variations caused by the changing load on the power supply are reaching the oscillator causing it to change frequency slightly. This is called "chirp". The changing load caused by the transmitter being keyed, causes a varying load on the oscillator and thus leads to chirp in the signal emitted. It is evidence of a slight shift in the oscillator frequency at key down and is an unpleasant sounding signal to receive.

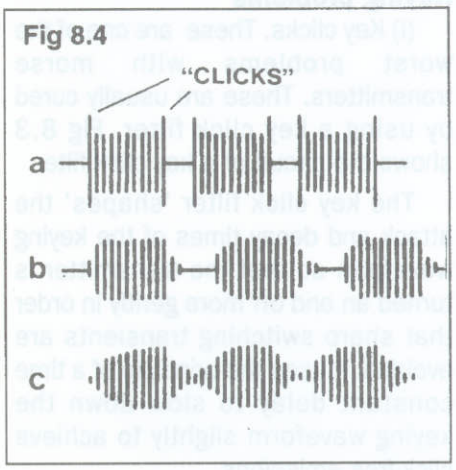
Monitoring of emissions

Fig 8.4 shows the waveforms of the output of a morse transmitter as seen on a Cathode Ray Oscilloscope (CRO).

(a) shows a signal having bad key clicks

(b) shows a correctly keyed click - free signal

(c) shows a signal having excessive time delay in the click filter and this leads to a "soft" signal which is not pleasant to receive.



Amplitude Modulation (AM)

Fig 8.5 shows an AM transmitter block diagram.

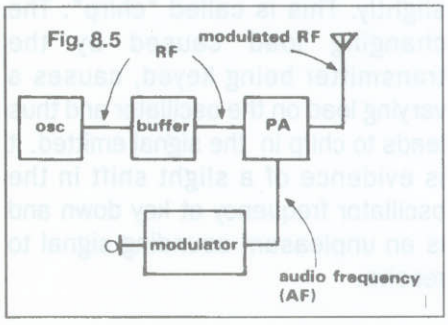
The oscillator, buffer and PA stages produce a continuous carrier wave.

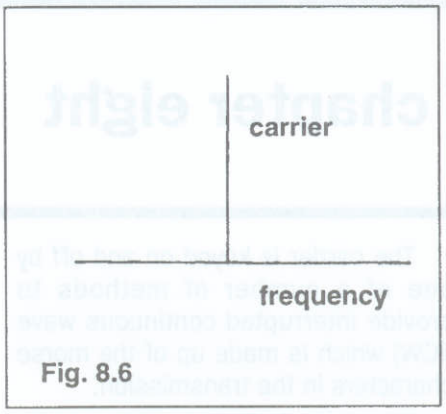
The carrier must be modulated so that voice or music can be conveyed to the distant receiver.

The modulator is an audio amplifier which is coupled to the PA stage and this applies the modulation to the emission.

fig 8.6 shows the spectrum display of the unmodulated carrier.

The vertical axis denotes the amplitude and the horizontal axis is the frequency.

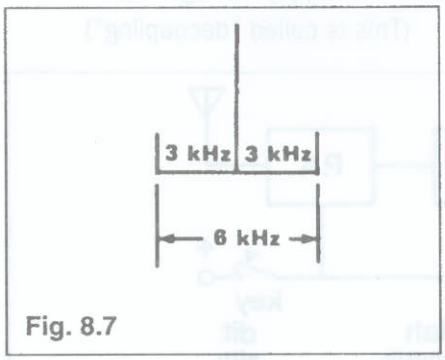




If you were to whistle an audio tone of say 3KHz into the microphone of the this transmitter, the spectrum display would be as shown in fig 8.7.

The carrier is still present but is added-to by an upper and lower side frequency of +/- 3KHz. So the emission would now have a bandwidth of 6 KHz. This is the most common bandwidth as used by amateurs and many commercial services for AM signals.

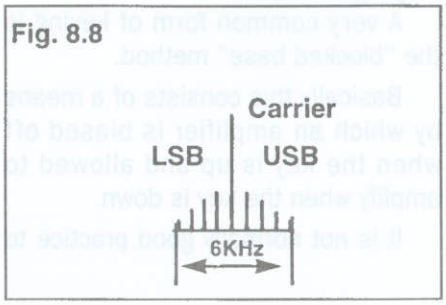
Broadcast stations use greater than 6 KHz modulation to provide better fidelity of the sound but 6 KHz



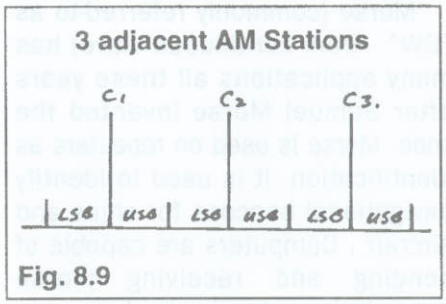
is quite adequate for communications purposes.

If you were to speak into the microphone of the transmitter, a set of upper and lower sidebands would be generated as shown in Fig 8.8.

To achieve a total bandwidth of 6KHz as in most amateur AM



emissions, the highest modulating frequency fed into the microphone would be 3 KHz. The total spectrum space taken up by an AM transmitter modulated with speech ranging from 300Hz to 3KHz is 6KHz. The highest modulating frequency is limited to 3KHz to permit the maximum possible number of stations within any given band. If a number of AM emissions were placed 6KHz apart as shown in Fig 8.9, then the receiver would produce "heterodynes" of 6KHz in the speaker. This is because each carrier would "beat" or "heterodyne" with the adjacent carriers and give rise to heterodyne whistles. In a crowded band full of AM emissions the heterodynes have to heard to be believed. And so SSB was developed to get around this and other problems.



<More about SSB later.>

Modulation

For best communications efficiency, the transmitter should be 100% modulated by the audio modulating signal (your voice).

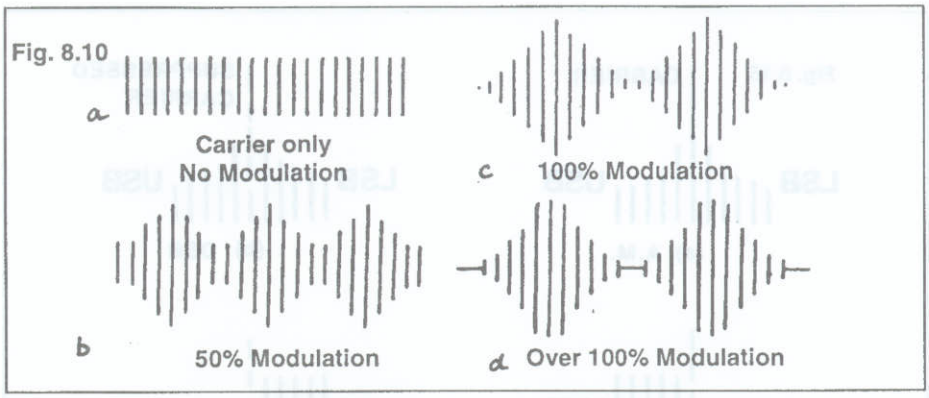
For example, if the PA power input is 300 watts, then the modulator must be able to produce 150 watts of power to fully modulate the carrier. So the rule is that the modulator must be able to produce about 50% of the DC power input to the PA.

Wave envelope patterns of an AM transmitter as seen on a CRO are shown in fig 8.10.

A 100% modulated carrier would sound much louder than a 50% modulated carrier to a distant receiver.

Fig 8.10a shows an unmodulated carrier. Fig 8.10b shows a carrier modulated about 50%.

Fig 8.10c shows a 100% modulated carrier. An over modulated carrier is shown in Fig 8.10d.



The power in an AM emission is divided between the carrier and the two sidebands. About 50% of the carrier power is found in the sidebands.

For example, if the carrier power level is 30 watts then there would be 7.5 watts in the upper sideband and 7.5 watts in the lower sideband. Thus the total power in each of the sidebands is 1/4 the power of the carrier. (in the case of a 100% modulated signal) .

Overmodulation

If the carrier is over-modulated, then its bandwidth increases, distortion occurs and interference to adjacent and other services would occur. Using too much microphone gain is usually the cause and despite opinions to the contrary, intelligibility suffers, aside from the annoyance to other stations. An over-modulated emission is said to have "splatter" and this is the interference caused by driving the transmitter into overload condition. The emission would be audible over much more than the usual 3 KHz of bandwidth.

High and low level modulation

An AM transmitter can be "high level" modulated. This is done by coupling a modulator to the PA stage. The modulator's power must be 50% of the PA stage's DC input power. This is probably the most common method of modulating an AM transmitter, but of course it requires a high power modulator and a modulation transformer capable of handling the power levels.

Low level modulation is achieved by using a low power modulator and coupling it to a stage or two prior to the PA stage. If this is done, however, all RF stages following the modulated stage must be linear amplifiers. This system has the advantage of requiring a low power modulator and a smaller modulation transformer but the disadvantage is that the stages following the modulated stage must be linear and this gives an overall lower efficiency for the transmitter.

MICROPHONES

A microphone is a transducer, converting sound waves into electrical signals.

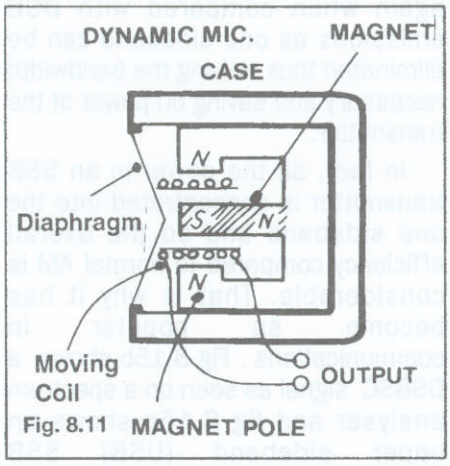


Fig. 8.11

The main types used in communications are:-

dynamic - (moving coil), ceramic/crystal, and the capacitor-Electret.

Fig 8.11 shows the construction of a dynamic microphone. It is basically the same as a moving coil speaker except that the size is considerably smaller. This type is probably one of the most commonly used in amateur radio.

As sound waves strike the diaphragm, they cause it to move back and forth. This causes the moving coil (attached to the diaphragm) to also move back and forth. AC voltages are induced in the moving coil as it is contained within a very strong magnetic field. These voltages can then be amplified and used to modulate a transmitter. Impedances for this mic. are typically 500 ohms, 10K ohms and 50k ohms.

The Ceramic microphone. This is shown in Fig 8.12 and its construction has a piezo-electric ceramic crystal supported on a case such that when the diaphragm is moved by sound waves, the crystal is flexed by mechanical forces . As the crystal is flexed, it develops a small AC voltage across its surfaces. This microphone has quite high impedance and is usually connected to a FET preamplifier connected in the common drain configuration to step its impedance down to a lower value for further amplification.

The Electret/condenser microphone (usually called an electret microphone) is shown in fig 8.13 This microphone uses the principle of the capacitor microphone.

An electret is a permanently polarised plastic film (usually fluorocarbon or polycarbonate)and so this type of microphone does not need a polarising voltage supply for the capacitor as this is already provided by the electret foil.

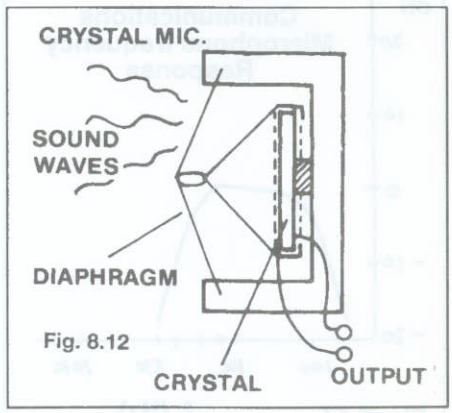


Fig. 8.12

As sound waves impinge upon the foil, (which is one plate of the capacitor,) it moves relative to the fixed plate and thus the electrostatic field is varied, developing an output voltage. It has relatively high impedance and is coupled to a FET preamp which provides high to low impedance transformation for further amplification at reasonable impedances.

Communication microphones usually have a specially tailored

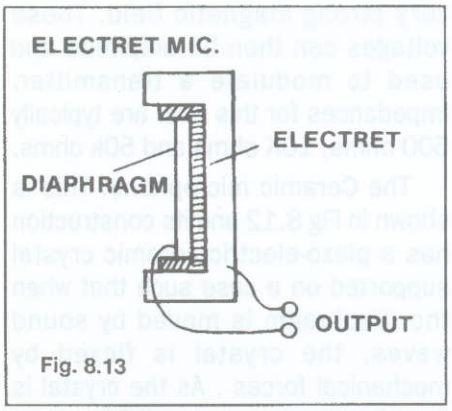


Fig. 8.13

frequency response to avoid too much bass and the treble is limited to roll off rapidly above 3 KHz to limit the bandwidth of the transmission. Fig 8.14 shows the frequency response of a communications microphone.

SINGLE SIDEBAND (SSB)

This is a very common mode of emission in amateur radio and has completely supplanted AM on most bands. It has many advantages in efficiency over AM .

SSB is a special form of Amplitude Modulation where the carrier has been suppressed and one of the sidebands has also been suppressed leaving the one sideband to carry all the intelligence in the signal.

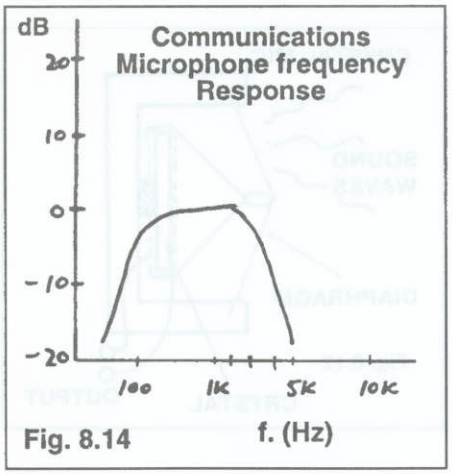
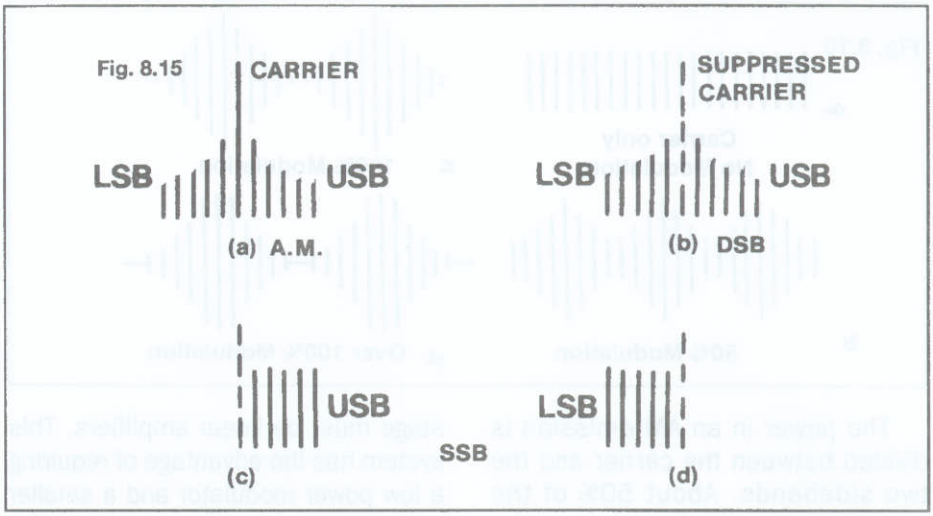


Fig. 8.14

The full and correct name for the most common SSB used by amateurs is - Single sideband suppressed carrier. (SSBSC)

Fig 8.15a shows an AM signal as it would appear on a spectrum analyser screen. Because AM has a carrier and two sidebands, the full name for AM is - double sideband full carrier. Incidentally, it's quite possible to construct a double sideband suppressed carrier (DSBSC) transmitter , however many receivers are not capable of resolving this kind of emission.



A DSBSC emission is more efficient than an AM full carrier emission because the carrier is not really essential in the system and can be dispensed with if suitable receivers are used .

SSB emissions are more efficient again when compared with DSB emissions as one sideband can be eliminated thus halving the bandwidth necessary and saving on power at the transmitter.

In fact, all the power in an SSB transmitter is concentrated into the one sideband and so the overall efficiency compared to normal AM is considerable. That is why it has become so popular in communications . Fig 8.15b shows a DSBSC signal as seen on a spectrum analyser and fig 8.15c shows an upper sideband (USB) SSB transmission and fig 8.15d shows a lower sideband (LSB) SSB emission. The dotted line indicates the carrier which has been suppressed within the transmitter circuitry.

Bandwidth

Let's assume we wish to transmit an upper sideband (USB) SSB signal at 21.2MHz. The speech frequencies reach a maximum of 3KHz and so the emission is only 3 KHz in width. This is exactly half of the bandwidth required by a normal AM signal. If we look at the spectrum display of the 21 MHz signal shown in fig 8.16, we see that it occupies from 21.2 to 21.203 MHz

Another advantage of SSB is that as there is no carrier, there is no production of the heterodyne whistles referred-to in the section on AM. Thus

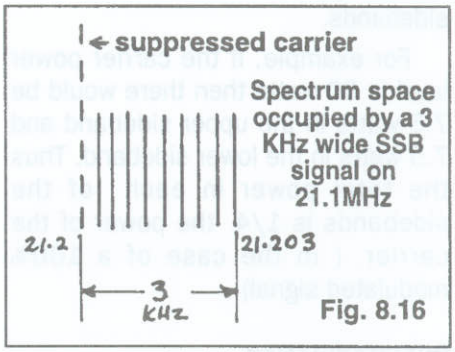


Fig. 8.16

many adjacent signals can exist in a given band with no detrimental effect to each other.

The main advantage of SSB is that all the power in the transmitter is concentrated upon carrying the intelligence rather than in a basically useless carrier and a mirror-image other sideband which carries identical information to its opposite number. In SSB, we can transmit either the upper OR the lower sideband for any given frequency, so we now have great flexibility with SSB.

TRANSMITTER STAGES

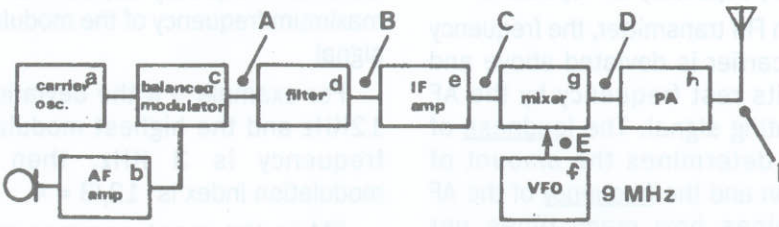
Now, refer to Fig 8.17 which shows the block diagram of the stages in an SSB transmitter.

(a). The carrier oscillator may be either a fixed frequency (crystal) oscillator or an L-C oscillator which can be tuned . i.e. a VFO- [Variable Frequency Oscillator].

(b) The AF amplifier. This amplifies the signal from the microphone produced by speech input.

(c) The Balanced Modulator combines the AF from the microphone amplifier with the RF from the carrier oscillator to produce an output containing both sidebands (upper & lower) but with the carrier being suppressed.

Fig. 8.17



(d) the sideband filter (usually called the filter) suppresses the unwanted sideband leaving just one sideband to be processed and fed to the transmitting antenna.

(e) the IF amplifier boosts the level of the signal-it is a linear amplifier

(f) this is the heterodyne oscillator and its signal is fed to the mixer

(g) the mixer combines the SSB signal with the signal from the heterodyne oscillator to produce the final transmit frequency for the band to be used.

(h) this is the PA stage and it is a linear amplifier.(in fact, the power amplifiers in an SSB transmitter must be linear amplifiers to prevent severe distortion of the signal)

Sideband switching

Referring to Fig 8.18, you can see the shape of the passband of the sideband filter. If the carrier oscillator is set to the left of the curve, then you can see that the upper sideband will be passed through the filter and become the emission.

If the carrier oscillator is changed slightly so it is placed at the right of the filter's passband, then the lower sideband will be passed. By having two suitable crystals for the carrier oscillator, you can conveniently shift from upper to lower sideband on any band .

TABLE 8.1 showing the frequencies (in MHz) at each stage of the transmitter in Fig 8.17

BAND	$A_{(MHz)}$	$B_{(MHz)}$	$C_{(MHz)}$	$D_{(MHz)}$	$E_{(MHz)}$	$F_{(MHz)}$
3.5	5.5_{DSB}	5.5_{SSB}	5.5_{SSB}	3.5_{SSB}	9.0_{SSB}	3.5_{SSB}
21.0	5.5_{DSB}	5.5_{SSB}	5.5_{SSB}	21.0_{SSB}	15.5_{SSB}	21_{SSB}
28.0	5.5_{DSB}	5.5_{SSB}	5.5_{SSB}	28.0_{SSB}	22.5_{SSB}	28.0_{SSB}

A Comparison between AM, SSB and CW :-

AM With 3KHz modulation, takes 6 KHz bandwidth. Inefficient as the carrier is not essential, also, radiating both sidebands is not essential.

SSB Puts all the power into the one sideband; highest efficiency, more complex transmitter circuitry, takes only 3KHz bandwidth.

CW takes up the least bandwidth, gets through under worst conditions, simplest transmitter circuitry.

TUNING A TRANSMITTER

To obtain best performance from a transmitter and to prevent interference as well as maximising life of the components in the transmitter, it is advisable to tune it up correctly.

Step 1: It is probably best to connect the transmitter to an artificial antenna (dummy load) so you don't cause interference to other stations.

2. The usual procedure is to tune up the earliest stages in the transmitter first so that the drive to the PA is maximum and then move along the controls until you reach the PA & Loading controls

3. the obvious thing is to tune each tank circuit in the transmitter to resonance at the correct frequency in a logical sequence

4. follow the maker's handbook fully when in doubt!

5. tune the PA tuning until a dip in current is indicated on the meter (this means that the tank is at resonance)

6. tune the loading control until the PA current shows an increase

7. re-dip the PA tuning again

8. repeat steps 6 & 7 until the maximum permissible current occurs in the PA but coinciding with the dip.

9. An RF output meter in the transmission line is useful, or a field strength meter can then be used for a last "fine-tuning" of the controls to give maximum indicated power output at maximum permitted final current.

10. disconnect the dummy load and reconnect the antenna and commence operating, ensuring that the frequency is clear!

11. if you shift frequency up or down the band, the tuning controls may need slight retuning so everything is kept "on the button".

12. Ensure that the transmitter is coupled to a correctly matched antenna. An Antenna Tuning Unit (ATU) may be necessary to achieve a good match. If the antenna is not properly matched to the transmitter, then distortion and flat topping is likely to occur. Also, the efficiency of your system will not be optimised and your signal will be weak to distant stations.

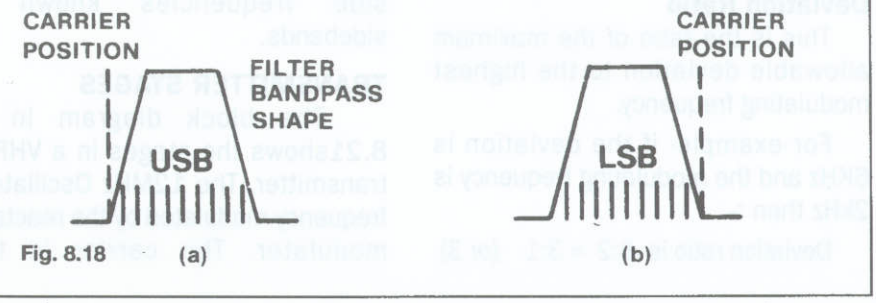


Fig. 8.18

The goal is to get as much power up to the antenna as possible.

Many recent designs of transceiver use broadband circuits which minimise the number of stages which need to be tuned, so less controls are needed on this equipment.

Two tone test waveforms

Two tone tests are used with SSB transmitters to check for linearity and power output.

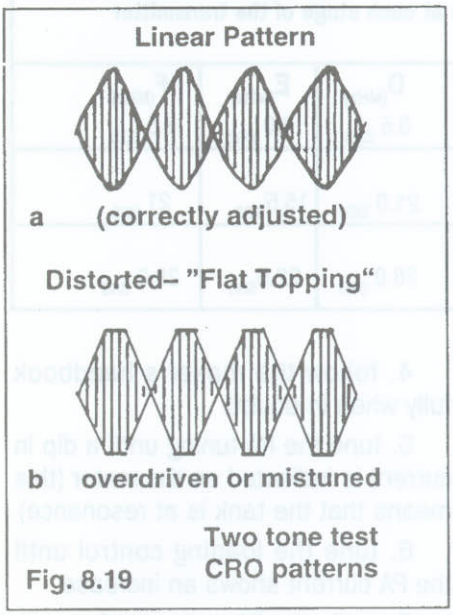


Fig. 8.19

A two tone oscillator using two non-harmonically related audio tones is used to modulate the SSB transmitter. This test, when viewed on a CRO will indicate if the transmitter is tuned and aligned correctly.

Fig 8.19a shows the Oscilloscope pattern you should see if the transmitter is adjusted and tuned correctly. If the transmitter is overdriven or mistuned, the CRO will show a waveform like the one in Fig 8.19b. This is called "Flat-topping" and indicates a distorted signal which will have splatter and will cause interference to other stations. The signal will take up more bandwidth than it should and you will become very unpopular with other operators on the band. One way to prevent flat topping is to use just sufficient microphone gain to correctly modulate the rig and no more. Talking too close to the microphone is an error many operators make. This only leads to flat topping and distortion which degrades the intelligibility of the signal.

FREQUENCY MODULATION

This mode is used mainly on VHF and UHF, especially on repeaters.

In an FM transmitter, the frequency of the carrier is deviated above and below its rest frequency by the AF modulating signal. The loudness of the AF determines the amount of deviation and the frequency of the AF determines how many times per second the carrier is deviated.

Fig 8.20 shows the block diagram of an FM transmitter.

The stages in the transmitter are:-

1. microphone amplifier
2. the modulator which is connected directly to the oscillator.
3. multiplier
4. multiplier
5. Driver
6. Power Amplifier

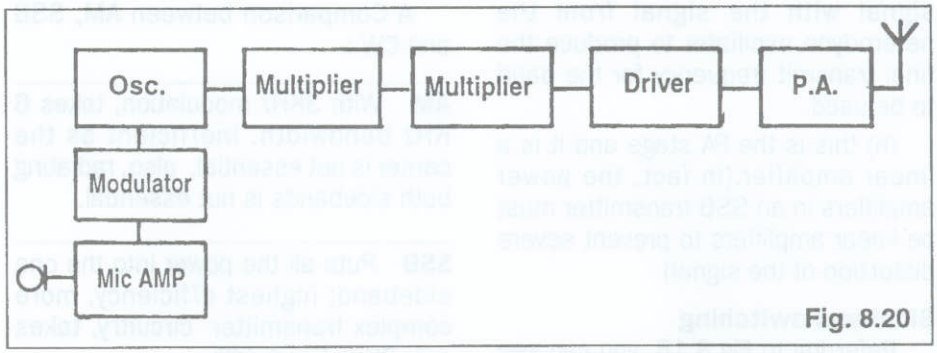


Fig. 8.20

Transmitter operation :

As you speak into the microphone, the frequency of the oscillator is varied slightly. The frequency variation is called "deviation". If you speak louder into the microphone, the deviation will be greater. When you are not speaking into the microphone, the carrier of the transmitter is at its "rest" frequency. Amateur radio uses Narrow band FM (NBFM) so that the bandwidth of each emission is usually restricted to a maximum of +/-6KHz. (on VHF and UHF).

Some terminology relating to FM:-

Deviation Ratio

This is the ratio of the maximum allowable deviation to the highest modulating frequency.

For example- if the deviation is 6KHz and the modulating frequency is 2kHz then :-

Deviation ratio is 6:2 = 3:1 (or 3).

Modulation index

This is the ratio between the maximum frequency deviation and the maximum frequency of the modulating signal

For example :- if the deviation is 12KHz and the highest modulating frequency is 3 KHz, then the modulation index is 12/3 = 4

FM is the most common mode used on repeaters, especially those on the 2 metre band. If signals are strong, FM has the advantage of noise immunity. Most noise is amplitude modulated and FM ignores this provided the receiver's limiter is operating fully with saturation signals.

Limiters

FM Receivers have one or more limiter stages to provide rejection of AM signals and noise.

Frequency modulation can be achieved in two main ways:

(i) the direct variation of frequency by varying the frequency determining components of the oscillator. (This is called FM.)

(ii) the varying of the phase of the carrier frequency after it has been generated , which in turn causes the frequency to be deviated . A modulator using this method is called a Phase Modulator and the output is said to be Phase Modulated. (PM) PM is most commonly referred-to by amateurs as FM but there is a subtle difference between both modes.

FM and PM signals have a range of side frequencies known as sidebands.

TRANSMITTER STAGES

The block diagram in Fig 8.21shows the stages in a VHF FM transmitter. The 12MHz Oscillator is frequency modulated by the reactance modulator. The carrier is then

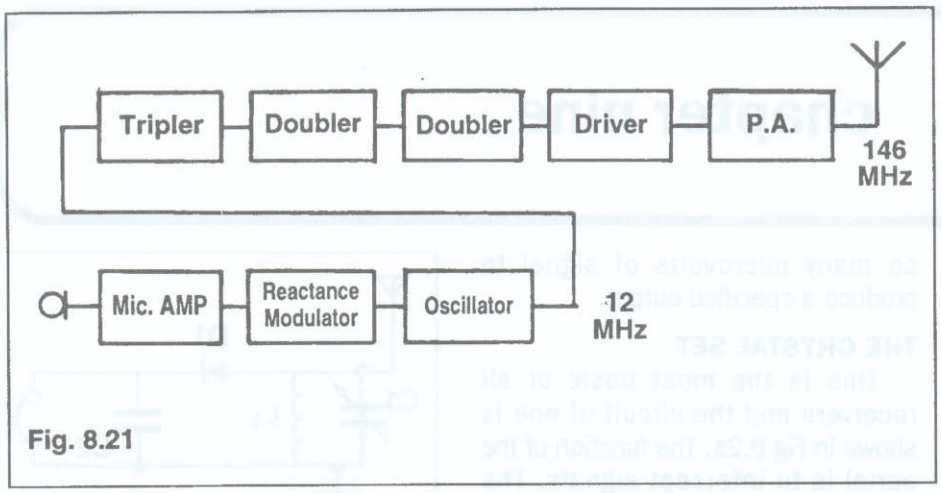


Fig. 8.21

multiplied up to the required frequency of 146MHz by a chain of frequency multipliers which also increase the deviation at each step. Multiplier number 1 is a tripler and multipliers 2 & 3 are doublers.

Pre-emphasis

This is a frequency equalisation technique used in FM to compensate for the low transmitter deviation which tends to occur with the higher modulation frequencies. In effect, the treble is boosted so that it modulates the transmitter more fully to overcome under-deviation. FM receivers have a de-emphasis circuit to compensate by restoring the balance between the treble and bass frequencies. If pre-emphasis was not used, the high frequencies would tend to become lost in the noise.

Repeaters

Repeaters are used in the amateur service on 50 MHz, 146 MHz, 432 MHz and other bands.

The main principle behind the use of repeaters is to provide communications between stations which cannot work each other direct.

In a repeater system, which is known as a duplex system, one frequency is used as uplink and another as downlink.

To use the repeater, your transceiver must be set to the duplex mode and if you press the push to talk button, your transmitter puts out a signal on the repeater uplink. The repeater receiver then detects your signal and puts the recovered modulation onto its transmitter which broadcasts your signal out far and wide on the downlink frequency.

Uplink and downlink frequencies are separated by 600kHz (0.6MHz) on the 2 metre band. Sometimes the uplink frequency is higher than the downlink and sometimes the opposite applies. When you let the button go, the repeater ceases to detect your signal and so it shuts down. If another station replies to you, his signal activates the repeater in the same way you did and you listen to him on the downlink. Most repeaters are set to time out after you have spoken for about 3 minutes and then shut down. The idea is for you to not speak too long through the repeater.

If you can hear a station direct (which is called simplex) it is common courtesy to change frequency (QSY) to a simplex channel so other stations can contact each other via the repeater.

Remember, callsigns are only needed every ten minutes so you don't have to waste repeater time by giving them on each and every over.

Fig 8.22 shows a typical repeater system.

Simplex operation

If you are working another station on a single frequency, you transmit an 'over' to him, and then 'put it over' to him. The other station then commences transmitting to you on the same frequency. This kind of operation is known as "Simplex".

Duplex operation

If you work another station via a repeater, then you will transmit on the uplink frequency to the repeater and it will re-transmit you out on the downlink frequency to the other station. This is known as "duplex" operation.

You can also work a station on split frequencies- you could be transmitting on say 146 MHz and the other station replies to you on 146.5 MHz for instance.

You both could be on different bands and this is known as "cross-band duplex".

"Full Duplex" is like the telephone where you can both speak and hear each other at the same time.

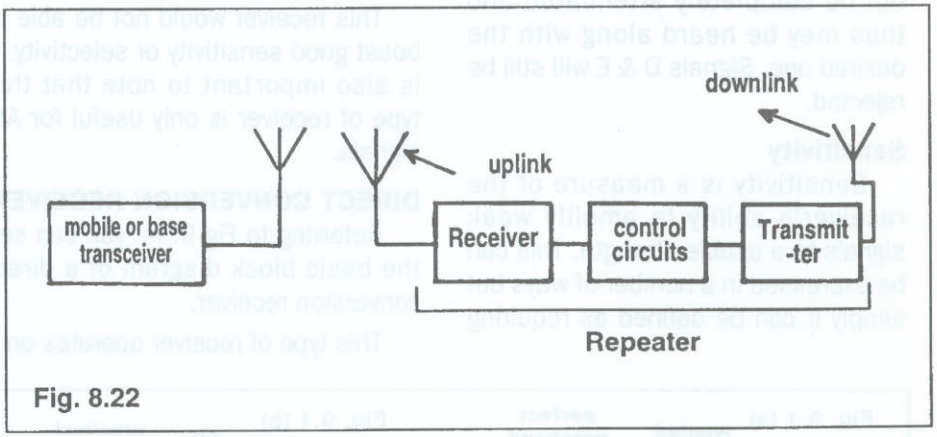


Fig. 8.22

chapter nine

RECEIVERS

Having covered the various ways in which signals can be modulated, e.g:- AM, CW, SSB and FM, we now need to look at how the signal is received and the original modulation recovered.

A receiver has to amplify signals as low as a few tenths of a microvolt in the presence of adjacent signals which are sometimes hundreds or thousands of times stronger. As well, there is the problem of noise - both man-made and atmospheric. To receive successfully, it has to excel in two main characteristics:- Selectivity and Sensitivity.

Selectivity

Selectivity is the ability of a receiver to accept a signal on a desired frequency and to reject all others.

Fig 9.1a shows a signal "A" to which the receiver is tuned. Signals B & C are immediately adjacent and should be rejected by the receiver. However, the shape of this receiver's passband is an ideal or perfect one which is difficult to achieve in practice. In Fig 9.1b we have a somewhat more realistic receiver response curve . Signals B & C will not be completely attenuated and thus may be heard along with the desired one. Signals D & E will still be rejected.

Sensitivity

Sensitivity is a measure of the receiver's ability to amplify weak signals to a usable strength. This can be expressed in a number of ways but simply it can be defined as requiring so many microvolts of signal to produce a specified output.

THE CRYSTAL SET

This is the most basic of all receivers and the circuit of one is shown in Fig 9.2a. The function of the aerial is to intercept signals. The tuned circuit C1/L1 selects the desired signal. D1 and C2 are the detector circuit. The detector's function is to demodulate the intelligence from the transmission being received and to pass the recovered audio to the headphones. The function of the headphones is to reproduce the original transmitted sound.

The receiver shown in Fig 9.2b would perform better than the one shown in Fig 9.2a. The reason for this is that the taps on L1 allow the impedance of the aerial to be more closely matched to that of the tuned circuit.

Also, the detector diode - usually a germanium type, has relatively low impedance when connected to the headphones and should be tapped to a low impedance point on L1. This will minimise the loading effect upon the tuned circuit caused by the low impedance of the headphones.

This receiver would not be able to boast good sensitivity or selectivity. It is also important to note that this type of receiver is only useful for AM signals.

DIRECT CONVERSION RECEIVER

Referring to Fig 9.3a, you can see the basic block diagram of a direct conversion receiver.

This type of receiver operates on a very simple principle. Let's assume we wish to hear a signal on 10 MHz. If we adjust the frequency of the oscillator so that it injects exactly 10MHz into the mixer, then the output of the mixer will be the audio (AF) modulation sent by the distant transmitter. If we alter the oscillator to 9.999MHz the output of the mixer will change to 1KHz.

Or, if we leave the oscillator tuned to 10 MHZ, and the signal changes to 9.999 MHz, then of course 1 KHz will be fed to the AF amplifier.

This receiver uses the "heterodyne" or mixing principle for its operation. If for instance, the incoming signal is an unmodulated carrier at 10 MHz and the oscillator is set to exactly 10 MHz then the output of the mixer will be zero. Now if we alter the oscillator to 1 KHz above or below the incoming carrier signal as shown in Fig 9.3b, the output of the mixer will be a 1 KHz tone. This would be useful for detecting morse code (CW) signals.

(The direct conversion receiver cannot be used to effectively receive AM signals.)

The AF amplifier will then

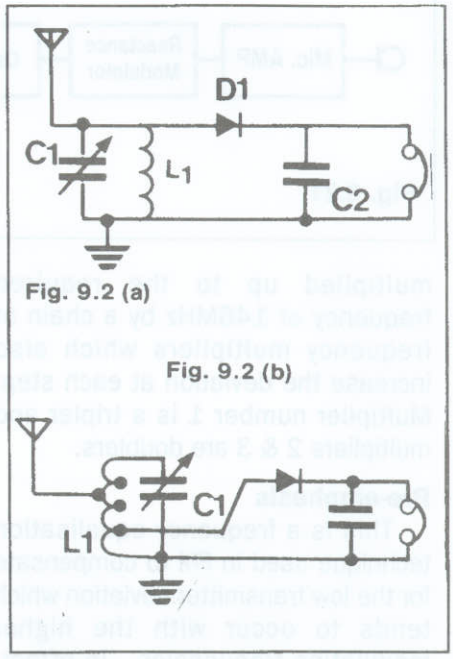
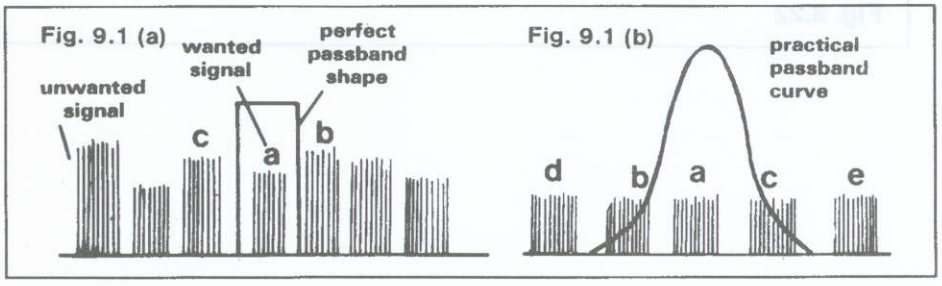


Fig. 9.2 (a)

Fig. 9.2 (b)



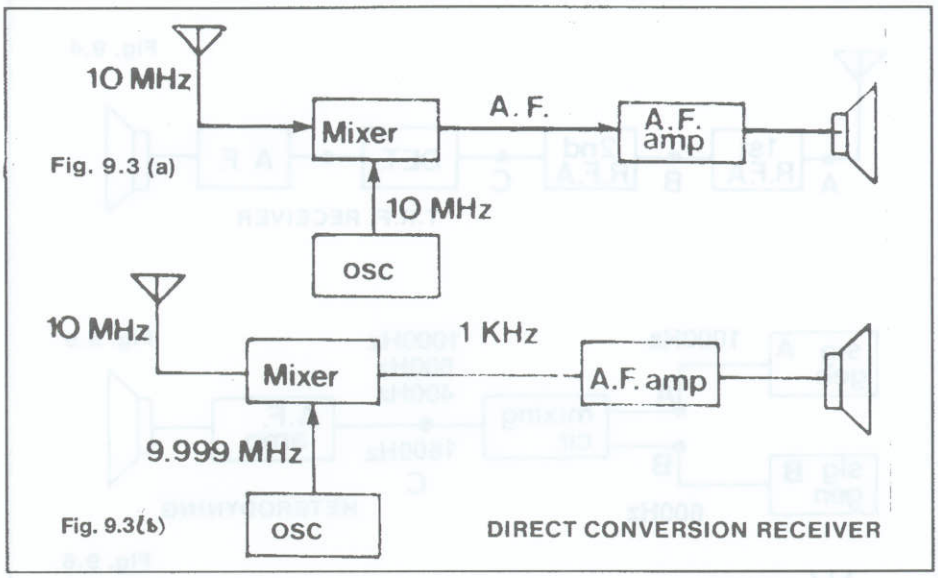


Fig. 9.3 (a)

Fig. 9.3(b) DIRECT CONVERSION RECEIVER

sufficiently boost the level of this signal to drive a loudspeaker or headphones. This type of receiver is really a simple design and therefore lacks some refinements such as Automatic gain control (AGC) and RF gain control.

The principle of this receiver has some similarities with the superheterodyne receiver design.

THE TRF RECEIVER

TRF means "tuned Radio Frequency". This type of receiver- (shown in Fig 9.4)- which was very popular in early valve radio days, (some solid state versions have been manufactured) uses a number of tuned amplifiers all set to the frequency of the incoming signal. The sensitivity and selectivity is determined by the number and quality of the RF amplifiers.

The detector then demodulates the signal and the resulting AF is amplified by the audio amplifiers and fed to the headphones or speaker.

This receiver would most likely have tuned circuits at points A, B & C. This would result in quite reasonable selectivity and sensitivity. The TRF principle , although not very common now has been used in HIFI tuners and some small transistor pocket size radios for its good fidelity of reproduction.

The disadvantages of the design are that it requires multi-ganged tuning capacitors and that each tuned circuit must "track" correctly. This means that each tank circuit must tune to exactly the same frequency as all others and this can be difficult to achieve in practice.

Also, having a number of RF amplifiers in a chain all tuned to the same frequency can lead to instability and possible oscillation of the entire receiver.

THE SUPERHETERODYNE RECEIVER.

Commonly called the superhet., this receiver uses a similar principle to the direct conversion RX. - (RX being a common abbreviation for receiver).

The heterodyne (or mixing) process:-

In Fig 9.5 we have connected two AF signal generators (A and B)operating on different frequencies into a mixing circuit. The frequency of sig gen A is set at 1000 Hz and B is set at 600 Hz.The output of the mixer is fed via an AF amplifier to a speaker. The output of this mixer will have two signals - 400 Hz (the difference frequency) and 1600 Hz (the sum frequency). If we should add a low pass filter at point "C" in Fig 9.5 we could reject the sum frequency of 1600 Hz and pass just the difference frequency of 400 Hz through to the speaker.

Now if the frequency of signal generator 'B' is slowly raised above 600 Hz, the output of the mixer will begin to fall below 400 Hz. When the frequency of signal generator 'B' reaches 1000 Hz, the output of the mixer will fall to zero- this is known as 'zero beat' and is similar to the situation described with the direct conversion receiver.

Well, after all this description, the principle of the superhet RX has been basically illustrated but it operates at RF rather than AF as discussed above.

The block diagram of a superhet RX is shown in Fig 9.6. All incoming signals are heterodyned down to one common frequency and this is known as the Intermediate Frequency or 'IF'.

Assume we wish to hear a signal on 10MHz. The aerial circuit at point 'A' will be tuned to 10MHz and at the same time the local oscillator will be tuned to 10.455 MHz. This is done by simultaneously tuning the oscillator tank circuit 'G' and the aerial tank circuit 'A' to their respective frequencies. The two tuning capacitors are coupled together on the one shaft and this known as a two gang capacitor. The oscillator tank circuit is designed to always tune 0.455 MHz above or below the signal frequency. The result is that the signal at point 'B' -the mixer output- will be the desired signal but it has been frequency 'translated' down from 10 MHz to the IF of 455 KHz. (Note:-0.455 MHz = 455 KHz)

If a careful analysis of the frequencies present at point 'B' is made, we would find these frequencies:-

(i) 10MHz - the original signal frequency

(ii) 10.455 MHz - the oscillator output

(iii) 0.455 MHz - the difference signal (which is the desired IF)

(iv) 20.455 MHz - the sum signal

The 3rd signal (the IF) is the desired signal to be processed further by the RX.

The RX circuit has a low pass filter at point 'B' which rejects all other signals except the IF. In fact there is a further filter at 'C' which is also tuned to 455 KHz. Now this is where the main advantage of the superhet RX lies:- the signal processing is all done at the IF once it is past the mixer, so all circuits and amplification can be optimised at one single known frequency. (the IF)

Most of the RX's selectivity and sensitivity is achieved within the IF stages. Most RXs would have at least 2 or 3 IF stages to produce good selectivity and sensitivity.

To improve its performance, a Rx may have one or two RF amplifier stages.

Fig 9.7 shows a RX having an RF stage and two IF stages. Note the frequency at each stage when the Rx is tuned to a 3.5 MHz signal.

The tuned circuits at points 'D', 'E' & 'F' are known as IF transformers (IFTs) and are all carefully tuned to the RX's IF which in this case is 455 KHz.

*This is a very commonly used IF as it is internationally agreed upon by Radio Communications Agencies.

It is thus kept clear of transmitters so that Rx performance is not degraded.

A superhet could use a lower or a higher IF, in fact, IFs as low as 50 KHz have been used and 1.6, 3, 9 and 10.7 MHz have been used in various designs. Other IFs are possible of course.

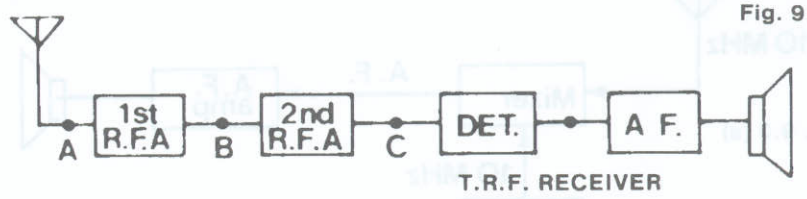
The RX in Fig 9.7 will have no output from its speaker as it is receiving a carrier only.

However, if we were to add another oscillator operating at 454 or 456 KHz and injected its signal into the detector, we would produce a 1KHz tone at the speaker. Now if the 3.5 MHz signal was CW, the RX would give a tone output corresponding with the morse code being sent.

This oscillator is called the BFO (Beat frequency Oscillator). Addition of the BFO to an AM receiver makes it possible to receive CW and SSB.

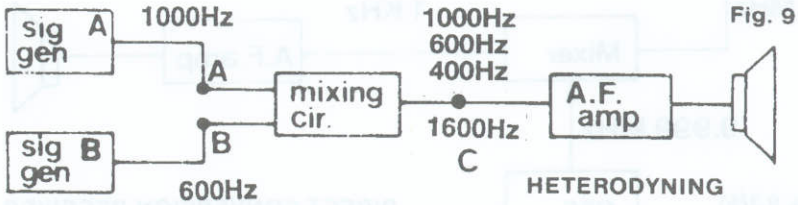
For CW, the BFO produces a tone output to make the morse easily recognisable and for SSB the BFO signal actually provides the carrier needed to detect the signal.

Fig. 9.4



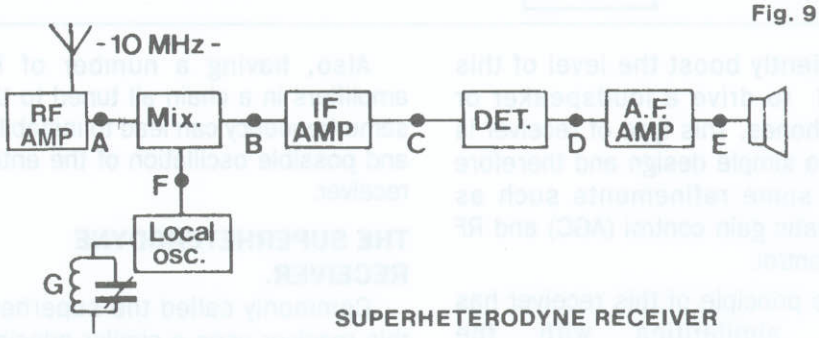
T.R.F. RECEIVER

Fig. 9.5



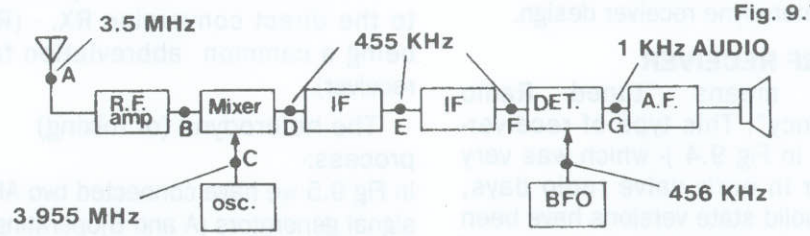
HETERODYNING

Fig. 9.6



SUPERHETERODYNE RECEIVER

Fig. 9.7



AGC

Looking further into the receiver's circuits we would find an AGC system. This is the Automatic Gain Control System. AGC is used to regulate the amount of amplification in the RF and IF stages . As a signal becomes stronger the AGC system reduces the RX gain and as the signal becomes weaker it allows the Receiver to amplify more (or increase its gain). The result is that the audio output of the receiver remains fairly constant over a wide range of signal strengths. This compensates to a large extent, a distant signal which is cyclically fading up and down in strength.

Fig 9.8 shows a block diagram of the AGC system.

The AGC system is basically a rectifier, filter and time constant DC control system that produces a DC control voltage which is proportional to the received signal strength. With no (or a very weak) signal the receiver's AGC opens up and allows the RX to operate at its maximum designed amplification.

A SUMMARY OF SUPERHET RECEIVER STAGES AND THEIR FUNCTION

RF stage

this amplifies the signal before it reaches the mixer and provides some extra selectivity and sensitivity over a receiver without such a stage. The RF stage also assists with some image rejection. (more on this later)

An RF stage helps to mask mixer noise to some extent and thus improves the RX's signal to noise ratio.

the mixer

the function of this stage is to mix the incoming signals with the local oscillator signal to produce an IF signal. (the mixer is sometimes called the converter or first detector)

the oscillator

this has to provide a signal for the mixing process. It must "track" exactly above or below the signal frequency by an amount equal to the IF. It must be a very stable oscillator or the Rx will suffer from drift, making it difficult to stay on the desired frequency. Ideally the oscillator signal should be a clean sine wave signal free of harmonics for best receiver performance.

The IF stages

These provide most of the gain (amplification) and selectivity of the receiver. The more amplification -the better the sensitivity.

The IF is chosen to provide a compromise between selectivity and a high level of stable amplification. (as well, the IF will determine the amount of image rejection -more on this shortly.)

The detector

This stage has to demodulate the signal so that the original modulating intelligence is recovered .

Fig 9.9a shows a typical diode detector circuit. Fig 9.9b shows a product detector circuit which is used to detect CW and SSB signals.

AGC system

The AGC system is used to compensate for signal strength variations due to fading and mobile conditions as well as different strengths of stations in a net . Without AGC the operator would be constantly changing the AF or RF gain controls on the Receiver to keep an acceptable level of audio from the speaker or headphones.

The AF Amplifier

This section of the RX may consist of a number of transistor amplifiers or a single IC. Its job is to take the output from the detector and raise it to a suitable power level to drive the headphones or speaker.

The BFO

This is an oscillator tuned very close in frequency to the IF and is used to provide a beat note for CW signals and to provide the missing carrier from SSB signals. If the BFO frequency is not correct it will cause an SSB signal to sound unnaturally high or low-pitched. Some BFOs are crystal controlled, making them very stable.

IMAGE SIGNALS

To illustrate image signals, let us look at a Receiver tuned to 14.1 MHz and having an IF of 455 kHz.(0.455 MHz). Fig 9.10 shows the block diagram of this receiver.

The aerial tuned circuit is set to 14.1 MHz and the oscillator is set to 14.1 + 0.455 = 14.555 MHz

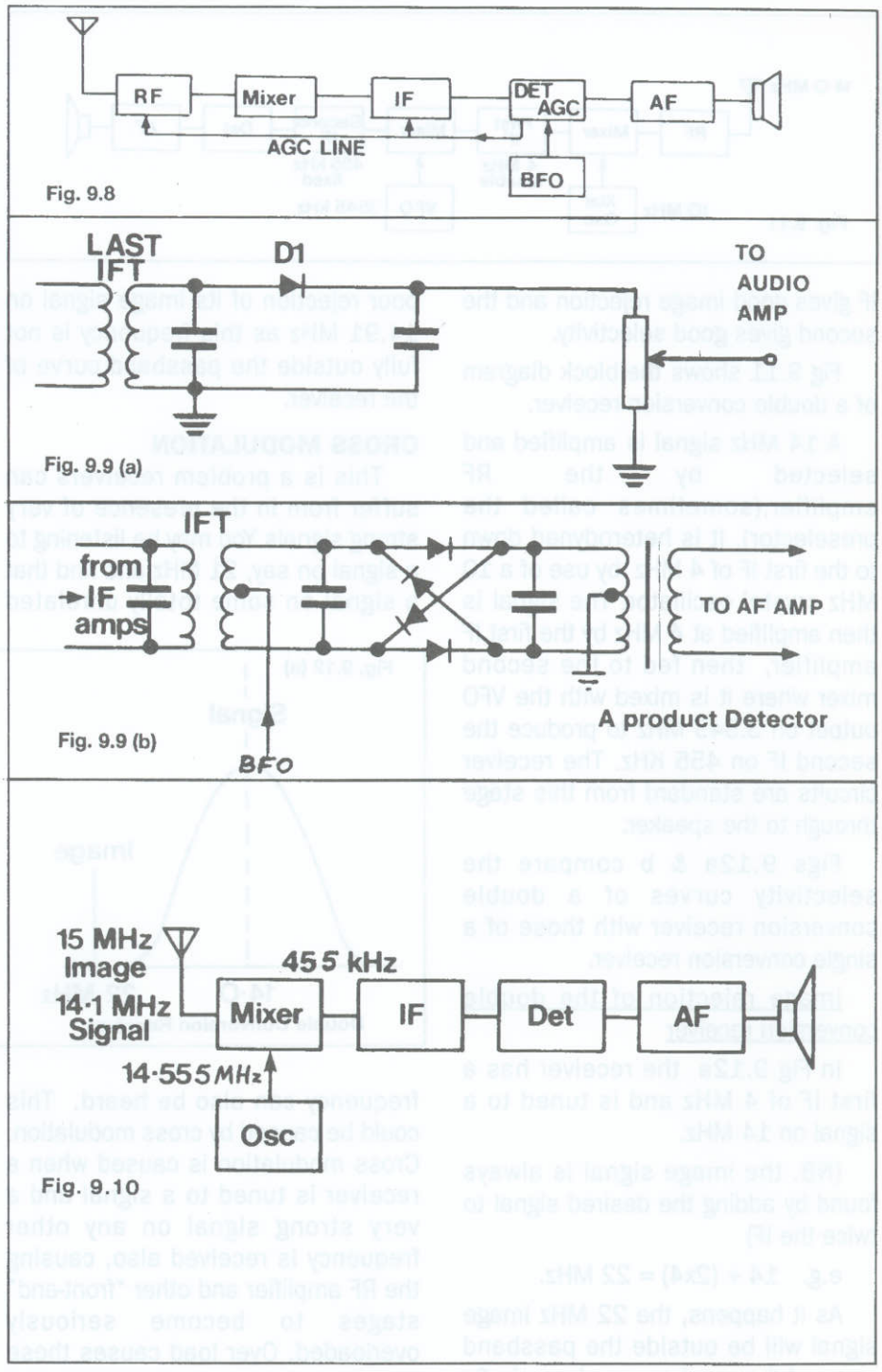


Fig. 9.8

Fig. 9.9 (a)

Fig. 9.9 (b)

Fig. 9.10

This will give an output from the mixer to the IF amplifier of 0.455 MHz.

Now if a strong signal (the image signal) at 15.01 MHz is present on the aerial, it will suffer slight attenuation (because the aerial tuned circuit is set to 14.1 MHz), it will pass to the mixer and be mixed with the signal from the oscillator. Thus 15.01-14.555 = 0.455 MHz

*And so we can see that this unwanted signal (called the Image) is able to be mixed down to the IF and it will be processed through the receiver to the speaker. So we now have two signals being heard in the speaker! - the desired signal and the image.

If the receiver has an RF stage it will have better image rejection due to extra tuned circuits but a strong image will not be entirely rejected.

The superhet receiver is used in TVs, Radars, Satellite systems, MF, HF ,VHF and UHF communication systems.

Double conversion receiver

To overcome the image response problem, two IF s are used in more advanced receivers . The first IF is high and the second is lower. The first

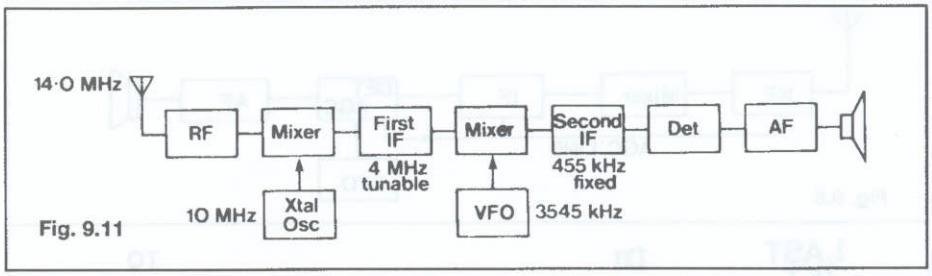


Fig. 9.11

IF gives good image rejection and the second gives good selectivity.

Fig 9.11 shows the block diagram of a double conversion receiver.

A 14 MHz signal is amplified and selected by the RF amplifier,(sometimes called the preselector). It is heterodyned down to the first IF of 4 MHz by use of a 10 MHz crystal oscillator. The signal is then amplified at 4 MHz by the first IF amplifier, then fed to the second mixer where it is mixed with the VFO output on 3.545 MHz to produce the second IF on 455 KHz. The receiver circuits are standard from this stage through to the speaker.

Figs 9.12a & b compare the selectivity curves of a double conversion receiver with those of a single conversion receiver.

Image rejection of the double conversion receiver

In Fig 9.12a the receiver has a first IF of 4 MHz and is tuned to a signal on 14 MHz.

(NB. the image signal is always found by adding the desired signal to twice the IF)

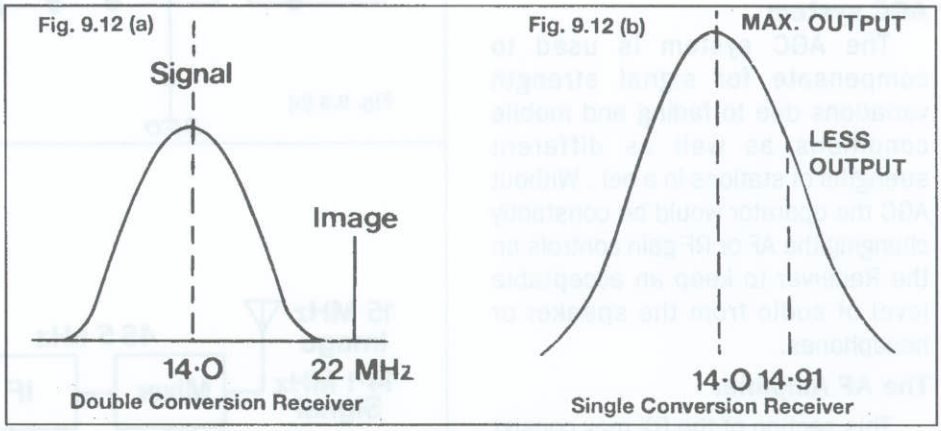
e.g. 14 + (2x4) = 22 MHz.

As it happens, the 22 MHz image signal will be outside the passband curve of the receiver as shown in fig 9.12a.

In Fig 9.12b you can see that the single conversion receiver will have poor rejection of its image signal on 14.91 MHz as this frequency is not fully outside the passband curve of the receiver.

CROSS MODULATION

This is a problem receivers can suffer from in the presence of very strong signals.You may be listening to a signal on say, 21 MHz and find that a signal on some totally unrelated frequency can also be heard. This could be caused by cross modulation. Cross modulation is caused when a receiver is tuned to a signal and a very strong signal on any other frequency is received also, causing the RF amplifier and other "front-end" stages to become seriously overloaded. Over load causes these stages to become non-linear and instead of just amplifying, they become mixers. And so the very strong unwanted signal 'cross-modulates' the wanted signal. The result can be very confusing and also very distorted. The remedy is to reduce the RF gain control setting or insert a resonant wave trap in the antenna circuit to reject a specific unwanted frequency.



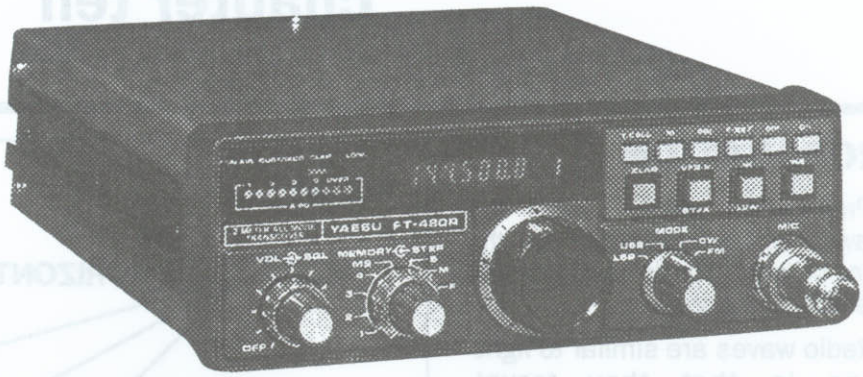
Controls

Refer to the receiver photograph for details on all common controls on a receiver and their functions.

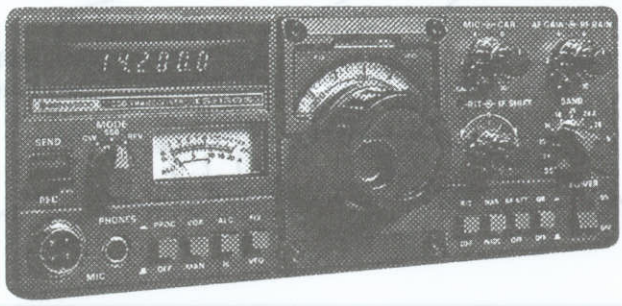
TRANSCEIVERS

A transceiver combines a receiver and a transmitter into the one unit. There are a number of stages in each which are common and so components and space are saved by preventing duplication .There is also a saving in cost overall as the two units - a receiver and a transmitter- would most probably be more expensive than the one transceiver. The stages common to both are :- sideband oscillators, mixing oscillator, IF amplifiers, and VFO.

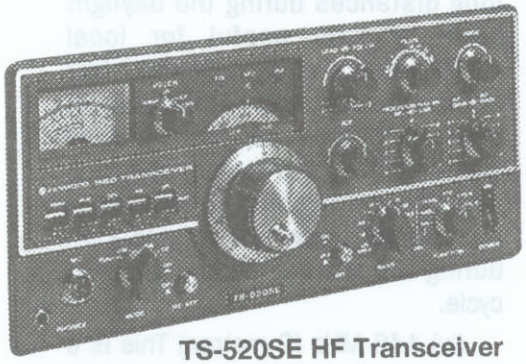
Some typical transceivers and their control functions



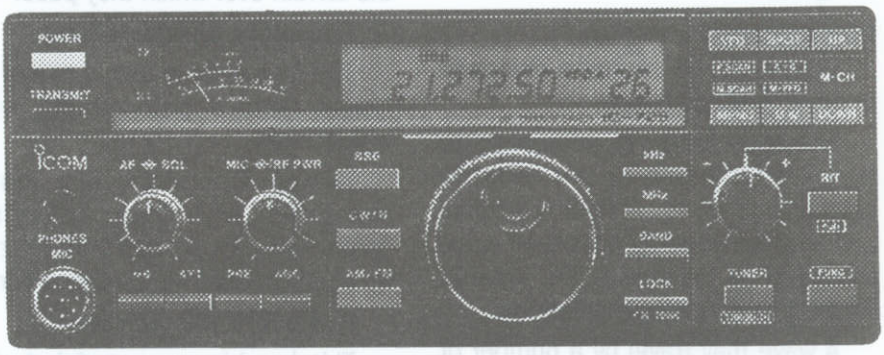
FT-480R 2 metre Transceiver



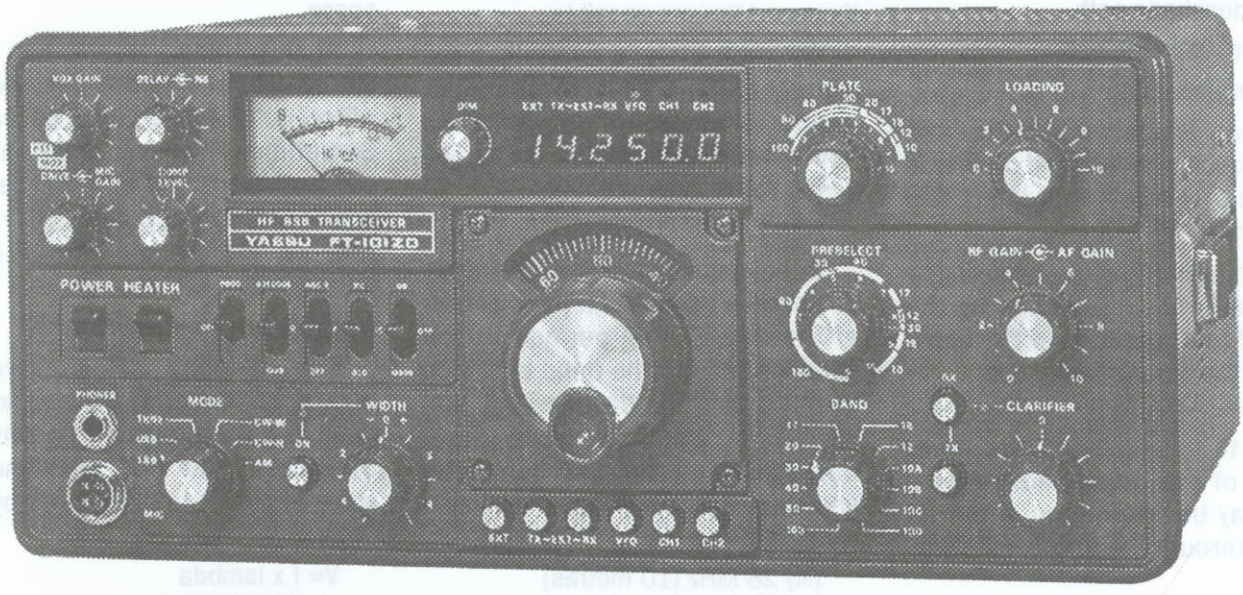
TS-130S HF Transceiver



TS-520SE HF Transceiver



IC-725 HF Transceiver



FT-101ZD HF Transceiver

chapter ten

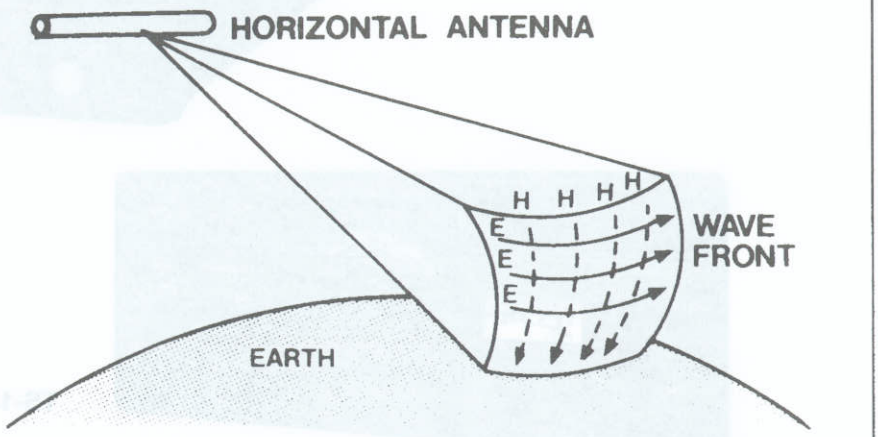
PROPAGATION

Propagation deals with the behaviour of the Ionosphere and the means by which signals travel from the transmitter to the receiver.

Radio waves are similar to light waves in that they travel at 300,000,000 metres ($300x10^6$metres/Sec.) per second in free space. They tend to travel in straight lines unless passing through differing media.

A radio wave consists of two main components - a magnetic component (H) and an electric (E) component. These two components are at right angles (90^0) to each other as shown in Fig 10.1.

Fig. 10.1



Polarisation

Waves can be vertically polarised or horizontally polarised.

The polarisation is referenced to the E or electric field. So in a vertically polarised wave, the E field is vertical and in a horizontally polarised wave the E field is horizontal. The wave in Fig 10.1 is horizontally polarised.

A wave may travel by a number of alternate paths from the transmitter to the receiver :-

(i) free space path

(ii) Ionospheric path

(iii) Tropospheric path

(iv) Ground path

(i) Free space path - the main consideration with this kind of wave is distance . It travels in a direct line from point to point.

(ii) Ionospheric -waves travelling by this means are influenced by the action of free electrons in the upper levels of the earth's atmosphere.

(iii) Tropospheric waves are subject to deflection in the lower regions of the atmosphere where there may be variations in the air layers through which the wave passes.

(iv) Ground waves are affected by the terrain over which they pass.

Frequency Considerations

The frequency in use is one of the major factors determining wave propagation.

Novice Operators are mainly concerned with their authorised bands:- 3.5, 21, 28 and 146 MHz, so we shall concentrate on these bands.

(i) 3.5 MHz (80 metres)

This band is more useful at night than by day.

Daytime distances are rarely better than 300 Km but at night several thousand Km are possible.

80 metres is a reliable band throughout the year and sunspot cycle. However, it is prone to atmospheric noise in the tropics and during thunderstorm activity.

(ii) 21 MHz (15 metres)

During peaks of the sunspot cycle this band is useful during a large part of the day. During periods of low sunspot activity, the band becomes useful during the daytime only and may even then be quite poor. Openings on this band will be shorter and shorter as the sunspot minimum is neared.

(iii) 28 MHz (10 metres)

This band is usually capable of long distances during the daylight hours and is useful for local communication at night for about half of the sunspot cycle. At the peak of the sunspot cycle, this band may be good for DX (long distance) operation well into the evening. This band is usually very poor for propagation during the low part of the sunspot cycle.

(iv) 146 MHz (2 metres) This is a VHF band and tends to propagate via direct wave or by Tropospheric ducting. VHF waves tend to penetrate the ionosphere and are lost out in space.

Most common propagation is by line-of-sight and hills and mountains will cut out direct paths in most cases. Sometimes, however, over sharply defined hilltops, the wave can be bent downwards into the next valley and this is known as "knife edge diffraction".

VELOCITY OF A WAVE

The velocity of a wave is 300,000,000 metres per second and there is a fixed relationship between the velocity, the frequency and the wavelength. It is expressed by the formula :-

V= f x lambda

where V is the velocity in metres/

second, f is the frequency in Hz and Lambda is the wavelength in metres.

Example 1. What is the wavelength of a wave having a frequency of 10 MHz ?

Transposing the formula we get -

$$\text{Lambda} = V/f$$

therefore

$$\text{Lambda} = 3 \times 10^8 / 10 \times 10^6$$

$$\text{Lambda} = 30 \text{ metres}$$

Example 2. what is the frequency of a wave having a wavelength of 40 metres?

transposing the formula we get -

$$f = V/\text{lambda}$$

$$= 3 \times 10^8 / 40$$

$$= 7\,500\,000 \text{ Hz}$$

$$= 7.5 \text{ MHz}$$

THE IONOSPHERE

Amateur Radio communication on the HF bands is probably via sky wave propagation for medium to long distances. The Ionosphere consists of four layers or regions in the Earth's upper atmosphere. Fig 10.2 shows the earth's atmosphere and the approximate altitudes of the layers.

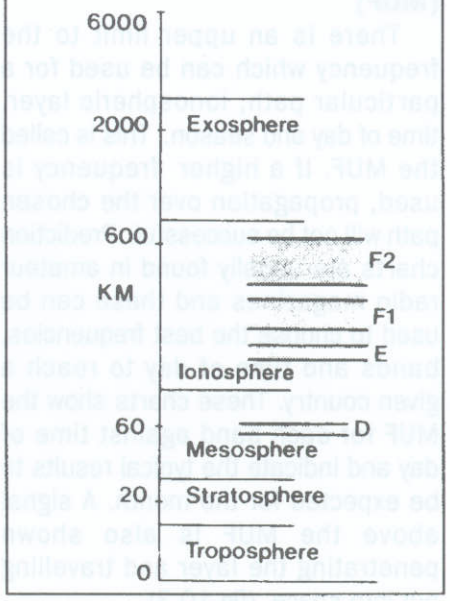
Within each layer there are electrons and ions of gases which can be ionised by radiations from the Sun. These layers vary in height and density hourly, daily, monthly and seasonally over the year. As well, the state of the Ionosphere varies on an 11 year cycle caused by variations in radiation from the sun.

The D layer is closest to the earth and has the highest level of ionisation during the day. After sunset, it rapidly deionises and disappears. During the day, this layer tends to absorb radio emissions - especially those at 1.85 and 3.5 MHz and thus range is quite attenuated .

The E layer is the next highest and is less dense being higher. Ionisation is greatest at mid-day and the layer disappears quickly after sunset. During some seasons, the E layer may have some highly localised areas of intense ionisation which is known as "Sporadic" E layer. This can provide good communications between specific places and on certain frequencies.

The F layer is the one responsible for most of the long distance HF communications. As it is the least dense layer, it deionises slowly and is at minimum just before sunrise. In the daytime, this layer splits into the F1 and F2 layers. The two layers are about 260 Km apart and merge again at sunset. Single hop sky wave propagation is typically 4000 Km via the F layer.

Fig. 10.2



Sky wave propagation

A radio wave may travel quite long distances via sky wave propagation. As the wave from the transmitter reaches the ionospheric layer, it is bent (refracted) and is curved back towards the earth. Eventually the wave will reach back to the surface of the earth if it is suitably refracted. If the frequency of the wave is high enough or the ionosphere is not ionised sufficiently, the wave may

Fig. 10.3

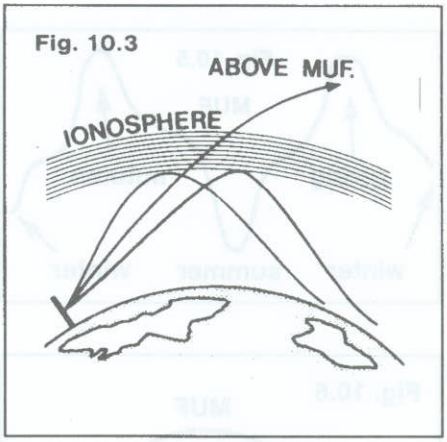


Fig. 10.4 (a)

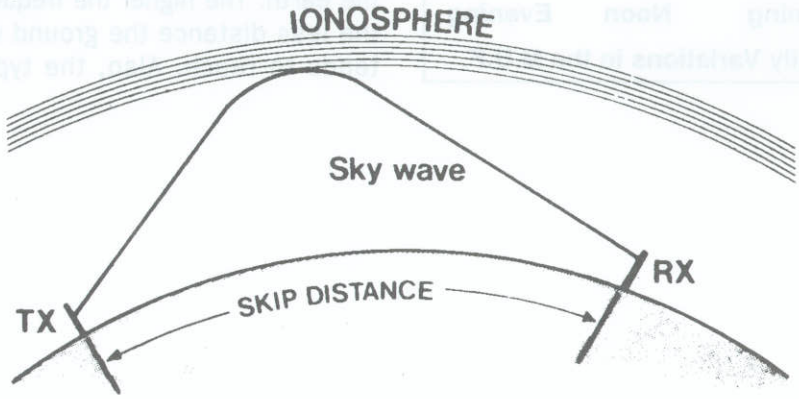
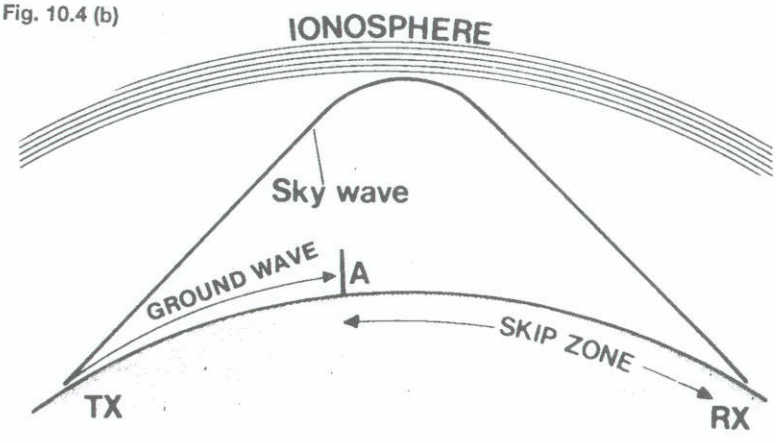


Fig. 10.4 (b)

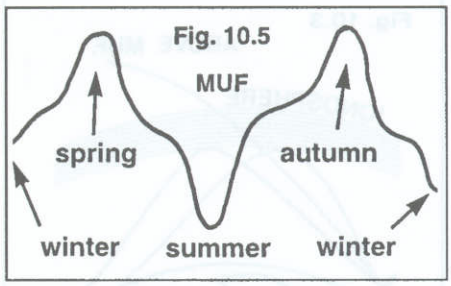


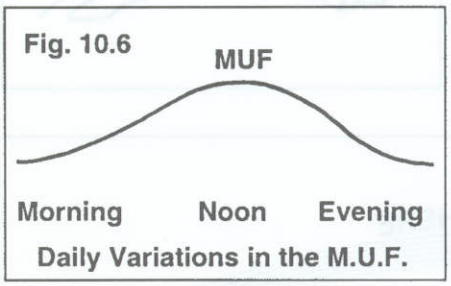
pass straight through and be lost out in space.Refer to fig 10.3 for sky wave refraction.

Skip distance

The distance along the surface of the earth between the transmitter and the first return to earth is known as the Skip Distance.

In the region between the extremity of the ground wave and the first return of the sky wave there is a zone where the signal is not heard. This is called the Skip Zone. Fig 10.4 shows the skip distance and the skip zone.





Maximum Usable frequency (MUF)

There is an upper limit to the frequency which can be used for a particular path, ionospheric layer, time of day and season. This is called the MUF. If a higher frequency is used, propagation over the chosen path will not be successful. Prediction charts are usually found in amateur radio magazines and these can be used to choose the best frequencies, bands and time of day to reach a given country. These charts show the MUF for each band against time of day and indicate the typical results to be expected for the month. A signal above the MUF is also shown penetrating the layer and travelling out into space. (fig 10.3)

Fig 10.5 shows how the MUF varies over the year.

Fig 10.6 shows how the MUF varies over the day.

Ground waves

A radio wave will have a ground wave component which will travel out to certain distances from the antenna. The ground wave is that part of the wave affected by the surface of the earth. The higher the frequency, the less distance the ground wave tends to reach. Also, the type of antenna used will affect to some extent the amount of sky and the amount of ground wave which is radiated . The height of the antenna is another factor to be considered. Paths over salt water will extend the ground wave.

FADING

Signals are often subject to fading due to variations in propagation conditions . The paths that a signal may follow can be varying and complex so fading can and does occur. The receiver may experience wide variations in signal strength at a slow or a fast rate. One cause of this is that the wave has split into a combination of single and multi hop paths as it passes through the ionosphere. As these waves re-combine at the receiver, they may be in phase one moment and out of phase the next thus either adding-to or subtracting-from each other. The combination of a ground wave with a sky wave may also lead to fading of a signal.

Fading may be rapid -like a flutter - or it may be quite slow . It may be shallow in nature or it may be so deep that the signal disappears for periods.

chapter eleven

ANTENNAS AND TRANSMISSION LINES

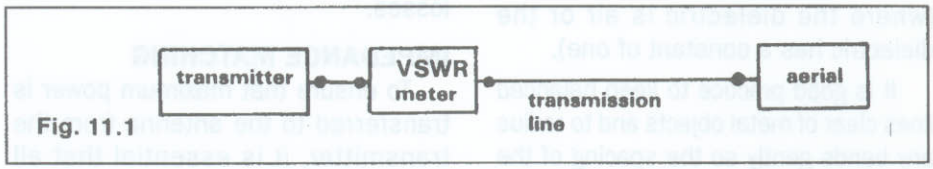


Fig. 11.1

Transmission lines

A vital link in any communications system is the antenna and transmission line. (Transmission lines are often called feedlines as they feed the RF power from the transmitter to the antenna).

The objective is to convey all the power from the transmitter with minimal loss to the antenna where it is radiated out to other stations. This is called 'maximum power transfer'.

A typical amateur installation is shown in Fig 11.1.To achieve maximum radiated power from the antenna it is necessary to ensure that impedances are correctly matched at all points in the system. Thus if the antenna has an impedance of 50 Ohms, then the feedline must have either the same impedance or be coupled via a matching device. Similarly the transmitter must be correctly matched to the feedline. Transmitters can be damaged if they are not correctly matched to the feedline or if the antenna is not matched properly to the feedline.

In fact, many transmitters will put out less power if there is a mismatch in impedance in the system, leading to eventual shutdown if the mismatch is serious.

There are two main types of feedline in common use by amateurs. These are the coaxial cable and the open wire line.

Coaxial lines

These are known as unbalanced lines as one conductor is earthed (the outer braid) and the other (the centre conductor) is above earth potential.

Referring to Fig 11.2, a coaxial cable (usually called coax) consists of an insulated inner conductor which is surrounded by an outer conductor usually called the braid. Then there is a weatherproof outer covering called the sheath. The insulation separating the inner conductor from the outer is often called the dielectric and most commonly is made from polyethylene (usually shortened to polythene).

The centre conductor is either single strand or multi stranded and is most commonly made from copper. The outer conductor is usually copper braid but may be aluminium or even copper tube.

Coaxial cables have typical characteristic impedances ranging from 36 ohms to 100 ohms. The most common impedances used in amateur radio are 50 and 75 ohms with 36 ohms for mobile quarter wave roof-mounted installations.

This impedance is determined by the physical dimensions of the cable.

Zo , (the characteristic impedance) is found by the formula -

Zo = 138 log b/a

where (a) is the outside diameter of the of the inner conductor , and (b) is the inside diameter of the outer conductor. (This assumes that the dielectric constant is one.)

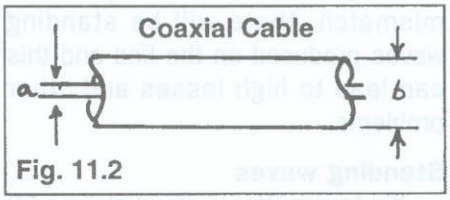


Fig. 11.2

Coaxial cable does suffer from the weather, so it should be protected wherever possible and sealed against moisture entry. Bends should be smooth and not too sharp. It is not good practice to coil up any excess length - the excess should be spread out straight or cut off. The outer conductor (or braid) is usually earthed and this gives a high degree of shielding from interference.

Balanced lines

Fig 11.3a shows a very familiar transmission line - 300 ohm TV ribbon. A balanced line consists of two parallel conductors spaced apart by a dielectric. [Telephone cables (the old type on poles) have an impedance of 600 ohms.] Feedlines used at high power short wave stations usually have an impedance of 300 or 600 ohms in practice. Amateurs do use 300 ohm TV ribbon in some cases and can build their own balanced lines by making up insulating spacers and assembling a length of line in the manner as shown in Fig 11.3b.

The lowest loss lines have air as the dielectric, so balanced lines with air dielectric are very efficient lines.

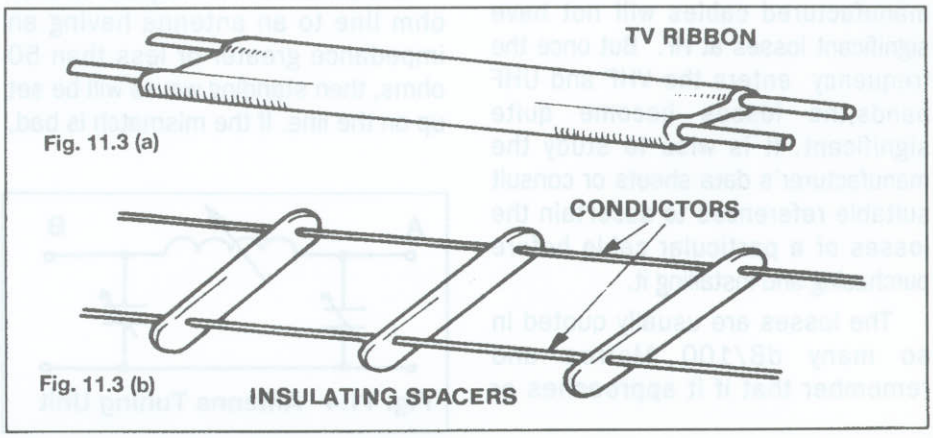


Fig. 11.3 (a)

Fig. 11.3 (b)

The characteristic impedance of balanced lines is found by the formula:-

$Zo = 276 \log b/a$

where a is the radius of the one of the conductors, and b is the centre-to -centre spacing of the conductors. (where the dielectric is air or the dielectric has a constant of one).

It is good practice to keep balanced lines clear of metal objects and to radius any bends gently so the spacing of the line does not change. It is also not good practice to coil up any excess balanced line. It should be cut just to the length needed.

exceeds 3dB per hundred metres, and you have a long run of cable at 146 MHz, then the losses can be quite high.

It is also good practice to use the best possible quality connectors for VHF antenna feedlines to minimise losses.

IMPEDANCE MATCHING

To ensure that maximum power is transferred to the antenna from the transmitter, it is essential that all impedances in the feedline system are correctly matched.

For example, if the transmitter has an output impedance of 50 ohms, ideally it should be coupled to 50 ohm transmission line and the input impedance of the antenna should be 50 ohms.

The usual problem is that not all antennas are 50 ohms at their feedpoint, however it's easy enough to match the transmitter to 50 ohm coaxial cable at the shack end of the system !

If there is an impedance mismatch, there will be standing waves produced on the line and this can lead to high losses and other problems.

TABLE 11.1

line	Velocity Factor	Impedance (ohms)
RG 58 AU	0.66	53
RG 59A-AU	0.66	73
RG 59 Foam Dielectric	0.79	75
RG 8/A-AU	0.66	52
300 ohm twin line	0.82	300
open wire	0.92	various

Velocity factor

The velocity of a radio wave in free space is 300,000,000 metres per second but when a wave is propagated via a feedline such as coax or twin line , depending upon the dielectric, the velocity of the wave is slowed down.

The velocity factor in vacuum or air is 1 but if polythene is used it changes to 0.66.

Table 11.1 shows some typical velocity factors for commonly used feedlines.

Line loss

Coaxial cable has losses which rise with frequency. These losses are mainly caused by the dielectric type. Most well-manufactured cables will not have significant losses at HF. But once the frequency enters the VHF and UHF bands,the losses become quite significant. It is wise to study the manufacturer's data sheets or consult suitable references to ascertain the losses of a particular cable before purchasing and installing it.

The losses are usually quoted in so many dB/100 Metres and remember that if it approaches or

Standing waves

If a transmitter is coupled via a 50 ohm line to an antenna having an impedance greater or less than 50 ohms, then standing waves will be set up on the line. If the mismatch is bad, the standing waves may cause damage to the transmitter, so it is most important to correctly match the entire radiating system to the transmitter. It's also in your best interests to have the system properly matched as you want every watt in the transmitter radiated by the antenna for best signal reports.

A properly matched system will not have standing waves and is said to be be "flat", that is no standing waves evident on the line, so if you were to insert an RF current meter in the line it would read the same value at any point. As well, if you were to put an RF voltmeter across the line it would read the same voltage at any point.

Now if the antenna was not matched to the line, standing waves would be set up and you would be able to see current maxima and minima at different points along the line. Also, if you were to measure the RF voltage at different points along the line, each reading would be different.

The ratio of voltage maximum to minimum is called the Voltage Standing Wave Ratio (VSWR). This is usually measured by a Standing Wave Ratio Bridge (or SWR Bridge).

Matching systems

To enable you to correctly match the antenna to the feedline there are a number of devices available:-

(i) Antenna Tuning Unit, (ATU) and (ii) the Balun.

(i) An ATU circuit is shown in Fig 11.4 . The principle of the ATU is to provide variable inductors and capacitors to 'tune out' any reactance in the line which is not resistive.

This ATU circuit is not the only configuration possible but it is a most universal type and allows many impedance mismatches to be corrected. It is known as the pi-coupler type as it resembles the Greek letter Pi . Basically it is a low pass filter and this has advantages in suppressing harmonic interference too, so there is a bonus in using an ATU like this. It can be connected in the line near the transmitter and is tuned to give the lowest SWR as indicated on an SWR Bridge. (See Fig 11.5 for the typical connection of

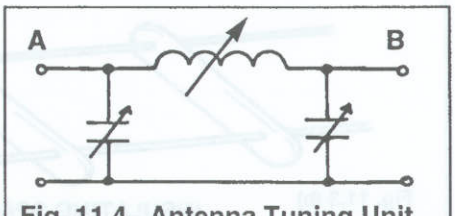


Fig. 11.4 Antenna Tuning Unit

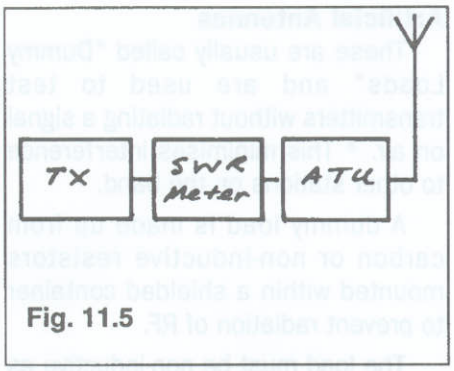


Fig. 11.5

transmitter, ATU and SWR bridge.)

(ii) Baluns

A balun is an RF transformer used to impedance-match antennas. It consists of a Ferrite toroid or rod wound with enamelled wire to give a match between the coaxial cable and the antenna. Because the dipole antenna is a balanced antenna and coaxial cable is unbalanced the 1:1 Balun (BAL anced to UN balanced) provides a means to couple the feedline to the antenna without disturbing the radiation pattern of the antenna.

Antenna changeover relays

Fig 11.6 shows the circuit of an antenna changeover relay. These are needed to provide switching so that the antenna is connected to the transmitter on transmit and to the receiver on receive. The coil of the relay is activated by the push-to-talk (PTT) switch on the microphone.

HF ANTENNAS

The role of the antenna is to radiate the transmitter signal as efficiently as possible and to receive signals. There are many many antenna designs to use but we shall restrict the discussion in this chapter to three main types:-

(i) the quarter wave vertical antenna

(ii) the horizontal half wave Dipole

(iii) the 3 element parasitic array

Any length of wire may be used as an antenna , however the best performance is obtained when the antenna is resonant for the band to be used.

The quarter wave vertical antenna shown in Fig 11.7a is a very simple and popular antenna. This antenna makes use of a ground plane or earth and has an imaginary 'image'

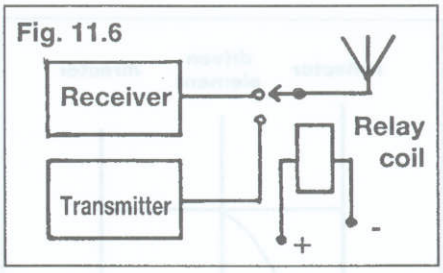


Fig. 11.6

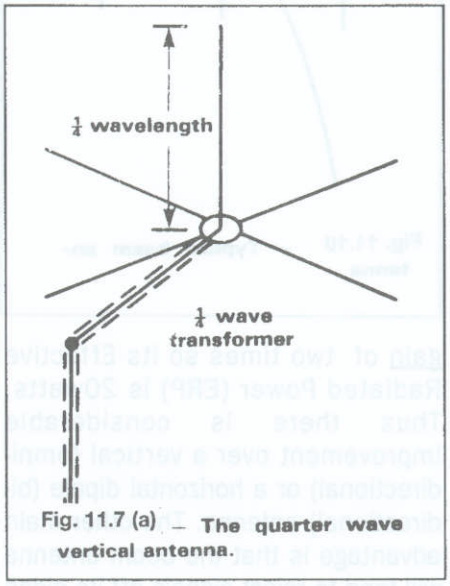


Fig. 11.7 (a) – The quarter wave vertical antenna.

in the ground below. The length of the vertical part of the antenna is cut to be one quarter of a wavelength at the desired frequency and it is insulated from the ground plane at the feedpoint. Its feed impedance is about 36 ohms and the best ground plane has at least 4 conductors (called radials) radiating out at 90 degrees to each other. Each of these radials should be at least one quarter wavelength long. The radiation pattern for this antenna is omni-directional - meaning that it radiates equally in every direction in the horizontal plane. This of course can be a disadvantage if you wish to target a particular station but if you are in a net with stations in all different directions, it is decidedly useful as

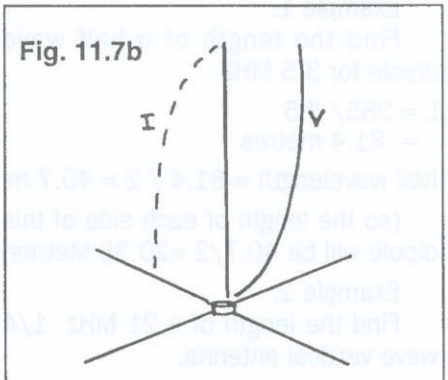


Fig. 11.7b

Voltage & Current distribution on 1/4 wave antenna

each station will be able to hear you no matter what their compass bearing may be.

The current and voltage distribution on this antenna is shown in Fig 11.7b.

Note that the current maximum is at the feedpoint and the voltage is minimum at the feed point, while the voltage maximums are at the ends of the antenna.

The polarisation of this antenna is vertical, so it works most favorably with any other vertically polarised antenna. If you work a station with a horizontally polarised antenna, a loss occurs due to the cross-polarisation.

Half Wave Dipole

This antenna, sometimes called the Hertz antenna is usually centre fed and has a feed impedance of about 53 ohms. (The actual feed impedance depends upon the height).

Referring to Fig 11.8, you can see that the current maximum is at the centre and the voltage at this point is minimum. At the ends, the voltage is maximum and the current at minimum.

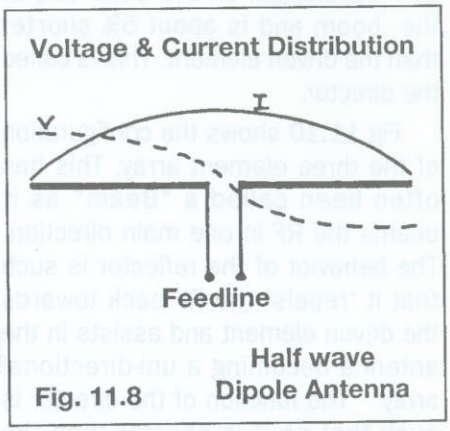


Fig. 11.8

The radiation pattern of the dipole is bi-directional broadside as shown in Fig 11.9.

As you can see, the dipole which is orientated from east to west will radiate best from north to south, -this is the typical broadside radiation pattern.

This antenna is usually centre-fed with 50 ohm coax cable and ideally a 50 ohm to 50 ohm (1:1) balun should be used to ensure that the radiation pattern is symmetrical. If the coax is directly connected to the antenna, the

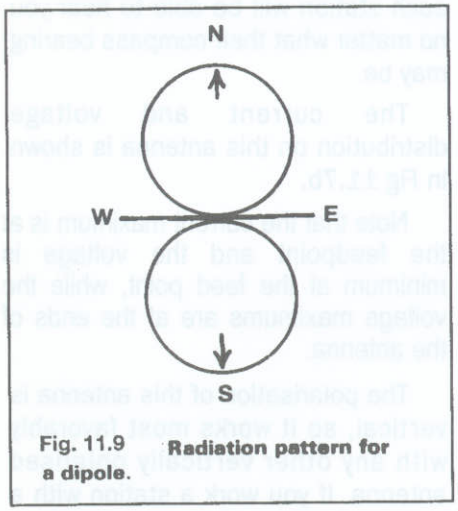


Fig. 11.9 Radiation pattern for a dipole.

braid would directly earth one side and distort the radiation pattern.

(iii) The Parasitic array

The parasitic array consists of two or more elements in close interaction with each other.

A three element array is often called a Yagi antenna -named after the Japanese designer. It consists of a half wave dipole 'driven element' with another element about 1/4 wavelength away which is about 5% longer. This element is called the reflector. Another element is fixed at 1/4 wavelength on the other end of the boom and is about 5% shorter than the driven element. This is called the director.

Fig 11.10 shows the configuration of the three element array. This has often been called a "Beam" as it beams the RF in one main direction. The behavior of the reflector is such that it 'repels' the RF back towards the driven element and assists in the antenna becoming a uni-directional array. The function of the director is such that as it is shorter than the driven element, it helps to radiate the RF in the one favored direction and aids in the function of the reflector to send most of the RF in the desired direction.

A Yagi has the property of concentrating the RF in one direction and it is said to have 'forward' gain. There is some RF radiated from the reflector end but this is considerably less than from the director, so there is said to be a 'front to back' ratio. It is not difficult to achieve a forward gain of about 3 dB and so if 10 watts is fed into this antenna it has a power

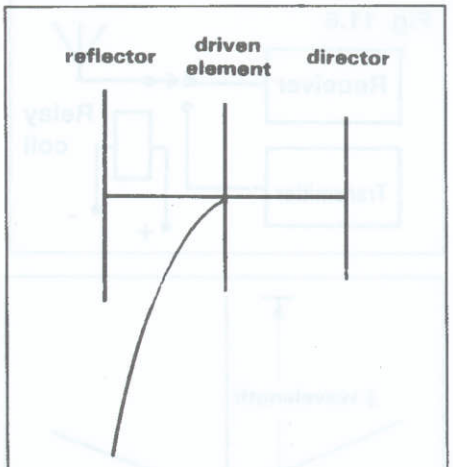


Fig. 11.10 – Typical beam antenna

gain of two times so its Effective Radiated Power (ERP) is 20watts. Thus there is considerable improvement over a vertical (omni-directional) or a horizontal dipole (bi-directional) antenna. The other main advantage is that the beam antenna will tend to reject signals off its sides and back so this provides some immunity to unwanted signals coming from different directions. This makes it possible for stations in different locations to share a frequency as the directivity of the beams minimises the potential interference.

CONSTRUCTION OF THE ANTENNA

First the band to be used is decided, then the length is calculated from the formula -

L= 285 / f (where f is the frequency in MHz.)

This will give the length of the antenna in metres for one wavelength, the result is divided by 2 to give the half wavelength and it is divided by 4 to give 1/4 wavelength.

Example 1.

Find the length of a half wave dipole for 3.5 MHZ

L = 285/ 3.5
= 81.4 metres

half wavelength = 81.4 / 2 = 40.7 m

(so the length of each side of this dipole will be 40.7/2 =20.36 Metres)

Example 2.

Find the length of a 21 MHz 1/4 wave vertical antenna.

L = 285/21
= 13.57 m (one wavelength)

1/4 wavelength = 13.57/4 = 3.39 m

Artificial Antennas

These are usually called "Dummy Loads" and are used to test transmitters without radiating a signal on air. * This minimises interference to other stations on the band.

A dummy load is made up from carbon or non-inductive resistors mounted within a shielded container to prevent radiation of RF.

The load must be non-inductive as it should be purely resistive to provide the transmitter with a 50 or 75 ohm load having no unwanted inductance or capacitance. (Refer to fig, 11.11)

Frequently the dummy load may have a blower fan to keep the resistor/s cool for prolonged test transmissions.

TUNING ANTENNAS

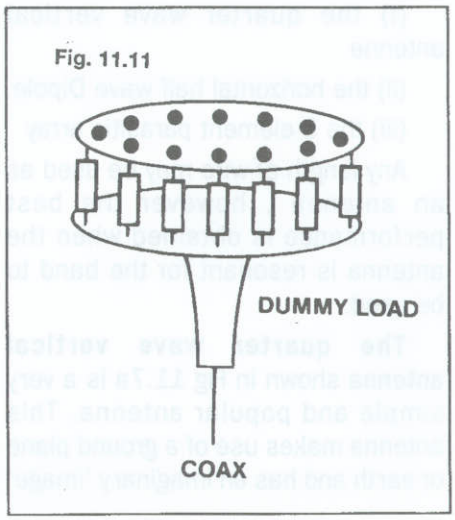
There are a few logical steps in optimising the antenna system.

1. First, adjust the antenna length so it is resonant at the required frequency -this can be done with the aid of a Dip Meter. (see chapter 12).

2. then the feed impedance can be checked with a noise bridge and receiver

3. an impedance matching device such as a balun or ATU may be needed to correctly match the feedline to the antenna.

4. now the transmitter can be connected and all tuning controls peaked up to give the best match and lowest SWR reading on the SWR Bridge.



chapter twelve

TEST EQUIPMENT AND MEASUREMENTS

The moving coil meter.

The most commonly used measuring instrument is probably the moving coil meter.

Fig 12.1 illustrates the construction of the meter movement.

Operation:- when a current flows through the coil via the hairsprings at each end, a magnetic field is established around the coil. This field reacts with the field from the permanent magnet poles and causes the coil to move. As the pointer is attached to the coil, it moves upscale indicating the value of the current. Once the current is switched off, the coil is returned to the zero position by the hairsprings. The amount of deflection of the coil is determined by the strength of the current, if the current value is high enough, the pointer will reach fullscale deflection (FSD).

Moving coil meters can be made with a variety of sensitivities from about 10 microamps up to several amps.

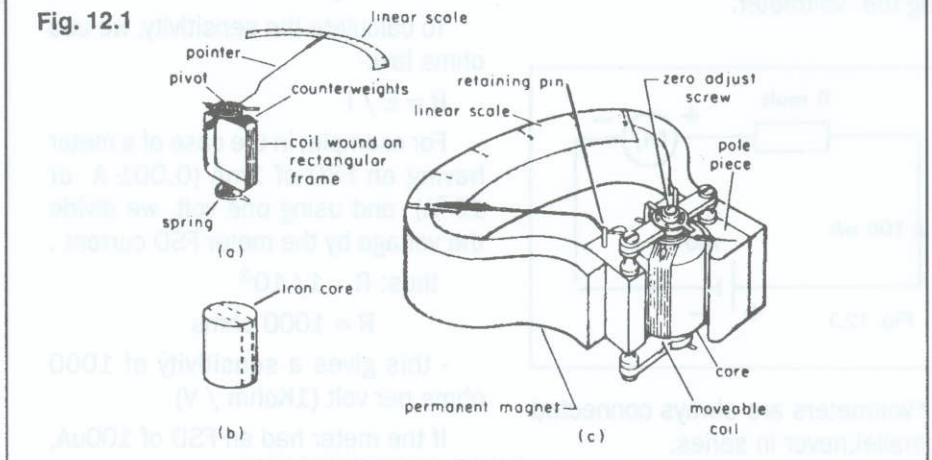
Damping

If the movement was not damped, the pointer would oscillate back and forth for some time after a current was connected to the meter. To alleviate this problem, damping is built into the meter movement to allow it to move quickly up to the reading with little or no oscillation.

Damping is achieved by winding the moving coil onto a cylindrical aluminium former. As the coil deflects upscale, an eddy current is induced in the aluminium cylinder and this produces a magnetic field which actually opposes the movement of the coil. This action damps the meter from 'over- swinging' past the correct reading and thus prevents oscillation of the pointer.

It's important to note that moving coil meters are used for DC measurements but with the aid of a rectifier, they can be used for AC measurements.

Fig. 12.1



THE D'ARSONVAL METER MOVEMENT

Pointer deflection is proportional to the current flowing through the instrument.

AMMETERS

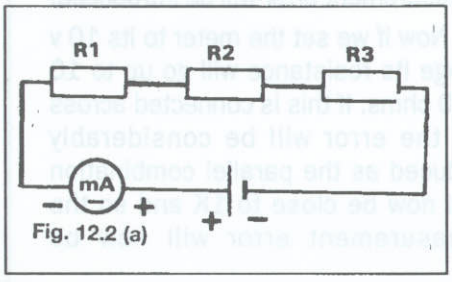
An ammeter is used for measuring current in a circuit. The connections for ammeters are shown in Fig 12.2a

The internal resistance of an ammeter must be very low of course as it must not introduce more resistance into the circuit it is measuring otherwise false readings will be obtained.

Ammeters are always connected in series with a circuit, NEVER in parallel, otherwise they will be damaged by a very high current flow.

Extending the range of an ammeter.

A resistor called a shunt is connected in parallel with the meter to allow it to read higher values of current than it is normally made to handle.



Example : If we wish to extend the range of a 100 microamp meter (having an internal resistance of 3500 ohms) to read 100 milliamps, we would need to add a shunt to carry 99.9 milliamps in a bypass route around the meter. This leaves only the remaining 100 microamps (0.1 milliamps) to flow through the meter. The meter scale can now be recalibrated to read 100 mA FSD.

The Shunt's value can be calculated as follows:-

First, we have to find the voltage drop across the meter-

Using ohm's Law -

$$E = I \times R$$

$$E = 100 \times 10^{-6} \times 3.5 \times 10^{3}$$

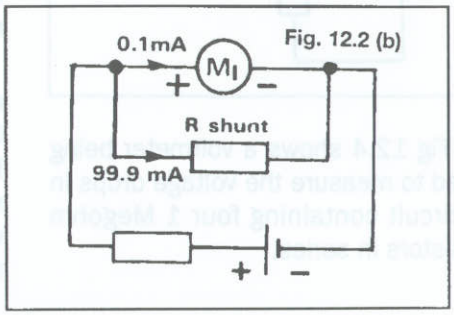
$$E = 350 \text{ mV}$$

Now to calculate the value of the shunt,we use Ohm's law again:-

$$R = E / I$$

$$R = 350 \times 10^{-3} / 99.9 \times 10^{-3}$$

$$R = 3.5 \text{ ohms}$$



See fig 12.2b for the circuit of the shunt resistor.

VOLTMETERS

By placing a suitable resistor in series with the above 100 microamp meter, we can convert it to read voltage. Fig 12.3 shows a circuit for using the voltmeter.

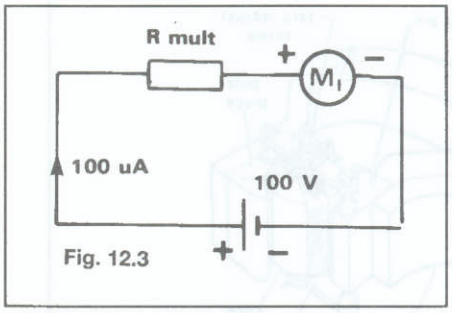


Fig. 12.3

*Voltmeters are always connected in parallel,never in series.

The value of the multiplier can be calculated using ohms law. In the case of the 100 uA meter, let's say we wish to use it read 100 v FSD. Then using ohms law -

$R = E / I$

$R = 100/100x10^{-6}$

$R = 1/10^{-6}$

R= 1,000,000 ohms (1 meg ohm)

the value of the multiplier will be slightly less than 1M ohm as the meter's internal coil resistance has to be taken into account.

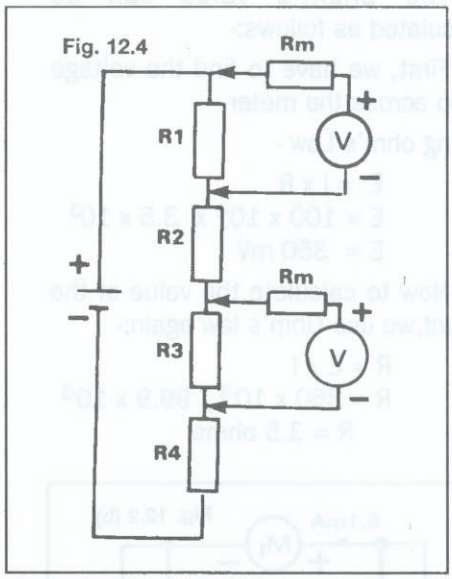


Fig 12.4 shows a voltmeter being used to measure the voltage drops in a circuit containing four 1 Megohm resistors in series.

Meter sensitivity

You will notice on the scale of most meters printing which says :- "10,000 ohms per volt." - or something similar. The higher this figure, the more sensitive the meter. Also the higher the figure, the more the meter is likely to cost.

To calculate the sensitivity, we use ohms law:-

$R = E / I$

For example, in the case of a meter having an FSD of 1mA (0.001 A or 10^{-3}A) and using one volt, we divide the voltage by the meter FSD current .

thus: $R = 1/ 10^{-3}$

$R = 1000$ ohms

- this gives a sensitivity of 1000 ohms per volt (1Kohm / V)

If the meter had an FSD of 100uA, then :-

$R = 1/100x10^{-6}$

$R = 1/ 10^{-4}$

R = 10 000 ohms.

which gives 10 000 ohms/Volt for this meter , so it is clearly more sensitive.

Loading effect of a meter

If we were to use a voltmeter having low resistance, for example the 1000 ohm/V meter in the circuit of fig 12.5a, we would discover that the loading effect of the meter can disturb true circuit conditions.

Let's assume that the meter is set to the 1 v range, so its resistance will be 1000 ohms. Now if we connect a 1000 ohm resistance (the meter)in parallel with RL (a 1k resistor) it can be seen that we have changed the effective resistance markedly from the correct value of 1K ohm.

In fact we have changed the effective resistance of the parallel combination thus created into a 500 ohm resistance. (fig 12.5b)

This will disturb the circuit conditions quite considerably and a measurement error will be introduced.

Now if we set the meter to its 10 v range its resistance will go up to 10 000 ohms. If this is connected across RL the error will be considerably reduced as the parallel combination will now be close to 1K and so the measurement error will now be minimal.

Referring to fig 12.5c, we see a higher quality meter of 20 000 ohms/volt used in place of the earlier meter. If the voltage across RL is now measured by this meter on its 1v

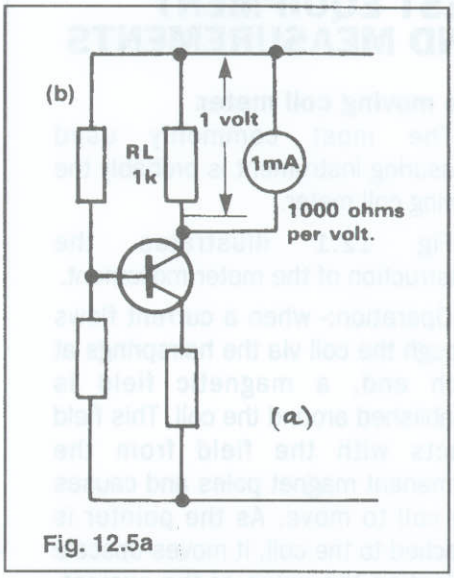


Fig. 12.5a

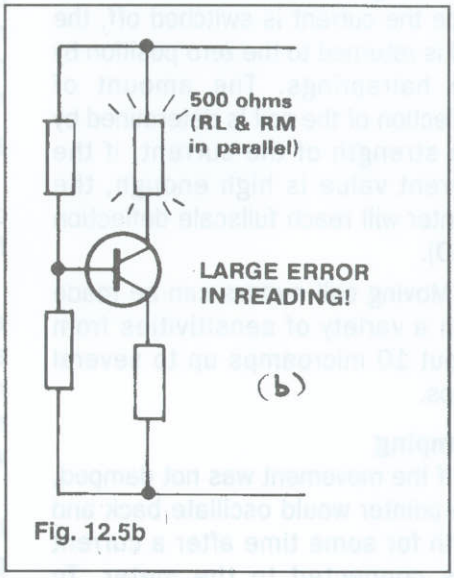


Fig. 12.5b

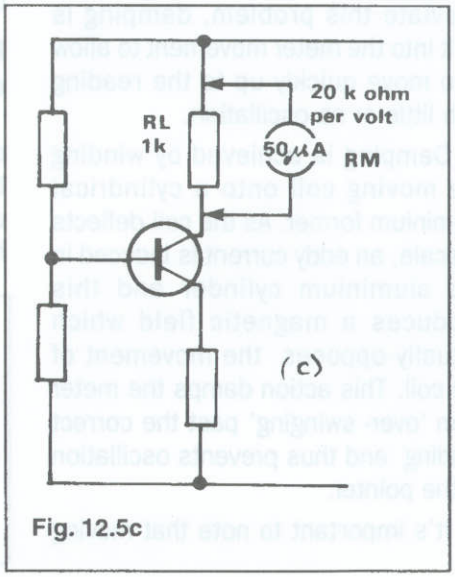


Fig. 12.5c

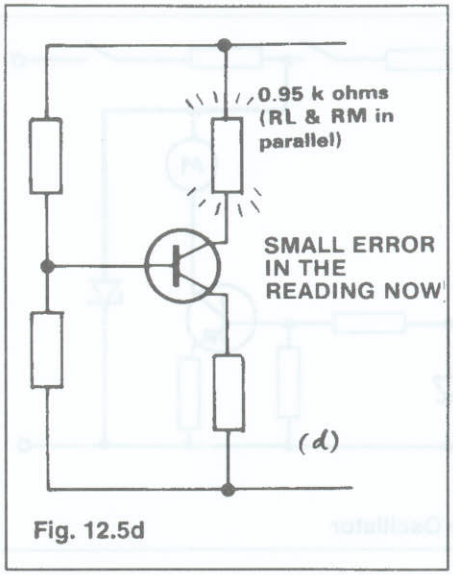


Fig. 12.5d

range, the effective resistance of the meter and RL in parallel is now 0.9524K ohms. This means that circuit conditions are hardly disturbed, thus leading to a much higher accuracy in the reading.

Fig 12.5d illustrates the situation.

OHMMETERS.

The value of a resistor can be found by use of an ohmeter. Fig 12.6 shows the circuit of an ohmeter.

The circuit consists of a meter, a battery and a pot all in series. To take a reading the prods are first shorted together and the meter should read full scale. This is the zero ohms position. If the meter does not read zero ohms, the pot can be adjusted so that the meter is correctly zero-set.

With the prods not shorted together, the meter reads oo - which is infinity or "open circuit".

Now any resistor can be placed between the prods and its correct value can be read directly from the meter scale which is calibrated from zero at its right hand side to oo at its left hand side.

MULTIMETERS

Multimeters are one of the most common test instruments in electronics and can provide a number of ranges for measuring voltage, current and resistance. Both analog and digital are available at affordable prices so the decision to make is about cost, accuracy, ranges needed and operating convenience.

On voltage ranges a number of multiplier resistors are switched into circuit to permit a variety of scales.

On current ranges the meter has a number of shunts which can be placed into circuit to offer a range of convenient scales.

Some meters have a number of resistance ranges so that low value resistors as well as high value ones can be accurately measured.

Some operating hints when using meters

1. start with the meter on its highest range and then switch it to lower ranges so a reasonable deflection of the needle is obtained. (this prevents damage to the meter caused by any overload).

2. park the meter on its highest voltage range if an off position is not provided

3. "think which then switch" - it's costly to repair an overloaded or burned out meter!.

4. do not measure ohms in a live circuit which has voltage applied.

5. replace the ohmeter batteries periodically in the meter to prevent damage from corrosion.

AC measurements

AC voltage can be measured by a moving coil meter if it is provided with a rectifier.

Fig 12.7 shows the circuit of an AC voltmeter.

AC current can also be measured by adding a rectifier to the meter circuit.

Fig 12.8 shows the AC current meter circuit.

FREQUENCY MEASUREMENTS

Frequency may be measured by the use of a frequency meter as shown in fig 12.9.

A frequency meter can be a very accurate instrument to use provided it is operated properly.

Some limitations and precautions are useful to know so that you can get the best performance and most accurate results however.

By connecting the frequency meter, circuit conditions can sometimes be disturbed and inaccurate results obtained. This is more likely to happen in VHF and UHF circuits.

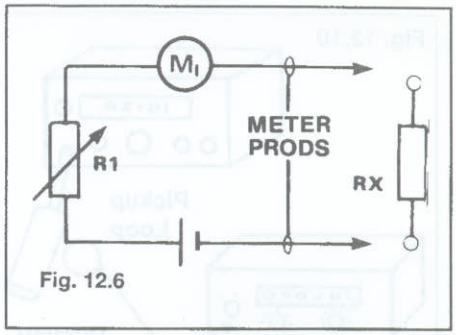


Fig. 12.6

As well, frequency meters have a finite sensitivity and if you provide too little or too much signal to the meter, it may give misleading readings. This is caused by either overload of the meter's input circuit or insufficient signal to properly trigger the meter accurately.

Another precaution is to take great care NOT to couple a transmitter directly into the meter as it may be severely damaged by RF at high power levels. RF from a transmitter can be safely coupled to the frequency meter by adding a pickup loop of wire at the

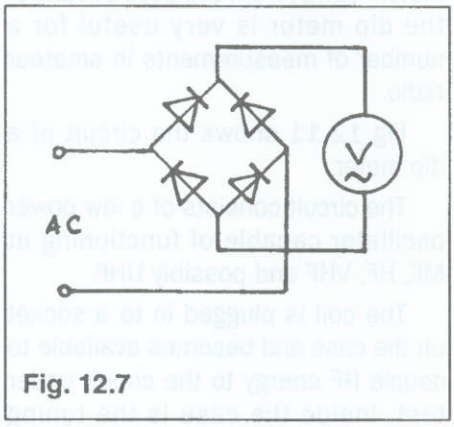


Fig. 12.7

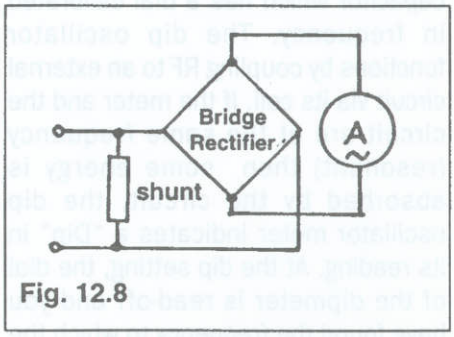


Fig. 12.8

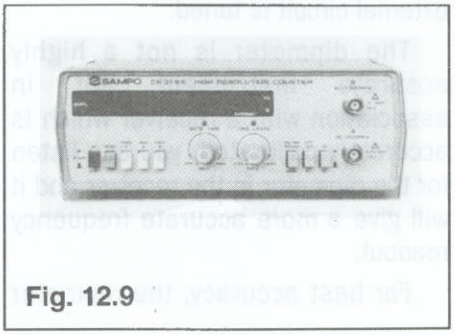
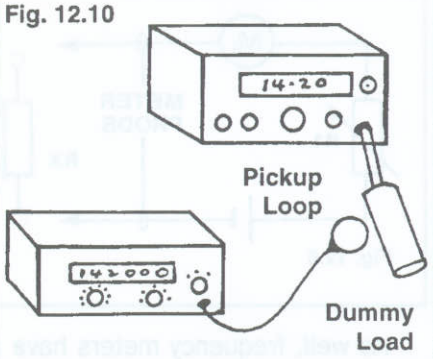

Fig. 12.9

Fig. 12.10



Frequency counter measuring output frequency of a transmitter

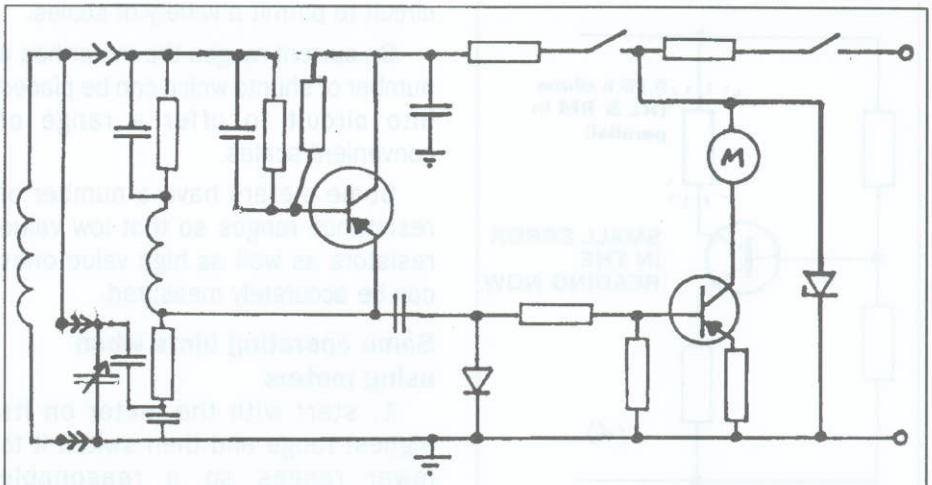


Fig. 12.11 Circuit of Dip Oscillator

end of the meter's cable and placing the loop at or near a suitable point in the transmitter so that just enough energy is coupled to the meter for satisfactory readings to be made.

Fig 12.10 shows a pickup loop used with a frequency meter in reading a signal from a transmitter.

DIP METERS

Commonly called the "grid dip meter" (GDO) from the days of valves, the dip meter is very useful for a number of measurements in amateur radio.

Fig 12.11 shows the circuit of a dip meter.

The circuit consists of a low power oscillator capable of functioning at MF, HF, VHF and possibly UHF.

The coil is plugged in to a socket on the case and becomes available to couple RF energy to the circuit under test. Inside the case is the tuning capacitor which has a dial calibrated in frequency. The dip oscillator functions by coupling RF to an external circuit via its coil. If the meter and the circuit are at the same frequency (resonant) then some energy is absorbed by the circuit, the dip oscillator meter indicates a "Dip" in its reading. At the dip setting, the dial of the dipmeter is read-off and you have found the frequency to which the external circuit is tuned.

The dipmeter is not a highly accurate instrument but in association with a receiver which is accurately calibrated, you can listen for the dipmeter in the receiver and it will give a more accurate frequency readout.

For best accuracy, the dipmeter should not be too closely coupled to the circuit under test. The rule is to just be able to detect the dip on the meter and this will give the best sensitivity as well as accuracy.

Fig 12.12 shows some methods of using a dipmeter in different situations.

WAVEMETERS

A dipmeter can be used as an absorption wavemeter. This means that the oscillator is switched off and the coil is coupled to a live circuit under test, the dial of the dipmeter is tuned until the highest reading is obtained. The dial of the dipmeter can now be read to obtain the frequency being radiated by the test circuit. In effect, the dipmeter is just acting as a crystal receiver to detect a signal.

RF MEASUREMENTS

Transmitter output power

The output power of a transmitter can be measured by a number of methods and of course it is a requirement that your transmitter power is within the limits of your licence conditions.

(a) CW power

The power output of an AM or CW or FM transmitter can be measured by using a dummy load (artificial antenna) and then measuring the current passing through it or the voltage across it.

The dummy load is usually 50 or 75 ohms and by using a suitable RF current meter or RF voltmeter, the power can then be calculated by using either of these formulae :-

$P = I^2 R$ or $P = E^2 / R$ where R is the 50 or 75 ohm dummy load.

(b) SSB peak envelope power (PEP)

The power output of an SSB transmitter can be measured by use of a two tone signal and oscilloscope. The AF signal from a two tone signal generator is fed into the microphone socket of the transmitter and the RF voltage across the dummy load is measured. (The tones must not be harmonically related frequencies).

With the two tones fed into the transmitter, the power output is calculated by using either :-

$P = *E^2/R$ or $P = +I^2R$

*The RF voltage is measured across the 50 ohm dummy load by use of an RF voltmeter.

+ The RF current through the 50 ohm dummy load is measured by an RF ammeter.

The PEP is then found by multiplying the average power (as measured above) by two.

*Note that it is not good practice to measure power by radiating a signal into an antenna. This can give misleading results and can cause interference to other stations.

TRANSMISSION LINE MEASUREMENTS

The Standing Wave Ratio (SWR) in the transmission line can be measured by use of an SWR bridge. This instrument takes many forms but usually compares forward power to reflected power in the line to give a SWR reading. The ideal situation is for the SWR to be 1:1. This means that the transmitter, line and antenna all have identical impedances and there

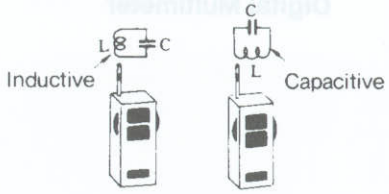
Test Equipment



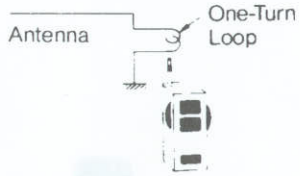
The Dip Oscillator can be used for a variety of applications. The diagrams below show some typical uses for this versatile instrument:-

APPLICATIONS

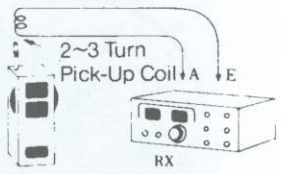
(1) Measure Resonant Frequency by Inductive or Capacitive Coupling.



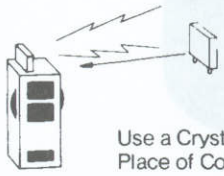
(2) Antenna Resonant Frequency.



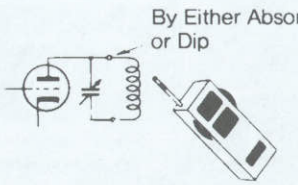
(3) Signal Generator.



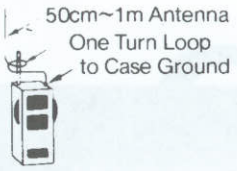
(4) X'tal Checker or Marker Generator.



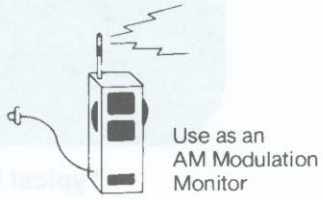
(5) Measure Tank Circuit Resonace.



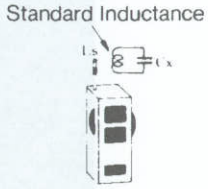
(6) Measure Field-Strength.



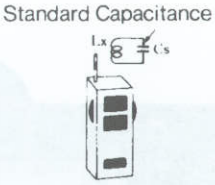
(7) Use as a Heterodyne Frequency Meter or CW Monitor.



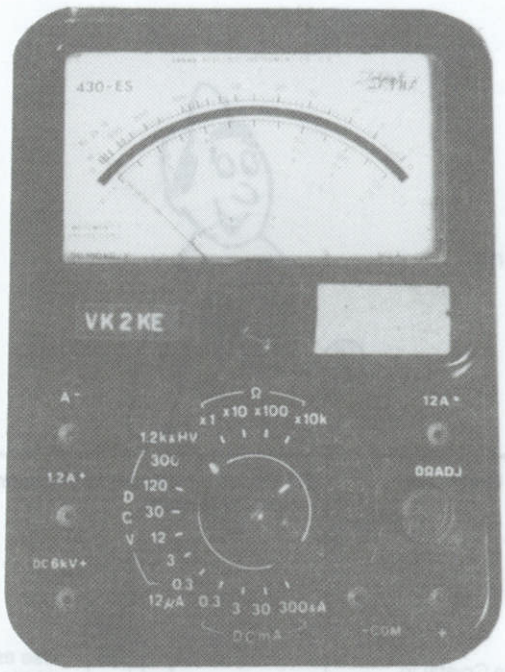
(8) Measure an Unknown C.



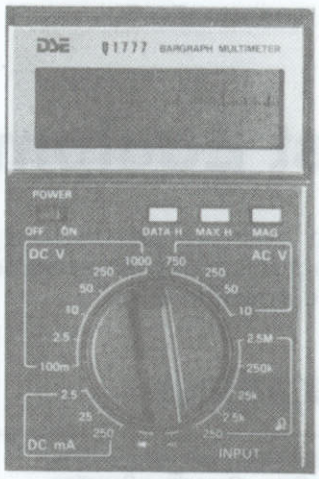
(9) Measure an Unknown L.



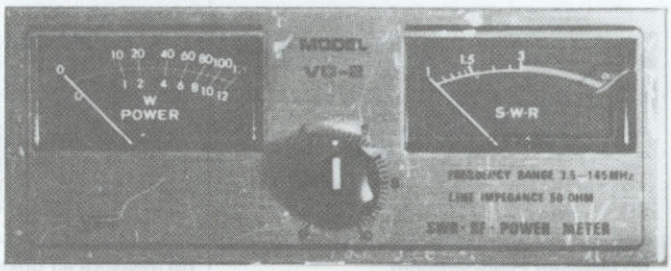
Test Equipment



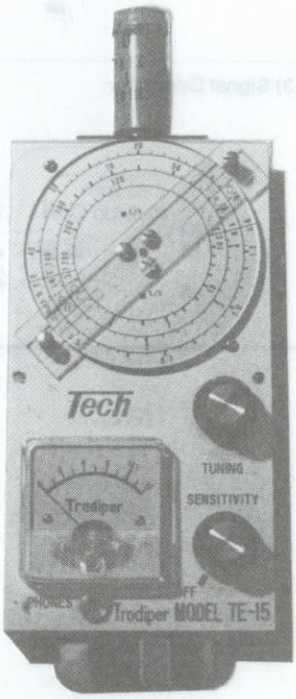
Typical Multimeter



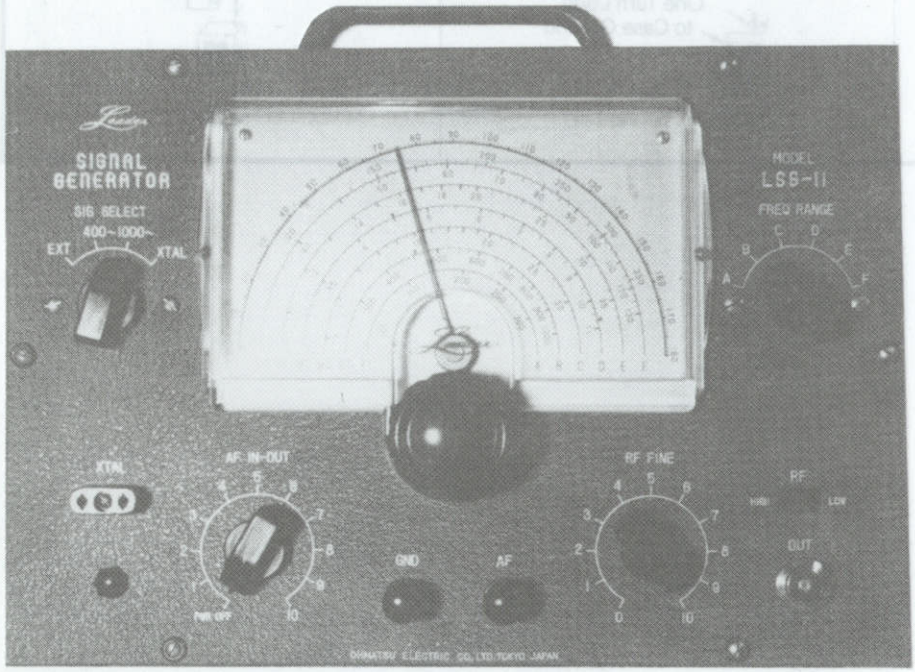
Digital Multimeter



SWR Bridge



Dip Oscillator



Signal Generator

are in fact no standing waves on the line. Thus losses will be minimal.

Standing Waves- If the transmission line is not properly impedance matched to the transmitter and the antenna, standing waves will be established on the line.

If you were to measure the RF current at various points along the transmission line and the readings were all the same, the line is said to be "flat' which means that there are no standing waves on the line. If you were to take measurements of the RF voltage across the line at various points and the readings were all identical, then there would be no standing waves on the line.

However, if there were found to be peaks of RF voltage or current in your measurements and nulls (lower readings) then the line clearly has standing waves established on it.

If the antenna is not properly impedance matched, there will be standing waves on the line and some power is reflected from the antenna termination back toward the transmitter. The SWR bridge can measure this reflected power and allow you to compare it with the forward power going from the transmitter to the antenna. The comparison between forward and reflected power will give the SWR.

Measurement error can occur with SWR bridges if they are connected at different points in the transmission line due to standing waves causing voltage maxima and minima in the line. The ideal situation to minimise errors is to connect the SWR bridge at a multiple of half a wavelength from the antenna termination. (every electrical half wavelength back from the antenna connexion, the impedance is repeated exactly).

THE CATHODE RAY OSCILLOSCOPE (CRO)

The CRO is one of the most useful instruments for AF and RF measurements in electronics.

The CRO uses a Cathode Ray Tube (CRT) to display waveforms on the screen. It is very similar in operation to a TV receiver.

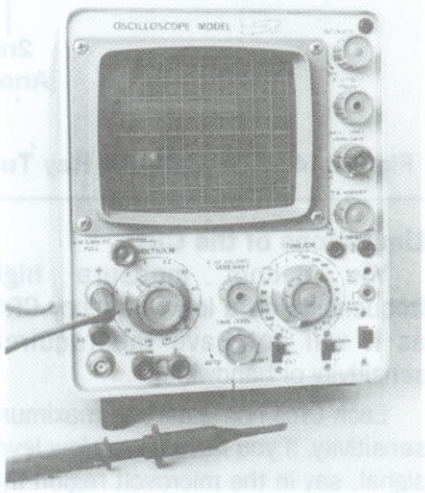
Fig 12.13 shows the basic configuration of the CRO in a block diagram and the CRT is shown in fig 12.14.

The CRT consists of a glass tube held at high vacuum. There is an 'electron gun' which is like a valve, in that there is a heater, cathode, grid and anode. The principle of operation is for a very finely focussed beam of electrons to be generated by the gun which fires them towards the screen at high velocity. The inside of the screen is coated with a phosphor which fluoresces under the stimulation of the electron beam. The electron beam can be deflected left, right up or down by suitable voltages being applied to deflection plates . These two pairs of plates are called the vertical and horizontal deflection . Sometimes the horizontal deflection is called the X axis and the vertical is called the Y axis.

If the beam is not deflected in any way, a bright spot will be visible at or near the centre of the screen. In normal operation , a timebase waveform which is sawtooth in shape is applied to the horizontal deflection plates and this gives a horizontal line across the screen. In other words, the spot is scanned from the left of the screen to the right, then it is blanked out and returned to the left and the scan commences again. The timebase generator repeats the scanning continuously until the CRO is switched off.

The timebase scan rate is variable by use of controls on the CRO panel and is usually calibrated in seconds, millisecs or microsecs/ cm. So the horizontal axis of the CRO is accurately related to time. (Each cm across the screen will be so many seconds/milliseconds or microseconds in other words.)

The vertical axis of the CRO measures amplitude and is usually calibrated in volts/ cm, or millivolts per cm.



Cathode Ray Oscilloscope

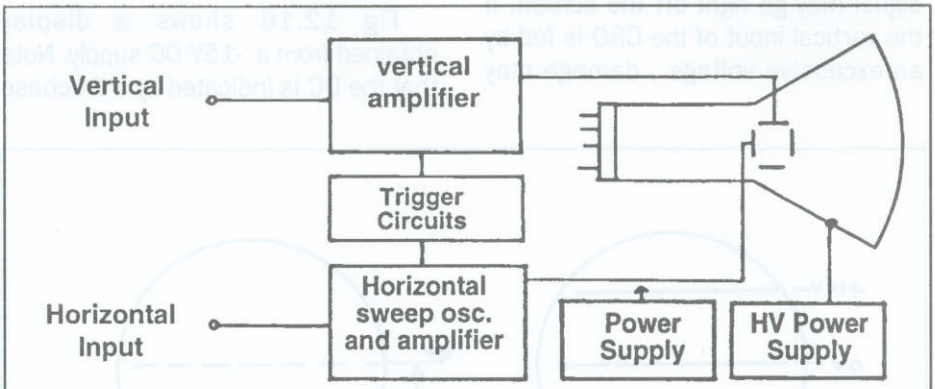


Fig. 12.13 Block Diagram of a CRO

By the above you can see that we have produced a 'visual voltmeter' in effect. All kinds of waveforms can be viewed and measured accurately on the CRO. Depending upon the quality and specifications of the CRO, you will be able to view and measure AF and RF waveforms or signals.

The more expensive the CRO, the higher its accuracy and the higher the frequencies it will be able to measure. One which is accurate at VHF and UHF will be much more expensive than one made for AF and HF work.

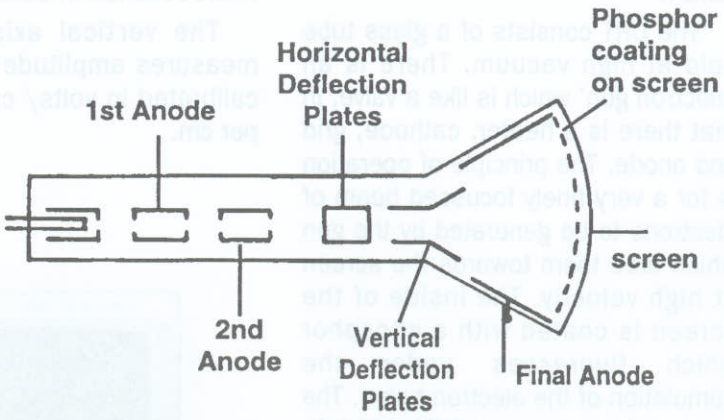


Fig. 12.14 Cathode Ray Tube (CRT) Construction

Limitations of the CRO

You cannot measure high frequencies on a low frequency CRO as it will not have the required sensitivity or bandwidth.

Each CRO has a certain maximum sensitivity. If you have a very low level signal, say in the microvolt region the CRO may not be able to amplify it and so it will just not be visible on the screen.

As well, each CRO has a maximum sensitivity and if you exceed this the signal may go right off the screen. If the vertical input of the CRO is fed by an excessive voltage , damage may be done to the input circuits of the CRO.

Waveform interpretation

The CRO display can give us a great deal of information and the following diagrams show the versatility of the CRO.

In fig 12.15 the display indicates a DC voltage of + 10V. Note the positive DC voltage is indicated by the timebase line being above the reference point at the centre of the screen.

Fig 12.16 shows a display obtained from a -15V DC supply. Note that the DC is indicated by a timebase line but offset below the reference line at the centre of the screen.

Fig 12.17 shows a sine wave of 24V Peak to peak (P-P) (amplitude

Fig 12.18 shows a sawtooth wave of 12V P-P amplitude

Fig 12.19 shows a square wave of 40V P-P.

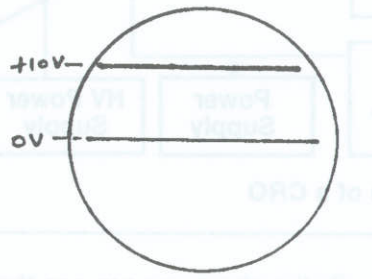


Fig. 12.15
Positive DC Voltage

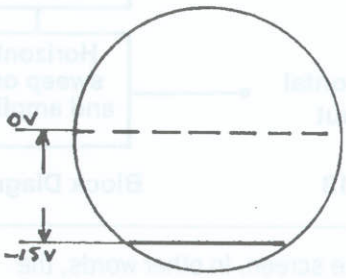


Fig. 12.16
Negative DC Voltage

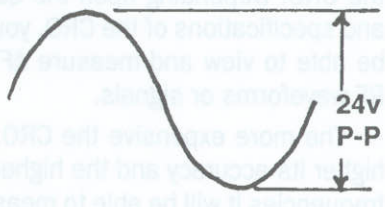


Fig. 12.17
24v peak to peak sinewave

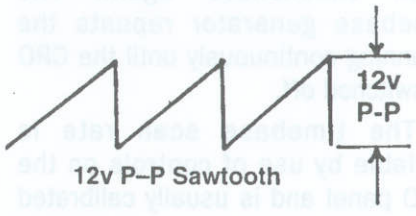


Fig. 12.18

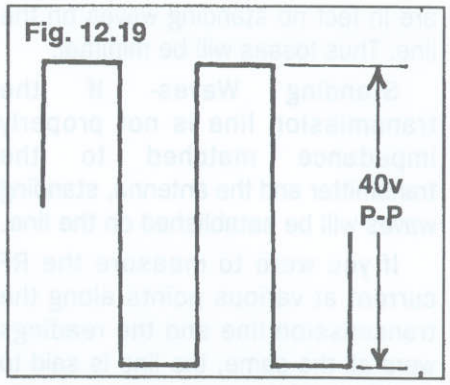


Fig. 12.19

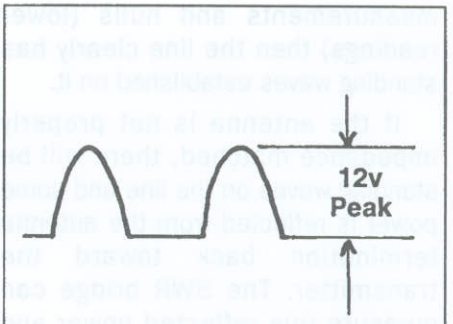


Fig. 12.20

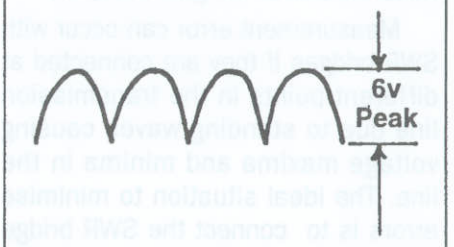


Fig. 12.21

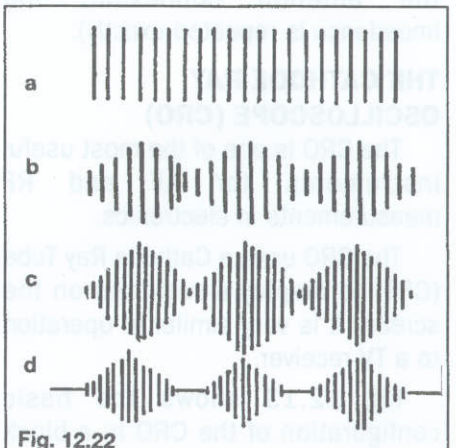


Fig. 12.22

Fig 12.20 shows the CRO display for a half wave rectified voltage of 12V Peak (this is known as pulsating DC)

Fig 12.21 shows the output waveform for a fullwave rectifier (6V Peak)

The percentage modulation of an AM transmitter can be measured by the CRO. Figs 12.22 a,b, c &d show an unmodulated carrier, a 50% modulated carrier, a 100% modulated carrier and an overmodulated carrier.

The RF output from an SSB transmitter being tested with a two tone signal is shown in Fig 12.23 . The CRO display indicates that the transmitter is linear and undistorted.

The RF from a CW transmitter being keyed with morse code is shown in Fig 12.24. in this case the emission has bad key clicks. In fig 12.25 the CRO display shows a CW transmitter keyed and that the emission is free of key clicks. (see earlier section on morse code transmitters).



Linear Signal - two tone test

Fig. 12.23



Fig. 12.24



Fig. 12.25

chapter thirteen

INTERFERENCE

Radio Frequency Interference (RFI)

NOISE

Communications via the radio frequency spectrum are subject to an ever-increasing range of interfering signals. Some are man-made and others are generated by nature.

Some of the interference is continuous and some is sporadic such as switching transients.(transients are momentary voltages caused by switching off and on of electrical devices)

Continuous noise is produced by a number of sources including the sun, space, antennas, and valves and transistors used in amplifiers.

The Lightning from thunderstorms is another source of noise which can cause communications difficulties on some bands. Noise is sometimes band-selective, for instance :- 1.85 and 3.5 MHz are very prone to electrical storm interference while amplifier noise is more of a problem at VHF and UHF.

Another source of noise is the power mains wiring in streets and buildings.

The Radio Amateur is faced with the situation that he or she is operating a transmitter producing considerable power levels in an environment where there are many electronic devices used by neighbors. These devices may have poor immunity to radiations from amateur transmitters. And so it is important to understand the problems in some detail so that interference problems are eliminated or minimised .

The 240 Volt power mains

This is a network which can carry interference signals to and from the Amateur radio station.

The street mains can carry interference from other consumers in the area, re -radiate it and generally make communications on MF and HF particularly difficult.

Proper design and operation of your station can prevent RF from your transmitter from being coupled to the mains and thus fed to the other consumers in the street.

Earthing of your radio equipment and proper connection of all the mains wiring in your station is vital not only from the legal viewpoint and safety angle but also from the need to prevent unwanted coupling of the RF into the network.

A mains filter can be used to keep RF from entering the mains from your transmitter. See fig 13.1 for details of a mains filter.

Sources of interference to your reception of signals:-

Fluorescent lamps, dimmers, drink mixers, street lights, kitchen blenders, thermostats in heaters, refrigerators, urns, air conditioners, power tools and welders.

Motor mowers and other petrol engines can also generate interference signals.

Computers and digital equipment can generate considerable interference too. In addition to this you may be unlucky enough to live close to high voltage power lines which can radiate varying levels of noise depending upon their location, condition , the weather and the amount of pollution or salt spray prevalent in the area.

TYPES OF INTERFERENCE

Interference can be experienced by TV, Radio and Audio equipment and these are referred to respectively as TVI, BCI and AFI.

TVI (television interference)

A TV receiver is a wide band VHF and UHF receiver which is processing an AM vision signal and an FM audio signal over a wide range of frequencies from about 45 MHz to about 820 MHz.

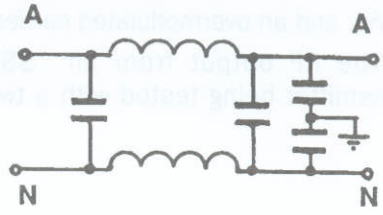


Fig. 13.1 Mains Filter

(i) Receiver overload

If a TV receiver is operating in the presence of a strong signal not necessarily on one of its tuning ranges, it may suffer from overload. This can occur if the interfering signal is sufficiently strong to drive the RF amplifier in the tuner into a non-linear condition. Once the RF amplifier has become non-linear, severe distortion of the TV signal may occur or in extreme cases, the amplifier just "blocks". When an amplifier blocks, it may go silent, passing no signal through and the picture and/ or sound may disappear. The transmitter causing the interference may be on MF, HF, VHF or even on UHF.

(ii) Harmonics

If your transmitter is radiating harmonics, the harmonics may fall within the channel being received and cause disruption of the TV signal.

An example of this is when a TV receiver is tuned to channel 1 or 2 and you are operating your 15 metre transmitter on about 21 MHz. The 3rd harmonic of your transmitter will fall within these TV channels on 56 to 70 MHz.

Another example is when the TV receiver is tuned to channel 9 (195 - 202 MHz) and you are transmitting on the 10 metre band (28MHz). The 7th harmonic of 28 MHz is 196 MHz and this clearly falls within channel 9's band width.

So it is clearly important to prevent (suppress) harmonics from being radiated by your transmitter.

This is achieved by proper design, tuning and operation and by use of a low pass filter at the output of the transmitter.

(iii) parasitic oscillations

If the transmitter is suffering from any parasitic oscillation, it may radiate a signal that can cause disruption of the TV reception. So suppression of parasitics is essential in any transmitter. (refer to section 7, Oscillators & Amplifiers).

(iv) overmodulation

Over modulating an AM or SSB transmitter can result in TV interference due to the production of splatter. An amplifier in a transmitter which is overmodulated may be over-driven and this results in "flat-topping" which is a non-linear condition. This results in unwanted emissions from the transmitter which are almost certain to produce TVI. The solution is to tune and operate your transmitter within its specifications and to ensure it is in its best possible condition. Usually too much microphone gain is the most common reason for splatter.

(BCI) Broadcast interference

(i) overload

A very strong signal can overload the "front end" of a receiver causing the RF amplifier to become non-linear. Once the amplifier is non-linear, it will distort the signals or possibly "block" - giving little or no output until the strong signal decreases in strength or disappears.

This effect can happen whether the strong signal is in-band or out of band.

(ii) fundamental overload

An example of this is when a receiver is tuned to say, 3.5 MHz and the received signal is on the same frequency but is very strong. The receiver front end (RF stage) may be driven into a non-linear state and if this occurs, the receiver may either block or give very weak or distorted output. A method of reducing or eliminating this overload condition is to reduce the setting of the RF gain control or to switch in the attenuator if one is provided.

(iii) cross modulation

This effect occurs when a receiver is tuned to a certain frequency and another very strong signal on some other frequency is also received. If the undesired signal is sufficiently strong, it can cause the RF amplifier to overload, driving it into a non-linear condition and mixing of the signals may then occur. They are said to be cross-modulating each other. One remedy is to reduce the RF gain control but this will also reduce the strength of the required signal. Another way is to install a wavetrap in series with the antenna circuit of the receiver. The wavetrap is tuned to reject the unwanted frequency .

AFI (Audio Interference)

Some domestic audio equipment can be prone to RF interference from nearby transmitters.

There are various ways in which this can occur.

One common problem is for long speaker leads to become antennas which pick up RF and convey it from the nearby transmitter into the amplifier where it is re-radiated into sensitive amplifier stages.

The signal can then appear from the speakers and disrupt the operation of the audio equipment. Fig 13.2 shows the situation often encountered in an audio installation where quite long speaker leads act as receiving antennas and carry RF signals into the amplifier where they can cause problems.

The remedy is to install bypass

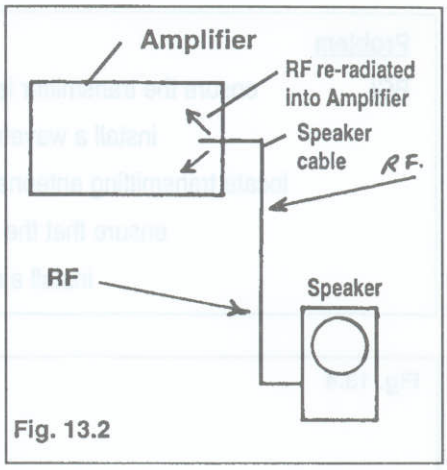
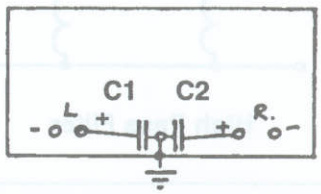


Fig. 13.2



Speaker terminals bypassed with capacitors

Fig. 13.3

capacitors on each active lead right at the amplifier terminals as shown in fig 13.3.

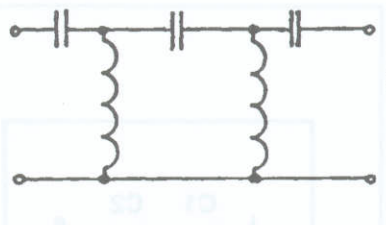
The bypass capacitors carry the RF currents to earth and prevent the RF from entering the amplifier case. As the value of these capacitors is quite small, they don't affect the audio frequency signals.

Tape recorders, CDs, Turntables, cassette decks and microphones can also pick up RF fields from transmitters and the interference can

Problem	remedial measure
TVI	install low pass filter at transmitter output
TVI	install high pass filter at TV receiver antenna terminals
TVI	install stub wavetrap at TV receiver antenna terminals
TVI	use an ATU at the output of the transmitter *(an ATU is an Antenna Tuning Unit)
TVI	ascertain which channel/s is/are being affected
	ascertain which band/s of operation is/are causing the problem
	locate the transmitting antenna as far from the TV antenna as possible
	examine the condition of the TV antenna & feedline, replace if suspect
	install a "braid breaker" in the TV receiver feedline
	ensure the transmitter is operating properly, tuned correctly and is not generating spurious emissions or harmonics

Problem	remedial measure
BCI	ensure the transmitter is tuned properly and is not over-modulated
	install a wavetrap at the radio receiver antenna terminals
	locate transmitting antenna as far away from the receiver as possible
	ensure that the CW transmitter is not producing key clicks
	install a mains filter to the transmitter power supply

Fig. 13.4



High Pass Filter

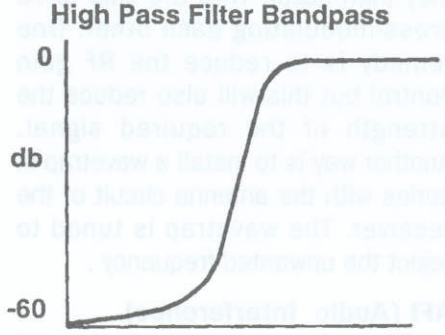


Fig. 13.5

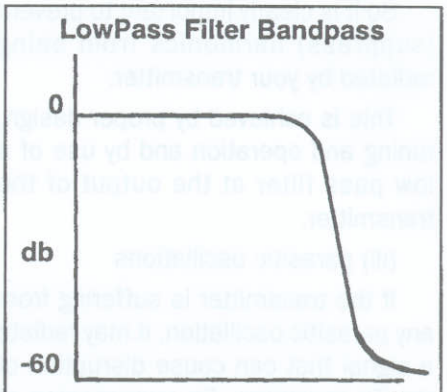
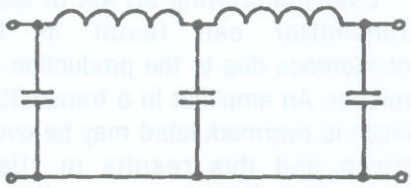


Fig. 13.7

Fig. 13.8



Low Pass Filter

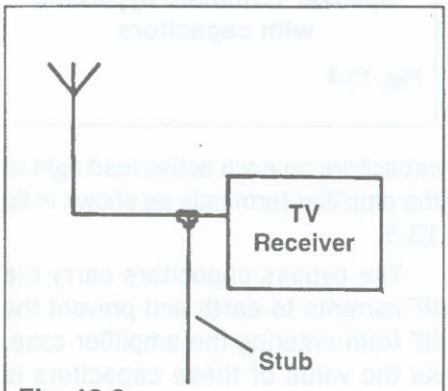


Fig. 13.6

come right through a stereo system. The problem here is that pickups and devices coupled to a stereo amplifier are producing quite low level signals and are thus prone to picking up strong RF fields. The best procedure is to disconnect all inputs to the amplifier and operate the transmitter in the normal way. The interference should have disappeared. If it hasn't, the speaker leads and mains may have to be bypassed with suitable capacitor filters. If it did disappear, replace one input connection at a time, while giving test transmissions. The moment the interference reappears, you have identified the offending cable and it will need to be bypassed with suitable capacitors or filters to eliminate the RF.

Remedial measures to eliminate interference

It is good practice to ascertain whether your own TV and stereo system etc. are suffering interference from your transmitters. If they are, it is then important to use a step by step process of elimination to rectify any problem. Refer to the checklist of remedies which can be implemented to achieve interference -free operation.

* If your own TV and stereo system are not suffering interference, this is a good indication that the transmitter is probably ok and that the neighbor's system is not as immune to RF from your transmitter as it could be.

With interference being suffered by a video recorder, much of the TV information applies of course. It is important that good quality coax cables are used between the TV and the recorder and that all connections are made reliably with the shield braids in each cable being intact and not damaged or disconnected in any way.

FILTERS

High pass filters

A high pass filter is designed to pass all frequencies above a set design point. In the case of a VHF TV receiver, the high pass filter allows all signals above about 40 MHz to pass through but attenuates all frequencies below 40 MHz. High pass filters are

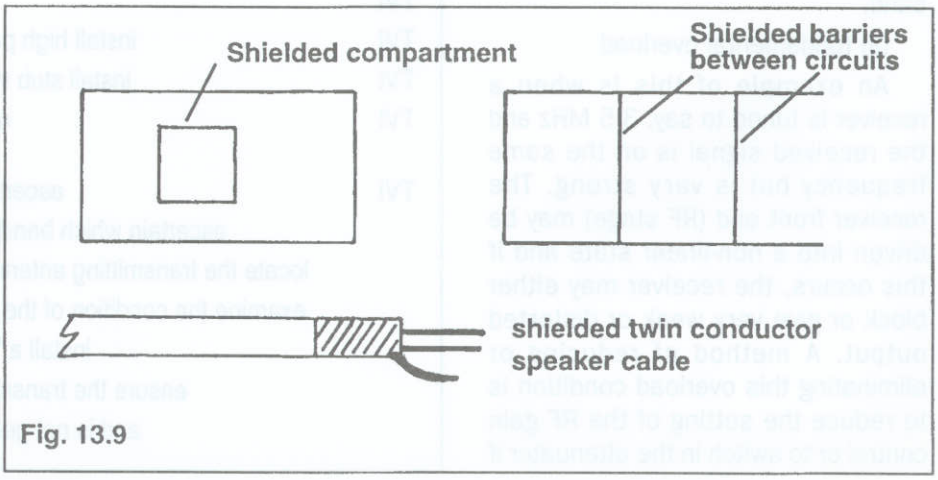


Fig. 13.9

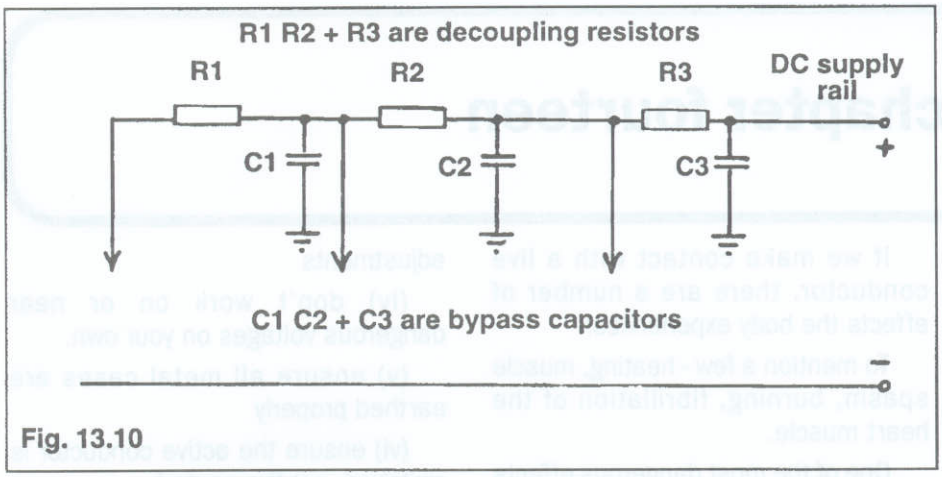


Fig. 13.10

always installed right at the TV receiver's antenna terminals to prevent any signal below 40 MHz from entering the receiver.The circuit configuration for a high pass filter is shown in fig 13.4.and the passband of the filter is shown in fig 13.5.

A tuned stub may also be used as a frequency selective attenuator at the TV receiver's antenna terminals. The stub is cut to be an electrical quarter wavelength at the unwanted frequency. It then provides a short circuit to the unwanted signal at the TV antenna terminals. The stub is illustrated in fig 13.6.

Low pass filters

These are used at the RF output terminals of the transmitter and prevent any signal above about 34 MHz from being radiated . In other words, they provide a high degree of attenuation to any signal above 34 MHz. For example if you are operating on 28 MHz, the second harmonic at 56 MHz will be attenuated by the low pass filter and will not be radiated, thus preventing TVI.

Fig 13.7 illustrates the passband of the low pass filter.

Fig 13.8 shows the circuit configuration of the low pass filter.

Other preventative measures

Earthing

It is essential to earth all points of a circuit or cable where they terminate or where it is good practice to do so.

Earthing is a most important aspect of electronics as it can help to eliminate stray fields from causing interference to sensistive circuits.

Shielding

Some circuits are so sensitive to picking up radiations that they have to be protected by shielding. This is done by surrounding the circuit with a metal enclosure which is earthed. This then prevents any stray radiation from reaching the sensitive circuit or component.

Fig 13.9 illustrates some examples of shielding used in practice.

Bypassing

Quite often , a conductor carrying just DC to an amplifier or other circuit can cause problems. The conductor or a track on a printed circuit board is carrying currents to various circuits and interaction can occur between these currents. This interaction can lead to instability and possible oscillation. To eliminate the problem, bypassing is used.

Referring to Fig 13.10, you can see some capacitors connected from the DC conductor (or supply rail as it's sometimes called) to earth. These bypass capacitors prevent the interaction between different circuits or amplifiers connected to the same rail. This is done by carrying any AC components of the current to earth (bypassing) and keeping the DC on the rail clean of any variations in voltage.

Some other precautions with RF at high power levels

Some medical equipment may be prone to malfunction if exposed to RF fields from transmitters. Examples of this may include:- Heart pacemakers, cardiographs, encephelographs, ear implants etc. So you should be careful not to expose any sensitive equipment or persons with medical devices attached to an RF field from your transmitter.

chapter fourteen

SAFETY

The Human body can suffer serious effects if exposed to sources of voltage.

Electrical shock is not a very pleasant experience and in some circumstances it can be fatal.

The human body contains a high percentage of fluid and electrolytes, for example salt. We thus have resistance which can be measured on an ohmeter.

The danger lies in the amount of current which flows through our body and the physiological effects the current has upon us. We often hear people talk about voltage being the danger but it is more important to appreciate that it is the value of the current flowing through our body which poses the risk to life. Low voltages such as 12 volts can be felt in some situations and 24 volts of course is more likely to be sensed. Once the voltage goes above 110 volts then we are moving into an area which should command great respect. If our resistance is high, it takes more voltage to force a current through our body but when our resistance is low such as on a hot day when we are perspiring, then the situation becomes very risky. Also, if we have bare feet and we are standing in an 'earthed situation' which means someplace where our feet are on a concrete floor (i.e. earthed) or somewhere similar to this, then the danger is greatly increased.

It's also important to realise that if the current flows from, say the left hand to the right hand due to inadvertently touching a live conductor while holding an earthed object, the situation is especially dangerous because the current can flow through the heart muscle.

Physiological effects of electrical current through the body-

If we make contact with a live conductor, there are a number of effects the body experiences:-

To mention a few - heating, muscle spasm, burning, fibrillation of the heart muscle.

One of the most dangerous effects is when sufficient current flows through the heart muscle to cause it to go into ventricular fibrillation. This is a condition when the heart muscle is not going through its normal full muscular contractions. In fibrillation, it is not operating properly and the blood is no longer being pumped through the body. This condition if left to persist for a short while will lead to death.

Muscle spasm - this is often experienced as a contraction where the hand may close tightly onto the live conductor and lead to the victim being unable to disconnect themselves from the voltage.The further danger is if someone tries to disconnect the patient and touches their skin, this can lead to the rescuer suffering a similar shock hazard.

RF burns

It can be quite dangerous to touch live circuits carrying RF energy as RF can cause burns to the skin.

High power RF can burn quite severely and it can cause damage to body tissue. So RF should be respected and contact avoided by not working on live equipment without taking safety precautions. RF radiation can be injurious to health, so exposure for long periods to high power levels should be avoided.

Some helpful rules when dealing with dangerous situations:-

(i) avoid earthed situations when near any voltage which could be dangerous

(ii) wear suitable clothing, footwear and protective gear

(iii) switch off and disconnect any equipment before making any adjustments

(iv) don't work on or near dangerous voltages on your own.

(v) ensure all metal cases are earthed properly

(vi) ensure the active conductor is switched, not the neutral

(vii) ensure all live conductors are effectively insulated to prevent accidental contact

(viii) treat all voltage sources with great respect

(ix) install core balance relay safety circuit breakers in your workshop and radio shack

(x) to remove a person suffering a shock situation :-

(a) try to disconnect the voltage supply first by pulling the fuse or switching off the main switch

(b) if this is not possible, use an insulating material such as a dry wooden broom handle to lever the victim clear of the conductor

Safety near high voltage

One of the first things is to ensure that all wiring is installed by a qualified electrician. It is illegal for an unlicenced person to install or modify the fixed wiring in a building.

Another hazard is erecting antennas near overhead power cables. The rule is to "look up and live". Before raising the antenna, look very carefully to ensure that the antenna will not be anywhere near power lines.

Main switch

Every Amateur radio station should have safety as its prime objective as high voltage and RF can be quite hazardous in many situations.

There should be a main switch in the immediate vicinity of the "shack" so that in the event of an emergency, the power can be easily and quickly cut off.

This main switch should be clearly labelled and in a conspicuous place.

Station layout

The Station layout should be such that no undue hazard should be created. For instance, all power circuits should be laid out safely and no exposed live terminals should exist.

Working on Live equipment

It is a very risky practice to work on live equipment. If this must be done it should be done with very great care and another operator or assistant should be in attendance to switch off the power if an accident should occur. NEVER work on live equipment on your own. A good practice is to keep your free hand in your pocket to avoid any direct earthing situation for your body.

Death is very permanent!

Frequently, live uninsulated conductors are accessible under the covers of transmitting and receiving devices. So once the covers are removed for inspection, modification or adjustment, you are exposing yourself to the danger of touching these conductors inadvertently and a shock may result.

When building equipment, it is very good practice to insulate any high voltage contacts or conductors to eliminate any shock hazards.

Condition of Cables

Any cables or wires which have been damaged or are suffering from old age and need repair, should be replaced or repaired as soon as possible to prevent any dangerous situations and this will no doubt help to prevent fire risks too.

Cables and wires should be inspected regularly as one conductor especially the earth, can break without the break being obvious. Equipment will usually continue to operate with a broken earth but of course with the earth disconnected, a very dangerous shock hazard now exists. A fault condition can now cause a metal case to become live with possibly dire consequences to the unsuspecting operator.

Earthing

RF needs a good earth, so an earth stake right outside the shack and driven into wet or damp ground is an ideal facility to have. Then all gear can then be properly earthed to this stake.



Preferred WICEN type

Fig. 14.1 Polarised Plugs and sockets for 12v DC connections

No power outlet used at 240 Volts should be unearthed. If you find that one lacks an earth, get a licenced electrician to instal earthing to render the outlet safe.

Circuit loading

Each standard 240 volt outlet is rated at 10 amps. Do not overload the outlet by putting too many appliances onto double adaptors.

Color coding of cables

The Active conductor of flexible mains leads is usually red, brown or white. The color of the neutral is black or blue and the color of the earth is green or green with a yellow tracer.

Wiring plugs and sockets

When wiring a plug or socket, be sure to adhere to the correct color coding for the wires.

Ensure that the cord grip is properly employed so no strain is placed on the connections.

Immediately replace any damaged plugs or sockets.

It is not good practice to use 240 volt 3pin mains type plugs and sockets for low voltage use such as 12 volts. Use polarised plugs and sockets as shown in fig 14.1 for this purpose.

240 Volts mains conductors

The active conductor of a mains cable is at 240 volts above earth and is the one to treat with great respect.

The Neutral is usually at or very near to earth potential as it is usually connected to earth at the neutral bar on the main switchboard.

The earth is usually provided at each power outlet and most lighting points in modern buildings.The earth is designed to provide a low resistance path for fault currents to flow to ground .

Should a fault occur in a receiver, transmitter or other device, the earth will provide a sufficiently low

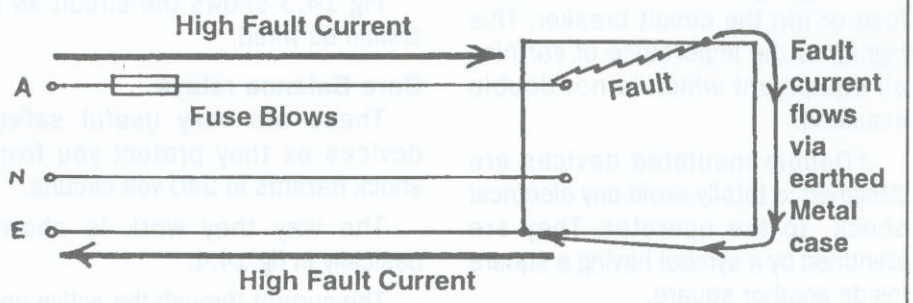
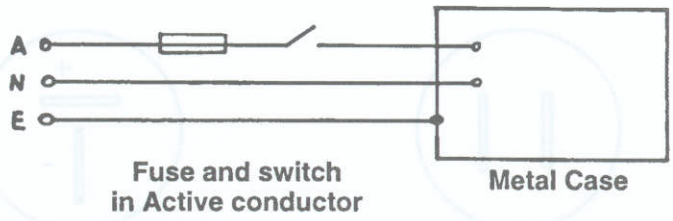


Fig. 14.2



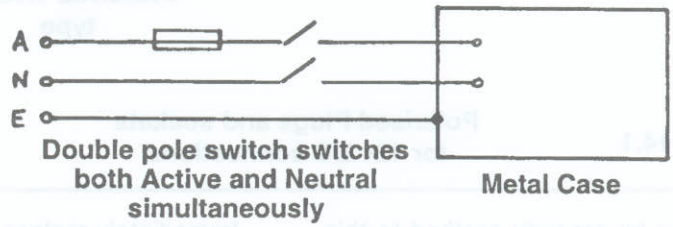
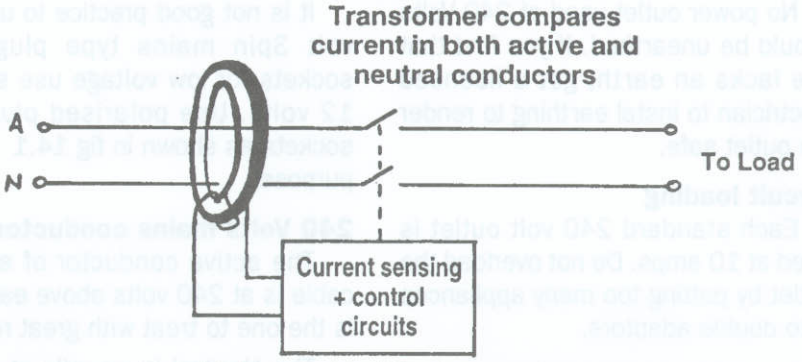


Fig. 14.3



Core Balance - Residual current protection circuit breaker

Fig. 14.4

resistance path for current to protect you from a shock hazard and it will also allow the fault current to blow a fuse or trip a circuit breaker, thus disconnecting the power from the circuit.

Fig 14.2 shows the situation when a fault occurs in some equipment . As the case of the equipment is connected to earth, the fault current flows via the earth conductor to the main earth in the installation and the resulting high current will blow the fuse or trip the circuit breaker. This highlights the importance of earthing all equipment which is not double insulated.

*Double insulated devices are designed to totally avoid any electrical shock to the operator. They are identified by a symbol having a square inside another square.

The earth circuit must always be intact and of low resistance so that the fault current will be sufficiently high to blow the protective fuse .

Switching

It is mandatory that the active in any piece of equipment be switched correctly. The neutral should never be switched unless the active is being simultaneously switched by the same switch such as a double pole switch. Normally the active conductor will contain a fuse so that the active conductor is open-circuited in the event of a fault blowing the fuse.

Fig 14.3 shows the circuit as it should be wired.

Core Balance relays

These are very useful safety devices as they protect you from shock hazards in 240 volt circuits.

The way they work is shown basically in fig 14.4.

The current through the active and the current in the neutral is constantly being compared electronically and if there is any difference then clearly a leakage has occurred and the relay will trip very quickly thus protecting you from any dangerous situation.

Power outlets are available commercially which have a core balance relay integrated into their construction and they can be wired so that they protect a number of power outlets connected to the same circuit.

Fuses and circuit breakers.

A fuse is designed to be the weak link in a circuit so that if the current exceeds a certain value the wire in the fuse melts and thus opens the circuit. Most fuses tend to blow at much higher currents than the normal running current of the circuit. In fact some fuses blow at twice their marked value or higher.

It is a very dangerous practice to upgrade the value of a fuse above its recommended value as damage is likely to occur in equipment which is not properly protected.

Slow-blow fuses are often used in equipment as they tend to handle many switch-on surges of current but will blow after a prolonged overload . An ordinary fuse will tend to blow after a number of switch-on cycles in some equipment having high surge currents which usually occur at the moment of being switched on.

The slow blow fuse has a capsule of metal which will eventually melt after an extended period of excessive current has occured past the moment of switch-on. The fuse is then cleanly broken by an internal spring which pulls the wire open fully after the metal capsule has melted.

Circuit breakers

A circuit breaker is either a thermal or magnetically activated switch.

If the current in a circuit exceeds the rating of the circuit breaker, a thermal element or a magnetic coil causes the mechanism to trip and open the circuit. They are more expensive than a fuse but can be quickly reset once the fault has been rectified.

Ratings of fuses and circuit breakers

The rating should be such that adequate protection is provided in the event of a fault .

If the rating is too low,the fuse or circuit breaker will trip unnecessarily and prematurely, however, if the rating is too high, the fuse or circuit breaker will not give protection in the event of a fault condition.

The main point is that when a fault occurs,the current is high and can cause a great deal of heating of circuit conductors which can lead to fires due to cables overheating.

Lightning

During thunderstorm activity, there is the likelihood that your antenna may be struck or a nearby point may be struck. For this reason it is not wise to be operating your equipment during a storm. It is good practice to disconnect the equipment from the mains during a storm.

In fact it is a good precaution to disconnect your antennas from equipment during storms as a great deal of damage can be done to equipment by lightning strikes.

It is not necessary for a direct strike to cause damage as induced voltages can be very high and can cause damage.

A high antenna, especially one having elements vertically polarised, puts a sharp point towards the sky and this has a very concentrated field which is most likely to present an attractive point to a lightning strike.

Lightning generates very high currents which produce a great deal of heating effect and so burns occur to cables and equipment which have been struck.

Telephone cables buried in the ground can be badly damaged by lightning which can travel reasonable distances in any conductor in the ground. Antenna cables can also be damaged even though they are run on, in or near the ground. The paths for lightning currents can be via antenna feedlines, rotator cables and mains power wiring.

Lightning Arrestors

It is a wise measure to include lightning arrestors in the feedlines where they enter the radio shack to give some protection against lightning damage to your transmitters and receivers.

The lightning arrestors should be connected directly to an earth just outside the shack .

In coaxial cable feedlines, the arrestor is a coaxial type available commercially and in the case of balanced lines, the arrestor can be home-made using appropriate spark gaps connected to the earth stake just outside the shack.

Hazardous materials

One of the most hazardous materials in radio is Beryllium Oxide. It is used in some high power valves and in some power transistors.

This substance is quite toxic to humans and any device containing it should be treated with great care. You should never cut, file, grind or break this material in any way as the dust is very toxic and if inhaled can cause a serious health hazard.

Dispose of these devices thoughtfully.

PCB's – These are toxic.

Battery charging

When a lead-acid battery is being charged it gives off Hydrogen gas. This is explosive and care should be taken to not have a flame or hot body anywhere near the battery when charging or after a battery has been charged.

The room in which the battery is contained, should be adequately ventilated so the gases can escape safely.

The Sulphuric acid in lead-acid batteries is very corrosive and should not be allowed to get onto the skin or into your eyes.

Wear suitable protective clothing and eye protection when handling batteries.

When disconnecting the charger or a load from the battery, switch off the charger or the load at a safe distance from the battery before removing the cables from the battery terminals. This will avoid any spark being caused near the battery.

When charging batteries, the current should not exceed the manufacturer's recommendations as the battery may overheat.

Similarly, if the discharge (load) current from the battery exceeds the manufacturer's specifications, then it may overheat.

SAFETY IN THE MOBILE STATION

Blasting areas

Because some detonators are sensitive to RF from a nearby transmitter, it is important to switch off your transmitter if you are near a site where explosives are being used. If you were to transmit, you may endanger the lives of the personnel who are working on the site.

Explosive situations

Also, if you are in a situation where there are explosive materials or explosive dusts, it is a wise precaution to switch off your transmitter.

When filling your vehicle fuel tank it is not advisable to operate your transmitter as a spark may occur at the tank filler spout and thus ignite the fuel.

Antenna safety

Care should be taken if you have a high antenna as it could contact overhead power lines and cause a shock hazard.

When raising a portable antenna, it is good practice to survey the site to ensure that there are no overhead power lines which could be accidentally touched by the antenna as you erect it.

"Look up and live" is a good motto.

Driving whilst holding a microphone is very dangerous as you don't have full control of the vehicle under these conditions. A boom or remote microphone should be used to leave both hands free to steer the vehicle.

*It is actually illegal in a number of states to hold or be using a microphone whilst driving .

Eye Injury

It is normal practice to cap any coax socket which could be emitting an RF signal. The RF, if emitted at certain power levels especially in the UHF bands can become an eye hazard.

questions

Use this section as a personal study promoter. If you can't answer any question, then look it up in the appropriate chapter. Confirm your answers by looking up the relevant text. This will assist you in learning the theory efficiently so that you will take the exam in your stride. You really need to have a good understanding of the theory to pass the exam well as the pass level is 70% NOT 50% !

Questions for Chapter One (Electrical Laws)

1. What is the typical no-load voltage for Nickel-cadmium cells?

(a) 1 volt
(b) 1.2 volts
(c) 1.5 volts
(d) 2.0 volts

2. When a resistor is carrying current, the voltage developed across it can be found by:-

(a) E=I+R
(b) E=I-R
(c) E= IxR
(d) E=I/R

3. What voltage would cause a current of 5 amps to flow through a 50 ohm resistor?

(a) 45 volts
(b) 20 volts
(c) 55 volts
(d) 250 volts

4. What voltage would be needed to supply a current of 200 milliamps to light a 25 ohm lamp?

(a) 5 V
(b) 8V
(c) 175 V
(d) 225 V

5. An EMF of 6 volts causes a current of 0.5 amps to flow through a resistor. To reduce the current to 0.25 amps, the voltage must:-

(a) increase to 12 volts
(b) increase to 24 volts
(c) decrease to 3 volts
(d) increase to 9 volts

6. The value of the current flowing through a resistor is found by :-

(a) I = E x R
(b) I = E / R
(c) I = E - R
(d) I = E + R

7. An 8 ohm resistor is connected to a 12 volts supply. What will be the value of the current flowing?

(a) 1.5 amps
(b) 0.66 amps
(c) 4.0 amps
(d) 20 amps

8. The total resistance of a circuit is 100 ohms.If 50 volts is applied,what current will flow?

(a) 50mA
(b) 500 mA
(c) 2.0 amps
(d) 20 amps

9. Which of the following resistors has the highest opposition to current flow?

(a) 250 ohms
(b) 1.0 Kohm
(c) 10Kohms
(d) 0.47Megohm

10. A signal is found to have two components, one of 3 MHz and one of 9 MHz.What are these two signals called respectively?

(a) fundamental and third harmonic
(b) overtone and fundamental
(c) multiplier and overtone
(d) overtone and harmonic

11. What is another name for an inductor?

(a) choke
(b) resistor
(c) semiconductor
(d) farad

12. Two capacitors of 100uF each are connected in parallel. What is the joint capacitance?

(a) 100uF
(b) 200 uF
(c) 50uF
(d) 400 uF

13. The reactance of an inductor:-

(a) rises with an increase in frequency
(b) falls with an increase in frequency
(c) is unaffected by a decrease in frequency
(d) for a given frequency, rises as the inductance is reduced

14. The losses in a transformer are primarily:-

(a) eddy current, hysteresis, copper
(b) iron, electrostatic, inductive
(c) copper, electromagnetic, capacitive
(d) hysteresis, resistive, reactive

15. A coil & capacitor are connected in parallel. Their resonant frequency can be raised if :-

(a) turns are added to the coil
(b) the value of the capacitor is increased
(c) turns are removed from the coil
(d) another capacitor is added in parallel.

* There are no questions for chapters 2 & 3.

Questions for Chapter Four (Semiconductors)

1. The forward conduction voltage for a silicon diode is:-

(a) 1 volt
(b) 0.9 volt
(c) 0.6 volt
(d) 0.2 volt

2. A semiconductor diode will conduct if:-

(a) the anode is negative with respect to the cathode
(b) the cathode is positive with respect to the anode
(c) the cathode is 0.1 volts more positive than the anode
(d) the anode is more positive than the cathode

3. The connections of a silicon diode are known as :-

(a) anode, gate
(b) cathode, drain
(c) source, anode
(d) cathode, anode

4. A diode with a 5.6 volt rating is likely to be :-

(a) a zener diode
(b) a rectifier diode
(c) a germanium diode
(d) a varactor diode

5. The terminal connections for a bipolar transistor are :-

(a) collector, gate, base
(b) emitter, base, collector
(c) gate, drain, collector
(d) source, base, emitter

6. Which electrode is considered to be the control electrode for an NPN bipolar transistor ?

(a) base
(b) collector
(c) emitter
(d) gate

7. The DC current gain for a transistor is usually called :-

(a) alpha
(b) beta
(c) lambda
(d) gamma

8. In a common emitter amplifier, the largest current flows in :-

(a) the emitter circuit
(b) the base circuit
(c) the collector circuit
(d) the gate circuit

9. Which is a correct statement about Field Effect Transistors (FETs) ?

(a) the input impedance is lower than that of a bipolar transistor
(b) the input impedance is higher than that of a bipolar transistor
(c) FETs are a current-operated device
(d) FETs have a high current gain.

10. Heat sinks are used with transistors to:-

(a) reduce forward leakage currents
(b) increase forward current
(c) increase reverse leakage currents
(d) control temperature rise

Questions for Chapter Five (Vacuum Tubes)

1. A vacuum tube relies upon thermionic emission.What produces the emission in the tube?

(a) the anode
(b) the grid
(c) the suppressor
(d) the cathode

2. When the highest level of current is flowing through a tube it is said to be :-

(a) saturated
(b) cut off
(c) reverse biased
(d) forward biased

3. A diode tube can :-

(a) amplify
(b) oscillate
(c) rectify
(d) modulate

4. For a diode to conduct, the voltages must be :-

ANODE	CATHODE
(a) positive	negative
(b) negative	positive
(c) negative	negative
(d) positive	positive

5. A tube containing a cathode, grid and an anode is a: -

(a) pentode
(b) triode
(c) tetrode
(d) diode

6. An amplifier is fed with a 1 KHz tone. The output signal is found to be a 1KHz tone of higher amplitude. Both signals have a sinewave shape. The amplifier is thus said to be:-

(a) a non-linear amplifier
(b) a modulated amplifier
(c) a class C amplifier
(d) a linear amplifier

7. Which amplifier has the most linear operation?

(a) class A
(b) class B
(c) class C
(d) class AB

8. In a triode amplifier circuit,the bias voltage is developed between :-

(a) the anode and the grid
(b) the cathode and the anode
(c) the grid and the cathode
(d) the cathode and the screen

9. Which electrode has the greatest control of the current in a triode tube?

(a) grid
(b) anode
(c) screen
(d) cathode

10. Which vacuum tube has the least capacitance between the anode and the cathode?

(a) diode
(b) triode
(c) tetrode
(d) pentode

Questions for Chapter 6 (power supplies)

1. A Novice transmitter power supply is fed from 240v AC mains. If it uses a half wave rectifier,what will be the output voltage ripple frequency?

(a) 50 Hz
(b) 100 Hz
(c) 25 Hz
(d) 150 Hz

2. A bridge rectifier uses (.....) diodes:-

(a) one
(b) two
(c) three
(d) four

3. What would be a suitable rating for a power supply to operate a transistor final power amplifier in a Novice morse code transmitter which is running the maximum legal power output?

(a) 1watt
(b) 5 watts
(c) 30 watts
(d) 150 watts

4. A DC supply has an input voltage of 20VAC. It uses a capacitor filter and a bridge rectifier. What would be the most suitable peak inverse voltage rating for the diodes?

(a) 25 volts
(b) 50 volts
(c) 12.5 volts
(d) 9 volts

5. What is the main function of a Zener diode?

(a) to regulate current
(b) to maintain constant current
(c) to maintain constant voltage
(d) to rectify current

6. The major component which determines the output voltage of a power supply is the :-

(a) transducer
(b) transformer
(c) filter
(d) rectifier

7. The main function of the filter in a DC power supply is to:-

(a) regulate the voltage
(b)act as a high pass component
(c) rectify the voltage
(d) to reduce the ripple on the DC

8. The metal case of any high voltage equipment such as a power supply is normally earthed.The prime reason for this is:-

(a) to reduce stray magnetic fields
(b) to reduce RF interference
(c) to prevent shock hazards
(d) to reduce hum radiation

9.The three essential components in a mains operated supply are:-

(a) transformer filter rectifier
(b) transformer fuse filter
(c) voltage divider filter rectifier
(d) voltage divider fuse rectifier

10. A power supply used to supply an SSB transmitter has larger filter capacitors than one supplying an AM transmitter. What is the reason for the difference?

(a) SSB transmitters operate at higher voltage
(b) AM transmitters operate at higher voltage
(c) AM transmitters operate at higher currents
(d) SSB transmitters have a wider current demand.

Questions for Chapter seven (Oscillators and amplifiers)

1. Frequency Multiplier stages are most commonly used :-

(a) to raise a transmitters frequency to a harmonic
(b) to increase a transmitters output
(c) to maintain the linearity of an SSB transmitter
(d) after the balanced modulator in an SSB transmitter

2. Which stage of an HF SSB Novice transmitter controls the frequency?

(a) oscillator
(b) balanced modulator
(c) buffer amplifier
(d) modulator

3. In order to obtain continuous output from an oscillator,what essential factor must be provided?

(a) negative feedback
(b) positive feedback
(c) degeneration
(d) attenuation

4. What property of a crystal causes it to be able to control the frequency of an oscillator?

(a) the Hall Effect
(b) the Magnetostrictive Effect
(c) the Capacitive Effect
(d) the Piezo-Electric Effect

5. To slightly change the frequency of a transmitter, it is only necessary to adjust the :-

(a) power amplifier
(b) buffer amplifier
(c) oscillator
(d) multiplier

6. A transmitter operating in the 80 metre (3.5MHz) band is found to be emitting signals on 3.55, 120 & 7.1 MHz. These signals are respectively: -

(a) fundamental parasitic third harmonic
(b) harmonic carrier overtone
(c) fundamental parasitic 2nd harmonic
(d) parasitic overtone fundamental

7. To correctly tune a transmitter final power amplifier, it is usual to :-

(a) peak the anode/collector tuning and dip the drive control
(b) dip the PA tuning control and peak the drive control
(c) dip the drive control, dip the loading control
(d) peak the loading control, peak the PA tuning control

8. Under normal conditions,the PA tuning, drive and loading controls of a transmitter are adjusted for these settings to maximise RF output as shown by an RF wattmeter.

PA tuning	Drive	Loading
(a) dip	dip	peak
(b) peak	peak	peak
(c) dip	dip	dip
(d) dip	peak	peak

9. If an 80 metre transmitter operating on 3525 KHz is found to be radiating harmonics, at what frequency will a receiver detect a signal?

(a) 3573KHz
(b) 7050 KHz
(c) 14025 KHz
(d) 21050 KHz

10. The input to the power amplifier stage of a transmitter is 21.0 MHz but the output is found to be 42 MHz. What is the most likely problem?

(a) harmonic radiation
(b) interstage coupling
(c) detuned drive control
(d)lack of neutralisation.

Questions for Chapter 8 (Transmitters)

1. A morse code transmitter is causing a 'clicking'interference to nearby broadcast receivers. What is the most likely remedy for the problem?

(a) installation of a high pass filter at the transmitter
(b) use of a lower level of modulation in the transmitter
(c) use of a key click filter at the transmitter
(d) use of a bypass capacitor in the receiver's antenna

2. Which morse transmitter stage is the most likely to be keyed?

(a) oscillator
(b) intermediate stage
(c) modulator
(d) PA filament

3. Keying a morse code transmitter can cause "chirps" which are slight frequency shifts. Which of these would NOT reduce the problem?

(a) use of a relay in place of the key
(b) better power supply voltage regulation
(c) buffering of the oscillator
(d) keying of the PA stage

4. When keying the PA stage of a transmitter, due care should be taken to ensure that :-

(a) the oscillator is off when the key is up
(b) the RF drive to the PA is not interrupted
(c) the key does not vary the RF output
(d) the varying load does not affect the oscillator

5. Which would be the most suitable method of monitoring the quality of the output of a morse code transmitter?

(a) view waveforms on an oscilloscope
(b) listen with an audio oscillator
(c) use a receiver with the antenna disconnected
(d) simultaneously key an audio oscillator

6. In a normal AM emission, the carrier is radiated :-

(a) only when the modulator applies audio to the PA stage
(b) only when the modulation exceeds 50%
(c) whenever the transmitter is turned on
(d) when the operator is not speaking into the microphone

7. In an AM transmitter the modulator superimposes audio onto the carrier. This results in a :-

(a) continuous wave emission
(b) carrier plus one sideband
(c) carrier plus two sidebands
(d) single frequency emission

8. The bandwidth occupied by an AM emission is :-

(a) determined by the phase of the modulating signal
(b) determined by the frequency of the modulating signal
(c) is greater when the modulation changes from 3 to 2 KHz.
(d) is less when the modulation changes from 2 to 3 KHz.

9. An AM transmitter has a DC input power to the PA of 10 watts. What would be the power level required from the modulator to 100% modulate the transmitter using high level modulation?

(a) 1 watt
(b) 2 watts
(c) 5 watts
(d) 10 watts

10. In an AM transmission, the RF wave has its (.....) by the modulating signal.

(a) frequency varied
(b) amplitude varied
(c) phase varied
(d) sidebands suppressed

11. Referring to a normal AM emission, which statement is correct:-

(a) the carrier only is radiated when there is modulation
(b) there are two sidebands whenever there is modulation
(c) the upper sideband is suppressed with tone modulation
(d) the lower sideband is not normally radiated on the HF bands

12. Which emission takes up the least band space?

(a) a 50% modulated AM signal
(b) a 75% modulated signal
(c) an AM carrier
(d) a 100% modulated signal

13. Which section of an SSB transmitter suppresses the carrier?

(a) the balanced modulator
(b) the heterodyne oscillator
(c) the crystal filter
(d) the mixer

14. Which section suppresses one sideband in an SSB transmitter?

(a) the balanced modulator
(b) the filter
(c) the carrier oscillator
(d) the mixer

15. What is the output from the balanced modulator in an SSB transmitter?

(a) a carrier
(b) double sideband suppressed carrier
(c) single sideband suppressed carrier
(d) double sideband half carrier

16. What is the function of the carrier oscillator in an SSB transmitter?

(a) it generates one sideband
(b) it produces the carrier
(c) it generates both sidebands
(d) it heterodynes the sidebands

17. To amplify SSB signals in a transmitter, it is necessary to use:-

(a) a class A linear amplifier
(b) a class B linear amplifier
(c) a non-linear amplifier
(d) a class C amplifier

18. The exciter in an SSB transmitter produces the signal at 9 MHz. What frequency should the heterodyne oscillator be tuned to for 3.5 MHz operation?

(a) 9.1 MHz
(b) 6.25 MHz
(c) 5.5 MHz
(d) 3.5 MHz

19. The filter in an SSB transmitter should ideally have a bandwidth of about :-

(a) 1 KHz
(b) 1.5 KHz
(c) 3.5 KHz
(d) 10 KHz

20. An on-air report suggests that your SSB transmitter is emitting a carrier. What would be the correct procedure in this case?

(a) ignore the report, emission of the carrier is normal
(b) check the alignment of the filter
(c) check the alignment of the balanced modulator
(d) check the tuning of the PA stage

21. The bandwidth occupied by a normal SSB emission is:

(a) 3 KHz
(b) 6 KHz
(c) 1.5 KHz
(d) 9 KHz

22. Which essential stage of an SSB transmitter is missing from this list?

carrier oscillator, Balanced modulator

driver, PA

(a) heterodyne modulator
(b) BFO
(c) mixer
(d) sideband filter

Questions for Chapter 9 (Receivers)

1. What determines the ability of a receiver to reject adjacent signals?

(a) selectivity
(b) sensitivity
(c) gain
(d) image ratio

2. A suitable detector for morse code signals is the: -

(a) phase detector
(b) discriminator
(c) ratio detector
(d) product detector

3. A BFO is needed in a receiver to resolve :-

(a) FM signals
(b) AM signals
(c) CW signals
(d) DSB full carrier signals

4. Which stage of a receiver is most likely to have its input and its output circuits tuned to the same frequency.

(a) mixer
(b) oscillator
(c) RF amplifier
(d) detector

5.The sensitivity of a receiver can be described as :-

(a) its ability to resolve weak signals
(b) its ability to discriminate between two adjacent signals
(c) its mode of detection
(d) its ability to reject image signals

6. A receiver used to detect AM signals can resolve :-

(a) SSB signals
(b) DSBSC signals
(c) CW signals with a BFO
(d) CW signals

7. A receiver possessing high selectivity has:-

(a) a narrow bandwidth
(b) a wide bandwidth
(c) high fidelity
(d) good AGC

8. A receiver being used for SSB signals needs a BFO because:-

(a) the carrier must be re-inserted
(b) stable detection is needed
(c) one sideband must be attenuated
(d) the carrier needs detection

9. Which would be the most practical way to improve the selectivity of a superhet. receiver?

(a) by adding a product detector
(b) by use of an AGC system
(c) by use of a crystal filter
(d) by use of a higher IF

10. The local oscillator in a superhet receiver:-

(a) normally operates above the desired signal by twice the IF
(b) is normally fixed-tuned
(c) is always tuned above the desired signal
(d) can be tuned above or below the desired signal

Questions for Chapter 10 (Wave Propagation)

1. Which upper atmosphere layer will best refract HF Radio signals to earth?

(a) auroral layers
(b) ionised layers
(c) inversion layers
(d) sporadic layers

2. The Ionosphere :-

(a) is a region in the upper atmosphere which refracts radio waves
(b) is a plasma of deionised gases which reflect waves
(c) is an equatorial belt of ionised air
(d) is a polar region of ionised chlorofluorocarbons

3. The distance between a transmitter and the point on the earth's surface where the wave returns is called the :-

(a) skip distance
(b) skip zone
(c) absorption limiting zone
(d) maximum usable zone

4. The skip distance of a sky wave will be maximum when:-

(a) the angle of radiation is low
(b)the power level is high
(c) the critical frequency is low
(d) the ionosphere is heavily ionised

5. If the height of an ionospheric layer increases, the skip distance of an SSB emission :-

(a) will increase
(b) will decrease
(c) remains static
(d) is unaffected

6. The velocity of a radio wave is :-

(a) 168,000 miles per second
(b) 3000 metres per second
(c) 18600 miles per second
(d) 300,000,000 metres per second

7. A horizontal antenna radiates a :-

(a) vertically polarised wave
(b) a horizontally polarised wave
(c) a circularly polarised wave
(d) an omni-polarised wave

8. For given conditions, when the emission is above the Maximum Usable Frequency:-

(a) the ground wave is heavily attenuated
(b) the sky wave refracts to a different point on earth
(c) the ground wave and the sky wave are co-planar
(d) sky wave propagation is unlikely

9. A radio wave which travels to a receiver via the ionosphere is called :-

(a) a sky wave
(b) a direct wave
(c) a ground wave
(d) a surface wave

10. The number of HF amateur bands open for use at any one time is determined by:-

(a) the critical frequency
(b) the absorption limiting frequency
(c) the maximum usable frequency
(d) the radiation angle

Questions for Chapter 11 (Antennas and transmission lines).

1. When the output from a transmitter is coupled to the antenna system with minimal losses,the system is said to be :-

(a) balanced
(b) matched
(c) reactive
(d) off-resonance

2. The feedline used with a half wave dipole antenna would normally be:-

(a) 75 ohms
(b) 300 ohms
(c) 36 ohms
(d) 95 ohms

3. Which statement is correct for unbalanced transmission lines:-

(a) the impedance is usually 200 ohms
(b) they have lower losses than balanced lines
(c) standing waves only appear on the outer conductor
(d) one conductor is usually at earth potential

4. The characteristic impedance of balanced transmission lines :-

(a) is usually lower than that of coaxial lines
(b) is usually inductive
(c) is measured in ohms
(d) varies with frequency

5. The characteristic impedance of transmission lines:-

(a) is determined by the frequency
(b) is determined by the velocity factor
(c) depends upon the SWR
(d) is not affected by frequency

6. The main function of a transmission line is to :-

(a) reduce standing waves
(b) operate with input and output impedance matched
(c) radiate RF energy
(d) couple the antenna to the transmitter

7. If a 75 ohm transmission line is coupled to an antenna with an impedance of 36 ohms:-

(a) the system will be at maximum efficiency
(b) there will be some standing wave losses
(c) a long line will have low losses
(d) a resistor of 39 ohms should be connected in series.

8. The impedance of a line is quoted as 300 ohms. When compared with a line of 50 ohms :-

(a) the 300 ohm line has lower losses
(b) the 50 ohm line has lower losses
(c) the 300 ohm line radiates more RF
(d) the 300 ohm line will match a folded dipole better

9. A transmission line is said to be "50 ohms". This refers to :-

(a) its DC impedance
(b) its reactance
(c) its DC resistance
(d) its characteristic impedance

10. A 75 ohm coaxial line can be matched to a folded dipole by:-

(a) use of a 1:1 balun
(b) use of multiple half wavelengths of line
(c) adjusting the length of the antenna
(d) use of a 1:4 balun.

11. The length of a dipole antenna is normally :-

(a) quarter wavelength
(b) half wavelength
(c) half wavelength per side
(d) one wavelength

12. To slightly lower the frequency of an antenna, one should :-

(a) lengthen it
(b) shorten it
(c) add capacitance in parallel with the feed point
(d) add a balun to the feed point.

13. The main characteristic of a vertical antenna is that :-

(a) it does not require a ground plane
(b) it receives horizontally polarised signals
(c) it has high impedance
(d) it has an omni-directional field strength pattern

14. A vertical antenna is :-

(a) usually half a wavelength long
(b) usually quarter wavelength long
(c) unable to receive horizontally polarised signals
(d) usually one wavelength long

15. A dipole antenna oriented east-west will radiate best :-

(a) north-south
(b) in end-fire mode
(c) east-west
(d) omni-directionally

16. The feed point of a centre-fed half wave dipole antenna is/has:-

(a) high voltage and low current
(b) low voltage and high current
(c) normally at high impedance
(d) low voltage and low current

17. A standard half wave dipole antenna is best fed with :-

(a) balanced 300 ohm line
(b) unbalanced 75 ohm line
(c) balanced 300 ohm line with a 1:1 balun
(d) unbalanced 75 ohm line with a 1:1 balun.

18. When testing a transmitter, use should be made of a/an:-

(a) open circuit transmission line
(b) short circuited transmission line
(c) reactive line impedor
(d) dummy load

19. In a three element antenna, the reflector and director elements are called:-

(a) resistive
(b) parasitic
(c) parametric
(d) inductive

20. A Yagi antenna has gain over a dipole antenna because :-

(a) it has a better impedance match
(b) a balanced driven element
(c) it concentrates the power in a given direction
(d) it can accept more power.

Questions for Chapter 12 (Test equipment)

1. Which would be the most suitable device to ascertain that a transmitter is on the correct frequency?

(a) an oscilloscope
(b) a digital voltmeter
(c) a receiver
(d) a multimeter

2. A Dip Oscillator is best used for :-

(a) measuring resonance
(b) measuring resistance
(c) measuring impedance
(d) measuring capacitive reactance

3. The range of a milliameter can be extended by using :-

(a) a shunt resistor
(b) a series multiplier
(c) a series capacitor
(d) a shunt diode

4. When using a crystal marker oscillator to calibrate a receiver, what should the receiver controls be set to ?

	AF Gain	RF Gain	BFO
(a)	maximum	zero	on
(b)	zero	maximum	off
(c)	20%	maximum	off
(d)	30%	maximum	off

5. What practical applications do stations WWV, WWVH, and VNG provide?

(a) an accurate standard frequency
(b) accurate reactance measurement
(c) precise impedance measurement
(d) precise pre-emphasis measurement

6. When the voltage across a resistor is to be measured, where should the meter be connected?

(a) in series with the resistor
(b) in parallel with the supply
(c) in parallel with the resistor
(d) in series with the supply

7. A multi meter is used most commonly to measure :-

(a) inductance, capacitance, reactance
(b) resonance , reactance, resistance
(c) voltage, current, impedance
(d) current, voltage, resistance

8. Standing wave measurements are:-

(a) only able to be made in coaxial lines
(b) able to be made in coaxial and balanced lines
(c) only able to be made in balanced lines
(d) cannot be made on lines feeding resonant antennas

9. The standing wave ratio on a transmission line is :-

(a) ideally low to optimise efficiency
(b) the ratio between forward voltage and reflected current
(c) the ratio between forward current and reverse voltage
(d) higher for coaxial lines than for balanced lines

10. When making transmitter measurements and adjustments,

(a) the transmission line should be shorted
(b) the transmission line should be open-circuited
(c) the transmitter should be coupled to a resistive load
(d) a capacitor should be connected across the transmitter output.

Questions for Chapter 13 (Interference)

1. Harmonics are present when :-

(a) a resonant circuit is tuned above resonance
(b) a resonant circuit is tuned below resonance
(c) a waveform is not a sine wave
(d) an amplifier is operated in class A

2. RF power amplifiers in transmitters can produce harmonics.What is the best method of suppressing them?

(a) use of capacitive interstage coupling
(b) use of a high pass filter
(c) use of a parallel resonant circuit in shunt
(d) use of a low pass filter

3. Parasitic oscillations are most likely to occur in:-

(a) a class A audio amplifier
(b) a class C RF power amplifier
(c) a low gain buffer amplifier
(d) high capacitance filters

4. When an AM transmitter is modulated to a level greater than 100% :-

(a) the sideband power is detected more easily
(b) the carrier has greater linearity
(c) the emission has greater bandwidth
(d)the emission has less bandwidth

5. When an SSB transmitter is operated with the linear amplifier driven above its normal conditions :-

(a) the emission is distorted
(b) the emission has less range
(c) the emission has greater intelligibility
(d) the power output increases dramatically

6. Interference on frequencies adjacent to the operating one occurs when :-

(a) the transmitter is modulated below 50%
(b) a linear amplifier is over-driven
(c) the gain of the RF power amplifier is reduced
(d) the RF power amplifier is slightly detuned

7.Radiation of harmonics can be reduced by:-

(a) use of a high pass filter at the transmitter
(b) use of a low pass filter at the TV receiver's antenna
(c) detuning the transmitter PA stage slightly
(d) use of a low pass filter at the transmitter output

8. Interference to stations adjacent to the operating frequency on SSB can be reduced by :-

(a) reducing the ouput power of the transmitter slightly
(b) installing a high pass filter at the transmitter
(c) reducing the microphone gain of the transmitter
(d) installing a high pass filter at the transmitting antenna

9. Harmonic interference to TV reception can usually be identified as :-

(a) diagonal lines on the screen in sympathy with modulation
(b) loss of vertical sync. in the TV receiver
(c) loss of AFC in the TV receiver
(d) snow in the TV picture

10.Use of a low pass filter at the output of an HF transmitter will :-

(a) allow higher frequency signals to reach the antenna
(b) allow all frequencies below 34 MHz to reach the antenna
(c) reduce the SWR on the transmission line
(d) reduce linear amplifier "flat-topping'

Questions for Chapter 14 (Safety)

1. What is the correct color for the earth conductor in a 3 core flexible power cord?

(a) yellow
(b) Red
(c) green/yellow
(d) blue/yellow

2. What is the standard color for the active conductor in a 3 core flexible power cord?

(a) black
(b) yellow
(c) brown
(d) blue

3. What is the main reason for earthing the metal cases of electronic equipment?

(a) to reduce harmonic generation
(b) to reduce shock hazards
(c) to increase mutual inductance
(d) to increase stray capacitance

4. What is the major reason to replace a fuse with one of identical ratings?

(a) to ensure safety ratings are maintained
(b) to avoid size problems
(c) to prevent undercurrent problems
(d) to maintain voltage drop

5. What is considered to be the lowest voltage which can be considered hazardous?

(a) 6v
(b) 12v
(c) 24v
(d) 48v

6. When a person is found to be touching live terminals and is suffering shock,what is the first step to be taken?

(a) call for assistance
(b) check their pulse
(c) check their breathing
(d) carefully remove them from the voltage

7. When working on live equipment the best procedure is :

(a) ensure all dangerous voltages are insulated
(b) place the equipment on a rubber mat
(c) wear leather soled shoes
(d) ensure that the equipment is earthed

8. When near a blasting site which is the best procedure?

(a) switch off the transmitter
(b) set the transmitter to low power
(c) keep transmissions short
(d) use a directional antenna

9. When erecting antennas in the vicinity of power lines:-

(a) use antennas with insulated bases
(b) use horizontally polarised antennas only
(c) connect the cable to the antenna last
(d) use great care and an observer to assist

10. The core balance relay is useful for:-

(a) avoiding unbalanced currents
(b) preventing unbalanced voltages
(c) limiting current flow
(d) preventing shock hazards

morse code

There are two morse code exams to be passed to obtain the Novice Operator's Licence:-

THE SENDING TEST.

This is at a speed of 5 words per minute and lasts for 2.5 minutes.

THE RECEIVING TEST.

This is also at a speed of 5 words per minute and lasts for 5 minutes

It is important to know that the exam pass level is about 90%,(not 50%) so there's not much room for errors!

The secret is to prepare yourself well so that under the pressure of the exam you perform well and take the tests in your stride.

Here are some tips on helping you to pass the exams :-

1. Practice the letter and number sounds regularly to become totally familiar with them as you are learning a new language and the sounds must be **automatically** recalled every time you hear them.

2. Use good practice tapes to learn how to take the copy down on paper.

3. You can listen to off-air signals or get a local radio operator to give you some practice sessions.

4. Do NOT try to use a key to send morse until you have a good receiving speed capability. This will help prevent you possibly learning errors which are very hard to correct.

5. Practice regularly. You should do at least 15 minutes every day on a REGULAR and CONSISTENT basis as this will be much more effective than trying to do long sessions sporadically which is NOT the way to learn efficiently.

6. Use headphones as they increase your concentration greatly and will give other members of the home a break from the sounds of the morse.

7. Try to listen to morse which is slightly too fast for you - it will "stretch you out" and cause your speed proficiency to rise. (you'll gradually increase the percentage of copy taken down accurately)

8. Practice copy that is plain language with numbers interspersed to simulate real exams and write the copy down. By this means you are "rehearsing" yourself for the actual exam conditions.

If you need more tapes contact the author (QTHR) via the Australian Callbook.

Best wishes for a pass in the exams and a long and happy involvement with the hobby !

A	di-dah
B	dah-di-di-dit
C	dah-di-dah-dit
D	dah-di-dit
E	dit
F	di-di-dah-dit
G	dah-dah-dit
H	di-di-di-dit
I	di-dit
J	di-dah-dah-dah
K	dah-di-dah
L	di-dah-di-dit
M	dah-dah
N	dah-dit
O	dah-dah-dah
P	di-dah-dah-dit
Q	dah-dah-di-dah
R	di-dah-dit
S	di-di-dit
T	dah
U	di-di-dah
V	di-di-di-dah
W	di-dah-dah
X	dah-di-di-dah
Y	dah-di-dah-dah
Z	dah-dah-di-dit
1	di-dah-dah-dah-dah
2	di-di-dah-dah-dah
3	di-di-di-dah-dah
4	di-di-di-di-dah
5	di-di-di-di-di
6	dah di di di dit
7	dah dah di di dit
8	dah dah dah di dit
9	dah dah dah dah dit
0	dah-dah-dah-dah-dah
CT	dah-di-dah-di-dah
AR	di-dah-di-dah-dit
*K	dah-di-dah

*means 'over to you'

**Morse Code Tapes at various speeds are available from the author, Graeme Scott, VK2KE by writing to-

P.O. Box 385
Albury, NSW 2640

glossary

AC - Alternating Current - obtained from alternators and oscillators and changes polarity from negative to positive cyclically

AFC - Automatic Frequency Control - used most commonly in FM, VHF and UHF receivers, esp. TV to prevent oscillator drift.

AGC - Automatic Gain Control - used in receivers to automatically control the volume over wide ranges of signal strengths

Attenuators - a resistive circuit which drops signal strengths or voltages to lower levels.

Bandwidth - the amount of spectrum space taken up by a signal

BCI - Broadcast Interference

BFO - Beat Frequency Oscillator - used in receivers to provide a beat note for morse signals and to provide the carrier for the demodulation of SSB signals

Bias - a voltage or current applied to an amplifier to set up its operating conditions

Bipolar transistor -an amplifying device made of silicon or germanium . Low impedance devices which are current-operated.

Class of operation - when a vacuum tube or transistor amplifier is set up with a particular level of bias. Class A is biased so that it provides very linear operation (very low distortion), whereas class C provides very high cutoff bias, very high efficiency but very high distortion

Continuous Wave - Morse Code is frequently called "CW"

Cross modulation- when two signals (one desired and the other unwanted)are mixed in the front end of a receiver (one being exceptionally strong , causing a non-linear operation of the amplifier.)

Cutoff - when a diode,valve or transistor is not conducting any current.

DC- Direct Current - a unidirectional current obtained from batteries and rectifiers in power supplies

Db - abbreviation for Decibel -a unit allowing voltage, current and power levels to be compared and calculated.

Deviation- the amount an FM signal is varied about its carrier or "rest" frequency

Doping - when elements like arsenic or aluminium (etc) are added to pure silicon or germanium to make diodes and transistors

Double conversion - Double conversion is used in a receiver where a high first IF is used to provide image rejection and a low second IF is used to provide high selectivity

EMF - Electromotive Force (measured in volts)

Emission - a signal generated by a transmitter or radiated by an antenna

ESD - Electrostatic Discharge - caused by lightning or static electricity discharges from very high voltages. (It can damage capacitors and semiconductors.)

Feedback - when part of the output signal is coupled back to the input of an amplifier. The feedback can be positive-where the feedback signal causes an increase in amplification ; or negative where the feedback reduces the amplifier's gain

FET -Field Effect Transistor -a high impedance amplifying device which is voltage operated

Fundamental frequency- the base or initial frequency of a signal

Harmonic- a signal which is a multiple of the fundamental frequency

Heterodyning - where two frequencies are mixed together to produce a new third frequency

IF - Intermediate Frequency - used in superheterodyne receivers to amplify signals at one common frequency .

Image - An image is an unwanted signal which is spaced away from the wanted signal by (signal +twice the IF)

MOS- Metal Oxide Semiconductor- this is used in field effect transistors and ICs in technology which provides high impedance, low current drain circuits .

Mode - the form of modulation of signal- AM-(Amplitude Modulation), FM (Frequency Modulation), SSB, CW (Morse Code) etc.

Modulation - when intelligence such as speech is applied to a transmitter such as FM, AM or SSB.

NPN - a transistor where the emitter and the collector are made from N-Type semiconductor and the Base is made from P-Type material

PNP - a complementary transistor configuration (to NPN)where the emitter and the collector are made from P-Type material and the Base is made from N-Type material

PD - potential difference- measured in volts

PIV - Peak Inverse Voltage this is the maximum reverse (inverse) voltage which can be placed across a diode or transistor without it breaking down

PLL - Phase locked loop- a circuit configuration for generating stable frequencies

Q-Factor - the "Quality factor" for crystals and tuned circuits. The higher the Q, the better for selectivity purposes in receivers. High Q usually equates with narrow bandwidth.

Resonance - when a coil and capacitor are connected in either series or parallel, they have one particular frequency to which they respond

Reverse-biased - when a transistor or diode has voltage polarity applied to it such that it does not conduct any current

RF I- Radio Frequency Interference

RX - an abbreviation for receiver

Saturated - when a diode, vacuum tube or transistor is conducting its maximum design current

Sky wave - a radio wave being propagated to distant points on the earth via ionospheric refraction

SSB - Single Sideband -where the carrier and one sideband are suppressed from being transmitted. and the remaining sideband carries the signal.

Superheterodyne- a receiver design where the incoming signal is converted down or up to another frequency for further processing and amplification

TANK - a tuned circuit where a capacitor and coil are connected in parallel to provide resonance properties in receivers, transmitters and antennas

TVI - Interference to Television reception

TX - an abbreviation for transmitter

Varactor/Varicap diode - a diode which is designed to provide variable capacitance depending upon the level of reverse bias which is applied

VFO - Variable Frequency Oscillator -tunable oscillators commonly used in receivers and transmitters

Zener Diode - A diode specially doped so that it conducts heavily in the reverse bias mode and provides voltage regulation characteristics.

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Answers to Questions

Chapter 1
1b 2c 3d 4a 5c 6b 7a 8b 9d 10a 11a 12b 13a 14a 15c
*There are no questions for chapters 2 and 3.

Chapter 4
(Semiconductors)
1c 2d 3d 4a 5b 6a 7b 8a 9b 10c

Chapter 5
(Vacuum tubes)
1d 2a 3c 4a 5b 6d 7a 8c 9a 10d

Chapter 6
(Power supplies)
1a 2d 3c 4b 5c 6b 7d 8c 9a 10d

Chapter 7
(Oscillators and amplifiers)
1a 2a 3b 4d 5c 6c 7b 8d 9b 10a

Chapter 8
(Transmitters)
1c 2b 3a 4b 5a 6c 7c 8b 9c 10b 11b 12c 13a 14b 15b 15b 16b 17a 18c 19c 20c 21a 22d

Chapter 9
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1a 2d 3c 4c 5a 6c 7a 8a 9c 10d

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1b 2a 3d 4c 5d 6d 7b 8d 9d 10d 11.11b 11.12a 11.13d 14b 15a 16b 17d 18d 19b 20c

Chapter 12
(Test equipment & measurements)
1c 2a 3a 4d 5a 6c 7d 8b 9a 10c

Chapter 13
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1c 2d 3b 4c 5a 6b 7d 8c 9a 10b

Chapter 14
(Safety)
1c 2c 3b 4a 5c 6d 7a 8a 9d 10d