सत्यमेव जयते

Ministry of Health and Family Welfare
Government of India

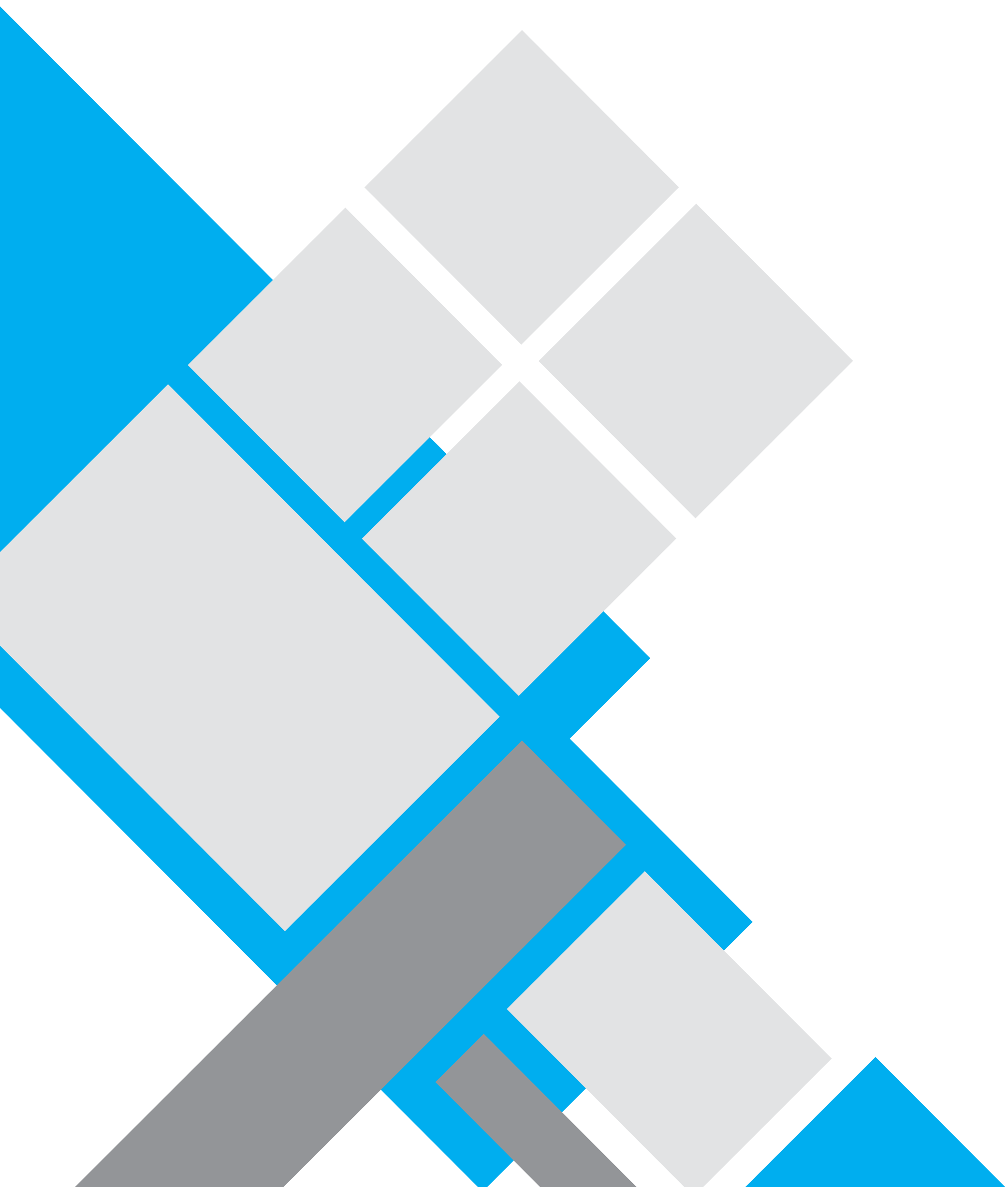
NATIONAL HEALTH MISSION
राष्ट्रीय स्वास्थ्य मिशन

Training Module

ICE LINED REFRIGERATORS, DEEP FREEZERS and VOLTAGE STABILIZERS

Repair & Maintenance

India 2017



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Acknowledgements

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ACRONYMS

ø =Phase

Ω=Ohm

a = absolute pressure amp = ampere

AC= Alternate Current

Atm = atmosphere

A.N.M. = Auxiliary Nurse Midwife

Btu = British thermal unit

cal = calorie

CCE = Cold Chain Equipment

CHC = Community Health Center

CO_2 = Carbon dioxide

CFC = Chlorofluorocarbons

CSCR = Capacitor Start Capacitor Run

CSIR = Capacitor Start Induction Run

^{0}C = degree Celsius

^{0}F = degree Fahrenheit

cm = centimeter

DC=Direct Current

DF = Deep Freezer

DVS = District Vaccine Store

EPI = Expanded Programme on Immunization

Ft = foot

g = gauge pressure/gram

GWP = Global Warming Potential

h = hour

HCFC = Hydro chlorofluorocarbons

HFC = Hydro fluorocarbon

HQ = Head Quarter

HST = High Starting Torque

ILR = Ice Lined Refrigerator

In = inch

ISI = Indian Standards Institute

j = joule

k = Kelvin

kcal = kilo calorie

Kg = kilogram

Kpa = Kilo Pascal

Kp = Kilopound

KWh = kilowatt hour

lb = pound

LMS = Line Mains Start

LST = Low Starting Torque

m = meter

mb = millibar

MCB = miniature circuit breaker

mmHg = millimeter mercury column

MO = Medical Officer

mwg = meter water gauge

N_2 = Nitrogen

NTC =Negative Temperature Coefficient

ODP = Ozone Depletion Potential

OEM = Original Equipment Manufacturer

Pa = Pascal

PC = Personal computer

PHC = Primary Health Center

psi = pound per square inch

PSC = Permanent Split Capacitor

PTC = Positive Temperature Coefficient

RSIR = Resistance Start Induction Run

s = Second

SI = System International

TEV = Thermostatic Expansion Valve

TP = Terminal plug

UIP = Universal Immunisation Programme

UV-B = Ultraviolet – B

VAC = Vacuum

Volt = voltage

W = watt

WHO = World Health Organisation

CONTENTS

A CHAPTER

Introduction

Immunization is one of the most well-known and effective methods of preventing childhood diseases. With the implementation of Universal Immunization Programme (UIP), significant achievements have been made in preventing and controlling the Vaccine Preventable Diseases (VPDs). Immunization has to be sustained as a high priority to further reduce the incidence of all VPDs, control measles, eliminate tetanus and eradicate poliomyelitis.

India has one of the largest Universal Immunization Program (UIP) in the world in terms of quantities of vaccines used, number of beneficiaries (27 million infants and 30.2 million pregnant women) covered, geographical spread (29 States and 6 Union Territories) and manpower involved. India spends more than Rs. 2000 crores every year in immunization program (including polio eradication) to immunize children against vaccine preventable diseases including polio eradication program.

Under UIP, all the children in the entire country are protected against the 7 deadly Vaccine Preventable Diseases (VPD) namely Tuberculosis, Diphtheria, Tetanus, Pertussis, Polio, Measles & Hepatitis B. Additionally Japanese Encephalitis (JE) & HiB vaccine in Pentavalent have been introduced in selected districts/ cities/States/ UTs. Immunization services are provided through vast health care infrastructure consisting of district hospitals, community health centers (CHC), primary health centers (PHC) and sub-centers. One of the important elements for improving the immunization is cold chain and vaccine logistics management which is backbone of immunization programme. Cold Chain and vaccine management are the left and right hands of immunization programme.

What is Cold Chain?

Cold Chain is a system of storing and transporting vaccines at recommended temperatures from the point of manufacture to the point of use. The key elements of the cold chain are:

- Personnel: to manage vaccine storage and distribution (vaccine and cold chain handler at each point).
- Equipment: to store and transport vaccine and to monitor temperature.
- Procedures: to ensure that vaccines are stored and transported at appropriate temperatures.

  As a Cold chain technician you should ensure that cold chain equipment is functional, storage temperatures are correctly maintained and recorded.

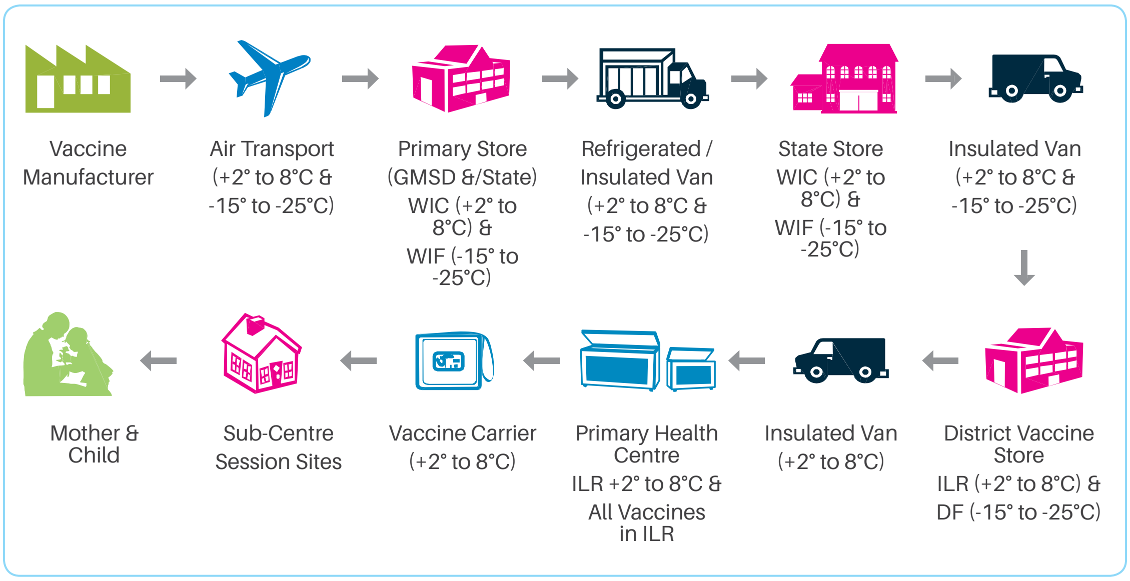

Figure A-1.1:

Vaccine sensitivities

All vaccines are heat sensitive and are damaged by temperatures more than +8 degree Celsius, whether they are exposed to a lot of heat in a short time (e.g., as a result of keeping vaccine in a closed vehicle in the sun) or a small amount of heat over a long period (e.g., as a result of the frequent opening of lid of ILR).

Reconstituted BCG, measles and JE vaccines are the most heat and light sensitive. Since these live vaccines do not contain preservatives, there is risk of contamination with Staphylococcus aurous leading to Toxic Shock Syndrome and, therefore, they should be used within 4 hours of reconstitution (4 hours for JE vaccine). These light sensitive vaccines are supplied in amber- colored vials.

DPT, TT, HepB and Penta vaccines are freeze sensitive i.e. they lose their potency if frozen. BCG, Measles and JE vaccines are light sensitive. The physical appearance of the vaccine may remain unchanged even after it is damaged. However, the loss of potency due to either exposure to heat or cold is permanent and cannot be regained.

The Cold Chain Room

Keep all electrical cold chain equipment in a separate room with restricted entry to keep the vaccines and cold chain equipment safe and secure. Follow the guidelines as mentioned in

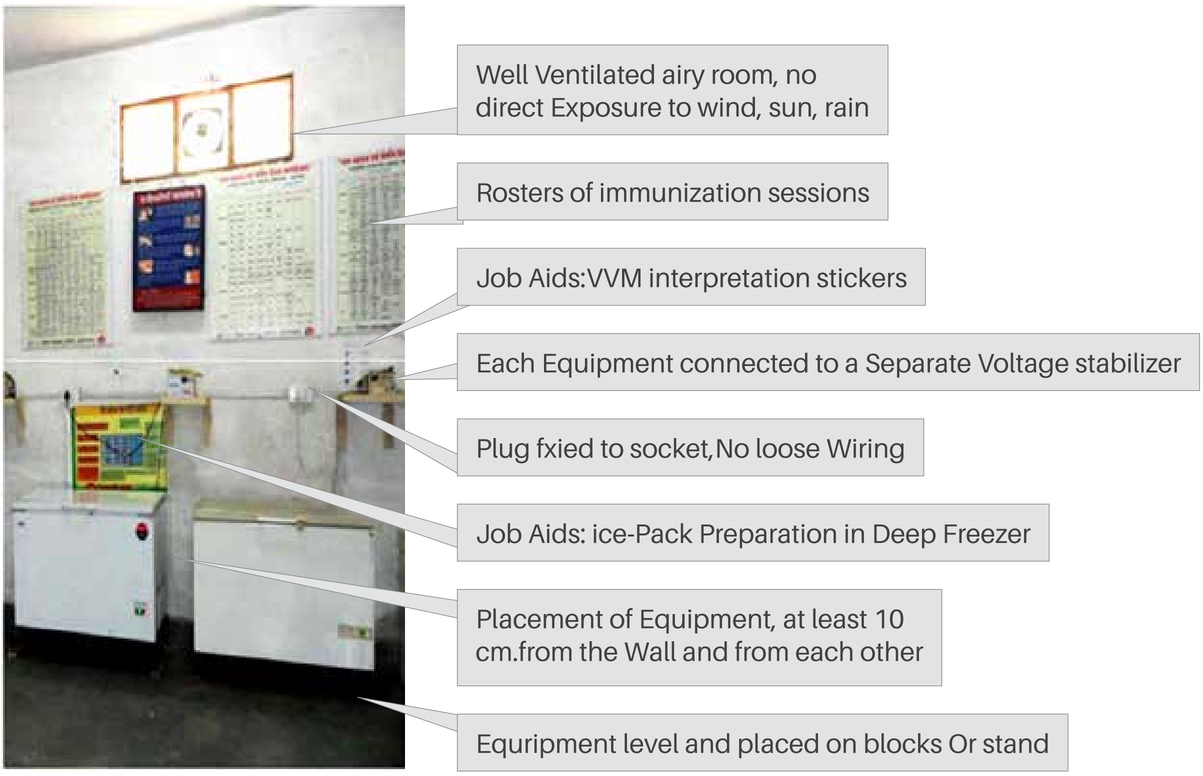

Figure A-1.2:

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SECTION

1. Refrigeration: An Introduction to the Basics

Introduction

The job of a refrigeration plant is to cool articles or substances down to, and maintain them at a temperature lower than the ambient temperature. Refrigeration can be defined as a process that removes heat. The oldest and most well-known among refrigerants are ice, water, and air. In the beginning, the sole purpose was to conserve food. The Chinese were the first to find out that ice increased the life and improved the taste of drinks and for centuries Eskimos have conserved food by freezing it.

At the beginning of the last century, terms like bacteria, yeast, mould, enzymes etc. were known. It had been discovered that the growth of microorganisms is temperature-dependent, that growth declines as temperature falls, and that growth becomes very slow at temperatures below +10 °C. As a consequence of this knowledge, it was now possible to use refrigeration to conserve foodstuffs and natural ice came into use for this purpose.

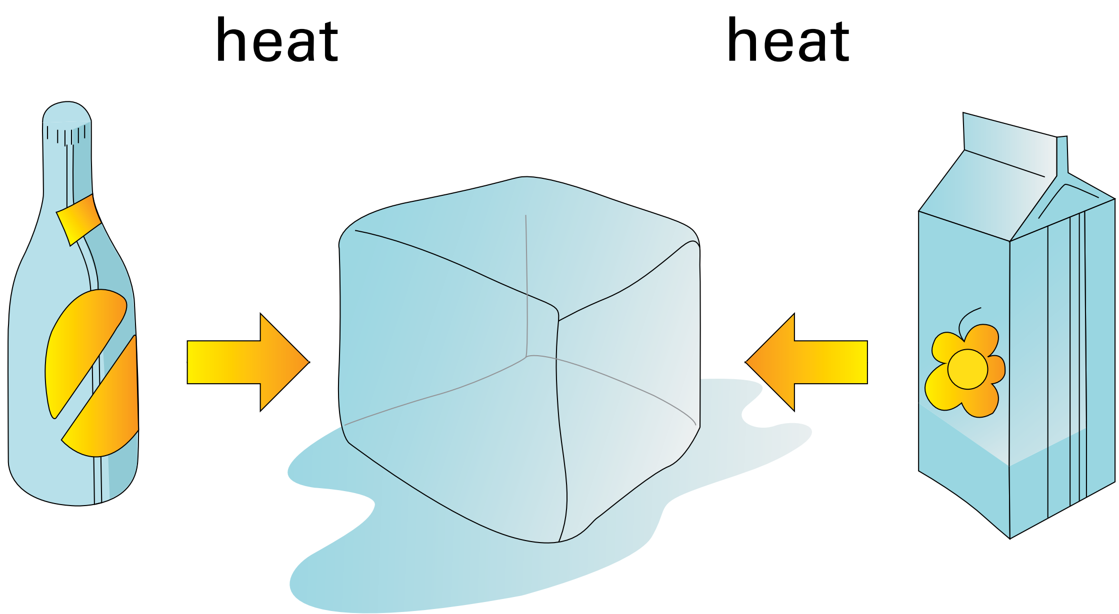


Figure A-1.3:

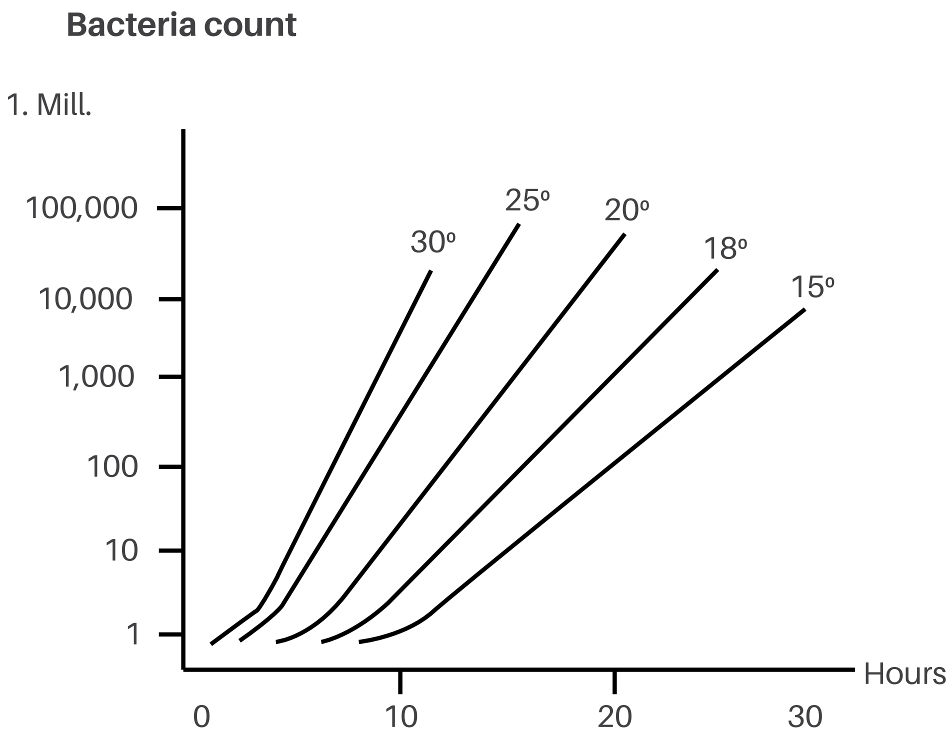


Figure A-1.4:

The first mechanical refrigerators for the production of ice appeared around the year 1860. In 1880 the first ammonia compressors and insulated cold stores were put into use in the USA.

Electricity began to play a part at the beginning of this century and mechanical refrigeration plants became common in some fields: e.g. breweries, slaughter-houses, fishery, and ice production.

After the Second World War the development of small hermetic refrigeration compressors evolved and refrigerators and freezers began to take their place in the home. Today, these appliances are regarded as normal household necessities.

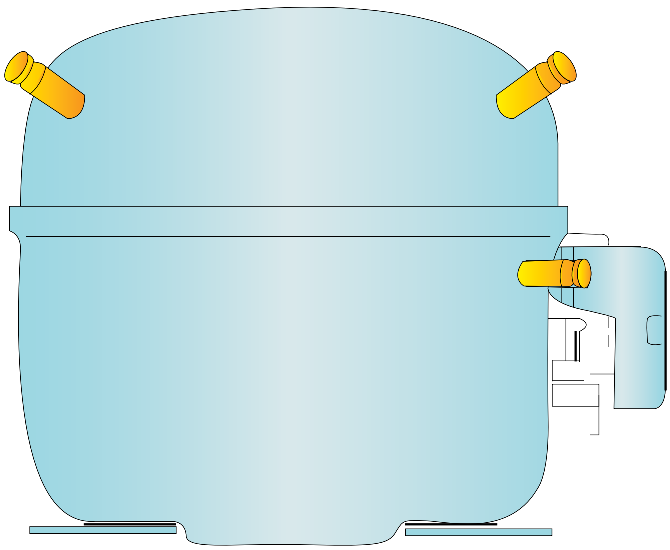


Figure A-1.5:

There are countless applications for refrigeration plants now.

Examples:

- Foodstuff conservation Process refrigeration Air conditioning plants Drying plants
- Fresh water installations Refrigerated containers Heat pumps
- Ice production
- Freeze-drying
- Transport refrigeration
- In fact, it is difficult to imagine life without air conditioning, refrigeration and freezing – their
- Impact on our existence is much greater than most people imagine.

2. Fundamental terms

2.1 UNIT SYSTEMS

On an international level, agreement has been reached on the use of the System International d'Unités - often referred to as the SI-system. For a number of countries the implementation of the SI-system is still an on-going process. However, in many parts of the refrigeration community it is still practice to use metric units or other alternative units. Therefore, the practically used alternative units will be given in parenthesis where needed.

The table shows the SI-units and the other often used alternative units for the quantities that are used in this booklet.

Quantity	SI-unit	Alternative units
Time	s (Second)	h (hour)
Length	m (meter)	in (inch) ft (foot)
Mass	kg (Kilogram)	Ib (pound)
Temperature	k (Kelvin)	^{0}C (Celsius) ^{0}F (Fahrenheit)
Force	N (Newton)	Kp (kilopond)
Pressure	Pa (Pascal) = N/m^2	bar atm (atmosphere) mm Hg (millimeter mercury column) psi (pound per square inch)
Energy	J (Joule) = Nm	kWh (kilowatt hour) cal (calorie) BTU(British Thermal Units
Power	W=Watt (J/s)	calorie/h, Btu/h

Table: **S.I. UNIT**

The practical use of the SI-units is strongly associated with the use of the decadic prefixes to avoid writing either very small or large numbers. A part of the prefixes used can be seen in the table below.

Example: The atmospheric air pressure is 101325 Pa. Using the decadic prefixes from the table below the best way of writing this would be 101.325 kPa.

The choice of prefix is "free" but the best choice will normally be the one where the value written will be in the range from 0.1 to 999.9.Prefixes should not be used for combined SI-units - except when [kg] is used.

Example: 2000 W/m^2 K should be written as 2.000 $\times 10^3$ W/m^2 K and not as 2 k W/ m^2 K.

Table: S.I. UNIT

Name	pico	nano	micro	mili	kilo	mega	giga	tera	peta
Prefix	p	n	µ	m	k	M	G	T	P
Factor	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{3}	10^{6}	10^{9}	10^{12}	10^{15}

2.2 TEMPERATURE

Temperature is a very central property in refrigeration. Almost all refrigeration systems have the purpose of reducing the temperature of an object like the air in a room or the objects stored in that room. The SI-unit for temperature Kelvin [K] is an absolute temperature because its reference point [0 K] is the lowest temperature that it in theory would be able to obtain. When working with refrigeration systems the temperature unit degree Celsius [°C] is a more practical unit to use. Celsius is not an absolute temperature scale because its reference point (0 °C) is defined by the freezing point of water.

(Equal to 273.15 K).The only difference between Kelvin and Celsius is the difference in reference point. This means that a temperature difference of 1 °C is exactly the same as a temperature difference of 1 K.

In the scientific part of the refrigeration community temperature differences are often described using [K] instead of [°C]. This practice eliminates the possible mix-up of temperatures and temperature differences.

2.3 FORCE AND PRESSURE

The SI-unit for force is Newton (N) which is actually a [kg m/s2].

A man wearing skis can stand in deep snow without sinking very deep - but if he steps out of his skis his feet will probably sink very deep into the snow. In the first case the weight of the man is distributed over a large surface (the skis). In the second case the same weight is distributed on the area of his shoe soles - which is a much smaller area than the area of the skis. The difference between these two cases is the pressure that the man exerts on the snow surface.

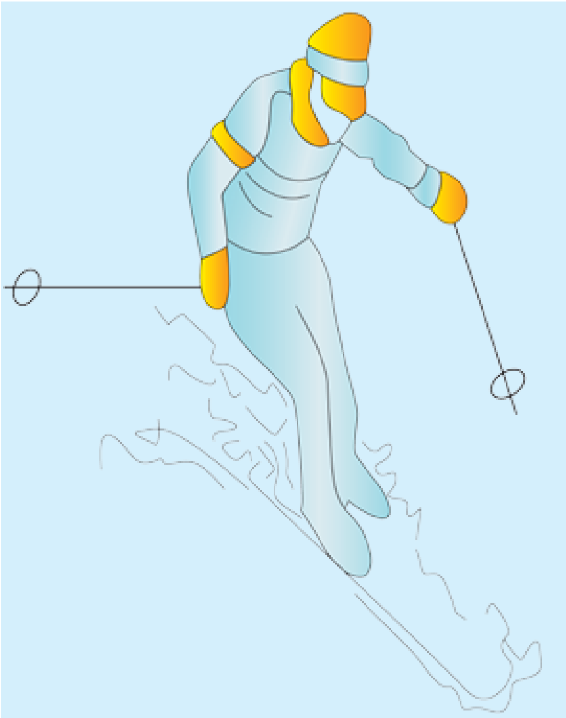


Figure A-1.6:

Pressure is defined as the force exerted on an area divided by the size of the area.

In the example with the skier the force (gravity) is the same in both cases but the areas are different.

In the first case the area is large and so the pressure becomes low. In the second case the area is small and so the pressure becomes high.

In refrigeration pressure is mostly associated with the fluids used as refrigerants. When a substance in liquid or vapour form is kept within a closed container the vapour will exert a force on the inside of the container walls. The force of the vapour on the inner surface divided by its area is called the absolute pressure.

For practical reasons the value for pressure is sometimes stated as "pressure above atmospheric "pressure" - meaning the atmospheric pressure (101.325 kPa = 1.013 bar) is subtracted from the absolute pressure. The pressure above atmospheric pressure is also often referred to as gauge pressure.

The unit used should reflect the choice of absolute pressure or gauge pressure. An absolute pressure is indicated by the use of lowercase "a" and a gauge pressure is indicated by a lowercase "g".

Example:

The absolute pressure is 10 bar (a) which converted to gauge pressure becomes (10 - 1.013) bar (g) 9 bar (g). The combination of the SI-unit for pressure [Pa] and the term gauge pressure is not recommended. Other units for pressure that are still used today are mm of mercury column [mmHg], and meter water gauge [mwg]. The latter is often used in connection with pumps to indicate the height of the water column that the pump is able to generate. Vacuum is defined as an absolute pressure of 0 Pa - but since it is almost impossible to obtain this the term "vacuum" is used generally to describe a pressure much lower than the atmospheric pressure.

Example:

The absolute pressure is 0.1 bar (a) which converted to gauge pressure becomes (0.1 - 1.013) bar (g) –0.9 bar (g). Vacuum is also often described in Torr (1 Torr is equal to 10 Pa) and millibar (a thousandth of a bar).

2.4 HEAT, WORK, ENERGY AND POWER

Heat and work are both forms of energy that can be transferred between objects or systems. The transfer of heat is closely connected to the temperature (or temperature difference) that exists between two or more objects. By itself heat is always transferred from an object with high temperature to objects with lower temperatures. Heating of water in a pot on a stove is a good everyday example of the transfer of heat. The stove plate becomes hot and heat is transferred from the plate through the bottom of the pot and to the water. The transfer of heat to the water causes the temperature of the water to rise. In other words, heating an object is the same as transferring energy (heat) to the object.

In many practical applications there is a need to reduce the temperature of an object instead of increasing it. Following the example above this can only be done if you have another object with a lower temperature than that of the object you wish to cool. Putting these two objects into contact will cause a transfer of heat away from the object you wish to cool and, consequently, its temperature will decrease. In other words, cooling an object is the same as transferring energy (heat) away from the object.

The transfer of work is typically connected to the use of mechanical shafts like the one rotating in an electric motor or in a combustion engine.

Other forms of work transfer are possible but the use of a rotating shaft is the primary method used in refrigeration systems. As mentioned both heat and work is forms of energy. The methods of transfer between objects are different but for a process with both heat and work transfer it is the sum of the heat and work transfer that determines the outcome of the process.

The SI-unit Joule [J] is used to quantify energy, heat and work. The amount of energy needed to increase the temperature of 1 kg of water from 15 to 16 °C is 4.187 kJ. The 4.178 kJ can be transferred as heat or as work - but heat would be the most used practical solution in this case.

There are differences in how much energy is required to increase the temperature of various substances by 1 K. For 1 kg of pure iron app.0.447 kJ is needed whereas for 1 kg of atmospheric air only app. 1.0 kJ is needed. The property that makes the iron and air different with respect to the energy needed for causing a temperature increase is called the “specific heat capacity”. It is defined as the energy required causing a temperature increase of 1 K for 1 kg of the substance. The unit for specific heat capacity is J/kg K. The rate at which energy is transferred is called power. The SI-unit for power is Watt (W).

Example:

If 10 J is transferred per second, the rate of energy transfer is stated as 10 J/s = 10 W. In the SI-system the choice of unit for power is the same for transfer of heat and work. In other unit systems the transfer rates for heat and work could have different units.

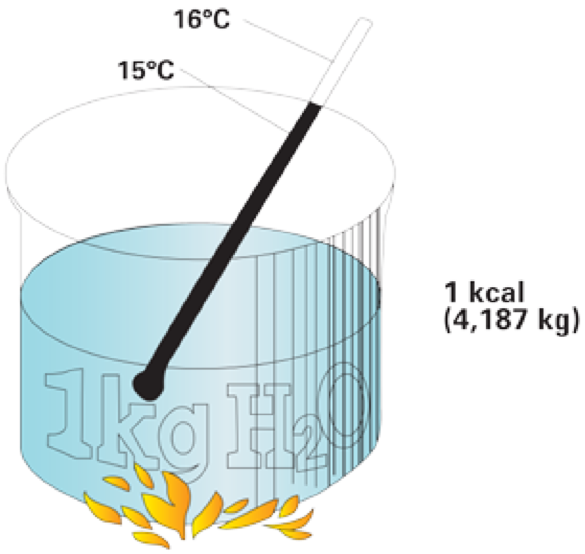


Figure A-1.7:

2.5 SUBSTANCES AND PHASE CHANGE

All substances can exist in three different phases: solid, liquid, and vapour. Water is the most natural example of a substance that we use almost every day in all three phases. For water the three phases have received different names - making it a bit confusing when using it as a model substance. The solid form we call ice, the liquid form we just call water, and the vapour form we call steam. What is common to these three phases is that the water molecules remain unchanged, meaning that ice, water, and steam all have the same chemical formula: H_2O. When taking a substance in the solid to the liquid phase the transition process is called melting and when taking it further to the vapour phase the transition process is called boiling (evaporation). When going in the opposite direction taking a substance from the vapour to the liquid phase the transition process is called condensing and when taking it further to the solid phase the transition process is called freezing (solidification).

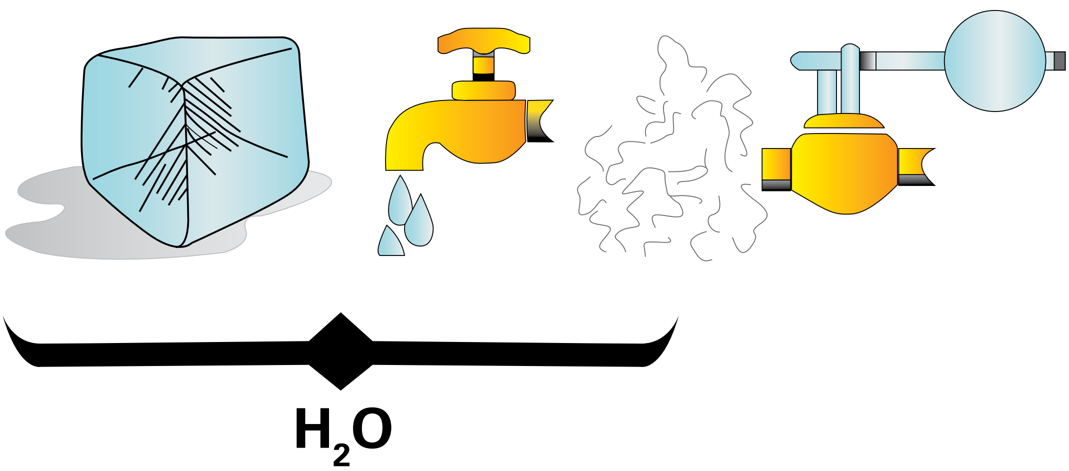


Figure A-1.8:

At constant pressure the transition processes display a very significant characteristic. When ice is heated at 1 bar its temperature starts rising until it reaches 0 °C - then the ice starts melting. During the melting process the temperature does not change - all the energy transferred to the mixture of ice and water goes into melting the ice and not into heating the water. Only when the ice has been melted completely will the further transfer of energy cause its temperature to rise. The same type of behavior can be observed when water is heated in an open pot. The water temperature increases until it reaches 100 °C - then evaporation starts. During the evaporation process the temperature remains at 100 °C. When all the liquid water has evaporated the temperature of the steam left in the pot will start rising. The temperature and pressure a substance is exposed to determine whether it exists in solid, liquid, or vapour form - or in two or all three forms at the same time. In our local environment iron appears in its solid form, water in its liquid and gas forms, and air in its vapour form.

Different substances have different melting and boiling points. Gold for example melts at 1064 °C, Chocolate at 26 °C and most refrigerants melt at temperatures around -100 °C!

For a substance that is present in two of its phases at the same time - or undergoing a phase change - pressure and temperature become dependent. If the two phases exist in a closed container and the two phases are in thermal equilibrium the condition is said to be saturated. If the temperature of the two-phase mixture is increased the pressure in the container will also increase. The relationship between pressure and temperature for saturated conditions (liquid and vapour) is typically called the vapour pressure curve. Using the vapour pressure curve one can determine what the pressure will be for an evaporating or condensing process.

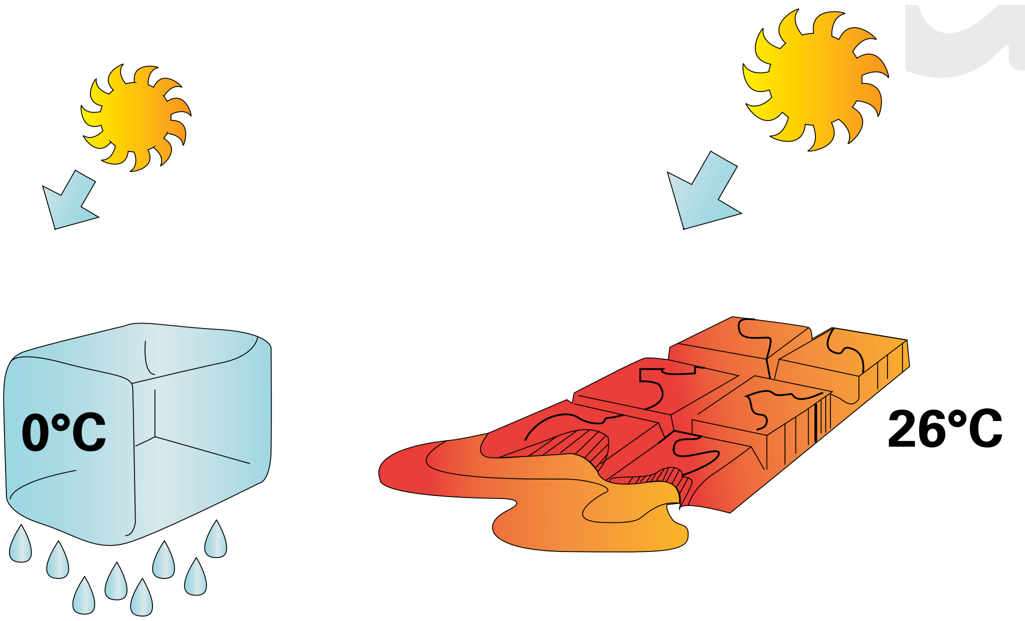


Figure A- 1.9:

2.6 LATENT HEAT

Going back to the process of ice melting it is important to note that the amount of energy that must be transferred to 1 kg of ice in order to melt it is much higher than the energy needed to change the temperature of 1 kg of water by say 1 K. In section 2.4 the specific heat capacity of water was given as 4.187 kJ/kg K. The energy needed for melting 1 kg of ice is 335 kJ. The same amount of energy that can melt 1 kg of ice can increase the temperature of 1 kg of water by (335 kJ/4. 187 kJ/kg K) = 80 K!

When looking at the boiling process of water the energy needed for evaporating 1 kg of water is 2501 kJ. The same amount of energy that can evaporate 1 kg of water can increase the temperature

Of not 1 but 6 kg of water by 100 K! These examples show that energy transfer related to the transitional processes between phases is significant. That is also why ice has been used for cooling - it takes a lot of energy to melt the ice and while the ice melts the temperature stays at 0°C.

The refrigerating effect in refrigeration systems is based on the use and control of the phase transition processes of evaporation. As the refrigerant evaporates it absorbs energy (heat) from its surroundings and by placing an object in thermal contact with the evaporating refrigerant it can be cooled to low temperature.

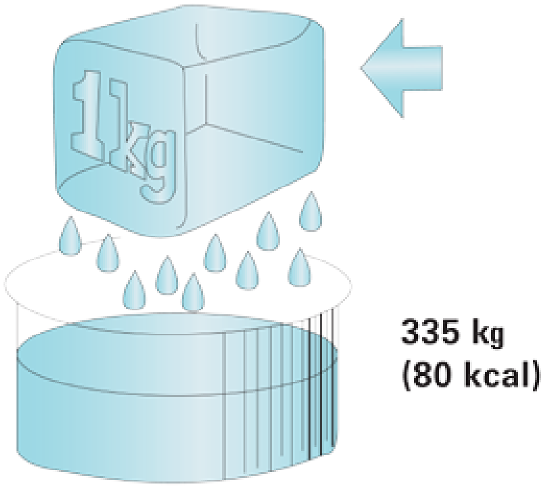


Figure A-1.10:

2.7 SUPERHEAT

Superheat is a very important term in the terminology of refrigeration - but it is unfortunately used in different ways. It can be used to describe a process where refrigerant vapour is heated from its saturated condition to a condition at higher temperature. The term superheat can also be used to describe - or quantify - the end condition of the before-mentioned process. Superheat can be quantified as a temperature difference - between the temperature measured with a thermometer and the saturation temperature of the refrigerant measured with a pressure gauge. Therefore, superheat cannot be determined from a single measurement of temperature alone - a measurement of pressure or saturation temperature is also needed. When superheat is quantified it should be quantified as a temperature difference and, consequently, be associated with the unit [K]. If quantified in [°C] it can be the cause of mistakes where the measured temperature is taken for the superheat or vice versa.

The evaporation process in a refrigeration system is one of the processes where the term superheat is used. This will be explained further in the next chapter.

2.8 REFRIGERANT DIAGRAMS

The characteristics of a refrigerant can be illustrated in a diagram using the primary properties as abscissa and ordinate. For refrigeration systems the primary properties are normally chosen as energy content and pressure. Energy content is represented by the thermodynamic property of specific enthalpy - quantifying the change in energy content per mass unit of the refrigerant as it undergoes processes in a refrigeration system. An example of a diagram based on specific enthalpy (abscissa) and pressure ordinate) can be seen below.

For a refrigerant the typically applicable interval for pressure is large - and therefore diagrams use a logarithmic scale for pressure. The diagram is arranged so that it displays the liquid, vapour and mixture regions for the refrigerant. Liquid are found to the left (with a low energy content) - vapour to the right (with a high energy content). In between you find the mixture region. The regions are bounded by a curve - called the saturation curve. The fundamental processes of evaporation and condensation are illustrated.

The idea of using a refrigerant diagram is that it makes it possible to represent the processes in the refrigeration system in such a way that analysis and evaluation of the process becomes easy. When using a diagram determining system operating conditions (temperatures and pressures) system refrigerating capacity can be found in a relatively simple and quick manner. Diagrams are still used as the main tool for analysis of refrigeration processes. However, a number of PC programmes that can perform the same analysis faster and with more details have become generally available.

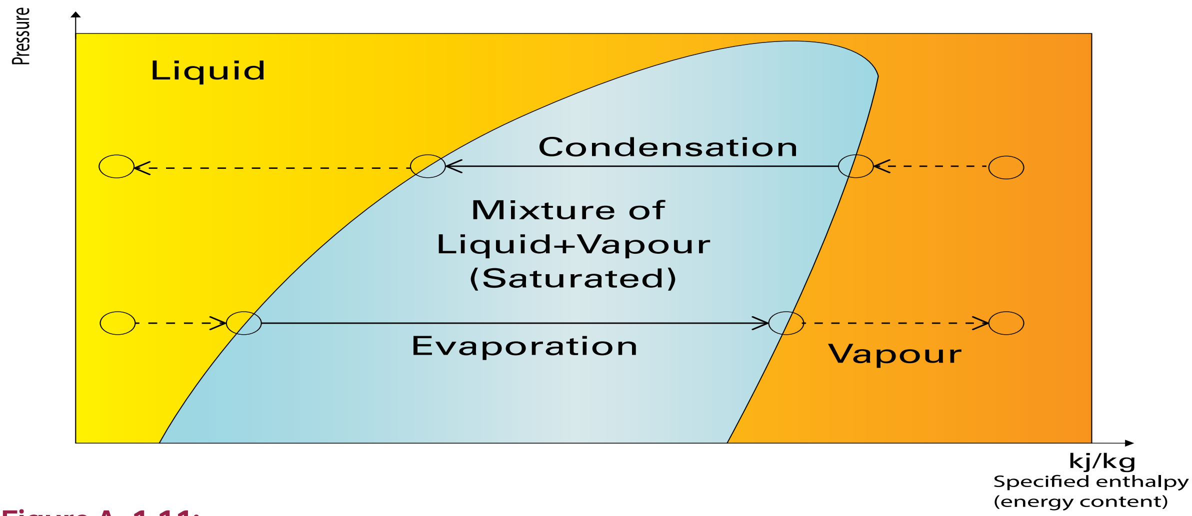


Figure A-1.11:

3. Refrigerant circuit

The physical terms for the refrigeration process have been dealt with previously, even though for practical reasons water is not used as a refrigerant. A simple refrigerant circuit is built up as shown in the sketch below. In what follows, the individual components are described to clarify a final overall picture.

3.1 Evaporator

A refrigerant in liquid form will absorb heat when it evaporates and it is this conditional change that produces cooling in a refrigerating process. If a refrigerant at the same temperature as ambient is allowed to expand through a hose with an outlet to atmospheric pressure, heat will be taken up from the surrounding air and evaporation will occur at a temperature corresponding to atmospheric pressure.

If in a certain situation pressure on the outlet side (atmospheric pressure) is changed, a different temperature will be obtained since this is analogous to the original temperature - it is pressure dependent. The component where this occurs is the evaporator, whose job it is to remove heat from the surroundings, i.e. to produce refrigeration.

3.2 COMPRESSOR

The refrigeration process is, as implied, a closed circuit. The refrigerant is not allowed to expand to free air. When the refrigerant coming from the evaporator is fed to a tank the pressure in the tank will rise until it equals the pressure in the evaporator. Therefore, refrigerant flow will cease and the temperature in both tank and evaporator will gradually rise to ambient.

To maintain a lower pressure, and, with it a lower temperature it is necessary to remove vapour. This is done by the compressor, which sucks vapour away from the evaporator. In simple terms, the compressor can be compared to a pump that conveys vapour in the refrigeration circuit.

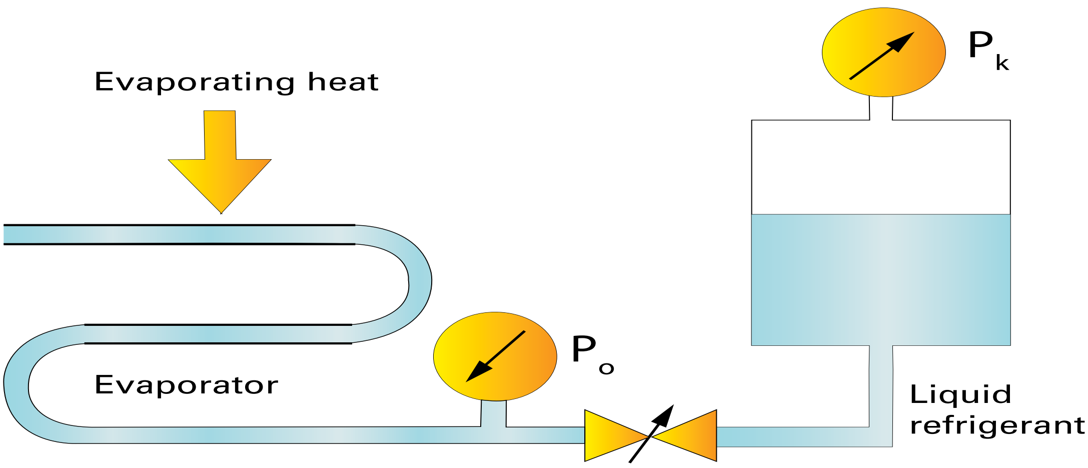


Figure A-1.12:

In a closed circuit a condition of equilibrium will always prevail. To illustrate this, if the compressor sucks vapour away faster than it can be formed in the evaporator the pressure will fall and with it the temperature in the evaporator. Conversely, if the load on the evaporator rises and the refrigerant evaporates quicker, the pressure and with it the temperature in the evaporator will rise.

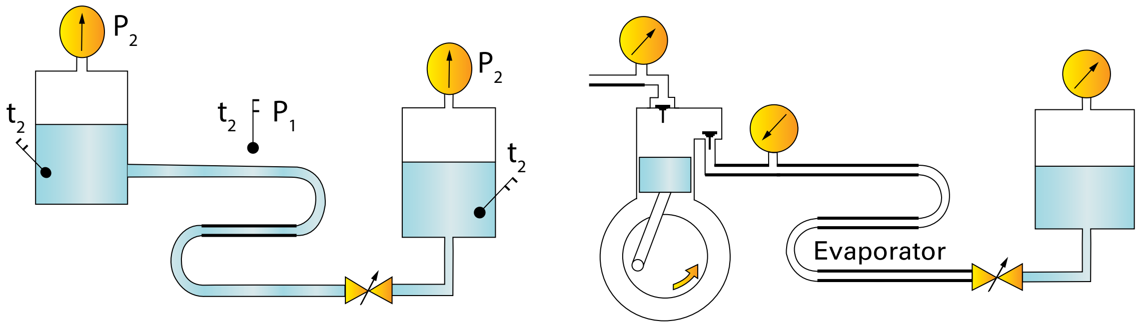


Figure A-1.13:

3.3 COMPRESSOR, METHOD OF OPERATION

Refrigerant leaves the evaporator either as saturated or weak superheated vapour and enters the compressor where it becomes compressed. Compression is carried out as in a petrol engine, i.e. by the movement of a piston. The compressor requires energy and carries out work. This work is transferred to the refrigerant vapour and is called the compression input. Because of the compression input, vapour leaves the compressor at a different pressure and the extra energy applied causes strong superheating of the vapour. Compression input is dependent on plant pressure and temperature. More work is of course required to compress 1 kg vapour 10 bar than to compress the same amount 5 bar.

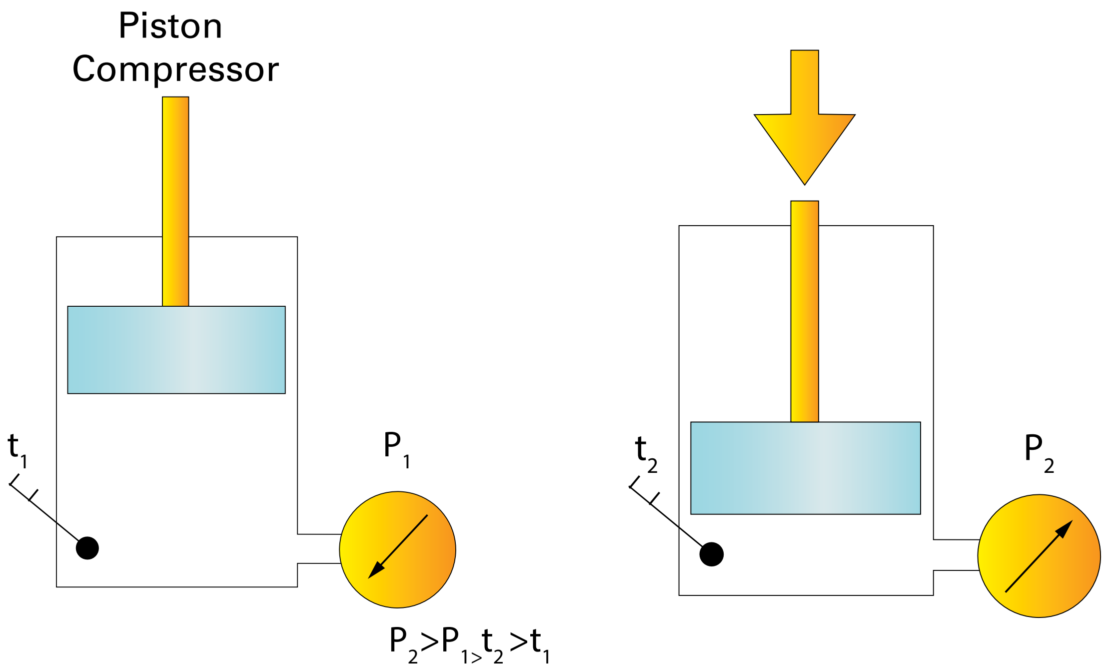


Figure A-1.14:

3.4 CONDENSER

The refrigerant gives off heat in the condenser, and this heat is transferred to a medium having a lower temperature. The amount of heat given off is the heat absorbed by the refrigerant in the evaporator plus the heat created by compression input. The heat transfer medium can be air or water, the only requirement being that the temperature is lower than that which corresponds to the condensing pressure. The process in the condenser can otherwise be compared with the process in the evaporator except that it has the opposite "sign", i.e. the conditional change is from vapour to liquid.

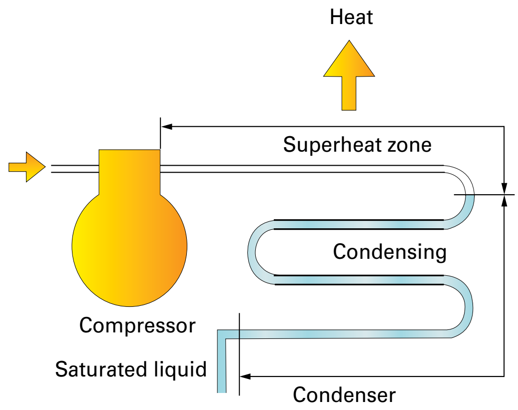


Figure A-1.15:

3.5 EXPANSION PROCESS

Liquid from the condenser runs to a collecting tank, the receiver. This can be likened to the tank mentioned under section 3.1 on the evaporator. Pressure in the receiver is much higher than the pressure in the evaporator because of the compression (pressure increase) that has occurred in the compressor. To reduce pressure to the same level as the evaporating pressure a device must be inserted to carry out this process, which is called throttling, or expansion. Such a device is therefore known either as a throttling device or an expansion device. As a rule a valve is used – a throttle or expansion valve.

Ahead of the expansion valve the liquid will be a little under boiling point. By suddenly reducing pressure a conditional change will occur; the liquid begins to boil and evaporate. This evaporation takes place in the evaporator and the circuit is thus complete.

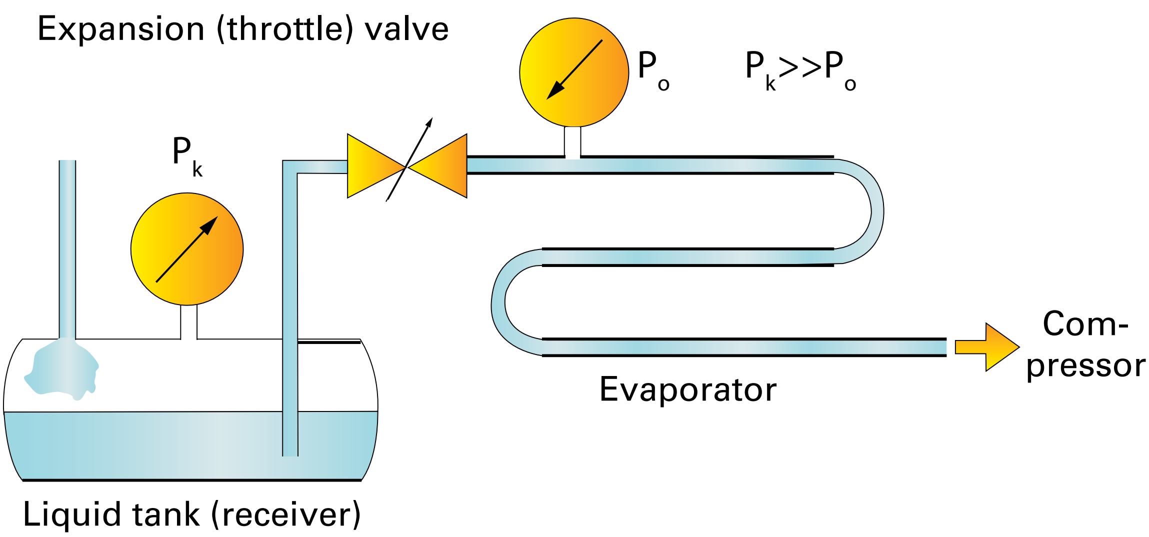


Figure A-1.16:

3.6 High Andlow Pressure Sides Of The Refrigeration Plant

There are many different temperatures involved in the operation of a refrigeration plant since there are such things as sub cooled liquid, saturated liquid, saturated vapour and superheated vapour. There are however, in principle, only two pressures; evaporating pressure and condensing pressure. The plant then is divided into high pressure and low pressure sides, as shown in the sketch.

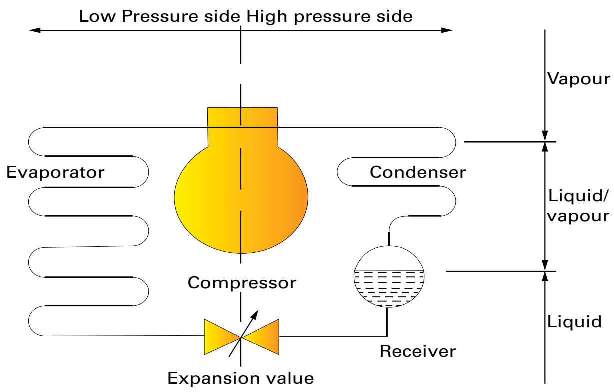


Figure A-1.17:

4. Refrigeration process, pressure enthalpy diagram

The condensed refrigerant in the condenser is in condition A which lies on the line for the boiling point of the liquid. The liquid has thus a temperature tc, a pressure Pc also called saturated temperature and pressure.

The condensed liquid in the condenser is further cooled down in the condenser to a lower temperature A^1 and now has a temperature tl and an enthalpy h_o. The liquid is now sub-cooled which means that it is cooled to a lower temperature than the saturated temperature. The condensed liquid in the receiver is in condition A^1 which is sub-cooled liquid. This liquid temperature can change if the receiver and liquid is either heated or cooled by the ambient temperature. If the liquid is cooled the sub-cooling will increase and visa versa. When the liquid passes through the expansion valve its condition will change from A^1 to B. This conditional change is brought about by the boiling liquid because of the drop in pressure to P_o.

At the same time a lower boiling point is produced, to, because of the drop in pressure. In the expansion valve the enthalpy is constant h_o, as heat is neither applied nor removed. At the evaporator inlet, point B, there is a mixture of liquid and vapour while in the evaporator at C there is saturated vapour. At the evaporator outlet point C^1 there is super-heated vapour which means that the suction gas is heated to a higher temperature than the saturated temperature. Pressure and temperature are the same at point B and at outlet point C^1 where the gas is super-heated the evaporator has absorbed heat from the surroundings and the enthalpy has changed to h_1. When the refrigerant passes through the compressor its condition changes from C^1 to D. Pressure rises to condensing pressure P_c. The temperature rises to hot gas which is higher than the condensing temperature t_c because the vapour has been strongly superheated. More energy (from the electrical motor) in the form of heat has also been introduced and the enthalpy therefore changes to h_2. At the condenser inlet, point D, the condition is thus one of superheated vapour at pressure P_c. Heat is given off from the condenser to the surroundings so that the enthalpy again changes to main point A^1. First in the condenser there occurs a conditional change from strongly superheated vapour to saturated vapour (point E), then a condensation of the saturated vapour. From point E to point A the temperature (condensing temperature) remains the same, in that condensation and evaporation occurs at constant temperature. From point A to point A^1 in the condenser the condensed liquid is further cooled down, but the pressure remains the same and the liquid is now sub-cooled.

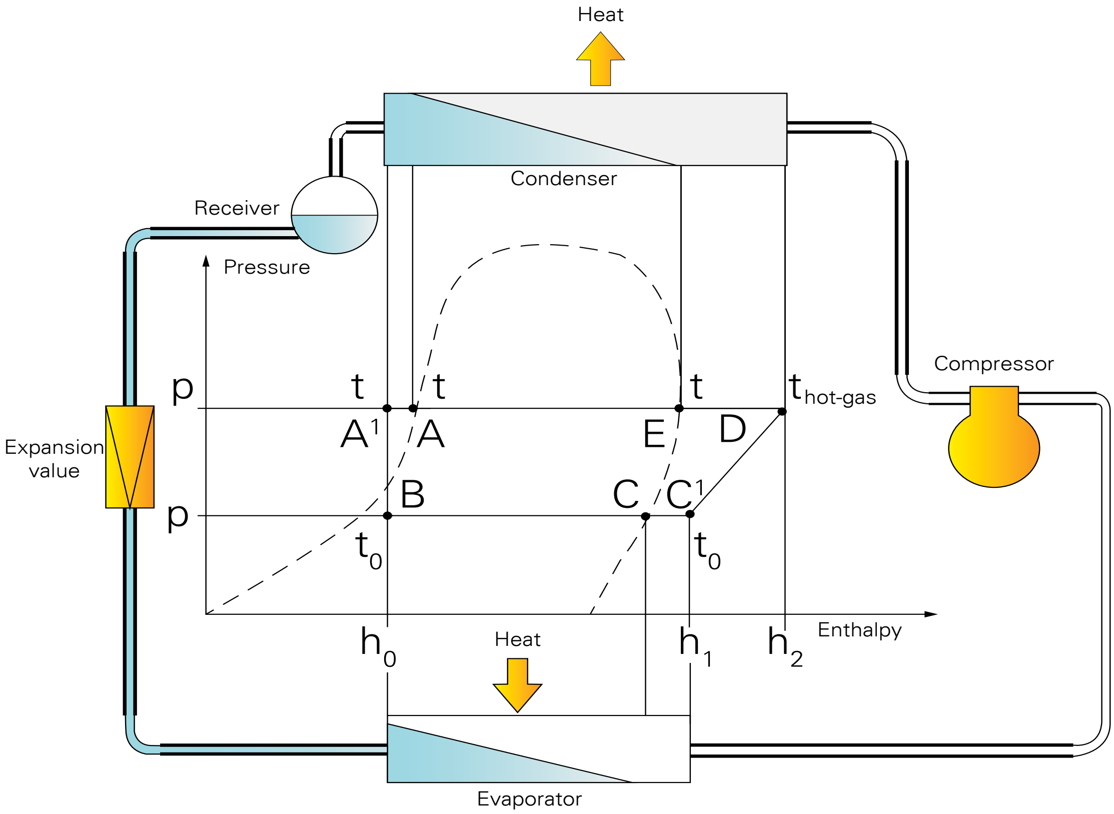


Figure A-1.18:

t_0 = condensing temperature

p_0 = condensing pressure

t_1 = liquid temperature

t_0 = evaporating temperature

p_0 = evaporating pressure

5. Refrigerants

A refrigerant is a substance or mixture, usually a fluid, used in a heat pump and refrigeration cycle. In most cycles it undergoes phase transitions from a liquid to a gas and back again. Many working fluids have been used for such purposes. Fluorocarbons, especially chlorofluorocarbons, became common place in the 20th century, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane.

The ideal refrigerant would have favorable thermodynamic properties, be noncorrosive to mechanical components, and be safe, including free from toxicity and flammability. It would not cause ozone depletion or climate change. Since different fluids have the desired traits in different degree, choice is a matter of trade-off.

The desired thermodynamic properties are a boiling point somewhat below the target temperature, a high heat of vaporization, a moderate density in liquid form, a relatively high density in gaseous form, and a high critical temperature. Since boiling point and gas density are affected by pressure, refrigerants may be made more suitable for a particular application by choice of operating pressures.

5.1 GENERAL REQUIREMENTS

During the examination of the refrigeration process the question of refrigerants was not discussed since it was not necessary to do so in connection with the basic physical principles of the conditional change of substances. It is well known, however, that in practice different refrigerants are used according to the specific application and requirements. The most important factors are as follows:

- The refrigerant ought not to be poisonous. Where this is impossible, the refrigerant must have a characteristic smell or must contain a tracer so that leakage can quickly be observed.
- The refrigerant ought not to be flammable nor explosive. Where this condition cannot be met the same precautions as in the first point must be observed and local legislations must be followed.
- The refrigerant ought to have reasonable pressure, preferably a little higher than atmospheric pressure at the temperatures required to be held in the evaporator.
- To avoid heavy refrigerator design the pressure, which corresponds to normal condensing pressure, must not be too high.
- Relatively high evaporating temperature is required so that heat transmission can occur with least possible circulating refrigerant.
- Refrigerant vapour ought not to have too high a specific volume because this is a determinant for compressor stroke at a particular cold yield.
- The refrigerant must be chemically stable at the temperatures and pressures normal in a refrigeration plant.

- The refrigerant ought not to be corrosive and must not, either in liquid or vapour form, attack normal design materials.
- The refrigerant must not break down lubricating oil.
- The refrigerant must be easy to obtain and handle.
- The refrigerant must not cost too much.

5.2 FLUORINATED REFRIGERANTS

Fluorinated refrigerants always carry the designation "R" followed by a number, e.g. R22, R134a, R404A and R407C. Sometimes they are met bearing their trade names. The fluorinated refrigerants all have the following features:

- Vapour is smell-free and non-irritant.
- Extensively non-poisonous. In the presence of fire the vapour can give off fluoric acid and phosgene, which are very poisonous.
- Non-corrosive.
- Non-flammable and non-explosive.

THE MOST COMMON FLUORINATED REFRIGERANTS ARE:

R134a, which is a substance of the ethane group with the formula CH_2FCF_3 and has a normal boiling point of –26.1 °C. Its thermodynamic properties make it suitable as a refrigerant for medium temperature applications such as domestic refrigerators.

R22, Which is a substance of the methane group with the formula CHF_2Cl and has a boiling point of –40.8 °C. Its thermodynamic properties make it suitable as a refrigerant for a wide range of applications in commercial refrigeration and air conditioning.R22 is being phased out as refrigerant in many countries due to its ozone depleting potential.

R404A/R507A (also known as R507), which is a mixture of the refrigerants R125 (CHF_2CF_3) and R143a (CH_3CF_3) with a boiling point at (-46.5 °C) which is slightly lower than for R22. Its thermodynamic properties make it suitable as a refrigerant for low and medium temperature applications in Commercial refrigeration.

R407C, which is a mixture of the refrigerants R32 (CH_2F_2), R125 (CHF_2CF_3) and R134a (CH2FCF3) with a boiling point at (–43.6 °C) which is slightly lower than for R22. Its thermodynamic properties make it suitable as a refrigerant for medium and high temperature applications in residential and commercial air conditioning.

R410A, which is a mixture of the refrigerants R32 (CH_2F_2) and R 125 (CHF_2CF_3) with a boiling point at (–51.4 °C) which is lower than for R 22. Its thermodynamic properties make it suitable as a refrigerant for medium and high temperature applications in residential and commercial air conditioning. Apart from these fluorinated refrigerants there is a long series of others not seen very often today:

R 23, R 123, R 124 and R 218. Except for R 22, systems with fluorinated hydrocarbons are in general lubricated with polyol ester oils (POE). These oil types are much more sensitive to react chemically with water, the so-called "hydrolysis" reaction. For that reason systems today are kept extremely dry with filter driers.

5.3 AMMONIA NH_3

Ammonia NH_3 is used extensively in large industrial refrigeration plants. Its normal boiling point is –33 °C. Ammonia has a characteristic smell even in very small concentrations in air. It cannot burn, but it is moderately explosive when mixed with air in a volume percentage of 13 to 28%. Because of corrosion, copper or copper alloys must not be used in ammonia plants.

5.4 SECONDARY REFRIGERANTS

The refrigerants mentioned above are often designated "primary refrigerants". As an intermediate link in heat transmission from the surroundings to the evaporator, the so-called "secondary refrigerants" can be used, e.g. water, brine, atmospheric air etc.

Refrigerant Environmental Issues

The inert nature of many halons, chlorofluorocarbons (CFC) and hydro chlorofluorocarbons (HCFC), with the benefits of their being non-flammable and nontoxic, made them good choices as refrigerants, but their stability in the atmosphere and their corresponding global warming potential and ozone depletion.

Potential raised concerns about their usage. In order from the highest to the lowest potential of ozone depletion are Bromochlorofluorocarbon, CFC then HCFC. Though HFC and PFC are non-ozone depleting, many have global warming potentials that are thousands of times greater than CO_2. Some other refrigerants such as propane and ammonia are not inert, and are flammable or toxic if released.

New refrigerants were developed in the early 21st century that are safer for the environment, but their application has been held up due to concerns over toxicity and flammability.

Uses

Refrigerants such as ammonia (R717), carbon dioxide and non-halogenated hydrocarbons do not deplete the ozone layer and have no (ammonia) or only a low (carbon dioxide, hydrocarbons) global warming potential. They are used in air-conditioning systems for buildings, in sport and leisure facilities, in the chemical/pharmaceutical industry, in the automotive industry and above all in the food industry (production, storage, and retailing). In these settings their toxicity is less a concern than in home equipment.

Emissions from automobile air conditioning are a growing concern because of their impact on climate change. From 2011 on, the European Union will phase out refrigerants with a global warming potential (GWP) of more than 150 in automotive air conditioning (GWP = 100 year warming potential of one kilogram of a gas relative to one kilogram of

CO_2). This will ban potent greenhouse gases such as the refrigerant HFC-134a—which has a GWP of 1410—to promote safe and energy-efficient refrigerants.

One of the most promising alternatives is CO_2 (R-744). Carbon dioxide is non-flammable, non-ozone depleting, has a global warming potential of 1. R-744 can be used as a working fluid in climate control systems for cars, residential air conditioning, hot water pumps, commercial refrigeration, and vending machines. R12 is compatible with mineral oil, while R134a is compatible with synthetic oil that contains esters. Dimethyl ether (DME) is also gaining popularity as a refrigerant, but like propane, it is also dangerously flammable.

Refrigerants by Class and R Number

Refrigerants may be divided into three classes according to their manner of absorption or extraction of heat from the substances to be refrigerated:

- **Class 1:** This class includes refrigerants that cool by phase change (typically boiling), using the refrigerant's latent heat.
- **Class 2:** These refrigerants cool by temperature change or 'sensible heat', the quantity of heat being the specific heat capacity x the temperature change. They are air, calcium chloride brine, sodium chloride brine, alcohol, and similar nonfreezing solutions. The purpose of Class 2 refrigerants is to receive a reduction of temperature from Class 1 refrigerants and convey this lower temperature to the area to be air- conditioned.
- **Class 3:** This group consists of solutions that contain absorbed vapors of liquefiable agents or refrigerating media. These solutions function by nature of their ability to carry liquefiable vapors, which produce a cooling effect by the absorption of their heat of solution. They can also be classified into many categories.

The R-# numbering system was developed by DuPont corporation (which owns the Freon trademark) and systematically identifies the molecular structure of refrigerants made with a single halogenated hydrocarbon. The meaning of the codes is as follows:

- For saturated hydrocarbons, subtracting 90 from the concatenated numbers of carbon, hydrogen and fluorine atoms, respectively gives the assigned R#.
- Remaining bonds not accounted for are occupied by chlorine atoms.
- A suffix of a lower-case letter a, b, or c indicates increasingly unsymmetrical isomers. For example, R-134a has 2 carbon atoms, 2 hydrogen atoms, and 4 fluorine atoms, an empirical formula of tetrafluoroethane. The "a" suffix indicates that the isomer is unbalanced by one atom, giving 1, 1,1,2- Tetrafluoroethane. R-134 (without the "a" suffix) would have a molecular structure of 1,1,2,2- Tetrafluoroethane—a compound not especially effective as a refrigerant.
- The R-400 series is made up of zeotropic blends (those where the boiling point of constituent compounds differs enough to lead to changes in relative concentration because of fractional distillation) and the R-500 series is made up of so-called azeotropic blends. The rightmost digit is assigned arbitrarily by ASHRAE, an industry organization.

Notable Blends

R407C pressure-enthalpy diagram, isotherms between the two saturation lines

Below are some notable blended HFC mixtures. There exist many more (see list of refrigerants). All R-400 (R-4xx) and R-500 (R-5xx) hydroflurocarbons are blends, as noted above.

- R-401A is a HCFC zeotropic blend of R-22, R-152a, and R-124. It is designed as a replacement for R-12.
- R-404A is a HFC"nearly azeotropic" blend of 52 wt. % R-143a, 44 wt. % R-125, and 4 wt. % R-134a. It is designed as a replacement of R-22 and R-502 CFC. Its boiling point at normal pressure is -46.7 °C, its liquid density is 0.485 g/cm3.
- R-406A is a zeotropic blend of 55 wt. % R-22, 4 wt. % R-600a, and 41 wt. % R-142b.
- R-407A is an HFC zeotropic blend of 20 wt. % R-32, 40 wt. % R-125, and 40 wt. % R-134a.
- R-407C is a zeotropic hydrofluorocarbon blend of R-32, R-125, and R-134a. The R-32 serves to provide the heat capacity, R-125 decreases flammability, R-134a reduces pressure.
- R-408A is a zeotropic HCFC blend of R-22, R-125, and R-143a. It is a substitute for R-502. Its boiling point is -44.4 °C.
- R-409A is a zeotropic HCFC blend of R-22, R-124, and R-142b. Its boiling point is -35.3 °C. Its critical temperature is 109.4 °C.
- R-410A is a near-azeotropic blend of R-32 and R-125. The US Environmental Protection Agency recognizes it as an acceptable substitute for R-22 in household and light commercial air conditioning systems. It appears to have gained widespread market acceptance under several trade names.

Notes

Notes

2

SECTION

Introduction to R134a, Recovery, Recycling of Refrigerants and Good Repair Practices

This section II is covering the following topics:

A. Working with R134a

B. Guidelines for introduction of CFC free equipment to National EPI Programmes

The objectives are to:

- Introduce the technician to the refrigerant HFC-134a (R134a).
- Introduce the technician to Recovery and Recycling technology for R134a
- Introduce the technician to service and repair practices for R134a
- Apply the new technologies in a set of practical exercises (hands-on activities).

1. Introduction

1.1. TOWARDS A CFC FREE WORLD

Global consensus supports the theory that chlorine from man-made substances, including CFC and HCFC refrigerants emitted into the atmosphere is responsible for depletion of the ozone layer. Ozone depletion is linked with increase in ultra-violet-B (UV-B) at the earth's surface. UV-B radiation is linked to skin cancer, plant and aquatic destruction.

The international community has recognized the linkage between CFC and HCFC and has committed to the elimination of the refrigerants in an accord named the Montreal Protocol. The Montreal Protocol calls for cessation of CFC production December 31, 1995 in the developed nations and provides a 10 year grace period for developing nations- The protocol calls for a 65% reduction in HCFC production beginning in 2004 and complete phase out by 2030. Global warming theory may also impact the success of the various alternative refrigerants or new technologies that can replace CFC and HCFC systems.

The clear conclusion is that all existing air conditioning and refrigeration systems operating today must be carefully and fully maintained with the desire to minimize all refrigerant to the atmosphere.

HFC's (Hydro fluorocarbon) refrigerants have been developed, which contain no chlorine at all.

HFC -134a (R134a) has an Ozone Depletion Potential of zero (ODP) and was one of the first refrigerants tested as an alternative for refrigerators and is the leading candidate to replace CFC -12. (R12) R134a has an impact on the Global Warming Potential, in order to minimize the release of R 134a to the atmosphere WHO/EPl has decided to introduce training courses for recovery and recycling of R134a.

WHO/UIP has decided to rise R134a as the gas of choice in replacement for R12.

After an introduction to R134a, we will work with recovery and recycling of R134a and service techniques for R134a systems.

Changing procedure of R134a compressor

1. Switch power off Open the protection cover by using cross screwdriver or universal
2. Screwdriver.
3. Remove electrical parts of compressor.
4. Remove the four mounting bolts of compressor by using fork wrench or universal tool.
5. Remove the compressor.
6. Install new compressor and new filter dryer and weld them. The open time of system shall not be more than 10 min.
7. Connect the R134a recovery unit to the low sideline of the compressor, and then evacuate. The evacuation time shall not be less than 45 min.
8. Fill system with R134a according to its original quantity.
9. Check if there is any leakage at brazing point by using soapsuds.
10. Use clean gauze to wipe away welding powder and flux.
11. Connect the electrical controlling unit of compressor.
12. Mount and adjust temperature controller.
13. Switch on power for test run, check unit operation.

Figure A-2.1:

2. Introduction to R134a

The refrigeration systems that are working with R134a are specially designed for this refrigerant and uses components specially designed for R134a Systems that are designed for R134a must not be charged with R12 and vice versa.

Physical and thermodynamic properties for RI34a

Chemical formula	-	$CH_2F\text{-}CF_3$
Chemical Name	-	1,1,1,2-tetrafluoroethane
Molar mass	g/mol	102.03
Boiling point at 1.013 bar	°C	-26.5
Critical temperature	°C	101.15
Critical Pressure (abs)	Bar	40.64
Critical Density	Kg/l	0.508
Density of liquid		
At 20°C	Kg/l	1.226
At 40°C	Kg/l	1.147
Density of saturated vapour		
At 20°C	Kg/m^3	27.91
At 40°C	Kg/m^3	50.27

Table: Properties of R134a

GWP	CO_2	CH_4	CFC-11	CFC-12	HCFC-22	HFC-134a
20 yrs	1	63	4500	7100	4100	3200
100 yrs	1	21	3500	7300	1500	1200
500 yrs	1	9	1500	4500	510	420

Normally a time horizon of 100 years is taken. Replacing CFC 12 by HFC 134a would imply a reduction by a factor of 6 in global warming, if the gas is emitted.

Table: Global warming potential

The global warming potential (GWP) is an index which compares the warming effect over time of different gases relative to equal emissions of CO_2 (by weight). The table below shows differences in GWP for different time horizons.

2.1. PROPERTIES AND CHARACTERISTICS OF R134 a

From a whole series of products investigated the choice of substitute for R12 became HFC 134a (tetrafluoroethane), or R134a as it is commonly called, because the physical and thermodynamic properties are very similar to R12.

R134a is chlorine free and have no ozone depletion potential, but will contribute to the greenhouse effect (the global warming potential)

The similarities in physical and thermodynamic properties between R134a and R12 can be seen from the table 2.2. below:

○ Compression ratio	P_c / P_o
○ Volumetric cooling capacity	qo.th
○ Compressor discharge temperature	t_E
○ Coefficient of performance	E_k

Table 2.2 lists these four variables for the following operating conditions:

○ Evaporating temperature	-25 to 0°C
○ Condensing temperature	40°C
○ Suction vapour superheating	10 K
○ Liquid sub cooling	5 K

METALS:

R 134a is similar to R12 in that it is compatible with all metals and metal alloys commonly used in machine and equipment manufacture. Only, magnesium, lead and aluminum alloys with more Than 2% by mass magnesium should be avoided.

2.2. NEED FOR OPTIMIZED SYSTEM DESIGN

Initial tests result with HFC-134a were not too encouraging because energy consumption was higher than that of CFC-12 and accelerated live tests revealed problems with high failure rates for some of the lubricants. Today lubricant manufacturers have developed synthetic ester oils. Tests carried out in conjunction with major application manufacturers have demonstrated that freezers and refrigerators using synthetic refrigeration lubricants (polyol ester oil) and optimized for HFC - 134a consume no more energy than their CFC -12/mineral oil counterparts.

Points where Rl34a systems differs from R-12 systems are.

- The compressor is optimized and uses polyol ester oil.
- The filter drier (filter drier with desiccant XH9) XH 9 can absorb more moisture than conventional filter dryers.
- Usually the evaporator has a larger surface in order to compensate for the slightly lower volumetric cooling capacity of R134a.
- Usually the diameter of the capillary tube is slightly less.
- R134a systems works at lower pressures.

Refrigerators and freezers operating with R134a that have been tested and approved by WHO/UIP meets the same specifications as those operating with R12.

2.3. RISK OF CONTAMINATION

It is necessary to emphasise, and it cannot be stated too often, that the inside of a refrigerating system must at all times be scrupulously clean. Contamination of any kind will cause continual breakdowns with perhaps permanent damage to internal metals. Whereas a factory production line lends itself to methodical cleaning procedures, including air conditioned assembly rooms, repairs carried out on site naturally lack these facilities. The possible intake of air and dirt when pipe ends, valves and other parts are open to the atmosphere represents a serious hazard. For this reason, meticulous care at all stages must be maintained to avoid expensive recalls later on.

When working with R134a special care has to be taken not to contaminate the system. Tools and other equipment that has been in direct contact with R12 must not be used for R134a systems. The chlorine in R12 may cause an unwanted chemical reaction and cause damage to the system.

The oil used in R134a systems absorbs much more moisture than the conventional mineral oil. It is therefore important to close (clog) all open ends while doing repairs.

Moisture, if entering the system, will block the capillary tube.

KEEP TOOLS AND SPARE PARTS USED FOR R134A SEPARATE FROM TOOLS AND SPARE-PARTS USED WITH R12.

2.4. REFRIGERATION OIL

Conventional compressor lubricants are miscible with CFC (R12) and HCFC (R22) refrigerants but are immiscible with R134a. Use of a conventional immiscible lubricant in conjunction with R134a adversely affects the efficiency of the refrigerating unit. In such case, the immiscible oil separates in congealed masses from the refrigerant a within condenser and thus impedes the flow through expansion devises (capillary tube) often causing “sputtering”. Once through the expansion device, the immiscible oil will settle at the bottom of the evaporator tubes causing further degradation in flow and heat transfer. In some cases, lack of oil return to the compressor can promote component wear and eventual failure through lubricant starvation.

The oil used for R134a is polyol ester oil. This oil is more sensitive to atmospheric moisture than the mineral oil used with R12.

The oil should be stored in closed air-tight container in dry surroundings, and only dry vessels may be used for filling.

If oil change becomes necessary, make sure that you choose the correct oil.

2.5. FILTER DRIERS

The filter driers used for R134a systems also differ from those normally used with R12.

A molecular sieve, XH-9 or XH-7 is recommended for R134a. These filter driers will absorb more moisture than conventional filter driers. XH-9 or XH-7 filters may also be used for R12.

Whenever the system has been opened the filter must be changed.

3. Handling of Tools and Service Equipment for R134a

3.1. KEEP TOOLS AND SPARE PARTS SEPARATE

It is of utmost importance to keep tools and spare-parts used for R12 separate from those used for R134a. If tools, such as vacuum pump, charging hoses and other tools that are in direct contact with the refrigerant' are mixed and used for both refrigerants the refrigeration system will be- contaminated and may cause the system to malfunction.

Spare-parts for R12 and R134a are not necessarily compatible and must be kept separately.

3.2. MARKING OF THE TOOLS

In order not to mix the tools used for R134a with the tools used for R12 it important to clearly mark the tools. If your R134a tool-kit is not marked upon reception, make sure to mark the tools so they can easily be distinct from-the tools you use for R12. The marking should be a blue circle. R134a The colour coding for R134a is blue.

3.3. ALL REPLACEMENTS MUST BE R134A COMPATIBLE

Whenever you make repairs to R134a systems ensure that you have spare-parts that are meant for R134a.

Using incorrect spare-parts may damage the system.

4. Service Procedures for R134a

4.1. FAULT FINDING PROCEDURES

Systems working with R134a have the same working principals as systems working with R12. Therefore the fault finding procedures are the same as we know from R12 systems. However, there are certain areas where attention must be drawn to the fact that you are working with R134a:

Service Tools

Do not use service tools that have been used for chlorine containing refrigerants (R12) because microscopic chlorine residues may cause an unwanted chemical reaction in the cooling system.

Evacuation

As the oil used for R134a has the properly that it absorbs more moisture than the oil used for R12, it is necessary to evacuate 5 - 10 minutes after the system has been evacuated to the required Vacuum (approx. 1mbar).

Filter Drier

A filter drier with desiccant XH9 or XH7 is to be used.

Oil

The oil used for R134a is polyol ester oil. This oil is more sensitive to atmospheric moisture than the mineral oil used with Rl2.

The oil should be stored in closed air-tight container in dry surroundings, and only dry vessels may be used for filling.

If oil change becomes necessary make sure that you choose the correct oil.

Leak Detection

When a system is thought to have a leak the whole system should be checked, with leaks found being marked for rectification. You should never assume a system has only one leak.

It should be noted that traditional “Halon lamps” cannot be used with H FCs such as R134a as they require the presence of chlorine to produce a coloured flame. Detection can be made electronically. Many sensors use the “Heated Diode” or “Corona Discharge” method of detection. These sensors have been tuned to measures chlorine content. With the introduction of fluorine based HFCs, the chlorine content has been entirely eliminated. It takes approximately 120 parts of Fluorine to equal one part of Chlorine. As a result, significant amplification is required to produce a reliable alarm signal. Many electronic leak detectors produced today do not have the sensitivity to detect HFCs - R134a leaks.

The leak detector supplied with the tool-kit is meant for R134a, but can also be used to detect leaks in R12 systems,

IN ORDER TO DETECT A LEAK IN A R134a SYSTEM, THE LEAK DETECTOR MUST BE MEANT FOR R134a.

The simplest and oldest method of leak detection is by means of soap bubbles. Swab a suspected leak with liquid soap or detergent and bubbles will appear if a leak exists. Despite its simplicity, the soap bubble method can be extremely helpful in pinpointing a leak which is difficult to locate.

4.2. IDENTIFICATION OF COMMON REFRIGERANTS

It has always been necessary to know which refrigerant is in a system in order that the correct refrigerant can be used when work is carried out on the system, Now that new refrigerants, that have to be recovered have been introduced, it has become of paramount importance.

Refrigerants may be identified by the following methods:

a. Refrigerants stamped on unit data plate
b. Blue colour coding on compressor indicates (R134a)

c. TEV for specific refrigerant (thermostatic expansion valve)
d. Standing Pressure

Refrigerants commonly used in UIP:

a. R12: Compression Refrigerators, freezers and Cold Rooms'
b. R22: Freezing Rooms.
c. R502: Freezing Rooms (rarely)
d. New refrigerants in UIP:
e. R134a: Compression Refrigerators, freezers and Cold Rooms'
f. R404a: Freezing Rooms.

Notes

5. Equipment Requirements for Recovery and Recycling of Refrigerants

1. LINE PIERCING WITH VALVE

Figure A-2.1: To access the system at the filter drier when recovering refrigerant use line piercing pliers and valve.

2. RECOVERY BAG (FOR FIELD USE

Figure A-2.3: For the recovery of refrigerant during field repairs a special bag has been designed. The inside of the bag is made of a foil resistant to the specific refrigerant. There is a layer of gas proof aluminium foil and an additional layer of foil which prevents the penetration of oxygen. The bag is equipped with a 1/4" flare connection with schrader valve This bag is used for recovery and transport of refrigerant.

3. FILLING STATION/VACCUM PUMP

Figure A-2.4:

4.RECOVERY & RECYCLING UNIT

Figure A-2.5:

RECOVERY AND RECYCLING UNIT[4]

When emptying and recycling the refrigerant from the bag to the cylinder designed for recycled refrigerant the recovery and recycling unit is used. The refrigerant is pumped out of the bag through the recovery and recycling rack. While passing through the rack the used and oil-mixed refrigerant is cleaned and is ready for reuse. (Before use refer manufacturer instructions)

5.5. Cylinder For Recycled Refrigerant (Do Not Use Disposal Cylinders) Must Be Clearly Marked With The Type of Refrigerant It Is Intended For

Figure A-2.6:

5.6. WEIGHING SCALE

Figure A-2.7:

[4] Should remain in work shop

WEIGHING SCALE FOR THE CYLINDER FOR USED REFRIGERANT

A weighing scale is used for the instant checking of the amount of refrigerant filled into the cylinder. An accurate scale should be used as it is important that not too much used refrigerant is filled into the cylinder.

5.7. SAFE HANDLING OF RECOVERED REFRIGERANT

5.7.1.

Become very familiar with your recovery equipment. Read the OEM manual and apply all prescribed methods and instruction every time equipment is employed.

5.7.2.

Liquid refrigerants can cause severe frost bite ... avoid possibility of contact through use of adequate gloves and long sleeved shirts/cover.

5.7.3.

The refrigerant being recovered could come from a badly contaminated system. Acid is a product of decomposition; hydrofluoric acid can be produced. Extreme care must be taken to prevent oil spills of refrigerant vapours from contacting skin and clothing surfaces when servicing contaminated equipment.

5.7.4.

Wear protective gear, such as safety glasses and shoes, gloves, safety hat or hard hat, long pants, and shirts with long sleeves.

5.7.5.

Refrigerant vapours can be harmful if inhaled. Avoid direct ingestion and always provide low-level ventilation

5.7.6.

Ensure that all power is disconnected and disabled to any equipment requiring recovery.

5.7.7.

Never exceed the cylinder's, refrigerant bag's safe liquid weight level, based upon net weight. Maximum capacity of any cylinder is 80% by maximum gross.

5.7.8.

When moving a cylinder, use an appropriate wheeled device ensure that the cylinder is firmly strapped in when device is a hand cart. NEVER roll a cylinder on its base on its bas e or lay it down to roll it from one location to another.

5.7.9.

Use top quality hoses. Make sure they are properly and firmly attached. Inspect all hose seals frequently.

5.7.10.

Hoses and electrical extension cords can be a trip hazard. Prevent an accident of this sort by placing proper barriers and signs. Place hoses sensibly to where risk is minimized.

5.7.11.

Label the cylinder or container with proper identification.

5.7.12.

Ensure that all cylinders are in a safe condition, capped as necessary, with proper identification.

6. Recovery and Recycling Procedures

6.1. RECOVERY DURING FIELD REPAIRS

The refrigerant must be recovered in a refrigerant bag. recycling will be done at district workshop. Following procedure must be followed:

Evacuation and recovery of Refrigerant

1. Fit line piercing pliers at the filter drier after thorough cleaning of filter surface.

2.

2 & 3.

2. Connect the refrigerant bag-open the valve
3. Close the valve after pressure equalizing - disconnect the refrigerant bag.
4. There will still be some refrigerant left in the oil- In order to have that recovered the vacuum pump must be connected.
5. Connect the refrigerant bag on the vacuum pump outlet

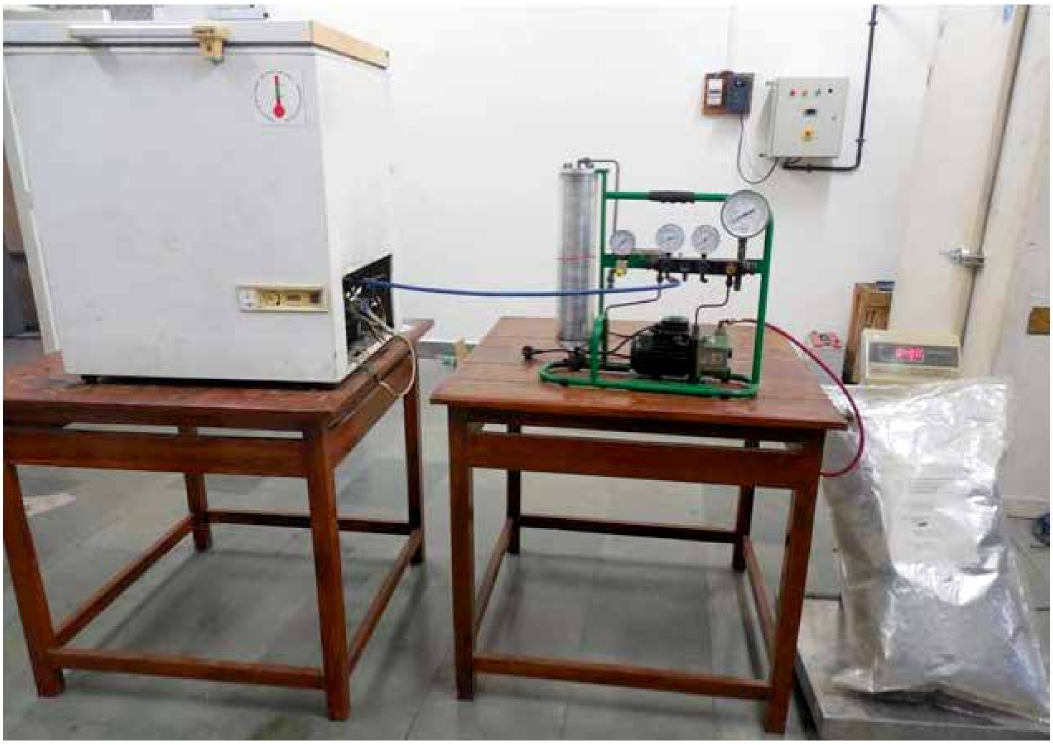


Figure A-2.8:

6. Connect the hose for the filling station at the piercing valve on the filter drier.

7. Open the valve and start evacuation.

The refrigerant is now "safe" in the refrigerant bag and can be transported to the District Repair Shop for recycling. The max. Contents of the bag is 200 g. See manufactures specifications at the bag.

6.2. RECYCLING (FROM REFRIGERANT BAG TO CYLINDER)

Emptying and recycling used Refrigerant from refrigerant bag to cylinder for recycled refrigerant, See fig. 6.1.

Connect the refrigerant bag(s), with a hose (**blue coded**) to the inlet valve on the recycling unit.

Connect the cylinder for recycled refrigerant, with a hose (**red coded**), to the sight glass on the recycling unit. This hose is to have a closing valve at the end connected to the recycling unit.

When the required bag(s) has/have been emptied the pressure sensitive switch will stop the recycling unit. In case unwanted air should enter the cylinder, causing the pressure to rise, the pressure sensitive switch will stop the emptying unit. The cylinder can be bled by means of the bleeder valve on the recycling unit.

Make sure to observe all existing rules concerning the accumulation of used refrigerant and the contents allowed for the cylinder- approx. 75% of the weight stated on the cylinder. (Before use refer manufacturer instructions)

Note the specifications stated on the refrigerant bags – eg. Refrigerant R134a Content max.-200g Temperature Max.-+60 degree C

Figure A-2.9:

6.3. SPECIAL CARE SHOULD BE TAKEN:

1. Not to overfill the cylinder
2. Not to mix grades of refrigerant or put one grade in a cylinder labelled for another
3. To use only clean cylinders, free from contamination by oil, acid, moisture etc.
4. To visually check each cylinder before use and make sure all cylinders are regularly pressure tested.

6.4. RECOVERY AND RECYCLING IN WORKSHOP

When working in the workshop and having access to the Recovery and Recycling unit the refrigerant bag can be omitted. The recovery and recycling can be done directly to the refrigerant cylinder for used refrigerant. Simply connect the Recovery and Recycling unit directly to the refrigerator/freezer. Being repaired and the cylinder for used refrigerant. See also user's manual

Direct recovery and recycling and evacuation of refrigerant

1. Fit line piercing pliers at the filter drier after thorough cleaning of filter surface.
2. Connect the suction side of the recovery/recycling unit to the valve at the line piercing pliers, use blue coded hose.
3. Connect the refrigerant cylinder to the recovery/recycling unit at the pressure side, use red coded hose. This hose must have a closing valve at the end connected to the recovery/recycling unit
4. Open the valves at line piercing pliers, recovery/recycling unit and recovery cylinder.
5. Start the recovery/recycling unit and wait tilt the unit automatically cuts out.
6. Now most of the refrigerant has been recovered, however there is still some refrigerant left in the oil of the system. The refrigerant in the oil can only be

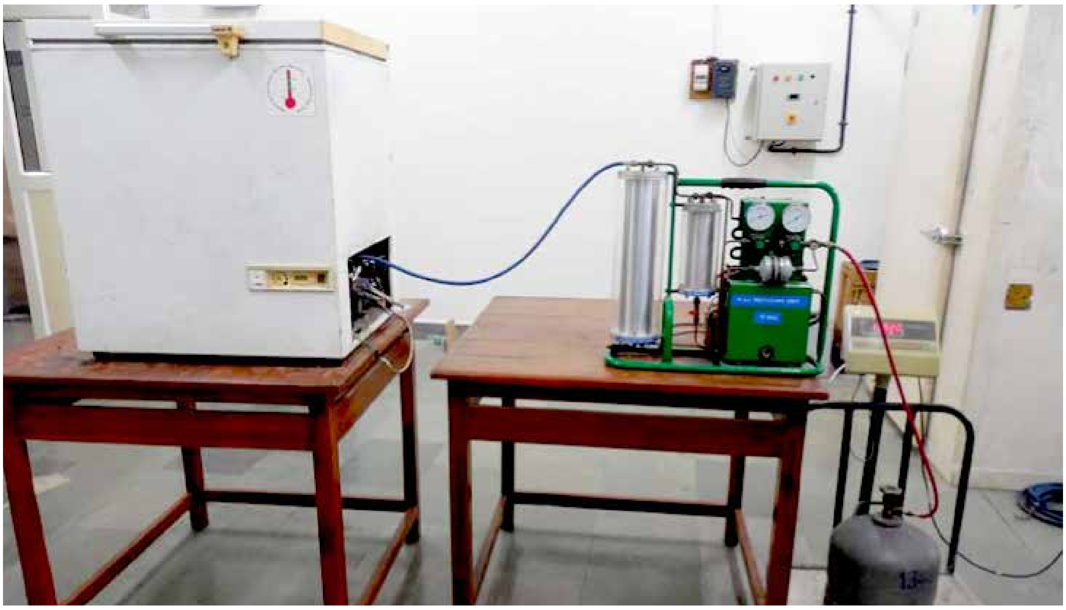


Figure A-2.10:

recovered by use of the vacuum pump, which is to be connected in series with the recovery/recycling unit. See next page.

7. Close all valves - leave the blue hose at filter drier valve.
8. Connect the blue hose from the recycling/recovery at the outlet of the vacuum pump
9. Connect the hose between vacuum pump inlet and the valve at the filter drier.
10. Open the valves (in following sequence) at filter drier. Suction side of vacuum pump (filling station). Suction side of the recycling/recovery unit. Pressure side of the recycling/recovery unit and finally cylinder for used refrigerant.
11. Start the vacuum pump and the recycling/recovery unit
12. Leave the vacuum pump and the recycling/recovery unit running till the vacuum gauge (at the filling station) shows approx. 5 mbar.
13. As much refrigerant as possible has now recovered and recycled.
14. The system pressure is negative (vacuum), equalize the pressure with nitrogen before opening the system, see section 8.

Figure A-2.11:

7. Good Repair Practices

7.1. BEFORE BEGINNING REPAIR ON A REFRIGERATION SYSTEM. ENSURE THE FOLLOWING:

- That you know which refrigerant is being used in the system that you are working on, see section 4.2.
- That you have the necessary tools and spare parts for the repair work to be carried out.

7.2. WHEN EVER A REFRIGERATION SYSTEM IS OPENED ENSURE THAT THE REFRIGERANT IS RECOVERED AND RECYCLED

7.3. NITROGEN (N_2)

- N_2 is used for purging/flushing, purging is even more important when you work with R134a system

Purging or flushing are terms used to describe the process of removing unwanted air, vapour, dirt or moisture from the system.

N_2 is used for blowing through the refrigerating system.

After removing the filter, blow N_2 into the system at the process pipe. Holding a hand in the flow at the filter site will allow an evaluation of the purity of the pipe system as well as the flow through the pipes.

Blow N_2 through the filter as well to check for possible block-age.

Always blow N_2 through a new component before installing.

- Leak detection and pressure testing

Dry nitrogen (N_2) is used:

1. To increase the pressure in the refrigerating system when leakage is very little.
2. If leakage is suspected in the evaporating system (low pressure side).
3. Mixed with refrigerant if the pressure in the refrigerating system is insufficient for effective leak detection (use up to 10 bar).

7.4. FILTER DRIER

Whenever a system has been opened - change the filter-drier. When you change the filter always use a bigger size filter than the filter originally fitted - minimum 20g.

Some moisture and impurities will always be accumulated in the filter drier, both from residue left in the system after installation and from contamination given off by the compressor, pipe system and refrigerant. When repairs are made to the refrigerating system, the filter will often be unable to absorb the extra contamination. Ice blockage and contamination of the capillary tube may be the result.

It is important to note that REPAIRS MADE TO THE REFRIGERATINGSYSTEM HAVE BEEN CORRECTLY CARRIED OUT UNLESS THE FILTER DRIER HAS BEEEN REPLACED.

Figure A-2.12: Filter drier

In order to ensure an efficient utilization of the filter drier, it should be positioned with an inclination of at least 15° and with the capillary tube entering from the bottom. If the filter is fitted horizontally the refrigerant may pass over the desiccant.

7.5. SEALING OF SYSTEMS

Never leave a refrigeration system open longer than absolutely necessary, R134a systems is highly sensitive to moisture because of the polyol ester oil. Always clog open tube ends.

7.6. COMPRESSORS

When changing the compressor make sure that the replacement compressor is of the same capacity as the broken compressor and that it is meant for R134a.

Do not use compressors that have been repaired in "non authorised" workshops.

7.7. EVACUATION AND CHARGING PROCEDURES

Follow manufactures instruction for use of the Evacuation and Charging unit (filling station)

7.8. CHECK SYSTEM BEFORE HANDING OVER TO CLIENT

Observe the system, check temperature, check that thermostat is cutting in and out, recheck for leaks and make sure that no pipes touch each other or any other objects.

7.9. SAFETY PRECAUTIONS

- Do not work where there is a high concentration of refrigerant R134a gas. If a leak occurs, or you have to release the refrigerant R134a from the system, open a window or door before starting work.
- Make sure that the refrigerant R134a gas does not come into contact with a very high temperature such as a blow torch flame or electric element.
- Do not smoke when refrigerant R134a gas is in the surrounding air.
- Do not use the brazing torch when refrigerant R134a is in the air.
- Do not let liquid refrigerant R134a get onto your skin. Take **extra** care that it does not get into your eyes.
- When transferring liquid refrigerant R134a (from a supply cylinder into a service cylinder) wear gloves and goggles in case a sudden leak occurs.

- Check that the fittings on top of the supply cylinder and service cylinder are tight, and test them for leaks.
- When the supply cylinder or service cylinder is not in use, fit a flare nut and bonnet to prevent any leakage.
- The refrigerant R134a inside the system is at high pressure. Work **carefully** when you are dismantling. The sudden escape of refrigerant R134a is dangerous.
- The compressor oil may have acid in it. Do **not** let old oil touch the skin when you are removing a faulty compressor.
- When charging a refrigerator make sure that you use the **correct** refrigerant R134a. The refrigerant R134a type is shown on the manufacturer's data plate.

8. Making Repairs to the Refrigeration System

8.1. OPENING THE REFRIGERATING SYSTEM FOR REPAIRS AND RECOVERY OF REFRIGERANT

If a hermetic refrigerating system is to function correctly and have a reasonably long life, it is essential that the amount of impurities present in the system, i.e. moisture, foreign gases, dirt, etc., be kept at a minimum.

Before commencing repairs, make sure that an exact diagnosis of the problem has been made. Make sure that it is necessary to actually open the hermetic system before doing so.

When you have decided that you need to make repairs to the system, e.g. changing the compressor the first you must is to recover the refrigerant.

Use following procedure to recover first part of the refrigerant:

1. Fit a service valve at the process pipe Connect a low pressure gauge and confirm your diagnosis.
2. Fit piercing pliers with valve at the filter drier, near pressure pipe.
3. Connect the refrigerant bag to the valve and open the valve. The refrigerant will now flow to the bag - be recovered:
4. When the pressure has equalized (as much refrigerant as possible has flown to the bag) close the valve. and Disconnect the bag.

2.

2 & 3.

Figure A-2.13:

Use following procedure to recover the refrigerant that is absorbed in the oil:

5. Connect the bag to the vacuum pump outlet.
6. Connect the hose from the suction side of the filling station to the valve at the filter drier.
7. Start evacuating and recovering by starting the vacuum pump. Do not overfill the refrigerant bag, as this may damage the vacuum pump. If a change of the refrigerant bag becomes necessary, the evacuation is stopped by closing the valve for the vacuum pump and the bag may be changed.
8. When the evacuation/recovery is completed (approx. 5mbar at vacuum gauge), close the valve at the fiter drier and disconnect the hose.

Before stopping the vacuum pump close the valve (for the vacuum meter) "VAC" at the front panel. If this valve is not closed oil might enter the vacuum meter and damage it.

Figure A-2.14:

9. In order to equalize the pressure in the system before opening, blow dry nitrogen (N_2) into the system. Connect the dry nitrogen (N_2) (adjust the pressure to 2.5 bars) to the valve at process tube and equalize.
10. Before opening the system collect all items needed for the repair. Do not leave the system open for longer than necessary (10-15 minutes)
11. Open the system by cutting off the capillary tube at the filter drier (clean with emery paper before cutting). This is done by using special- purpose pliers or capillary tube scissors in order to avoid burrs and deformation of the tube.

Clean and cut off the filter drier with a pipe cutter. The filter must never be soldered off, as any moisture collected in the filter will evaporate and be pressed back into the system, where it may form ice in the capillary tube. Blow dry nitrogen (N_2)

through the process pipe into the system. The inlet pressure should be approx. 5 bar. Purge for half a minute.

Figure A-2.15:

Continue purging for 1 - 2 minutes if the compressor is electrically burned.

12. Now the actual repair can take place. e.g. changing the compressor.
13. **All cuts must be made with pipe cutters and all joints must be made with suitable brazing torch.**
14. Change the compressor
15. Blow dry nitrogen (N_2) through the system.
16. Fit a new filter drier.
17. Evacuate until a **stable** vacuum of 1 mbar has been reached. Check for stability by separating the vacuum pump from the system. When a stable vacuum of 1 mbar has been achieved, close the valves for vacuum gauge and vacuum pump. Switch off the vacuum pump.
18. Connect the charging cylinder to the process tube and charge the correct amount of refrigerant (normally stated on the rating plate).
19. Start the compressor.
20. Use the suction gauge to verify that the system is running correctly.
21. Pinch the process tube, remove the service valve and pinch the pipe with the use of appropriate brazing torch.
22. Leak detect and test the unit. Test the high pressure side with the compressor switched on. Switch off the compressor, leave it for 5 minutes and test the low pressure side. **Note, the leak detector is very sensitive a might sense the humidity. If the detector is felt too sensitive fit the black cap supplied with the sensor. The tip of the detector must not touch the tubing when detecting as dirt and oil on the tubes with interfere with the detection. (Refer manufacturer instructions for details.)**
23. Disconnect the refrigerant bag from the vacuum pump, the refrigerant in the bag is now ready for recycling, see section 6.2.

9. Exercises

ALL TOOLS AND OTHER EQUIPMENT USED FOR THESE EXERCISES MUST BE FOR R134a

9.1. LET THE REFRIGERATOR/FREEZER STABILISE

Check that the refrigerators/freezers that was started at least 48 hours prior to this exercise have stabilised, i.e. the compressor stops and starts automatically and the desired temperature range has been reached.

9.2. IDENTIFY R134a TOOLS

Check all the tools in the tool-kit, see that they correspond with the list of tools on page. Read all instructions and familiarise yourself with the new equipment.

9.3. MONITOR THE R134a SYSTEM

Connect the low pressure gauge to the process tube and the high pressure gauge to the high pressure side at the filter dryer.

On the **stabilised** system read the thermometer. The low pressure gauge and the high pressure gauge, note the results in table 1 (page 64). Note whether compressor is running or not.

Make two readings, one with the compressor running and one with the compressor stopped. Materials required.

- Working Refrigerator/freezer (R134a)
- Line piercing valves
- High and low pressure gauges with charging hoses (filling station)
- Thermometer
- Table 1 (page 64)

9.4. REMOVE THE COMPRESSOR FROM THE SYSTEM WHERE YOU HAVE MONITORED TEMPERATURES AND PRESSURES APPLY THE RECOVERY/ RECYCLING TECHNOLOGY DESCRIBED IN SECTION 6.4. DO NOT SOLDER, USE PIPE CUTTER AND TUBE SCISSORS.

Materials required

- Working Refrigerator/freezer (R134a)
- Line piercing valves
- Filling station/vacuum pump with charging hoses
- Cylinder for used refrigerant (R134a)
- Weighing scale
- Pipe cutter

- Tube scissors
- Dry nitrogen (N_2)
- Hand tools

9.5. REPLACE THE COMPRESSOR, CHANGE THE FILTER DRIER AND RECHARGE UNIT WITH R134a.

Materials required:

- Refrigerator/freezer (R134a)
- Line piercing valves
- Filling station/vacuum pump with charging hoses
- R134a
- Filter drier
- Dry nitrogen (N_2)
- Hand tools
- Brazing torch, brazing rods - flux and cylinder

9.6. CHECK THAT THE SYSTEM IS FUNCTIONING AND REPEAT EXERCISE 9.3. AND NOTE THE RESULTS IN TABLE 2.

Materials required:

- Refrigerator/freezer (R134a)
- Leak detector
- Thermometer
- High and low pressure gauges and charging hoses

Notes

Table 2

TOOL-KIT FOR CFC FREE REFRIGERATOR REPAIR COURSES	
LIST OF RECOMMENDED TOOLS	
No`. of tools	DESCRIPTION
1	PROCESS TONGS
1	CAPILLARY TUBE SHEARS
1	MIRROR
1	TUBE CUTTER
3	STEEL BRUSHES
1	TOOL BAG WITH LOCK & KEYS
2	REFRIGERANT BAGS
1	CHARGING UNIT
1	ELECTRONIC LEAK DETECTOR 134a
2	DRILLING TONGS (FILTER)
1	SCRADER VALVE REMOVER
1	DIGITAL MULTIMETER WITH CASE
1	ELECTRONIC THERMOMETER
1	CAP FOR PRESSURE CYLINDER
1	TOOL FOR DEBURRING
1	PRESSURE CYLINDER, DRY N_2, 2 LIT
1	POINTED PLIERS
1	MULTI GRIP PLIERS
1	CUTTING PLIERS
1	BITS – ASSORTED
1	PLASTIC HAMMER
1	ORDINARY HAMMER
1	SAW, SMALL WITH BLADES
1	SCREW DRIVER ORDINARY SLOT
1	SCREW DRIVER CROSSHEAD
1	ADJUSTABLE SPANNER 4”
1	ADJUSTABLE SPANNER 6”
1	RATCHET
1	REFRIGERANT R134a,950g
1	VALVE FOR DISPOSABLE BOTTLE FOR 134a
10	FILLING TUBES 6mm W/O SCHRADER
1	SLIDE GAUGE
1	EMERY PAPER
1	FLAT FINE FILE WITH HANDLE 150mm
1	ROUND FILE WITH HANDLE 150mm
1	MEASURING TAPE 2m
1	SET OF HEXAGON SOCKET SPANNERS
1	ELECTRICIANS CRIMPING TOOL WITH CABLE SHOES
2	GASKETS FOR DRILLING TONGS

1	NEEDLE FOR DRILLING TONGS
1	EXTRA WHEEL FOR PIPE CUTTER
1	EXTENSION FLEX (3 METRES)
1	PROTECTION GLASSES
1	MOBILE EMPTYING & CLEANISNG UNIT (R134a)
1	VESSEL FOR USED REFRIGERANT
1	BRAZING TORCH WITH SET OF NOZZLE

10. Temperature/Pressure Tables

Type of refrigerator :____

Date and time of start of compressor: ____

Refrigerant: ____

Fill in this table before dismantling the system

TEMPERATURE/PRESSURE TABLE 1

TIME	INTERNAL TEMPERATURE	LOW PRESSURE READING	HIGH PRESSURE READING	COMPRESSOR RUNNING	
HH MM	^{0}C	bar	bar	YES	NO
1 PM	27.3^{0}C				
2.15	12.3^{0}C				
2.45	8.5				
3.45	3.3				
10Am	1^{0}C				

Fill this table following the refitting of compressor

TEMPERATURE/PRESSURE TABLE 2

TIME	INTERNAL TEMPERATURE	LOW PRESSURE READING	HIGH PRESSURE READING	COMPRESSOR RUNNING	
HH.MM	^{0}C	bar	bar	YES	NO
12.25	26	3.8			2.2

Notes

3

SECTION

TROUBLE SHOOTING:

FAULT LOCATION OVERVIEW & GENERAL CHECKS

Categorization

Fault location without the use of instruments

After gaining a little experience, many common faults in a refrigeration system can be localized visually, by hearing, by feel, and sometimes by smell. (The faults that can be observed directly with the senses) Other faults can only be detected by instruments.

Knowledge of the system is required

An important element in the fault location procedure is familiarity with how the system is built up, its function and control, both mechanical and electrical. Unfamiliarity with the system ought to be remedied by carefully looking at piping layouts and other key diagrams and by getting to know the form of the system (piping, component placing)

A certain amount of theoretical knowledge is required if faults and incorrect operation are to be discovered and corrected.

The location of all forms of faults on even relatively simple refrigeration systems is conditional on a thorough knowledge of such factors as:

- The build-up of all components, their mode of operation and characteristics.
- Necessary measuring equipment and measuring techniques.
- All refrigeration processes in the system.
- The influence of the surroundings on system operation.
- The function and setting of controls and safety equipment.
- Legislation on the safety of refrigeration systems and their inspection.
- Before examining faults in refrigeration systems, it could be advantageous to look briefly at the most important instruments used in fault location.

The **Measuring Instruments** required generally for fault detection are discussed in the following chapter.

Instruments for fault location

The items of equipment most often used for locating faults in refrigeration systems are as follows:

1. Pressure gauge
2. Thermometer
3. Leak detector
4. Vacuum gauge
5. Clamp ammeter
6. Megger

Classification of instruments

Instruments for fault location and servicing on refrigeration systems should fulfil certain reliability requirements. Some of these requirements can be categorized thus:

1. Uncertainty
2. Resolution
3. Reproducibility
4. Long-term stability
5. Temperature stability

The most important of these are a, b and e.

a. Uncertainty

The uncertainty (accuracy) of an instrument is the accuracy with which it is able to give the value of the measured variable.

Uncertainty is often expressed in % (±) of either: Full scale (FS) or the measuring value.

An example of uncertainty for a particular instrument is 2% of measuring value, i.e. less uncertain (more accurate) than if the uncertainty is +/-2% of FS.

b. Resolution

The resolution of an instrument is the smallest unit of measurement that can be read from it.

For example, a digital thermometer that shows 0.1°C as the last digit in the reading has a resolution of 0.1°C.

Resolution is not an expression of accuracy. Even with a resolution of 0.1°C, an accuracy as poor as 2 K is not uncommon. It is therefore very important to distinguish between the two.

c. Reproducibility

The reproducibility of an instrument is its ability to repeatedly show the same result for a constant measuring value. Reproducibility is given in % (+/-).

d. Long-term stability

Long-term stability is an expression how much the absolute accuracy of the instrument changes in, say, one year. Long-term stability is given in % per year.

e. Temperature stability

The temperature stability of an instrument is how much its absolute accuracy changes for each °C temperature change the instrument is exposed to. Temperature stability is given in % per °C.

Knowledge of the temperature stability of the instrument is of course important if it is taken into a cold room or deep freeze store.

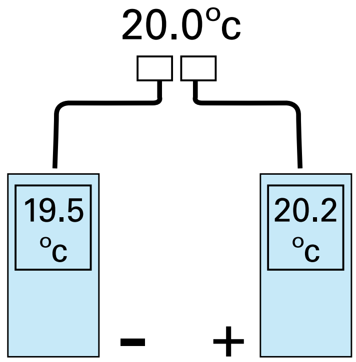


Figure A-3.1:

Electronic instruments

Electronic instruments can be sensitive to humidity. Some can be damaged by condensate if operated immediately after they have been moved from cold to warmer surroundings.

They must not be operated until the whole instrument has been given time to assume the ambient temperature. Never use electronic equipment immediately after it has been taken from a cold service vehicle into warmer surroundings.

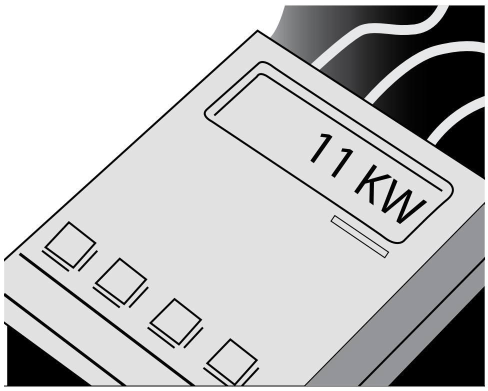
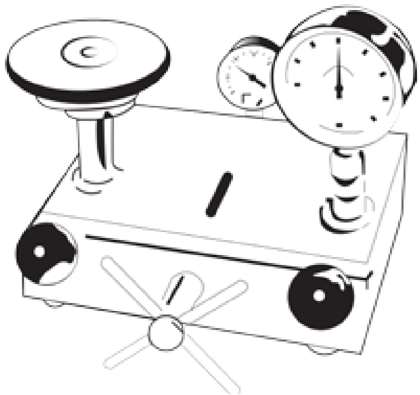


Figure A-3.2:

Check and adjustment

Readings from ordinary instruments, and perhaps some of their characteristics, change with time. Nearly all instruments should therefore be checked at regular intervals and adjusted if necessary. Simple checks that can be made are described below, although they cannot replace the kind of inspection mentioned above.

The proper final inspection and adjustment of instruments can be performed by approved test institutions.



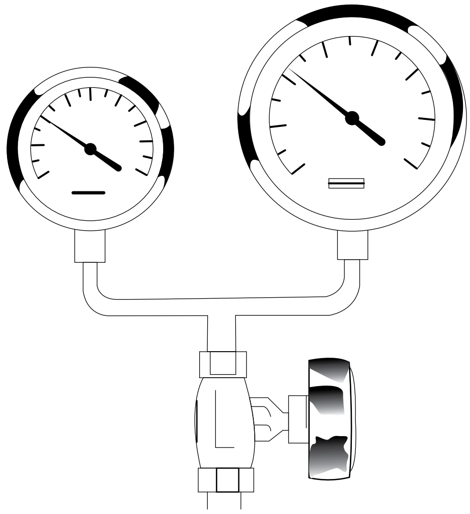


Figure A-3.3:

Adjustment and calibration

PRESSURE GAUGES

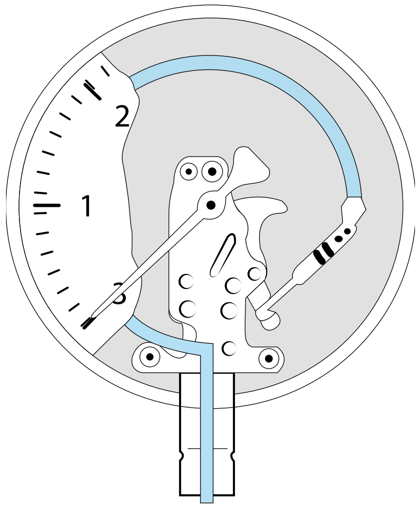


Figure A-3.4:

Pressure gauges for fault location and servicing are as a rule of the Bourdon tube type. Pressure gauges in systems are also usually of this type. In practice, pressure is nearly always measured as over pressure. The zero point for the pressure scale is equal to the normal barometer reading.

Therefore, pressure gauges have a scale from –1 bar (–100 kPa) greater than 0 to + maximum reading. Pressure gauges with a scale in absolute pressure show about 1 bar in atmospheric pressure.

SERVICE PRESSURE GAUGES

As a rule, service pressure gauges have one or more temperature scales for the saturation temperature of common refrigerants. Pressure gauges should have an accessible setting screw for zero-point adjustment, i.e. a Bourdon tube becomes set if the instrument has been exposed to high pressure for some time. Pressure gauges should be regularly checked against an accurate instrument. A daily check should be made to ensure that the pressure gauge shows 0 bar at atmospheric pressure.

VACUUM GAUGES

Vacuum gauges are used in refrigeration to measure the pressure in the pipe work during and after an evacuation process. Vacuum gauges always show absolute pressure (zero point corresponding to absolute vacuum).Vacuum gauges should not normally be exposed to marked overpressure and should therefore be installed together with a safety valve set for the maximum permissible pressure of the vacuum gauge.

Figure A-3.5:

THERMOMETER

Electronic thermometers with digital read-out are in widespread use for servicing. Examples of sensor versions are surface sensors, room sensors and insertion sensors.

Thermometer uncertainty should not be greater than 0.1 K and the resolution should be 0.1°C.

A pointer thermometer with vapour charged bulb and capillary tube is often recommended for setting thermostatic expansion valves. As a rule, it is easier to follow temperature variations with this type of thermometer.

Thermometers can be relatively easily checked at 0°C in that the bulb can be inserted 150 to 200 mm down into a thermos bottle containing a mixture of crushed ice (from distilled water) and distilled water. The rushed ice must fill the whole bottle. If the bulb will withstand boiling water, it can be held in the surface of boil over water from a container with lid. These are two reasonable checks for 0°C and 100°C.A proper check can be performed by a recognized test institute.

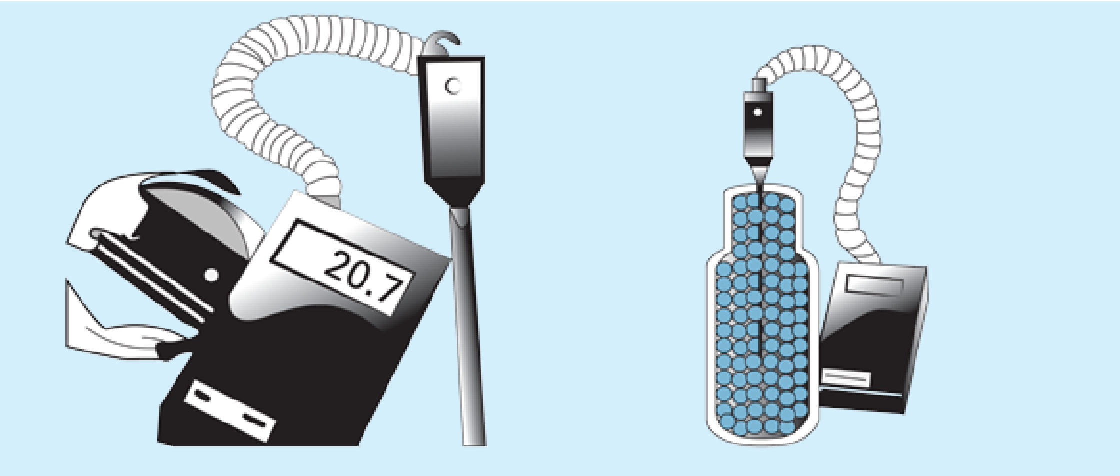


Figure A-3.6:

Notes

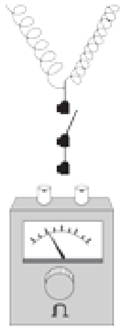
Fault location in refrigeration circuits with hermetic compressors

1. COMPRESSOR/SYSTEM DOES NOT RUN (START)

Fault observation of first analysis

Main switch drop-out	Blown fuse Short-circuiting to frame Motor defect Defective current lead-in Electrical equipment
Compressor	Compressor motor/motor protector mechanically blocked.
	Overload
	Voltage/frequency
	Pressure irregularity
	Refrigerant type
	Pressure equalization
	Fan drop-out
Thermostat	Mechanical defect Incorrect connection Differential too small Incorrect cut out value

Table: Fault observation of compressors



If the main fuse blows, the cause must be found. This will most often be a defect in the motor windings or motor protector, short-circuiting to frame or a burnt current lead-in which, in turn, causes main fuse drop-out. If a compressor motor refuses to start, always check the resistances first. All compressors have their main and start windings located as shown in the sketch below.

Resistance values are stated in the individual data sheets.

As a rule, a motor protection is built into all compressor motors. If the winding protector cuts out the motor, due to the heat accumulated in the motor the cut-out period can be relatively long (up to 45 minutes). When the motor will no longer run, resistance measurement will confirm whether a motor protector has cut out or whether a winding is defective. A mechanical seizure in the compressor will show itself by repeated start attempts accompanied by high current consumption and high winding temperatures that cause motor protector cut out.

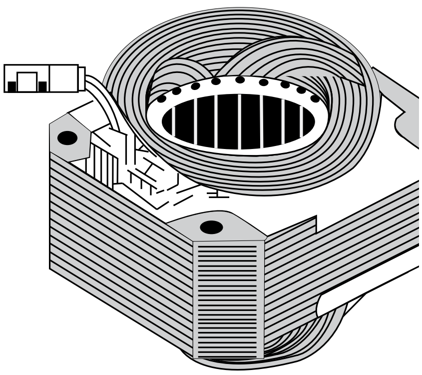


Figure A-3.7:

Compressors for capillary tube systems are usually equipped with a PTC LST starting device. Starting via a PTC requires complete pressure equalization between the high and low-pressure sides on every start. In addition, before it can operate, the PTC requires a stands till time of about 5 minutes to ensure that the PTC component is cooled down in order to achieve maximum starting torque. When a "cold" compressor is started and the current is cut off a short time after, conflict can arise between the PTC and the motor protector. Because the motor retains heat, up to approx. 1 hour can elapse before normal start is possible.

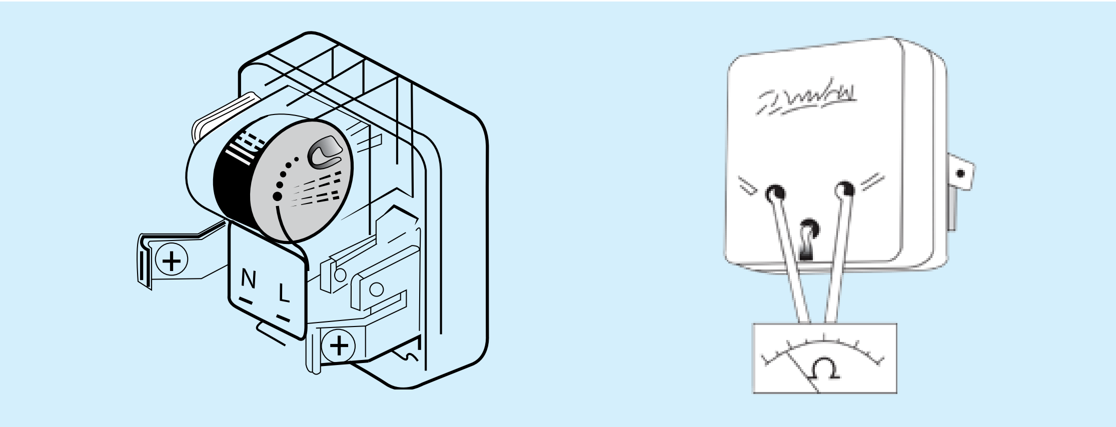


Figure A-3.8:

The PTC (25 V for 220 V mains and approx. 5 V for 115 V mains) can be checked using an ohmmeter.

In systems where pressure equalization on starting is not certain, the compressor must be equipped with an HST starting device. This also applies to capillary tube systems with a stands till time of less than 5 minutes. Defective or incorrect relays and starting capacitors can cause starting problems or that the compressor is cut out via the motor protector. Note the manufacturer's compressor data. If the starting device is thought to be defective the whole equipment must be replaced, including the relay and starting capacitor.

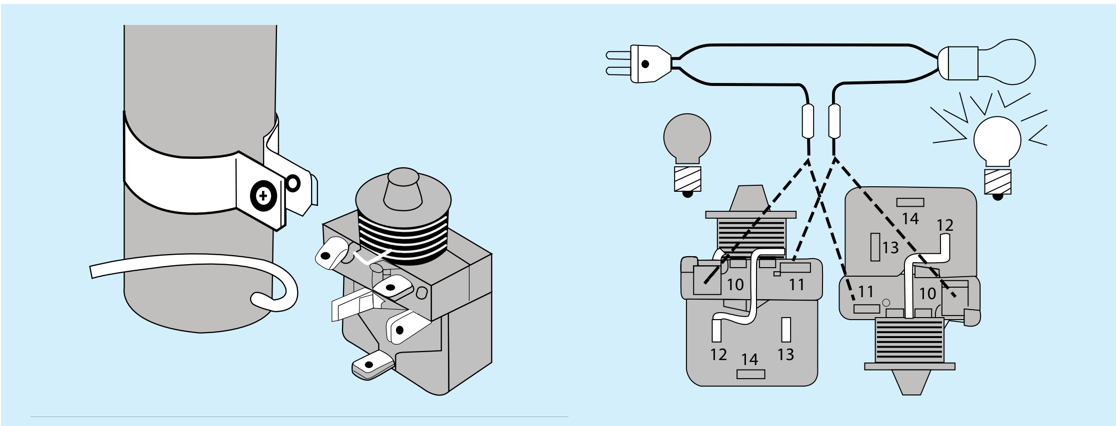


Figure A-3.9:

A starting relay can be checked with a lamp, see sketch. The relay is in order if the lamp does not light up when the relay is upright. The relay is also in order if the lamp lights up when the relay is upside down.

A starting capacitor can also be checked by applying rated mains voltage to it for a few seconds and then short-circuiting the leads. If sparks appear, the capacitor is in order.

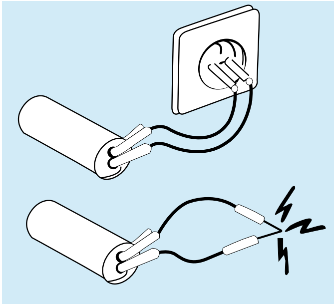


Figure A-3.10:

The system can also cut out because of a defective or incorrectly set/sized thermostat. If the thermostat loses charge or if the temperature setting is too high, the system will not start. If the temperature differential is set too low, compressor standstill periods will be short and there might be starting problems with an LST starting device and shortened compressor life with an HST starting device. The guideline for pressure equalization time using an LST starting device is 5 to 8 minutes for refrigerators and 7 to 10 minutes for freezers. If an HST starting device is used, the aim is to keep the cut-in periods per hour as few as possible. Under no circumstances must there be more than ten starts per hour.

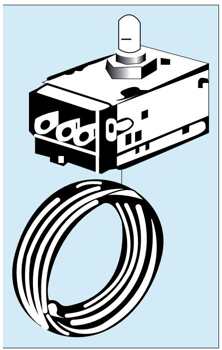


Figure A-3.11:

2. THE COMPRESSOR/SYSTEM RUNS, BUT WITH REDUCED REFRIGERATION CAPACITY

Compressor	Leakage Choking
Pressure irregularity	Blockage Non-condensible gases Moisture Dirt Fan defect Refrigerant loss Refrigerant overcharging Icing
Throttling device Capillary tube/thermostatic expansion valve	Static superheat setting Orifice size/diameter

Frequent causes of reduced refrigeration capacity are choking, and copper plating which lead to reduced life time of the compressor and burst gaskets in the compressor valve system.

Choking occurs mainly as a result of moisture in the refrigeration system. In high temperatures, the presence of moisture also causes copper plating on valve seats. The burst gaskets are the result of an excessive condensing pressure and excessively high short-lived pressure peaks >60bar (liquid hammer).

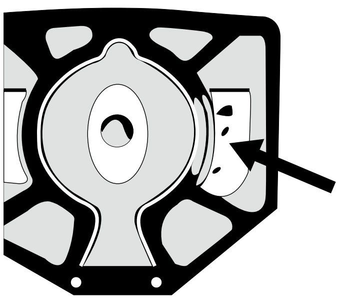


Figure A-3.12:

Recommended is installation of good quality filter driers. If the filter material is of poor quality, wear will occur which will not only cause the partial blockage of capillary tube and the filter in the thermostatic expansion valve, but it will also damage the compressor (mainly seizure). The filter drier must be replaced after every repair. When replacing a "pencil drier" (often used in refrigerators) care must be taken to ensure that the filter material used is suitable for the refrigerant and that there is sufficient material for the application.

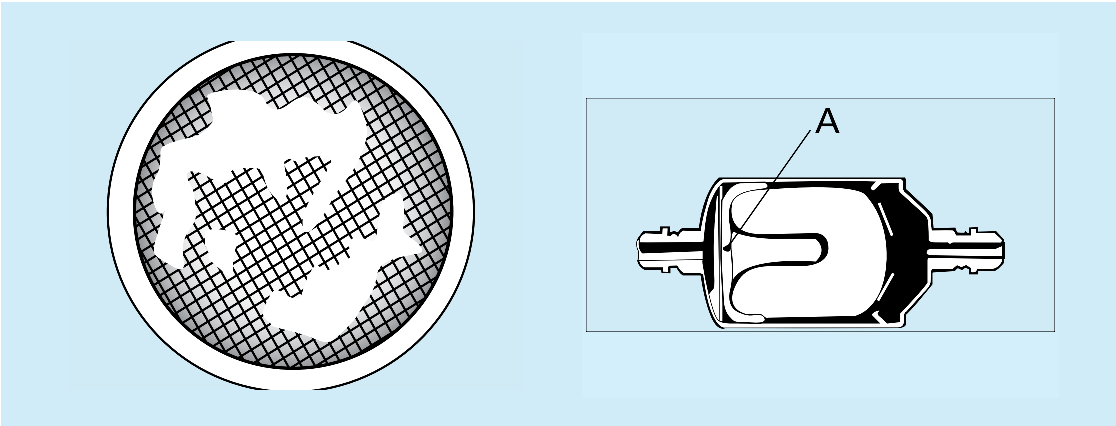


Figure A-3.13:

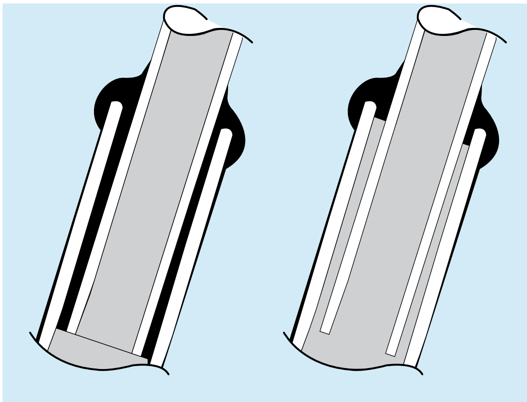


Figure A-3.14:

Poorly soldered joints can also cause system blockage. Making good soldered joints is conditional on using the correct soldering metal containing the correct percentage of silver. The use of flux should be limited and kept to a minimum as possible.

Poorly soldered joints can also cause leakage and thereby choking. In a refrigeration circuit the proportion of non-condensable gases should be kept below 2%, otherwise the pressure level will rise. The main purpose of evacuation is to remove non-condensable gases before the refrigerant is charged. This also produces a drying effect in the refrigeration system. Evacuation can be performed either from both discharge and suction sides or from the suction side only. Evacuation from both sides gives the best vacuum. Evacuation from the suction side only makes it difficult to obtain sufficient vacuum on the discharge side. Therefore, with one sided evacuation, intermediate flushing with dry Nitrogen is recommended until pressure equalization is achieved.

Dirt on the condenser and a fan motor defect can cause excessive condensing pressure and thereby reduced refrigeration capacity. In such cases the built-in high-pressure switch provides overload protection on the condenser side.

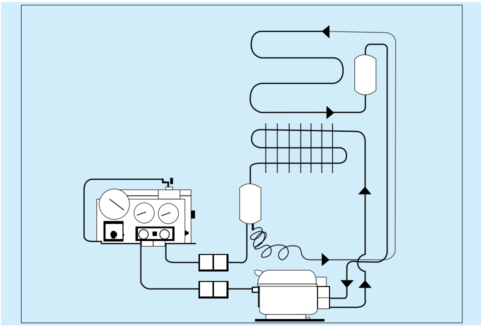


Figure A-3.15:

NOTE

The built-in motor protector does not give the compressor optimum protection if the condensing pressure rises as a result of a fan motor drop-out. The temperature of the motor protector does not rise quickly enough to ensure the protector cut out. This also applies when the refrigerant quantity is greater than can be accommodated in the free volume on the discharge side.

It is important to determine the quantity of refrigerant precisely – especially in capillary tube systems. The guidelines are that the temperature on the evaporator inlet must, as far as possible, be the same as the temperature at its outlet, and that as much superheating as possible must be obtained between the evaporator outlet and the compressor inlet. (The inlet temperature on the compressor must be about 10 K less than the condensing temperature).

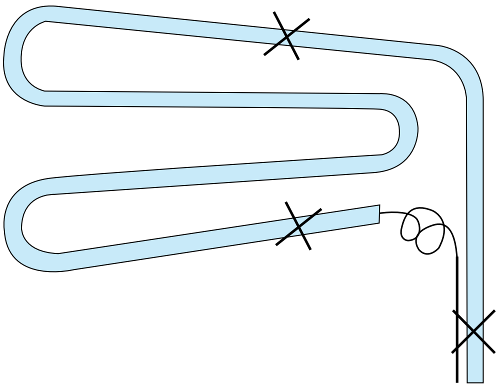


Figure A-3.16:

Notes

3. POWER CONSUMPTION TOO HIGH

Fault obrservation	First analysis
Compressor	Signs of compressor wear Motor defect Reduced refrigeration capacity Compressor cooling
Pressure irregularity	Blockage Non-condensible gases Moisture Dirt Fan defect
Overload	Application limits exceeded Voltage/frequency Pressure irregularity Temperature Refrigerant type

Pressure irregularity and overload often cause compressor defects that show themselves in the form of increased power consumption. Excessive evaporating and condensing pressures cause compressor motor overload which leads to increased power consumption. This problem also arises if the compressor is not sufficiently cooled, or if extreme overvoltage/ under voltage occurs.

4. NOISE

Fault obrservation	First analysis
Compressor	Pressure circuit Oil level Clearance: piston/cylinder Valve system
Fan	Deformed fan blades Bearing wear Base plate
System noise	Liquid noise (mainly in evaporator)
Installation	Piping Compressor, fan

To prevent noise transfer, pipe work should not be allowed to touch the compressor, the heat exchanger or the side walls. When installing a compressor, the fittings and grommet sleeves supplied must be used to avoid the rubber pads being compressed so much that they lose their noise-suppression properties.

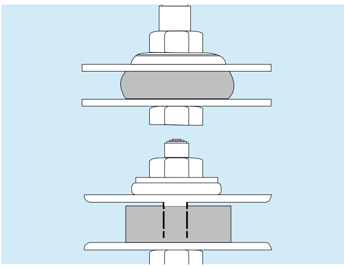


Figure A-3.17:

Fans are used mostly in commercial refrigeration systems. Noise will be generated if the fan blades become deformed. Worn bearings also produce a great deal of noise. Additionally, the fan unit must be firmly secured so that it does not move in relation to its mounting bracket. Normally, fans have a higher noise level than compressors.

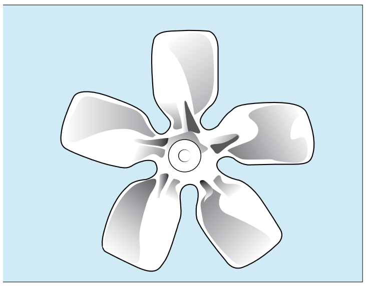


Figure A-3.18:

If the noise comes from the valves, the cause is usually incorrect sizing. Solenoid and check valves must never be sized to suit the pipe connections, but in accordance with the kv value. This ensures the min. pressure drop necessary to open the valve and keep it open without valve "chatter". Another phenomenon is "whistling" in thermostatic expansion valves. Here a check should be made to ensure that the size of the orifice corresponds to the system characteristics and that above all there is sufficient liquid sub cooling ahead of the expansion valve [approx. 5 K].

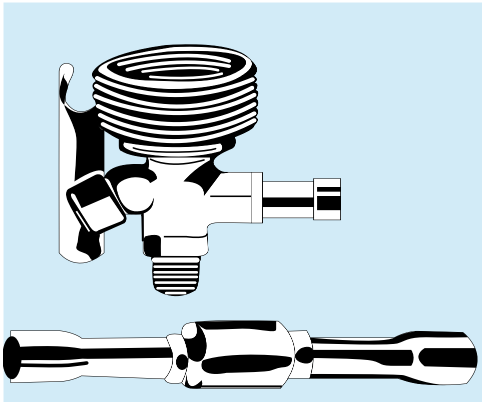


Figure A-3.19:

GENERAL CHECK

Compressors are equipped with a PTC starting device (fig. 1) or a relay and start capacitor (fig. 2). The motor protector is built into the windings.

In the event of a start failure, with a cold compressor, up to 15 minutes can elapse before the protector cuts out the compressor.

When the protector cuts out and the compressor is warm, it can take up to 1 hour before the protector cuts in the compressor again.

The compressor must not be started without the electrical equipment.

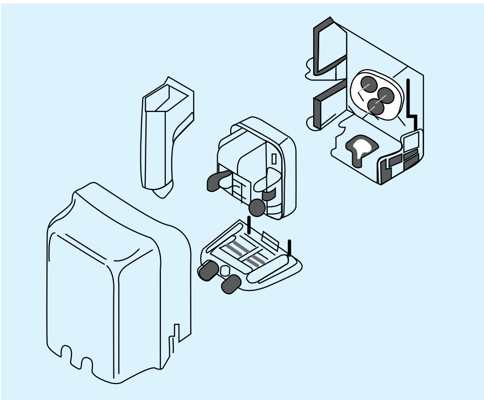


Figure A-3.20: PTC starting device

FAULT LOCATION

Before beginning systematic fault location, a good rule is to cut the supply voltage for at least 5 minutes. This ensures that the PTC starting device has cooled off and is ready for start.

A voltage drops or blackout within the first minutes of a pull down of the appliance with cold compressor, can lead to an interlocking situation.

A compressor with PTC cannot start at non equalized pressure and the PTC does not cool down so fast. It can take more than 1 hour until the appliance then operates normally again.

ELECTRICAL COMPRESSOR QUICK CHECK

To avoid unnecessary protector operation and consequent waiting time, it is important to carry out fault location in the sequence given below. Tests are made according to descriptions on following page.

- Remove electrical equipment.
- Check electrical connection between main and start pins of compressor terminal.
- Check electrical connection between main and common pins of Compressor terminal.
- Replace compressor, if above connection checks failed.
- Else, replace electrical equipment.

If the compressor still does not operate, most probably it is no electrical compressor failure. For more detailed fault location, see the tables.

CHECK MAIN AND START WINDING

Resistance between pins M (main) and S (start) on compressor terminals is measured with an ohm-, meter see figure.3.

Connection →	Mains and start windings normally ok →	Replace relay
No Connection →	Mains and start windings defective →	Replace compressor

At cold compressor (25°C) the values are 10 to 100 Ohm for 220-240 V compressors. For partial short circuit detection, exact values are needed from data sheets of the specific compressor.

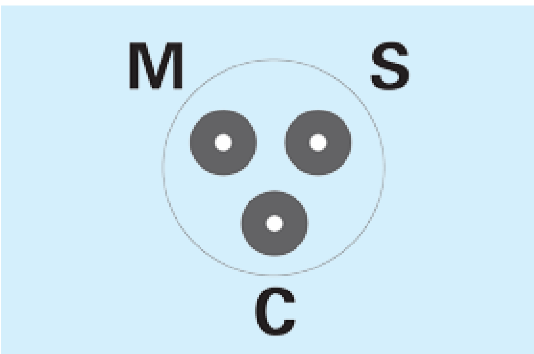
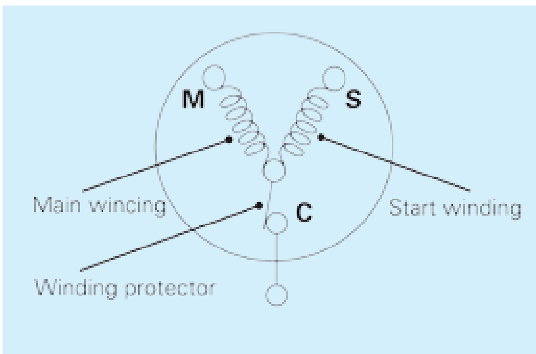


Figure A-3.21: Compressor terminals



Windings and protector

CHECK PROTECTOR

Resistance between pins M (main) and C (common) on compressor terminals is measured with an ohm-meter, see fig. 3 and 4.

Connection →	Protector ok →		
No Connection →	Compressor cold →	Protector defective →	Replace compressor
	Compressor hot	Protector could be ok, but cut out →	Wait for reset

CHECK RELAY

1. LMS Relay (Magnetic (solenoid) type relay.) ......

Remove relay from compressor.

Measure connection between connectors 10 and 12 (see fig. 5):

No Connection	Relay defective	Replace relay	

Measure connection between connectors 10 and 11: In normal vertical position (like mounted, solenoid upward):

CHECK PTC

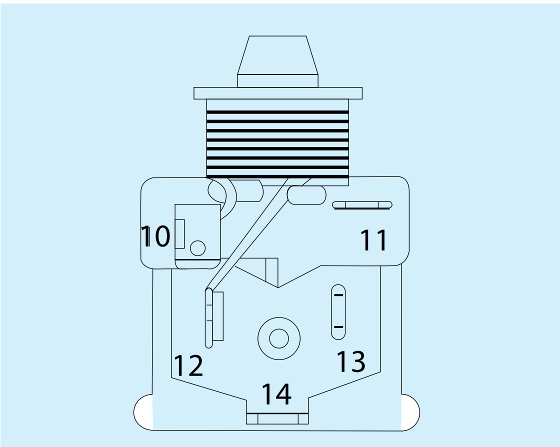


Figure A-3.22: Relay connections

2. Solid-state relay-electronic (P.T.C. type) relay...........

Carry out the tests to know the heating effects PTC material.

Remove PTC from compressor Shake by hand. Pin C can slightly rattle

Internal rattle noise (except pin C)	PTC defect	Replace PTC	

Measure resistance between pins M and S, see fig. 6.

Resistance value between 10 and 100 Ohm at room temperature for 220 V PTC.

Connection	PTC Working	OK	
NO Connection	PTC defect	Replace PTC	

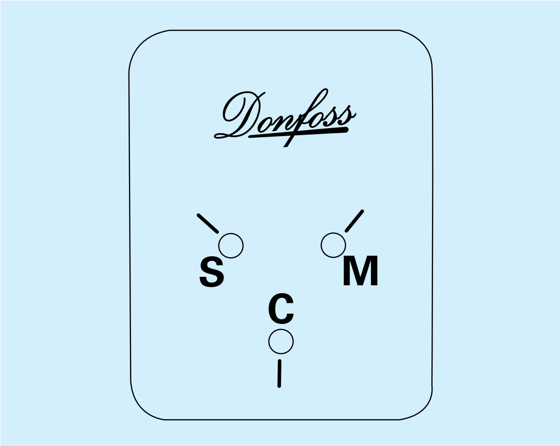


Figure A-3.23: PTC connections (backside)

Notes

REFRIGERATOR PROBLEM ANALYSIS AND SERVICE

PROBLEMS	REASONS	REMOVING METHODS
Compressor cannot be started	1. Fuse is broken 2. The contact of plug, socket and cable is not good. Cable broken 3. The voltage is too low, 10-15% less than rated voltage 4. The knob of temperature controller is at "rest" position 5. The temperature controller is out of order 6. Starting relay or thermal protection unit is out of order or broken 7. Wire broken of motor starting coil or operation coil 8. The compressor motor is burned or rotator and stator are blocked to dead 9. There is leakage of high pressure gas valve or the shaft is embraced to dead	1. Check if there is short circuit and solve it, if not, change capable fuse 2. Check and connect tightly, or change 3. Use till voltage rises to rated value or attach a stabilizer 4. Rotate the knob to wanted position for suitable temperature 5. Change the controller 6. Change starting relay or thermal protection unit 7. Measure using Rx1 position of avometer, if there is wire broken, change compressor 8. Change compressor 9. Change Compressor
Compressor starts too starts too frequent, operation time too long but temperature drop in refrigerator is too slow	1. The distance between temperatures sensing tube of temp. controller and evaporator are too big 2. The temperature controller is out of order 3. Vaccine Load in the refrigerator too much, door opens too frequent and open time too long 4. The environment temperature is too high, humidity too high, airflow is impeded 5. The frost layer at the evaporator is too thick 6. The refrigerant is insufficient or leakage 7. Compressor efficiency is reduced 8. The drying filter is blocked	1. Adjust and make it close to evaporator cover 2. Change the temperature controller 3. Reduce them 4. Out the refrigerator to suitable place and make air circulate well 5. Remove frost regularly 6. Check or supplement refrigerant 7. Change compressor 8. Change new drying filter
Compressor runs without stop, temperature in refrigerator is too low	1. The knob of temperature controller has been set to "over cooling" position 2. The contacting point of temperature controller is adhered 3. The temperature sensing probe of controller is not placed well, and causes maladjustment 4. Compressor efficiency reduced	1. Change the position to moderate 2. Repair or change 3. Adjust to suitable position, normally contact tightly with evaporator cover 4. Change Compressor

PROBLEMS	REASONS	REMOVING METHODS
Compressor buzzes and cannot be started, thermal protection unit jump repeatedly	1. Voltage is too low 2. Starting relay out of order 3. The starting coil of starting motor is broken 4. Compressor does not run	1. Supplement a stabilizer, adjust to rated value 2. Change starting relay 3. Change compressor 4. The shaft and piston in the compressor is blocked, please change
After short time of operation, overload protection unit cuts off	1. The voltage is too high 2. Over load protection unit is not good, it jumps earlier 3. Starter contacting point is adhered 4. There is short circuit in compressor 5. There is mechanical problem in the compressor 6. Temperature around compressor is too high	1. Supplement a stabilizer and adjust its value to rated 2. Change over load protection unit 3. Change starting relay 4. Change compressor 5. Change compressor 6. Increase heat radiation space
Too much noise when compressor runs	1. The floor is loose 2. The refrigerator body is not stable and in level 3. When compressor runs, friction between tubes and refrigerator body cause resonance 4. Compressor fixing screw is loose 5. The vibration absorption cushion for compressor fixing is too tight, or too loose or ageing 6. Compressor inside noise is too big or vibration absorption suspending spring is broken	1. Reinforce the floor 2. Make the refrigerator body stable 3. Move the tube a little away to avoid friction 4. Make the screw tight 5. Adjust the degree of tight or loose of vibration absorption cushion, or change cushion 6. Change compressor
There is no frost at evaporator	1. There is serious leakage of refrigerant 2. There is dirt blocked the capillary or system	1. Check leakage, make welding repair and fill refrigerant again 2. Clean the capillary or change filter
Frost at evaporator is not full	1. There is some leakage of refrigerant 2. There is dirt block, but not serious 3. Refrigeration quantity of compressor is reduced	1. Check leakage, make welding repair and fill refrigerant again 2. Clean the capillary and filter 3. Change compressor
Evaporator frosts too rapid, frost layer too thick or frozen to ice	1. Vaccines put into refrigerator contains water 2. Too much vaccines has been stored	1. Please let or make vaccines dry after cleaning, then store it. 2. Store only corrects quantity of vaccines.

PROBLEMS	REASONS	REMOVING METHODS
Electricity leakage of Refrigerator body, you will feel tingle when touching by hand	1. Refrigerator body has not been connected to the ground 2. The compressor terminal contacts body shell and causes short circuit 3. When the components of electrical system get wet insulation ability is dropped, electricity leaks.	1. Make the ground connection as stipulated 2. Change compressor. 3. Check carefully step by step, If insulation is seriously damaged, please change, remove wet parts and put them into drying box to make them dry.
Electricity leakage of fan	1. Environment temperature too high or insulation ability of insulator is dropped. 2. There is short circuit between fan coils or the fan coil is burned.	1. Change the fan. 2. Change the fan.
Fan too noisy	1. The blade of fan is blocked or fan supporter is loose. 2. The clearance of fan axle is too big.	1. Clear obstacles around the fan or tighten the supporter 2. Change the fan
The fan doesn't run	1. Check if any connection has come off 2. Check is the fan is burned	1. Change the fan. 2. Change the fan
Electricity leakage of temperature controller	1. The service time is too long 2. The environment is too dirty 3. Humidity is too high	1. Change temperature controller 2. Use brush to remove dust 3. Make the temperature dry and control the environment humidity
Temperature controller out of order	1. There is leakage of temperature sensing medium 2. Damage of cam of contacting point spring etc	1. Change temperature controller
The probe of temperature sensing tube doesn't contact evaporator well	It has not been mounted to position or changed during transportation	Mount it again

Connection	Relay defective	Replace relay	
No connection	ok		

In top- position (solenoid downward)

Connection	ok		
No connection	Relay defective	Replace relay	

Most common fault reasons, detectable before dis-mounting compressor.

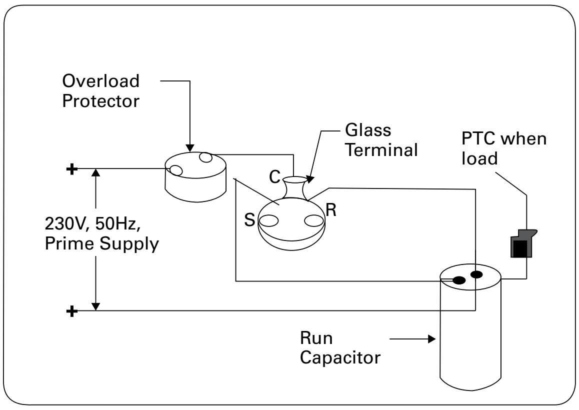
Fault observed	First analysis	Possible cause	Check	Activity (depends on result)
No/reduced cooling	Compressor does not run	Compressor gets no or bad power supply	Voltage at plug and fuse	
			Appliance energized	
			Thermostat function	
			Cables and connections in appliance	
			Voltage at compressor terminals	
		Defective relay	Relay function by shaking to hear if armature is working	Replace relay
		Defective start cap	Start capacitor function	Replace start capacitor
		PTC defective	PTC by shaking	Replace if noise appears
			resistance 10 to 100 Ohm between M and S pin	Replace PTC, if not 10 to 100 Ohm
		Compressor with PTC cannot start at pressure difference	Stop time long enough for pressure equalization	Adjust thermostat difference
		PTC defective	PTC resistance 10 to 100 Ohm between M and Spin	Replace PTC
		Relay defective	Relay function by shaking, to hear moving of armature	Replace relay and capacitor
		Compressor overloaded	Condenser pressure and ventilation	Ensure proper ventilation
			Ambience temperature too high according to type label of appliance	
		Defective motor windings	Check winding resistances	Replace compressor
		Defective protector	Check protector with ohm meter	Replace compressor
		Mechanically blocked compressor	Start with proper starting equipment, voltage and conditions, windings and protector OK	Replace compressor

Fault observed	First analysis	Possible cause	Check	Activity (depends on result)
	Compressor run 100%	No or low refrigerant charge	Recharge and search for leaks	Ensure leak free system and proper charge
		Too high ambient temperature	Ambient temperature according to type label of appliance	Replace drier
		Too high condensing temperature	Condenser and compressor ventilation	Ensure proper ventilation and wall distance
		Capillary partly blocked	Recharge and search for leaks, measure suction pressure. Capillary blocked, if pressure very low.	
		Valves choked or damaged	Recharge and search for leaks	Replace compressor, if still not cooling properly
	Compressor runs on/ off	Thermostat not OK	Thermostat type and function	Replace thermostat
		Wrong refrigerant charge	Recharge and search for leaks	Ensure leak free system and proper charge
		Ice block built up on evaporator	Check for ice on evaporator	Replace drier
			Thermostat function and settings	Defrost properly
			Internal no-frost fan function	Replace thermostat
		Compressor trips on motor protector	Compressor load, compressor and condenser ventilation	Ensure proper ventilation and wall distance
			Compressor voltage supply for minimum	Ensure proper power supply
			Compressor voltage supply for drop outs. Check thermostat and appliance cables for loose connections	Fix all connections
			Motor windings resistance for partly short circuit or earth connection	Replace compressor

Fault observed	First analysis	Possible cause	Check	Activity (depends on result)
Noise	Rattle or humming	Tube touching cabinet	Tube placing	Bend tube to their right place, carefully
		Compressor touching cabinet	Compressor mounting and rubber feet	Place rubber feet and mounting accessories correctly
		Broken internal suspension spring or discharge tube	Listen to compressor with screw-driver against compressor with edge and to your ear with grip	Replace compressor, if abnormal sounds
		Resonance	Find vibrating mounting parts	Place or fix correctly
		Fan noise	Vibration of fan or fan mounting	Fix fan and blade, replace, if defective
	Banging at start or stop of compressor	Compressor block hitting housing internally	Compressor overload by pressure	Clean condenser if dusty. Make sure, that ventilation gaps for air circulation are satisfactory
			Fan function	
			Refrigerant charge	Recharge, if too high
			Pressure equalization before start and number of on/off cycles	Adjust thermostat, if stop time less than 5 min
			Ambient temperature according to type label	Take applicant out of function, if ambient too hot
	Relay clicking frequently after start	Compressor over loaded	Ventilation to compressor and condenser. Check fan function	Clean condenser if dusty. Make sure, that ventilation gaps for air circulation are satisfactory

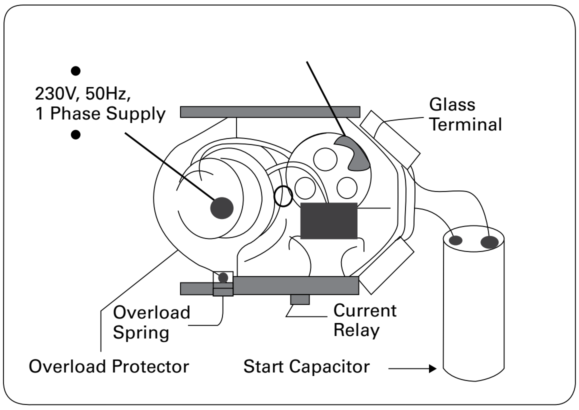
Fault observed	First analysis	Possible cause	Check	Activity (depends on result)
Fuses are blown by appliance	Short circuit in appliance	Defective cabling in appliance	All connecting cables and power supply cord for loose connections, short circuits	Fix connections properly
		Defective thermostat	Thermostat connections	Fix connections properly
		Ground connection	Resistance from line/ neutral to earth	
	Shorty circuit in compressor	Defective terminals	For burns on the terminals pins	Replace electrical accessories
		Short circuit between cables at terminals	Connectors and cables at compressor	Insulate cables and connectors
		Short circuit in compressor motor	Resistance values in windings Resistance between terminals and earth	Replace compressor, if short circuited
	Fuse blown at compressor start	Supply voltage too low	Supply voltage at compressor start is low than permissible	
		Fuse loaded by too many appliances	Total fuse load	Connect appliance to different fuse
		Resettable fuse too quick acting	Fuse load and type	If possible replace by slightly slower type
		Partly short circuit to earth	Resistance between terminals and earth	Replace compressor, if short circuited
	Starting capacitor exploded	Defective relay	Relay function by shaking, to hear moving of armature	Replace relay and capacitor
		Wrong relay type	Relay type	Replace relay and cap
		Extremely many starts and stops of compressor	Relay type	Replace relay and cap
			Thermostat defect or differences too small	Adjust or replace thermostat
	Starting relay cap blow off	Short circuit in compressor motor	Compressor motor resistances	Replace compressor

Wiring Diagrams



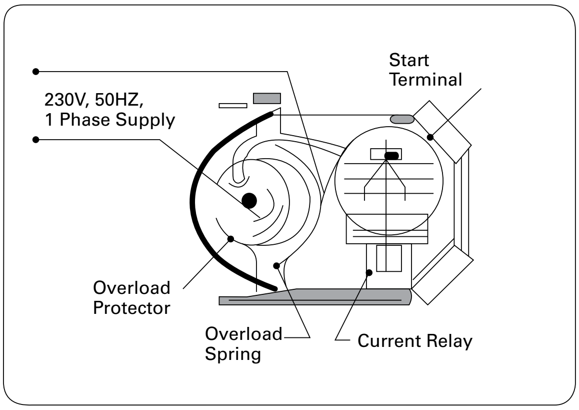
PERMANENT SPLIT CAPACITOR (PSC)

Figure A-3.24:



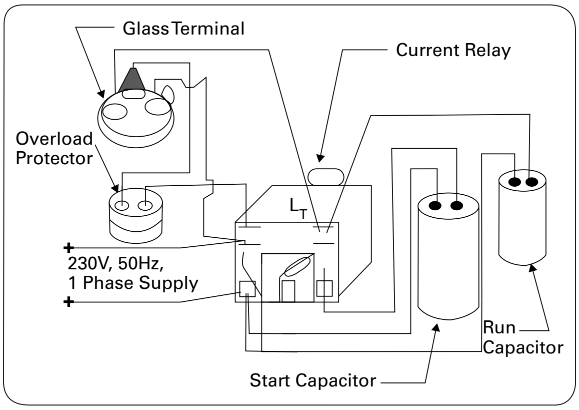
CAPACITOR START INDUCTION RUN (CSIR) WITH PLUG-IN START RELAY

Figure A-3.25:



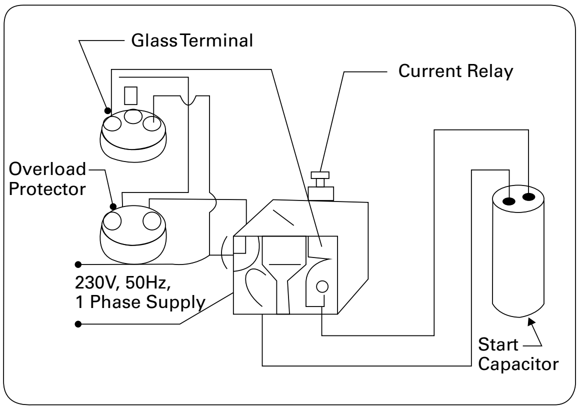
RESISTANCE START INDUCTION RUN (RSIR) WITH PLUG-IN START RELAY

Figure A-3.26:



CAPACITOR START CAPACITOR RUN (CSCR)

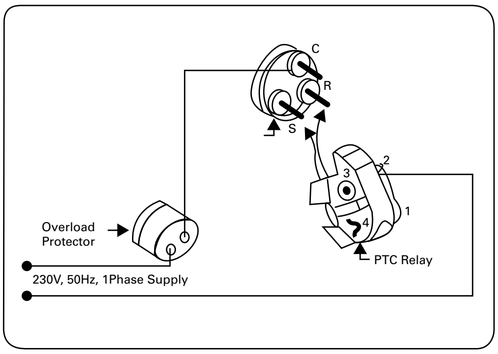
Figure A-3.27:



CAPACITOR START INDUCTION RUN (CSIR)

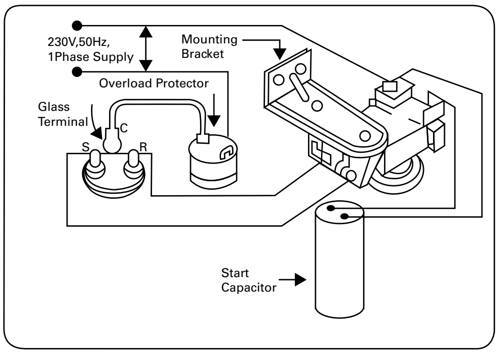
Figure A-3.28:

Wiring Diagrams



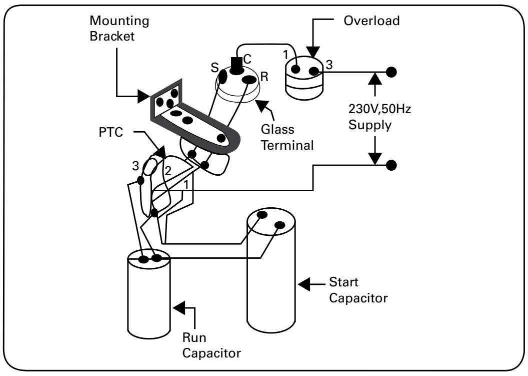
RESISTANCE START INDUCTION RUN (RSIR)
WITH PTC RESISTOR

Figure A-3.29:



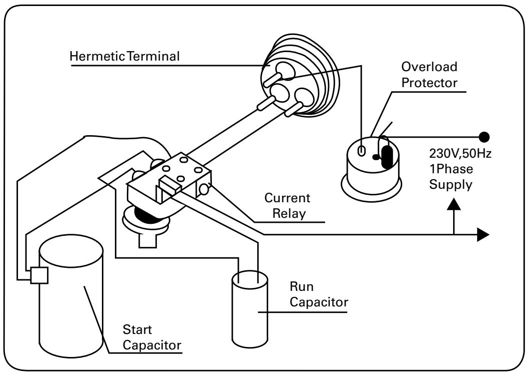
CAPACITOR START INDUCTION RUN (CSIR)
WITH CURRENT RELAY

Figure A-3.30:



CAPACITOR START CAPACITOR RUN (CSCR)
WITH PTC

Figure A-3.31:



CAPACITOR START CAPACITOR RUN WITH NTC

Figure A-3.32:

Useful Conversions

Pressure

1 micron	= 0.001 mm
0.1 mm Hg	= 100 microns
1 mmHg	= 1 Torr
1 Kg/cm2	= 14.223psig
1 bar	= 14.504 psig
1 bar	= 1.0197 kg/cm2

Temperature

F	= 1.8 x °C - 32

Volume

1 ft2	= 28.3 Liters
1 ft2	= 0.283 meter2
1 metre2	= 35.315 ft2
1 metre2	= 1000 Liters
1 cc	= 1 militer
1 oz	= 29.57 militer

Energy

Watt/hr x 0.8598 = kcal/hr	
Watt/hr x3.413	= Btu/hr
1 ton	= 12000 Btu/hr
1 kilojoule	= 0.95 Btu
kcal/hrx3.968	= Btu/hr

Area

1 ft2	= 0.929 metre2
1 metre2	= 10.758 ft2

Distance

1 inch	= 25.4 mm
1 ft	= 12 inch
1 meter	= 3.28 foot
1 meter	= 39.36 inch
1 yard	= 36 inch

Weight

1 ton	= 1000 kg
1 kg	= 2.2 pounds(lb)

Table: Conversions

Best Practices Guide

SYSTEM CLEANLINESS

- It is absolutely necessary that all impurities/ contamination like moisture, burr, cleaning agent and chemicals are removed from the system before operation in order to avoid compressor failures.
- All system components have to be de-hydrated and should be Nitrogen charged till they are taken for assembly. Use bright annealed refrigeration grade Copper tubes.
- Use tri-chloro Ethylene for flushing followed by Nitrogen to remove the trace of tri-chloro Ethylene.

BRAZING

Brazing is a process that joins two pieces of base metal when a melted metallic filler — the braze — flows across the joint and cools to form a solid bond. Similar to soldering, brazing creates an extremely strong joint, usually stronger than the base metal pieces themselves, without melting or deforming the components. Two different metals, or base metals such as silver and bronze, are perfect for brazing. This method can be used to make a bond that is invisible, is resilient in a wide range of temperatures and can withstand jolting and twisting motions.

- While brazing all the joints purge low pressure Nitrogen through the tube. This will avoid internal oxidation and formation of contamination. Use adequate amount of flux while brazing.
- The joints have to be free from oil and grease before brazing. For Copper to Copper joints use phosphorous Copper as brazing alloy and Copper –Silver for Copper to Steel joints. Oxy Acetylene is best suited for brazing.

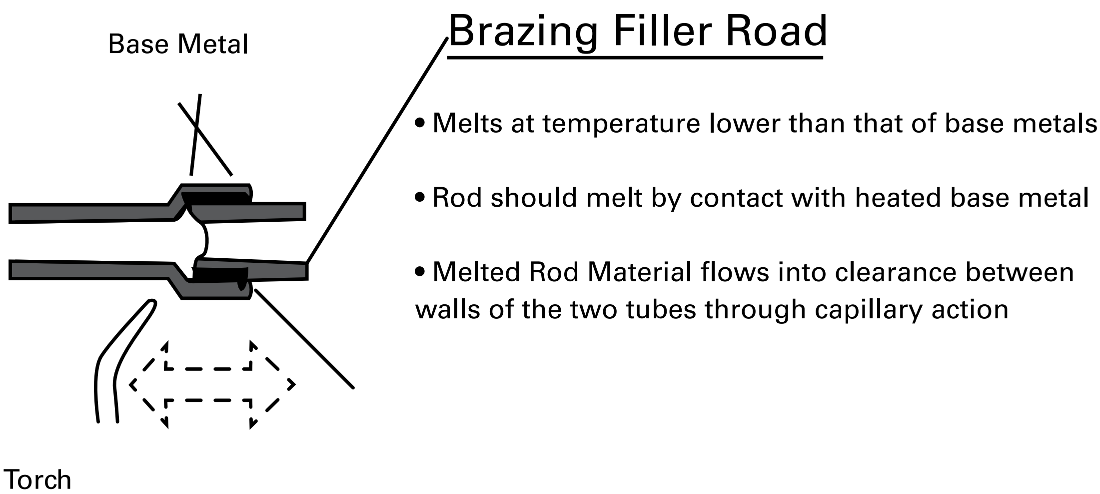


Figure A-3.33:

Shapes

The process of brazing is the same as soldering, although the metals and temperatures differ. Pipes, rods, flat metals or any other shape of metals can be brazed, as long as the pieces fit neatly against each other without large gaps. Brazing can handle more unusual configurations with linear joints, whereas most welding is done for spot welds on simpler shapes.

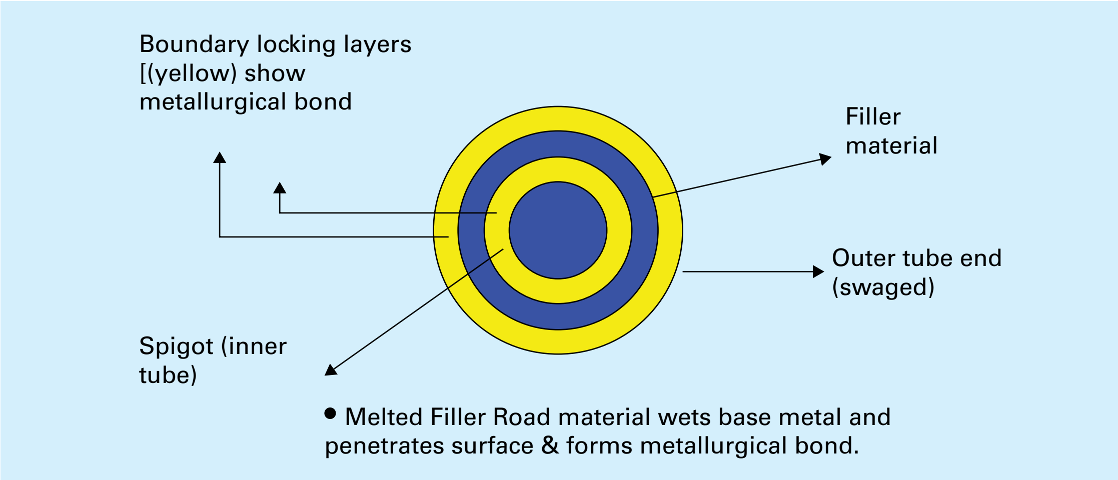


Figure A-3.34:

Preparing the Metals

Before brazing can begin, the entire area to be joined must be cleaned, or the melted braze mixture will clump instead of flow, making an inconsistent joint. The surface is then washed, and melted flux is applied. Flux removes oxides, prevents more oxidation during brazing and smooth's the surface so that braze flows evenly across the joint.

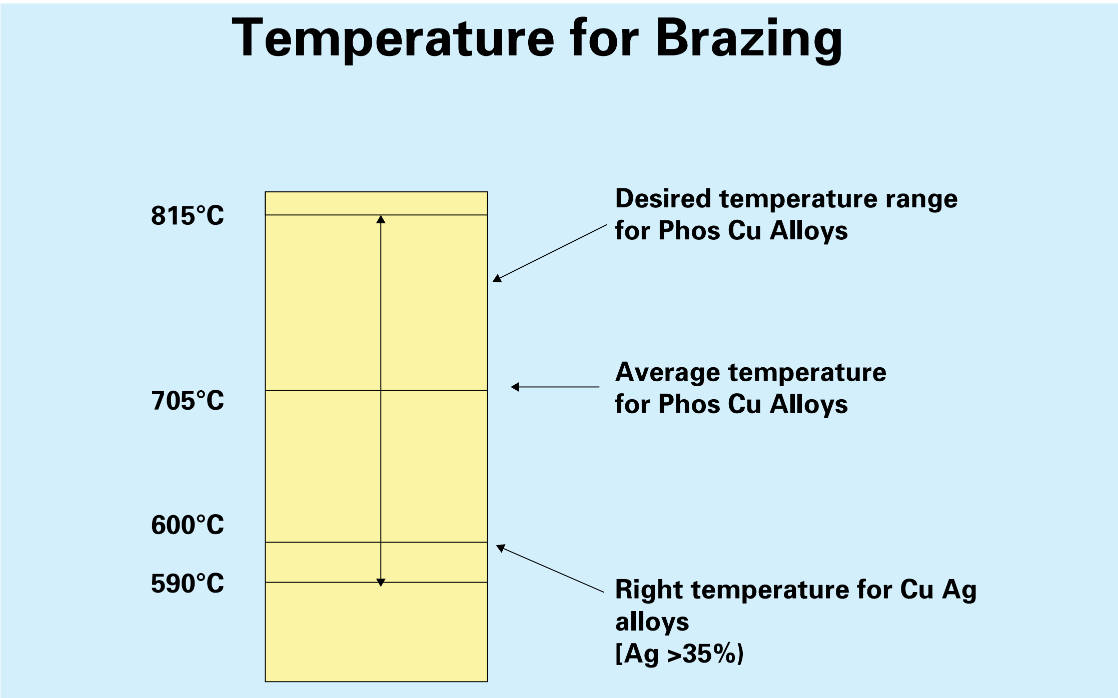


Figure A-3.35:

Torche

The torch for this process uses fuels such as acetylene and hydrogen to create an extremely high temperature, often between 800° and 2,000° Fahrenheit (between 430 & deg and 1,100° Celsius). The temperature must be low enough that the base metals don't melt but high enough to melt the braze. Torches have sensitively controls to reach the proper temperature, depending on the associated melting points.

Applying the Braze

To complete the joint, the braze is applied. Braze, like solder, comes in a stick, disc or wire, depending on the user's preference or the shape of the joint. After the base metals near the joint have been heated with the torch, the braze is applied to the hot pieces so that the braze melts and flows around the joint. This means that it penetrates the joint, working into every crevice. If the process was performed correctly, the bond is very strong after it cools and solidifies.

Advantages

This process offers many advantages over spot welding or soldering. For instance, a brazed joint is smooth and complete, creating an airtight and watertight bond for piping that can be easily plated so the seam disappears. It also conducts electricity like the base alloys. Only brazing can join dissimilar metals that have different melting points, such as bronze, steel, aluminum, wrought iron and copper.

LEAK TESTING

- The system has to be adequately pressurizes with Nitrogen.
- Conventional methods of checking the leaks are the best suited one & use of electronic leak detectors is another way to detect leaks.
- Do not pressurize the system with air and R134a

EVACUATION

Effective evacuation of the system ensures removal of moisture. For achieving desired vacuum level of 200 microns:

- Pull vacuum from both sides
- Use adequately sized two stage rotary vacuum pump having anti-suck back provision
- Use vacuum gauge to measure the vacuum level
- Never use a hermetic compressor for evacuation. It is not meant for evacuation and cannot achieve desired vacuum level

REFRIGERANT CHARGING

- Quality and quantity of refrigerant immensely influences the performance and reliability of any refrigeration system.
- Refrigerant should be procured from genuine source. Use digital weigh balance during refrigerant charging.

- Maintain a separate set of hoses, tubes, valves for different refrigerants. Do not use anti-chock as the damage the compressor
- Use pressure temperature chart of refrigerant for achieving optimum system performance.

COMPRESSOR MOUNTING

- Torque the nut adequately and ensure that the water/ bolt head rest on the sleeve and not on the rubber grommet.
- The suction and discharge piping should be properly looped to avoid vibrations and refrigerant leakages. The compressor should not be held rigidly by any means.

ELECTRICALS

- Always check the voltage across C & R terminals. Voltage at this point should fall within the prescribed operating voltage range. If the supply voltage conditions are poor. Use appropriately sized voltage stabilizer with low. High voltage cut-out and on-delay timer.
- Always use genuine electrical accessories.
- Earthing the appliance is necessary from the safety stand point.
- All electrical joints have to be firm and properly insulated.

ATTENDING THE FIELD COMPLAINTS

Verify the field complaint based on facts and observations made through use of proper tools and equipment. Rule out all the possibilities before replacing the compressor. Analyze the compressor independently for its proper functioning.

Removing of compressor from the system without understanding the root cause will lead to another compressor failure.

Notes

Notes

4

SECTION

JOB AIDS REQUIRED FOR OPERATIONS, MAINTENANCE& GENERAL UPKEEP\

The following chapter covers proper installation procedure/installation checks & preventive maintenance of equipment, to ensure a more durable quality operation. This describes the routine and periodic maintenance of equipment and what sort of records need to be maintained.

The care and servicing by personnel is necessary for the purpose of maintaining equipment in satisfactory operating condition by providing for systematic inspection, detection and correction of incipient failures either before they occur or before they develop into major defects.

Maintenance, including tests, measurements, adjustments, and parts replacement, performed specifically to prevent faults from occurring. It is designed to preserve and restore equipment reliability by carrying out regular preventive maintenance before they actually fail. Proper preventive maintenance plan benefits in terms of reducing the sickness rate of equipment & leads to a “more reliable cold chain system”

An itemized preventive maintenance plan covering routine preventive maintenance of equipment can help to sustain the proper functioning of respective items for long duration. This will useful for equipment and machinery to perform at its optimum. The incorporation & effective implementation of planned preventive maintenance reliable cold chain management system is very much needed. It should be ensured that the user/ refrigerator technician carries out the periodic preventive maintenance.

Ice Lined Refrigerator

UNPACKING and INSTALLATION

UNPACKING

Unpack the appliance and check that it has not been damaged. If you observe any damage, inform your supervisor.

Check the rating for correct voltage and frequency. Open and remove all internal packing material.

INSTALLATION

LOCATION:

The appliance must be placed in a well-ventilated room, not in direct sunlight and away from other heating sources.

Place the appliance on the floor, ensure that it is level. Distance between the wall and the back and side of the appliance must be minimum 50 mm, and the distance between the wall and the right side of the appliance must be minimum 100 mm. If installed in a room with other refrigerators/ freezers, ensure a minimum distance between the appliances of minimum 200 mm.

PREPARATION

Check that the plug fits your type of socket. If it does not fit, have a qualified electrician to fit the plug. This appliance must be earthed.

Connect the plug to the socket and switch on the appliance.

Check, by listening, that the compressor is running, if it does not run, contacts your supervisor.

TEMPERATURE ADJUSTMENT

This appliance is generally equipped with an adjustable mechanical type thermostat or has a electronic thermostat that controls the temperature in the vaccine compartment.

COOL DOWN OF THE APPLIANCE

Before the appliance is loaded with vaccines the ice-lining in the 4 sides must be frozen.

To ensure that the ice-lining in the 4 sides is frozen do the following:

1. Set the thermostat on maximum cold setting
2. Place a thermometer in the top basket.
3. Check the temperature in the top and bottom basket (must be between +2° and +8°C).

The temperature in the vaccine compartment must always be monitored on the thermometer and be within the range +2° to +8°C.

LOADING THE APPLIANCE STARTING PROCEDURE

Connect the mains lead to the power supply. The supply lamp must light to indicate that the appliance is operating. The thermostat is set on max cold position or adjusted to be between +2°C- 8°C. Keep this position for at least 24 hours.

The electronic thermostat makes a self-test, 20 seconds before the compressor start.

TEMPERATURE CONTROL

The temperature is checked with an accurate thermometer which is placed at the bottom of the top vaccine basket.

LOADING VACCINES

When the temperature in the vaccine compartment has stabilized, i.e. and the temperature is between +2° and +8°C and the compressor stops and starts, vaccines can be loaded.

The vaccines should be placed and arranged in the baskets.

ILR & DEEP FREEZER INSTALLATION CHECK LIST

Sr.No.	Items	Status
1	Instruction and service manual is received	Yes / No
2	Baskets are provided with the equipment	Yes / No
3	Fixed foam is provided with the equipment	Yes / No
4	Placed in the room having sufficient space	Yes / No
5	Cold Chain room is Spacious, well ventilated (cross-ventilation) dry air and no dust	Yes / No
6	No Direct Sun light on the equipment. Protected from rain, flooding.	Yes / No
7	Equipment placed on stand & leveled or Equipment placed on leveled ground and level adjusted by adjusting screws	Yes / No
8	Equipment placed at least 10 cms away from surrounding in all sides	Yes / No
9	The ambient temperature is less than 43 °C	Yes / No
10	Proper earthling is available in the power socket	Yes / No
11	The power socket is ISI marked and equipment placed near to it (No extension cord is used)	Yes / No
12	Plug points permanently fixed to power socket, labeled "DO NOT UNPLUG"	Yes / No
13	Cold Chain Equipment properly connected to a Voltage Stabilizer	Yes / No
14	Equipment run for 48 hrs before loading of vaccines	Yes / No
15	Inside temperature is (-) 15/(+)4 oC and stable before loading any icepacks/ vaccine	Yes / No
16	Equipment locked and Door (Lid) keys accessible to designated staff	Yes / No

Notes

ILR-DF- Preventive MaintenanceAspect

MAINTENANCE - PREPARATION

Preparation of tasks checklists for user

- **Routine care of the equipment by the user**
  Daily, Weekly, monthly
  Exterior, interior
- **Periodic technical maintenance by a technician**
  Preparation of travel plans by the mechanic
  Ensuring mechanic has adequate tool and training
  Vehicle maintenance schedule

MAINTENANCE BY USER

Daily Checkup

1. Outside equipment neat and clean
2. Equipment is level
3. Recording temperature twice daily

Weekly Checkup

1. Check rubber seal (Gasket) of the lid suing the paper test. the paper should not slide easily.
2. Monitor temperature
3. Defrost if necessary

Monthly Checkup

1. Defrost equipment
2. Adjust thermostat/temperature controller if necessary

DEFROSTING AND CLEANING

For the appliance to operate well and to save energy, it is important that it is cleaned and defrosted regularly.

When opening the appliance, moisture enters and settles on inner cold surfaces and forms a layer of frost or ice. The layer of ice makes the refrigerator less efficient and must be removed, “defrosted”. When ice formation is greater than 0.5 cm thick. Frost causes more electricity to be consumed to keep the equipment cold.

It is recommended that the appliance be defrosted every third month. Frost formation is a common occurrence in cold chain equipment. If it forms in an ILR which is to maintain $+2^0$C to $+8^0$C, it is a sign of malfunctioning of the equipment, either due to incorrect setting of the thermostat, or incorrect operation of the equipment. It needs technical intervention as the vaccines are at risk.

FROST FORMATION INCREASES IF:

- Equipment is opened too frequently
- Door not closing properly
- Door seal is defective
- High level of humidity

DEFROSTING

Before defrosting the vaccines must be moved to another working refrigerator or cold box with icepacks. Switch off the appliance and pull out the plug.

Steps to be followed for defrosting...

1. Before defrosting the vaccines must be moved to another working refrigerator or cold box with icepacks.
2. Switch off the appliance and pull out the plug.
3. Open the lids and leave open
4. Keep the lids open to allow the frost to melt completely.
5. Do not try to remove the ice with a knife or ice pack, since doing so can permanently damage the refrigerator.
6. Open the stopper at the bottom of the ILR/DF so that the water drains out.
7. Clean the inside of the refrigerator and door seal (specially the rubber) with a cloth.
8. Turn the refrigerator on again.
9. When the temperature in the main section falls to 8°C or lower, return the vaccines, diluents, and ice packs to their appropriate places.

CLEANING

Once the appliance is defrosted it must be cleaned.

Clean the inside of the appliance with a mixture of lukewarm water and a mild detergent.

Allow the cleaned parts to dry completely.

Clean the outside of the appliance with a mixture of lukewarm water and a mild detergent or soap.

Close the lid and follow the procedures in COOL DOWN OF THE APPLIANCE.

TROUBLE SHOOTING

If you observe that the appliance is not working at all or not working properly - please check the following before contacting your supervisor:

Is the power supply lamp on?

Is the plug correctly in the socket?

Has the fuse blown?

Is there a power failure?

Is the setting of the thermostat correct?

Is the appliance placed too close to a heat source?

If the compressor makes repeated attempts to start without result, then turn off the electricity supply for about 20 minutes and then try again.

Tasks Checklist Preventive maintenance - by User	
EXTERIOR	**INTERNAL**
1. Exterior is clean and dry. 2. Equipment is leveled and firmly placed on the floor 3. Placed at least 10 cm away from walls. 4. Away from direct sunlight 5. Room is well ventilated 6. Equipment opened only when necessary 7. Lid is closing correctly without any gap. 8. Lid seal is clean	1. Ice packs are in proper position 2. Ice packs filled with water to correct level. 3. There is no frost in ILR 4. Thickness of frost formation in DF is less than 5 mm. 5. Baskets are used and all vaccines are neatly placed with space for air circulation. 6. Freeze sensitive vaccines are not touching the cooling surface. 7. A good working thermometer is placed with the vaccine. 8. Temperature is recorded twice a day.
SEMI-TECHNICAL- BY USER	**TECHNICAL TASK TO BE CARRIED OUT BY A TRAINED MECHANIC**
1. All indicators are working correctly 2. Voltage stabilizer is working properly & equipment are connected through it. 3. Plug of the voltage stabilizer is correctly fitted. 4. Connection of equipment to voltage stabilizer is in order. 5. There is no abnormal noise.	1. Check temperature records – adjust thermostat if needed. 2. Correct all electrical wiring if case there is any damages, or loosening. 3. Test the input and output voltage of the stabilizer. 4. Compressor mounting bolts are tight. 5. Ensure there is no abnormal noise.

Table : Preventive maintenance

INSPECTION REPORT OF COLD CHAIN EQUIPMENT

State:... District:.. Date:......../......../........

Cold Chain Facility:...

Level: State/Regional/Divisional/ District/PHC..

Equipment...

Make..Model..Equipment Serial No...................................

(PLEASE FOR = OK, X = NOT OK AND X = REPAIRED)

A. Condition of:

1. Building wiring :--
2. Electric wall socket :--
3. Three core cable :--
4. Terminal plug (TP) of Cold Chain Equipment :--
5. Voltage stabilizer :--
6. Terminal plug (TP) of voltage stabilizer :--
7. Wire (terminal plug to voltage stabilizer) :--
8. Earthing :--
9. Connections of terminal plug to earth wire :--
10. Connections of compressor wiring :--
11. Wire between voltage stabilizer and terminal plug :--

B. Please State:

12. Minimum distance between two ice packs :--
13. Minimum distance between two vaccine packs (boxes) :-------------------------------- cms.
14. Maximum thickness (approx) of ice formation (Frost) :-------------------------------- cms.
15. Input voltage of Grid electricity :-------------------------- voltage
16. Output voltage-for voltage stabilizer :-------------------------- voltage
17. Minimum distance between wall and CCE :------------------------------ cms.

C. Please answer as 'Yes', 'No' and No/ Yes for made OK. Whether-

18. Cold Chain equipment is connected to Voltage Stabilizer? :--
19. Quick start mechanism functions property? :--
20. MCB (miniature circuit breaker) functions properly? :--
21. Cold Chain equipment properly placed? :--
22. Sufficient ventilation is available? :--

23. Sunlight is falling on cold chain equipment? :--
24. Any heat source nearby cold chain equipment? :--
25. Cold Chain equipment is on level ground? :--
26. Compressor bolts are tightened? :--
27. Result of sprit level test is O.K.? :--
28. Elect. Connections of compressor are fully tight? :--
29. Condition of icepacks of CCE is O.K.? :--
30. Indicator lights of CCE are glowing? :--
31. Outer panels are warm? :--
32. Top lid properly fitted? :--
33. Cold chain equipment is locked? :--
34. Temperature chart maintained? :--
35. Thermometer is in the basket? :--

D. Remarks:

Signature.. Signature.. Signature..

Name of A.N.M.............................. Name of Technician....................... Name of MO-in-charge..................

This following format shows the equipment history sheet. We have to ensure that this system must be used while maintaining the equipment.

Doing this we can prepare all plans to maintain our equipment working round the clock. Preventive maintenance activities include partial or complete overhauls at specified periods.

In addition, workers can record equipment deterioration so they know to replace or repair worn parts before they cause system failure.

Notes

MACHINERY DATA HISTORY SHEET

State:... District:... Date:......../......../........

Cold Chain Facility:...

Level: State/Regional/Divisional/ District/PHC..

Name of Supervisor:..

Designation:_...

Type of equipment (ILR/DF/Combo/Solar Refrigerator)...

Make... Model... Equipment serial No...

Sr. No.	Gross/ Net Capacity	CFC/ CFC Free	Date of Receipt /IV No.	Date of Installation	Stabilizer (Independent attached- Y/N)	If stabilizer not attached (NA/UR/ BR)	CCE Operational Status W/ NW/UR/BR/ Cond	No. of times equipment repaired (major – since last one year)	Total Expenditure incurred for repairs during lifecycle.	Details have been entered in NCCMIS (Yes/No)

Acronyms in the format are as below.

CCE =Cold Chain Equipment.

W= Working,

NA= Not available

NW= Not Working,

UR = Under Repairs,

BR=Beyond repairs,

Cond= Condemned

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RECORD OF BREAKDOWN EQUIPMENT

Below given format is to keep record of breakdown equipment.

If emergency repairs are a frequent occurrence, this is an indication that the routine maintenance and overhaul regime is not working.

RECORD OF BREAKDOWN EQUIPMENT

State:... District:.. Date:......../......../........

Cold Chain Facility:...

Level: State/Regional/Divisional/ District/PHC..

Name of Supervisor:...

Designation:_..

Type of equipment (ILR/DF/Combo/Solar Refrigerator)..

Make.. Model.. Equipment serial No..

Sr. No.	Date since not working	Date of reporting	Date equipment was attended	Date equipment became functional	Reason of failure	Spare parts used / Expenditure incurred if any	Operational status W/ NW/UR/BR/ Cond	Details have been entered in NCCMIS (YES/ NO)	Remarks if any

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INSPECTION REPORT OF OUT-OF-ORDER EQUIPMENT

1. Name Cold Chain Facility:..
2. Level: State/Regional/Divisional/ District/PHC...
3. Type of equipment (ILR / Deep Freezer/Solar Refrigerator):...
4. Make.. Model...
5. Equipment Serial No: (8 digit No.):...
6. Not working since (date) : 00/00/0000..

Defect summary:

» Equipment gets power but not working
» Equipment working but no cooling
» Equipment working but less cooling
» Thermostat/Temperature controller is faulty
» Voltage stabilizer not working
» Starting device/capacitor/thermostat faulty
» Compressor faulty
» Abnormal noise
» Others

If equipment is Solar Battery Powered additional checks are

» Battery discharged
» No voltage from Solar panel
» No charging from charge controller
» Dust on condenser
» Solar panel dirty or shaded
» Freezer section needs defrosting

Both compartments too warm

» User error (too many ice packs)
» Bad weather
» Fan not working
» Thermostat fault
» Wiring fault
» Charge controller fault

One compartment too warm

» Gas leak
» Fuse blown
» Compressor fault
» Compressor controller fault

Detail of the defects observed from checking / testing and repairs done :

....

....

Signature of Technician :... Date :..

SERVICE REPORT FOR THE EQUIPMENT REPAIRED/ SERVICED

1. Name Cold Chain Facility:..
2. Level: State/Regional/Divisional/ District/PHC...
3. Type of equipment (ILR / Deep Freezer/Solar Refrigerator):...
4. Make... Model...
5. Equipment Serial No: (8 digit No.):...
6. Not working since (date) : 00/00/0000..

Nature of Repairs/servicing carried out:

- » Loose connections found & rectified.
- » Mains chord replacement
- » Minor repairs in voltage stabilizer (Quick start/MCB reset)
- » Gasket not fitting /door hinge adjustment
- » Control panel rewiring
- » Setting of temperature controller/thermostat
- » Abnormal noise found & rectified
- » Fan motor oiling
- » Tightening of compressor bolts
- » Replacement of spares. Starting devices/Thermostat/Fan motors/capacitors
- » Compressor replacement/Gas charging
- » Others

If equipment is Solar Battery Powered additional corrective measures are

- » Battery terminal cleaning/Charge controller connections tightening
- » Solar panel wire connections/output voltage checks & rectified
- » Replaced battery/charge controller/temperature controller/solar panel

Detail of the defects observed from checking / testing and repairs done :

....

....

Signature of Technician :... Date :...

INSPECTION REPORT OF CONDEMNED EQUIPMENT

1. Name Cold Chain Facility:..
2. Level: State/Regional/Divisional/ District/PHC...
3. Type of equipment (ILR / Deep Freezer/Solar Refrigerator):...
4. Make.. Model...
5. Equipment Serial No: (8 digit No.):...
6. Not working since (date) : 00/00/0000...

Defect summary:

- Body Rusted
- Internal Leakage
- Refrigerant is not available as equipment is CFC based
- Equipment Model & its Spares have became obsolete
- Expenditure to be incurred is more than 50% of cost of equipment
- Equipment's expected/useful life in over. (10 Years)
- Failure is repeated /poor performance.

If equipment is Solar additional reasons to add are

- Battery defective & need replacement
- Solar panel defective & needs replacement
- Charge controller defective & needs replacement

Recommended for condemnation: YES/NO.

....

....

Detail of the defects observed from checking / testing and repairs done :

....

....

Signature of Technician :... Date :...

Notes

....

....

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....

Please find below the suggested alternatives to be followed in emergency situations.

Type of failure	Equipment	Primary Health Centre	Districts
Power failure of long duration (more than 6-8 hours)	ILR Freezer	Observe temperature of vaccines. If it reaches 8°C, transfer and store them in cold boxes with frozen ice-packs from the freezer place thermometer inside the cold box. No action required as vaccines are not preserved in freezer.	Similar to PHC if OPV is preserved in freezer, transfer them to cold box and preserve with frozen icepacks or commercial ice in polythene bags. Place thermometer inside the cold box.
Equipment Breakdown (Select suitable alternative indicated	ILR	Store vaccines in cold boxes with frozen icepacks. Transfer to domestic refrigerator if available in the vicinity. Transfer to any nearby PHC or other department's vaccine storage facility if available.	Store in cold box with frozen icepacks Transfer to other ILR or Refrigerator available Transfer to any other storage facility available
Equipment Breakdown (Select suitable alternative indicated)	Freezer Voltage Stabilizer	Freeze icepacks in domestic refrigerator/s or in commercial ice factory, if available. Collect required quantity of frozen icepacks from nearby PHC in cold boxes Distribution Disconnect the stabilizer and obtain replacement immediately from District/Regional HQ and reconnect.	Store vaccine in ILRs or refrigerator available Dispatch vaccines for PHC using commercial ice. Ask recipient of vaccine to bring frozen icepacks while coming for collection. Replace from float assemblies immediately from District/Regional HQ stock

Notes

Task sheet

Task sheet No.1: Copper Pipe work

Tools required: Pipe cotter, tape measure, and crimping tool, bending spring, pipe reamer

Materials required: One coil of 1/4 inch copper pipe.

ACTION:

1. Cut 35cm of pipe from the coil and re-seal the end of the coil by crimping.
2. Bend pipe to form the shape.
3. Give your pipe to your instructor to check.

Task sheet No. 2: Pipe flaring

Tools required: : flaring tool, tape measure, hand vice, adjustable Wrench, pipe cutter, crimping tool, pipe reamer,

Materials required: : one coil of Y4 inch copper pipe, pipe section, Prepared in Task No. 1, union connectors (2), flare Nuts (4), bonnets (2), Oil.

ACTION:

1. Remove 15cm of pipe from coil and re-seal.
2. Form a flare at each and of the pipe.
3. When you can make a good flare, start work on the pipe section prepared in Task No. 1.
4. Place flare nuts on pipe.
5. Flare ends of pipe.
6. Fit union connector to each flare nut and tighten.
7. Fit flare nut and bonnet to both ends of pipe to form a sealed system.
8. Keep this piece of pipe for use in later tasks.

Notes

Task Sheet No. 3: Pipe swaging

Tools required: Pipe cutter, tape measure, crimping tool, swaging Tool, pipe reamer,

Materials required: Coil of 1/4 inch copper pipe, oil.

ACTION:

1. Remove 60 cm of pipe from coil and reseal.
2. Cut pipe into 4 equal lengths of 15cm.
3. Swage out the end of one piece of pipe until another piece fits inside.
4. Repeat Action 3 until all 4 pieces of pipe have been properly swaged.
5. Examine the swaged ends. If any are cracked or badly formed, cut them off and re-swage.

Task sheet No. 4: Pipe brazing (with brazing torch)

Tools required: brazing torch with cylinder (with adapter and hose), hand vice, goggles.

Materials required: copper pipe sections (prepared in Task No.3), steel wool, brazing rods, flux, spirit, soap solution,

ACTION:

1. Read the manufacturer's instructions for the brazing torch, make sure that you Understand how to;

   (a) Connect the torch; (Check for gas leaks at all)

   (b) Control the gas flow
2. Clean all surfaces to be brazed with steel wool.
3. Hold one pipe section securely,
4. Apply a small amount of flux (If required) to the surfaces to be joined. Insert the other pipe section into the swaged end.
5. Heat the joint with the brazing torch.
6. Dip the end of a brazing rod into the flux. Touch the joint with the end of the brazing rod. When the flux starts to melt, let it flow into the joint.
7. Braze the other pipe sections together in the same way.
8. Practice brazing until you are able to make a joint that you think is leak – right (it will be tested in a later task).

Task sheet No.5: Examination of brazed joints

Tools required: hacksaw, hand vice, pipe cutter, dentist mirror

Materials required: 3/8 inch copper brazed lengths prepared in Tasks 3 or 4.

ACTION:

1. Cut out one brazed joint with the pipe cutter, Cut about 1/2 inch on either side of the joint
2. Hold the brazed joint with the hand vice.
3. Cut right through the length of the joint (the blade of the hacksaw must be in line with the pipe).
4. Examine the inside of the brazed joint. Brazing metal must, go to the bottom of the swage to give a strong joint.
5. Cut and examine all brazed joints in the pipe section. Use dentist mirror

Task sheet No.6: Refrigerant handling

Tools required: refrigerant services cylinder (cold), charging hose, adjustable wrench, goggles and gloves.

Materials required: Supply cylinder of refrigerant R134a.

ACTION:

1. Before starting read refrigerant R134a safety precautions, make sure that you understand these instructions.
2. If there is anything you do not understand, ask your instructor.
3. Transfer approximately 1 kg of refrigerant R134a from the supply cylinder into the service cylinder/ destillator (Charging Unit) until the service cylinder is about half full (1kg).
4. Ensure the cap nuts tightened.
5. Check for leak.

   Note: Your cylinder has been evacuated for you. When you re-fill the cylinder you must do the evacuation yourself.

Task sheet No. 7: Removing the filter drier.

Tools required: Brazing torch, file.

Materials required: none.

ACTION:

1. Remove the filter drier from the system.
2. Take care not to damage the filter drier. It is good and can be used in a later task.
3. Put some insulating tape over the open ends of the copper pipe from where the drier has been removed, as this will stop dirt and moisture getting inside.
4. Keep this filter drier in the toolbox for piercing practice.

Task sheet No. 8; Fitting a replacement filter drier

Tools Required: Brazing torch, pipe reamer.

Materials required: brazing rods, flux, and replacement filter drier.

ACTION:

1. Fit the replacement filter drier to the system.
2. Do not flush the system. (This will be done in the later task)

Task sheet No.9: Testing for refrigerant leaks

Tools required: connecting hose, leak detector, cylinder and refrigerant R134a, adjustable wrench

Materials required: soap solution.

ACTION:

1. Check for gas leaks at all connections with soap solution.
2. Check at cap nut on the refrigerant R134a cylinder connection.
3. Test for leaks at the refrigerant R134a cylinder outlet/inlet of destillator.
4. Ensure the cap nut is tightened and fully close the valve on the service cylinder.
5. Test the outlet for leaks.
6. On equipment service, check the brazed joints for leakages.

Task sheet No.10: Charging the system

Tools Required: none.

Materials required: Charging station for refrigerant R134a

ACTION:

1. Add refrigerant R134 slowly to the system (Using Charging station)
2. During charging measure the following:
   a. Suction and delivery pressures
   b. Compressor running amps
3. Note that during charging, the pressures and amps increase.
4. Make sure that the correctly charged conditions are obtained

Task Sheet No. 11: Understand how the cooling system works.

Tools required: None, **Material required:** None

ACTION:

1. Find the following parts on your ILR/DF and point them cut to your instructor.
2. Compressor Terminal box, Power supply cable, Thermostat
3. Plug in the ILR/DF and set it running.
4. Find, and point out to your instructor:

Delivery pipe – is it hot or cool?

Condenser is it hot or cool at the top and bottom?

Secondary condenser oil cooling, pipes, filter drier – hot or cool?

Capillary tube/Evaporator/Inside cabinet, suction pipe - hot or cool?

Process tube

Answer the questions below.

1. Which of the three pipes on the compressor is the smallest?
2. Which two pipes are at the same level on the compressor?
3. Is the refrigerant R134a in the filter drier a liquid or a gas?
4. Does the compressor pump a liquid or a gas?

Task Sheet No. 12: Measuring refrigerator compressor running amp

Tools required: ammeter with a range from 0 to 3 amps (minimum).

Materials required: none.

ACTION:

1. Remove the ILR/DF plug from the electric supply socket.
2. Remove the cover of the compressor terminal box.
3. Connect the Tong tester to the electrical supply connections.
4. Caution: all of the electric connections in the terminal box are now "live". Work carefully...
5. After the compressor has been running for 5 minutes, measure and write down the amps being used
6. Remove the ILR/DF plug from its socket, Disconnect the ammeter/Tong tester.
7. Replace the cover of the compressor terminal box tightly.

Task sheet No. 13: Testing a magnetic (solenoid) type relay.

Tools required: powered test lamp, electrician's screwdriver.

Materials required: replacement compressor fitted with a magnetic (solenoid) type relay.

ACTION:

1. Remove the relay from the compressor motor winding pins.
2. Carry out the continuity tests
3. Notify your instructor if the result of these tests is not satisfactory.
4. After completion. Replace the relay, Re-fit the electrical connections. Replace the compressor terminal box cover. Make sure that the compressor starts and runs normally.

Task sheet No. 14: -Testing the compressor motor protector.

Tools required: powered test lamp, electrician's screwdriver.

Materials required: replacement compressor fitted with a magnetic (solenoid) type relay.

ACTION:

1. Remove the relay from the compressor motor winding pins.
2. Remove the protector from the relay
3. Test the protector for the continuity.
4. Notify your instructor if the test lamp does not light when connected to the terminals of the protector.
5. On completion. Re-fit the protector to the relay, the relay to the compressor and all electrical connections.
6. Replace the compressor terminal box cover, make sure that the compressor starts and runs normally.

Task sheet No. 15: Testing a P.T.C. type starting device

Tools required: Simple test lamp with 100-watt bulb, electrician's screwdriver. **Materials required:** P.T.C. type starting device,

ACTION:

1. Carry out the tests to know the heating effects PTC material.
2. Notify your instructor if the result of these tests is not satisfactory.

Task sheet No. 16: Identify the compressor terminals.

Tools required: ohmmeter, screwdriver.

Materials required: None.

ACTION:

1. Identify the start, run and common terminal on your compressor.
2. Draw a diagram below with the terminals and the resistances.
3. On completion, re-fit the starting device and all electrical connections, replace the terminal box cover, check that the compressor starts and runs normally.

Task sheet No. 17: Testing the motor capacitor.

Tools required: ohmmeter, electrician's screwdriver, powered test Lamp, simple test lamp (not powered).

Materials required: motor capacitor (any capacity).

ACTION.

1. Examine the outside of the capacitor, look for the defects
2. Carry out the ohmmeter test.
    a. Put the plug of the powered test lamp into a socket.
    b. Put the probes of the powered test lamp onto the capacitor connections.
    c. Make sure that the lamp lights.
    d. After about 5 seconds, remove the probes and pull out the test lamp plug.

Task sheet No. 18: Testing the thermostat.

Tools required: electrician's screwdriver.

Materials required: Insulating tape.

ACTION:

1. Remove the thermostat from its fixing inside the ILR/DF.
2. Disconnect and join together the wires of the thermostat.
3. Plug in the ILR/DF, observe that the compressor runs continuously.
4. Check the continuity for Thermostat.
5. Unplug the ILR/DF, Re-connect and re-fix the thermostat.
6. Plug in the ILR/DF; Make quite sure that the compressor cuts out and cut s in properly.
7. Set the thermostat to maintain correct storage temperature for vaccine.

Notes

Task No. 19: Repairing a magnetic (solenoid) type relay

Tools required: hand drill and drill bit, hand vice, knife, powered test lamp, electrician's screwdriver.

Materials required: The compressor of which has a magnetic (solenoid) type relay, spare magnetic (solenoid) type relay, small nut and bolt.

ACTION:

1. Using the spare relay, remove the contact assembly from the body of the relay
2. Test the solenoid winding.
3. Test the start winding
4. Inspect and test the contacts. Note: the relay is new and the contacts must not be cleaned.
5. Inspect and test the solenoid plunger. Note: do not oil the plunger. If it does not move easily, notify your instructor.
6. On completion. Re-assemble the relay
7. Fit the spare relay to the compressor. Make sure the spare relay works properly.
8. Remove the spare relay and re-fit the original relay to the compressor.
9. Make sure the cover of the terminal box is re-fitted tightly.

Diagnosis test

1. Observe Equipment is running & note down the performance reading. Checks for not working equipment....
2. Write on a separate sheet of paper the following.
   a. What you consider the fault is.
   b. What symptoms indicate the fault?
   c. What tests you has carried out to confirm the fault.
3. Hand over the sheet to your instructor.
4. If he agrees with your result, repair the fault and get the ILR/DF cooling properly.

Notes

Notes

GENERAL SAFETY TIPS & GUIDELINES

GENERAL SAFETY TIPS

- Safety glasses with side shields must be worn at all times.
- Do not wear loose clothing, loose neckwear or exposed jewelry while operating machinery.
- Pull back and secure long hair. (Use hair net or ball cap)
- Do not wear thin fabric shoes, sandals, open-toed shoes, and high-heeled shoes.
- A machinist’s apron tied in a quick release manner should be worn.
- Always keep hands and other body parts a safe distance away from moving machine parts, work pieces, and cutters.
- Use hand tools for their designed purposes only.
- Report defective machinery, equipment or hand tools to supervisor.

SAFETY GUIDELINES: Fire Extinguisher

- When used properly, a portable fire extinguisher can save lives and property by putting out a small fire or controlling it until the fire department arrives. Portable extinguishers, intended for the home, are not designed to fight large or spreading fires. However, even against small fires, they are useful only under certain conditions:
- The operator must know how to use the extinguisher. There is no time to read directions during an emergency.
- The extinguisher must be within easy reach and in working order, fully charged.
- Some models are unsuitable for use on grease or electrical fires.

Select Your Extinguisher

Choose your extinguisher carefully. A fire extinguisher should bear the seal of an independent testing laboratory. It should also be labeled as to the type of fire it is intended to extinguish.

The extinguisher must be large enough to put out the fire. Most portable extinguishers discharge completely in as few as eight seconds.

Classes of fires: There are three basic classes of fires. All fire extinguishers are labeled with standard symbols for the classes of fires they can put out. A red slash through any of the symbols tells you the extinguisher cannot be used on that class fire. A missing symbol tells you only that the extinguisher has not been tested for use on a given class of fire.

Class A: Ordinary combustibles such as wood, cloth, paper, rubber, and many plastics.

Class B: Flammable liquids such as gasoline, oil, grease, tar, oil-based paint, lacquer, and flammable gas.

Class C: Energized electrical equipment including wiring, fuse boxes, circuit breakers, machinery, and appliances.

JOB RESPONSIBILITIES OF COLD CHAIN TECHNICIAN

He/she is responsible

1. To maintain the Cold Chain equipment available in the district irrespective of level of store through timely response, repair and planned preventive maintenance.
2. To undertake major repairs like compressor replacement, gas filing at district HQ & minor repair like replacement of spare parts, electrical faults at the spot (Cold Chain point).
3. To maintain a Sickness rate of cold chain equipment at a level less than 2% at any given point of time in a particular district.
4. To monitor the Breakdown Time & Response Time of the Cold Chain equipment at district level
5. To maintain Response Time at 48 hours in plain and 72 hours in hilly terrain.
6. To maintain the Breakdown Time for major repair at less than 15 days in plain and 21 days in hilly terrain.
7. For indenting of spare parts as per actual requirement in advance from the higher stores.
8. To develop a plan for undertaking preventive maintenance of cold chain equipment like WIC, WIF, ILR, DF, stabilizer, DG set, Cold Box, Vaccine Carrier using the specified checklists in advance & submitted to the authority. This includes supportive supervision of Cold Chain Handlers also. This may involve certain days of tour in a month depending on the no. of cold chain points and equipment.

9. To maintain a District level inventory of all types of Cold Chain equipment and Spare parts and updatingthe same annually.

10. To ensure proper record keeping of Cold Chain equipment, updating the status of Cold Chain equipment in NCCMIS regularlywith the help of Immunization Computer Assistant.

11. For condemnation of beyond repair equipment and disposal /auctioning of condemned equipment at district level.

12. To review of the status of Cold chain equipment at district level in monthly meeting and ensure follow up action.

13. For supporting the District Immunization Officer in Cold Chain planning, monitoring, replacement of equipment, capacity building and training of Cold Chain Handlers.

14. For contingency planning for emergency needs,breakdown of equipment, alternate storage arrangement and managing logistics.

15. For maintaining appropriate electrical connections at all cold chain points.

16. To ensure all ILRs & DFs are connected with independent functional Voltage Stabilizers.

17. For recording& reporting, which includes maintaining Temperature records (as per UIP guidelines) for all working electrical cold chain equipment at all levels, Service report, work register, delivery challan and spare parts details etc.

18. To send monthly report to the Directorate in time regularly for better cold chain management.

19. To undertake any other program related activities as assigned by the supervising authority.

Source of information

1. Notes... Trouble shooting - Fault location overview (Danfoss compressors)

2. Emerson-catalogue-sealed-comp

3. Training Material. Refrigeration & Air conditioning division, www.danfoss.com 4 UNICEF_ Draft Training Manual (Module B)

4. Draft material, NCCVLAP document.

Notes

B CHAPTER

Introduction

Ice lined refrigerators (ILRs) and deep freezers (DFs) to store vaccines at suitable temperature range to serve about 1,48,124 sub-centre sites. Many developing countries, including India face an overall situation of poor quality grid supply voltage with large fluctuations, particularly in rural areas. The biggest concern that voltage fluctuations can harm voltage sensitive appliances & which is true to a great extent for Cold Chain Equipment (CCE) used in immunization programme. Most of the PHC's (The last cold chain points) are in villages and faces issues of power crisis and also the poor supply voltage. (sometimes voltage level is too low i.e. up to 130-140 volts). This kind of large fluctuation in voltage level also affects the working and life of cold chain equipment; especially ILR and deep freezer, as this equipment are installed at sub district vaccine storage (PHC/CHC) points. These factors put large impact on immunisation programme, as vaccines could not be preserved properly which ultimately having adverse

effect on conduction of various routine vaccination camps and pulse polio campaign. The overall scenario necessitates, taking some corrective measures for addressing this situation. Maintaining healthy cold chain is possible only, if CCE provides trouble-free operation, which ultimately rely stable supply voltage. The unsafe voltage (lower and higher than specified operating range) is having adverse effect on CCE functioning & hence it needs to be protected both from high as well as low voltages, which necessitates to put voltage stabilizer to protect this equipment.

Voltage Stabilizer Repair & Maintenance

Electrical Fundamentals

Sources of Electricity

Electricity can be created by several means: Friction, Heat, Light, Pressure, Chemical Action, or Magnetic Action.

Friction creates static electricity.

Heat can act upon a device called a thermo couple to create DC.

Light applied to photoelectric materials will produce DC electricity.

Pressure applied to a piezoelectric material will produce DC electricity.

Chemical Action of certain chemicals will create electricity.(Battery)

Magnetic action produces electricity (The alternator)

Ohm's Law

Ohm's law defines a linear relationship between the voltage and the current in an electrical circuit. The resistor's voltage drop and resistance set the DC current flow through the resistor.

With water flow analogy we can imagine the electric current as water current through pipe, the resistor as a thin pipe that limits the water flow, the voltage as height difference of the water that enables the water flow.

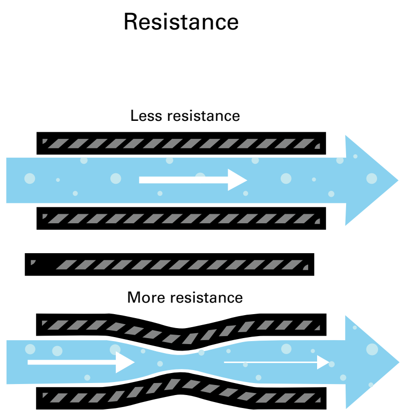


Figure B-1.1:

Ohm's Law Formula / Equation

When we know the voltage and resistance, we can calculate the current.

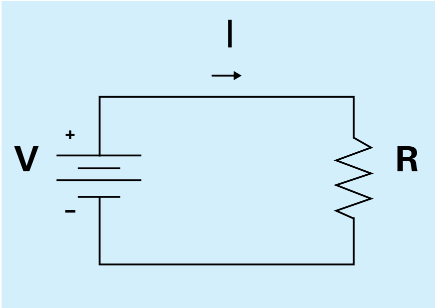


Figure B-1.2:

Ohm's law definition

The resistor's current I in amps (A) is equal to the resistor's voltage IR=V in volts (V) divided by the resistance R in ohms (Ω):

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

V is the voltage drop of the resistor, measured in Volts (V). In some cases, Ohm's law uses the letter E to represent voltage. E denotes electromotive force.

I is the electrical current flowing through the resistor, measured in Amperes (A)

R is the resistance of the resistor, measured in Ohms (Ω)

Voltage calculation

When we know the current and resistance, we can calculate the voltage.

The voltage V in volts (V) is equal to the to the current I in amps (A) times the resistance R in ohms (Ω):

$$V=I \times R$$

Resistance calculation

When we know the voltage and the current, we can calculate the resistance.

The resistance R in ohms (Ω) is equal to the voltage V in volts (V) divided by the current I in amps (A):

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

Since the current is set by the values of the voltage and resistance, the Ohm's law formula can show that:

- If we increase the voltage, the current will increase.
- If we increase the resistance, the current will reduce

Ohm's Law for AC Circuit

The load's current I in amps (A) is equal to the load's voltage VZ=V in volts (V) divided by the impedance Z in ohms (Ω):

$$I=\frac{V}{Z}$$

V is the voltage drop on the load, measured in Volts (V)

I is the electrical current, measured in Amps (A)

Z is the impedance of the load, measured in Ohms (Ω)

Electrical Voltage

Voltage is the electrical force that moves electrons through a conductor. Voltage is electrical pressure also known as EMF (Electro Motive Force) that pushes electrons.

The greater the difference in electrical potential push (difference between positive and negative), the greater the voltage force potential.

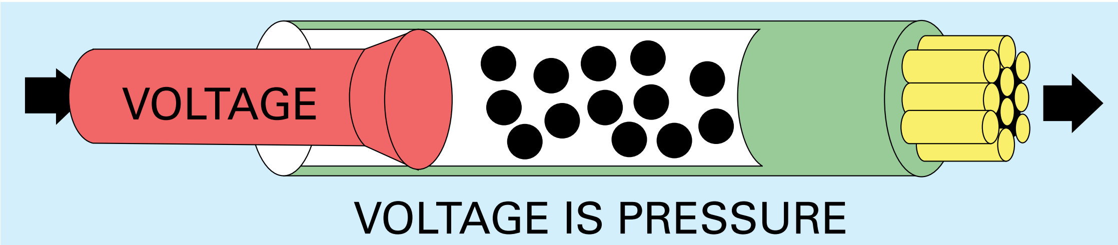


Figure B-1.3:

Electrical voltage is defined as electric potential difference between two points of an electric field.

Using water pipe analogy, we can visualize the voltage as height difference that makes the water flow down.

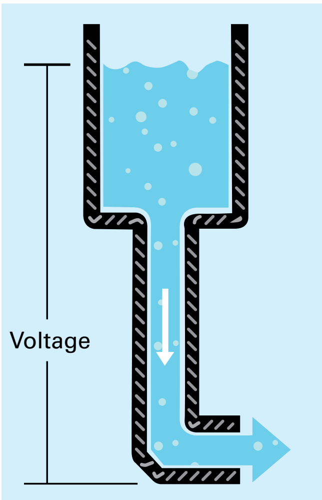


Figure B-1.4:

In an electrical circuit, the electrical voltage V in volts (V) is equal to the energy consumption E in joules (J)divided by the electric charge Q in coulombs (C).

$$V=\frac{E}{Q}$$

V is the voltage measured in volts (V)

E is the energy measured in joules (J)

Q is the electric charge measured in coulombs (C)

Voltage in series

The total voltage of several voltage sources or voltage drops in series is their sum.

VT = V1 + V2 + V3 +...

VT - the equivalent voltage source or voltage drop in volts (V).

V1 - voltage source or voltage drop in volts (V).

V2 - voltage source or voltage drop in volts (V).

V3 - voltage source or voltage drop in volts (V).

Voltage in parallel

Voltage sources or voltage drops in parallel have equal voltage.

VT = V1 = V2 = V3 =...

VT - the equivalent voltage source or voltage drop in volts (V).

V1 - voltage source or voltage drop in volts (V).

V2 - voltage source or voltage drop in volts (V).

V3 - voltage source or voltage drop in volts (V).

DC circuit

Direct current (DC) is generated by a constant voltage source like a battery or DC voltage source.

The voltage drop on a resistor can be calculated from the resistor's resistance and the resistor's current, using Ohm's law:

Voltage calculation with Ohm's law

$$V_R = I_R \times R$$

VR - voltage drop on the resistor measured in volts (V)

IR - current flow through the resistor measured in amperes (A)

R - resistance of the resistor measured in ohms (Ω)

AC circuit

Alternating current is generated by a sinusoidal voltage source.

Ohm's law

$$V_Z = I_Z \times Z$$

VZ - voltage drop on the load measured in volts (V)

IZ - current flow through the load measured in amperes (A)

Z - Impedance of the load measured in ohms (Ω)

Voltage drop

Voltage drop is the drop of electrical potential or potential difference on the load in an electrical circuit.

Electric current

CURRENT is the quantity or flow rate of electrons moving past a point within one second. Current flow is also known as amperage, or amps for short.

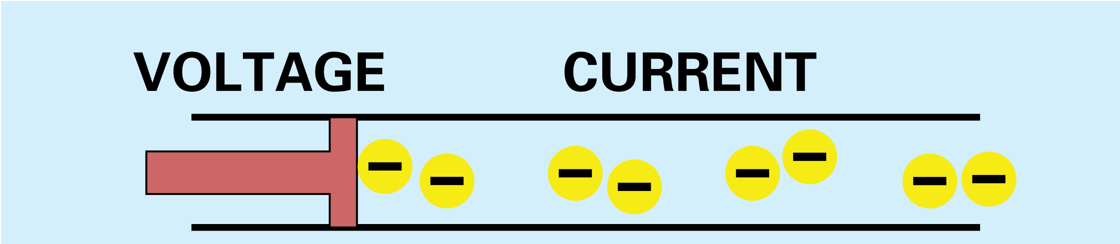


Figure B-1.5:

Current can be expressed in a number of different ways, such as:

Electrical current is the flow rate of electric charge in electric field, usually in electrical circuit.

Using water pipe analogy, we can visualize the electrical current as water current that flows in a pipe.

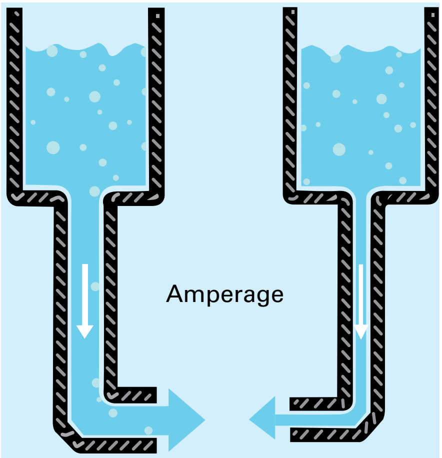


Figure B-1.6:

Alternating Current (AC)

Electricity with electrons flowing back and forth, negative - positive- negative, is called Alternating Current, or AC.

The electrical appliances in your home use AC power.

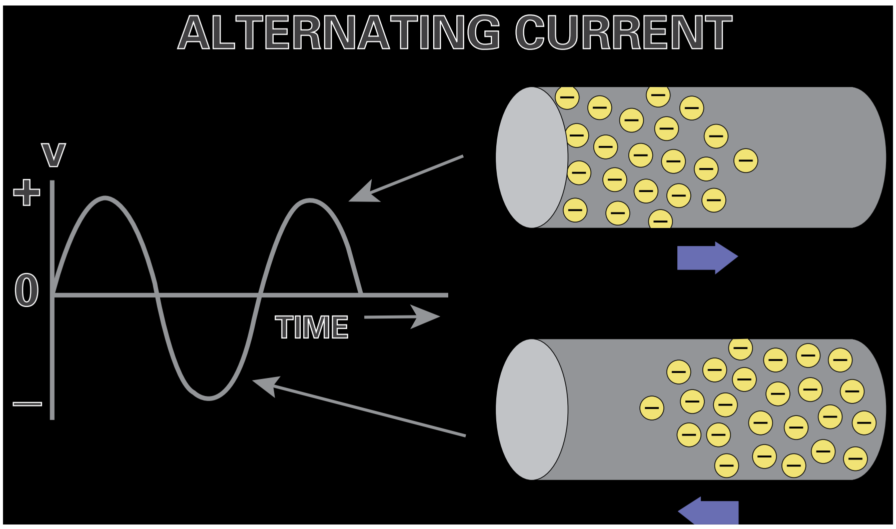


Figure B-1.7:

Direct Current (DC)

Electricity with electrons flowing in only one direction is called Direct Current or DC.

DC electrical systems are used in cars.

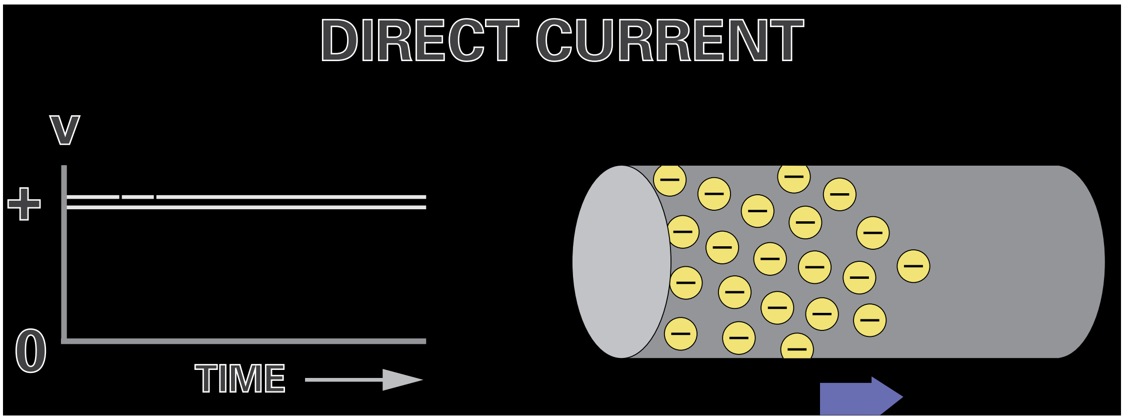


Figure B-1.8:

Affects of Current Flow

Two common effects of current flow are Heat Generation and Electromagnetism.

HEAT: When current flows, heat will be generated. The higher the current flow the greater the heat generated. An example would be a light bulb. If enough current flows across the filament, it will glow white hot and illuminate to produce light.

ELECTROMAGNETISM: When current flows, a small magnetic field is created. The higher the current flow, the stronger the magnetic field. An example: Electromagnetism principles are used in alternators, ignition systems, and other electronic devices.

Current calculation with Ohm's law

The current I_R in amps (A) is equal to the resistor's voltage V_R in volts (V) divided by the resistance R in ohms (Ω).

$$I_R=V_R \times R$$

Current direction

current type	from	to
Positive charges	+	-
Negative charges	-	+
Conventional direction	+	-

Table: Current direction

Current in series circuits

$I_{Total} = I_1 = I_2 = I_3 = ...$

I_{Total} - the equivalent current in amps (A).

I_1 - current of load 1 in amps (A).

I_2 - current of load 2 in amps (A).

I_3 - current of load 3 in amps (A).

Current in parallel circuits

Current that flows through loads in parallel - **just like water flow through parallel pipes.**

The total current I_{Total} is the sum of the parallel currents of each load:

$I_{Total} = I_1 + I_2 + I_3 + ...$

I_{Total} - the equivalent current in amps (A).

I_1 - current of load 1 in amps (A).

I_2 - current of load 2 in amps (A).

I_3 - current of load 3 in amps (A).

Resistance

Resistance is an electrical quantity that measures how the device or material reduces the electric current flow through it.It is the force that reduces or stops the flow of electrons. It opposes voltage.

Higher resistance will decrease the flow of electrons and lower resistance will allow more electrons to flow. The resistance is measured in units of ohms (Ω).

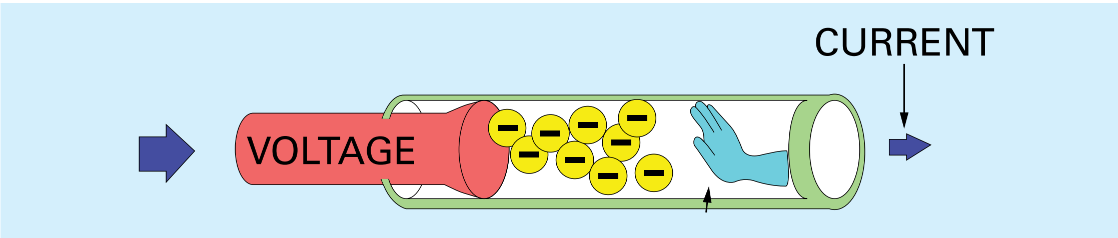


Figure B-1.9:

Resistance calculation

Resistance Factors

Various factors can affect the resistance. These include:

LENGTH of the conductor. The longer the conductor, the higher the resistance.

DIAMETER of the conductor. The narrower the conductor, the higher the resistance.

TEMPERATURE of the material. Depending on the material, most will increase resistance as temperature increases.

PHYSICAL CONDITION (DAMAGE) to the material. Any damage will increase resistance.

TYPE of MATERIAL used. Various materials have a wide range of resistances.

The resistance of a conductor is resistivity of the conductor's material times the conductor's length divided by the conductor's cross sectional area.

$R = p x \frac{l}{A}$ $\quad\quad$ $R = p x \frac{l}{A}$

R is the resistance in ohms (Ω).

p is the resistivity in ohms-meter (Ω×m)

l is the length of the conductor in meter (m)

A is the cross sectional area of the conductor in square meters (m^2)

Resistance calculation with ohm's law

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

R is the resistance of the resistor in ohms (Ω).

V is the voltage drop on the resistor in volts (V).

I is the current of the resistor in amperes (A).

Temperature effects of resistance

The resistance of a resistor increases when temperature of the resistor increases.

$R_2 = R_1 \times (1 + \alpha (T_2 - T_1))$

R_2 is the resistance at temperature T_2 in ohms (Ω).

R_1 is the resistance at temperature T_1 in ohms (Ω).

α is the temperature coefficient.

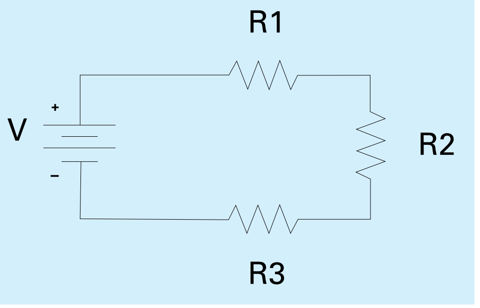


Figure B-1.10:

Resistance of resistors in series

The total equivalent resistance of resistors in series is the sum of the resistance values:

$R_{Total} = R_1 + R_2 + R_3 + ...$

Resistance of resistors in parallel

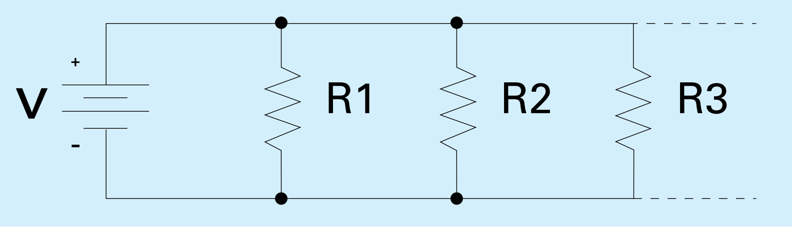


Figure B-1.11:

The total equivalent resistance of resistors in parallel is given by:

$$R_{Total} = R_1 + R_2 + R_3 + ...$$

Electric power definition

The electric power P is equal to the energy consumption E divided by the consumption time t:

$$P=\frac{E}{t}$$

P is the electric power in watt (W).

E is the energy consumption in joule (J).

t is the time in seconds (s).

Electric power calculation

$P = V \cdot I$

or

$P = I^2 \cdot R$

or

$P = V^2 / R$

P is the electric power in watt (W).

V is the voltage in volts (V).

I is the current in amps (A).

R is the resistance in ohms (Ω).

Real power or Active Power

Real or true power is the power that is used to do the work on the load.

$P = VI\cos\varphi$

Reactive power

Reactive power is the power that is wasted and not used to do work on the load.

$Q = VI\sin\varphi$

Apparent power

The apparent power is the power that is supplied to the circuit.

$S = VI$

P is the real power in watts [W]

Q is the reactive power in volt-ampere-reactive [VAR]

S is the apparent power in Volt-amper [VA]

V is the rms voltage in Volts [V]

I is the rms current Amperes [A]

φ is the impedance phase angle = phase difference between voltage and current.

Real / Reactive / Apparent powers relation

The real power P and reactive power Q give together the apparent power S:

$P^2 + Q^2 = S^2$

P is the real power in watts [W]

Q is the reactive power in volt-ampere-reactive [VAR]

S is the apparent power in Volt-amper [VA]

Power Factor

In AC circuits, the power factor is the ratio of the real power that is used to do work and the apparent power that is supplied to the circuit.

The power factor can get values in the range from 0 to 1.

When all the power is reactive power with no real power (usually inductive load) - the power factor is 0.

When all the power is real power with no reactive power (resistive load) - the power factor is 1.

Electrical Energy: - Electrical energy is energy that's stored in charged particles within an electric field.

Electrical Units of Energy

In the "International System of Units", which are based on metric units, and which form the basis for the electrical, both work and energy have the same unit, called the "Joule".

After powering appliances with electricity, the rate of energy use, or in other words, how much energy per unit time the appliance draws. This quantity is called the "power":

Power = Energy / Time

In particular, for electrical power the "Watt" (named after the scientist James Watt): 1 Watt = 1 Joule / Second.

Power and energy, are closely related. Power is the rate at which energy is delivered, not an amount of energy itself.

Energy = Power x Time.

For example, using the definition of the word watt given above, a 100 watt light bulb is a device that converts 100 joules of electrical energy into 100 joules of electromagnetic radiation (light) every second.

If you leave a 100 watt light on for one hour, that is, 3600 seconds, then the total energy you used was:

Energy = Power x Time = (100 Joules/Second) x (3600 Seconds) = 360,000 Joules

Electrical unit definitions

Volt (V)

Volt is the electrical unit of voltage.

One volt is the energy of 1 joule that is consumed when electric charge of 1 coulomb flows in the circuit.

1V = 1J / 1C

Ampere (A)

Ampere is the electrical unit of electrical current. It measures the amount of electrical charge that flows in an electrical circuit per 1 second.

1A = 1C / 1s

Ohm (Ω)

Ohm is the electrical unit of resistance.

$1\Omega = 1V / 1A$

Watt (W)

Watt is the electrical unit of electric power. It measures the rate of consumed energy.

$1W = 1J / 1s$

$1W = 1V \cdot 1A$

Farad (F)

Farad is the unit of capacitance. It represents the amount of electric charge in coulombs that is stored per 1 volt.

$1F = 1C / 1V$

Henry (H)

Henry is the unit of inductance.

$1H = 1Wb / 1A$

siemens (S)

siemens is the unit of conductance, which is the opposite of resistance.

$1S = 1 / 1\Omega$

Coulomb (C)

Coulomb is the unit of electric charge.

1C = 6.238792×1018 electron charges

Ampere-hour (Ah)

Ampere-hour is a unit of electric charge.

One ampere-hour is the electric charge that flow in electrical circuit, when a current of 1 ampere is applied for 1 hour.

1Ah = 1A • 1hour

One ampere-hour is equal to 3600 coulombs.

1Ah = 3600C

Tesla (T)

Tesla is the unit of magnetic field.

1T = 1Wb / 1m2

Weber (Wb)

Weber is the unit of magnetic flux.

1Wb = 1V • 1s

Joule (J)

Joule is the unit of energy.

1J = 1 kg • 1(m / s)2

Kilowatt-hour (kWh)

Kilowatt-hour is a unit of energy.

1kWh = 1kW • 1h = 1000W • 1h

Kilovolt-amps (kVA)

Kilovolt-amps is a unit of power.

1kVA = 1kV • 1A = 1000 • 1V • 1A

Hertz (Hz)

Hertz is the unit of frequency. It measures the number of cycles per second.

1 Hz = 1 cycles / s

Electrical & Electronic Units Table

Unit Name	Unit Symbol	Quantity
Ampere (amp)	A	Electric current (I)
Volt	V	Voltage (V, E) Electromotive force (E) Potential difference (Δφ)
Ohm	Ω	Resistance (R)
Watt	W	Electric power (P)
Decibel-milliwatt	dBm	Electric power (P)
Decibel-Watt	dBW	Electric power (P)
Volt-Ampere-Reactive	var	Reactive power (Q)
Volt-Ampere	VA	Apparent power (S)
Farad	F	Capacitance (C)
Henry	H	Inductance (L)
siemens / mho	S	Conductance (G) Admittance (Y)
Coulomb	C	Electric charge (Q)
Ampere-hour	Ah	Electric charge (Q)
Joule	J	Energy (E)
Kilowatt-hour	kWh	Energy (E)
Electron-volt	eV	Energy (E)
Ohm-meter	Ω·m	Resistivity (ρ)
siemens per meter	S/m	Conductivity (σ)
Volts per meter	V/m	Electric field (E)
Newtons per coulomb	N/C	Electric field (E)
Volt-meter	V•m	Electric flux (Φe)
Tesla	T	Magnetic field (B)
Gauss	G	Magnetic field (B)
Weber	Wb	Magnetic flux (Φm)
Hertz	Hz	Frequency (f)
Seconds	s	Time (t)
Meter / metre	m	Length (l)
Square-meter	m^2	Area (A)
Decibel	dB	
Parts per million	ppm	

Table: Unit Table

Units prefix table

Prefix	Prefix Symbol	Prefix factor	Example
pico	p	10^{-12}	1pF = 10^{-12}F
nano	n	10^{-9}	1nF = 10^{-9}F
micro	µ	10^{-6}	1µA = 10^{-6}A
milli	m	10^{-3}	1mA = 10^{-3}A
kilo	k	10^{3}	1kΩ = 1000Ω
mega	M	10^{6}	1MHz = 10^{6}Hz
giga	G	10^{9}	1GHz = 10^{9}Hz

Table: Units Prefix Table

Notes

Introduction to Electrical Measurements

Introduction to Electrical Measurements

Electrical measurements often come down to either measuring current or measuring voltage. Even if you are measuring frequency, you will be measuring the frequency of a current signal or a voltage signal and you will need to know how to measure either voltage or current. In this short lesson, we will examine those two measurements - starting with measuring voltage. However, first we should note a few common characteristics of the meters you use for those measurements.

Many times you will use a digital multimeter - a DMM - to measure either voltage or current. Actually, a DMM will also usually measure frequency (of a voltage signal) and resistance. You should note the following about typical DMMs.

- Polarity is important. Usually the terminals of the DMM will be coded to indicate polarity. Often that polarity is indicated by a red terminal (positive) and a black terminal (negative). In other cases, the polarity could be indicated by printed notes on the terminals.
- Often one of the terminals on the DMM may be connected to the ground. That would normally be the black terminal, or it may be indicated with a ground symbol.

Voltage Measurement

Voltage is one of the most common quantities measured.

Electrical voltage is measured with Voltmeter. It measures the voltage potential across or parallel to the circuit. The Voltmeter is connected in parallel to the measured component or circuit & measures the amount of electrical pressure difference between two points being measured.

Voltage can exist between two points without electron flow. The voltmeter has very high resistance, so it almost does not affect the measured circuit. However, digital multimeters (DMMs) - which can function as voltmeters - often have considerably more capability and can measure current, resistance and frequency. And, there are other instruments - like oscilloscopes - that measure voltage and should be thought of as voltmeters. No matter what the instrument is, if it measures voltage you have to treat the instrument as a voltmeter.

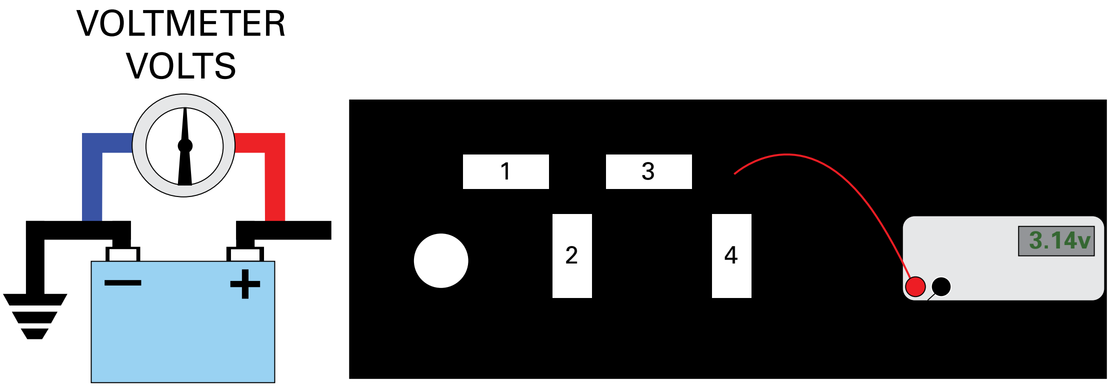


Figure B-1.12:

Voltage Units

Voltage is measured in units called VOLTS.

Voltage measurements can use different value prefixes such as millivolt, volt, Kilovolt, and Megavolt.

VOLTAGE	LESS THAN BASE UNIT	BASIC UNIT	LARGER THAN BASE UNIT
Symbol	mV	V	kV
Pronounced	millivolt	Volt	Kilovolt
Multiplier	0.001	1	1,000

Current Measurement

The electrical current is measured in ampere (amp) unit.

Higher voltage will produce higher current flow, and lower voltage will produce lower current flow. Current measurement is done by connecting the ammeter in series to the measured object, so all the measured current will flow through the ammeter.

The ammeter has very low resistance, so it almost does not affect the measured circuit.

An AMMETER measures the quantity of current flow. Ammeters are placed in series (inline) to count the electrons passing through it.

Example: A water meter counts the gallons of water flowing through it.

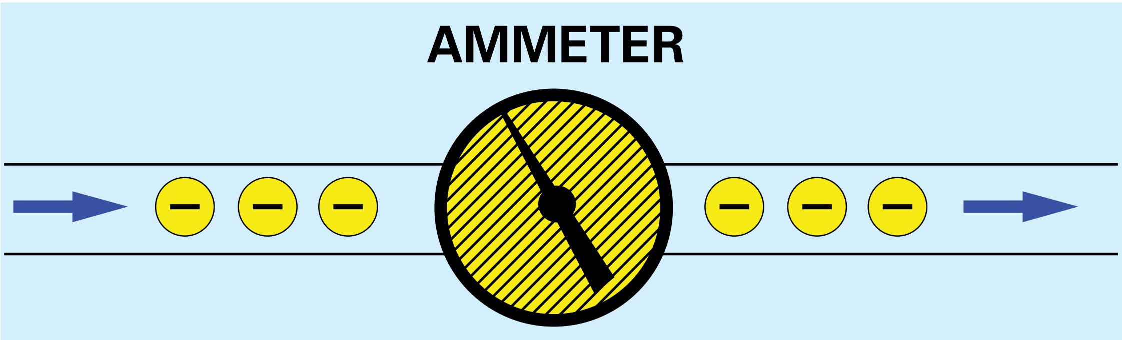


Figure B-1.13:

Though, Voltage is a more common measurement, it is often necessary to measure current. When measuring current, it is important to remember that current is a flow variable. Current flows through electrical elements, and if you want to measure current you have to get it to flow through the ammeter. Here's the same circuit we used in the example above. Consider what we would have to do to measure the current flowing through element 4.

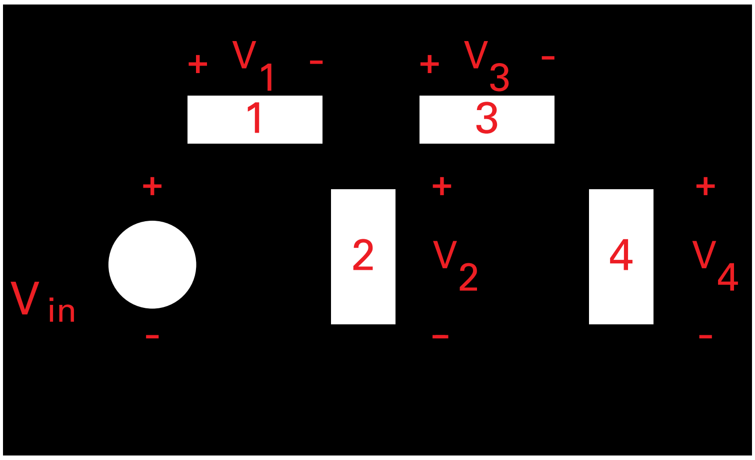


Figure B-1.14:

If we want to measure the current through element #4, we have to get that current to flow through the ammeter. Here's a way to insert an ammeter into the circuit to measure that current.

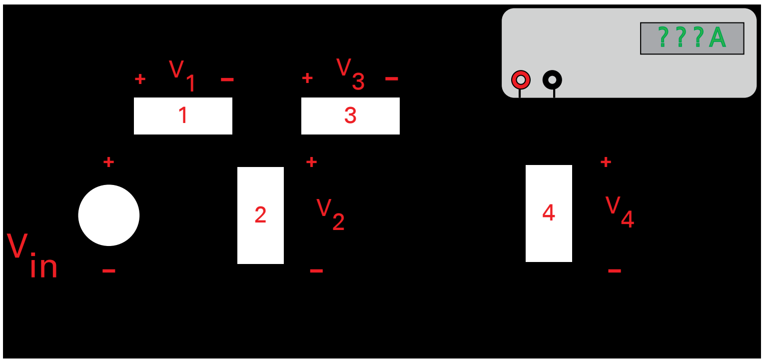


Figure B-1.15:

Current Units

Current flow is measured in units called Amperes or AMPS. Amperage measurements can use different value prefixes, such as micro amp, milliamp, and Amp.

AMPERAGE	LESS THAN BASE UNIT	LESS THAN BASE UNIT	BASIC UNIT
Symbol	µA	mA	A
Pronounced	Microamp	milliamp	Amp
Multiplier	0.000001	0.001	1

Table: Current units

Measuring electrical resistance

An OHMMETER measures the resistance of an electrical circuit or component. In order to measure the resistance of a resistor or a circuit, the circuit should have the power supply turned off.

The ohmmeter should be connected to the two ends of the circuit so the resistance can be read.No voltage can be applied while the ohmmeter is connected, or damage to the meter will occur.

Example: Water flows through a garden hose, and someone steps on the hose. The greater the pressure placed on the hose, the greater the hose restriction and the less water flows.

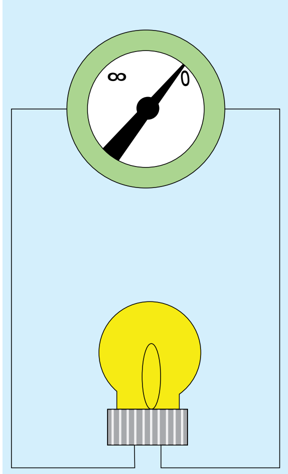


Figure B-1.16:

RESISTANCE UNITS

Resistance is measured in units called OHMS.

Resistance measurements can use different value prefixes, such as Kilo ohm and Mega ohms.

RESISTANCE	BASIC UNIT	MORE THAN BASE UNIT	MORE THAN BASE UNIT
Symbol		K	M
Pronounced	Ohm	Kilo ohm	Megaohm
Multiplier	1	1,000	1,000,000

Table: Resistance units

Notes

Notes

1

SECTION

Introduction

All electrical and electronic systems are designed and manufactured to operate at maximum efficiency with a given supply voltage, called the nominal operating voltage.

For various reasons the grid voltage of the energy distribution does not remain constant, showing considerable fluctuations in the nominal value, which leads to the apparatus, not only a loss of efficiency (sometimes even the impossibility of operation), but also a significant increase in failure rate.

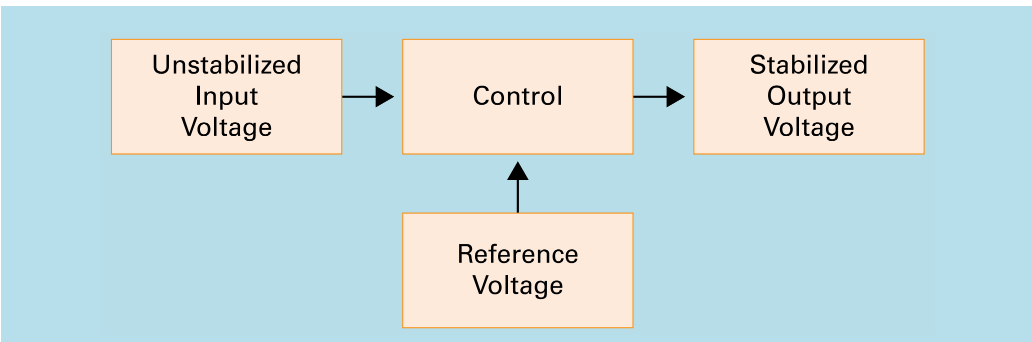
In India, electricity distribution is at 230V for single phase and 415 V for three phase. Voltage lower and higher than this range needs to be corrected if the appliance cannot handle that voltage. Voltages at many places, especially in interior parts of the country go down to 150-160 V on a regular basis & so it is very common to have a voltage stabilizer with refrigerators, air conditioners, televisions, furnace equipment, micro oven, music systems, washing machines, etc. The main intention behind the usage of voltage stabilizers is to protect the devices against voltage fluctuations. This is because each and every electrical appliance is designed to operate under a specific voltage to give desired performance.

So, it is required to supply stable voltage to the load & the same is very true for Cold Chain Equipment (CCE). Considering CCE' importance under immunization programme and the need for their protection. Voltage stabilizers are used for maintaining a stable voltage supply to the CCE such that it can be protected from over and under voltages.

What is Stabilizer?

A Stabilizer is a device used to maintain something or a quantity steady or stable. There are different types of stabilizers based on the quantity they are used for maintaining stability. For example, a stabilizer used for maintaining the voltage quantity stable in a power system is called as voltage stabilizer.

Below block diagram will give you the idea for working of stabilizer.



As the name suggests, a voltage stabilizer stabilizes or regulates the voltage if the supply voltage varies or fluctuates over a given range. It is an electrical appliance that feeds more or less constant voltage to a load during over and under voltage conditions. This device detects these voltage conditions and correspondingly brings the voltage to desired range. Voltage stabilizers provide a means to regulate the supply voltage to the load. These are not meant to provide a constant voltage output; instead it operates the load or system in an acceptable range of voltage. The internal circuit of a stabilizer is shown in figure below. It consists of auto transformer/ transformer, rectifier unit, comparators, switching circuit and relays.

Internal diagram of stabilizer

There are different types of voltage stabilizers available & it comes with a different KVA rating for normal range (ranging boost-buck range for input voltage 20-55V) applications. These are high efficiency devices, typically 95 to 98% & can be single phase or three-phase, both non digital and digital.

In case of modern digital type stabilizers, a microcontroller or microprocessor is used as central control unit.

Need of Voltage Stabilizers

Voltage fluctuations are nothing but the change in magnitude of voltage, of which normally exceeding or below the steady state voltage range prescribed by some standards. Voltage fluctuations cause temporary or permanent failure of the load. These voltage fluctuations also reduce the life span of the equipment due to the unregulated low or higher voltage than the intended voltage required for the load. These voltage fluctuations occur due to sudden load changes or due to faults in the power system. If this voltage is below or above certain value, the appliance would malfunction or might operate at worse condition or even it might get damaged.

Grid-mains operated Cold Chain Equipment, i.e.ILR-DF are equipped with compressors having specified operating voltage range. It can provide optimum performance, only if it is operated within recommended range of operating voltage. This equipment does not work well at low voltages. Chances of its failure will become extreme. if the voltage provided to them is lower than their operating voltage range as either they will not start at all, and if they are already running, they will start producing a humming sound. This humming sound happens as these motors draw more current to run the system. This can lead to overheating and burning of the motor if persistent. Thus saving induction motors (inside compressor) from voltage fluctuations is very important.

At high voltages these appliances draw more current only at the time of starting, but once they reach steady state the current is much less. But still the high starting current can damage the system and thus equipment with motors need to be protected both from high as well as low voltages. So you do need to put voltage stabilizer to protect this equipment. However before putting a voltage stabilizer, it is very important to find the operating voltage range of the equipment and the fluctuations that happen in the particular area.

Types of Voltage Stabilizer

There are different types of voltage regulators such as electronic voltage regulators, electromechanical voltage regulators, automatic voltage regulators and active regulators. Similarly, there are different types of voltage stabilizers such as servo voltage stabilizers, automatic voltage stabilizers, AC voltage stabilizers and DC voltage stabilizers.

Stabilizers are broadly classified into different types such as........

1. Coil rotation AC voltage regulators,
2. Step type Voltage Stabilizers. (Automatic /Solid State)
3. Electromechanical regulators
4. Constant-voltage transformer.
5. DC Voltage Stabilizers
6. Under immunization programme, stabilizers most commonly used, are briefly discussed as follows.

Step Type Voltage Stabilizers.

It works on the principle of a transformer, where the input current is connected to primary windings and output is received from secondary windings. When there is a drop in incoming voltage, it activates electromagnetic relays which add to more number of turns in the secondary winding, thus giving higher voltage which compensates for loss in output voltage. When there is rise in the incoming voltage, the reverse happens, and, thus, the voltage at the output side remains almost unchanged.

Automatic Voltage Stabilizers

Figure B-1.1:

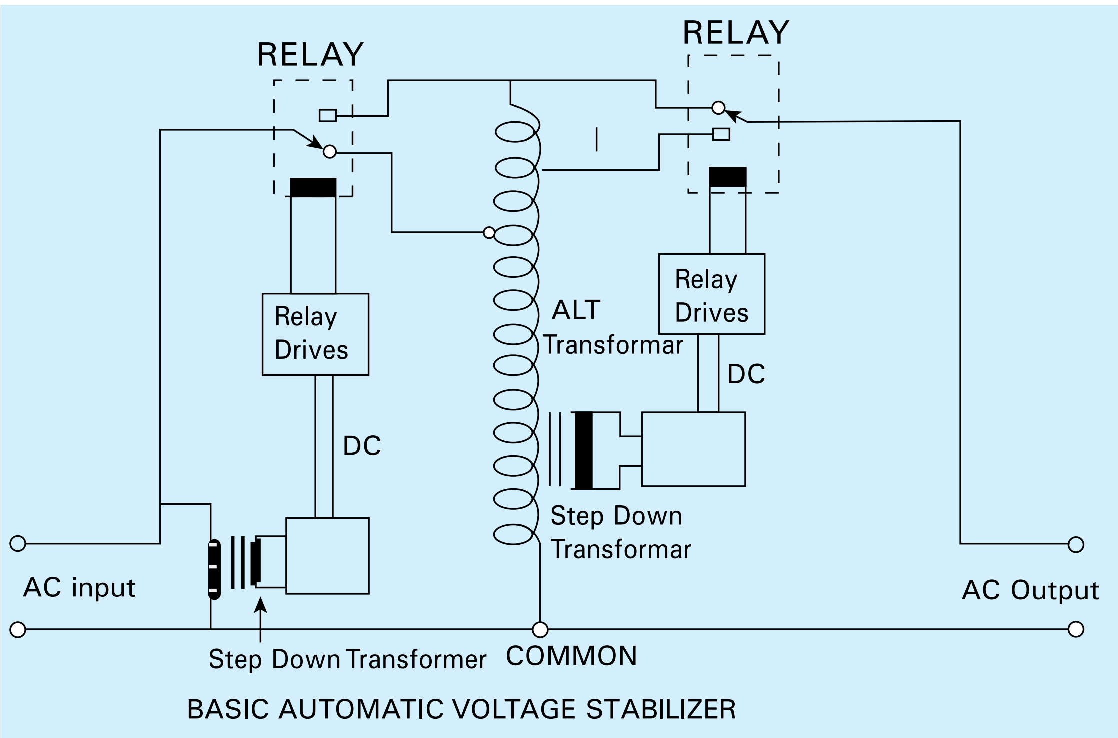


Figure B-1.2: Automatic Voltage Stabilizers

Electromechanical Regulators (Servo Voltage Stabilizers)

Electromechanical voltage regulators that are used for regulating the voltage on AC power distribution lines, also called as voltage stabilizers or tap-changers. To select an appropriate tap from multiple taps of an autotransformer, these voltage stabilizers utilize the servomechanism operation.

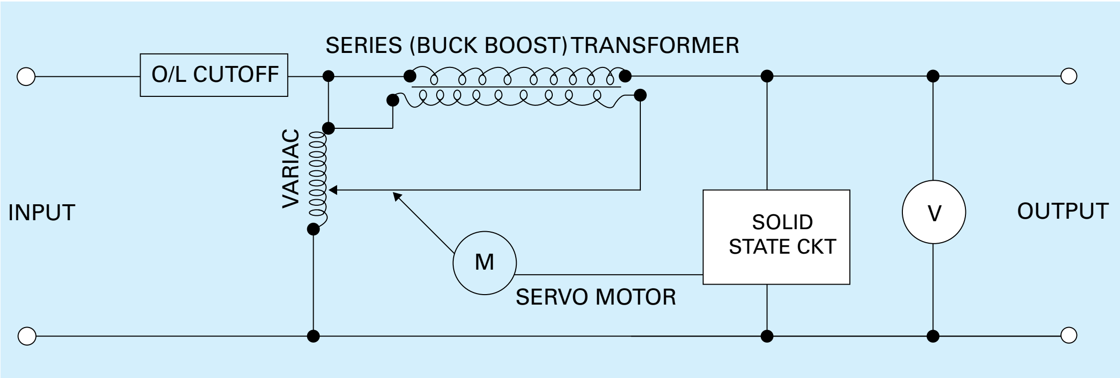


Figure B-1.3:

There are several varieties of servo voltage stabilizers that are principally used for domestic and industrial purpose. These stabilizers work on SERVO mechanism. The servo stabilizer gives a constant flow of voltage to the device and manages big flow of current moments. Servo controlled Voltage stabilizer is basically used to manage the voltage on AC power distribution lines. This is also known as electromechanical device.

In case of automatic voltage stabilizers, the speed of voltage correction is very less. The high speed voltage correction at a greater precision is achieved with servo controlled stabilizers.

In servo controlled stabilizers, voltage correction is done very precisely, i.e., closer to the base voltage value. The main components of a servo stabilizer include servo motor driven continuously variable auto transformer, buck-boost transformer and solid state control circuit as shown in the figure below.

Figure B-1.4: Servo Controlled Voltage stabilizer

In this stabilizer, solid state control circuit sense voltage fall and rise from a predetermined value and correspondingly operates the servo motor.

Basic Principle of Operation of Voltage Stabilizer

The voltage regulation is required for two distinct purposes; over voltage and under voltage conditions. The process of increasing voltage from under voltage condition is called as boost operation, whereas reducing the voltage from overvoltage condition is called as buck operations.

These two main operations are essential in each and every voltage stabilizer.

As discussed earlier the components of voltage stabilizer include a transformer, relays, and electronic circuitry. If the stabilizer senses the voltage drop in incoming voltage, it enables the electromagnetic relay so as to add more voltage from transformer so that the loss of voltage will be compensated.

When the incoming voltage is more than normal value, stabilizer activates another electromagnetic relay such that it deducts the voltage to maintain the normal value of voltage.

Boost Operation

The principle of boost operation of a voltage stabilizer is shown in figure below.

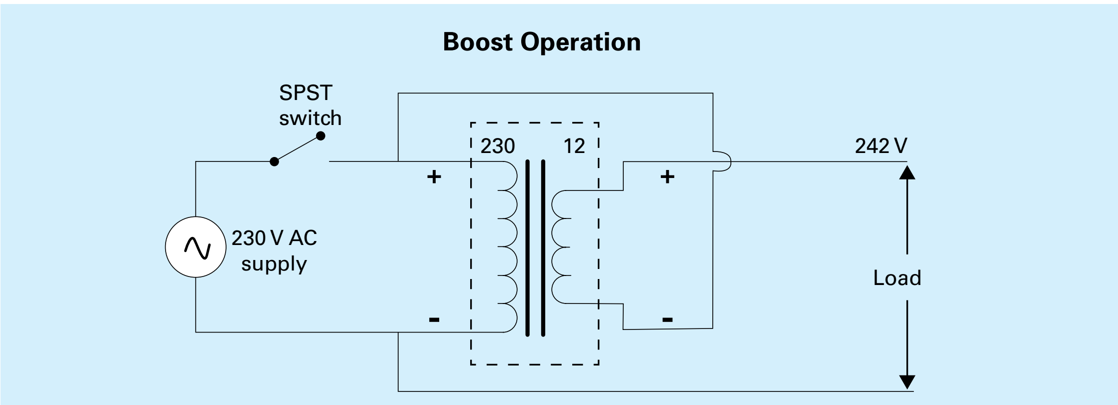


Figure B-1.5:

Here, the supply voltage is given to a transformer, which is normally a step-down transformer. This transformer is connected in such a way that the secondary output is added to the primary supply voltage. In case of low voltage condition, the electronic circuit in the stabilizer switches corresponding relay such that this added supply (incoming supply + transformer secondary output) is applied to the load.

Buck Operation

The principle of buck operation of a voltage stabilizer is illustrated in figure below.

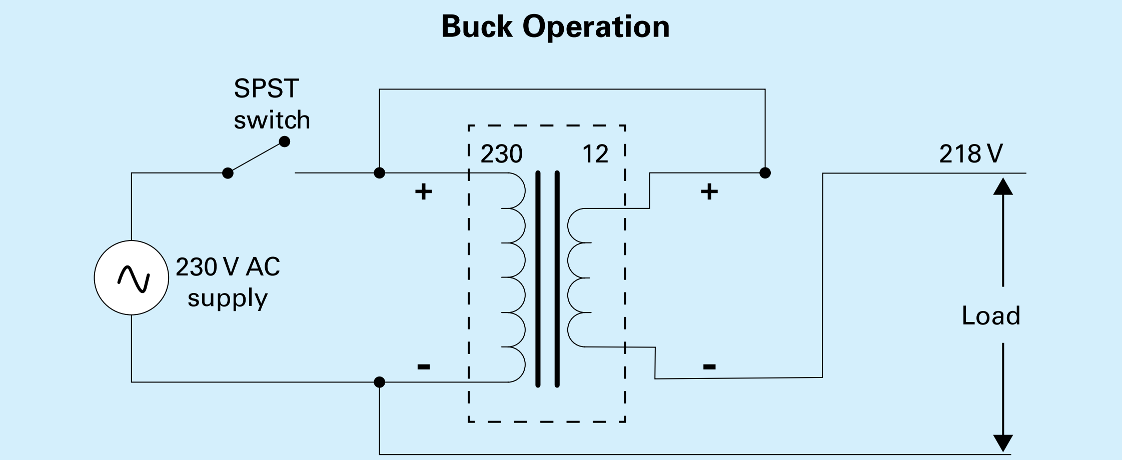


Figure B-1.6:

In buck operation, the secondary of step-down transformer is connected in such a way that secondary output voltage is deducted from incoming voltage.

Therefore, in case of incoming voltage rise, the electronic circuit switches the relay that switches deducted supply voltage (i.e., incoming voltage –transformer secondary voltage) to the load circuit.

In case of normal voltage operating condition, electronic circuit switches the load entirely to incoming supply without any transformer voltage.

These buck, boost and normal operations are same for all stabilizers whether they are normal type or servo mechanism type stabilizers. In addition to these two main operations, voltage stabilizer also performs lower and higher voltage cut off operations.

Notes

Voltage Stabilizer Working.

The voltage stabilizer is used to deliver voltage at its output within a specified narrow range, when the input voltage has very large variations. This is achieved by addition or subtraction of required voltage through an autotransformer or in other words by varying its turn ratio with the help of suitable control circuit. The autotransformer's input & output winding has many tappings, whose selection, for obtaining the required turn ratio, is done through electromagnetic relays controlled by control circuit. This constantly senses the input voltage and actuates the right relay sequence to keep the output voltage within the specified range.

The control circuit consist of comparator (IC) circuits, set at different levels. Each of the comparator circuit is fed with the unregulated voltage (derived & supplied from the input supply through sensing transformer) which is compared with a regulated supply & each comparator operates particular relay at a particular input voltage & changes the auto transformer's tappings in order to keep turn ratio such that the output is maintained within the range specified.

Voltage Stabilizer consists of auto transformer/ transformer, rectifier unit, comparators, switching circuit and relays.

The figure below shows the working model of a voltage stabilizer that contains a step-down transformer (usually provided with taps on secondary), rectifier, operational amplifier/microcontroller unit and set of relays.

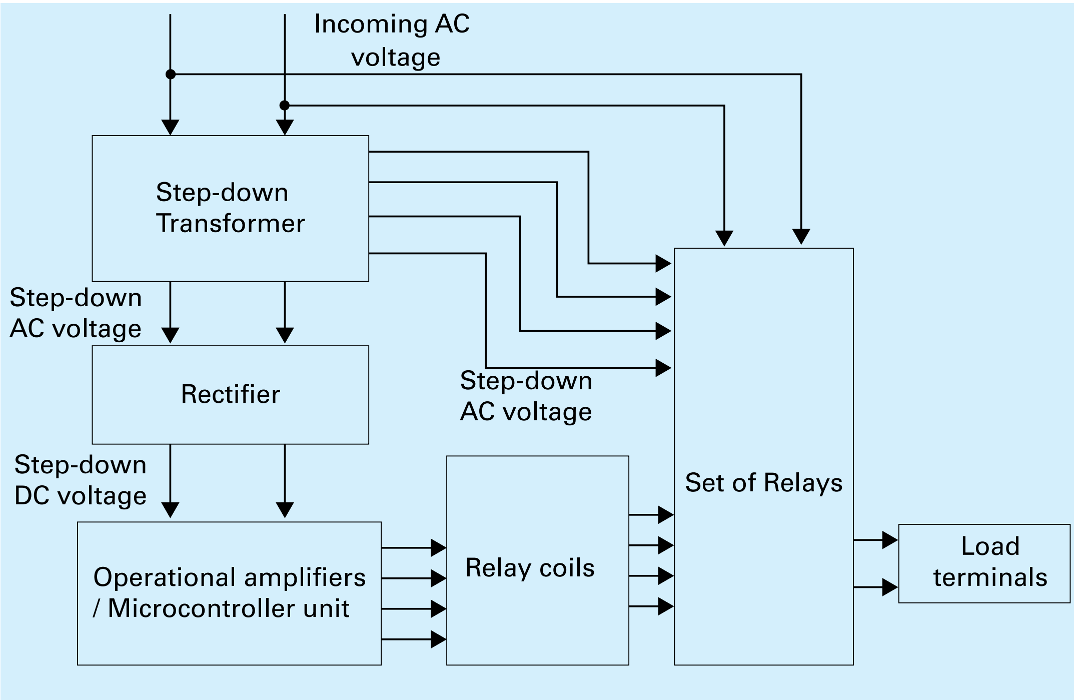


Figure B-1.7:

Operational Amplifier/Microcontroller Unit

In this, op-amps are tuned in such way that they could sense various set voltages such as lower cut off voltage, boost condition voltage, normal operating voltage, higher cut off voltage and buck operating voltage.

Set of Relays

A set of relays are connected in a manner that they trip the load circuit during higher and lower cut off voltages and also they switch buck and boost voltages to the load circuit.

Step down Transformer

A step-down tap changing transformer has different secondary voltage tapping which are helpful for operating operational amplifier for different voltages and also to add-up and deduct voltages for boost and buck operations respectively.

Rectifier

A rectifier circuit converts AC supply into DC to power-up entire electronic control circuit as well as relay coils.

- Let us assume that this is 1 KVA single phase stabilizer that provides stabilization for voltage range of 200 to 245 with a boost-buck voltage of 20-35 V for input voltage of 180 to 270 V.
- If the input supply is, say 195 V, then operational amplifier energizes boost relay coil such that 195 + 25 = 220V is supplied to the load. If the input supply is 260 V, corresponding op-amp energizes buck relay coil so that 260-30 = 225 V is supplied to the load.
- If the input voltage is below 180 V, corresponding op-amp switches lower cut off relay coil such that load is disconnected from the supply.
- And if the supply is beyond 270 V, corresponding op-amp energizes higher cut off relay coil and hence load is terminated from the supply.
- All these values are approximate values; it may vary depending on the application. By this way, a stabilizer operates under different voltage conditions.

Modern Voltage Stabilizers do come with following Features ....

- High & Low voltage protection,
- Time delay protection{(ITDS) Intelligent Time Delay System technology}
- Overload protection,
- Built in Thermal Overload Protection.
- Zero voltage switching,
- Frequency variation protection,
- Equipped with electronic filters, to suppress noise and peak voltage.
- Smoothing impulsive noise.

- Voltage cut off display, etc.
- Fail Safe circuit protection
- ZCD or Zero Crossing Detection Technology helps enhance the stabilizer's life and reduce the radio frequency noise generation.

Overall to summarize a voltage stabilizer:

- Increases useful life of equipment:
- Reduces malfunctions rate of equipment;
- Make the output voltage that feeds the equipment connected to it as much as possible equivalent to the ideal electrical power supply, ensuring that the oscillations in electrical power are offset, and its output maintain a stable value, preventing them from being experienced by equipment and thereby avoiding their damage.
- Maintains a stabilized power supply & constant voltage level.
- It contains electromechanical or electronic components to regulate one or more AC or DC voltages.
- Maintain an output that is close to the normal mains voltage as possible, under conditions of fluctuation.
- Attenuates noise, interference and lightning;
- Protects equipment against under-voltages and over-voltage of the mains;
- Operates in cases of overloading and overheating;
- Operates in a wide input voltage range and has spike protection too.
- Signals events from the mains.
- Different in rating/capacity for different appliance according to the specification and usage of each device.

Notes

2

SECTION

Components used & its functional description.

Transformer

Autotransformer

Electromechanical Relay

Miniature Circuit Breaker

Electronic Components

Electronic Components......General Abbreviations used

Commonly used Electronic Components and Their Functions

Resistor

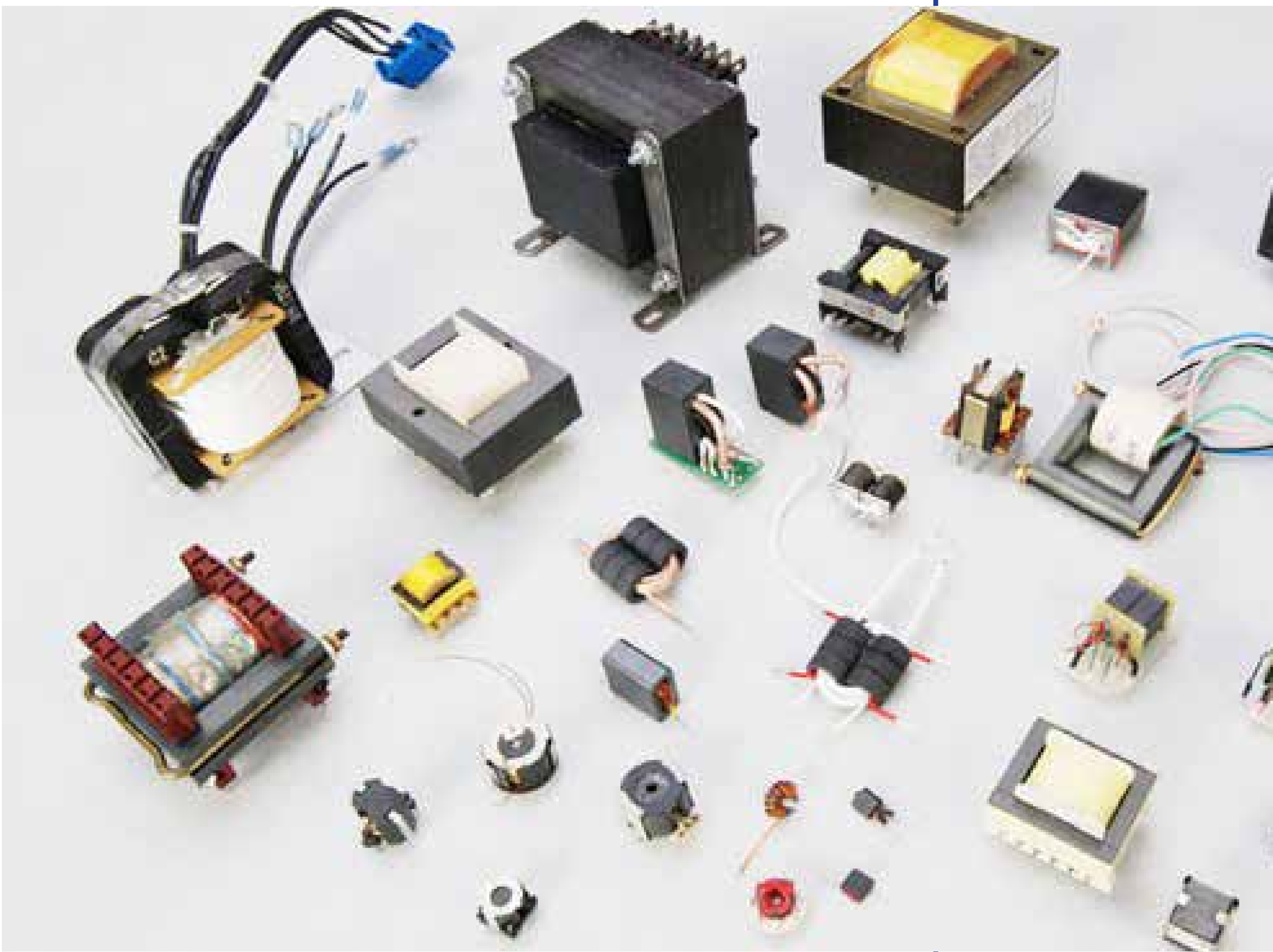
Potentiometer

Capacitor

Diode

Transistor

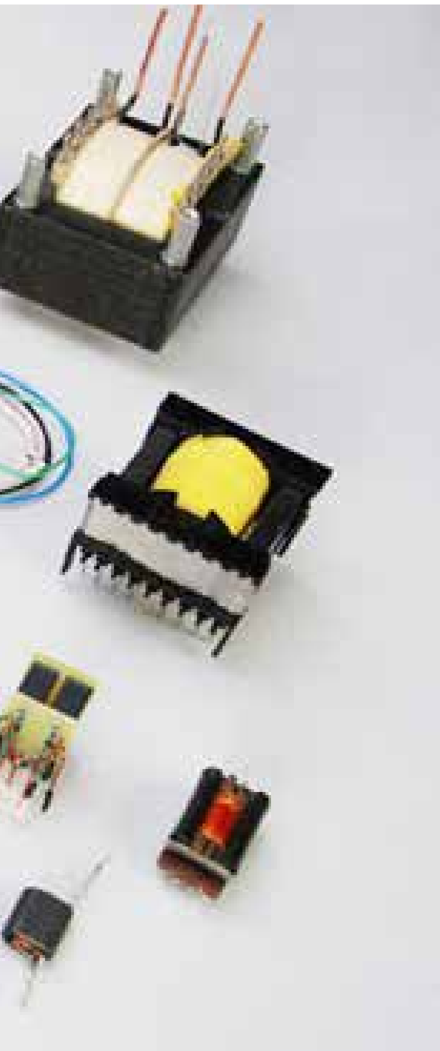
ICs (Integrated Circuits)



Transformer

The transformer is one of the most common devices found in electrical system that links the circuits which are operating at different voltages. These are commonly used in applications where there is a need of AC voltage conversion from one voltage level to another. It is possible either to decrease or increase the voltage and currents by the use of transformer in AC circuits based on the requirements of the electrical equipment or device or load. Various applications use wide variety of transformers including power, instrumentation and pulse transformers.

In a broad, transformers are categorized into two types, namely, electronic transformers and power transformers. Electronic transformers operating voltages are very low and are rated at low power levels. These are used in consumer electronic equipment like televisions, personal computers, CD/DVD players, and other devices. The term power transformer is referred to the transformers



with high power and voltage ratings. These are extensively used in power generation, transmission, distribution and utility systems to increase or decrease the voltage levels. However, the operation involved in these two types of transformers is same

What is an Electric Transformer?

The transformer is a static device (means that has no moving parts) that consists of one, two or more windings which are magnetically coupled and electrically separated with or without a magnetic core. It transfers the electrical energy from one circuit to the other by electromagnetic induction principle. The winding connected to the AC main supply is called primary winding and the winding connected to the load or from which energy is drawn out is called as secondary winding. These two windings with proper insulation are wound on a laminated core which provides a magnetic path between windings.

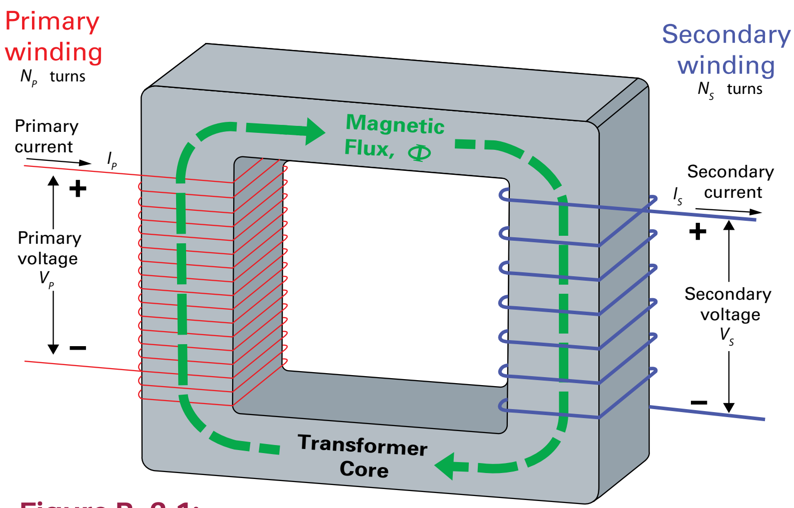


Figure B-2.1:

When the primary winding is energized with alternating voltage source, an alternating magnetic flux or field will be produced in the transformer core. This magnetic flux amplitude depends on the applied voltage magnitude, frequency of the supply and the number of turns on the primary side. This flux circulates through the core and hence links with the secondary winding. Based on the principle of electromagnetic induction, this magnetic linking induces a voltage in the secondary winding. This is called as mutual induction between two circuits. The secondary voltage depends on the number of turns on the secondary as well as magnetic flux and frequency.

Transformers are extensively used in electrical power systems to produce the variable values of voltage and currents at the same frequency. Therefore, by an appropriate primary and secondary turns proportion desired voltage ratio is obtained by the transformer.

Classification of Transformers

Transformers are classified into several types depends the various factors including voltage ratings, construction, type of cooling, number of phases of the AC system, the place where it is employed, etc. Let us discuss some of these types of transformers.

Based on Function

Transformers are classified into two types based on the conversion of voltage level. These are step-up and step-down transformers.

Step-up Transformers

In step-up transformer, the secondary voltage is more than the primary voltage.

Step-down Transformers

In step-down transformer, secondary voltage is less than the primary voltage due to the less number of turns in the secondary winding.

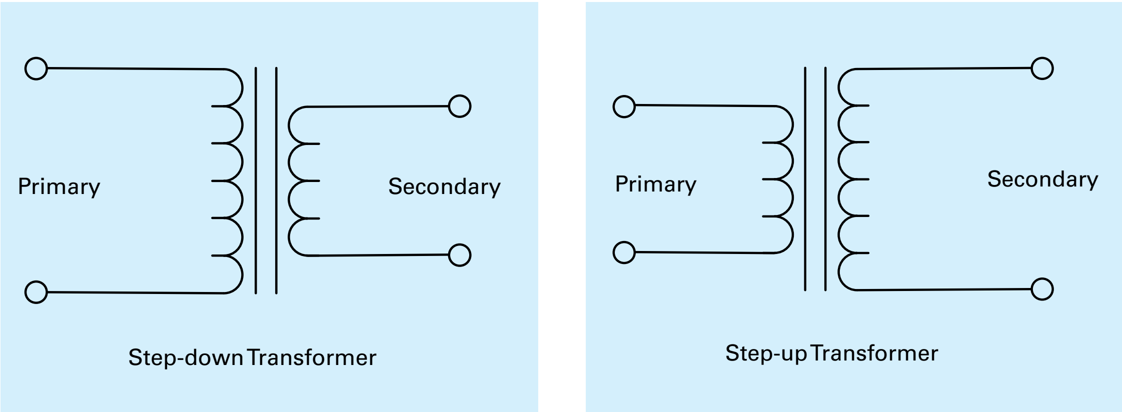


Figure B-2.2:

Based on Core Construction

Based on the construction, transformers are classified into two types in the manner in which the windings are placed around the core. These types are core and shell type transformers.

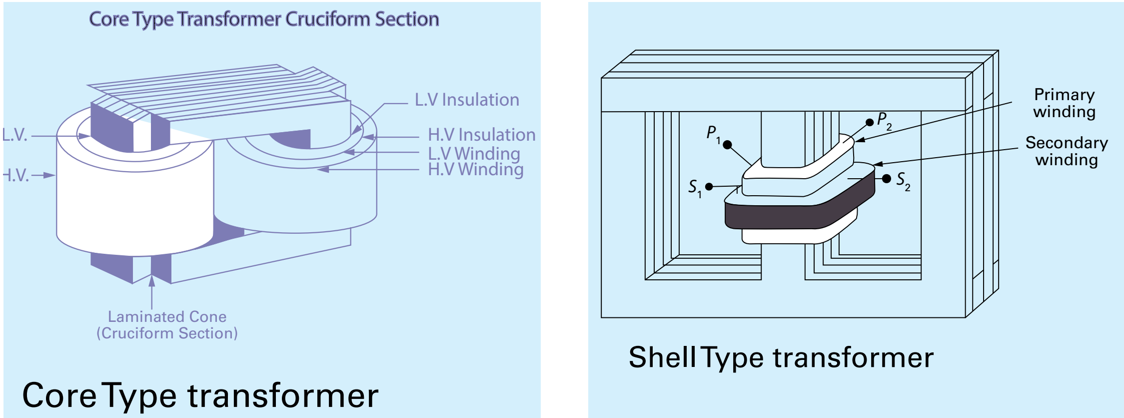


Figure B-2.3:

Based on Nature of Supply

- Single phase transformers.
- Three phase transformers

Based on the type of cooling these are classified into

- Self-air cooled transformer
- Air blast cooled transformer
- Oil filled self-cooled transformer
- Oil filled water cooled transformer
- Oil filled forced oil cooled transformer

Based on Use

- Power transformer
- Distribution transformer
- Instrument transformer

Autotransformer

Auto Transformers are used in applications where there is no requirement for electrical insulation between input and output windings. These are popular for many industrial automation and marine applications.

Autotransformer Types:

There are 3 general types of autotransformers categorized on the basis of the use of autotransformer:

- Step Up Autotransformer
- Step Down Autotransformer
- Variable Autotransformer

1) Step Up Autotransformer:

In this type of autotransformer input voltage is stepped up to the desired voltage and output voltage will depend on the turn ratio of the auto transformer.

2) Step Down Autotransformer:

Construction is same for both step up and step down autotransformer but in this configuration primary voltage is high and secondary voltage is low that's why it is called step down transformer.

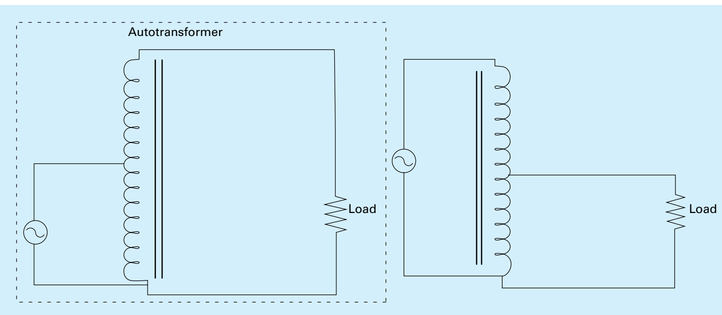


Figure B-2.4: Step Up Transformer Step Down Transformer

3) Variable Autotransformer (Variac or Dimmer Set):

Fixed turn ratio auto transformers are widely used for many applications but sometimes it is required to have variable output voltage capability. Such transformers are very useful because they can be adjusted to any required voltage by just rotating the knob. They can be used in the place of step up and step down auto transformer.

Figure B-2.5:

Electromechanical Relay

Relays can be used for switching as well as protection application. A relay is used to switch a circuit such that current through it can be diverted from present circuit to another. This switching operation can be performed either manually or automatically. Manual operation for switching a relay is performed through push buttons and other conventional switches. In most of the cases control circuit output drives the relay for automatic operation.

Figure B-2.6:

In Attracted type electromagnetic relay(common in use for voltage stabilizers), armature is attracted towards the electromagnet or armature through a plunger is drawn into a solenoid. It works on the principle of electromagnetic attraction. The electromagnetic force experienced on the armature or plunger is proportional to the square of the current or the square of the magnetic flux in the air gap. These are again classified into several types such as hinged armature type, plunger type, balanced beam type, moving coil type and reed type relays.

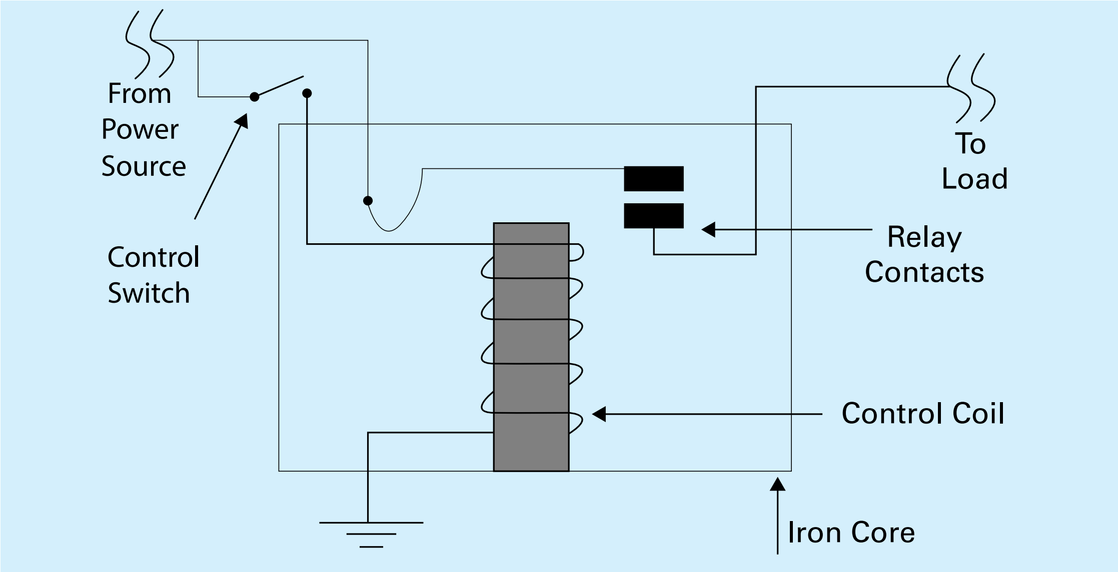


Figure B-2.6:

Relay Contact Types

Relays come in a variety styles, configurations, sizes and technologies. Depends on the application, suitability of the relay is considered. Basically, a relay has three contacts which are necessary to connect the two circuits but the way these contacts are configured or switching action of the contacts, relays are classified into different types.

Depends on the poles and throws, relays are classified into

- Single pole single throw
- Single pole double throw
- Double pole single throw
- Double pole double throw

By considering the above relay contact concepts, we can obtain the relays with NO and NC contacts for various switching operations as shown in below figure.

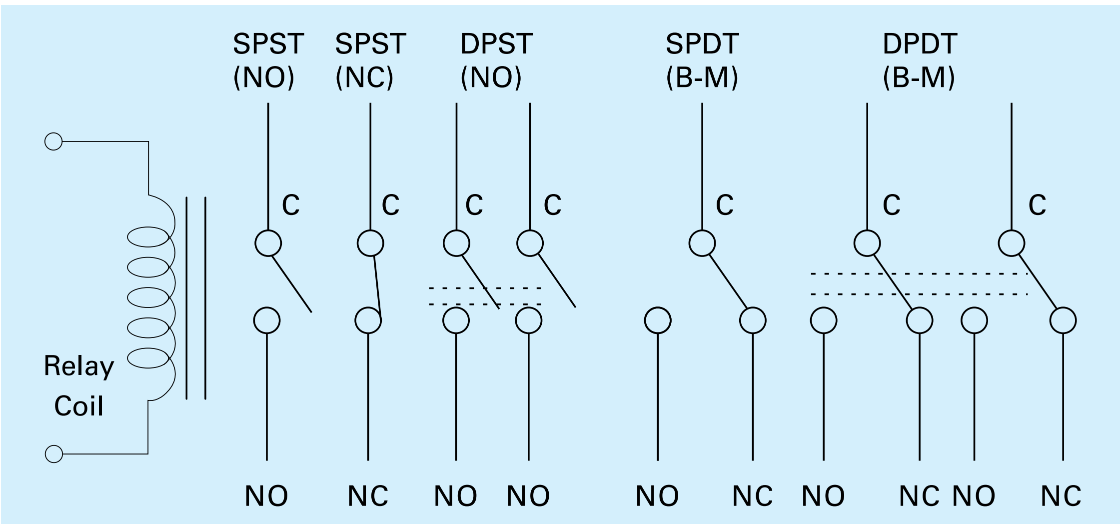


Figure B-2.7:

Miniature Circuit Breaker

Figure B-2.8:

MCBs or Miniature Circuit Breakers are electromechanical devices which protect an electrical circuit from an over current. The over current, in an electrical circuit, may result from short circuit, overload or faulty design. An MCB is a better alternative to a Fuse since it does not require replacement once an overload is detected. Unlike fuse, an MCB can be easily reset and thus offers improved operational safety and greater convenience without incurring large operating cost.

Working Principle

There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current.

The thermal operation of miniature circuit breaker is achieved with a bimetallic strip whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts.

But during short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts. This is a simple explanation of miniature circuit breaker working principle.

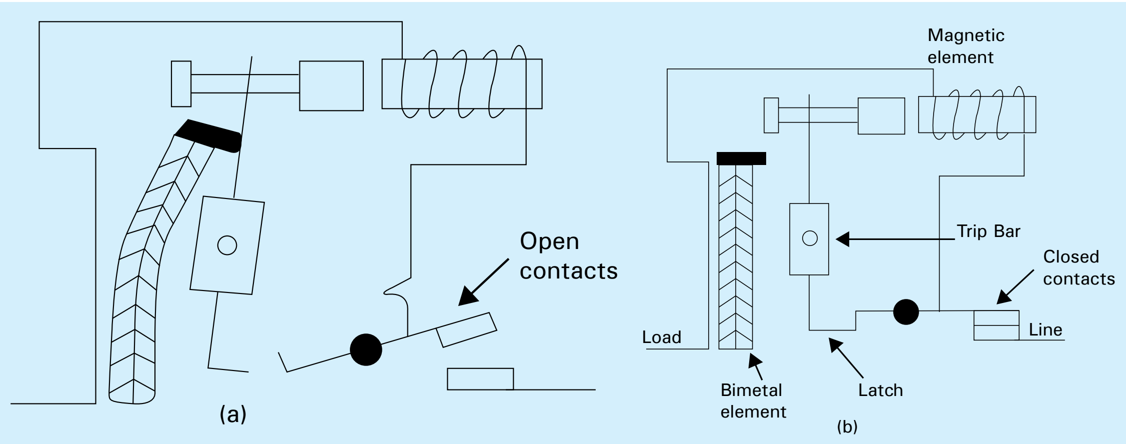


Figure B-2.9:

Construction

Miniature circuit breaker construction is very simple, robust and maintenance free. Generally a MCB is not repaired or maintained, it just replaced by new one when required. A miniature circuit breaker has normally three main constructional parts. These are:

- Frame of Miniature Circuit Breaker
- Operating Mechanism of Miniature Circuit Breaker
- Trip Unit of Miniature Circuit Breaker

This section covers the insight of a single pole MCB commonly used in the house hold. The following image shows the different internal parts of an MCB with top casing removed.

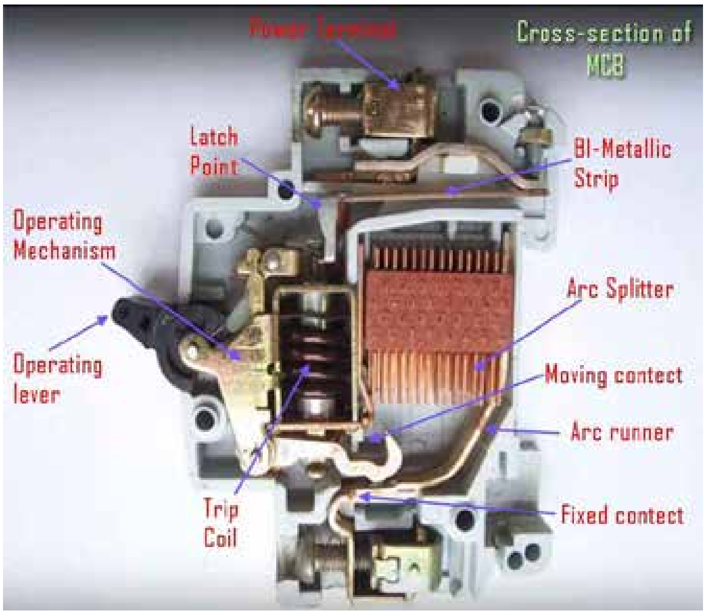


Figure B-2.10:

Application

MCBs are popularly used for load break, protection and isolation of a sub-circuit including motor sub-circuits, lighting circuits and control circuits. The main usage area of MCBs is LV side, i.e., mainly in domestic, light-industrial or commercial applications. These are manufactured in 1, 2, 3, and 4 pole versions of different current and voltage ratings.

Notes

Electronic Components

Electronic components are basic electronic element or electronic parts usually packaged in a discrete form with two or more connecting leads or metallic pads.

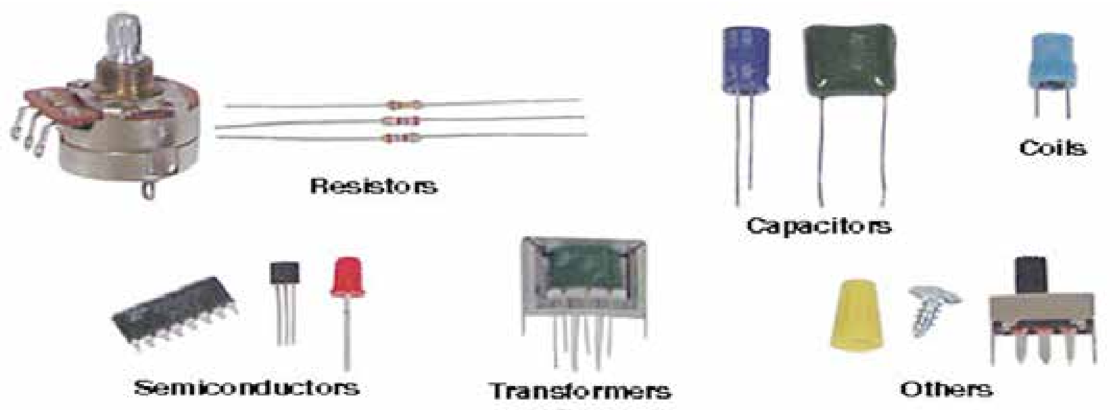


Figure B-2.11:

Electronic Component are intended to be connected together, usually by soldering to a printed circuit board (PCB), to create an electronic circuit with a particular function (for example an amplifier, radio receiver, oscillator, wireless). Some of the main Electronic Components are: resistor, capacitor, transistor, diode, operational amplifier, resistor array, logic gate etc. Electronic components, **both active and passive**, is lifeline of any printed circuit assembly. They both play vital roles in the functioning of any electronic device. Electronic Components are intended to be connected together, **usually by soldering to a printed circuit board (PCB), to create an electronic circuit with a particular function**.

Most electronic equipment and products have circuit boards. Printed circuit board (PCB / PWB), is a board made out of non-insulating and highly heat-resistant insulating material such as fiberglass. These boards are also called substrates.(refer below fig.)A PCB substrate may have only one single layer (single-layer circuit board) or more than one layer (multilayer circuit board).

Figure B-2.12:

A conductive metal such as copper is used to make conductive pathway or traces to facilitate flow of electricity. Once PCB itching is done, it is termed as a "printed circuit board".

Here is a list of Electronic Component name abbreviations widely used in the electronics industry:

AE: aerial, antenna	**R:** resistor
B: battery	**RLA:** RY: relay
BR: bridge rectifier	**SCR:** silicon controlled rectifier
C: capacitor	**FET:** field effect transistor
CRT: cathode ray tube	**MOSFET:** Metal oxide semiconductor field effect transistor
D or CR: diode	**TFT:** thin film transistor(display)
F: fuse	**VLSI:** very large scale integration
GDT: gas discharge tube	**DSP:** digital signal processor
IC: integrated circuit	**SW:** switch
J: wire link	**T:** transformer
JFET: junction gate field-effect transistor	**TH:** thermistor
L: inductor	**TP:** test point
LCD: Liquid crystal display	**Tr:** transistor
LDR: light dependent resistor	**U:** integrated circuit
LED: light emitting diode	**V:** valve (tube
LS: speaker	
M: motor	**VC:** variable capacitor
MCB: Miniature circuit breaker	**VFD:** vacuum fluorescent display
Mic: microphone	**VR:** variable resistor
Ne: neon lamp	**X:** crystal, ceramic resonator
OP: Operational Amplifier	**XMER:** transformer
PCB: printed circuit board	**XTAL:** crystal
PU: pickup	**Z:** zener diode
Q: transistor	

Table: Electronic Component its Abbreviations

Commonly used Electronic Components and Their Functions

1. **Resistors:** Components used to resist current.
2. **Capacitors:** Components that store electrical charge in an electrical field.
3. **Diodes:** Components that conduct electricity in only one direction.
4. **Transistors:** A semiconductor device capable of amplification.
5. **Semiconductors:** Electronic control components with no moving parts.
6. **Integrated Circuits or ICs:** A microelectronic computer electronic circuit incorporated into a chip or semiconductor; a whole system rather than a single component
7. **Magnetic or Inductive Components:** These are Electrical components that use magnetism.
8. **Network Components:** Components that use more than 1 type of Passive Component.

9. **Piezoelectric devices, crystals, resonators:** Passive components that use piezoelectric. effect.

10. **Terminals and Connectors:** Components to make electrical connection.

11. **Switches:** Components that may be made to either conduct (closed) or not (open).

12. **Below given brief information for someof the components,which we generally come across, especially dealing with voltage stabilizers...........**

Resistor

The resistor is an electrical component which creates a resistance in the flow of electric current.In other words, A Resistor is an electrical device that resists the flow of electrical current. It is a passive device used to control, or impede the flow of, electric current in an electric circuit by providing resistance, thereby developing a drop in voltage across the device.

Standard Resistor Symbols

The symbol used in schematic and electrical drawings for a Resistor can either be a "zig-zag" type line or a rectangular box.

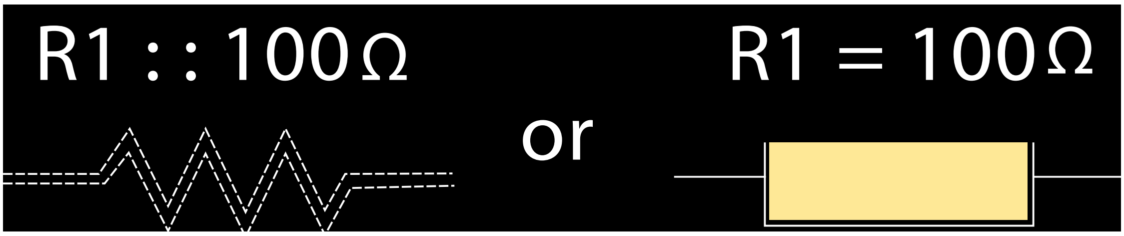


Figure B-2.13:

All modern fixed value resistors can be classified into following broad groups;

1. Composition Types of Resistor

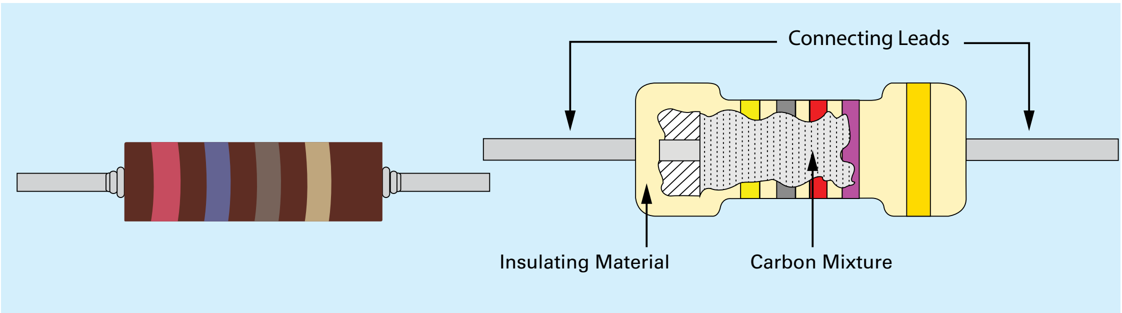


Figure B-2.14:

Carbon Resistor

Carbon Resistors are the most common type of Composition Resistors.

The main advantage of carbon resistors is that they are easily available at very low cost at all local vendors and the durability is good. The only disadvantage is that they are very sensitive to temperature. Due to its low cost, they are used in circuits where cost is a criterion rather than the performance.

2.Film or Cermet Resistor

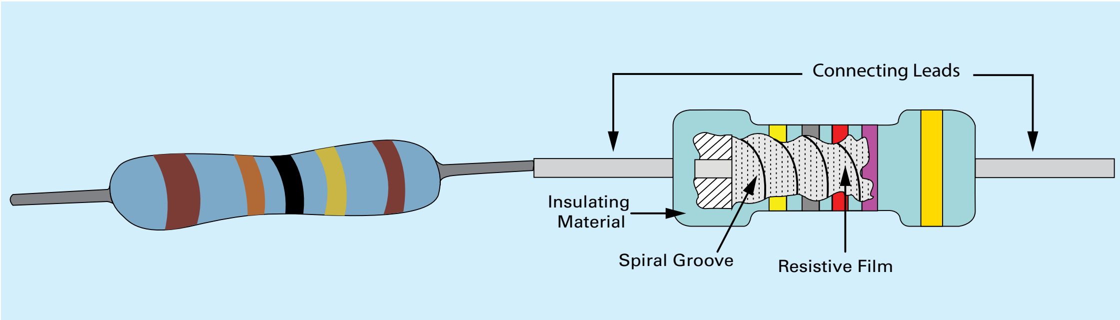


Figure B-2.15:

Film Resistor

The generic term "Film Resistor" consist of Metal Film, Carbon Film and Metal Oxide Film resistor types, which are generally made by depositing pure metals, such as nickel, or an oxide film, such as tin-oxide, onto an insulating ceramic rod or substrate.

These are made from conductive metal oxide paste& have very low wattage values.

The resistive value of the resistor is controlled by increasing the desired thickness of the deposited film giving them the names of either "thick-film resistors" or "thin-film resistors".

3.Wire wound Types of Resistor

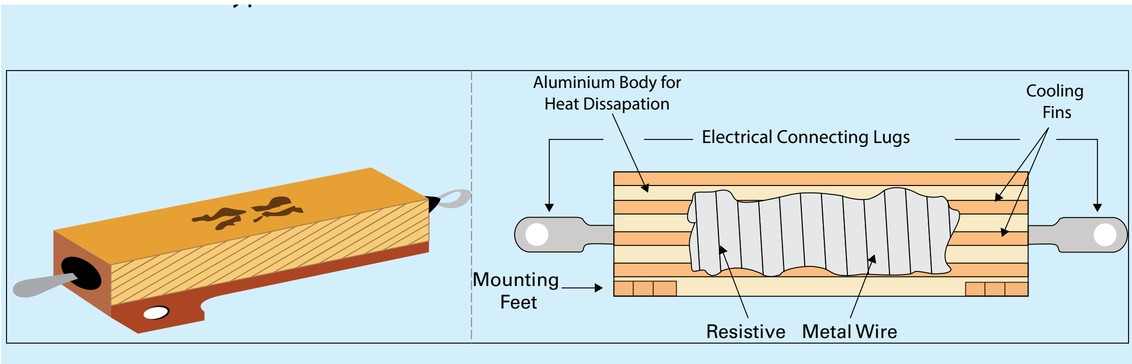


Figure B-2.16:

Wire wound Resistor

Another type of resistor, called a Wirewound Resistor, is made by winding a thin metal alloy wire (Nichrome) or similar wire onto an insulating ceramic former in the form of a spiral helix similar to the film resistor above. These are Metallic bodies for heatsink mounting and with very high wattage ratings. These types of resistor are generally only available in very low ohmic high precision values (from 0.01 to 100kΩ) due to the gauge of the wire and number of turns possible on the former making them ideal for use in measuring circuits and Whetstone bridge type applications.

Resistance Units

Resistance R = V/I

This results in the units of resistance as volts per ampere. This combination is given a special name called Ohm named after the physicist Georg Simon Ohm.

i.e.1Ω = 1 volt per ampere.

Resistance value can also be given as$R = (\rho \times L) / A$.

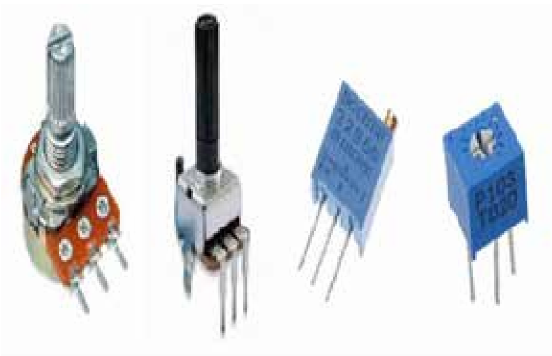
'L'is a length of material in meters and 'A' is the area of cross section in m2,whereas 'ρ' is specific Resistivity is the measure of a conductors' ability to resist the flow of electric current.

Resistance to the of the material is directly proportional to the length 'L' and inversely proportional to area of cross section 'A'.

Elements like copper, aluminum will have low resistivity. Units of resistivity are Ohm-meter (Ω-mt).

Potentiometer

Potentiometers are used in circuits, when it is necessary to alter the resistance. Dark/light and temperature sensors usually have these components, as the potentiometer / variable resistor allows the circuit to be made more or less sensitive (they can be turned up or down - reducing or increasing resistance).



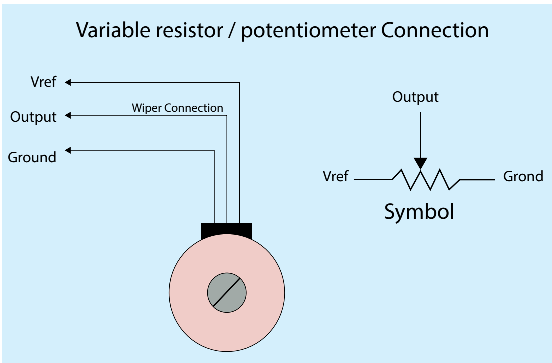


Figure B-2.17:

Potentiometers are variable resistors and they function to alter their resistance via a knob or dial. Potentiometers have a range of resistance. It can be attuned from zero ohms to whatever maximum resistance that is specific to it. For example, a potentiometer of 10 kΩ can be adjusted from 0 Ω to its maximum of 10 kΩ.

All potentiometers have three pins. The outer pins are used for connecting power source (Vref and gnd). The middle pin (output) gives us the variable of resistance value.

Capacitor

Capacitor is also known as condenser. This is one of the passive components like resistor. Capacitor is generally used to store the charge. In capacitor the charge is stored in the form of "electrical field".

There are different types and different shapes of capacitors available, from very small capacitors which are used in resonance circuits to large capacitors for stabilizing HVDC lines. But all capacitors are doing the same work that is storing the electrical charge.

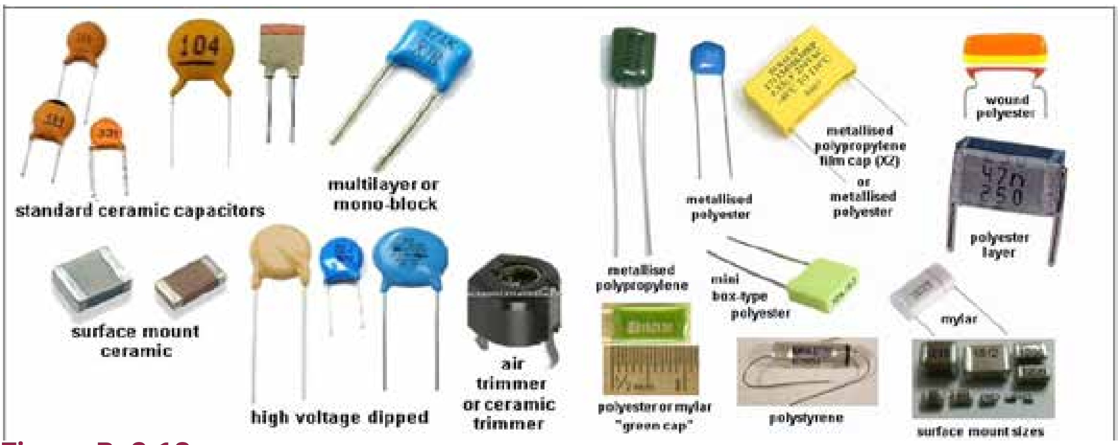


Figure B-2.18:

The shape of a capacitor is rectangular, square, circular, cylindrical or spherical shape. Unlike a resistor, an ideal capacitor does not dissipate energy. As the different types of capacitors are available different symbols were available to represent them which are shown below.

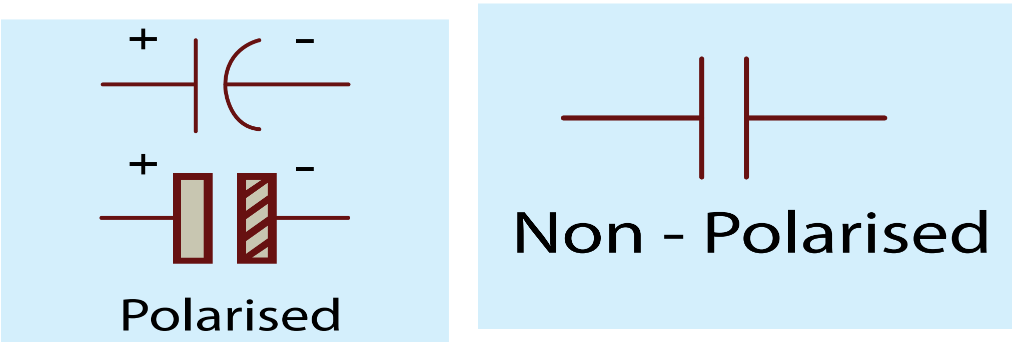


Figure B-2.19:

CAPACITOR VALUES

Capacitance can be expressed Farads (F) which is named after English physicist Michael Faraday.

Generally Farads is a high value so, capacitance is expressed as sub units of capacitor real time such as as micro farads(uF) , nano farads(nF) and pico farads(PF).

Most of the electrical and electronic applications are covered by the following standard unit (SI) prefixes for easy calculations,

1 mF (milli farad) = 10^{-3} F = 1000 μF = 1000000 nF

1 μF (microfarad) =10^{-6} F = 1000 nF = 1000000 pF

1 nF (nano farad) = 10^{-9} F = 1000 pF

1 pF (picofarad) = 10^{-12} F

Pico Farads (pF)	Nano Farads (nF)	Micro Farads (μF)
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1
10,000,000	10,000	10
100,000,000	100,000	100

Table: Chpacitor Values

Voltage Rating of a Capacitor

This is not voltage until which the capacitor charges but the maximum voltage until which the capacitor can operate safely. This voltage is called as working voltage (WV) or DC working voltage (DC-WV).

Below figure shows the voltage rating of the capacitor.

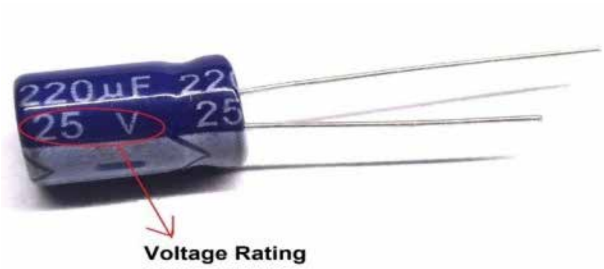


Figure B-2.20:

If the capacitor is applied with voltage greater than this voltage, it may be damaged by producing an arc between the plates due to dielectric break down.

Diode

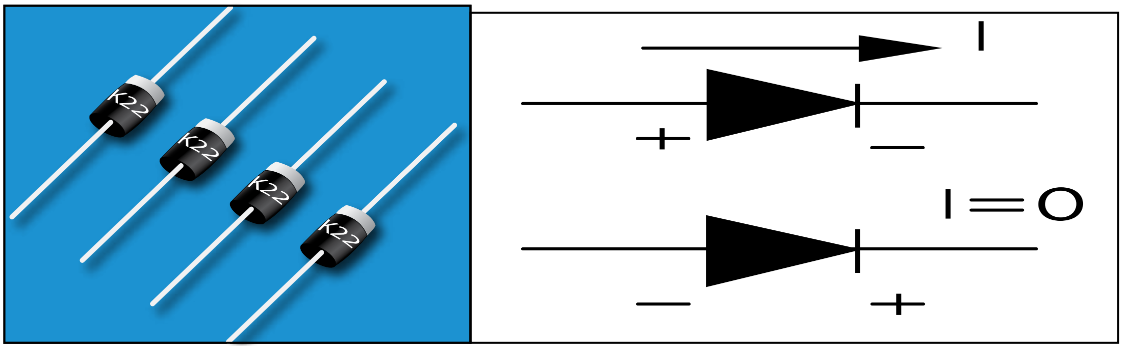


Figure B-2.21:

Diodes are electronic components functions as a one-way valve it means it allow current to flow in one direction. These diodes are manufactured by the semiconductor materials germanium, silicon and selenium. Operation of diode can be classified in two ways, if it allows the current then it is forward biased otherwise it is reverse biased. This device can be operated by controlling the voltage applied to it.

There are many types of diodes, but here few discussed only, which are common in use with voltage stabilizers

P-N Junction Diode

PN junction diode is a diode which can be used as a rectifier, logic gate, voltage stabilizer, switching device, voltage dependent capacitor and in optoelectronics as a photodiode, light-emitting diode (LED), laser diode, Photo detector or solar cell in electronics.

Zener Diode

It is a passive element works under the principle of zener breakdown.It is similar to normal diode in forward direction, it also allows current in reverse direction when the applied voltage reaches the breakdown voltage. It is designed to prevent the other semiconductor devices from momentary voltage pulses. It acts as voltage regulator.

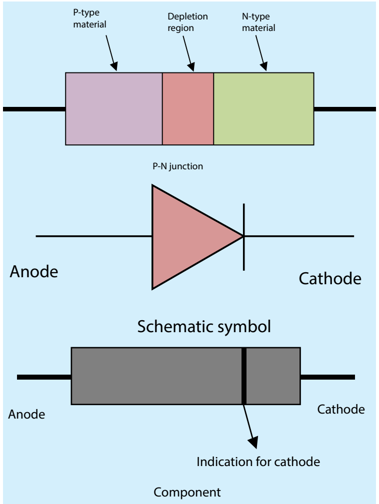


Figure B-2.22:

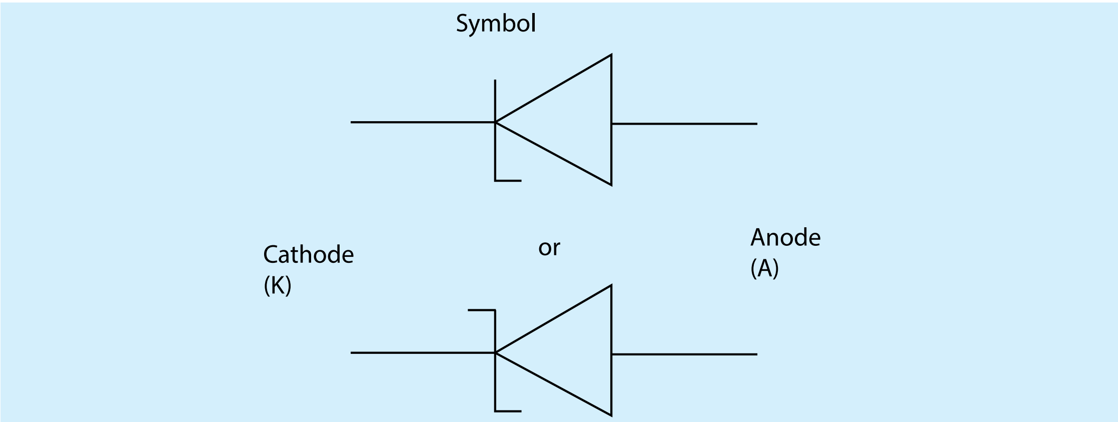


Figure B-2.23:

Light Emitting Diode (LED)

Light Emitting Diodes (LEDs) are diodes that produce light when current flows from anode to cathode. The LED does not emit light when it is revered-biased. It is used as a low current indicator in many types of consumer and industrial equipment, such as monitors, TV's, printers, hi-fi systems, machinery, aviation lighting, traffic signals, camera flashes and control panels.

The light produced by a LED can be visible, such as red, green, yellow or white. It can also be invisible and these LEDs are called Infrared LEDs.

An LED needs about 2v - 3.6v across its leads to make it emit light, but this voltage must be exact for the type and colour of the LED. The simplest way to deliver the exact voltage is to have a supply that is higher than needed and include a voltage-dropping resistor. The value of the resistor must be selected so the current is between 2mA and 25mA.

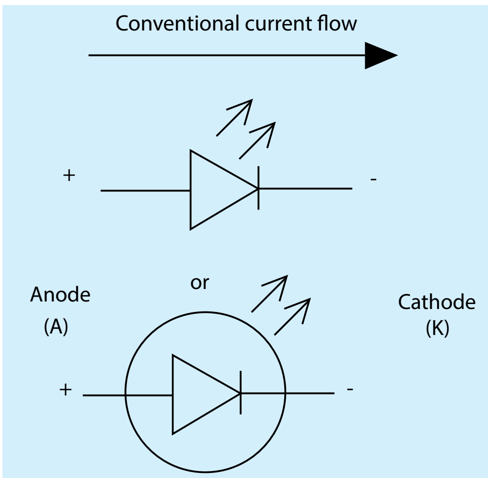


Figure B-2.24:

Diode Applications:

As a simplest semiconductor component, diode has a wide variety of applications in modern electronic systems. The following description describes the various applications of diodes briefly.

1. Diode as a Rectifier
2. Diode in clipping circuit
3. Diode in clamping circuit
4. Diode in logic gates
5. Diode in voltage multiplier circuit
6. Diode in reverse current protection
7. Diode in Voltage Spike Suppression
8. Diode in Solar Panels

Transistor

All transistors have three leads. Base (b), Collector (c), and Emitter (e).

For an NPN transistor, the arrow on the emitter points away from the base.

It is fortunate that the arrow on both symbols points in the direction of the flow of current (Conventional Current) and the symbols have been drawn exactly as they appear on a circuit diagram.

A transistor is a semiconductor device. It is the fundamental building block of the circuitry in several other electronic devices. A transistor has very fast response and is used in a number of functions including voltage regulation, amplification, switching, signal modulation, and oscillators. Transistors may be packaged individually or they can be a part of an integrated circuit. Some of the ICs have billions of transistors in a very small area.

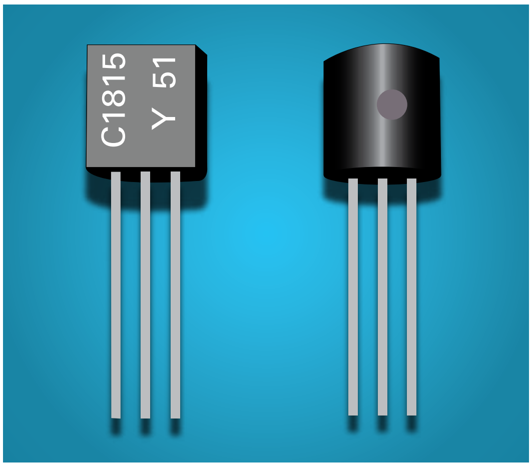


Figure B-2.25:

Generally, transistor is made of solid material which contains three terminals such as emitter (E), Base (B) and Collector (C) for connections with other components in the circuit. Some transistors contain fourth terminal also i.e. substrate (S). Transistor is one of the active components.

Earlier vacuum tubes are replaced with transistors because the transistors have more benefits over vacuum tubes. Transistors are small in size and it requires low voltage for operation and also it has low power dissipation. Due to these reasons the transistor is used in many applications such as amplifiers, switching circuits, oscillators and also in almost all electronic circuits.

Transistor Symbols:

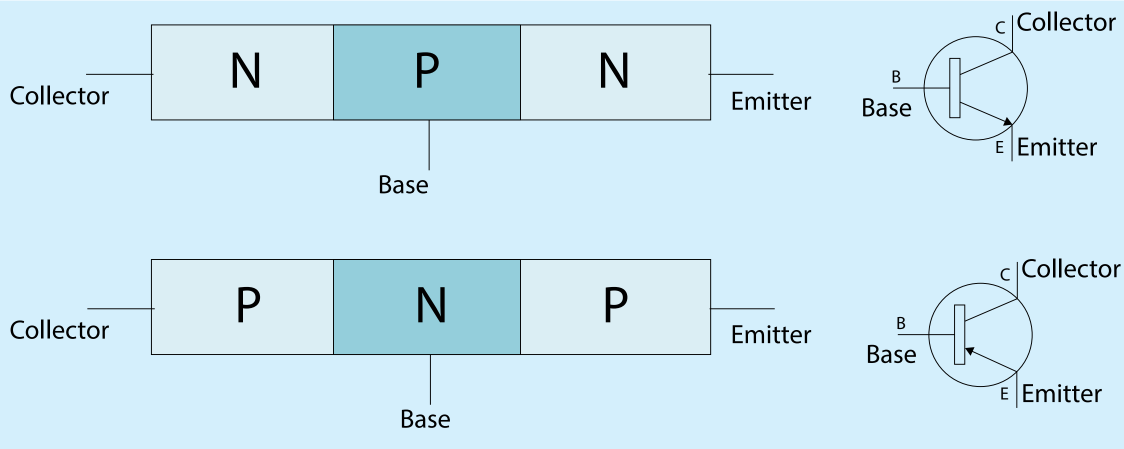


Figure B-2.26:

Easy way to remember these transistor symbols is that

PNP-Points in Permanently

NPN-Never Points in

In the symbol of a transistor the arrow indicates the direction of the current flow.

Operation Modes of the Transistor

There are four modes of operations................

Saturation Mode: In this mode transistor acts as a switch. From collector to emitter the current will flow unconditionally (short circuit). Both diodes are in state of forward biased.

Cut-off Mode: In this mode also transistor acts like a switch but there is no current flow from collector to emitter (open circuit). There is no current flow through both emitter and collector terminals.

Active Mode: In this mode the transistor acts like an amplifier that is the current from the collector terminal to emitter terminal is corresponding to the current through the base terminal. Base will amplify the current moving into the collector terminal and outgoing from the emitter terminal.

Reverse active Mode: The current from the collector terminal to emitter terminal is corresponding to the current through the base terminal but this flow is in reverse direction.

Transistors Classification and Types

From the time of first transistor invention to present days the transistors are classified into different types depending on either construction or operation, they are explained using tree diagram as below.

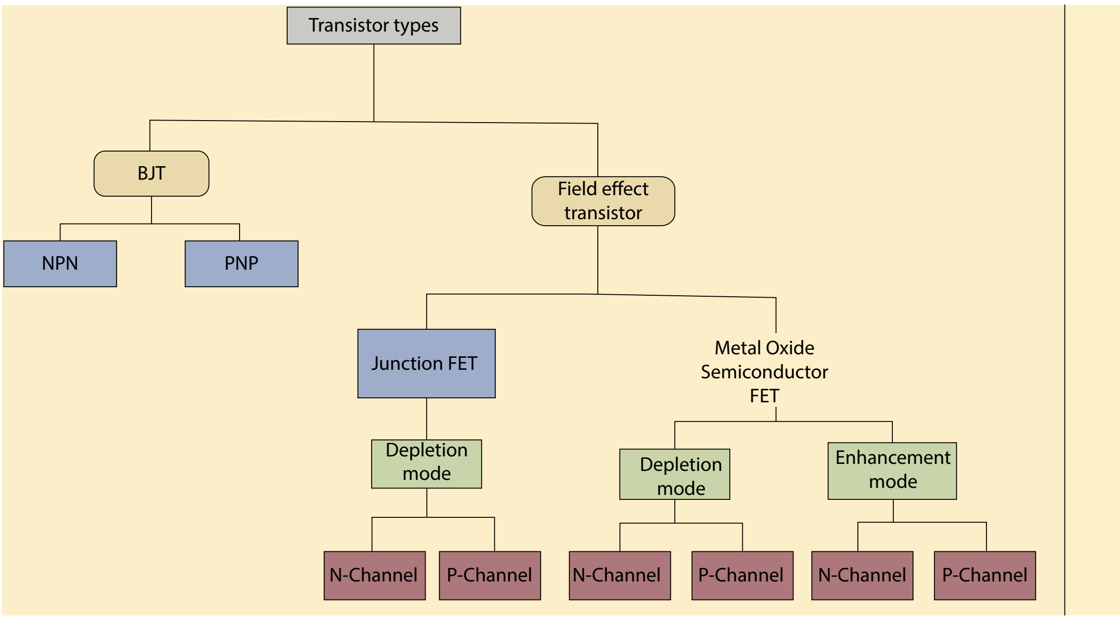


Figure B-2.27:

1.LM 339

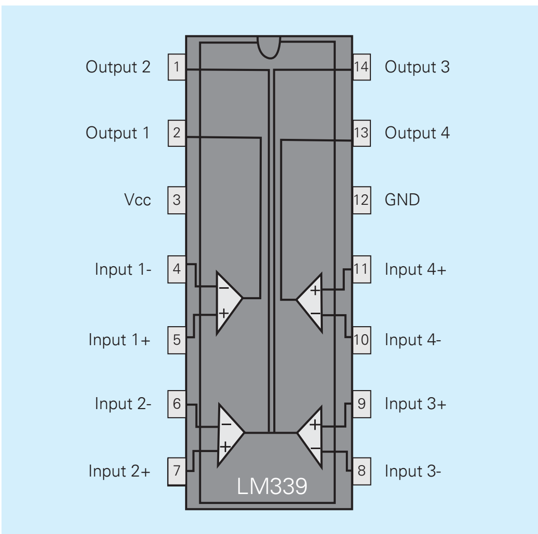
ICs (Integrated Circuits)

Integrated Circuits play a very important part in electronics. Most are specially made for a specific task and contain up to thousands of transistors, diodes and resistors. Some of the simple Integrated Circuits are shown in figure

Integrated Circuits are package of several complex circuits. ICs are available in a wide variety of packages and sizes. Their applications are as varied as their packages.

ONE FIG IN EARLIER MODULE HAS BEN MISSED OUT HERE

Depending on the way they are manufactured, integrated circuits can be divided into two groups: hybrid and monolithic. The pin-out for some of the common packages is shown in Figure



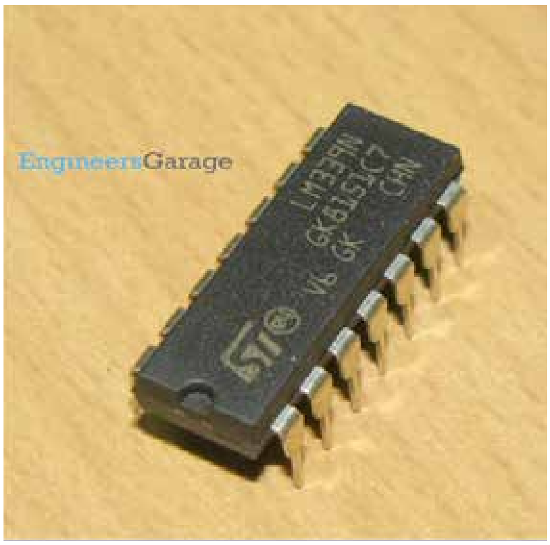
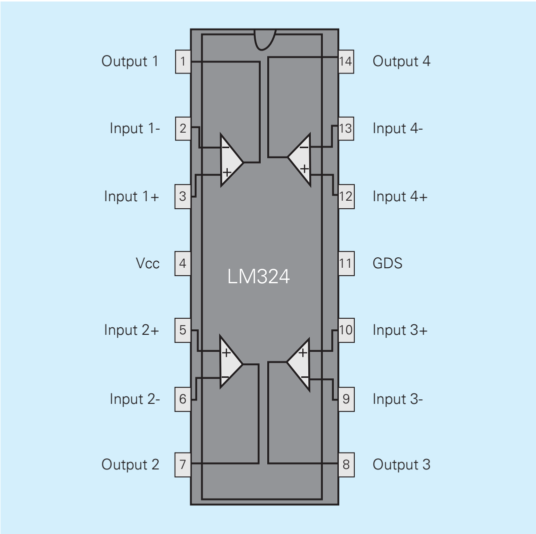


Figure B-2.28:

LM339 is a comparator IC with four inbuilt comparators. A comparator is a simple circuit that moves signals between the analog and digital worlds. It compares two input voltage levels and gives digital output to indicate the larger one.

2. LM 324



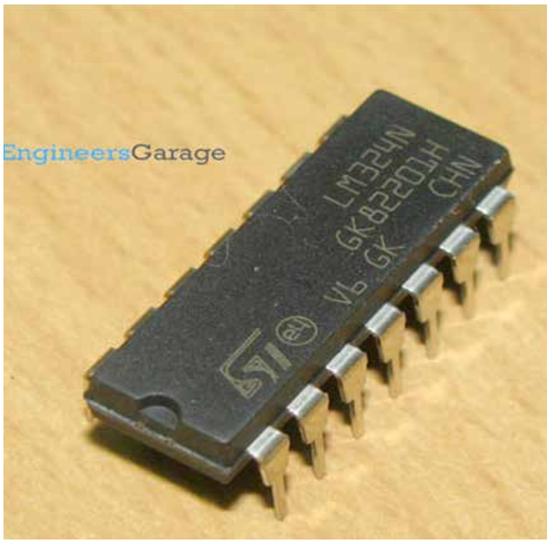
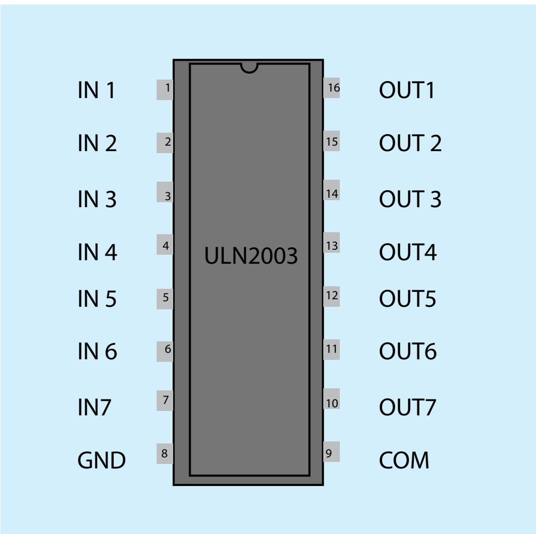


Figure B-2.29:

LM324 is a 14pin IC consisting of four independent operational amplifiers (op-amps) compensated in a single package. Op-amps are high gain electronic voltage amplifier with differential input and, usually, a single-ended output. The output voltage is many times higher than the voltage difference between input terminals of an op-amp.

3. ULN2003



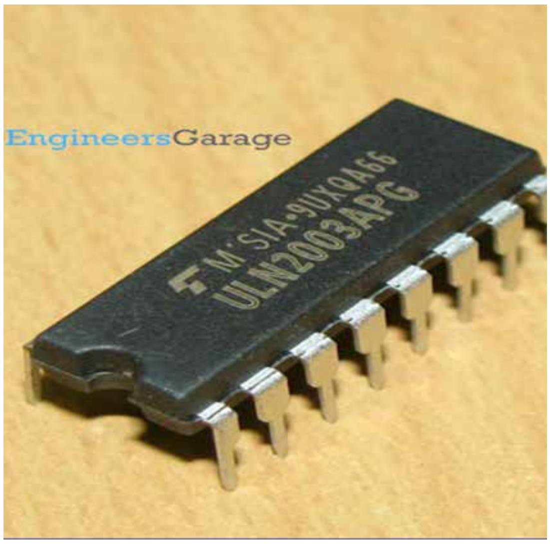


Figure B-2.30:

ULN 2003 is a high voltage and high current Darlington array IC. It contains seven open collector darlington pairs with common emitters.

These ICs are used when driving a wide range of loads and are used as relay drivers, display drivers, line drivers etc.

Operational Amplifier

An operational amplifier commonly known as op-amp is a two-input single-output differential voltage amplifier which is characterized by high gain, high input impedance and low output impedance.

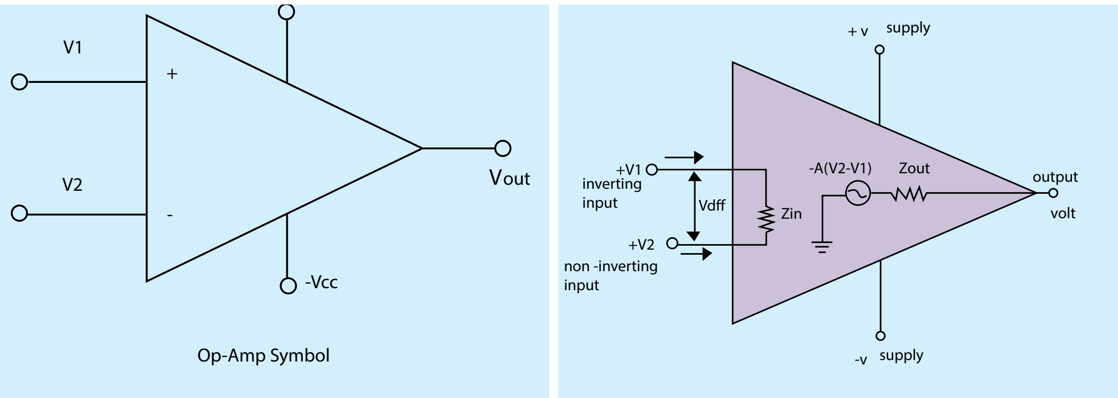


Figure B-2.31:

Op-Amp Symbol
Equivalent circuit of an ideal Op-Amp

Because of their versatile uses Op-amps are used in conjunction with resistors and capacitors to build functional circuits such as Inverting, Non-inverting, voltage following, summing, subtracting, integrating and differentiating type amplifiers.

4. Regulator IC 7805

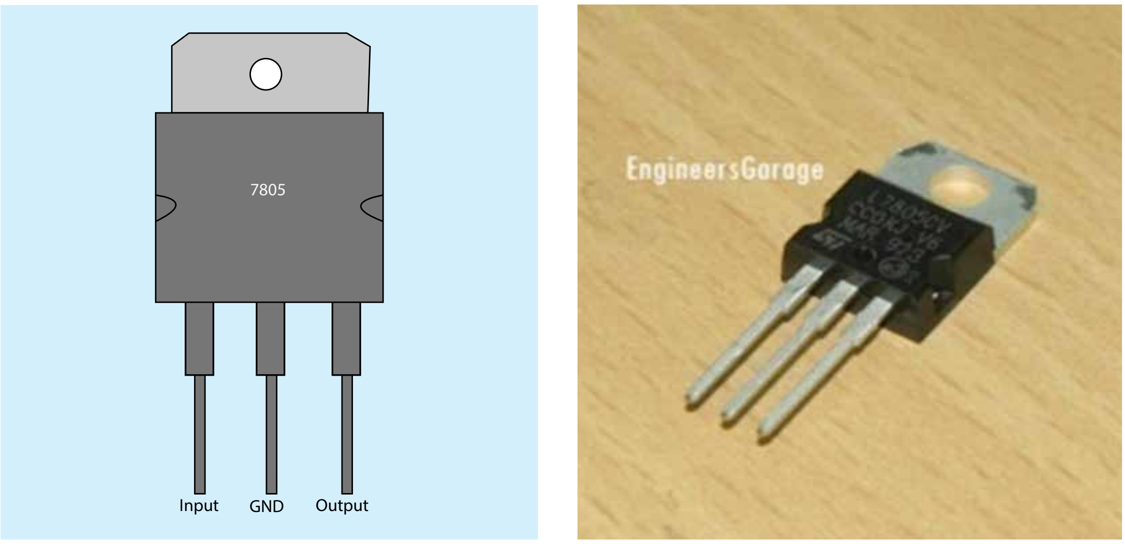
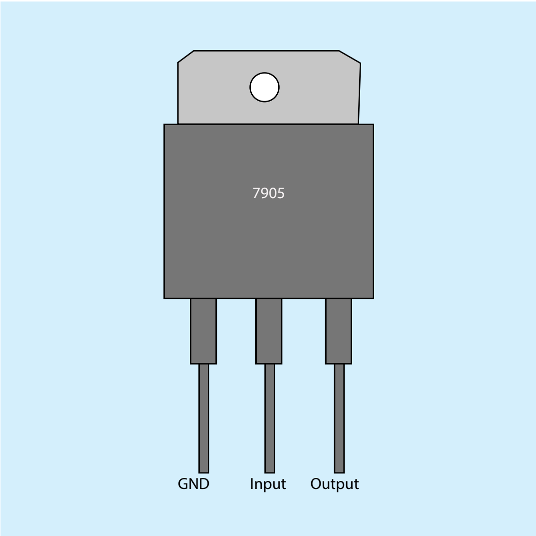


Figure B-2.32:

7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805 provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

5. Regulator IC 7905



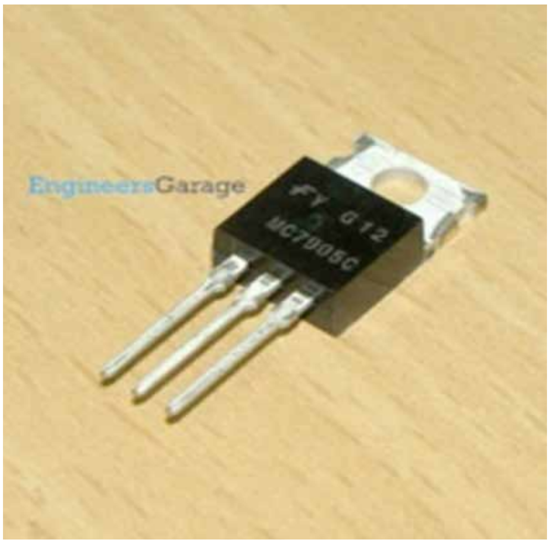


Figure B-2.33:

7905 is a voltage regulator integrated circuit. It is a member of 79xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7905 provides a regulated supply of -5 V and 1A current. Its additional features include internal thermal overload protection, short circuit protection and output transistor safe operating area compensation.

6.IC 555

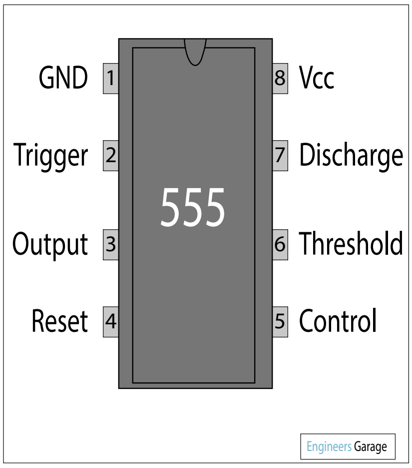


Figure B-2.34:

IC 555 timer is a one of the most widely used IC in electronics and is used in various electronic circuits for its robust and stable properties. It works as square-wave form generator with duty cycle varying from 50% to 100%, Oscillator and can also provide time delay in circuits. The 555 timer got its name from the three 5k ohm resistor connected in a voltage-divider pattern.

3

SECTION

Electronic Circuits

Definition

Electronic circuit category

Commonly used Electronics Circuits for Voltage Stabilizer

Electronic Circuits

Definition

A Electronic Circuit may be defined as a collection of electronic elements that performs a prescribed function. It is an electrical circuit that also contains active electronic devices such as transistors or vacuum tubes.

Electronic circuits are categorized as............

- Analog circuits,
- Discrete circuits,
- Mixed-signal electronic circuit (a combination of analog and discrete).

Analog circuits:

Analog electronic circuits are those in which signals may vary continuously with time to correspond to the information being represented. Electronic equipment like voltage amplifiers, power amplifiers, tuning circuits, radios, and televisions are mainly analog.

The basic units of analog circuits are passive (resistors, capacitors and inductors) and active. There are two main types of circuits: series circuit and parallel circuit.

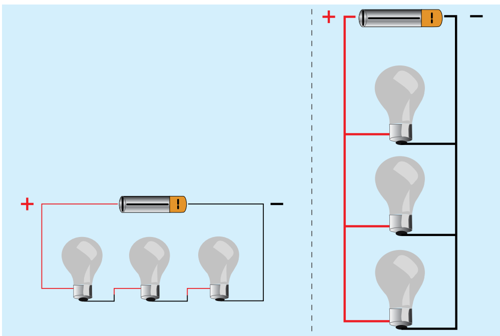


Figure B-3.1: Series Circuit Parallel Circuit

Discrete circuits:

In digital electronic circuits, electric signals take on discrete values, which are not dependent upon time, to represent logical and numeric values. These values represent the information that is being processed. The transistor is one of the primary components used in discrete circuits, and combinations of these can be used to create logic gates. These logic gates may then be used in combination to create a desired output from an input.

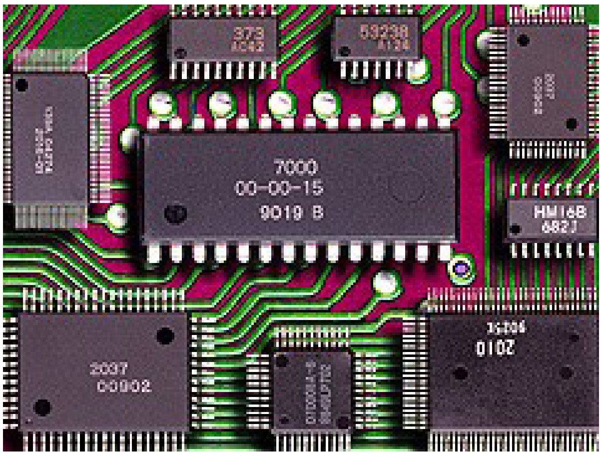


Figure B-3.2:

Mixed-signal circuits:

Mixed-signal, are also called hybrid circuits, contain elements of both analog and digital circuits. Examples of Mixed-Signal Circuits are - comparators, timers, PLLs, ADCs (analog-to-digital converters), and DACs (digital-to-analog converters).

Commonly used Electronics Circuits for Voltage Stabilizer

Power Supply

Many electronic circuits need a direct current (DC) voltage source, but what we commonly find are voltage sources of alternating current (AC).In order to achieve a direct current voltage source, the alternating current input must follow a conversion process.

The picture shows the operation of a voltage power supply using a block diagram.

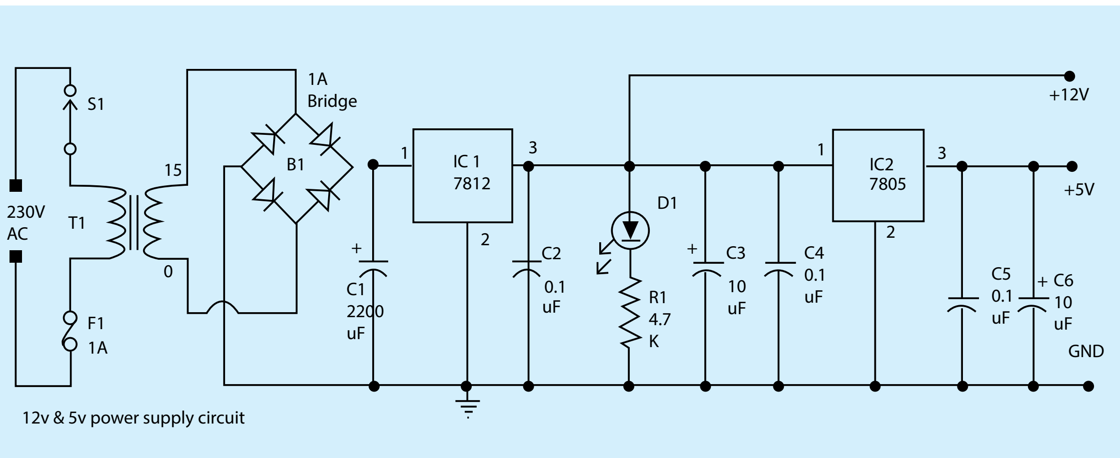


Figure B-3.3:

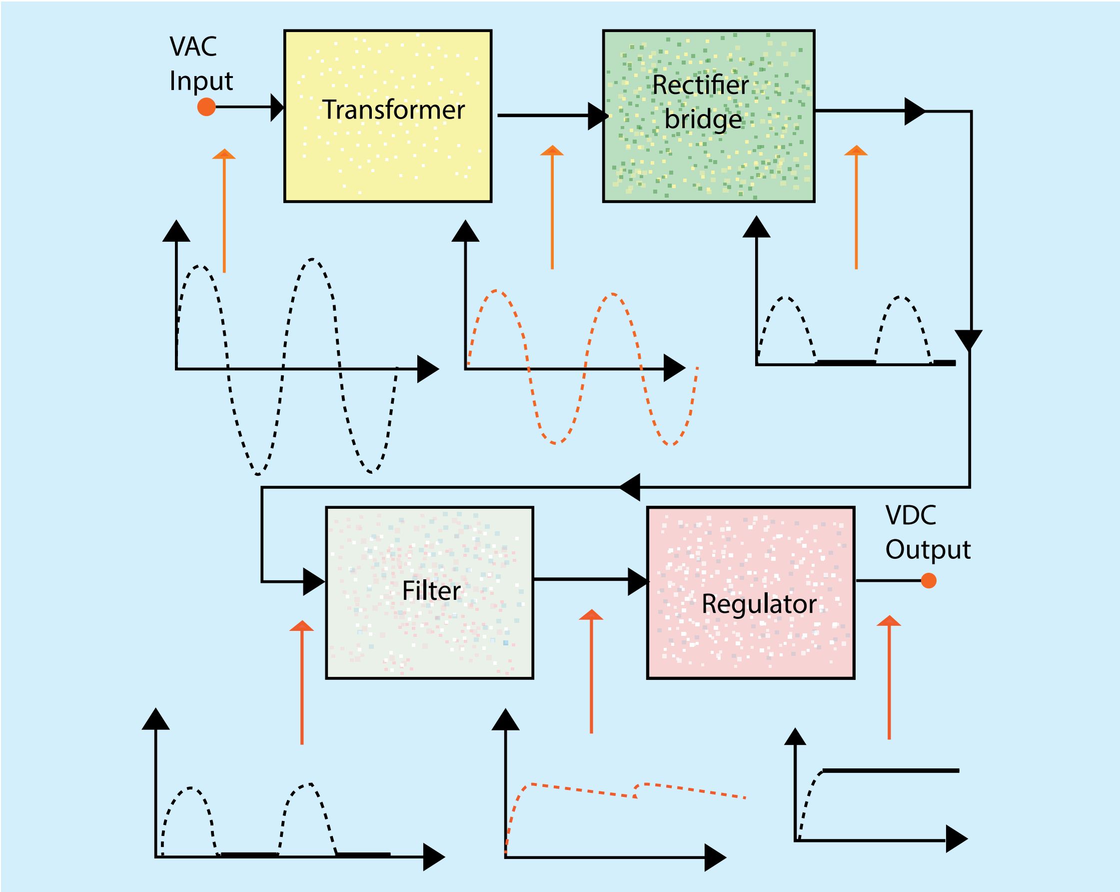


Figure B-3.4:

The Power Supply Circuit (pl refer above block diagram)

The Electrical Transformer

The electrical transformer receives on the primary winding an AC voltage and delivers on the secondary winding a different AC voltage (a lower one). This AC output voltage must be according to the DC voltage we want to obtain at the end.

The Rectifier

The rectifier transforms the secondary winding AC voltage into a pulsating DC voltage. (look at the picture).As we have noted when looking at the Elements of a Power Supply, the purpose of the rectifier section is to convert the incoming ac from a transformer or other ac power source to some form of pulsating dc.

However, all rectifier circuits may be classified into one of two categories, as follows:

Half-Wave Rectifiers

The simplest possible circuit for converting AC into DC is a half-wave rectifier. This circuit consists of a single diode that only allows current to flow in one direction. A possible circuit is shown below in figure.

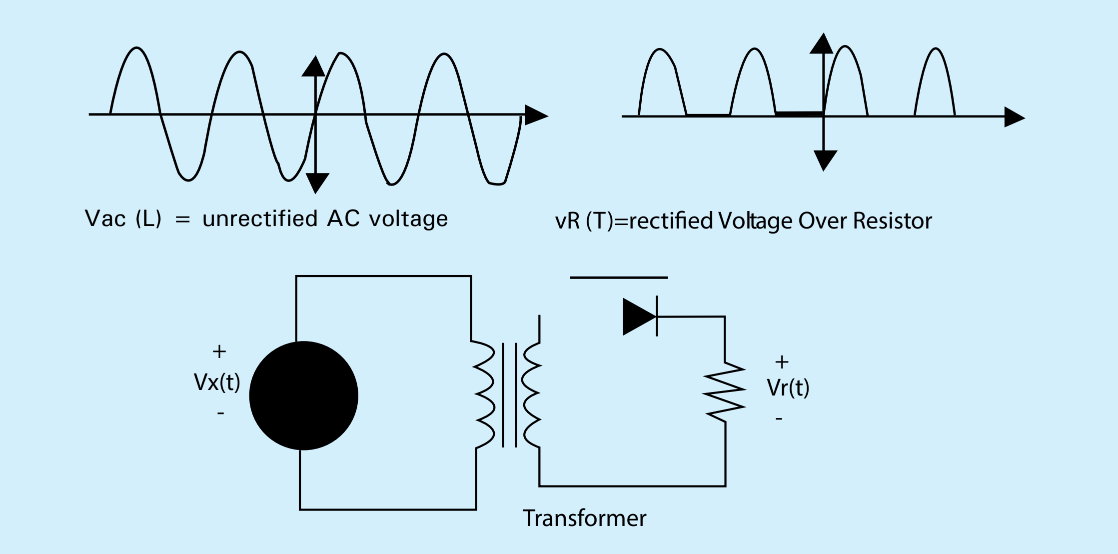


Figure B-3.5:

Full-Wave Rectifiers.

More common approach is to manipulate the incoming ac wave so that both halves are used to cause output current to flow in the same direction. Because these circuits operate on the entire incoming ac wave, they are known as full-wave rectifiers.

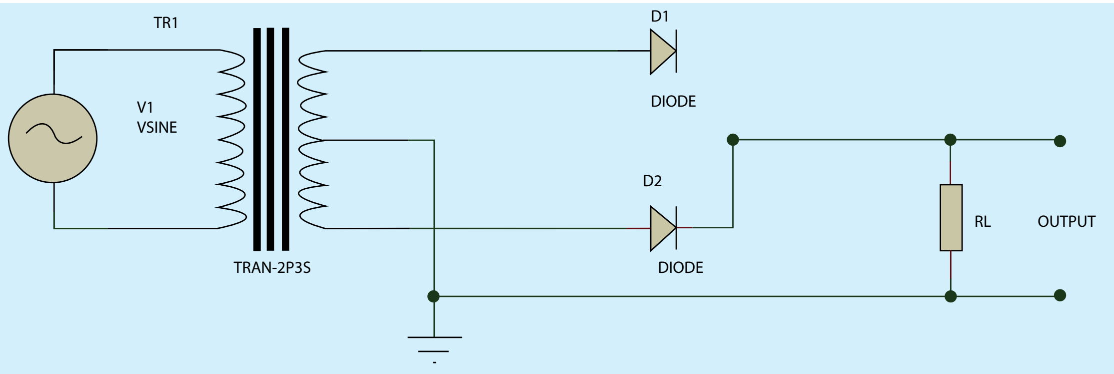


Figure B-3.6:

Full wave rectifier rectifies the full cycle in the waveform i.e. it rectifies both the positive and negative cycles in the waveform.

Notes

Full Wave Bridge Rectifier

In bridge rectifier four diodes are used. These are connected as shown in the following circuit diagram. The four diodes are connected in the form of a bridge to the transformer and the load as shown.

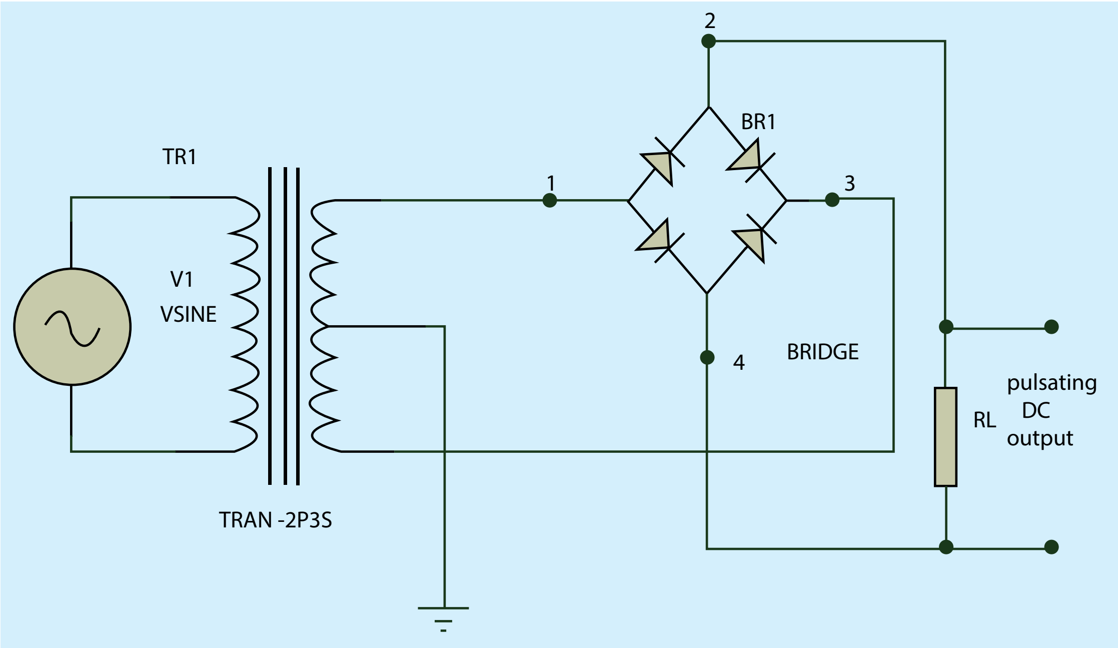


Figure B-3.7:

Filter

The filter, formed by one or more capacitors, flattens or smoothes the previous wave eliminating the alternating current (AC) component delivered by the rectifier. Electrical filter is a circuit, designed to reject all unwanted frequency components of an electrical signal and allows only desired frequencies.

These filters are mainly categorized into 2 types.

They are **Active filter & passive filter**

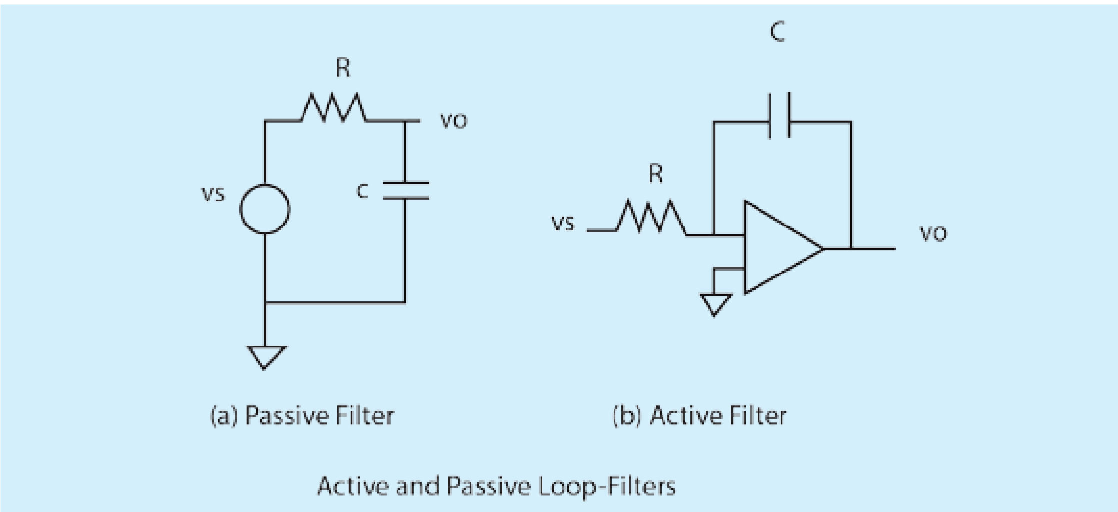


Figure B-3.8:

The Voltage regulator

The voltage regulator receives the signal from the filter and delivers a constant voltage regardless of the variations on the load or the voltage supply.

IC 7805 is a DC regulated IC of 5V. This IC is very flexible and is widely employed in all types of circuit like a voltage regulator. It is a three terminal device and mainly called input , output and ground. The use of 78XX series regulatoris shown in the diagram above.

Type number	Output voltage
7805	+5.0 V
7806	+6.0 V
7808	+8.0 V
7809	+9.0 V
7812	+12.0 V
7815	+15.0 V
7818	+ 18.0 V
7824	+ 24.0 V

Table: Series regulatoris

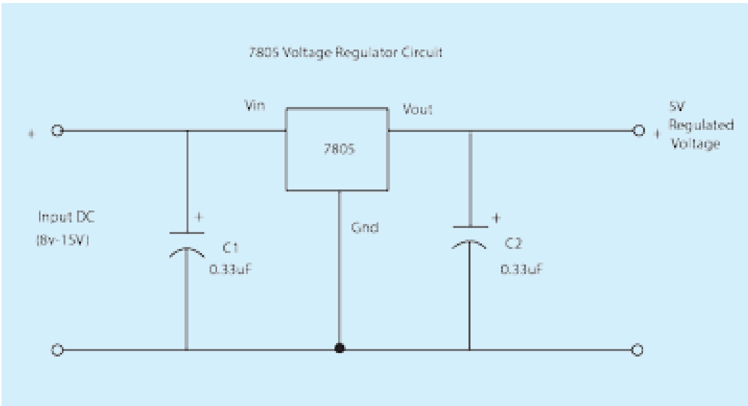


Figure B-3.9:

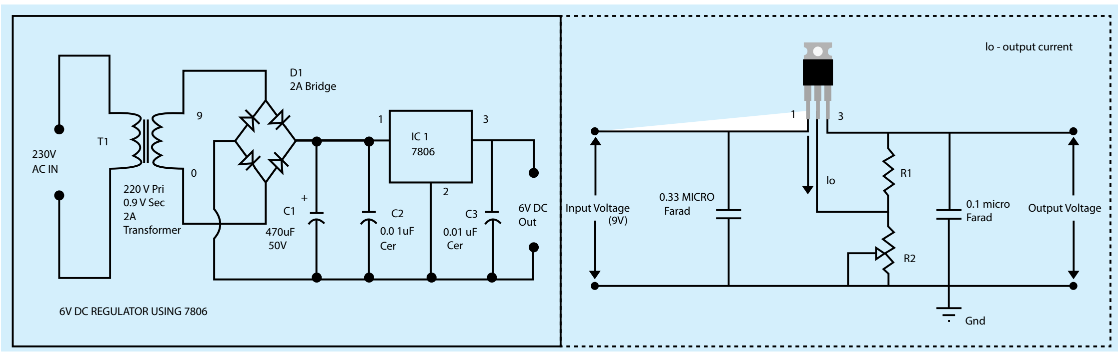


Figure B-3.10:

Relay Driving Circuit

As we have discussed, a relay allows for switching a high power circuit with a low power circuit. So to make a relay operate, we have to energize the coil by passing a current through it. Therefore, a driving circuit is necessary which nothing but a control circuitry of the relay. A relay driving circuit operates or drives the relay in order to perform switching function appropriately in a given circuit. Majorly there are two types of driving circuits for driving a relay namely AC relay driver circuit and DC relay driver circuit.

DC Relay Driver Circuit

There are numerous ways to operate a DC relay using different types of control devices ranging from simple transistor devices to high end integrated type devices.

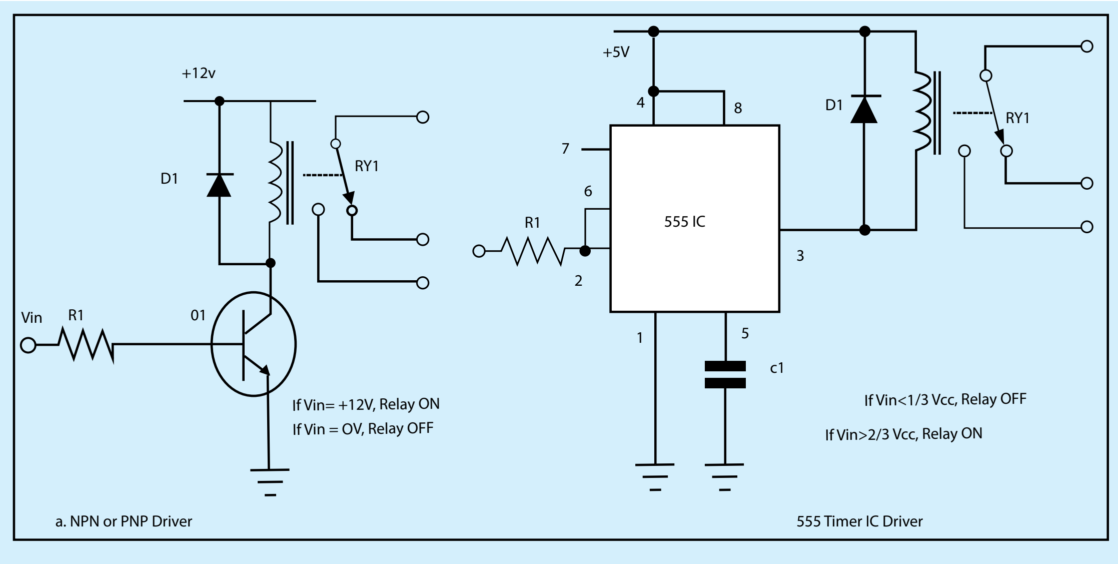


Figure B-3.11:

Driver ICs

Alternative to the above discussed transistor and timer based driver circuits, relay driver ICs can drive multiple devices. These drives are ICs are of different types such as bipolar transistor driven ICs, Darlington pair driven ICs, MOSFET bridge type ICs, etc with various channel configuration like 8 channel, 16 channel, and so on. These ICs are allows to connect more than one relay coils in order to perform the switching application. Some of the popular relay driver ICs used in controlling the electronic equipments includes UL2803, ULN2003, TLC5940, etc.

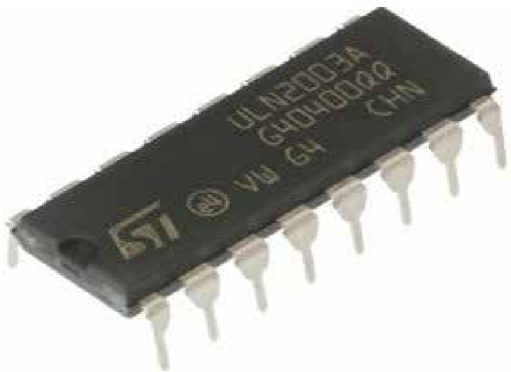


Figure B-3.12: ULN2003

Notes

AC Relay Driver Circuit

The figure below shows the relay operation in an AC circuit. In this circuit relay is used to control the heater by using the relay.

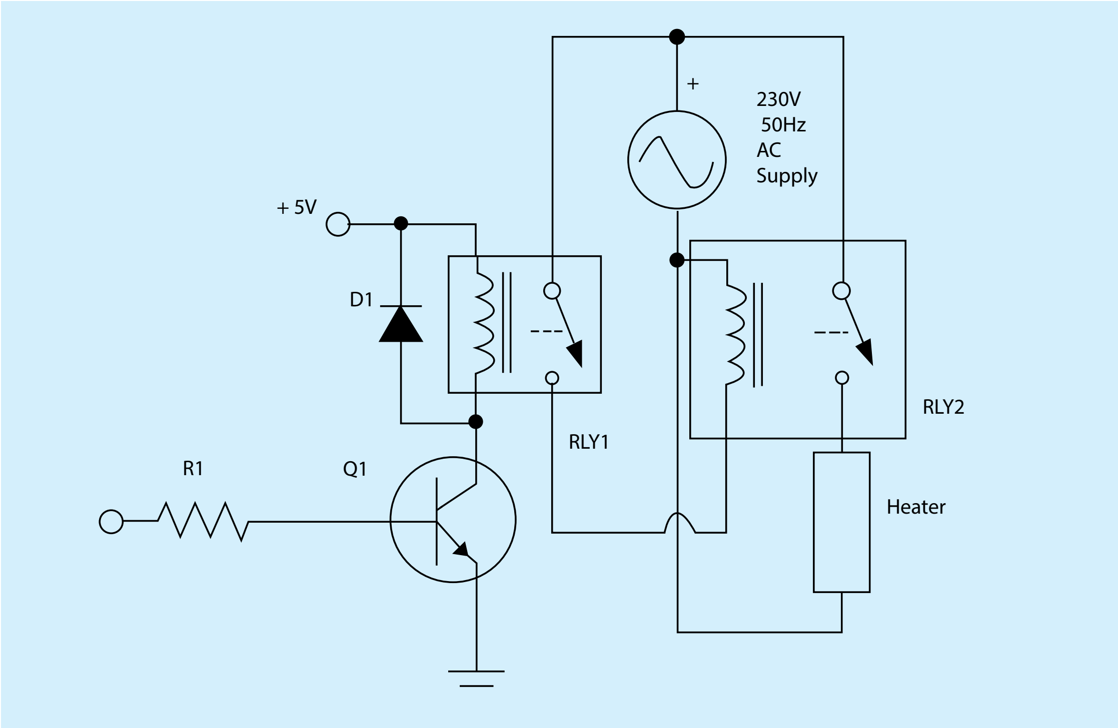


Figure B-3.13:

High & Low Voltage cut off with Delay & Alarm

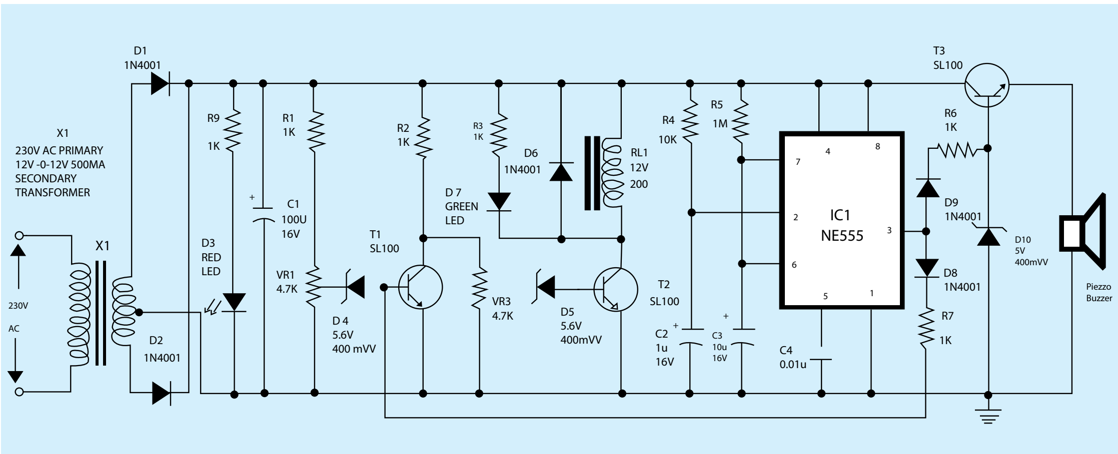


Figure B-3.14:

This above circuit protects electrical appliances from over voltage as well as under voltage. The circuit also produces an alarm when the power supply comes back. The same circuit with some modifications is used to make a automatic voltage stabilizer.

Over & Under Voltage protection circuit

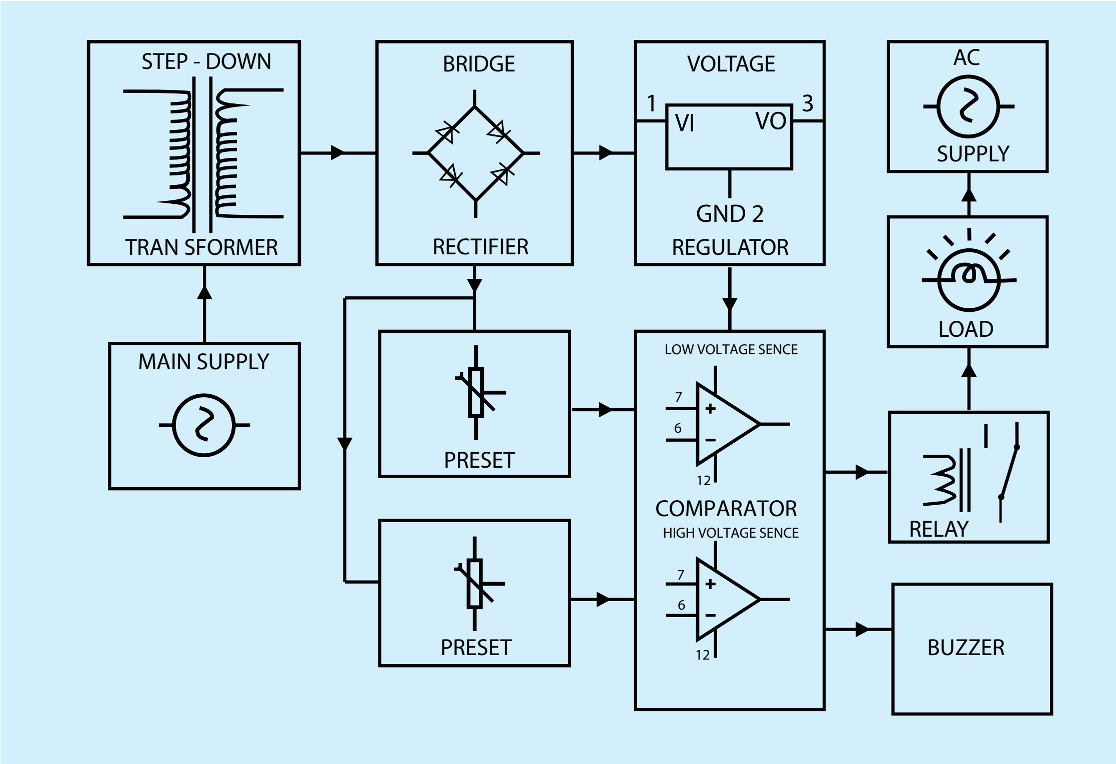


Figure B-3.15:

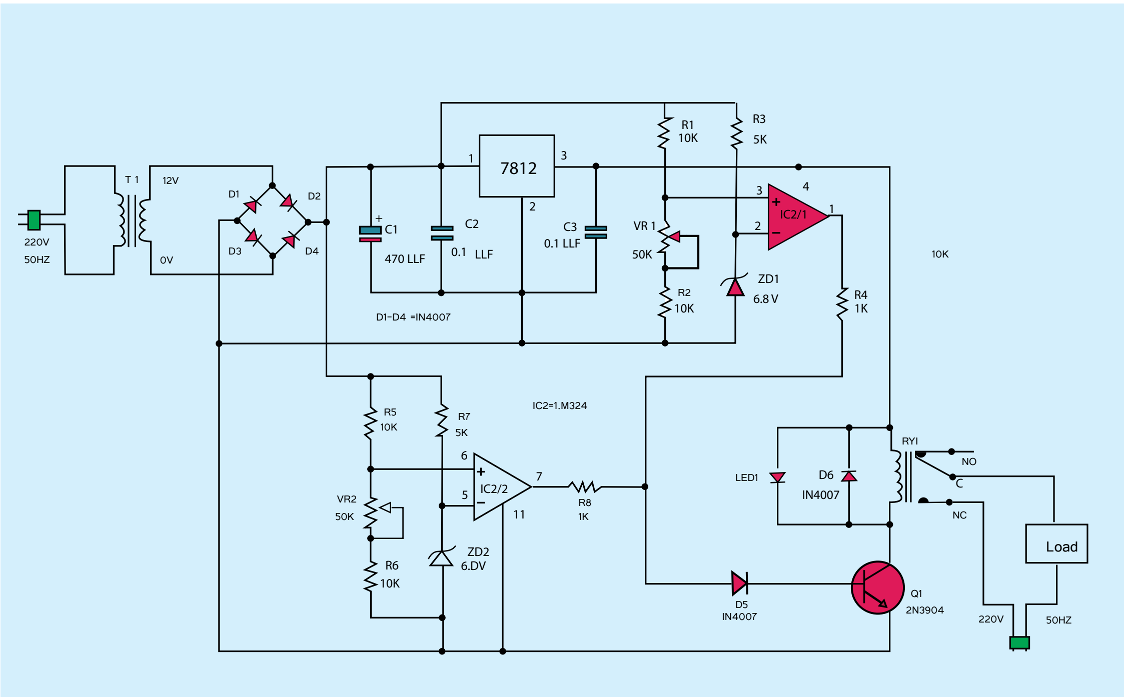


Figure B-3.16:

4

SECTION

Common Faults & Remedies

Dos & Don'ts

List of common Spares/component

List of necessary tools required

FAQ

Common Faults & Remedies

	Symptoms	Cause	Check	Action
1	Unit does not switch on	Plug or lead broken MCB not working Main board defective	Check lead continuity/plug Check voltage & MCB ends Check main supply at the socket	Replace lead/plug Replace MCB Replace main board & socket
2	No output	Voltmeter connection broken Voltmeter defective On/Off or input/output switch Defective Control circuit not function main voltage beyond specified	Check voltmeter connection Check voltage across voltmeter Check both switches Check relay connection/contact	Re-solder connections Replace voltmeter Replace defective switches Replace defective components PCB / relays
3	High/low output voltage	Control circuit/relays not function	Check relay function as per relay truth table	Replace defective components PCB/ relays
4	No switch on delay	Quick start switch permanently pressed Relay permanently on	Release switch / check for broken connection on switch Check DC voltage across relay coil, voltage absent	Replace relay Replace switch
5	Voltage stabilizer don't operate / trip on load	Neutral weak Main transformer primary winding over heated	Check main wire neutral wire	To repair main supply connection called electricity board electrician for repair the same
6	Received output one step but not others	No proper output voltage	Check trigger transformer	If defective change trigger transformer
7	Fluctuating Voltage	Loose terminal Voltage regulation unstable Intermittent short in exciter field coil	Check terminal Check Voltage regulator Check Intermittent short in exciter field coil	All electrical connections tight Follow voltage regulator test procedure & replace Measure field coil resistance for short

Table: **Common Faults**

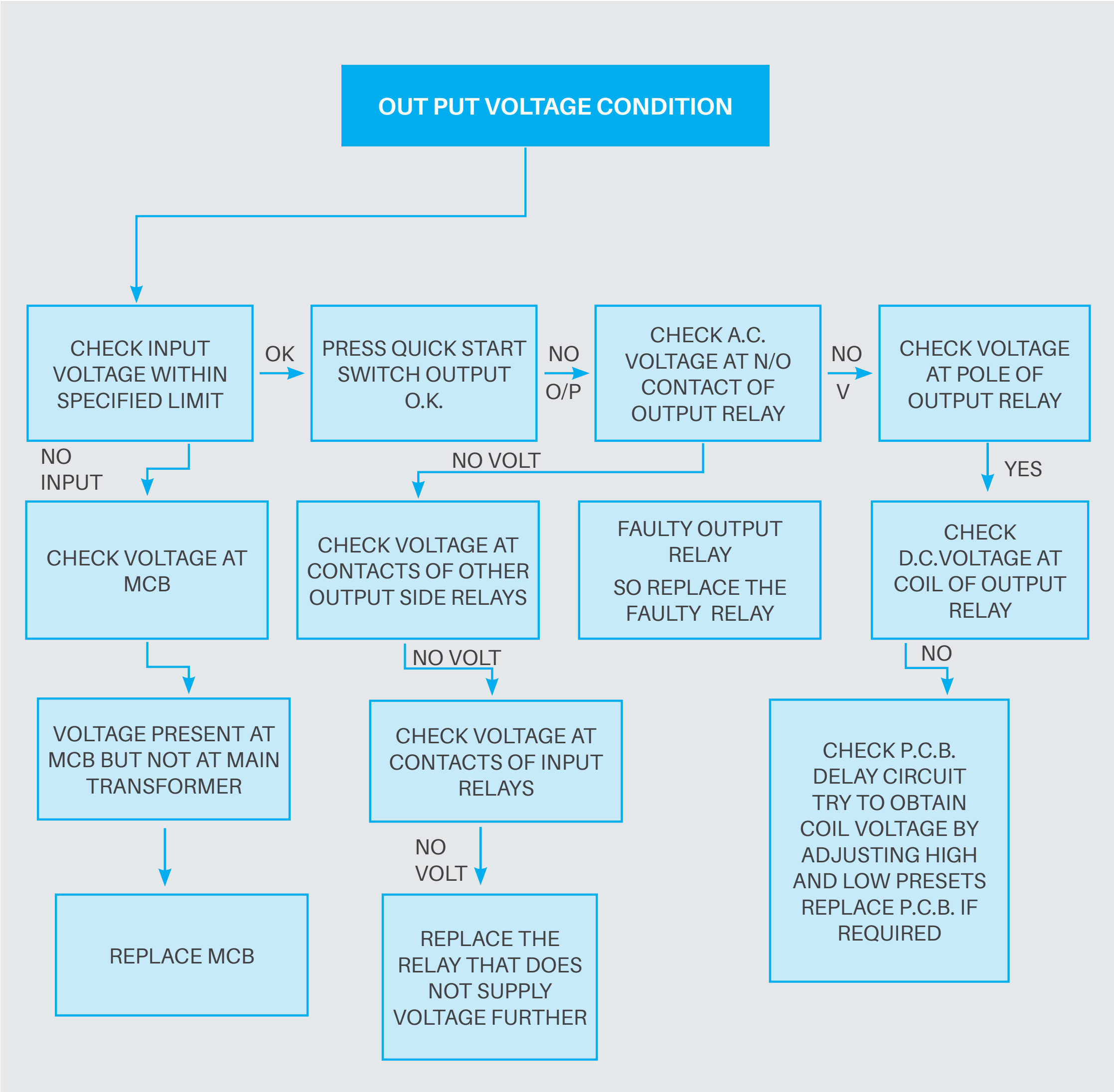


Table: Out Put Voltage Condition

Notes

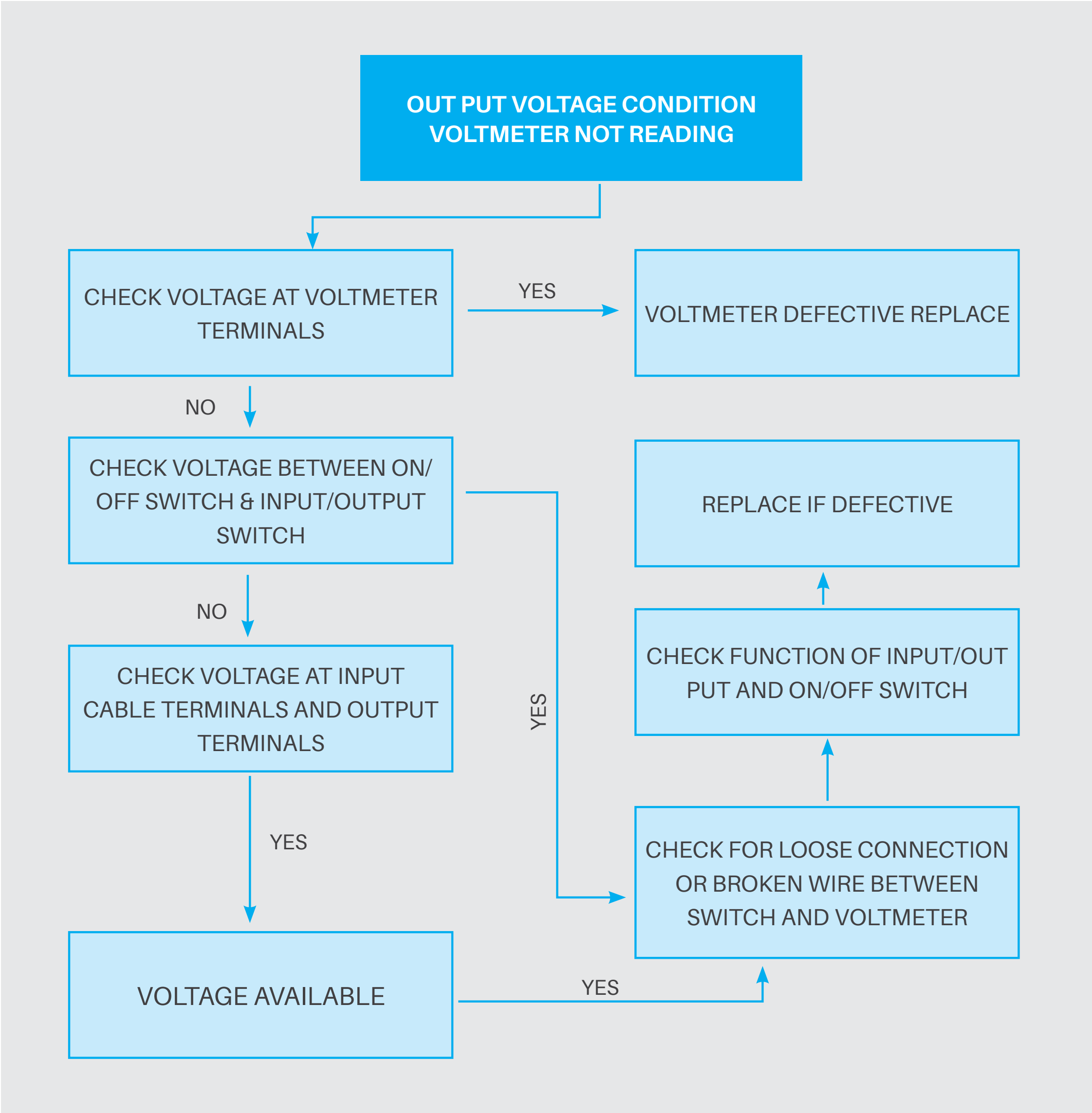


Table: Out Put Voltage Condition Voltmeter Not Readingv

Notes

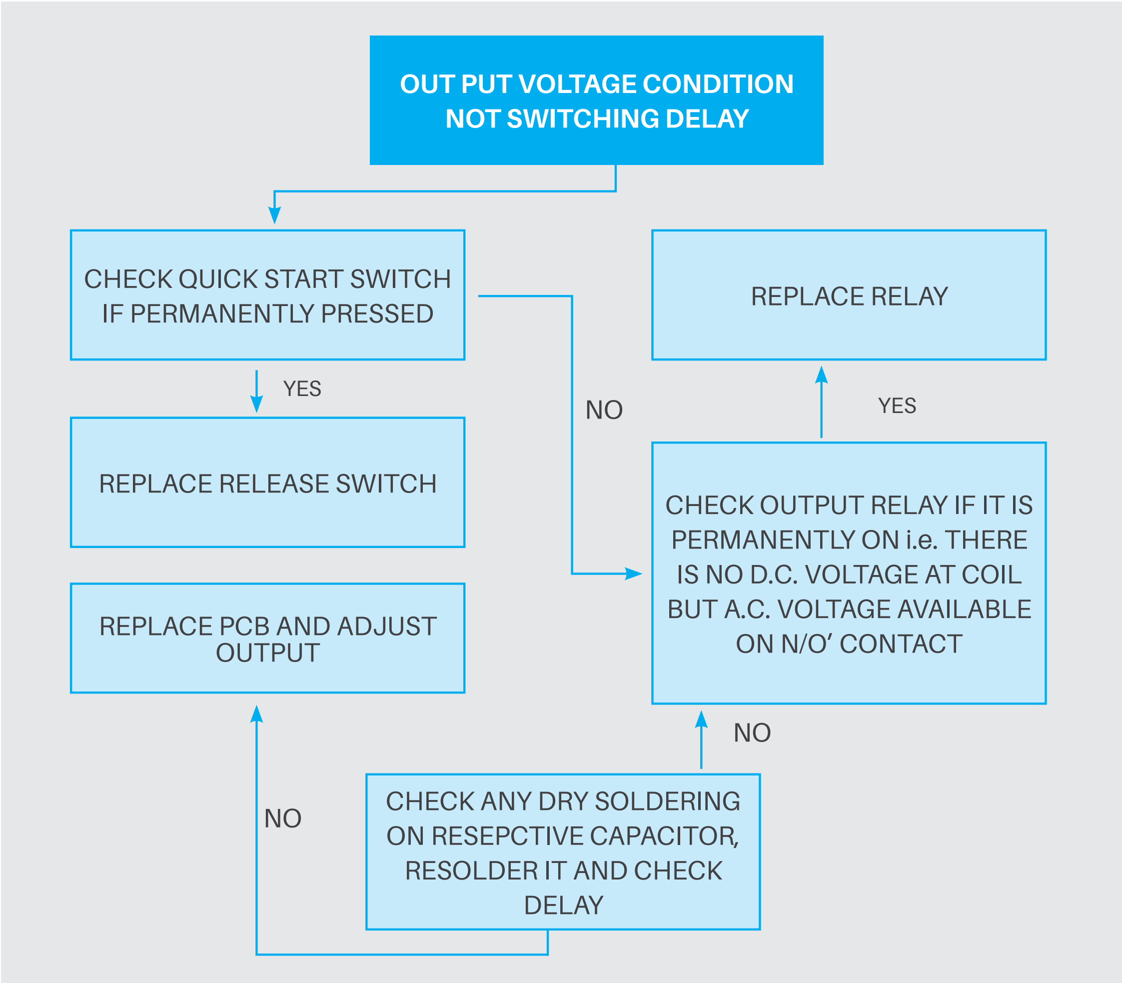


Table: Out Put Voltage Condition Not Switching Delay

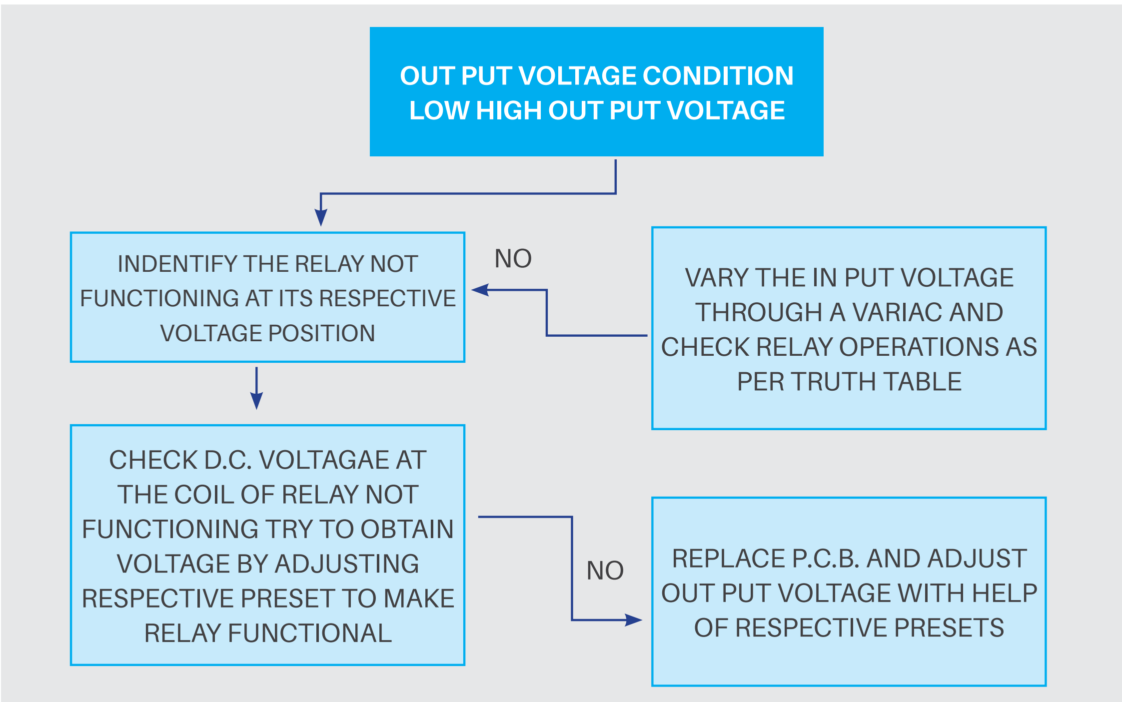


Table: Out Put Voltage Condition Low High Out Put Voltage

DO'S & DON'TS

Do's

- Always use correct tools.
- Before connecting stabilizer, always check mains for: (a) Proper connection in socket. (b) Proper grounding. (c) Less than 5V between neutral and ground.
- After connecting the ILR/freezer to stabilizer always recheck the connections.
- Before checking stabilizer, always disconnect ILR/Freezer.
- During repair work, let the soldering iron heat up to proper temperature before using it.
- After repairing stabilizer, always check it on "no load"
- In case the stabilizer is required to be transported, always use proper parking (preferably the original).

Don'ts

- DO NOT – Keep the stabilizer on floor (stabilizer should always be kept 12" above the ground, and minimum 6" always from the wall)
- DO NOT – Connect stabilizer without proper plug top.
- DO NOT – Open the stabilizer with mains or load connected to it.
- DO NOT - Cut wires of any part while replacing (de-solder the wires carefully).
- DO NOT – Adjust presets without 'variac'
- DO NOT – Use multi-meter without re-confirming that the leads are connected to proper range.

Notes

List of common Spares/component

Part Name

1. Main Transformer
2. Control Transformer
3. Sensing Transformer
4. Relay with double contacts
5. Relay with single contacts
6. Printed wired assembly
7. Miniature circuit breaker
8. Time delay by pass switch
9. Input / Output switch
10. Voltmeter
11. Unit connector strip
12. Mains lead (Input)
13. Unit chasis
14. Led strip with resistances
15. LED
16. Connecting strip/Terminal Strip for Output

List of necessary tools/equipment required

1. Multi meter
2. Long Nose plier
3. Combination plier
4. Neon Tester
5. Twiser
6. Screw Driver Set
7. Connector
8. Watch maker screw driver set
9. Soldering Gun
10. Solder wire
11. De soldering pump
12. Variac/Dimmerstat
13. Tool kit case

5

SECTION

TESTING OF COMPONENTS

Use Of Multimeters

Measuring Voltage

Measuring Current

Measuring Resistance

Testing Potentiometers (Variable Resistors)

Continuity

Testing Switches And Relays

Testing A Capacitor

Testing Diodes

Testing Light Emitting Diodes (Leds)

Testing Zener Diodes

Testing Voltage Regulators

Testing Transistors

Testing Ic's - Also Called "Chips"

Use Of Multimeters

Multimeters are really needed both types to cover the number of tests needed for designing and repair-work. Let us discuss how it work, how to use them.

There are two types:

DIGITAL and ANALOGUE

A Digital Multimeter has a set of digits on the display and an Analogue Multimeter has a scale with a pointer (or needle).

Figure B-5.1:

USING A MULTIMETER

Analogue and digital multimeters have either a rotary selector switch or push buttons to select the appropriate function and range. Some Digital Multimeter (DMMs) are auto ranging; they automatically select the correct range of voltage, resistance, or current when doing a test. However you need to select the function.

Before making any measurement you need to know what you are checking.

If you are measuring voltage,

○ Select the AC range (10v, 50v, 250v, or 1000v) or DC range (0.5v, 2.5v, 10v, 50v, 250v, or 1000v).

○ **If you are measuring resistance,**

○ Select the Ohms range (x1, x10, x100, x1k, x10k).

If you are measuring current,

○ Select the appropriate current range DCmA 0.5mA, 50mA, 500mA. Every multimeter is different however the photo below shows a low cost meter with the basic ranges.

The most important point to remember is this:

○ You must select a voltage or current range that is bigger or HIGHER than the maximum expected value, so the needle does not swing across the scale and hit the "end stop."

If you are using a DMM (Digital Multi Meter),

○ The meter will indicate if the voltage or current is higher than the selected scale, by showing "OL" - this means "Overload."

- If you are measuring resistance such as 1M on the x10 range the "OL" means "Open Loop" and you will need to change the range.
- Some meters show "1' on the display when the measurement is higher than the display will indicate and some flash a set of digits to show over-voltage or over-current.
- A "-1" indicates the leads should be reversed for a "positive reading."

If it is an AUTO RANGING meter, it will automatically produce a reading, otherwise the selector switch must be changed to another range.

Figure B-5.2:

The black "test lead" plugs into the socket marked "-" "Common", or "Com," and the red "test lead" plugs into meter socket marked "+" or "V-W-mA." The third banana socket measures HIGH CURRENT and the positive (red lead) plugs into this.

Before we cover the normal uses for a multimeter, it is interesting to note that some **Digital Multimeters** (**DMM**) have features such as Capacitance, Frequency and measuring the gain of a transistor as well as a number of other features using probes such as a temperature probe.

Measuring Voltage

Most of the readings taken with a multimeter will be VOLTAGE readings.

- Before taking a reading, select the highest range and if the needle does not move up scale (to the right), you can select another range.
- Always switch to the highest range before probing a circuit and keep your fingers away from the component being tested.
- If the meter is Digital, select the highest range or use the auto-ranging feature, by selecting "V." The meter will automatically produce a result, even if the voltage is AC or DC.
- If the meter is not auto-ranging, you will have to select Vdc if the voltage is from a DC source or Vac if the voltage is from an AC source.

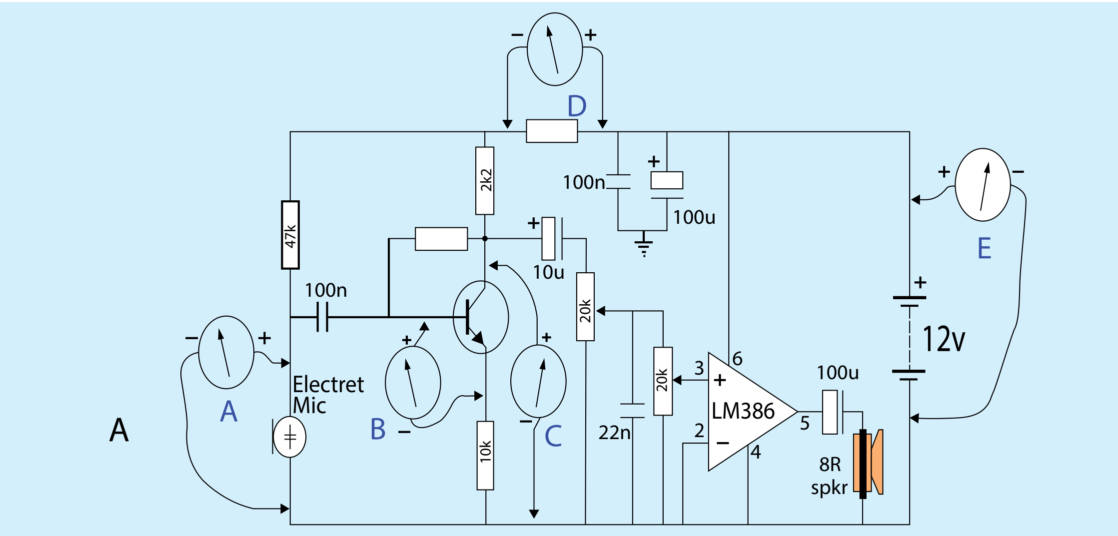


Figure B-5.3:

Measuring Current

You will rarely need to take current measurements, however most multimeters have DC current ranges such as 0.5mA, 50mA, 500mA and 10Amp (via the extra banana socket) and some meters have AC current ranges.

Measuring the current of a circuit will tell you a lot of things. If you know the normal current, a high or low current can let you know if the circuit is overloaded or not fully operational.

Current is always measured when the circuit is working (i.e: with power applied).

It is measured IN SERIES with the circuit or component under test.

The easiest way to measure current is to remove the fuse and take a reading across the fuse-holder. Or remove one lead of the battery or turn the project off, and measure across the switch.

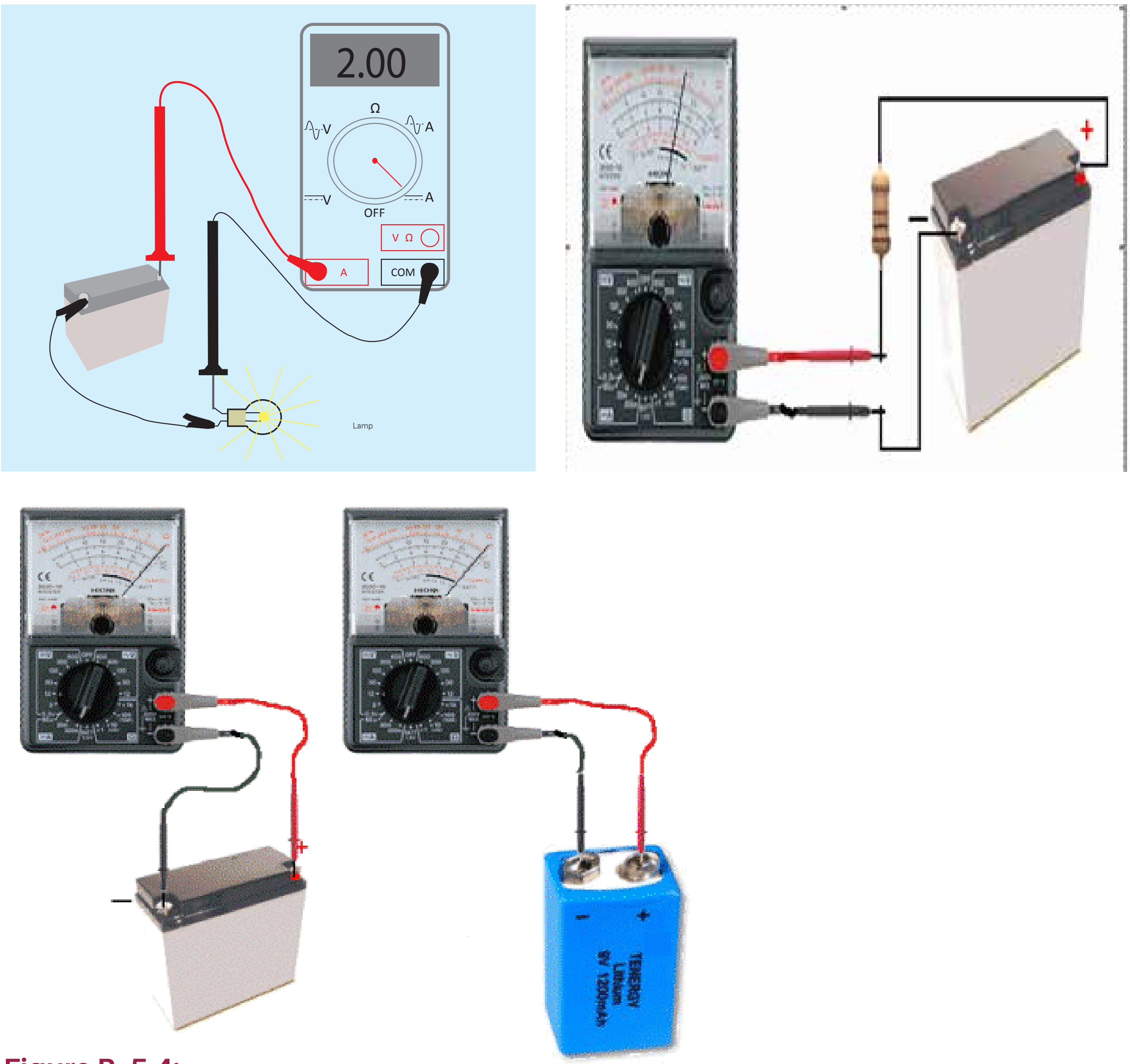


Figure B-5.4:

Do not measure the "current a battery will deliver" by placing the probes across the terminals. It will deliver a very high current and damage the meter instantly. There are special battery testing instruments for this purpose.

Measuring Resistance

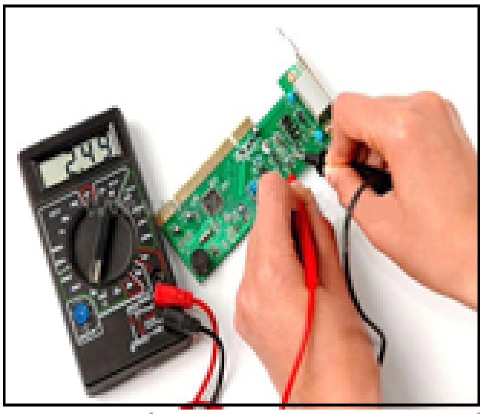
Resistors are main components in electric and electronic circuits as they determine the amount of current that flows in a circuit and also the potential at different points in a circuit. Therefore, it is important to make sure that the value of resistance is known for a given resistor which is placed in a circuit.

Turn a circuit off before measuring resistance, as If any voltage is present, the value of resistance will be incorrect.

In most cases you cannot measure a component while it is in-circuit. This is because the meter is actually measuring a voltage across a component and calling it a "resistance." The voltage comes from the battery inside the meter.

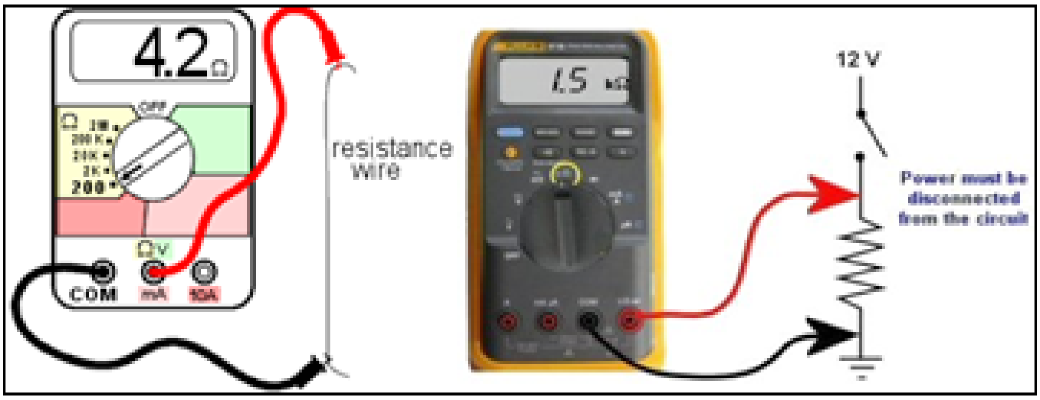
If any other voltage is present, the meter will produce a false reading.

If you are measuring the resistance of a component while still "in circuit," (with the power off) the reading will be lower than the true reading.

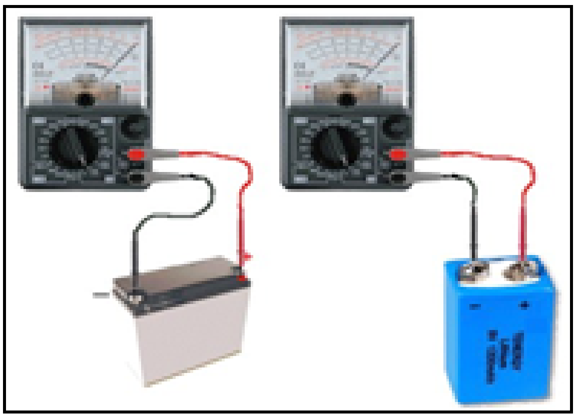


Measuring resistance

Measuring resistance of a heater (via the leads)



Measuring the resistance of a piece of resistance-wire



Do not measure the "Resistance of a Battery"

Figure B-5.5:

1. Do not measure the "resistance of a battery." The resistance of a battery (called the Internal impedance) is not measured as shown in the diagrams above. It is measured by creating a current-flow and measuring the voltage across the battery. Placing a multimeter set to resistance (across a battery) will destroy the meter.
2. Do not try to measure the resistance of any voltage or any "supply."
3. Addition to muiltimeter methods, resistance can also be measured by following various methods.
4. Ohmmeter
5. Voltmeter& Ammeter
6. Colour coding
7. In electronics, the most commonly in use is Colour Coding Method & following figure shows measurement of resistance of “carbon resistors “with the colour coding method.

Band Color	Digit	Multiplier	Tolerance
Black	0	1	---
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1,000	±3%
Yellow	4	10,000	±4%
Green	5	100,000	---
Blue	6	1,000,000	---
Violet	7	10,000,000	---
Gray	8	100,000,000	---
White	9	---	---
Gold	---	0.1	±5%
Silver	---	0.01	±10%
None	---	---	±20%

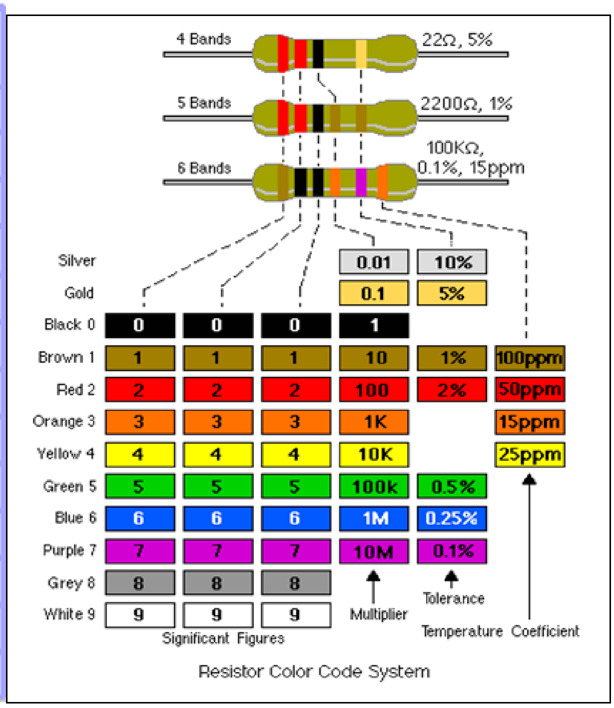
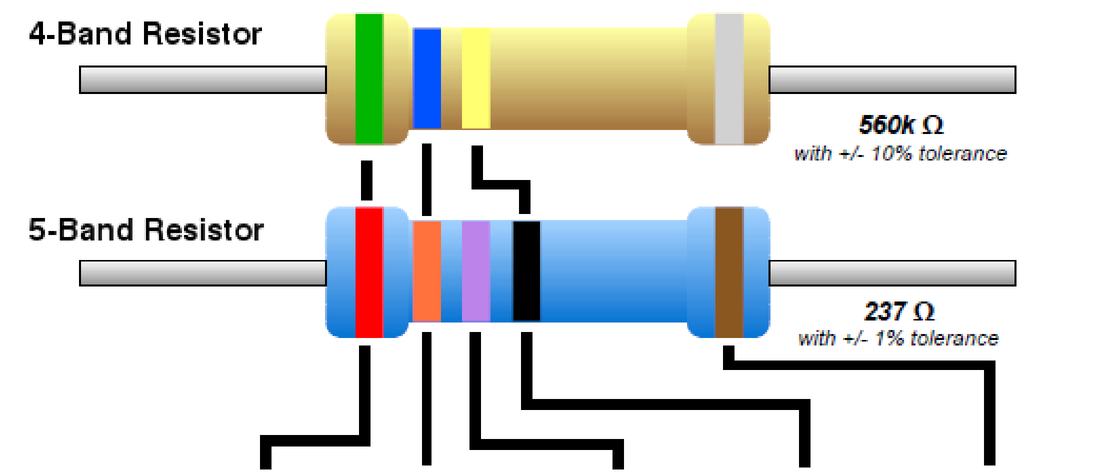


Table: Resistor Color Code

HOW TO REMEMBER THE COLOUR CODE:

Each colour has a "number" (or divisor) corresponding to it.

Most of the colours are in the same order as in the spectrum. You can see the spectrum in a rainbow. It is: ROY G BIV and the colours for resistors are in the same sequence.



Color	A	B	C	Multiplier	Tolerance
Black	0	0	0	x 1 Ω	
Brown	1	1	1	x 10 Ω	+/- 1%
Red	2	2	2	x 100 Ω	+/- 2%
Orange	3	3	3	x 1K Ω	
Yellow	4	4	4	x 10K Ω	
Green	5	5	5	x 100K Ω	+/- .5%
Blue	6	6	6	x 1M Ω	+/- .25%
Violet	7	7	7	x 10M Ω	+/- .1%
Grey	8	8	8		+/- .05%
White	9	9	9		
Gold				x .1 Ω	+/- 5%
Silver				x .01 Ω	+/- 10%

Table: Resistor Color Code

Resistors are identified on a circuit with numbers and letters to show the exact value of resistance - such as **1k 2k2 4M7**

The letter Ω (omega - a Greek symbol) is used to identify the word "Ohm."

but this symbol is not available on some word-processors, so the letter "R" is used. The letter "E" is also sometimes used and both mean "Ohms."

A one-ohm resistor is written "1R" or "1E." It can also be written "1R0" or "1E0."

A resistor of one-tenth of an ohm is written ”0R1" or "0E1." The letter takes the place of the decimal point.

10 ohms = 10R

100 ohms = 100R

1,000 ohms = 1k (k= kilo = one thousand)

10,000 ohms = 10k

100,000 ohms = 100k

1,000,000 ohms = 1M (M = MEG = one million)

A "BURNT" RESISTOR - normally and technically called a "burnt-out" resistor.

The resistance of a "burnt" resistor can sometimes be determined by scraping away the outer coating - if the resistor has a spiral of resistance-material.

You may be able to find a spot where the spiral has been damaged.

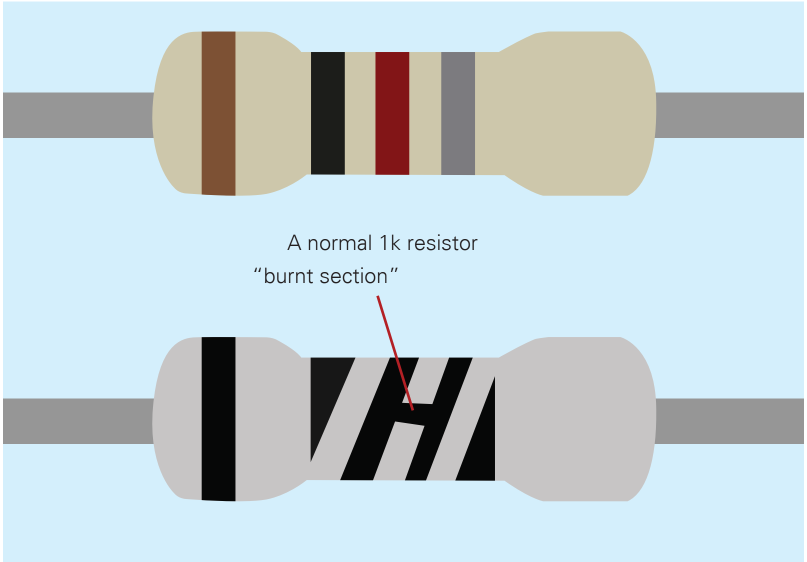


Figure B-5.6:

There is another way to determine the value of a damaged resistor.(This is the best advice in a situation where you do not know the value of a resistor)...Perform voltage tests

There is a third way to determine the value and this requires measuring the voltage drop across the resistor and the current-flow.

Testing Potentiometers (Variable Resistors)

Testing the potentiometer is important to make sure you’re getting the most of your device and that you are using the right type. Here are some tips that will help you conduct a simple test to determine the efficiency of potentiometer.

Figure B-5.7:

- Look at the Written Value
- Before you do anything else, find the rating or written value of the potentiometer.
- It is typically measured in the unit Ohms, and engraved on the side or bottom of the chip.
- The written value here will serve as the baseline or benchmark of the entire test.

- Check the Tabs.
- Potentiometers have three tabs. Two of them are called ends, the third is called the wiper.
- To check the value of a potentiometer (variable resistor), it should be removed from circuit or at least 2 legs should be removed.
- Use a Volt-Ohm meter/Multimeterto measure the resistance of the potentiometer.
- Note that multimeters come in different measuring ranges. They also come in different models, each with specific functions, so choose the one that suits the specifications of your potentiometer.
- You will put the probes of your multimeter on these ends to start the test.
- Adjust the Resistance.The resistance between the two outside pins is the value marked on the component and the centre leg will change from nearly zero to the full resistance as the shaft is rotated.
- Set the multimeter to a range that is higher than your potentiometer's resistance.
- If your potentiometer is fixed at 2,000 Ohms, for example, set your multimeter to 10,000 or 15,000 Ohms. Adjust the resistance to its minimum value.
- "Pots" generally suffer from "crackle" when turned and this can be fixed by spraying up the shaft and into the pot via the shaft with a tube fixed to a can of "spray-lubricant" (contact cleaner).
- "Pre-set pots" and "trim pots" are miniature versions of a potentiometer and they are all tested the same.
- CONTINUITY
- Some multimeters have a "buzzer" that detects when the probes are touching each other or the resistance between the probes is very LOW. This is called a CONTINUITY TESTER.

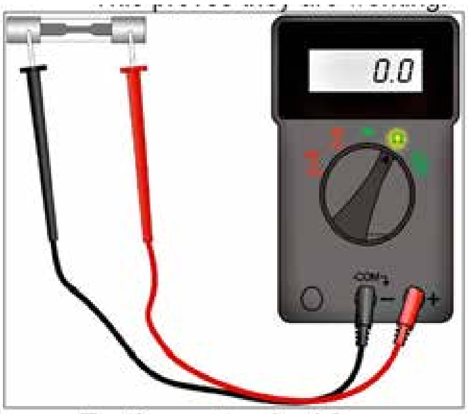
Figure B-5.8:

You can use the resistance scale "x1" or "x10" to detect low values of resistance.

Set the pointer to "0" (right end of the scale) by touching the probes together and adjusting the "zero ohms" control. (For Analog type meter)

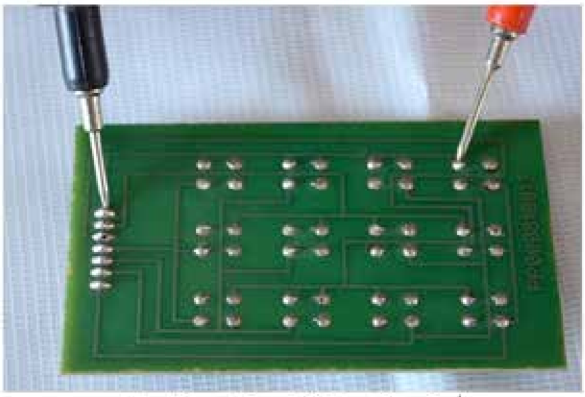
TESTING FUSES, LEADS AND WIRES

- All these components come under the heading TESTING for CONTINUITY.
- Turn off all power to the equipment before testing for shorts and continuity.
- Use the low resistance "Ohms Scale" or CONTINUITY range on your multi meter.
- All fuses, leads and wires should have a low, very low or zero resistance.
- This proves they are working.



Testing a standard fuse

Figure B-5.8:



Testing Circuit Continuity

Figure B-5.9:

Testing Switches And Relays

Switches and relays have contacts that open and close mechanically and you can test them for CONTINUITY. However, these components can become intermittent due to dirt or pitting of the surface of the contacts due to arcing as the switch is opened. Switches are the biggest causes of fire in electrical equipment and households.

It is best to test these items when the operating voltage and current is present as they quite often fail due to the arcing. A switch can work 49 times then fail on each 50th operation. The same with a relay. It can fail one time in 50 due to CONTACT WEAR.

As we know that, an electromagnetic relay is a switch operated by magnetic force. This force is generated by current through a coil. The relay opens and closes a set of contacts.

If the contacts do not touch each other with a large amount of force and with a large amount of the metal touching, the current flowing through the contacts will create HEAT and this will damage the metal and sometimes reduce the pressure holding the contact together.

This causes more arcing and eventually the switch heats up and starts to burn.

The contacts allow a current to flow and this current can damage the contacts.

Connect 5v or 12v to the coil (or 24v) and listen for the "click" of the points closing.

Measure the resistance across the points to see if they are closing.

It is necessary to put a load on the points to see if they are clean and can carry a current.

If the relay is not labelled, use an ohmmeter and check to see which pins are connected to each other. You should typically find an ohm value of approximately 50 to 120 ohms between two of the pins. This is the control circuit. If the coil is less that 50 ohms it could be suspect. Refer to manual to verify reading. The remaining two pins should read OL (infinite) if it's a normally open relay or 0 ohms (continuity) if it's a normally closed relay.

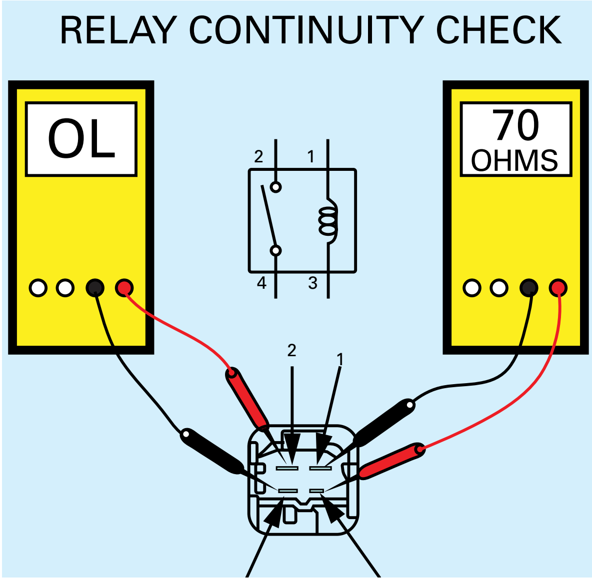


Figure B-5.10:

OPERATIONAL CHECK WITH AN OHMMETER

An ohmmeter can also be used to test the load circuit, but the same problem as the voltmeter comes into play. Energize the relay (control side). Supply B+ to pin 1 and a ground (neg.) to pin 3. A click should be heard. Place the leads on an ohmmeter to across pin 2 and pin 4. Assuming it is a normally open relay the ohmmeter will indicate a complete circuit (close to zero -0 ohms).

- De-energize the control circuit at pin 1(remove B+). The ohmmeter should indicate OL (an open circuit - infinite).
- Re-energize the relay and the ohmmeter should return to "zero" ohms.

  Note: some manufactures provide a maximum ohm value when the switch contacts are closed, example 5 ohms max.

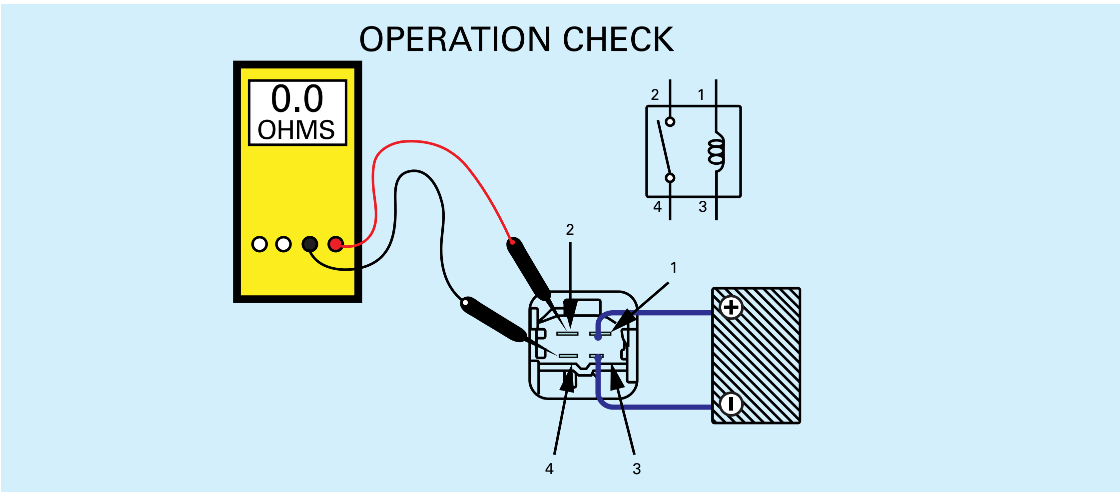


Figure B-5.11:

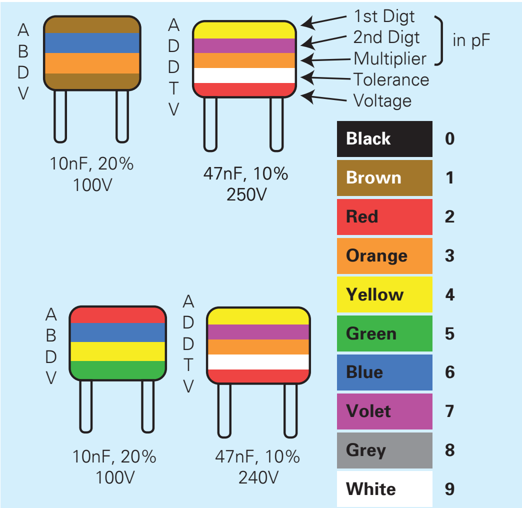
Testing a Capacitor

Non Polarity Capacitor

First step to test a capacitor is to calculate the value. Without knowing the capacitor value you will not know if a capacitor is good or bad. Capacitor values come in the unit of picofarad(pf), nanofarad(nf) and microfarad(uf). Here are just some of the examples of capacitor values:

Capacitor Color Codes

As you know, capacitance of a capacitor is the ability of a capacitor to store maximum charge on its plates. The capacitance of a capacitor is measured in the units of Farads. Generally the capacitance values, working voltage and tolerance values are indicated on the body of a capacitor. But sometimes it is difficult to identify these



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

Table: Capacitor Color

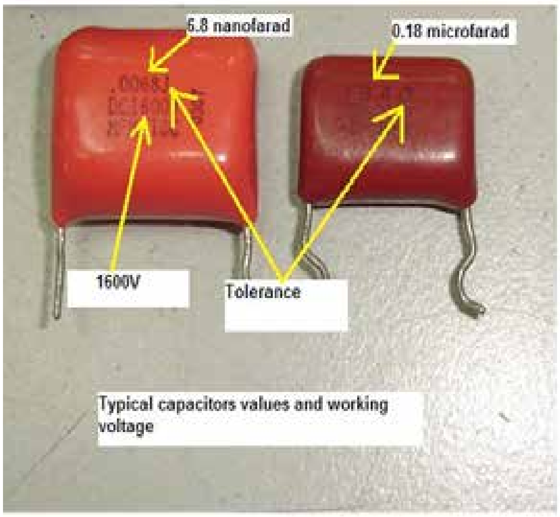
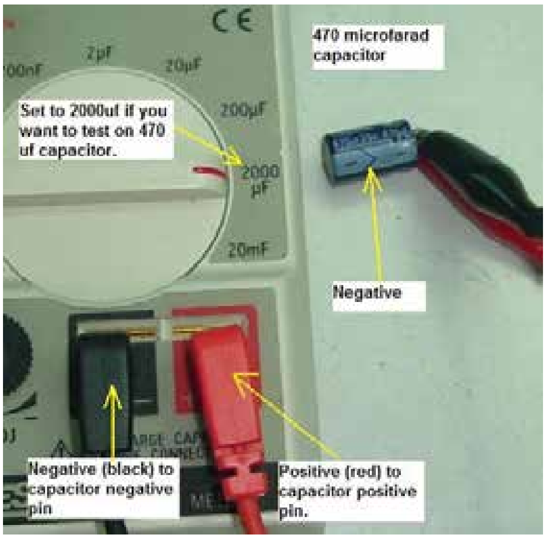


Figure B-5.12:

Every capacitors comes with a working voltage and the the typical values are 100 Volts, 250 Volts, 400 Volts, 1000 Volts, 1600 Volts and etc.



Testing the Capacitor

Electrolytic capacitor has the capacitance value printed on its body thus no calculation involved! Look at the picture below:

Figure B-5.13:

The right way to test the value of capacitors

In order to test capacitor value you **must use a digital capacitance meter** as shown above, simply connect any capacitors to the digital capacitor meter. If you want to check an electrolytic capacitor make sure you connect the black probe to the negative lead while the red probe to the other lead. Read from the LCD display the capacitance value. Set the capacitance meter to higher range if you want to check a capacitor.

For example, if you want to test the 470 micro farad capacitor, the meter have to be set to 2000 micro farad as shown from the picture above. If you want to test on the non polarity capacitor like the ceramic capacitor, you can connect your test probes on either leads of the capacitor and read from the LCD display of the meter. If the LCD display shows a result of 330 microfarad when measuring a 470 microfarad capacitor, you would know that the capacitance value has changed and need a replacement. **It is as simple as that to test a capacitor if it good or bad.**

Figure B-5.14:

Second method is to use analog meter and place the probes across the capacitors lead. You can't test the capacitance value with this method. What you can test is the charging and discharging of the capacitor. Set the ohm meter range to low ohms first and gradually increase the range when you come to test smaller capacitor value like the 0.1 micro farad capacitor.

The disadvantage of this method is even if there is a bad capacitance value, the meter would still shows charging and discharging in the faulty capacitor. Avoid using this method to test capacitor.

Also values below 1 microfarad will not respond to charging and the needle will not deflect.

REPLACING A CAPACITOR

Always replace a capacitor with the exact same type.

A capacitor may be slightly important in a circuit or it might be extremely critical.

A manufacturer may have taken years to select the right type of capacitor due to previous failures.

We cannot go into the theory on selecting a capacitor as it would be larger than this Book, so the only solution is to replace a capacitor with an identical type.

Many times, capacitors can produce very unusual faults and no piece of test equipment is going to detect the problem. Rather than spending money on a capacitance meter, it is cheaper to replace any suspect capacitor or electrolytic.

In most cases, it is a simple matter to solder another capacitor across the suspect component and view or listen to the result.

Testing Diodes

Diodes can have 4 different faults.

1. Open circuit in both directions.
2. Low resistance in both directions.
3. Leaky.
4. Breakdown under load.

TESTING A DIODE ON AN ANALOGUE METER

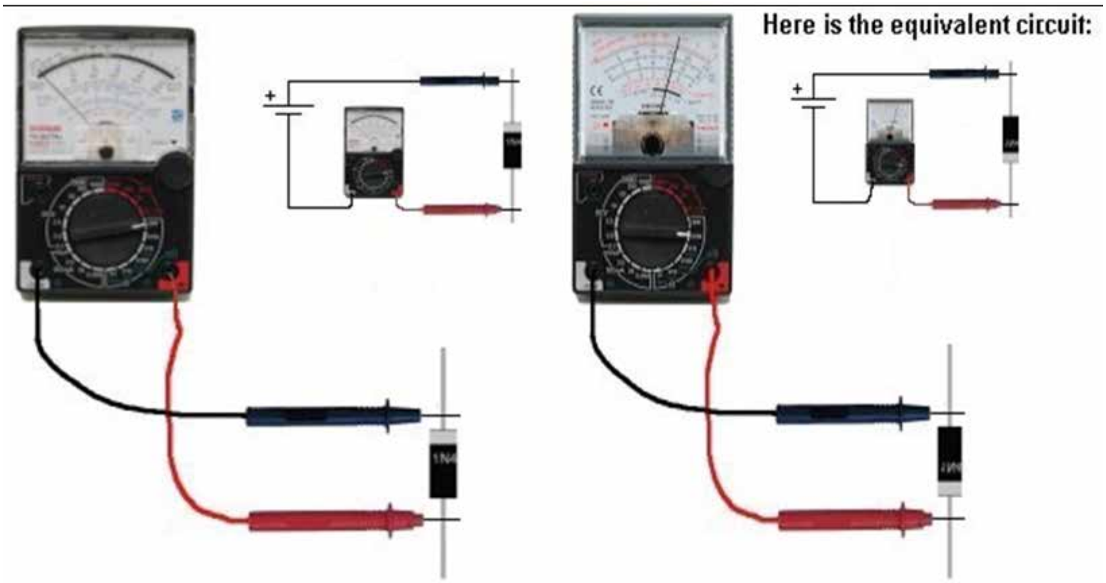
Testing a diode with an Analogue Multimeter can be done on any of the resistance ranges. [The high resistance range is best - it sometimes has a high voltage battery for this range but this does not affect our testing]

There are two things you must remember.

1. When the diode is measured in one direction, the needle will not move at all. The technical term for this is the diode is reverse biased. It will not allow any current to flow. Thus the needle will not move.

   When the diode is connected around the other way, the needle will swing to the right (move up scale) to about 80% of the scale. This position represents the voltage drop across the junction of the diode and is NOT a resistance value. If you change the resistance range, the needle will move to a slightly different position due to the resistances inside the meter. The technical term for this is the diode is forward biased. This indicates the diode is not faulty.

2. The leads of an **Analogue Multimeter** have the positive of the battery connected to the black probe and the readings of a "good diode" are shown in the following two diagrams:



The diode is REVERSE BIASED in the diode is FORWARD BIASED in the diagram above and diodes not conduct diagram above and it conducts.

Figure B-5.15:

TESTING A DIODE ON A DIGITAL METER

Testing a diode with a Digital Meter must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.

The best thing to do with a "suspect" diode is to replace it. This is because a diode has a number of characteristics that cannot be tested with simple equipment.

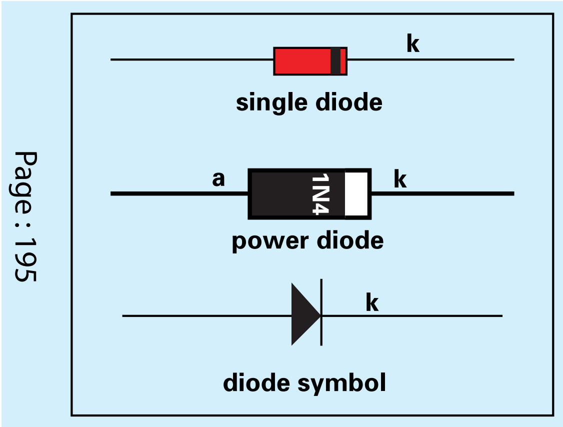


Figure B-5.16:

Some diodes have a fast recovery for use in high frequency circuits. They conduct very quickly and turn off very quickly so the waveform is processed accurately and efficiently.

If the diode is replaced with an ordinary diode, it will heat up as does not have the high-speed characteristic.

Other diodes have a low drop across them and if an ordinary is used, it will heat up.

Most diodes fail by going: SHORT-CIRCUIT. This can be detected by a low resistance (x1 or x10 Ohms range) in both directions.

A diode can also go OPEN CIRCUIT. To locate this fault, place an identical diode across the diode being tested.

A leaky diode can be detected by a low reading in one direction and a slight reading the other direction.

However this type of fault can only be detected when the circuit is working. The output of the circuit will be low and sometimes the diode heats up (more than normal).

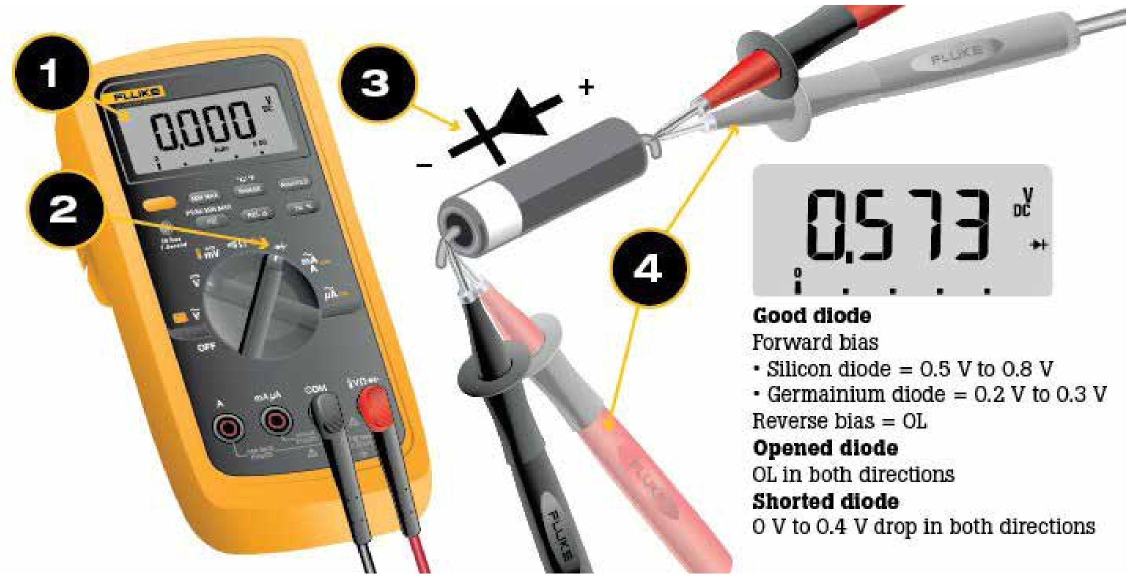


Figure B-5.17:

Steps for using a multimeter in the Diode Test mode.

How to test diodes

Digital multi meters can test diodes using one of two methods:

1. Diode Test mode: almost always the best approach.
2. Resistance mode: typically used only if a multimeter is not equipped with a Diode Test mode.

   Note: In some cases it may be necessary to remove one end of the diode from the circuit in order to test the diode.

   Things to know about the Resistance mode when testing diodes:

- Does not always indicate whether a diode is good or bad.
- Should not be taken when a diode is connected in a circuit since it can produce a false reading.
- CAN be used to verify a diode is bad in a specific application after a Diode Test indicates a diode is bad.

A diode is best tested by measuring the voltage drop across the diode when it is forward-biased. A forward-biased diode acts as a closed switch, permitting current to flow.

A multi meter's Diode Test mode produces a small voltage between test leads. The multi meter then displays the voltage drop when the test leads are connected across a diode when forward-biased. The Diode Test procedure is conducted as follows:

1. Make certain a) all power to the circuit is OFF and b) no voltage exists at the diode. Voltage may be present in the circuit due to charged capacitors. If so, the capacitors need to be discharged. Set the multimeter to measure ac or dc voltage as required.
2. Turn the dial (rotary switch) to Diode Test mode (→|). It may share a space on the dial with another function.
3. Connect the test leads to the diode. Record the measurement displayed.
4. Reverse the test leads. Record the measurement displayed.

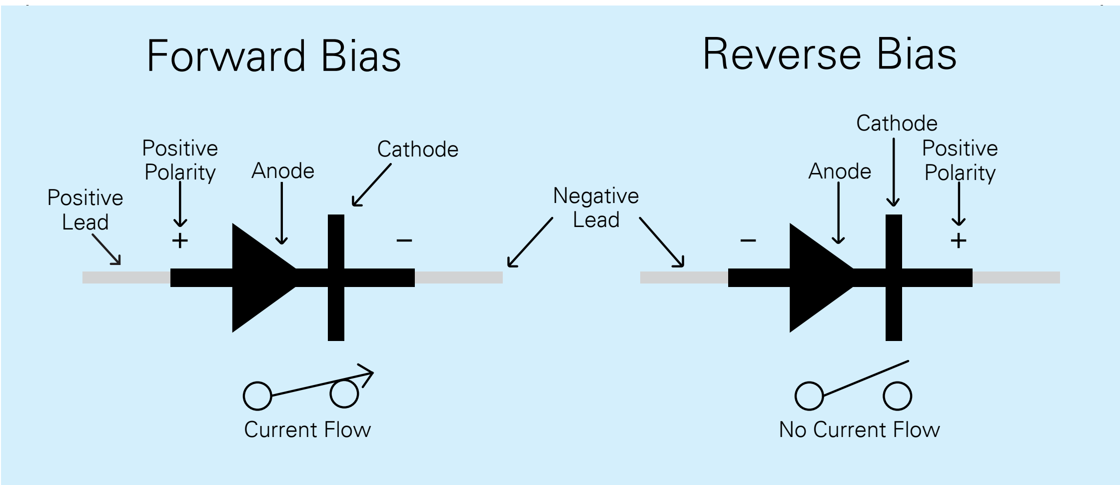


Figure B-5.17:

Diode test analysis

- A good forward-based diode displays a voltage drop ranging from 0.5 to 0.8 volts for the most commonly used silicon diodes. Some germanium diodes have a voltage drop ranging from 0.2 to 0.3 V.
- The multi meter displays OL when a good diode is reverse-biased. The OL reading indicates the diode is functioning as an open switch.
- A bad (opened) diode does not allow current to flow in either direction. A multi meter will display OL in both directions when the diode is opened.
- A shorted diode has the same voltage drop reading (approximately 0.4 V) in both directions.
- A multi meter set to the Resistance mode (Ω) can be used as an additional diode test or, as mentioned previously, if a multi meter does not include the Diode Test mode.

  A diode is forward-biased when the positive (red) test lead is on the anode and the negative (black) test lead is on the cathode.

- The forward-biased resistance of a good diode should range from 1000 Ω to 10 MΩ.
- The resistance measurement is high when the diode is forward-biased because current from the multimeter flows through the diode, causing the high-resistance measurement required for testing.
- A diode is reverse-biased when the positive (red) test lead is on the cathode and the negative (black) test lead is on the anode.
- The reverse-biased resistance of a good diode displays OL on a multimeter. The diode is bad if readings are the same in both directions.

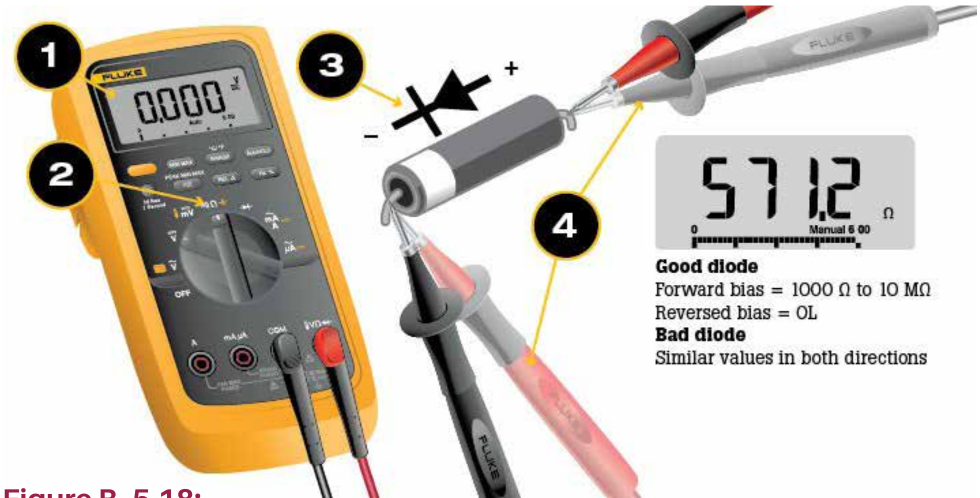


Figure B-5.18:

The resistance mode procedure is conducted as follows:

1. Make certain a) all power to the circuit is OFF and b) no voltage exists at the diode. Voltage may be present in the circuit due to charged capacitors. If so, the capacitors need to be discharged. Set the multimeter to measure ac or dc voltage as required.
2. Turn the dial to Resistance mode (Ω). It may share a space on the dial with another function.
3. Connect the test leads to the diode after it has been removed from the circuit. Record the measurement displayed.

4. Reverse the test leads. Record the measurement displayed.
5. For best results when using the Resistance mode to test diodes, compare the readings taken with a known good diode.

Testing Light Emitting Diodes (LEDs)

The cathode of the LED is identified by a flat on the side of the LED. The life expectancy of a LED is about 100,000 hours. LEDs rarely fail but they are very sensitive to heat and they must be soldered and de-soldered quickly. They are one of the most heat-sensitive components.

Light emitting diodes cannot be tested with most multimeters because the characteristic voltage across them is higher than the voltage of the battery in the meter.

However a simple tester can be made by joining 3 cells together with a 220R resistor and 2 alligator clips:

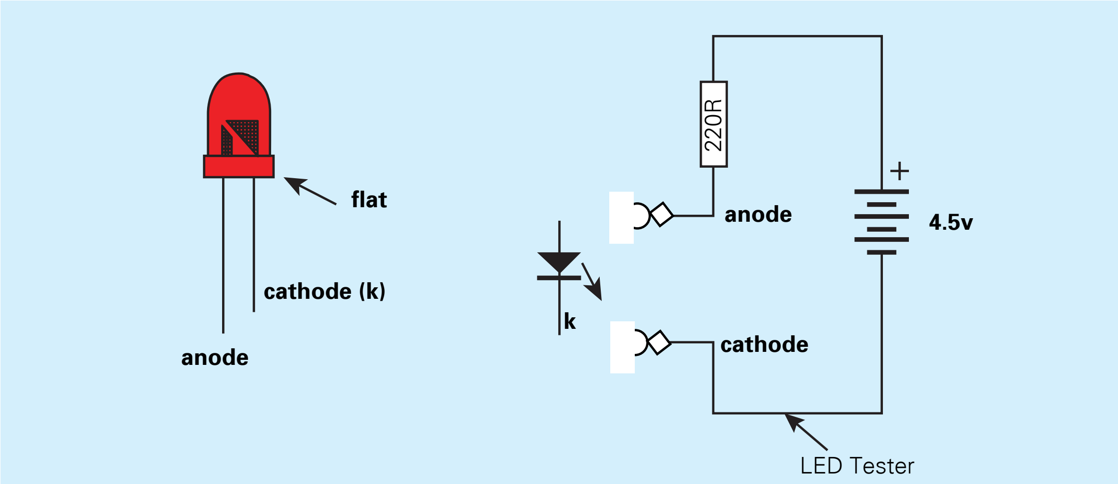


Figure B-5.19:

Connect the clips to a LED and it will illuminate in only one direction.

The colour of the LED will determine the voltage across it. You can measure this voltage if you want to match two or more LEDs for identical operation.

Red LEDs are generally 1.7v to 1.9v. - depending on the quality such as "high-bright"

Green LEDs are 1.9v to 2.3v.

Orange LEDs are about 2.3v and

White LEDs and IR LEDs are about 3.3v to 3.6v.

The illumination produced by a LED is determined by the quality of the crystal. It is the crystal that produces the colour and you need to replace a LED with the same quality to achieve the same illumination.

Never connect a LED across a battery (such as 6v or 9v), as it will be instantly damaged. You must have a resistor in series with the LED to limit the current.

Testing Zener Diodes

All diodes are Zener diodes. For instance a 1N4148 is a 120v zener diode as this is its reverse breakdown voltage.And a zener diode can be used as an ordinary diode in a circuit with a voltage that is below the zener value.

For instance, 20v zener diodes can be used in a 12v power supply as the voltage never reaches 20v, and the zener characteristic is never reached.

To tests a zener diode you need a power supply about 10v higher than the zener of the diode. Connect the zener across the supply with a 1k to 4k7 resistor and measure the voltage across the diode. If it measures less than 1v, reverse the zener.

If the reading is high or low in both directions, the zener is damaged.

Here is a Zener Diode Tester.The circuit will test up to 56v Zener.

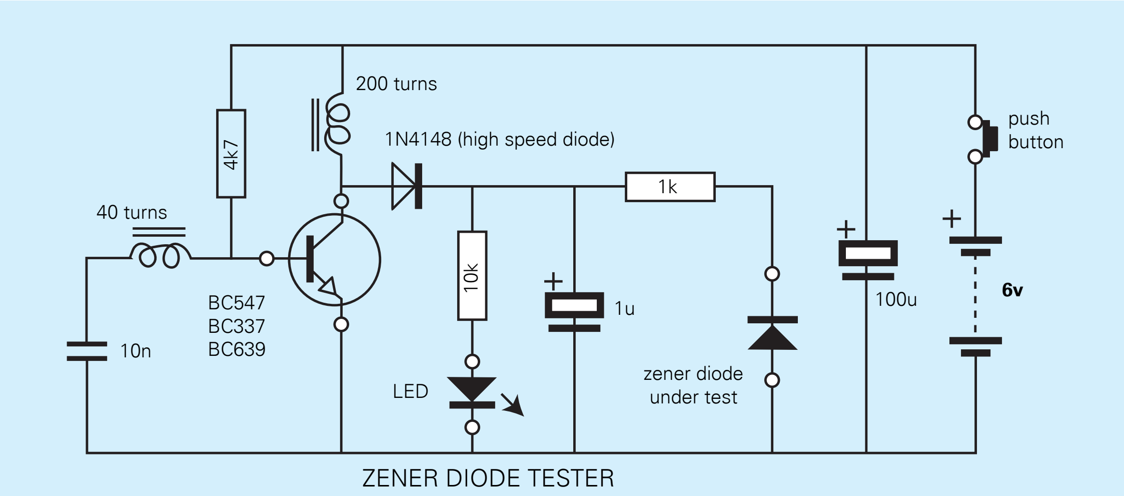


Figure B-5.20: ZENER DIODE TESTER

Testing Voltage Regulators

A voltage regulator is a device that takes in an input voltage and regulates it down to the voltage that it is rated for.

In most cases, a voltage regulator gets quite hot and for this reason it has a high failure-rate. If a regulator is not getting hot (or warm) it has either failed or the circuit is not operating. A regulator can only decrease the voltage. It cannot increase the current. This means the current being supplied to a circuit must also be available from the circuit supplying the regulator.

Being that a voltage regulator passes out a regulated output voltage, the only test we must do to check a voltage regulator is a voltage test.

We check the voltage input into the voltage regulator and the voltage output from the regulator.

If we read a higher voltage at the input which we feed into it and read the output voltage which the regulator is rated for, then we know that the voltage regulator is good. If we don't, then read the correct voltages, then it may be a defective regulator.

So we'll now go through specificially now how to test a voltage regulator.

Before we get into how to read the voltages with a multimeter, first we'll go over the pinout of a voltage regulator, so that you'll know which pins to read voltages from.

As an example, we'll use the popular voltage regulator, the LM7805. Below is the pinout of the LM7805 voltage regulator:

The input voltage that needs to be regulated down goes into pin 1 (Input). The ground pin is pin 2. And the regulated output voltage comes out from pin 3 (Output).

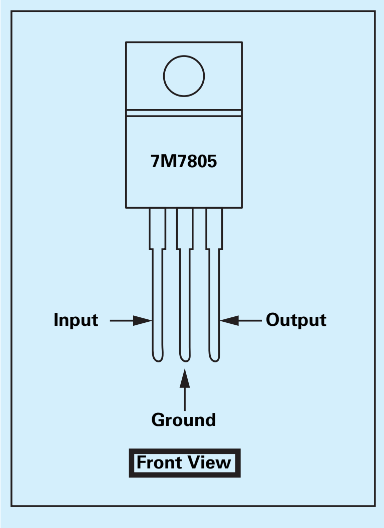


Figure B-5.21:

Measuring the Input Voltage

When test the voltage of a voltage regulator, we first check the voltage from the input pin to ground. This is to make sure that voltage is, in fact, being supplied to the regulator. If the regulator isn't receiving sufficient voltage, of course it will not be able to output its rated regulated voltage. This is why we do this test.

To test the voltage going into the voltage regulator, we take a multimeter and place it in the DC voltage setting. The DC voltage setting is the setting of the multimeter that has the following symbol or sign, $\overline{\text{V}}$

We take the probes of the multimeter and place the positive probe (normally the red probe) on the input pin of the voltage regulator and the negative probe (normally black probe) on the ground pin. The voltage that we should read should be higher than the voltage the regulator is rated to output. This is normally 1-2 volts higher.

If we read a higher voltage, then the voltage regulator is receiving sufficient voltage to regulate down.

Figure B-5.22:

Measuring the Output Voltage

Now that this step is complete, we now read the output voltage. If the regulator is rated to output 5 volts, then we should read a voltage very near 5 volts coming out from its output. The LM7805 is a voltage regulator is rated to output 5 volts, so we should read this output.

To measure the output voltage, we place the same multimeter set in the DC voltage setting and now place the positive probe of the multimeter on the output pin of the regulator and the negative probe on the ground pin of the regulator. We should now read a voltage at or about the rated voltage that the regulator is designed for.

Figure B-5.23:

If the multimeter does read a voltage near its rated output voltage, the voltage regulator is functional and is good.

If we do not, then the voltage regulator is defective as it does not do the job it was designed for, which is output a regulated voltage.

An adjustable regulator can be tested in the same way. Unliked fixed voltage regulators, adjustable regulators can be regulated to output adjustable voltages. All a user must do is calculate the output that the regulator should output and perform the same test as is shown above to see whether it is good or defective.

With the power turned off or the regulator removed from the circuit, you can test it with a multimeter set to resistance to see if it is ok. If any resistance readings are very low or zero ohms, the regulator is damaged.

Testing Transistors

Transistors are solid-state devices and although they operate completely differently to a diode, they appear as two back-to-back diodes when tested.

There are basically 2 types of transistor NPN and PNP.

A transistor is sometimes referred to as BJT (Bi-polar Junction Transistor) to distinguish it from other types of transistor such as Field Effect transistor, Programmable Unijunction Transistor and others.

In the following diagram, two diodes are connected together and although the construction of a transistor is more complex, we see the transistor as two diodes when testing it.

All transistors **are the same** but we talk about digital and analogue transistors. There is no difference between the two.

The difference is the circuit. And the only other slight difference between transistors is the fact that some have inbuilt diodes and resistors to simplify the rest of the circuit.

All transistors work the same way. The only difference is the amount of amplification they provide, the current and voltage they can withstand and the speed at which they work. For simple testing purposes, they are all the same.

NPN transistors are the most common and for an NPN transistor, the following applies. (the opposite applies for PNP)

To test a transistor, there is one thing you have to know:

When the base voltage is higher than the emitter, current flows though the collector-emitter leads.

As the voltage is increased on the base, nothing happens until the voltage reaches 0.55v. At this point a very small current flows through the collector-emitter leads. As the voltage is increased, the current-flow increases. At about 0.75v, the current-flow is a MAXIMUM. (can be as high as 0.9v). That's how it works. A transistor also needs current to flow into the base to perform this amplifying function and this is the one feature that separates an ordinary transistor from a FET.

If the voltage on the base is 0v, then instantly goes to 0.75v, the transistor initially passes NO current, then FULL current. The transistor is said to be working in its two states: OFF then ON (sometimes called: "cut-off" and "saturation"). These are called digital states and the transistor is said to be a **DIGITAL TRANSISTOR** or a **SWITCHING TRANSISTOR** , working in **DIGITAL MODE.**

If the base is delivered 0.5v, then slowly rises to 0.75v and slowly to 0.65v, then 0.7v, then 0.56v etc, the transistor is said to be working in ANALOGUE MODE and the transistor is an ANALOGUE TRANSISTOR.

Since a transistor is capable of amplifying a signal, it is said to be an active device. Components such as resistors, capacitors, inductors and diodes are not able to amplify and are therefore known as passive components.

In the following tests, use your finger to provide the TURN ON voltage for the base (this is 0.55v to 0.7v) and as you press harder, more current flows into the base and thus more current flows through the collector-emitter terminals. As more current flows, the needle of the multimeter moves UP-SCALE.

TESTING A TRANSISTOR ON A DIGITAL METER

Testing a transistor with a **Digital Meter** must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.

The "DIODE" setting must be used for diodes and transistors. It should also be called a "TRANSISTOR" setting.

TESTING AN unknown TRANSISTOR

The first thing you may want to do is test an unknown transistor for COLLECTOR, BASE AND EMITTER. You also want to perform a test to find out if it is NPN or PNP.

That's what this test will provide.

You need a cheap multimeter called an ANALOGUE METER - a multimeter with a scale and pointer (needle).

It will measure resistance values (normally used to test resistors) - (you can also test other components) and Voltage and Current. We use the resistance settings. It may have ranges such as "x10" "x100" "x1k" "x10"

Look at the resistance scale on the meter. It will be the top scale.

The scale starts at zero on the right and the high values are on the left. This is opposite to all the other scales.

When the two probes are touched together, the needle swings FULL SCALE and reads "ZERO." Adjust the pot on the side of the meter to make the pointer read exactly zero.

How to read: "x10" "x100" "x1k" "x10"

Up-scale from the zero mark is "1"

When the needle swings to this position on the "x10" setting, the value is 10 ohms.

When the needle swings to "1" on the "x100" setting, the value is 100 ohms.

When the needle swings to "1" on the "x1k" setting, the value is 1,000 ohms = 1k.

When the needle swings to "1" on the "x10k" setting, the value is 10,000 ohms = 10k.

Use this to work out all the other values on the scale.

Resistance values get very close-together (and very inaccurate) at the high end of the scale. [This is just a point to note and does not affect testing a transistor.]

Step 1 - FINDING THE BASE and determining NPN or PNP

Get an unknown transistor and test it with a multimeter set to "x10"

Try the 6 combinations and when you have the black probe on a pin and the red probe touches the other pins and the meter swings nearly full scale, you have an NPN transistor. The black probe is BASE

If the red probe touches a pin and the black probe produces a swing on the other two pins, you have a PNP transistor. The red probe is BASE

If the needle swings FULL SCALE or if it swings for more than 2 readings, the transistor is **FAULTY**.

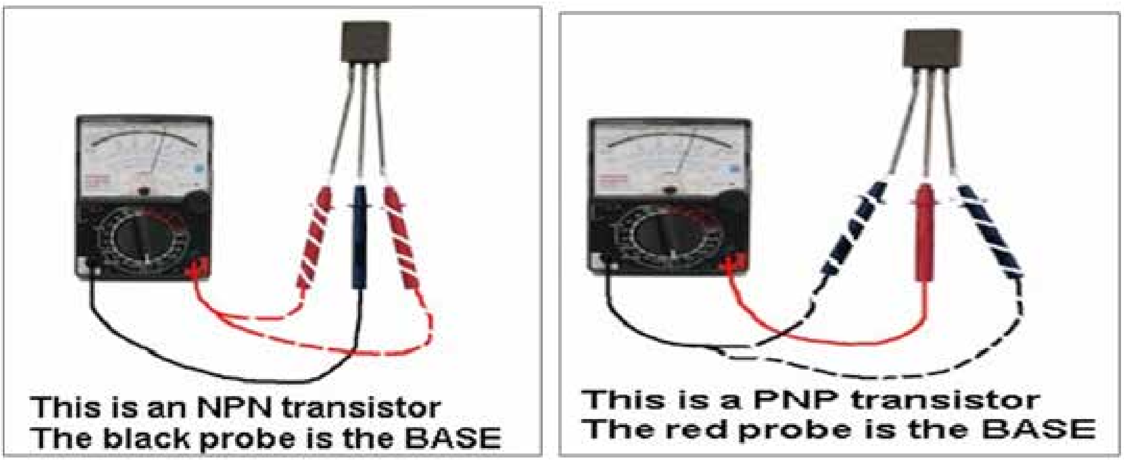


Figure B-5.24:

Step 2 - FINDING THE COLLECTOR and EMITTER

Set the meter to "x10k."

For an NPN transistor, place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

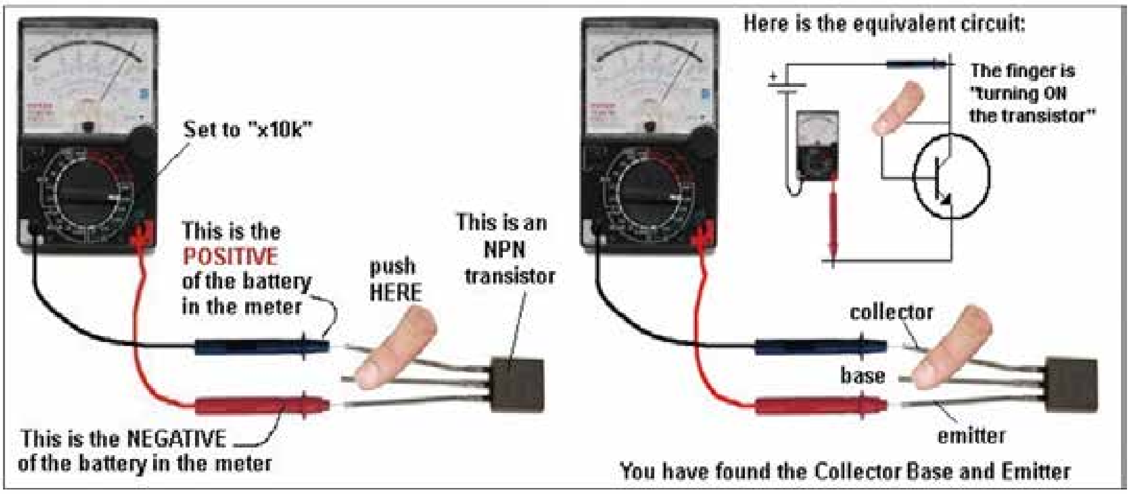


Figure B-5.25:

For a PNP transistor, set the meter to "x10k" place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

TRANSISTOR REPLACEMENT

If you can't get an exact replacement, refer to a transistor substitution guide to identify a near equivalent.

The important parameters are:

- Voltage
- Current
- Wattage
- Maximum frequency of operation

  The replacement part should have parameters equal to or higher than the original.

Points to remember:

- Polarity of the transistor i.e. PNP or NPN.
- At least the same voltage, current and wattage rating.
- Low frequency or high frequency type.
- Check the pinout of the replacement part
- Use a desoldering pump to remove the transistor to prevent damage to the printed circuit board.
- Fit the heat sink.
- Check the mica washer and use heat-sink compound
- Tighten the nut/bolt - not too tight or too loose.
- Horizontal output transistors with an integrated diode should be replaced with the same type.

Testing IC's - also called "CHIPS"

An Integrated Circuit is also called a "chip." It might have 8 pins or as many as 40.

Some chips are ANALOGUE. This means the input signal is rising and falling slowly and the output produces a larger version of the input.

Other chips are classified as DIGITAL and the input starts at 0v and rises to rail voltage very quickly. The output does exactly the same - it rises and falls very quickly.

You might think the chip performs no function, because the input and output voltage has the same value, but you will find the chip may have more than one output and the others only go high after a number of clock-pulses on the input, or the chip may be outputting when a combination of inputs is recognised or the output may go HIGH after a number of clock pulses.

ANALOGUE CHIPS

Analogue chips are AUDIO chips or AMPLIFIER chips.

To test these chips you will need three pieces of test equipment:

1. A multimeter - this can be digital or analogue.
2. A Signal Injector
3. A Mini Bench Amplifier.

DIGITAL CHIPS

It is always best to have data on the chip you are testing, but if this is not available, you will need three pieces of equipment:

1. A multimeter - this can be digital or analogue.
2. A Logic Probe,
3. A logic Pulser.

FAQs

1. How does the stabilizer protect the connected equipment?

The stabilizer will give a stabilized and safe voltage to the connected equipment within the specified limit even if the input voltage is high or low. It does so by using electromagnetic regulators that use tap changers with autotransformers.

2. Can TV stabilizers be used for refrigerators?

Most electronics like TVs, DVD players, have an internal device called SMPS (Switch Mode Power Supply) which converts incoming 230 V to 12V or 24V (whichever is required by the appliance). The power consumption of electronic products does not change with voltage fluctuations. Also, their output does not change.

Whereas, all appliances with motors have an operating voltage range. Appliances like a refrigerator/ air conditioners have limited operating voltage range and thus they do not work at low voltages. If the voltage provided to them is lower than their operating voltage range, then either they will not start at all, and if they are already running, they will start producing a humming sound. This humming sound happens as these motors draw more current to run the system. This can lead to overheating and burning of the motor if persistent. Thus saving induction motors from voltage fluctuations is very important.

At high voltages these appliances draw more current only at the time of starting, but once they reach steady state the current is much less. But still the high starting current can damage the system and thus appliances with motors need to be protected both from high as well as low voltages. So to put voltage stabiliser to protect these appliances is very much required

3. Can a refrigerator stabilizer be kept on top of the refrigerator?
   It is always advisable to keep it on a separate stand.

4. In voltage stabilizer,what is the importance of Time Delay?
   Time Delay system helps the compressor to get proper balancing time during power cuts. It will protect the compressor from frequent re-starting and ensures the safety of the connected equipment, in case of Voltage fluctuation by providing a delay. Usually, the duration of Time Delay is between 2 to 4 minutes.

5. What is ITDS?
   ITDS means Intelligent Time Delay System. This feature provides a Time Delay only when it is actually necessary, which means there is no initial Time Delay.

6. How does the Time Delay increase the life of the compressor?
   Time Delay gives the compressor balancing time between power cuts thereby enhancing its life.

7. Why are the Low voltage cut-off and High voltage cut-off necessary?
   Appliances with motors (inductive load) are very sensitive for voltage fluctuations. Its exposure to low voltage leads to overheating and burning of the motor if persistent, whereas high starting current at high voltages can damage the system. Hence appliances with motors need to be protected both from high as well as low voltages.

8. What is meant by Spike?
   Spike is a sudden jump in the voltage which lasts for a very brief period. Such a jump in voltage can damage sensitive electronic equipment if not suppressed.

9. How will I select stabilizer rating?
   Before selection the stabilizer you need to know how much power you use. By taking an inventory of all the essential electrical loads and doing a basic electrical load evaluation, one can get a good idea how much power your system needs to produce. Second, you have to know about the power Fluctuations situations also that mean what voltage minimum / maximum you are getting from the main A.C supply. In brief, you have to select the Input Voltage window and the power consumption of your appliance.

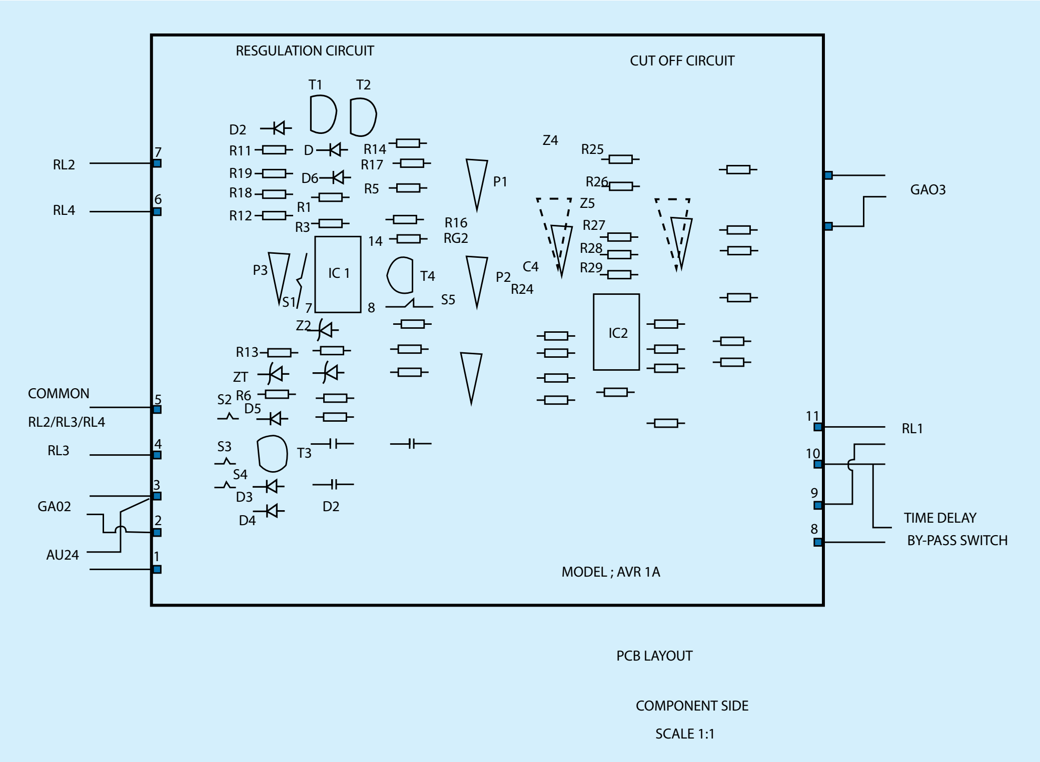
CHAPTER

1

ANNEXURE

Circuit Diagram

A. Blue Line



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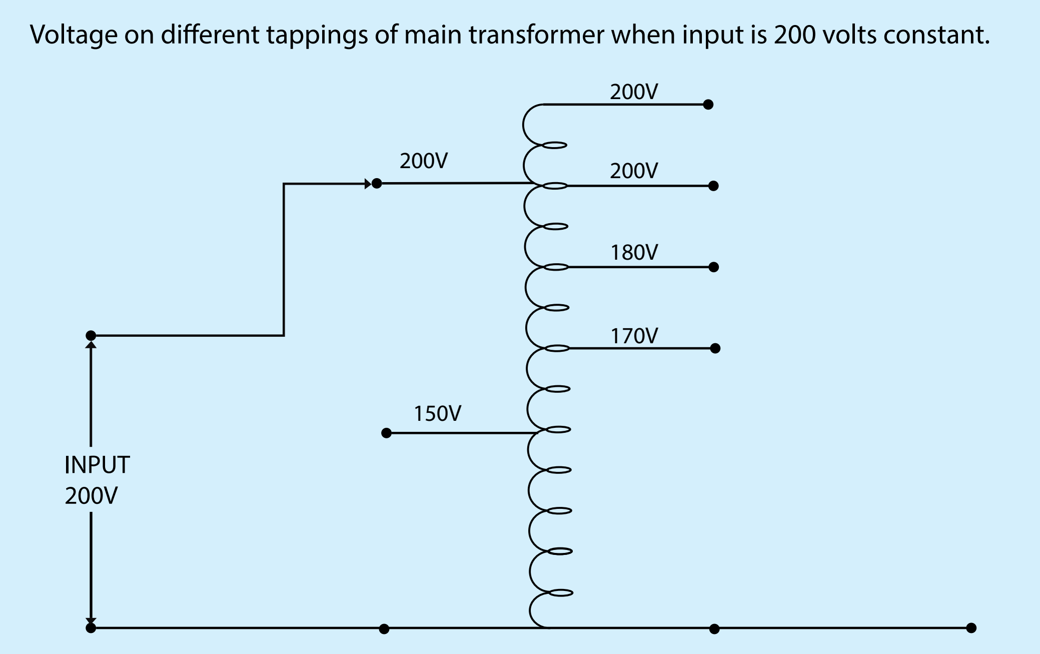
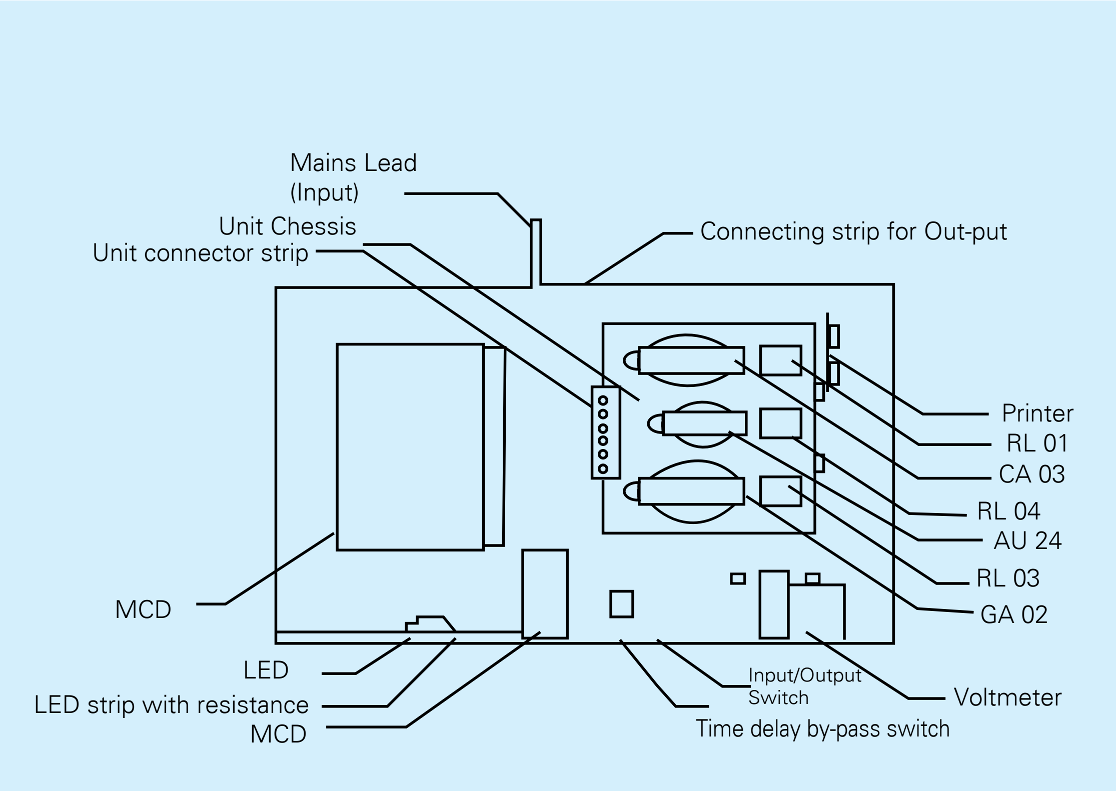


Figure C-1.2:



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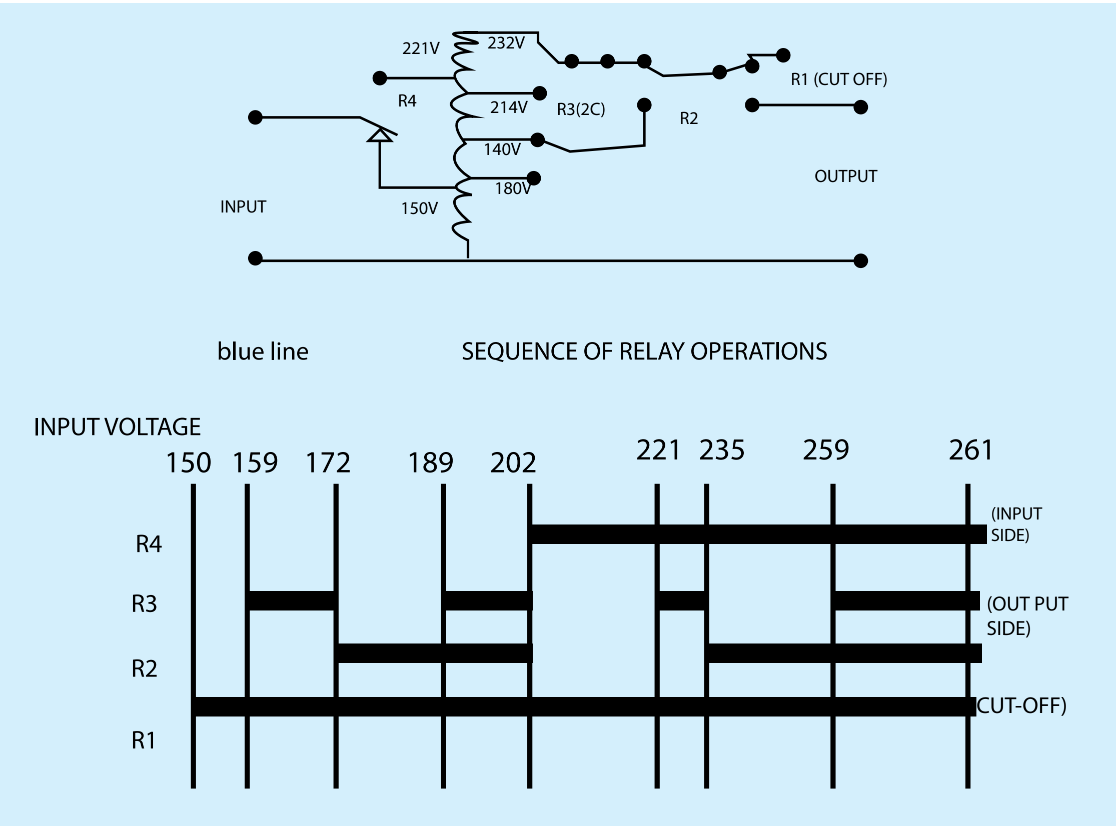

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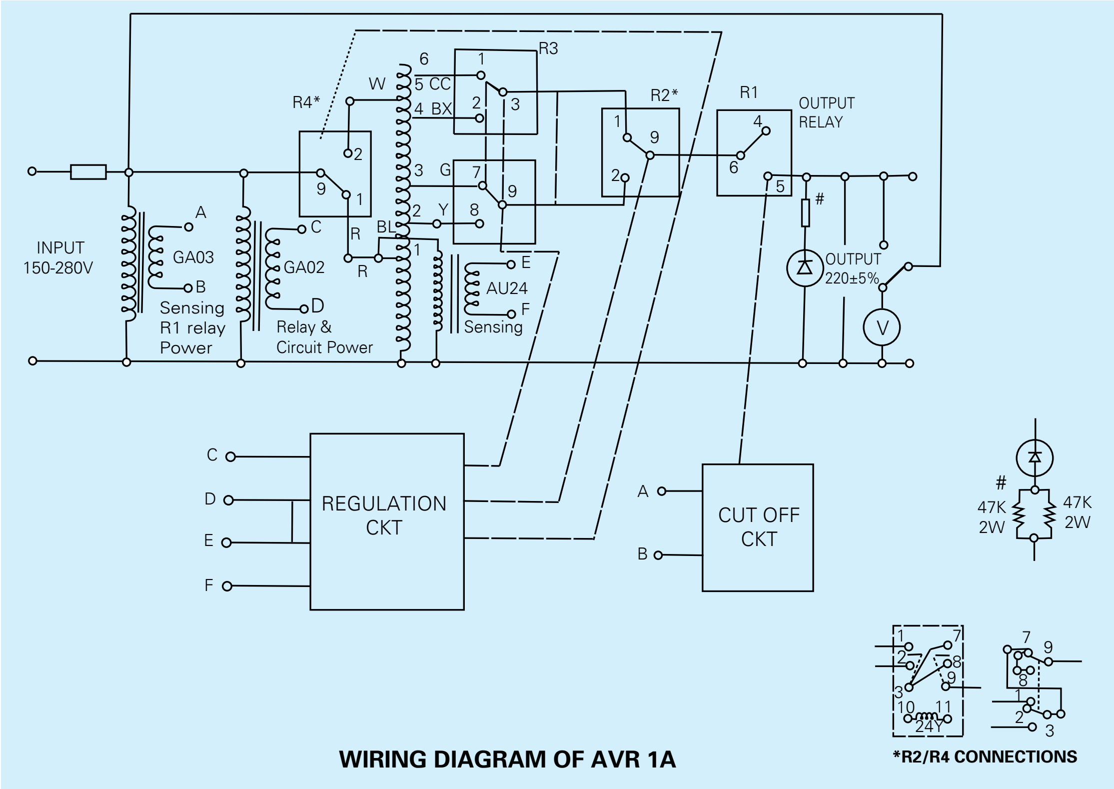

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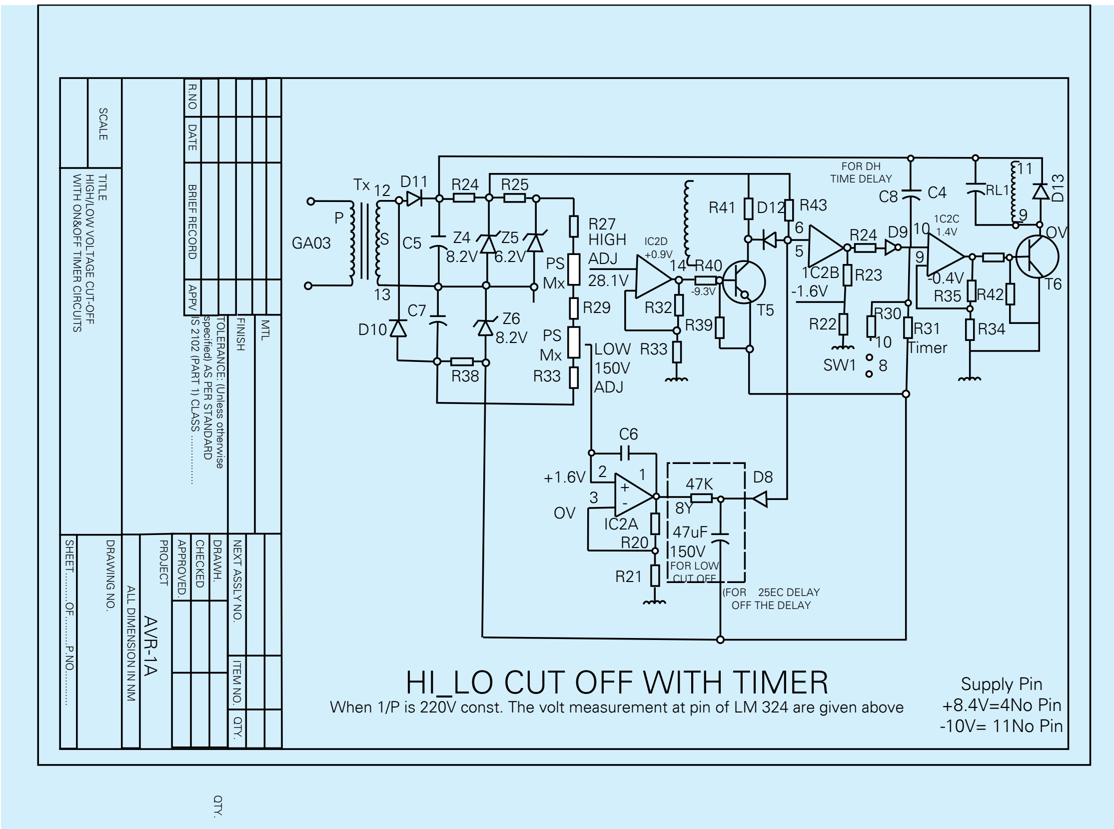
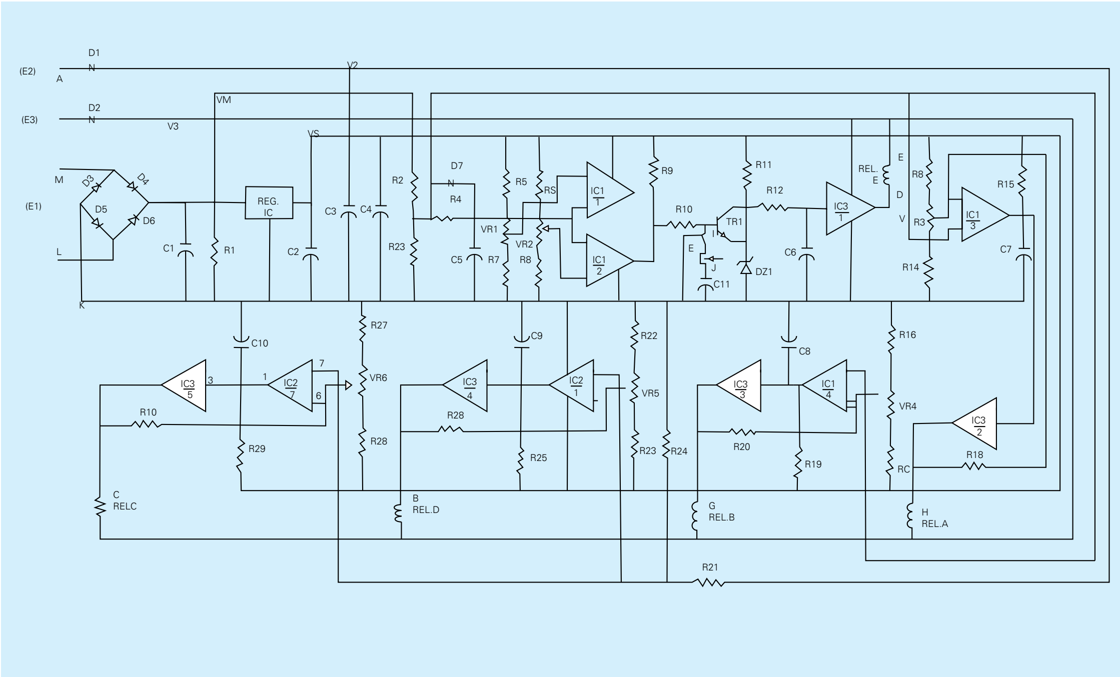


Figure C-1.6:

B. Electrogaurd



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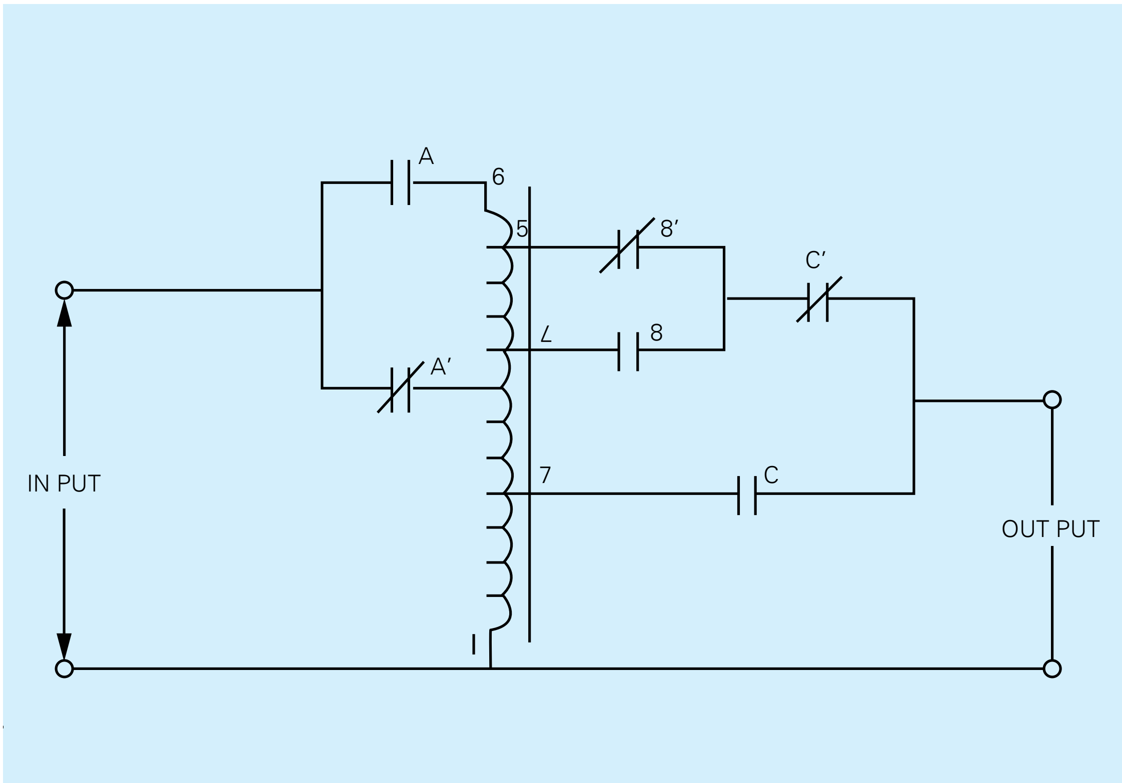

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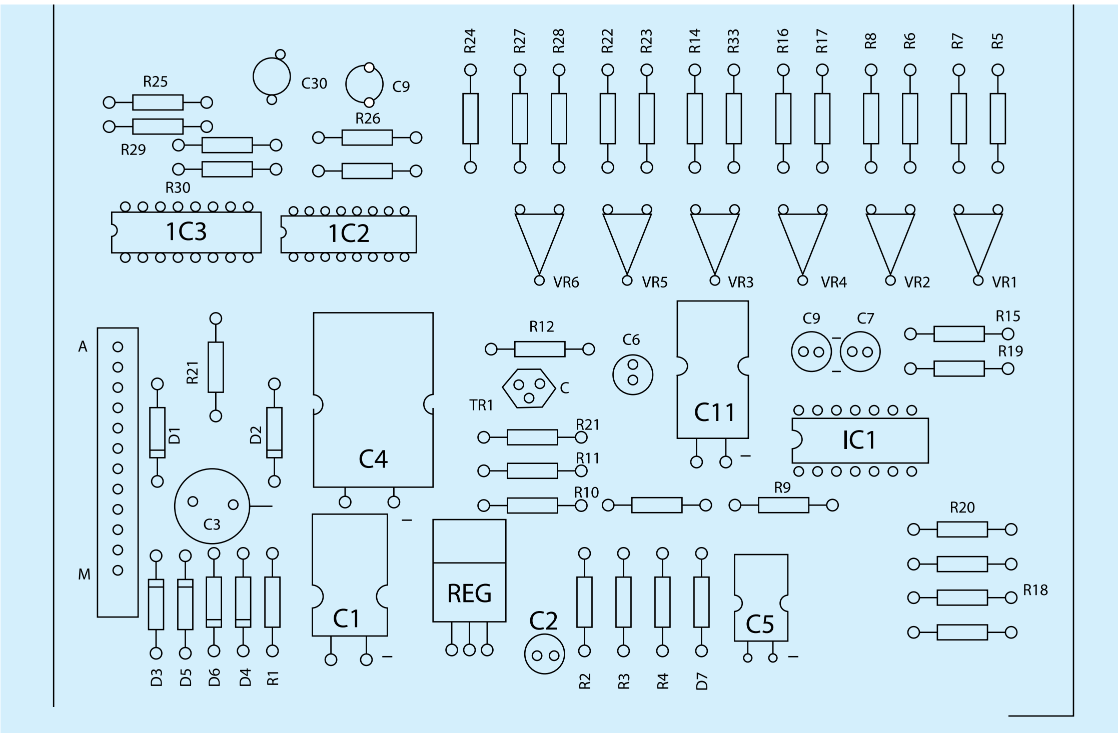

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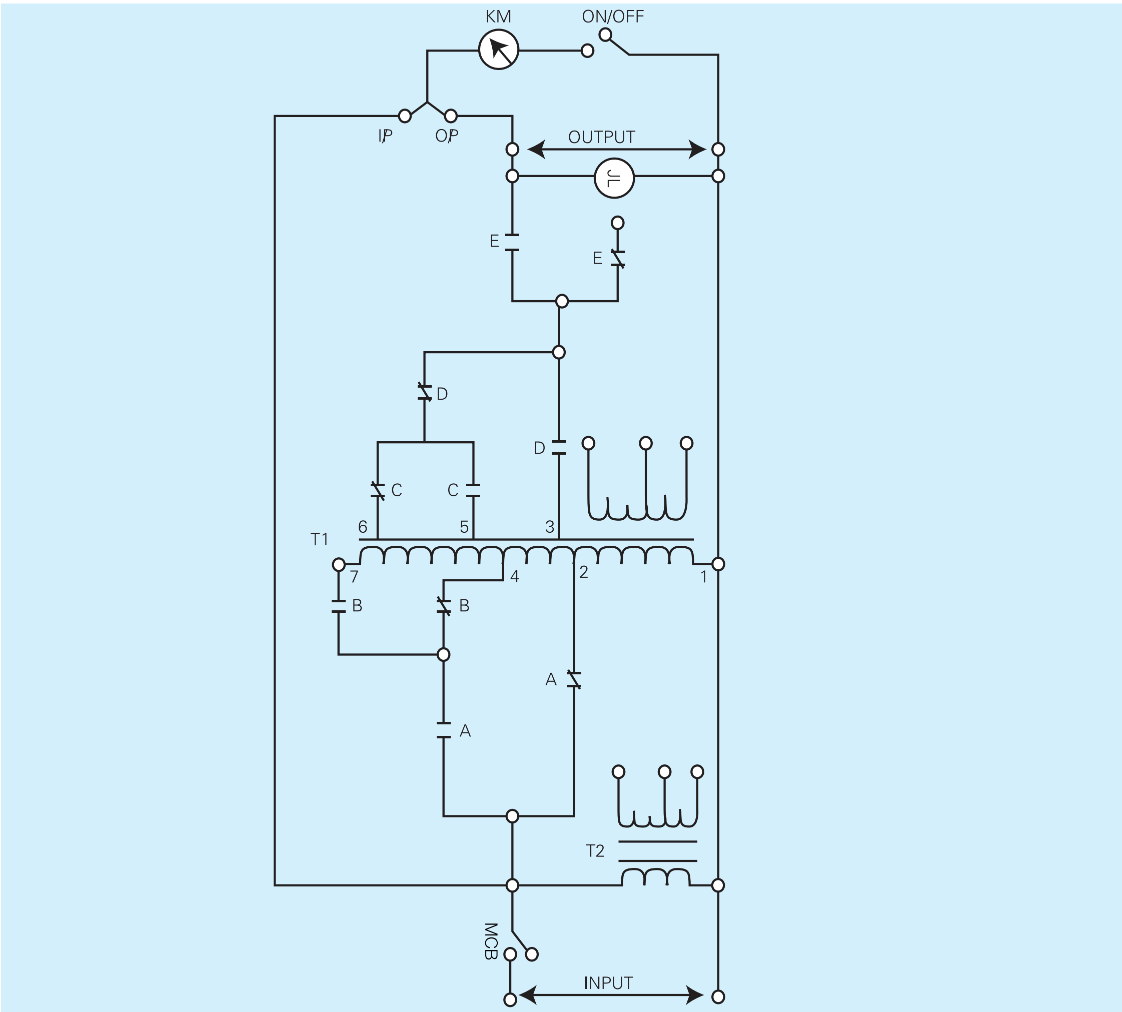

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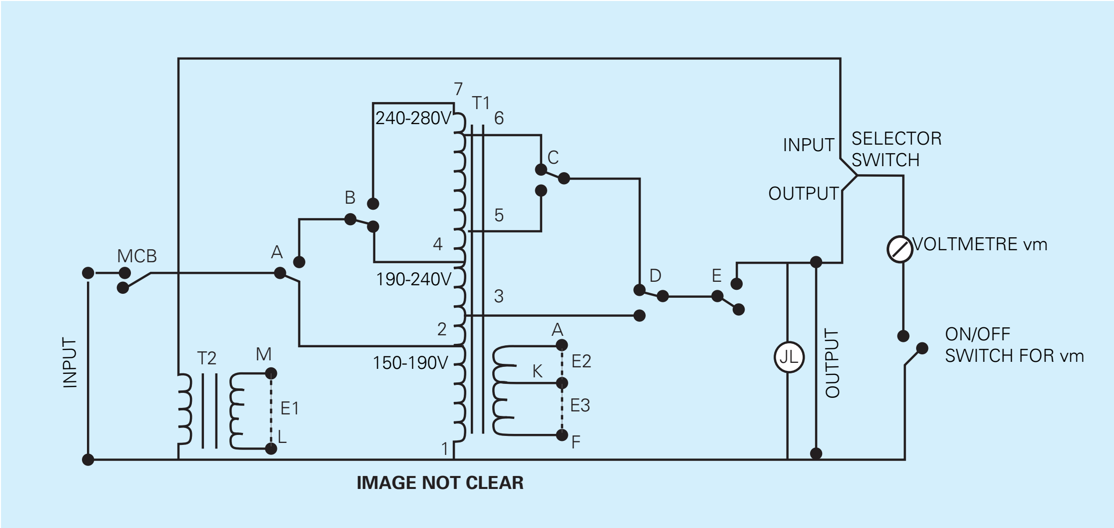

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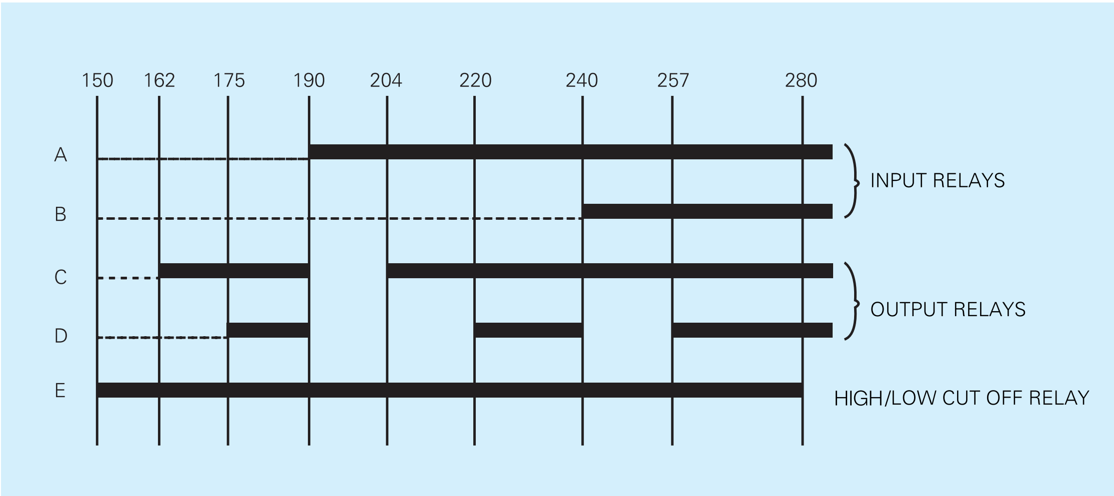

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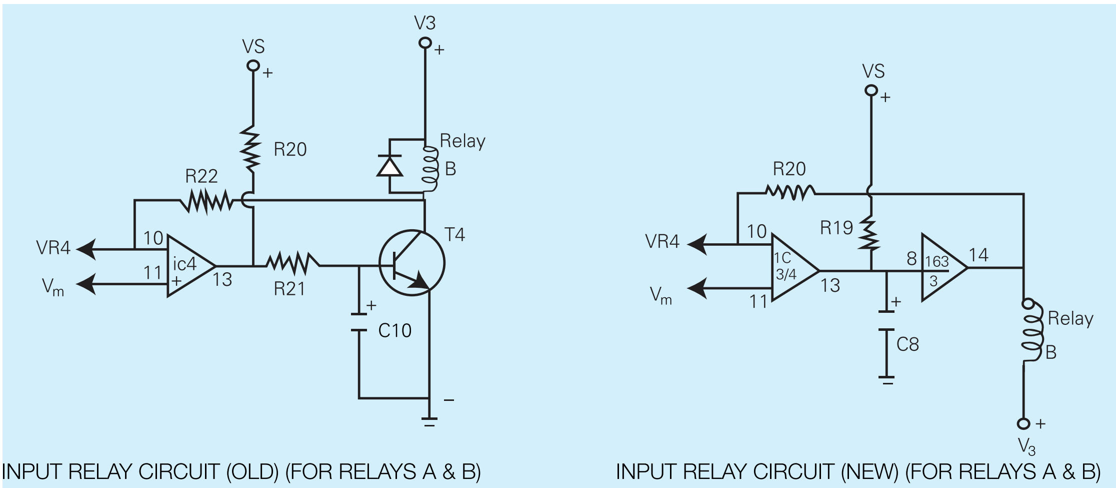
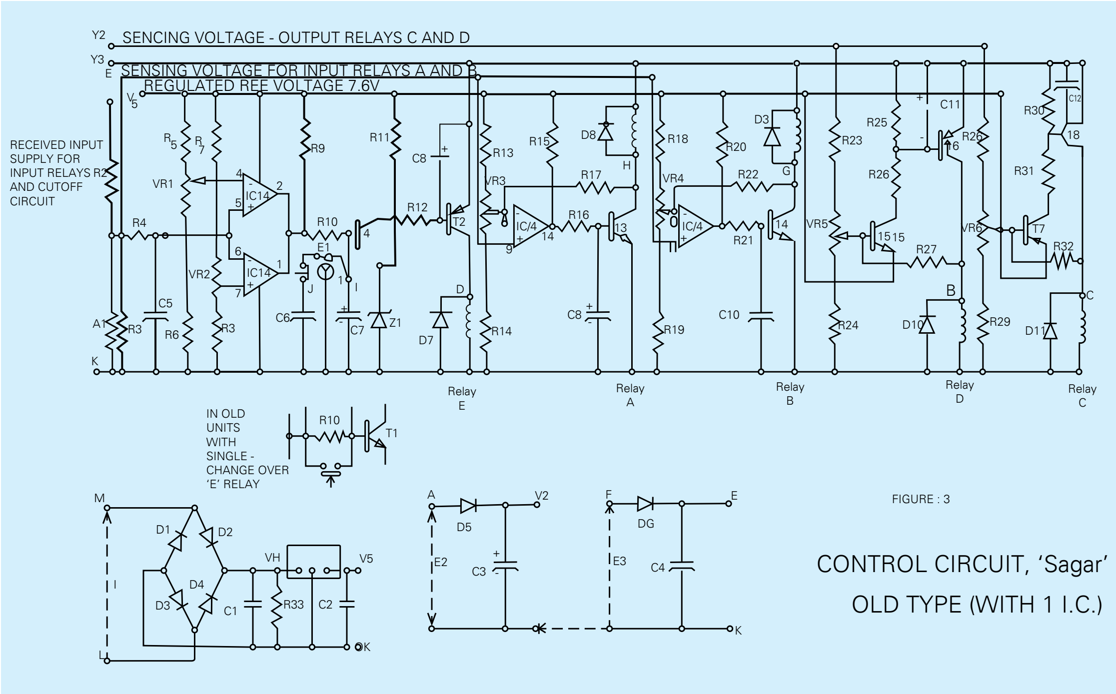


Figure C-1.13:

C. Sagar



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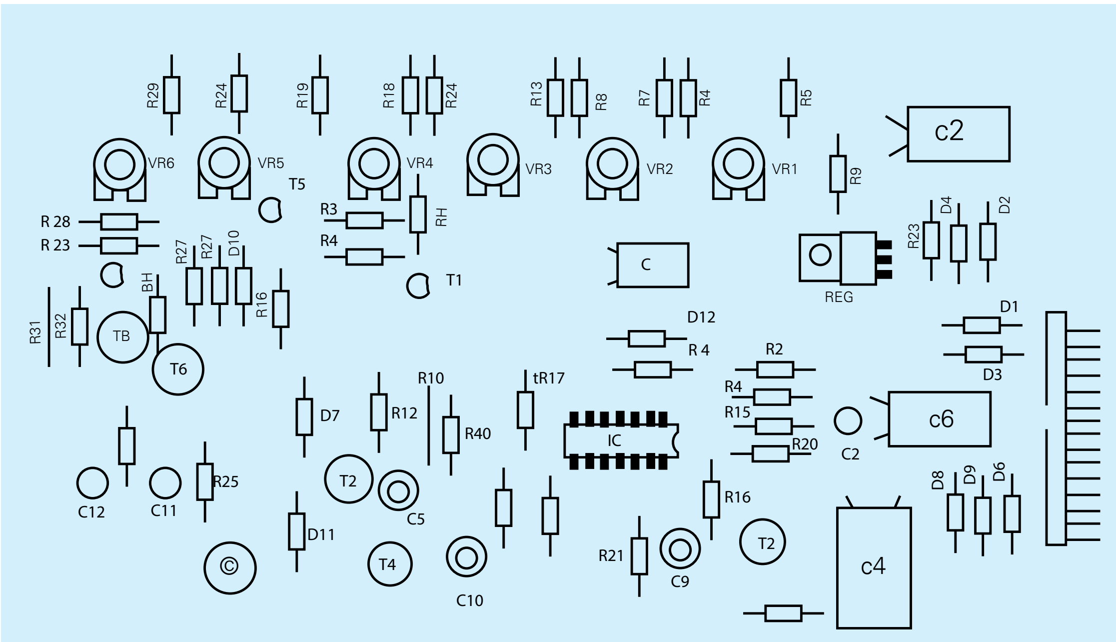
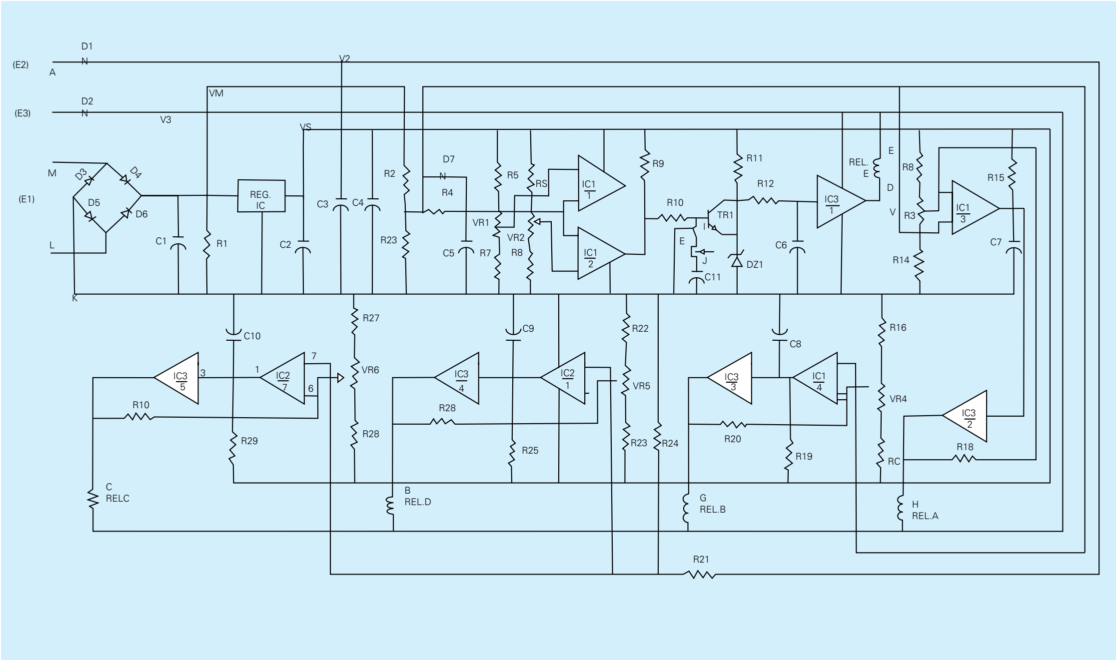


CONTROL PCB 'SAGAR'
OLD TYPE (with 1 IC)

Figure C-1.15:



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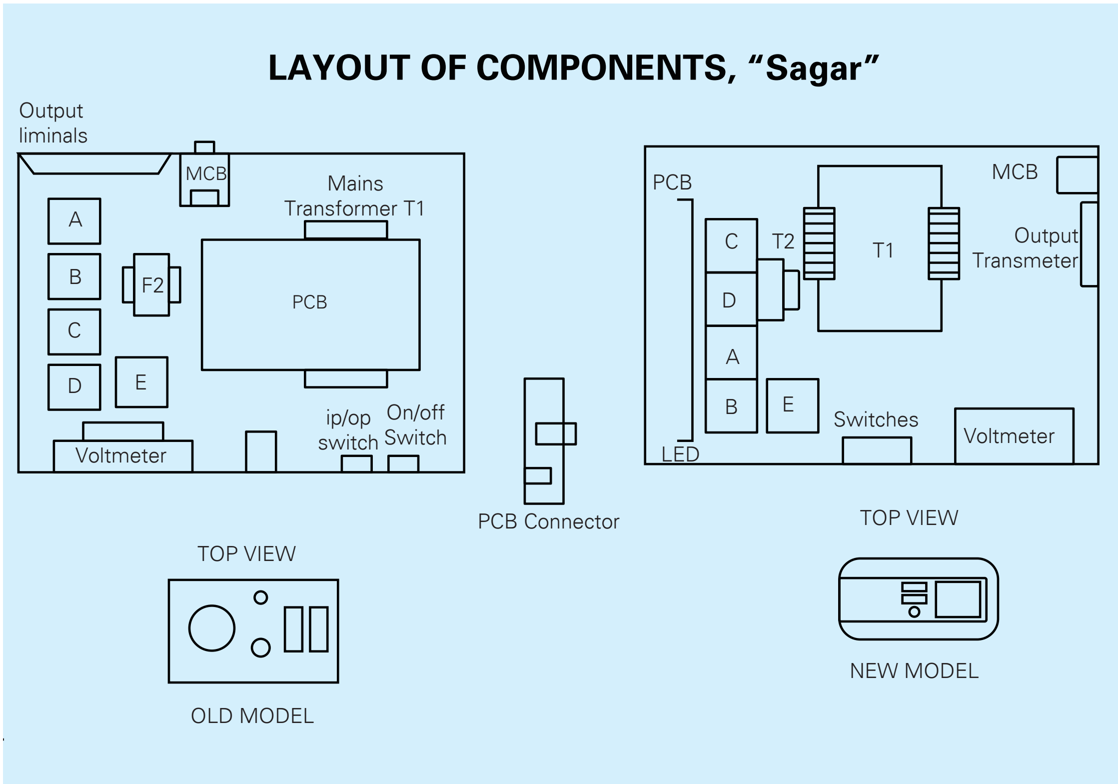

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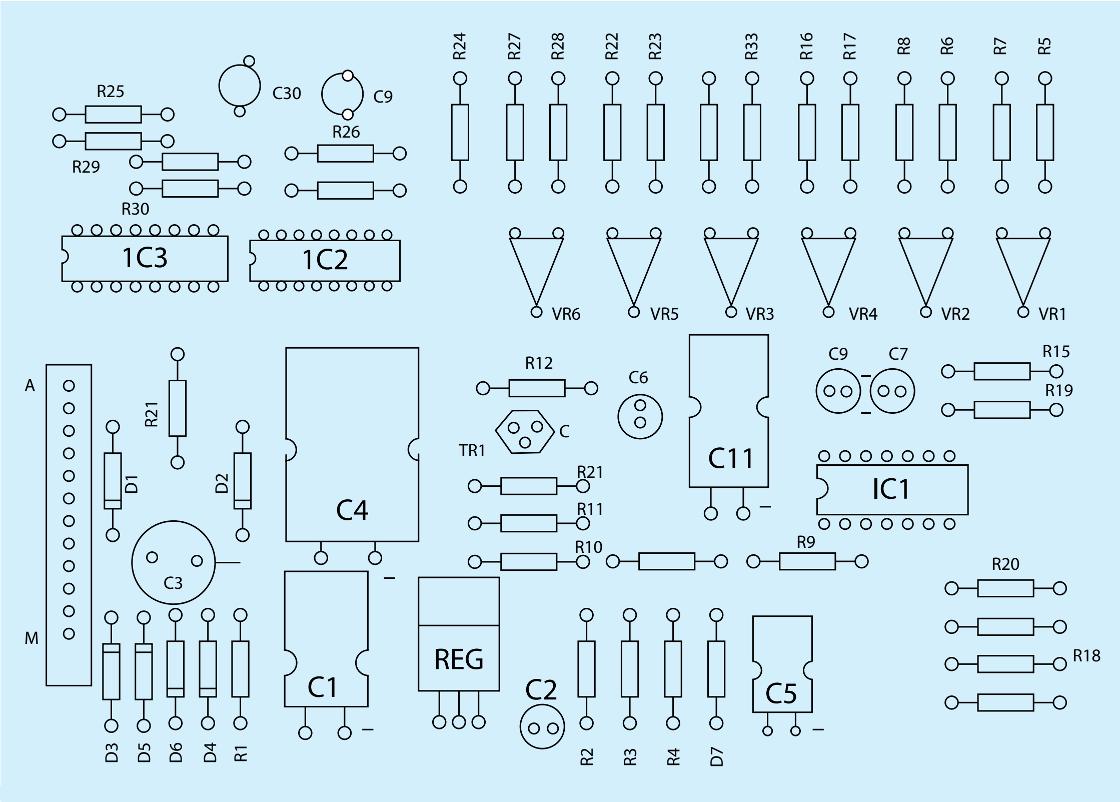

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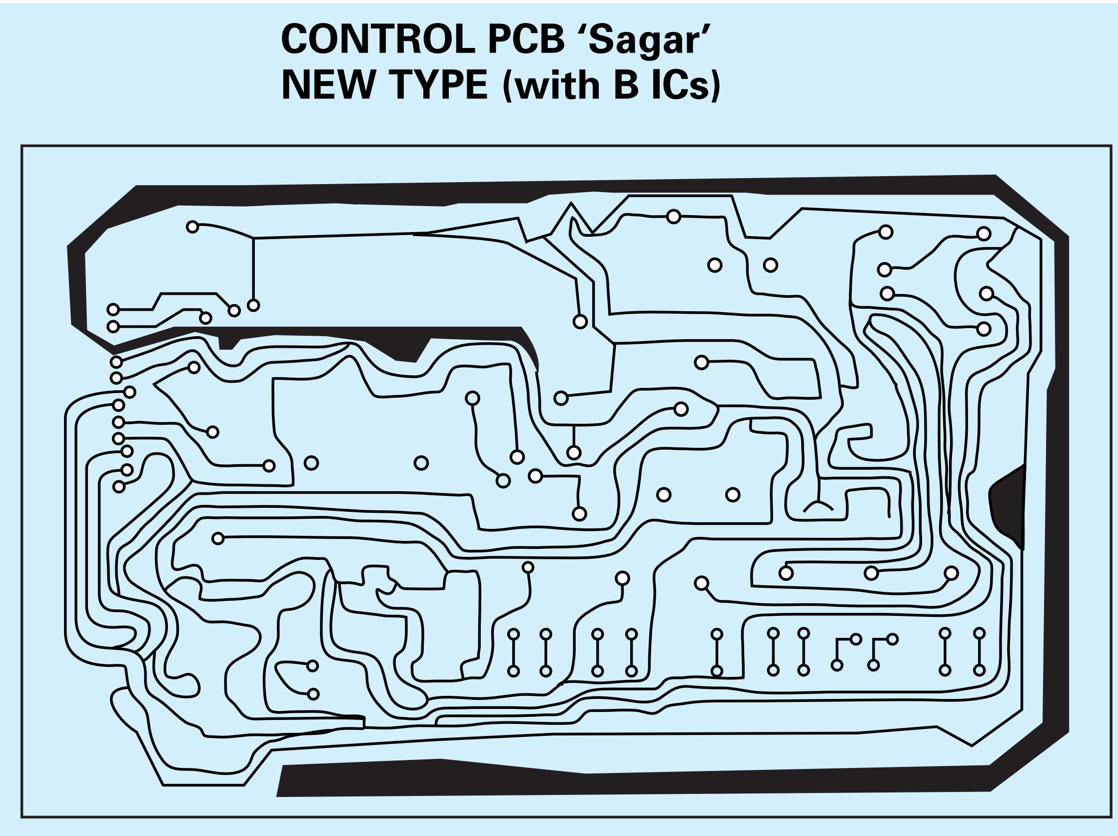

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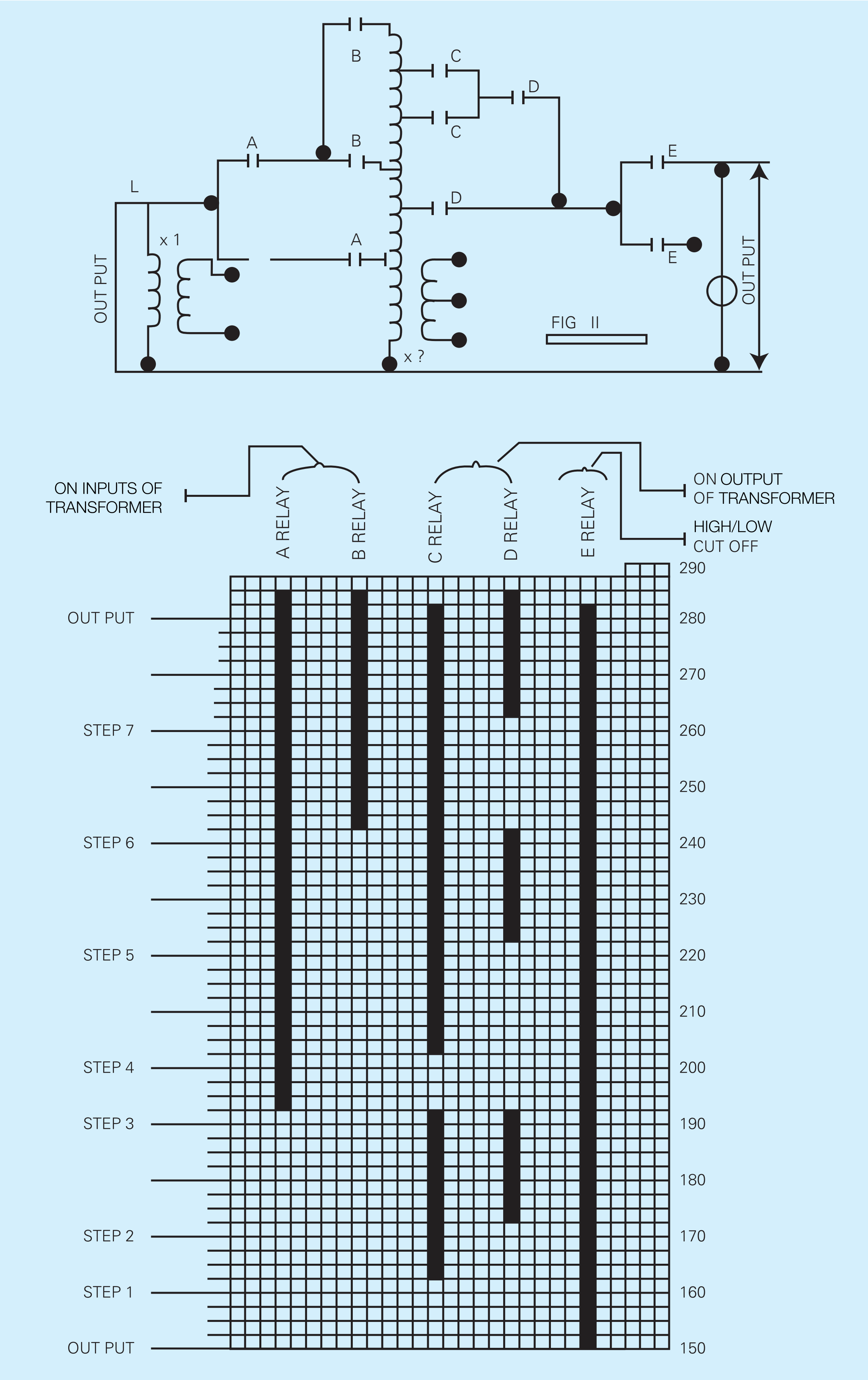
B
C
D
C
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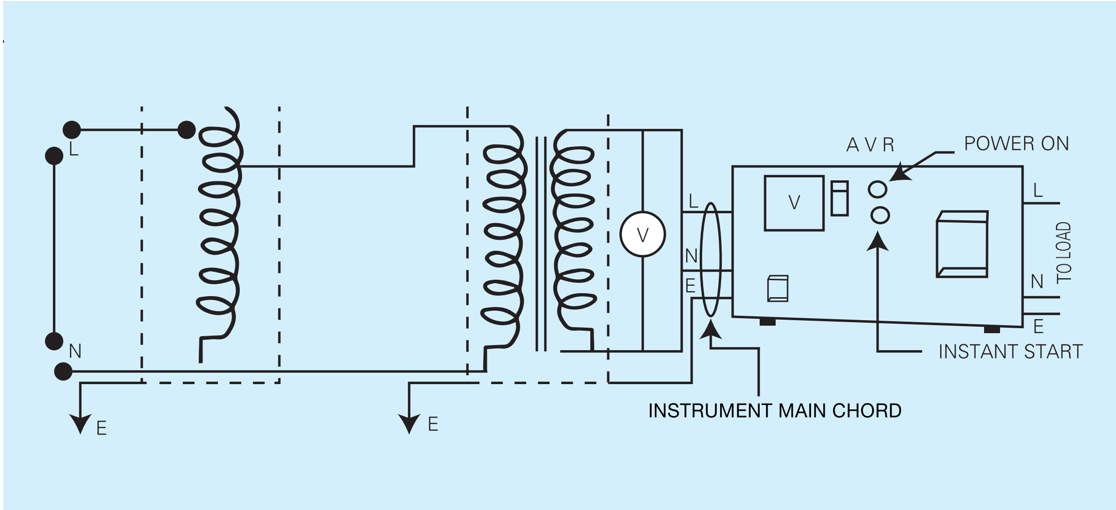
B
L
D
E
x 1
A
E
OUT PUT
OUT PUT
FIG II
x ?
ON INPUTS OF TRANSFORMER
A RELAY
B RELAY
C RELAY
D RELAY
E RELAY
ON OUTPUT OF TRANSFORMER
HIGH/LOW CUT OFF
OUT PUT
STEP 7
STEP 6
STEP 5
STEP 4
STEP 3
STEP 2
STEP 1
OUT PUT
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150

Figure C-1.20:

D. SERVAL



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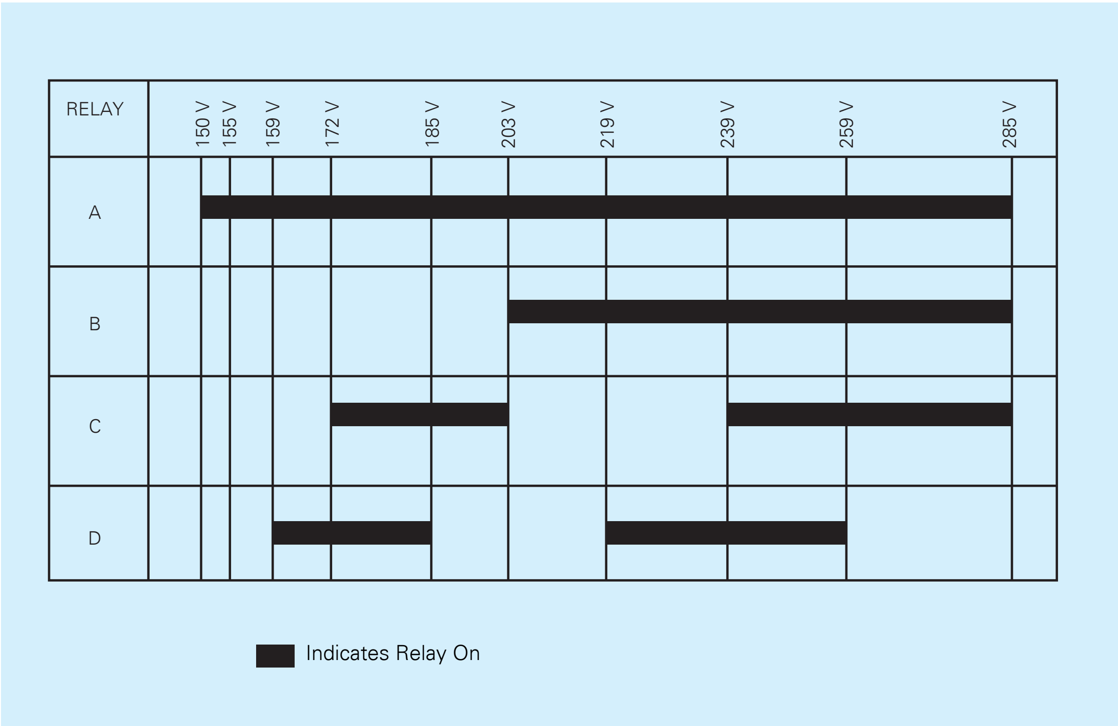

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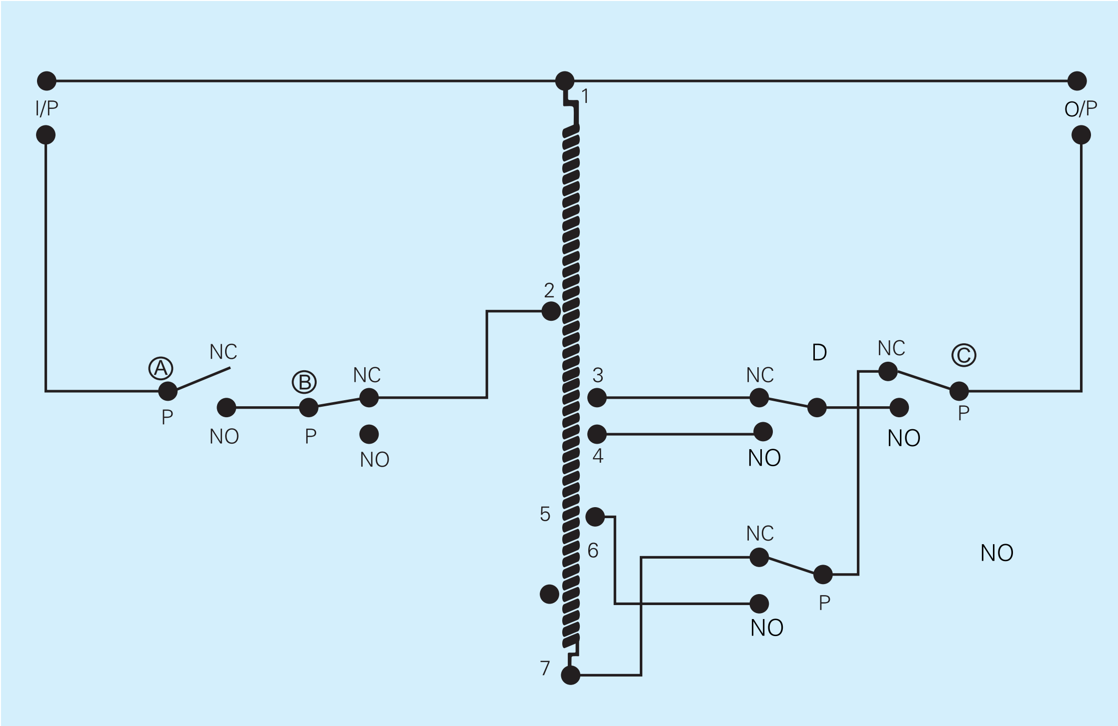

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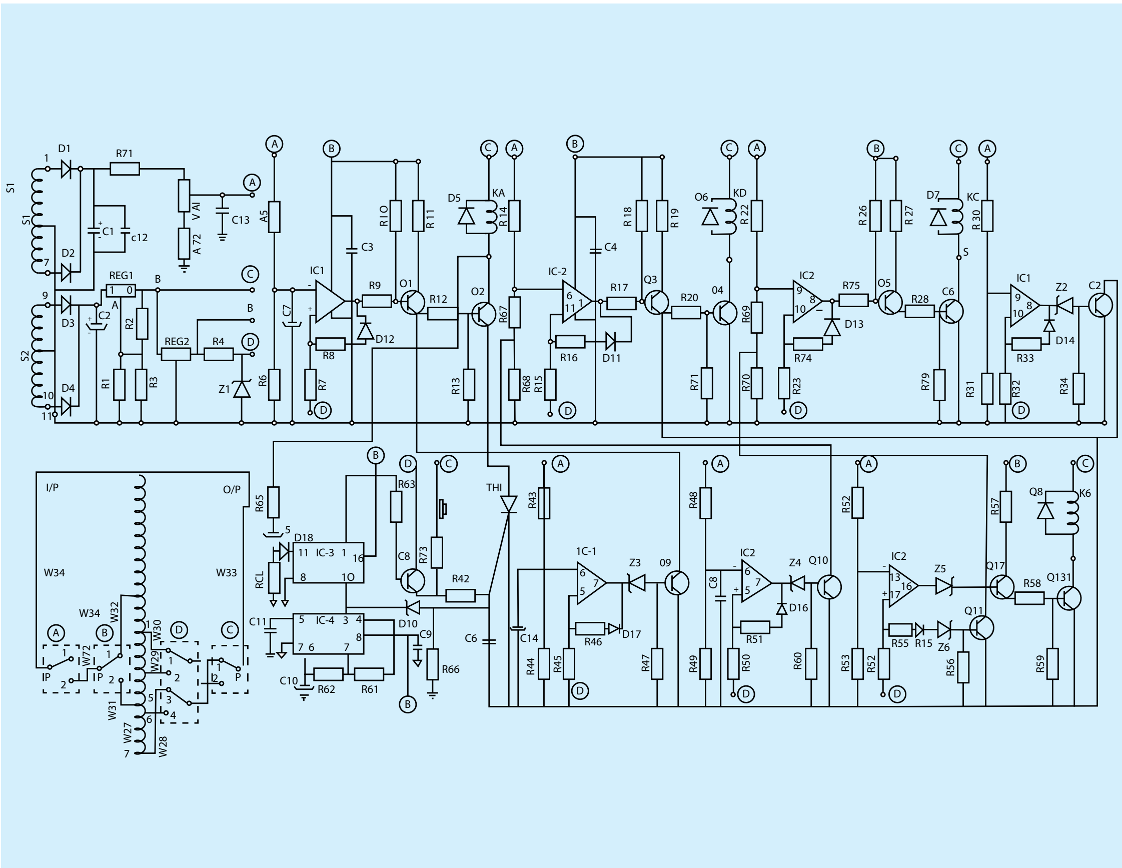


Figure C-1.21:

Notes

2

ANNEXURE

A. Emerging Newer Technologies in Cold Chain.

The Immunization Division of the Ministry of Health and Family Welfare (MoHFW) is taking strong proactive steps to continuously upgrade the infrastructure utilized for India's Universal Immunization Programme (UIP). This is done with a view to improving immunization coverage rates and providing safe and efficacious vaccines across the country. New Technology Cold Chain Equipment (CCE) solutions, if procured and deployed in an evidence based manner could help achieve this goal.

In recent months, many new and innovative cold chain technologies have been developed and almost in parallel many commercially available products have also been released in the market which uses these new technologies to provide various benefits. WHO PQS is also strongly focussed on developing certification and testing standards for these new technology solutions and products. Overall the efforts are towards improving immunization coverage across the country with due care of protecting vaccines from damage due to temperature excursions, as in doing so there are lot of challenges involved in terms of.....

1. Non availability of Grid electricity & quality of power supply available in the health facilities located at remote/interior part of the country.
2. Cold Chain Equipment Operational issues, i.e. Hold over Time/Cabinet Temp excursion above/below permissible limits.
3. Replacement plan for CFC based Cold Chain Equipments for environmental issues & implication. (Transition step towards CFC free world..... (Use of Environment friendly refrigerants)

For meeting challenges & addressing these issues, the Immunization Division of the MoHFW is in process of adopting newer technologies in cold chain, which are innovative & emerging rapidly in the cold chain and particularly quite noticeable in following sector.

1. Refrigeration using Solar Power
2. Sure Chill Technology..... (New Kind of Cooling System)
3. Freeze Protection Technology.
4. Use of Natural Refrigerants (Hydrocarbons)
5. Solar Inverters....Power backup systems for Cold Chain Equipments

   Let us have an overlook, these upcoming technologies......

1. Refrigeration using Solar Power

Introduction

Accurate and uniform temperature in a refrigerator plays a key role in ensuring the life& potency of vaccines. Keeping heat-sensitive vaccines at the right temperature is crucial yet often difficult in areas with limited or no electrical power or frequent or long-duration power outages that make the use of grid-powered cooling impractical for vaccine storage.

Extensive immunization programmes are in progress throughout the developing world in the fight against the common communicable diseases. To be effective these programmes must provide immunisation services to rural areas.

Solar radiation tends to be high in climates that have great needs for cooling, a great deal of effort has been directed to develop solar powered refrigerators.

Although some solar absorption (thermal) refrigerators have been developed only solar photovoltaic (electric) refrigerators have so far proved reliable.

Solar photovoltaic power for refrigerators has great potential for lower running costs, greater reliability and a longer working life than kerosene refrigerators or diesel generators, which have been generally used in remote areas.

The need

All vaccines have to be kept within a recommended temperature range throughout transportation and storage. The provision of refrigeration for this, known as the Vaccine 'Cold Chain', is a major logistical undertaking in areas where electricity supplies are non-existent or erratic. The performance of refrigerators fuelled by kerosene and bottled gas is often inadequate. Diesel powered systems frequently suffer fuel supply problems. Solar power is therefore of great importance to health care.

Solar Powered Refrigerators.

Photovoltaic refrigerators operate on the same principle as normal compression refrigerators but incorporate low voltage (12 or 24v) dc compressors and motors, rather than mains voltage ac types. A photovoltaic refrigerator has higher levels of insulation around the storage compartments to maximize energy efficiency

Although solar-powered refrigerators are rare, they are found useful in rural health centres. As RI Vaccines must be stored at carefully controlled, in designated temperatures (+2^{0}C to +8^{0}C), Solar refrigerators are expensive but provide the only way that vaccines can be stored at many remote sites.

It is usually best to connect high-quality, high-efficiency appliances so that the PV system can be kept as small and low in cost as possible.

Most refrigerators include a freezer compartment for ice pack freezing. Other systems have separate units to provide solely for refrigeration or freezing. Available sizes range between 10 and 85 litres of vaccine storage capacity with ice production rates of up to 6.4 kg per 24 hours. A typical refrigerator layout is as shown below Figure

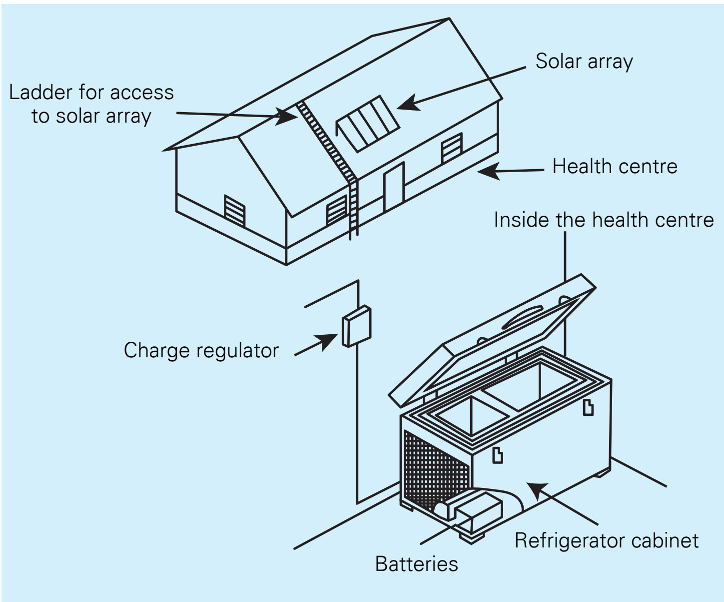


Figure C-2.1:

Three types of solar photovoltaic refrigerators are available today.

The most widely used and generally the most satisfactory is the compressor refrigerator.

In this type, a refrigerant is circulated and, through mechanical compression and heat transfer, alternates between being a liquid and being a gas.

A second common type is the absorption refrigerator.

In this type, the two materials in the refrigeration circuit get cold when they are mixed together. Kerosene and liquefied petroleum gas (LPG) refrigerators use this system as they require a high temperature to operate. Electricity can be used but absorption refrigerators use much more electrical energy than compression refrigerators. Traditional absorption, compression and solar refrigerators struggle to maintain constant temperatures and are prone to overheating or freezing.

The third type is the thermoelectric refrigerator. It uses a solid-state device, similar to a solar cell or a transistor, with two poles. One pole is cooled and one pole is heated when an electric current is passed through the device. This type of refrigerator can be made very small and is the best choice where less than a liter of refrigeration capacity is needed. The larger sizes usually needed for vaccine storage or domestic use is very expensive and uses considerably more energy than the compressor type.

As the solar photovoltaic vapour compression refrigerators are most widely adopted & also very common in immunization programme, here the discussion is limited with focus on newer technologies used in Solar Powered Refrigerators based on Vapour Compression System.

Broad classification for Solar Refrigerators is...

- Solar Direct Drive (SDD) Refrigerator
- Solar Refrigerator Battery Powered

1.1. Solar Direct Drive (SDD) Refrigerator

Direct Drive technology in solar refrigerator eliminates the use of battery & charge controller. These vaccine refrigerators run on solar power. In the latest generation, each one of these devices comes with a solar panel that is mounted on either a pole or on the roof of the health facility, and is connected to the device by power cable. Solar Direct Drive refrigeration systems are the new generation of solar powered refrigeration systems bypassing the use of a battery, instead the power is stored using different non battery based technologies. Unlike battery powered solar devices, they do not need batteries and, as a result, they require less maintenance. Solar-powered refrigeration equipment runs on electricity provided by solar energy. They are able to keep vaccines at their appropriate temperature, without the need for electricity from grid.SDD technology offers improved functionality, environmental impact considerations and reduced demand on human and financial resources as SDD

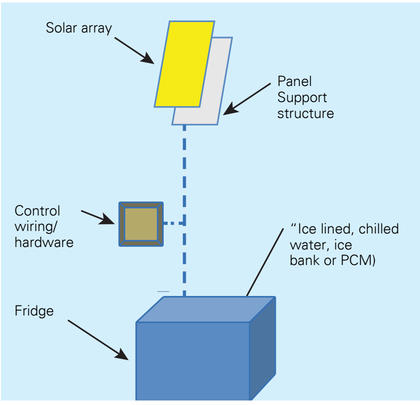


Figure C-2.2:

refrigeration systems have significant advantages compared to Battery Powered Solar products. SDDs do not depend on the timely replacement of batteries, which have a relatively short lifespan (3-5 years).. There are currently four technologies existing: PCM (phase change material), Ice-lined (ILR), water- lined and ice bank

Solar Direct Drive (SDD) Combo Units

SDD Combo units have the capability to provide both fridge and freezer benefits in one combined unit with two separate sections for each use. Further, they do not require grid power because these units draw power from solar panels which come with the units. Typically, vaccines can be safely stored between 2°C to 8°C in the larger fridge section while ice packs can be generated and stored between -15°C to -25°C in the smaller freezer section. Most SDD combo units are do come with freeze protection technology & have long autonomy times and are certified for Extended ambient temperature ranges.

SDD Combo units are best suited for power deficit smaller facilities which are intended to serve a smaller than average birth cohort and/or are housed inside smaller buildings with space constraints. They help provide immunization services in those areas which do not have adequate electricity and also do not have adequate physical space available for housing the cold room.

Components associated with Solar Refrigerator (Direct Drive)

Solar Panel

Solar Array and support structure:

Wires to carry the electricity.

In recent years a new approach to solar refrigerator design has emerged that eliminates the expensive (and problematic) energy storage batteries. "Direct-drive" technology uses the sun's energy to freeze water or other phase change material and then uses the cooling from that "ice bank" to keep the refrigerator cold during the night and cloudy days. These refrigerators are called "Solar direct-drive refrigerators" because they are wired directly to the photovoltaic generators.

In developing countries the electricity grid often does not reach rural areas, and is not always reliable. As keeping vaccines at the appropriate temperature is vital, solar powered refrigerators are proving cost-effective alternative that can be highly reliable. A typical system will use a solar photovoltaic panel to generate electricity from sunlight.

Notes

Advantages:-

- Do not require a battery to store energy
- Do not require electricity and can be used in rural areas where sunshine is abundant
- Do not require solar charge regulators
- Easy installation
- Easy maintenance
- Cheaper in comparison to the battery powered systems

Disadvantages

- Relatively new innovation & lacking data on performance for the long term analysis

Choosing Solar Powered Direct Drive Systems

Surveys conducted on Battery Powered Systems have found that a large proportion of equipment failures are related to the batteries. It is not a question of if a battery will fail, but rather when it will fail. Batteries can fail due to improper design, misuse, poor installation, over use of the refrigerator, overload of the refrigerator resulting in prolonged running cycles and lack of maintenance and delayed repairs.

1.2. Solar Refrigerator Battery Powered.

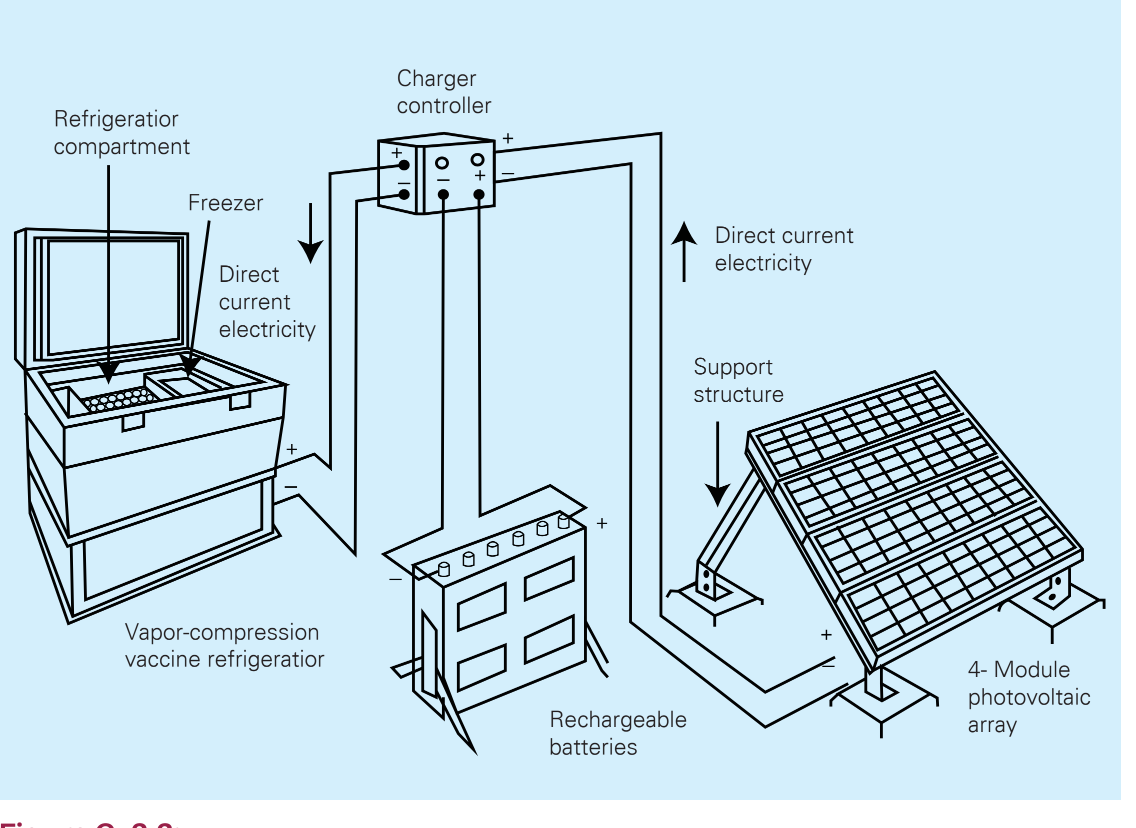


Figure C-2.3:

In principle, operation & construction almost very similar to SDD, incorporating additional components like Battery & charge controller. A battery bank for electricity storage, a battery charge regulator and a controller which converts the power from the battery to a form required by the compressor motor.

This results in increased maintenance, especially for battery & in turn overall cost of the system.

When a PV system is first designed, the size of the system is carefully matched with the equipment to be used. If you want to increase the size or number of refrigerators connected to the system, larger solar panels and batteries must be installed. If new equipment is attached to an existing PV system without increasing the size of the panels and batteries, the battery life will be shortened and the system will probably not work well.

The solar panels that produce electrical power and the batteries that store the power are expensive. So equipment that is connected to PV systems should use as little energy as possible.

The advantage with this type of system is Battery backup for Solar Refrigerator when there is no power from Solar Panel. i.e. During night period/cloudy weather/ rainy days.

Components associated with Solar Refrigerator (Battery Powered)

Solar Panel

Solar Array and support structure:

Batteries

Charge Controllers

Wires to carry the electricity to and from the battery.

Relative merits of using solar refrigerators

Compared to kerosene or bottled gas fuelled refrigerators, photovoltaic systems have the following advantages:

Improved vaccine storage facilities as a result of:

- Elimination of fuel supply & quality problems
- Greater refrigerator reliability
- Better refrigerator performance (and temperature control).

Reduced running costs as a result of:

- Elimination of kerosene fuel & its transportation costs
- Reduced vaccine losses
- Lower refrigerator maintenance costs
- Reduced needs for back-up refrigerators where there are fuel supply or repair problems.

Cold chain management benefits due to:

- Ideal solution, where there are issues of absence of grid electricity.
- Longer life [photovoltaic array 15 years, refrigerator 10 years, battery 5 years(For battery powered equipment)]
- Reduced logistical problems arising from non-availability of working refrigerators & lower vaccine losses.

The above operational advantages of introducing solar refrigerators into the cold chain (especially at remote health facilities) indicate that solar refrigerators can provide a more sustainable vaccine cold chain. It should be noted however, that as each system is site specific, and more time is necessary for planning and implementing a project with solar refrigerators.

User training demands are also higher, since a new technology is being introduced.

2. Sure Chill technology. (New Kind of Cooling System)

Normal refrigerators need to have constant connection to power and even in the best conditions do not control temperature well. Newer fridges which have revolutionary Sure Chill Technology are Grid operated & also SDD (Soalr Direct Drive). The SDD with Sure Chill technology do not require batteries to maintain temperatures.

This newer technology Refrigerators available in the globe uses an intelligent monitoring system which limits the temperature variation within the cabinet to less than 1^{0}C, eradicating freezing problems which can occur with more conventional refrigerators. In these type of New technology refrigerators, ice never forms on the walls of the cabinet and so refrigerators never need defrosting and can be kept running at all times.

The Sure Chill technology provides constant reliable cooling in the environment scenario where electricity supplies are intermittent or where ambient temperatures are high. Sure Chill is a brand new kind of cooling system. It doesn't need a constant power source. In an off-grid situation, solar panel may be used. Refrigerator using Sure Chill technology doesn't even need a rechargeable battery.

About Sure Chill technology.

Water has an amazing property that's unique in the universe. At four degrees, water is at its heaviest. At four degrees it sinks. At any other temperature it rises. This scientific fact is the reason behind creation of new kind of refrigeration system with Sure Chill Technology. Sure Chill refrigerators works on the same principle. In this type of refrigerators, water surrounds refrigeration compartment. When it has power, the water cools and forms ice above the compartment leaving only water at four degrees cooling the contents. When the power is switched off, the water warms and rises while the ice begins to melt, keeping only four-degree water cooling the contents of the compartment. So it has its own internal and entirely natural energy store that maintains a completely steady temperature. The system can operate like this, without power, for days and even week.

This cooling technology used enables the refrigerators to run on as little as 4 hours of Electricity a day & additional energy received is used to build its internal thermal energy store for use in the event of electricity failure.

The Refrigerators available, adopting this technology is either Solar powered (SDD) or Grid powered with following features.....

- In the absence solar power & Grid power, hold over time is in days (7 to 11) at 43^{0}C ambient.
- Operation is frost free.
- The temperature variation within the cabinet to less than 1^{0}C, as refrigerators do come equipped with intelligent monitoring system. This feature may help in eradicating freezing problems which may occur with conventional refrigerators.
- There is no ice formation on the walls of the cabinet and refrigerators need not requires defrosting and can be kept running at all times.

3. Freeze Protection Technology.

Temperature in colder areas with ambient temperature near 0^{0}C, especially parts of J&K, Uttarakhand, Punjab and Himachal Pradesh to assess incidences of freezing when ambient temperature falls below zero. Other reasons for vaccine freezing may be due to Thermostat failure/ sensor failure or incorrect adjustment of thermostat,which leads temperature excursion in the vaccine storage compartment.To prevent this to happen, “Freeze protection technology” is needed one, which can keep the stored vaccine safe in recommended temperature range & also prevent costly vaccines. Freeze Protection technology ensures that vaccines do not get damaged from freeze excursions & ensures a more uniform cooling and better thermal control inside the storage area, which ultimately benefits in terms improving the potency of the vaccines which are to be administered.

Notes

Incorporation of Freeze Protection technology in CCEs has got following programmatic advantages

- As long as deployed within its certified ambient temperature range, vaccines stored cannot be damaged at all by freeze excursions regardless of how they are physically placed inside it.
- Incorporation of such kind of technology helps in eliminating direct intervention from healthcare workers, any particular storage area inside the CCE, any baskets or any adjustment of thermostats in order to protect vaccines from freeze damage.
- Especially beneficial in case 24-hour active monitoring of stored vaccines is not feasible or in case the deployed human resource for vaccine and cold chain management needs capacity building.
- Currently, there are three pathways for achieving Freeze Protection technology:
- A combination of water in different phases usually around the fridge
- Phase Change Material (PCM) between the outer and inner walls of the fridge
- Reengineering of the existing products
- CCE models equipped with "Freeze Protection Technology" being released in the commercial market are categorised under Grade A User Independent Freeze Protection (UIFP). In many cases, the pricing of the Grade A UIFP models is comparable to or not much higher than that of the non-Grade A models. Manufacturers are also quickly upgrading existing models to Grade A UIFP and also getting them WHO PQS certified for the same.

Recently supplied MK304 ILR model is equipped with "Freeze Protection Technology", features of which are outlined as below.

Figure C-2.4:

Airflow System

Reliable and stable temperatures are ensured via the built-in Airflow System. A heating element secures frost protection.

Digital Display

A solar driven digital display shows the current temperature. The self-regulating system means that no manual adjustment is needed.

Ice lining

The thick ice lining and ballast boxes ensure temperature stability and extended hold-over time in case of power cut.

Baskets

Practical baskets are included to facilitate organized storage of vaccines inside the cabinet.

Electronic Thermostat

The appliance has an electronic thermostat (Dual Sensor) that controls the temperature in the vaccine compartment & heating element supply. The thermostat is set by the factory

This feature, i.e. Freeze Protection Technology (Use of Airflow system/dual sensor Thermostat/Heating element circuit) makes MK304 model different in comparison with earlier models.

Notes

4. Use of Natural Refrigerants-HC-600.

Natural refrigerants are inexpensive, available in abundance and today can cover nearly every refrigeration application already today. Furthermore, they have a very low global warming potential (GWP) compared to synthetic refrigerants. This alone is reason enough to recommend their use, as refrigerants, i.e.CFCs, HCFCs & HFCs common in use, do have harmful effects to the environment. The reason behind increased use of Natural refrigerant in Refrigeration engineering is not only, as because of its energy efficiency but also for its environment friendly nature helpful to save the "Mother Earth". This necessitates strong advocacy towards increased use of natural refrigerants & in view of this many countries are putting their efforts for the promotion of public awareness and acceptance of natural refrigerants. The ultimate objective is to promote the use of natural refrigerants in the interest of a healthy environment, and thereby encourage a sustainable approach in refrigeration engineering.

Factors influencing selection of refrigerants in Cold Chain

- Environment friendliness – ODP / GWP
- Cost of Refrigerant
- Availability of refrigerant with local production
- Equipment availability thru local manufacturing
- Ease of maintenance of equipment & availability of spare parts & services thru local agencies
- Energy efficiency of the system-Most important due to high cost & problems in availability of adequate power supply.
- Requirement of trained operating personnel
- Feasibility of centralized integrated plants for multi temp units.
- Automation facility of plants

Why Natural Refrigerant?

Refrigerant	ODP	GWP 100 years	Safety Group	COP Ratio	Refrigeration capacity	Discharge Pressure MPa	Discharge Temp.
HCFC-R22	0.055	1700	A1	1	1	1.53	57.5
HFC-R 134a	0	1300	A1	0.99	0.91	1.02	44.5
HFC-R404A	0	3870	A1/A1	0.89	0.68	1.83	44.8
HFC-R407C	0	1650	A1/A1	0.99	0.99	1.64	53.6
HFC-R410A	0	1980	A1/A1	0.93	1	2.41	57.2
HFC-R507A	0	3850	A1	0.88	0.65	1.88	44.4
R717(Ammonia)	0	<1	B2	1.04	6.9	1.55	93.3
R290(Propane)	0	3	A3	0.97	1.71	1.37	44.2
R600a(Isobutane)	0	3	A3	1.01	1.66	0.53	40
R744(CO2)	0	1	A1	0.63	0.85	9	72

Table: Natural Refrigerant

- ODP : Ozone Depletion Potential
- GWP : Global Warming Potential
- COP & Refrigeration capacity ratios are compared with R22
- Discharge pressure at discharge temperature of 4000C
- Safety group is according to ASHRAE standard (safety group 34)
- A : Lower toxicity
- B : Higher toxicity
- 1 : Nonflammable
- 2 : Flame resistant
- 3 : Inflammable

Hydrocarbons

Hydrocarbon refrigerants are the natural refrigerants and have neither ozone depletion potential (ODP = 0) nor significant direct global warming potential (GWP = 3). HCs are long term solutions & being used safely in appliances in many countries in Europe. HCs are also used to some extent already in some developing countries like China and India.

Refrigeration plants using hydrocarbons such as propane (R 290, C_3H_8), propene (R 1270,C_3H_6) or isobutane (R 600a, C_4H_{10}) have been in operation all over the world for many years.

Hydrocarbons have excellent thermodynamic properties, which is why refrigerating and airconditioning systems operating with these substances are particularly energy-efficient. They are well miscible with conventional refrigerating oils and have a relatively high critical temperature. The main disadvantage of HCs is that they are flammable. This safely issues need to be addressed. Some electrical components require changes. While the flammability of hydrocarbons requires hermetically sealed systems with explosion protection for electrical components, all components are easily available and current technology copes well with the demands of safe operation. Given the high energy saving potential of systems with hydrocarbons many refrigeration companies have build their roadmap for operating new refrigerating systems with hydrocarbons.

For HCs, safe manufacturing and servicing practices are essential, which requires some special training.

Characteristics of Hydrocarbon refrigerants are.....

Environmental Impact:-
HC's have zero ODP & negligible GWP.

Pressure & Temperature:-
HC's have pressure & temperature characteristic quite similar to HCFC's / HFC's

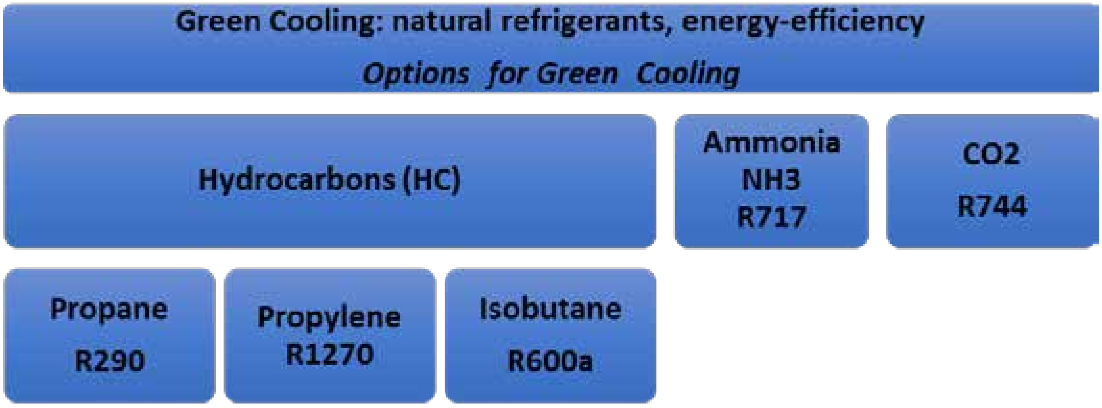
Chemical Properties:-
Commonly used HC's are compatible with standard refrigeration materials & oils.

Economic Aspects:-
For domestic & light commercial application, cost comparable with HFC's systems

For industrial & large commercial application, cost slightly higher due to need for explosion proof enclosures for electrical equipment.

Refrigerants & Systems – The Current Scenario

- Large industrial / Cold Chain plants – Use Ammonia / CO2, HFC 134a / 404A
- Smaller Systems – HFC 134a / 404A / R-290 / 600a
- New Trends
  - Low Charge Ammonia Systems
  - CO2 Systems – CO2 as Primary / Secondary Refrigerant, CO2 – Ammonia Cascade Systems
  - Ammonia Water Absorption Systems
  - HFO's & R-723 Systems
  - Smaller Systems with 'HC' Refrigerant.



Commonly used HC's :-

Hydrocarbons such as butane, propane and propene are ideal refrigerants.

- R – 290 Propane – Long History as Refrigerant. Very similar thermodynamic properties to R22. Some Asian countries have therefore replaced R22 with propane in central air-conditioning systems. Butane for example is very successful domestic refrigerators currently being used. Furthermore, butane can also increasingly be found in smaller commercial refrigerating systems.
- R - 600a Isobutene – Used in Household Appliances in Western Europe.
- R -1270 Propylene – Introduced later to replace R-134, R-22, R-404a.
- Methane was also used as Refrigerant.

  The Solar Refrigerators introduced in immunization programme, whether it is Direct Drive/ Battery powered or with sure chill technology are using HC refrigerant that is HC600a.Hence following section has been dealt for some of the properties related to HC 600a- isobutene.

- Single component refrigerant with a normal boiling point of –12°C.
- The vapour pressure is much lower than other refrigerants.
- Fully miscible with mineral oils.

- The combination HC600a/Mineral Oil is compatible with traditional materials used in CFC12 compressors.
- Colourless and nearly odourless gases that liquefy under pressure
- Outstanding thermodynamic characteristics
- Highly energy-efficient
- Flammable, hence need to be used with safety devices & must be used responsibly
- Explosion risk only between Lower & Upper explosion limits.
- Refrigerant losses are near zero.
- Low cost
- Ideal refrigerant for small plants with low refrigerant charges.
- Mostly Non Toxic
- Need only certified persons for handling
- Widely used in domestic and small commercial refrigerators in Europe. A few million refrigerators are already in use with HC600a.

Refrigerant	R 600a	R 134a	R 12
Name	Isobutane	1,1,1,2-Tetraflouro-ethane	Dichloro-difluoro-methane
Formula	(CH3) 3CH	CF3-CH2F	CF2Cl2
Critical temperature in °C	135	101	112
Molecular weight in kg/kmol	58.1	102	120.9
Normal boiling point in °C	-11.6	-26.5	-29.8
Pressure at -25 °C in bar (absolute)	0.58	1.07	1.24
Liquid density at -25 °C in kg/l	0.60	1.37	1.47
Vapour density at to-25/+32 °C in kg/m³	1.3	4.4	6.0
Volumetric capacity at -25/55/32 °C in kJ/m³	373	658	727
Enthalpy of vaporisation at -25 °C in kJ/kg	376	216	163
Pressure at +20 °C in bar (absolute)	3.0	5.7	5.7

Table: Refrigerants Properties

HC 600a Operating Conditions

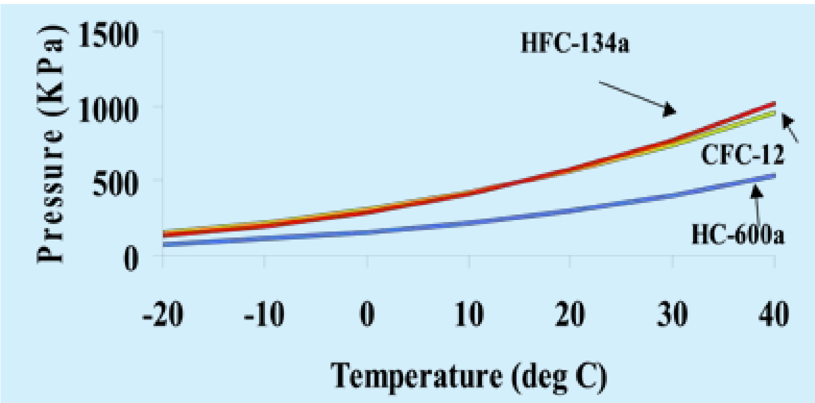


Table: Refrigerants Characterstich

The pressure vs. temperature graph is plotted for CFC12, HFC134a and HC600a. The vapour pressure curves for CFC12 and HFC134a are similar. However, for HC600a, the pressures are much lower than for the other two refrigerants.

HC 600a Characteristics

Appliances have low noise.

Operates at lower condensing and evaporating pressures. Therefore, HC600a systems are quieter during operation.

Being used extensively in domestic and commercial systems.

Precautionary Measures.

Taking into consideration the safety issues for HC refrigerants, following simple precautions must be implemented.

1. Any kind of repair/servicing work must be carried out in a well-ventilated area so as to prevent accumulation of refrigerant, if leaked out.
2. Smoking while working will have dangerous consequences and should be strictly prohibited in the work area.
3. Do not work within 2 meters of any ignition source.
4. Always wear protective gadgets like goggles and gloves and clothing that covers, as a precautionary measure.
5. Keep minimum amount of HCs in the work/storage area so that there is no possibility of HC accumulation.
6. Use dry powder fire extinguishers only.

Notes

5. Solar Inverters Power Backup System for Cold Chain Equipment.

In India, most of the Health Centres are in villages and at many such locations there an issue of shortage of electricity & don't have electricity available almost for 14-15 hours. Also the quality of available power supply is very poor (sometimes voltage level is too low, which hampers proper functioning of equipment). Large fluctuation in voltage level also affects the working and life of cold chain equipment. This greatly affects the cold chain equipment especially ILR and deep freezer, as these are the only storage equipment at last cold chain point. Due to non-availability of grid for extended period of time, the vaccines could not be preserved properly which ultimately having adverse effect on conduction of various routine vaccination camps and pulse polio campaign.

In view of this, to provide uninterrupted power supply to cold chain equipment Stand-alone Solar Inverter Systems/Hybrid Solar Inverter Systems is good option & has proven useful now days. High-quality refrigerator intended for ac operation can be used/connected by installing a high-quality sine-wave inverter to convert the solar dc power to mains ac power.

About the technology.......

Solar Inverter systems are an integrated systems consisting of a solar panel, charge controller, inverter and also battery bank. If the system is with dual source of energy (Hybrid), i.e. Grid Power. In Hybrid system, there is a facility to charge the battery bank either through Solar or Grid.

The power conditioning units (PCU) in the circuit, continuously monitors the state of Battery Voltage, Solar Power output and the loads. Due to sustained usage of power, when the Battery Voltage falls below a preset level, the PCU will automatically disconnect the load.In case hybrid systems transfer the load to the Grid power and also charge the Batteries through the in-built Grid Charger. Once the Batteries are charged to the preset level, the PCU will restore to feeding the loads from the battery bank & continue to charge the battery bank from the available solar power. While doing so it also cuts off the Grid power from the system, if the system is hybrid in nature.

In the hybrid systems, the PCU always gives preference to the Solar Power and will use Grid power only when the solar power/ Battery charge is insufficient to meet the load requirement. The PCU do come with special feature like pure sine wave output and more for using in remote areas, where grid power is weak and solar power is available.

The technology does come with the advantages, which are quite noticeable in following areas............

O/P voltage always regulated: 230VAC +/-2%

Load will be continuously fed through inverter & output continuously available without any change over...... (In online versions)

- Pure Sine wave output: distortion can be kept less than 3%
- No effect of INPUT transient, surge, under voltage, over voltage, spikes and others disturbances present in the Input mains supply on the output signal.
- Automatic feed the power from Solar panel to the load when Sun is available (The PCU used in Solar Hybrid Inverter always gives preference to solar power while charging the battery.
- Real time web based monitoring and web enabled activation is possible
- Multi-information display panels are there to show parameters, i.e. Battery voltage/system status & even Rs saved from Solar etc.

Relative Merits.

- Systems do come integrated with Solar Charge Controller that enables the conversion of solar power to electricity.
- Generally designed to give you maximum benefit from the sun and less dependency on grid power.
- System installation is easy as electrical interconnections are of plug n play nature.
- Eco Friendly, as draws power from solar energy & unlike conventional energy fuel, Solar PV Panel doesn't emit any gases or leaves any residuals, thus reducing global warming and contributing towards a greener environment.
- Solar Hybrid Inverter can operate on both Solar Power as well as Grid Power.

Major components of a Solar Inverter Backup system are:

Solar Panel

Solar Array and support structure

Batteries

Charge Controllers & Inverter.

B. VESTFROST MK - 304

Figure C-2.5:

Installation

Location

The appliance must be placed in a well ventilated room, not in direct sunlight and away from other heating sources.
When installing the appliance please ensure that the floor is level. Please see figure 2 for further directions.

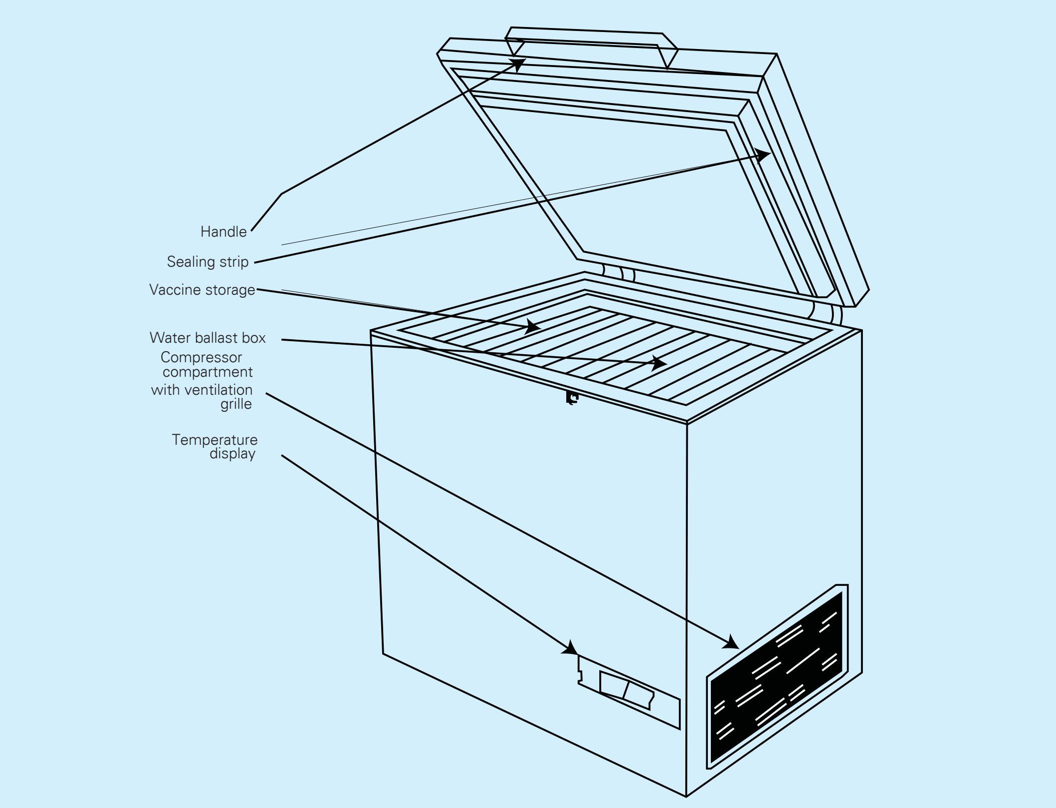


Figure C-2.6:

Electrical connection

Preparation

Check that the plug fits your type of socket.
If it does not fit, have a qualified electrician to fit the plug. This appliance must be earthed.

Colour code for leads:

Lead of cord		Pin of plug
230 V	115 V	
Brown	White	Live
Blue	Black	Neutral
Green/Yellow	Green	Earth

Connect the plug to the socket and switch on the appliance.

- Check, by listening, that the compressor is running, if it does not run, contact your supervisor.

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Operation and function

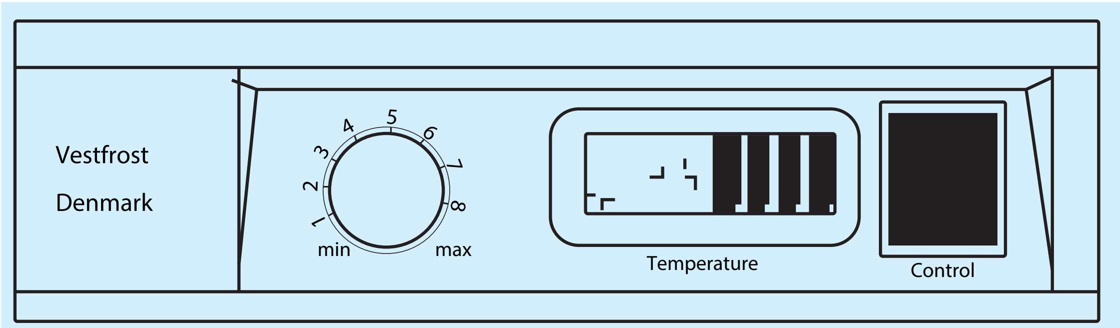

Figure C-2.7:

Electronic thermostat

The appliance has an electronic thermostat that controls the temperature in the vaccine compartment. The thermostat is set by the factory

1. The green lamp is on when the appliance is connected to the power supply.
2. Thermometer.

Starting procedure

Connect the mains lead to the power supply. The green lamp must light (fig. 4) to indicate that the appliance is operating. The electronic thermostat makes a self test, 20 seconds before the compressor starts.

Temperature control

It is recommended to check the inside temperature with an accurate thermometer once a day. The inside temperature must be checked regularly according to WHO's standards and specifications.

Cool down of the appliance

Before the appliance is loaded with vaccines the ice-lining in the 4 sides must be frozen. To ensure that the ice-lining in the 4 sides is frozen do the following:

1. 1. Place a thermometer in the top basket.
2. 2. Plug in the appliance, and let it run for 24 h.
3. 3. Check the temperature in the top and bottom basket (must be between +2° and +8°C).

The temperature in the vaccine compartment must always be monitored on the thermometer and be within the range +2° to +8°C. Due to tolerance of the thermostat you should always control the temperature during cool down.

Loading the appliance

Loading vaccines

When the temperature in the vaccine compartment has stabilized, i.e. and the temperature is between +2° and +8°C and the compressor stops and starts, vaccines can be loaded. The vaccines should be placed and arranged in the baskets, and remember to place the water filled ballast lids at the top of the upper baskets. (fig. 5)

To ensure air-circulation and prevent too low vaccine temperature, direct contact to the inside walls must be avoided. The Vaccine load in the bottom basket shall not be higher than 250 mm.

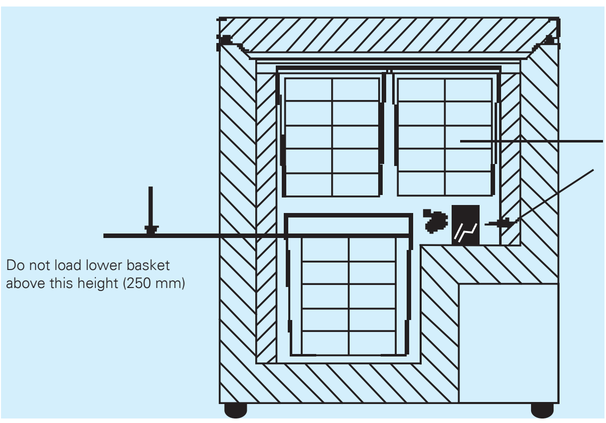

Figure C-2.8:

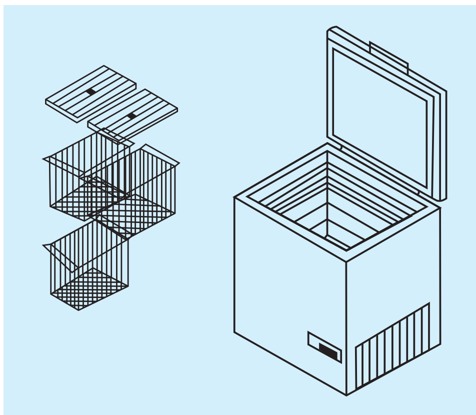

Figure C-2.9:

Maintenance and cleaning

Daily maintenance:

The temperature in the vaccine compartment must always be monitored on the thermometer every day. Please note that the vaccine in the appliance may not freeze.

Weekly maintenance:

During normal use, water can accumulate at the bottom of the appliance; remove with a cloth or through the drainage hole. Wipe of water droplets on the inside wall at the same time.

Under certain ambient conditions, rime can form on the inside wall. Remove the rime without using sharp edged tools.

Check if lid gasket is sealing tight to the top frame when the lid is closed. A tight sealing lid reduces accumulation of water and formation of rime significantly.

Monthly maintenance:

Clean the grill on the right side of the refrigerator once each month.

Yearly maintenance:

Electric connections and components are to be checked and cleaned once a year or more if necessary.

Cleaning

Disconnect the power supply before cleaning. The best way to clean the appliance is by using luke warm water with a small amount of unscented detergent. Never use cleaning agents that scour. Use a soft cloth. Rinse with clean water and dry thoroughly. It is important to prevent water from running into the control panel. The sealing strip around the lid must be cleaned regularly to prevent discolouration and prolong service life. Use clean water. After cleaning the sealing strip, check that it continues to provide a tight seal. If the appliance is not being used for any period of time, switch off the appliance, disconnect the power supply, empty the appliance, clean the inside, and leave the lid open to allow air circulation and prevent smells.

Fault	Possible cause	Remedy
Compressor is not running, and the ice packs are not cold	Be patient, it is most likely that the compressor will start within a few minutes.	If this is not the case, check the following: Check that power is connected. Check the fuse and replace it if necessary. If the above is OK, call technical supervisor.
Compressor is running, and the temperature is too high	The ventilation grille is blocked. The lid is not closed properly. The temperature in the room in which the appliance is installed is too high.	Ensure unhindered air circulation. Ensure that the lid is closed properly. Shield the appliance against direct sun light and ensure more ventilation to the room.
No temperature is displayed	The thermometer is broken. There is not enough light for the solar sensor	Change the thermometer. Turn on the light.
Temperature goes below +2°C in a specific basket	Air circulation is restricted. Basket in direct contact with wall	Check load height is not above 250mm (or load line) in lower baskets. Move the end basket a little to leave a gap between the basket and the wall.

Notes

GB Warranty, spare parts and service

Warranty disclaimer

Faults and damage caused directly or indirectly by incorrect operation, misuse, insufficient maintenance, incorrect building, installation or mains connection. Fire, accident, lightening, voltage variation or other electrical interference, including defective fuses or faults in mains installations are not covered by the warranty.

Repairs performed by others than approved service centres and any other faults and damage that the manufacturer can sub- stantiate are caused by reasons other than manufacturing or material faults are not covered by the warranty.

Please note that changes to the construc- tion of the appliance or changes to the component equipment of the appliance will invalidate warranty and product liability, and the appliance cannot be used lawfully. The approval stated on rating plate will also be invalidated.

Spare parts

When ordering spare parts, please state the type, serial and product numbers of your appliance. This information is given on the rating plate. The rating plate contains various technical information, including type and serial numbers.

Notes

MK 304 PQS E003/007

Position	Item number	Item name
0061	0-6538001	Filter drier,
0070	A921001	Cover + wirring clamp
0087	0-6038175	Base plate fittings, set, complete
0129	8-036038480	Compressor - FR 8,5 G,HST Complete, R134a
2168	0-03930206	Display with remote control - EPT-R1
5000	3010049	Drain plug
5002	6000959	Foot with pin
5118	5000904671	Lid foamed without handle/hinges
5119	3020107-01	Rubber gasket
5372	A93010210	Water ballast box
5401	1510031	Hinge 30
5450	3010040-01	Top part for hinge cover
5451	3010032-01	Bottom part for hinge cover
5605	304090501	Handle with lock (push and turn)
5606	8090342-94	Inlay for handle,
5682	1510046	Key, set - 2pc.
5683	2040145	Catch for handle
5684	3010265-01	Cover for catch
5685	600098801	Lock with keys,(push and turn)
5714	7020144	Thermostat phial (Fan box)
5714	7510582	Thermostat phial
5717	7020293	Thermostat
5738	7010027	Pilot lamp, green
5756	7020164	Thermometer, solar
5783	3040141	Control panel
5812	6520106	Starting device, 117U6015
5850	6520004	Starting condenser 117U5015
5870	6000902	Fan
5876	7090047	Fan box, complete, inclusive heating element
5907	3510024	Basket
5927	3510023	Basket
5963	A93010357	Eutectic element
5970	3010308-01	Motor screen
6553	7535008	Mains lead
6760	7030108	Transformer, 230/2X12 DC
7100	7030333	Fan

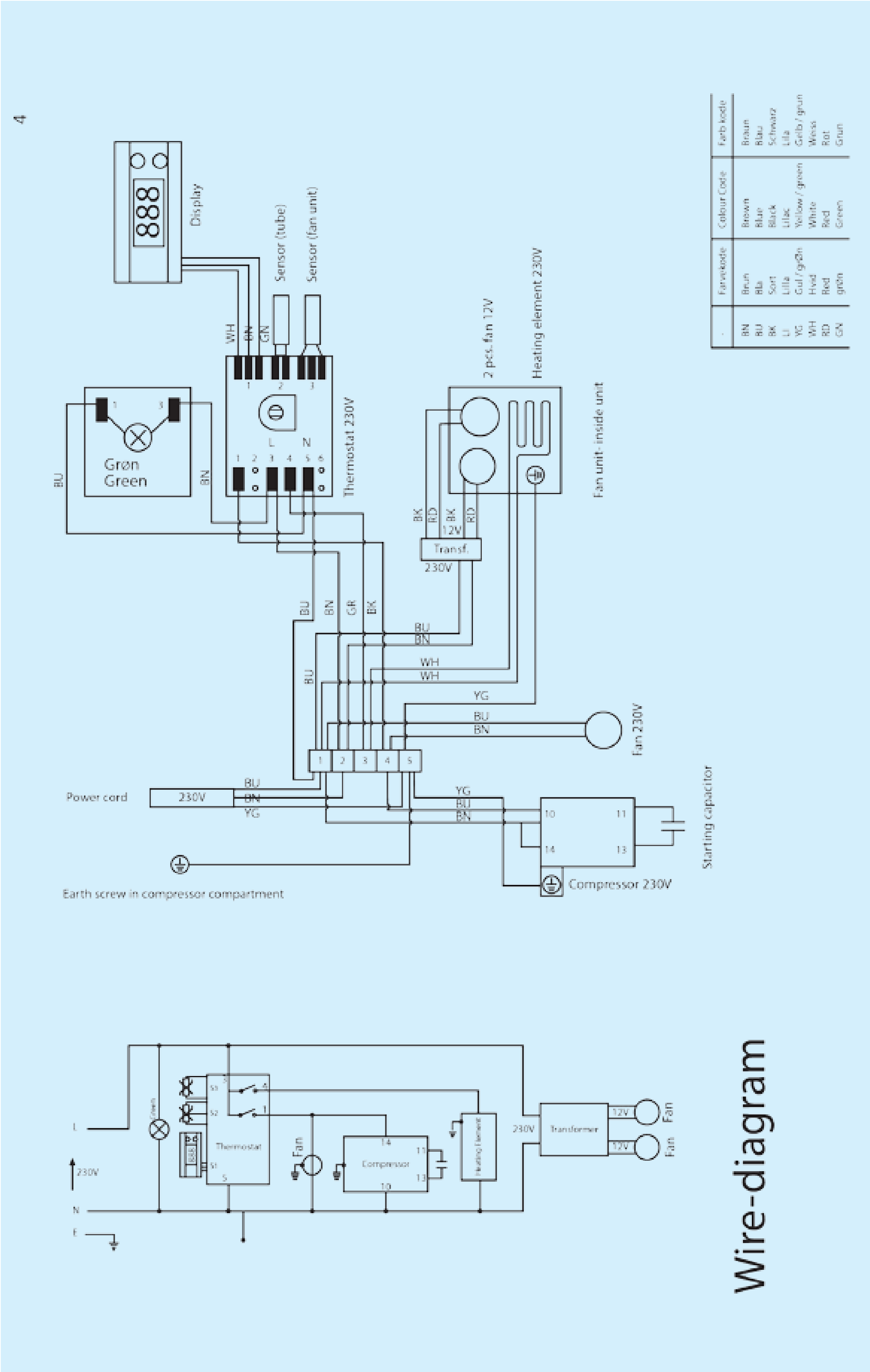
Wire-diagram
Display
888
Sensor (tube)
Sensor (fan unit)
Thermostat 230V
Grøn
Green
2 pcs. fan 12V
Heating element 230V
Fan unit - inside unit
Transf.
12V
230V
Fan 230V
Starting capacitor
Compressor 230V
Power cord
Earth screw in compressor compartment
Transformer
Thermostat
Compressor
Heating Element
Fan
Farvekode
Colour Code
Farb kode
BN Brun Brown Braun
BU Blå Blue Blau
BK Sort Black Schwarz
LI Lilla Lilac Lila
YG Gul / grøn Yellow / green Gelb / grün
WH Hvid White Weiss
RD Rød Red Rot
GN grøn Green Grün

Figure C-2.10:

Training Agenda

Day 1		
Time	**Session**	**Facilitator**
9.00 – 9.30	Registration of participants	NCCVMRC/ NCCRC Facilitators
9.30 – 10.00	Welcome and Introduction	Director, NIHFW
10.00 – 10.30	Brief comments/ Course background	Representatives of MOHFW /UNICEF/ N.O
10.30 - 11.00	Pre-training test, Expectations of participants	NCCVMRC/ NCCRC Facilitators
11.00 - 11.15	**Tea break**	
11.15 - 12.15	UIP, vaccines, Imm, Vaccine storage and logistics management	NCCVMRC/ NCCRC Facilitators
12.15 – 13.00	Recommended vaccine storage temperature & temperature monitoring of Cold Chain Equipment	NCCVMRC/ NCCRC Facilitators
13.00 - 14.00	**Lunch**	
14.00 – 14.30	Roles and Responsibilities of Cold Chain Technicians	NCCVMRC/ NCCRC Facilitators
14.30 – 16.00	Refrigeration – Basic principles, failure of compressors	NCCVMRC/ NCCRC Facilitators
16.00 - 16.15	**Tea break**	
16.15 – 17.00	Environmental Impact of ODS & GWP; alternate refrigerant technology	NCCVMRC/ NCCRC Facilitators
17.00 – 17.30	Servicing of ILRs/DFs, service practices - Dos and Donts	NCCVMRC/ NCCRC Facilitators

Notes

Day 2		
Time	**Session**	**Facilitator**
09.00 – 09.15	Recap of Day 1	NCCVMRC/ NCCRC Facilitators
09.15 – 10.15	Electric wiring of ILR and DF	NCCVMRC/ NCCRC Facilitators
10.15 – 11.00	Management of cold chain issues, Immunization PIP - Part C, maintenance fund, condemnation	NCCVMRC/ NCCRC Facilitators
11.00 - 11.15	**Tea break**	
11.15 – 11.45	Inventory of CCE	NCCVMRC/ NCCRC Facilitators
11.45 – 13,00	Overview and discussion of NCCMIS	NCCVMRC/ NCCRC Facilitators
13.00 – 14.00	**Lunch**	
14.00 – 15.00	Fault Discussion of ILRs and DFs, Issues or problems- haier microprocessor	NCCVMRC/ NCCRC Facilitators
15.00 – 16.00	Voltage stabilizer introduction & it's principles. Govt. recommended voltage stabilizer & its types	NCCVMRC/ NCCRC Facilitators
16.00 – 16.15	**Tea Break**	
16.15 – 17.30	Electric wiring of stabilizer & components Components description of Voltage & testing	NCCVMRC/ NCCRC Facilitators

Day 3		
Time	**Session**	**Facilitator**
09.00 – 09.15	Recap of Day 2	NCCVMRC/ NCCRC Facilitators
9.15 - 11.00	Fault finding of voltage stabilizer & High Voltage risk Factor	NCCVMRC/ NCCRC Facilitators
11.00 - 11.15	**Tea break**	
11.15 – 13.00	Testing other spares, replacement of parts, Time delay relay, distribution of spare parts to groups	NCCVMRC/ NCCRC Facilitators
13.00 – 14.00	**Lunch**	
14.00 – 14.45	Tool kit distribution, Fault finding,	NCCVMRC/ NCCRC Facilitators
14,45 – 16.00	Fault diagnose, Compressor testing and Gas recovery	NCCVMRC/ NCCRC Facilitators
15.30 – 15.45	**Tea break**	
15.45 – 17.30	Equipment dismantling, nitrogen flushing	NCCVMRC/ NCCRC Facilitators

Day 4		
Time	**Session**	**Facilitator**
09.00 – 09.15	Recap of Day 3	NCCVMRC/ NCCRC Facilitators
9.15 – 11.00	Assembling the system, leak test with Nitrogen	NCCVMRC/ NCCRC Facilitators
11.00 – 11.15	**Tea break**	
11.15 – 13.00	Cont.----------Assembling the system, leak test with Nitrogen	NCCVMRC/ NCCRC Facilitators
13.00 – 14.00	**Lunch**	
14.00 – 16.00	Evacuation and gas charging, performance test and sealing	NCCVMRC/ NCCRC Facilitators
16.00 – 16.15	Tea break	
16.15 – 17.30	Cont.------evacuation and gas charging, performance test and sealing	NCCVMRC/ NCCRC Facilitators

Day 5		
Time	**Session**	**Facilitator**
09.00 – 09.15	Recap of Day 4	NCCVMRC/ NCCRC Facilitators
09.15 – 11.00	Thermostat setting, Testing other spares, replacement of parts	NCCVMRC/ NCCRC Facilitators
11.00 – 11.15	**Tea break**	
11.15 – 13.00	Cont.-----Thermostat setting, Testing other spares, replacement of parts	NCCVMRC/ NCCRC Facilitators
13.00 – 14.00	**Lunch**	
14.00 – 16.00	Repair and maintenance of voltage stabilizer.	NCCVMRC/ NCCRC Facilitators
16.00 – 16.15	**Tea break**	
16.15 – 17.30	Cont.-------repair and maintenance of voltage stabilizer	NCCVMRC/ NCCRC Facilitators

Notes

Day 6		
Time	**Session**	**Facilitator**
09.00 – 09.15	Recap of Day 5	NCCVMRC/ NCCRC Facilitators
09.15 – 11.00	Practical testing of PCB circuit and repairing	NCCVMRC/ NCCRC Facilitators
11.00 – 11.15	**Tea break**	
11.15 – 13.00	Cont.----Practical testing of PCB circuit and repairing	NCCVMRC/ NCCRC Facilitators
13.00 – 14.00	**Lunch**	
14.00 – 16.00	Cont.----Practical testing of PCB circuit and repairing	NCCVMRC/ NCCRC Facilitators
16.00 – 16.15	**Tea Break**	
16.15 – 17.30	Good service practices & voltage stabilizer rating	NCCVMRC/ NCCRC Facilitators

Day 7		
09.00 – 09.15	Recap of the Day 6	NCCVMRC/ NCCRC Facilitators
09.15 – 11.00	Discussion regarding fault and spare parts description & cost	NCCVMRC/ NCCRC Facilitators
11.00 – 11.15	**Tea Break**	
11.15 – 13.00	Discussion regarding fault and spare parts description & cost	NCCVMRC/ NCCRC Facilitators
13.00 – 14.00	**Lunch**	
14.00 – 14.30	Post training evaluation	NCCVMRC/ NCCRC Facilitators
14.30 – 15.15	Feedback format	NCCVMRC/ NCCRC Facilitators
15.15 – 16.00	Certificate Distribution & wrap up	NCCVMRC HOD/ NCCRC HOD
16.00	Tea & Valedictory	

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