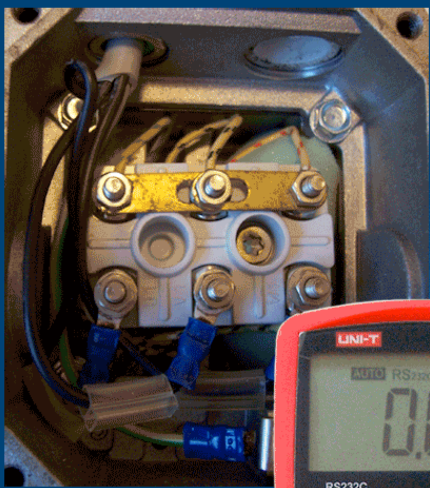
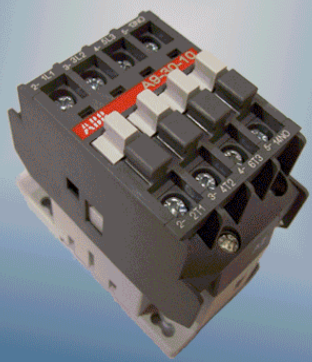
Electrical Principles, Components and Systems

Sample Booklet





An invaluable guide to Industrial Electrical Systems

Brian Tinson

Electrical Principles, Components and Circuits

Brian Tinson

------ SAMPLE ------

Introduction

These notes are intended for anyone who has little electrical knowledge or experience and would like to understand more about electrical systems and equipment. They are ideal for someone whose job could easily involve some form of electrical testing and component replacement. The notes are aimed at industrial electrical engineering and is not for those people who wish to install electrical supplies.

The notes are written in a language that is easy to follow and keeps the maths to a minimum and are therefore aimed at someone who wishes to understand enough to be able to carry out electrical checks and repairs without getting too involved in electrical theory.

At the end of each chapter there are On Line Assessments that allow you to check out your understanding of the topics covered. Internet access is obviously required to undertake these exercises.

Chapter 1

Basic Electrical Principles

At the end of this section you will have an understanding of

- basic electrical quantities
- electrical power
- conductors and insulators
- simple circuit theory
- Ohms Law

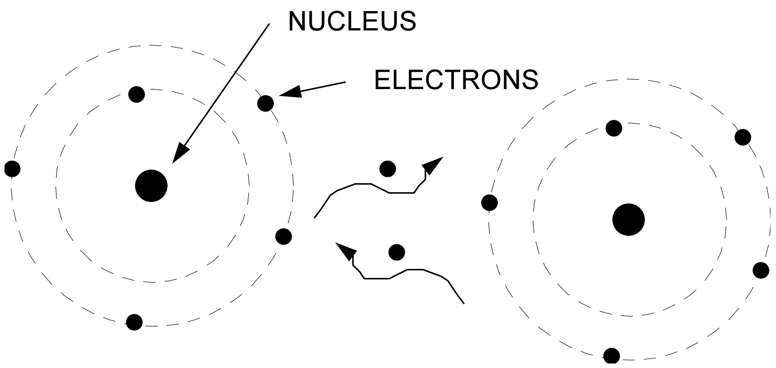
Basic Principles

Electrical Physics

As a starting point it is important to understand what is happening within an electrical system to take away the unknown and feel confident about working with electricity. First we will consider the physics behind electricity.

All matter is composed of atoms. Each atom comprises of a central nucleus with a number of electrons associated with it. One particular model suggests that this can be considered rather like the sun (the nucleus) surrounded by planets (the electrons). The number of electrons orbiting the nucleus determines the property of the atom. The simplest atom is hydrogen which has only one electron, whilst copper has twenty nine electrons surrounding it's nucleus.

Each electron carries a negative charge of electricity and this negative charge is balanced by an equal and opposite positive charge on the nucleus. The atom, as a whole is electrically neutral.



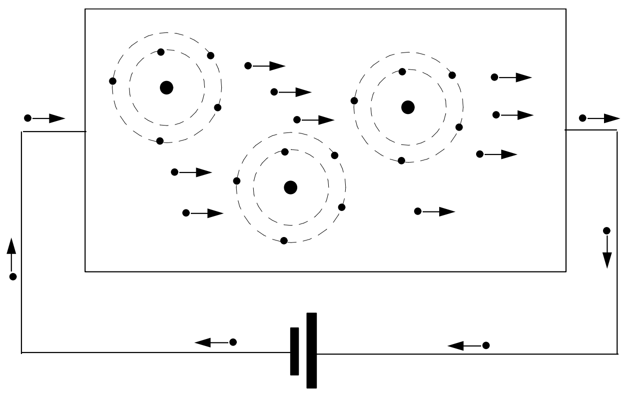
Atoms and Electrons

The electrons are able to move from atom to atom due to energy that they absorb in the form of heat. This movement can be considered as being random.

Conductors and Insulators

Electrons which carry charge are subjected to forces where - like polarities repel and unlike polarities attract. If an external positive charge is applied to a material then electrons may well be attracted to that positive charge. This can be considered very similar to magnetic effects where like poles repel and unlike poles attract. If there is an overall movement of electrons in one direction towards a positive charge then this constitutes an electric current.

Electric current is the steady flow of electrons moving from atom to atom. These electrons are moving under the influence of an external potential and they will be attracted towards the positive. Current is defined as the movement of positive charge and this will be in the opposite direction to the direction in which the electrons are flowing. Disregarding this anomaly electric current can simply be thought of as the flow of electricity from POSITIVE TO NEGATIVE. Current is the rate of flow of electrons.



Electron Flow

Charge can occur when an imbalance occurs between electrons and nucleus. If a material loses electrons it becomes positively charged. If a material gains electrons it becomes negatively charged.

In general, in circuits, the overall structure of electrons is not changed and therefore electrons entering a circuit will be the same as electrons leaving. This means that the materials in the circuit do not become charged. This leads to a very important concept that electrical current does not disappear. Whatever current flows into a circuit flows out of it. **Current cannot disappear.** In the case of a fault, current might be leaving a circuit through a fault condition (a short circuit to earth for example). The rule apply that the total current entering the circuit equals the total current leaving the circuit. A Residual Current Device (RCD see section Cables and Protection) makes use of this principle.

Electrical current is created by applying an external charge to a circuit. As a result of current flow there are several possible effects created.

Chemical Effect

Generally there is no change in a metal during the passage of an electric current but some materials are chemically changed by the passage of electric current. Solutions of acid in water are decomposed. The chemical affects of an electric current are utilised in electroplating and accumulators.

Heating Effect

When electric current flows through a substance that has resistance to the flow of electric current, discussed later, that substance becomes heated. Conductors will posses resistance and some conductors are arranged to posses resistance to utilise the heating effect.

An immersion heater comprises of a length of mineral insulated cable in which the conductors are resistance wires. An electric fire element is a coil of resistance wire on a heatproof insulating rod. A lighting bulb has a very fine resistance wire known as the filament. The filament heats under the effect of the current until it becomes incandescent and emits light.

Magnetic Effect

An electric current passing through a conductor produces a magnetic field around that conductor. The polarity and intensity of the magnetic field is dependent on the direction and size of current respectively. Motors make use of the magnetic effects to create forces between magnetic fields that in turn create motion.

Electrical Units

Voltage

Voltage can be described as the driving force or pressure behind electricity. The physical term electromotive force (emf) is used to describe this quantity although the term is not used generally. Voltage is measured in volts and is often the fixed quantity in an electrical system. The voltage is the supply of energy to a circuit and consequently is supplied from a number of sources. A DC system will have a fixed DC voltage supplied from say a battery. An AC system will have its AC supply typically from the mains or on occasions a local generator.

BASIC ELECTRICAL PRINCIPLES

Current

Current is the flow of electrons that arises from applying a voltage to a circuit. Current is measured in amps (amperes). A flow of 1 amp is approximately six million, million, million electrons flowing per second. Current will flow when a voltage is applied and there is a complete circuit (or path). The total current flowing in a circuit will be determined by the resistance.

Resistance

Resistance is determined, amongst other things, by the material where all materials have a property called **resistivity**. This property depends upon the ability of electrons in that material to be able to leave their orbits around the nucleus and contribute to current flow. Materials where this can happen easily will be referred to as conductors whereas materials where this cannot happen easily will be referred to as non conductors or insulators. Resistivity is measured in Ohms / metre.

Some typical values of resistivity are shown in the table below

Material	Resistivity (Ω/m)	Type
Silver	1.59×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Gold	$2.44 \times 10^{-}$	Conductor
Aluminium	2.82×10^{-8}	Conductor
Tungsten	5.6×10^{-8}	Conductor
Platinum	1.06×10^{-7}	Conductor
Carbon	3.5×10^{-5}	Conductor
Germanium	4.6×10^{-1}	Semi Conductor
Silicon	6.4×10^{2}	Semi Conductor
Glass	$10^{10} - 10^{14}$	Insulator
Hard Rubber	10^{13}	Insulator
Teflon	$10^{22} - 10^{24}$	Insulator

Resistance is the opposition to the flow of current. Resistance is measured in Ohms, symbol Ω and is determined by the type and size of material in which the current is attempting to flow.

The size of the material will be given by it's length and it's cross sectional area.

Resistance is calculated from

$$\text{Resistance} = \frac{\text{Resistivity of the material X length}}{\text{Cross Sectional area}}$$

It can be seen from this formula that the longer a piece of material is then the more resistance it will have and the smaller the cross sectional area i.e. the smaller the diameter of the cable, the less resistance it will have.

This is important in as much as cables have to be of a given size to be adequate for a particular function. Cables that are longer than they need to be could possess too much resistance and cables that are too thin could also possess too much resistance.

Conductors

In a conductor the electrons are not firmly attached to the nucleus and are normally interchanging between atoms in a random manner. They can easily leave their orbit when an external potential is applied and so will cause current to flow. A conductor is classified as a material in which there will easily be current flow i.e. one that possesses a low resistivity. Examples: silver, copper, aluminium,

Insulators

In an insulator the electrons are firmly attached to the nucleus and will not be moved from their orbit when an external potential is applied. The interchange of electrons will not take place and consequently there will be no current flow. An insulator is defined as material that will not pass current and will have a high value of resistivity. (rubber, PVC, porcelain,…)

Energy

Energy is the capacity of an object or a system to do work and is measured in Joules.

energy can neither be created nor destroyed.

Energy is converted from one source to another

Example:
A lamp converts electrical energy into light energy.
A motor converts electrical energy into mechanical energy
A battery converts chemical energy into electrical energy

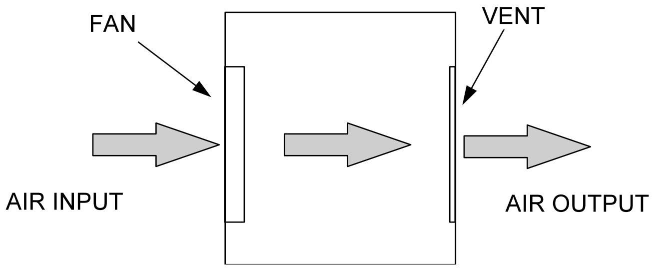
The potential energy of water in a highland reservoir is converted into kinetic energy as the water flows down the inlet tube where it is converted into electrical energy by a generator driven from a turbine.

Power

Power is the rate at which energy is delivered or consumed and is measured in Watts. In most cases the conversion of energy is not 100% efficient and a proportion of the input power appears as wanted output. The total wanted power at the output compared to the input is indicated by the efficiency of the system.

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Input}} \times 100\%$$

Another form of energy is always produced as a *by product*. Most commonly this *by product* is heat and it is often necessary to find ways of disposing of this heat by providing extra methods of cooling by having fins or fans. Failure to dispose of this heat can cause the equipment to overheat with serious consequences. It is important to understand how a piece of equipment is cooled and any factor that hinders this process can result in damage.



Air Cooling

Restricting the throughput of air can affect the cooling and result in overheating.

Power is lost through resistance as this causes heat. Conductors possess resistance and this generates heat and results in a power loss. For example a loud speaker coil possesses resistance. This resistance is not needed in the process of converting electrical power to sound power but will produce heat. This heat will need to be dissipated to protect the speaker from overheating.

Electrical Power

Electrical power is supplied to a circuit whenever a voltage is applied and current flows. The power supplied to that circuit will the product of voltage times the current and will be measured in watts, symbol W

$$\text{POWER (Watts)} = \text{VOLTAGE (Volts)} \times \text{CURRENT (Amps)}$$

A car starter motor taking 200A from a 12V battery will be taking 2400W of power.

Also

$$\text{CURRENT (Amps)} = \frac{\text{POWER (Watts)}}{\text{VOLTAGE (Volts)}}$$

A 2400W heater element connected to a 240V supply will take 10 A.

For a given power requirement the lower the operating voltage; the higher the current consumption and vice versa. For example the car starter motor takes 200A due the low voltage whereas the same power requirement using a 240V motor would only consume 10A.

By looking at the power rating of some items of equipment it is possible to establish from this calculation the level of current that will be consumed. It is important to appreciate that some items of equipment such as motors specify the mechanical output that is available as a maximum. If the motor is not on it's maximum load (which it ought not to be) the current drawn would be less. By looking at the motor power rating it is possible to determine the maximum current that should be drawn by the motor.

Unit Multiples and Submultiples

It is often necessary to deal with very large or very small electrical quantities and multiplying factors can be used. It would be awkward to deal with say 0.00001 amps.

ABBREVIATION	UNIT	VALUE	EXAMPLE
T	TERRA	1,000,000,000,000	Thz (Terra Hertz)
G	GIGA	1,000,000,000	Ghz (Giga Hertz)
M	MEGA	1,000,000	Mhz (Mega Hertz)
K	KILO	1,000	kV (kilovolts)
m	MILLI	0.001	mV (millivolts)
µ	MICRO	0.000001	µA (microamps)
n	NANO	0.000000001	nF (nanofarads)
p	PICO	0.000000000001	pF (picofarads)

Index Notation

Index Notation is where a number is raised to the power of 10

For example 10^3 is 10 raised to the power of 3 which is 10 X 10 X10 = 1000 = kilo

Similarly

10^6 is 10 raised to the power of 6 which 10 X 10 X 10 X 10 X 10 X 10 = 1000000=mega

10^9 = 1000000000 = giga

5 X 10^3 = 5000
7 X 10^6 = 7000000

Negative Power

10^{-1} is

$$\frac{1}{10} = 0.01$$

10^{-3} is

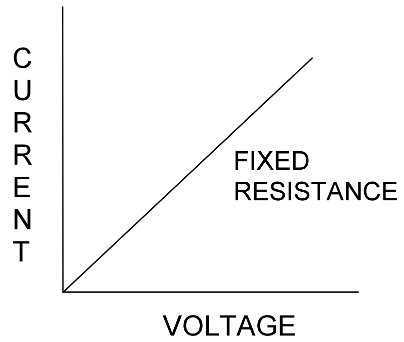
$$\frac{1}{10^3} = 0.003 = \text{mili}$$

5 X 10^{-3} A = 5mA
8 X 10^{-6}A = 8μA (micro Amp)

Ohm's Law

The most commonly used principle in electrical systems is Ohm's Law, that gives the relationship between voltage, current and resistance.

VOLTAGE = CURRENT × RESISTANCE



Current v Voltage Graph

BASIC ELECTRICAL PRINCIPLES

The relationship between voltage and current is linear i.e. as the voltage increases then the current increases and vice versa. Simple calculations can be carried out to determine the current that will flow in a circuit of a given resistance.

Alternative forms of Ohms Law

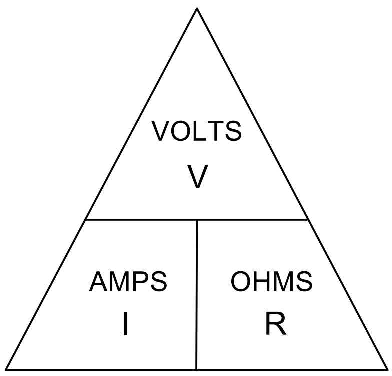
$$\textbf{CURRENT} = \frac{\textbf{VOLTAGE}}{\textbf{RESISTANCE}}$$

and

$$\textbf{RESISTANCE} = \frac{\textbf{VOLTAGE}}{\textbf{CURRENT}}$$

For simplicity Ohm’s Law can be viewed as a triangle that reminds us of the relationship between voltage, current and resistance.

Ohm’s Law Triangle



Example:

A 20 volt supply is applied to a circuit that has a resistance of 10 ohms. What current will flow.

From

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$I = \frac{20V}{10\Omega} = 2A$$

Using Ohm's Law to understand electrical fault conditions

Using the expression

$$\textbf{CURRENT} = \frac{\textbf{VOLTAGE}}{\textbf{RESISTANCE}}$$

it is possible to consider the causes of problems in electrical systems.

Current is what creates the end result; current through a heater element creates heat; current through a motor creates the torque and therefore the movement. If the current through any device or circuit is not what it is supposed to be the output will not be what it is supposed to be.

Too little current

If the current flow through a item of equipment is too low the output from the equipment, in whatever energy form this is, will be low (ie insufficient heat) this would be created by either a

(a) too low voltage applied to the equipment

or

(b) a too higher resistance within the equipment

If the voltage supplied to equipment is low then this could mean that the supply voltage coming into the equipment is low which needs to be investigated. Alternatively the supply voltage could be at it's correct level but there is a fault which is causing a volt drop within the control circuit. See Volt Drops.

If the resistance of the equipment (or the circuit supplying the equipment) is too high then this could be caused by a loose connection, a worn contact.

The extreme situation would be ZERO current. This situation would be caused by

(a) no supply voltage

or

(b)a very, very high (infinite) resistance which would mean that the circuit has no path through it and there is a complete disconnection of the circuit. This condition is known as an **OPEN CIRCUIT**. The symptom of an open circuit is the equipment or system does not operate.

Too much current

If a circuit tried to take too much current this would be caused by

(a)too much voltage (a higher than normal voltage)

or

(b)too little resistance.

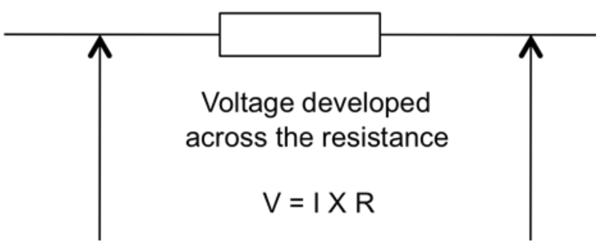
An over-voltage condition would suggest that there is a problem with the supply. This condition is fairly rare for extended periods but can happen as a surge for a short duration of time. Such effects might occur for example during electric storms.

Too little resistance is caused when the circuit path is in someway reduced. This can be caused by conducting parts coming into contact such as cables with damaged insulation coming into contact with each other or the casing or enclosure. This condition is referred to as a **SHORT CIRCUIT**.

NOTE: Excessive current would be prevented by the operation of a circuit protection device such as a fuse or circuit breaker.

Volt Drops

Whenever current flows through a resistance there will be a voltage developed across that resistance.



Voltage across resistance

Example:

A current of 10A flows through a resistance of 5Ω. What will be the voltage developed across the resistance.

VOLTAGE = CURRENT × RESISTANCE

Voltage = 10 × 5 = 50V

Volt drops can be created by faults is systems. See Electrical Circuits for descriptions of faults.

Heating Effects Within Circuits

When current flows through a resistance heat is produced. This heat is produced by the energy needed to move electrons through a material. All electrical systems need to manage the heat that is produced and ensure that it is displaced. Therefore all conductors (and other parts that will absorb the heat from conductors) will have a method by which heat is removed. In many cases that heat removal is by convection and radiation into the surrounding air.

It is important to appreciate that any change in the system that will reduce the ability of the conductor to cool will cause heat to be retained and therefore the conductor could overheat. Such things might include the covering of cables, leaving cables wound on a reel, covering ventilation holes or failures of fans.

The heat within a conductor can rise considerably which could eventually lead to the melting of insulation and subsequent exposure of live conductors which exposes a real danger of electric shock. Heat can also increase to the extent that there is a danger of fire. Any given conductor in a circuit will have a maximum current that can flow through it whilst allowing for the heat that is generated to be removed by the cooling method. Currents in excess of this value will cause potential overheating and dangers. Conductors therefore can never be allowed to have more than this maximum value of current flowing in them and a means has to be provided to prevent this over-current. Such protection is provided by the use of fuses and circuit breakers. See Cables and Protection.

The heat produced within a conductor would be given by I^2R *(the square of the current multiplied by the resistance). This means that the heat that is produced is proportional to the square of the current.
If the current in a conductor doubled the heat would increase by a factor or four (two squared). If the current in a conductor increased by factor of three the heat would increase by a factor of nine (three squared). This can explain why conductors will soon get very hot within a circuit if excessive current is allowed to flow.

This principle applies to any conductor in any position within a circuit including cables, switches, connectors, plugs, sockets, fittings etc.

* This formula is determined by combining Ohms Law with the formula for power.

POWER = VOLTAGE X CURRENT

From Ohms Law

VOLTAGE = CURRENT X RESISTANCE

By replacing VOLTAGE in the Power equation with CURRENT X RESISTANCE we have

POWER = CURRENT X RESISTANCE X CURRENT

= CURRENT X CURRENT X RESISTANCE

= CURRENT ^{2} X RESISTANCE

= I^2 R

EXERCISES

Click here for On Line Exercises

Appendix A

Electricity at Work Regulations 1989

The Electricity at Work Regulations 1989 were made under the Health and Safety at Work Act 1974 and reinforce the requirements of the HASAWA with respect to the use of electricity.

The 1989 regulations apply to employers, the self employed and employees, all of whom will be responsible where matters are within their control.

A summary of the responsibilities called for under the 1989 regulations are given against the relevant regulation number.

4(1) to ensure at all times that the electrical system is of such construction as to make it safe

4(2) the electrical system is maintained so that it remains safe

4(3) that no person is in danger whilst using, operating, maintaining, or working near such a system

4(4) that any equipment provided for the purpose of protecting persons at work, on or near electrical equipment, shall be suitable for that purpose, shall be maintained and shall be properly used

5 that the system has sufficient strength and capability for any short circuit currents, overload currents and voltage surges etc. That can foreseeable occur

6 the equipment is suitable for any environmental conditions to which it may be reasonably and foreseeable be exposed

7 all conductors that can give rise to a danger to be insulated, protected or suitable placed so as not to cause a danger

8 precautions to be taken either by earthing or other suitable means to prevent a danger when any conductor (other than a circuit conductor) becomes charged (has a voltage on it); the earthing conductor being capable of carrying any fault current without danger

10 that every joint and connection in a system is mechanically and electrically suitable so as not to prevent a danger

11 that where necessary protection is provided to disconnect any excess current before danger can occur

12 that provision is made for cutting off the supply or isolating equipment as may be necessary to prevent danger

13 when equipment and conductors are made dead, suitable precautions must be taken to ensure that do not become electrically charged

14 that no person shall be allowed to work on or near any live conductor where a danger could arise unless:
a) it is unreasonable in all circumstances for the equipment or conductor to be dead and
b) it is reasonable in all circumstances for that person to be at work on or near it while it is live

15 that there is adequate working space, access and lighting for working on or near an electrical system

16 that no person is engaged in any work or activity unless they are competent for the duties they have to perform

Appendix B

The IEE Wiring Regulations (BS 7671 – 2008)

The IEE Wiring Regulations is the British standard that covers the safe design, installation and testing of electrical installations in building systems. In addition the regulations define special locations as

- Bathrooms
- Swimming Pools
- Hot Air Saunas
- Construction Sites
- Horticultural and Agricultural Locations
- Restrictive Conductive Locations
- Caravan and Camping Parks
- Marinas
- Exhibition shows and stands
- Solar Photo Voltaic Supply Systems
- Mobile and Transportable Units
- Caravans and Motor Caravans
- Amusement Devices, Fairgrounds and Circuses
- Floor and Ceiling Heating Systems

APPENDIX B

In the most simple form the wiring regulations are concerned with the following

- Use of good workmanship.
- Use of approved equipment and materials.
- Ensure that the correct type, size and current carrying capacity of cables are used.
- Ensure equipment is suitable for the maximum power demanded of it.
- Make sure conductors are insulated and sheathed or protected if necessary, or are placed in a position to prevent danger.
- Joints and connections should be properly constructed to be mechanically and electrically sound
- Always provide over current protection for every circuit in an electrical installation and ensure that protective devices are suitably chosen for their location and duty that they have to perform.
- Where there is a chance of metalwork becoming live owing to a fault, it should be earthed and the circuit concerned should be protected by an over current device or a Residual Current Device.
- Ensure that all necessary bonding of services is carried out.
- Do not place a fuse, or a switch or a circuit breaker unless it is a linked switch or circuit breaker in an earthed neutral conductor. The linked type must break all line conductors.
- All single pole switches must be wired in the line conductor only.
- A readily accessible means of isolation must be provided so that all voltages may be cut off from an installation or any of it’s circuits.
- All motors must have a readily accessible means of disconnection.

APPENDIX B

- Ensure that any item of equipment which may normally need operating or attending by persons is accessible and easily operated.

- Any equipment required to be installed in a situation exposed to weather or corrosion, or in explosive or volatile environments, should be of the correct type for such adverse conditions.

- Before adding to or altering an installation ensure that such work will not impair any part of the existing installation and that the existing installation is in a safe position to accommodate the addition.

- After completion of an installation or alteration to an installation, the work must be inspected and tested, so far as reasonably practical, that the fundamental requirements for safety have been met.

It is worth noting that although the wiring regulations are not statutory they may be used to claim compliance with statutory regulations such as the Electricity at Work Regulations, Health and Safety at Work Act and Part P of the building regulations.

Appendix C

Glossary of Electrical / Electronic Terms

Alternating Current	Current that reverses direction in response to a change in voltage polarity
Alternator	A rotating machine used to produce electrical energy
Amp	The unit of electrical current
Amplification	The process of increasing power, voltage or current of an electrical signal
Anode	The more positive terminal of a diode or other electronic device
Attenuation	The reduction in the level of power, current or voltage
Capacitor	A device capable of storing electrical charge
Cathode	The more negative terminal of a diode or other electronic device
Circuit Breaker	A protective device that will break the supply to a circuit in the event of excessive current
Contactor	An electromechanical device used to switch supplies on to equipment
Current	The rate of flow of electrons
Decibel	The unit of the logarithmic expression of a quantity
Diode	A two terminal electronic device that permits current flow in only one direction

APPENDIX C

DVM /DMM	Digital Voltmeter / Digital Multimeter
Electron	The basic particle of a negative electrical charge
Frequency	The measure of rate of change of an AC supply.
Full wave	The entire ac cycle consisting of both the positive and negative parts
Fuse	A protective device that will rupture in the event of excessive current in a circuit
Generator	An energy source for producing electrical signals
Giga	A prefix denoting 100,000,000 times abbreviated to G eg Ghz (gigahertz)
Ground	In electrical circuits the common reference points
Half wave	One half of an ac signal
Hertz (Hz)	The unit of frequency
Impedance	The total opposition to ac current
Inductor	An electrical device consisting of a coil of wire and having the capability to store energy in it's magnetic field
Kilo	A prefix designating one thousand
LED	Light emitting diode
Magnitude	The value of a quantity
Mega	A prefix designating one million
Megger	A common name for an insulation tester.
Micro	A prefix designating one millionth abbreviated to µ

APPENDIX C

Milli	A prefix designating one thousandth abbreviated to m
Nana	A prefix denoting a 1,000,000,000th abbreviated to n
Noise	An unwanted signal
Ohm	The unit of resistance
Period	The time interval of one cycle of a periodic waveform
Phase	The angular displacement of one alternating signal with respect to another
Power	The rate of energy consumption
Protection	The equipment necessary in a circuit to prevent overcurrent
Rectifier	An electronic circuit that converts ac into dc
Relay	An electromechanical device used to switch signals
RCCB	Residual current circuit breaker
RCD	Residual Current Device
Resistance	The opposition to the flow of current
rms	Root mean square
Tera	
Three phase	A supply consisting of three ac voltages with a phase difference of 120º
Transistor	A semiconductor device used for amplification or switching
Volt	The unit of voltage
Voltage	The amount of energy, or driving force, available to move electrons from one point to another in a circuit path

APPENDIX C

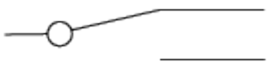
Appendix D

Electrical Symbols

Switches and Buttons

Normally open Contact
(N/O)

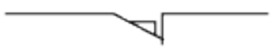
Normally Closed Contact
(N/C)



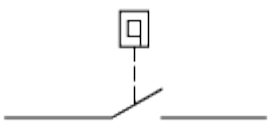
Change Over or 2 way Contact
Made position

Fused Switch Open Contact
(N/O)

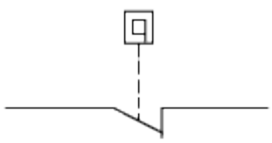
Limit Switch
(N/O)



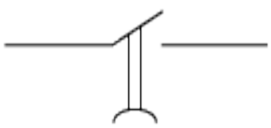
Limit Switch
(N/C)



Flow Switch
(N/O)



Flow Switch
(N/C)

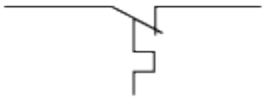


Time Delay
(N/O)
Delay on Closing

APPENDIX D

Time Delay
(N/O)
Delay on re-opening

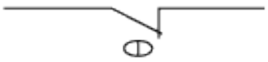
Thermal Switch - Overload
(N/O)



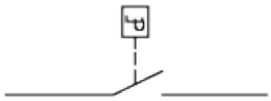
Thermal Switch - Overload
(N/C)

Normally Open PB
(N/O)

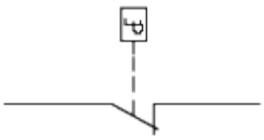
Temperature Switch
(N/O)



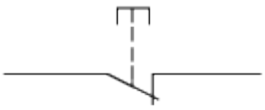
Temperature Switch
(N/C)



Pressure Switch
(N/O)

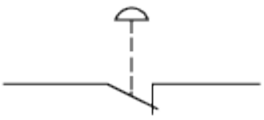


Pressure Switch
(N/C)

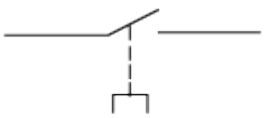


Normally Closed PB
(N/C)

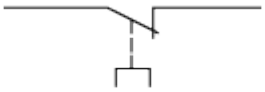
Emergency Stop PB
(N/O)
Indication Contact



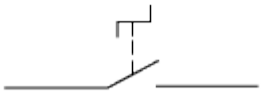
Emergency Stop PB
(N/C)



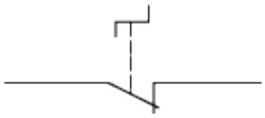
Pull Switch
(N/O)



Pull Switch
(N/C)

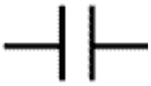


Turn/Rotary Switch
(N/O)

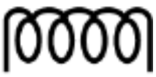


Turn/Rotary Switch
(N/C)

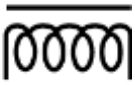
Components



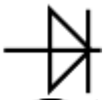
Capacitor, general symbol



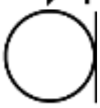
Inductor, coil, winding or choke



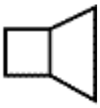
Inductor, coil, winding or choke with magnetic core



Semi Conductor Diode - general symbol

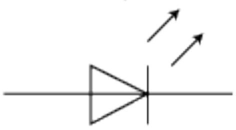


Microphone



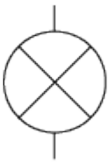
Loudspeaker

Antenna



Light Emitting Diode

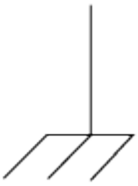
Fluorescent luminaire



Lamp

APPENDIX D

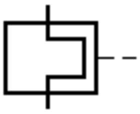
Earth Connection



Chassis Earth

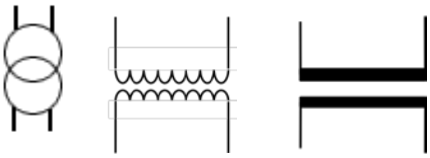
Ammeter

Voltmeter

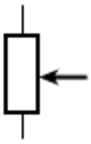


Thermal Overcurrent

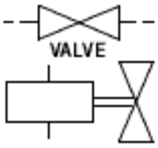
Mechanical Interlock



Transformer

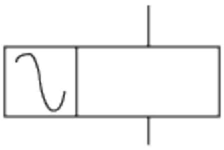


Potentiometer

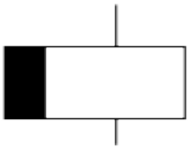


Solenoid Valve

Contactor Coil



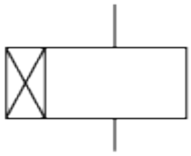
Relay with AC Supply



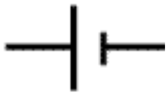
Slow Release Relay Delay Off

Relay Coil

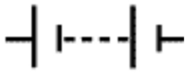
APPENDIX D



Relay delay On



Primary Cell – Long line Positive Short Line Negative



Battery

Fuselink rated in Amps

Letters used to identify Components

Component	Symbol / Letter
Motor	M
Contactor	K, C
Motor Contactor	KM
Relay	R , K
Lamps	H
Transformers	T
Fuses	F
Circuit Breakers	Q , F
Sensors	B
Solenoids	Y

Appendix E

Index of Protection (Ingress Protection) IP Rating

EN 60529 outlines an international classification system for the sealing effectiveness of enclosures of electrical equipment against the intrusion into the equipment of foreign bodies (i.e. tools, dust, fingers) and moisture. This classification system utilizes the letters "IP" ("Ingress Protection") followed by two or three digits. (A third digit is optional. An "x" is used for one of the digits if there is only one class of protection; i.e. IPX4 which addresses moisture resistance only.)

The standard aims to provide users more detailed information than vague marketing terms such as "waterproof".

For example, an electrical socket rated IP22 is protected against insertion of fingers and will not be damaged or become unsafe during a specified test in which it is exposed to vertically or nearly vertically dripping water. IP22 or IP2X are typical minimum requirements for the design of electrical accessories for indoor use.

Degrees of Protection - First Digit

The first digit of the IP code indicates the degree that persons are protected against contact with moving parts (other than smooth rotating shafts, etc.) and the degree that equipment is protected against solid foreign bodies intruding into an enclosure.

APPENDIX E

Level	Description
0	No Special Protection
1	Protection against solid objects greater than 50mm dia
2	Protection against solid objects greater than 12mm dia
3	Protection against solid objects greater than 2.5mm dia
4	Protection against solid objects greater than 1.0mm dia
5	Dust protected
6	Dust tight

Degrees of Protection - Second Digit

The second digit indicates the degree of protection of the equipment inside the enclosure against the harmful entry of various forms of moisture (e.g. dripping, spraying, submersion, etc.)

Level	Description
0	No special protection
1	Protection from vertically dripping water
2	Protection from sprayed water up to 15° from the vertical
3	Protection from sprayed water up to 60° from the vertical
4	Protection from splashed water
5	Protection from water projected at low pressure in all directions from a nozzle
6	Protection from heavy seas or powerful water jets
7	Protection against immersion between 15cm and 1m for 30 minutes
8	Protection against complete continuous submersion in water

APPENDIX E

Third Digit – Optional

Level	Protection against access to hazardous parts with
A	Back of hand
B	Finger
C	Tool
D	Wire

Appendix F

BS7671-2008 Conductor Cable Colours

Function	Alphanumeric	Colour
Protective Conductor		Green and yellow
Functional earthing conductor		Cream
AC Power Circuits		
Line of single phase circuit	L	Brown
Neutral of Single or three phase circuit	N	Blue
Line 1 of three phase ac circuit	L1	Brown
Line 2 of three phase ac circuit	L2	Black
Line 3 of three phase ac circuit	L3	Grey
Two Wire unearthed DC Power Circuit		
Positive of two wire circuit	L+	Brown
Negative of two wire circuit	L-	Grey
Two wire earthed DC Power Circuit		
Positive (of negative earthed) circuit	L+	
Negative (of negative earthed) circuit	M	Brown
Positive (of positive earthed) circuit	M	Blue
Negative (of positive earthed circuit)	L-	Grey

APPENDIX F

Three Wire DC Power Circuit		
Positive of three wire circuit	L+	
Mid wire of three wire circuit	M	
Negative of three wire circuit	L-	

Appendix G

Electrical Colour Codes

Number	Colour
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White

Appendix H

Three Phase Motor Current Calculations

Three Phase Power is calculated from

Power = $\sqrt{3}$ X V X I X Power Factor (pf) watts

Where

V is the voltage between phases in volts
I is the phase current in amps
Power Factor is the power factor of the motor

The power rating of the motor is the mechanical power output and therefore in terms of electrical power input, the efficiency (η) of the motor has to be taken into account. An efficiency of 90% would be a good assumption.

Current drawn by 10KW three phase motor

Assuming η = 0.9 and pf = 0.85

Power supplied to the motor taking account of the efficiency is

$$\frac{\text{Output Power}}{\text{Efficiency}} = \frac{10000}{0.9} = 11111 \text{ Watts}$$

11111 = $\sqrt{3}$ X 415V X I X 0.85

$$I = \frac{11111}{\sqrt{3} \times 415 \times 0.85} = 18.2\text{A / Phase}$$

APPENDIX H

NOTE: Wiring regulations need to be consulted to determine the size of cable needed for the type of installation.