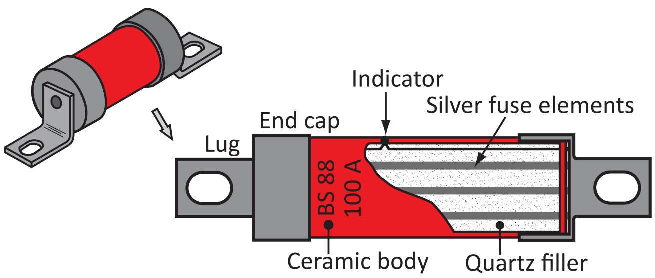
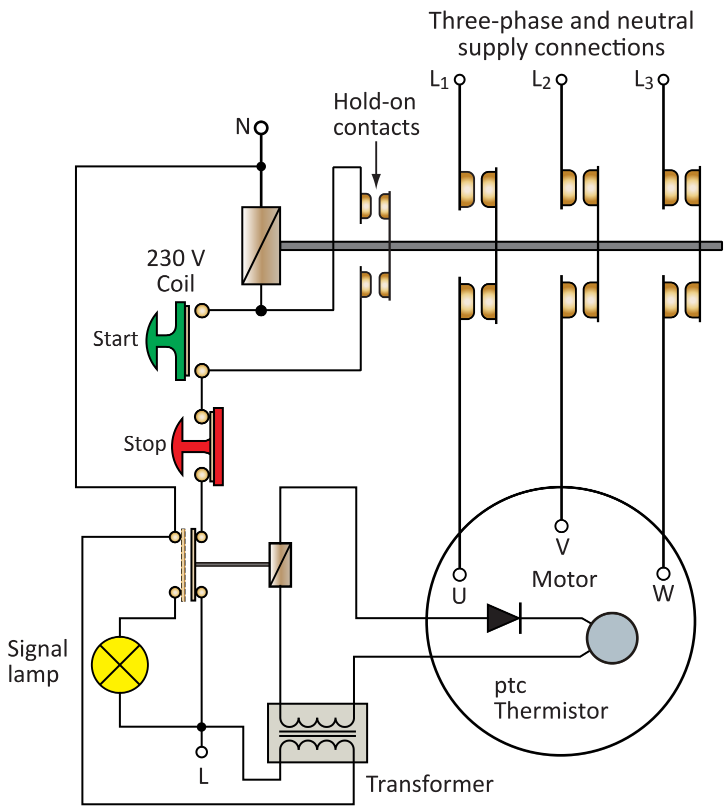
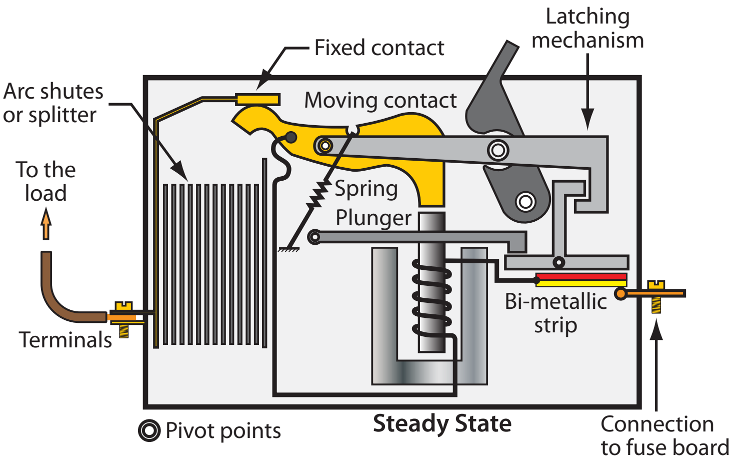
Level 3 Diploma
in
Installing Electrotechnical Systems & Equipment

C&G 2357

Unit 309-9 Understand the operating principles of different electrical componants







B&B Training Associates Ltd
Learning Materials for the Electrical Industry

Produced by

B&B Training Associates Ltd

For further information contact:

Mrs A Bratley

23 St Pauls Drive,

Tickton, Nr Beverley,

East Yorkshire

HU17 9RN

Tel:-01964 – 543137

Fax:-01964 – 544109

Email:- sales@bbta.co.uk

timbenstead@bbta.co.uk

terry@bbta.co.uk

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Aims and objectives

By the end of this outcome you will be able to:

- Specify the main types and operating principles of:
    - Contactors.
    - Relays.
    - Solenoids.
    - Overcurrent protection devices:
        - Fuses.
        - Circuit-breakers.
    - RCDs.
    - RCBOs.

- Describe how the following components are applied in electrical systems/equipment and state their limitations:
    - Contactors.
    - Relays.
    - Solenoids.
    - Overcurrent protection devices:
        - Fuses.
        - Circuit-breakers.
    - RCDs.
    - RCBOs.

1: Solenoids, relays and contactors

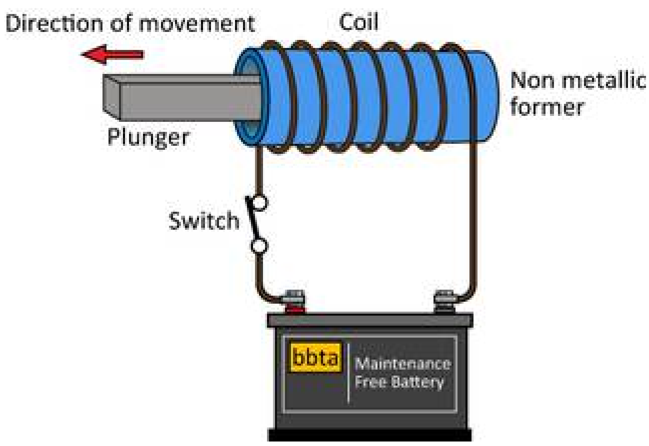
In this session the student will:

- Be able to describe what a solenoid is and where it might be used
- Know the difference between a relay and a contactor
- Be able to state typical applications for relays and contactors

Within your career as an electrician, it is more than likely that you will come across electrical components such as solenoids, relays and contactors. Although some of these items have been dealt with before in other units, the purpose here is to state more clearly how they work and where they could be used.

Solenoids

A solenoid is quite simply a coil of wire wrapped around a former. Generally, the former is hollow to allow a plunger or rod to move inside it.



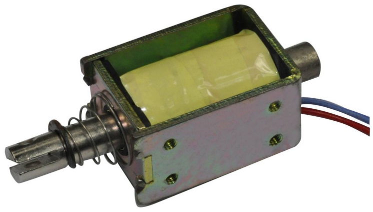
When the switch is closed the coil acts as an electromagnet and moves the plunger to the left.

When the switch is opened the plunger moves back to its default position, usually under the influence of a spring.

The end of the plunger could be switch contacts, a ball to shut off the flow of liquid etc.
A battery has been shown above but the source of supply could equally be mains a.c.

There are many applications where solenoids can be found; uses will include some of the following:


These two when activated will prevent the flow of liquid or gas. This could equally be a safety or **control** measure depending upon the process.



Upon the coil being energised, the rod will move to activate some mechanism giving linear control.

This is a typical starter solenoid. When the coil is energised, the rod moves to push the starter pinion onto the flywheel, at nearly the same time the contacts at the end are shorted to allow current from the battery to turn the starter motor.

Normally solenoids are non-repairable, should you find a faulty one the only course of action is to replace it.

Relays and Contactors

What is the difference between a relay and a contactor? As the principle of operation for both is the same, the answer is very little really. It is generally considered that a relay is used for more low current control circuit applications, whilst a contactor is for more heavy duty use such as for controlling motors, banks of lighting etc. Also a contactor can be stripped down and have the coil replaced or changed for one matching the source of supply.

Consider the two images below:

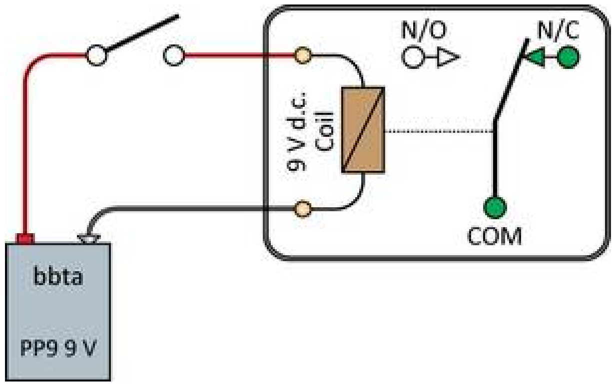
Typical relay, the voltage shown is 24 V

Typical contactor. It can be seen that it is more robust than a relay!

From previous work you already know that a relay/contactor is just an electromagnetic switch, and to get the contacts to make or changeover just requires a supply being put onto the coil terminals.

A basic function of a relay and a contactor, is for a small current to control a much larger one. The coil of the relay/contactor will consume very little current, whereas the rating of the N/O and N/C contacts is for heavier duty use.

The diagram shown below is of a very simple relay. Its purpose is to show that the control side is separate from the main switching part. There is an inherent degree of isolation between what could be low voltage control, in this case 9 V d.c. and high voltage switching, possible 230 V a.c..

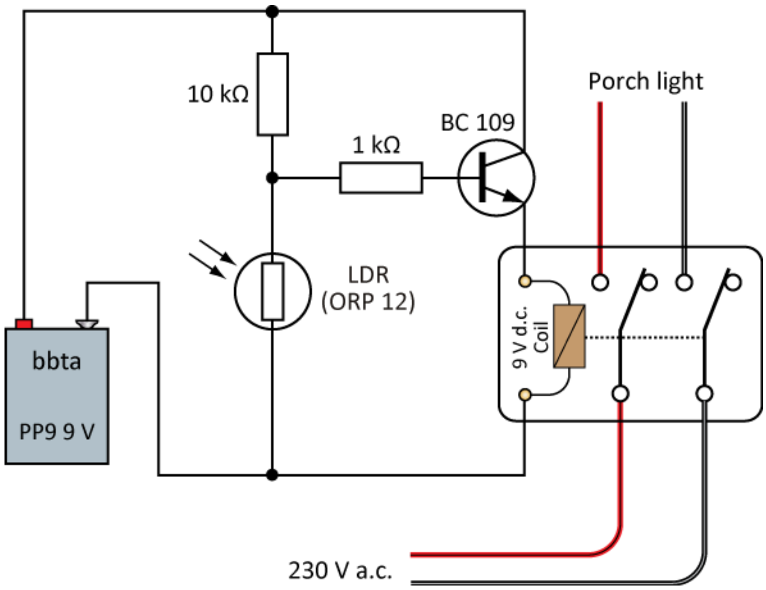


The relay shown only has one moveable contact but it can be in one of two places. By that I mean it can be making a normally closed connection when de-energised and moving to the normally open contact when energised.

Such a switching arrangement as this is called single-pole double-throw.

Relays are always shown in the de-energised position.

An example of how a small current can control a larger one is shown in the crude diagram below, which is an automatic light control circuit. We can greatly improve on this circuit when we come to the unit on Electronics, however, it will serve our purpose here.



When the light decreases, the resistance of the light dependant resistor (LDR), increases until eventually the transistor conductors. This allows current through the coil of the relay and switches on the load, which in this case could be some outside lighting.

Before we go any further, let us familiarise ourselves with the terminology for typical relay and switch positions.

Contact Arrangement

All relays contain normally open and normally closed contacts depending whether they are energised or not. The main difference really between a control relay and a contactor, is the size and number of contacts. The contacts in a control relay are relatively small because they need to handle only the small currents used in control circuits.

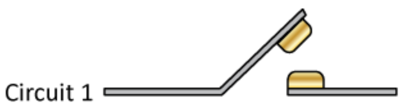
Some relays have a greater number of contacts than are found in the typical contactor. The use of contacts in relays can be complex.

There are two words which must be understood when dealing with relays.

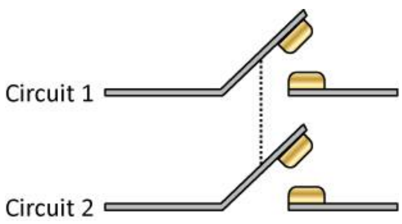
1. Poles
2 Throw

1. Pole

Pole describes the number of isolated circuits that can pass through the relay at one time. A single-pole circuit can carry current through one circuit. A double-pole circuit can carry current through two circuits simultaneously. The two circuits are mechanically connected so that they open or close at the same time.



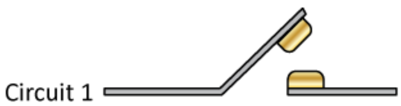
Single-pole



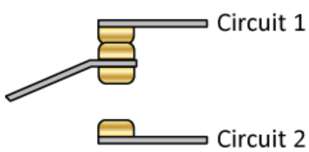
Double-pole

2. Throw

Throw is the number of different closed-contact positions per pole. This is the total number of different circuits each pole controls.



Single-throw



Double throw

The following abbreviations are frequently used to indicate contact configurations:

- SPST Single-Pole, Single-Throw
- SPDT Single-Pole, Double-Throw
- DPST Double-Pole, Single-Throw
- DPDT Double-Pole, Double-Throw

Just to conclude this session on relays, it is worth mentioning that there are special devices such as a timer relay, a typical example is shown below. These relays are used extensively in industrial logic control processes. They will also be found in the automotive industry as most modern cars have multi-setting time delay windscreen wipers.

The coil connections are usually labelled A1 and A2, which can be seen at the top of the relay. Because of the option of N/O and N/C contacts the mode of operation can be either delay on or delay off.

These are designed to be mounted on a din rail.

All that has been mentioned above equally applies to the contactor. The contactor is generally used on three-phase circuits because of it being more robust and the contacts are more able to make or break inductive currents.

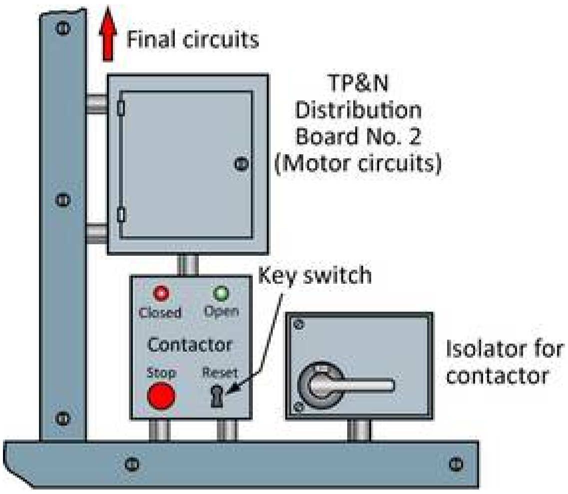
Exercise 1.

1. A pub cellar is prone to flooding. The landlord would like to have an automatic pumping system installed. Design a simple system using a 230/12 V a.c. transformer, float switch, relay and a pump. For safety reasons the float switch is rated at 12 V a.c.

   State additional safety features you would install if you were given the contract for the work.

2. The control for the motors in a college workshop is shown in the block diagram below.

   Draw the control circuit only for the arrangement. The key switch is of the momentary action, it does not latch. The green indicator is to show power is on and the red indicator is to show the contactor is energised. The stop button will disengage the contactor.



3. A 400 V a.c. 10 kW 3-phase motor is to be controlled by a contactor, but the control circuit is to be 24 V a.c. because of safety factors. It is unlikely that the 24 V circuit will create enough current to pull in the heavy duty contactor needed for the motor. Therefore, using the following items design a suitable control circuit.

   400/24 V a.c. transformer

   24 V a.c. relay

   400 V a.c. contactor

   Overload module for the motor (at this stage don't worry about the current rating, just make sure you fit one).

   1 start push button assembly

   1 stop push button assembly.

2: Protective devices

In this session the student will:

- Gain an understanding of why protection devices are necessary.
- Be able to describe the different types of protective device in common usage.

The last session saw how we can control different current consuming equipment with the aid of relays and/or contactors. In this session we will consider how we can provide protection against any overcurrents.

There is a clear relationship between the nature of the fault/overcurrent and the type of protective device that we use. This means we have to have some idea of the nature of the problem before we make our choice(s).

Before we go any further, let us be clear on one important aspect.

Why are protective devices fitted, what is their primary function?

Is it to?

a) protect the cable
b) prevent anybody receiving an electric shock
c) protect the equipment that has been installed
d) prevent electrical fires from starting

I hope you said option a); the primary function of a protective device is to protect the cable.

Option b) can be minimised by suitable barriers and enclosures and by protective bonding.

Option c) this is achieved by making sure the equipment is in good condition and fit for the environment it is to be installed.

Option d) one of the major causes of electrical fires is due to lack of maintenance. Electrical fires can also be caused by overloading badly protected circuits.

From previous work you may already know that there are two types of overcurrent. These are:

- Overload
- Short circuit

Overload

The term overload describes excess current flowing in a circuit which is electrically sound.

For example; one very cold day, every person in an office has plugged in a 3 kW convector heater into the ring final circuit. After a period of time the protective device operates. There has been no fault; just more current has been consumed than the circuit was designed for.

An overload current is usually not much more than the full-load current but has the potential to cause damage if allowed to persist.

Short circuit

A short circuit or its close relative, the earth fault, is due to a breakdown in the electrical system. The potential current flow is far greater than the normal full-load current of the system. Short circuits have the capacity to weld contacts together, cause fires and because of the energy involved, can cause harm to personnel and to the system in general.

For both overload and short circuit protection, the requirement of the protective device is that it should limit the time or duration of the excess current. With short-circuits, there is also the energy to consider due to the high current flow.

Therefore, protection against overcurrent is absolutely essential.

What protective devices are available, and which ones should be used where?

Overcurrent protective devices

Protective devices fall into two categories

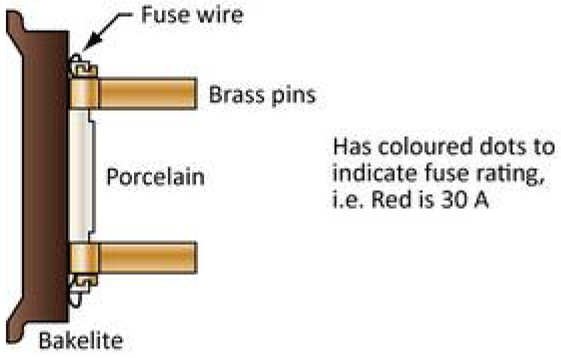
- Fuses
  - BS 3036 semi-enclosed fuse
  - BS 1361 (superseded by BS 88-3) & 1362 cartridge fuses
  - BS 88 Part 2&6 (HRC) HBC cartridge fuses
- Circuit-breakers
  - BS EN 60898 circuit breakers
  - BS EN 60947 moulded case circuit-breakers

BS 3036 semi-enclosed fuses

The BS 3036 type (semi-enclosed fuse) of protective device are very simple yet reasonably effective.

When current flows in a circuit heat is given off. If the current is lower than the fuse rating then the fuse can dissipate (get rid of) the heat into the surrounding air. If, however, current greater than the rating of the fuse flows in the circuit then the fuse will be unable to dissipate (get rid of) the heat as easily and the fuse wire will overheat. When the fuse wire reaches a set temperature it will melt.

Look at the diagram below; it should give you some idea of what a rewireable fuse looks like, and what its component parts are.



This type of fuse is only good for currents up to 100 A and voltages up to 250 V. This is fine as we are supplied at 230 V.

Advantages	Disadvantages
No moving parts	Incorrect element size can be installed
Cheap	Element cannot be repaired quickly
Melted element easy to see	Element deteriorates with age
Low replacement cost	Poor discrimination
	Can cause damage during very high fault current faults
	Poor breaking capacity – between 1-3 kA
	Can be dangerous if inserted when a fault is still on an installation.

There are a number of advantages and disadvantages attached to this particular fuse type, as can be seen above.

These fuses are seldom found nowadays but would have been extensively used on the smaller installations, typically domestic.

Two new terms have been used to describe this fuse. As they will be used further we had better investigate what they mean.

1. **Discrimination** This basically means that only the fuse nearest the fault operates leaving the rest of the electrical system intact. With a semi-enclosed fuse this cannot be guaranteed as the time taken for the fuse wire to heat up and melt can be excessive.
2. **Breaking capacity** Breaking Capacity is the ability of a circuit protective device to successfully interrupt the flow of current in a short-circuit situation, without causing damage to itself or its housing.

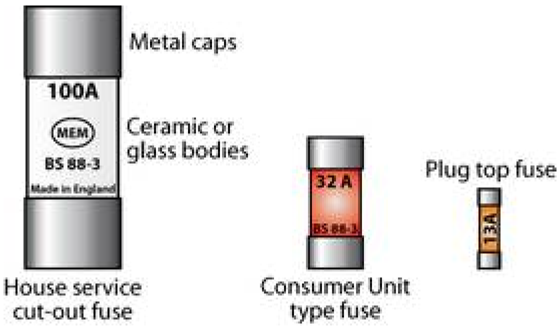
With a semi-enclosed fuse, there is a thin piece of wire that under short-circuit conditions would explode and splatter hot globules of metal into the fuse housing. This action aided the development of the cartridge fuse. It was always possible when replacing the fuse wire to determine if the fault was an overload or a short-circuit.

BS 1361 (superseded by BS 88-3) & 1362 cartridge fuses

The BS 1361 and 1362 are common types of fuse and are found in plug tops, small control circuits and domestic installation and similar distributor cutouts. It has a number of advantages and disadvantages.

Advantages	Disadvantages
No moving parts	Incorrect cartridge can be installed in plug tops (BS 1362) although not for BS 88-3 devices
Small physical size	More expensive than rewirable devices
Accurate current rating	Not suitable for high fault currents – The old BS 1361 had a breaking capacity of 16.5 kA for Type I and 33 kA for Type II and a BS 1362 has a breaking capacity of 6 kA. BS 88-3 Type I rated currents up to 45 A a.c. and a rated voltage of 230 V. BS 88-3 Type II rated currents up to 100 A a.c. and a rated voltage of 400 V.
Not liable to deterioration	Can be shorted out using ‘silver foil’

Have a look at the diagram of this type of fuse.



The body of the fuse is usually made of a glass type material, with the fuse element connected to the two end caps. The fuse may be filled with silica sand, although not always.

Both types of fuse are rated at 250 V, although the 60 A, 80 A and 100 A fuse are rated at 415 V. BS 88-3/1362 fuses are better than the BS 3036 fuse for discrimination, but are still not that wonderful.

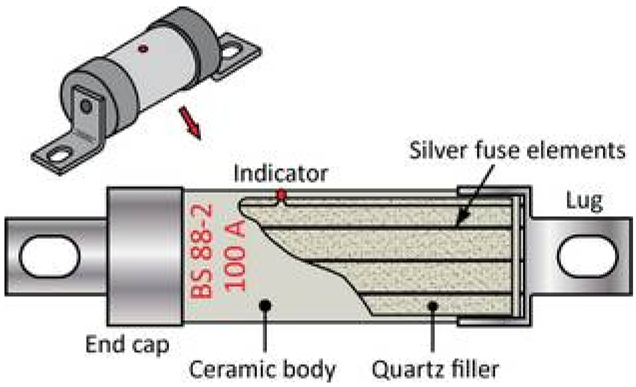
The BS 1361 fuse type is no longer listed in BS 7671 and has been superseded by BS 88-3: 2010 fuse system C (Low voltage fuses Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) – Examples of standardized systems of fuses A to F).

BS 88 Part 2&6 (superseded by BS 88-2) HRC cartridge fuses

This type of fuse is quite expensive and yet it is very commonly used in industry.

HRC (Higher Rupturing Capacity) fuses, although they have sometimes been called ***HBC (Higher Breaking Capacity)*** fuses, have been designed to take into account the electromagnetic effects that occur when certain pieces of equipment are turned on.

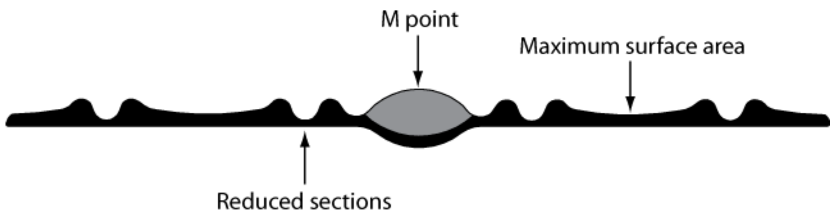
The structure of a HRC fuse is shown below. These fuses would normally be bolted or screwed into their carrier.



You can see that a number of silver elements are connected to the end caps.

The elements are contained within a ceramic chamber and protected using a quartz filler. The indicator shows when the fuse has operated (this is not always present). The elements vary in thickness according to the rating of the fuse.

If you were to look at the elements that run through the fuse you would see that they seem to be rippled. Have a look below.



The fuse element is made of silver, however at a certain point of the element (the overload zone-M point) a precise amount of low melting point tin is added to the element. As the current rises under overload then the temperature rises and at the desired point the fuse will operate. This is called the '**M**' effect. Note that this is for overload conditions, not short circuit conditions.

Under short-circuit conditions the reduced sections of the element will all melt and a series of multiple arcs will be created. These multiple arcs burn together and when the silver melts there is a reaction that takes place with the filler in the fuse. The arcs are therefore quenched very quickly: within the first half-cycle of the fault.

Rather than using fusing factor as a measure of the 'performance' of the protective device, the HRC fuse has three separate labels. This change occurred in 1988 when BS 88 was amended.

'**gG**' (General purpose) A breaking capacity of at least 80 kA at 415 V a.c. at 0.2 pf.
The temperature rise of the fuse must not exceed 70 °C when carrying the rated current.
They must have the ability to protect thermoplastic insulated cables from damage due to overload currents.

'**gM**' These fuses are used for back-up protection of motor circuits and are usually found in a smaller package.
A gM rated fuse has two currents ratings. The first deals with the rated current of the fuse and the fuseholder. The second deals with the time-current characteristic of the fuse link. So ratings such as 32M63 and 200M315 are found.

What does this mean?
The first letter relates to the normal full load current, which would be created when the motor is running. The second letter relates to the stalled rotor current. The stalled rotor current is considered to be the current that is present at the moment a motor is turned on.

'**aM**' These are a back up type fuse and are used for motor protection. They are based on a European standard and are similar to the gM fuselink. They do not provide overload protection and therefore have to be coordinated with other devices.

HRC fuses range in value from 6 A up to 1 200 A, which is quite a wide range.

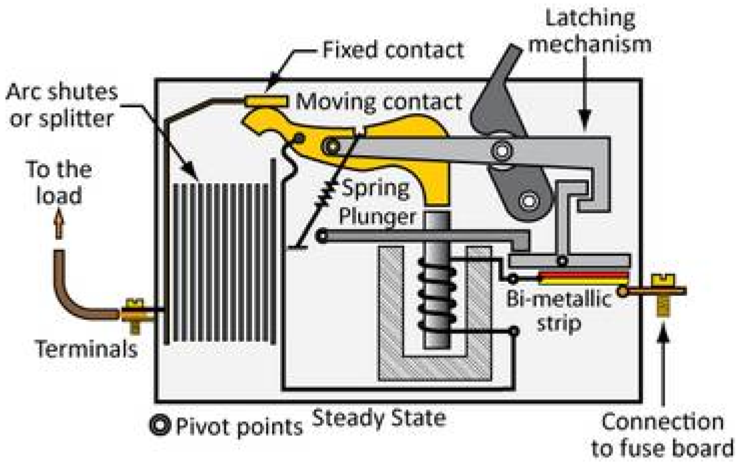
Advantages	Disadvantages
Discriminates between short duration overloads and high fault currents	Expensive
Simple (usually) to observe when the fuse has blown	Can be replaced with a larger fuse rating
Accurate current rating	
Consistent in operation – every fuse is the same	
High breaking capacity – up to 80 kA	
Not liable to deterioration	

The cost of this type of fuse is quite high however, and it is important that care is taken with both the design of the system and the maintenance of the system.

BS EN 60898 circuit-breakers

Have a look at the diagrams below. You can see how much more complex it is compared to any of the fuses described earlier.

All the types of protective devices considered so far have operated on the basis of heat – if too much heat is generated in the element of the fuse then it 'blows'. A circuit-breaker operates on slightly different principles. It usually has two means of tripping, a magnetic and a thermal.

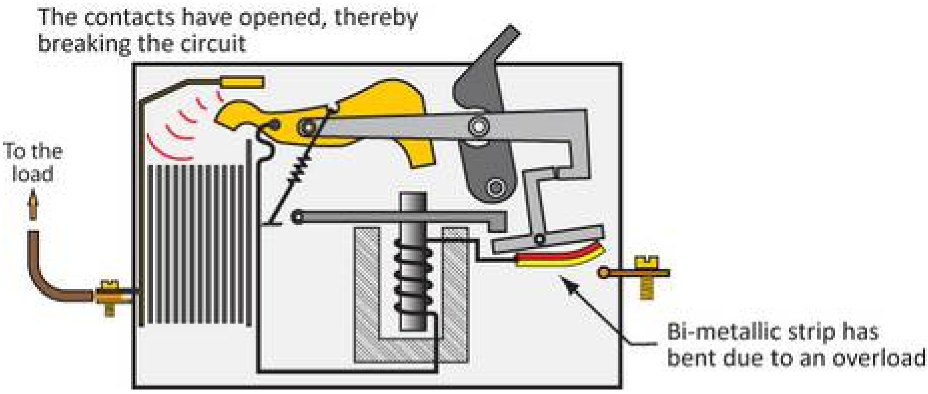


As you can see, the diagram for the circuit-breaker is much more complex than that of fuses.

It can be difficult following the diagram, yet the two key tripping mechanisms are explained over the next few pages.

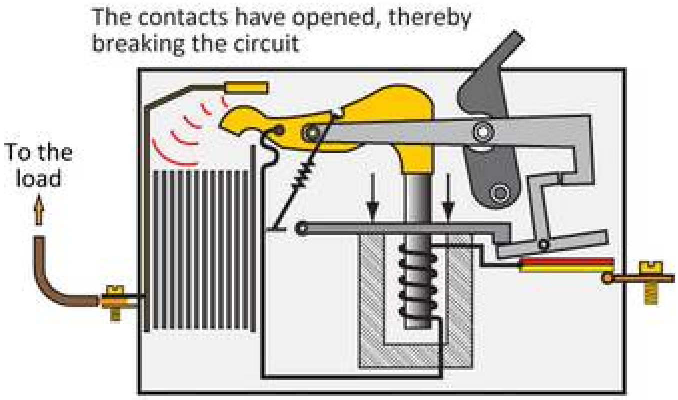
Above we have the circuit-breaker in its normal steady state. Current is flowing, yet neither the bi-metallic strip nor the magnetic trip is affected. The latching mechanism is held in place and the plunger is low down and not affecting the trip mechanism.

Over the page we can see that the bi-metallic strip has moved.



The circuit-breaker now has an overload occurring. The bi-metallic strip has heated up slowly, moved upwards and has tripped the latching mechanism. This tripping of the latching mechanism has moved the spring-loaded contact and opened the circuit.

Below it is the magnetic part of the circuit that is affected.



Operation due to a short-circuit current

In this instance there is a rapid increase in current. The bi-metallic strip has little time to heat up, yet the magnetic coil builds up a large magnetic field around itself. This magnetic field moves the plunger upwards and pulls another part of the tripping mechanism down. This leads to a rapid break in the circuit. This is another example of a solenoid.

When the design current of the circuit is exceeded two things happen in a circuit-breaker:

- the increased current causes an increase in heat and the bimetallic strip bends; this is the thermal part of the circuit-breaker
- with an increase in current there is a corresponding increase in the strength of the magnetic field.

As with any type of protective device there are a number of advantages and disadvantages.

Advantages	**Disadvantages**
Tamper proof	Expensive
Simple to observe when the circuit breaker has tripped	Regular testing is necessary to guarantee safe operation
Supply can be restored quickly	Have moving parts
Pre-set tripping characteristics-can't be altered, although special circuit breakers can have time lag and variable settings.	Variations in temperature affect the operation
Can differentiate between short term and prolonged overload	Breaking capacity limited to either 6 kA or 10 kA
Single as well as multi-pole units available	May need to be replaced if large fault currents occur

As with the HRC fuses, which are capable of separating out short term and long term (persistent) overloads, circuit-breakers are also capable of differentiating between them.

According to BS EN 60898 there are three types of circuit-breaker, ***Type B, Type C*** and ***Type D***. These letters relate to their ability to handle inductive loads.

Type	**Uses**
B	General circuits where the load does not exhibit high inrush currents. This would typically be; tungsten lighting, heating, showers, cooker circuits etc.
C	General circuits where the connected load has moderate to medium inrush currents. This would typically be small to medium sized motors, large banks of fluorescent lighting etc.
D	Circuits where the inrush currents are severe. These sorts of loads would be X-ray machines, electric welders, large transformers, DOL started motors etc.

The inrush current relates to the current range for the instantaneous operation of the circuit breakers shown in the table below.

To consider discrimination when looking at circuit-breakers life becomes a little more complicated. Each type of circuit-breaker has a range of values attached to the tripping current.

Type	**Rating I_n (A)**	**Current required for overload (A)**	**Current range for instantaneous operation (A)**	**Current causing instantaneous operation (A)**
B	All	$1.45 \times I_n$	$(3-5) \times I_n$	$5 \times I_n$
C	All	$1.45 \times I_n$	$(5-10) \times I_n$	$10 \times I_n$
D	All	$1.45 \times I_n$	$(10-20) \times I_n$	$20 \times I_n$

For each of the types of circuit-breaker you can see the range of values that a circuit-breaker can operate within. The general rule to follow for the information provided in the fourth column in the above table, is to recognise that no mechanical device can operate at an exact point in time. We can engineer tolerances very closely, but after a time, there is a need to produce economical devices.

As an example, let us consider the Type B circuit-breaker. This circuit-breaker has a stated range of 3 to 5 times the rating of the device.

- At any current less than three times the rating of the circuit-breaker, the device is guaranteed *not* to operate in 0.1 s.
- At a current of five or more times than the rated current of the circuit-breaker, the device is guaranteed to operate within 0.1 s.
- Between three and five times the rating of the circuit-breaker we are just not sure when it will operate. This, if you like, is the range of its tolerance.

These ranges and the value of the fault current will lead to a variation in the way that discrimination is achieved for any particular type of circuit-breaker. This is quite complex and is dealt with in the design course.

Moulded case circuit-breaker to *BS EN 60947*

The moulded case circuit-breaker (MCCB) is used where higher levels of fault current are expected and are often used instead of the HRC fuse. They are generally rated at values from 100 A up to 3 200 A. The higher rated devices can be adjusted and provide greater levels of flexibility to the skilled operator and designer.

The breaking capacity of the MCCB can be as high as 150 000 A (150 kA). They are found more often at the mains positions where it can also act as the device necessary for an adequate breaking capacity, whilst all other devices can have a lower rating.

MCCBs are defined in terms of their trip mechanism. As with most other types of protective devices they have thermal and magnetic trips, and in many cases these can be altered. In addition they can be fitted with auxiliary items such as extended operating handles, shunt relays, undervoltage release etc.

The main features of a modern MCCB are:

- They have a high breaking capacity and low let-through energy $\left(I^2t\right)$ which enables safe operation under large fault currents
- Simultaneous opening and closing of all main poles
- Toggle always shows the position of the main contact. This means that even if the switch seems to be open, the toggle may show that it is still made. The toggle is correct
- Test button for periodic testing of the mechanism.

Although MCCBs are larger and more capable of withstanding very large fault currents, they are still low voltage devices. They are characterised by the following category.

- **Category A** MCCBs are generally smaller devices and for which there is no short-circuit trip delay possible. These breakers will trip instantaneously when the fault current is greater than the magnetic trip setting of the circuit breaker.
- **Category B** MCCBs have a time delay mechanism. It is possible to delay tripping under short circuit conditions with values lower than the rated short time withstand current.

Exercise 2

1. Why do the various types of circuit-breaker exist?

2. You are to install an electric arc welder. What type of protective device would you use and why would you choose it?

3. A circuit which normally takes 18 A is subjected to a 100 A instantaneous fault current.
Using the time/current characteristic curves in Appendix 3, complete the table below by finding the disconnection time for each protective device.
I_n = 20 A

Protective device	Disconnection time (s)
BS 3036	
BS 88-3	
BS 88-2	
BS EN 60898 Type B	
BS EN 60898 Type C	
BS EN 60898 Type D	

4. A 5 A BS 3036 fuse protects a lighting circuit of 10 GLS (general lighting service) tungsten filament lamps. The lamps are to be changed for twin fluorsecent luminaires to improve the energy efficiency of the installation. Are there any consequences for the nature of the protective device and what are they? (Assume each tube is 36 W. Don’t forget to apply the 1.8 factor given in Note 2 Appendix A of the OSG)

5. Why would an HBC fuse be chosen instead of a BS 1361 fuse?

6. Why would you use a gM rated HBC fuse rather than a gG fuse?

7. What type of circuit-breaker would be used to protect a two-phase industrial welding machine? What are your reasons?

3: Residual current devices

In this session the student will:

- Gain an understanding of the types of residual current devices (RCDs)
- Gain an understanding of the limitations associated with RCDs.

In the last session we considered the nature of standard protective devices and how they handled large values of current. In this session we are going to deal specifically with the Residual Current Device (RCD).

Residual Current Device

Over the years the RCD has gone through a number of name changes. It has been the ELCB (Earth Leakage Circuit Breaker) and it has been the RCCB (Residual Current Circuit Breaker). The names changed to move people away from thinking that the RCD operated in the same way as all other protective devices. The latest hybrid is the RCBO or combined RCD and circuit breaker.

They come in all shapes and sizes; some have time delay features whilst others operate on slightly different principles. The main types you will probably come into contact with are shown below.

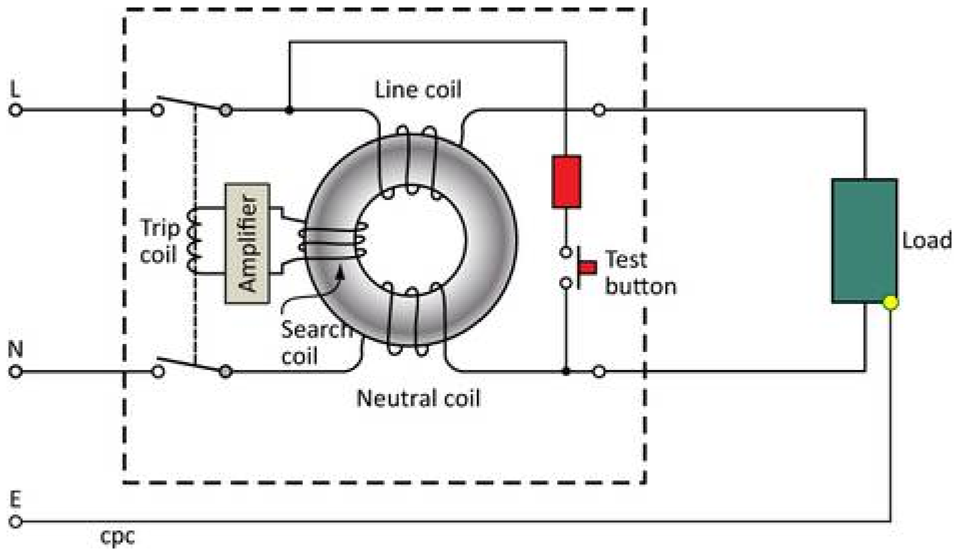
RCBO	RCD	RCD with time delay
		
Conforms to BS EN 61009	These conform to BS EN 61008	
This device offers overcurrent **and** earth leakage protection.	These devices **only** provide earth leakage protection. They must be used in conjunction with some form of overcurrent protective device.	

The common current tripping ratings are (although there may well be others as the market develops):

- 10 mA
- 30 mA (this is the maximum for socket-outlets rated at not more than 20 A, as 30 mA is considered to be the maximum current a body can withstand before death could occur)
- 100 mA
- 300 mA
- 500 mA.

The RCD is special. All other devices operate on either overload or short circuit. If enough current flows either from line to neutral or from line to earth then the protective device will heat up and either the wire will melt or the device will trip. The RCD does not operate on the heating principle, but rather by balancing a magnetic circuit.

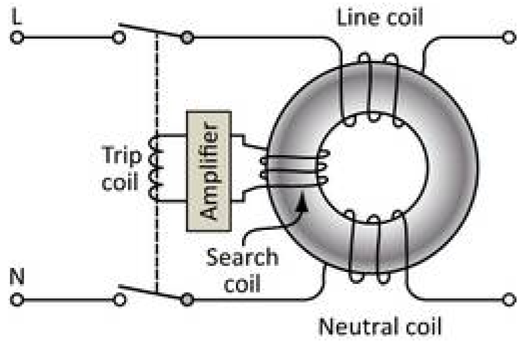
The diagram below illustrates the basic setup of an RCD. We can see that it consists of a toroid (magnetic circuit) wound with a line, neutral and trip winding. In addition there is a double-pole switch and a test circuit.



RCDs operate by sensing an imbalance between the line and neutral currents, and this is usually caused by current 'leaking' to Earth or leaking elsewhere such as through a body.

An RCD only operates on an imbalance between line and neutral conductors – generally caused by current flowing to Earth.

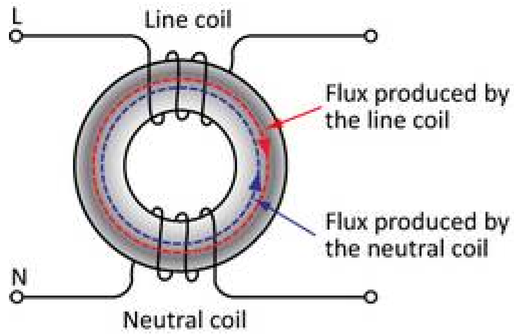
This may seem a little strange so let's have a look at a diagram of how it operates.



As you can see there is an iron (easily magnetised) core. This core is wound with a search coil, which is connected to a trip coil. The coil also has two other coils (line and neutral) wrapped around it. These are the line and neutral conductors.

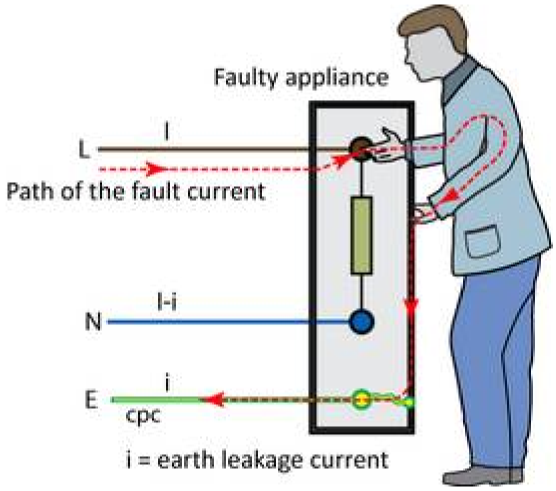
The principle of operation is:

In a healthy circuit



- the same current flows in the line and neutral conductor
- the current in each conductor produces a changing magnetic field around itself
- the change in the magnetic field around the conductors produces a magnetic circuit in the coil
- the interaction of the two magnetic fields produced by the conductors cancel each other out and the search coil cannot '***sense***' (have a current induced in it) any difference between the two.

In a circuit with a fault to Earth



As you can see there is now a difference between the line and the neutral current. The reason for this is that current will follow any path provided for it and under earth fault conditions we have provided at least one other path. We can't have more current than is in the line conductor however.

- a different current flows in the line and neutral conductors
- the currents in the line and neutral produce a changing magnetic flux around themselves
- these magnetic fluxes produce a magnetic circuit in the core
- as the two currents are different, so the magnetic fluxes are different, and the magnetic circuit in the core is not cancelled out and the search coil 'picks up' the difference. If the two currents are out by a set amount then the search coil will operate a small relay that will trip a switch, opening the circuit.

Everything operates on balance. If the currents aren't the same then the RCD will operate. If the currents are the same then the RCD will not trip. This means that we have to be aware that an RCD ***will not trip*** under an overcurrent condition, it only operates on earth leakage faults where an imbalance occurs. If there is a fault between line and neutral, and the current flowing is 500 A, then because the magnetic circuit in the core of the RCD is balanced then it will not trip. It may well blow up!

Some older RCDs were not able to '***see***' the negative half cycle of the a.c. supply and so were less than effective. This is why both the positive and negative half cycles of the a.c. supply must be tested when testing and RCD.

Applications of RCDs

The following table gives an indication of the wide use of RCD devices, it is by no means exhaustive.

Location	Regulation	Brief outline
General	411.3.3	Where sockets outlet rated at 20 A or less are to be used by ordinary persons. For mobile equipment used outdoors having a current rating not exceeding 32 A.
General (TT systems)	411.5.2 411.5.3	Where the earth fault loop impedance is too high to cause effective disconnection times for fault protection.
General	522.6.100 522.6.102	Where the installation is not under the control of skilled personnel, and other precautions for buried cables have not been applied, then an RCD shall be used.
General (TT systems)	531.4.1	If an installation is protected by a single RCD, it shall be placed at the origin
General, where there is increased fire risk	532.1	An RCD shall be used where it is necessary to limit the consequences of fault currents in a wiring system due to fire risk. See also Regulation 422.3.9 for details.
Electrode water heaters & boilers	554.1.4	Where a water heater or electrode boiler is connected to a supply which exceeds low voltage (1 kV a.c.)
Lighting in public places	559.10.3.2	Lighting in places such as telephone kiosks, bus shelters etc.
Special locations		The use of RCDs in the special locations listed in Part 7 is considerable and would form a long list. Have a look yourself!

Exercise 3

For some of the questions below you will need access to your copy of BS 7671:2008 AMD No. 1

1. Describe how a typical RCD operates.

2. What type of faults will an RCD not operate with?

3. Name four different circumstances where you would expect to use an RCD. What reasons can you give for your choices from BS 7671.

4. What is the maximum rating of and the maximum disconnection time for a RCD used to provide additional shock protection?

5. A computer suite is to be installed. The circuits are to be protected by a series of RCBOs. Can you think of any particular problems that might be created and how they might be overcome?

6. You are called to a small village hair dressing salon as the owner complains of the power frequently going out. Upon investigation you notice that the fuseboard incorporates an RCD unit as the main switch. The owner mentions that every time she uses one of her large mobile hair dryers the power goes off. She asks that you take the 'thingy' out that causes her to lose power. What is your response?

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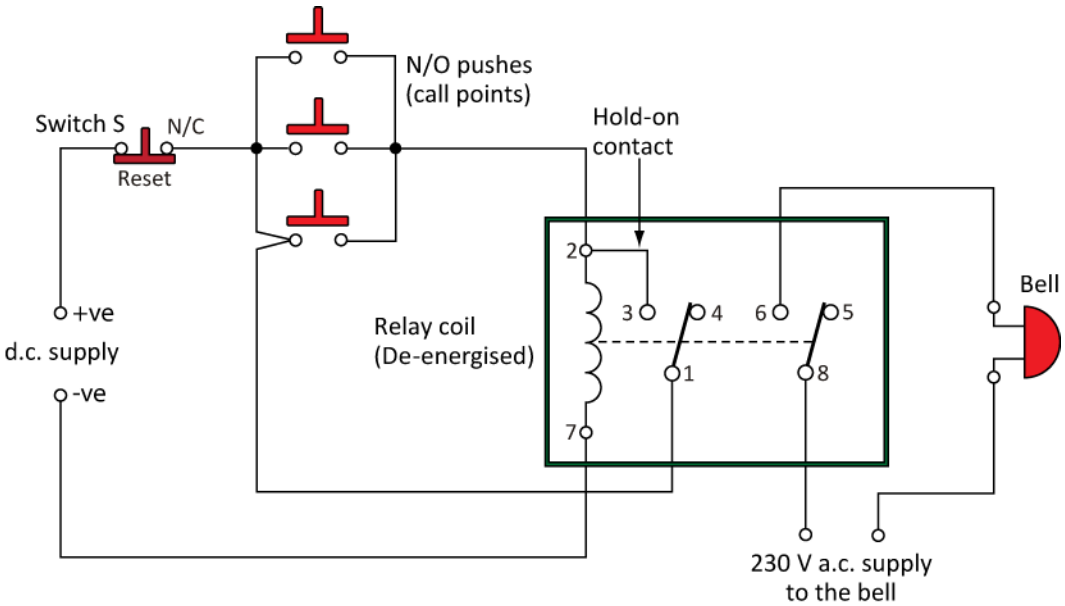
Attempt all questions.

All marks are shown in the right-hand margin.

Anything less than this mark should lead you to re-read the text.

1. This circuit diagram is of a simple open-circuit fire alarm. Redraw the circuit to make it a closed-circuit alarm system That is, instead of breaking the glass on the N/O call points to energise the relay to make the bell ring, you need to have the N/C call points break the circuit to cause the bell to sound. 8



2. What do you understand by the terms; short-circuit, overload, overcurrent and earth fault? 4
3. Explain where you might use HBC fuses. 2
4. What current must flow to cause a 16 A type B, type C and type D to operate within 0.4 s? 2
5. What are the key problems of protecting circuits with BS 3036 fuses? 2
6. You are to install a new circuit feeding a motor rated at 89 A. The fault current has been measured at 8 000 A. What type of protective device would you choose and why? 2

Total 20