# Electrical Installations

## Introduction

An assembly (connected as a complete set) of associated electrical equipment to fulfill a specific purpose and having certain coordinated characteristics.

### Standard colors

- Protective earth: mixed yellow and green
- Neutral: blue
- Single phase line: black or brown

## Nomenclature

### Electrical equipment

Any item used in generation, transmission, distribution and utilization of electrical energy.

Examples: generators, transformers, measuring instruments, protective devices, wiring materials, etc.

### Overcurrent

Current that exceeds the rated value. Includes overload and fault current.

### Current carrying capacity

The rated value of current, for conductors.

### Faulty current

Can be subdivided into:

- short-circuit current
- earth fault current

## Most common types of faults

### Short-circuit fault

Large current will flow. Over heating will occur. Damages may occur to wires, insulators, switches, etc. Aka. phase-neutral fault.

### Insulation failure

Fault between phase conductor and non-current carrying metallic parts. High voltages may appear on the frames of electrical equipment.

## Protection for safety

Protecting livestock and electrical equipments from electric faults.

- Prevent damage by fire or shock
- Maintain supply continuously
- Minimize the system interruptions under faulty conditions.
- Against direct contact: Relates to live parts.
- Against indirect contact: Relates to exposed parts. Conductive but not normally live. Made live by fault.

### Properties of protective equipment

- Certainty and reliability of operation under normal, fault, non-operational conditions
- Discrimination: ability to isolate faulty part from the system
- Rapidity of operation: how fast the equipment responses
- Simplicity
- Low initial and maintenance cost
- Easy adjustment and testing

### Protection methods

- Earthing of equipments
- Use of circuit breakers/fuses
- Use of residual current circuit breakers

# Fuses

A device for opening a circuit by means of a conductor designed to melt when an excessive current flows along it. Simple. Relatively cheap.

When overcurrent flows through a fuse, the fuse element melts, vaporizes. A gap is formed in the circuit. Electrical current tries to *jump* over the gap causing a high-temperature plasma path, which is seen as an arc.

### Fuse element

Part of a fuse. Designed to melt and open the circuit when overcurrent flows.

### Fuse link

Part of a fuse, which comprises a fuse element and a cartridge (or other container) and is capable of being attached to the fuse contacts.

### Current rating

Maximum current the fuse can carry without breaking.

### Fusing current

Minimum current that will cause the fuse element to heat up melt or blow.

### Fusing factor

$$\text{Fusing factor} = \frac{\text{Fusing current}}{\text{Current rating}}$$

Always greater than $1$. Usually in the range of $1.7 - 2$.

### Rupturing capacity

Product of maximum current and supply voltage.

## Types of fuses

### Semi-enclosed fuse

Consists of a fuse holder, which is made up of a fuse base and a fuse carrier. The fuse carrier contains the fuse element usually in wire form. “Rewireable” because the elements are directly replaceable. Cheap. Low rupturing capacity.

#### Disadvantages

But not recommended nowadays because of these disadvantages:

- **Deterioration with time** - due to oxidation. cross sectional area might get reduced with time. resistance will increase. may operate at lower currents than expected.
- Very easy for an inexperienced person to replace a blown fuse-element with a wire of incorrect size or type
- **Slow**: time taken for the fuse to blow may be as long as several seconds during which time considerable electrical and physical damage may result to the circuit conductors and the equipment being protected.
- **Not accurate**: calibration of re-wirable fuse can never be accurate
- Unsuitable for circuits which require discriminative protection. i.e. it is possible in certain circuit conditions for the 15 A rated fuse element to start melting before the 10 A rated element completes fusing
- Not capable of differentiating between a transient high current and a continuous fault current
- Has an associated fire risk
- When the fault current is particularly high, though the fuse works, an arc may still be maintained by the circuit voltage (through air and metallic vapour)

### Fully enclosed (catridge) fuse

Developed to overcome the disadvantages of the re-wirable type of fuse. Fuse wire is enclosed in a evacuated glass tube with metal end chips. Expensive compared to semi-enclosed fuses. Low rupturing capacity.

> **Note**
>
> Both semi-enclosed and fully-enclosed fuses are generally used in house-hold, commerical and small scale industrial applications.

### High-rupturing capacity (HRC) fuse

Used for high current applications. Expensive.

## Circuit Breaker

A device for making and breaking a circuit. Operated by hand or automatically. Can be used to isolate part of a circuits. More accurate protection compared to semi-enclosed or fully-enclosed fuse.

Things to consider when choosing a circuit breaker:

- the normal current it will have to carry
- the amount of current it will have to interrupt

### Protection

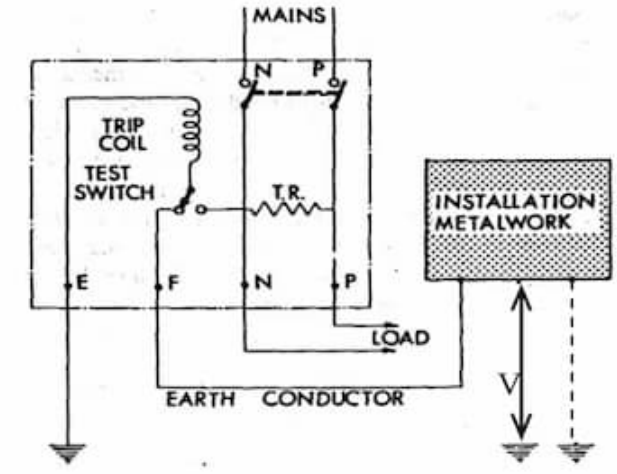
#### Earth leakage current

Can be used to detect electrical faults to earth in electrical. There are 2 types of circuit breakers to detect electrical faults to earth.

- Voltage operated protection - Earth Leakage Circuit Breaker
- Current operated protection - Residual Current Circuit Breaker or Residual Current Device

The earth leakage protection device is called as trip switch.

## ELCB




Short for Earth Leakage Current Breaker. Detects if electricity is leaking to earth from an appliance. Protects from shocks.

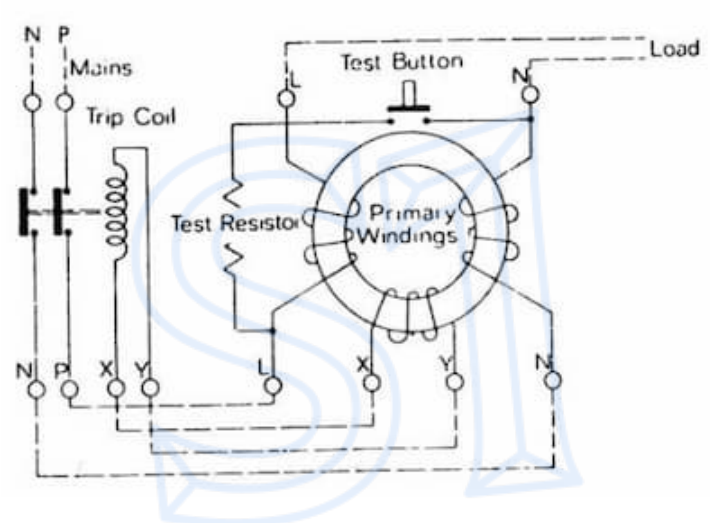
Has a trip coil. Trips when voltage difference between the frame earth and the reference earth exceeds the rated voltage (usually $40\ \mathrm{V}$). The trip coil is energized by the voltage difference, and the spring-loaded contact is released which breaks the circuit and cuts off power. Up to about $50\ \mathrm{V}$ has been traditionally considered as a safe voltage.

2 earth terminals are required for the proper operation.

- Frame earth: to which all non-conducting metallic parts of equipment are connected
- Reference earth

Current through the body, not voltage, is what harms people. Because of that RCCBs are preferred instead of ELCBs.

## RCCB




Short for Residual Current Circuit Breaker.

Trips when line current and neutral current are different. Residual current is the difference between live and neutral currents. Provides protection against earth faults and leakage currents.

Consists of a solonoid coil.

Under normal operating conditions, two identical windings will carry the main current. Since the currents are equal and opposite through the two windings, there is emf balance and there will be no induced emf on the detector winding. Thus the operating coil will not be energized.

In case of a fault, the line and neutral currents will not be equal and the trip coil will be energized due to the induced currents in the detector winding.

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> **Note**
>
> In both ELCB and RCCB, a test switch is provided to create an artificial fault.

### Advantages of RCCB

Suppose the live wire is exposed. If somebody touches it, they may get a shock if a current passes through them.

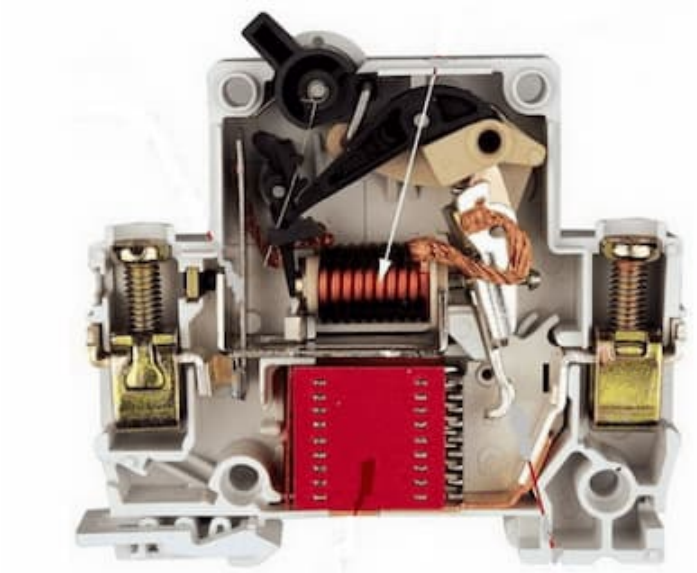
In the case of voltage-operated ELCB, this earth current is not going through the tripping coil and will cause danger. But in the case of RCCB, the return path is going to loose part of the current, which passed through the human body, which in turn would cause a resultant flux within the ring energizing the tripping circuit.

### Ratings

- Rated current
- Rated voltage
- Sensitivity

> **Note**
>
> 2 Pole RCCB - used in single-phase supply connection that has only a live and neutral wire.

## MCB



MCB is short for miniature circuit breaker. Not main circuit breaker. Each sub circuit in the consumer unit starts with a MCB. Protects against overcurrent, caused by both overload and short-circuit current.

Has 4 functional components:

- A thermal overload trip (bi-metal)
- An electromagnetic short-circuit trip
- A switching mechanism with contacts
- Arc exhausting system

### Advantages

Advantages of a MCB over fuses:

- **Non-destructive**
- **Fast**
    - Shorter tripping times under moderate overcurrents
    - Immediate indication of faulty current
- **Manual operation**: can be used as a circuit control switch
- **Easy to use**
    - No stock of fuses required
    - Reclosing can be effected at once after the fault has been cleared

### Ratings

- Rated current
- Rated voltage (single phase and 3-phase)

## Differences to a fuse

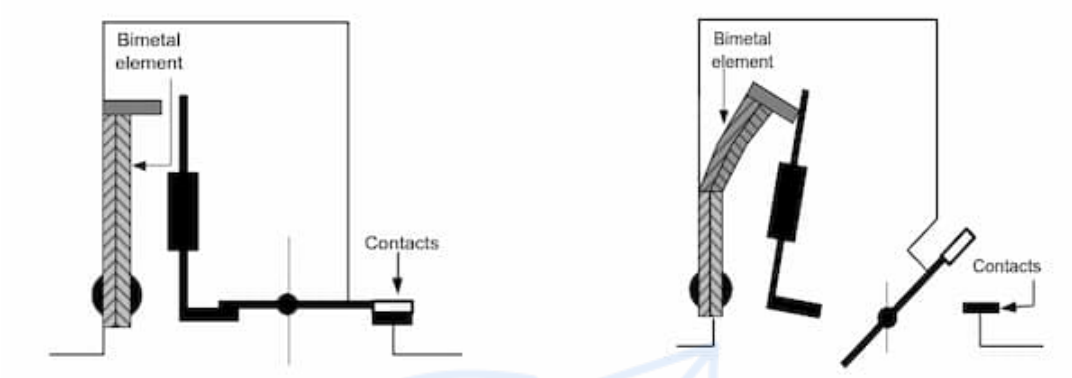
| MCB | Fuse |
| --- | --- |
| Non-destructive | Self-destructive |
| Used repeatedly | Wire must be replaced before reuse |
| Automatic or manual | Only automatic |
| High cost | Low cost |

| MCB | Fuse |
| --- | --- |
| More accurate | Less accurate |

In MCBs, both a thermal device and an electromagnetic device are involved.

- Thermal mechanism for small overloads and time-graded operation
- Electromagnetic mechanism for high fault currents and near-instantaneous operation

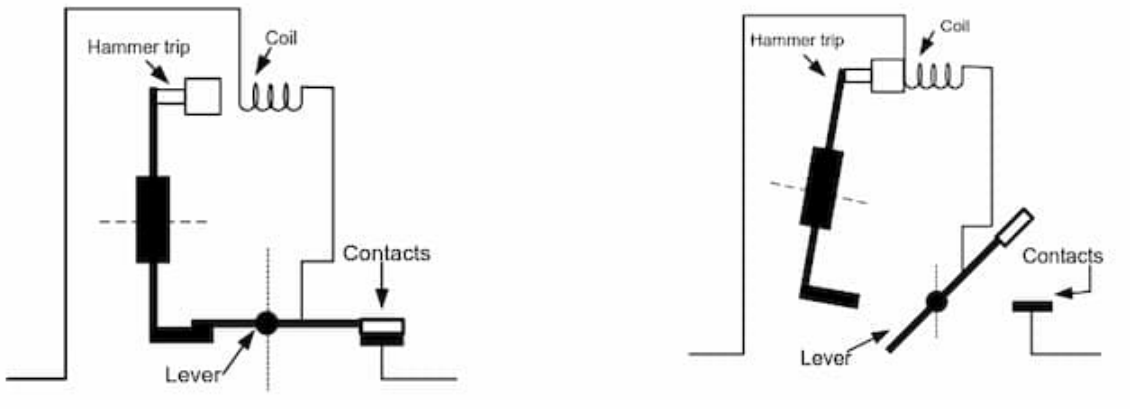
## Function of the thermal device




Consists of a bi-metal strip. When overheated from overload current, the bi-metal strip is deflected. The deflection depends on the heat which depends on:

- Intensity of current flow
- Duration

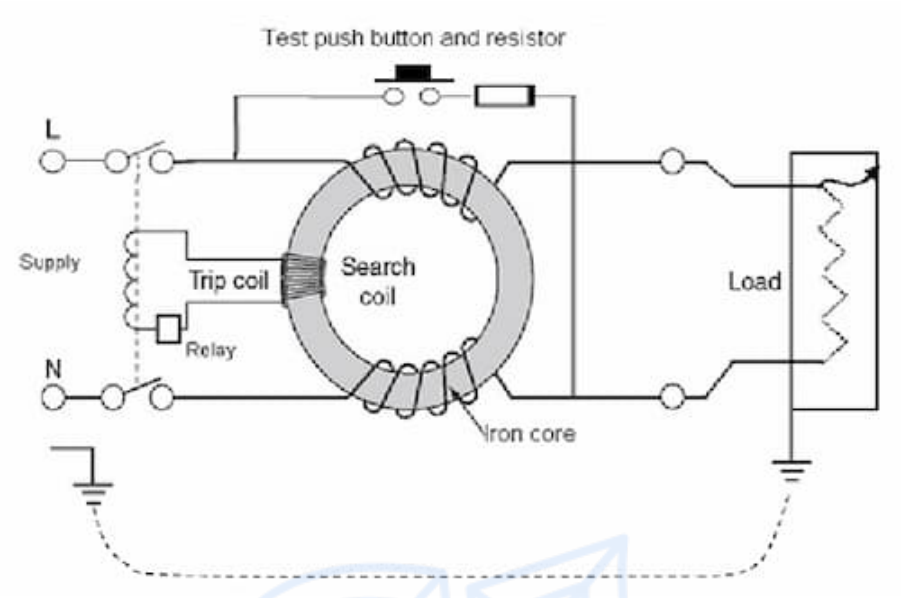
## Function of the EM device




Consists of a solenoid coil. Load current is set to flow through the coil.

In this coil, there is a fixed iron-core with a movable armature. When the current exceeds the rated value, the coil exerts sufficient electromagnetic force to attract the armature against the force of the spring. A switch mechanism is activated by the lever, to open the contacts.

## RCD




Short for Residual Current Device. Protects against electric shock and fire risks.

Works by monitoring the residual current between the live and neutral lines.

Under normal operation, the residual current is $0$. Generated magnetic fields cancel each other out.

When some current leaks to earth (like when someone touch the live wire), there will be a residual current. Which causes an unbalanced flux. Trips when the residual current exceeds the rated sensitivity (usually $30\,\mathrm{mA}$).

## Earthing

Earthing of equipment refers to the connection of non-current carrying parts of electrical equipment to the earth to maintain earth potential. Usually the earthing circuit is connected to a burried electrode. Done using a low-resistant conductor.

An effective earthing system avoids having dangerous potentials on the equipment even during electrical faults and also ensures the proper operation of electrical protection equipment during fault condition.

Potential of an installation is measured with respect to earth.

## Purposes

### Neutral Earthing

Limiting the voltage of current carrying conductors forming a part of the system.

This is important because the performance of the system in terms of short circuits, stability, protection, etc., is greatly affected by the state of the neutral conductor. When the neutral is properly grounded, voltages of the phases are limited to near phase to ground voltage.

### Equipment Earthing

Limiting the potential of non-current carrying metal work associated with equipment, apparatus and appliances in the system.

Governed by various regulations such as the IEE regulations. The objectives of this grounding are:

- To ensure effective and rapid operation of the protective gear in the event of earth fault currents. Otherwise, those currents might be undetected, and cause fire
- Protect against shocks caused by installation metal work having a dangerous potential

## Types of earthing arrangements

In the regulations for electrical installations, the types of earthing systems are identified as follows, depending on the relationship of the source (supply authority network) and of the exposed conductive parts of the installation, to earth.

- TN - earthing of the installation is done to that supplied by the supply authority
- TT - supply authority earth and the installation earth is independent
- IT - supply authority has effectively an isolated neutral and the installation has an independent earth

Above the first letter means:

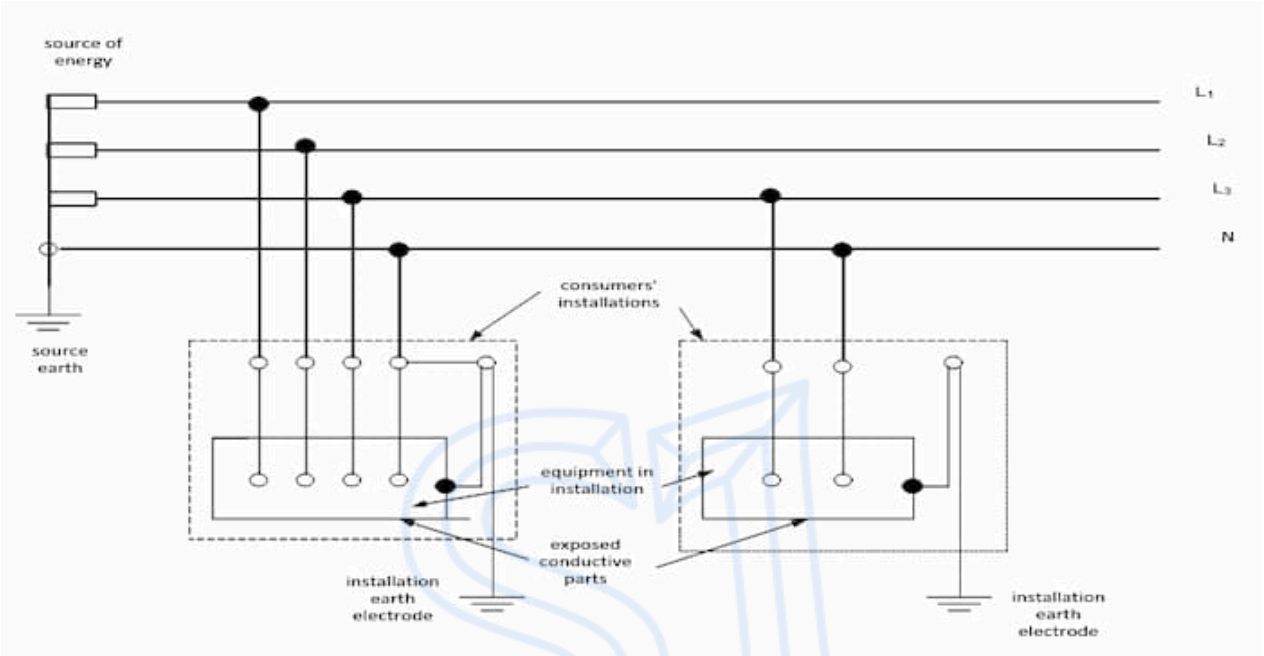
- **T** - Short for terra. Means the source is earthed at its star point.
- **I** - Short for isolated. Indicates either:
    1. all live parts are isolated from earth
    2. one point of live is connected to earth through high impedance

Above the second letter means:

- **T** - Means all exposed conductive parts of consumer installation are directly earthed independently.
- **N** - Denotes a direct electrical connection of the exposed conductive parts to the earthed point of the supply authority side (which is usually the neutral point)

### TT system

Used in Sri Lanka. Supply is earthed at the source end. All exposed conductive parts of the installation are connected to earth (independent earth electrode) at consumer end. Earth serves as the return path for the fault current.




> **Note**
>
> In domestic systems, the earthing circuit is usually earthed through buried metallic pipes. The electrode's resistance depends on the condition of soil and may have values in excess of $100\,\Omega$. Thus in the TT system of earthing, it is now essential to use an RCCB for protection.

The normal earthing practice is to provide a circuit protective conductor throughout every installation. A circuit protective conductor connects exposed conductive parts of equipment to the main earthing terminal.

## Household Wiring

Most domestic installations in Sri Lanka use single phase. For higher loads, third phase can be installed on request. The electricity is supplied through a service cable which includes a live wire and a neutral wire and in $230\,\mathrm{V}$.

The service cable first goes into the energy meter.

### Electric meter

Installed by the electric utility, for billing purposes. Can either be electromechanical, electronic, or smart meter. Measures energy in $\mathbf{kWh}$. Up to the electric meter, the equipment belongs to the supply utility. Consumer's installation starts from the main switch. After the electric meter, the live and neutral wires are connected to the main switch in the consumer board.

### Consumer unit

Aka. distribution unit. Size of the consumer unit depends on the size of the property and how many circuits are being controlled.

- Controls the distribution of power
- Provides protection against faults

### Main circuit breaker

Aka. main switch. Controls the electricity to the rest of the consumer unit and all the circuits in the property. Can be operated manually to cut the power. Disconnects both live and neutral wires. Operates automatically if the overall load demand grows too high. Has a rated voltage and rated current.

After the main switch, the wires are connected to the RCCB. After RCCB:

- the live wire goes to live bus bar
- the neutral wire goes to neutral bus bar
- the earth bus bar will have a wire earthed separately

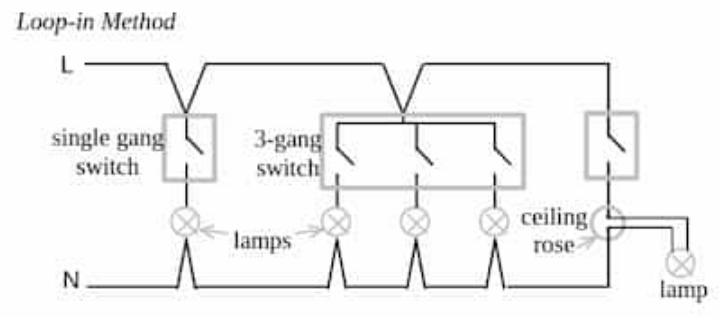
### Bus bar

A conductive metal thing. Used to reduce the number of wires. There are earth, live and neutral bus bars.

After the live bus bar, the live wire is connected to multiple MCBs.

## Wiring a final circuit

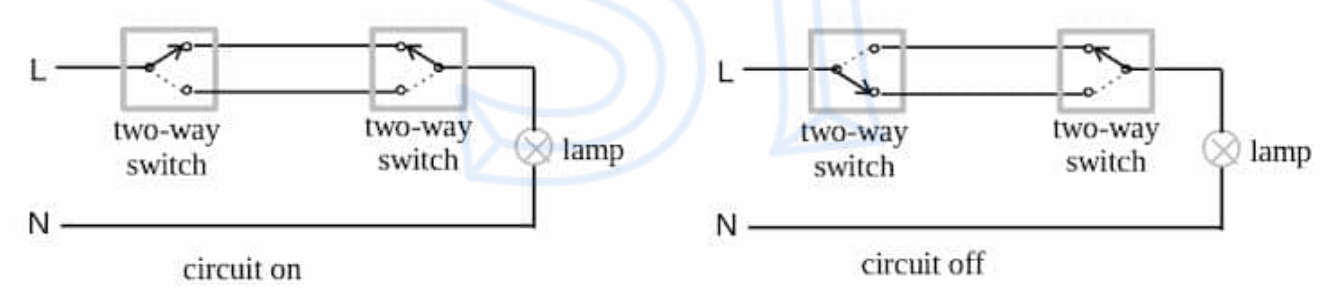
### Loop-in method




Enables all joints and terminations in a single final circuit to be made at ceiling roses, switches or other accessories. This makes all joints accessible for testing and alterations. Each final circuit has both its live and neutral conductors terminating at the consumer unit. Wires are usually laid in PVC conduits.

> **Note**
>
> Lamp circuits do not normally need an earth wire unless there is a metallic fitting which needs to be earthed for safety.

### Two-way switches




Used when it's necessary to operate an equipment from 2 positions.

## Socket outlets

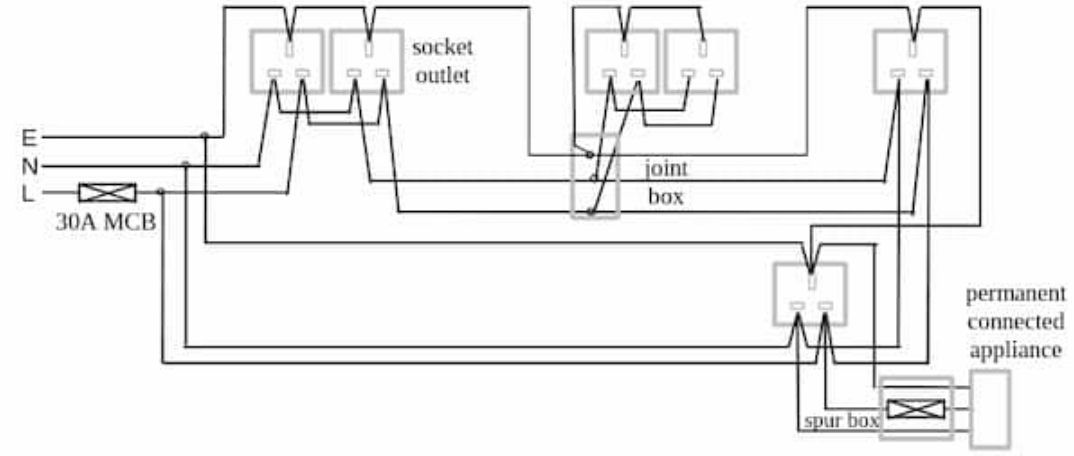
There are 3 types of socket outlets.

- $5\,\mathrm{A}$ - Circular holes
- $13\,\mathrm{A}$ - Rectangular holes. Currently recommended one. Safest one compared to other. Better because of flat-to-flat contact.
- $15\,\mathrm{A}$ - Bigger circular holes

## Final circuits for socket outlets

Electrical equipments can be wired in 2 ways.

### Ring circuit




Each circuit commences from consumer unit through an MCB (or fuse), loops into each socket outlet and returns to the same MCB (or fuse) in the consumer unit.

Looping must be done for the live, neutral and the protective conductors in separate rings. Electricity can flow from either ends. This increases the current carrying capacity without increasing the wiring size.

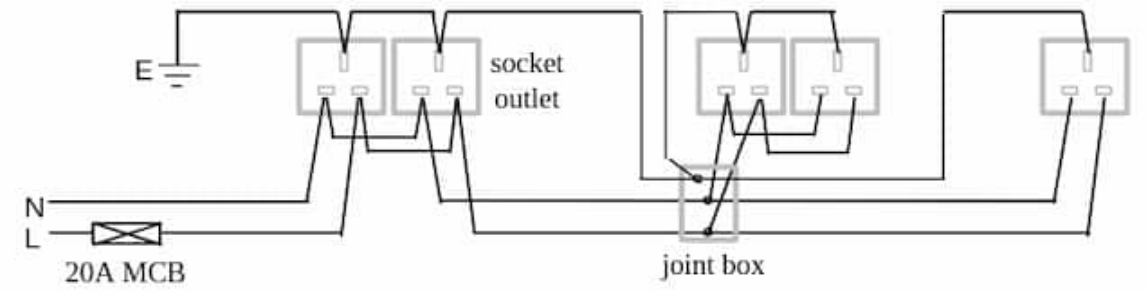
A ring circuit can only be used when:

- The floor area served by the ring does not exceed $100\,\mathrm{m}^2$
- Maximum demand of the circuit doesn't exceed the MCB (or fuse) rating

To connect 2 equipments in ring connection:

- A live wire starts from a MCB, connects to the 2 equipments and come back to the MCB
- Similarily neutral wire is connected in a ring starting from neutral bus bar

### Radial connection



Each circuit commences from consumer unit through an MCB (or fuse), loops into each socket outlet and terminates at the last socket outlet.

To connect 2 equipments in radial connection:

- 2 switches are required. Both switches are connected to a MCB. Each connect to the equipments
- 2 live wire connects 2 switches to of them to a MCB
- Neutral wires of the 2 equipments is connected to the neutral bus bar.

> **Note**
>
> Clip-on meter can be used to measure the current drawn by an electrical equipment.

# Installation Tests

After an electric installation is done, it must be tested for faults, to ensure the safety of users and electrical appliances. Megger or insulation resistance tester can be used for these tests.

## Insulation test

To make sure there are no short circuits and the circuit is properly insulated.

### Procedure

1. Turn off all main circuit breaker, RCCBs
2. Turn on all MCBs and switches
3. Unplug all appliances
4. Set the appropriate scale on the tester
5. Connect one probe to the earth bus bar
6. Connect other probe to the live of the load
7. Use $500\,\mathrm{V}$ in the Megger. A higher voltage is used so that even minor insulation weaknesses can be noticed.
8. Test the circuit

If the reading is higher than $1\,\mathrm{M\Omega}$, test is passed.

## Continuity test

To check if current passes through 2 points of the circuit continuously. Can be checked for all 3 wires (live, neutral and earth).

### Procedure

1. Turn off main switches, MCBs, RCCBs - to disconnect the installation
2. Unplug all appliances
3. Turn on all switches (optional when testing earth wire)
4. Set appropriate scale on the tester
5. Connect one probe to the appropriate bus bar
6. Connect other probe to the appropriate endpoint of the socket
7. Use $0\,\mathrm{V}$ in the Megger
8. Test the circuit

If the reading is less than $10\,\Omega$, test is passed.

# Electric Shock

Occurs when current flows through the human body.

### Ventricular fibrillation

Prevention of the heart to act as an effective pump. Stops blood circulation to all parts of body. Causes death in a very short time.

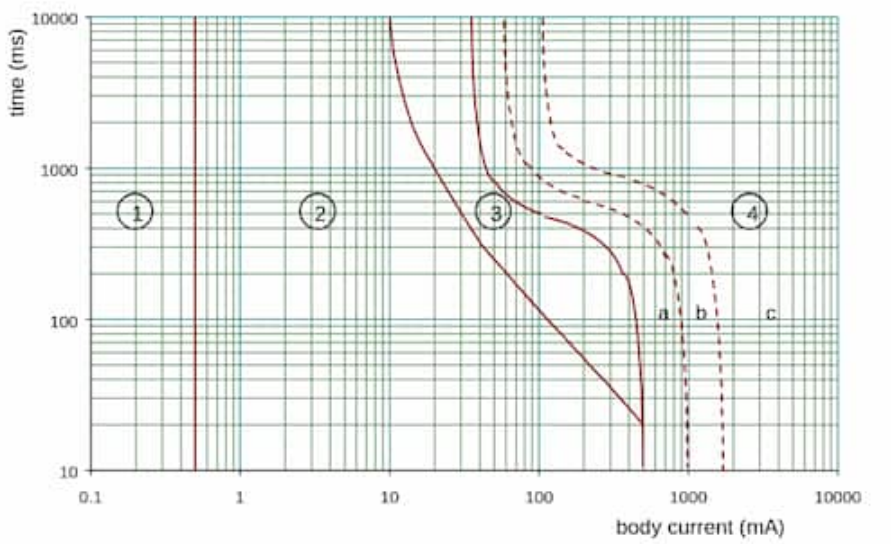
## Degree of danger

Depends on

- Value of the body current
- Time for which the current flows

## Zones

The below chart shows the time/current zones of effects of $50\,\mathrm{Hz}$ current on the human body:




| Zone | Description |
|---|---|
| Zone 1 | No sensation |
| Zone 2 | Perceptable. Not harmful. 10mA is the threshold of let-go |
| Zone 3 | Mascular contractions and difficulty in breathing. Usually no danger of ventricular fibrillation. (0.5% possibility) |
| Zone 4 | Probability of ventricular fibrillation increases. (a - up to 5%, b - up to 50%, c - more than 50%) |

**Note**

From the above chart, 30mA never goes into zone 4. Thus typically used in residual current devices for the safety of people.