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Luceco Brands

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Environmental and energy Saving LED lighting

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A traditional wiring accessory manufacturing brand, serving the professional electrical trade

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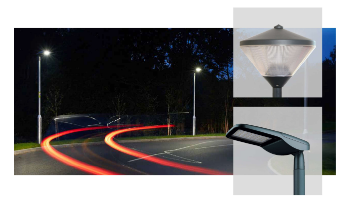
Kingfisher Lighting

High Performance Products Affordable, reliable & practical lighting technology



www.kingfisherlighting.com

My background

- Electrical industry for many years
- Installing within residential, commercial, agricultural and industrial environments
- Marketing & Product management covering Motor Control Gear and Automated Systems
- Marketing & Product management covering Electrical Distribution Systems
- Designing and testing Three-Phase and Single-Phase assemblies

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Principles of RCD Operation
Why we have them.
What they do

- RCD by definition
- Electrocution & Fire Prevention
- RCD Standards
- What is an RCD
- Earth leakage
- Additional Protection
- Automatic Disconnection of Supply

RCDs

RCDs have been around from the 1940s, improving in sensitivity and reliability.

Type G RCD was introduced in the late 1950s with a 10ms delay time to inhibit the affects of lightning strokes to network cables where transients caused RCDs to trip.
And we are still talking about SPDs ☺

The same principle of delay used in G and S type RCDs. S Type more common.

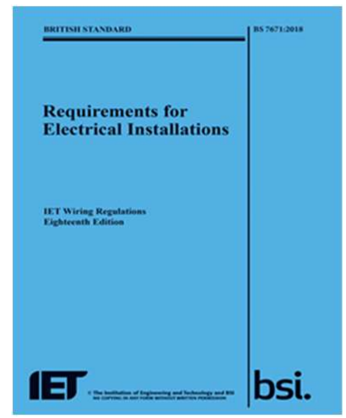
In the 1960s, protection using RCDs started to become widely used. First in Bathrooms, outdoor installations and in Agriculture.

Later to become mandatory for all installations where ordinary persons could come into contact with electrical equipment.

RCD Definition BS 7671 18th Edition

Residual current device (RCD). Mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions.

NOTE 1: A residual current device can be a combination of various separate elements designed to detect and evaluate the residual current and to make and break current.
NOTE 2: RCD includes devices such as RCCB, RCBO, CBR and MRCD.
NOTE 3: MRCD is a modular residual current device.



CBR (Circuit-Breaker incorporating Residual Current Protection) (IEC 60947-2)

RCCB Residual Current Circuit breaker

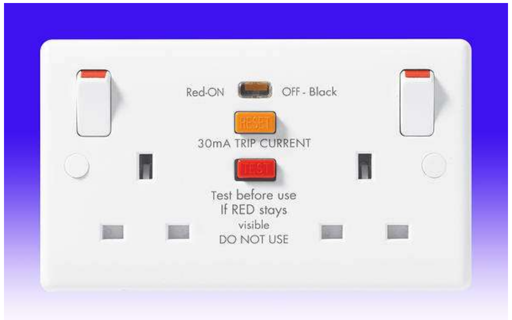
RCBO Residual Current Operated Circuit-Breaker

RCM
Residual current monitors

MRCD (Modular Residual Current Device)

Toroidal Ring CT
(Current Transformer)

SRCD (Socket-Outlet incorporating a Residual Current Device)



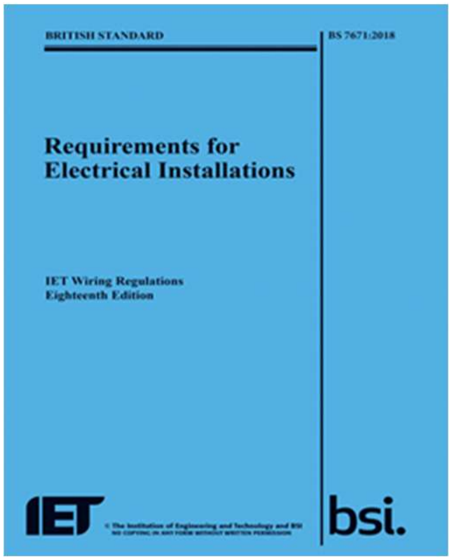
FCURCD (Fused Connection Unit incorporating a Residual Current Device)

PRCD (Portable Residual Current Device)
A device comprising a plug, a residual current device and one or more socket-outlets

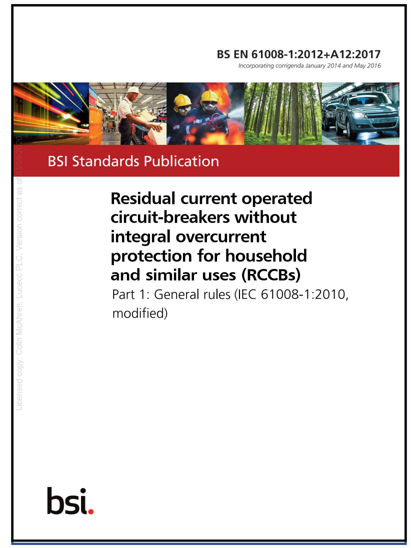
IC-CPD (In Cable Control and Protection Device)
30mA RCD and control unit in Mode 2 Charging Cable

RCDs and British Standards

BS7671 provides the installer with guidance of what where and when to install RCD protection

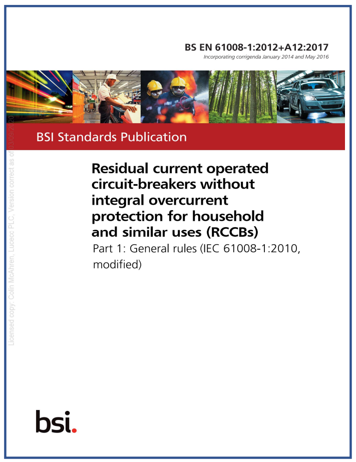


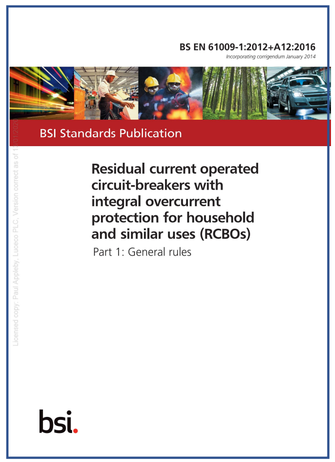
BS EN 61008, 61009 & 62423 & 60947 not for use by ordinary persons Provides the manufacturer with the design and verification guidance to ensure devices enable the installer to meet the wiring regulation

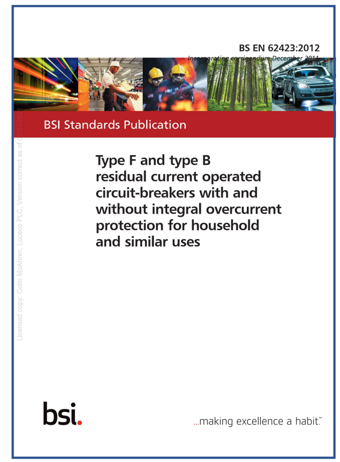


RCDs and BS EN British Design Standards

Topic	PPT/Part/Time	BS
RCCB	Part 1 & 3	BS EN 61008-1
RCBO	Part 1 & 3	BS EN 61009-1
RCCB & RCBO Types e.g. F & B	Part 1 & 3	BS EN 62423







RCD by definition – R.C.D - generic acronym for Residual, Current, Device.

This is the generic term, given to devices that can detect residual currents and disconnect a circuit in the event of an earth fault, or earth leakage current above the set value of the RCD

British standard BS EN 61008-1 define an RCD as:

Residual Current operated Circuit-Breakers without integral overcurrent protection for household or similar uses. - RCCB

RCDs can be found in a range of devices and accessories, briefly covered in later parts

Consumer units typically use RCCBs – **R**esidual **C**urrent **C**ircuit **B**reaker &
RCBOs - **R**esidual current operated **C**ircuit **B**reak with **O**vercurrent Protection

BS EN 61008, 61009, 62423 overview

Type AC , Type A RCCB's and RCBO's must meet BS EN 61008, or 61009

Introduction to B & F Type RCDs BS EN 62423.

The tests shall first be applied according to IEC 61008-1 for Type F or Type B RCCBs and according to IEC 61009-1 for Type F or Type B RCBOs.

Initial tests will be for AC wave forms and then latter tests for AC / DC combined waves forms and frequency ranges specific to the F or B Type.

The standard introduces F for Frequency in frequency converters. Available for single phase and 3 phase applications

This standard also introduces Type B RCD to be used in case of residual pulsating rectified direct current which results from one or more phases, and smooth DC residual current in addition to the cases covered by Type F RCDs.

Electrocution & Fire Prevention

To fully appreciate what an RCD is…. And their function within an electrical circuit.

We must first understand their prime purpose.

To assist in the prevention of injury, death and destruction to:

- Human Life
- Livestock (Pets & Animals)
- Property

By electrocution, or risk of fire

Electrocution

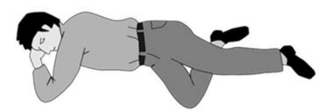
At currents as low as 40 mA a person would experience severe shock

With a high chance of suffering non-reversable disturbances to the normal Cardiac Cycle. Medically referred to as 'Ventricular Fibrillation'.

The effects electrocution can cause to the human body… only get worse, as time and current increase.

Here's a few other effects to be mindful of when considering the risks of electrocution.

- Loss of consciousness.
- Muscle spasms.
- Numbness & Tingling
- Breathing problems.
- Headache.
- Problems with vision and hearing.
- Burns.
- Seizures.



Fire

When considering the risks concerning electrical fault, we often think of electrocution as the leader in the risk to human life.

But in fact, Fires of electric origin are far more common.

Between 2019 & 2020 there were 14977 fire incidents recorded directly relating to Domestic Appliances.

Like electrocution the current levels to start a fire are relatively low and the use of RCDs rated at 300mA or lower provide protection levels for Fire protection.

Given the correct conditions, without the protection of an RCD its very easy for a fire to break out.

Fire A few installation risks where an RCD provides protection.

- Mechanical damage of cables.
- Penetration of cable insulation in floors and walls.
- Damaged, trapped or poorly maintained extension leads.
- Old cable insulation failure
- Rodents chewing through cables
- Lawn mower mistakes.

Regulation 531.3.3 from BS 7671

Regulation 531.3.3 Types of RCD Introduces us to the types of RCDs and their specific characteristics

Type AC: Resistive, Capacitive, Inductive loads generally without any electronic components, typically: (No DC content)

- Immersion heater
- Oven/Hob with resistive heating elements
- Electric shower
- Tungsten & halogen lighting

Type A: As AC +Single phase with electronic components, typically: (accepts up to **6mA DC**)

- USB socket outlets.
- Single phase invertors
- Class 1 IT and Multimedia equipment
- Power supplies for Class 2 equipment
- Appliances such as a washing machine that is not frequency controlled e.g. d.c. or universal motor
- Lighting controls such as a dimmer switch and home and building electronic systems LED drivers
- Induction hobs
- Electric Vehicle charging where any smooth DC fault current is less than 6 mA

Regulation 531.3.3 from BS 7671

Regulation 531.3.3 Types of RCD Introduces us to the types of RCDs and their specific characteristics

Type F:

Frequency controlled equipment / appliances, typically: (accepts up to **10mA DC**)

- Some washing machines, dishwashers and driers e.g. containing synchronous motors
- Some air conditioning controllers using variable frequency speed drive
- Electric Vehicle charging where any smooth DC fault current is greater than 10mA

Type F is also suitable for Type AC and Type A applications.

Type B: Three phase electronic equipment typically: (accepts up to **10mA DC**)

- Inverters for speed control
- UPS
- Photo voltaic

- Electric Vehicle charging where any smooth DC fault current is greater than 10mA

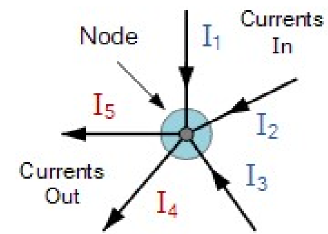
Power Electronic Converter Systems (PECS) typically:

- industrial machines
- cranes

Type B is also suitable for Type AC, Type A and Type F applications

Type B+ As B, with frequency up to 100KHz,

Fundamental Principle of how an RCD works



$I_1 + I_2 + I_3 = I_4 + I_5$

Current Entering the Node = Current Leaving the Node

A little technical stuff about Kirchhoff's law

Kirchhoff's Current Law [KCL]

This is Kirchhoff's first law based on the current source in the electrical circuit. This law is also known as the 'Node Law

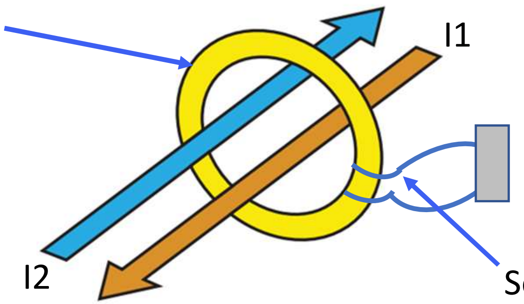
Kirchhoff's current law is stated as, 'The algebraic sum of all currents at a node or meeting at a single point is zero'

In another way, Kirchhoff's current law is stated as :-

"The sum of all leaving current at the node is equal to the sum of all entering current at the node".

Fundamental Principle of how an RCD works

Kirchhoff simplified: “What goes in Must come out”

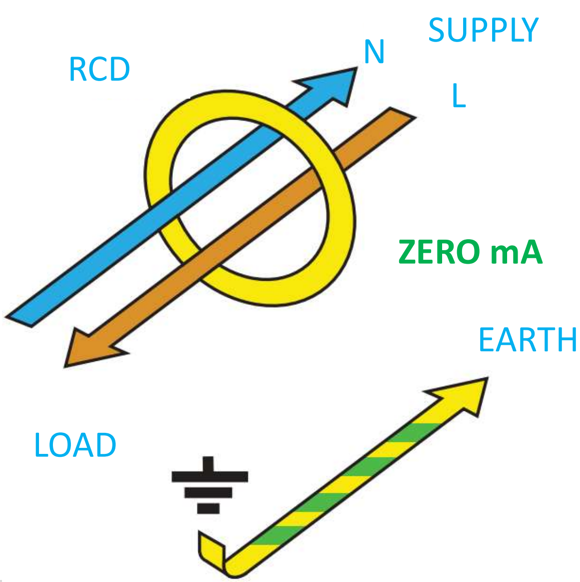


Note: RCD’s do not measure what current is flowing into the circuit protection cables to earth!

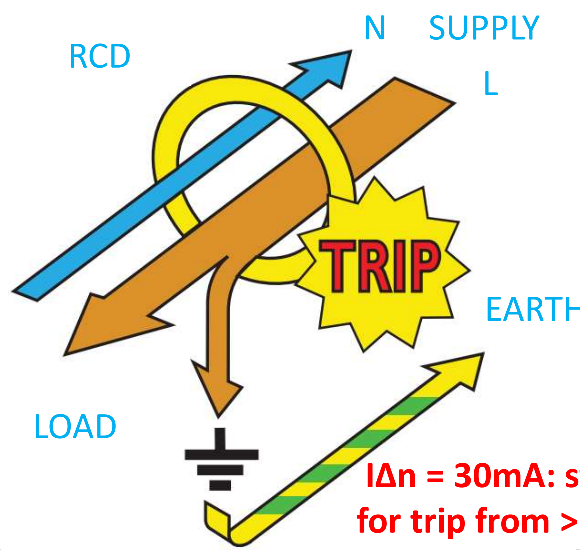
Fundamental Principle of how an RCD works

In an RCD, the line and neutral conductors of a circuit pass through a sensitive current transformer. If the line and neutral currents are equal and opposite, the core remains balanced

= Zero mA loses



If there is an earth fault or leakage, the neutral current will be lower than the line current. This imbalance produces an output from the current transformer which is used to trip the RCD and so break the circuit



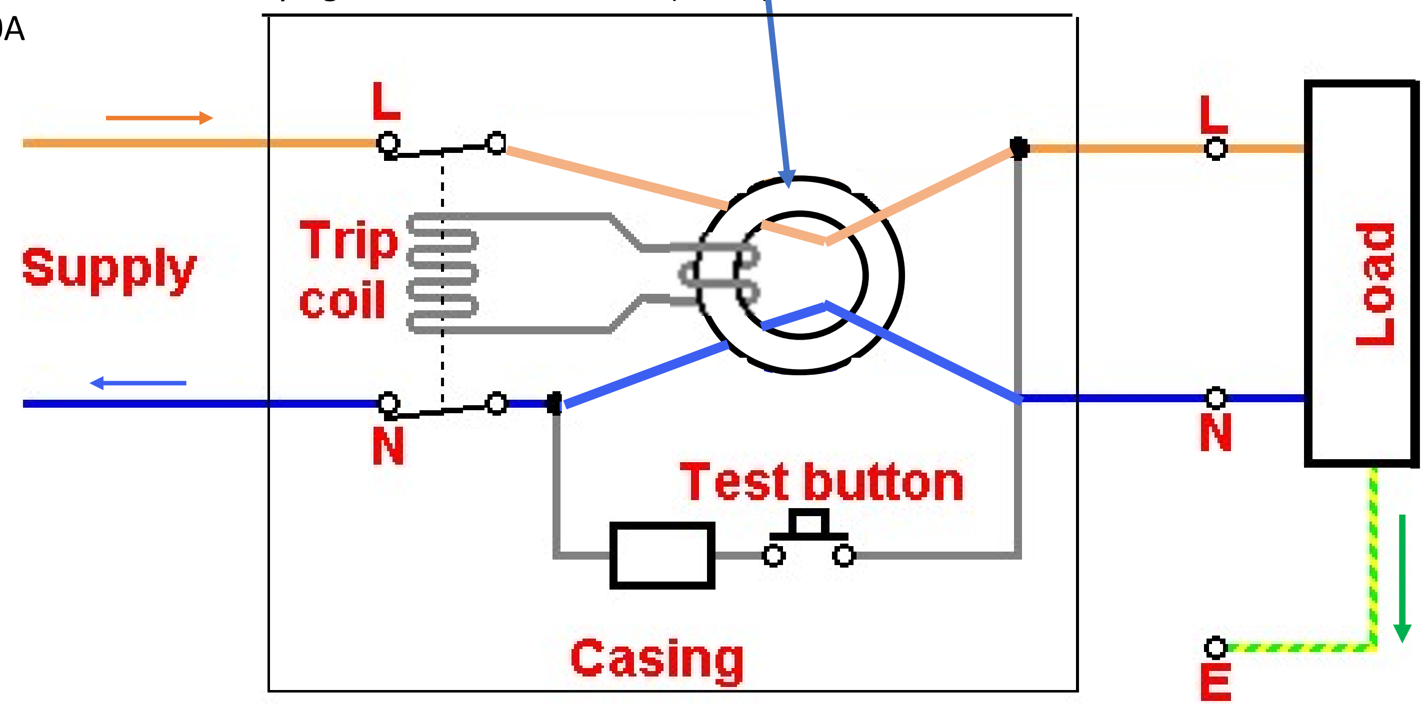
IΔn = 30mA: standard allows for trip from >15mA to 30mA

Type AC Residual current device (RCD) BS EN 61008 / 61009

Demonstrates current carrying conductors will pass through transformer. Consider size of conductor for current carrying capacity of 100A

Summation Transformer (Node)

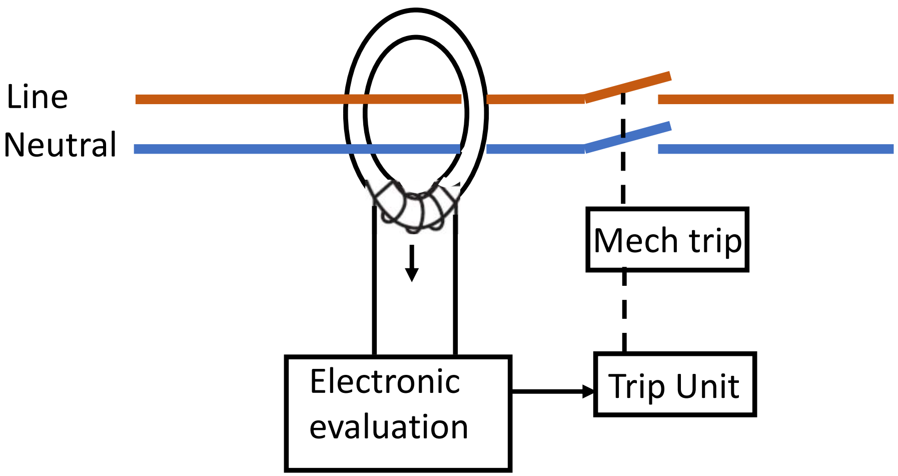
What goes in must come out

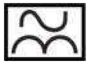
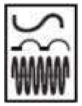


Leakage current mA somewhere in electronic circuits. Insulation failures leading to earth fault.

Basic typical internal design for AC,A,F RCCD

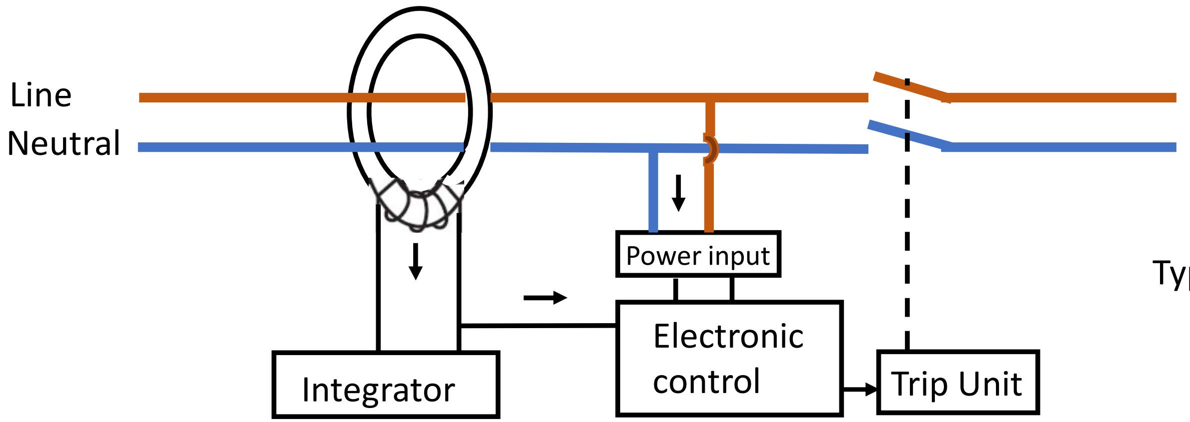
Typical circuit design below is true for AC,A & F types RCD apart from variations in the tripping circuit. Basic components would be Summation transformer Electronics for measuring, evaluating variables, converting into mechanical latch release to trip the RCD



	symbol	
Type AC		AC Sinusoidal Wave form
Type A		AC Sinusoidal Wave form + smooth residual DC current up to 6 mA.
Type F		As type A , and including detection of composite residual currents, frequencies 10Hz to 1000Hz. And smooth DC residual current of up to 10 mA

Basic typical internal design for B RCCB

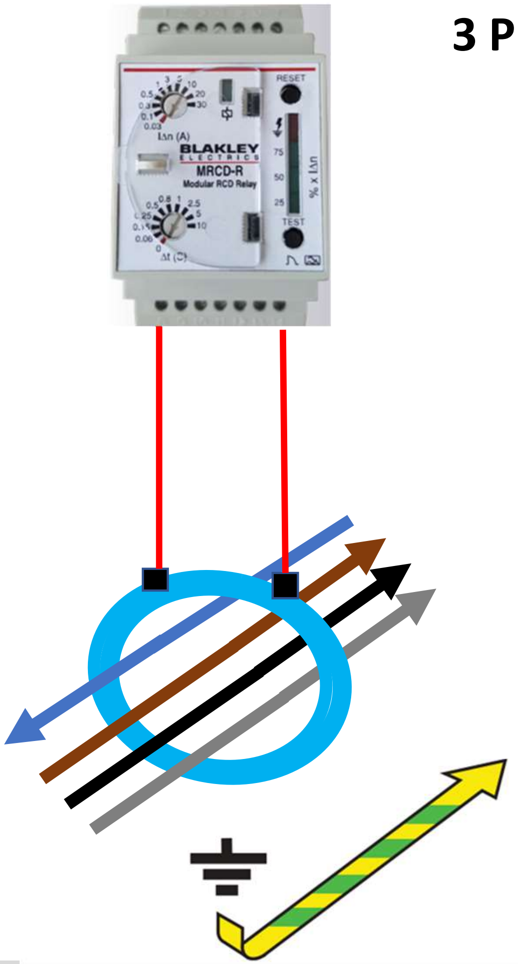
Fluxgate technology can be used to detect DC currents. Using amplifier circuitry and shunt resistors to accurately produce a voltage directly proportional to the current in the conductor being measured, this will accurately provide us with the true current levels of AC and DC within the circuit. Converting the variables into mechanical latch release current to trip the RCD when trip level reached.



symbol

Type B

The standard Type B RCD will detect residual current faults comprising of pure AC up to 1000 hertz, rectified AC, Smooth DC and pulsating DC Up to 10mA



3 Phase principle is the same as single phase

Sum of the 3 phase in a balanced load is 0
No Neutral required for Motor Loads, the 3 line cables pass through the CT

For unbalanced loads. The neutral will be passed through the summation transformer in the same way as single phase. When Neutral return is not the same as the sum of the 3 phases. There will be a current produced in the coil around the CT.

If the RCD is an integral part of the switching device tripping will occur exactly the same as with single phase RCDs

If the summation transformer is remote from the RCD Relay, the connected device will pick this up and trip at the level pre-set on device
Example settings could be anywhere between 0.01 to 30A depending on the application it is being used for.

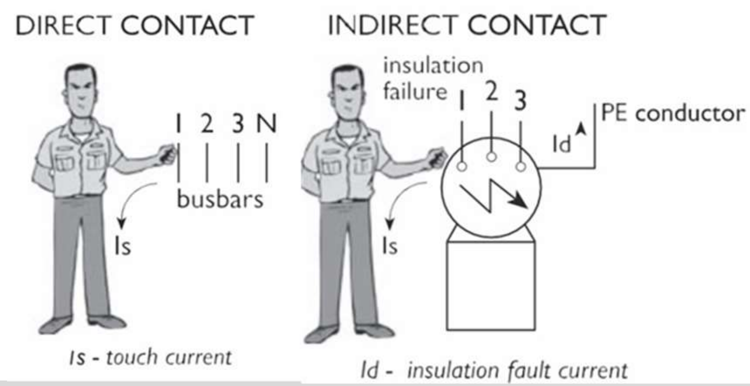
Types of Electrocution Risk.

1. **Direct Contact:** cable leads insulation becomes damaged exposing the conductors. If a person comes into contact with the live and earth conductors there is a more serious risk. The current flowing in the human body.
2. **Indirect Contact** is when the metal enclosure of equipment or any metal fixture such as exposed metalwork of an appliance, sink or plumbing metalwork comes into contact with a live conductor causing the metalwork to become live.

The body is a poor conductor as a result the current flow will be low, approximately **60 mA to 230 mA,**

10 mA – 40mA Severe pain. Breathing difficulties, **continued contact over time**, **may cause cardiac arrest**

Additional protection provided by an RCD IΔn ≤ 30 mA must trip within 300ms at X 1



Effects of Electricity

CPC & Equipotential Bonding

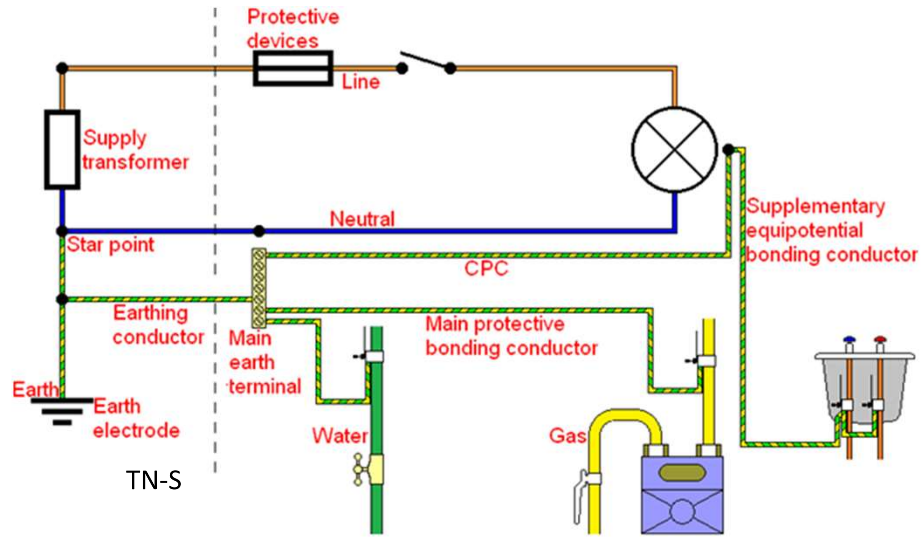
In an installation the earthing system, Circuit Protection Conductors and equipotential bonding form an area containment system to maintain good earth connection to equipment. In a fault, persons could touch an exposed metal part.

Protective Bonding conductors – see 544

TN-C-S system. Table 54.8 minimum of 10mm2

544.1.1 TN-S & TT system. The CSA of bonding conductors shall have a cross sectional area of not less than is half the size of the earthing conductor, 16mm earthing conductor – 8mm not available, so 10mm2… ☺ "subject to a minimum of 6mm and need not exceed 25mm"

Different types of earthing systems must be understood and considered



TN-S

Effects of Electricity - Leakage

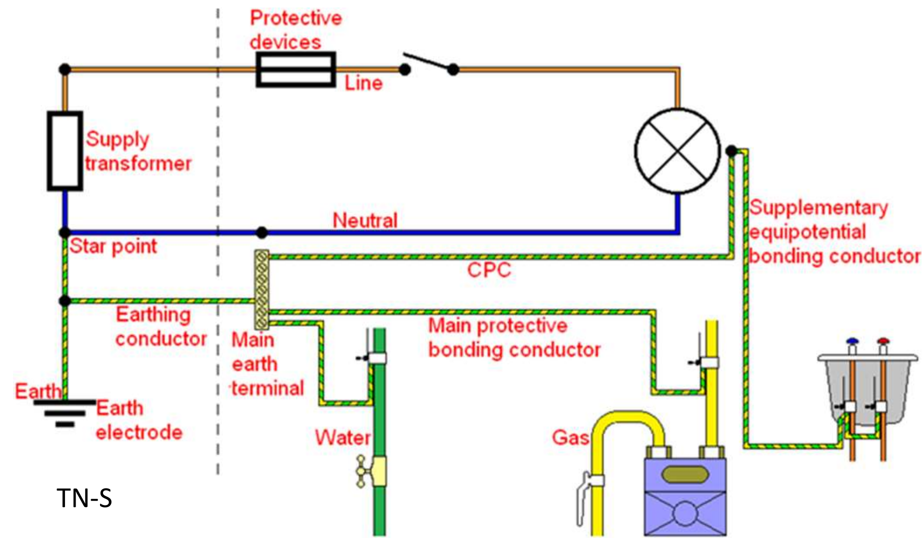
CPC & Equipotential Bonding:

Earth Leakage Current (Protective Conductor Current): Electrical appliances, connections and cables allow some current to leak to earth, due to internal or natural capacitance and inductance associated with the installation.

Different types of earthing systems must be understood and considered

Capacitors connected to earth in switch mode power supplies as an example, will produce leakage. This current should travel to earth via the (PE) protective earth conductor.

If the PE conductor is disconnected or faulty (high resistance), a person touching uninsulated parts of the equipment or pipe work would be subject to the leakage current, that normally flows through the PE conductor.



TN-S

Regulation 531.3.2. Unwanted tripping

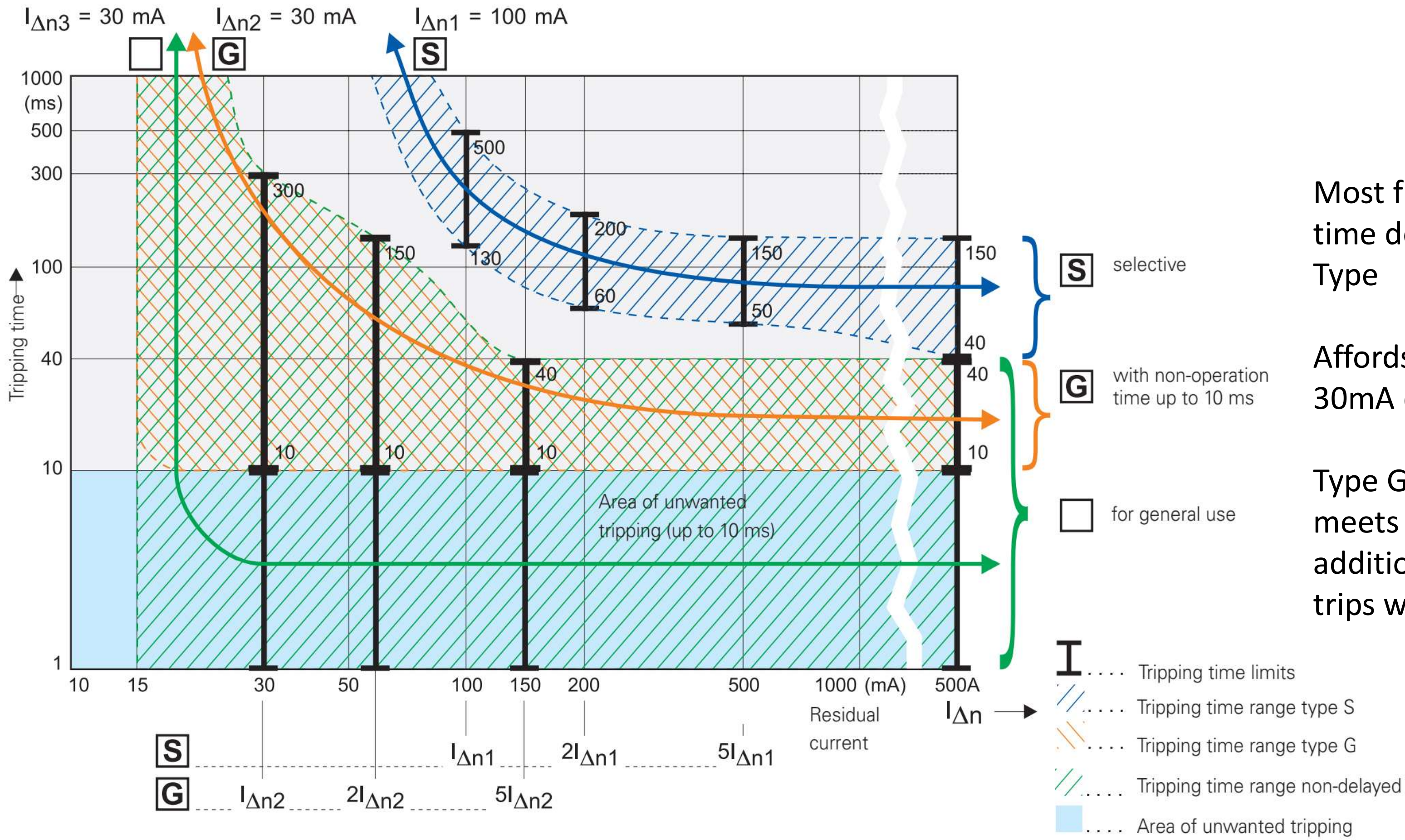
(Consideration: Division of circuits 314.1 & 314.2)

Options to meet this regulation for consumer units are:

1. Calculate each final circuit, add the values of the combined circuits to ensure RCD total leakage does not exceed trip 30% of trip value, (standards allow an RCD to trip between 50% to 100% of $I\Delta n$ Rating) not greater than 9mA, 30% of 30 mA (Ramp test for exact operating value)
2. **Use RCBO's no need to calculate.**

BS7671 recognises that earth leakage exists without any fault on a circuit

Tripping characteristics of non-delayed & Delayed RCD



Most frequently used time delay RCD is the S Type

Affords selectivity to 30mA down stream RCD's

Type G offers 10ms delay, meets requirement of additional protection, trips within 40ms.

Electric Shock Protective measures

Automatic Disconnection of supply

411.3: Requirements for fault protection. Provides regulations to guide the installer as to the requirements for protective earthing and protective equipotential bonding: 411.3.1.1 and 411.3.1.2

Where specified, additional protection is provided by and RCD with a rated operating current not exceeding 30mA, in accordance with:- see 415.1

415.1: The use of RCDs with a rated residual operating current not exceeding ≤ 30mA is recognized in AC systems as additional protection in the event of failure of the provision for basic protection and/or the provision for fault protection or carelessness by users.

From the above we see that an RCD can be used for additional protection against electric shock and for the provision for fault protection. *Note: must be used with overcurrent protective device*.

Types of Electrocution Risk. <u>Fault current</u>

Regulation 411.5.3 Where an RCD is used for fault protection the following conditions shall be fulfilled
(i) The disconnection time shall be that required by regulation 411.3.2.2 or 411.3.2.4 and
(ii) RA x IΔn ≤ 50 V (where RA is not known, it may be replaced by Zs)

See table 41.5 BS 7671

	Non-delayed RCD Rated		Max Value Earth fault	
	RCD Operaing current	Safe	Loop impedance, Zs	Division of
IAn (mA)	IAn (mA)	Voltage	Ohms	V / IAn (mA)
0.03	30	50	1677	1666.67
0.1	100	50	500	500.00
0.3	300	50	167	166.67
0.5	500	50	100	100.00

1 x IΔn rating to meet automatic disconnection times an RCD must demonstrate the following

≤ 300ms TN installations
≤ 200ms for TT installations

Electric Shock Protective measures

When do we need to consider RCD for fault protection

Zs Values relating to rating of MCB Table 41.3 BS7671 (0.95 applied)

(a) Type B circuit-breakers to BS EN 60898 and the overcurrent characteristics of RCBOs to BS EN 61009-1														
Rating (amperes)	3	6	10	16	20	25	32	40	50	63	80	100	125	I_n
Z_s (ohms)	14.57	7.28	4.37	2.73	2.19	1.75	1.37	1.09	0.87	0.69	0.55	0.44	0.35	230 x 0.95/(5I_n)
(b) Type C circuit-breakers to BS EN 60898 and the overcurrent characteristics of RCBOs to BS EN 61009-1														
Rating (amperes)		6	10	16	20	25	32	40	50	63	80	100	125	I_n
Z_s (ohms)		3.64	2.19	1.37	1.09	0.87	0.68	0.55	0.44	0.35	0.27	0.22	0.17	230 x 0.95/(10I_n)
(c) Type D circuit-breakers to BS EN 60898 and the overcurrent characteristics of RCBOs to BS EN 61009-1														
Rating (amperes)		6	10	16	20	25	32	40	50	63	80	100	125	I_n
Z_s (ohms) 0.4 sec		1.82	1.09	0.68	0.55	0.44	0.34	0.27	0.22	0.17	0.14	0.11	0.09	230 x 0.95/(20I_n)
Z_s (ohms) 5 secs		3.64	2.19	1.37	1.09	0.87	0.68	0.55	0.44	0.35	0.27	0.22	0.17	230 x 0.95/(10I_n)

Regulation 411.5.4
Derived from using the formula
Zs x Ia ≤ Uo x (Cmin)   (+20% temp)

32 B Type 5 times In Automatic disconnection
32 x 5 = 160 = Ia

<u>230/160</u> = 1.4375 x 0.95 = 1.365625 or 1.37
<u>Uo/Ia = Zs x CMIN</u>

<u>1.37 X 0.8 (temp factor) =1.096 0r 1.1 ohms</u>

Table 41.1 applied to final circuits maximum disconnection times

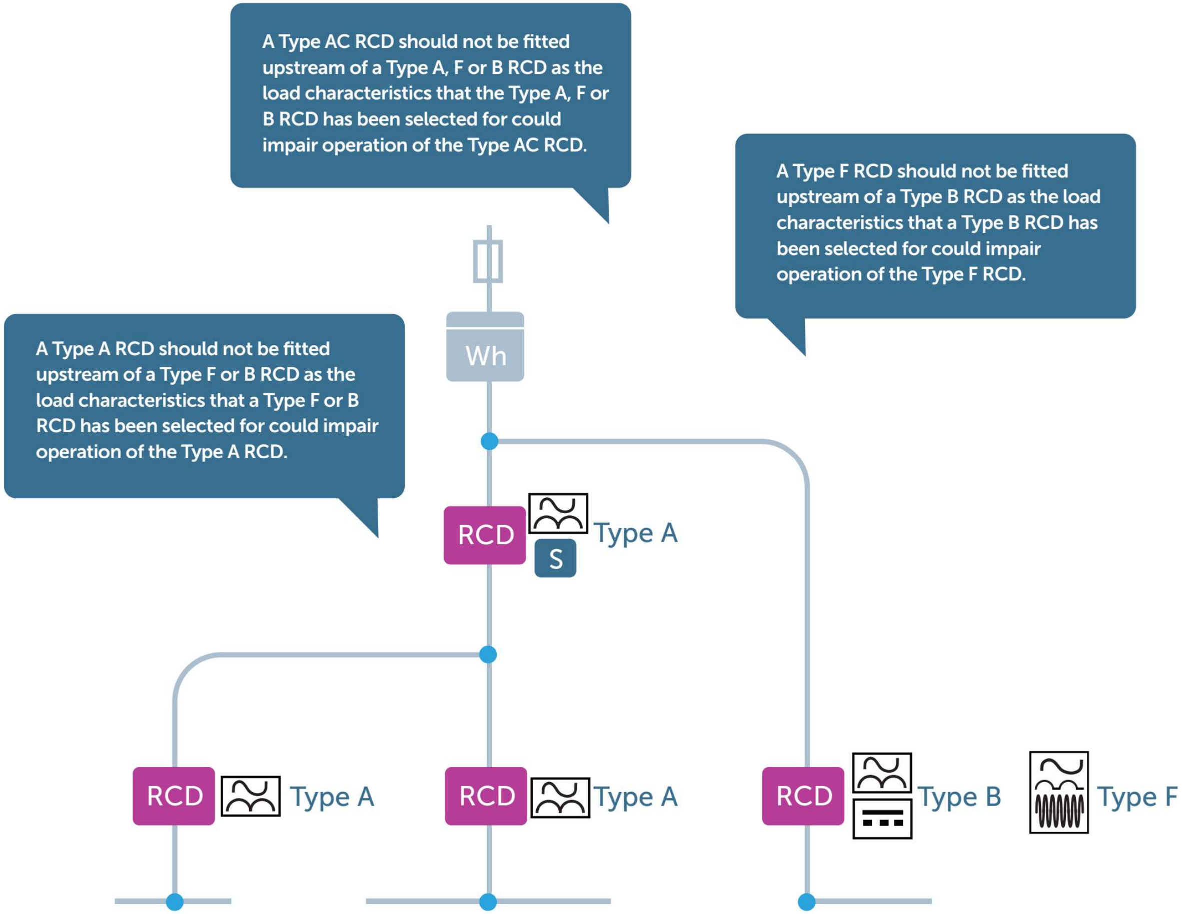
411.3.2.2 applicable to a final circuit with rated current not exceeding
(i) 63A with one or more socket outlets
(ii) 32A supplying only fixed connected current- using equipment

411.3.2.3 TN disconnect not exceeding 5s for distribution circuit see
411.3.2.4 In a TT system a disconnection not exceeding 1s time

TABLE 41.1
Maximum disconnection times

System	$50\ V < U_0 \leq 120\ V$ seconds		$120\ V < U_0 \leq 230\ V$ seconds		$230\ V < U_0 \leq 400\ V$ seconds		$U_0 > 400\ V$ seconds	
	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.
TN	0.8	NOTE 1	0.4	5	0.2	0.4	0.1	0.1
TT	0.3	NOTE 1	0.2	0.4	0.07	0.2	0.04	0.1

Installation Topology



When considering selectivity we must also consider the Type of RCD to be installed in terms of their protection characteristics Types AC, A, B, F types

We could for example add a Type AC to a branch circuit where the load was only resistive.

BS7671 18th edition 2018 Regulations relating to RCDs *(The following should be considered as a non exhaustive list)*

Division of Installation

•314.1: Division of installation, reduce possibility of unwanted tripping of RCDs

Protection against Electric Shock

•411: Protective measure: Automatic disconnection of supply: 411.1: General, additional protection is provided by an RCD with rated operational current nit exceeding 30mA, see regulation 415.1

•411.3.3: Additional requirements for socket-outlets & supply of mobile equipment.

•411.3.4: In domestic (household) premises additional protection by RCD =< 30mA shall be used for luminaires

•411.4: TN Systems

•411.4.4: RCD installed for automatic disconnection. See regulations: 411.3.2 (.2, .3, .4) TN & TT systems

•411.4.5: (ii) An RCD may be used for fault protection where the circuit also incorporates an overcurrent device. RCD shall not be used in a TN-C system

•411.5 TT Systems

•411.5.3: earth fault loop impedance: Table 41.5

•411.6: IT Systems, see regulations required for IT systems.

•414.4.204: where RCD used to satisfy disconnection times for requirements of: 411.3.2 (.2, .3, .4) TN & TT systems

•415; Additional Protection: 415.1.1 The use of RCDs with rated residual operating current not exceeding 30 mA

BS7671 18th edition 2018 Regulations relating to RCDs *(The following should be considered as a non exhaustive list)*

Selection and Erection of Wiring Systems

- •522.6.202: cable installed in a wall at a depth less than 50mm. Or comply with 522.6.204
- •522.6.203: cable buried in wall containing metal parts shall be protected by RCD see 425.1.1
- •522.6.204: SWA cable, metal conduit, metal ducting or trunking, mechanically protected against damage or form part of SELV, PELV circuit meeting regulation 414.522.6.204:

Protection, Isolation, Switching, Control and Monitoring

- •531.1.1 Automatic disconnection of supply, Automatic reclosing of devices (RCBOs, RCCBs)
- •531.3 Residual current devices (RCDs); 51.3.1 General, 531.3.1.201, 531.3.1.202.
- •531.3.2 Unwanted tripping: RCDs shall be selected and erected such as to limit the risk of unwanted tripping.
- •531.3.3 Types of RCD
- •531.3.4: RCDs, Selection according to the accessibility to the installation.
- •531.3.5: RCDs for fault protection:
- •531.3.6: RCDs for additional protection
- •532.2: Devices for the protection against the Risk of Fire.
- •536.4.1.4: Selectivity between RCDs
  (ii) selectivity in case of residual currents : RCD type S (time delayed) with ratio of at least 3:1

BS7671 18th edition 2018 Regulations relating to RCDs *(The following should be considered as a non exhaustive list)*

Inspection and Testing

- 643.7: Protection by automatic disconnection of the supply
- 643.7.1: see TN, TT & IT systems regarding RCDs
- 643.8: Additional Protection: Note, deemed verified when RCD to 415.1.1 disconnects within 40 ms @ 5X or higher than $I\Delta n$
- 643.10: Functional testing: Where fault and/or additional protection provided by RCD effectiveness of any incorporated facility shall be verified

BS7671 18th edition 2018 Regulations relating to RCDs *(The following should be considered as a non exhaustive list)*

Special Installations or Locations:

Locations containing a Bath or Shower
•701.411.3.3: Additional protection by RCDs
•701.415: Additional protection

Rooms and cabins containing sauna heaters
•703.411.3.3 Additional Protection by RCDs

Solar Photovoltaic (PV) Power supply systems
•712.411.3.2.1.2: automatic disconnection of supply

Outdoor Lighting Installations
•714.411.3.3: Additional protection

Electric Vehicle Charging Installations
•722.531.2 RCDs
•722.531.2.1.1: RCDs shall disconnect all live conductors

Heating Cables and Embedded Heating Systems
753.411.3.2: RCDs used as disconnecting device
753.415.1: RCDs Additional Protection.
753.514.1: Identification, General: (xiii) Rating of residual operating current of RCD.

BS7671 18th edition 2018 Regulations relating to RCDs *(The following should be considered as a non exhaustive list)*

Special Installations or Locations: *Generally commercial applications, but not limited to*

Swimming pools

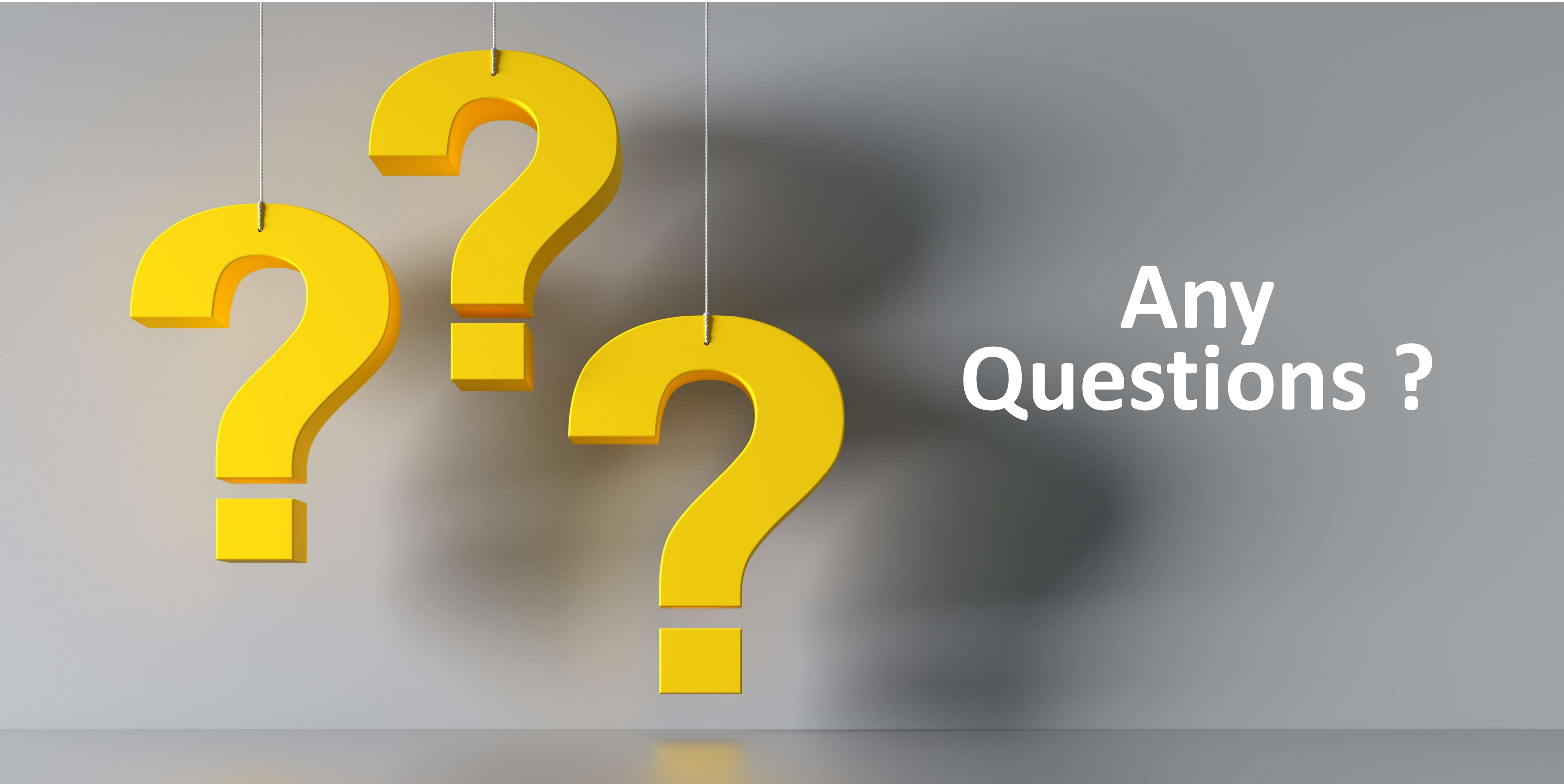
- 702.410.3.4.2701.415:
- 702.419.3.4.3
- 702.53
- 702.55.1

Construction sites

- 704.410.3.10

Agricultural and Horticultural Premises

- 705.411.1


Any
Questions ?