The 50plus Essential Home Electrical Guide

For Repair and DIY Personnel

2nd edition – with new sections

Includes:

- **Safety**
- **Overview of household electrics**
- **Test equipment and how to use**
- **Fault finding:**
    - **Electric water heaters & showers**
    - **Rings mains, RCDs and MCBs**
    - **Lighting circuits**
    - **Central heating electrics**
- **Handy summaries**

Roger Runswick

The 50plus Essential Home Electrical Guide for Repair and DIY Personnel

Other books in this series:

The 50plus Essential Home Plumbing Guide for Repair and DIY Personnel

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The essential electrical guide for repair personnel

Welcome. This book provides a guide to the electrical systems found in UK households and how they operate. It is designed to be an aid to faultfinding, which is about breaking down problems into logical parts such that each step can be tested and the results verified.

Do use the book as point of reference. There is comprehensive index to help with finding information. There is also a set of summaries at the end to provide a useful reminder.

I hope it goes without saying that electricity can be dangerous. Respect it and it will respect you. Don't skip the safety chapter. Being safe is just plain sensible. If you are not confident in what you are doing, stop and get help.

The IEE (formally now the IET) publishes the IET Wiring Regulations (BS 7671). If you don't wish to purchase the regulations themselves it is worth having the 'On-site Guide'.

Additionally Unite (Amicus) publish a very useful 'Electricians Guide to Good Electrical Practice', which is in effect a condensed set of the regulations. Always ensure the edition of any document purchased incorporates the latest Amendments.

If you wish to comment on any aspects of this book please let me know by email at roger.runswick@the50plus.co.uk.

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Safety first!

Most electrical installations in houses are quite simple and by following basic safety rules you can prevent accidents.

1. Don’t work on live equipment or circuits unless it is absolutely necessary.

2. Check to see if a cable is live before working on it by using a voltage detector. If in any doubt turn off the circuit or all power and if you turn off only the circuit check again.

3. Take precautions to ensure that other people in the household cannot access any live parts when you are working. Don’t leave live parts accessible when working elsewhere in the property. Ensure no one else can turn on a circuit that you are working on.

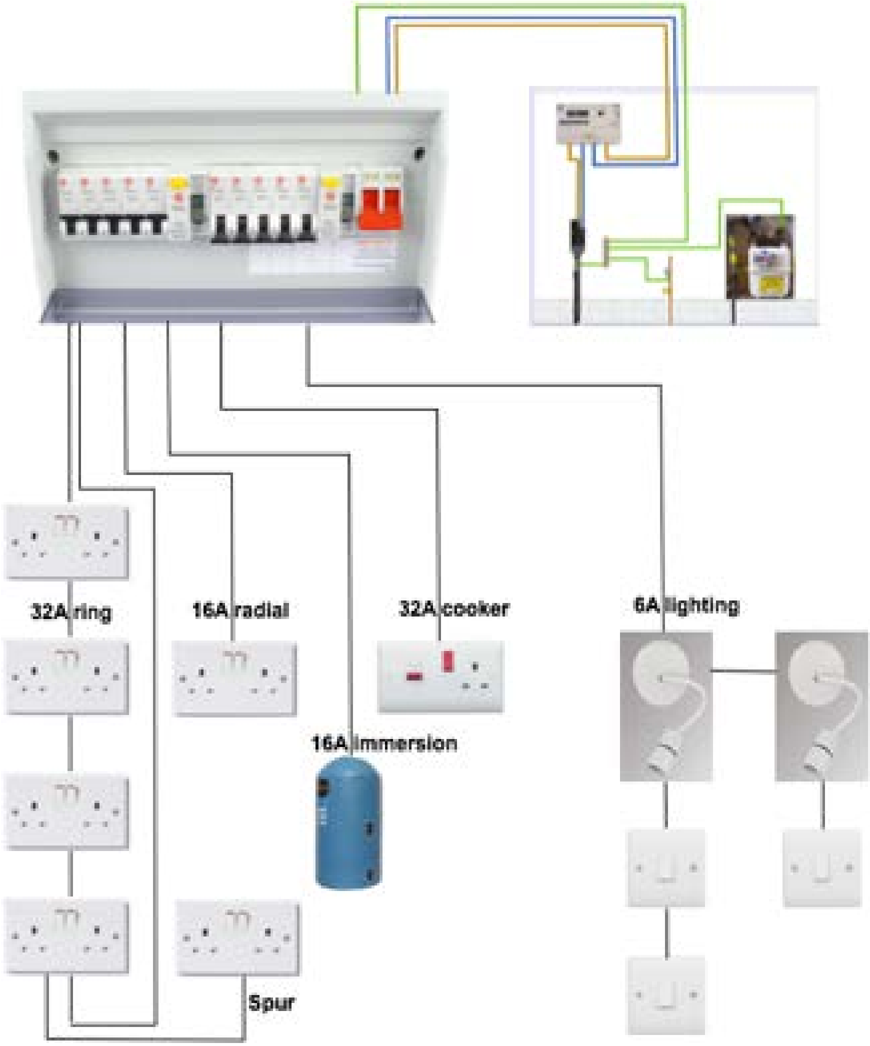
4. Do not use defective equipment.

5. Work within the guidelines set out in BS7671 'Requirements for electrical installations, also known as the IET Wiring Regulations (formally the IEE Wiring Regulations).

6. Work within the requirements of Part P of the Building Regulations, which stipulates which electrical work needs registering with Building Control.

The key household electrical components

Figure 1 - Overview of a household installation



The key components of a UK household electrical installation are shown in Figure 1. Typical circuits are:

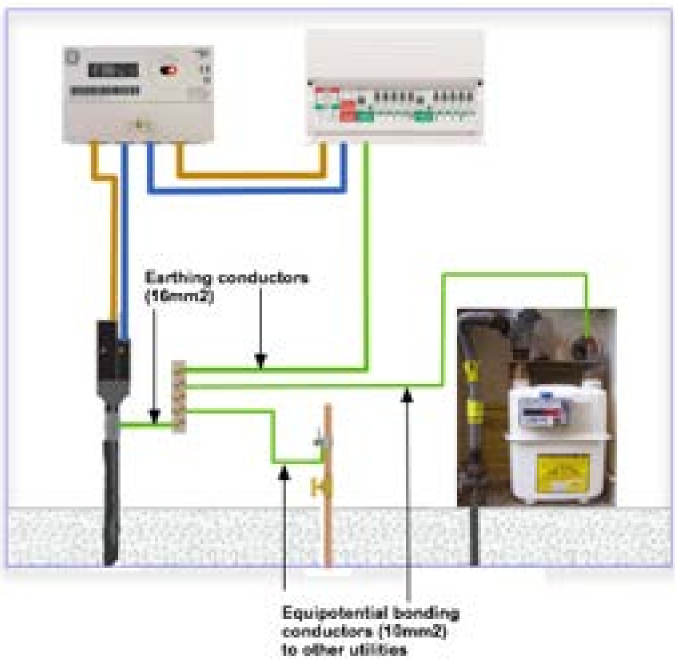
32 Amp MCB - ring main	Three in the average house (up, down and kitchen). 2.5mm^2 cable.
Spur	One per ring main socket. 2.5mm^2 cable.
16 or 20 Amp MCB – radial	On its own MCB. Typically 2.5mm^2 cable.
16 Amp - immersion	On its own MCB. 2.5mm^2 cable.
32 Amp MCB - cooker	On its own MCB. 6mm^2 cable. Electric hobs are almost always on their own MCB. Single ovens can be plugged into a ring main. Doubles ovens and freestanding cookers cannot and must be on a dedicated oven circuit.
6 Amp MCB – lighting	Two in the average house (up and down). 1.5mm^2 cable. Often additional circuits for e.g. outside lights

Other circuits may also be found. These often include:

- 40 or 50 Amp MCB - shower (if electrically heated)
- 6 Amp MCB - security alarm
- 6 Amp MCB - smoke alarms
- Various - radial to e.g. a shed – typically 16 or 20 Amp

If you have fuses the colour codes are: 5A white, 15A blue, 20A yellow, 32A red and 45A green.

The main earth and consumer unit earth cables should be sized at $16mm^2$. The equipotential bonding (earth cables) to gas and/or oil and water should be sized at $10mm^2$. A diagram of an ideal installation is shown below.



The one formula you need to know

The one formula you really need to know is Ohms law. This is written as:

V = I x R

Which stands for voltage = current x resistance. We'll be using this again when fault finding.[1]

<table>
<tr>
<td>
</td>
<td>We measure voltage between the live and neutral connections.

We measure resistance e.g. of an immersion heater by passing a small current, generated by the meter through the load, so we ALWAYS do this with the load disconnected and the supply turned off.</td>
</tr>
</table>

Another helpful formula is W = V x I or Watts = Volts x Amps. This is useful to determine current flow for items of equipment. For example using a 3000 Watt heater will cause approximately 12.5 Amps of current to flow.

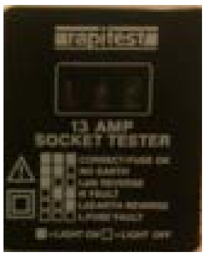
Note 1: Strictly speaking Ohms law in the terms described here applies to DC circuits. The AC analog is V = I x Z where Z is impedance and V and I are the RMS or effective values of voltage and current. However in most households we can equate resistance and impendence for the purpose of approximate calculations.

Test equipment

Essential test equipment

To undertake testing and repair work safely three items of test equipment are needed. These are shown in Figure 2.

Figure 2 - Required test equipment

A multimeter. We use this to measure volts, ohms and simple continuity. The 'must have' ranges are AC Volts and a low Ohms range (e.g. 200).	
A voltage detector pen or voltage tester. We use these to help us be safe and to conduct very simple tests.	
A socket tester. We use this to conduct basic tests on ring mains and radial circuits.	

How to use a multimeter

Multimeters typically measure:

- AC Volts: identified by the symbol V~
- DC Amps: identified by the symbol A ⎓
- Resistance: identified by the symbol Ω for Ohms
- DC Volts: identified by the symbol V ⎓

They also measure continuity •))) and sometimes transistors (hFE).

Will be using AC Volts, resistance and continuity only.

Do not try and measure DC voltages or any current when working on 240 Volt AC circuits.

Where to plug in the multimeter test leads

<table>
<tr>
<td></td>
<td>The test leads should be plugged in as shown in the figure to the left. The black lead goes to COM and the red to VΩmA.

DO NOT plug leads into 10ADC. This is for measuring current.

NB – typical multimeters have rather a lot of exposed metal on the end of the test probes. Be careful not to touch these when measuring AC voltage. It is preferable to have leads meeting Guidance Note GS38 meaning they will have a minimum of exposed metal.</td>
</tr>
</table>

Measuring AC voltage

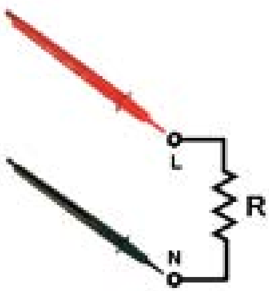
Look at your multimeter. Next to the 600 V~ range you will see a 'lightning' symbol. It's there for a reason; to remind you that the voltage you are about to measure is dangerous and will result in an electric shock if you touch something live. Don't - be safe!

To measure AC voltage set the meter to the 600 Volt AC range.

Check the 'hold' button is not depressed.

Take the red and black leads, put the red on a live terminal and the black on a neutral terminal.

You will get a reading of circa 240 Volts.



Measuring AC voltage.

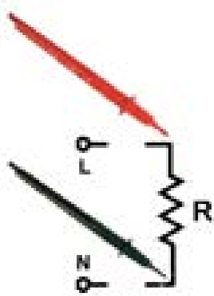
Test leads are still coloured red & black in most cases as were the old live and neutral wires in cable. The colour scheme in the UK has changed to brown for live and blue for neutral with green/yellow earth.

Measuring resistance and continuity

Before measuring resistance in an operational circuit ensure that the supply is off; refer to the section titled 'Using a voltage detector pen '. If you don't ensure the supply is off you will need a new test meter and may suffer an electric shock.

As an example we'll measure the resistance of a 100 Watt incandescent light bulb.

	Set your test meter to 200Ω. Check the 'hold' button is not depressed. Take the red and black leads, put the red on one terminal and the black on the other terminal. It doesn't matter which way round the leads go. You will get a reading of circa 40Ω. NB – don't bother with using the result to calculate the current. The resistance of the bulb will increase significantly as it heats up. If we use W = V x I then a 100W bulb will use 100/240 = around 0.42 amps. Substitute this into R = V/I then we can see the operational resistance is around 576Ω.

	Measuring resistance (Ohms). Note the load is disconnected. We are normally checking circuit continuity, immersion heaters, thermostats or switches with resistance measurements.

Measuring continuity is much the same process. Again ensure the supply is off if working on an operational circuit.

Set your test meter to •))). Check the 'hold' button is not depressed; take the red and black leads and hold them together so the tips are touching. It doesn't matter which way round the leads go when checking continuity.

You will get two results:

(i) A reading of 0Ω indicating a 'short circuit' and

(ii) The buzzer will sound.

You can try this same test on a fuse; the result will be the same as long as the fuse is good.

If you wish to measure something that is likely to have a resistance of over 200Ω then you can change the resistance range on the meter to e.g. 2KΩ (2000Ω).

Crocodile test leads

Keep a pair of crocodile test leads with your test meter. These are particularly useful for 'looping' circuits to enable continuity to be checked when tracing out wiring. Always use with the power off.

Using a voltage detector pen or voltage tester

The great benefit of voltage detector pens is that they are contact free. They are very useful to check that the power you think you have turned off is actually off. But do remember they are battery powered and if the batteries are flat then they won't light up, so test them regularly.

It is also essential to understand that whilst these pens are very useful for detecting the presence of voltage they don't just tell you mains voltage is present. Many will light up when just about any voltage is detected (try an Ethernet computer cable for instance) so they should be used only as a rough guide and cannot be a substitute for a test meter.

A voltage tester provides a better indication of actual voltage but requires physical contact. Testers also rely on batteries.

Notes about neon screwdrivers

Neon screwdrivers are often used to conduct some simple testing, such as the presence of voltage.	

They are now rather frowned upon, as they are a crude measure, which relies on using you as part of the circuit. This can have its downsides; one being that if you touch the wrong part a dangerous electric shock is a distinct possibility.

Similarly to the voltage detector pen using a neon screwdriver is about understanding what it won't tell you as well as what it will. Key points to consider are:

- A neon screwdriver will illuminate across a broad range of voltages.
- It can be difficult to see an illuminated neon in bright light conditions, leading to a user thinking there is no voltage present when there is.
- Neon screwdrivers can and do fail and when failed will not illuminate when voltage is present.

So if you do use a neon screwdriver do so with caution.

They do have their uses however, particularly where there are a number of live terminals in close proximity such as on a wall thermostat. And as they illuminate on the live but not on the neutral they are particularly useful in tracing failed neutrals in lighting circuits, as with an incandescent bulb in place and the neutral disconnected the 'faulty' neutral will illuminate the neon.

Using a socket tester


Socket testers come in a variety of forms. Most have three indicator lights to show 'good' or 'fault' conditions and some also have an audible signal. More expensive versions provide an indication of loop impedance but not an actual reading.

They are simple and fast to use and show up basic faults but only under 'live' conditions.

All socket testers have a description of what the display is telling you on the front but beware if you use more than one model as not all use the 'three lights is good' indication.

Test equipment for certification

Electricians who regularly undertake installation work and complete test certificates and need more complex test equipment that can accurately measure:

- Continuity with low Ohms values
- Insulation at 500V
- Loop impedance
- RCD trip times
- And check polarity and sometimes, maximum fault current, although this can be calculated.

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An example of a multi-function installation tester, which performs the range of tests required to certify an installation.

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Electric water heaters and showers

Types of water heaters and showers

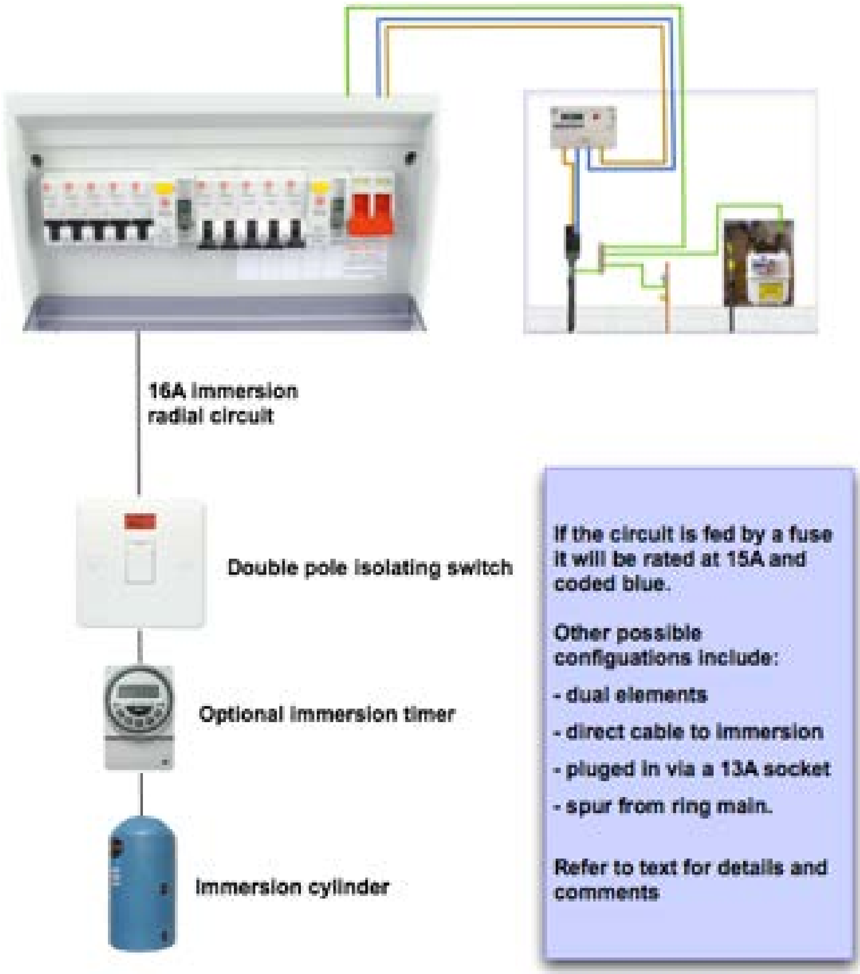
There are two types of electrical water heaters found in households:

Immersion type heaters, which heat up water on a timed or continuous basis. Examples of these include the common immersion, as found in cylinders in airing cupboards. Similar examples can also be found over and under sinks. They all have an element, which is immersed in the water to be heated, a thermostat and in all modern units a means of preventing overheating should the thermostat fail. This is frequently in the form of a cutout. All water heaters of this type store the hot water within the heater cylinder. Electrically they are characterized by being rated at up to 3KW (3000 Watts) and as such can be fed from a 2.5mm cable.

Instantaneous water heaters, which provide instant hot water without the need for storage. These come is a considerable number of differing types and include the common electric shower and simple over sink hand wash unit. Instantaneous water heaters do not store heated water but heat the water as it flows through the device. This requires more power, albeit for a shorter period. The larger devises such as electric showers are rated at up to 11KW (11,000 Watts). This type of power demands a 10mm cable and an MCB rated at 50 Amps.

Immersion heaters

Figure 3 - A typical immersion circuit



Typical immersion configurations

An immersion circuit is a radial circuit using 2.5mm cable from the consumer unit and protected by a 16 Amp MCB or 15 Amp fuse and should be dedicated to supplying power to the immersion heater. The immersion is usually switched via an isolating switch situated locally to the immersion tank. Figure 3 provides an overview.

Because of the lack of power sockets in airing cupboards, where immersion cylinders are usually situated and the convenience of installing central heating controls for example in the same location, it is not unusual to find the immersion circuit has been high-jacked to power other items of equipment.

It is also not unusual to find that an immersion heater is plugged in via a 13 Amp plug.

Occasionally immersions can be found connected to ring mains.

Sharing an immersion circuit, plugging in an immersion or running it from a ring main is poor practice. Using the formula $W = V \times I$ and noting that most immersion elements are rated at 3000 watts (3 KW) at 240 Volts we can see that $I = W/V = 12.5$ Amps. This is why an immersion circuit is rated at 15 or 16 Amps and why a 13 Amp plug with a slightly resistant connection can easily overheat when used on an immersion circuit. This current also tells us that:

- An immersion would use up a considerable quantity of available power on a ring main and
- That any timer used in the circuit must be capable of switching the full rating of the immersion.

In all electric households a twin immersion heater installation is common. In this type of installation the lower element uses off peak (overnight) electricity and heats up the whole tank of water. It is usually connected to a secondary (white/economy 7) meter, often via a second consumer unit, which often also powers night storage heaters. Some older installations may also have electro-mechanical timers.

The upper element, controlled by a second isolating switch, runs on peak daytime electricity and heats only the water at the top of the tank, thus providing a daytime boost. It is fed from the main consumer unit.

In twin installations there is typically no power to the lower element during the day and any testing must recognize this fact.

The immersion in detail

Figure 4 - Immersion heater assembly

Am immersion is an electrical heated element inside a looped copper or incaloy tube. Incoloy is used in hard water areas, as it is more corrosion resistant. With immersion elements designed for smaller tanks the end of the heater is curved around to allow it to fit the smaller tank.

The second tube contains the thermostat, which switches off the heater once a preset temperature has been reached.

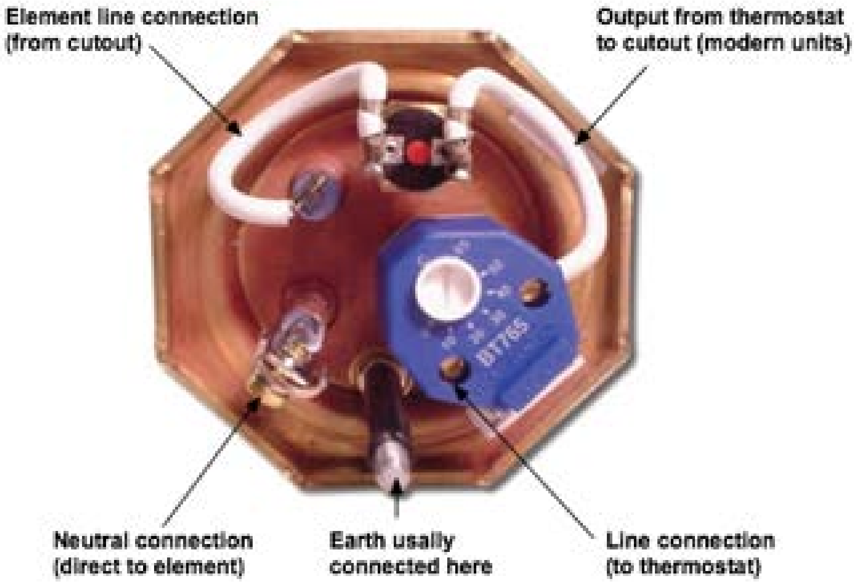
The two components together with in modern units, a third, the resetable automatic cutout, are housed in a single assembly as shown in Figure 4. The thermostat as shown in Figure 5 can usually be withdrawn once its connecting cable are removed.

Figure 5 - Immersion thermostat

Once the immersion cover is removed the connections can be seen as shown in Figure 6.

The connecting cable should be heat resistant as it is often exposed to constant heat, which can damage standard PVC cable.

Figure 6 - Immersion with cover removed



Note: Some thermostats have a cutout built in. It can be a very small, unmarked button so look carefully.

Fault finding immersion heaters

Immersions are a point where water meets electricity and corrosion takes place and as such are frequent causes of electrical issues. Typical faults include:

- Not heating
- Tripping RCD
- Overheating

Let's look at faultfinding. You will need a multimeter and a voltage detector pen.

Not heating. This is usually a faulty element but can also be caused by a faulty thermostat or a tripped cutout. Cutouts usually trip for a reason and that's often overheating caused by lime scale buildup on the element or within the tank.

The following tests should be conducted.

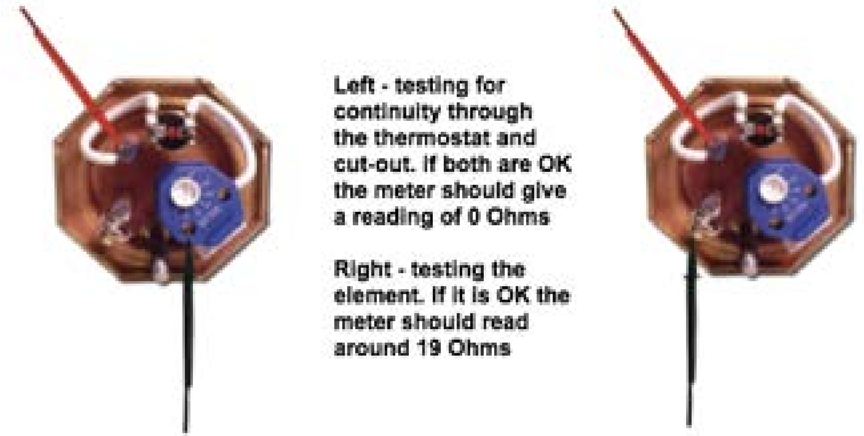
(i) Is there power getting to the immersion assembly? Use a voltage detector pen on the incoming cable to check for the presence of voltage. If there is no power you need to find out why; assuming it's not an off peak immersion, in which case start at (ii).

(ii) Is the immersion assembly working correctly? Turn off the isolating switch and the MCB in the consumer unit (or remove the fuse from the fuse box). Double check there is no power at the unit using the voltage detector pen and the multimeter on the AC volts range.

(iii) Switch the multimeter to Ohms (200). Place one test lead on the live connection to the thermostat and the second on the element live connection. You should get a zero Ohms reading. If it's one or two Ohms join the test leads together and see if the meter is zeroing. We are checking to see if there is continuity through the thermostat and the cutout (if present). If there is continuity move to the next test. If there is not, test for continuity through the thermostat and the cutout and if not test each in turn. If the thermostat is faulty it will need replacing. Cutouts can generally be reset by pushing the popped up button on the top of the cutout. Refer to Figure 7 for a pictorial view of testing.

(iv) So you have continuity between the incoming live cable and the element. Now test the element. Place one lead of the multimeter on the neutral connection to the element and the other on the live. With the meter set to 200 Ohms you should get a reading of around 19 Ohms. If not the element is open circuit and a new one needs to be fitted. Why 19 Ohms? Using Ohms law and with the knowledge that a 3KW element takes around 12.5 Amps at 240 Volts the R = V/I which is 240/12.5 = 19.2 Ohms.

Figure 7 - Testing an immersion (power off)



Tripping RCD. It's not unusual for immersion elements to develop leakage current to earth and thus cause an RCD to trip. Assuming the immersion has been connected via a double pole isolating switch (not always the case) then it's fairly easy to track this down by turning off the switch and seeing if the RCD stops tripping. If a single pole isolating switch has been used then the neutral will need to be disconnected as well in order to isolate the immersion element. If the RCD is holding with the immersion switched off or disconnected then a new immersion is needed.

If there is intermittent tripping then measure between the immersion earth and the live and neutral element connections in turn with a multimeter set to 2M (2 Meg Ohms). Again the immersion needs to be isolated completely from the supply. You should get an open circuit reading circuit (many multimeters read 1. in this condition). If you get any other reading then the chances are the element is on it's way out and it should be replaced. Do make sure you don't touch the metallic part of the meter of the immersion element when undertaking this test, as your body itself will provide a reading.

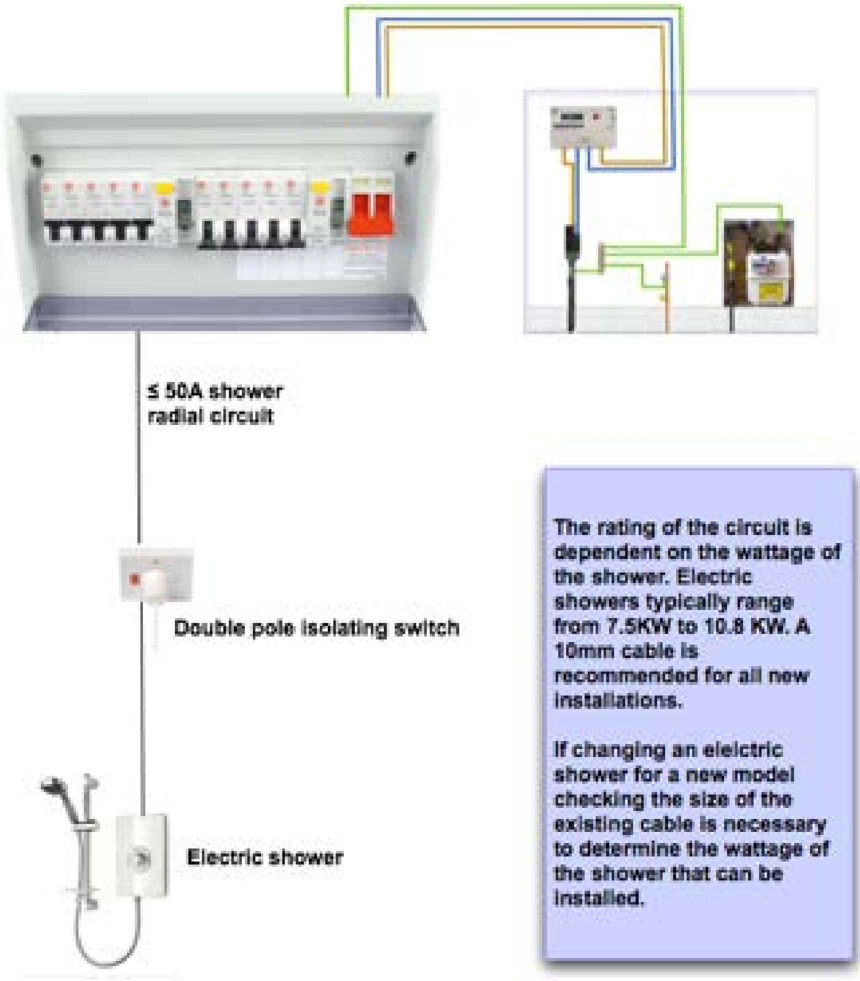
Overheating. This is relatively unusual and is typically caused by a faulty thermostat. It is why cutouts are now fitted. If you already have a tank of hot water then isolate the power supply to the immersion, remove the cover, turn the thermostat down and then slowly turn it back up. You should hear it click when the water temperature is reached. At this point test for continuity through the thermostat with your multimeter. It should be open circuit (1.). As the thermostat is turned down it should click again and continuity (0 Ohms) should be read on the multimeter. If these actions don't happen replace the thermostat.

Scaling in immersion cylinders

When an immersion is used to heat water in hard water areas the water adjacent to the element is heated to the extent that scale will form. Those with electric kettles will have noticed a similar build up of scale. Similarly to a kettle scale will build up on the immersion element but as it expands and contracts a good deal will crack off. This scale builds up in the cylinder and can in time substantially reduce it's capacity, efficiency and should it build to the extent that some of the element is sitting in the scale, cause the element to fail prematurely. It is therefore worth checking, where possible, for scale build up when replacing an element.

Instantaneous water heaters

Figure 8 - Typical electric shower installation



Shower types

Showers with power connections come in a two types, which are often confused. They include:

Electric showers; these heat the water as it passes through and require high power. They have a cold water feed only.

Power showers; which are an integrated pump and mixer. They take hot water that has been heated elsewhere, typically in a central heating system, mix it with cold water and pump the mixed water to the showerhead. They do not require high power.

Both the above types are also available in 'digital' formats where a low voltage control panel communicates with a distant power unit to adjust flow and temperature.

Shower pumps are also common. These are separate pumps, which increase the hot and cold water pressure and pump separate water supplies to a mechanical shower mixer valve or shower panel. Pumps are relatively low power devises.

Typical and alternative supply arrangements

Figure 8 shows a typical electric shower circuit where the shower is powered from the household consumer unit or fuse box on radial circuit. New shower installations must be protected by an RCD although a considerable number of older installations exist where no RCD protection is provided. In the latter case supplementary bonding (local bonding of metallic parts in the bathroom) is essential to maintain safety.

Where an electric shower has been added it is common to find a shower consumer unit has been installed in addition the household consumer unit or more likely fuse box. A typical shower consumer unit is shown in Figure 9.

Figure 9 - Shower consumer unit

The unit comprises and RCD (left) and MCB (right).

It will have a power in – usually meter tails and power out to the shower double pole isolating switch

In some instances an RCBO (integrated RCD and MCB and standing for Residual Current circuit Breaker with Overload protection) may have been fitted in place of an MCB in a consumer unit, which does not have it's own RCD or where the shower circuit is on a part of the consumer unit not provided with RCD protection.

Electric shower circuits are dedicated to a single shower and must not be used to power any additional devises. Circuits for power showers and shower pumps, requiring much lower power can be fused radial spurs from rings mains. They should never be attached to lighting circuits.

Repairing electric showers

If attempting a repair on an electric shower only do so with the power off. Water flying around and exposed electrical connections is not a safe situation.

If an electric shower has suffered failure, is more than a few years old and is in frequent use, it's often more economic to replace the entire unit. If doing so try and find a unit with a similar 'footprint' (electrical and plumbing connections) as this will keep the installation costs down. You can check footprints on the shower-spares web sites. There are a number of outlets that provide spares but if one item has failed it not infrequent for it to be followed by another and before long the expense has equaled the cost of a new shower.

Fault finding electric showers

Cutting out is the most common fault in electric showers. It is typically not an electrical fault but is caused by a reduced flow rate due to scale build up on the shower or a blocked input filter. Checking the flow rate is always a good starting point for electrical shower issues. Some showers have 'low flow' indicators, which illuminate under these conditions.

A shower not heating is also a common fault. Showers are essentially like kettles with an element set in a 'can' through which the water flows. Typical failure conditions are that the shower turns on, pumps water through but the water remains cold. If this occurs a decision needs to be taken on obtaining and fitting a spare part or replacing the shower.

Power failure to the shower is not uncommon. Assuming the RCD and MCB have not tripped (and the isolating switch is on) isolate the power to the shower and carefully remove the cover. Restore the power and use a voltage indicator pen to see if voltage is present at the input terminals. DO NOT turn the shower on when doing this. If voltage is present then the shower unit itself is faulty and a decision needs to be taken on whether to fault find the device and attempt a repair or replace the unit.

If power is not present at the shower, isolate the circuit at the consumer unit and dismantle and test the isolating switch. Failed isolation switches are not uncommon. Both mechanical and electrical failure can occur together with overheating caused by loose (resistant) connections. Examine the switch for signs of failure and then test it using a multimeter. To do this firstly check there is no voltage present using a light pen and then with the multimeter set to Ohms (200) check there is continuity through the switch between the two live terminals (in and out) and similarly the two neutral terminals. Switches are relatively simple to replace. When changing switches ensure the input and output is configured correctly otherwise the neon indicator will be permanently on.

If there is no power at the switch then the next point of call is the consumer unit or fuse box. Use the light pen to check for presence of voltage on the shower cable (identifiable by its size). Note that light pens in the proximity of consumer units can provide erroneous indications due to the proximity of a range of circuits. If possible turn off all other circuits so only the shower has power on. If there is no power at this point the consumer unit or fuse box requires investigation. Only do this with power fully isolated and if unsure consult a professional.

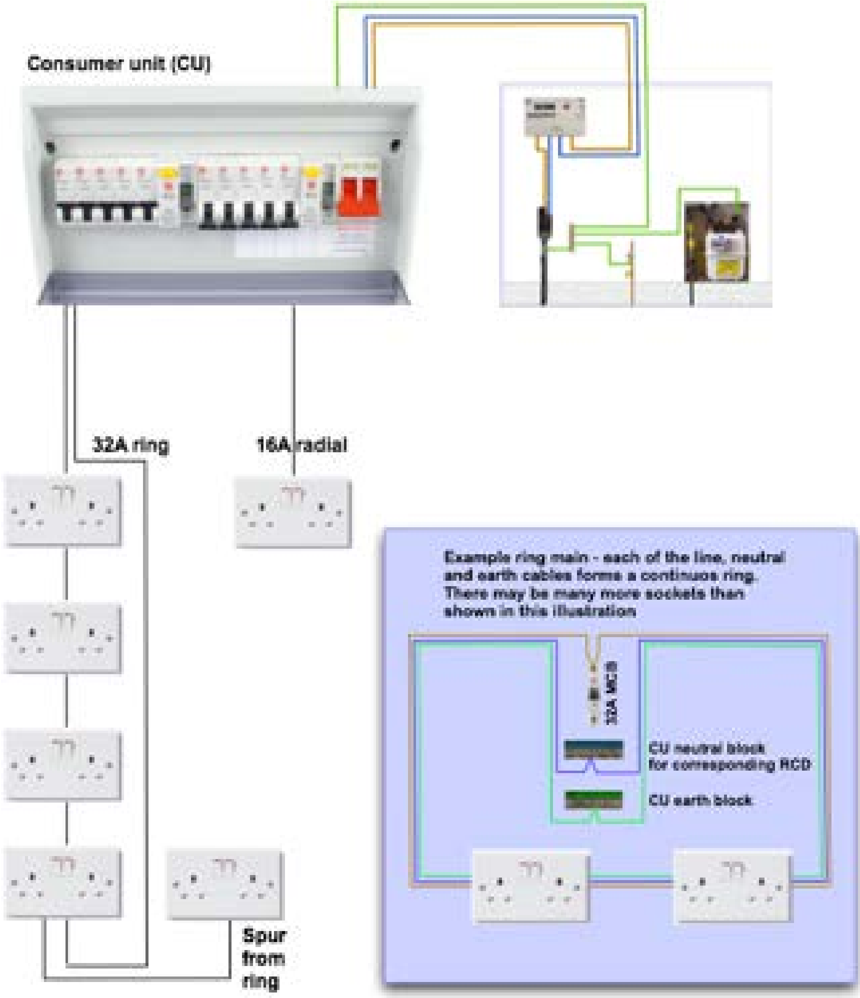
A tripping RCD with the shower on is an indication of a fault in the shower itself, usually the water heater and again a decision needs to be taken on whether to fault find the device and attempt a repair or replace the unit.

A tripping MCB is unusual as it means the circuit is taking too much current. Firstly disconnect the shower using the isolation switch and see if this cures the fault. If so there is something seriously wrong with the either the shower or the wiring between the shower and the switch. Turn off the power; mechanically inspect the switch and the shower. If all seems well remove the cover from the shower and disconnect and safely set to one side the live connection and see if this cures the problem with the power back on. If so once again a decision regarding faultfinding or replacement is required.

Ring mains, RCDs and MCBs

The UK ring main

Figure 10 - The ring main



Ring mains – key points

Ring mains are a peculiarly British electrical feature. Developed after World War II they were designed to reduce the amount of copper and number of protection devices required in electrical circuits when the UK's housing stock was being rebuilt. They are cabled using 2.5mm cross sectional area cable and rely on individual accessories being protected by their own fuse in the '13 Amp' plug.

Traditionally the majority of households had one ring main each for the upper and lower parts of the house. Modern households typically have a separate ring for the kitchen, as this is where the principle power hungry devices tend to reside.

The principle issue with regard to ring mains is that a circuit will continue to operate if the ring is broken. The break in the ring can result in part of the circuit being overloaded. It is not uncommon to find rings that have been 'modified' when wiring has been altered and as a result are no longer rings.

It is simple to test if a ring main is actually a ring. With the power off remove the live, neutral and earth cables from the back of a ring main socket (it should have two cables per terminal) and check the Ohms reading between the two live, then two neutral and finally two earth cables. Each should give a low Ohm reading, typically less than 0.75 Ohms. The live and neutral readings should be similar. The earth reading will be higher as the cross sectional area of the earth cable is less than that for the live and neutral and as such is has a higher resistance.

How to fault find broken ring mains

If only a single cable on the ring e.g. the earth is not a ring then, unless someone has been active with a power drill or fixing items to walls there will be a disconnected cable or bad connection on the back of a socket. With power off identify the likely sockets on the ring and examine each in turn until the problem is found.

If live, neutral and earth are no longer a ring there are two likely causes:

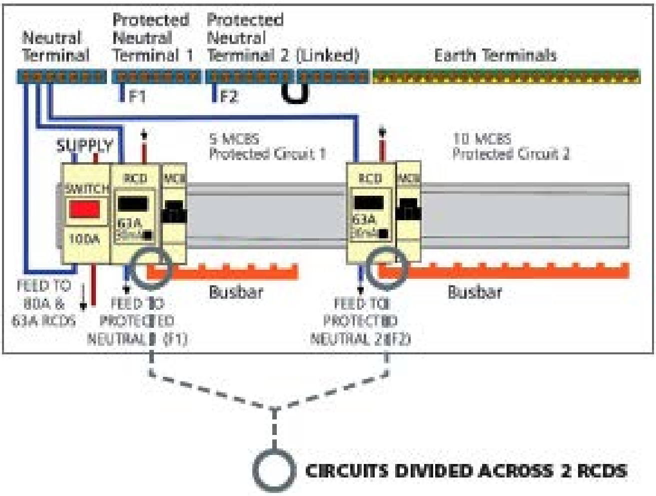
- Some building work has taken place.
- Someone who didn't understand ring mains has made a circuit alteration.

There is only one way to fault find and that is to find out exactly where the ring runs, beginning at the consumer unit / fuse box and working from socket to socket back to the fuse box. The simplest way is to power off and disconnect every socket that is likely to be on the ring. Then with a multimeter on Ohms (200) or continuity trace the circuit physically using a long cable to extend a multimeter test lead.

If it is possible to identify the two 'ends' of what should be the ring then a new cable can be run to facilitate the repair. If not, or if a new cable is impractical then serious consideration will need to be given to reconfiguring the two radial circuits on 16A MCBs. This has the effect of protecting each cable from overload and leaving a safe condition. It may not however be practical where higher current devices are in use such as in a kitchen. In this case some re-running of cables may be required.

RCDs and MCBs

Figure 11 - Typical modern consumer unit



Source: MK

A consumer unit typically consists of a main on-off switch, one or two RCDs and a series of MCBs as shown in Figure 11.

Many consumer units have two RCDs fitted to prevent all power and light being lost in the case on an RCD tripping. In this illustration the MCBs associated with (fed through) an RCD are on the right of each RCD.

Figure 12 - Typical RCD

Example of an RCD with its T (test) button. These can be a range of colours. Pushing the button should cause the RCD to trip.

Down is off and up is on.

An RCD (Residual Current Devise as shown in Figure 12) is an item of equipment commonly found in consumer units. They became effectively compulsory for new installations in 2008 and can be clearly identified by the 'test' button. An RCD detects imbalance between the current flow in the live and neutral circuits. RCDs in domestic consumer units are rated at 30mA (30 milliamps or 30 thousands of an Amp). Where the supply company has not provided an earth (and an earth rod is in use) then a 100mA RCD can be found on the input to the consumer unit. In some instances and in smaller consumer units an RCD may be used in place of the main on-off switch.

Figure 13 - Typical MCB

Example of an MCB, in this case rated at 16 Amps and type ‘B’ (trips between 3 and 5 times full load current). Only Type B MCBs are normally used in domestic premises. Types C & D are used in non-domestic situations.

Down is off and up is on.

An MCB (miniature circuit breaker) is the modern equivalent of the fuse. Hence ratings are similar to fuses; 6A or 10A for lighting, 16A for immersion and other radial circuits, 32A for rings mains and often cookers and higher for items such as showers. An MCB trips when a circuit draws too much current. A tripped MCB is normally an indication of a fairly serious fault condition or for a single occurrence a blown light bulb.

RCBO’s as shown in Figure 14 can also be found. The RCBO stands for Residual Current Breaker with Overload protection. These are an integrated version of the RCD and MCB and means that each circuit which has one fitted has it’s own RCD. They look like an MCB with the addition of a ‘test’ button.

Figure 14 – Typical RCBO

Example of an RCBO, in this case rated at 6 Amps and type ‘B’ type. RCBO's can usually be identified by the fact that they take up only the space of an MCB and also contain a ‘T’ (test) button.

Down is off and up is on.

Tripping RCDs and fault finding

There are two types of tripping associated with RCDs

- Infrequent tripping e.g. when a light bulb fails. This can occur, particularly with halogen mains voltage bulbs, which can create a high current spike when they fail. Other causes of intermittent tripping are damp and for IT buffs, a lot of computers with smoothing power supplies. Tripping with bulb failure is a fact of life and has to be lived with.
- Permanent tripping means there is an imbalance between the live and neutral current and a fault somewhere.

In many house-fault situations one or more RCDs will be fitted and one has tripped. Remember the RCDs are the switches with an adjoining test button. Look at Figure 11. There are two RCDs and each is associated with the MCBs to it's right; it may be to the left in your unit, it varies. MCBs replace old style fuses so there is one for each circuit. Hopefully your board will be marked up to tell you what each circuit is. If not it’s a good idea to find out and mark up by turning each MCB off in turn and seeing which circuits stop working.

The red switch is the main on/off switch - this should be up. It can't 'trip' itself, it can only be turned on or off manually.

Identify which one of the RCDs has tripped i.e. is down. Then turn off (down) all the associated MCBs. Now reset the RCD by pushing it up. In some cases you have to push down first and then up.

If the RCD resets then push up the associated MCBs one by one. If everything is working then the chances are you just have a blown light bulb. Check all bulbs and replace as necessary. If you were trying to use an appliance when the power tripped then there's a good possibility that the appliance is the cause of the problem. Unplug it and put it to one side. If it's a toaster or kettle the bin is probably the next stop for it. If it's a washing machine, dryer or dish washer then check the appliances service guide in the instruction book or call a white goods repair company.

If the RCD won't reset then there is probably a fault on the circuit. Most faults are caused by appliances or circuits that supply something wet or that can get wet e.g. outside lights, garden circuits, electric water heaters such as immersions or central heating. Unplug (not just switch off) everything you can by pulling out plugs and in the case of items such as central heating turn off the isolating switch, typically a switch with a built in fuse. If the RCD will now reset plug items back in (and/or switch on) one by one until it trips again - now you will know where the fault is.

If you can't reset an RCD with all the MCBs off (down) and all appliances unplugged then it's possible there is a neutral fault. If this is suspected first check again that everything is unplugged or switched off. It’s no use just switching off most 13 Amp sockets as many only isolate the live connection and not the neutral. In the case of items such as immersion heaters and central heating supplies make sure the isolating switch or fused spur switch is double pole and if not disconnect the apparatus by removing cables.

Also check for any cables running to outside locations or sockets. If they were installed properly it should be possible to fully isolate them but it is not uncommon to find e.g. garden circuits wired into the back of a convenient 13 Amp socket.

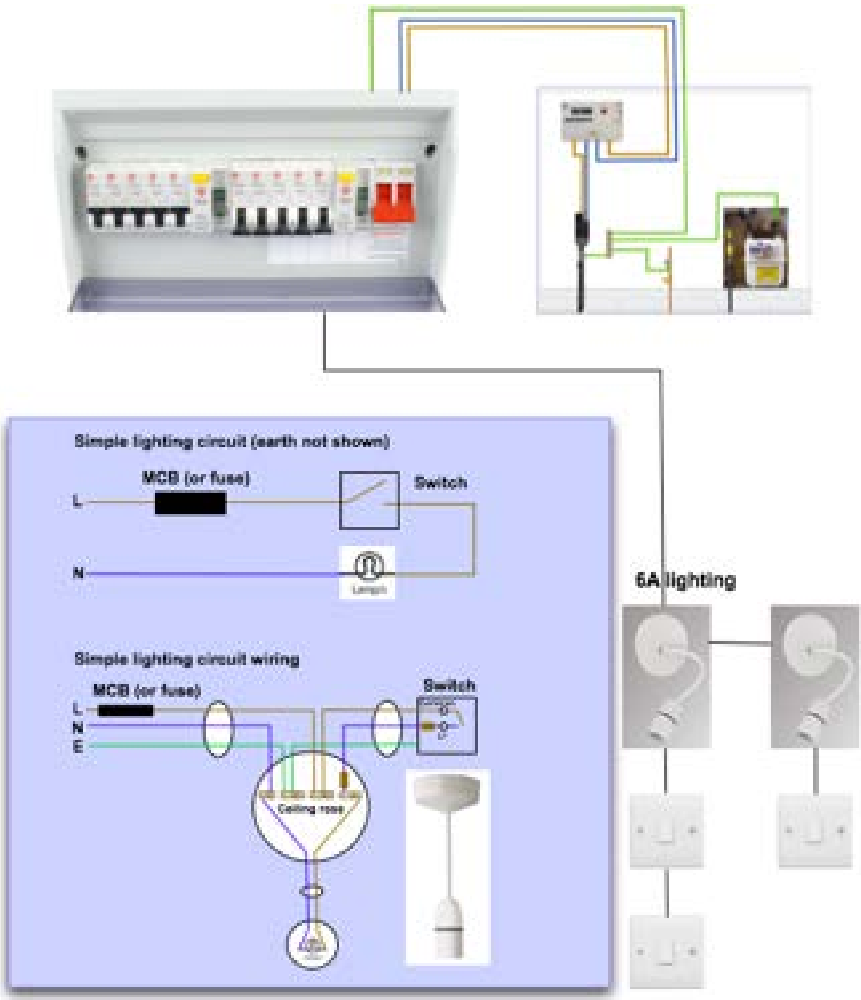
Once all this has been completed try the RCD again. If it's now OK then restore circuits one by one until the faulty one is found.

If all was not OK then a lighting circuit is a possibility. It's not possible to isolate the neutral of a lighting circuit outside the consumer unit but the usual cause of issues is outside lighting. Look carefully for such items before taking the final step, which is to start disconnecting neutrals inside the consumer unit, providing you are competent to do so.

It should be noted that it is possible for an RCD fail. It is however uncommon.

Lighting circuits

Figure 15 – Lighting circuit overview



Lighting circuits

Lighting circuits are radial circuits emanating from the consumer unit / fuse box. Sometimes they are also starred from intermediate points, usually a ceiling rose.

The use of the ceiling rose as the junction box is common and makes sense, as it is a readily accessible point. The down side is that it can lead to:

- Overcrowded cabling in the ceiling rose
- Untidy and potentially unreliable installations when a ceiling rose is replaced with connector blocks behind or inside feature lights without a ceiling rose.

The trick with fault finding lighting circuits is to understand how they are wired.

Lighting circuits are very simple. It is the physical presentation, which can cause confusion. A basic lighting circuit is shown in Figure 15. Physically the wiring requires a feed from the consumer unit/ fuse box and a connection to the switch, typically via the ceiling rose. Note that the return live wire from the switch is supposed to be sleeved to indicate that despite its colour it is live. There is no neutral present at a light switch unless it has been used as a junction box, in which case additional terminals or connector blocks will have been added. In reality we often have a number of lights running on the same circuit. So in a typical house we will find something like Figure 16 except that there are likely to be several more lights on the radial circuit.

The other common circuit found in a household is a two way switched light where a single light is controlled from two switches, each of which can turn the light on or off. The typical means of achieving this is shown in

Figure 17.

The 3-core and earth cable connecting the two switches is the indicator that two way switching is in use.

Figure 16 - Practical lighting circuit

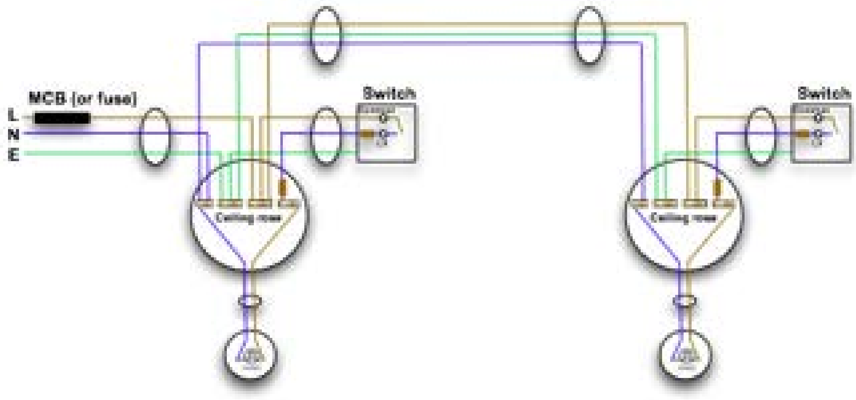
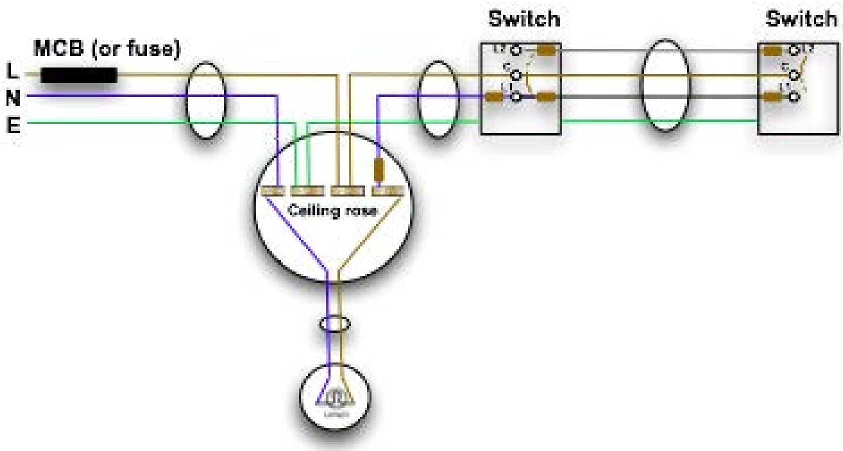


Figure 17 - Two way switched lighting

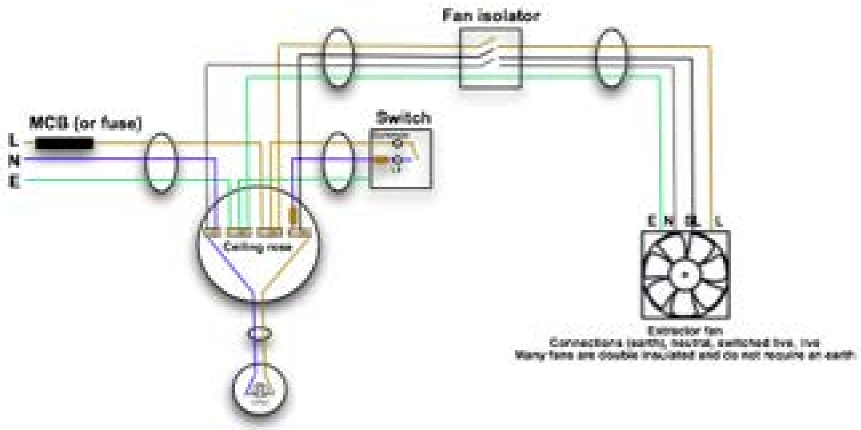


Extractor fans

Extractor fans are typically found in kitchens and bathrooms. The kitchen variety usually run from a fused spur so the wiring is straightforward.

Bathroom extractor fans are usually wired so the fan comes on with the light. The fan often has a timer, which allows the fan to continue running when the light is turned off to clear the warm air and prevent condensation. To facilitate this mode of operation the fan is provided with both a permanent live and a switched live, as shown in Figure 18. Fan isolating switches are fitted in modern installations.

Figure 18 - Bathroom extractor wiring



Note that the colour codes for the 3-core and earth cable have changed in line with the code change for 2-core and earth cable. The equivalents are:

Old = Red,	New = Brown
Old = Yellow	New = Black
Old = Blue	New = Grey

The earth remains green/yellow.

Also note the common wiring approach of the same terminals on each switch being connected to each other.

Terminology

A CABLE is a grouping of two or more wires, usually in a PVC sheath. A lighting cable typically has three WIRES. Most lighting cables are 'twin and earth' (T&E) meaning there is a live (brown or red) wire, a neutral (blue or black) wire and an earth wire which is bare copper until it is sleeved at the point of connection (in green/yellow or green).

The majority of lighting circuits are wired in T&E. In older properties (pre mid 1960's) there may be no earth so cables with just a live and neutral may have been used. In these properties metallic light fittings or metallic switches should not be installed unless a separate earth cable is run.

There are some properties using conduit where each wire is run separately in a metal conduit, which forms the earth circuit. Always check the earth continuity of the conduit, as it is sometimes the case that the conduit has been removed at some point so the earth circuit no longer exists.

Fault-finding lighting circuits

Like many faultfinding situations undertake the following before starting:

- Enquire of the occupier whether any work has been undertaken recently. This will provide the best starting point. Include work in lofts where it's possible cabling could have been disturbed.
- Use your mobile telephone to take a picture of any wiring connections you will work on before you begin. If need be you can use this as a reference and can go back if necessary.
- Check all of the light bulbs are working, if need by exchanging with others elsewhere or on a different circuit to the one being worked on.

MCB tripping / fuse blowing

MCB tripping (or fuses blowing) is often associated with the finding that one light is not working after an attempt to repair / replace. The pre-eminent cause is incorrect wiring in a ceiling rose (or connection block replacement) due to an attempt to rewire. Faultfinding is straight forward if a simple process is followed. The following steps should be followed to identify the wires and reconnect them correctly.

The following steps are shown in Figure 19.

Step 1 - Turn the power to the lighting circuit OFF and using a light pen and test meter make sure none of the cables in the ceiling rose are live.

Step 2 - Disconnect all of the wires from the ceiling rose except the brown and blue, which go to the light bulb and the earth wires. (The normally brown and blue wires to the bulb may be red and black or even not colour coded in older properties).

Step 3 - Make sure you can see which cable each wire comes from (you may need to remove the ceiling rose to do this). If there is a blue (or black) wire, which has a piece of brown (or red) sleeving on it then this should be the return live wire from the switch and the cable it is in is the cable going to the switch. Prove this by using a test meter on the 'Ohm' (200) range to test the resistance across the brown and blue (or red and black) wires, which you think go to the switch. With the switch in the on position a reading of near zero Ohms should be obtained; with the switch off an open circuit reading (usually 1.) should be obtained).

If there was no sleeved wire then take each pair of brown and blue (or red and black) wires and test them with the multimeter on Ohms (200) until the above result is obtained. Then mark the blue (or black) wire from the switch with a piece of brown or red sleeving (or suitably coloured insulating tape if no sleeving is available) and write S/W with a biro on the outer sheath of the cable and pull it carefully to one side.

Step 4 - Make sure none of the bare ends of the wires are touching each other and are safely accessible. With the power ON (and taking care not to touch any wires yourself) identify the incoming 'live' feed; this is one occasion where a neon screwdriver is useful. It will be a brown (or red) wire. The cable 'pair' of this live feed (a blue or black) will be the incoming neutral. Carefully pull this pair of wires to one side and remember which they are. Turn the power OFF and write 'I/C' (for incoming) on the cable using a ballpoint pen.

Step 5 - Connect the wires as follows:

- The incoming live to the central terminal block in the ceiling rose.
- The incoming neutral to the right hand terminal block in the ceiling rose. This is where the blue wire going to the light fitting is connected.
- The brown (or red) switch wire to the centre terminal block in the ceiling rose (the same as the incoming live).
- The blue (or black) switch wire (sleeved brown or red) to the left hand terminal block in the ceiling rose. This is where the brown wire going to the light fitting is connected.

Any cables left will be outgoing live/neutral pairs. Connect the brown (or red) wires of these cables to the central terminal block in the ceiling rose with the incoming live and connect the blue (or black) wires of these cables to the right hand terminal block in the ceiling rose – the neutral.

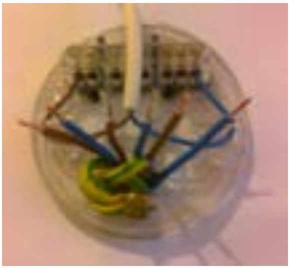
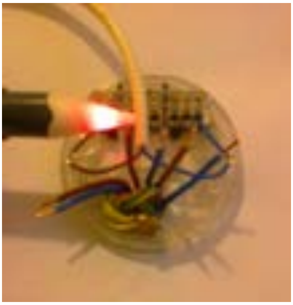
Sleeve all the earth cables green/yellow and connect these to the single earth terminal in the ceiling rose.

The ceiling rose should now look like should now look like step 5 in Figure 19.

Double check your wiring then turn the power back on and test that the light is working and switches on and off.

Test all other lights on the same floor of the property (or if it's a small property all other lights).

Figure 19 – The step-by-step process

	Steps 1 and 2: power off, wires disconnected and separated. In these examples the white cable goes to the lamp holder.
	Step 3: find the switch pair. Meter on Ohms (200) and showing just 0.5 Ohms in this example, some of which is probably due to a poor connection between the meter probe and the wires.
	Step 4 – wires safe, switch pair to one side, power back on and the live feed identified. This may be easier with a voltage tester as light pens illuminate too easily when wires are in close proximity
	Step 5: reconnected and working correctly. Note the blue switch return wire is sleeved brown to indicate it is a live wire.

One or more lights fail to operate

The failure of one or more lights to operate is often associated with:

- A live connection coming adrift in a ceiling rose (or connection block replacement). If this is the case a neon screwdriver or test meter (AC volts) will show no voltage present at a ceiling rose
- A neutral connection coming adrift in a ceiling rose (or connection block replacement). In this instance a neon screwdriver or test meter (AC volts 600) will show voltage being present on both live and neutral wires and in many cases odd voltage readings such as 130V between live and neutral. This is caused (if incandescent lamps are in use) by the lamp acting as a resistor in what is effectively an open circuit.

There are two ways of tracing this type of fault. The first is to take an educated guess at what could be the first light connected to the consumer unit / fuse box and start looking for the presence of the correct 240V at that point using the multimeter and then work your way around the circuit. Frequently one has no way of guessing the circuit so it's a case of picking a starting point and testing each ceiling rose in turn. Hint - the fault is often in the one with the most cables in it!

It has been known for cables to snap within the PVC covering so check carefully.

Mis-operation of two way switching

Mis-operation of two way switching is sometimes associated with incorrect operation of other lights operated by other switches on the same switch plate. If this seems likely turn the power off, remove the shared switch plate from the wall and carefully examine the wiring. Note that:

- Switches are normally mounted such that the first switch has it's common connection to the top, the second it's common connection to the bottom and any third with its common connection to the top again.
- If only one switch is acting as one of a pair of two-way switches only that switch should be connected to the 3-core and earth cable.
- The remaining switches should only have wires going to C (common) and L1 or common and L2.

If there is confusion due to mis-wiring take a photograph of the wiring before making and changes. Now disconnect the 3-core and earth cable and work on getting the remaining switch(s) wired correctly – simply each cable pair of live and switched live should be connected across common and L1 or common and L2.

Once the simpler wiring is taken care of look at the other switch acting as one of the two-way pair and ascertain the wiring colour used on C, L1 and L2. Now replicate this on the switch on the shared plate, re-connect and test.

Variations and safety

Electricians (and others) have been known to cable lighting in a wide variety of ways and there will always be installations, which don't follow the norm. The trick is to gain an understanding and mental picture of what you have, even if you can't see it all. The wiring must result in a circuit, which looks like those described above, even if the physical presentation varies. The only exception to this is where wiring has been interfered with – and that's why it is worth asking if work has been undertaken.

If need be, meter out cables (with the power off) using a multimeter (on continuity) and a long test wire. This will enable a picture to be built up.

Low voltage lighting

Low voltage lighting is increasingly prevalent and has it's own fault predilections. First is the failure of fittings themselves due to heat and higher currents (same watts and low volts equals more amps). If the fitting looks like it's seen better days it probably has.

Secondly transformers often fail. It's becoming less common but there are still many (sometimes pre-wired) lighting fittings where around three low voltage bulbs share a single transformer. If two or three low voltage fittings are out the testing at the transformer is a must (when you can find it – take out the fitting and feel around in the roof space). Always undertake the latter with the power off, just in case a 240v connection has come adrift.

Dimmers, halogen and low energy bulbs

Dimmer failure, particularly when halogen bulbs fail, is common. Bulbs can create a significant electrical spike on a circuit when failing and halogens are prone to large ones. Dimmers have increased resistance to this problem but it is worth looking carefully at the dimmer rating and if it seems appropriate fit a higher and well over rated (wattage) dimmer if failures are occurring.

Installing 'feature lights'

When replacing ceiling roses with 'feature' lights of some description it is often necessary to replace the ceiling rose with a 4-way terminal block which can be located in the ceiling void as:

- Most feature lights do not have an adequately sized 'fitted' terminal block
- Cables that were previously terminated in the ceiling rose are often not long enough to reach the terminal block in the feature light.

If this is the case run a 1.5mm^2 two core and earth cable from the new terminal block to the light fitting - this often makes installing the light simpler.

Central heating and controls

Types of central heating systems

In order to understand the functions of the electrical controls in central heating systems some knowledge of the plumbing side is required.

Central heating systems from a plumbing perspective are fully described in this books companion plumbing fault finding guide. Although there are many variations and refinements the majority of installations (excluding night storage and panel heaters) are either sealed or conventional (vented) based systems powered by gas or oil.

The term 'central heating' systems is taken to mean a system that provides heating through a common central boiler which also provides hot water.

The two most common systems are:

- A 'combi' boiler with a sealed system operating under pressure.
- A system with a conventional boiler and indirect hot water cylinder.

The majority of controls for variations on these systems will be similar and operate on similar principles.

The two systems are shown in Figure 20.

Figure 20 – Common forms of central heating system

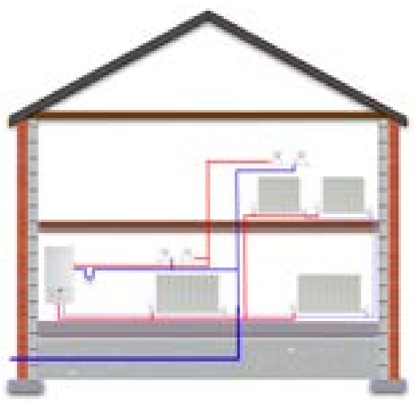
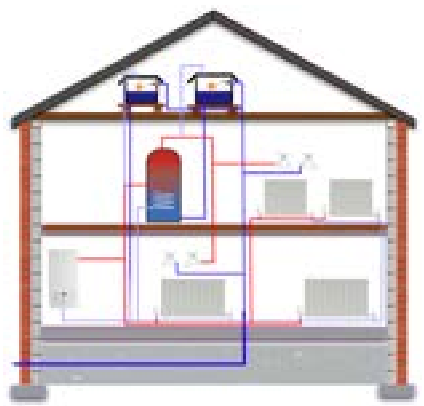
Combi sealed system	Conventional system
	

Figure based on an original idea by UWE

Central heating controls

The primary components and controls associated with central heating systems are:

- The boiler, usually gas or oil, which heats water for either the taps, the radiators or both. Faultfinding boilers is outside the scope of this book.
- A cylinder containing a coil, which is separated plumbing wise from the water to be heated. Water is passed through the coil to heat the water, which flows to the hot taps. Systems using solar heating panels have a second coil, which is heated by a solar water circuit.
- A pump, which pumps the hot water around the radiators. Some systems are fully pumped (i.e. a pump operates when either hot water and/or central heating is called for; some only pump water for the

radiators. In the former case water is also pumped around the cylinder coil. Some more complex systems have multiple pumps.

- One or more motorised valves. Three port (also known as mid-position) valves switch the direction of the primary circuit so water flows to either the radiators (always pumped), the hot water cylinder coil (may or may not be pumped) or to both. Often one or more two port valves are used, e.g. one to control the radiator circuit, the other the water heating circuit.
- A timer (programmer) to control when the system operates. Typically they control heating and hot water times. In a number of older systems the hot water needs to be on in order for the heating to function in which case the timer/programmer is set accordingly, usually via a small switch.
- A wall thermostat which instructs the heating to turn and off according to room temperature.
- A cylinder thermostat which instructs the hot water to turn and off according to the water temperature.

Many installations also contain thermostatic radiator valves. These are purely mechanical devices and are addressed in the companion plumbing fault finding guide.

Table 1 provides a list of controls and notes which control is usually found in each type of system.

Examples of these controls are shown in Figure 21, which shows the controls in a conventional system.

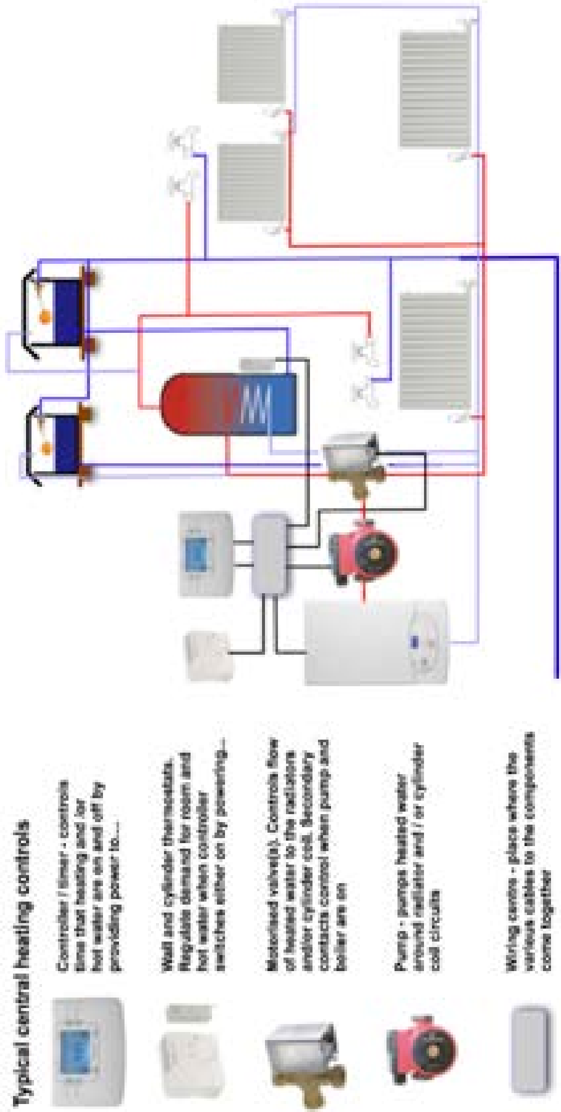
Table 1 - Typical controls and locations

Control	Location (combi)	Location (conventional)
Timer/programmer	Within the boiler. May have external secondary control	Suitable location within the house
Pump	Often within the boiler	Usually outside and near the boiler or the cylinder
Motorised valve(s)	Not required	Usually outside and near the boiler or near the cylinder. In a typical household just one is used. May be one per 'zone' (group of rooms) or as many as one per room in more complex systems
Wall thermostat	Suitable location with the house	Suitable location with the house
Cylinder stat	Not required	Mounted on the outside of the cylinder

More sophisticated systems may have additional controls such as weather compensators which measure the internal and external temperature and make the heating system respond accordingly, usually by adjusting the on/off periods.

Figure 21 - Example central heating controls

Figure shows controls for a conventional system
Figure based on an original idea by UWE



Battery powered controls

Battery powered controls are increasingly common in central heating systems. The contacts used to control the heating system in such controls are independent of the control circuit within them, which is battery powered. They take two forms:

- A hard-wired device such as a programmable room thermostat, which is independently programmable to control the room temperature being called for by time of day.
- A wireless device linked by radio to the central timer/programmer, either within the boiler (combi) or an independent timer/programmer (conventional system). Examples are wall thermostats, cylinder thermostats and in combi systems remote central controls.

The issue with battery-powered controls is the simple fact that batteries go flat. Some controls provide an audible low-battery signal, most provide only a visual signal and frequently these are ignored. If fault finding a system with wireless controls always ensure the batteries are good before starting and that the start-up procedure that allows the central (wired) receiver to communicate with the remote wireless battery operated device has been followed.

Typical wiring (conventional boiler)

Central heating systems are usually wired through a central wiring point (or hub). Typically:

- There is a fused spur to provide power to the system. A 3 Amp fuse is usually sufficient.
- The power goes initially to the central controller, which then provides power to the other system

electrical components (motorized valve, pump, and thermostats). Central heating controls are binary in nature, i.e. are on or off and operate at mains voltage.

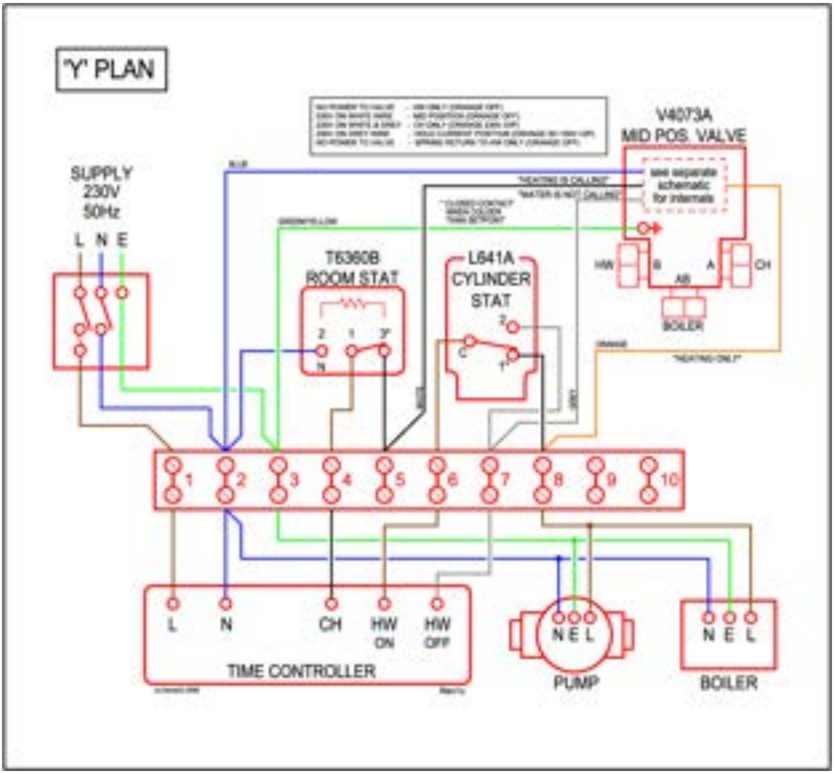
- Motorized valves have secondary contacts, which in turn operate the pump and boiler.

The way a system is wired practically can vary substantially installation by installation. This is because different installers have their own methods and the way wiring is distributed is often dictated by the practicalities of running it when a system has been fitted after a house was built. If you have a core understanding of how systems operate it's usually relatively straightforward to determine how a system has been wired.

There is one installation fault that is sadly not uncommon. Because many thermostats and controllers require a 3-core and earth cable some (usually DIY) installers have been known to utilize a 3-core cable with the earth used as one of the lives. Always check for safe wiring before starting and that earth cables are really earth. If they are connected to what should be a live terminal deal with the safety aspects before faultfinding.

Figure 22 - Example wiring diagram

Figure shows a conventional boiler with cylinder and wall thermostats



Source Wikipedia

'Plans' refer to a number of wiring methods driven by the plumbing components used.

Faults in central heating

It is necessary to differentiate between boiler, plumbing and electrical faults. This book addresses the latter. The starting point is to determine which type of system we are dealing with. Table 2 provides a guide to faults and how to start. It assumes any potential wireless control issues have been dealt with first.

Table 2 - Initial fault finding guide

	Start
	What kind of system is in place? A combi boiler or a conventional boiler? If you have a cylinder (usually in an airing cupboard), then you have a conventional boiler. If there is no cylinder then you have a combi boiler. For combi boilers follow path A. For conventional boilers follow path B.
	Path A – combi boilers
A1	*Has both the heating and hot water stopped working?* If both have stopped then check power to the boiler and the pressure in the system. If there is no power check the RCD/MCB/fused spur. Reset the RCD/MCB / replace the fuse. If one blows again you have boiler fault and need a Gas Safe registered person.
A2	*Is the system pressure within the specified limits?* If the pressure is low re-pressurise the system (see the plumbing fault finding guide).

A3	If only one service has ceased and the controls are functioning (see thermostat fault finding in path B) then the chances are you have a boiler fault and need a Gas Safe registered person. Note that most combi boilers have fault indicators. Use these in conjunction with the manual (most manuals are available as a free download on the Internet).
	Path B – conventional boilers
B1	*Has both the heating and hot water stopped working?* If both have stopped then check power to the timer/programmer. If there is no power check the RCD/MCB/fused spur. Reset the RCD/MCB / replace the fuse. If one blows again you have a component that has failed. The primary candidate is the pump. Go to B2
B2	*Suspect pump failure?* If a faulty pump is suspected isolate the pump at the wiring centre or another convenient point and see if power can be restored. If yes then replace the pump. If not leave the pump isolated and remove the timer/programmer. You should now have power on the AC input terminals on the wall plate. Run a temporary power feed to the pump. If this does not operate correctly replace the pump. If it does operate correctly go to B3. Note: a pump failure will cause poor or no circulation of water. You should be able to 'feel' a pump running by checking the pipe temperature on either side of the pump (beware – these pipes can be hot enough to burn) and/or by placing a screwdriver tip on the pump and

	your ear on the handle of the screwdriver If you think the pump is not operating try changing the speed switch (usually 3-position).
B3	*Suspect timer/programmer?* A system can be operated without the timer/programmer in circuit. With power off install a safe temporary jumper on the timer/programmer back plate between the incoming live and the CH on terminal (refer to Figure 23). Turn the power back on. If the system operates then replace the timer/controller. The hot water side can be similarly tested. Failed pumps have been known to cause the failure of a timer/programmer. Always ensure the pump is functioning before replacing a failed timer/programmer. Electronic timer/programmers usually have back up batteries, often rechargeable. These can fail over time causing the timer/programmer to operate inconsistently or not at all. Such batteries can usually be replaced (see Figure 23).
B3	*Suspect motorized valve?* A failed valve and / or valve actuator usually exhibits one of the following fault conditions: ▪ Heating but no hot water ▪ Hot water but no heating ▪ Cannot turn off heating or hot water. If this is the case see if the valve can be operated

	manually using the mechanical slide as shown in Figure 24. If possible and with power off remove the valve actuator cover and see if it operates when the appropriate timer/controller and thermostat controls are actuated. If it sticks or jumps turn off the power and see if the actuator can be independently removed (many can). If so set the valve manually to the mid-position (3-port valve) or open position (2-port valve) and test the system. Replace the valve actuator or if the valve has also ceased to operate both the actuator and valve – which means a plumbing job.
B4	*Suspect wall thermostat?* Wall thermostats fail infrequently. Although it seems a wall thermostat has failed if it is not possible to control the heating the more likely candidate is the motorized valve, which the thermostat controls. A thermostat can be easily tested with a multimeter as shown in Figure 25. If replacing a wall thermostat ensure a compatible device is used. Some simple stats only have a make/break contact whilst many systems require a changeover contact in order to turn the zone valve off.
B5	*Suspect cylinder thermostat?* Like wall thermostats, cylinder thermostats fail infrequently. A failure would exhibit a no hot water fault. They can be tested in the same way as a wall thermostat.

Figure 23 - Central heating controller

Figure shows a controller in a conventional system

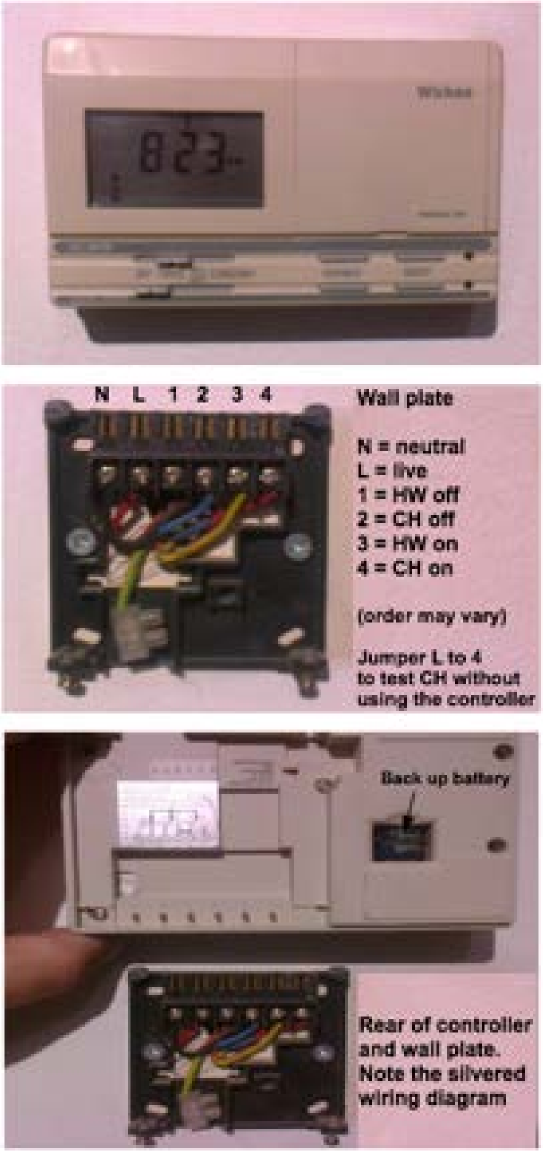


Figure 24 - Typical motorized valve

Figure shows a typical valve with a mechanical override (lever just behind the black cable)

Motorized valves are usually three-port (also know as mid-position) valves as shown above or two-port.

On a three port valve the hot water arrives at the valve at the central port and leaves by either the left, right or when the valve is in mid-position, both ports. One output port will be connected to the cylinder coil circuit, the other to the radiator circuit.

If a valve actuator has failed and can't be immediately replaced remove the actuator and leave the valve in the mid-position (or open position for a two-port valve). The heating and hot water should operate but without the usual thermostatic control.

Figure 25 - Wall thermostat testing

Electro-mechanical wall thermostat with cover removed (above left) and connection plate cover swung open (above right).The changeover switch contacts can be seen to the upper left. These should operate as the stat is turned up and down.

Using a multimeter on the Ohms (200) range to test a wall thermostat with it's cables disconnected. This test can also be carried out with the cables connected and the power off.

Digital wall thermostats operate in a similar way and are provided with 'volt free' contacts, which are independent of the internal electronics.

Storage Heaters

Background and power supply

Storage heaters (commonly known as night storage heaters) utilise electrical power to heat elements that are set inside clay bricks. The bricks store the heat and release it slowly.

The electricity companies have two tariffs that are used where storage heaters are fitted in a household:

- Economy 7. This provides lower cost electricity overnight, typically from midnight to 7am and this is used to run the heaters.
- Economy 10. This provides lower costs electricity over night and in the afternoon for a 'boost'.

In older electrical installations the storage heaters (and usually the lower element in an immersion heater) are supplied from a separate fuse board or consumer unit, fitted with 15A fuses or 16A MCBs. In modern installations there may be only a single consumer unit. Where there is a separate fuse board or consumer unit there will also be an electricity company time switch, which allows power to be provided to the storage heater fuse board or consumer unit only at specified times.

The typical lifetime of a storage heater is 10 to 15 years. Parts can fail sooner. Some storage heaters have two supplies to them:

- The economy 7 or 10 supply
- A second supply to run an auxiliary fan (or fan heater) in the base of the heater to provide additional heat when required during the day (peak charge) period.

This second supply will be from the main fuse board or consumer unit.

A storage heater will typically be rated at between 1KW and 3KW (KW = 1000 watts).

Older versus modern storage heaters

All storage heaters have:

- An input control (electrical), which governs the amount of heat stored.
- An output control (mechanical which allows some control over the rate of heat release).
- Insulation.

More modern storage heaters have improved input controls including a thermostat, which senses the room temperature and reduces the heat if the room is naturally warm. Newer models also have improved insulation, which in turn improves storage and allows greater output control.

What's in a storage heater

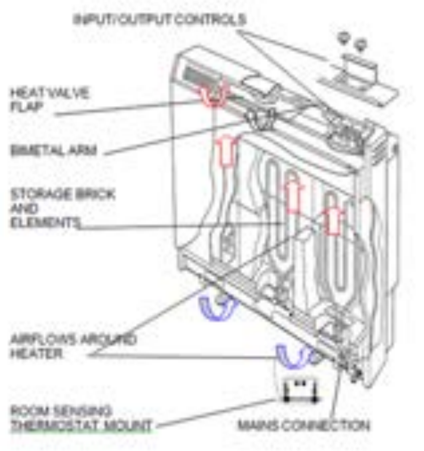
A typical storage consists of:

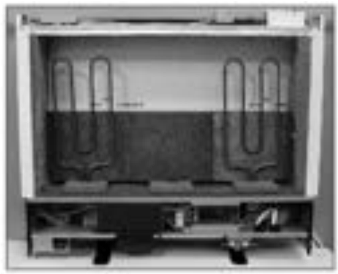
- A thermal fuse (on older heaters) or input cutout. These are designed to deal with the potential problem of a heater being covered.
- An input charge control thermostat.
- A charge limiter (in some models).
- The heating element(s), which for multiple elements are in parallel.

- The cabling, terminal blocks and mechanical parts.

An overview of a typical heater is shown in Figure 26.

Figure 26 - Typical storage heater





The photograph shows a storage heater with the front cover, bricks and one element removed.

Storage heaters with the bricks in are very heavy and should only be moved with the bricks removed. New heaters are supplied with the bricks packed separately.

The diagram for a simple heater is shown in Figure 2 and for a more complex model in Figure 3. Both figures are sourced from Creda.

Figure 27 - Typical storage heater circuit diagram

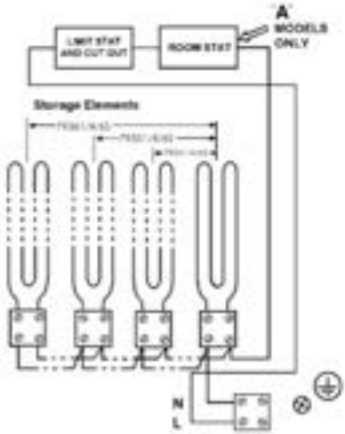
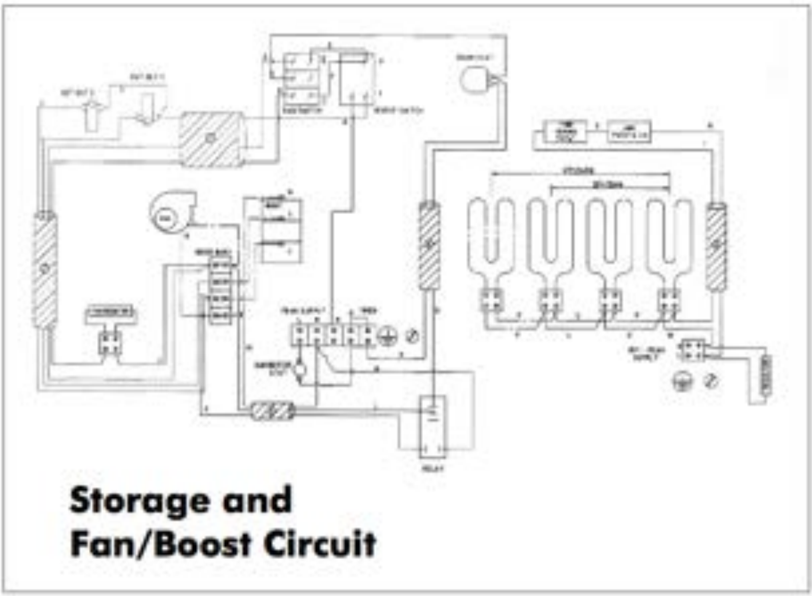


Figure 28 - Storage heater with fan heater built in



Common problems

There are three sets of common problems with storage heaters:

(i) Input cutout tripped or thermal fuse-link blown due to overheating, usually caused by something being placed over the heater. Typically these can be reset. Usually the front panel and top need to be removed. The cutout will be adjacent to or integrated with the controls. Look for a small round device about the size of a penny with a red or white dot in the centre, which can pop up. With the power off push this down, you should hear a click. Re-assemble the heater and it should work on the next charge period. See 'Testing and fault finding' below for how to double check.

(ii) Input charge control thermostat faulty. This can in some circumstances, be caused by a build up of dust. If there is a large build up of dust a good clean (with the power off) is required. If it's still faulty replacement thermostats can often be obtained.

(iii) An element is open circuit. This can be ascertained by measurement with a test meter.

Testing and fault finding

Normally one is fault finding a storage heater when the supply to it is not available during the day. Do double check and remember if it's an economy 10 installation the power may come on – so isolate the heater in all circumstances. Most have an isolating switch on the wall. Also remember that if there is an integrated fan or fan heater then this will have a second supply, which also needs isolating.

It is possible to see if a storage heater will call for power when electricity is available by measuring the 'Ohms' between the live and neutral at the input. Ensure when doing this that the live and neutral are disconnected from the supply; otherwise one is measuring all the heaters and quite possibly an immersion element all via the fuse box or consumer unit.

A 3KW heater should have an input impedance in the region of 19 Ohms, a 1KW heater in the region of 57 Ohms. These figures are only guides.

One can also meter out any input cutouts and thermostats simply by measuring from the main live input through each component in turn to check for continuity.

A note of warning; older heaters can deteriorate (due to constant heating) to the extent that cable insulation and connections literally fall apart when touched. If the heater you are working on is in this condition then it should be replaced.

If you are planning to fault find a working or partially working heater ask a customer to ensure it is turned off the day before. Otherwise it could be too hot to work on.

Finally and as last resort it is possible to connect a storage heater temporarily to a 13 Amp power point. This will allow live testing but be aware of the current the heater will take and the fact that it will not heat up quickly.

Replacing a storage heater

There are a number of points to consider when replacing a storage heater:

- Removal of the original heater. Remove the bricks before trying to lift a heater. Do this before unscrewing it from the wall. Most heaters need a trolley or sack truck to move. There will also be a good deal of dust and old insulation tends to break down. Storage heaters made from 1974 onwards have been asbestos free. There are few heaters of this age in circulation.
- Disposal will need to be via a Hippo Bag or similar with the bricks taken to the bag separately.
- The new heater will be delivered on a pallet, adjacent to the kerb only and with the bricks packed separately.

Moving a storage heater

If you are considering moving a storage heater within a property or to another property then bear in mind that:

(i) You will have to remove the bricks

(ii) The heater needs to be in reasonable condition to tolerate the move

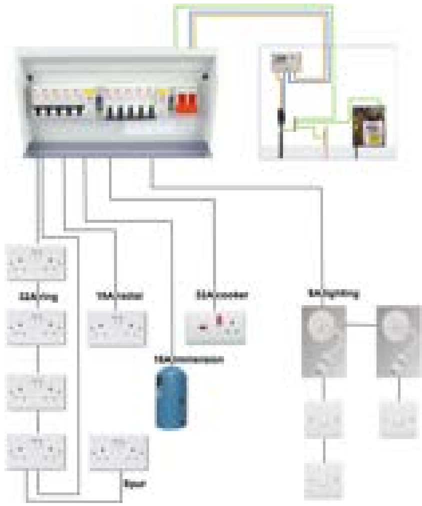
(iii) A power supply in a new location has to be wired back to the storage heater distribution fuse box or consumer unit. You should not connect a storage heater to a ring main or spur from a ring main.

Use of storage heaters

As seen in this guide most storage heaters are very simple. However many end-users do struggle with how to use them. The simple rules are:

- Set the input to about 4-5 – this ensures the heater will charge
- Set the output to 0 until heat is required. Setting the output to a low level prevents a heater running out of stored heat too soon.
- Remember a fan-assisted heater may not have a mechanical flap but could utilise an electric fan to dispel the heat into the room.

Summary - Overview and test equipment

<table>
<tr>
<td>

Multimeters:

AC Volts: identified by
the symbol V~
Resistance: identified by the symbol Ω for Ohms – always power off
Continuity

</td>
<td>
40A (or 50A) - shower
32 Amp - ring main
20 Amp - radial
20 Amp - supply to a shed
16 Amp - immersion
16 Amp – storage heater
32 Amp - cooker
6 Amp - lighting
6 Amp - security alarm
6 Amp - smoke alarm
V = I x R   W = V x I
</td>
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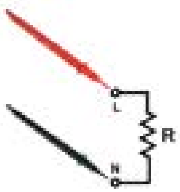
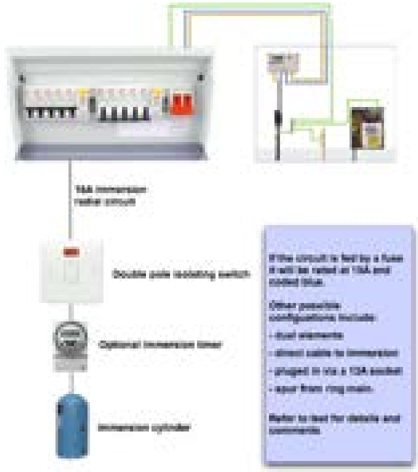
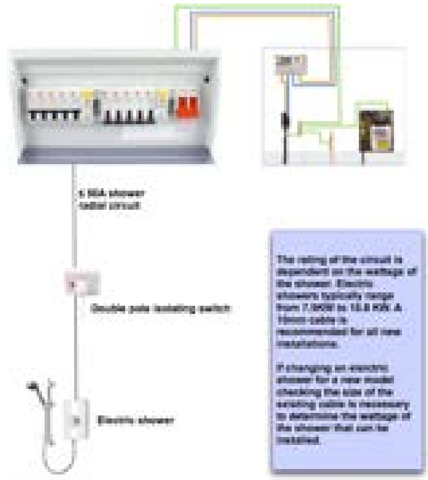
<tr>
<td>

Measuring AC voltage (~)
</td>
<td>

Measuring resistance or continuity (Ω)
</td>
</tr>
</table>

Summary - Water heaters and showers

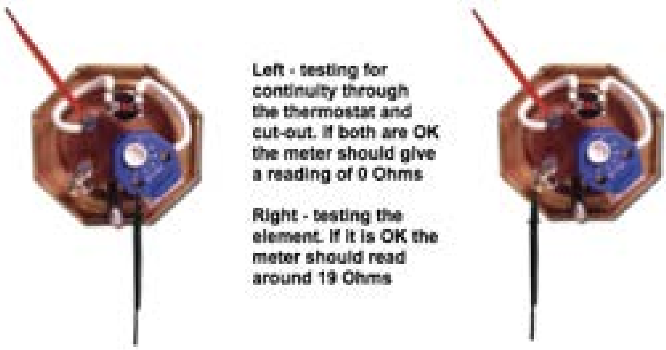




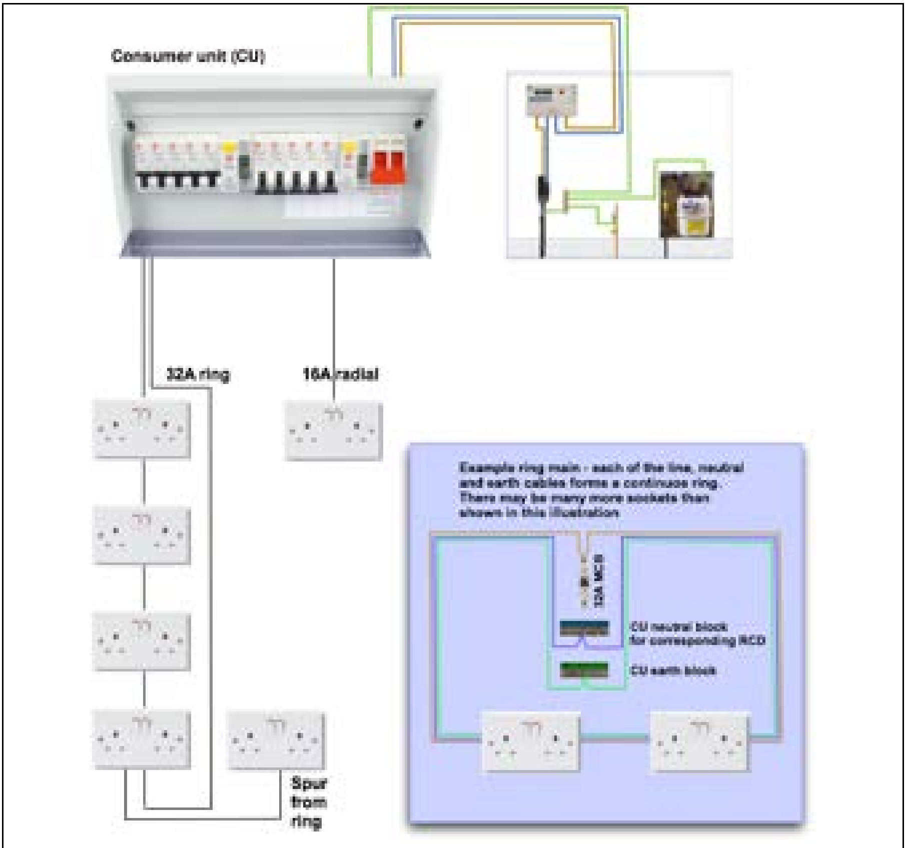
Multimeters:

- AC Volts: identified by the symbol V~
- Resistance: identified by the symbol Ω for Ohms – always power off
- Continuity •)))

Shower consumer unit with RCD (left) and MCB (right).



Summary - Ring mains, RCDs and MCBs

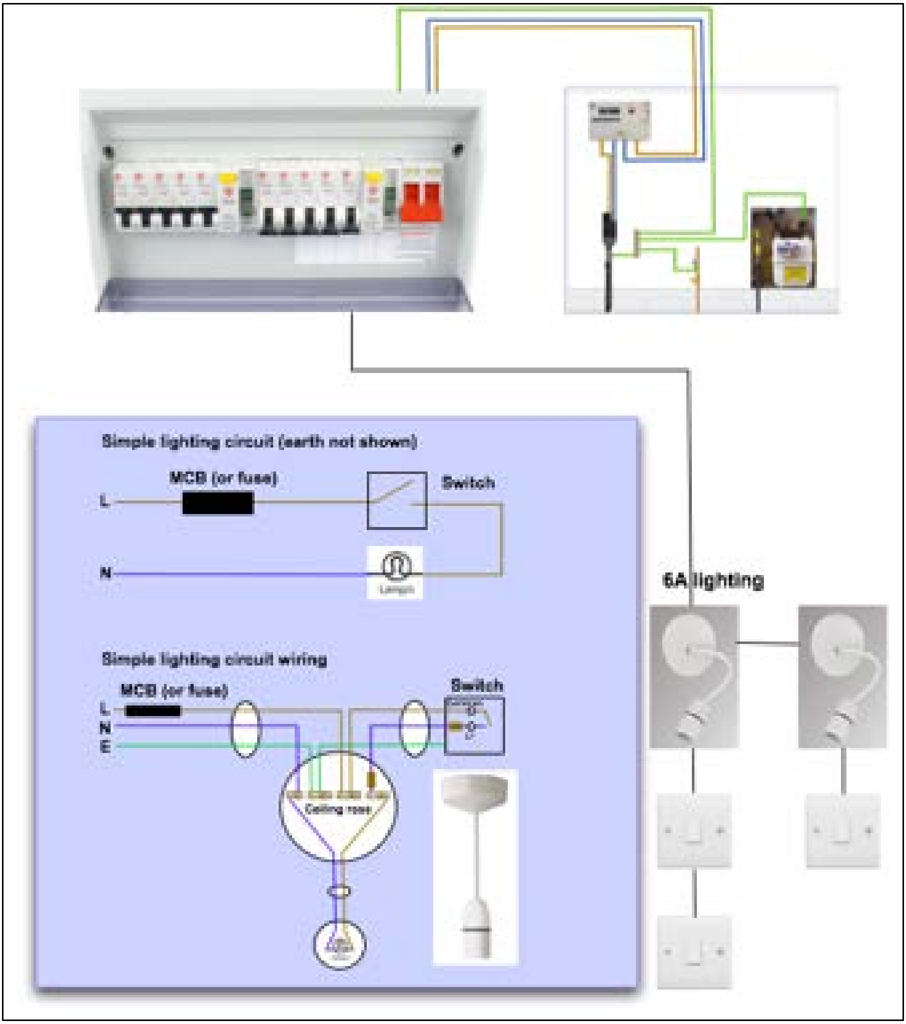


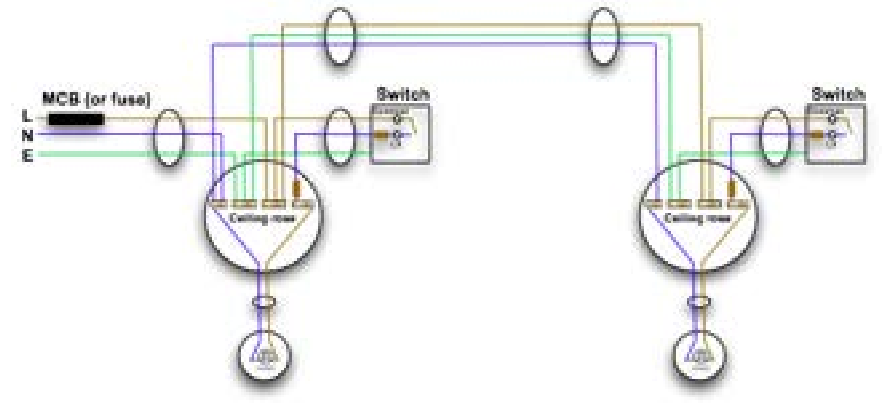
Left to right – RCD, MCB and RCBO.

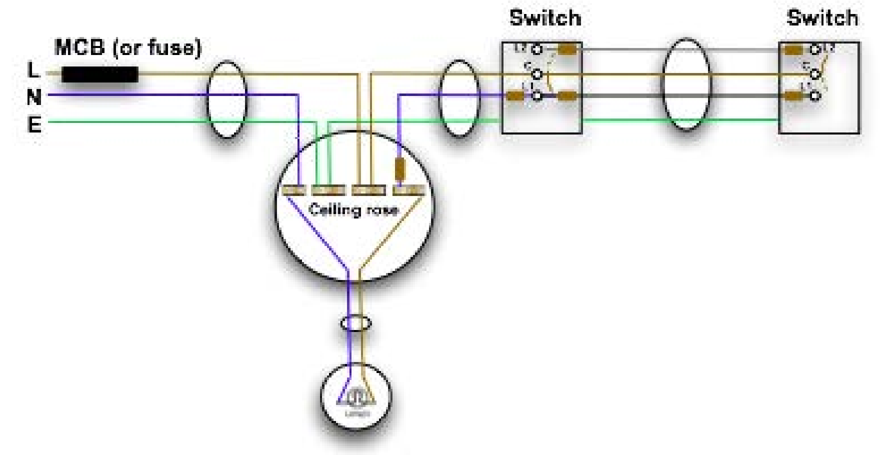
Multimeters:

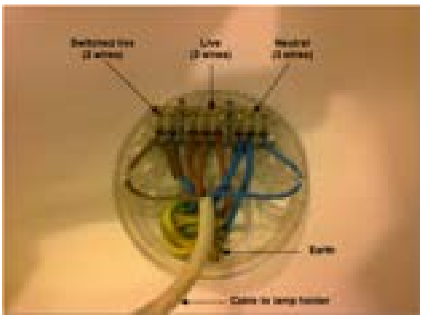
- AC Volts: identified by the symbol V~
- Resistance: identified by the symbol Ω for Ohms – always power off
- Continuity •)))

Summary - Lighting







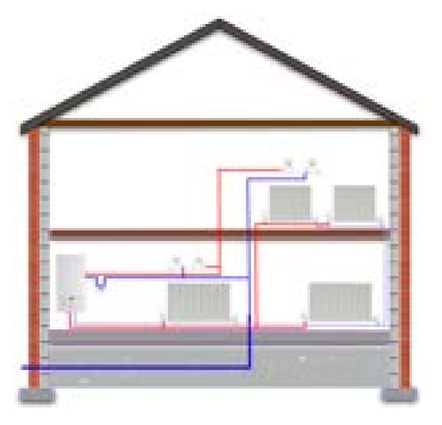
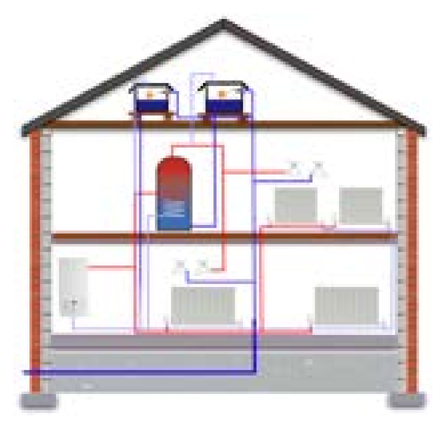


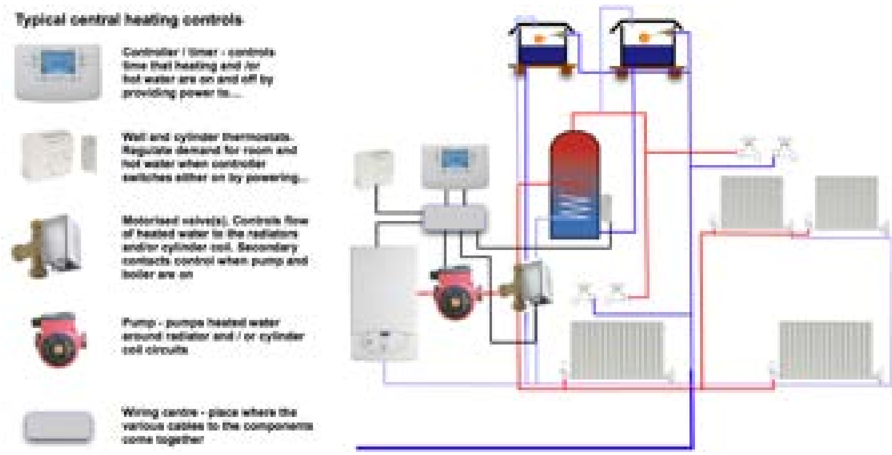
Multimeters:

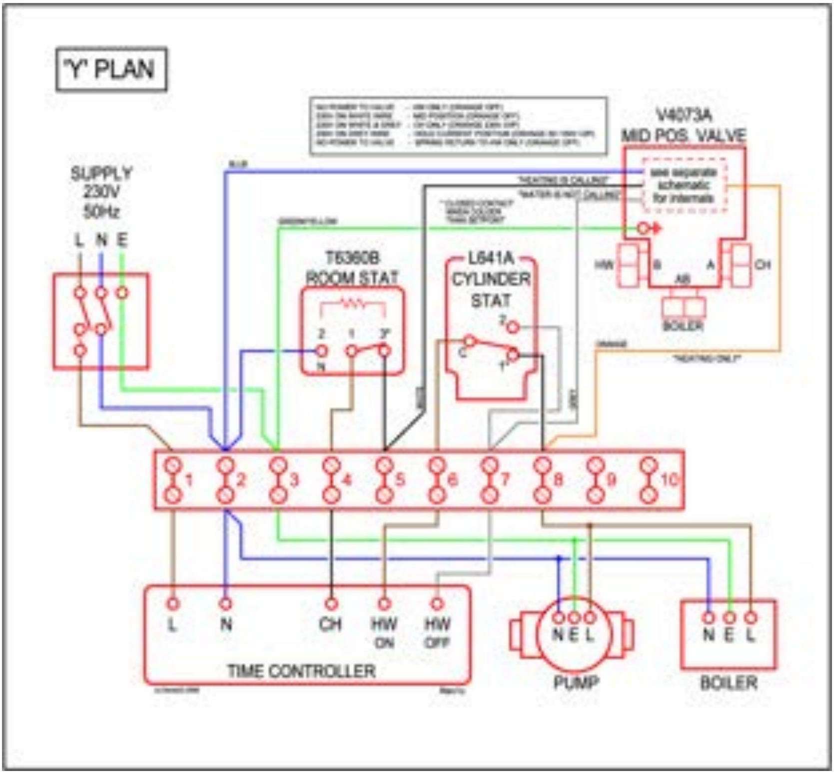
- AC Volts: identified by the symbol V~
- Resistance: identified by the symbol Ω for Ohms – always power off

Continuity

Summary - Central heating

Combi sealed system	Conventional system
	




"Y" PLAN
V4073A
MID POS. VALVE
see separate schematic for internals
SUPPLY
230V
50Hz
L N E
T6360B
ROOM STAT
L641A
CYLINDER
STAT
HW
CH
BOILER
1
2
3
4
5
6
7
8
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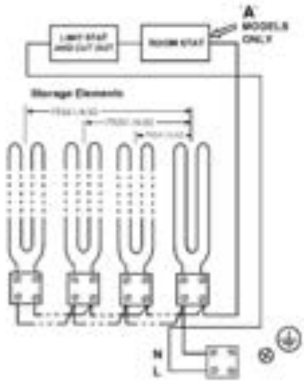
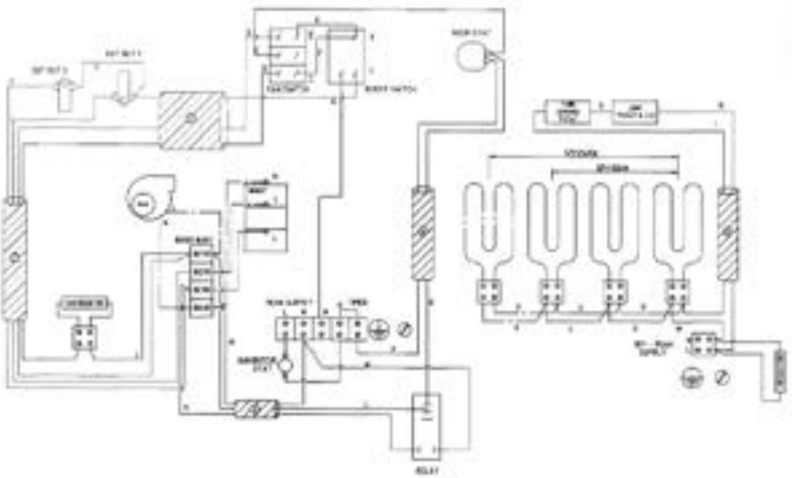
L
N
CH
HW ON
HW OFF
TIME CONTROLLER
N E L
PUMP
N E L
BOILER

Summary – Storage Heaters





Storage and Fan/Boost Circuit

END