Royal Conservatoire of Scotland

Electrical Basics for Theatre

Electricity is dangerous, invisible, and potentially deadly. Treat it with respect.

What is electricity?

Electricity is the flow of electrons in a conductor. In many ways, this flow of electricity behaves similarly to the flow of water. The equivalent of the water pressure is the Electro Motive Force, or potential, which we measure in Volts. The flow of electrons, the current, is measured in Ampères. Just like pipes of different sizes would make it harder or easier for water to flow, different types and sizes of conductors affect the resistance of a circuit, measured in Ohm. The relationship between resistance, current and voltage is called Ohm's law, after Georg Ohm (1789-1854). This is an extremely useful formula and well worth remembering:

$V = I \times R$ or $I = \frac{V}{R}$ or $R = \frac{V}{I}$

Where V is the potential (measured in Volts [V]), R the resistance (measured in Ohm [Ω]), and I is the current (measured in Ampère [A]).

Power is a measure of energy and is measured in Watts. To calculate the power in a circuit you need this formula:

$P = V \times I$ or, using measures: $W = V \times A$

Where P is the power (measured in Watts [W]), V the potential (measured in Volts [V]) and I is the current (measured in Ampère [A]).

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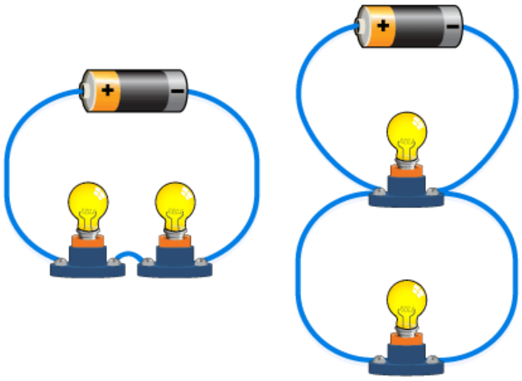
In order for electricity to flow there needs to be a complete circuit. There are two basic kinds of circuits, parallel and series.



The main practical difference between the two is that in series circuit, when the flow of electricity is broken by one blown lamp, the whole of the circuit stops working, whereas in a parallel circuit the remaining part still forms a complete circuit and therefore carries on working.

In a series circuit, the voltage is divided evenly between the components, in a parallel circuit the voltage is the same for each component. For example if the battery in the example above was a 1.5V AA battery, each lamp in the series circuit would receive 0.75V, each lamp in the parallel circuit receives 1.5V.

There are two basic kinds of electricity supply, DC (Direct Current) and AC (Alternating Current). In a DC circuit electricity flows evenly in one direction, for example in batteries. In an AC circuit the electricity reverses direction in frequent intervals. The frequency of these intervals is measured in Hertz (Hz). That means that a lamp on a standard circuit in the UK is actually constantly flickering as it is being switched off and on 50 times per second as the flow of electrons changes direction. But because it flickers so fast, it appears to the human eye as if it was continuously lit.

Basic supply voltage in the UK is 230V (+10% - 6% tolerance), 50Hz AC (alternating current). Until 1995 it was officially 240V, but was changed to 230V to harmonise it with other European countries. The actual voltage delivered hasn’t changed, most households still get 240V, which is within the tolerance. Similarly, most households for example in Germany still get 220V as they did before 1995, though officially the voltage is the same as it is here. The tolerance allows for these discrepancies and equipment works fine within these parameters. You’ll find that lamps last a little longer in lower voltage supply areas and are a little dimmer, but without direct comparison, you are unlikely to notice a difference.

The US have 120V/60Hz as their standard supply.

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Three Phase Power

The way power is generated in a power plant results in a so-called three phase power supply. A generator converts mechanical power into three sets of AC current, one from each coil of the generator. The coils are offset by 120º resulting in the current created being offset by one third of a complete turn, thus creating three "phases".

Power is supplied in three phases, colour coded brown (L1), black (L2) and grey (L3), with blue for the neutral and green/yellow for the earth. This colour coding has been introduced in 2006, you will still find the old colour coding in many places, which is red (L1), yellow (L2) and blue (L3), with black for the neutral and green/yellow for the earth.

	Earth	Neutral	L1	L2	L3
OLD	Green/ Yellow	Black	Red	Yellow	Blue
NEW	Green/ Yellow	Blue	Brown	Black	Grey

You can see that it is very important that you know which colour scheme is being used so you do not get the neutral mixed up with a phase.

The potential between two phases is 400V. A normal household would be supplied by one single phase, so the potential in the house can never be more than 230V. Places that require more power will be supplied with a three-phase supply. If a fault was to occur on two pieces of equipment supplied by two different phases, it is theoretically possible that the fault potential would be 400V. This would almost certainly be lethal.

That is why we generally try to use different phases in different areas. A common distribution would be L1 for FOH, L2 for flown rig on stage and L3 for all the floor power. It is usually not possible to completely separate the phases, but we do try and minimise crossover.

Especially in the studio spaces the separation becomes almost impossible.

We should also try to load the phases as equally as possible. This reduces the amount of current carried on the neutral and avoids overheating of parts of the system. Again, this is not always possible and will vary from scene to scene.

A three phase cable has 5 wires, one for each phase, one neutral and one earth.

A distribution box would look something like this:

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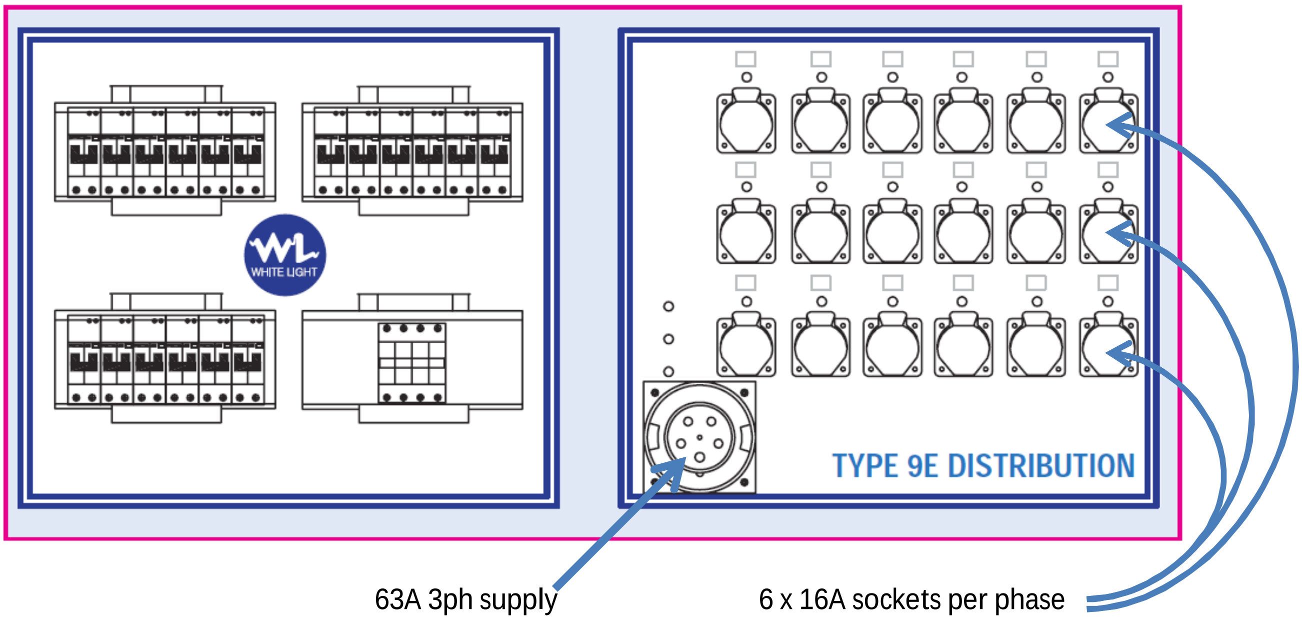
Input: ....63A 3Ø chassis
Protection: ....4 pole isolator
O/P: ....18 x 16A 1Ø CEE17, 6 per phase
Protection: ....16A Type C RCBO per socket
Earth point provided on distro



Protection

Most electrical equipment is earthed. This means that any metal parts of the casing that in a fault condition could become live are connected to the earth via an earth bond. Since Voltage is a measure of potential, it means that if due to a fault the case carries 240V, because of its connection to earth the ground you stand on and with it yourself also carry 240V, thus making the potential (difference in voltage between two points) 0V, therefore harmless.

The simplest form of protection is the fuse. It acts as a circuit breaker in the event that the load exceeds the rating of the fuse, which should be related to the thickness of the cable and the available supply. For example if you were to plug two kettles into an extension with a fused 13A plug on the end and each kettle draws 3kW, the fuse will blow (13A * 240V = 3120W).

An MCB fulfils the same purpose (overload protection), but rather than needing to replace the fuse after removing the overload, it can just be switched back on.

Generally all equipment used on stage should be protected by an RCD (Residual Current Device). This is a device that measures the difference of current going into a circuit against the current coming out. If the difference is too great, the device cuts the power, usually within 30-50ms. It can also be combined with an overload protection, which would then be called an RCBO.

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All appliances used in theatre need to be PAT tested annually. PAT stands for Portable Appliance Testing. Pretty much anything that is mains powered and not permanently hard wired into a supply comes under the term “Portable Appliance”, even when it isn’t really portable (washing machines etc).

PAT testing only covers electrical safety, not functionality, so it is possible to have equipment that passed a PAT test and does not work.

Connectors

The most commonly used connector in every household in the UK is the 13A connector.

Because it has a fuse inside the plug it is less commonly used in theatre lighting. The fuse would create a major inconvenience when fault finding in a large rig.

Instead most theatres use 15A connectors, which are very similar to 13A connectors but with round pins and no built in fuse.

Two split a circuit and “pair” several units into the same supply you can use “Grelcos” or “Trelcos” (like a Grelco but with three outlets) or “Squellies”.

Another type of connector frequently found in theatres, especially on units with particularly high power consumption, is the 16A CEE form connector.

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These have the benefit that they have a higher IP rating (if wired correctly the connector is safe to use outdoors in the rain), and the plug locks in with the lid of the socket, creating a very solid connection.

Three phase connectors are either CEE form (up to 125A)or powerlock (up to 400A):

 

Very often 15A or 16A connectors are pooled in groups of 6 to form multicores. There are two basic types of multicore, one is called Lectriflex (also sometimes referred to as Harting after a manufacturer), the other one is called Socapex. We only use Socapex here at the Conservatoire:

There are both male and female “fan-outs” or “spiders” to connect 15A plugs and sockets either end.

Appliance connectors:

Most lanterns have their electrical supply lead (“tail”) hard wired to the inside of the lantern. Some however do use connectors. Often these are so called IEC leads, or kettle leads. The term IEC lead is slightly misleading, since a lot of connectors fall under the IEC standard. We generally use the term for the IEC C15/C16 connector, which you’d commonly find on a kettle or other appliances that get hot.

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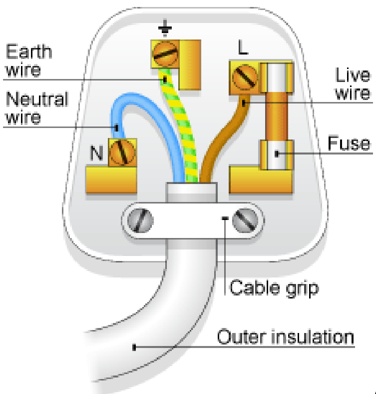
There is also a variation called the IEC C13/C14 conector, which is almost the same except it hasn't got the little notch on the long side. You'd find this on any appliance that doesn't get hot (computers etc).

A lot of the more recent lighting fixtures, especially LED ones, now come with a Powercon connector.

This looks similar to a Speakon connector but is shaped so accidentally cross plugging it with a Speakon is impossible. Often low powered LED fixtures have a Powercon in and output, which allows for daisy chaining, so a number of units in a row can be powered from one non-dim supply.

All connectors have the same conductors, which are Live, Neutral and Earth. Which of these goes where is clearly marked on the inside of each of the above connectors.



(Picture stolen from bbc.co.uk)

The colours used in UK wiring are:

Colour	Wire
Brown	Live
Blue	Neutral
Green/Yellow	Earth

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Cable Rating Guide

Flexible Mains Cable

- TRS = Toughened Rubber Sheath
- PVC = Poly Vinyl Chloride
- TSR = Toughened Silicone Rubber

Cross Sectional Area	Current Rating
0.5 mm	3A
0.75 mm	6A
1.0 mm	10A
1.25 mm	13A
1.5 mm	15A
2.5 mm	20A
4.0 mm	24A

Electrical Installation

- Conduit cable
- armoured cable
- mineral insulated cable
- Surface wiring (Twin & Earth)

CSA	Current Rating
1.0 mm	13A
1.5 mm	17A
2.5 mm	24A
4.0 mm	32A
6.0 mm	41A
10.0 mm	55A
16.0 mm	74A
25.0 mm	97A

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