Learning resource

Select and install flexible cords and cables

Level 2 | Credits 4

Te Pūkenga

Contents

Flexible cords and cables

If you got a piece of ordinary flat TPS and wired it into your electric hand drill, it wouldn't be many days before the copper conductors broke from all the bending.

TPS is great for house and building wiring where it doesn't flex but no good for a hand drill.

In applications where a cable gets moved and flexed, flexible cords and cables come into their own.

Flexible cables

Photo by Graeme Jeffrey

AS/NZS 3000 1.4.20 defines a flexible cable as - 'A cable, the conductors, insulation and covering of which afford flexibility'.

A typical application for a flexible cable would be the trailing cables that feed an elevator cage.

Though all cables have some degree of flexibility to allow them to be installed, only flexible cables will last in these situations.

Cables may be required to resist environmental conditions such as direct sunlight, moisture and extremes of temperature.

Other installations may require cables to resist various chemicals, mechanical damage or fire.

Commonly, copper and aluminium are used for conductors and these can be made into single solid or stranded cores as required.

Flexible cords

A flexible cord is defined as a cable in which the individual wire strands are smaller than 0.31mm diameter, and the overall stranded conductor in the cord is smaller than 4 mm2 cross sectional area.

Once the conductor cross sectional area in a flexible cable exceeds 4 mm2, it is no longer referred to as a cord.

Also, a flexible cord cannot have more than 5 cores in the sheathing (AS/NZS 3000 1.4.36).

The most common types of flexible cord for electrical work are:

- Textile braided overall - includes un-kink-able cords.
- Light duty, sheathed
- Ordinary duty, sheathed
- Heavy duty, sheathed
- Single core, unsheathed

A flexible cord consists of very small individual strands of copper wire, making up a flexible conductor core which is then insulated. Up to 5 cores are combined and a sheath of insulation is put around the outside.

The thickness of the sheathing governs the duty type of the cord, a thin sheath being light duty, then there is ordinary duty and heavy duty.

The 'size' of a flexible cord is usually expressed as the cross sectional area (in mm^2) of each of the individual cores.

Photo by Graeme Jeffrey

The conductor cores in a flexible cord may have a cross sectional area of 0.75 mm^2 and it would be referred to as 0.75 mm^2 flex.

Cords can also be referred to by stating the number of strands and diameter of each strand in each core. A common type of 0.75 mm^2 flexible cord could be referred to as 24/0.20 (24 strands, each 0.2mm in diameter).

Each core in a flexible cord is the same size. Some types of flexible cord have a greater number of very small strands of smaller wire to provide even greater flexibility, even though the overall cross sectional area may be the same as other types.

The most common types of flexible cord used for portable electrical appliances, range in size from 0.75 mm^2 to 1.5 mm^2 with two or three sheathed cores.

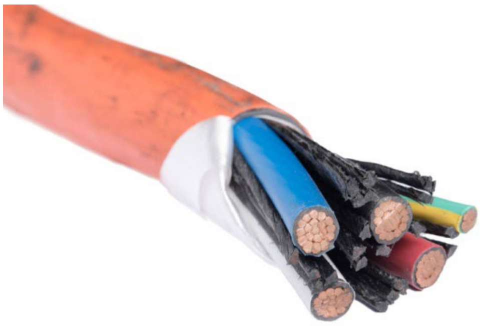
In some situations, bare copper can be subject to corrosion and it is here that other metals such as tin and nickel are used to coat individual copper strands.

This significantly increases their resistance to corrosion without adversely affecting their electrical properties.

Photo by Graeme Jeffrey

Cable construction

Basic cables have one or several insulated conductors encased in a sheathing material (like 2.5 mm^2 twin + earth TPS). Many cables also have other components such as fillers, binders, strength members, shields and armouring incorporated into their structure.



Fillers, Binders, Binder shells, strength members

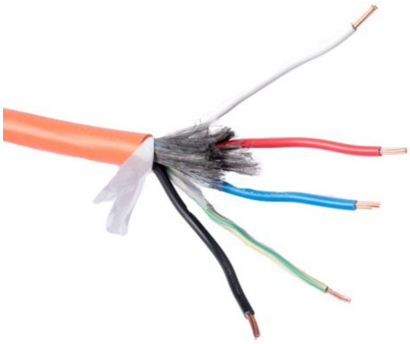
Fillers

Fillers “fill” the gaps between individual conductors and help maintain the shape of the cable. They can also add strength to the cable and secure the position of each conductor in the cable.

The temperature rating of the cable will determine the product used to make the filler.Fillers can be solid plastics, foamed plastics, paper as well as cotton, rayon and Kevlar fibres.

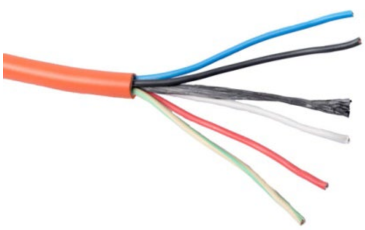
Binders

Binders are often made from nonwoven polyester or PTFE for higher temperatures, and are used in cables to improve the flexibility or shape uniformity of the cable. They are also used to prevent wear on the core material from flexing and to improve the insulation and heat resistance of the cable.



Fillers and binders in a cable

Strength members



Strength member cable

Strength members are sometimes added to improve a cables strength against stretching under physical load.

Strength members are usually found in the centre of the cable and can be made of synthetic or natural fibres and sometimes even metal.

Fiberglass, fiberglass reinforced plastics and carbon fibres are sometimes used for strength members.

Flexibility, high mechanical strength, light weight, resistance to abrasion and temperature are taken into account when the cable construction is being designed.

Shields

Shielding is a conductive layer built into a cable which is designed to reduce the effects of electromagnetic radiation entering or leaving the cable.

Shielded power cable

Armouring

Steel Wire Armoured Cable

To provide mechanical protection for cables used in tough heavy-duty environments, armouring made of multiple steel wires is wound in a spiral pattern around the cable.

The armour sits just below the outer sheath of the cable and above a layer of insulation.

Manufacturer's information

Cable manufactures provide information about their cables such as operating voltages, temperature ratings and conductor type and size.

Further cable specifications, such as those below, can be found in the manufacturer's technical data publications:

- overall cable dimensions
- resistance to direct sunlight
- chemical or water resistance
- weight of cable per unit of length
- mechanical properties of insulating materials
- minimum bending radius of cables
- chemicals released when combusted

Different manufacturer's specification tables vary in detail, so it is important that you get the appropriate tables for the particular cable that you are using.

An example is shown on the following page. It is the characteristics from Nexans for their PVC Flexible Cord.

Characteristics

CONSTRUCTION CHARACTERISTICS

Conductor material	Flexible Copper
Insulation	PVC
Outer sheath	PVC

ELECTRICAL CHARACTERISTICS

Rated Voltage Uo/U	250/440 V

USAGE CHARACTERISTICS

Maximum operating surface temperature	60°C

SPECIFIC CHARACTERISTICS

Docs and info

CORE COLOURS

No. of Cores	Colour
2	BN, BU
2 (Plus Earth)	BN, BU, GNYE
3 (Plus Earth)	BN, WH, BU GNYE
4 (Plus Earth)	BN, WH, BU, BK, GNYE

ELECTRICAL PERFORMANCE DATA FLEXIBLE CORDS

Conductor Cross Section mm²	Current Carrying Capacity (Amps)	Voltage Drop Single Phase (mV/A.m)	Voltage Drop Three Phase (mV/A.m)
0.5	3	90.3	78.2
0.75	7.5	60.2	52.1
1	10	45.2	39.1
1.5	16	30.8	26.7
2.5	20	18.5	16.0
4	25	11.5	9.92

The values in the above table are based on typical New Zealand conditions of:-
Ambient Air Temperature 25°C

Selecting cables

Obviously, you must select a cable or cord that can cope with the environment that it will be used in.

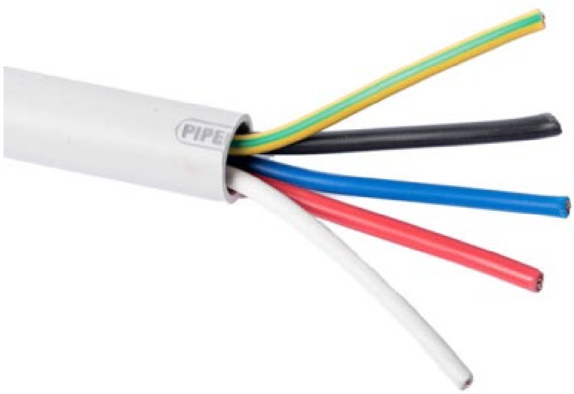
When selecting cables or cords, there are a few things you need to consider such as the environment in which the cable will be required to operate in.

You may need to consider things like:

- Oils and chemicals.
- UV light.
- Temperature (hot or cold).
- Movement, vibration or flexing.
- Mechanical damage.
- Short circuit ratings.
- Voltage ratings.
- Current carrying capacity.
- Volt drop.

Examples of cords and cables

Conduit wire



Thermoplastic insulated in conduit

Single core insulated cables without a sheath are called conduit wire (sometimes referred to as building wire).

A few strands make up the conductor then coloured polyvinylchloride (PVC) is used as the single layer of insulation.

Conduit wire is manufactured in a range of sizes and is often used for wiring in enclosures such as internal switchboard wiring.

Restrictions:

Conduit wire must be installed with extra protection, such as conduit, if it is to be used for subcircuit wiring as it only has one layer of insulation.

Tough plastic sheathed cable (TPS)

Tough plastic sheathed cable is probably the most common type of cable available in the electrical industry and is used for fixed wiring in installations. TPS cables have both conductor insulation and a layer of sheathing over the top, usually manufactured from PVC.

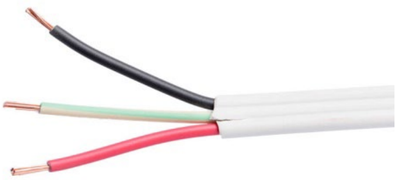
This cable is said to be double insulated as there are two layers of insulation material protecting the conductors. PVC is one of several types of thermoplastic insulation used in the electrical industry.

All thermoplastics soften when heated and harden when cooled, so thermoplastics have a defined operational temperature range, operating a cord or cable outside this temperature range will compromise the insulations integrity.

The white sheathed flat TPS cable in the photo is not a flex as its cores have larger strands of copper.

It has multiple stranded conductors with coloured PVC primary insulation then a flat PVC insulation is used as the outer sheath.

These TPS cables are used for lighting and power circuits in domestic, commercial and industrial installations where they are not subject to movement or mechanical damage.



Fixed wiring flat TPS cable

TPS comes as a flexible cord as well and is one of the most commonly used flexes for appliances, power tools and extension cords. The black TPS cable in the photo is a flexible cord with many very small strands of copper. TPS flex comes in a range of colours like white, orange, yellow, green etc.

TPS flexible cord

Restrictions:

Standard V-75 (75^0 C maximum operating temperature) or V-90 TPS should not be used in ambient temperatures of less than 0^0 C as the insulation becomes brittle and will shatter under stress in freezing conditions.

These cables must also be protected from external influences such as UV radiation and shouldn't be used around chemicals or oils as they can damage the insulation.

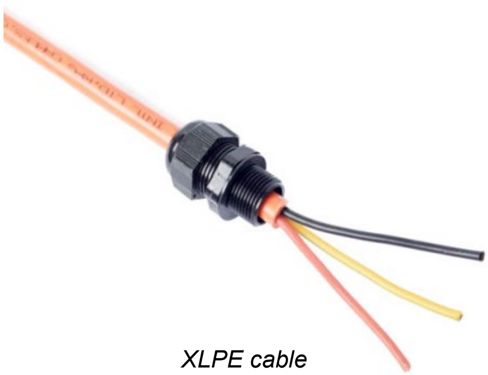
The PVC plastic commonly used in standard cable insulation can also be destroyed if it is in contact with styrene, Styrofoam, polyurethane and bituminized building papers.

If you need to install a PVC cable near these types of building materials, it will need to be either prevented from touching them or a cable manufactured to cope with contact must be used.

You may have seen this cable, it is often coloured purple and sometimes other colours like green.

Photo by Graeme Jeffrey

Cross linked polyethylene



XLPE cable

Cables insulated with Cross linked polyethylene (XLPE) can have slightly smaller dimensions compared to PVC insulated cables as XLPE is a higher temperature insulation material.

XLPE also remains flexible at low temperatures and is resistant to stress cracking and aging.

Cables insulated with XLPE have higher current carrying capacities (CCC) than equivalent size PVC insulated cables and can withstand temperatures up to 250^{0}C.

They have much higher insulation properties and are far more moisture resistant making them suitable for medium range voltages.

Due to their all-round better performance than TPS cables, XLPE cables are usually considered for electrical installations where the cable could be subjected to periodic overload.

Restrictions:

The XLPE insulation is used around the cable cores and is not mechanically strong enough to comply with AS/NZ standards for use as the external cable sheathing. Some XLPE sheathed cables are available but are not compliant and must not be installed in New Zealand.

Also, XLPE cables must not be bent too sharply and the manufacturers minimum bending radius' must be observed. If bent too sharply the XLPE insulation may be damaged.

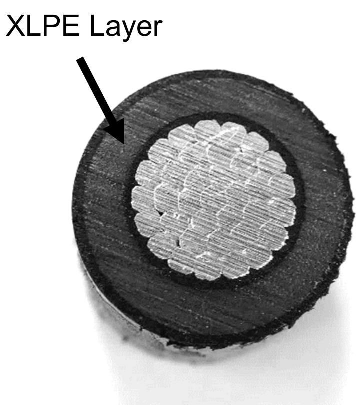
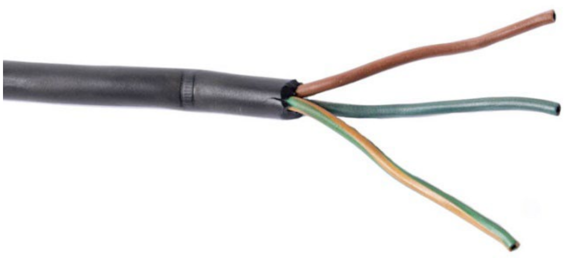


Photo by Graeme Jeffrey

Elastomeric insulated



Elastomeric insulated cable

This insulation is synthetic rubber based and includes EPR (Ethylene Propylene Rubber), PCP (Polyclorophospat) CSP (Cross section polyethylene) and Silicon rubber.

Elastomeric insulation is very flexible and can allow for tight bends in cables.

Silicon rubber can have operating temperatures of 150^0 C or more and is often used in high temperature situations that would damage other insulation types.

Tough Rubber sheathed (TRS) cables are used in areas where abrasion resistance, corrosion and water resistance are required.

Braided textile cord

These cords have both practical and decorative uses including pendant lighting and heating appliance cords.

When used with appliances such as clothes irons, this cord offers protection from accidental contact with the heating plate surface as the fabric does not transfer heat energy readily.

Braided cord

Mechanical protection

In some installations, protection against mechanical damage of a cable is required.

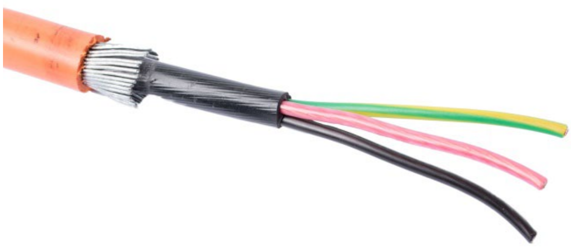


Photo by Graeme Jeffrey

Steel wire armoured cable (SWA) has internal insulated conductors that are then sheathed with insulating material.

A layer of steel wire then surrounds this sheathing and is itself covered with a layer of sheathing to complete the cable.

Restrictions:

The armour is not to be used as a phase or a neutral conductor.

These cables have to be terminated with specialized metal glands that mechanically (and electrically) secure the armouring to the point of connection at either end of the cable.

Neutral screened cable

A neutral screened cable is constructed with the insulated phase conductors located in the centre of the cable.

Next, an insulating sheath is fitted over the central conductors. Then bare copper conductors are spiralled in a "screen" around the cable.

The copper screen is generally used as the neutral conductor, if not, it is to be earthed.

An outer sheath of either PVC or XLPE insulation is fitted over the screen to complete the cable structure.

This type of construction creates a strong cable that if accidentally cut into, causes contact with neutral first.

Neutral screened cable

This gives some additional "user" protection over some other types of cables. They are very good for use as underground mains cables in particular.

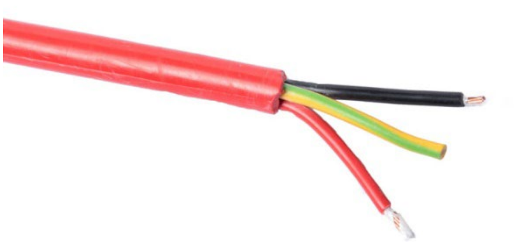
Neutral screened cables are available with both copper and aluminium conductors. Large neutral screened cables can have aluminium phase conductors and copper screen conductors.

Restrictions:

As with any standard PVC insulated cables, neutral screen cables need to be kept away from oils, chemicals and polystyrene.

Fire performance cables

Insulation material on cables can emit large amounts of smoke containing highly toxic and corrosive gasses when they burn. This poses a serious threat to human life in a fire emergency.



Fire stop cable

Halogen free cables that don't give off corrosive gasses and create very little smoke when burning, are a more modern innovation.

These cables do not spread flame and will extinguish when the fire source is removed.

The cables are not designed to continue to function for any time in a fire situation, they are just not going to contribute to the poisonousness of the fire.

In a fire emergency, there may be some essential services such as fire detection, fire protection systems, smoke ventilation systems and emergency lighting that need to be maintained for a period of time.

Cables designed to continue to operate when exposed to fire use high performance polymeric material for insulation and sheathing materials. Conductors can also be covered with a Mica-glass tape flame barrier.

Mineral Insulated Metal Sheathed (M.I.M.S) cables are often chosen for continued service during fire or in very hot environments such as in boiler houses.

MIMS cables have a copper tube as the sheath, and can have a layer of PVC on top of that again. The conductors are surrounded by tightly packed magnesium oxide powder and the cable can withstand very high temperatures.

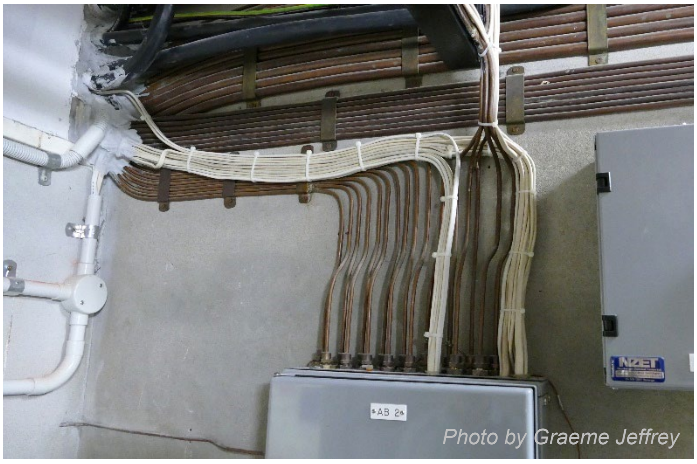


Photo by Graeme Jeffrey

Data cables

At the moment, Cat 6 cables are the standard cable for hard wiring computer networks and home phone systems.

Cat 6 cables have twisted pairs of conductors fitting into a spiral plastic former inside the cable. This is to ensure the optimum electron speed for high speed data transfer. The cable is then encased in the outer sheath.

Cat 6 cables lose their performance if they are bent sharply, care should be taken to install them with long gentle curves and to retain the twisting of the pairs up to as close to the terminations as possible.


Photo by Graeme Jeffrey

Restrictions:

As they are extra low voltage cables, Cat 6 cables must not be installed near low voltage cabling.

It is dangerous to have them together because the higher voltages could get through the insulation into the cable so they must be kept away from higher voltage wiring and not run in the same conduit or the same holes in timber.

Shielded cables

Cables designed to carry electrical signals for control rather than high levels of current are often required to be shielded from the influence of magnetic fields produced by other electrical equipment or cables in close proximity to them.

Shielding is also used to contain the signals sent down the cable within the cable itself. This prevents the cable from becoming a source of interference to other cables, electrical equipment or electronic equipment.

Shielding can work by either reflecting a signal or picking it up and conducting the electrical noise to ground.

Electromagnetic shielding comes in four main types:

- Metalised foil
- Braided wire
- Spiral wrap
- Combination

Metalised foil shielding is ideal for data cables as it covers 100% of the conductors. This shielding is often aluminium foil bonded to a polyester or polypropylene film.

To eliminate problems with connecting the shield to ground, a bare conductor in contact with the shield, called a drain wire, is incorporated into the cable.

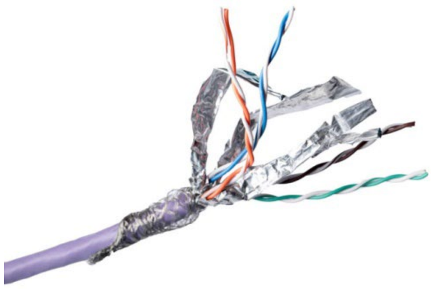
Though effective, this shielding is not particularly flexible or mechanically strong.

Braided shielding uses a woven lattice of bare or coated copper strands and is both flexible and mechanically strong.

Braided screening is most suitable to protect against lower frequency interference (called noise). These cables are heavier than metalized foil cables due to the extra material used in construction.

Spiral wrap involves either a metal mesh or thin conductors wrapped around the cable length.

This system is reasonably flexible and is effective in the audio range of frequencies (20 Hz to 20 kHz).



Combination shielding incorporates metalised foil and braiding which not only improves the cables overall shielding qualities, but also its mechanical properties.

These types of cables are more expensive to manufacture and would typically be used in electrically noisy environments.

Speaker cables

Audio cables have many fine strands of copper surrounded by a single layer of insulation. The strands are often made from oxygen free copper and tinned to improve performance.

Restrictions:

Speaker cables, while useful for audio, cannot be used for power wiring as they are not double insulated and the insulation has too low a voltage rating.

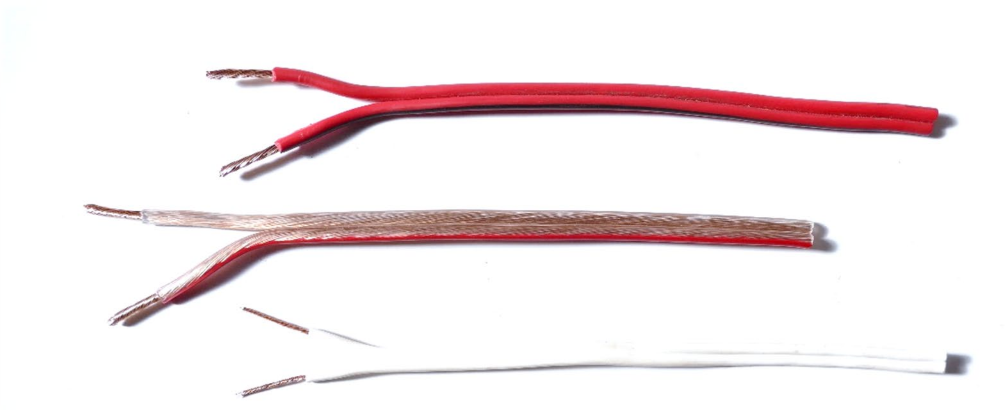
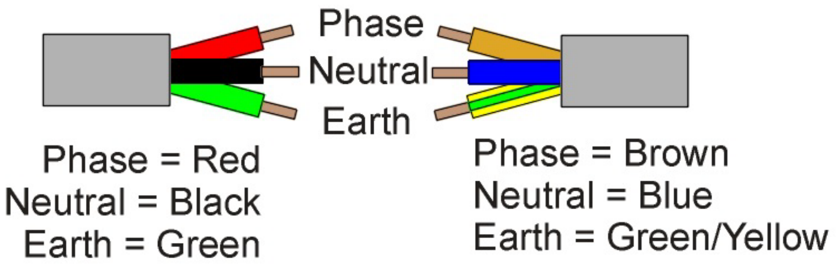


Photo by Graeme Jeffrey

Flexible cord insulation colour

AS/NZS 3000 3.8 covers conductor identification colours. In table 3.4 you can see that green/yellow is used for the earth conductor in both cords and cables.

Single phase cords have a brown phase conductor, light blue neutral conductor and a combination green/yellow earth conductor.



The old colour coding for single phase cords was red for phase, the neutral was black and earth was green.

In a three-phase cord, as there are multiple phase conductors they can be identified by colour or number.

Phase conductors in multi-phase cords can be identified by colour with AS/NZS 3000 recognising red, white and blue as phase conductors in a three phase electrical cord.

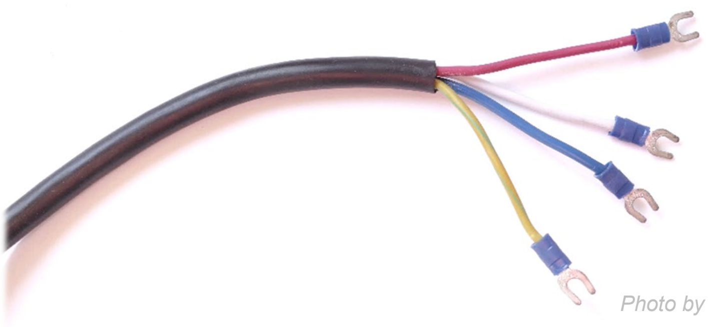
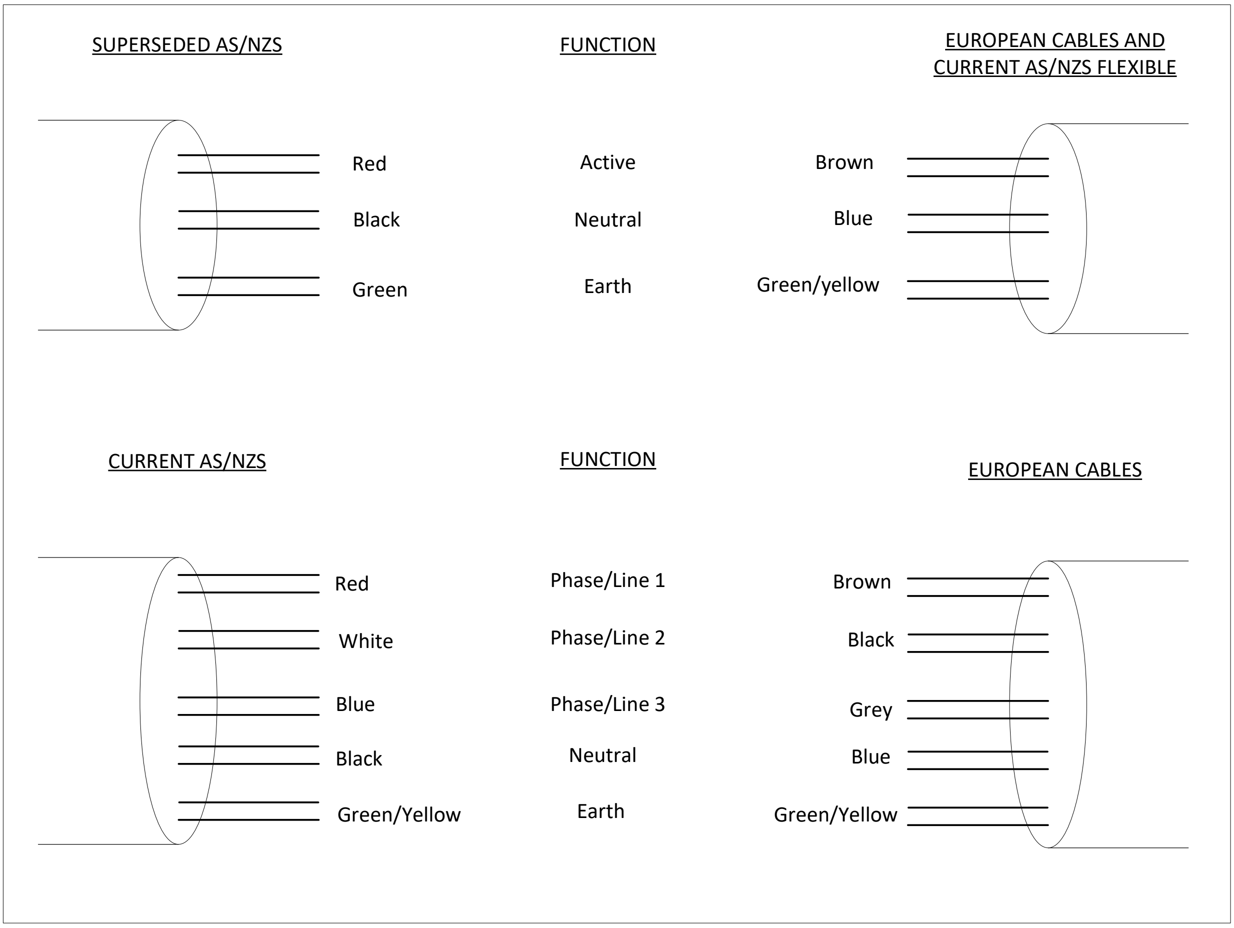


Photo by Graeme Jeffrey

European multi-phase cord colour coding is an alternative accepted by AS/NZS 3000, with brown, black and grey being the phase colours. Neutral is blue, and earth is a green/yellow combination.

> When flexible cords or cables are used for installation wiring purposes (not extension or appliance cords), black and light blue are not to be used as active conductors.

The comparison of conductor insulation colours of multiphase cables manufactured to current AS/NZS Standards, as well as equipment manufactured to typical European practices, is shown below:



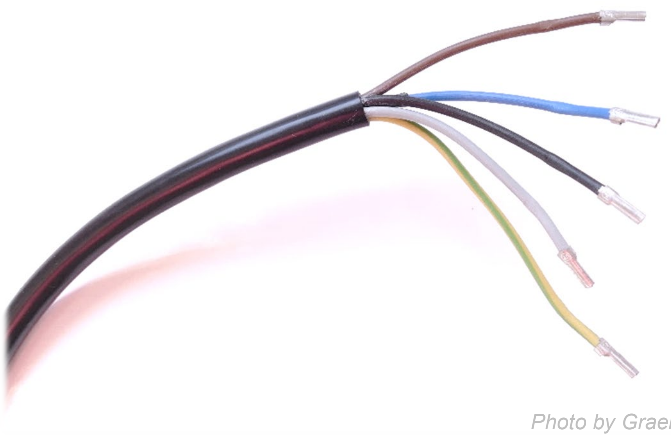


Photo by Graeme Jeffrey

Terminal abbreviations

When terminating cords or cables you will need to understand the terminal abbreviations found on single-phase and three-phase flexible cord and cable accessories.

The table below shows the terminal abbreviations you may come across.

Single phase flexible cord label	Abbreviation	Colour
Phase (or active)	A or L or P	Brown
Neutral	N	Light blue
Earth	⏚ or E	Green/Yellow
Three phase flexible cord/ cable label	Abbreviation	Colour
Line 1	L1 or A	Red (or brown for flex)
Line 2	L2 or B	White (or black for flex)
Line 3	L3 or C	Blue (or grey for flex)
Neutral	N	Black (or blue for flex)
Earth	⏚ or E	Green/Yellow
Terminal abbreviation	Meaning	
U	3 phase motor connection L1	
V	3 phase motor connection L2	
W	3 phase motor connection L3	

Suitable cable types

The table below shows a summary of the common flexible cords and cables that are used in electrical industry and their application.

Type	Nominal CSA of Conductors	Applications
Parallel 2 Core unsheathed	0.5 mm^2	▪ Hand held double insulated (or equivalent) appliances of small current rating, not exceeding 3 amps. ▪ Not allowable for use in damp situations.
	0.75 mm^2	▪ Double insulated (or equivalent) appliances or luminaires where the cord is not subject to rough usage. ▪ For unsupported pendants provided the cord is not subject to excessive temperature. ▪ Not allowable for use in damp situations, temperature
Textile Braided overall. (Including unkink-able cords)	Not smaller than 0.75 mm^2	▪ Any appliance or luminaire where the cord is not subject to rough usage. ▪ Not allowable for use in damp situations. ▪ For unsupported pendants provided that the cord is not subject to excessive temperatures.
Light Duty Sheathed	Not smaller than 0.75 mm^2	▪ Appliance or luminaires where the cord is not subject to rough usage. ▪ For unsupported pendants provided that the cord is not subject to excessive temperatures.
Ordinary Duty Sheathed	Not smaller than 0.75 mm^2	▪ Any appliance or unsupported pendant provided that the cord is not subject to excess temperatures.
	Not smaller than 1 mm^2	▪ Any appliance or unsupported pendant. Flexible extension cord.
Heavy Duty Sheathed	Not smaller than 1 mm^2	▪ Any appliance or unsupported pendant. Flexible extension cord, fixed wiring.

Unsuitable cables

The following table shows some of the commonly used cables that are not suitable as flexible cords.

Their use is restricted due to their special construction and insulation type.

Type	Nominal CSA of Conductors	Applications
Single Core unsheathed (Conduit/ Building wire)	Not smaller than 1 mm^2	▪ Internal wiring of light fittings and other electrical equipment. ▪ Switch boards and control panels. ▪ Requires secondary layer of insulation or enclosures as protection.
Thermoplastic (tough plastic) Sheathed (TPS)	Not smaller than 1 mm^2	▪ Fixed wiring for stationary appliances and equipment. ▪ Mains and sub-mains. ▪ May require mechanical protection when subject to movement, disturbance or compaction. ▪ Not suitable for Flexible application because its conductors and insulation will become fatigued due to movement, temperature and aging.
Cross linked polyethylene (XLPE)	Not smaller than 1 mm^2	▪ Very rarely used as flexible cord. ▪ Where heat from the equipment and the environment may affect the performance of the cable. ▪ Large mains and sub-mains. ▪ Where moisture, chemicals and rugged surface demands a tougher insulation. ▪ Bunched insulated aerial wiring.
Screened		▪ Used for Mains and submains. ▪ Neutral screen protects phase conductors. ▪ Mechanically strong and can take knocks.
Steel Wire Armoured (SWA)		▪ Used in fixed wiring. ▪ Can handle compaction and impacts. ▪ Does not need extra protection in a majority of installations, ▪ The armouring must be earthed at its origin.

Connect to appliances

Flexible cords

Flexible cords are used where electrical equipment is subjected to frequent movement.

Cord entry points into the terminal boxes of appliances or equipment, need to be supported against wear and tear.

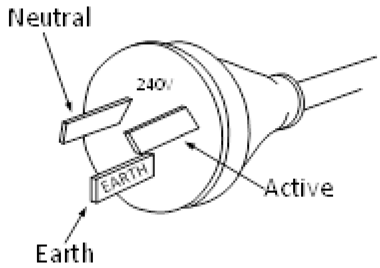
These supports will need to hold onto the outer sheath of the cord without causing it to break up.

The flexible cord entry supports are called glands, flexible cord clamps, cord grip clamps and strain relief bushings or grommets, depending on their shape and the method of support they provide.

The connection to the supply point is usually through a plug top that plugs into a socket outlet. Cord entry into the plug top should also be supported to prevent undue stress on the connections, due to frequent plugging and unplugging action.

Plugs and Sockets

There are many types of plug tops, the most common being the 10A three pin plug top. This plug top has three flat pins – the phase pin, the neutral pin, and the largest, the earth pin.



The plug top is suitable for cord connected appliances rated at not more than 10A and intended for supply from a standard socket outlet.

Voltage and Current Rating

A plug top must have a voltage and current rating not less than that of the appliance it supplies and its intended socket.

Protection Rating

A plug top must be suitable for the environment in which it is to be used. Electrical equipment including plugs and sockets are given an international protection (IP) rating which indicates where it can be used. The IP rating indicates the level of protection against the entry of moisture and foreign bodies into a plug enclosure.

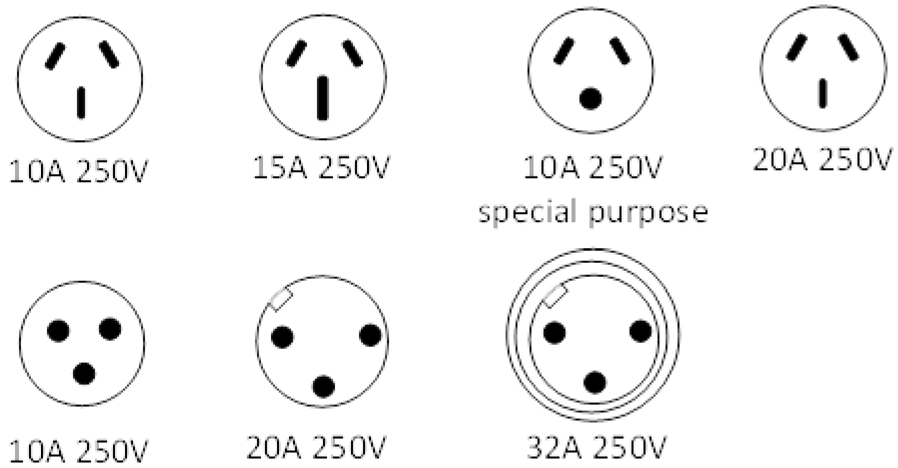
2 IP66 3 phase plug

1 IP66 Single phase plug

Socket Configurations

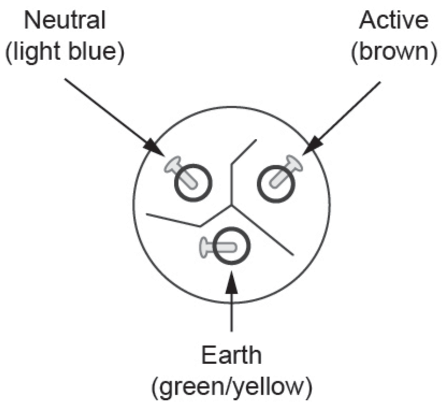
Plug tops and sockets are designed with various pin styles and configurations to prevent an appliance being supplied from an inappropriately rated socket. For example, a 15A three (flat) pin plug will not fit into a 10A three (flat) pin socket.

Some single-phase plug and socket configurations are shown below:

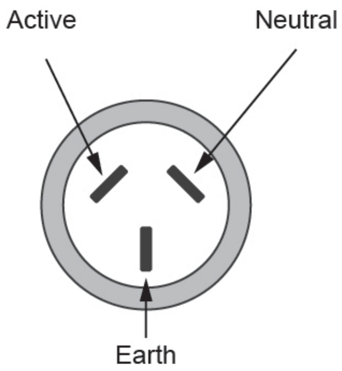


Single phase plug & socket configs

Extension cords also use flex and will be something you will work on at times. The have a length of flex, a plug and socket and are often used in situations where they can be damaged. If they are used for business, they must be tested and tagged at specific time intervals.



Socket connections, rear view



Socket polarity, front view

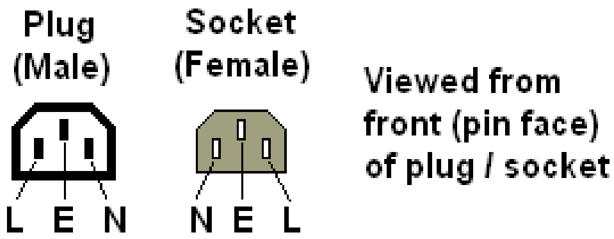
Appliance cords

Many electrical appliances and equipment have detachable flexible cords called an appliance cord.

They are easily removed and replaced. The plug that plugs into the appliance socket is called an appliance connector. The following pictures and diagrams show one such cord and its polarity.

Appliance Cord

Appliance cord socket on the right, appliance cord connector on the left

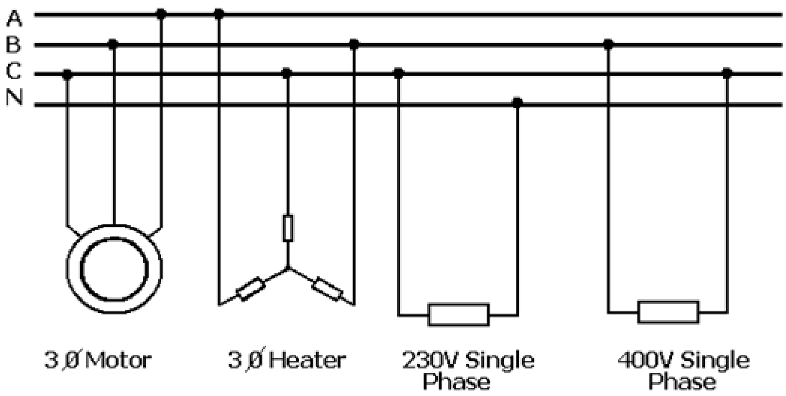


Polarity

Multiphase Cords and Plugs

Multiphase Supply

Three phase and neutral supplies provide two different levels of voltage. The supply system has three supply wires, and one neutral.



Typical 400/230V system

In a typical 400/230V three phase and neutral system, the voltage between any two phases is 400V and the voltage between any phase and neutral is 230V.

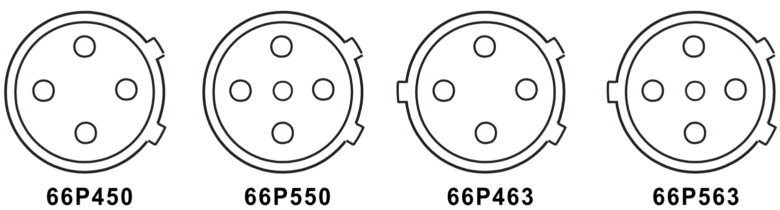
Multi-phase Plug Top and Socket Outlet Patterns

Multiphase socket outlets are available in a wide range of styles, with manufacturers using a standard pattern for the socket.

This means that plug tops produced by one manufacturer will fit sockets produced by a different manufacturer.

The pattern of the sockets is arranged so that an appliance requiring a current greater than the rating of the outlet cannot be plugged into that outlet.

For example, a 20A plug will not fit into a 10 amp socket neither a 32A plug into a 20 amp socket. This load matching is achieved with the use of a varying keyway design, moulded into the socket.



The figures below show a 3-phase plug top, with neutral and the earth pin, viewed from the front (Pins side) and the rear (the connection side).

Note that the neutral connection will always be in the middle and the earth pin oriented downward. The three (3) phase conductors are connected clockwise from earth pin when looking at the back of the plug top.

IP66 3 phase plug top

Cord connected equipment

Flexible cords are also used for connection of electrical equipment to the fixed part of electrical installations.

In such cases, this part of electrical wiring is called “equipment wiring” according to AS/NZS 3000, figures 4.3 to 4.5. AS/NZS 3000 4.3.5 gives some restrictions on equipment wiring such as having:

- A maximum length of 2.5 meters.
- A capacity equal to the load they are supplying.
- Minimum cross-sectional area of 0.75 $mm^{2.}$
- Protection against short circuits.
- If required by the load, a protective earthing conductor contained within its sheath which meets the protection requirements.

The length of the cord for an appliance is determined by the type of appliance, the environment in which it is used, and the load's requirements. The following Standards may be referred to for cord length:

- AS/NZS 3100
- AS/NZS 3012
- AS/NZS 3760.

A lot of domestic appliances have a cord length of 1.8 metres.

Appliance Insulation Classifications

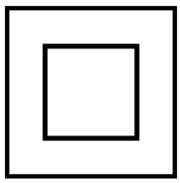
Most low voltage electrical appliances are manufactured to one of three general insulating specifications, namely:

Single Insulated (Class I) - In a single insulated appliance there is one layer of insulation between the internal live components and the outer metal enclosure. See AS/NZS 3760 1.4.2 (Class I equipment). An earth symbol such as the one below identifies the appliance as a Class I Appliance.

Class I appliances must have their metal casing and any exposed metal connected to earth and the live terminals or parts must not be accessible to the user.

The operating switch of the appliance disconnects all the live conductors. This is to avoid any danger in the case of incorrect polarity of supply cord.

Double insulated (Class II) - In a double insulated appliance there are two layers of insulation between the internal live components and the outer metal enclosure; the layers of insulation are called the primary insulation (closest to the electrical parts) and the secondary insulation (the casing of the appliance).



The international symbol to indicate double insulation is one square inside another.

Double insulated appliances must NOT have exposed metal connected to earth, and they may have a warning label such as 'DO NOT EARTH – DOUBLE INSULATED'. See AS/NZS 3760 1.4.3.

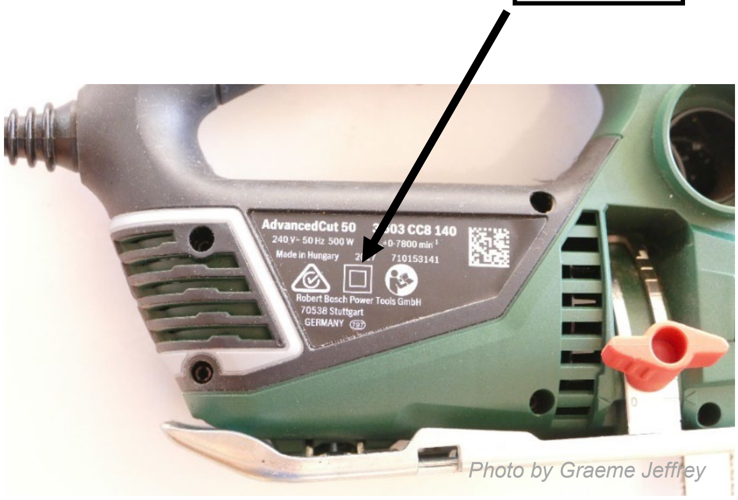


Photo by Graeme Jeffrey

All insulated. All insulated appliances have no exposed metal parts. For all purposes, an all insulated appliances could be dealt with as a double insulated one.

Three Pin Plug Tops


Photo by Graeme Jeffrey

Portable single-phase appliances are usually connected to the supply by means of a flex and a three pin plug top.

The two most common plugs are the 230 volt 10 amp and 15 amp plugs.

Each type of plug top can be similar in appearance, but the 15 amp type has a wider earth pin than the 10 amp type.

The purpose of the wider earth pin is, that the 10A plug can be plugged into a 15A socket-outlet, but a 15A cannot be plugged into a 10A outlet.

When fitting a three pin plug top to a length of three-core flexible cord there is a ‘right end’ and a ‘wrong end’ of the cord.

The ‘right end’ is the end in which the cable cores naturally lay so they can enter the correct terminal without crossing over within the plug top.

Although selecting the ‘right end’ is not a mandatory requirement by any standard, it is good work practice. If a plug top is being replaced on an existing cord, it is not essential to reverse the ends of the flexible cord.

Stripping the Cable

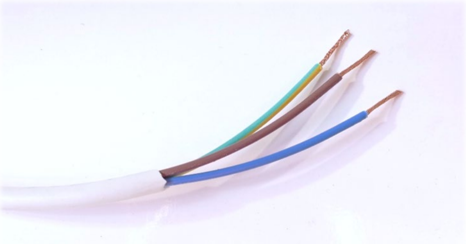


Photo by Graeme Jeffrey

When stripping the outer sheath of the flexible cord, care must be taken to ensure that the insulation around the individual core conductors are not cut or nicked – cuts or nicks in the cable insulation are not acceptable at any time.

Ringing the sheath with a sharp knife is not good practice because of the potential of cutting or nicking the insulation around the core conductors.

Photo by Graeme Jeffrey


A preferred method of removing the sheath is to cut along the cable from the end just sufficiently to be able to grip the conductors.

Then grip the sheath and pull the conductors one way and the sheath the other. The sheath will tear along the line started with the initial cut.

Once enough of the sheath has been ripped back, rim the sheath with a pair of side-cutters.

Another good solution is using a pair of cable strippers that can strip the outer layer of insulation off without damaging the inner core insulation.

The preferred method of removing the insulation around each core conductor is to use correctly adjusted wire strippers. It is possible with practice to use diagonal cutters or side cutting pliers as long as none of the strands of the conductor are damaged at all or removed during the process.

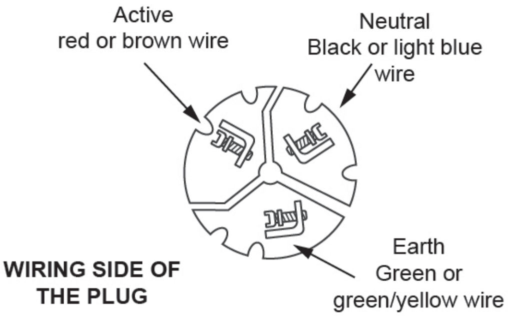
Connections

The outer cover of the plug-top and the cord-grip ferrule (if necessary) should be placed over the flexible cord before fitting the plug-top.

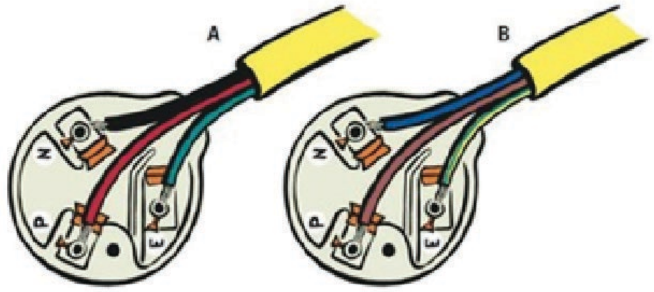
- It is really annoying when you finish wiring the plug and find the plug top on the bench and all you have done has been for nothing as you have to take it off again.
- In a typical three pin plug-top, each termination must be made by stripping sufficient insulation from the cable core and twisting the strands together making sure that you follow the lay of the cable.
- Next, you need to double over the twisted conductor where it enters the clamping terminal or terminal post.
- Ensure that the cable insulation is not clamped between the metal surfaces of the termination.
- The doubled over conductor should be visible at the bottom of the termination. When terminating the cores, check that you are following the correct plug top polarity.
- Some plugs have provision to make the termination under the enlarged heads of brass screws. In such cases, the strands must be twisted together as tightly as possible and then wrapped around the screw one (and only one) turn.
- The conductor must be wrapped around the screw in a clockwise direction (the direction you will turn it to tighten) so that when you tighten the screw it pulls the strands under rather than pushing them out.
- Ensure that all strands are under the head of the screw.

Photo by Graeme Jeffrey

- The earth conductor should be left about 5 to 10 mm longer than the other cores so that the earth connection would be the last to disconnect if someone somehow manages to accidentally rip the flex out of the plug.
- Under no circumstances should individual cable cores be visible or accessible after the protective cover has been fitted to the plug-top, the sheath must go into the body of the plug.
- Insert each wire into the correct terminal, the cables need not be looped around the anchoring points until they have all been terminated.



A			OR	B		
P -	Phase	Red		P -	Phase	Brown
N -	Neutral	Black		N -	Neutral	Light Blue
E -	Earth	Green		E -	Earth	Yellow/Green



Plug top connections, rear view

- The conductors should be gripped firmly by the terminal connector, but not overtightened or the screw or clamp will cut into the copper.
- The insulation should extend up to but not into the connector. Remember, it is essential that the insulation is not clamped by the connector as this will result in a poor connection and it will loosen over time.
- After they have been connected, each core should be fitted into its appropriate anchoring path. Next, screw down the sheath clamp and fit the cover over the plug top.

Flexible cords of the textile braided type must have the braiding whipped with thin strong thread, or they must be fitted with a suitable tensioned rubber sleeve, or heat shrink, to prevent the braiding creeping back up the cord to expose the internal cable cores during use.

Taping the braid with insulation tape is not an acceptable means of retaining the braiding in its correct position. Flexible cords must be completely replaced if any internal core is visible; taping over a frayed or damaged area is not acceptable either.

Testing

After terminating any cords and plugs at the appliance you must conduct both a visual and electrical test to ensure the appliance is safe for use.

The procedure for verifying the earth continuity is explained in AS/NZS 3760, Appendix D. In appendix E, it explains the procedure for verifying the insulation resistance of flexible cords. Additionally, any testing of the appliance and cord must also satisfy the requirements of AS/NZS 5762.

The same technique can be used to test the phase and neutral conductors, to ensure their connection and polarity is sound and verified.

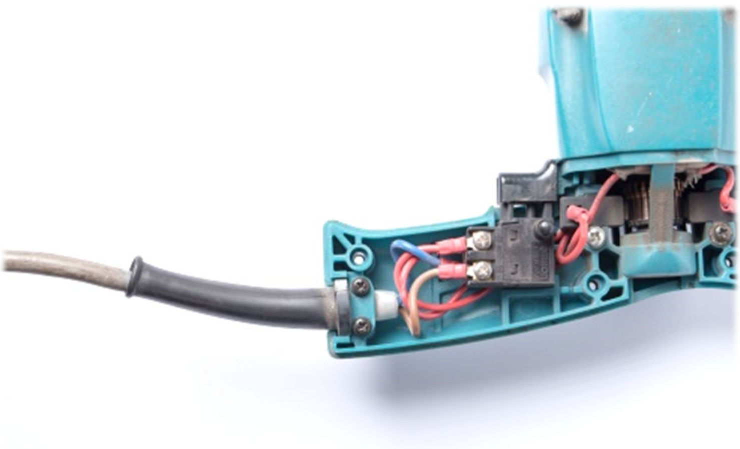
When testing insulation resistance, temporarily connect the phase and neutral conductors together then test between them and the earth pin with an insulation tester.

Testing double insulated appliances

Double insulated appliances also require the same level of diligence when they are being connected.

Even though they do not have as many conductive parts that could become live, the insulation of the cords and frames may have become compromised due to overheating, breakage or moisture.

Their switch is similar to Class I Appliances and the cable entry must be supported against wear and tear. The picture below shows an electric drill with its terminals exposed.



The strain relief moulding is installed in addition to the cord grip clamp on the sheathing of the cord. This will reduce the tension on the conductors and their terminals.

You need to do an insulation resistance test between the conductors and any metal parts of the casing, to make sure there is no connection.

Inspection and Testing of Plugs and Sockets

Reject and replace a plug or socket if any of the following faults are evident:

a) No strain relief loop (or tortuous path) in the plug.
b) Inadequate cord grip on the plug cover, especially on heavily used equipment.
c) Loose pins.
d) Damaged casing.

The wear and tear on cords and plugs can be quite high. If the earth falls out of its terminal at the plug end, it may go undetected until one of two things happen:

a) The appliance develops an earth fault and the appliance case becomes live.
b) The bare end of the loose earth wire touches the phase terminal inside the plug (2 more chances in a 3-phase plug) making the equipment case live without operating the protective device.

Sometimes, the earth wire may be broken inside a flexible cord leaving no protection should an earth fault occur.

Inspection

A cord extension set must be inspected and visually checked for the following things before it can be regarded as safe to use:

a) Correct polarity of all connections.
b) Correct colour coding of all conductors.
c) Correct terminations and tightness of connections at each clamping terminal.
d) No insulation removed unnecessarily.
e) No cable cores extending outside of the outer cover of the plug top or extension socket.
f) No cuts or nicks in the cable insulation or sheathing.
g) No insulation between clamping terminals.
h) Cable cores doubled over before connecting (where applicable).
i) No mechanical damage to any of the accessories of the flexible cord.
j) The correct accessories and cable have been used.

Photo by Graeme Jeffrey

Testing flexible cords

When a flexible cord set has been repaired or replaced it must be tested for the following:

a) Polarity of the plug top (earth, phase, neutral in a clockwise direction when viewed from the back of a single phase plug-top) and socket.

b) Insulation resistance between all conductors (>1MΩ).

c) Continuity resistance of the earth conductor (less than 1 ohm).

d) Continuity of the other conductors (can also be checked in the same way).

Three Phase Test Procedure

The principle of inspection and testing multiphase cords is the same as for single phase cords.

A visual inspection is looking for any

a) Any obvious defects

b) Deformation to the cable which will reduce the insulation quality.

c) Appropriate anchorage of the cable at the plug and the appliance end.

d) Correct polarity and cable termination.

Photo by Toi Ohomai

The electrical tests are carried out as follows:

e) Polarity of the three-phase plug top (earth, L1, L2, L3 and neutral where it exists).

f) Insulation resistance between all conductors and conductors and earth (>1MΩ).

g) Continuity resistance of the earth conductor (less than 1 ohm).

h) Continuity of the other conductors (can also be checked in the same way).

Choosing cable size

AN/NZS 3008.2.2 outlines the cable selection process based on three main factors:

- Cable short circuit temperature limit, which depends on the energy produced in the cable under short circuit conditions.
- Current carrying capacity, taking into account external influence such as thermal building insulation.
- Volt drop, which depends on cable impedance, load current and power factor.

Short circuit capacity

A cable may be subjected to short circuit fault current which can be many times greater than its normal operating current capacity.

When choosing a cable, its short circuit capacity needs to be taken into account.

A short circuit is a fault that allows current to bypass (short circuit) the normal load of a circuit.

The load normally keeps the current under control, but when the load is able to be bypassed, the current is then only limited by the ability of the power supply to supply current and the opposition to current flow of the circuit conductors themselves.

Under short circuit conditions, extremely high current will flow in a cable. This current can heat the cable badly. The heat energy produced in the cable is a product of the square of the fault current and time (I^2t).

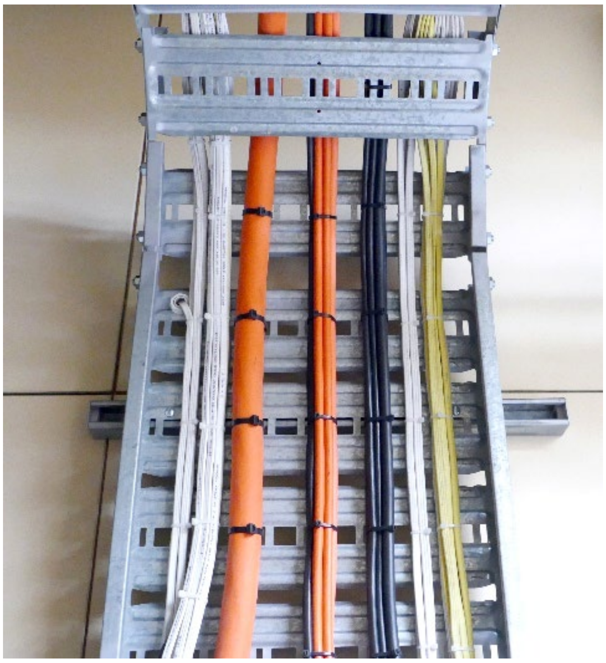


Photo by Graeme Jeffrey

The insulating material of any conductor has a maximum temperature limit that it can withstand before melting.

It is essential that under fault conditions, this maximum insulation temperature is not exceeded.

AS/NZS 3008 section 5 contains tables and calculations regarding short circuit performance of cables.

It is a requirement of AS/NZS 3000 that a protection device, such as a circuit breaker, must operate in the prescribed time to clear a fault. The cable needs to be able to cope until it does.

Cable current carrying capacity

All cables and flexible cords used in permanent wiring installations must operate within their design parameters. Cables and cords that do not, may be damaged or cause damage to the installation (like fire).

Cross sectional area (CSA)

If you think of a cable as a water pipe, it is easy to understand that a larger pipe will allow a greater water flow for the same water pressure. This is because the larger pipe is less restrictive to water flow.

Electric cables are principally the same with resistance reducing as the cross-sectional area increases.

A larger cross-sectional area cable will allow a greater current flow for the same electrical pressure (voltage).

Photo by Graeme Jeffrey

To choose a cable size, AS/NZS 3008 has tables that allow you find the current carrying capacity of different cables in different environments.

By selecting the column with the correct environmental conditions and looking down to the design circuit current, the table indicates what size conductors you will need for the current.

Maximum demand

Photo by Graeme Jeffrey

Obviously, current flow in a circuit may vary. If you think of your house, it may have eight double socket outlets rated at 10A (x 2 per outlet) on one circuit.

Is it normal, or even likely, that all sixteen outlets on that circuit will have a load plugged in and all be drawing the maximum of 10A at the same time? 160A? Probably not.

The eight double socket outlets are placed for convenience, to have an outlet where you might need it rather than being loaded all the time.

Imagine if you had to wire each socket outlet circuit to cope with 160A all the time, the cables would be huge and the switchgear and switchboards massive. It just isn’t necessary.

AS/NZS 3000 sets out guidelines for you to work out a reasonable loading for circuits so that, you can design an installation that will be reliable but not overboard on the size of gear.

The term for this is maximum demand, it is the reasonably normal maximum expected current demand on circuits or an installation. You can work out the maximum demand current and use that to choose the size of your mains cables.

AS/NZS 3000 appendix C has a great deal of information on working out maximum demand.

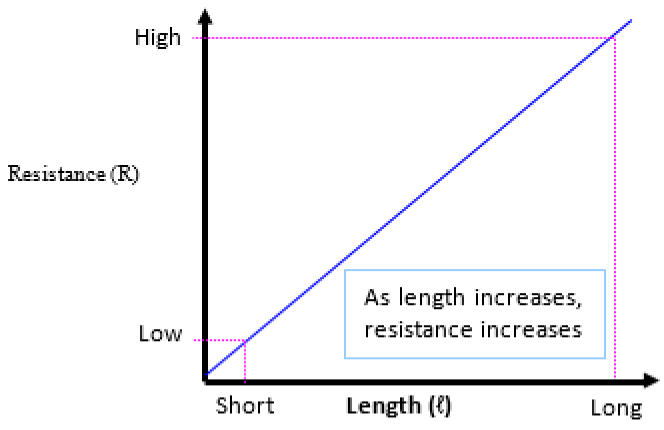
There are four methods of determining it as mentioned in AS/NZS 3000 2.2.2. These four methods are:

1. Calculation based on Appendix C.
2. Assessment based on the methods of use.
3. Measurement based on 15 minutes of peak demand during the peak time, or,
4. Limitation of the demand by a device such as a circuit breaker.

Cable resistance and volt drop

As the length of a cable or cord increases, so does the resistance of the cable.

1. **The length of the conductor.**
   - The shorter the conductor, the lower the resistance.
   - The longer the conductor, the higher the resistance.



The graph above shows that as the length of a conductor increases, the resistance also increases.

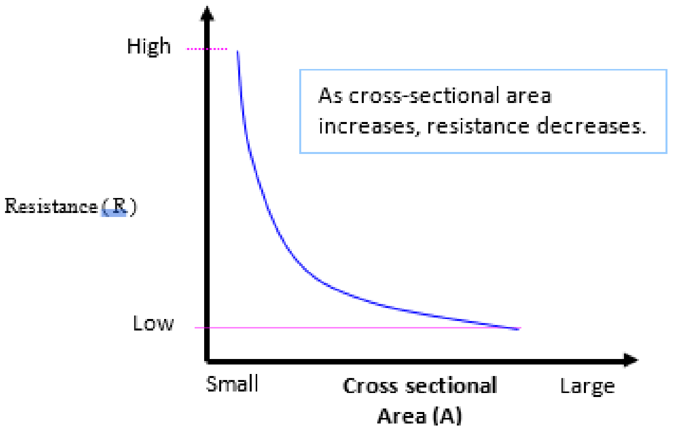
Photo by Graeme Jeffrey

2. The cross-sectional area of the conductor.

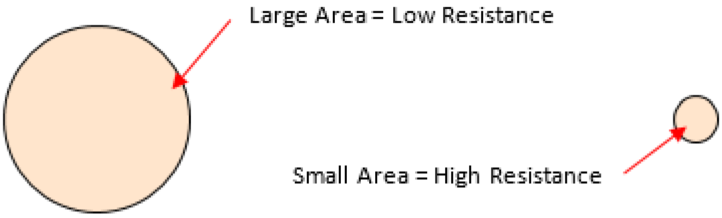
- The greater the conductor area, the lower the resistance.
- The smaller the conductor area, the higher the resistance.

$\boldsymbol{f(x)}$	*Resistance is indirectly proportional to the cross-sectional area of the conductor,* $R \propto \frac{1}{A}$

Photo by Graeme Jeffrey



$\boldsymbol{f(x)}$	*Resistance is proportional to the length of the conductor* $\boldsymbol{R \propto l}$



3. The temperature of the conductor.

- The higher the conductor temperature, the higher the resistance.
- The lower the conductor temperature, the lower the resistance.

$f(x)$	*Resistance is proportional to the temperature* $R \propto l$

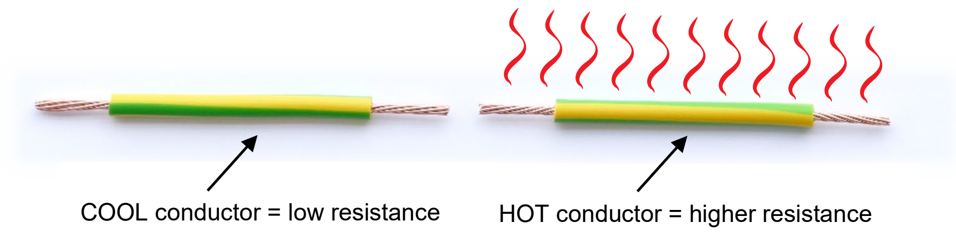


Photo by Graeme Jeffrey

A conductor may be being used in a cool store with an ambient temperature (generally normal temperature in that area) of -20˚C, or it may be in a bakery above the ovens, or surrounded by thermal insulation in a roof space.

The temperature will make a difference to the resistance of the conductor.

	The shorter, fatter and colder a conductor is the less resistance it will have. The longer, skinnier and hotter a conductor is the more resistance it will have.

Volt drop

All conductors have some electrical resistance.

Because of the resistance of the conductors, cords and cables experience “volt drop” when current flows through them. Voltage is used up pushing the current through the resistance of the conductor.

Length

If the length of a cable of a given cross sectional area is doubled, the resistance will also effectively double. The voltage drop will increase with the length and this must be factored in when calculating volt drop in cables.

Temperature

As current passes down a conductor, heat is generated. The greater the current flow, the more heat produced. If the ambient temperature around a cable increases, it will also cause the temperature of the cable to increase.

As a conductor’s temperature increases so does its resistance to current flow, which also increases the voltage dropped over the length of that cable.

These factors need to be taken into consideration when selecting a cable for a specific installation.

Bunched cables

Cable circuit runs are often secured to the same cable tray or enclosed in the same conduit or trunking, for at least part of their run. Cables that are touching or are in close proximity to other cables can heat or be heated by other cables.

Photo by Toi Ohomai

Heat is a major concern for bunched circuits and AS/NZS 3008.1.2 contains tables that give current carrying capacity derating factors for cables installed with others in groups.

An example of this might be a three-phase cable with a current carrying capacity of 100A when installed on a cable tray by itself.

With two other cables laid alongside and touching the original cable, the original cables current carrying capacity goes down to 88A.

When current passes down any conductor or cable, a magnetic field is produced around it which can also have an effect on other conductors in close proximity to it.

Appendix D of AS/NZS 3008 gives suggested circuit configurations to minimize these effects when cables are grouped together.

Maximum voltage drop

AS/NZS 3000 states that the maximum allowable volt drop at any point in an installation can be no more than 5% of the nominal voltage at the point of supply.

What does that mean?

1. Point of supply is the point where the supply to the property is connected to the distribution system e.g. pole top fuses or supply toby.
2. "Any point" of the installation, could be the power circuit at the end of the outbuilding which means that we have potentially used four cables to get there – from point of supply to meter board, to main board to sub distribution board to the power point.

As an example of this, if the supply voltage to an installation is 230V then the voltage at any point in that installation cannot be lower than 218.5V.

As a "rule of thumb", when selecting a single cable for an installation, we allow for a maximum volt drop of 2.5% per cable.

Volt drop in the cable tables is usually given as mV/A/m, this is not as scary as it sounds.

What it means is for every amp flowing through the cable, through every metre of cable, * milli volts is going to be "dropped" i.e. *mV/A/m.

If you have 20 amps flowing in a 10 metre long cable that has a rating of 18.92 mV/A/m, you lose 18.92mV for every amp and every metre of cable. I.e. 18.92 x 20 x 10 = 3784mV or 3.784V in total.

Solution

If voltage drop calculations for a particular cable indicate that the voltage drop is too high, then choosing a bigger cross-sectional cable with lower resistance (and as a result, a lower volt drop) is usually the solution.

Determining conductor size

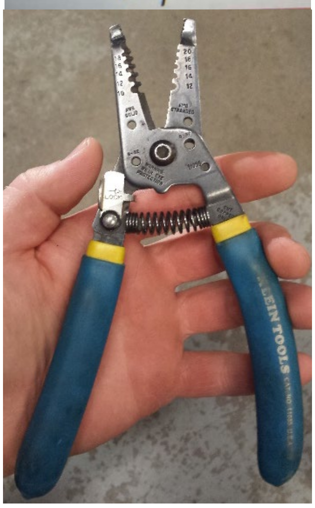
It can be difficult to judge the size of conductors just by looking at them, particularly when looking at the end of the conductor. Sometimes cables have the size marked on them, but often they don't.

The consequences of selecting the incorrect size cable could range from expense for oversize cable to potential for fire or worse, because of undersizexd cable.

One way to determine conductor size, is to have a wire gauge similar to that of a drill bit gauge and use this. Another way is to compare unknown conductors with a known size one.

This wire gauge measures both SWG (standard wire gauge) and Metric as it is 2-sided. Other similar gauges measure AWG (American wire gauge) and Metric or SWG and AWG. While useful, it does not give the exact sizes we use for cables in the electrical industry.

Known conductors for comparison. You can make this up yourself using scraps from the workplace.



Some multipurpose plier/strippers also show wire sizes. Make sure to buy a metric one.

Another technique is to use a crimp lug. Slip it over the cable to check the size.

Cable markings

Cables often have markings which may include the size of the conductors in mm^2 as well as the insulation type voltage and temperature rating.

For example, a cable marking may say "V90 2.5 mm² 450/750V" which means the cable insulation is rated up to a maximum of 90˚C, has 2.5 mm^2 conductors and has voltages rating as below. Other markings on the cable may include the "meter markings" which helps with working out how much of the cable is being used.

Voltage rating

It is important that cables to be installed have a voltage rating suitable for the supply potential they will be connected to.

The voltage rating of a low voltage cable may appear on the information sticker on the drum or the cable sheath itself.

A common value is 0.6/1kV which means that the maximum working voltage is 600V AC between any conductor to earth and 1000V AC between adjacent conductors. Another common voltage rating for cables is 450/750V.

Manufacturers also label the cable drums with other useful information. The main piece of information however, is the cable size and its number of conductors. For example, the following information could be found on a cable drum label.

Some example of cable markings are as follows:

25 mm^2 3C V90 NS PVC 1KV

- 25 mm^2 = conductor size
- 3C = 3 cores (3phase) cable
- V90 = PVC 90˚C high temp insulation
- NS = Neutral Screened cable
- 1KV = voltage rating

2.5 mm^2 2C+E V75 PVC 750V

- 2.5 mm^2 = conductor size,
- 2C = 2 cores (Phase + Neutral)
- +E = includes earthing conductor
- V75 = PVC 75˚C insulation
- NS = Neutral Screened cable
- 750V = voltage rating

In some cases, you may also find that the number and diameter of strands is recorded. For example, 1mm^2 - 32/0.2 means each conductor in that cable has 32 strands of wires of 0.2mm diameter.

Examples of cables used for specific situations

Situation	Suitable cable type
Single phase mains cable buried directly.	1 core V90 1kV neutral screen cable
230V LED light fitting.	1.0mm^2 2 core plus earth V90 750V flat TPS
Domestic socket outlets.	2.5mm^2 2 core plus earth V90 750V flat TPS
Internal wiring to oven elements.	180˚C silicone rubber insulated flexible cable with fibreglass braiding

Cable installation

As we have already said, extra low voltage cables must not be installed near low voltage cabling.

Where parallel cables are used in general, they should be installed in such a manner to reduce the effects of mutual inductance on other nearby conductors.

If installing parallel 3 phase conductors, one way to reduce unwanted inductance effects is to install the three individual cables in a trefoil arrangement, or increase the spacing between cables.

Passive fire protection

AS/NZS 3000 1.5.12 states that electrical equipment will have protection to stop it causing fires or allowing fire to spread or cause problems for people escaping from a building. See also AS/NZS 3000 3.9.9 and appendix E for more information.

Many buildings have active fire protection systems, such as sprinklers, which operate to extinguish any outbreak of fire.

A building structure can have passive fire protection built into it, for the purpose of slowing or containing the progression of fire and smoke through the structure.

Special fire-resistant walls and doors which are designed to resist fire for a period of time (to allow time for people to get out of a building and fire fighters to get in), are an integral part of modern building design.

If electrical or communication cables are installed through a fire wall or floor, steps must be taken to maintain the fire rating of the structure

AS/NZS 3000 3.9.9 defines a number of requirements for cables passing through elements of building construction that are required to be fire-rated such as.

- If openings remain after the passage of the wiring system, the fire-rating of structures must be reinstated in accordance with the National Building Codes.
- The opening must be close-fitting to the wiring system.
- The cross-sectional area of the opening should not usually be greater than 500mm2 (25mm in diameter if it is circular).
- The opening must be at least 50mm from any other service opening.

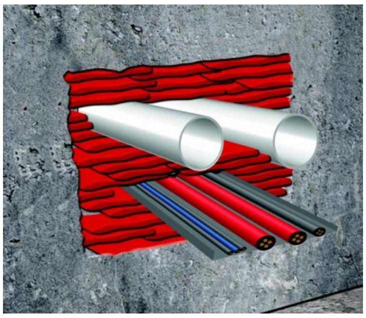
When installing wiring, it is important to identify any wall, floor or roofing material that may form part of a fire cell structure.

Sealing types

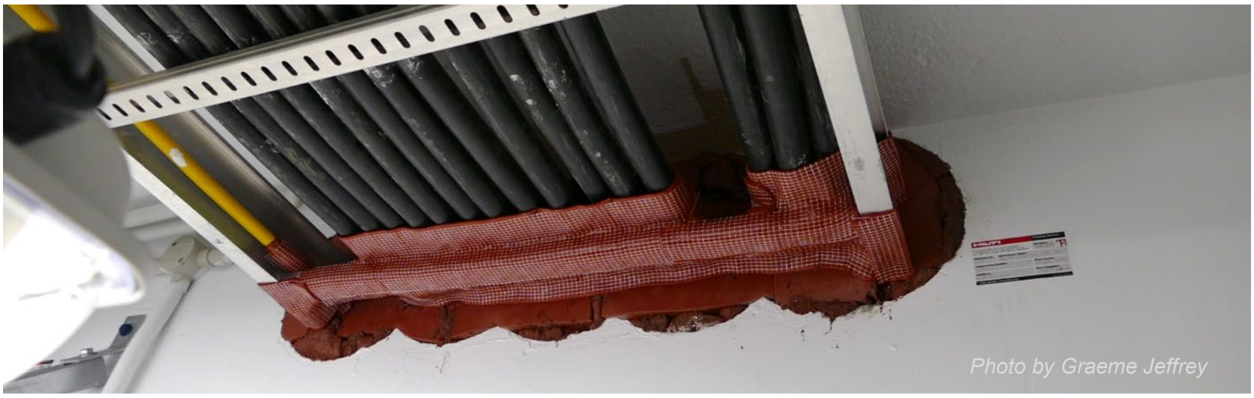
There are various systems available that are designed for the sealing of firecell penetrations such as collars, wraps, flexible sealants, barriers, mineral wool, cement based products, PU foam and box transit systems.

While manufacturers include detailed installation instructions for their products, installation of these systems should only be undertaken by competent people.

Any new installation or modification to existing installations may require building consent and varification of compliance with supporting documentation by building management.



3 Fire penetration sealer - sourced from IFSEC



Cables for mains

Here are 4 common cables that are used for mains cables with comments about their suitability for some situations.

Cable type	General comments
XLPE cable	Can carry higher current due to high temperature insulation so a smaller cable comparing current carrying ability but costs more as a result. Cannot be bent too sharply.
Neutral screen cable	Is ideal for direct burial, is mechanically strong, reasonably easy to bend and priced well to be used for general mains cable applications.
Flat TPS	Is the most economical out of this group but is mechanically weaker and often requires extra protection in particular when buried. Not made in larger sizes.
Steel wire armour cable	Is very strong mechanically and it is ideal for using where it is likely to be hit but is more bulky, more expensive and requires specialised termination glands.

Consumers Mains

Consumer's mains (CM) cables are used to connect the whole of the electrical installation to the supply network at the point of supply or meter board. AS/NZS 3000 defines consumers mains as '…*those conductors between the point of supply and the main switchboard*…'.

Often simply called mains, the selection criteria for consumer's mains are based on an anticipated or estimated current rather than an accurate figure. This is called the maximum demand of the installation.

Sub-Mains

Sub-main's (SM) are similar to consumer's mains in that they supply more than one circuit. They connect the main distribution board to a sub-distribution board which in turn feeds other circuits.

Sub-mains are protected from both over-load and short circuit current at the main distribution board.

Sub-main cables are used to reduce the number and length of cables that would otherwise be installed in the main distribution board. Similar to consumer mains, sub-mains load current needs to be determined by applying maximum demand.

Mains cable selection process

The Electricity Safety Regulations 2010 (ESR) state that electrical installations must comply with the requirements of AS/NZS 3000.

In turn, AS/NZS 3000 refers to AS/NZS 3008 for cable selection criteria for New Zealand conditions.

In this resource, we will not cover many cable calculations, that is covered in another unit. Here you must have a basic understanding of how to choose an appropriately sized cable from information given to you.

The three main steps we will cover for choosing a mains cable are:

1. Determine the size of the conductors based on the load current.
2. Check that the cable size chosen meets the voltage drop requirements.
3. Choose the type of cable that is suitable for the environment it will be installed in.

Example 1

You are required to select an underground mains cable for a single phase (230V) domestic house that has a maximum demand of 75A. The cable is 17 metres long.

The cable must have no more than 2.5% volt drop from the point of supply. 2.5% volt drop comes to a maximum permissible volt drop of 230 x 2.5 % = 5.75V.

The cable will be buried directly in the ground and will need to have a volt drop of less than 4.49 mV/A/m.

1. Step 1 - Choose a cable suitable for 75A from the table below.
   a. Column 4 is the one for buried cable.
   b. Looking down that column, you can see that $10mm^2$ cable goes up to 73A and so is too small.
   c. The $16mm^2$ cable does up to 125A and so is the correct cable to choose.

Current carrying capacity for 230V (2 Core) cables

1	2	3	4	5
Conductor size (mm^2)	**Partial thermal insulation – unenclosed (A)**	**Partial thermal insulation - enclosed (A)**	**Buried direct (A)**	**Prospective short circuit capacity rating (kA)**
6	40	35	43	1.0
10	55	48	73	1.5
16	73	62	125	2.5

2. Step 2 – If $16mm^2$ is used, does it give a mV/A/m of less than 4.49mV/A/m which satisfies the maximum allowable volt drop?
   a. Looking at the table below, 16mm2 cable has a volt drop of 2.43 mV/A/m which is less than 4.49mV/A/m so it is acceptable as it will drop less voltage than 5.75V.

Voltage drop (Vc)

Conductor size (mm^2)	mV / A / m
6	6.49
10	3.86
16	2.43

3. Step 3 – What type of cable will be the most suitable for burying directly into the ground?

    a. Single core neutral screen cable is suitable for the mains cable. It would be chosen for both economy and its mechanical strength/protection.

Cable type
XLPE cable
Single core neutral screen cable
TPS - 2 core and earth
Steel wire armour cable

Example 2

You are required to select a three phase (400V) industrial building submain cable that has a maximum current requirement of 93A per phase. The cable will be run in the crawl space of a factory, partially covered in insulation but not in an enclosure.

The selected cable needs to have a volt drop of less than 1.19 mV/A/m.

1. Step 1 - Choose a cable suitable for 93A from the table below.

    a. Column 2 is the one for unenclosed but partially installed in insulation.

    b. Looking down that column, you can see that 25mm^2 cable can carry 97A and so is big enough for the job.

Current carrying capacity and short circuit rating for 400V (3 or 4 Core) cables

1	2	3	4	5
Conductor size (mm^2)	**Partial thermal insulation – unenclosed (A)**	**Partial thermal insulation - enclosed (A)**	**Buried direct (A)**	**Prospective short circuit capacity rating (kA)**
16	73	62	125	2.5
25	97	82	162	3.5
35	120	103	196	4.0

2. Step 2 – If 25mm^2 is used, does it give a mV/A/m of less than 1.19mV/A/m which will satisfy the maximum allowable volt drop?

    a. Looking at the table below, 25mm^2 cable has a volt drop of 1.54 mV/A/m which is too much, while it is able to carry the current without getting hot, the cable will drop too much voltage.
    b. 35mm^2 has volt drop of 1.11mV/A/m which is less than 1.54mV/A/m so it is more than adequate for the current and also acceptable for volt drop as it will drop less voltage than the maximum allowable volt drop of 10V.

Conductor size (mm^2)	mV / A.m
25	1.54
35	1.11
50	0.829

3. Step 3 – What type of cable will be the most suitable for running in the crawl space?

    a. An XLPE or steel core cable is overkill and more expensive than necessary. A three core neutral screen cable is the best on the list for suitability and economy.

Cable type
Three core XLPE cable
Three core neutral screen cable
TPS - 2 core and earth
Tree core steel wire armour cable

Te Pūkenga

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