Notes on the
Unit
Electrical wiring

Course Title:

Electrical circuits and Network skills

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Unit: Electrical wiring

1.Electrical Conductor

Definition: The conductor is the type of metal which allows the electrical current to flow through it. The electrical conductor is generally made up of metals like copper, aluminium and their alloys. In an electrical conductor, the electrical charges moves from atom to atom when the potential difference is applied across them. The electrical conductors are used in the form of the wire. The choice of the conductor can be taken into account by considering the various factors like tensile strength, fatigue strength, corona loss, local conditions and cost.

The electrical conductor which is used for power transmission is usually stranded. Stranded conductors have great flexibility and mechanical strength as compared to a single wire of the same cross-section area. In stranded conductor usually, the centre wire is surrounded by the successive layers of wires containing 6, 12,18, 24,… wires.

The size of the conductor is determined by its equivalent copper cross section area and the number of strands with the diameter of each strand. The equivalence cross section of a stranded conductor is the area of a cross section of the solid conductor of the same material and length as the stranded conductor.

Types of Electrical Conductors

Hard-drawn copper, hard-drawn aluminium conductors and steel-cored aluminium conductors are most commonly used in a power. Some of the important types of conductors are explained below in details.

i) Hard Drawn Copper Conductor

Such type of conductors gives high tensile strength. It has high electrical conductivity, long life, and high scrap value. It is most suitable for distribution work where spans and tapping are more.

ii) Cadmium Copper Conductor

The tensile strength of the copper is increased by approximately 50 percent by adding about 0.7 to 1.0 percent cadmium to it, but their conductivity is reduced by about 15 to 17 percent. The property of higher tensile strength enables the conductor to be erected on longer spans with the same sag. This conductor possesses the advantages of easy joining, more resistance to atmospheric condition, better resistance to wear, easy machinability, etc.

The temperature at which copper anneals and softens is also increased, and temperature effects on stresses are less. The variation in sag due to changes in load and temperature is minimized.

iii) Steel-Cored Copper Conductor (SCC)

In steel cored copper conductor one or two layers of copper strands surround a steel cored copper conductors. The steel core adds the tensile strength to the conductor.

iv) Copper Welded Conductor

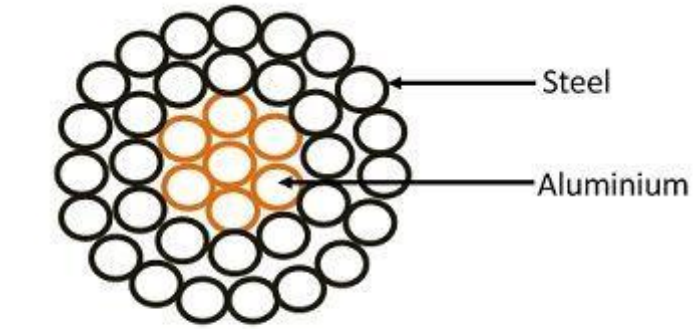
In such type of conductors, the uniform layers of copper are welded onto a steel wire. The conductivity of the copper welded conductor varies from 30 to 60 percent to that a solid copper conductor with the same diameter. Such types of conductors may be used for longer span such as a river crossing.

v) Hard-Drawn Aluminium Conductor or All-Aluminum Conductor

The cost of the copper conductor is very high, and hence it is replaced by the aluminium conductor. The handling, transportation and erection of the aluminium wires become very economical. It is used in distribution lines in the urban area and short transmission line with the lower voltages.

vi) Aluminium Conductor Steel Reinforced

All aluminium conductors are not sufficiently strong mechanically for the construction of long span lines. This deficiency in strength can be compensated by adding a steel core to the conductor. Such a conductor is called steel-cored aluminium conductor (SCA) or aluminium conductor steel reinforced (ACSR).



Aluminium Conductor Steel Reinforced

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The ACSR conductor has seven steel strands forming a central core around which there are two layers of 30 aluminium strands. The conductor stranding is specified as a 30 Al/7 St.The ACSR conductors have high tensile strength and light weight and hence it is used for small sag.

vii) Smooth Body ACSR Conductor

Such type of conductor is also called Compacted ACSR. The conventional ACSR conductor is pressed through dies to flatten the aluminium strands into segmental shape. The interstrand space is filled, and the diameter of the conductor reduces without affecting its electrical and mechanical properties. This conductor can be made with different ratios of aluminium to steel. The figure shows below the conductor having ratio 6 Al/1 St.



Convenctional ASCR Conductor

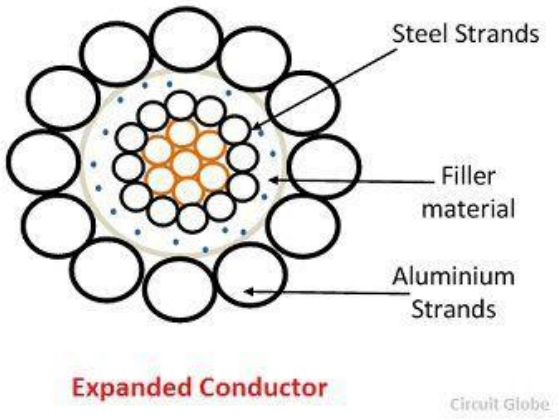


Compacted ASCR Conductor

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viii) Expanded ACSR Conductor

For reducing the corona loss and radio interference at a high voltage a fibrous or plastic material is filled between the strands. The diameter of the conductor expands due to the filling material and hence, it is called an expanded conductor. These conductors consist of paper material which separates the inner aluminium strands from the outer steel strands.



ix) All Aluminum Alloy Conductor

Such type of conductor is mostly used in urban areas. This conductor has a good combination of conductivity and tensile strength. One of the alloys which are used for making such conductor is Silmalec. This alloy contains 0.5% silicon, 0.5% magnesium and the remainder aluminium. These alloys are very costly as they are heat treated.

x) ACAR Conductor

Aluminium Conductor Alloy Reinforced has a central core of alloys of aluminium surrounded by the layers of conductor aluminium. Such conductor gives a better conductance with the strength-weight ratio equal to ACSR construction of the same diameter.

xi) Alumoweld Conductor

Aluminium powder is welded onto a high strength steel wire. About 75% of the area of the conductor is covered by aluminium. This is more costly than core silicon conductor. It has been used an earth wire for making cores of SCA conductors.

xii) Phosphor Bronze Conductor

Phosphor bronze is used as a conductor material for very long spans such as river crossing. It is stronger than copper conductor but has got a low conductivity. This conductor is superior to the aluminium bronze conductor for atmospheres containing harmful gases such as ammonia.

xiii) Galvanized Steel Conductor

The galvanized steel conductor has high tensile strength. They are used in a very long span and in a rural area where the load is small. In such cases, the steel conductors may be replaced by a steel

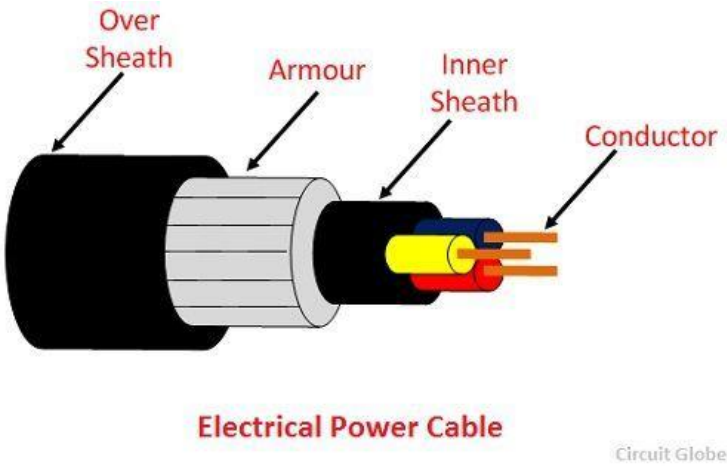
core conductor to deal with the extra future load. This conductor has a large resistance, inductance and voltage drop. But it has a small life as compared to other conductors.

2. Electrical Power Cable

Definition: A cable used for the transmission and distribution of electrical energy is called electrical power cable. Power cable consists two or more electrical conductors join with an over sheath. It is used for the transmission of extra high voltages in a place where overhead lines are impracticable to use like, the sea, airfield crossing, etc. But underground cable is more costly as compared to aerial cable for the same voltage which is one of the main draws back of electrical power cable.

Construction of Cable

The power cable mainly consists of three main components, namely, conductor, dielectric, and sheath.The conductor in the cable provides the conducting path for the current. The insulation or dielectric withstands the service voltage and isolates the conductor with other objects. The sheath does not allow the moistures to enter and protects the cables from all external influences like chemical or electrochemical attack, fire, etc. The main components of electrical power cables are explained below in details.



Electrical Power Cable

Conductor

Coppers and aluminum wires are used as a conductor material in cables because of their high electrical conductivity. Solid or number of bare wires made of either copper or aluminum are used to make a power cable.

For a conductor having more than three wires, the wire is arranged around a center wire such that there are six in the first layer, twelve in the second, eighteen in the third, and so on. The number of wires in the conductors are 7, 19, 37, 61, 91, etc., The size of the conductor is represented by 7/A, 19/B, 37/C, etc., in which first figures represent the number of strands and the second figure A, B, C, etc., represents the diameters in cm or mm of the individual wire of the conductors.

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Insulation

The most commonly used dielectric in power cables is impregnated paper, butyl rubber, polyvinyl chloride cable, polyethylene, cross-linked polyethylene. Paper insulated cables are mostly preferred because their current carrying capacity is high, generally reliable and having a long life. The dielectric compound used for the cable should have following properties.

- The insulator must have high insulation resistance.
- It should have high dielectric strength so that it does not allow the leakage current to pass through it.
- The material must have good mechanical strength.
- The dielectric material should be capable of operating at high temperature.
- It should have low thermal resistance.
- It should have a low power factor.

The cables used for submarine and damp soil should use synthetic dielectrics like polyvinyl chloride, polyethylene, etc. These materials are comparatively lighter and have nonmigratory dielectric. Also, such type of dielectric material has good dielectric strength, low power loss, and low thermal resistance.

Inner Sheath

It is used for protecting the cable from moistures which would affect the insulation. Cable sheath is made up of lead alloy, and these strengths withstand the internal pressures of the pressurized cables. The material used for inner sheath should be nonmagnetic material.

The aluminum sheath is also used in a power cable because it is cheaper, smaller in weight and high mechanical strength than the lead sheath. In oil-filled cables and telephone, cables corrugated seamless aluminum sheath is used because it has better-bending properties, reduced thickness, and lesser weight.

Protective Covering

Lead sheath cables when directly laid down on the ground are damaged by corrosion and electrolyte. For protecting the cables against corrosion layers of fibrous material like paper, hessian, etc., or polyvinyl chloride is used. Layers of fibrous material spread with the waterproof compound to the outside of the electrical cable are called serving.

Armouring: Armouring is the process in which layers of galvanized steel wires or two layers of metal tape are applied over sheath for protecting it from mechanical damage. The steel wires are normally used for armouring because it has high longitudinal strength. Armouring is also used for earthing the cable. When the fault occurs in the cable (due to insulation failure) the fault current flows through the armour and get earthed.

OverSheath:

It gives the mechanical strength to the cables. It protects the cable from overall damage like moisture, corrosion, dirt, dust, etc. The thermosetting or thermoplastic material is used for making over the sheath.

Types of Cables

1. Twisted pair cable – A twisted pair cable includes 2 cables that are twisted together. This twisting can avoid the noise produced by magnetic coupling and thus it is used to carry signals. Twisted pair cable is generally used in data communication and telecommunication.

2. Multi-conductor cable – This cable has 2 or more than 2 conductors which are insulated and their purpose is to protect the signal integrity. Both twisted pair cables and multi-conductor are known as balanced line configuration cables.

a) 2-Core Cables

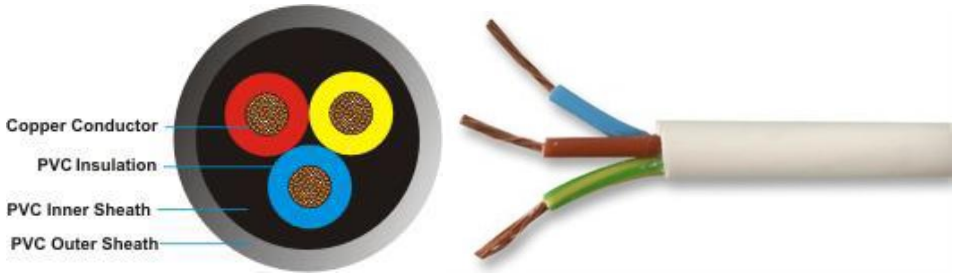
In 2 Core cable, one conductor acts as a phase and another acts as natural conductors, both the conductors have equal cross sectional area.



It is used in telephone service and to connect computer devices.

b) 3 Core Cable

In 3 Core cable all the conductors have equal cross sectional area. 3 strands carry R,Y & B phase respectively It is used as a Neutral wire.



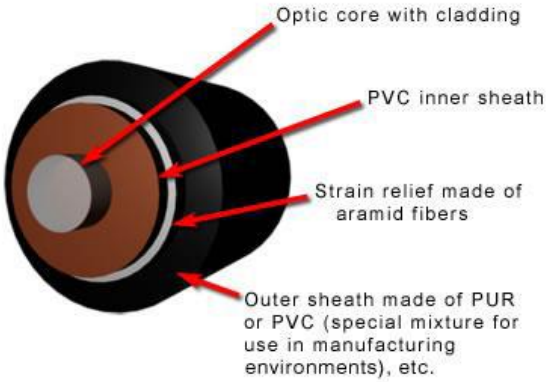
c) 4 Core Cable

In case of unbalanced load some neutral current exists. Therefore in some cases 4 core cable is proffered. It is used for lighting, load distribution & applications where unbalanced loading conditions occur frequently.



3. Coaxial cable – A coaxial cable has an inner conductor which is surrounded by a parallel outer foil conductor which is protected by insulating layers. In the cable, the 2 conductors are being separated

from each other by an insulating dielectric. These cables are generally used in TV cable as its performance is more stable than the twisted pair cable.



4. Fibre optic cable – The fibre optic cable transmits the signals through a bunch of glass threads and comparatively, it has a greater bandwidth than metal conductors and that means they can carry more information and data. For this reason, fibre optic cables are used instead of traditional copper cables.

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3. Power losses in cables

Cable power losses or power drop are due to the conductor resistance heating that occurs when current flows. These cable losses are more often called KW losses or I^2R losses. This is expressed by the following formula:

$$\textbf{Power losses} = 3 \times (I^2R) / 1000$$

where, Power losses in kW units, I is the current (in amps) and R (in ohms) is the average conductor resistance.

How to lower the resistance in the cable?

Power lost in a cable depends on the cable length, cable size and the current through the cable. Therefore, there are three ways to lower the resistance in the cable:

- Shorten the length of the cable,
- Increase the size of the conductor,
- Decrease the current through the cable.

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4. Underground and overhead system of power transmission (a Comparison)

S.No.	Particular	Overhead system	Underground system
1.	Public safety	It is less safe.	It is more safe.
2.	Initial cost	It is less expensive.	It is more expensive.
3.	Faults	Faults occur frequently.	Very rare chances of faults.
4.	Appearance	It gives shabby look.	Its appearance is good as wires are not visible.
5.	Flexibility	It is more flexible as new conductors can be laid along the existing conductors.	It is not flexible, as new conductors are to be laid in new channels.
6.	Location of fault	Fault point can be easily located.	Fault point cannot be easily located.
7.	Repair	Can be easily repaired.	Cannot be easily repaired.
8.	Working voltage	It can work upto 400 *kV*.	It can work only upto 66 *kV* due to insulation difficulty.
9.	Lightning thunder	More chances of being subjected to lightning.	Very little chances of being subjected to lightning.
10.	Supply interruption	More chances of supply interrruption.	Very little chances of supply interruption.
11.	Frequency of accidents	More chances of accidents.	Little chances of accidents.
12.	Interference with communication system	It interferes with communication systems.	No interference with communication system.
13.	Insulation cost	Less. The overhead conductor are bare. Supported on steel towers, insulated from the towers through insulators.	More insulation cost. Underground cables are provided with various wrappings of high grade tape etc. Lead sheath is also provided.
14.	Erection cost	Much less comparatively	Erection cost of high voltage cable is quite high.
15.	Uses	This is used for long distance transmission	The large charging current on high voltage limits the use of long distance transmission.

5. Solid and Stranded Wires

1. Solid – A solid wire has a single conductor and is either insulated or bare and it is usually protected by a coloured sheath. This wire offers a lower resistance and is best to use in higher frequencies. If bent or flexed repeatedly, it may break. It is typically used in applications not subject to repeated stresses, such as house wiring.



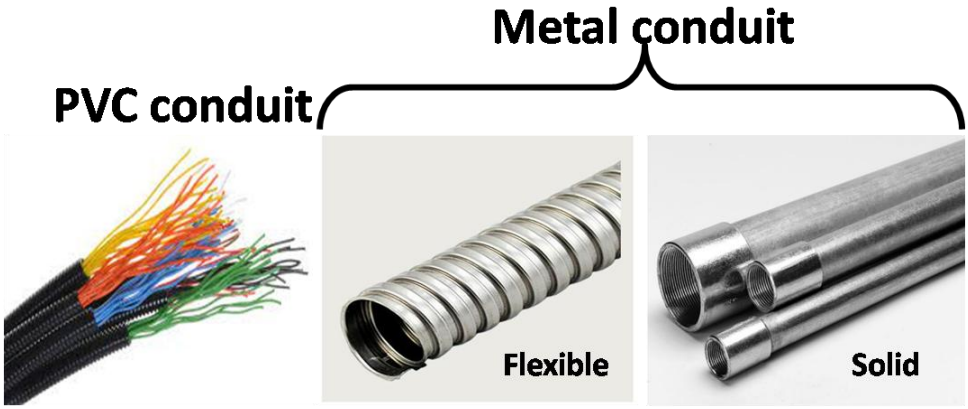
2. Standard – A standard wire contains many thin wire strands that are twisted together. These wires are used where the flexibility is required, standard wire can be used over a long period of time. Comparatively, the standard wire has larger cross-sectional area than the solid wire. It is typically used in applications like telephone and extension cords, and in speaker wire.

6. Color coding for the conductors used in electrical wiring

Function	Color Code
Single phase neutral	Black/Blue
Single phase protective ground or earth	Green
Three phase line 1	Red
Three phase line 2	Yellow
Three phase line 3	Blue
Three phase neutral	Black
Three phase protective ground orearth	Green (or) Green -Yellow

7. Electrical conduit

An **electrical conduit** is a tube used to protect and route electrical wiring in a building or structure. Electrical conduit may be made of metal, plastic, fiber, or fired clay. Most conduit is rigid, but flexible conduit is used for some purposes.



Electrical conduit provides very good protection to enclosed conductors from impact, moisture, and chemical vapors. Varying numbers, sizes, and types of conductors can be pulled into a conduit, which simplifies design and construction compared to multiple runs of cables or the expense of customized composite cable.

A conduit system can be made waterproof or submersible. Metal conduit can be used to shield sensitive circuits from electromagnetic interference, and also can prevent emission of such

interference from enclosed power cables. Non-metallic conduits resist corrosion and are light-weight, reducing installation labor cost.

Classification of Conduit:

Conduit systems are classified by the wall thickness, mechanical stiffness, and material used to make the tubing. They are broadly classified into –

i) Metal Conduit

ii) Non-metal Conduit

i) Metal Conduit

(a) Rigid metal conduit (RMC) is a thick-walled threaded tubing, usually made of coated steel, stainless steel or aluminum.

(b) Galvanized rigid conduit (GRC) is galvanized steel tubing, with a tubing wall that is thick enough to allow it to be threaded. Its common applications are in commercial and industrial construction. It is designed to protect wire and connectors.

(c) Intermediate metal conduit (IMC) is a steel tubing heavier than EMT but lighter than RMC. It may be threaded.

(d) Electrical metallic tubing (EMT), sometimes called thin-wall, is commonly used instead of galvanized rigid conduit (GRC), as it is less costly and lighter than GRC. EMT itself is not threaded, but can be used with threaded fittings that clamp to it. Lengths of conduit are connected to each other and to equipment with clamp-type fittings. Like GRC, EMT is more common in commercial and industrial buildings than in residential applications. EMT is generally made of coated steel, though it may be aluminum.

(e) Aluminum conduit, similar to galvanized steel conduit, is a rigid tube, generally used in commercial and industrial applications where a higher resistance to corrosion is needed.

ii) Non-metal Conduit

(a) PVC conduit, has long been considered the lightest in weight compared to steel conduit materials, and usually lower in cost than other forms of conduit. The plastic material resists moisture and many corrosive substances, but since the tubing is non-conductive an extra bonding (grounding) conductor must be pulled into each conduit. PVC conduit may be heated and bent in the field, by using special heating tools designed for the purpose.

(b) Reinforced thermosetting resin conduit (RTRC) or fiberglass conduit, is light in weight compared to metallic conduits, which contributes to lower labor costs. Fiberglass conduit is available in multiple wall thicknesses to suit various applications and has a support distance very similar to steel.

(c) Rigid nonmetallic conduit (RNC), is a non-metallic unthreaded smooth-walled tubing.

(d) Electrical nonmetallic tubing (ENT), is a thin-walled corrugated tubing that is moisture-resistant and flame retardant. It is pliable such that it can be bent by hand, and is often flexible although the fittings are not. It is not threaded due to its corrugated shape, although some fittings might be.

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8. Cable tray

In the electrical wiring of buildings, a **cable tray** system is used to support insulated electrical cables used for power distribution, control, and communication. Cable trays are used as an alternative to open wiring or electrical conduit systems, and are commonly used for cable management in commercial and industrial construction. They are especially useful in situations where changes to a wiring system are anticipated, since new cables can be installed by laying them in the tray, instead of pulling them through a pipe. Common cable trays are made of galvanized steel, stainless steel, aluminum, or glass-fiber reinforced plastic. The material for a given application is chosen based on where it will be used.





9. Preparation of extension board

Extension board as the name implies, is used for extending the circuit means providing the power supply at the desired place. Extension boards are part of every house, every commercial establishment and even every industrial establishment.

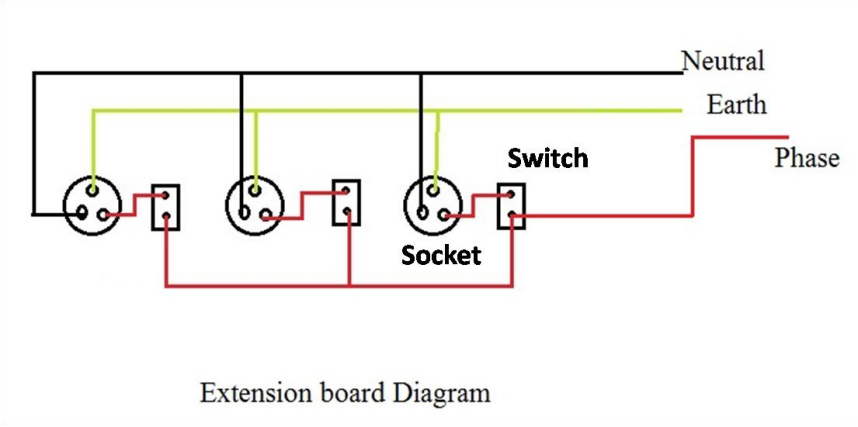
Extension boards are readily available in the market and these can be designed as per requirements. There is very simple circuit diagram of an extension board. An extension board can be designed from one switch socket to as many as required. The method of constructing an extension board is very simple and is explained below-

An Extension board mainly consists of the following parts-

1. Switches
2. Sockets
3. Extension cord
4. Box on which switch sockets mounted

The circuit diagram for constructing an extension board is as described below-

Unit: Electrical wiring

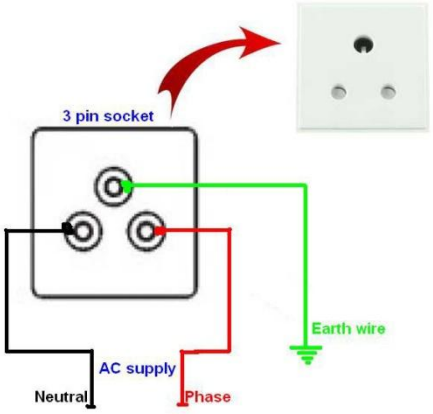


Extension board Diagram

Phase is circulated in sockets through switches and neutral and earth is connected at every socket directly as shown in the figure. Depending upon the load requirement 5A or 15 A switch and sockets may be installed. The size (cross section) of the copper wires used for the extension depends upon the number of sockets and their current ratings. e.g.,

- for 3 no.s 5A switch sockets; a 2.5 mmsq copper wire for phase, neutral and earth is required.
- for 3 no.s ,15 A switch sockets the copper wire should be of 4 mmsq.

All connections should be tightly done. Any loose wiring may lead into short circuit and shocks. After doing the connections as stated above, connect a plug top to the free ends of the copper wire as per rating of switch and sockets as shown in the figure.

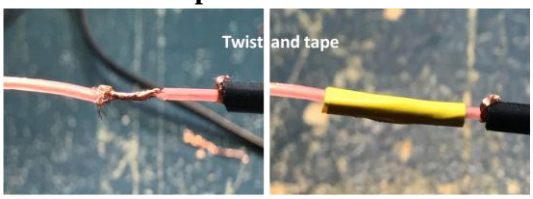


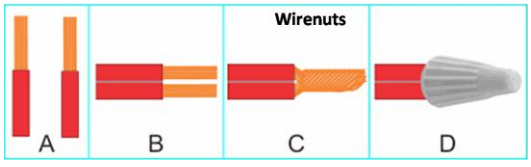
10. Splices

A **splice** is the process of combining 2 or more conductors of varying lengths of wires so that they can carry a current.

Different methods of splicing:

1. Twist and Tape





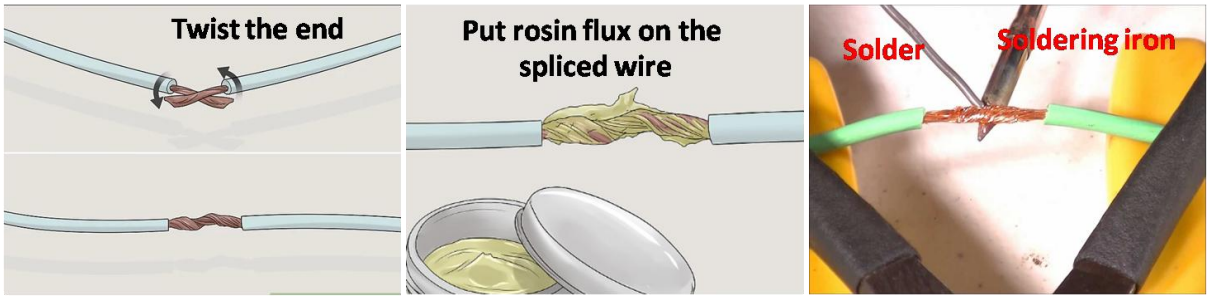
For any project where a temporary fix is needed, or a project that will be largely stationary, a simple twist of wires wrapped in electrical tape can do the trick. The benefits of a simple twist and tape maneuver are mainly economical – there are no tools required, outside of a roll of electrical tape. Due to the nature of the connection, this can be very easily redone or reinforced later; as a result, this is a great solution for prototyping a build before committing to a more

permanent splice.

In place of a tape, a twist on this method would be to utilize a **wire nut** (shown in the figure) – these are little plastic caps that act as a secure housing to host a twisted pair of wires. While they are more secure, they are also a fair bit bulkier, and can be difficult to fit into a small chassis.

2. Soldering

As compared to twist and tape or wire nuts, soldering provides a secure, electrically sound, and budget-friendly method of joining two wires.



For best soldering results when splicing wires, the following rules to be followed-

i) Twist the wire securely – test with a tug.

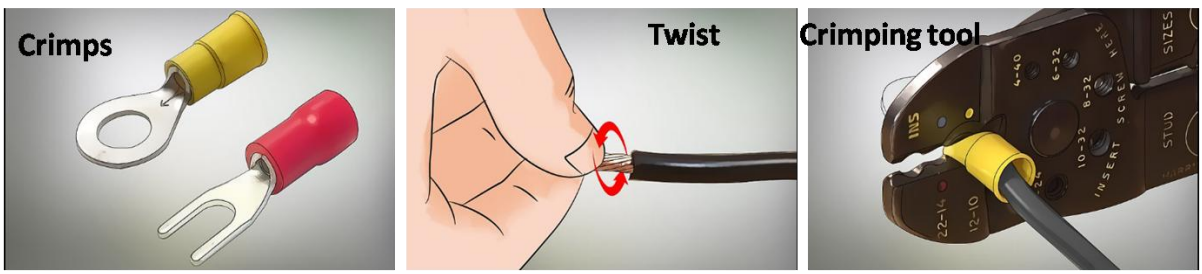
ii) Apply rosin flux to the twisted pair. This helps with proper heat distribution and ensures smooth flow of solder.

iii) Tin your iron with a little bit of solder, so it has a shiny coating.

iv) Heat the twisted pair from below and apply solder from above. Let the solder melt and flow down through the wires. This will help to avoid globules of solder and make connection throughout.

3. Crimp

For something with the strength of solder but none of the heat, a crimped connection is the alternative for connecting wires. It requires only a crimping tool and the proper connectors, crimping provides a super solid splice with minimal cost of entry.



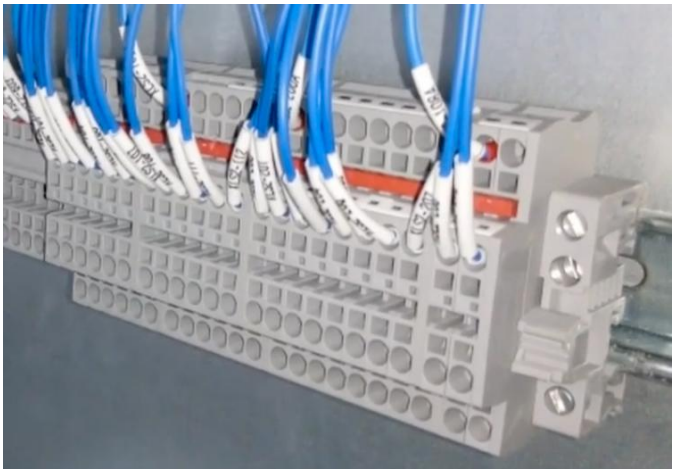
In essence, crimping squishes the wires together into a connection piece; the intense pressure and friction delivered by the crimping tool provides a gas-tight connection, which helps to prevent corrosion of the wires. Crimped connections are extremely mechanically strong, and very resistant to

mechanical stresses, making them an ideal splice for a project that will be on the move, or out in the weather.

The downside to such a mechanically strong connection is that they are non-reversible. Unlike a solder joint, which could be melted and redone if need be, a crimped connection is one and done.

4. Terminal Blocks

One of the quickest and bulkiest methods of splicing wires, the terminal block provides a flexible connection without requiring any specialized tools. To utilize a terminal block only a screwdriver is sufficient.



Similar in design to the screw terminals often found on hi-fi equipment, terminal blocks form connections by physically pinning the wire ends in place. A contact between the two terminal inputs connects the wires, and a splice is made.

These units are fantastic choices for easy connections, and for connecting more than two wires together. Instead of trying to solder multiple wires together, a simple terminal block can provide a contact across dozens of wires at once.

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