Google AV Standards Guide

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Provided by Google AV Engineering

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Introduction

The purpose of the Google AV Standards Guide is to define the minimum standards that must be met by all involved in AV installations within Google.

Multiple parties must coordinate efforts during the life cycle of an AV system. This guide should help all parties understand some of the complexities and amount of time involved in installing AV systems.

This guide provides examples of good and bad practices and gives general guidance on:

- Choosing appropriate wire and cable types
- Choosing connectors
- Numbering cables
- Handling cables
- Stripping and prepping cables
- Terminating cables
- Building racks
- Creating cable assembly instructions
- Performing verification and testing
- Meeting product and documentation requirements

This guide is part of the AV Engineering (AV Eng) team's initiative to improve the quality of Google AV installations and is subject to periodic review. All readers are invited to submit comments and suggestions for improvements to avstandards@google.com.

Requirements vs. Recommendations

The words "must" and "shall" denote mandatory provisions.

The word "should" denotes a provision that is recommended but not mandatory.

There are different reasons why some provisions are not mandatory, but these provisions are still part of the standard to improve quality. The fact that a provision is not mandatory shall not be a valid excuse for continually ignoring that provision.

1. Wire and Cable Types

Overview

Wire and cable are used to interconnect the various components used in an electrical system. The terms “wire” and “cable” are often interchanged, but there are important distinctions:

Wire

- Wire contains only one conductor.
- The conductor may be solid or stranded.
- The conductor may or may not be insulated.

Cable

- Cable contains multiple insulated wires.
- There may be a shield.
- Individual wires may be bonded together and/or protected with a sheath or jacket.

There are many different types of wire and cable, depending on the intended use. There are a variety of factors that can affect the way a wire or cable is constructed, including voltage level, current rating, signal type, and the intended environment.

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1.1 Wire

1.1.1 Wire Sizing

Using a wire gauge is the historical way to size wire and is based on how the wire is made. Wire is made by drawing a metal cylinder through a series of dies to reduce the cross section. The wire gauge indicates how many dies the wire has been drawn through: the larger the number, the smaller the wire size. The wire gauge method was used before it was technically possible to produce a wire of a specific size.

As technology improved, it became possible to manufacture wire to a specific size, and standard gauges were adopted. Standard Wire Gauge (SWG) became the legal standard in the UK in 1884, but the IEC standards are now used. IEC 60228 defines standard wire sizes with size denoted by cross sectional area (CSA).

American Wire Gauge (AWG) is the standard used in the USA and Canada. Table 1.1 shows a comparison of IEC 60228 Standard Wire Sizes with AWG for wire sizes commonly found in AV systems. Note that there are no directly comparable sizes between IEC 60228 and AWG standards.

Table 1.1. IEC 60228 Standard vs. AWG Wire Sizes

IEC 60228 Standard	AWG	CSA in mm^2
0.5		0.5
	20	0.52
0.75		0.75
	18	0.82
1		1
	16	1.31
1.5		1.5
	14	2.08
2.5		2.5
	12	3.31
4		4
	10	5.26
6		6
	9	6.63
	8	8.36
10		10

1.1.2 Wire Construction

Stranding

1.1.There are two types of conductors: solid and stranded. Solid wire is cheaper to manufacture than stranded wire and tends to be used for permanent installations where there is minimal to no movement (i.e., minimal risk of metal fatigue). Stranded wire is best used where flexibility is required: the more strands that a wire of a particular size has, the more flexible it will be.

IEC 60228 defines the standard wire CSAs and has four classes of conductors:

- Class 1: Solid Conductor
- Class 2: Stranded Conductor (intended for permanent installations)
- Class 5: Flexible Conductor
- Class 6: Very Flexible Conductor

For classes 1 and 2, the number of defined strands is mandatory. For classes 5 and 6, the defined strand diameter is the maximum, and the wire may have less strands as long as the maximum resistance figure is not exceeded. Table 1.2 shows the four classes of stranding that apply to a 1.5 mm^2 wire.

Table 1.2. IEC 60228 Stranding for a 1.5 mm^2 Wire

1.5 mm^2 Wire	Stranding (number of strands x diameter in mm)	Maximum Resistance at 20^{0}C (ohm/km)
Class 1	1 x 1.38	12.1
Class 2	7 x 0.53	12.1
Class 5	30 x 0.26	13.3
Class 6	84 x 0.16	13.3

AWG defines wire stranding standards with three numbers:

- Number of strands
- AWG size of individual strands
- Overall AWG size: Describes a wire of equal conductor CSA (i.e., does not measure gaps between strands).

Insulation

For most practical purposes, use insulated wire. For Low Voltage (LV) wiring, insulation is a safety requirement. For Extra Low Voltage (ELV) wiring, there may not be a safety requirement, but keep conductors separate to prevent short circuits and keep circuit integrity.

On modern wire, the insulation is usually a plastic or polymer material. Materials that have reduced smoke or corrosive gas emissions are available. These are also used in cable sheaths.

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1.2 Cable

1.2.1 Cable Construction

There are many different ways of constructing cables that can be used in various combinations. This section explains some of the more common construction methods found in AV cabling and the effects these methods have on performance.

Bonded Cable

This cable is formed by bonding the insulation of two or more wires together.

Cable Sheath

The cable sheath holds the cable wires together and protects them. A cable sheath is sometimes also used in a cable jacket. The sheath material is selected based on the protection required in the particular environment of the cable. For example, protection may be required against abrasion, water, oil, sunlight, temperature, etc.

The sheath material may be required to produce minimal smoke or toxins if burnt. IEC and NEC rules have different requirements. The rules vary depending on where and how the cable is installed:

- IEC specifies the use of Low Smoke Zero Halogen (LSZH) cables. These cables give off less smoke with a much lower toxicity than standard sheath materials such as PVC.
- NEC specifies Plenum rated cables, which meet National Fire Protection Agency (NFPA) standards.

In general, LSZH cables do not meet NFPA standards to be used as Plenum cables under NEC rules, and Plenum rated cables tend to contain halogens. Care must be taken to specify and install the correct type of cables according to rules and regulations in the work location.

Twisted Pair

A twisted pair cable is simply two wires twisted together. The number of twists per unit length is called the pitch. One wire forms the forward path, and the other wire forms the return path of a single circuit. Twisted pair construction reduces both induced and emitted EMI. In other words, a twisted pair construction reduces the:

- Effect of external EMI or noise from the signal that the cable carries
- Radiated emissions from the cable

Star Quad Cable

The star quad cable is four wires twisted together. Two of the wires form the forward path, and two form the return path. By using four smaller conductors, compared to the two larger ones in a twisted pair, the loop area of the cable is reduced, and rejection of EMI is improved by 20 dB.

Shielded Cable

A shielded cable has one or more insulated cables surrounded by a common conductive layer called the shield. The shield is effectively a Faraday cage that reduces both induced and emitted EMI. The shield is usually covered by a sheath and may act as the return path for a signal or act as screening only. The shield is typically made of a:

- Foil shield
    - 100% coverage
    - Low cost
    - Easy to terminate
    - Most effective at high frequencies
    - Normally attached to polymer to add strength
    - Modern foil polymer shields are flexible

- Braided stranded wire
  - 40% to 98% coverage, depending on weave of braid
  - More expensive than a foil shield
  - Heavier than a foil shield
  - Harder to terminate than a foil shield
  - Most effective at low frequencies
- Combination of a foil shield and braided stranded wire: Provides the maximum shield effectiveness.

Coaxial Cables

A coaxial cable consists of a central conductor surrounded by an insulator, which is surrounded by a tubular conductor. The tubular conductor is normally braided and protected with a sheath.

Coaxial cables are typically used to carry radio and video signals, as well as data.

By controlling the radii of the central and tubular conductors and selecting an insulator with the appropriate dielectric constant, coaxial cables are made to have a specific characteristic impedance. Selection of cable materials also affects the bandwidth of the signal that the cable can carry.

Cable Fillers

Non-conducting fillers are sometimes used inside the sheath to either maintain a uniform cable shape or keep uniform separation between elements of the cable.

Some cables may have additional structural elements to increase their strength. Additional structural elements protect the cable when being pulled through conduits, taking any resulting strain and leaving the cable undamaged.

1.2.2 Cable Types

This section lists various cable types used in electrical systems. Project documentation will specify cable types to use in a system, as well as acceptable cables that meet the required specification.

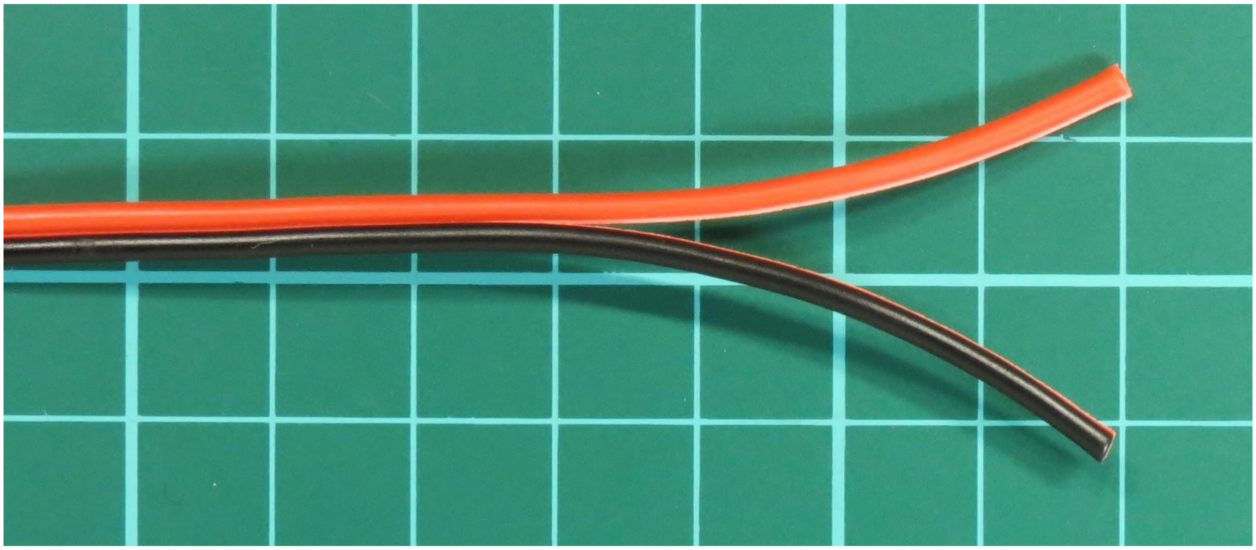
Bell Wire

Technically, bell wire is an insulated wire that is usually solid rather than stranded. However, the name is commonly used to describe a cable made of two insulated wires bonded together in a “figure of eight” pattern.

This type of cable is often found on door bells (even though the name “bell wire” originates from its use in early telephone systems).

Bell wire is not used in Google systems.

Speaker Wire (Figure of Eight)

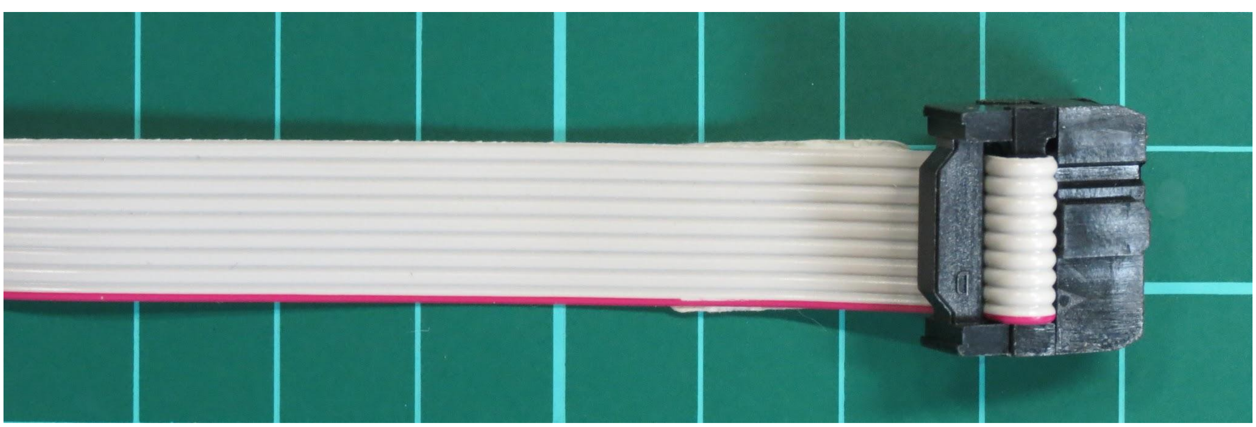


This cable is made of two stranded wires bonded together with the polarity indicated. The most visible form of polarity indication is a printed stripe on one conductor.

This type of cable may be used to connect loudspeakers to flat panel video monitors or other similar short runs for domestic equipment.

It must not be used for standalone program loudspeakers or 70/100V distributed systems.

Ribbon Cable



This cable is made of multiple wires bonded together in the same plane.

Ribbon cables are cheap, easy to terminate, and found in many electronic devices. There are two standards for colour coding ribbon cables:

- The conductor on one edge of the cable is marked with a red stripe, which is conventionally connected to Pin 1 on the connector.

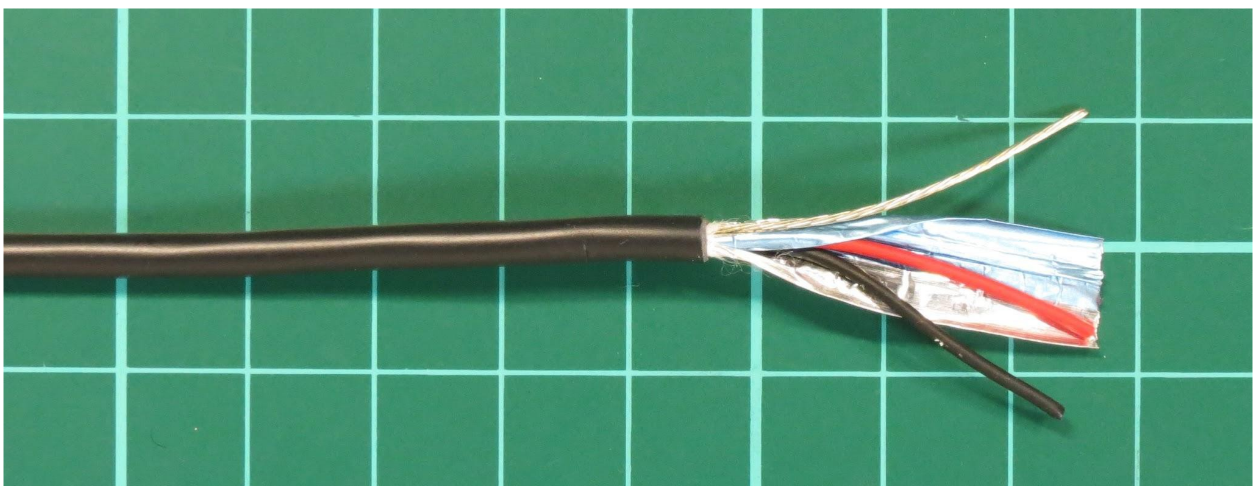
  Note: This is the simplest standard and is fine for point-to-point connections, but can be confusing if one end of a ribbon cable is split for termination in multiple connectors.

- Individual cores of the conductors in the ribbon cable are colour-coded according to the standard resistor colour codes.

  Note: The colour code can be repeated as necessary (e.g., Core 11 is brown, Core 12 is red, etc.).

This type of cable may be used for connecting Google systems when specified by the manufacturer.

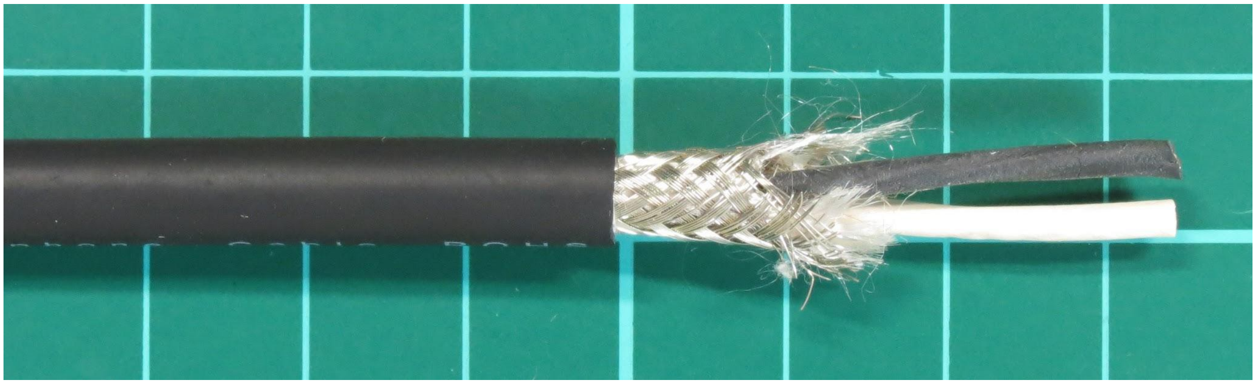
Foil Shielded Twisted Pair Cable (FST)



This cable consists of a twisted pair with an uninsulated drain wire and foil shield. The foil is not bonded to sheath so that it can be left on when stripping the cable.

FST is an installation cable used for microphone and line level audio signals. Multicore versions of this cable are available. These are used when running multiple audio lines from point to point for easier handling and installation.

Braided Shield Twisted Pair Cable

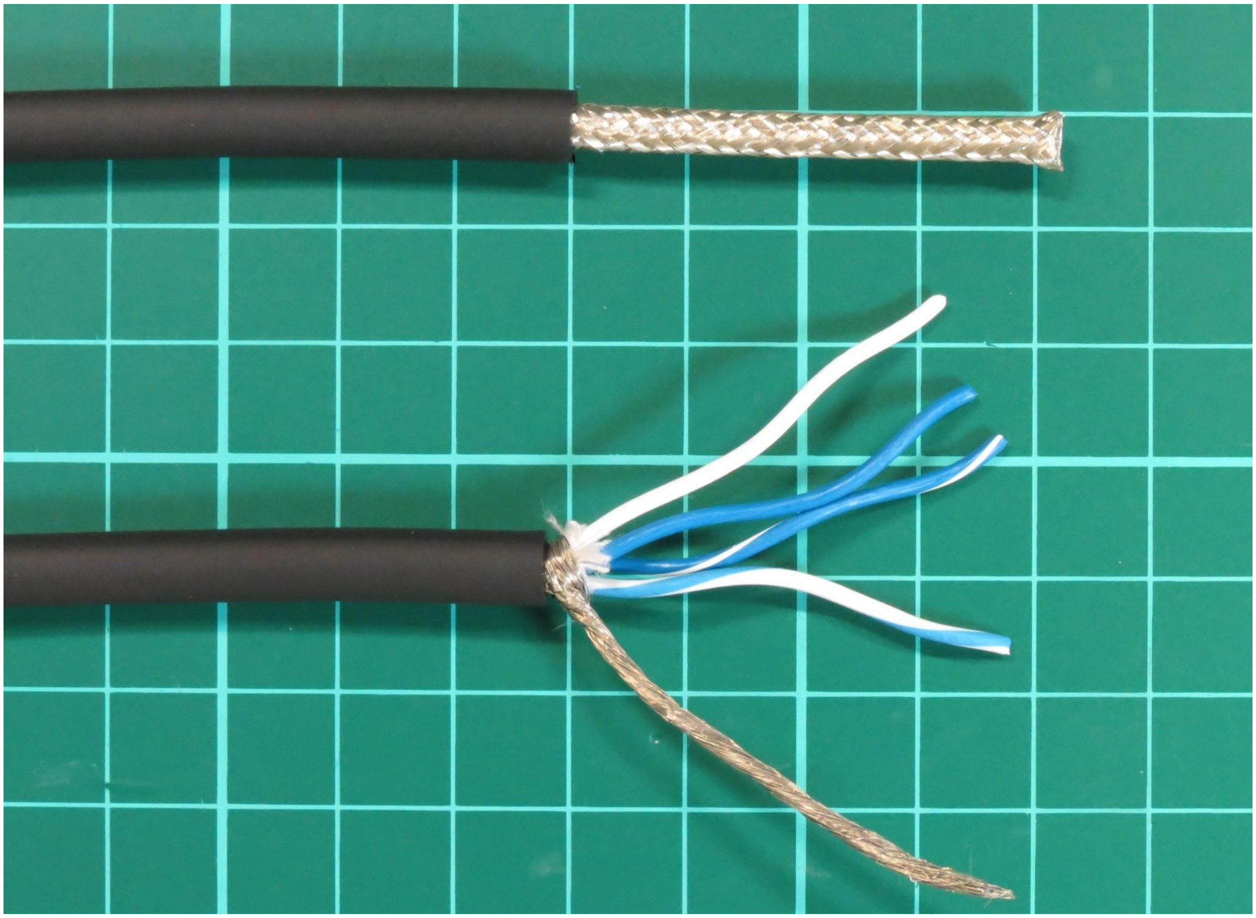


This cable consists of a twisted pair with a braided shield.

This type of cable is flexible and used for microphone and line level signals. It is sometimes referred to as a microphone cable.

This cable is used when flexible audio connections are required. It can also be used as an installation cable, but it is thicker and more expensive than FST, so there is no advantage in doing so. Multicore versions of this cable are available.

Star Quad Microphone Cable

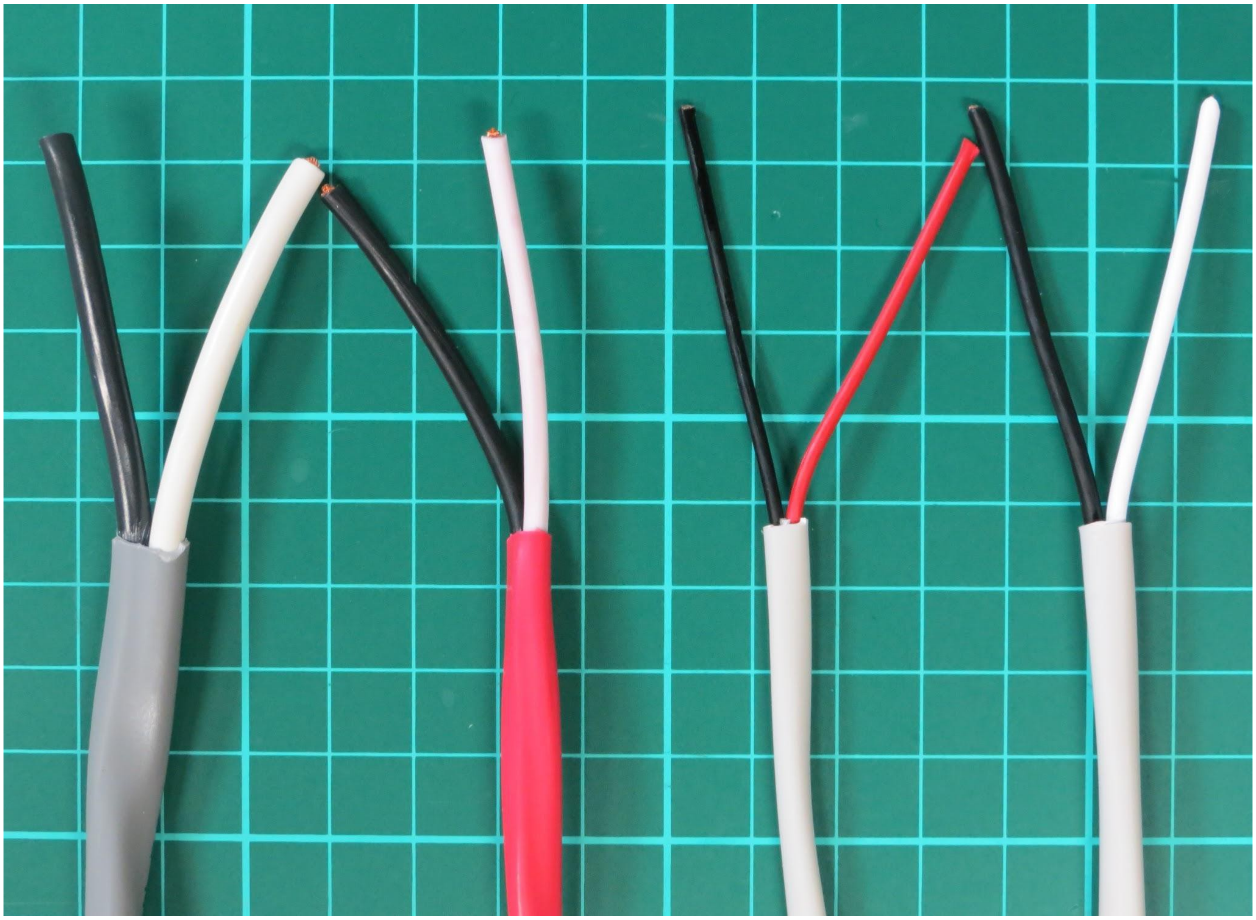


This is a star quad cable with a braided shield.

This type of cable is used for both installation and instrument cables for microphone and line level audio signals. It is also used when there may be higher levels of external EMI. This cable is more expensive and harder to terminate than the braided shield twisted pair cable. Multicore versions of this cable are available.

This is the preferred cable type for audio signals in Google event spaces.

Loudspeaker Cable



This is a sheathed twisted pair loudspeaker cable. The twisted pair reduces radiated emissions that may interfere with other signals while the sheath protects the insulation on the conductors.

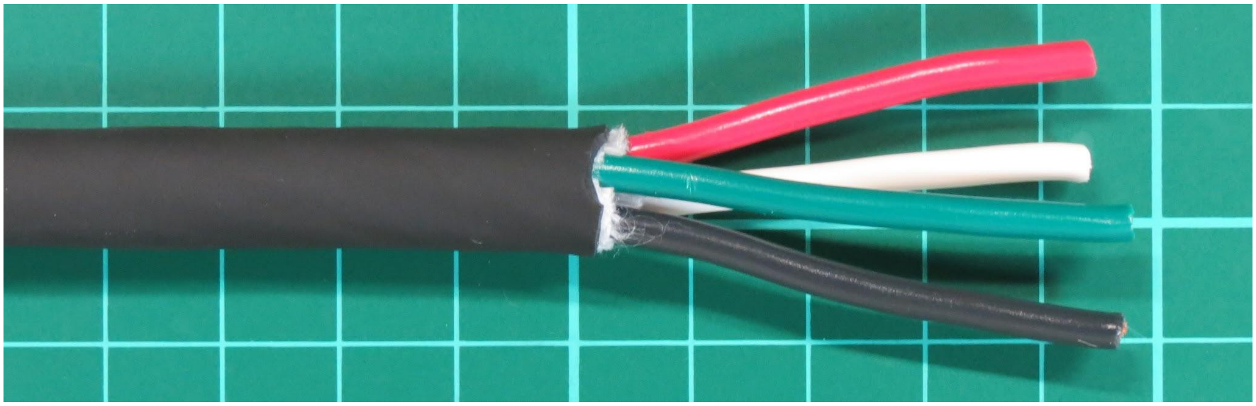
The sheath also makes this cable suitable for 70V and 100V line systems.

This type of cable comes in various wire sizes. Large wire sizes are used for long cable runs to keep resistance low.

Note: Resistance is proportional to the CSA.

This is the standard cable type used for all installed loudspeakers in Google systems.

Star Quad Loudspeaker Cable

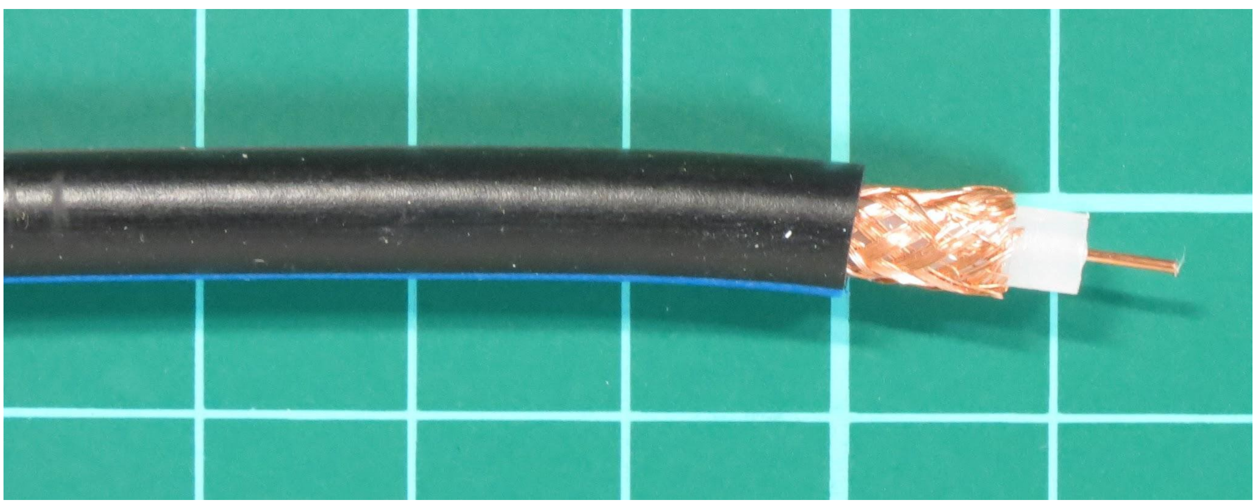


This is a sheathed star quad loudspeaker cable. It emits a lot less EMI than the twisted pair loudspeaker cable and is used in areas where low noise is very important.

This sort of cable is also used for bi-amped and tri-amped systems.

This cable type is seldom used in Google systems.

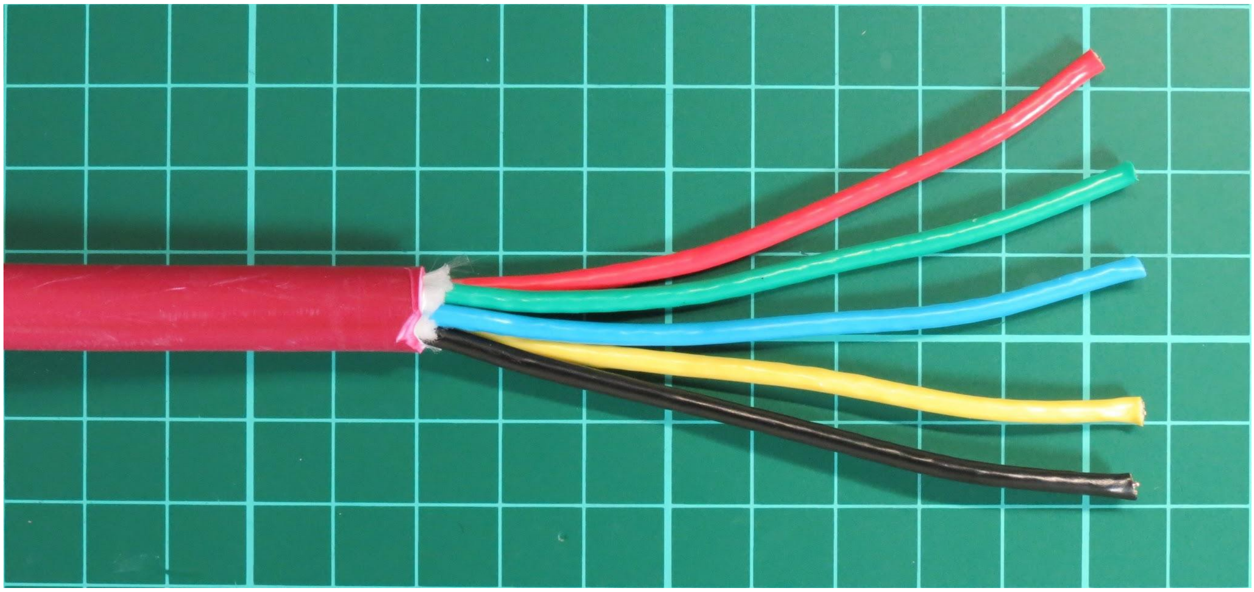
Analogue Video Cable



This is a 75-ohm coaxial cable used for composite video signals. There are standard and miniature versions of this cable.

Composite video is not used in Google systems.

Multicore Analogue Video Cable



This is a multicore 75-ohm coaxial cable used for component and RGBHV video signals. For component and RGBHV signals, it is essential that the signal paths are the same length because multicore cables must be used. Use of separate cables is forbidden.

This cable is available with different numbers of cores in standard and miniature versions. The size difference between the standard and miniature versions is significant. For ease of installation, the miniature version is normally preferred. However, the miniature version attenuates signal more, so sometimes the standard version must be used for long runs.

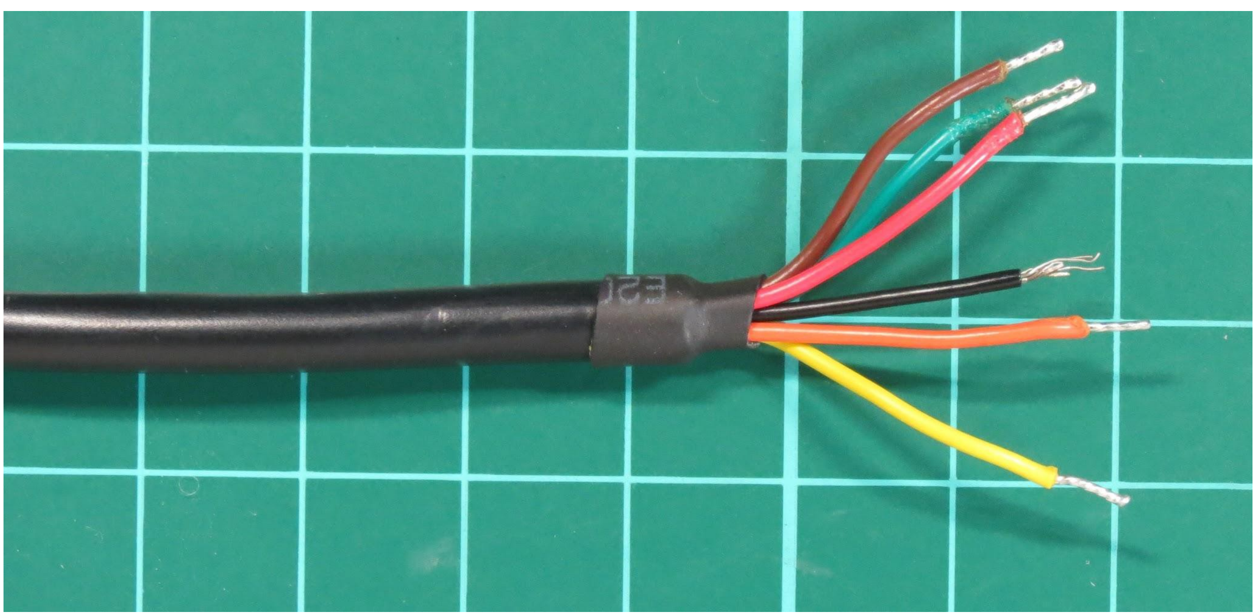
It is acceptable to use a multicore cable with more cores than required to reduce the number of cable types required. Similarly, use of higher specification cables is also acceptable.

SDI Video Cable

This is a 75-ohm coaxial cable used for Serial Digital Interface (SDI) video signals. SDI is a family of interfaces that has different definitions and bandwidth requirements.

All SDI cables used in Google systems must be capable of transmitting 3G-SDI.

Multicore Control Cables



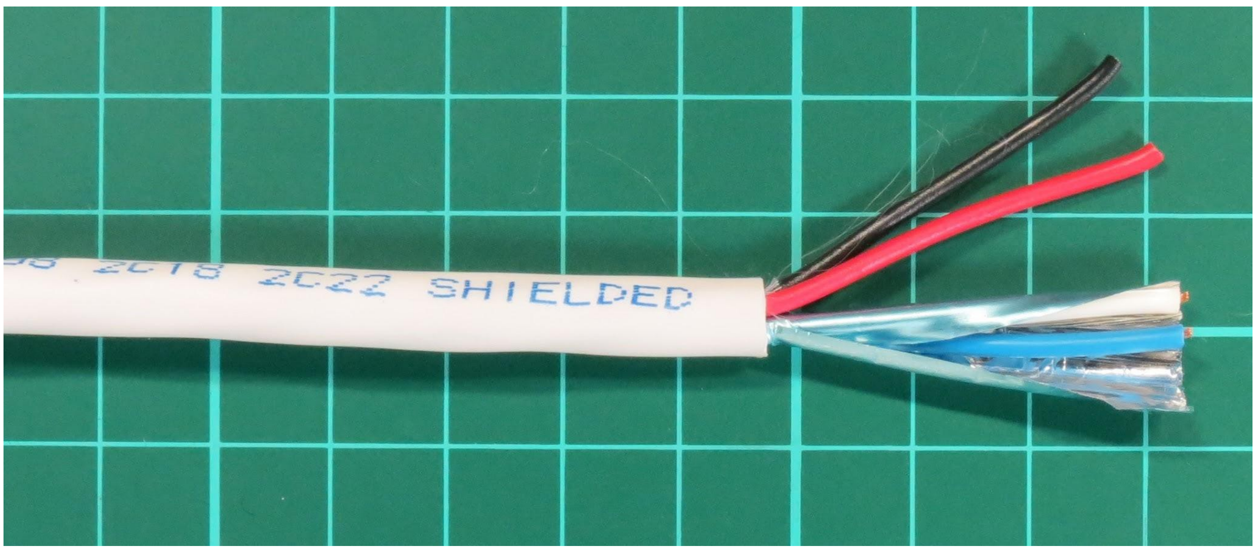
These are cables with multiple cores, which are often used for relay control indicator lamps and other devices with similar functionality.

For RS-232, RS-422, RS-485, and other similar standards, a low capacitance cable with multiple twisted pairs, a drain wire, and a foil shield must be used.

The drain wire should not be used for signal ground in a control cable.

Twisted pair cables can be used for other functions and are preferred in Google AV systems.

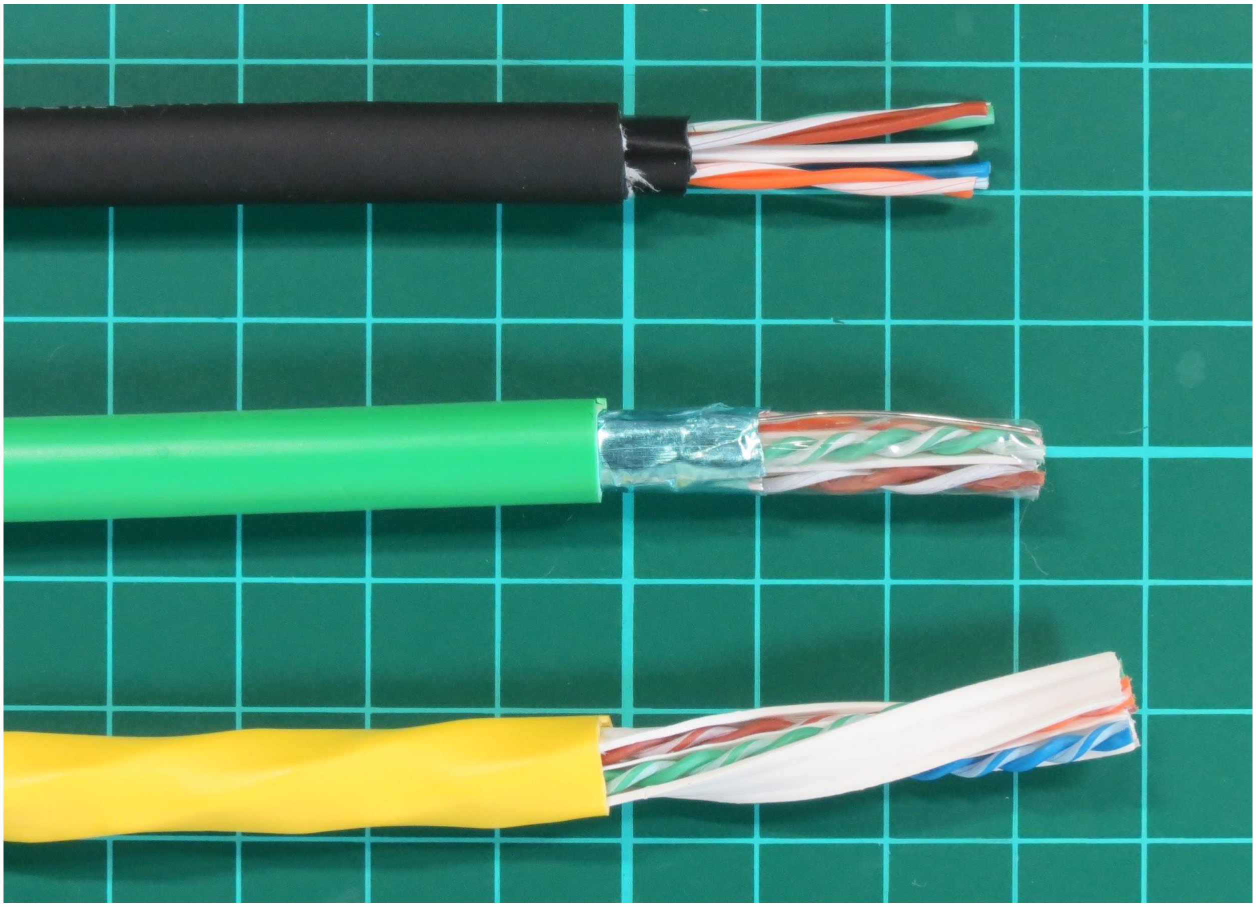
Media Control Cable



This cable consists of a foil-shielded twisted data pair and two twisted wires for DC power.

This cable is used for Crestron Cresnet in Google systems.

CATx Cable



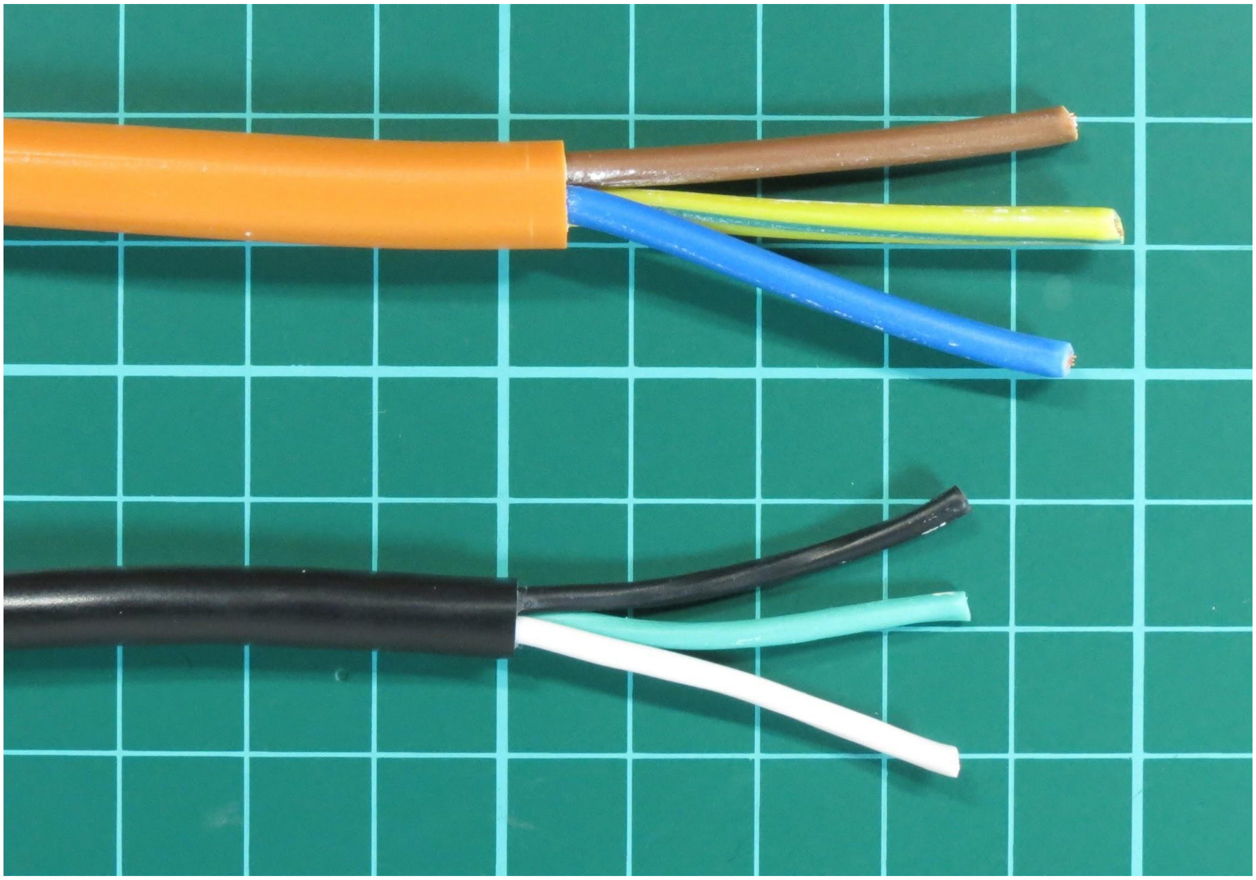
CATx is a shorthand representation for the Ethernet cable category. Cables in current usage are CAT5e, CAT6, and CAT6a with a maximum bandwidth of 100 MHz, 250 MHz, and 500 MHz, respectively. CAT6a has an internal spacer to keep a specified distance between the four pairs, which makes it thicker than the other categories.

The cable consists of four unshielded twisted pairs and comes in shielded and unshielded versions. Solid wire versions are used for installation cables, and stranded wire versions are used for patch cables.

Note: The pitch on the four pairs is different to reduce crosstalk. This leads to time delays between the pairs and should be considered when using CATx for non-Ethernet applications.

AV systems use Ethernet networks. Due to the relatively low cost of CATx cable, it is often used in AV systems with signal extenders or baluns.

Flexible Power Cable



This cable is used to connect equipment to an electrical supply. It comes in various sizes with different current ratings. It is essential that power cables with appropriate current ratings are used.

There are two main colour codes for flexible electrical wiring: IEC and NEC. See Table 1.3.

Table 1.3. Colour Codes for Flexible Electrical Wiring

Colour Code Standard	Live	Neutral	Earth
IEC	Brown	Blue	Green/Yellow
NEC	Black	White	Green

The correct colour code for the region of the installation must be used.

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2. Connectors

Overview

Cables carry the signals between equipment in a system. It is important to use the correct connector on a cable to ensure the mechanical integrity of the connection and the electrical requirements of the signal.

To differentiate between the two connectors in a mating pair, each connector is assigned a gender. In general, the male connector is inserted into the female connector. Male connectors are also known as plugs and female connectors as sockets.

A connector will have one or more contacts, or terminals, to terminate wires. It is important that all wires are terminated correctly inside the connector.

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2.1 Termination Methods

There are many ways of terminating wires to the contacts of a connector. The most common methods are described below, but these methods are not necessarily common in AV systems.

2.1.1 Crimping

The wire is inserted into the contact, which is then mechanically deformed and compressed around it. This is very common in AV systems.

2.1.2 Push Fit

The wire is pushed into contact and held in place by friction. This is only suitable for solid wire and not common in AV systems.

2.1.3 Screw Compression

The wire is held by the tightening of a screw. The wire may be wrapped directly under the head of the screw, at the point of the screw, or by a metal plate forced down by the screw. This is very common in AV systems.

2.1.4 Lever Compression

The wire is held in place by closure of a lever. This is not common in AV systems.

2.1.5 Soldering

The wire is joined to the contact with a metal, or solder, that has a much lower melting point than the wire or contact. This is very common in AV systems.

2.1.6 IDC (Insulation Displacement Connector)

An IDC contact has blades. Insulated wire is inserted into the terminal and blades cut through the insulation to make contact. This is very common in AV systems.

2.1.7 Wire Wrap

Wire is wrapped around the terminal. The terminal is designed for wrapping and is a very effective connection. This is not common in AV systems.

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2.2 Common AV Connectors

This section describes connectors commonly found in AV systems, including all the connectors found in standard Google AV designs.

2.2.1 Crimped Ferrule

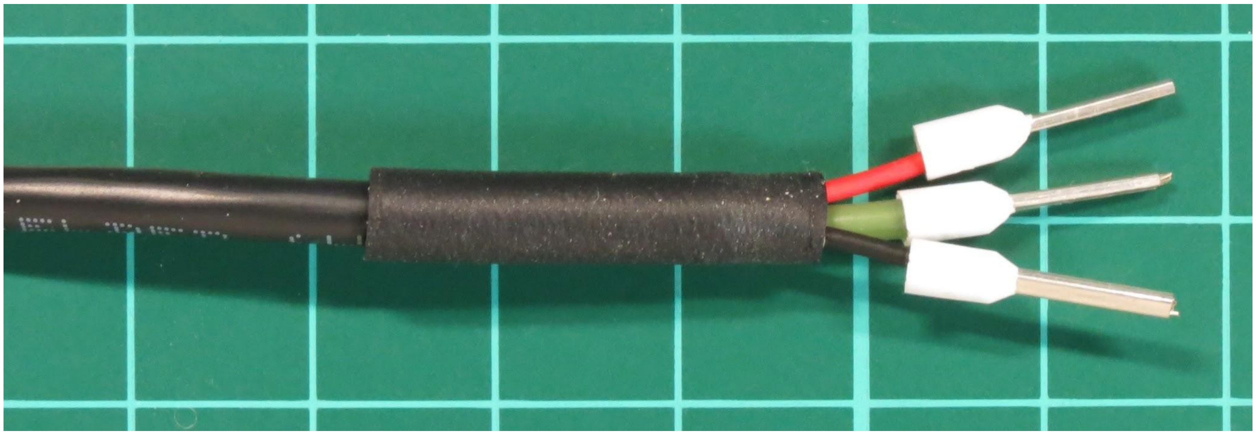
A ferrule is a metal tube that crimps over stranded wire. It can be insulated or not. Ferrules ensure neat insulation at the end of multi-stranded wires. Using ferrules turns stranded wire into a solid one, making it easier to insert cables into screw terminals and preventing breaking or fraying of individual strands.

All stranded cables that terminate in a screw terminal must use crimped ferrules in Google AV systems.

Ferrules are manufactured to DIN Standard 46228. For insulated ferrules, the insulation is colour-coded to indicate the wire size. For historical reasons, there are three different colour standards to identify crimp size: DIN (D), German (W), and French (T).

When using insulated ferrules, DIN standard colours should be used in Google AV systems.

Bootlace Ferrule



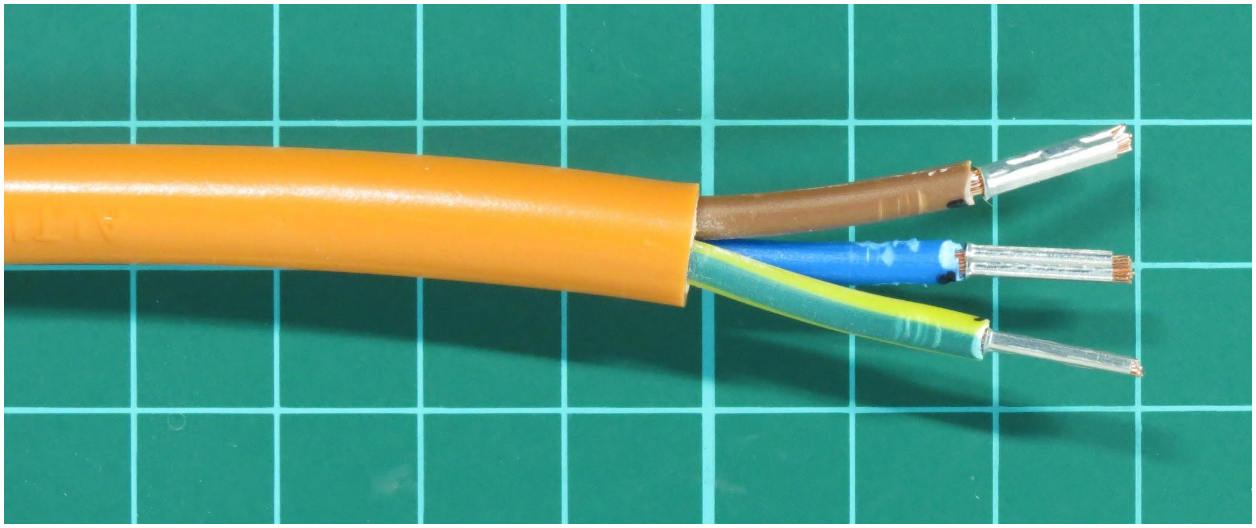
This is an insulated ferrule where the insulated part covers the wire. In addition to having the advantage of a solid wire, the extra width of the insulation makes it easy to ensure the insulation does not enter the terminal.

Twin Entry Bootlace Ferrule

This is an insulated ferrule designed for two wires of the same size. The colour coding is the same as for the standard bootlace ferrule. It can be distinguished from single entry by a rectangular barrel.

This type of ferrule is used when two wires must be terminated in the same terminal. A common use of this ferrule is for stereo-balanced audio connections, in which the two signals share the same ground terminal.

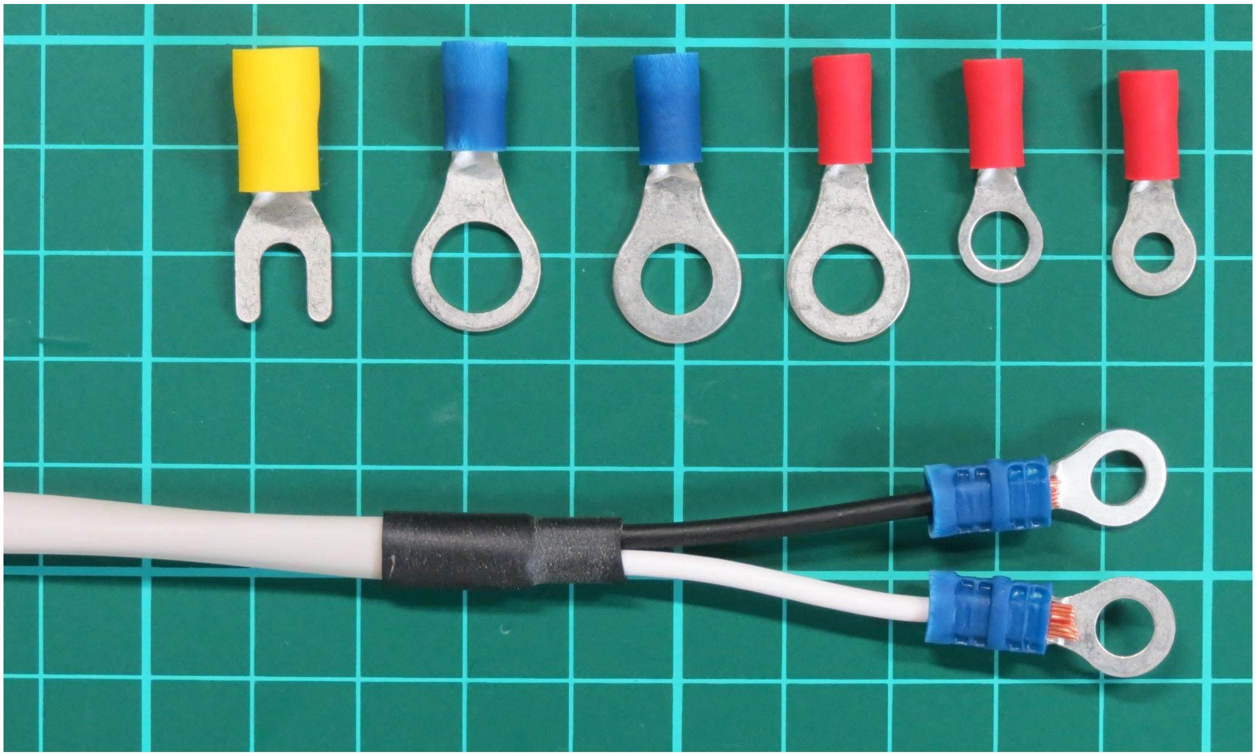
Uninsulated Bootlace Ferrule



This is a metal tube that covers the stranded wire only and is sometimes called an end sleeve.

This type of ferrule is used when wires are terminated inside an enclosure that prevents the use of insulated ferrules. A common use of this ferrule is to terminate power cabling.

2.2.2 Crimped Terminal



This category covers a wide range of connectors with different tongues. The tongue is the end of the terminal that attaches to other components. There are various tongue configurations, including the:

- Spade
- Ring
- Hook
- Male quick disconnect
- Female quick disconnect

These connectors come in three sizes, as shown in Table 2.1. They allow for a variety of wire sizes in the same crimp, unlike DIN ferrules, which only work with a specific wire size.

Table 2.1. Wire Sizing for Crimped Terminals

Crimp Colour	AWG	mm^2	DIN Ferrule Size
Red	22 - 16	0.5 - 1.5	1
Blue	16 - 14	1.5 - 2.5	2.5
Yellow	12 - 10	6	6

In addition to accommodating different wire sizes, some terminal types come with different tongue sizes. For instance, spade, ring and hook terminals are sized based on the stud for attachment. The correct type and size of tongue must be used.
The tongues of terminals must not be modified in any way. Modifications include:

- Splaying out a spade to fit a stud that is larger than intended for the tongue
- Compressing a spade to fit a stud smaller than intended for the tongue
- Cutting a ring to use as a spade
- A combination of cutting a ring to use as a splade and either splaying out a spade or compressing a spade to fit a stud

The only crimped terminal commonly used in Google AV systems is the spade. It is used for connecting cables to loudspeakers and amplifiers.

2.2.3 Screw Terminal

Terminal Block

A terminal block is an insulated connector used to connect two wires. Terminal blocks are sized according to the current rating. Insulation is normally plastic, but ceramic insulation is available for high temperature applications.

Plastic insulated terminal blocks normally come in strips that can be cut to provide the required number of terminals. This type is commonly referred to as the chock block.

Ceramic terminal blocks normally have two or three terminals.

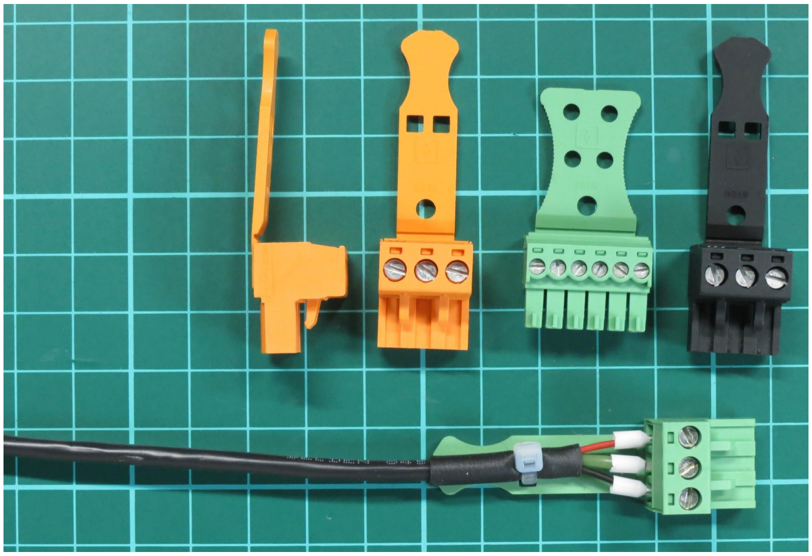
Barrier Strip

A barrier strip is a connector used to connect wires to a piece of equipment. It is available with different numbers of terminals and terminal sizes.

Technically, terminal blocks can be used as barrier strips, but with AV equipment, one side of the terminal is normally connected to a PCB with the screw terminal chassis mounted.

Barrier strips are cheap and allow for high connection density. However, barrier strips have a disadvantage when it comes to testing systems: When a cable is removed, there is no guarantee that the individual wires will be reconnected to the correct terminals.

Phoenix Connector

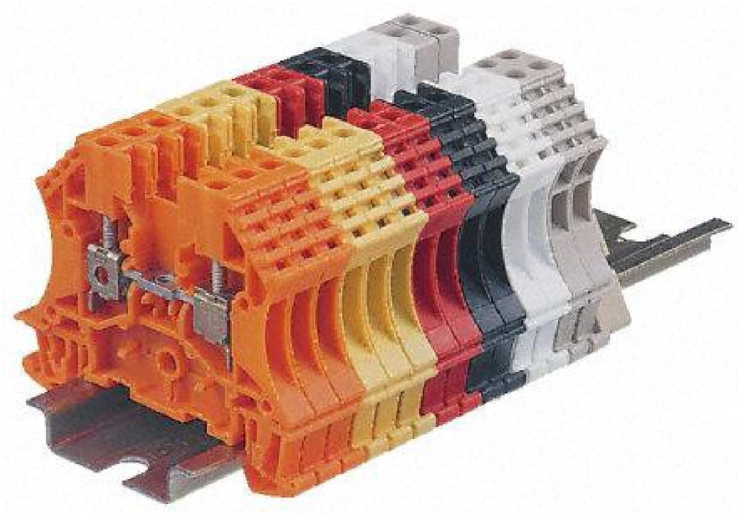


A Phoenix connector is a 2-part barrier strip, consisting of a header and a plug. The wires are connected to the plug with screw terminals, and the header is connected to a PCB. The plug and header are keyed to prevent incorrect connections. It is available with different numbers of terminals and terminal sizes.

Phoenix connectors are more expensive than barrier strips, but they have the advantage when it comes to testing and commissioning systems: When a cable is disconnected, the terminal wiring remains the same. High connection density is also retained.

These connectors are commonly used for audio and control signals.

DIN Rail Terminal Block



A DIN rail terminal block is a range of terminals designed to clip onto a DIN rail. The DIN rail is an ISO standard type of metal rail used to mount low voltage switchgear and controlgear.

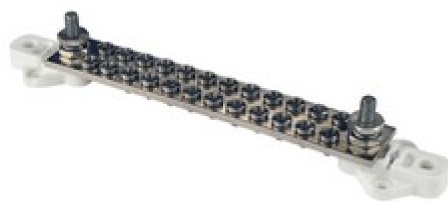
This type of terminal is often used within custom enclosures.

Busbar

A busbar is used to connect several wires. There are two types of busbars:

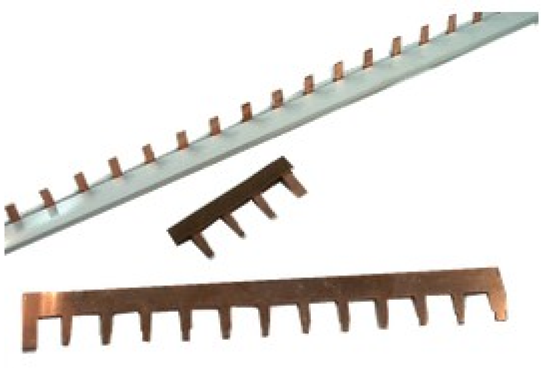
Solid conductor with multiple screw terminal

- Often found in electrical cabinets
- Used to bus earth or neutral cables together
- The technical earth busbar can be found in some rooms with AV systems



Solid conductor connected to multiple terminal blocks

- Often in the shape of a comb
- The teeth of the comb are spaced so that they fit into the individual terminals of a terminal block



Binding Post

A binding post has a stud and a captive nut that screws down on the stud. The nut is normally insulated with a plastic cap. The plastic caps are often colour-coded red for positive and black for negative.

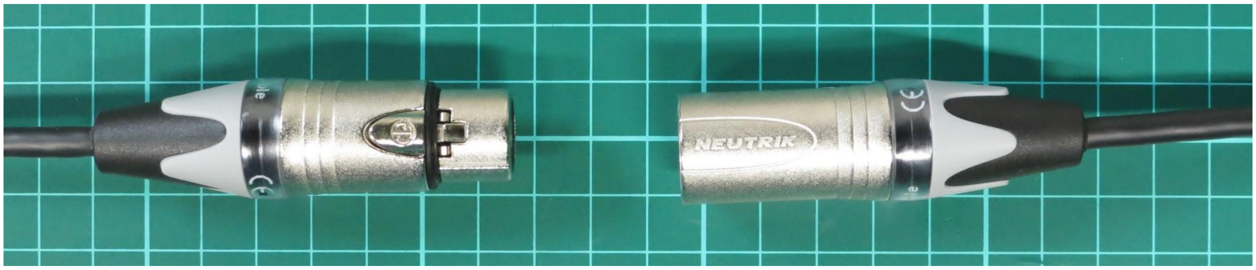
Depending on the design, there are several different connection methods:

1. A crimped fork terminal clamped around the stud
2. A crimped ferrule inserted in the hole of the stud and clamped down
3. Bare wire inserted in the hole of the stud and clamped down
4. Bare wire wrapped around the stud and clamped down
5. Banana plug inserted into the open end of a binding post

Method 1 is the preferred Google solution. Method 2 is acceptable as is Method 3 for solid cable. Methods 4 and 5 must not be used.

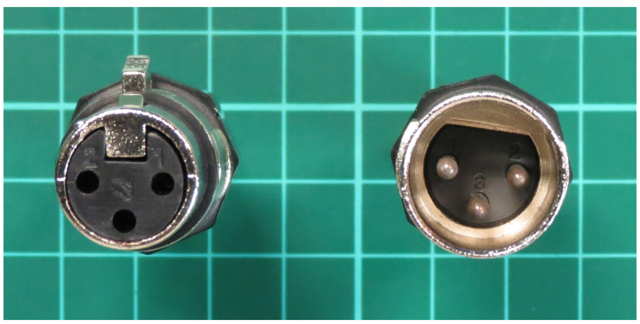
These connectors are commonly found on loudspeakers and audio equipment.

2.2.4 XLR Connector



This is a circular, polarised latching connector with 3-7 pins. The wire connection is usually solder, but IDC cable mounts are available. Below are the most common uses.

3-Pin XLR



This is by far the most common style XLR and is the industry standard for balanced audio signals.

The standard signal flow for audio in an XLR connector is output via a male connector and input via a female connector. This would appear to be the opposite of power connection standards, but if you consider the microphone as a device requiring power (as some do), it is not.

4-Pin XLR

This is the standard connector for intercom headsets. It is also used for DC power on some devices.

5-Pin XLR

This is the standard connector for DMX512 lighting control. It is also used for dual element microphones.

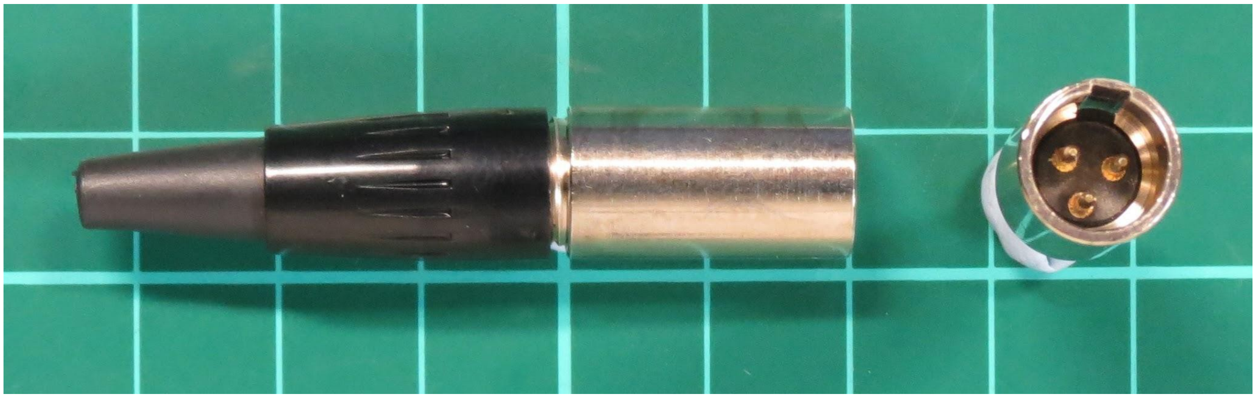
6-Pin XLR

This is the standard connector for dual channel intercom systems.

7-Pin XLR

This connector is used in some control applications.

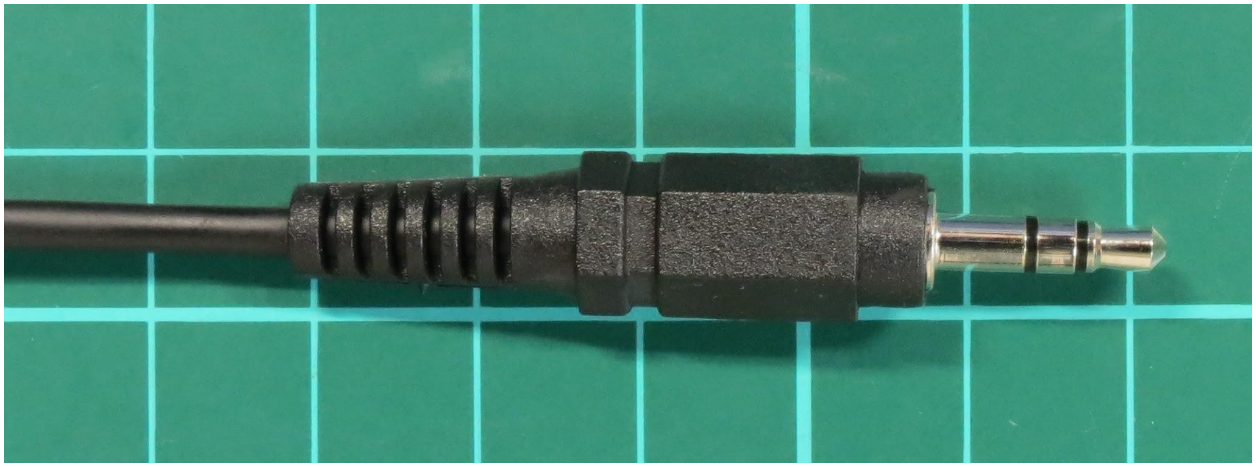
Tiny QG (Mini XLR)



This is a miniature, polarised latching connector with 3-8 pins. It is often referred to as a Mini XLR.

The 3-pin version is used on small profile and radio microphones.

2.2.5 TRS (Stereo) Connector



This is a cylindrical connector with three contacts: tip, ring, and sleeve. This nomenclature came from the ¼ inch versions originally used in telephone systems.

There are three common sizes: 6.35 mm (¼ inch), 3.5 mm, and 2.5 mm. The size is the outside diameter of the sleeve conductor. The 6.35 mm plug is also known as the A-gauge.

Typically, a cable will have a plug and equipment will have a socket, but cable-mounted sockets are available.

These connectors are commonly used for balanced audio or unbalanced stereo audio signals.

2.2.6 TS (Mono) Connector

This is a cylindrical connector with two contacts: tip and sleeve.

These connectors come in the same sizes and with the same form factor as the TRS connectors.

These connectors are commonly used for unbalanced mono audio signals.

TRS to TS Connections
If a TS plug is connected to a TRS socket, the ring channel is connected to the sleeve.
If a TRS plug is connected to a TS socket, the ring channel is left unconnected.

2.2.7 B-Gauge TRS (BPO 316)

This plug is similar to the 6.35 mm A-Gauge but has a different tip shape and insulation spacing. The A-Gauge and B-Gauge are not compatible, and damage can occur if they are mixed up.

The B-Gauge is commonly used in professional audio patchbays.

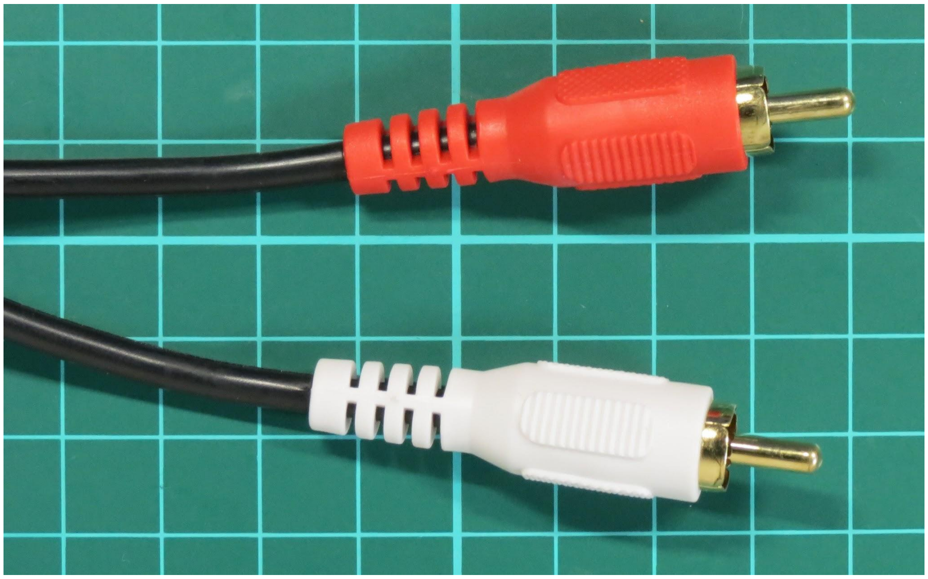
B-Gauge patch cables should not be manufactured by the contractor but supplied as an OEM product.

2.2.8 Bantam Jack Plug

This plug is a 4.4 mm cylindrical connector used with Bantam audio patchbays.

Bantam patch cables should not be manufactured by the contractor but supplied as an OEM product.

2.2.9 RCA Phono Connector



This is a circular connector with two concentric contacts. The signal is on the inner contact with the ground on the outer contact.

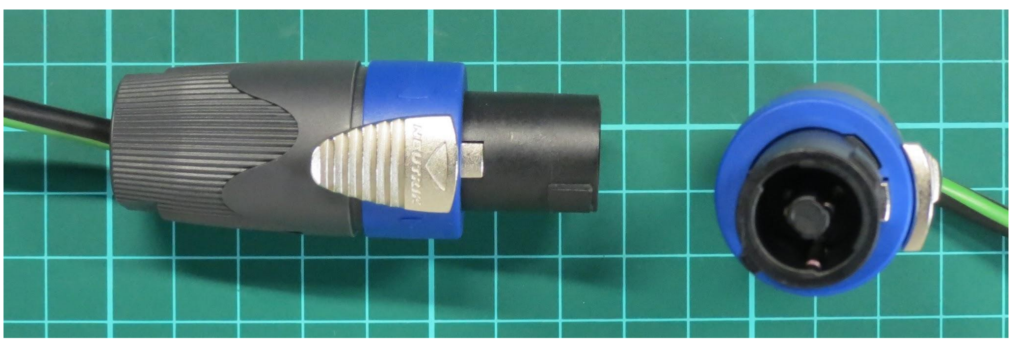
Typically, a cable will have a plug and equipment will have a socket, but cable-mounted sockets are available.

These connectors are used for unbalanced analogue audio and video, especially in consumer equipment. The wire connection is usually by solder, but crimp versions are available for connecting to a coaxial cable for video.

The connectors are colour-coded according to signal type:

- Left channel audio: White or black
- Right channel audio: Red
- Composite video: Yellow

2.2.10 Speakon Connector



This is a circular latching connector designed for loudspeaker and amplification connections. It is available in 2-, 4-, and 8-pole variants. The connector on the cable is always a plug, and the connector on the chassis is always a socket. Couplers are available to join cables.

Connectors are available with solder or screw terminals.

Note: Speakon is a Neutrik trademark, but other manufacturers make compatible products.

2.2.11 DIN Connector

This is a circular polarised connector with 3-8 pins. It is used for audio and control signals.

These connectors are seldom found on modern equipment used in AV systems.

2.2.12 Mini-DIN Connector

This is a circular polarised connector with 3-9 pins. It is similar to older, larger DIN connectors.

These connectors are only 9 mm in diameter, making solder termination of connectors exceptionally difficult. Use of OEM cables or adaptors is preferred when using these connectors.

S-Video

This is a standard connector for S-Video with a 4-pin mini-DIN.

PS/2

This is a standard connector for PS/2 with a 6-pin mini-DIN. These are colour-coded purple for keyboards and green for mouse devices.

Sony Visca

This is a control protocol designed by Sony for PTZ cameras. The connector on the camera is often an 8-pin mini-DIN.

2.2.13 D-Subminiature Connectors

This is a family of polarised multi-pin connectors, also known as D-Sub and D-Type connectors. The name comes from the D-shaped metal shield around the connector. There are five shell sizes: A, B, C, D and E. There are three pin layouts for each shell: normal density, high density, and double density.

The convention for naming connectors is *D [Shell Size]-[number of pins][Gender]*.

Note: Gender was originally denoted by P (plug) or S (socket), but M (male) and F (female) are sometimes used now.

Table 2.2 shows connector names and pin layouts. Figure 2.1 shows the five shell sizes with the normal density pin layout.

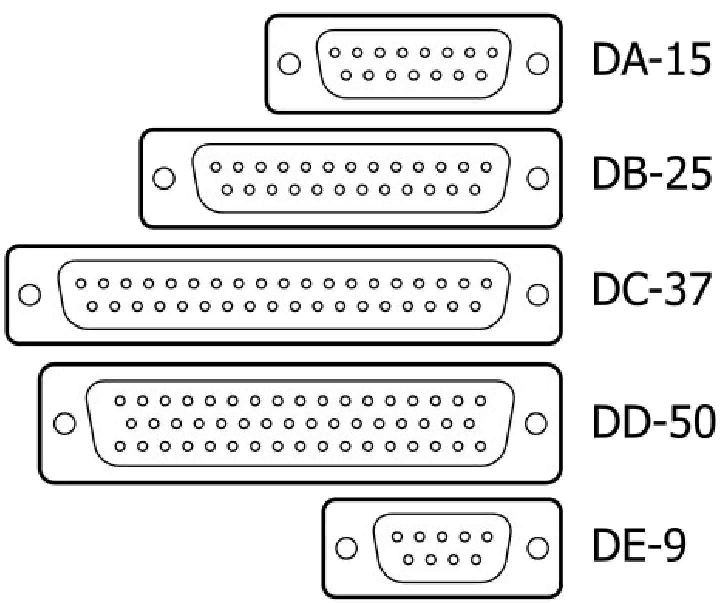
Table 2.2. D-Subminiature Connector Names and Pin Layouts

Normal Density		High Density		Double Density	
Name	**Pin Layout**	**Name**	**Pin Layout**	**Name**	**Pin Layout**
DA-15	8-7	DA-26	9-8-9	DA-31	10-11-10
DB-25	13-12	DB-44	15-15-14	DB-52	17-18-17
DC-37	19-18	DC-62	21-21-20	DC-79	26-27-26
DD-50	17-16-17	DD-78	20-19-20-19	DD-100	26-25-24-25
DE-09	5-4	DE-15	5-5-5	DE-19	6-7-6

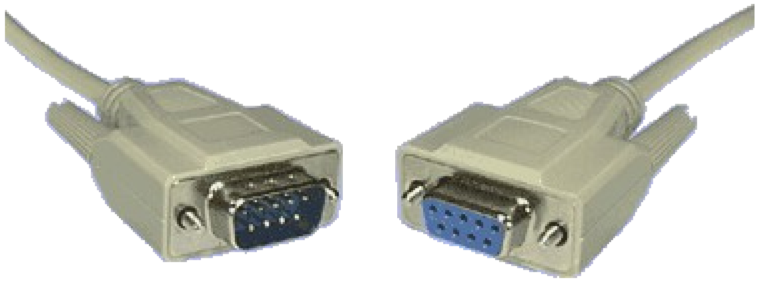
Note: The naming convention is not always followed. DE-9 is often referred to as DB-9, and DE-15 is often referred to as DB-15HD.

With all these connectors, the cable shield should be connected to a shell, not to a pin. See Figure 2.1.

Figure 2.1. D-Type Shells with Normal Density Pin Layout



Normal Density Connector



This is widely used for audio and control connections. The DB-25 is the connector recommended in the original RS-232 standard, but RS-232 is typically used now on DE-9 connectors.

High Density Connector

The DE15 is the only high density connector commonly used in AV systems. It is used for analogue video on computers and is often referred to as a VGA connector. With the move to digital video, use of this connector will decline.

Solder terminal versions of this connector exist, but they are extremely hard to terminate and must not be used.

Double Density Connectors

These are not commonly used in AV systems.

2.2.14 EDAC 516 Series Connectors

The EDAC 516 Series connectors are a range of locking, polarised rectangular multi-pin connectors. They are commonly referred to simply as EDAC connectors. They are fully compatible with ELCO 8016 Series connectors.

The connectors are available in five sizes, denoted by the maximum number of contact pins that can be housed: 20, 38, 56, 90, and 120. The number of wires to connect determines the number of pins required. Pins are available with either crimp or solder contacts. The pins are hermaphroditic contacts. Pins in the male connector are set at 90º in relation to pins in the female connector.

Each connector has two 6-way polarising sockets, allowing differentiation between cable assemblies.

These connectors are commonly used for multiple audio and control connections.

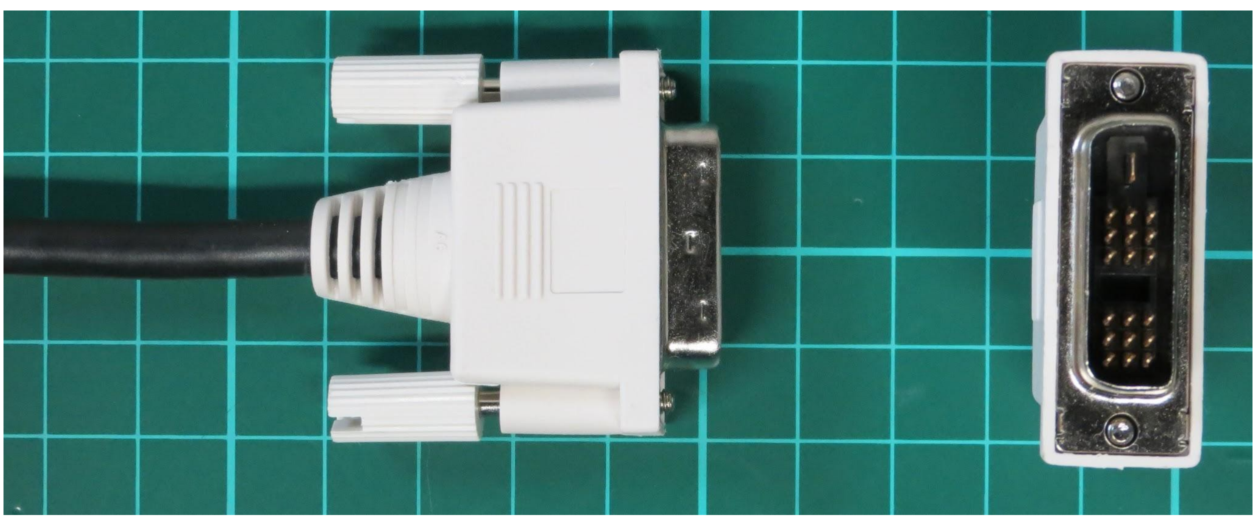
2.2.15 BNC Connector

This connector is a circular locking connector used for coaxial cables. It is made to match the characteristic impedance of the cable. 50 ohms and 75 ohms are common, but there is also a 95-ohm variant. It is extremely important to use connectors with the correct impedance.

All types of BNC are compatible and will mate with each other. However, there are many types and sizes of coaxial cables. BNC connectors must be selected to match the cable type.

BNC connectors are commonly used for analogue and SDI video signals, as well as radio antennas, such as those used with wireless microphones.

2.2.16 DVI Connector



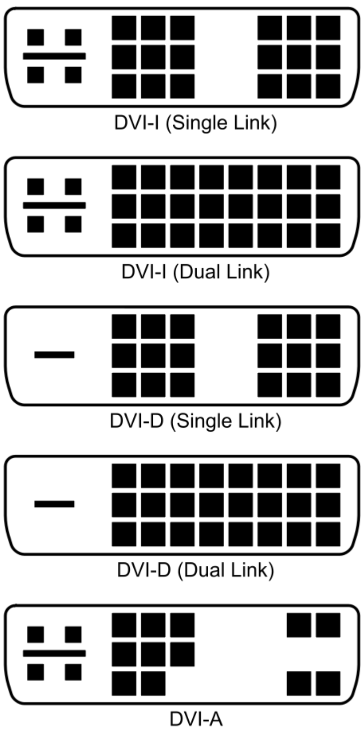
This connector is used for video signals. DVI is an acronym for Digital Visual Interface. This is a video signal mainly associated with computers, but it can be found on other equipment.

There are three different types of DVI connectors:
- DVI-D: Digital video only
- DVI-A: Analogue video only
- DVI-I: Integrated (analogue and digital video)

The three types have the same form factor, but cannot mate with each other.

For DVI-D and DVI-I, there are single link and dual link connectors, as shown in Figure 2.2. The dual link has nine extra pins and twice the bandwidth. Single link and dual link connectors of the same type can mate. This is useful when a source has a dual link output, but the display only has a single link input. When connecting a single link source to a dual link display, it is best to use a single link cable.

Figure 2.2. Male DVI Connector Pin Outs (Pin Side View)



DVI cables are always purchased as OEM products.

2.2.17 HDMI Connector

This is a connector used for HDMI, which can carry audio, video, control, and data signals. HDMI is an acronym for High Definition Multimedia Interface. HDMI is backwards-compatible with DVI since video uses the same encoding method.

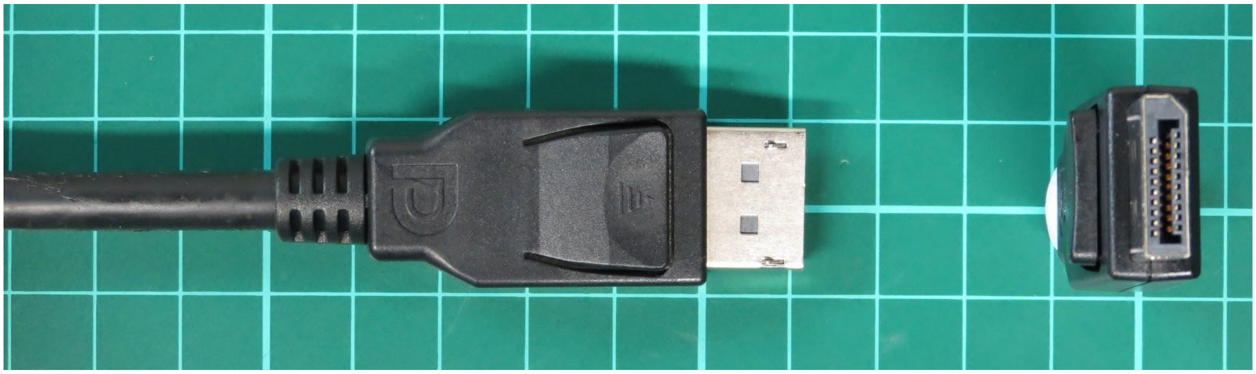
There are five types of HDMI connectors:

- Type A: 19-pin connector commonly found on computers and consumer AV equipment (HDMI 1.0)
- Type B: 29-pin connector compatible with dual link DVI that is not yet used on any product (HDMI 1.0)
- Type C: 19-pin mini-connector intended for portable devices (HDMI 1.3)
- Type D: 19-pin micro-connector (HDMI 1.4)
- Type E: Automotive connection system with a locking tab to prevent cables from coming loose and a shell to prevent moisture and dirt ingress (HDMI 1.4)

Nearly all HDMI connections in Google AV systems are Type A.

HDMI cables are always purchased as OEM products.

2.2.18 DisplayPort Connector



This connector has an interface that can transmit 1-8 channels of audio and/or digital video. The DisplayPort connector is a polarised 20-pin connector.

DisplayPort cables are always purchased as OEM products.

2.2.19 USB Connector

This connector is a standard for communication and power between computers and electronic devices. USB is an acronym for Universal Serial Bus.

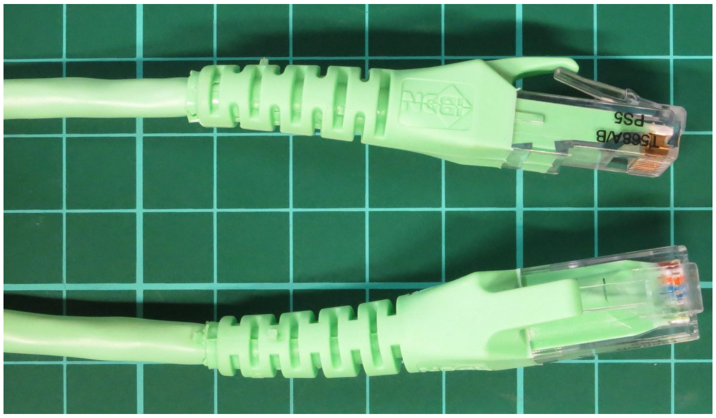
There are several types of USB connectors:

- Type A: Intended for a host device that supplies power
- Type B: Intended for target devices that receive power
- Multi-purpose/mini/micro versions: Function varies

The connectors for USB 3.0 are different from those for USB 2.0. Type A connectors for the different versions can interoperate, but type B cannot.

USB cables are always purchased as OEM products.

2.2.20 Position 8 Contact (8P8C) Connector



The 8P8C connector is a modular connector used for CATx cables. It is often referred to as RJ45, but this is not technically correct.

8P8C is IDC, so it is important to use connectors that match the cable.

For structured cabling, only sockets can be field-terminated. Solid wire is used and all circuits are tested once complete. Patch leads using stranded cabling must be OEM.

CATx cable is increasingly used in AV systems. Wherever possible, the structured cabling standards should be adopted. Field termination of 8P8C plugs should be avoided.

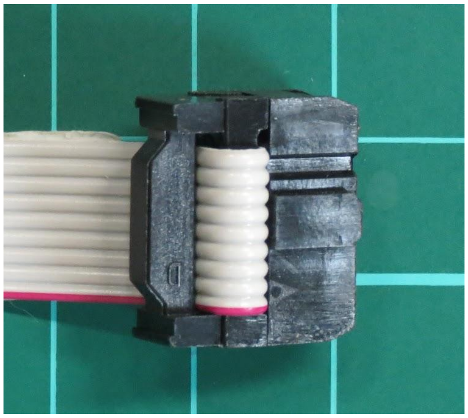
2.2.21 Banana Connector

This connector is a single wire plug. It can mate with a binding post connector, and there are variants where plugs have the socket on the rear for stacking.

These connectors are often used for patch cords on electrical test equipment and for connecting amplifiers and loudspeakers.

This connector must not be used in Google AV systems.

2.2.22 Ribbon Cable Connector



A multi-pin header is normally used to connect ribbon cables, and it is nearly always an IDC type connector. Headers are available in polarised and non-polarised versions. This connector is likely to be used in custom built kits, in which case, the polarised version must be used.

Care must be taken to ensure that the ribbon is correctly aligned with the IDC contacts when terminating.

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2.3 AC Electrical Connectors

2.3.1 Installed Domestic Socket and Plug Types

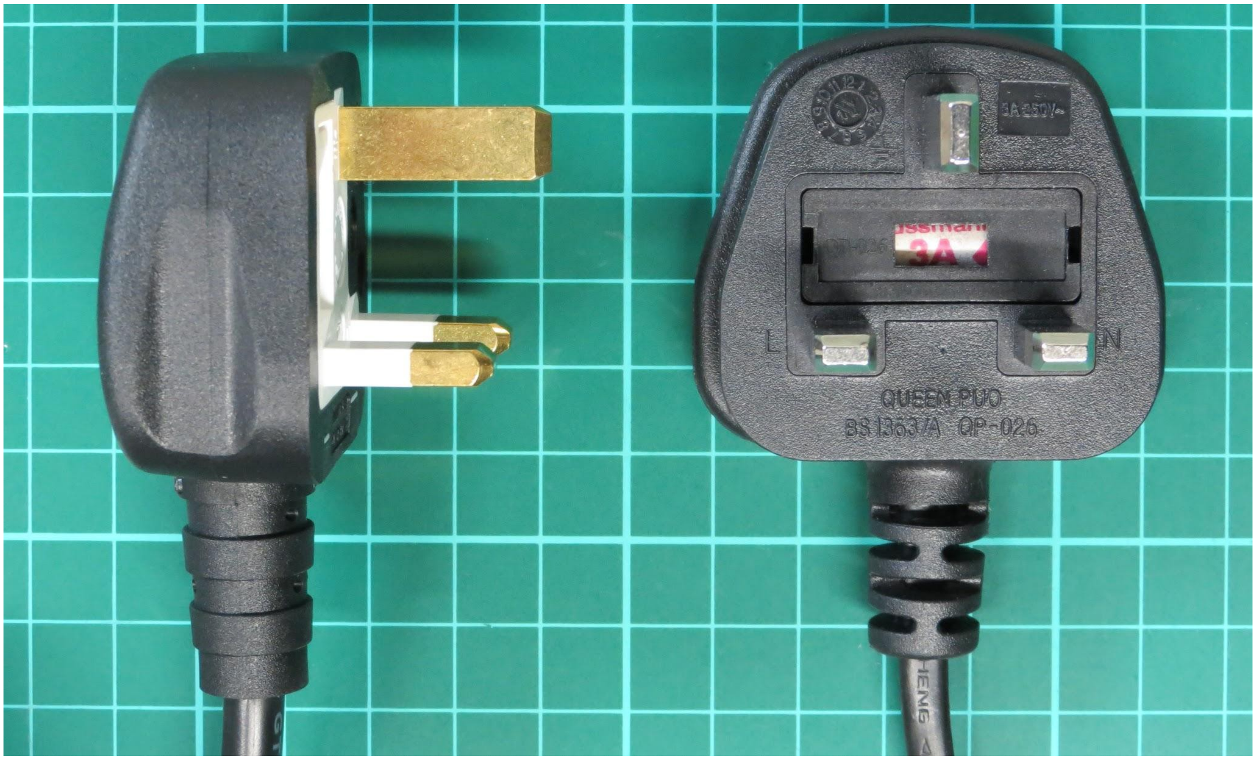
There are about 20 different types of electrical sockets in common usage around the world. The type that can be used as part of a permanent building installation are prescribed by local regulation and can not be standardised globally.

Some sockets will accept multiple plug types and some plugs will fit multiple sockets especially within the CEE 7 standards.

2.3.2 Australian/New Zealand Standard AS/NZS 3112

This connector is polarised. The plug has an earthing pin and two current-carrying pins angled at 30° to the vertical. There is a 2-pin version of the plug with no earthing pin, but all sockets have earth.

2.3.3 United Kingdom BS1363



This connector is polarised. The plug has three rectangular pins and contains a fuse.

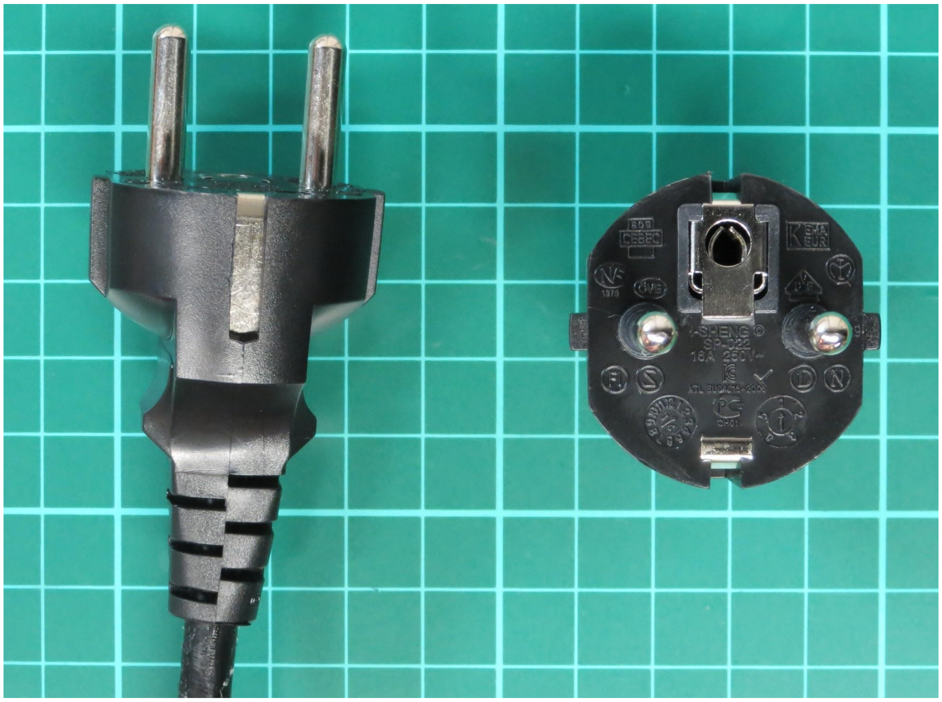
2.3.4 CEE 7/4 (German “Schuko”)

This connector is not polarised. The plug has two round current-carrying pins with two earthing clips on either side.

2.3.5 CEE 7/5 (French)

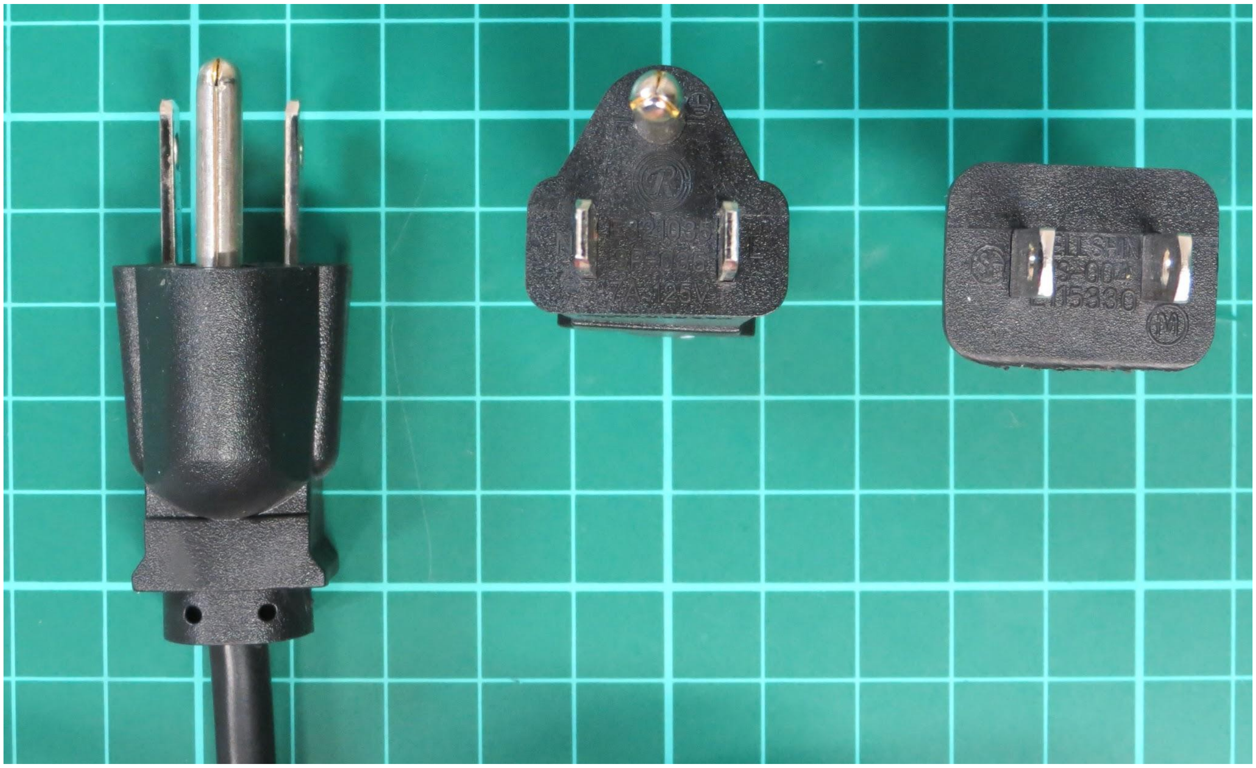
This connector is polarised, but there is no standard for the current-carrying terminals. The plug has two round current-carrying pins and a recess to accept the round earth pin that is part of the socket.

2.3.6 CEE 7/7 Plug



This is a plug that bridges the difference between CEE 7/4 and CEE 7/5 sockets. It allows equipment to be sold with the same plug but used on different sockets.

2.3.7 USA/Canada NEMA 5-15



This is a polarised connector. It has two parallel current-carrying blades and a round earth pin. NEMA 1-15 is a 2-blade variant with no earth. A NEMA 1-15 plug will mate with a NEMA 5-15 socket.

2.3.8 Installed Industrial Socket Types

IEC 60309 defines sockets for industrial purposes. There is a range of plugs and sockets with different numbers of pins and current ratings. They are colour-coded, and the different types cannot mate with each other. They are sometimes referred to as Commando plugs.

This type of connector is often used in dedicated equipment rooms. The most common type used for an AV rack would be 2P+E 16A 230V.

2.3.9 Appliance Coupler

IEC 60320 specifies appliance couplers for non-locking power supply cables to electrical appliances. Various connectors are defined for different requirements and are distinguished by shape and size. This particular IEC standard is in use in North America, allowing manufacturers to use the same input socket on a piece of equipment worldwide with just a different power cable.

This standard also allows a power supply from one piece of equipment to power another. An example of this would be a desktop computer powering a monitor via a cable with a C13 to C14 coupler.

The C13/C14 coupler pair is very common. It is rated 250V/10A/70ºC. Power distribution blocks with C13 female outlets are readily available. Available products range from simple extensions to PDUs with monitoring and switching of individual outlets with IP control.

All power distribution within equipment racks in Google AV systems should use C13/C14 couplers.

2.3.10 Powercon Connectors

These are locking electrical connectors manufactured by Neutrik for connecting the main power. They look and work similar to Speakon connectors. These are not designed to be connected or disconnected under load, making these connectors unsuitable for an environment where untrained personnel can access them.

<u>Note</u>: Googlers like playing with things. Do not use this connector if you want to keep the magic smoke inside your devices.

2.3.11 Powercon True1 Connectors

These are locking electrical connectors manufactured by Neutrik that can be connected and disconnected under load. These connectors can be used instead of appliance couplers when a locking connection is required.

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3. Cable Numbering

Overview

It is important that each and every cable in a system can be easily and readily identified at all times. To this end, each cable must have a unique ID displayed on both ends of the cable. Even though this ID can be alphanumeric, it is normally referred to as a cable number.

Note: During the installation process, temporary labeling is allowed, but a permanent solution is required for completion to be accepted.

The cable number is the only information required on the cable. All cable information can be found in the cable schedule. Figure 3.1 shows part of a cable schedule from an actual project.

Figure 3.1. Cable Schedule Example

		From				To				Notes
Cable No.	Cable Type	Location	Equipment	Label	Connector	Location	Equipment	Label	Connector	
8101	SDI	Stage	Lectern L	SDI IP	BNC	Desk Rack	Musa 1	OP 01	BNC	
8102	SDI	Stage	Lectern R	SDI IP	BNC	Desk Rack	Musa 1	OP 02	BNC	
8103	SDI	Stage	Lectern C	SDI IP	BNC	Desk Rack	Musa 1	OP 03	BNC	
8201	SDI	Desk rack	Musa 1	IP 01	BNC	Desk Rack	SDI Matrix	IP 01	BNC	OEM
8202	SDI	Desk rack	Musa 1	IP 02	BNC	Desk Rack	SDI Matrix	IP 02	BNC	OEM

The example is a spreadsheet, which includes columns (not shown) for when cables were run, when they were terminated, who terminated them, when they were tested, and who tested them. The “Notes” column can be used for any purpose, such as references for wiring details. In the example, “OEM” in the “Notes” column indicates that the cable should be purchased, not manufactured by the contractor.

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3.1 Cable Numbering Methodology

There is often a methodology used in how cables are numbered, but this may not be obvious at first glance. In Figure 3.1, the first number indicates the signal type: “8” for SDI.

If cables must be added to a system, then the original numbering methodology must be used for permanent numbering. Temporary numbering is allowed if additions are required on short notice and as long as unique numbers are used.

The cable numbers must be shown on the system drawings, but must be generated on a spreadsheet first. This is done to avoid duplication and keep numbers unique.

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3.2 Multiple Systems

When there are multiple identical systems wholly contained within a single room or suite of rooms, it is preferable to use the same numbering methodology on all systems. However, any connections between systems must have unique IDs.

3.2.1 Permanent Labeling

Types

Two methods are allowed for permanent labeling:

- Machine-printed, self-laminating labels
- Resistor colour-coded Chevron cut markers

The method chosen for numbering cables should be included in project documents. The chosen method will vary, according to to the circumstances of the project. Both methods can be used within the same project. If Chevron cut markers are the preferred choice, self-laminating labels will have to be used on all OEM cables.

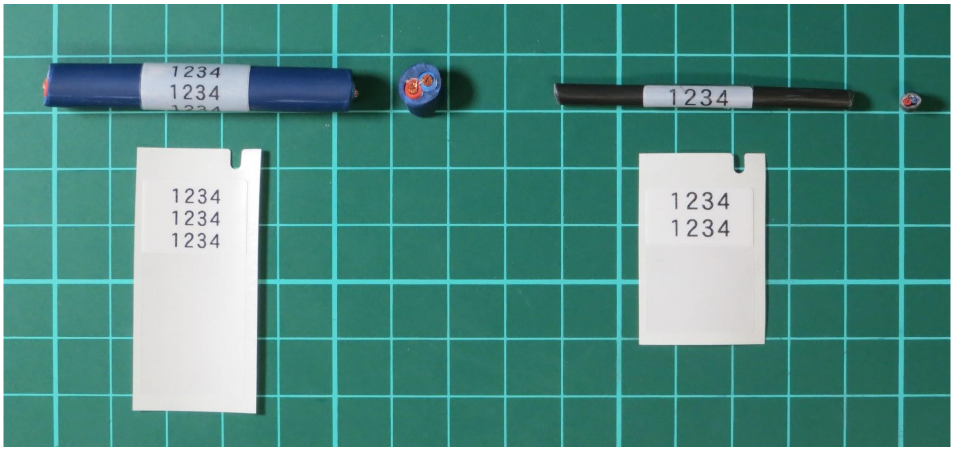
Chevron cut markers that are not colour-coded and snap-on markers must not be used. Permanent labels must not be handwritten.

Self-laminating Labels

Self-laminating labels have a legend area that can be written or printed on with a transparent tail. As the label is wrapped around the cable, the transparent tail covers the legend to protect it.

By printing the cable number on multiple lines of the legend, it can be seen from different angles. This reduces the need to move an installed cable to check its number. Figure 3.2 shows two labels of different sizes and how they are used.

Figure 3.2. Self-laminating Labels



Application

- The cable needs to be clean.
- Hands must be clean to avoid getting smudges on the adhesive that will mask the legend.
- The cable must be straight when the label is applied. Otherwise, it will wrinkle.
- The top of the label needs to be placed squarely on the cable with the tail wrapped around.

Advantages of Use

- Permanent, long-lasting identification
- Easy and quick to apply
- Cable numbers can be imported from the cable schedule, allowing easy printing of labels

Disadvantages of Use

- Can be difficult to read the number without moving the cable in some equipment racks and other situations

Chevron Cut Markers

Chevron cut markers are individual markers printed with a single alphanumeric character. Multiple markers are used to form the cable number with the Chevron cut, allowing the characters to be aligned. Figure 3.3 shows resistor colour-coded Chevron markers.

Figure 3.3. Chevron Cut Markers

Application

- The various markers used to make up the cable number are put on a thimble jig.
- The thimble jig allows the individual markers to fit over the cable easily and makes it easy to check that the numbers are correct before application.
- The thimble jig is placed over the cable, and the markers are slid onto the cable.

Figure 3.4 shows three jigs of different sizes with assembled numbers. Figure 3.5 shows how the jig slides over the end of the cable.

Figure 3.4. Cable Numbers Assembled on Thimble Jigs

Figure 3.5. Thimble Jigs Placed Over Cable

Advantages of Use

- Very easy identification of cables from any angle by means of colour coding

- Can be slid along cable so there is no need to keep renumbering during the installation process when cables are cut

Disadvantages of Use

- More time-consuming than using labels
- Cannot be used on OEM cables
- Adds a lot to the diameter of cables, which can be an issue in some circumstances

Hybrid Method

For some installations, a hybrid method is appropriate. The full cable number is printed on a label, but Chevron cuts are used for the last 2-3 digits only.

This is useful for equipment with several numbered connections, such as matrix switchers with a suitable cable numbering methodology. The cable numbers are chosen such that the last digits of the number match the number of the connection. For example, for 32 inputs, cables could be numbered ###01 to ###32. The cable label has the full number referenced in the cable schedule and drawing, but colour coding makes it easy to visually check connections.

3.2.2 Temporary Labeling

During installation, cables are often cut back and have to be relabelled. For this reason, rules on temporary labels are not stringent. Contractors may use whatever method they wish, and handwritten labels are allowed.

It is the contractor's responsibility to ensure that labels are durable, as no allowance will be given if cables cannot be identified.

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3.3 Label Placement

3.3.1 Direction of Label

Labels can be applied to cable ends in two directions:

- Right-handed: Label is read towards the cable end.
- Left-handed: Label is read from the cable end.

The easiest way to remember which way to label a cable is to think about writing on the cable end directly. If you are right-handed, you would hold the cable in your left hand and write with your right, as shown in Figure 3.6.

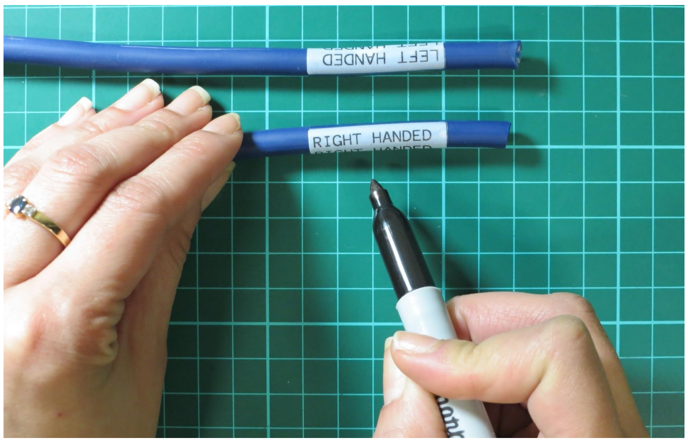
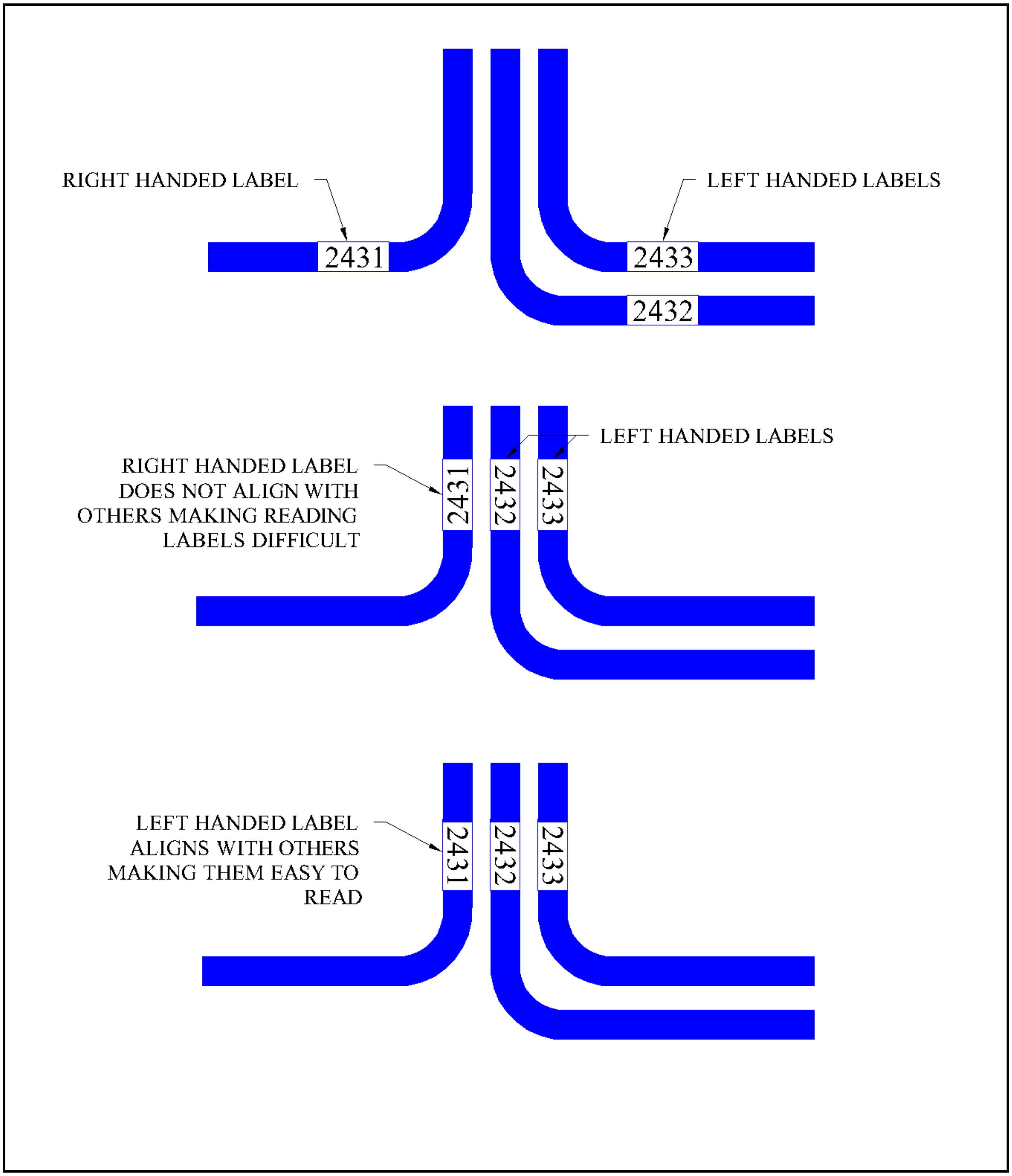


Figure 3.6. Example of Right- and Left-handed Labels

For loose cables, labeling should always be right-handed. For constrained cables, consideration should be taken as to which direction will be easiest to read.

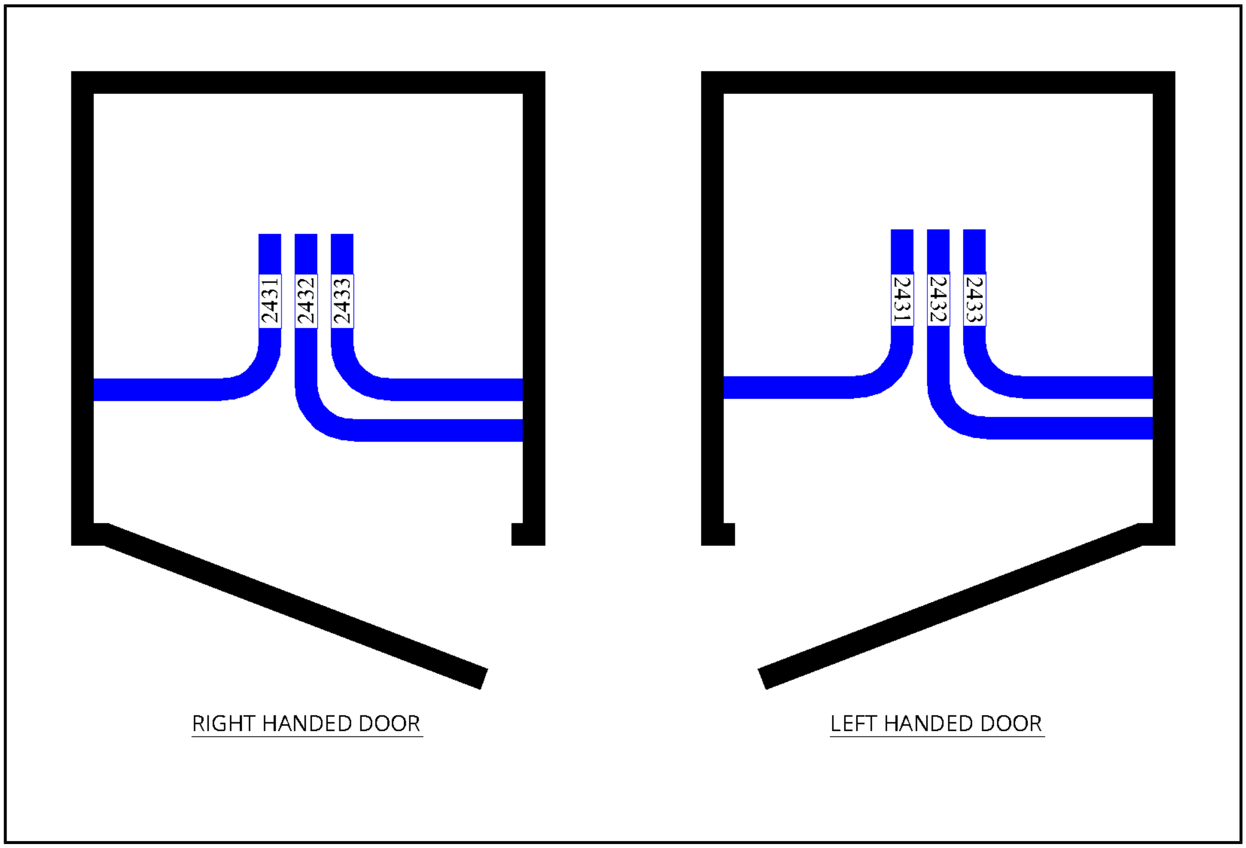
All labels in a given location should have the same orientation from a viewing position, which can require a mix of left- and right-handed labels, as shown in Figure 3.7.

Figure 3.7. Examples of Mixed Left- and Right-handed Labeling



For wiring within an enclosure, the major factor in deciding which way to apply labels is where they will be viewed. In general, left-handed labels should be used with left-handed doors and right-handed labels with right-handed doors, as shown in Figure 3.8.

Figure 3.8. Label Direction Dependent on Direction of Enclosure Door



3.3.2 Positioning of Label

Permanent Labels

Permanent labels need to be attached close to the end of the cable, but far enough back from the connector so that the connector shell can be slid back for inspection without disturbing the label. As a general guideline, there should be a gap of 100 mm from the rear of the connector to the start of the label.

Note: Depending on how cables are loomed, there might be a need for the gap to be greater or smaller for easy reading. It is important that the same distance is maintained for all cables in one location.

Temporary Labels

Temporary labels should be fixed 0.5-1 m from the end of the cable. This distance helps ensure that the label is not damaged while cables are being handled.

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4. Cable Handling

Overview

In any well-engineered system, function is more important than form. However, that does not mean that we do not care about form. We want our systems to look as good as possible. Unless there is a functional reason that trumps form, all cable installations must be neat and tidy.

Cable installations that in any part resemble the proverbial rat's nest, bowl of noodles, or plate of spaghetti will not be tolerated.

Neat and tidy installations show the installers have taken pride in their work, and this should give confidence in other parts of the installation.

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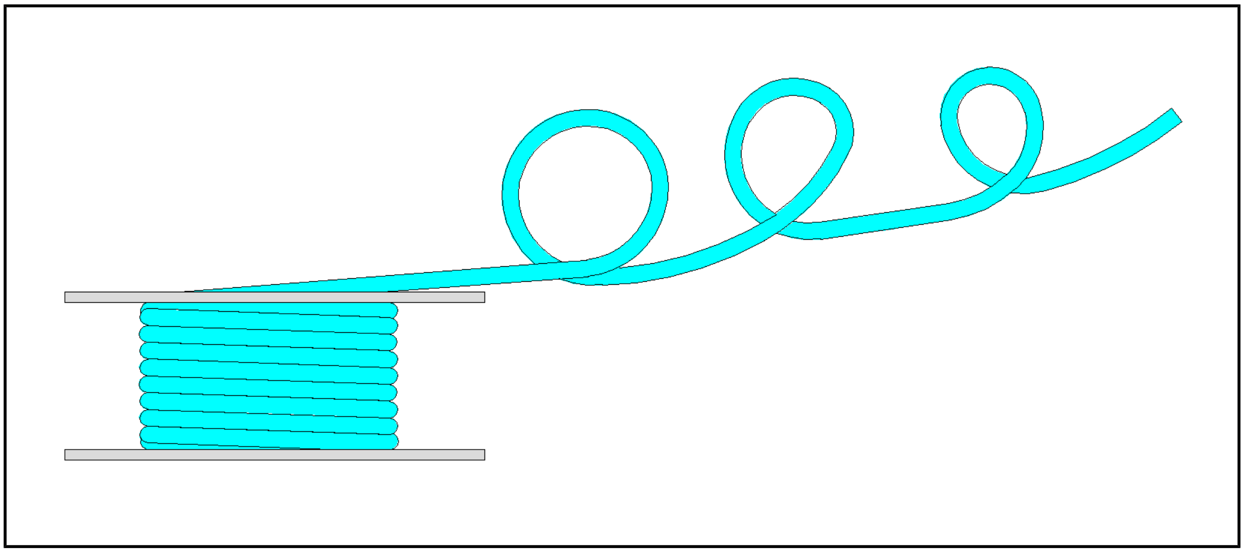
4.1 Unreeling Cables

When a cable is taken off a reel, it has a tendency to coil again. There is little that can be done about this. It is an effect of the cable being tightly coiled after manufacture, and it takes time for the cable to "relax".

The severity of this effect on the cable varies with how the cable is unreeled. If the cable is just pulled off a stationary drum, it will have a spiral twist, as shown in Figure 4.1.

Figure 4.1. Cable Pulled off Stationary Drum



This spiral twist leads to problems during installation. Cables tangle more easily, making a neat job almost impossible and adding time to the installation. As cable is pulled during installation, the loops can tighten into a kink-damaging cable. (See Minimum Bend Radius.)

The correct way to unreel a cable is to roll it off the reel. There are two ways to do this:

- The cable reel is rolled, leaving cable on the floor, as shown in Figure 4.2.
- The cable reel is placed in a spool holder or on a drum roller, allowing the reel to rotate while cable is pulled off, as shown in Figure 4.3.

Figure 4.2. Unrolling Cable

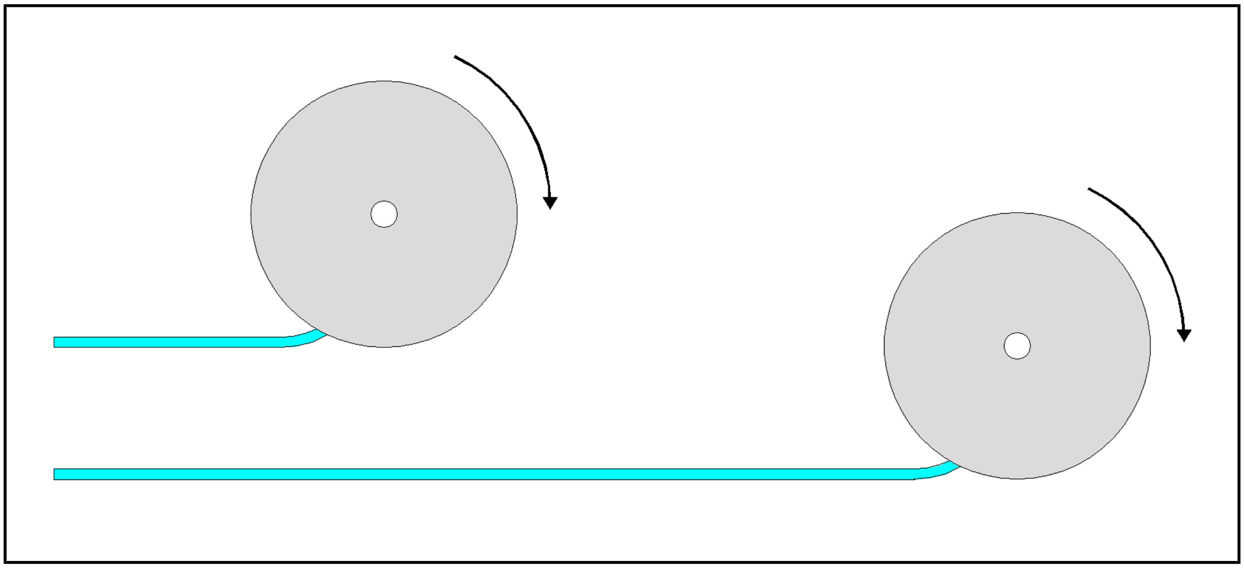
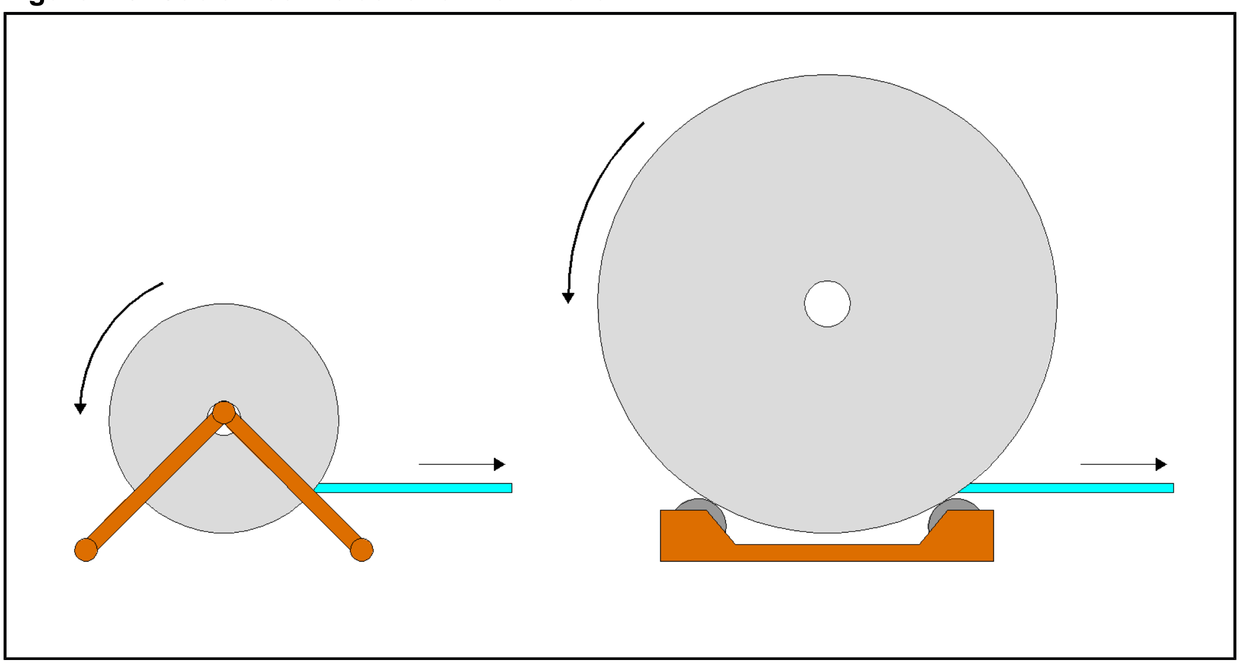


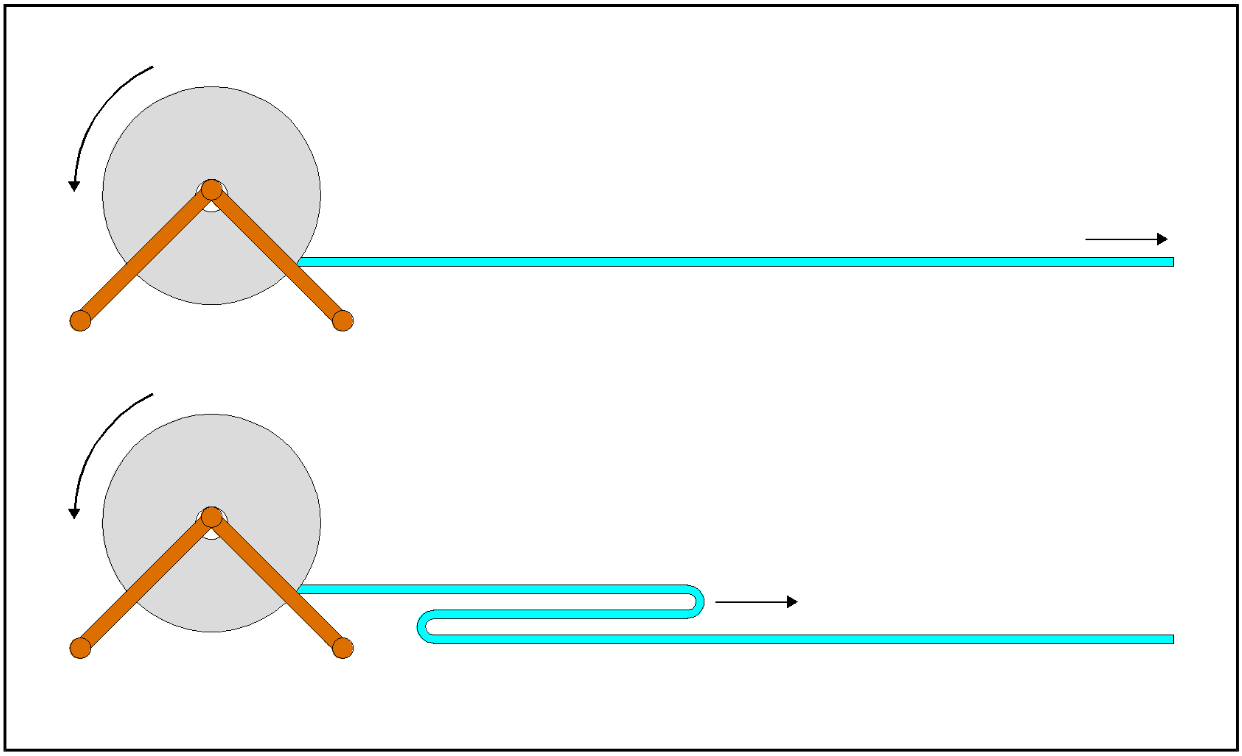
Figure 4.3. Cable Reel Holder and Drum Roller



Using a cable reel holder or a drum roller is easier and preferred. Where possible, cables should be installed straight from the reel. When multiple runs need to be cut from the same reel for the same cable path, they should be pulled and cut to length and then installed together.

To prevent tangling, cables should be unrolled in a straight line. The cables must not be left in a pile or heap where they can easily tangle. Where floor space is limited or long cable runs are required, the cable should be run up and down the floor, as shown in Figure 4.4.

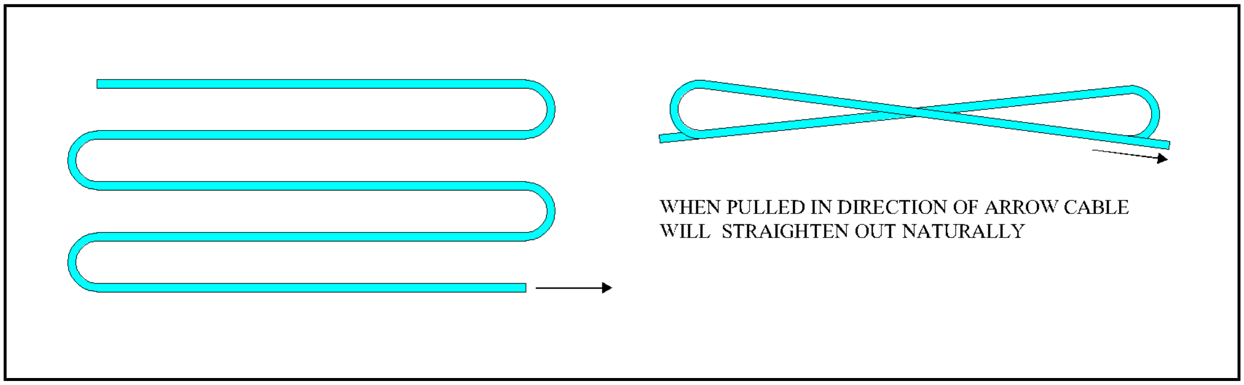
Figure 4.4. Unreeling Long Lengths of Cable



When the cable is pulled from an up/down cable run, it will naturally straighten out. This is also the case if the cable is run in a “figure 8”, as shown in Figure 4.5.

The Figure 8 run is useful when space is tight, but care must be taken, as it is very easy for the cable to get tangled.

Figure 4.5. Up/Down Cable Run Compared with Figure 8 Cable Run



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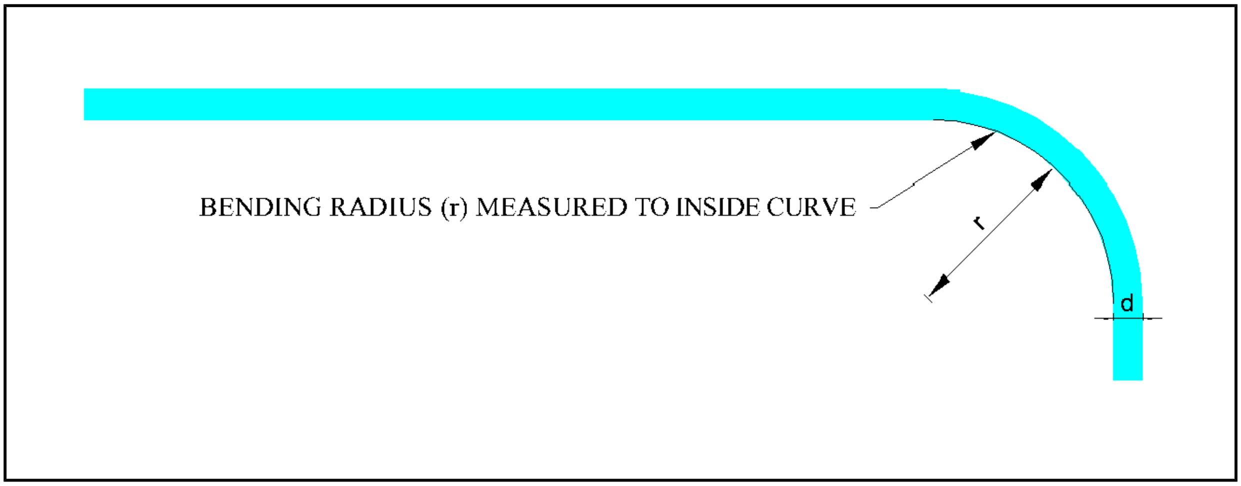
4.2 Minimum Bend Radius

The bend radius of a cable is the radius of the curvature measured to the inside curve, as shown in Figure 4.6.

Figure 4.6. Cable Bend Radius



The minimum bend radius is the smallest radius (i.e., tightest curve) that can be used on cable without damaging the cable or compromising quality. The manufacturer’s data sheet will state the minimum bend radius for each type of cable. The minimum bend radius must not be exceeded at any time during installation.

In all cases, the minimum bend radius will be equivalent to at least 10 times the diameter of the cable.

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4.3 Maximum Cable Pulling Tension

When pulling cables during installation, the cables are put under tension. The manufacturer's data sheet will state the maximum tension that the cable can support. Care should be taken to ensure the maximum tension is not exceeded.

International measurements of tension will be in Newtons (10 Newtons is approximately equivalent to 1 kg) and US measurements in pounds. Installers are not normally expected to measure tension as they are pulling cables, but should be aware of how much force they are using.

If cables are sticking and not pulling easily, there is a problem that should be investigated and fixed. Brute force should not be used as a remedy.

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4.4 Cable Damage During Installation

If a cable is damaged during installation by exceeding the minimum bend radius, applying too much tension, or handling the cable poorly in some other way, it should be replaced immediately. Failure to do so will add cost and delay to the project, as the fault will not be discovered until the cable is terminated and tested.

It will be the installer's responsibility to replace any damaged cables, and no additional time nor money will be allowed for such a replacement.

It is not alway obvious from visual inspection that a cable has been damaged. If a cable has been kinked and then straightened out, the internal structure may have been damaged with no obvious external signs. Possible damage could include:

- Reduced CSA of the conductor

- Broken conductor
- Untwisting: Twisted pair untwists along a section with pitch increased on either side
- Changed dielectric shape affects frequency response (likely in coaxial cables)

All in all, it is a lot cheaper and quicker to spend a little bit more time ensuring cables are installed correctly in the first place.

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4.5 Cable Grouping

Cables carrying the same type or level of signal should be grouped together. Cables carrying different signal levels and types should be kept separate to avoid crosstalk. The greater the difference in level, the greater the separation should be. If possible, try to keep different signal types 100 mm apart. Site conditions do not always allow this, but best endeavour should be applied. Particular care should be taken to avoid dimming light circuits and other noisy electrical interfaces.

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4.6 Single Run Cables

All point-to-point cables must be run as a single length of cable. Joining of cables is expressly forbidden.

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4.7 Cable Tails

When a cable is pulled to a point, a tail needs to be left that will be long enough to reach the final destination. The final destination might not always be known. Often, cable will be run to an equipment room before a decision has been made about the destination equipment rack. Tails must be long enough to allow for this. It is far better to have a tail that is too long than too short. Too long and it can be cut to length; Too short and the cable has to be run again.

Joins are not allowed!

When terminating cables, it is good practice to leave the cable long enough to allow for it to be re-terminated at least twice, if possible. This allows errors to be fixed without re-running cables.

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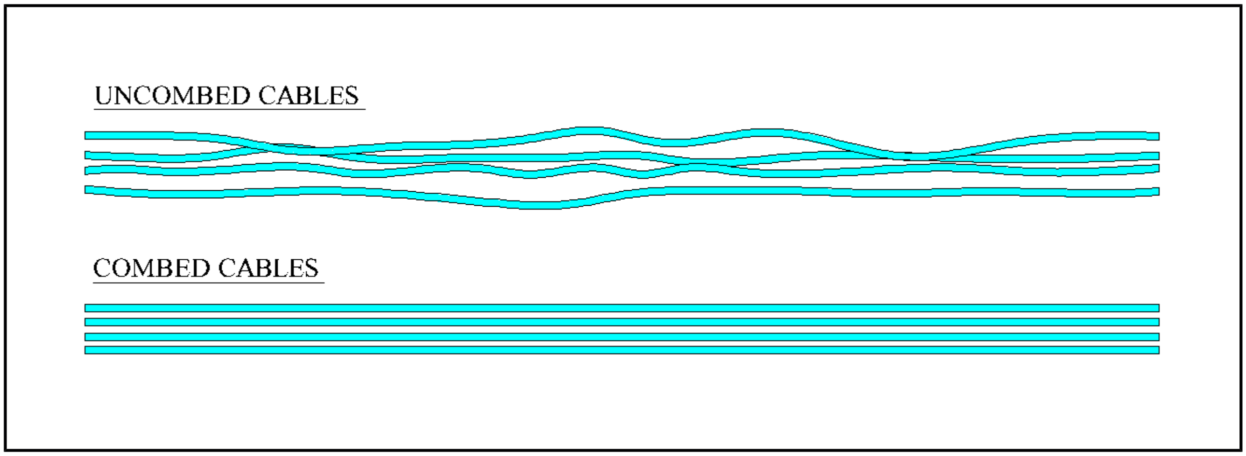
4.8 Cable Combing

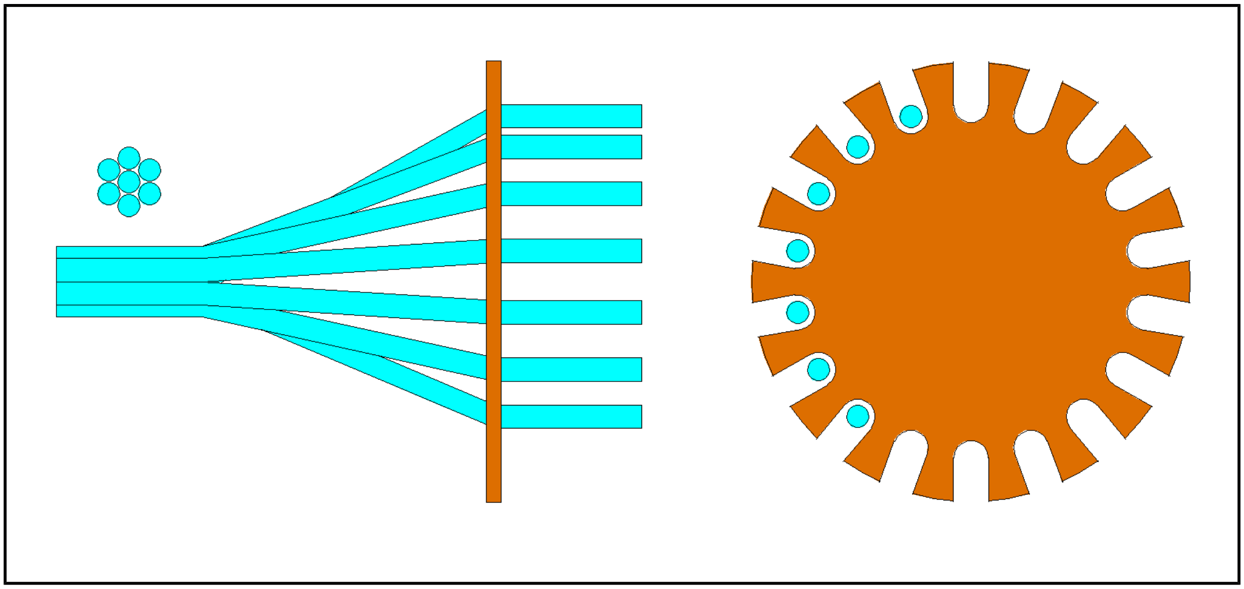
Figure 4.7 shows an example of uncombed and combed cables. The combed cables look neater and make it easier to trace individual cables than uncombed cables. For a small number of cables, as in Figure 4.7, cables can be easily combed by hand, running the cables between fingers.

Figure 4.7. Uncombed and Combed Cables



For larger numbers of cables, a cable comb can be used, as shown in Figure 4.8.

Figure 4.8. Cable Comb



Cable combs can be bought in different sizes, but it is a tool that can be easily made. There are no restrictions on what can be used to comb cables as long as the minimum bend radius and maximum tension are not exceeded.

Tip: Slotted plastic trunking can be used very effectively.

If cables are in trunking, run on cable trays concealed under the floor, or in ceiling space, they do not need to be combed. However, they should be laid neatly to prevent tangling.

Unless specifically stated in project documentation, wherever cables are visible (e.g., an open ceiling, an equipment rack, or other space), they must be combed. One exception would be to reduce alien crosstalk in high frequency signals.

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4.9 Cable Fasteners

Cables are fastened by means of clips or ties. Clips are normally used for individual cables and are either screwed or nailed to a supporting structure. Cable clips must not be used in Google AV systems.

4.9.1 Types

There are three types of ties that can be used:

- Cable lacing
- Locking cable tie
- Velcro tie

Cable Lacing

Cable lacing is the traditional method for fastening cables. It uses waxed thread and a series of knots to secure cables. It predates the invention of both locking cable ties and Velcro ties. It has its advantages and is still used in some industries, but not in AV.

Locking Cable Ties

A locking cable tie is a strap with teeth on one side and a locking head at one end. The strap passes through the head and a ratchet action, which, when engaged with the teeth, allows tightening but not loosening of the strap. The tie is adjusted to the correct tension to secure cables and then the excess strap is cut off.

Cable ties come in different sizes and can be made of plastic or steel. Steel ties are intended for hostile environments or applications where fire resistance is required. For Google AV systems, only plastic ties may be used.

Velcro Ties

Velcro is a trademark name, but is commonly used for any hook-and-loop fastener. They come in two forms:

- Wrap around: This is a strap with the hooks on one side and loops on the other. It wraps around cables and sticks to itself.
- Adjustable strap: This is a strap with a buckle on one end. The loose end passes through the buckle and back on itself. More tension can be applied with this type.

4.9.2 Choice of Tie

Velcro ties are wider than cable ties and normally thicker. For this reason, cable ties are often more aesthetically pleasing, especially on smaller cable bundles. On larger cable bundles, there is not such a great aesthetic difference and Velcro ties are easier to use.

When tightening a tie, it is important not to compress any of the cables. It is a lot harder to overtighten a cable tie than it is a Velcro one. Therefore, only Velcro ties may be used on CATx and SDI cabling. Cable ties must not be used on these cable types at any time during installation.

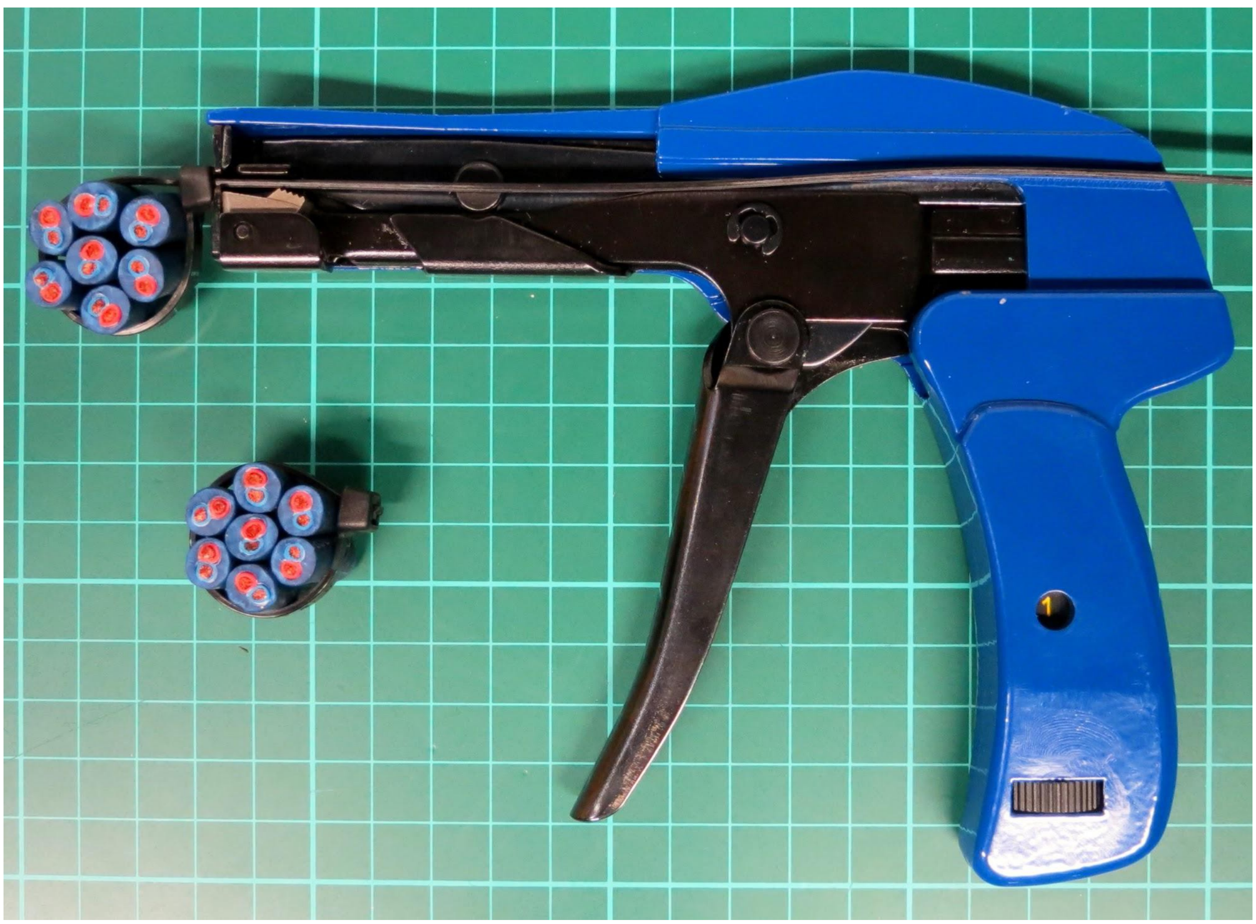
Apart from CATx and SDI cabling, either type of tie may be used.

4.9.3 Applying Cable Ties

Cable ties should be wrapped around cables and tightened by hand until they are just holding the cables. A cable tie gun shall then be used to ensure correct tension and a clean cut.

Figure 4.9 shows a cable tie gun ready to tension and cut a cable tie. When the trigger is pulled, the jaws pull the tie until the correct tension is achieved before the knife cuts the end off. A finished tie is shown inset.

Figure 4.9. Cable Tie Gun in Use



Cable ties of different sizes require different tensions. The gun shown in Figure 4.9 has the tension adjustment set to “1” in the handle.

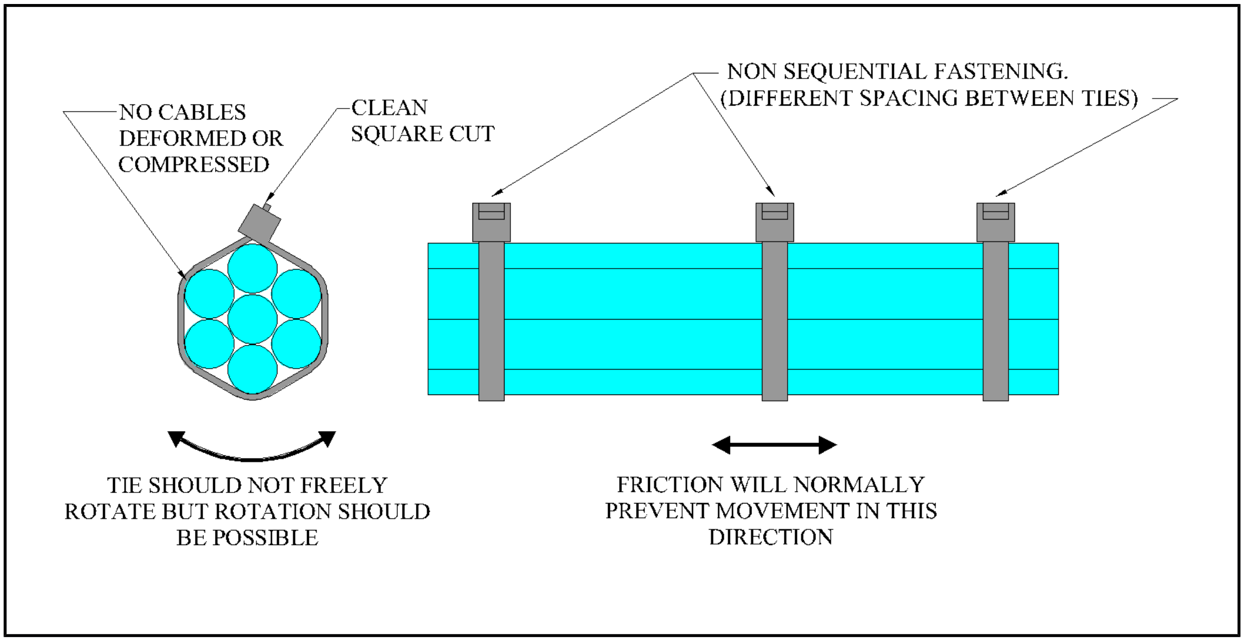
The clean cut is as important as getting the correct tension. Cable ties left with sharp edges can cause injury. Reaching into a rack with badly cut ties can be similar to reaching into a thorny bush.

A suitable cable tie gun must be used to finish off all cable ties. Other forms of tightening or cutting are not allowed.

Figure 4.10 shows correctly applied cable ties with:

- No cables deformed or compressed
- All ties cut cleanly
- All ties wrapped around in the same direction
- Cable tie heads all aligned

Figure 4.10. Correctly Applied Ties



4.9.4 Applying Velcro Ties

Velcro ties are simply wrapped around the cable and secured. Care must be taken not to apply too much tension, especially with the adjustable strap type.

4.9.5 Non-sequential Fastening

Sequential fastening is when ties are equidistant. Non-sequential fastening is when there is different spacing between ties. Figure 4.10 shows non-sequential fastening.

Sequential fastening can degrade cable performance by creating standing waves. For this reason, non-sequential fastening must be used wherever possible and must always be used with SDI cables.

For lower frequency signals, sequential fastening may not be an issue, but as a precaution to prevent any issues, sequential fastening is not allowed.

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4.10 Supporting Cables

All cables must be supported with supports no further than 1 m apart. If self-adhesive cable tie bases are used, they must be screwed in place. The adhesive helps to position cables, but it is not strong enough to provide adequate support.

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5. Cable Stripping and Preparation

Overview

This section details tools and procedures for stripping cables and preparing them for termination. When preparing cables, it is important to use tools appropriate for the cable and connector type.

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5.1 Removing Cable Sheath

The cable construction and its geometry determines the method to remove the sheath or outer jacket and the appropriate tools to use.

5.1.1 Methods

Using a Cable Knife

The traditional tool is a cable knife, but this needs to be used with care to avoid damaging the cable. Where possible, the knife should be used to score and then break the sheath rather than cut all the way through it. Figure 5.1 shows a loudspeaker cable that has been stripped with a cable knife.

Figure 5.1. Loudspeaker Cable with Non-uniform Sheath Removed with Cable Knife

This loudspeaker cable is a twisted pair cable with a loose non-uniform sheath. For this type of cable, a knife is often the easiest tool to use for stripping.

Using a Flex Stripper

A flex stripper is a tool with a blade exposed enough to cut the sheath without damaging the wires. As the name suggests, this is for use on flexible cables.

Figure 5.2 shows an electric flex with the sheath moulded around the three wires to provide a cable with a uniform cross section. It was stripped with the tool shown in Figure 5.3.

Figure 5.2. Electrical Flex with Sheath Removed

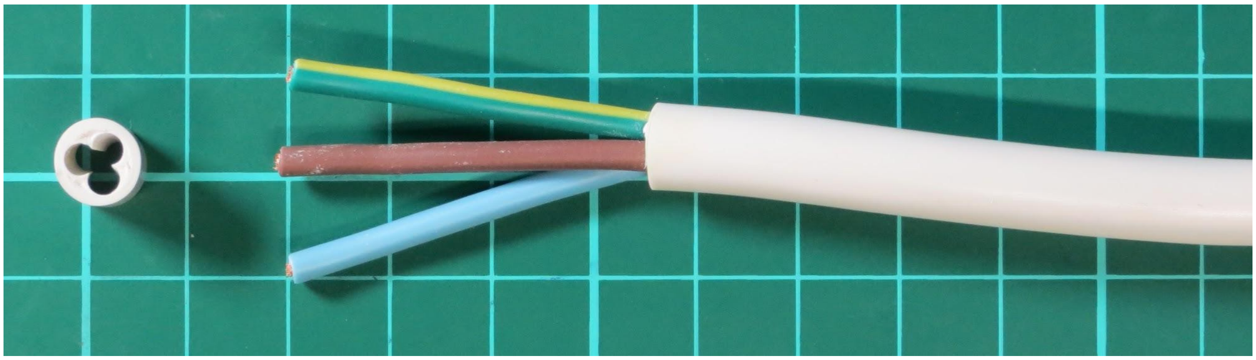
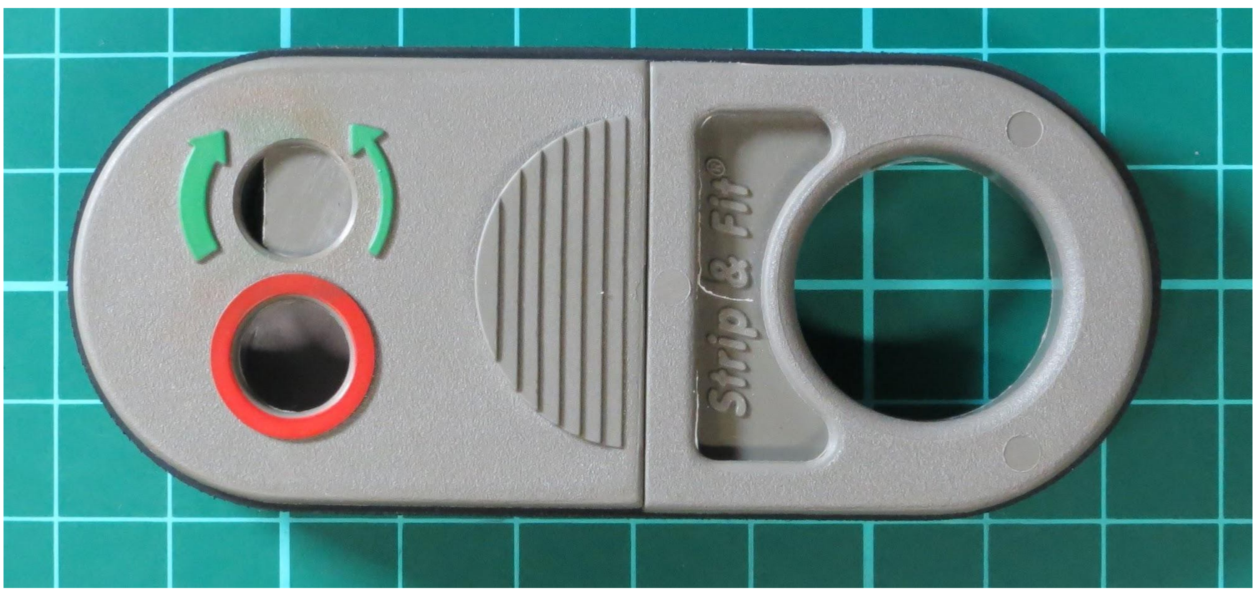


Figure 5.3. Flexible Mains Sheath Stripper

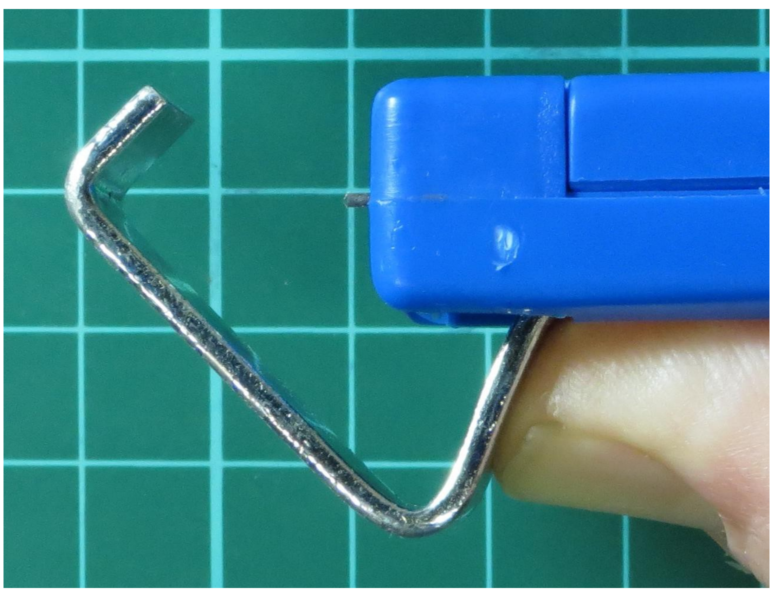


An appropriate flex stripping tool should always be used for stripping sheath on flexible cables. There are different flex strippers for different cables and using the wrong tool for the cable can cause damage. Figure 5.4 shows a flex stripper for flat and round cables that includes a 3-size wire stripper.

Figure 5.4. Cable Stripper for Use with Flat and Round Cables

Figure 5.5 shows an adjustable flex stripper. It has a spring-loaded guide (shown open) to accommodate cables of different sizes. The height of the blade is adjustable to allow for different thickness sheaths. When using this type of tool, make sure it is set correctly.

Figure 5.5. Adjustable Flex Stripper



Using Wire Strippers

When a cable has a uniform circular cross section beneath its sheath, it can be stripped using appropriately sized wire strippers.

Figure 5.6 shows an audio cable with its sheath removed using wire strippers. It is possible to use wire strippers as filler to ensure a uniform cross section within the sheath. There is a paper layer between the foil shield and sheath. The paper layer has been removed, but the foil shield and drain wire are completely untouched.

Figure 5.6. Audio Cable with Sheath Removed Using Wire Strippers

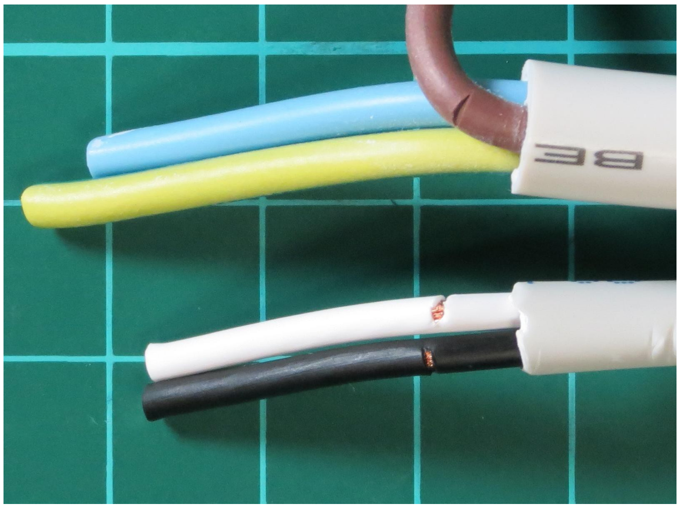
5.1.2 Choice of Stripping Method

So many different types of cables with different sheath materials are used in AV systems that it is not possible to define the stripping method for all of them. For flexible cable, using a flex stripper is the best choice, but for other cables, different methods might be of equal merit. The most important thing is to select a method that poses the least risk of damaging cable.

No damage to cables will be accepted. If cable is damaged by poor stripping, it must be cut back and redone.

Figure 5.7 shows two examples of damaged cables. In both, the damage was originally where the sheath was cut. The sheath has been cut back further to allow damage to be seen more clearly. On the power cable, the insulation on the brown wire has been nicked, reducing its integrity. On the speaker cable, the insulation on both conductors has been cut through, leaving bare wire exposed.

Figure 5.7. Cables Damaged while Stripping Sheath



5.2 Stripping Wire

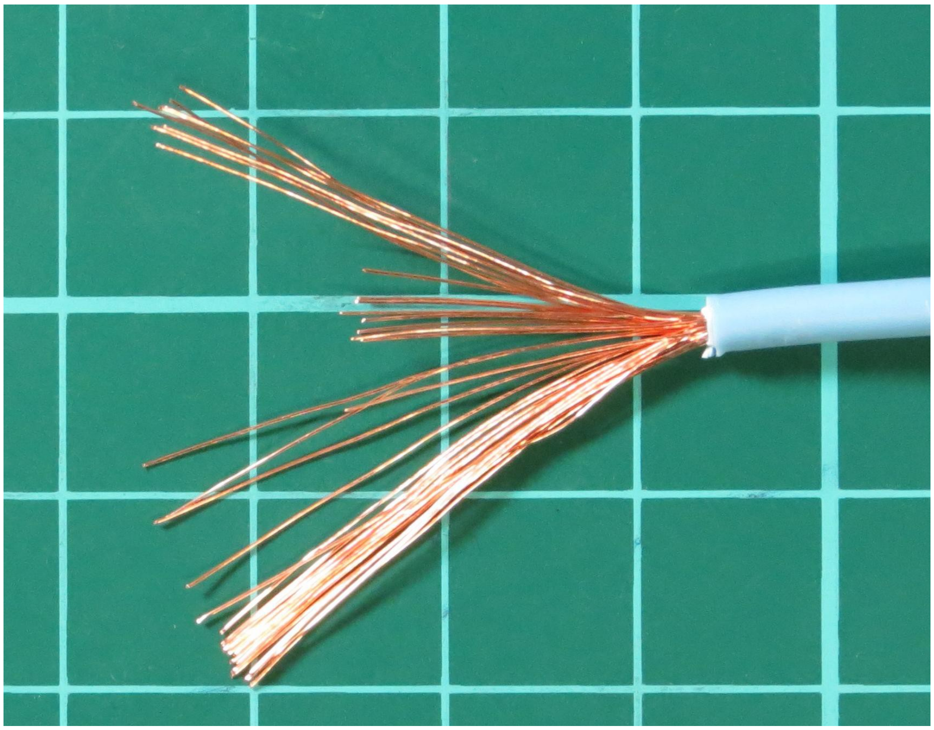
When stripping wire, only appropriate wire stripping tools suited for the size of the wire are allowed. For example, cutters are not designed for stripping wire and must not be used to do so.

Use of inappropriate wire stripping tools will not be tolerated.

Wire stripping of stranded cables should be left until just before tinning or crimping to prevent strand damage. It should not be necessary to twist wire before tinning or terminating. If wire is untwisted during stripping, it should be restored to its original lay.

Figure 5.8 shows a cable where strands have been cut by using an inappropriate tool. Wire has been stripped further back to illustrate the damage caused. Damage was not clear even when the cable was stripped back, so the strands have been fanned out to make the damage more obvious.

Figure 5.8. Wire Strands Cut While Stripping



There is further damage to some of the strands in Figure 5.8 that are not visible in the photo. Though not broken, some of the strands have been nicked, and the CSA is smaller than it should be, leading to increased resistance.

5.2.1 Wire Stripping Tools

There are many different types of wire stripping tools that can be used. The choice of tool depends on the type of wire being stripped. Tools must be appropriate for the cable or wire, and blades must be kept sharp. Within these constraints, the choice often comes down to personal preference.

Figure 5.9 shows a very common style of wire stripper. It strips several different wire sizes. The one shown is for AWG wire sizes. This wire stripper is also available for metric sizes. This tool also has different versions for stranded and solid wire. Care must be taken to use this tool with the appropriate gauge and cutting die for the wire.

Figure 5.9. Wire Stripper

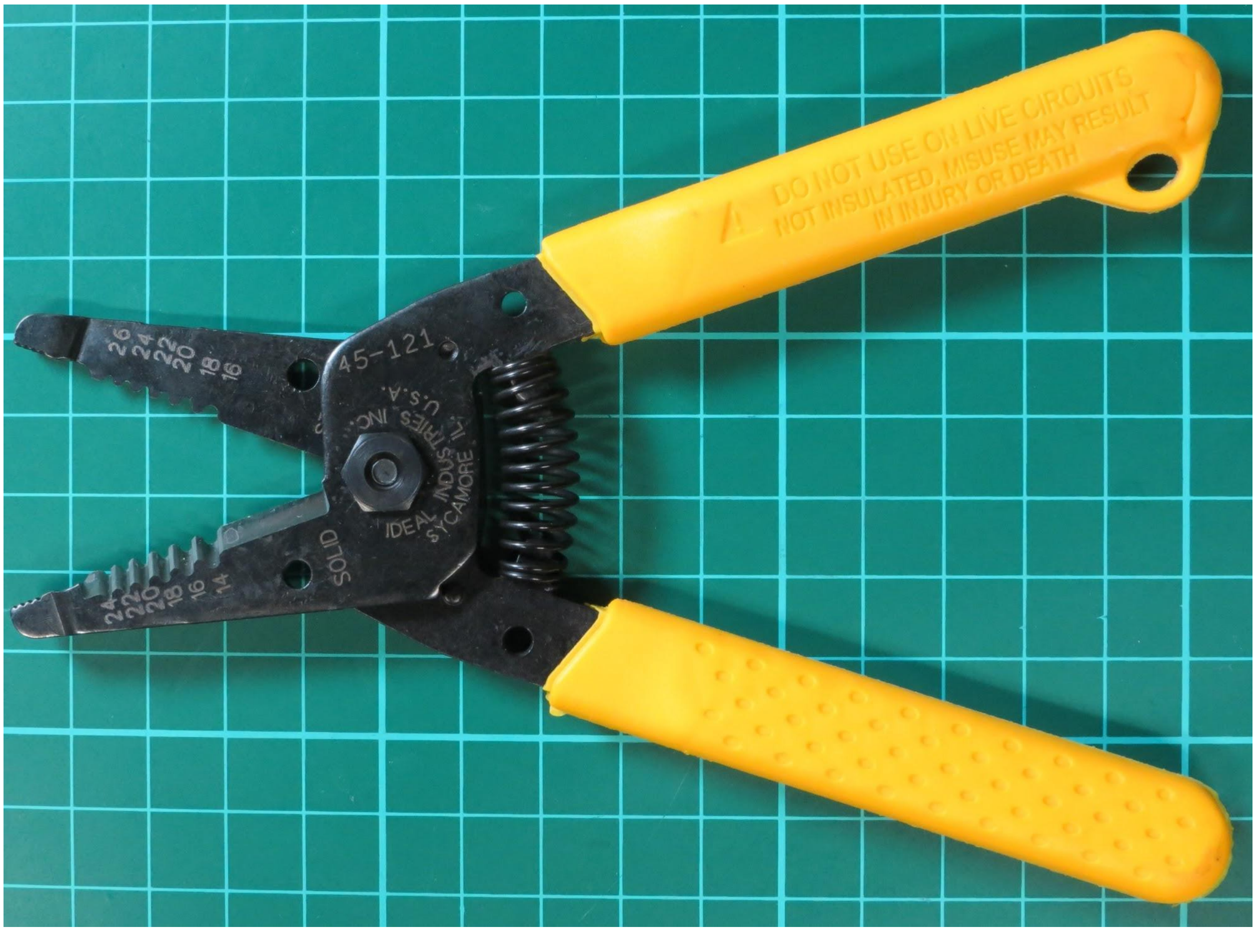


Figure 5.10 shows an adjustable wire stripper. The one shown strips 0.5-5 mm^2 wires. The cutting size is adjustable with a screw thread, so it will work on any cable within limits. Care needs to be taken to set this kind of tool correctly. It is bad practice to use such a tool on multiple cable sizes during one work session. Continually readjusting is likely to lead to errors.

Figure 5.10. Adjustable Wire Stripper

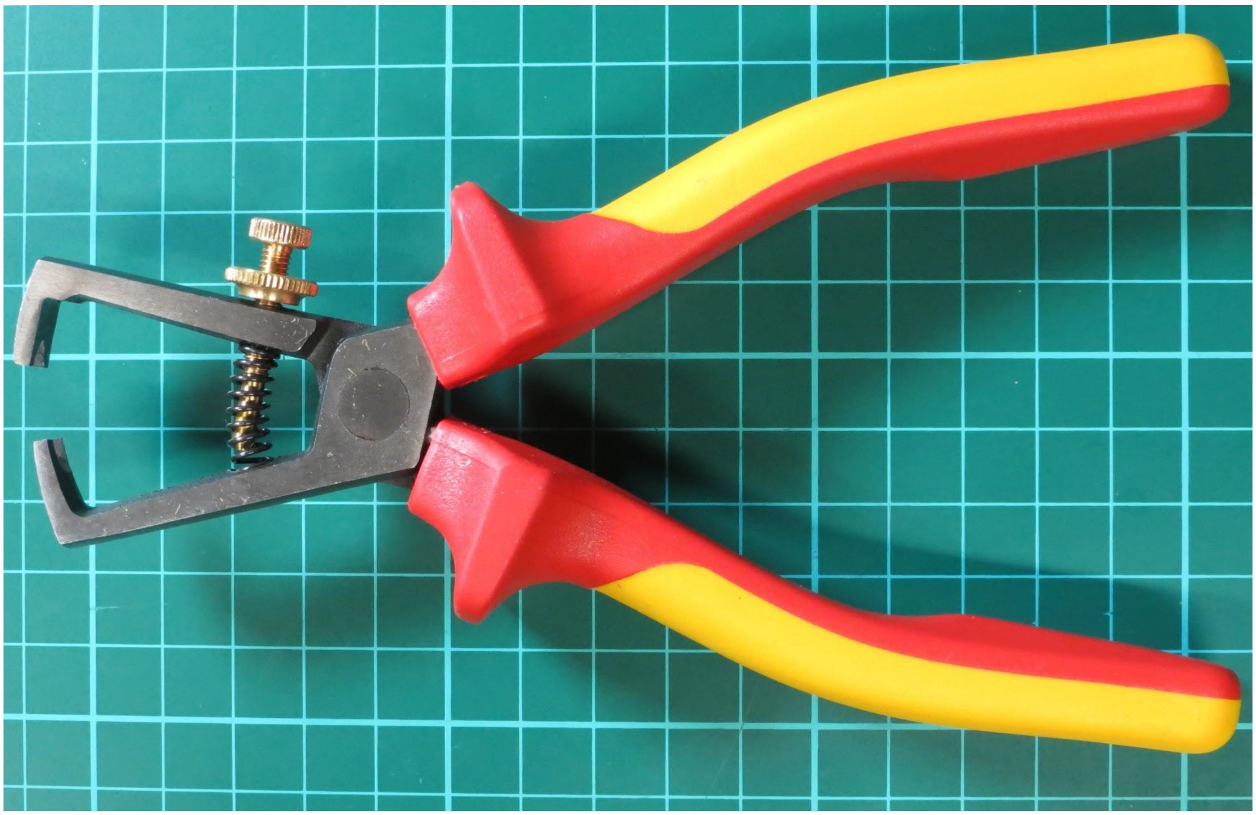


Figure 5.11 shows another type of adjustable wire stripper. With this type, there are preset sizes selected by turning the rotary dial. This one also has a depth gauge, so it can easily strip the same length every time.

Figure 5.11. Adjustable Wire Stripper with Depth Gauge

Figure 5.12 shows two automatic wire strippers. They both work on the same principle, but have different-sized cutting dies. This is a lever action tool. As the tool is closed, a vice grips the wire, allowing a clean cut. Care must be taken to use the correct cutting die, but otherwise, this is an easy tool to use. One advantage of this tool is that replacement cutting blades are available.

Figure 5.12. Automatic Wire Strippers

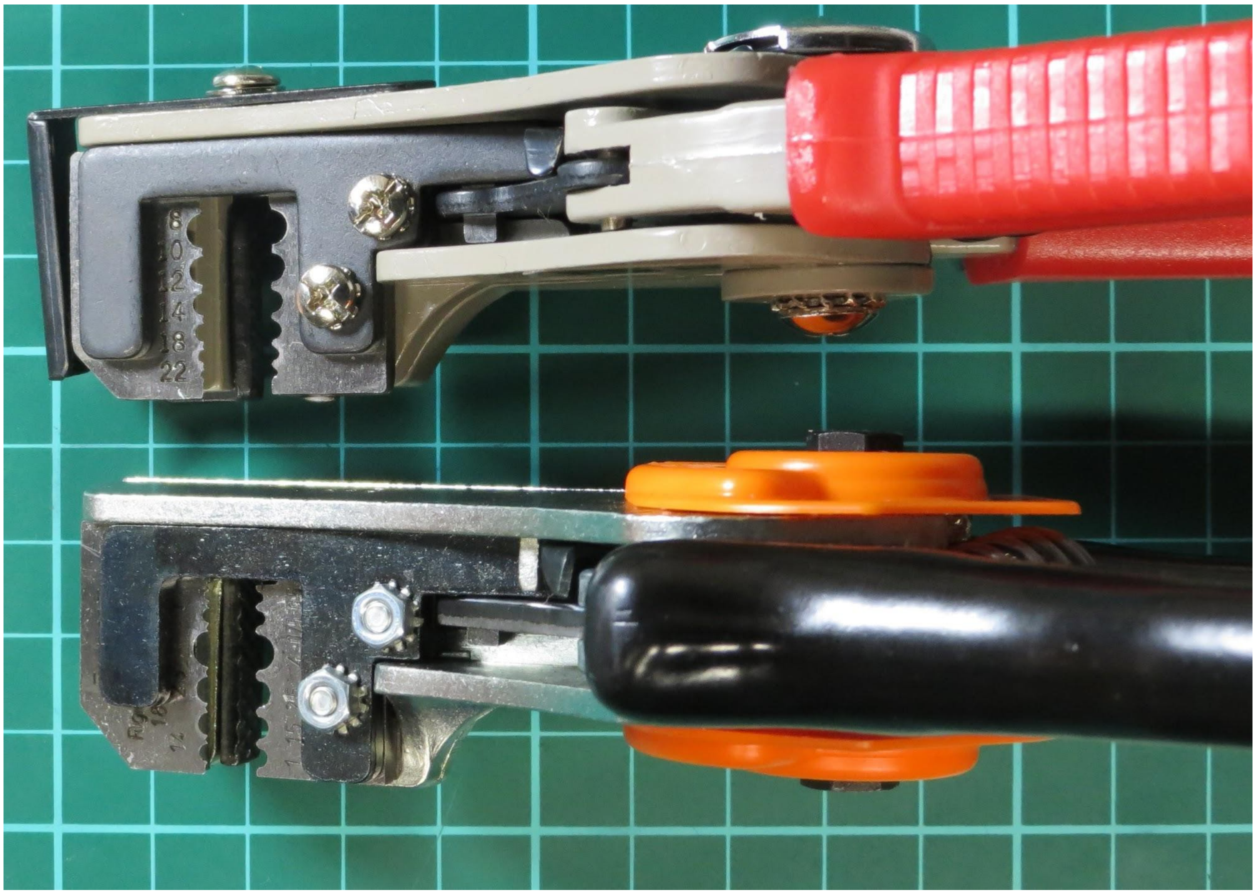


Figure 5.13 shows a fully automatic wire stripper. The one shown has a depth gauge and strips 0.08-2.5 mm^2 wires. When the trigger is closed, the jaws secure the cable, allowing the knife blades to strip the wire. This is a an easy tool to use and replacement jaws are available.

Figure 5.13. Fully Automatic Wire Stripper

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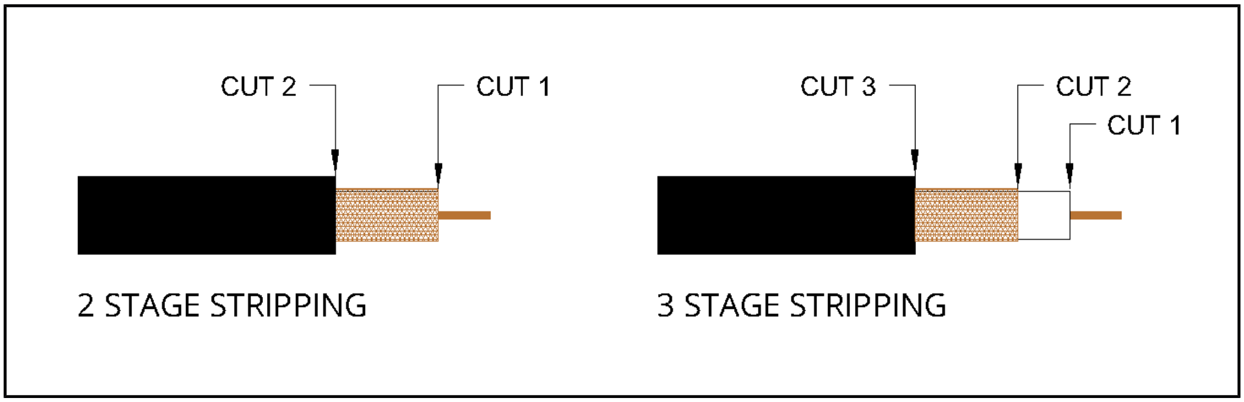
5.3 Stripping Coaxial Cable

Depending on the type of connector being used, coaxial cables require either 2- or 3-stage stripping, as shown in Figure 5.14.

Figure 5.14. 2- and 3-Stage Stripping of Coaxial Cable



Both 2- and 3-stage stripping can be done in one cycle when using an appropriate coaxial multi-cut stripping tool. These tools have multiple blades set apart at different depths. The tool is rotated around the cable to perform the stripping action. Figure 5.15 shows a coaxial multi-cut cable stripper.

Figure 5.15. Coaxial Multi-cut Cable Stripper

It is important that blades are sharp and set to the correct depth. On most types of coaxial strippers, the cutting depth is adjustable to allow it to be set for different types of cables. When a new tool is being used or when blades have been changed, the cutting depth will need to be adjusted.

It is unusual to adjust a tool for a different cable type. Normal practice is to have a separate tool for each cable type. Some tools have the blades in a cassette, so the same tool is used with different cassettes for different cable types.

Setting the blade depth correctly takes time and patience, but it is worth the effort, as the tool is easy and fast to use when set correctly.

Figure 5.16. Stripped Coaxial Cable

Figure 5.16 shows a stripped coaxial cable with all of the cuts clean and square. (There is a bit of variance on the shield, but this is due to the loose weave of the braid, and it is exaggerated by the camera.)

There are coaxial stripping tools that require more than one cycle as shown in Figure 5.17.

Figure 5.17. Coaxial Single Cut Stripper

This type of tool cuts in the same way as the multi-cut one by being turned around the cable. However, it has to be removed and reapplied, ensuring that the second application is in the correct place.

Appropriate coaxial strippers must be used to strip coaxial cables, with multi-cut tools preferred to single-cut ones. Cable knives must not be used.

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5.4 Cable Sleeving

When preparing cables for termination, it is often necessary to insulate shield and drain wires using appropriately sized sleeving. When sleeving is done, the colour must always be green. Silicon sleeving is preferred, but heat shrink is acceptable.

Sleeving is also often used to cover areas where the cable sheath has been cut. This is not done to hide damage to wires, but rather to provide:

- Strain relief
- Insulation where there is an overall shield under the jacket
- A neat identical look to all cables

Hellermann sleeves or heat shrink may be used.

If all wires in a cable do not need to be terminated, they are sometimes folded back under the sleeving rather than cut. This allows them to be used later if required. This is sometimes done with multi-core control cables and should always be done with balanced audio cables where the shield is not connected.

Figure 5.18 shows a sleeved and unsleeved loudspeaker cable. Sleeving gives a neat appearance and provides strain relief.

Figure 5.18. Sleeved and Unsleeved Loudspeaker Cable

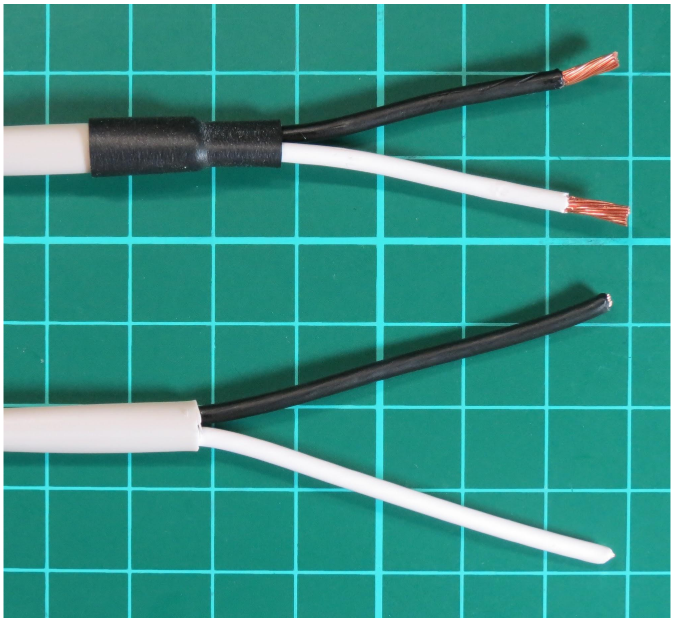
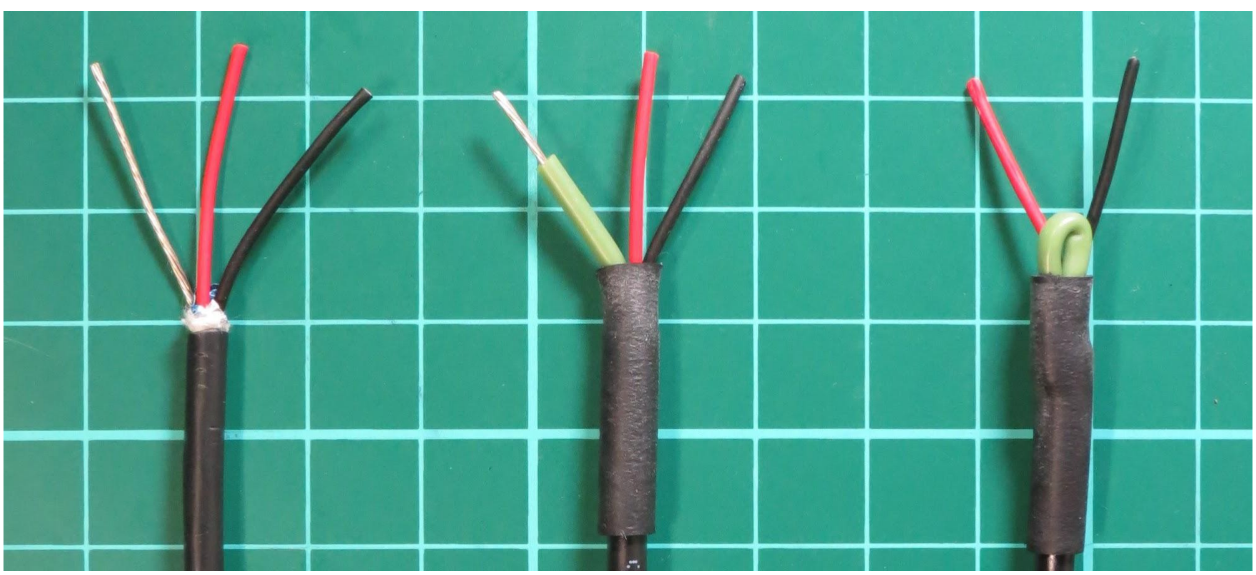


Figure 5.19 shows sleeved and unsleeved audio cables. On the unsleeved cable, the foil sleeve is visible. Sleeving insulates the foil sleeve.

Figure 5.19. Sleeved and Unsleeved Audio Cable



5.4.1 Using Green Silicone Sleeving

Silicone sleeving is slid over the drain wire. It is held in place by the sleeving that covers the sheath.

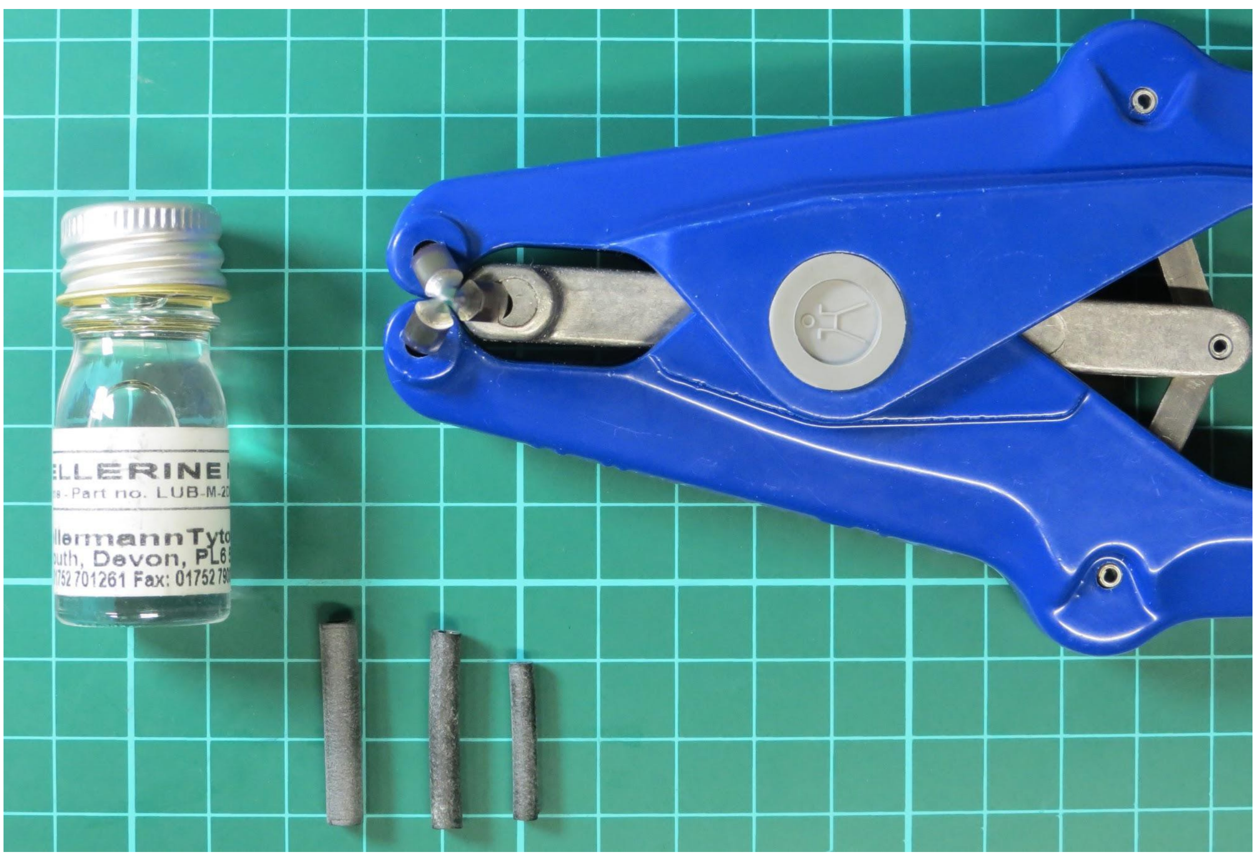
5.4.2 Using Hellermann Sleeves

Hellerman sleeves are rubber tubes that come in various diameters and can be expanded up to 500% to apply and 200% in use. They are stretched over cable with elasticity holding them in place.

They should be applied using Hellermann pliers. This is a 3-pronged tool. The prongs stretch the tubing, allowing it to be applied over the cable. This is a lot easier when used with Hellerine lubricant.

Figure 5.20 shows a pair of Hellermann pliers with three sleeves of different sizes and a bottle of Hellerine lubricant.

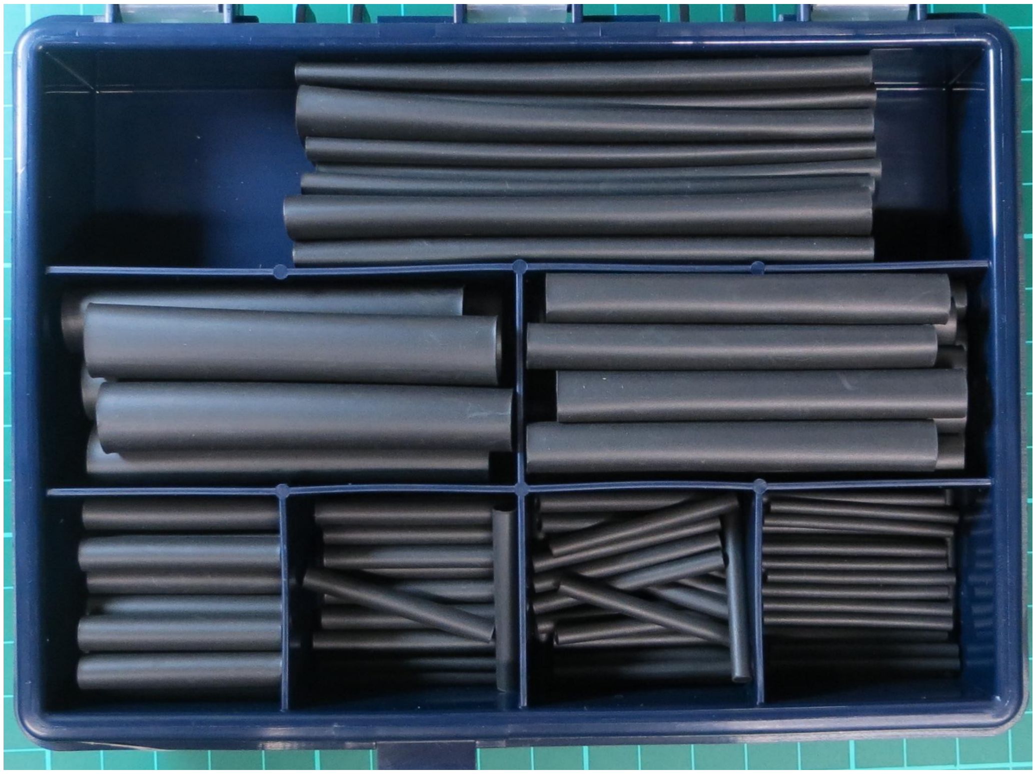
Figure 5.20. Hellermann Pliers and Sleeves with Hellerine Lubricant



5.4.3 Using Heat Shrink

Heat shrink is a plastic tube that shrinks in the plane of its diameter. It gets narrower (not shorter) when heat is applied. Heat shrink comes in various diameters. It can come in reels or can be cut to size. Figure 5.21 shows a selection of heat shrink in different sizes that is pre-cut and ready for use.

Figure 5.21. Pre-cut Heat Shrink in Various Sizes



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Heat shrink is placed over the cable and then shrunk using a hot air gun, as shown in Figure 5.22.

Direct heat or naked flames (including cigarette lighters) must not be used on heat shrink.

A gas-soldering iron fitted with a hot blow nozzle may be used. The hot air exhaust of gas-soldering irons must not be used directly.

Figure 5.22. Hot Air Gun

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6. Termination

Overview

Termination is the process of connecting cables to connectors. Poor termination is the most common cause of problems in electronic systems. These problems can be expensive to track down and fix once the system is assembled, as they are often intermittent and hard to locate. There can also be an issue where poor termination leads to failure after the system has been commissioned.

Termination errors are easily avoided by using the appropriate tools and connectors and taking the time to do the job properly.

This section gives general guidance on how to correctly terminate cables.

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6.1 Crimping

There are many different types of crimp terminations. This section covers those commonly used in AV systems. To ensure a good termination and connection, it is essential to use a terminal correctly sized for the wire and the correct tool for the crimp.

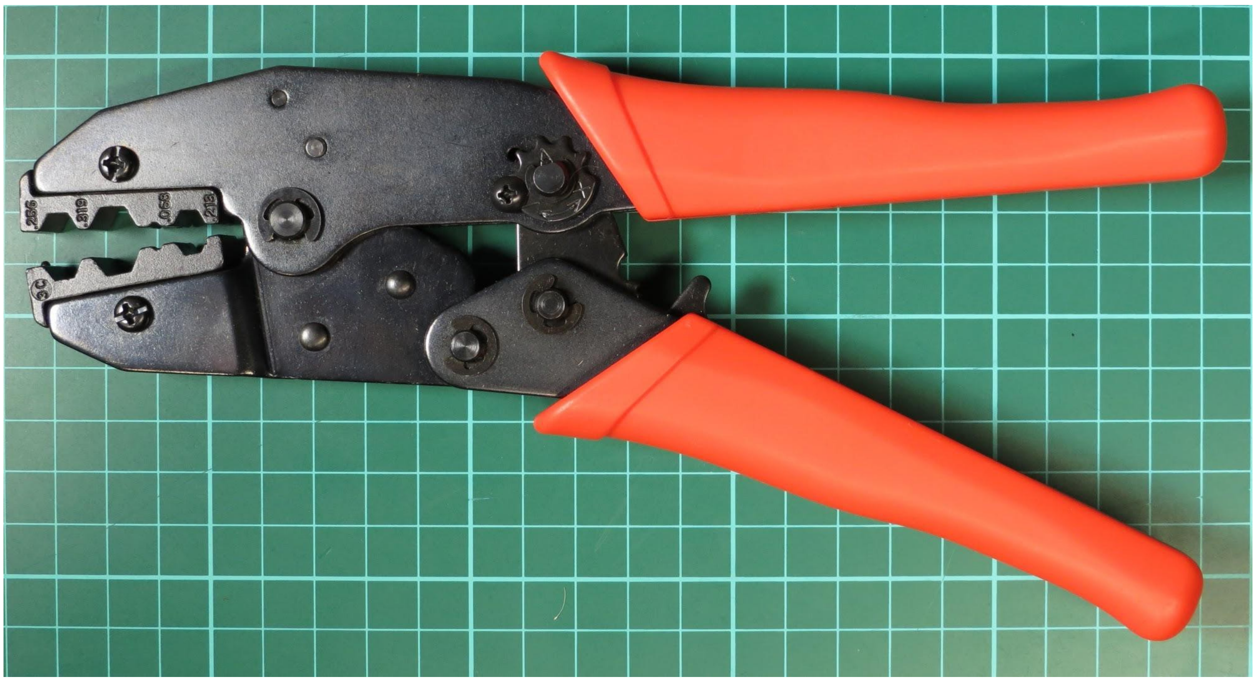
Wire must not be tinned or soldered before being crimped, as this leaves the connection prone to failure by creep.

6.1.1 Crimp Tools

There are different grades of crimp tools. A ratchet tool is shown in Figure 6.1 with an assured-closed feature, which will not allow the tool to open until it has gone through a full cycle. This ensures that the tool will always close to the correct dimensions. It is important to ensure the correct die is set for the connector.

Crimp terminals should only be crimped once. There is no need to apply the crimp tool to the same terminal twice.

Figure 6.1. Ratchet Crimp Tool with Assured-closed Feature



Plier-type crimp tools, as shown in Figure 6.2, must not be used. There is no way to ensure that the correct pressure has been applied or that the tool has been closed to the correct dimensions. To ensure these tools are not used, they are not allowed on Google AV sites.

Figure 6.2. Plier Crimp Tool: Not to Be Used

It should go without saying, but other tools capable of applying pressure (e.g., pliers, mole grips, pipe wrenches, etc.) must not be used for crimping.

Use of incorrect tools will not be tolerated.

Anyone caught using incorrect crimp tools will be removed from the site, and any evidence of incorrect tool use may result in all crimp terminations on site being condemned. Offending contractors will be held responsible for any delay or financial penalties incurred.

Bootlace Ferrules

Bootlace ferrules should be used on all stranded wire that will be terminated in a screw terminal. Figure 6.3 shows a range of insulated ferrules (DIN Colour Standard) and a 1.5 mm^2 uninsulated one.

Figure 6.3. Bootlace Ferrules

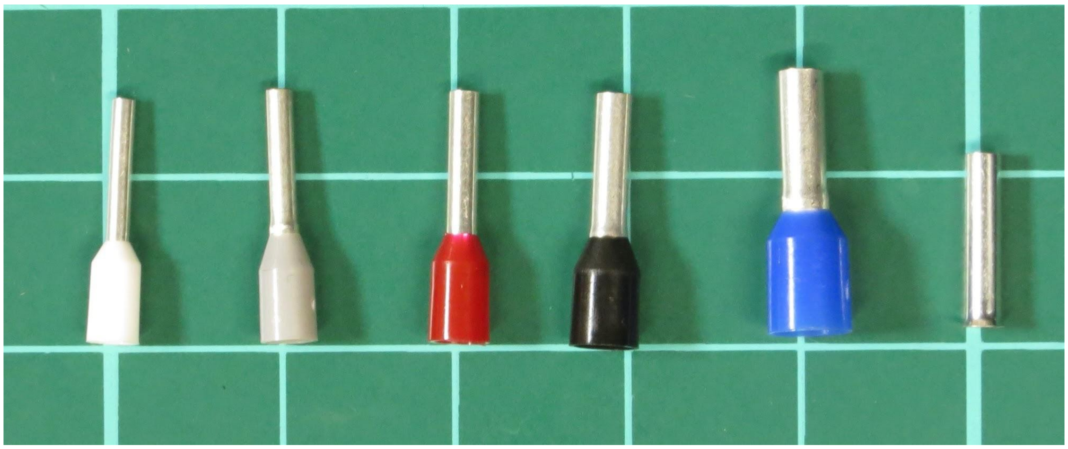


Figure 6.4 shows a bootlace ferrule die set to crimp 0.25-6 mm^2 ferrules.

Figure 6.4. Bootlace Ferrule Die Set

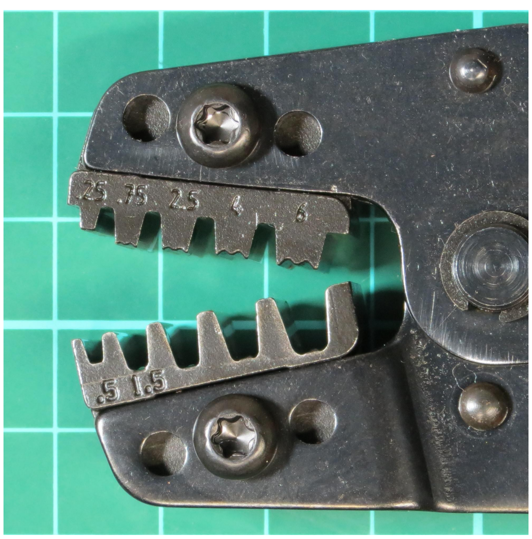
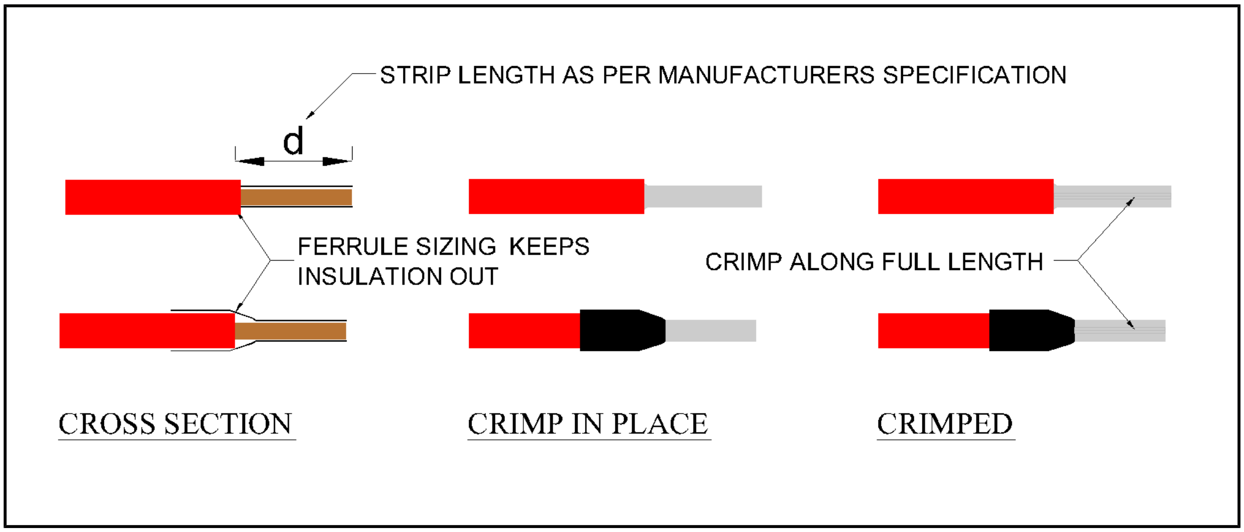


Figure 6.5 shows the steps to correctly terminate a bootlace ferrule. After stripping, the ferrule is placed on the wire and pushed back until it is stopped by insulation. If there is any doubt as to the strip length, then bare wire should reach to the end of the ferrule.

The ferrule should be placed in the correct slot of the die and pushed fully in so that the die crimps along the whole length of the ferrule. Ensure the wire is pushed fully in and then crimp.

Figure 6.5. Bootlace Ferrule Termination (Uninsulated and Insulated)



Bootlace ferrules may be cut to size to fit the terminal in the same way as the stripped wire.

Crimp Terminals

Figure 6.6 shows a selection of the wide variety of crimp terminals available.

Figure 6.6. Crimp Terminals

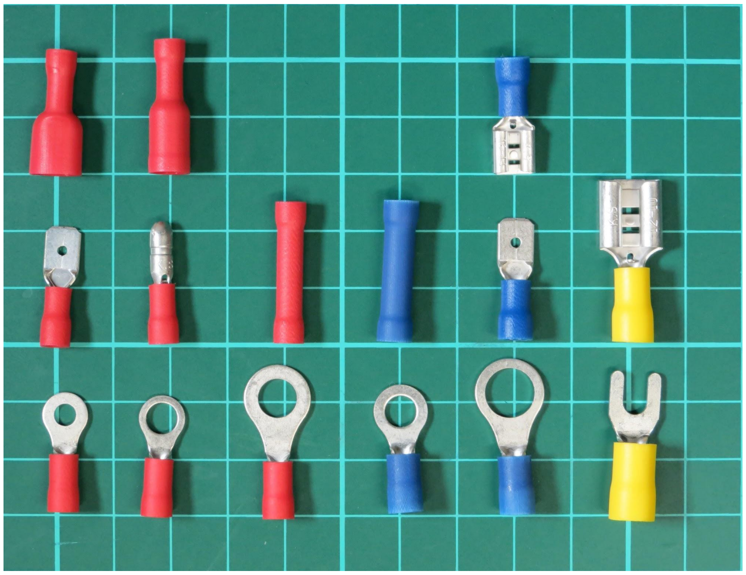


Figure 6.7 shows a crimp terminal die set. Note the colour coding for easy selection of the correct position.

Figure 6.7. Colour-Coded Crimp Terminal Die Set

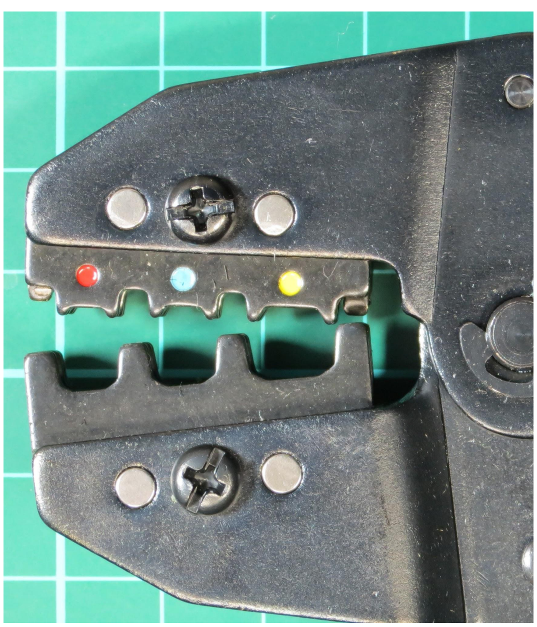
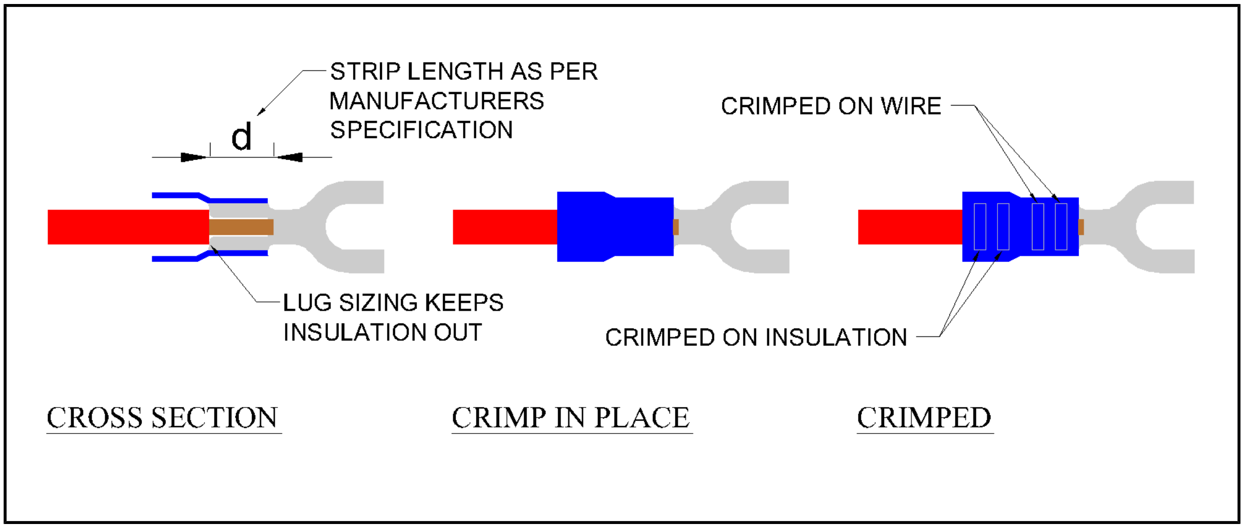


Figure 6.8 shows the steps to correctly terminate a crimp terminal. After stripping, the terminal is placed on the wire and pushed back until it is stopped by insulation. If there is any doubt as to the strip length, then bare wire should extend slightly beyond insulation.

The terminal should be placed carefully in the correct slot of the die, ensuring the jaws are correctly positioned to crimp the wire and insulation. Ensure the wire is pushed fully in and then crimp.

An alternative method is to place the terminal in the die first and then close the crimp to secure it (but not deform it) before putting the wire in the terminal.

Figure 6.8. Crimp Terminal Termination



3-Part BNC Crimp

Figure 6.9 shows a 3-part BNC crimp connector together with a strain relief boot. The three parts are the crimp sleeve, centre pin, and connector body.

Figure 6.9. 3-Part BNC Crimp and Strain Relief Boot

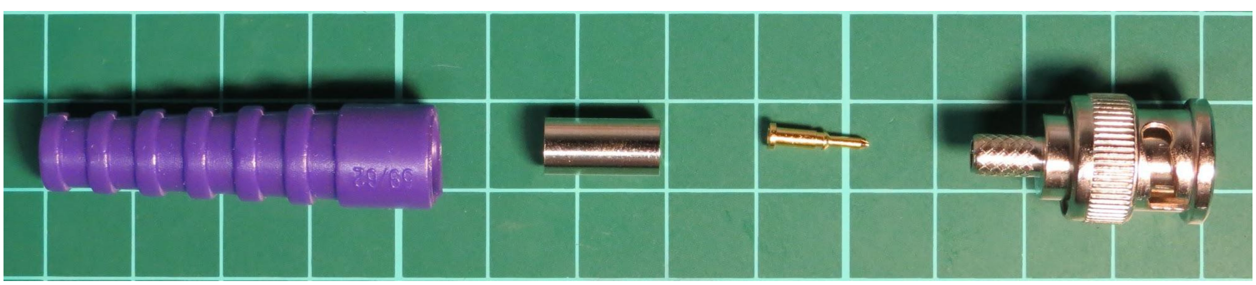


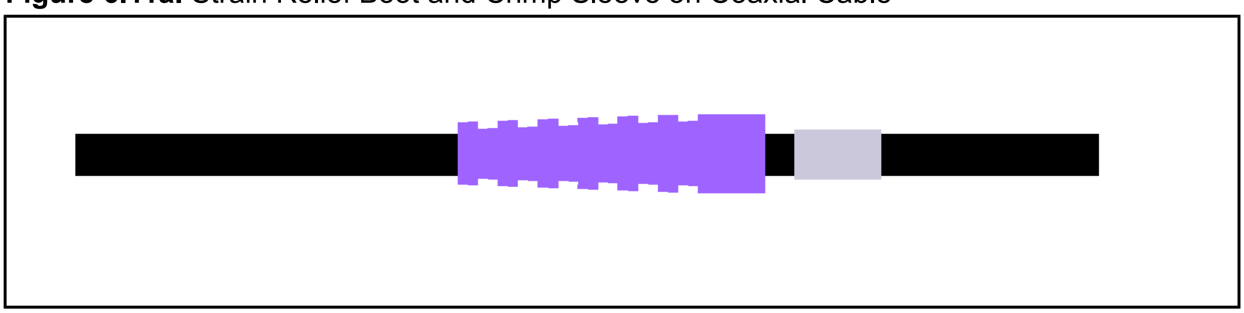
Figure 6.10 shows a BNC crimp die set. Note that this die will accommodate two different types of BNC. The sizing of the crimp side of the BNC is dependent on the cable type. There are many different-sized cables and associated connectors, so it is essential to ensure the correct die size is used.

Figure 6.10. BNC Crimp Die Set

The procedure to terminate a 3-part BNC connector is similar for all connectors. Refer to the manufacturer's instructions for precise details.

Appropriate strain relief boots must be used for all connections. The strain relief boot and crimp sleeve must be put on the cable before it is stripped, as shown in Figure 6.11a.

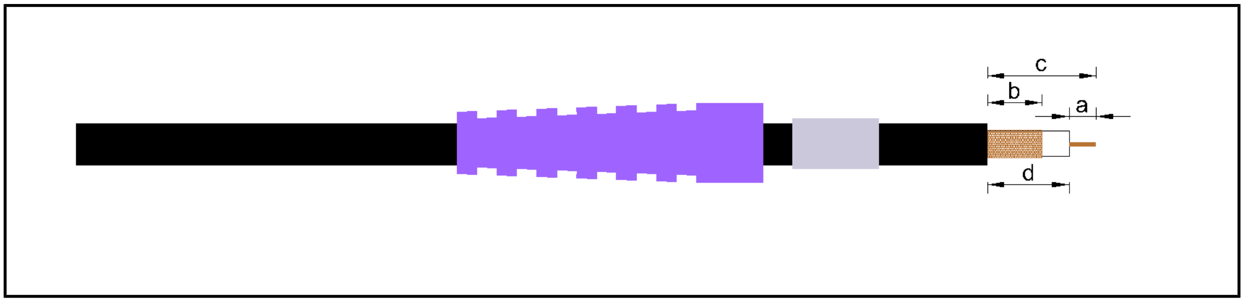
Figure 6.11a. Strain Relief Boot and Crimp Sleeve on Coaxial Cable



The cable is then stripped using a multi-cut coaxial stripper with the correct preset distances and depths, as shown in Figure 6.11b. For commonly used cables, including all those used for video, the use of multi-cut coaxial strippers is compulsory. For cables used infrequently, such as those for long antenna runs, single-cut coaxial strippers may be used.

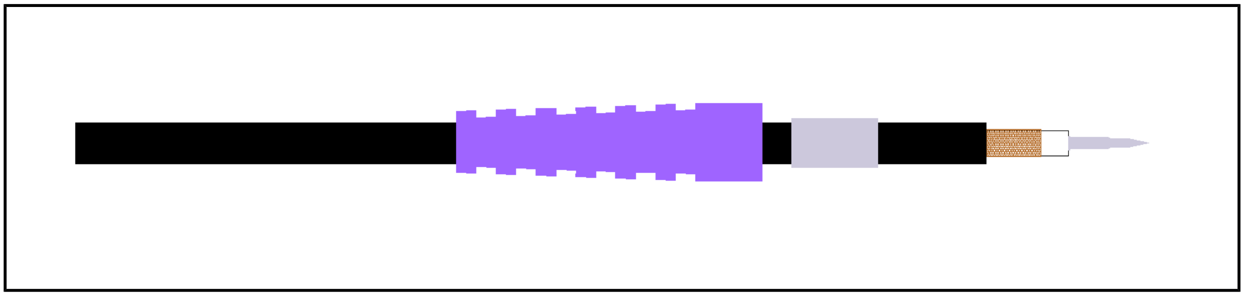
In all cases, cuts must be sharp and square. The braid, dielectric insulation, and centre conductor must not be nicked.

Figure 6.11b. Stripped Coaxial Cable



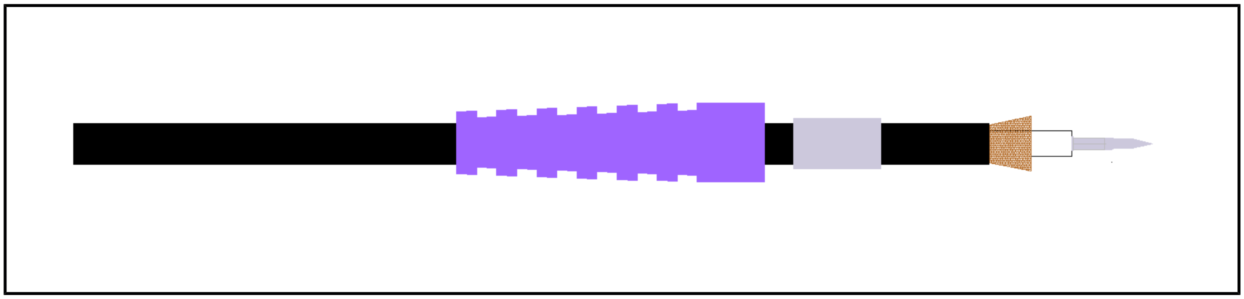
The centre pin is then slid over the centre connector. The pin must be positioned firmly against the dielectric, as shown in Figure 6.11c. With some connectors, the pin has an inspection hole. If one is present, ensure that the centre conductor is visible.

Figure 6.11c. Centre Pin Crimped in Position



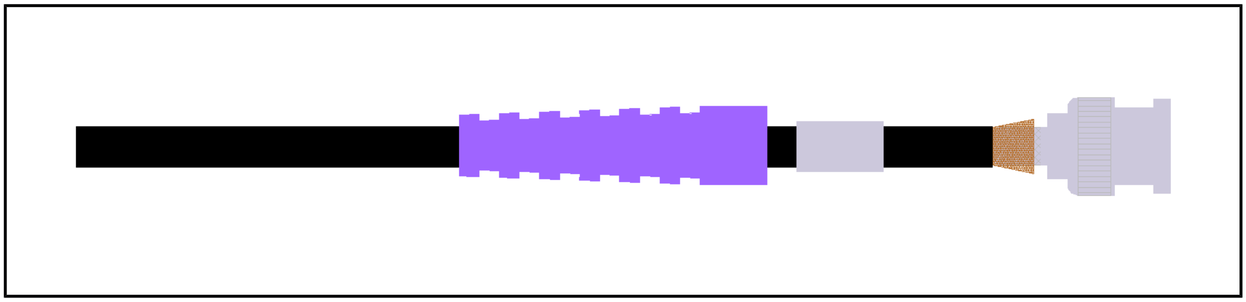
The braid should then be fanned out, as shown in Figure 6.11d, to allow the connector body to slide under it. The braid should not be folded back on itself; the weave of the braid should be maintained.

Figure 6.11d. Braid Fanned Out



The connector body is then slid over the centre pin and under the braid. Push it back until it locks in position, as shown in Figure 6.11e.

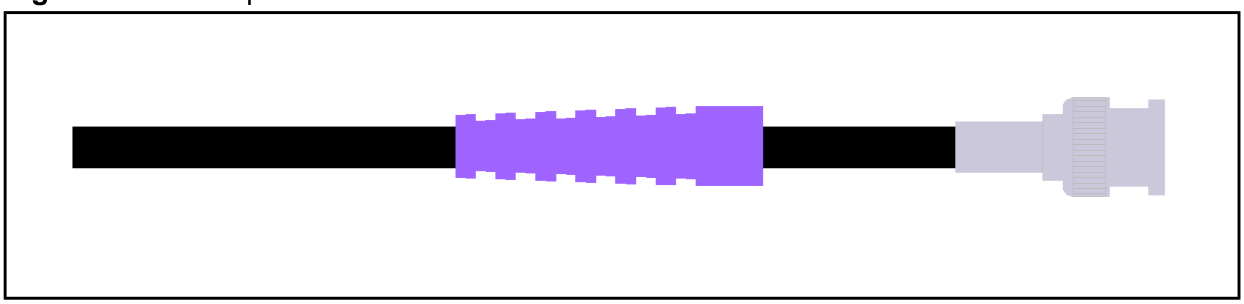
Figure 6.11e. Connector Body in Place



The crimp sleeve is then slid over the braid until it touches the connector body. The entire braid should be under the sleeve; none should be visible at the junction between the sleeve and connector body, as shown in Figure 6.11f.

If there a few strands showing, they should be trimmed before crimping. If a lot of braid is exposed, then the connector should be cut off and termination should be restarted, ensuring wire is stripped to the correct dimensions and fanned out carefully.

Figure 6.11f. Crimp Sleeve in Place

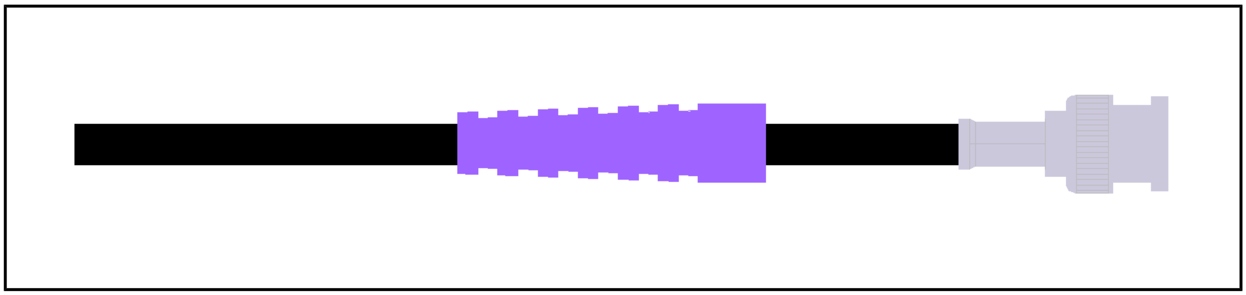


The crimp tool is then placed on the sleeve. With the jaws just touching the connector body, the sleeve is crimped to support the connection. Figure 6.11g shows what the crimp should look like. The sleeve is flared to form a bell mouth at the cable end, providing strain relief.

For most connectors used in AV applications, the bell mouth is created by the jaws of the crimp tool, which are shorter than the sleeve. The end furthest from the connector body is not crimped.

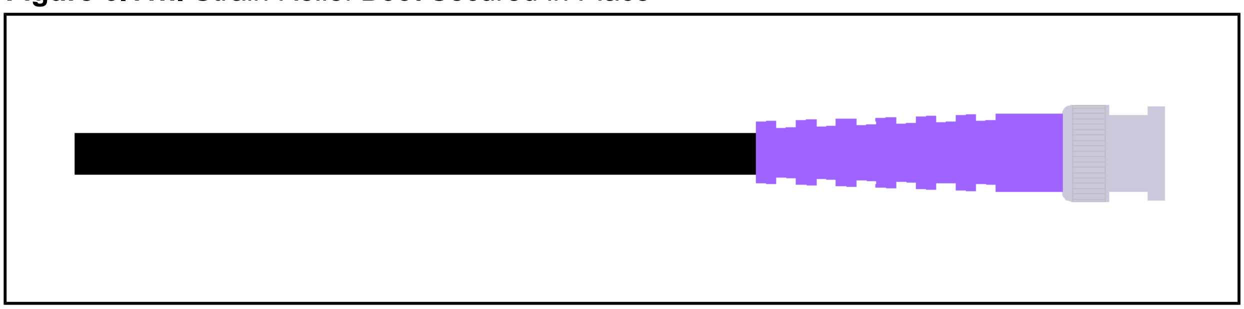
For some connectors, the crimp tool will be flared to create a bell mouth of a particular shape. With such connectors, it is important to ensure that the crimp jaws are the right way around before crimping.

Figure 6.11g. Sleeve Crimped Leaving Bell Mouth



The final stage is to secure the strain relief boot. Apply one drop of the appropriate adhesive to the cable sleeve, slide the boot onto the shaft of the connector, and then twist the boot to distribute the glue. Figure 6.11h shows the finished connection.

Figure 6.11h. Strain Relief Boot Secured in Place



1-Piece Compression BNC

1-piece compression BNCs are quicker to apply than the 3-piece ones, but tend to have a higher return loss. For this reason, 3-piece BNCs are preferred. 1-piece compression BNCs are allowed, but finished cables must pass the same cable tests.

Manufacturer instructions must be followed, and cable must be stripped using a multi-cut coaxial stripper with the correct preset distances and depths, as shown in Figure 6.11b for the 3-part BNC.

EDAC Crimp Pins
Figure 6.12 shows an EDAC crimp pin. This is a hermaphrodite contact.

Figure 6.12. EDAC Crimp Pin

Figure 6.13 shows an EDAC crimp die with the contact guide visible between the jaws. There are two slots in the die. They both use the same pin, but one is for AWG 18-20 (0.50 to 0.75 mm^2) and the other is for AWG 22-25 (0.20 to 0.25 mm^2).

EDAC crimp pins may only be used for single wires within these two ranges. For any other wire size or when two wires must be connected to one pin, solder pin contacts must be used.

Figure 6.13. EDAC Crimp Die Set

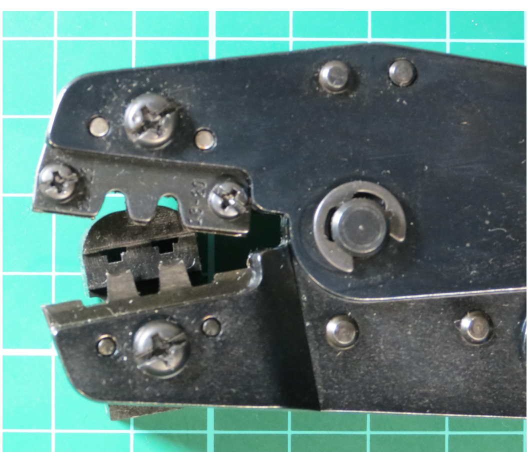
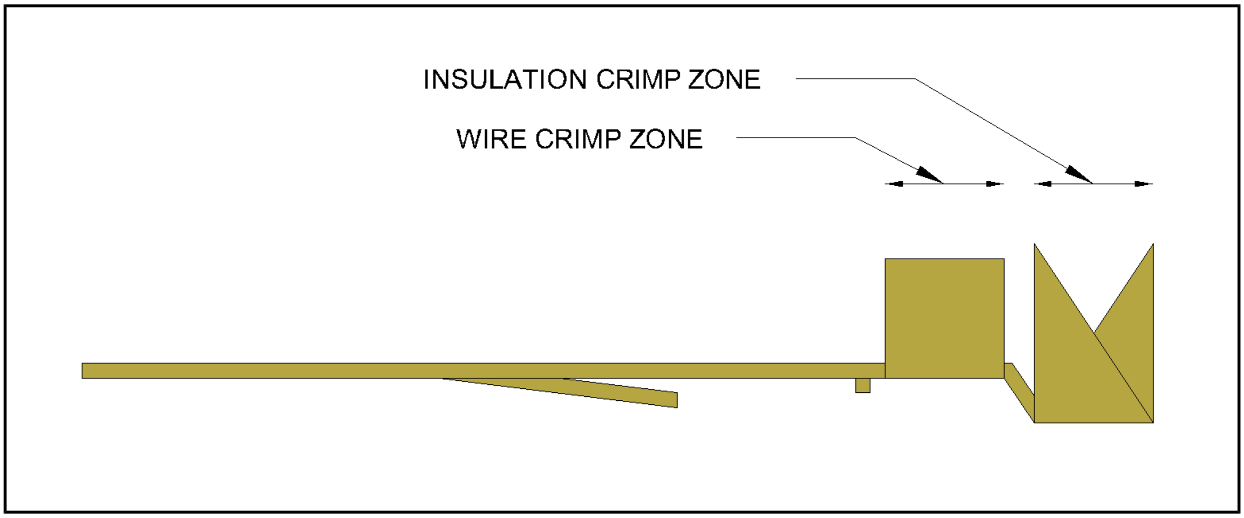


Figure 6.14 shows a diagram of the two crimp zones on an EDAC pin. The wire crimp forms the electrical contact, and the insulation crimp provides strain relief. Insulation must not enter the wire crimp zone.

Figure 6.14. EDAC Pin Crimp Zones



The crimp tool has a guide to hold the contact. This ensures the contact is in the correct position and the wire is in the correct location. Figure 6.15 shows a contact in the guide with the wire in place and ready for termination.

Figure 6.15. Diagram Showing Crimp in Guide with Wire Ready for Termination

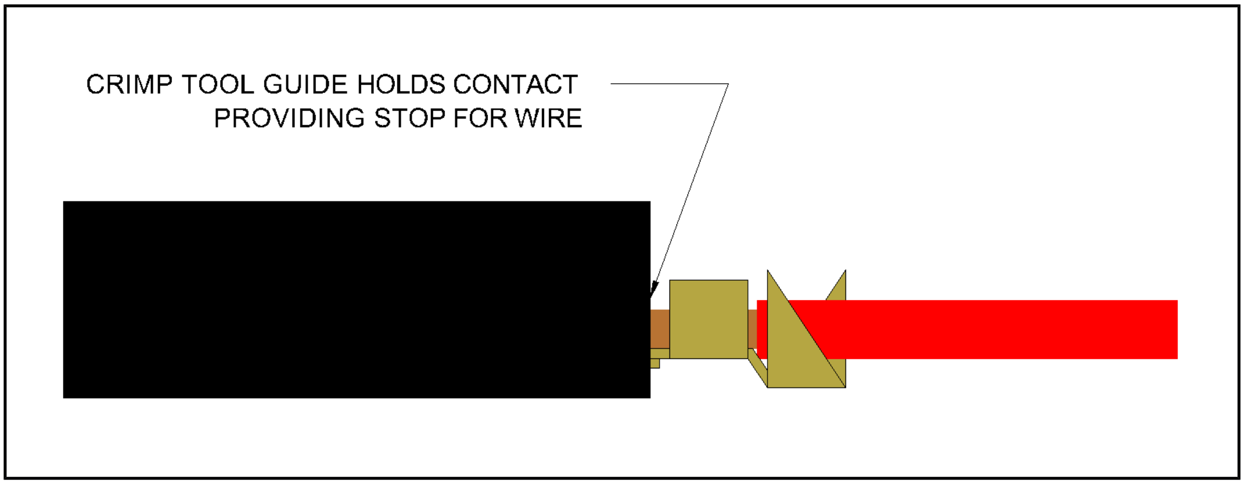


Figure 6.16 shows the pin being held in the guide.

Figure 6.16. Crimp Pin in Guide

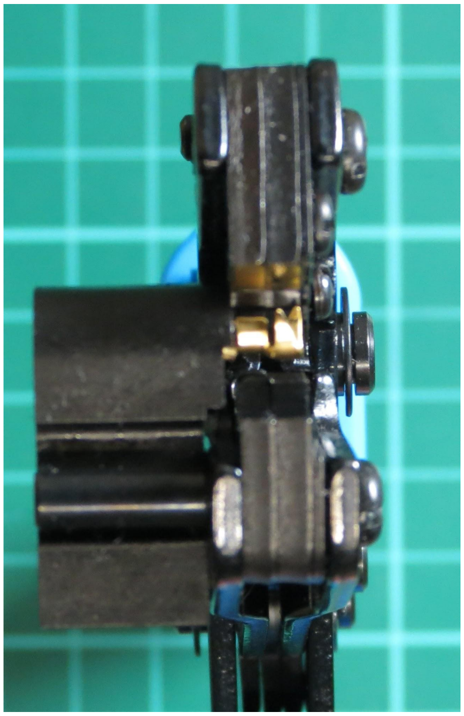
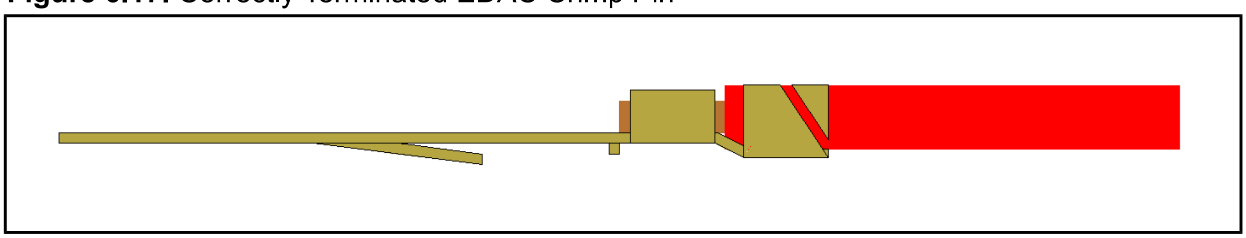


Figure 6.17 shows a correctly terminated EDAC pin.

Figure 6.17. Correctly Terminated EDAC Crimp Pin



8P8C Crimp Plug

As per Google AV policy, avoid field termination of 8P8C plugs wherever possible. The eventual aim is to eliminate this practice to better align with structured cabling standards. Therefore, no guidance is given on the use of this connector.

If field termination of 8P8C plugs cannot be avoided, manufacturer instructions must be followed without deviation.

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6.2 Screw Terminals

There are three types of screw terminals:

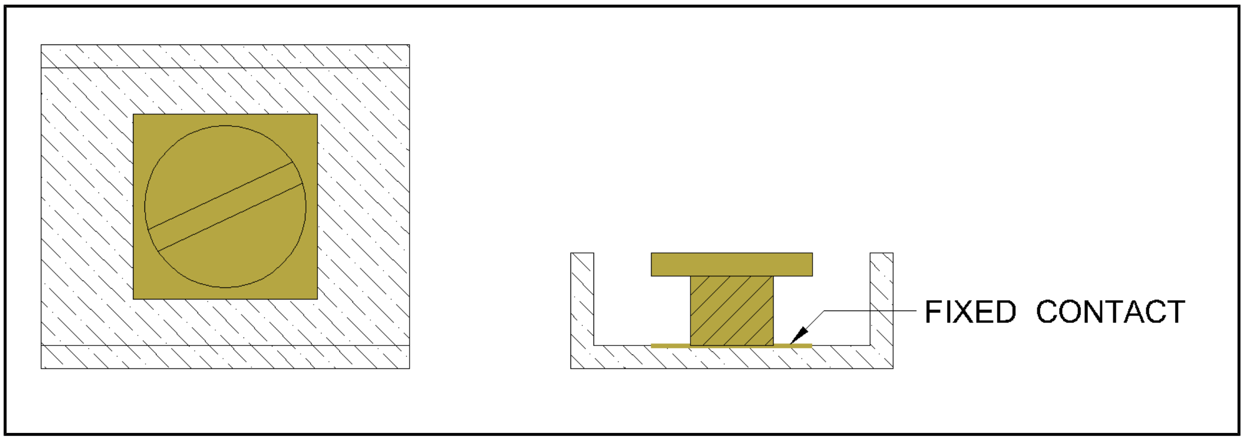
- Head of screw type: The wire is secured by a screw head or nut on a captive bolt. Sometimes a washer is also used.
- Point of screw type: The wire is secured under the point of a screw.
- Metal plate type: The wire is secured by a metal plate forced down with a screw.

For all screw terminal types, an appropriate ferrule or crimp terminal must be used with the stranded wire.

6.2.1 Head of Screw Type

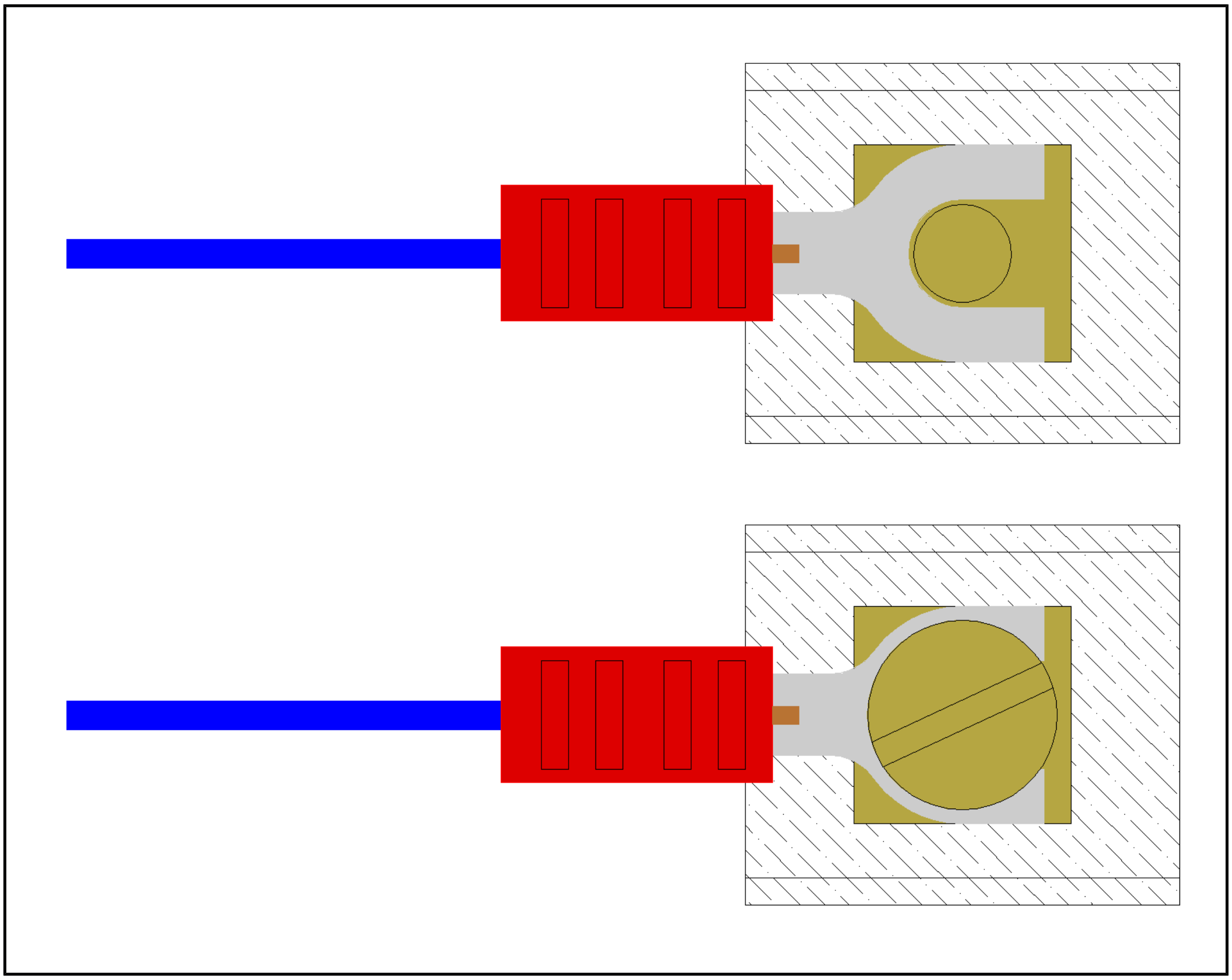
Figure 6.18 shows a generic head of screw type terminal.

Figure 6.18. Generic Head of Screw Type Terminal



For stranded wire, an appropriate terminal lug must be used. If the terminal has a captive screw or nut, this should be a spade terminal. If not, a ring terminal may be used. Figure 6.19 shows a spade terminal correctly terminated.

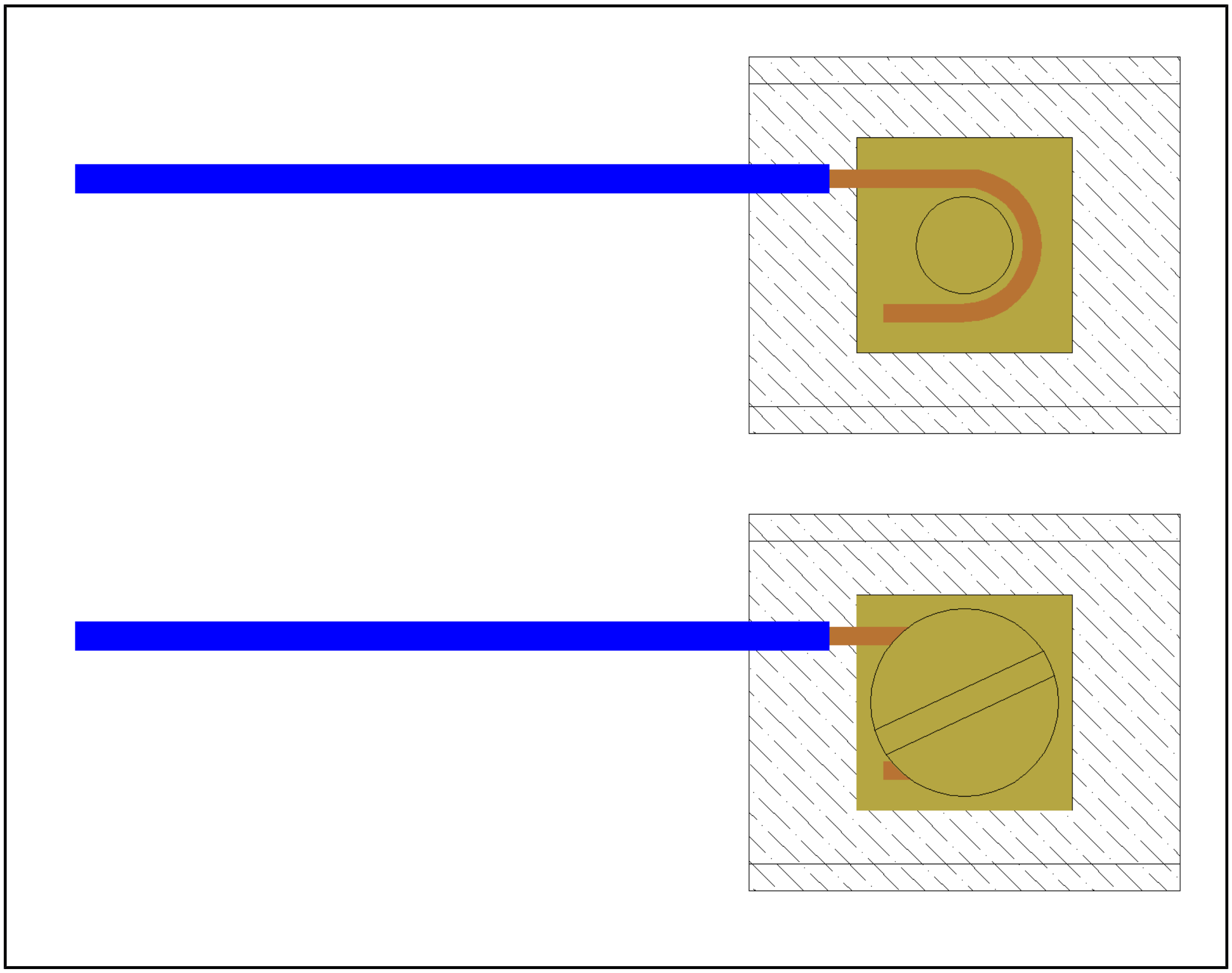
Figure 6.19. Spade Terminal Connection



For solid wire, the wire is stripped and bare wire is looped 180° to fit around the screw. Wire is looped around the screw clockwise. Tightening of the screw will then tend to pull the wire closer to the screw. If wrapped counter-clockwise, it will tend to push the wire out. Figure 6.20 shows a correctly terminated solid wire.

The insulation must not extend under the screw, and there should be no bare wire beyond the insulation of the terminal.

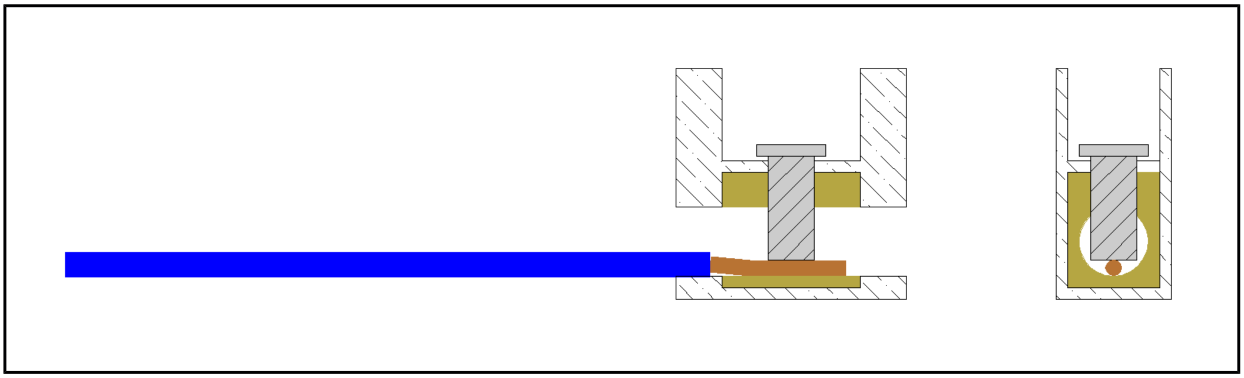
Figure 6.20. Correct Termination of Solid Wire



6.2.2 Point of Screw Type

Figure 6.21 shows a solid wire correctly terminated in a generic screw point terminal.

Figure 6.21. Generic Screw Point Type Terminal



The bare wire must extend past the screw. The insulation must not be in contact with the screw and should not be in contact with the terminal. There must be no bare wire beyond the insulation of the terminal on either side.

If using stranded wire, a bootlace ferrule must be used.

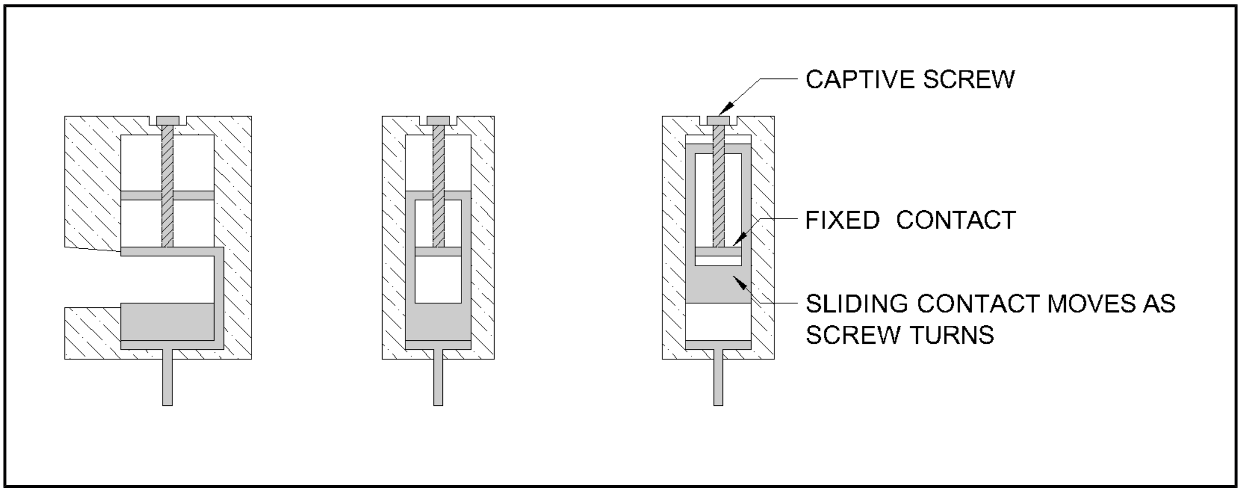
This type of terminal is found within rewireable power plugs and sockets. In this instance, an uninsulated bootlace ferrule should be used.

The same conditions apply for the correct termination of ferrules as with solid wire for this terminal.

6.2.3 Metal Plate Type

Figure 6.22 shows a generic metal plate terminal.

Figure 6.22. Generic Metal Plate Type Terminal



Wire should touch the rear of the terminal for maximum mechanical reliability. No insulation must be in the jaws of the terminal and no bare wire should be exposed.

When using stranded wire, insulated bootlace ferrules must be used with this terminal type. Figures 6.23 and 6.24 show a bootlace ferrule and a solid wire terminated correctly.

Figure 6.23. Correct Termination of Stranded Wire With Bootlace Ferrule

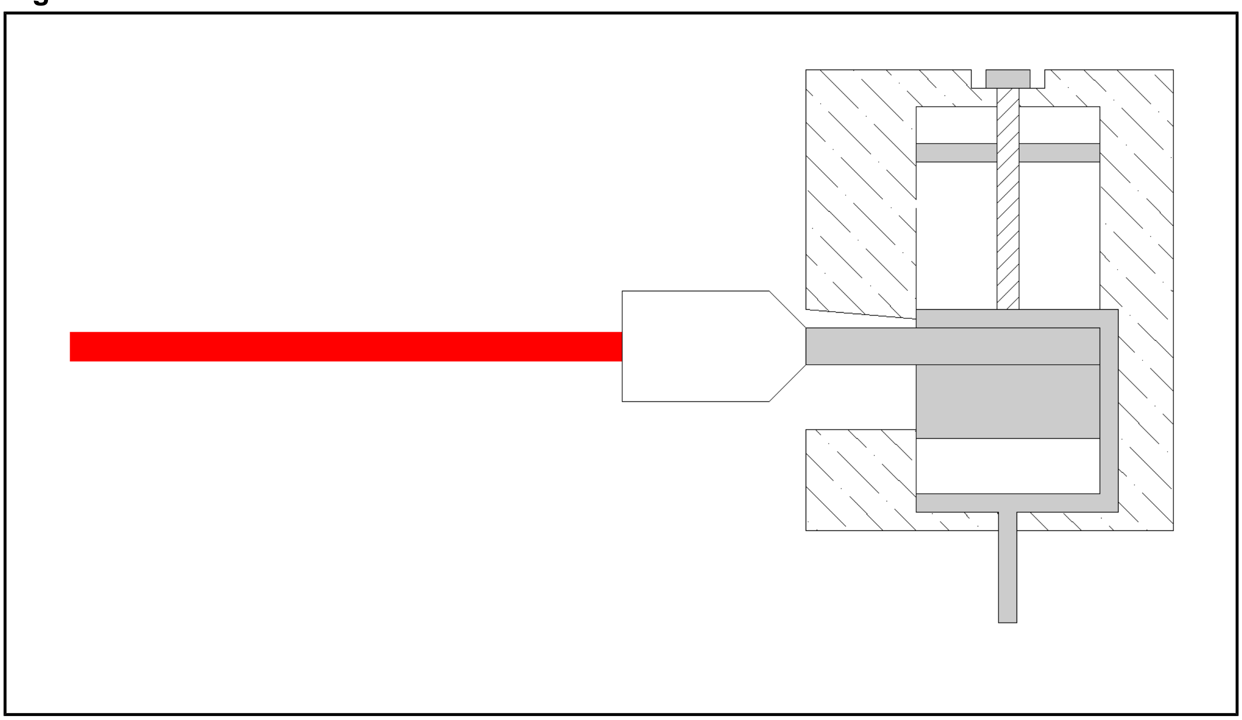
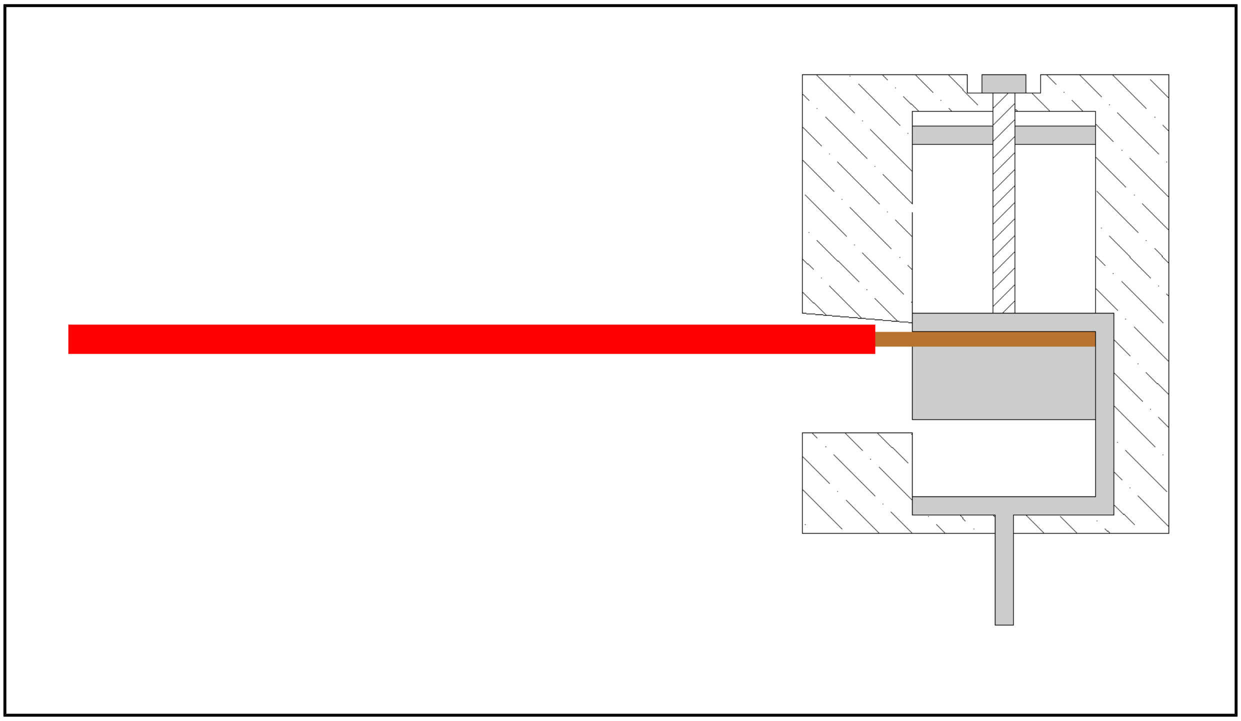


Figure 6.24. Correct Termination of Solid Wire



Figures 6.25, 6.26 and 6.27 show incorrectly terminated solid wires with bare wire exposed, insulation trapped in the jaws, and not enough wire in the jaws.

Figure 6.25. Incorrect Termination Solid Wire: Bare Wire Exposed Outside Terminal

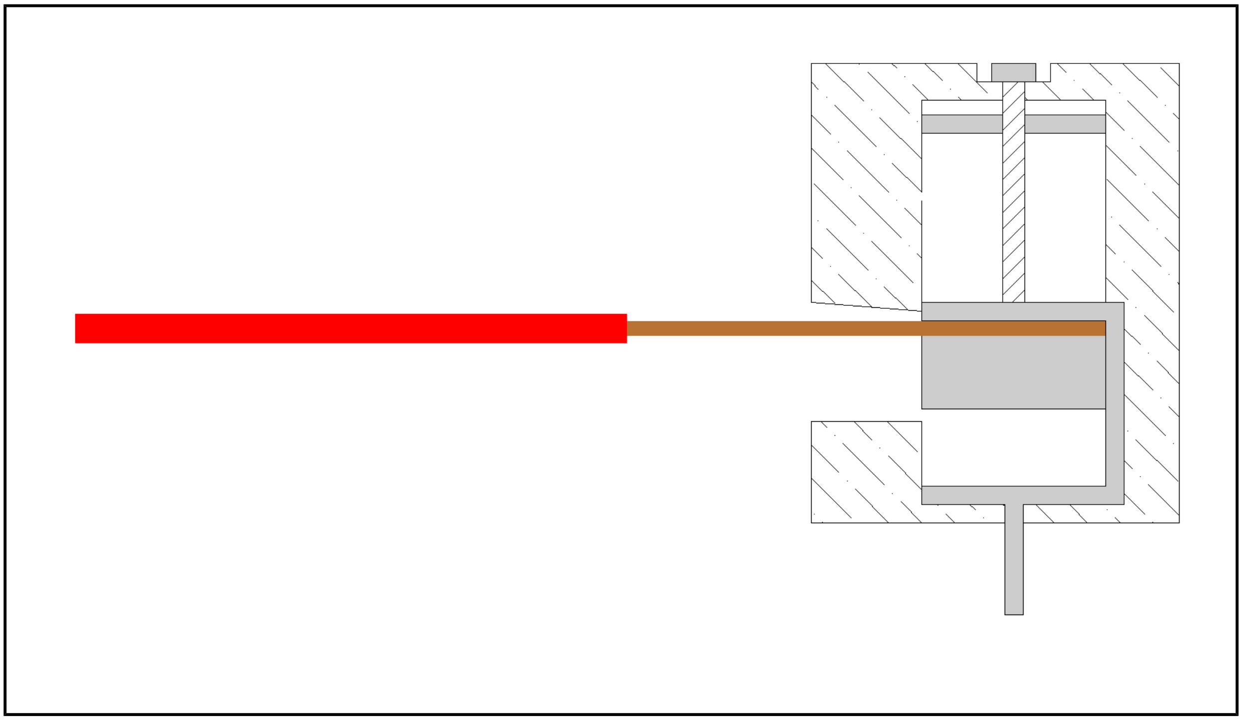


Figure 6.26. Incorrect Termination Solid Wire: Insulation Trapped in Jaws of Terminal

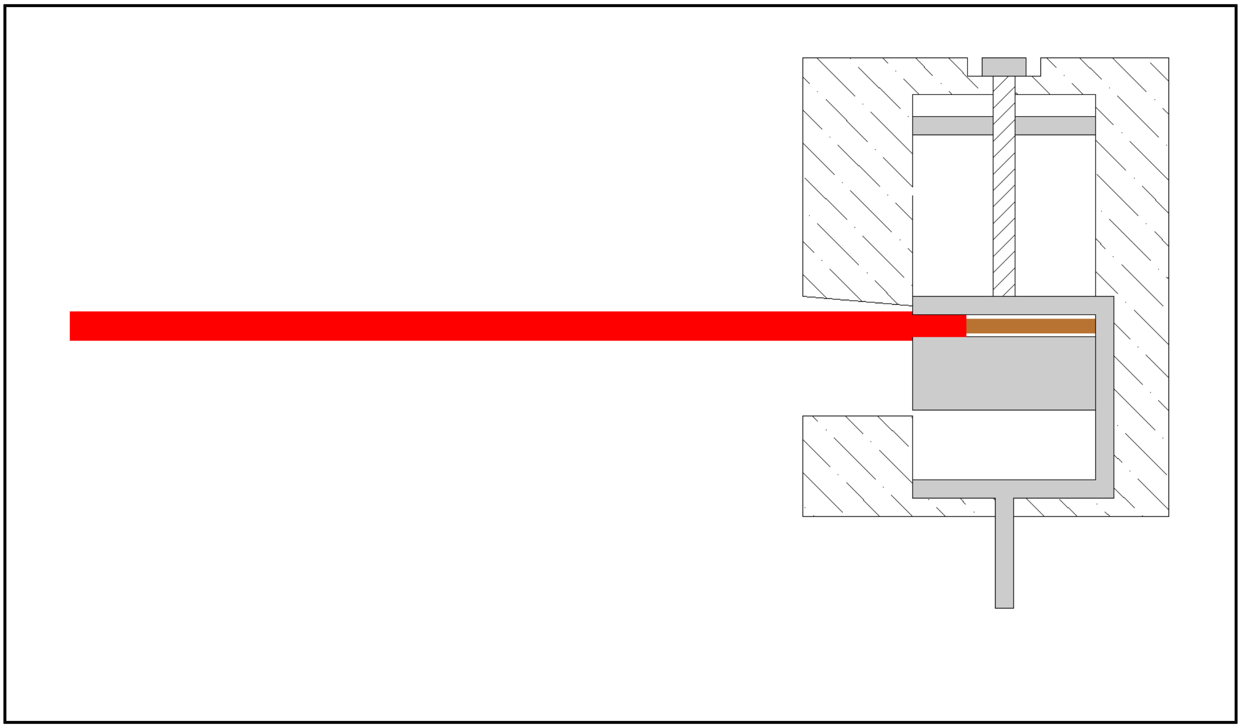
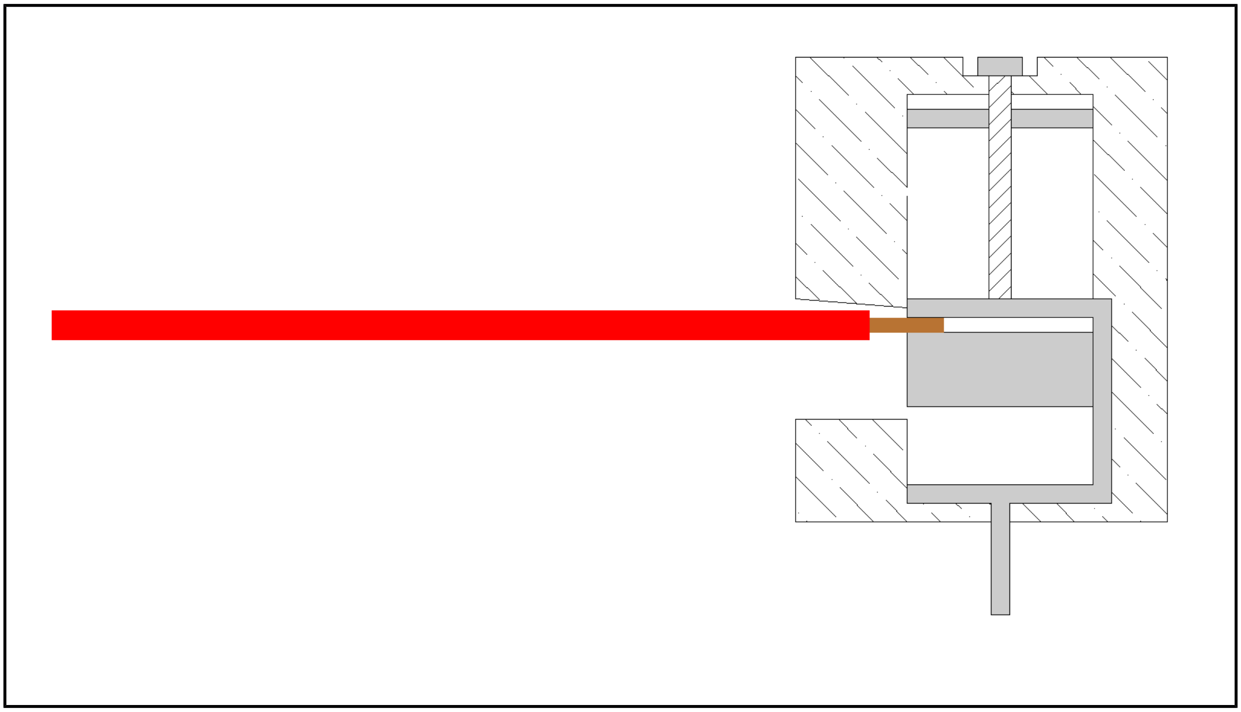


Figure 6.27. Incorrect Termination Solid Wire: Not Enough Wire in Jaws of Terminal



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6.3 Soldering

This section outlines the basic soldering principles with details on good practices that should be followed and bad practices that must not be followed. With traditional lead-based solder, it is easy to define what solder joints should look like: colour, texture and fillet shape are all standard. Different formulations of lead-free solder available now give satisfactory joints that look very different from each other. It is still easy to see when too much solder has been used, though.

This section is not intended as a guide on to how to solder.

Soldering is a skilled task and anyone undertaking soldering on a Google AV system must have appropriate training and skills, including a proper understanding of solder characteristics, how a soldering iron works, how to maintain tips, correct techniques, recognizing good solder joints, and potential problems.

6.3.1 Correct Use of Soldering Iron

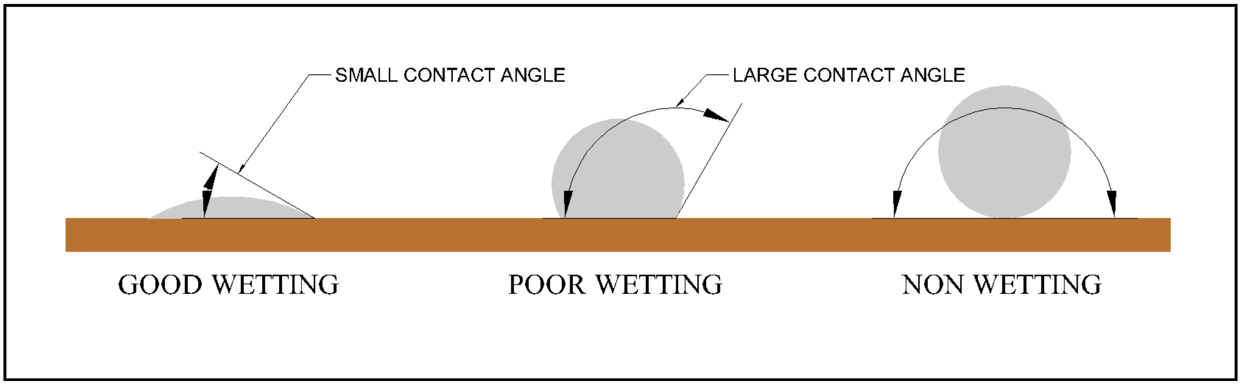
When soldering, a small amount of solder is used on the iron to get a good thermal contact. The iron is used to heat the contact or contacts above the melting point of the solder. The solder is melted on the contacts, not the iron. If a contact is not heated above the melting point of the solder, it will cause an unreliable cold joint.

The quicker the contacts are heated to the correct temperature, the less chance there is of thermal damage to the components. This does not mean using a hotter iron or bigger tip than is required: it means placing the iron on the biggest mass. The iron should be held in place only long enough to get the job done.

6.3.2 Wetting

For soldering, good wetting is required. Wetting is the ability of a liquid to cover a surface. In this case, the liquid is molten solder. Poor wetting will lead to droplets being formed, as can be seen with water on a waxed surface. Figure 6.28 shows examples of good wetting, poor wetting, and non-wetting. For good wetting, we want a small contact angle. Ideally, the contact angle should be below 30^0, but the closer to zero, the better.

Figure 6.28. Diagram Showing Good Wetting, Poor Wetting, and Non-wetting



For good wetting, the surfaces to be soldered must be clean, and there must be enough heat. The flux in the solder will clean the oxides of metal surfaces, allowing solder to adhere.

6.3.3 Tinning

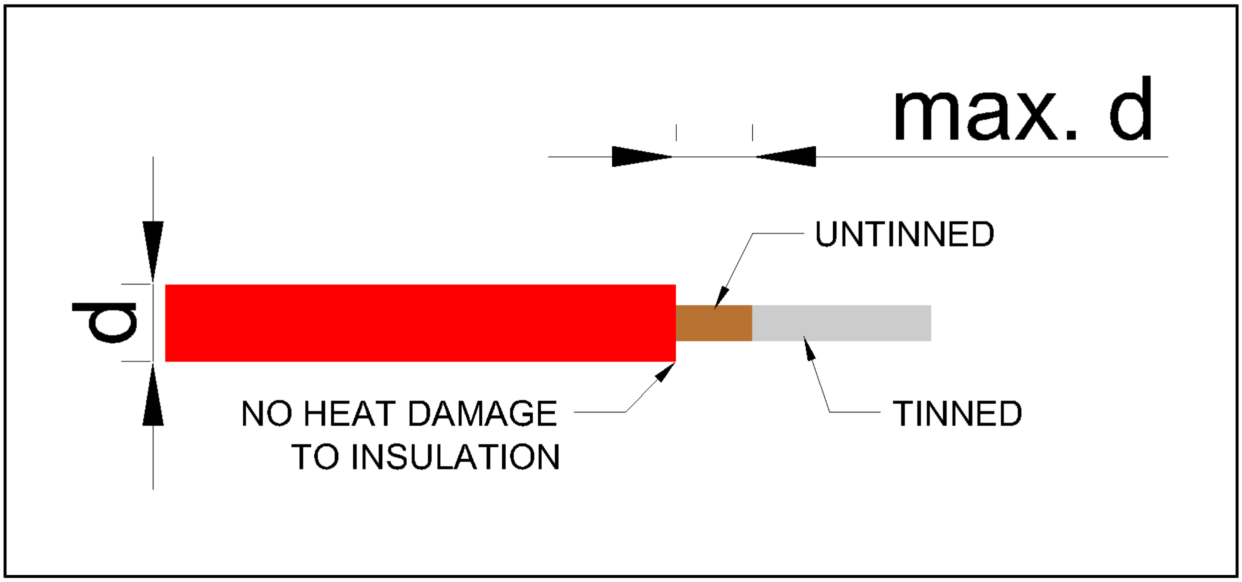
Parts must be tinned before being joined. They must have a thin layer of solder properly applied to give them a uniform and readily solderable surface. All portions of wire or connector that are to be soldered must be tinned.

Wire

When tinning stranded wire, the solder should penetrate and wet the inner strands, leaving a smooth coat, but with individual strands still visible. For smaller diameter wires, individual strands will not be visible, but tinning should not add greatly to the diameter of the wire.

When tinning wire, it is important not to let heat damage the insulation. To help prevent damage, it is acceptable to leave the wire at the junction with insulation untinned for a distance equivalent to the diameter of the wire, as shown in Figure 6.29.

Figure 6.29. Maximum Amount of Wire that can be Left Untinned



Solder will sometimes wick down wire under the insulation. This is acceptable as long as it does not extend to a portion of the wire that is required to be flexible.

For thin wires, it is acceptable practice to strip more cable than is required for tinning and then cut them to size afterwards. This makes it easier to tin without damaging the insulation.

Solder Cup Terminals

When tinned, the solder should wet the entire inside of the cup.

Perforated Terminals

On a perforated terminal, the wire should pass through the eye and contact both sides of the terminal. The eye must, therefore, be left open when the terminal is tinned.

6.3.4 Soldering Connections

The tinned parts to be joined are heated with iron, and solder is melted on components, not iron. With good wetting, there will be a small contact angle between the solder and both components, giving a concave fillet as shown in Figure 6.30 (A).

Figure 6.30. Solder Joint Cross Sections

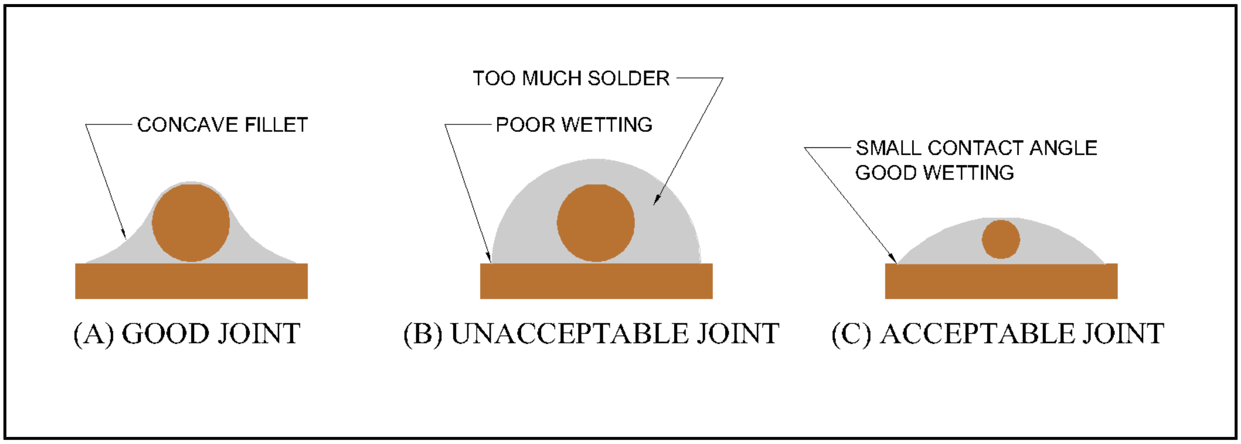


Figure 6.30 (B) shows an unacceptable joint with poor wetting and too much solder used. If solder reached to the end of the copper, it is possible that wetting and the joint could be okay, but too much solder has been used. It is not possible to tell, so the joint would still be unacceptable.

With thin cables, it is not always possible to get a concave fillet as shown in Figure 6.30 (C). This is an acceptable joint because there is a small contact angle with the terminal where the wire is attached.

Parts must be held still while a solder joint cools. Any movement while solder cools will cause an unreliable dry joint.

A solder joint must be allowed to cool naturally. The cooling rate affects the crystalline structure of the joint. If it cools too quickly, it causes an unreliable joint. Blowing on solder joints to cool them is expressly forbidden.

Insulation

The insulation on the wire must not enter the solder joint. There should be a distance equivalent to the diameter of the cable between the insulation and joint.

Solder Cup Terminals

The tinned wire should touch the bottom of the cup. The cup should be filled completely without overflowing. The outside of the cup should be free from solder but a thin film is acceptable.

The cup must be at least 75% full. A small solder buildup outside the cup that does not affect form, fit, function, or reliability may be accepted. If there is any doubt, remove solder and re-terminate the connection.

6.3.5 Resoldering

Care should be taken to avoid the need for resoldering, as it actually weakens the joint. Every time a joint is heated, the intermetallic layer grows. There is no joint without this layer, but the bigger it is, the more fragile the joint.

Cold and dry joints can often be fixed by reheating with the addition of a little flux. (Finding such faults is much harder than fixing them.)

If connectors need to be resoldered, it is often best to desolder first using a suction tool or solder wick.

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6.4 IDC

With insulation-displacement (IDC) connections, the connector, cable, and IDC punchdown tool must all be compatible. If one of the three is inappropriate, a poor connection will result. Therefore, it is essential to read and follow the manufacturer's instructions.

6.4.1 Punchdown Connections

A punchdown tool presses a wire into an IDC socket, ensuring it is terminated correctly and cuts the wire to size. There are different punchdown tools available. They all look similar, but they are not the same. The correct tool must be used at all times. It is expressly forbidden to use a screwdriver or other such tool to try and punch a wire into an IDC terminal.

With punchdown connections, each wire is terminated in turn. The most common example of this type of connection is 8P8C sockets, but it is also widely used on other connectors.

6.4.2 Ribbon Cable Connections

With a ribbon cable connector, all the wires are terminated at the same time. To ensure a good connection, the ribbon must be carefully aligned in the connector, and an appropriate ribbon cable crimp tool should be used to close the connector.

Pressure has to be applied equally along the ribbon cable connector to ensure proper termination. Therefore, use of pliers or other similar tools is expressly forbidden.

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7. Rack Building

Overview

Rack building is part science, part art. There are rules that need to be followed, but these rules sometimes conflict and compromises have to be made. Part of the art comes from experience in knowing which rules should take precedence in particular situations.

It is not possible to write a set of rules to cover all the possible compromises that might be required or are acceptable. There will be differences of opinion, and different approaches might be equally valid. What is not acceptable is to ignore all the rules.

Anyone building racks for Google should feel free to consult the AV Eng Design team if they need further guidance.

It is expected that this section of the document will be refined over time to improve guidance given and help improve standards of rack builds. Any contractor meeting or exceeding the requirements in this section is asked to submit photographs for the next edition.

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7.1 Rack Layout

When planning an equipment rack layout:

- Equipment should be grouped by signal type.
- Equipment should be arranged so that the signal path flows from top to bottom.
- Inter-rack connections should be minimised if multiple racks are used in a system.
- Ergonomics should be considered with any equipment that requires the user interface to be positioned at a suitable height (e.g., keyboards, mice, monitors, Blu Ray players, etc.).
- Thermal management should be considered to ensure there is adequate cooling and ventilation.
- Heavier equipment should be located towards the bottom of the rack to make the rack more stable and minimise manual lifting when building or servicing the rack. If it is not possible to keep heavy equipment low in the rack, care must be taken to ensure the rack is mounted securely.

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7.2 Supporting Equipment

Heavy equipment should not be supported by rack ears alone. Doing so puts excessive torque on the rack rails and the equipment itself. More importantly it causes problems with service and maintenance if equipment needs to be removed from rack and a potential injury risk.

Any piece of equipment that weighs more than 7.5 kg (16lb) must not be supported by rack ears. Additional support must be provided, such as sliding rack rails or chassis runners.

One pair of Chassis runners may be used to support two pieces of identical equipment such as amplifiers in an audio rack. No more than two pieces of equipment may be supported by one pair of chassis runners.

If a rack shelf is required to support heavy loads, it should be mounted in the front and rear when possible.

Under no circumstances should a rack shelf be used for more than its rated load.

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7.3 Connection Panels

If possible, an AV system should be designed to have a connection panel or panels between site wiring and equipment racks. This allows testing of systems in equipment racks while they are still in the workshop. The site wiring can also be tested, minimising time required onsite after a clean building handover.

A connection panel necessarily puts more connectors in a signal path, which is something we try to avoid under other circumstances. However, the benefits of workshop testing normally outweigh potential issues. If there is likely to be an issue with a signal type, then a connection panel for those signals should not be used.

HD-SDI is a signal type that should not use extra connections. MUSA patch bays are typically used for all connections, as shown in Figure 7.1. Cables cannot be terminated before the rack is installed, but the systems in the rack can be tested.

Figure 7.1. HD-SDI Connections to MUSA Patch Bay

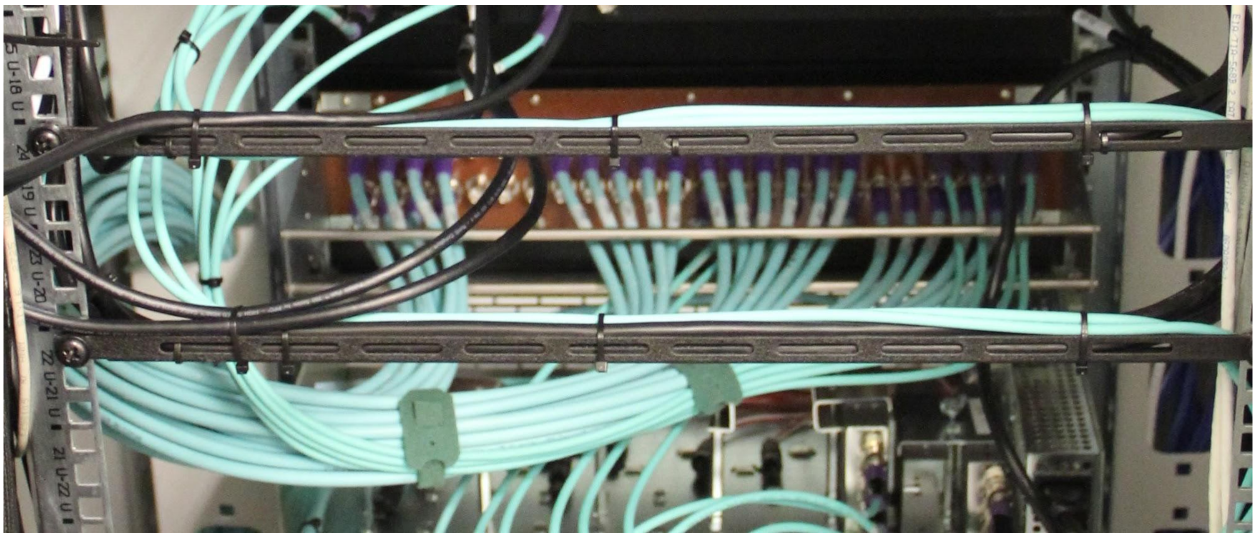
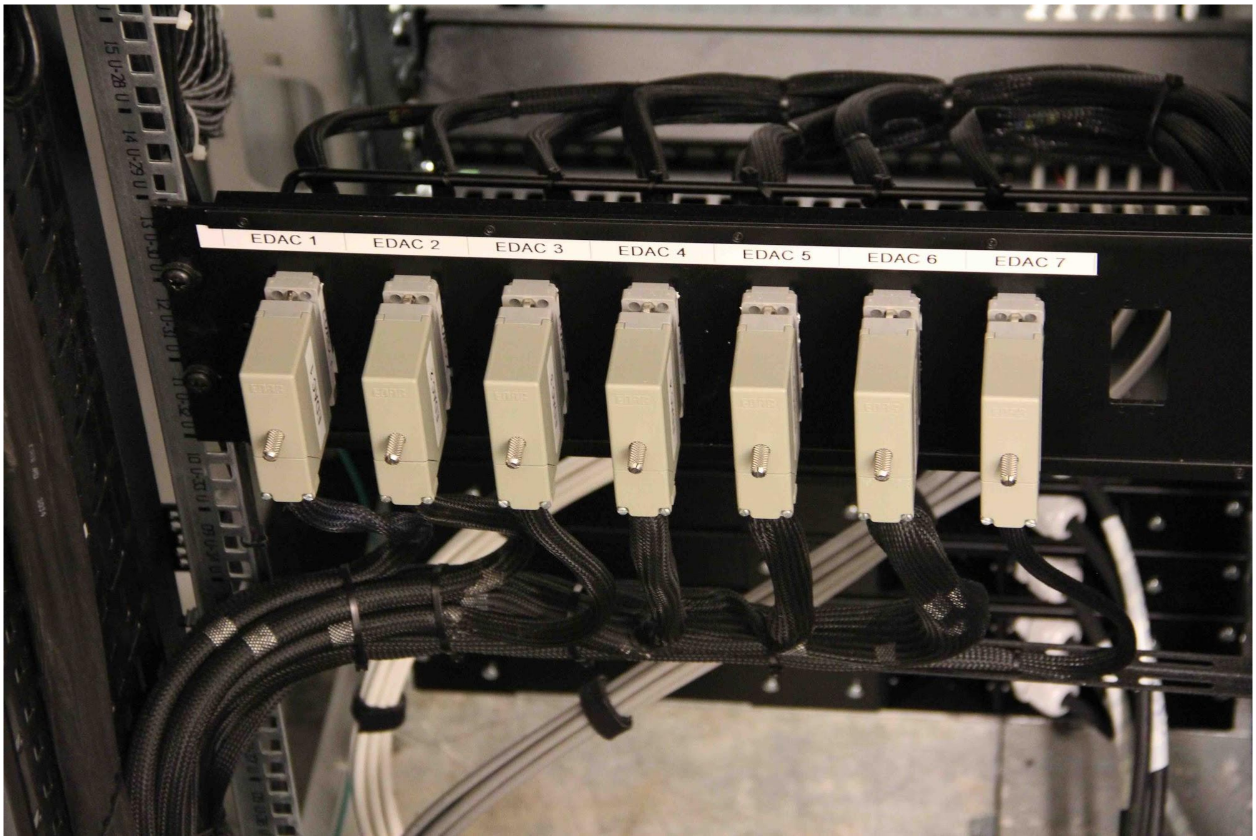


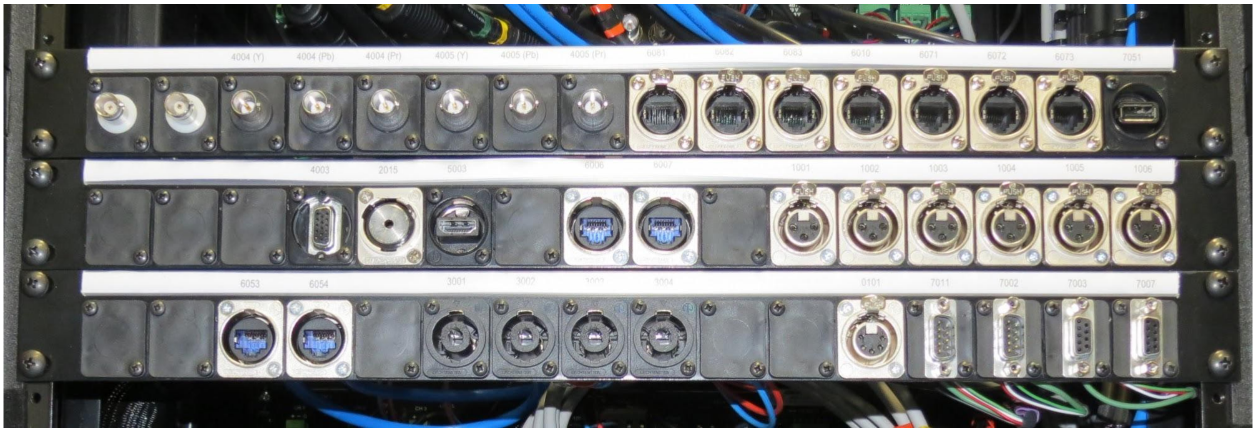
Figure 7.2 shows an EDAC connection panel for the audio part of a system. The cables from each of seven locations are terminated in a separate connector. This not only facilitates easy testing of cables before rack installation, but also allows for convenient maintenance and servicing.

Figure 7.2. EDAC Connection Panel



In a Tech Talk system, there is a connection panel on the rear of the rack that connects all site wiring, including network connections, as shown in Figure 7.3.

Figure 7.3. Tech Talk Connection Panel



The panel in Figure 7.3 adds more connections than networking standards allow, but this was a conscious design decision to have a single product that could be tested and deployed.

The connection panel does not have to be mounted in the rack. Figure 7.4 shows a wall-mounted connection panel. The site cables are visible entering from below, with the looms from the rack connected on the front. This arrangement is useful when space is limited and/or there is no raised floor.

Figure 7.4. Wall-mounted Connection Panel

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7.4 Cable Management and Dressing

Rack cabling must be neat, tidy, and properly dressed. This aids testing, commissioning, service, and maintenance.

7.4.1 Cable Entry

Equipment racks typically used in AV systems are not as deep as those used for networks and are only 600 mm wide. For this reason, it is preferred that cables enter from beneath the rack. If there is no raised access flooring, then racks may be raised up on a platform to allow this.

Cable entry from above is allowed, but if a standard AV rack is being used, care must be taken to ensure cable entry does not interfere with ventilation.

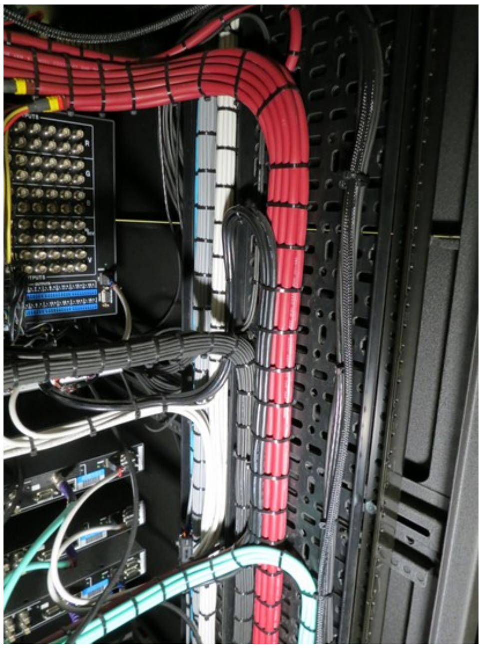
In portable racks, the cable entry may be from the rear. However, this method should be avoided for permanent installations whenever possible.

7.4.2 Cable Separation

Different signal types should be kept separate as much as possible. There will not be enough space within a rack to keep the same separation as for site cabling, but best efforts should be employed.

The interference caused by having different signals too close together is proportional to the distance between them. There will be places in the rack where it is physically impossible to maintain separation, but these should be kept as small as possible by separating signals at first opportunity. Figure 7.5 shows good cable separation in a rack.

Figure 7.5. Vertical Cable Separation

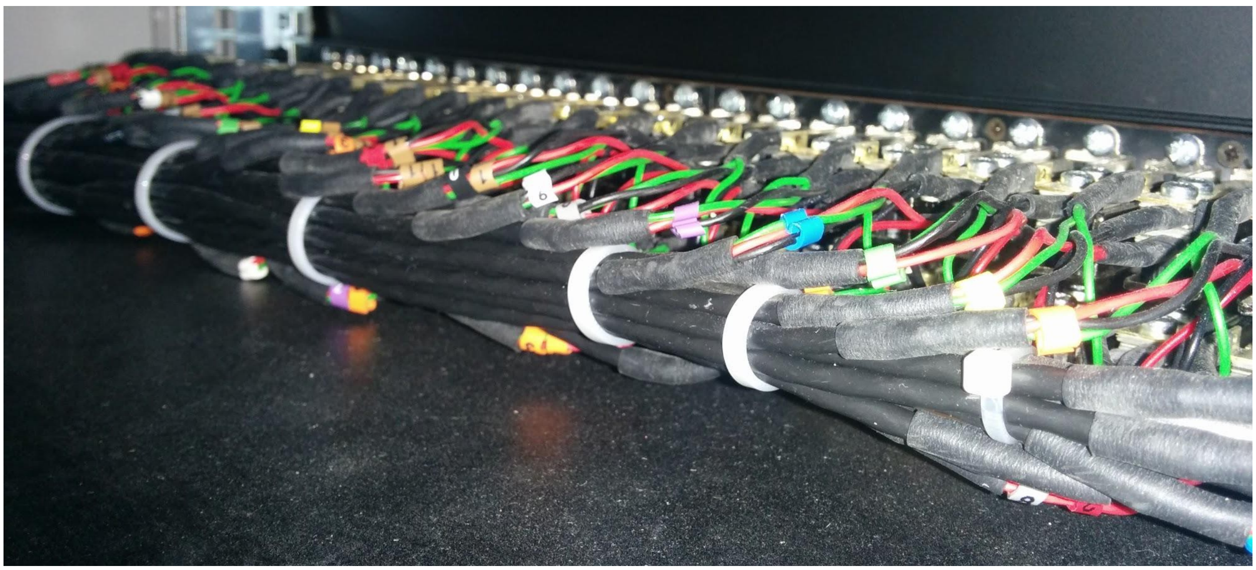


When there is enough space in the rack, maximum separation can be achieved by keeping the signal cables to one side of the rack and power on the other. Loudspeaker cables have high signal levels and can be put on the same side as power.

7.4.3 Lacing Bars
Lacing bars are used to manage cables connected to equipment. They support the weight of the cables, preventing undue stress on connections.

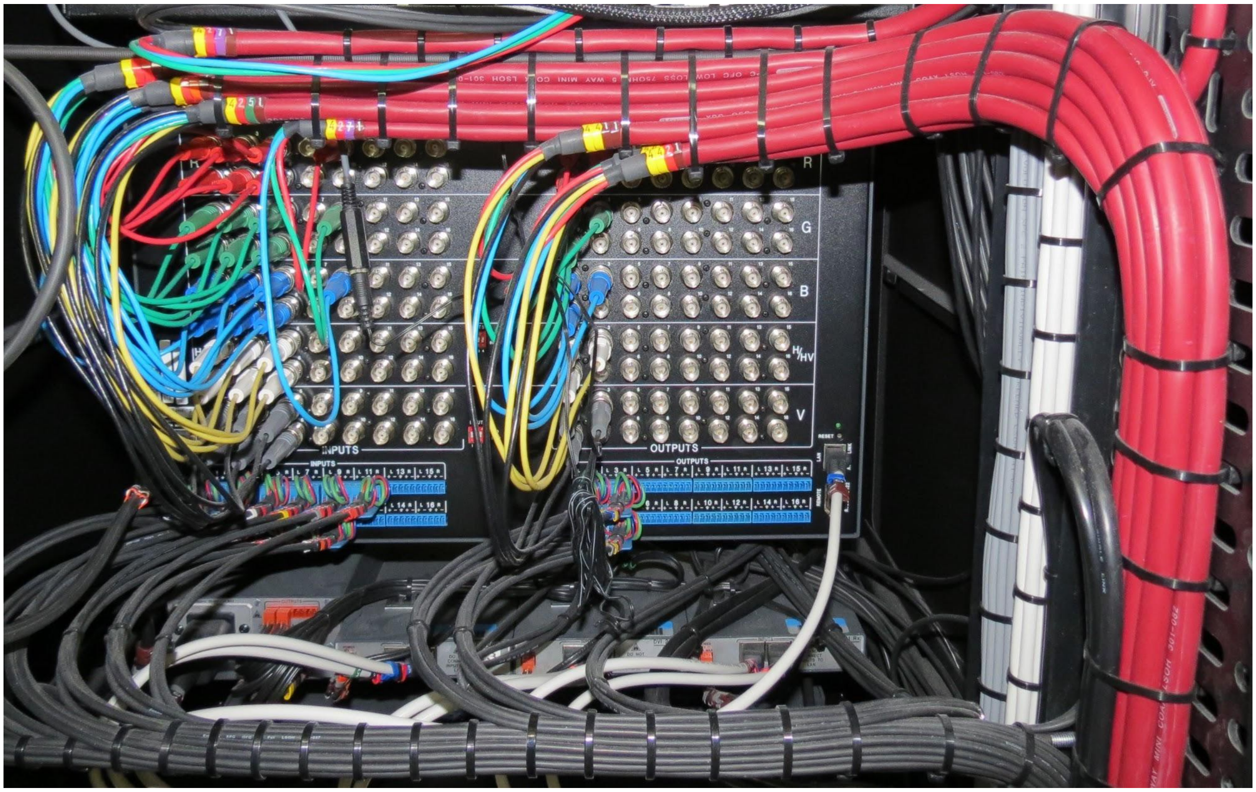
Lacing bars may be fixed to the rack or to an individual piece of equipment. If cables are permanently connected to equipment, then the lacing bar must be attached to the equipment. An example of this would be an audio patch bay where cables are soldered to the patches. Figure 7.6 shows an audio patch bay with a lacing bar. There are 48 audio cables so the lacing bar is not visible. Note that cable ties on the lacing bar are non-sequential.

Figure 7.6. Audio Patchbay with Fixed Lacing Bar



Where lacing bars are fixed to the rack, they should be located above or below the equipment so that they do not obstruct access. Figure 7.7 shows an RGBHV matrix switcher with a lacing bar above for RGBHV cables and one below for audio.

Figure 7.7. RGBHV Matrix Switcher with Lacing Bars Above and Below



Both audio and RGBHV looms have sequential fastening, which is not necessary in either case.

This should have been done non-sequentially.

The cable numbers on the RGBHV cables (red) are further from the connector than recommended at 100 mm, but this is a good practice. The cable numbers have been put in the most logical place to easily identify them.

The minimum bend radius on the coaxial cores of the RGBHV cable is much less than that of the overall cable. Stripping the cable sheath to a point on the lacing bar gives maximum flexibility.

A 3.5 mm socket and jack can be seen hanging down with a bunch of cable connected to an audio output. This was added to the system after commissioning. It should not be there.

7.4.4 Service Looms
A service loom allows equipment to be removed from the front of the rack for inspection without disconnecting. Service looms are required when cables are permanently attached to equipment, as with the patch bay in Figure 7.6. The service loom must be supported so that its weight does not put stress on any connectors.

7.4.5 Rack Cabling
Cabling between equipment in a single rack or between colocated racks does not need to be of the same specification as that used for site cabling. Signals must not be degraded by using different cable in the rack, but the short distances help limit this. Thinner cables take up less space inside racks and more flexible ones make wiring easier.

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7.5 Visual Examples
At the time of writing, there are no AV equipment racks on the estate that fully meet the standard. There are two reasons for this:

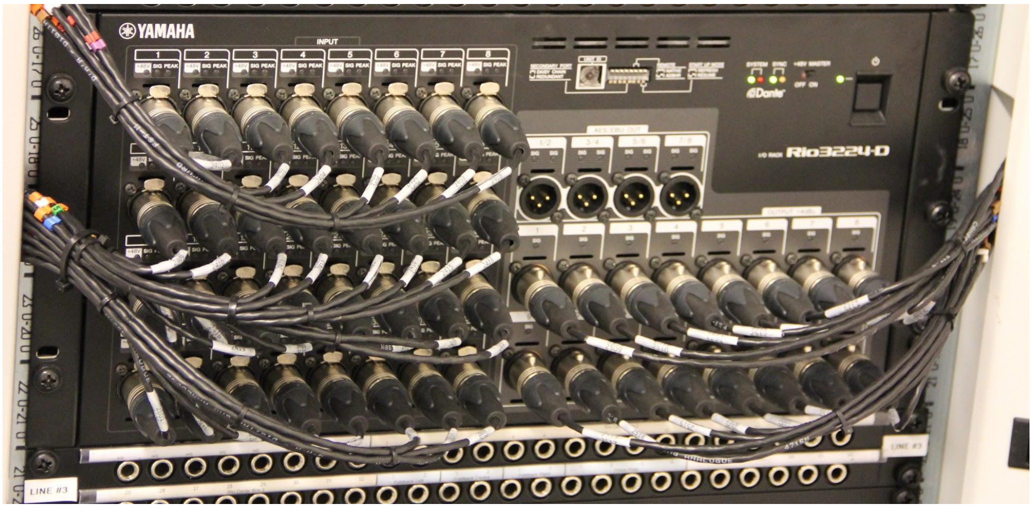
- We are intentionally setting the bar very high with this standard. For instance, sequential fastening was previously allowed.
- We have had some poor installations.

This makes showing photographs of expected quality difficult. In this subsection, we show photographs that contain both good and bad examples.

Figure 7.8 shows an equipment rack that contains only audio equipment. There are a lot of connections in the rack, and all cables have been neatly loomed and dressed. There are two Dante units that have the connections on the front, as shown in Figure 7.9. The cable labels are a bit too close to the connectors, but this is not a major issue.

Figure 7.8. Audio Equipment Rack

Figure 7.9. Front Panel Audio Connections



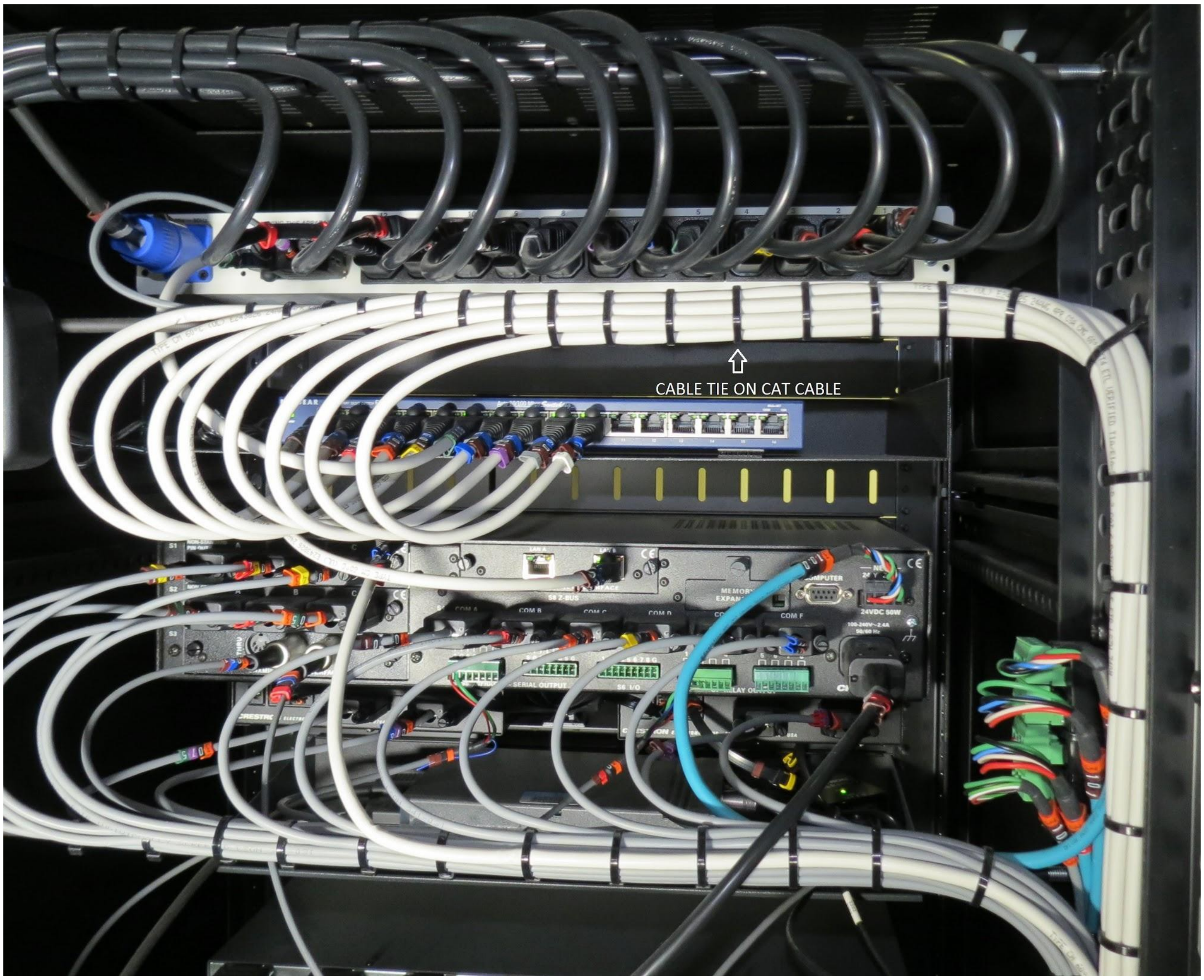
However, if we take a closer look at the back of the lower Dante unit in Figure 7.10, we see that the white network cables have been cable-tied and the minimum bend radius has been exceeded. This cable should be replaced. The system was working, but there is no guarantee it will continue to do so.

Figure 7.10. Detailed View of Dante Unit Showing Badly Installed Network Cables

Figure 7.11 shows some very neatly loomed cables but with sequential fastening. Also, cable ties have been used on network cables. This is a control network with low speed connections, but that is no excuse to use cable ties.

Cable ties must not be used on network cable.

Figure 7.11. Cable Ties on Network Cable and Sequential Fastening



To comply with this standard, cables should be replaced and velcro ties should be used. Replacing the ties would not be compliant, as cable ties must not be used at any stage.

Figure 7.12 shows another neat lacing bar, but cable ties have been used on the SDI cable instead of velcro ties. Some cable ties have been applied too tightly, pinching the coaxial video cable. The minimum bend radius has also been exceeded on the SDI cable. At the time of installation, velcro ties were not specified for use with SDI, but there is no excuse for the pinched cable nor exceeding the minimum bend radius.

Figure 7.12. Coaxial Cable Pinched and Bent Beyond Minimum Radius

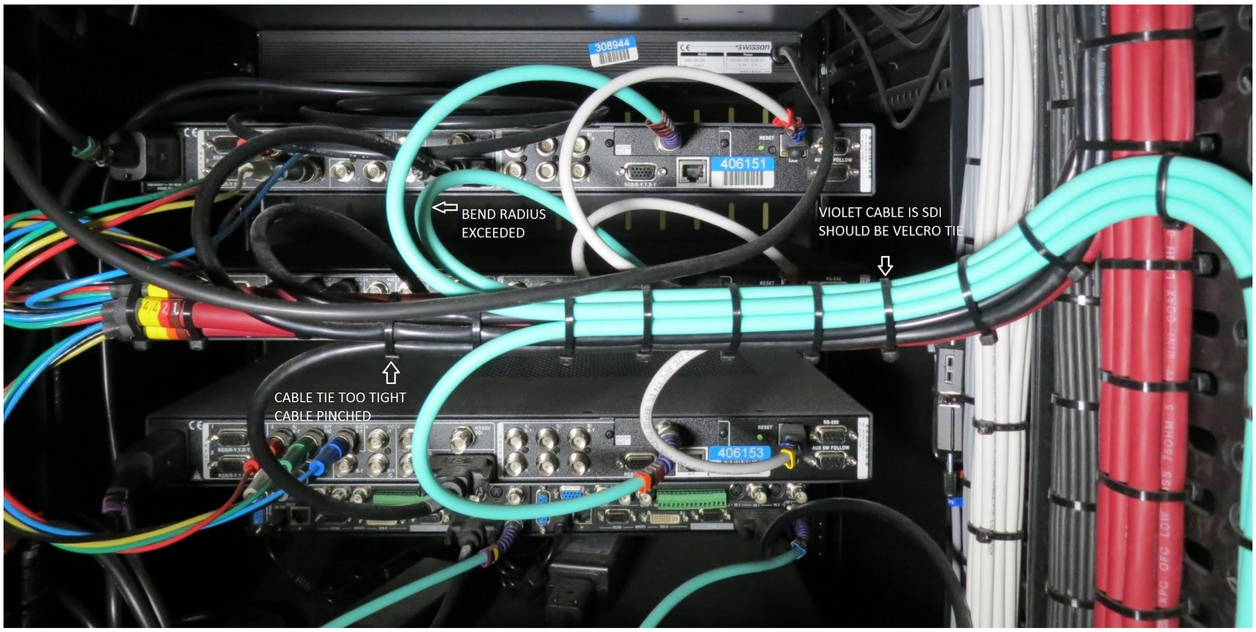


Figure 7.13 shows neatly labeled control cables, but with the numbers upside down. This rack does not have a door, but is placed against a wall so that cables can only be viewed from this side.

Figure 7.13. Cable Numbers Upside Down

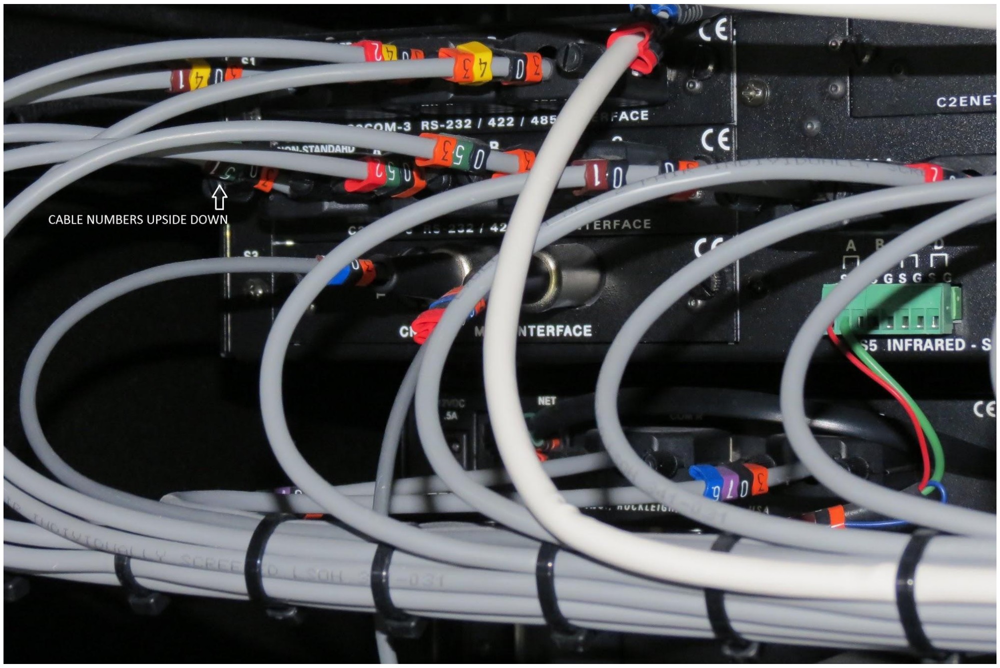


Figure 7.14 shows a good example of looming network patch leads. There are 24 DVI extenders connected to the structured cabling network. This is a network rack and the patch leads are managed in the sides of the rack. They are labelled, loomed neatly, and secured with velcro ties.

Figure 7.14. Network Leads Loomed Correctly

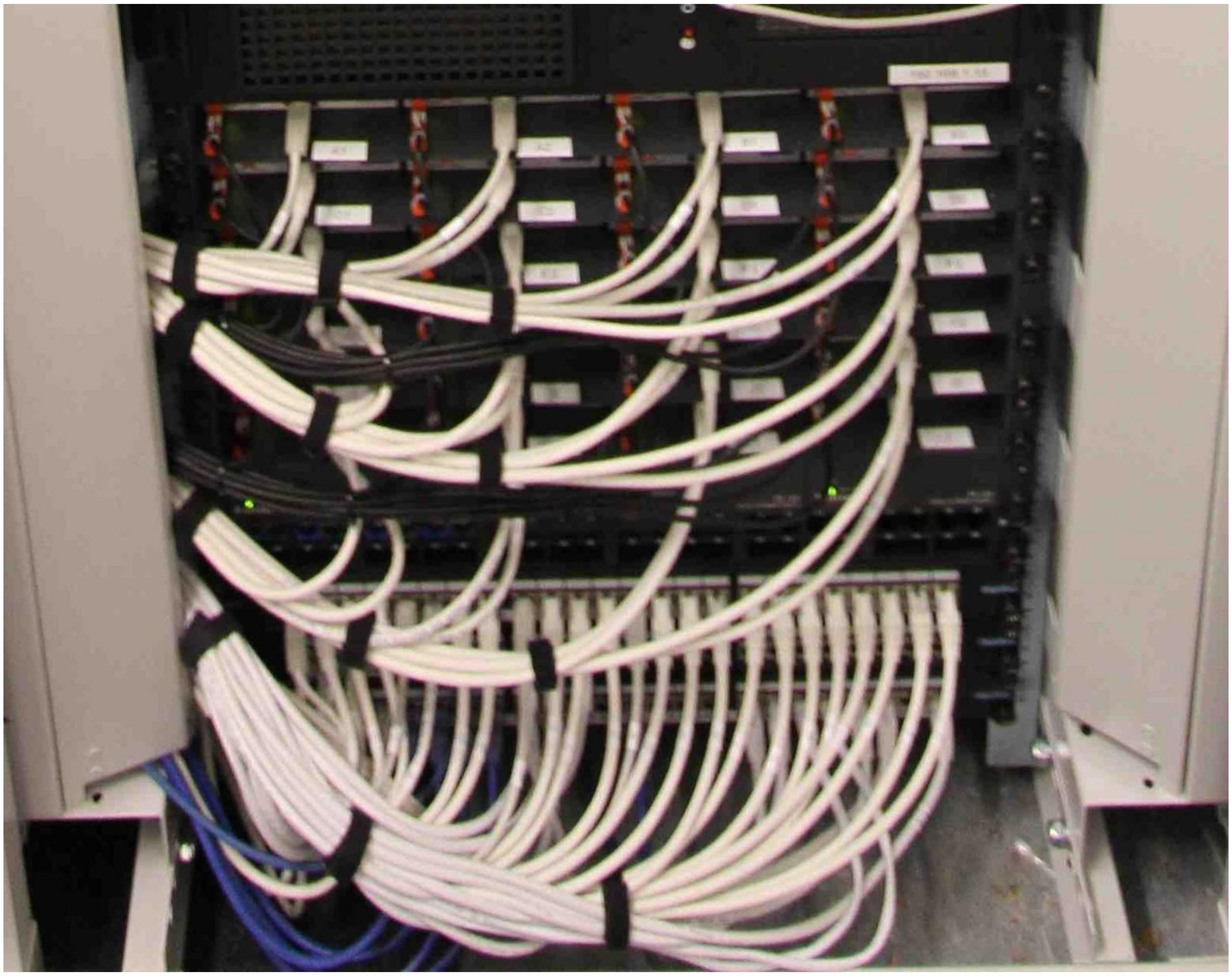
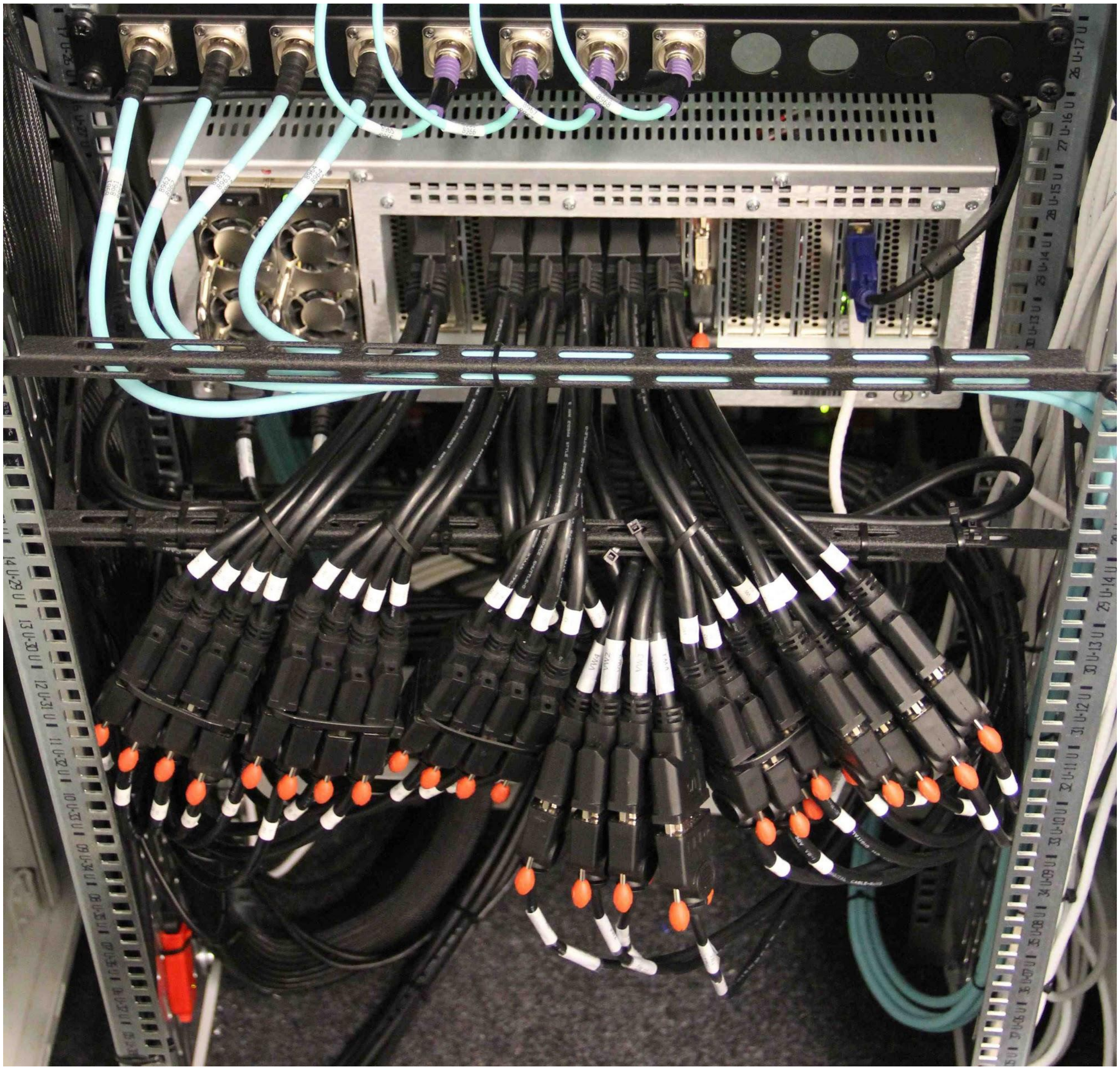


Figure 7.15 shows the connections to a video wall controller. There are 24 outputs connected to DVI extenders, as shown also in Figure 7.14.

Figure 7.15. Video Wall Controller Connections



The video wall controller uses breakout cables that have 4 DVI connectors. There is no ideal way to manage this situation, but here a lacing bar is used to support the weight of the breakout cables so that there is no stress on the connection to the controller. The DVI cables to the extenders are supported by another lacing bar that cannot be seen in this image.

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8. Cable Assembly Instructions

Overview

Google requires that all cable terminations of any type meet the same high standard in quality. To achieve this, providing detailed instructions on each type of termination is required such that a competent technician can make a connector to the required standard, using the right tools and materials without reference to anything or anyone else.

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8.1 Cable Termination Details

Contractors are required to provide full details of how all cables will be terminated. These are required for every type of termination or cable assembly. The details should include:

- Cable and connector types
- Tools to be used
- Consumables required
- Detailed instructions for the procedure, including drawings (if required)
- Pinouts: If in drawing form, must be from the solder or termination side of the connector

The approved procedure must be followed. Use of any tools not detailed in the approved procedure is not allowed.

The requirement to use only tools included in the approved procedure is to prevent the use of the wrong tools, not to limit choices for appropriate tools. It is perfectly acceptable to have a list of alternative tools in the instructions.

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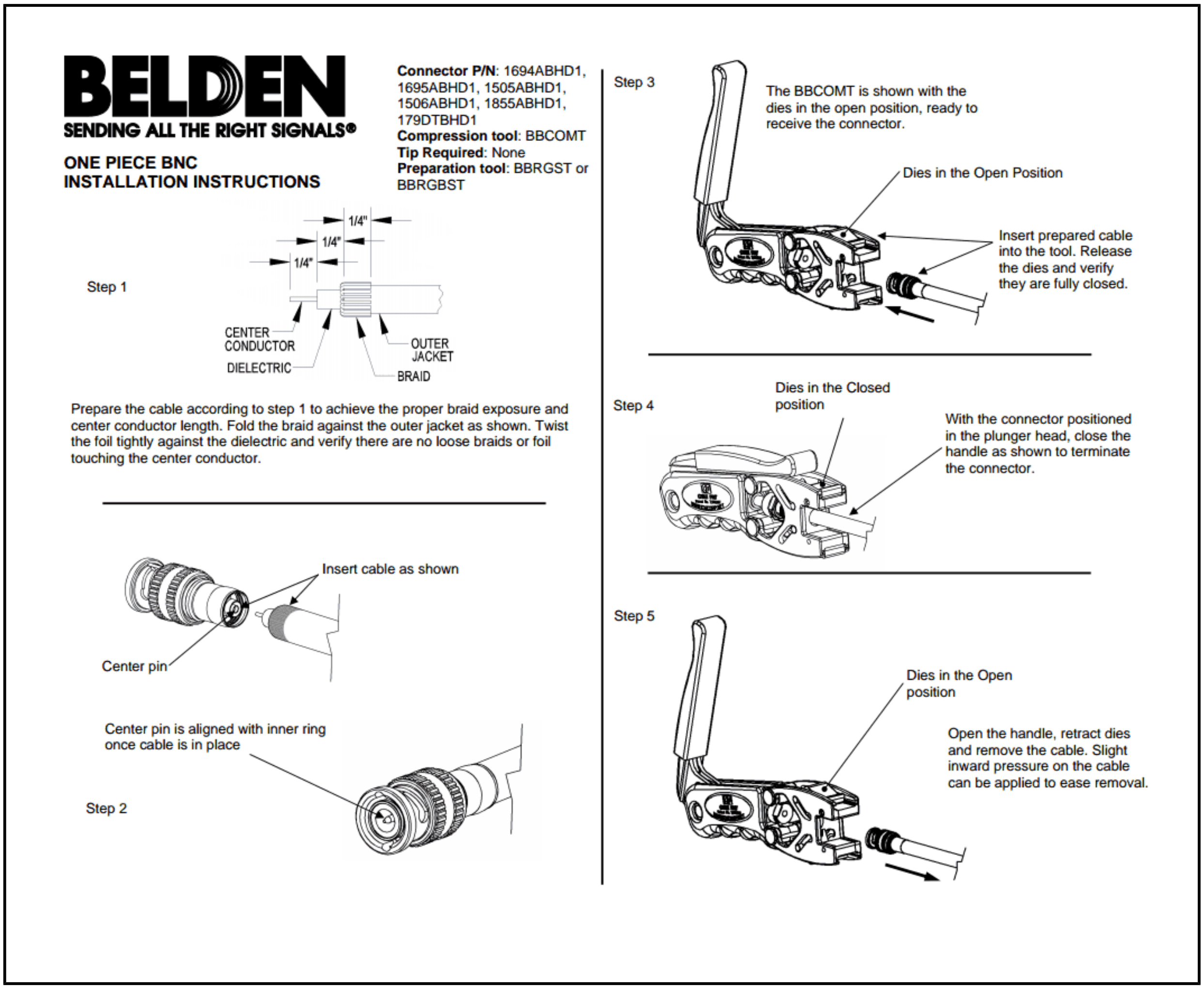
8.2 Examples

Manufacturers should provide instructions on how to terminate their connectors.

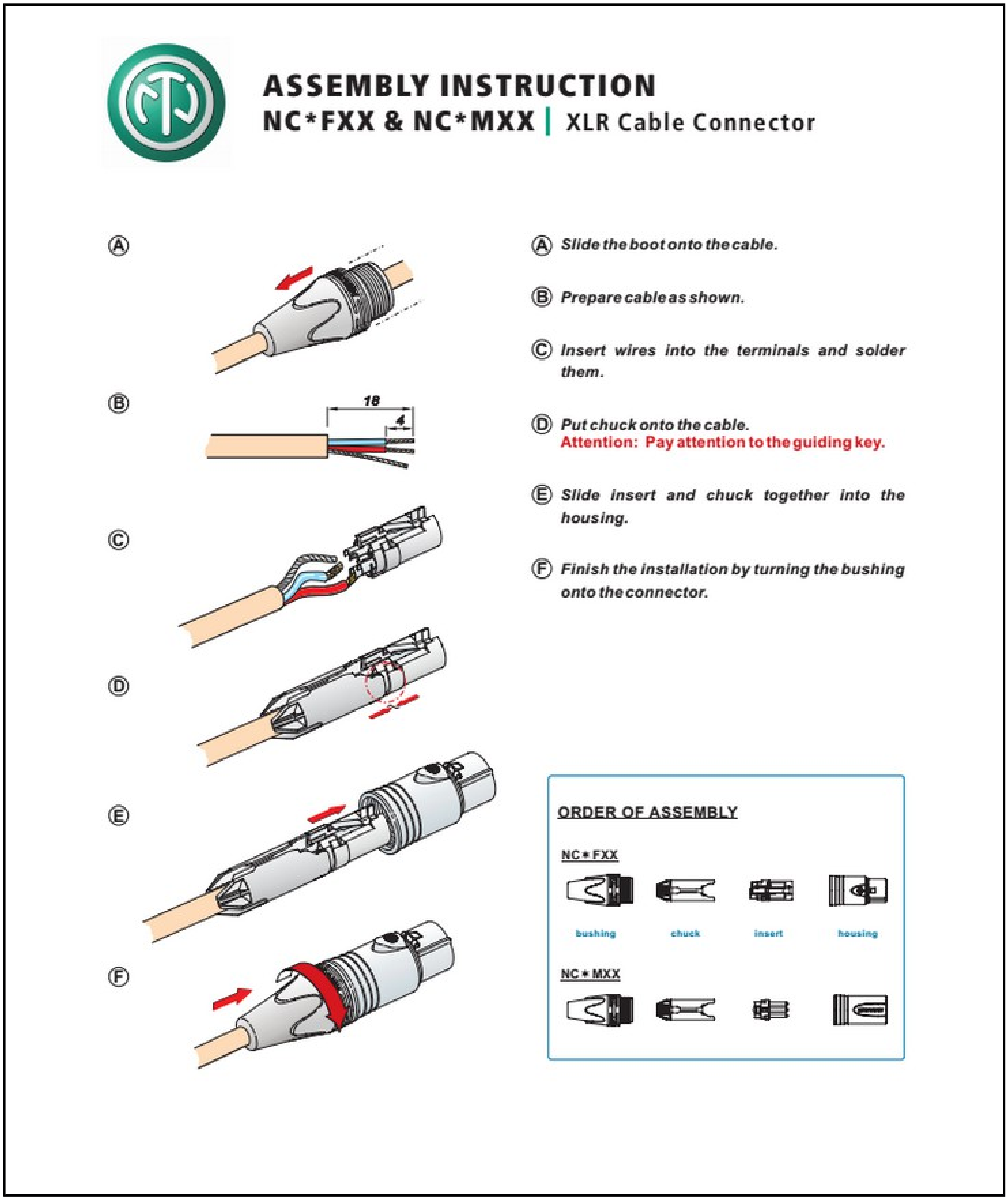
In some cases, such as the Belden example in Figure 8.1, all the required information is present.

Figure 8.1. Belden Cable Assembly Instructions



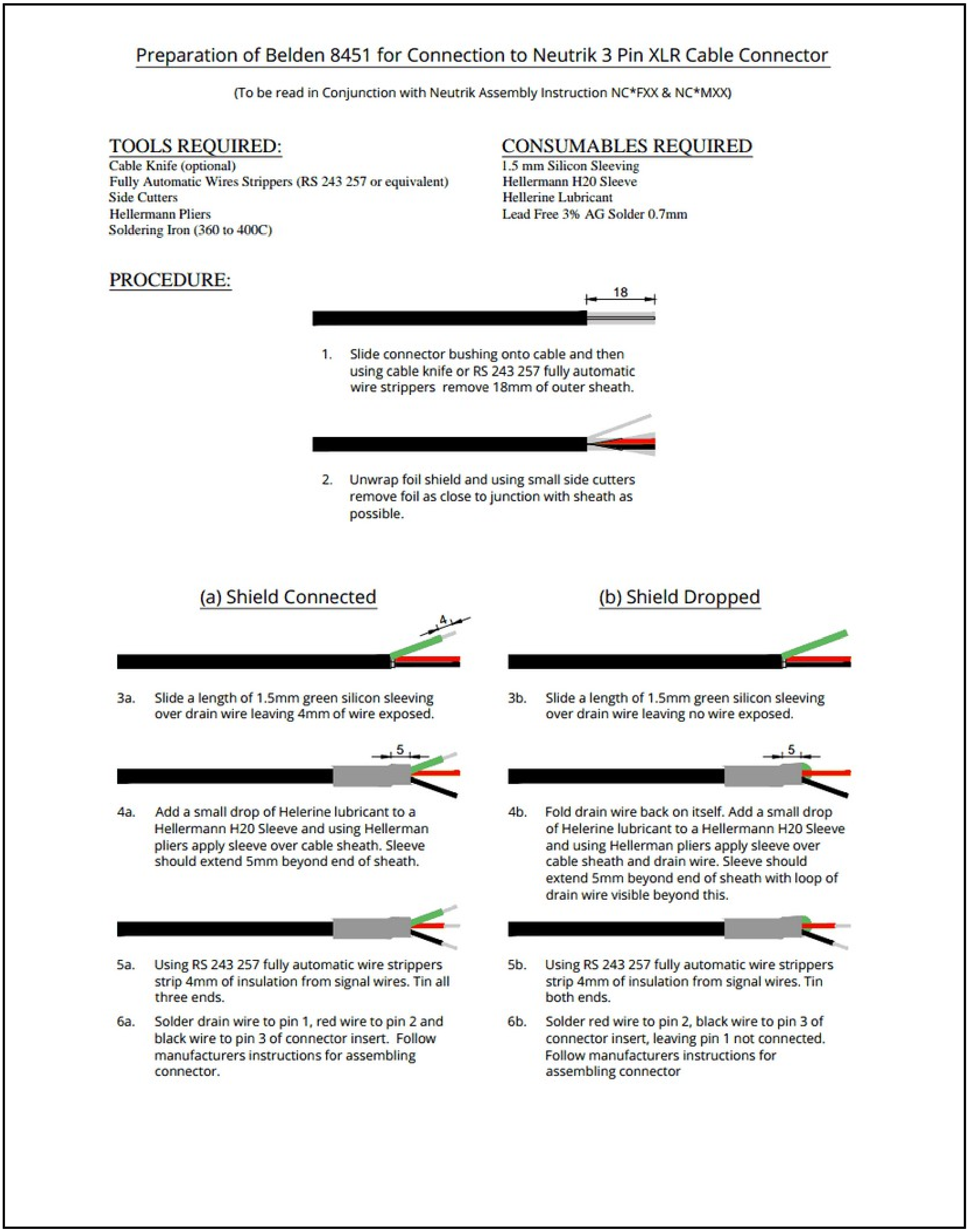
In the Neutrik example in Figure 8.2, there are details on how to assemble the connector, but no information on what tools to use, or which wire to solder to which terminal.

Figure 8.2. Neutrik Cable Assembly Instructions



In addition to the manufacturer's assembly instructions, cable preparation details are required, as shown in the audio cable example in Figure 8.3.

Figure 8.3. Cable Preparation Details



Preparation of Belden 8451 for Connection to Neutrik 3 Pin XLR Cable Connector

(To be read in Conjunction with Neutrik Assembly Instruction NC*FXX & NC*MXX)

TOOLS REQUIRED:
Cable Knife (optional)
Fully Automatic Wires Strippers (RS 243 257 or equivalent)
Side Cutters
Hellermann Pliers
Soldering Iron (360 to 400C)

CONSUMABLES REQUIRED
1.5 mm Silicon Sleeving
Hellermann H20 Sleeve
Hellerine Lubricant
Lead Free 3% AG Solder 0.7mm

PROCEDURE:

18

1. Slide connector bushing onto cable and then using cable knife or RS 243 257 fully automatic wire strippers remove 18mm of outer sheath.

2. Unwrap foil shield and using small side cutters remove foil as close to junction with sheath as possible.

(a) Shield Connected

4

3a. Slide a length of 1.5mm green silicon sleeving over drain wire leaving 4mm of wire exposed.

5

4a. Add a small drop of Helerine lubricant to a Hellermann H20 Sleeve and using Hellerman pliers apply sleeve over cable sheath. Sleeve should extend 5mm beyond end of sheath.

5a. Using RS 243 257 fully automatic wire strippers strip 4mm of insulation from signal wires. Tin all three ends.

6a. Solder drain wire to pin 1, red wire to pin 2 and black wire to pin 3 of connector insert. Follow manufacturers instructions for assembling connector.

(b) Shield Dropped

3b. Slide a length of 1.5mm green silicon sleeving over drain wire leaving no wire exposed.

5

4b. Fold drain wire back on itself. Add a small drop of Helerine lubricant to a Hellermann H20 Sleeve and using Hellerman pliers apply sleeve over cable sheath and drain wire. Sleeve should extend 5mm beyond end of sheath with loop of drain wire visible beyond this.

5b. Using RS 243 257 fully automatic wire strippers strip 4mm of insulation from signal wires. Tin both ends.

6b. Solder red wire to pin 2, black wire to pin 3 of connector insert, leaving pin 1 not connected. Follow manufacturers instructions for assembling connector

The drawings in the audio cable example are drawn 1:1 so that a PDF can be printed without scaling (i.e., fit to page). Having a PDF printout makes it a lot easier for technicians to see they are getting things right. It does not include a drawing of the pinouts to prevent confusion, as instructions are for both male and female connectors.

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9. Verification and Testing

Overview

It is important to verify the functionality and performance of installed systems against the specified design. Historically, a lot of AV designs have not had much in the way of functional or performance specifications, and when they have, they often lack any criteria that can be verified.

Consider the following three statements:

1. There must be electrical lighting in the room.
2. There must be sufficient light for reading.
3. The average illuminance at working level shall be 400 lux.

Now consider what you might get if those were the contractual terms:

1. Lighting is installed, but it could be either very dim or so bright that it is blinding.
2. Arguments about light levels are likely.
3. Light levels can be measured and verified.

AV Eng Technical Lead Tristan Gfrerer was on the task group that developed the "Audiovisual Systems Performance Verification" standard (ANSI/Infocomm 10:2013). Google intends to develop its project documentation in line with this standard.

This section details verification and testing required for all projects where ANSI/Infocomm 10:2013 has not been applied. Project documentation may require further verification and testing not detailed here.

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9.1 Verification Levels

This section details three levels of verification:

- Basic
  - Verification is compulsory.
  - Cost of verification shall be included in the installation price.
  - Contractors must have all necessary test equipment required for verification, and test equipment must be available whenever required.
- Advanced
  - Verification is compulsory.
  - Cost of verification shall be a separate line item.
  - Test equipment may be hired.
- Optional
  - Project documentation will state when verification is required.
  - Cost of verification shall be a separate line item.
  - Test equipment may be hired.

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9.2 Testing Methodology and Reporting

All verification items require some form of testing to ensure requirements have been met. This section details what needs verifying, not what form of testing is required. Contractors will be responsible for submitting testing methodology for approval. This should be a written statement detailing:

- Test equipment to be used
- Step-by-step testing process
- Details of how results will be recorded
- Details of the test report that will be generated and submitted

Test reports should include the following details:

- Serial numbers of test equipment used
- Calibration certificates for test equipment when appropriate
- Date tested
- Tester
- Pass/Fail

If a test is failed, then remedial action and retesting will be required.

Details of failed tests and remedial action to solve them should be included in the report, as well as details of retesting. This information may be of use for future service and maintenance.

9.2.1 Cable Testing

All terminated cables must be tested to ensure they are fit for the purpose. OEM cables from reputable manufacturers are exempt from contractor testing. This section lists verification requirements for cables commonly found in AV systems.

Balanced Audio Cable

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between any pins.
3. Verify that the shield wire is on the ground terminal.

Optional Test

Measure and record the frequency response of the cable. Verify this meets project requirements.

Unbalanced Audio Cable

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

Balanced/Unbalanced Audio Cable

Baluns are preferred to connect balanced and unbalanced equipment, but this is not always practical.

There are several different ways of wiring such cables, depending on equipment, connectors, and signal path (i.e., balanced-to-unbalanced or vice versa).

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

Analogue Video Cable

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

Optional Test

1. Measure and record the frequency response of the cable. Verify this meets project requirements.
2. Measure and record the return loss of the cable. Verify this meets project requirements.

Digital Video Cable

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

Advanced Test

1. Measure and record the frequency response of the cable.
2. Measure and record the return loss of the cable.
3. Verify all advanced tests meet project requirements.

Control Cables

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

CatX Cables

Basic Test

Verify full test results are in accordance with the latest version of ANSI/TIA-568.

Power Cables

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

Optional Test

PAT testing (or regional equivalent)

Other Cables

These tests apply to any cable not specifically mentioned in this section.

Basic Test

1. Verify correct pin-to-pin wiring.
2. Verify no shorts between pins.

9.2.2 System Testing

Cable and Signal Routing

Basic Test

Verify that all cables are routed as per the system drawings and that all signals reach the intended destination.

Loudspeaker Phase

Basic Test

In systems with more than one loudspeaker, verify that all loudspeakers are in phase.

70V/100V Loudspeaker Circuit Impedance

Basic Test

Measure impedance of all 70V/100V loudspeaker circuits before the connection to the amplifier. Verify that measured impedance is within 30% of the expected impedance.

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10. Product and Documentation Requirements

10.1 Product Qualification

The Google AV Eng team has a policy of qualifying equipment before authorising its use in AV systems wherever possible. For standard system designs, all equipment is qualified.

For some products, approved alternatives are allowed. When this is the case, the system documentation will specify the manufacturer and model of a piece of equipment and then state “or approved alternative”.

In general, alternative products are allowed for non-active system components, such as connectors and cables.

The Google AV Eng team maintains a list of approved alternative products, which is available to all approved suppliers.

Requests to approve alternative products will be considered by the Google AV Eng’s Design team. It is the requester’s responsibility to prove the product meets or exceeds the specifications of the original product.

Only approved products may be used.

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10.2 Cable Assembly Instructions

Approved cable assembly instructions must be in place for all cable assemblies and terminations before work may start on a Google AV system.

Google AV Eng will maintain a copy of all approved documents, which will be valid until further notice for all Google AV projects.

The contractor must reference the approved termination details for all cables in project-specific documentation.

Cable assembly instructions shall be submitted to the Google AV Eng’s Design team for approval. Submissions must have a unique document name and revision number. It is the contractor’s responsibility to maintain proper document control of all submissions.

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10.3 Testing Procedures

Approved testing procedures must be in place for all contractually required testing and verification before work may start on a Google AV system.

Google AV Eng will maintain a copy of all approved procedures, which will be valid until further notice for all future Google AV projects.

Testing procedures shall be submitted to the Google AV Eng's Design team for approval. Procedures must include details of how test results will be reported. Submissions must have a unique document name and revision number. It is the contractor's responsibility to maintain proper document control of all submissions.

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10.4 Standard System Designs

Google AV Eng maintains standard designs for different types of systems. There is a very limited amount of flexibility within these designs. The options available are detailed within the design to primarily cater to different room sizes.

It will be the responsibility of the Google Deployment Program Manager (DPM) to provide the standard designs to the contractor and advise the contractor on which options are required for every system.

It will be the contractor's responsibility to provide design documentation for every system, using the standard designs with the required options. This documentation will be submitted to the DPM for approval.

Absolutely no customisation of standard designs is allowed.

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10.5 Custom System Designs

Google AV Eng's Design team is responsible for any custom AV designs required within Google facilities, such as event spaces. Custom systems tend to require additional staff and resources to use and maintain, and no detailed design work will be undertaken until a budget is approved for the system and required staffing levels are met.

Google AV Eng's Design team will undertake a 2-stage needs analysis, including budget estimates to determine the scope of custom designs and staffing levels required for support. The first stage will be a staffing level and lump sum cost estimate, based on similar existing installations. If the estimates align with the business case, then a full needs analysis will be done, which will include a non-technical narrative of what will be provided and more detailed cost estimates.

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References

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Glossary

Term	Description
8P8C	8-position, 8-contact modular connector specified by ISO/IEC 8877:1992. Often incorrectly referred to as RJ45.
A-gauge	6.35 mm (1/4") TRS jack commonly used on audio equipment. Not compatible with B-gauge.
Alien crosstalk	A specific form of crosstalk where EMI is caused by other cables routed to the cable of interest.
ANSI	American National Standards Institute
AWG	American Wire Gauge
B-gauge	6.35 mm (1/4") TRS jack originally used on telephone systems. Commonly used in professional audio patchbays. Has a different tip shape and insulation spacing compared to A-gauge.
Balanced audio	3-conductor audio connection where the signal is carried on two wires in antiphase. Allows audio signals to reject noise and travel over longer distances.
Balun	A device that converts between a balanced and unbalanced signal. The name comes from "bal" in "balanced" and "un" from "unbalanced".
Bantam	A TRS jack used in high density audio patchbays. Essentially, a miniature version of B-gauge.
Barrier strip	Multiple screw terminals used for connecting different components.
Bell wire	An insulated wire that is usually solid rather than stranded. Commonly used to refer to a cable made of two such wires bonded together.
BNC	Bayonet type connector used on coaxial cables.
Bus bar	Electrical conductor used to make a common connection between several circuits in a system.
Cable	An assembly of more than one conductor or wire.
Cable jacket	See "Cable sheath".
Cable sheath	The outer, non-conductive layer of a cable holding wires together and protecting them.
Characteristic impedance	The impedance a transmission line would have if it were infinitely long.
Chock block	Common name for terminal block.
Coaxial cable	A cable where all conductors share the same axis.
Conductor	A material that permits the flow of electrical charges.
Crosstalk	A form of EMI where a signal on one circuit or wire affects the signal on an adjacent one.
CSA	Cross Sectional Area
D subminiature connector	Connector with two or more parallel rows of pins or sockets surrounded by a D-shaped metal shield.
D type connector	Common name for D subminiature connector
Dielectric	An electrical insulator that can be polarized by an applied electric field.

DIN	Deutsches Institut für Normung (German Institute for Standardisation)
DIN connector	In AV, refers to DIN 41524 standard. Circular polarised connector with 3-8 pins.
DisplayPort	Digital display interface developed by VESA.
DVI	Digital Video Interface
EDAC	A connector manufacturer, but commonly used to refer to EDAC 516 series multiway connectors.
ELV	See "Extra low voltage".
EMI	Electromagnetic Interference
Extra low voltage	Defined by IEC 60038 as below 50V RMS AC or 120V DC.
Faraday cage	An enclosure formed by a conducting material that blocks electromagnetic fields.
Figure eight cable	Cable consisting of two bonded wires with a cross section that resembles a "figure eight".
FTP	Foil-screened Twisted Pair
HDMI	High Definition Multimedia Interface
High voltage	Defined by IEC 60038 as above 1000V RMS AC or 1500V DC.
HV	Stands for High Voltage. See "High voltage".
IDC	Insulation Displacement Connection/Connector
IEC	International Electrotechnical Commission. The IEC develops international standards for all electrical, electronic, and related technology.
IEC 60038	Standard for voltage values. Intended to serve as preferential values for the nominal voltage of electrical supply systems, and as reference values for equipment and system design.
IEC 60228	Standard for nominal cross sectional areas. Range is from 0,5 square mm to 2 500 square mm for conductors in electric power cables and cords of a wide range of types.
Insulator	In electrical terms, a material that does not conduct current.
ISO/IEC 8877:1992	Standard specifying the 8-pole connector and wiring assignments for use in physical interfaces.
Low voltage	Defined by IEC 60038 as between 50-1000V RMS AC or between 120-500V DC.
LS0H	Alternative nomenclature for LSZH.
LSF	Low Smoke and Fume (to describe cable sheath material)
LSZH	Low Smoke Zero Halogen (to describe cable sheath material)
LV	See "Low voltage".
Mini XLR	Connector similar in design to XLR but with smaller form factor.
Mini-DIN connector	Circular polarised connector with 3-9 pins. Similar in design to older and larger DIN connector.
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
PDU	Power Distribution Unit
Phantom power	Method of transmitting DC power through audio cables for microphones that have active electronics.

Pinout	Cross reference showing either function of terminals on a device and/or connections made to each terminal. Can be plain text, table, or drawing.
Pitch	The twist rate in a twisted pair or star quad cable. Usually expressed as twists/m.
Plenum Rated Cable	Cable with a fire retardant sheath, as regulated by the US National Fire Protection Association (NFPA) 90A Standard.
PS/2	6-pin mini DIN connector used for connecting keyboards and mouse devices to some computers.
PSU	Power Supply Unit
PTZ	Pan, Tilt, Zoom: Remote controls available on some cameras.
RCA	Coaxial connector commonly used for audio and video connections.
Ribbon cable	Cable with multiple wires bonded on same plane.
RJ45	Modular connector and wiring standard developed by Bell System. Often incorrectly used to describe the Ethernet connector.
S-Video	Standard Definition video signal that has separate channels for chroma and luma signals. Standard connector is a 4-pin mini DIN.
Screw terminal	Electrical terminal where wire is held by tightening of a screw.
SDI	Serial Digital Interface
Sheath	See "Cable sheath".
Shield	A common conductive layer surrounding insulated conductors.
Speakon	Locking circular connector used on amplifiers and loudspeakers. Speakon is a registered Neutrik trademark. There are compatible products from other manufacturers.
Star quad	Cable with four wires twisted together: two forming forward path and two the return path.
STP	Shielded Twisted Pair
Stranded Wire	Wire made up of multiple strands, allowing more flexibility than a solid wire.
SWG	Standard Wire Gauge
Terminal block	A screw terminal contained within an insulting block, often in multiple arrangements.
Tiny-QG	Trademarked name for Mini XLR.
Tongue	The end of a terminal that attaches to other components.
TRS	Tip, Ring, Sleeve: A cylindrical 3-conductor connector.
TS	Tip, Sleeve: A cylindrical 2-conductor connector.
Twisted pair	Type of wiring where two conductors are twisted around each other.
Unbalanced audio	2-conductor audio connection.
USB	Universal Serial Bus
UTP	Unshielded Twisted Pair
VESA	Video Electronics Standards Association
Visca	PTZ camera control protocol designed by Sony and based on RS232.
Wire	A single conductor.
XLR	Circular, polarised latching connector with 3-7 pins. 3-pin version is commonly used for balanced audio signals.

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