SECURITY INDUSTRY ASSOCIATION

VIDEO SECURITY SYSTEMS TECHNICIAN

Level I Study Guide

We support and encourage NICET certification.

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Study Guide for

NICET Video Security Systems Technician

Level I Certification

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Video Security Systems Technician VSST I

INTRODUCTION

You might be relatively new to our important and increasingly high profile industry or you may already have years of experience and field knowledge. By participating in the NICET Video Security Systems program, you will be able to earn certifications that reflect your experience, knowledge and skills.

NICET does not offer training. They offer certifications based upon successfully passing computer- based examinations and providing evidence of appropriate work experience for each level. The objective is to encourage candidates to constantly improve their job performance by obtaining additional knowledge, skills and abilities (KSA's). The practice analysis for the Video Security Systems Technician outlining the specific KSA's for Level I are at the end of this document.

BACKGROUND

The security industry has long sought to elevate the technical and professional competency of its technicians (service, install, etc.) and designers (sales, project managers, etc.). For manufacturers, higher levels of technical proficiency in the field mean lower tech support costs and product return rates. For installing dealers, it means lower installation and customer support costs. For end-users, it means better system performance. All of this results in a stronger, more vibrant CCTV industry.

Although training is available from many sources including manufacturers, trade organizations and professional training companies, most people do not participate unless they need to satisfy a specific training requirement or have another compelling reason.

The Security Industry Association (SIA) is an international nonprofit trade association representing electronic and physical security product manufacturers, specifiers and service providers. In 1999, a sub-committee of the SIA's CCTV Interest Group initiated a certification program to create a compelling reason to participate in training and personal professional advancement. SIA chose the National Institute for Certification in Engineering Technologies (NICET) to administer this program. NICET is a non-profit organization dedicated solely to certification. They currently administer over thirty widely respected technical certification programs.

With the help of SIA and and National Systems Contractors Association, NICET formed an advisory board of subject matter experts (SMEs) comprised primarily of installing dealers from large and small companies. The advisory board developed the practice analysis that was the basis for exam questions written by a larger group of SMEs. Another group of SMEs analyzed each of the questions for suitability and fairness.

ACKNOWLEDGMENT

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STRUCTURE & OVERVIEW

The phrase "Closed Circuit Television" (CCTV) has served the security industry well for many years. However, with the rapid changes in technologies, including megapixel cameras, network transmission and video analytics, the SIA sub-committee felt that a more inclusive title should be used for this program, hence, the name **Video Security Systems (VSS)** . For the purpose of this course, **VSS** and **CCTV** are interchangeable.

Video Security Systems certification is provided in two tracks: one for **Technicians** and one for **Designers**. The tracks have been carefully constructed over several years, with the help of three industry associations, five major manufacturers, dozens of expert volunteers, and hundreds of survey respondents and beta testers. Some of the more obvious benefits of this program are:

* Technicians and Designers can distinguish themselves and their qualifications.
* Employers can hire and promote with greater confidence, and market the quality of their people.
* End-users can have the assurance that those who design, install, and service their systems have met a nationally-based set of qualifications.

VSST - VIDEO SECURITY SYSTEMS TECHNICIAN

This program track includes a sequence of four levels of certification, based on the complexity of the systems being installed/serviced. NICET bases the content of the levels largely on a system classification scheme involving three system types; A, B, and C. Certification at a particular level is achieved by demonstrating knowledge of and experience in the work associated with certain types of systems.

The system classifications follow on the next page.

Level I ***In training; assists on VSS Projects***

Level II ***Installs Type A Systems***

Level III ***Installs Types A and B System***

Level IV ***Installs Types A, B and C Systems***

VSSD - VIDEO SECURITY SYSTEM DESIGNER

This program track includes a sequence of two levels of certification related to the complexity of the systems being installed/serviced.

The system classifications follow on the next page.

Level I ***Designs Types A and B Systems***

Level II ***Designs Types A, B and C Systems***

NICET VIDEO SECURITY SYSTEMS CLASSIFICATIONS

The following are some of the types of equipment and system characteristics that delineate Type **A**, Type **B** and Type **C** systems, as referred to in this content outline.

Type A Systems

These are basic systems with standard components, low bandwidth transmission, and menu-driven set-up, such as:

* Multiplexer/VCR
* Quad/VCR
* Digital Video Recorders (DVRs)
* Sequential switcher
* Single Keyboard
* Indoor/Outdoor
* Standard Cable runs not requiring repeaters of amplifiers
.. (less than 800 ft for coaxial; less than 1500ft for twisted pair)

Type B Systems

These systems can include specialized components, programmable controls, and high-bandwidth transmission, such as:

* PTZ
* Multiple keyboards
* Matrix interfaced with alarms, A/C, or intercom (GPI or dry contact)
* Digital video recorders with programmable, alarm-based resolution and frame rate
* Fiber transmission systems
* Low light
* Long cable runs
* Covert or portable systems
* RF modulators

Type C Systems

These systems can include PCs, serial communication, and wireless transmission, such as:

* Integrated systems / serial communications / GUI's
* LANs / WANs
* Remote Systems
* Microwave and IR transmission
* Digital video recorders with remote interface

VSST LEVEL I CERTIFICATION

Now that we have presented the background and overview of the NICET VSS program we can focus on the Level I Certification process. Application forms and current information are available at *www.nicet.org.*

In order to earn the VSST-I Certification you will need to:

1. *Pass the Level I exam*
2. *Have at least three months VSST experience, including significant hours in VSST primary activities.*
3. *Provide verification of all Level I performance measures.*

A general description or profile of a Level I Technician includes the following characteristics:

- **Education:** Formal education not required but educational experiences at least equivalent to a high school diploma are expected.
- **Work Experience:** A minimum of three (3) months of video systems installation and maintenance activities in an employment setting.
- **Responsibility:** Work under direct supervision. Scope of work is restricted to assisting a more experienced technician.
- **Acquired Competencies:** Assist in simple installation tasks such as camera mounts and cable runs. Read plans. Use simple hand and power tools and basic electronic test equipment.

The KSA's (knowledge, skills and abilities) for Level I are grouped into larger areas of responsibilities, or "domains":

- System Installation
- System Testing and Commissioning
- Troubleshooting
- Documentation

The exam will be administered on a computer.

Computer-based testing (CBT) will allow NICET to extend several benefits to their customers: more flexible exam dates and appointment times, immediate scheduling and confirmation, and quicker exam scoring. NICET has teamed with Prometric to offer proctored computer-based tests at over 200 Prometric sites. Note: these tests will not be given at NICET test centers.

The exam will be closed-book.

You will not be permitted to use standards or other references during the test. You are expected to be familiar with the references included in the content outline. The "Selected General References" are a few (not the only) resources that could help you prepare for the exam and/or expand your industry knowledge.

GOOD LUCK!

Standards & Professionalism

Closed Circuit Television (CCTV) systems are designed and installed in accordance with various electrical and CCTV (television) standards. As the name implies, standards are the reference points against which other things can be evaluated—whether technical, operational, professional or industry best practices.

Standards are a very important part of our daily lives. Their purpose is to make our life safer, easier and to ensure that equipment of various origin are compatible with each other.

There are two main **electrical** aspects of CCTV system installation:

- The powering of components, which requires understanding of safe voltages and safe work site practices and

- Understanding of the video signal's specifics produced by the video signal generating equipment (cameras, signal generators, digital recorders, encoders and decoders) and how they can be affected and/or protected against unwanted signals and noise.

Electricity has to be handled with utmost care, not only from the perspective of electrical safe work site practices, but also from the perspective of ensuring "healthy power" to the system components, as well as highest quality video signals.

This requires understanding the basic principles of electrical engineering, television standards and installation techniques and practices.

This guide will cover electricity and other standards that affect the quality of CCTV installations.

It is up to you, the reader, to enhance and expand on the knowledge summarized here with real practical experience.

As a future representative of the security industry specializing in CCTV, you will have an obligation to the Industry to represent it in its best light as a responsible professional.

1. The Basic Principles of CCTV

The intention of this Study Guide is to teach relatively inexperienced installers how to install CCTV cameras, cable them for power and video, install a rack with CCTV equipment and troubleshoot problems. To do this, basic descriptions about the principles of CCTV are necessary. The following headings will summarize the most important concepts.

Why use Closed Circuit Television?

CCTV has many purposes, but the most common and obvious one is improving the ***security*** of objects, establishments, schools, hospitals, city malls, shopping centers and the public in general. By use of a properly installed CCTV system, we improve the security of objects and the safety of people. Having an overt system in place can be a good deterrent to would-be intruders, criminals and terrorist.

CCTV is used to ***observe*** and react according to certain changes. A typical CCTV application is traffic monitoring whereby the visual information is used to deploy certain actions and improve the traffic and safety of passengers. Observation CCTV can be used in hospitals to monitor patients as part of a hospital procedure or teaching purposes. CCTV can be used to manage personnel and resources in retail, manufacturing, distribution and other venues. High end CCTV is also used in astronomy, military reconnaissance and specialized observation units to monitor wildlife, dams, volcanoes, etc.

Since no one can watch multiple cameras simultaneously, the typical modern CCTV system consists of, in addition to cameras and monitors, ***recording*** devices (VCRs or DVRs) that can be used to play-back camera footage, analyze the recorded history and find the potential event of interest. Modern analytical software is available to alert us and highlight potentially important video information.

CCTV is very effective in ***behavior modification*** of people. Intruders and would-be-thieves think twice before committing a crime if they know there is CCTV in place. No one can say that crime is reduced completely, but statistics have shown that it certainly reduces it.

In a way, CCTV is also used in ***communication*** between distant and remote places. This includes video conferences, internet live chats, etc.

Last, but not least, CCTV is also a good ***medium for entertainment*** such as projecting larger images of the entertainers or speakers.

As can be concluded from the above, Closed Circuit Television has a wide application in many areas.

How does it work?

The easiest way to understand how CCTV works is by reviewing the logical flow of information.

- Light rays strike the objects in the scene.
- Some of the light rays bounce off of the object and strike the front of the lens.
- The lens refracts the light rays and projects them as a focused image onto the pickup device in the camera.
- The circuitry in the camera converts the image into an electrical video signal.
- The signal is transmitted to a monitor, recorder or other devices to be stored, processed and/or converted to an image that can be viewed.

Before we can starting assembling CCTV systems we must understand basic concepts and terminology. Since they are at the beginning of the process, it is logical that we start with Lenses before proceeding to Cameras.

Lenses

The first element in a CCTV system is the camera, and the first element of the camera that actually "sees" the surveyed area is the lens. The primary purpose of the lens is to gather light and project a focused image on the imaging chip, which is usually a CCD (Charge Coupled Device) chip, or a CMOS (Complementary Metal Oxide Semiconductor) chip.

Fig.1 Variety of CCTV lenses

The lens has an iris, which, like the human iris, opens and closes (manually or automatically) in to let more or less light fall onto the imaging chip.

The human iris opening and closing is controlled automatically and subconsciously by the brain. When it is sunny and bright, the human iris closes, and, when it is dark, it opens.

A very similar thing happens with the CCTV lens that has automatic iris control. The camera or lens electronics plays the role of the human brain, i.e., it closes the iris when the object the camera sees is very bright, and opens when it is dark. The image that the lens "sees" is projected onto the imaging device upside down, as he human eye does. We never notice the image is upside down because our brain "fixes" this. The same happens with the camera electronics, when a monitor reproduces the image; it is in the same orientation as we see it

Focal Plane

Behind every lens is a line where the light rays meet to form the most perfectly focused image. This line is called the **focal plane**. When we turn the "focus" ring on a lens, we are actually turning a very fine screw thread that moves the lens in or out. When we adjust the course "back focus" on the camera, we are moving the imaging chip in or out in relationship to the lens mount. Focusing is the act of aligning the focal plane of the lens with the face of the imaging chip by moving the lens and/or the imaging chip.

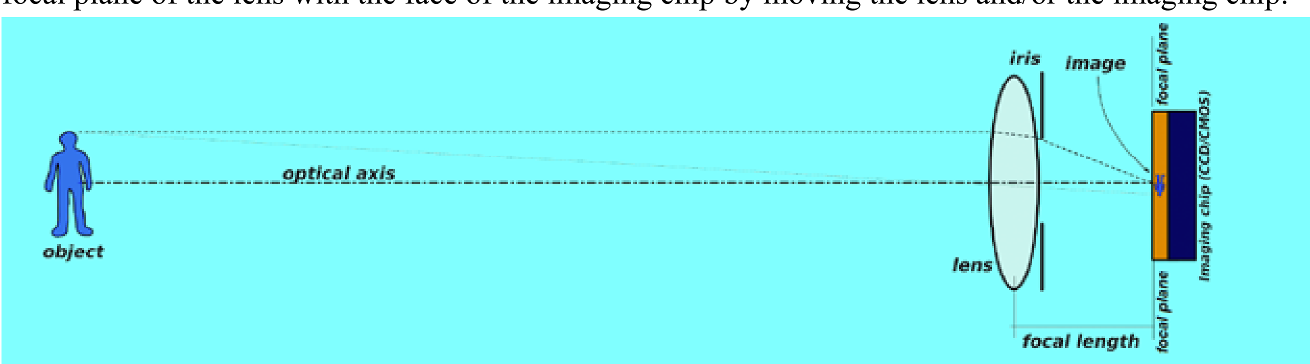


Fig.2 The focal plane is the line behind the lens where the light rays converge to form a focused image

We will explain the proper way to focus lenses later in this section, after we discuss "depth of field."

Format

Format refers to the diagonal dimension of the imager in the camera. Years ago we used 1" diagonal vacuum tubes. Technology has allowed for progressively smaller pickup devices with constantly improving optical characteristics. Our industry has witnessed the evolution from 1" and 2/3" tubes to 2/3", 1/2", 1/3" and 1/4" chip. Although most of today's box cameras use 1/3" chips it is not uncommon to find 1/2" and 1/4."

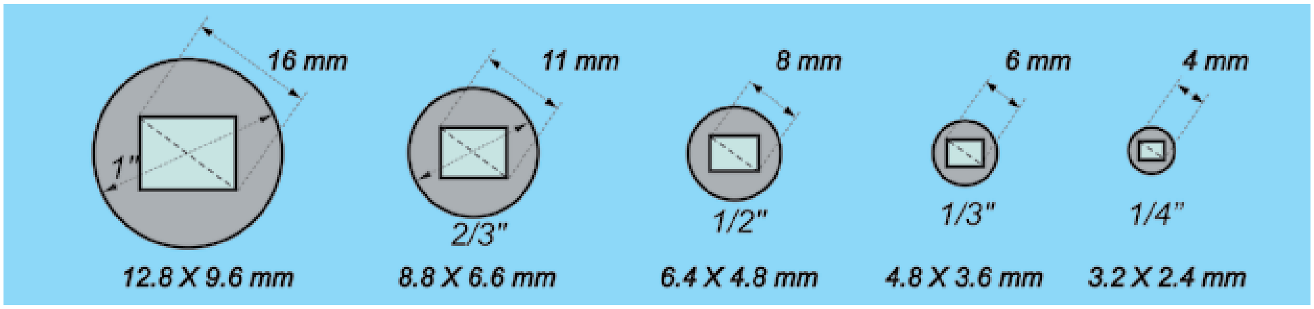


Fig.3 Format refers to the diagonal size of the camera imager (from 1" down to 1/4")

Focal length

The width of the image is determined by the ***focal length*** of the lens, expressed in millimeters (mm).

The focal length is the effective distance from the lens to the focal plane. Despite the word "length" in its name, focal length determines the **width** or **field of view** of the lens.

The shorter the focal length, the wider the angle of view.

Typically, the widest horizontal angle of view we have in CCTV is around 90˚ and the narrowest could be as narrow as 1˚. As the focal length of lenses approach 90˚, they start to distort the image and create a "fish-eye" effect. There are a few manufacturers that make CCTV lenses as wide as 180˚ but these drastically distort the image and require the use of special software to make the images usable.

Lenses can be (1) fixed focal length, (2) vari-focal or (3) zoom.

(1) Fixed focal length lenses are typically 2.6mm, 4mm, 6mm, 8mm, 12mm, 16mm or 25mm.

(2) Vari-focal lenses allow us to change the focal length within a range such as 3.5mm~8mm, 6mm~12mm, or 5-50mm. Vari-focal lenses need to be re-focused after each focal length change, but this is not a major issue since once the width of the scene is set, it is not often changed.

The advantage of vari-focal lenses is that one lens can provide a wide range of angles by merely adjusting two rings on the lens; one for focal length, the other for focus. The disadvantage is that vari-focal lenses may not be optically as good as fixed focal lenses due to their optically compromising design. They provide great value, however, by offering an infinite range of focal lengths within a single lens. By varying the settings on the lens, the desired coverage is usually decided on the spot. Once the correct focus and angle is achieved, vari-focal lenses need to be carefully locked in place so that they do not loose focus or change the angle of view.

(3) Zoom lenses are different than the vari-focal as they have additional optical elements and gearing inside to keep the lens in focus as the focal length changes. When a zoom lens is properly installed; once focused on an object, the object will stay in focus throughout the full zoom range. Zoom lenses can be manual or motorized. Because of their construction they are very expensive compared to fixed or vari-focal lenses.

Various chip sizes "see" various angles of view with the same lens.

Since the angle of view produced by a lens depends on both the focal length and the size of the imaging chip in the camera, it is important to understand the relationship between the two.

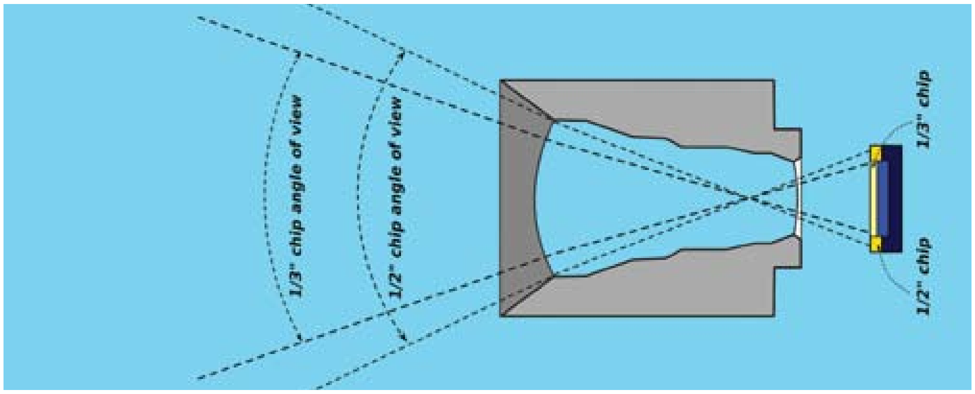


Fig.4 The same focal length gives different angles of view for different size chips

In theory, a "standard" lens, represents what the human eye sees without taking into account peripheral vision. For those who are familiar with 35mm photography this is a 50mm lens and has a angle of view of about 30˚ degrees.

For a 1" imager, the standard lens is 25mm also with an angle of view of about 30 degrees. A "wide angle" lens is 12mm and is twice as wide at 60 degrees.

There is simple mathematical relationship between imager size and focal length. Refer to Table 1.

Looking at the "standard view" column, the focal length of 12mm for a 1/2" lens is approximately half of 25mm for a 1" format. 8mm for a 1/3" format is approximately one-third of 25mm.

This means that if we took five cameras with all five of the image sizes listed in first column of the chart and fitted them with the appropriate "standard" mm lens, placed them side-by-side and aimed them at the same target, we would get roughly the same picture from all five.

TABLE 1 (Standard and wide view)		
Imager size	Standard view	Wide view
1"	25mm	12mm
2/3"	16mm	8mm
1/2"	12mm	6mm
1/3"	8mm	4mm
1/4"	6mm	3mm

There are various tools for determining the correct angle of view, including tables, sliding or rotating rules, formulas, optical viewfinders, experience and a simple "rule of thumb."

The "rule of thumb" is very useful in determining the correct focal length. (see Fig 6)

For a "wide-angle" lens, for every foot away from the camera, the view will be approximately one foot wider. At 50 feet away, we see roughly 50 feet left-to-right. At 100 feet away, 100 feet left-to-right. This is known as the "T" effect.

A "standard" lens is half the left-to-right distance. At 100 feet, the width is approximately 50 feet. (

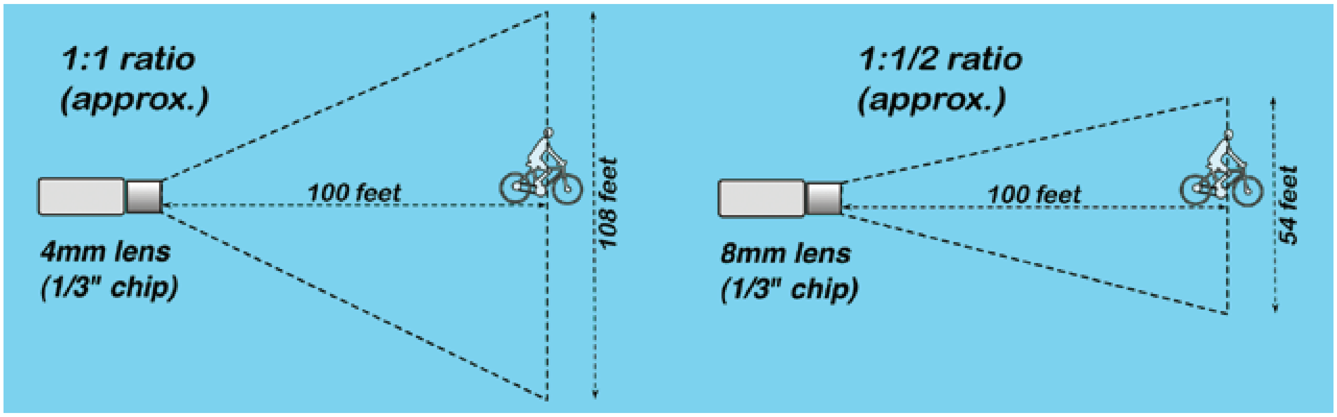


Fig.5 A simple rule of thumb for focal length

Using this rule of thumb, using a 1/3" camera, the distance from the camera to the target will equal the width of the view at the target, an 8mm will be half that width. A 16mm will be 1/4 the width of the distance from camera to the target.

To simplify this further, using a 1/3" chip (since most of today's box cameras are 1/3") a wide angle lens is 4mm and a standard is 8mm. That is why some of the most popular vari-focal lenses are 3.5-8mm. One lens can cover the entire range of the most commonly used focal lengths.

f-stop (iris opening)

The iris is the mechanical device that controls the size of the opening known as the aperture. The iris functions the same as the human eye iris; closing to let less light in and opening to let more light in onto the imaging chip. The size of the opening is referred to as the "f-stop" or "speed." **The larger the value, the smaller the opening.**

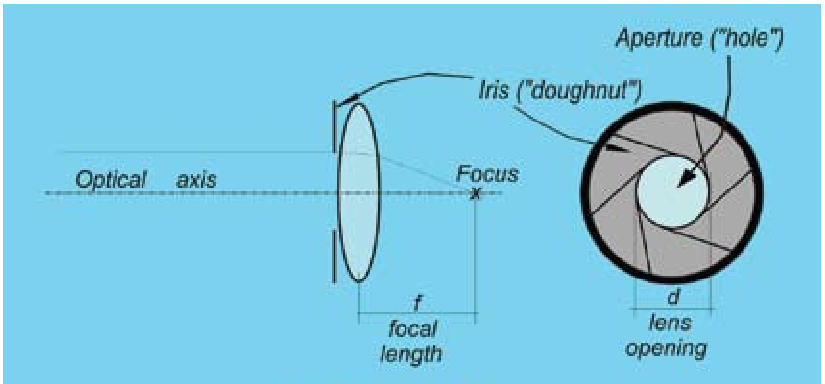


Fig.6 F-stop

Fig.7 Changing from one f-stop to the next either doubles or halves the amount of light.

When f-stops are printed on the lens (normal for 35mm photography, rare for CCTV), there are specific numbers normally starting with f1.4 and ending with f22 (see Fig 8). These are not random numbers. Moving from one f-stop to the adjoining one will either double or half the amount of light striking the imaging chip.

Typically, lenses are specified with the lowest F-stop they can achieve, which represents the maximum iris opening, i.e., the maximum light gathering ability.

The F-stop of a lens is usually indicated on the lens itself, which is also the case with the focal length. For example, a typical lens could be written as "6mm/1.4," which would mean the focal length is 6mm and maximum iris opening F-1.4.

IRISES

There are four types of iris.

(1) **Fixed-Iris**, with no adjustments.

These are typically found on very inexpensive lenses or on "board," "bullet," and other small cameras where there is no provision for adjusting the size of the iris opening.

(2) **Manual-Iris** (M/I, m/i or mi)

The aperture can be opened or closed by turning a ring on the lens. Manual-iris lenses are typically used for indoor applications that are not exposed to direct sunlight. They are used in conjunction with the "electronic shutter" in the camera or with "wide-dynamic-range" cameras that control the light levels electronically. (discussed later)

Fig.8 A typical CCTV camera with a manual-iris, vari-focal lens

(3) **Motorized-Iris**

A small motor in the lens opens or closes the iris. This is typically found in motorized zoom lenses where the operator needs to precisely control the amount of light entering the camera.

(4) **Auto-Iris** (A/I, a/i or ai)

The aperture is opened or closed by small motors in the lens. The camera requests more or less light via a small cable on the lens that connects to a socket on the camera. Auto-iris lenses are normally used for outdoor cameras where there is a wide fluctuation in light levels from night-time to full daylight

There are two different type of auto-iris lens; the older Video Drive and newer DC Drive. In recent years, the industry has standardized by using a small square 4-pin connector for both types.

Video Drive Lens uses electronic circuits within the lens to determine whether to open or close the iris based on the signal level it receives from the camera. The Video Drive lens can be recognized by the presence of two potentiometers marked “ALC” and “Level.” These are used to adjust the base light level “L” to “H” or to give more value to the bright portion or to the average value of the picture by adjusting “PK” and “AV.” (peak or average)

Fig.9 Video Drive A/I lens (with potentiometers)

DC Drive Lens (also known as DD for Direct Drive) uses electronics in the camera rather than in the lens to “decide” whether the iris needs to open or close. This allows the lens to be smaller and cheaper than the video drive lens. It also means that the base iris level is set by an adjustment on the camera since the lens does not have any potentiometers.

Fig.10 DC driven AI lens (no potentiometers)

Although the connector is the same, the wiring and purpose of the pins vary greatly between the Video and DC Drive lens. When mating the lens to the camera it is very important to know which type is being used and set the camera accordingly.

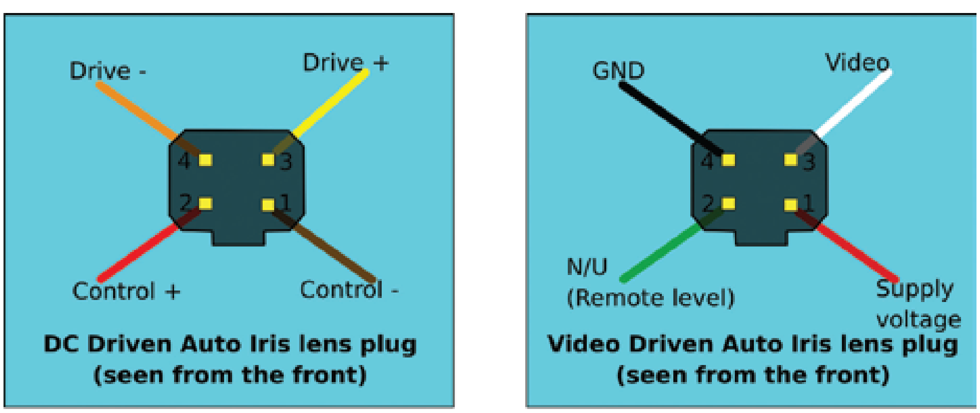


Fig.11 DC and Video driven auto iris typical pin diagram

Depth of field

Depth of field is the distance between the nearest and farthest points away from the lens that appears to be in good focus. *The depth of field is an optical effect directly dependant on the iris opening, i.e., the f-stop of the lens.* (see Fig 12)

Portrait photographers will focus on the subject while intentionally blurring the foreground and background in order to draw our attention to the primary point of interest. They do this by opening the iris to shorten the depth of field. A properly installed video security system will strive to obtain the deepest depth of field by closing the iris.

Two factors effect depth of field: the focal length and the iris opening.

Depth of field is increased by a smaller iris and/or a shorter focal length (wide angle). A small pinhole lens will have an almost infinite depth of field. Anything from a few inches to infinity will be in focus.

Depth of field is decreased by a larger iris and/or a longer focal length (telephoto)

One of the most common problems in CCTV is not understanding the effect of depth of field and the steps required to properly focus a lens. It is fairly common to install cameras with auto-iris lenses that look sharp and clear during the day. Reviewing the recorded night-time images show that some of them are slightly or greatly out of focus. They still look great during the day. How is this possible?

The simple explanation is that during day-time, when the iris is at the smallest iris opening , we have such a large depth of field, that all objects appear to be sharp and in focus. The problem becomes apparent at night, when the iris opens, the depth of field becomes so shallow that if focusing is not done correctly, objects are out of focus.

We have to balance the need for sufficient light with the need for a finely focused image.

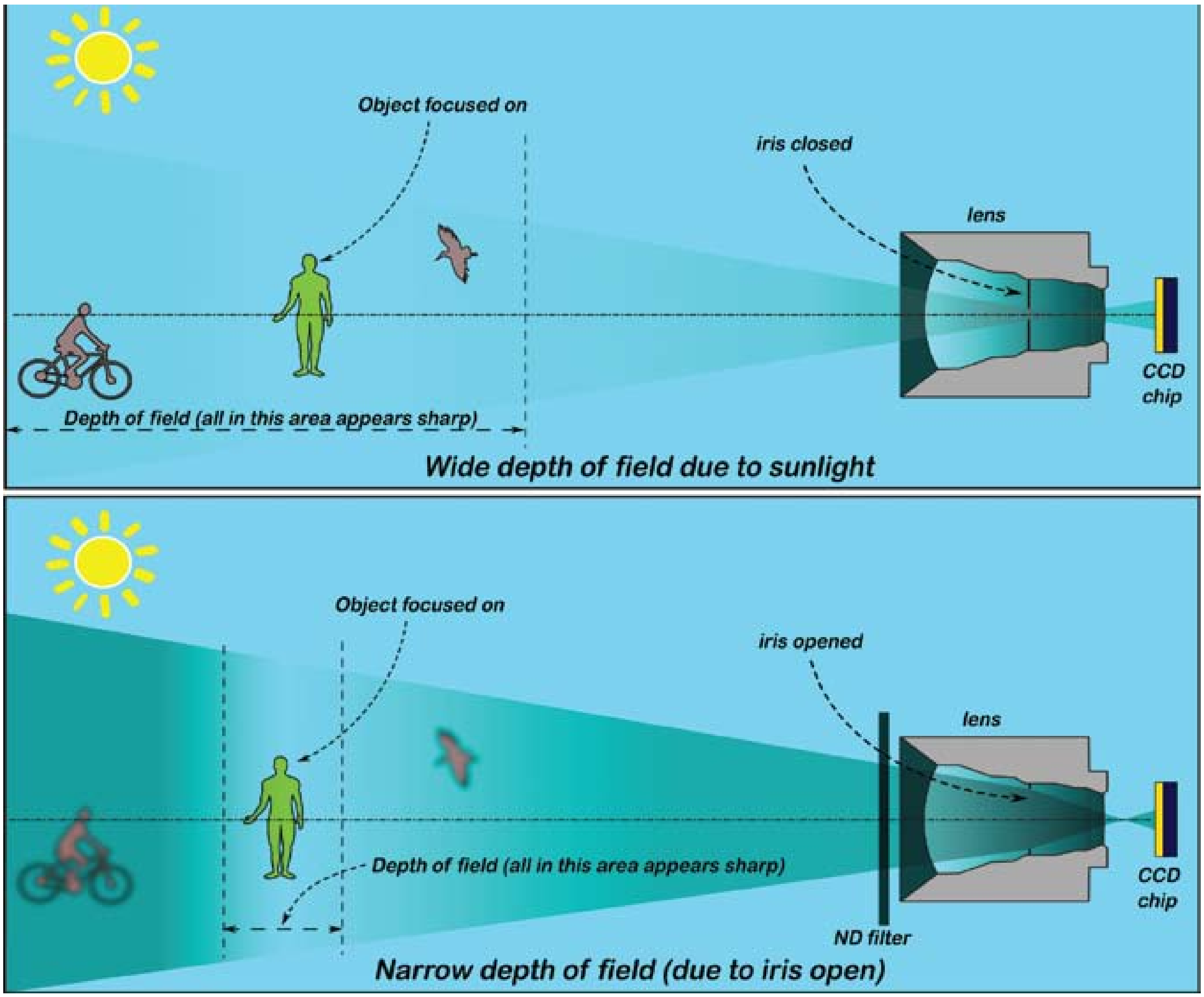


Fig.12 Using a Neutral Density filter during daytime simulates the narrow depth of field that occurs

To achieve the sharpest possible image, we have to create the worst case scenario by opening the iris to create the shortest depth of field. If using a manual iris lens, we simply open the iris. With an auto-iris lens, we could wait until dark. Since this is not practical, we can temporarily put Neutral Density (ND) filters in front of the lens. The ND filters have tinted glass which simulates night-time conditions and force the auto iris to open up, producing a shallow depth of field. From practical experience, if an ND filter is unavailable, a number 5 welders lens (cutting torch goggle) or several layers of window tinting material work reasonable well. Once the depth of field is shallow, focus on the object of interest. After focusing, close the iris to improve the depth of field by removing the filter or, if using a manual iris, simply close down the iris. The process of using a ND filter or equivalent not only insures that focusing is done properly but allows us to check the camera for proper low light operation.

Three steps to proper focusing:

1. Open the iris
2. Focus on the primary point of interest.
3. Close the iris

Again, we have to balance the need for sufficient light with the need for a finely focused image

CCTV CAMERAS

Let's now see the basic concepts of how cameras work and what settings and switches of which you need to be aware.

Once a lens projects an image on the imaging chip (CCD or CMOS), the optical information is converted into electrons, which represent the electronic information. Basically, the bright areas of the projected image produce more electrons, the darker areas less electrons. This will eventually be converted to a video signal where the electron current is converted into a video signal represented with voltage. How this conversion is done is beyond the scope of this manual, but there are certain properties of a video signal and the camera that should be understood by installers in order to be aware of certain settings during installation. In order to discuss certain topics, we have to explain the very basics of the video signals produced by analog CCTV cameras.

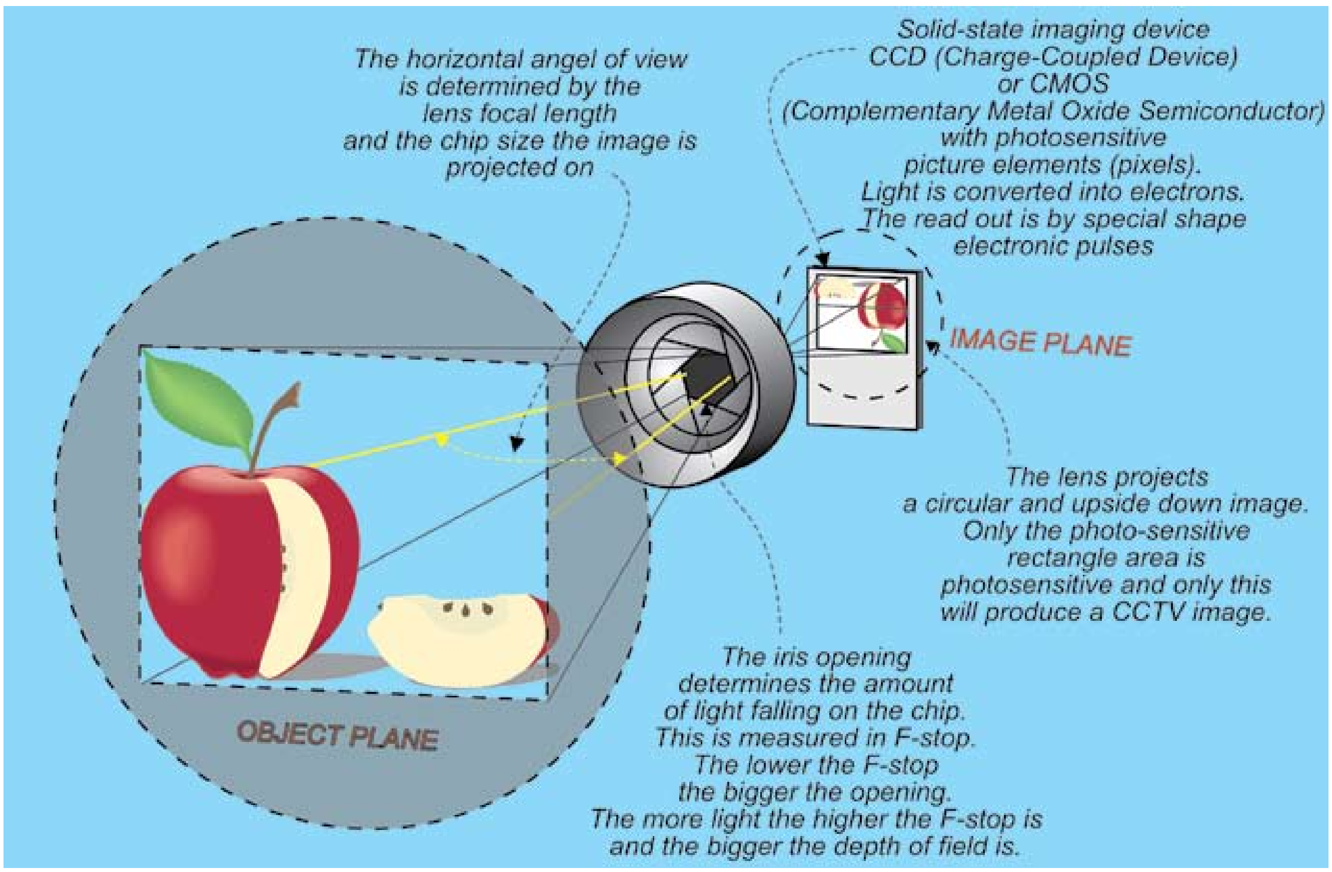


Fig.13 The principles of imaging

When we view a television image our eyes tell us that we are seeing a solid picture. Actually, we are seeing a very complex set of individual lines that are scanned so quickly that they appear to be a complete image or field. Although television signal theory is included in VSST2, it is important for us to understand some basic concepts at Level I. In the early1940's a series of standards were created by the National Television Systems Committee in order to insure compatibility between television equipment. The NTSC standard dictates the number and frequency of scan lines, the delays at the end of each scan line and at the end of each field known as sync pulses, and luminance (video information) needed to create, transmit and display video signals. This combination of information is known as ***composite*** video. Since the whitest portion of the image is only 1 volt, it is also referred to as a 1volt peak-to-peak signal.

The Institute of Radio Engineers (IRE) developed a unit of measure called the IRE in to measure video signals. 40 IRE units is the value of the sync pulses and the blackest portion of the image. The "luminance" or image portion of the signal has a range from 0 to 100 IRE. The combined value of sync and luminance has a maximum value of 140 IRE. Remember that the video signal at it's highest level is only one (1) volt. That is less voltage than a AAA battery. ***It must be treated with care in to insure it's integrity***. Once a video signal has been produced by the camera, it needs to be transported to the receiving equipment (which could be a monitor, digital video recorder, encoder, or similar) by using some kind of video transmission media. This is most often in the form of coaxial cable, twisted pair cable, fiber-optics or possibly wireless RF transmission.

When a video signal is "received" by a monitor, the lines of video are "painted" (displayed) on the screen one by one, very quickly, thus converting the electronic video information back into optical (the screen visual display).

In a similar way, if a digital video recorder is used, it will convert the analog composite signal into digital and then records it onto a hard disk drive. Then, when video footage needs to be seen, it is decoded again into an analog signal and displayed on a monitor.

Clearly the quality of the video images displayed on the monitor will depend on the quality of all these components. These include the lens, the focusing of the lens, the angle of coverage of the lens, the quality of the imaging chip, the quality of the camera, the quality of the transmission media and, finally, the quality of the recorder (encoding) and display devices. You, as a professional CCTV installer, should be aware that each and every component in this chain plays a role in the overall picture quality. The video picture will be as good as the weakest part in this chain.

Let's explore the most important settings and parameters you can change or set on a typical CCTV camera.

Camera power supply

Most current CCTV cameras are powered by safe, Class 2 low voltages (see more in this manual under "Low voltage power connections"). Most common are 12VDC or 24VAC. Many cameras have terminals that will accept either of these two voltages. So, what is the difference and which one should you use or recommend?

Fig.14 Multi-camera 24VAC power supply

Fig.17 Some cameras can accept both 24VAC and 12VDC power

One of the key reasons to choose 24VAC is when the cameras are powered from one central power supply and are reasonably far apart (over 300 feet, for example). The 24VAC will have less of a voltage drop since it is alternating current and starts at a higher voltage.

Fig.15 Usually 24VAC cameras can be line-locked

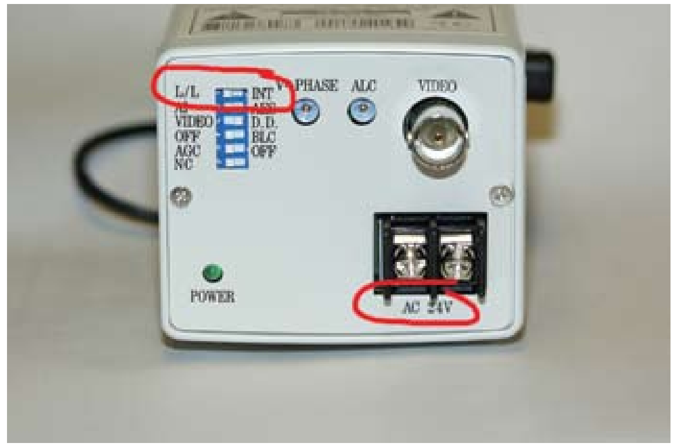


Fig.16 LL can be switched Off or On

Another important reason to use 24VAC powered cameras is their capability to be switched to *line-lock (LL)*. This is an effect that will be explained later. Its benefit it that it synchronizes the cameras to follow the pulse of the alternating current to perform reasonably roll-free video switching when viewing multiple cameras on one system. Line-locking can be done only on 24VAC powered cameras. When the line-lock feature is used, or selected, there is usually a switch or setting in the camera menu that shows "External line-lock" or "LL". It should be noted that having a 24VAC power supply on a 24VAC camera doesn't automatically mean that cameras are line-locked. In areas where the local power is not reliably synchronized at 60hz, the variation in the power frequency can distort the video. If there are no plans to line-lock the cameras or if 12VDC is used, the LL switch should be set to Internal Lock (Int).

There is nothing wrong with using 12VDC cameras if line-lock is not required. The first advantage of 12VDC cameras is that they require lower voltage than 24VAC. Because it is DC (Direct Current) it can be powered by plug-in power supplies, batteries or by solar cells.

Care should be taken when connecting DC powered cameras, since many of them are ***polarity sensitive***. ***The installer must know which wire is positive and which negative***. There are some models that do not have polarity sensitive terminals. Don't assume. Read the installation manual.

Additional caution must be given to selecting power supplies for 12VDC. Many plug-in 12VDC power supplies are too small to power CCTV cameras with sufficient amperage causing the power supply to fail.. Many 12VDC power supplies are "unregulated" which means that they have the potential to hit the camera with much higher than 12VDC and damage to the camera.

V-Phase or LL-Phase

This setting should only be used if 24VAC cameras are used and the LL switch is set to the external (sync) synchronization position (LL). The explanation of what it does and how this affects the camera operation is beyond this level of training, so the suggestion is to not touch it.

Fig.18 V-Phase works only when LL is On

Lens mounting C/CS-mount

For years the standard lens for CCTV was the "C-mount" It uses a 1" diameter opening using 32 screw threads per inch (32TPI). The distance from the back of the lens to the pick-up device is set at 17mm.

Engineers discovered by shortening the distance from the back of the lens to the pick-up device by 5mm, the rest of the lens could be proportionately smaller, saving material and costs. This short lens is called "CS-mount" for "C-Short". The only difference is that the lens is designed to be installed on a camera that is 5mm shorter. Some cameras have a mechanism to move the pick-up device or lens mount by 5mm to accommodate both mounts. A 5mm spacer can be installed on the front of a CS-mount camera to make it longer to allow the use of a C-mount (long) lens.

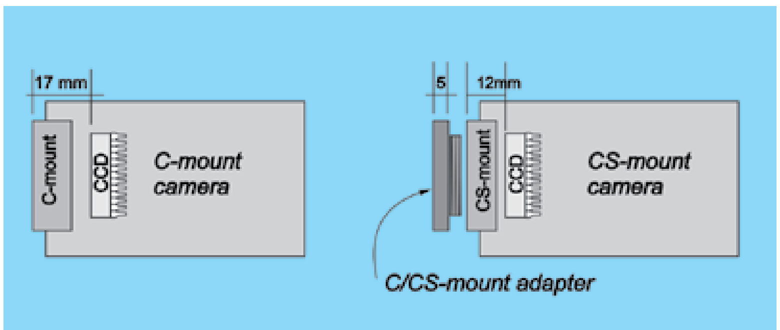


Fig.19 ***C-mount and CS-mount cameras***

Fig.20 Some cameras can be switched between C and CS-mount

Auto Iris Lenses

Most CCTV cameras have an auto iris lens socket which is used when an auto iris lens is attached to the camera. As discussed earlier, there are two main types of auto iris lenses; Video Drive and DC Drive. The selector switch on the camera must be set to the appropriate type for the camera and lens to function properly. Please note that some cameras do not have the option to select the type of auto-iris lens. In that case it is imperative to choose the lens that works with that camera. Make it a standard practice to test the auto iris function after mating the lens to the camera.

Fig.21 Auto iris 4-pin socket

Iris Light Levels on Video Drive Lenses

When using a Video-Drive auto-lens, the light levels can be adjusted by using the potentiometers on the side of the lens. The presence of the potentiometers is a sure indication of a video drive lens. If the image is too light or too dark, adjust the light **level** towards **H** or **L** by using a small screwdriver as if you were adjusting the sound on a radio. The **ALC** tells the lens to give more priority to the average or the brightest portion of the image by adjusting between **PK** for peak or **AV** for average.

Fig.22 Light level adjustment on video lens

Iris Light Levels using DC Drive Lenses

DC auto iris lenses do not have potentiometers (adjusting screws). The iris light levels are controlled by adjusting the level setting on the camera. This adjustment might be labeled ALC, Iris Level or it might be included in an on-screen menu.

By adjusting the level, the iris is forced to open a bit or close a bit in order to achieve the optimum light levels. Once this is set, care should be taken to test the lens operation in both light extreme situations - in the brightest conditions and in the darkest, to make sure that it operates well at both extremes.

Fig.23 Lens Level is sometimes called ALC

Fig.24 Level only works with DC driven lenses

Electronic shutter

Most CCTV cameras have internal ***electronic shutter***, sometimes called ***electronic iris***. This might be referred to as Electronic Shutter (ES), Automatic Electronic Shutter (AES), or CCD-iris.

Many cameras have a selector switch on the camera body, while others may have this function in an on-screen menu.

While, the electronic shutter appears to work the same way as an auto iris, it is completely different. The auto iris controls the amount of light entering the camera via the mechanical iris. The electronic shutter on a camera does this by controlling the exposure time of the imaging chip.

An electronic shutter should only be used with manual iris lenses unless the task is to obtain clear images of fast moving objects such as vehicles in full daylight.

In most outdoor situations, an auto-iris lens is required because an electronic iris cannot cope with the tremendous light level differences between darkness and full sunlight. In addition to controlling

Fig.25 CCD iris is the same as electronic shutter

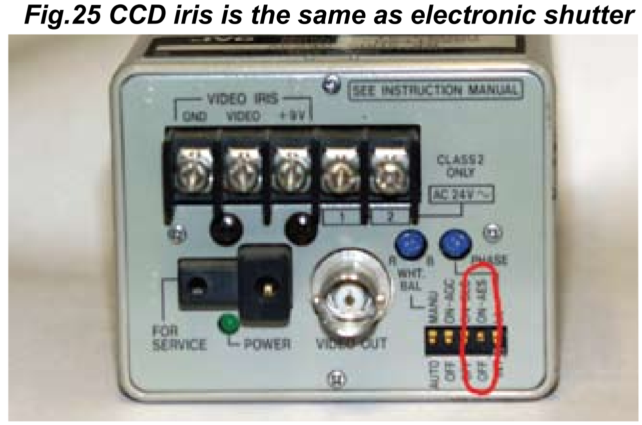


Fig.26 AES should be ON with manual iris lenses

the light level, it also products a wider depth of field in bright conditions (as explained previously) which makes the picture look sharper. This is not the case with the electronic shutter because the electronic shutter cannot alter the depth of field.

Frame Integration

For low light conditions, it is possible to lengthen the exposure time beyond 1/60 or a second using a process call frame integration (also referred to as "sens-up)." This is a process where the imager is allowed to have an exposure time over multiple fields of video. The benefit of this is that a longer exposure time greatly increases low light sensitivity. The disadvantage with frame integration is that with longer exposure times, fast moving objects can produce smeared images. Most cameras that offer frame integration can be programmed for a maximum exposure time to limit smear.

Back Light Compensation (BLC)

Another very common setting on most CCTV cameras is the Back Light Compensation (BLC).

This can usually be turned on or off. Again, the switch can be mechanical on the camera body, or software switched via an on-screen menu.

BLC is simply used in situations where there is very strong back-light when viewing an object or a person. A typical example is an image of a hallway with natural light coming through the main glass door. A person standing in the hallway will be very difficult to recognise as they would normally appear as a dark silhouette. To see such a person against the back light the BLC should be turned on.

Some cameras allow programming of the backlight compensation for specific areas of the picture. This makes them more effective in certain situations such as ATM cameras.

BLC is usually not turned on unless there is a specific need, since it will have very little effect if there is no strong backlight.

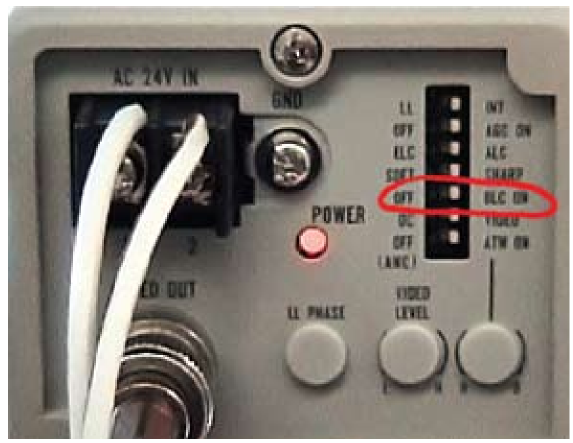


Fig.27 Back Light Compensation Switch

Fig.28 BLC is normally indoor looking out

Fig.29 Use BLC only in high contrast light scenes

Wide Dynamic Range (WDR)

There are many applications in CCTV where large areas of both bright and dark areas appear in the image. Backlight compensation is often not adequate. There are some newer cameras on the market that promote wide dynamic range of WDR. The feature uses advanced image processing and in some case specialized imagers. Some imagers adjust the light levels on a pixel by pixel basis in order to achieve good result in bad lighting situations.

Automatic Gain Control (AGC)

Most CCTV cameras have Automatic Gain Control (AGC). *This is electronic circuitry inside the camera that adjusts the signal level output even if there is insufficient light coming through the lens.* If there was no AGC you would see nothing but a dark image in very low light scenes.

Some cameras can switch this function or on off, and or vary the AGC signal level. Since the AGC also amplifies the noise, it might be useful in some situations to turn off the AGC.

Fig.30 AGC is usually always On

Dynamic Noise Reduction (DNR)

DNR is relatively new technique that electronically smooths out the excess noise from the AGC circuit that reduces that amount of “snow” on over amplified images.

White Balance

Automatic White Balance (AWB) / Automatic White Tracking White Balance (ATW)

Different light sources can produce light with different color temperatures which affect how our cameras reproduce colors. Fluorescent light produces a greenish tint, incandescent light has a reddish hue, sodium vapor is orange/yellow. The color white is an even balance of all the primary colors, If a camera is not properly adjusted to compensate for the color temperature, it will not be able to produce accurate color. Cameras use white to adjust for various color temperatures. This is known as white balance. It is also possible with most cameras to use manual white balance settings. The disadvantage is that as the lighting temperature changes, the color rendition will be inaccurate. Today’s cameras have electronic circuitry to automatically perform this function.

Fig.33 ATW is more universal than AWB

Auto White Balance (AWB), also called Auto White Control (AWC), automatically adjusts the brightest areas of the scene to look natural white when seen on a monitor. Using AWB, the white level is set while the camera is looking at a white object such as a piece of paper at the moment of turning on the camera power or by depressing the “set” button. This method has limited value since once the color temperature of the scene changes (such as from daylight to fluorescent light) the colors will no longer appear natural.

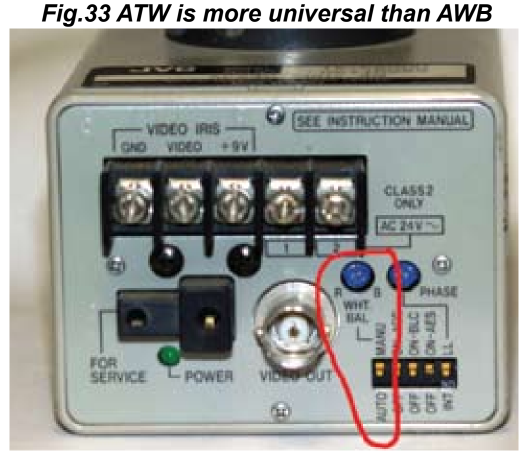


Fig.34 Some situations may require manual white balance adjustment

Most cameras today use a form of automatic tracking white balance (ATW) which constantly updates the white balance as lighting conditions change. ATW should work “on the fly,” without the need to set the camera with a piece of white paper. Cameras from different manufacturers differ in their ability to compensate for different lighting conditions. If you have trouble obtaining natural looking color in your application, try various white balance settings or experiment with different manufacturers.

2. Assemble camera hardware and place assembled camera on mount

(Tools required for this section: screwdrivers, hex wrenches, pliers, volt ohm meter, CCTV monitor)

In CCTV there are various types of cameras:

- Fixed "box" cameras, where the lens is supplied and installed separately

Fig.35 Box camera

- Fixed dome cameras, where the camera and the lens come packaged together, mounted in a dome housing

Fig.36 Fixed dome camera

Fig.37 Traditional style PTZ camera

- Pan/Tilt/Zoom (PTZ) cameras, of a "traditional" design, where separate components are put together in a PTZ camera: a camera, zoom lens, housing, Pan/Tilt head and PTZ driver (which sometimes is built into the housing or pan/tilt head). This section will be covered in Level II.

- PTZ dome cameras, where the camera is bundled with a zoom lens, and pan/tilt assembly and driver all pre-packaged in a dome. These are the most common PTZ cameras lately. This section will be covered in VSST-II.

Fig.38 PTZ dome camera

Assembling and mounting each of these may require some specific knowledge and understanding of the basic CCTV principles of operation. These include focus, iris, depth of field, back-focus, electronic camera shutter, and minimum illumination.

One of the first and most important camera installation and mounting procedures is to achieve a sharp image with optimum focus at the area of interest. The camera/ lens should also be checked to verofy that it works in the full lighting range of area, from the lowest illumination at night to the full bright sunny day conditions.

No transmission, video processing or recording equipment can make the picture better than the original signal coming our from the camera. It is the responsibility of the installing technician to make such a picture as good as possible.

Fixed "box" cameras with separate lenses

Fig.39 Box camera with auto-iris lens.

These types of cameras are almost always supplied without lenses, as the choice of which lens is needed will be up to the system designer or installer. Each CCTV camera usually comes with a standard C/CS lens screw-mount.

There are a few important considerations to make sure that a correct lens is selected.

1. C or CS Mount. Not all cameras can use both C and CS Mount lenses. Confirm that the lens mount type will work with the mounting options of the camera.

Fig.40 Left, a lens for 1" camera, right for 1/3"

2. FORMAT. The second consideration is that ***the lens should be suitable for the camera chip size***. Format refers to the diagonal size of the imager chip. Each lens has a circle of image projection. This circle needs to be equal to or bigger than the diagonal size of the imaging chip. There are imaging chips of various sizes, such as 2/3", 1/2", 1/3" and 1/4". It is obvious that a lens designed for 1/3" imaging chip will have an insufficient circle of projection for a 1/2" chip. These details can be found from the manufacturer or supplier of the lenses.

3. FOCAL LENGTH. The third consideration is ***the focal length of the lens***. Each different size of imaging chip will have a different angle of view with the same focal length lens. Determine if a fixed focal length is appropriate or if a vari-focal lens be the best fit.

4. MANUAL or AUTO IRIS. The fourth consideration is whether a ***Manual Iris*** (MI) **or *Auto Iris*** (AI) lens is most appropriate. If using an Auto-Iris, be sure that the camera will work with the type selected. Not all cameras can use both Video-Drive and DC-Drive lenses.

If using a Manual-Iris lens, small variations of light are handled by the camera's automatic electronic shutter (AES) control combined with the Automatic Gain Control (AGC) circuitry.

Whether using a manual-iris lens with AES or an auto-iris lens, the mated camera-lens combination should be tested to verify that the camera will work properly in changing light conditions. Point the camera at a bright light source and verify that the camera will reduce the light down to proper levels. Move the camera from the light source back to a normal or dark area to make sure the camera properly increases the light levels.

5. BACK-FOCUS. The distance from the back of the lens to the pick-up device should be either 12.5 or 17.5mm. The back focus is an adjustment on the camera to offset minor manufacturing variations. When the back focus is properly adjusted, turning the focus ring on the camera until it stops will produce an out of focus image. Turning the ring towards the other direction will start bringing the camera into focus. Continuing on, the lens will start going out of focus again. By "hunting" in the middle, the best focus is found.   If the camera were to come into focus as it hits the stop, you are not certain that the lens could be adjusted just a little bit better. Change the back-focus on the camera to get benefit of the full range of the focus ring on the camera. Remember, focusing is the procedure of aligning the focal plane of the lens with the face of the imaging chip.

Camera Mounts

The primary purpose of a camera mount is to hold and secure the camera so that the selected image does not change. Obviously, the mount must be attached to firm surface that can support the weight of the camera package with a minimum of movement or vibration that will affect the video image. We will discuss various methods for attaching hardware to the building structures in Section 6.

Camera mounts are made from a wide variety of materials and in a multitude of shapes and styles. They are designed to be mounted on almost any imaginable type of walls, parapet or ceiling.

A word of caution; the National Electrical Code does not allow the attachment of any item on a drop ceiling, grid or grid wire unless it is listed (approved) by the ceiling manufacturer. There are special "t-bar" clip mounts that are designed to wrap around the ceiling grid to hold cameras. They must be attached to the permanent structure of the building by their own wire, chain, etc., so that they do not add any weight to the ceiling.

When the camera placement requires that the camera be on the surface of the tile, then the camera should be attached through the tile to a "bridge." The bridge straddles the ceiling tile from above, supplying a solid material to attach the camera mount from below and providing an attachment point for the cable or chain that connects to the permanent structure.

The total length of the camera, lens, connectors and cables should be taken into account to insure that there is sufficient space behind the camera without hitting the wall or ceiling. Sufficient slack should be left when terminating the cables so that the camera can re-aimed for other potential views

There are several concerns to addressed with the simple task of mounting the camera to the camera mount. In the US, we use a standard 1/4" screw with 20 threads per inch. Care must be taken when installing the mounting bolt to insure that the camera is secure without using undue force. Many cameras have been ruined when a longer bolt than necessary was forced into the camera body. Short bolt/screws and washers can be indispensable when mounting cameras.

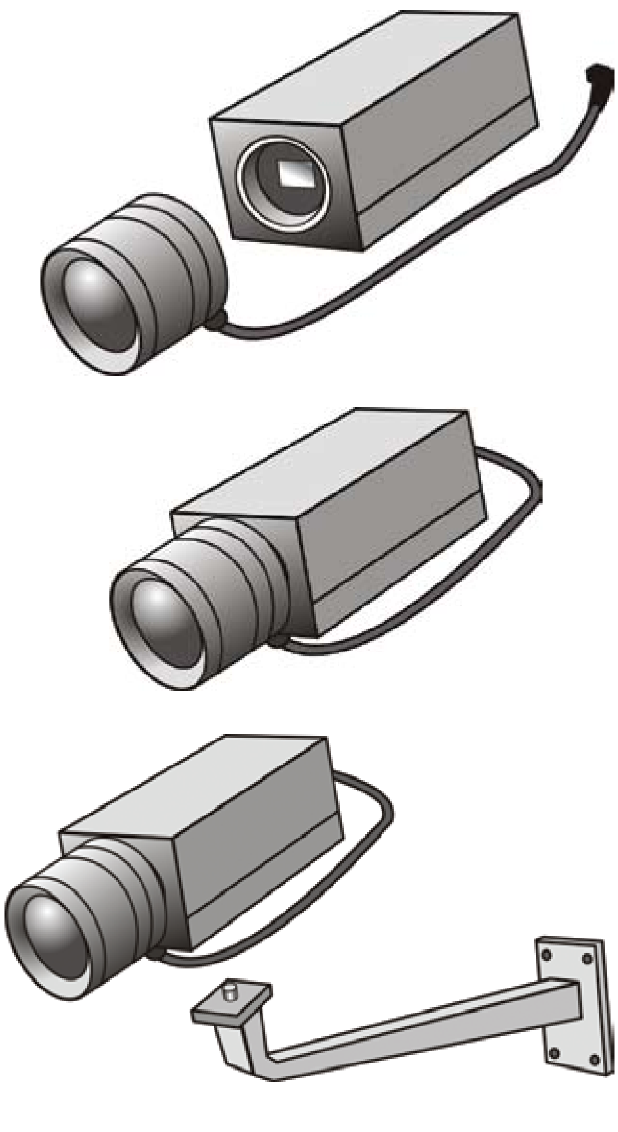


Fig.41 Sequence when mounting a fixed camera

Fig.42 A standard 1/4" mount

Camera Housings

There are a wide variety of housings designed to serve one or more purposes. Housings might protect the camera from the environment or the environment from the camera. They might be used to improve aesthestics by blending the camera into the background or they might be used to make the camera more obvious.

Indoor housing are designed to protect the camera and lens from dust, dirt, moisture and other contaminants. Outdoor housings also take on wind, rain, snow and ice. Explosion proof housings, despite the name, are not designed to protect their contents but are designed to be "intrinsically safe." A failure inside the housing cannot serve as the ignition source in a flammable or explosive environment.

As a Level I technician, you may not choose the housing, but you should be aware of some basic concerns when installing the camera, lens and other devices.

Most manufacturers list the maximum camera length (MCL). The camera length includes the camera, lens, and cable connector. If using a twisted pair balun or a fiber optic module, these items should also be added to the camera length. Allow a couple of extra inches of room to allow for cable management.

The front surface of the lens should be a close as possible to the front window without touching. This lessens the optical effect of dirt on the window and the chance of having parts of the housing appear in the field of view. Although zoom lenses are not included in Type A systems, they do deserve a word of caution. The front element of zoom lenses move when changing focal lengths. Be sure that there is clearance between the lens and the front window when it is fully extended. Also, be aware that some lens bodies are made of plastic and could be damaged by heater elements mounted nearby.

To complicate things even more, many housings also include heaters and/or fans, some have washers and wipers. Some housings have provisions for all of the internal cabling. Others depend on the installer to neatly place and connect all of the required wiring.

Outdoor camera housings may be subjected to severe environmental conditions. Most manufacturers provide gaskets, grommets and other accessory hardware to seal the housing and the cable entries to prevent the entry of undesired elements. Be sure to follow the manufacturers' instructions for best performance. (Silicon glue can sometimes to be used in a pinch, but use with care.)

Some modern housings are designed to neatly conceal the video and power cables with the mounting bracket. This makes for a neater installation and less likely for the cables to be tampered with.

Photo courtesy of Videotec

Photo courtesy of Videotec

Fig.43 One of many style of camera housings.

Fixed dome cameras with integral lenses

Fixed dome cameras have become a very popular and practical type of camera. They are aesthetically pleasing and easier to install since everything is included within the dome and base. Many have additional on-board options such as twisted-pair baluns, fiber optics adaptors, and built-in infrared illuminators.

The internal mounting of the camera module allows for positioning in two axis (up/down and left/right), or three axis models (adds rotation) depending of the make and model of the camera. The three axis models allows for mounting of the domes on vertical or sloped walls or on ceilings. There are many options for lowering the cameras from the ceiling via conduit brackets or "goose-neck" type brackets for positioning the camera away from walls in order to provide optimum views.

Many dome cameras have an arrow marking the front view direction of the dome. These require that the side with the arrow be oriented in the general direction of view. Pay attention to these markings as it will be much easier to position the camera correctly. With some models the camera mount allows the camera to be oriented in any direction after the housing is mounted. It would be wise to determine what type of internal mount (sometimes referred to as a gimbal) prior to mounting the housing.

Fig.44 A typical vandal resistant dome camera

In addition to positioning the viewing direction, some dome cameras have vari-focal lenses. Lenses are available with fixed, manual, or auto-iris.

Never touch a camera lens glass with fingers. If you see finger prints or other marks on the lens use a photographic lens cleaning cloth to gently wipe off the marks. Lenses are always cleaned with a light circular motion. Rather than using your breath to blow off dust and dirt, use clean compressed air or a photographer's brush.

Most dome bubbles are made of polycarbonate plastic. Although it is impact resistant, it is easily scratched. Ptotect the domes during handling and installation to prevent scratching.

Camera installation checklist

On the workbench

1. Mate the lens to camera
   a. Check the lens and camera for fingerprints/debris, clean if necessary
   b. Verify C/CS compatibility.
   c. Set "auto iris" for type of lens (DC/Video)
2. Make sure correct power is available (AC or DC)
3. If necessary, set the back-focus on the camera to allow the focus adjustment ring on the lens to move through the full range of "out-of focus", "in-focus", and back "out-of-focus." This will allow you to center on the best focus position.
4. Check the position of the other camera switch settings such as;
   a. White Balance (ATW, AWB, Manual)
   b. Back Light Compensation (BLC)
   c. Iris Level (Level)
   d. Automatic Gain Control (AGC)
   e. Automatic Noise Reduction
   f. Line-Lock or Internal Sync
   g. Wide Dynamic Range

On site

1. Mount and position the camera
2. Choose the angle of view if a vari-focal or or manual zoom lens is used
3. Focus
   a. Open the iris (either manually or by placing darkening filter in front of lens)
      This creates the "worst case" scenario, shortest depth of field & low light.
   b. Focus on the primary target by adjusting the fine focus ring on the lens.
   c. Close the iris (remove the darkening filter or manually close the iris)
      This improves the depth of field.

3. Low voltage power connections

(Tools required for this section: volt-ohm meter, flat and philips screwdrivers)

In order to work with electricity it is important that the installer first understand some basic principles about electricity.

Electricity is the flow of electrons through materials and devices. Certain elements such as copper, silver, gold and aluminum have free electrons that can easily be displaced and are considered electrical conductors. Compounds, such as glass and rubber do not have free electrons and are therefore electrical insulators.

Electricity must have a closed circuit in order to flow. Electricity will not flow if the circuit is "open."

Electricity powers our equipment and provides the means for transmission of our video signals, yet it can cause interference in our images and has the potential for harm if not handled with care.

The National Electrical Code (NEC) is the set of standards that govern much of what we do. Based on the power energy that can be delivered through certain circuits and wires, the NEC offers classification in three classes. These are as follows:

Class 1 circuits are that portion of the wiring between our electrical panel and the wall outlet where we plug in our equipment. Class-1 circuits typically operate at 120V, although the NEC permits them to operate at up to 600V.

Class 2 circuits are power-limited low voltage (under 30V, and less than 100VA of power). This is the class in which a typical CCTV camera would operate. Other uses of Class 2 circuitry are low-voltage lighting, thermostats, PLCs, security systems, intercoms, and the like. Class 2 power supplies are fused so that a fault in the circuit will not be able to do physical harm as either a shock hazard or a fire initiation source. All of the power supplies we use for CCTV should be labeled "Class 2."

Class 3 circuits have higher voltage and power limits than Class 2, and the NEC has additional requirements for safety, as a class 3 circuit can be up to 100 volts, a dangerous voltage. We should not use Class 3 for CCTV.

Installers must be aware that they should stay within the limitations of Class 2 circuits in most CCTV installations. Class 1 circuits (120VAC) for powering the head-end of the system are not normally within the realm of the low voltage technician. .

The key points that are worth remembering and are explained in more details in the following are:

1. ***Use the correct type of fuel (electricity)***. CCTV cameras are normally powered by either 12VDC or 24VAC. Do not power 12VDC cameras with 24VAC, or vice versa as this could damage the cameras. There are *some* cameras that can operate on either 12VDC or 24VAC without damage to the camera. Look at the terminals on the camera and/or read the installation manual. Don't assume... read.

2. ***Have a surplus capacity of fuel (electricity).*** The capacity (rating) of the power supply (shown in Amps, Watts or VAs) must be greater than the total draw of all of the devices connected to it.

3. There is a voltage drop between the power supply and the camera(s). Later on we will show how this is calculated based on the length and size of the power cable and the total number of connected cameras.

Understanding voltage and electric current

The following analogy has helped many technicians better comprehend (invisible) electricity:

Imagine a big river and a waterfall. The height of the waterfall represents voltage. The amount of water pouring down represents current. Imagine now you have rocks and stones just before the waterfall that block the water from falling at its full potential. They would represent the resistance. The bigger the rocks are - the higher the resistance, allowing only a smaller flow of current to fall down the waterfall. The power of the water falling down to the bottom is proportional to the height frin the water falls (voltage) and the amount of water you have (current).

Other than the 120VAC line power voltage used for powering most of the CCTV and Security equipment installed in central control areas, there are two most common low voltages used in CCTV when powering remote equipment, such as cameras, encoders, transmitters and the like; 12VDC and 24VAC.

On occasion you may encounter equipment that is neither of the above, such as 6VDC, 9VDC in 14VDC. Just because the power plug fits into the equipment jack doesn't mean that the power is correct.

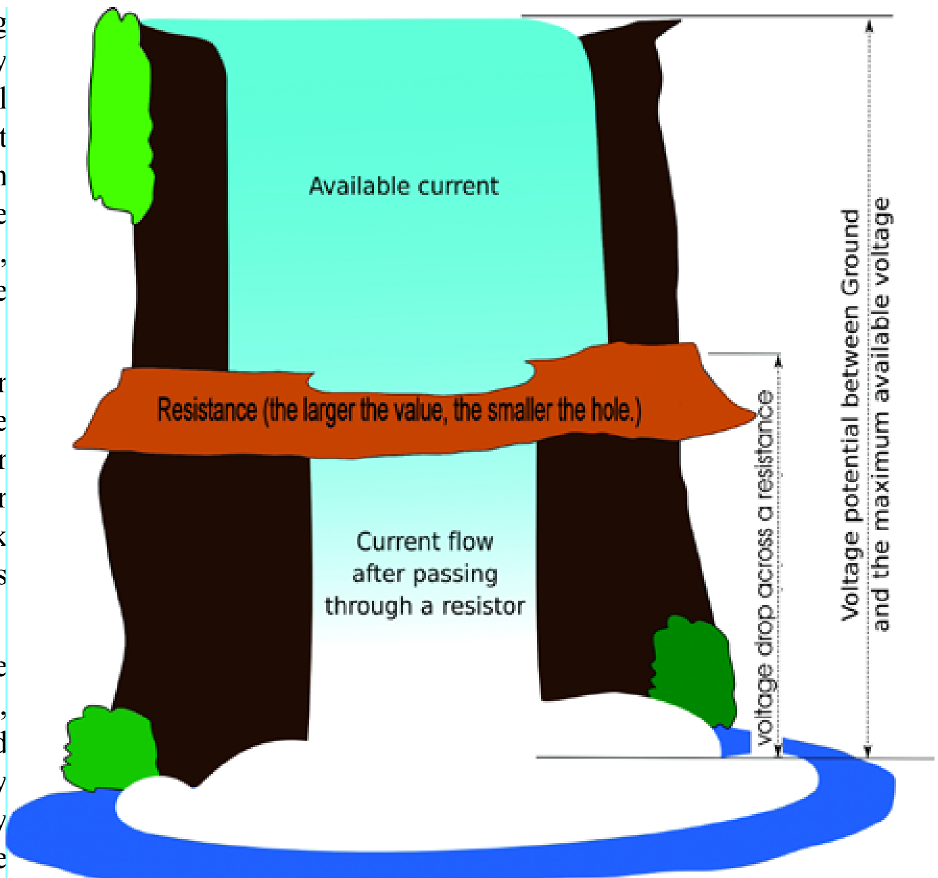


Fig.45 Representation of voltage, resistance and current with a waterfall

As mentioned in the chapter Safe Voltage Electrical Practices, voltages under 50V are classified as safe and do not necessarily pose a health risk if touched by an installer. This is one of the main reasons why 12V and 24V are used for the equipment that is handled and installed in an area that is not necessarily out of the reach of public, employees or children. This is not to say that this voltage can not cause damage, start a fire, shut down equipment by short circuits and other failures. One of the main reasons it has become de-facto industry standard is that it is well below the 50V health-risk level.

An installing technician should be aware of all the aspects of low voltage usage, including, of course, the electrical current requirement of CCTV equipment, their connecting in parallel or serial circuits, calculating voltage drop for long distance powering, and the advantages and disadvantages of using alternate current supply (AC) versus direct current (DC).

Basic electrical units

There are a few electrical units that an CCTV / VSS technician needs to understand clearly, since they will be part of every job. **Volts**, **Amps**, **Ohms** and **Watts** are closely interrelated. If these terms are new to you, plan on reading the following section more than once.

Volts

The Volt is one of the most common units of measuring and quantifying electrical properties.

A **Volt** is defined as the **electric potential difference across a conductor when a current of one Ampere dissipates one Watt of power. The symbol for volt is "V" or "I" for "intensity."**

If electricity was water then voltage would be pressure.

The typical source of electrical power in a household in the US and Canada uses 120V of alternating current (120VAC). A typical AA battery has 1.5VDC while a typical car battery has 12VDC.

Voltage (often referred to as "electrical potential") is always measured in **parallel** to the terminals delivering the voltage. When using a Voltmeter, and measuring DC voltage, the red probe is usually connected to the positive terminal and the black one on the negative. Voltmeters normally have a way to switch between AC or DC measurement. A voltmeter has very high input impedance, meaning it draws hardly any current from the source. Still, be very careful when measuring non-safe voltages (above 50V) and make sure you have good probes with insulation.

There should be a common rule to determine which wire is positive and which one negative. ***Typically, the wires will be colored red and black or one of the wires will be marked with a stripe***. If common rules are used throughout your practice, mistakes with reverse polarity connections can be eliminated or, at least, minimized.

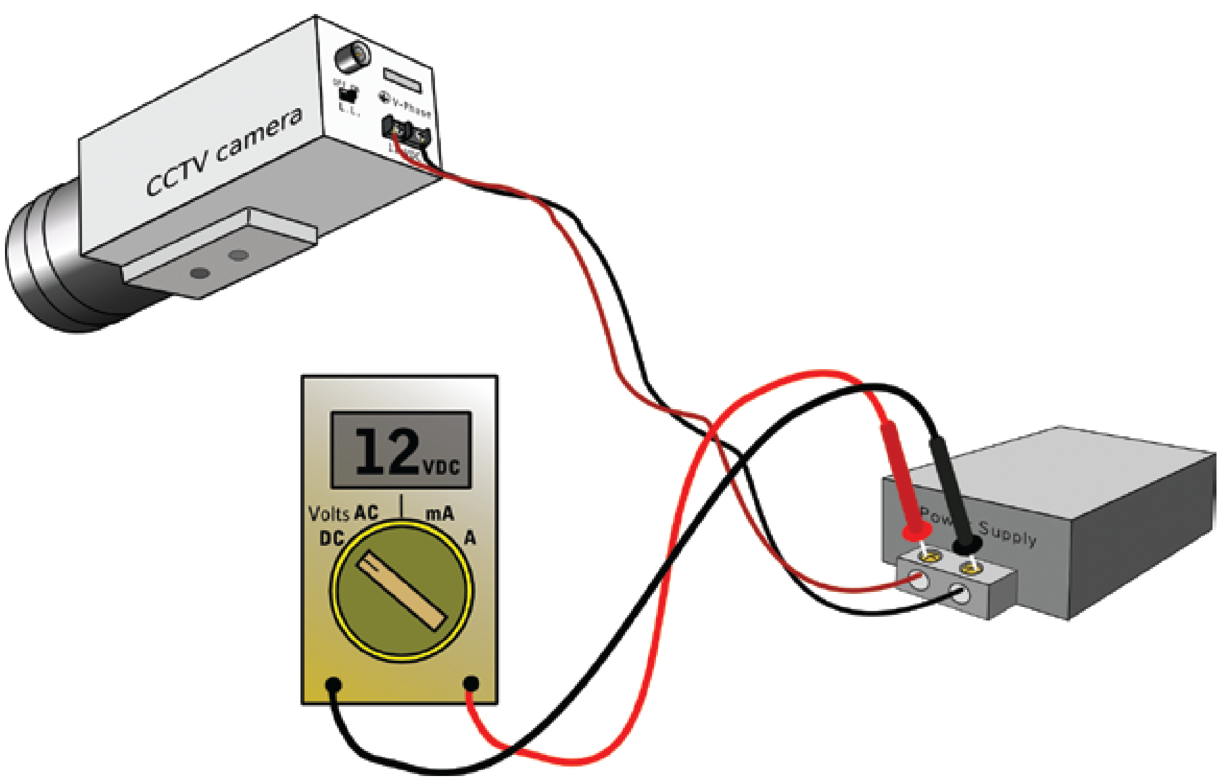


Fig.46 Voltage is measured in parallel with the source

When measuring the voltage of alternative current, the polarity of the probes is irrelevant, since the polarity of the electricity alternates 60 times each second. With AC, one of two wires delivering voltage is an active ("hot") wire, while the other is the neutral. Normally it does not matter which wire is connected to which terminal of the device being powered, but when using line-locked 24 VAC cameras it is important to know that the same "polarity" of wires is connected across all cameras. If all cameras are connected the same way, once the cameras are line-locked in the workshop, they should be line-locked when connected to real power source.

Cables carrying alternating power can easily be detected by cable tracers, also known as power probes, because alternating current produces electromagnetic field along the wires. If wires are not energized, using a tone generator tool can be helpful when determining which wire is which.

Amperes

The unit for measuring electric current, or the amount of an electric charge per second, is called Ampere [A] or sometimes abbreviated "I" for Intensity of electrical current.

Current is always measured in **series** with the source of electricity. The input impedance of the ampere-meter (amp meter) is close to zero. This means, when using an amp meter the probes are connected so that they interrupt the current between the source and the device they supply with current. If a DC current is measured, the red probe is connected first to the positive terminal, and if AC is measured the polarity is not important. The critical setting on the amp meter is the range of expected current measurement.

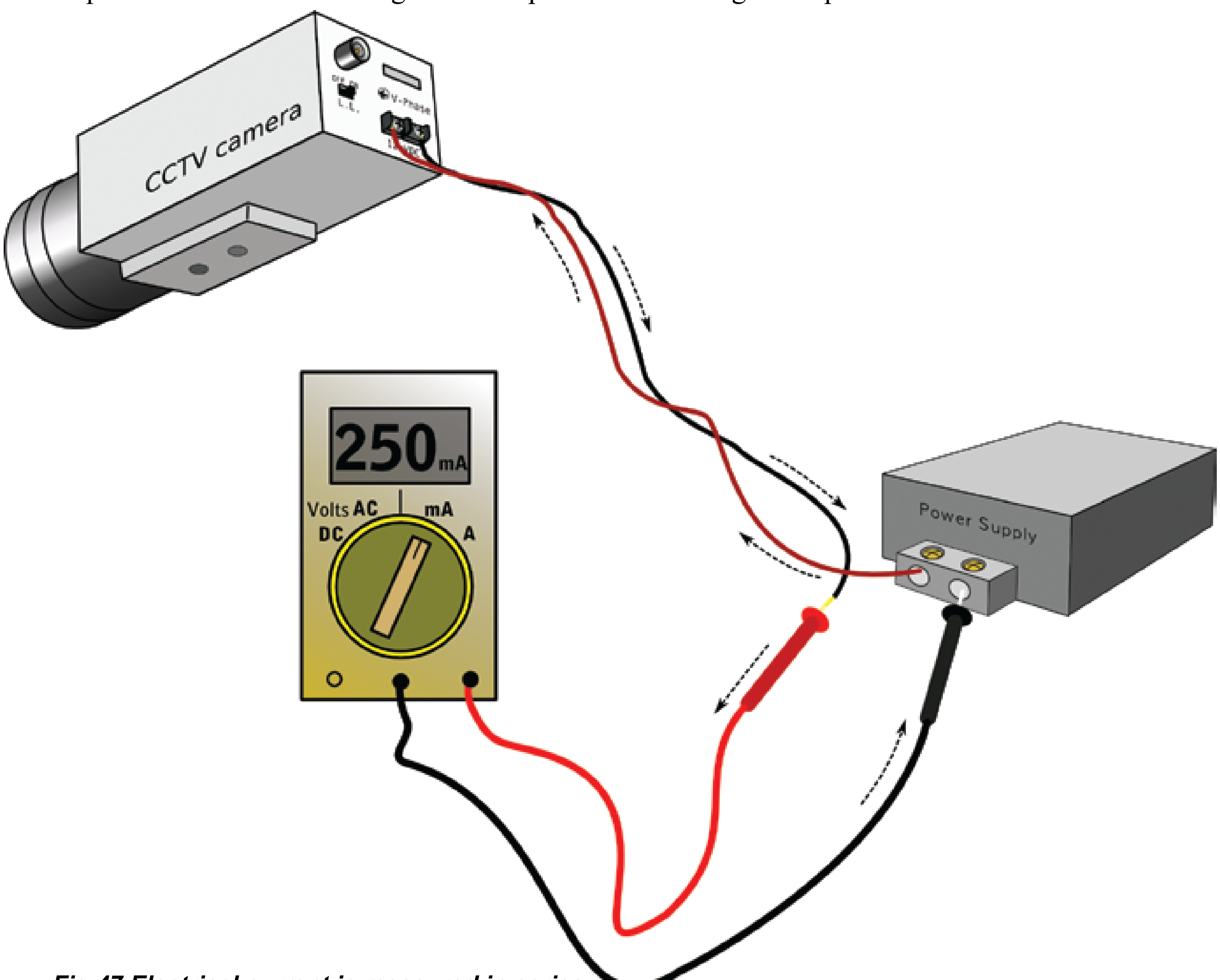


Fig.47 Electrical current is measured in series

The current should not exceed the maximum current range on the meter. Be extremely careful if you are measuring current of non-safe voltages (above 50V).

Warning: ***Make sure you have some idea of how much current the device to be measured can pull. If the current exceeds the meter's specifications it may blow the fuse or damage the meter.***

You should be able to safely measure current through CCTV cameras since they have a low current consumption (usually less then 0.5A).

Ohms

The Ohm [Ω] is the **unit of *resistance* [R] when using direct current or electrical *impedance* when using alternating current.** An Ohm is the electrical resistance offered by a current-carrying element that produces a voltage drop of one Volt when a current of one Ampere is flowing through it.

Resistance increases with longer wires, thinner wires or warmer wires.

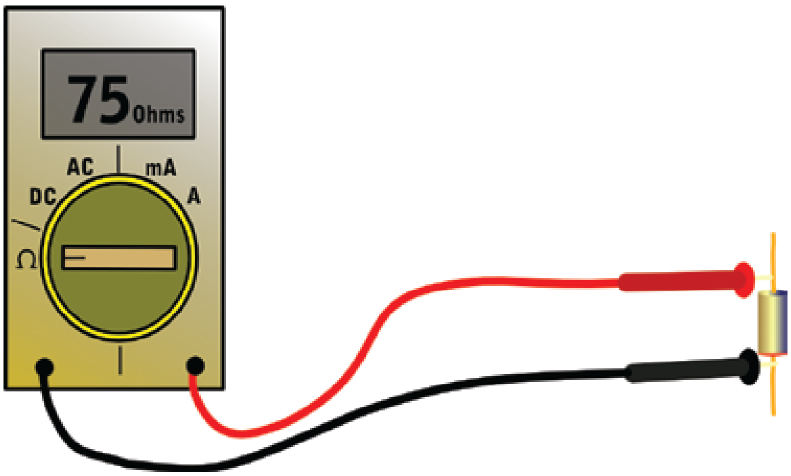


Fig.48 Resistance measurement

Measuring resistance is reasonably easy and simple. It should always be measured **without power applied**. An Ohm-meter delivers a small current through the meter's test leads, measures the current drawn from the internal batteries, then calculates and indicates the resistance value in Ohms. The lower the resistance, the more current drawn when connected to a power source.

When checking cables for their continuity, there are only two possibilities: short circuit or open circuit. When a cable has a short circuit at the other end the multi-meter measures very low resistance in Ohms. Depending on the cable length, the number shown on a digital multi-meter can be anything from 0 to a couple of ohms. When a cable is open at the other end, the resistance is infinite (very high) and is usually displayed as 0.L M Ohms. Many multi-meters have the physical symbol for Ohms - Ω.

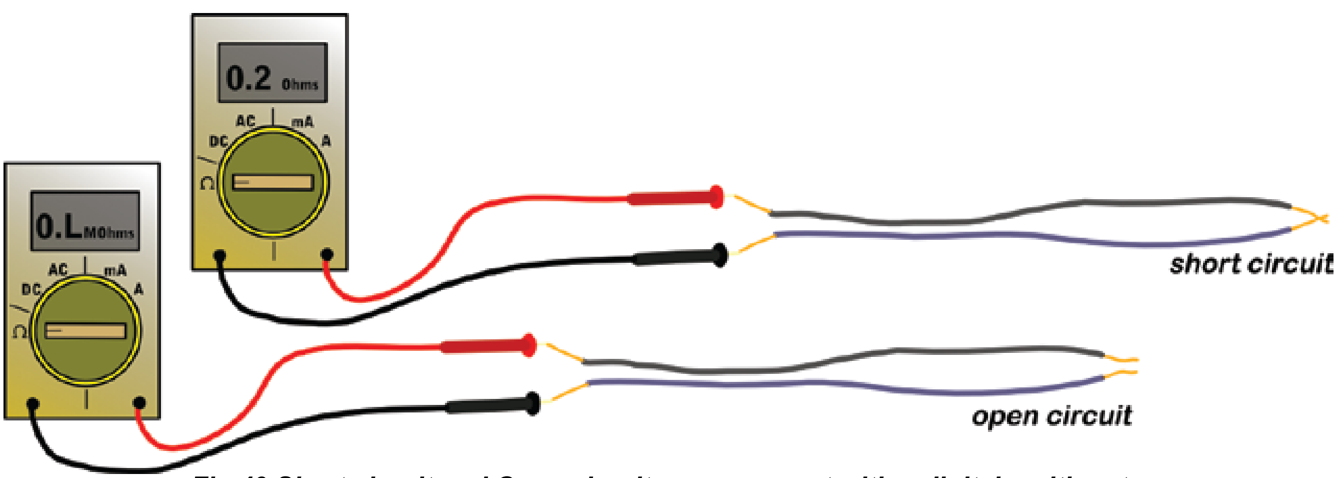


Fig.49 Short circuit and Open circuit measurement with a digital multi-meter

Watts

A Watt [W] is a **unit of power.**

Watts = Volts x Amps

Low voltage transformers will normally list the voltage followed by the VA (Volt-Ampere) or Watts such as "24VAC 40va."

Although, there are special Watt-meters for measuring wattage, we don't normally use them in CCTV. We typically calculate the wattage by measuring current consumption at a known voltage.

Hertz

A Hertz [Hz] is the **unit of frequency**. ***It describes the number of cycles an event occurs in one second***, it can also be expressed as [cycles/s]. The power grid in the US and Canada produces AC power with 60Hz, while Europe and many other countries use 50Hz.

There are instruments to measure all of the above units in one test equipment, often called Multi-meters, Volt Ohm Meters (VOM) or Digital Volt Ohm Meters (DVOM). Some multi-meters can also measure frequency and perform other functions such as diode and continuity testing.

DC and AC voltage

Direct Current electricity is what the name suggests. **This is a source of electrical energy, in which electrons flow in only one direction, from the negative to the positive terminal.** When the particles of the atom were defined, the electron was identified with a negative sign [-].

DC voltage can be produced by batteries, solar cells and other sources where one type of energy is converted into electrical. An advantage of DC is that it can be stored in batteries (for battery backup), transported if necessary, and used when needed.

Alternating Current electricity is a source of energy where the electron flow alternates between two terminals. *There is no positive or negative terminal here,* as their role of being positive or negative alternates 60 times per second, i.e., 60Hz. AC current is mechanically produced by the movement of magnetic fields through coils of wires.

The main advantage of AC electricity is that it creates alternating electromagnetic fields around the conductors through which it flows. In turn, this can create alternating electrical current in a conductor passing through that field. This is the principles of transformers were AC voltages can be decreased or increased. DC electricity cannot create an electromagnetic field but only an electrostatic field, which doesn't have the same properties as AC.

Being able to transform AC voltage by using a transformer allows us to deliver less current to achieve the same power delivery (since power is the product of voltage and current). We can power 24VAC cameras at longer distances than 12VDC cameras due to the lower current and the higher starting voltage. We will calculate voltage drop later this the chapter.

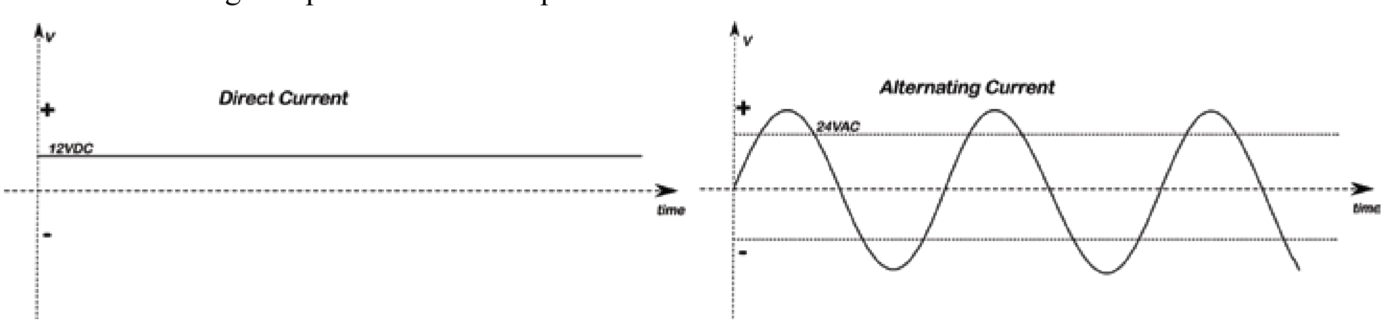


Fig.50 The difference between Direct Current (DC) and Alternating Current (AC) power sources

Another important advantage of AC powered cameras is that they are usually designed to be able to lock their vertical TV field rate (60Hz) to the frequency of the power grid. When all cameras in a system are set to follow the grid frequency, they are "Line-Locked" (LL). The end result is that all cameras will be synchronized to the line power (providing they are on the same phase) and to each other. This makes video signal switching between various cameras smooth and without picture-roll. It also helps some recorders record faster as they do not need to do time base correction (TBC) internally.

When using LL cameras, the installer should also be aware of the three-phase power system. Each of these phases delivers 120VAC relative to ground, but their phases are displaced by 120˚ between each other (this is a result of the way three phase generators produce electricity). If one LL camera is connected to one phase, and another remote camera to another, they cannot be synchronized between themselves unless there is a way of adjusting the trigger point for locking the video signal to the line power to compensate for the 120˚ phase difference. Most line-lockable cameras have phase adjustment.

Electrical parallel and serial connections

Before describing electrical circuits, we need to define some basic electrical symbols.

Here is a basic circuit with a camera being powered by a battery:

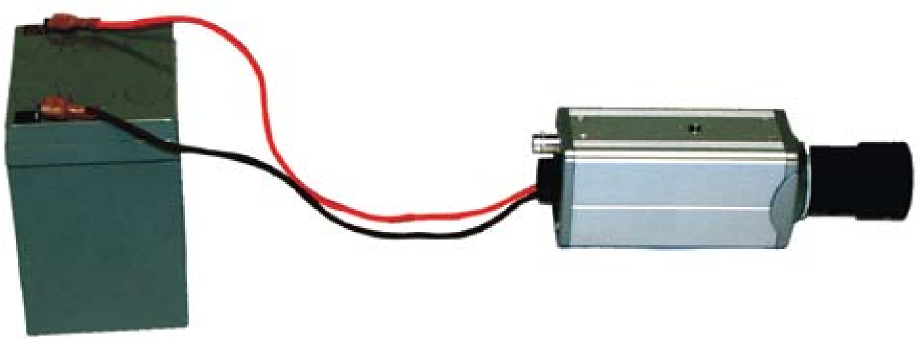


Fig.51 A 12VDC battery can power a DC-powered camera

This is a schematic representing the above picture:

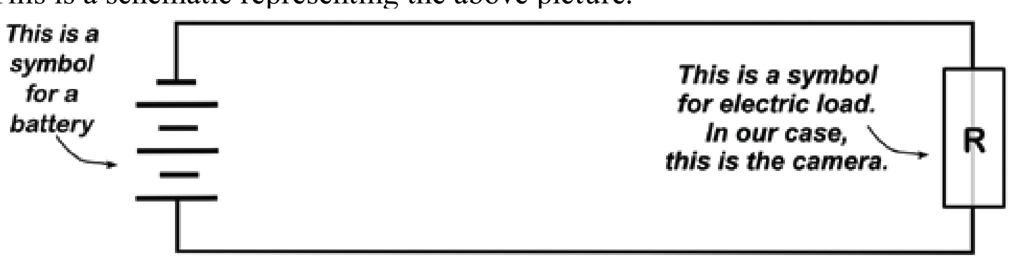


Fig.52 This is a schematic representing above Fig.49

Here is a basic circuit with a camera being powered by an AC transformer:

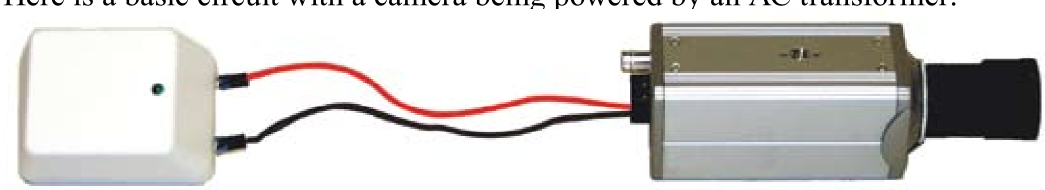


Fig.53 A 24VAC camera powered by a transformer

This is the symbol for an alternating current power supply (transformer)

Fig.54 An electric circuit symbolizing the connection on Fig.51

This circuit shown below is an open circuit (possibly a switch, or broken wire). Current cannot flow.

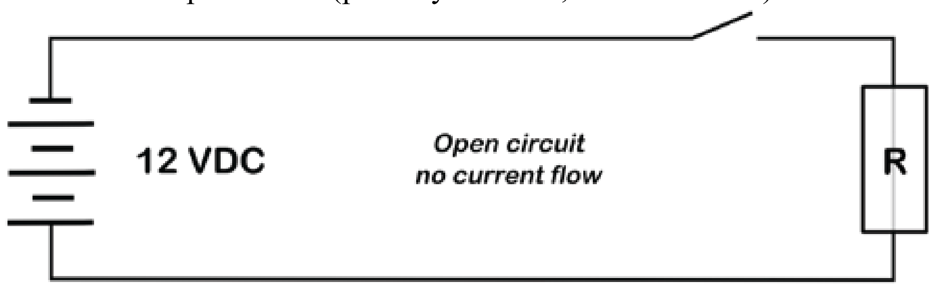


Fig.55 Open circuit

This circuit shown below is a short. Current will flow through the path of least resistance and not flow through the camera. The power supply will fail because of the current overload.

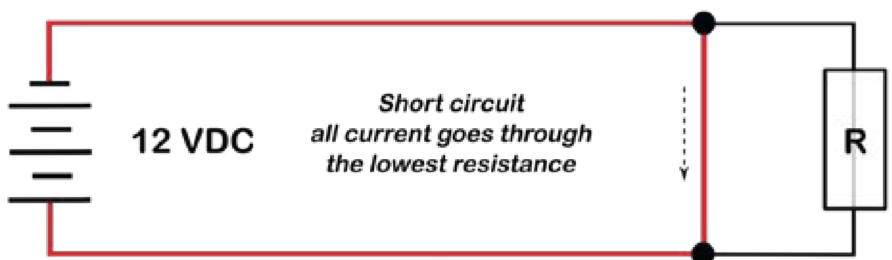


Fig.56 Short circuit

Serial and Parallel Circuits

The connection of two or more power sources or powered devices are described as serial, parallel or a mixture of both. In serial circuits, the devices are daisy chained; each one connected through the next.

Although serial circuits are common in alarm systems, they are rarely used in CCTV systems.

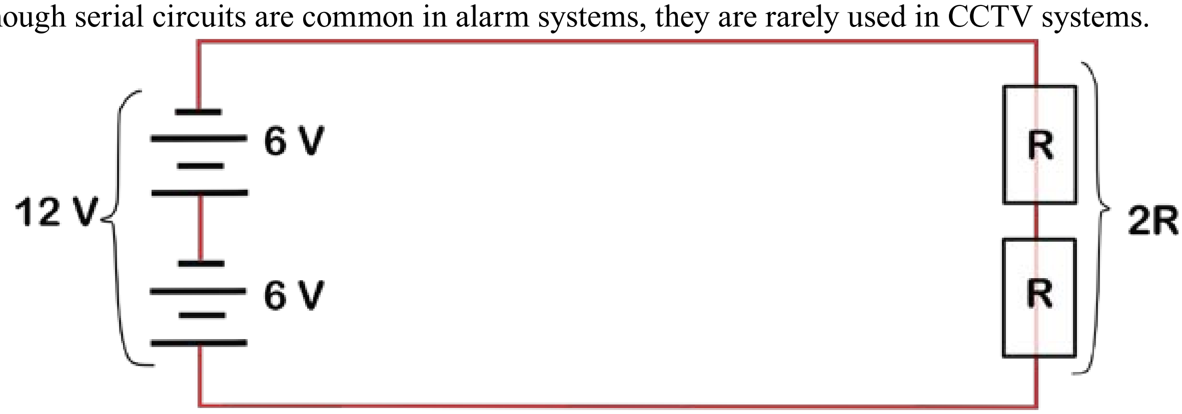


Fig.57 Serial connections of power and serial loading

We would NEVER connect cameras in series as the voltage potential between cameras would not be sufficient to power the cameras.

Although rarely used, an example of a mixed circuit would be if we needed to connect two 6 Volt batteries in series to power one or more 12VDC cameras. By connecting the positive side of one battery to the negative terminal of the other, we "create" a 12VDC battery.

We commonly use parallel circuits to connect multiple cameras to a single power supply.

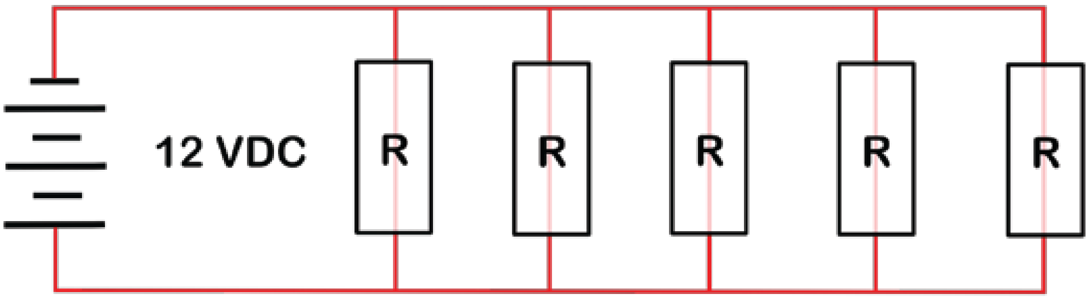


Fig.58 Parallel loads circuit

Be very critical when choosing a power supply. When some manufacturers quote 12V/2A, the 2A may only be a maximum rating. This is usually defined for short periods of peak deliveries. You cannot count on a constant load of 2A with any 2A supply. It really depends on the make and model.

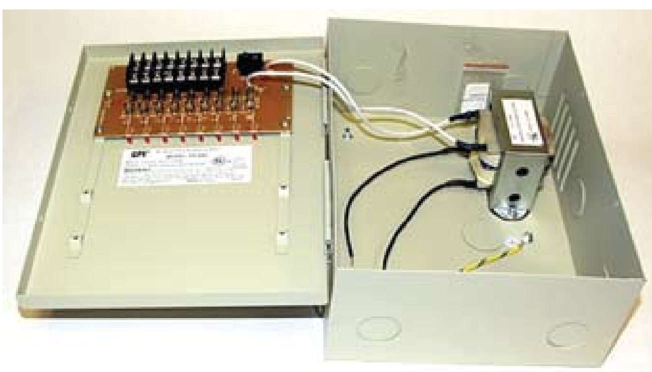


Fig.59 Power supply for parallel cameras

There are three basic plug-in power supplies that are very common and look very similar; **24VAC**, **12VDC** and **regulated 12VDC**. It is important that you recognize and understand the differences. Many **12VDC** cameras have been ruined (had the magic smoke come out) when they were inadvertently connected to a **24VAC** supply. (Remember that voltage equates to pressure.)

Fig.60 Plug-in Transformer

Using a volt meter to check the voltage of a 24VAC transformer without any cameras attached will normally read several volts high. Once one or more cameras are attached, the voltage will drop to an acceptable range. Since 24VAC plug-in's normally range from 10va to 50va, even the smallest (10va) has enough current to power most cameras (3-4 watts).

DC power supplies are made by installing rectifiers and filtering circuits within the case with the transformers. Be aware that a camera that draws 3 or 4 watts is using in excess of 300 milliamperes. Many small DC plug-in's are rated less than that and could be permanently damaged if used to power a camera and certainly would be destroyed if trying to power more than one camera.

Unregulated 12VDC power supplies might read as high as 19 volts without a load and even with a camera attached might still read several volts higher than 12. Usually no intervention is required for a couple of hundred feet of power cable run because of the voltage drop, but if the camera is in the vicinity of the power supply, the excessive power must be dissipated somewhere and, normally, this is in the camera, causing premature failure.

Regulated 12VDC power supplies have additional circuitry to keep the output voltages within safe tolerances to limit over voltage damage to the camera. Again, be sure that the power supply is rated for more amps than the total draw of the attached camera(s).

Ohms law

Ohms law states the basic electrical relationship between Voltage (pressure), Amperage (current flow) and Ohm's (resistance).

Amperage = Voltage / Resistance

or restated as:

Voltage = Amperage x Resistance

Just as important as being able to solve the above simple formula is understanding the basic relationship between Voltage, Amperage and Resistance.

Imagine that electricity is water, as illustrated in the beginning of this chapter. Assume that we have steady water pressure coming from our garden faucet. The resistance to the flow of water would be determined by the length of the hose and the diameter of the hose. When we attach a hose that is 3/4" in diameter and 100ft long we will have a certain amount of water flowing through the hose. Imagine we have a sprinkler on the end of the hose that has enough water flow to produce a perfect spray pattern. If we make the hose longer or smaller we increase the resistance and the flow will be reduced and our sprinkler will no longer work properly. Conversely, if the hose is shorter or larger the resistance will decrease and the flow will increase and the sprinkler works properly again. If we need a certain amount of flow and our resistance is fixed, then the only way to increase the flow would be to increase the pressure at the faucet by further opening the valve.

If we substitute electricity for water we have the following:

The faucet is the power supply that supplies a certain pressure (voltage). Our hose is replaced by the wire and other devices in our circuit. As in the hose analogy, resistance increases if the wire is longer, smaller in diameter and if it is warmer. We need a certain amount of pressure and flow at our cameras to insure that they work properly. There are a couple of simple formulas that will allow us to ensure that our cameras have the power they need.

Besides understanding the basic relationship in Ohm's law, there is another simple formula;

Power (expressed in Watts) = Volts x Amps

This is fairly easy to remember because most of our power supplies' capacities are listed with imprints such as 24VAC/40VA, or perhaps 24VAC/1.6A, which would indicate the same capacity. Most of our cameras are clearly marked with the required voltage and the current draw, or power capacity.

Power to the camera

There are three critical issues to be addressed when powering cameras:

1. Right type of power AC or DC
2. Correct voltage
3. Sufficient power supply capacity (amps, VA or watts)

First, the voltage (pressure) and type of electricity (AC vs DC) from the power supply must be the voltage and type that the camera requires. Although diesel fuel and gasoline are both petroleum products they are not interchangeable. Using the wrong type of fuel will damage the engine. 12VDC and 24VAC are not interchangeable.

Since we know that the voltage will drop depending on the length and gauge of the wire, we need to ensure that our camera power cable will transmit sufficient power to the camera. We do that by solving a simple voltage drop calculation and eventually with experience we will develop a "feel" for what will work.

The American Wire Gauge (AWG) defines the sizes of wire from 0000 to 40. **The larger the number, the smaller the wire. Roughly, for every 6 gauge decrease, the diameter will double. Every 3 gauge decrease doubles the cross section. The wire we normally use would be in the range of 16AWG to 22AWG.**

TABLE 2 (Wire gauge)	
AWG	**Ω (Ohms) per 1000'**
24	25.7
22	16.2
20	10.1
18	6.4
16	4.02
14	2.52
12	1.59

Fig.61 Wire gauge wheel

We have already mentioned that wire resistance increases as the wire gets smaller, longer or warmer. The wire gauge chart (Table 2) is based upon an ambient temperature of 68˚F. Note that the larger the number, the smaller the diameter of the wire.

As you can see from the AWG table, there is a big difference between the resistance of 16 gauge wire at 4 ohms per thousand feet and 22 gauge at 16 ohms per thousand.

Voltage Drop Calculations

Fig.62 Camera power consumption details

Let's see what happens when we try to power a single 12VDC camera 1000 feet away using 22 gauge, 18 gauge and 16 gauge wire.

We will then do the same calculations using a 24VAC camera.

We normally have to solve two basic equations to arrive at the answer. Before we can solve Ohm's law (Voltage = Amperage x Resistance), we will need to determine the current draw of the camera. Camera power consumption is normally listed in Watts, while the transformer's capacity is shown in VA's, which is from the formula Volts x Amps.

Let's assume we are using a single 12VDC camera that has a label indicating that it consumes 4W.

Using basic algebra: Watt = Volts x Amps, we obtain: 4w = 12v x Amp

Amp = 4w / 12v

Amp = 0.33A

Our cable resistance can be determined from the table 2 on the previous page. Since we are using 22 gauge wire and going 1000 feet from the power supply to the camera and then returning 1000 feet from the camera to the power supply, our power is actually "traveling" 2000 feet. From the table we see that 22 AWG wire is 16.2Ω per thousand, our total resistance is 32.4Ω.

Inserting our known values into Ohms law: Volts = Amps / Resistance

Volts = .33 x 32.4

Volts = 10.69

If we start with 12 volts less 10.69, we have less than 2 volts at the camera. Not good!

18 awg wire is 6.4Ω per thousand, total resistance is 12.8Ω.; voltage drop = .33 x 12.8; or 4.22volts

If we start with 12 volts less 4.22, we have 7.78 volts at the cameras. Still not good.

16 awg wire is 4.02Ω per thousand, total resistance is 8.04Ω.; voltage drop = .33 x 8.04; or 2.65volts

If we start with 12 volts less 2.65, we have 9.35 volts at the cameras. Still not there.

There is a solution that might be used if a better alternative is not available. We might use 18awg but this time use a 16VDC power supply. 16 volts less 4.22 would give us 11.78 volts. Close enough!

What if we use a 24VAC camera instead?

The current required by a camera is 4W / 24V = 0.17A. Note that our amperage is half because our voltage is double. Because of this, there will be less voltage drop across the same power cable length when compared to the 12VDC powered camera. Repeating the calculations we just worked for 12volts;

22 AWG wire is 16.2Ω per thousand, our total resistance is 32.4Ω.

Inserting our known values into Ohms law: Volts = Amps / Resistance

Volts = .17 x 32.4

Volts = 5.5 drop

If we start with 24 volts less 5.5, we have 18.5 volts at the camera. Not quite enough

18 awg wire is 6.4Ω per thousand, total resistance is 12.8Ω.; voltage drop = .17 x 12.8; or 2.17volts

If we start with 24 volts less 2.17, we have 21.8 volts at the cameras. Very close.

16 awg wire is 4.02Ω per thousand, total resistance is 8.04Ω.; voltage drop = .17 x 8.04; or 1.37volts

If we start with 24 volts less 1.37, we have 22.63 volts at the cameras. Close enough.

As mentioned earlier, power supplies tend to supply slightly higher voltage than what is listed. A single 24VAC camera might work properly at 1000 feet but it is rare that we would ever run power cable that distance.

From the preceding set of calculations have shown that we can almost double the distance to the camera by switching from 12VDC to 24VAC using the same gauge of power cable.

Power supply capacity calculation

The power supply must have sufficient current capacity (amperage) to power all of the cameras attached to it with power to spare. The amperage of the power supply must be greater than the total amperage draw of all of the attached devices.

Compared to calculating voltage drop this is very easy.

Let’s assume that you are using cameras with power consumption of 4W each and that the power supply is rated at 40VA.

Mathematically, you should be able to connect 10 cameras; after all, 10 cameras times 4watts each would be 40 watts. Practically, this is a false assumption.

Never run a power supply to it’s full capacity as this will overheat the components in the supply and eventually damage or shut down the supply. This is especially critical if you don’t have sufficient cooling where the power supply is installed. Heat reduces the power supply’s efficiency and causes the maximum current delivery to be reached sooner. Cameras need to run constantly, 24 hours a day. The best rule is to leave at least 30%-40% “breathing” capacity. Your 40VA supply shouldn’t have more than 6 or 7 cameras attached to leave adequate headroom.

Now for a “real world” example:

Let’s assume you are given an 8-camera POWER SUPPLY (24VAC, 100VA), seven (7) CAMERAS (24VAC, 4W), and a box of 18/2 cable (18AWG with 2 conductors). Three (3) of the cameras are on individual runs of 100ft. Three cameras share a single run of 200ft. The last camera is on a single run of 400 feet.

The totals are 7 cameras x 4W = 28W of power draw.

A 100VA power supply is sufficient with plenty of spare power.

Known values are 6.4Ω /1000ft; 0.17A draw per camera (4W/24VAC)

TABLE 3 (Example voltage drop)						
Numbers	Distance (feet)	Resistance (Ω)	Current (A)	Voltage drop (V)	Total	24VAC (less drop)
1	100	1.28	0.17	0.17/1.28	0.22	23.18
2	100	1.28	0.17	0.17/1.28	0.22	23.18
3	100	1.28	0.17	0.17/1.28	0.22	23.18
4,5,6	200	2.56	0.68	0.68/2.56	1.74	22.26
7	400	5.12	0.17	0.17/5.12	0.87	23.13

In the above example, both our voltages and draw are well within acceptable limits

4. Make low voltage splices and junctions

(Tools required for this section: cutters, stripping tool, crimping tool, soldering iron, screwdrivers, heat-gun, heat-shrink)

Low voltage splices and junctions

During the cable installation process, it is important to know the maximum distance required for the cable runs, so that adequate cable can be prepared. If, however, the cable run needs to be longer than the available cable lengths, proper splices and junctions need to be made. The length of the cable on a new roll or box is usually printed on an attached label.

The procedure in preparing junctions and splices has certain simple rules, which an installer needs to learn and put in practice. There might be some differences if a power cable needs to be extended, as opposed to a signal cable (like coaxial or UTP), but we will cover both instances here.

One very common method of joining wires is by use of a joint terminal or terminal strip. Although this method does not protect the wires from oxidations and exposure to environments, it is very easily implemented as it only requires correct stripping of the wires and joining them properly. Using proper copper crimping terminals with labels will make life easier to anyone trying to service later.

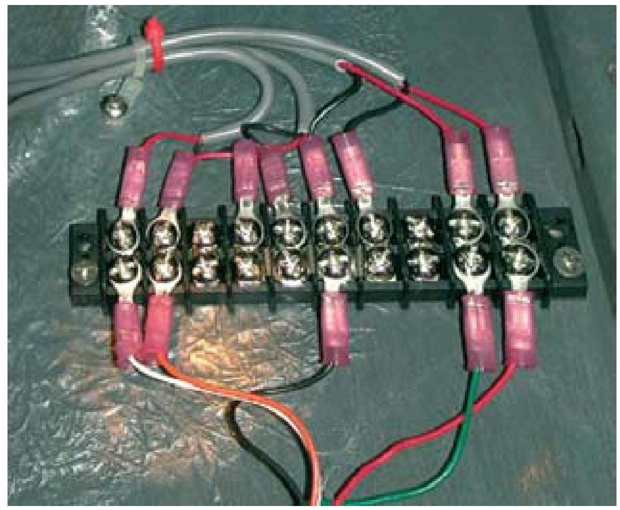


Fig.63 Terminals are often unavoidable

If spade lugs are not available to crimp onto the ends of the wires (see Fig 63), stripped wire can be twisted and/or soldered to prevent short circuits between terminals. The terminals can be wrapped with waterproof and fireproof tape for further protection. Attention should be paid to the length of the bare wires extending out of the terminals to prevent short circuits. The length of the stripped wires of the joining cables should be only long enough to be inserted in the terminal. Before this is done, wires should be twisted in to improve the electrical contact between them, or better still, they could be soldered after being twisted. Soldering can be done with an electric or gas soldering iron. To prevent melting the insulation, care should be taken not to overheat the wires. Terminal strip extending or joining cables is also very practical if voltages needs to be verified.

A second method is to use crimp connectors that are specifically designed to facilitate secure splices. Some connectors require that the wire not be stripped prior to splicing. With others, stripping is required. The connection is completed by using special pliers or crimping tools. Some connectors are filled with a moisture resistance gel to prevent premature oxidation of the cable and metal parts of the connector. Follow the manufacturer's instructions!

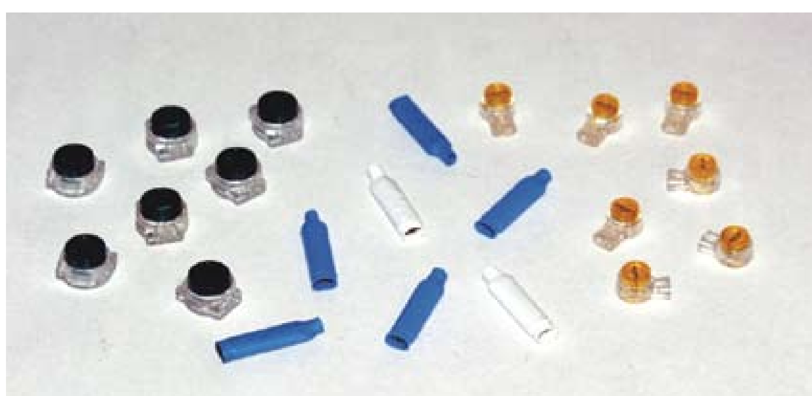


Fig.64 Crimp connectors for low voltage wire. Stripping is not necessary for the terminals on the left and on the right

The third method involves a bit more preparation and work, but is more protected and secure. This is the method of stripping the wire insulation at a standard length of 1/2 inch, twisting the wires symmetrically around each one, soldering them and finally heat shrinking them at the point of joining. Then, joined wires are symmetrically bent each one to the other side of the cable (if there are more then one pair, separate them equally) and, finally, all these joints are covered with an appropriate sized heat-shrink and mold them.

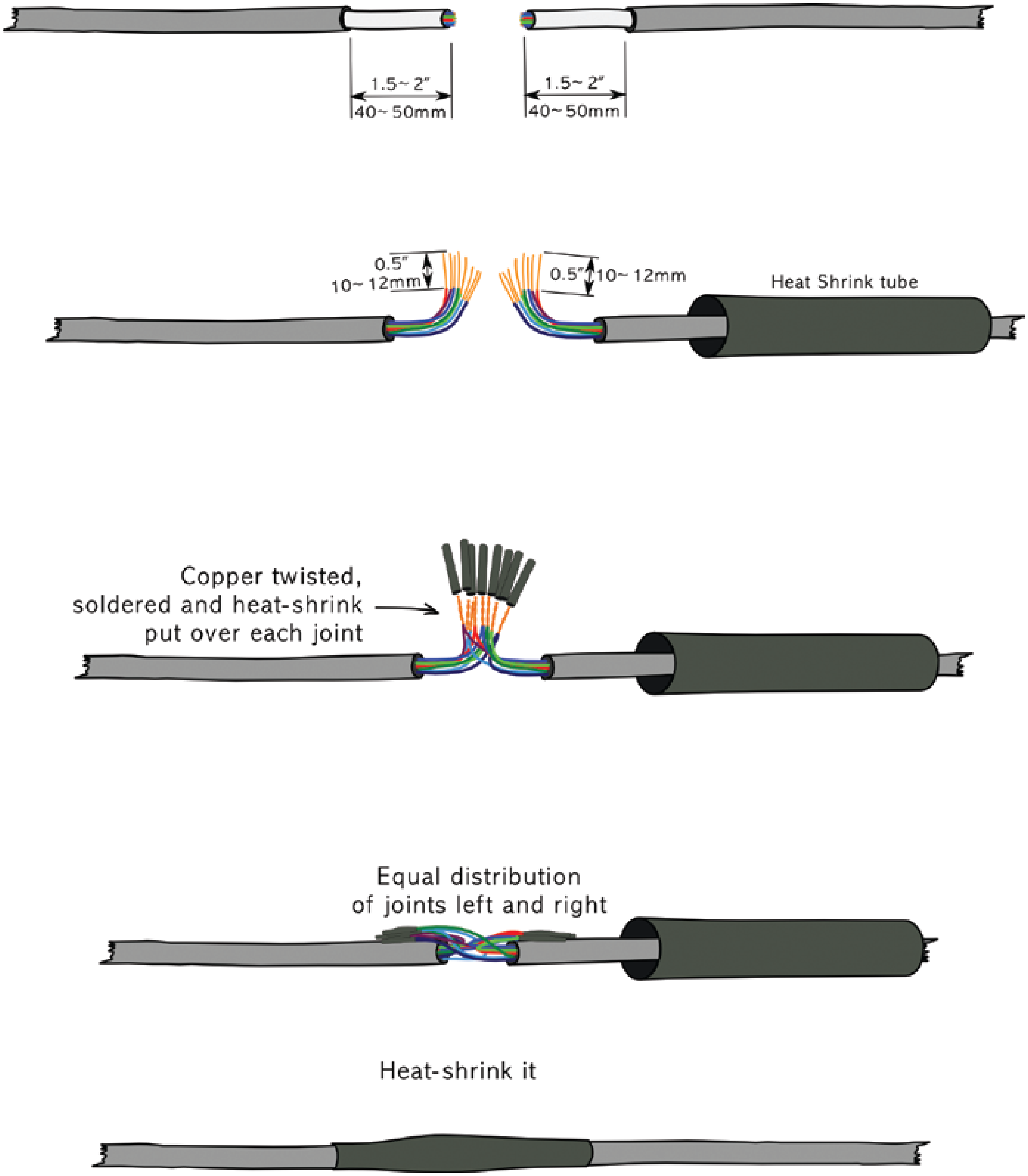


Fig.65 Good quality joining of multi wire cables is very important

Coaxial Cables

Fig.66 BNC barrel

Extending coaxial cable length can be made with BNC-BNC male-female terminators. More common though, is to have male BNC's on both ends of the coaxial cables, which are then joined by using a barrel adaptor (female BNC sockets on both ends). Introducing more points of possible failure is more risky in the long term (two in this case, as opposed to one when male-female BNCs are used), so efforts should be made that there are as few breaks in a cable run as possible. If this is the only option available, utmost care should be given to these connections and terminations. Always use the best BNC terminators, preferably gold-plated so that oxidizing is minimized. When two such terminations are made and joint, usually a heat shrink protector is put on top to further protect from breaks, oxidizing and exposure to environments. If heat shrink is not a viable option, use good quality electrical tape to keep the connection from touching other connectors, metal or an electrical ground. Failure to do so could result in ground loops or interference in the cable. Care should be always be given to keep all BNC connections isolated. Some installers use bright colored electrical tape to make the splice easier to find in the future.

Fig.67 Rubber sleeves help prevent oxidation and sharp bending

Keep in mind that 1000 ft. is the theoretical maximum distance for a single run when RG-59/U cable is used. An equalizing amplifier is required for longer distances.

The specifications for **network** data cables using Cat-5 and Cat-6 limit single runs to no more than 100 meters (330 ft). Splices are not recommended and can reduce the total functional length of the run.

Cat-5 cable used as **unshielded twisted pair** (UTP) cable (discussed in a later section) is not considered "data" and can 3000 ft. or longer. If RJ45 extenders are used, they should be made of good quality, non-oxidizing contacts (such as gold plated) to insure good, reliable connectivity.

Figure 68 shows a RJ-45 female-female adaptor that can be used with Cat-5 or Cat-6 cable.

Courtesy of Lindy

Fig.68 RJ-45 extender adaptor

5. Coax and twisted pair terminations

(Tools required for this section: coax stripping and crimping tools, Cat-5 stripping and RJ-45 crimping tool)

The most common methods of connecting analog CCTV cameras to monitors or other receiving equipment (such as digital video recorders) are by coaxial cable or by Unshielded Twisted Pair (UTP).

Although the fiber-optics method is not covered in this certification level, it is theoretically the best method of signal transmission (assuming the terminations and fiber cable run are done correctly). The signal is transmitted by light instead of electrical current flowing through copper wire. There are several strong reasons for using optical fiber. The light is immune to electromagnetic interference (EMI), radio frequency interference (RFI) and grounding issues. Fiber optic also provides a very wide signal bandwidth and is able to travel very long distances.

Fig.69 A typical copper braided coaxial cable

Fig.70 A typical Cat-5 cable

In this manual, we are going to concentrate on video and data transmission via coaxial and/or twisted pair cables.

Plenum and Non-plenum cables

In general, an installer must use either *plenum* or *non-plenum* type cable, depending upon where it is to be run. This applies to all cable types. Be sure that the cable you are using meets all the applicable building codes where you are working.

Plenum cable is cable which is rated to be run through plenum spaces. The plenum is the hidden space within a building that is used for the return air for heating, ventilation, and air conditioning unless the return air is within return air ducts. Plenum space is normally above a suspended ceiling or under a raised floor. If a buildings doesn't seem to have plenum spaces, then most likely the cabling and the HVAC ducts will be within plain view.

Plenum cable must meet two requirements to meet most fire codes:

- Must not burn easily
- Must not emit toxic fumes when exposed to extreme heat

Because of these requirements, plenum cable is usually much more expensive than non-plenum cable. Plenum cable is normally more stiff and difficult to work with than non-plenum cable. Most plenum cable is covered with Teflon.

Non-plenum cables are used in general purpose cabling installations. They are very flexible and less expensive. In a server environment, non-plenum cables are usually enabled for use in the main area of the room, below the ceiling or above the raised floor. Non-plenum cables are often made of polyvinyl chloride, (PVC), and if they catch fire, produce toxic smoke.

There are several types of non-plenum cable including; communication (CM), Class 2 (CL2), Class 3 (CL3), Riser (R) and others. Cables of a higher rating may be substituted for a lower one.

Riser rated cable must be used for vertical runs penetrating more than one floor or in vertical shafts. Riser rated cable has a lower burn rate than standard communication cable.

Irrespective of which type of cable you are going to install, there are a few common and important rules to follow:

- Conduct a thorough site survey prior to cable placement.
- Develop a cable running or pulling plan.
- Do not exceed the cable minimum bend radius.
- Do not exceed the cable maximum pulling force and recommended load.
- Use good tools and connectors when terminating cables.
- Label all cables and document the installation.
- Test all cables for continuity.

Coaxial cables

The signal transmission using coaxial cable is also known as *unbalanced* signal transmission. The term "unbalanced" is used because of the way the video signal travels along the coaxial cable length. The center core is the actual "active" wire with the signal, while the copper braided shield protects the center core from external electromagnetic interferences and it is also used to connect the two ground potentials between the source (the camera) and the recipient (the monitor or DVR). This is probably the most common method of transmitting video in small– to medium– sized systems, but it is also very prone to interferences due to ground potential difference between the camera end and the monitor/DVR end.

Fig.71 A good BNC termination with sleeve

This difference in potential allows current to flow through the shield and is call a Ground Loop. This kind of problem is similar to the 60Hz buzzing you may have heard on badly connected audio Hi-Fi equipment where many audio components are not connected to a common ground. The demonstration of ground-loop in CCTV can be seen as faint, horizontal bars going slowly up or down the screen. Remember, our video signal is only 1 volt at it's brightest. It doesn't take much outside interference to effect our video signal.

Although any electromagnetic interference (EMI) in the vicinity of the coaxial cables can be induced in the cable shield, the theory is that, if the ground potential on both ends are the same, the EMI would be discharged and not pose any noticeable problem. If, however, the ground potentials are different, than the induced EMI creates a current loop that goes from the higher ground potential to the lower one, hence the name "ground-loop." Since most of the coaxial cable is run in buildings near line power cables and along power cable trays, the 60 Hz EMI from the power cables in a building is the strongest and most common "creator" of ground-loop current. The real problem is that this can vary with time of day and it depends on the amount of power consumption by the users of the power. A ground-loop might not be visible during summer and daytime when power usage is minimal compared to mornings and evenings in winter time. Another factor is the length of the coaxial cable being run close to the power cables, where clearly the longer cables will pick up more of the EMI. In summary, the coaxial cable shield acts as a big receiving antenna.

The real problem with potential ground-loop in a system is that it cannot be predicted, as it depends on so many variables. Only when cables are installed and terminated, and the site is operational at its full extent (e.g. a newly completed and opened-up shopping center), ground-loops might become evident. Eliminating the ground-loops after all the installation is done is difficult and some-times impossible.

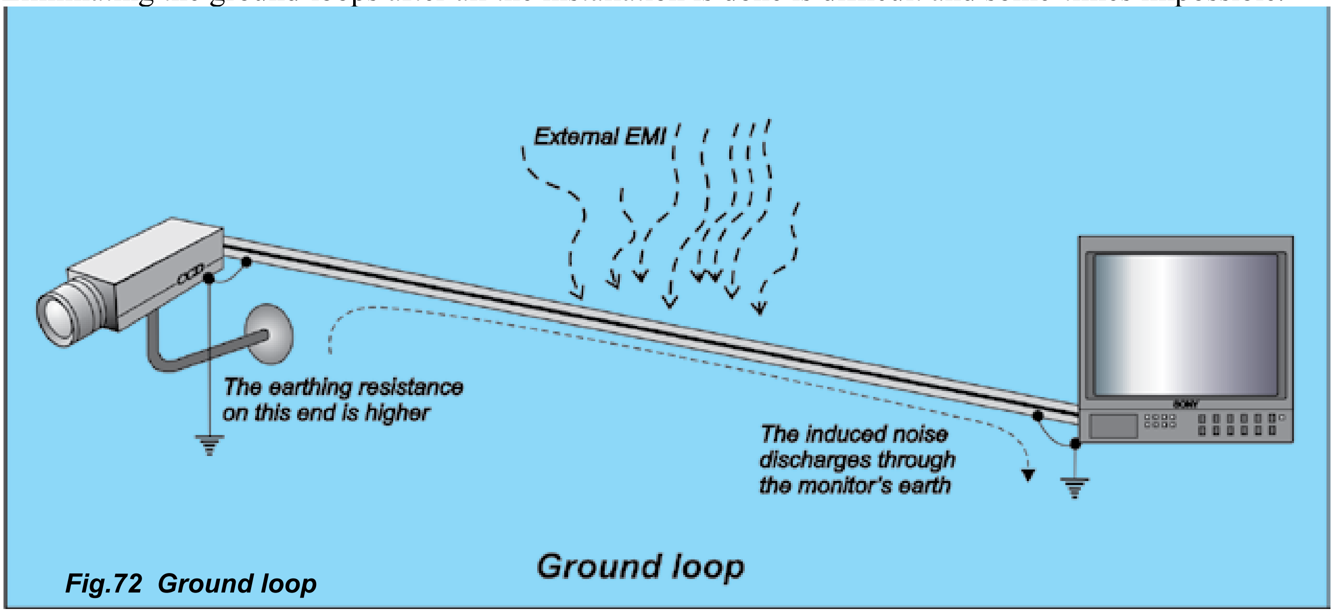


Fig.72 Ground loop

Typical resolution of an existing ground-loop is by isolating the camera end from the receiving end using ground-loop isolators, also known as ground isolation transformers. This is a costly exercise and does not always fix the problem in its entirety, as it depends on the quality and the design of the ground-loop isolating devices. A real problem for installers/technicians is finding out which of the many camera signals (coaxial cables) is the one that has the strongest EMI. This is why some of the most important rules in running and terminating coaxial cables have to do with minimizing the potential problems that can become obvious only after the installation is completed.

A basic rule when installing any low voltage cables near power cables is to maintain a separation of at least 12 inches. If low voltage cables need to cross power cables, they should cross at a 90 degree angle.

Whenever possible, use a multi-camera power supply to supply power to all of the cameras. It should be plugged in at the the same point as the rest of the head-end equipment, preferably using an Uninterruptable Power Supply (UPS). Good grounding practices on power plugs is very important. Lastly, the coaxial cable termination must be as good as possible, using proper installation tools and the correct connectors.

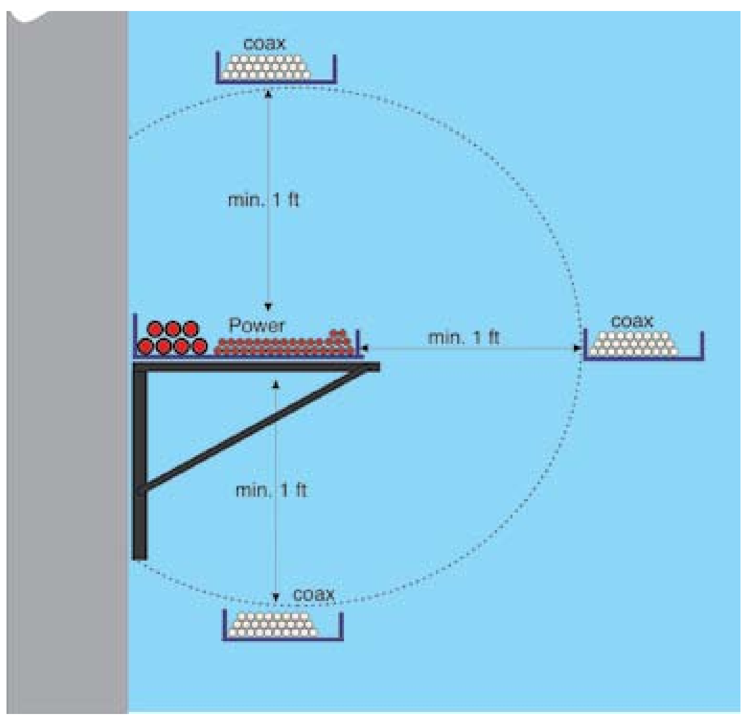


Fig.73 All low voltage cables including Coaxial should be at least 1 foot away from power cables

The overall quality of the coaxial cable termination depends on the quality of the cable, the connectors (the precision of the manufacturing, as well as the material, e.g. gold-plated pins vs. oxidizing coating), the tools, and certainly the skills of the installer technician.

There are some basic cable run and termination rules that we will cover, but to explain this, technicians must first understand the meaning of impedance.

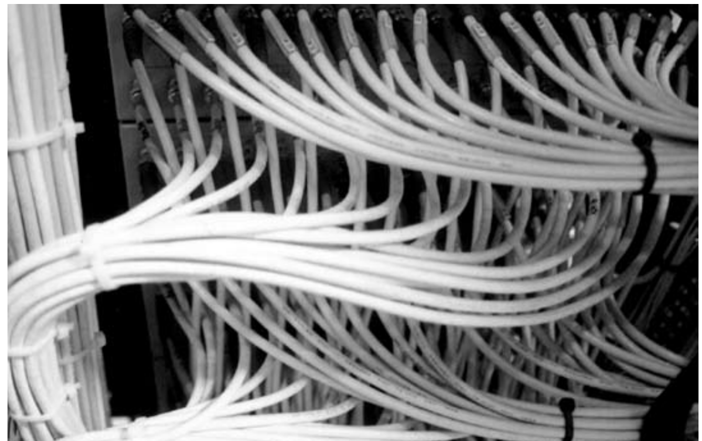


Fig.74 Neat cabling is especially important in large

Impedance and minimum bending radius

The theory of electrical circuits says that *maximum energy transfer from a source to a recipient over an electric cable happens when the output impedance of the source is matched by the input impedance of the transmission cable and this is then matched by the input impedance of the recipient.*

In practice, this means a camera as a source has an output impedance which, in CCTV, happens to be defined by the design and the television standards as 75Ω (Ohms). The coaxial cable and the terminating impedance should be 75Ω. The output impedance of a video source and the input impedance of a recipient device are defined by their electronic design. ***The impedance of the cable is defined by it's physical parameters.*** This includes the electrical property of the conductors (the shield and the center core), the dielectric properties of the insulator, the physical diameter of the center conductor and the diameter of the shield.

For a good signal propagation, all of these parameters need to be ***uniform and consistent along the cable length***. If. however, there are inconsistencies, even with the best coaxial cable it is possible to get bad video signals if it was run in a manner that affects the physical properties at certain points, such as too small bending radius, heavy weight on the cables that squashes it physically, too tight cable ties that change the diameter of the dielectric at that point, and so on.

Cable impedance cannot be measured with a digital voltmeter. This is a complex electrical composition of inductance, capacitance, resistance and conductance along the cable itself. This is out of the scope of this manual. The important point to understand is that ***the impedance of a cable is defined by its electromechanical properties.*** There are various sizes of coaxial cable, which could have 75Ω impedance. The thicker the center core, the lesser the electrical resistance, thus making the "thicker" cable capable of delivering video signals to longer distances.

One of the important reasons for not exceeding the minimum bending radius during installation is to preserve the impedance of the cable at each point. A basic rule of thumb is that ***the bending radius of any coaxial cable should not be smaller than 10x the diameter of the cable***. For example, if the outer diameter of RG-59 cable is around 6mm, then the minimum bending radius should be 60mm (2.5"). Sharp bends with smaller radius will squash the coaxial cable at the point of bending affecting the impedance at that point. This causes a

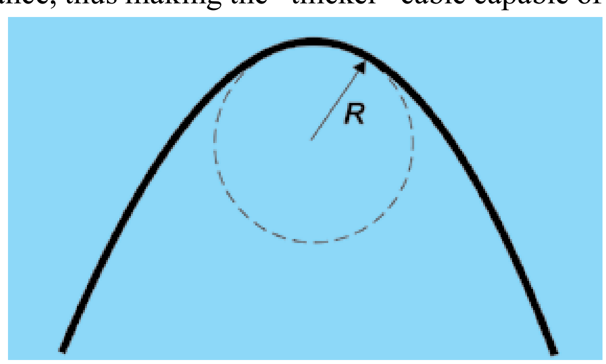


Fig.75 An important rule - Minimum bending radius should not be smaller than 10X the diameter of a cable

signal reflection from that point, which visually appears like double imaging on the monitor screen and/or loss of high frequencies, appearing as loss of sharpness.

Types of coaxial cables and connectors

The most common types of 75Ω coaxial cables in CCTV are RG-59, RG-6 and RG-11. The abbreviation RG comes from Radio Guide which represents the diameters and thickness of the wire components.

Installers should be aware of different RG coax constructions, all of which may offer 75Ω impedance, but not all are suitable for CCTV. The two most common styles of construction are; solid copper center core with 95% copper braided shielding -and- copper clad steel center core with a foil-lined steel braided shielding. A **solid copper center core is needed for CCTV signals** which are low frequency (usually lower than 10 MHz bandwidth) and require the full cross section of the center conductor for the least electrical resistance. Cable Television (CATV), Antenna (MATV), Satellite and other broadcast signals are modulated to specific channels. These higher frequencies (VHF/UHF) force the signal to travel more on the outer surface of the center conductor and make the use of copper clad steel center core more desirable. This is known as “skin-effect.”

A fairly common mistake for inexperienced installers is to use readily available RG6 copper-clad foil-shielded cable because they see it is commonly used for cable and satellite. This is not suitable for BNC crimping termination, and does not have suitable properties for basic composite CCTV signals.

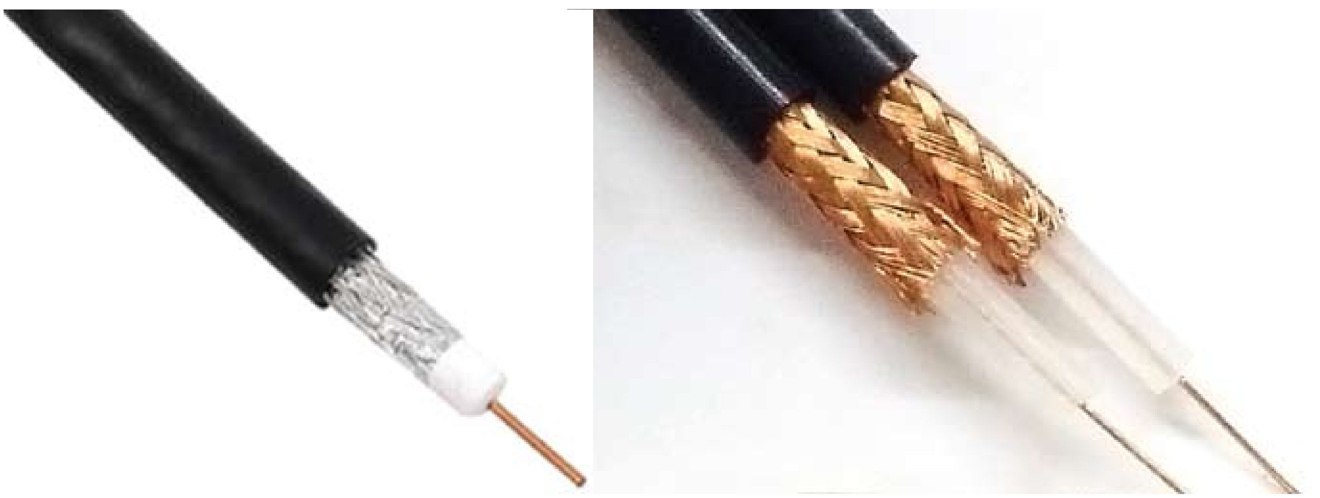


Fig.76 Only copper braided coaxial cables (on the right) are suitable for CCTV. The left coax is for MATV.

It should be noted that not all RG-59 coaxial cables, even if they are 95% copper shield, have the same gauge copper center conductor. The preferred cable has a center of 20AWG. Beware of cheaper cable that is manufactured with a 22AWG center conductor. Not only does 22AWG have higher resistance (only shorter cable runs are possible) but crimping of the center pin is more difficult.

Typical maximum distances allowed (without amplification) for various cables can be different, but the following is a safe recommendation: RG-59 from 750-1000 ft, RG-6 from 1000-1500 ft and RG-11 from 1500-2500 ft.

These numbers are only a guide and need to be verified for every different model of cable. They can also can be different when a color signal is used instead of a black & white due to the high frequencies losses. In actual practice, if a run is longer than a standard 1000ft roll of RG59, then alternative cabling such as twisted pair or fiber optic is often used.

TABLE 4 (COAXIAL CABLES - TYPICAL PARAMETERS)				
Cable type	**Center conductor**	***Maximum distance for color signal without amplifier**	***Outside Diameter (nominal)**	**Impedance Ohms**
RG-59	22 awg	less than 750 ft	.242 in	75Ω
RG-59	20 awg	750 to1000 ft	.242 in	75Ω
RG-6	18 awg	1000 to 1500 ft	.332 in	75Ω
RG-11	14 awg	1500 to 2500 ft	.412 in	75Ω

.* Note: these values will vary depending on each manufacturer's specifications.

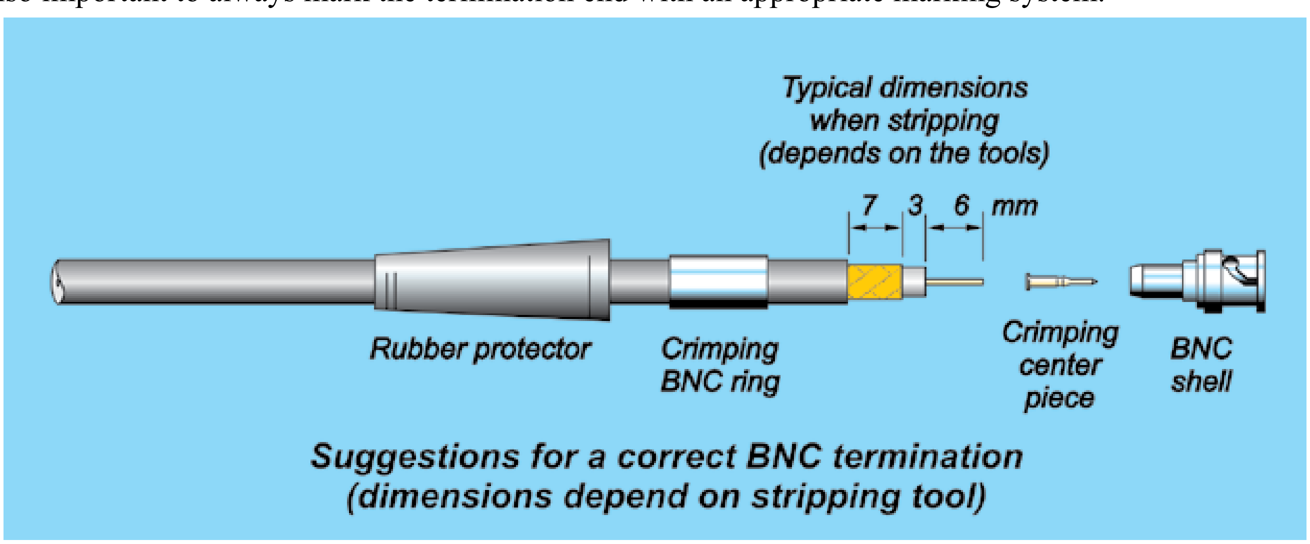
Fig.77 Crimping BNC components

The most common connector type for coaxial cables is BNC. BNC stands for *Bayonet Neill Concelman* and is named after Amphenol engineer Carl Concelman. The BNC features two bayonet lugs on the female connector. Mating is achieved with only a quarter turn of the coupling nut. BNCs are ideally suited for cable termination for miniature to subminiature coaxial cables (RG-58, 59, to RG-179, RG-316, etc.).

Using good connectors and good tools is of utmost importance. There are plenty of good quality brands out on the market and one should pay attention to get the best tools. The same applies when getting the actual connector. Most good quality connectors are made with better precision and material quality, such as gold-plated parts that have better conductivity and do not oxidize.

For terminating coaxial cable, the two most important tools are the coax cable stripping tool and the crimping or compression tool. Certain tools might be designed to incorporate cutting, stripping and terminating in one. Some types of connectors may require specific dimensions on how much stripping of the cable needs to be done to fit the connector perfectly. Practice your stripping techniques before committing to terminate cables on the job site.

The result of a well terminated cable is a connector that cannot be pulled off easily (this is why a good crimping or compression tool is important) and looks nice and clean, without any wires protruding. It is also important to always mark the termination end with an appropriate marking system.



Automatic cable stripping and terminating machines can shorten the labor in systems where there are literally thousands of terminations, such as casino projects.

The illustration on the previous page illustrates some termination recommendations for a typical BNC crimping tool. It is important that the spacing of the blades in the cable stripper and the dies in the crimping tool match the dimensions required for the specific connector and cable.

Fig.79 Important for quality: Crimping and stripping BNC tools

Fig.80 Compression BNC tools are also very good

Some new and equally good tools have become available for terminating with compression style BNCs instead of crimping.

Avoid the temptation to use "twist-on" style BNC connectors. Although easy to use, there is no guarantee of reliable connectivity of the center pin

Cable testing

Often, installed cables may need to be tested for continuity, breaks or bad termination. This becomes even more important when inheriting an existing installation, without any documentation and without any knowledge about the cables' length and quality. Such testing can be done by an instrument called the *Time Domain Reflectometer* (TDR). This device inserts very short and strong pulses of energy into one end of the cable and then measures the reflected signals, which can be plotted on a graph indicating the approximate length of the cable, and the points of signal reflection and possible problems. Often coaxial cables are run inside a conduit, which is installed first. Corners and bends present a problem here too, not only because of the minimum bending radius, but also because of possible difficulties while pulling the cables through the conduits. A common procedure is by using a steel or plastic "fish-tape",- onto which the cable ends are secured and then pulled through from the other side. When pulling coaxial cable, one should carefully consider the maximum pulling force that can be applied to the cable. The maximum pulling force depends on the design of the cable, and it can be found in manufacturers' specifications. Typical pulling force (also known as tensile strength) for coaxial cable is around 200 pounds.

Frictional force becomes apparent due to the weight of the cable and the coefficient of friction between the cable and the conduit. **Remember that the cable weighs the same whether it is in a roll or stretched out**. The longer the length, the greater the frictional force. The coefficient of friction can be reduced if lubrication is used. Check for correct and nonabrasive lubricator before use. Do not use soap and other chemicals that may damage the cable protective sheath.

During the pull, the tension can be monitored with an in-line dynamometer to ensure that the pull force does not exceed the maximum recommended pull force of the cable, the pull line, cable grip, winch or any of the components used for the pull. If there are multiple cables being pulled at the same time, the above tension is increased by a factor of 3 to 7 times due to a cradling effect.

UTP - Unshielded Twisted Pair

With twisted pair cables, also known as Unshielded Twisted Pair (UTP), we most often use the principle of *balanced signal transmission*.

This method is smart because it "preempts" the unavoidable EMIs, the undesirable electromagnetic interference that is created by a multitude of sources The term "balanced" is used because the video signal is sent over two wires, with inverted phases, so that at the receiving end the signal is extracted from the two wires by a differential amplifier. External EMIs induce unwanted signals in the twisted pair, but since the twisted pair are exposed more-or-less equally to the EMI, the difference is the original video signal, without noticeable EMI induction.

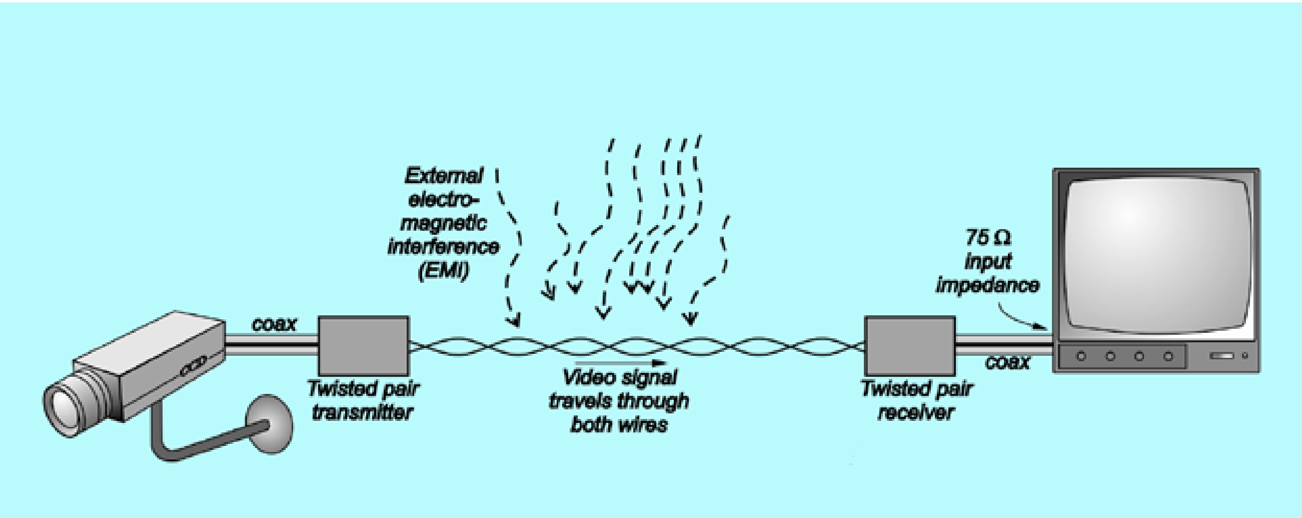


Fig.81 Balanced (twisted pair) video transmission

In the olden days of CCTV, there were special cables made for twisted pair video, which were not cheaper than coaxial cable. These days, however, not only is the twisted pair much better, it is cheaper and it is available as it is used as network cable in the IT industry as Category 5 or 6 cable. The twisted pair transmitter and receiver devices are getting better in quality, and also more affordable. The whole concept of twisted pair video is becoming a more attractive alternative to the coaxial cable.

Transmitters and receivers are often called "baluns"- derived from "balance"-"unbalanced." They might be passive (non-powered) or active (powered). The maximum distances achievable with good quality twisted pair equipment can surpasses those of coaxial cable without any visible loss of picture quality.

It is not unusual to transmit 750ft or more when using good passive baluns along with quality Cat-5 cable. With active baluns (which will require local power) distances of over 3,000ft can be achieved.

The twisted pair cable, transmitters and receivers all have impedance of 100Ω.

Fig.82 Twisted pair components

Category 5 and 6 cables

NOTE: While Networking is not included in the Level I certification, the following information may have practical value for the Level I candidate

It all started with Category 1 wiring many decades ago, also known as Cat-1, which supported only voice communications, such as POTS/PSTN, the “good old” analog telephones.

When networking was introduced, Category 2 (Cat-2) wiring passed data at up to 4 megabits per second, written as Mb/s. A bit is either a “1” or a “0”. Eight bits are used to make a Byte or a single digital word. Mega Bytes per second is written as MB/s, and it is not the same as Mb/s.

Category 3 (Cat-3), one of the most widely deployed UTP products, was adopted in 1991 at the advent of the wildly popular 10Mb/s Ethernet network. Cat 3 also supported 4Mb/s Token-ring environments.

The Category 4 standard was instituted in 1993 with 16-Mbps token-ring networks in mind and supported data speeds to 20 Mb/s.

Then, in 1994, Category 5 wiring specifications were adopted to support Ethernet and fast Ethernet networks, with speeds up to 100 Mb/s.

The Cat-5 unshielded twisted pair is exclusively designed for high signal integrity. The cable consists of four pairs of 24-guage twisted copper pairs with an exact known order of wire coloring, following the EIA T-568 standards.

Fig.83 Various color RJ45’s

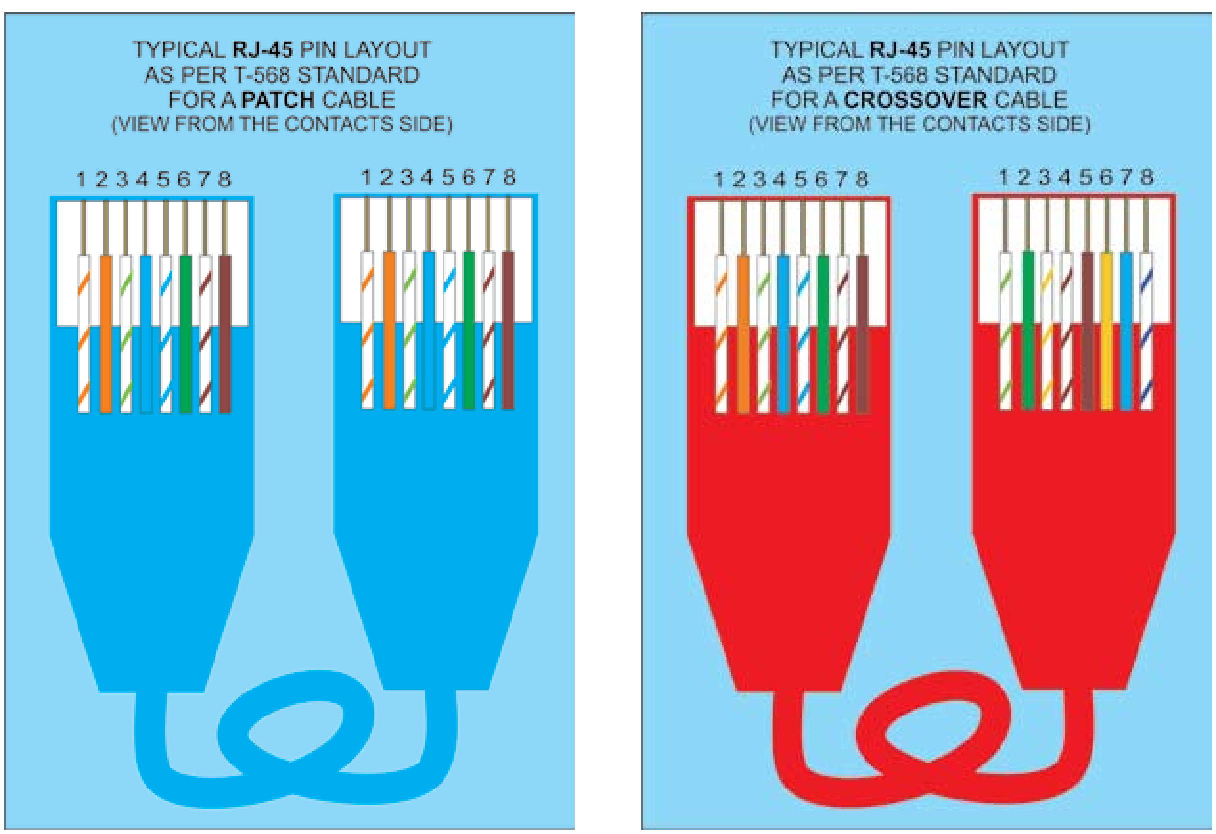


Fig.84 RJ-45 pins in networking: Note that the blue pair is always in the center (4&5) and that brown pair is always to right side (7&8). Neither the blue nor brown pair is used. T568-B has the orange pair to the left (1&2) and the green pair straddling the blue pair (3&6). T568-A has the green and orange swapped with green (1&2) and orange (3&6). Notice that the crossover cable has one of each.

The actual Cat-5 standard describes specific electrical properties of the wire, but Cat-5 is most widely known as being rated for its Ethernet capability of 100 Mb/s. This cable can also be used, as mentioned previously, for balanced analog video signal transmission without the risk of having ground-loops created. Cat-5 cable comes with approximately three twists per inch (approximately 100 twists per meter) of each of the four twisted pairs of 24 AWG copper wires within the cable. The twisting of the cable helps to decrease electrical interference and crosstalk. Each wire in a Cat-5 cable is insulated with a plastic (FEP) that has low dispersion. The importance of this insulation is that the dielectric constant of the plastic does not depend mainly on frequency.

Although quite impressive, Cat-5 wiring has been superseded by the 1998 Cat-5E (Enhanced Category 5) wiring standard. Cat-5E supports the same 100 Mb/s, but has much higher performance specifications and was enacted to support 1000Base-T (Gigabit Ethernet, or 1-Gb/s) networks along with applications like 155-Mb/s ATM (Asynchronous Transfer Mode). In addition to its greater throughput, Cat-5E is usually tested to a bandwidth of 155 MHz, despite its 100-MHz specified bandwidth. Testing is more stringent with Cat-5E than it was with Cat 5 and includes additional measurements, several of which help to better quantify the UTP cable’s noise characteristics. When used for networking, no more than 1/2 inch of each pair of wires may be untwisted when attached RJ45 connectors or punching down on wall jacks.

Cat-5E cable is similar to Cat-5 cable, except that it is made to somewhat more stringent standards and lower losses. This enhanced version of Cat-5 cable is designed for use with gigabit networks, but it can also be used for analog twisted pair video.

Solid core cables are commonly used for connecting wall socket and patch panels. Stranded cables, being more flexible, are used for connecting patch leads between patch panel sockets and network switches. Stranded cable is also used for the connections between computers wall ports.

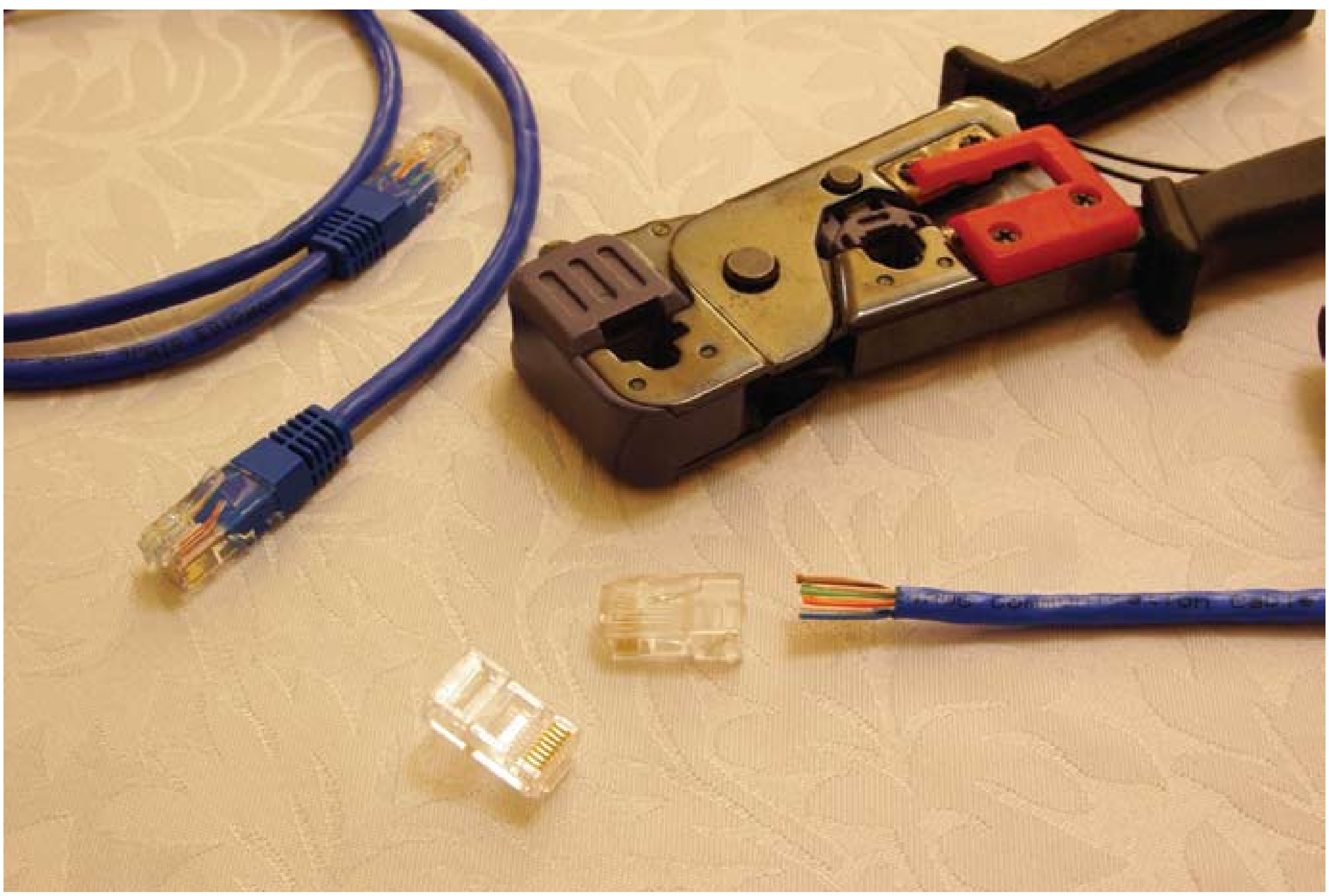


Fig.85 A typical tool for terminating Cat cables

Category 6, or Cat-6, is a cable standard with even better manufacturing specifications. It comes with four twisted copper wire pairs separated by a plastic spline. Each twisted pair is built of larger 23 AWG copper, as opposed to 24 AWG of Cat-5. In wire gauges, a larger number means a smaller wire. The most important quality of Cat-6 is the consistency of twists per foot. The insulation and copper quality is even higher, thus allowing for even better propagation of both digital and analog signals alike. Cat-6 cable is backward compatible with the Cat-5, Cat-5E, and Cat-3 cable standards. Cat-6 is used to carry Ethernet 10Base-T, 100Base-T, and 1000Base-T (Gigabit Ethernet) connections, and, as we said earlier, ideal for twisted pair analog video. Cat-6 cable is backed with more stringent specifications for crosstalk and system noise than earlier cabling standards. Installation of Cat 6 cable is thought to be more difficult than Cat 5 or Cat-5E cable, because the conductors are wrapped around the center spline and none of the wire may be untwisted when attaching RJ45's or punching down on Cat 6 wall jacks.

Fig.86 Other tools for terminating Cat cables

All Cat-5, 5E and 6 cables are typically terminated with *RJ-45 connectors*.

The maximum length of Cat cables, when used in data network, is by definition limited to 100m (330 feet), if data bandwidth is to be preserved as per the cable specifications, but when used in CCTV for analog signal transmission it can be much longer, as explained earlier.

As with the coaxial cable termination techniques, there are special tools for terminating Cat-5 and Cat-6 cables. It is recommended that best tools are chosen so that they can perform the cutting, stripping and crimping for many years. Practicing how to terminate is the best way to learn and get used to specific cables, connectors and tools. Care should be taken to not mix the order of the wires and be be consistent with the standards.

The TIA/EIA defines two standard pinning specifications (T568-A and T568-B). All pin/pair assignments must conform to one of these specifications. T568-A is generally used for analog voice applications requiring two lines. T568-B is more commonly used for data applications. Take care to ensure that all terminating hardware has the same category and pinning specification as your cable, because mixing the two standards may result in crossed pairs that can bring down your network.

Clearly, at the end of the termination session, testing and labelling of all connectors should be the finishing touch of a good installer. There are many tools on the market to test the continuity and integrity of the cables.

One tool that can be very useful with Cat types of cables (and also with coaxial) is the "Cable Tracer" tool, which can help you out find which of the 4 pairs of wire is which, particularly useful in cases when you lose track, or you want to find these details on existing cabling. Also, a "Tone Generator" tool can be used to identify which of the existing wires is which.

6. Install camera mounts

(Tools required for this section: electric drill, drill bits for wood, metal and concrete, screwdrivers, ladders)

Cameras are usually mounted on brackets, which are mounted on walls, ceilings, poles or any other structure near the area of surveillance.

It is important to consider the material properties onto which a camera is installed.

The material properties define electrical and mechanical features, including potential ground-loops, resistance against wind, vibration properties, corrosion or rotting and mounting of conduit and cable around or through the area.

The bracket elasticity depends on the material (plastic, aluminium, steel, etc.) and the design (round cross-section, hexagonal, triangular, etc.). The same logic applies when choosing poles for stand-alone camera installation. Typically, steel has three times higher elasticity than aluminium for the same physical design.

Wood

Wood is a natural material found in a lot of old and some new constructions. Drilling in wood is considerably easier and faster than drilling in metal. The main issue in drilling wood is assuring clean entry and exit holes and preventing burning. Sharp drill bits need to be used and as well as the appropriate (not very high) drilling speed. Holes are easier to start in wood as the drill bit can be accurately positioned by pushing it into the wood and creating a dimple. The bit will thus have no tendency to wander.

Fig.87 Wood drill bits are used for wood

It might be reasonably easy to install a bracket on a wooden base, but certainly there are a few consideration to take into account:

- Make sure that the construction is not a listed building, and if it is, make sure you obtain the appropriate permits before drilling and/or mounting equipment.
- Find out about the wood properties, so that you can prepare the correct size screws and drill bits.
- Make sure that drilling the wood does not affect the structural (weight carrying) properties.

Metal

In metal working, an accurate position needs to be marked with a punch to avoid the bit wandering from the desired position of the hole.

Fig.88 Drill bits for various materials

Under normal usage, swarf is carried up and away from the tip of the drill bit by the fluting. The continued production of chips from the cutting edges produces more chips which continue the movement of the chips outwards from the hole. This continues until the chips pack too tightly, either because of deeper than normal holes or insufficient backing off (removing the drill slightly or totally from the hole while drilling). Lubricants and coolants (i.e., cutting fluid) are sometimes used to ease this problem and to prolong the tool's life by cooling and lubricating the tip and chip flow.

For heavy feeds and comparatively deep holes, oil-hole drills can be used, with a lubricant pumped to the drill head through a small hole in the bit and flowing out along the fluting. A conventional drill press arrangement can be used in oil well drilling, but is more commonly seen in automatic drilling machinery in which it is the work piece that rotates rather than the drill bit.

Photo courtesy of DeWALT

Fig.89 No substitute for good tools

Concrete

Drilling concrete walls and surfaces is different from drilling woods or metal. It is granular, not fibrous like wood, or smooth and monolithic like metal. It is made of sand grains and gravel chunks glued together with a cement and water paste. This in a sense is similar to sandpaper composition. Drilling concrete will dull even the hardest cobalt or titanium twist-drill bit as fast as sandpaper.

The main idea when dealing with concrete is not to cut it or slice it, but rather pulverize it. Once its grains are pounded apart, all you need to do is sweep away the resulting powder. For this purpose *masonry* drill bits need to be used. They consist of a wedge of very hard material, typically carbide, which is only a few steps away from a diamond in its toughness. The shanks of these masonry bits are smooth, either round or hex-shaped, and they'll fit in your regular drill. Making concrete holes is a slow, but patient process. Masonry drill bits are not that expensive and every installer should have a few. For more or bigger holes, a *hammer drill* is better choice. The hammer drill does exactly what the name indicates; it adds impact vibration to the drilling process, thus improving the speed of making larger or deeper holes in the concrete.

Fig.90 Masonry drill bits

Once the holes are drilled, blow out any concrete debris with a large air hose or compressed air in a can or vacuum it clean (wearing protective goggles). Use the right size anchoring nuts and bolts. If your progress is too slow, use a smaller drill bit and drill a pilot hole.

Many drills have depth gauges which could be used to help you make the hole the correct depth. If your drill doesn't have one, try wrapping masking tape around the bit at the desired depth of penetration.

When selecting a masonry drill bit, there are two types: multi-purpose, and those made exclusively for hammer-type drilling. The hammer-type bits will not drill into concrete using regular, non-hammer type drills.

Fig.91 Appropriate protection when drilling concrete

Do not bear down on the drill with all your strength. Not only will smaller bits break, but the chisel-type tip for regular, non-hammer type drilling will create an advantageous hammering effect. When using a hammer drill, you only need to withdraw the bit occasionally to remove concrete dust.

Running a small amount of water over the area while drilling will reduce the heat of the bit and the friction between the sides of the concrete and the drill.

Obviously, the combination of a good quality hammer drill with the correct drill bit will save time and effort.

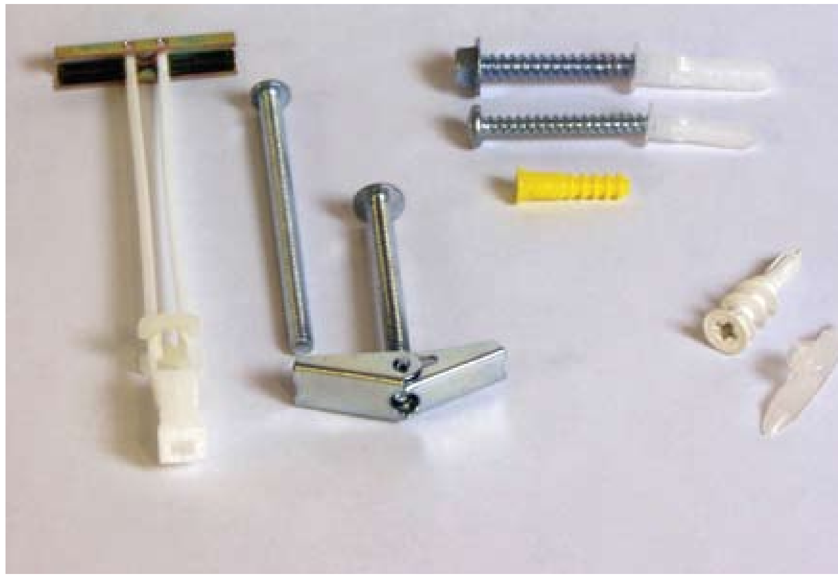


Fig.92 Various methods for mounting heavy items on drywall, concrete blocks and solid concrete.

If you have a wall with mortar between blocks or bricks, drill and screw into the mortar if possible as it is much easier to drill into mortar than concrete block.

CAUTION: Mortar could be in poor condition and may be too soft to hold the anchor.

Always use ***masonry anchors (lead or appropriate plastic)*** to hold the screws into place if you drill into the mortar, as screws set in mortar will work themselves loose over time. For some applications (electrical boxes, conduit straps) standard "Tapcon" concrete screws (without anchors) are adequate. (These screws are easy to identify, as they are blue in color.)

Verify that whatever mounting method you choose is adequate not only to handle the weight of the device(s) you are mounting but any additional load that might be added by snow, wind, rain or additional accessories. A separate safety cable should always be considered if there is any chance of failure from the primary mounting.

When installing cameras or monitor brackets on plaster walls be very aware of the low carrying capcity such walls have. There are methods and anchors to use on such a surface, and it is recommended that the load rating is chosen to suit the weight.

In all of the drilling and installation techniques described previously, good understanding and familiarity with the OSHA 3080 recommendation is needed. Installers are encouraged to download this brochure for free from ***http://www.osha.org/***.

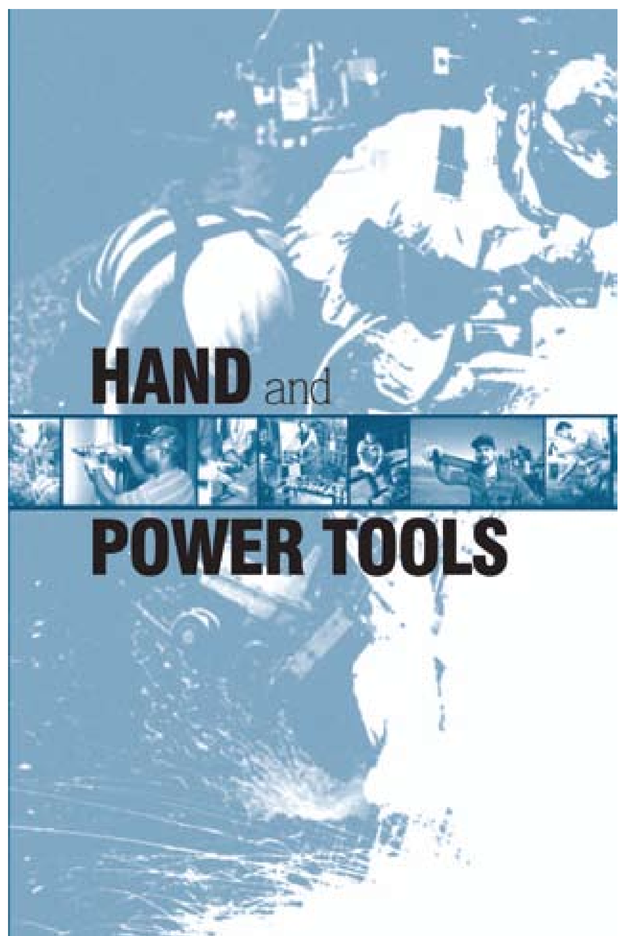


Fig.93 A good Guide to have

7. Cabinets and racks

(Tools required for this section: Phillips screwdriver, room thermometer, cable ties, cutters, ruler)

CCTV and Security equipment is commonly installed in cabinets and racks.

Cabinets and racks offer physical protection of the equipment, allow for neater and more organized cabling and labelling, and allow for logical separation of the security and CCTV equipment from other systems, allowing for quicker access to the video information when needed by the authority.

Cabinets

If a system is reasonably small, it is possible to have only one or two digital recorders, some camera power supplies and an uninterruptable power supply (UPS), in a small lockable cabinet. Cabinets can be made to sit on the floor on casters (wheels). Some are made to be installed on the walls with a proper mounting support. It is not uncommon to have cabinets hinged so that the whole front part of the cabinet can be opened, allowing an easy access to the cabling at the back of the video equipment.

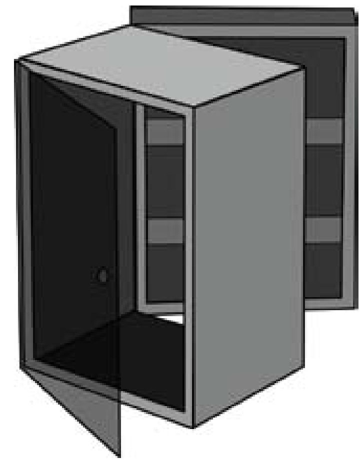


Fig.94 A wall mounting cabinet

EIA-310-D racks

The Electronic Industries Alliance (EIA) created the EIA-310-D standard in 1992 for cabinets, racks, panels, and associated equipment. This is the most common enclosure when larger systems are used, also popularly known as 19" rack system. The EIA-310-D specification addresses form, fit, and function for system spacing, mounting, and bezel clearance.

The majority of CCTV head-end equipment is designed to fit neatly and easily in EIA-310-D racks, either by way of mounting special 19" mounting brackets, or by using shelves.

The smallest elementary equipment height based on this standard is the "Rack Unit" (RU) which is 1.75".

There are different rack heights available, up to 45 RU height (as shown in Table 5).

The depth of EAI-310-D racks can also be different, but most common are internal depths of 19", 27", 31" and 35".

No matter what size rack is used in a system, the most important aspects are the cabling and the cooling. There are many accessories for proper cable tracing, depending on the type of cables and how many are entering the equipment cabinet.

Fig.95 EIA-310-D racks come in various sizes

Table 5 EIA 310-D Standard		
Rack units	RU Height in mm	Height in inches
1	44.50	1.75
10	445	17.5
15	667	26.25
20	890	35
25	1,112.50	43.75
30	1,335	52.5
31	1,379.50	54.25
32	1,424	56
33	1,468.50	57.75
34	1,513	59.5
35	1,557.50	61.25
36	1,602	63
37	1,646.50	64.75
38	1,691	66.5
39	1,735.50	68.25
40	1,780	70
41	1,824.50	71.75
42	1,869	73.5
43	1,913.50	75.25
44	1,958	77
45	2,002.50	78.75

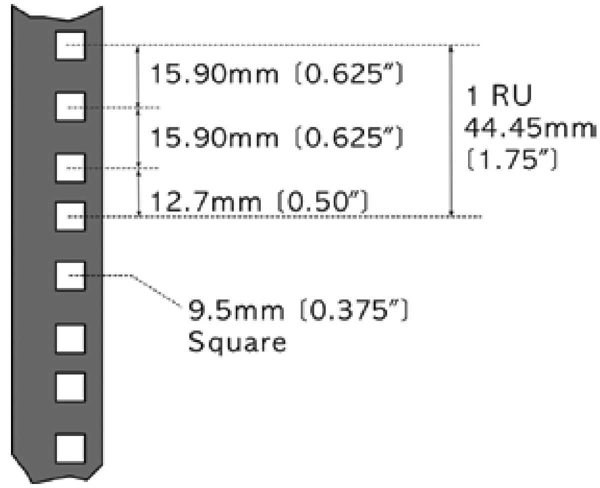


Fig.96 Some standard rack dimensions

One very common and unforeseen problem is the weight of unsecured cables on DVRs, NVRs, matrix switchers, etc, can physically distort or even break the ports on the back panels of the equipment.

This is the reason that cable support railing is very important. The installer should be aware that such accessories are also available from the rack manufacturers.

Cooling is another very important part of the cabinet design. Most computer equipment, DVRs, NVRs and matrix switchers have suction fans at the front, which suck in the air from the front and push it usually behind the equipment. Considering that most racks are locked-up cabinets from all sides, it is important to take hot air out of the cabinet in to keep it and the internally mounted equipment cool. Obeying the basic law of physics that hot air goes up, cooling fans are typically installed at the top of the racks. It should be ensured that the air taken out of the rack should be taken completely out of the equipment room via the room ventilation.

Whenever possible, thermometers should be used to monitor the room and rack's inside temperature. There is no clear-cut rule for acceptable temperature levels, but most equipment utilizing processors and hard disks will work better in colder environment. The colder the better. This is why many computer server rooms are air conditioned to temperatures preferably below 70˚F. Clean air and cold rooms with low humidity are the best environment for any active electronic equipment.

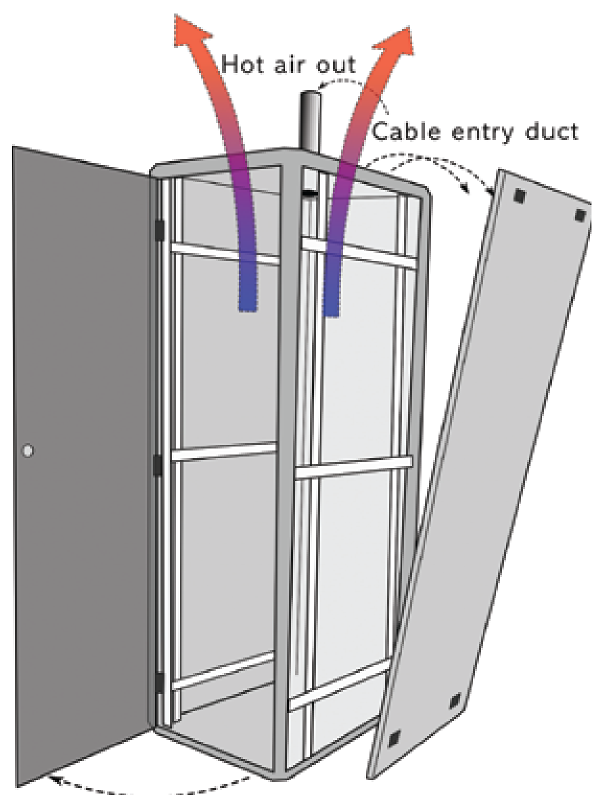


Fig.97 Planning of the cable and air flow are very important in cabinets

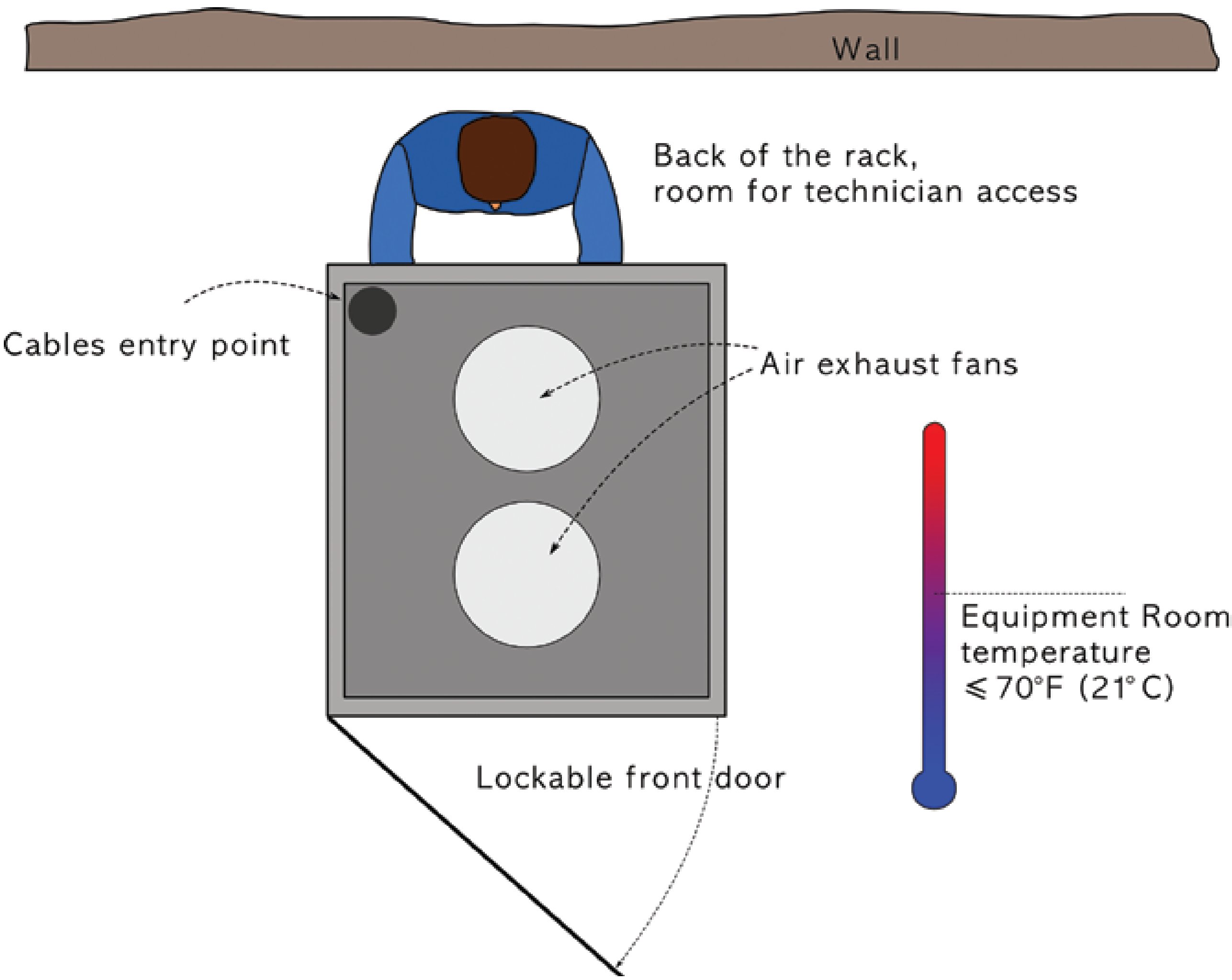


Fig.98 Always leave room behind the cabinet for cable access and maintenance.

A common method for routing cables is to use a cable entry duct from the ceiling. If the equipment room has been planned to have a false floor, then another convenient method is to run cables from under the cabinet. In either case, suitable cable entries protected by cable ducts or raceways need to be made. The proper use of cable hooks and raceways inside the cabinet define the neatness of the installation. Care should always be taken not to exceed the minimum recommended bending radii of all cables and not to overtighten with cable ties. Slack cable, also known as "service loops" should be left for testing and future service purposes.

Fig.99 Cable management for rack cabinets

Available access for working with cables and maintenance is another important consideration when positioning racks in a room. Most racks are designed so that equipment access can be made from all sides via removable door-panels. The most common access required is from the back of the equipment where most of the video cables come in and terminate.

If multiple rack cabinets need to be placed next to each other, suitable plans need to be made for access to all cabinets from the back.

If video or network patch-panels are to be installed as part of the system design, then appropriate accessories should be sought for such purposes. Some specialized rack manufacturers offer neat protection for various patch panels.

All cables must be marked appropriately, according to the common marking system used throughout the installation. All cables belonging to different purposes should be grouped in their distinct group, such as power, network, data and video. When using a variety of network sources and groups, it might be useful to have various colors of network cables.

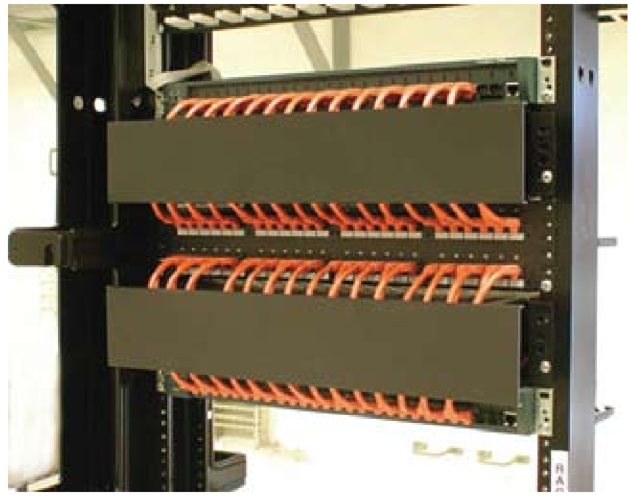


Fig.100 Neatness indicates a professional installation

When mounting equipment in the cabinets, whenever possible, allow for some room between devices in order to allow for better cooling. Equipment that needs regular visual inspections, such as LEDs showing the working status, should be placed at eye level. The same logic should be applied when installing patch-panels, switches and equipment that may require changing cables or connectors. They should be installed at eye-level for easier and quicker identification.

At the completion of the rack/cabinet installation, it should be a common practice to prepare and leave documentation (typically on the inside of the cabinet doors) with all the layout of the equipment and its position in the rack, cables that go to it and come out of it. Contact information of the installer or system integrator in charge of the installation should also be made available.

CCTV and security installation concentrate all the signals into these cabinets and racks, this is the most representative part of someone's work. Show that you are a true professional by leaving at neat, easily serviceable, well labeled and documented installation.

8. System Testing and Commissioning Tasks

(Tools required for this section: VOM (volt-ohm meter), inductor probe, screwdrivers)

When a system installation comes nears completion, the installer may be asked to conduct some basic testing to make sure there are no major faults with the cabling and prepare the system for commissioning.

It is also possible that an installing technician may be asked to perform such testing and pre-commissioning tasks on a site with an existing installation with little or no documentation.

System interconnecting diagram (Shop Plan)

The video security technician should start the system analysis from the existing system interconnecting diagram (shop plan).

This is the best point to start in understanding the system design. A visual inspection of the plan will give you an idea of the number of cameras in the system, the type of cabling used for video transmission (coax, twisted pair, or fiber) and power.

Most shop plans typically come designed in AutoCAD format, Visio, or CorelDRAW, but other formats are also possible. On occasion the plan might be hand drawn. Unfortunately, there is no accepted international standard in CCTV for diagrams and plans, but if common sense is used, all vital information of a particular system should be available from the plan.

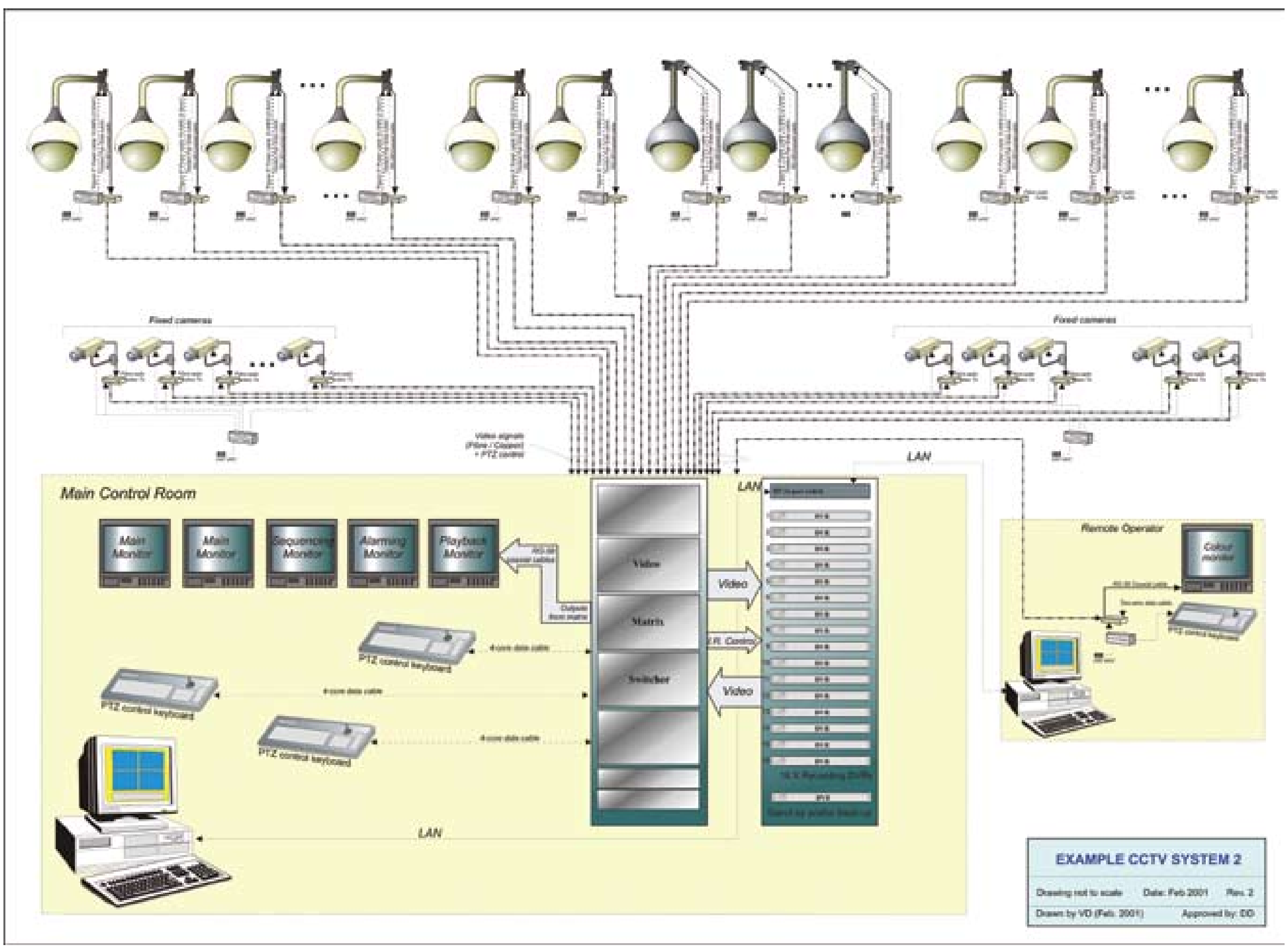


Fig.101 An example of a CCTV interconnecting diagram

After this basic overview, or when working with an existing installed system without any documentation, the next logical thing to do is check for the overall system concept. The best place to start learning this is at the equipment head-end where the cables terminate. Make a list of equipment in the cabinet, or where cables terminate. Check the type of video cables, how they are interconnected and labeled.

Make a list of items connected to the head-end and their numbers: cameras, monitors, operators, control stations and any other possible equipment connected to it (fire-protection, elevator-control, access control, etc.).

If there are any splices, connections or patch points that are known to the installer, they should be marked in the shop plan. It would be very useful if cable lengths (if known) are marked on the diagram. These would be very helpful later on in determining video signal loss or power voltage drop. If the installation doesn't have any such information, or was done by an unknown installer, it is possible to determine cable lengths using various hand-held meters.

If there is no system drawing made prior to the installation the installer should draw a simple, but detailed, interconnecting diagram based on the system understanding during the installation. Later on during the commissioning and handing over of the system, this diagram can be confirmed and completed showing the actual interconnecting of the CCTV components. The system documentation is usually inserted on the cabinet door so that it is easily accessible and obvious to anybody working on the system in the future.

Accurate documentation that you leave will serve as "treasure maps" for those who might need to service the system in the future. That might be you!

Remember, the faintest of ink is better than the best of memories.

Verifying cables

For verifying or identifying the existing power and data cables, the most common method would be by using a sound (or inductive) probe. The inductive probe has two parts, the inductor and the detector. The inductor produces an oscillating electric signal and the detector can identify which wire has the oscillation by producing an audible signal.

The wire that needs to be identified is connected to the inductor probe at one end, and at the other side is being picked up by the distinguishable sound that is induced in the detector.

Once they are found and identified make sure you label them (if they haven't been labelled). Continue with the rest of the cables and make a list of all that are identified.

Once continuity and consistency of the cabling are identified, make sure all cables are marked and entered in the drawing plan you have, or the one you made.

Although it is possible to identify coaxial cables with the inductive probe method, there is another common method for tracing and verifying coaxial cables by using test pattern generator.

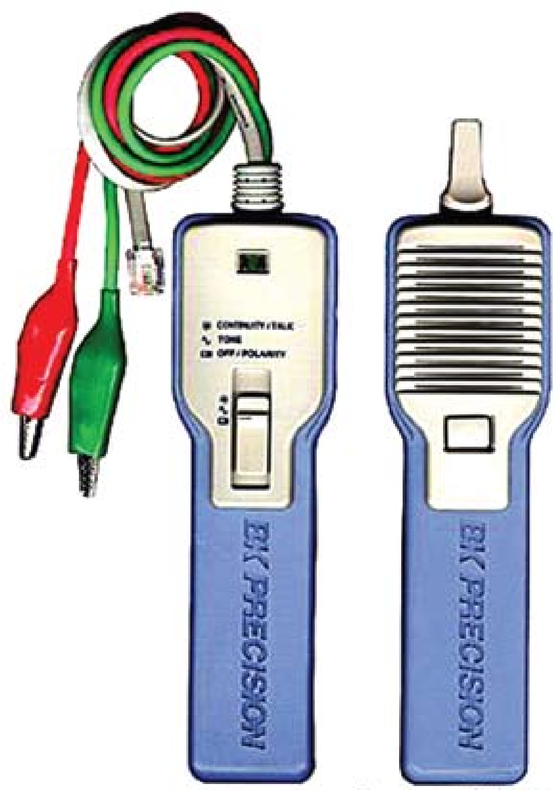


Photo courtesy of BK Precision

Fig.102 Inductive probe for tracing cables

Using a video signal test generator, a signal is inserted at one end of the coaxial cable and using a portable monitor at the other end it is determined where that video signal appears at the receiving end. Another advantage of this method is that the video signal quality is also checked, indicating any impedance problems or signal losses. Once the cable is traced this way, both ends should be permanently labelled .

There are a number of labelling systems available on the market from which to choose, but even a fine tip permanent marker might be sufficient, providing the writing is protected from erasure.

Video signal levels

Video and CCTV standards require all analog video signal at the receiving end to have voltage levels of 1 Vpp ("one volt peak-to-peak"). This would be valid only if the signal is terminated with 75 Ohm impedance. This is because the basic rule in electric signal transmission theory is that a maximum signal transmission is achieved if the cable and the terminating device (monitor, DVR, ...) have the same impedance as the output impedance of the source. Since this is 75 Ohm (all analog output CCTV cameras have this impedance) all devices that have a video input (BNC connector) will have 75 Ohm input impedance.

Fig.103 A test pattern generator

Excessive cable length, as discussed earlier in this guide, can cause voltage drop (voltage loss) so that a correct video signal of 1 Vpp at the camera end may have a considerable voltage drop of even 50% or more by the time it gets to the end, making the signal level 0.5 Vpp. Although a low signal can be seen by most video monitors, some devices, such as DVRs, may have a problem with low video signal levels. If this is the case, the most appropriate thing to do is amplify the signal with an in-line amplifier, or perhaps shorten the cable distance (if possible), or maybe use better cable with lower losses (such as RG-6 or RG-11 instead of RG-59). In order to verify video signal levels the best tools to use are an the *oscilloscope or digital camera meter*. These devices shows the most accurate and realistic video signal level, provided correct impedance termination is obtained during measurements. It is important to know that the input impedance of the oscilloscope is very high, which means the video cable termination has to be done by either a *dummy load* of 75 Ohms, or by connecting it to a monitor and inserting the oscilloscope "in-line".

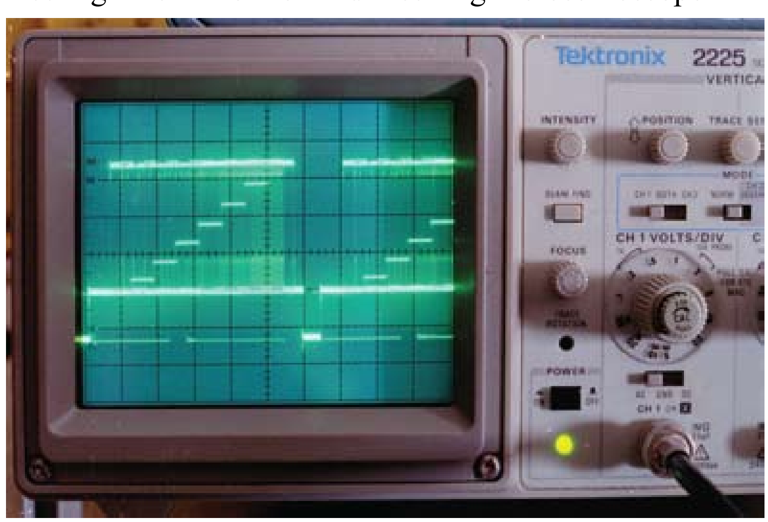


Fig.104 Oscilloscope, beyond Level I,but important.

Using an oscilloscope or a digital video meter, a trained technician can also judge the video signal quality without seeing the monitor display of the signal. If the signal has nice and sharp edges of the synchronization (sync) pulses, and they are 300 mV in height, the signal is rich with high frequency and hasn't lost voltage. If the sync pulses display rounded edges and the level is below 300 mV-, it indicates that there are losses of high frequencies because the cable is imperfect or too long. Also, if there is ripple of 60Hz on the signal display when time base is set to vertical frequency (100 ms per division), then there are some line power frequency induction in the cable (possible "ground loop"). A good signal should be straight and "rich with details." If a camera has saturated signal levels or the auto iris is not working properly, there will be a lot of white peak levels where the signal reaches 0.7 V when measured from the pedestal level (where the sync finishes). Although oscilloscope use is not tested at Level I, you will do well to begin to learn it now. Note that there are some handheld test instruments to test video in lieu of the oscilloscope such as those shown in Fig 105 & 106.

Fig.106 Digital Video Meter w/built in Monitor

Fig.105 Digital Video Meter.

Power consumption

Based on the number of items at the head-end, it should be reasonably easy to calculate the total power consumption required. This would be needed to determine the capacity of an Uninterruptable Power Supply (UPS) which should be a common practice in all security systems. Do not forget to consider the camera power consumption in this total (except in systems where cameras are powered at a remote location). Having the head-end equipment backed by a UPS is of no use if the cameras are not. Also, add the consumption of the monitors and computers at the head-end of the system.

Using a volt meter, verify the voltage arriving at the camera terminals, making sure there is sufficient power for the cameras to operate without failure.

For the purpose of calculating the overall system power consumption it is important for the installer to have a rough idea about the consumption of each component in a CCTV system. Here are some typical values:

CCD camera = approx. 3~4 W

LCD monitor = approx. 30~50 W (for 19" screens)

PC / DVR (without monitors) = approx. 200~300 W (depends on number of hard drives)

Refer to the labels on the equipment or refer to the manufacturer's specification sheet to determine the actual rated power draw.

The total power consumption should always be at least 25% less than the maximum output rating of the UPS, or the system current rating.

9. Troubleshooting Tasks

(Tools required for this section: VOM (volt ohm meter), pencil & paper)

The Video Security System technician should be capable of ***troubleshooting systems***, irrespective of whether they have been installed by him/her, or are inherited; whether a new install or upgrading an old one, perhaps, an undocumented installation.

Troubleshooting is an art based on knowledge of basic low voltage electricity.

Although overly simplistic, an installer might ask the basic questions: “Is it plugged in? Is it turned on?” Many times the following might be added: ”Are the cables connected? If it’s plugged in, turned on, connected and it contains a microprocessor, then a simple answer to a problem might be to “reboot.”

There are other questions that might help identify the cause of the problem:

1. Did the entire system ever work? Sometimes we’re called on to fixed what has never worked.
2. What happened at the time of failure? Thunderstorm? Power surge? Other workers in the area?

If the above doesn’t point to a specific problem then it’s time to “divide and conquer.”

Break the system at the logical middle and test to determine which “half” has the problem. Keep splitting the “half” with the issue to take advantage of the law of diminishing returns to most efficiently locate the problem.

Another method to use in basic troubleshooting is to reduce the system to it’s most basic configuration, removing anything it does not need in order to function such as network cable. You might want to work with a known “good”, such as resetting the equipment to the factory defaults **after saving the configuration settings/files.**

Document your actions and results as you go. Many times these notes will assist in highlighting the solution. Clearly, one of the most important presumptions before starting cable fault-finding is having cables markings, or at least a basic system-wiring drawing. Cable faults can be in either the power or video cable.

Power cable troubleshooting

Check the power. Even a momentary short circuit can blow a fuse or power supply. Check the voltage at the terminals, using a Volt/Ohm meter (VOM).

Fig.107 Digital VOM

Fig.108 Analog VOM

If there is no power on the terminals but the power has been switched on, the first thing to do is make certain that there is not a short circuit by disconnecting all the cables at the power point. Individual measurement of each pair of cables using a VOM meter in resistance-mode (Ohms) should pin-point the short circuited cable easily.

Although the majority of modern VOMs are digital, analog meters (indicating needle) are still available. Some digital VOMs have an analog scale in addition to the digital display.

Digital VOM are usually “auto-ranging”, which means they select the appropriate range of measurement for

Fig.109 Cable tester

the signal measured. For example if a signal is less than 1 V, the VOM may switch to mV If however the signal is 120V, the VOM may switch to Volts. Just reading the value without paying attention to the range could give you the wrong conclusion about the voltage. **Make sure you read the range level**.

Attention should also be paid to selecting AC or DC current when measuring, so that wrong conclusions are not made (such as reading a DC voltage of an AC power source).

Video cables troubleshooting

Video cable faults are the most common in CCTV as they are influenced not only by the cable type, but also by the quality of BNC connector attachment, cable length, bending radii and double or open terminations.

The first and simplest method of video cable fault finding is by observing the video signal display on a monitor. In such a case one must make sure that the camera signal and camera settings are good, and the monitor has correct impedance (typically 75Ω).

It is very common to have a bad camera signal but conclusions made as if the cabling is not good, and vice versa.

Simple tests would be to:

1. Check the voltage at the camera.
2. Replace the camera with a known "good" camera.
3. Measure the resistance along the length of the video cable.

There are special tools such as oscilloscopes, test pattern generators and TDR's (time domain reflectometer) which can be used in extreme cases, but these devices are beyond the scope of a Level I technician.

Fig.110 Another cable tester

Fig.111 A tool for testing PTZ cameras

10. Documentation Tasks

(Tools required for this section: pen, pencil, paper, markers, etc.)

Every installation should be accompanied by a set of documents, including a system interconnecting diagram, a blueprint, shop drawing, wiring legend, schematics, installation and operational manual, and any related technical bulletins and updates, if necessary.

The system interconnecting diagram is typically prepared by a design engineer from the company offering the system, or perhaps by the sales engineer. This is the first and most important document, which will give you a good understanding of the size of the system, number of cameras proposed, how they are interconnected, and how they are displayed, e.g. on how many monitors and how many operators are able to see the cameras. A system interconnecting diagram may not necessarily include details on makes and product models used to achieve the system requirements, but rather shows a general concept of the system.

A blueprint might be available if a more detailed interconnecting is proposed, typically by an architect or building engineer associated with the building site where your CCTV system is proposed for installation. This kind of document is typically available as a copy of an original architectural plan (hence the name blueprint, which is typically the old method of making copies of large building drawings). The blueprint document usually refers to the actual building construction, and cameras might be shown there in the exact location in the building, relative to the exact layout of the site. A blueprint would typically contain all relevant information required by the standards for architectural drawings, such as the name of the architects, the name of the builder, the scale of the drawing, the date of issue and revisions, legend of all symbols shown, including CCTV components, etc.

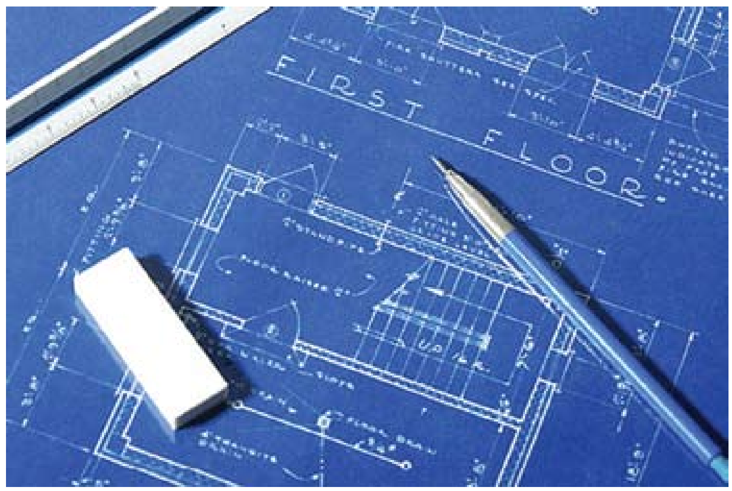


Fig.112 A blueprint

The site plan is the view of the blueprint from above, the “birds-eye” view. The elevation is the view of the blue print from the front, sides and/or back, the “ground” view.

A shop drawing is the contractor’s drawn version of information shown in the blueprint. The shop drawing normally shows more detail than the construction documents as it is drawn to explain the exact items and models of each component used in the CCTV system. The style of the shop drawing is usually very different from that of the architect’s drawing. The shop drawing’s primary emphasis is on the particular product or installation and excludes notation concerning other products and installations.

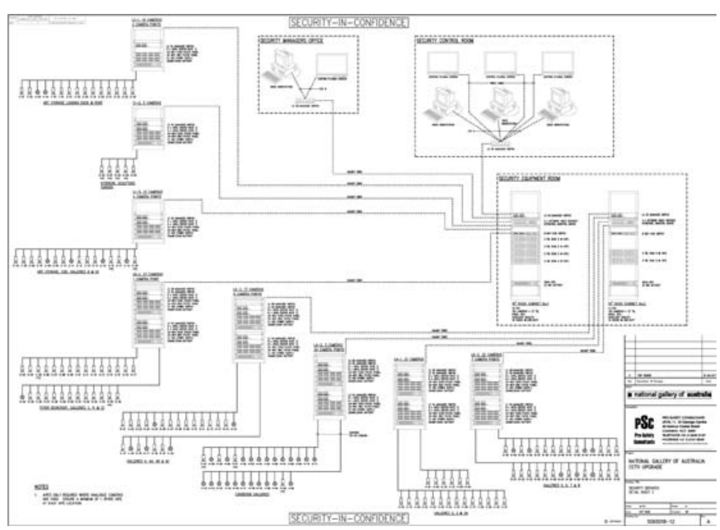


Fig.113 Another typical CCTV diagram

The wiring legend would usually be part of the blueprint, but it might be a separate document. For larger installations it is required that installers add the details of their cabling and labeling to a general wiring diagram, showing a distinct variety of cables, such as power, video, data and networking.

In a CCTV installation, there is typically no need for a separate schematic document, but if there are some specific and custom made devices that require explanation about their purpose and where they fit in the total system, a schematic might be required.

Typically, when the CCTV installation is completed, and all components are put in place and are tested, there should be a folder with all the installation and operational manuals. The complete site operational manuals are typically prepared by the contractor design engineers, who have designed the system and know exactly how the system is supposed to operate.

If there are any updates to the products, software or firmware, they should be included in this document.

11. Temporarily mark cables for construction

(Tools required for this section: pen, pencil, marker, marking set, etc.)

During the installation and while a building site is under construction, it is a good habit to agree with your colleagues and other people involved in the installation on marking your cables in a uniform and non-confusing way. This could be an extremely important decision in larger projects where there might be many other cables for other services and systems.

Don't forget that CCTV and security is only one of the many services a building can have. Others include access and fire control, air-conditioning, lift and light control, power, etc.

Cables should be marked temporarily until the installation is completed since their length, raceway paths, and termination location is not always known. Once all are in place, final cable labeling can be performed according to the contractual requirements. To many, *marking* is the temporary identification of the cables while *labeling* is the final clean identification.

Fig.114 "Badge" labeling method

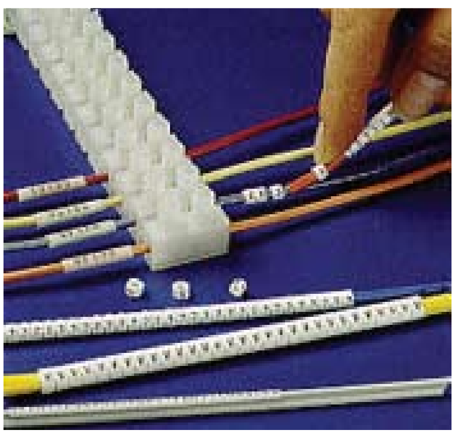


Fig.115 Rings with letters and numbers can be used to mark each wire

It is important that these markings, although temporary, need to be consistent and clear. There are many different technologies of marking and labeling and installers should seek the most suitable to them. Some of them may involve labeling with letters (Fig.115), some could be using a special adhesive tape onto which writing can be made (Fig.116).

Perhaps the most important thing is that these temporary markings have to be able to stay where they were attached/inserted in first place, even after the cable has been pulled though holes, cavities and conduit. Not only should they be able to stay in place, but they should not cause any additional friction or stress to the pulling of cable.

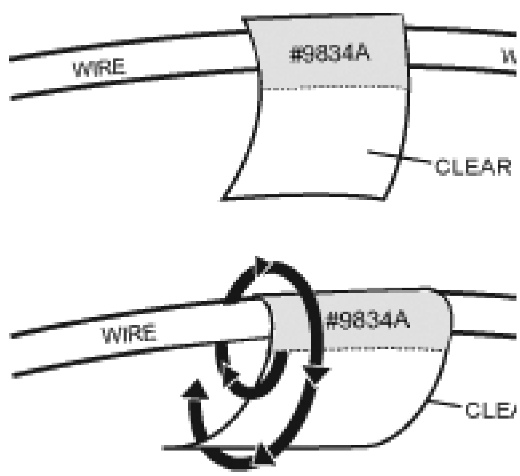


Fig.116 There are some practical labeling systems where labels can be printed from a computer spread-sheet

12. Record serial numbers of installed devices

(Tools required for this section: pen, pencil, spread-sheet, etc.)

During the system installation, many expensive items, such as cameras, monitors, digital recorders, etc. are installed. The customer typically gets a warranty for all of the equipment, as well as the workmanship of the installation.

For this reason it is very important to write down the make, model and serial numbers of all items in the installation. It is best for this to be done during the installation time, especially because some of the items installed cannot be easily accessed at a later time in order to check the serial number, make and model. This is clearly the case with the cameras, digital recorders and all other equipment installed in racks.

The best person to do this is the installer.

One of the simplest methods to record serial numbers would be to create a simple spread sheet on a notebook computer, and go through the equipment before they are installed, or write them down as they being installed. Beside the serial number of the item, make and model, it is also very important to write down the date of the actual start of operation of each item, allowing for easy warranty tracking.

Fig.117 Serial Numbers should not be confused with Part Numbers

Care should be taken not to confuse the serial number (usually written as S/N) with a part number or model. Typically, some manufacturers have bar codes next to the serial numbers, but this isn't a rule.

Some CCTV items, such as digital video recorders, may actually require serial numbers for obtaining release codes and in order to increase the functionality of the product at a later time.

One can almost say with certainty that cameras have very low probability of failing and will typically serve quite a long time. This is unfortunately not the case with digital video recorders and hard disks.

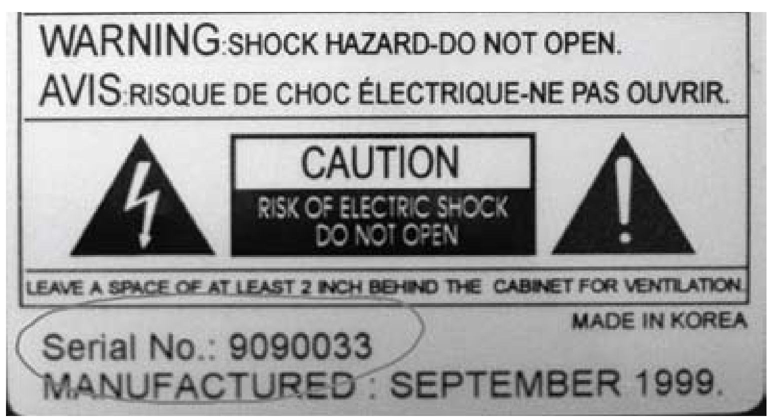


Fig.118 Some devices may have manufactured date

In a larger system using DVRs, one of the most common items that can fail is the hard disk, so it is important to clarify with the DVR supplier if serial numbers of the hard disks need to be logged for warranty purposes. If so, there might be a need for opening each DVR (or device containing hard disks) and reading the serial of each drive. Extra care should be taken here, as hard disks are very sensitive to static electricity, shocks and dust.

It would be easy for anybody to recognize certain patterns of the serial numbers, as each manufacturer may have their own way of doing so. This might help later on tracking the age of each product, relative to the new ones that might be installed at a later date, perhaps as an expansion of the system.

13. Recover and store equipment documents

(Tools required for this section: pen, pencil, folders, paper, etc.)

In addition to the previously described recording of serial numbers of all items, the installer is also required to collect and store all warranty cards of each item installed, their manuals (which later on will be included in the master folder, as described under “documentation tasks”) and any other items that might have come with the items, such as programs on CD or DVD.

The documents for all of the equipment installed should be installed in one master folder, as already hinted in the previous section “Documentation tasks.”

Fig.119 Documentation is extremely important

It is possible, however, that an installation is not a new one, but rather extension of an existing one, or even retrofitting an existing non-functioning or renewed CCTV system. During such a time, it would be required to complete the product documentation and manuals of the existing equipment, and to add the new documents that might have been added to the system.

Operations and Engineering (O&E) manuals are all to be combined in one complete document that would be easy to identify and use.

Most contemporary documentation is made on computers, but a hard copy is always the preferred form for quick use and reference because documentation is (and should always be) in the vicinity of the system control room or equipment room.

It is a good idea to have both the hard and electronic copies not only for the customer but for the service personnel as well.

14. Safe worksite practices

Most of the time, as a video security system technician you will be working on site, which is where Security and CCTV system installations would happen. Typically, these are new buildings and construction sites which require extra care because of the possible health and safety risks not only for you, but also for all involved in such a building project. To be safe at work, be aware of the safety of others. Having the same precautionary attitude also applies when working in your workshop or office.

The US Department of Labor, Occupational Safety and Health Administration (OSHA), has many guidelines about what you should and what you shouldn't do in your work in order to maximize safety.

All brochures and recommendations can be found at the OSHA web site **http://www.osha.gov**, a recommended search under the standard No.1926. There are sub-sections in the 1926 for many different industries and although having a global overview is very useful, for the purpose of this Study Guide we will concentrate on the safety requirements more specific to this industry.

Important for this NICET Level I certification and a familiarity with the requirements for safety when working on a site, and a understanding of the tools used in this industry.

Fig.120 OSHA Construction Industry Digest

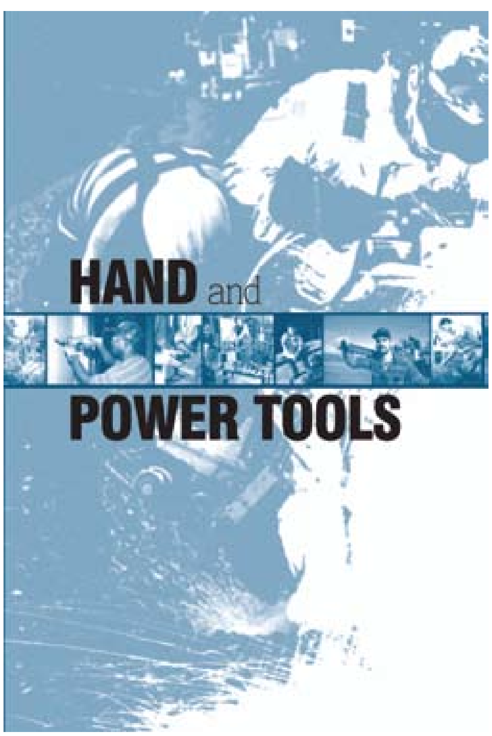


Fig.121 Hand and power tools guide

Most of these guidelines can be found in the OSHA publication 2202 - *Construction Industry Digest,* which is freely downloadable from **http://www.osha.gov/Publications/osha2202.pdf**. The guidelines for *Hand and Power Tools* can be found in the OSHA publication 3080, freely downloadable from **http://www.osha.gov/Publications/osha3080.pdf.**

We are going to summarize the most important aspects of these booklets, but the reader is encouraged to download them and read them in their entirety.

OSHA 2202 (Construction Industry Digest)

OSHA advises and encourages employers and contractors to institute and maintain in their establishments a program that provides adequate systematic policies, procedures, and practices to protect their employees from, and allow them to recognize, job-related safety and health hazards.

An effective program includes provisions for the systematic identification, evaluation, and prevention or control of general workplace hazards, specific job hazards, and potential hazards that may arise from foreseeable conditions.

Contractors and employers who do construction work also must comply with standards in 29 CFR 1926. Subpart C, General Safety and Health Provisions, as well as other specific sections of these standards include the responsibilities for each contractor/employer to initiate and maintain safety and health programs, provide for a competent person to conduct frequent and regular inspections, and instruct each employee to recognize and avoid unsafe conditions and know what regulations are applicable to the work environment.

Electrical Installations

Employers must provide either ground-fault circuit interrupters (GFCIs) or an assured equipment grounding conductor program to protect employees from ground-fault hazards at construction sites. The two options are detailed below.

(1) ***All 120-volt, single-phase, 15- and 20-ampere receptacles that are not part of the permanent wiring must be protected by GFCIs****.*

Receptacles on smaller generators are exempt under certain conditions.

(2) ***An assured equipment grounding conductor program covering extension cords, receptacles, and cord- and plug-connected equipment must be implemented.*** *The program must include the following:*

- *A* ***written*** *description of the program.*
- *At least one competent person to implement the program.*
- *Daily visual inspections of extension cords and cord- and plug-connected equipment for defects. Equipment found damaged or defective shall not be used until repaired.*
- *Continuity tests of the equipment grounding conductors or receptacles, extension cords, and cord- and plug-connected equipment. These tests must generally be made every 3 months.*
- *Paragraphs (f)(1) through (f)(11) of this standard contain grounding requirements for systems, circuits, and equipment.* ***1926.404(b)(1)(i) through (iii)(e)***

Fig.122 A GFCI unit

Light bulbs for general illumination must be protected from breakage, and metal shell sockets must be grounded. ***1926.405(a)(2)(ii)(e)***

Temporary lights must not be suspended by their cords, unless they are so designed. ***1926.405(a)(2)(ii)(f)***

Portable lighting used in wet or conducive locations, such as tanks or boilers, must be operated at no more than 12 volts or must be protected by GFCIs. ***1926.405(a)(2)(ii)(g)***

Extension cords must be of the three-wire type.

Extension cords and ***flexible*** *cords used with temporary and portable lights must be designed for hard or extra hard usage (for example, types S, ST, and SO).* ***1926.405(a)(2)(ii)(j)***

Worn or frayed electric cords or cables shall not be used. ***1926.416(e)(1)***

Extension cords shall not be fastened ***with*** *staples, hung from nails, or suspended by wire.* ***1926.416(e)(2)***

Work spaces, walkways, and similar locations shall be kept clear of cords. ***1926.416(b)(2)***

Listed, labeled, or certified equipment shall be installed and used in accordance with instructions included in the listing, labeling, or certification. ***1926.403(b)(2)***

Electrical Work Practices

Employers must not allow employees to work near live parts of electrical circuits, unless the employees are protected by one of the following means:

- *De-energizing and grounding the parts.*
- *Guarding the part by insulation.*
- *Any other effective means.* ***1926.416(a)(1)***

In work areas where the exact location of underground electrical power lines is unknown, employees using jack hammers, bars, or other hand tools that may contact the lines must be protected by insulating gloves, aprons, or other protective clothing that will provide equivalent electrical protection. ***1926.416(a)(2) and .95(a)***

Barriers or other means of guarding must be used to ensure that workspace for electrical equipment will not be used as a passageway during periods when energized parts of equipment are exposed. ***1926.416(b)(1)***

Flexible cords must be connected to devices and fittings so that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws. ***1926.405(g)(2)(iv)***

Equipment or circuits that are de-energized must be rendered inoperative and must have tags attached at all points where the equipment or circuits could be energized. ***1926.417(b)***

Ladders

Portable and fixed ladders with structural defects—such as broken or missing rungs, cleats or steps, broken or split rails, or corroded components—shall be withdrawn from service by immediately tagging "DO NOT USE" or marking in a manner that identifies them as defective, or shall be blocked, such as with a plywood attachment that spans several rungs. Repairs must restore ladder to its original design criteria. ***1926.1053(b)(16), (17)(i) through (iii) and (18)***

Portable non-self-supporting ladders shall be placed on a substantial base, have clear access at top and bottom, and be placed at an angle so the horizontal distance from the top support to the foot of the ladder is approximately one-quarter the working length of the ladder. Portable ladders used for access to an upper landing surface must extend a ***minimum*** *of 3 feet above the landing surface, or where not practical, be provided with grab rails and be secured against movement while in use.* ***1926.1053(b)(1) and (b)(5)(i)***

Ladders must have non-conductive side-rails if they are used where the worker or the ladder could contact energized electrical conductors or equipment. ***1926.1053(b)(12)***

Job-made ladders shall be constructed for their intended use. Cleats shall be uniformly spaced not less than 10 inches apart, nor more than 14 inches apart. 1926.1053(a)(3)(i)

A ladder (or stairway) must be provided at all work points of access where there is a break in elevation of 19 inches or more except if a suitable ramp, runway, embankment, or personnel hoist is provided to give safe access to all elevations. 1926.1051(a)

- *Wood job-made ladders with spliced side rails must be used at an angle where the horizontal distance is one-eighth the working length of the ladder.*
- *Fixed ladders must be used at a pitch no greater than 90 degrees from the horizontal, measured from*

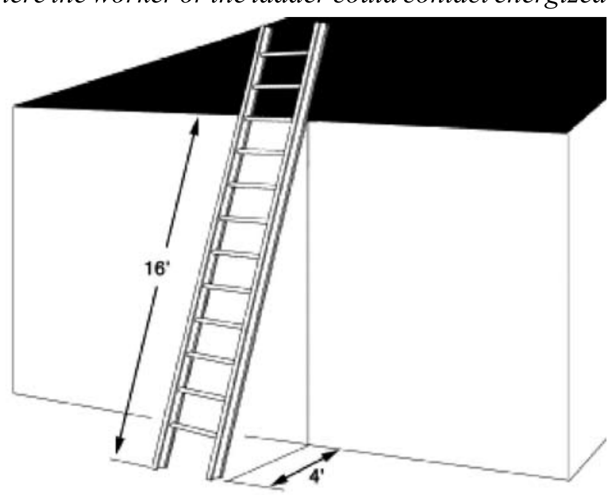


Fig.123 Recommendation for using ladders

the back side of the ladder.

- *Ladders must be used only on stable and level surfaces unless secured to prevent accidental movement.*
- *Ladders must not be used on slippery surfaces unless secured or provided with slip-resistant feet to prevent accidental movement. Slip resistant feet must not be used as a substitute for the care in placing, lashing, or holding a ladder upon a slippery surface. 1926.1053(b)(5)(ii) through (b)(7)*
- *Employers must provide a training program for each employee using ladders and stairways. The program must enable each employee to recognize hazards related to ladders and stairways and to use proper procedures to minimize these hazards.*
- *For example, employers must ensure that each employee is trained by a competent person in the following areas, as applicable:*
- *The nature of fall hazards in the work area;*
- *The correct procedures for erecting, maintaining, and disassembling the fall protection systems to be used;*
- *The proper construction, use, placement, and care in handling of all stairways and ladders; and*
- *The maximum intended load-carrying capacities of ladders used.*

In addition, retraining must be provided for each employee, as necessary, so that the employee maintains the understanding and knowledge acquired through compliance with the standard. 1926.1060(a) and (b)

Lasers

Only qualified and trained employees shall be assigned to install, adjust, and operate laser equipment. 1926.54(a)

Employees shall wear proper (anti-laser) eye protection when working in areas where there is a potential exposure to direct or reflected laser light greater than 0.005 watts (5 milliwatts). 1926.54(c)

Beam shutters or caps shall be utilized, or the laser turned off, when laser transmission is not actually required. When the laser is left unattended for a substantial period of time—such as during lunch hour, overnight, or at change of shifts—the laser shall be turned off. 1926.54(e)

Employees shall not be exposed to light intensities in excess of the following: direct staring—1 microwatt per square centimeter, incidental observing—1 milliwatt per square centimeter diffused reflected light—2-1/2 watts per square centimeter. 1926.54(j)(1) through (3)

Employees shall not be exposed to microwave power densities in excess of 10 milliwatts per square centimeter. 1926.54(1)

Scaffolds, General Requirements

Scaffolds are any temporary elevated platform (supported or suspended) and its supporting structure (including points of anchorage), used for supporting employees or materials or both. 1926.450(b)

Each employee who performs work on a scaffold shall be trained by a person qualified to recognize the hazards associated with the type of scaffold used and to understand the procedures to control or minimize those hazards. The training shall include such topics as the nature of any electrical hazards, fall hazards, falling object hazards, the maintenance and disassembly of the fall protection systems, the use of the scaffold, handling of materials, the capacity and the maximum intended load. 1926.454(a)

Fall protection (guardrail systems and personal fall arrest systems) must be provided for each employee on a scaffold more than 10 feet above a lower level. 1926.451(g)(1)

Each scaffold and scaffold component shall support without failure its own weight and at least 4 times the maximum intended load applied or transmitted to it. Suspension ropes and connecting hardware must support 6 times the intended load. Scaffolds and scaffold components shall not be loaded in excess of their maximum intended loads or rated capacities, whichever is less. 1926.451(a)(1), (a)(4), (f)(1)

The scaffold platform shall be planked or decked as fully as possible. 1926.451(b)(1)

The platform shall not deflect more than 1/60 of the span when loaded. 1926.451(f)(16)

The work area for each scaffold platform and walkway shall be at least 18 inches wide. When the work area must be less than 18 inches wide, guardrails and/or personal fall arrest systems shall still be used. 1926.451(b)(2)

Access must be provided when the scaffold platforms are more than 2 feet (0.6 m) above or below a point of access. Direct access is acceptable when the scaffold is not more than 14 inches horizontally and not more than 24 inches vertically from the other surfaces. Cross-braces shall not be used as a means of access. 1926.451(e)(1) and (e)(8)

A competent person shall inspect the scaffold, scaffold components, and ropes on suspended scaffolds before each work shift and after any occurrence which could affect the structural integrity and authorize prompt corrective action. 1926.450 (b), 451(f)(3), and (f)(10)

Motor Vehicles and Mechanized Equipment

All vehicles in use shall be checked at the beginning of each shift to ensure that all parts, equipment, and accessories that affect safe operation are in proper operating condition and free from defects. All defects shall be corrected before the vehicle is placed in service. 1926.601(b)(14)

No employer shall use any motor vehicle, earth moving, or compacting equipment having an obstructed view to the rear unless:

• The vehicle has a reverse signal alarm distinguishable from the surrounding noise level, or

• The vehicle is backed up only when an observer signals that it is safe to do so.

1926.601(b)(4)(i) through (ii) and 602(a)(9)(i) through (ii)

Fig.124 Marked vehicle helps advertise your work

Heavy machinery, equipment, or parts thereof that are suspended or held aloft shall be substantially blocked to prevent falling or shifting before employees are permitted to work under or between them. 1926.600(a)(3)(i)

Storage

All materials stored in tiers shall be secured to prevent sliding, falling, or collapsing. 1926.250(a)(1)

Aisles and passageways shall be kept clear and in good repair. 1926.250(a)(3)

Storage of materials shall not obstruct exits. 1926.151(d)(1)

Materials shall be stored with due regard to their fire characteristics. 1926.151(d)(2)

OSHA 3080 (Hand and Power Tools)

Tools are such a common part of our lives that it is difficult to remember that they may pose hazards. Tragically, a serious incident can occur before steps are taken to identify and avoid or eliminate tool-related hazards.

Employees who use hand and power tools and are exposed to the hazards of falling, flying, abrasive, and splashing objects, or to harmful dusts, fumes, mists, vapors, or gases must be provided with the appropriate personal protective equipment. All electrical connections for these tools must be suitable for the type of tool and the working conditions (wet, dusty, flammable vapors). When a temporary power source is used for construction a ground-fault circuit interrupter should be used.

Employees should be trained in the proper use of all tools.

Workers should be able to recognize the hazards associated with the different types of tools and the safety precautions necessary.

Five basic safety rules can help prevent hazards associated with the use of hand and power tools:

- *Keep all tools in good condition with regular maintenance.*
- *Use the right tool* ***for*** *the job.*
- *Examine each tool for damage before use and do not use damaged tools.*
- *Operate tools according to the manufacturers' instructions.*
- *Provide and use properly the right personal protective equipment.*

Employees and employers should work together to establish safe working procedures. If a hazardous situation is encountered, it should be brought immediately to the attention of the proper individual for hazard abatement.

Hand tools are tools that are powered manually. Hand tools include anything from axes to wrenches. The greatest hazards posed by hand tools result from misuse and improper maintenance.

Some examples include the following:

- *If a chisel is used as a screwdriver, the tip of the chisel may break and fly off, hitting the user or other employees.*
- *If a wooden handle on a tool, such as a hammer or an axe, is loose, splintered, or cracked, the head of the tool may fly off and strike the user or other employees.*
- *If the jaws of a wrench are sprung, the wrench might slip.*
- *If impact tools such as chisels, wedges, or drift pins have mushroomed heads, the heads might shatter on impact, sending sharp fragments flying toward the user or other employees.*

The employer is responsible for the safe condition of tools and equipment used by employees. Employers shall not issue or permit the use of unsafe hand tools. Employees should be trained in the proper use and handling of tools and equipment.

Employees, when using saw blades, knives, or other tools, should direct the tools away from aisle areas and away from other employees working in close proximity. Knives and scissors must be sharp; dull tools can cause more hazards than sharp ones. Cracked saw blades must be removed from service.

Wrenches must not be used when jaws are sprung to the point that slippage occurs. Impact tools such as drift pins, wedges, and chisels must be kept free of mushroomed heads. The wooden handles of tools must not be splintered.

Iron or steel hand tools may produce sparks that can be an ignition source around flammable substances. Where this hazard exists, spark-resistant tools made of non-ferrous materials should be used where flammable gases, highly volatile liquids, and other explosive substances are stored or used.

Appropriate personal protective equipment such as safety goggles and gloves must be worn to protect against hazards that may be encountered while using hand tools.

Workplace floors shall be kept as clean and dry as possible to prevent accidental slips with or around dangerous hand tools.

Power tools must be fitted with guards and safety switches; they are extremely hazardous when used improperly. The types of power tools are determined by their power source: electric, pneumatic, liquid fuel, hydraulic, and powder-actuated.

To prevent hazards associated with the use of power tools, workers should observe the following general precautions:

- *Never carry a tool by the cord or hose.*
- *Never yank the cord or the hose to disconnect it from the receptacle.*
- *Keep cords and hoses away from heat, oil, and sharp edges.*
- ***Disconnect** tools when not using them, before servicing and cleaning them, and when changing accessories such as blades, bits, and cutters.*
- *Keep all people not involved with the work at a safe distance from the work area.*
- *Secure work with clamps or a vise, freeing both hands to operate the tool.*
- *Avoid accidental starting. Do not hold fingers on the switch button while carrying a plugged-in tool.*
- *Maintain tools with care; keep them sharp and clean for best performance.*
- *Follow instructions in the user's manual for lubricating and changing accessories.*
- *Be sure to keep good footing and maintain good balance when operating power tools.*
- *Wear proper apparel for the task. Loose clothing, ties, or jewelry can become caught in moving parts.*
- *Remove all damaged portable electric tools from use and tag them: "Do Not Use."*

Guards

The exposed moving parts of power tools need to be safeguarded. Belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or moving parts of equipment must be guarded.

Machine guards, as appropriate, must be provided to protect the operator and others from the following:

- *Point of operation.*
- *In-running nip points.*
- *Rotating parts.*
- *Flying chips and sparks.*

Safety guards must never be removed when a tool is being used.

Portable circular saws having a blade greater than 2 inches in diameter must be equipped at all times with guards.

An upper guard must cover the entire blade of the saw. A retractable lower guard must cover the teeth of the saw, except where it makes contact with the work material. The lower guard must automatically return to the covering position when the tool is withdrawn from the work material.

Operating Controls and Switches

The following hand-held power tools must be equipped with a constant-pressure switch or control that shuts off the power when pressure is released:

- *Drills;*
- *Tappers;*
- *Fastener drivers;*
- *Horizontal, vertical, and angle grinders with wheels more than 2 inches in diameter ;*
- *Disc sanders with discs greater than 2 inches;*
- *Belt sanders;*

- *Reciprocating saws;*
- *Saber saws, scroll saws, and jigsaws with blade shanks greater than 1/4-inch wide; and other similar tools.*

These tools also may be equipped with a "lock-on" control, if it allows the worker to also shut off the control in a single motion using the same finger or fingers.

The following hand-held power tools must be equipped with either a positive "on-off" control switch, a constant pressure switch, or a "lock-on" control:

- *Disc sanders with discs 2 inches or less in diameter;*
- *Grinders with wheels 2 inches or less in diameter;*
- *Platen sanders, routers, planers, laminate trimmers, nibblers, shears, and scroll saws;*
- *Jigsaws, saber and scroll saws with blade shanks a nominal 1/4-inch or less in diameter.*

It is recommended that the constant-pressure control switch be regarded as the preferred device.

Other hand-held power tools such as circular saws having a blade diameter greater than 2 inches (5.08 centimeters), chain saws, and percussion tools with no means of holding accessories securely must be equipped with a constant-pressure switch.

Electric Tools

Employees using electric tools must be aware of several dangers.

Among the most serious hazards are electrical burns and shocks*.*

Electrical shocks, which can lead to injuries such as heart failure and burns, are among the major hazards associated with electric-powered tools. Under certain conditions, even a small amount of electric current can result in fibrillation of the heart and death. An electric shock also can cause the user to fall off a ladder or other elevated work surface and be injured due to the fall.

To protect the user from shock and burns, electric tools must have a three-wire cord with a ground and be plugged into a grounded receptacle, be double insulated, or be powered by a low-voltage isolation transformer. Three-wire cords contain two current-carrying conductors and a grounding conductor. Any time an adapter is used to accommodate a two-hole receptacle, the adapter wire must be attached to a known ground. The third prong must never be removed from the plug.

Double-insulated tools are available that provide protection against electrical shock without third-wire grounding. On double-insulated tools, an internal layer of protective insulation completely isolates the external housing of the tool.

The following general practices should be followed when using electric tools:

- *Operate electric tools within their design limitations.*
- *Use gloves and appropriate safety footwear when using electric tools.*
- *Store electric tools in a dry place when not in use.*
- *Do not use electric tools in damp or wet locations unless they are approved for that purpose.*
- *Keep work areas well lighted when operating electric tools.*
- *Ensure that cords from electric tools do not present a tripping hazard.*

In the construction industry, employees who use electric tools must be protected by ground-fault circuit interrupters or an assured equipment-grounding conductor program.

Portable Abrasive Wheel Tools

Portable abrasive grinding, cutting, polishing, and wire buffing wheels create special safety problems because they may throw off flying fragments. Abrasive wheel tools must be equipped with guards that:

- *(1) cover the spindle end, nut, and flange projections;*

- *(2) maintain proper alignment with the wheel; and*
- *(3) do not exceed the strength of the fastenings.*

Before an abrasive wheel is mounted, it must be inspected closely for damage and should be sound- or ring-tested to ensure that it is free from cracks or defects. To test, wheels should be tapped gently with a light, non-metallic instrument. If the wheels sound cracked or dead, they must not be used because they could fly apart in operation. A stable and undamaged wheel, when tapped, will give a clear metallic tone or "ring."

To prevent an abrasive wheel from cracking, it must fit freely on the spindle. The spindle nut must be tightened enough to hold the wheel in place without distorting the flange. Always follow the manufacturer's recommendations. Take care to ensure that the spindle speed of the machine will not exceed the maximum operating speed marked on the wheel.

An abrasive wheel may disintegrate or explode during start-up.

Allow the tool to come up to operating speed prior to grinding or cutting. The employee should never stand in the plane of rotation of the wheel as it accelerates to full operating speed. Portable grinding tools need to be equipped with safety guards to protect workers not only from the moving wheel surface, but also from flying fragments in case of wheel breakage.

Security and CCTV Systems specific hazards

In addition to known and common potential hazards, the Video Security System technicians should also be aware of some CCTV specific hazards in addition to the ones listed previously.

These include:

- Excessive exposure to infrared (IR) illumination when setting up night vision cameras and potential danger of blindness if viewing IR light from close proximity at night. This is due to IR illuminators with wavelength above 700 nm being invisible to the human eye. The iris of the human will not close to protect the retina from excessive IR illumination.
- Installing cameras on poles and high altitudes without proper harnesses and securing objects from falling. Always consider the total weight of the camera with the bracket and make appropriate preparations for installing. Never install such equipment by yourself, always ask for an assistant.
- When using soldering equipment, follow the manufacturers' instructions and be vigilant. A hot soldering iron may look the same as a cold one. Avoid unnecessary burns.
- When installing and terminating fiber-optics cables, it is important to wear protective glasses so that breaking of micro-sized fiber glass pieces do not get into your eyes.
- When running various types of cables through potentially dangerous areas, such as cable trays with high voltage, gas pipes, fire-sprinkler equipment, water areas that may become energized and conductive, extreme caution has to be exercised.

Workplace hazards can be as temporary as a loose power cable on the floor, waiting for somebody to trip over it, an open file drawer or a slippery floor. Care should be taken not only to avoid such "traps", but also not to create ones.

Things that typically shouldn't be there once a job is finished—(like ladders and stools), can be hazardous. A simple "housekeeping" rule— to clean up after the work is done is one of the most important rules.

Hazards can also be a more persistent problem, like machinery that emit hazardous fumes, electric drills or saws creating dust, which can be hazardous not only to installers, but also to the equipment sensitive to dust, especially DVRs. Poor lighting can be an indirect cause of accidents, as well as excessive noise, defective tools or machinery.

Injuries are caused by accidental slips, trips, falls, vehicle accidents, repetitive motion, fires, exposure to harmful substances, over-exertion, being struck by an object or caught between two objects, getting something in your eye, spilling a hot liquid, getting burned, or receiving an electric shock – just to name a few. Injuries can include hurt backs, hernias, sprains, strains, bruises, contusions, cuts, fractures, heat burns, chemical burns, carpal tunnel syndrome, fractures, and dislocations.

Most accidents are avoidable. If it look dangerous, it is.

If it doesn't look dangerous, it still could be.

Don't take a stupid chance and endanger yourself or others.

Fig.125 Isolated ladder

15. Safe voltage electrical practices

Every electrician, CCTV and security installer or technician, in addition to being exposed to the typical safety risks on new buildings and construction sites associated with the physical construction itself, could also be exposed to the invisible forces of electricity. This is not only because all security and CCTV products are designed to work with electrical power, but also because most of the tools used to perform a proper installation are powered by electricity. Every technician working with electricity must be aware of the safe voltage electrical practices.

The U.S. Department of Labor has a number of Occupational Health and Safety standards that cover a large spectrum of safety recommendations in relation to electricity. They are mentioned under the Part Number 1910, and more details can be found on http://www.osha.gov/ web site. We will, however, cover and summarize the most common and important facts that need to be clearly understood by all VSST Level I technicians.

The source of a power supply for any security or CCTV system installation is typically drawn from the 120VAC line power available in each building. It is a common knowledge that touching "naked" energized wires with bare hands can be fatal. Some people may have survived electrical shocks by chance or because of some special circumstance, but it is a simple and basic fact that everybody working with electricity should protect themselves, and their surroundings, from getting in direct contact with line power. Direct contact with 120VAC can not only electrocute a person, but may also cause fire, damage the equipment it touches or simply cause a local blackout with unknown consequences.

Typically, all voltage above 50V is considered dangerous. Most of the modern days electronic equipment used in Security and CCTV works with voltages lower than 50V on the inside of the apparatus. This voltage is derived from the 120VAC line power that is usually brought from a typical power outlet. This makes it dangerous even though the inside might not be so, and extra care should be taken. Some CCTV devices, such as CRT screens, may have high voltage on the inside also, and thus are health hazards if working on the component level.

This is what the OSHA 1910 standards states:

Safety-related work practices must be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts, when work is performed near or on equipment or circuits which are or may be energized. The specific safety-related work practices must be consistent with the nature and extent of the associated electrical hazards.

Live parts to which an employee any be exposed must be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. (Examples of increased or additional hazards include deactivation of emergency alarm systems, shutdown of hazardous location ventilation equipment, or removal of illumination for an area. Examples of work that may be preformed on or near energized circuit parts because of infeasibility include testing of electric circuits that can only be performed with the circuit energized.)

If the exposed live parts are not de-energized (i.e., for reasons of increased or additional hazards or infeasibility), other safety-related work practices must be used to protect employees who may be exposed to the electrical hazards involved. Such work practices must protect employees against contact with energized circuit parts directly with any part of their body or indirectly through some other conductive object. The work practices that are used must be suitable for the conditions under which the work is to be performed and for the voltage level of the exposed electric conductors or circuit parts.

Live parts that operate at less than 50 volts to ground need not be de-energized if there will be no increased *exposure to electrical burns or to explosion due to electric arcs.*

There is even higher danger when working in the vicinity of areas with voltages higher than 110 VAC, such as near power stations, distribution points or high voltage transformers. There are known levels of voltage that can be dangerous even without getting in contact with the wires carrying such voltage, but just by being in close proximity.

TABLE 6 (Minimum approach distances)	
Alternating Current Voltage range (phase to phase)	**Minimum approach distance for a qualified technician**
300 V and less	Avoid Contact
300 V ~ 750 V	1 ft. 0 in. (30.5 cm)
750 V ~ 2 kV	1 ft. 6 in. (46 cm)
2 kV ~ 15 kV	2 ft. 0 in. (61 cm)
15 kV ~ 37 kV	3 ft. 0 in. (91 cm)
37 kV ~ 87.5 kV	3 ft. 6 in. (107 cm)
87.5 kV ~ 121 kV	4 ft. 0 in. (122 cm)
121 kV ~ 140 kV	4 ft. 6 in. (137 cm)

This training will include isolation of energy, hazard identification, premises wiring, connection to supply, generation, transmission, distribution installations, clearance distances, use of personal protective equipment and insulated tools, and emergency procedures.

Qualified Person - Those persons who are permitted to work on or near exposed energized parts and are trained in the applicable electrical safe work practices.

Qualified Persons shall, at a minimum, be trained in and familiar with:

The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment.

The skills and techniques necessary to determine the nominal voltage of exposed live parts.

The clearance distances specified in Table I and the corresponding voltage to which the qualified person will be exposed.

All electrical energy sources must be locked out when any employee is exposed to direct or indirect contact with parts of fixed electrical equipment or circuits.

Safety related work practices will be used to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts. Safety related work practices will be consistent with the nature and extent of the associated electrical hazards.

Specific types of work practices covered by this safety procedure include:

- *Working with de-energized parts*
- *Working with energized parts*
- *Vehicular and mechanical equipment near overhead lines and underground lines*
- *Illumination*
- *Conductive materials and equipment*
- *Portable Ladders*
- *Housekeeping*

Portable Equipment

All portable electric equipment will be handled in such a manner that will not damage or reduce service life. Flexible cords connected to equipment may not be used for raising or lowering equipment and will not be used if damage to the outer insulation is present. Additionally, visual inspections are required and unauthorized alterations of the grounding protection are not allowed to ensure the safety of employees. Prior to each shift, a visual inspection will be performed for external defects and for possible internal damage. Attachment plugs and receptacles may not be connected or altered in a manner that would prevent proper continuity of the equipment grounding conductor.

In addition, these devices may not be altered to allow the grounding pole of a plug to be inserted into slots intended for connection to the current-carrying conductors.

Portable electric equipment and flexible cords used in highly conductive work locations or in job locations where employees are likely to contact water or conductive liquids shall be approved by the manufacturer for those locations. The hazardous locations that employees should be aware of include, wet locations and locations where combustible or flammable atmospheres are present.

For wet locations, employees' hands will not be wet when plugging and unplugging energized equipment. Energized plug and receptacle connections will be handled only with protective equipment if the condition could provide a conductive path to the employee's hand (if, for example, a cord connector is wet from being immersed in water). In addition, ground-fault circuit interrupter (GFCI) protection is required for some equipment/locations and is also recommended for use in all wet or highly conductive locations.

For combustible/flammable atmospheres, all electric equipment and wiring systems in classified locations must meet The National Electric Code requirements for that particular classification.

Protective Equipment

Employees working in confined areas such as electrical vaults or any other area where there are potential electrical hazards will be provided with and use protective equipment that is appropriate for the work to be performed.

Examples of Personal Protective Equipment (PPE) which might be needed for protection against electric shock include but are not limited to:

- *Non-conductive hard-hats, gloves, and foot protection or insulating mats*
- *Eye and face protection whenever there is danger from electric arcs or flashes*
- *Insulated tools or handling equipment*
- *Protective shields and barriers to protect against electrical shock and burns*

Additionally, other ways of protecting employees from the hazards of electrical shock will be implemented, including insulation and guarding of live parts. The insulation must be appropriate for the voltage and the insulating material must be undamaged, clean, and dry. Guarding prevents the employee from coming too close to energized parts. It can be in the form of a physical barricade or it can be provided by installing the live parts out of reach from the working surface.

Conductive Materials and Equipment

Conductive materials and equipment (e.g., hand tools) will be handled to prevent contact with exposed energized conductors or circuit parts. Conductive articles of jewelry and clothing (such as watch bands, bracelets, rings, key chains, necklaces, metallized aprons, cloth with conductive thread, or metal headgear) will not be worn.

De-energized Parts

All electrical parts exceeding 50 volts will be de-energized before an employee works on or near equipment unless:

- *The de-energizing creates a more hazardous situation*
- *The equipment, by design, cannot be shut down*

The decision to work without de-energizing shall be made by management and documented before work begins

When any employee is exposed to direct or indirect contact with parts of fixed electrical equipment or circuits which have been de-energized, the electrical energy source will be locked out.

Energized Parts

If work must be performed while equipment is energized or if de-energizing is not feasible, additional safety measures will be taken to ensure the safety of the qualified employee and any other persons who may be exposed. Protection from energized parts will be suitable for the type of hazard involved. Exposed energized parts in areas accessible to the public shall be continuously protected by an authorized attendant. In areas not accessible to the public, employees shall be protected from exposed energized parts by the use of signs or tags. In addition to signs or tags, barricades shall be used where necessary to limit access to areas with exposed energized parts.

Only Qualified Persons will be allowed to perform work directly on energized parts or equipment. Qualified Persons will be capable of working safely on energized circuits and will be familiar with special precautionary techniques, personal protective equipment, insulating and shielding materials and insulated tools. Qualified Persons must also have received the training required in this safety procedure.

Illumination

Employees will be provided with adequate light to work on energized equipment or equipment will be relocated to ensure adequate light is available.

Portable Ladders

Portable ladders will have non-conductive surfaces if they are used where the employee or the ladder could be exposed to electrical shock hazards.

Reclosing Circuits

If circuits are tripped using a protective device such as ground fault circuit interrupter (GFCI), power will not be restored until the reason for the interruption is determined and corrected.

Fuses or breakers will not be replaced or reset until it is determined that the circuit is safe to operate. Fuses will not be replaced with higher rated fuses or with makeshift devices to bypass circuit protection as designed. Problems will be identified and promptly repaired by a qualified person.

Vehicular and Mechanical Equipment Near Overhead Power Lines

Overhead power lines will be de-energized and grounded before any work is performed by any vehicle or mechanical equipment near the energized overhead power lines. If the overhead lines can not be de-energized, then the overhead power lines will be de-energized and grounded before any work is performed by any vehicle or mechanical equipment near the energized overhead power lines. If the overhead lines can not be de-energized, then the vehicle or mechanical equipment will be operated so that a clearance of 10 feet is maintained. If the voltage of the overhead line exceeds 50 kV, the distance will be increased 4 inches for every 10 kV increase in power. If lines are protected with properly rated insulating devices, the distance may be decreased. If the equipment is an aerial lift insulated for the voltage involved and if the work is performed by a Qualified Person, the clearance may be reduced to a distance given in Table I. If protective measures such as guarding or isolation are provided, these measures must protect the employee from contacting such lines directly with any part of the body or indirectly through conductive materials, tools, or equipment.

Electrical Equipment/Machinery

All electrical equipment and machinery must be grounded effectively so that there is no potential difference between the metal enclosures. Use the voltage detector to find discrepancies and other test equipment to determine the corrective action required. Disconnects should be easily identified with the specific machinery they shut off. Disconnects should also be accessible near the machinery for use in an emergency. The disconnects should be activated periodically to be sure they are operable. All electrical connections to the equipment must be secure *so that no cord or cable tension will be transmitted to the electrical terminals within the equipment. The wiring installation should be such that it is protected from damage at all times*

GFCI Protection

Generally, GFCI protection is not required by the NEC on a retroactive basis. Where there is an employee exposure to potential line-to-ground shock hazards, GFCI protection should be provided. This is especially important in work areas where portable electrical equipment is being used in wet or damp areas in contact with earth or grounded conductive surfaces.

Wiring

Temporary wiring that is being used on a permanent basis should be replaced with fixed wiring.

Conduit and/or cable systems must be protected from damage by vehicles or other mobile equipment. All fittings and connections to junction boxes and other equipment must be secure.

No exposed wiring can be allowed. Check for missing knockouts and cover plates. Jerry-rigged splices on flexible cords and cables should be correctly repaired. Electrical equipment should be installed in a neat and professional manner. Check for damaged insulation on flexible cords and pendant drop cords.

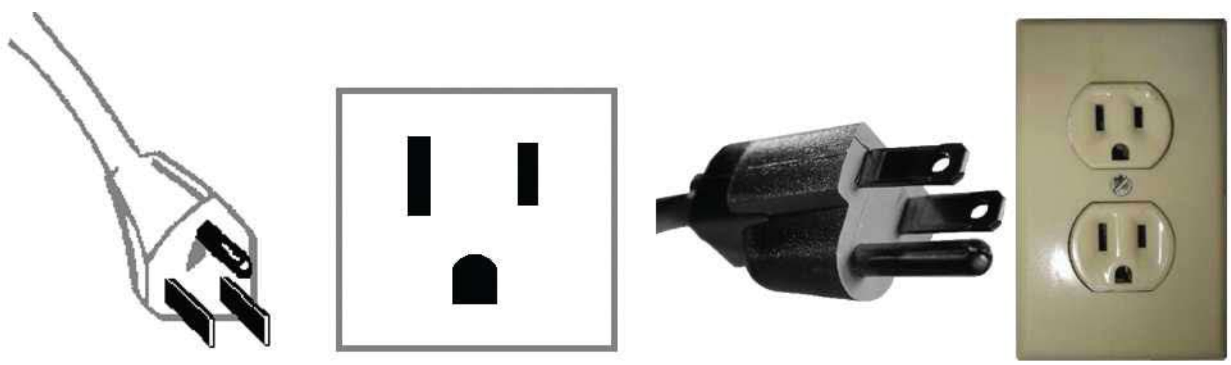


Fig.126 Power plug with a grounding pin

NICET's Practice Analysis outlining tasks Performed by the Level I Technician

1.1 "Project Planning" Tasks

None at this Level

1.2 "System Installation" Tasks

1.2.1 Follow safe worksite practices.

Knowledge:

OSHA publication 2202 - "Construction Industry Digest"

OSHA publication 3080 - "Hand and Power Tools"

Skills:

Safely place and use ladders and scaffolding

Safely use power tools in Level I Tool Kit

1.2.2 Follow safe low voltage electrical practices.

Knowledge:

Personal safety implications of class 1, 2, and 3 voltages

OSHA publication 3007 - "Ground Fault Protection"

Skills:

Recognize wires carrying different voltage classes.

Safely use soldering equipment.

1.2.3 Install correct coaxial and twisted pair video cables with terminations.

Knowledge:

Proper cable pulling techniques and tools, including maximum cable strength in lbs. for coaxial cable, category 5, and power lines (16, 18, and 22 Awg twisted pair), and maximum bend recommendations

Difference between coaxial cable for CCTV and for modulated signals

Difference between cables for plenum and non-plenum areas

Distance limitations of cable types

Connectors required for termination of video cables, including BNC, RCA, and PL2

Which crimping tools to use in properly terminating video cables

Which crimping tools to use in properly terminating video cables

Skills:

Read and interpret shop plans, architectural drawings, and blueprints as necessary for cable location and identification.

Recognize inappropriate cable hangers.

Recognize physical hazards that could threaten the integrity or function of the cable

Identify cable by name, type, number, and suffix.

Use a tone generator and inductive probe to identify cables.

Properly use crimping tools for terminating video cables.

Properly select and use tools from the Level I toolkit for cable installation.

Recognize and report problems

1.2.4 Install camera mounts.

Knowledge:

Properties of wood, steel, concrete, and drywall mounting surfaces and the appropriate hardware for each

OSHA publication 3080 - “Hand and Power Tools”

Skills:

Apply basic construction techniques necessary to mount cameras and associated hardware.

Properly select and use tools from the Level I toolkit.

Recognize and report problems

1.2.5 Assemble camera hardware and place assembled camera on mount.

Knowledge:

Correct orientation of lens and camera for proper functioning

Basic mechanical requirements for mounting a fixed camera

Skills:

Properly select and use tools from the Level I toolkit.

Properly mate a lens to a camera.

Properly adjust lens focus on camera for best image.

Recognize and report problems

1.2.6 Make low voltage power connections.

Knowledge:

Applications of series and parallel circuits

Electrical units such as volt, ohm, amp, watt, and hertz

Proper equipment applications for various power connectors (see Appendix)

Power connection requirements for proper phasing of cameras

Skills:

Identify the proper cable and connection point for the requested connection.

Use a tone generator and inductive probe to identify power cables.

Select and properly use the correct tools and equipment for general low voltage connection points and splice connectors.

Read and interpret shop plans, architectural drawings, and blueprints as necessary for proper power connections.

Properly protect connection points.

Recognize and report problems

1.2.7 Make low voltage splices and junctions.

Knowledge:

Types of low voltage splices and junctions and the function and proper assembly of each

Skills:

Properly select and use tools from the Level I toolkit to access, make, and manipulate splices and junctions.

Properly use VOM/DVM in checking slices and junctions.

Read shop plans to determine locations in facility.

Recognize and report problems

1.2.8 Assemble cabinets and racks and mount equipment.

Knowledge:

ANSI/EIA-310-D rack unit standards and how they affect cabinet dimensions and space requitements

Thermal and ergonomic considerations in the proper placement of equipment

Skills:

Properly select and use tools from the Level I toolkit.

Provide proper service loops.

Label and organize power, data, video, and other cables within a control panel or splice box to insure easy access and identification.

Recognize and report problems

1.3 System testing and commissioning tasks

1.3.1 Verify cable labeling and check cable continuity and point-to-point continuity

Knowledge:

Characteristics of series, parallel, closed, open, short, and grounded circuits

Skills:

Read and interpret shop plans as necessary for cable location and identification.

Identify the proper points on the electrical pathway to take requested measurements.

Determine cable path, length, and purpose.

Locate splices, taps, and patch points.

Use a VOM/DVM, toner and inductive probe, and/or telephone test set in testing and checking continuity.

1.4 "Troubleshooting" Tasks

1.4.1 Locate basic cable faults.

Knowledge:

Characteristics of low voltage circuits, including series and parallel, open, short, and grounded circuits

Electrical units including volt, amp, and ohm

Factors that can cause various types of cable faults

Skills:

Properly select and use tools from the Level I toolkit to access and manipulate cable.

Properly use multimeters, toner and inductive probes, telephone test sets, and/or portable monitors for finding faults in cables, including junctions, splices and termination connection points.

Determine cable path from shop plans.

1.5 "Planning and Conducting User Training" Tasks

None at this level

1.6 "Documentation" Tasks

Note: The letters following some tasks indicate for whom the documentation is required:

S = Shop, C = Customer, G = Government

1.6.1 Locate standard job documentation needed for the installation process.

Knowledge:

Purposes of blueprints, shop drawings, wiring legends, schematics, installation and operation manuals, and related technical bulletins and updates

Skills:

Identify each of the documents listed above.

1.6.2 Temporarily mark cable for construction (S)

Knowledge:

Conventional methods for properly labeling cables

Skills:

Read and interpret the appropriate shop drawings, blueprints, and wiring legends to determine cable runs and assigned cable markings.

Correctly and legibly mark cables.

1.6.3 Record serial numbers of installed devices. (SC)

Knowledge:

Purpose for recording serial numbers

Skills:

Locate and recognize serial numbers on various pieces of equipment.

1.6.4 Recover and store equipment documents.

Knowledge:

Purpose for recovering and storing equipment documents

Skills:

Identify O&E manuals and warranty cards.

1.7 "Project Management" Tasks

None at this Level

Check www.nicet.org to check for updates and/or changes to this practice analysis.

Level I Installer's Toolkit

The NICET Level I task descriptions assume that Level I video systems installers would be familiar with the names, proper usage, and safety considerations for the following tools:

Hand-Tools:

Screwdrivers:

- # 1, 2, 3 flat blades
- # 1, 2, 3, Phillips
- Jeweler's flat blades
- Jeweler's Phillips

Hammer
12" bubble level
Standard set sockets
Razor knife
Flashlight
Wire Snake
Flexible wire-puller
Pliers/wire cutters

Power Tools:

Professional, Heavy duty ½" Hammer Drill

- Set of concrete bits: 1/8" to ½"

Standard power drill ½"

- Set of paddle wood bits: 1/4" to 1"
- Set of metal bits: 1/8" to ½"
- Screwdriver bits

Solder Iron (electric)
Solder Iron (Butane)

Specialty tools:

BNC Crimper (RG59, RG6 3-Piece Dies)
BNC cable stripper
Tone generator/inductive probe
Medium duty 2" needle nose pliers
Light duty 3" needle nose pliers
General duty pliers
Adjustable channel lock
Heavy duty wire cutter
Light duty wire cutter
Spade/lug crimping tool

Meters and monitors:

Digital volt meter (DVM) and/or
2.5" to 5" hand held video monitor or PDA

Acronyms, Definitions of Terms and Codes used in this guide:

°C = degrees of temperature, Celsius scale (0˚C = 32˚ F; 30˚C = 86˚F; 100˚C = 212˚F)

°F = degrees of temperature, Fahrenheit scale (0˚F = -18˚C; 32˚F = 0˚C; 100˚F = 38˚C)

A = Ampere (electrical current flow)

AC = Alternating Current

AGC = Automatic Gain Control

ANSI = American National Standards Institute

AWG = American Wire Gauge

BICSI = Building Industry Consulting Service International

BNC = Video connector used in commercial applications (Bayonet-Neill Concelman)

Cat-5 = Category 5

Cat-6 = Category 6

CCTV = Closed Circuit Television

dB= deciBel

DNR = Dynamic Noise Reduction

DC = Direct Current

DSS = Digital Slow Shutter

DVD = Digital Video Disk

DVM = Digital Volt Meter

DVR = Digital Video recorder

EIA = Electronics Industry Alliance

EMI = ElectroMagnetic Interference

FCC = Federal Communications Commission

ft = foot or feet (approx. 0.3m)

GFCI = Ground-Fault Circuit Interrupter

GLC = Ground Loop Correction

HD = High Definition

Hz = Hertz (oscillations in one second)

I/O = Input/Output

ICEA = Insulated Cable Engineers Association

IEEE = Institute of Electrical and Electronics Engineers

IR = InfraRed

IRE = Institute of Radio Engineers (unit of measure of analog video signal)

ISDN = Integrated Services Digital NetworkISO = International Organization for Standardization

IT = Information Technology

kHz = kiloHertz

km = kilometer

LAN = Local Area Network

lbf = pound of force

m = meter

MATV = Master Antenna TeleVision

Mb = Megabits

MB = MegaBytes

MHz = MegaHertz

mm = millimeter

NEC = National Electrical Code

NEMA = National Electrical Manufacturers Association

NESC = National Electrical Safety Code

NFPA = National Fire Protection Association

NICET = National Institute for Certification in Engineering Technologies

NIC = Network Interface Card

NVR = Network Video recorder

OSHA = Occupational Health and Safety Administration

OTDR = Optical Transducer Directional Reflectometer

PL2 = A screw-on coaxial cable connector that has been replaced by the BNC type

PoE = Power over Ethernet

POTS = Plain Old Telephone Service

PSI = Pounds per Square inch

PSTN = Public Switched Telephone Network

PVC = PolyVinyl Chloride

RCA = “tulip” type video connector used primarily for consumer video and audio

RF = Radio Frequency

RFI = Radio Frequency Interference

RMS = Root-Mean-Square

SIA = Security Industry Association

SVHS = Super Video Home System

UHF = Ultra High Frequency

UL = Underwriters Laboratories

UTP = Unshielded Twisted Pair

V = Volt (voltage levels)

VAC = Volts Alternating Current

VCR = Video Cassette Recorder

VDC = Volts Direct Current

VHF = Very High Frequency

VHS = Video Home System

VOM = Volt-Ohm Meter

W = Watt (power)

WAN = Wide Area Network

WDR = Wide Dynamic Range

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About the authors

Vlado Damjanovski

Vlado Damjanovski is an author, lecturer and CCTV expert, well known to the Australian and international CCTV industry. He has a degree in Electronics Engineering and Television.

Vlado has designed and commissioned many CCTV systems in Australia and around the world.

He has written three books on the topics of CCTV, some of which are translated in other languages. He conducts CCTV seminars based on his books throughout the Australia and overseas and has trained thousands of industry people.

Vlado is currently the Standards Australia CCTV Standards Sub-Committee Chairman and has been a leading proponent in the development of the first Australian CCTV standards, published in 2006.

Howard Kohnstamm

Howard Kohnstamm got his start in CCTV distribution in 1988 after a 20-year career in accounting. He discovered that most of his customers were self-taught or only received informal on the job training. There was a lack of formal CCTV training in 1988, so he asked a lot of questions and did a lot of research. What started out as an after lunch talk on common mistakes evolved into a 16-hour course "CCTV Essentials." Since 1991, Howard has provided training to installers and designers throughout the Southeast United States.

Howard has been an active committee participant since the idea of CCTV certification was initiated by SIA many years ago. He was one of nine subject matter experts (SME) who developed the VSS practice analysis.

To maintain the integrity of the certification process, NICET does not allow active trainers to participate in the question writing process. Howard has the distinction of being the only author and trainer who is an active systems integrator, served as a NICET SME and has taken and passed all six NICET VSS exams.