Cable Product Guide

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STP24LC Cable
SPK Series Cable
Cable Assemblies
Adapters
Custom Cables

Extron® Electronics

Extron Cables

Specifically Designed and Precision Engineered for the A/V Industry

One stop Cable Shopping

Extron Electronics offers a complete line of cable products specifically designed and engineered for the professional A/V industry. Our cable product portfolio includes high quality bulk cables and cable assemblies, problem-solving adapters, as well as Extron's new Universal Crimp Tool and precision machined BNC crimp connectors with Secure-Lock pin positioning.

Multiple Cable Warehouses

In order to provide timely and cost-effective delivery, we maintain a robust worldwide distribution network with warehouses in California, North Carolina, The Netherlands, Singapore and Japan. Each of our cable products is backed by a 24-hour Sales and Technical Support Hotline, and range of support services that is second to none.

Shipped from CA, Anaheim warehouse

Shipped from NC, East coast warehouse

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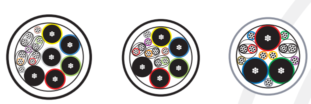
Introduction

Extron Electronics has a complete line of quality audio, video, and control cables specifically designed and engineered to meet the needs of professional A/V environments - from large universities and businesses to small residential installations. Whether you need to send digital video signals down the hall or control communication signals across campus, Extron cables are available for every signal type with the bandwidth and performance for the most demanding applications. Integrator-oriented features include pre-terminated cable assemblies in cut lengths for shorter runs, and bulk cables with smooth SuperFlex jackets that are marked at one-foot intervals for convenient measurement and boxed in self-dispensing rolls.

Complementing the cables and cable assemblies are precision machined problem-solving adapters and ergonomic, time-saving termination tools. In addition, Extron carries an extensive line of audio, video, and control adapters and gender changers, including the most frequently used barrel, right angle, t-type, and panel mount adapters that increase installation options. Save time and money, and ensure quality with our universal crimp termination system engineered for reliable and consistent impedance matched terminations. A universal compression termination system with high quality BNC, F-type, and RCA connectors is available as well. Extron's complete line of cables, cable assemblies, adapters, and connectors are rigorously tested to ensure they meet published performance specifications, as well as applicable safety ratings, which are clearly noted.

Inside this catalog you will find educational material that addresses: Understanding Cables in the A/V Industry, Deciphering Cable Safety Ratings and Applications, Analog Versus Digital Video Signal Formats, and Selecting the Right Cable. Throughout are detailed photographs and product descriptions with performance specifications to help guide your selections. Whether you are relatively new to the A/V industry or a seasoned systems integrator, this Product Catalog contains the essential information you need to make well-informed product choices that provide the performance you expect and keep your customers satisfied.



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Understanding Cables in the A/V Industry

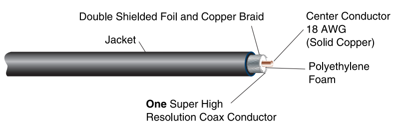
EDUCATION

Cable Types

So many different models and types of cables exist that one could easily become intimidated by glancing through a cable catalog. But when you think about it, all of the various cable types really aren't that different. They are simply combined variations of basic cable configurations. When you look at it this way, thi ngs become clearer. These different types of cables vary greatly in size, capabilities, quality, and performance within their own groups, but most of the cables used in the A/V industry fall within four main groups: individual conductor, twisted pair, coaxial, and fiber optic.

Individual Conductor

This is the most basic of cables, commonly referred to as wire. It consists of a center conductor that is wrapped in a plastic or rubberized outer jacket. This cable type is generally used to distribute low-frequency signals such as speaker audio or computer ID-bit information. Larger variations of this cable type are used to distribute power or for grounding.



Individual Conductor Cable

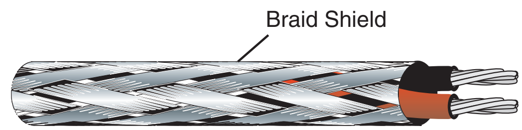
Twisted Pair

Twisted pair cable is available in two styles. Shielded and unshielded twisted pair (UTP) cables can be found in many types of environments, ranging from telephony to professional audio. Twisted pair cable consists of two individual conductors – generally running signal and return – that have been twisted together to form one pair. Usually found with 100 ohm impedance values in 20 to 24 American Wire Gauge (AWG) sizes, twisted pair cable is inexpensive and easy to work with. Because both conductors have equal exposure to extraneous noise (which can be cancelled out at a receiver with a differential amplifier), twisted pair cabling, by design, provides an inexpensive form of protection from outside electromagnetic interference (EMI).

Unshielded Twisted Pair (UTP) — Most commonly seen in telecommunications and computer networking environments, UTP is categorized by its compatibility with the many different data transfer rates associated with these types of equipment. For example, the most popular, Category 5/5e/6 cable, can accommodate transmission rates up to 100 Mbps (megabits per second).

Unshielded Twisted Pair Cable

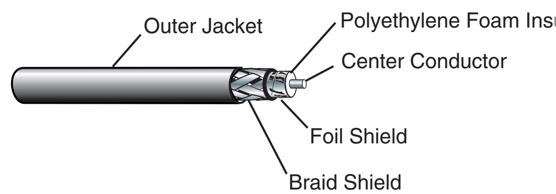
Shielded Twisted Pair (STP) — Shielded Twisted Pair cable consists of a regular twisted pair that is surrounded by a wire braid shield or a foil shield with a drain wire. Either shield provides additional protection against RFI (radio frequency interference) and EMI (electromagnetic interference), making it useful for sensitive signal distribution of audio and computer sync information. A conductor called a drain wire is used to provide a solid connection for the foil shield to each end of the cable.



Shielded Twisted Pair Cable

Coaxial

Coaxial cable is a complex cable that consists of two conductors. The center conductor carries the signal. The outer conductor (shield) provides a return path for the current to ground, and it provides protection against outside interference. The two conductors are separated by a dielectric material (insulation) that establishes electrical characteristics and provides physical protection for the center conductor.



Coaxial Cable

All of these components are jacketed to make one cable. In the A/V industry, coaxial cables generally have 75 ohm impedance and are used in video applications. They are also used with test equipment and RF distribution, and are found in many other environments. Due to the complex design of coaxial cable, it is more expensive than twisted pair cable, but it provides excellent performance and shielding characteristics that make it very reliable. The frequency and resolution of your signal, and the distance of the cable, are very important determining factors in deciding which grade of coaxial cable should be used. Some have better signal loss characteristics than others. The crimp or compression style of cable termination (connectorization) used with these cables makes them very easy to terminate in field applications, and they offer very consistent and reliable connections.

Fiber Optic

Fiber optic cable is the best choice for hardwired signal transmission over long distances. This is due to the extremely low attenuation characteristics (signal loss). Fiber optic cable accomplishes this by transmitting light (photons) instead of electricity (electrons). The way it works is simple: electrical energy from the source device is converted, via the transmitter, into light energy. This light energy is then injected via a laser diode or high performance LED into the fiber optic core. At this point, the light bounces off the walls of the core in a very controlled manner and propagates to the end of the cable, where it is detected by a wavelength-matched photodiode and converted back to electrical energy at the receiver location. The core is a strand of glass wrapped with a cladding material to refract the light back into it. This makes fiber optic cable extremely efficient, creating the near-perfect transmission medium. The core and cladding are covered by a protective coating that provides added strength. Finally, there is an outer jacket for additional strength and protection. Single mode and multimode cable types are available to provide multiple signal distribution options.

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Fiber optic signal transmission is immune to many of the effects that reduce signal quality in traditional wired environments, and therefore, offers many advantages:

1. **Complete immunity from EMI —** Traditional wire and cable can act like an antenna, picking up unintended stray signals. This poses problems, particularly for display systems. Because fiber optic cable is constructed of glass and the signal is light, it is not subject to outside noise.

2. **Small size —** Because most fiber optic cores are no larger than human hair, these cables tend to be very small and lightweight.

3. **Low attenuation —** Because fiber optic transmission is accomplished with light sent through glass, the normal resistance and capacitance factors that introduce loss into traditional systems do not apply. This provides high bandwidth capabilities, and the ability to run long distances while protecting against outside interference.

4. **High security —** Transmission of light is not subject to electronic eavesdropping, making fiber optic cable useful for secure communications.

Although fiber optics would appear to be the ultimate method of signal transmission, there are some drawbacks:

1. **Higher price —** Overall, a system that uses fiber optic runs will be more expensive. This is in part a result of the costs associated with fiber, transmitters, receivers, and labor.

2. **Difficult to use —** Termination of fiber optic cable is crucial in establishing a good transmission path. Fiber cable end termination is somewhat specialized, and it is not something that is quickly accomplished. This could contribute to a longer and more expensive installation.

3. **Performance —** While fiber optic cable is the near-perfect transmission medium, system limitations are introduced by the technical performance of the transmitting and receiving equipment. In digital systems, fiber is very robust, particularly when based on laser emitters. For most video systems, there are some very capable fiber transmission systems, but virtually all are analog-based with commensurate difficulty maintaining high speed performance and linearity. The cost for transmitter/receiver combinations with high performance graphics capability can be very costly compared to good quality copper-based transmission lines.

Anatomy of a Cable

Most people view cable simply as something that is used to connect two pieces of equipment together. Not much attention is given to what is inside. The inner components of a cable and the materials used during construction are absolutely critical in establishing how a given cable will perform in an application. In this section, we will use coaxial cable as an example because a coaxial cable consists of all of the following components. In one form or another, all cables will use some, if not all, of these components in their construction.

Conductors

The center conductor of a cable carries the signal from one point to another. Center conductors are made of highly conductive materials, which are capable of carrying electrical current. The most commonly used material is copper, due to its overall conductive properties, availability, cost, and workability. Other materials are available and are used in specific applications. Examples of other conductors that may be found include aluminum, silver, and gold. Solid and stranded center conductors are readily found in the construction of cable.

Solid — A solid center conductor is one that is made of one single wire. The diameter, or AWG (American Wire Gauge), size may vary, but solid conductor cables are generally easier to manufacture and are therefore less expensive. These conductors are formable but not very flexible. For that reason, solid center conductor cables are generally used in permanent installations.

Stranded — Stranded center conductors are comprised of multiple small gauge wires that are twisted together to form a larger single conductor. The advantage of this type of conductor is the increased flexibility. These cables are easy to work with, and are found in more mobile applications.

Gauge

Gauge is the diameter of a conductor with higher gauges being smaller and lower gauges being larger. For instance, an 18 gauge wire is very thin, while a 12 gauge wire is much thicker. It is generally preferable to use lower gauge wires whenever possible. The thicker wires allow a signal to travel more freely over longer distances and generally allow greater quality. Wires with a thicker gauge have less resistance to current flow (impedance) than thinner wires, making them preferable for connecting equipment, especially if the lengths of wire are fairly long. (See American Wire Gauge chart on page 17).

Dielectric

The dielectric, also known as cable insulation, serves an important dual role in coaxial cables. It is the material that separates the center conductor from the outer shield. This protects the center conductor. But, more importantly, it establishes electrical characteristics, such as impedance and capacitance that greatly influence the overall cable performance. Some of the more common insulation materials include polyethylene for general purpose cable and fluoropolymers for plenum-rated cables.

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Shielding

Shields also serve an important dual role. They work as a second conductor, which acts as a return path for the signal current to the system ground. They also provide signal protection from outside interference. Several shielding methods are available to handle the different types of interference that cables may encounter. Foil shields, braided shields, and combination foil/braid shields serve specific purposes.

Braid shield — This type of shield is made of many fine strands of wire woven together to form a braid that encompasses the internal conductor(s) and dielectric of the cable. A braid shield is typically lower impedance than a foil shield and offers better immunity from stray electromagnetic fields or interference (EMI). Interference can take many forms, from low frequencies (such as rolling hum bars) to higher frequencies (such as noise generated by appliances and switching power supplies). Braid shields may be used in combinations of multiple braids or with copper or aluminum foils to offer higher percentages of shielding coverage.

Foil shield — Foil shields provide 100% shielding effectiveness when used in conjunction with a braid shield. Whereas copper braid shields may have more than 90% shielding effectiveness, realizing 100% with braid usually requires two braid shields at higher cost, weight, and stiffness. A foil/braid combination accomplishes 100% shielding effectiveness much more easily.

The foil shield is a foil-sided tape wrapped completely around the insulation of the cable. In some cable designs, a small-gauge drain wire will accompany a foil shield. The drain wire facilitates shield connection to a connector shell. The foil/drain wire approach provides only minimal shielding effectiveness, primarily at lower frequencies.

Jacket

Overall protection to the inner components is provided by the outer jacket. The outer jacket of a cable protects against weather, chemicals, liquids, and sunlight. Cable must conform to any of a number of classifications to be installed in specific environments. These standards are governed by the NEC (National Electric Code) and have certain UL (Underwriters Laboratories) certifications.

Plenum — A typical projection system installation involves cable distribution through walls and ceilings. If you climb a ladder and observe the labyrinth that exists above ceiling panels, chances are you may see air conditioning ducts and other air movement systems. This type of area would be categorized as a plenum ceiling or plenum environment. It has this designation because the air return system for a building is located in this area. Special consideration must be taken for all other equipment in this environment. Therefore, cables that are used must be either plenum rated (CL2P/CMP) or run through electrical conduit. Local fire codes dictate what equipment requirements are necessary. CL2P or CMP-rated cables not only have special fire-resistant jackets, but they also use special compounds in the insulation material. This provides for low flame and smoke output in the event that the cable is exposed to fire. Plenum cable can be run through open air spaces, so the need for conduit is eliminated and installation costs can be reduced.

Halogen-Free — Halogen-free cables utilize a low smoke and fumes, zero halogen jacket material that meets European safety code requirements (IEC 33203 flame test, IEC 61034 smoke test, and IEC 754-1corrosivity test).

Jacket materials go a long way in establishing the overall flexibility of the cable. For example, because of the jacket material, a plenum-rated cable will be more stiff, and therefore more difficult to maneuver and terminate. Depending on the certification needs of the system, you would normally want to use the most flexible cable that is available.

Shielding Effectiveness for Multiconductor Cables

The concept of a shield is simple. Think of it as an all-encompassing metal envelope surrounding that which is to be protected. Nothing gets out. Nothing gets in. The concept is that it must be continuous and unbroken; otherwise, energy may ingress or egress at the point where the continuity is broken. This idea is the essence of the Faraday shield, which shunts electromagnetic fields. Not having this quality shielding means that a system is susceptible to outside noise and/or may radiate undesirable interference into other systems.

Carrying the Faraday shield idea forward, the metal enclosure surrounding a product can be a Faraday shield if constructed properly. The outer shield of a cable, be it the shield of a single coax or the shield of a complex group of wires, is a Faraday shield when terminated properly between the systems that it interconnects. Again, the idea is a continuous, uninterrupted metallic surface that shunts around its exterior unwanted noise and shunts within its interior all locally generated noise. This can be accomplished in cables only when the outer shield is terminated intimately at the connector body utilizing the full circumference of the shield itself.

With VGA style terminations, shielding of the entire connector body is crucial in attaining EMI compliance. The shield is typically made of a solderable, soft, drawn metal. One end of the metal shield must contact and be bonded (soldered) to the full circumference of the shield braid. The other end must conform to the shape of the connector body and be bonded (soldered) to it as well. Only in this way is a complete Faraday type shield created. Implementing quality shielding in cables and systems usually means more cost. Typically, better constructed cable assemblies cost more.

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Cable Performance/Specifications

Performance Factors

The way a cable performs in a system is largely determined by its physical construction. While the following factors are somewhat related to the physical cable, they have a large effect on the integrity of the signal at the destination.

Length — As cable length increases, signal loss increases as governed by the laws of physics. As the signal propagates along the cable, its performance is impeded by interactive factors associated with the dielectric materials and its relationship to other conductors. Losses in cable are calculated based on a unit length such as feet or meters. As transmission distance increases, loss of image brightness and detail gradually become apparent with analog signals. With digital signals, losses are not obvious until the receiving device can no longer recognize the signal.

Frequency — Consistent with cable length, increasing frequency is another fundamental factor affecting signal transmission distance. As frequency increases, skin effect, dielectric quality, and cable construction determine how the cable will perform. For coaxial cables, the dielectric material must be a higher grade as frequency and distance requirements rise. Since image detail is carried by the higher frequency components of a signal, image fuzziness is the first sign of poor high frequency performance.

Interference — Interference is any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment. A cable may act as a large antenna. Outside interference can pose significant problems to signal integrity when the cable does not have adequate shielding properties.

Crosstalk — Crosstalk is a condition that occurs when signal information on one conductor is electromagnetically induced into a nearby conductor. This condition is usually thought of as degrading to system performance and often occurs between conductors run in close proximity without proper shielding or decoupling.

Temperature — A cable is an electronic component that is subject to the same physical laws as other devices. All materials used within cable construction are susceptible to performance variation due to heat-related conditions. Because cables are typically installed in non-ventilated or inadequately ventilated environs such as walls, ceilings, and equipment racks, they tend to be exposed to higher-than-expected temperatures. Therefore, it is important to select cables capable of consistent performance under those conditions.

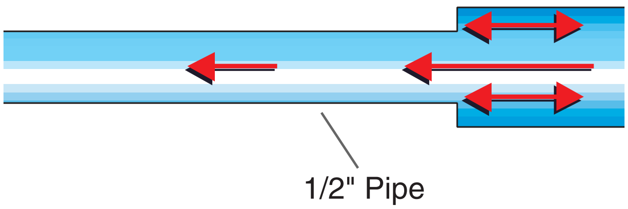
Skew — Skew, in cabling terms, is used to describe the timing difference between two signals traveling over two separate conductors of differing length (or other properties) and reaching their destinations at different time intervals. Just as sound requires additional time to travel additional distance, so does an electrical signal propagating over a wire. As the wire length increases, the time required to travel the length of the wire increases proportionally. In multiconductor transmission systems, such as video over twisted pair cable, simultaneous arrival of the red, green, and blue signals is essential for good video quality. Therefore, construction of cables for multi-channeled signal systems requires that cable lengths be matched as closely as possible in order to minimize skew time. In some cases, electronic time delay circuitry may be employed to make up for cable variation leading to skew. As well, cables designed for minimum skew may be used.

Cable Specifications

Cable specifications are the most important determining factor of how well a given cable will perform in a system. A cable can never be any better than the specifications allow it to be. For this reason, careful attention should be paid to these important numbers before a cable purchasing decision is made. Many specifications for cables exist; some of the most important ones are listed below.

Impedance — Impedance is one of the most critical specifications. It establishes the baseline for the flow of the signal. This flow must be maintained throughout the entire system for proper transfer of power. If there are impedance mismatches, the possibility that reflections will occur is very high. A reflection is essentially a faded, less powerful representation of an image that is being displayed. This reflected image will be noticed to the right of the original image. Reflections are caused by impedance mismatches as well as improperly terminated connectors.

Here is how reflections occur: Imagine water flowing through a large diameter pipe. No problems exist as long as the pipe diameter remains the same. If this pipe feeds into a smaller-diameter pipe, the water flow is disrupted. As this bottleneck occurs, not all of the water will be able to flow through the smaller opening. This will cause some of the water to flow back into itself, and it will eventually be reintroduced into the main water flow. A similar situation occurs with cable. The signal that is reintroduced to the original signal is called a reflection. Most commonly used impedance for coax cable is 75 ohms.



Impedance mismatch

Attenuation — The next most important performance specification of a cable is attenuation. Attenuation is a measurement of the amount of loss that will occur from one point to another. Attenuation is also referred to as insertion loss, and it is measured in dB (decibels). Typical cable specifications include a "loss table" which provides the dB loss value at some selected frequencies for a standard length. For example, -2.2 dB/100 ft. @ 100 MHz would be a typical way of indicating a loss specification. Cable loss is cumulative; so, at 200 MHz, the same 100-foot cable would have a different attenuation value. But, relative to one frequency (e.g. 100 MHz), the cumulative loss is additive as length increases. The same cable having 2.2 dB loss at 100 MHz at 100 feet will have 4.4 dB loss at 100 MHz at 200 feet.

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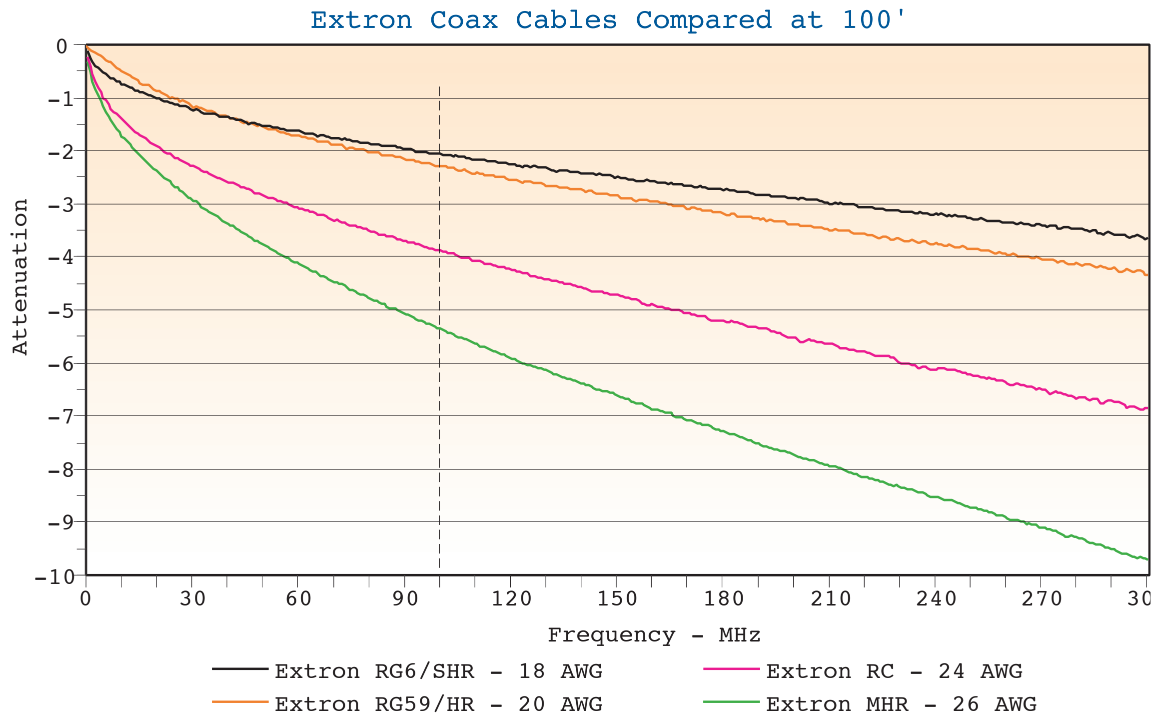

Using The Cable Loss Table

Most coaxial cable specifications include loss values in dB for a range of frequencies over a standard length, usually 100 feet or 100 meters. Depending on the most popular recommended application by the manufacturer, the list of frequencies will include "round number listings" like 1, 5, 10, 20 MHz, etc. We use the loss at, or near, one of the specified frequencies to predict signal loss. This is a normal course at the beginning of system design since most signal loss will occur in the cabling system over any significant distance between electronic components. Some tables will include loss values at very specific frequencies: 72, 135, 177, 270 MHz, etc. These frequencies relate to applications carrying serial digital television signals. Serial digital interface (SDI) signals operate at specific speeds, or bit rates. System designers need to know the specific loss values at these operating rates for SDI in order to better predict system performance. Serial digital signals are unforgiving in that the signal will not be recoverable if loss values exceed the receiver's ability to read and decode the signal.

Follow the cable's specified insertion loss figure for 100 feet (or 100 meters) at the highest frequency of interest in your system design. For example, if the highest frequency of interest in your design is 100 MHz, then look for the loss value in dB at that frequency in the column having the units you use, either

100 feet or 100 meters. Let's say it is -2.5 dB for 100 feet. If your design is distributing analog RGB signals, you will likely not want a loss more than -3 dB without taking other action (outlined below). So, if we take the ratio -3 dB/-2.5 dB, we obtain a value of 1.2. This 1.2 factor is now used as a multiplier against the 100 foot standard length cable used to build the loss table. Multiplying 100 by 1.2 equals 120 feet that we can run with that cable and not exceed -3 dB loss. If the loss factor exceeds our 3 dB budget, our choices would be to select a larger, lower-loss cable or consider using interfaces or line drivers to compensate for the extra loss. Should the table not include the frequency of concern, you can interpolate a loss value between known values in the table or obtain a representative piece of the cable and have it measured specifically at the frequency of interest. Cable losses are cumulative and are generally linear, which makes interpolation of values fairly accurate.

Suppose your design calls for distribution of SDI signals. If you are distributing the most common rate from SMPTE 259M mode C, you will now look for the loss value corresponding to 135 MHz in the cable's loss table. For all SDI and HD-SDI loss calculations, the one-half clock rate frequency is used. For 270 Mbps (270 MHz) component SDI, that would be 135 MHz. Divide the dB loss value into 30 (SMPTE 259M allows a maximum loss of -30 dB in which a Class A receiver should recover) and the result will be the multiplier indicating how many multiples of 100-foot lengths can be used. For example, if the loss at 135 MHz is -3 dB, we divide -30 by -3 to obtain a multiplier of 10. Now, with that specific cable, we can multiply 100 feet by 10 to obtain 1,000 feet. This would be the recommended length cable that could be run assuming a Class A receiver. A class B receiver could reduce the run to -20/-3 = 6.67 for a run length of 100 x 6.67 = 667 feet. Cables recommended for SDI or HD-SDI service may include a 10% length reduction allowance to establish some margin against sudden signal loss, or the "cliff effect." Usually, this will be noted in the table. If not, decrease your run length by about 10% to obtain some margin. If any questions arise, consult with the cable manufacturer before completing your calculations.

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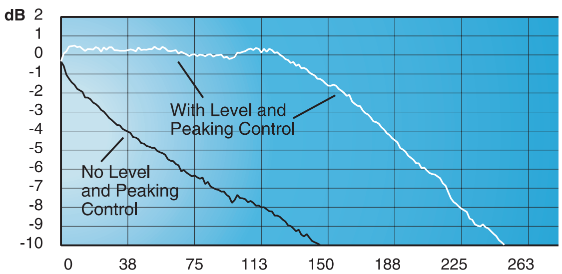
Electronic Compensation for Cable Loss

Although good cable loss planning is essential, there are times when no amount of cable planning will solve the real problem of high frequency loss in a system. In this situation, electronic compensation may be the only reasonable solution. For this reason, all interfaces and line drivers, and some distribution amplifiers and switcher/routers contain compensation circuitry that provides for direct adjustment and compensation. Typically, these components will have at least two controls, level (or gain) and peaking, which can make the difference between a usable or unusable system. The best application for these compensation components is at the system head-end.



Level Control — The level control increases the overall signal level so as to overcome resistive losses in the cable. The resistive loss in a cable can easily amount to 5% or more. Against an analog signal of 0.7 volt, this translates to a 35 mV signal decrease. This is significant in terms of driving displays to full light output. Resistive losses are linear with cable length and often can be much greater than 5%.

Peaking Control — The peaking control increases, or emphasizes, the high frequency content of the signal. Coaxial cable losses increase with frequency. So, in any system design, high frequency loss is of prime concern since the high frequencies carry the fine detail in the image. The peaking control will boost system gain over a range of higher frequencies to overcome the attenuation curve of the cable. Normally, the level control is set to return the low frequency signal amplitude to normal level (0.7 volt, for example) and the peaking control is adjusted to provide the most recovery of the high frequencies without over compensating. Over-compensating the high frequency loss may generate other noise and image artifacts considered more undesirable than a softer image. During system calibration, both level and peaking setup can be interactive and should be aligned using test equipment or a display of known performance.

With some experience calculating real losses in cable, you will see that the cable is the weakest link in any system design. While it is usually the last item considered in the system, it plays an extremely important role in your realization of the expected system performance. Cabling is most often the lowest cost area for ultimate realization of system performance, but often the first thing overlooked. Overcoming losses imposed by inappropriate cable selection is often more expensive than installing a larger, better quality cable in the beginning. Remember, -3 dB is the common reference point for specification of analog bandwidth, but keep in mind that cumulative cable loss and real system bandwidth will change as length is increased or decreased.

Resistance — A definition of resistance is "that property of a substance that impedes current and results in the dissipation of power in the form of heat." Simply put, resistance is the characteristic of a conductor that slows the flow of electrons. This specification is measured in ohms (W) and represents the simple direct current, DC, loss in the conductor. In cable, resistance (DCR) is expressed as W/1,000 feet (ohms per one thousand feet). Resistance of a material is determined by material type, dimensions, and temperature.

Resistance affects the voltage (amplitude) of a signal. Long cable runs or cable with high resistance values will make a displayed image appear dim. For example, a piece of video equipment with an output of 0.7V p-p is connected to a display via a 200-foot length of cable. The actual signal level available at the display is only about 0.63 volt (loss of approximately 10%), for a mini high resolution cable with a DC resistance of 41W/1,000 feet. This is a result of the resistance of the center conductor reducing the voltage level of the signal. Fortunately, there is equipment with features specifically designed to compensate for these types of losses, such as the level control on an Extron interface or line driver. The level control is used to boost the signal voltage to compensate for resistive loss. The peaking control is used to increase the voltage of the high frequency information.

Capacitance — Capacitance is defined as "the property of an electric system that determines how much electrical charge will be stored in the dielectric for a given potential difference between the conductors." This can be interpreted as the ability of a component to charge, hold a charge, and discharge. The unit of measurement for capacitance is the farad (F). In cable, capacitance is expressed as pF/ft. (picofarads per foot). A coaxial cable is electrically nothing more than a large capacitor. How does this affect the signal? Well, it affects the sharpness and detail of video signals. This occurs due to the time it takes for a given cable to charge and discharge. Imagine a length of garden hose attached to a water faucet. When the faucet is turned on, it takes some period of time before a full flow is achieved. It first starts as a trickle and then gradually builds to the full pressure. A similar situation occurs when the faucet is turned off; the water does not immediately stop flowing. It first slows, then gradually stops. The same concept holds true with the electron flow through cable. A video signal transition that is supposed to be black-to-white may, due to this delay, appear as black-to-gray instead. Capacitance actually affects the rise and fall times of a signal; this translates to changes in the sharpness or detail. Fortunately, there is equipment with features specifically designed to compensate for these types of losses, such as the peaking control on an Extron interface.

Cable Termination

Another critical element affecting the overall performance of an A/V system is the connectors that link the cables to the display devices and other components within an A/V system. Extreme care must be taken when connecting cables within the system. One poorly constructed cable connection can erase all the care and attention to detail that went into the rest of the system. For example, an improperly crimped BNC connector can result in signal reflections. A center conductor that has been damaged by poor installation stripping processes can have the same result.

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Impedance Matching

In video systems, proper impedance matching is the right thing to do. For many years, the only cost-effective coaxial cable connector available was the 50 ohm BNC. The 50 ohm version dominated because of the RF equipment industry. We connected our test signal generator (VTG 400) through a 12-foot length of 75 ohm cable using, in one test, 75 ohm BNC connectors and, in the second test, 50 ohm BNC connectors. The test signal is a step response. The transient response at the leading edge tells us if we will see any anomaly attributable directly to the mismatch. Any serious perturbations here could translate into image artifacts that affect high frequency details in an image. Compare the two waveforms of Figure 1. The yellow waveform illustrates the performance with a 75 ohm BNC connector. The blue waveform represents the 50 ohm situation. You'll see that no difference is visible. This is our experience overall.

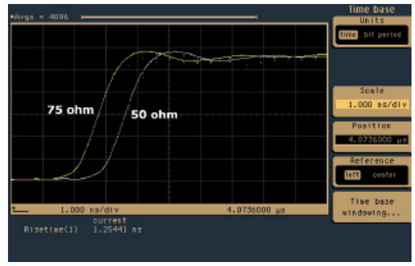

Figure 1. Step response comparison of 50 ohm versus 75 ohm BNC connector in a 75 ohm system

The actual dimensions of BNC connectors are small enough that we will not see significant effects created by the connector in a system until we approach 3,000 MHz where the connector's physical length approximates one-quarter wavelength of the frequency of interest. Therefore, the reason that BNC impedance mismatch effects are not prevalent in systems we design is that the connector dimension is a miniscule part of the transmission line length at frequencies for which we are primarily interested. In the microwave industry, the connector dimension is significant. Now, refer to Figure 2, which shows the TDR (time domain reflectometry) presentation of a 50 ohm BNC. Compare this to the TDR image of a 75 ohm BNC in Figure 3. These images represent time domain measurements of an SDI signal carried on a 12-foot length of 75 ohm cable. Perturbations seen for either connection impedance center primarily on the connector crimp and contact interface.

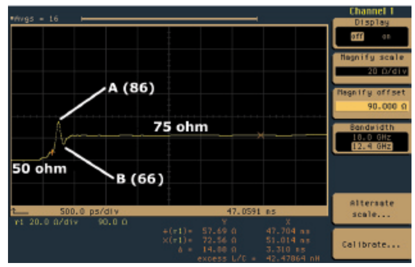

Figure 2. TDR of a 50 ohm BNC connector in a 75 ohm system

A= Ferrule Interface
B= Ground Crimp

Does this mean you can actually ignore coaxial cable impedance in system design? NO. The electrical length of cables is significant at the frequencies we encounter with graphics systems. This is why you see poor performance with some cables. They are not the correct impedance and, therefore, reflect much of the transmitted energy back to the signal source. Mismatched impedance levels can cause signal reflections (ghosting) and attenuation, particularly with signals of 500 MHz or higher.

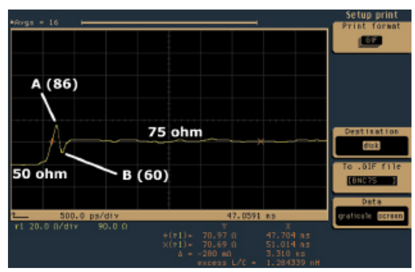

Figure 3. TDR of a 75 ohm BNC connector in a 75 ohm system

A= Ferrule Interface
B= Ground Crimp

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Deciphering Cable Safety Ratings and Applications

Have you ever found yourself confused or unsure of the type of wire or cable to use in a project as it relates to local codes and safety requirements? What do the various cable safety ratings mean? What materials and characteristics make one cable less flammable than another? What is meant by halogen-free cable? Is plenum cable cheaper to run than cable in conduit?

The building authorities (usually county or city) in your locality adopt standards and codes to which construction must conform for the overall good and safety of the community. Remember that regardless of national codes and standards, the local building authorities have the last word on what is considered acceptable building and wiring practice in your area.

For both high voltage and low voltage electrical wiring, all building authorities in the United States adopt standards from the National Electrical Code (NEC). The NEC is a collection of requirements for electrical wiring and appliances that safeguard against electrical fire and electrocution. A committee under the supervision of the National Fire Protection Association, (NFPA), creates the NEC. The NEC is just one code document among many created by the NFPA (visit www.nfpa.org for more information). It's important to note the difference between a standard and a code. A standard is a level of performance that may be adopted as an option, but a code is a mandate imposed by some authority.

Cable Types

All signal cable used for computer networks, telephone, video, audio, and control applications of less than 50 volts is considered low voltage cabling. Low voltage wiring is categorized into the following five basic groups within the NEC:

Cable Type	Use
CM	Communications
CL2, CL3	Class 2, Class 3 remote-control, signaling, and power-limited cables
FPL	Power-limited fire protective signaling cables
MP	Multipurpose cable
PLTC	Power-limited tray cable

Fire safety ratings under the NEC are conducted according to a common group of flame retardancy tests, which makes the cable markings similar across all of these designations. The NEC's cable substitution hierarchy for fire safety is shown in Table 1. Video, audio, and low voltage control cables fall into Class 2 typically due to the available power limits set in the NEC. All computer network and telecommunications cabling falls into the CM class. CM and CL2 categories of cabling are of primary concern in the A/V industry.

Cable Marking Designations

Table 2 is a handy applications table that will help you organize the cable marking designations mentally.

Plenum-rated cables (suffix "P") are at the top of the cable safety food chain because they are constructed of materials having very low "fire load." Fire load is the term used to describe how much fuel a given material provides a fire. A lower fire load rating means that the material is more fire resistant and produces less smoke. Smoke accounts for most fire-related deaths. Cables obtain the plenum rating upon successfully passing UL 910, Test for Flame-Propagation and Smoke-Density Values for Electrical and Optical-Fiber Cables Used in Spaces Transporting Environmental Air. Plenum is a commonly used term in the construction and system installation industries because, in most cases, plenum-rated cables may be installed in air handling systems (air plenums) without expensive metallic conduit. Plenum cable can cut installation costs dramatically.

NEC Cable Substitution Hierarchy

Cable Type	Permitted Substitution																	
	MPP	CMP	CL3P	CL2P	FPLP	MPR	CMR	CL3R	CL2R	FPLR	MPG	MP	CMG	CM	PLTC	CL3	CL2	FPL
MPP	•																	
CMP	•	•																
CL3P		•	•															
CL2P		•	•	•														
FPLP	•	•			•													
MPR	•					•												
CMR	•	•				•	•											
CL3R		•	•				•	•										
CL2R		•	•	•			•	•	•									
FPLR	•	•			•	•	•			•								
MPG	•					•					•							
MP	•					•						•						
CMG	•	•				•	•				•	•	•					
CM	•	•				•	•				•	•		•				
PLTC															•			
CL3		•	•				•	•					•	•	•	•		
CL2		•	•	•			•	•	•				•	•	•	•	•	
FPL	•	•			•	•	•			•	•	•	•	•				•
CMX	•	•				•	•				•	•	•	•				
CL3X		•	•				•	•					•	•	•	•		
CL2X		•	•	•			•	•	•				•	•	•	•	•	

- Plenum Types
- Riser Types
- General Purpose Types
- Dwelling Types

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Deciphering Cable Safety Ratings and Applications (continued)

Cable Marking Designation

Application	Cable Family					
	MP	CM	CL2	CL3	FPL	PLTC
Plenum	MPP	CMP	CL2P	CL3P	FPLP	–
Riser	MPR	CMR	CL2R	CL3R	FPLR	–
General Purpose	MP, MPG	CM, CMG	CL2	CL3	FPL	PLTC
Dwelling	–	CMX	CL2X	CL3X	–	–

Table 2. Cable Marking Designations for NEC Application Categories

Riser (suffix "R") describes cables having a lesser degree of flame retardancy than plenum, but may be used to convey signals vertically (i.e. floor to floor) in air shafts without requirement for metallic conduit. The compliant cable has a flame propagation of less than 12 feet and has a temperature of 850 degrees Fahrenheit or less at a height of 12 feet per UL 1666. General-purpose (no suffix) cables may be used in conduit, behind walls, or other enclosed locations where the cable is protected and not in an air plenum. Commercial installations, at a minimum, must use general-purpose cables (the typical CL2 designation for coaxial video cables, for example). This type of cable must comply with UL 1581, the Vertical-Tray Flame Test. For CSA (Canadian Standards Association), the vertical flame test differs in loading (more cable in bundles), burner angle, and failure criterion.

CL2X and CL3X are the lowest rated cable and must comply with UL VW-1 Vertical-Specimen Flame Test. The cable is not marked VW-1. This rating may be used in residential dwellings.

PLTC (power-limited tray cable) complies with a 70,000 BTU/hour vertical-tray flame test. Cables of this type are marked PLTC with ink or marker tape.

Plenum Rating

The term "plenum" is used to describe the open space or environment above ceiling panels that typically house air return systems for a building. In such environments cables must either be plenum-rated (meet certain low flame and smoke output requirements in the event of a fire) or run through conduit. Plenum-rated cables (designated by CL2P or CMP by the National Electric Code) have special fire-resistant jackets and special compounds in the insulation material.

The most common insulation and jacketing material used on wire and cable is polyvinyl chloride i.e., PVC. PVC has many attributes that make it a great material for general-purpose wire. Unfortunately, PVC is very flammable. When PVC burns, a key byproduct is hydrochloric acid. The smoke and residues are very corrosive. While there are several versions of PVC with varying characteristics, basic PVC is not capable of passing the plenum test. Only special formulations of PVC containing flame and Smoke Suppressants are capable of attaining the plenum rating. Some versions of PVC and another group of polymers from the family of plastics called polyolefin may attain plenum capability when combined with certain other polymers and fire resistant non-organic materials. However, maintaining the safety margins against the plenum flame test is sometimes difficult. Cable construction must be highly controlled in order to maintain the necessary design margin for maintenance of the plenum rating.

The best insulation for fire resistance to date is also one of the best dielectric materials for lower loss cables… Teflon® FEP (fluorinated ethylene propylene). Teflon FEP is a registered trademark of DuPont. But, Teflon FEP is much more expensive to manufacture which explains the higher cost of plenum rated cables. The material is tougher and more difficult to extrude. This is why plenum cables are not as flexible as PVC.

To obtain a plenum rating, the cable must pass the Steiner Tunnel Test within UL 910. The Steiner Tunnel is a specially constructed fire chamber that positions a group of cables of the same type and about 24 feet in length into a horizontal frame within an air handling plenum. Air rushes into one end of the plenum. Gas burners supply a specific level flame under the cable bundle about 4.5 feet from the end near the air inlet. While the flame is applied for a specified period of time, the length of flame travel along the cable is monitored as well as the amount of smoke produced. At the opposite end of the tunnel, a vent shaft funnels the air and smoke past photoelectric sensors. Test criteria with which the cable must comply are:

- Smoke Peak Optical Density: less than 0.50
- Smoke Average Optical Density: less than 0.15
- Maximum Flame Propagation: less than 5.0 feet (1.524 m) from point of application

Halogen Used in Insulation

Most of the wire and cable insulation made in the US depends on the addition of halogens for fire retardancy. What are halogens? Halogens are the elements in group VIIa on the periodic chart (yes, you will now use some of that obscure high school chemistry). The name is of Greek origin, meaning "salt-bearing." The naturally occurring halogens are fluorine (F), chlorine (Cl), bromine (Br), and iodine (I). Halogens are nonmetallic and closely resemble one another. They readily form bonds among themselves and with most other elements.

While PVC contains chlorine, it is not fire resistant. PVC and polyolefin products must have concoctions of other elements added in order to achieve any degree of flame resistance. Most fire resistant compounds contain fluorine or are said to be fluorinated, such as FEP (fluorinated ethylene propylene).

Halogen-Free Cables

European building authorities typically do not allow use of halogenated cables. When halogen-based cables burn (at whatever level they will produce smoke), the smoke is corrosive and contains poisonous gases. There is high concern about the true safety of halogen-based cables. (More information on the move away from halogens in cable insulation may be obtained at: www.halogenfree.org.)

While the European Union designs the safety tests for that region, there is great debate over the relevance of their position on cable flame retardancy and safety versus that in the US. Halogen-free polymers require other formulations of compounds in order to obtain low smoke cable products.

MHRHF-5
Five Conductor Mini High Resolution Halogen-Free Cable

Cable Ratings

The cable rating to use on a project is, first and foremost, dictated by the local building authorities. Always check on your local codes before committing to the cabling design. In the United States, a general-purpose cable, like CL2 or CM, is acceptable in enclosed raceways and protected regions not used as air plenums. Cable runs between floors in air spaces must be riser-rated (CL2R or CMR) at a minimum or else installed within an approved type of conduit. Cables installed within horizontal air plenum spaces must be plenum-rated (CL2P or CMP), or installed within approved conduit.

In Europe, local cable ratings and requirements are much different. Halogen-free cabling may be required in some countries. There may be some instances where cable designs conforming to US standards may be useable. Again, always check with local authorities.

Recognized Testing Laboratories

NRTL – Testing laboratories in the United States which intend to have their recognition mark affixed to an electric or electronic appliance must attain NRTL, Nationally Recognized Testing Laboratory, status through the US Department of Labor Occupational Safety and Health Organization, OSHA. A testing laboratory becomes "recognized" when capable of meeting the legal requirements for product safety testing in 29 CFR 1910.7. NRTLs are private organizations or companies that operate businesses. There are several NRTLs throughout the United States, each with their own registered trademark symbol.

The CE mark is unrelated to the requirements for product safety in the US. It is a generic mark used in the European Union (EU) to indicate that a manufacturer has declared that the product meets requirements in the EU for product safety.

Underwriters Laboratories–UL – UL has become something of an icon associated with US product safety. UL is a very successful not-for-profit testing organization totally supported by fees charged to clients. UL is very independent and, certainly, the most widely recognized mark in the US and in more than 70 countries. But, UL is not the only recognized product safety testing facility. There are many others with equal credibility.

ETL – Another well-known product safety listing mark is ETL. Intertek Testing Services NA, Inc. (ITSNA) (formerly ETL Testing Laboratories, Inc.) is an internationally recognized, fully independent testing company. The ETL mark is widely recognized as equivalent to UL, since all test methods and standards used by either organization must be recognized within the NRTL system. Many are not familiar with ETL because they attained NRTL status in 1989…relatively recent compared to UL.

Trends in Changing Standards

One may expect that codes and standards supporting fire safety will continue their evolution. The NFPA 262 (UL910) test standard has undergone change and update. Tougher regulations on plenum cable requirements are anticipated. While NFPA 262 prescribes the testing regimen for plenum-rated cable, the NFPA 90A code determines where plenum-rated cables may be used. As of the release of the 2002 version of the NEC, all accessible, abandoned communications cables in plenum spaces must be removed unless inventoried and tagged for future use. Network system growth has created a burgeoning quantity of potential fire fuel (load) in most commercial applications. This means that contractors have a responsibility (and a business opportunity) to work with clients to not just install cabling systems, but manage them as well.

Cost

Most systems installation companies find a significant cost advantage in using plenum-rated cable in commercial projects. The popularity of plenum-rated cable pretty well tells the story. Of course, your costs will vary due to local building codes and labor rates. If you have not used plenum on a job, then talk with experienced contractors to obtain real numbers for your area and situation. Although the incremental cost of plenum-rated cable is only a fraction of the cost of labor to run standard cable within metal conduit, new mandates by NFPA codes for the management of abandoned cable adds a new dimension to both the contractor's and the client's concern for project cost in addition to the need for education on changing code requirements.

Recycling

As cable management requirements become mandatory, recycling should be considered among the resources that contractors make available to their clients. Copious quantities of cabling removed from installation sites present a new threat to our environment if not disposed of appropriately. While technology brings us newer materials and products to solve technical problems each day, our ability to properly dispose of those materials and products at the end of their useful life is now a serious consideration.

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Extron®

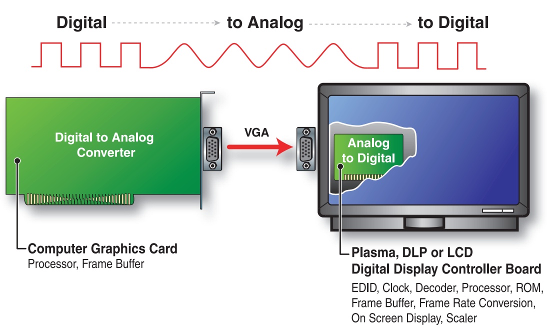
Analog Versus Digital Signal Formats

EDUCATION

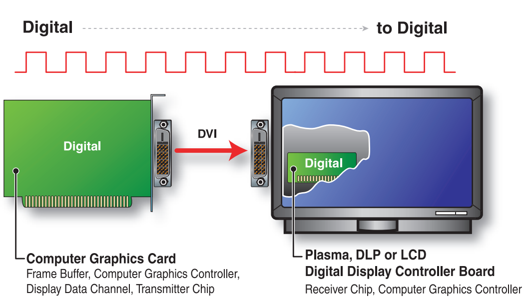
Consider the different sounds delivered by a piano and a violin. When a pianist strikes the keys he plays first one tone, and then another; however, when the violinist slides his fingers up the strings he can play not only those same tones but all the tones in between. The piano can be considered a digital device, delivering exactly the tones desired, while the violin is analog, less exact but with infinite flexibility.

With analog video we have a variable signal that creates an image by scanning information across a screen. With digital video, we have fixed pixel locations, each of which requires specific image information at a specific time. When we convert analog video to digital video, we must capture samples of a "moving" signal, translate the color and intensity of each sample, and then deliver it to a specific address on the digital display. We must also deal with probable losses in translation. A good analogy would be this — a story translated from English to Japanese and then back to English would not read the same as the original English-language story.

Currently, most desktop computers are all digital up to the point of the video card, which provides analog output. This means that the digital display must convert that analog signal to digital (as illustrated in Figure 1).



If the graphics card provides direct digital output, this eliminates both the digital-to-analog (D/A) circuits in the host computer, and the analog-to-digital (A/D) circuits in the digital display. (See Figure 2.) When analog signals are sent through a cable to the display, they are susceptible to interference and signal degradation. Digital signals are largely immune to such effects, subject to distance limitations. If we use all-digital computer-video interfacing, we no longer need A/D and D/A conversion circuits, so we get a better video image at a lower cost.



With an all-digital connection between the display and computer, the display tells the computer graphics card to only output a resolution that exactly matches that of the display. This saves the display from needing to do any scaling and preserves the integrity of the image. The direct digital standards also specify the transmission of a pixel clock signal; this gives the display an exact reference for the timing of the video signals and removes the need for both the pixel phase and horizontal phase controls.

As our industry evolves and the use of digital signals grows, understanding digital formats and the equipment that delivers them becomes increasingly important to all A/V professionals. As with other A/V systems, the performance of systems utilizing digital formats is highly dependent on the cables and connectors used. The following section will introduce digital video signals by reviewing digital signals we are familiar with — control communications — and then we will explore how cabling affects various digital video formats.

Control Communications

Control communications, or data communications, uses digital signals. While analog and digital video signals require high-performance cabling, control communications typically allows lower-performance cabling. Data communications for control typically carries less information, hence requiring less bandwidth. It is also more forgiving than digital video. In high-speed data communications systems, there is significant overhead added to handle error correction. And, if some data is lost, it can be re-sent. With digital video, there is some error correction facility, but the delivery is a one-way street. If you fail to receive all the data bits required to make the system work, you lose picture information or lose the picture completely.

Coax and SDI

Most professional broadcast formats (SDI, SDTI, SDTV, and HDTV) are serial and use a single coaxial cable with BNC connectors. The first part of this section will involve the cables used for serial digital formats. The next section discusses parallel digital formats.

Cables and SDI

Cable loss specifications for standard SDI, SDTI, and uncompressed SDTV are addressed in SMPTE 259M and

ITU-R BT.601. In these standards, the maximum recommended cable length equals 30 dB loss at one-half the clock frequency. Note that this high loss value does not correlate with losses normally accepted for analog video and graphics signals. This serial digital loss level is acceptable due to the serial digital receiver. Serial digital receivers have special signal recovery processing.

For HD-SDI running at 1.5 Gbps, SMPTE 292M governs cable loss calculations. In that standard, maximum cable length equals 20 dB loss at one-half the clock frequency. Due to the data coding scheme, the bit rate is effectively the same as the clock frequency in MHz. Similarly, high definition serial digital receivers have special signal recovery capability as well. See Table 1 for some examples of cable length calculations.

Recommendations among cable manufacturers will certainly vary, but it is good practice to limit your run lengths to no more than 90% of the calculated value. This provides leeway for cable variations, connector loss, patching equipment, etc. Table 1 includes this allowance. In all cases, your system must operate solidly before the "cliff region" where sudden signal

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dropout occurs. Recall that digital systems do not perform linearly to cable losses. Final performance rests with the cable and the type of receiver used. The bottom line in these systems is maintaining low BER (bit error rate). SDI signals are nominally 800 millivolts… not much different in level from analog video signals. Refer to Figure 3 for a standard-level SDI signal that conforms to SMPTE specifications.

	SMPTE 259								SMPTE 292	
	Level A		Level B		Level C		Level D			
Application	NTSC 4fsc Composite		PAL 4fsc Composite		525/625 Component		525/625 Component		HDTV	
Data Rate in Mbps (clock)	143		177		270		360		1485	
1/2 Clock Rate in MHz	72		89		135		180		743	
Extron Cable Product	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
MHR 26 AWG (22-020-xx)	583	178	531	162	428	130	365	111	94	29
M59, 24 AWG (22-127-xx)	813	248	736	224	600	183	519	158	150	46
RG59, 20 AWG (22-124-xx)	1034	315	944	288	801	244	687	209	188	57
RG6 18 AWG (22-098-xx)	1406	429	1274	388	1067	325	915	279	285	87

Table 1. Recommended Serial Digital (SDI) Transmission Distances Through Extron Coaxial Cable

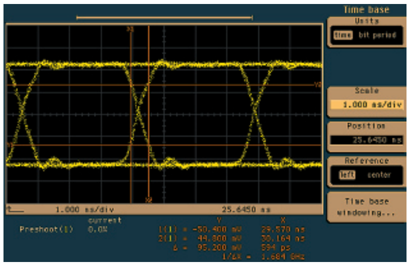

Figure 3. Standard reference level SDI signal conforming to SMPTE 259M

Comparing Digital Formats

Standard	Format Serial/Parallel	Intended Use	Connector Style	Cable Type	Transmission Distance [4]	Sample Rate	Data Rate (Mbps)	Guiding Document
D1 component	parallel	broadcast	multi-pin D	multi-pairs	few meters	27 MHz	270	ITU-R BT.601-5
SDI	serial	broadcast	one BNC	coax [1]	100s of meters	27 MHz	270	SMPTE 259
SDTI	serial	data transport	one BNC	coax [1]	100s of meters	variable	270 or 360	SMPTE 305
SDTV	serial	broadcast	one BNC	coax [1]	100s of meters	27 MHz	3 to 8	ATSC; A/53
HDTV	serial	broadcast	one BNC	coax [1]	100s of meters	74.25 MHz	19.4	ATSC; A/53
HD-SDI	serial	broadcast	one BNC	coax [1]	100s of meters	74.25 MHz	1500	SMPTE 292M
DV	serial	prof/consumer	(see IEEE 1394)	(see IEEE 1394)	4.5 meters	20.25 MHz	25	IEC 61834
IEEE 1394 (FireWire)	serial	prof/consumer	1394	6 conductors, 2-STPs/2 pwr	4.5 meters	n/a	100,200,400 Mbps	IEEE 1394
USB 1.1	serial	consumer	USB A & B 1-UTP & 2 pwr	4 conductors,	5 meters	n/a	12 Promoter Group	USB 1.1
USB 2.0	serial	prof/consumer	USB A & B 1-UTP & 2 pwr	4 conductors,	5 meters	n/a	480 Promoter Group	USB 2.0
DVI	serial/parallel	consumer	DVI (multi-pin D)	Four STPs	10 meters	to 165 MHz	1650	DDWG; DVI 1.0

[1] Also implemented over fiber systems
2 STP = Shielded Twisted Pair; UTP = Unshielded Twisted Pair
3 n/a = not applicable
[4] Transmission distances may vary widely depending on cabling and the specific equipment involved.

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What is different about SDI cable loss considerations? With SDI signals, the receiver is more complex in its ability to equalize and recover the signal. Signal recovery is nonlinear. SMPTE 292M describes the minimum capabilities of what it calls a type A receiver (the better) and a type B receiver. Like RF receivers, SDI receivers are adaptive in their ability to amplify, equalize, and filter out the information. Selecting the best receiver will make a tremendous difference in the final performance of a serial digital system. Figure 4 shows the loss effect on an SDI signal after it runs through 100 feet of Extron MHR cable. Although rise time is significantly affected, all quality receivers can recover this signal. In fact, for this particular cable a class "A" receiver can recover a solid image after 425 feet (see Table 1, page 13). Figure 5 illustrates signal quality after it passes through 100 feet of Extron RG6 cable. Note that the improved signal waveform ensures that the signal can be conveyed much longer distances. For RG6 cable, standard SDI can be transmitted over 1,000 feet.

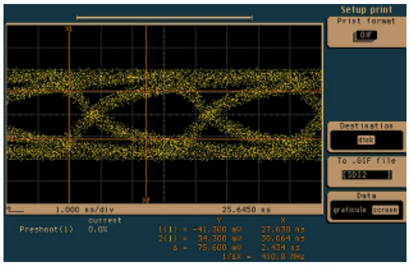

Figure 4. SDI signal after (100 feet / 30.48 m) of Extron Mini High Resolution coax cable

Cable Versus Receiver

So, how much of your system performance depends on the cable and how much depends on the receiver? It's a good idea to know this boundary as receiver and cable specs vary. The primary loss parameters that affect serial digital losses are rise time/fall time degradation and signal jitter. This is why serial digital signals normally undergo reshaping and reclocking as they pass through major network hubs like matrix routers. Interestingly, viewing the SDI signal waveform on a scope will not really tell you much once signal level drops to a certain point. Only specific instrumentation made for testing SDI signals will yield the ability to receive a proper image transmission. Figure 6 shows a typical scope presentation after 700 feet of Extron RG6 cable.

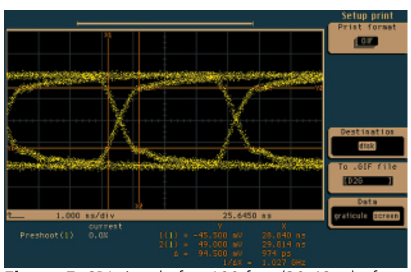

Figure 5. SDI signal after 100 feet (30.48 m) of Extron RG6 Super High Resolution coax cable

Although the SDI waveform is not discernable, a good receiver will capture it. By using color enhancement modes on a time domain reflectometer (see Figure 7), you can see a pattern in the data that is somewhat recognizable.

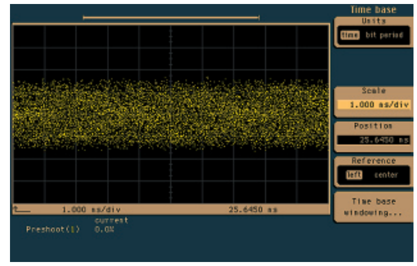

Figure 6. SDI signal after (700 feet / 213.4 m) of Extron SHR coax cable

Table 2 provides the performance specifications mandated in SMPTE 259M and SMPTE 292M. This is the benchmark in terms of rise/fall time performance and jitter as it guides the design of equipment sourcing the serial digital signal. Basically, if your system design provided this level of performance after your longest cable run, then you would have a benchmark design with little, if no, concern about the receiver's ability to decode the signal. Any SDI receiver of reasonable design could display the image.

But we don't live in an ideal world. The economy of distributing SDI and HD-SDI lies in the ability of the serial digital receiver to recover a low-level signal much like TV receivers recover a complex television image from a weak RF signal. The extended capability of the serial digital receiver makes the run lengths in Table 1 (shown on page 13) possible with few exceptions. Just what is the receiver's contribution? Well, comparing the SMPTE loss calculation to the –3 dB point used in regular video systems suggests an effect upwards of 10 times; i.e. 30 dB compared to 3 dB.

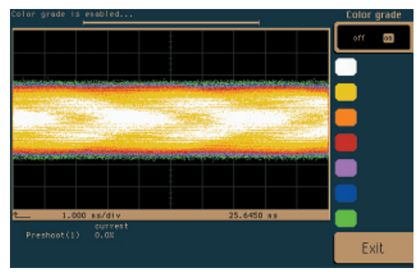

Figure 7. Color enhancement shows essence of the data pattern in the image of Figure 4

	SMPTE 259				SMPTE 292*	
	Level A	**Level B**	**Level C**	**Level D**	**Level D**	**Level L**
Parameter	NTSC 4fsc Composite	PAL 4fsc Composite	525/625 Component	525/625 Component	1920x1080 Interlaced	1280x720 Progressive
Data Rate in Mbps (clock)	143	177	270	360	1485	1485
1/2 Clock Rate in MHz	71.5	88.5	135	180	742.5	742.5
Signal Amplitude (p–p)	800 mV	800 mV	800 mV	800 mV	800 mV	800 mV
DC Offset (volts)	0 +/- 0.5	0 +/- 0.5	0 +/- 0.5	0 +/- 0.5	0 +/- 0.5	0 +/- 0.5
Rise/Fall Time Max. (nS)	1.50	1.50	1.50	1.50	0.27	0.27
Rise/Fall Time Min. (nS)	0.40	0.40	0.40	0.40	—	—
Rise/Fall Time Differential (nS)	0.5	0.5	0.5	0.5	0.10	0.10
% Overshoot Max.	10	10	10	10	10	10
Timing Jitter (nS)	1.40	1.13	0.74	0.56	0.67	0.67
Alignment Jitter (nS)	1.40	1.13	0.74	0.56	0.13	0.13

Table 2. SMPTE Serial Digital Performance Specifications
*SMPTE 292 guides the interface for multiple high definition standards; i.e., SMPTE 260M A/B, 295M C, 274M D-K, 296M 6/L.

DVI, Firewire, and USB 2.0

Cabling for DVI, Firewire, and USB 2.0 is paramount for each format in order to provide you with the performance specified. Recall that DVI (Digital Visual Interface) is penetrating the computer-monitor interface market as flat panel LCD monitors become affordable.

Firewire, or IEEE-1394, is that tiny, square-like connector tucked away on the side of your digital camcorder that allows you to upload DV format signals to your computer, among other things. USB has received a major overhaul... analogous to jacking up your radiator cap and driving in a new car underneath it. Yes, USB 2.0 brings us hot swappable, hosted peripherals now capable of talking at 480 Mbps instead of just 12 Mbps.

Getting from Here to There with DVI

The DVI connection between local monitors and computers presents an interesting interfacing environment. It is a combination serial digital interface and a parallel interface format, somewhat like combining the broadcast serial digital and parallel digital interfaces.

Transmission of the TMDS (transition minimized differential signaling) format combines four differential, high-speed serial connections (in its base configuration) transmitted in a parallel bundle. When the DVI specification is extended to the dual mode operation, greater data rates for higher display resolutions are possible, but now there are seven parallel, differential, high-speed pairs. Cabling and connection become extremely important. In this way, DVI is similar to the original D1 parallel interface which requires eight or 10 differentially driven serial lines capable of handling a full byte on each clock cycle. If you have the opportunity, take a look at available D1 cables, and you will find them limited in usable lengths — very much like DVI.

The nominal DVI cable length limit using low cost patch cables is 4.6 meters (about 15 feet). Using specialized high performance DVI cables, signals can be transmitted up to 75 feet. Electrical performance requirements are similar to serial digital. Signal rise time (0.330 nanoseconds), cable impedance (100 ohms), far end crosstalk (FEXT) of no more than 5%, and signal rise time degradation (160 picoseconds maximum) are the key parameters highlighted in the DVI specification regarding the physical connection. Cable for DVI is application specific because maintaining these specifications is no easy feat since the actual bit rate per channel is 1.65 Gbps. And we're talking twisted pair cable here.

With digital video interfaces, if any vital data is missing, you lose picture information or even the entire picture. So, the DVI cable and its termination is very important. The physical parameters of the twisted pairs must be highly controlled. Specifications for the cable and the receiver are given in fractions of bit transmission time. Therefore, the requirements depend on the clock rate or signal resolution being used. Transferring the maximum rate (1600 x 1200 at 60 Hz) for a single link system means that one bit time (10 bits per pixel) is 0.1(1/165 MHz), which is only 0.606 nanoseconds. Ten bit times describe one pixel in this system.

The DVI receiver specification allows only 0.40 x bit time, or about 0.242 nanoseconds intra-pair skew (within the twisted pair). Remember, this is differential transmission. The "eye" pattern seen at the receiver end must be as symmetrical as possible. Further, the inter-pair skew, which governs how bits will line up in time at the receiving decoder, may only be 0.6 x pixel time, or 3.64 nanoseconds. These parameters are largely responsible for the short transmission distances for DVI.

In addition to the above requirements, a cable for DVI should be evaluated on its insertion loss for a given length. The DVI transmitter output eye pattern is specified into a nominal cable impedance of 100 ohms. A normal signal swings +780mV to –780mV. The minimum positive signal swing is +200mV and the minimum negative swing is –200mV (total swing of 400mV). When the signals are combined in the differential receiver, the resulting signal level is two times the swing value. But, for the cable situation, we must assume minimum performance on the transmitter side and best sensitivity on the receiver end. The receiver must operate on signals as low as +75mV to -75mV, or a total swing of 150mV. This means that under worst-case conditions, the cable attenuation can be no more than 8.5 dB at 1.65 GHz (10 bits/pixel times 165 MHz clock). As you can imagine, maintaining this type of performance on twisted pair wires is relatively difficult.

DV and Firewire – Serial Digital for the Rest of Us

The DV, or digital video, recording standard now driving most consumer camcorder purchases is a serial digital format of 25 Mbps, sometimes called DV25. The Firewire (IEEE 1394) interface conveniently handles the data rate of DV, and then some. The DV format is the first application making tremendous use of the IEEE 1394 capability. IEEE 1394 is much bigger than DV in terms of data handling. This specification supports up to 400 Mbps currently and extensions to the standard are under consideration. Its key strengths are its "just-in-time" data delivery and peer-to-peer relationship… meaning that Firewire appliances can communicate without need for a host controller.

So, when we talk DV, we are really talking about using 1394 and a portion of its capability. The connection scheme and cabling for this interface are specific as well. The 1394 system uses two shielded twisted pairs and two single wires. The twisted pairs handle differential data and strobe (assists in clock regeneration) while the separate wires provide the power and ground for remote devices needing power support. Signal level is 265mV differential into 110 ohms.

The 1394 specification limits cable length to 4.5 meters in order to satisfy the round trip time maximum required by the arbitration protocol. Some applications may run longer lengths when the data rate is lowered to the 100 Mbps level. The typical cable has 28 gauge copper twisted pairs and 22 gauge wires for power and ground. A Firewire connected appliance may or may not need power from its host, but must be capable of providing limited power for downstream devices.

The 1394 specification provides electrical performance requirements that leave open the actual parameters of the cable design. As with all differential signaling systems, pair-to-pair data skew is critical… $\leq$ 0.40 nanoseconds. Crosstalk must be maintained below -26 dB from 1 to 500 MHz. The only requirement on the size of wire used is that velocity of propagation must not exceed 5.05 ns/meter. Refer to Table 3 for other critical details of the physical interface system for 1394. Figure 8 shows the cable internal conductor arrangement.

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USB 2.0 – Fire in Another Wire

The USB, universal serial bus, simplifies connection of computer peripherals. USB 1.1 is limited to a communications rate of 12 Mbps, which is plenty fast for most items like printers, audio devices, keyboards, scanners, etc. During 1999 the USB Implementers Forum began work to upgrade USB capability by more than 40 times. The new USB 2.0 interface supports up to 480 Mbps communication. It is anticipated that USB 2.0 will replace higher cost SCSI interfaces for some peripherals. The Implementers Forum says that fully compliant USB 1.1 cables will perform at USB 2.0 speeds. In-depth information is available at www.usb.org.

The USB cable consists of one twisted pair for data and two untwisted wires for powering downstream appliances. Specifically, a full-speed cable contains a 28-gauge twisted pair, an untwisted pair of 28 to 20 gauge power conductors, an aluminized polyester shield, a drain wire, and an overall 65% (minimum) copper braid. Nominal impedance for the data pair is 90 ohms. The maximum cable length for USB is a function of signal propagation delay. The cable may have no more than 26 ns delay from connector A to connector B. An additional allowance of 4 ns is split between the sending device connection and the receiver connection/response function, making the entire one-way delay 30 ns maximum. In addition, the cable may not have a velocity of propagation greater than 5.2 ns per meter. The length and twist of the data pair must be matched well enough so that no more than 0.10 ns time skew exists between bit polarities. The nominal differential signal level is 800mV.

The digital video and data world is exciting, but, as you can see, assembling high-speed data cables is not going to be a trivial or casual task.

Parameter	100 Mbps	200 Mbps	400 Mbps
Max Tr/Tf	3.20 ns	2.20 ns	1.20 ns
Bit Cell Time	10.17 ns	5.09 ns	2.54 ns
Transmit Skew	0.40 ns	0.25 ns	0.20 ns
Transmit Jitter	0.80 ns	0.50 ns	0.25 ns
Receive End Skew	0.80 ns	0.65 ns	0.60 ns
Receive End Jitter	1.08 ns	0.75 ns	0.48 ns

Table 3. Critical IEEE 1394 Timing Parameters

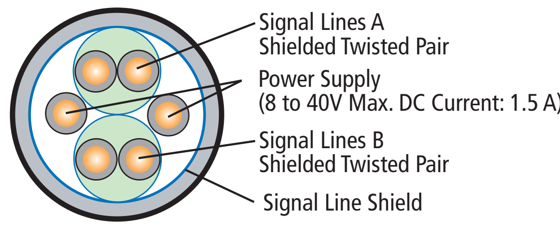


Figure 8. IEEE 1394 Cable

Understanding Audio Cable

Properly conveying audio signals embodies many of the same considerations applied to the transmission of video signals. Since the audio range resides at much lower frequencies, certain electrical parameters are now more important than others. At the outset, it's important for audio cable to maintain fairly low elements of inductance, capacitance, resistance, and impedance. To minimize these elements and ensure optimum performance, the cable's conductors should be made of high conductivity electronic-grade copper. This means the purity of the copper ranges from 99.95% to 99.99% pure. In addition, the proper type of insulation is important. Depending on the application, shielding is a key consideration. Audio cable may be divided into two basic categories: line level group and speaker group.

Line Level Group

Cable for audio and control applications falls within the line level group and is usually constructed of one or more pairs of stranded wires, or stranded twisted pairs. Shielded, twisted pairs are commonly used for line level audio and control applications. The twisted pair, as we have already learned in this guide, provides a balanced signal path that minimizes susceptibility to outside interference. Combining a shield with the twisted pair improves unwanted signal rejection significantly. For line level audio and control applications, balanced line (twisted pair) construction and shielding are the most important features.

The small values of cable capacitance encountered with shielded twisted pair cable have little impact on audio performance since the equivalent impedance offered by the typical shunt capacitance represents much larger impedance than the typical audio circuit impedances; thus it can be largely neglected. For control applications involving communications protocols operating at relatively high speeds compared to audio, the shunt capacitance values are more important. Lower cable capacitance values mean less impact on control code transmission speeds.

Wire gauge size for line level audio and control applications is a lesser consideration and is usually dictated, to some degree, by transmission distance and by termination hardware. Larger gauge wire has less DC resistance per unit length; hence, less signal loss over long distance paths.

Speaker Group

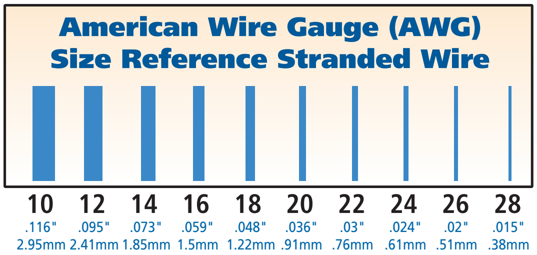
Speaker cables fall within the speaker group and require the delivery of significant levels of current necessary to drive speakers directly. In those special instances where powered speakers are specified, the amplifier driving the speaker's current demand is local to the speaker. Therefore, the cable required to drive this type of system falls within the line level group previously discussed.

Wire gauge or diameter is the key attribute distinguishing cables in the speaker group. The conveyance of high currents directly to speakers requires wires of the appropriate cross-sectional area. Choosing the proper gauge size for your A/V system is determined by the length of the cable runs compared to the load (speaker) impedance and the power to be delivered. As power delivery or current demand increases, the cable diameter must increase as well. Thicker gauge wires have less resistance to the flow of electric current than thinner wires. It's a good idea to err on the side of heavier, or thicker, gauge wires for speaker connections rather than install thinner gauge wire which limits performance and could overheat. While heavier gauge wire may cost a little more, the return on investment in terms of time and performance are usually worthwhile.

Most speakers have very low operating impedance. It is important that the selected wire have a DC resistance much lower than the impedance provided by the speaker. Good practice recommends keeping speaker wire resistance lower than 5% of the speaker impedance so as to ensure that most audio power is transferred to the speaker where it is needed. In any case, a speaker wire resistance of 10% (loss of 0.5 dB) of the speaker impedance should not be exceeded. Commercial audio distribution systems utilizing 70/100 volt audio drive may utilize smaller gauge wiring, relative to low impedance speakers. In these applications DC resistance is important and should be kept low compared to the system's operating power, but since the operating voltage is higher, the insulation rating of the speaker cable is now more important.

When selecting speaker wire, it is important to know that the lower the gauge number, the thicker the wire. An 18 gauge wire is thinner, or smaller diameter, than a 14 gauge wire, for example. To maximize the potential of your audio signal, it is generally preferable to use lower gauge wires whenever possible.

Actual Size



For any A/V application, cable length should be kept to the minimum required. When driving speakers, the wire lengths should be equal for both left and right channels to ensure balanced transfer of power from the amplifier. Long runs of 50 feet or more should use thicker gauges (14 or larger) to ensure that enough power is transferred to the speaker. Defaulting toward heavier gauges of wire is also a good idea in the event that a system design is upgraded to higher power output in the future. Installing new wire will cost more in the long run.

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Selecting The Right Cable

Deciding on the correct cable for an application in system designs today is, in many cases, augmented by the devices to be interconnected. For example, the connection of network components typically dictates the use of Category 5 (or better) type cable. Digital appliances have specific requirements that are generally straight forward. In the area of analog video signal distribution, cable selection is more challenging.

Analog video signals degrade at a generally predictable rate during distribution; so the designer is faced with balancing tradeoffs involving cable type, image quality, and economics. Do not underestimate the importance of the cabling decision. Cabling is an infrastructure investment that should yield long term benefits for upgrading the system; not just satisfy the current need. While the cost of cable is relatively low compared to many components and devices connecting to it, its total cost after installation is significant. In most cases, the cabling infrastructure will outlast those components, like displays, that connect to it. The effect of signal loss in a system is cumulative and, once performance is sacrificed, recovery is difficult to impossible.

Harmonic Considerations

Analog video signal distribution requires that the designer consider cable distance, the source signal characteristics, allowable raceway space, application environment, the cable's technical specifications, and the need for upgrade. Often, we are asked how far a particular cable may be run for a specific signal type. Giving a simple answer is difficult because video signals are complex and made up of many frequency components, called harmonics. A harmonic is an integer multiple (i.e. 1st, 2nd, 3rd, 4th, etc.) of a fundamental frequency component which is not a sine wave, or non-sinusoidal. Harmonics respond differently to cable loss depending on the type of cable and the run length within the application. An array of pixels make up the video graphics image and a single pixel represents what we call the fundamental frequency component within the image. As pixels are bunched together along a horizontal line to create line structure, sub-harmonics exist which approach the horizontal line rate frequency. As lines are created on the screen to scan the image, sub-harmonics exist near the vertical refresh frequency. A video image is rich in harmonic content and it is this content that contributes to image sharpness and clarity.

Visible effect of signal roll off

Original (Fundamental) Signal Waveform

-3 dB Loss*

-6 dB Loss*

-9 dB Loss*

*** Loss measured at 3rd harmonic of fundamental**

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A spectrum analysis of a video signal will show that harmonics exist above and below some fundamental repetition frequency used to create the image. In other words, the clock frequency of the graphics system is the basis for timing and graphic image creation. Ironically, when a full screen of white pixels are clocked into the display, we see a full white screen and while the system worked hard to accomplish that, the result represents very low frequency content to the display device. If we wish to fully challenge the display, we send it alternating pixels that appear as a screen full of vertical stripes. In this instance, the display must work harder to transition between full black and full white at maximum rate. This is why we halve the pixel count or take one-half the clock rate in bandwidth calculations. This is a worst-case image.

Now, back to harmonics. Once we have a single pixel event on the screen, we are witnessing the fundamental frequency component of the image. In order for it to look very crisp, the sides of the pixel must have a very fast, or sharp looking, rise time (transition to white). Likewise, it must have a very fast, or sharp, fall time (return to black). A mathematical concept, called Fourier Analysis, describes the makeup of any non-sinusoidal waveform, such as a pulse or pixel, by showing that it is made up of a fundamental frequency and an infinite number of harmonics. The addition of those harmonics add up, one by one, to create the fast rise and fall edges of the pixel. Further, an analysis of that addition process shows that about 80% of the harmonic energy needed to reasonably recreate a pixel event extends from near DC through the third harmonic. Beyond the third harmonic, the gain in rise time or sharpness is negligible in visual terms. This is why we concentrate on maintaining the third harmonic performance of the video signal in system design. Even digital signals contain these harmonics, which provide the fast transitions required for digital systems to perform properly. So, this concept extends beyond any discussion of analog signals.

The third harmonic will be attenuated in a cable sooner than the second harmonic. The second harmonic will be attenuated sooner than the fundamental. Harmonic content in a signal exists at a lower amplitude relationship to the fundamental frequency on a somewhat nonlinear scale. In other words, the harmonics of the fundamental are decreasing as their frequency increases. So, each successive harmonic provides less energy toward the creation of fast, square-looking pixels used to create an image.

Since this harmonic energy is lost more or less in a linear fashion as cable length increases, one should pay attention to the cable's loss performance in the third harmonic frequency region when designing distribution systems. The appearance of the image will degrade as harmonic energy is lost. You must be the judge of the importance of maintaining full image content, or harmonic content. This is where our ability to provide the answer to the original question of signal run distance is not easy to provide. One of the more effective ways to understand the effect of cable loss is through actual images. To that end, we are providing images showing how the loss will manifest under those conditions. Ultimately, you and/or the client must decide if image quality is adequate based on the tradeoffs of a given application.

Example: The design calls for transmission of RGBHV graphics at a resolution of 1024 x 768 at 60 Hz refresh. The graphics card clock rate will be about 65 MHz for this resolution. Now, we take one half the clock rate since this represents the highest viewable resolution, which yields 32.5 MHz. About 80% of the energy required to create sharp edge detail in the image rests with all frequency components from near DC to the third harmonic frequency: 3 x 32.5 = 97.5 MHz. Use this 97.5 MHz value to peruse the loss tables of various coax types to determine the distance at which losses will mount to a noticeable level. Look at the loss table for Cable Type A (refer to table on following page) and note that the loss will be -5.4 dB at 100 MHz for 100 feet of this type cable. This loss

Maximum Recommended RGB Video Transmission Distance (Without Using an Interface or Line Driver)

Resolution	VGA – 640x480			SVGA – 800x600			XGA – 1024x768			SXGA – 1280x1024			UXGA – 1600x1200			
Image Refresh Rate	60Hz	75Hz	85Hz	60Hz	75Hz	85Hz	60Hz	75Hz	85Hz	60Hz	75Hz	85Hz	60Hz	75Hz	85Hz	
Horizontal Scan Rate	31.5KHz	39KHz	45KHz	38KHz	50KHz	54KHz	48KHz	60KHz	68KHz	64KHz	80KHz	91KHz	75KHz	94KHz	107KHz	
Extron Cable Type	**Recommended Distance (in feet) Based on 3rd harmonic at -3 dB**															
MHR (26 Gauge)	85	69	59	56	44	37	33	26	23	20	15	13	13	10	9	-3 dB
M59 (24 Gauge)	152	123	106	100	78	67	59	46	40	35	27	24	24	18	16	
RG59 (20 Gauge)	309	249	215	204	158	136	121	94	82	71	56	49	48	38	33	
RG6 (18 Gauge)	560	452	389	368	286	246	219	171	149	128	101	88	87	68	60	
Extron Cable Type	**Recommended Distance (in feet) Based on 3rd harmonic at -6 dB**															
MHR (26 Gauge)	328	265	228	216	167	144	128	100	87	75	59	52	51	40	35	-6dB
M59 (24 Gauge)	613	495	426	404	313	269	240	187	163	141	110	96	95	74	65	
RG59 (20 Gauge)	1120	903	778	737	571	491	438	341	298	257	201	176	174	136	119	
RG6 (18 Gauge)	1800	1452	1250	1184	918	789	703	549	479	413	324	283	280	218	191	

Based on Resolution and Refresh Rate

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Selecting the Right Cable (continued)

Cable Type A

MHz	dB/ 100 ft.	dB/ 100 m
1	-0.5	-1.7
5	-1.2	-3.9
10	-1.7	-5.5
20	-2.4	-7.8
50	-3.8	-12.3
71	-4.5	-14.8
100	-5.4	-17.6
135	-6.3	-20.6
180	-7.3	-23.9
200	-7.7	-25.4
270	-9.1	-29.9
400	-11.5	-37.3
750	-16.4	-53.8
1000	-19.5	-64.0
3000	-43.6	-143.0

Cable Type B

MHz	dB/ 100 ft.	dB/ 100 m
1	-0.3	-1.0
5	-0.6	-2.0
10	-0.9	-3.0
20	-1.2	-3.9
50	-1.3	-4.3
71	-2.1	-6.9
100	-2.3	-7.5
135	-2.7	-8.9
180	-3.0	-9.8
200	-3.2	-10.5
270	-3.8	-12.5
400	-4.7	-15.4
750	-6.5	-21.3
1000	-7.8	-25.6
3000	-17.6	-57.7

is approaching the -6 dB value for a distance of 100 feet. Scale the loss downward linearly if your design requirement is for a shorter distance (see frequency/loss chart on page 6 for loss curves). For any type cable, we can see from the accompanying photos taken from an actual graphics monitor the typical image degradation encountered with increasing loss of the third harmonic energy. Included are actual oscilloscope measurements showing the loss of the high frequency information (narrow pulse height) compared to low frequency information (wider, flat step function next to it). In addition, the flatness of the lower frequency step function is rounded from the leading edge and takes a comparatively longer time to settle to its normal amplitude. This effect will be seen as the dark streaking that occurs to the right of the text or other detail transitions from dark to light. Compare the likely performance of Cable Type A with the -6 dB images shown.

Note that as cable losses rise, the intensity of the image, or brightness, is affected to some degree. The brightness loss is in addition to the loss of high frequency information. Images appear fuzzy or smeared on analog (CRT) displays or on digital displays like LCD projectors, lower brightness on some pixels. See Figure 1. Now, look at losses for Cable Type B. Note that, at 100 MHz, the loss is less than -3 dB. This cable would provide a better result if our run distance is 100 feet. Again, you can scale the loss value against the distance to interpolate closely to the performance you might expect.

The solution to the loss problem is to specify a cable which, at its -3 dB point for the highest frequency of interest, will yield an image no worse than the -3 dB shown on the previous page 18. Should you not be able to attain a loss budget of -3 dB or less for a given cable type and distance, then select a lower loss cable type.

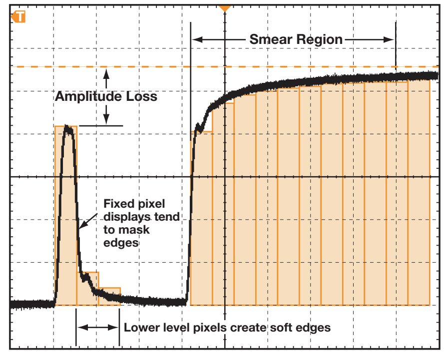
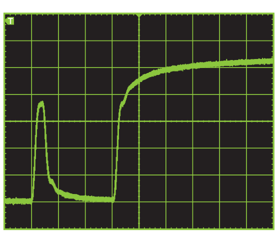


Figure 1: Pulse and Bar may be partially "repaired" by fixed pixel boundary effects, but amplitude is not restored.

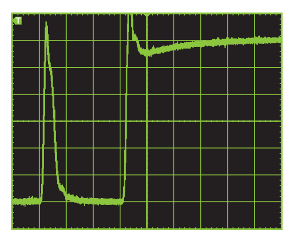
If other factors such as cost or cable size become an issue, the other alternative is the use of an interface or other type of cable driver amplifier capable of adding level and pre-emphasis (peaking) to overcome some or all of the loss. The interface or line driver would best be applied at the head-end of the cable run. By increasing the level and peaking controls, the head-end can be pre-emphasized to overcome some, or all, of the cable loss characteristic.

A typical amount of high frequency peaking available in most cable drivers of this type will be at least +3 dB and may extend to as much as +12 dB or more. Refer to -9 dB Loss diagram. If you are considering a design situation with a potential loss of 6 dB, the cable interface/driver can potentially overcome a significant portion or all of the cable loss. At a minimum, you can see that the goal should be no more loss than -3 dB for best results. Adjusting the level control provides the necessary gain to restore overall image brightness lost in the cable DC resistance, as shown in the -12 dB Loss diagram below.



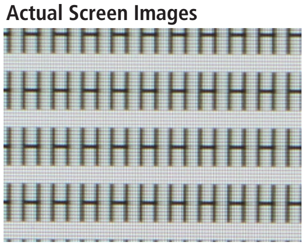
-12 dB Loss

RGB 201 Rxi Interface

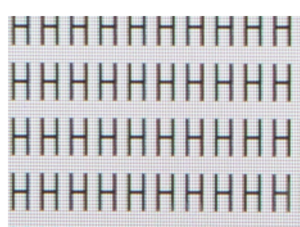


Signal recovery using RGB 201 Rxi

Actual Screen Images



-12 dB Loss



After level and peaking

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