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INFRASTRUCTURE – Designing Value Into The Future

When it comes to designing audio visual systems, thoughts will usually be filled with equipment choices to be made, cable selections, hardware and rack enclosures and how the system will ultimately satisfy our clients. However, there is more - we also need to think seriously about how we will get the signals to the equipment locations. Not just on the cabling itself, but the conveyance infrastructure that will house and support the chosen cabling between equipment locations.

The conveyance infrastructure design is one of the more important elements in the overall design. Done correctly, the conveyance design is the foundation to create manageable blocks of scalable connections between equipment locations. The value of this well-designed infrastructure allows a smoother initial installation and adds flexibility for maintenance, when additional equipment needs to be added or equipment upgrades need to be done.

Audio visual system infrastructures need to be coordinated with data / telecom networking resources and power systems, so that a converged and coordinated infrastructure emerges in a successful deployment for a truly usable system to support an audio visual system.

In addition, there are emerging trends in our industry that gives this need even more importance. For example, InfoComm International (ICIA) has recently partnered with Building Industry Consulting Service International (BICSI) to create a training program that will train technical staff in the design and installation of structured cable conveyance, for the support of the data networks and audio visual systems. The reasoning behind this initiative is that we as AV designers are not alone in the need to coordinate services between low-voltage systems such as life safety, data and telecom networks and AV systems. In addition, the Construction Specification Institute (CSI) Master Format Section 27 changes in the United States; offers the opportunity to coordinate schematic drawings and specifications that will illustrate all low-voltage communication resources in one section of plans. With all of these recent changes, the outcome becomes obvious. This is a forward direction for the AV industry as a whole as it becomes more firmly entrenched as a part of the construction industry. It is a wise decision for the designers of these systems to move forward and to get new sets of skills needed to work with these significant changes.

What are the Standards?

In the United States, structured cable infrastructure standards are based on the data / telecom standards – TIA / EIA 569 and in the design of power distribution in compliance with the National Electrical Code (NEC). There is much written about these standards and it is not within the scope of this article to cover these in detail here. In addition, there are electrical codes that are regional or local that can supercede the NEC and the TIA / EIA 569 recommended standards that must be followed in your local areas. It is suggested that if you wish to work with your networking engineers, electrical engineers and contractors, that you take the time to find out what are the details that govern your local region and always follow your local codes. In the United States, the National Electrical Code (NEC) and BICSI has published best practices that follow in many instances, the TIA / EIA 569 recommended standards. Again, local codes will supercede the national recommended practices.

Fortunately, there is constant review of these recommended practices and as the building industry evolves and new products and practices are developed, the published recommendations will change from year to year.

What are the kinds of conveyance and what are the conduit sizes needed for AV installations?

There are many types of conduit available on the market. Each type has its place in the structured cable infrastructure design. To keep this discussion manageable, I will not go into all of the products available, but will stay with ones commonly found in AV structured designs.

Rigid Metal Conduit – RMC (ferrous metal conduit)
RMC is a threaded metal conduit that comes in 10′ (3 m) sections colour-coded on the thread protectors to aid with size identification and to keep the threads clean and free from damage during shipping, until it is ready for installation. RMC is available in sizes from 1/2″ to 6″ (12.7 mm to 152 mm). RMC is the heavy weight of conduits, has thick walls and is sometimes coated or galvanized to resist corrosion. This product can be used indoors, outdoors or underground in concealed and exposed applications.

Intermediate Metal Conduit – IMC (ferrous metal conduit)
IMC is also a threaded metal conduit that comes in 10′ (3 m) sections colour-coded for size on the thread

protectors. IMC is available in sizes from 1/2" to 4" (12.7 mm to 152 mm). IMC has a thinner wall construction than the RMC products, but uses the same couplers and fittings. This product has a zinc-based coating and can be used interchangeably with RMC products. The advantage is that it is a lighter product and hence it can be used in overhead and vertical applications where appropriate.

Electrical Metallic Tubing – EMT (ferrous metal conduit)
EMT is a thinner wall steel raceway which also comes in 10' (3 m) sections which is unthreaded. Like IMC the coating applied to this raceway is zinc based and provides protection from corrosion. EMT is joined together by either set screws, indentation, or compression fittings. EMT is a more flexible raceway and can be bent into sweeps to enable it to be dealt with in special circumstances. Even though this product is lighter in weight, it will still provide substantial physical protection and strength and can be used in most exposed locations. This product is widely used to support AV conveyance systems.

Polyvinyl Chloride – PVC (metallic conduit with PVC outside)
PVC conduits come in three types:
1) PVC over steel - which is similar to RMC for environmental demands.
2) PVC over galvanized steel - for severely corrosive environments.
3) PVC over a supplementary coating of zinc - for extremely corrosive environments.

PVC applications need to have fittings that are also coated in PVC to maintain environmental needs. However, using these products requires that the installers follow the manufacturer's instructions to maintain system integrity.

Liquid-tight Flexible Metal Conduit- LFMC

The flexible nature of the liquid-tight conduits makes them appealing for runs that need to be "snaked" into place. This conduit has a liquid tight jacket over a flexible non-metallic core and can be used with fittings to allow it to interface with other conduit products. The typical size runs from 1/2" to 2" (12.7 mm to 50.8 mm) diameter.

This of course is not a complete list of the kinds of conduit product lines that are manufactured and most of these products above can be found in metric sizes that are similar in nature to the size ranges I have listed above. The advice here is to do some research on the anticipated products needed for the design before writing any specifications.

Size is Important

When considering the size of the conduit to be used in the system, do bear in mind that it should not only support enough room for installing the necessary cables planned for the run, but also allowing for future expansion. Filling the conduits with cables on the first pass is not a recommended practice. Many manufacturers will specify approximately 40% fill for most applications, but my experience in the AV world usually indicates that 30% is a better fill leaving some room for extra cable runs, which seem to be inevitable in our business.

There is a rule of thumb that applies to conduit fills where one or more cables are being pulled into the raceways. For example, if the cable pull into the conduit is based on three cables, the combined cross sectional area of the three cables should not exceed 30% of the conduit's interior volume. For pulls that have only one cable, the percentage fill can be increased slightly to approximately 50% because of the cross section of the cable using the space more efficiently then multiple cables. See Figure 1.

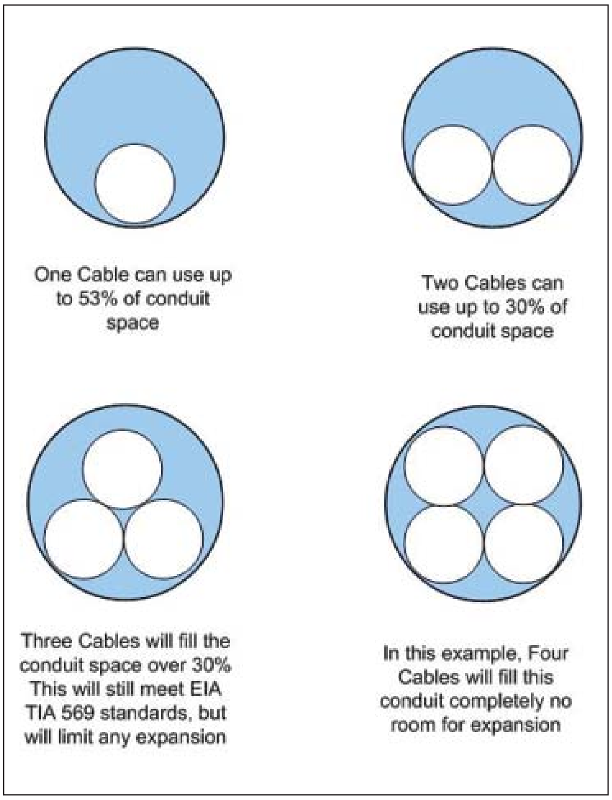

Figure 1 - Multiple Cables in Conduit and Fill relationships

Keep in mind that as the conduits specified for the job has more than one cable or any number greater than one, it will tend to form a circular shape thus filling the conduit quicker.

If you are re-using conduits, keep in mind how many cables are to be installed and the cross-sectional dimensions of the new cables being pulled. Hint: There are some really handy conduit fill calculators available on the Internet that can take the math out of doing this work. However, you will still need to find the outside dimension of the cables from the manufacturers to use these tools effectively.

For example, if you were planning to re-use an EMT $^{3}/_{4}$" (20 mm) conduit (ID = 0.824" (20.9 mm)) and need to install four RG 59 cables (OD = 0.230" (5.84 mm)) using the 30% fill, it would require a 1" (25 mm) conduit (ID = 1.049" (26.6 mm)). This existing $^{3}/_{4}$" (20 mm) conduit would not be large enough to do the job of leaving some room for additional cables for future expansion. However, this same $^{3}/_{4}$" conduit could be used to support the four RG 59 cables if a 40% fill was used and the expansion capability was given up.

When considering the fill of conduit, be sure to check the product's Interior Dimension (ID). These sizes may differ slightly from product to product.

Do the Math

The Formula for Calculating Conduit Sizes:

If you would rather not use an Internet calculator here are the basics:

First, find the Cable Cross-Sectional Area -

Basic Formula:
Cable Diameter Squared x 0.7854 = Cross Sectional Area

Please note that the number 0.7854 is arrived at by dividing π (pi) by 4
(3.1416 ÷ 4 = 0.7854)

So returning to the RG 59 example above- the cable's diameter is 0.230" (5.84mm), we calculate:

Detailed Formula:
0.23 x 0.23 = 0.0529 (Cable Diameter Squared Inches of 1 RG 59 cable)
5.84 x 5.84 = 34.1 (Cable Diameter Square Millimeters of 1 RG 59 cable)

0.0529 x 0.7854 = 0.0415476 (Square inches per cable in Cross Sectional Area)
34.1 x 0.7854 = 26.7 (Square mm per cable in Cross Sectional Area)

0.0415476 x 4 = 0.1661904 (Total of square inches in Cross Sectional Area)
26.7 x 4 = 107.15 (Total of square mm in Cross Sectional Area)

Total area inside conduit:
$^{3}/_{4}$" = 0.533"
20.9 mm = 343.87 sq mm
1" = 0.864"
26.6 mm = 557.41 sq mm

30% fill on $^{3}/_{4}$" (20.9 mm) conduit = 0.165" (106.4 sq mm) – In this case, the cable would fit without any planned expansion.

30% fill on 1" (26.6 mm) conduit = 0.268" (172.9 sq mm) – This choice has some substantial expansion.

Sizing the conduits is only part of the job. The boxes installed along the way that acts as pull boxes, junctions and termination points, are just as important as the raceways that connect them. Again, a little over sizing is a modest price to pay for the ability to be able to add services at a later time.

Conduit Run Construction

When you are planning the conduit runs, the construction of the actual conveyance is important to the overall ease of the installation and the ability to maintain and add additional services in the future.

The installed conduit provides protection for the cabling from both physical and environmental abuses. In underground installations, the conduit protects the cables from shifting rocks, aggressive rodents, and damage from hand shovels. For interior installations, it provides protection from moisture, corrosion and physical damage from general use of the building.

Pull Boxes and Conduit Bends

Pull Boxes need to be installed in the conveyance at appropriate distances to allow for the efficient pulling of new cables. The layout and location(s) of the pull boxes should not replace the need for proper sweeps around corners. Instead use pull boxes to reduce the strain on the cable (and installers) as it is being pulled to the next box or termination point. See Figure 2.

Placing a large enough box so that a large number of cables can be pulled into a loop or a figure eight while the installation is in progress is a better practice than straining a cable during the pull that could cause the cable to be stretched or damaged. The type of cable being pulled has much to do with how far apart the pull boxes have to be located. For example- If Fiber Optic cables are being installed, there is a need to use less force to pull these cables into the conveyance. Therefore, it would be better to have more pull boxes installed over the length of the run so as to lessen the friction factor and the tension needed to pull the cable into the raceway. In addition, keep in mind that sometimes there is a need for cable lubricants that can make the installation job much easier. However, the application of cable lubricants should be checked with the cable manufacturer's guidelines and recommendations for use with the cable jacket's composition.

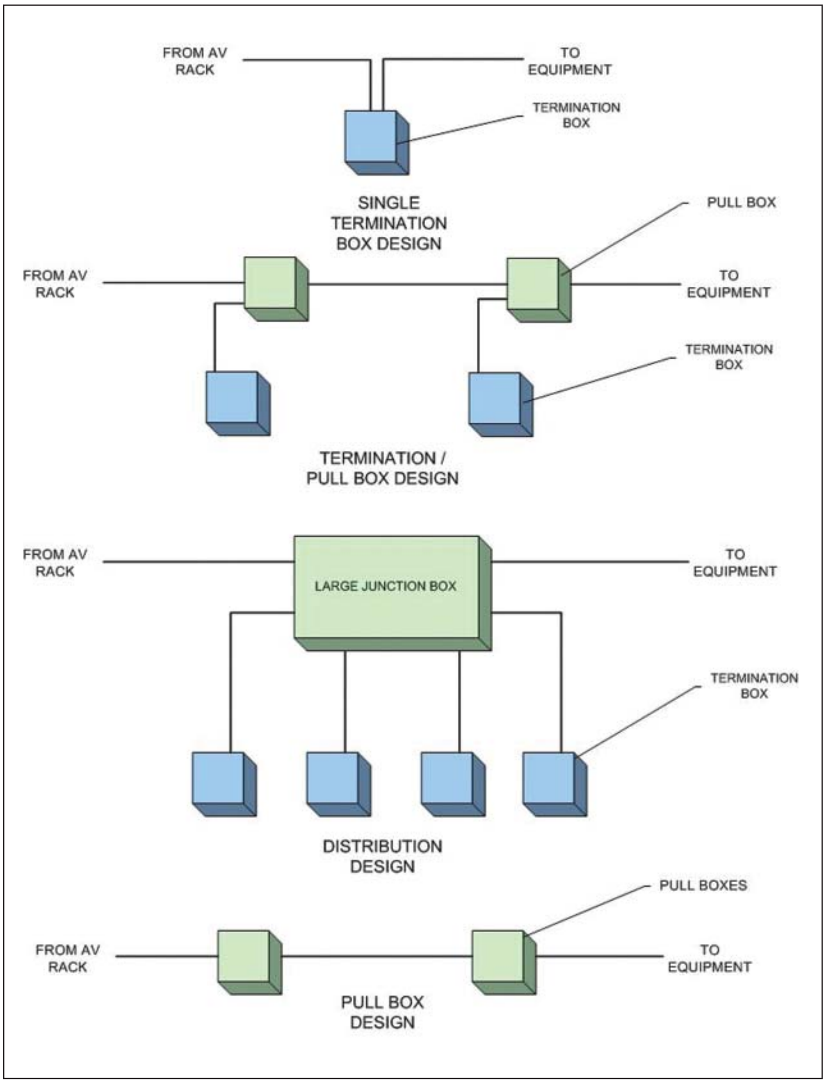

Figure 2 - Conduit Run Designs

Termination Boxes

The termination boxes used for the conveyance system have to be specific in accordance to the needs of the termination or interface. Typically, the AV interface or termination will have either the cables directly connected to an AV interface product or will need to have the cables terminated with standard connectors that connect or barrel through the interface plate, which connects the AV equipment or AV rack to the cabling system.

Here is where the design tolerances are critical. There needs to be enough room in the termination box to support whatever plate design is chosen to be used as the interface plate for the AV equipment. If standard connectors are being used to barrel through to connect the equipment, there needs to be enough room in the termination back box to store not only the connectors but also the interface plate structure that will protrude back into the box. In addition, there are some interface plates that require a smaller voltage to power the interface. Hence, a low-voltage power line will also be needed to power the electronics in the interface. In some places, this may be an electrical code issue and it is best to find out if a low-voltage DC line can be run into the same box as the AV signals before you purchase the interface solution for your project.

Beyond the sheer length of the run, the number of sweeps or bends have to be figured in the design of the run. In addition, the number of 90° sweeps have to be figured out to allow for proper pull box locations.

For Pull Boxes:

The NEC rule of thumb is - "There shall be no more than four cable bends of 90° equalling 360° in a run between the pull points or pull boxes."

The TIA / EIA 569 rule of thumb is a bit different - "No section of conduit shall be longer than 100' (~30 meters) or contain more than two 90° bends between pull points or pull boxes."

There may be other design recommendations for your local area. It is always recommended that you follow the local codes pertaining to your specific location.

Other termination locations may just be a simple stub out of a ceiling or floor. In this case, it is best to have a plastic collar installed on the conduit stub so that cables will not be damaged as the cable pull is done. Actually, it is recommended to install the plastic collar or grommet on all termination boxes as well, so as to protect the cable's jacket as it is pulled into the conveyance.

Cable Pulling

The most common method of installing cables is via the cable pull. First, a line is threaded into the conveyance and the line is simply attached to the cable that is to be installed. The line is then pulled back through the conveyance dragging the new cable with it. This method is then repeated for additional lines until all cable are installed.

Determining the maximum distance that a cable can be pulled without damaging them or having to splice the cable will maximize the efficiency of labour, reduce overall costs and ultimately provide longer cable life.

Other benefits to proper conveyance designs are the limiting of frictional force needed to pull the cables. Keep in mind that cable and conduits are not flat and that with more than one cable installed, it can result in more complex rubbing surfaces. Pulls are not straight, so forces other than gravity are at work at conduit bends and in multi-bend pulls, resulting in increase in pulling tension and sidewall pressures.

Finally, cable pulling is something experienced professional AV installers are familiar with. The cables used to support AV systems are somewhat delicate in nature because of the smaller conductors used in the construction of the cables to maintain high frequencies across long runs. It is recommended that you seek out the proper level of installation experience needed to do the job correctly.

Separate Signals

Lastly, for AV systems it is recommended that signals that are fundamentally different be separated. For example, lines that carry microphone-level audio should be not mixed in the same conveyance with video signals. The Electromagnetic Force Fields (EMF) that are present in video signals can possibly interfere with low-level audio cabling (even if shielded cables and balanced lines are used), thereby introducing the possibilities of noise in the audio signals. Therefore, by separating the video cables in its own conduit away from the audio cables will insure that the signals are shielded from any EMF leakage that could be radiating from the video cables. In many cases, the physical locations for video and audio resources are very close and the tendency is to want to share conveyance to minimize costs. The downside of this is that if a common conveyance is used to combine video and audio in the same run, that if EMF leakage occurs due to the tightly packed cables possibly wrapping around each other, you will have a situation where the interference problems will not go away.

With power distribution, there are usually electrical code issues that regulate the isolation of power sources from all low-voltage conveyance. In short, **do not run power sources with audio or video cables in the same conveyance. This is not a safe practice!**

The best practice is to run cables that have similar signals in their own conveyance to maintain isolation from radiating EMF:

- Video and Control
  (control is bursty and not usually a problem)
- Audio
- Power
- Network

Summary

Designing a conveyance system that meets the needs of your communication system is an important part of the overall planning for efficient system deployment. Working with electrical contractors or electricians to design the proper conveyance builds in protection of the cable investment, reliability and the need for expansion of services or system upgrades and maintenance.

Once properly installed, the conveyance is a reliable part of the system that can provide many years of service and protection for your cable runs. This is a true value added feature that is sometimes not realized as a selling point to clients. Nevertheless, it can be a great help in scaling up the system in the long run.

Article Resources

Designing Conduit Runs: EIA/TIA 569 vs. NEC - by Tony Casazza, RCDD www.Lanshack.com

Installing Communications Cable in Conduit – White Paper presented at the China Telecommunications Exposition – no author credited www.Polywater.com

Types of Steel Conduit- no author credited www.steelconduit.org

ICIA® & BICSI partner for AV Design Manual & Education By InfoComm International® News Release May 11, 2005 www.infocomm.org

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