BTS Introduction to Video Transmission and Distribution Hardware

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This guide is intended to serve as a basic introduction to the video transmission hardware used by Backstage. It is split into five sections: Section 1 discusses physical video cabling, Section 2 covers methods of transporting video signals over Cat5 ("Ethernet") cabling, Section 3 introduces a couple of common pieces of video distribution hardware, and Sections 4 and 5 cover video sources and displays respectively.

0 – Motivation:

For events use, both live and theatrical, it is necessary to distribute video to multiple output surfaces: projectors, TVs, computer monitors, or recording apparatus are all commonly used.

For theatrical purposes, the most common video application is the provision of "cueing" monitors so that members of stage crew can observe the status of the stage/wing areas from multiple locations, in both light and dark conditions. Occasionally, projection is employed in a theatrical context as part of a set piece of backdrop, but this tends to be rarer.

In a live events setting, video duty primarily consists of *Video DJ* displays: large screens on/around the stage on which are shown close-up views of the DJ/band performing. In addition, custom animated branding/graphics may be shown on these screens, too.

1.1 – Composite video:

Composite video is one of the oldest and most basic video transmission standards. Composite sends black-and-white or colour standard-definition video as a continuous analogue signal over coaxial cabling. This video transmission method has the advantage of being able to travel over long distances without any additional hardware and without any major loss of picture quality. For this reason, it is commonly employed for CCTV camera connections (see Section 4.1), such as may be found for cueing feeds in a theatre. Composite video is also included on many TVs for connecting camcorders, DVD players, set-top boxes, and games consoles, although this is becoming rarer.

Composite video connections are usually made using one of two connector types: *RCA* ("phono") or *BNC*.

The former type of plug, pictured right, is more common on consumer devices. Most TVs featuring a composite input do so via an RCA connector, for example.

The latter plug, pictured right, is more often used for professional purposes, because it is more robust and features a secure latching collar, ensuring that the connector cannot work its way loose. An example application of BNC composite video connectors would be CCTV camera connections – often positioned in inaccessible locations, meaning that cables should not be able to come loose easily.

1.2 – VGA:

VGA stands for *Video Graphics Array* and is a common connector traditionally used in IT for connecting monitors to PCs. As a result of this ubiquity in the computing world, many TVs and also projectors feature VGA inputs. VGA sends separate analogue signals for red, green, and blue – the three optical primary colours – over different pins in a multi-pin *D-SUB* (D-Subminiature) connector, pictured right.

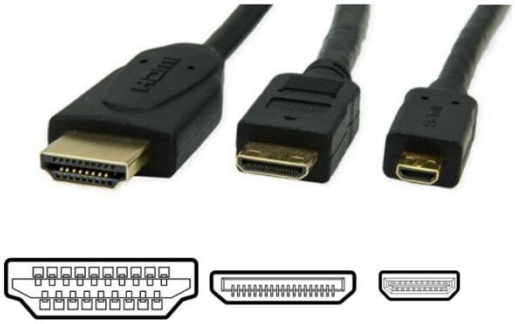
Having separate pins for each primary colour improves picture quality compared with composite video, so that although VGA is analogue, it is capable of transmitting full HD pictures. However, the need for multiple separate pins – as opposed to the single large pin used for composite video – results in a cable that is bulky and less well-suited for long-distance transmission. Therefore, in a Backstage use-case, it is more common to carry out long-distance transmission of video over some other medium, only converting back to VGA right next to where such a signal is needed.

1.3 – HDMI:

HDMI stands for *High-Definition Multimedia Interface* and is now more or less an industry standard for digital video interconnection of TV and entertainment equipment. Being digital, HDMI signals suffer from minimal losses over long distances, meaning that cable distances of up to 20m are perfectly achievable with excellent reliability and full-HD picture quality. Many modern TVs, games consoles, PC monitors, PC video cards, and laptops all include HDMI ports as standard. For many applications, particularly entertainment and projection systems, HDMI has effectively totally superseded older analogue standards such as composite video (see Section 1.1).

Uniquely, HDMI has the ability to transmit *audio* alongside video on the same connector, reflecting its origin as a connector for multimedia/entertainment systems. This is a great benefit when connecting, for example, a laptop to a TV for film screening purposes, as separate audio cables need not be used.

Finally, it should be noted that there exist two common variants of full-size HDMI connectors: *Mini-HDMI* (shown below centre) and *Micro-HDMI* (shown below right). Both of these transmit the exact same underlying signal as full-size HDMI, simply over a smaller connector. This means that adaption between mini-/micro-/full-size HDMI can easily be done with "dumb" passive adapter dongles:



1.4 – DVI:

Digital Visual Interface, or DVI, would best be described as a "digital like-for-like equivalent of VGA". It is a digital, multi-pin, screw-locking, connector designed as a connection for PC monitors. Interestingly, the underlying electrical signal transmitted by DVI is the same as that transmitted by HDMI (see previous section), meaning that conversion between the two can simply be achieved with a "dumb" passive adapter.

Whilst occasionally used for certain monitors, DVI has never especially caught on as a popular computer monitor connector in the same way as the likes of VGA, DisplayPort (see proceeding section), and to some extent HDMI, have. Likewise, some projectors include DVI connectors, but HDMI is now more common.

A final noteworthy element is that certain DVI connectors – notably the *DVI-I* variety – contain an additional four pins at their end to transmit a "backwards-compatible" analogue VGA signal alongside the main digital signal. The presence of such extra analogue pins allows for the use of "dumb" passive DVI-VGA dongles to directly connect older VGA monitors to a DVI port.

Below is shown a comparison of a DVI-I port, with its extra analogue pins, versus a digital-only (*DVI-D*) DVI port:

Note that, whilst a DVI-D plug can be inserted into a DVI-I socket, the same is not true in reverse: the extra pins on a DVI-I connector prevent it from being connected to a DVI-D socket, reflecting the DVI-D connector's inability to generate analogue signals for these extra pins.

1.5 – DisplayPort:

DisplayPort (DP) is functionally very similar to HDMI: a digital high-definition connector which can transmit both audio and video. It differs from HDMI in its useful inclusion of a latch, to prevent the connector from falling out of its socket. DP mostly finds use for connecting PCs to monitors, with very few (if any) TVs, projectors, or other entertainment equipment having DP connectivity.

Whilst DP and HDMI have different physical connectors, the underlying electrical signal is essentially identical, allowing conversion between the two connector types to be achieved with simple "dumb" adapter dongles.

1.6 – Cat5:

Whilst not strictly a *video* cable, as such, it is worthwhile discussing Cat5 ("Ethernet") cable, because it is frequently used to assist video transmission in some way. Cat5 cable is typically used for the purposes of constructing computer Ethernet networks. For this reason, Cat5 cabling is optimised to run over very long distances (e.g. across entire buildings) and is often installed within walls in modern/newly-renovated buildings.

Given its ubiquity and ability to transfer signals over long distances, it therefore makes sense that video transmission over Cat5 cable might be greatly beneficial. Therefore, the exist numerous kinds of signal converters for sending video connections, including composite, VGA, and HDMI over Cat5. Some of these solutions (colloquially termed "dumb" units) require a dedicated point-to-point Cat5 cable and must not be connected to any other kind of equipment, whilst other "smart" solutions allow video to be transmitted in a manner which can coexist with other conventional Cat5-connected Ethernet devices, such as computers, switches, and network routers. The latter variety of video-over-Cat5 opens up the potential for video to be transmitted across wide-area Ethernet networks, up to and including the Internet. See Sections 2.1 and 2.2 for detailed explanations of video-over-Ethernet hardware.

1.7 – SDI:

Serial Digital Interface, or SDI for short, is a professional-grade transmission standard used for broadcast-quality video distribution. In essence, it combines the benefits of composite video (see Section 1.1) – long-distance capability – with those of HDMI – high-definition picture quality and embedded audio transmission. SDI transmits an entirely *uncompressed* signal over a coaxial cable, resulting in an excellent-quality, low-latency picture.

SDI uses exclusively BNC connectors on the ends of its coaxial cables. Note that, whilst this is the same type of connector employed on some composite-capable hardware (see Section 1.1), the two standards are completely incompatible.

In terms of connecting video input/output gear to SDI networks, it is common to use various converters which input/output desired signals such as HDMI, VGA, or DVI. It is also the case that broadcast-quality cameras, monitors, and projectors, most often include direct SDI input/output capability, making connectivity easy and reliable.

2.1 – Video over Ethernet (dumb):

There exist many different kinds of so-called "baluns" for sending analogue video signals passively over Cat5 cabling. A classic example, illustrated right, is a composite video BNC to Cat5 balun. These are commonly used for sending composite CCTV signals over a building's installed Cat5 cabling. A balun is placed at either end of the Cat5 cable, in effect making it "appear" to the composite video devices at either end as a regular length of BNC coaxial cabling.

Another example of an analogue video balun might be a VGA to Cat5 balun, which may be used in certain situations to connect a projector to a PC over a greater distance than would be practical with a direct length of VGA cable.

In the case of any passive "dumb" balun, it is of utmost importance that, in spite of using the same physical Cat5 connectors as conventional Ethernet devices (switches, laptops, PCs, etc.), they not be connected to anything other than identical baluns on the other end of a given cable run.

2.2 – Video over Ethernet (smart):

Unlike passive “dumb” Cat5 video media converters, smart video *encoders* contain active electronics to encode an incoming video signal and distribute it *as compliant Ethernet signals*. This means that, in stark contrast to passive converters, smart encoders are electrically compatible with conventional network-connected Ethernet devices, such as network switches and PCs. These video encoders are typically distinguished by their description as “video over *IP*” devices, where “IP” stands for *Internet Protocol* – the communication method employed within regular computer Ethernet networks.

Topologically, IP video encoders may be utilised in a simple point-to-point fashion, each one being connected to the end of a single Cat5 cable run: an encoder at the source end and a *decoder* at the destination end. This is much the same as the topology required by basic passive converters. Alternatively, however, multiple encoders and decoders may be connected to a central Ethernet *switch* which acts as a single point of convergence for all the units’ video streams. Different encoders can then be routed to different decoders, either using settings on the devices themselves or within the network switch.

Furthermore, certain video encoders/decoders, such as the bidirectional *BirdDog* units owned by Backstage, can share an Ethernet network with a PC. The PC is then able to directly send or receive video streams over its own Ethernet port. With this kind of topology, it becomes easy to distribute video feeds over wide-area networks, such as the University’s campus network.

3.1 – Distribution Amplifiers (DAs):

A Distribution Amplifier (henceforth referred to simply as a *DA*) is a *multi-way video amplifier*. That is to say, it receives a single video feed, buffers it up using an internal amplifier circuit, and sends it to multiple outputs. This allows a single video source (e.g. a PC’s VGA port) to run multiple displays, each one showing a “copy” of the same feed.

DAs exist for the vast majority of video formats which one is likely to encounter: VGA, DVI, HDMI, VGA, and even composite. Note that a DA requires external mains power to supply its internal amplifier.

3.2 – Matrix Switchers:

A matrix switcher, occasionally referred to as a *crosspoint*, is a device with multiple inputs and multiple outputs. Each input may be *electronically* routed to one or more different outputs. This routing can be changed dynamically within the unit’s settings. Some matrix switchers use a set of front-panel buttons as their routing control; others additionally have a PC interface of some kind.

As with DAs, matrix switchers exist for most common video formats: HDMI, DVI, VGA, and composite. An example use-case of a matrix switcher within Backstage is for routing the various composite cueing CCTV camera feeds in the ALT (“Edge Theatre”) to the different monitors around the venue.

3.3 – Digital Video Recorders (DVRs):

DVRs are largely confined to CCTV applications. Essentially, they receive multiple video inputs (most often over composite, or some variation thereof) from cameras and record them to a built-in hard drive. DVRs typically include some degree of “alarm” functionality, to trigger alerts or recording based on motion detection within camera pictures. Usefully, modern DVRs have the ability for their video feeds to be viewed on a PC interface; the ALT CCTV network includes a DVR mainly for this reason.

4.1 – CCTV Cameras:

In terms of video sources, composite CCTV cameras, connected over BNC, are perhaps one of the most basic video devices which one is likely to encounter in Backstage use-cases. These are used more or less exclusively in theatrical settings and are usually positioned overlooking the main stage, theatre wings, and band conductor. The Stage Manager can then view any camera from the control booth.

An important feature of most CCTV cameras is *night vision* capability. This is implemented in the form of infrared (IR) LEDs on the front of the camera. When the ambient light level falls below a certain amount, the camera's lens becomes IR-sensitive and the front IR LEDs illuminate. This results in the camera being able to view its surroundings even if they are dark to a human observer. It should be noted that, when in night vision mode, a CCTV camera's picture becomes black-and-white; this is normal.

4.2 – PC Video Outputs:

A more complex but common video source is a computer. Typically, a PC may be connected for the purposes of a film screening or slide show. Alternatively, for a large live event, a PC (often the BTS Mac Pro) is connected up to various video projectors/walls on or around the main stage, for video DJ/branding purposes.

Most PC video connection is now done over HDMI. However, Backstage owns a large number of passive VGA-over-Cat5 baluns (see Section 2.1), meaning that on occasion it may be preferable to employ a VGA connection. In the event that a given computer ~~is not a real computer~~ doesn't have a VGA port, HDMI- or USB-C-to-VGA converter dongles may be used.

Another alternative to HDMI cabling would be to use smart Ethernet video decoders such as the Backstage *BirdDog* units discussed in Section 2.2. These can accept a network video stream generated directly from a PC's Ethernet port, mitigating the need for any PC-side display connection at all. The most common professional network video transmission standard of this kind is the *Network Device Interface*, or NDI [1].

A final note when connecting PC video for presentation/show purposes is that any potential "distracting" software on the computer should be disabled. This includes anything which could result in the presentation picture quality being compromised. For example, screensavers and e-mail notification pop-ups should be switched off.

5.1 – Projectors:

Video projection is an integral part of many events which Backstage now handle. This includes large live events, conferences, and certain theatre shows. Backstage owns an assortment of projectors, ranging from brightnesses of 2500 to 8000 Lumens.

Projectors are typically supplied with a video signal over either HDMI or VGA. If a projector is particularly far away from its video source, it is appropriate to use a Cat5 balun in a point-to-point setup, or a network video decoder.

Projectors are often controlled using a hand-held remote control. However, if the projector is located in a particularly distant/inaccessible location, this becomes impractical. Most projectors therefore include a *LAN* port for connection to a local Ethernet network, from which they can then be controlled using a web interface accessible from any PC on this same network.

When selecting a projector for a given event, attention should be paid to its *lens ratio*. This refers to the width of the output picture at a given distance from the projector's lens. Most projectors have a zoom lens which permits this ratio to be adjusted within certain boundaries.

5.2 – Video Wall:

There are times when a large video screen is required but when a projector is not an entirely suitable option: perhaps there is not a convenient "front-on" position where a projector can be placed, or the ambient light level may be so high that it "washes out" a projector screen. In these cases, a *video wall* is appropriate.

A video wall is a large RGB LED matrix display, where each pixel corresponds to a single colour-changing LED. The biggest advantage of a video wall is its brightness: it can easily outshine even outdoor levels of ambient light. For this reason, as well as the fact that no external projection source is necessary, video wall is ideal for stage screens on large live events.

It should be noted that, owing to each video wall pixel being a single RGB LED, the resolution of a video wall is considerably lower than that of a projector. However, for the viewing distances involved on most live events, this is not a problem and is more than compensated for by the excellent brightness.

A video wall consists of multiple *panels* which are latched together and interlinked by dedicated power and data cables. The array of panels is then suspended from a scaffolding or truss structure. In terms of video input to the panel array, this is somewhat different to a simple projector input: instead of sending a video signal (DVI/HDMI etc.) directly into the wall, a specialised *controller* acts as an intermediary between the wall panels and the video source. The controller is linked to the panels using a custom cable. The controller is necessary to ensure that the incoming video signal is suitably scaled to fit the number of panels in use and that the brightness is manageable.

References:

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1. https://www.ndi.tv/