Advanced AV System Trends, Technology & Design Considerations for Datacom Professionals
Today’s Agenda

• Introductions and overview
• Exploring the AV Quality Triangle
  – The Phi phenomenon
  – Temporal resolution in AV systems
  – HDR and deep color
  – Radiometric resolution in AV systems
  – Acuity of vision
  – Spatial resolution in AV systems
  – Calculating digital video bandwidth
• ANSI/AVIXA AV Standards
  – PISCR, DISCAS...
• Digital video analysis
  – Deep inside HDMI
  – Deep inside DisplayPort
  – Deep inside HDCP
• USB for AV applications
  – Deep inside USB 1.1, 2.0, 3.1 iterations
  – USB BC and PD implementation
  – Deep inside USB Type-C
• HDBaseT
  – Deep inside HDBaseT
  – Fiber and composite solutions
• AV-over-IP
• Summary and Q&A
• What’s Convergence? When Did It Start?
“In the near Future, A/V will be a part of IT, and everything will just be on the network”
• The future of convergence can be found in the ubiquity of “ambient computing” power.
• Evolution and Revolution
• Four Vectors of A/V Communication
• Experience Architecture
• AV Is IoT!
How Do We See?

- Electromagnetic energy (light) reflects off of an object and enters your eye
  - Only a small portion of the spectrum is visible
- Light enters through the cornea, is regulated by the iris, is focused onto the retina
  - The retina has “sensors” that convert light to electro-chemical signals, making us powerful analog/digital converters!
  - Digital information regarding the experience of “seeing” is transported to the brain by the optic nerve
Experiencing the Blind Spot

- Close or cover your left eye, then look at the cross with your right eye.
  - Move your head slowly either toward or away from the image, staring at the cross with your right eye, until the circle disappears.
  - When the circle disappears, you have found your right eye's blind spot.
The Phi Phenomenon

• *Phi Phenomenon* is the optical illusion of perceiving as motion a series of still images

• *Persistence of vision* makes interframe changes unperceivable
  - Flicker fusion
    - Frames per second *(fps)*
    - Fields per second (interlacing)
  - Motion is perceived between 2 patterns only when the elements are displaced by ¼ degree of visual angle or less
Measuring The “Resolution” Of Vision

– 360 Degrees Of Angle In a Circle
  ✓ The approximate field of view of an individual human eye is 95° away from the nose, 75° downward, 60° toward the nose, and 60° upward, allowing humans to have an almost 180-degree forward-facing horizontal field of view

– 60 Arc Minutes In 1 Degree

– 60 Arc Seconds In 1 Arc Minute
## Visual Acuity

<table>
<thead>
<tr>
<th>Visual acuity</th>
<th>Subtended MOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 12</td>
<td>0.6</td>
</tr>
<tr>
<td>20 14</td>
<td>0.7</td>
</tr>
<tr>
<td>20 16</td>
<td>0.8</td>
</tr>
<tr>
<td>20 18</td>
<td>0.9</td>
</tr>
<tr>
<td>20 20</td>
<td>1.0</td>
</tr>
<tr>
<td>20 22</td>
<td>1.1</td>
</tr>
<tr>
<td>20 24</td>
<td>1.2</td>
</tr>
<tr>
<td>20 26</td>
<td>1.3</td>
</tr>
<tr>
<td>20 28</td>
<td>1.4</td>
</tr>
<tr>
<td>20 30</td>
<td>1.5</td>
</tr>
<tr>
<td>20 32</td>
<td>1.6</td>
</tr>
<tr>
<td>20 34</td>
<td>1.7</td>
</tr>
<tr>
<td>20 36</td>
<td>1.8</td>
</tr>
<tr>
<td>20 38</td>
<td>1.9</td>
</tr>
<tr>
<td>20 40</td>
<td>2.0</td>
</tr>
<tr>
<td>20 42</td>
<td>2.1</td>
</tr>
<tr>
<td>20 44</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Market Disruption

“Performance is your reality. Forget everything else.” – Harold Geneen
• 4K Is An Irresistible Force...

• 4K Outpacing Analog Changeover
  - 95 million to ship this year
  - 21% growth projected for 2018

• Fully Mainstream In 2 to 4 Years
• 4K Is About More Than Pixel Count

• It’s “shorthand” for displays that include additional interoperability standards
  
  ▪  **HDCP 2.2, ATSC 3.0, HDR, Deep Color**
  
  ▪  **Multi-Content Multi-tasking**
The AV Quality Triangle
Resolution
Spatial Resolution

- Each pixel on a screen could be considered an optotype element
- Depending on the quality of the content, the recommendations of the past are often inadequate to enable maximum viewable image information intake

This is a close-up of the actual pixels of the Sony KV55XBR850 4K UltraHD LCD Display
xvYCC or Extended-gamut YCC (also x.v.Color) is a color space that can be used in the video electronics of television sets to support a gamut 1.8 times as large as that of the sRGB color space.

- Proposed by Sony, specified by the IEC in October 2005 and published in January 2006 as IEC 61966-2-4

High-dynamic-range imaging (HDRI) is a technique used in imaging and photography to reproduce a greater dynamic range of luminosity than is possible with standard digital imaging or photographic techniques.

- The aim is to present a similar range of luminance to that experienced through the human visual system.
A color space is a specific organization of colors. In combination with physical device profiling, it allows for reproducible representations of color, in both analog and digital representations.

- A way of specifying a color numerically, usually as a triplet of numbers representing positions in a three-dimensional “space” of color.
- Most content is in 4:2:0 space where, if the resolution of the overall image is 1920×1080, the Cb and Cr portions of the image will be at 960×540 resolution.
Chroma Subsampling

Y + U+V → YUV

4:4:4

4:2:2

4:2:0
Radiometric Resolution – HDR

2-bit = 4 radiance levels

8-bit = 256 radiance levels
HDR Displays

- LCD displays must achieve 20,000:1 contrast ratio
  - 1000 cd/m² - black level below 0.05 cd/m²
- OLED displays must achieve 1,080,000:1 contrast ratio
  - 540 cd/m² - black level below 0.0005 cd/m²
Radiometric – HDR, Deep Color
Temporal Resolution
Temporal - Fps
Bandwidth Must Be Examined More Closely in the New 4K World

- “Old” Formula to calculate analog video bandwidth
  - $H_p \times V_p \times F_r \times 3 / 2$
  - There is no correction for **bit depth** or **dark pixels**
  - This formula is a holdover from analog days
Data Signaling Rate for calculating digital video bandwidth

HDMI uses 8b/10b line coding, which is a line code that maps 8-bit words to 10-bit symbols to achieve DC-balance and output bounding. 8b/10b line coding increases the number of bits per color component by a factor of 1.25 (10/8). The 24-bit color we take for granted is a 10-bit per sub-pixel value across each of the RGB channels.

- \( H_p \) = Horizontal Pixels
- \( V_p \) = Vertical Pixels
- \( F_r \) = Frame Rate
- \( B_d \) = Bit Depth
- \( cf \) = chroma decimation factor
- \( M \) = deep color factor
- \( Q \) = Compression
The “deep color factor” comes about because scanning time for each pixel is bounded by the frame rate. For color depths higher than 24-bit/pixel standard, more data bits must be transmitted within the same time frame. The factor describing this increase is given by the ratio of deep color mode to standard color mode (n-bit/pixel : 24-bit/pixel). The table below describes this relationship.

<table>
<thead>
<tr>
<th>Color Bit Depth</th>
<th>Bits Per Sub-Pixel</th>
<th>Clock Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 bits</td>
<td>8 bits per “color”</td>
<td>1.00</td>
</tr>
<tr>
<td>30 bits</td>
<td>10 bits per “color”</td>
<td>1.25</td>
</tr>
<tr>
<td>36 bits</td>
<td>12 bits per “color”</td>
<td>1.50</td>
</tr>
<tr>
<td>48 bits</td>
<td>16 bits per “color”</td>
<td>2.00</td>
</tr>
</tbody>
</table>
Some Examples

• Calculate the video data signaling rate for a UHD 2160p60 signal operating in a 4:2:0 color space
  
  \[ \text{Payload rate} = 4120 \times 2205 \times 60 \times (10 \times 0.5) \times 1 = 2,727,380,000 \text{ per RGB color channel} \]
  
  \[ (2.73 \times 3) = 8.19 \text{ Gbit/s total payload rate} \]
  
  • This is uncompressed. Multiply by Q for compression

• Calculate the video data signaling rate for a UHD 2160p60 signal operating in a 4:2:0 color space
  
  \[ \text{Payload rate} = 2200 \times 1125 \times 60 \times (10 \times 1) \times 1 = 1,485,000,000 \text{ per RGB color channel} \]
  
  \[ (1.49 \times 3) = 4.47 \text{ Gbit/s total payload rate} \]
  
  • This is uncompressed. Multiply by Q for compression
The Old Way of Selecting the Right Display Size for an A/V Project

“What we see depends mainly on what we look for.” - John Lubbock
The 4-6-8 Rule

- Based on image (display) height & width only
  - Based on 4 “tasks”
    - General Viewing
    - Viewing with Clues
    - Viewing with No Clues
- Doesn’t reference resolution or picture quality at all!
Sight lines & Displays

- Reference 90-degrees perpendicular to the center of the screen
- Closest viewer should be no more than 1x screen width away
  - 27” LCD monitor viewed from 2 feet
  - 110” projection image viewed from 8 feet
  - No consideration of resolution!
Could This Really Be True for Both 480i and 2160p?

- 4x Image Height
  - Inspection of visuals "without clues" (maps, drawings, medical charts)
- 6x Image Height
  - Reading spreadsheets and websites
- 8x Image Height
  - For general video and “non-critical” viewing
The 150x Text Rule

- This is 14 point Calibri font
- This is 16 point Calibri font

- This is 18 point Calibri font
  - This is 20 point Calibri font
  - This is 24 point Calibri font
  - This is 28 point Calibri font
  - This is 32 point Calibri font
  - This is 36 point Calibri font
  - This is 36 point Arial font
The goal of DISCAS is to create a scientific standard, based on human vision, to define the screen size for a given audiovisual system based on audience viewing distance.
• DISCAS is a scientific standard, based on human vision, that defines the screen size for a given audiovisual system based on audience viewing distance.

• ANSI/AVIXA V202.01:2015 DS1 Display Image Size for 2D Content in Audiovisual Systems (DISCAS)
What DISCAS Addresses

- Comprehensive Human Factors for visual acuity and position relative to the image, including:
  - Image Height
  - Image Resolution
  - Size of Image Content
  - Closest and Farthest Viewer Distances
  - Relative Horizontal and Vertical Viewing Locations
What is Analytical Decision Making?

• ADM is a more specialized calculation
  – Concerned with the finest of details
  – Pixel-level detail required
  – Used for things like medical imagery, technical drawings, and photographic evaluation
Basic Decision Making

- BDM is the most common type of viewing category and included most business and education applications
  - Concerned with overall content rather than fine detail
  - Legibility and content assimilation are key
  - Typical content includes PowerPoint, text, illustrative images, spreadsheets
Let’s Begin with Analytic Viewing

• The ability to discern individual line pairs, which in today’s technology, can be related to pixels.
  – Based on “Acuity of Vision” concepts

• Determining angles and sizes is explained by the Pythagorean Theorem in Euclidean geometry

\[ a^2 + b^2 = c^2 \]
The Formula

Image Height = (Farthest Viewing Distance \* # Vertical Pixels) / (1/ \tan \left( \frac{MOA}{2} \right))

Farthest Viewing Distance = (Image Height \* (1/ \tan \left( \frac{MOA}{2} \right))) / # Vertical Pixels
VISUAL ACUITY FOR ANALYTICAL VIEWING

Pixel Height = a
Line Pair Height = 2 * a
Visual Acuity for Category = 2 * A
Viewing Distance at Stated Acuity = b
\[ \tan(A) = \frac{a}{b} \]
\[ b = \frac{a}{\tan(A)} \]

ACUITY FACTOR FOR ANALYTICAL VIEWING

\[ \frac{1}{\tan(\text{Visual Acuity}/2)} = 3438 \text{ for 2 Minutes of Arc} \]
Simplifying the Math...

• *Image Height* =

  • *Farthest Viewing Distance*\# Vertical Pixels
    
  • 3438

• *Farthest Viewing Distance* =

  • Image Height*3438
    
  • \# Vertical Pixels
A Practical Example

• A project demands maximum visual information. What image resolution is required for a viewer, positioned 3 meters from the screen, to result in maximum appreciated visual detail (additional resolution no longer affects image appreciation)?
Image Height for Maximum Visual Detail

- **Image Height** = \( \frac{\text{Farthest Viewing Distance} \times \# \text{Vertical Pixels}}{3438} \)

- Image Height = \( \frac{3 \text{ meters} \times 2160 \text{ Vertical Pixels}}{3438} \) = 1.88 meters

- Image Height = \( \frac{3 \text{ meters} \times 1080 \text{ Vertical Pixels}}{3438} \) = 0.95 meters

- Therefore screen height should fall between 
- .95 and 1.90m for maximum 4K utility
A Practical Example

• A project demands maximum visual information. What is the maximum recommended viewer distance for an 85-inch diagonal measure LDC 4K flat panel?

• What if the panel is 2K?
Viewing Distance for Maximum Visual Detail

- **Farthest Viewing Distance** = \( \frac{\text{Image Height} \times 3438}{\text{# Vertical Pixels}} \)

- Distance to the farthest viewer = \( \frac{41 \text{ inches} \times 3438}{2160} \) = 65.25 inches (5.4’)

- Farthest Viewing Distance = \( \frac{41 \text{ inches} \times 3438}{1080} \) = 130.5 inches (10.8’)

- Therefore viewers between 5.4’ and 10.8’ may be well served by 1080p, viewers closer than 1.6 meters need 2160p
How Do We Handle Basic Decision Making?

• “Decisions are made by people who have time, not people who have talent.”
  • Scott Adams
Calculating The $BDM_{AF}$

- DISCAS Task Group used “Human Factors Ergonomics Society” standard, the 150-Rule, and acuity factor to facilitate objective guidance
  - For Basic Decision Making an Acuity factor of 200 was selected
- In BDM, viewer can make basic decisions that are not dependent on critical details within the image, but there is assimilation and retention of information.
The Formula

\[ \text{Image Height} = \frac{\text{Farthest Viewing Distance}}{0.5 / \tan \left( \frac{\text{MOA}}{2} \right) \times \% \text{Element}} \]

\[ \text{Farthest Viewing Distance} = \text{Image Height} \times \frac{0.5 \times \tan \left( \frac{\text{MOA}}{60} \right)}{\% \text{Element}} \]
VISUAL ACUITY FOR NON-ANALYTICAL (BASIC) VIEWING

Element or Character Height = 2a
Visual Acuity for Category = 2A
Viewing Distance at Stated Acuity = b
\[ \tan(A) = \frac{a}{b} \]
\[ b = \frac{a}{\tan(A)} \]

ACUITY FACTOR FOR NON-ANALYTICAL (BASIC) VIEWING

\[ \frac{0.5}{\tan(\text{Visual Acuity}/2)} = 200 \text{ for 17.25 Minutes of Arc} \]
Simplifying the Math...

- Image Height \( = \frac{\text{Farthest Viewing Distance}}{200 \times \% \text{Element}} \)

- Farthest Viewing Distance \( = \) Image Height \( \times 200 \times \% \text{Element} \)

- Note: Outcome loosely reflects the earlier 4-6-8 RoT
  - 2.0% @ 4, 3.0% @ 6, 4.0% @ 8
What Is %Element?

Element is a character, symbol or image item.

E/H = %Element
An Example of 2.5% Element

This is a 2.5 %E displayed on a 55-Inch LCD screen. This image was captured 8 feet from screen surface (4X screen height) and demonstrates legibility when the BDM is applied to a project.
VIEWING PARAMETERS FOR BDM

NO SCALE  I.H. = IMAGE HEIGHT
IMAGE HEIGHT BASED ON 16:9 (1.78:1) ASPECT RATIO
A Practical Example For Basic Decision Making

- A 75” 16:9 LCD display has an image height of 37”
- Using 2.0%Element, we calculate the farthest acceptable viewer distance at 12.3 feet
- Using 3%Element, we calculate the farthest viewer at 18.5 feet
Which display would you choose and why?

Three different image sizes:

- 42 inch (1054.3mm) for a 4% Element Height
- 56 inch (1405.7mm) for a 3% Element Height
- 84 inches (2108.5mm) for a 2% Element Height.

Sizes of the displays change, the physical size of a character: 1.68 inches (42.2mm)
Common Elements of Connectivity
Power of Another Sort –
The Hardware “Handshake”
• Hot Plug Detect – Step 1
• Hot Plug Detect – Step 2
• Hot Plug Detect – Step 3
• Hot Plug Detect – Step 4

Image from Extron’s white paper, EDID: A Guide to Identifying and Resolving Common Issues
• **Why Does This Matter?**

• *Hot plug detect* is a signal that informs the source that a sink (display or load) is connected
  
  – Source provides +5V to the sink, which the sink sends back to the source as an assertion voltage
  
  – Repeaters and switchers may be required to pass a hot plug pulse to an upstream device
• Voltage Drop Over Interconnect?

• HPD flows from the device to the display
• And then from the display back to the device
• What Can Go Wrong?

• Detecting proper voltages is the core of the hardware “handshake”

• When proper voltages are not present in a connected system...
  – Complete loss of picture – **Hot plug related**
  – Distorted video - **EDID related**
  – Flashing images - **HDCP related**
High Bandwidth Digital Content Protection

- HDCP 2.2 is designed to create a secure 4K content connection
  - Encryption on HDCP2.2 keys is more advanced
  - Includes “locality check” which requires \( \leq 20\text{mS} \) latency source-to-sink
- HDCP 2.2 is not a firmware upgrade. This technology demands full hardware compatibility
  - All components in a system must support HDCP 2.2, including switchers, D/A, audio devices, etc...
21st Century Connectivity Formats
It can be helpful to envision physical layer A/V connectivity as “wheels inside wheels” with each successive layer encompassing more categories of connectivity and bridging longer distances.

• A/V Connector Ecosystem
The Most Ubiquitous AV Connector
• HDMI Pin-Out
• HDMI Power

• HDMI specification requires all source devices to provide at least 55mA on the 5V line
  – Located on Pin 18, must be 4.7 to 5.3V
  – 55mA is not enough current to operate most HDMI accessory devices, but in common practice most source devices provide more current on the 5V line than the HDMI specification requires
  – Design considerations should be based on specification, not “common practice”

• HDMI power is intended for hot plug detection
  – HDMI source provides +5V to the sink which the sink sends back as the hot plug assertion voltage on pin 19
• Active HDMI Over Copper

• Directional, active cables that incorporate a chip set to pre-equalize the signal so that it maintains eye pattern fidelity
  • *Bus powered solution – no external power supply option.*
  • *Chipset is embedded at the sink connection*
• “Stacking” an active, embedded chip with an external bus-powered device (a switch, for example) may cause system instability
• If embedded chip is at the sink, voltage drop over the length of the cable may still be an issue
• HDMI Embedded Media Converters

• An embedded media converter is a chip that fundamentally changes the signal to leverage a completely different optical or electrical connection topology
  – Some examples include RapidRun Optical, AOC, Celerity Optical Gateway

• Often these systems will leverage a USB power connection
  – When copper is not co-run with the optical channel, the power must be sourced at both the source and sink
  – However, the transmitter function may be powered by the HDMI or DisplayPort bus
• Many installation failures associated with sagging power and/or under-current situations can be addressed with a voltage inserter
  – However, multiple breaks in HDMI connection can induce distortion in the eye pattern. It’s important to analyze connection segment lengths.

• How Can You “Fix” It?
DisplayPort
• DisplayPort Pin Out
The difference between DP1.2a Standard and the DP++ option is the ability of the later to “speak” to an HDMI display without the need for active circuitry.
Interface Using Dual-mode adapter

Diagram showing the connection between a PC system and a Dual-mode DisplayPort Video Adapter, including DisplayPort Plug with or without short cable, DVI or HDMI Receptacle, and various signal connections like TMDS Data, TMDS Clock, DDC, DDC Buffer w/ HDMI Dot, HPD, Adapter Detect, CEC, Power, and 3V to 5V Converter.
• Potential DisplayPort Issues

  • DisplayPort exhibits similar potential for Hot Plug Detect or DDC/EDID failure as other connection standards
    – With the added complexity that the sink must pull voltage up to 5V from 3.3V
  • DisplayPort to VGA adapters include a D/A chip set
    – Chip set requires power to operate and this may affect battery life and/or link length
Universal Serial Bus
• The USB Ecosystem

- USB 3.1, PD & Type-C
- USB 3.0 & BC 1.2
- USB 2.0 & USBOtG
### USB Speed and Power Comparison

<table>
<thead>
<tr>
<th>Version</th>
<th>Year</th>
<th>Low Speed 1.5 Mbps</th>
<th>Full Speed 12 Mbps</th>
<th>High Speed 480 Mbps</th>
<th>Super Speed 5 Gbps</th>
<th>Super Speed + 10 Gbps</th>
<th>Power Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>1998</td>
<td>■</td>
<td>■</td>
<td></td>
<td></td>
<td></td>
<td>500mA</td>
</tr>
<tr>
<td>2.0</td>
<td>2000</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td></td>
<td></td>
<td>900mA* *during data transfer</td>
</tr>
<tr>
<td>3.0</td>
<td>2008</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td></td>
<td>900mA*</td>
</tr>
<tr>
<td>3.1</td>
<td>2013</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>You Won’t Believe Me!</td>
</tr>
</tbody>
</table>
• Physical Connections

USB 2.0 “A” and “B”
USB 2.0 Type A and Micro B
USB 3.0 “A” and “B”
USB 3.0 Type A and Micro B
• USB On One End, HDMI On The Other
• **MHL In The Market**

• Leverages HDMI form factor
  – Runs efficiently – uses less battery life than wireless connectivity
  – Charges mobile devices during operation
  – Allows for use of device remote control for transport functions
• USB Type-C
Type-C to Type-B
Type-C to Type-A
Type-C to DisplayPort
Type-C to Micro-B
USB operates on a strict hierarchy of 7 tiers

- All functions occupy layer 7
- Tiers 2-6 are reserved for hubs only.
- Extenders are almost always seen as Hubs
• *Isochronous* transfers at some guaranteed data but with possible data loss
• *Interrupt* transfers guarantee quick responses (bounded latency)
• *Bulk* transfers are for large sporadic transfers using all remaining available bandwidth, but with no guarantees on bandwidth or latency
• *Control* transfers are used for short, simple commands or device status response
• USB 1.1 & 2.0 are half-duplex systems that operate within rigid time constraints
  —Hubs and functions must respond to the host within a tightly defined time frame
  —5 Meter USB length limitation is derived from this time constraint
  —Velocity of propagation = the speed of transmission through a physical medium such as a cable or fiber.
• Hubs have three functions
  ▪ Repeater - connects and releases functions
  ▪ Controller - communicates with the host
  ▪ Transaction translator – controls speeds
• Hubs are self-powered or bus powered
• Example of a 7-Port Hub
Power In The USB Environment

- USB specifies 5 V (+/-5%)
- Power is delivered in quanta of unit loads
- A single unit load is 100mA for USB 1.1 & 2.0, 150mA for USB 3.0
- Low-power devices draw 1 unit load
- High-power devices may draw up to the maximum number of unit loads permitted after negotiation
• USB Power & Charging

Broad international adoption of USB Battery Charging standard for mobile devices
• China, Europe drove standardization as a means to increase charger reuse and reduce electronic waste

Agreement reached on Micro-USB connector and the standard for the common mobile charger
CENELEC and the USB Implementers Forum reach agreement on memorandum of understanding

BRUSSELS – March 1, 2011 – A Memorandum of Understanding (MoU) was signed today between the USB-IF and CENELEC, the European Committee for Electrotechnical Standardization.
A Closer Look At BC 1.2

- Negotiation of power capability is performed on USB 2.0 D+/D- before standard USB enumeration and requests. Ports are categorized into 1 of 3 possible configurations:
  - **Standard Downstream Port (SDP):** 500mA with USB 2.0 data, describes a typical USB port
  - **Dedicated Charging Port (DCP):** 1.5A or beyond with no USB 2.0. This kind of port is typically found as a wall adapter or mobile charger
  - **Charging Downstream Port (CDP):** Supports high current and USB 2.0. Typically a port specifically labeled for fast charging by the PC/Laptop manufacturer.
Beyond standard implementation, many vendors have their own implementations involving custom protocols such as:

- Apple Charging
- Sony Charging

These protocols are not necessarily compatible, resulting in chargers that work well for some devices, but very poorly for others as the higher power levels cannot be negotiated.
• Extender Systems

• Extenders typically occupy a tier – they are seen by the host as a hub
• SuperBooster systems are powerful components of a USB network design
• Extension Techniques
  • Equalization based
    – Limited to short distances, typically around 10 meters
  • Emulation based
    – Achieving interoperability is difficult
  • Protocol conversion based
    – Complex implementation
    – Icron’s ExtremeUSB® extension technology, considered to be the benchmark for industry, is based upon protocol conversion and can extend up to 10km
• **USB 3.0**
  
  • USB 3.0 SuperSpeed uses eye pattern rather than a time envelope
  
  • USB 3.0 is similar to USB 2.0 in transfer type
    – Isochronous
    – Bulk Transfer
    – Interrupt
    – Control
• USB 3.1 Gen 1 and Gen 2
  • In 2013, USB-IF introduced USB 3.1, also known as SuperSpeed+
  • 10 Gbps USB data rate
  • There are differences in Gen1 & Gen2 at Phy, Data and Protocol layer
  • Remember This:
    – USB 3.1 Gen 1 = USB 3.0 = SuperSpeed = 5 Gbps
    – USB 3.1 Gen 2 = SuperSpeed+ = 10 Gbps
• Video over USB (DisplayLink)
  • USB 3.1 Gen 1 allows USB to Video converters from DisplayLink to support much higher resolutions and frame rates at a higher quality than previously possible with USB 2.0 solutions
    – Capable of supporting up to 5Kp60 (5120x2880) over DP interfaces and 4K UHD over DP and HDMI interfaces
    – Also include integrated support for separate Stereo/5.1 Audio and Gigabit Ethernet channels
    – Typically found in docking stations or Unified Communication equipment
• USB 3.1 Gen 1 and Gen 2 Challenges

• USB 3.0 cable length is typically limited to 3m
• Three main contributing factors to signal degradation:
  – Insertion Loss
  – Cross Talk
  – Reflections
• So What Is Type-C?
This next generation of USB technology opens the door for the invention of an entirely new, super thin class of devices that consumers haven’t even seen yet.

- Designed for 10,000 plug/unplug cycles
- Robust enough for laptops and tablets; slim enough for mobile phones
Apple, Google, Microsoft...
• USB Power Delivery Profiles

<table>
<thead>
<tr>
<th>PDP (W)</th>
<th>Current at 5V (A)</th>
<th>Current at 9V (A)</th>
<th>Current at 15V (A)</th>
<th>Current at 20V (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 ≤ x ≤ 15</td>
<td>x ÷ 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 &lt; x ≤ 27</td>
<td>3</td>
<td>x ÷ 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 &lt; x ≤ 45</td>
<td>3</td>
<td>3</td>
<td>x ÷ 15</td>
<td></td>
</tr>
<tr>
<td>45 &lt; x ≤ 60</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>x ÷ 20</td>
</tr>
<tr>
<td>60 &lt; x ≤ 100</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>x ÷ 20¹</td>
</tr>
</tbody>
</table>

¹ Requires a 5A cable.

- Sources & Sinks must claim their capable Power Delivery Power (PDP)
- Based on PDP, various voltage levels are available
- Sources and Sinks negotiate voltage levels compatible at the appropriate PDP
Extend ease of use, reduce clutter, reduce even more waste

USB Power Delivery
• EMCA stands for the Electronically Marked Cable Assembly
• E-marking/EMCA is required under the following conditions:
  – USB-C cable is required to support more than 3A current (more than default)
  – USB-C cable is a full featured cable, cable supports either USB 3.1 Gen1 or USB 3.1 Gen2 signaling
• USB-C cable malfunction prevention
  – Authentication
• **What Does It Do?**
• Type-C Pin Out

- High Speed Data Path (TX for USB, or for DP Alt Mode)
- USB 2.0 Interface
- High Speed Data Path (RX for USB, or TX for DP Alt Mode)

- A1
- A2
- A3
- A4
- A5
- A6
- A7
- A8
- A9
- A10
- A11
- A12

- GND
- TX1+
- TX1−
- Vbus
- CC1
- D+
- D−
- SBU1
- Vbus
- RX2−
- RX2+
- GND

- B1
- B2
- B3
- B4
- B5
- B6
- B7
- B8
- B9
- B10
- B11
- B12

- GND
- RX1+
- RX1−
- Vbus
- SBU2
- D−
- D+
- CC2
- Vbus
- TX2−
- TX2+
- GND

- Cable Ground
- Cable Bus Power
- For Sideband Use (not used for USB)
- Plug Configuration Detection
  - One becomes VCONN, for cable or adaptor power
  - CC is used for USB-PD communication
• **DisplayPort 1.2a and Dual Mode/DP++**

  • Dual Mode/DP++ is an optional component of the DisplayPort Specification
  • DP 1.2a supports MST for extended desktop & multi-display installations
  • Dual lane allocation supports UltraHD 2160p resolutions
  • Supports RGB and YCbCr Color Space

• However, **DisplayPort 1.2a and not DP++ is embedded in USB Type-C!**
The difference between DP1.2a Standard and the DP++ option is the ability of the later to “speak” to an HDMI display without the need for active circuitry.
• USB Type-C Leverages DP 1.2a
What Is Alternate Mode?

“Any sufficiently advanced technology is indistinguishable from magic.”
– Arthur C. Clarke
• Type-C Supports Multiple Modes

• Type-C Can support USB, DisplayPort, Thunderbolt 3, SuperMHL and HDMI through “Alternate” Modes
  – Supports up to 4Kp60 4:4:4 with DP 1.2a/1.3/1.4
  – Simultaneous Support for USB 3.1 Gen 2 USB 2.0
  – Power transfer up to 100W
  – USB 2.0 available in all configurations
• HDMI Alternate Mode

- Supports HDMI 1.4b spec (4Kp30, 4Kp60 4:2:0)
- Cannot support simultaneous USB 3.1 or USB 2.0 data in any configuration
- No devices currently on the market supporting this mode
• Protocol Conversion To 10GE

• No timing or compatibility issues associated with Re-Driver or an Emulator solutions
• Distribution, switching achieved with off the shelf switches
• Proper VBUS handling to ensure stable reliable connections
• Power Delivery Negotiation with POE switches
• Type-C Extension Solutions

Maverick 63104

Summary of Features
- DisplayPort 1.2a with embedded audio support
- Resolutions up to 4096x2160 @60Hz
- YCbCr 4:4:4 and RGB 10 bit colour
- USB 3.1 Gen 1 data rate up to 5 Gbps
- Supports all USB 3.1, 2.0, 1.1 devices simultaneously at full bandwidth
- Four available 3.1 Gen 1 ports
- 100/1000 Ethernet channel, LAN pass-through
- Bidirectional RS232, 9600-115200 baud rate
- Single cable, CAT 6a up to 100m
- Point-to-point connection

Raven 3104

Summary of Features
- USB 3.1 Gen 1 data rate up to 5 Gbps
- Supports all USB 3.1, 2.0, 1.1 devices simultaneously at full bandwidth
- Four available 3.1 Gen 1 ports
- 100/1000 Ethernet channel, LAN pass-through
- Single cable, CAT 6a up to 100m
- Point-to-point connection
Understanding HDBaseT
HDBaseT is a packet based; switched networking standard which consolidates networking of high throughput, time sensitive data and control streams with Ethernet data networking over home span, standard CAT5e/6 structured cabling.
HDBaseT As An IEEE Standard(s)

- 1911.1 “a connectivity standard which consolidates...HDCP, uncompressed, multimedia, bidirectional data over standard CAT5e/6 structured cabling. The scope of the HDBaseT specification version 1.1.0 is to specify the HDBaseT link between HDBaseT Source Port device and HDBaseT Sink Port Device. Devices complying with this document shall interoperate in Direct Peer to Peer applications and shall interoperate as End Node devices over the future HDBaseT network.”

- 1911.2 expands scope to include “1. HDBaseT link between two HDBaseT Ports 2. Services provided by HDBaseT network to protocol/interface/application end point clients 3. HDBaseT entities and devices 4. Control & Management scheme 5. End point adaptor entities, which provide communication over HDBaseT for the following interfaces: 6. HDMI 1.4 7. USB 8. S/PDIF 9. Consumer IR 10. UART

- 1911.3 “… defines a protocol for communicating 5Play over a single long distance Local Area Network (LAN) cable. Building on …, this standard further enhances HDBaseT 5Play by broadening the variety of cables that the protocol can transfer over, expanding wireless compatibility, increasing power throughput over the HDBaseT link, harmonizing with Internet Protocol (IP), and adding security features.”
HDBaseT 5Play™

- 4K UHD 4:2:0 up to 10Gbps
- 100BaseTX “Fast Ethernet”
- Up to 100 watts DC
- Infrared relay
- Embedded CEC
- RS232
- USB 2.0
- Performance

HDBaseT Source

100m/328ft F/UTP CatX

HDBaseT Display
Interoperability is defined as the ability of systems and equipment to work together.
- Products can be interoperable for some features and not for others
- Certification only ensures compliance to the HDBaseT standard

First check at http://hdbaset.org/products_list
Then verify whether products support the same features
Check Mfr recommendations
POC is a pretty good idea!
What payload does HDBaseT actually send through the wire?
Increasing Data Rates - Baud

- For nearly 50 years, multilevel signaling has been used to provide high-speed symbol-transfer rates at low line speeds.
- 5-level (quinary) pulse amplitude modulation (PAM5) enables Gigabit Ethernet (1000BaseT) to achieve data rates of 1 Gbit/s over four parallel differential signal lines, each operating at only 125 MHz.
Symbol, Baud, Modulation & Bitrate

- When the transmission medium’s *bit-rate* isn’t sufficient for the baseband signal, modulation schemes are used.
- Symbol rate, also known as baud rate, is the number of *symbol changes* per second.
  - Each symbol can represent several bits of data, the raw rate of transfer is called bit-rate.
  - Symbol rate allows data transfer ≥ bit-rate.
  - 1,000 baud = 1,000 symbols per second.
  - Each symbol can represent a different step on a binary scale.
    - Example: a system using 2 bits per symbol doubles the effective bit rate, 1000 baud = 2000 bits.

This is the physical configuration (PHY) of 1000BaseT with a bit rate of 125 Mbps.
Multilevel Modulation

- By using multiple symbols, multiple bits can be transmitted per symbol
- Example:
  Symbol rate is 4800 baud
  Each symbol represents 3 bits
  Delivers an overall bit rate of 14.4K
  - There are a number of different modulation techniques that may be applied
    Frequency-Shift Keying (FSK)
    Phase-Shift Keying (PSK)
    Quadrature Amplitude Modulation (QAM)
Pulse Amplitude Modulation

- PAM is a form of signal modulation where the message information is encoded in the amplitude (magnitude) of a series of signal pulses.
  1) Original Signal
  2) PAM Signal
     a) Amplitude
     b) Sampling Frequency
- So ubiquitous it’s even used for LED lighting control!
Multi-Level Signaling in PAM
Gigabit Ethernet Uses PAM-5

- 1000Base-T uses PAM5 encoding, where each transmitted symbol represents one of five levels: –2, –1, 0, +1, +2
  - Four levels represent two bits; the fifth level supports forward error correction (FEC)
  - As the number of levels increases, susceptibility to noise increases proportionately
- Broadcast digital television (ATSC) 8VSB uses Pam-3, 32Mbit/s over 6MHz channel
- 10GBase-T, 25GBase-T and 50GBase-T use a far more demanding PAM-16 scheme
HDBaseT Uses PAM-16

HDBaseT uses PAM16 - each symbol is transmitted using one of 16 discrete, differential voltage levels = $2^4$ symbols

PAM16 TX Eye Pattern

0000 : 15
0001 : 13
0011 : 11
0010 : 9
0110 : 7
0111 : 5
0101 : 3
100 : 1
1100 : -1
1101 : -3
1111 : -5
1110 : -7
1010 : -9
1011 : -11
1001 : -13
1000 : -15
The disadvantage of increasing bit rate by using multilevel modulation is that the receiver has to distinguish many levels (symbols) from each other.
Physical Layer Considerations

• Near End Crosstalk (NEXT)
  • EMI Crosstalk from one pair to another pair
  • Expressed in dB/ft or dB/1000ft

• Far End Crosstalk (FEXT)
  • Interference between two pairs measured at the far end with respect to the interfering transmitter

• Alien Crosstalk (AXT)
  • Interference caused by other cables routed close to the cable of interest
Example of Cat6 F/UTP

**SPECIFICATIONS**

- **Configuration**: Copper pairs surrounded by aluminum PET foil with an outer drain wire and jacket
- **Pair Count**: 4
- **Conductor**: Solid annealed copper
- **AWG (mm)**: #23 (0.57)
- **Insulation**: CMR: Thermoplastic
  CMP: FEP
- **Insulation Colors**:
  - Pair 1: ColorTip Light Blue, Blue
  - Pair 2: ColorTip Light Orange, Orange
  - Pair 3: ColorTip Light Green, Green
  - Pair 4: ColorTip Light Brown, Brown
- **Separator**: Cross-web
- **Shield**: Aluminum/PET with 10% overlap
- **Drain Wire**: Tinned copper
- **Jacket**: CMR: Flame retardant (FR) PVC
  CMP: FR, low smoke PVC
- **Characteristic Impedance Ohms**: 100 ± 15
- **Nominal Velocity of Propagation %**:
  - CMR: 66%
  - CMP: 71%

Example – HDBaseT Certified
Superior Essex 6T-246-3A
Non-Continuous Shielding

Segmented shield can provide protection similar to continuous shield

Example – HDBaseT Certified Superior Essex Category 10Gain® XP CAT 6A U/UTP
Power Over HDBaseT - PoH

- PoH is based on the IEEE 802.3at-2009 POE+
- 50- to 57-volt DC over four pairs
  - 1000mA per two-pairs
- Instead of the powered device assuming worst-case cabling, POH allows the device itself to identify the cable length and draw more power as long as it does not exceed 100W
- Backwards compatible with section 33.7.1 mandate to conform to IEC 60950-1:2001
- Classified as a Limited Power Source (LPS), compliant with all PoE safety requirements
PoH Midspan

- PoH supports midspan options
  - HDBaseT Alliance chose Microsemi 4-pair detection methodology to insert power
  - Heat rise in cable bundles is a concern – operating temp 60°C (140°F) specified by TIA standards
- DC Ω imbalance can distort payload

![Diagram of PoH Midspan configuration](image)
Highlights of HDMI 2.0

- HDMI 1.4 describes most current product, including 4:2:0 4096x2160p24 and 3840x2160p30 (UltraHD, UHD)
  - HDBT does not support HDMI HEAC
- HDMI 2.0 “supports” 4:4:4 2160p60
  - Bandwidth increased from 10.2Gbps to 18Gbps
  - Supports single display MST (*Multiple Stream Transport*)
  - Improved CEC extensions
- HDMI 2.0 is not a “firmware” upgrade for almost all relevant products
HDBT 2.0 and HDMI 2.0 Aren’t Equal

- At this time, HDBT2.0 is limited to 10.2Gbps
  - Eventual support for 2160p60 4:4:4 will require new HDBaseT hardware
  - Existing HDBT solutions are limited to a 4:2:0 color space
- HDBT2.0 does deliver the following:
  - Point-to-Multipoint connectivity
  - Support for USB 2.0
  - Leverages full OSI model
Is There An HDBaseT 3.0 Coming?

- CEDIA 2016 HDBaseT Alliance demonstrated a working example of an HDBT solution that can handle up to 18Gbps
- Will require Cat6a “for optimum performance”
- This could allow for support of 2160/p60 in a 4:4:4 RGB color space
Understanding AV-over-IP
Thank you for participating in our first AV Transport Methods Master Class. Are there any questions about the material we’ve presented today?
Course Follow-Up

• CTS and BICSI CEC’s
  – You will receive an email in 8 to 10 business days with an attached certificate of completion. This course delivers 6 BICSI and 6 AVIXA CTS credits.

• Copies of the Slide Deck and White Papers mentioned in this seminar
  – You will receive an email with attached .pdf formatted copies of all the resources we’ve discussed today.

• Email invitation to participate in a follow-up survey to help us design and deliver future seminars and classes

• Please complete the final course evaluation sheet provided at the beginning of this event. A location will be provided for you to turn in the evaluation before you leave.
A Final Thought To Take With You...

“If it works, it’s obsolete” – Marshall McLuhan
• Thank You!