Understanding Digital A/V Principles, Technology and Connectivity – A Comprehensive Overview

Where we are and where we’re going, from Alexander Graham Bell to Zigbee

Presented by
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Technology Evangelist
Legrand
Let’s Start With Some History…

“Some mornings it just doesn't seem worth it to gnaw through the leather straps.” - Emo Phillips
1927 – NBC & CBS radio broadcasts
1941 – 525 Line
1944 – 625 Line
And then...
CONVERGENCE

The merging of distinct technologies, industries, or devices into a unified whole
The Genesis of Convergence

“I just wondered how things were put together.”

- Claude Shannon’s thesis explained that electrical applications of Boolean algebra could construct any logical, numerical relationship (1937)
- A Mathematical Theory of Communication marks the genesis of the digital epoch (1948)
- Information can be defined and quantified with absolute precision
A/V In Today’s Market

“I was born not knowing and have had only a little time to change that here and there.” – Richard Feynman
Four Ways A/V Communicates
Experience Architecture
AV Is IoT!

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“Performance is your reality. Forget everything else.” – Harold Geneen
I currently own, or plan on purchasing, a 4K display or device.
• 4K Outpacing Analog Sunset Changeover
• 40% of 2017 Sales will be UltraHD screens
  ✓ 76 million to ship this year
  ✓ 21% Increase projected 2018
• Fully Mainstream In 3 to 6 Years
4K Is About More Than Resolution

It’s really “shorthand” for displays that include additional interoperability standards.

**HDCP 2.2, ATSC 3.0, HDR, Deep Color**

**Multi-Content Multi-tasking**
• 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)
Mobile Integration Drives Change

There are more than 1.6 billion mobile devices in the workforce, and that number will continue to grow...
Mobile Sources - Fixed A/V Assets

- 38% of companies will stop providing devices to workers by 2017
  – *From Gartner “Global Market for Enterprise Mobility Mgmt”*
- BYOD market in NA estimated to grow from $29.5B in 2014 to $89.6B by 2019
- EU market will grow from $19.35B in 2013 to $74.70 by 2019
- BYOD is saving companies money and helping their employees become more productive
  – *From Cisco “The Financial Impact of BYOD”*
Rules For Wireless Connectivity
Bluetooth

- Secure
- Convenient
- Designed for low bandwidth applications where a cable-free connection is desired
Bluetooth 5

4 times speed, double range

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Network Capacity – An Immovable Object

- Over 50% of all N.A. peak Internet traffic supports YouTube and Netflix content

- Enterprise IT networks are struggling to keep up with bandwidth demands

- There’s no simple way to shift the total connectivity of “the last 100 meters” to the LAN
Important Digital A/V Concepts

“All truths are easy to understand once they are discovered; the point is to discover them.” - Galileo Galilei
Baseband and Passband
Series vs Parallel
Squares, Sines and Eyes

A digital signal waveform: (1) low level, (2) high level, (3) rising edge, and (4) falling edge
• In the digital world there are no copies, only clones
• Blom's Scheme: a symmetric threshold key exchange protocol used in cryptography
  — A trusted party gives each participant a secret key and a public identifier, which enables any two participants to independently create a shared key for communicating.
  — Keys updated after each encoded frame
AV-Over-IP

• Leverages the LAN
• JPEG2000, H.264, H.265, HTML 5, WEB RTC, etc.
• Ideal for remote connections
• Streaming codecs are “lossy” and that’s a decision point for certain applications
“I’m looking for a lot of men who have an infinite capacity to not know what can’t be done.” – Henry Ford
## Spatial Resolution

<table>
<thead>
<tr>
<th>Horizontal Pixels</th>
<th>Vertical Pixels</th>
<th>Total Pixel Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>720</td>
<td>480</td>
<td>.35 Megapixel</td>
</tr>
<tr>
<td>1280</td>
<td>720</td>
<td>.92 Megapixel</td>
</tr>
<tr>
<td>1920</td>
<td>1080</td>
<td>2.07 Megapixel</td>
</tr>
<tr>
<td>3840</td>
<td>2160</td>
<td>8.29 Megapixel</td>
</tr>
</tbody>
</table>

- Horizontal pixels describe how many “columns” of pixels make up the total image
- Vertical pixels describe how many “rows” of pixels make up the total image
## Actual Pixel Count

<table>
<thead>
<tr>
<th>H-Active</th>
<th>H-Blank</th>
<th>H-Total</th>
<th>V-Active</th>
<th>V-Blank</th>
<th>V-Total</th>
<th>Image</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>720</td>
<td>138</td>
<td>858</td>
<td>480</td>
<td>45</td>
<td>525</td>
<td>345,600</td>
<td>450,450</td>
</tr>
<tr>
<td>1280</td>
<td>370</td>
<td>1650</td>
<td>720</td>
<td>30</td>
<td>750</td>
<td>921,600</td>
<td>1.24 M</td>
</tr>
<tr>
<td>1920</td>
<td>280</td>
<td>2200</td>
<td>1080</td>
<td>45</td>
<td>1125</td>
<td>2.07 M</td>
<td>2.48 M</td>
</tr>
<tr>
<td>3840</td>
<td>560</td>
<td>4400</td>
<td>2160</td>
<td>90</td>
<td>2250</td>
<td>8.29 M</td>
<td>9.9 M</td>
</tr>
</tbody>
</table>

- Additional Bandwidth provided by horizontal and vertical blank pixels is used for embedded information such as EDID, audio content, HDCP, etc...
Temporal Resolution

- Interlacing splits frames into fields
  - Every even number scan line
  - Every odd number scan line
  - Effective frame rate is \( \frac{1}{2} \) scan frequency

- Progressive scanning presents full frames by building the image sequentially
Radiometric Resolution

- Determines how finely a system can represent or distinguish differences of intensity, and in digital systems is expressed as a number of levels or bits. The higher the radiometric resolution, the better subtle differences of intensity of reflectivity can be represented.
True Color

- Red, Green and Blue (RGB)
- 8-bits per color = 256 “shades”
- $256 \times 256 \times 256 = 16.77$ million possible colors
  - 24-bit color
  - 30-bit color w/ 8b-10b line coding
Chroma Subsampling

*Color sample ratio* refers to the ratio of luma (Y’) samples to each color difference sample (CB and CR). Less color detail is recorded and less bandwidth is required for storage and transmission. Because we are less sensitive to color detail than we are to luma detail, subsampling the chroma signal can be considered perceptually lossless.

<table>
<thead>
<tr>
<th>Color Sample Ratio</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:4:4</td>
<td>Each R, G, and B channel, or each Y’, CB, and CR channel, is sampled at the same rate. Maximum color detail is maintained.</td>
</tr>
<tr>
<td>4:2:2</td>
<td>The color channels are subsampled so that the color resolution is halved. For example, the first pixel in a line contains Y’, CB, and CR samples. The next pixel contains only a Y’ sample. This pattern repeats. Most professional video formats use 4:2:2 color subsampling.</td>
</tr>
<tr>
<td>4:1:1</td>
<td>The color is subsampled so that the color resolution is quartered. The first pixel in a line contains Y’, CB, and CR samples. The next three pixels only contain Y’ samples. This pattern repeats.</td>
</tr>
<tr>
<td>4:2:0</td>
<td>This ratio indicates that the CB and CR channels are subsampled both horizontally (as in 4:2:2) and vertically. This reduces color resolution in both the horizontal and vertical dimensions compared to 4:2:2, which only reduces horizontal chroma resolution. There are several methods for locating CB and CR samples relative to Y’ samples, yielding several different 4:2:0 formats.</td>
</tr>
</tbody>
</table>
## Determining Bandwidth in the 20th Century

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal active pixels</td>
<td>1920</td>
</tr>
<tr>
<td>Vertical active pixels</td>
<td>1080</td>
</tr>
<tr>
<td>Frame Rate</td>
<td>60 fps</td>
</tr>
<tr>
<td>RGB X 3</td>
<td></td>
</tr>
<tr>
<td>Chroma Decimation</td>
<td>( \div 2 )</td>
</tr>
<tr>
<td><strong>186,625,000 Hz</strong></td>
<td></td>
</tr>
<tr>
<td>Or</td>
<td></td>
</tr>
<tr>
<td><strong>187 MHz</strong></td>
<td></td>
</tr>
</tbody>
</table>
Determining Bandwidth in the 21st Century

*Total* horizontal pixels: 2200
*Total* vertical pixels: 1125
Frame Rate (refresh rate): 60 fps
Color bit-depth x 3: 24
8b/10b line coding: 1.25
÷ Chroma decimation: 1 (4:4:4)

4,455,000,000
Or
4.46 Gbps

And then account for codec signal compression and IP overhead...
Selecting Display Size For An A/V Project

“What we see depends mainly on what we look for.” - John Lubbock
Sight lines and Distances

- 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
- Top of the screen no more than 30-degrees above line of sight
The 4:6:8 Rule of Thumb

- 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
• This is 14 point Calibri font
• This is 16 point Calibri font
• This is 20 point Calibri font
• This is 28 point Calibri font
• This is 36 point Calibri font
• This is 36 point Arial font
Display Image Size for 2D Content in Audiovisual Systems

- ANSI/AVIXA V202.01:2015 DS1
- 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.
Defining Viewing Categories

- DISCAS deals with Analytical Decision Making (ADM) and Basic Decision Making (BDM) although there are four viewing categories in PISCR
  - Analytical Decision Making:
  - Basic Decision Making:
- Based on “Acuity of Vision” concepts
  - The ability to discern individual line pairs, which in today’s technology, can be related to pixels.
What is Analytical Decision Making?

• Concerned with the finest of details
• Pixel-level accuracy required
• Used for medical imagery, technical drawings, e-evidence, photographic evaluation
What is Basic Decision Making?

• BDM is the most common type of viewing category
• Concerned with overall content rather than detail
• Optimized for PowerPoint, text, spreadsheets, and unified collaboration and communications
Break – 10 Minutes Please
“To manage a system effectively, you might focus on the interactions of the parts rather than their behavior taken separately.” – Russell L. Ackoff
SDI - Serial Digital Interface

- SDI (1989)
- HD SDI (1998)
- 12G SDI (2014) — 12 Gbit/s for 2160p60
- 24G SDI (2014) — 24 Gbit/s and 8Kp60
DisplayPort & DisplayPort Dual Mode

Diagram showing connections and labels:
- Power Return
- AUX
- Hot Plug
- Config
- Lane 0
- Lane 1
- Lane 2
- Lane 3

Additional notes:
+3.3V @ 500mA
Understanding MST
High Definition Multimedia Interface
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HDBT – A New IEEE Standard

“The nice thing about standards is that there are so many of them to choose from.” – Andrew S. Tanenbaum
HDBaseT History And Operation

- HDBaseT Alliance was established in 2010
  - LG electronics, Samsung Electronics, Sony Pictures, Valens Semiconductor
- A global standard for advanced digital media distribution
  - HDBaseT 2.0 standard finalized in August 2013
- Link can be via copper or fiber
HDBaseT™ Supports Daisy Chain Architecture

Perfectly Suits Digital Signage Installations

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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
- 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
USB and Interactive A/V

“The real problem is not whether machines think but whether men do.” – B. F. Skinner
USB 2.0 And 3.0

USB 2.0 “A” and “B”

USB Type A and Micro B

USB 3.0 “A” and “B”
USB “Pyramid” Topology

- **Host**: Host is tier 1 (inside the computer)
- **Tier 2**: Tier 2 hub (typically inside computer)
- **Tier 3**: Tier 3 may be a passive hub
- **Tier 4**: Tier 4 may be a passive hub
- **Tier 5**: Active Hub required here
- **Tier 6**: Tier 6 may be a passive hub
- **Tier 7 - Functions**: This level is for the device, aka “function”
USB 1.1, 2.0 And 3.0

- FireWire 400: 400 Mb/s
- USB 2.0: 480 Mb/s
- FireWire 800: 800 Mb/s
- eSATA: 3 Gb/s
- SuperSpeed USB 3.0: 5 Gb/s
A Relationship With Time

- USB 1.1 & 2.0 are half-duplex systems that operate within rigid time constraints where 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.
USB Pin Out

4 3 2 1

5 4 3 2 1

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USB From 4 Pins to 9
USB On One End, HDMI On The Other?

- Established in 2010 by Nokia, Samsung, Silicon Image, Sony and Toshiba
- MHL signaling uses 5 pins and can map itself to other popular connectors in the eco-system.
- The 2012 installed base of 300 million devices will grow to more than 1.4 billion devices by 2016
One Connector To Rule Them All?

• Designed for 10,000 plug/unplug cycles
• Robust enough for laptops and tablets; slim enough for personal portables

“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”

USB 3.1

• Designed for 10,000 plug/unplug cycles
• Robust enough for laptops and tablets; slim enough for personal portables

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Converging Data, DisplayPort, Power, Analog Audio
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)

Cable Ground

Cable Bus Power

For Sideband Use (not used for USB)

Plug Configuration Detection
- One becomes $V_{CONN}$, for cable or adaptor power
- CC is used for USB-PD communication

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USB Host or Device with DisplayPort Alternate Mode Capability.

USB 3.1 Data
USB Power Delivery
DisplayPort A/V

USB Type-C to Type-C Cable.
Either end can serve as USB Host, USB-PD Power Consumer, and DisplayPort Video Source (these services are orthogonal to each other).
Say Hello To SuperMHL

- SuperMHL debuted at CES 2015
- Supports 4320p120 w/ 48-bit color depth and advanced audio formats
  - Yes, this is 8K @ 120 frames per second!
- New 32-pin symmetrical connector w/ 6-lanes, HDCP 2.2 & support for up to 8 simultaneous displays
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Mobile integration will put a spotlight on wireless problems that may have been masked

“I have not failed. I have just found 10,000 ways that won’t work.” — Nikola Tesla
Wireless Connections Leverage Elements All Devices Have in Common
AppleTV, Chromecast, FireTV, etc...

- **Apple TV** - MacBooks, iPads and iPhones
- **Miracast/WiDi** - Android and recent Windows systems, but not Apple products
- **AllShare** - Only Samsung Galaxy phones and tablets
- **Chromecast** - Macs, PCs, iOS and Android devices - relies on apps rather than true mirroring
- **Roku** – Miracast embedded
How Can We Minimize Impact On The LAN?
Miracast

- Based on Wi-Fi-Display (WiDi)
- Peer-to-peer wireless connection leveraging Wi-Fi Direct
  - Does not require a WAP
  - Connects devices from different manufacturers
  - Negotiates the link using WPS for “pairing”
- There are nearly 4,000 Miracast devices certified today
The Power of the App

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Example of MirrorOp System

The AMX Enzo is a good example of a MirrorOp based BYOD solution. A “task specific computer” (NMX-MM-100) anchors the design.
The conclusion is the place where you get tired of thinking...

“If you're not scared or angry at the thought of a human brain being controlled remotely, then it could be this prototype of mine is finally starting to work.” - John Alejandro King
Fascinating...

- Network connectivity will not replace “the last 100 meters” of connectivity to the user/operator any time soon
- Mobile integration and UltraHD will place new and unexpected demands on A/V design and system performance
- HDMI is the most ubiquitous port for accessing A/V content
- DisplayPort is the global replacement for VGA
- HDBaseT is the new IEEE industry standard for connecting digital media devices at length
- USB enables interactivity in A/V systems
- USB Type C will have a profound impact on many categories of devices including portable and fixed A/V assets - particularly in the desktop environment
- The evolution of A/V technology is not over!

“Live long and prosper.”
Questions?