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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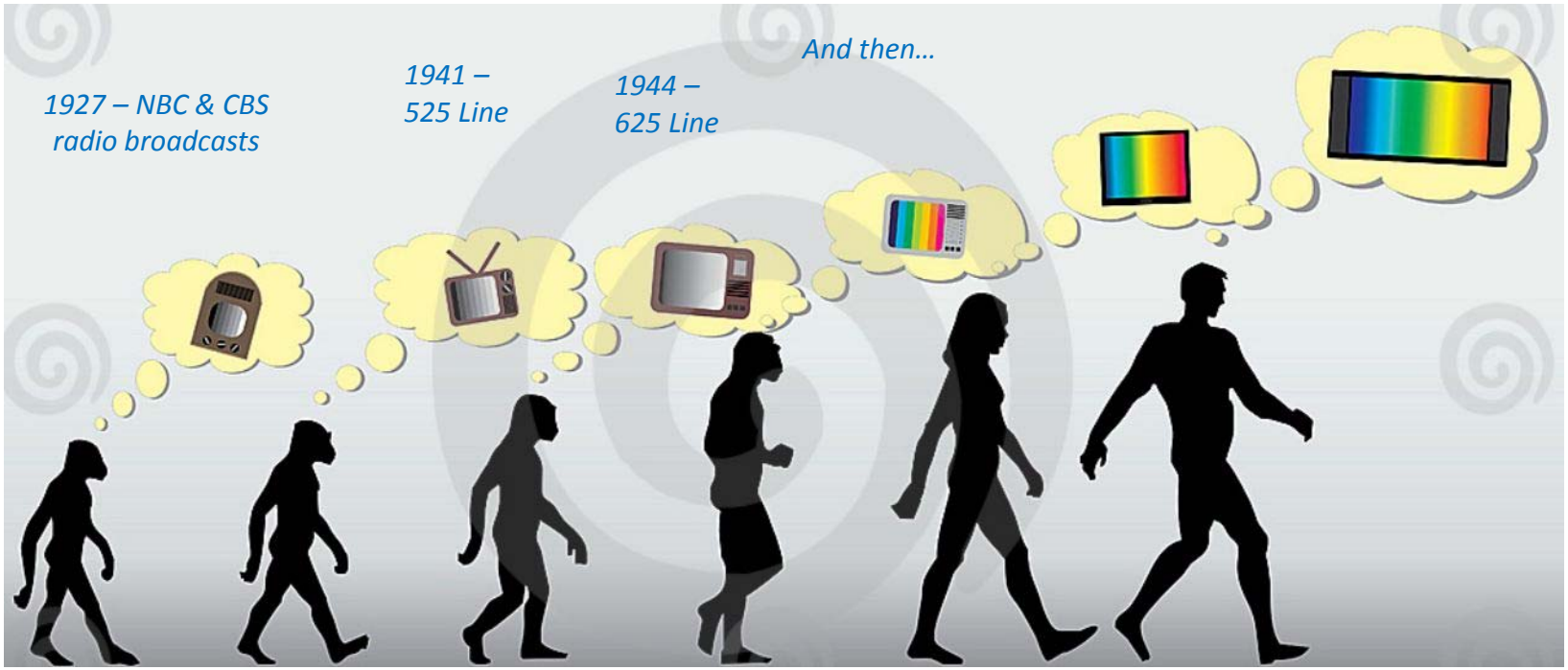
Technology Evangelist
Legrand

Our Agenda

A/V History	Market Disruption	Critical Digital A/V Concepts
Selecting A/V Display Size	*Break*	A/V Ecosystem
USB and A/V	A/V and 802.11	What's Next?

Let's Start With Some History…

"Some mornings it just doesn't seem worth it to gnaw through the leather straps." - Emo Phillips



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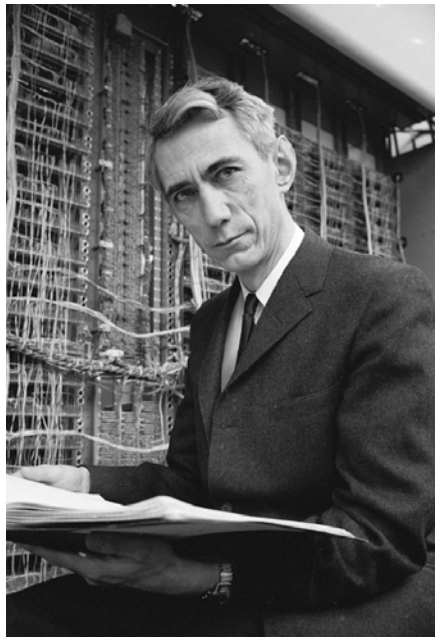
CONVERGENCE

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



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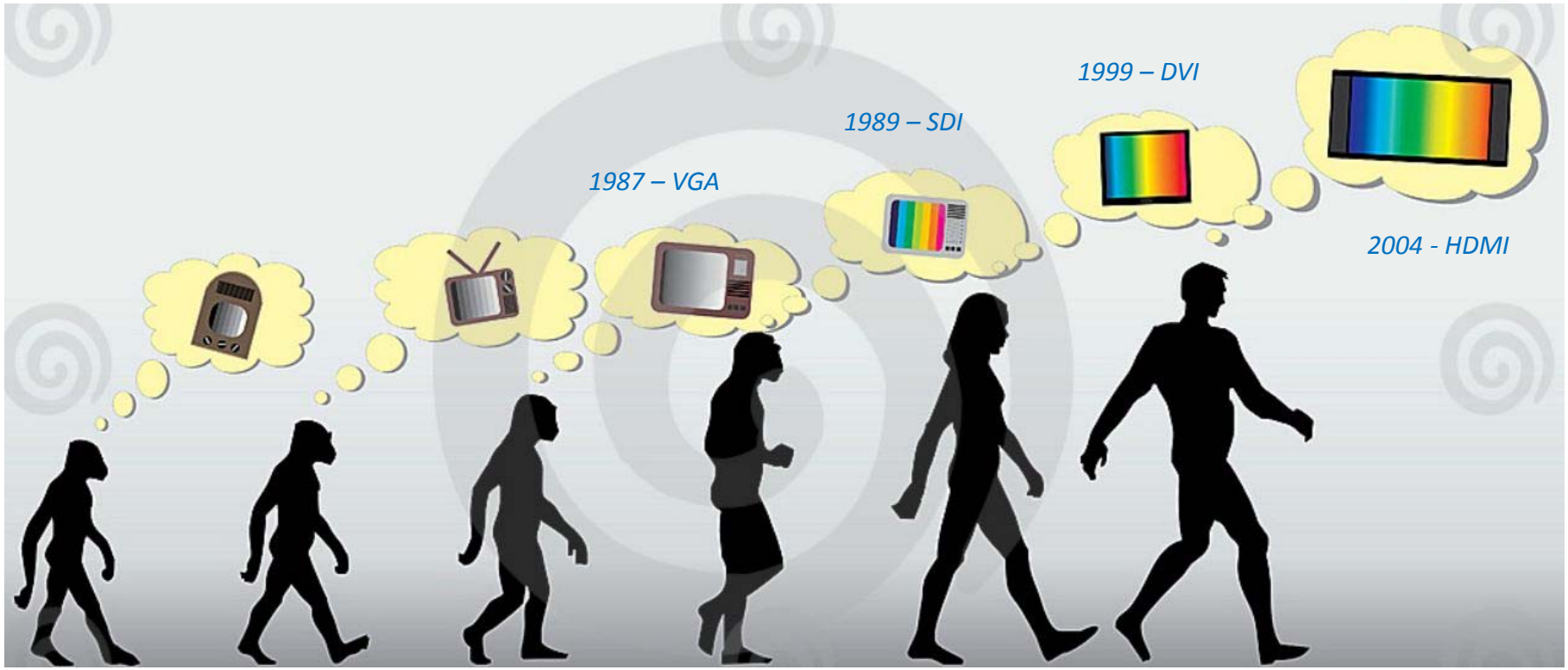

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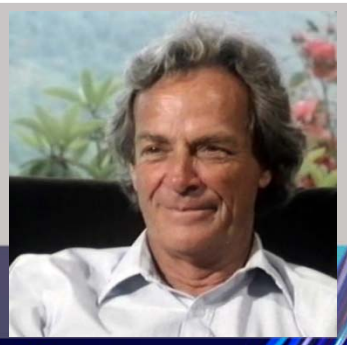
A/V In Today's Market

"I was born not knowing and have had only a little time to change that here and there." – Richard Feynman



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Experience Architecture

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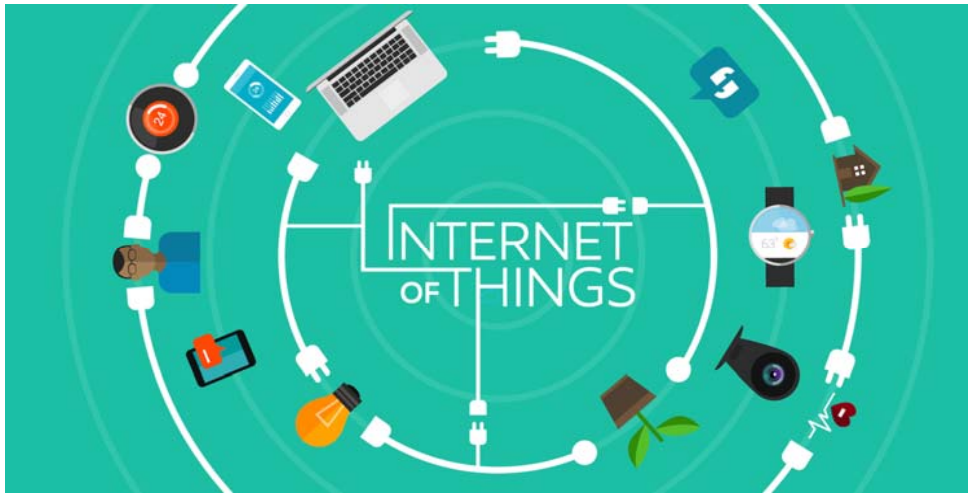
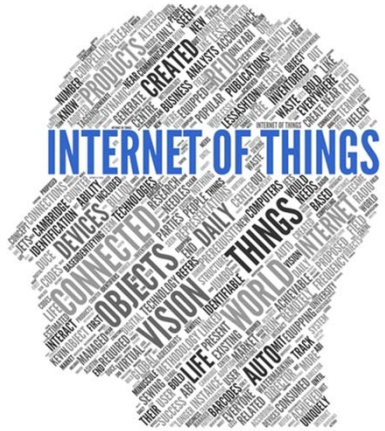
AV Is IoT!

Internet of Things (IOT)

Eliot

Electricity





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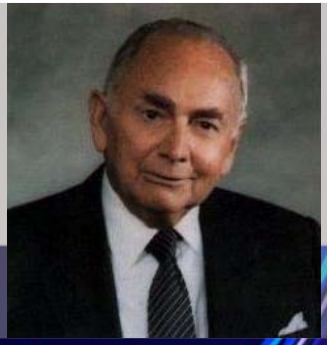
Market Disruption

"Performance is your reality. Forget everything else." – Harold Geneen



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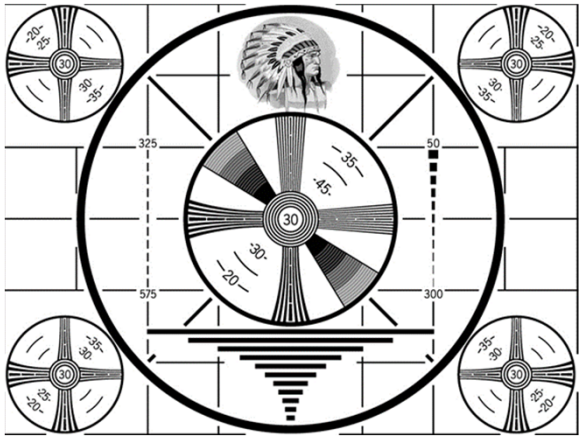
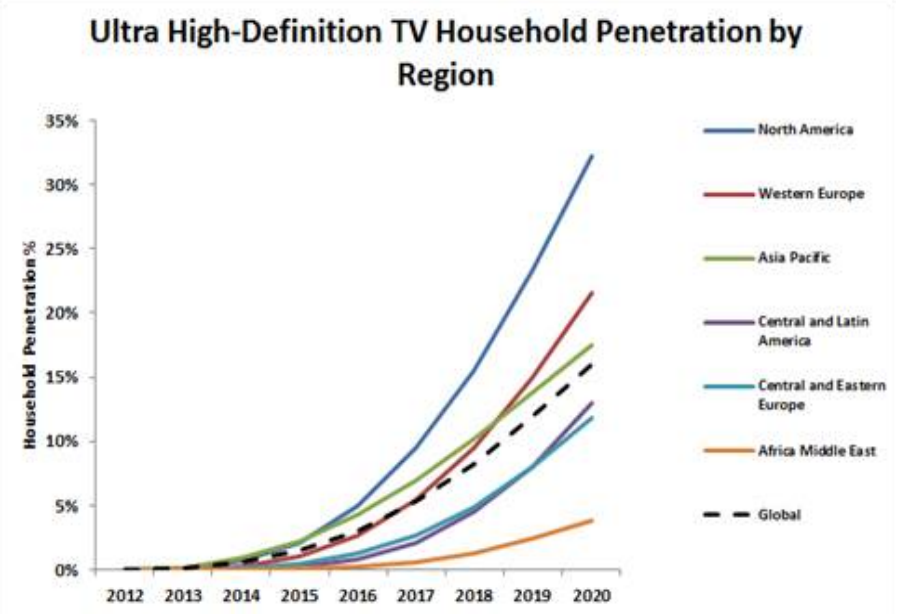
I currently own, or plan on purchasing, a 4K display or device.



- 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



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4K Is About More Than Resolution

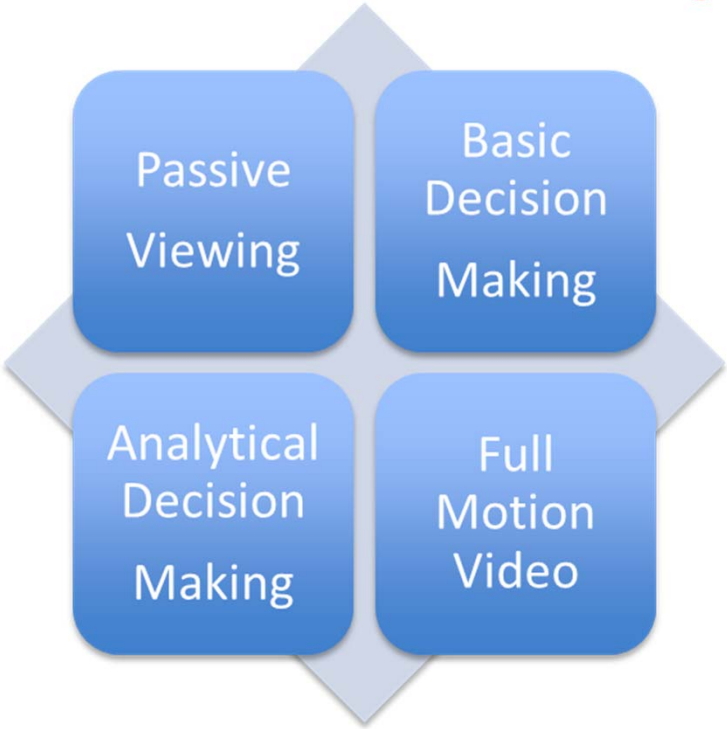
It's really "shorthand" for displays that include additional interoperability standards

HDCP 2.2, ATSC 3.0, HDR, Deep Color

Multi-Content Multi-tasking

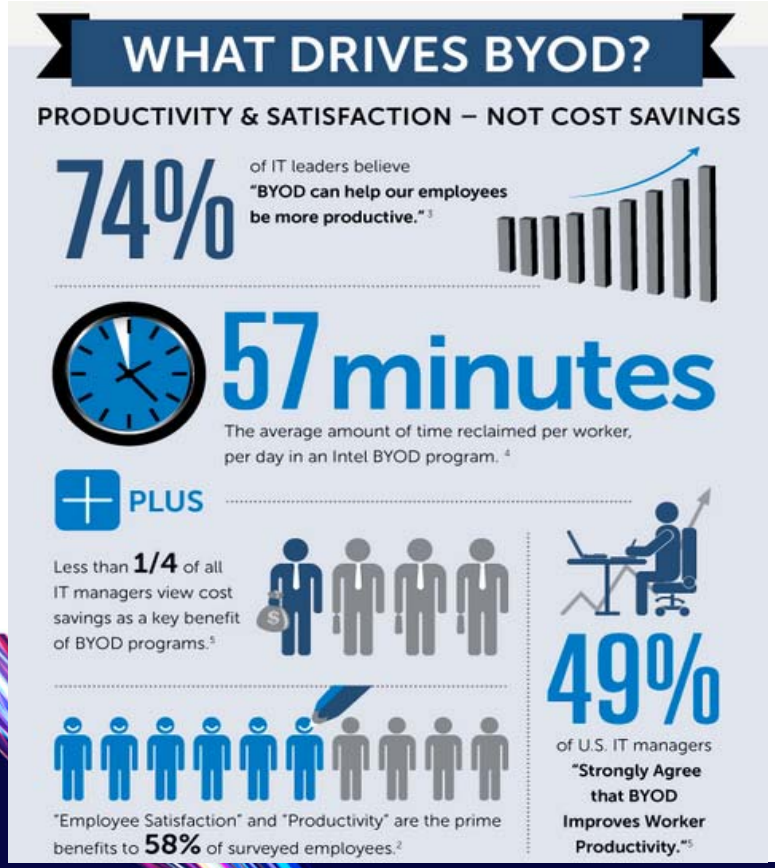
HDCP 2.2 | JPEG 2000 | H.265 HEVC High Efficiency Video Coding | HDR High Dynamic Range

- 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

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

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Bluetooth

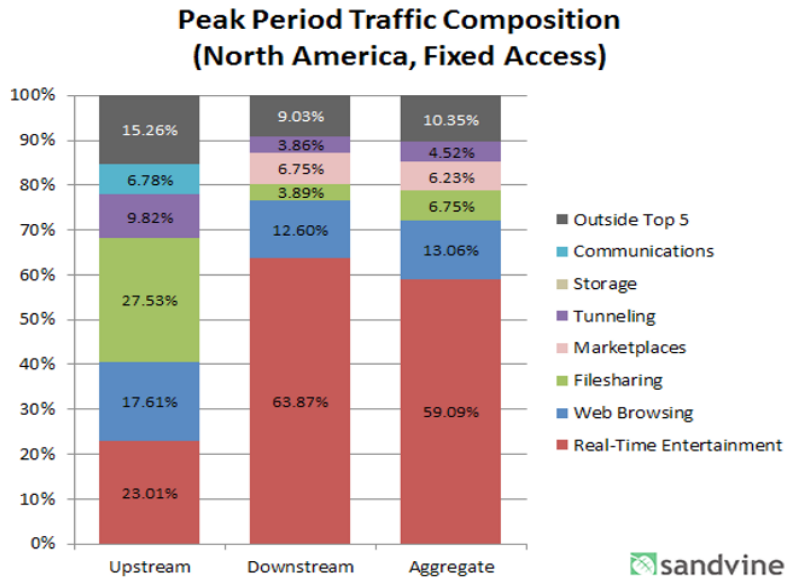
- Secure
- Convenient
- Designed for low bandwidth applications where a cable-free connection is desired

Bluetooth 5

4 times speed, double range

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



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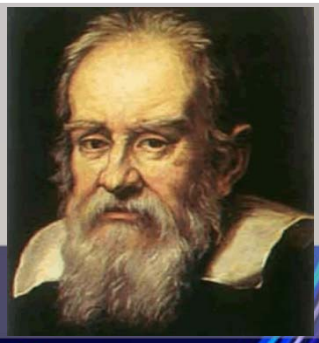
Important Digital A/V Concepts

"All truths are easy to understand once they are discovered; the point is to discover them." - Galileo Galilei



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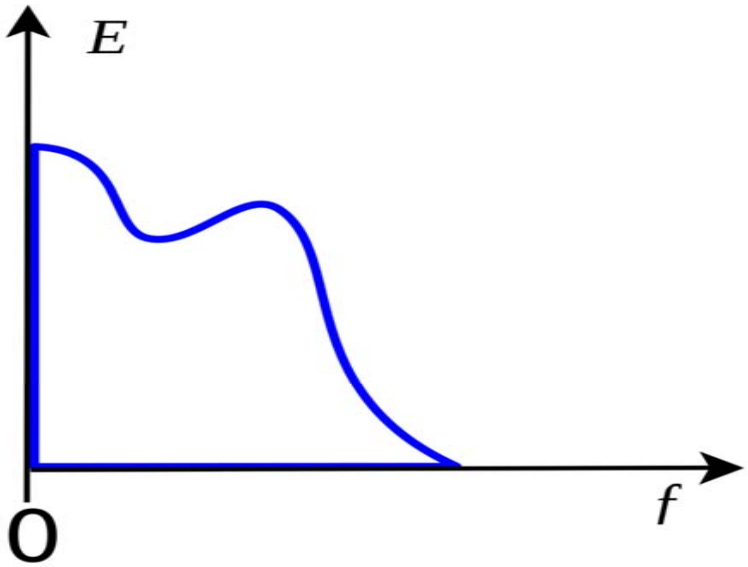
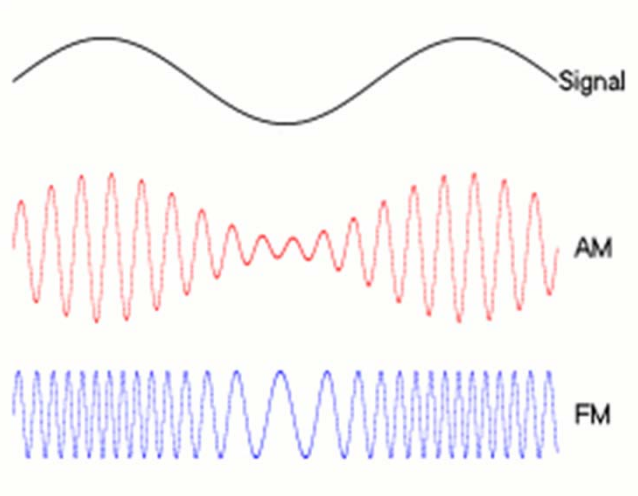
Baseband and Passband





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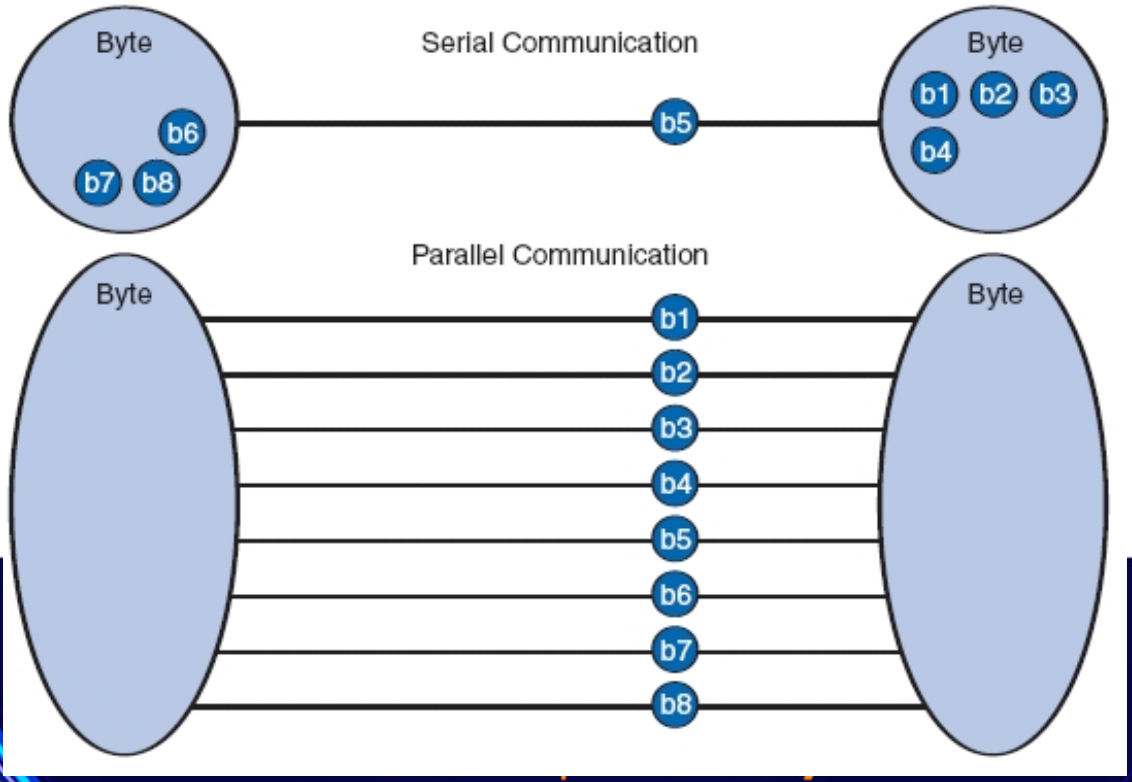
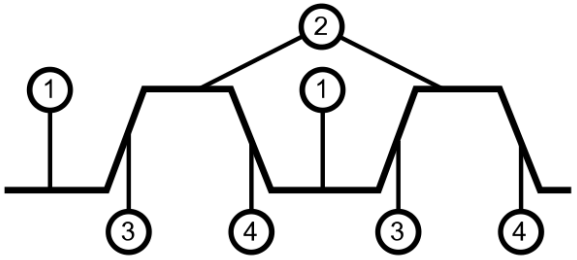
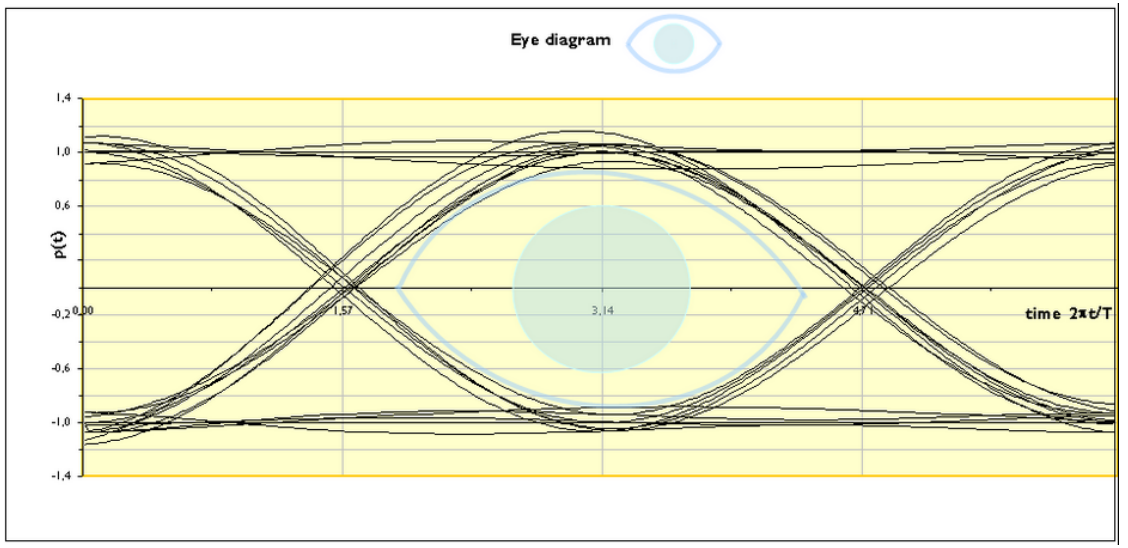
Series vs Parallel



Squares, Sines and Eyes



A digital signal waveform: (1) low level, (2) high level, (3) rising edge, and (4) falling edge



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- 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

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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

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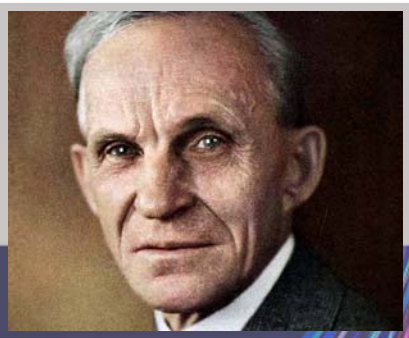
Exploring Bandwidth

"I'm looking for a lot of men who have an infinite capacity to not know what can't be done." – Henry Ford



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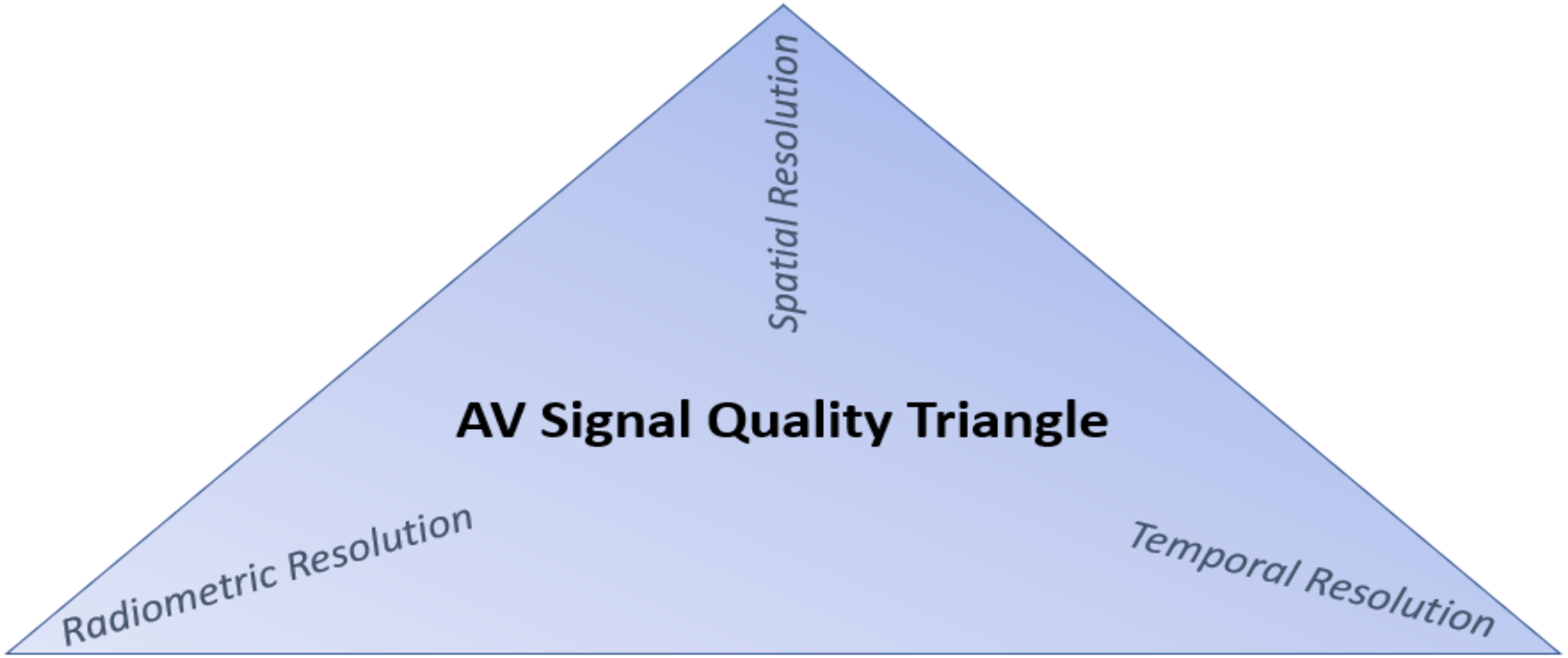

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Spatial Resolution

Horizontal Pixels	Vertical Pixels	Total Pixel Count
720	480	.35 Megapixel
1280	720	.92 Megapixel
1920	1080	2.07 Megapixel
3840	2160	8.29 Megapixel

- 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

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

- 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 ½ scan frequency
- Progressive scanning presents full frames by building the image sequentially

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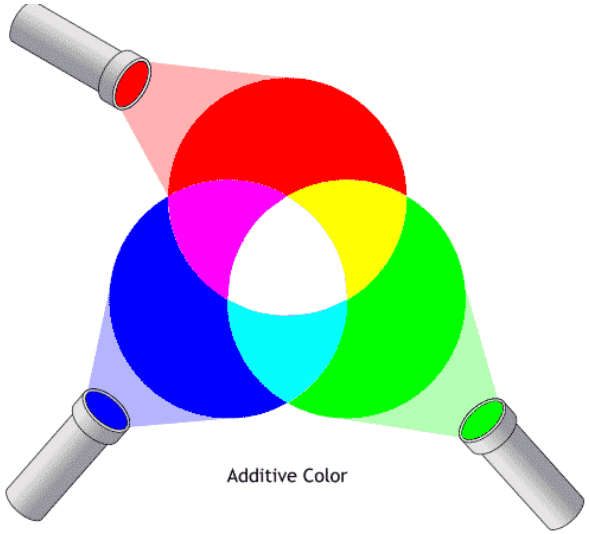
Radiometric Resolution

- 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 x 256 x 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.

4:4:4	Each R, G, and B channel, or each Y', CB, and CR channel, is sampled at the same rate. Maximum color detail is maintained.
4:2:2	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.
4:1:1	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.
4:2:0	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.

Determining Bandwidth in the 20th Century

Horizontal active pixels	1920	
Vertical active pixels	1080	**186,625,000 Hz**
Frame Rate	60 fps	**Or**
RGB	X 3	**187 MHz**
Chroma Decimation	÷ 2	

Determining Bandwidth in the 21st Century

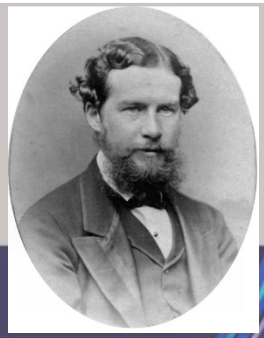
Total horizontal pixels	2200
Total vertical pixels	1125
Frame Rate (refresh rate)	60 fps
Color bit-depth x 3	24
8b/10b line coding	1.25
÷ Chroma decimation	1 (4:4:4)

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



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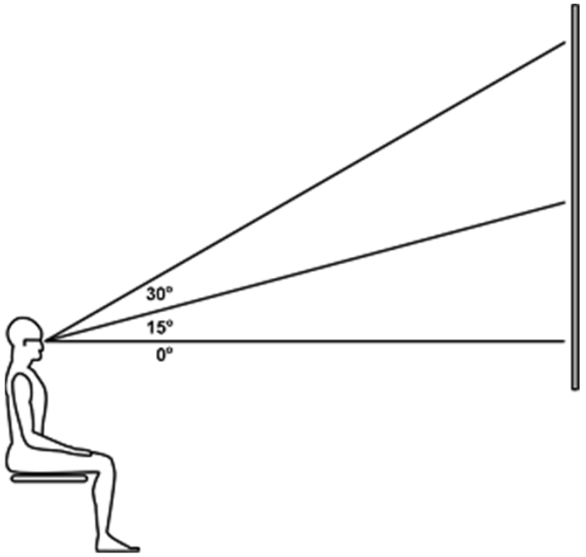
Sight lines and Distances



- 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

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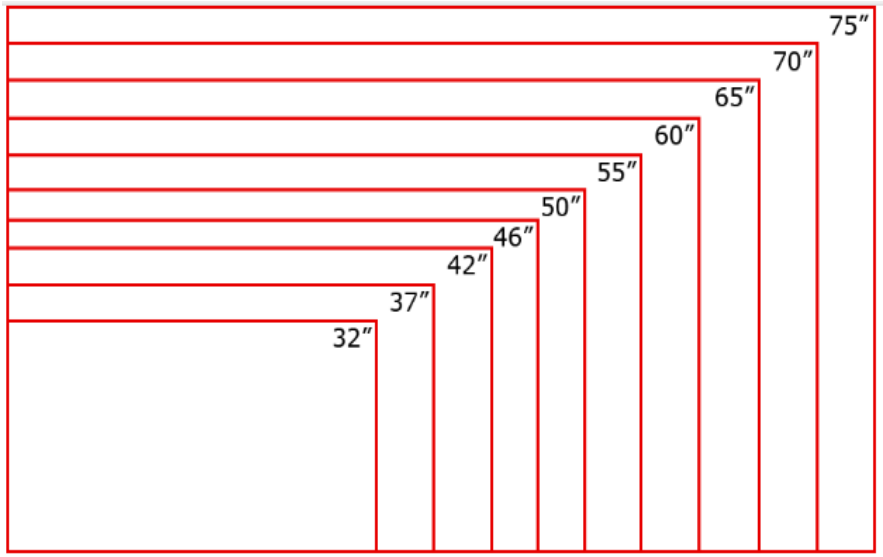
The 4:6:8 Rule of Thumb

- 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



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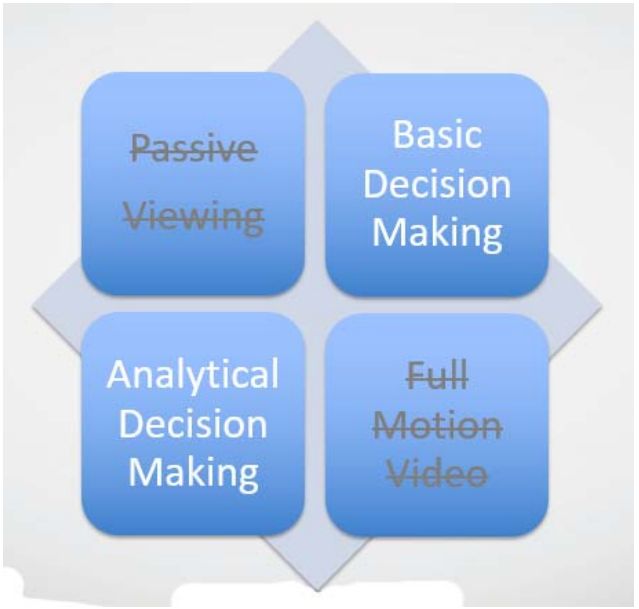
- This is 14 point Calibri font
- This is 16 point Calibri font
- This is 20 point Calibri font
- This is 28 point Calibri font
- This is 36 point Calibri font
- This is 36 point Arial font

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

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Break – 10 Minutes Please

Digital A/V Ecosystem

"To manage a system effectively, you might focus on the interactions of the parts rather than their behavior taken separately." – Russell l. Ackoff

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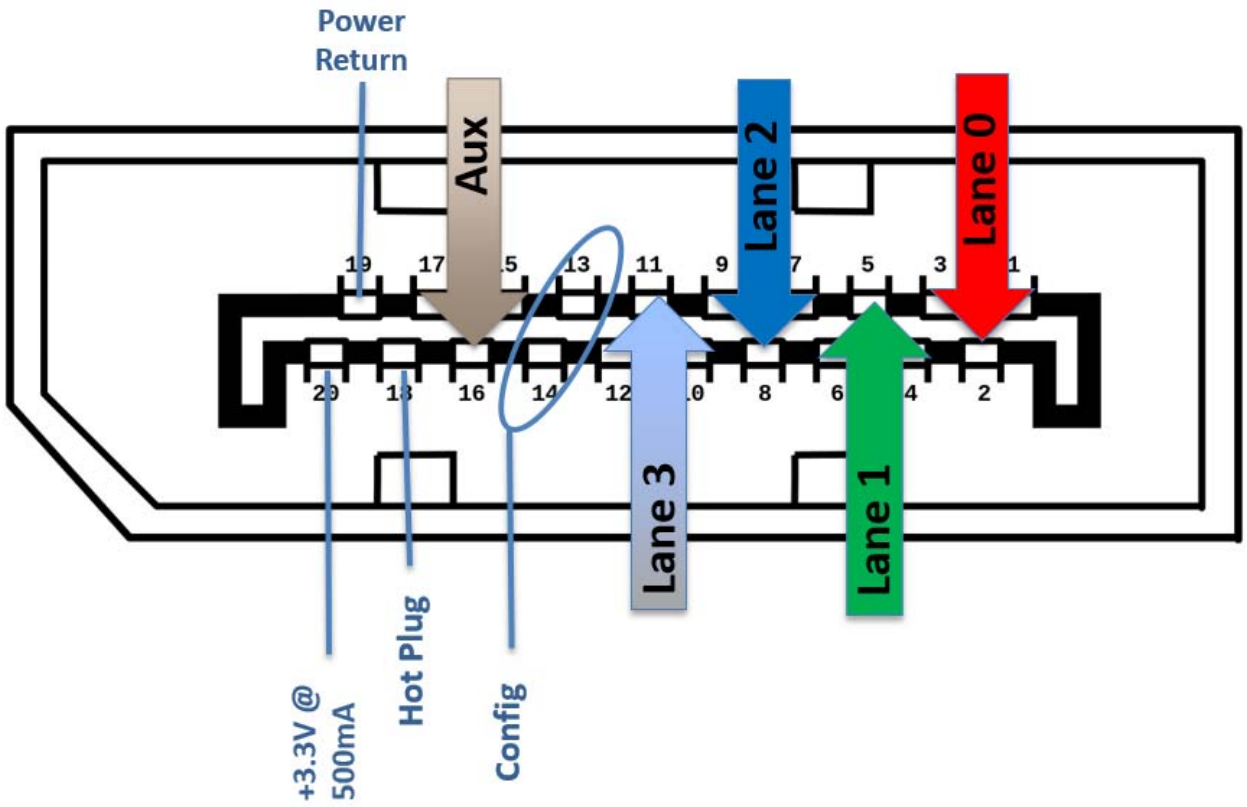
SDI - Serial Digital Interface

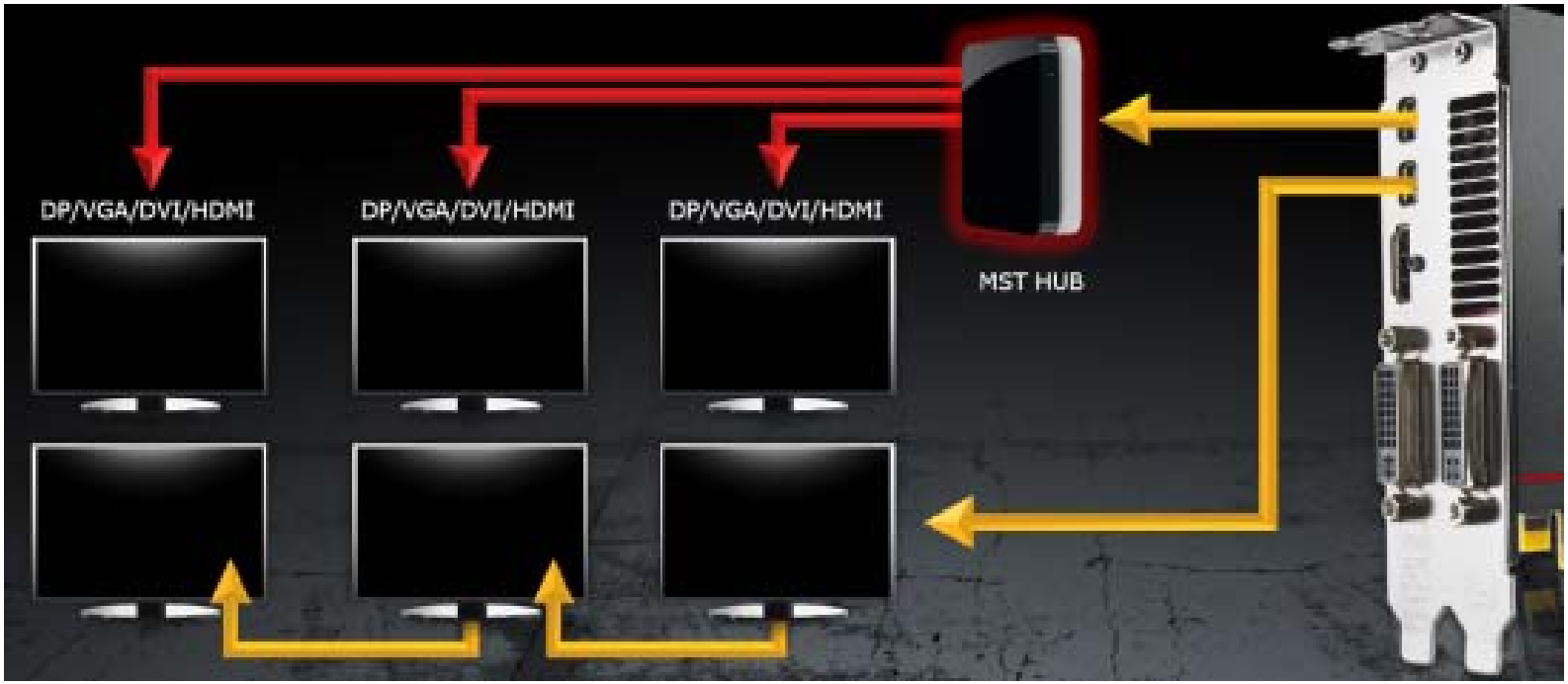
- SDI (1989)
- HD SDI (1998)
- 3G SDI (2006)
  - 3 Gbit/s for 1080p

- 6G SDI (2014)
  - 6 Gbit/s for 2160p30
- 12G SDI (2014)
  - 12 Gbit/s for 2160p60
- 24G SDI (2014)
  - 24 Gbit/s and 8Kp60

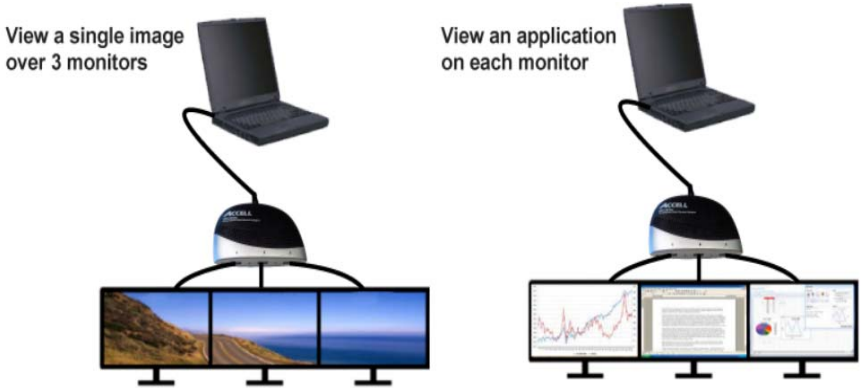
DisplayPort & DisplayPort Dual Mode



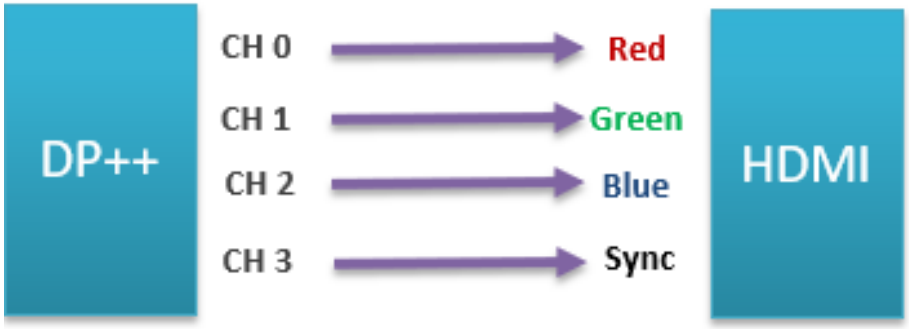
Understanding MST



MST Operation



DP++ Operation



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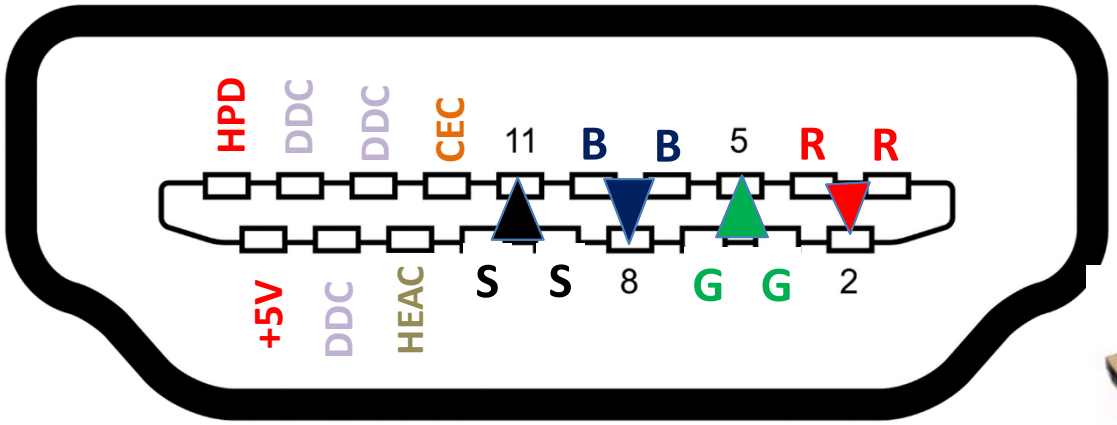
High Definition Multimedia Interface



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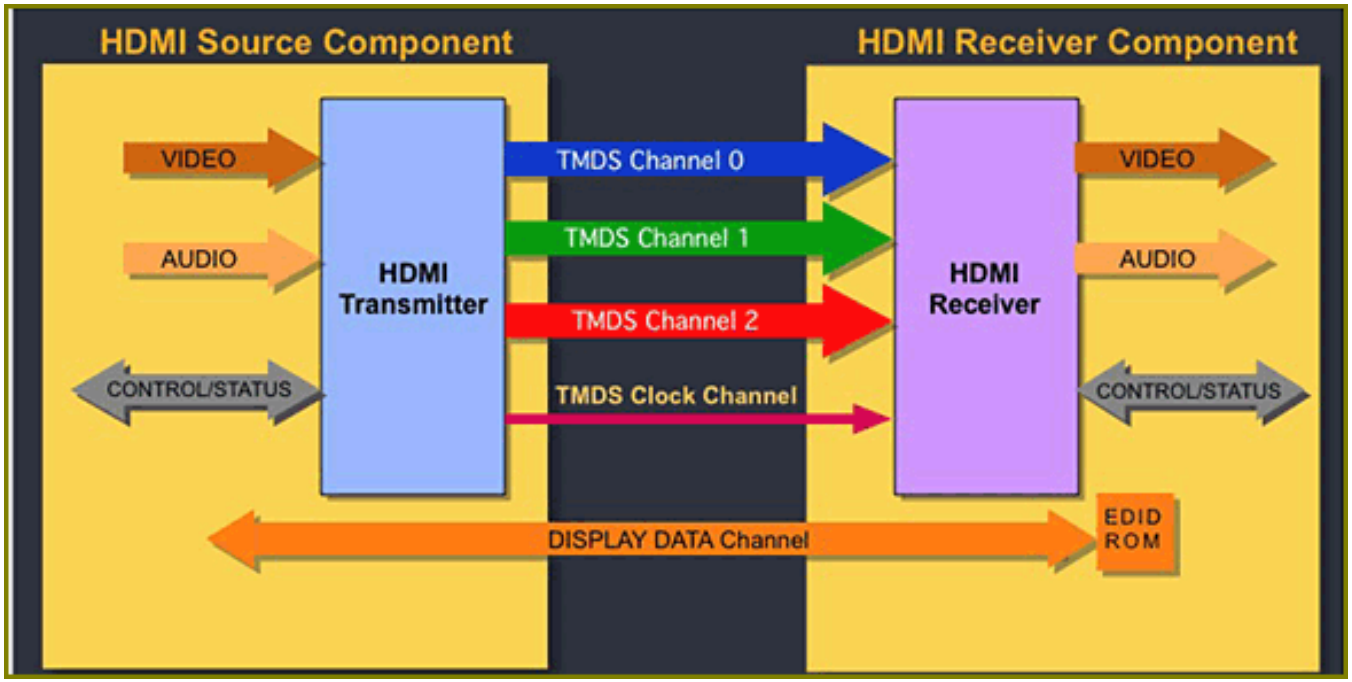

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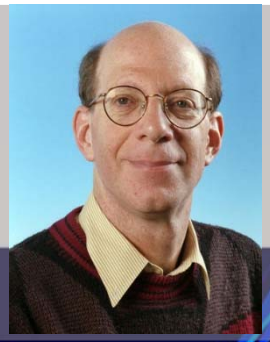
HDBT – A New IEEE Standard

"The nice thing about standards is that there are so many of them to choose from." – Andrew S. Tanenbaum



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HDBT® ASE

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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

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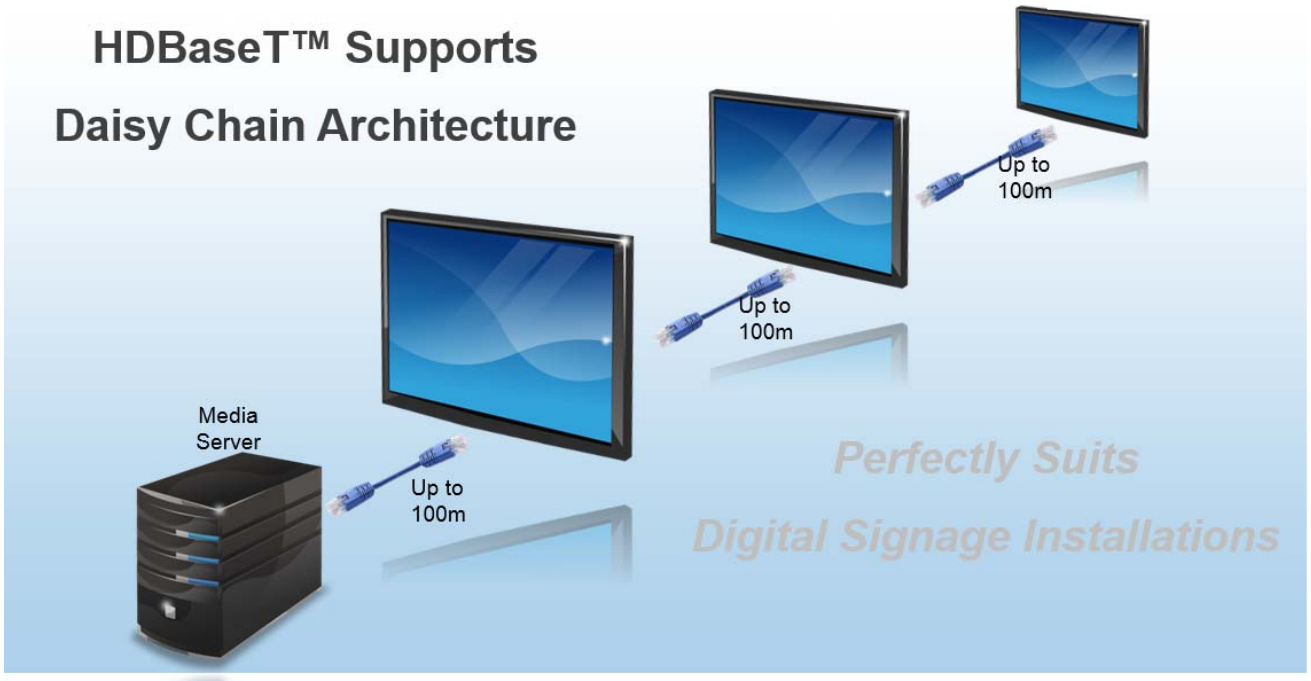
HDBaseT™ Supports Daisy Chain Architecture



Perfectly Suits Digital Signage Installations

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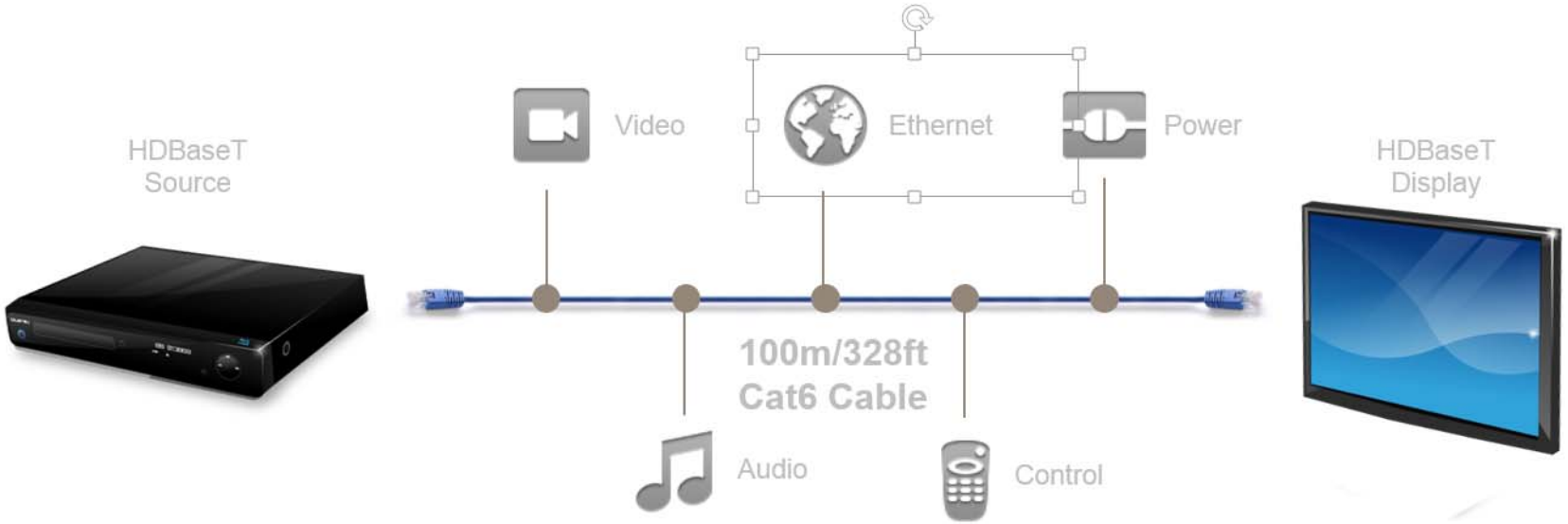

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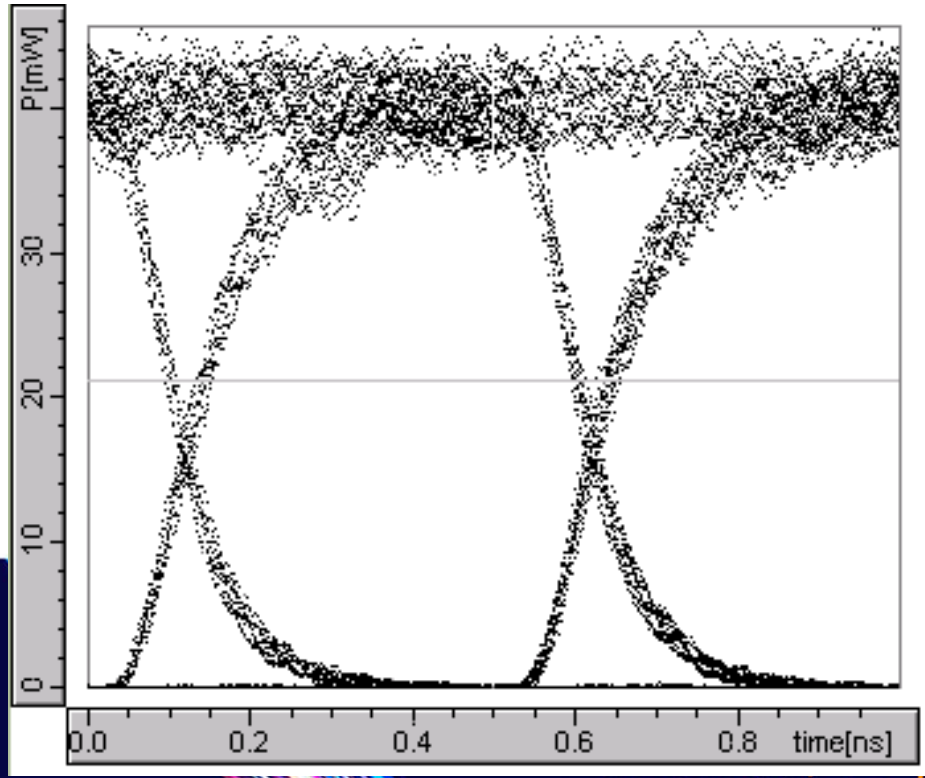
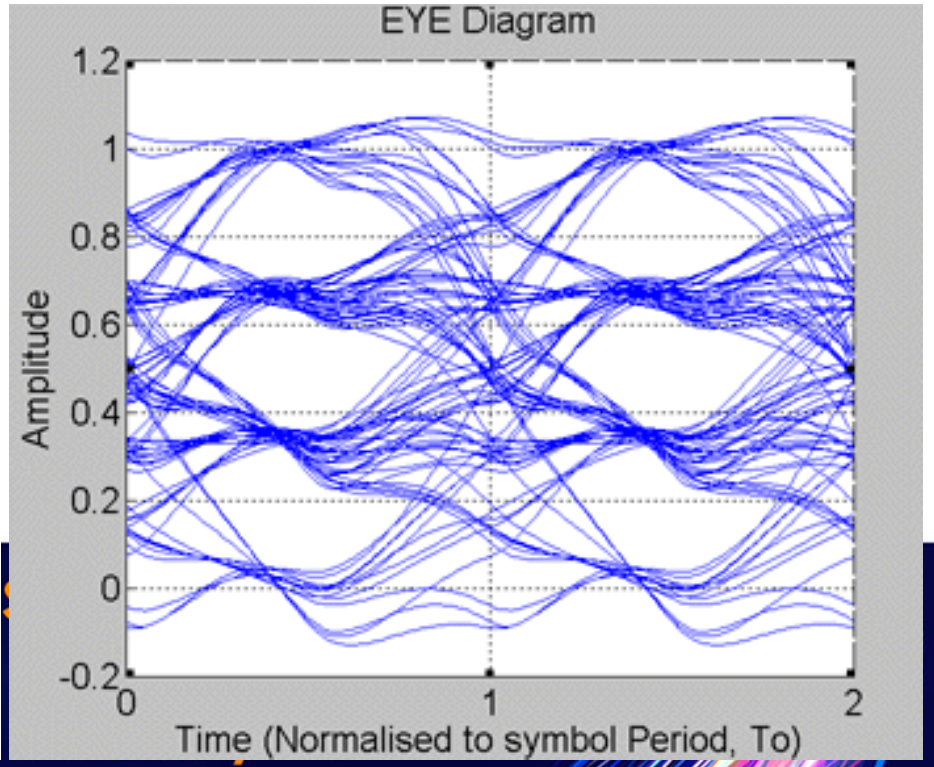
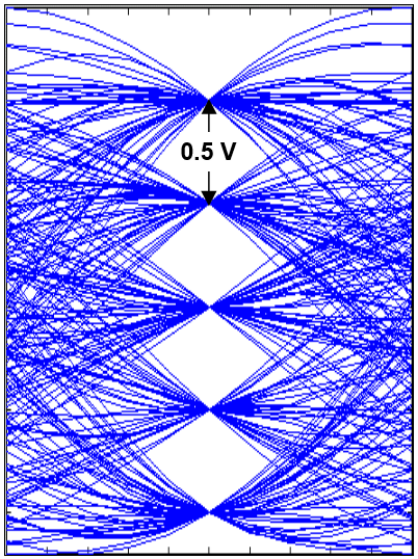
Multi-Level Signaling in PAM





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



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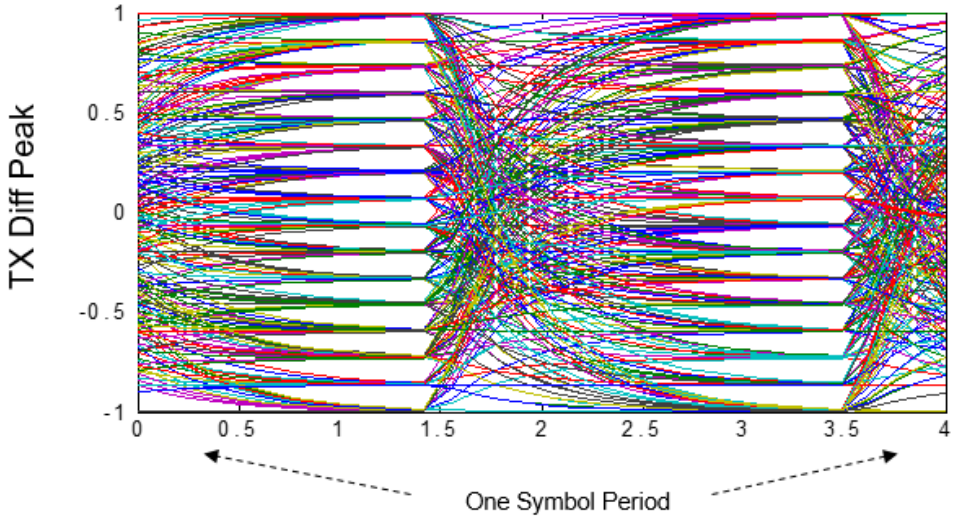
HDBaseT Uses PAM-16

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

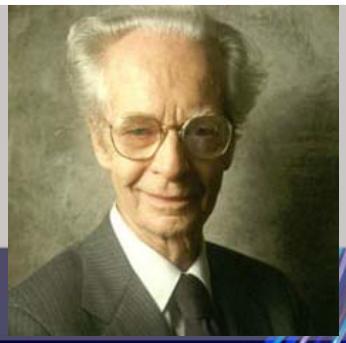


4bits Level	
0000 :	15
0001 :	13
0011 :	11
0010 :	9
0110 :	7
0111 :	5
0101 :	3
0100 :	1
1100 :	-1
1101 :	-3
1111 :	-5
1110 :	-7
1010 :	-9
1011 :	-11
1001 :	-13
1000 :	-15

PAM16 TX Eye Pattern

USB and Interactive A/V

"The real problem is not whether machines think but whether men do." – B. F. Skinner



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USB 2.0 And 3.0

USB 2.0 “A” and “B”

USB Type A and Micro B

USB 3.0 “A” and “B”

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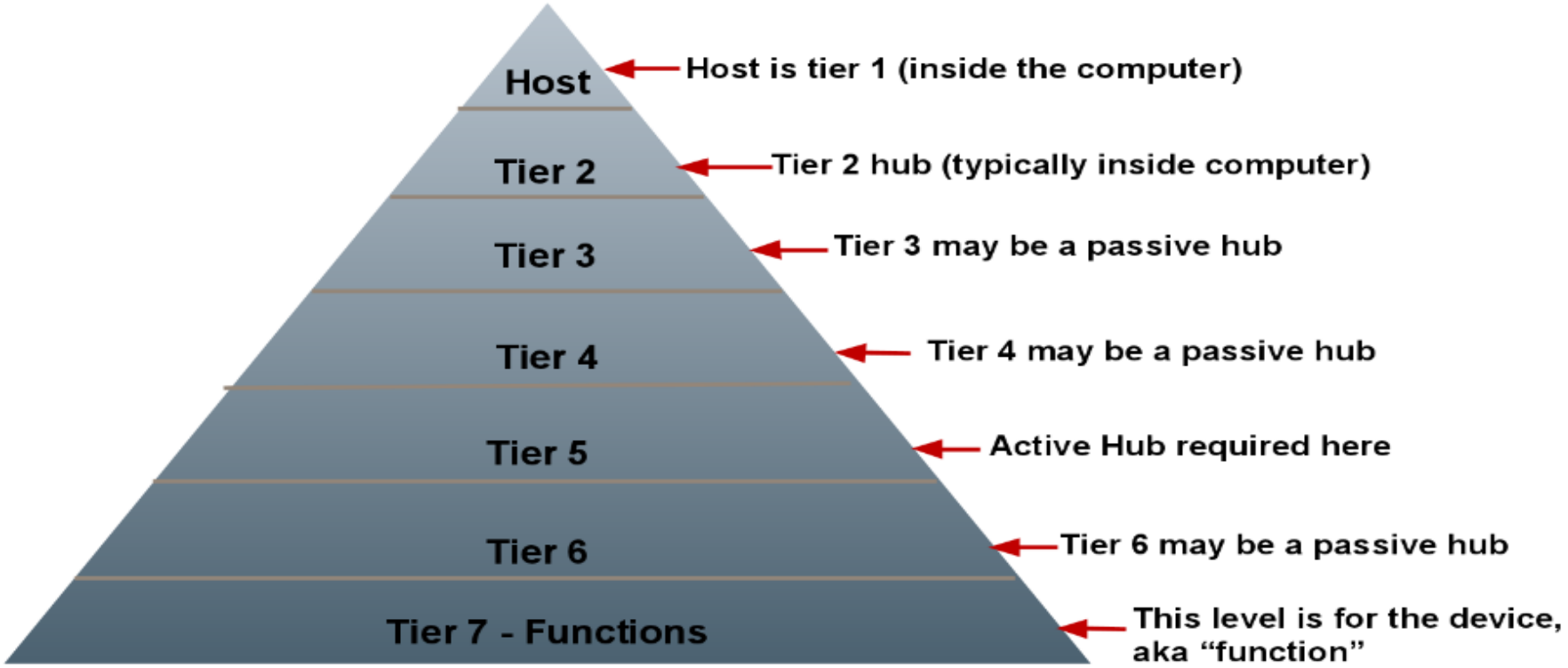
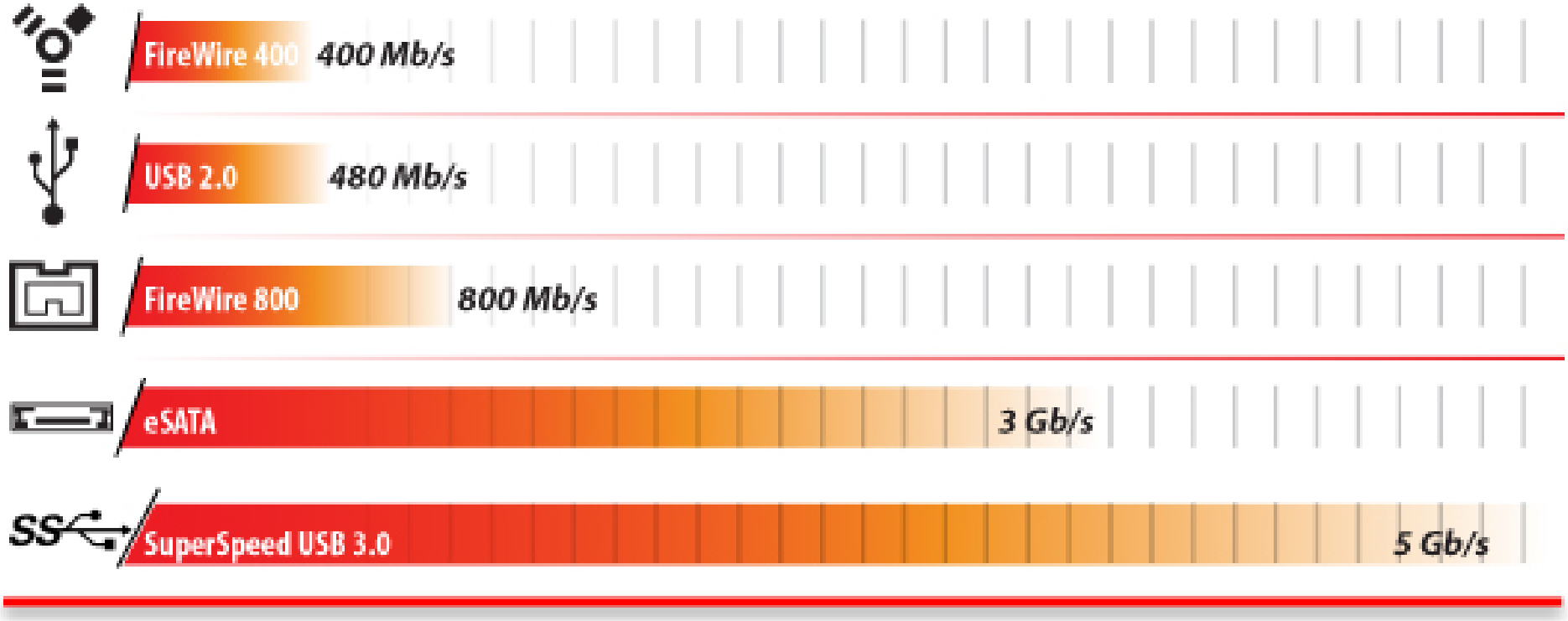
USB “Pyramid” Topology

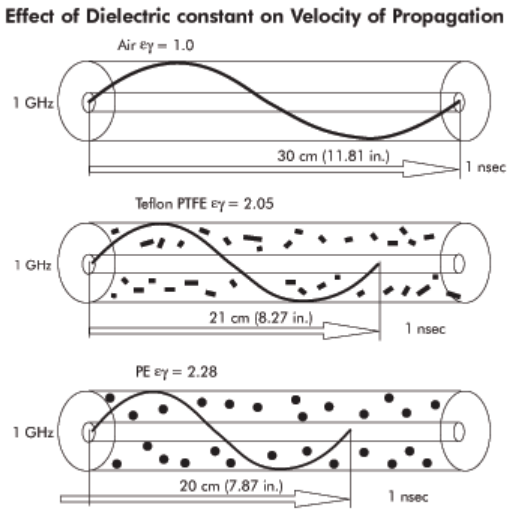


USB 1.1, 2.0 And 3.0

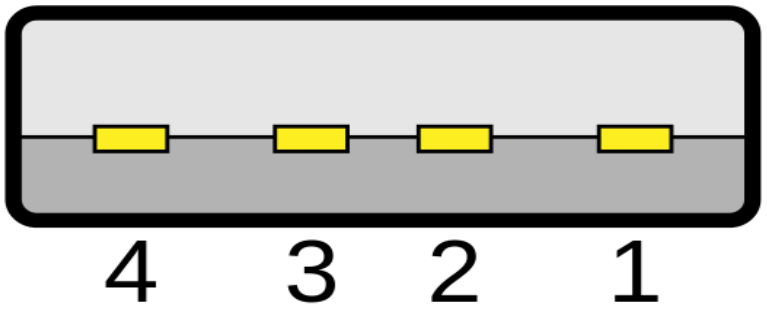


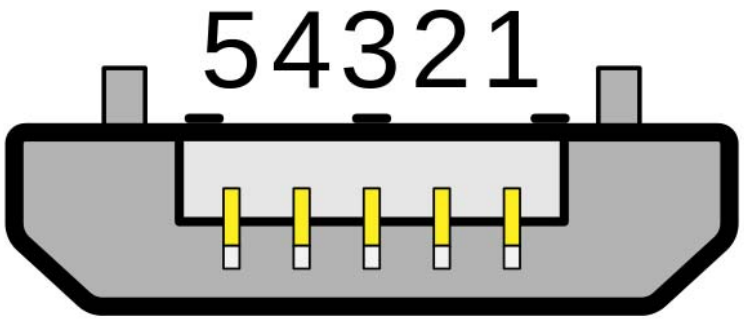
A Relationship With Time

- 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





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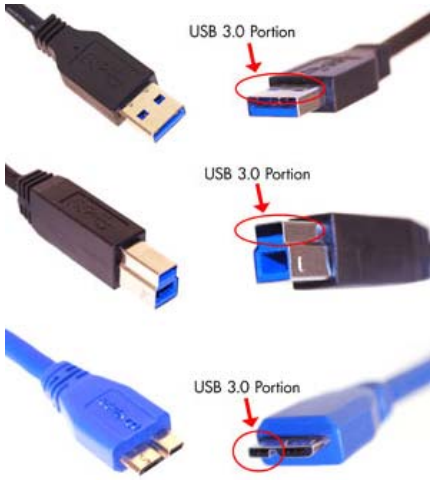
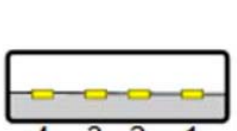
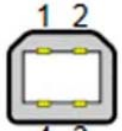
USB From 4 Pins to 9

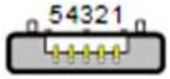




Type A

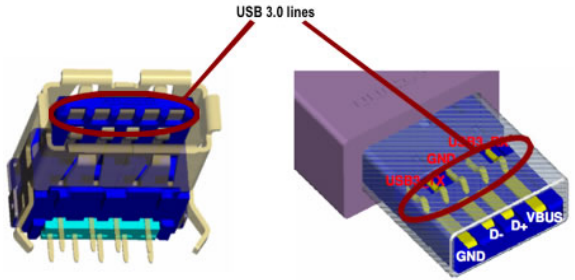


Type B



Micro-A

Micro-B



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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

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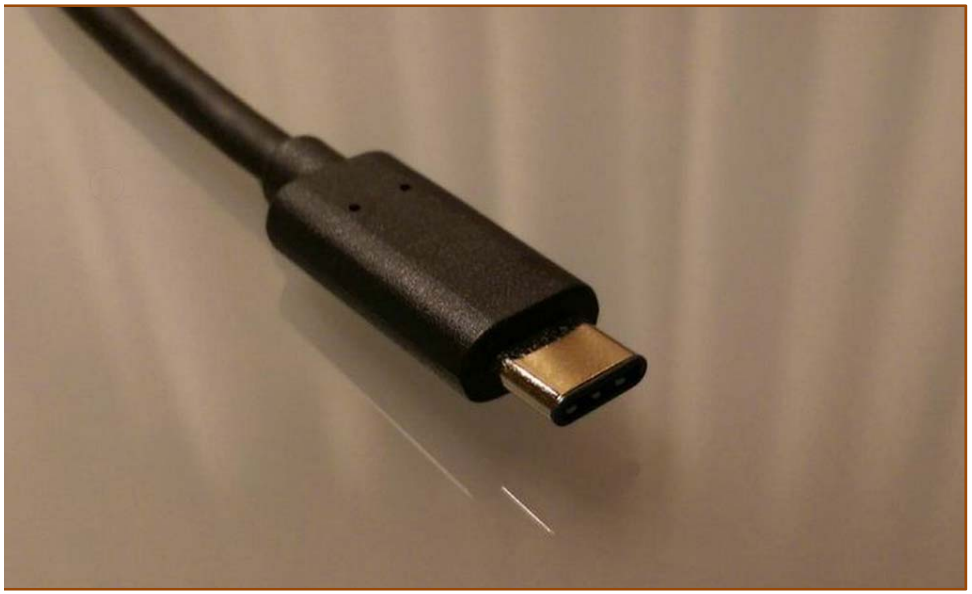
One Connector To Rule Them All?



"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

SUPERSPEED+ CERTIFIED USB 10Gbps

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

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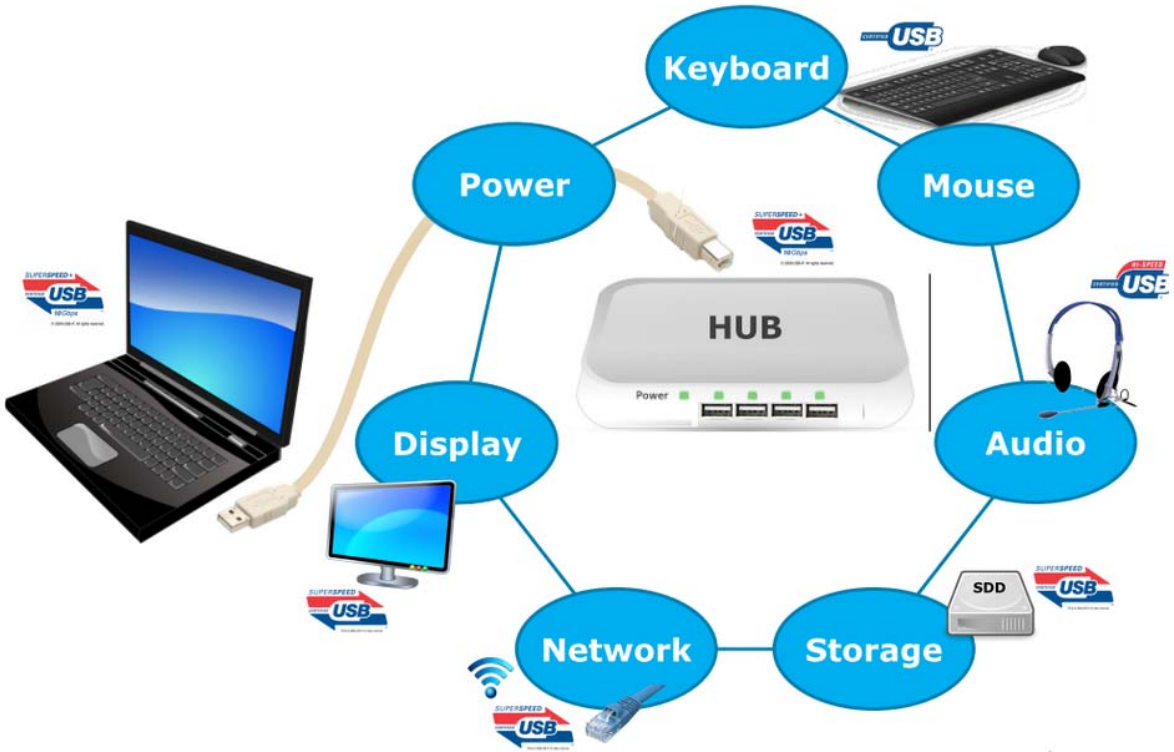
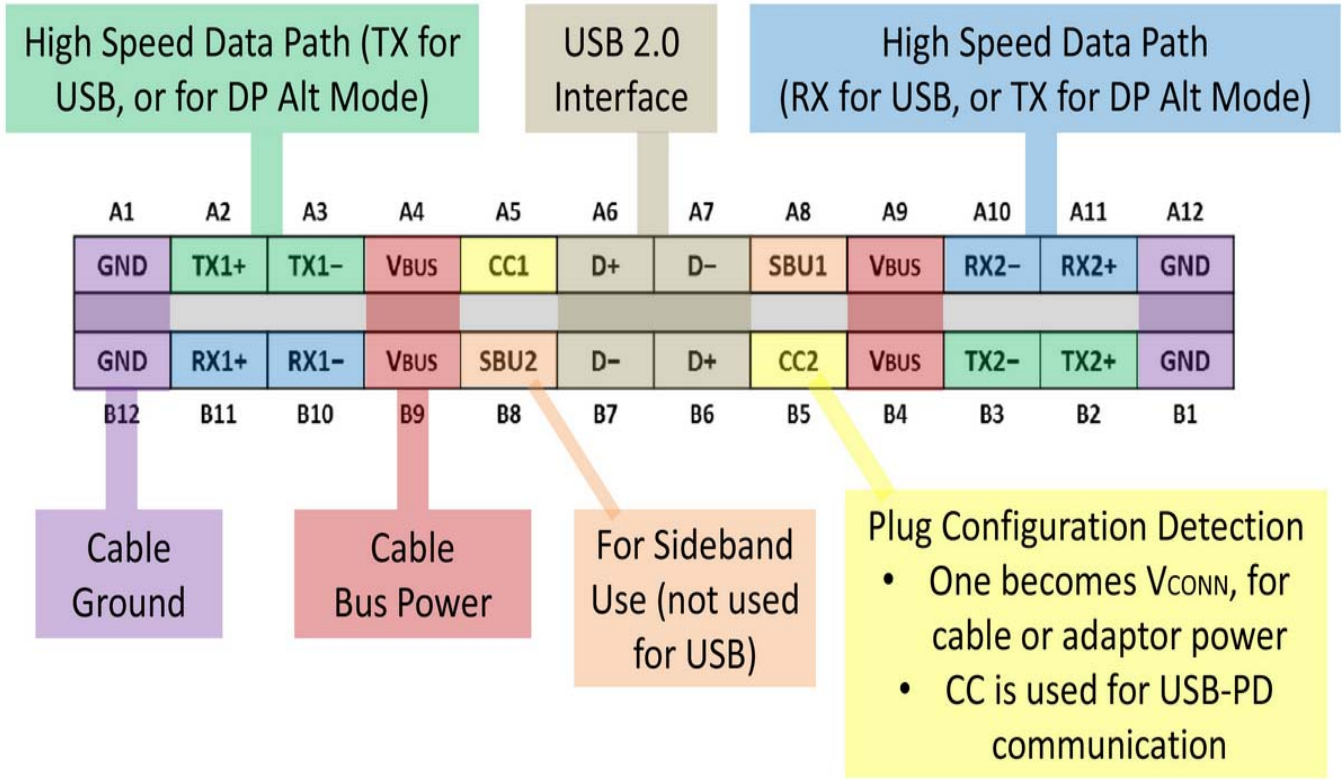
Converging Data, DisplayPort, Power, Analog Audio





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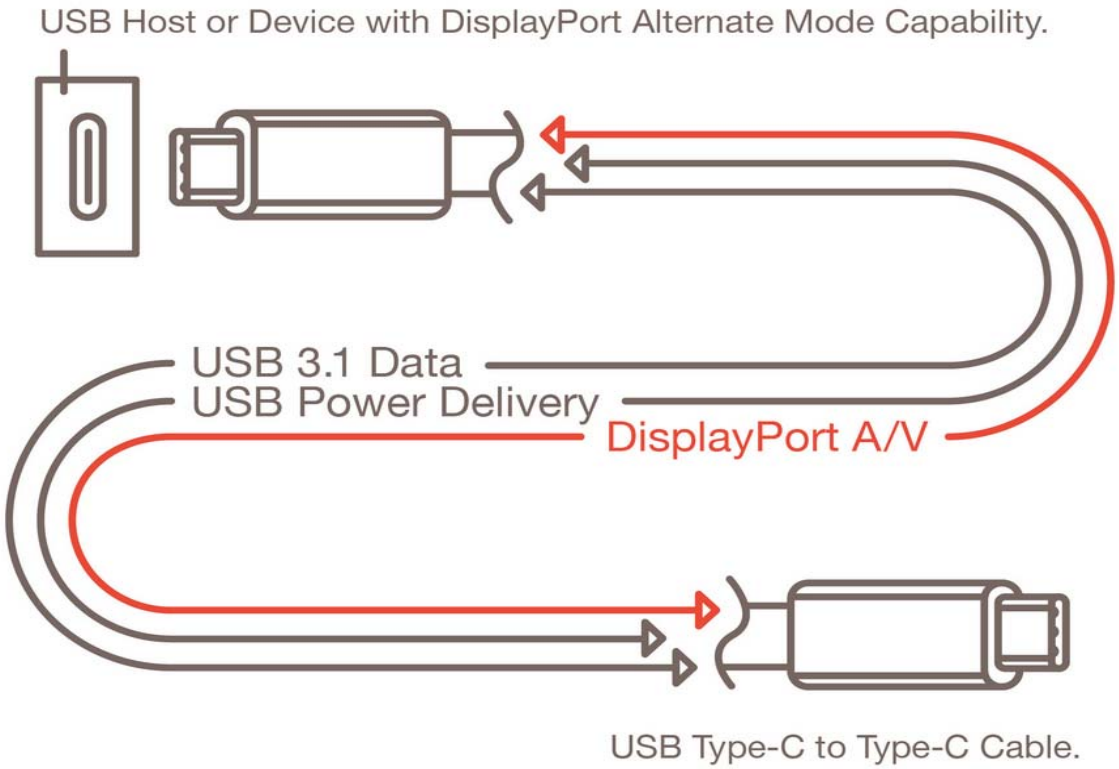

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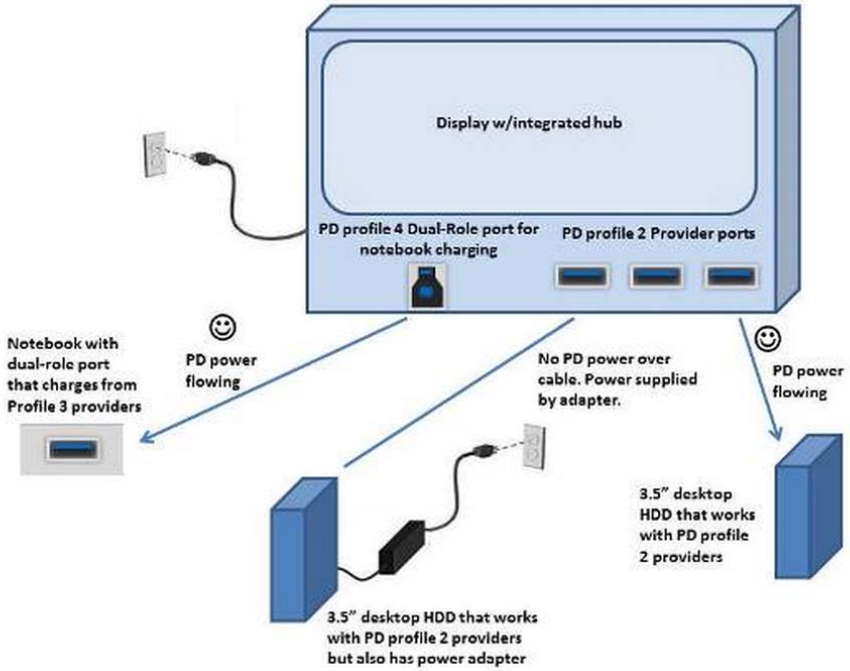
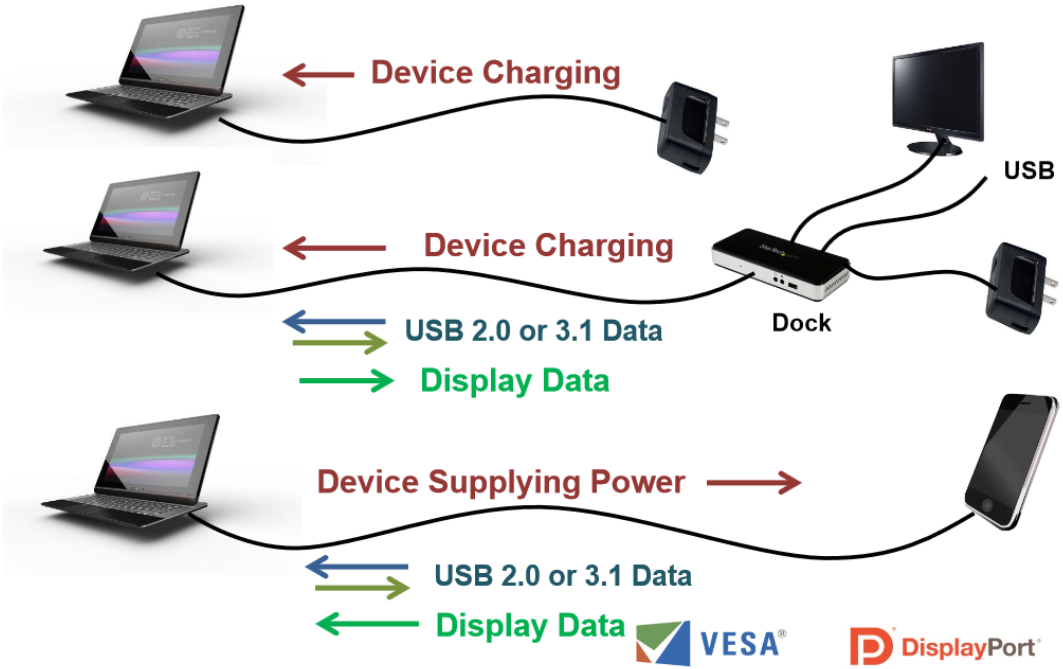

Display w/integrated hub
PD profile 4 Dual-Role port for notebook charging
PD profile 2 Provider ports
Notebook with dual-role port that charges from Profile 3 providers
PD power flowing
No PD power over cable. Power supplied by adapter.
PD power flowing
3.5" desktop HDD that works with PD profile 2 providers
3.5" desktop HDD that works with PD profile 2 providers but also has power adapter

MORE
POWER

Either end can serve as USB Host, USB-PD Power Consumer, and DisplayPort Video Source (these services are orthogonal to each other)



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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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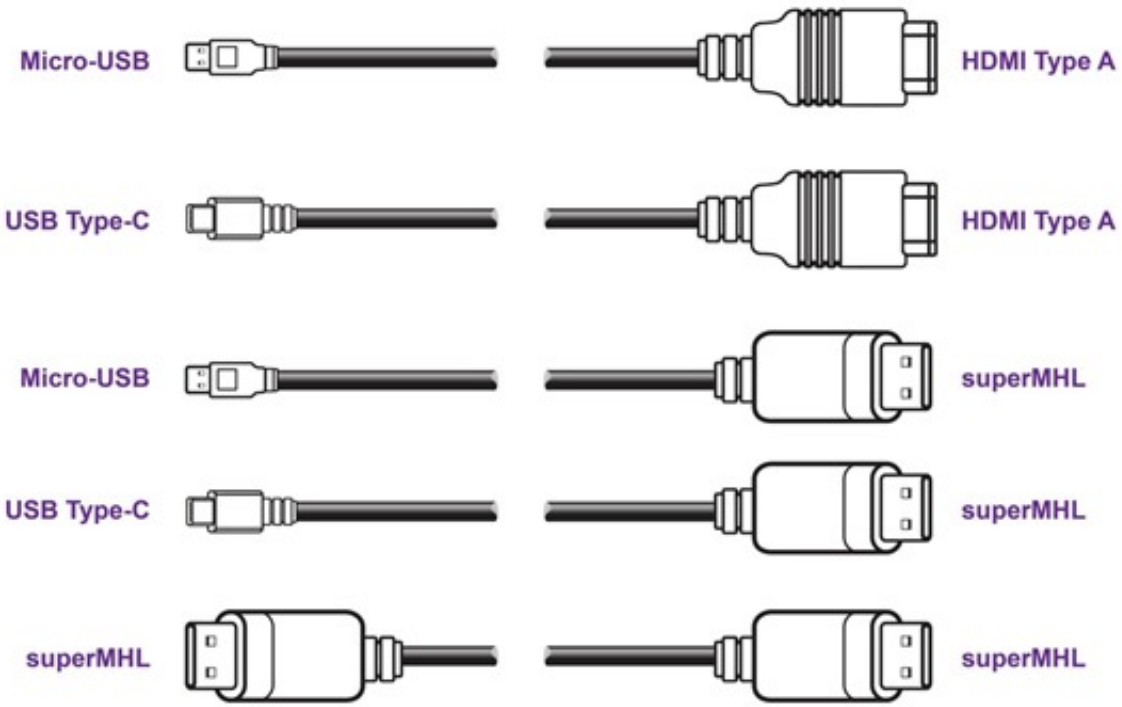

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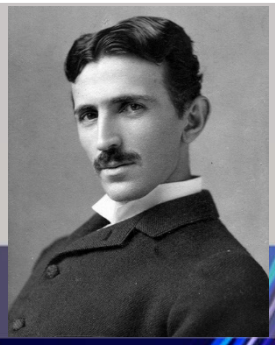
Mobile integration will put a spotlight on wireless problems that may have been masked

"I have not failed. I have just found 10,000 ways that won't work." — Nikola Tesla



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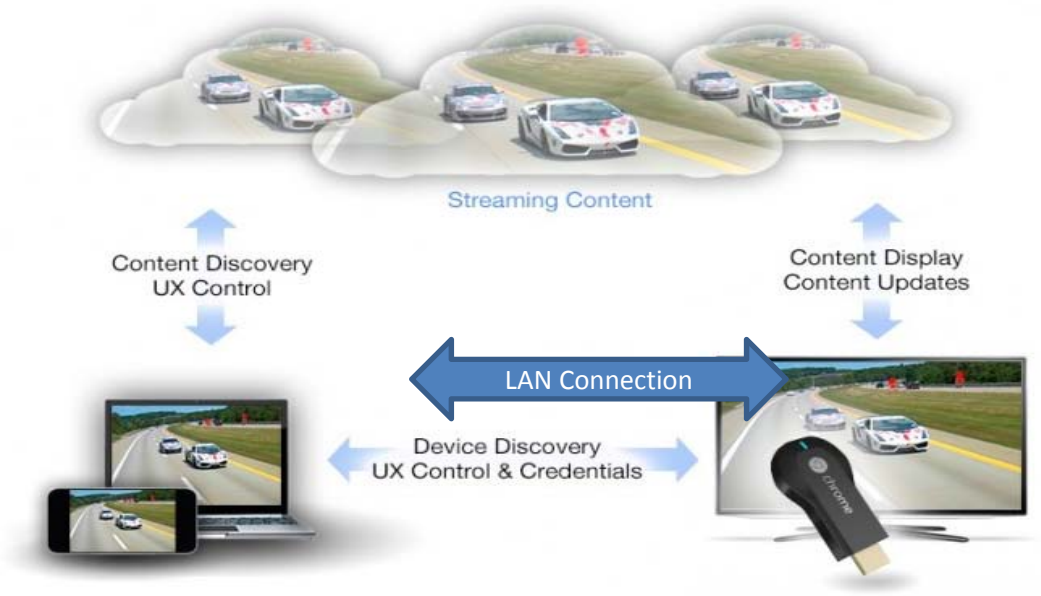
Wireless Connections Leverage Elements All Devices Have in Common

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

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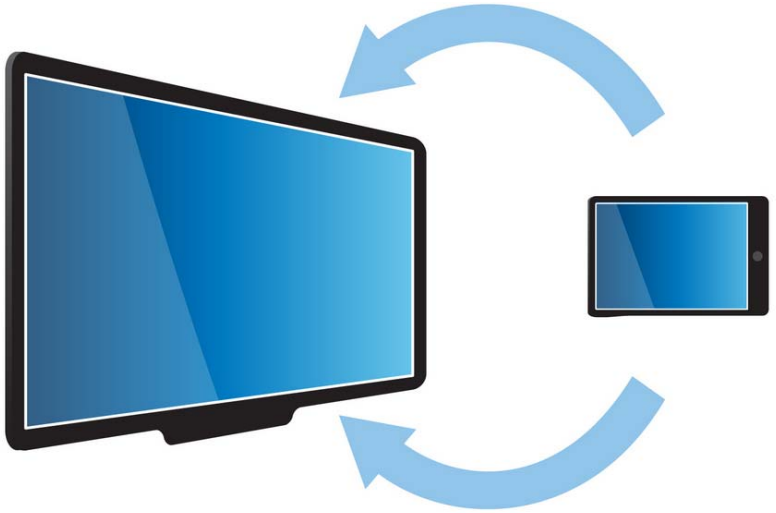
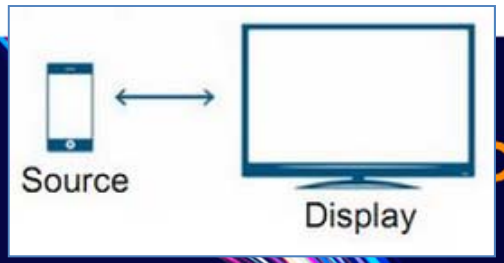
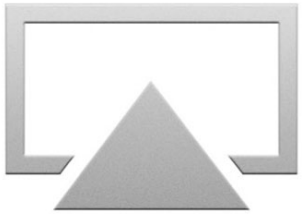
How Can We Minimize Impact On The LAN?



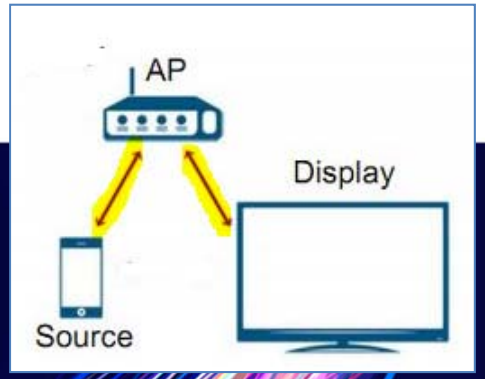
Wi-Fi Mirroring

Miracast





AirPlay



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.

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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

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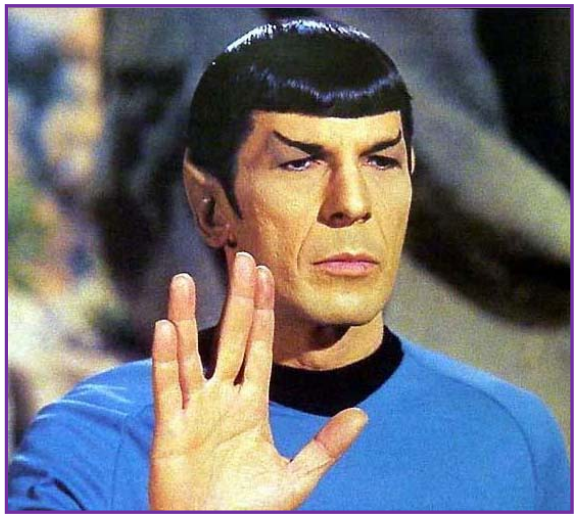
Fascinating…

- 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?

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