Advanced AV System Trends, Technology & Design Considerations for Datacom Professionals

Today's Agenda

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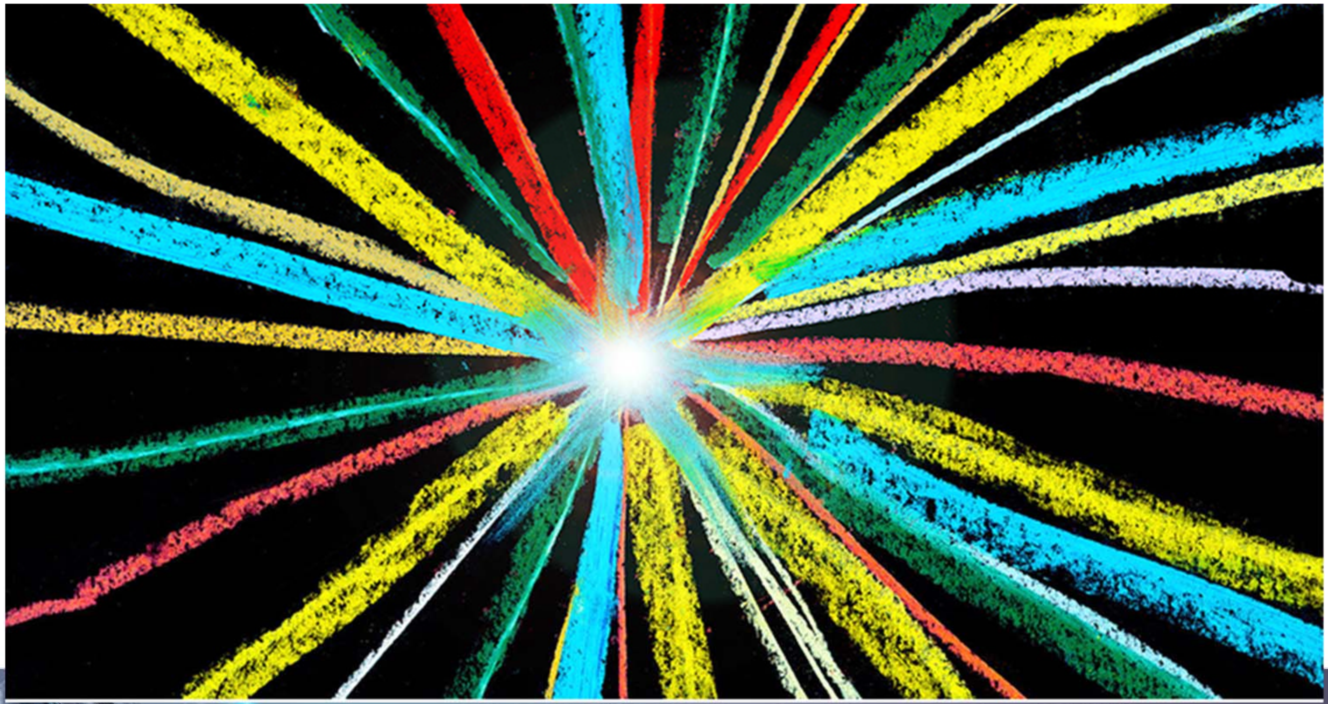
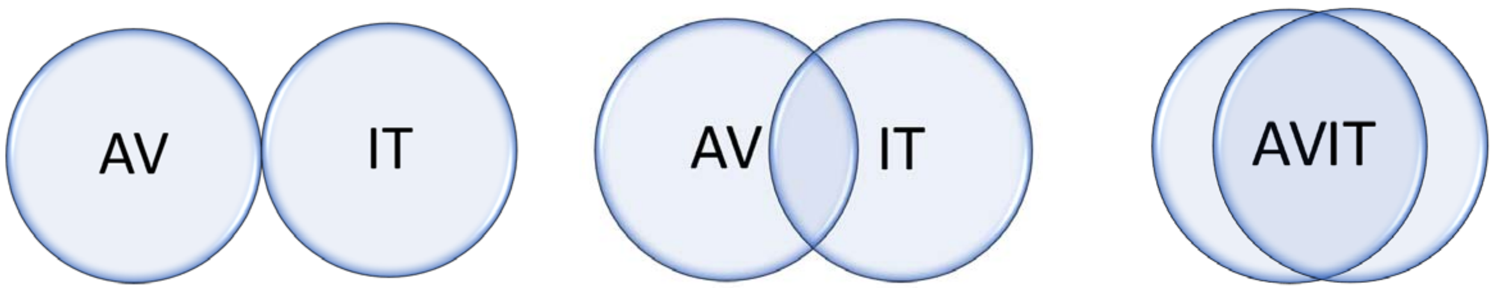
- Introductions and overview
- Exploring the AV Quality Triangle
  - The Phi phenomenon
  - Temporal resolution in AV systems
  - HDR and deep color
  - Radiometric resolution in AV systems
  - Acuity of vision
  - Spatial resolution in AV systems
  - Calculating digital video bandwidth
- ANSI/AVIXA 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?



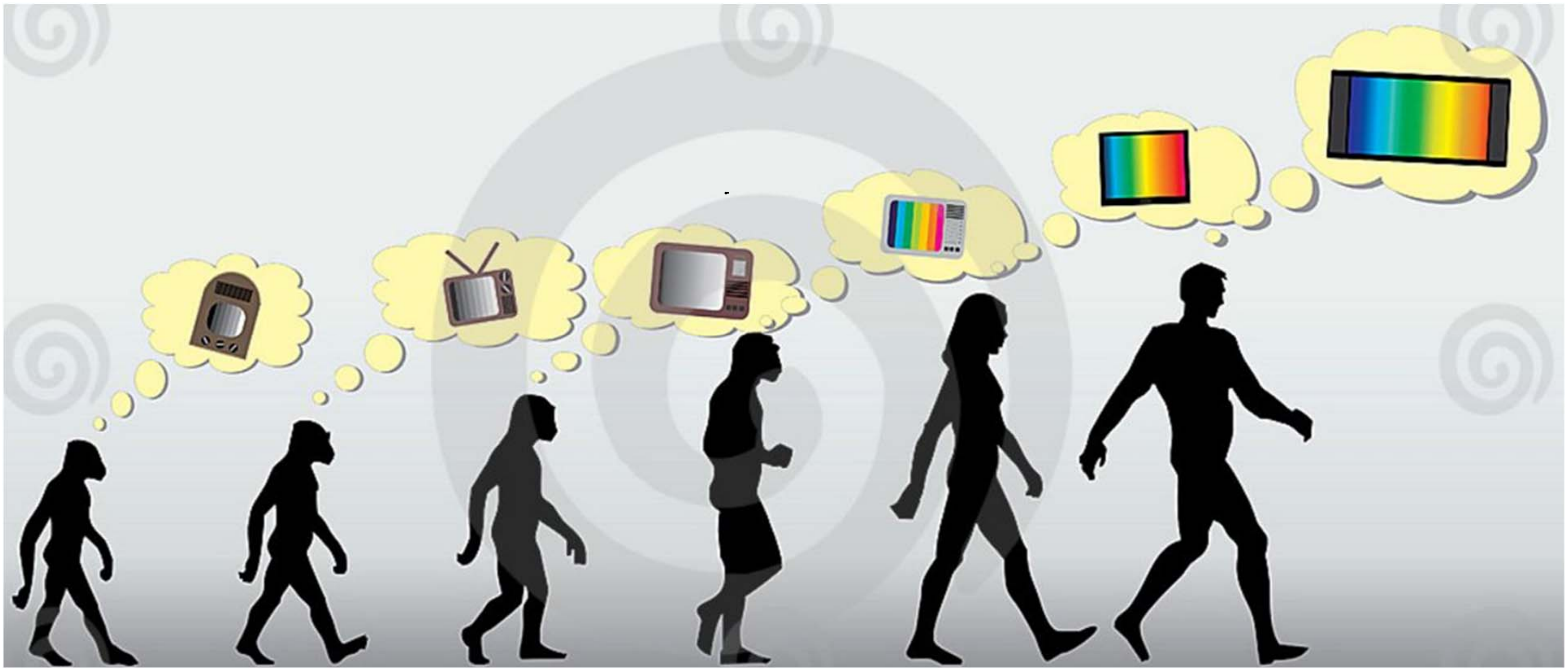
"In the near Future, A/V will be a part of IT, and everything will just be on the network"



- The future of convergence can be found in the ubiquity of “ambient computing” power.


STAR TREK

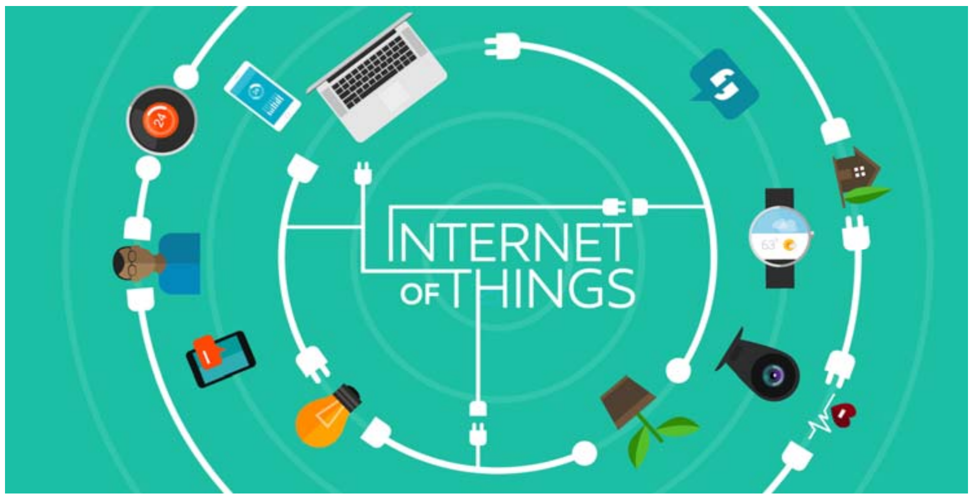
- Evolution and Revolution

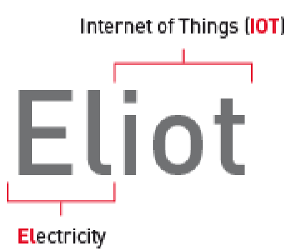


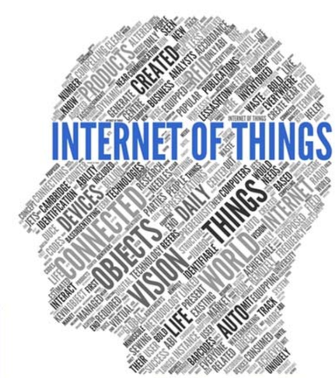
- Four Vectors of A/V Communication

- Experience Architecture

- AV Is IoT!

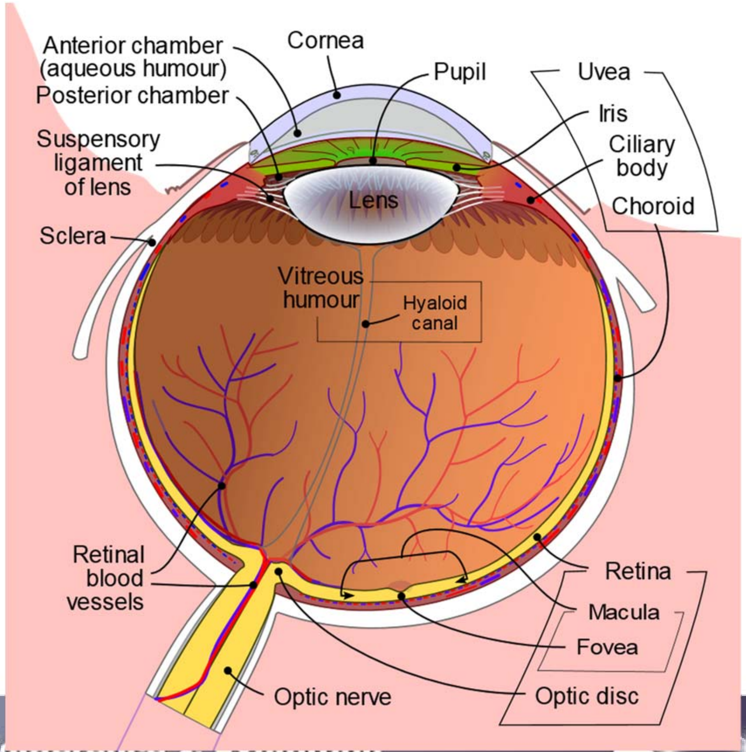

INTERNET
OF THINGS


Internet of Things (IOT)
Eliot
Electricity


INTERNET OF THINGS

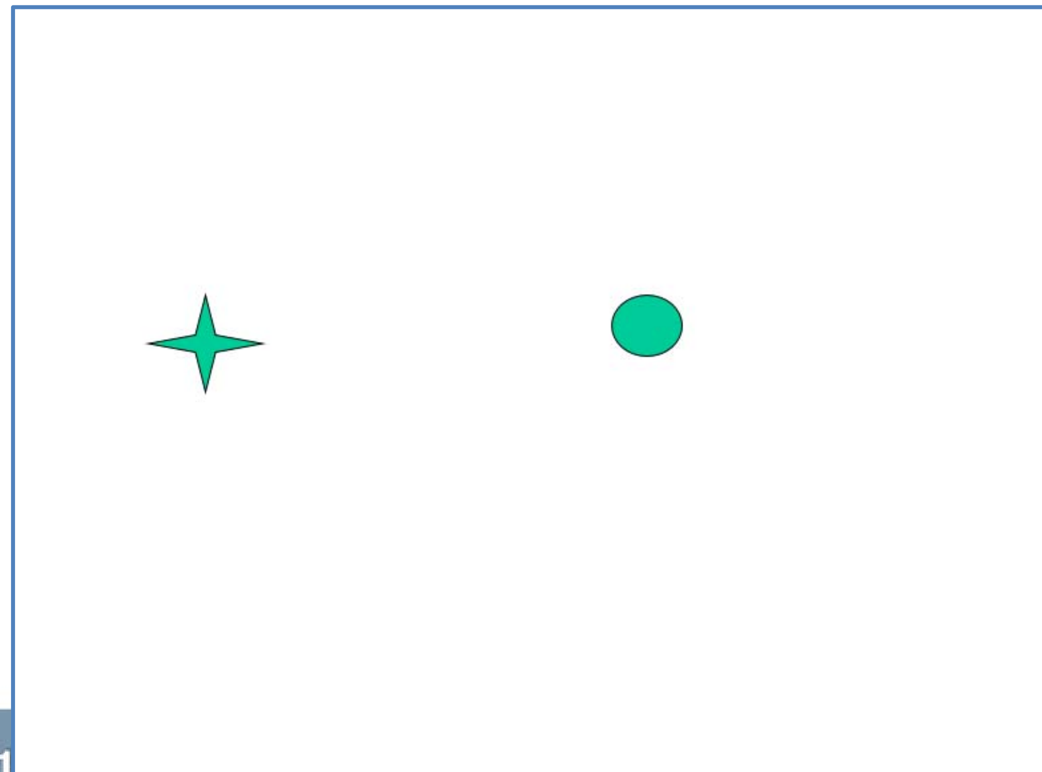
How Do We See?

- Electromagnetic energy (light) reflects off of a 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



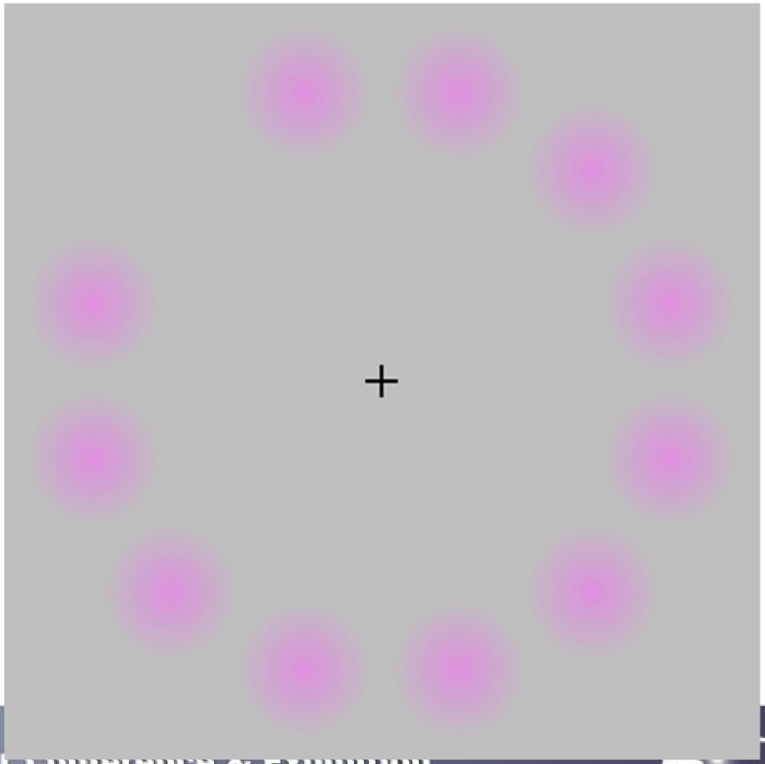
Experiencing the Blind Spot

- 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*.



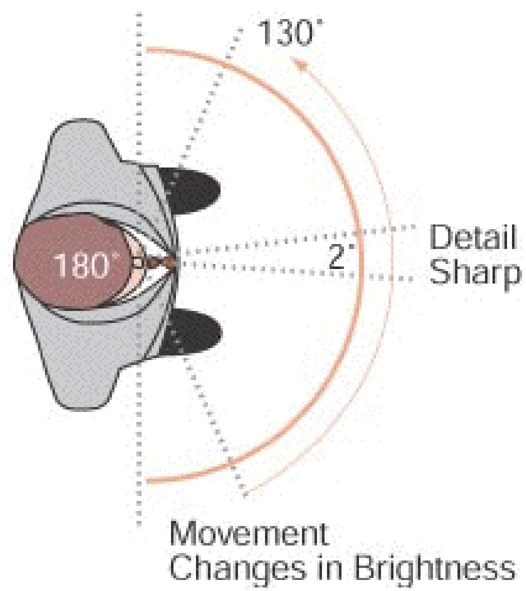
The Phi Phenomenon

- *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

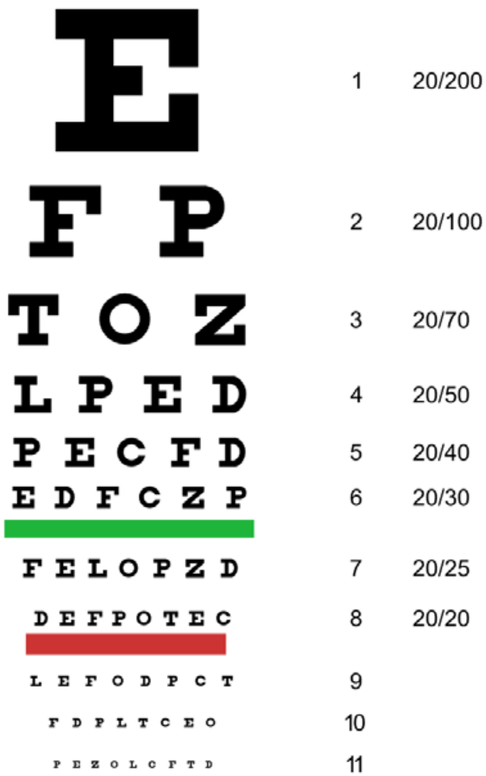


Measuring The “Resolution” Of Vision

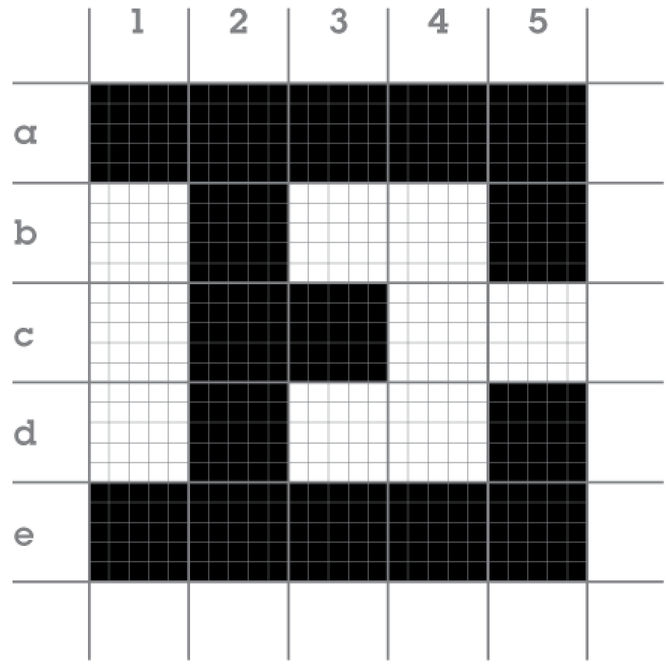
- 360 Degrees Of Angle In a Circle
  - ✓ The approximate field of view of an individual human eye is 95° away from the nose, 75° downward, 60° toward the nose, and 60° upward, allowing humans to have an almost 180-degree forward-facing horizontal field of view
- 60 Arc Minutes In 1 Degree
- 60 Arc Seconds In 1 Arc Minute



Optotype



E 1 20/200
F P 2 20/100
T O Z 3 20/70
L P E D 4 20/50
P E C F D 5 20/40
E D F C Z P 6 20/30
F E L O P Z D 7 20/25
D E F P O T E C 8 20/20
L E F O D P C T 9
F D P L T C E O 10
P E Z O L C F T D 11



1
2
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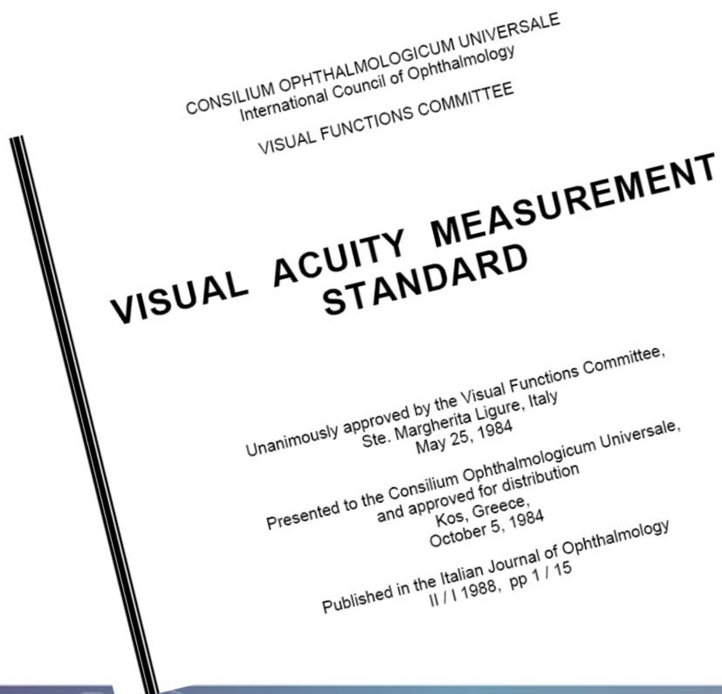
Visual Acuity


CONSILIUM OPHTHALMOLOGICUM UNIVERSALE
International Council of Ophthalmology

VISUAL FUNCTIONS COMMITTEE

VISUAL ACUITY MEASUREMENT STANDARD

Unanimously approved by the Visual Functions Committee,
Ste. Margherita Ligure, Italy
May 25, 1984

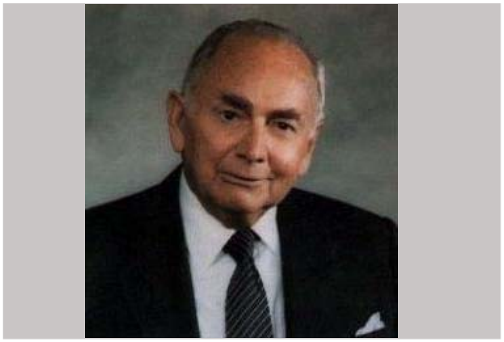
Presented to the Consilium Ophthalmologicum Universale,
and approved for distribution
Kos, Greece,
October 5, 1984

Published in the Italian Journal of Ophthalmology
II / I 1988, pp 1 / 15

Visual acuity			Subtended MOA
20	12		0.6
20	14		0.7
20	16		0.8
20	18		0.9
20	20		1
20	22		1.1
20	24		1.2
20	26		1.3
20	28		1.4
20	30		1.5
20	32		1.6
20	34		1.7
20	36		1.8
20	38		1.9
20	40		2
20	42		2.1
20	44		2.2

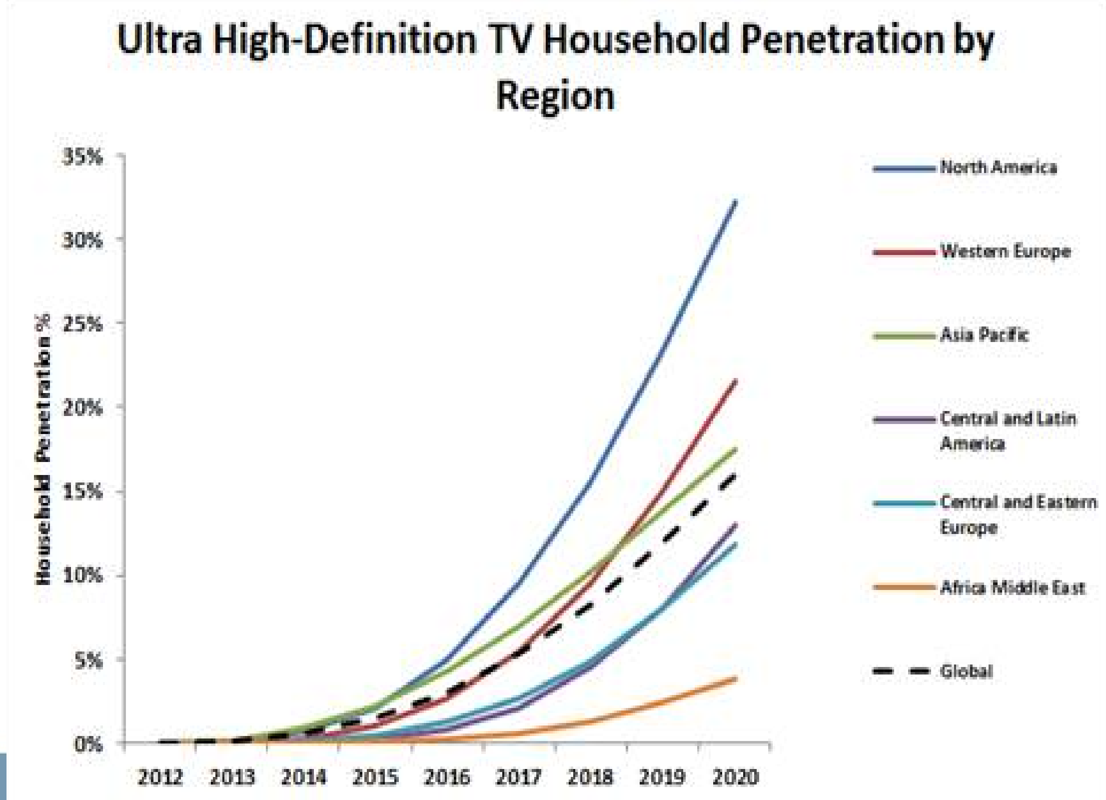
Market Disruption

- *"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*

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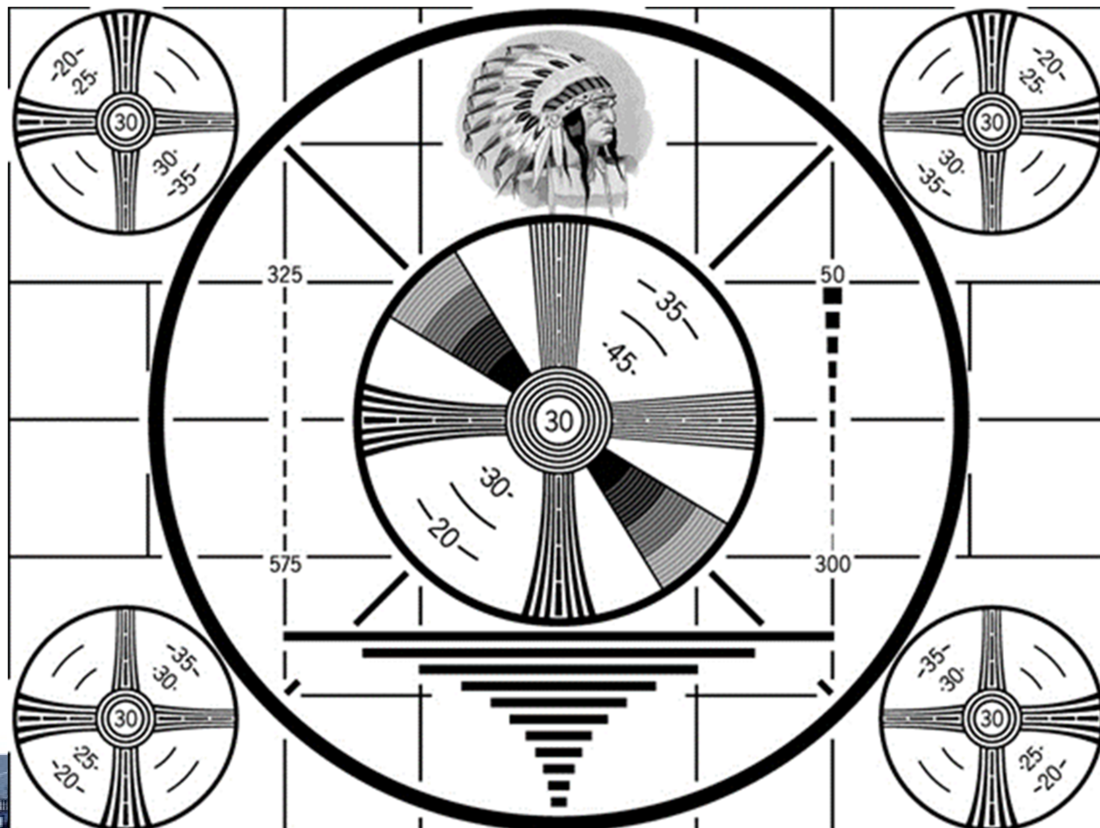
The AV Quality Triangle

Resolution



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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

HDR - xvYCC

•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.

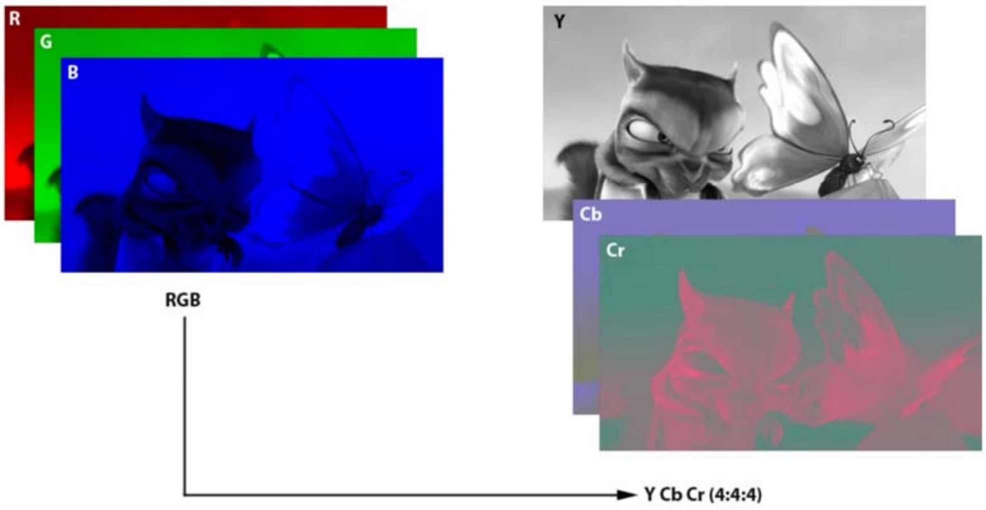
- The aim is to present a similar range of luminance to that experienced through the human visual system.

ULTRA HD™ PREMIUM

DOLBY VISION

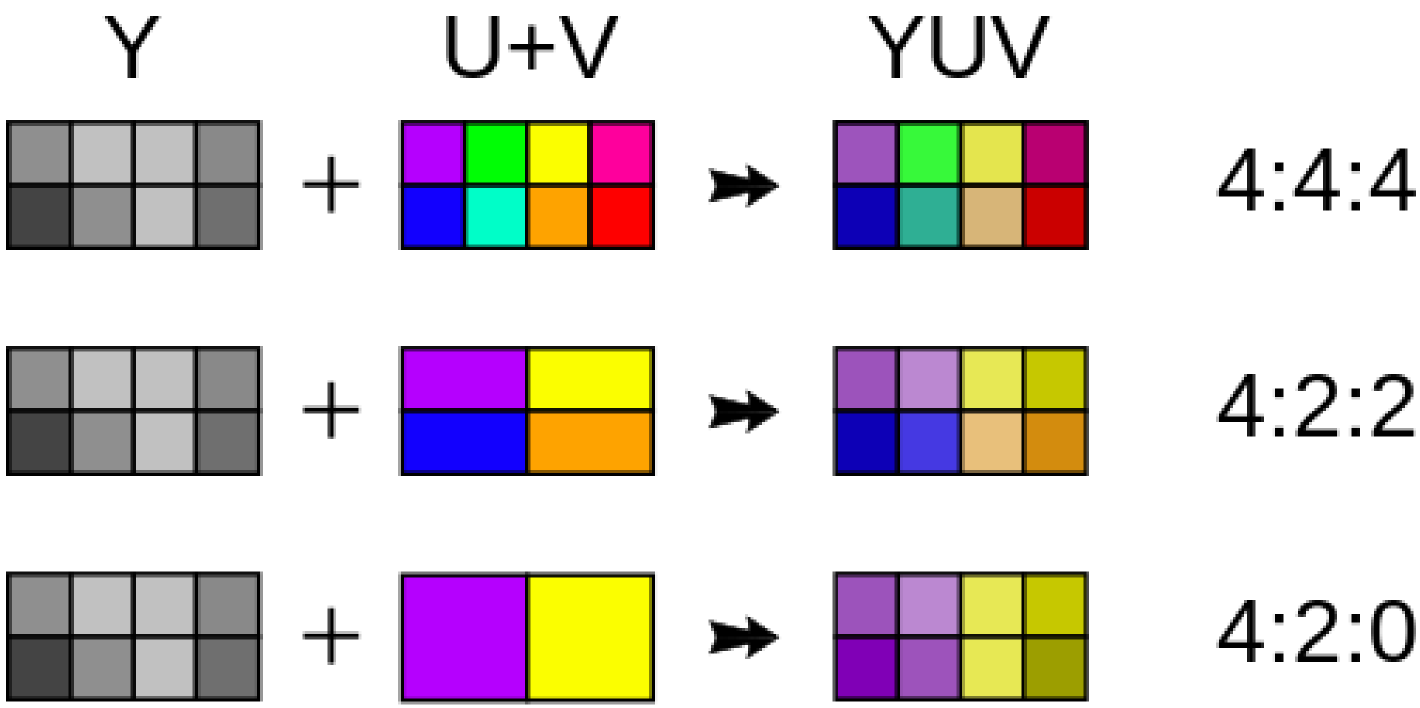
Color Space

- 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



RGB to 4:4:4

Chroma Subsampling



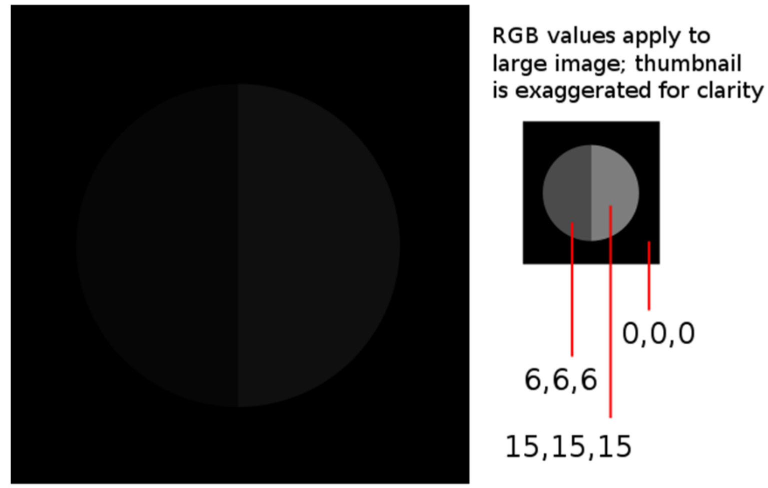
Radiometric Resolution – HDR

2-bit = 4 radiance levels

8-bit = 256 radiance levels

HDR Displays

- LCD displays must achieve 20,000:1 contrast ratio
  - 1000 cd/m^2 - black level below 0.05 cd/m^2
- OLED displays must achieve 1,080,000:1 contrast ratio
  - 540 cd/m2 - black level below 0.0005 cd/m2



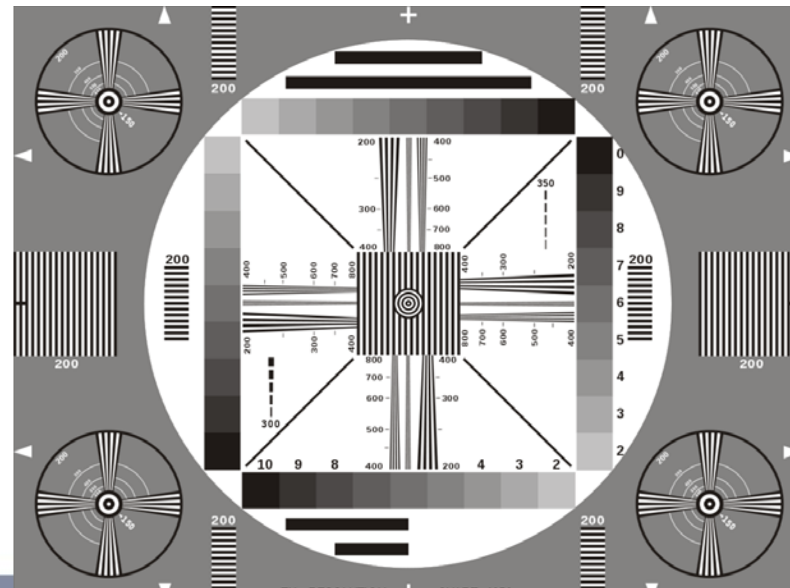
Radiometric – HDR, Deep Color

Temporal Resolution

Temporal - Fps

Bandwidth Must Be Examined More Closely in the New 4K World

- "Old" Formula to calculate analog video bandwidth
  - $H_p * V_p * F_r * 3 / 2$
  - There is no correction for ***bit depth*** or ***dark pixels***
  - This formula is a holdover from analog days



$H_{pf} * V_{pf} * F_r * B_{d(*cf)} * M * 3 * Q$

- 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 information comes from the CEA-861 specification

Rate (fps)	Hactive	Vactive	Color Depth	Prog/Inter	Htotal	Hblank	Vtotal	Vblank	Rate (Gbps)	Pixel Freq. (MHz)
50	1440	576	24	I	1728	288	625	49	0.6	27
50	1440	288	24	P	1728	288	312	24	0.6	27
50	1440	288	24	P	1728	288	313	25	0.6	27
50	1440	288	24	P	1728	288	314	26	0.7	27
50	2880	576	24	I	3456	576	625	49	1.3	54
50	2880	288	24	P	3456	576	312	24	1.3	54
50	2880	288	24	P	3456	576	313	25	1.3	54
50	2880	288	24	P	3456	576	314	26	1.3	54
50	1440	576	24	P	1728	288	625	49	1.3	54
50	1920	1080	24	P	2640	720	1125	45	3.6	149
50	2880	576	24	P	3456	576	625	49	2.6	108
50	1920	1080	24	I	2304	384	1250	170	1.7	72
60	640	480	24	P	800	160	525	45	0.6	25
60	720	480	24	P	858	138	525	45	0.6	27
60	1280	720	24	P	1650	370	750	30	1.8	74
60	1920	1080	24	I	2200	280	1125	45	1.8	74
60	1440	480	24	I	1716	276	525	45	0.6	27
60	1440	240	24	P	1716	276	262	22	0.6	27
60	1440	240	24	P	1716	276	263	23	0.6	27
60	2880	480	24	I	3432	552	525	45	1.3	54
60	1920	1080	24	P	2200	280	1125	45	3.6	149
60	2880	480	24	P	3432	552	525	45	2.6	108
100	1920	1080	24	I	2640	720	1125	45	3.6	149
100	1280	720	24	P	1980	700	750	30	3.6	149
100	720	576	24	P	864	144	625	49	1.3	54
100	1440	576	24	I	1728	288	625	49	1.3	54
100	1920	1080	24	P	2640	720	1125	45	7.1	297
120	1920	1080	24	I	2200	280	1125	45	3.6	149
120	1280	720	24	P	1650	370	750	30	3.6	149

check also http://wiki.osdev.org/File:VGA_crtc.gif

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.

Color Bit Depth	Bits Per Sub-Pixel	Clock Multiplier
24 bits	8 bits per “color”	1.00
30 bits	10 bits per “color”	1.25
36 bits	12 bits per “color”	1.50
48 bits	16 bits per “color	2.00

Some Examples

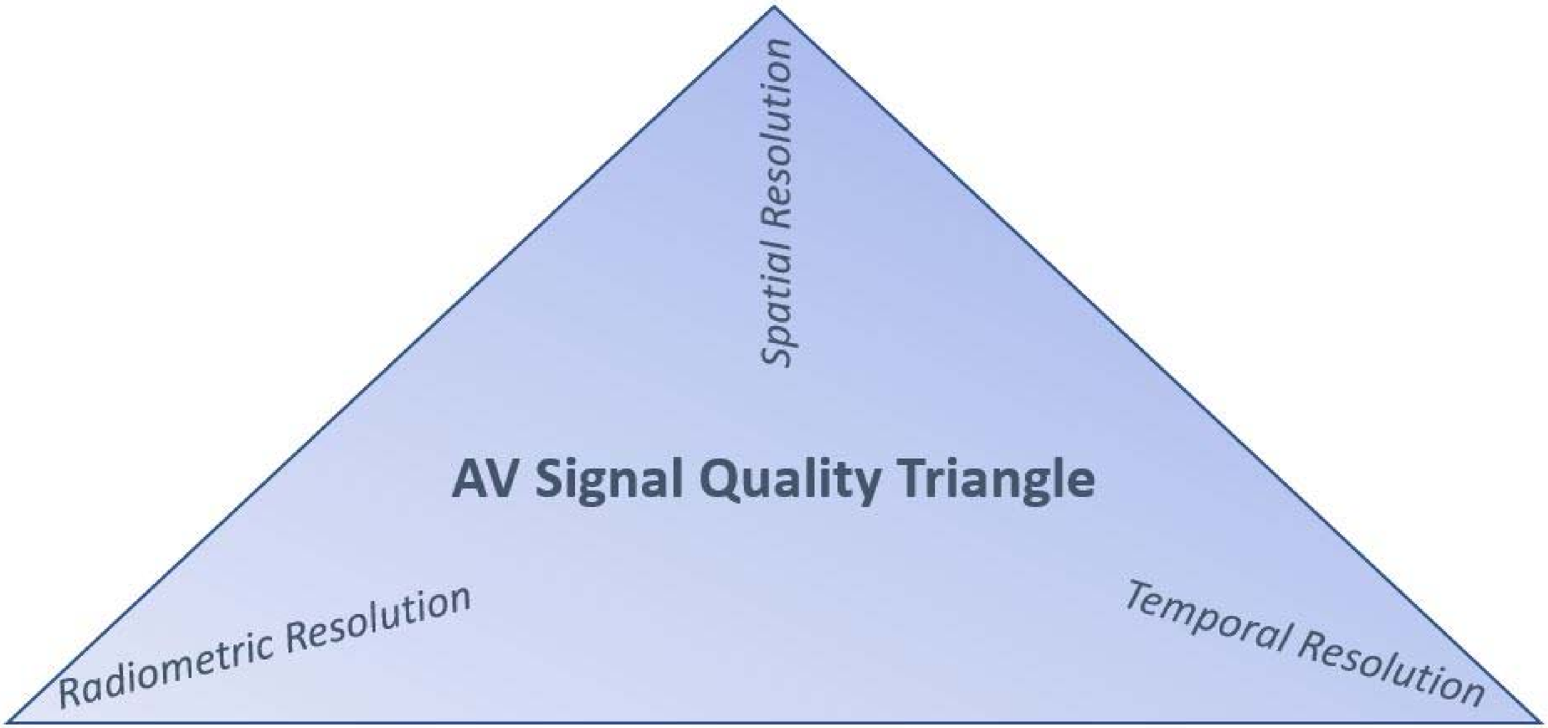
- Calculate the video data signaling rate for a UHD 2160p60 signal operating in a 4:2:0 color space

- *4120*2205*60*(10*.5)*1 = 2,727,380,000 per RGB color channel*
- *(2.73 x 3) = 8.19 Gbit/s total payload rate*
- *This is uncompressed. Multiply by Q for compression*

- Calculate the video data signaling rate for an HD 1080p60 signal operating in a 4:4:4 color space

- *2200*1125*60*(10*1)*1 = 1,485,000,000 per RGB color channel*
- *(1.49x 3) = 4.47 Gbit/s total payload rate*
- *This is uncompressed. Multiply by Q for compression*

The AV Signal Quality Triangle

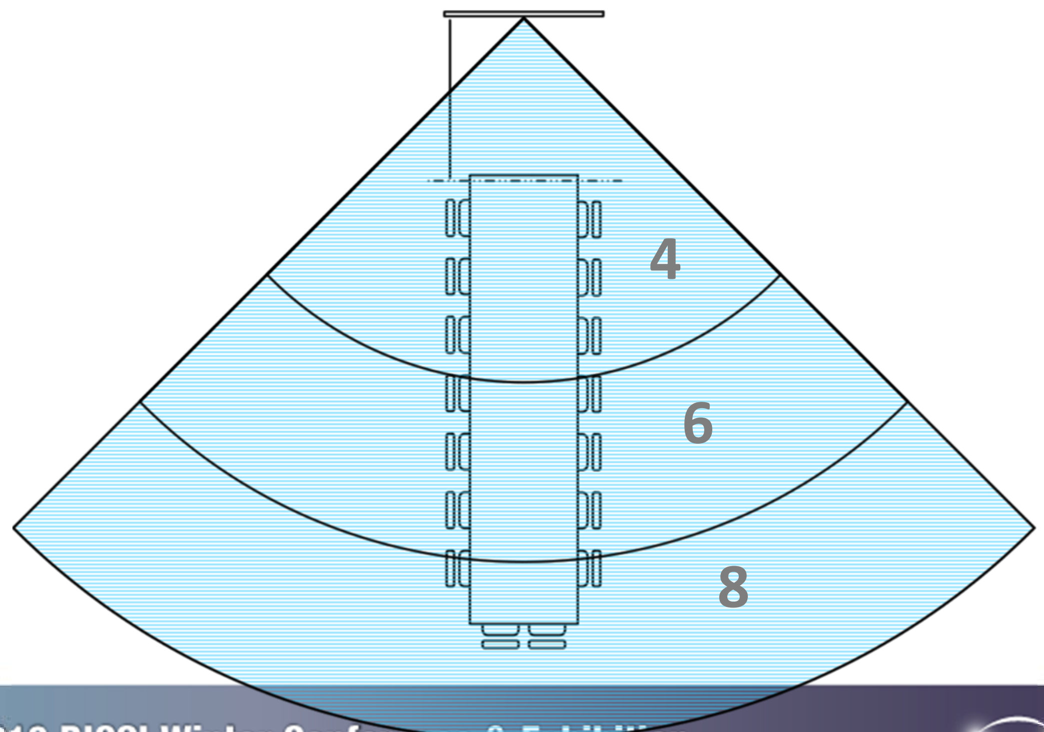


The Old Way of Selecting the Right Display Size for an A/V Project

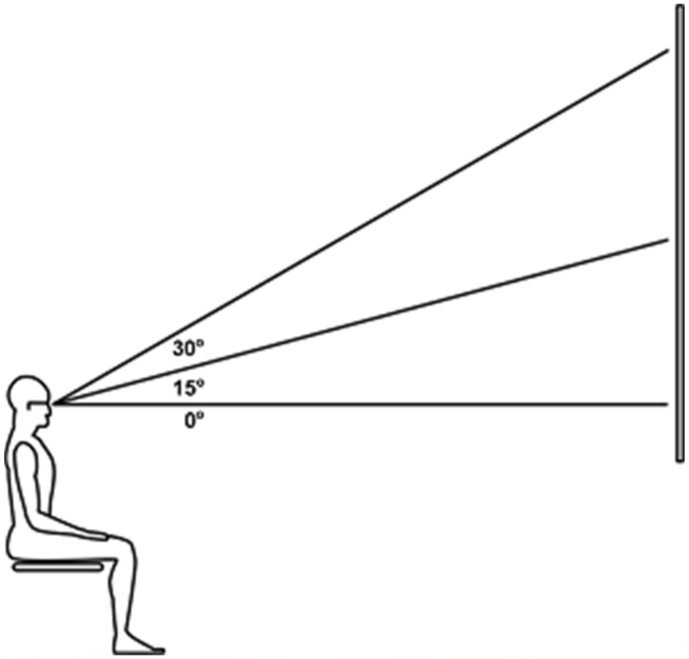
"What we see depends mainly on what we look for." - John Lubbock

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!



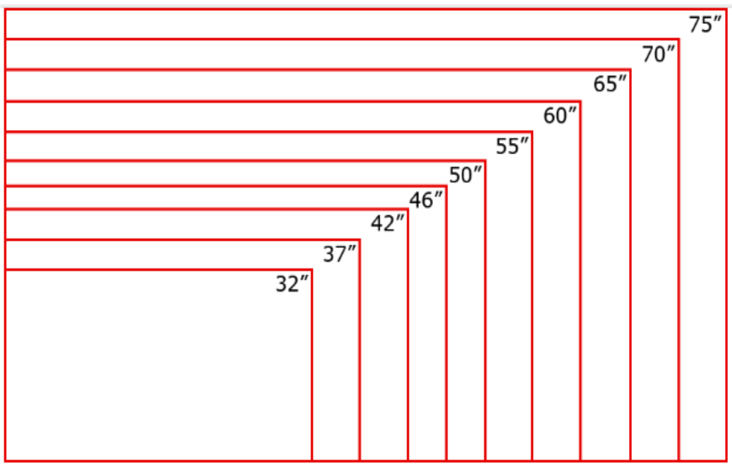
Sight lines & Displays



- 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



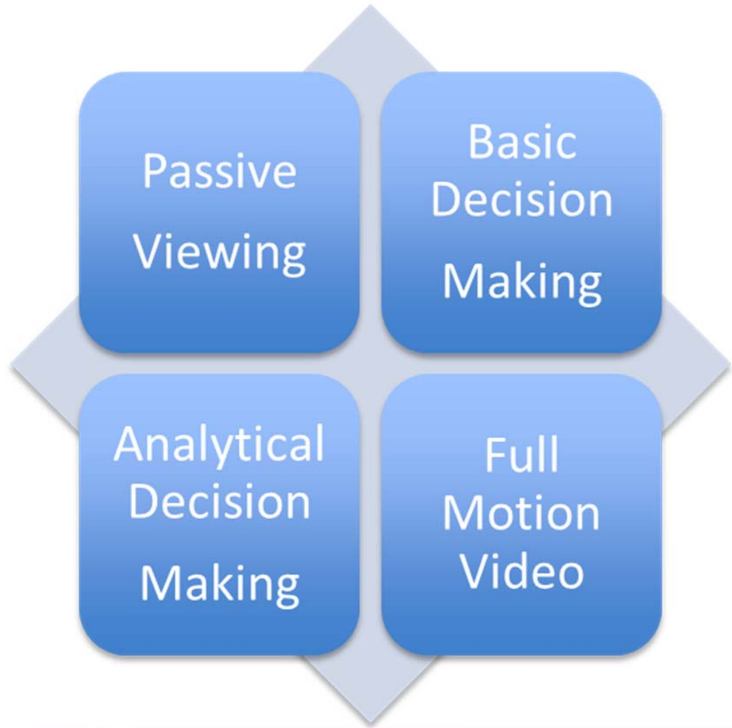
The 150x Text Rule

- 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 New ANSI/AVIXA Standard – DISCAS

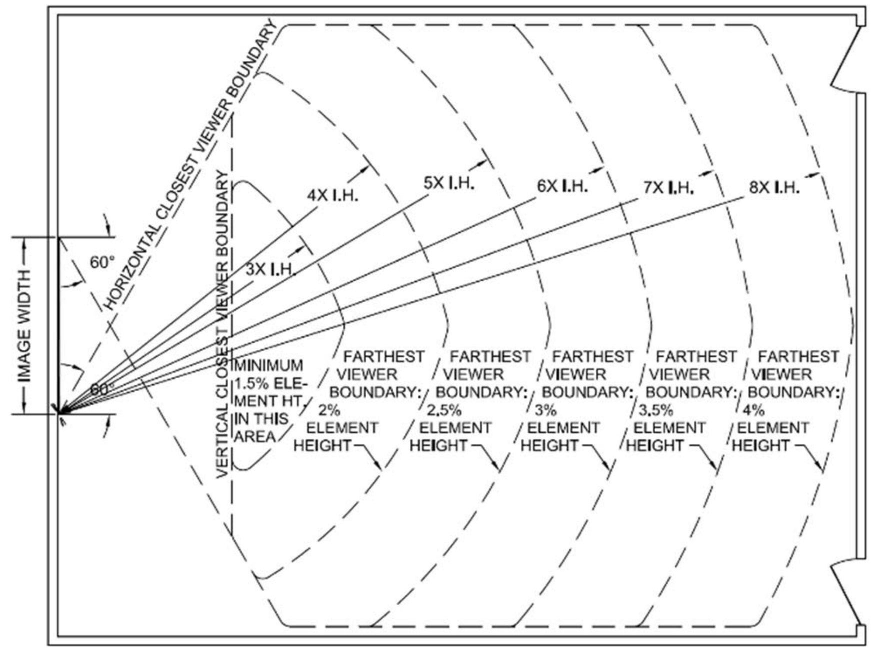
- *The goal of DISCAS is to create a scientific standard, based on human vision, to define the screen size for a given audiovisual system based on audience viewing distance.*

- 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



VIEWING PARAMETERS FOR BDM

NO SCALE I.H. = IMAGE HEIGHT

IMAGE HEIGHT BASED ON 16:9 (1.78:1) ASPECT RATIO

What is Analytical Decision Making?

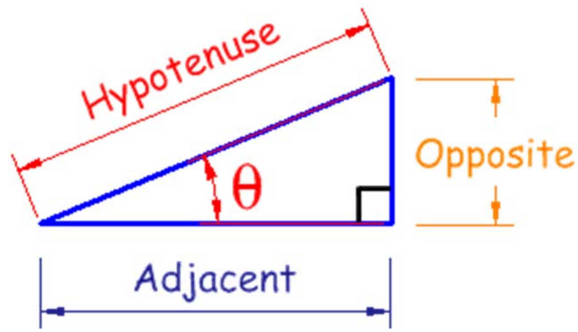
- ADM is a more specialized calculation
  - Concerned with the finest of details
  - Pixel-level detail required
  - Used for things like medical imagery, technical drawings, and photographic evaluation

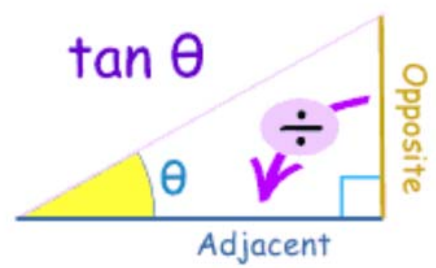
Basic Decision Making

- 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





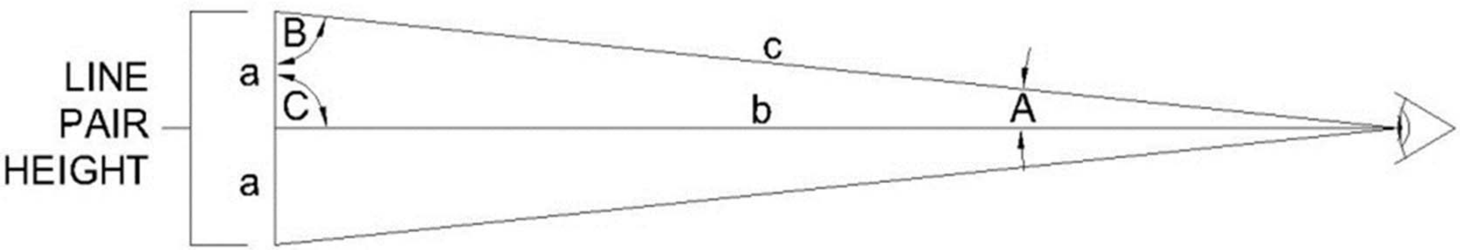
$$a^2 + b^2 = c^2$$

The Formula

$$Image\ Height = (Farthest\ Viewing\ Distance * \#\ Vertical\ Pixels)/(1/\ \tan\left(\frac{\frac{MOA}{60}}{2}\right))$$

$$Farthest\ Viewing\ Distance = (Image\ Height * (1/\tan\left(\frac{\frac{MOA}{60}}{2}\right)))/\#\ Vertical\ Pixels$$

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)=a/b

b=a/tan(A)

ACUITY FACTOR FOR ANALYTICAL VIEWING

$$\frac{1}{\tan(\text{Visual Acuity}/2)} = 3438 \text{ for 2 Minutes of Arc}$$

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Simplifying the Math…

- $Image\ Height =$
- $\frac{Farthest\ Viewing\ Distance * \#\ Vertical\ Pixels}{3438}$
- $Farthest\ Viewing\ Distance =$
- $\frac{Image\ Height * 3438}{\#\ Vertical\ Pixels}$

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

- $$\boldsymbol{Image\ Height = \frac{Farthest\ Viewing\ Distance * \#\ Vertical\ Pixels}{3438}}$$
    - Image Height = $\frac{3\ meters\ *2160\ \boldsymbol{Vertical\ Pixels}}{\mathbf{3438}}$ = 1.88 meters
    - Image Height = $\frac{3\ meters\ *1080\ \boldsymbol{Vertical\ Pixels}}{\mathbf{3438}}$ = 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

- $\boldsymbol{Farthest\ Viewing\ Distance = \frac{Image\ Height * 3438}{\#\ Vertical\ Pixels}}$

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

    - $\mathbf{Farthest\ Viewing\ Distance = \frac{41\ inches * 3438}{1080}}$ = 130.5 inches (10.8’)

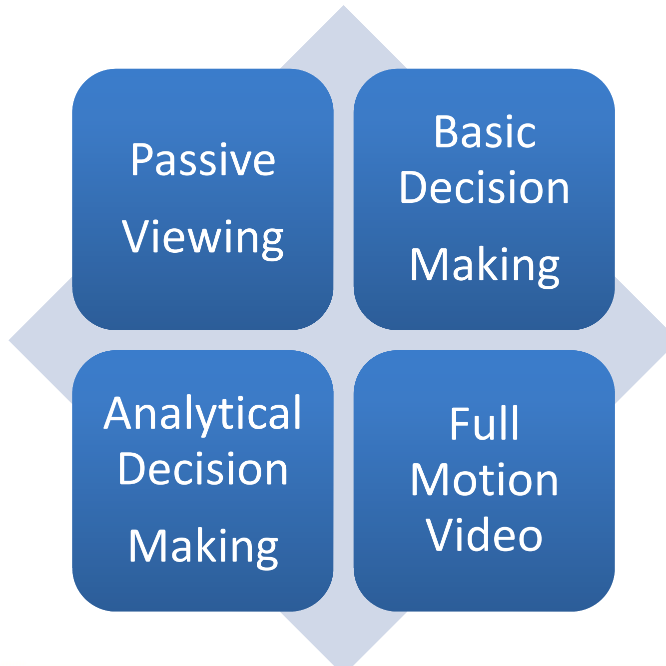
- *Therefore viewers between 5.4’ and 10.8’may be well served by 1080p, viewers closer than 1.6 meters need 2160p*

How Do We Handle Basic Decision Making?

- *"Decisions are made by people who have time, not people who have talent."*
  - Scott Adams

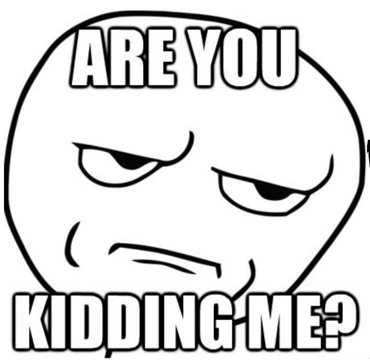
Calculating The BDM_{AF}

- 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

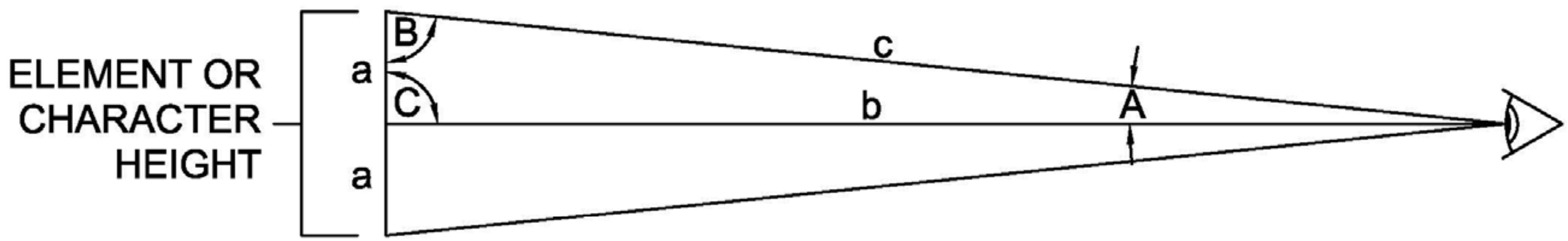
$$Image\ Height = \frac{Farthest\ Viewing\ Distance}{0.5/\tan\left(\frac{\frac{MOA}{60}}{2}\right) * \%Element}$$



$$ving\ Distance =$$

$$Image\ Height * \frac{0.5}{\tan}\left(\frac{\frac{MOA}{60}}{2}\right) * \%Element$$

VISUAL ACUITY FOR NON-ANALYTICAL (BASIC) VIEWING



Element or Character Height=2*a

Visual Acuity for Category=2*A

Viewing Distance at Stated Acuity=b

$\tan(A)=a/b$

$b=a/\tan(A)$

ACUITY FACTOR FOR NON-ANALYTICAL (BASIC) VIEWING

$$\frac{0.5}{\tan(\text{Visual Acuity}/2)} = 200 \text{ for } 17.25 \text{ Minutes of Arc}$$

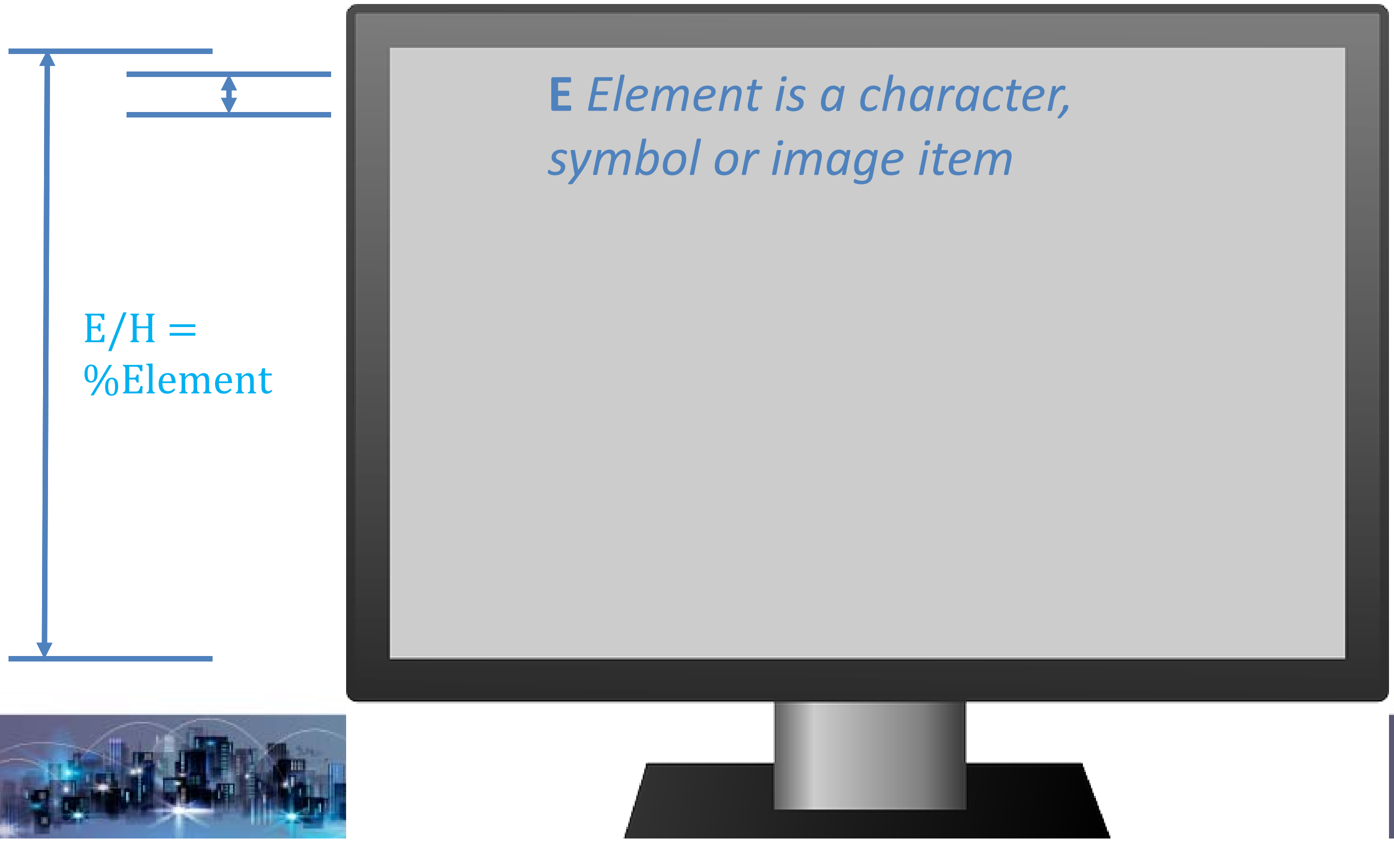
Simplifying the Math…

- $$\textbf{Image Height} = \frac{\textbf{Farthest Viewing Distance}}{\textbf{200} * \textbf{\%Element}}$$

- $\textbf{Farthest Viewing Distance} = \text{Image Height} * 200 * \%\text{Element}$

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

What Is %Element?



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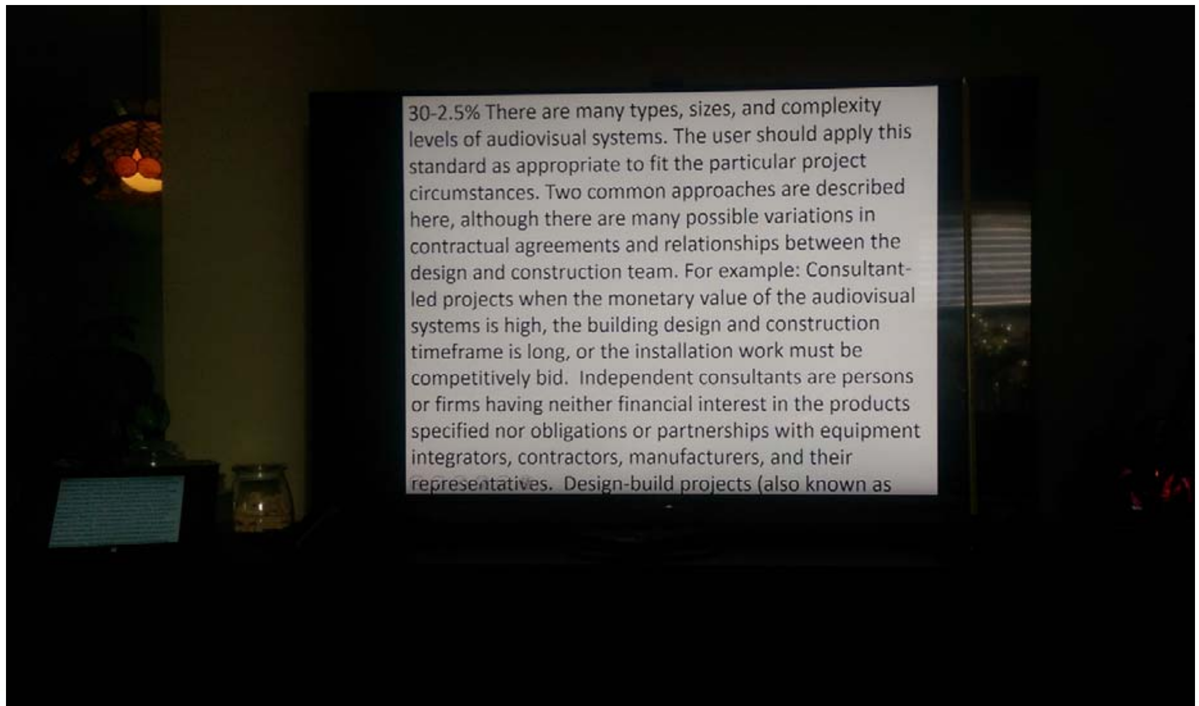
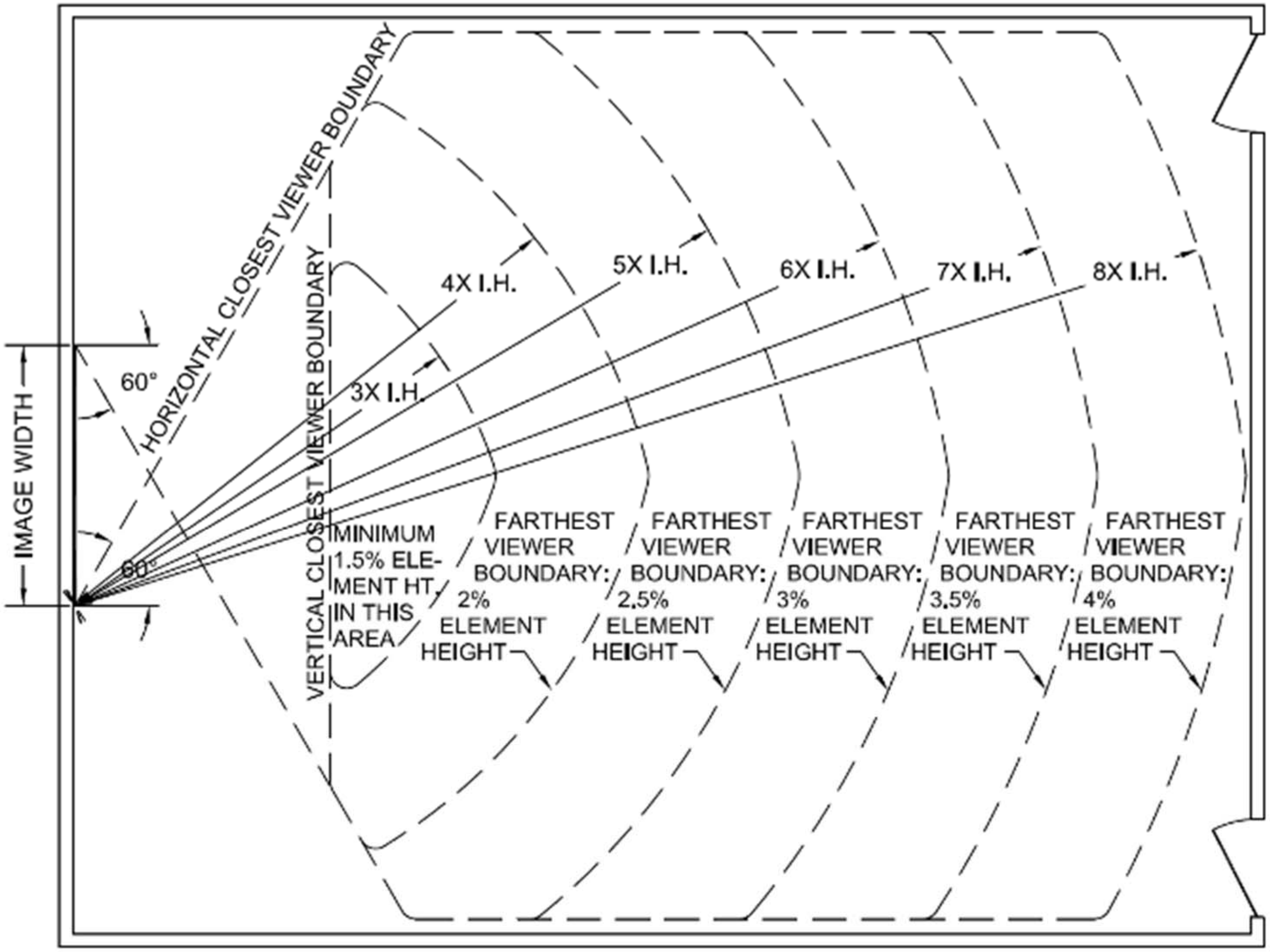
An Example of 2.5% Element

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

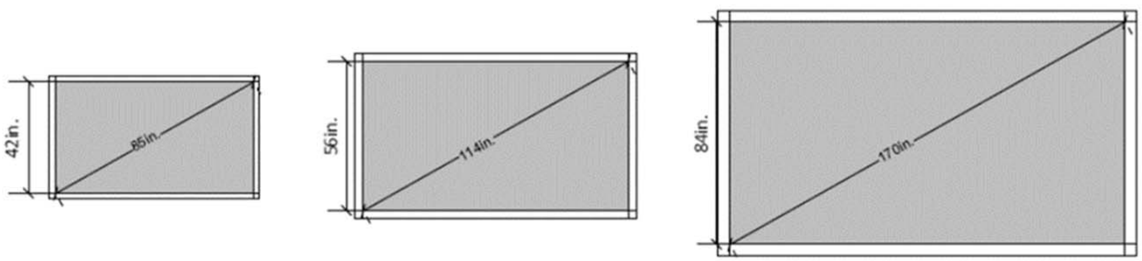
- A 75” 16:9 LCD display has an image height of 37”
- Using 2.0%Element, we calculate the farthest acceptable viewer distance at 12.3 feet
- Using 3%Element, we calculate the farthest viewer at 18.5 feet

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)



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Common Elements of Connectivity

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Power of Another Sort –
The Hardware “Handshake”

EDID

Voltage Assertion

plug and play

Hot Plug Detect

HDCP

- Hot Plug Detect – Step 1

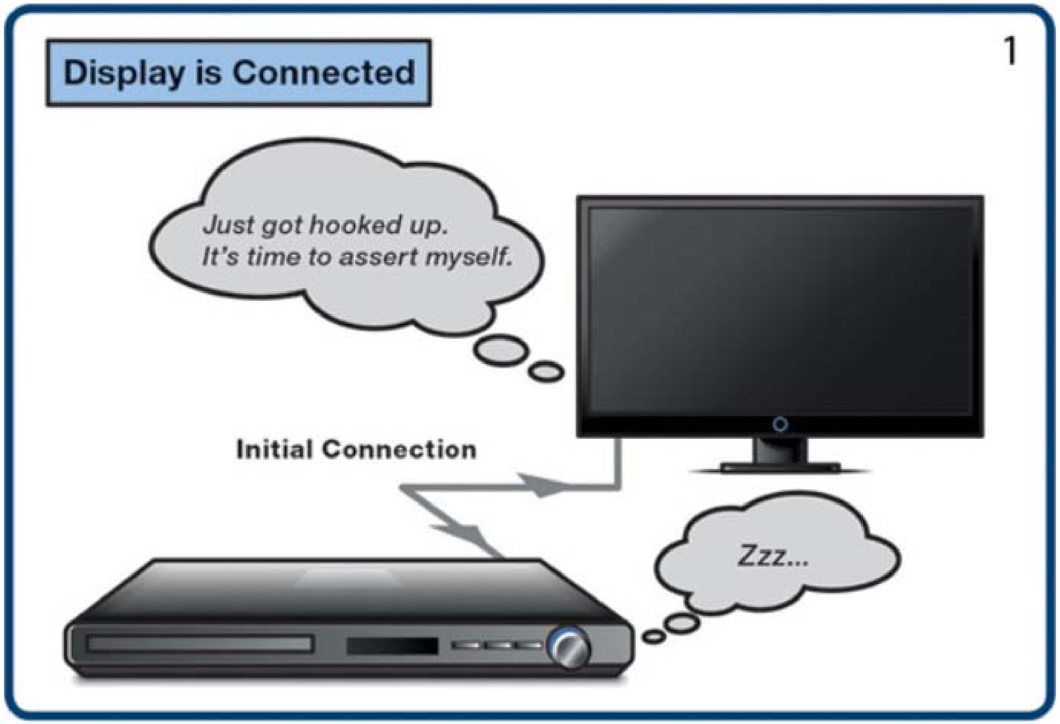


Image from Extron's white paper, EDID: A Guide to Identifying and Resolving Common Issues

- Hot Plug Detect – Step 2

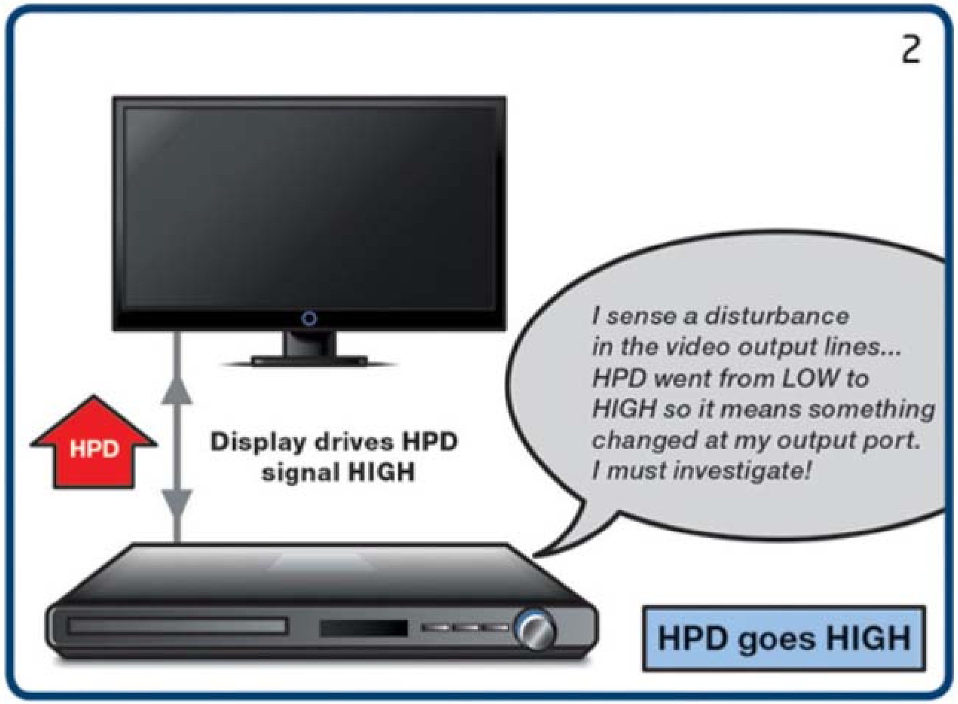


Image from Extron's white paper, EDID: A Guide to Identifying and Resolving Common Issues

- Hot Plug Detect – Step 3

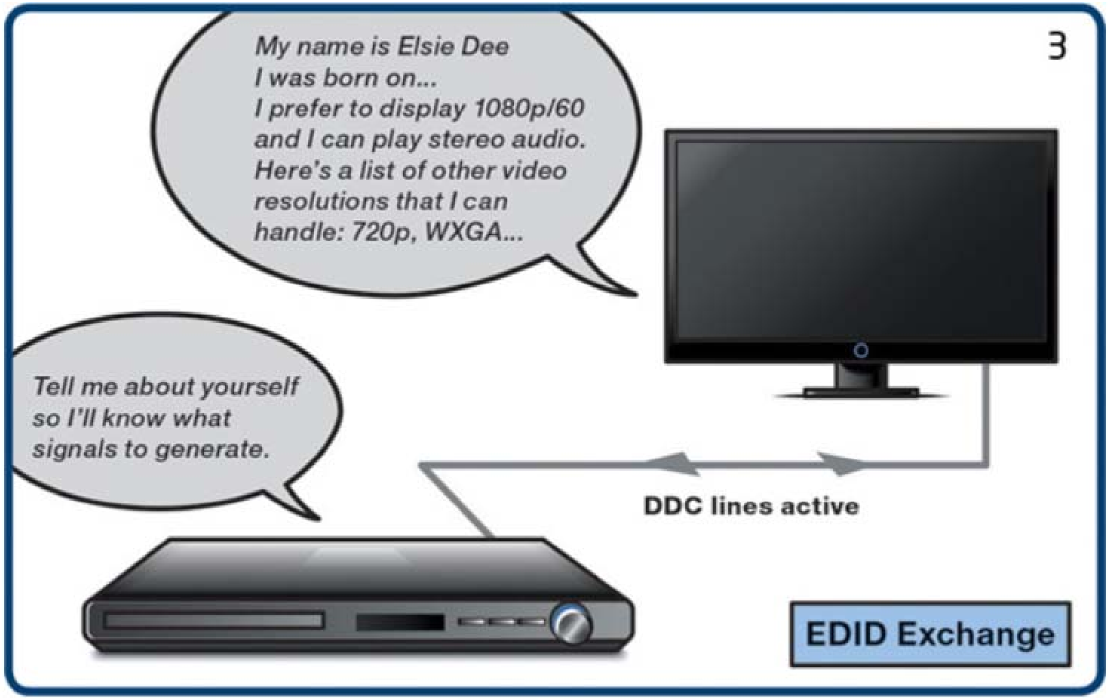


Image from Extron's white paper, EDID: A Guide to Identifying and Resolving Common Issues

- Hot Plug Detect – Step 4

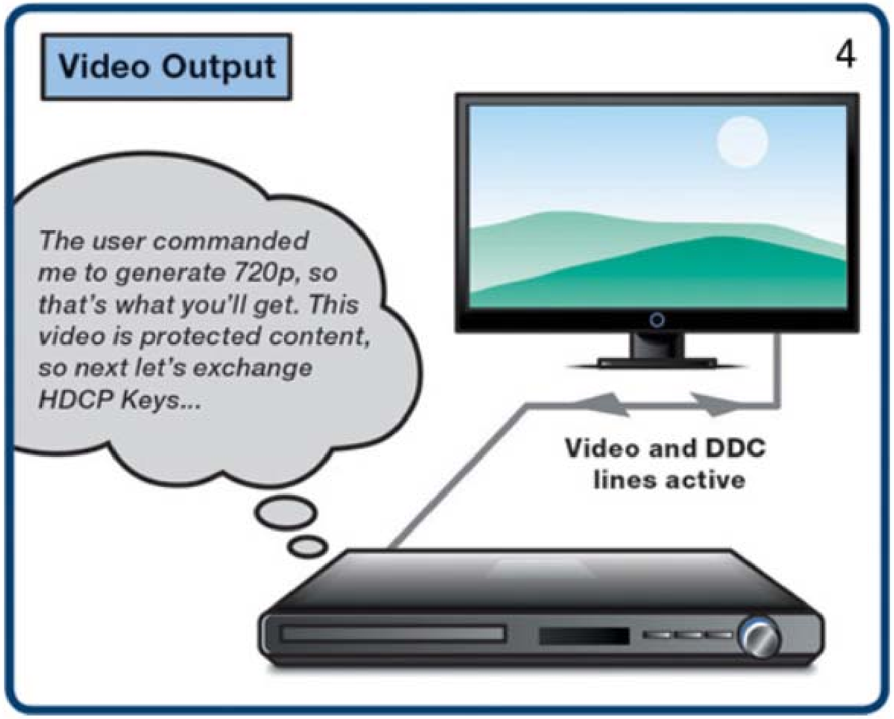
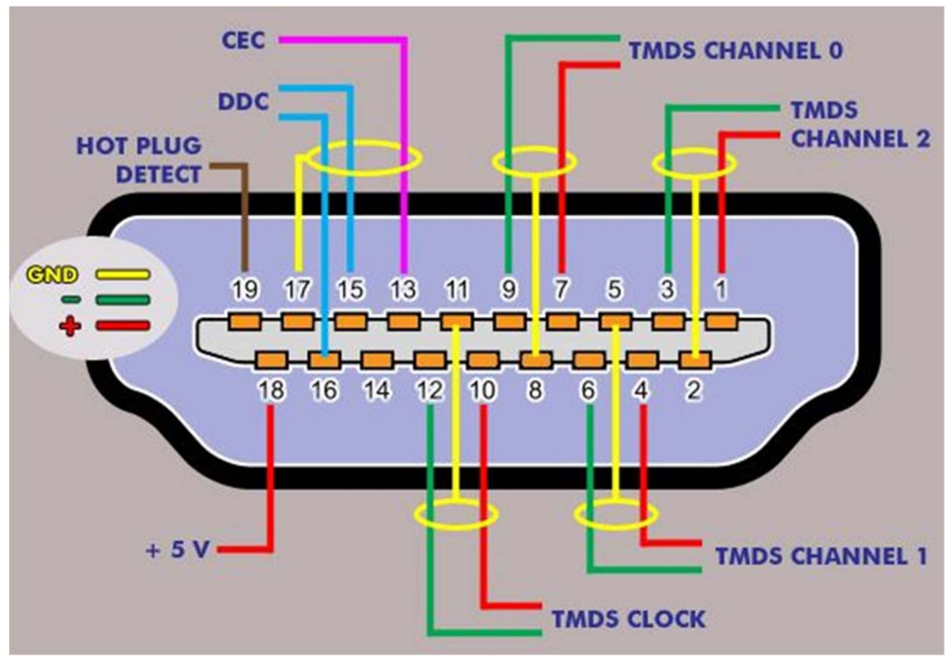


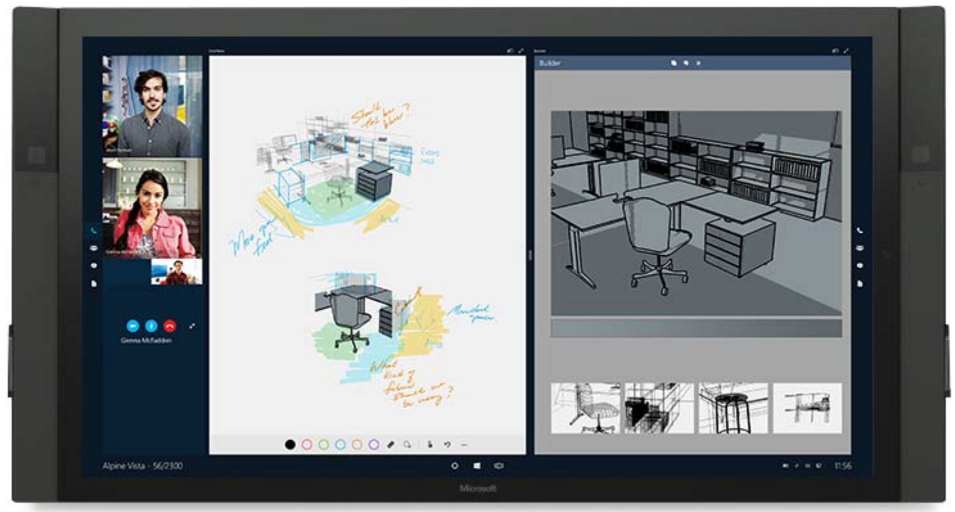
Image from Extron's white paper, EDID: A Guide to Identifying and Resolving Common Issues

- 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



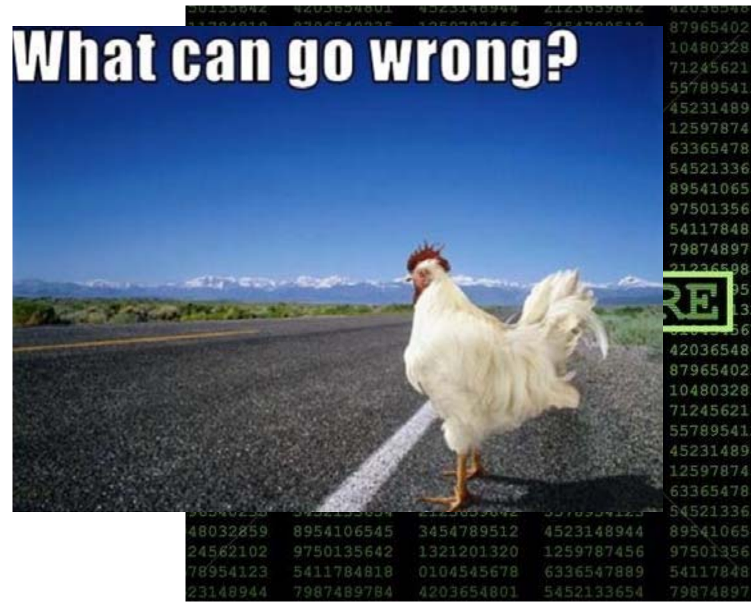
• Voltage Drop Over Interconnect?



- 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 ≤20mS latency source-to-sink
- HDCP 2.2 is <u>not</u> 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…

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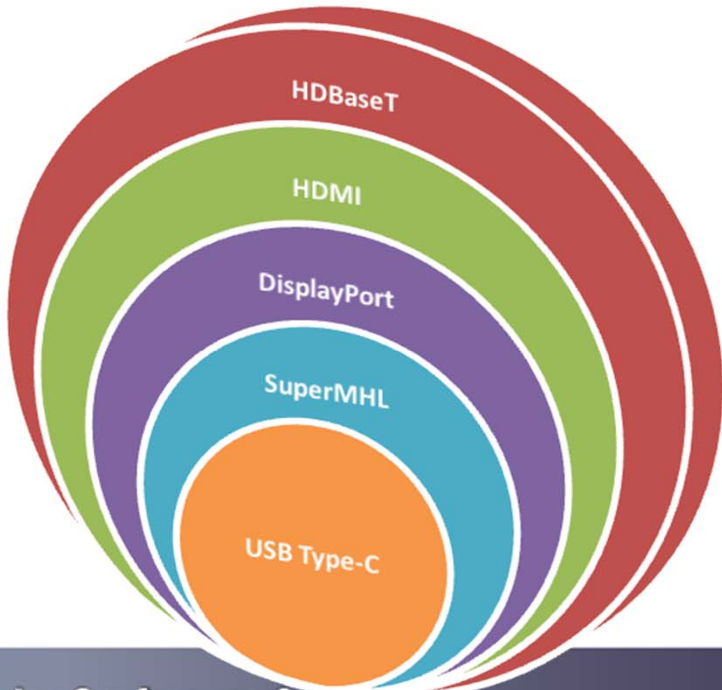
21st Century Connectivity Formats

- A/V Connector Ecosystem

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.



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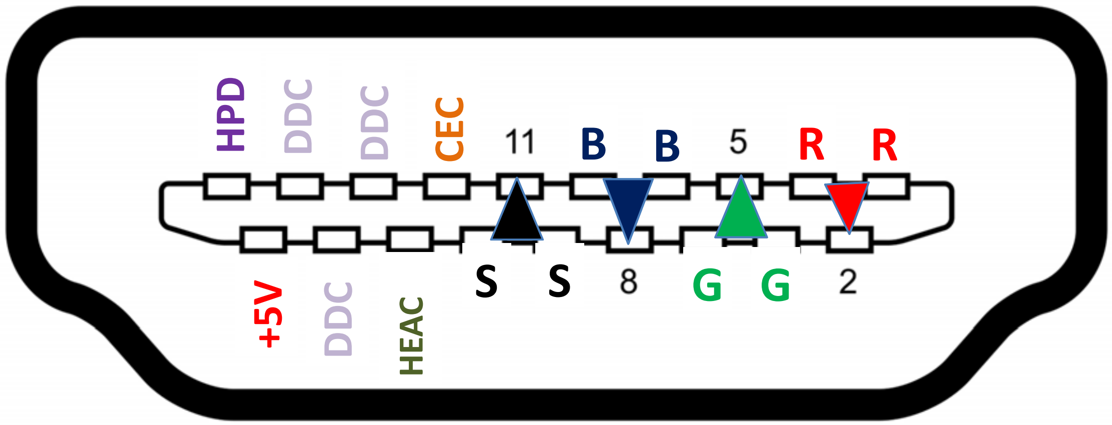
The Most Ubiquitous AV Connector

- 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, <u>not</u> “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

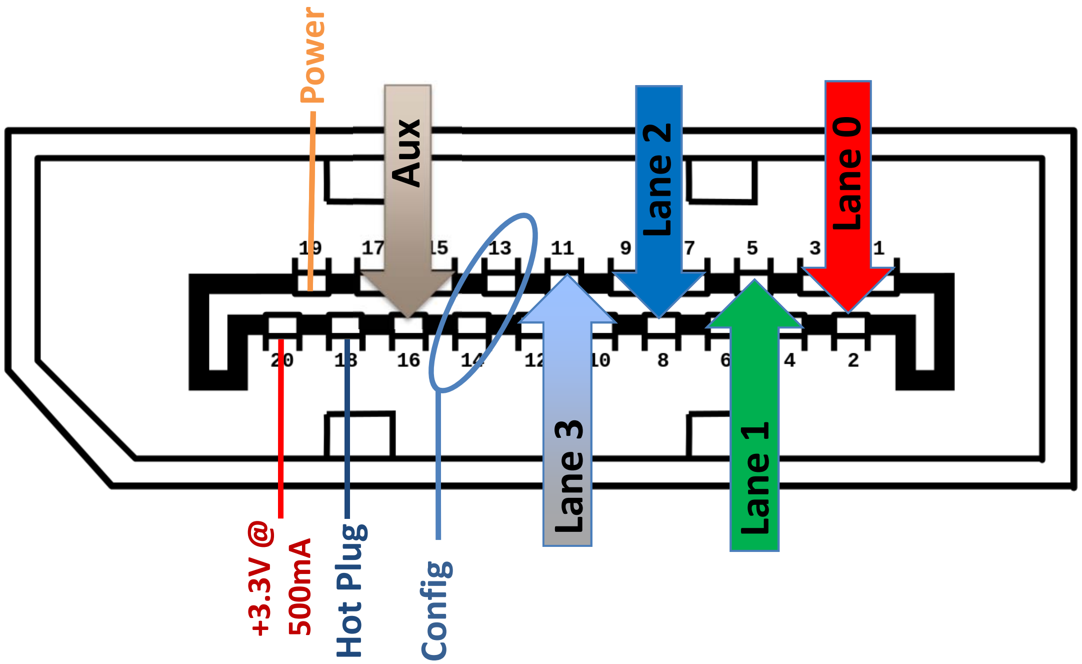
- An embedded media converter is a chip that fundamentally changes the signal to leverage a completely different optical or electrical connection topology
  - Some examples include RapidRun Optical, AOC, Celerity Optical Gateway
- Often these systems will leverage a USB power connection
  - When copper 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

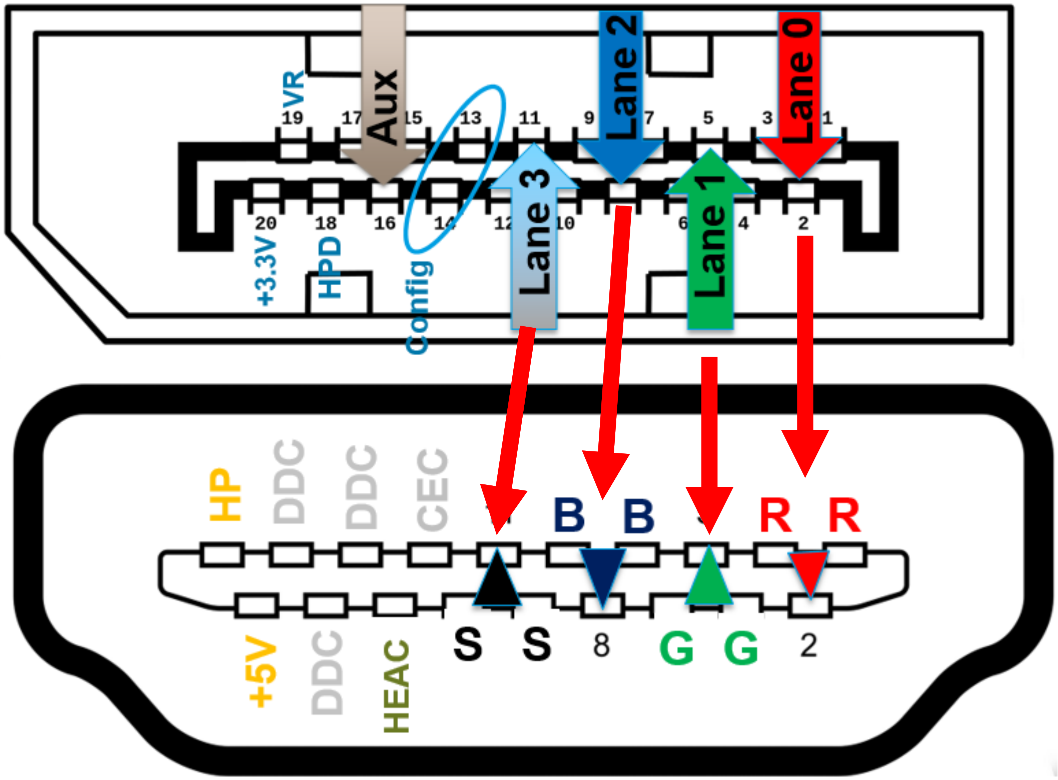
- How Can You "Fix" It?

- 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.

DisplayPort

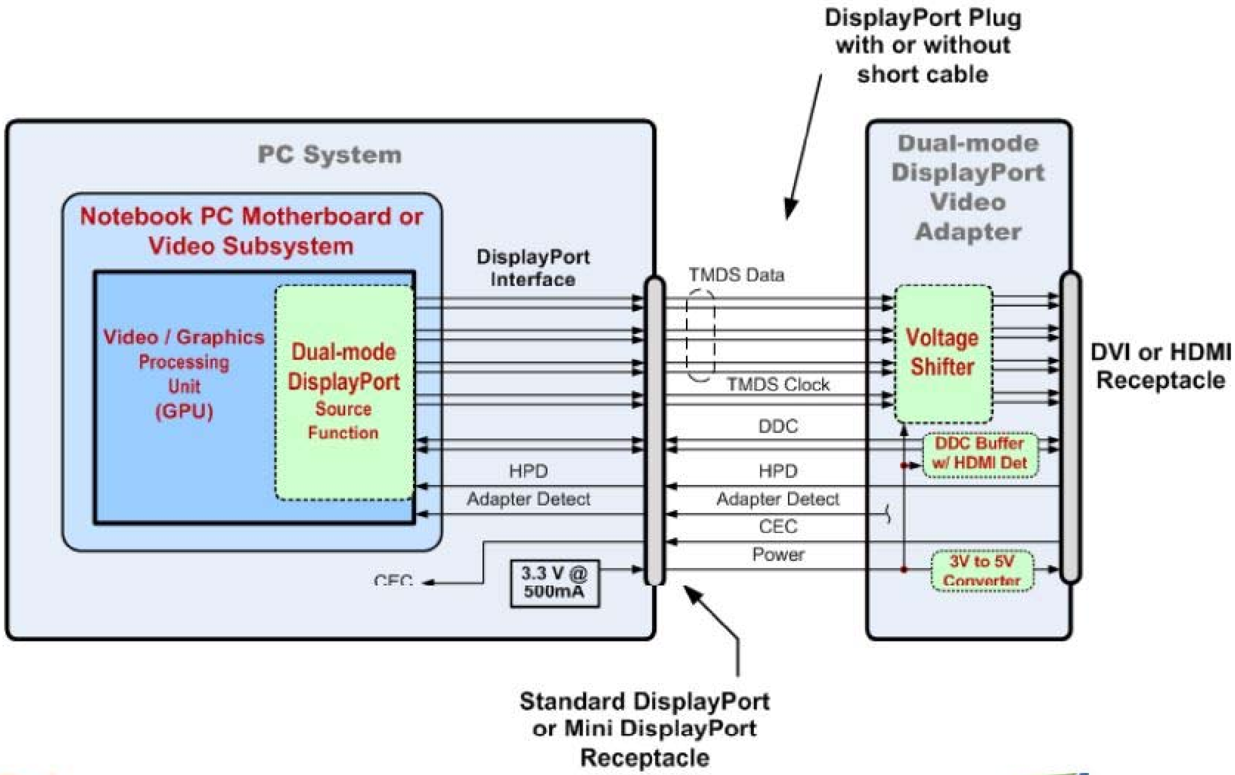
- DisplayPort Pin Out





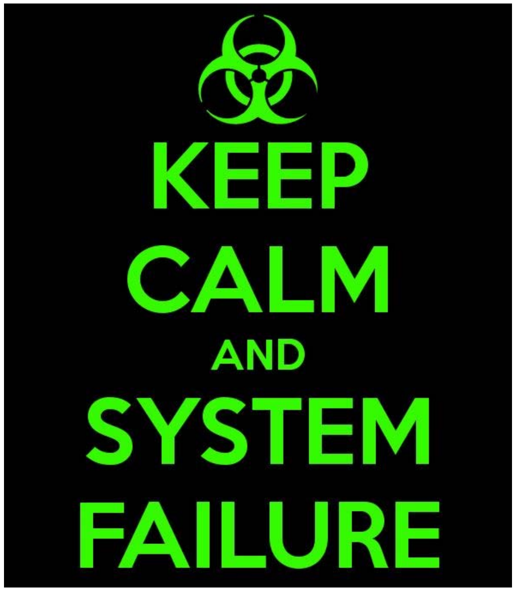
The difference between DP1.2a Standard and the DP++ option is the ability of the later to "speak" to an HDMI display without the need for active circuitry

Interface Using Dual-mode adapter



• 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**



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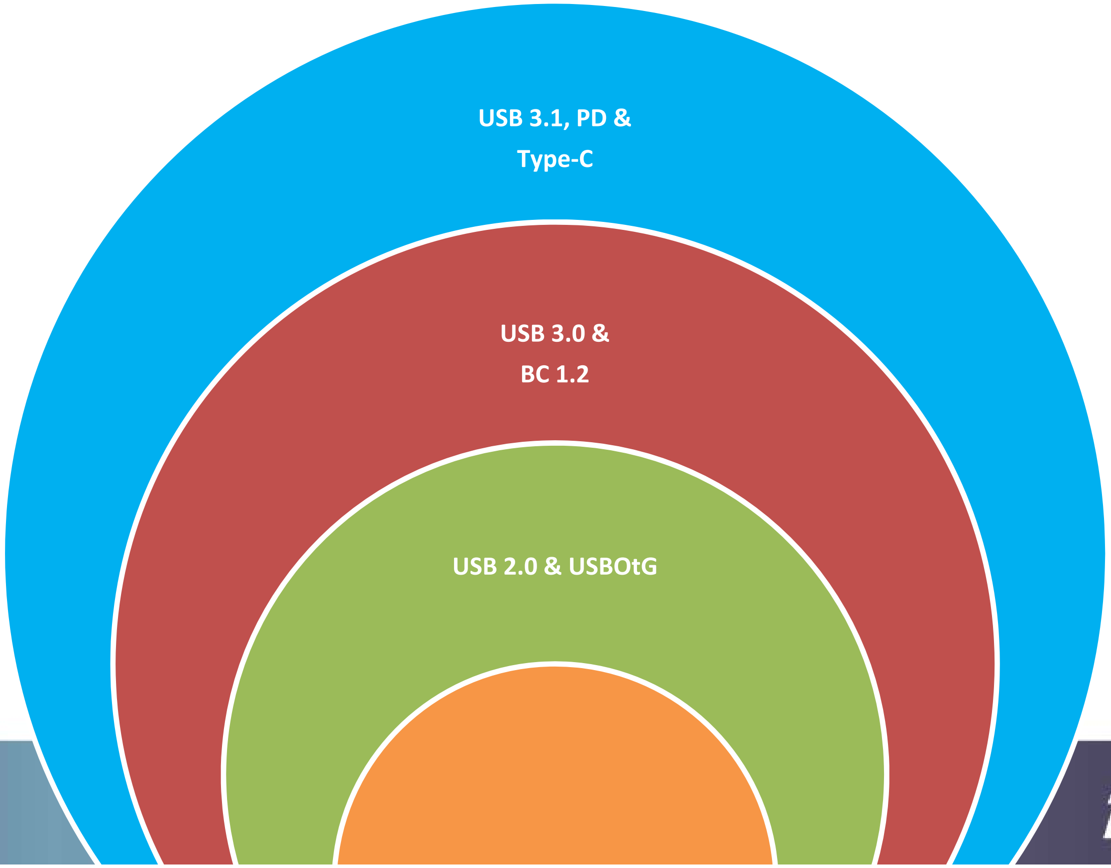
Universal Serial Bus

- The USB Ecosystem



- USB Speed and Power Comparison

Version	Year	Low Speed 1.5 Mbps	Full Speed 12 Mbps	High Speed 480 Mbps	Super Speed 5 Gbps	Super Speed + 10 Gbps	Power Limit
1.1	1998	■	■				500mA
2.0	2000	■	■	■			900mA* **during data transfer*
3.0	2008	■	■	■	■		900mA*
3.1	2013	■	■	■	■	■	*You Won't Believe Me!*

- 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

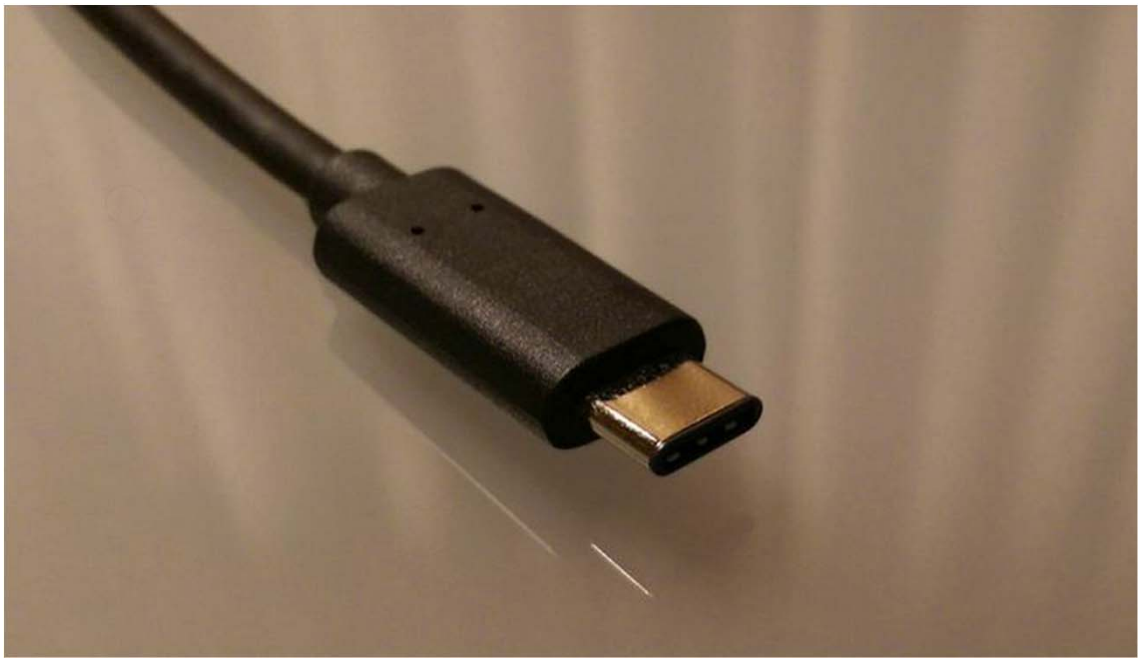
- USB On One End, HDMI On The Other

MHL
Mobile High-Definition Link

• MHL In The Market

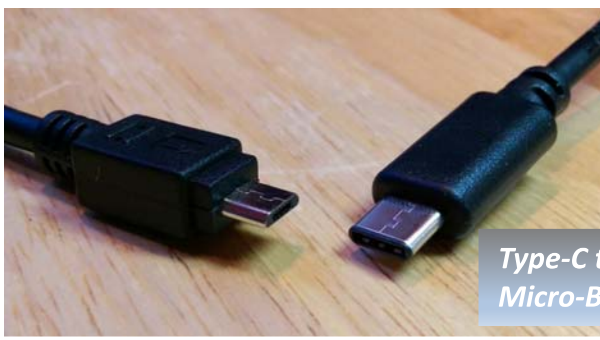
- Leverages HDMI form factor
  - Runs efficiently – uses less battery life than wireless connectivity
  - Charges mobile devices during operation
  - Allows for use of device remote control for transport functions

- USB Type-C



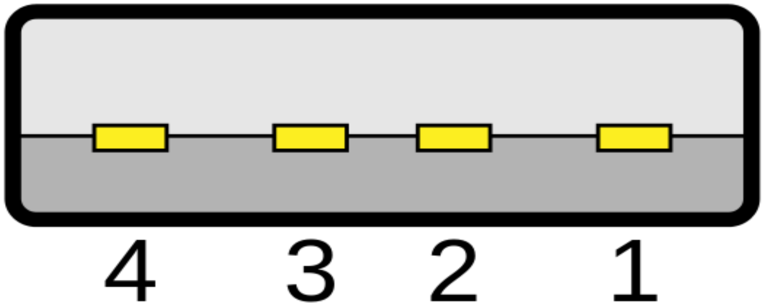

Type-C to
Type-B


Type-C to
DisplayPort

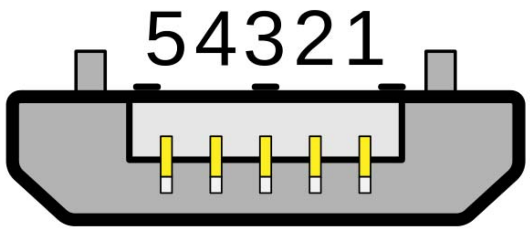

Type-C to
Micro-B


Type-C to
Type-A

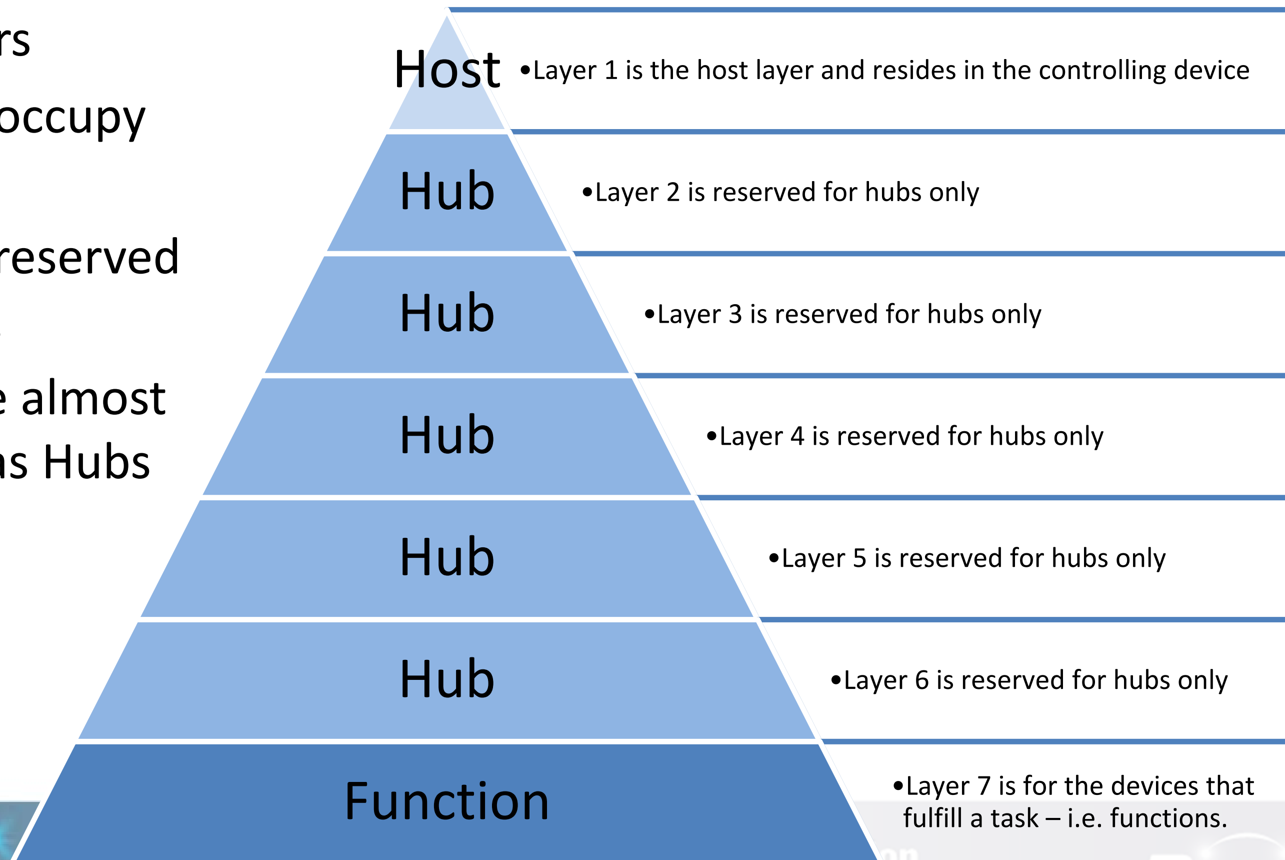
USB 2.0 “A“ Connector

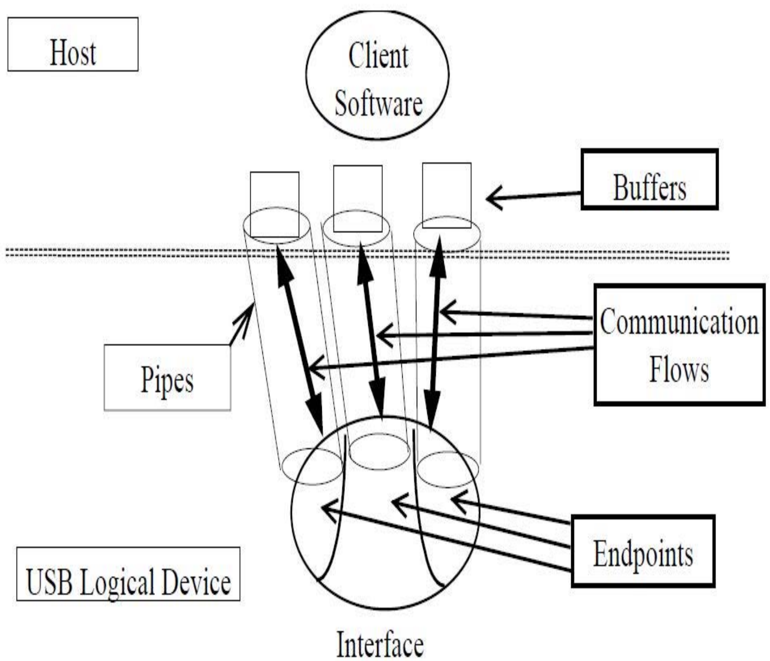


USB 2.0 “Micro B“ Connector



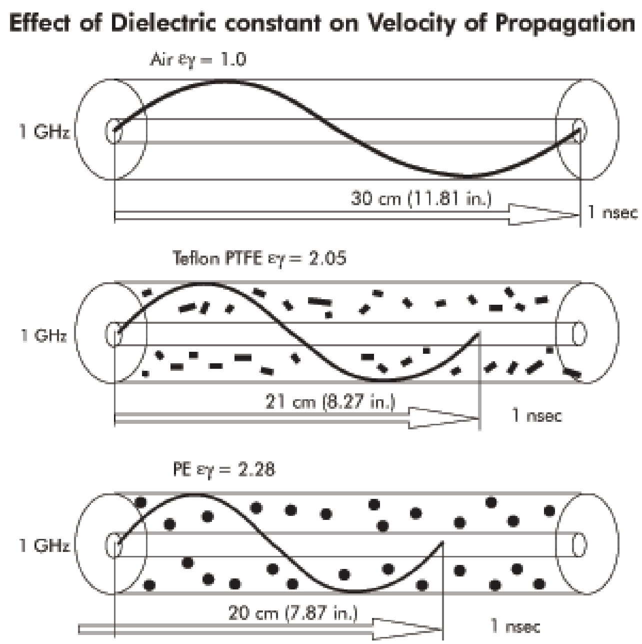
- USB operates on a strict hierarchy of 7 tiers
  - All functions occupy layer 7
  - Tiers 2-6 are reserved for hubs only.
  - Extenders are almost always seen as Hubs





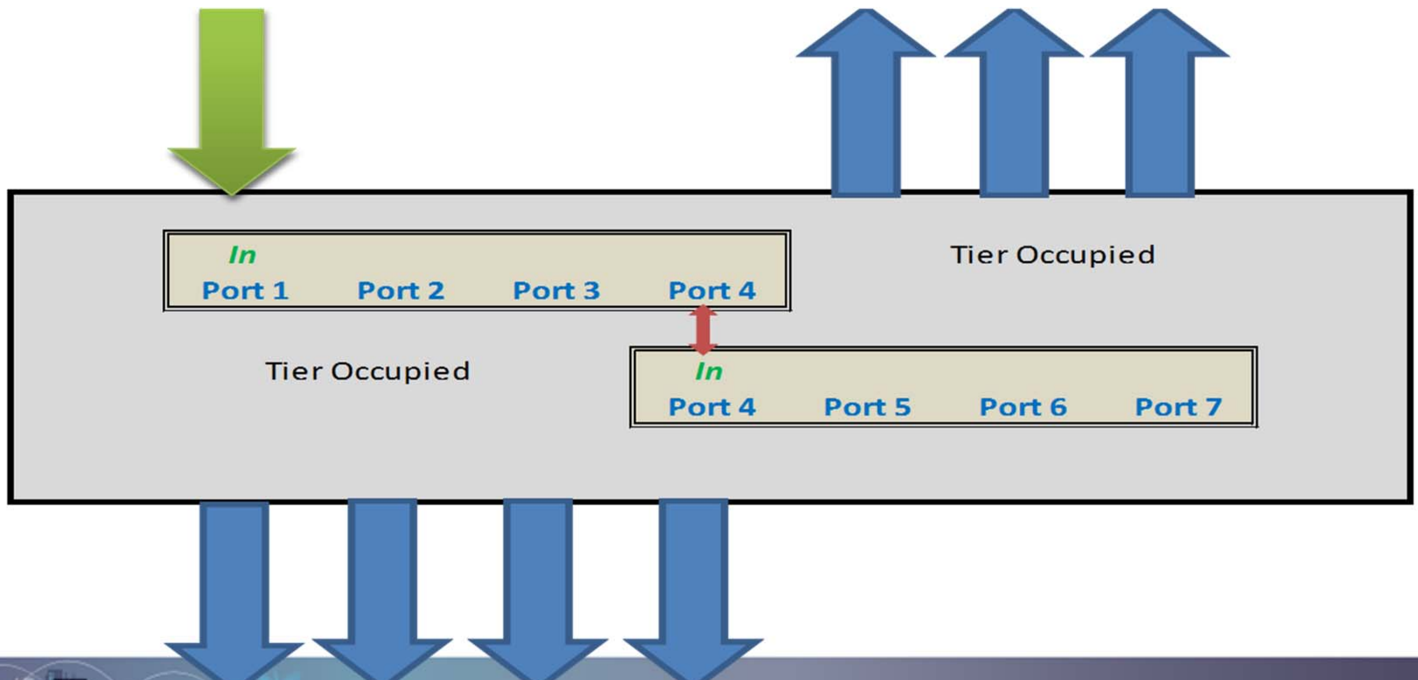
- *Isochronous* transfers at some guaranteed data but with possible data loss
- *Interrupt* transfers guarantee quick responses (bounded latency)
- *Bulk* transfers are for large sporadic transfers using all remaining available bandwidth, but with no guarantees on bandwidth or latency
- *Control* transfers 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.

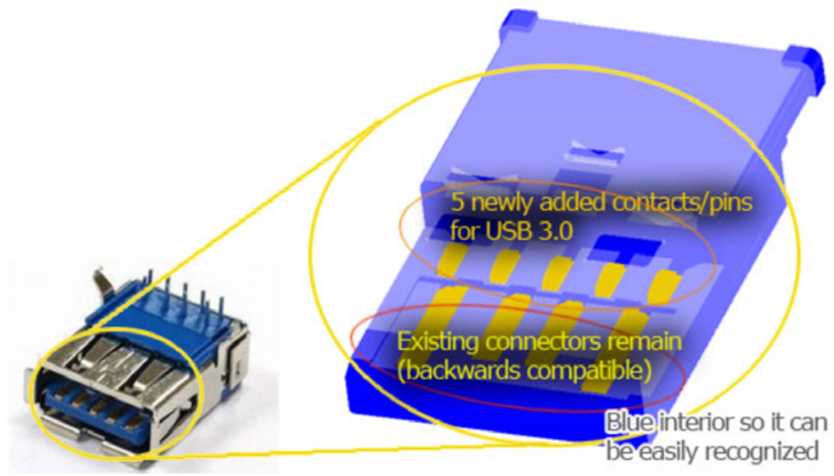
• Extender Systems

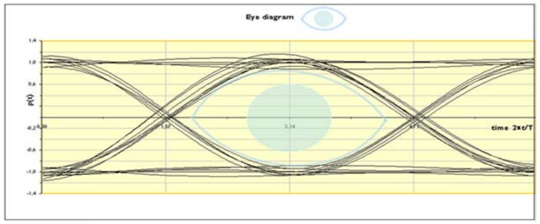
- Extenders typically occupy a tier – they are seen by the host as a hub
- SuperBooster systems are powerful components of a USB network design

- 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 10k

- # 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

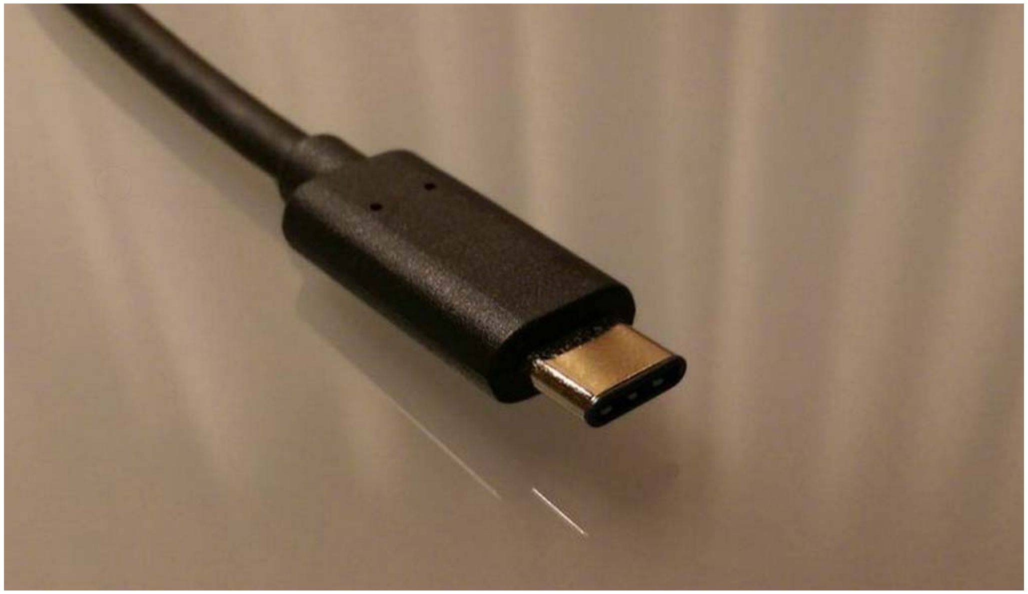
• USB 3.1 Gen 1 and Gen 2 Challenges

- USB 3.0 cable length is typically limited to 3m
- Three main contributing factors to signal degradation:
  - Insertion Loss
  - Cross Talk
  - Reflections

3 meters

Extra distance

- So What Is Type-C?



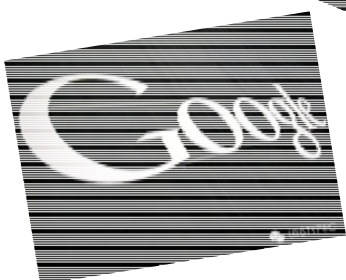
"This next generation of USB technology opens the door for the invention of an entirely new, super thin class of devices that consumers haven't even seen yet"

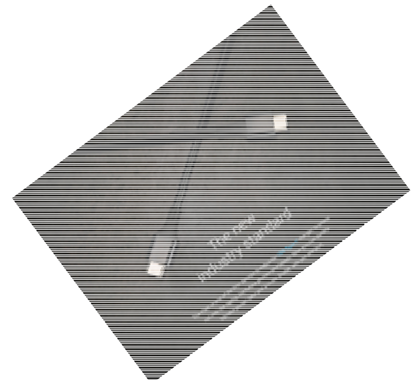
USB 3.1

SUPERSPEED+ CERTIFIED USB 10Gbps

- *Designed for 10,000 plug/unplug cycles*
- *Robust enough for laptops and tablets; slim enough for mobile phones*

- Apple, Google, Microsoft…

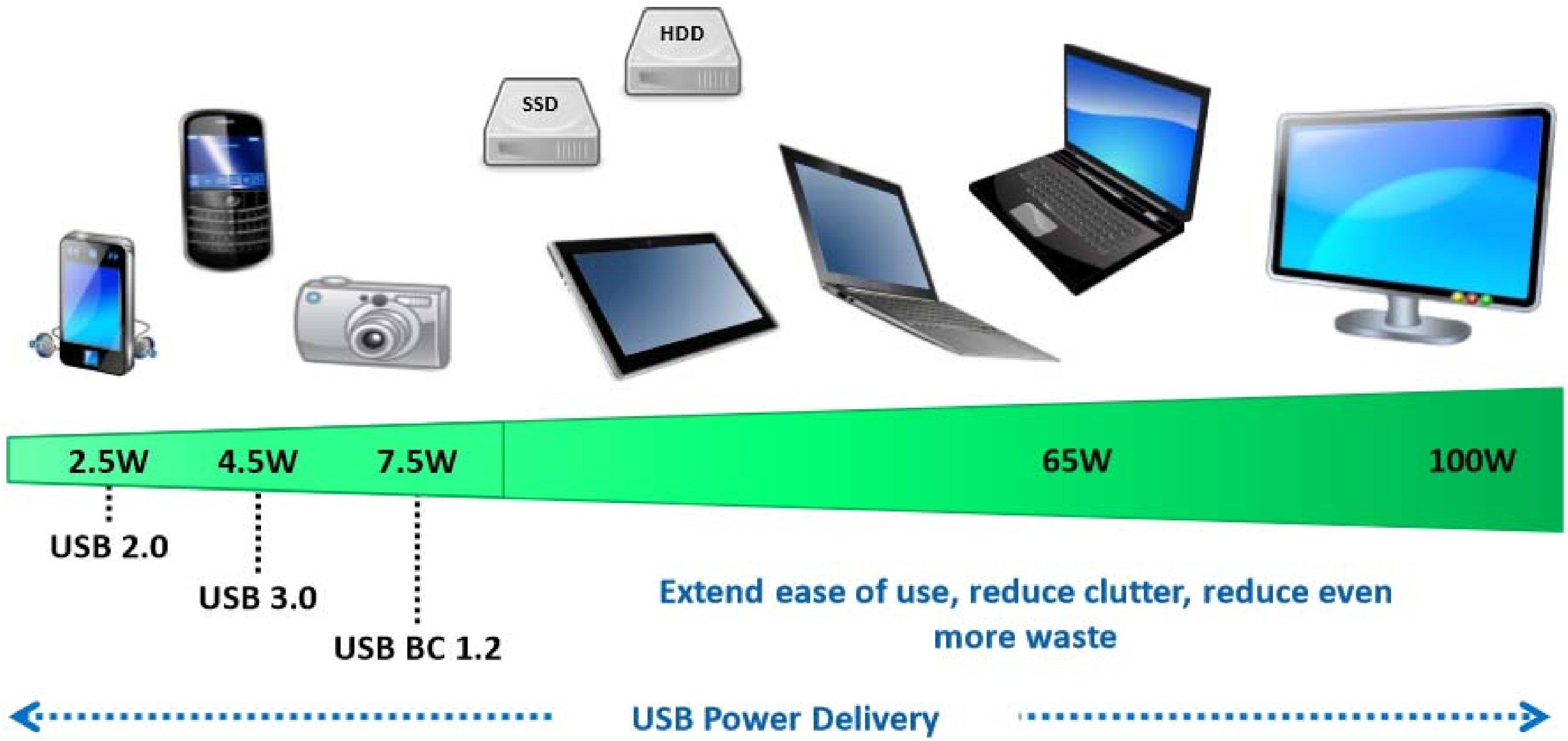




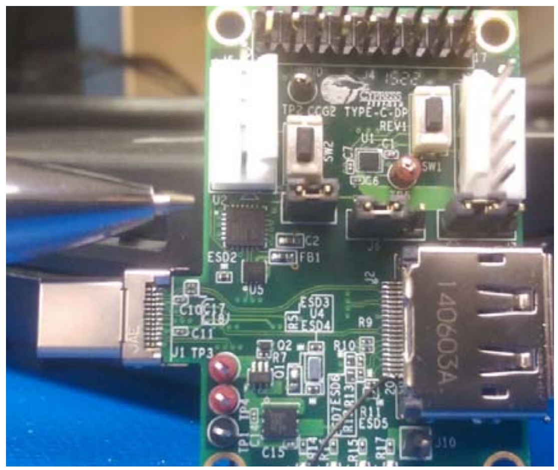
- USB Power Delivery Profiles

PDP (W)	Current at 5V (A)	Current at 9V (A)	Current at 15V (A)	Current at 20V (A)
$0.5 \le x \le 15$	$x \div 5$			
$15 < x \le 27$	3	$x \div 9$		
$27 < x \le 45$	3	3	$x \div 15$	
$45 < x \le 60$	3	3	3	$x \div 20$
$60 < x \le 100$	3	3	3	$x \div 20$[1]
[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

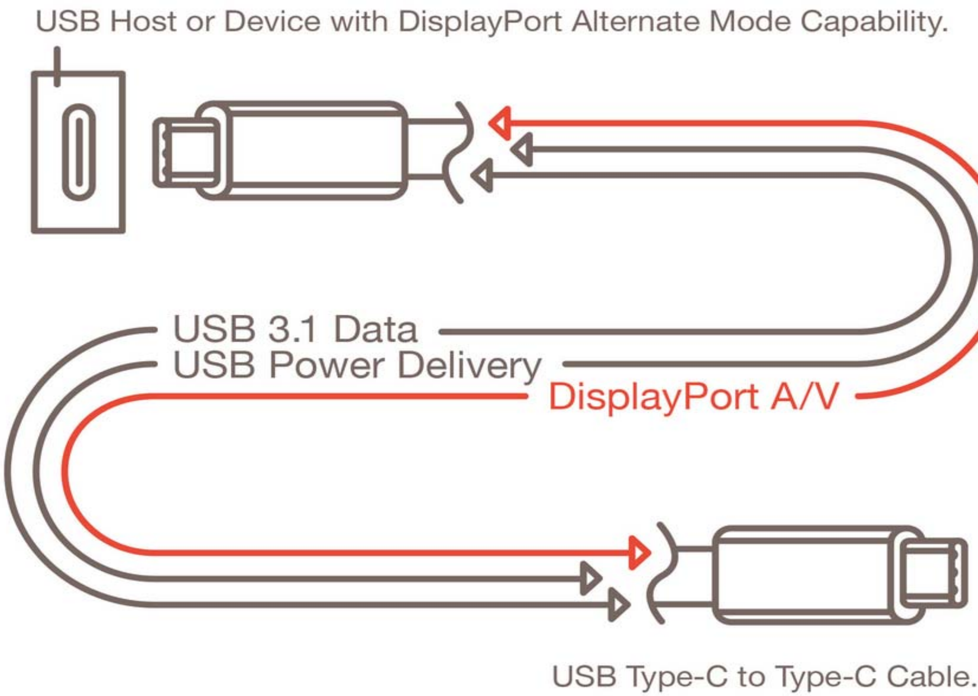

HDD
SSD
2.5W
4.5W
7.5W
65W
100W
USB 2.0
USB 3.0
USB BC 1.2
Extend ease of use, reduce clutter, reduce even more waste
USB Power Delivery

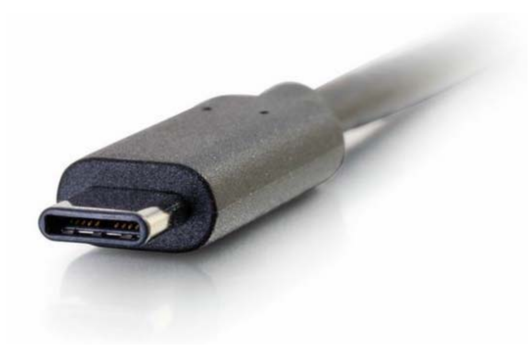
- E-Markers and Billboards



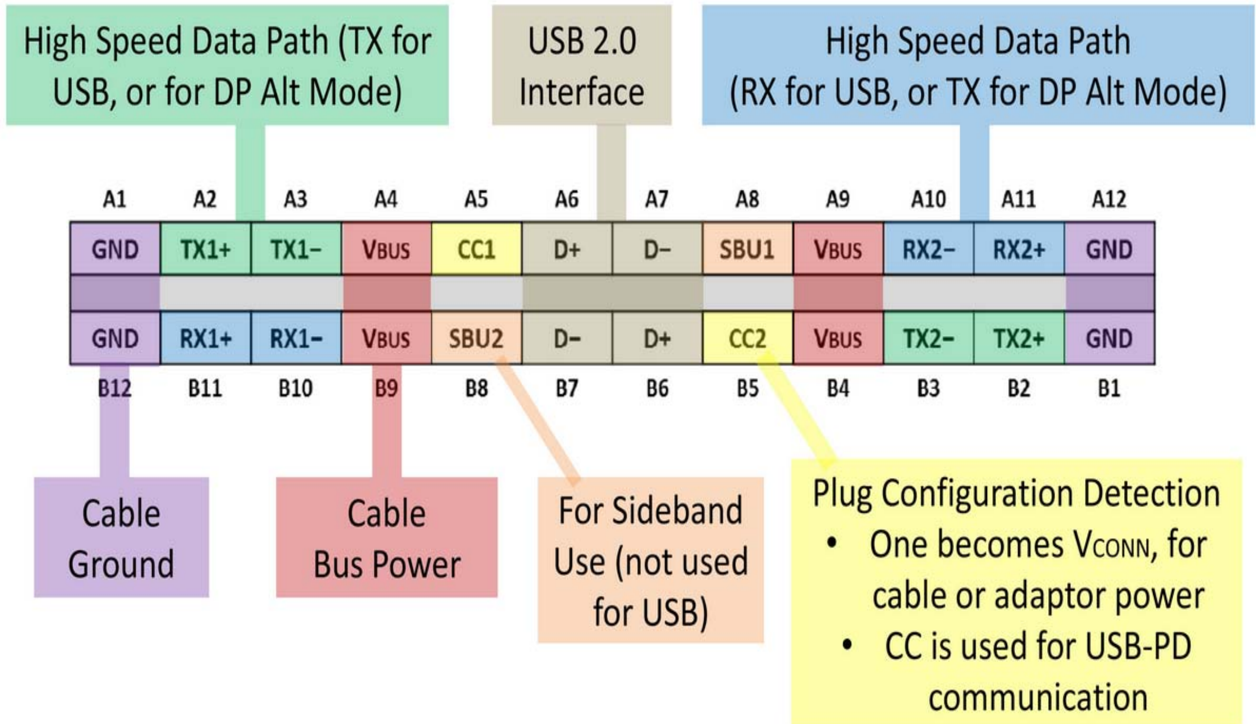
- EMCA stands for the Electronically Marked Cable Assembly
- E-marking/EMCA is required under the following conditions:
  - USB-C cable is required to support more than 3A current (more than default)
  - USB-C cable is a full featured cable, cable supports either USB 3.1 Gen1 or USB 3.1 Gen2 signaling
- USB-C cable malfunction prevention
  - Authentication

- What Does It Do?



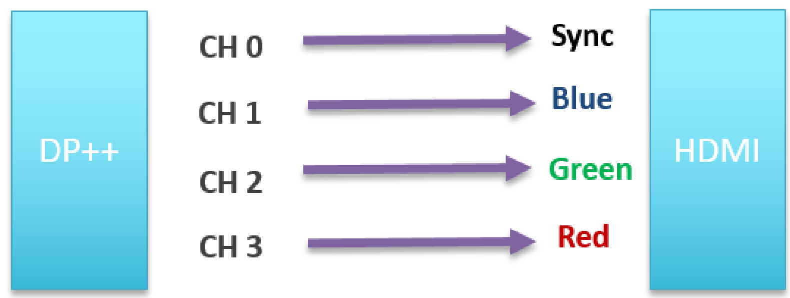


- Type-C Pin Out

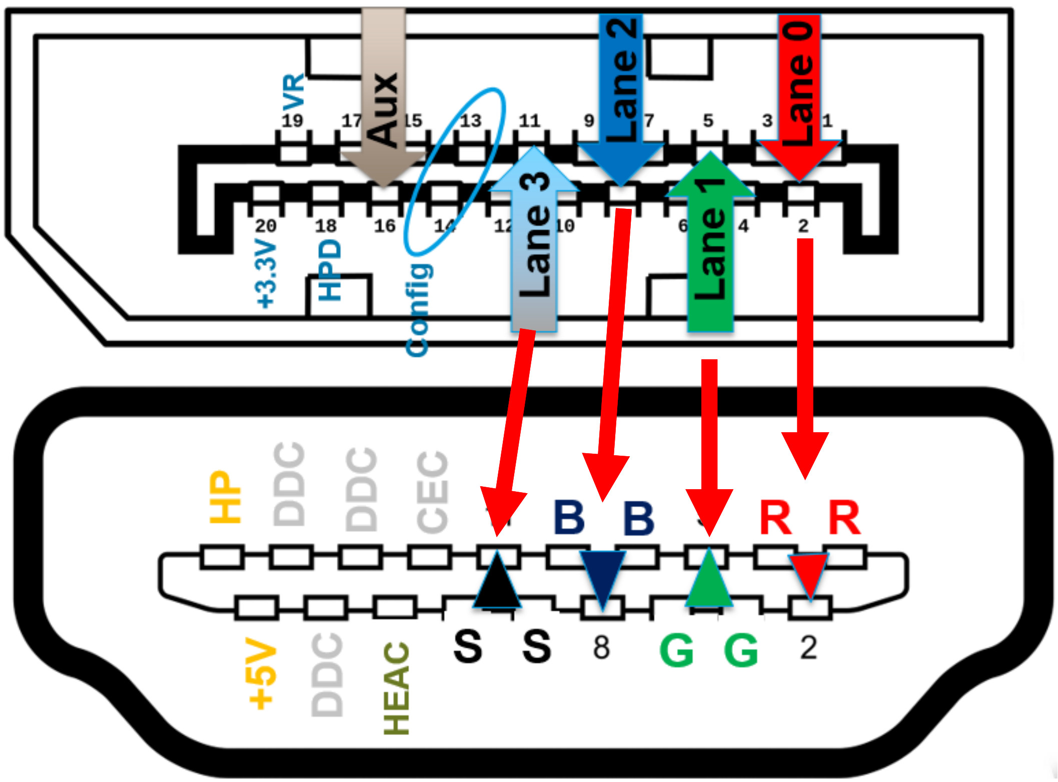


• DisplayPort 1.2a and Dual Mode/DP++

- 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

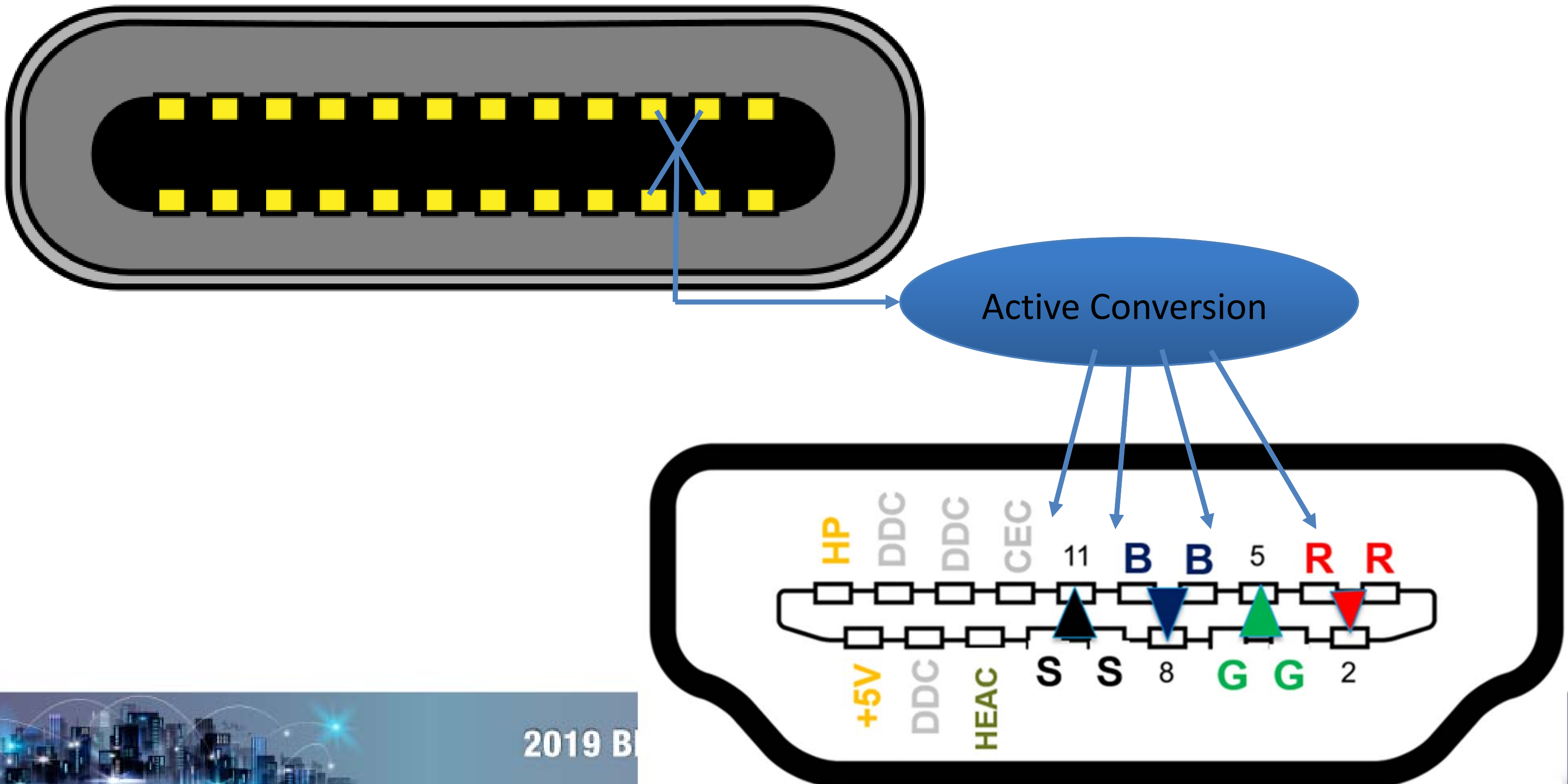


•However, DisplayPort 1.2a and not DP++ is embedded in USB Type-C!



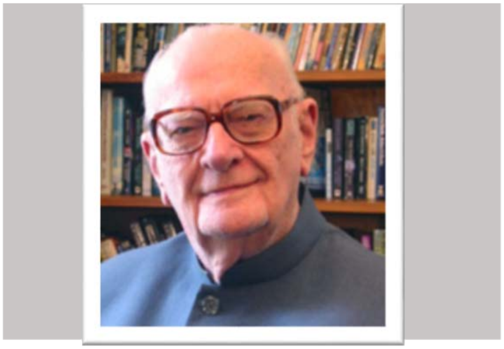
The difference between DP1.2a Standard and the DP++ option is the ability of the later to "speak" to an HDMI display without the need for active circuitry

- USB Type-C Leverages DP 1.2a



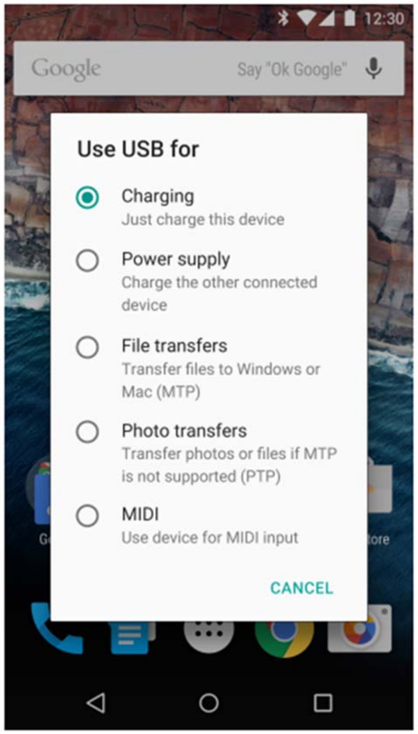
What Is Alternate Mode?

"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

Local Extender　　Remote Extender

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

Local Extender　　Remote Extender

Summary of Features

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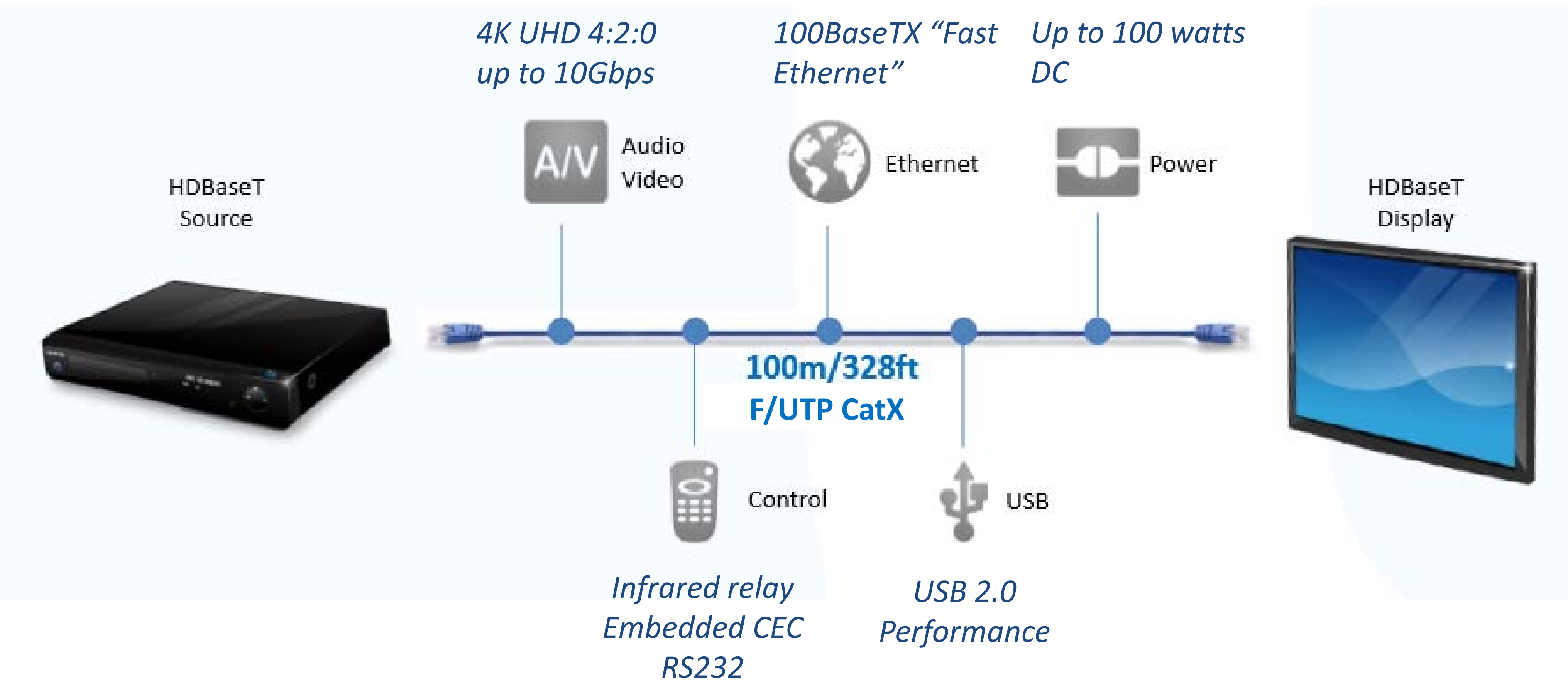
Understanding HDBaseT

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)

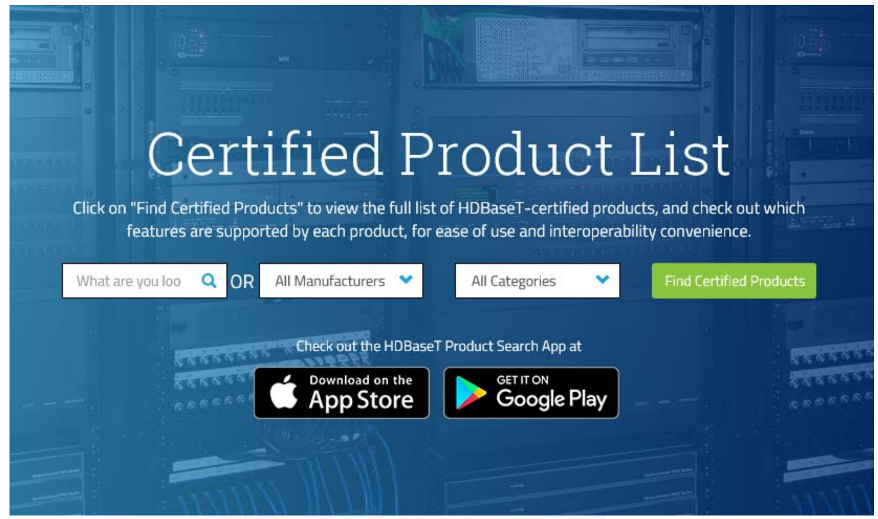
- 1911.1 "a connectivity standard which consolidates…HDCP, uncompressed, multimedia, bidirectional data over standard CAT5e/6 structured cabling. The scope of the HDBaseT specification version 1.1.0 is *to specify the HDBaseT link between HDBaseT Source Port device and HDBaseT Sink Port Device*. Devices 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.

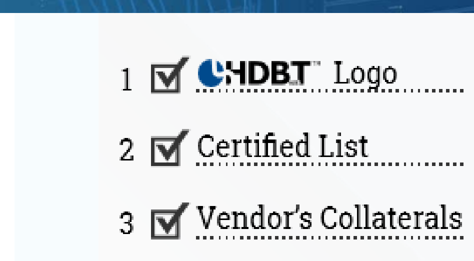
HDBaseT 5Play™



HDBaseT Interoperability

- 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!*





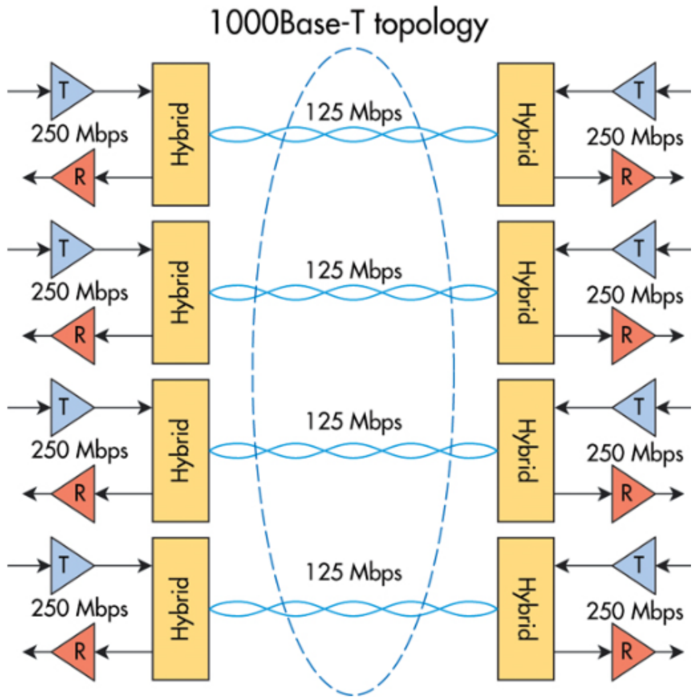
What payload does HDBaseT actually send through the wire?

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

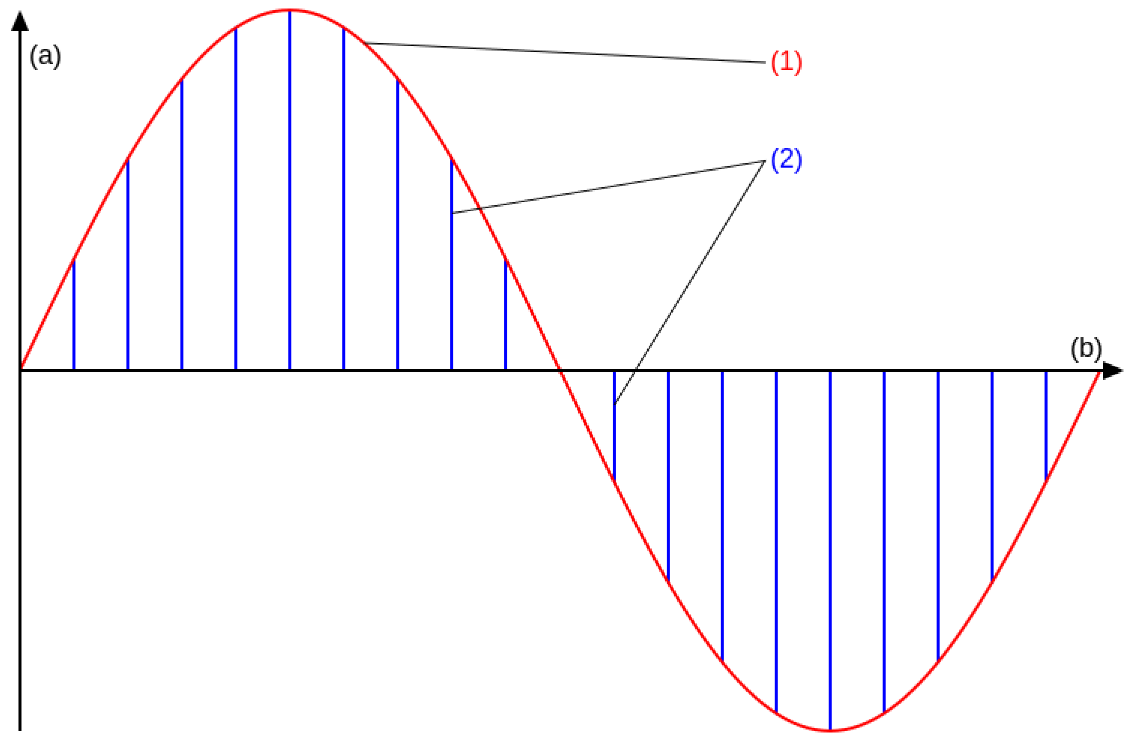
  Frequency-Shift Keying (FSK)

  Phase-Shift Keying (PSK)

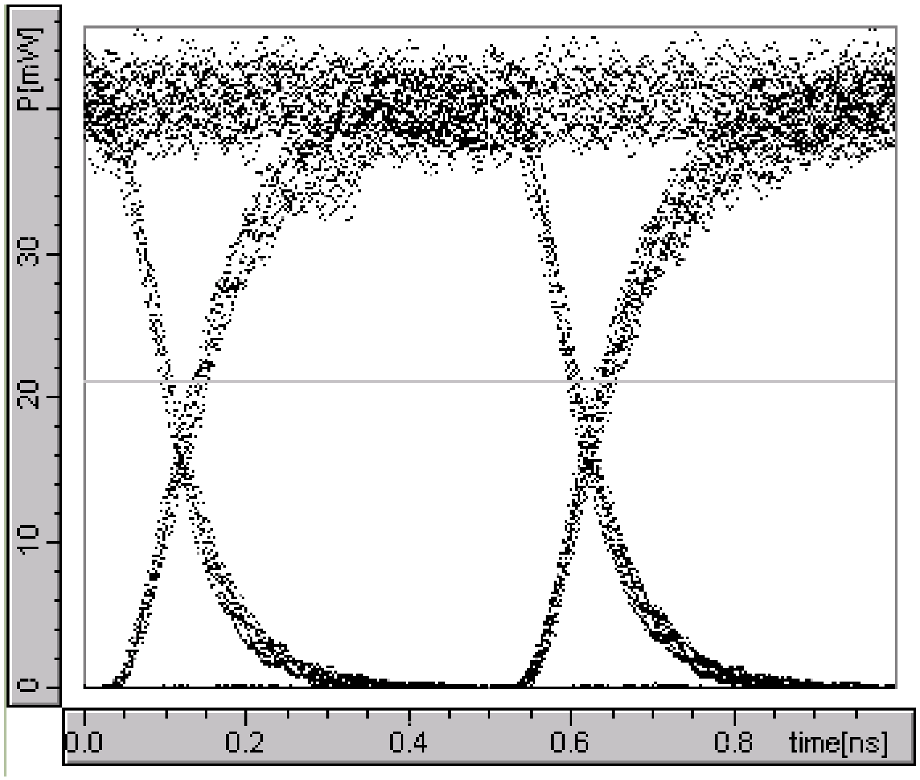
  Quadrature Amplitude Modulation (QAM)

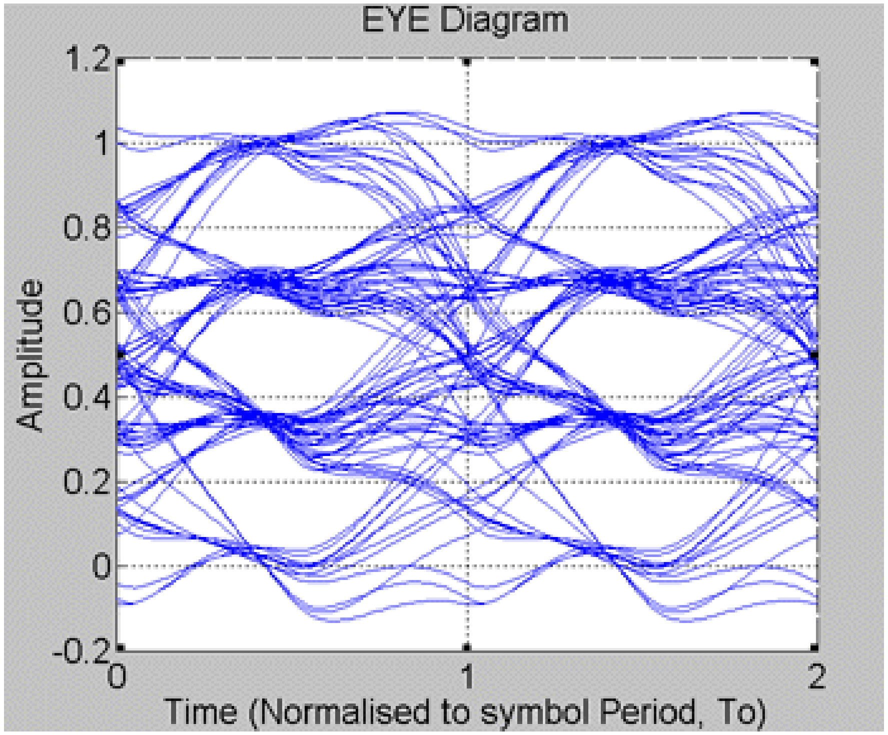
Pulse Amplitude Modulation

- 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 its even used for LED lighting control!



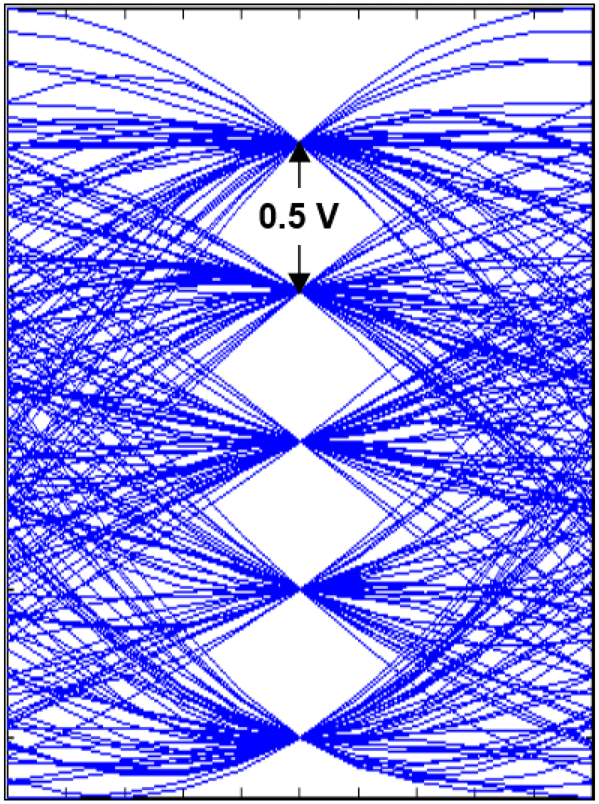
Multi-Level Signaling in PAM





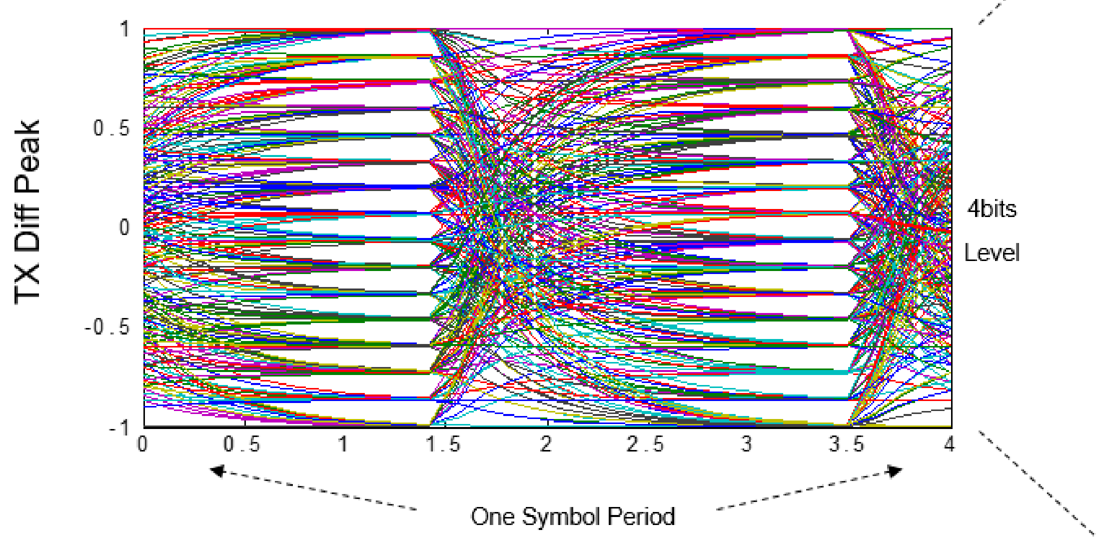
Gigabit Ethernet Uses PAM-5

- 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

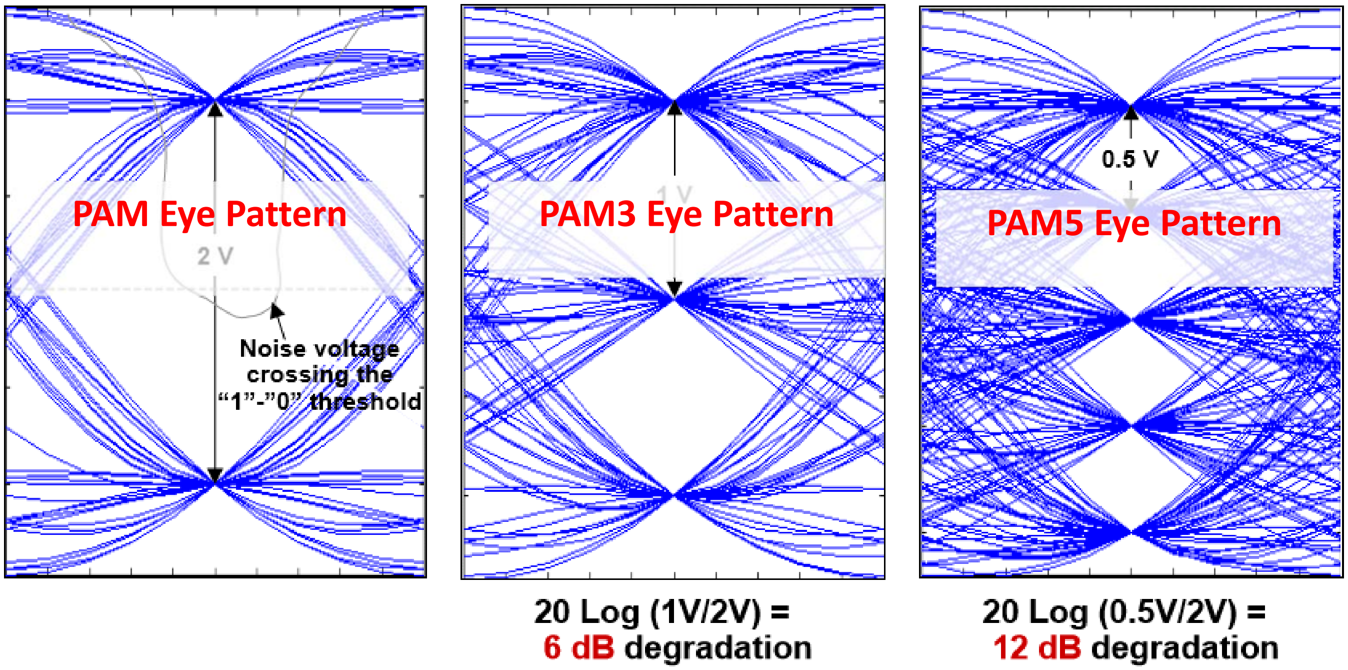
HDBaseT uses PAM16 - each symbol is transmitted using one of 16 discrete, differential voltage levels = 2^4 symbols



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

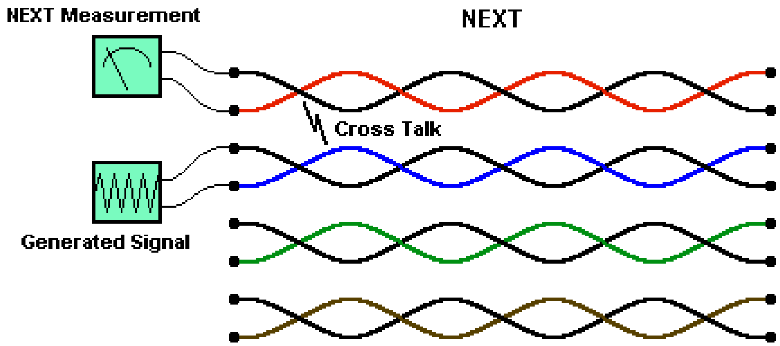
Everything Comes At A Cost

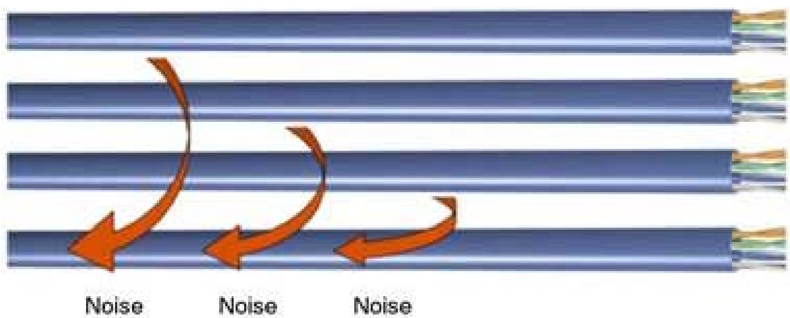


- The disadvantage of increasing bit rate by using multilevel modulation is that the receiver has to distinguish many levels (symbols) from each other

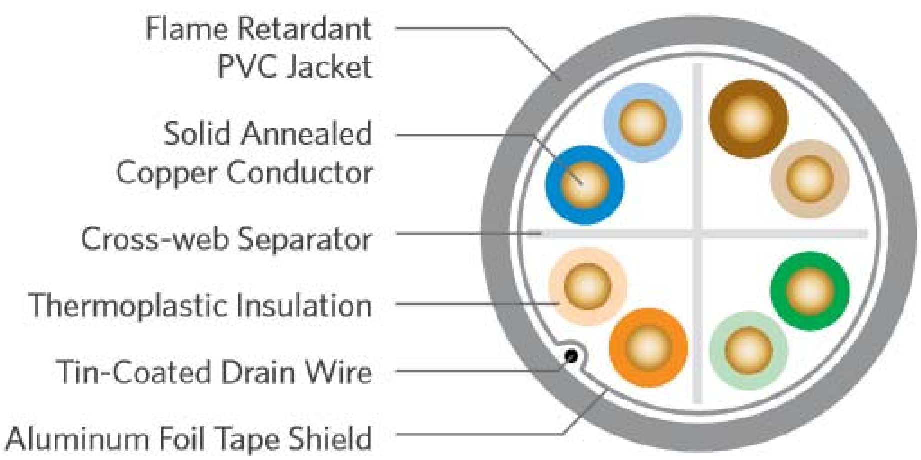
Physical Layer Considerations

- 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

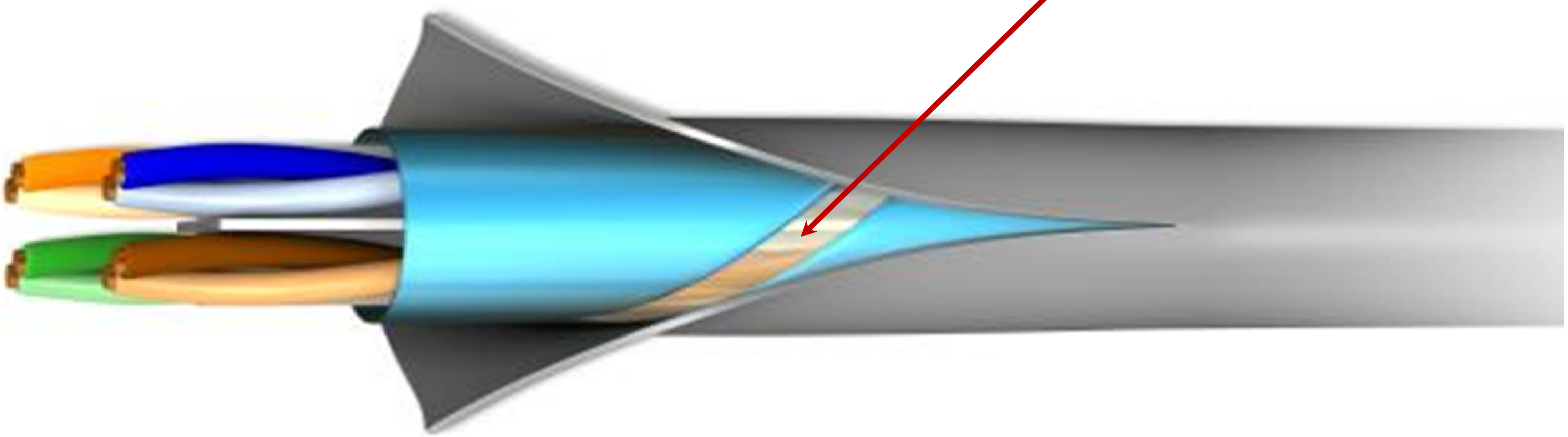


SPECIFICATIONS	
Configuration	Copper pairs surrounded by aluminum PET foil with an outer drain wire and jacket
Pair Count	4
Conductor	Solid annealed copper
AWG (mm)	23 (0.57)
Insulation	CMR: Thermoplastic CMP: FEP
Insulation Colors	Pair 1: ColorTip Light Blue, Blue Pair 2: ColorTip Light Orange, Orange 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

Air Gap Shield =
No Grounding, No Bonding

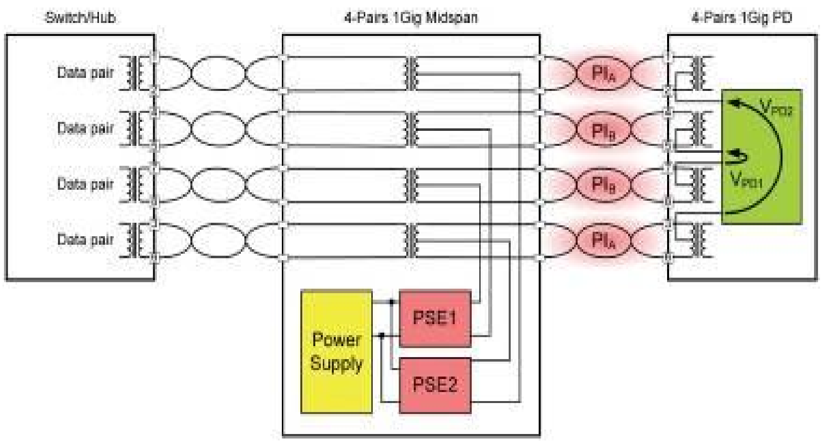


Segmented shield can provide protection similar to continuous shield

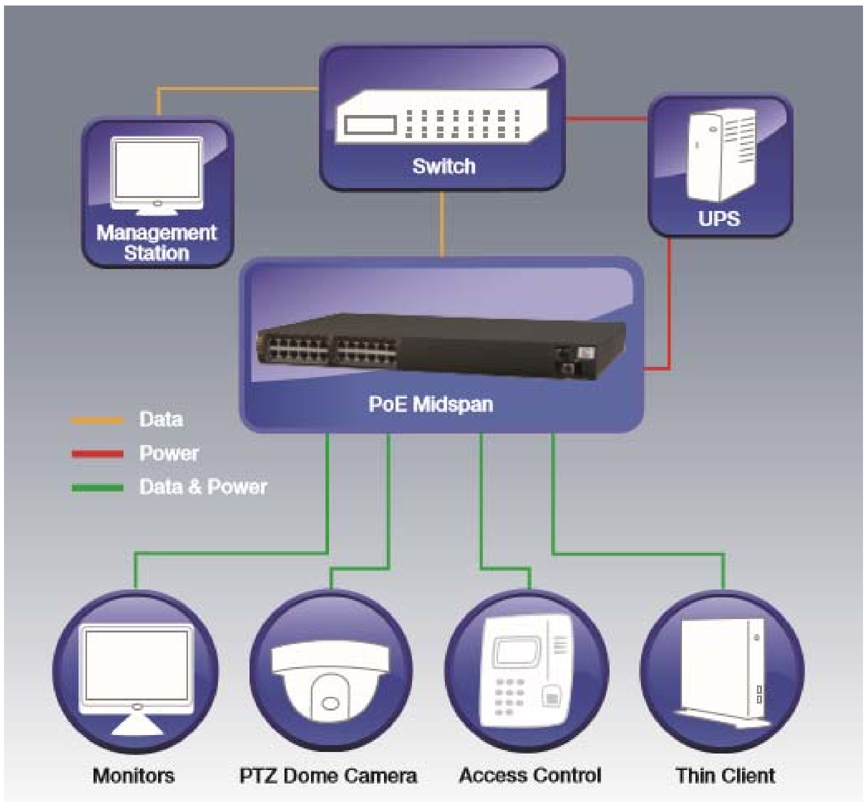
Example – HDBaseT Certified Superior Essex Category 10Gain® XP CAT 6A U/UTP

Power Over HDBaseT - PoH

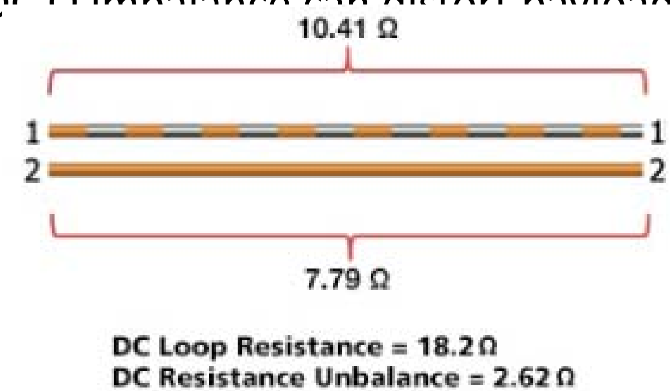
- PoH is based on the IEEE 802.3at-2009 POE+
- 50- to 57-volt DC over four pairs
  - 1000mA per two-pairs
- Instead of the powered device assuming worst-case cabling, POH allows the device itself to identify the cable length and draw more power as long as it does not exceed100W
- Backwards compatible 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^{o}C (140 ^{o}F) specified by TIA standards
- DC Ω imbalance can distort payload



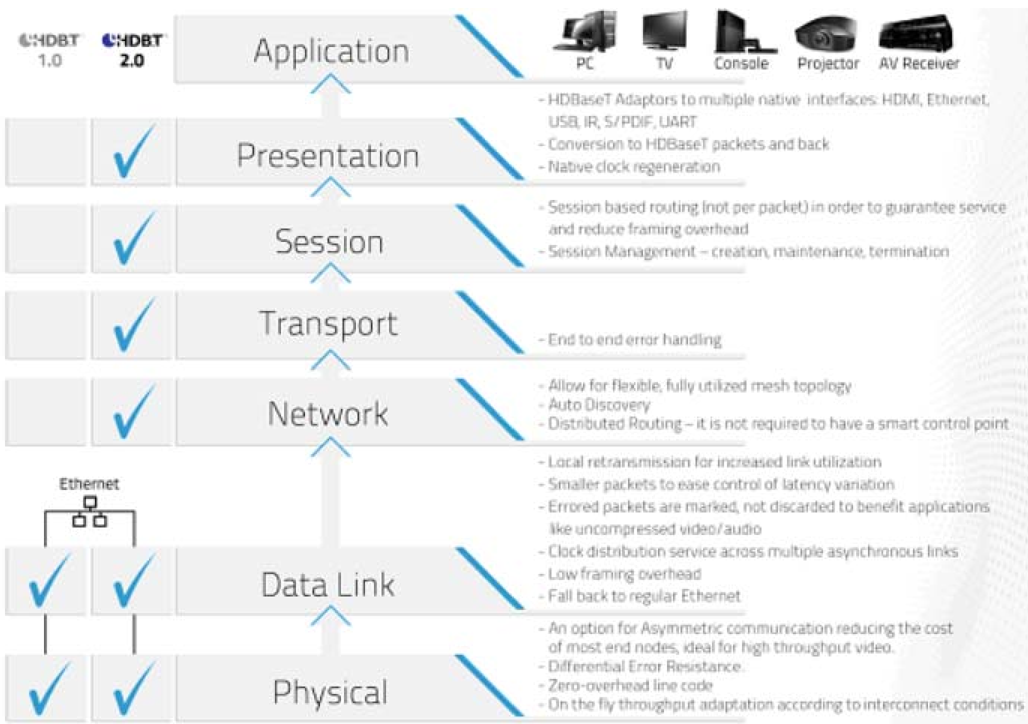
Highlights of HDMI 2.0

- 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

<table>
<tr><th></th><th>8bit</th><th>10bit</th><th>12bit</th><th>16bit</th></tr>
<tr><td>4K@24</td><td rowspan="3">RGB
4:4:4</td><td rowspan="3">RGB
4:4:4</td><td rowspan="3">RGB
4:4:4
4:2:2</td><td rowspan="3">RGB
4:4:4</td></tr>
<tr><td>4K@25</td></tr>
<tr><td>4K@30</td></tr>
<tr><td>4K@50</td><td rowspan="2">RGB
4:4:4
4:2:0</td><td rowspan="2">4:2:0</td><td rowspan="2">4:2:2
4:2:0</td><td rowspan="2">4:2:0</td></tr>
<tr><td>4K@60</td></tr>
</table>

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?

legrand

- 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

legrand

Understanding AV-over-IP

legrand

Thank you for participating in our first AV Transport Methods Master Class. Are there any questions about the material we've presented today?

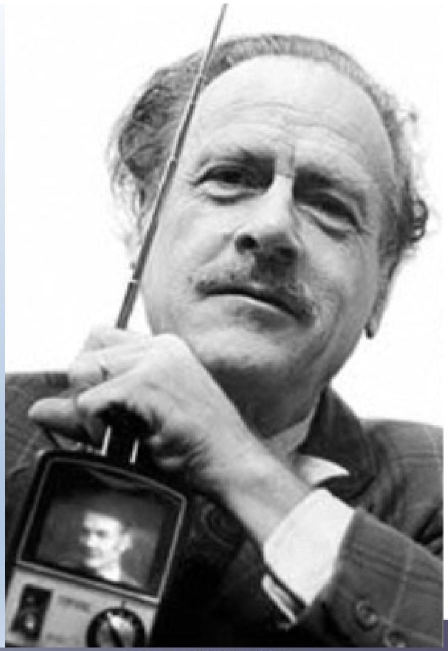
Course Follow-Up

- 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!