



4K, HDR

— Video Over IP & PTP

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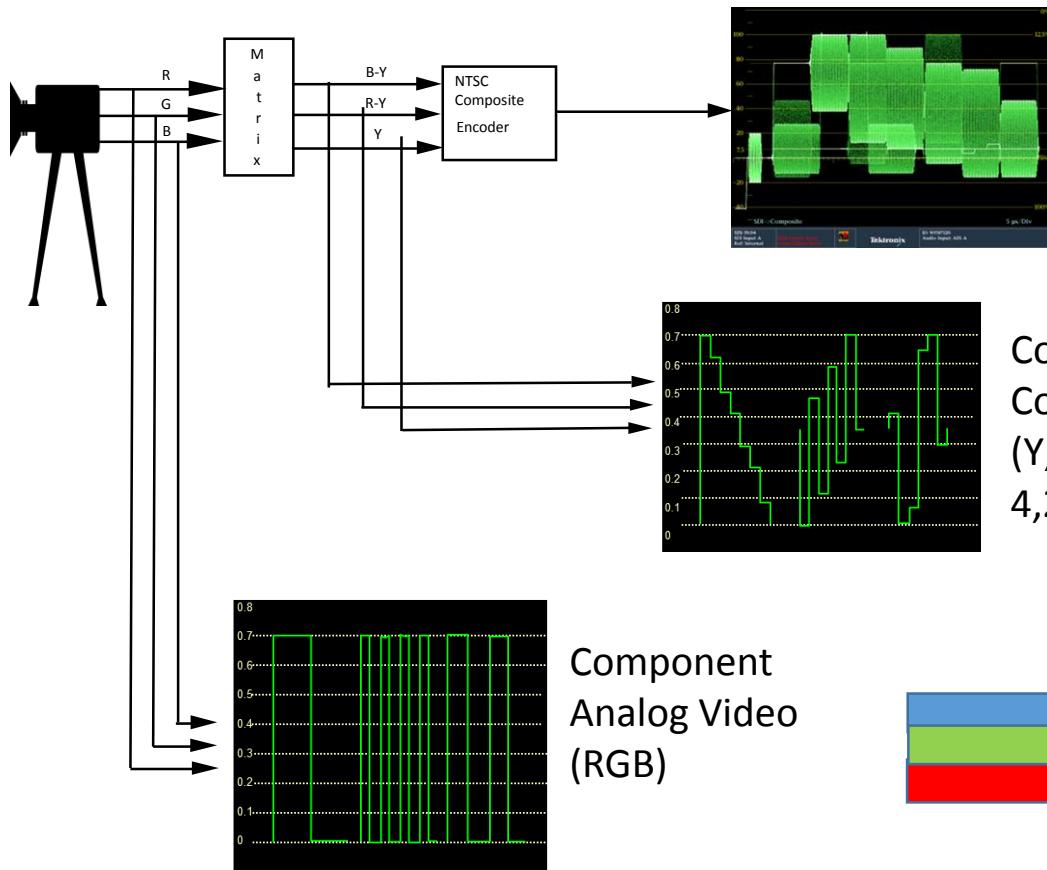
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The Industry is Used to Change

BUT NOT EVERYTHING AT ONCE

- Frame Rate
 - Some new TV can natively support up to 240 FPS
- Resolution
 - UHD and 4K even 8K
- Interlace or progressive
 - Hopefully we are moving to Progressive
- Color space
 - 709, P3 and 2020
- Dynamic Range
 - SDR and HDR
- Video Interfaces
 - SDI changing to IP
- Reference
 - Moves from pulses to time as reference

Television Signal Formats



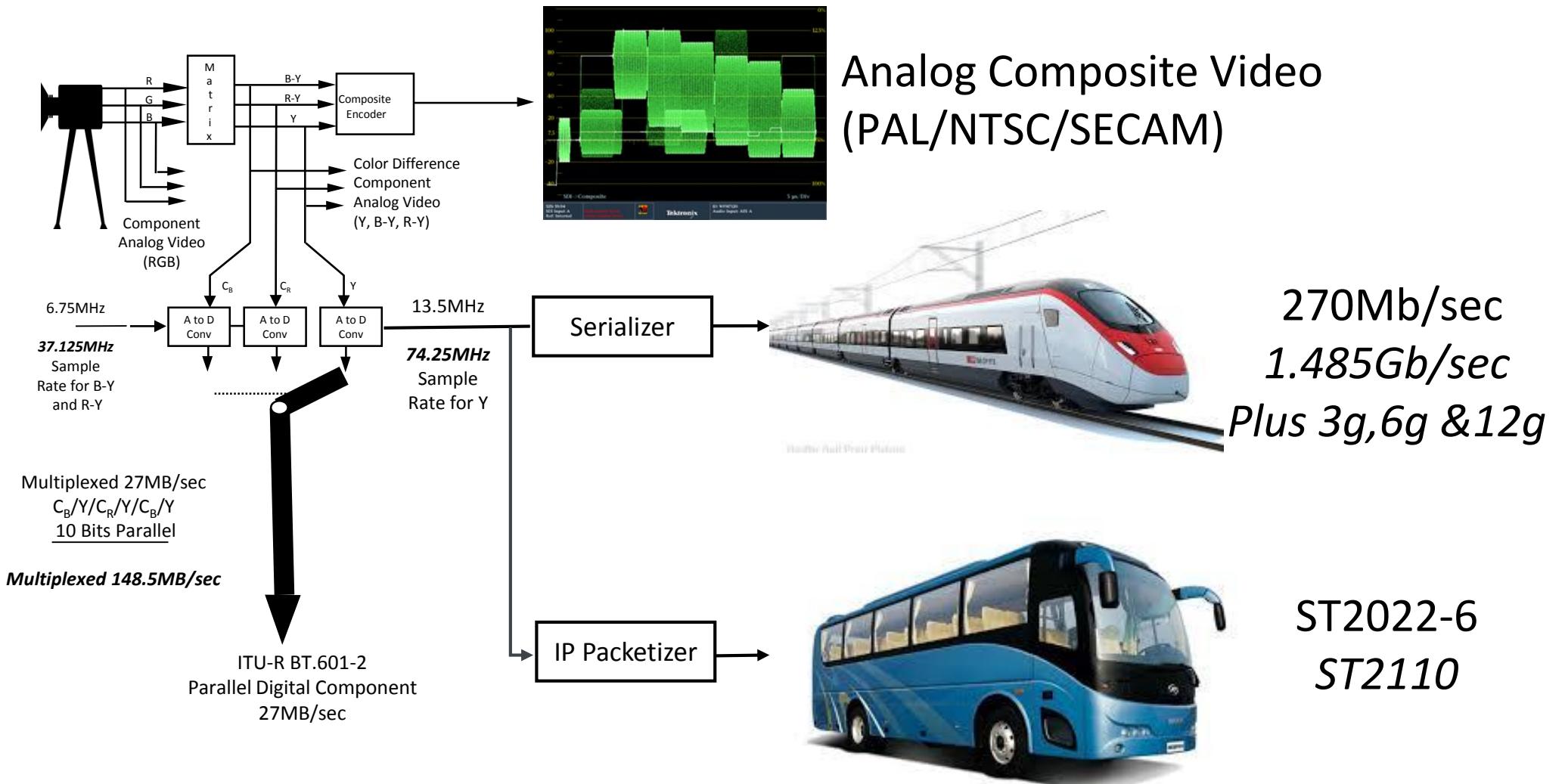
Analog Composite Video
(PAL/NTSC/SECAM)

Color Difference
Component Analog Video
(Y, B-Y, R-Y)
4,2,2 sampling

Component
Analog Video
(RGB)

Y is Created from RGB
The Approx. mix is
59% is Green
30% is Red
11% is Blue

Video I/Os



Will need not only deal with the travel distance
But will also with varying traffic conditions.

The Transition To IP Is Not New

- Video distribution began the transition from ASI to TS over IP almost 15 years ago
- IT technology enabled the transition to file-based workflows over 10 years ago
- Production is the last remaining stronghold for SDI

IP Video

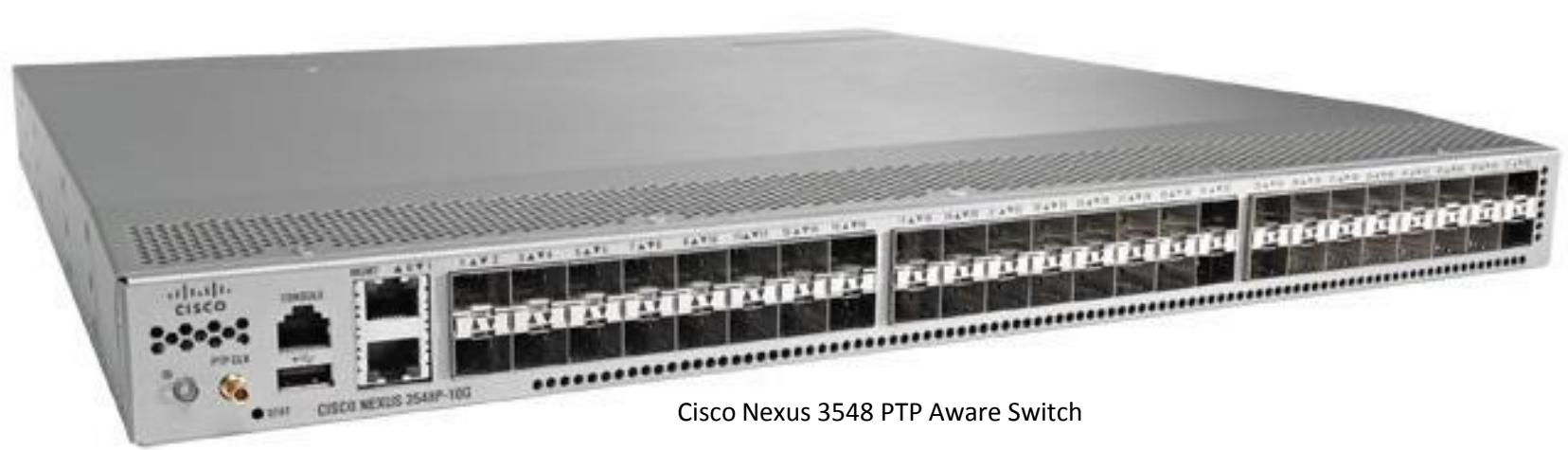
- There are different types of IP video
 - Compressed and Uncompressed
- Compressed
 - SPTS (single program transport stream)
 - MPTS (multiple program transport stream)
 - J2KTS
- Lightly Compressed
 - JPEG 2000 (not in a Transport stream)
- Uncompressed
 - SDI over IP
- Point to point SDI over Fiber is not IP
 - SMPTE 297- A

Why Video over IP?

- Can use IT-based COTS (commercial off-the-shelf) equipment
 - Economy of scale
 - Reduced cabling cost and weight
- Much greater flexibility provided by IP routing & networking versus SDI routing & networking
- Enabler for new workflows such as centralised/downstream production
- All-IP networks could enable new content and related sources of revenue
- Scalable - 400G Ethernet under development
 - Scalability driven by bandwidth not ports

What Are The Challenges of Using IP?

- Latency
- Jitter
- Dropped Packets
- Asynchronous
- Asymmetric
- A complex bi-directional set of protocols that requires knowledge of both the source and destination to deploy



Cisco Nexus 3548 PTP Aware Switch

All are surmountable

Trading floor switches deliver latencies <250nS



4K and HDR

17 SEPTEMBER 2017



Motivation for the 4K Digital Conversion

- *35 mm Film Process:*
- **35mm film can distribution**
 - Expensive (\$1,200 per screen)
 - Slow
 - Inflexible
 - Manual process for assembling shows
- Studios spend **\$2 - \$3 billion per year** on release prints
- 4K emulates the resolution of 35mm Film
- 2K emulates the resolution of 16mm Film
- Film prints get scratched and dirty after only a few plays, 4K D Cinema keep a pristine image at all times.



4K Formats Market Drivers for Broadcast

- Ability to Pan and Scan
- Region of Interest to 1080
- Red Zone Full Coverage
- Virtual Camera Fly Around
- Seamless Stitch Together
- Reverse Angle
- Replay Extreme Zoom
- Remote Camera Operation

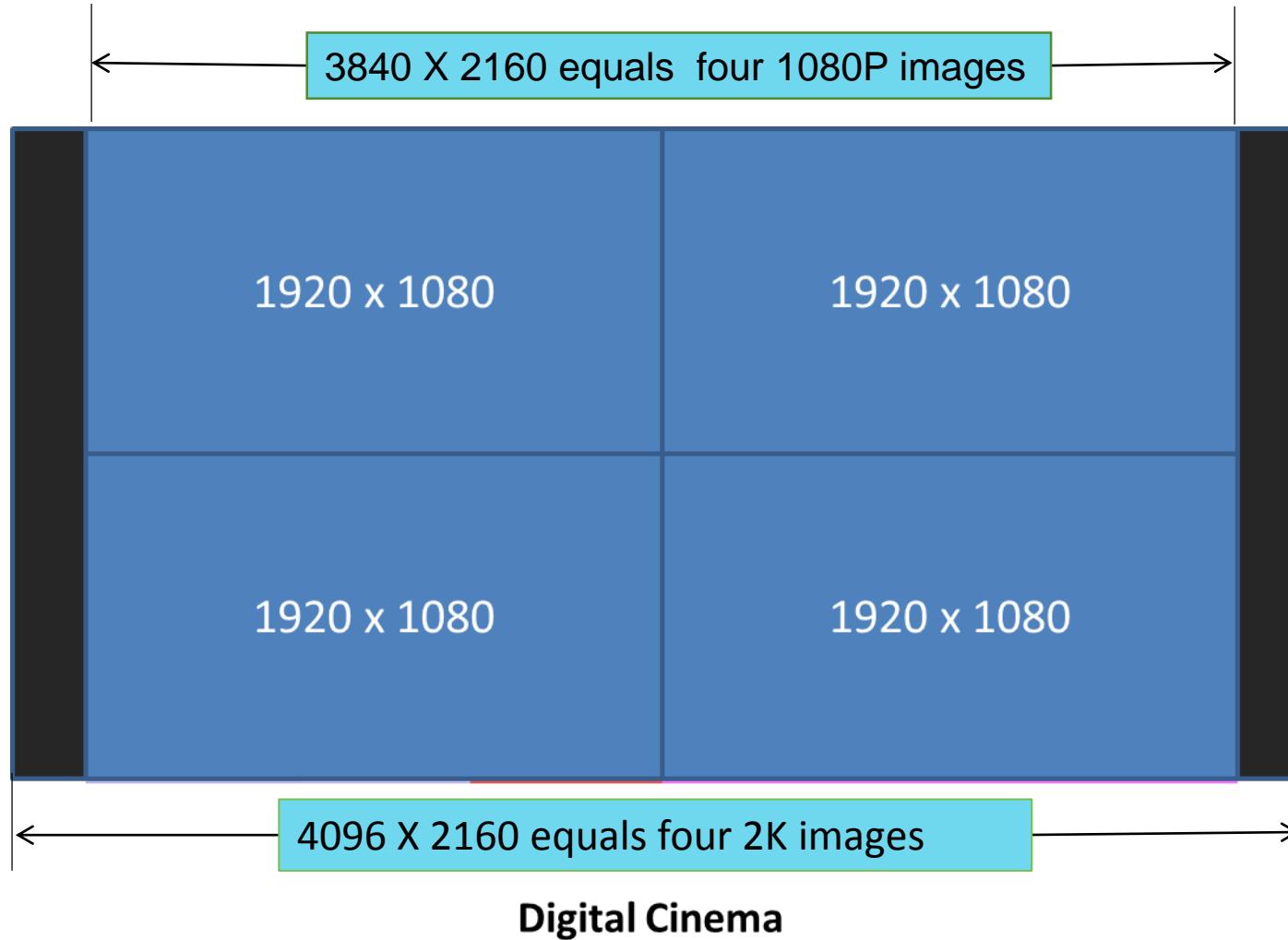


Image Sizes



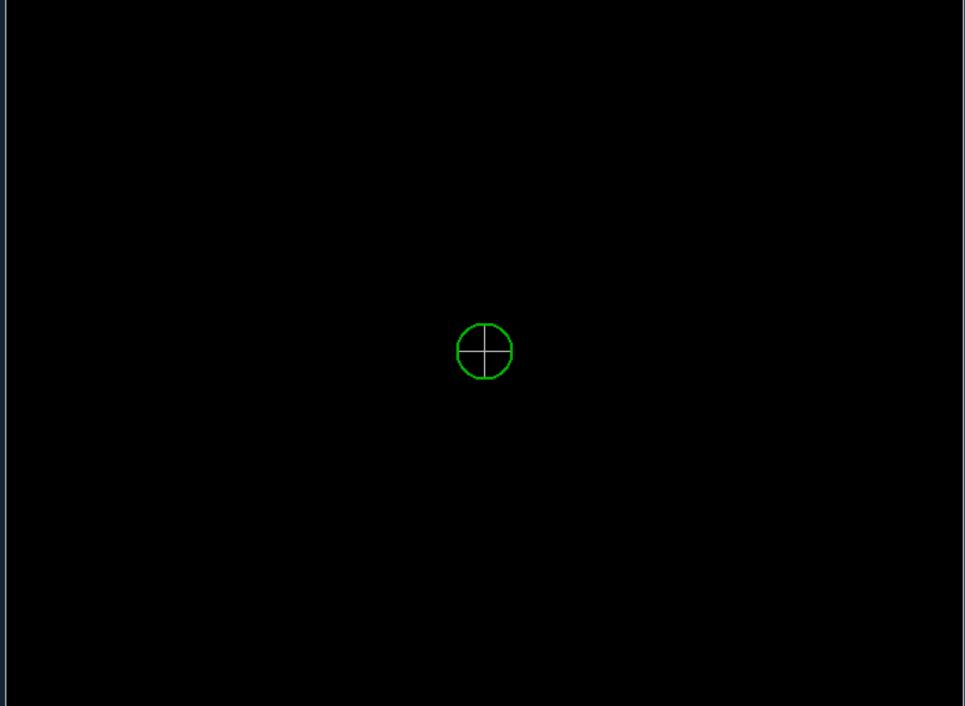
Quad SDI approach

- In SDI we break the screen into 4 quadrants using 3gig per Quadrant



Inter Link Timing

Input Timing To External Reference



Vertical Offset:
Internal Reference

Horizontal Offset:
Internal Reference

Relative to:
Analog(DAC)

Link B to Link A:
26.962 ns delayed
4 clocks delayed

Link C to Link A:
20.222 ns delayed
3 clocks delayed

Link D to Link A:
26.962 ns delayed
4 clocks delayed

Circle will be in the center when input timing matches the Reference

3840X2160p 59.94
SDI In Quad-3Ga
Ref: Internal

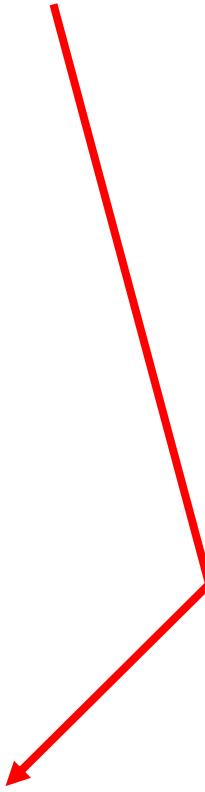
Mar 18 10:04:07

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ID: WFM8300_212607
Emb: PPPP PPPP PPPP PPPP -----
Anc LTC: 01:00:00:00 30 fps Still

Inter Link Timing

Big gap between bottom left and bottom right?

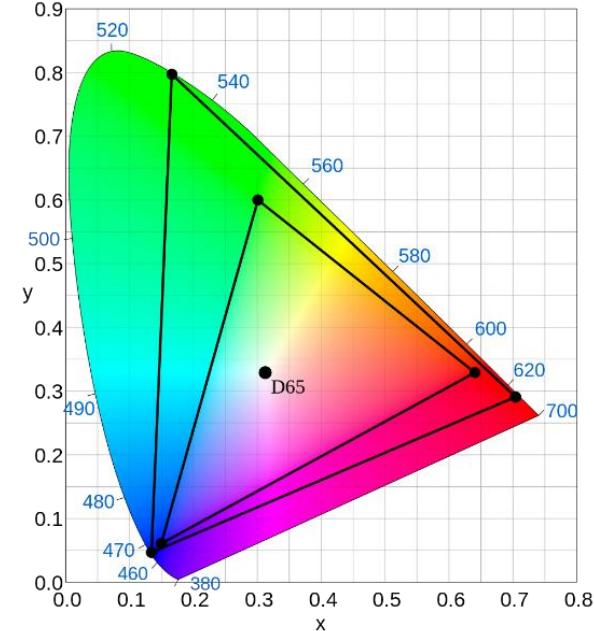


Ultra HD- Aimed at Consumer Television

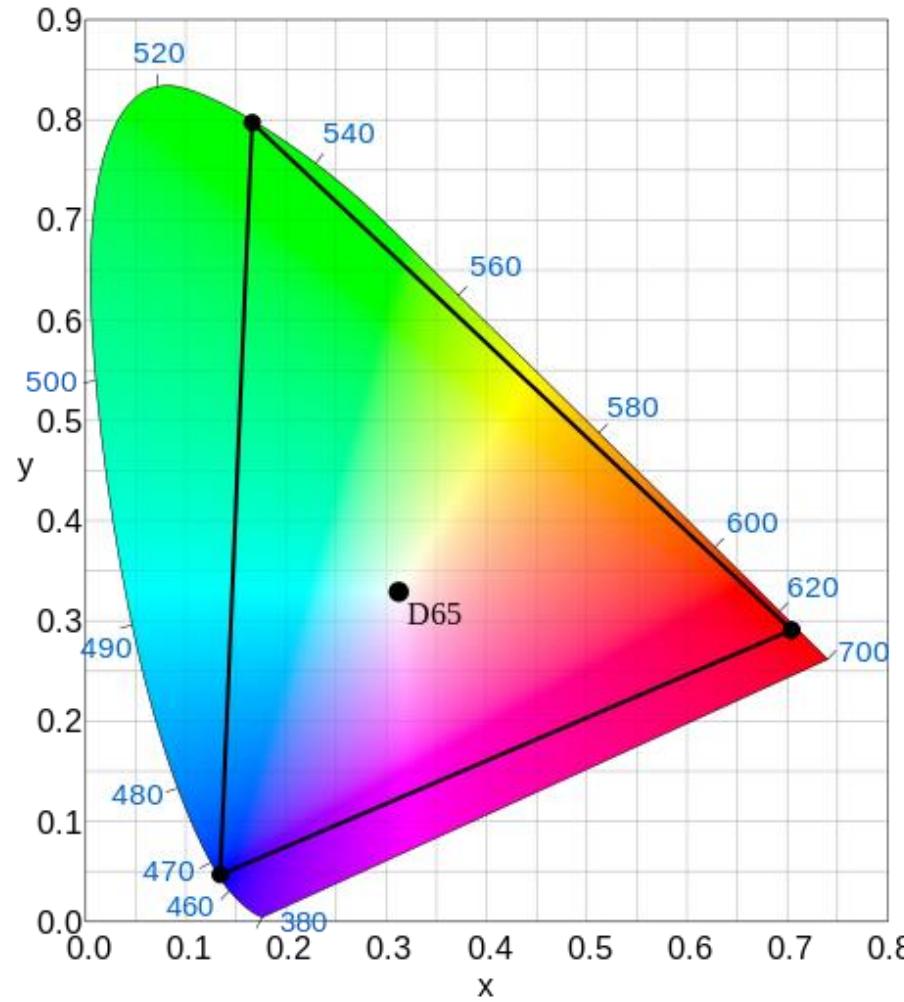
- 4K - 3840×2160 16:9 8.3M Pixels
- Has twice the resolution of the 1080p with four times as many pixels
- 8K- 7680×4320 16:9 33.2M Pixels.

Rec. 2020

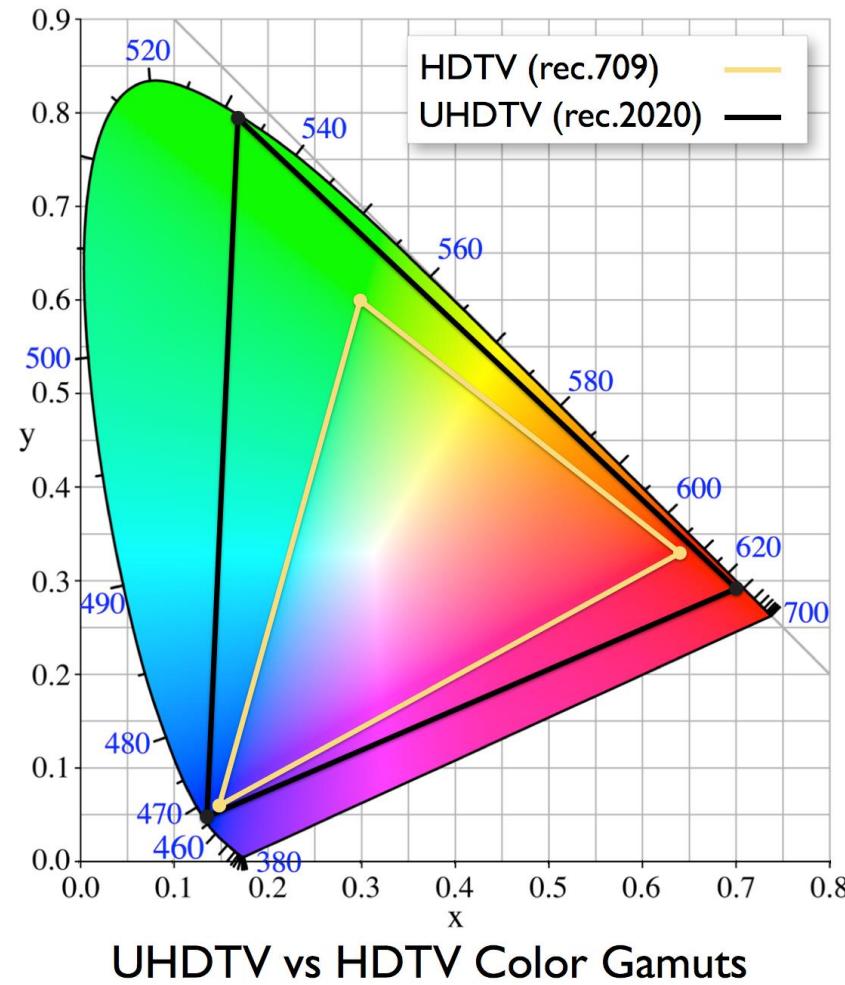
- Defines two resolutions of 3840×2160 and 7680×4320 .
- Defines a bit depth of either 10-bits per sample or 12-bits per sample
- Specifies the following frame rates: 120p, 119.88p, 100p, 60p, 59.94p, 50p, 30p, 29.97p, 25p, 24p, 23.976p.
- Only progressive scan frame rates are allowed.



Rec 2020 Color



Rec 2020 and Rec 709 overlay





HDR,
Who's, How



DSLR HDR

Over exposed



Under exposed



Combined



HDR what is it?

- There are two parts to High Dynamic Range (HDR) the Monitor (Display) and the Camera (Acquisition)
- In the Monitor it is trying to get the display to have the range of the material presented to it. Not just making things brighter with no more resolution of what is being shown. But brighter with more resolution.
- In the Camera it is trying to get many more ‘F’ stops, wider dynamic range with the data for that range.
- SDR is Standard Dynamic Range
- Sometimes there is a tendency to try and raise the diffuse white point too high and the pictures look washed out and too bright.

HDR is not High brightness

- Its High Dynamic Range
High brightness (high contrast)



High Dynamic Range

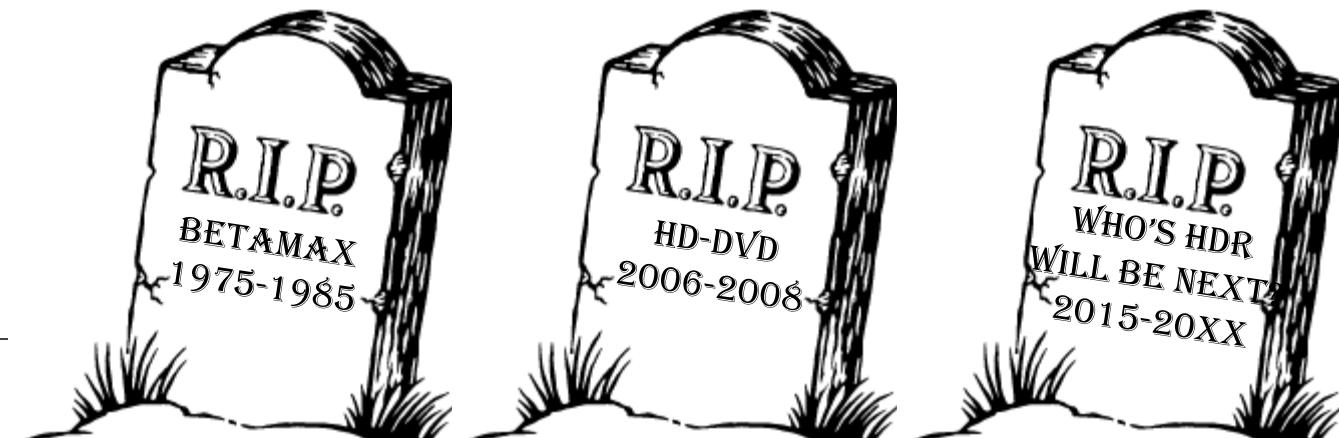
Who's HDR?

HDR FROM A DISPLAY PERSPECTIVE

- Canon
- Dolby, Philips, Hisense, Toshiba, and Vizio (ST2084)
- Sony
- Samsung
- LG
- Panasonic



- Well with Dolby and the TV giants, someone said "I smell format war."



Proposed HDR Formats

ROUGHLY IN ORDER OF POPULARITY

SMPTE ST.2084:2014 “Dolby Vision” with PQ encoding

- Perceptual Quantizer (PQ) based on Barten contour perception
- EOTF is inverse of OETF allowing .001 to 10K nits with 10-bits
- Current “Pulsar” display peaks at 4K nits, water-cooled, noisy fan, not for sale

Hybrid Log-Gamma, “HLG”, from BBC/NHK (ARIB STD-B67)

- Extends log processing (de-facto in many cameras) of high brightness peaks to mitigate blown-out or clipped whites
- Seamless “gamma” power-law processing in blacks as in BT.709/BT.2020 but without linear segment
- Displays can evolve to allow 400X to 800X increase in display brightness
- Allows display EOTF to adjust system gamma to correct for viewing environment

Philips / Technicolor Parameter-based from HDR master

- Embed low bit-rate HDR and SDR conversion parameters into metadata
- Extract parameters during decode and tune display for peak luma
- Optional Y'u'v' encoding (more perceptually uniform)

ULTRA HD PREMINUM

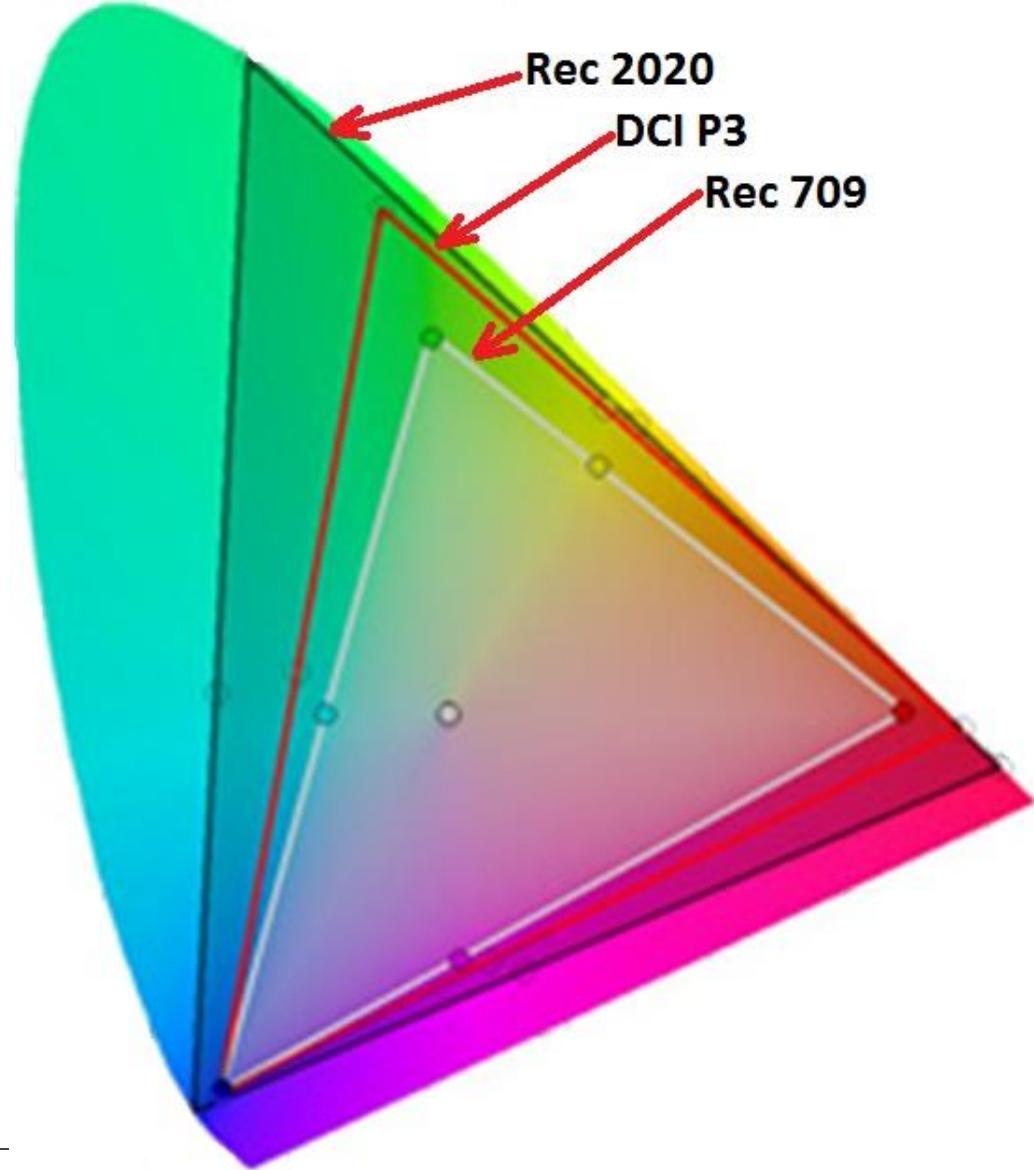
Is your 4K set ULTRA HD PREMINUM? It must carry the Logo and meet the standards below....



- **Minimum resolution of 3,840 x 2,160** – The number of pixels that make up the TV's screen of 4K/Ultra HD TVs.
- **10-bit color depth** – This means that the TV must be able to receive and process a 10-bit color signal, Blu-rays use 8-bit color, which equates to just over 16 million colors. 10-bit color, often called 'deep color', contains over a billion colors. This doesn't mean the TV has to be able to display all those colors, only that it can process the signal. Most decent ones can, so there's no problem here.
- **Minimum of 90% of P3 color space** – DCI P3 Color Space is an RGB color space that was introduced in 2007 by the SMPTE.
 - What about Wide Color Rec 2020 color, it is 27% wider than P3.
- **Minimum dynamic range** – TVs must meet a minimum for the maximum brightness they can reach and the black level they can achieve.
 - **OPTION 1:** More than 1,000 nits peak brightness and less than 0.05nits black level
 - **OPTION 2:** More than 540 nits brightness and less than 0.0005 nits black level

Color Space DCI, 709, 2020

- 4K can use Rec 709, DCI P3, or Rec 2020.
- In SDR Translating from one color space to the next will automatically expand the colors due to the fact that SMPTE 100% levels of 3ACh is 100% of Rec-709, Rec-2020, and DCI-P3.
- It's the receiver that determines what the code value means.



HDR10

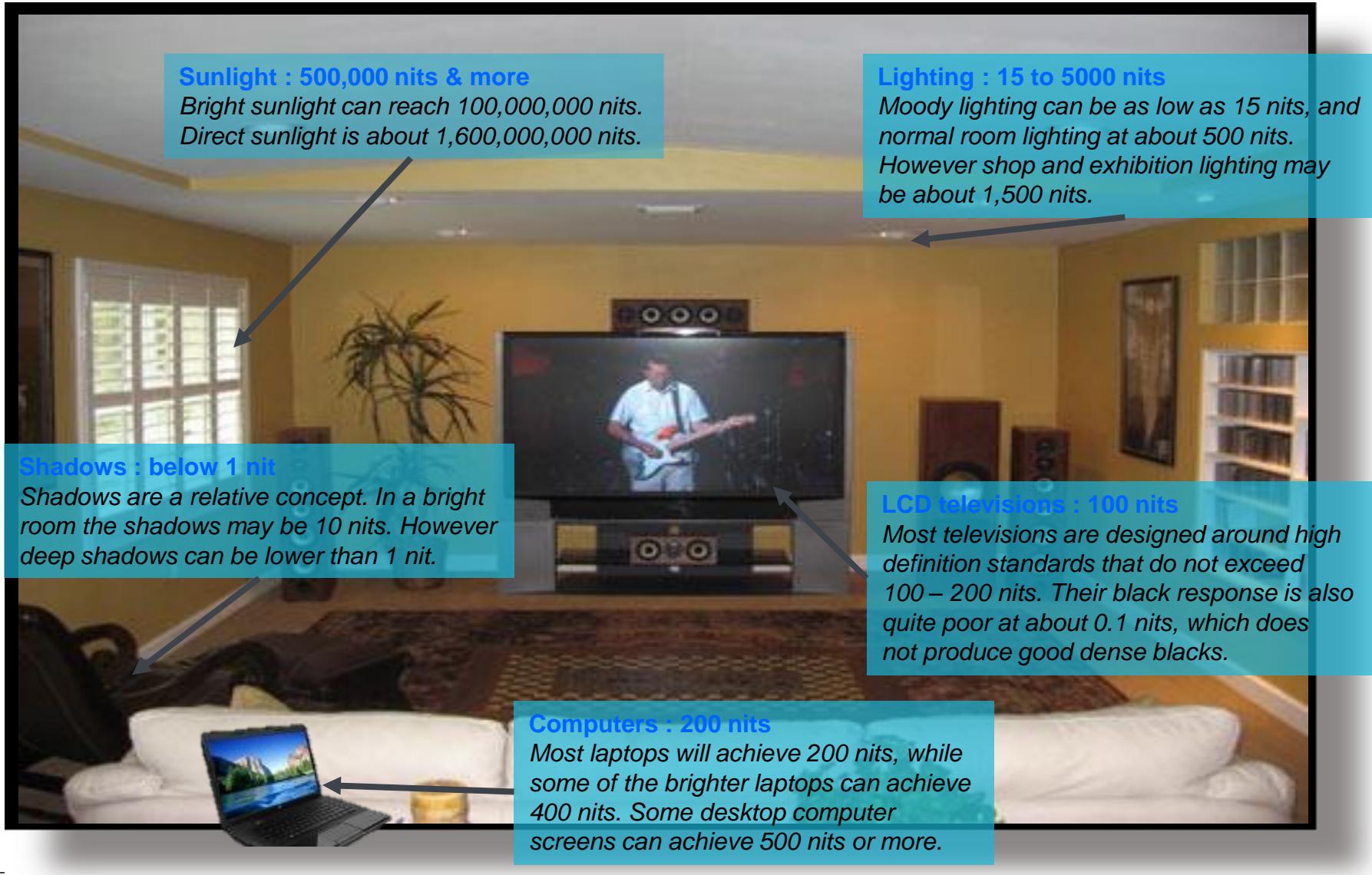
- HDR10 - Is an open platform version of HDR that has been adopted by the **Blu-ray Disc Association** (BDA) for 4K Ultra HD Blu-ray. Under the specifications for 4K UHD Blu-ray HDR will use a 10-bit video depth and up to Rec.2020 color space. It also uses the SMPTE 2084 EOTF (Electro-Optical Transfer Function) and SMPTE 2086 metadata for delivering the extended dynamic range, which is mastered using a peak brightness of 1000 Nits. This version of HDR has been adopted by for the 4K Ultra HD and it is also being used by both Amazon Instant and Netflix to deliver HDR content.
 - **4K / 60p** High speed display in 60 frames per second of 4K video (3,840 x 2,160 pixels - Ultra HD)
 - **10-bit gradation** Previous Blu-ray Discs were 8-bit
 - **High Dynamic Range** A technology that drastically expands the brightness peak from the previous 100 nit to 1000 +
 - **BT.2020 wide color gamut** previous Blu-ray discs were BT.709.
 - **HEVC (H.265) / 100Mbps** previous Blu-ray discs used MPEG-4/AVC (H.264), maximum 40Mbps



Light Levels

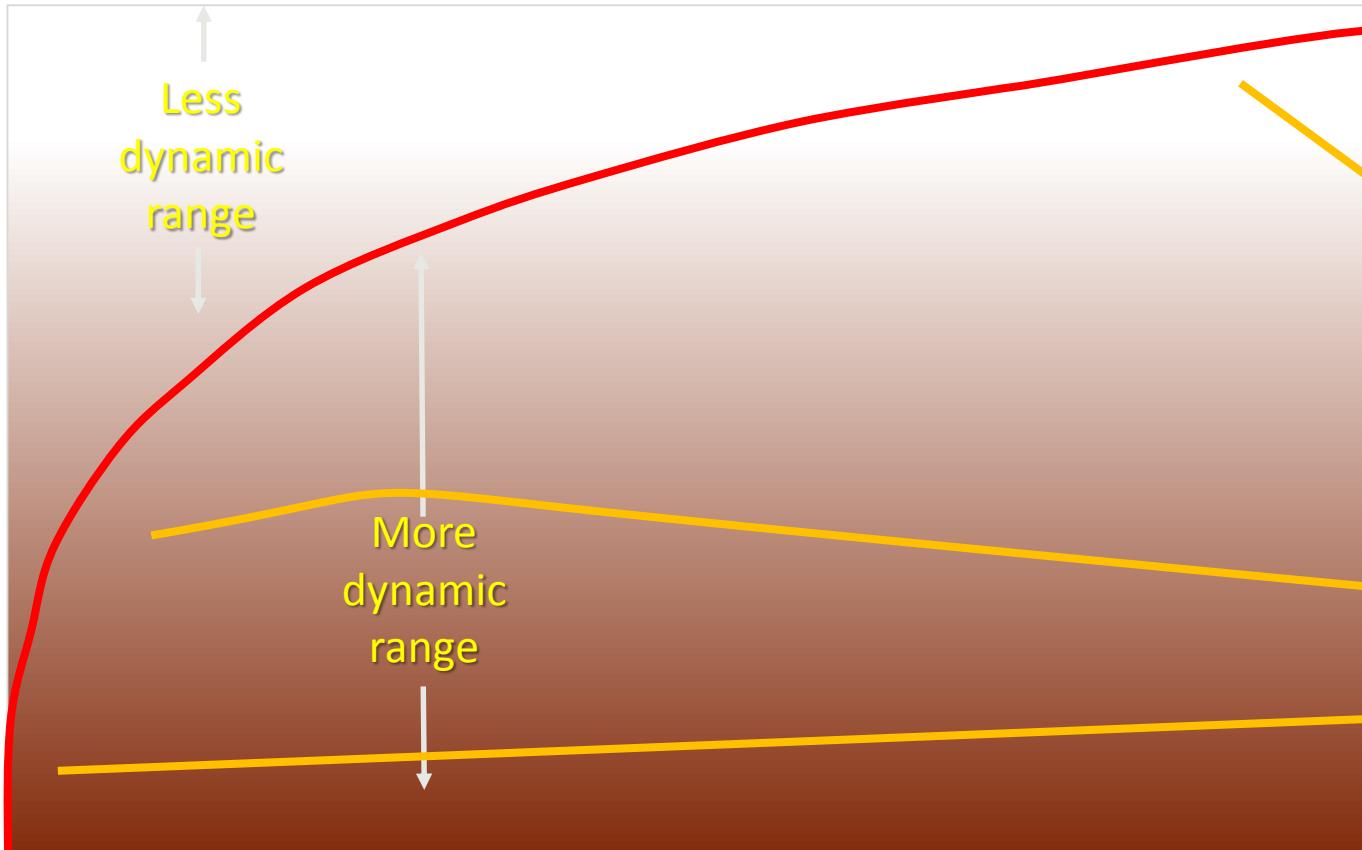
- In measuring the light output of a TV, Monitor or screen we use the measurement unit Nit (cd/m^2).
- In lighting, the nit is a unit of visible-light intensity, commonly used to specify the brightness of a cathode ray tube or liquid crystal display computer display. One nit is equivalent to one candela per square meter (cd/m^2). The candela, formerly called candlepower, is approximately the amount of light emitted by a single common tallow candle.

Light Levels



Human Eye Sensitivity

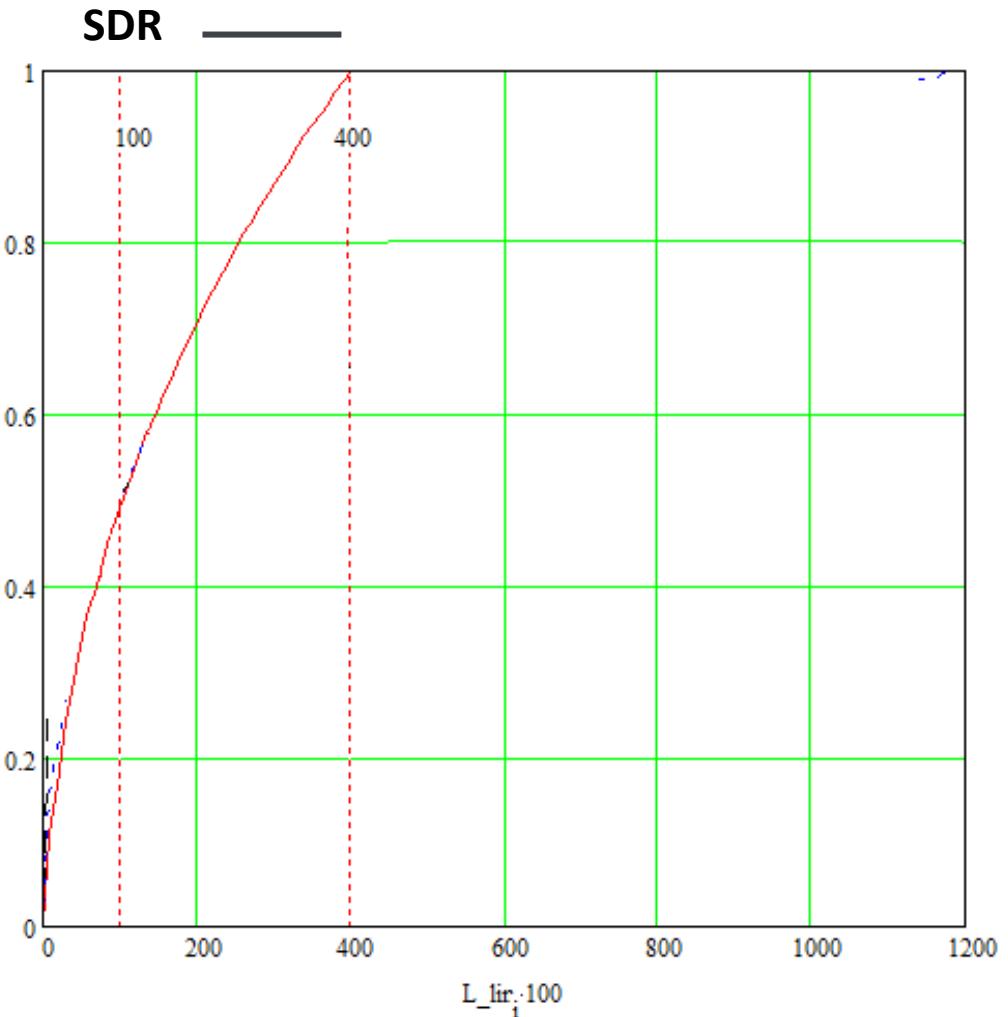
The eye sees change in low light levels much more than in High light levels
So we need to give more bits to the lower light levels than we do to bright areas



Standard 709 Gamma curve

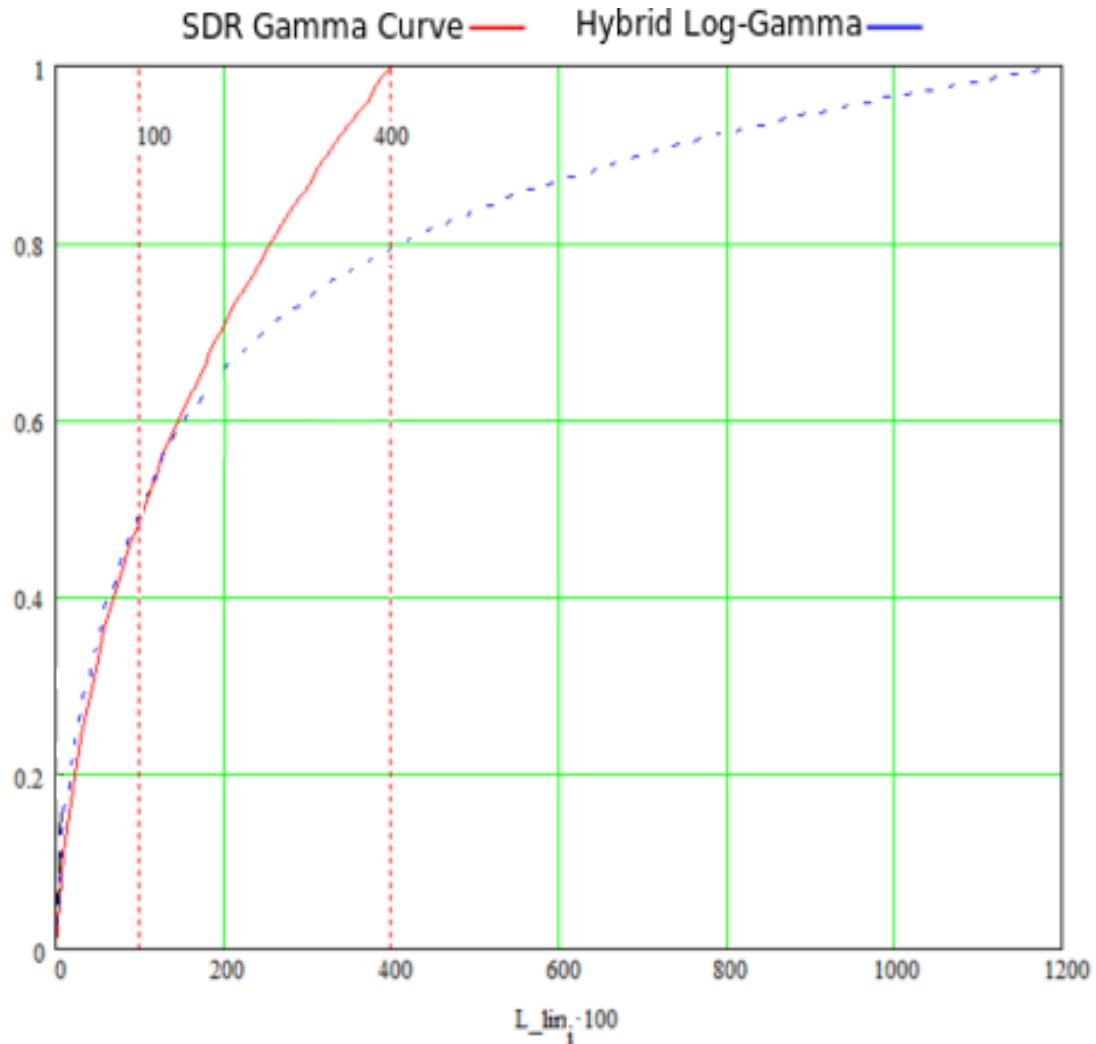
ITU-R BT.1886 SDR

- This Recommendation specifies the reference electro-optical transfer function (EOTF) that the displays used in HDTV program production should follow in order to facilitate consistent picture presentation. The reference EOTF is specified as a simple equation, with exponent function, based on measured characteristics of the Cathode Ray Tube (CRT).



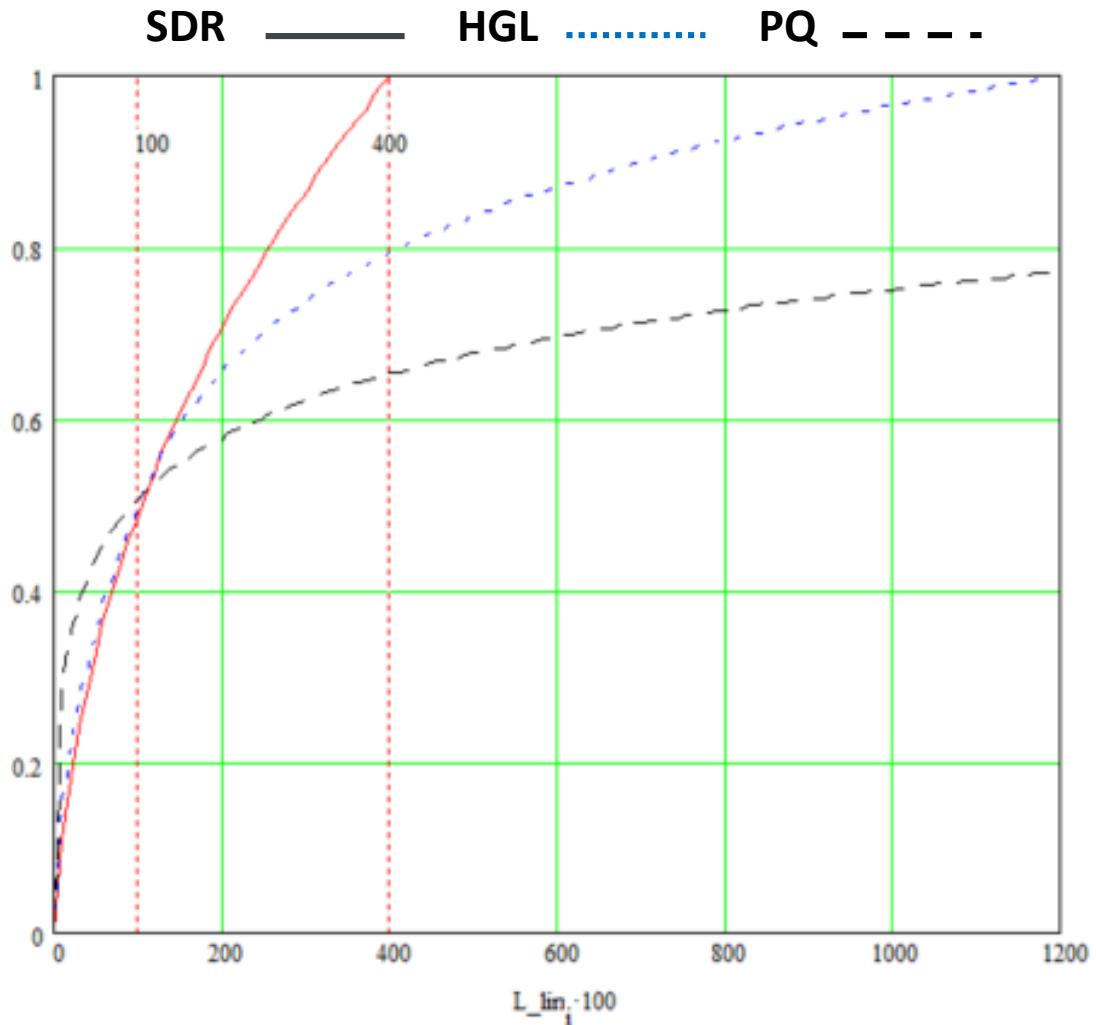
Hybrid Log-Gamma (HLG)

- The ITU-R announced its UHD standard, BT-2020 in October 2015. UHDTV Recommendation BT.2020
- The HDR-TV Recommendation details two options for producing High Dynamic Range TV. The Perceptual Quantization (PQ) specification—standardized by and the Hybrid Log-Gamma (HLG) specification—supported by the BBC and Japan's NHK—offers a degree of compatibility with legacy displays by more closely matching the previously established television transfer curves.
- Chart showing a conventional SDR gamma curve and Hybrid Log-Gamma (HLG). HLG uses a logarithmic curve for the upper half of the signal values which allows for a larger dynamic range.



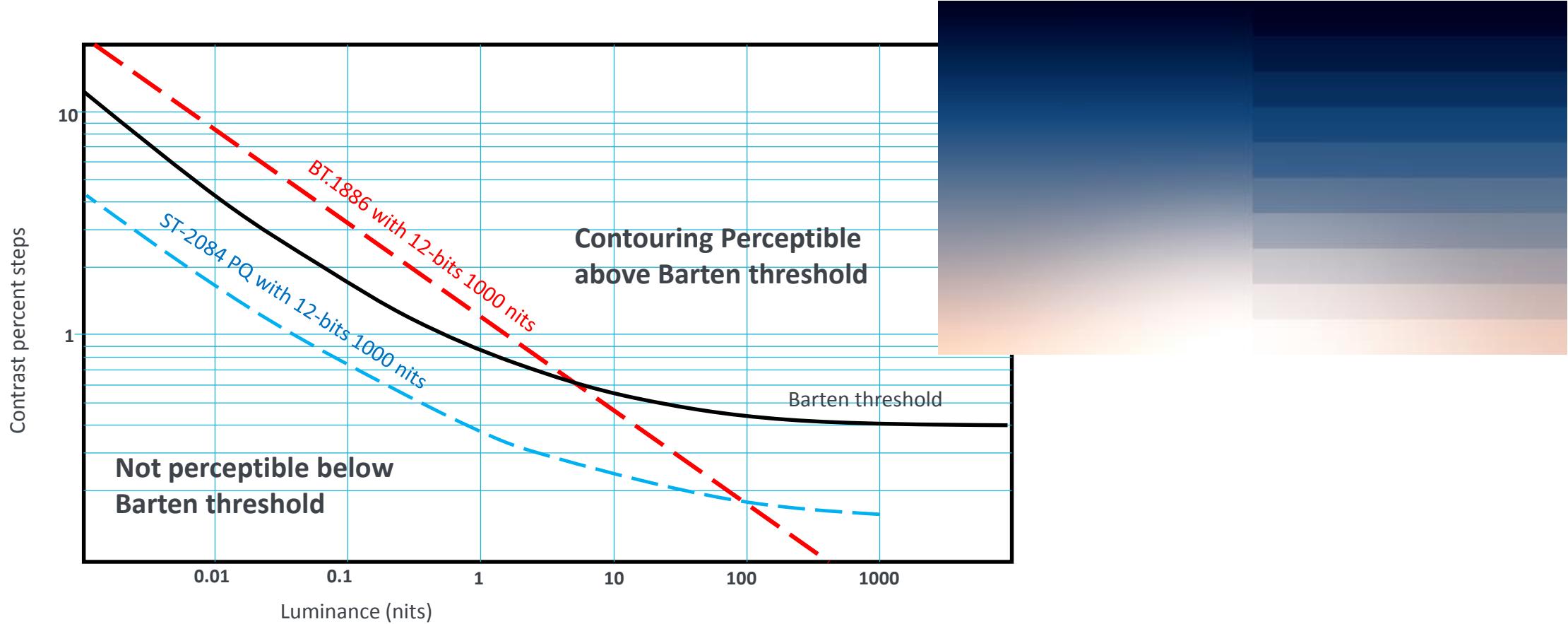
SMPTE 2084

- AKA Perceptual Quantizer (PQ), published by **SMPTE ST 2084**, is a transfer function that allows for the display of HDR video with a luminance level of up to 10,000 Nits (cd/m^2) and can be used with the Rec. 2020 color space. Rec-2020 gives more bits to the darker areas. And allows for much brighter specular highlights that do not need as many bits to represent them due to the fact of how the human vision system works.
- Humans see minor changes in the darker areas of a picture much more than we do in brighter areas of a picture.



ST.2084 with Perceptual Quantizer for HDR

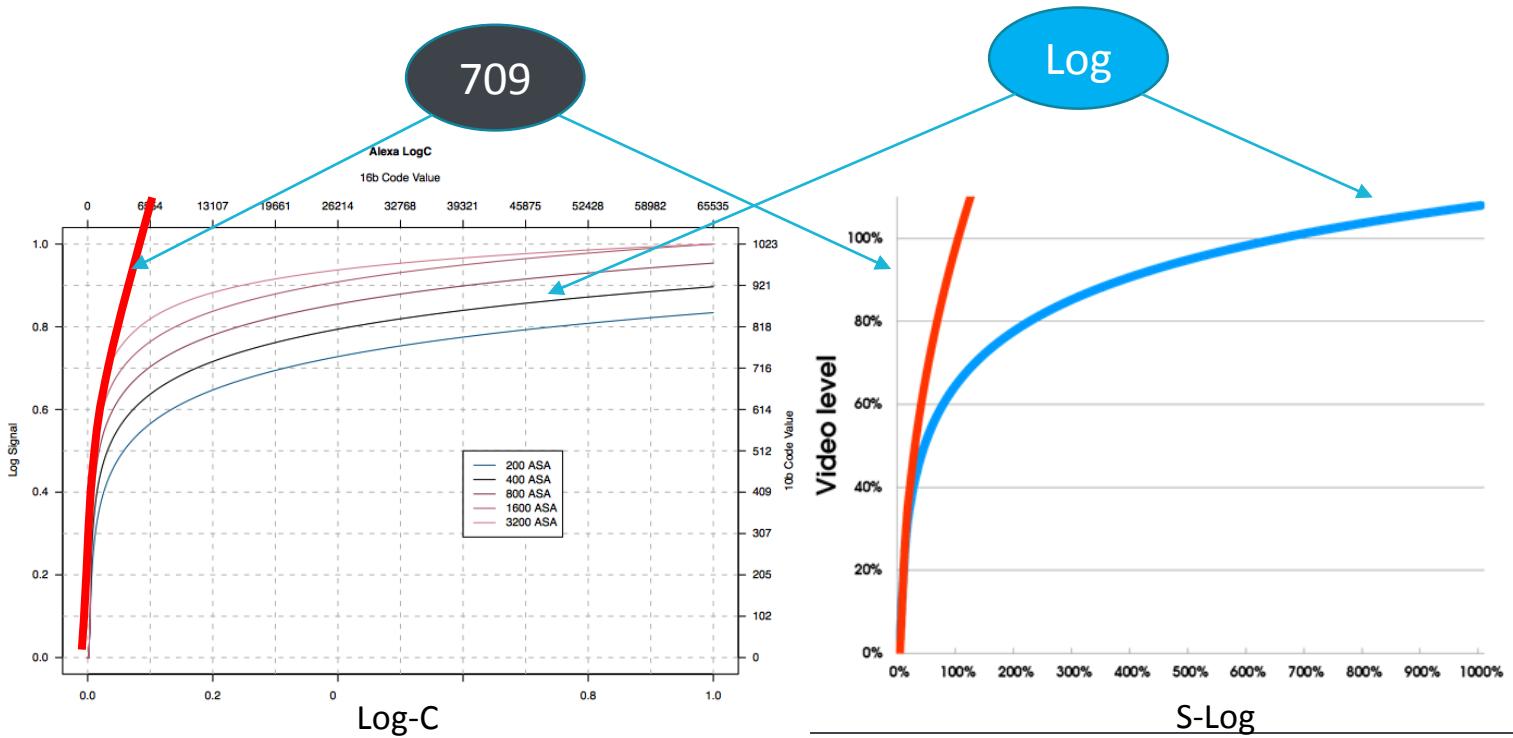
12-BIT PQ AND REC-1886 COMPARED WITH BARTEN THRESHOLD



Camera Raw (Log Scale on Waveform Monitor)

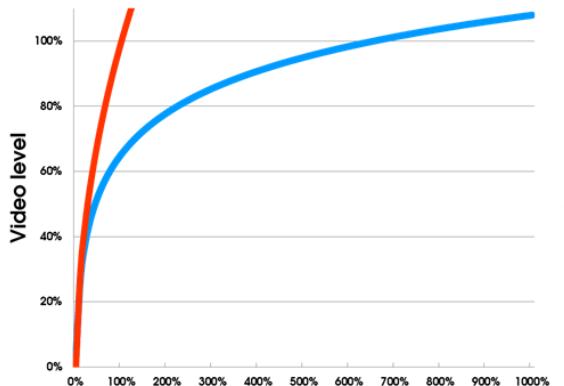
Log

- What is Log gamma? It's an option on most modern digital cinema cameras that allows you to shoot as flat an image (color and luminescence wise) as possible.
- Look at these charts below that show the difference between two cameras' default color options and their log options:



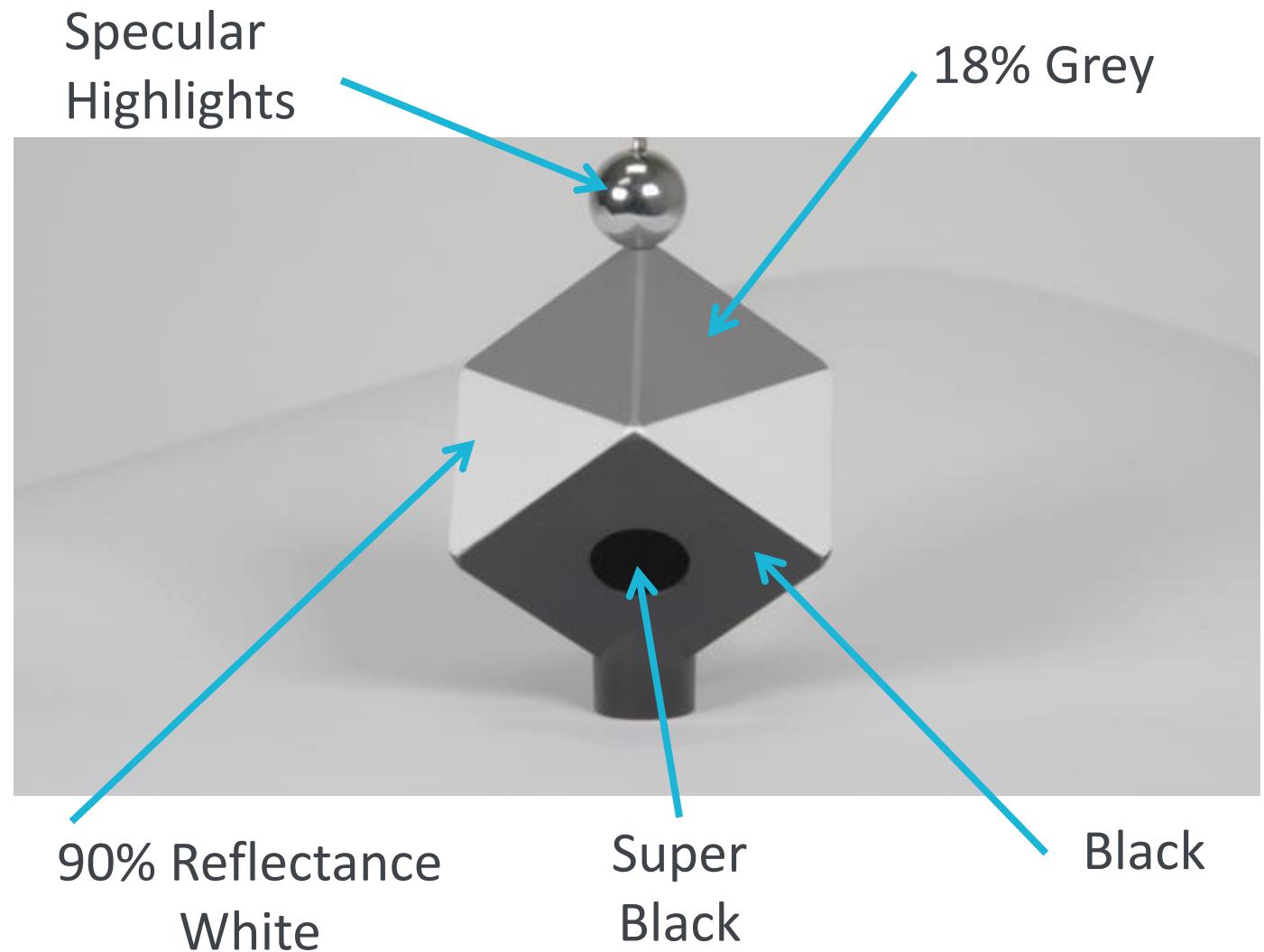
Log (cont)

- In this chart the further to the right the line is the **longer it takes to reach the top, the more information is being recorded**. This extra information gives you much **more latitude in post-production** to manipulate the colors, shadows, and highlights.
- Sometimes shooting log gamma is also **referred to as “shooting flat”** Shooting a flat image gives you **more details in both highlights and dark areas**. While a **flat image may not look pleasing while on set**, it provides more freedom for color grading in post-production. It allows you to show what's outside the window as well as what's inside the room.

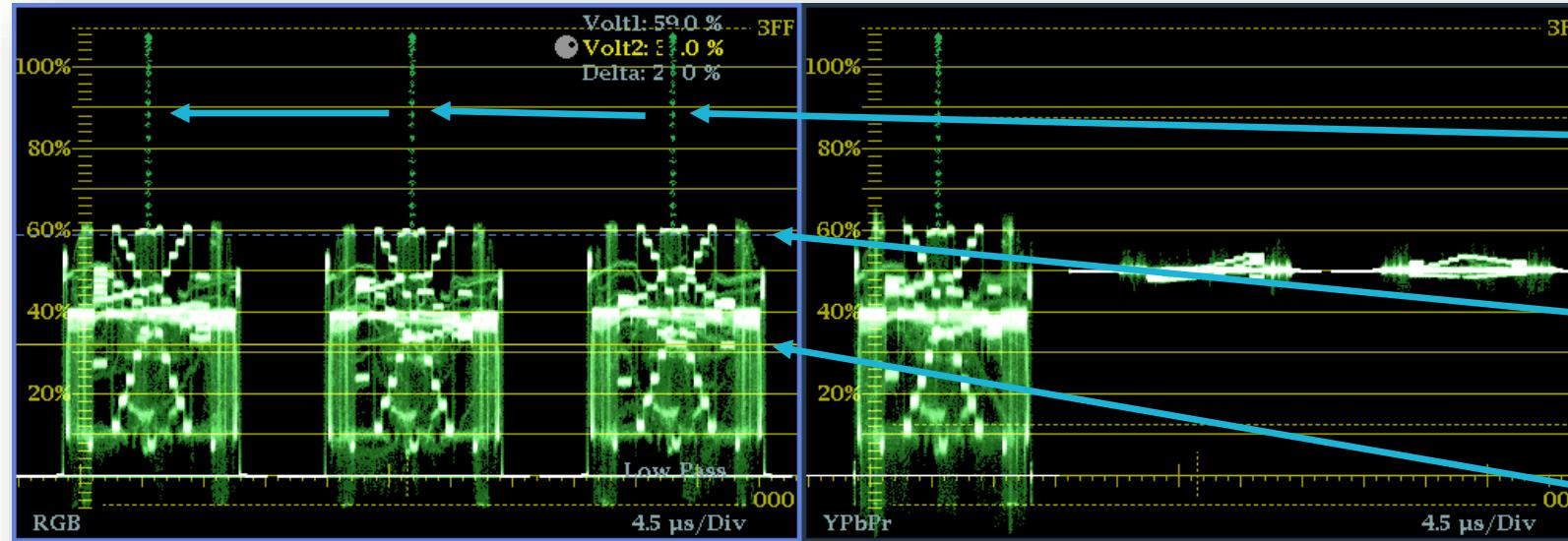


Capturing Camera RAW Footage (Spider cube)

- Setup your test chart within the scene
- Adjust the lighting to evenly illuminate the chart
- Adjust the camera controls to set the levels
 - ISO/Gain, Iris, Shutter, White Balance



Raw Log Waveform (S Log 2)



Specular highlight is going to the top

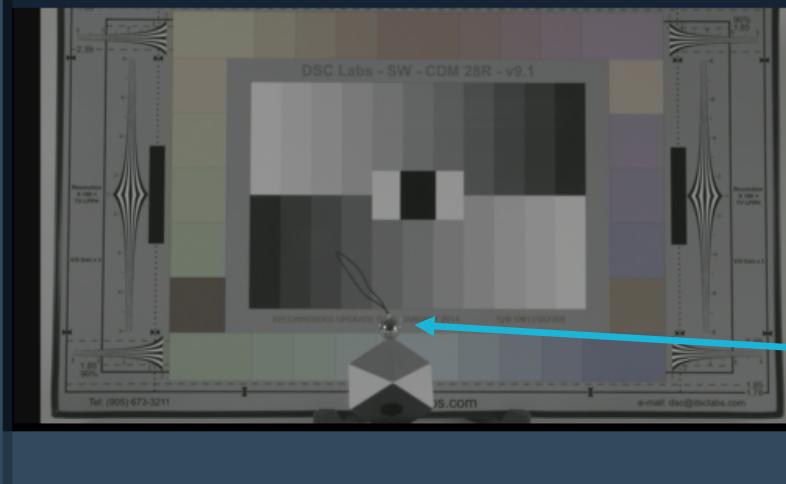
Normal White is at 59%

18% black is at 32%

We have placed cursors at 59% and 32%

Highlight is from the silver ball

Video Session				Page 1 of 2	
Input:	SDI Input 1A	Signal:	Locked	Colorimetry:	BT709
Effective:	Auto 4096X2160p 23.98 - HD SDI 422 - 4x1.485/M Gbps Sq				
Selected:	Auto Format - Auto Structure - Auto Transport				
Links	352M Payload	Y Stuck Bits	C Stuck Bits	AP CRC	
A	85h C2h 40h 01h	-----	-----	8359h F6CEh	
B	85h C2h 40h 41h	-----	-----	A5C2h B35Eh	
C	85h C2h 40h 81h	-----	-----	8481h AD5Bh	
D	85h C2h 40h C1h	-----	-----	D284h 0913h	
Ancillary Data: Y and C Present CRC Changed since reset: Yes					
SAV Place Err:	OK	Line Length Err:	OK		
Field Length Err:	OK	Line Number Error:	OK		
Press SEL - reset. L/R arrow key stop/start. Up/Down change page					



ID: WFM8300_TEK001
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TC: Disabled



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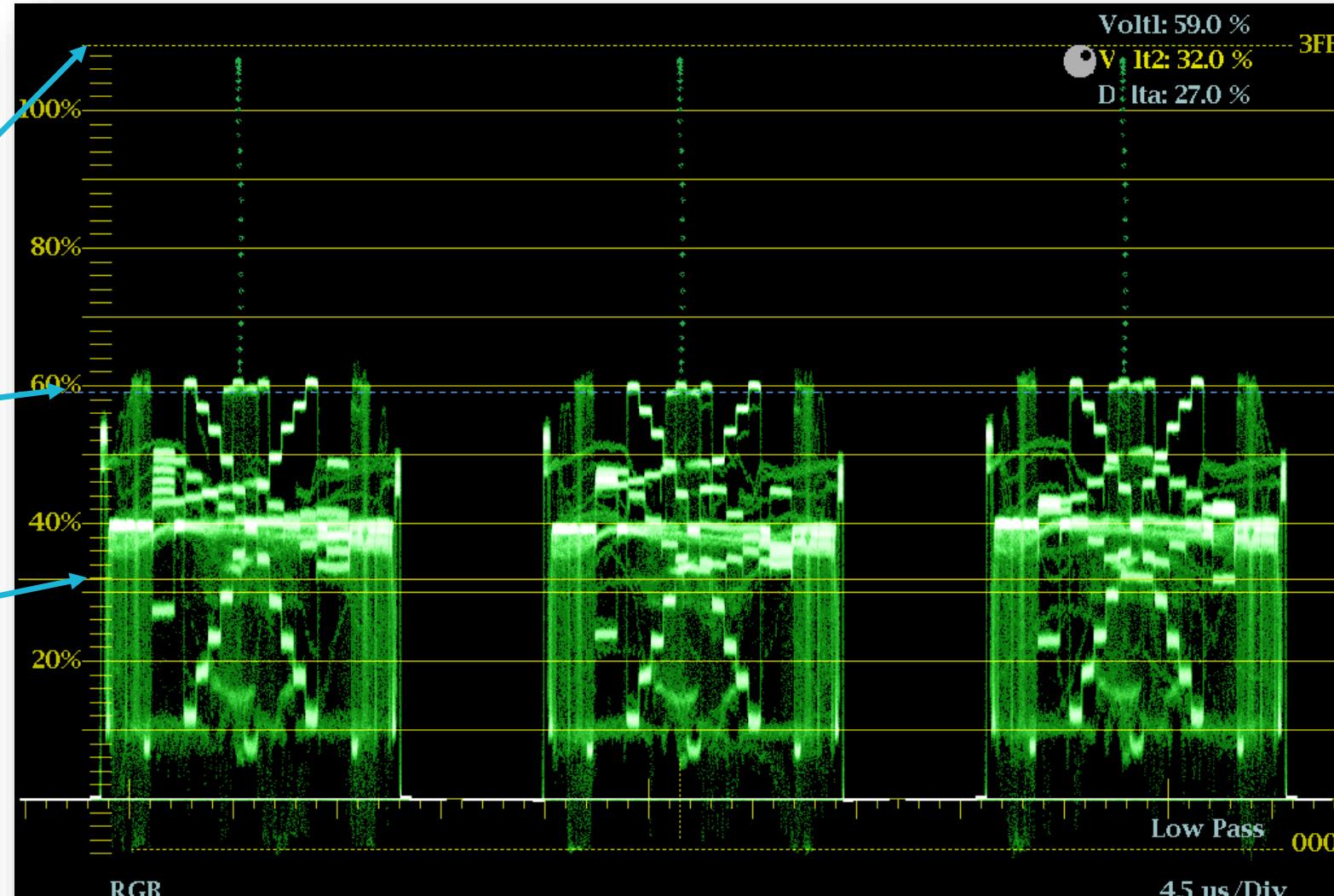
4096X2160p 23.98
SDI In Quad-HD
Ref: Internal

S Log 2 Waveform to Nits

540 or 1000 Nits
Max Highlights
Monitor dependent

100 Nits
Normal White

20 Nits
18% Grey

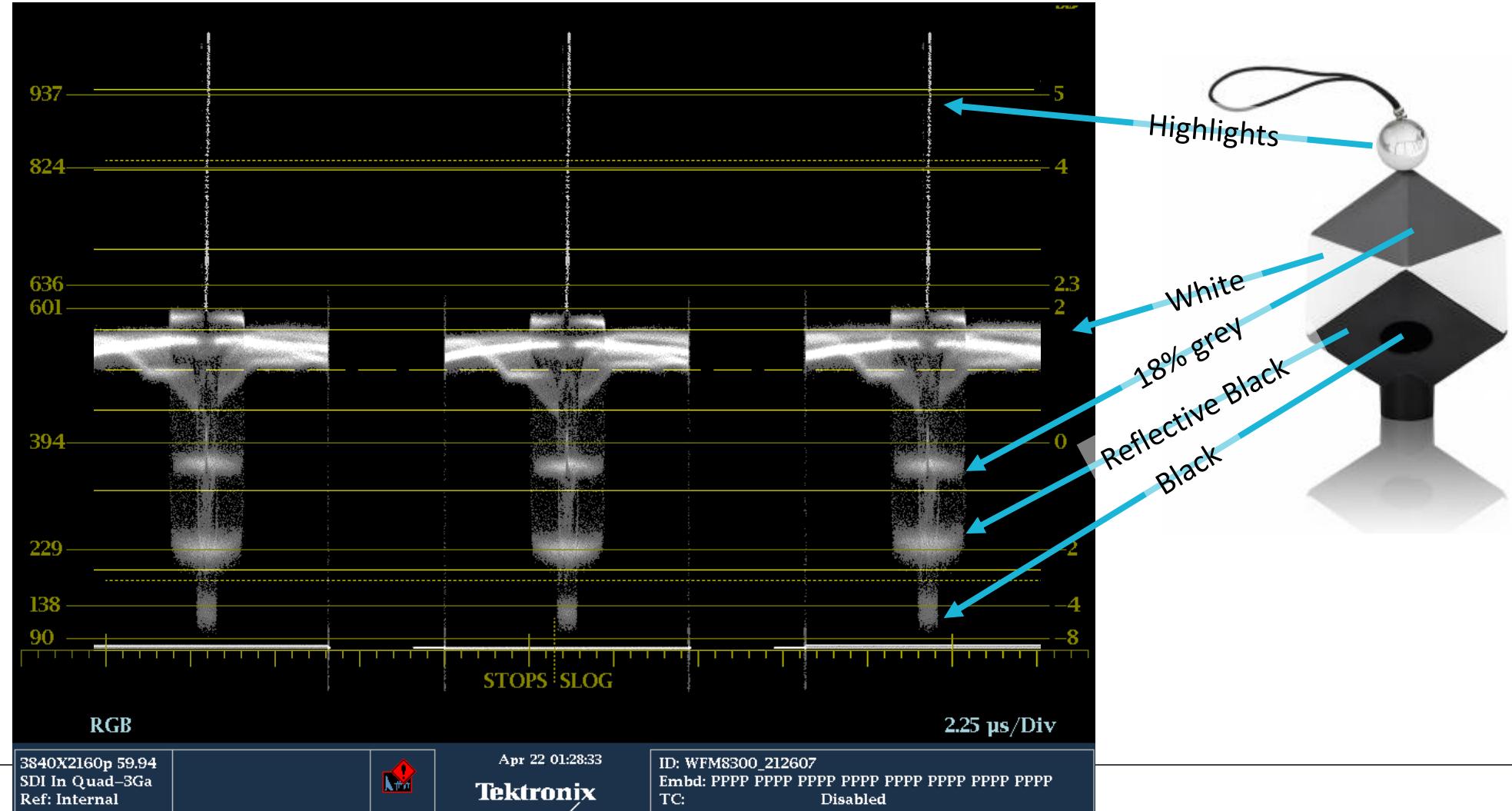


Spider Cube S Log 2 as shot from the Camera raw

Showing Graticules in Digital Values and Stops

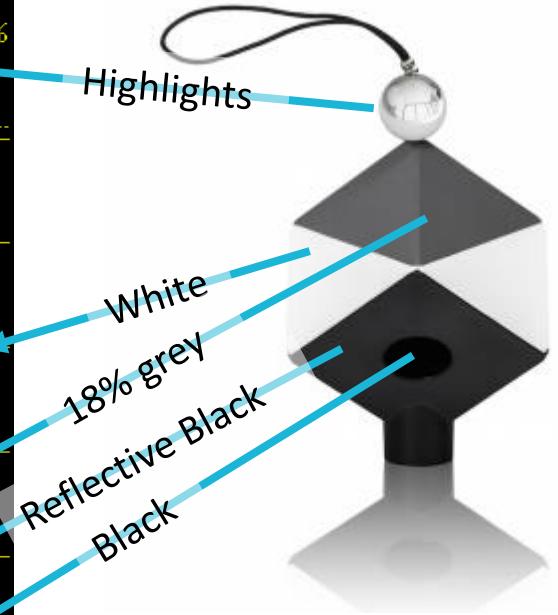
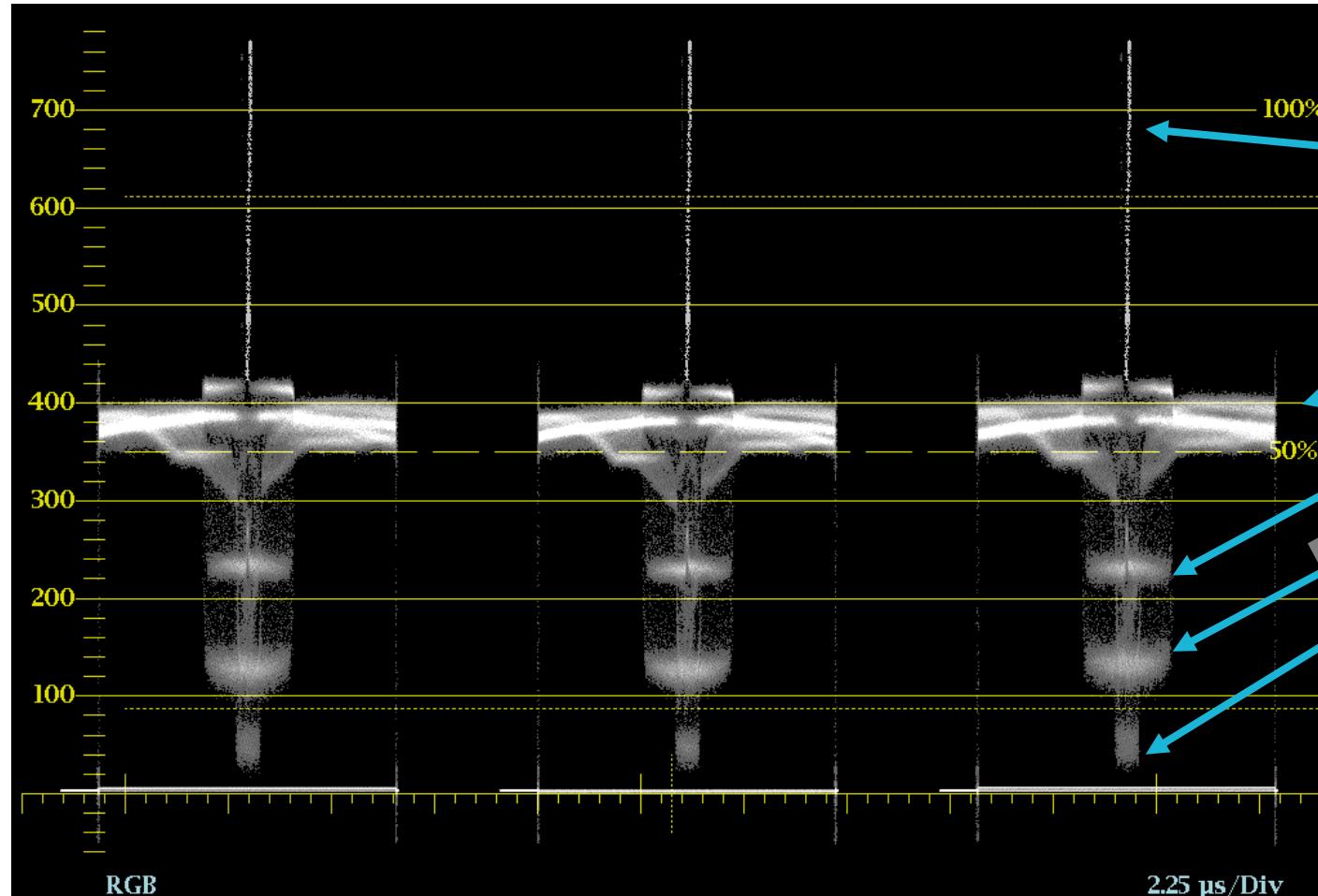
Digital
Values on
the Left side

Stop values
on the right
side.



Spider Cube S Log 2 as shot from the Camera raw

Showing S Log 2 in normal 709 type screens



3840X2160p 59.94
SDI In Quad-3Ga
Ref: Internal



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TC: Disabled



S log 2 to PQ Curve (Adobe)

Showing Graticules in Nits ST2084 1K

SMPTE Levels

1000 Nits

Max Highlights

Monitor dependent

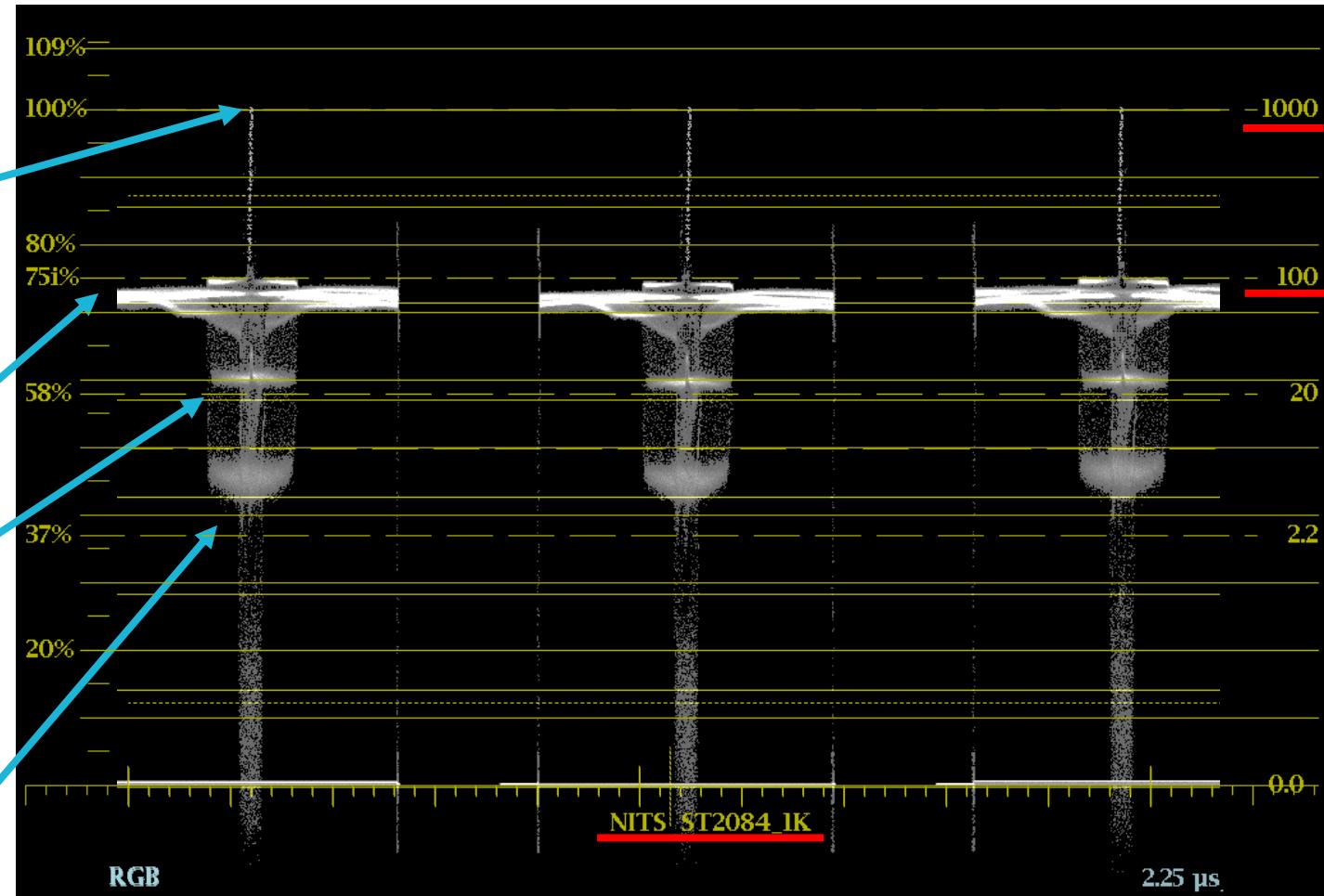
~100-200 Nits

Normal White

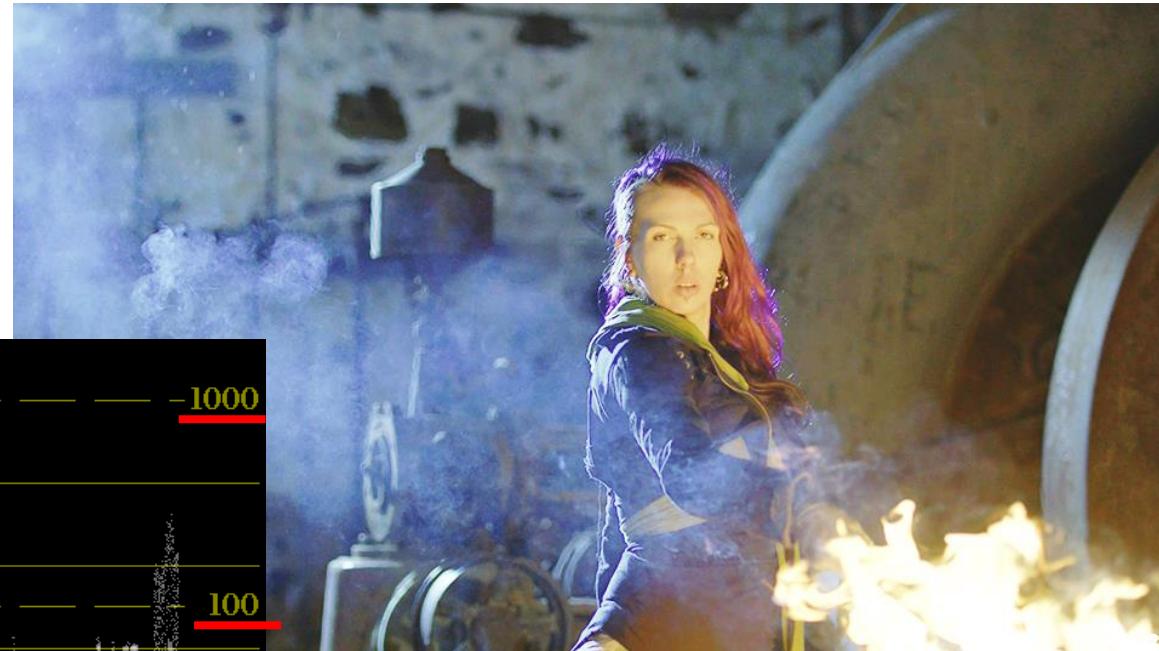
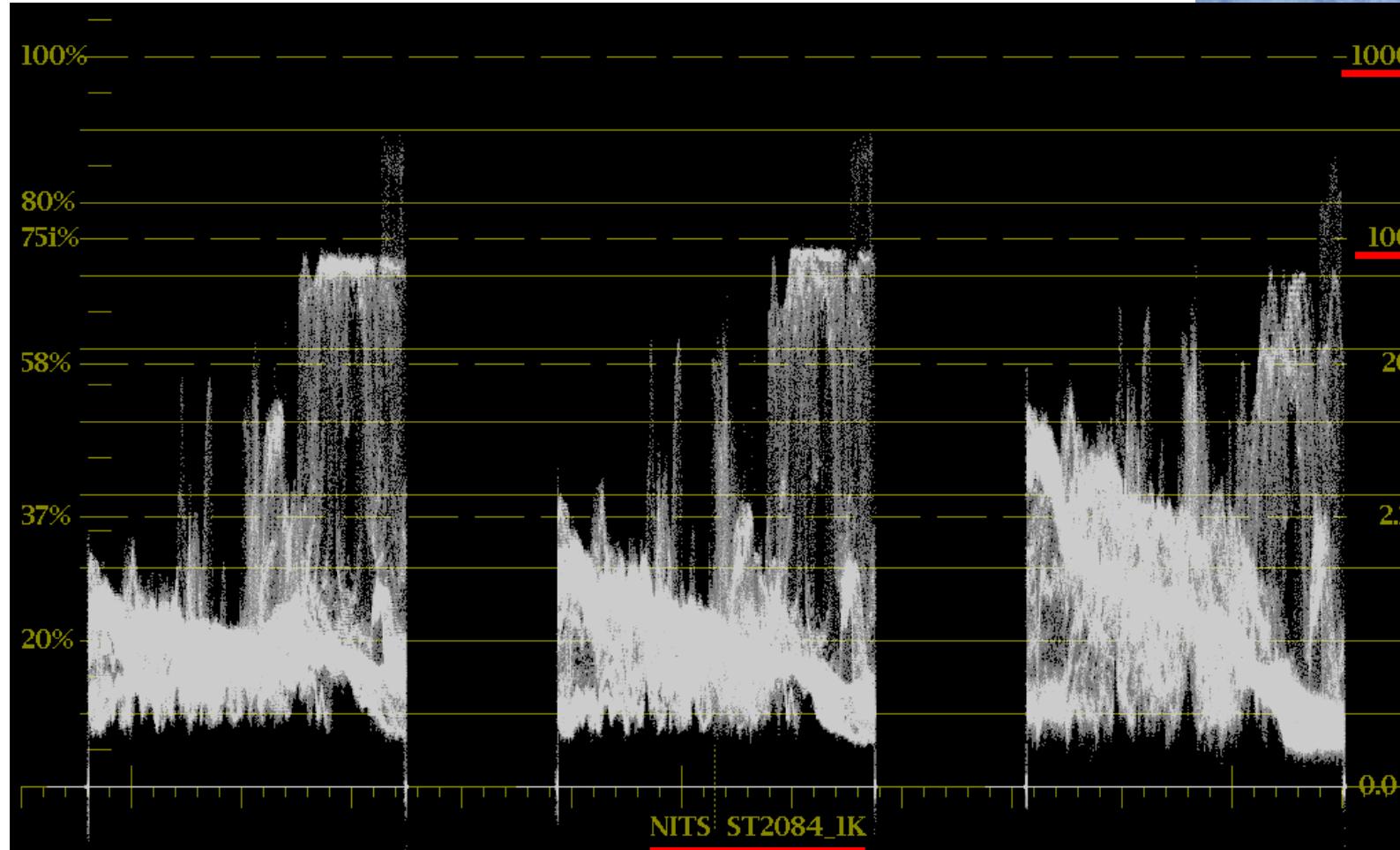
20 Nits

18% Grey

Reflective Black



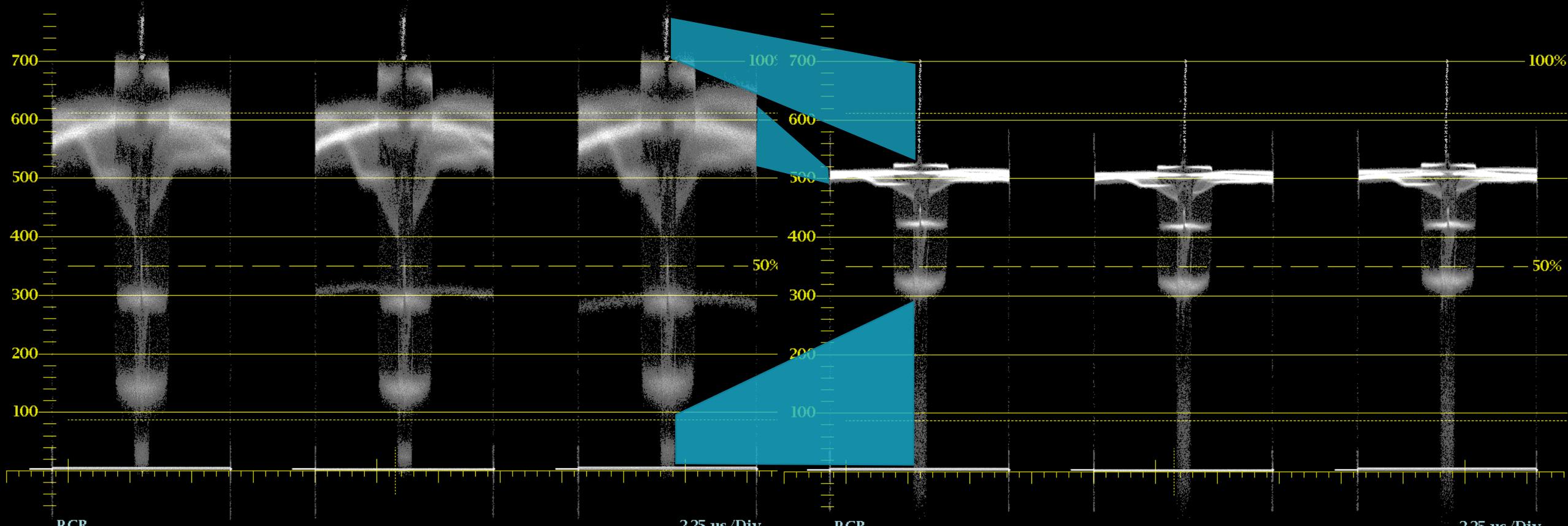
Waveform Screen with HDR



- You can see how the Blacks are expanded and the Whites are compressed.
- With Some Highlights over 100 Nits

Side by side 709 and PQ

709



3840X2160p 59.94
SDI In Quad-3Ga
Ref: Internal

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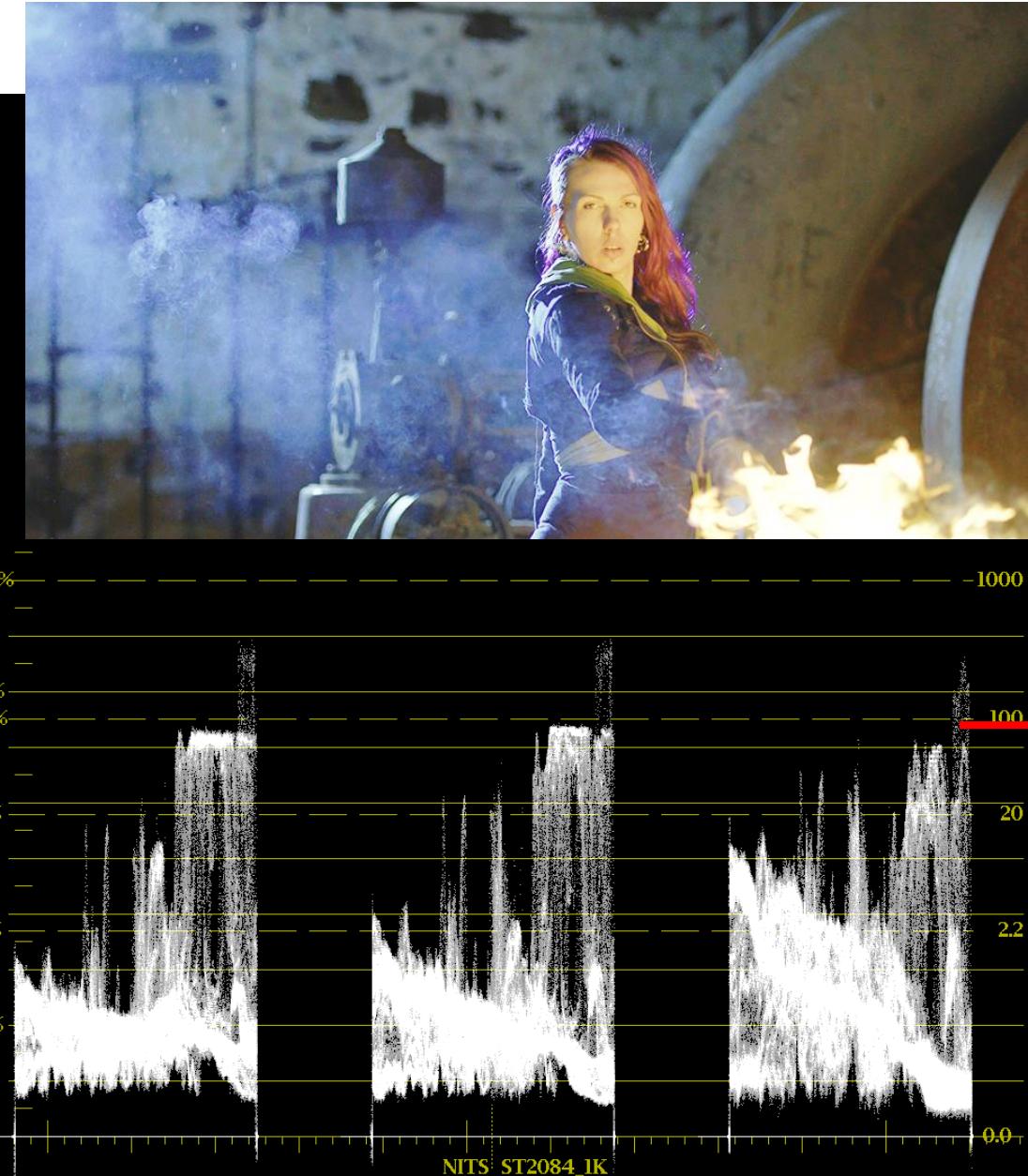
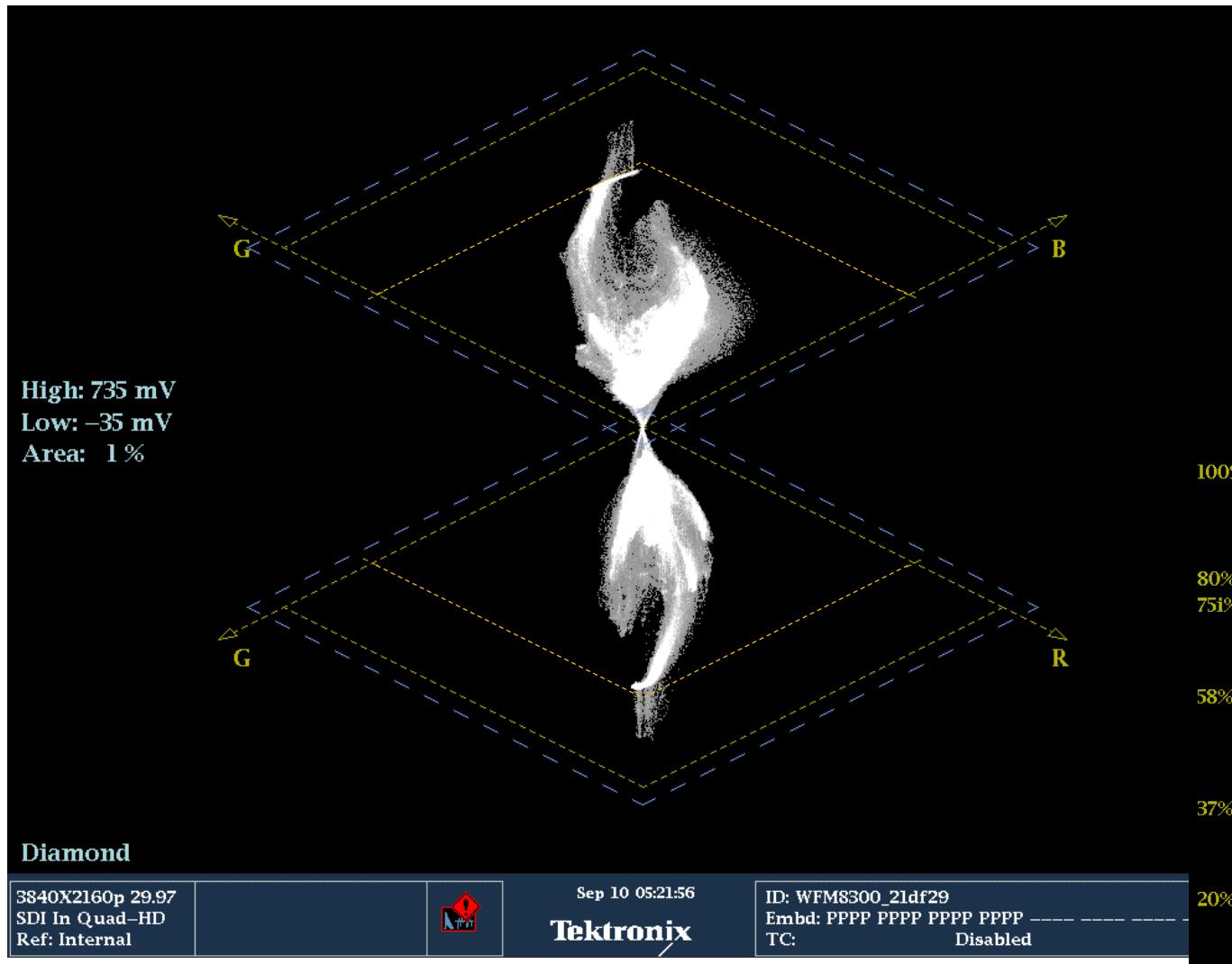
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SDI In Quad-3Ga
Ref: Internal

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Emb'd: PPPP PPPP PPPP PPPP PPPP PPPP PPPP
TC: Disabled



Diamond Screen with HDR

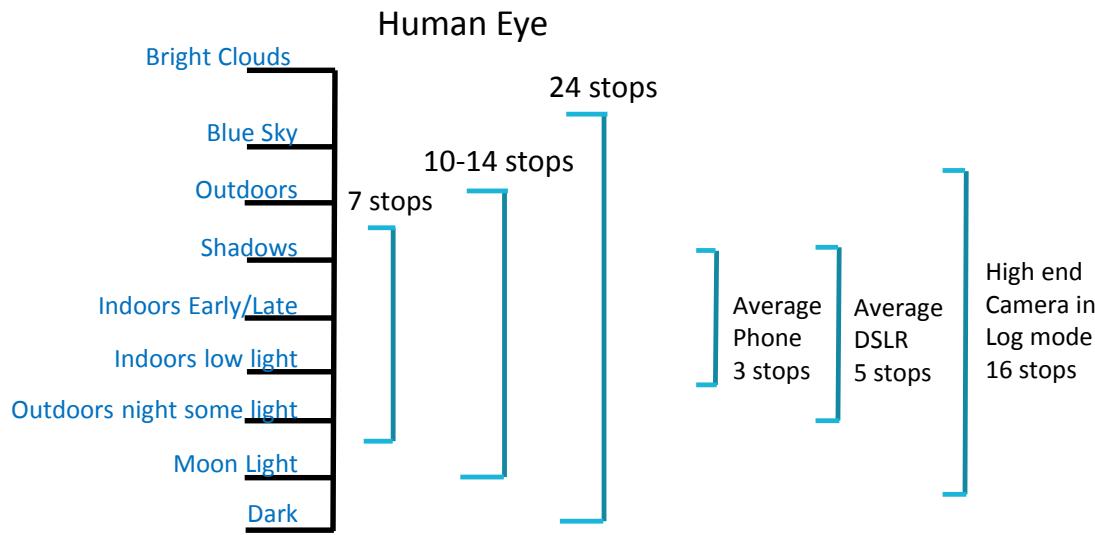


Contrast Ratios

The adapted human eye can see about 7 stops but, with local adaption, can see 10-14 stops of dynamic range in a single, large area image.

With longer term adaption the human eye can see about 24 stops! Therefore, higher dynamic range results in an experience closer to reality.

Also, higher dynamic range increases the subjective sharpness of images and perceived color saturation.



The human eye can adapt to different lighting conditions quickly Sliding up and down the scale

References

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- ITU-R BT.709 (2002) “Parameter values for the HDTV standards for production and international program exchange”
- ITU-R BT.1886 (03/2011) “Reference electro-optical transfer function for flat panel displays used in HDTV studio production”
- Dolby Vision White Paper www.dolby.com/.../dolby-vision-white-paper.pdf
- Philips HDR technology – white paper www.ip.philips.com/data/.../philips_hdr_white_paper.pdf
- S-2013-001 “ACESproxy, an Integer Log Encoding of ACES Image Data”, Academy Color Encoding System (ACES), ver. 1.1 8-2-2013
- Vimeo “Trick Shot”, <https://vimeo.com/124750526> and “Trick Shot: Behind the Scenes”, <https://vimeo.com/124750682>

References

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- Hybrid Log Gamma BBC white paper; <http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP283.pdf>
- Various examples of 4K where HDR makes it better; <http://4k.com/video/>
- Stop Weighted Waveform; US Patent Application 20150348281, published Dec. 3, 2015, Baker, Daniel G., Tektronix, Inc.



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Standards SMPTE 2022 & 2110

17 SEPTEMBER 2017

Standards SMPTE 2022

- Part 1
 - Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks
- Part 2
 - Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks
- Part 3
 - Unidirectional Transport of Variable Bit Rate MPEG-2 Transport Streams on IP Networks
- Part 4
 - Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks

Standards SMPTE 2022 -5, 6, & 7

(High Bit Rate Media Transport)

- Part 5
 - Configurable Forward Error Correction for Transport of High Bit Rate Media Signals over IP Networks (HBRMT)
- Part 6
 - Uncompressed SD/HD Video/Audio Transport of High Bit Rate Media Signals over IP Networks (HBRMT)

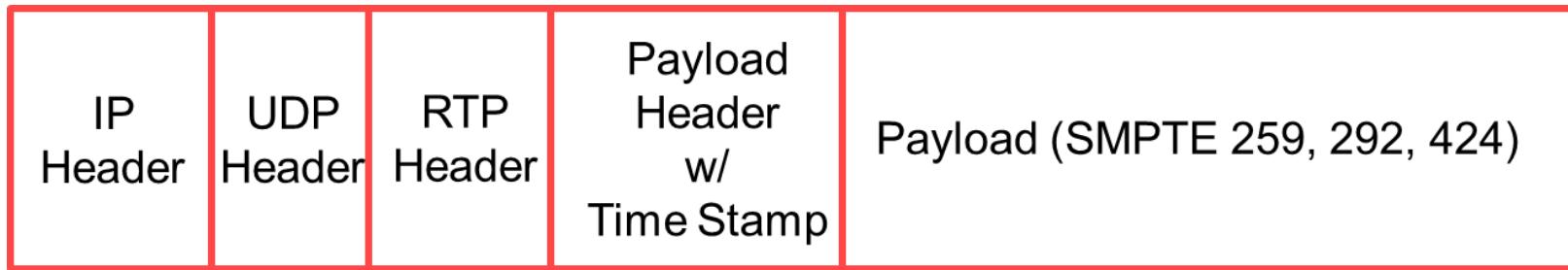
- Part 7
 - Specifies timing and characteristics of 2022 streams such that a device at the receiver can switch between the two streams transparently



SMPTE 2022-5&6

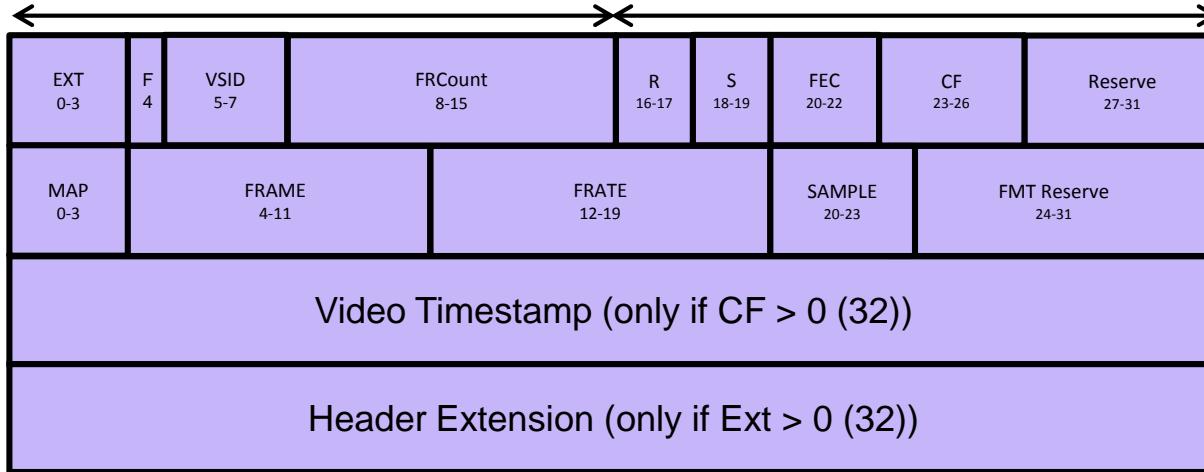
- Support video stream rates: 270Mbps, 1.485Gbps, and 2.97Gbps
 - Entire video signal including VANC and HANC will be encapsulated into a single stream
- Video payload is frame centric
 - Frame will start on a datagram
 - A bit is set to mark the last datagram of the video frame
 - All datagrams of the same frame have the same FRCount number
- Transport will be robust over a wide range of network performance by utilization of flexible column or row column based FEC
 - FEC is optional
 - FEC is a separate stream
 - Adds latency
- FEC will be utilized for short duration outages
 - 270 Mb/s (SD-SDI) – maximum 33 ms protection
 - 1.485 Gb/s (HD-SDI 1080i) – maximum 6 ms protection
 - 2.97 Gb/s (3G-SDI 1080p) – maximum 3 ms protection

ST2022-6 Media Datagram



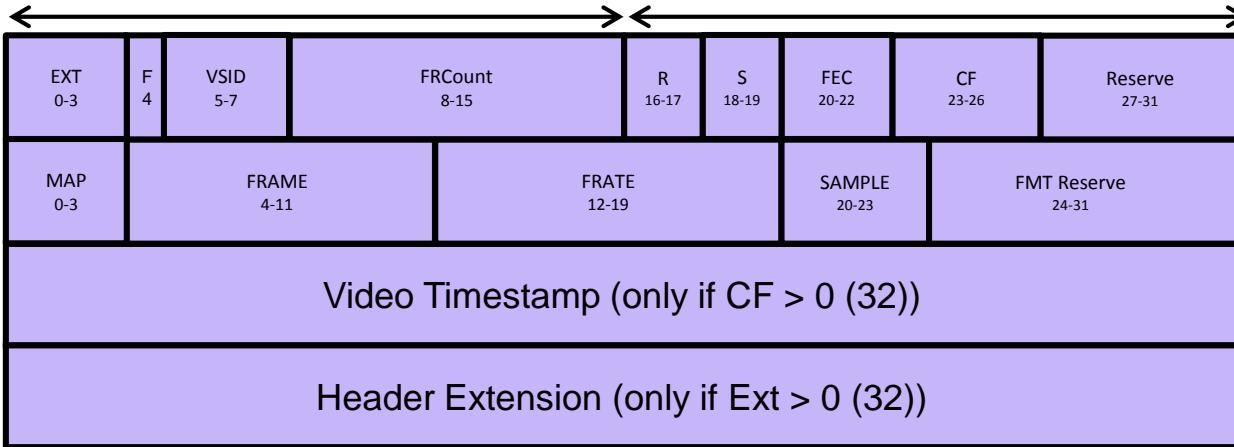
- IP Header
- UDP Header
- Real Time Protocol Header
- Media Payload Header
- Media Payload

High Bit Rate Media Payload Header



- FRCOUNT All datagrams of the same frame have the same number
 - Will roll over after 256 frames
- R Reference locked/locked/reference to UTC
- S Payload Scrambling
- FEC FEC and type sent
- CF Clock frequency for video time stamp

High Bit Rate Media Payload Header



- MAP Direct or Dual Link
- Frame Horizontal/Vertical, Progressive/Interlace
- Frame Rate
- Sample 4:2:2, 4:4:4, 4:4:4:4 etc.
- Video Timestamp: 32 bits
 - The timestamp will indicate the time of the first pixel whose complete data word is contained in the current datagram.

Prism Displays IP Header Info

IP Session Run Time: 1d, 20:29:47 Running

10GbE Link: OK

LAYER 2 (L2)	VIDEO	PTP

L3 IP
Source/Destination Addr 192.168.0.2 / 239.0.0.2

L4 UDP
Source/Destination Port 10000 / 20000

L5 RTP
Version 2
Padding false
Extension false
CSRC 0
Marker 0
Payload type S2022.6 (98)
Sequence Number 0x790A
Time Stamp 3413831181

Home Presets Settings Capture Alarm Input INPUT: SDI-In 4 1080p 60 AUD:PPPP PPPP PPPP PPPP
RTC:2017-01-07 19:26:33 Tektronix

Prism Displays IP Header Info

IP Session Run Time: 1d, 20:30:29 Running

10GbE Link: OK

LAYER 2 (L2)	VIDEO	PTP
✓	✓	✗

HBRMT

Extension	0
Video Source Format	Present
Video Source Id	Primary (0x0)
Frame count	255
Reference for time stamp	Unlocked (0x0)
Video Payload Scrambling	Unscrambled (0x0)
FEC usage	No FEC (0x0)
Clock Frequency	No Timestamp (0x0)
Reserved	0
Video Source Format fields	
MAP	Direct (0x0)
FRAME	1920x1080p (0x21)

INPUT: SDI-In 4
1080p 60 AUD: PPPP PPPP PPPP PPPP
RTC:2017-01-07 19:27:16

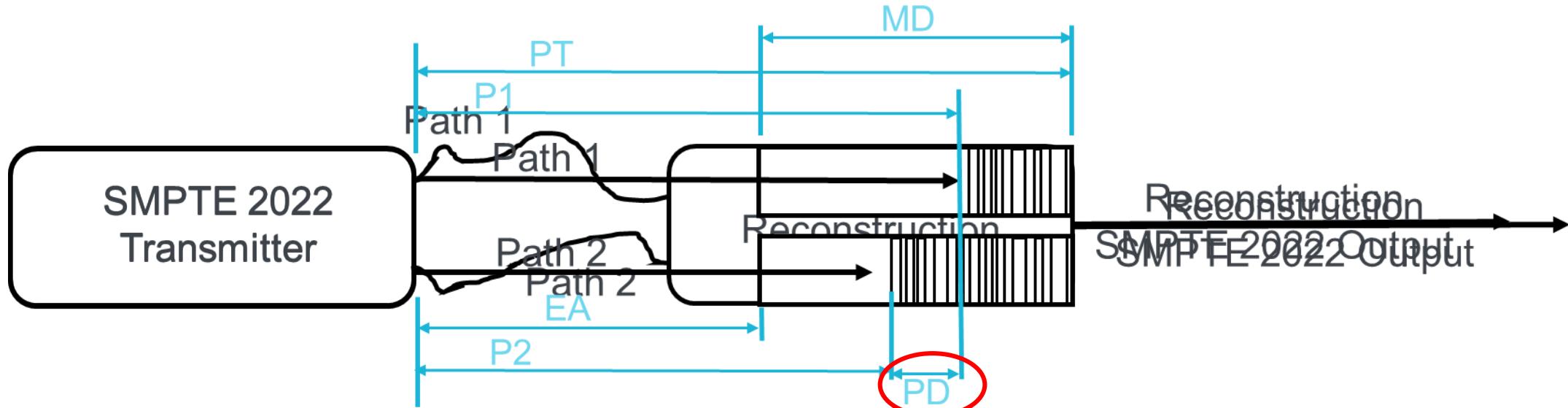
Home Presets Settings Capture Alarm Input

Tektronix

ST 2022-7

17 SEPTEMBER 2017

SMPTE ST 2022-7



P1 is the instantaneous latency from transmission to reception of datagrams on path number 1.

P2 is the instantaneous latency from transmission to reception of datagrams on path number 2.

P1 and P2 are inclusive of any network jitter.

PT is the latency from transmission to the final reconstructed output. It is also the latest time that a packet could arrive at the receiver to be part of the reconstructed output.

EA is the earliest time that a packet could arrive at the receiver to ensure seamless reconstruction.

MD is the maximum differential and is the difference of PT and EA. ($MD = PT - EA$)

PD is the instantaneous path differential, and is always equal to the absolute value of $(P1 - P2)$. ($PD = |P1 - P2|$)

Alliance for IP Media Solutions (AIMS)

Road to ST2110

ST 2022-6 vs ST 2110

- 2022-6
 - Bundled (Audio, Video, Metadata together)
 - Audio/Video/Metadata/Sync travel coherently
 - Needs to unpack to use separate essences
 - All packets of a given timestamp based on when it was created
 - Suited for Playout/Distribution workflows
 - WAN/Contribution across timing domains
- 2110
 - Essence Based (Audio, Video, Metadata separate)
 - Ideal for Studio/Production workflows
 - Individual essence kept in sync using PTP timing
 - All packets of a given video frame share the same timestamp

SMPTE ST 2110



Video uses the internet IETF standard RFC 4175 as a sort of template.



AES 67 for the carriage of uncompressed PCM audio signals,



CEA-608 and CEA-708 closed captioning, timecode, AFD, and other VANC data will be a separate stream

- Only elements of interest need to be delivered
- Bandwidth saved by not sending empty elements of SDI
- Low Processing latency, few lines

SMPTE 2110 by Group

- 2110-10 Timing PTP
- 2110-20 Video
- 2110-30 Audio AES67
- 2110-40 Ancillary Data

The SMPTE ST 2110 sections: part 1

- 2110-10
 - Describes the system timing and how RTP packets will be used,
 - How each of the streams will be carried in the network.
 - Describes how SMPTE 2059-1/2 should be used and the PTP packets are used as reference when “stamping” video, audio, and data packets.
- 2110-20
 - Video uses the internet IETF standard RFC 4175 as a sort of template.
 - Eliminates the need for the vertical blanking interval and other historical encapsulations of additional signals.
 - The video supports video stream without sync and Video Ancillary Data (VANC); just the pixels that make up lines of video, no matter the desired resolution and frame rate.

The SMPTE ST 2110 sections: part 2

- 2110-21 (timing models for video)
 - Timing model for “narrow” timing for much tighter specifications,
 - Timing model for “wide” timing for software models
 - Models offer users some flexibility for current designs based on hardware and future implementations using software designs.
- 2110-30
 - AES 67 for the carriage of uncompressed PCM audio signals,
 - Not just in paired channels but in multiple channels of audio
- 2110-31 (legacy AES3 audio)
 - AES3 has been used for decades
 - Will require support legacy metadata formats into the future,

The SMPTE ST 2110 sections: part 3

- 2110-40 (ancillary data)
 - CEA-608 and CEA-708 closed captioning, timecode, AFD, and other VANC data will be a separate stream
- 2110-50
 - Based on VSF's TR-04 and is a derivation of 2022-6 and AES 67,
 - Uses SMPTE 2059-1/2 as the timing mechanism.
 - The simplicity of 2022-6 with separate AES 67 audio.

Alliance for IP Media Solutions (AIMS)

- VSF TR-04 / 2110-50
 - Uses two existing standards:
 - ST2022-6 for Video and Ancillary data
 - AES67 for Audio
 - Uses SMPTE 2059-1/2 as the timing mechanism.
 - The simplicity of 2022-6 with separate AES 67 audio.

ST2110-30

BUILT ON AES67 -- PCM AUDIO (ONLY)

- 48kHz sampling support is required for all devices
 - Sampling Rate (48 kHz usually)
- Support for 1ms packet time is required for all devices
 - Packet Time (1ms usually)
- Support 1..8 channels per stream is required for all devices
 - Channels Per Packet (a choice)
- 16 & 24 bit depth support is required for all devices
- Does not carry AES User Bits

AES67 Stream channel count

The maximum number of channels per stream is limited by the packet time, encoding format and network MTU*

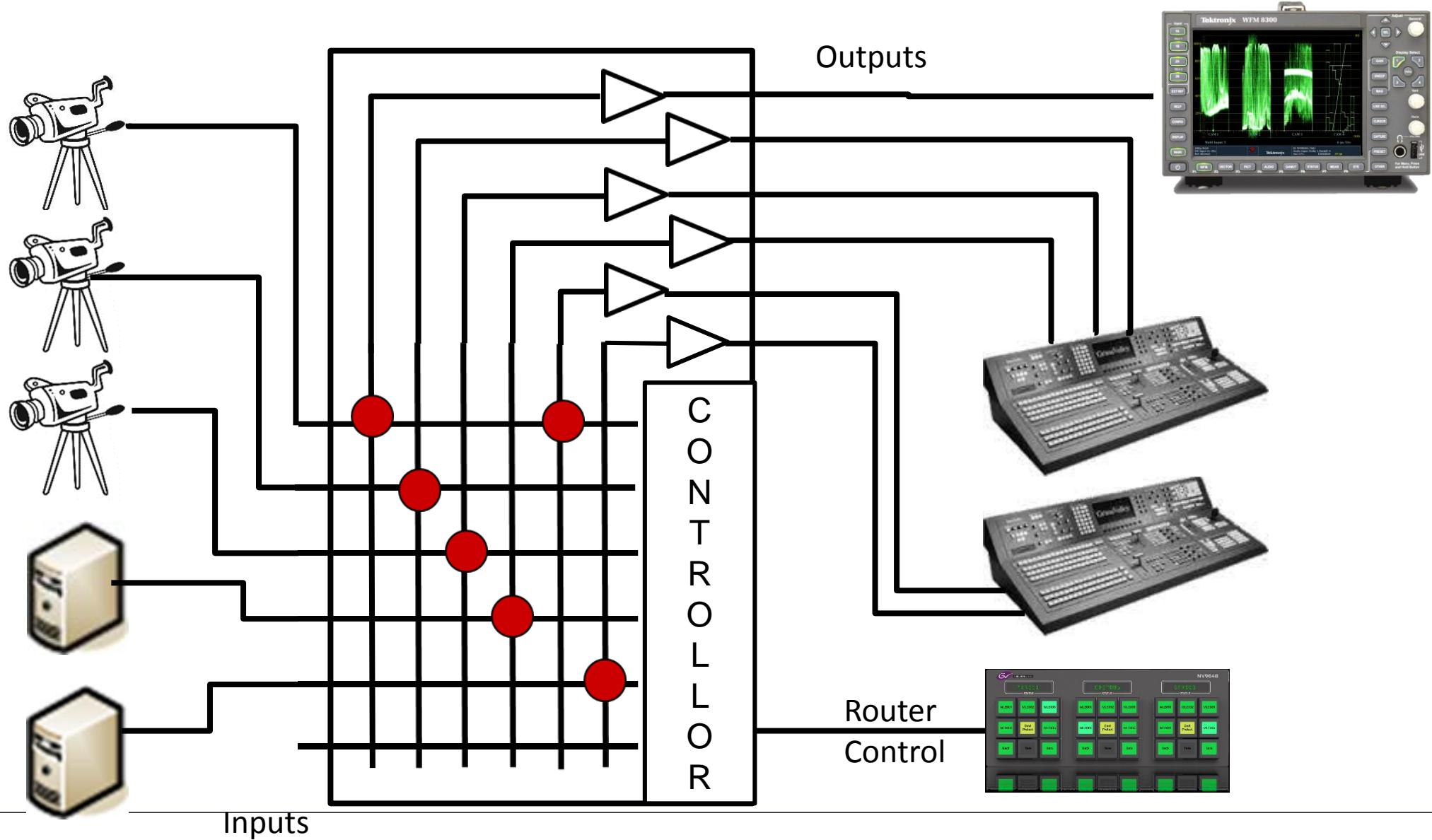
Format, sampling rate	Packet time	Maximum channels per stream
L24, 48 kHz	125 microseconds	80
L16, 48 kHz	250 microseconds	60
L24, 48 kHz	250 microseconds	40
L24, 48 kHz	333-1/3 microseconds	30
L24, 96 kHz	250 microseconds	20
L24, 48 kHz	1 millisecond	10
L24, 48 kHz	4 milliseconds	2



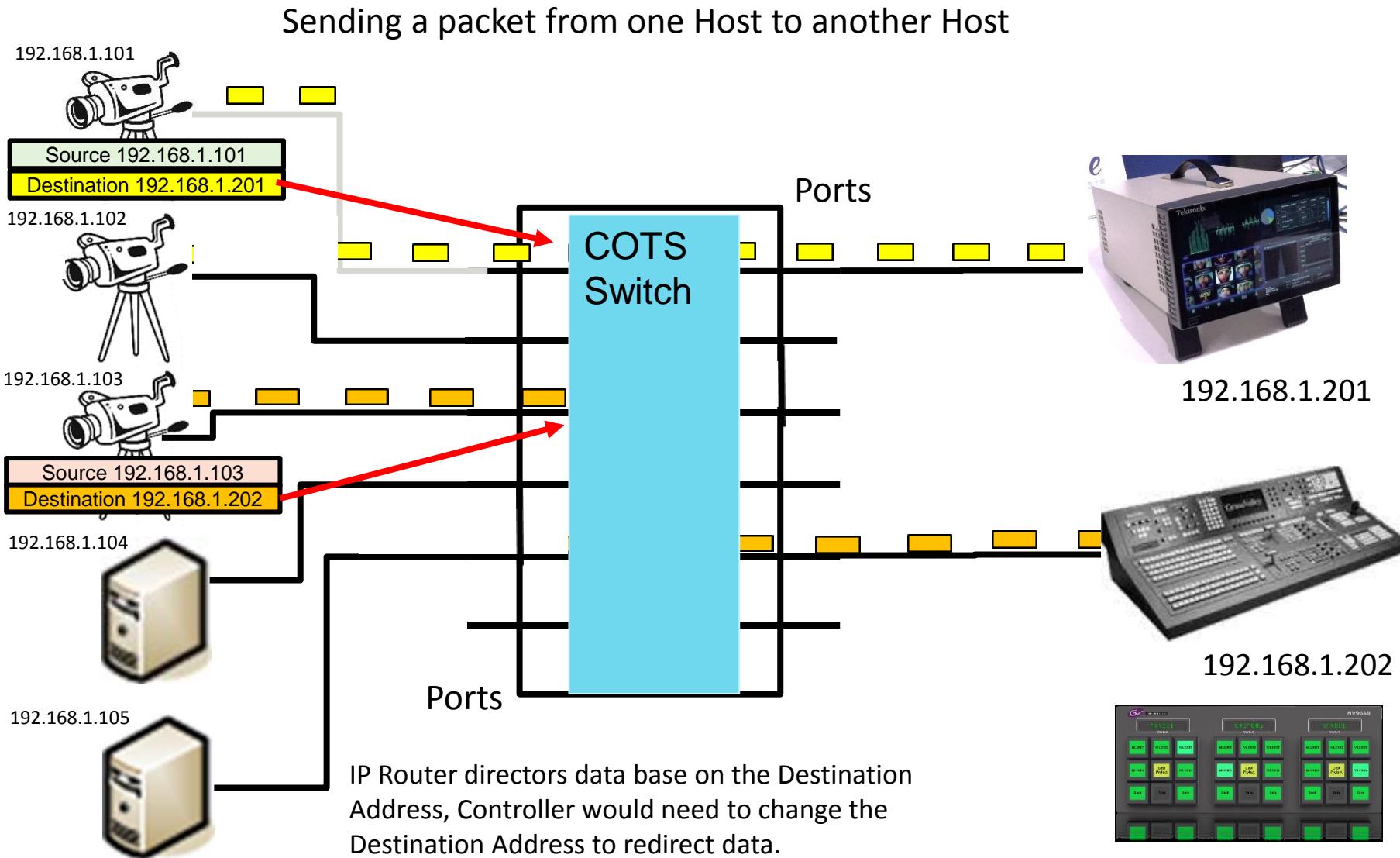
ST2110-30 / ST2110-31

- ST2110-30 is tiny (compared to the video)
- A 2-channel stream is:
 - $(2 \text{ channels}) * (24 \text{ bits}) * (48000 \text{ samples}) * (1.08 \text{ RTP}) = 2.5 \text{ Mbits/sec}$
- An 8-channel stream is:
 - $(8 \text{ channels}) * (24 \text{ bits}) * (48000 \text{ samples}) * (1.05 \text{ RTP}) = 9.7 \text{ Mbits/sec}$
- **2110-31 provides bit-transparent AES3 over IP**
 - Can handle non-PCM audio
 - Can handle AES3 applications that use the user bits
 - Can handle AES3 applications that use the C or V bits
- 2110-31 is always “stereo” (like AES3)

SDI Router

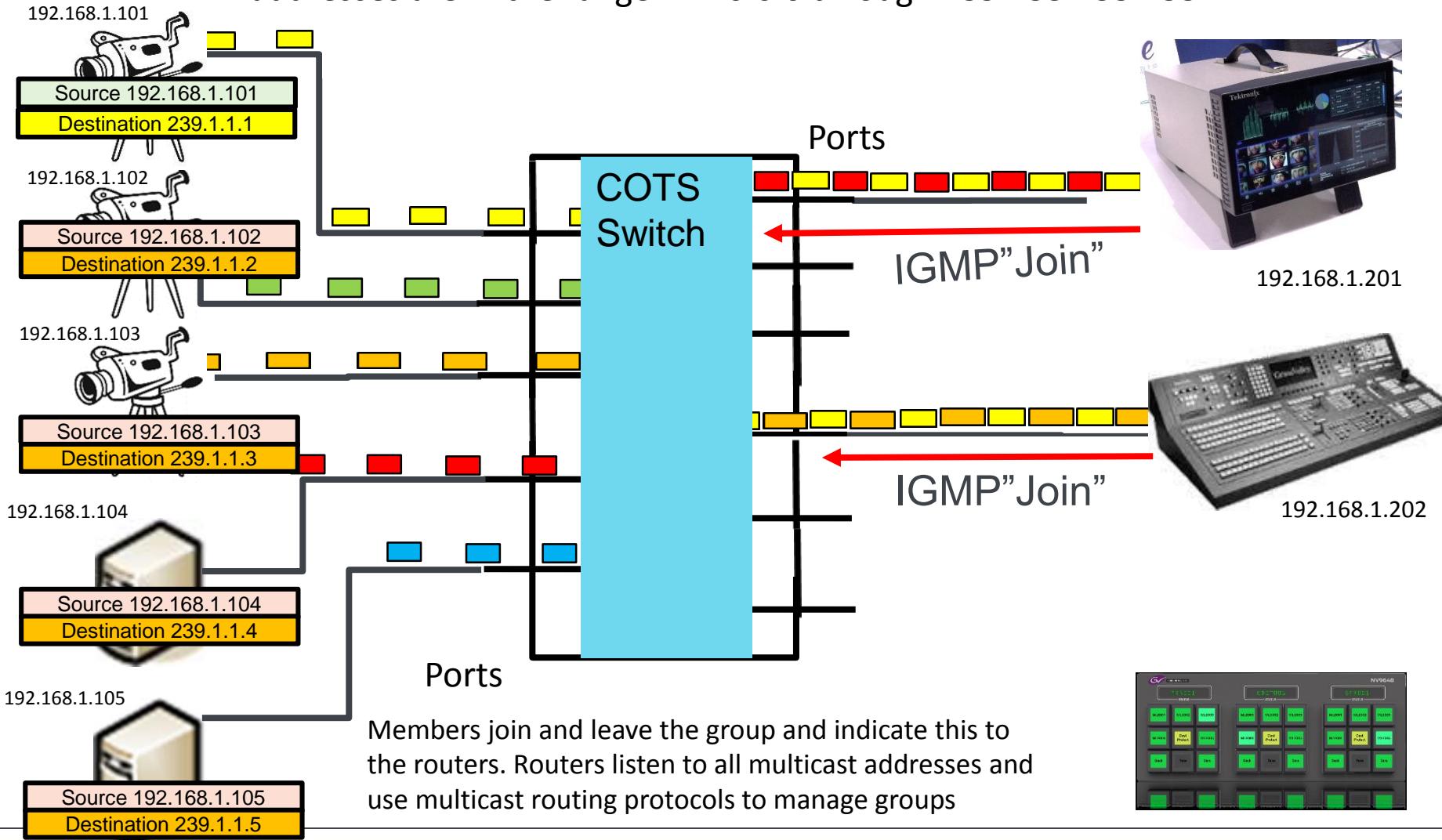


IP Router Layer 3 Switching: Unicast

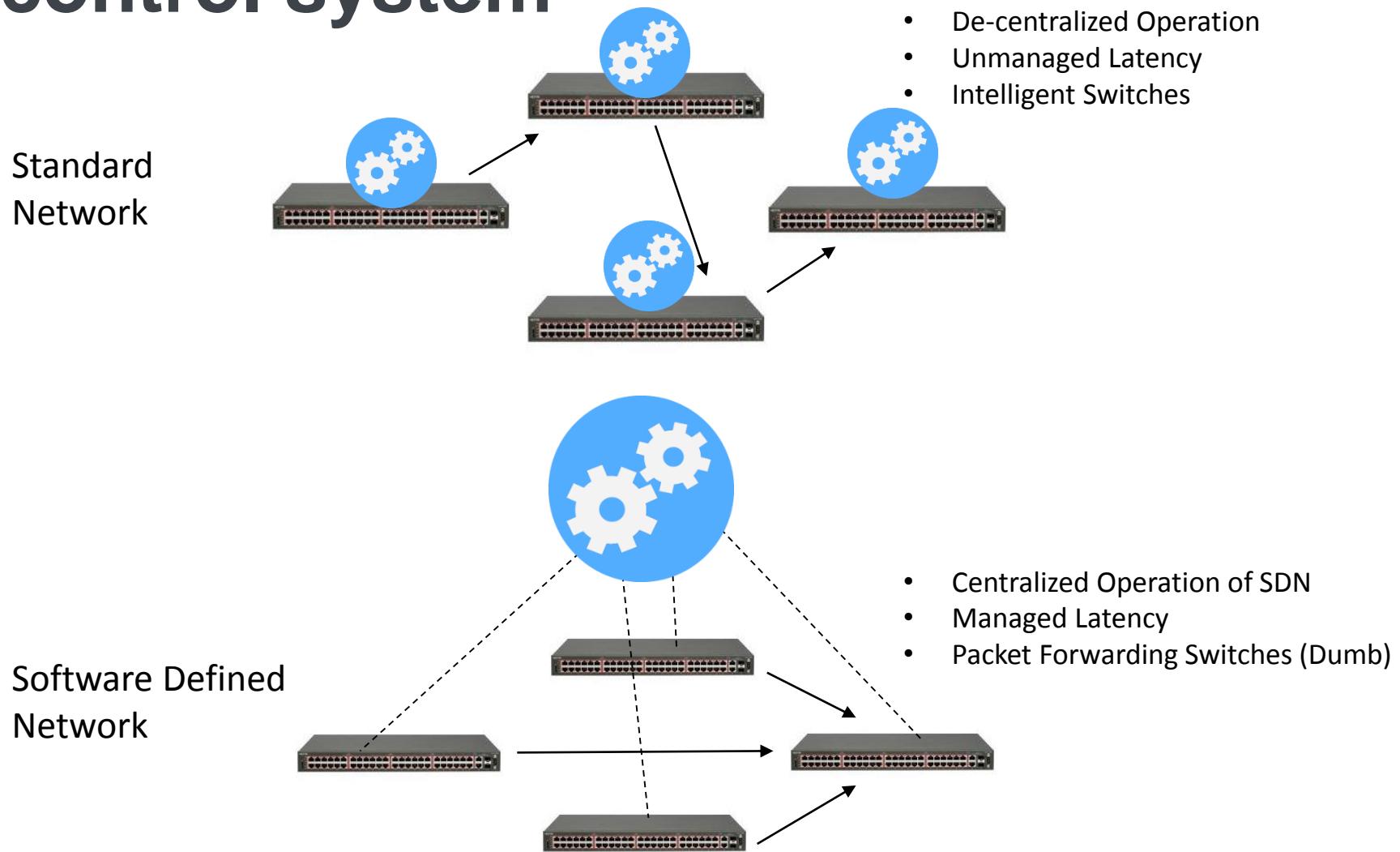


IP Router Layer 3 Switching: Multicast

Sending a packet from one host to a selected group of hosts
addresses are in the range 224.0.0.0 through 239.255.255.255



The importance of SDN within the control system

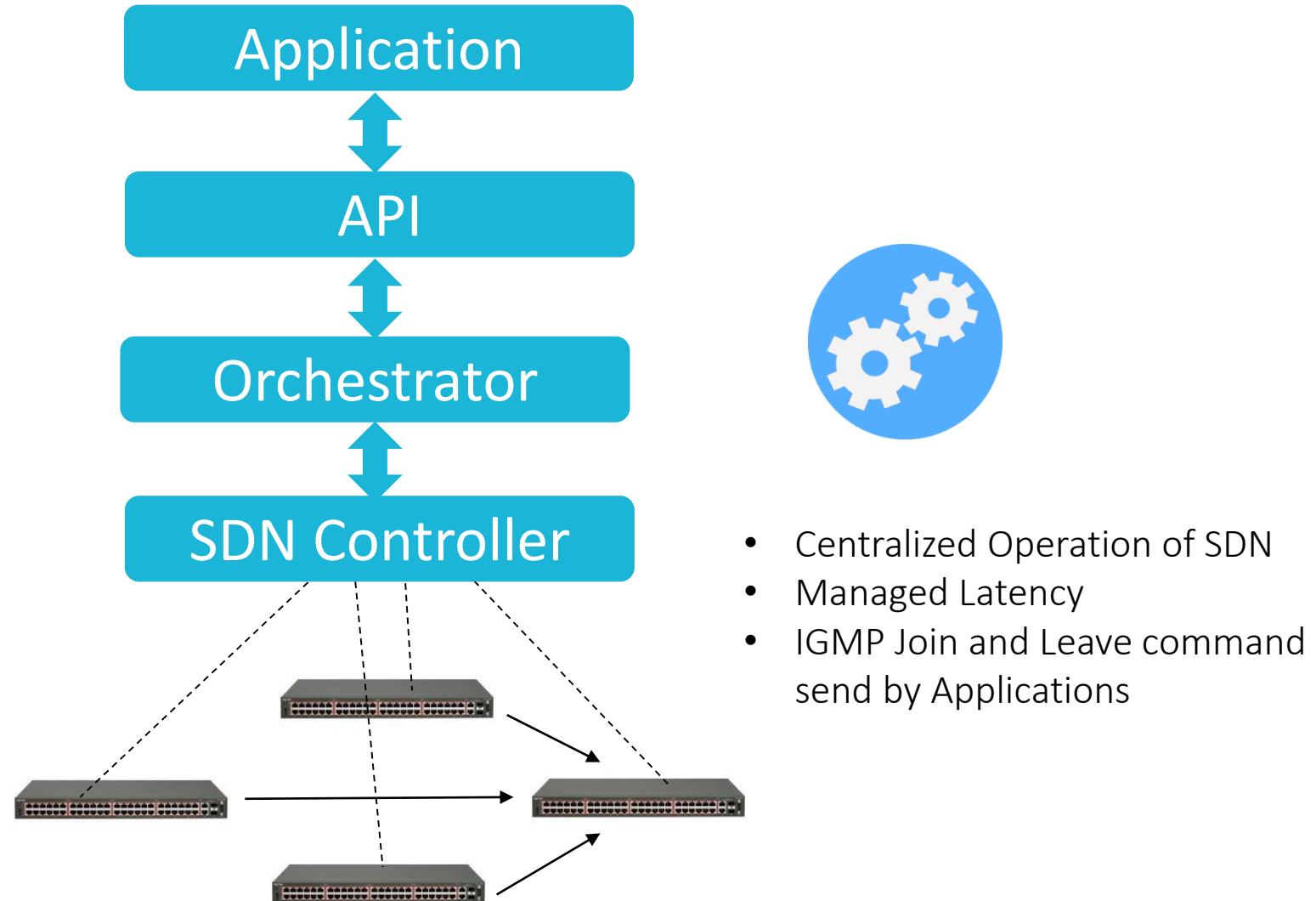


The importance of SDN within the control system

Evertz's MAGNUM
Acts as the SDN Orchestrator
and Controller

Third party System
Integrated via APIs

Software Defined Network

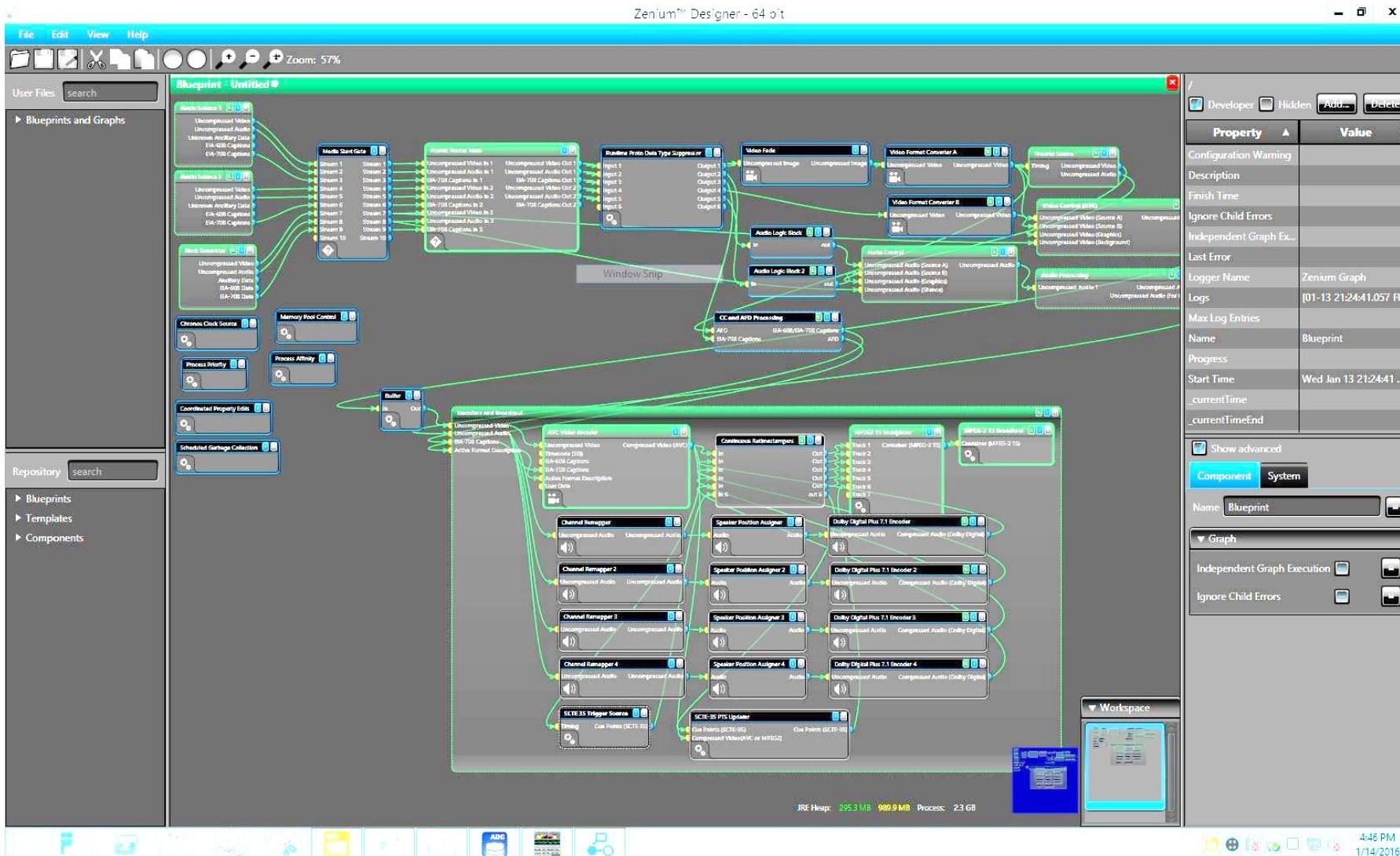


- Centralized Operation of SDN
- Managed Latency
- IGMP Join and Leave command send by Applications

<https://www.opennetworking.org/sdn-resources/sdn-definition>

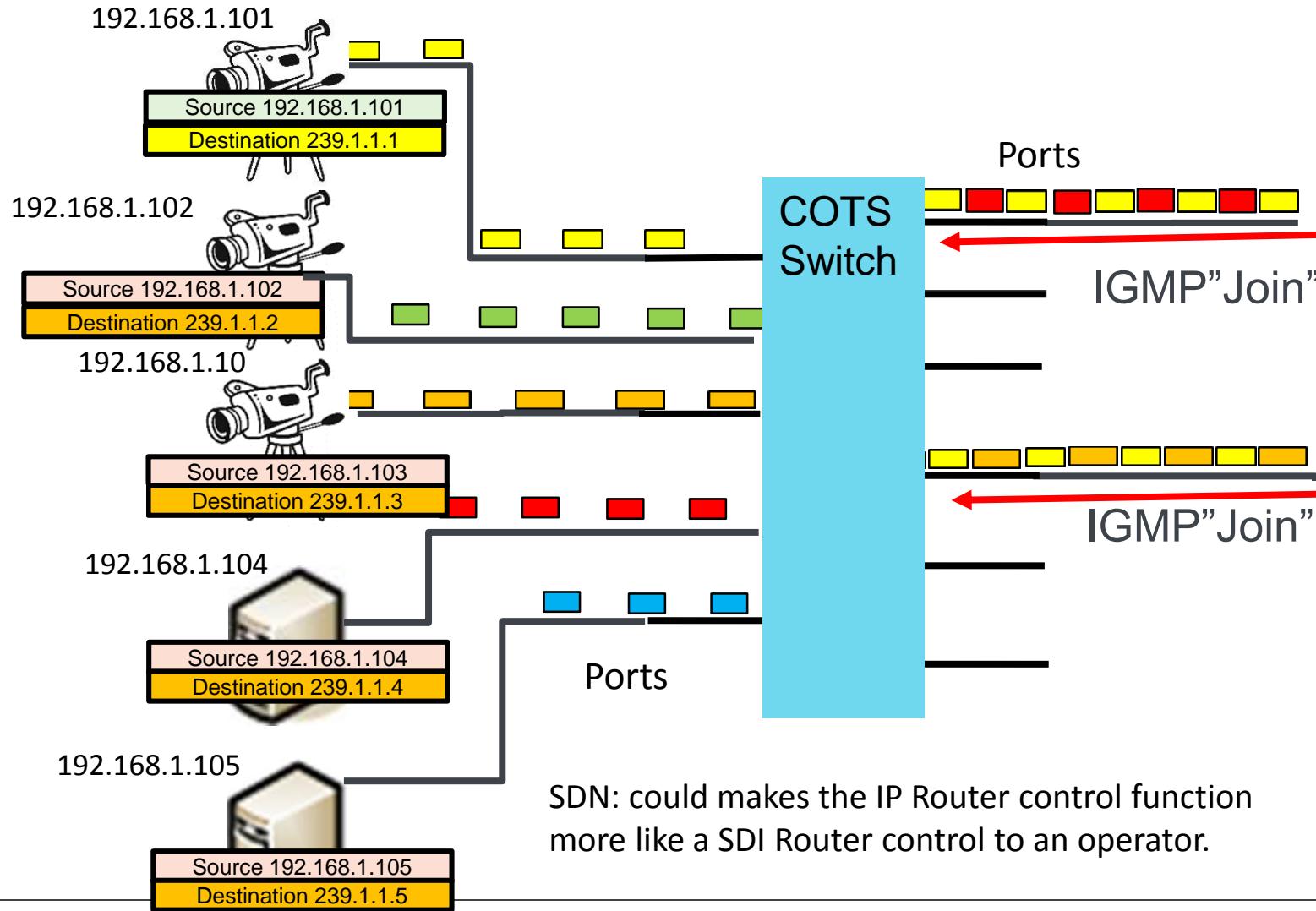
https://en.wikipedia.org/wiki/Software-defined_networking

SDN Configuration



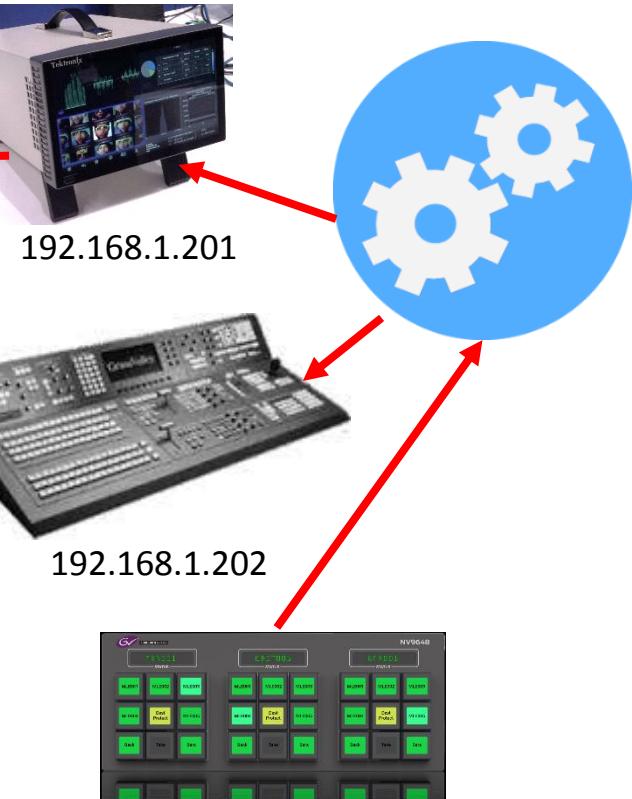
IP Router Layer 3 Switching: SDN

SDN: separates the control plane (deciding where network traffic is sent and why) from the data plane (which moves packets from here to there).



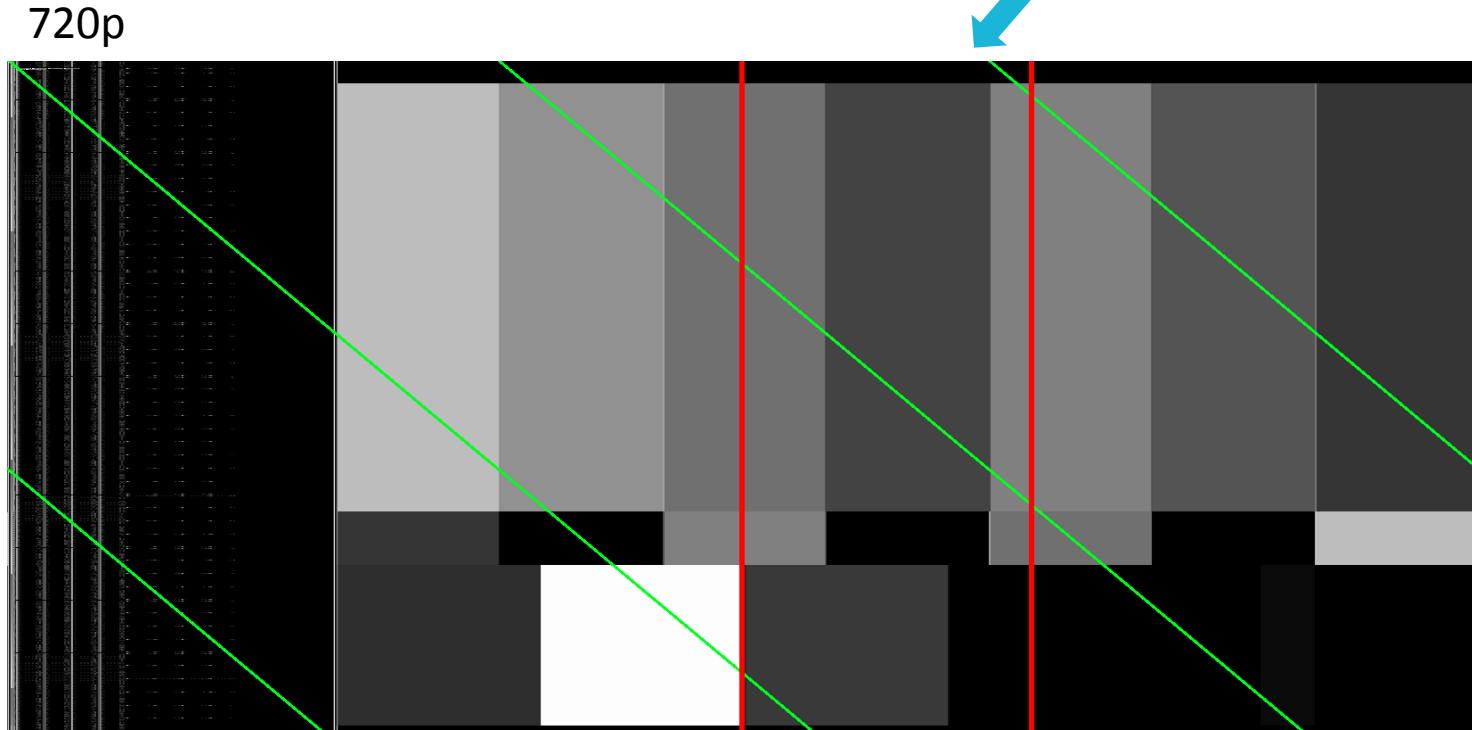
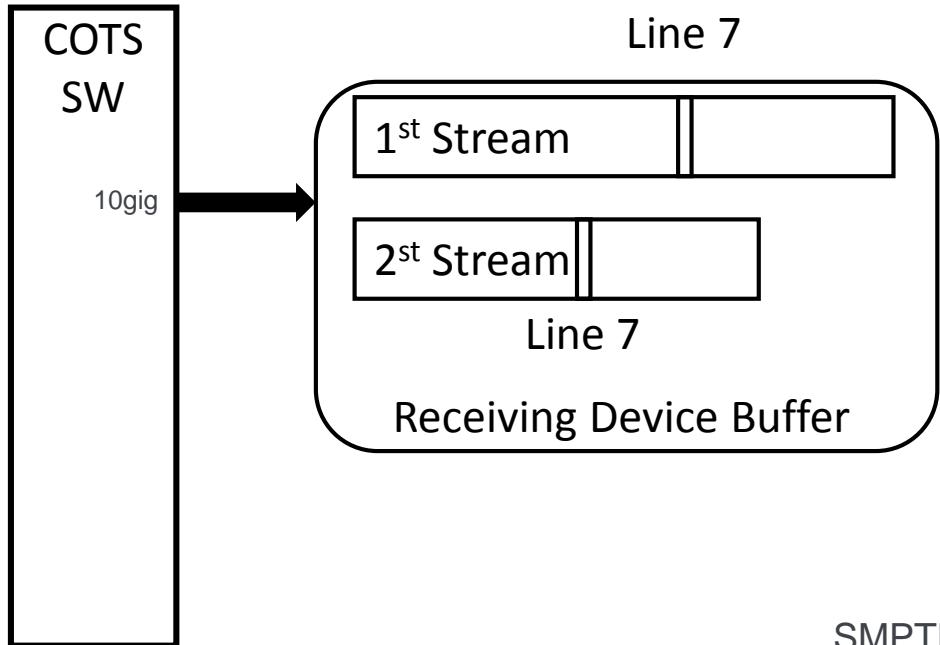
API

Function	Mode
/api/configureInput	GET
/api/configureInput	POST
/api/activeInput	GET
/api/activeInput	POST
/api/help	GET



Some devices will switch
cleanly between signals

Clean Switching between Streams





Doug Keltz
Sr Video Account Manager
Doug.Keltz@Tektronix.com





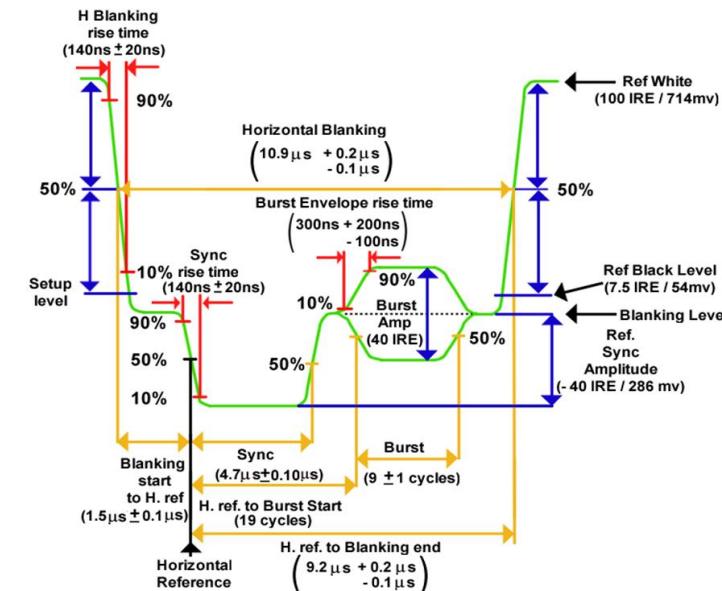
Precision Time Protocol (PTP)

17 SEPTEMBER 2017

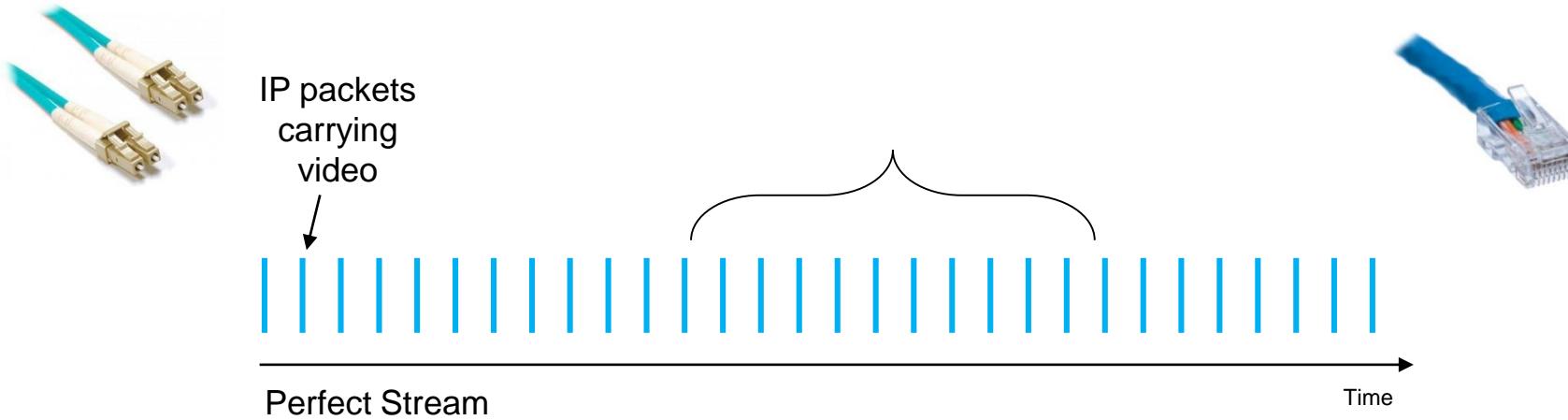


A Brief History of Time and Synchronization

- H & V Drive, Burst Flag and Subcarrier
- Composite Sync plus Subcarrier & Burst Flag
- Genlock
 - Black-burst
 - Tri-level sync
 - DARS (AES3, AES11)
- Network Time Protocol (NTP)
 - For computers and routers on IP networks
 - Uses Stratum clocks (0 = atomic or GPS at top level)
 - Only good down to sub-millisecond level over a local area network
- Precision Time Protocol (PTP)
 - IEEE 1588
 - Uses hardware to process for accuracy and precision.



Low-Jitter on Video over IP

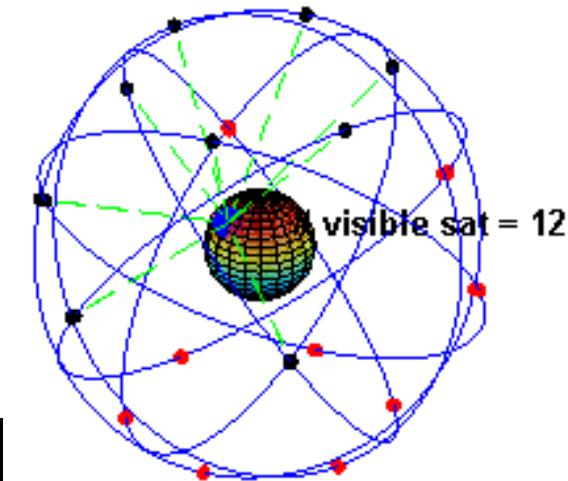
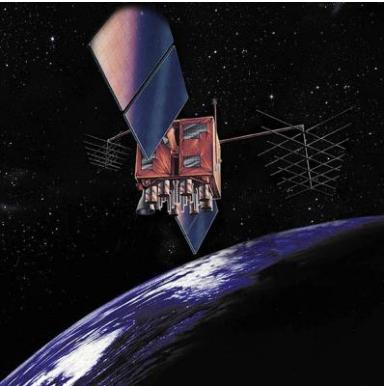


Point to Point Jitter is low



We need a Universal Time Clock

- Global Positioning System
 - Utilizes 24 to 32 satellites in Medium Earth Orbit
 - Currently 30 healthy satellites in orbit
 - Number of visible satellites depends on location on Earth and time of day
 - Usually 8 satellites visible, maximum 12
 - Local obstacles will reduce visibility

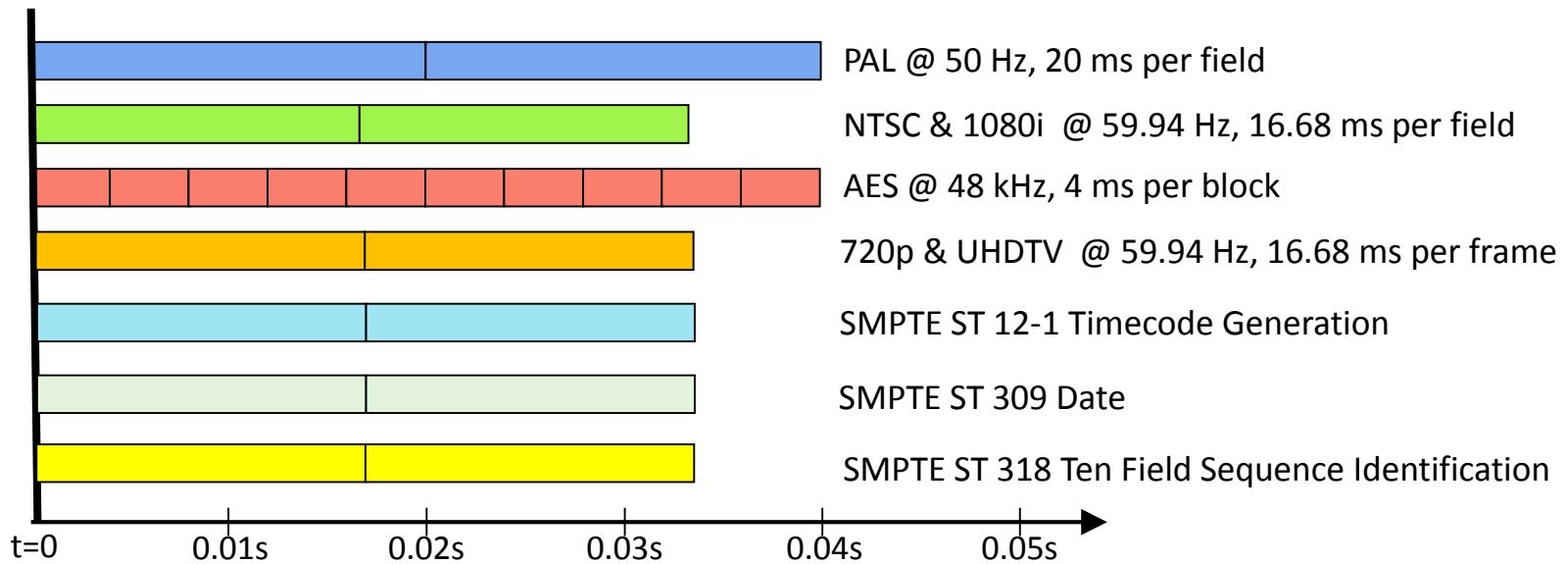


Standards

- IEEE 1588-2008 (289 Pages)
Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
- IEEE 802.1AS Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.(Audio Video Bridging (AVB))(gPTP)
- SMPTE ST 2059-1 2015
Generation and Alignment of Interface Signal to the SMPTE Epoch
- SMPTE ST 2059-2 2015
Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications
- AES 67 is a standard for High-performance streaming audio-over-IP
Has a Profile for IEEE-1588

SMPTE ST 2059-1

- Defines SMPTE Epoch same as IEEE-1588
 - Date 1970-01-01 Time 00:00:00 TAI
 - Provides Alignment Points for

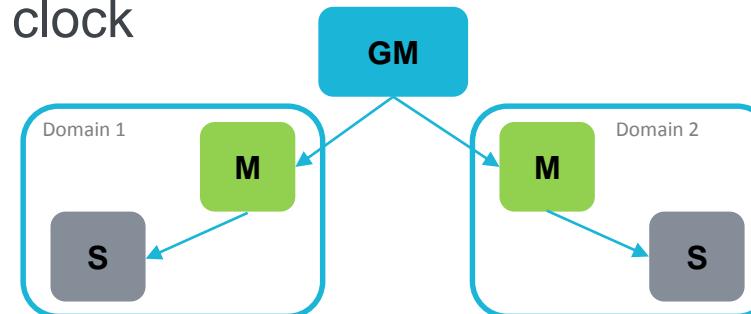


SMPTE ST 2059-2

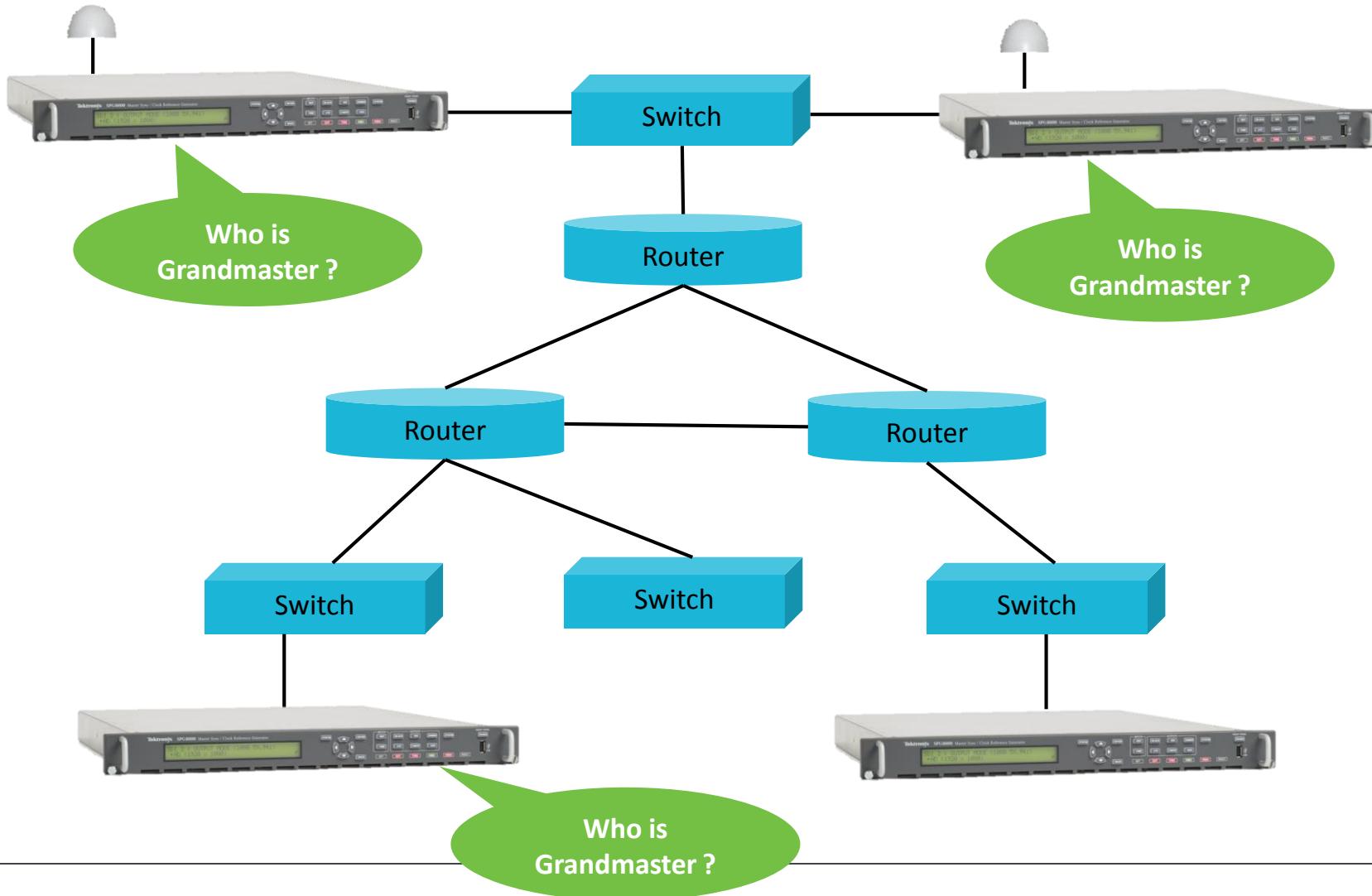
- PTP Profile
 - Profile Identification
 - Best Master Clock Algorithm (BMCA)
 - Management Mechanism
 - Path Delay Measurement Mechanism
 - PTP Attribute Values
 - Slave Clocks
 - Clock Physical Requirements
 - Node Types Required, Permitted or Prohibited
 - Transport Mechanisms Permitted
 - Communication Model
 - PTP option
 - Alternate Master
 - Organization Extension TLV Synchronization Metadata Setting
 - Dynamic SM TLV Values.

PTP Terms and Definitions

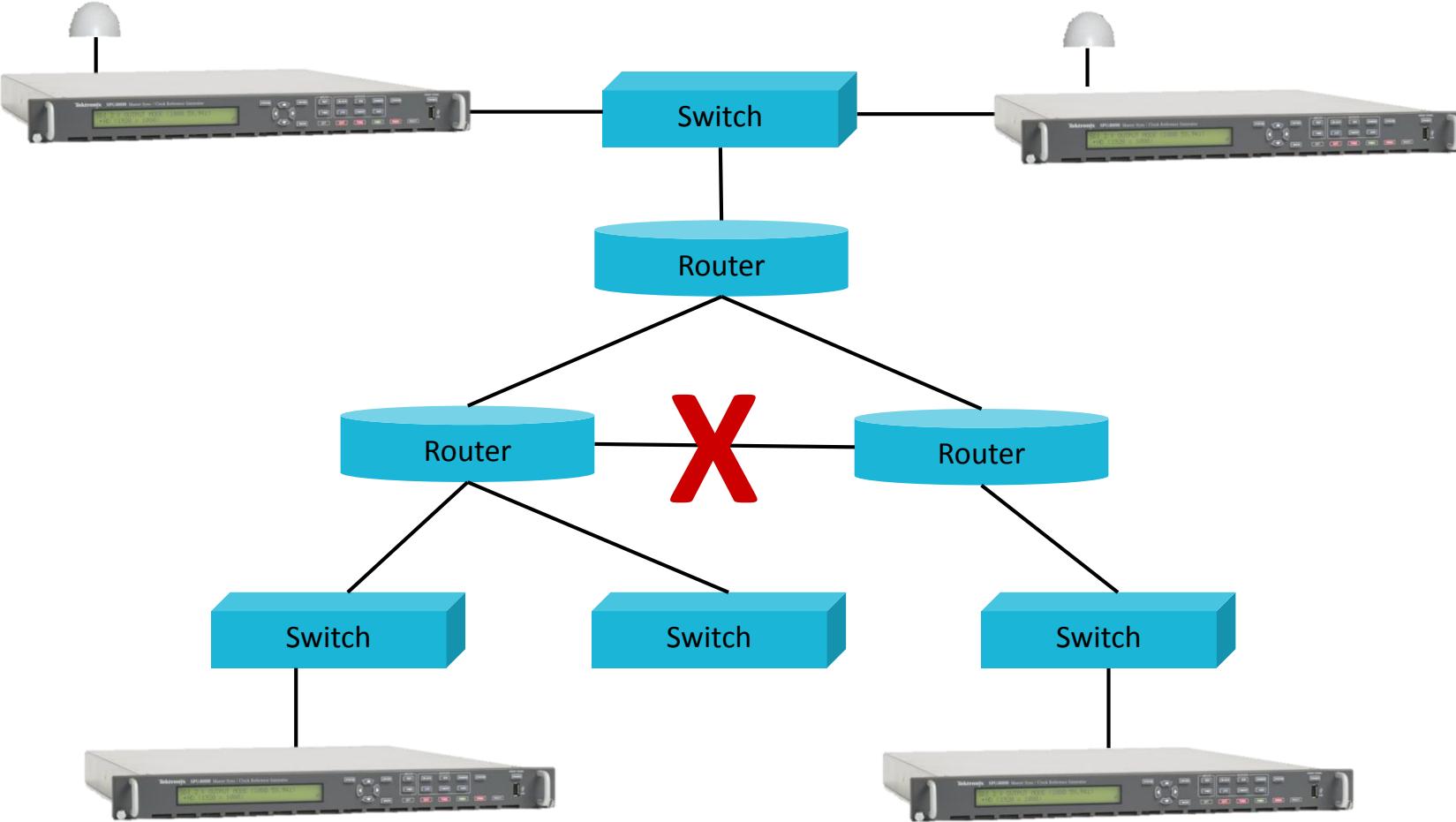
- PTP Domain
 - Logical grouping of clocks that are synchronised to each other using PTP, but may not be synchronised to other clocks in another domain
- Grandmaster Clock
 - Ultimate source of time for clock synchronisation using PTP
 - In broadcast applications, these are usually synchronised to GPS, GLONASS or both
- Master Clock (Mode)
 - A clock that is the source of time to which all other clocks in that domain are synchronised
- Slave Clock (Mode)
 - A clock that is synchronised to another clock



Best Master Clock Algorithm (BMCA)



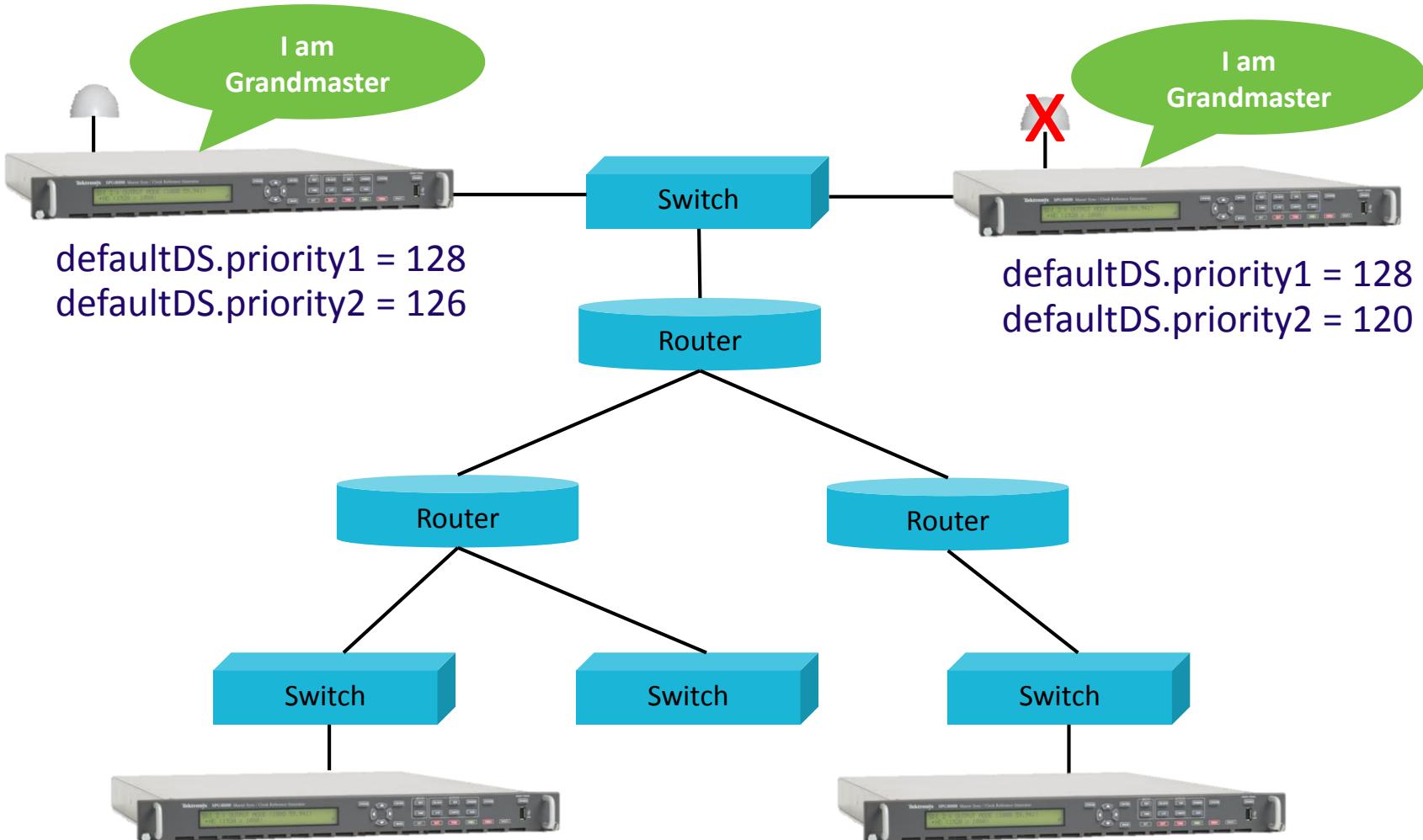
Best Master Clock Algorithm (BMCA)



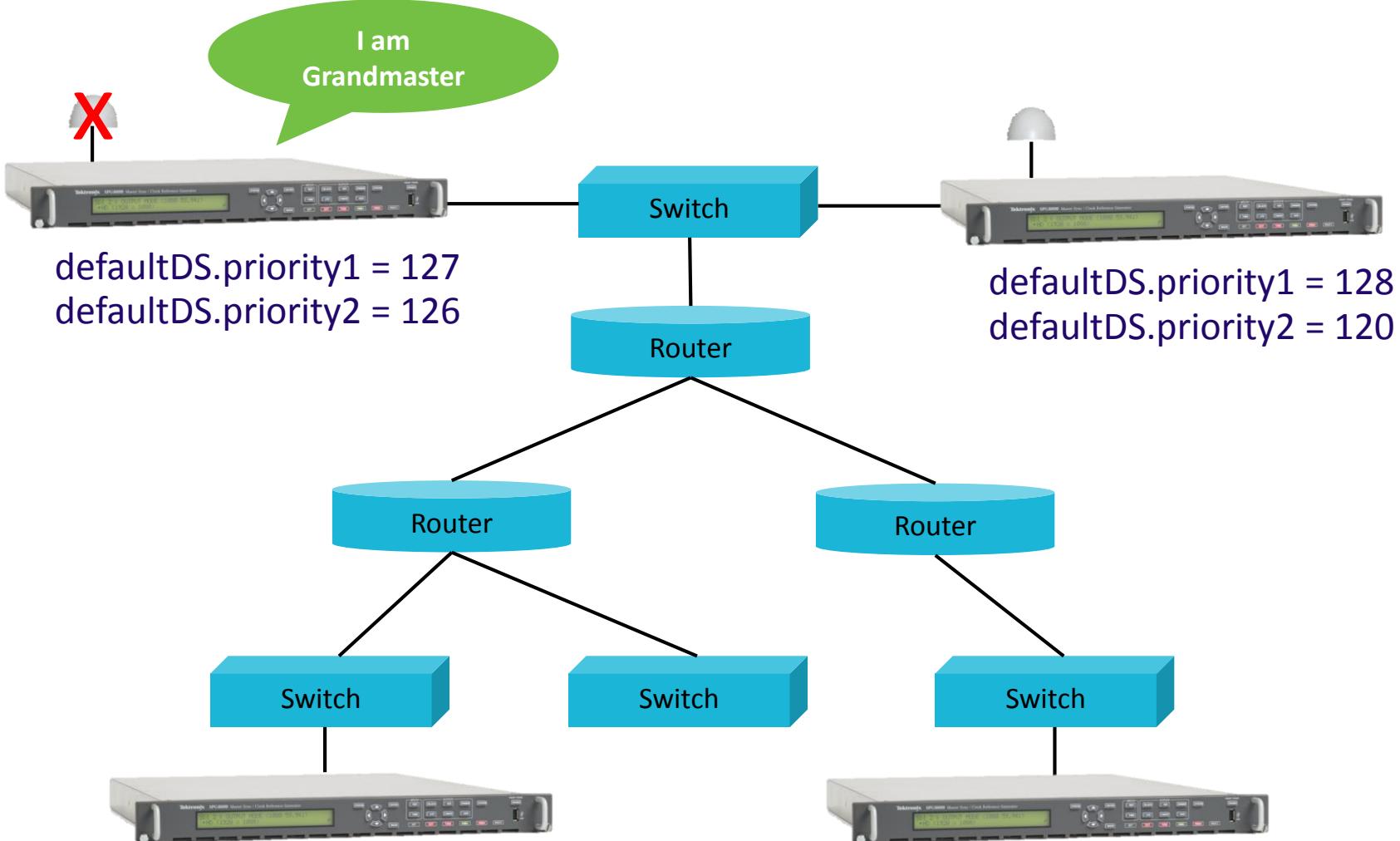
Best Master Clock Algorithm (BMCA)

- BMCA runs on all devices
- Master based on several parameters
- Priority 1 **defaultDS.priority1** Default Value 128
 - Lowest value wins (Range 0-255)
- Clock Class
- Clock Accuracy
- Clock Variance
- Priority 2 **defaultDS.priority2** Default Value 128
 - Lowest value wins (Range 0-255)
- Final tie breaker
 - Clock ID usually MAC address

Best Master Clock Algorithm (BMCA)



Best Master Clock Algorithm (BMCA)

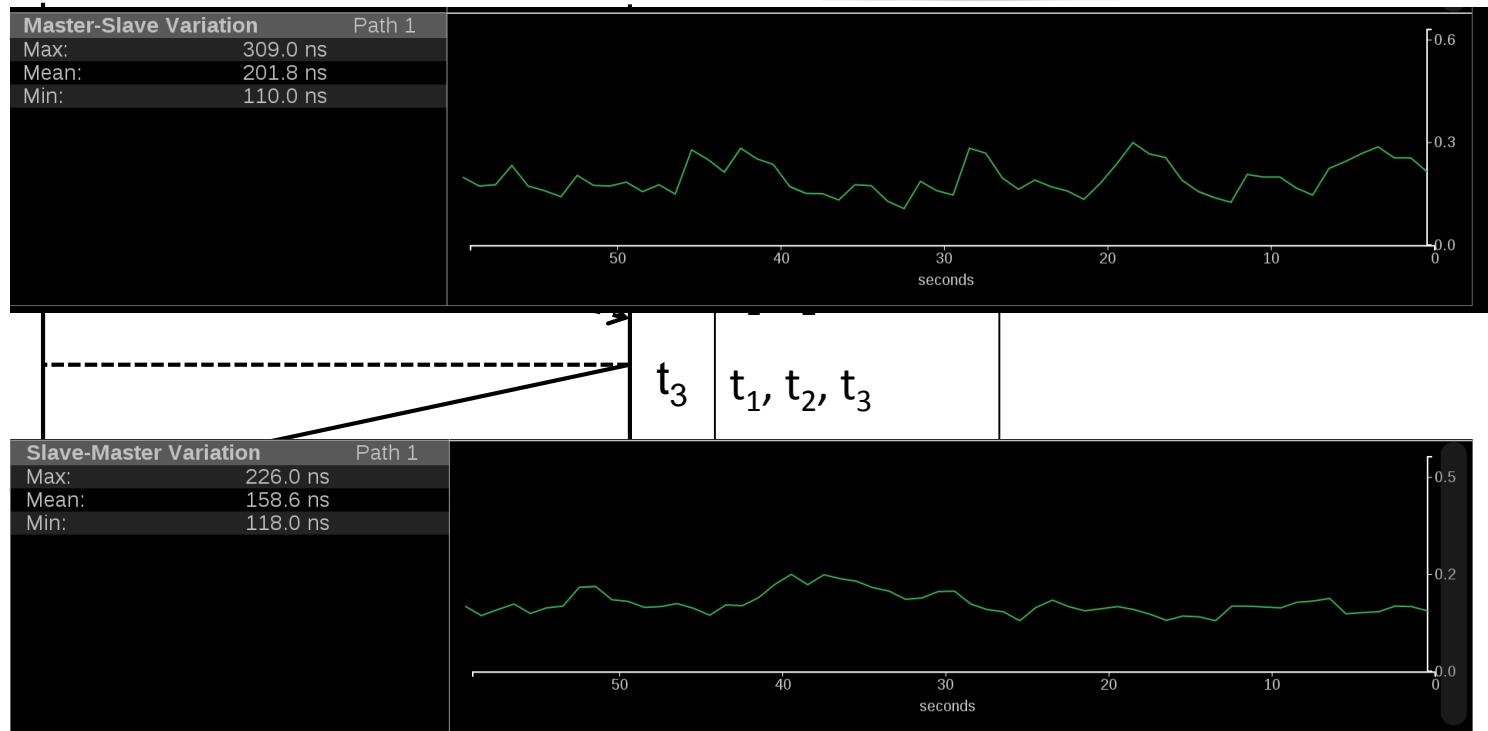
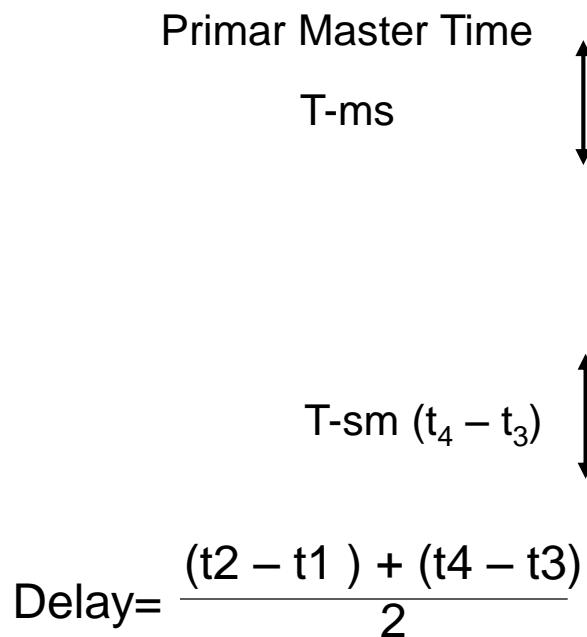


PTP Messages

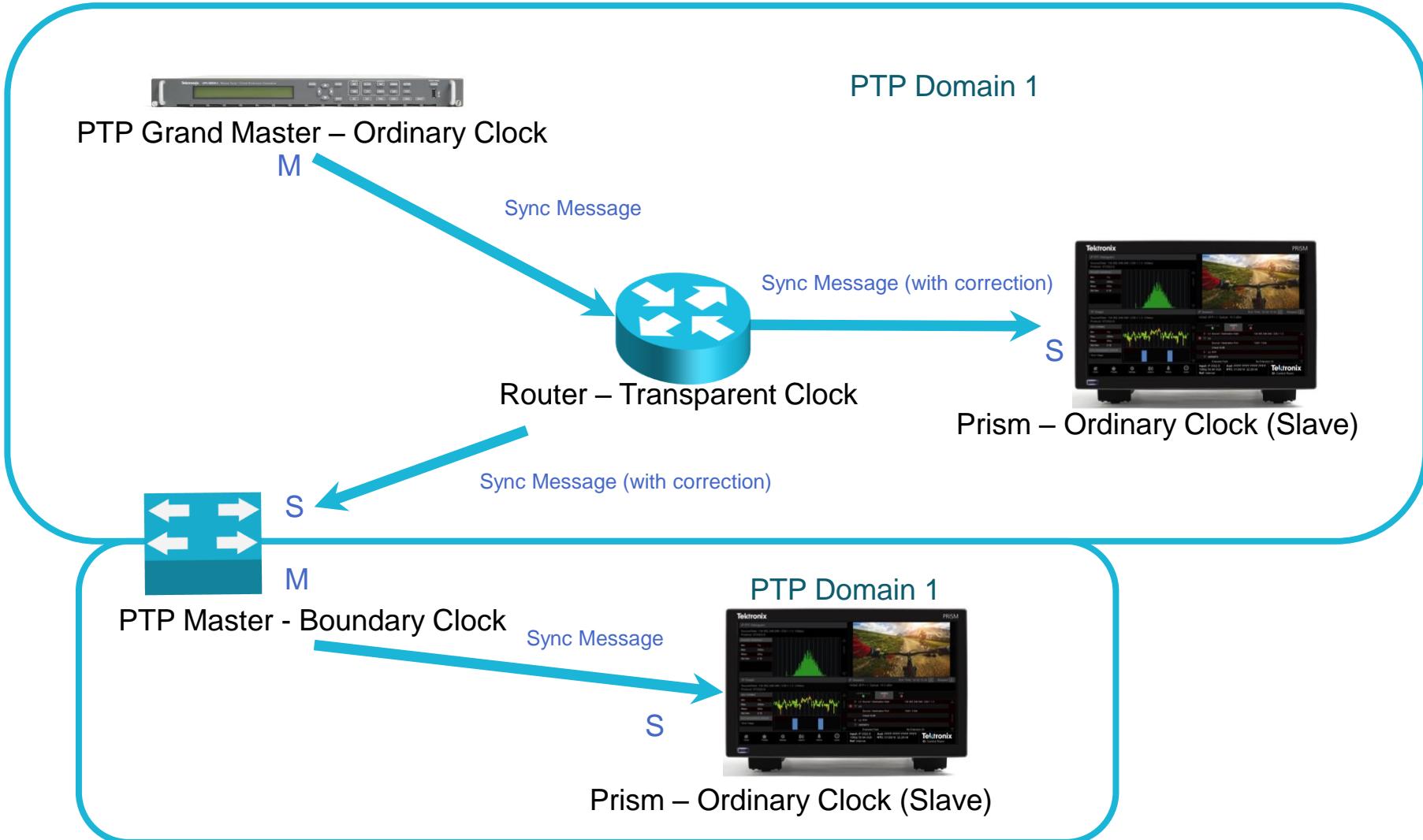
- Announce
 - Establish the synchronization hierarchy
 - Provide Status and Characterization used to determine BCMA and Grandmaster
- Sync
 - Provides value of **originTimestamp**
- Follow-Up (Used in the Two Step Mode)
 - Provides value of **SyncEventEgressTimestamp**
- Delay Request
 - Use to measure propagation delay between two PTP ports
- Delay Response
 - Provides value of **delayReqEventIngressTimestamp**

Synchronization Message Exchange

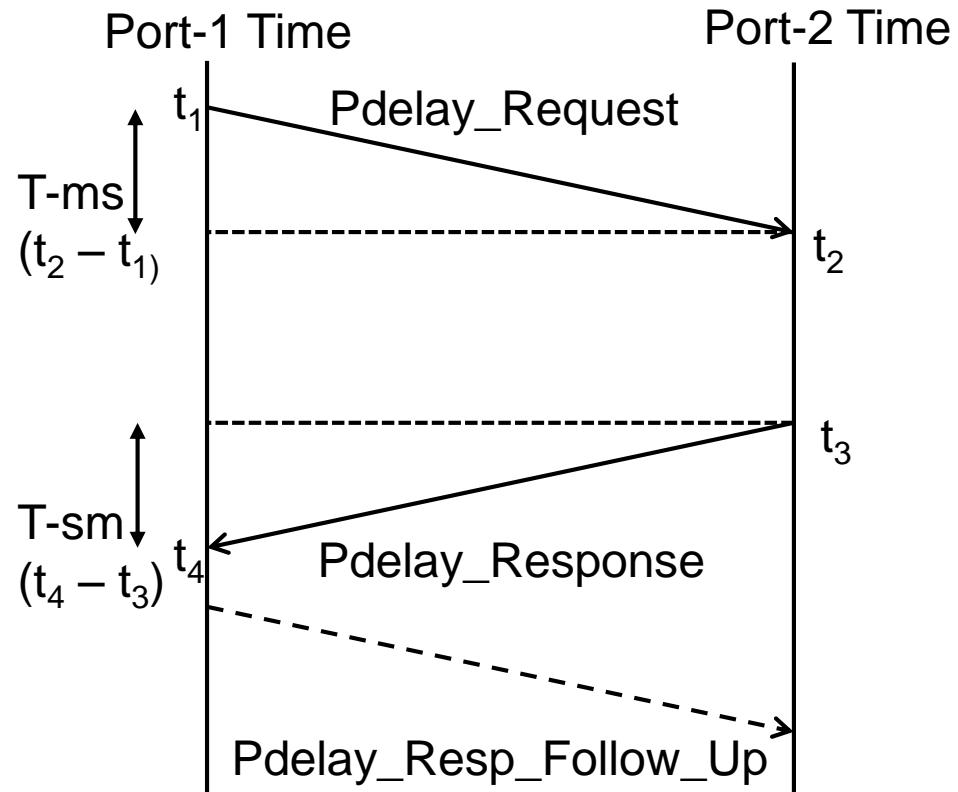
Used by Ordinary and Boundary Clocks



PTP Clock Types In A Network

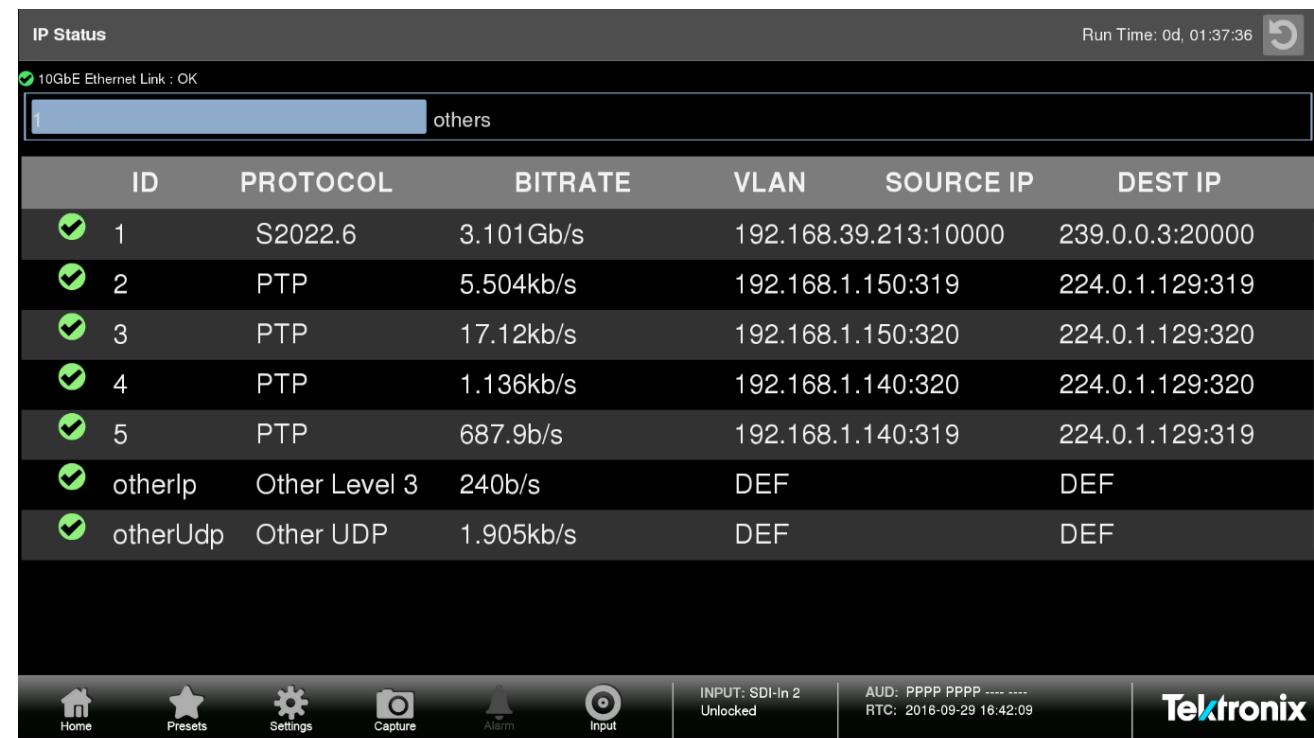


Peer to Peer Synchronization Message Exchange



PTP Communication modes

- ST2059 supports:
 - **Multicast**
 - Sending a packet from one host to a selected group of hosts
 - PTP uses a default Multicast address 224.0.1.129
 - Announce & Follow-UP messages uses port 320
 - Sync & Delay-Request messages uses port 319
 - **Unicast**
 - Need to enter IP Address of all possible GM
 - **Mixed Mode**
 - Announce/Sync/Follow-up all Multicast from GM
 - Delay messaging from the Slaves are Unicast
 - **Mixed SMPTE w/o negotiation**
 - Mixed SMPTE without negotiation does not allow master to regulate load



The screenshot shows a network monitoring interface titled "IP Status". It displays a table of PTP traffic statistics. The table has columns for ID, PROTOCOL, BITRATE, VLAN, SOURCE IP, and DEST IP. There are 8 entries in the table:

ID	PROTOCOL	BITRATE	VLAN	SOURCE IP	DEST IP
1	S2022.6	3.101Gb/s	192.168.39.213:10000	239.0.0.3:20000	
2	PTP	5.504kb/s	192.168.1.150:319	224.0.1.129:319	
3	PTP	17.12kb/s	192.168.1.150:320	224.0.1.129:320	
4	PTP	1.136kb/s	192.168.1.140:320	224.0.1.129:320	
5	PTP	687.9b/s	192.168.1.140:319	224.0.1.129:319	
otherIp	Other Level 3	240b/s	DEF	DEF	
otherUdp	Other UDP	1.905kb/s	DEF	DEF	

At the bottom of the interface, there is a navigation bar with icons for Home, Presets, Settings, Capture, Alarm, Input, and a status bar showing "INPUT: SDI-In 2 Unlocked", "AUD: PPPP PPPP ---- ----", "RTC: 2016-09-29 16:42:09", and the Tektronix logo.

Troubleshooting PTP

- Ensure Symmetry of Network
- Check Domain of each device.
 - All devices should be on same Domain.
- Check the communication mode (Multicast, Unicast or Mixed)
- If using Multicast make sure all devices in same group
- Check Priority Levels to ensure correct Master used and suitable Backup chosen.
- Used Holdover recovery when loss of sync.
- Ensure set-up of Jam Sync at suitable time.



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