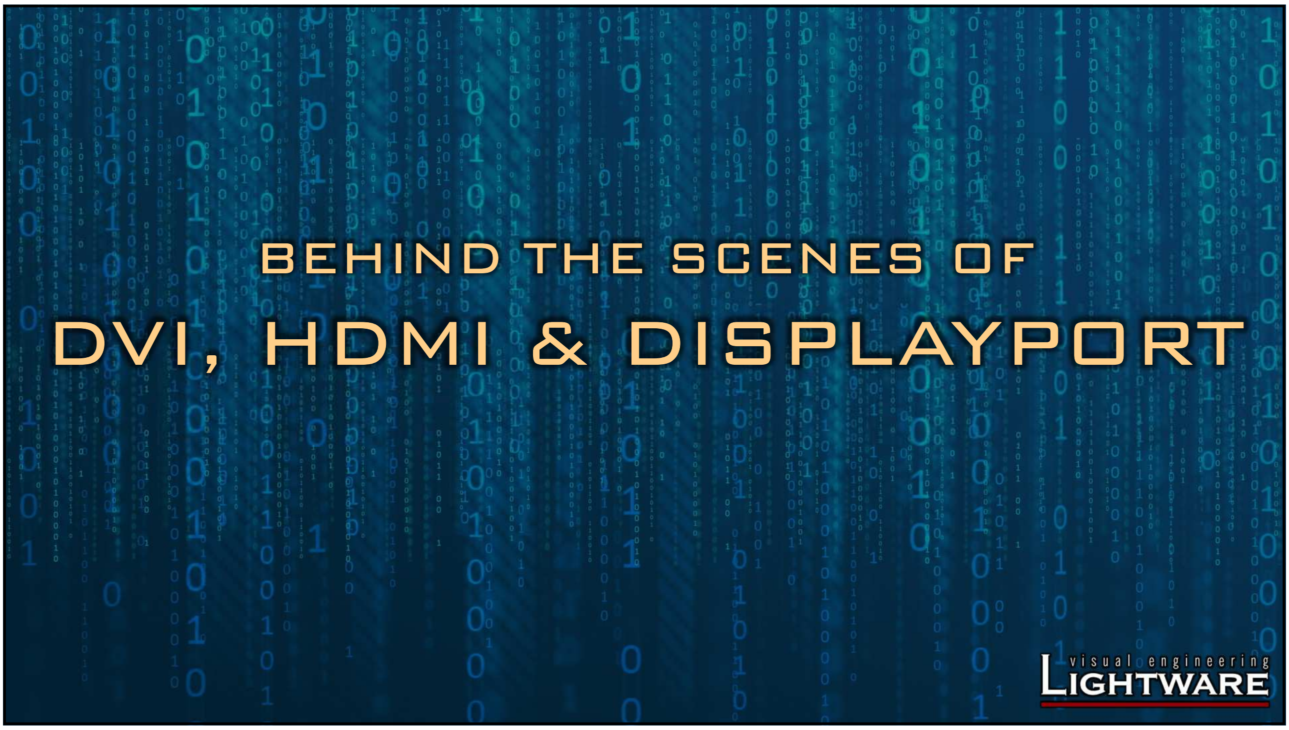
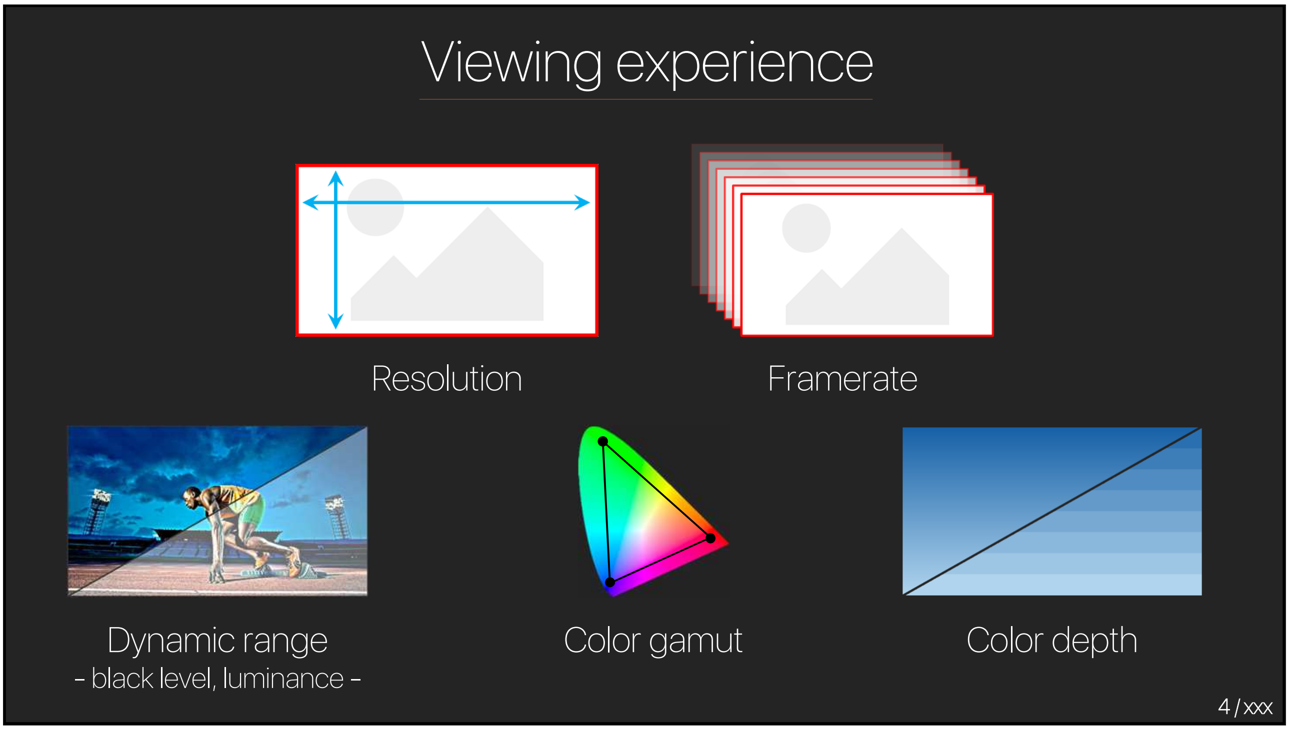
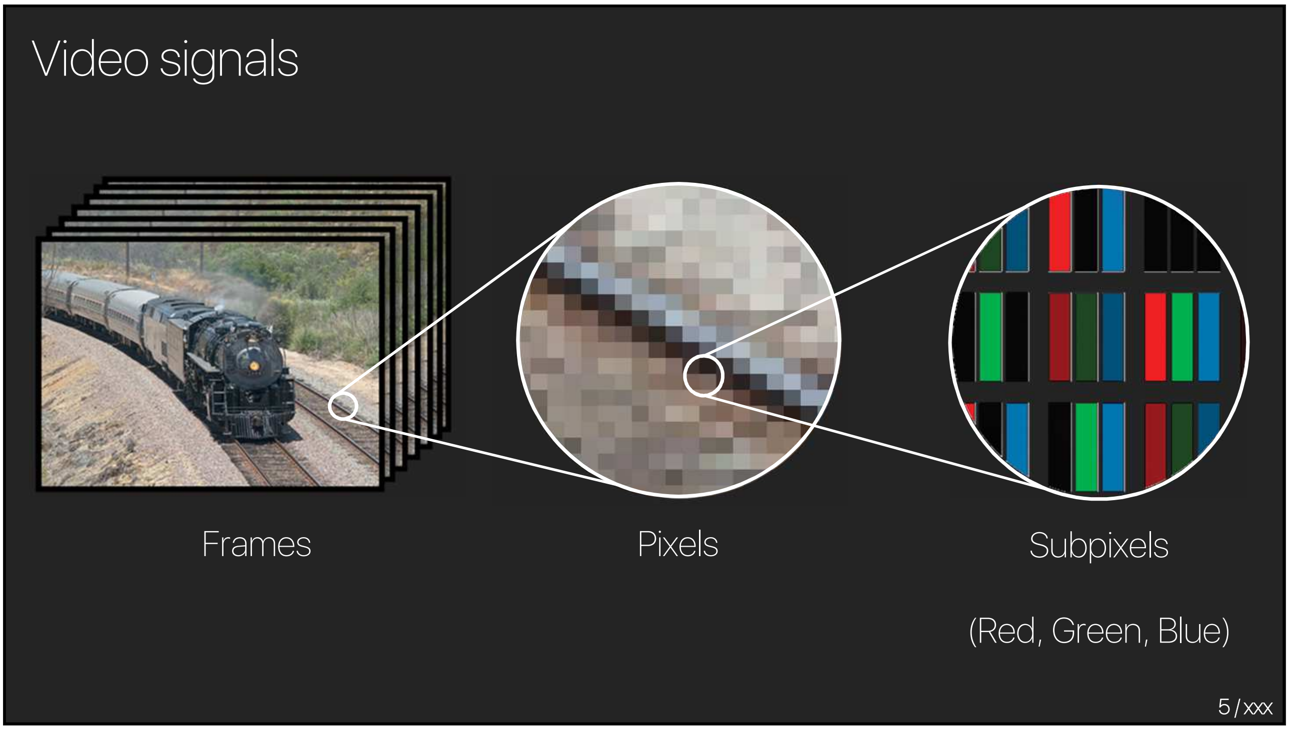
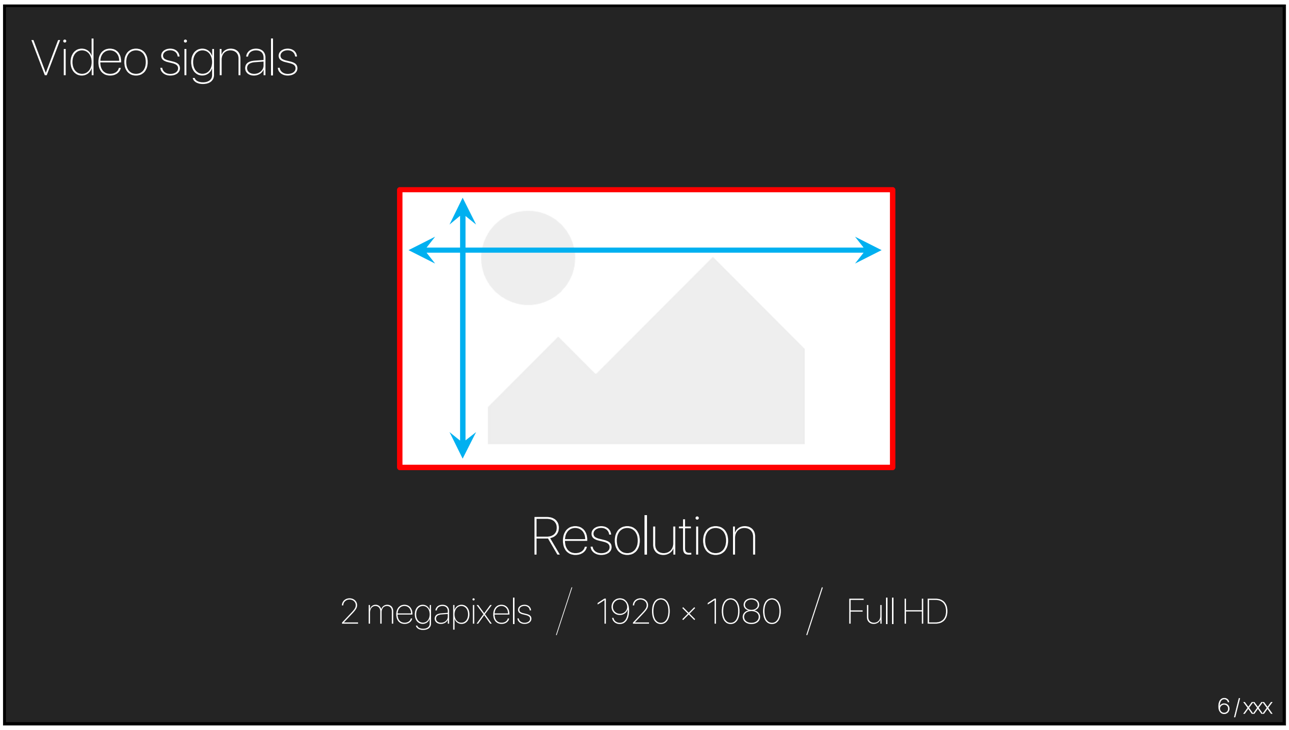

BEHIND THE SCENES OF
DVI, HDMI & DISPLAYPORT
visual engineering
LIGHTWARE

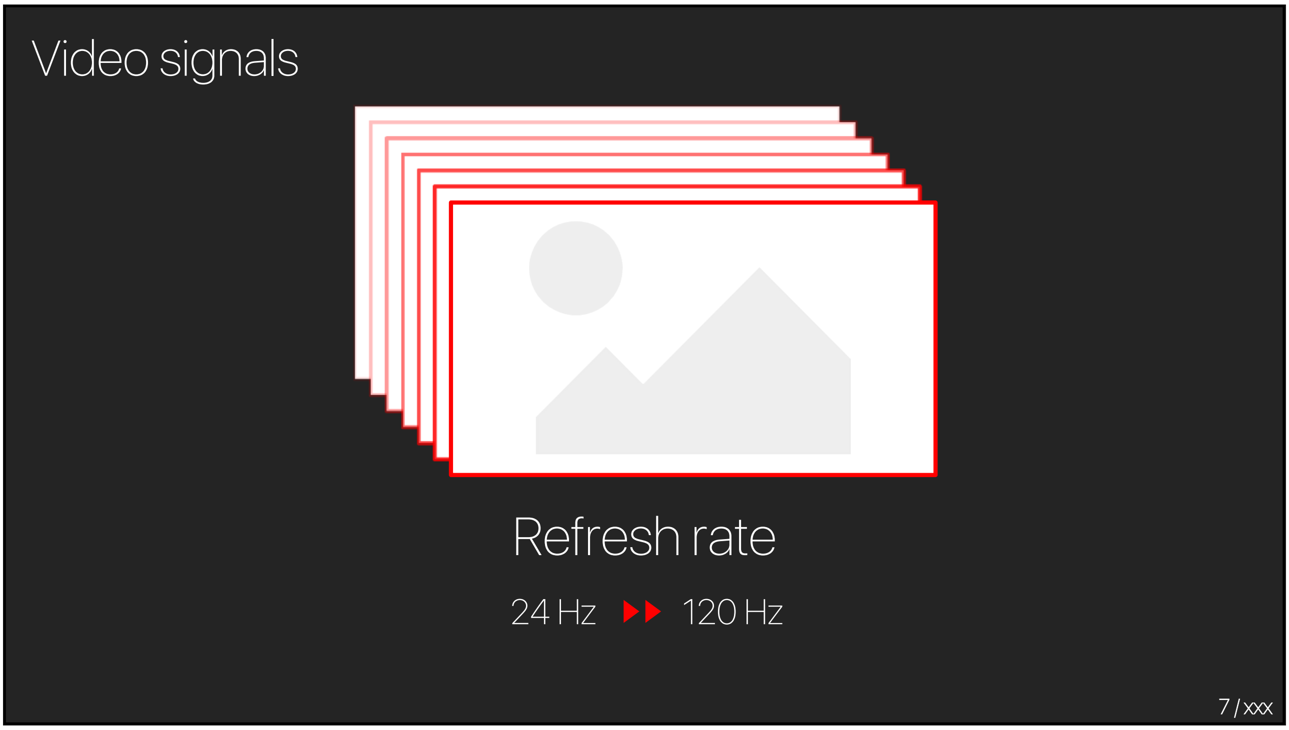

BASICS
Video signals
2 / xxx

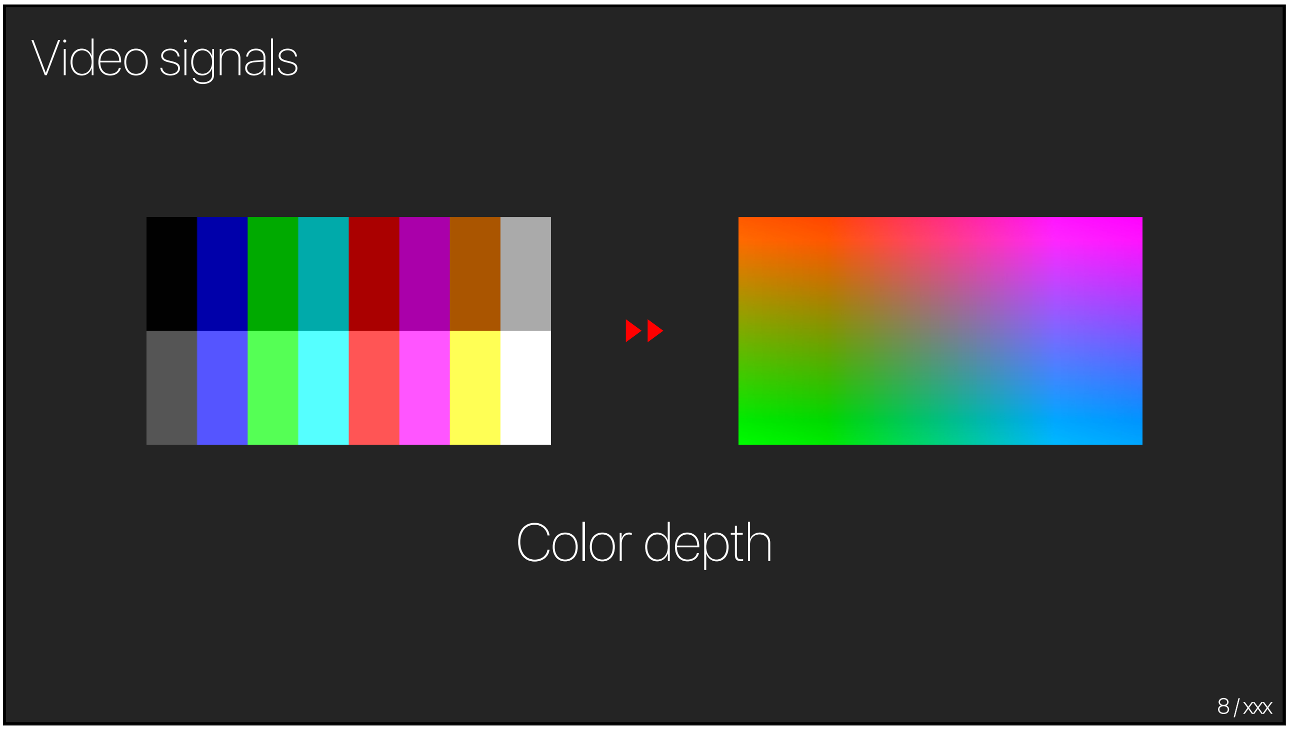

The trick
3 / xxx

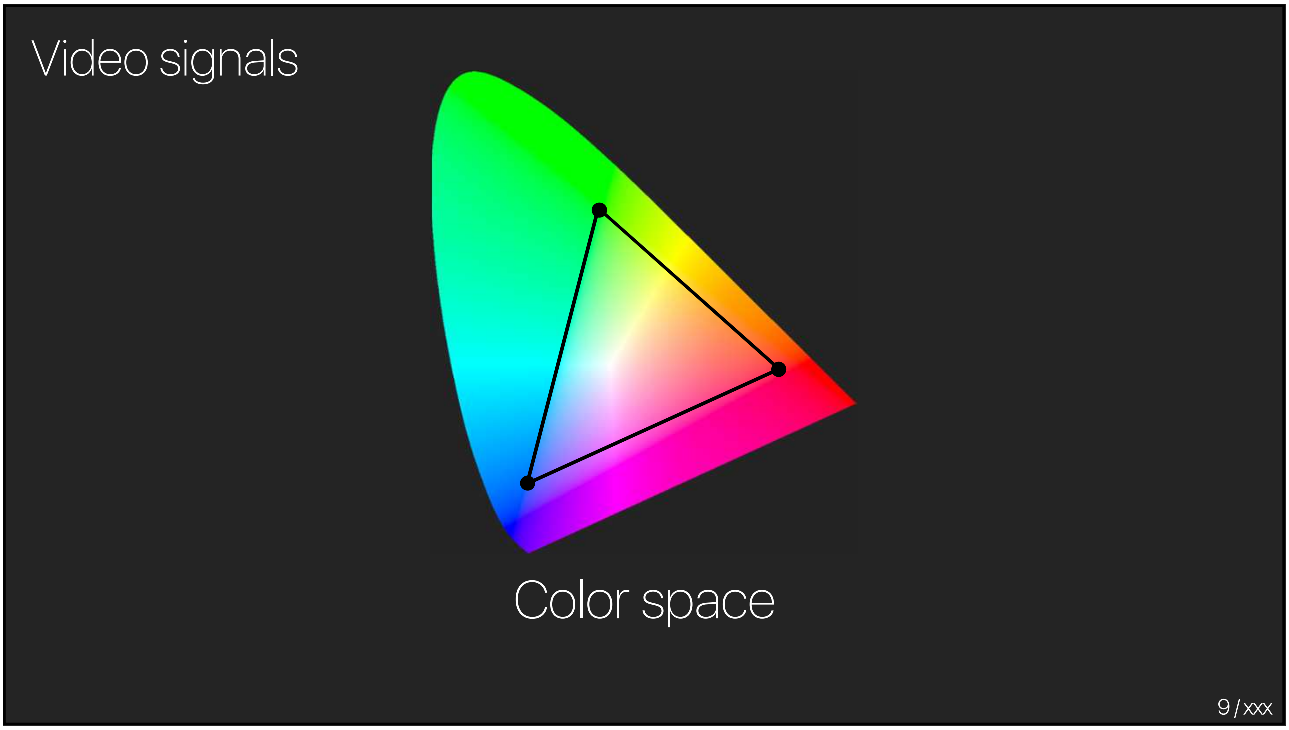

Viewing experience
Resolution
Framerate
Dynamic range
- black level, luminance -
Color gamut
Color depth
4 / xxx

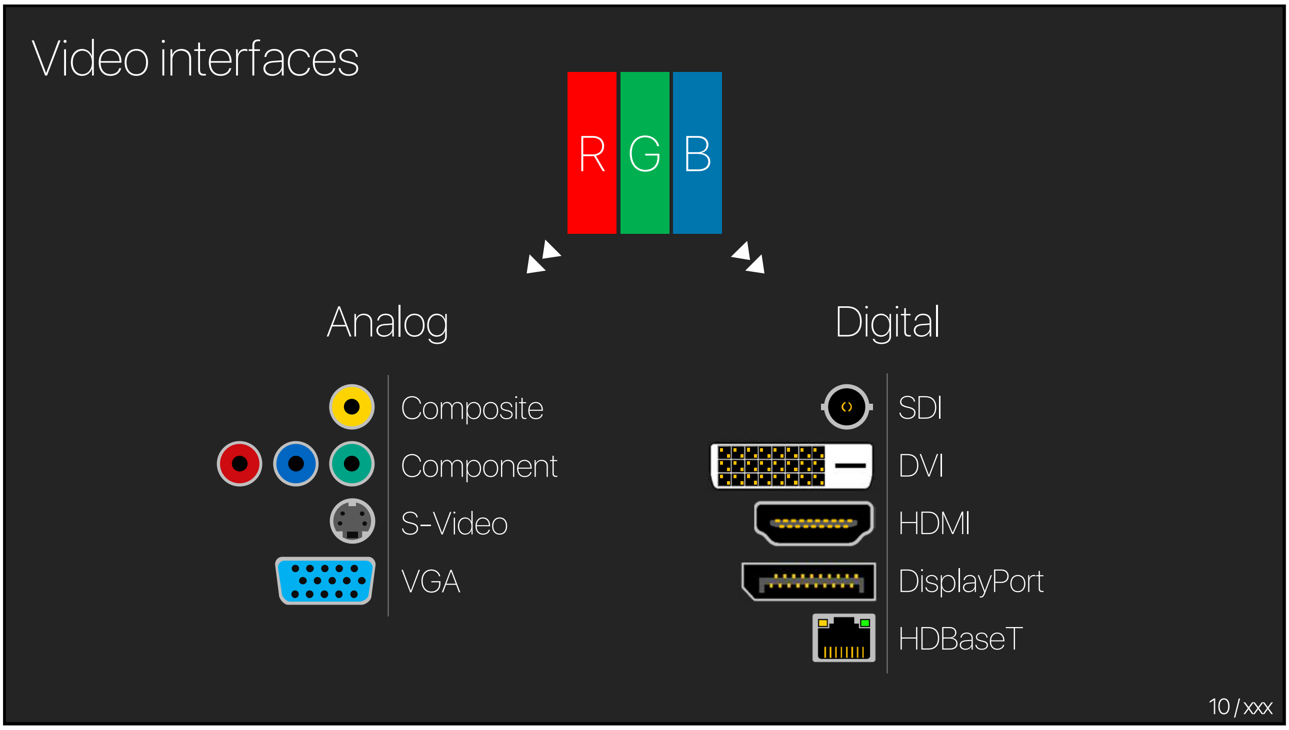

Video signals
Frames
Pixels
Subpixels
(Red, Green, Blue)
5 / xxx

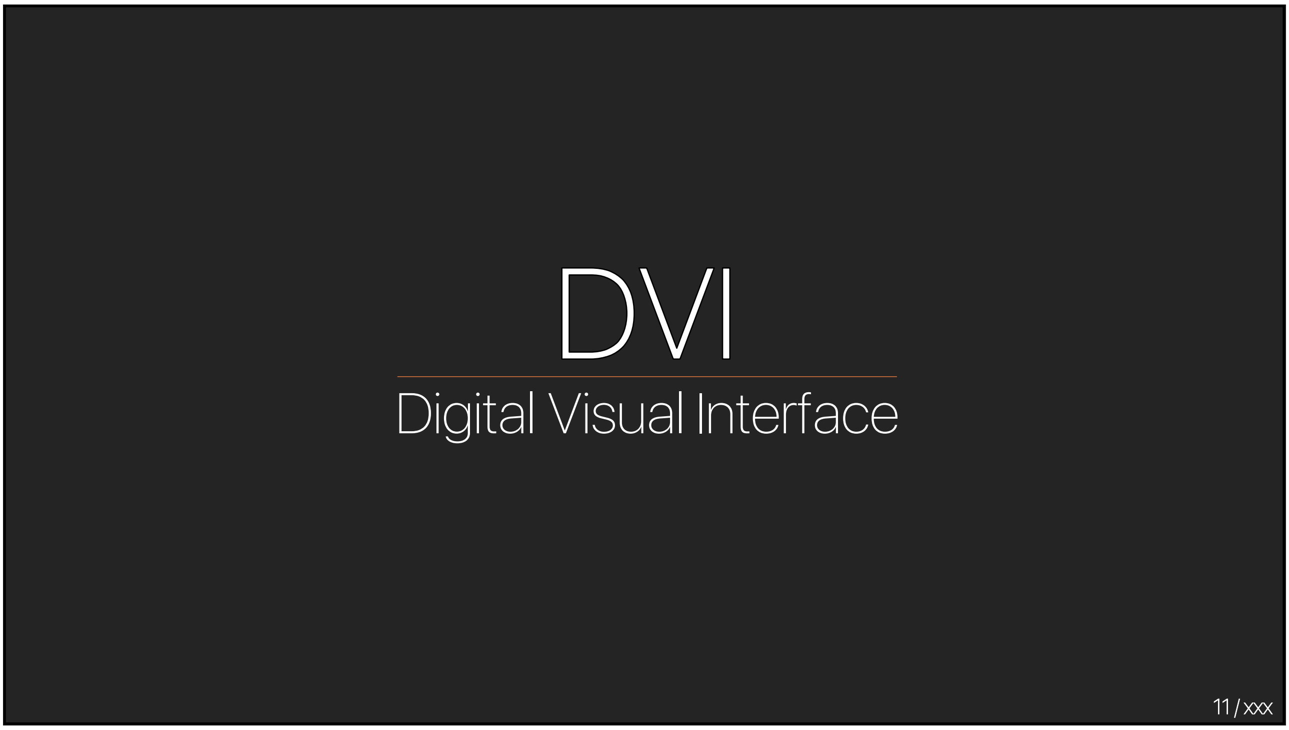

Video signals
Resolution
2 megapixels / 1920 × 1080 / Full HD
6 / xxx

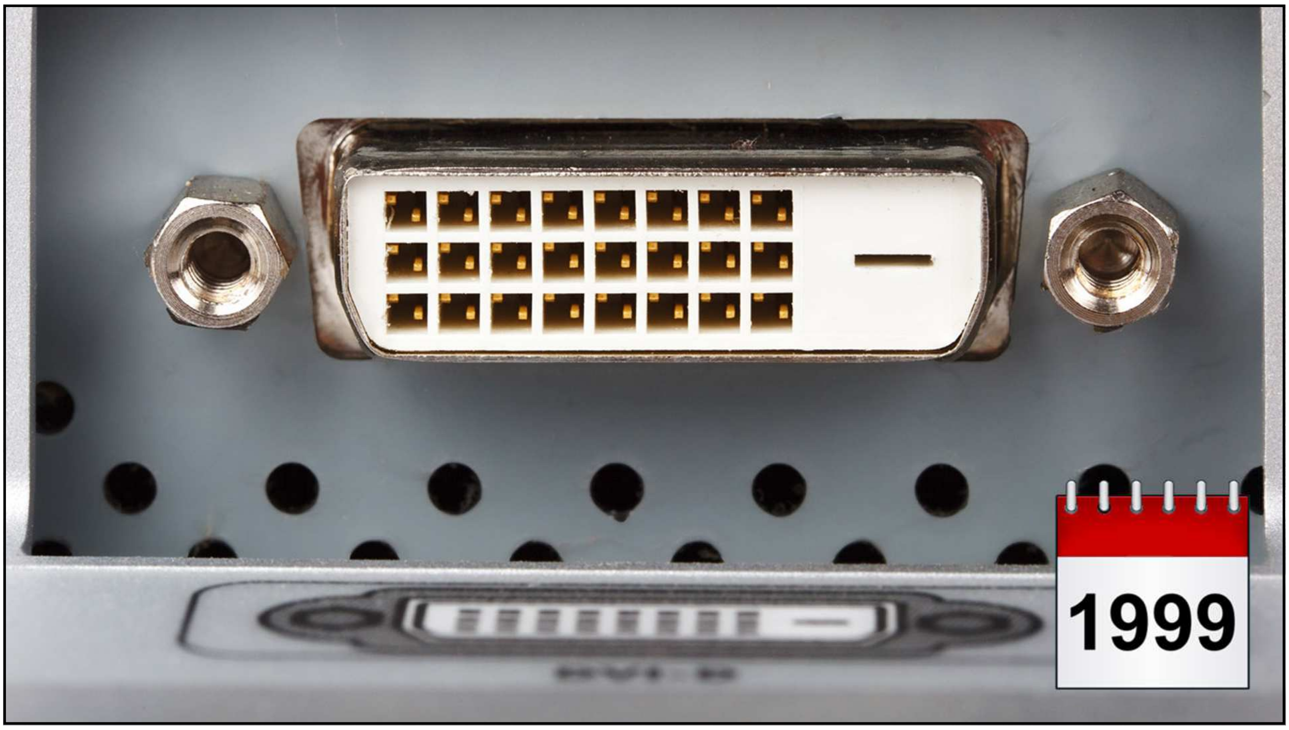

Video signals
Refresh rate
24 Hz
120 Hz
7 / xxx

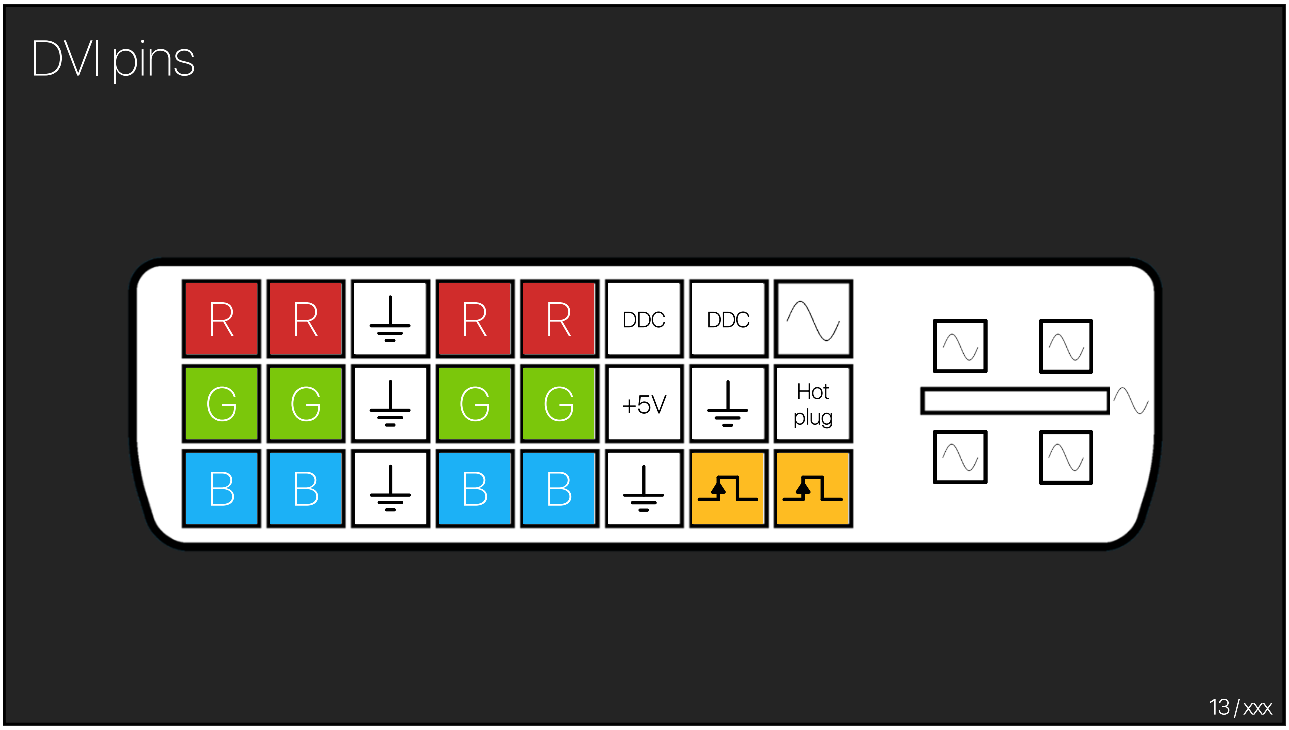

Video signals
Color depth
8 / xxx


Video signals
Color space
9 / xxx

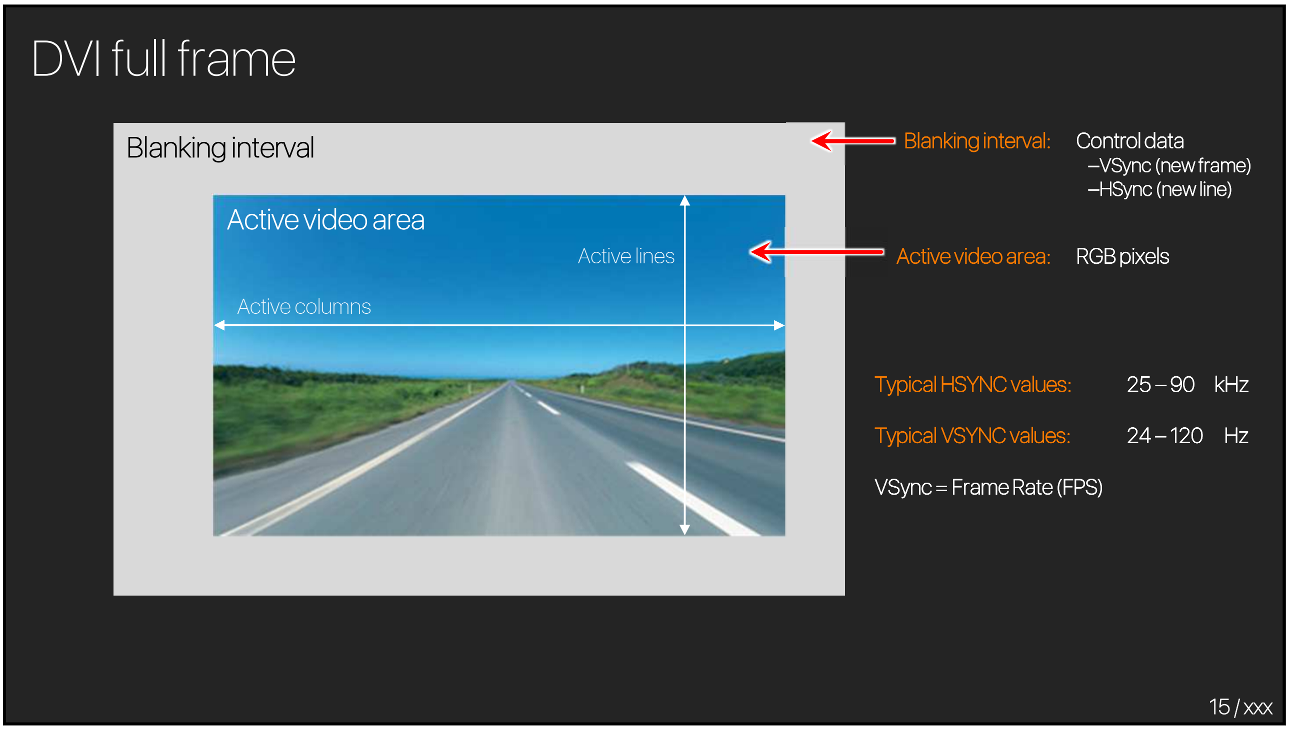

Video interfaces
R
G
B
Analog
Composite
Component
S-Video
VGA
Digital
SDI
DVI
HDMI
DisplayPort
HDBaseT
10 / xxx

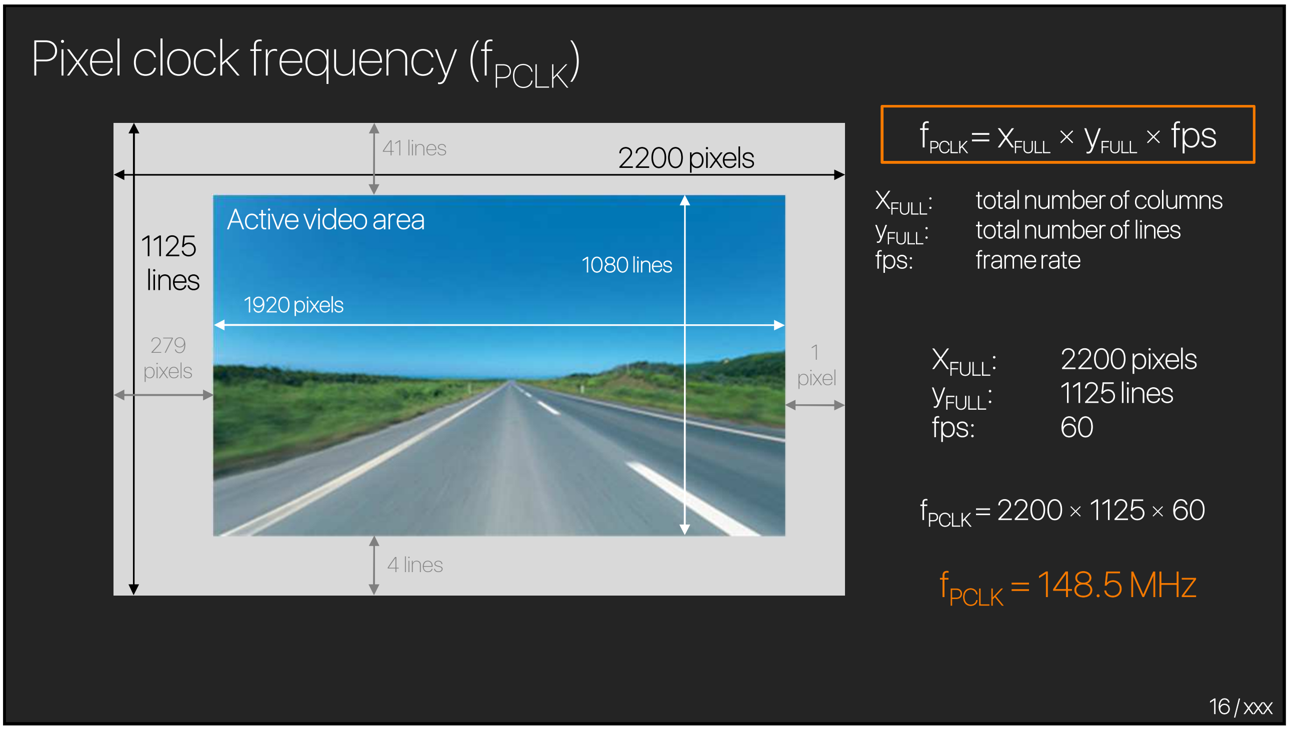

DVI
Digital Visual Interface
11 / xxx

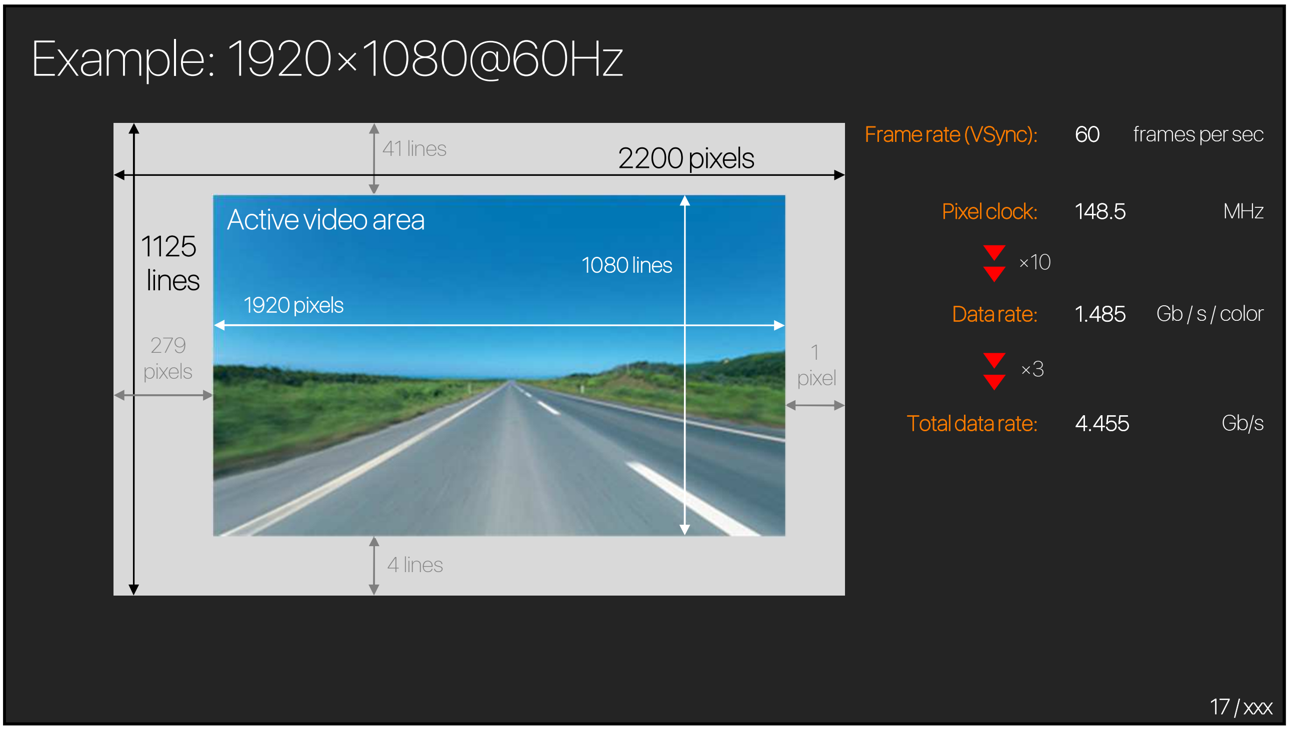

1999

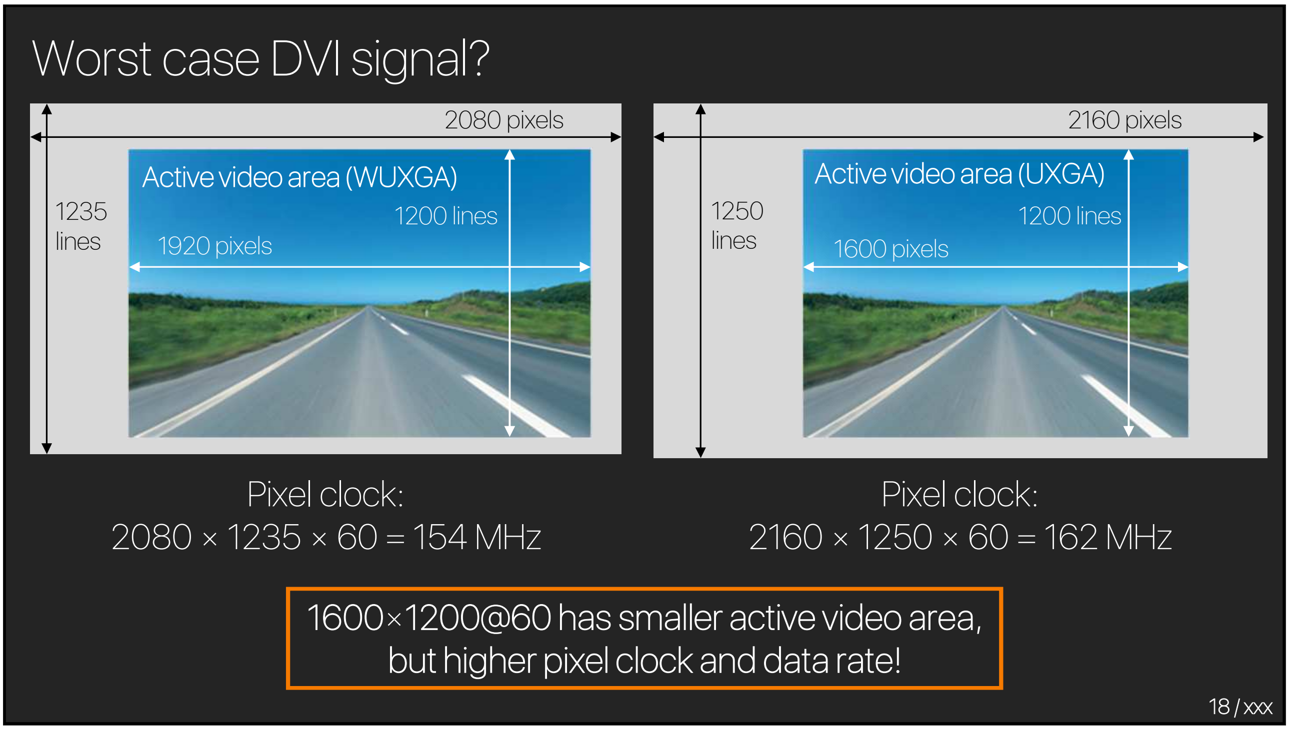

DVI pins
R
R
R
R
DDC
DDC
G
G
G
G
+5V
Hot plug
B
B
B
B
13 / xxx

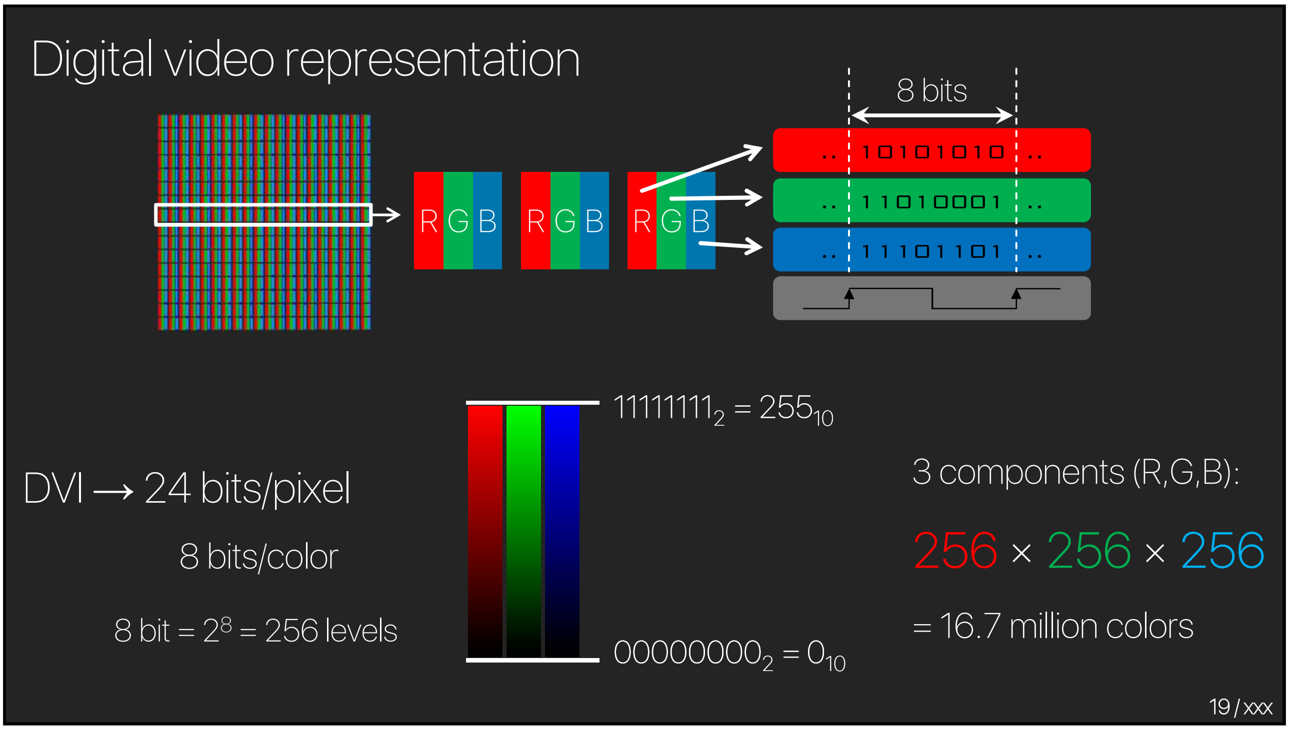

DVI full frame
Active video area
Active lines
Active columns
14 / xxx

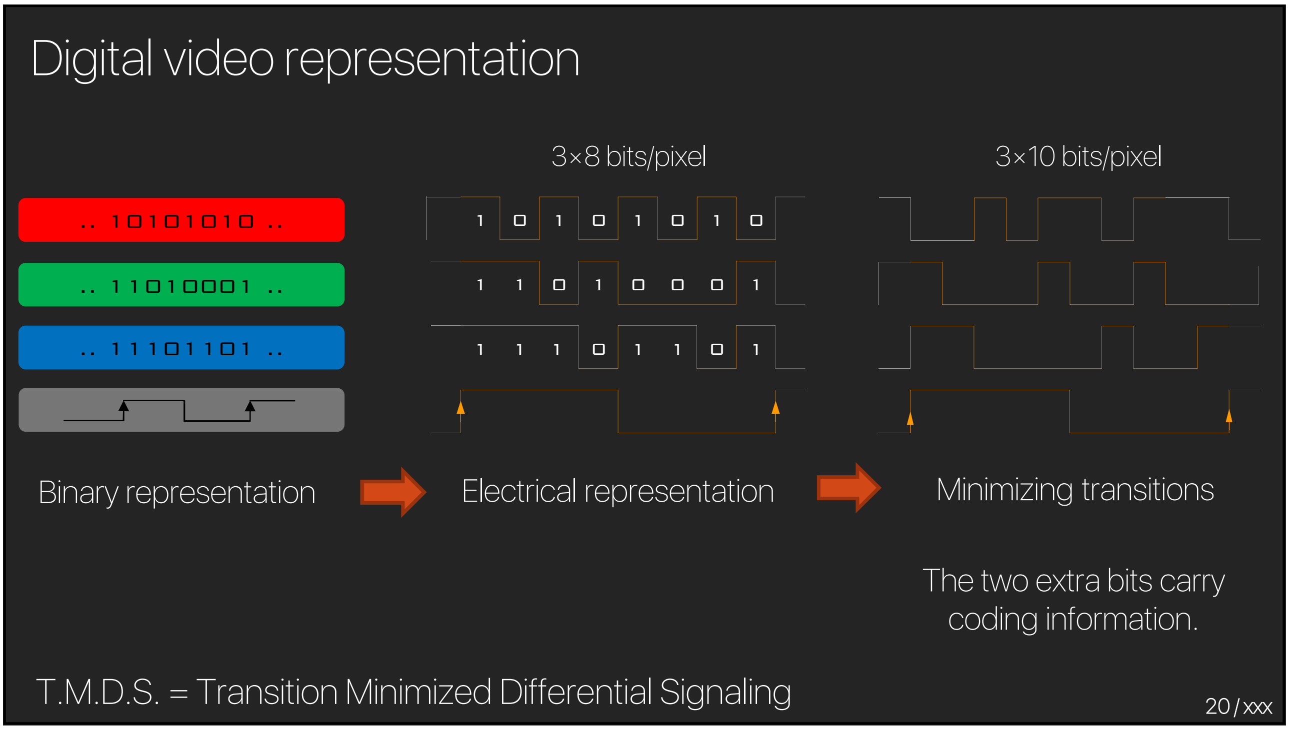

DVI full frame
Blanking interval
Active video area
Active lines
Active columns
Blanking interval: Control data
–VSync (new frame)
–HSync (new line)
Active video area: RGB pixels
Typical HSYNC values: 25 – 90 kHz
Typical VSYNC values: 24 – 120 Hz
VSync = Frame Rate (FPS)
15 / xxx

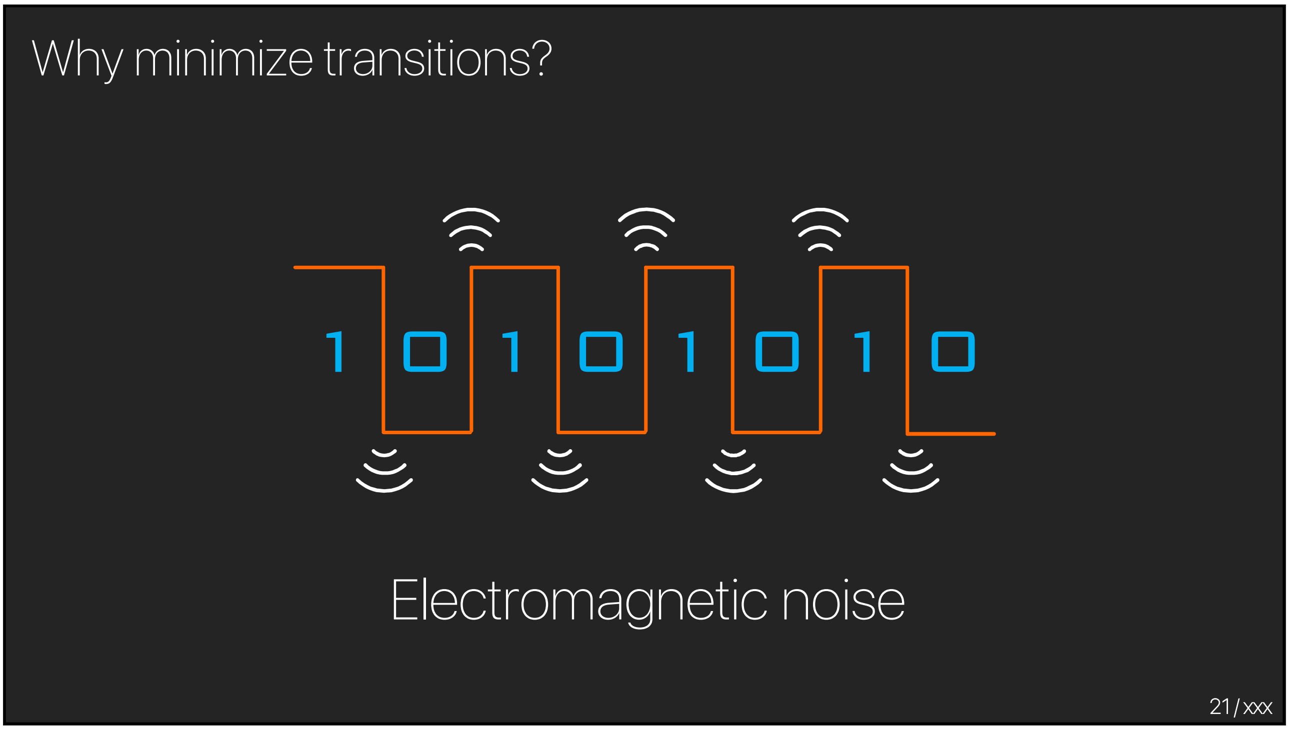

Pixel clock frequency (f_{PCLK})
41 lines
2200 pixels
1125 lines
279 pixels
Active video area
1080 lines
1920 pixels
1 pixel
4 lines
$f_{PCLK} = x_{FULL} \times y_{FULL} \times fps$
x_{FULL}: total number of columns
y_{FULL}: total number of lines
fps: frame rate
x_{FULL}: 2200 pixels
y_{FULL}: 1125 lines
fps: 60
$f_{PCLK} = 2200 \times 1125 \times 60$
$f_{PCLK} = 148.5$ MHz
16 / xxx

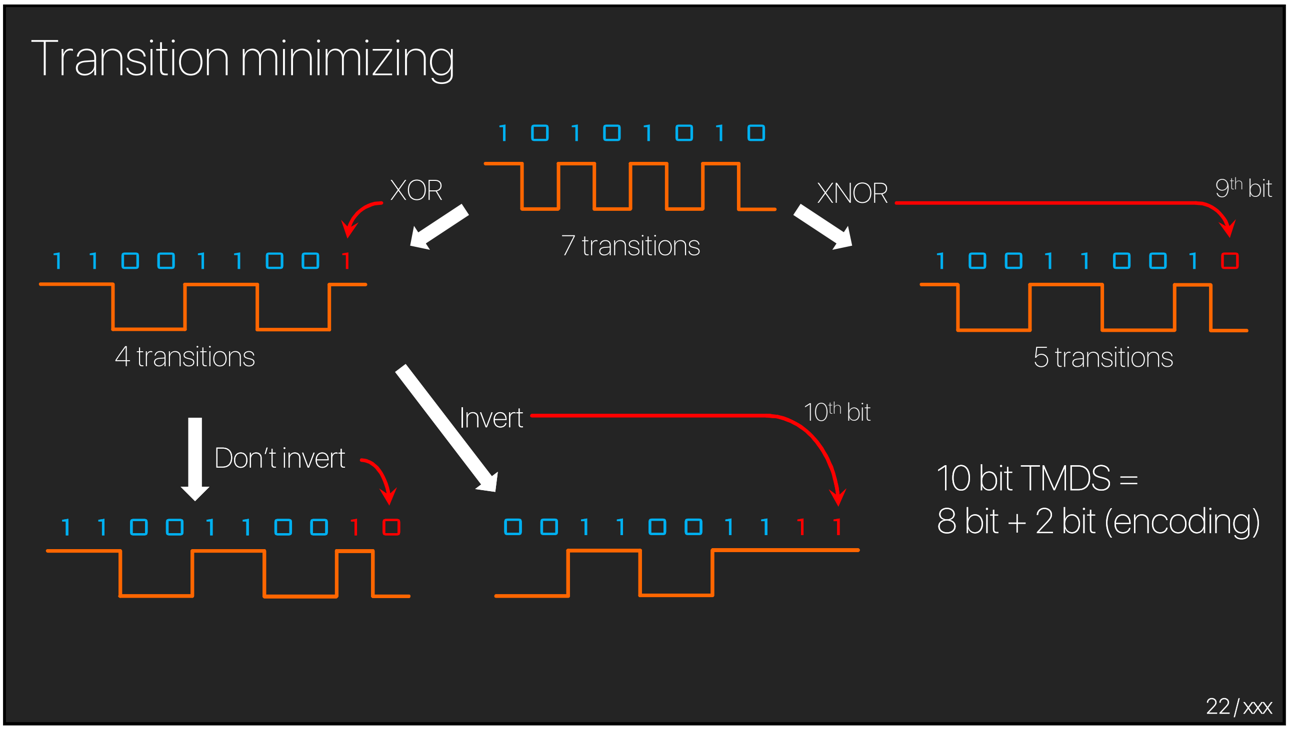

Example: 1920×1080@60Hz
41 lines
2200 pixels
Active video area
1080 lines
1125 lines
1920 pixels
279 pixels
1 pixel
4 lines
Frame rate (VSync): 60 frames per sec
Pixel clock: 148.5 MHz
×10
Data rate: 1.485 Gb / s / color
×3
Total data rate: 4.455 Gb/s
17 / xxx

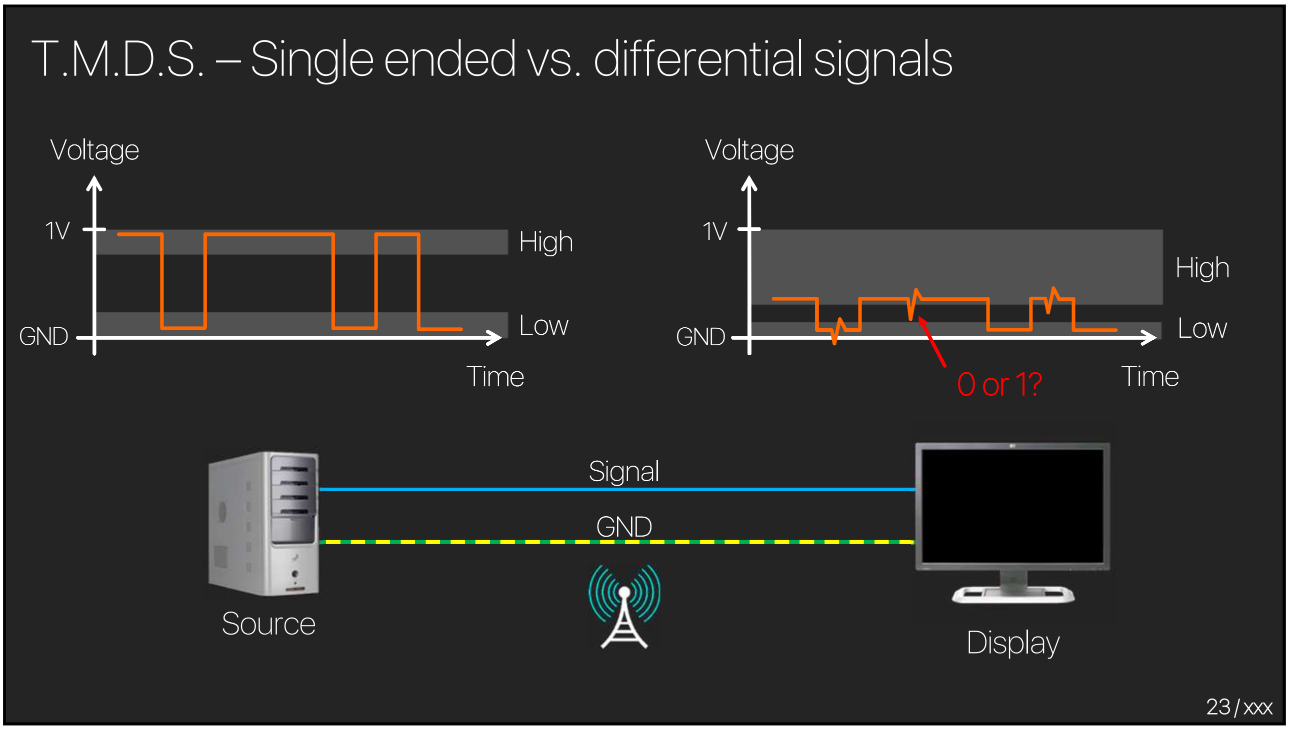

Worst case DVI signal?
2080 pixels
Active video area (WUXGA)
1235 lines
1200 lines
1920 pixels
2160 pixels
Active video area (UXGA)
1250 lines
1200 lines
1600 pixels
Pixel clock:
2080 × 1235 × 60 = 154 MHz
Pixel clock:
2160 × 1250 × 60 = 162 MHz
1600×1200@60 has smaller active video area,
but higher pixel clock and data rate!
18 / xxx

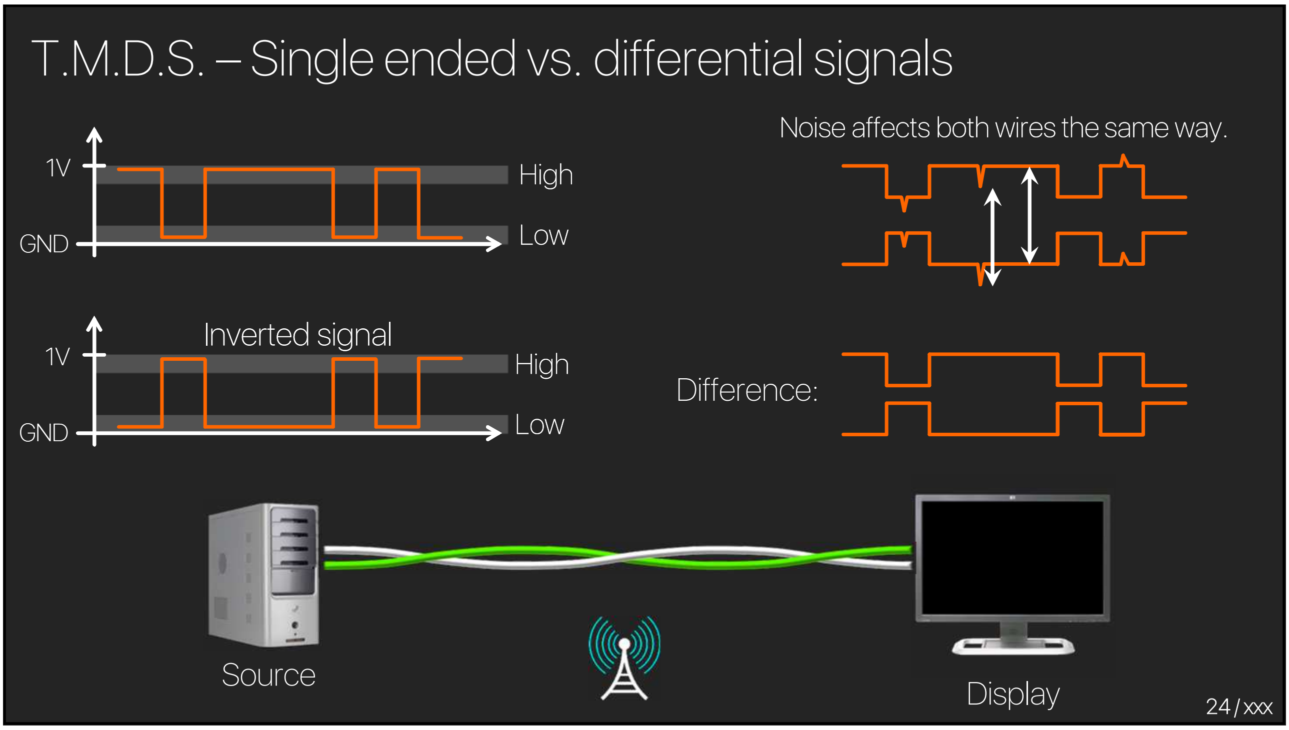

Digital video representation
8 bits
.. 10101010 ..
.. 11010001 ..
.. 11101101 ..
R G B
R G B
R G B
DVI → 24 bits/pixel
8 bits/color
8 bit = 2^8 = 256 levels
11111111₂ = 255₁₀
00000000₂ = 0₁₀
3 components (R,G,B):
256 × 256 × 256
= 16.7 million colors
19 / xxx


Digital video representation
3×8 bits/pixel
3×10 bits/pixel
.. 10101010 ..
.. 11010001 ..
.. 11101101 ..
1 0 1 0 1 0 1 0
1 1 0 1 0 0 0 1
1 1 1 0 1 1 0 1
Binary representation
Electrical representation
Minimizing transitions
The two extra bits carry coding information.
T.M.D.S. = Transition Minimized Differential Signaling
20 / xxx


Why minimize transitions?
1 0 1 0 1 0 1 0
Electromagnetic noise
21 / xxx


Transition minimizing
1 0 1 0 1 0 1 0
7 transitions
XOR
1 1 0 0 1 1 0 0 1
4 transitions
XNOR
9th bit
1 0 0 1 1 0 0 1 0
5 transitions
Don't invert
1 1 0 0 1 1 0 0 1 0
Invert
10th bit
0 0 1 1 0 0 1 1 1 1
10 bit TMDS =
8 bit + 2 bit (encoding)
22 / xxx


T.M.D.S. – Single ended vs. differential signals
Voltage
1V
GND
High
Low
Time
Voltage
1V
GND
High
Low
0 or 1?
Time
Signal
GND
Source
Display
23 / xxx


T.M.D.S. – Single ended vs. differential signals
1V
GND
High
Low
Noise affects both wires the same way.
Inverted signal
1V
GND
High
Low
Difference:
Source
Display
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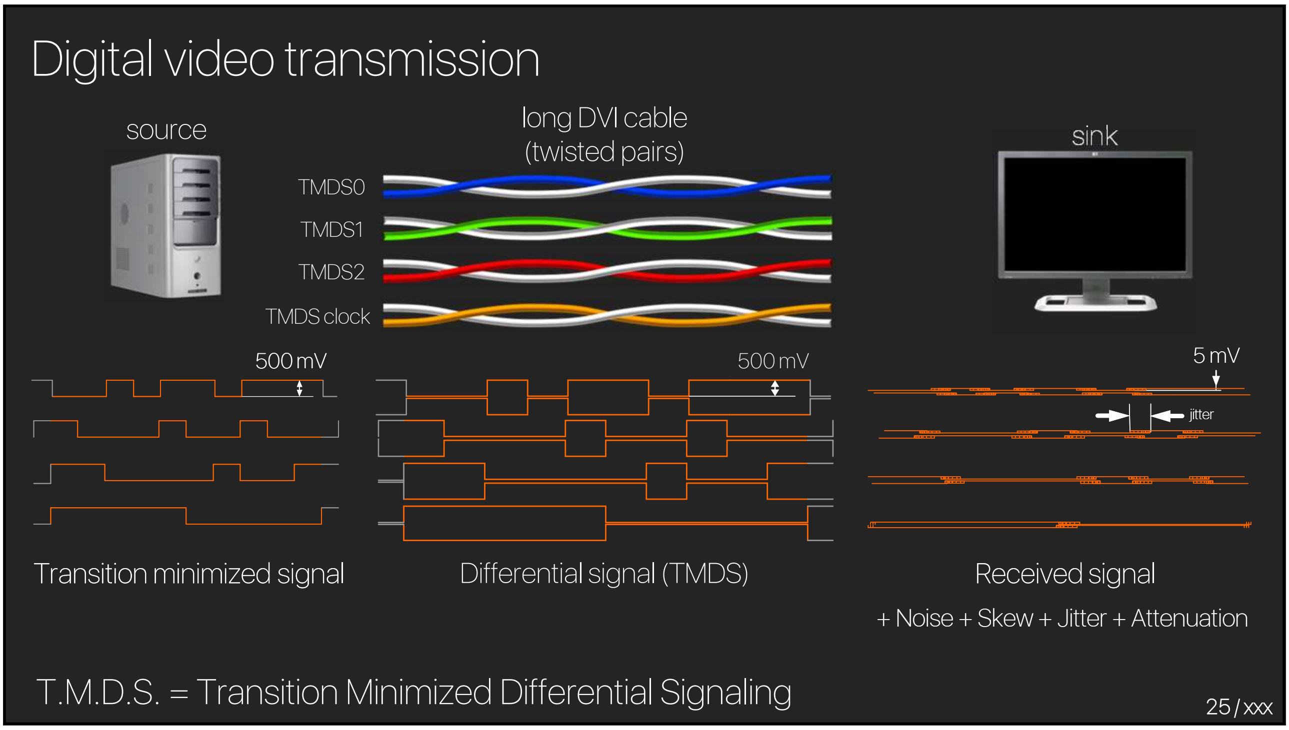
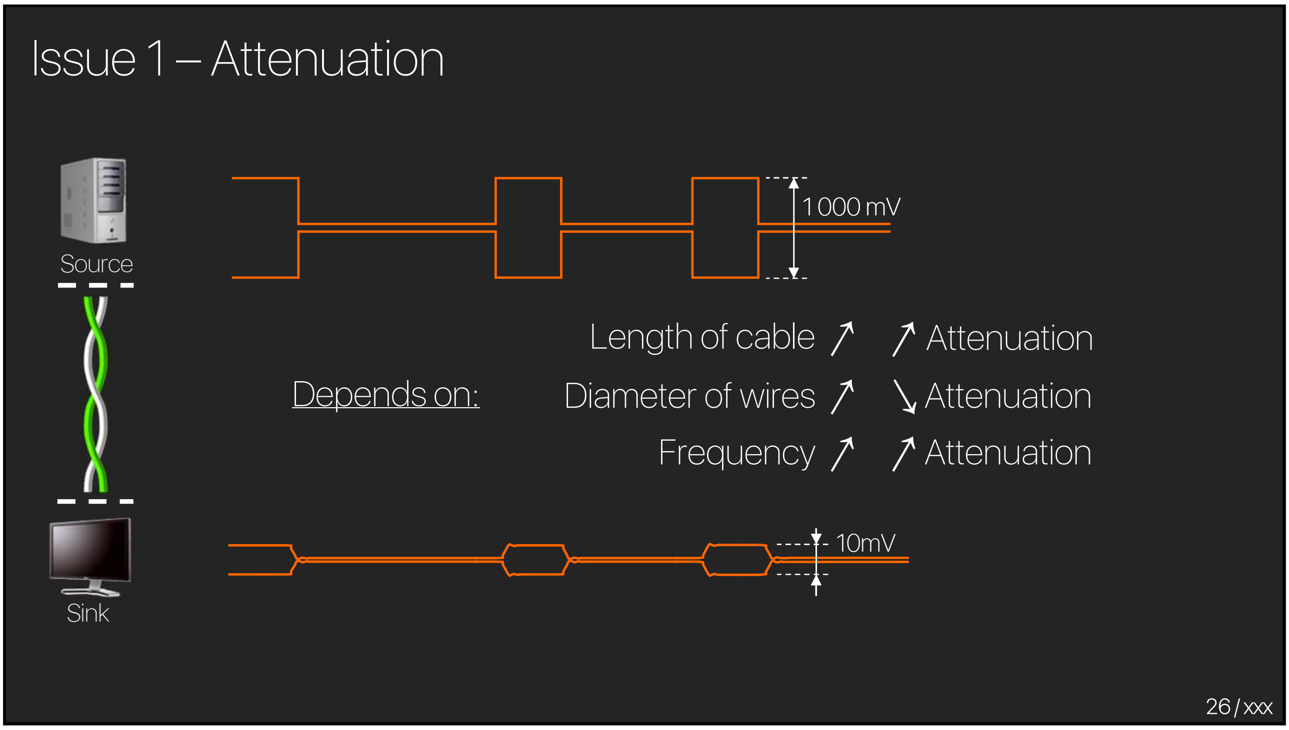

Digital video transmission
source
long DVI cable
(twisted pairs)
sink
TMDS0
TMDS1
TMDS2
TMDS clock
500 mV
500 mV
5 mV
jitter
Transition minimized signal
Differential signal (TMDS)
Received signal
+ Noise + Skew + Jitter + Attenuation
T.M.D.S. = Transition Minimized Differential Signaling
25 / xxx


Issue 1 – Attenuation
Source
Sink
1 000 mV
Depends on:
Length of cable ↗ ↗ Attenuation
Diameter of wires ↗ ↘ Attenuation
Frequency ↗ ↗ Attenuation
10mV
26 / xxx

Issue 1 – Attenuation

What can you do?

1. Decrease the frequency
   - → lower resolution
   - → lower refresh rate
   - → reduced blanking signal
2. Use thicker cables
3. Use shorter cables (optimize cable path)
4. Use equalization (EQ)

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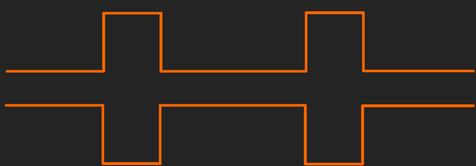
What is EQ?

1. Amplify
2. Shape



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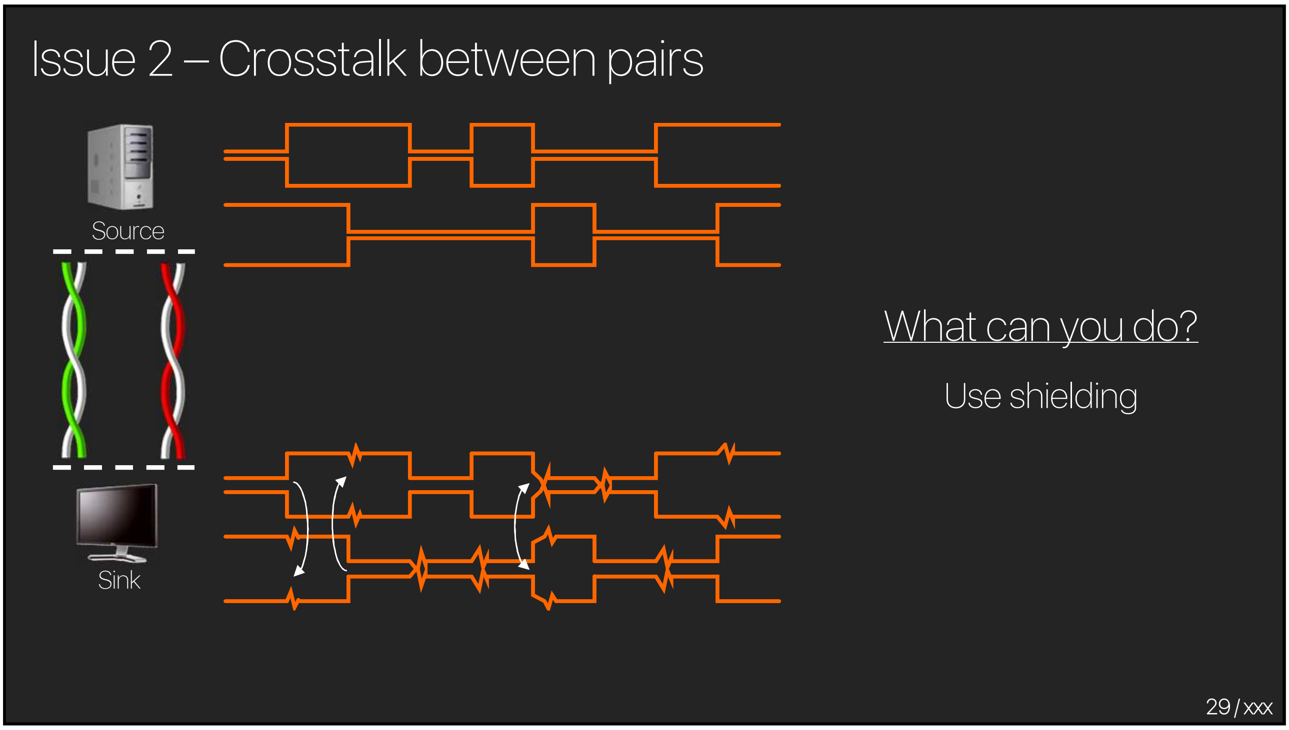
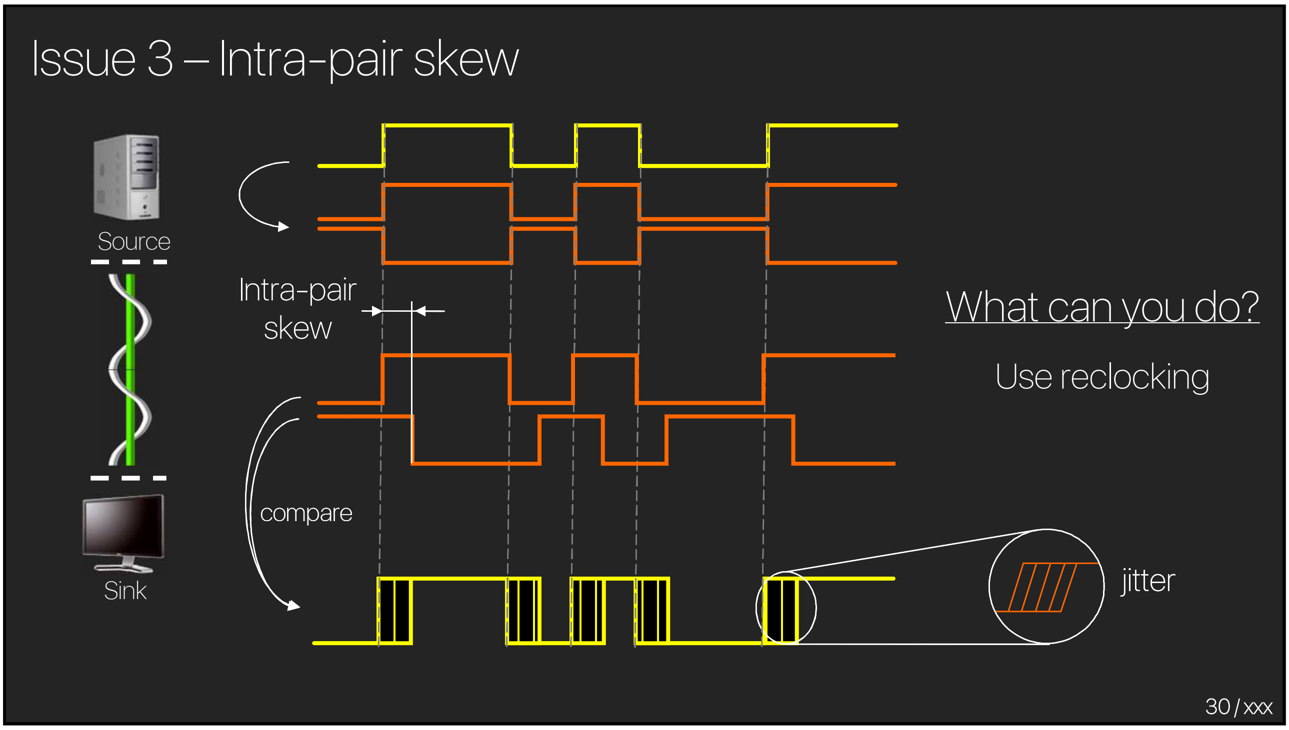
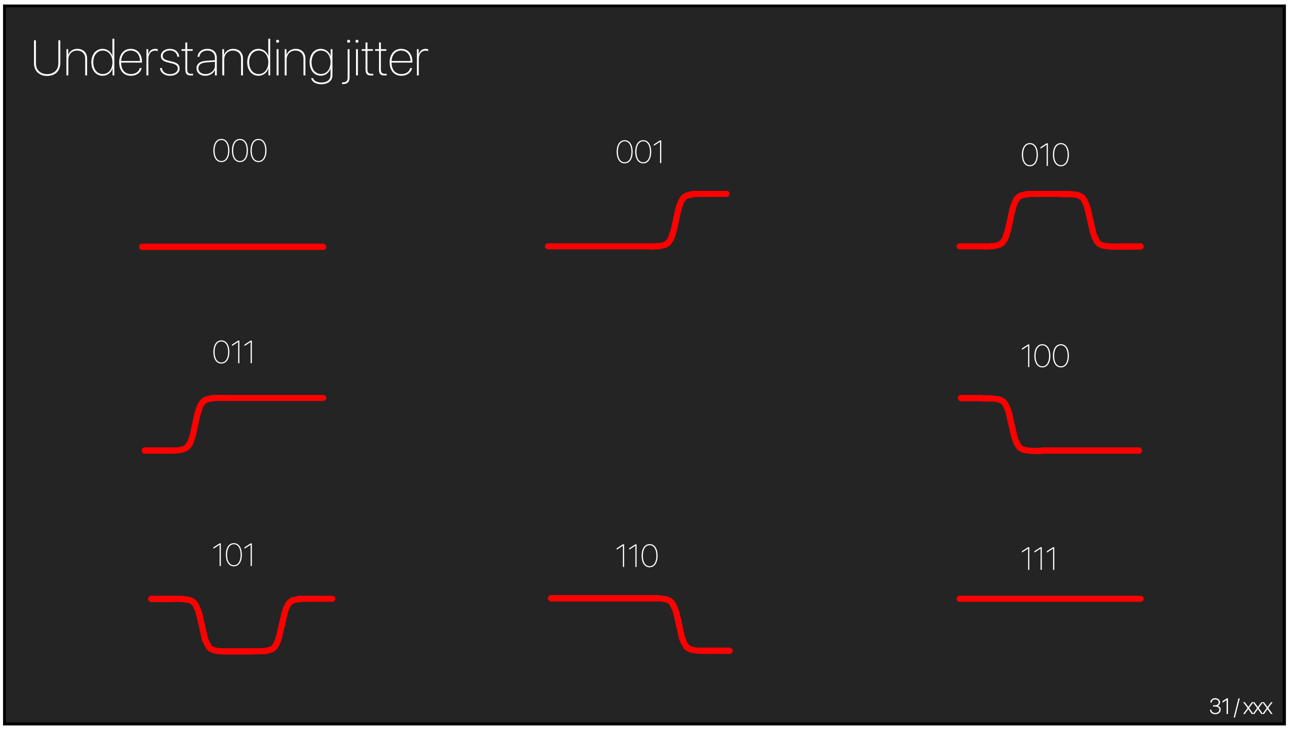
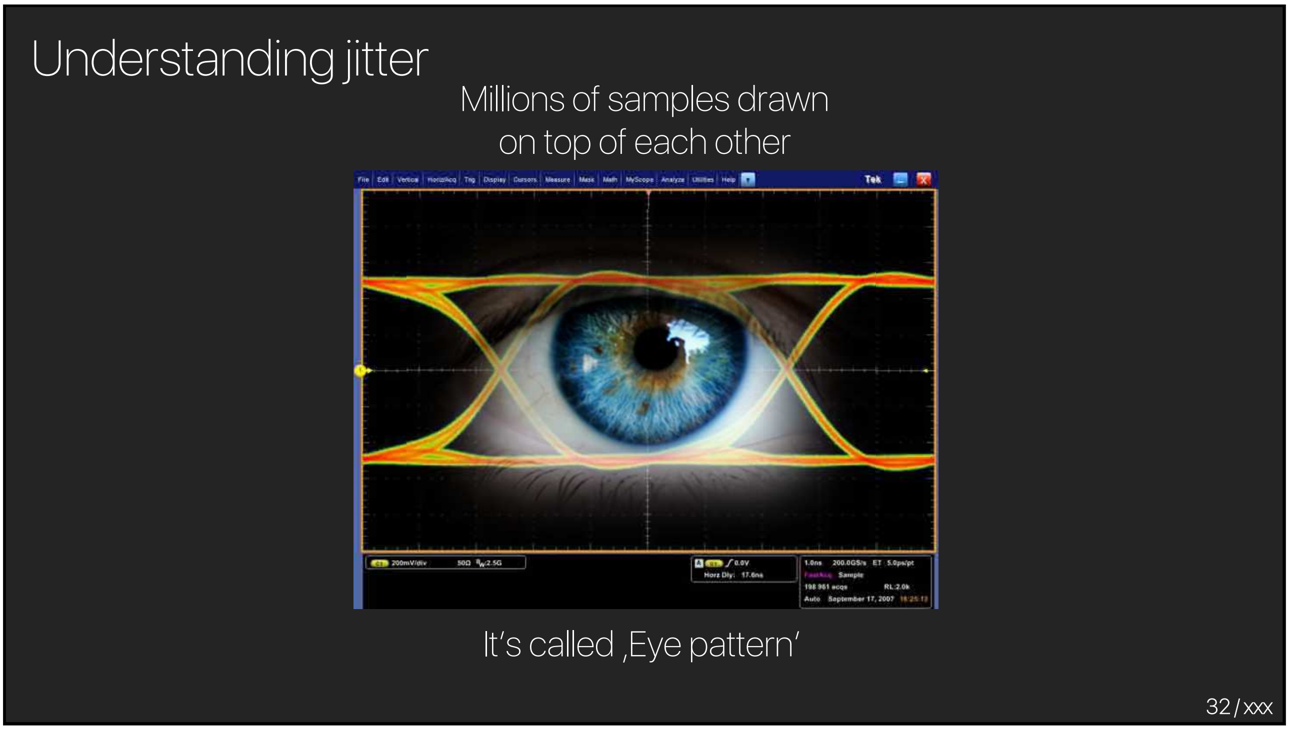
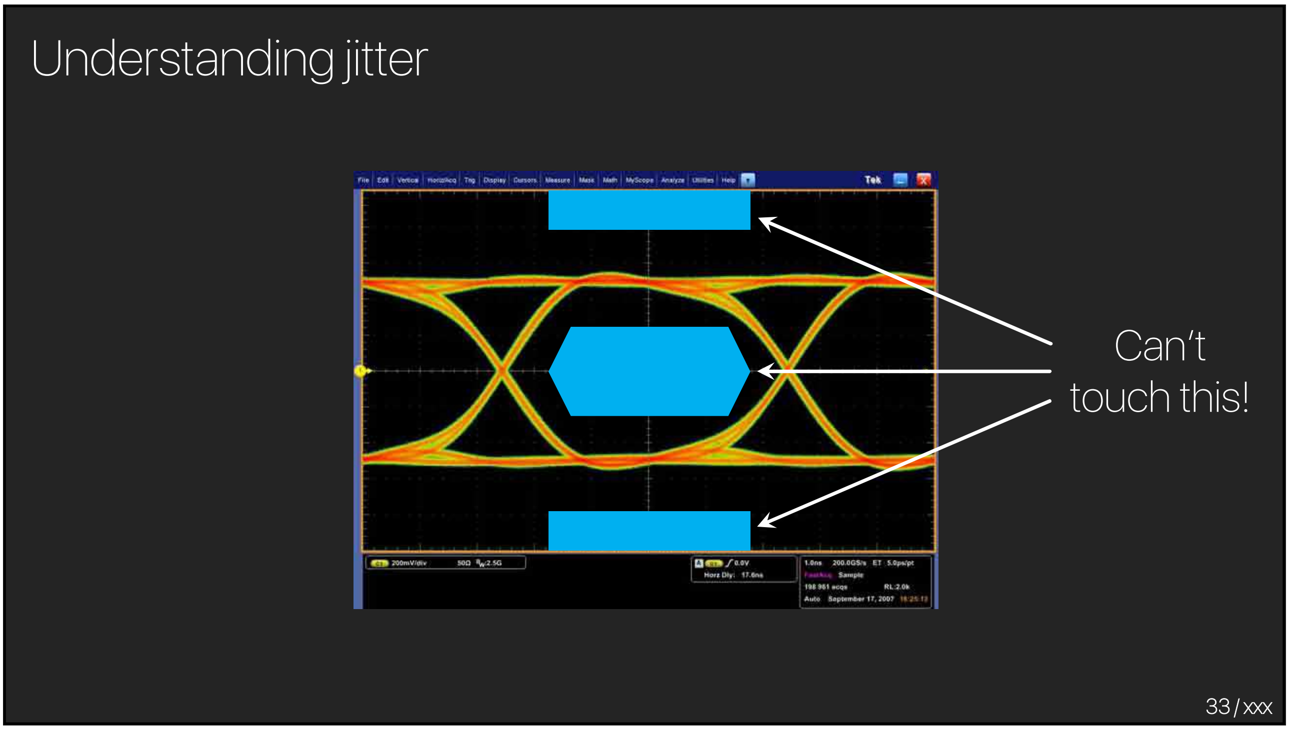
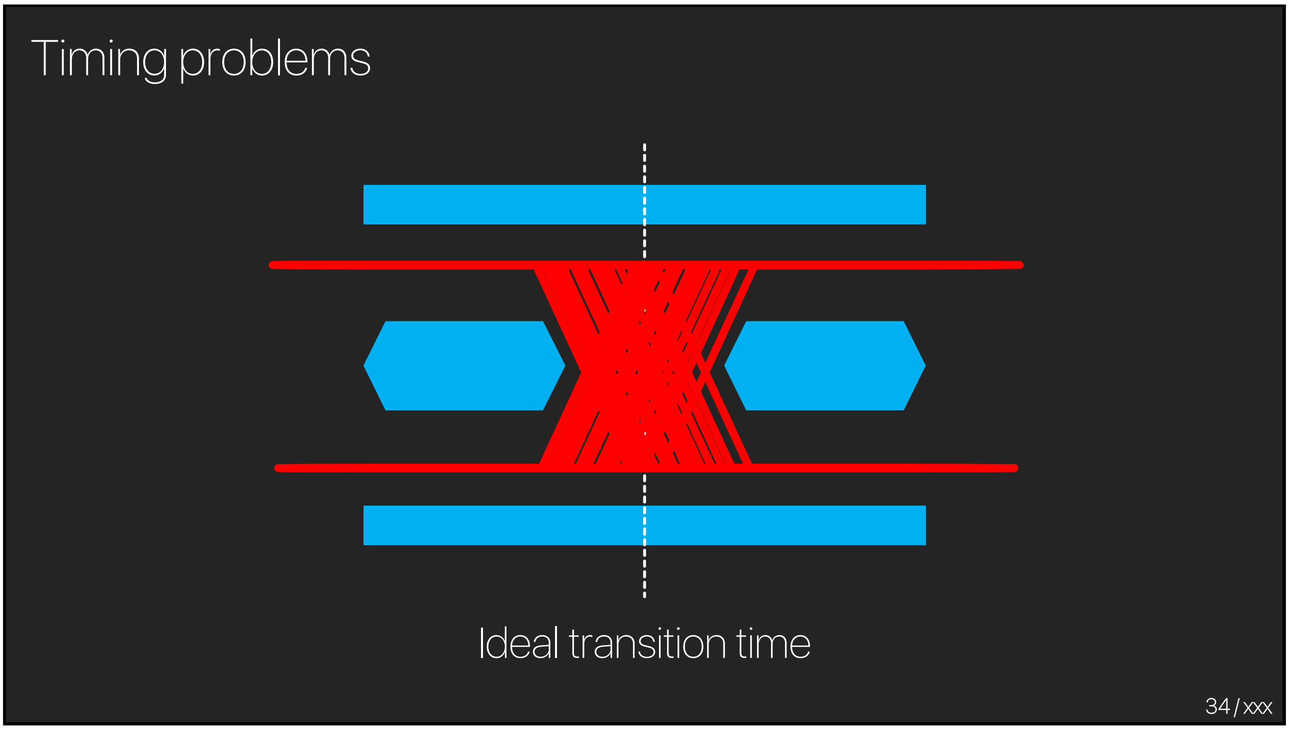

Issue 2 – Crosstalk between pairs
Source
Sink
What can you do?
Use shielding
29 / xxx


Issue 3 – Intra-pair skew
Source
Sink
Intra-pair skew
compare
jitter
What can you do?
Use reclocking
30 / xxx


Understanding jitter
000
001
010
011
100
101
110
111
31 / xxx


Understanding jitter
Millions of samples drawn on top of each other
It's called ‚Eye pattern'
32 / xxx


Understanding jitter
Can't
touch this!
33 / xxx


Timing problems
Ideal transition time
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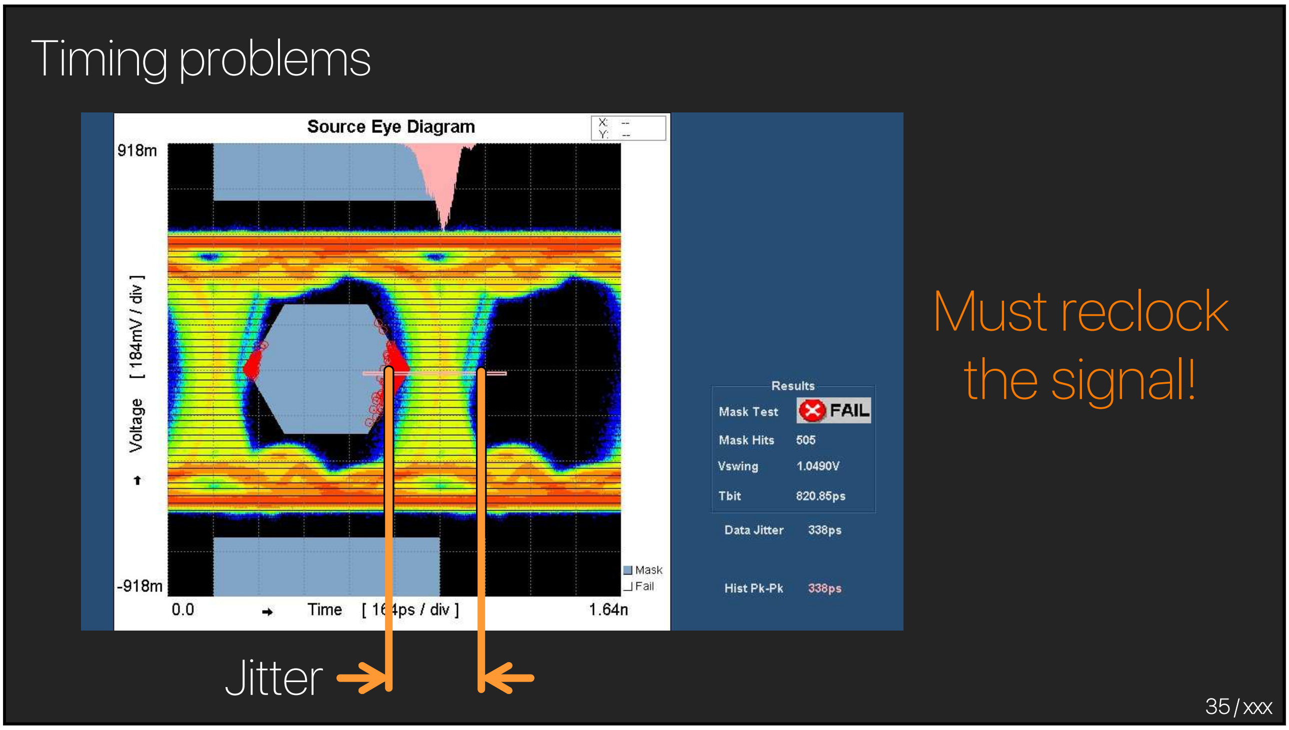
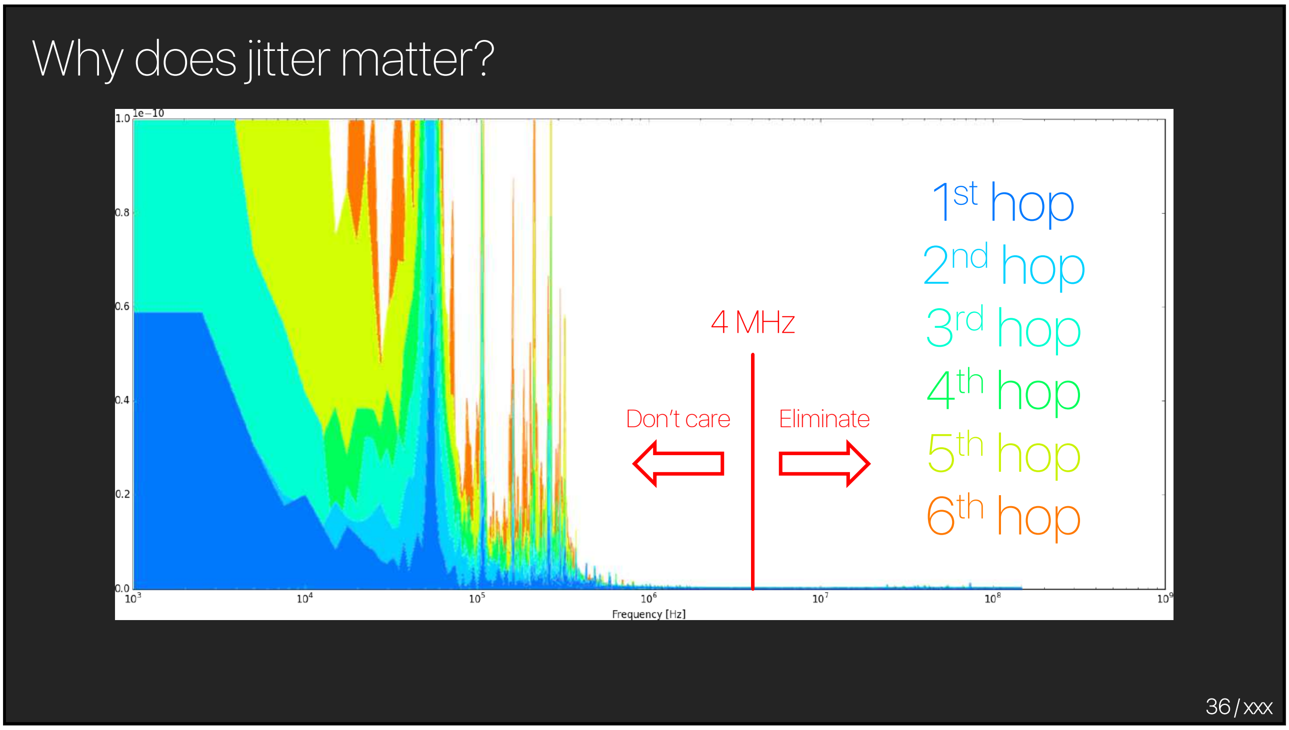

Timing problems
Source Eye Diagram
918m
Voltage [184mV / div]
-918m
0.0
Time
1.64n
Mask
Fail
Results
Mask Test FAIL
Mask Hits 505
Vswing 1.0490V
Tbit 820.85ps
Data Jitter 338ps
Hist Pk-Pk 338ps
Must reclock the signal!
Jitter
35 / xxx


Why does jitter matter?
4 MHz
Don't care
Eliminate
1st hop
2nd hop
3rd hop
4th hop
5th hop
6th hop
Frequency [Hz]
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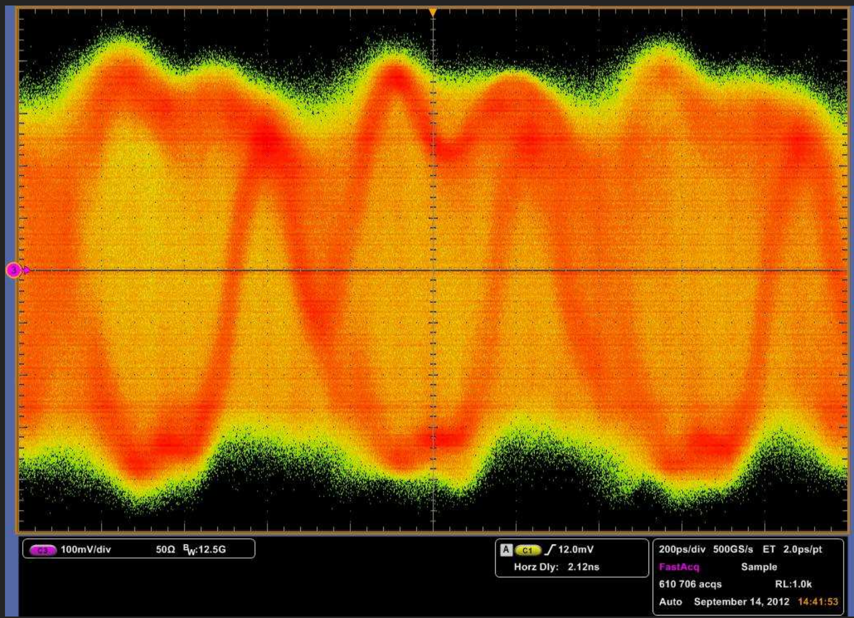
Timing problems



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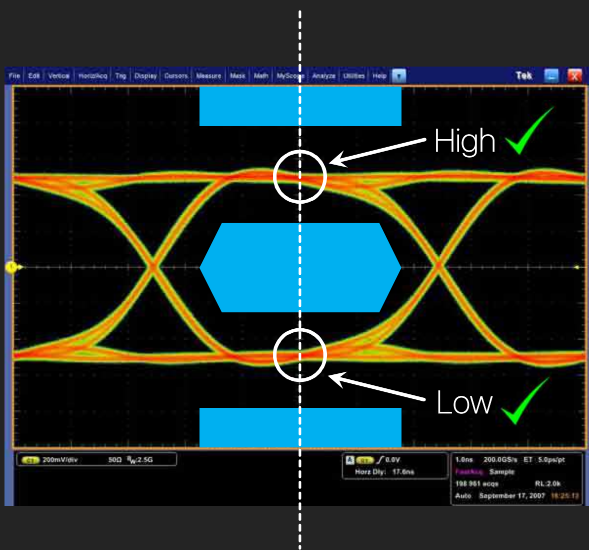
Amplitude problems



Samples are taken at this moment

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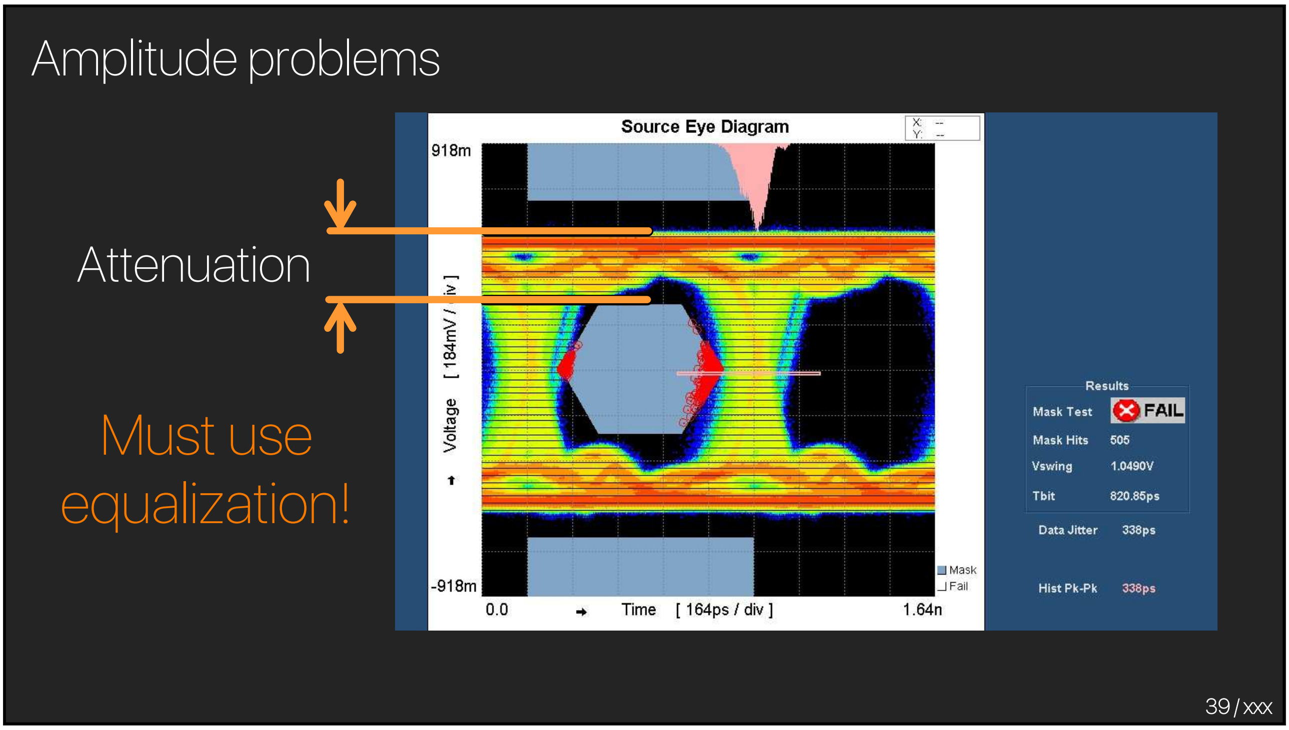
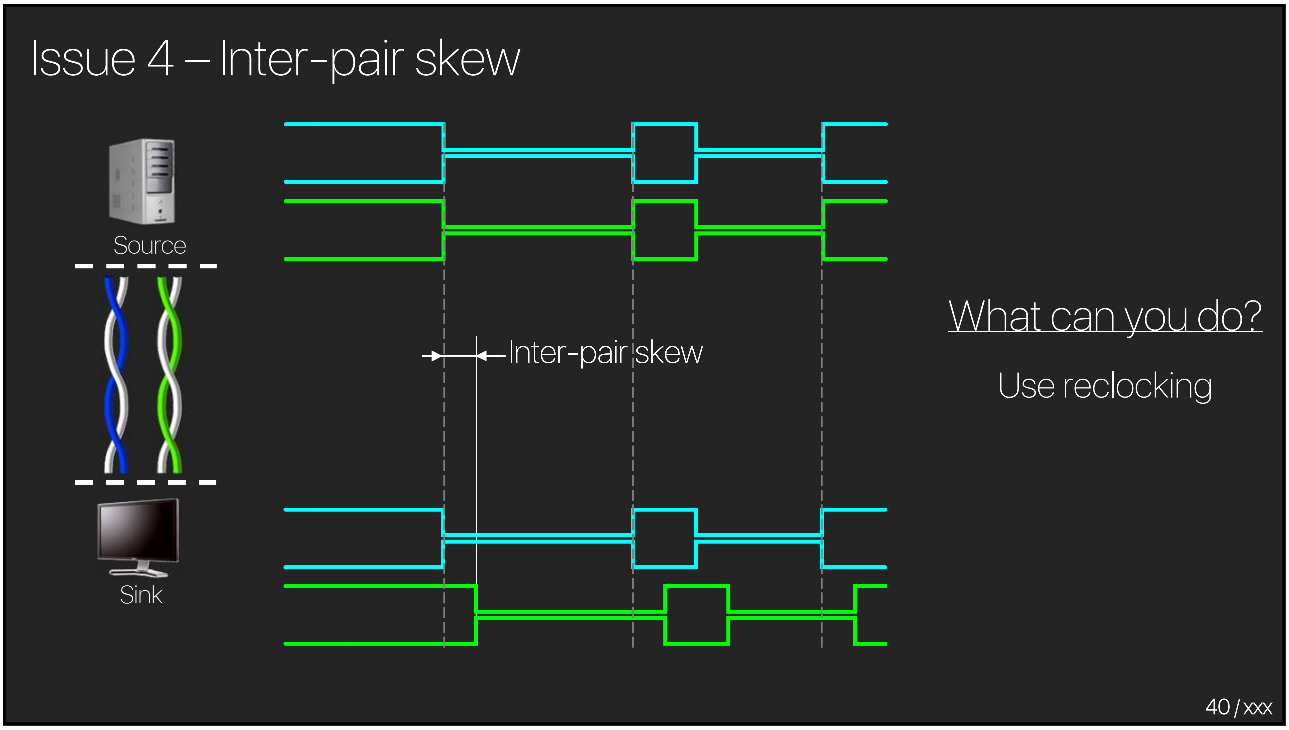
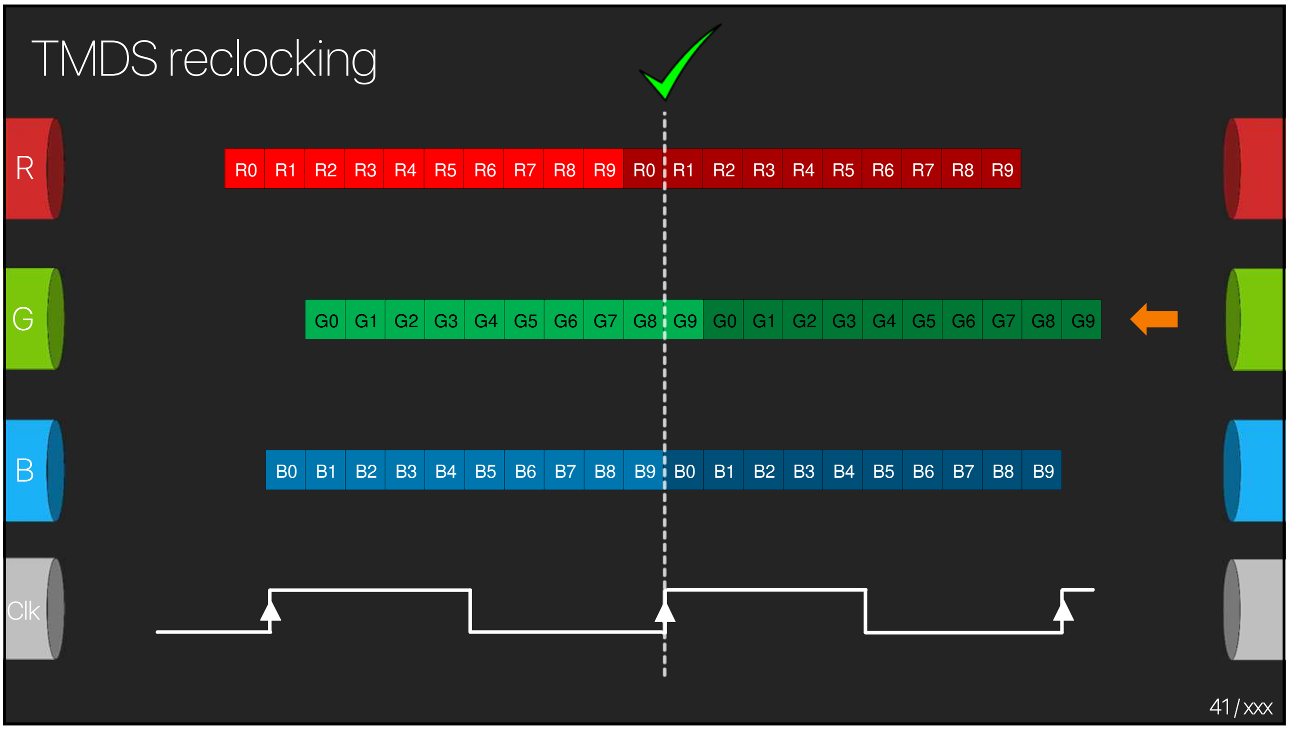

Amplitude problems
Attenuation
Must use equalization!
Source Eye Diagram
918m
-918m
Voltage [184mV / div]
0.0
Time [164ps / div]
1.64n
Mask
Fail
Results
Mask Test
FAIL
Mask Hits
505
Vswing
1.0490V
Tbit
820.85ps
Data Jitter
338ps
Hist Pk-Pk
338ps
39 / xxx


Issue 4 – Inter-pair skew
Source
Sink
Inter-pair skew
What can you do?
Use reclocking
40 / xxx


TMDS reclocking
R
G
B
Clk
R0 R1 R2 R3 R4 R5 R6 R7 R8 R9 R0 R1 R2 R3 R4 R5 R6 R7 R8 R9
G0 G1 G2 G3 G4 G5 G6 G7 G8 G9 G0 G1 G2 G3 G4 G5 G6 G7 G8 G9
B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 B0 B1 B2 B3 B4 B5 B6 B7 B8 B9
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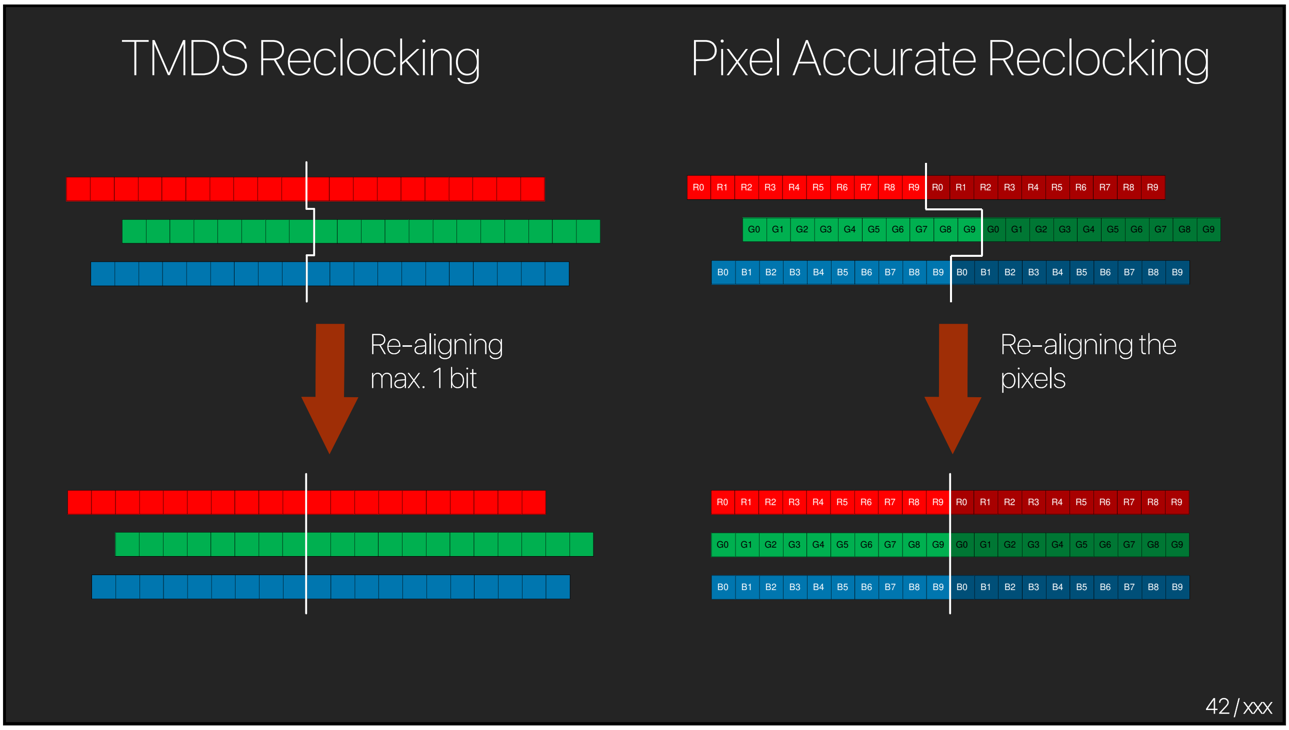
TMDS Reclocking
Pixel Accurate Reclocking
Re-aligning max. 1 bit
Re-aligning the pixels
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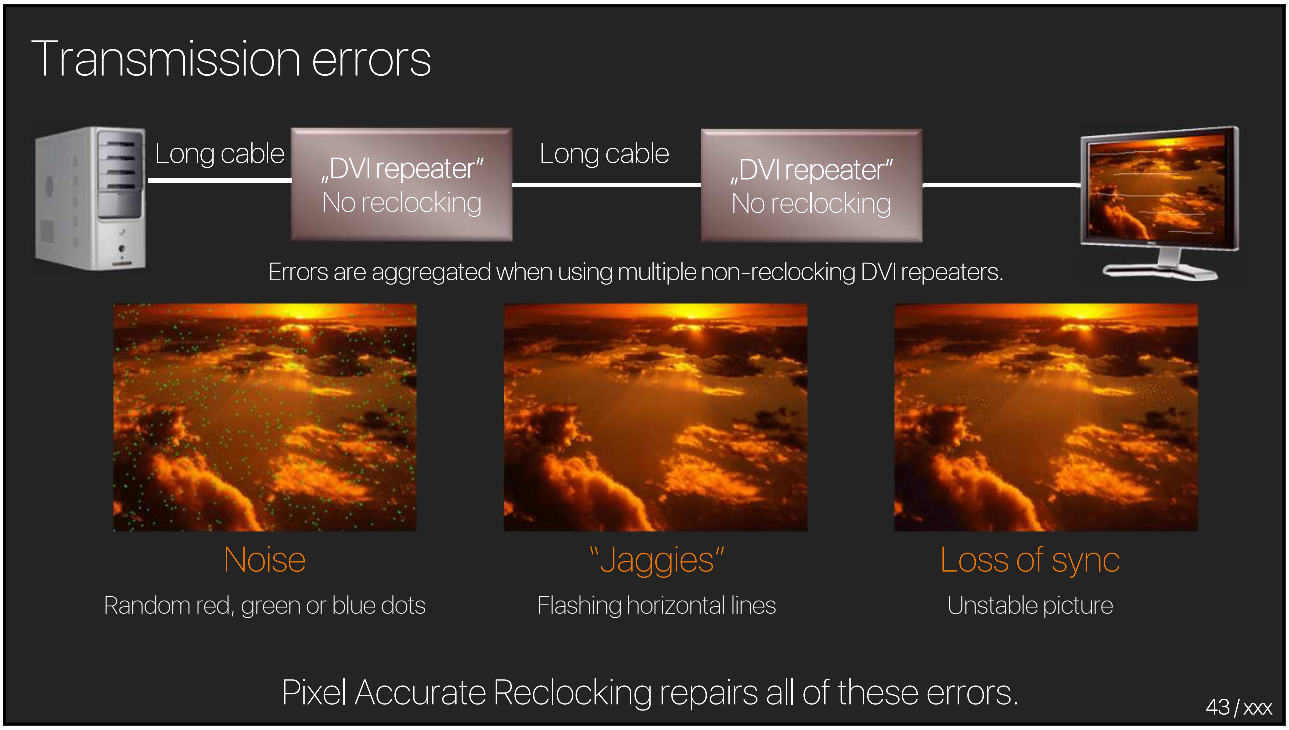
Transmission errors
Long cable
„DVI repeater"
No reclocking
Long cable
„DVI repeater"
No reclocking
Errors are aggregated when using multiple non-reclocking DVI repeaters.
Noise
Random red, green or blue dots
"Jaggies"
Flashing horizontal lines
Loss of sync
Unstable picture
Pixel Accurate Reclocking repairs all of these errors.
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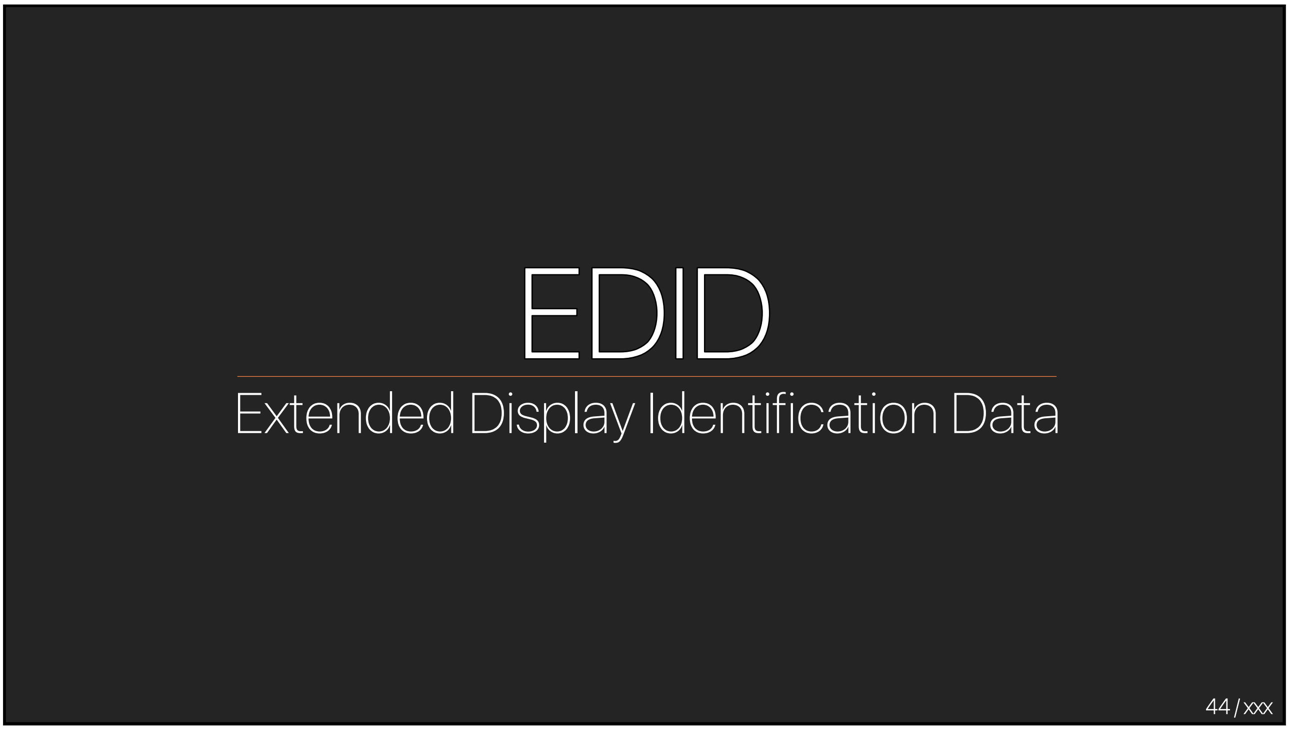
EDID
Extended Display Identification Data
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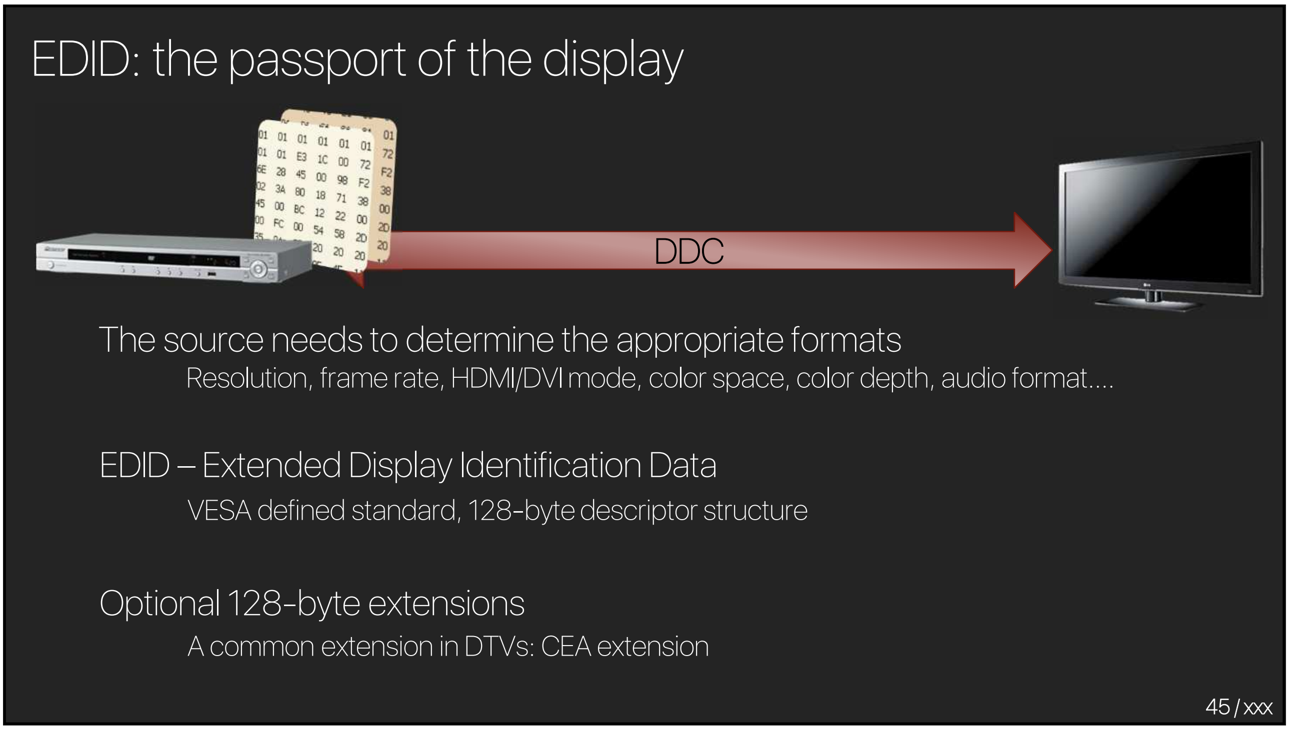
EDID: the passport of the display
DDC
The source needs to determine the appropriate formats
Resolution, frame rate, HDMI/DVI mode, color space, color depth, audio format....
EDID – Extended Display Identification Data
VESA defined standard, 128-byte descriptor structure
Optional 128-byte extensions
A common extension in DTVs: CEA extension
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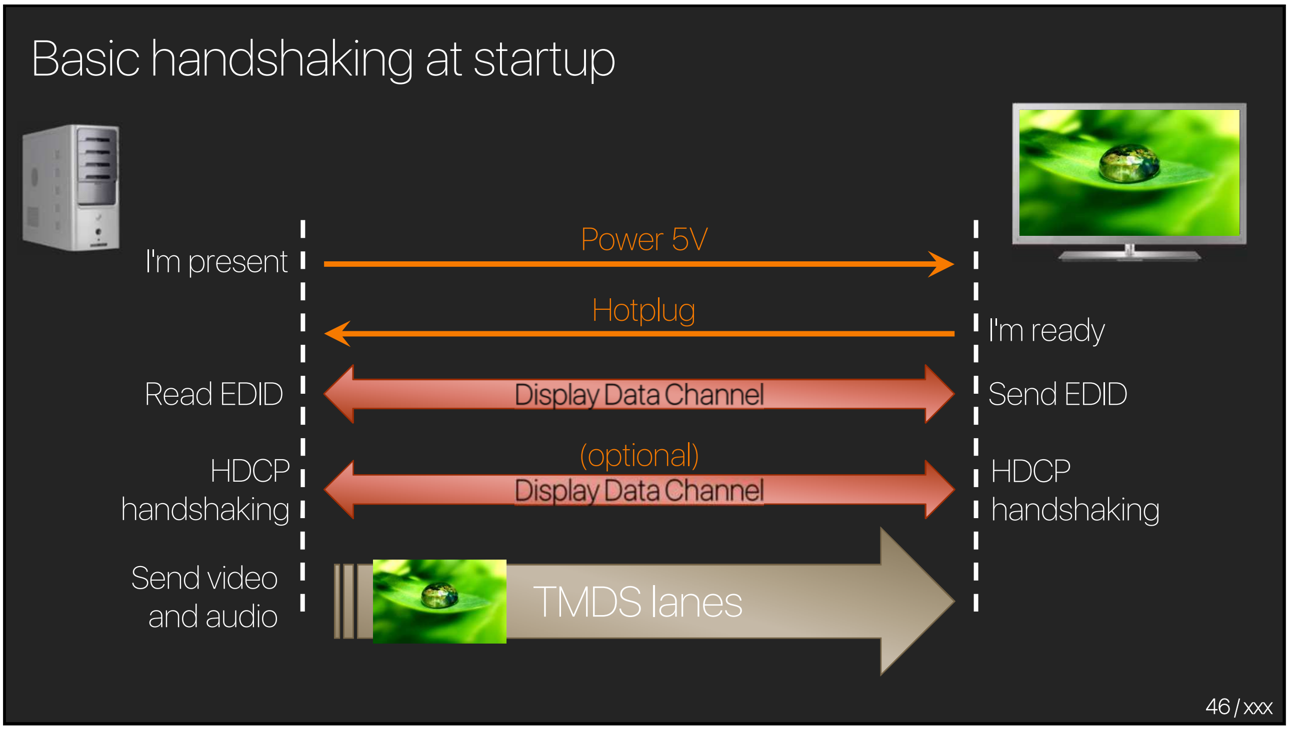
Basic handshaking at startup
Power 5V
I'm present
Hotplug
I'm ready
Read EDID
Display Data Channel
Send EDID
HDCP handshaking
(optional)
Display Data Channel
HDCP handshaking
Send video and audio
TMDS lanes
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An EDID example

EDID header

EDID version 1.3

	0	1	2	3	4	5	6	7	8	9
0	00	FF	FF	FF	FF	FF	FF	00	1E	6D
10	66	76	01	01	01	01	01	13	01	03
20	80	46	27	78	EA	D9	B0	A3	57	49
30	9C	25	11	49	4B	A5	6E	00	31	40
40	45	40	61	40	81	80	01	01	01	01
50	D1	C0	01	01	1A	36	80	A0	70	38
60	1F	40	30	20	35	00	E8	26	32	00
70	00	1A	1B	21	50	A0	51	00	1E	30
80	48	88	35	00	BC	86	21	00	00	1C
90	00	00	00	FD	00	39	4B	1F	54	12
100	00	0A	20	20	20	20	20	20	00	00
110	00	FC	00	33	32	4C	47	35	37	30
120	30	0A	20	20	20	20	01	3F		

Manufacturer PNPID: GSM (Goldstar Company)
Product code: 6676
Serial number: 16843009
Date: 01/2009
Screen size: 70 cm × 39 cm (27.6″ × 15.4″)

Standby: supported
Suspend: supported
Active off: supported

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An EDID example

Preferred timing mode (most likely signal to be displayed)

	0	1	2	3	4	5	6	7	8	9
0	00	FF	FF	FF	FF	FF	FF	00	1E	6D
10	66	76	01	01	01	01	01	13	01	03
20	80	46	27	78	EA	D9	B0	A3	57	49
30	9C	25	11	49	4B	A5	6E	00	31	40
40	45	40	61	40	81	80	01	01	01	01
50	D1	C0	01	01	1A	36	80	A0	70	38
60	1F	40	30	20	35	00	E8	26	32	00
70	00	1A	1B	21	50	A0	51	00	1E	30
80	48	88	35	00	BC	86	21	00	00	1C
90	00	00	00	FD	00	39	4B	1F	54	12
100	00	0A	20	20	20	20	20	20	00	00
110	00	FC	00	33	32	4C	47	35	37	30
120	30	0A	20	20	20	20	01	3F		

Pixel clock: 148.5 MHz
Active resolution: 1920×1080p60
Horizontal blanking: 160 pixels
Vertical blanking: 31 lines
Horizontal Sync offset: 48 pixels
Vertical Sync offset: 3 lines
HSync pulse width: 32 pixels
VSync pulse width: 5 lines
HSync polarity: positive
VSync polarity: negative
Scan mode: progressive
Border size: 0 mm × 0 mm

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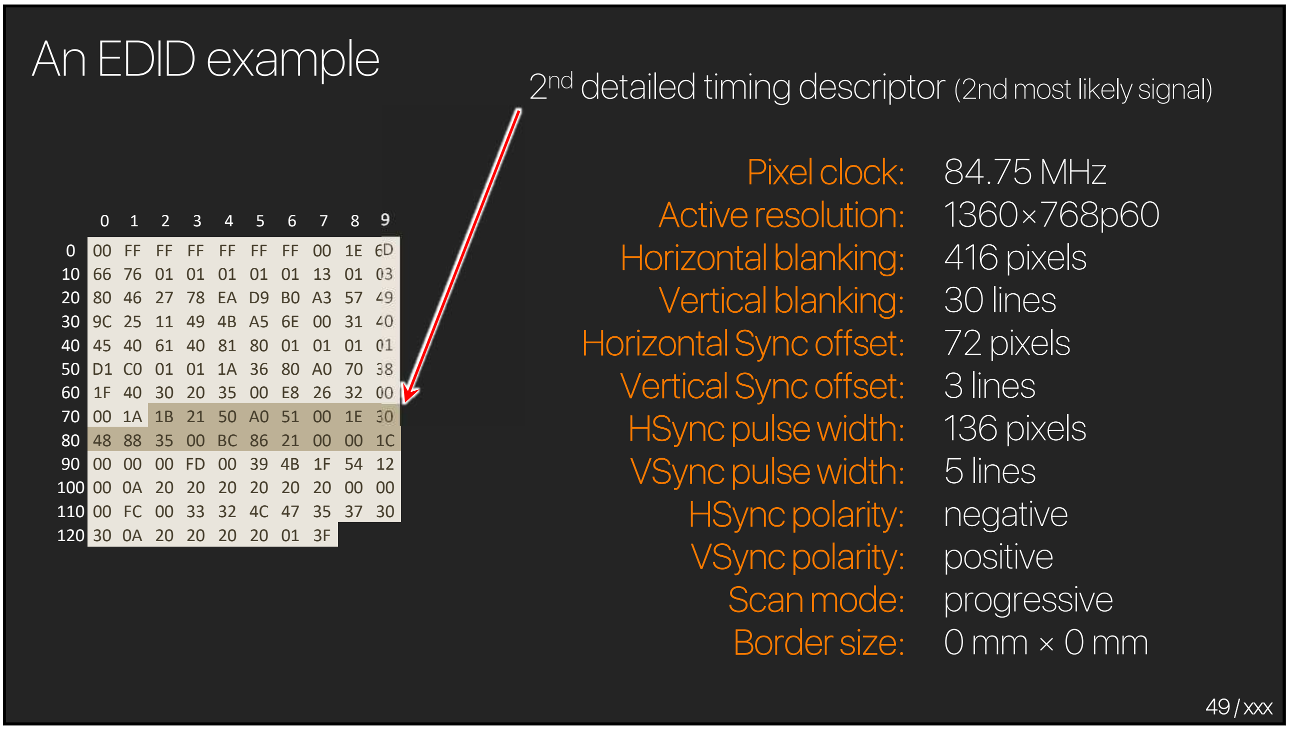
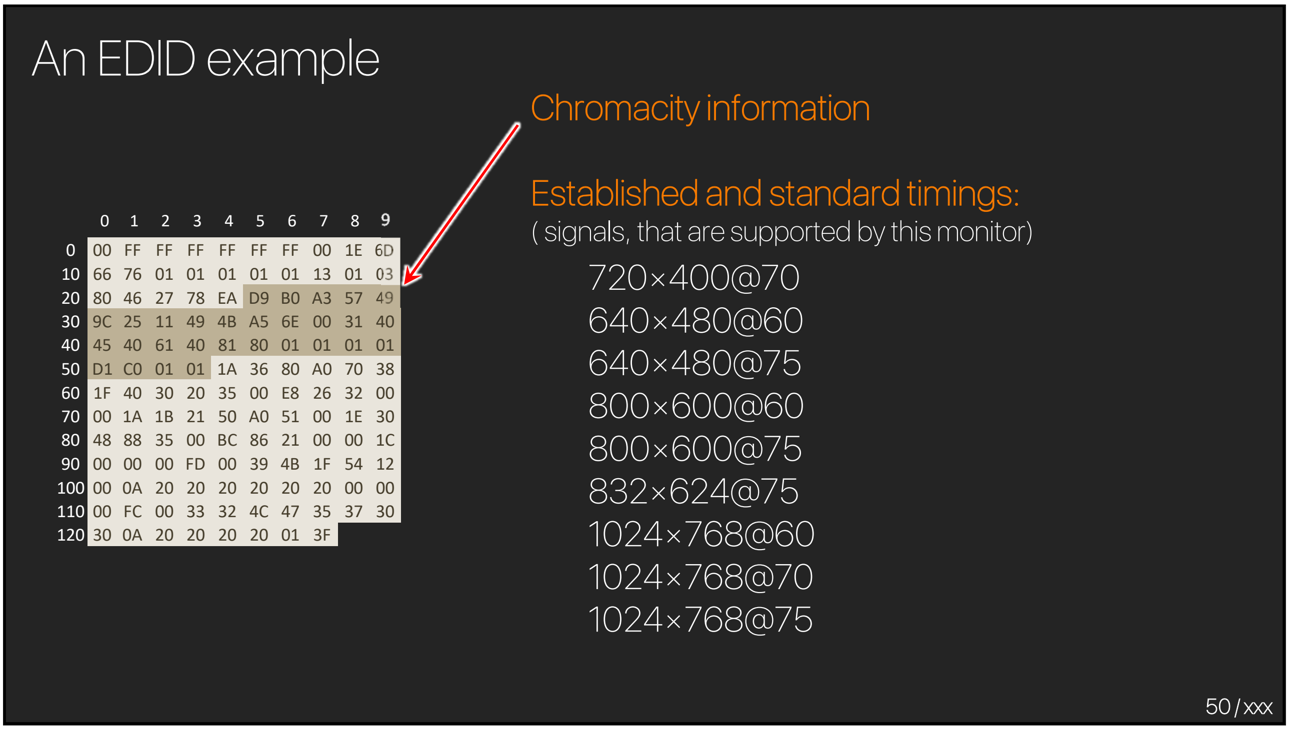

An EDID example
2nd detailed timing descriptor (2nd most likely signal)
0 1 2 3 4 5 6 7 8 9
0 00 FF FF FF FF FF FF 00 1E 6D
10 66 76 01 01 01 01 01 13 01 03
20 80 46 27 78 EA D9 B0 A3 57 49
30 9C 25 11 49 4B A5 6E 00 31 40
40 45 40 61 40 81 80 01 01 01 01
50 D1 C0 01 01 1A 36 80 A0 70 38
60 1F 40 30 20 35 00 E8 26 32 00
70 00 1A 1B 21 50 A0 51 00 1E 30
80 48 88 35 00 BC 86 21 00 00 1C
90 00 00 00 FD 00 39 4B 1F 54 12
100 00 0A 20 20 20 20 20 20 00 00
110 00 FC 00 33 32 4C 47 35 37 30
120 30 0A 20 20 20 20 01 3F
Pixel clock: 84.75 MHz
Active resolution: 1360×768p60
Horizontal blanking: 416 pixels
Vertical blanking: 30 lines
Horizontal Sync offset: 72 pixels
Vertical Sync offset: 3 lines
HSync pulse width: 136 pixels
VSync pulse width: 5 lines
HSync polarity: negative
VSync polarity: positive
Scan mode: progressive
Border size: 0 mm × 0 mm
49 / xxx


An EDID example
Chromacity information
Established and standard timings:
(signals, that are supported by this monitor)
720×400@70
640×480@60
640×480@75
800×600@60
800×600@75
832×624@75
1024×768@60
1024×768@70
1024×768@75
0 1 2 3 4 5 6 7 8 9
0 00 FF FF FF FF FF FF 00 1E 6D
10 66 76 01 01 01 01 01 13 01 03
20 80 46 27 78 EA D9 B0 A3 57 49
30 9C 25 11 49 4B A5 6E 00 31 40
40 45 40 61 40 81 80 01 01 01 01
50 D1 C0 01 01 1A 36 80 A0 70 38
60 1F 40 30 20 35 00 E8 26 32 00
70 00 1A 1B 21 50 A0 51 00 1E 30
80 48 88 35 00 BC 86 21 00 00 1C
90 00 00 00 FD 00 39 4B 1F 54 12
100 00 0A 20 20 20 20 20 20 00 00
110 00 FC 00 33 32 4C 47 35 37 30
120 30 0A 20 20 20 20 01 3F
50 / xxx

An EDID example

	0	1	2	3	4	5	6	7	8	9
0	00	FF	FF	FF	FF	FF	FF	00	1E	6D
10	66	76	01	01	01	01	01	13	01	03
20	80	46	27	78	EA	D9	B0	A3	57	49
30	9C	25	11	49	4B	A5	6E	00	31	40
40	45	40	61	40	81	80	01	01	01	01
50	D1	C0	01	01	1A	36	80	A0	70	38
60	1F	40	30	20	35	00	E8	26	32	00
70	00	1A	1B	21	50	A0	51	00	1E	30
80	48	88	35	00	BC	86	21	00	00	1C
90	00	00	00	FD	00	39	4B	1F	54	12
100	00	0A	20	20	20	20	20	20	00	00
110	00	FC	00	33	32	4C	47	35	37	30
120	30	0A	20	20	20	20	01	3F		

Display range limits descriptor

VSync frequency: 57 – 75 Hz
HSync frequency: 31 - 84 kHz
Maximum pixel clock: 180 MHz

Product name: 32LG5700

Number of extensions: 1 (128-byte CEA extension fields)
Checksum: 0x3F

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CEA extension fields

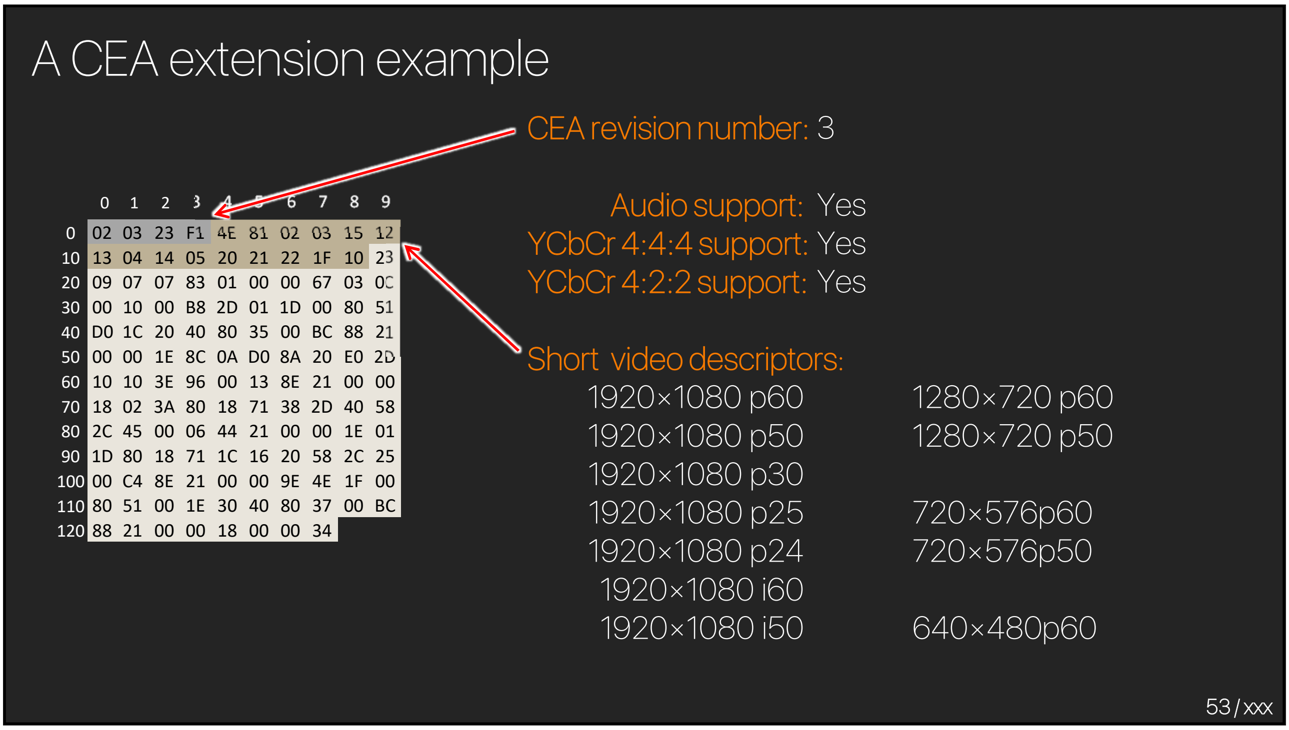
HDMI

x.v.Colour

YCbCr

- Supported colorspaces
- Short video descriptors
  - 59 CEA-defined DTV standard resolutions
- Supported audio formats
- Available speakers
- HDMI compatibility, Deep Color
- Additional detailed timing descriptors

52 / xxx


A CEA extension example
CEA revision number: 3
0 1 2 3 4 5 6 7 8 9
0 02 03 23 F1 4E 81 02 03 15 12
10 13 04 14 05 20 21 22 1F 10 23
20 09 07 07 83 01 00 00 67 03 0C
30 00 10 00 B8 2D 01 1D 00 80 51
40 D0 1C 20 40 80 35 00 BC 88 21
50 00 00 1E 8C 0A D0 8A 20 E0 2D
60 10 10 3E 96 00 13 8E 21 00 00
70 18 02 3A 80 18 71 38 2D 40 58
80 2C 45 00 06 44 21 00 00 1E 01
90 1D 80 18 71 1C 16 20 58 2C 25
100 00 C4 8E 21 00 00 9E 4E 1F 00
110 80 51 00 1E 30 40 80 37 00 BC
120 88 21 00 00 18 00 00 34
Audio support: Yes
YCbCr 4:4:4 support: Yes
YCbCr 4:2:2 support: Yes
Short video descriptors:
1920×1080 p60
1920×1080 p50
1920×1080 p30
1920×1080 p25
1920×1080 p24
1920×1080 i60
1920×1080 i50
1280×720 p60
1280×720 p50
720×576p60
720×576p50
640×480p60
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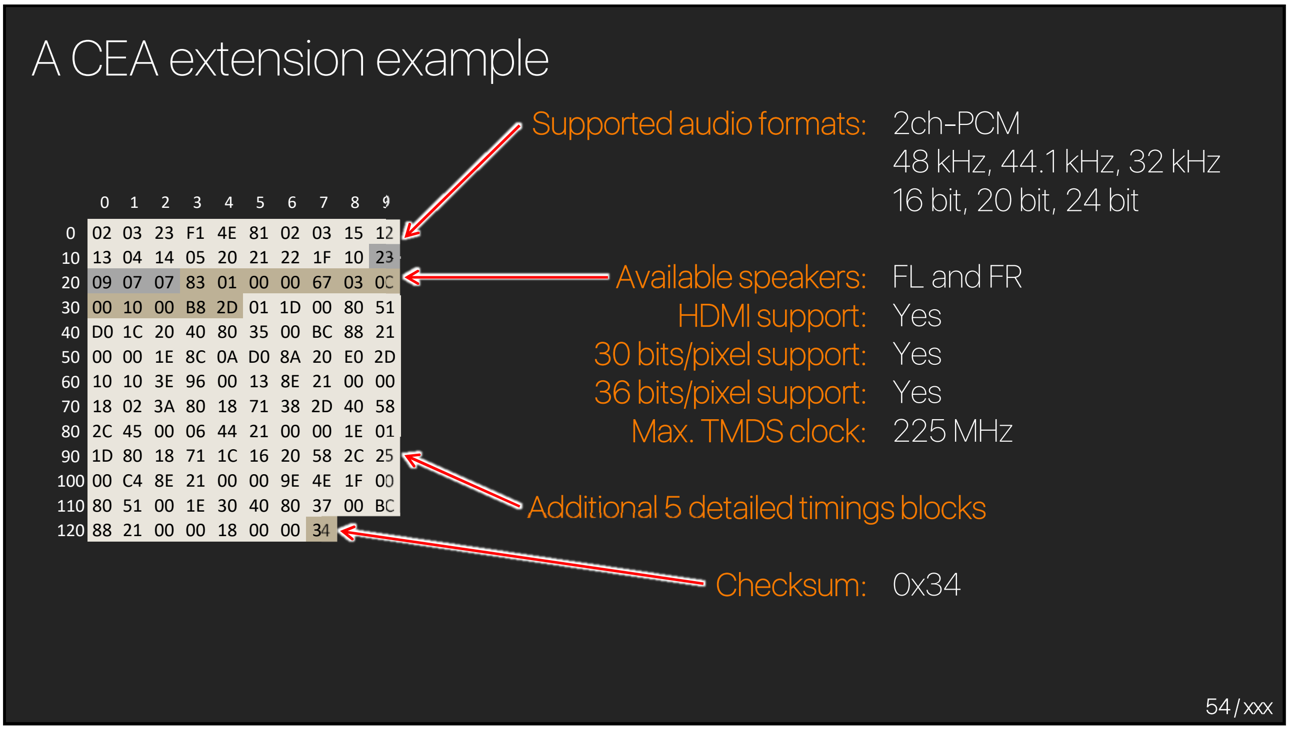
A CEA extension example
0 1 2 3 4 5 6 7 8 9
0 02 03 23 F1 4E 81 02 03 15 12
10 13 04 14 05 20 21 22 1F 10 23
20 09 07 07 83 01 00 00 67 03 0C
30 00 10 00 B8 2D 01 1D 00 80 51
40 D0 1C 20 40 80 35 00 BC 88 21
50 00 00 1E 8C 0A D0 8A 20 E0 2D
60 10 10 3E 96 00 13 8E 21 00 00
70 18 02 3A 80 18 71 38 2D 40 58
80 2C 45 00 06 44 21 00 00 1E 01
90 1D 80 18 71 1C 16 20 58 2C 25
100 00 C4 8E 21 00 00 9E 4E 1F 00
110 80 51 00 1E 30 40 80 37 00 BC
120 88 21 00 00 18 00 00 34
Supported audio formats: 2ch-PCM
48 kHz, 44.1 kHz, 32 kHz
16 bit, 20 bit, 24 bit
Available speakers: FL and FR
HDMI support: Yes
30 bits/pixel support: Yes
36 bits/pixel support: Yes
Max. TMDS clock: 225 MHz
Additional 5 detailed timings blocks
Checksum: 0x34
54 / xxx

Lightware factory EDIDs vs. display EDIDs

	Lightware factory EDID	Display EDID
Preferred timing mode:	1920×1080p60	1920×1080p60
2nd detailed timing:	–	1360×768p60
Established and std. timings:	–	720×400@70, 640×480@60, 640×480@75, 800×600@60, 800×600@75, 832×624@75, 1024×768@60, 1024×768@70, 1024×768@75
CEA short video descriptors:	1920×1080p60	640×480p60, 720×576p50, 720×576p60, 1280×720p50, 1280×720p60, 1920×1080i50, 1920×1080i60, 1920×1080p24, 1920×1080p25, 1920×1080p30, 1920×1080p50, 1920×/1080p60,

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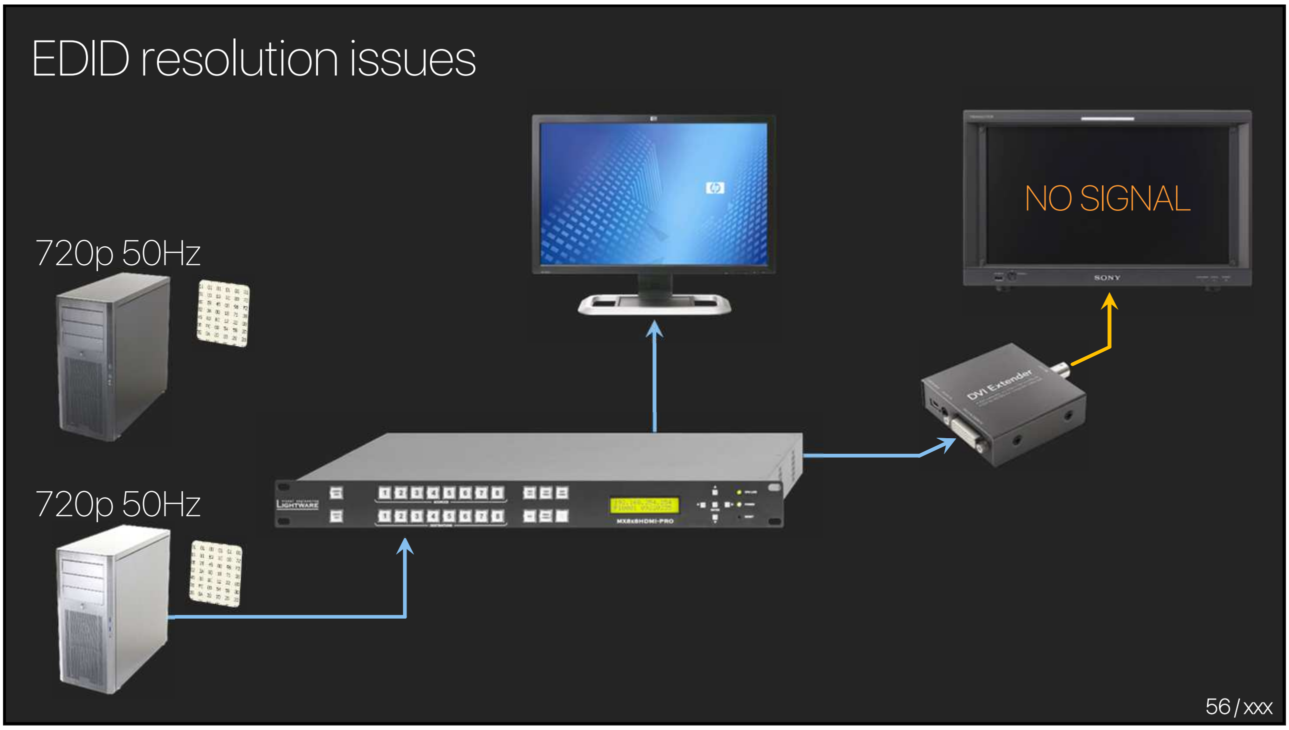

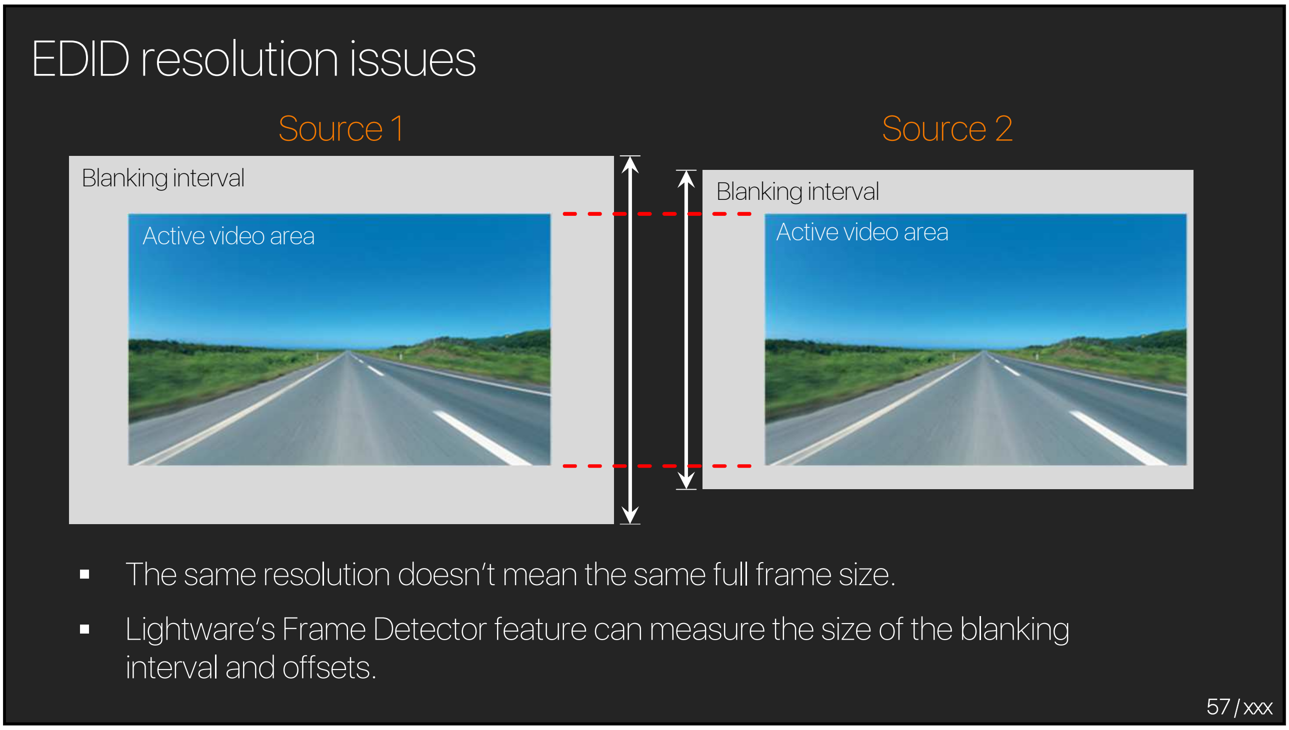

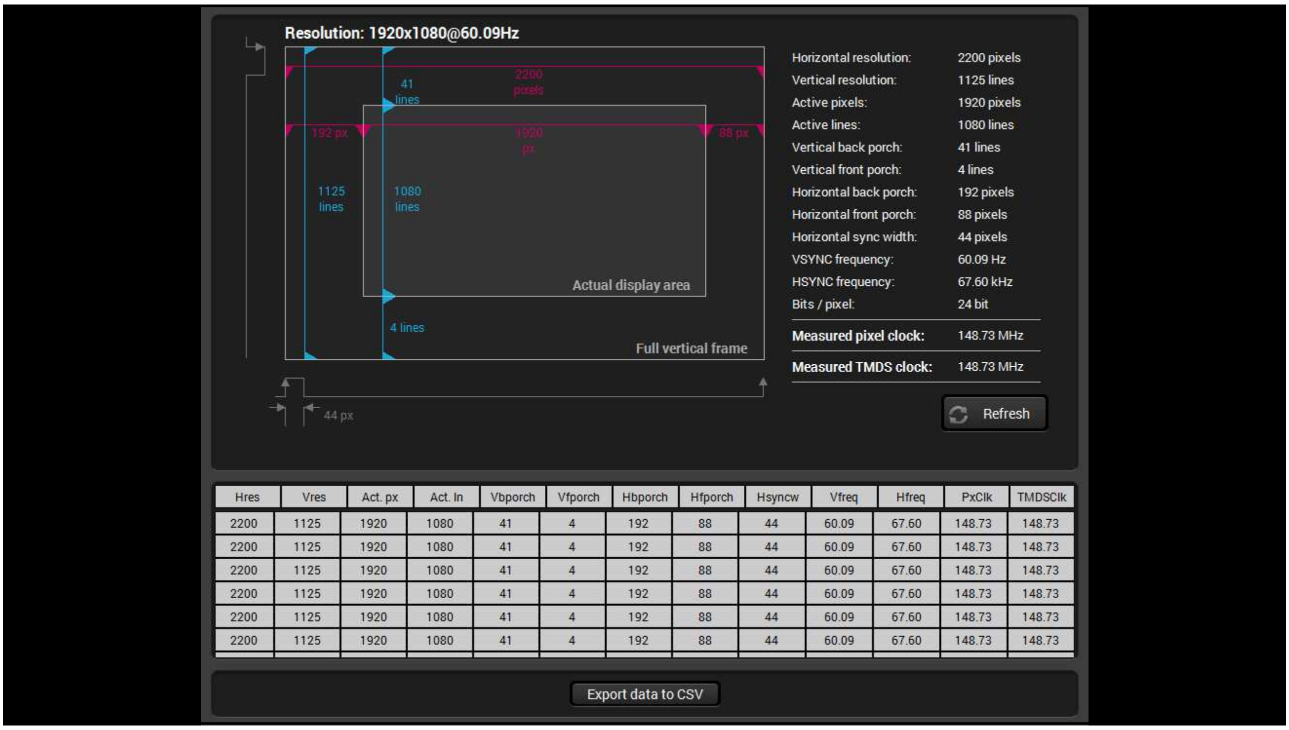

Hres	Vres	Act. px	Act. ln	Vbporch	Vfporch	Hbporch	Hfporch	Hsyncw	Vfreq	Hfreq	PxClk	TMDSClk
2200	1125	1920	1080	41	4	192	88	44	60.09	67.60	148.73	148.73
2200	1125	1920	1080	41	4	192	88	44	60.09	67.60	148.73	148.73
2200	1125	1920	1080	41	4	192	88	44	60.09	67.60	148.73	148.73
2200	1125	1920	1080	41	4	192	88	44	60.09	67.60	148.73	148.73
2200	1125	1920	1080	41	4	192	88	44	60.09	67.60	148.73	148.73
2200	1125	1920	1080	41	4	192	88	44	60.09	67.60	148.73	148.73

EDID vs. chip capabilities

What can be different?

- Blanking size (reduced blanking or standard)
- Frame rate (60 Hz vs. 59.94 Hz)
- HSync & VSync polarities
- HSync & VSync pulse width
- Audio sampling frequency, sample size
- Color space

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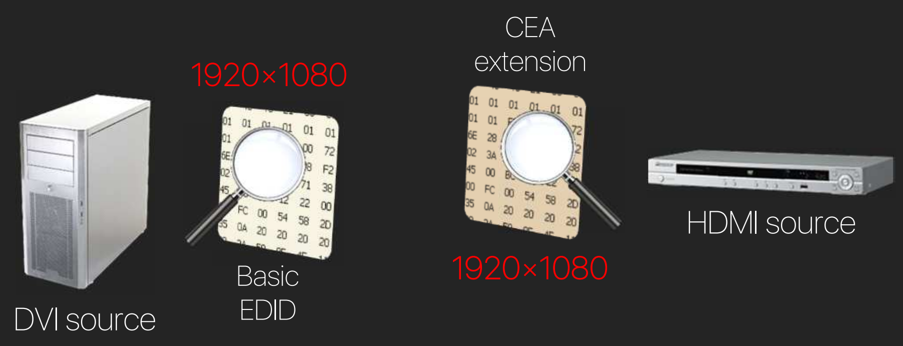
VESA and CEA resolutions

VESA standard resolutions (basic EDID):

- 1920×1200 (16:10)
- 1600×1200 (4:3)

CEA standard resolutions (CEA extension):

- 1920×1080 (16:9)
- 1280×720 (16:9)



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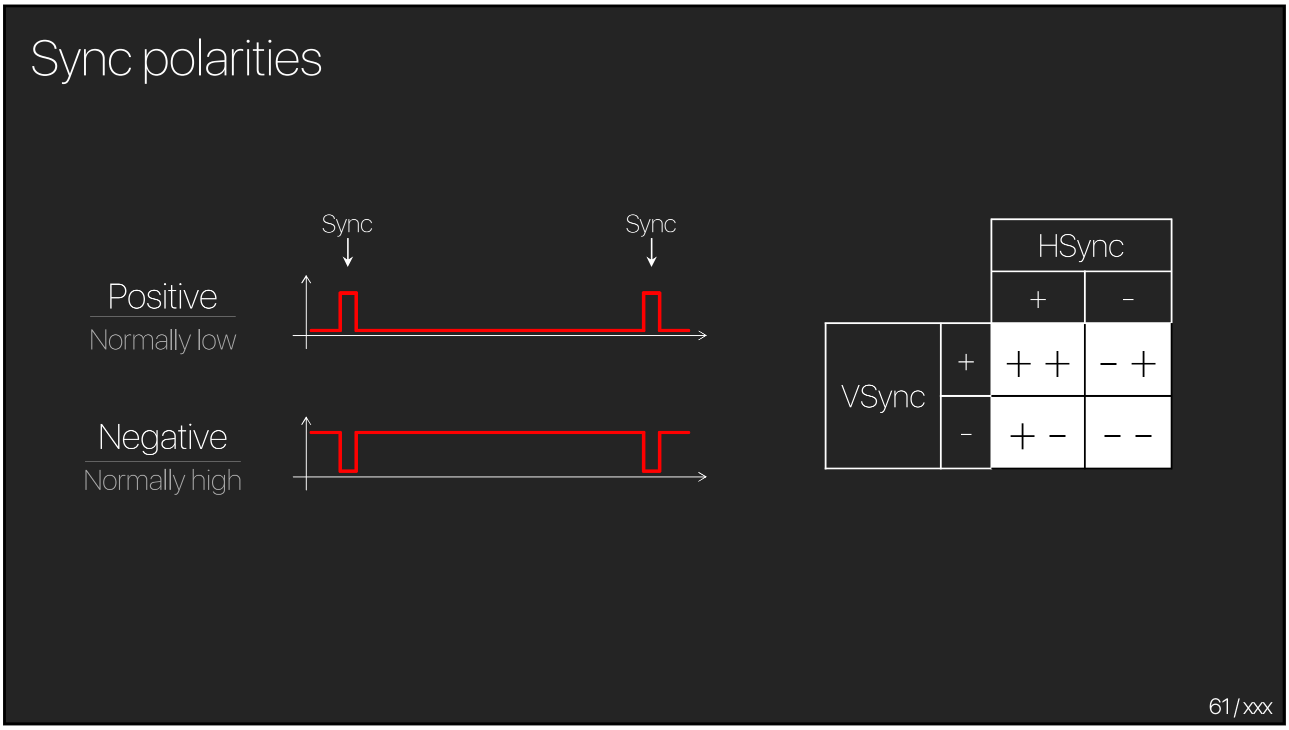
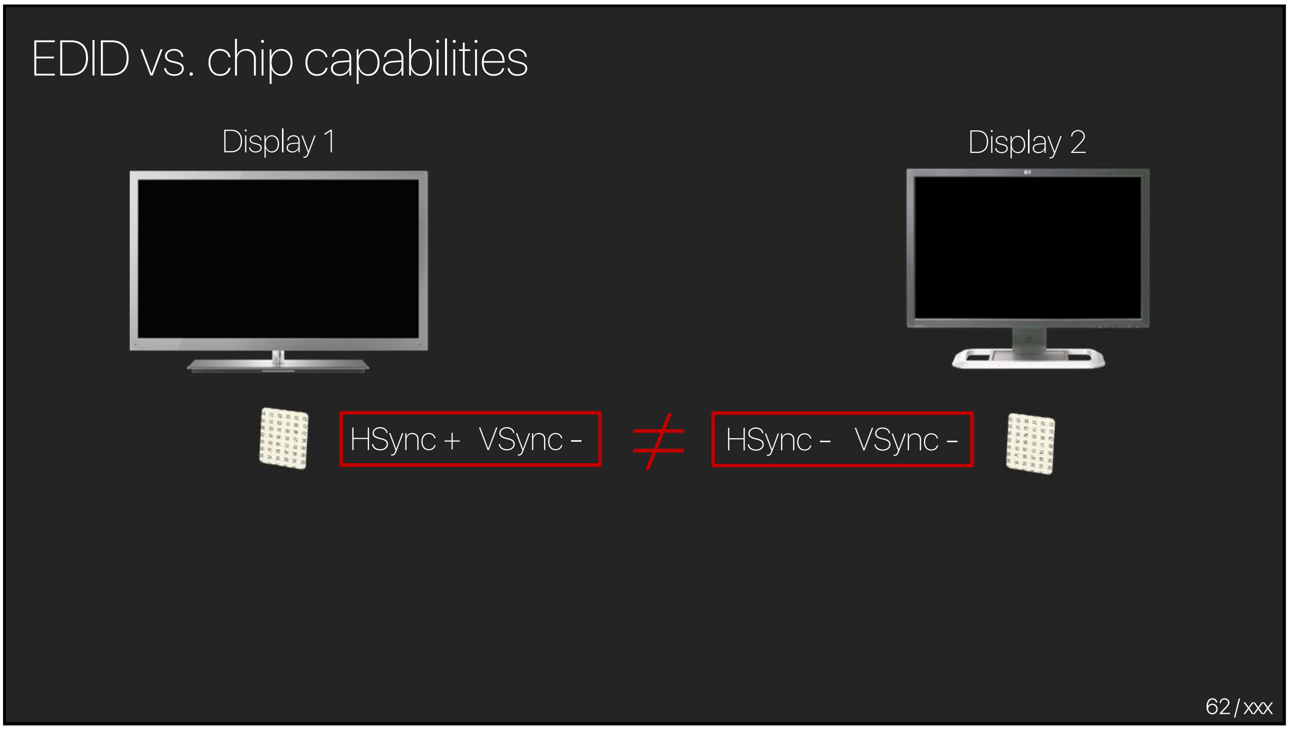
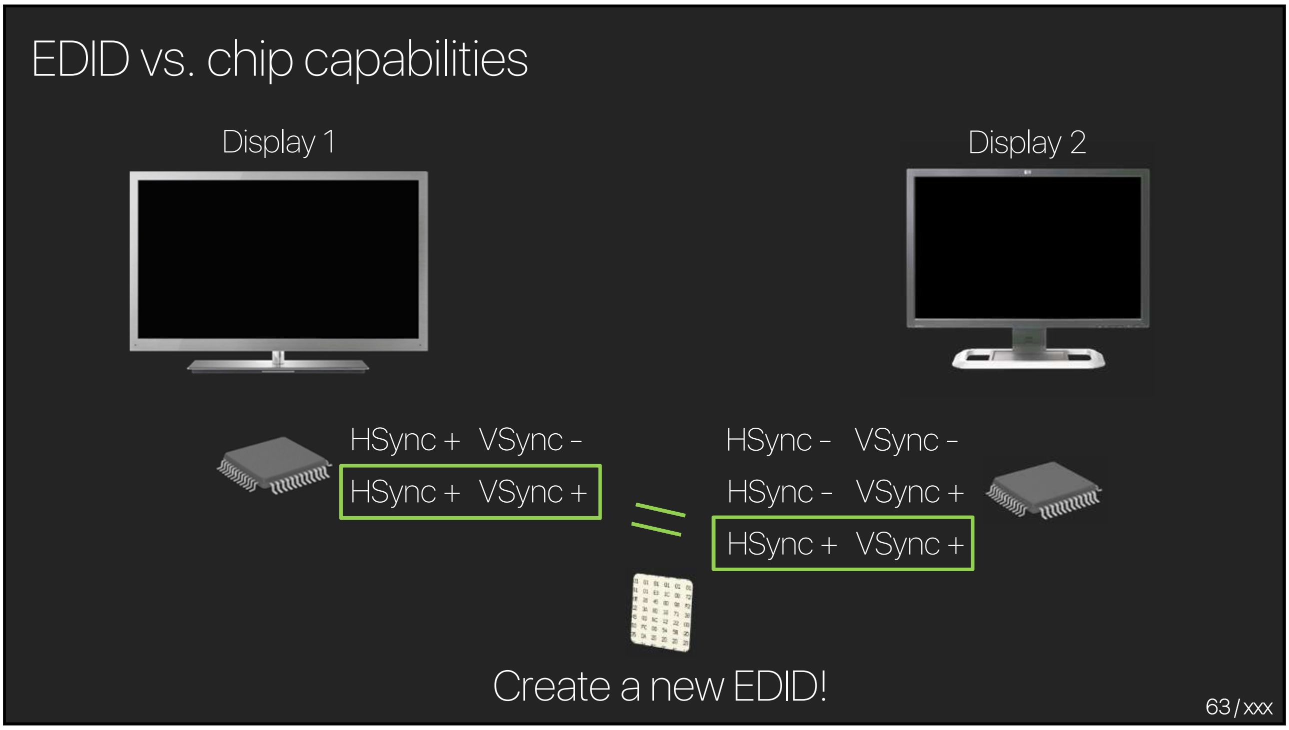

Sync polarities
Sync
Sync
Positive
Normally low
Negative
Normally high
HSync
+
-
VSync
+
-
+ +
- +
+ -
- -
61 / xxx


EDID vs. chip capabilities
Display 1
Display 2
HSync + VSync -
≠
HSync - VSync -
62 / xxx



Color spaces

Some HDMI devices cannot convert color spaces!

Requesting the correct color space from the source is essential!

	Capabilities reported in the EDID	
	RGB Only	RGB and YCbCr supported
Win 7 PC (AMD 6670)	RGB	YCbCr 4:4:4
Asrock ION 3D 1.A (NVIDIA GT218-ION)	RGB	RGB
Pioneer BDP-150 BluRay	RGB	RGB and YCbCr 4:2:2

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EDID Management
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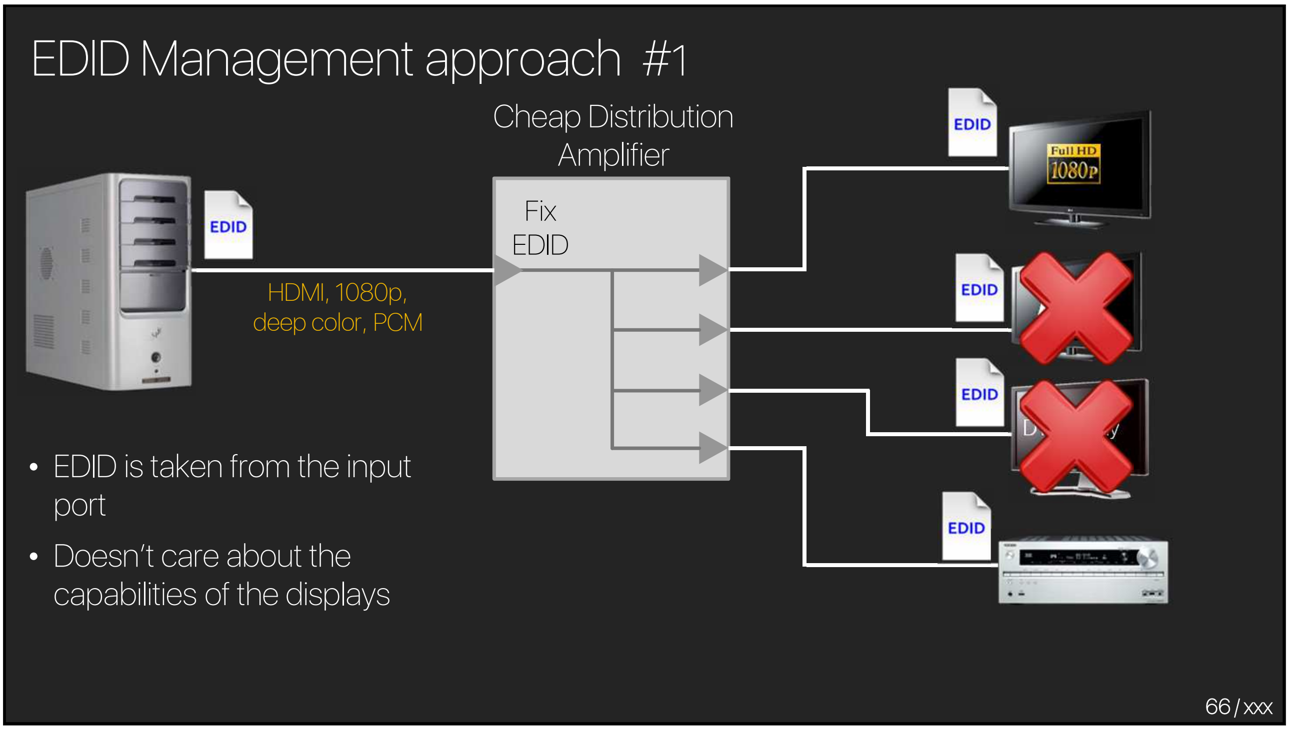
EDID Management approach #1
Cheap Distribution Amplifier
Fix EDID
EDID
HDMI, 1080p, deep color, PCM
EDID
EDID
EDID
EDID
Full HD 1080p
• EDID is taken from the input port
• Doesn't care about the capabilities of the displays
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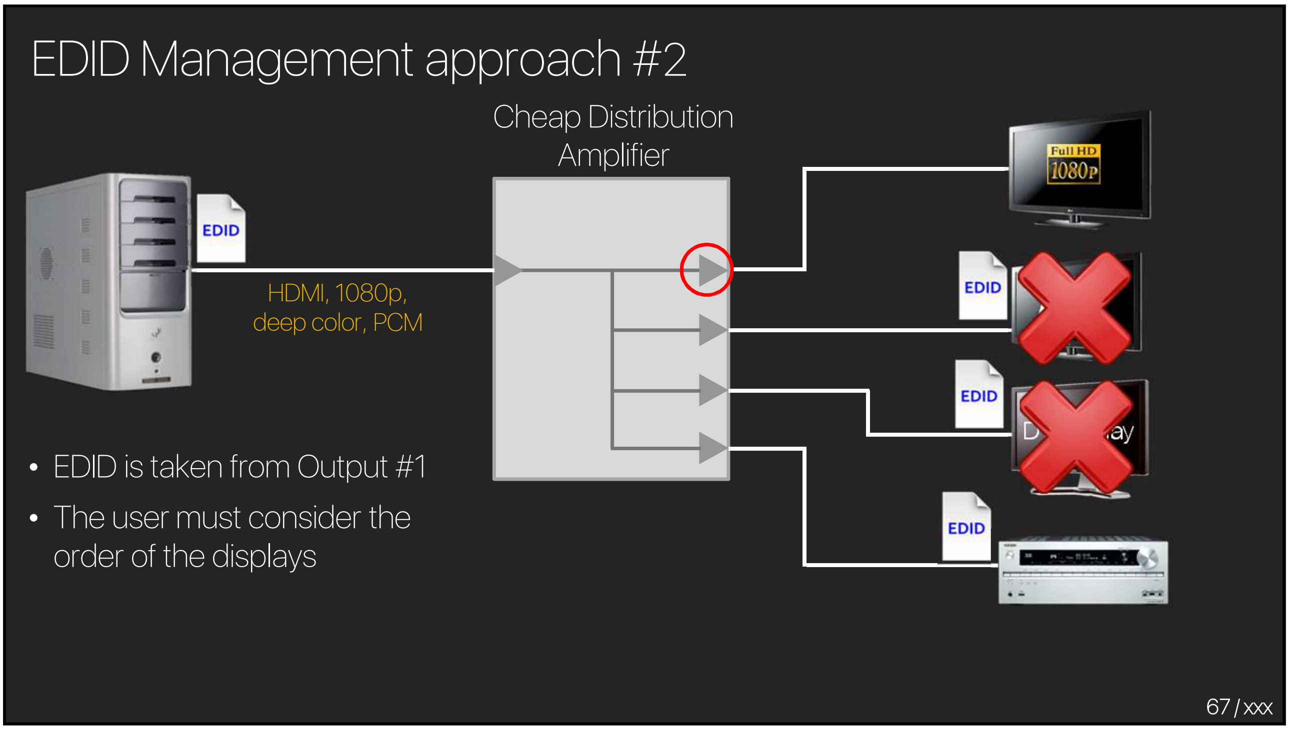
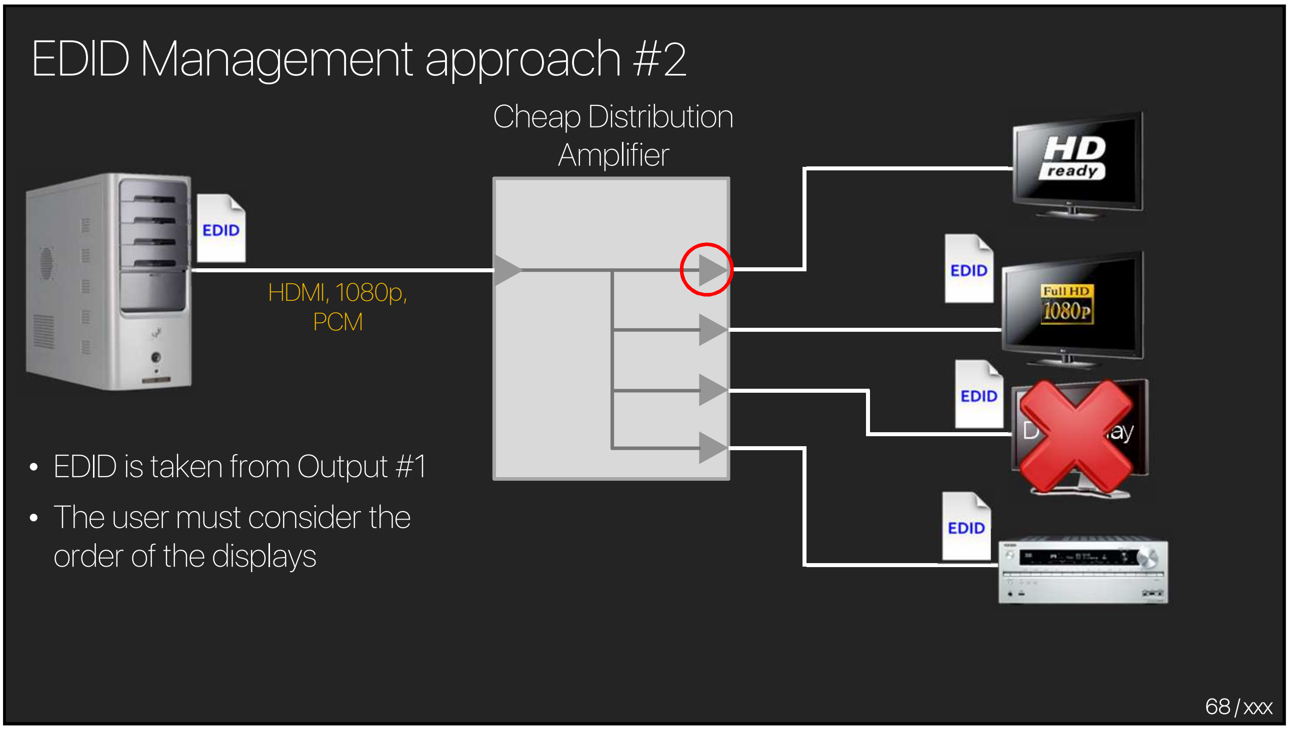

EDID Management approach #2
Cheap Distribution Amplifier
EDID
HDMI, 1080p, deep color, PCM
Full HD 1080p
EDID
EDID
EDID
• EDID is taken from Output #1
• The user must consider the order of the displays
67 / xxx


EDID Management approach #2
Cheap Distribution Amplifier
EDID
HDMI, 1080p, PCM
HD ready
EDID
Full HD 1080p
EDID
EDID
• EDID is taken from Output #1
• The user must consider the order of the displays
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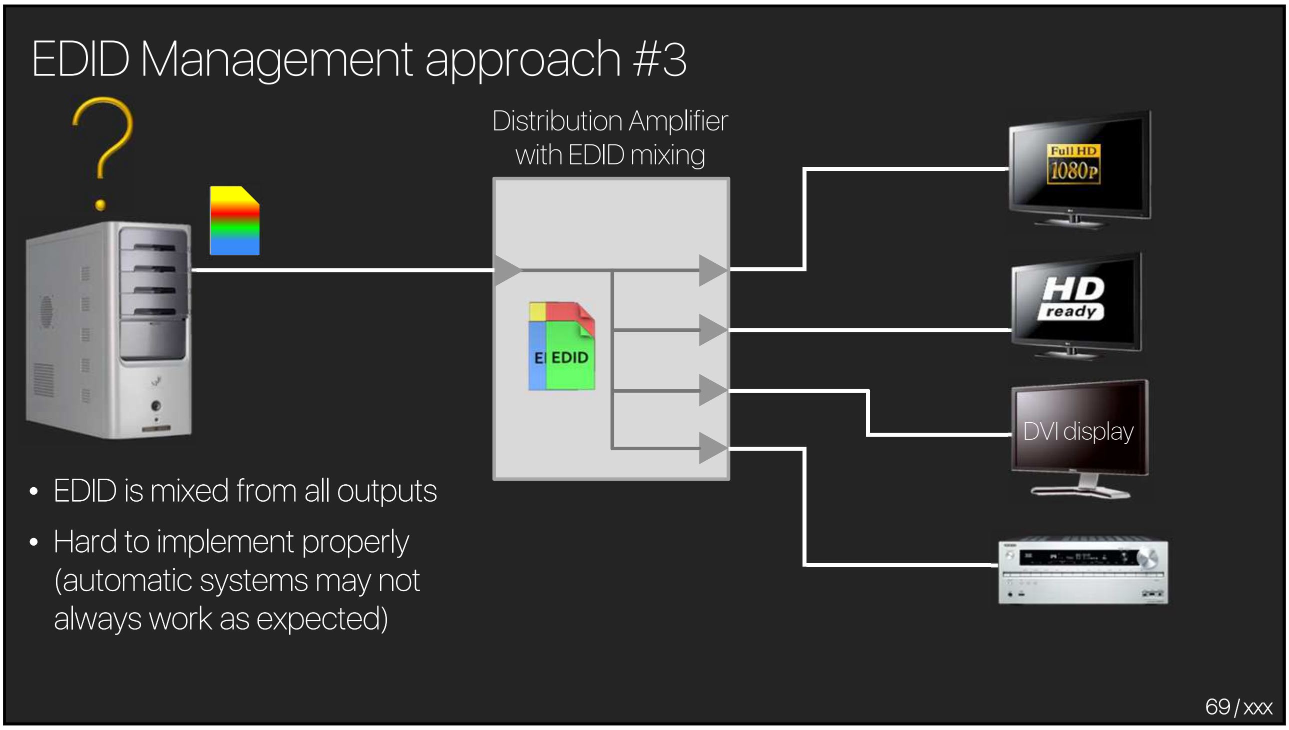
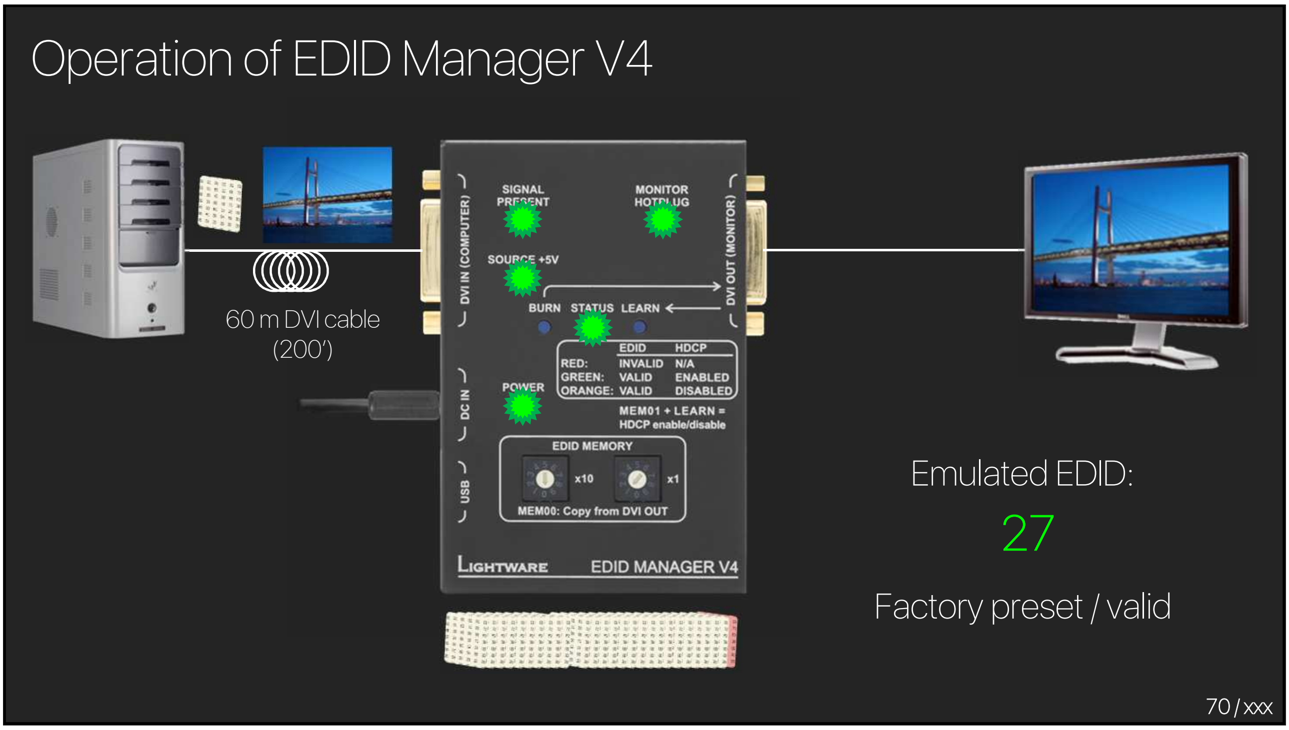
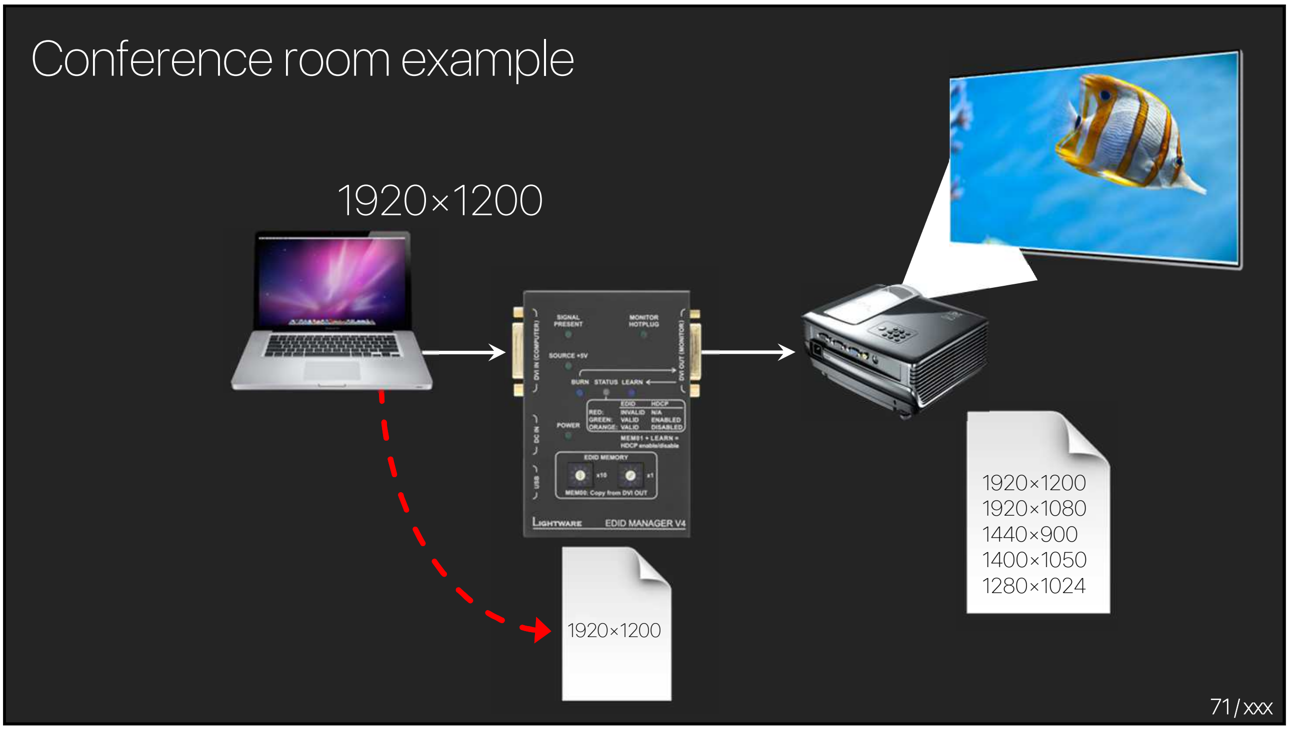
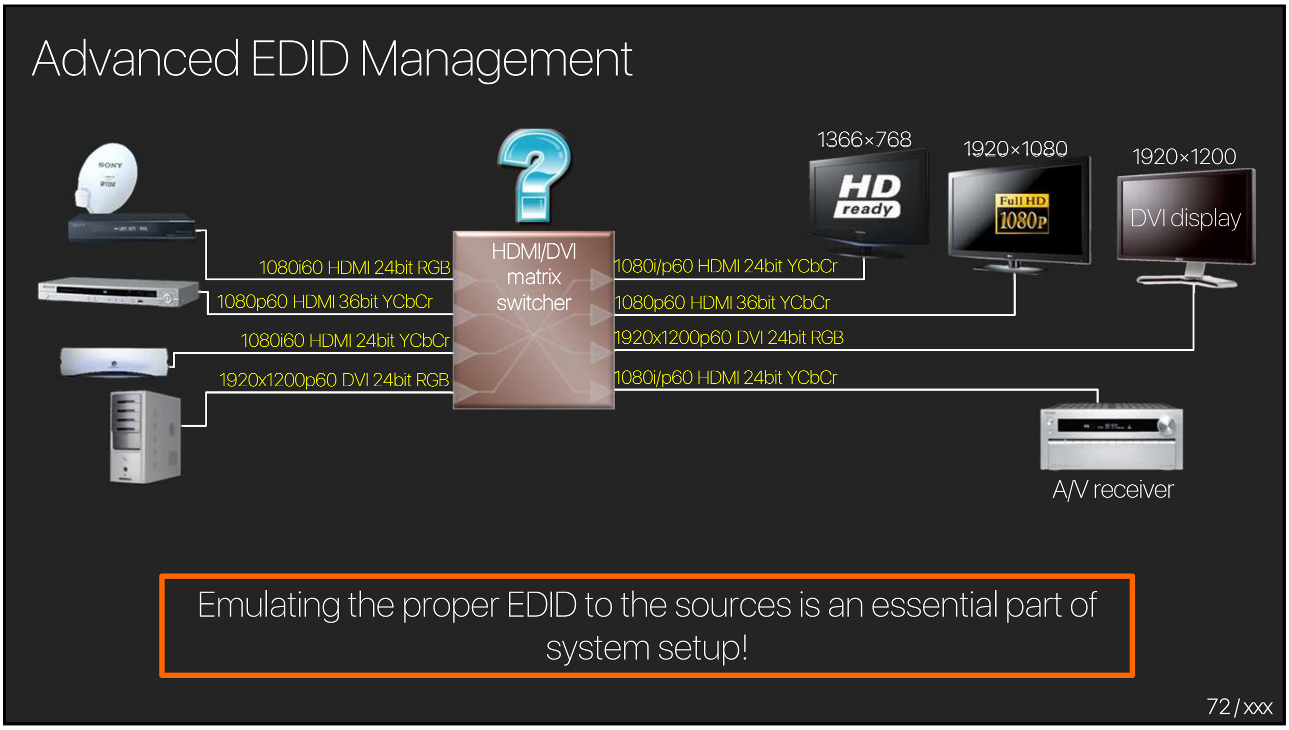

EDID Management approach #3
Distribution Amplifier with EDID mixing
EDID
Full HD 1080p
HD ready
DVI display
• EDID is mixed from all outputs
• Hard to implement properly (automatic systems may not always work as expected)
69 / xxx


Operation of EDID Manager V4
60 m DVI cable (200')
DVI IN (COMPUTER)
DVI OUT (MONITOR)
SIGNAL PRESENT
MONITOR HOTPLUG
SOURCE +5V
BURN
STATUS
LEARN
EDID
HDCP
RED: INVALID N/A
GREEN: VALID ENABLED
ORANGE: VALID DISABLED
MEM01 + LEARN = HDCP enable/disable
POWER
DC IN
USB
EDID MEMORY
x10
x1
MEM00: Copy from DVI OUT
LIGHTWARE
EDID MANAGER V4
Emulated EDID:
27
Factory preset / valid
70 / xxx


Conference room example
1920×1200
1920×1200
1920×1200
1920×1080
1440×900
1400×1050
1280×1024
71 / xxx


Advanced EDID Management
1366×768
1920×1080
1920×1200
DVI display
HDMI/DVI matrix switcher
1080i60 HDMI 24bit RGB
1080p60 HDMI 36bit YCbCr
1080i60 HDMI 24bit YCbCr
1920x1200p60 DVI 24bit RGB
1080i/p60 HDMI 24bit YCbCr
1080p60 HDMI 36bit YCbCr
1920x1200p60 DVI 24bit RGB
1080i/p60 HDMI 24bit YCbCr
A/V receiver
Emulating the proper EDID to the sources is an essential part of system setup!
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Advanced EDID Management

- Static EDID emulation
  - From Factory Preset or User programmable memory.
- Dynamic EDID emulation
  - Copy EDIDs from any display to any input. The emulated EDID changes if the display is replaced.
- EDID storing
  - Store EDID from any display.
- EDID editing functions
  - Edit EDIDs with the Advanced EDID Editor.
- EDID transfer into/from the router
  - Upload/download EDID files through any of the control ports.
- Custom EDID creation
  - Custom EDID creation with Lightware Easy EDID Creator.

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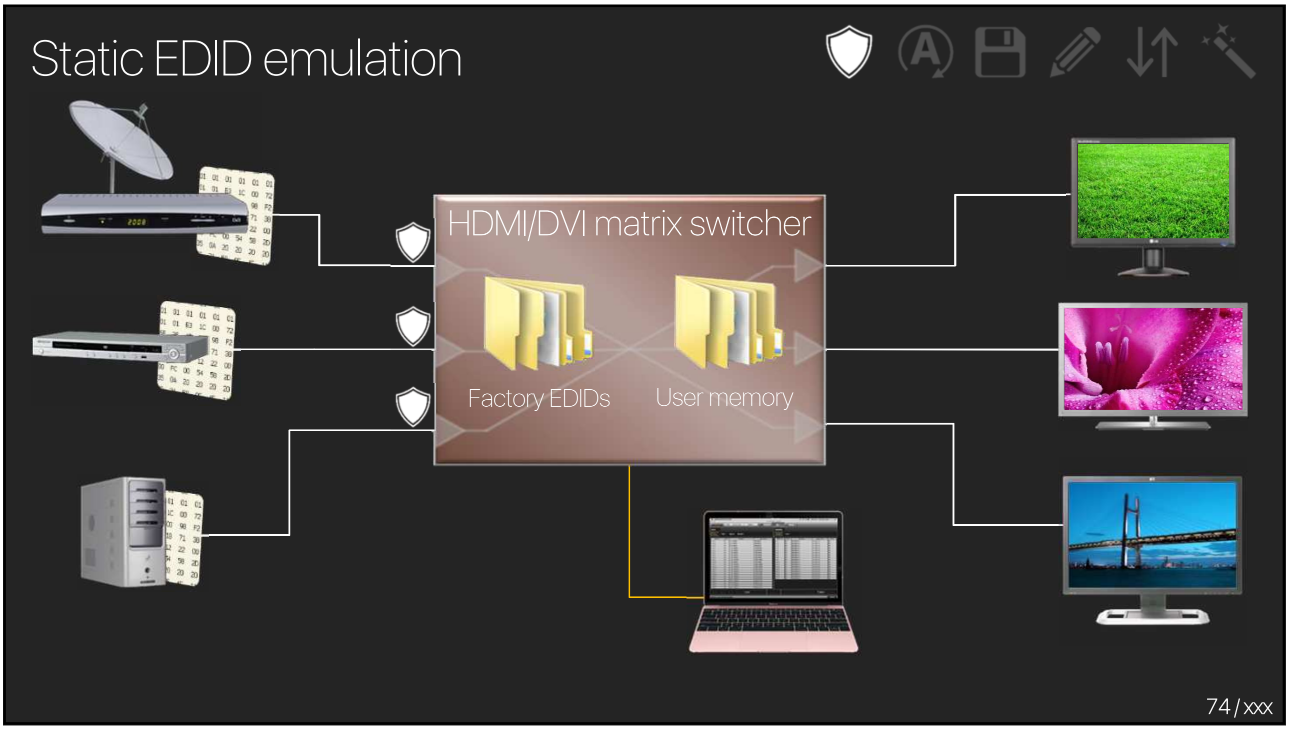
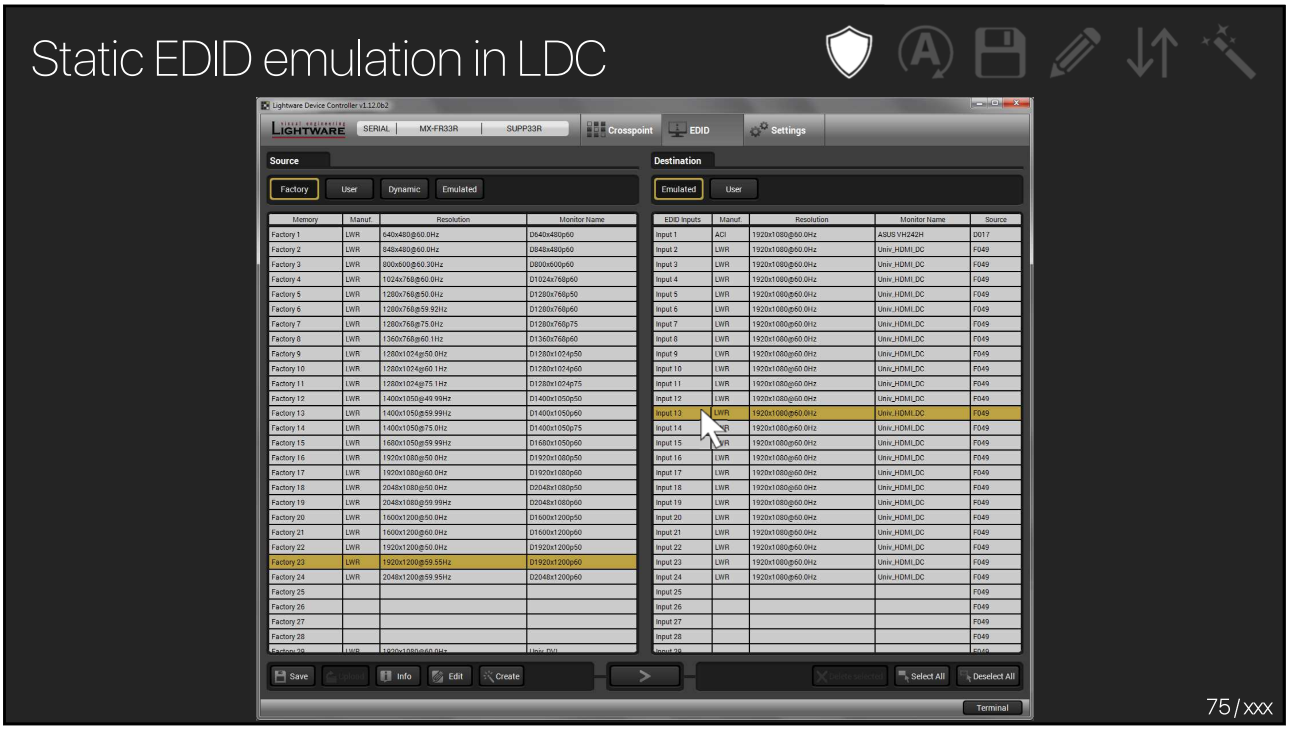
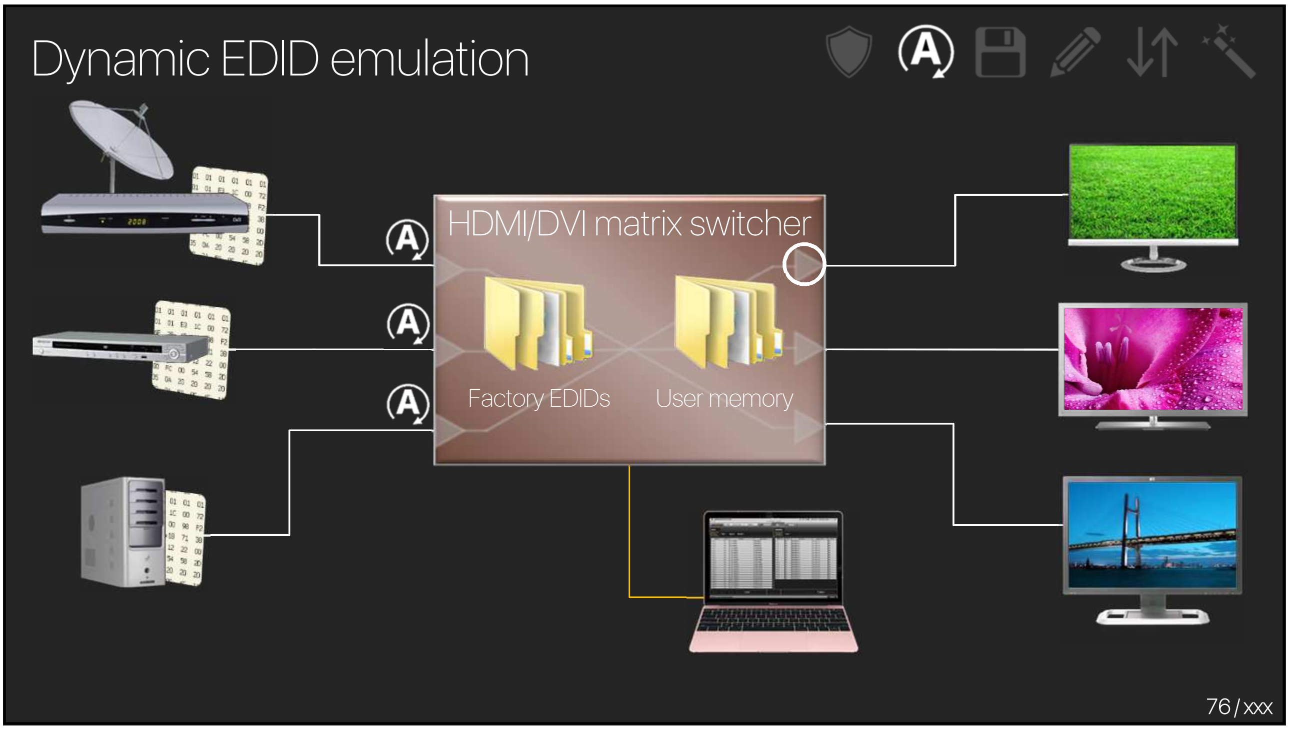



Static EDID emulation in LDC
Source
Factory
User
Dynamic
Emulated
Destination
Save
Info
Edit
Create
Select All
Deselect All
Terminal
75 / xxx


Dynamic EDID emulation
HDMI/DVI matrix switcher
Factory EDIDs
User memory
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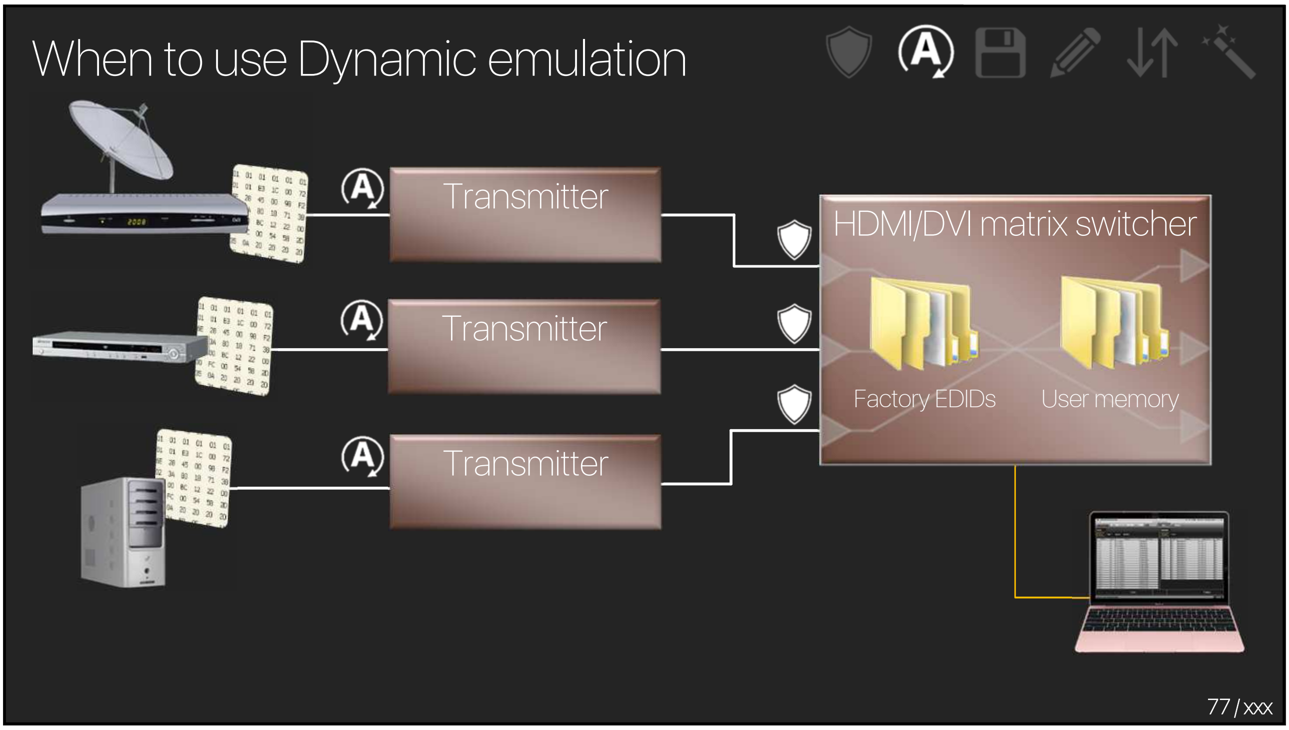
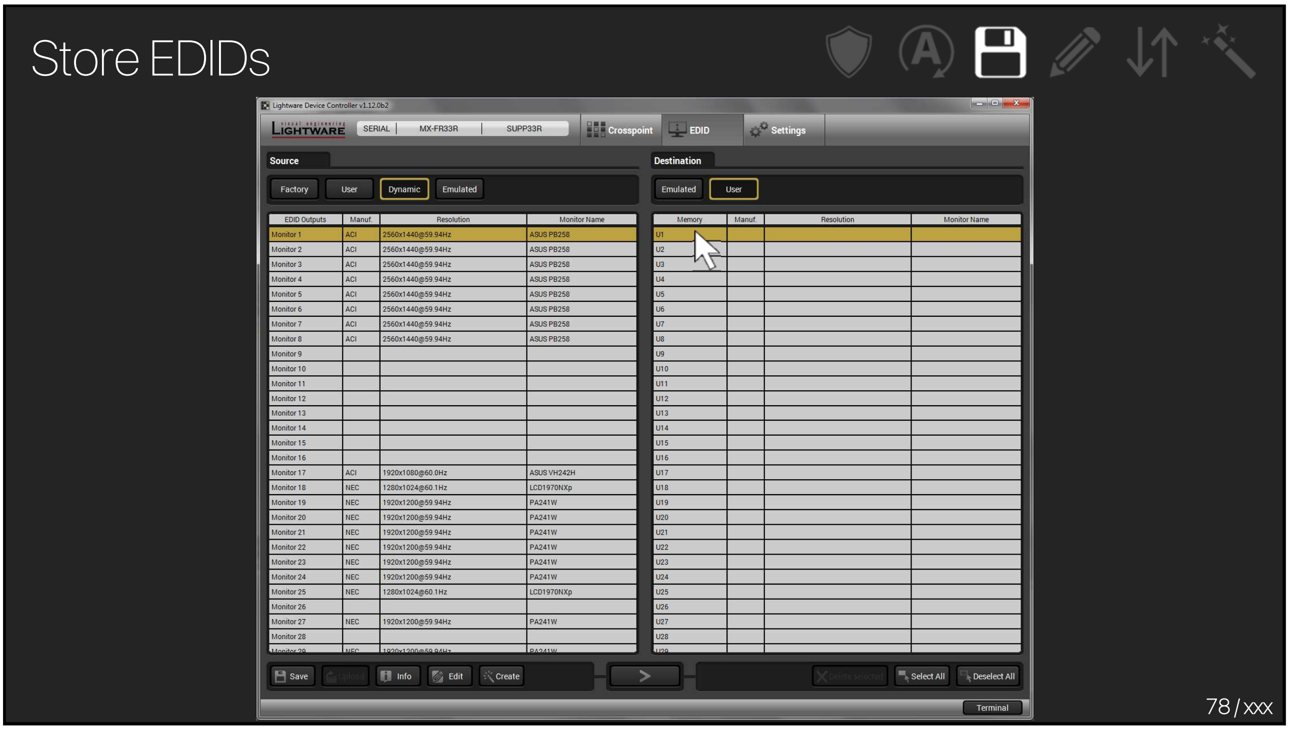

When to use Dynamic emulation
Transmitter
Transmitter
Transmitter
HDMI/DVI matrix switcher
Factory EDIDs
User memory
77 / xxx


Store EDIDs
Source
Destination
Factory
User
Dynamic
Emulated
Emulated
User
Save
Info
Edit
Create
Select All
Deselect All
Terminal
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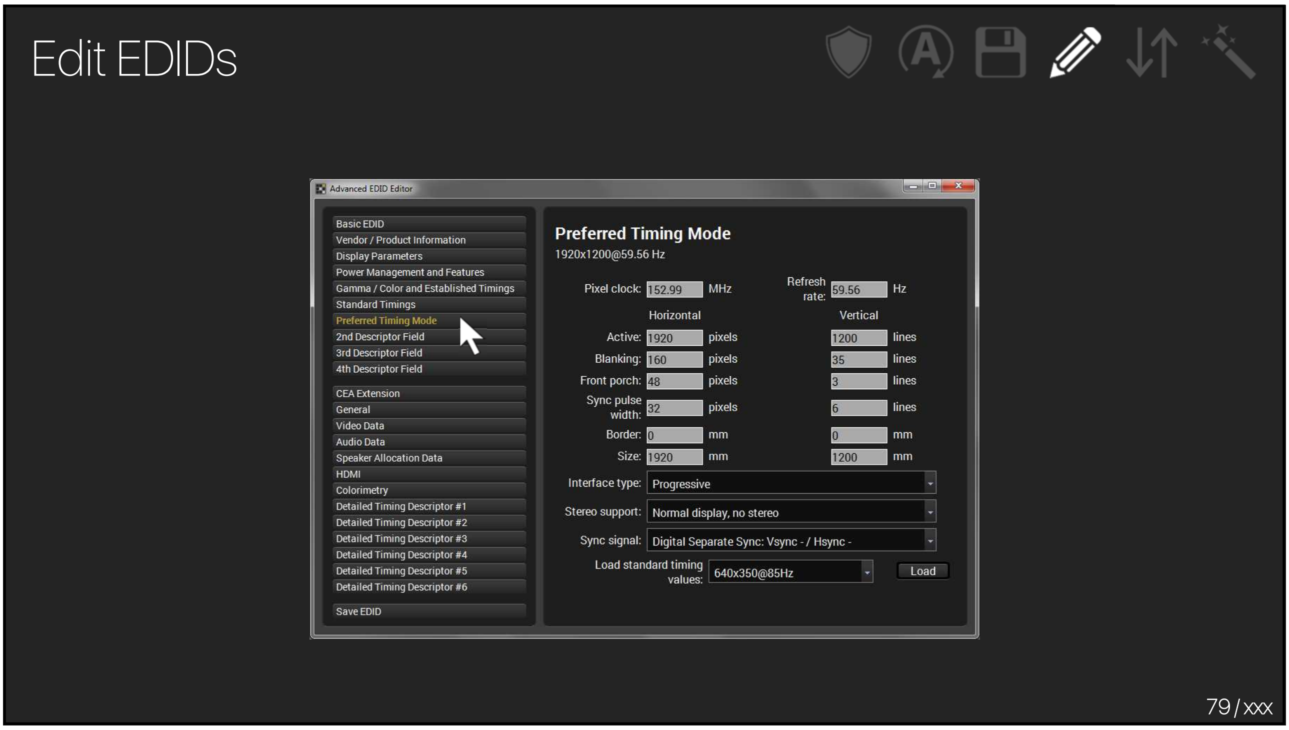
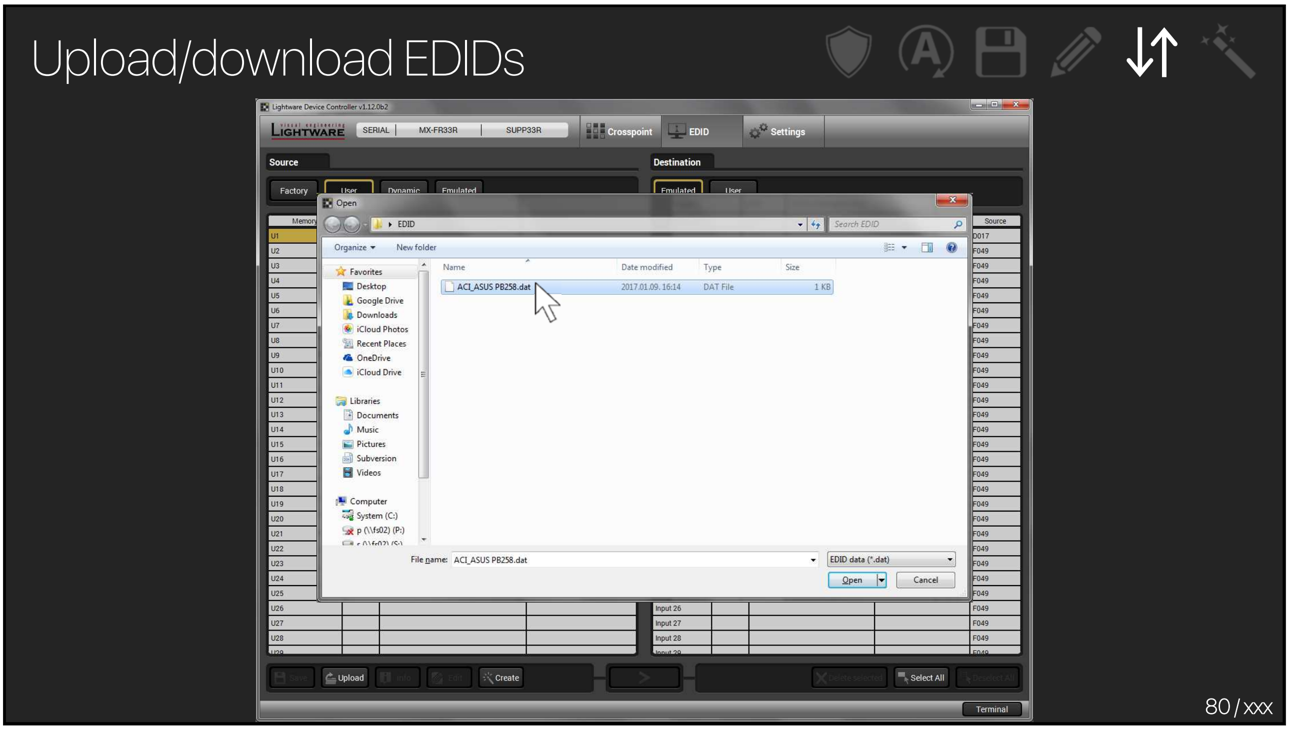
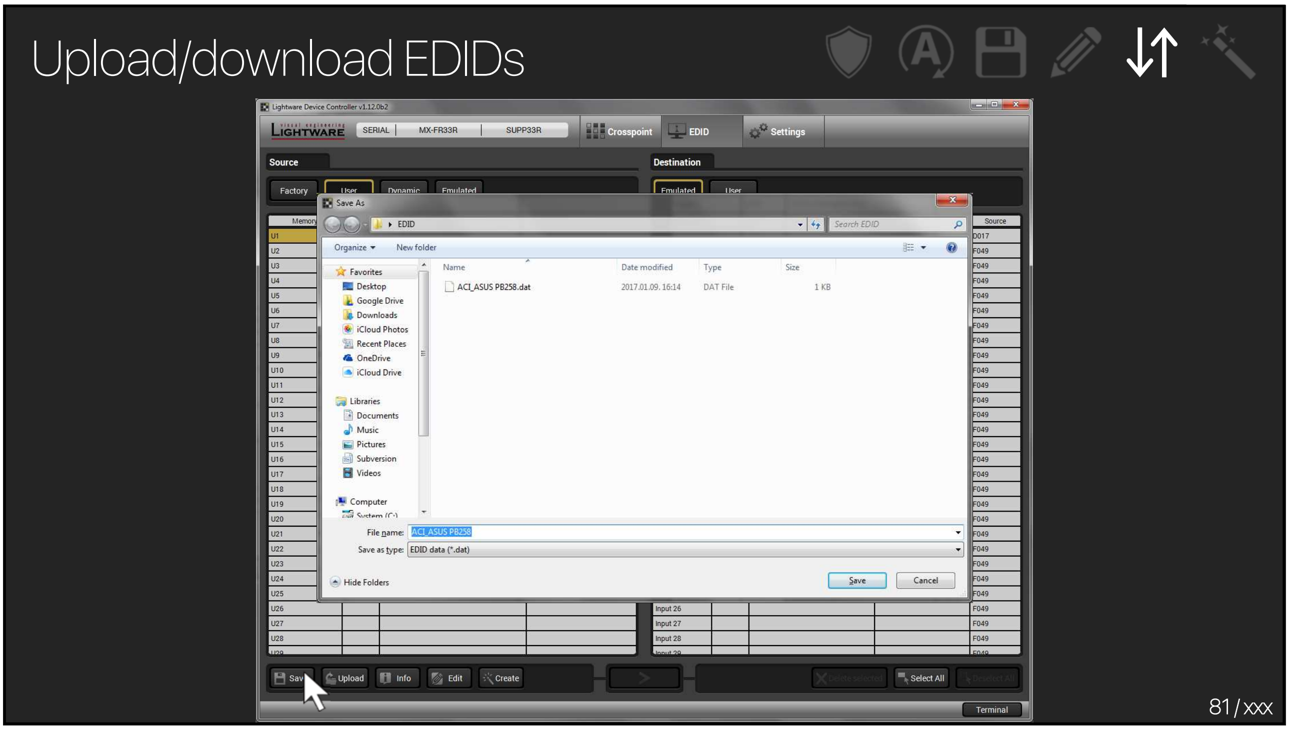

Edit EDIDs
Advanced EDID Editor
Basic EDID
Vendor / Product Information
Display Parameters
Power Management and Features
Gamma / Color and Established Timings
Standard Timings
Preferred Timing Mode
2nd Descriptor Field
3rd Descriptor Field
4th Descriptor Field
CEA Extension
General
Video Data
Audio Data
Speaker Allocation Data
HDMI
Colorimetry
Detailed Timing Descriptor #1
Detailed Timing Descriptor #2
Detailed Timing Descriptor #3
Detailed Timing Descriptor #4
Detailed Timing Descriptor #5
Detailed Timing Descriptor #6
Save EDID
Preferred Timing Mode
1920x1200@59.56 Hz
Pixel clock: 152.99 MHz
Refresh rate: 59.56 Hz
Horizontal
Vertical
Active: 1920 pixels 1200 lines
Blanking: 160 pixels 35 lines
Front porch: 48 pixels 3 lines
Sync pulse width: 32 pixels 6 lines
Border: 0 mm 0 mm
Size: 1920 mm 1200 mm
Interface type: Progressive
Stereo support: Normal display, no stereo
Sync signal: Digital Separate Sync: Vsync - / Hsync -
Load standard timing values: 640x350@85Hz
Load
79 / xxx


Upload/download EDIDs
Lightware Device Controller
SERIAL
MX-FR33R
SUPP33R
Crosspoint
EDID
Settings
Source
Destination
Factory
User
Dynamic
Emulated
Open
EDID
Search EDID
Organize
New folder
Favorites
Desktop
Google Drive
Downloads
iCloud Photos
Recent Places
OneDrive
iCloud Drive
Libraries
Documents
Music
Pictures
Subversion
Videos
Computer
System (C:)
Name
Date modified
Type
Size
ACI_ASUS PB258.dat
2017.01.09. 16:14
DAT File
1 KB
File name: ACI_ASUS PB258.dat
EDID data (*.dat)
Open
Cancel
Upload
Create
Select All
Terminal
80 / xxx


Upload/download EDIDs
Save As
File name: ACI_ASUS PB258
Save as type: EDID data (*.dat)
Save
Cancel
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Create new EDIDs
Easy EDID Creator
Step 1 - Select Resolution
Step 2 - Signal Type
Step 3 - Select Audio
Step 4 - Finish
Back
Next
Select Resolution
Welcome to the Easy EDID Creator!
With this program you are able to create a unique EDID according to your demands by answering three simple questions. Details can be added or changed later if needed.
Please select the preferred resolution, scan mode and frame rate. If you don't find the proper mode in the list, then enter it and the program will estimate the best blanking times.
Preferred resolution:
640x400@85Hz
720x400@85Hz
640x480@60Hz
640x480@72Hz
640x480@75Hz
640x480@85Hz
Timing standard:
VESA CVT-RB (Flat panels)
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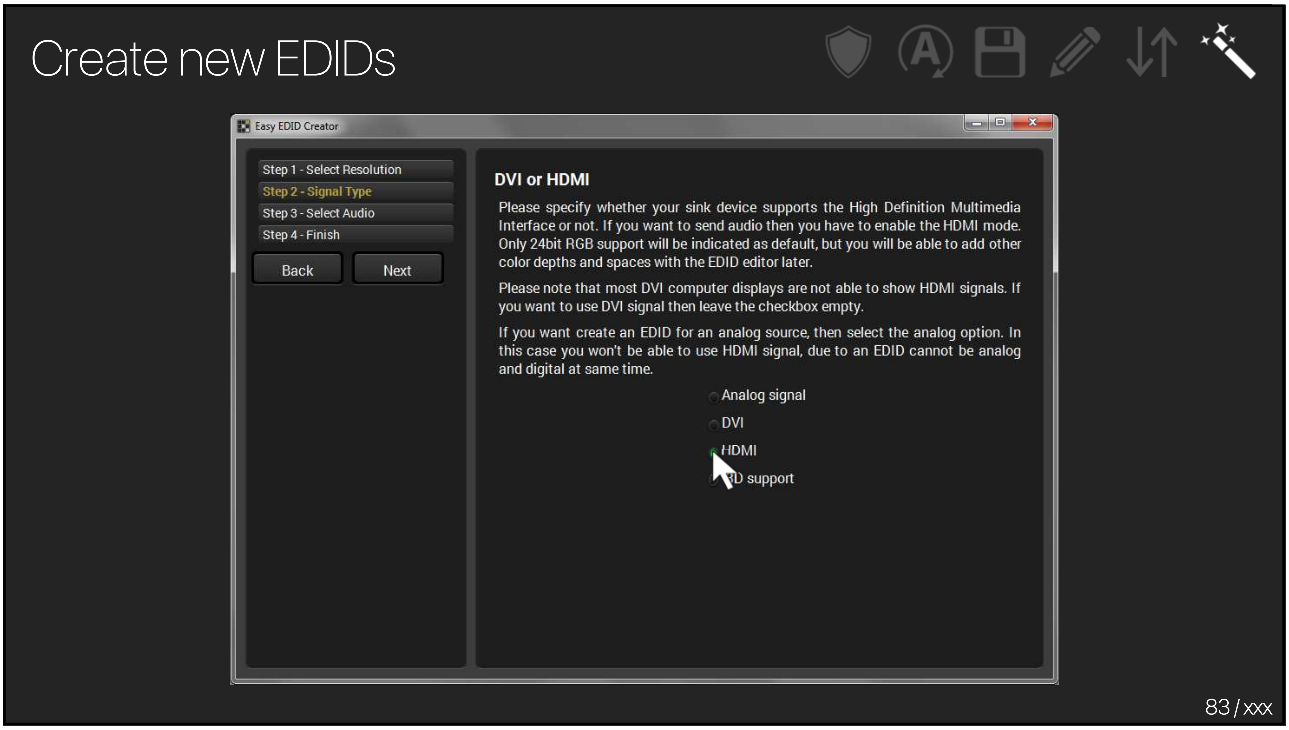
Create new EDIDs
Easy EDID Creator
Step 1 - Select Resolution
Step 2 - Signal Type
Step 3 - Select Audio
Step 4 - Finish
Back
Next
DVI or HDMI
Please specify whether your sink device supports the High Definition Multimedia Interface or not. If you want to send audio then you have to enable the HDMI mode. Only 24bit RGB support will be indicated as default, but you will be able to add other color depths and spaces with the EDID editor later.
Please note that most DVI computer displays are not able to show HDMI signals. If you want to use DVI signal then leave the checkbox empty.
If you want create an EDID for an analog source, then select the analog option. In this case you won't be able to use HDMI signal, due to an EDID cannot be analog and digital at same time.
Analog signal
DVI
HDMI
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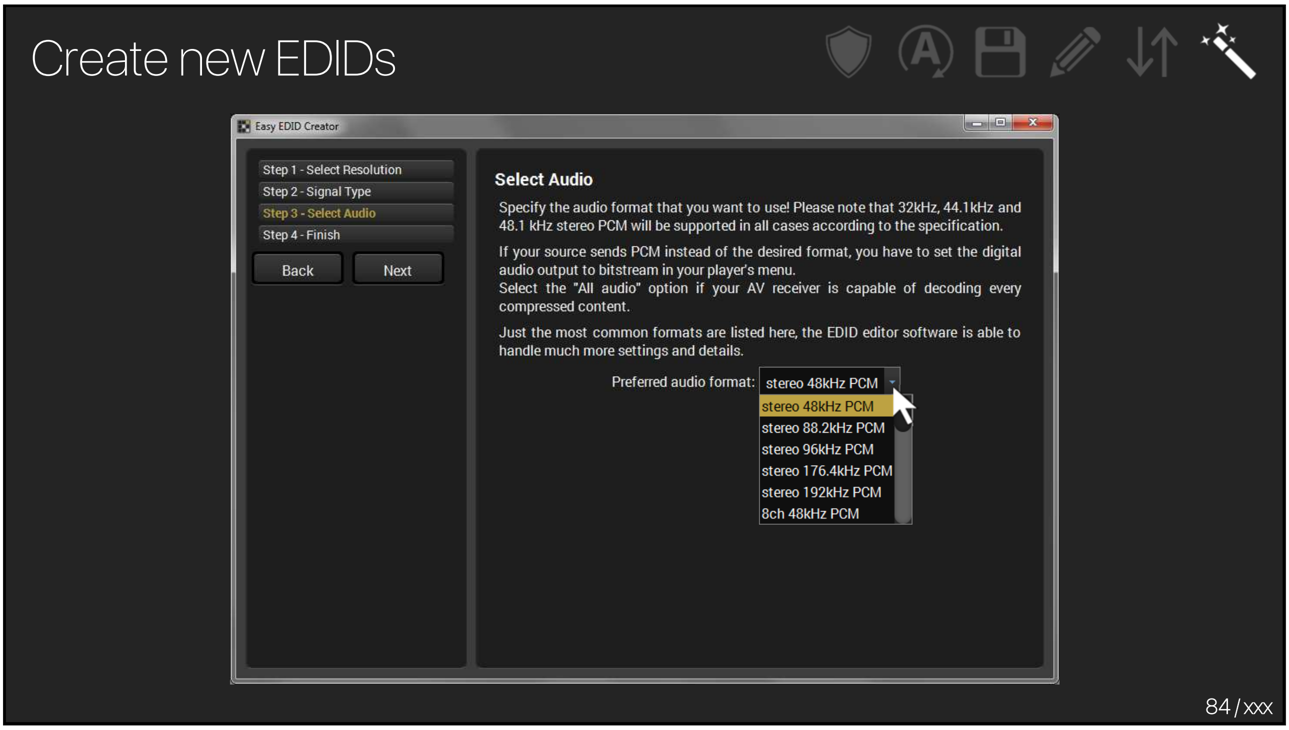
Create new EDIDs
Easy EDID Creator
Step 1 - Select Resolution
Step 2 - Signal Type
Step 3 - Select Audio
Step 4 - Finish
Back
Next
Select Audio
Specify the audio format that you want to use! Please note that 32kHz, 44.1kHz and 48.1 kHz stereo PCM will be supported in all cases according to the specification.
If your source sends PCM instead of the desired format, you have to set the digital audio output to bitstream in your player's menu.
Select the "All audio" option if your AV receiver is capable of decoding every compressed content.
Just the most common formats are listed here, the EDID editor software is able to handle much more settings and details.
Preferred audio format:
stereo 48kHz PCM
stereo 48kHz PCM
stereo 88.2kHz PCM
stereo 96kHz PCM
stereo 176.4kHz PCM
stereo 192kHz PCM
8ch 48kHz PCM
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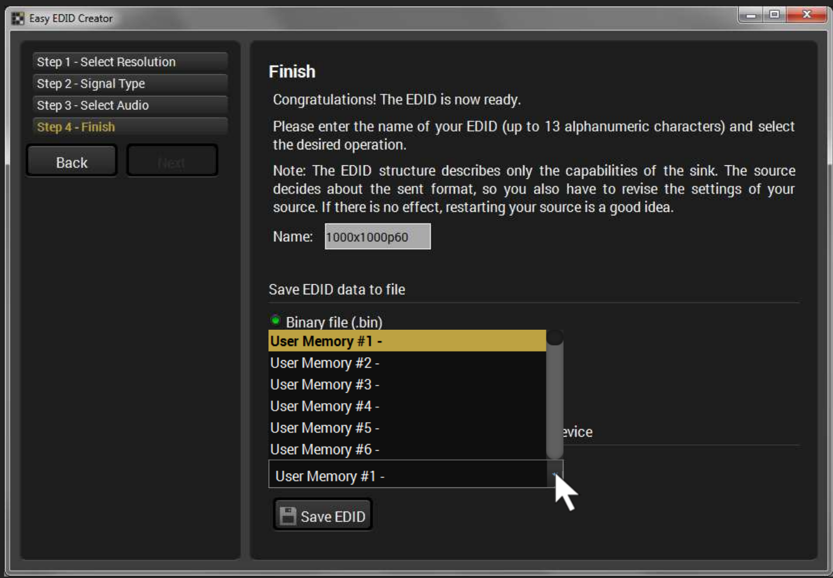
Create new EDIDs



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Advanced EDID Management

Static EDID emulation
- From Factory Preset or User programmable memory.

Dynamic EDID emulation
- Copy EDIDs from any display to any input. The emulated EDID changes if the display is replaced.

EDID storing
- Store EDID from any display.

EDID editing functions
- Edit EDIDs with the Advanced EDID Editor.

EDID transfer into/from the router
- Upload/download EDID files through any of the control ports.

Custom EDID creation
- Custom EDID creation with Lightware Easy EDID Creator.

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HDMI

High Definition Multimedia Interface

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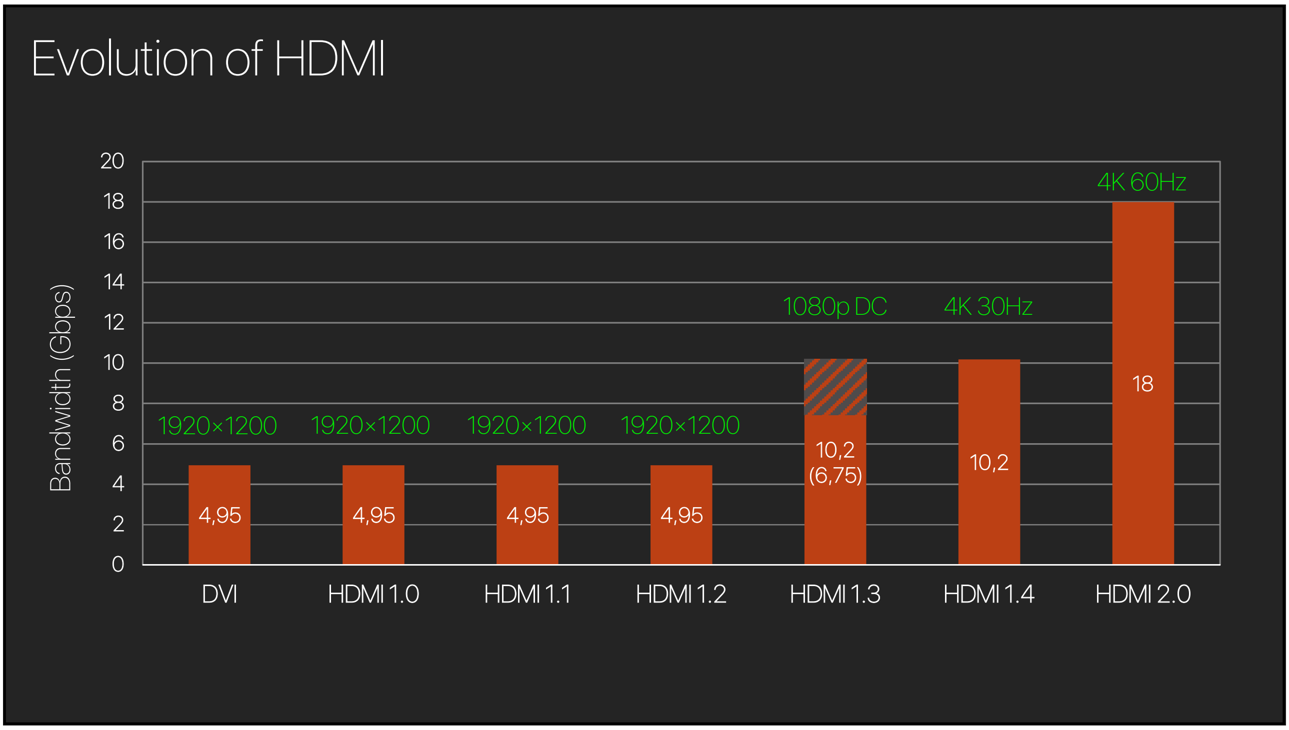
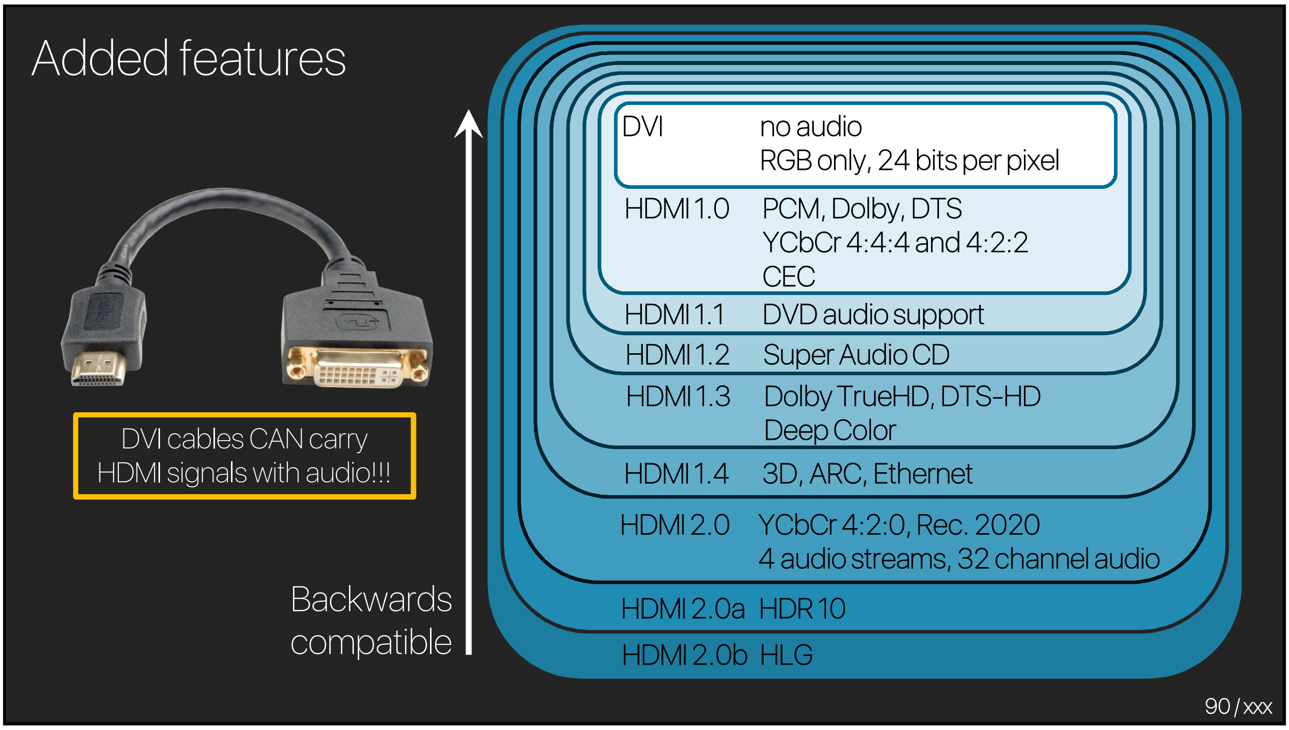
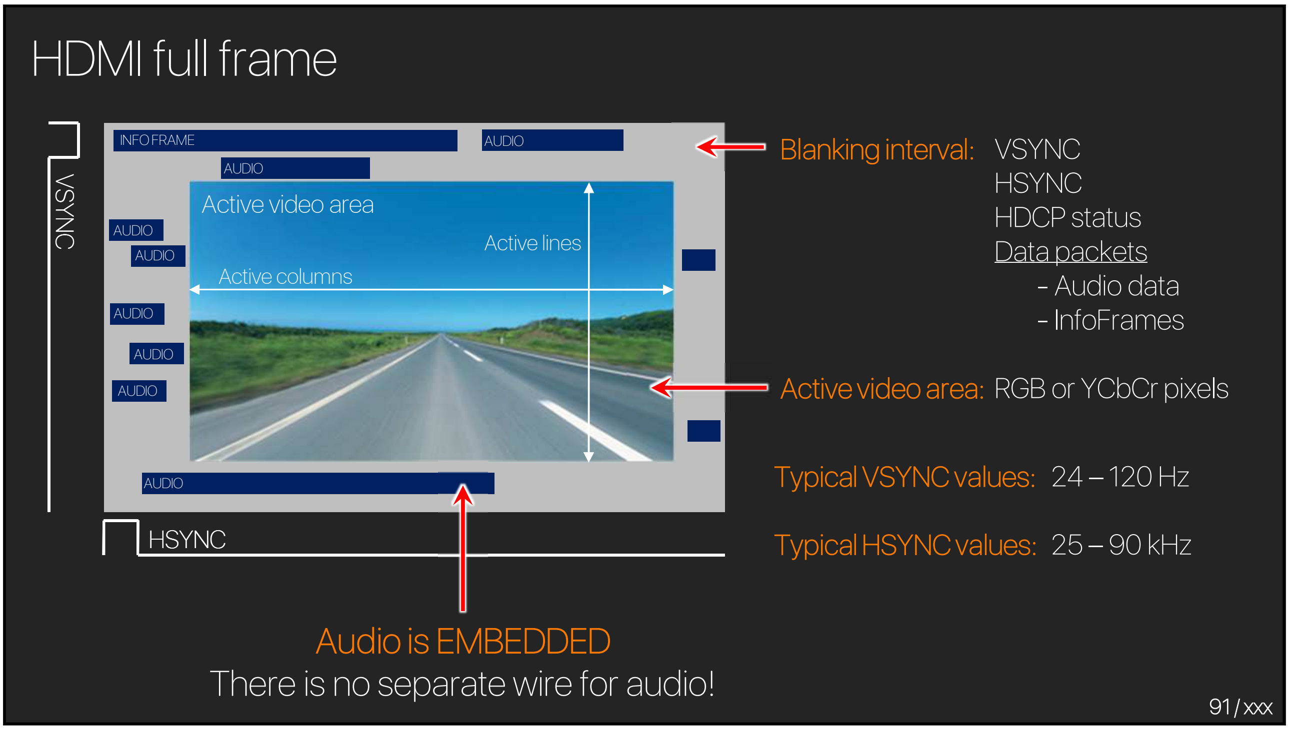
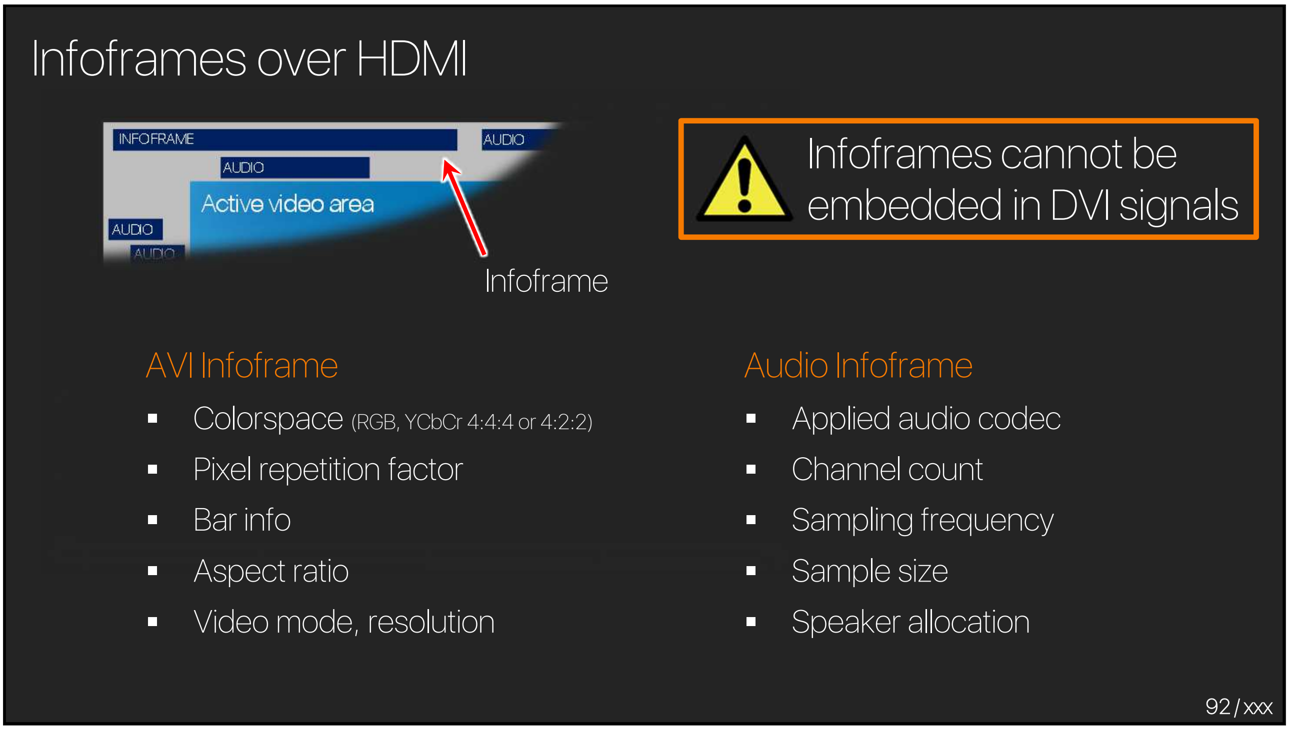
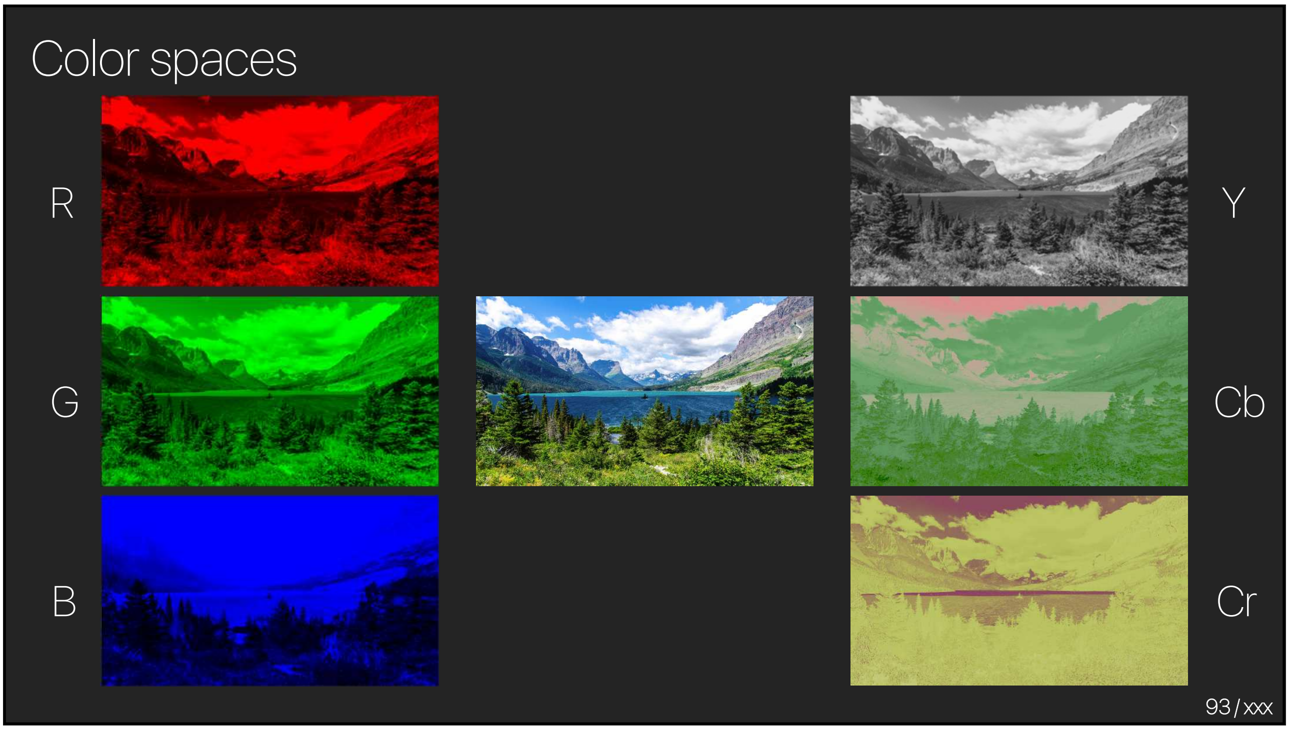
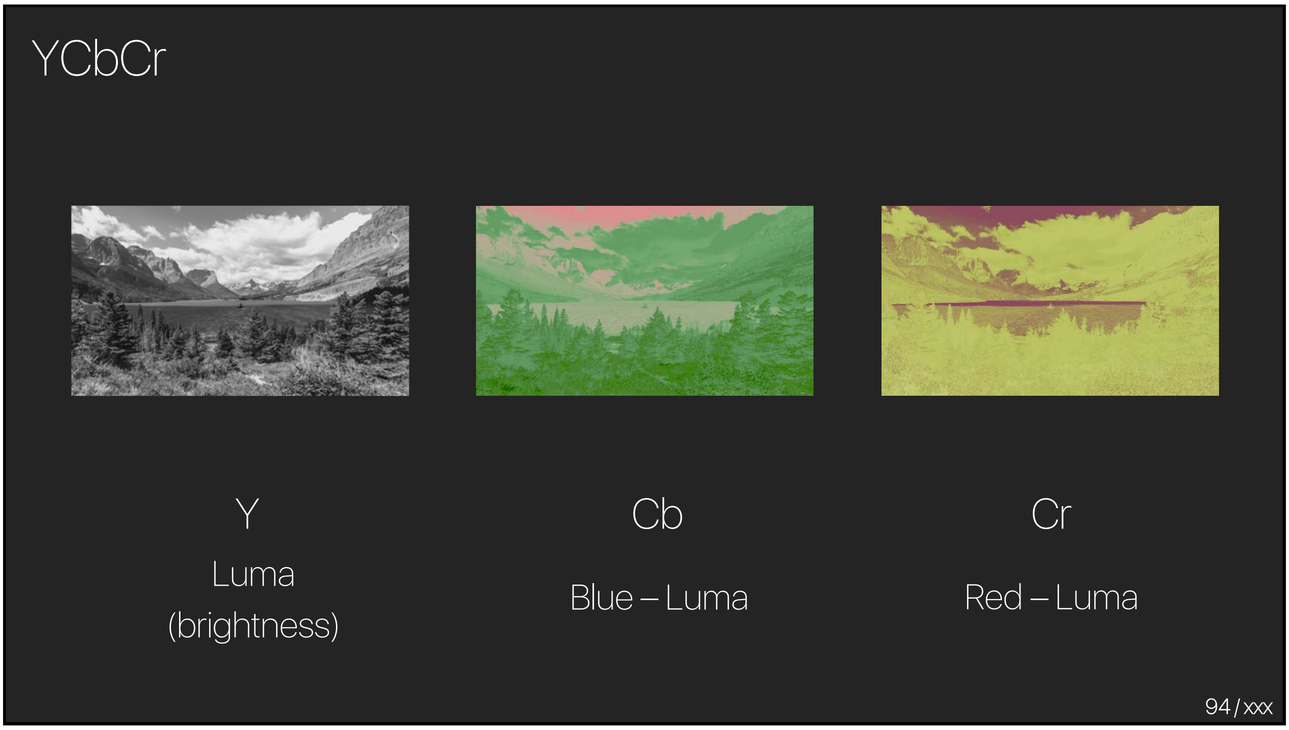

Evolution of HDMI
Bandwidth (Gbps)
20
18
16
14
12
10
8
6
4
2
0
1920×1200
1920×1200
1920×1200
1920×1200
1080p DC
4K 30Hz
4K 60Hz
4,95
4,95
4,95
4,95
10,2
(6,75)
10,2
18
DVI
HDMI 1.0
HDMI 1.1
HDMI 1.2
HDMI 1.3
HDMI 1.4
HDMI 2.0

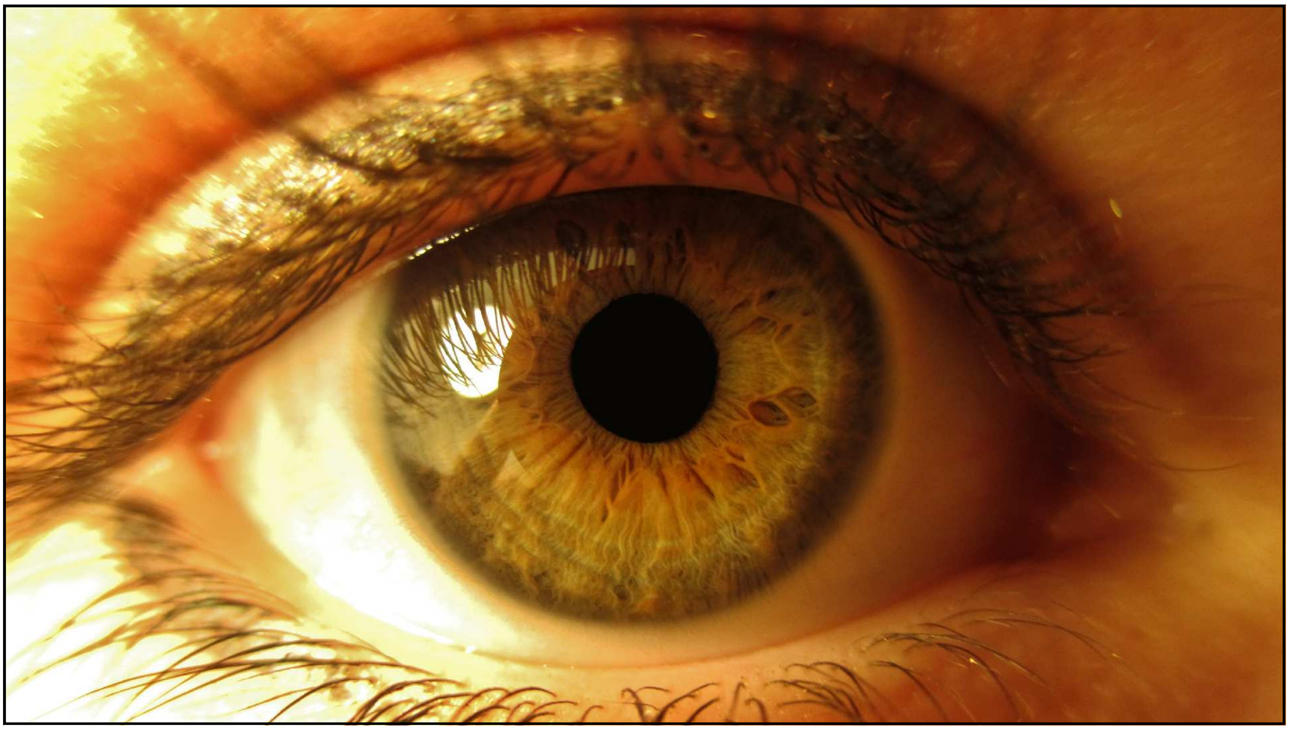

Added features
DVI cables CAN carry
HDMI signals with audio!!!
Backwards
compatible
DVI no audio
RGB only, 24 bits per pixel
HDMI 1.0 PCM, Dolby, DTS
YCbCr 4:4:4 and 4:2:2
CEC
HDMI 1.1 DVD audio support
HDMI 1.2 Super Audio CD
HDMI 1.3 Dolby TrueHD, DTS-HD
Deep Color
HDMI 1.4 3D, ARC, Ethernet
HDMI 2.0 YCbCr 4:2:0, Rec. 2020
4 audio streams, 32 channel audio
HDMI 2.0a HDR 10
HDMI 2.0b HLG
90 / xxx

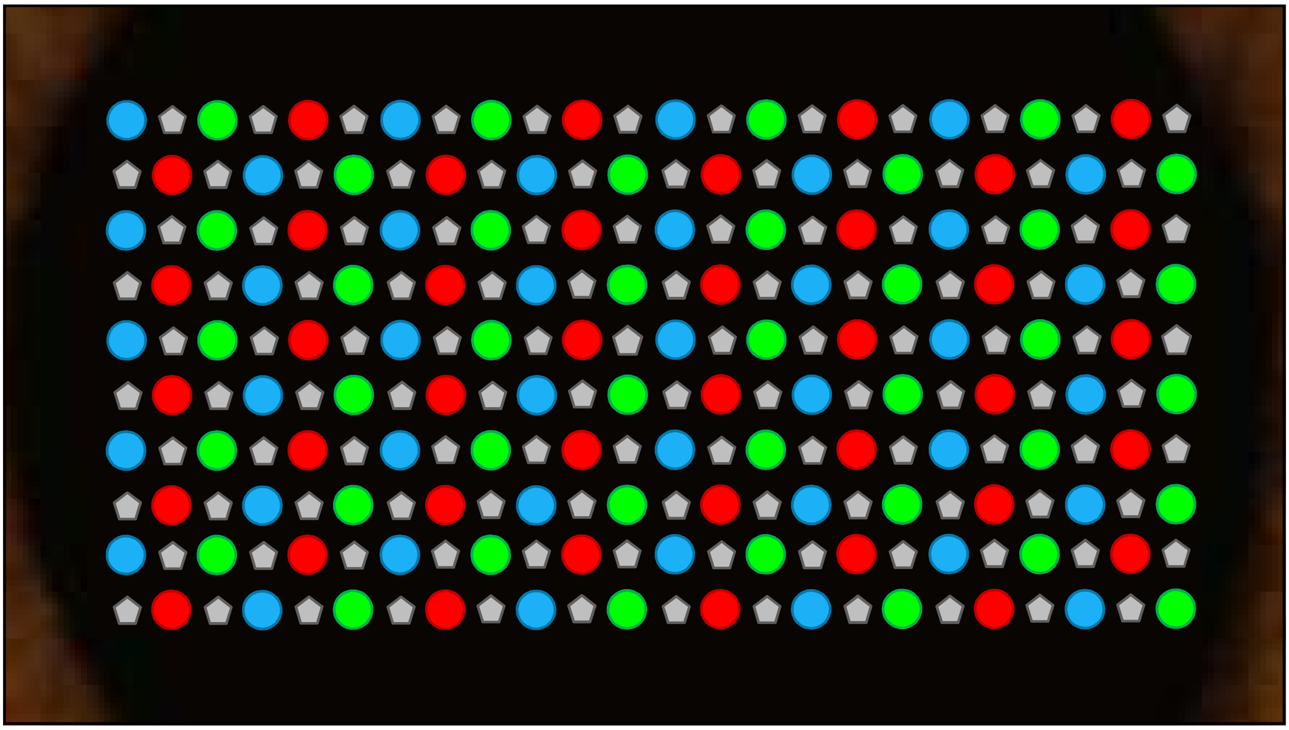

HDMI full frame
INFO FRAME
AUDIO
AUDIO
VSYNC
Active video area
Active lines
Active columns
AUDIO
AUDIO
AUDIO
AUDIO
AUDIO
AUDIO
HSYNC
Blanking interval: VSYNC
HSYNC
HDCP status
Data packets
- Audio data
- InfoFrames
Active video area: RGB or YCbCr pixels
Typical VSYNC values: 24 – 120 Hz
Typical HSYNC values: 25 – 90 kHz
Audio is EMBEDDED
There is no separate wire for audio!
91 / xxx


Infoframes over HDMI
INFOFRAME
AUDIO
AUDIO
Active video area
AUDIO
Infoframe
Infoframes cannot be embedded in DVI signals
AVI Infoframe
Colorspace (RGB, YCbCr 4:4:4 or 4:2:2)
Pixel repetition factor
Bar info
Aspect ratio
Video mode, resolution
Audio Infoframe
Applied audio codec
Channel count
Sampling frequency
Sample size
Speaker allocation
92 / xxx

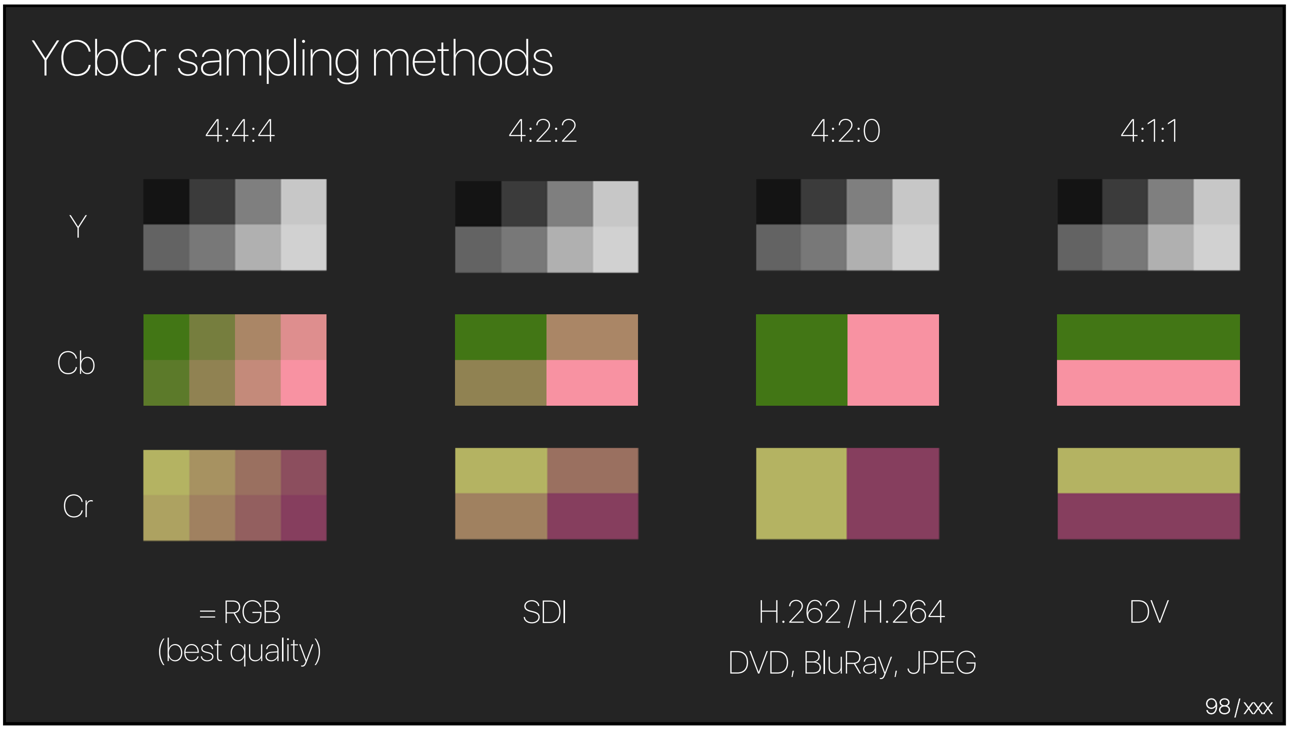

Color spaces
R
G
B
Y
Cb
Cr
93 / xxx

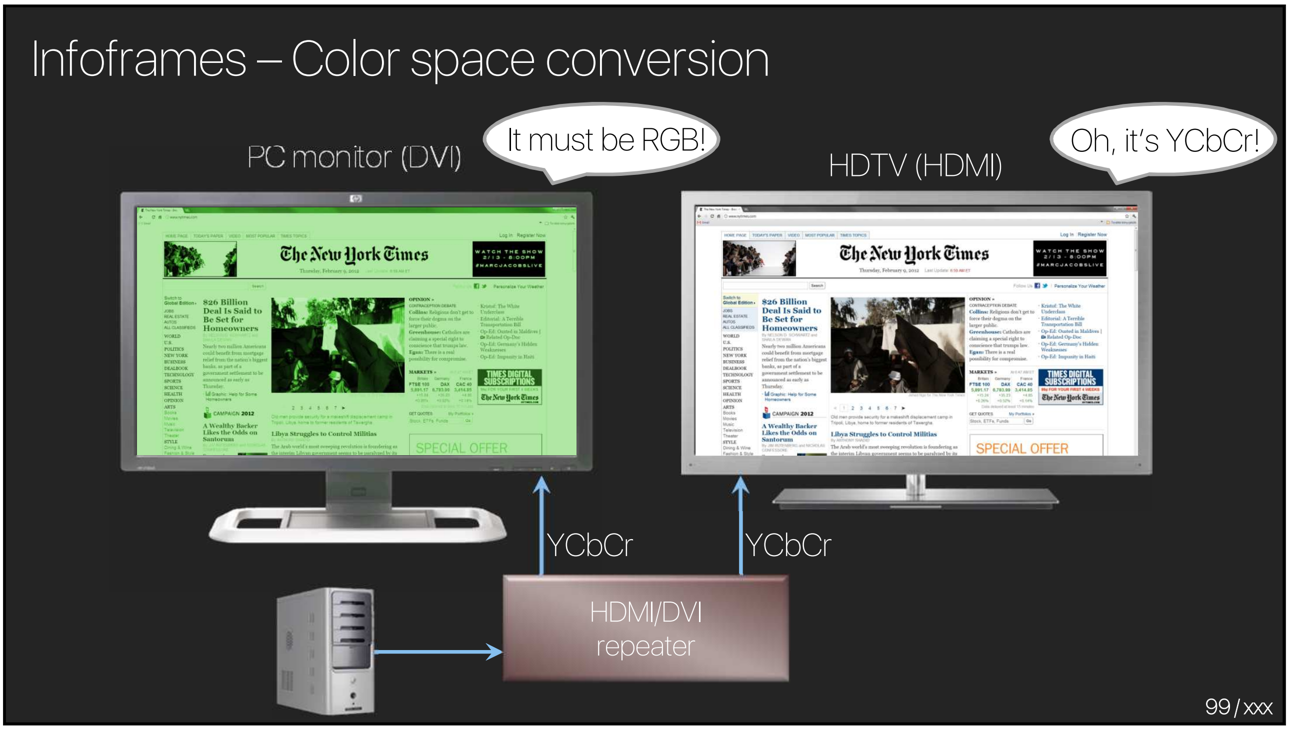

YCbCr
Y
Luma
(brightness)
Cb
Blue – Luma
Cr
Red – Luma
94 / xxx



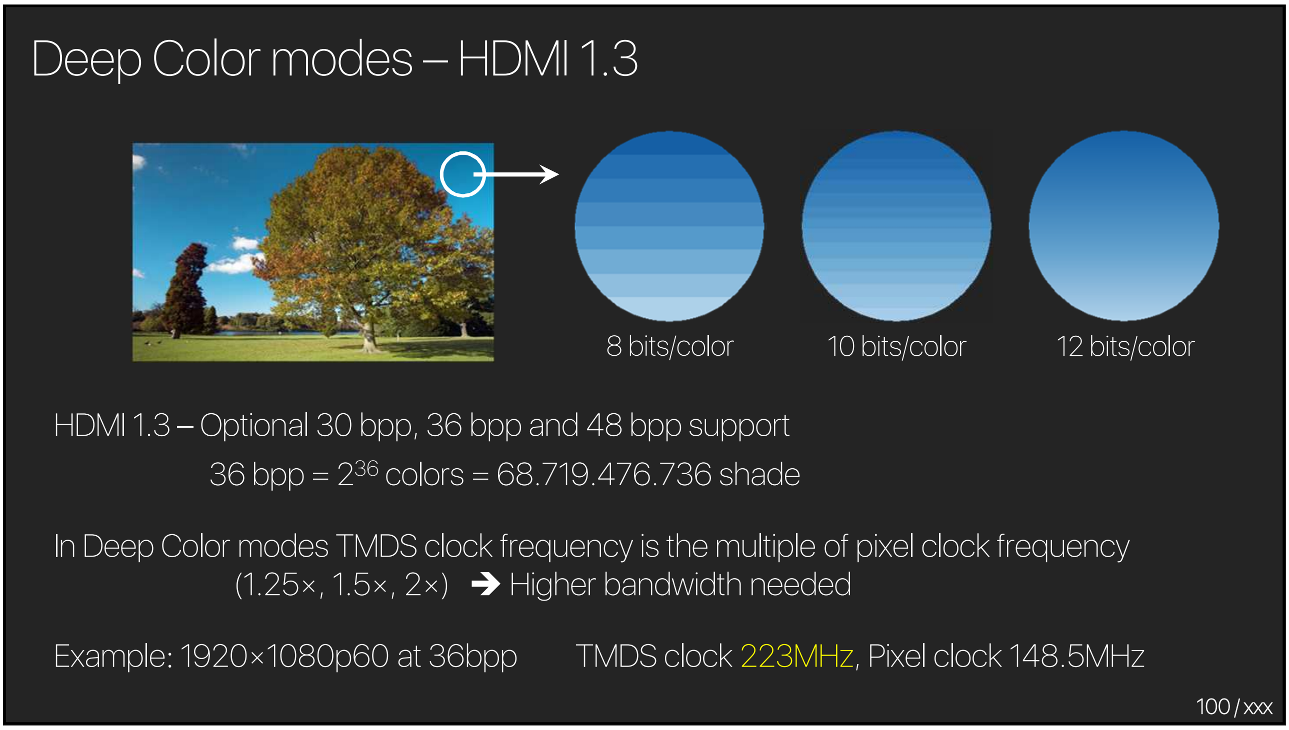



What color is
the bedsheet?


YCbCr sampling methods
4:4:4
4:2:2
4:2:0
4:1:1
Y
Cb
Cr
= RGB
(best quality)
SDI
H.262 / H.264
DVD, BluRay, JPEG
DV
98 / xxx



Infoframes – Color space conversion
PC monitor (DVI)
It must be RGB!
HDTV (HDMI)
Oh, it's YCbCr!
YCbCr
YCbCr
HDMI/DVI repeater
99 / xxx



Deep Color modes – HDMI 1.3
8 bits/color
10 bits/color
12 bits/color
HDMI 1.3 – Optional 30 bpp, 36 bpp and 48 bpp support
36 bpp = 2^{36} colors = 68.719.476.736 shade
In Deep Color modes TMDS clock frequency is the multiple of pixel clock frequency
(1.25×, 1.5×, 2×) ➔ Higher bandwidth needed
Example: 1920×1080p60 at 36bpp
TMDS clock 223MHz, Pixel clock 148.5MHz
100 / xxx

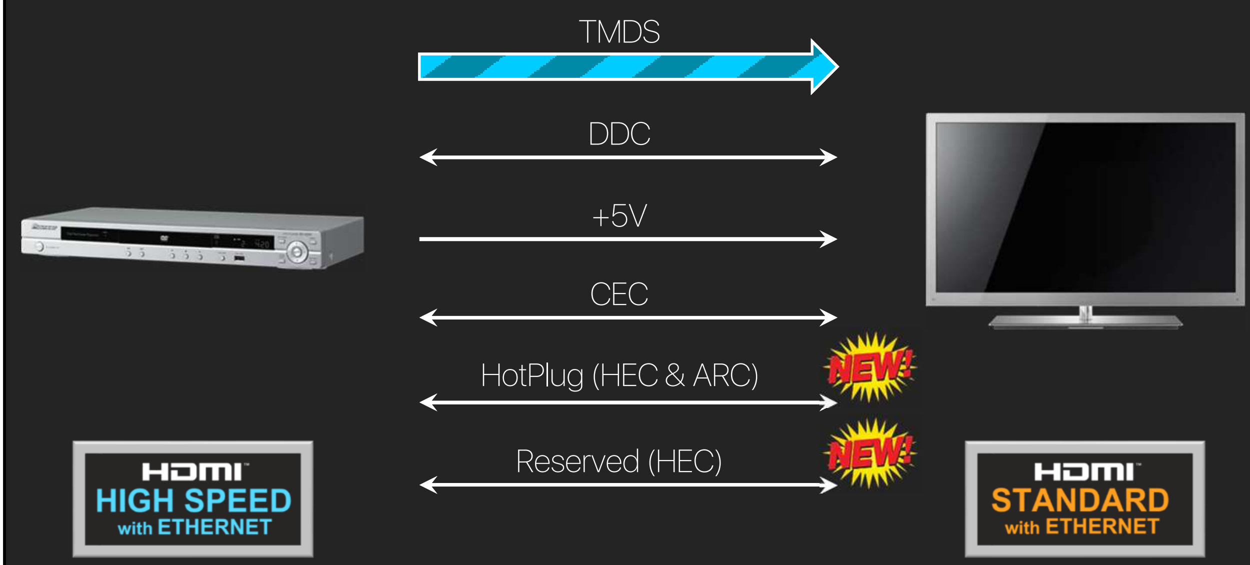
HDMI 1.4

- 10.2 Gbps bandwidth
- 4K resolution support (30 Hz 4:4:4)
- HDMI Ethernet Channel (HEC)
- Audio Return Channel (ARC)
- 3D support

101 / xxx

HDMI 1.4

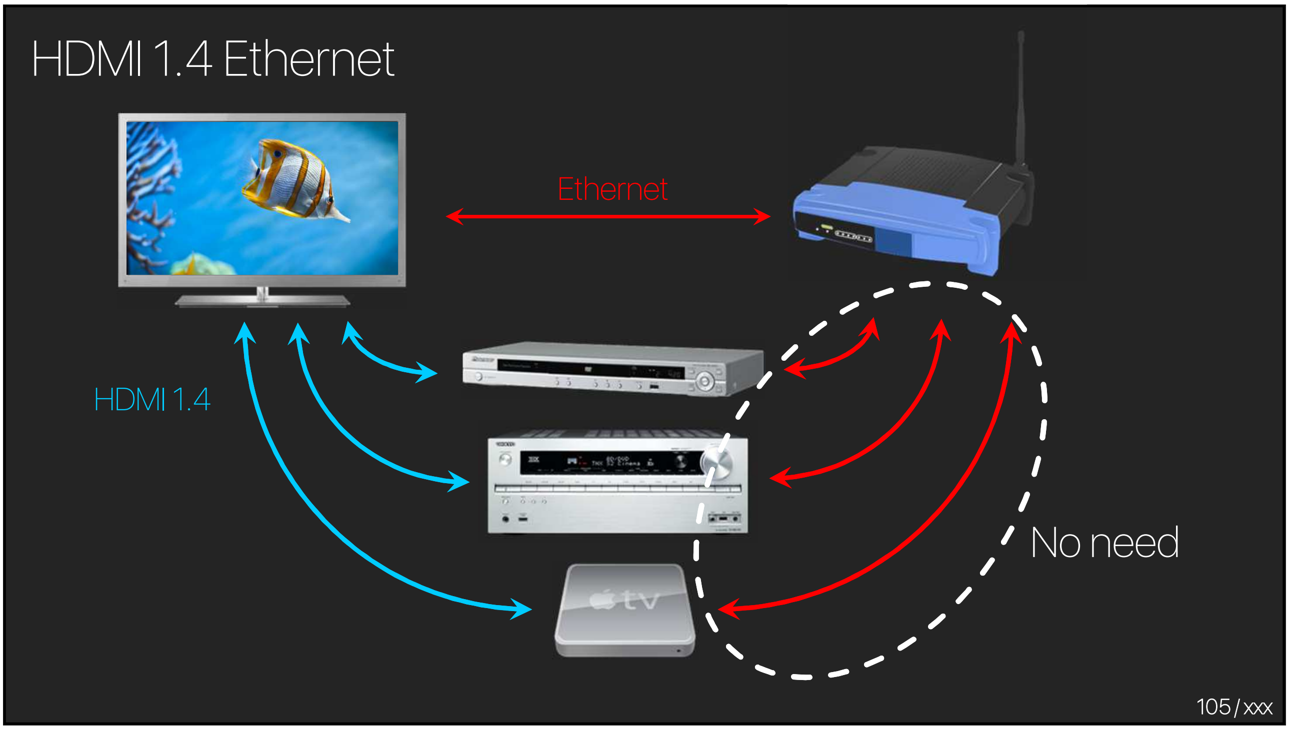
HEC: HDMI Ethernet Channel
ARC: Audio Return Channel



102 / xxx


HDMI 1.4 Audio Return Channel
Video
Audio
HDMI (embedded audio)
5.1 audio
2.0 audio
HDMI 1.3 scenario
103 / xxx

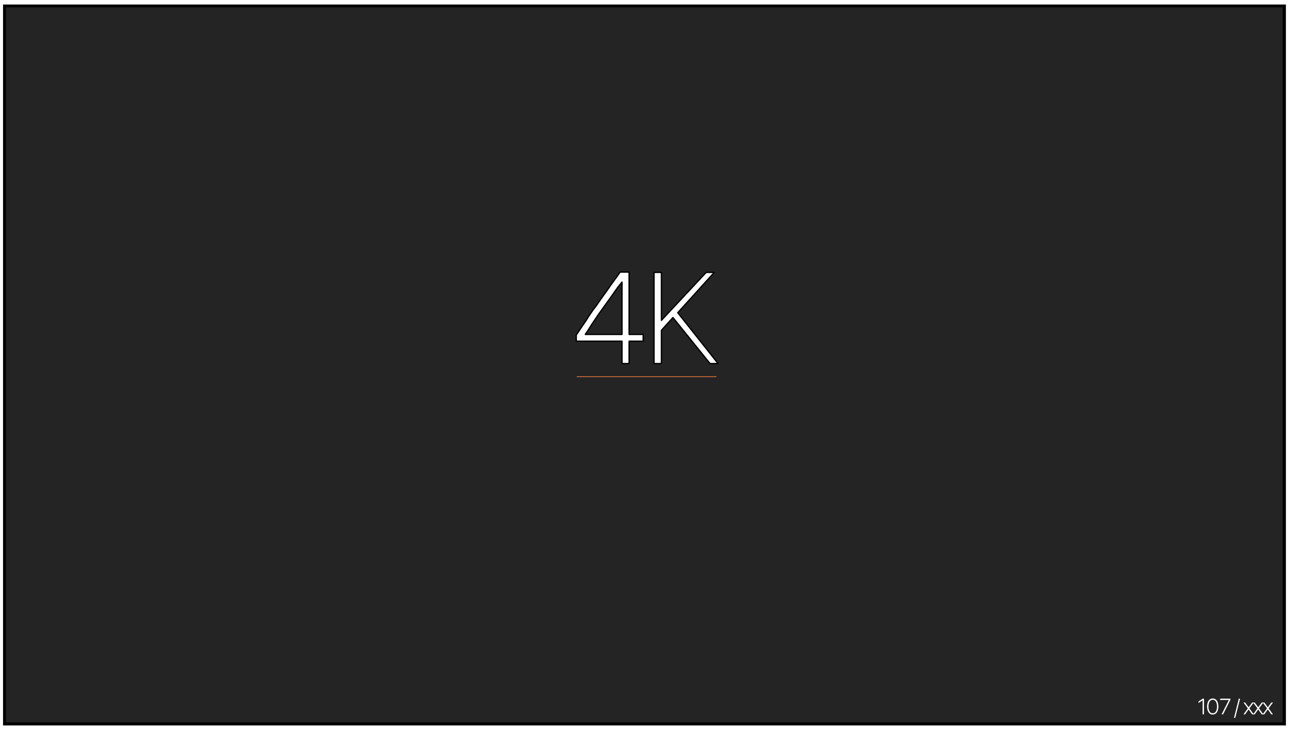

HDMI 1.4 Audio Return Channel
Video
Audio
HDMI (embedded audio)
5.1 audio
2.0 audio
HDMI 1.4 with ARC
104 / xxx

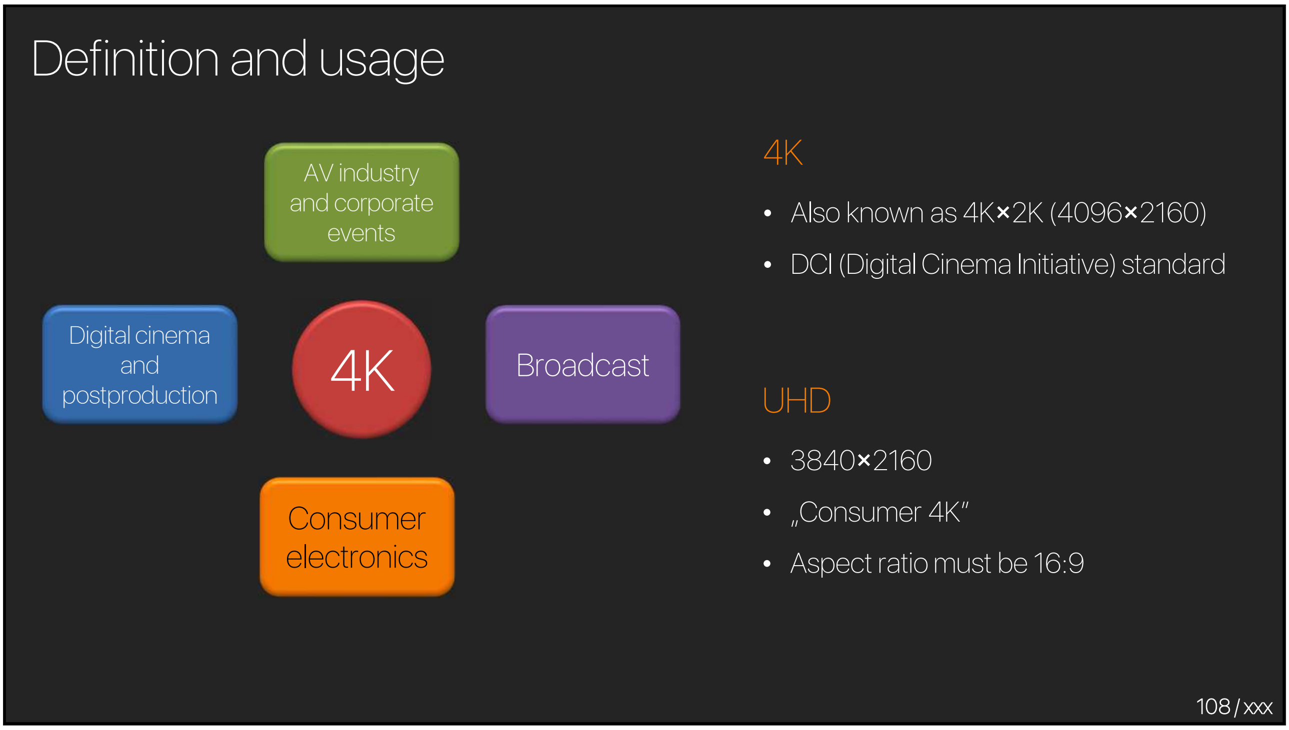


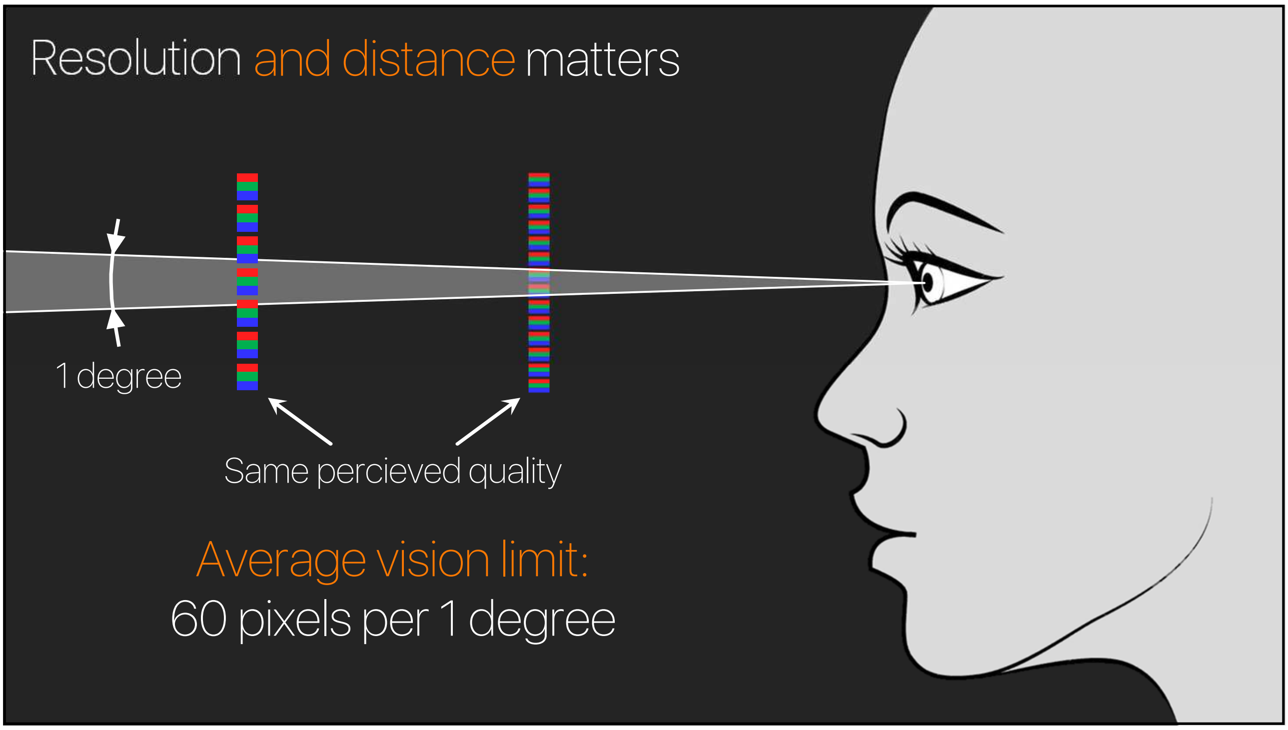
HDMI 2.0 – The newest standard

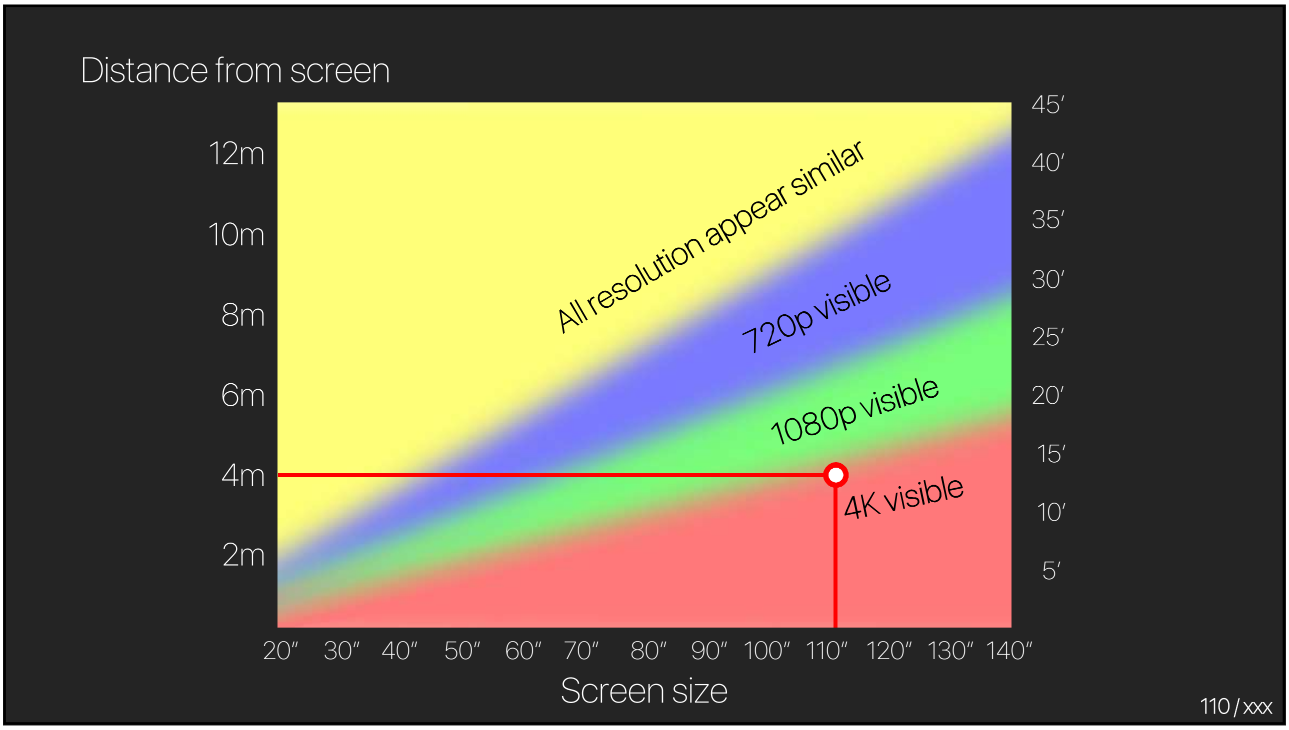
- 18 Gbps bandwidth
- True 4K @ 60Hz 4:4:4 support
- YCbCr 4:2:0
- Rec. 2020 color space
- 32-channel audio
- 4 audio streams, 2 video streams
- 21:9 aspect ratio

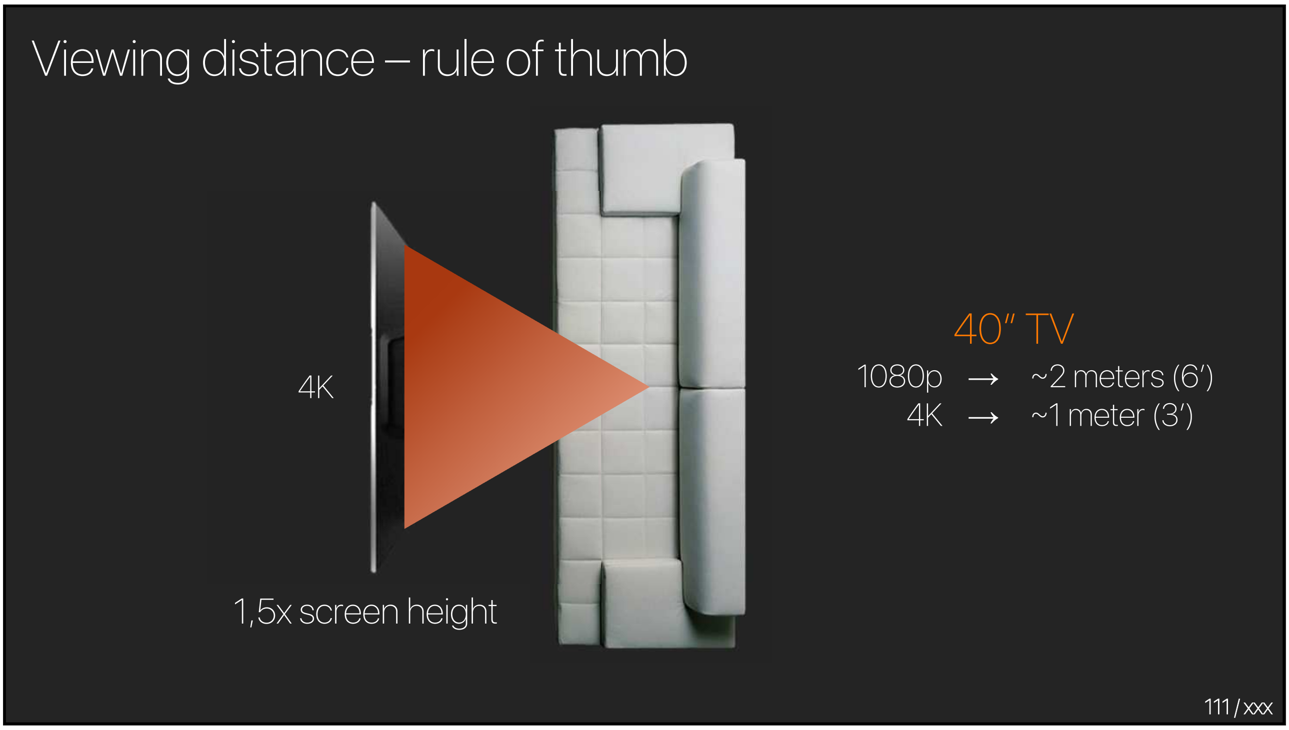
106 / xxx

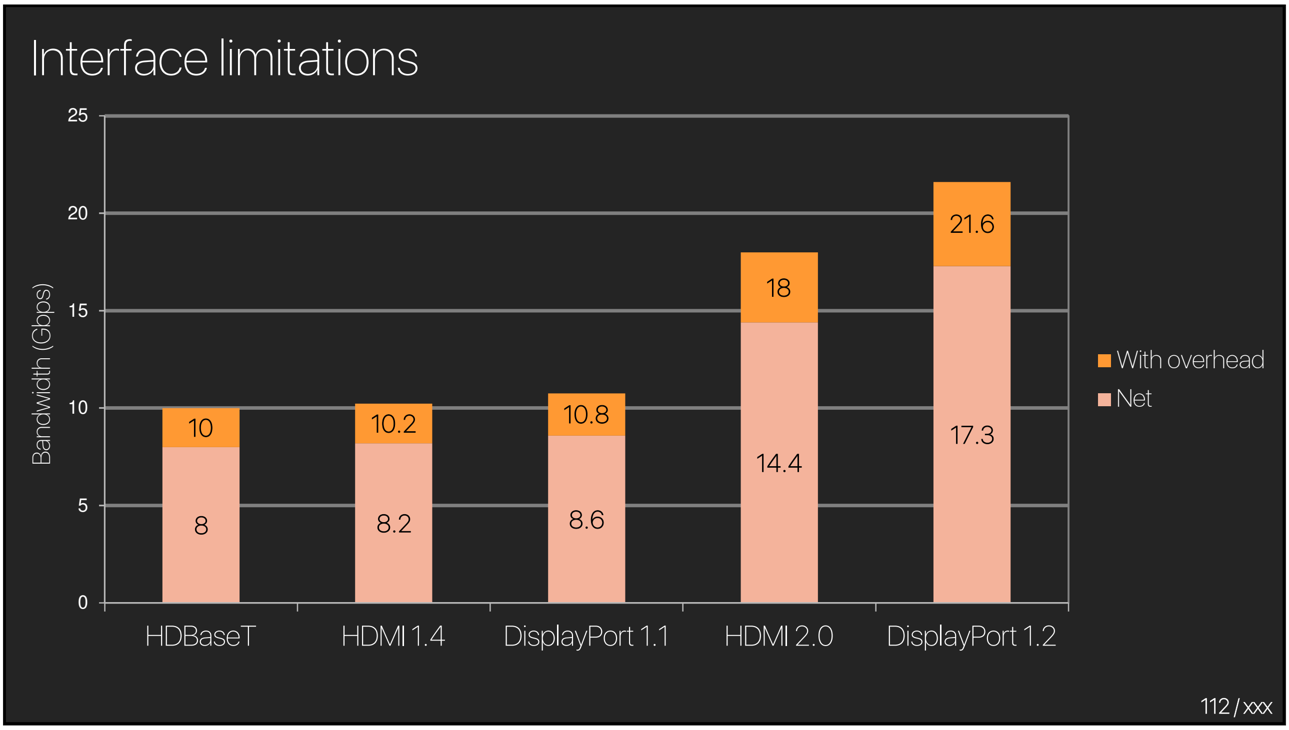

4K
107 / xxx

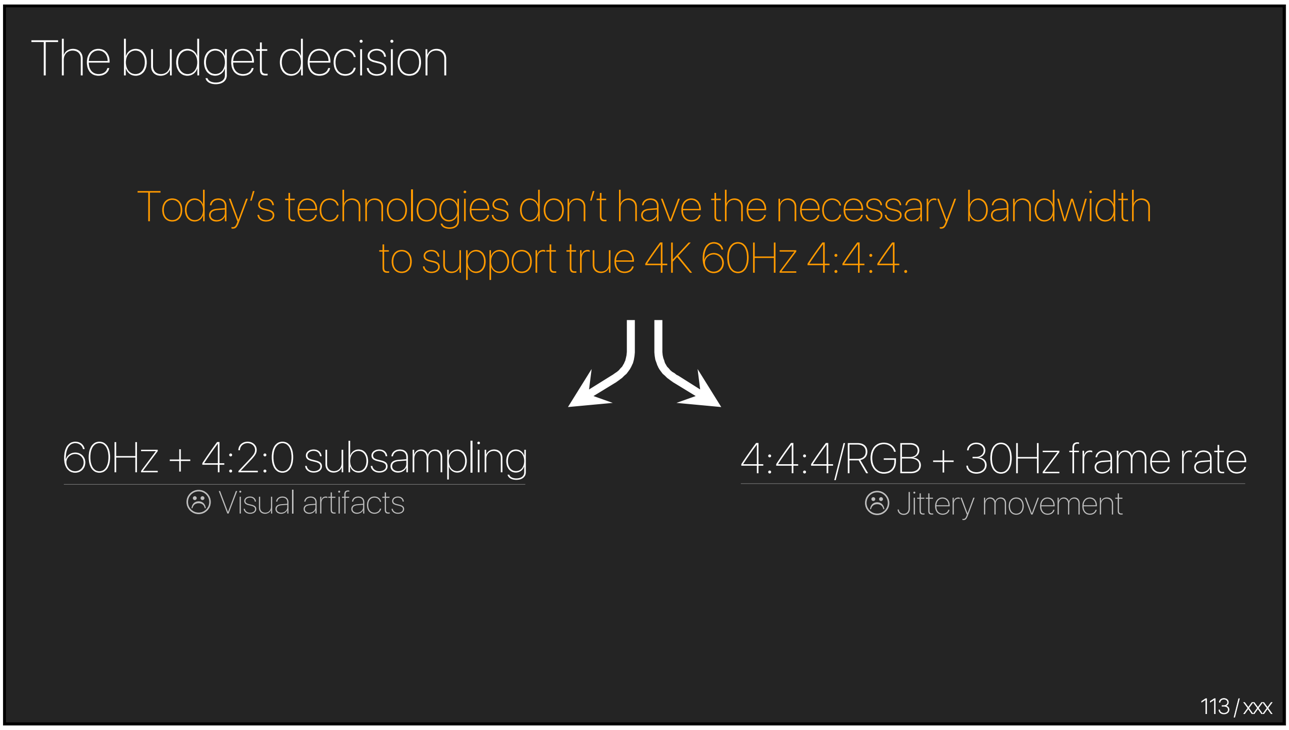

Definition and usage
AV industry and corporate events
Digital cinema and postproduction
4K
Broadcast
Consumer electronics
4K
• Also known as 4K×2K (4096×2160)
• DCI (Digital Cinema Initiative) standard
UHD
• 3840×2160
• „Consumer 4K"
• Aspect ratio must be 16:9
108 / xxx

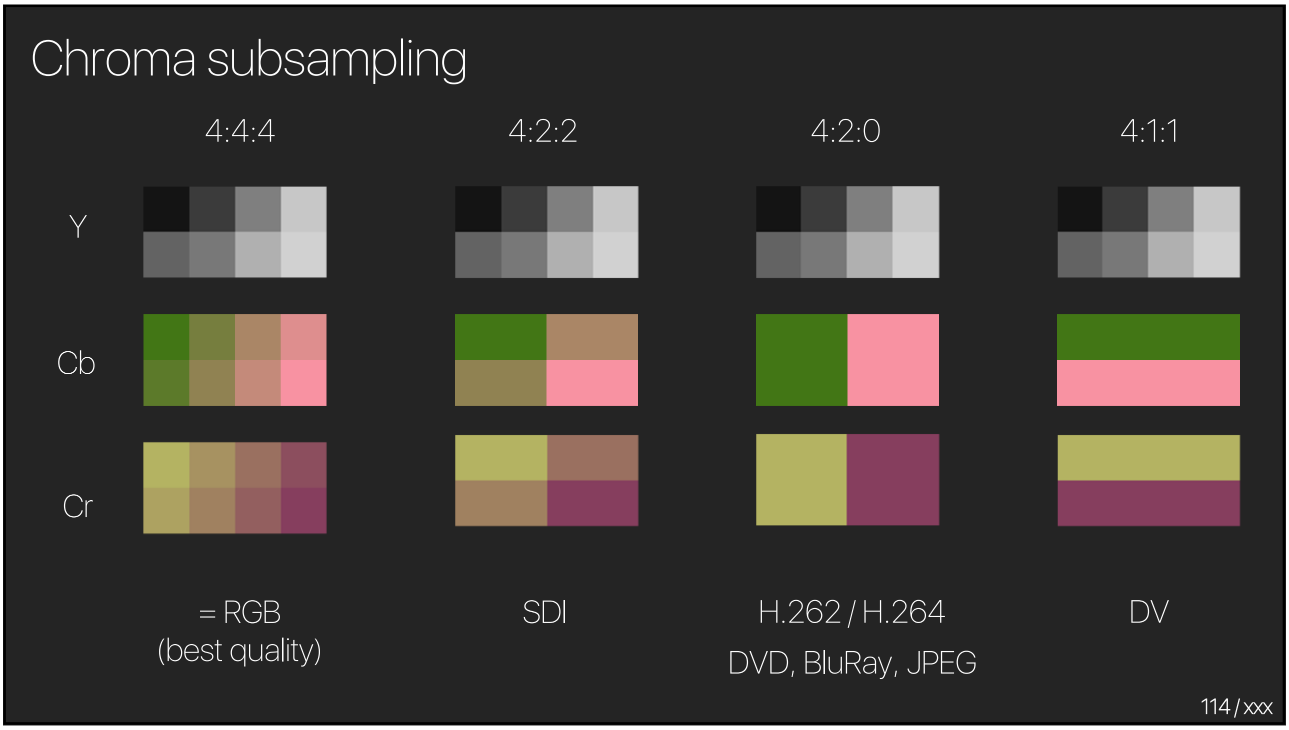

Resolution and distance matters
1 degree
Same percieved quality
Average vision limit:
60 pixels per 1 degree

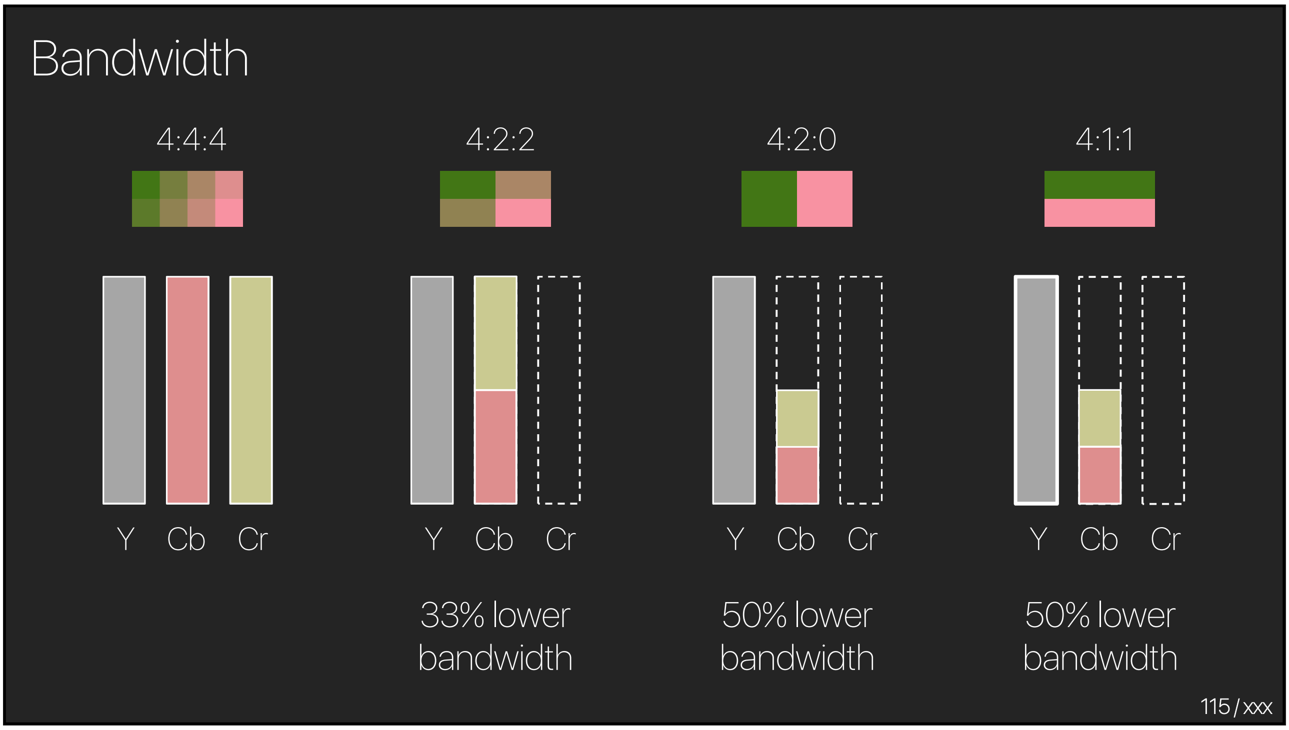

Distance from screen
12m
10m
8m
6m
4m
2m
45′
40′
35′
30′
25′
20′
15′
10′
5′
All resolution appear similar
720p visible
1080p visible
4K visible
20″ 30″ 40″ 50″ 60″ 70″ 80″ 90″ 100″ 110″ 120″ 130″ 140″
Screen size
110 / xxx

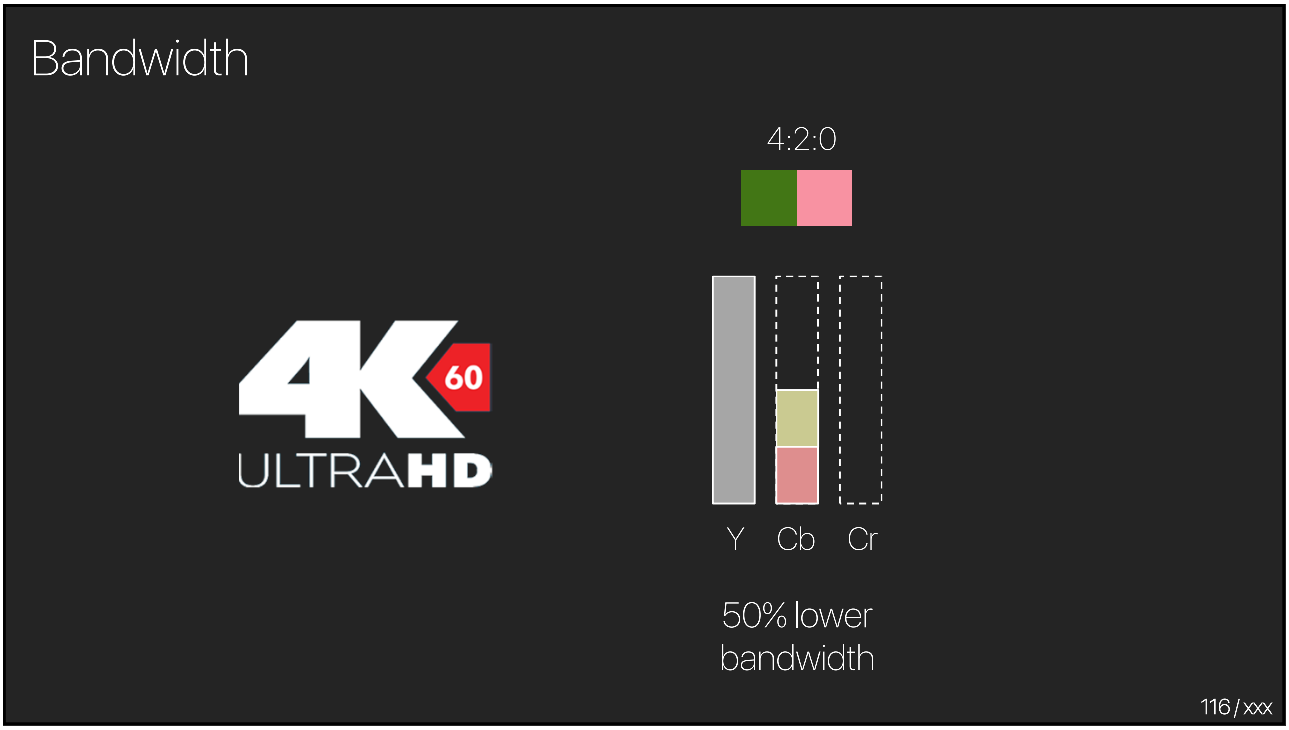

Viewing distance – rule of thumb
4K
1,5x screen height
40" TV
1080p → ~2 meters (6')
4K → ~1 meter (3')
111 / xxx

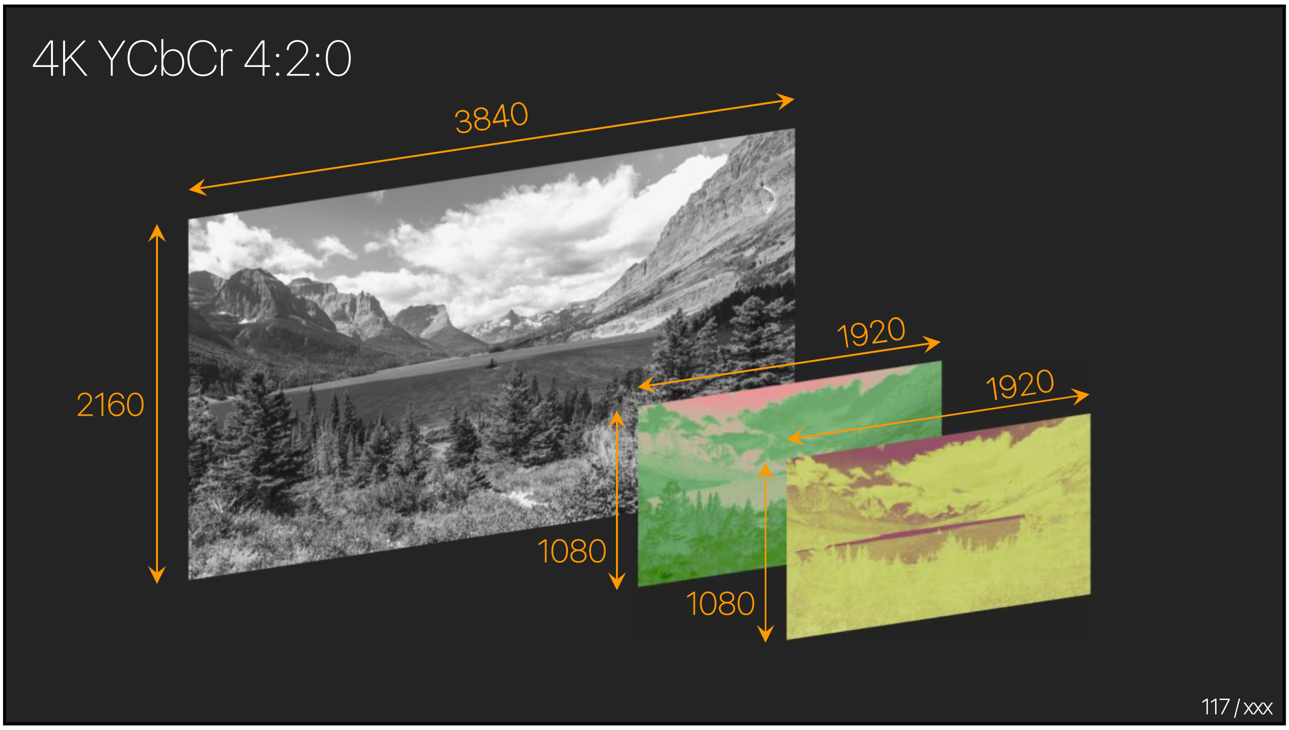

Interface limitations
Bandwidth (Gbps)
25
20
15
10
5
0
HDBaseT
HDMI 1.4
DisplayPort 1.1
HDMI 2.0
DisplayPort 1.2
10
8
10.2
8.2
10.8
8.6
18
14.4
21.6
17.3
With overhead
Net
112 / xxx

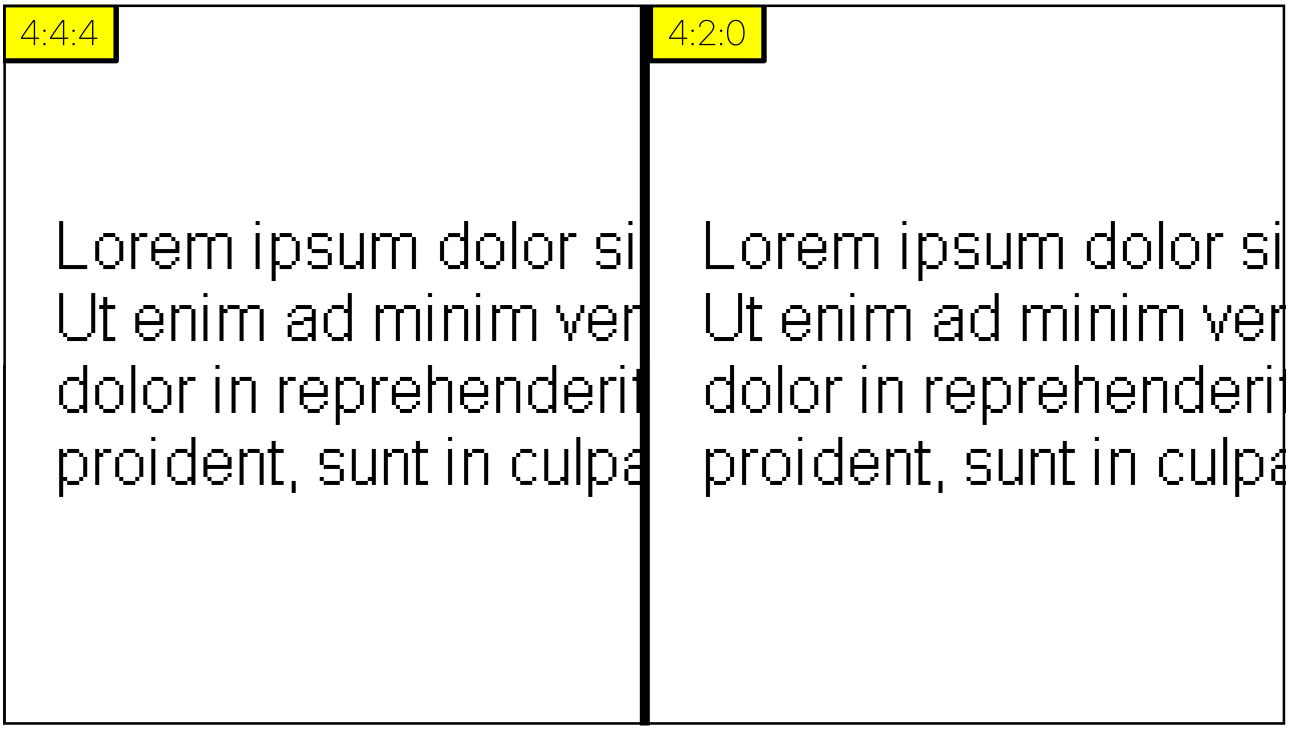

The budget decision
Today's technologies don't have the necessary bandwidth to support true 4K 60Hz 4:4:4.
60Hz + 4:2:0 subsampling
☹ Visual artifacts
4:4:4/RGB + 30Hz frame rate
☹ Jittery movement
113 / xxx

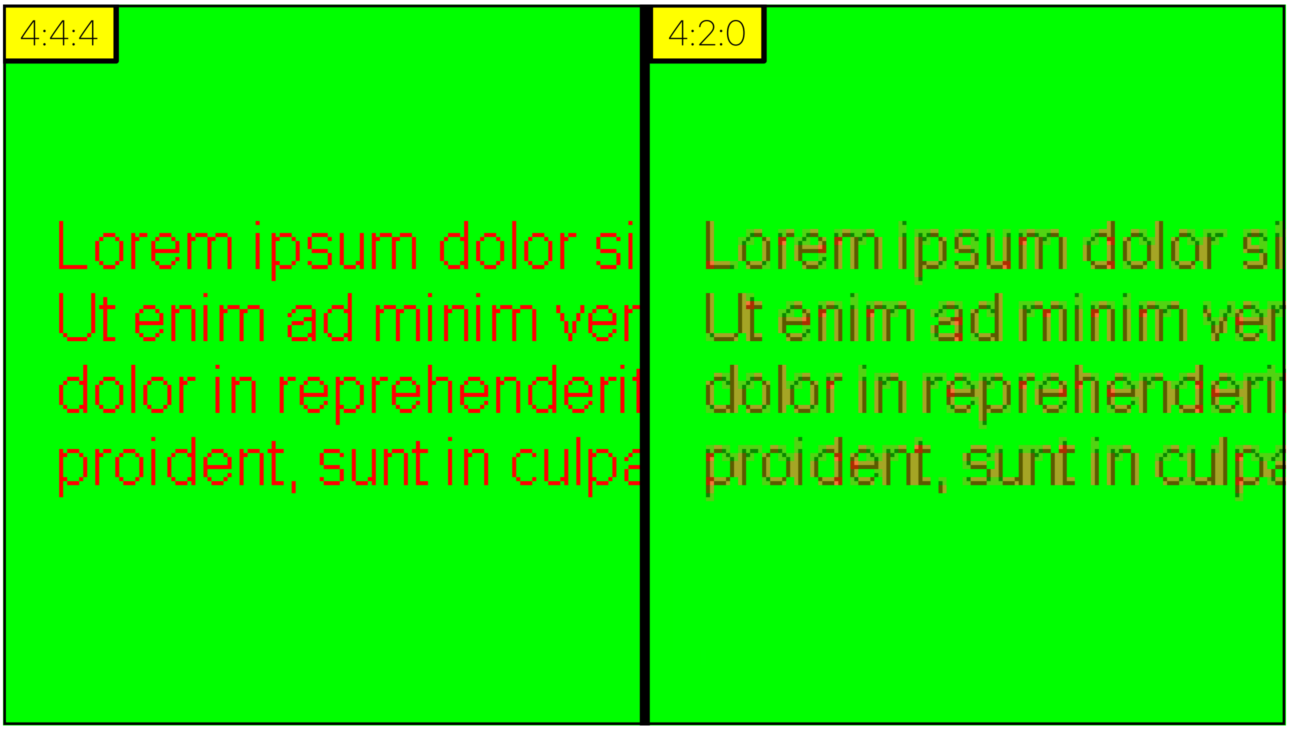

Chroma subsampling
4:4:4
4:2:2
4:2:0
4:1:1
Y
Cb
Cr
= RGB
(best quality)
SDI
H.262 / H.264
DVD, BluRay, JPEG
DV
114 / xxx

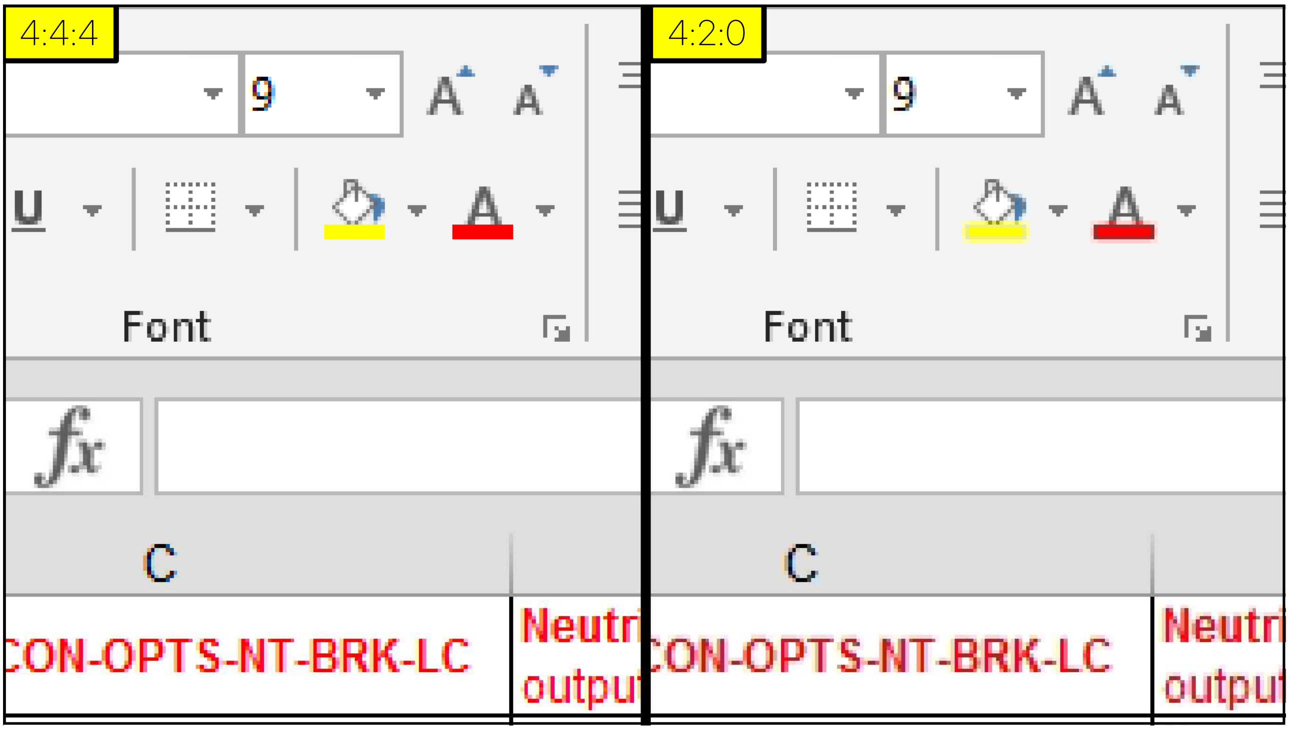

Bandwidth
4:4:4
4:2:2
4:2:0
4:1:1
Y Cb Cr
Y Cb Cr
Y Cb Cr
Y Cb Cr
33% lower bandwidth
50% lower bandwidth
50% lower bandwidth
115 / xxx

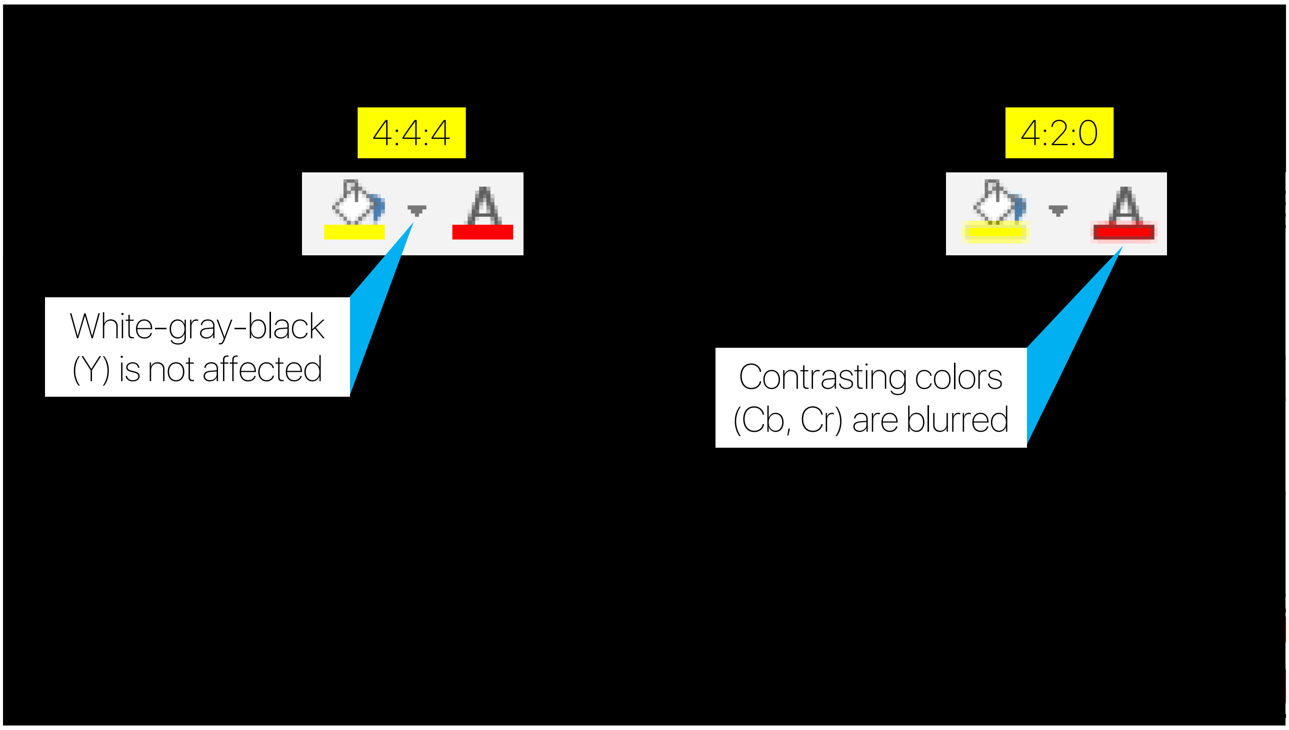

Bandwidth
4K 60
ULTRAHD
4:2:0
Y Cb Cr
50% lower bandwidth
116 / xxx

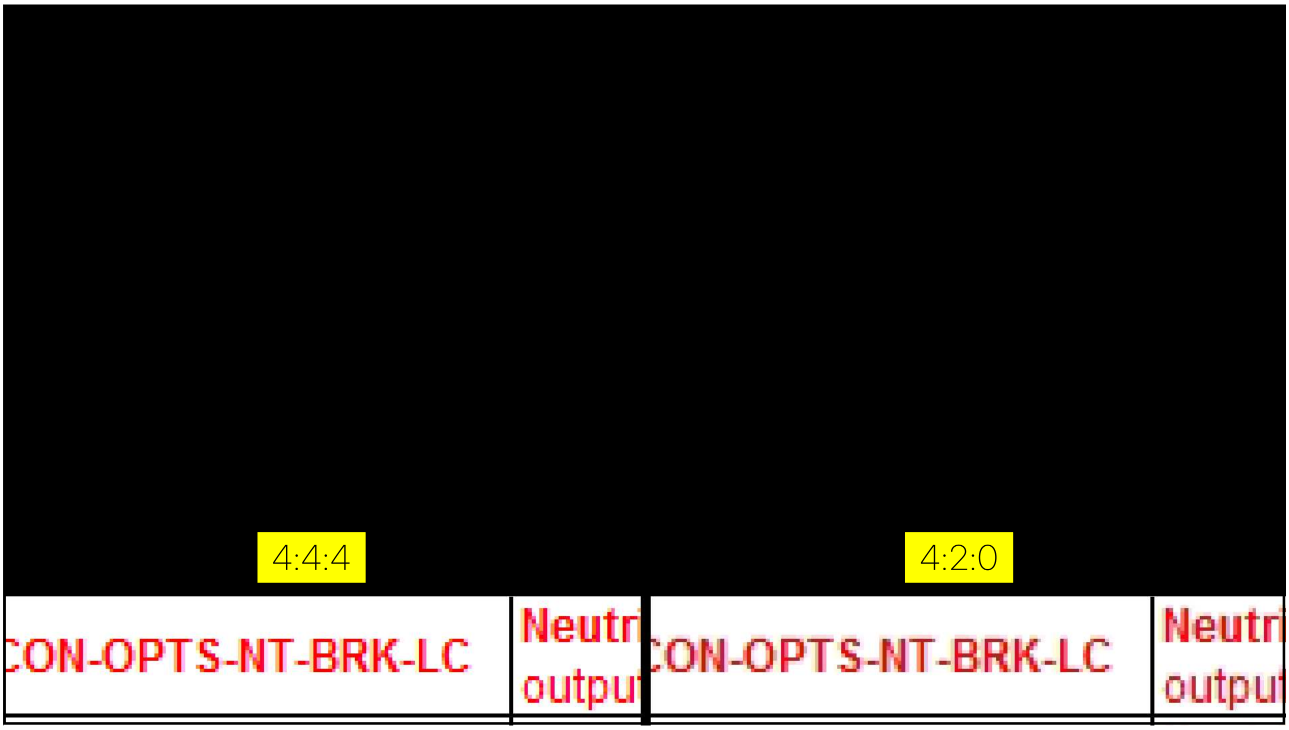

4K YCbCr 4:2:0
3840
2160
1920
1080
1920
1080
117 / xxx


4:4:4
Lorem ipsum dolor si
Ut enim ad minim ver
dolor in reprehenderit
proident, sunt in culpa
4:2:0
Lorem ipsum dolor si
Ut enim ad minim ver
dolor in reprehenderit
proident, sunt in culpa


4:4:4
Lorem ipsum dolor si
Ut enim ad minim ver
dolor in reprehenderit
proident, sunt in culpa
4:2:0
Lorem ipsum dolor si
Ut enim ad minim ver
dolor in reprehenderi
proident, sunt in culpa


4:4:4
9
Font
C
CON-OPTS-NT-BRK-LC
Neutr
outpu
4:2:0
9
Font
C
CON-OPTS-NT-BRK-LC
Neutr
outpu

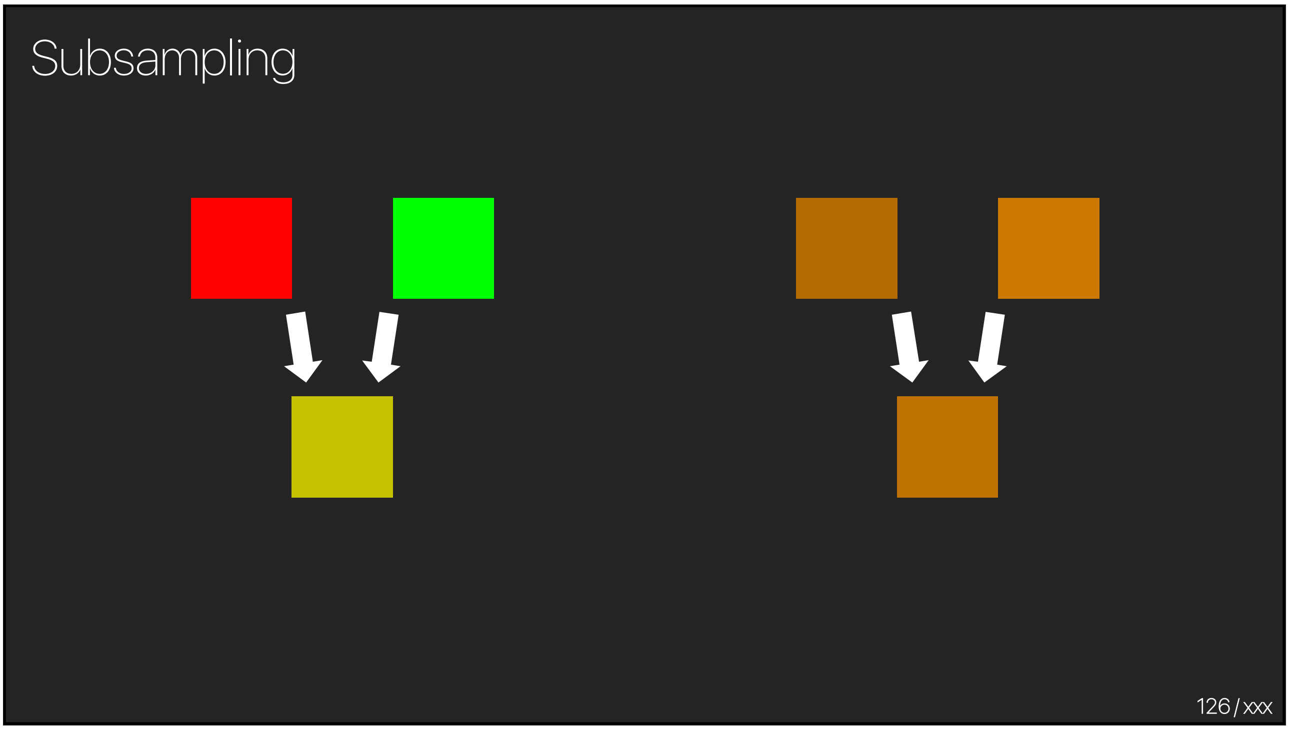

4:4:4
4:2:0
White-gray-black (Y) is not affected
Contrasting colors (Cb, Cr) are blurred

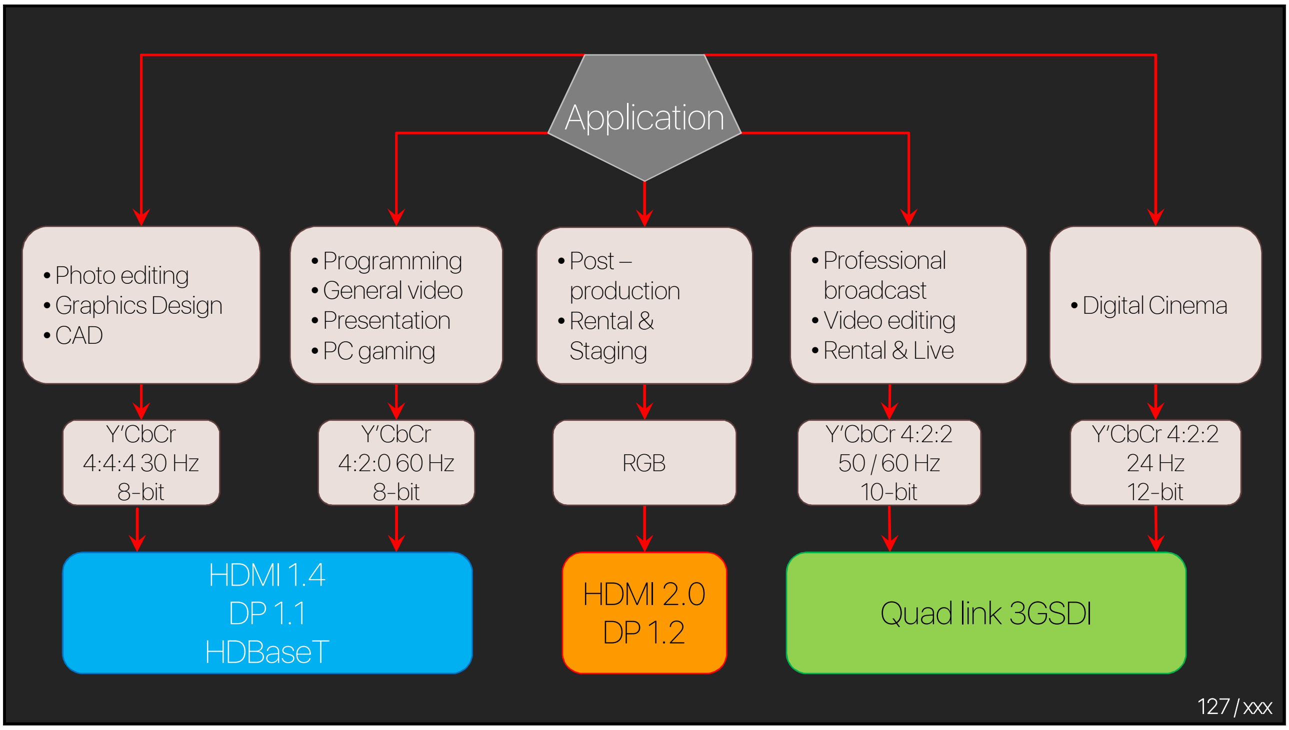

4:4:4
4:2:0


4:4:4 photo


4:2:0 photo


4:4:4
4:2:0


Subsampling
126 / xxx

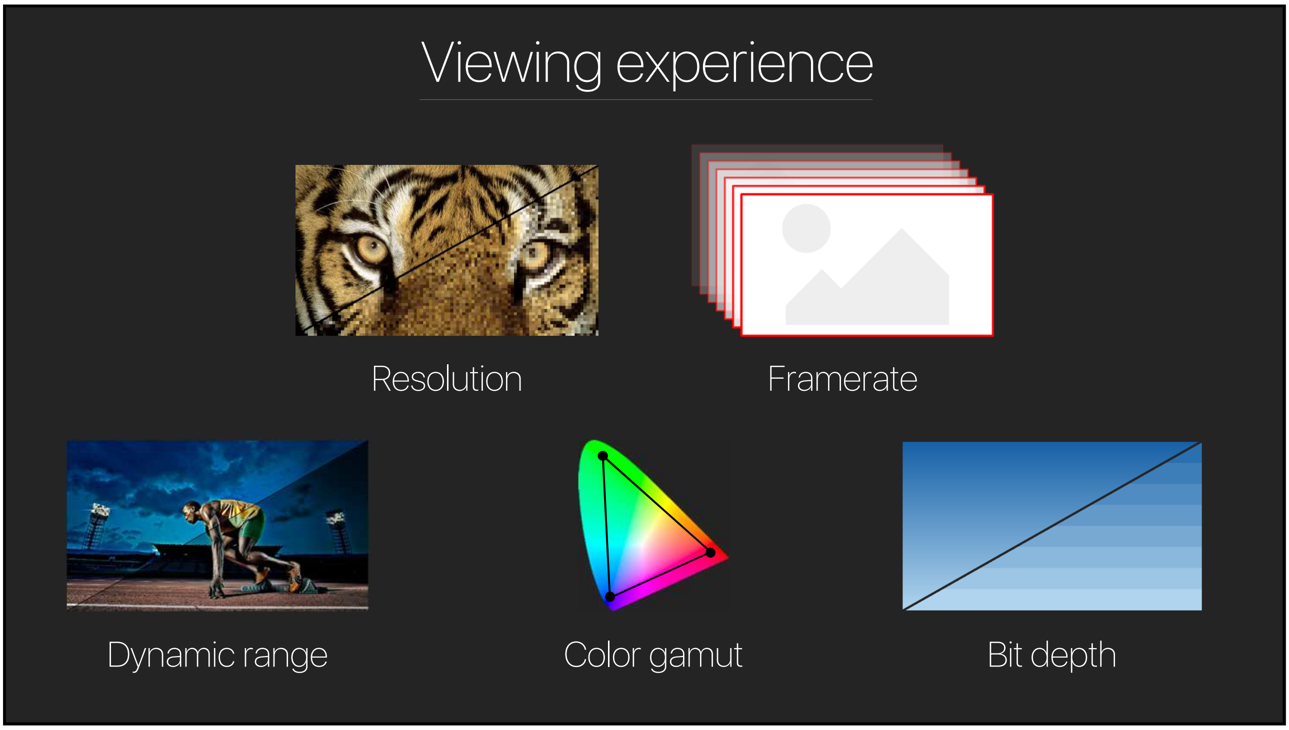

Application
• Photo editing
• Graphics Design
• CAD
• Programming
• General video
• Presentation
• PC gaming
• Post – production
• Rental & Staging
• Professional broadcast
• Video editing
• Rental & Live
• Digital Cinema
Y'CbCr 4:4:4 30 Hz 8-bit
Y'CbCr 4:2:0 60 Hz 8-bit
RGB
Y'CbCr 4:2:2 50 / 60 Hz 10-bit
Y'CbCr 4:2:2 24 Hz 12-bit
HDMI 1.4
DP 1.1
HDBaseT
HDMI 2.0
DP 1.2
Quad link 3GSDI
127 / xxx

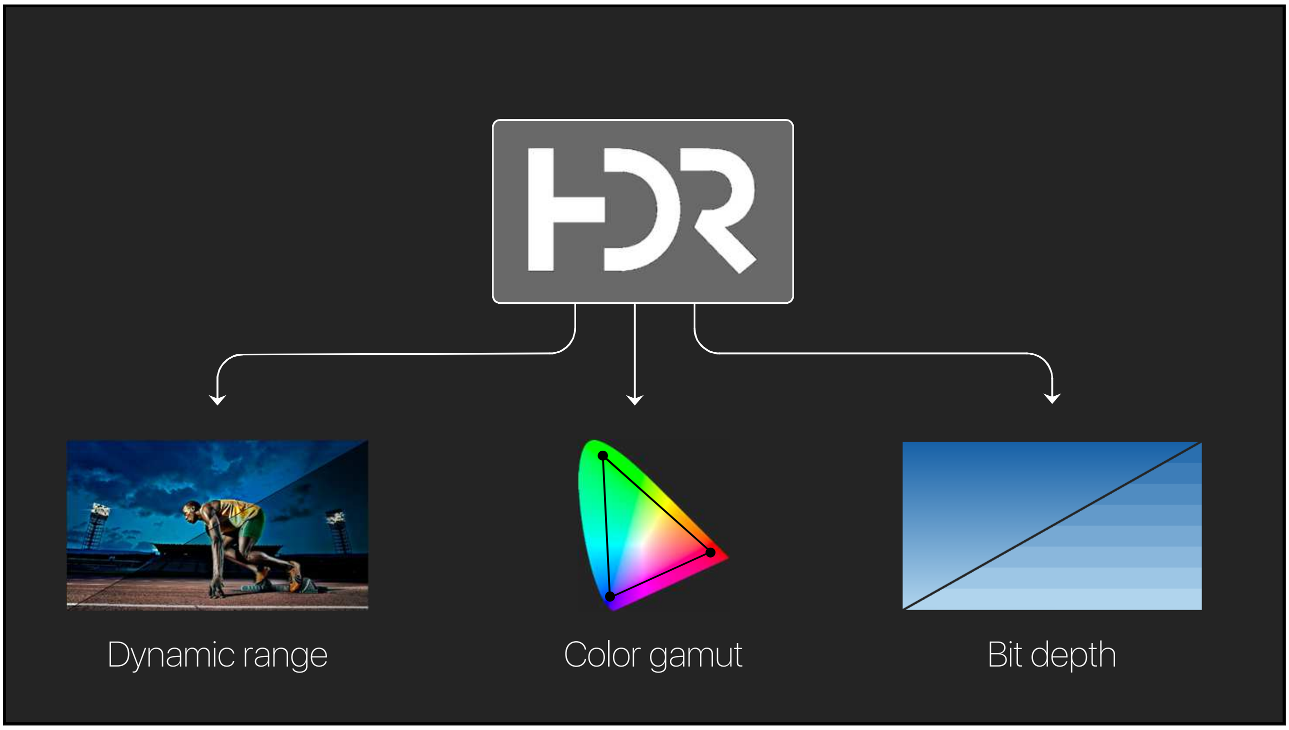

HDR
High Dynamic Range

What's the point of these improvements?

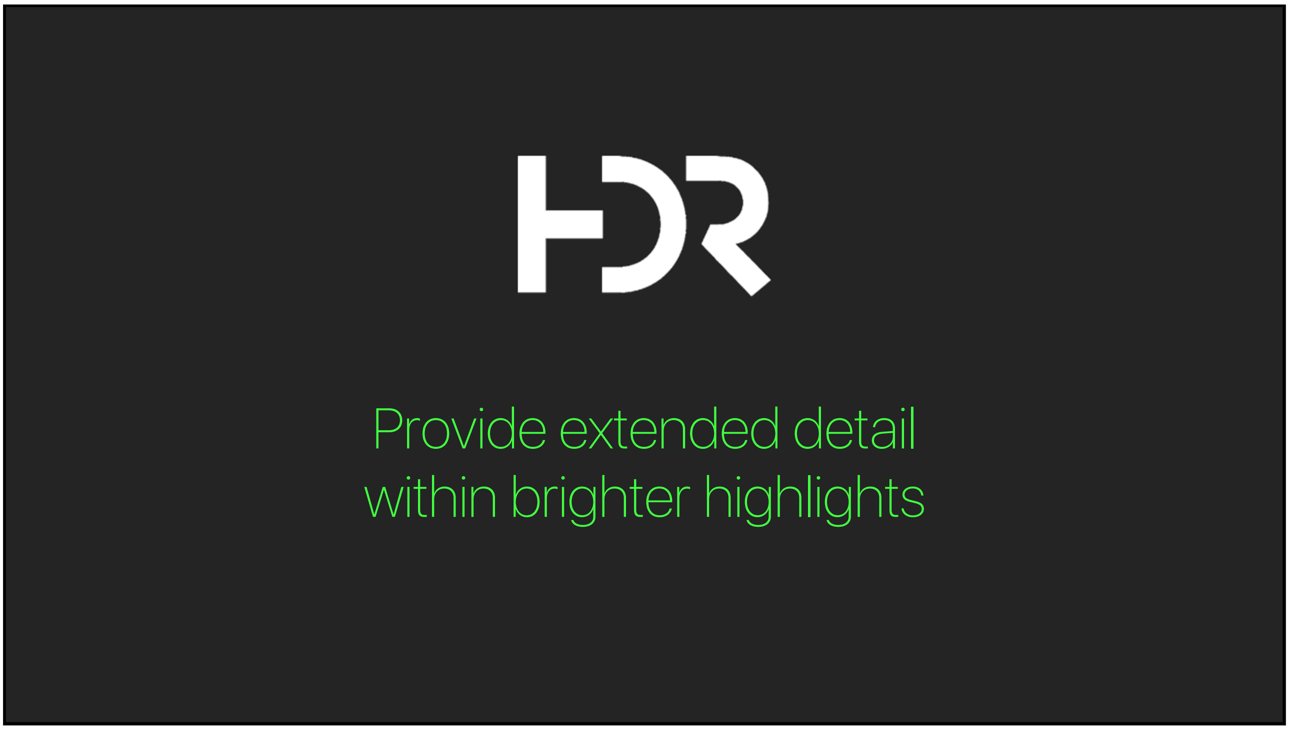
To re-create

what we see in real life


Viewing experience
Resolution
Framerate
Dynamic range
Color gamut
Bit depth

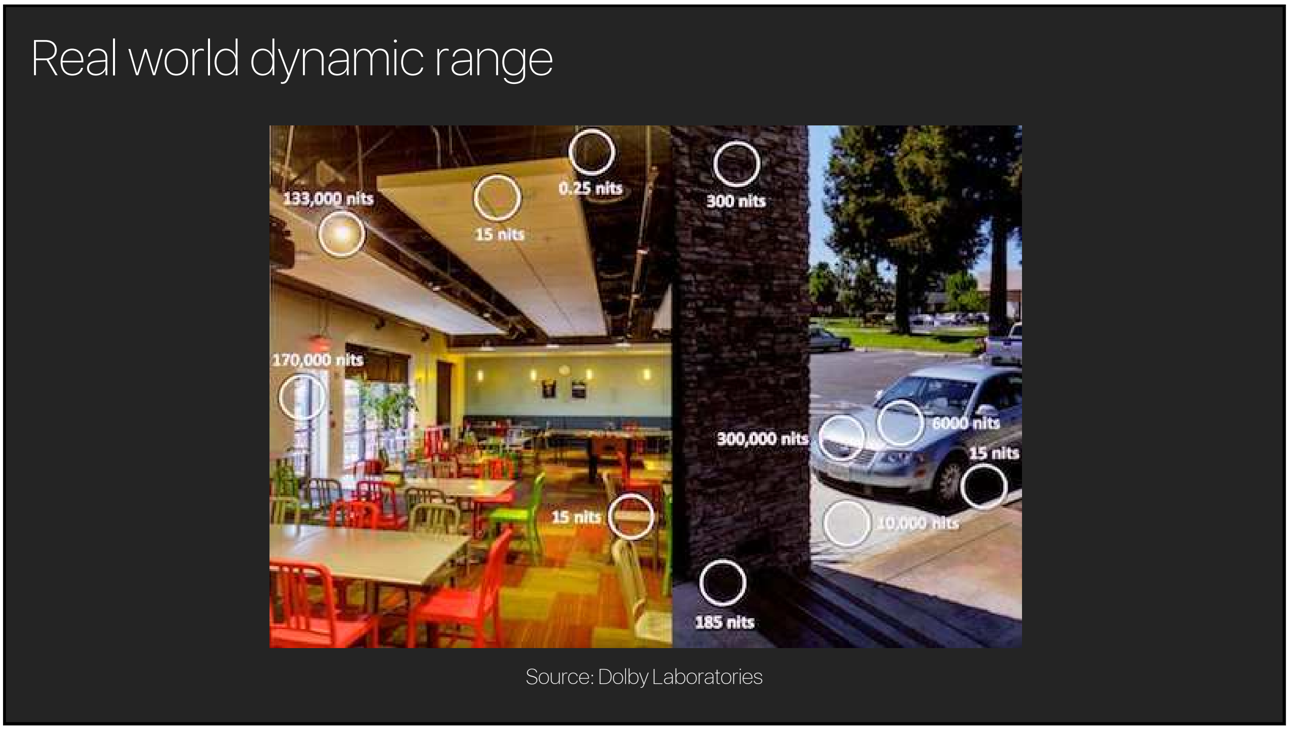

HDR
Dynamic range
Color gamut
Bit depth

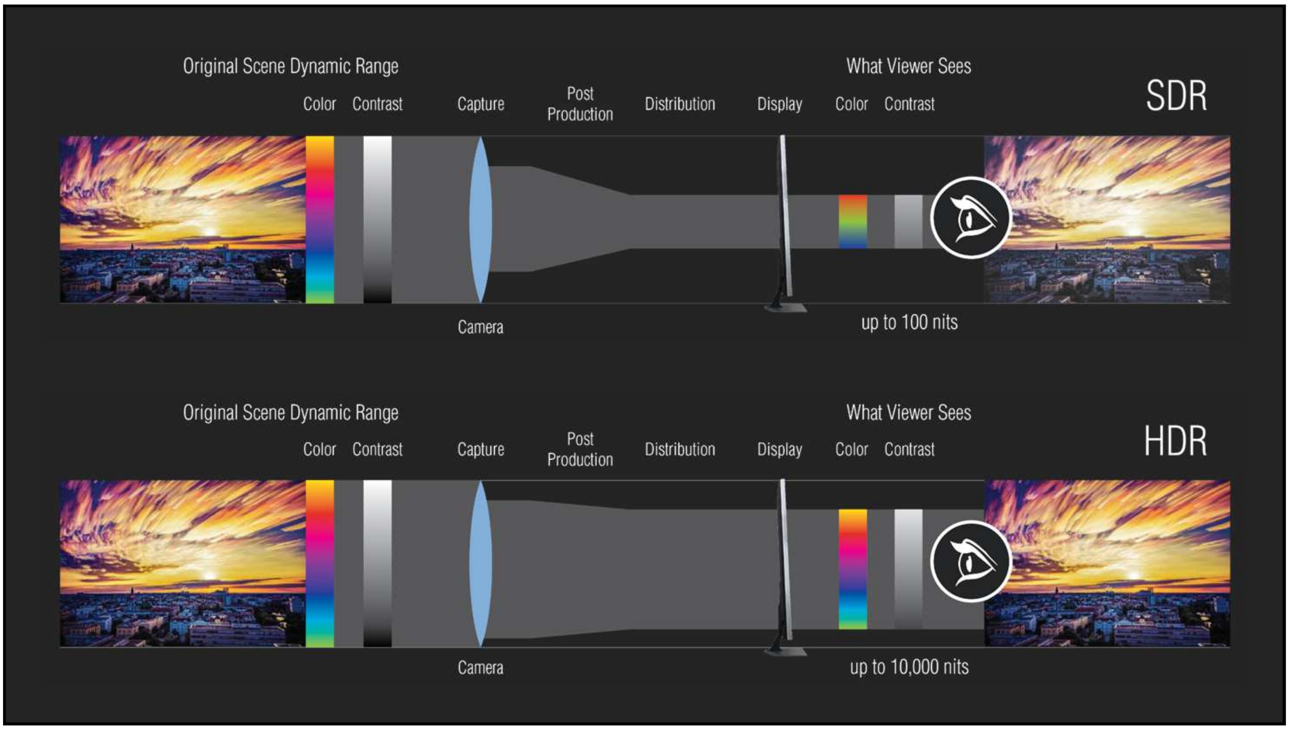

Dynamic range

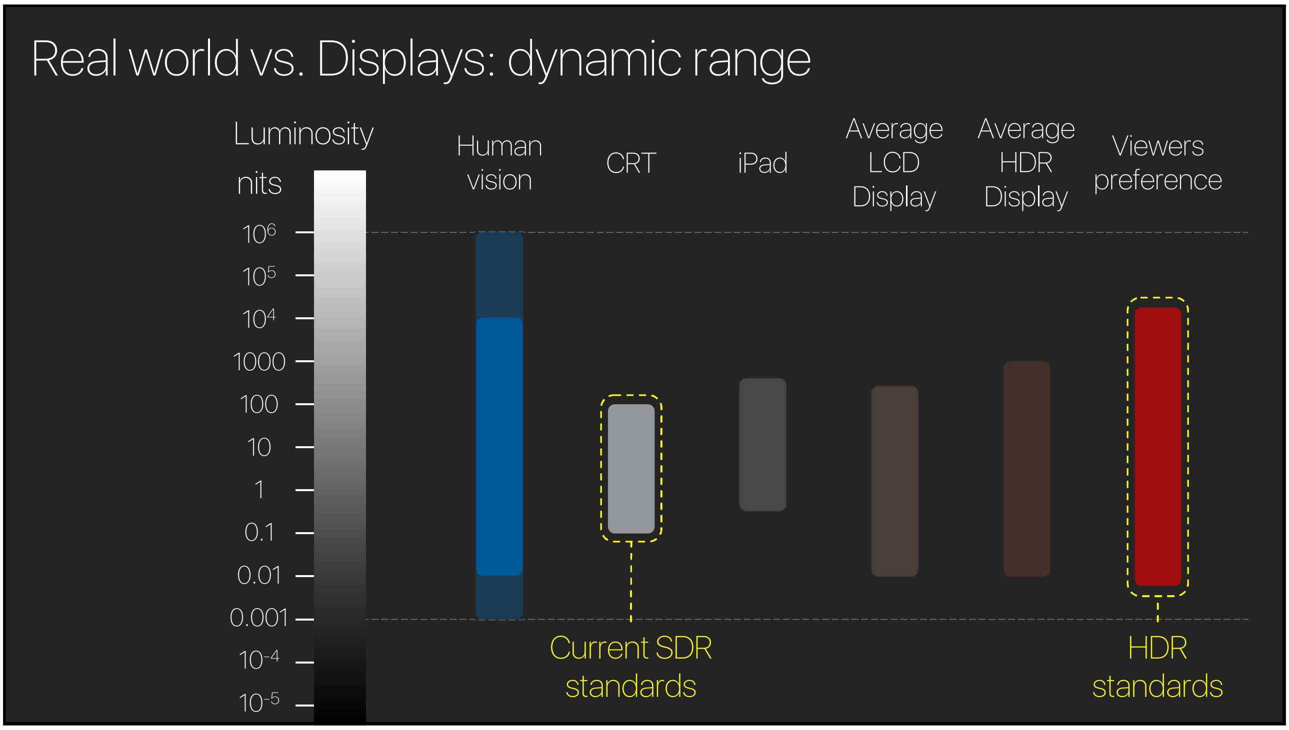

HDR
Provide extended detail
within brighter highlights

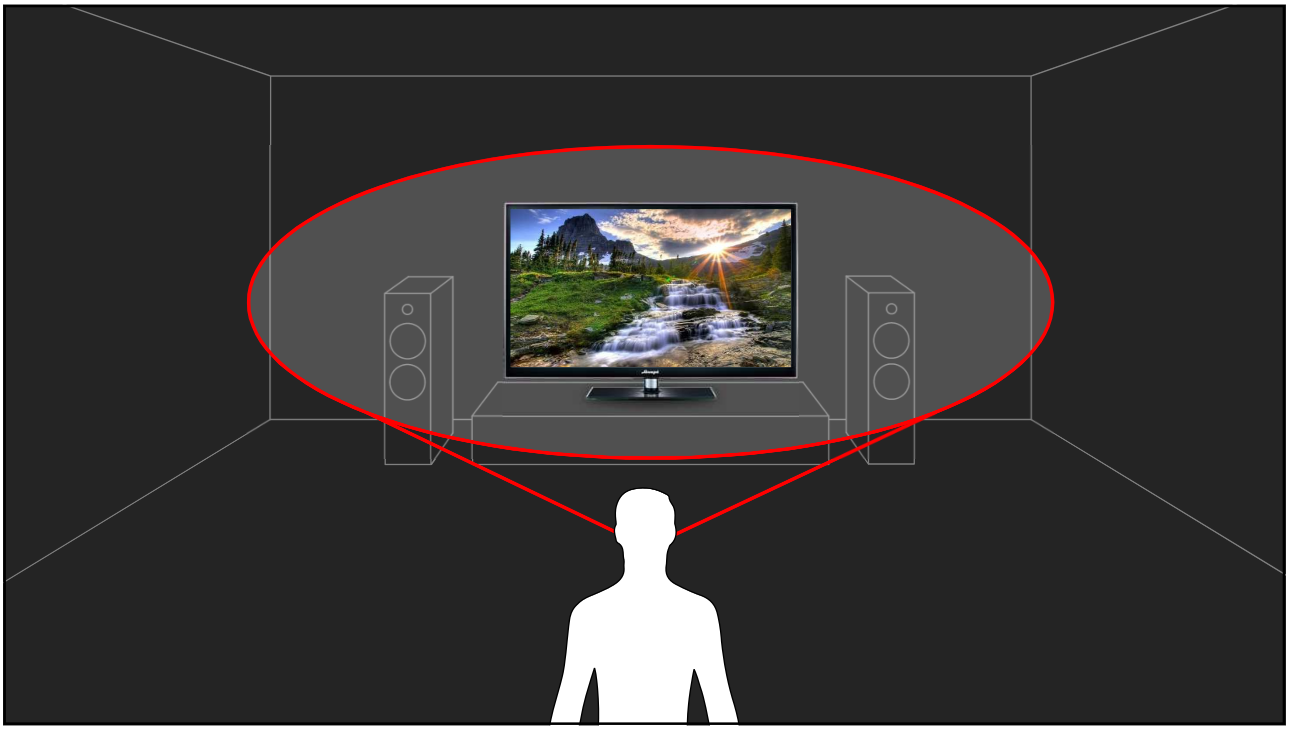

HDR
SDR


SDR
HDR


Real world dynamic range
133,000 nits
0.25 nits
15 nits
300 nits
170,000 nits
300,000 nits
6000 nits
15 nits
15 nits
10,000 nits
185 nits
Source: Dolby Laboratories


Original Scene Dynamic Range
Color
Contrast
Capture
Post Production
Distribution
Display
What Viewer Sees
Color
Contrast
SDR
Camera
up to 100 nits
Original Scene Dynamic Range
Color
Contrast
Capture
Post Production
Distribution
Display
What Viewer Sees
Color
Contrast
HDR
Camera
up to 10,000 nits


Real world vs. Displays: dynamic range
Luminosity
nits
10^6
10^5
10^4
1000
100
10
1
0.1
0.01
0.001
10^-4
10^-5
Human vision
CRT
iPad
Average LCD Display
Average HDR Display
Viewers preference
Current SDR standards
HDR standards



Color gamut

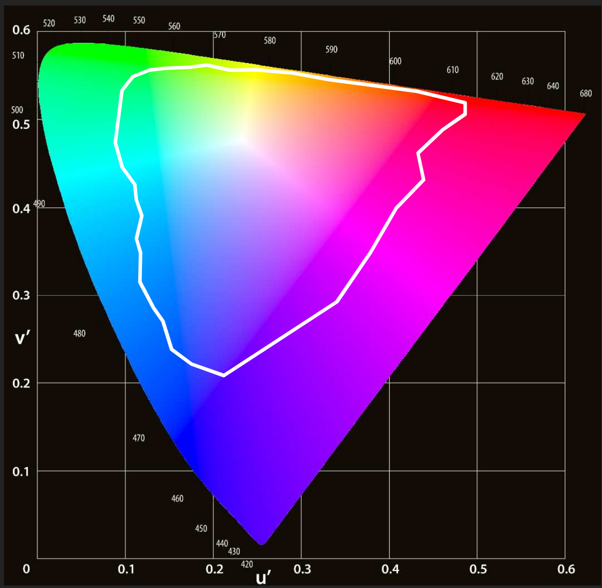
Color gamut

Pointer's gamut:

Colors reflected by any natural or man-made object

46%

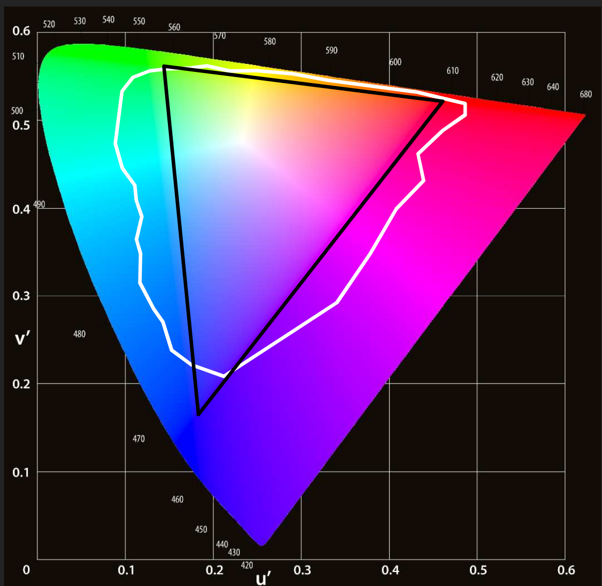
of CIE u' v'



Rec. 709 (sRGB)

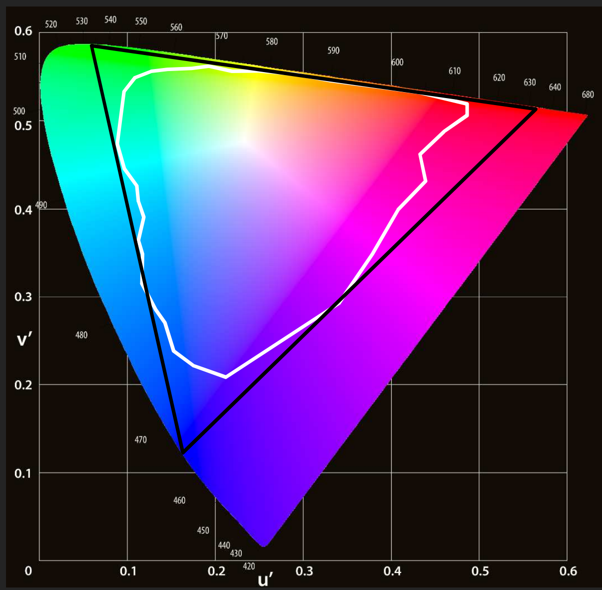
70%

of Pointer's gamut

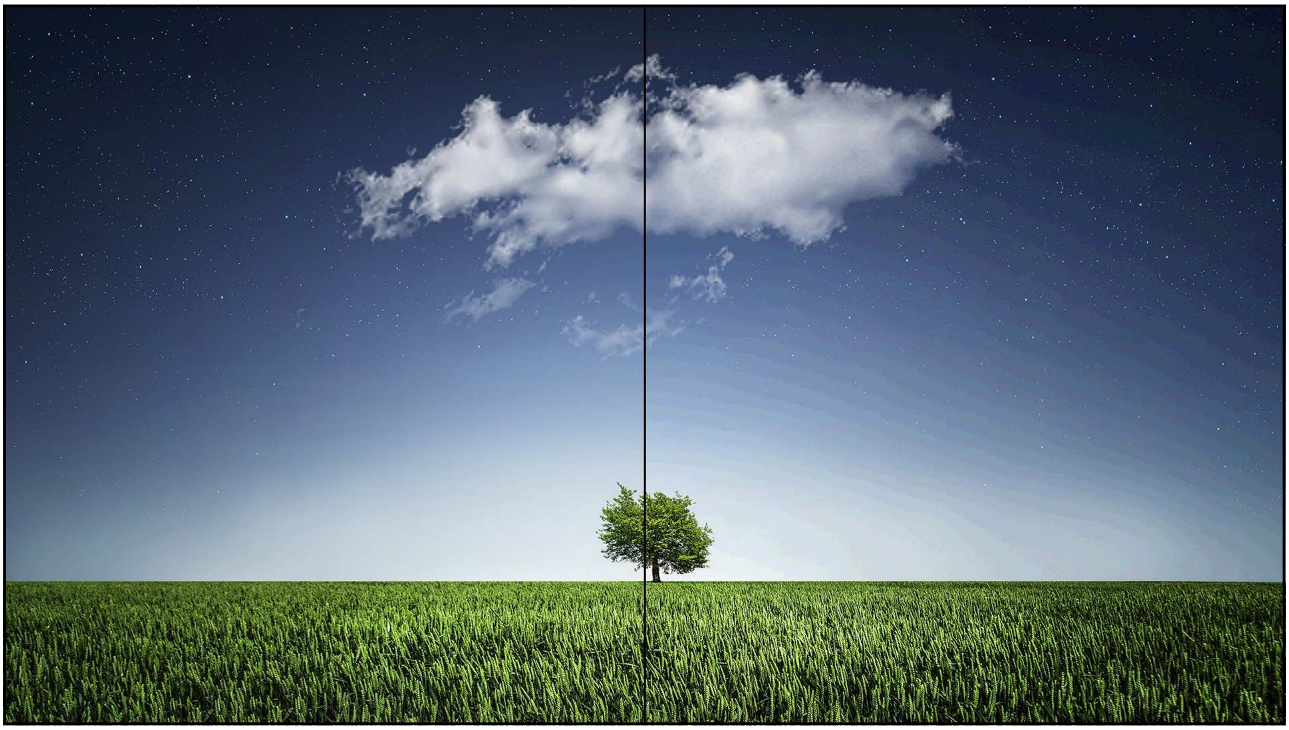


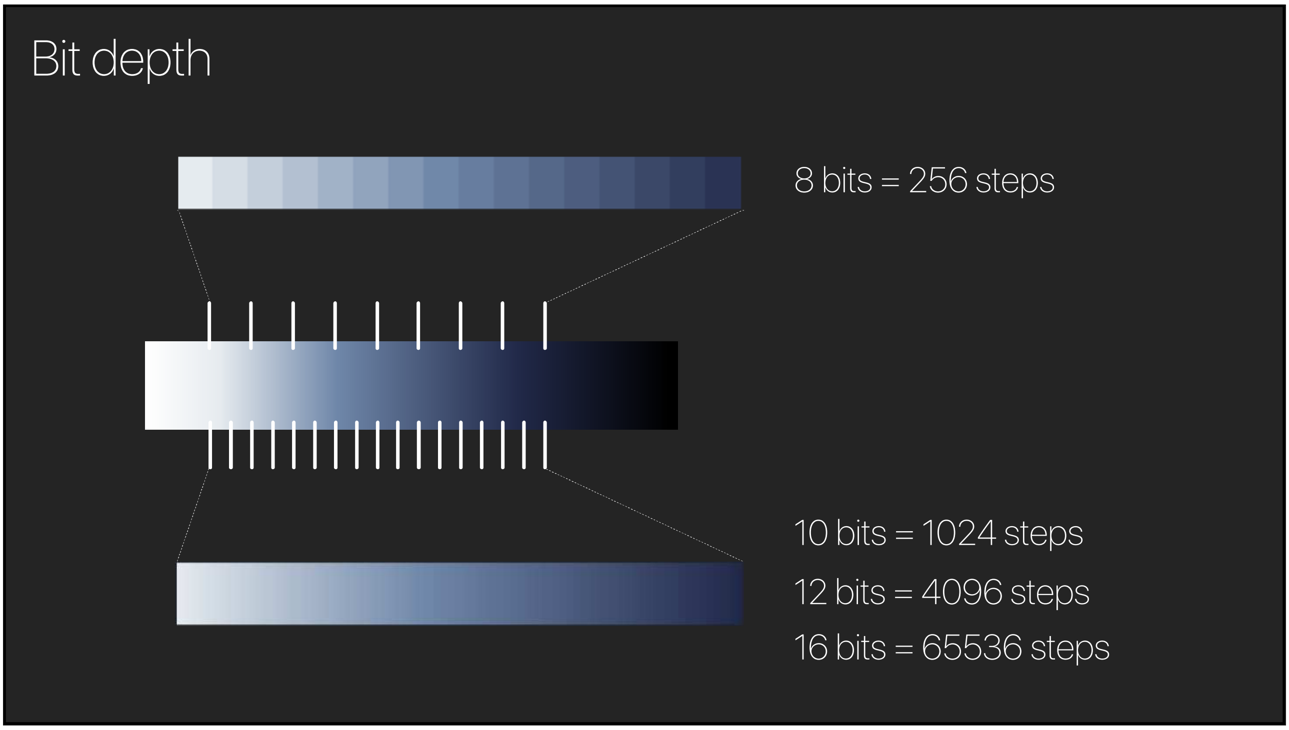
Rec. 2020

of Pointer's gamut

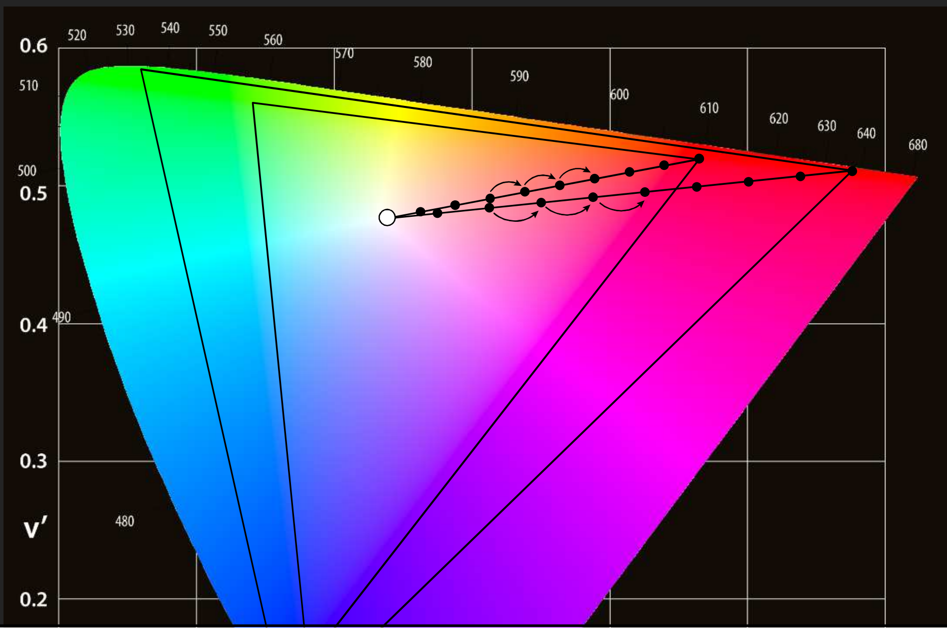


Bit depth




Bit depth
8 bits = 256 steps
10 bits = 1024 steps
12 bits = 4096 steps
16 bits = 65536 steps

Bit depth

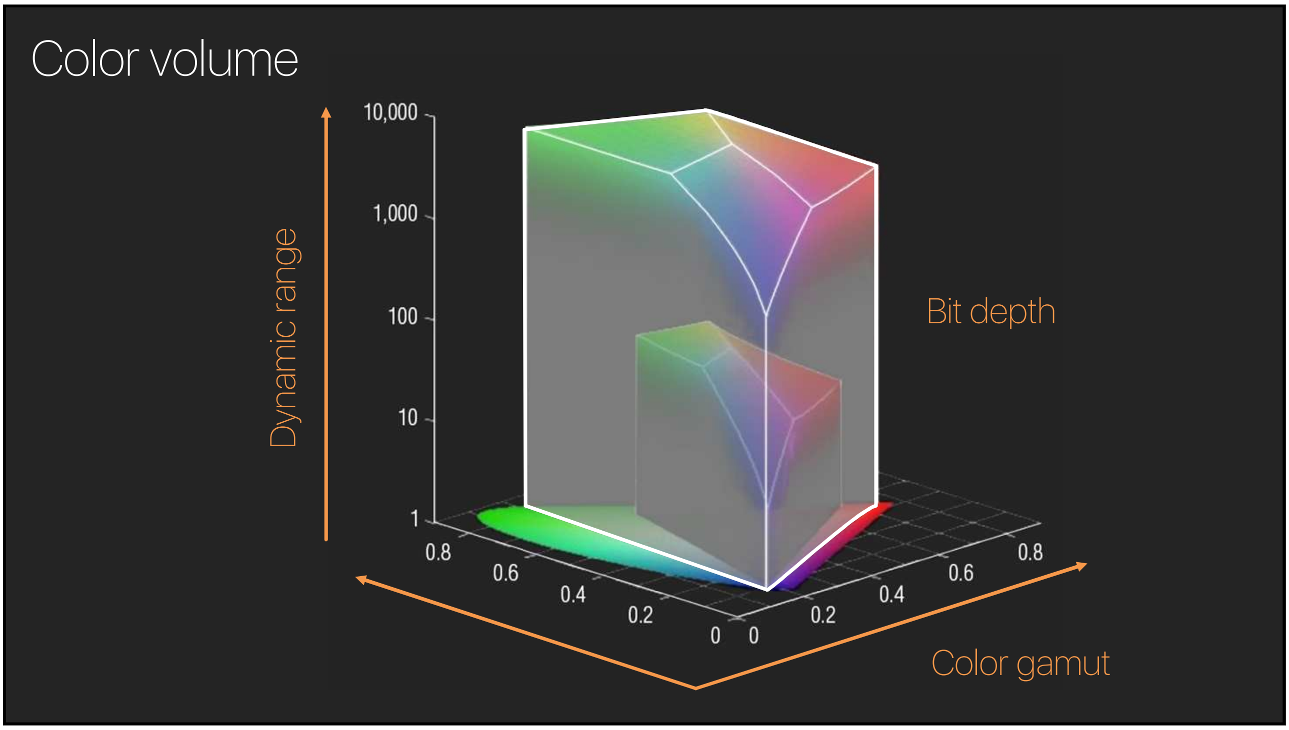


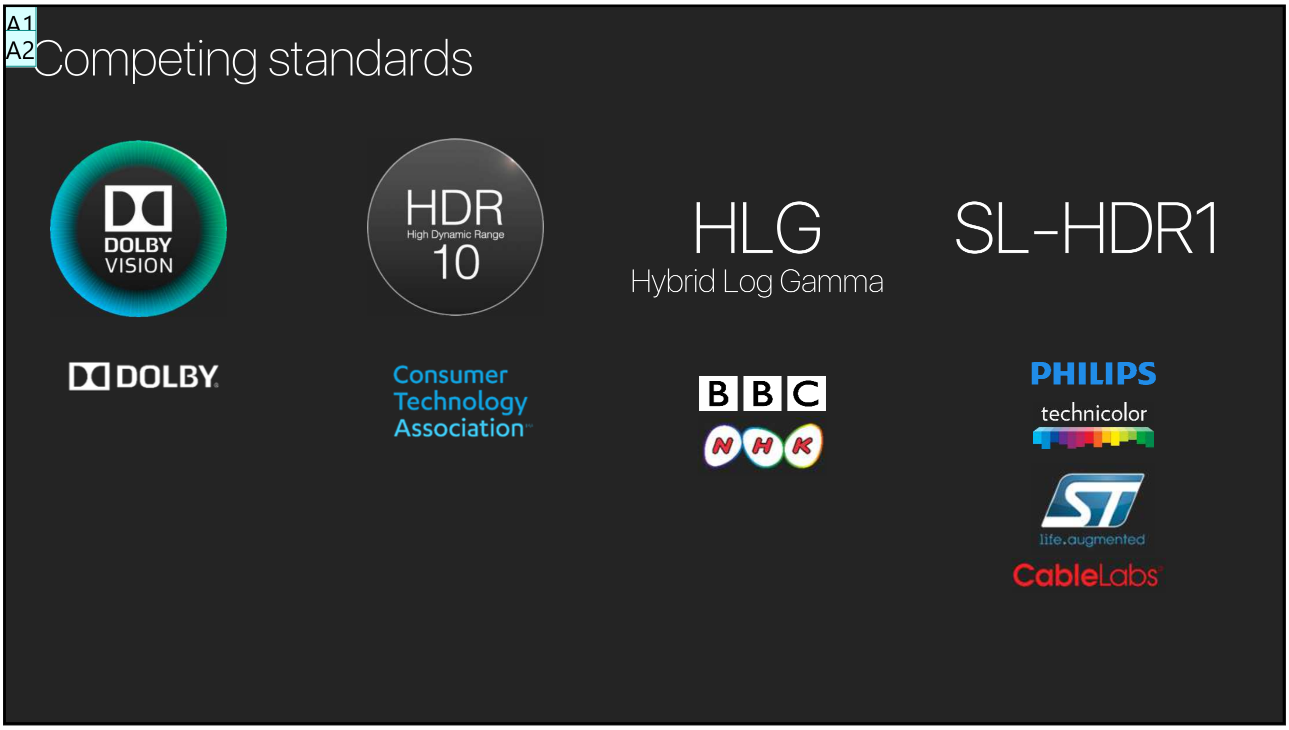
Recipe for HDR

More contrast + More colors + Higher bit depth

=

New set of standards


Color volume
Dynamic range
10,000
1,000
100
10
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
Bit depth
Color gamut


Competing standards
DOLBY VISION
DOLBY
HDR High Dynamic Range 10
Consumer Technology Association
HLG
Hybrid Log Gamma
BBC
NHK
SL-HDR1
PHILIPS
technicolor
ST life.augmented
CableLabs

Slide 154

A1 A HLG is maradjon benne
Author; 2018. 03. 27.

A2 Open standard
Backwards compatible with SDR
10-bit
Author; 2018. 03. 27.

Competing standards

DOLBY VISION

- Proprietary ($3/unit)
- 12 bit
- 10,000 nits
- Dynamic metadata

HDR10+

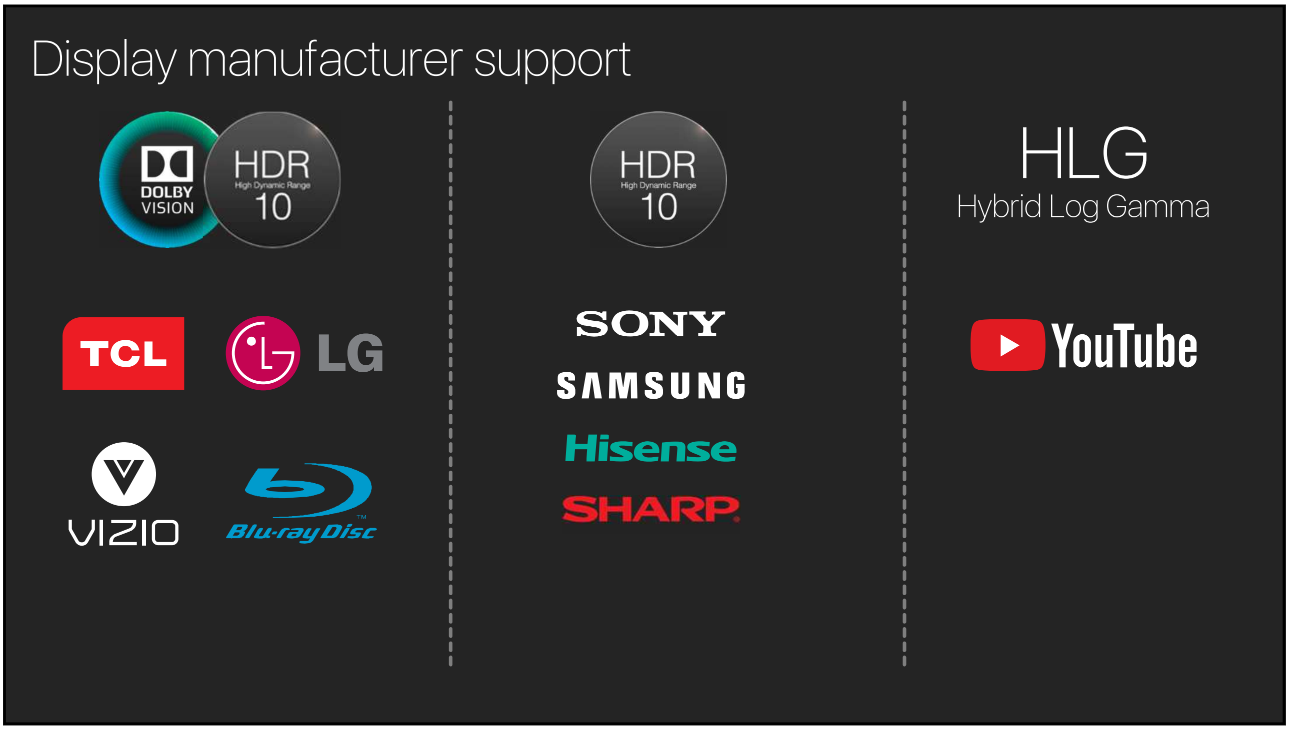
- Open standard
- 10 bit
- 1,000 nits
- Dynamic metadata

HLG
Hybrid Log Gamma

- Open standard
- 10 bit
- 1,000 nits
- No metadata (backwards compatible)

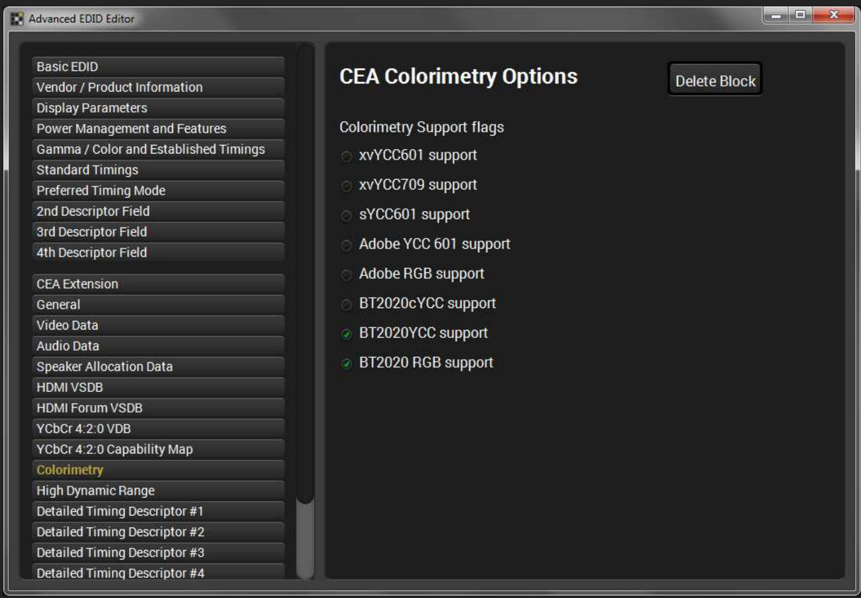
Source manufacturer support

DOLBY VISION	DOLBY VISION + HDR 10	HDR 10
VUDU	Apple	Roku
	NETFLIX	XBOX
	amazon	PS4 Pro

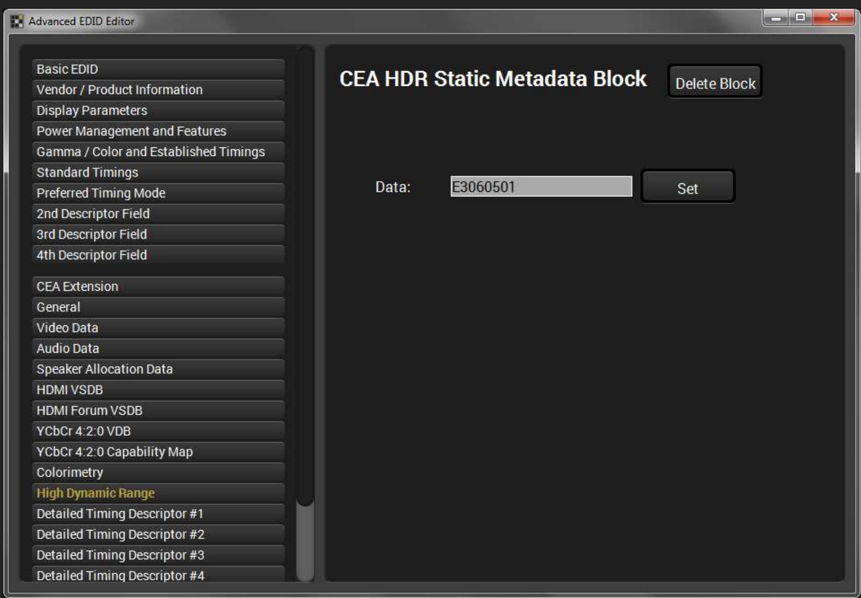

Display manufacturer support
DOLBY VISION
HDR High Dynamic Range 10
TCL
LG
VIZIO
Blu-ray Disc
HDR High Dynamic Range 10
SONY
SAMSUNG
Hisense
SHARP
HLG
Hybrid Log Gamma
YouTube

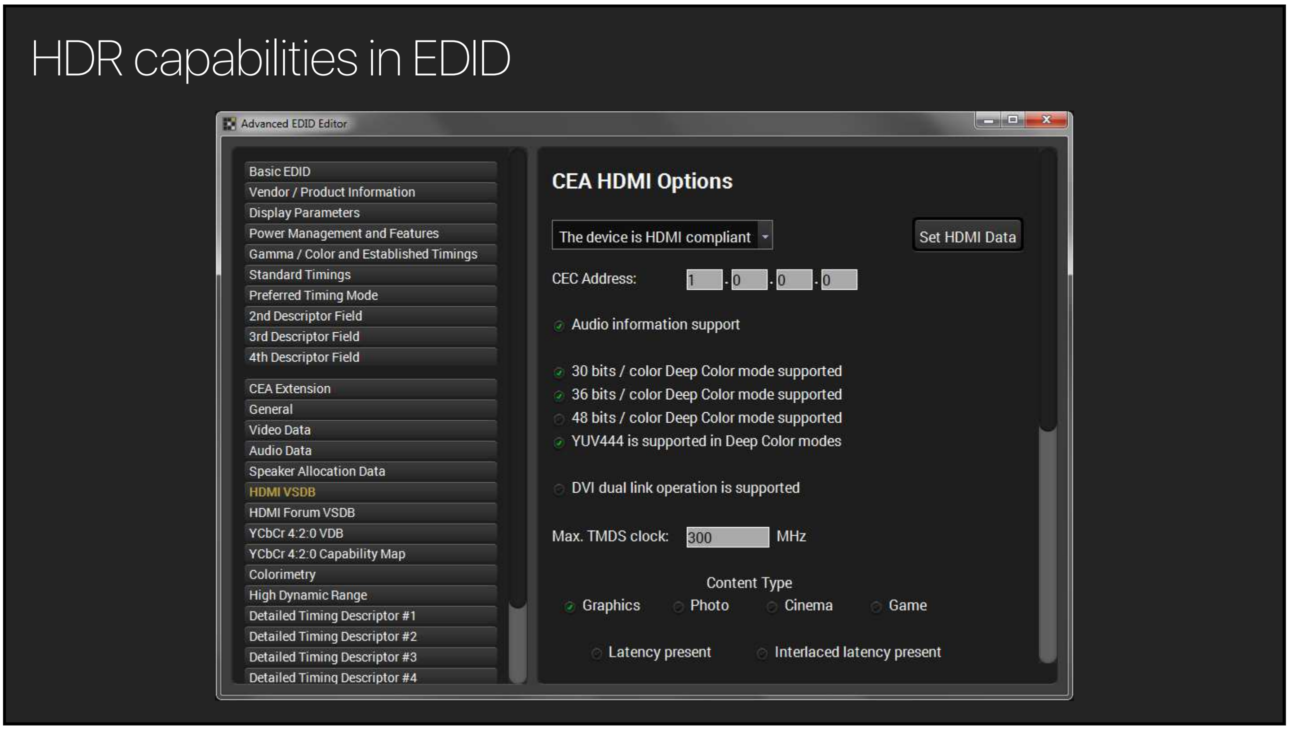

HDR capabilities in EDID
HDR
Dynamic range
- black level, luminance -
Bit depth
Color gamut

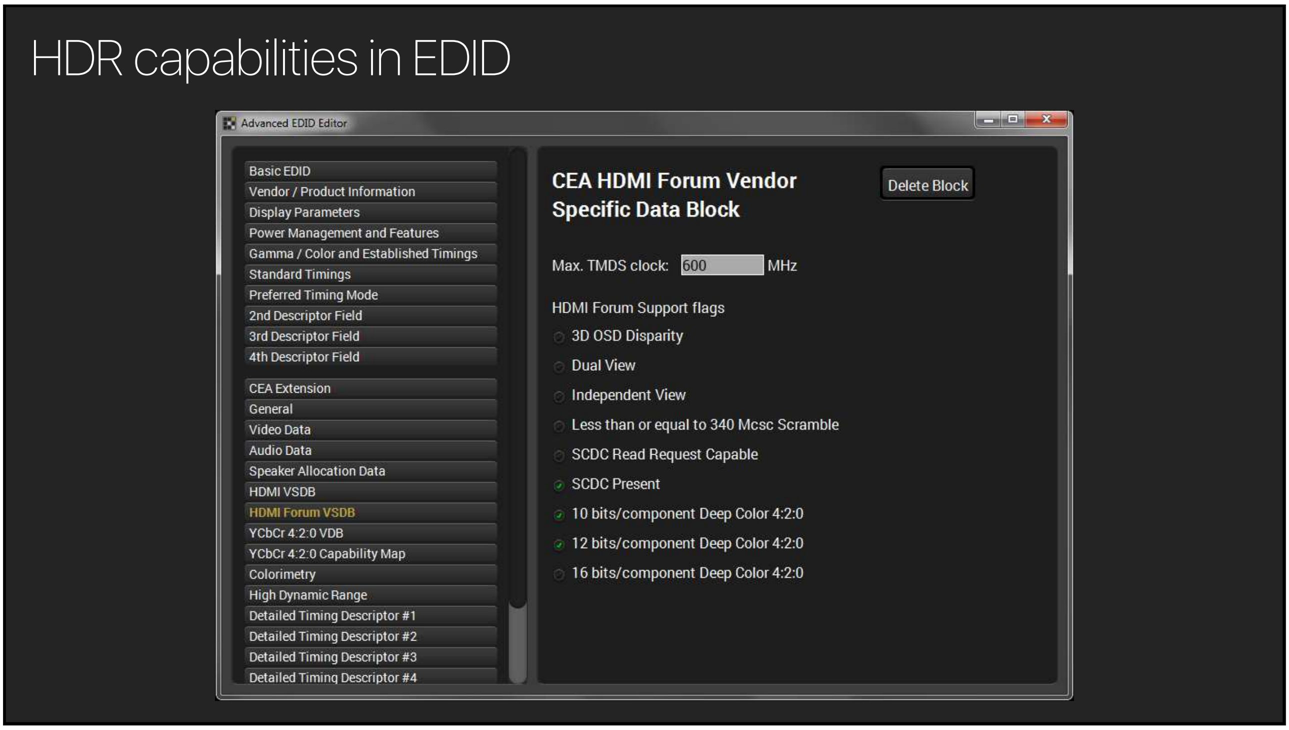
HDR capabilities in EDID



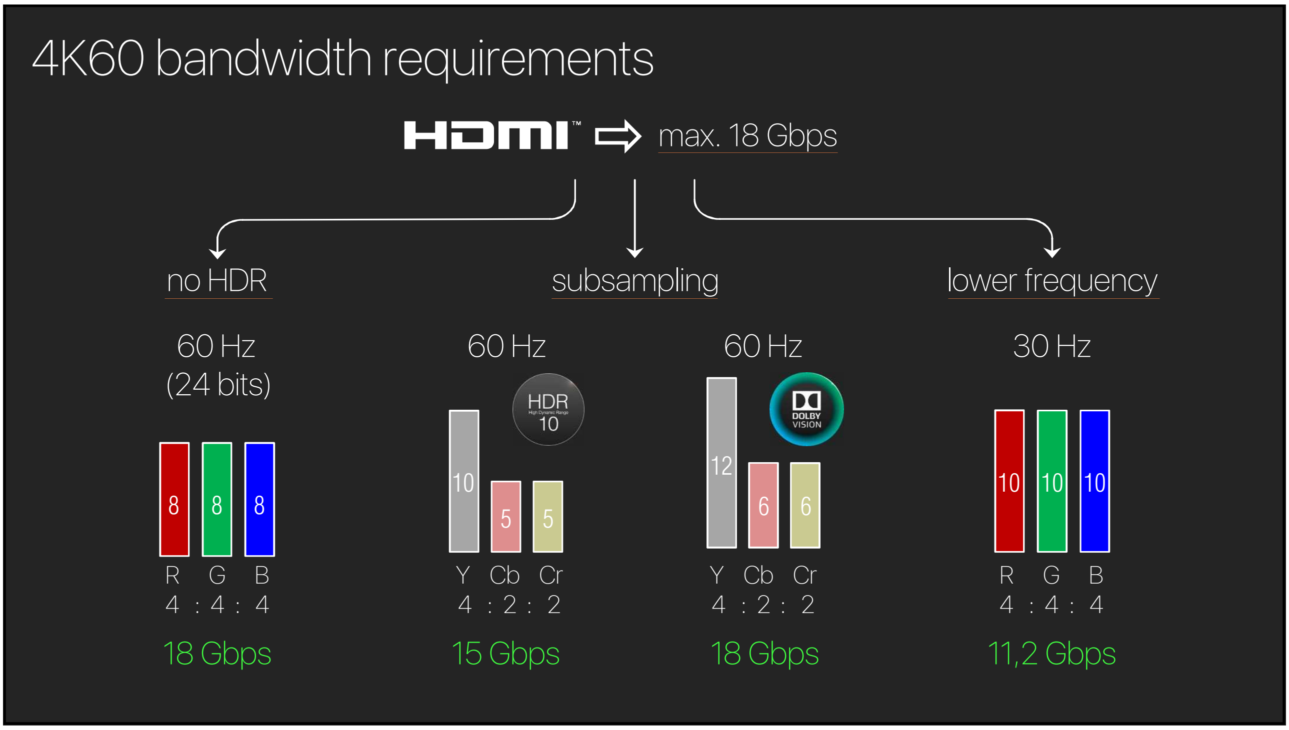
HDR capabilities in EDID




HDR capabilities in EDID
Advanced EDID Editor
Basic EDID
Vendor / Product Information
Display Parameters
Power Management and Features
Gamma / Color and Established Timings
Standard Timings
Preferred Timing Mode
2nd Descriptor Field
3rd Descriptor Field
4th Descriptor Field
CEA Extension
General
Video Data
Audio Data
Speaker Allocation Data
HDMI VSDB
HDMI Forum VSDB
YCbCr 4:2:0 VDB
YCbCr 4:2:0 Capability Map
Colorimetry
High Dynamic Range
Detailed Timing Descriptor #1
Detailed Timing Descriptor #2
Detailed Timing Descriptor #3
Detailed Timing Descriptor #4
CEA HDMI Options
The device is HDMI compliant
Set HDMI Data
CEC Address: 1 . 0 . 0 . 0
Audio information support
30 bits / color Deep Color mode supported
36 bits / color Deep Color mode supported
48 bits / color Deep Color mode supported
YUV444 is supported in Deep Color modes
DVI dual link operation is supported
Max. TMDS clock: 300 MHz
Content Type
Graphics
Photo
Cinema
Game
Latency present
Interlaced latency present


HDR capabilities in EDID
Advanced EDID Editor
Basic EDID
Vendor / Product Information
Display Parameters
Power Management and Features
Gamma / Color and Established Timings
Standard Timings
Preferred Timing Mode
2nd Descriptor Field
3rd Descriptor Field
4th Descriptor Field
CEA Extension
General
Video Data
Audio Data
Speaker Allocation Data
HDMI VSDB
HDMI Forum VSDB
YCbCr 4:2:0 VDB
YCbCr 4:2:0 Capability Map
Colorimetry
High Dynamic Range
Detailed Timing Descriptor #1
Detailed Timing Descriptor #2
Detailed Timing Descriptor #3
Detailed Timing Descriptor #4
CEA HDMI Forum Vendor Specific Data Block
Delete Block
Max. TMDS clock: 600 MHz
HDMI Forum Support flags
3D OSD Disparity
Dual View
Independent View
Less than or equal to 340 Mcsc Scramble
SCDC Read Request Capable
SCDC Present
10 bits/component Deep Color 4:2:0
12 bits/component Deep Color 4:2:0
16 bits/component Deep Color 4:2:0


HDR capabilities in EDID
Advanced EDID Editor
Basic EDID
Vendor / Product Information
Display Parameters
Power Management and Features
Gamma / Color and Established Timings
Standard Timings
Preferred Timing Mode
2nd Descriptor Field
3rd Descriptor Field
4th Descriptor Field
CEA Extension
General
Video Data
Audio Data
Speaker Allocation Data
HDMI VSDB
HDMI Forum VSDB
YCbCr 4:2:0 VDB
YCbCr 4:2:0 Capability Map
Colorimetry
High Dynamic Range
Detailed Timing Descriptor #1
Detailed Timing Descriptor #2
Detailed Timing Descriptor #3
Detailed Timing Descriptor #4
CEA YCbCr 4:2:0 Capability Map
Delete Block
3840x2160p60
1920x1080p60
1920x1080p50
1280x720p60
1280x720p50
1920x1080i60
1920x1080i50
1920x1080p24
1920x1080p25
1920x1080p30
3840x2160p24
3840x2160p25


4K60 bandwidth requirements
HDMI
max. 18 Gbps
no HDR
subsampling
lower frequency
60 Hz
(24 bits)
8 8 8
R G B
4 : 4 : 4
18 Gbps
60 Hz
HDR 10
10 5 5
Y Cb Cr
4 : 2 : 2
15 Gbps
60 Hz
DOLBY VISION
12 6 6
Y Cb Cr
4 : 2 : 2
18 Gbps
30 Hz
10 10 10
R G B
4 : 4 : 4
11,2 Gbps

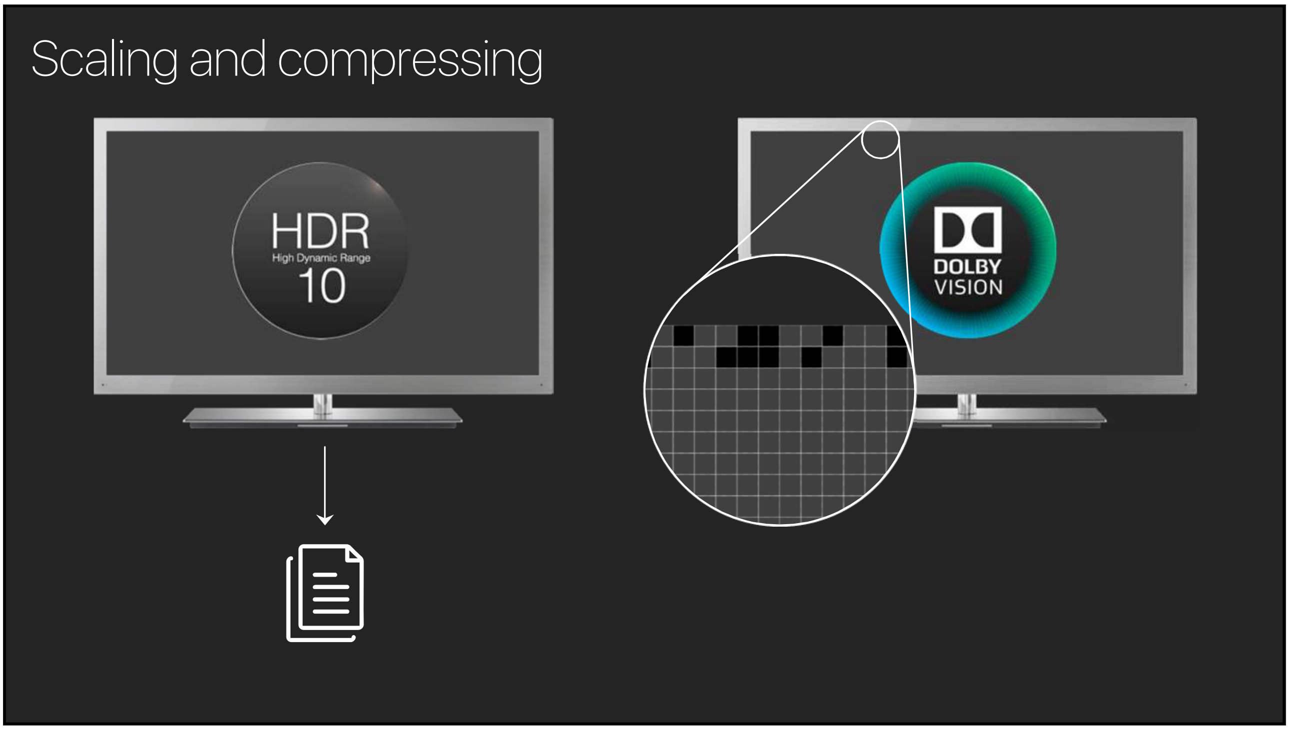
Extension

HDMI20-OPTJ-TX/RX

HDMI20-OPTC-TX/RX

Switching

MX2-8x8HDMI20-Audio


Scaling and compressing
HDR
High Dynamic Range
10
DOLBY
VISION


HDCP
High-bandwidth Digital Content Protection
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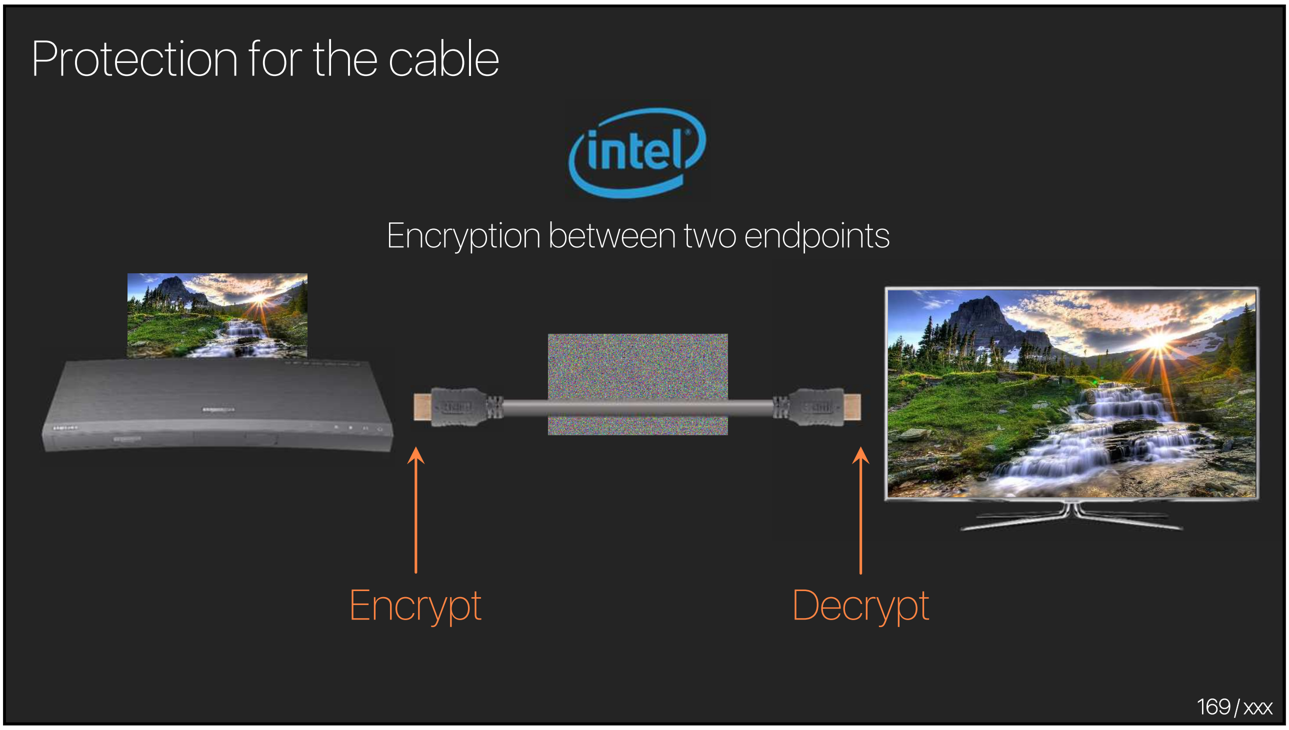
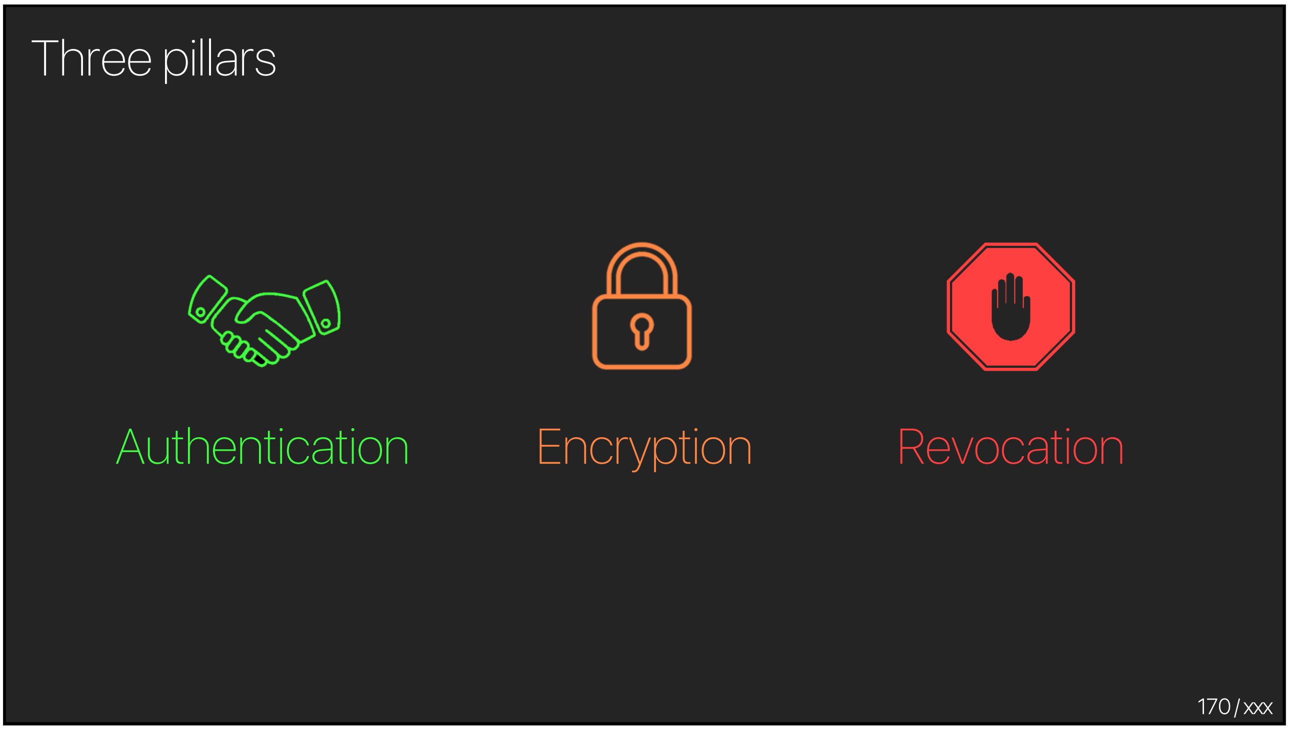

Protection for the cable
intel
Encryption between two endpoints
Encrypt
Decrypt
169 / xxx


Three pillars
Authentication
Encryption
Revocation
170 / xxx

HDCP – Legal stuff

- Manufacturers must obtain a licence from Digital Content Protection LLC
- ... and pay an annual fee.
- A set of unique public and secret keys is required, which is generated by DCP LLC using a master key matrix.
- Making a secret key public is a huge violation. Not even device manufacturers have access to the secret keys in the chips.
- DCP LLC knows which key set has been sold to which manufacturer so that they can be revoked.

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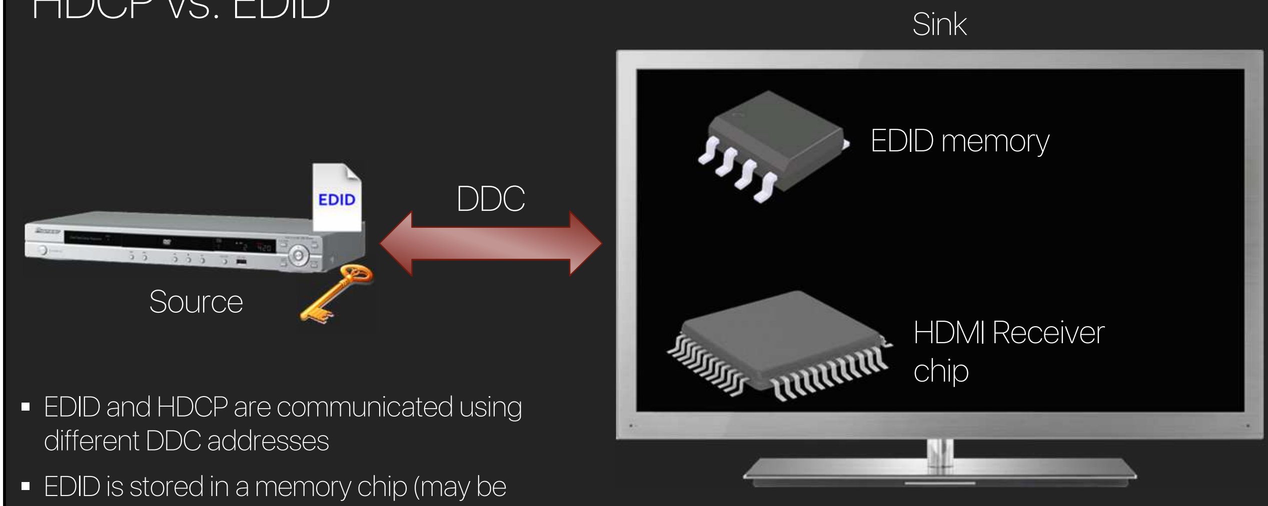
HDCP vs. EDID



- EDID and HDCP are communicated using different DDC addresses
- EDID is stored in a memory chip (may be implemented in Receiver chip)
- HDCP is a complicated handshaking process between Source and Receiver chip

EDID does not contain HDCP related information

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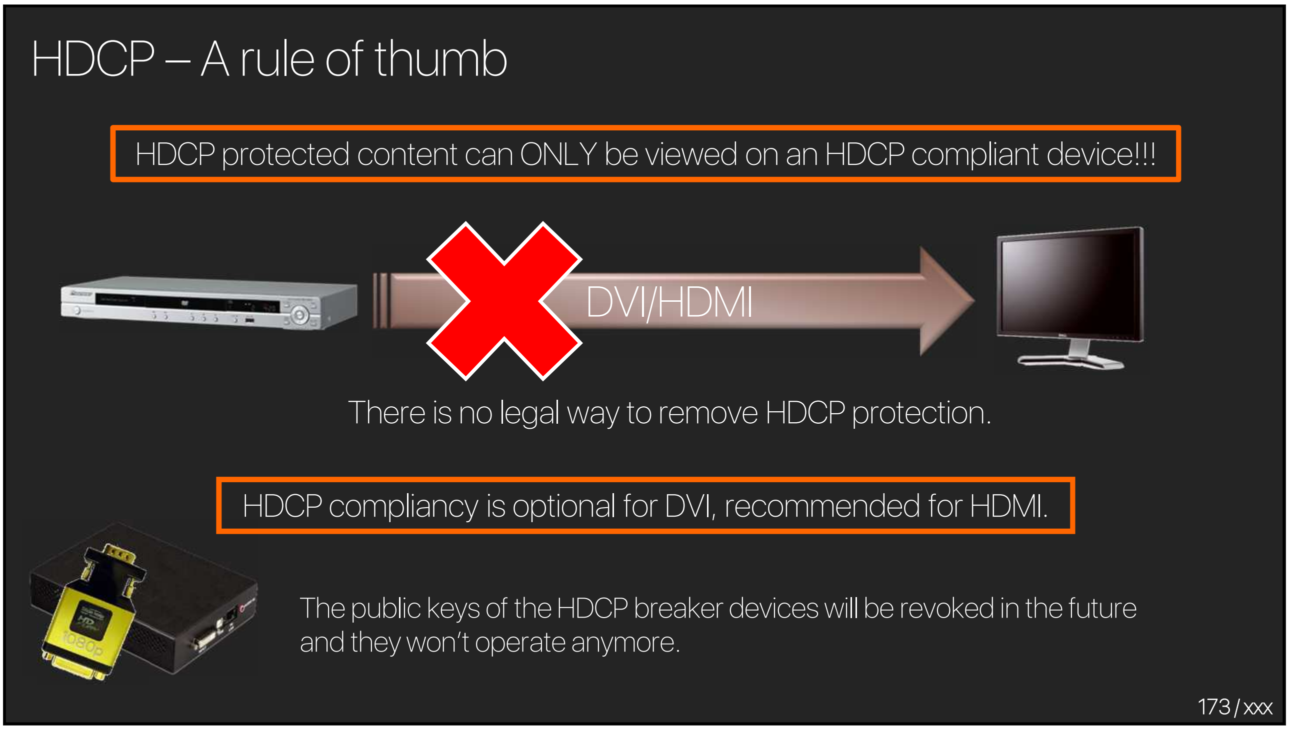
HDCP – A rule of thumb
HDCP protected content can ONLY be viewed on an HDCP compliant device!!!
DVI/HDMI
There is no legal way to remove HDCP protection.
HDCP compliancy is optional for DVI, recommended for HDMI.
The public keys of the HDCP breaker devices will be revoked in the future and they won't operate anymore.
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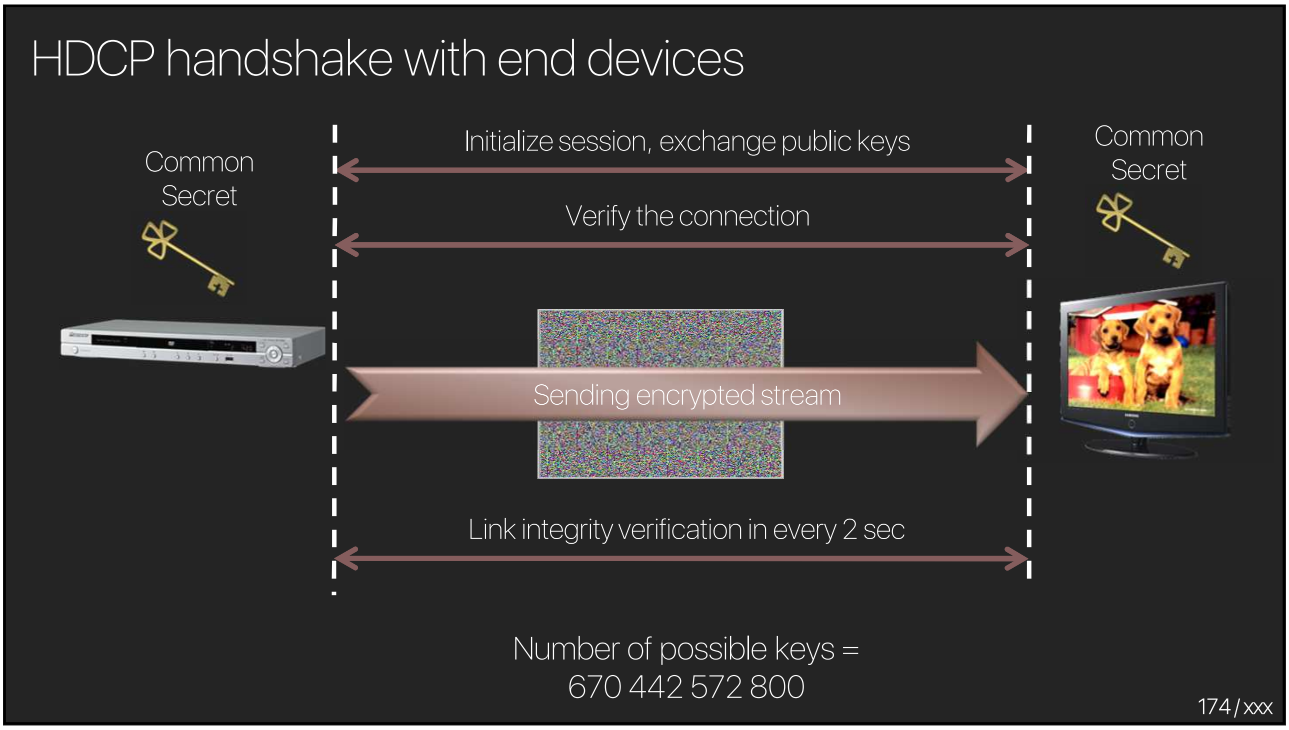
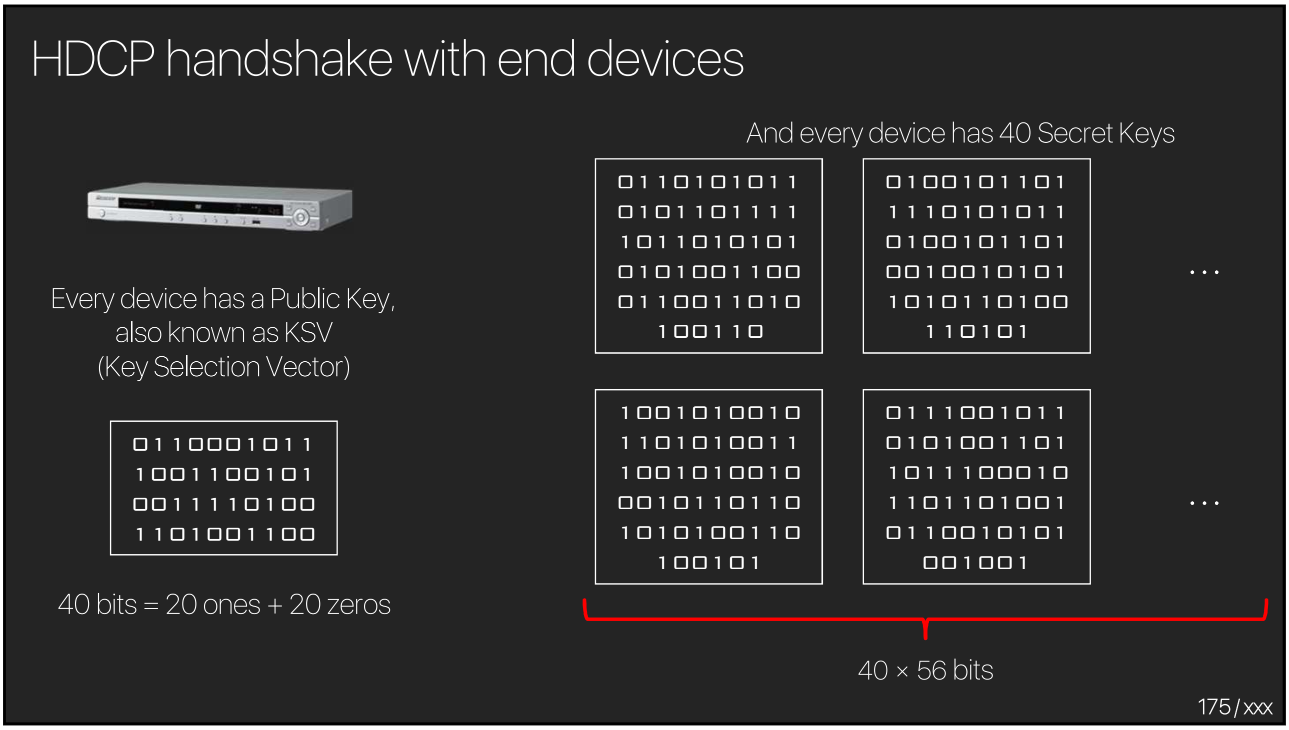

HDCP handshake with end devices
Common Secret
Initialize session, exchange public keys
Common Secret
Verify the connection
Sending encrypted stream
Link integrity verification in every 2 sec
Number of possible keys =
670 442 572 800
174 / xxx


HDCP handshake with end devices
And every device has 40 Secret Keys
Every device has a Public Key, also known as KSV (Key Selection Vector)
0110001011
1001100101
0011110100
1101001100
40 bits = 20 ones + 20 zeros
0110101011
0101101111
1011010101
0101001100
0110011010
100110
0100101101
1110101011
0100101101
0010010101
1010110100
110101
1001010010
1101010011
1001010010
0010110110
1010100110
100101
0111001011
0101001101
1011100010
1101101001
0110010101
001001
. . .
. . .
40 × 56 bits
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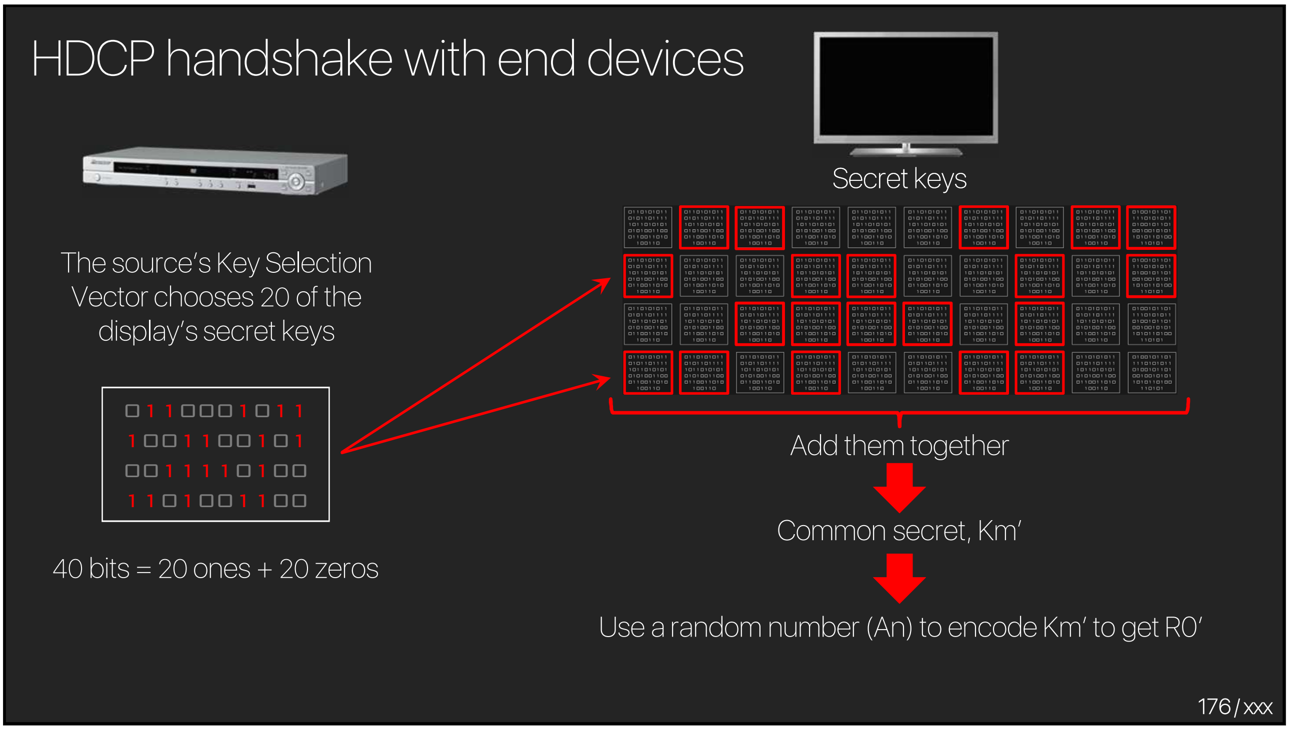
HDCP handshake with end devices
Secret keys
The source's Key Selection Vector chooses 20 of the display's secret keys
0110001011
1001100101
0011110100
1101001100
40 bits = 20 ones + 20 zeros
Add them together
Common secret, Km'
Use a random number (An) to encode Km' to get R0'
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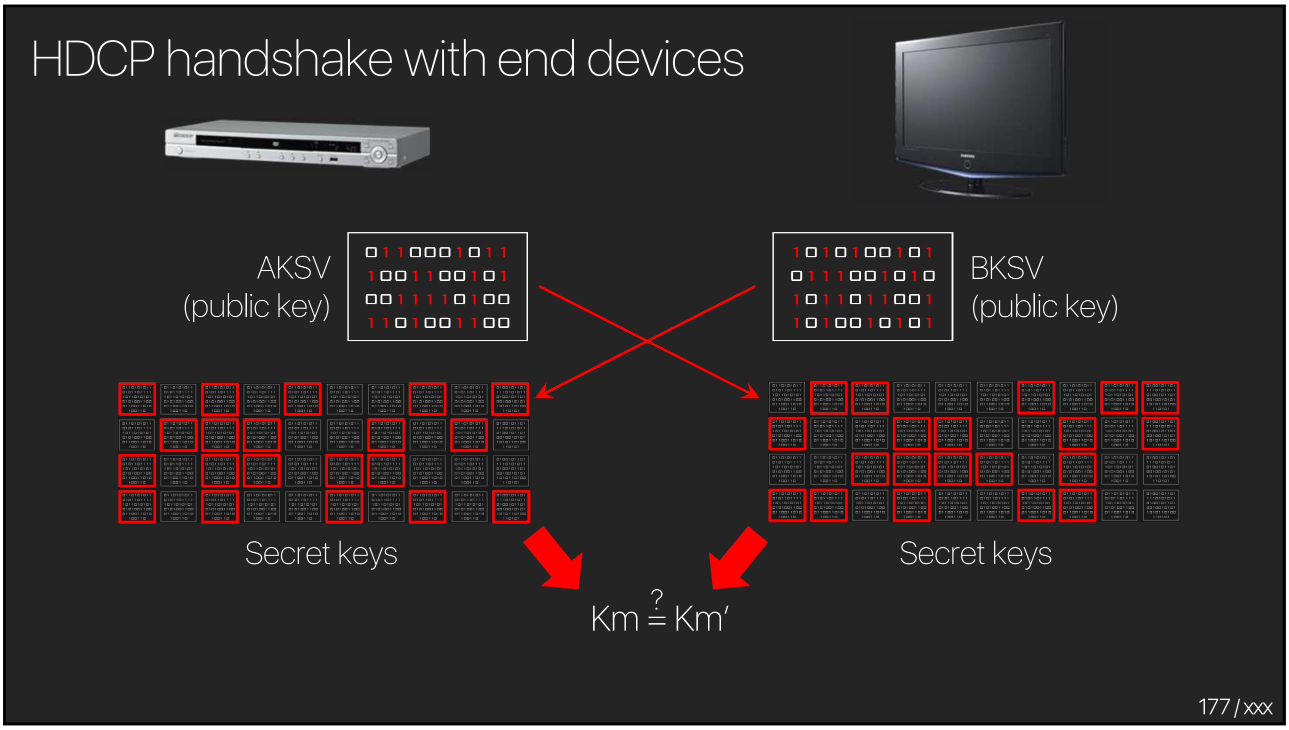
HDCP handshake with end devices
AKSV
(public key)
BKSV
(public key)
Secret keys
Secret keys
Km ≟ Km'
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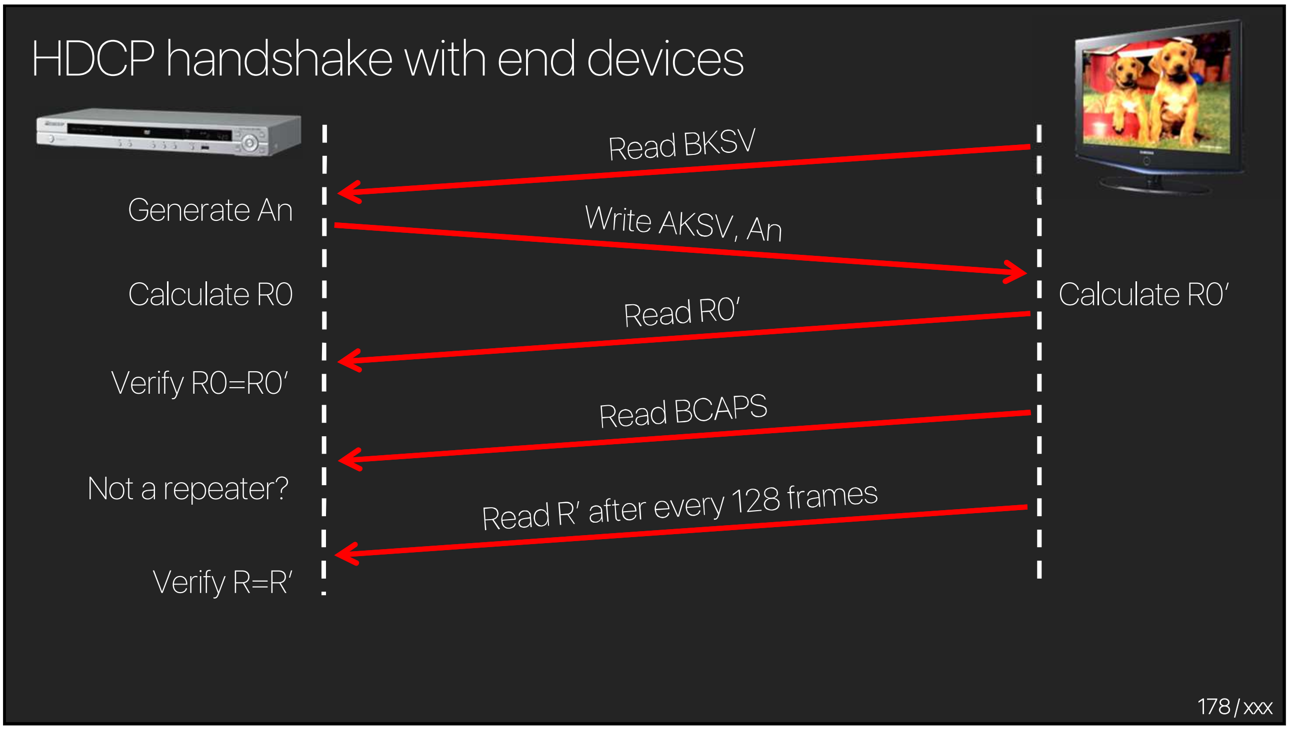
HDCP handshake with end devices
Read BKSV
Generate An
Write AKSV, An
Calculate R0
Calculate R0'
Read R0'
Verify R0=R0'
Read BCAPS
Not a repeater?
Read R' after every 128 frames
Verify R=R'
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BCAPS and repeaters

- BCAPS = B device capabilities, 8-bit register
- Can B device communicate at 400 kbit/s?
- Is B device a repeater? (1 bit, called repeater bit)
- If repeater, is the KSV list ready?

A Repeater is a device that decodes and re-encodes an HDCP encrypted signal and sends it to one or multiple destinations. For example matrices, distribution amplifiers, switchers, signal processors, etc.

Cable extenders are not always repeaters!

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HDCP snowing

- K and K' are re-calculated after each frame.
- If one of the devices makes an calculation error, then the common secrets won't match, which means the signal cannot be decoded, this is when you see snowing.
- The source reads R' after every 128th frame.
- The snowing should disappear after 128 frames.

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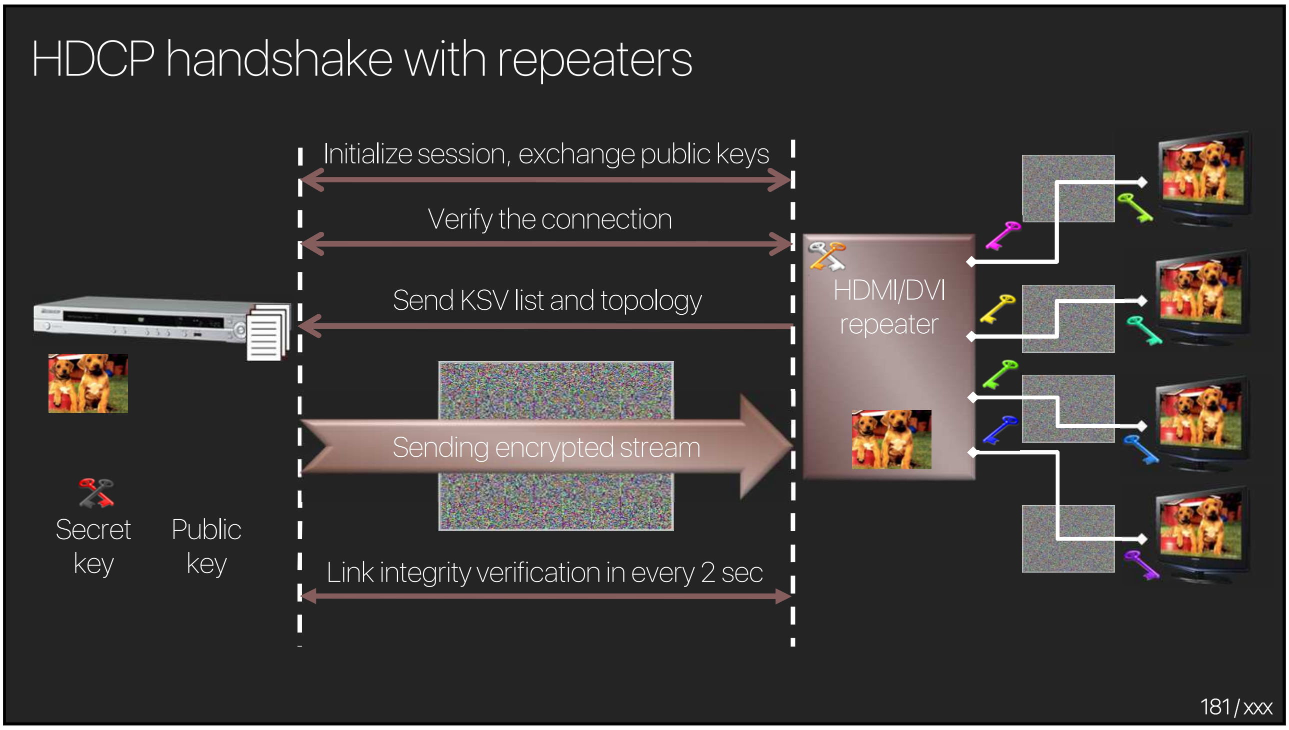
HDCP handshake with repeaters
Initialize session, exchange public keys
Verify the connection
Send KSV list and topology
Sending encrypted stream
Link integrity verification in every 2 sec
HDMI/DVI repeater
Secret key
Public key
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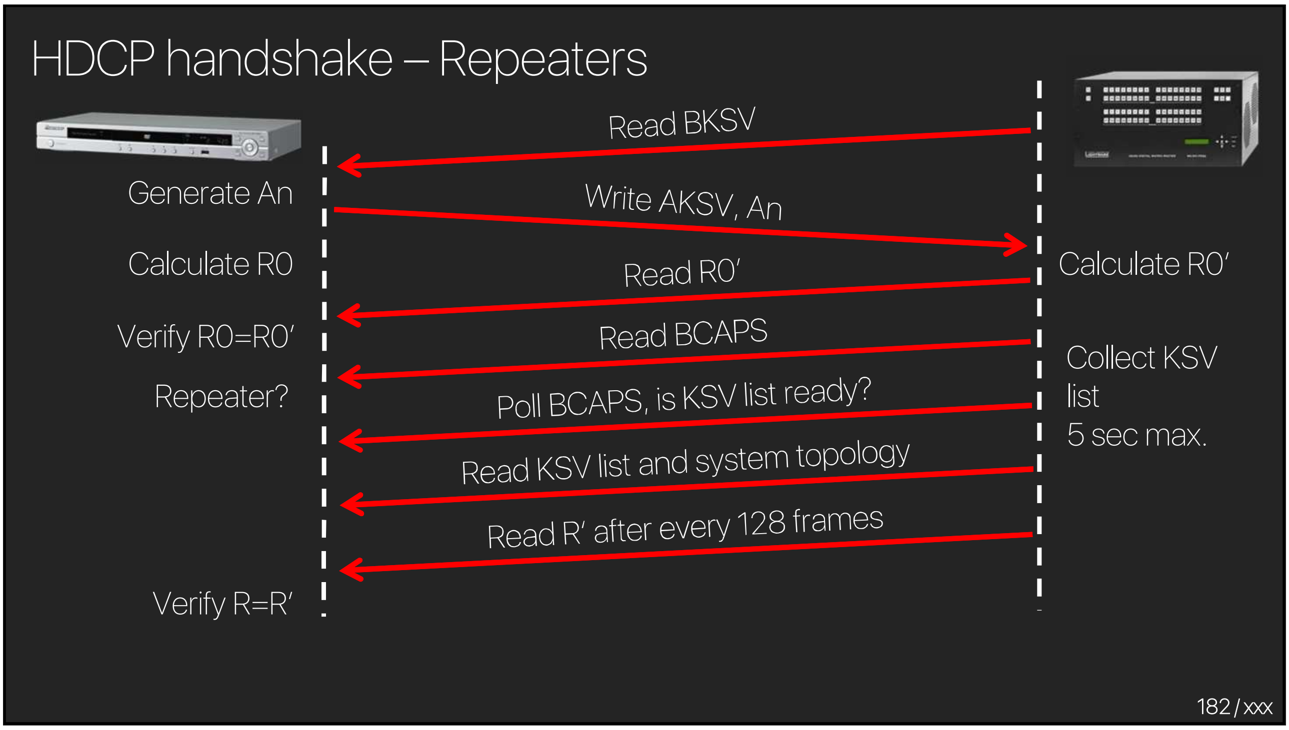
HDCP handshake – Repeaters
Read BKSV
Generate An
Write AKSV, An
Calculate R0
Calculate R0'
Read R0'
Verify R0=R0'
Read BCAPS
Collect KSV list
5 sec max.
Repeater?
Poll BCAPS, is KSV list ready?
Read KSV list and system topology
Read R' after every 128 frames
Verify R=R'
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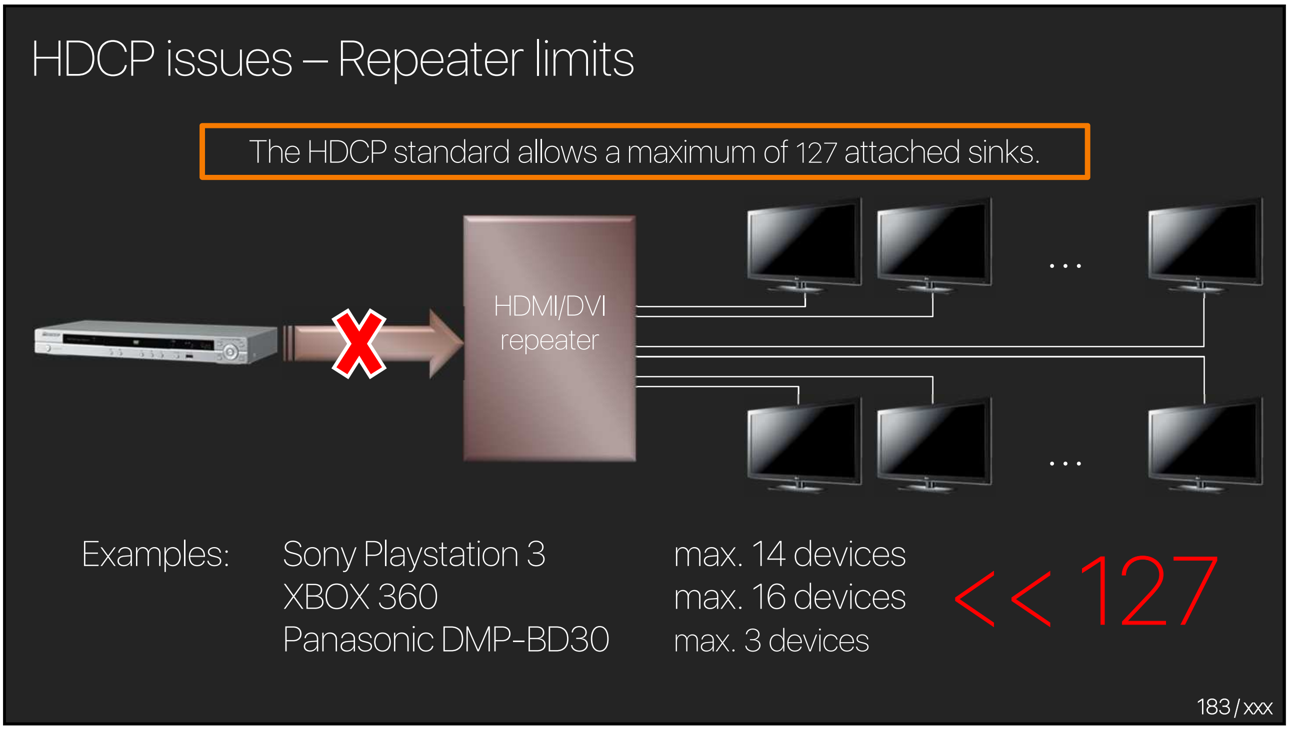
HDCP issues – Repeater limits
The HDCP standard allows a maximum of 127 attached sinks.
HDMI/DVI repeater
. . .
. . .
Examples:
Sony Playstation 3
XBOX 360
Panasonic DMP-BD30
max. 14 devices
max. 16 devices
max. 3 devices
<< 127
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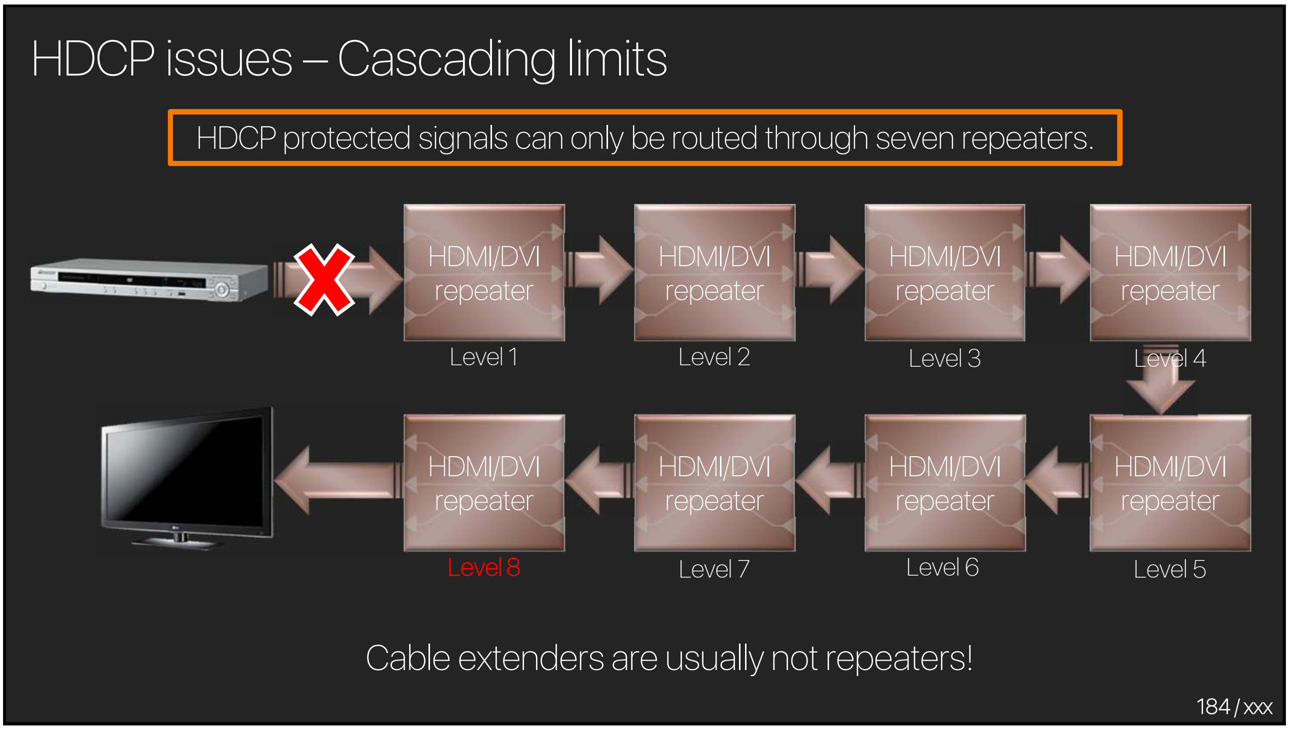
HDCP issues – Cascading limits
HDCP protected signals can only be routed through seven repeaters.
HDMI/DVI repeater
Level 1
HDMI/DVI repeater
Level 2
HDMI/DVI repeater
Level 3
HDMI/DVI repeater
Level 4
HDMI/DVI repeater
Level 8
HDMI/DVI repeater
Level 7
HDMI/DVI repeater
Level 6
HDMI/DVI repeater
Level 5
Cable extenders are usually not repeaters!
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HDCP issues – Revoking list
A compromised device affects the whole system.
Revocation list
HDMI/DVI repeater
Compromised device
Revocation list is distributed on DVD and BluRay discs.
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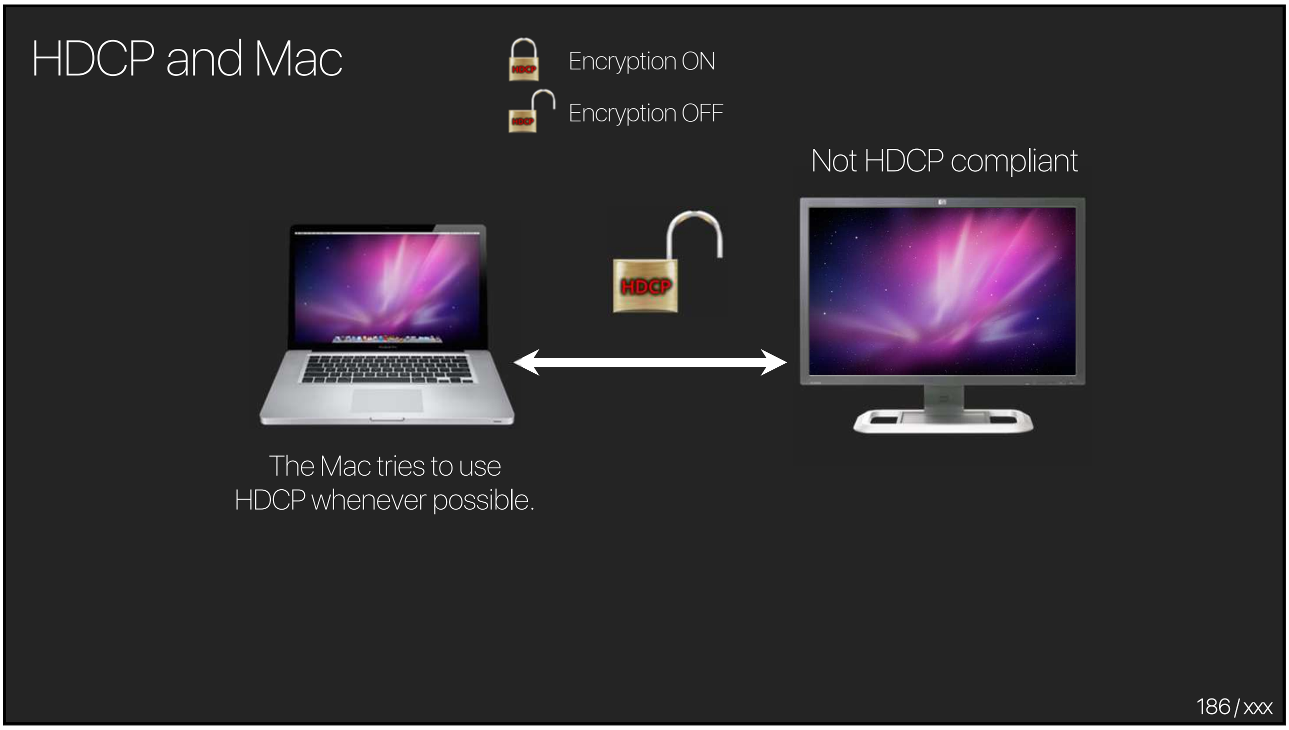
HDCP and Mac
Encryption ON
Encryption OFF
Not HDCP compliant
HDCP
The Mac tries to use HDCP whenever possible.
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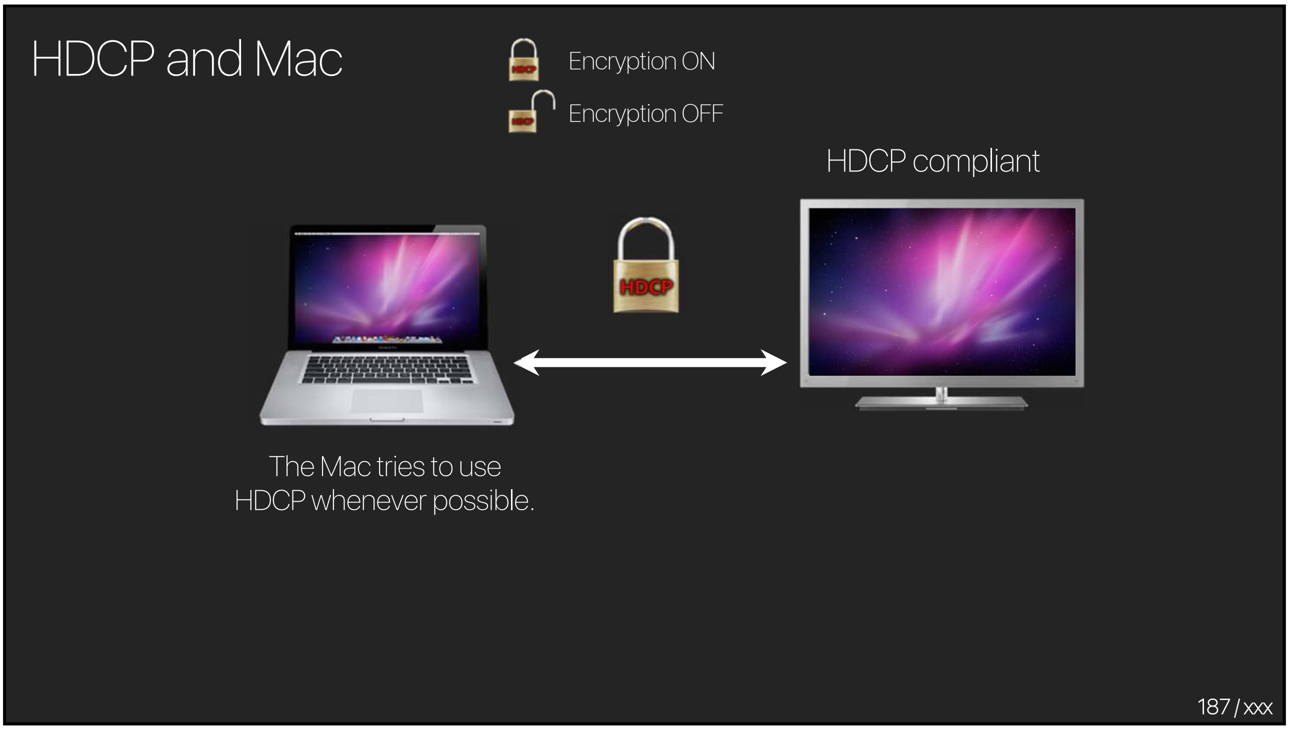
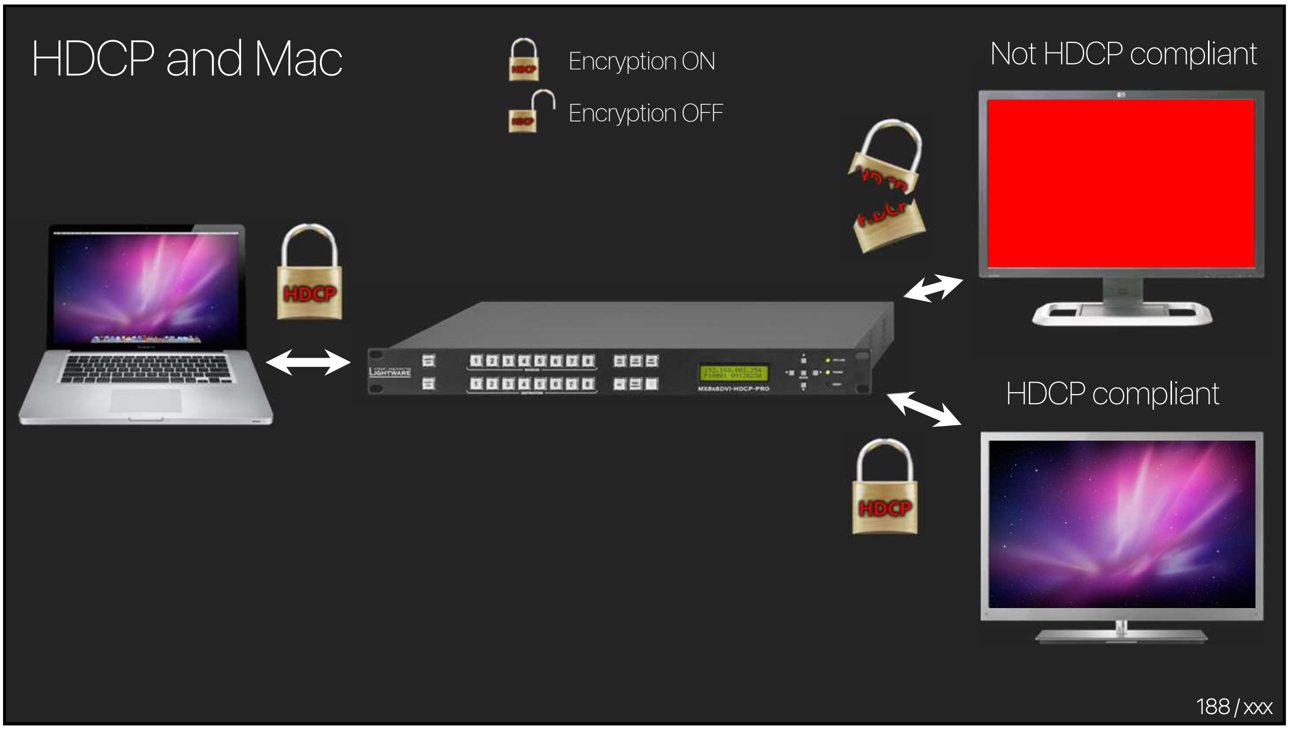

HDCP and Mac
Encryption ON
Encryption OFF
HDCP compliant
HDCP
The Mac tries to use
HDCP whenever possible.
187 / xxx


HDCP and Mac
Encryption ON
Encryption OFF
Not HDCP compliant
HDCP
HDCP compliant
HDCP
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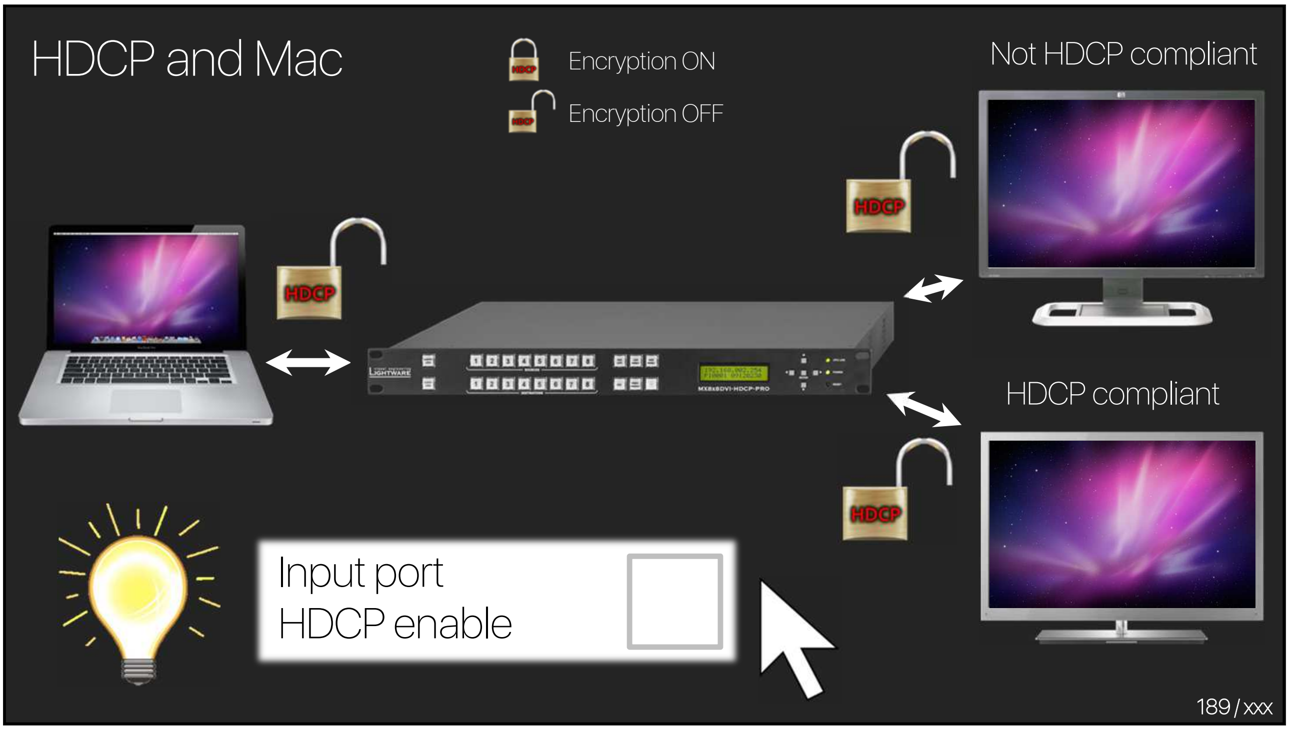
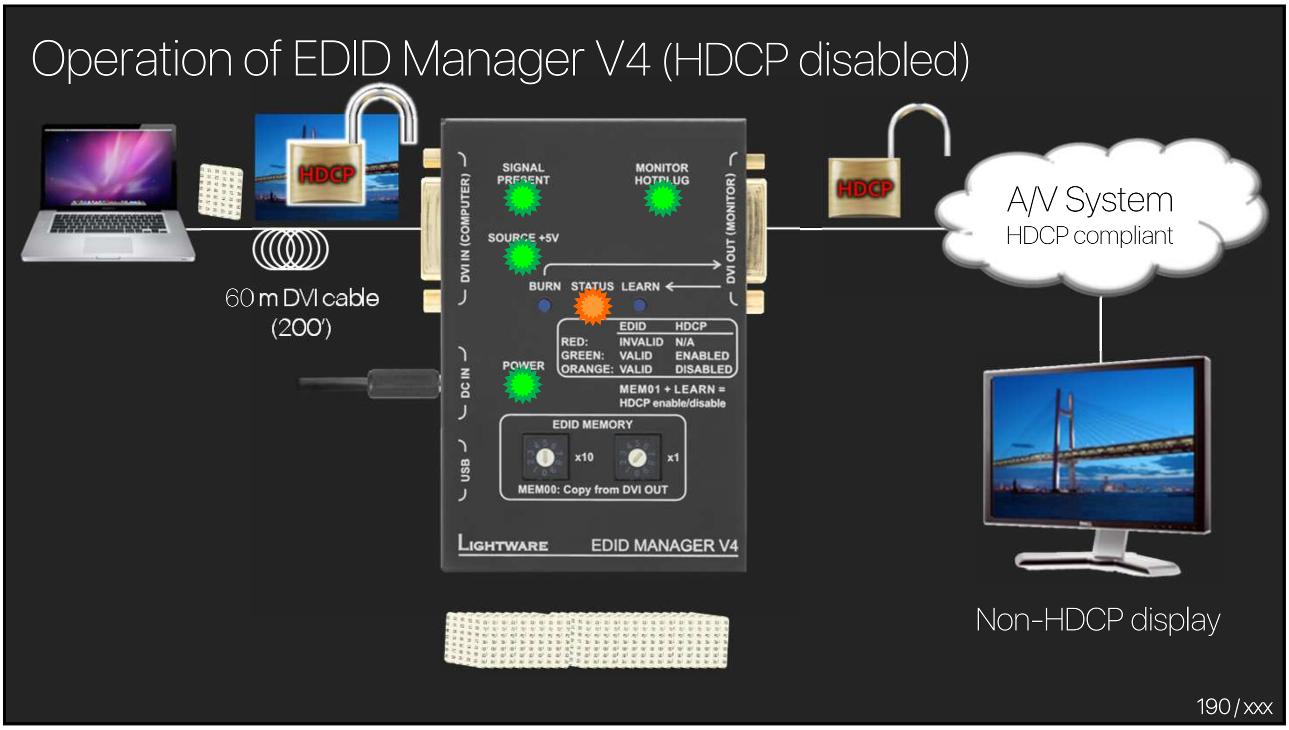

HDCP and Mac
Encryption ON
Encryption OFF
Not HDCP compliant
HDCP compliant
Input port
HDCP enable
189 / xxx


Operation of EDID Manager V4 (HDCP disabled)
60 m DVI cable
(200')
A/V System
HDCP compliant
Non-HDCP display
SIGNAL PRESENT
MONITOR HOTPLUG
SOURCE +5V
BURN
STATUS
LEARN
EDID
HDCP
RED: INVALID N/A
GREEN: VALID ENABLED
ORANGE: VALID DISABLED
MEM01 + LEARN = HDCP enable/disable
POWER
EDID MEMORY
MEM00: Copy from DVI OUT
EDID MANAGER V4
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Most common HDCP problems and possible reasons

Problem	Possible reason
No image	Non-compliant display Non-compliant device in the signal chain Compromised device in the signal chain Too many KSVs are reported to the source Too many levels in the HDCP device tree
Periodic Snowy Image	Unstable DDC connection Too long or too low quality cable UTP cable and ambient electromagnetic noise
Red (or any color) image	Intelligent repeater indicating HDCP error (non-compliant display or failed authentication)

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HDCP 1.4 master key published

In 2010 the HDCP Master Key was published

- Leaked or reverse engineered (theoretically possible).
- Intel confirmed that it is the real Master Key, but says it's irrelevant.
- Anyone can create their own HDCP keys.
- Revocation list is neutralized.

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HDCP 2.2

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What's changed?

1. XOR stream cipher 56-bit key ⇩ Standard RSA + AES algorythms
2. 31 Max. devices
3. 4 Max. levels
4. Locality check

5. Content types

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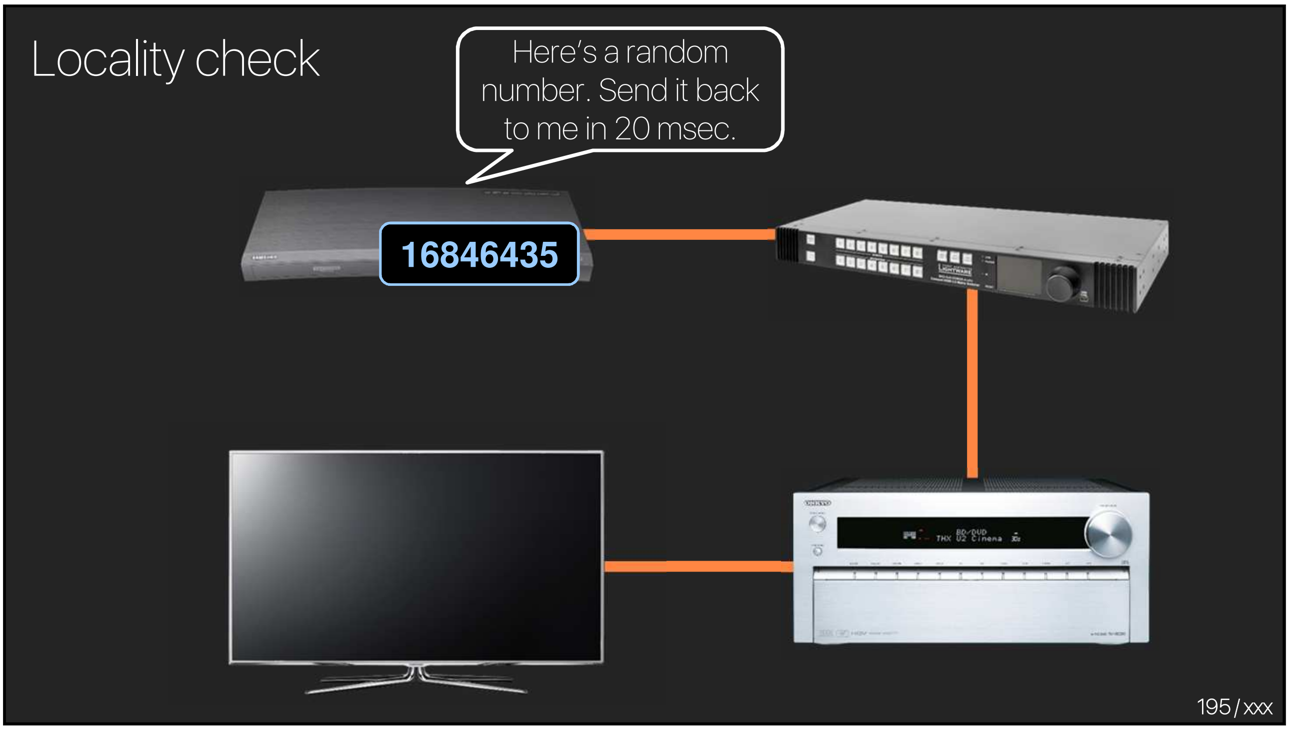
Locality check
Here's a random number. Send it back to me in 20 msec.
16846435
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Content types
HACKED
HACKED
HACKED
HDCP 2.2
Content providers demand a solution to disallow compromised versions.
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Content types

Type 0

- Any type of HDCP encryption can be used.
- The strongest possible encryption will be used.

Type 1

- ‚High Value'
- HDCP 2.2 must be used.
- Only applies to UHD content.
- 1080p is not affected.

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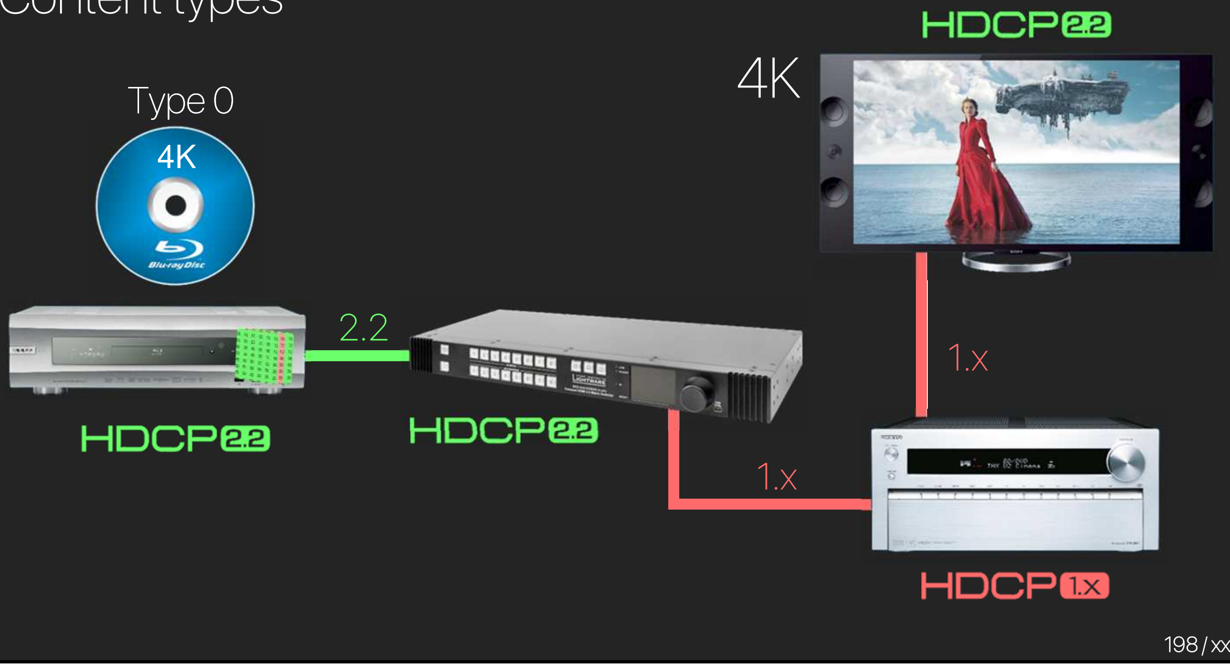
Content types



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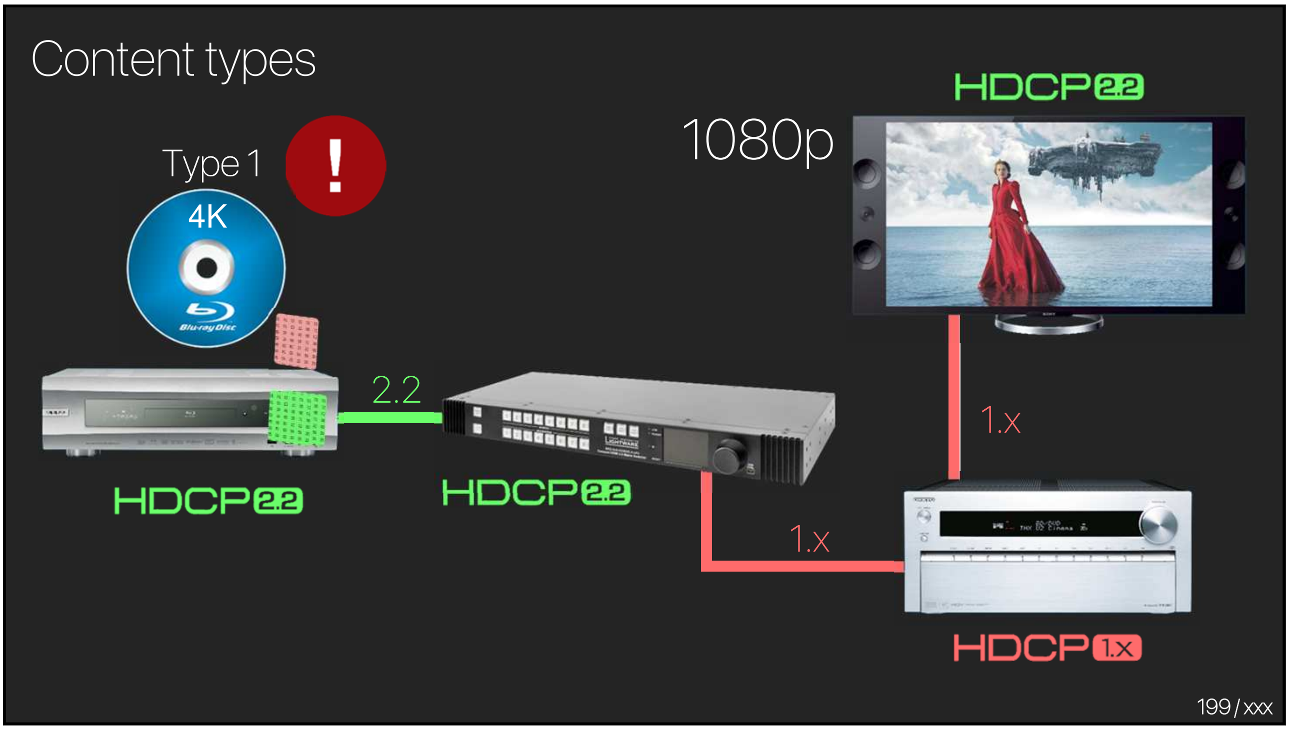
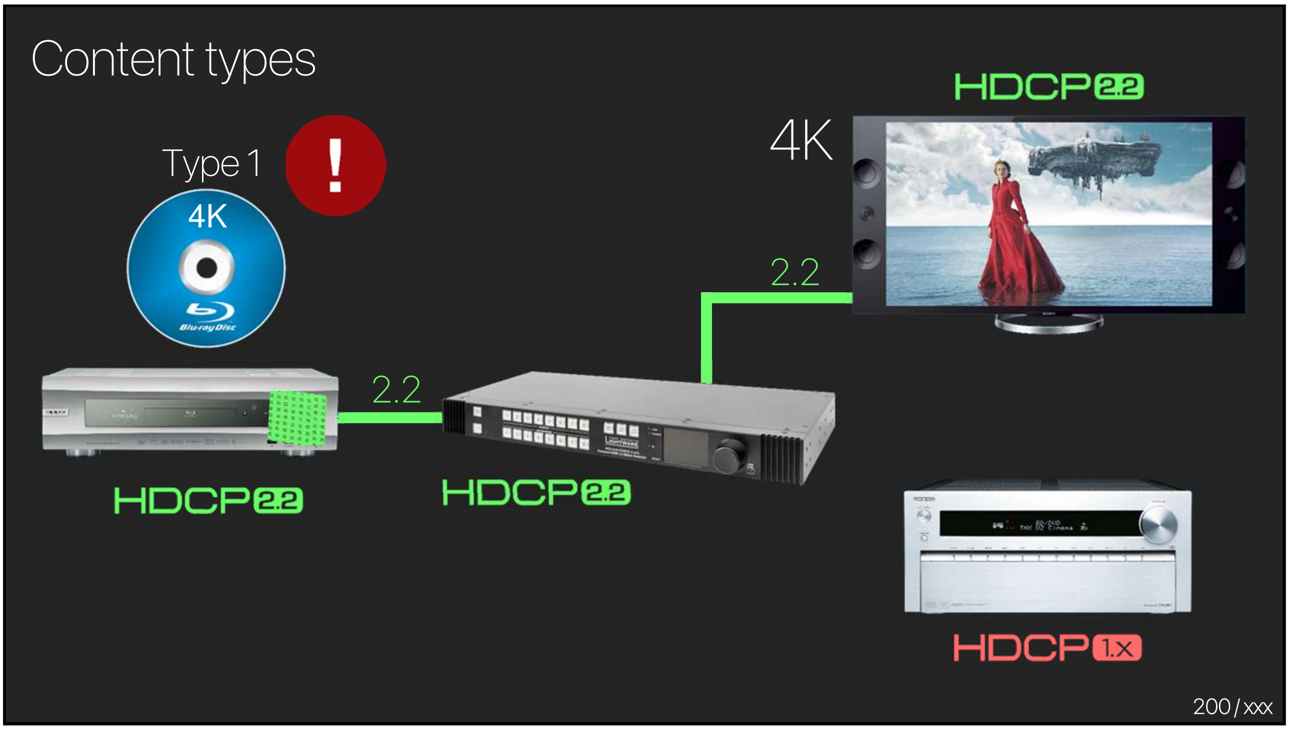
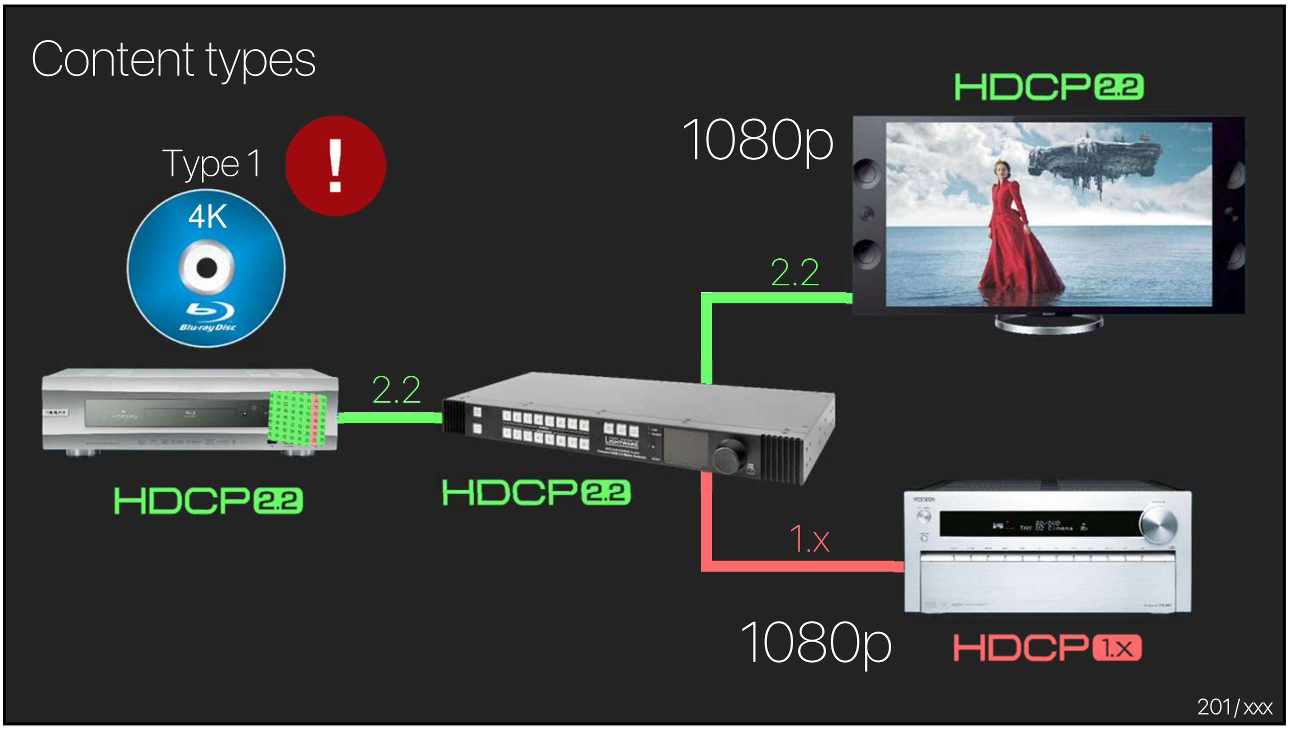
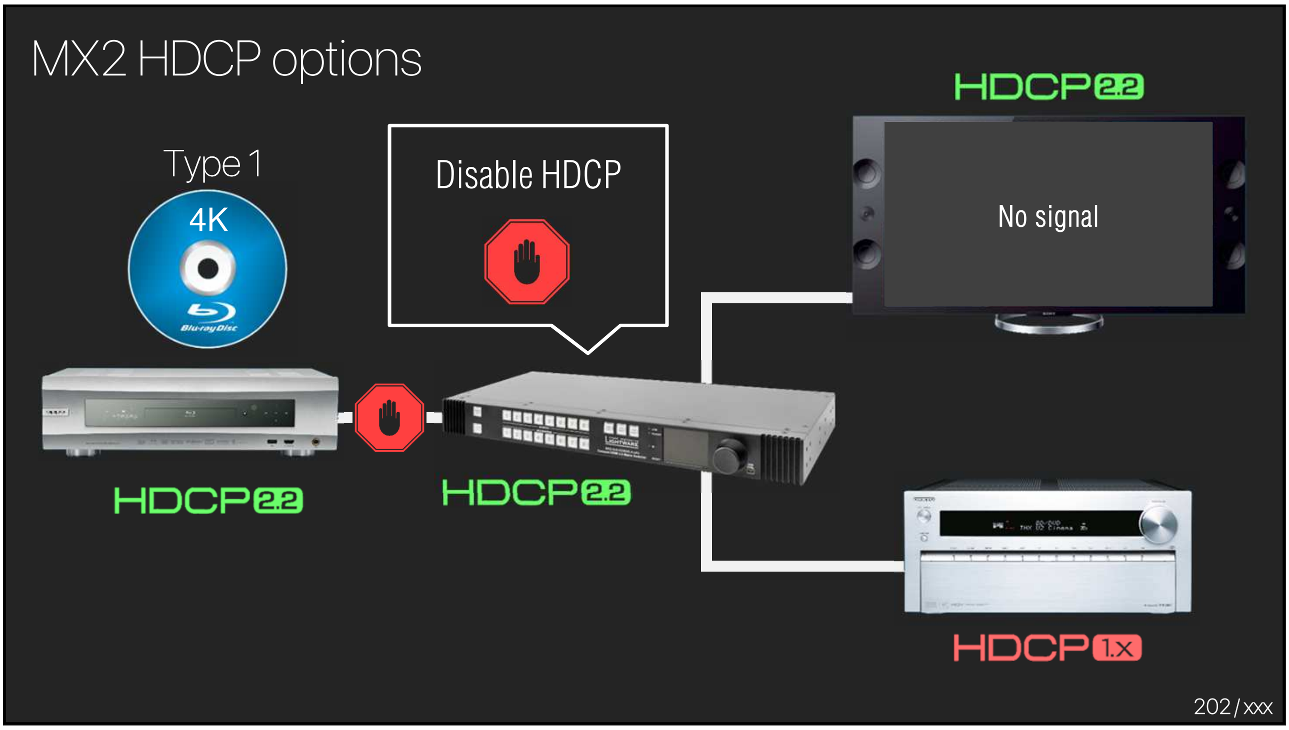
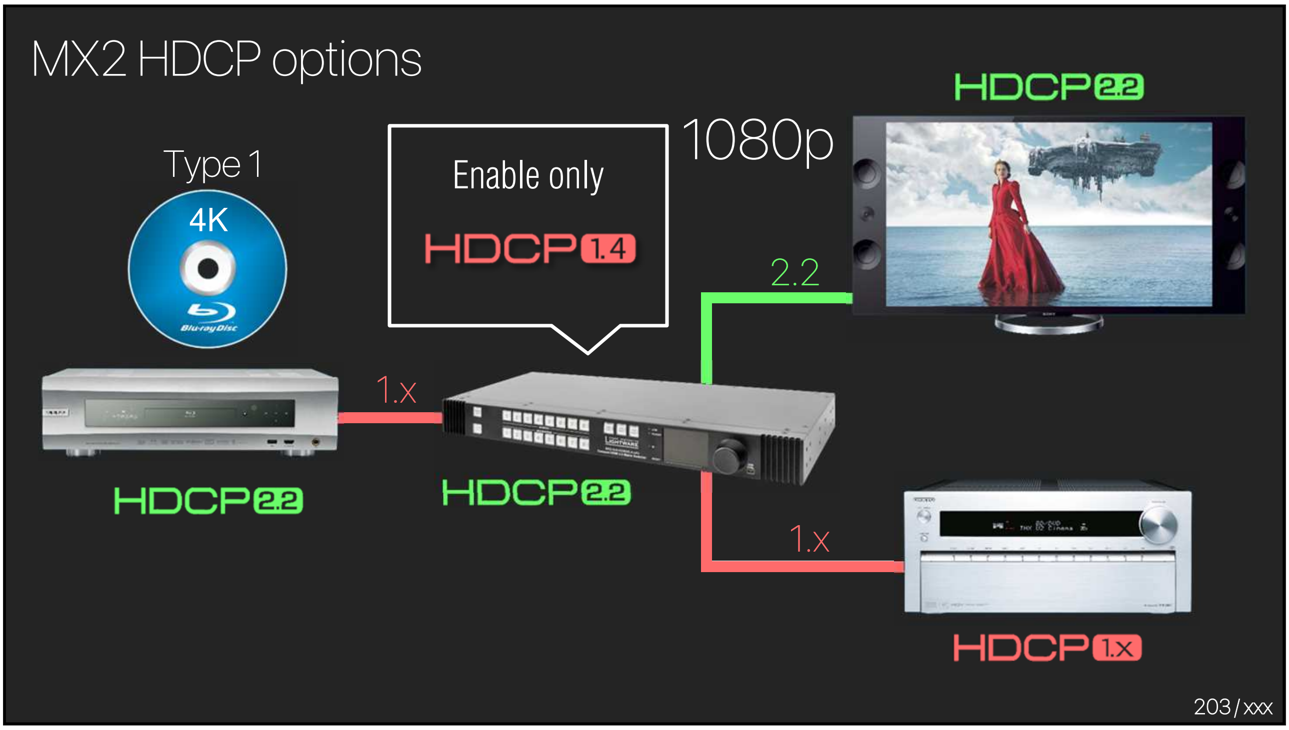
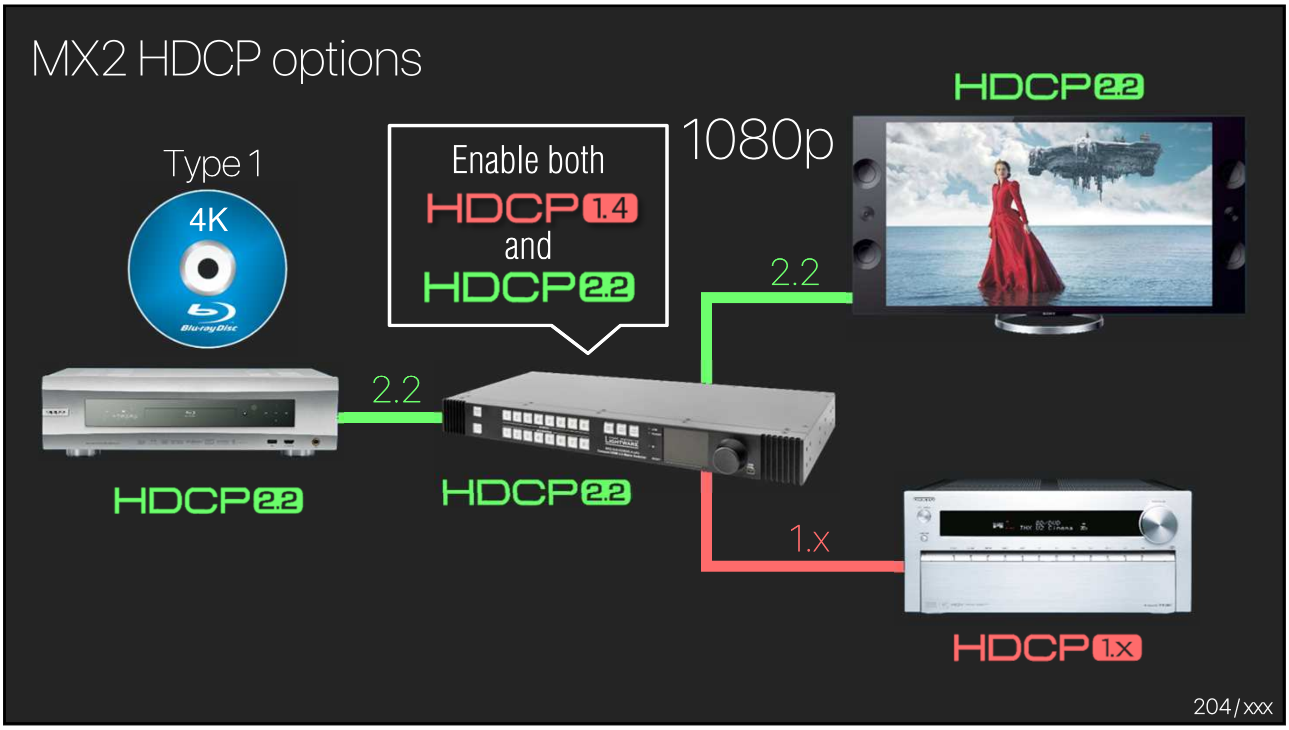

Content types
Type 1
4K
Blu-ray Disc
2.2
HDCP 2.2
HDCP 2.2
HDCP 2.2
1080p
1.x
1.x
HDCP 1.x
199 / xxx

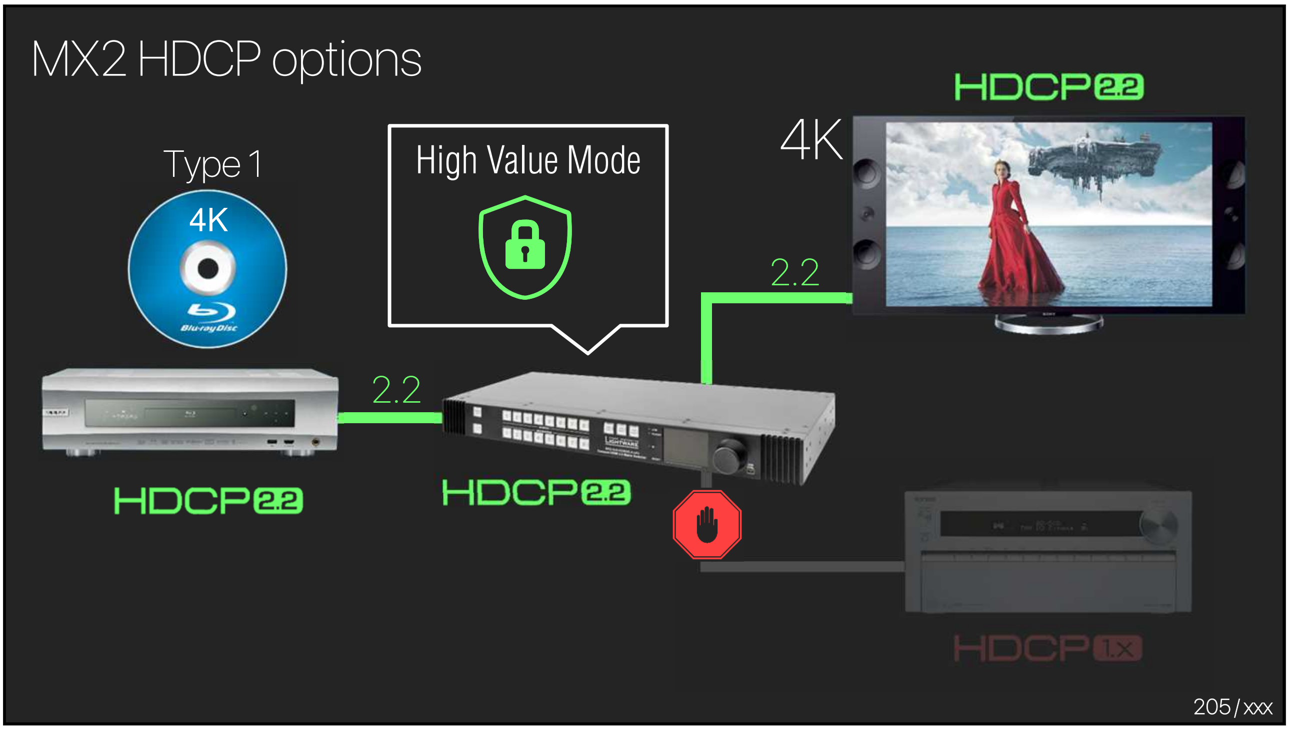

Content types
Type 1
4K
Blu-ray Disc
2.2
HDCP 2.2
HDCP 2.2
HDCP 2.2
4K
2.2
HDCP 1.x
200 / xxx


Content types
Type 1
4K
HDCP2.2
1080p
2.2
2.2
HDCP2.2
HDCP2.2
1.x
1080p
HDCP1.x
201/xxx


MX2 HDCP options
Type 1
4K
Disable HDCP
HDCP2.2
No signal
HDCP2.2
HDCP2.2
HDCP1.x
202/xxx


MX2 HDCP options
Type 1
4K
Blu-ray Disc
Enable only
HDCP 1.4
1080p
HDCP 2.2
2.2
1.x
HDCP 2.2
HDCP 2.2
1.x
HDCP 1.x
203 / xxx


MX2 HDCP options
Type 1
4K
Blu-ray Disc
Enable both
HDCP 1.4
and
HDCP 2.2
1080p
HDCP 2.2
2.2
2.2
HDCP 2.2
HDCP 2.2
1.x
HDCP 1.x
204 / xxx


MX2 HDCP options
Type 1
4K
High Value Mode
4K
HDCP 2.2
2.2
2.2
HDCP 2.2
HDCP 2.2
HDCP 1.X
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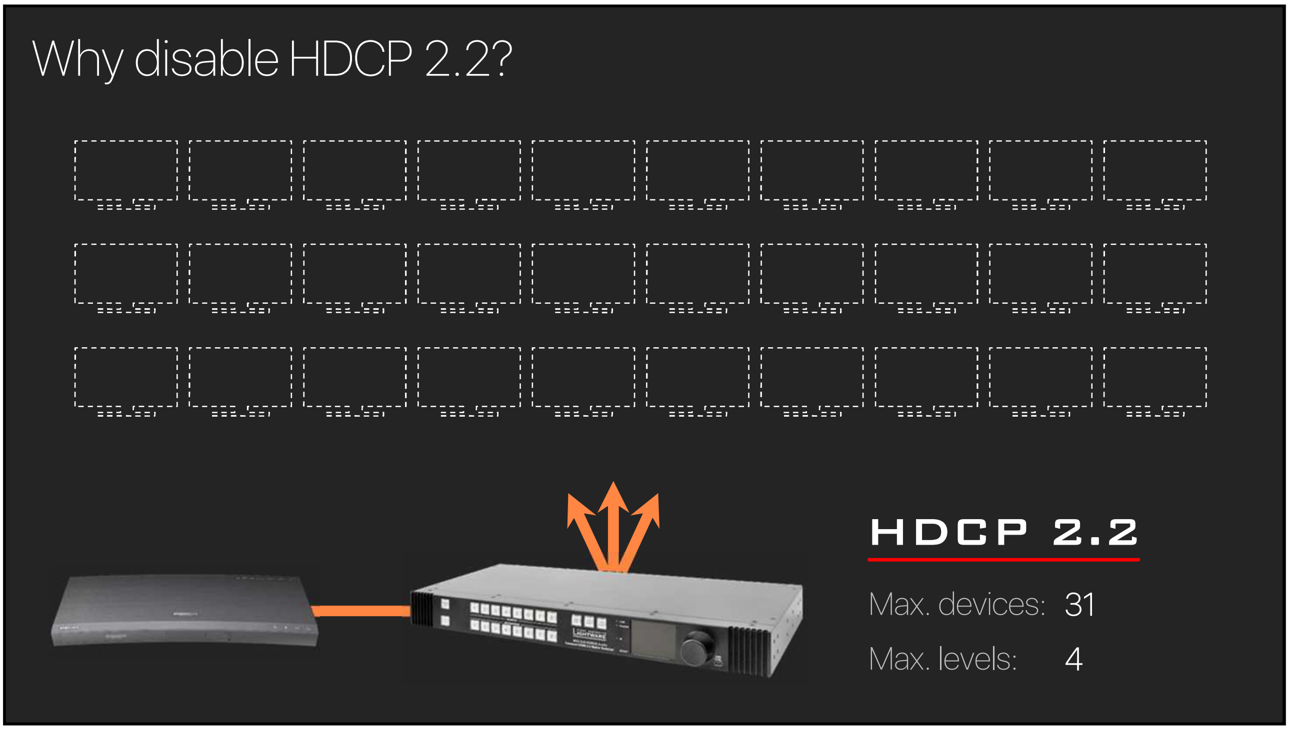
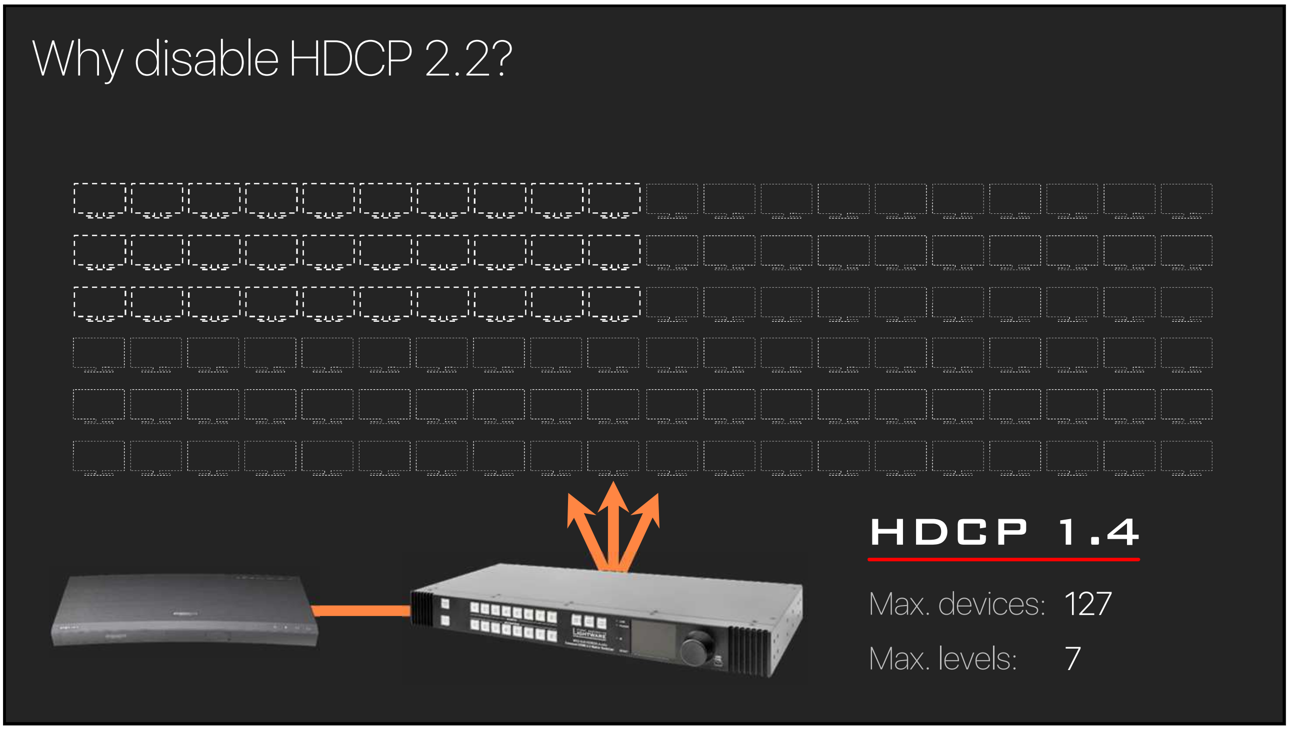
Content types
HDMI 2.0 ≠ HDCP 2.2
Some early* UHD displays are not HDCP 2.2 compliant.
*mostly manufactured before 2014
These might not work with Type 1 content.


Why disable HDCP 2.2?
HDCP 2.2
Max. devices: 31
Max. levels: 4


Why disable HDCP 2.2?
HDCP 1.4
Max. devices: 127
Max. levels: 7

Cables & Connectors

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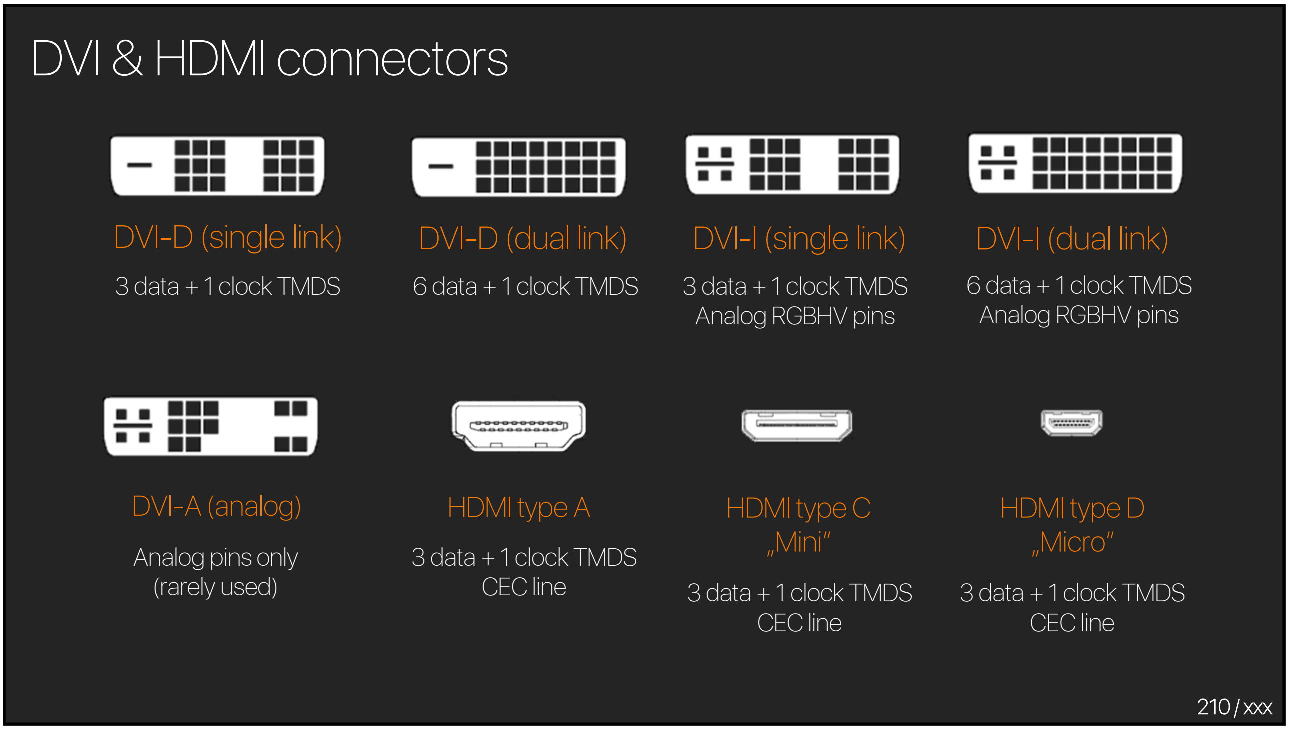
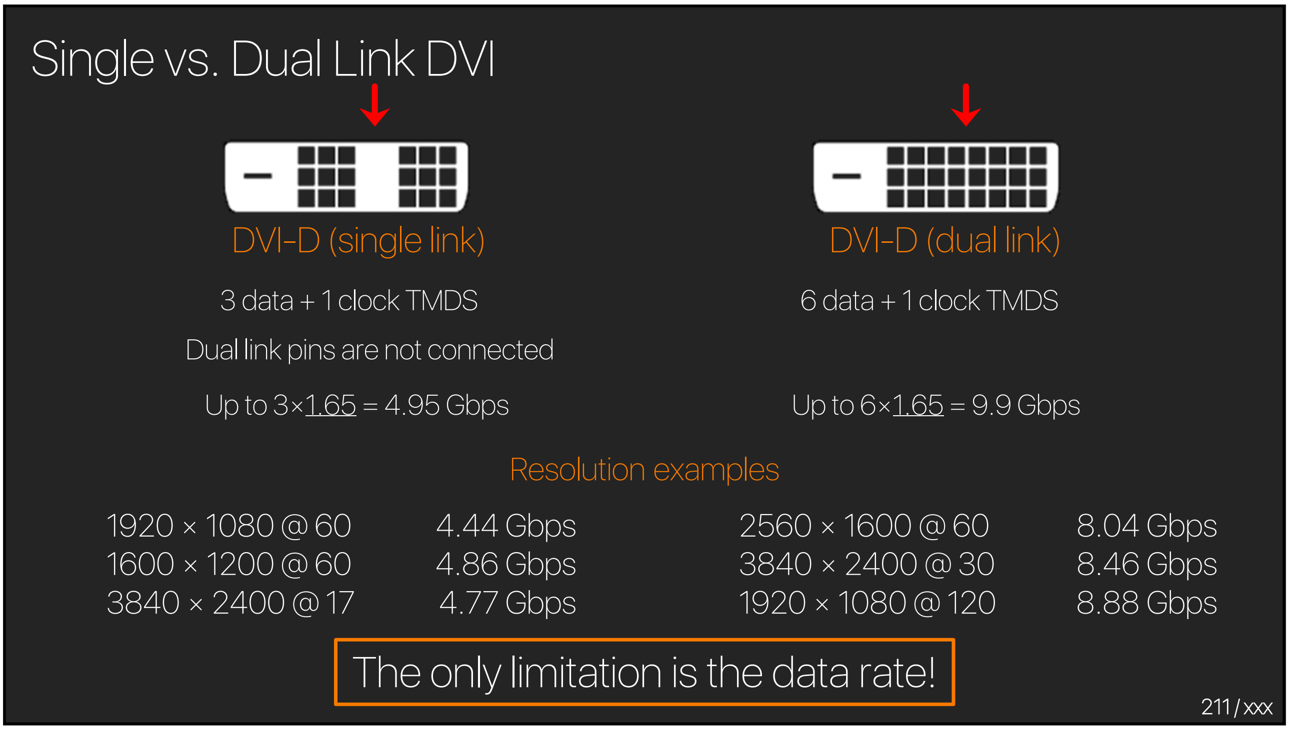
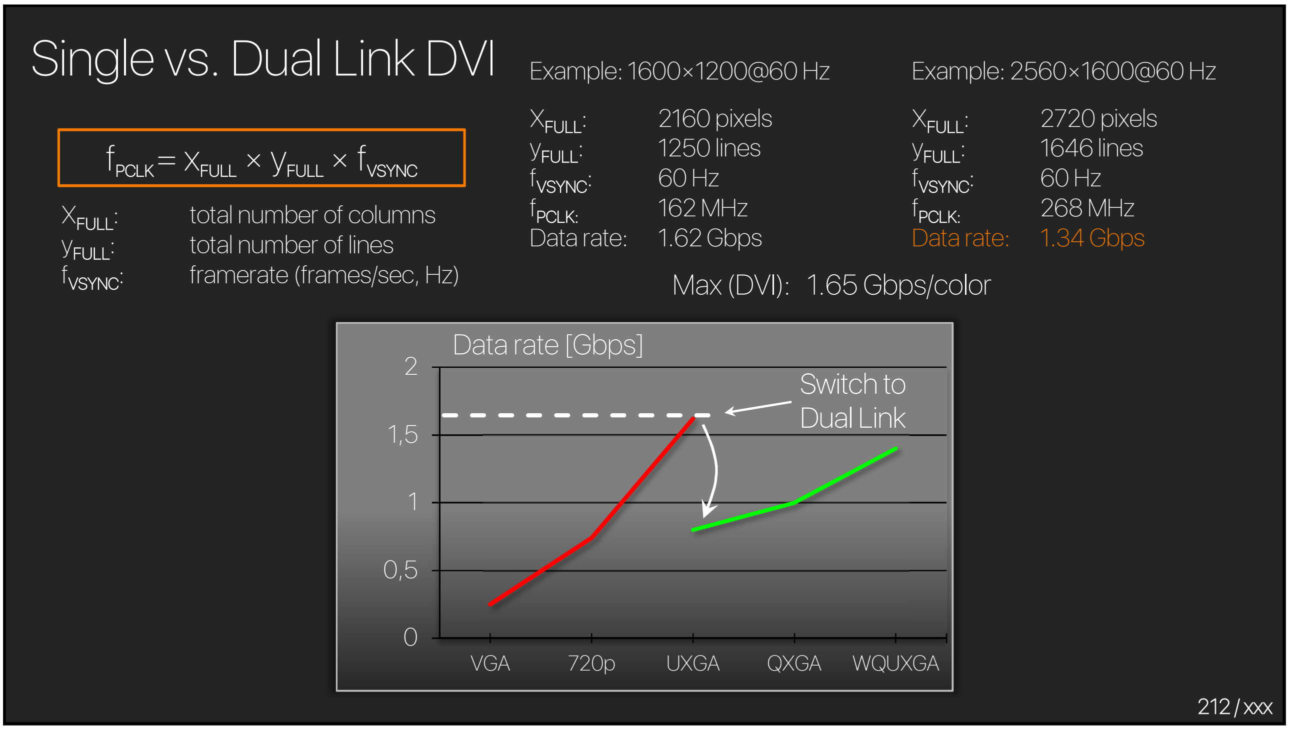
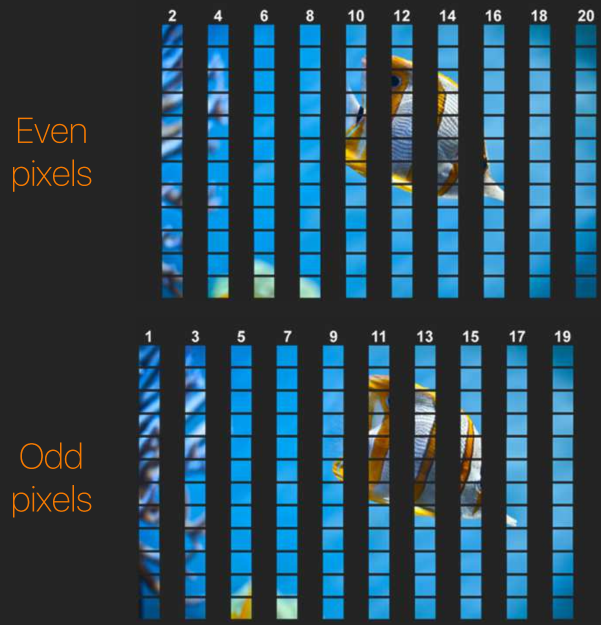



Single vs. Dual Link DVI
DVI-D (single link)
3 data + 1 clock TMDS
Dual link pins are not connected
Up to 3×1.65 = 4.95 Gbps
DVI-D (dual link)
6 data + 1 clock TMDS
Up to 6×1.65 = 9.9 Gbps
Resolution examples
1920 × 1080 @ 60 4.44 Gbps
1600 × 1200 @ 60 4.86 Gbps
3840 × 2400 @ 17 4.77 Gbps
2560 × 1600 @ 60 8.04 Gbps
3840 × 2400 @ 30 8.46 Gbps
1920 × 1080 @ 120 8.88 Gbps
The only limitation is the data rate!
211 / xxx


Single vs. Dual Link DVI
$f_{PCLK} = X_{FULL} \times y_{FULL} \times f_{VSYNC}$
X_{FULL}: total number of columns
y_{FULL}: total number of lines
f_{VSYNC}: framerate (frames/sec, Hz)
Example: 1600×1200@60 Hz
X_{FULL}: 2160 pixels
y_{FULL}: 1250 lines
f_{VSYNC}: 60 Hz
f_{PCLK}: 162 MHz
Data rate: 1.62 Gbps
Example: 2560×1600@60 Hz
X_{FULL}: 2720 pixels
y_{FULL}: 1646 lines
f_{VSYNC}: 60 Hz
f_{PCLK}: 268 MHz
Data rate: 1.34 Gbps
Max (DVI): 1.65 Gbps/color
Data rate [Gbps]
2
1,5
1
0,5
0
Switch to Dual Link
VGA
720p
UXGA
QXGA
WQUXGA
212 / xxx

Dual Link transmission

- Doubles the number of wire pairs to double the maximum bandwidth
- 6 TMDS wire pairs carry color information, 1 TMDS wire pair carries the clock
- The „Single Link" wire pairs carry the odd pixels
- The „Dual Link" wire pairs carry the even pixels



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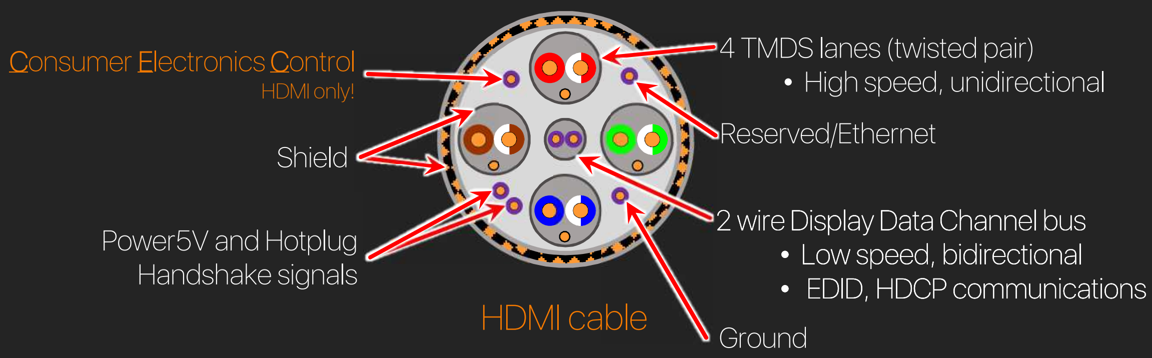
DVI & HDMI cables



There is no seperate wire for audio!
Audio is EMBEDDED

AWG: American Wire Gauge

- Lower is thicker
- Thicker is better

Typical values:

- 24 AWG
- 22 AWG

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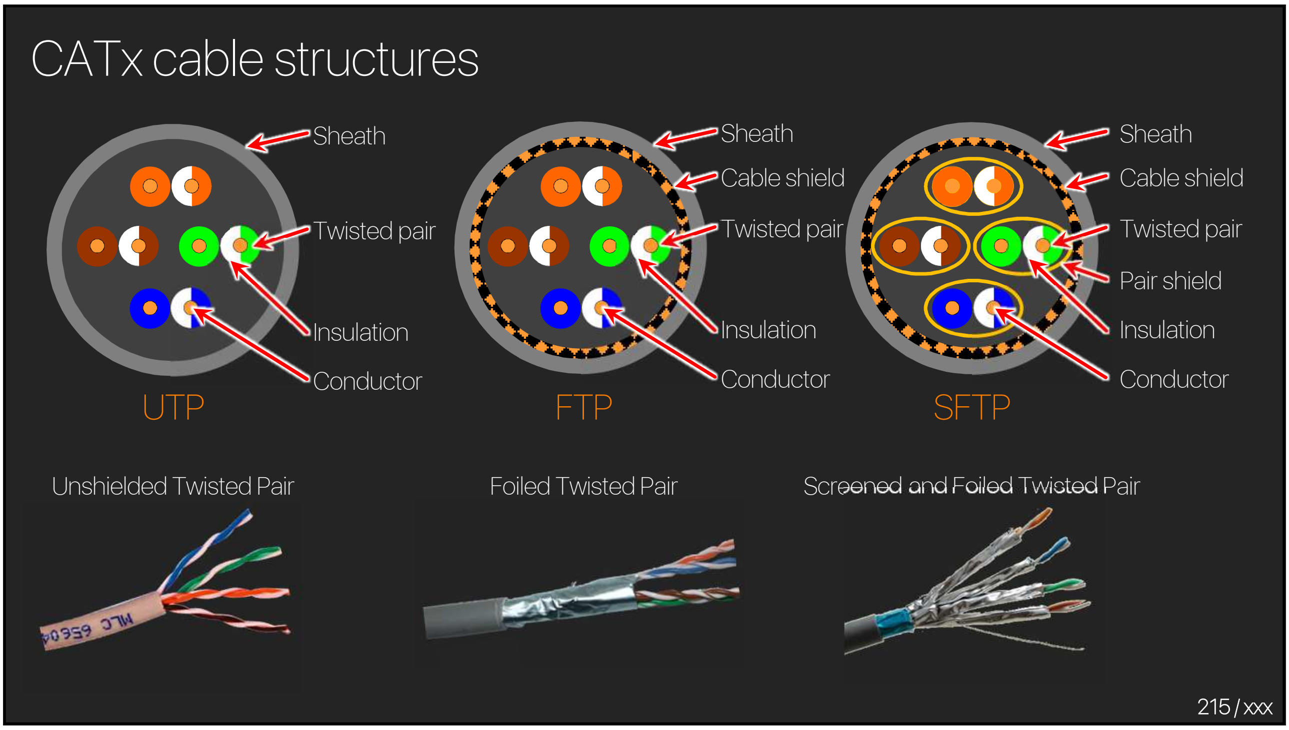
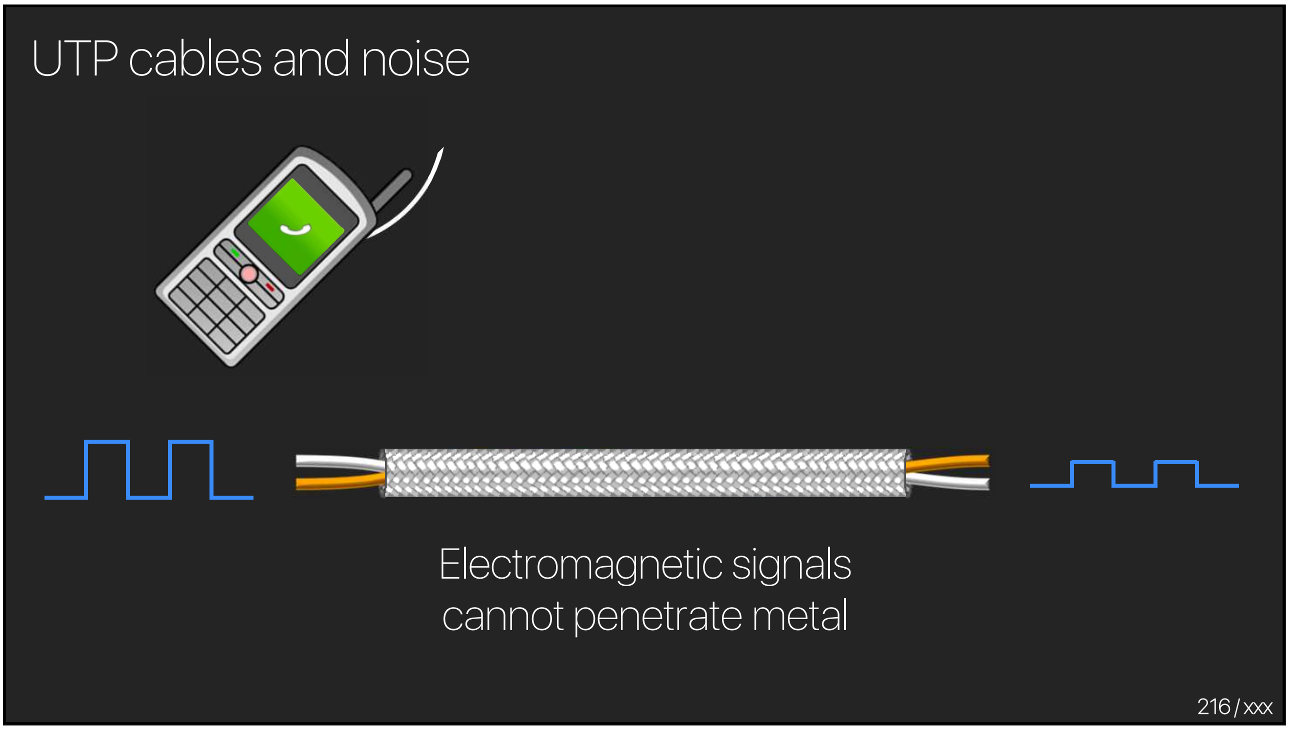

CATx cable structures
Sheath
Twisted pair
Insulation
Conductor
UTP
Sheath
Cable shield
Twisted pair
Insulation
Conductor
FTP
Sheath
Cable shield
Twisted pair
Pair shield
Insulation
Conductor
SFTP
Unshielded Twisted Pair
Foiled Twisted Pair
Screened and Foiled Twisted Pair
215 / xxx


UTP cables and noise
Electromagnetic signals
cannot penetrate metal
216 / xxx

CATx categories

Specification	Cat5	Cat5e	Cat6	Cat6a	Cat7	Cat7a
Type	UTP / FTP	UTP / FTP	UTP / FTP / SFTP	FTP / SFTP	SFTP	SFTP
Frequency	100 MHz	100 MHz	250 MHz	500 MHz	600 MHz	1000 MHz
Attenuation (at 100MHz)	24 dB	24 dB	21.7 dB	18.4 dB	18.4 dB	17 dB
Far end crosstalk	N/A	-27.1 dB	-42.3 dB	-59.1 dB	-59.1 dB	-70 dB
Max delay skew (on 100 m)	50 ns	45 ns	45 ns	45 ns	20 ns	20 ns

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Maximum achievable cable lengths

Resolution	f_{PCLK}	Cat5e UTP	Cat5e FTP	CAT6 UTP	CAT6 FTP	CAT6 SFTP	CAT7 SFTP	24 AWG	22 AWG
640×480p60	25.2 Mhz	60 m	60 m	65 m	70 m	70 m	80 m	100 m	120 m
800×600p60	40.0 MHz	60 m	60 m	65 m	65 m	65 m	75 m	84 m	100 m
1024×768p60	65.0 MHz	55 m	55 m	60 m	60 m	60 m	75 m	77 m	92 m
1280×720p60	74.2 MHz	55 m	55 m	60 m	60 m	60 m	70 m	77 m	92 m
1280×1024p60	108.0 MHz	50 m	50 m	55 m	60 m	60 m	65 m	62 m	75 m
1400×1050p60	121.8 MHz	45 m	45 m	45 m	55 m	55 m	60 m	62 m	75 m
1920×1080p60	148.5 Mhz	30 m	35 m	35 m	45 m	45 m	50 m	50 m	60 m
1920×1200p60	153.0 MHz	30 m	35 m	35 m	45 m	45 m	50 m	50 m	60 m
1600×1200p60	162.0 MHz	30 m	35 m	35 m	45 m	45 m	50 m	50 m	60 m

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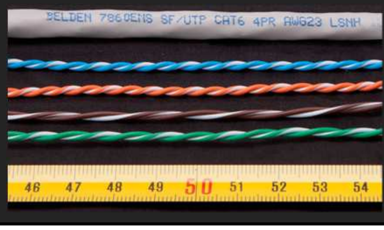
CATx cables for DVI and HDMI

Advantages

- Thin, flexible, easy to string
- Easy to crimp
- Cost effective
- Already in the building

Disadvantages

- Unreliable
- High attenuation
- Noise sensitive (no shield)
- Different twist ratio
  - + Decreases crosstalk
  - − Increases inter-pair skew



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Lightware CATx solutions

Transmit DVI and HDMI over CATx

Main applications:
- Digital Signage
- Fixed installations
- Conference room
- Classrooms

- 100 EDID memory (50 programmable)
- One cable without HDCP
- Two cables with HDCP
- Up to 50 meters (165') at 1080p60

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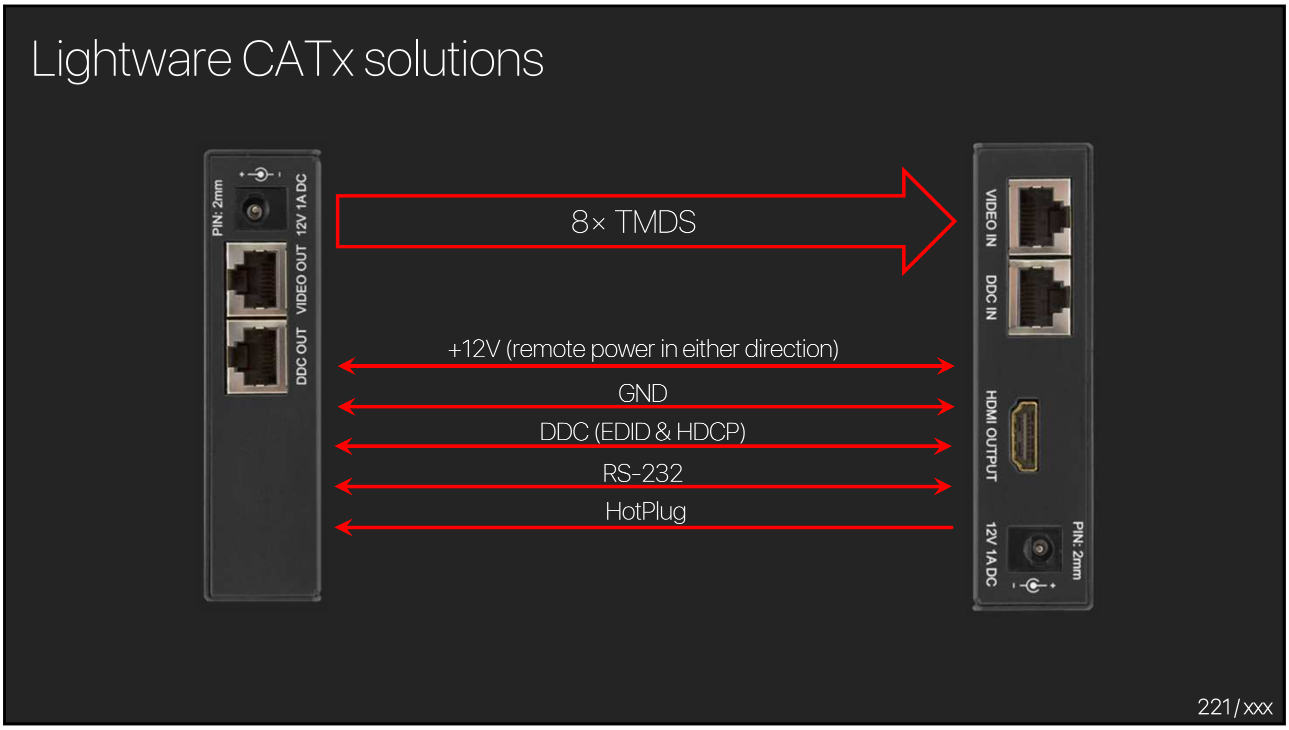
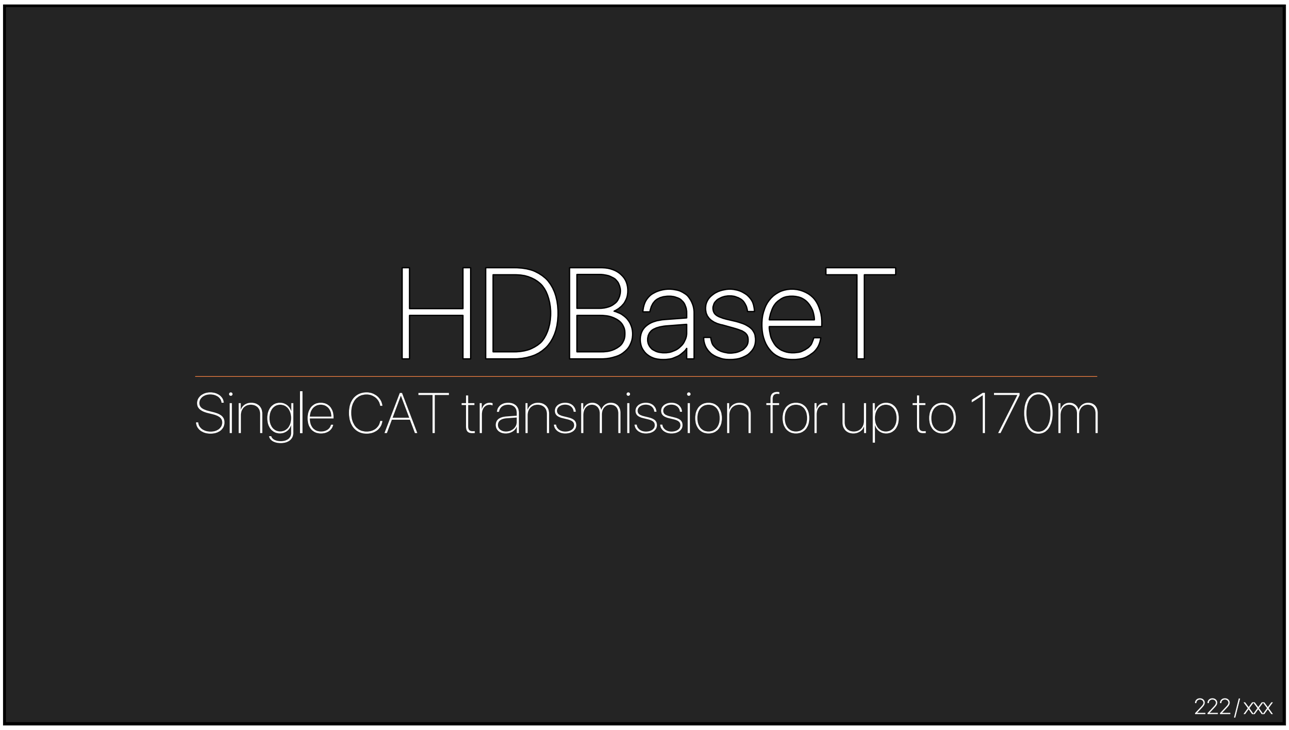
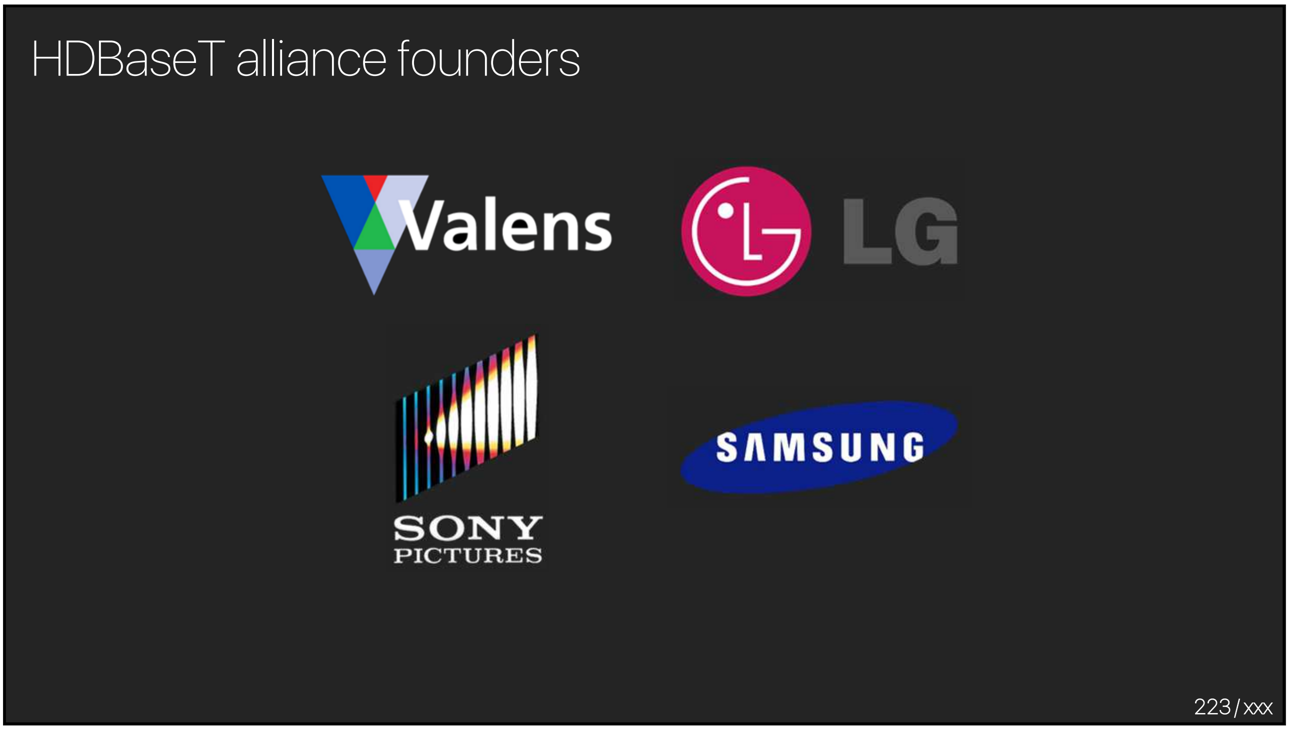
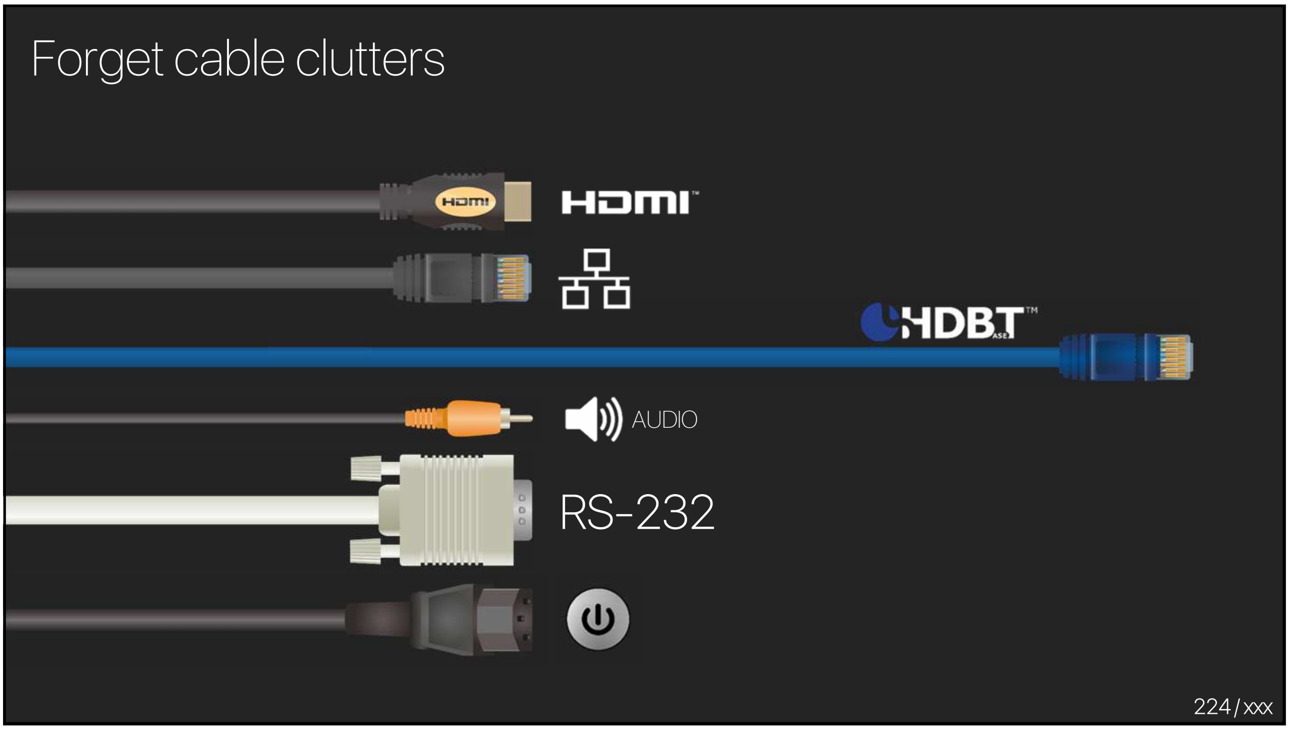
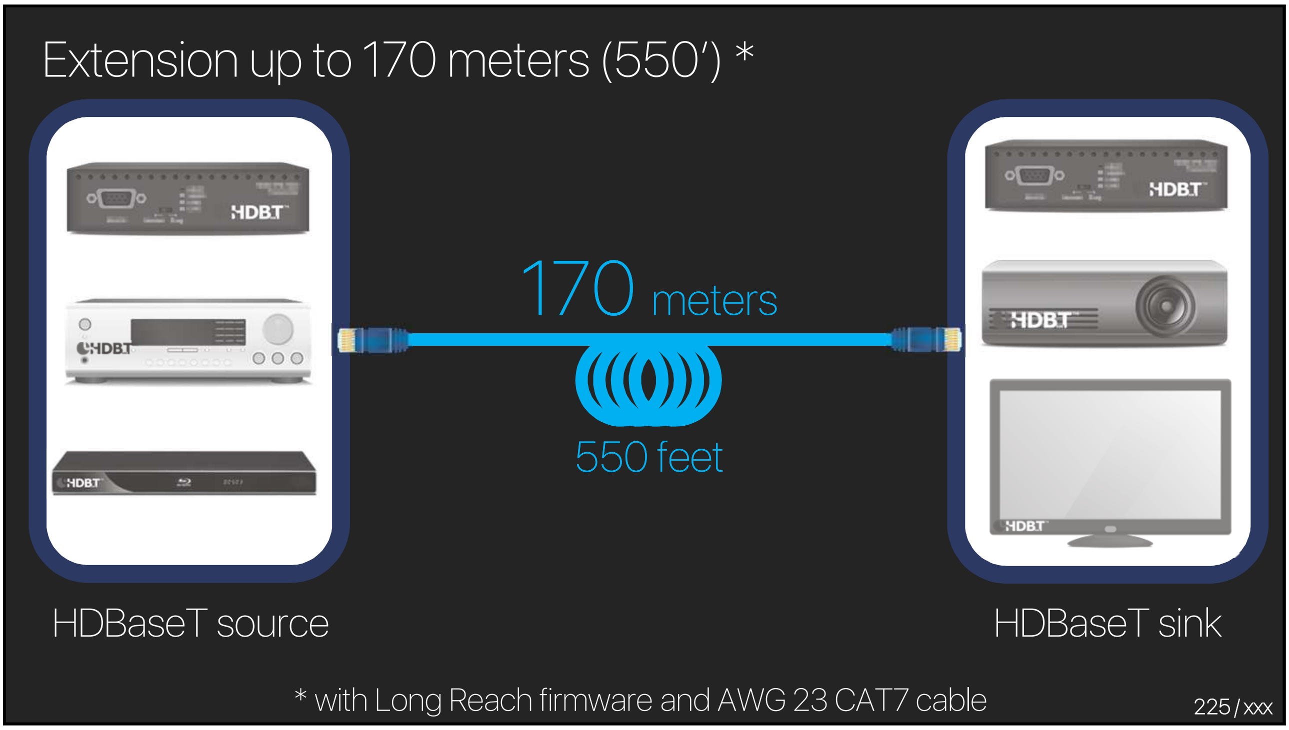

Lightware CATx solutions
8× TMDS
+12V (remote power in either direction)
GND
DDC (EDID & HDCP)
RS-232
HotPlug
PIN: 2mm
12V 1A DC
VIDEO OUT
DDC OUT
VIDEO IN
DDC IN
HDMI OUTPUT
221 / xxx


HDBaseT
Single CAT transmission for up to 170m
222 / xxx


HDBaseT alliance founders
Valens
LG
SONY
PICTURES
SAMSUNG
223 / xxx


Forget cable clutters
HDMI
HDBT
AUDIO
RS-232
224 / xxx


Extension up to 170 meters (550') *
170 meters
550 feet
HDBaseT source
HDBaseT sink
* with Long Reach firmware and AWG 23 CAT7 cable
225 / xxx


HDMI™
VS
HDBASET™
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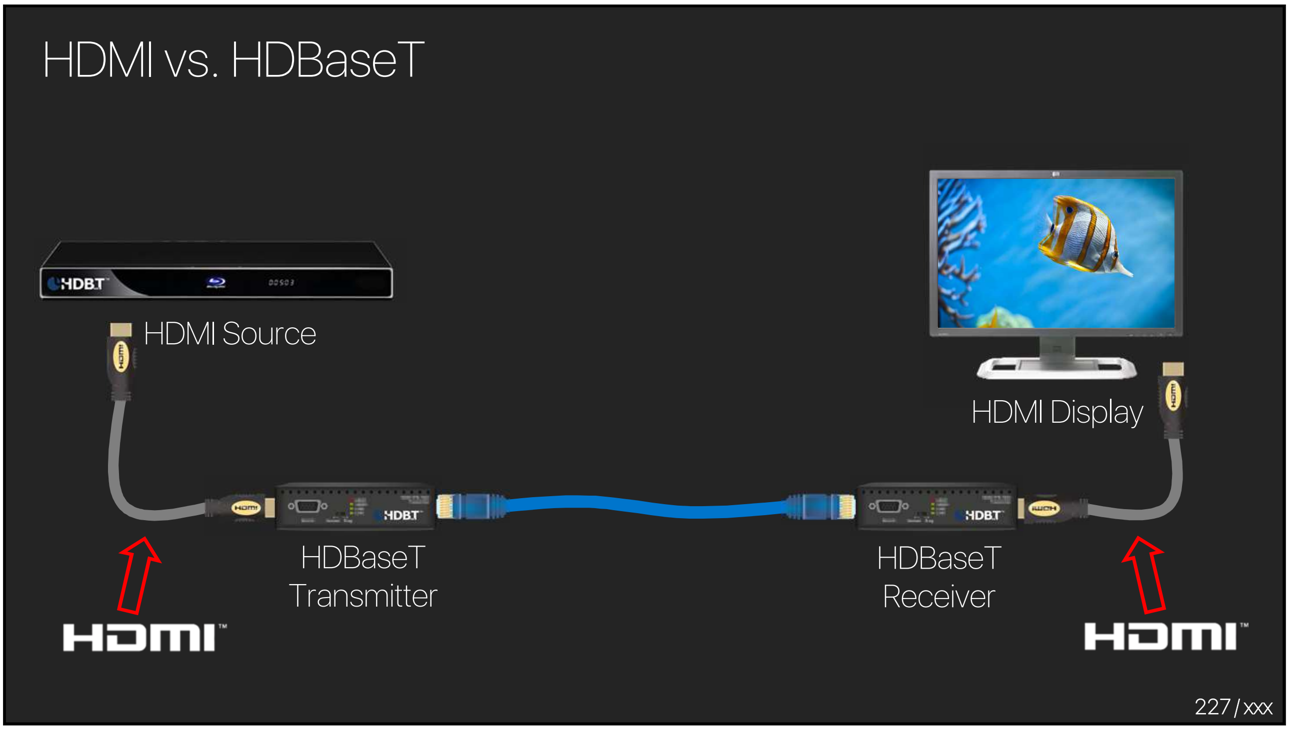
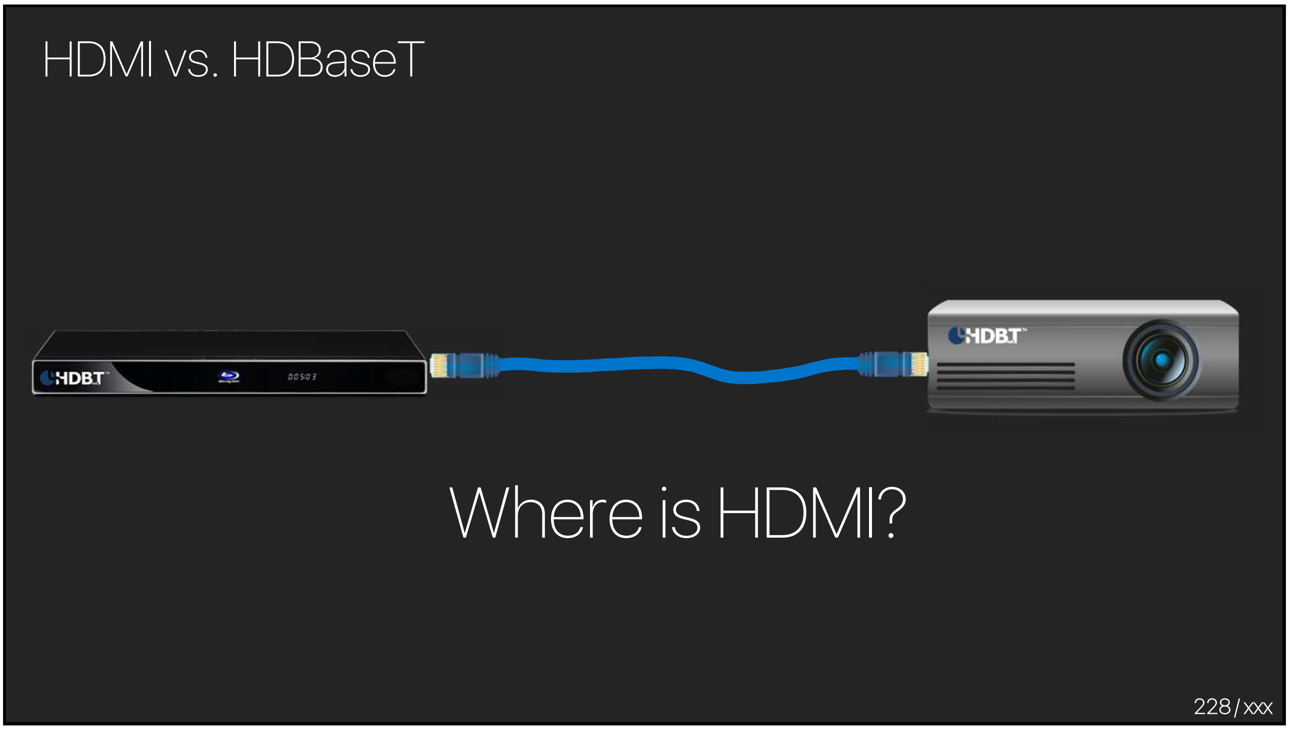
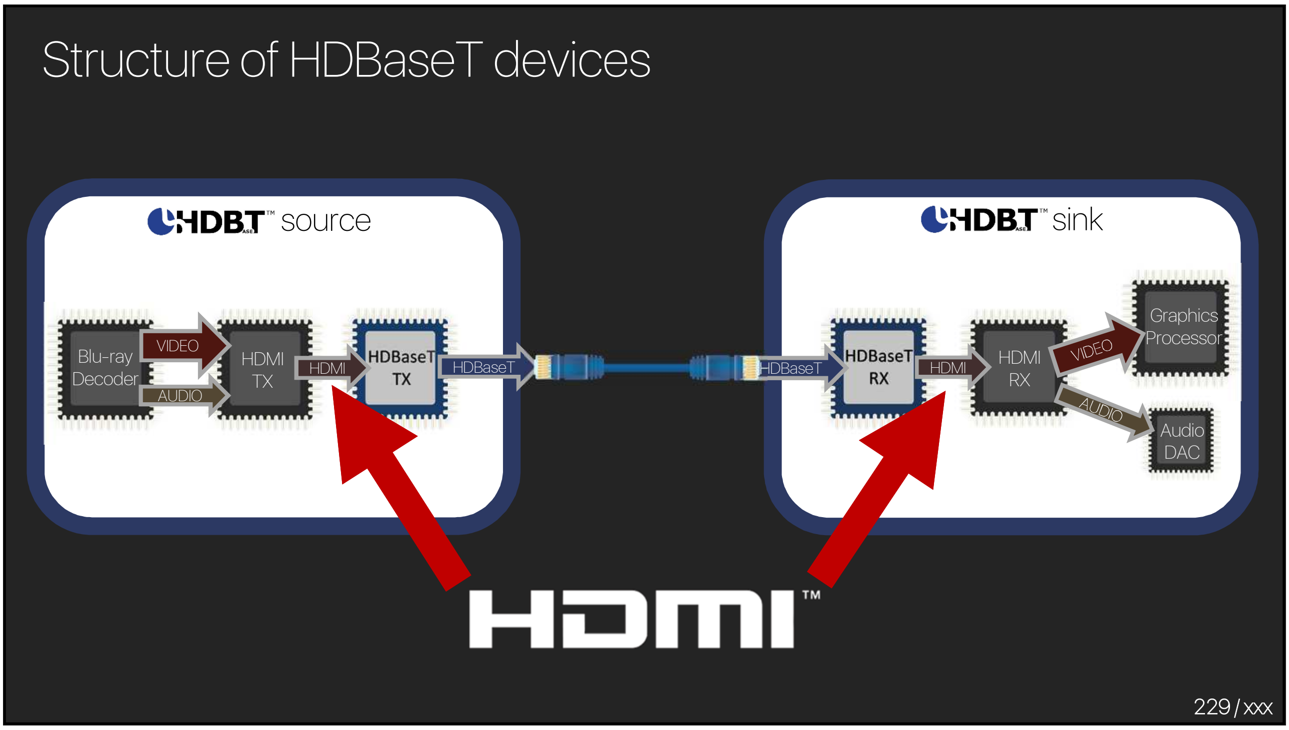
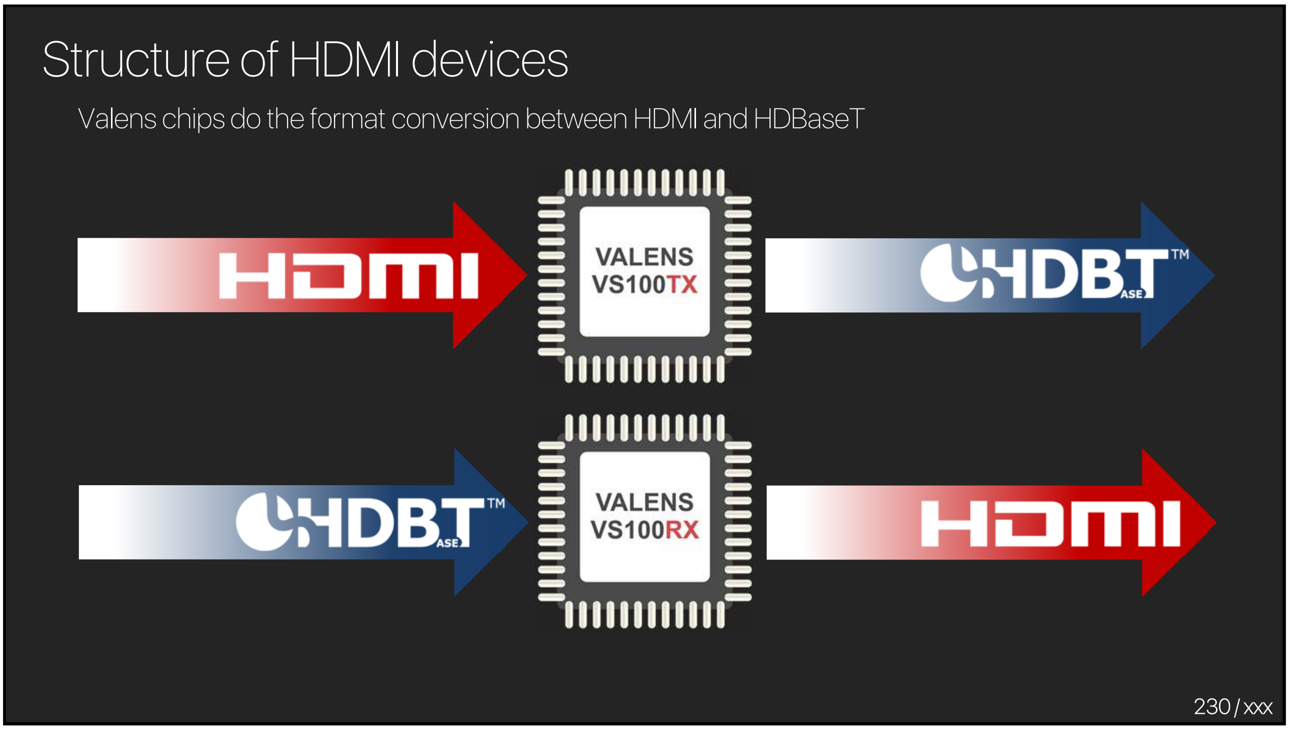
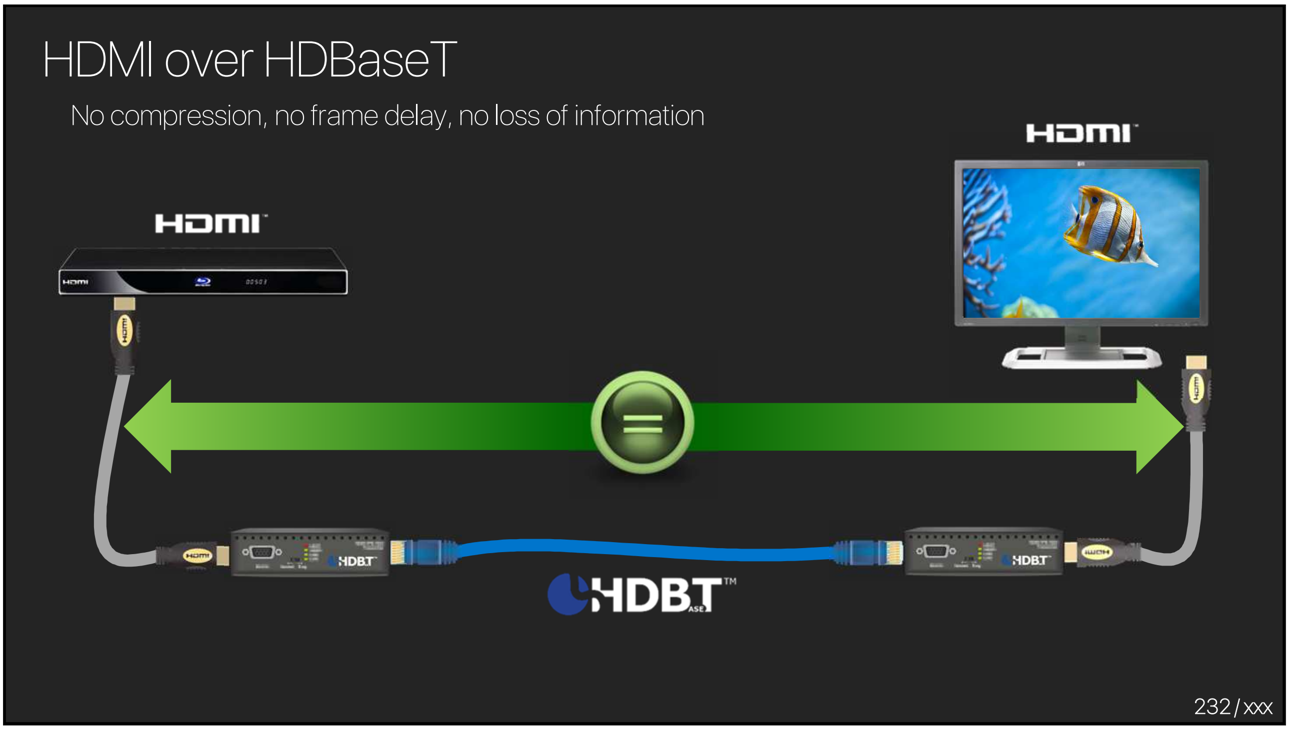

HDMI vs. HDBaseT
HDMI Source
HDMI Display
HDBaseT Transmitter
HDBaseT Receiver
HDMI
HDMI
227 / xxx


HDMI vs. HDBaseT
Where is HDMI?
228 / xxx

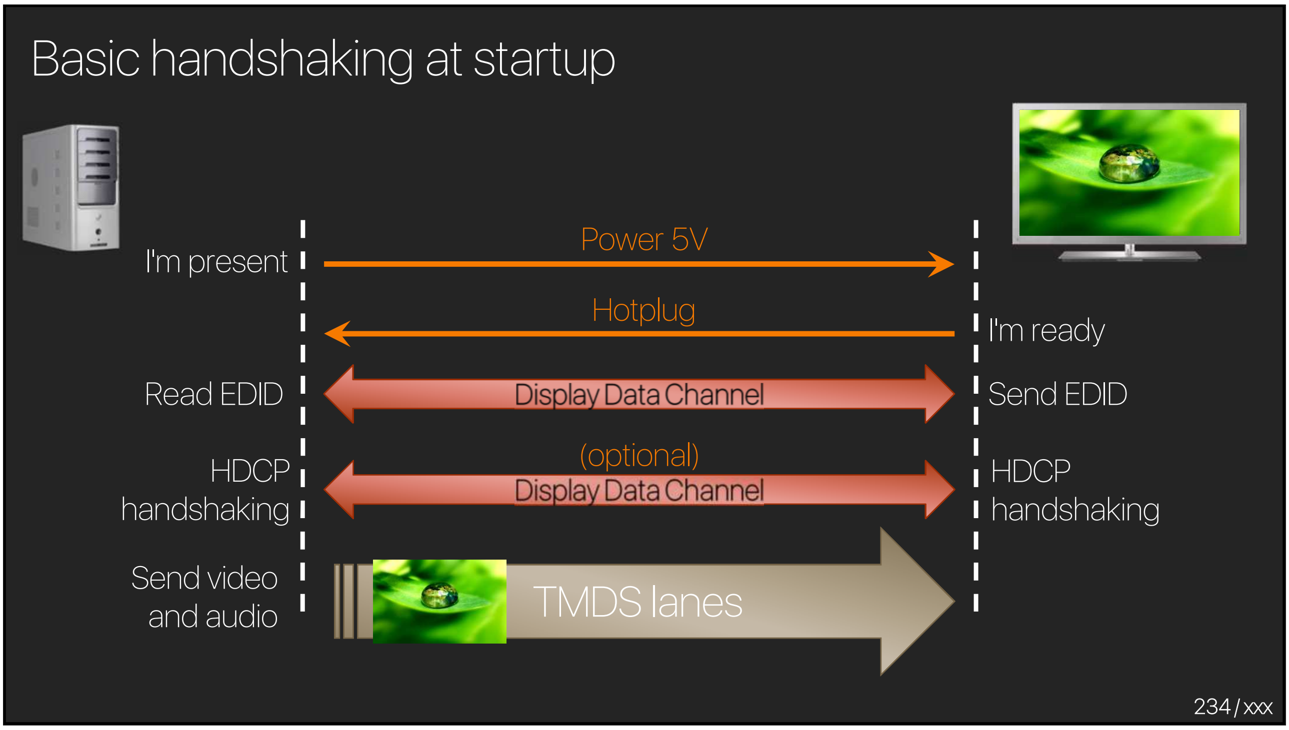

Structure of HDBaseT devices
HDBT source
Blu-ray Decoder
VIDEO
AUDIO
HDMI TX
HDMI
HDBaseT TX
HDBaseT
HDBaseT
HDBT sink
HDBaseT RX
HDMI
HDMI RX
VIDEO
AUDIO
Graphics Processor
Audio DAC
HDMI
229 / xxx

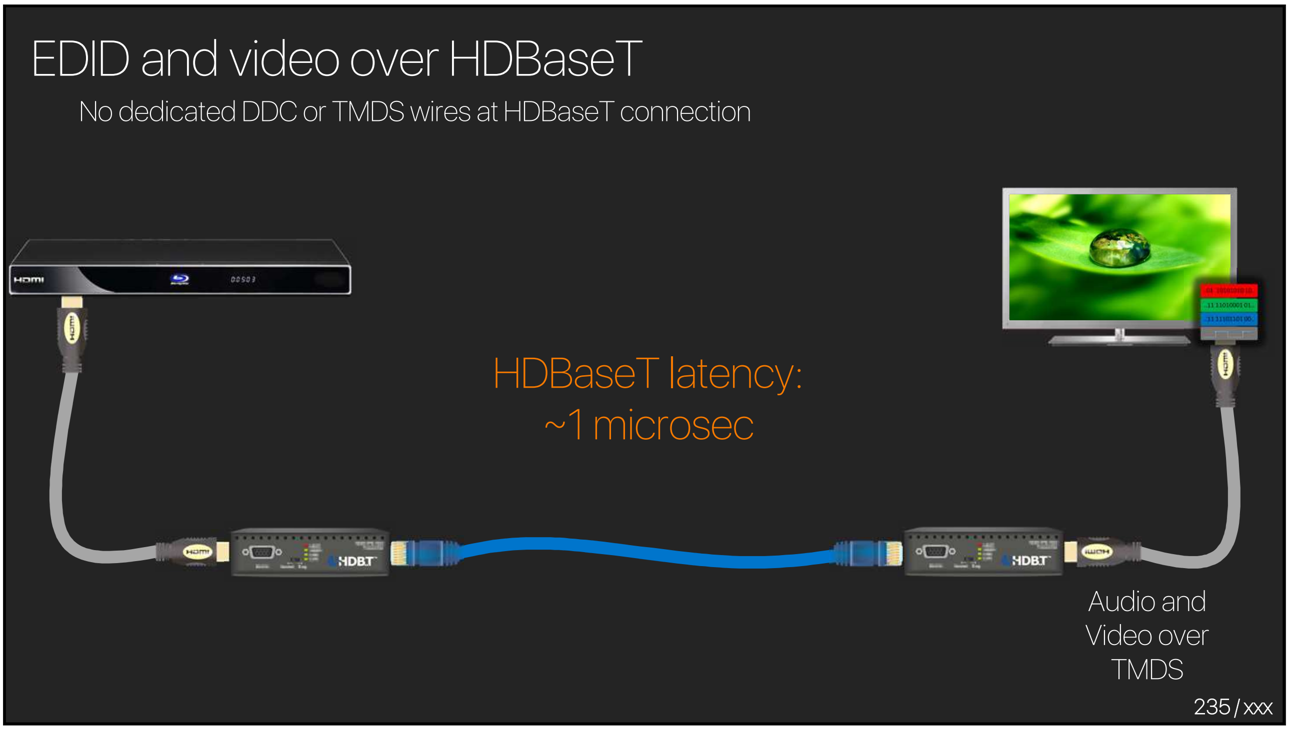

Structure of HDMI devices
Valens chips do the format conversion between HDMI and HDBaseT
HDMI
VALENS VS100TX
HDBT
HDBT
VALENS VS100RX
HDMI
230 / xxx

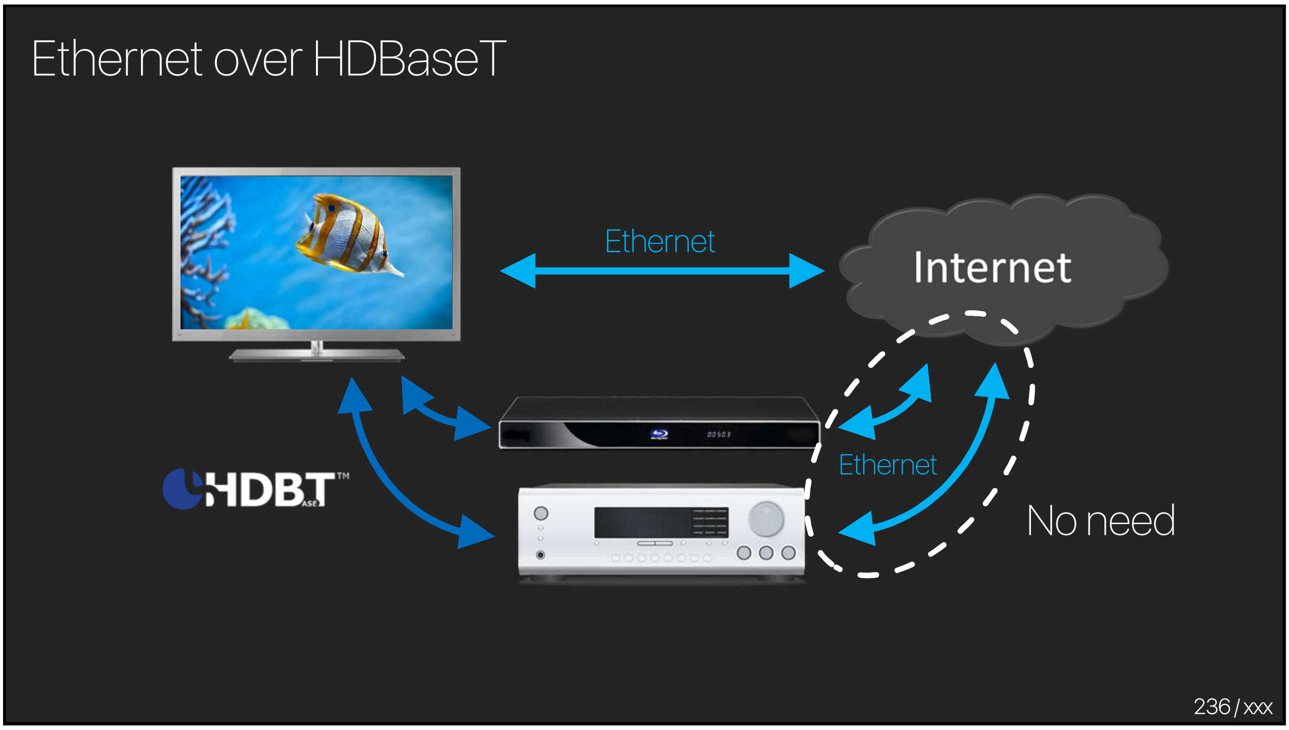

Structure of HDMI devices
HDMI™
HDBaseT™
HDBaseT wouldn't exist without HDMI
231 / xxx

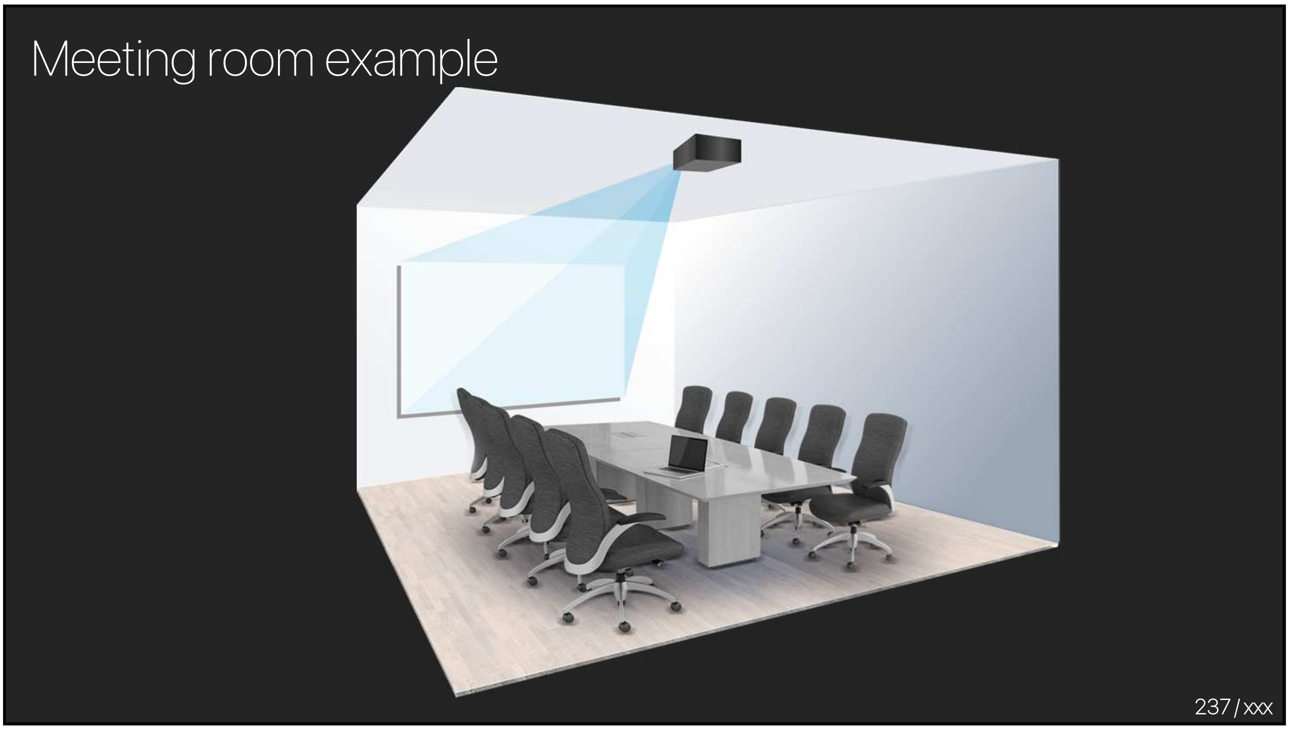

HDMI over HDBaseT
No compression, no frame delay, no loss of information
HDMI
HDMI
HDBaseT™
232 / xxx

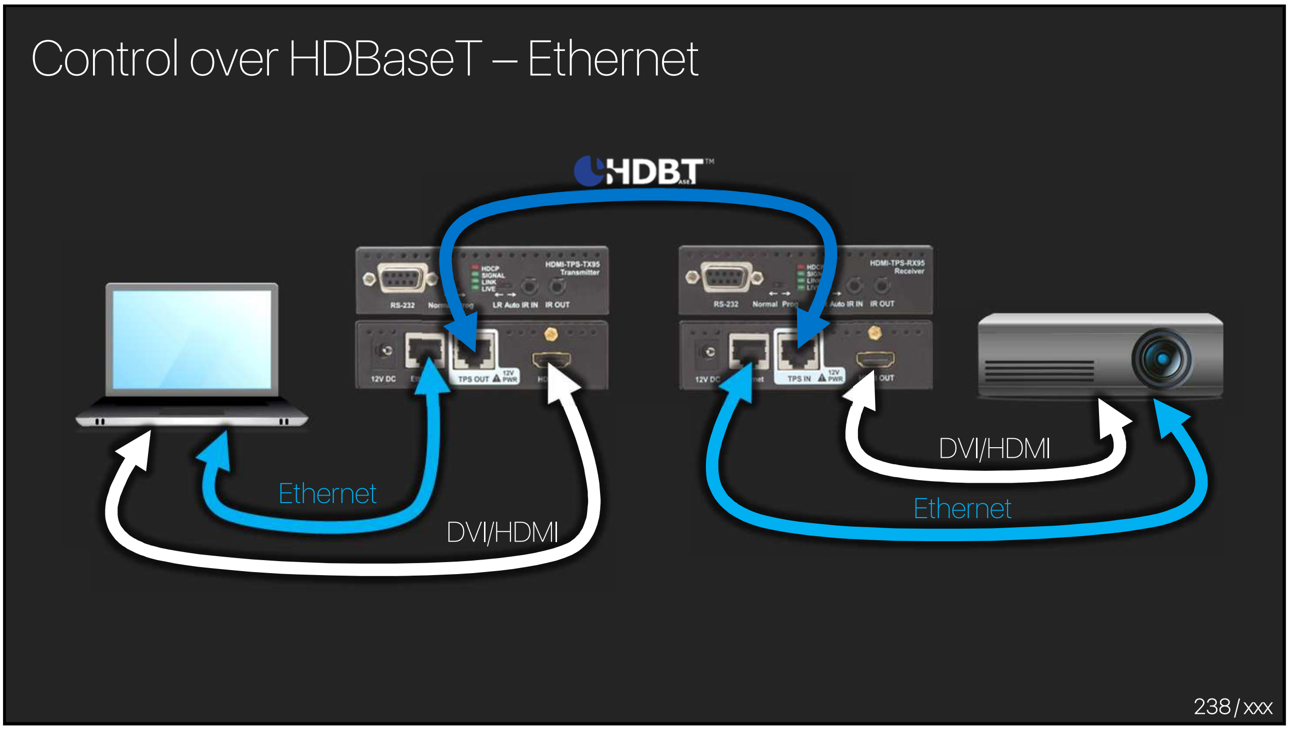

HDMI over HDBaseT
HDMI 1.4, UHD, 3D, Various color spaces, Multichannel audio
HDMI™
x.v.Color
4K 30
ULTRAHD
HDCP
3D
233 / xxx

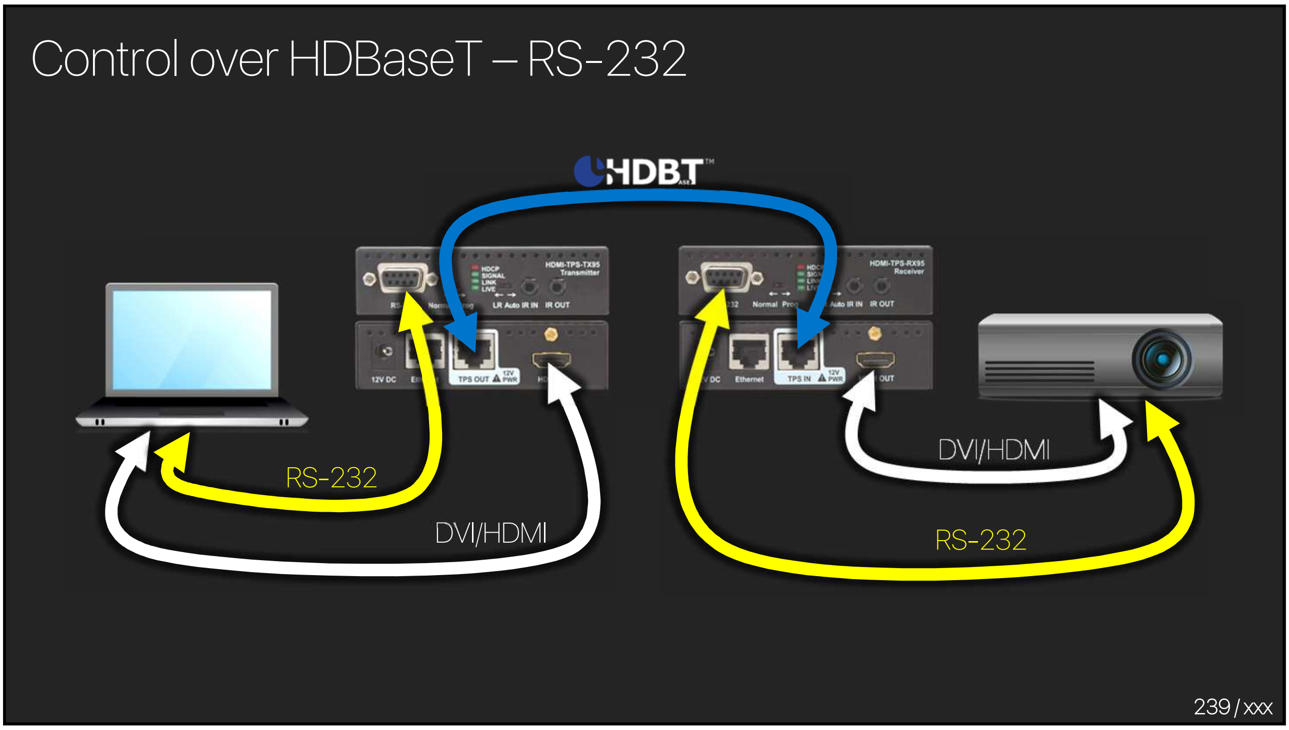

Basic handshaking at startup
I'm present
Power 5V
Hotplug
I'm ready
Read EDID
Display Data Channel
Send EDID
HDCP handshaking
(optional)
Display Data Channel
HDCP handshaking
Send video and audio
TMDS lanes
234 / xxx

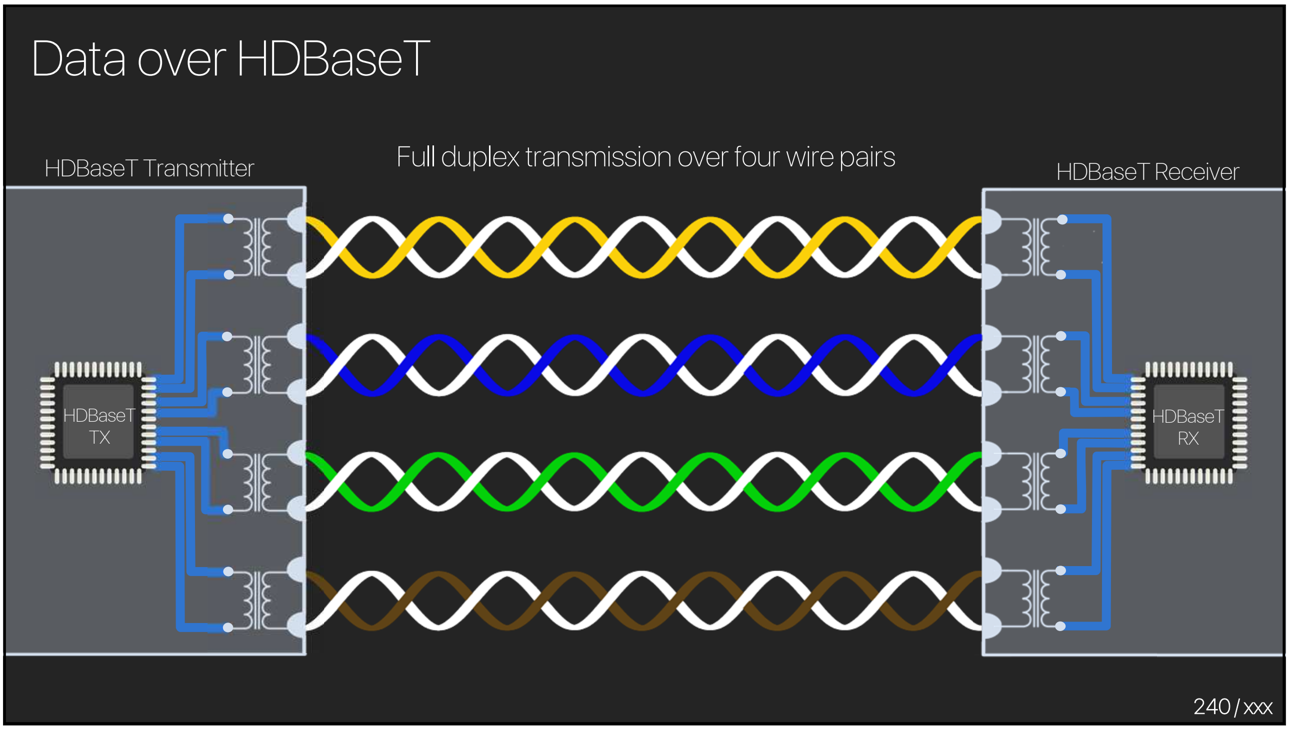

EDID and video over HDBaseT
No dedicated DDC or TMDS wires at HDBaseT connection
HDBaseT latency:
~1 microsec
Audio and
Video over
TMDS
235 / xxx

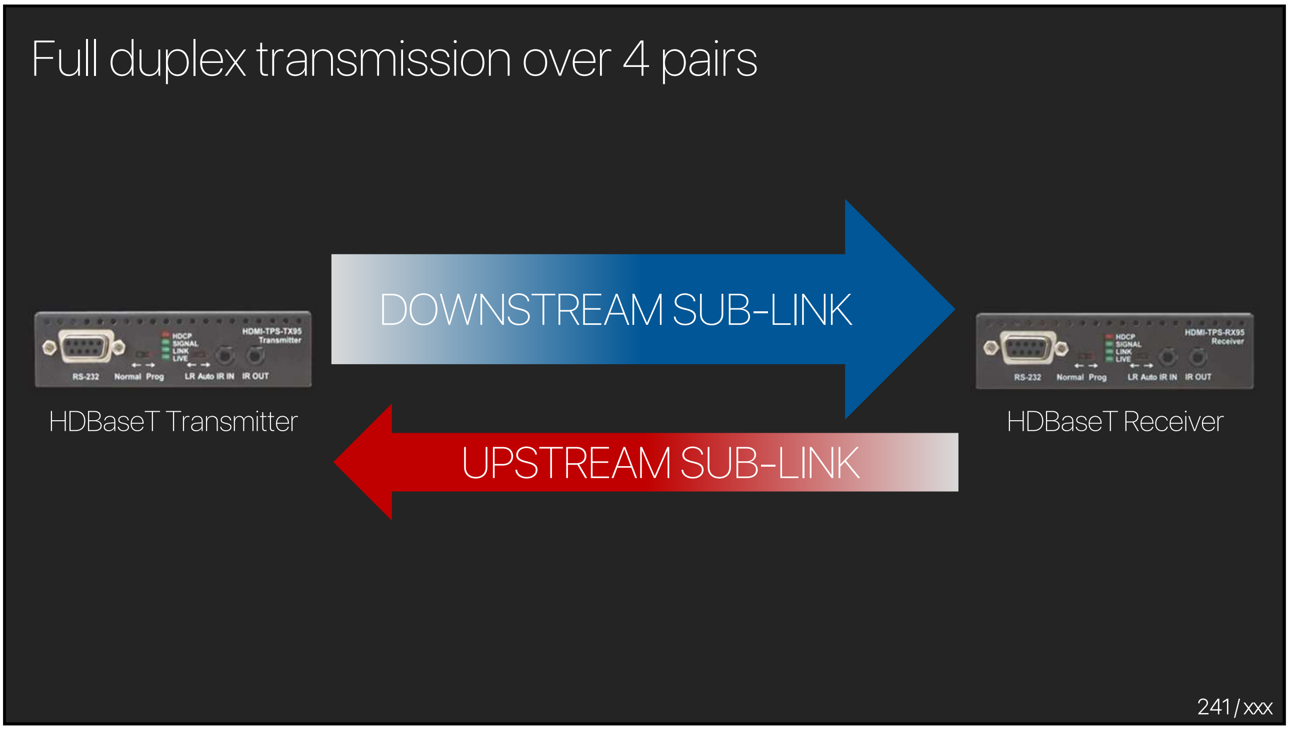

Ethernet over HDBaseT
Ethernet
Internet
Ethernet
No need
HDBT
236 / xxx

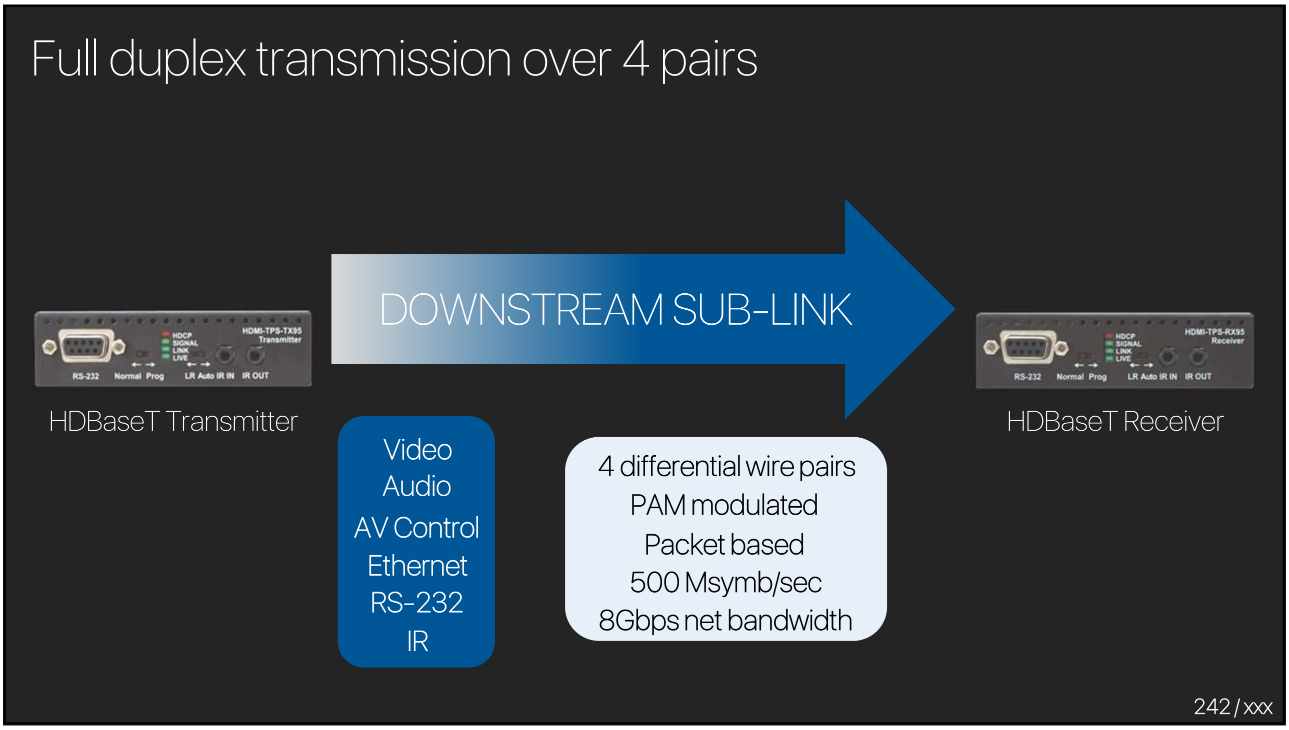

Meeting room example
237 / xxx

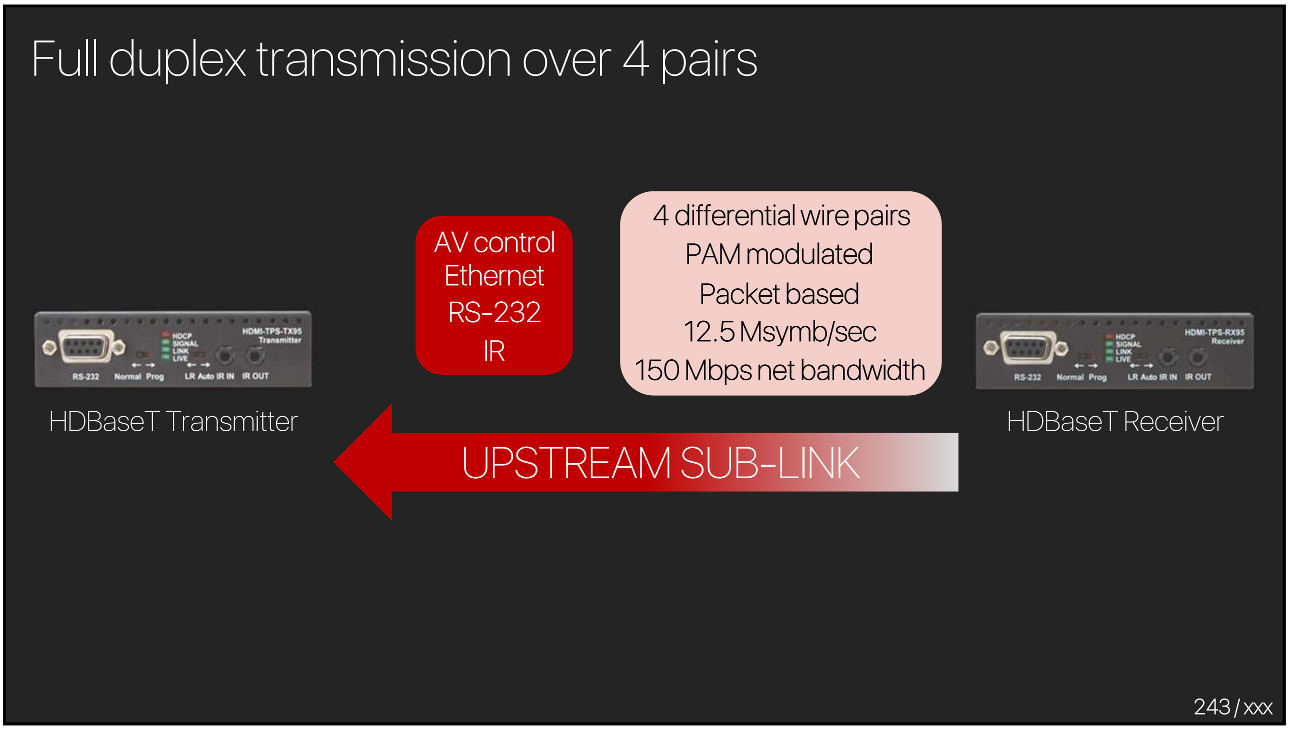

Control over HDBaseT – Ethernet
HDBT
Ethernet
DVI/HDMI
DVI/HDMI
Ethernet
238 / xxx

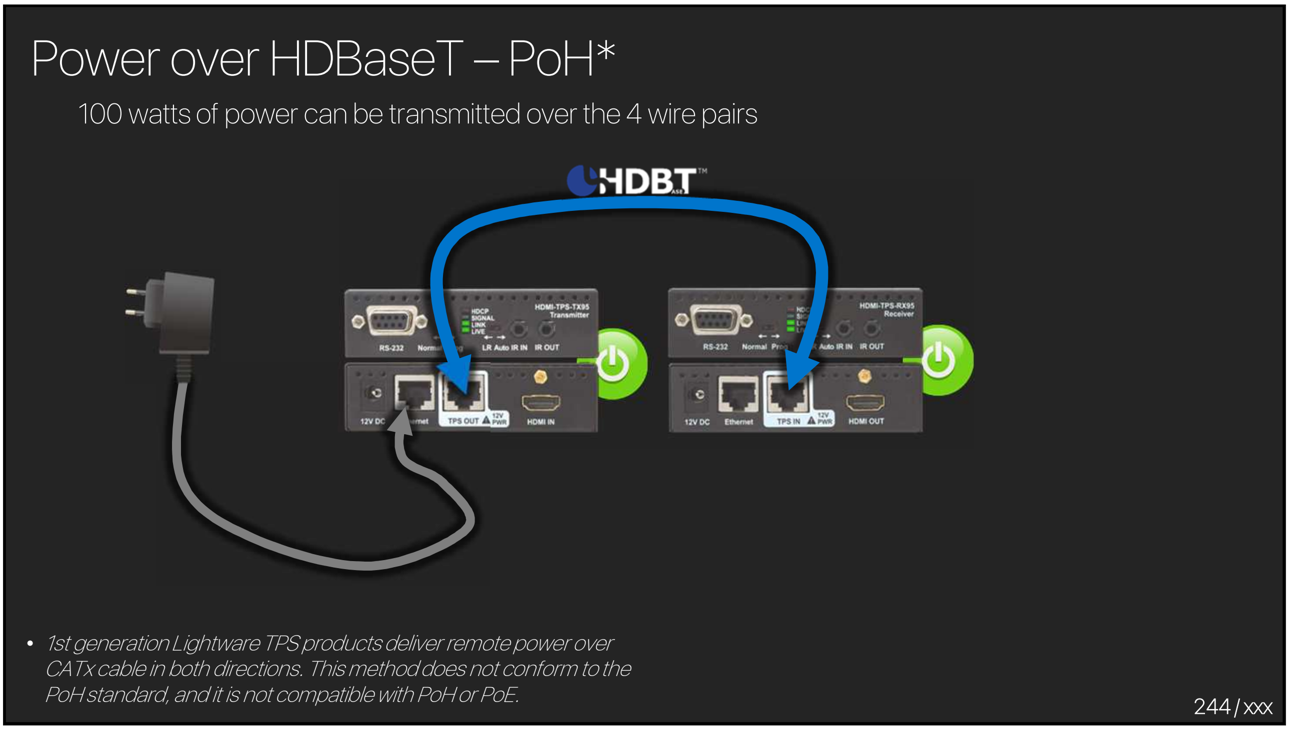

Control over HDBaseT – RS-232
HDBT
RS-232
DVI/HDMI
DVI/HDMI
RS-232
239 / xxx

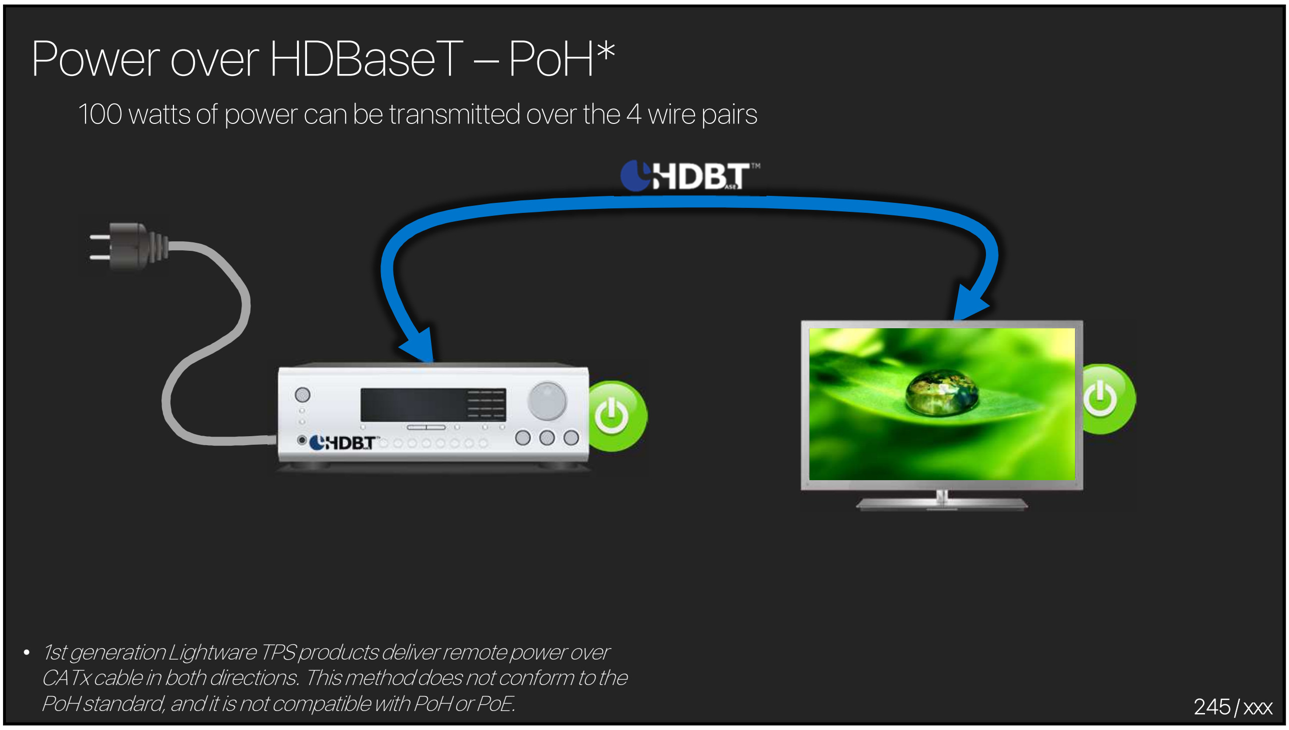

Data over HDBaseT
HDBaseT Transmitter
Full duplex transmission over four wire pairs
HDBaseT Receiver
HDBaseT TX
HDBaseT RX
240 / xxx

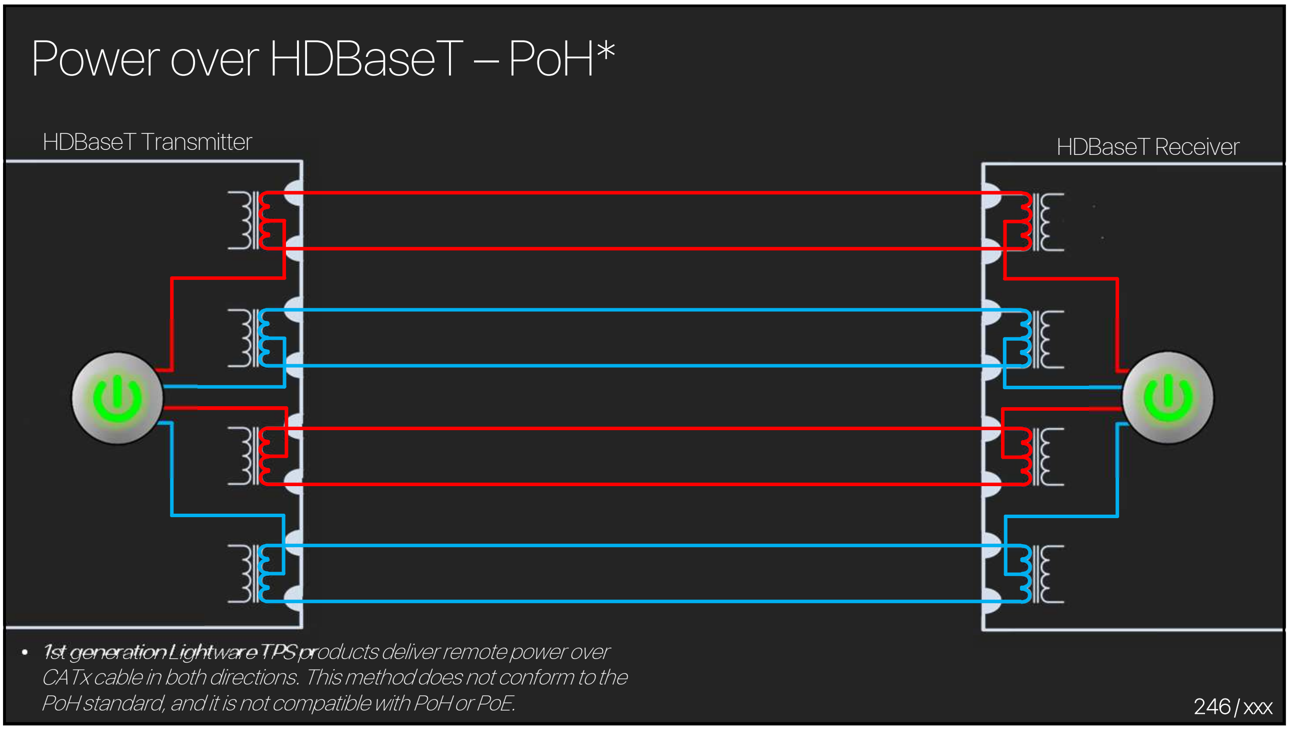

Full duplex transmission over 4 pairs
DOWNSTREAM SUB-LINK
UPSTREAM SUB-LINK
HDBaseT Transmitter
HDBaseT Receiver
241 / xxx

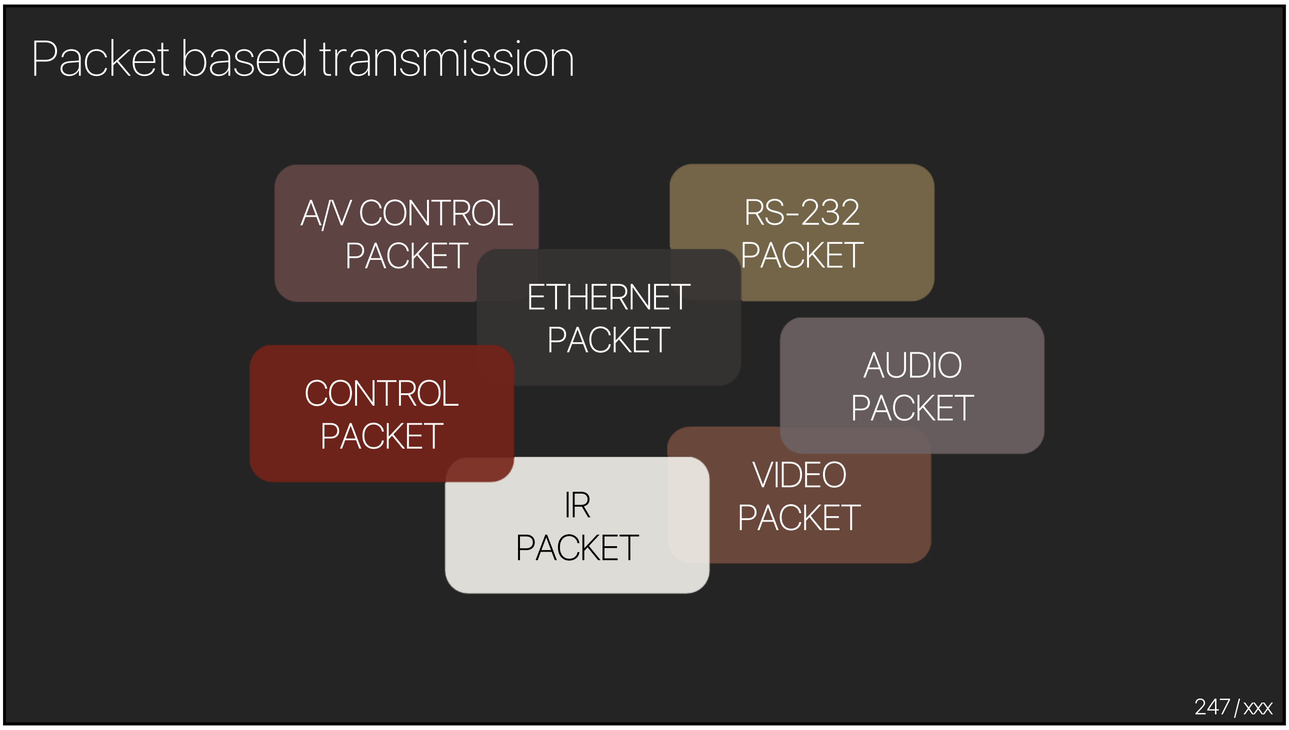

Full duplex transmission over 4 pairs
DOWNSTREAM SUB-LINK
HDBaseT Transmitter
HDBaseT Receiver
Video
Audio
AV Control
Ethernet
RS-232
IR
4 differential wire pairs
PAM modulated
Packet based
500 Msymb/sec
8Gbps net bandwidth
242 / xxx

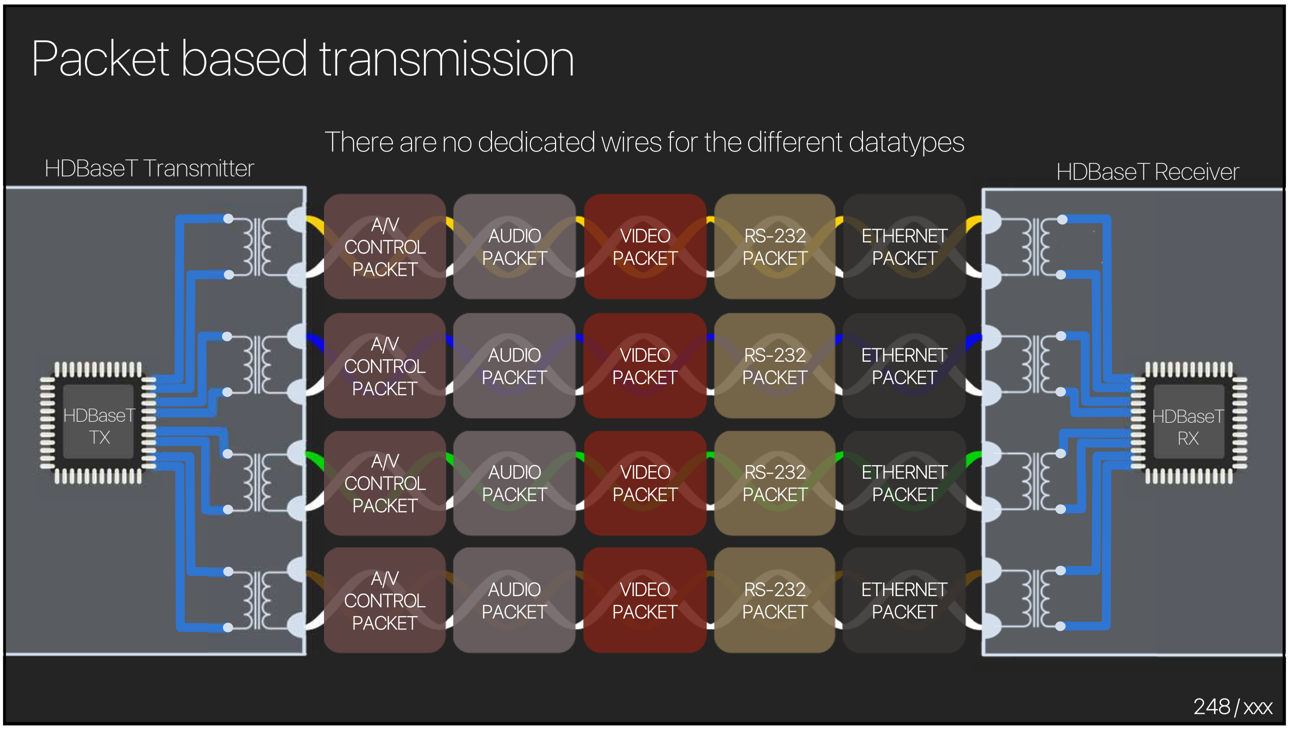

Full duplex transmission over 4 pairs
AV control
Ethernet
RS-232
IR
4 differential wire pairs
PAM modulated
Packet based
12.5 Msymb/sec
150 Mbps net bandwidth
HDBaseT Transmitter
HDBaseT Receiver
UPSTREAM SUB-LINK
243 / xxx


Power over HDBaseT – PoH*
100 watts of power can be transmitted over the 4 wire pairs
HDBT
• 1st generation Lightware TPS products deliver remote power over CATx cable in both directions. This method does not conform to the PoH standard, and it is not compatible with PoH or PoE.
244 / xxx

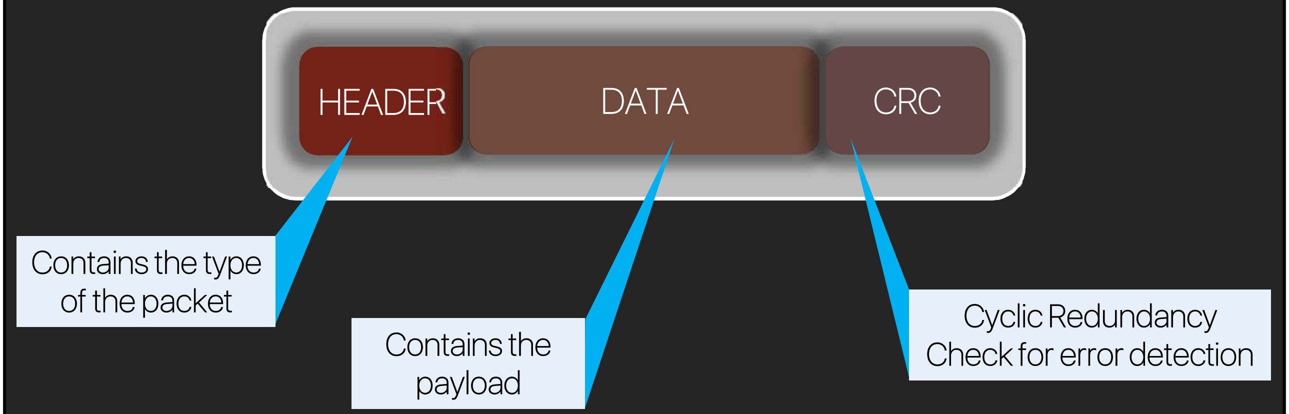

Power over HDBaseT – PoH*
100 watts of power can be transmitted over the 4 wire pairs
HDBT
HDBT
• 1st generation Lightware TPS products deliver remote power over CATx cable in both directions. This method does not conform to the PoH standard, and it is not compatible with PoH or PoE.
245 / xxx


Power over HDBaseT – PoH*
HDBaseT Transmitter
HDBaseT Receiver
• 1st generation Lightware TPS products deliver remote power over CATx cable in both directions. This method does not conform to the PoH standard, and it is not compatible with PoH or PoE.
246 / xxx


Packet based transmission
A/V CONTROL PACKET
RS-232 PACKET
ETHERNET PACKET
AUDIO PACKET
CONTROL PACKET
VIDEO PACKET
IR PACKET
247 / xxx


Packet based transmission
There are no dedicated wires for the different datatypes
HDBaseT Transmitter
HDBaseT Receiver
HDBaseT TX
HDBaseT RX
A/V CONTROL PACKET
AUDIO PACKET
VIDEO PACKET
RS-232 PACKET
ETHERNET PACKET
248 / xxx

HDBaseT link - Packet based architecture



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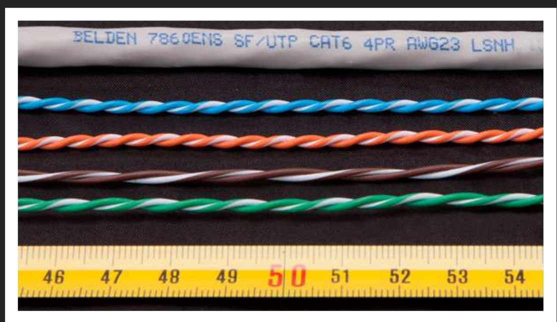
Difficulties of CATx extension

- Attenuation – depends on data rate
- Reflection adds noise – patch panels
- Different twist ratio – inter pair skew!!!



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HDBaseT – Physical layer: 10GbE

- Error rate measurements
- Reflection compensation
- Compensation for different twist ratios
- Compensation for attenuation by measuring cable length and data rate
- Pulse Amplitude Modulation - PAM
- Point-to-point – no extra overhead coming from addressing

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Start-up period

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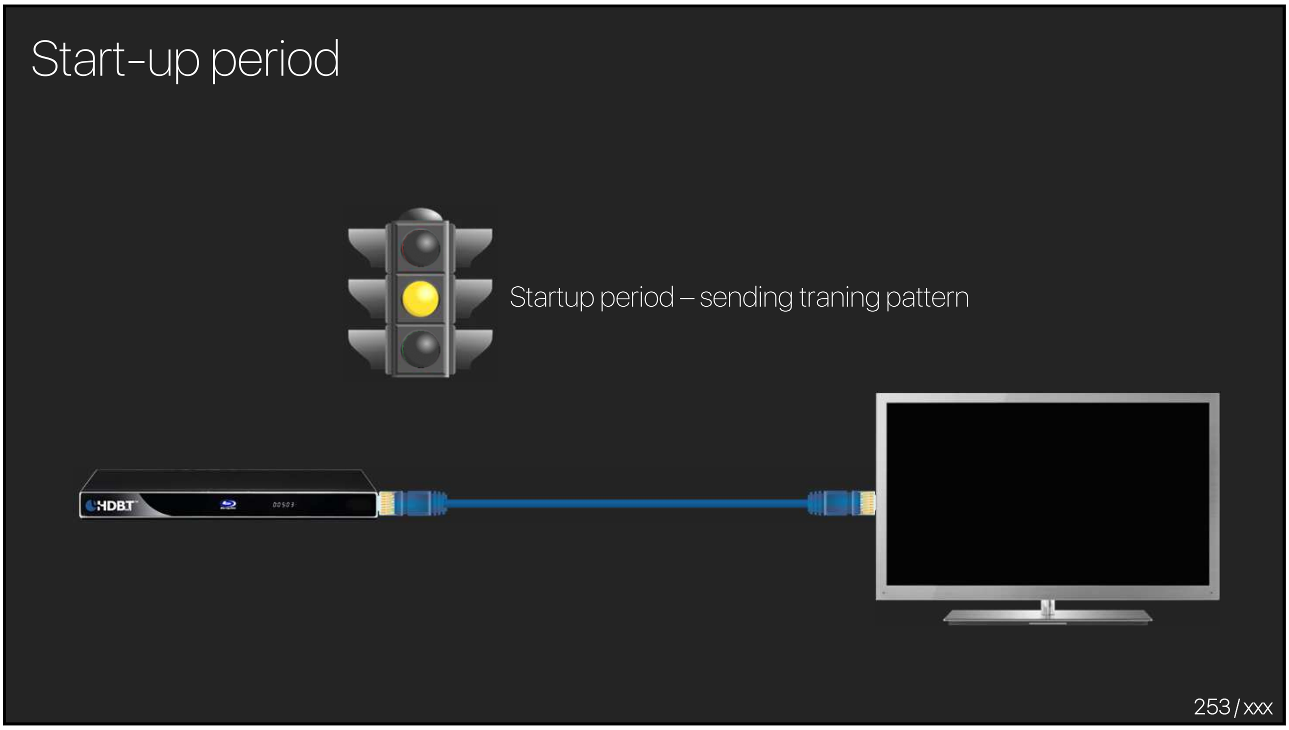
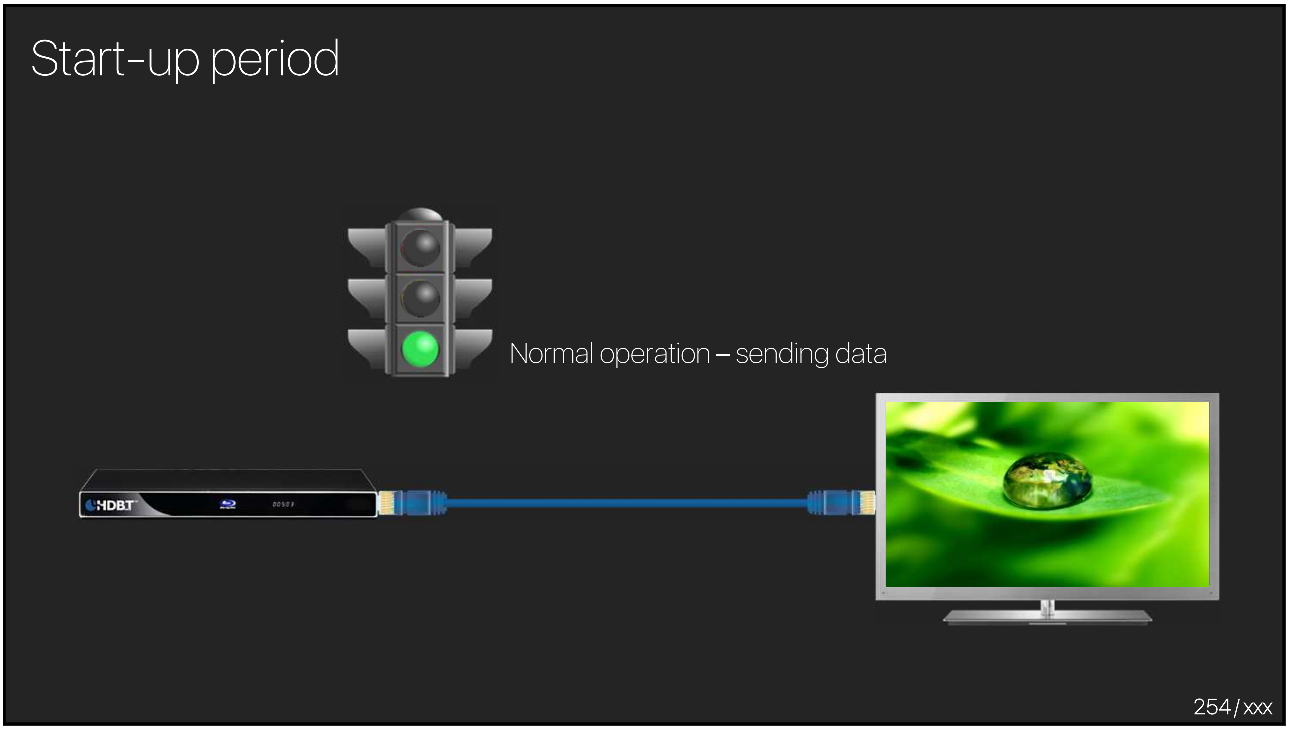
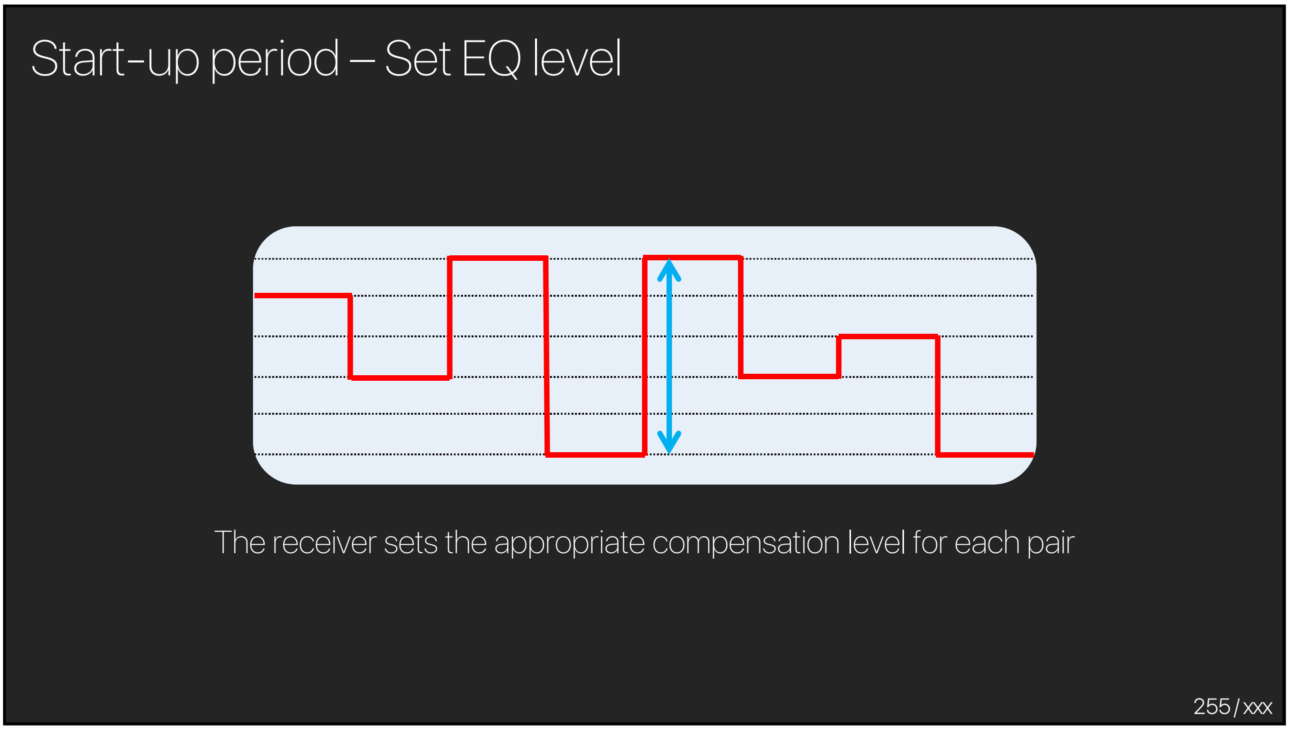
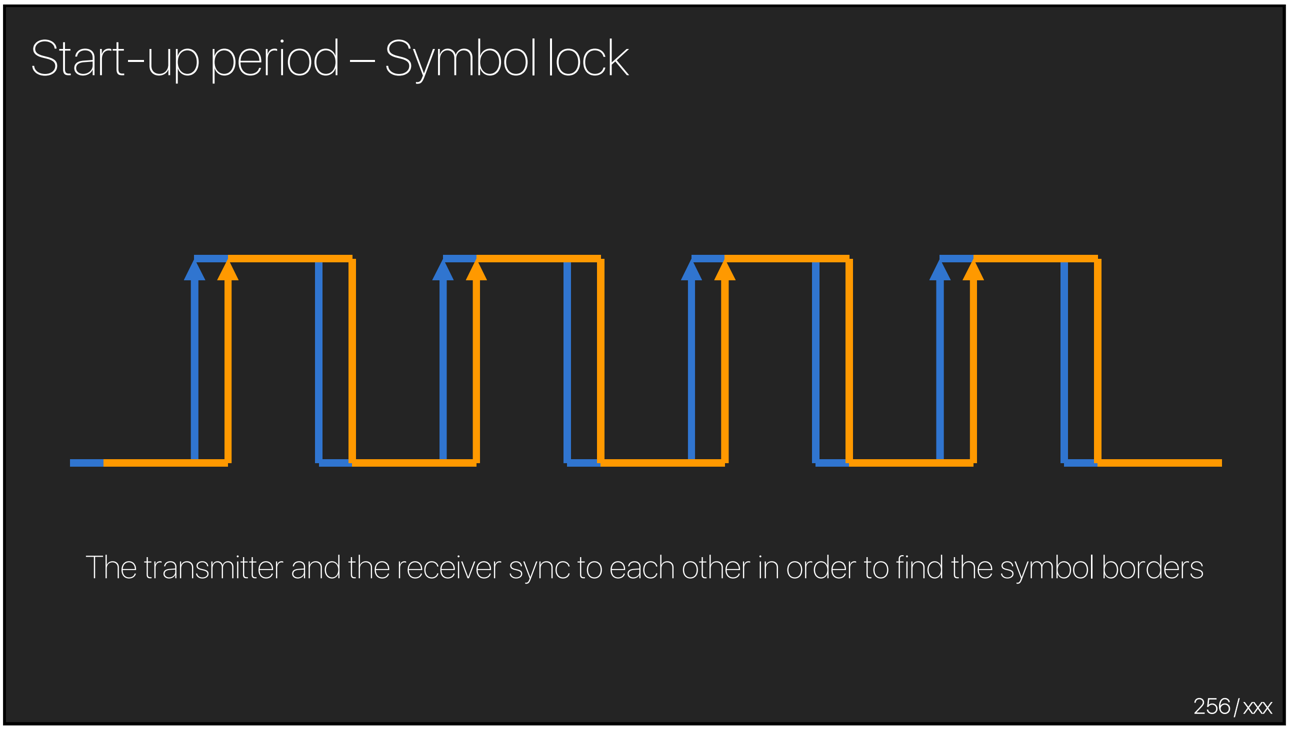
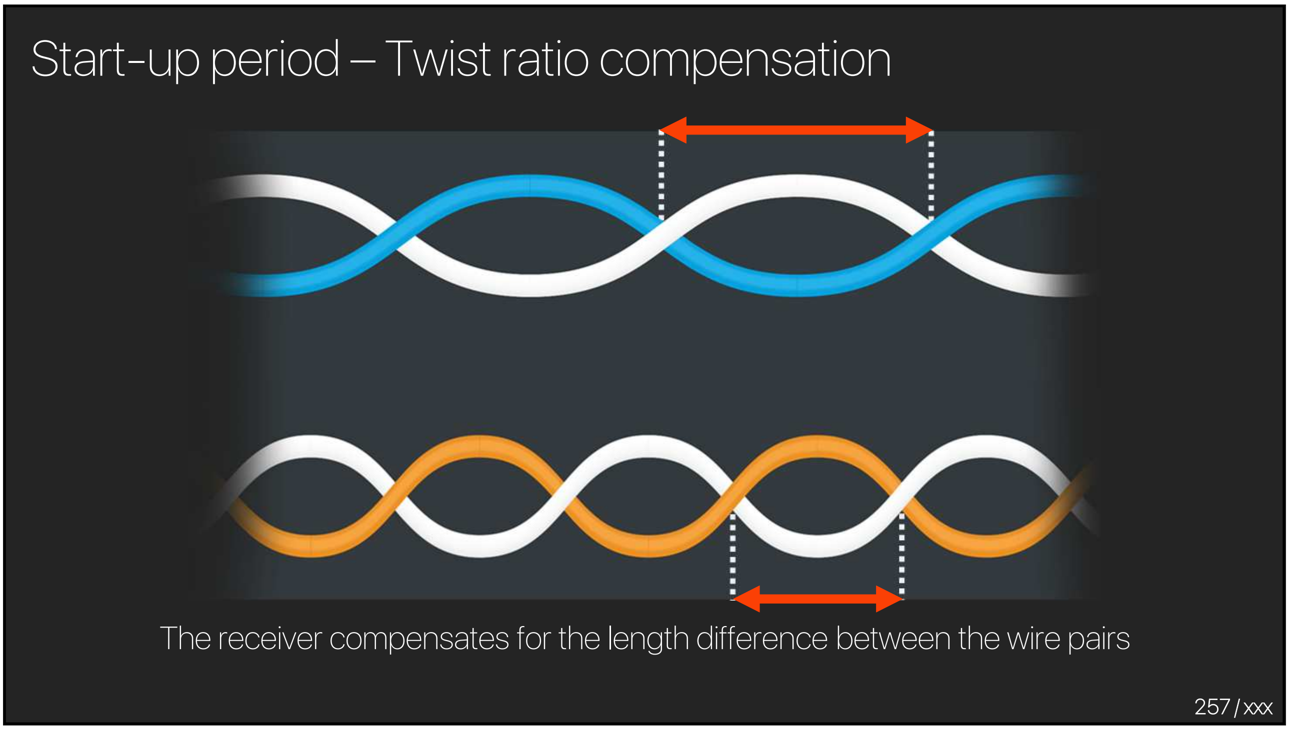
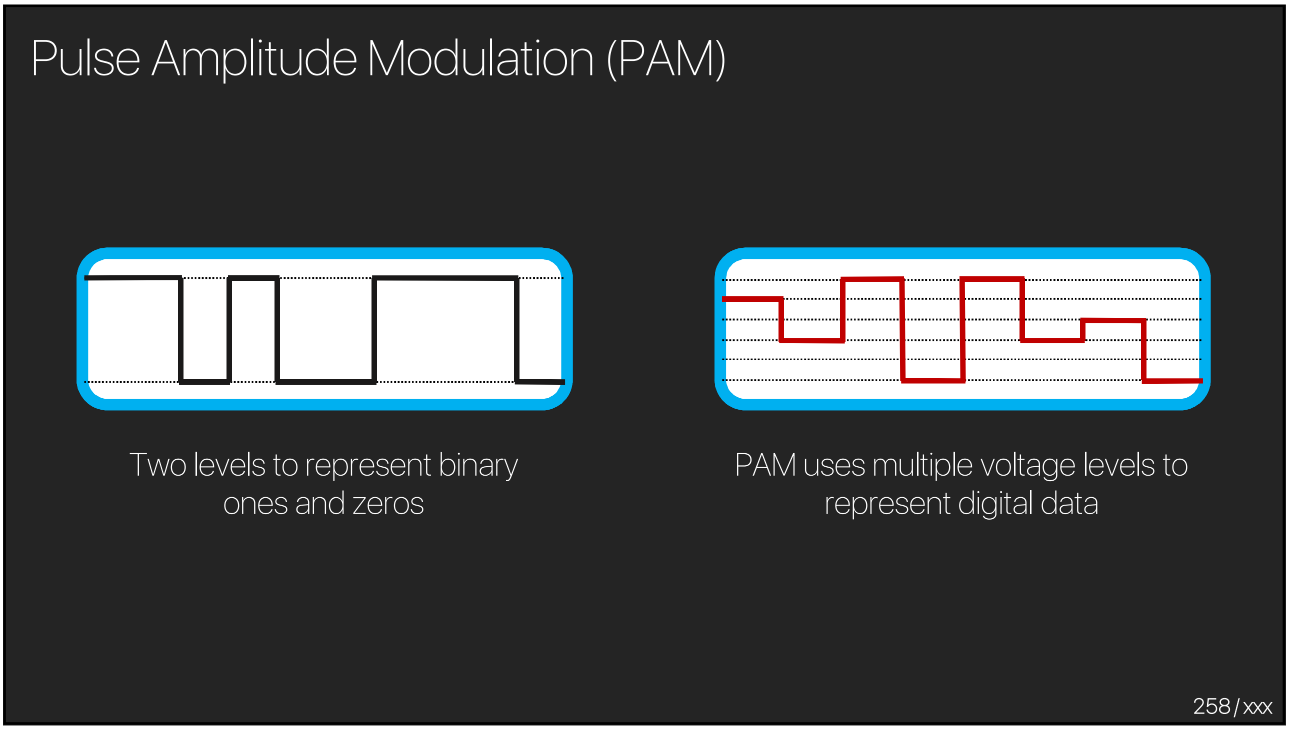

Start-up period
Startup period – sending traning pattern
253 / xxx


Start-up period
Normal operation – sending data
254 / xxx

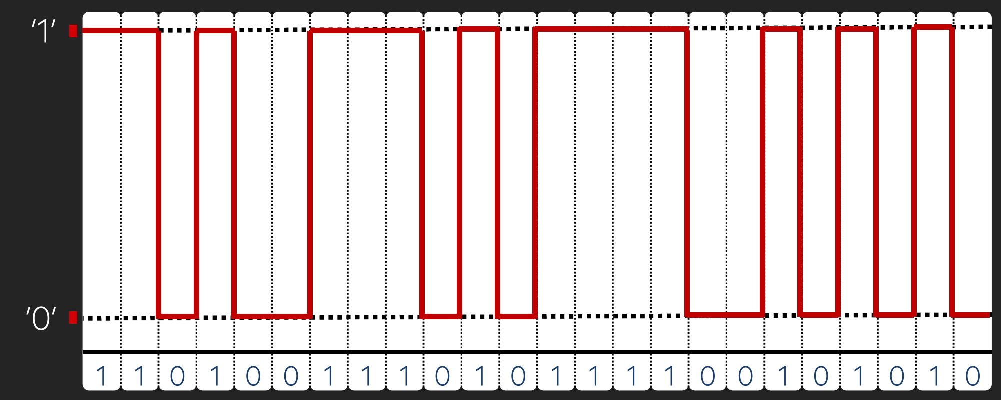

Start-up period – Set EQ level
The receiver sets the appropriate compensation level for each pair
255 / xxx


Start-up period – Symbol lock
The transmitter and the receiver sync to each other in order to find the symbol borders
256 / xxx


Start-up period – Twist ratio compensation
The receiver compensates for the length difference between the wire pairs
257 / xxx


Pulse Amplitude Modulation (PAM)
Two levels to represent binary ones and zeros
PAM uses multiple voltage levels to represent digital data
258 / xxx

Example – PAM2



2 voltage levels, each level representing 1 bit

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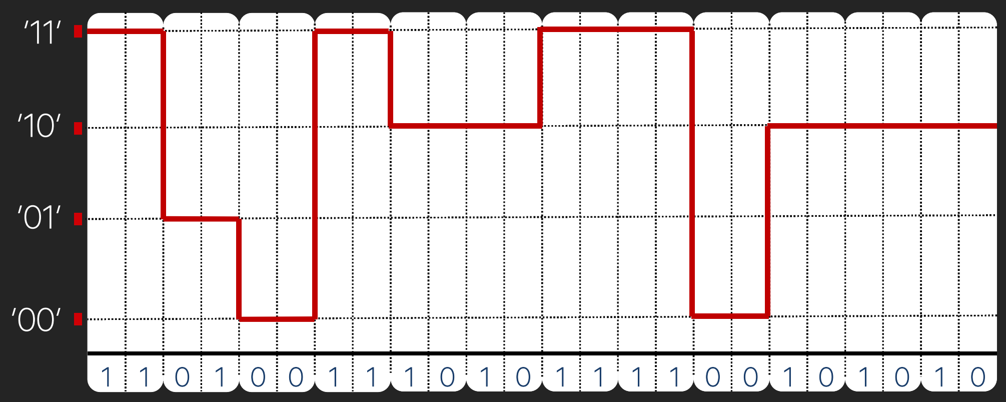
Example – PAM4



4 voltage levels, each level representing 2 bits

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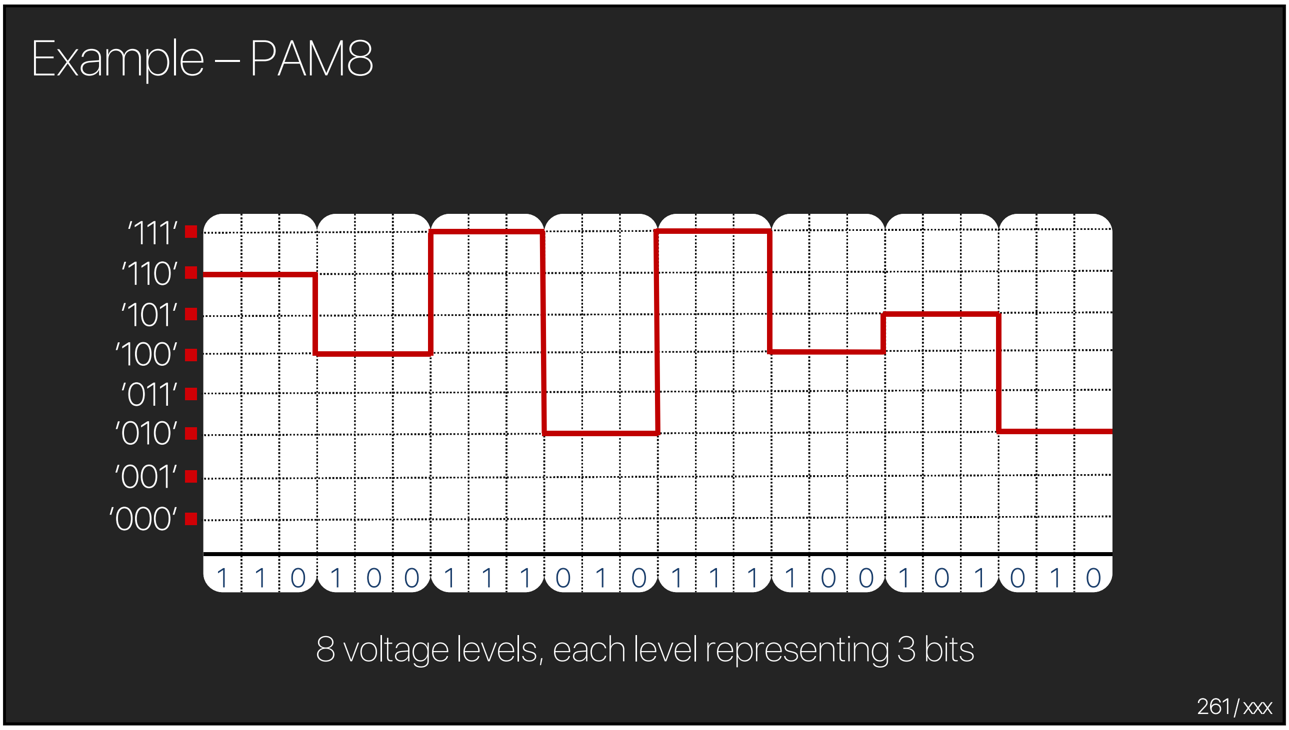
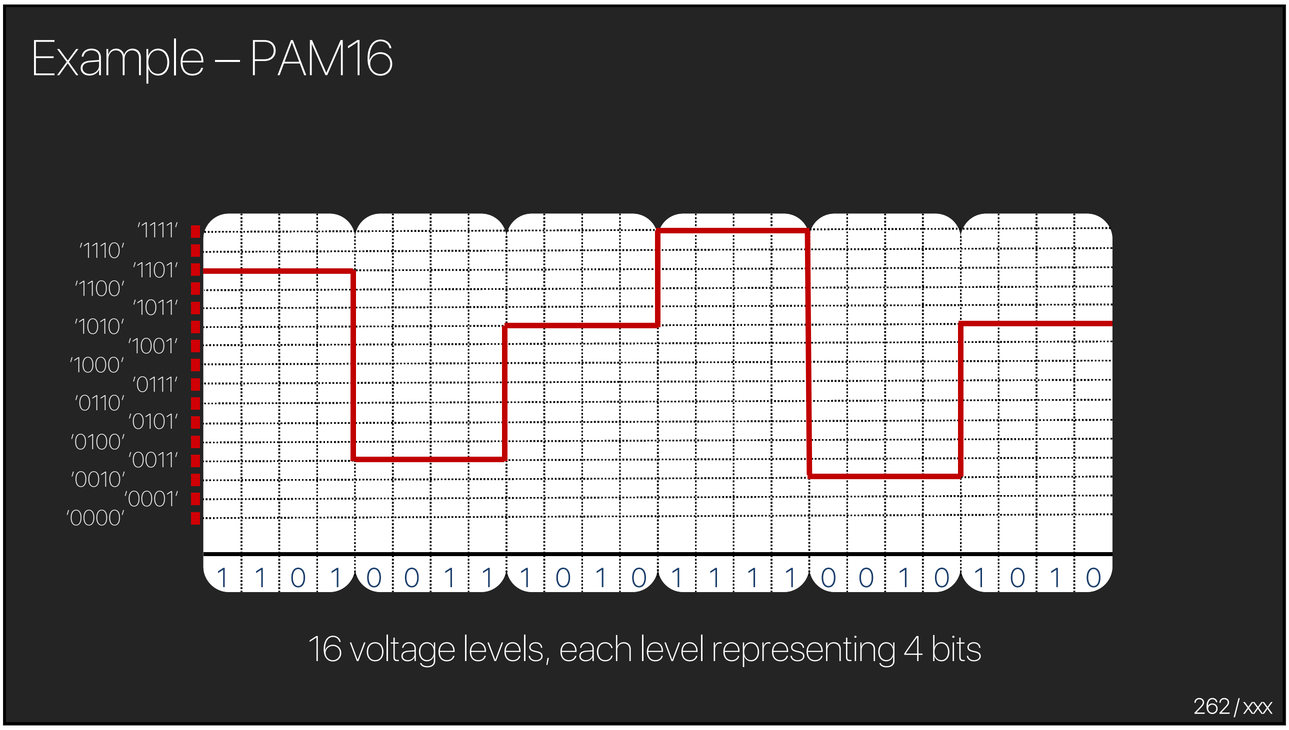
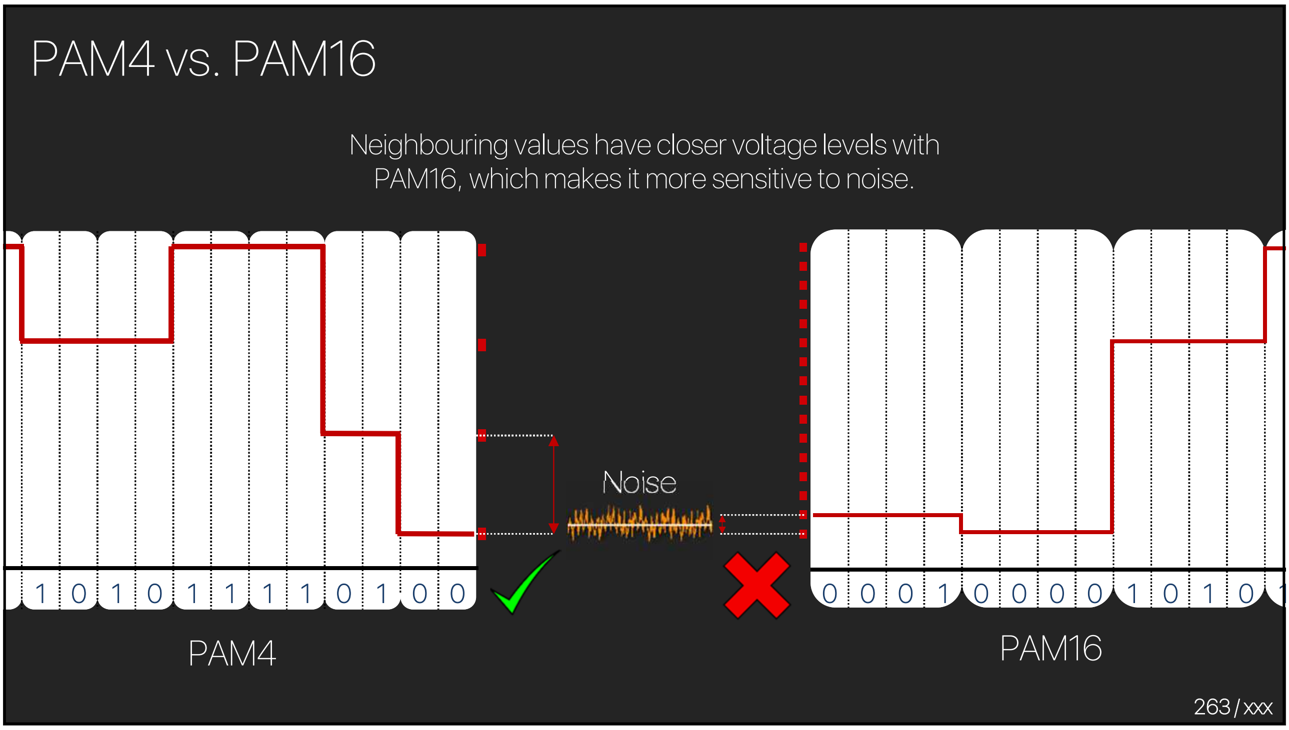
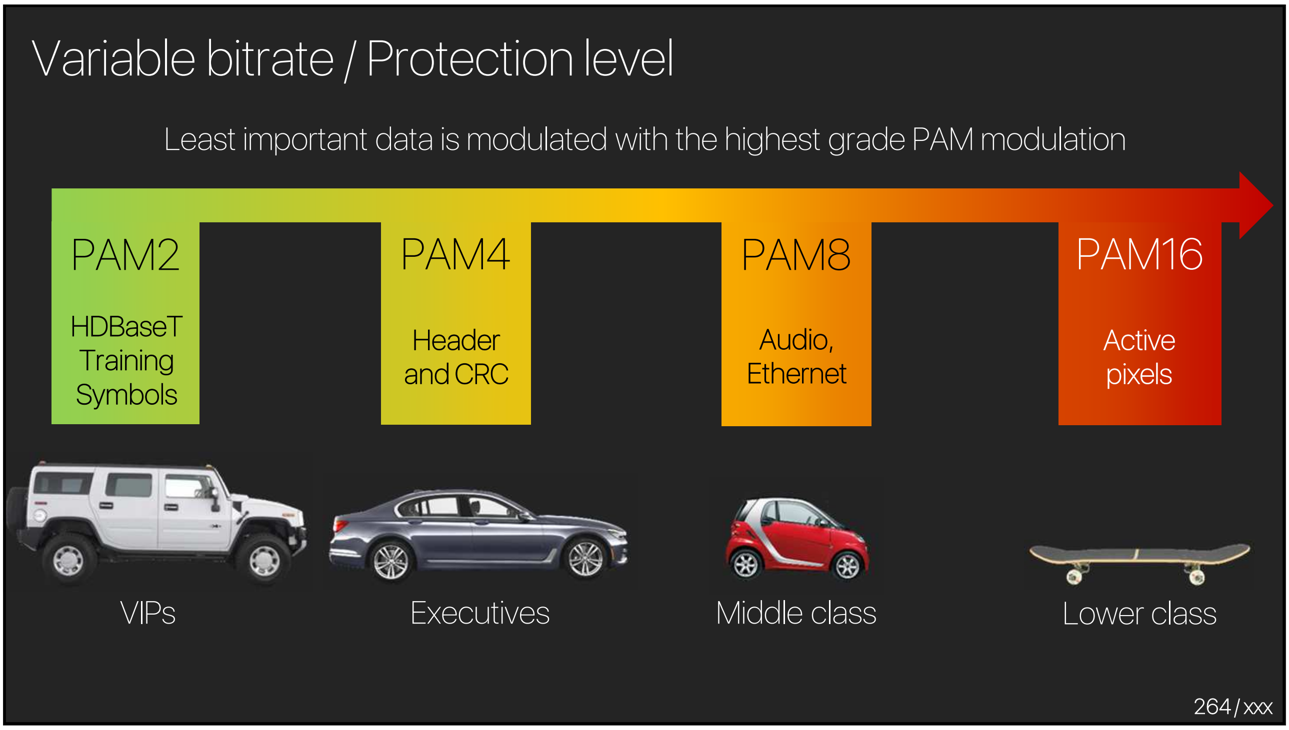

Example – PAM8
'111'
'110'
'101'
'100'
'011'
'010'
'001'
'000'
1 1 0 1 0 0 1 1 1 0 1 0 1 1 1 1 0 0 1 0 1 0 1 0
8 voltage levels, each level representing 3 bits
261 / xxx


Example – PAM16
'1111'
'1110'
'1101'
'1100'
'1011'
'1010'
'1001'
'1000'
'0111'
'0110'
'0101'
'0100'
'0011'
'0010'
'0001'
'0000'
1 1 0 1 0 0 1 1 1 0 1 0 1 1 1 1 0 0 1 0 1 0 1 0
16 voltage levels, each level representing 4 bits
262 / xxx


PAM4 vs. PAM16
Neighbouring values have closer voltage levels with PAM16, which makes it more sensitive to noise.
Noise
1 0 1 0 1 1 1 1 0 1 0 0
0 0 0 1 0 0 0 0 1 0 1 0
PAM4
PAM16
263 / xxx


Variable bitrate / Protection level
Least important data is modulated with the highest grade PAM modulation
PAM2
HDBaseT Training Symbols
PAM4
Header and CRC
PAM8
Audio, Ethernet
PAM16
Active pixels
VIPs
Executives
Middle class
Lower class
264 / xxx

Installation recommendations

- Use high quality cables
- Cables should be laid in a straight manner
- Avoid noise sources in the cable's environment
- Use maximum of two patch panels
- Max number of cables in a bundle (for 100m, 330'):
  - Six for Cat6a/7
  - Only one for Cat5e/6

265 / xxx

HDBaseT 2.0

- Backwards compatible with HDBaseT 1.x (5Play™), new feature set: HomePlay
- Audio Return Channel
- USB 2.0 support at up to 190 Mb/s and max. 22 endpoints (practically 7 devices)
- Upstream sublink's BW was increased from 150 Mbps to 300 Mbps
- Downstream sublink's BW is unchanged (8 Gbps)
- Multistreaming support - HDBaseT hubs, and daisy chainable devices

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HDBaseT summary

- Designed to complement HDMI, not to replace it
- 5Play™: Video + Audio + Control + Ethernet + Power
- Proprietary coding scheme (PAM16)
- Similar to 10GBaseT, but doesn't use IP protocol
- Less sensitive to CATx cable problems (skew, crosstalk, attenuation)

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Lightware TPS solutions

How Lightware enhances HDBaseT:

- 15 kV ESD protection
- Steel enclosure for EMI protection
- Two modes (HDBaseT and Long Reach)
- Cable diagnostics
- EDID Management
- Hybrid signal conversion
- Audio embedding/de-embedding
- Event Manager

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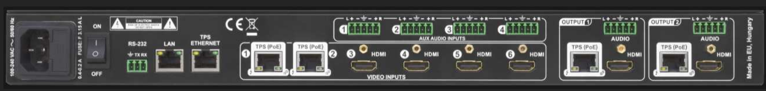
Lightware TPS solutions



MMX6x2-HT220

MX-TPS-IB/OB

WP-UMX-TPS-TX

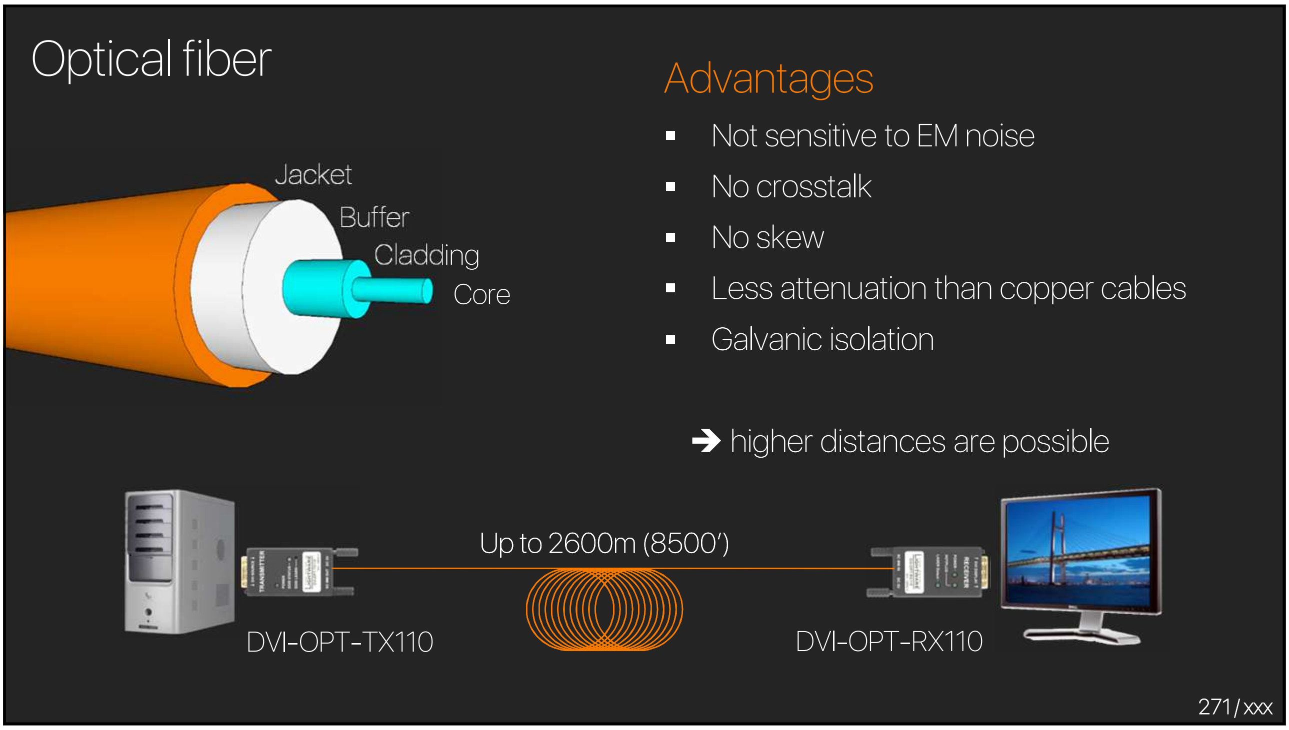
TPS-TX95/RX95

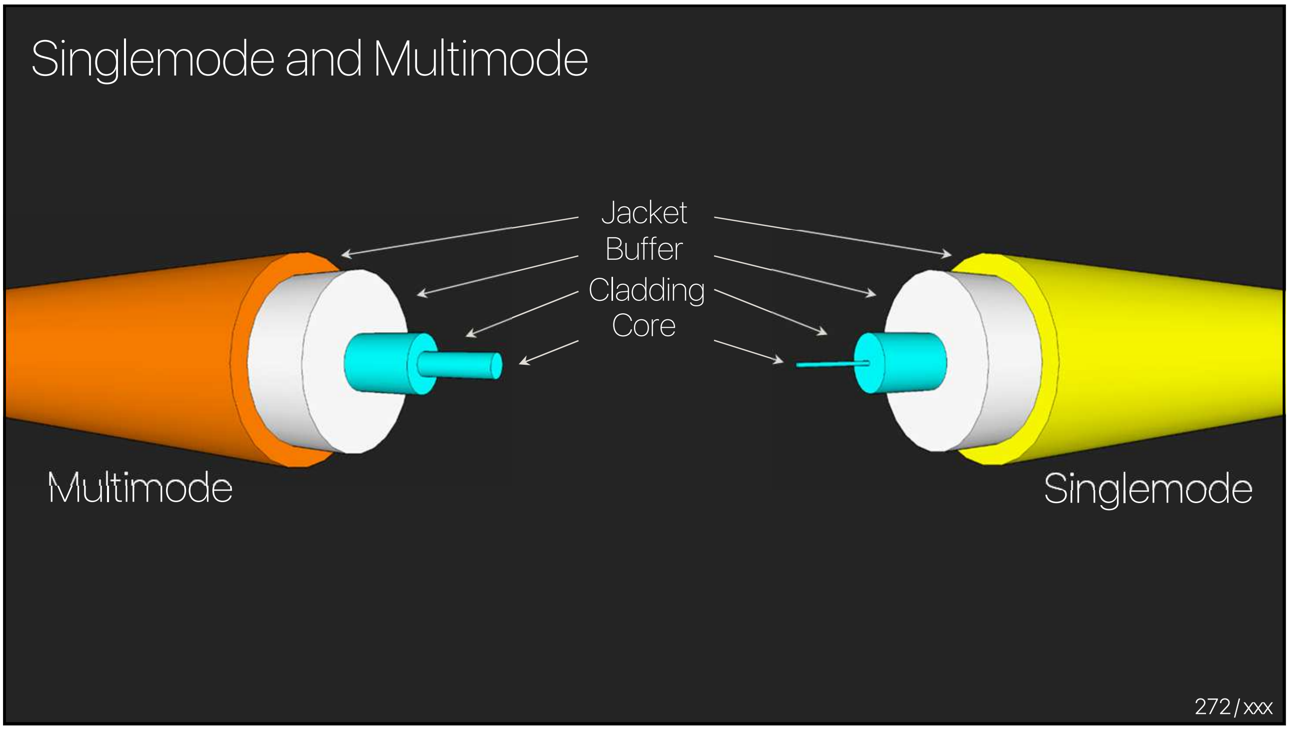
UMX-TPS-TX

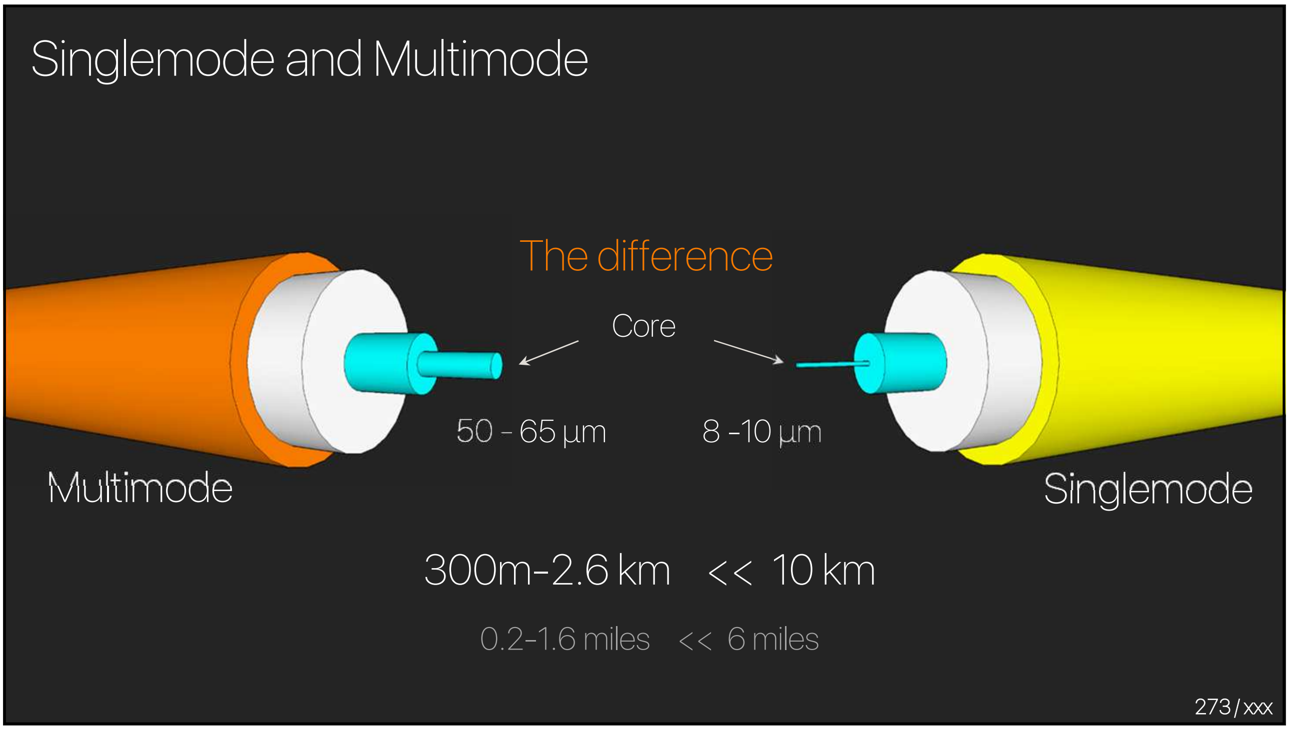
269 / xxx

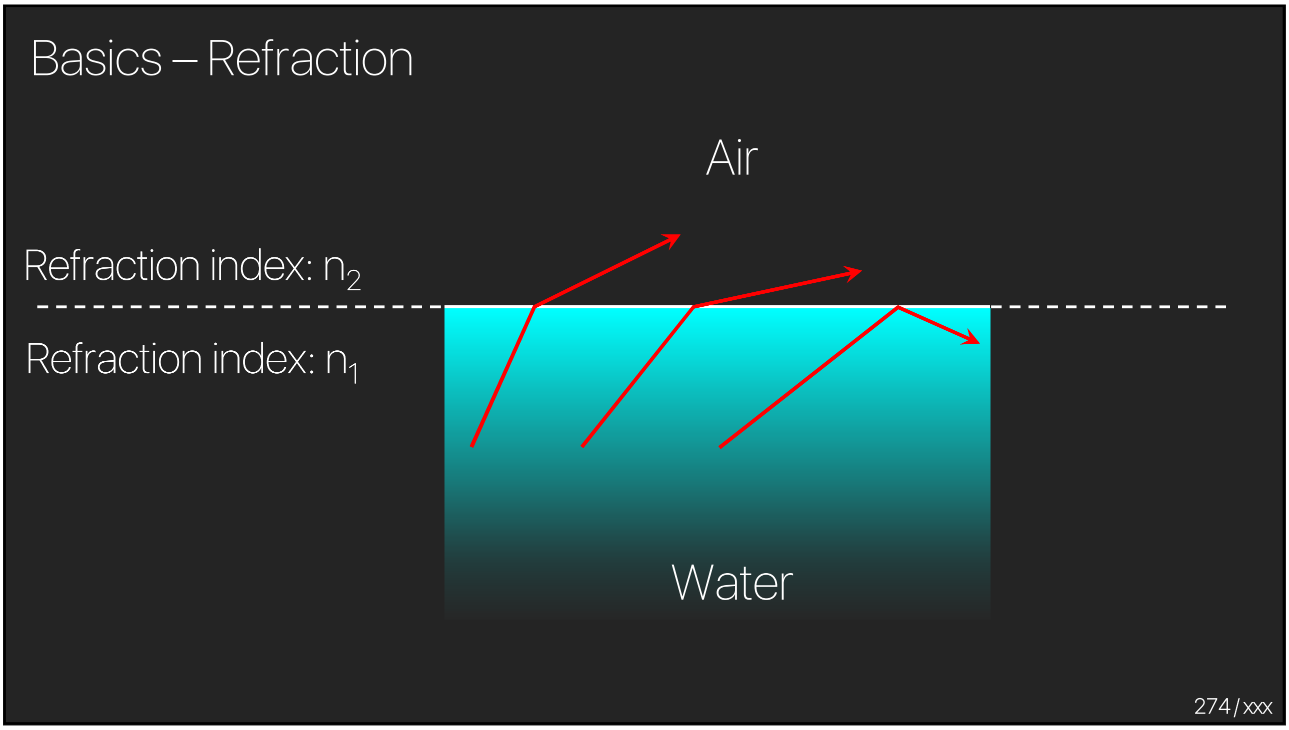
Fiber optical transmission

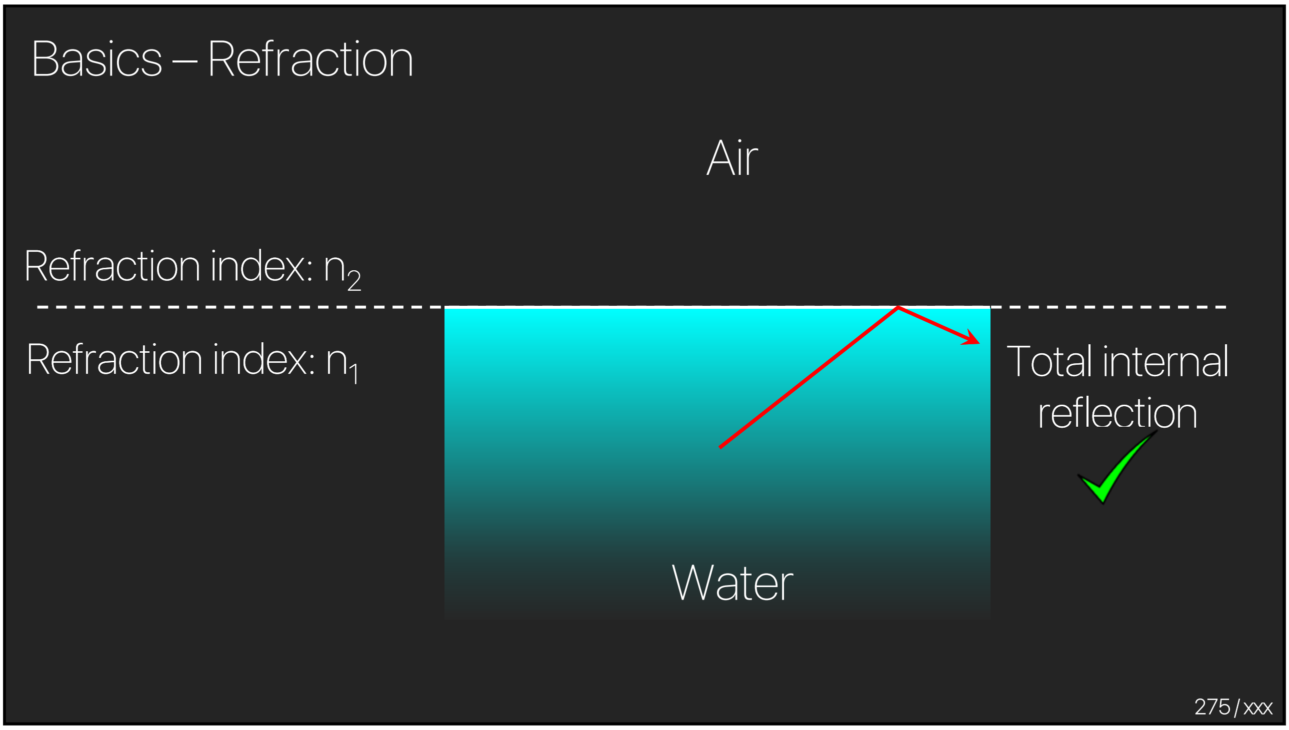
270 / xxx

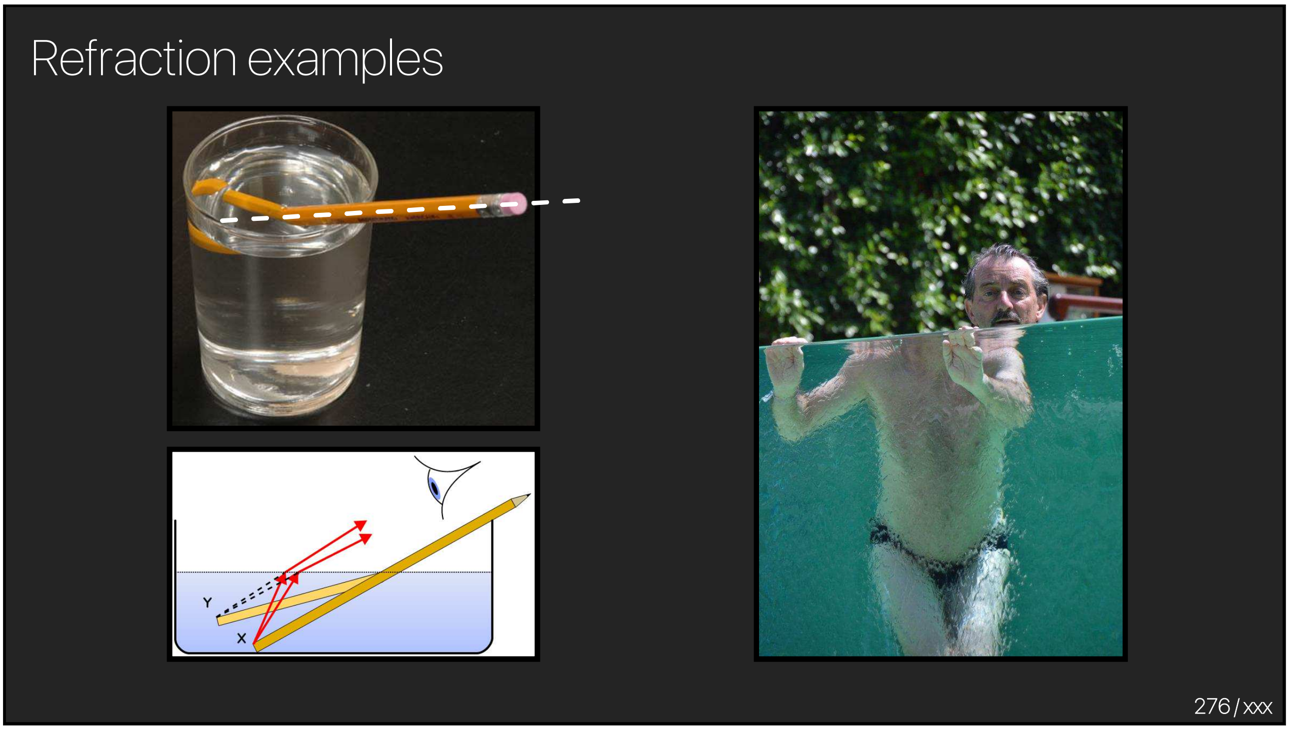

Optical fiber
Jacket
Buffer
Cladding
Core
Advantages
Not sensitive to EM noise
No crosstalk
No skew
Less attenuation than copper cables
Galvanic isolation
➔ higher distances are possible
Up to 2600m (8500')
DVI-OPT-TX110
DVI-OPT-RX110
271 / xxx

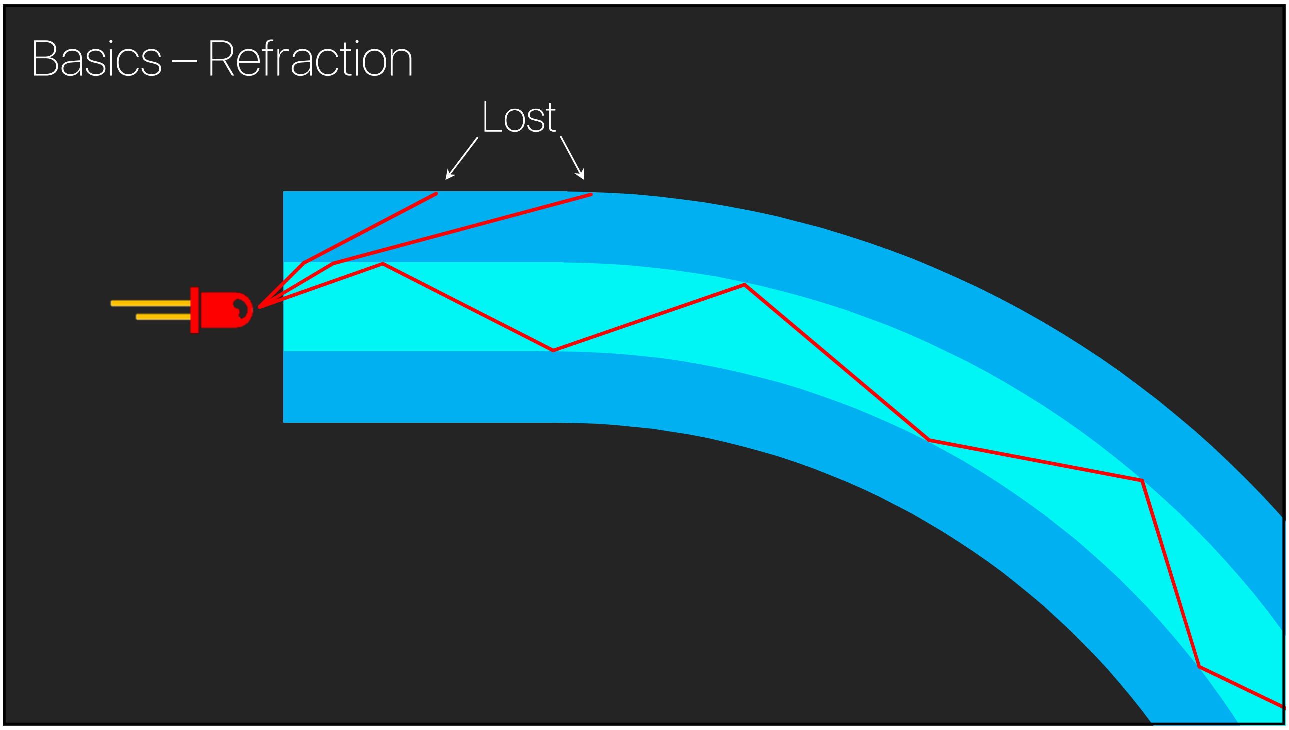

Singlemode and Multimode
Jacket
Buffer
Cladding
Core
Multimode
Singlemode
272 / xxx

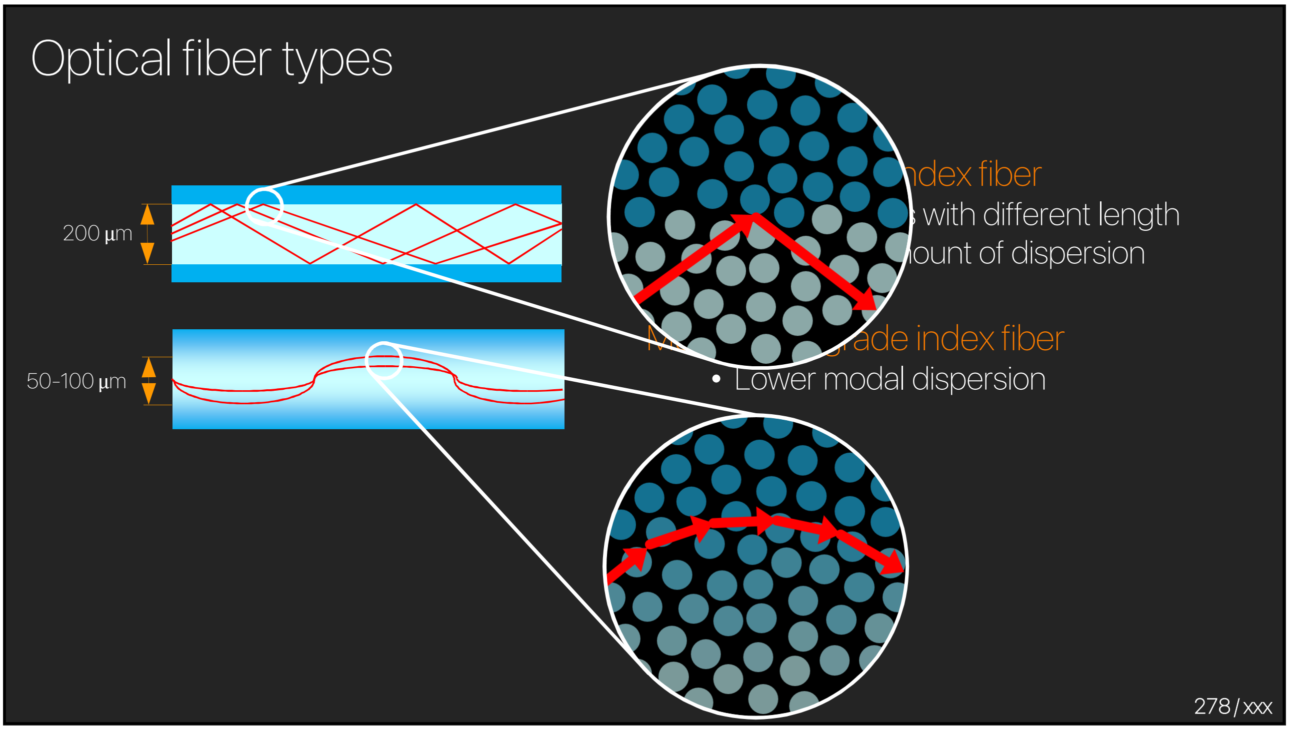

Singlemode and Multimode
The difference
Core
50 - 65 µm
8 -10 µm
Multimode
Singlemode
300m-2.6 km << 10 km
0.2-1.6 miles << 6 miles
273 / xxx

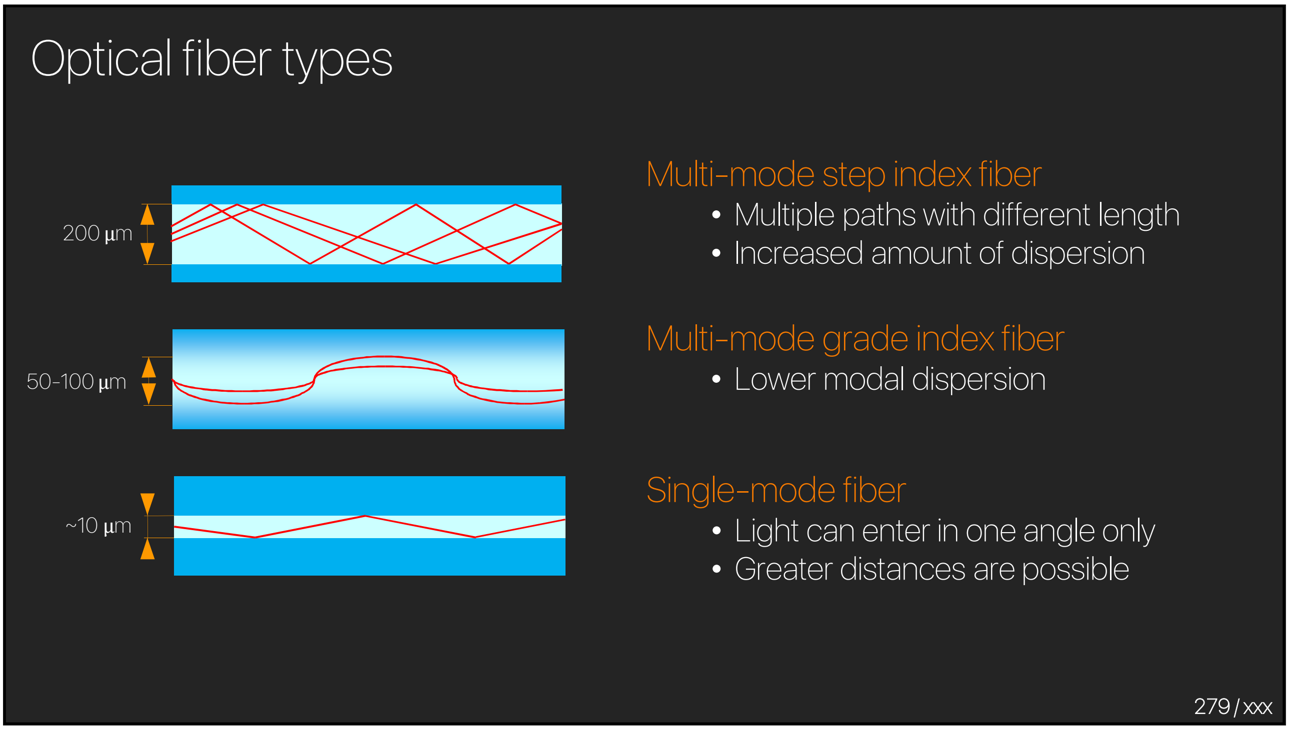

Basics – Refraction
Air
Refraction index: n2
Refraction index: n1
Water
274 / xxx

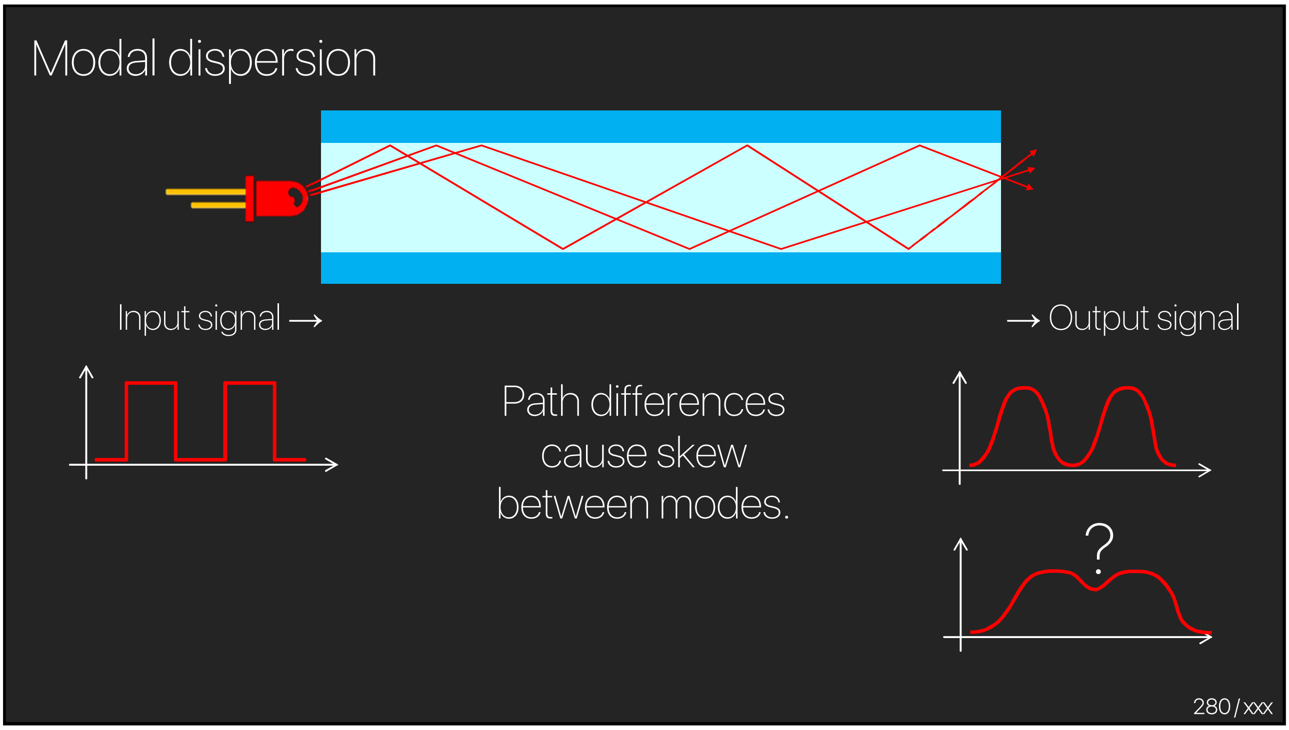

Basics – Refraction
Air
Refraction index: n_2
Refraction index: n_1
Total internal reflection
Water
275 / xxx


Refraction examples
Y
X
276 / xxx


Basics – Refraction
Lost


Optical fiber types
200 µm
50-100 µm
ndex fiber
s with different length
ount of dispersion
rade index fiber
• Lower modal dispersion
278 / xxx


Optical fiber types
200 μm
50-100 μm
~10 μm
Multi-mode step index fiber
• Multiple paths with different length
• Increased amount of dispersion
Multi-mode grade index fiber
• Lower modal dispersion
Single-mode fiber
• Light can enter in one angle only
• Greater distances are possible
279 / xxx


Modal dispersion
Input signal →
→ Output signal
Path differences cause skew between modes.
?
280 / xxx

Multimode fiber types

Transmission properties	Fiber type L (OM1)		Fiber type F (OM2)		Fiber type I (OM3)		Fiber type OM3e		Fiber type J (OM4)	
Wavelength	850	1300	850	1300	850	1300	850	1300	850	1300
Attenuation	3.2	0.9	3.0	1.0	2.5	0.7	2.5	0.7	2.5	0.7
Bandwidth (MHz km)	200	500	500	500	1500	500	3500	500	3500	500
Numerical aperture	0.275 ± 0.015		0.2 ± 0.02		0.2 ± 0.015		0.2 ± 0.015		0.2 ± 0.015	

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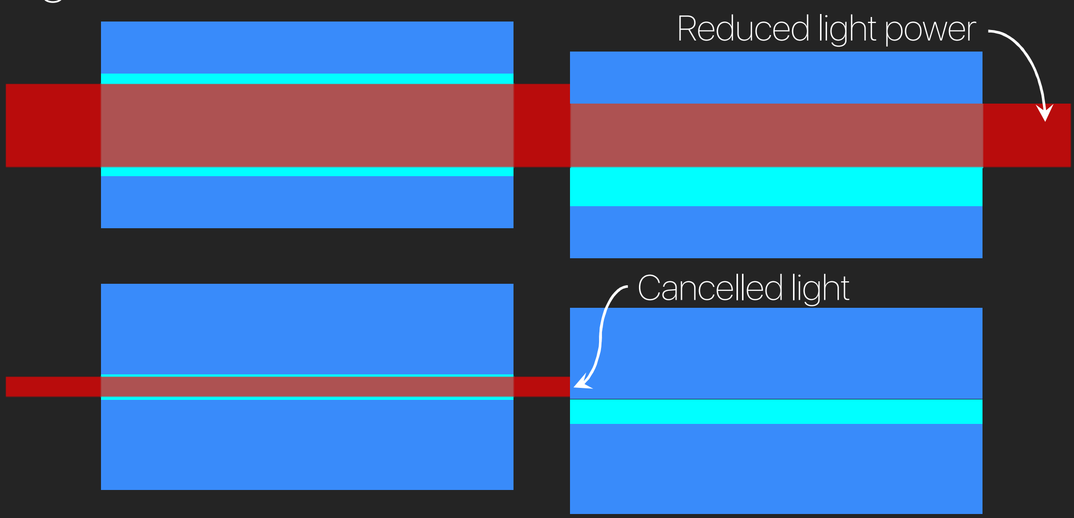
Misalignment



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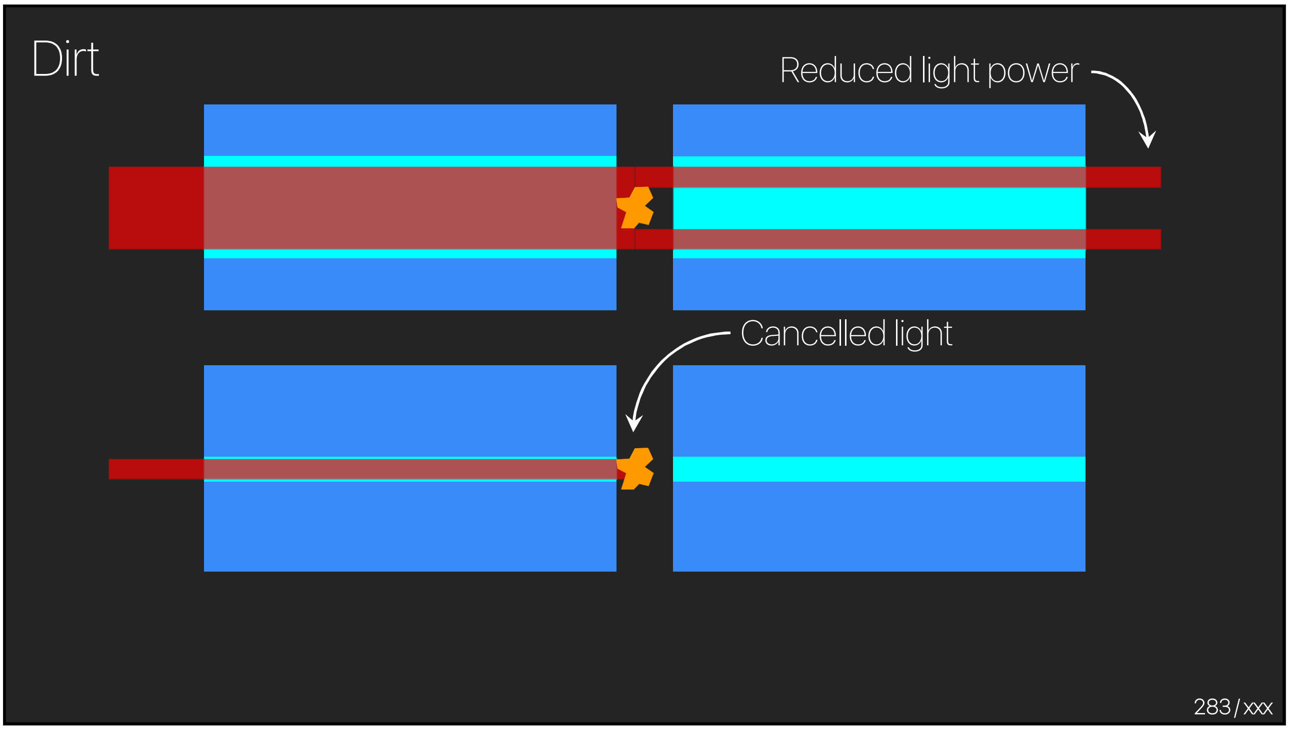
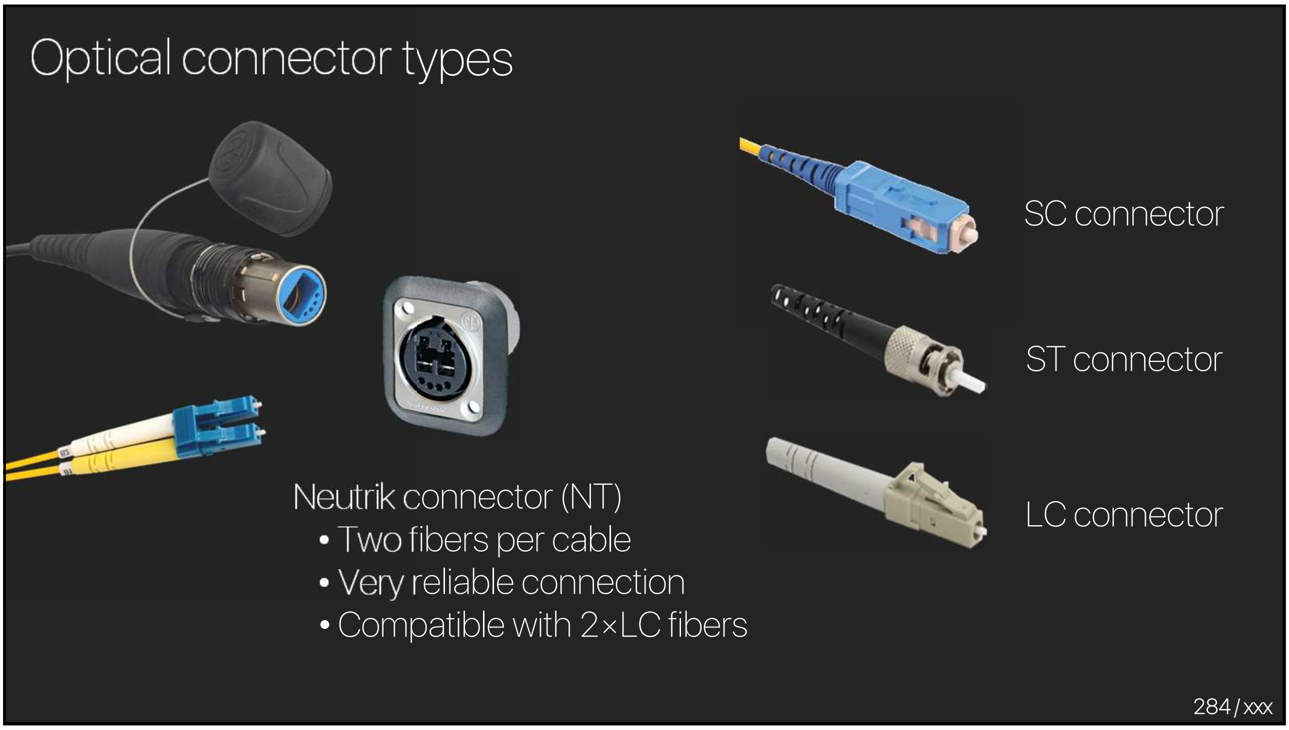

Dirt
Reduced light power
Cancelled light
283 / xxx


Optical connector types
SC connector
ST connector
LC connector
Neutrik connector (NT)
• Two fibers per cable
• Very reliable connection
• Compatible with 2×LC fibers
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OPT series

DVI-OPT and HDMI-OPT

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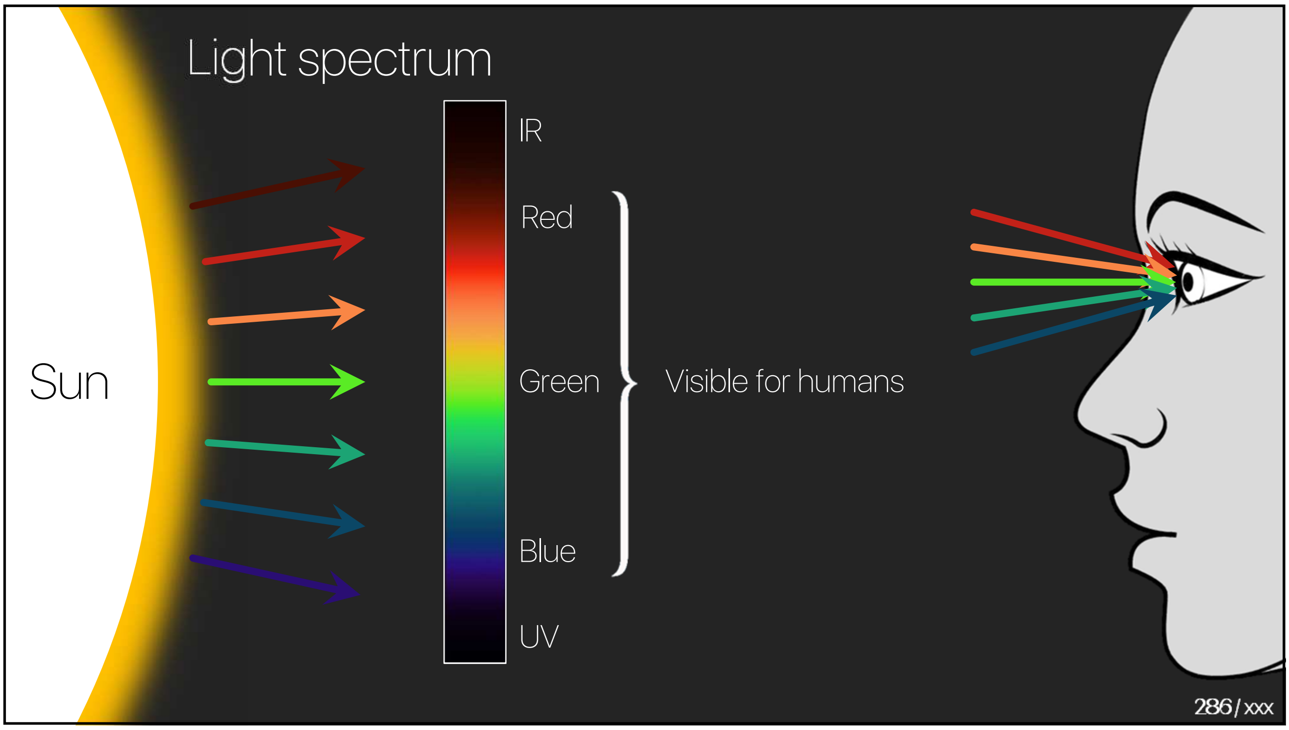
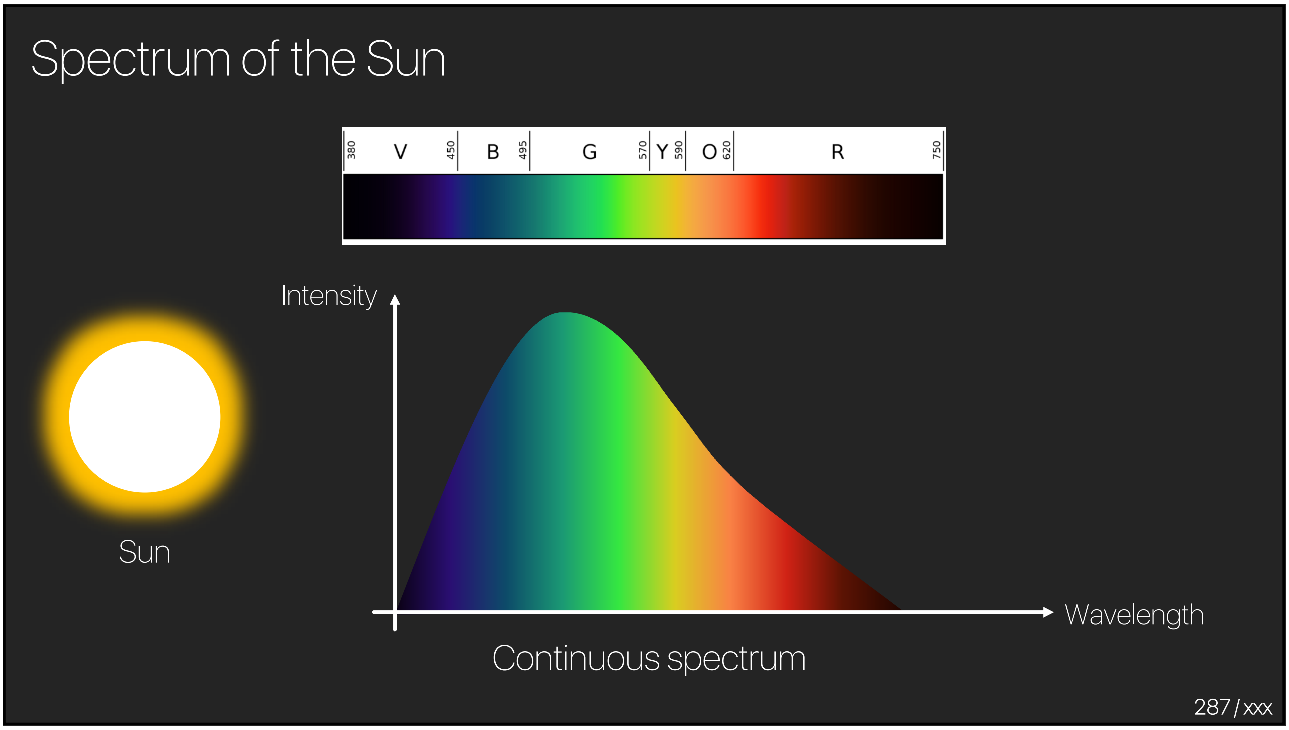
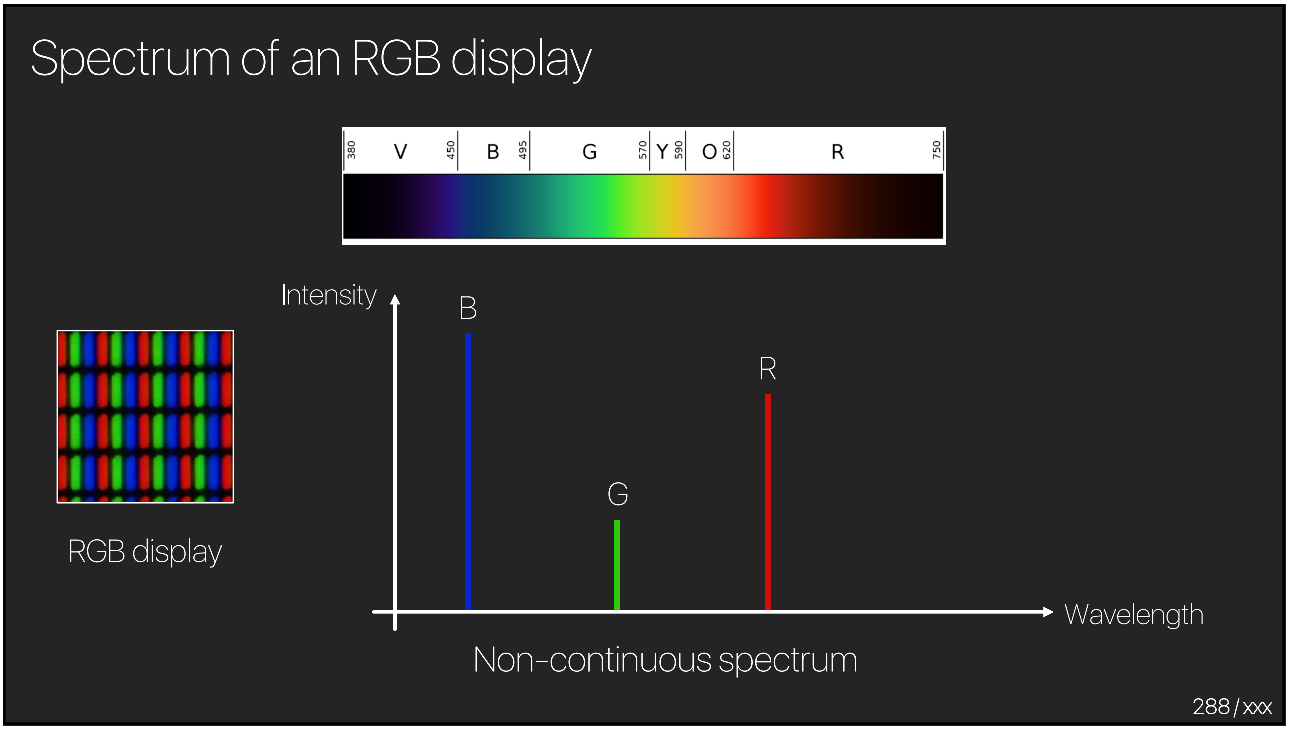
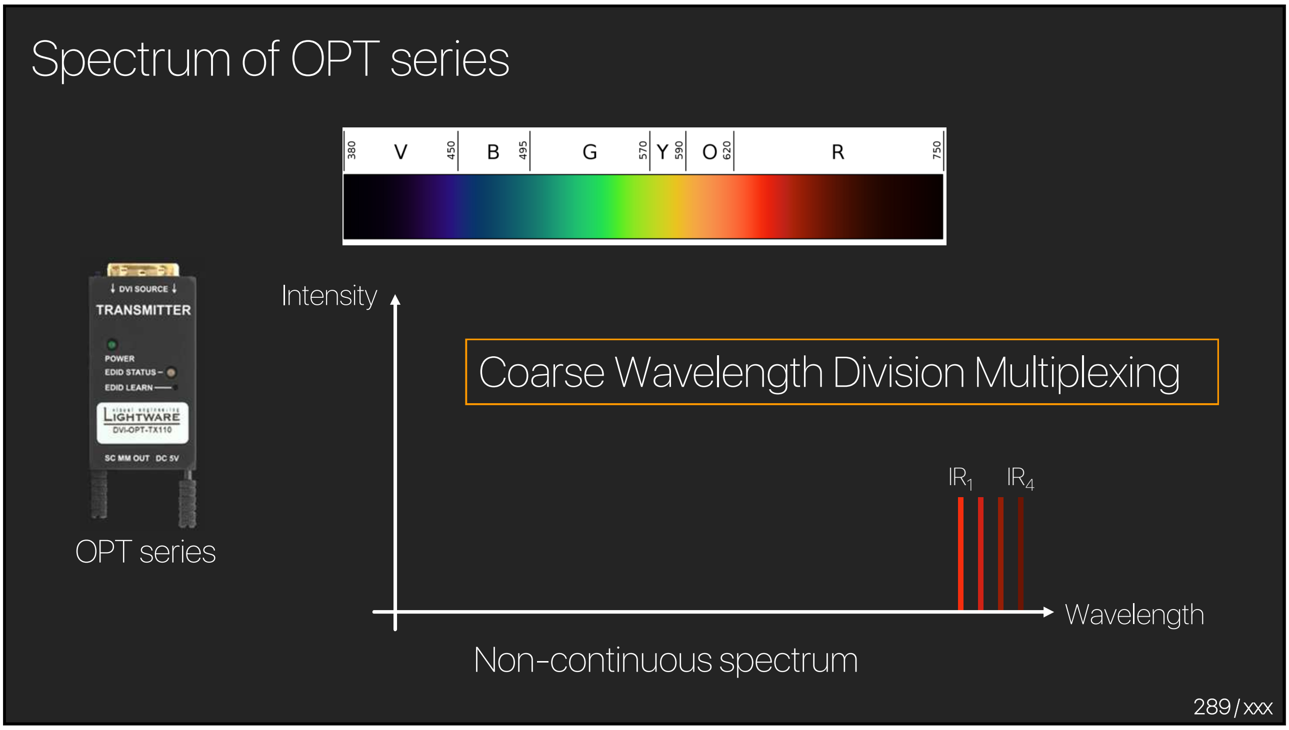
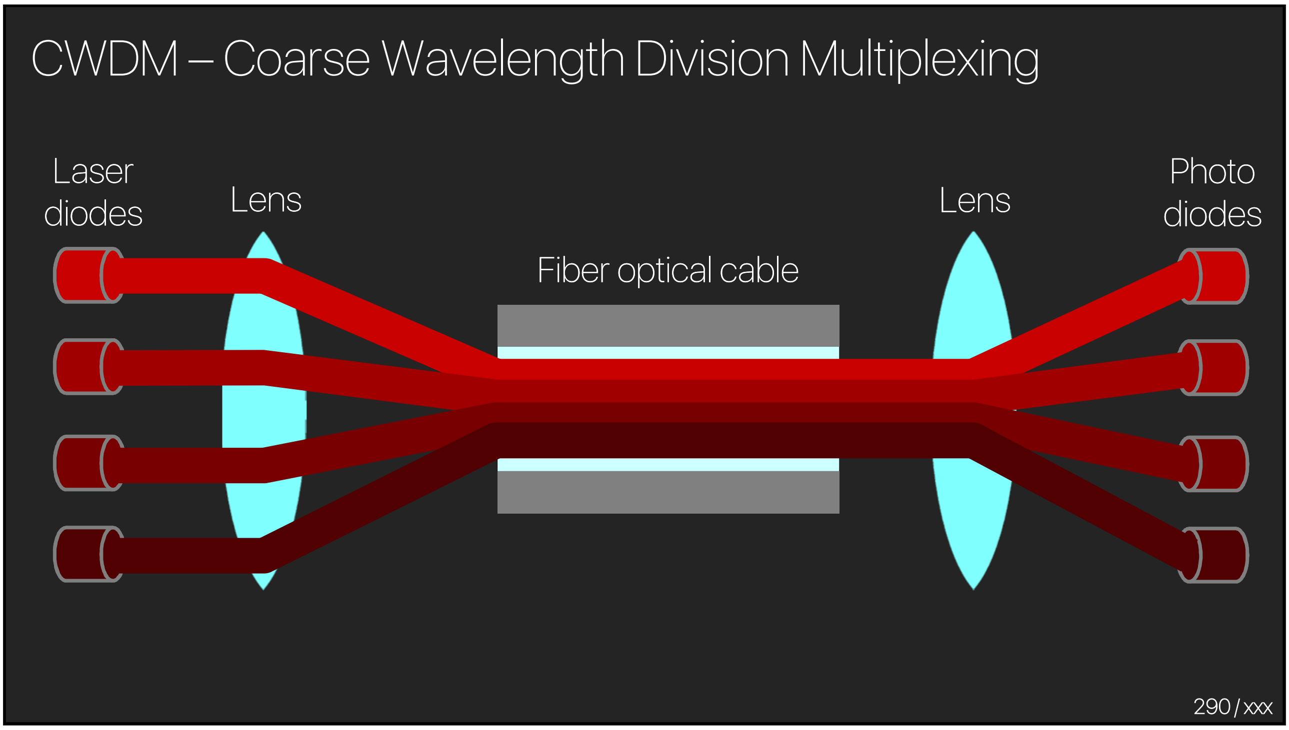


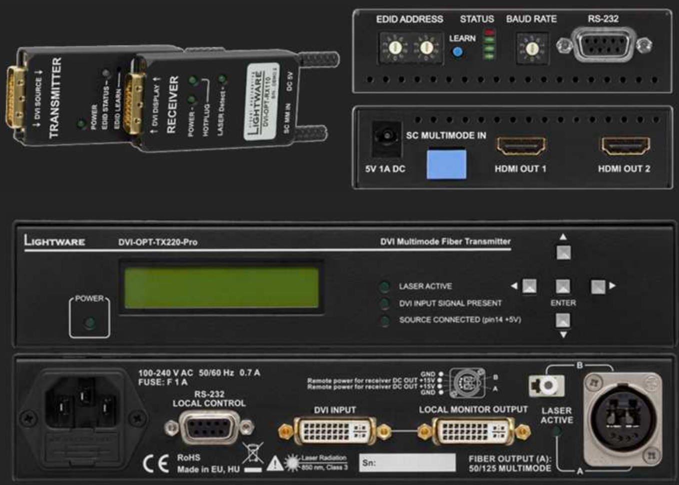

Spectrum of the Sun
380
V
450
B
495
G
570
Y
590
O
620
R
750
Intensity
Sun
Wavelength
Continuous spectrum
287 / xxx


Spectrum of an RGB display
380
V
450
B
495
G
570
Y
590
O
620
R
750
Intensity
B
R
G
RGB display
Wavelength
Non-continuous spectrum
288 / xxx


Spectrum of OPT series
380
V
450
B
495
G
570
Y
590
O
620
R
750
TRANSMITTER
OPT series
Intensity
Coarse Wavelength Division Multiplexing
IR_1
IR_4
Wavelength
Non-continuous spectrum
289 / xxx


CWDM – Coarse Wavelength Division Multiplexing
Laser diodes
Lens
Lens
Photo diodes
Fiber optical cable
290 / xxx

Lightware OPT technology



- One multimode Fiber
- Zero frame delay
- No compression
- DVI, HDMI and DisplayPort
- Up to 2600 meters (1.6 miles)

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Lightware OPT technology

- Input and Output cards
- NT, SC, ST and LC connectors
- DVI and HDMI compliant
- With or without Pixel Accurate Reclocking
- Can be mixed with any other card

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OPTM/OPTS series

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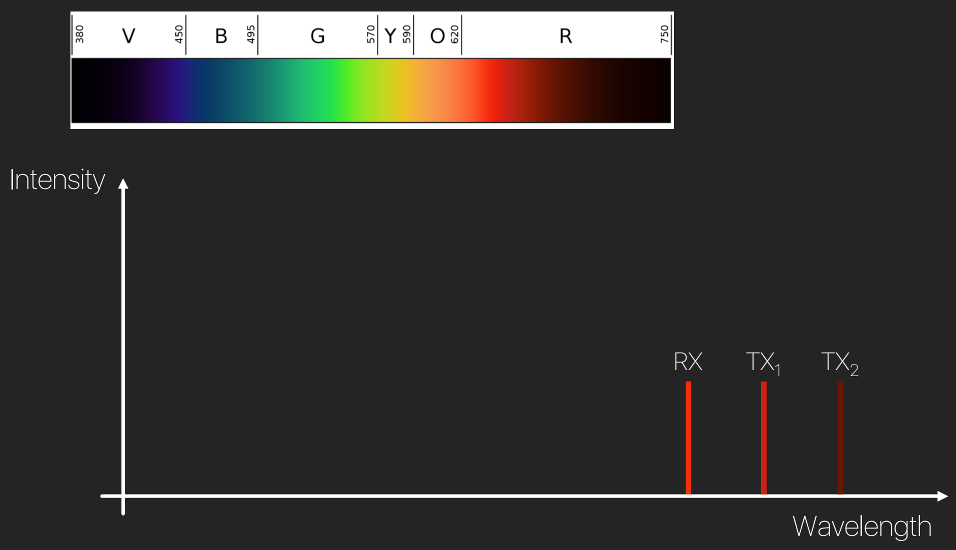
Spectrum of OPTM/OPTS series

OPTM/OPTS series



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Hybrid router concept

Modular System Structure (2007)

- Single Link DVI
- Dual Link DVI
- HDMI
- DVI-I
- 3G-SDI
- Fiber
- CATx (TP and TPS)

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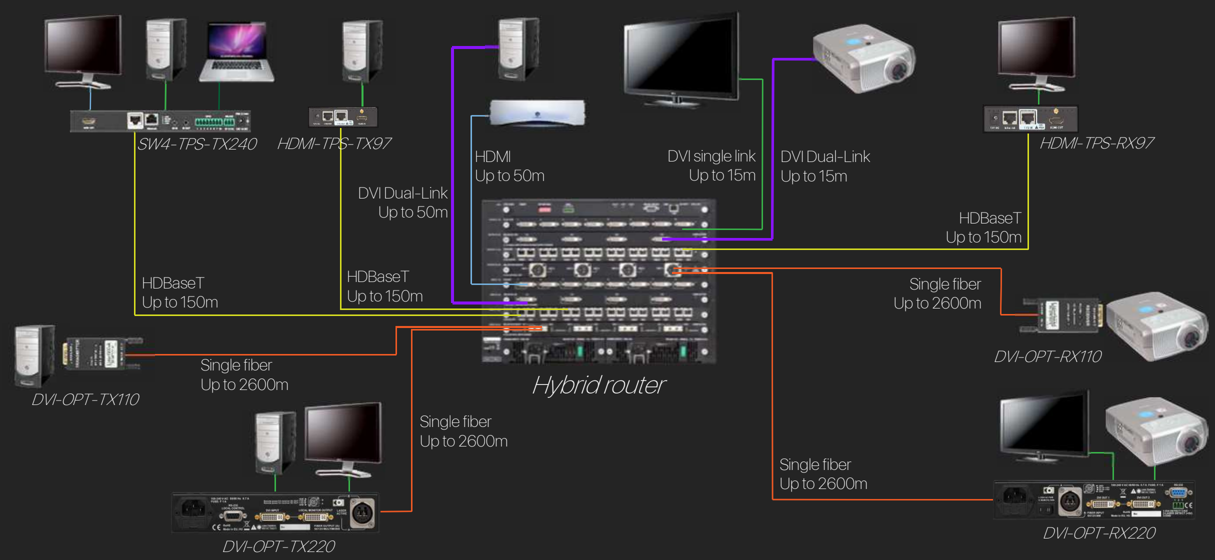
Hybrid router concept example



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DisplayPort

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Industry needs for DisplayPort

- Common standard for internal and external display connections.
- Simplify cabling.
- Reduce cost and complexity.
- Enable digital audio transmission.
- Enable content protection.
- Higher bandwidth on fewer wires.
- Apply embedded clock to reduce EMI.
- Provide a small form factor and latching connector.
- Create an open and extensible standard.
- Provide legacy support.

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Features of DisplayPort

- Standard by VESA
- 1, 2 or 4 data pairs
- 8B/10B Encoding
- Up to 21.6 Gbps (DP v1.2)
- RGB, YCbCr and xvYCC (only in v1.2)
- Deep color
- Supports all HDMI resolutions
- 8 channel audio
- Content protection (HDCP, DPCP)

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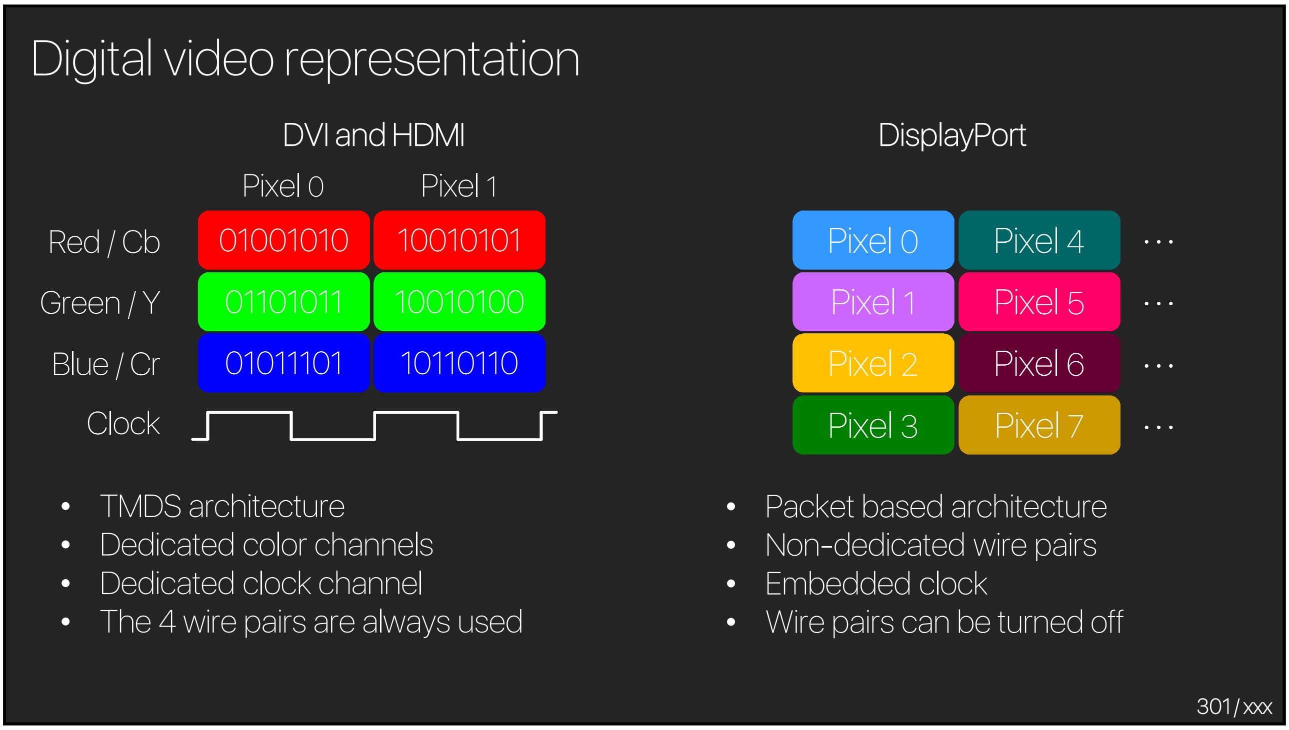
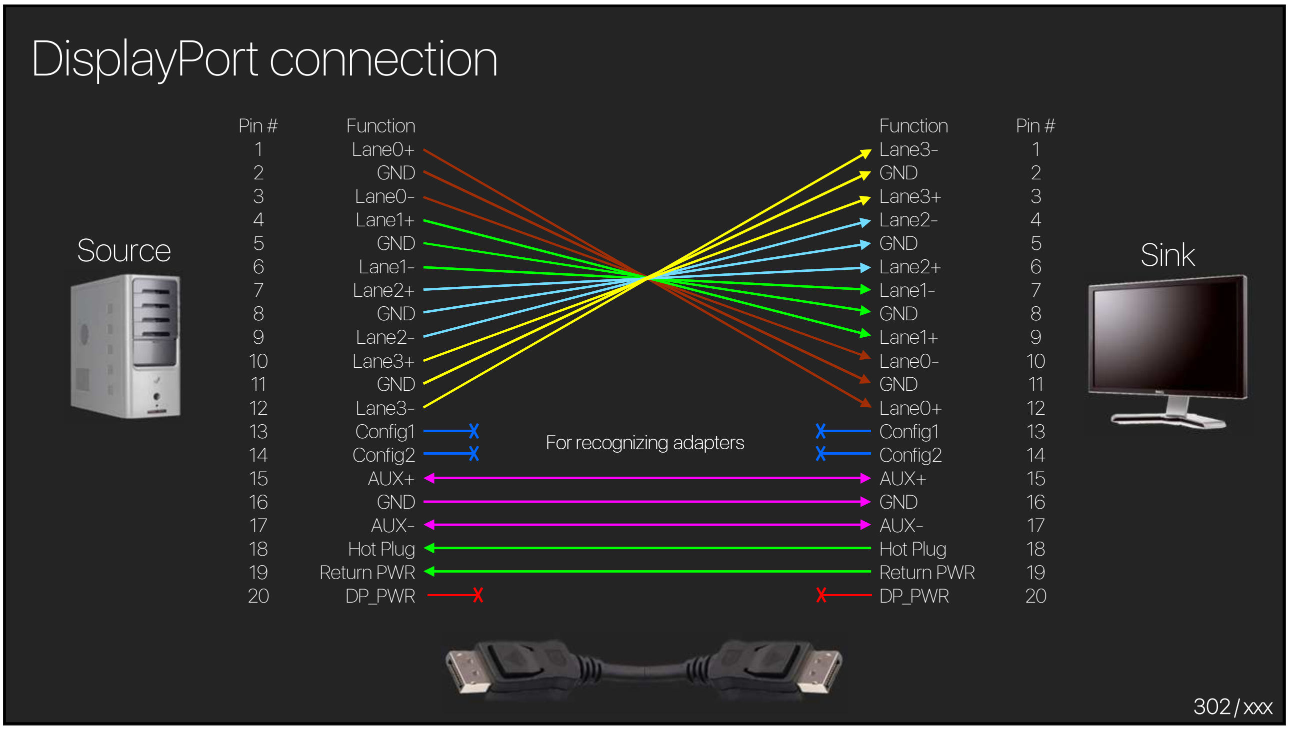
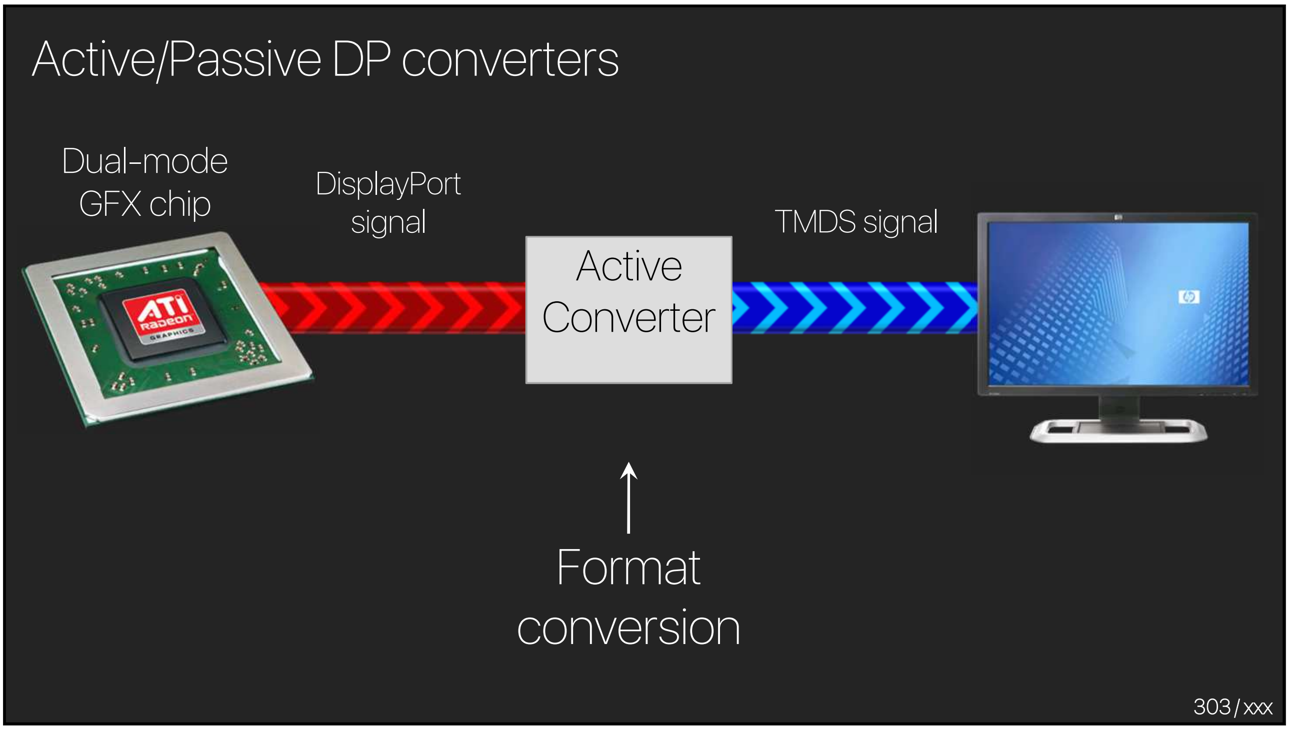
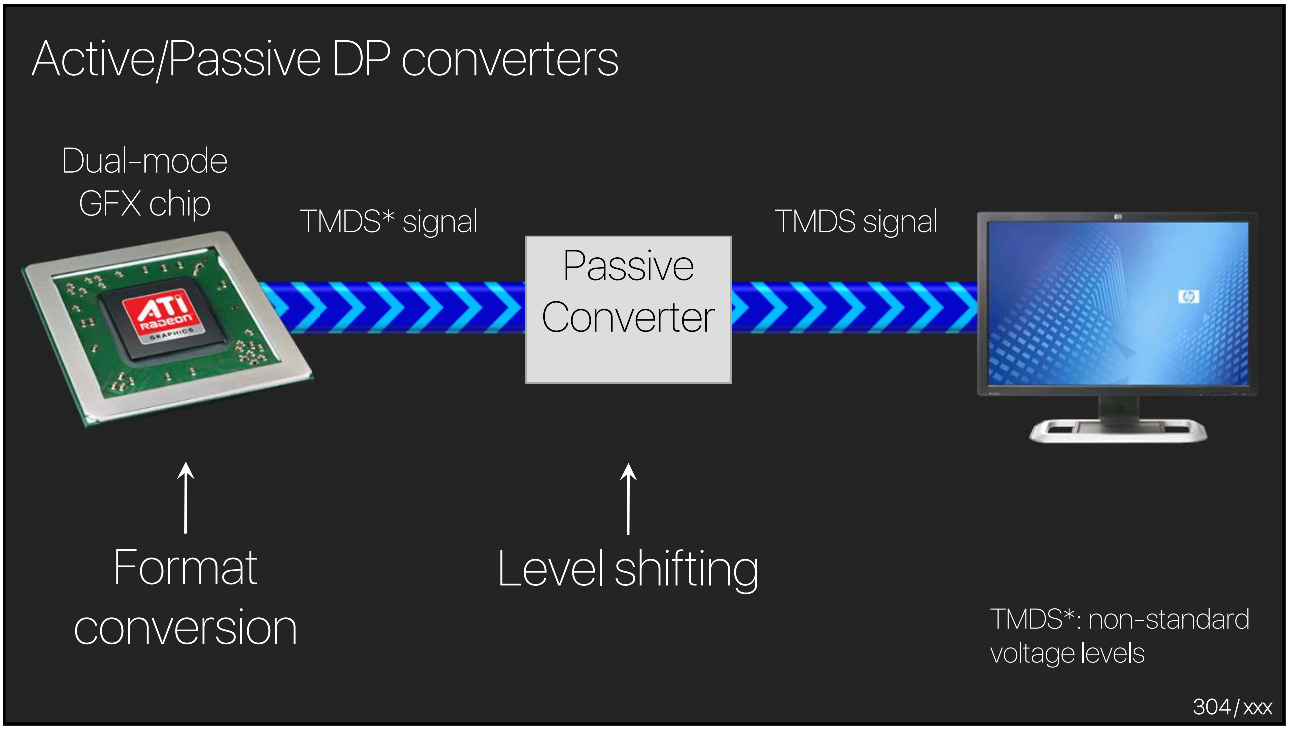

Digital video representation
DVI and HDMI
Pixel 0
Pixel 1
Red / Cb
01001010
10010101
Green / Y
01101011
10010100
Blue / Cr
01011101
10110110
Clock
DisplayPort
Pixel 0
Pixel 4
Pixel 1
Pixel 5
Pixel 2
Pixel 6
Pixel 3
Pixel 7
• TMDS architecture
• Dedicated color channels
• Dedicated clock channel
• The 4 wire pairs are always used
• Packet based architecture
• Non-dedicated wire pairs
• Embedded clock
• Wire pairs can be turned off
301 / xxx


DisplayPort connection
Source
Sink
Pin #
Function
1 Lane0+
2 GND
3 Lane0-
4 Lane1+
5 GND
6 Lane1-
7 Lane2+
8 GND
9 Lane2-
10 Lane3+
11 GND
12 Lane3-
13 Config1
14 Config2
15 AUX+
16 GND
17 AUX-
18 Hot Plug
19 Return PWR
20 DP_PWR
For recognizing adapters
Function
Pin #
Lane3- 1
GND 2
Lane3+ 3
Lane2- 4
GND 5
Lane2+ 6
Lane1- 7
GND 8
Lane1+ 9
Lane0- 10
GND 11
Lane0+ 12
Config1 13
Config2 14
AUX+ 15
GND 16
AUX- 17
Hot Plug 18
Return PWR 19
DP_PWR 20
302 / xxx


Active/Passive DP converters
Dual-mode GFX chip
DisplayPort signal
Active Converter
TMDS signal
Format conversion
303 / xxx


Active/Passive DP converters
Dual-mode GFX chip
TMDS* signal
Passive Converter
TMDS signal
Format conversion
Level shifting
TMDS*: non-standard voltage levels
304 / xxx

Active/Passive DP converters

Passive or active DP to DVI/HDMI

- Small form factor
- One-chip solution
- Low power consumption

DP to VGA

- Medium form factor
- Active converter
- Signal format conversion (D/A)
- Low power consumption

DP to Dual Link DVI

- Bigger size (more chips)
- Active converter
- Expensive converter chips
- Signal format conversion
- High power consumption

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Dual-mode pin mapping

DisplayPort	DP++ to DVI/HDMI Passive Adapter
Main Link Lane 0	TMDS Channel 2
Main Link Lane 1	TMDS Channel 1
Main Link Lane 2	TMDS Channel 0
Main Link Lane 3	TMDS Clock
AUX Ch+	DDC Clock
AUX Ch-	DDC Data
DP_PWR (+3.3V)	DP_PWR (source for DVI 5V)
Hot Plug Detect	Hot Plug Detect
Config 1	Video Adapter Detect
Config 2	CEC (HDMI only)

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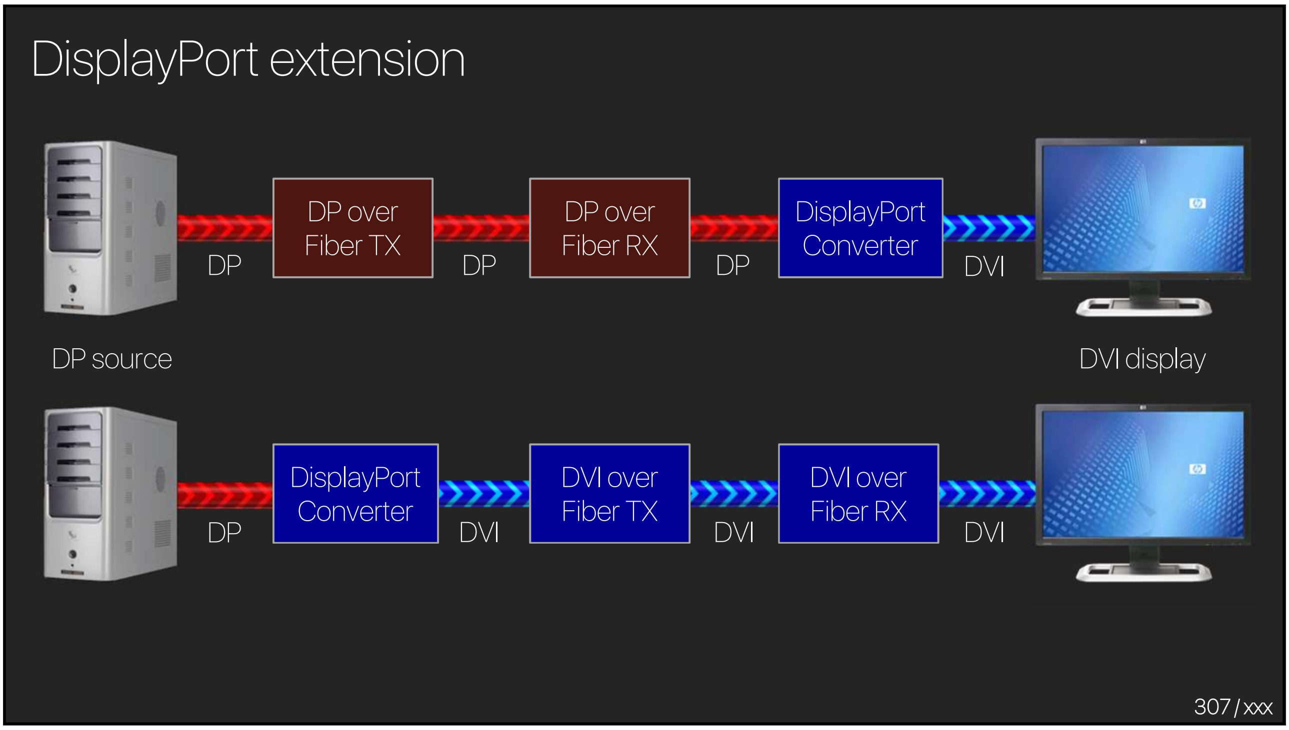
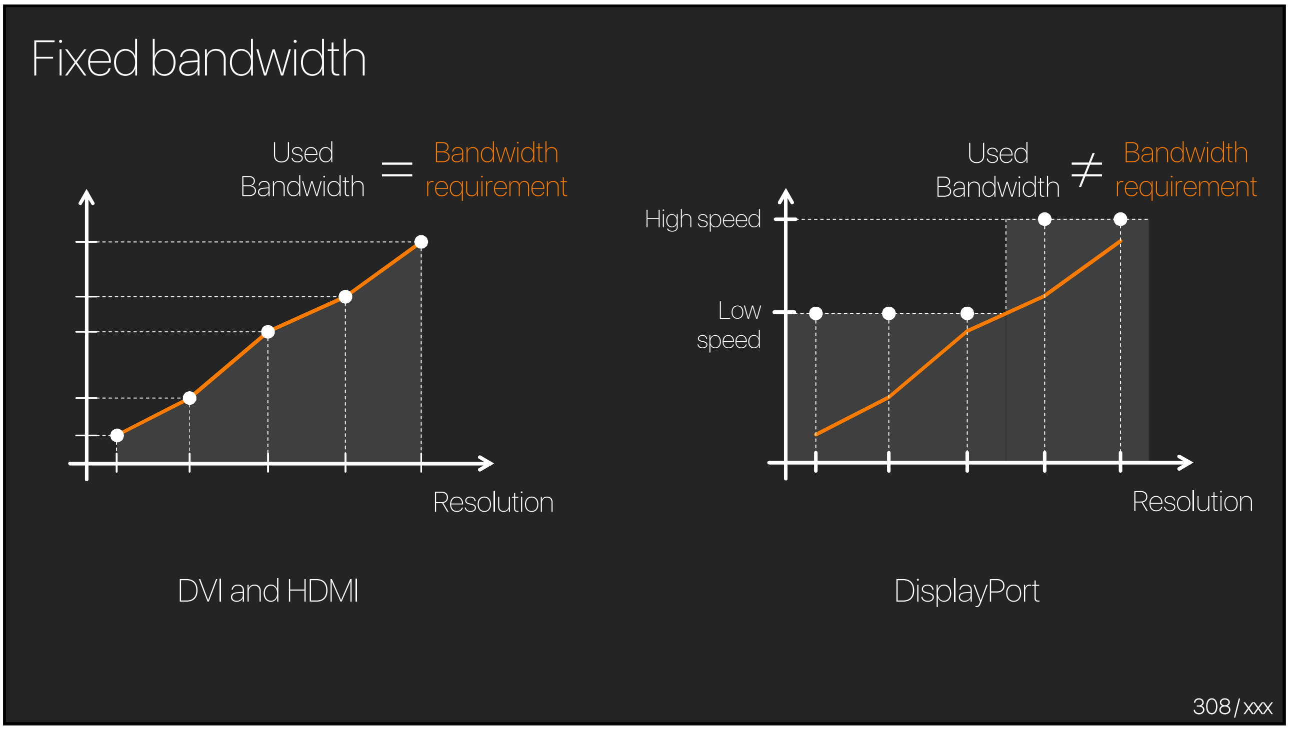
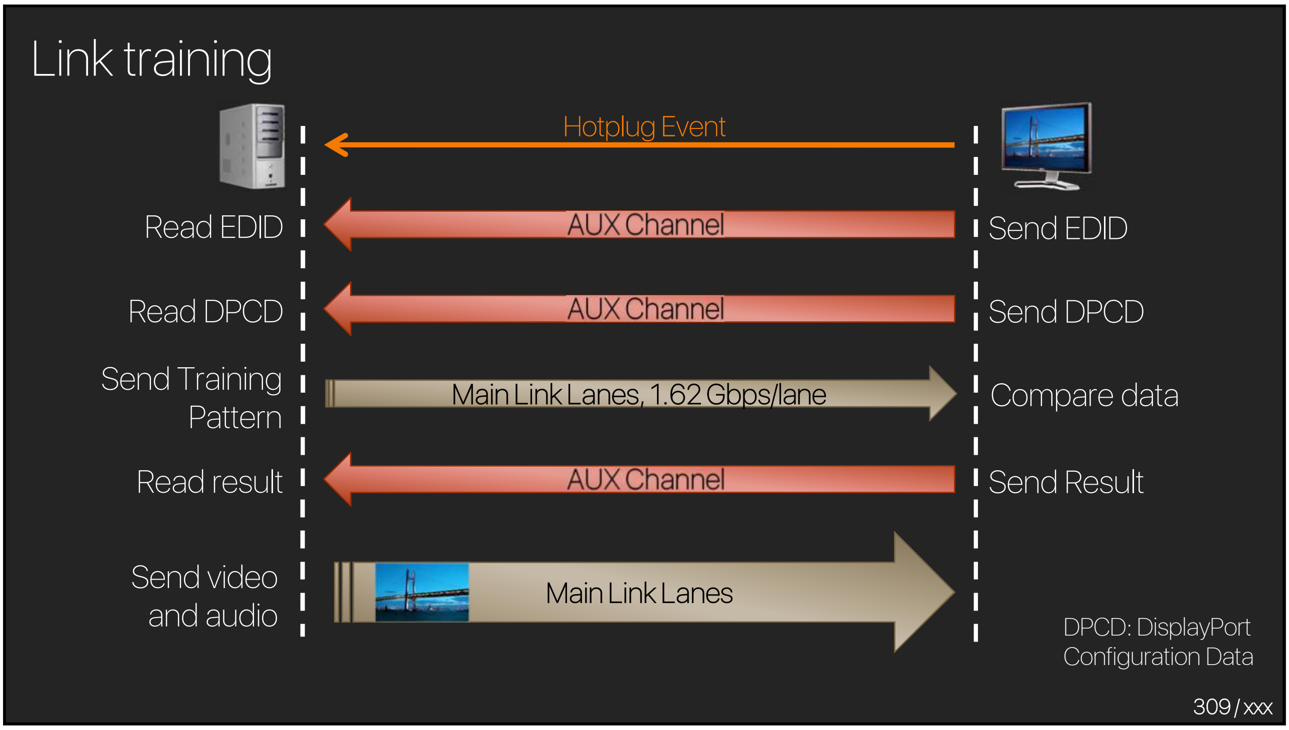


DisplayPort extension
DP over Fiber TX
DP over Fiber RX
DisplayPort Converter
DP
DP
DP
DVI
DP source
DVI display
DisplayPort Converter
DVI over Fiber TX
DVI over Fiber RX
DP
DVI
DVI
DVI
307 / xxx



Fixed bandwidth
Used Bandwidth
=
Bandwidth requirement
Resolution
DVI and HDMI
High speed
Low speed
Used Bandwidth
≠
Bandwidth requirement
Resolution
DisplayPort
308 / xxx



Micro-packets and lane count

Lane 0	Lane 1	Lane 2	Lane 3
Pixel 0	Pixel 1	Pixel 2	Pixel 3
Pixel 4	Pixel 5	Pixel 6	Pixel 7
CTRL	CTRL	CTRL	CTRL
4N	4N+1	4N+2	4N+3

Lane 0	Lane 1
Pixel 0	Pixel 1
Pixel 2	Pixel 3
Pixel 4	Pixel 5
Pixel 6	Pixel 7
CTRL	CTRL
CTRL	CTRL
2N	2N+1

Lane 0
Pixel 0
Pixel 1
Pixel 2
Pixel 3
Pixel 4
Pixel 5
Pixel 6
Pixel 7
CTRL
CTRL
CTRL
CTRL
All pixels

- All lanes use embedded clock.
- Control data is always sent 4 times.
- The highest possible bitrate and lowest number of lanes are used.
- Pixel information is put into packets.
- Packets are carried by the assigned Main Link lane.

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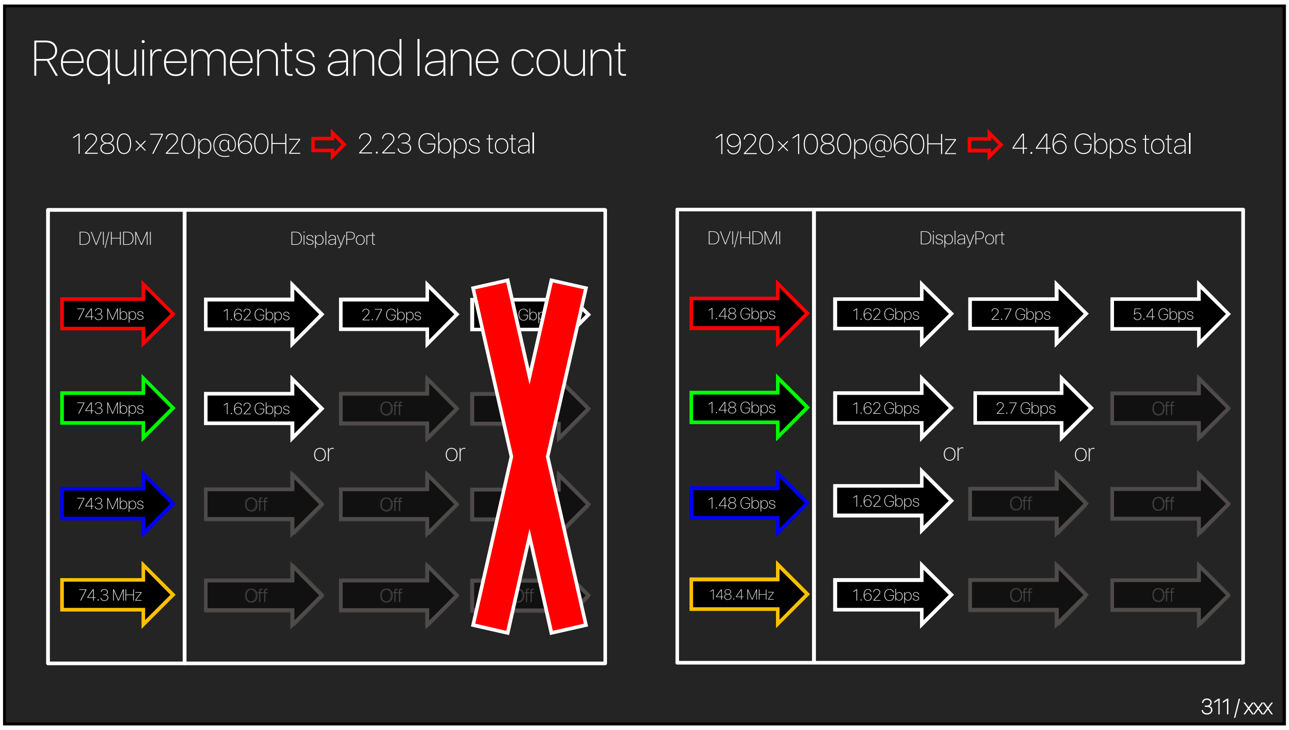
Requirements and lane count
1280×720p@60Hz 2.23 Gbps total
1920×1080p@60Hz 4.46 Gbps total
DVI/HDMI
DisplayPort
743 Mbps
743 Mbps
743 Mbps
74.3 MHz
1.62 Gbps
2.7 Gbps
1.62 Gbps
Off
or
1.48 Gbps
1.48 Gbps
1.48 Gbps
148.4 MHz
5.4 Gbps
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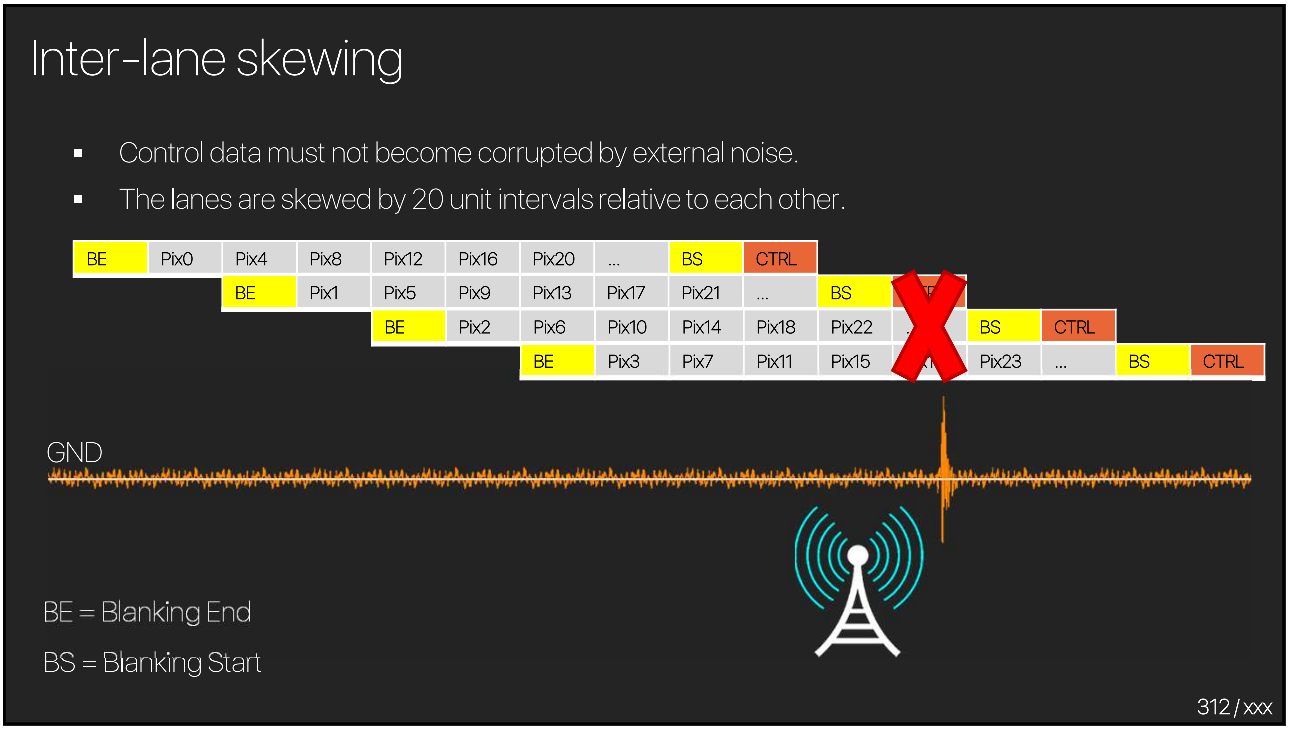
Inter-lane skewing
▪ Control data must not become corrupted by external noise.
▪ The lanes are skewed by 20 unit intervals relative to each other.
BE Pix0 Pix4 Pix8 Pix12 Pix16 Pix20 ... BS CTRL
BE Pix1 Pix5 Pix9 Pix13 Pix17 Pix21 ... BS
BE Pix2 Pix6 Pix10 Pix14 Pix18 Pix22 BS CTRL
BE Pix3 Pix7 Pix11 Pix15 Pix23 ... BS CTRL
GND
BE = Blanking End
BS = Blanking Start
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DisplayPort v1.2

- Backwards compatible with v1.1a
- Maximum data rate: 21.6 Gbps with multi-streaming → 4 Full HD signals with audio or 2560×1600@120Hz or 4K60
- 720 Mbps bi-directional AUX channel → High-speed USB 2.0, ethernet
- Audio Copy Protection, support for new audio formats → New and exciting problems ☺

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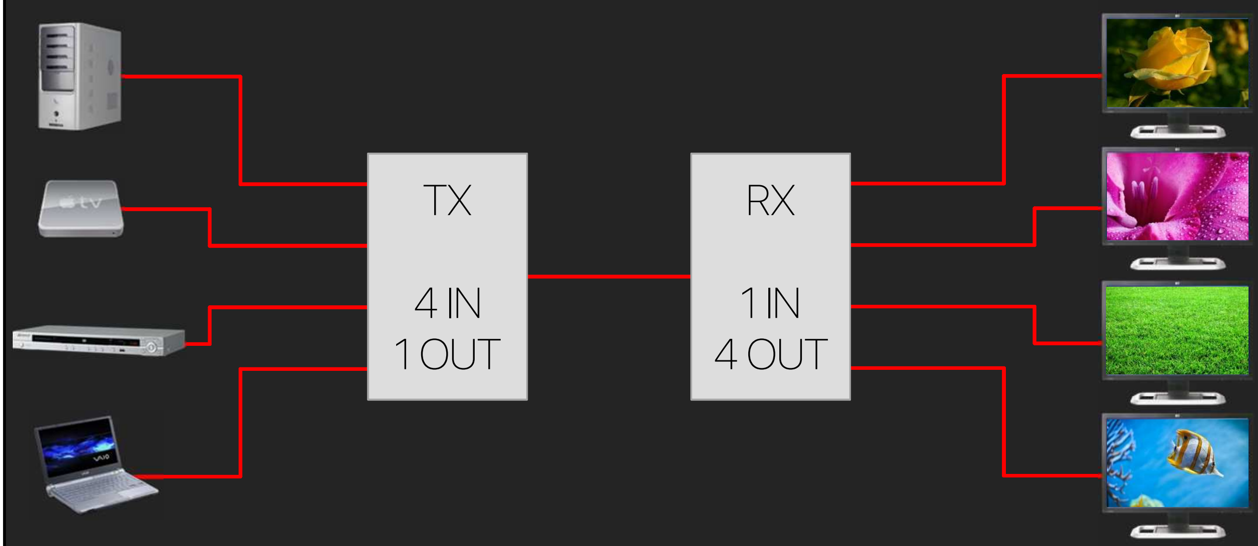
Multistreaming



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Multistreaming

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Future of DisplayPort

PC Market

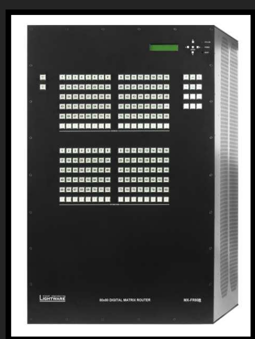
- Performance demand
- High resolution gaming and graphics work

Consumer Market

- Millions of HDMI devices have been sold
- No need for higher resolutions

Professional Manufacturers

- Serving both markets



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Comparison

	Max. Bandwidth (Gbps)	Max. Resolution (@60Hz)	Deep Color	Audio	Ethernet	USB	Audio Return Channel
Single Link DVI	4.95	1920×1200 or 2K	–	–	–	–	–
Dual Link DVI	9.9	2560×1600	–	–	–	–	–
HDMI 1.3	6.75	1920×1200 or 2K	Yes	Yes	–	–	–
HDMI 1.4	10.2	2560×1600	Yes	Yes	10/100	–	Yes
HDMI 2.0	18	4K	Yes	Yes	10/100	–	Yes
DisplayPort v1.1a	10.8	2560×1600	Yes	Yes	–	–	–
DisplayPort v1.2	21.6	4K	Yes	Yes	10/100	Yes	–

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Thunderbolt

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Apple Thunderbolt
Thunderbolt
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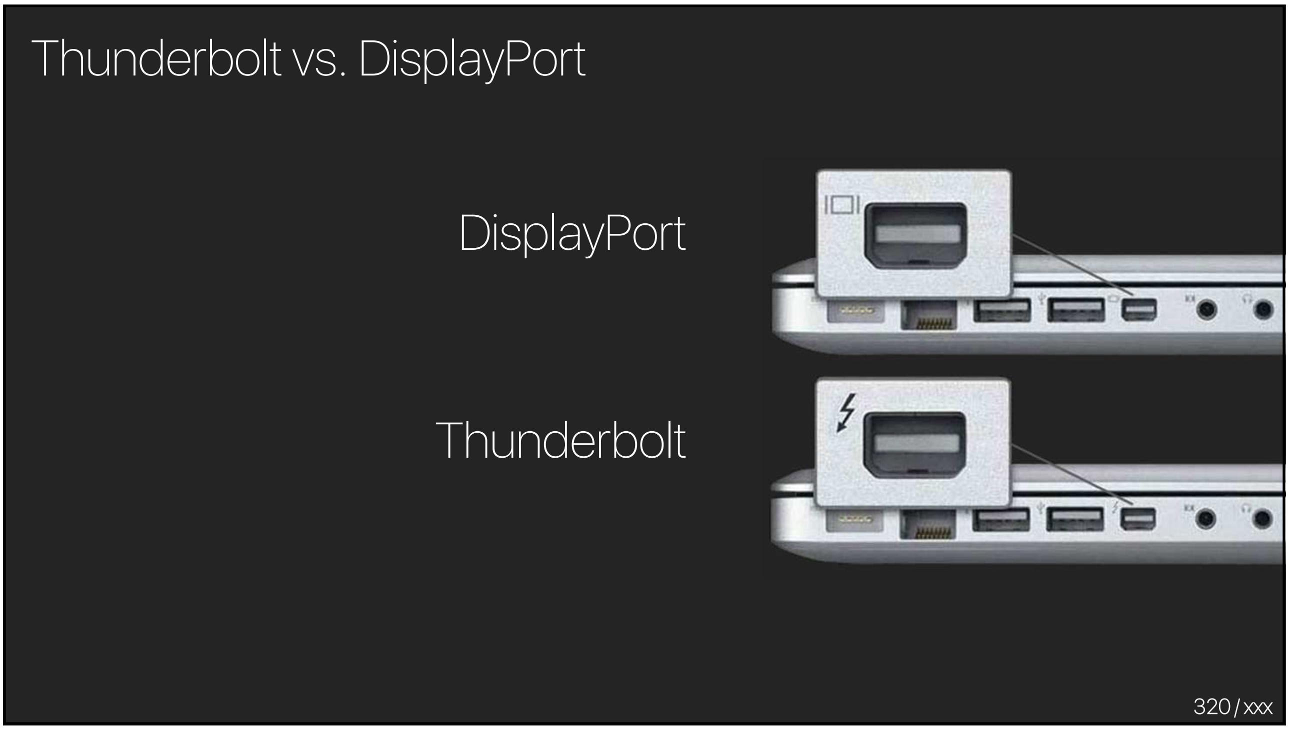
Thunderbolt vs. DisplayPort
DisplayPort
Thunderbolt
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Thunderbolt

- Created by Intel (codenamed Light Peak)
- First introduction: Apple MacBook Pro, February 24, 2011
- Uses the same connector as Mini DisplayPort (Apple's standard)
- Backwards compatible with DisplayPort architecture
- Existing DP-to-VGA, -DVI and -HDMI converters can be used

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Technical details

- Multiplexes PCI Express data and DisplayPort data
- Two 10 Gbps bi-directional channels, allowing a total throughput of 40 Gbps
- 10 W power over copper cable
- Thunderbolt uses an active cable, which has 5 wires:
  - 1 for maintenance
  - 2 uni-directional pairs, one for incoming, one for outgoing data

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DP vs. Thunderbolt pinout

DisplayPort Pin #	DisplayPort Function	Thunderbolt Function	Thunderbolt Pin #	
1	Lane0+	GND	1	
2	GND	Hot Plug	2	
3	Lane0-	High Speed 0 TX+	3	Channel 1
4	Lane1+	High Speed 0 RX+	4	Channel 1
5	GND	High Speed 0 TX-	5	Channel 1
6	Lane1-	High Speed 0 RX-	6	Channel 1
7	Lane2+	GND	7	
8	GND	GND	8	
9	Lane2-	Low Speed TX	9	
10	Lane3+	GND	10	
11	GND	Low Speed RX	11	
12	Lane3-	GND	12	
13	Config1	GND	13	
14	Config2	GND	14	
15	AUX+	High Speed 1 TX+	15	Channel 2
16	GND	High Speed 1 RX+	16	Channel 2
17	AUX-	High Speed 1 TX-	17	Channel 2
18	Hot Plug	High Speed 1 RX-	18	Channel 2
19	Return PWR	GND	19	
20	DP_PWR	DP_PWR	20	

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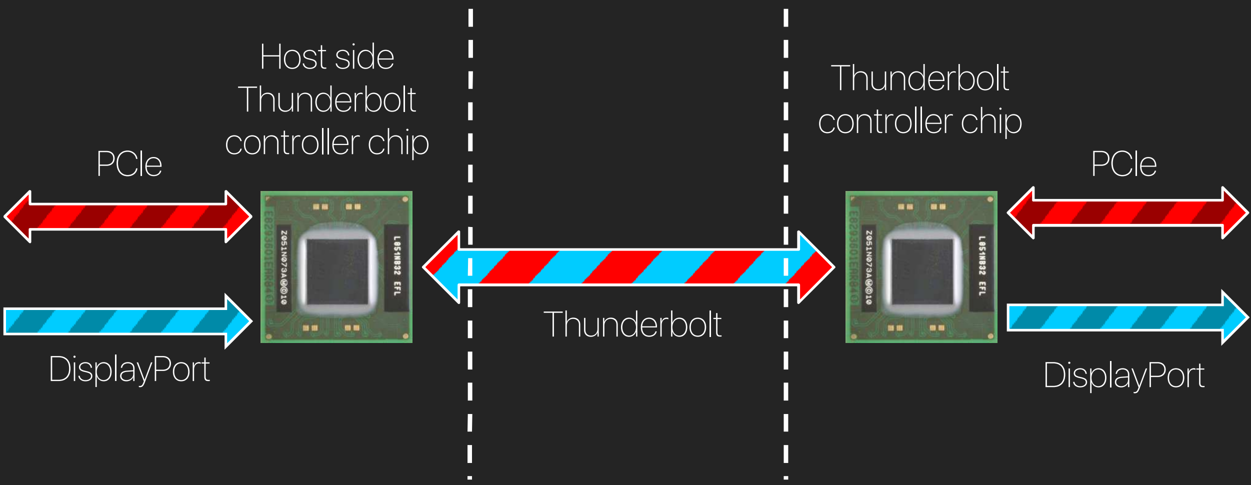
Apple Thunderbolt



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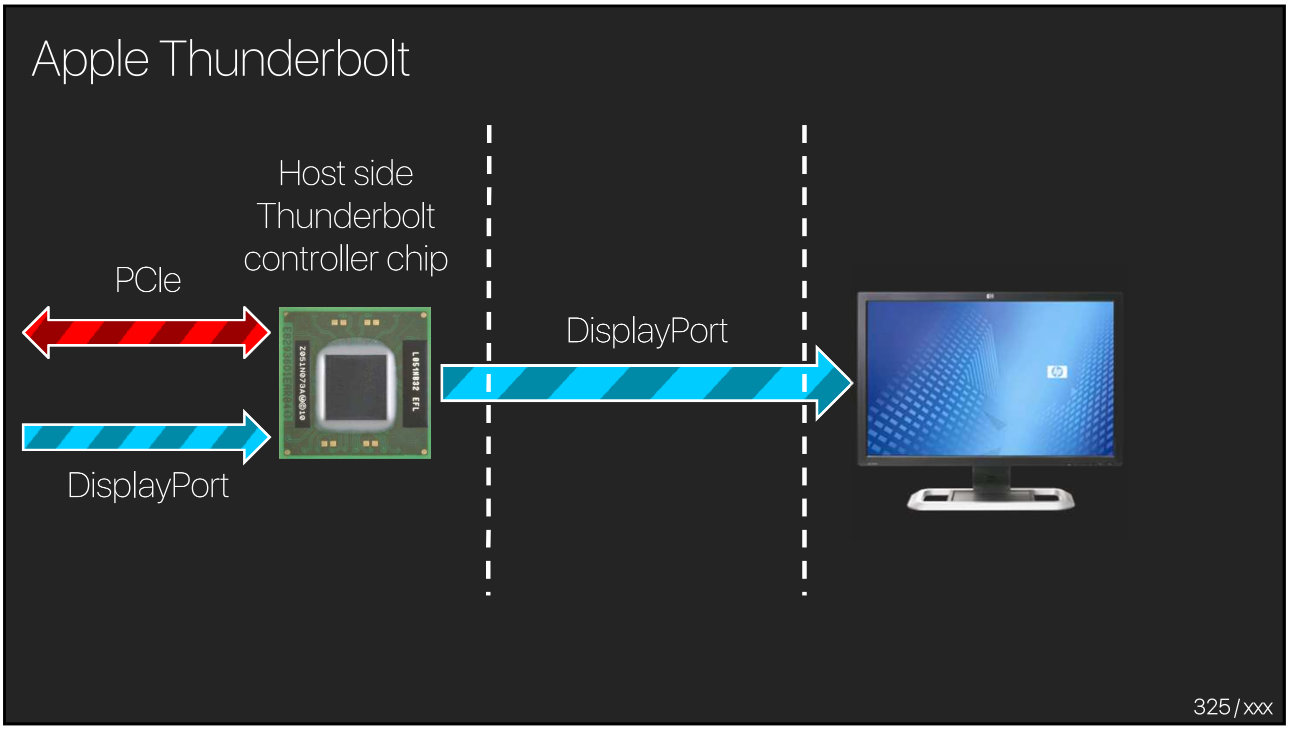
Apple Thunderbolt
Host side Thunderbolt controller chip
PCIe
DisplayPort
DisplayPort
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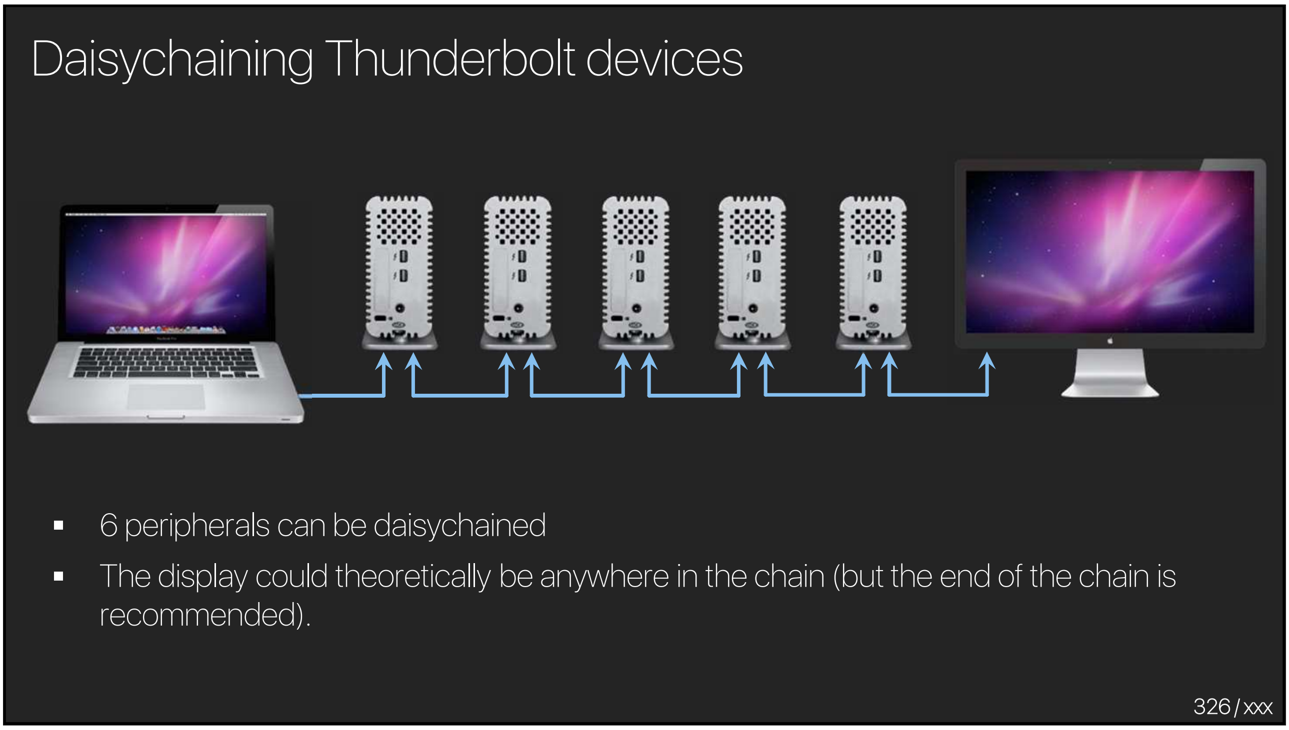
Daisychaining Thunderbolt devices
6 peripherals can be daisychained
The display could theoretically be anywhere in the chain (but the end of the chain is recommended).
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Future of Thunderbolt

- Very good for data intensive work (video editing, video capturing).
- USB is a big competitor, the speed of USB 3.0 is enough for the majority of applications in the PC Market.
- Probably not a big hit in the Pro A/V world.
- SDI, HDMI and DisplayPort are more likely to rule.

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System level issues

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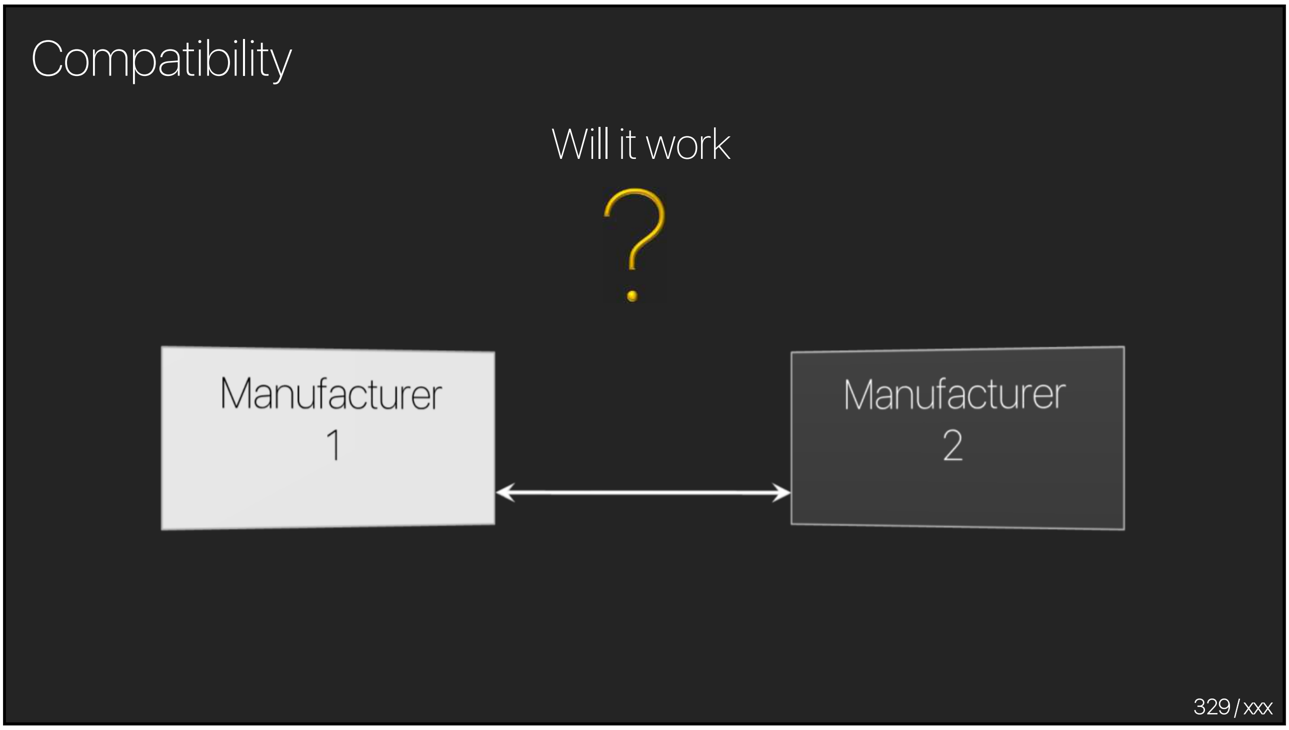
Compatibility
Will it work
?
Manufacturer 1
Manufacturer 2
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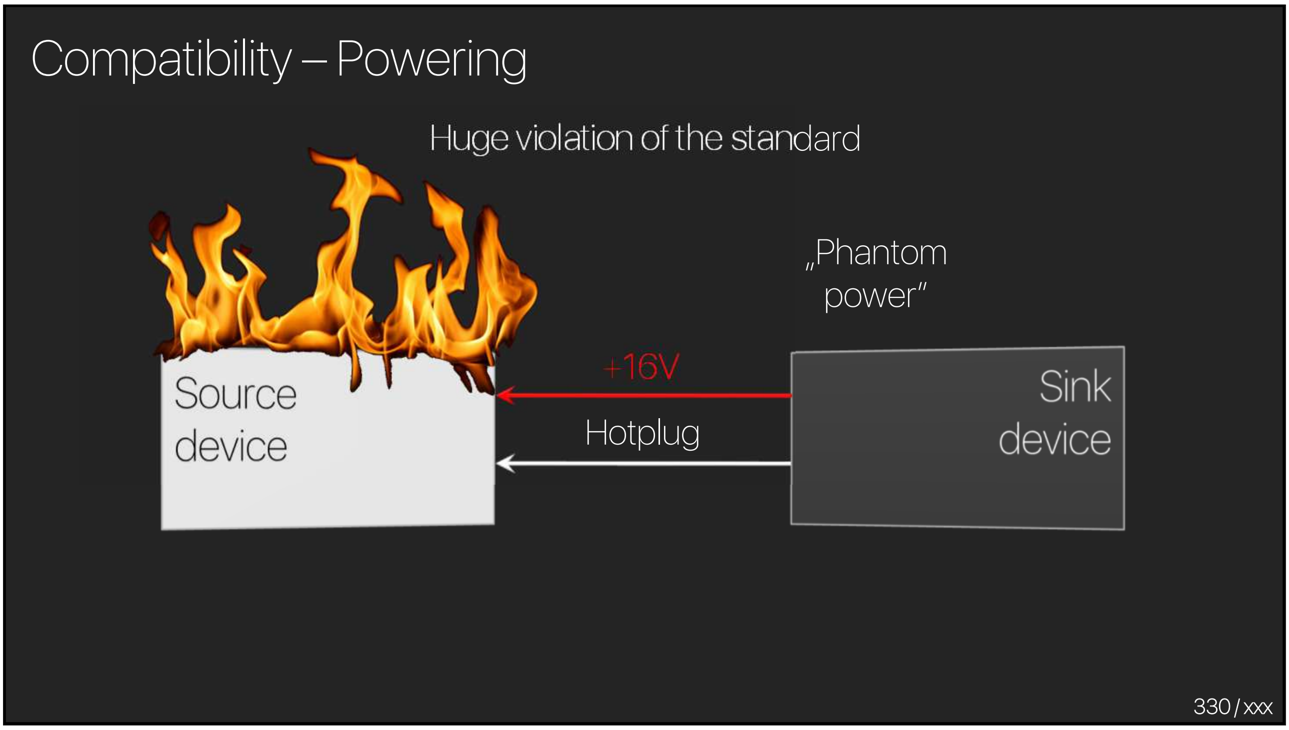
Compatibility – Powering
Huge violation of the standard
„Phantom power"
+16V
Hotplug
Source device
Sink device
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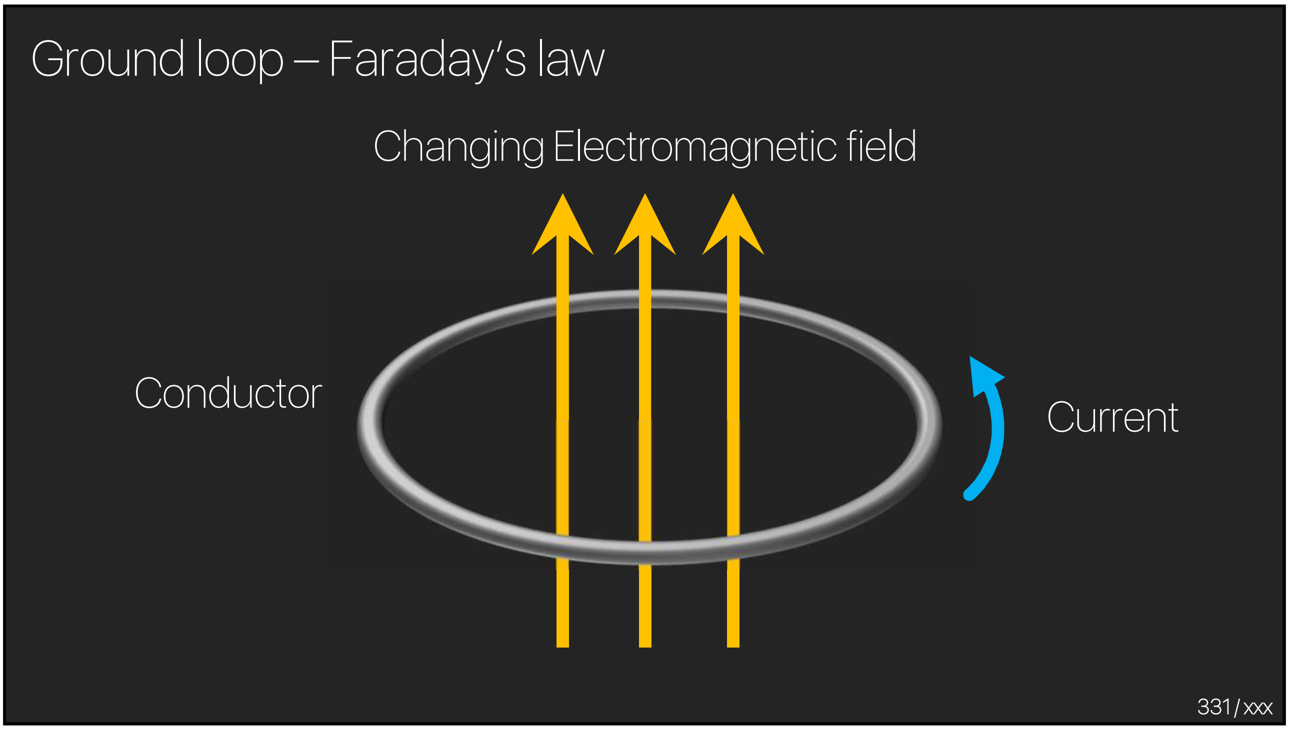
Ground loop – Faraday's law
Changing Electromagnetic field
Conductor
Current
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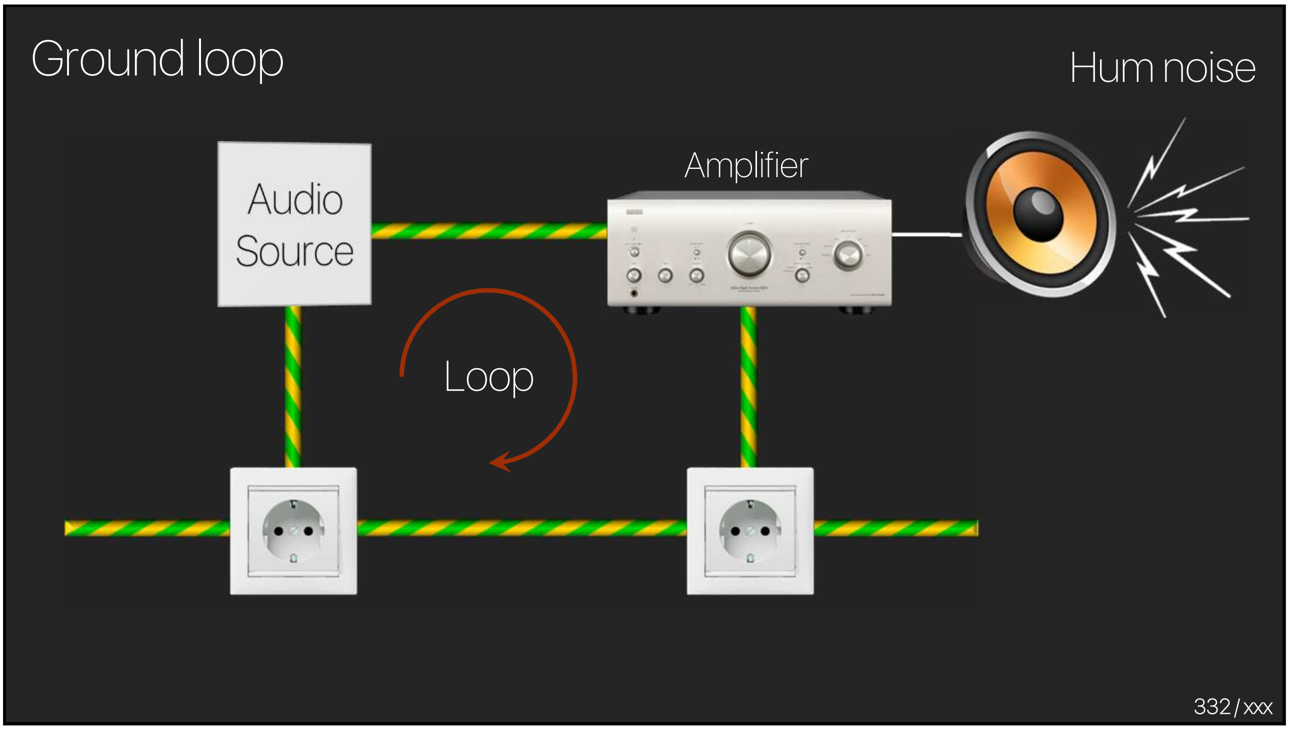
Ground loop
Hum noise
Audio Source
Amplifier
Loop
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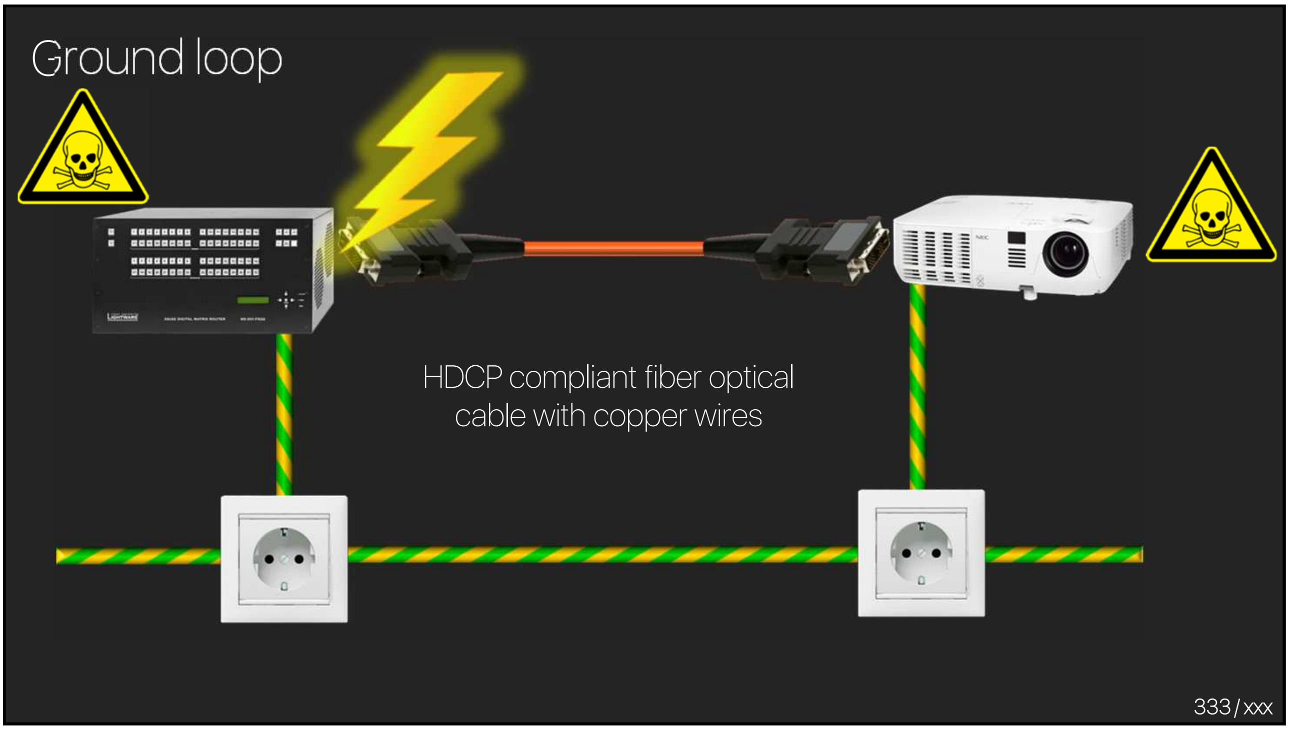
Ground loop
HDCP compliant fiber optical cable with copper wires
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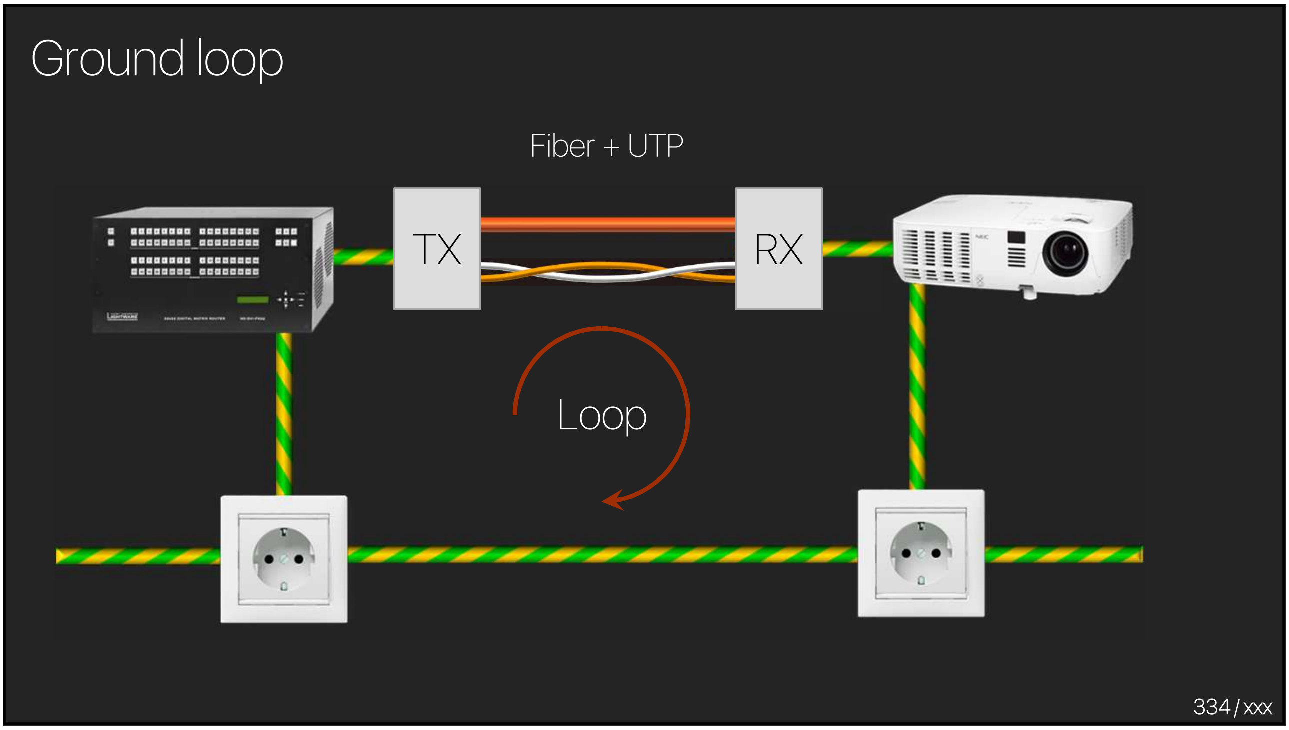
Ground loop
Fiber + UTP
TX
RX
Loop
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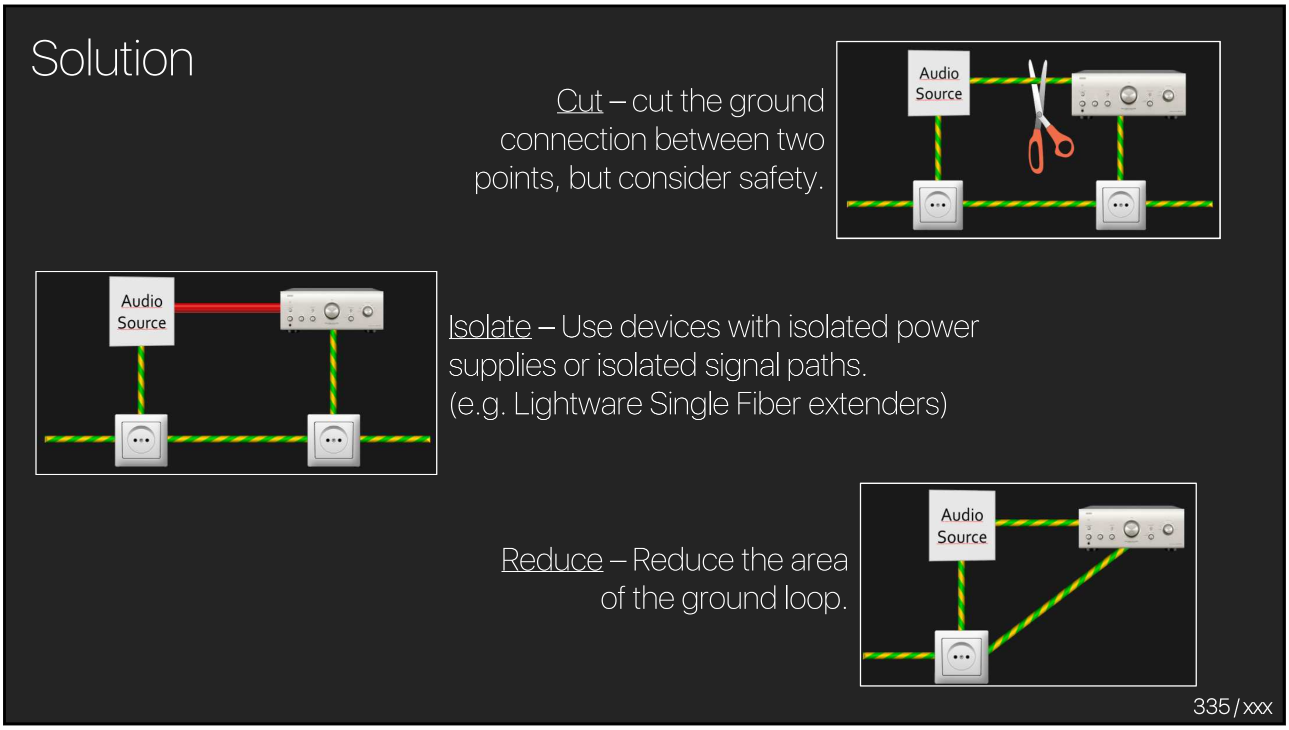
Solution
Cut – cut the ground connection between two points, but consider safety.
Audio Source
Audio Source
Isolate – Use devices with isolated power supplies or isolated signal paths.
(e.g. Lightware Single Fiber extenders)
Reduce – Reduce the area of the ground loop.
Audio Source
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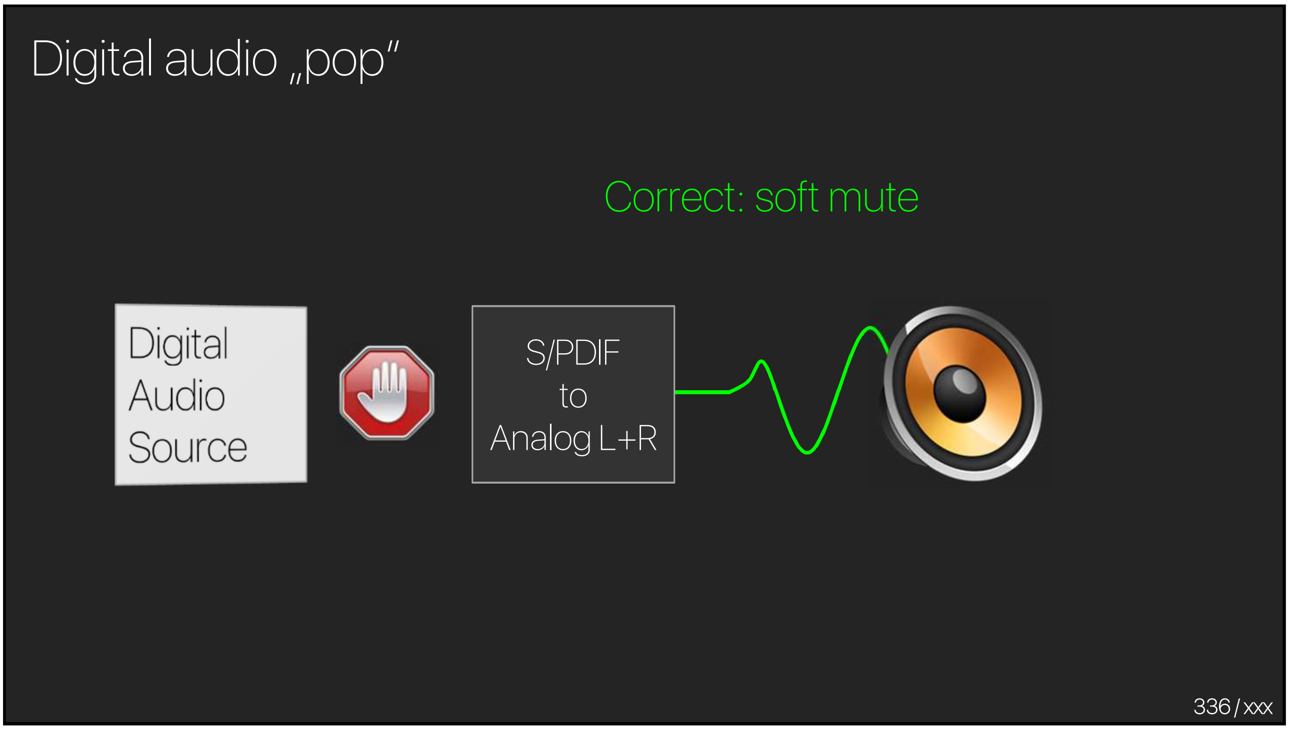
Digital audio „pop"
Correct: soft mute
Digital Audio Source
S/PDIF to Analog L+R
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Problem finding

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The ultimate solution

Have you tried turning it OFF and ON again?

Chris O'Dowd – IT Crowd

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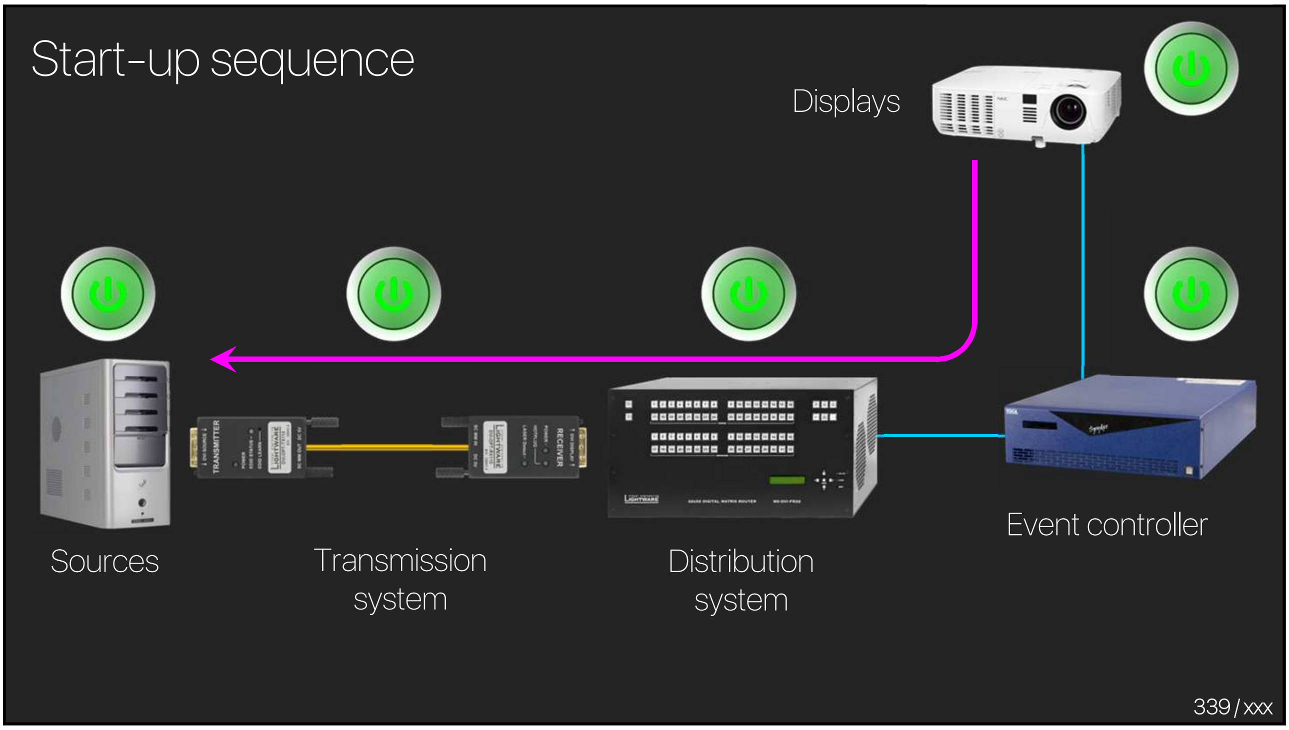

Asking for technical support

- If you have a problem, try to reproduce it.
  - Problems that cannot be reproduced in the manufacturer's lab are extremely hard to solve.
- Document the circumstances, used devices (serial numbers, firmware versions), order of steps that lead to the problem.
- Document the symptoms by photo or video.
- Send a schematic! A hand drawing can be sufficient.
- Every little detail counts (patch panels, gender changers, cable lengths, resolution, refresh rate).

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Systematic problem finding

The rule of problem finding: only change one thing at a time!

You can use different methods:

1. Start at the source side and go towards the displays.
2. Start at the display side and go backwards.
3. Cut the system in half and see which half the problem moves with.
4. Based on past experience and intuition you can start anywhere. If that doesn't work, choose one from the above.

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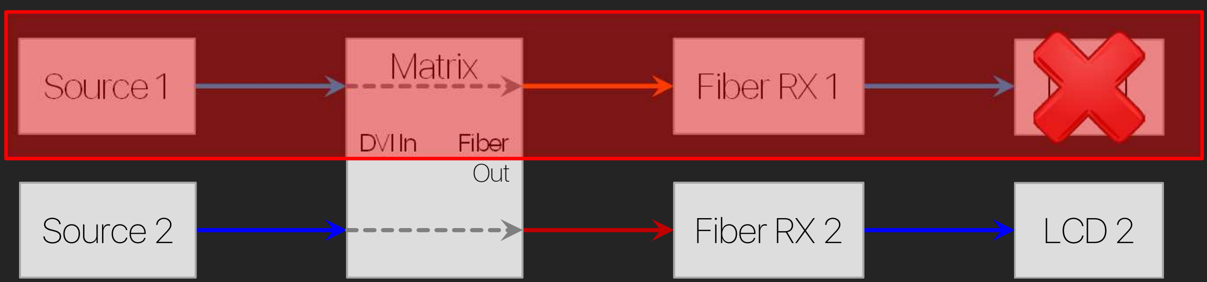
Systematic problem finding – Hardware issue



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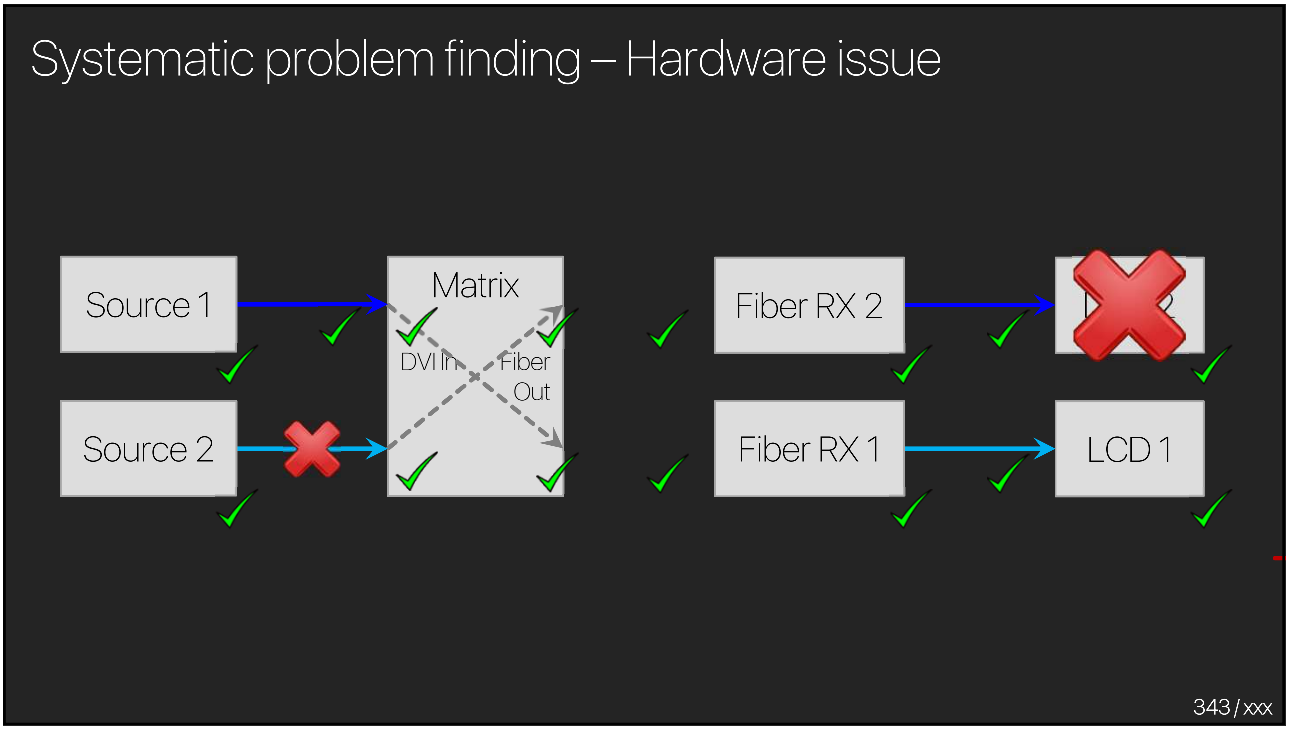
Systematic problem finding – Hardware issue
Source 1
Source 2
Matrix
DVI In
Fiber Out
Fiber RX 2
Fiber RX 1
LCD 1
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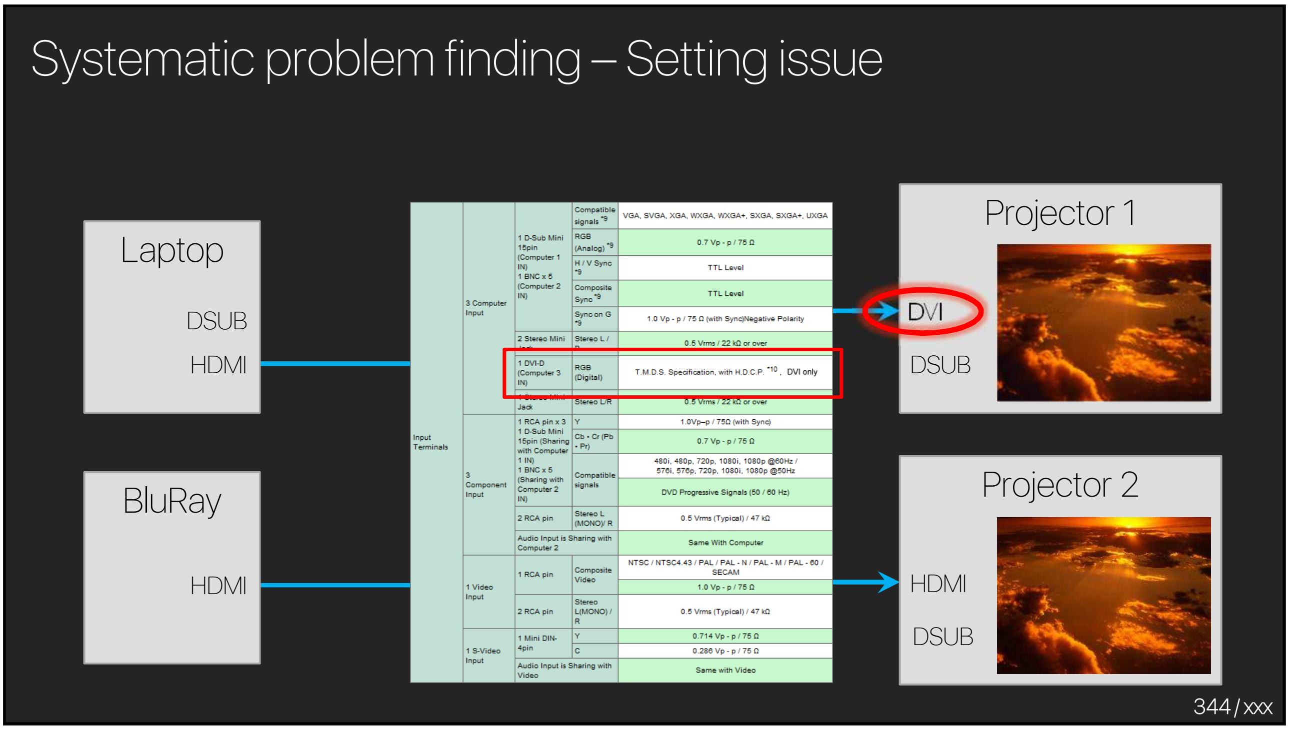
Systematic problem finding – Setting issue
Laptop
DSUB
HDMI
BluRay
HDMI
Input Terminals
3 Computer Input
1 D-Sub Mini 15pin (Computer 1 IN) 1 BNC x 5 (Computer 2 IN)
Compatible signals *9
VGA, SVGA, XGA, WXGA, WXGA+, SXGA, SXGA+, UXGA
RGB (Analog) *9
0.7 Vp - p / 75 Ω
H / V Sync *9
TTL Level
Composite Sync *9
TTL Level
Sync on G *9
1.0 Vp - p / 75 Ω (with Sync)Negative Polarity
2 Stereo Mini
Stereo L /
0.5 Vrms / 22 kΩ or over
1 DVI-D (Computer 3 IN)
RGB (Digital)
T.M.D.S. Specification, with H.D.C.P. *10 , DVI only
Jack
Stereo L/R
0.5 Vrms / 22 kΩ or over
3 Component Input
1 RCA pin x 3 1 D-Sub Mini 15pin (Sharing with Computer 1 IN) 1 BNC x 5 (Sharing with Computer 2 IN)
Y
1.0Vp–p / 75Ω (with Sync)
Cb • Cr (Pb • Pr)
0.7 Vp - p / 75 Ω
Compatible signals
480i, 480p, 720p, 1080i, 1080p @60Hz / 576i, 576p, 720p, 1080i, 1080p @50Hz
DVD Progressive Signals (50 / 60 Hz)
2 RCA pin
Stereo L (MONO)/ R
0.5 Vrms (Typical) / 47 kΩ
Audio Input is Sharing with Computer 2
Same With Computer
1 Video Input
1 RCA pin
Composite Video
NTSC / NTSC4.43 / PAL / PAL - N / PAL - M / PAL - 60 / SECAM
1.0 Vp - p / 75 Ω
2 RCA pin
Stereo L(MONO) / R
0.5 Vrms (Typical) / 47 kΩ
1 S-Video Input
1 Mini DIN-4pin
Y
0.714 Vp - p / 75 Ω
C
0.286 Vp - p / 75 Ω
Audio Input is Sharing with Video
Same with Video
Projector 1
DVI
DSUB
Projector 2
HDMI
DSUB
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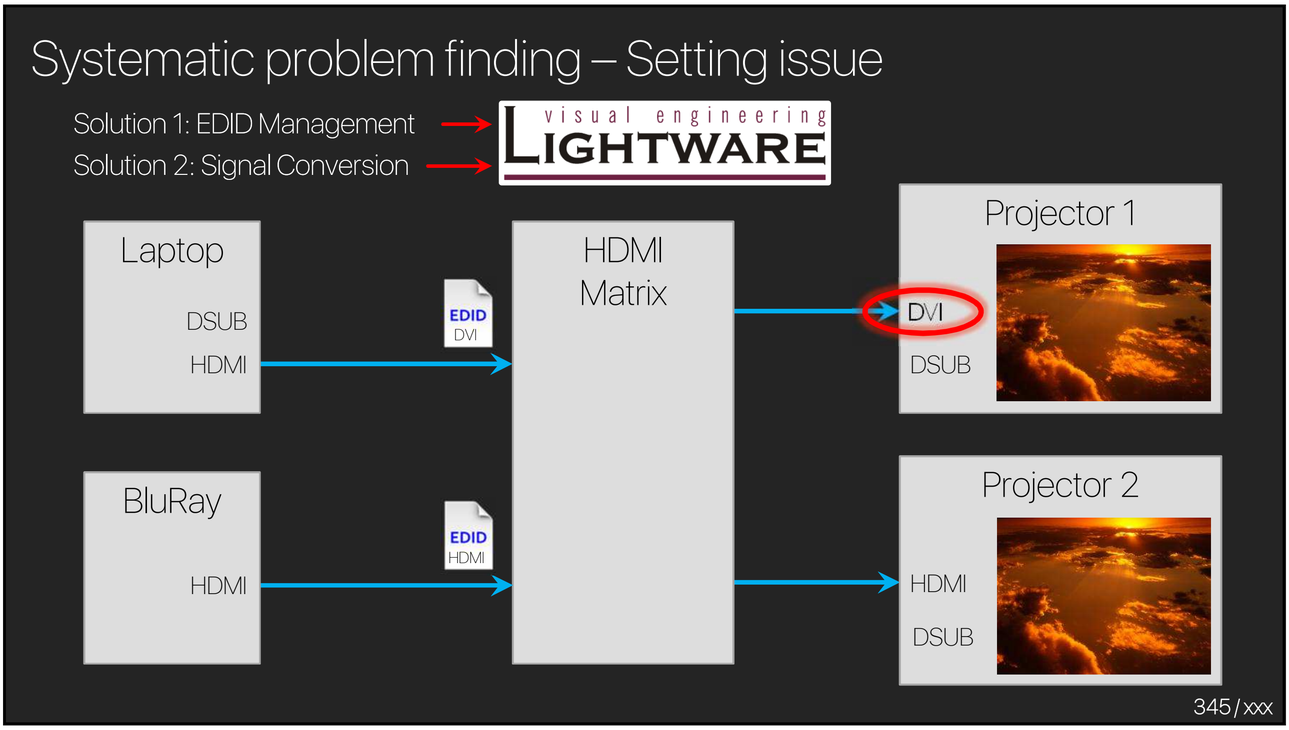
Systematic problem finding – Setting issue
Solution 1: EDID Management
Solution 2: Signal Conversion
visual engineering LIGHTWARE
Laptop
DSUB
HDMI
EDID DVI
HDMI Matrix
Projector 1
DVI
DSUB
BluRay
HDMI
EDID HDMI
Projector 2
HDMI
DSUB
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Questions
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