

VideoQ - Archimedia Test Patterns Set

Training Presentation

October 2013



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Applications

Picture quality control and calibration tools for hardware and software developers, video development labs, production, post-production and content distribution facilities in the fields of:

- ÿ Broadcast SDTV & HDTV
- ÿ Consumer Electronics
- ÿ Video Transcoding
- ÿ Video Data Compression
- ÿ Digital Cinema
- ÿ Mobile TV
- ÿ IPTV

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Methodology

Our approach combines “classic” and “digital” methodologies, sharing same test patterns and covering all 3 levels of video quality control:

1. Instant visual-aural
Quality Estimation



2. **Objective Measurements**
of video and audio performance



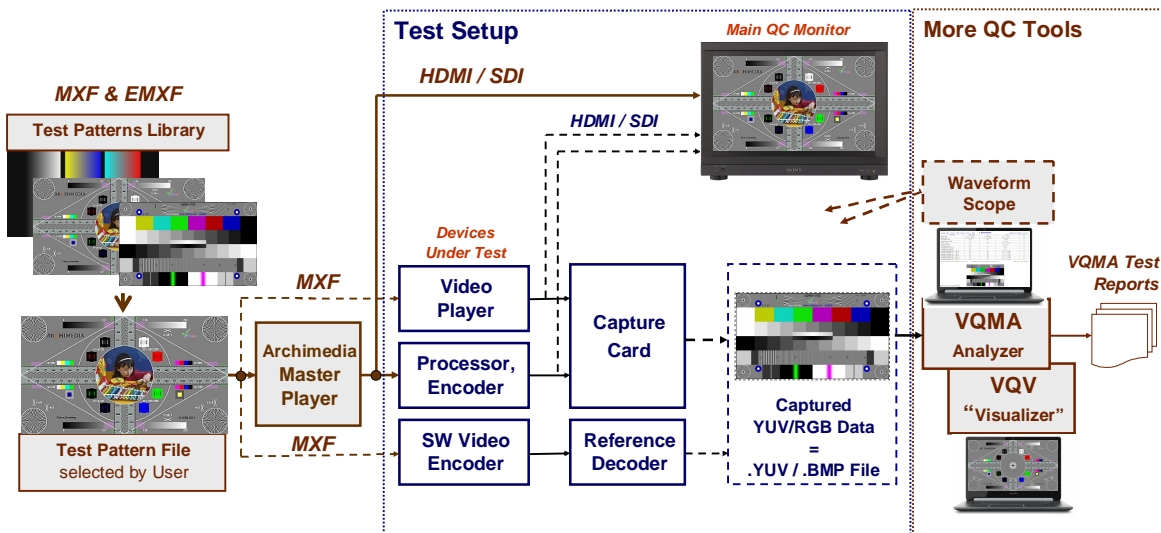
3. Fully automated (robotic)
Quality Control



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Workflow

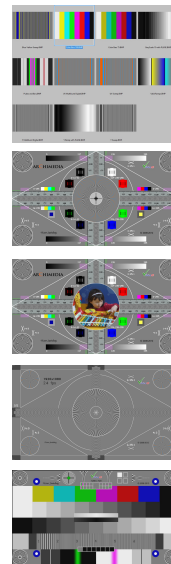


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Test Pattern Categories

1. **Basic Static Tests**
2. **A1** – Universal Static Test Chart
3. **A2** – Universal Static Test Chart with photo insert
4. **VST** – Dynamic Scaling and De-interlacing Test
5. **VQMA** – Matrix Test for VideoQ VQMA Analyzer



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File Formats

All Test Patterns are provided as **MXF** wrapped uncompressed **YCbCr** (aka YUV) data files in a variety of frame sizes and frame rates.

*A1, A2 and VST files are in **EMXF** format, i.e. encrypted for copy protection*

Video data formatted as SDI compatible **4:2:2 CbYCrY (UYVY)** interleaved sequence of **16 bit** samples, optionally rounded to 8 bit (for compression codecs), 10 bit (for SDI output) or 12 bit (HDMI connectivity).

Frame sizes:

- **4096x2160** (DCI flat), **Rec. 709** Color Matrix
- **3840x2160** (UHD), **Rec. 709** Color Matrix
- **1920x1080** (HD), **Rec. 709** Color Matrix
- **1280x720** (sub-HD), **Rec. 709** Color Matrix
- **720x576** (SD PAL), **Rec. 601** Color Matrix
- **720x480** (SD NTSC), **Rec. 601** Color Matrix

Frame rates and interlace: **p23.976, p24, p25, p29.97, i50, p50, i59.94, p59.94**

Audio components format:

Uncompressed **24 bit** per sample, **48 kHz**, **MXF** wrapped or separate **WAV** formatted files;
LR stereo and **5.1 surround sound** variants

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Color Spaces and Display Issues -1

Background Info

With 50 years time difference **two sets** of standard **RGB to Y** conversion coefficients have been adopted:

- **1st set** devised for broadcast TV (*now it is called **Standard Definition***), with the precision of **3 decimal places** (*which then was thought to be high enough precision*) and the magic numbers are:
0.299 , **0.587** and **0.114** - these are nicknamed "SD" or "Rec.601" after the corresponding ITU-R standard
- **2nd set** created later for **High Definition** broadcast TV, and the coefficients are specified with **4 decimal places**. HD coefficients **differ** from the SD ones and the magic numbers are:
0.2126 , **0.7152** and **0.0722** - these are nicknamed "HD" or "Rec.709" after the corresponding ITU-R standard

The conventional form of presenting complete set of RGB to YCbCr (YUV) color space conversion coefficients is 3x3 matrix:

$$\begin{array}{c}
 \text{In: R} \quad \text{G} \quad \text{B} \\
 \text{RGB2YUVHD} = \begin{pmatrix} 0.2126 & 0.7152 & 0.0722 \\ -0.11457 & -0.38543 & 0.5 \\ 0.5 & -0.45415 & -0.04585 \end{pmatrix} \begin{matrix} \text{Y} \\ \text{U} \\ \text{V} \end{matrix} \text{ O u t} \\
 \\
 \text{In: Y} \quad \text{U} \quad \text{V} \\
 \text{YUV2RGBHD} = \begin{pmatrix} 1 & 0 & 1.5748 \\ 1 & -0.18732 & -0.46812 \\ 1 & 1.8556 & 0 \end{pmatrix} \begin{matrix} \text{R} \\ \text{G} \\ \text{B} \end{matrix} \text{ O u t} \\
 \\
 \text{In: R} \quad \text{G} \quad \text{B} \\
 \text{RGB2YUVSD} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.16874 & -0.33126 & 0.5 \\ 0.5 & -0.41869 & -0.08131 \end{pmatrix} \begin{matrix} \text{Y} \\ \text{U} \\ \text{V} \end{matrix} \text{ O u t} \\
 \\
 \text{In: Y} \quad \text{U} \quad \text{V} \\
 \text{YUV2RGBSD} = \begin{pmatrix} 1 & 0 & 1.402 \\ 1 & -0.34414 & -0.71414 \\ 1 & 1.772 & 0 \end{pmatrix} \begin{matrix} \text{R} \\ \text{G} \\ \text{B} \end{matrix} \text{ O u t}
 \end{array}$$

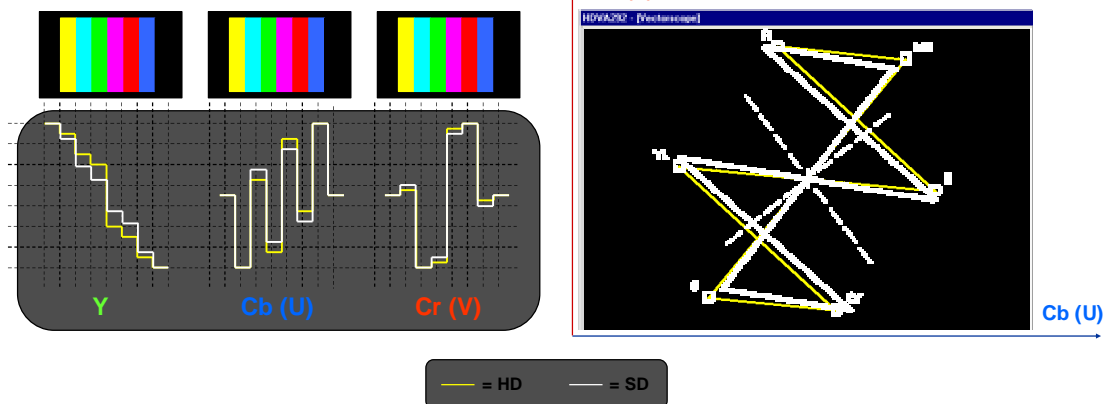
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Color Spaces and Display Issues -2

HD and SD YUV levels are significantly different:

100% Color Bars (100/0/100/0)



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Color Spaces and Display Issues -3

There are also **two sets** of **Reference Black** and **Reference White** levels, typically designated by **8 bit values**, even if actual number of bits is 10 or 12:

- **1st set** was devised for general 8 bit representation of RGB color data (*without any headroom*) and it is commonly nicknamed "**0 - 255**" aka "Computer Graphics" or "High RGB"
- **2nd set** was created later for broadcast TV (*with extra levels reserved below Reference Black and above Reference White*) and it is commonly nicknamed "**16 - 235**" aka "Broadcast" or "Low RGB". In theory,

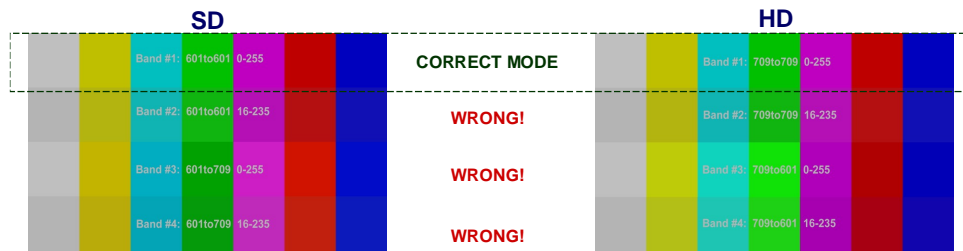
Professional YUV data **must be** in **16-235** format, but RGB data could be **either** 0-255 or 16-235.

On the other hand, **display** should produce nearly zero light on black, which implies **0-255 RGB** scheme **after** YUV to RGB conversion.

Two **Color Matrices** and two **Level Schemes** produce **four combinations**, i.e. four possible **YUV → RGB Conversion Modes**.

This is especially important for professional QC Displays, where these modes are switched either automatically or manually.

In any particular case, only **one** of 4 combinations is correct, 3 others are leading to **erroneous display modes**:



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Color Spaces and Display Issues -4

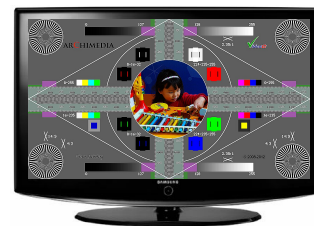
Typically there are two quite different sets of **Display Settings**:

- **1st set** is required by Engineers for QC Monitors: all picture enhancing features must be OFF (so called "Professional Display Mode"). "Crispening", "Vivid Colors", "Theater Mode", "Noise Reduction", etc. may conceal, distort or boost important picture details.
- **2nd set** is required by Content Creators, Producers, etc., who want to see **the same pictures** as millions of **consumers**; this implies the need to get **typical** modern TV and switch all the enhancing features ON ("Consumer Display Mode").

Thus, in professional environment **both** types of displays are necessary.



YOU NEED BOTH!



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Color Spaces and Display Issues -5

VideoQ **VQV1** viewer displaying the same A2.YUV file in different YUV to RGB conversion modes

Manually selected default **16-235** YUV range
Auto-detected **Rec. 709**:
Correct RGB values on 100% Green Bar

Regular **16-235** Bars on A2 Test Pattern

Manually selected **16-235** YUV range & **Rec. 601**:
Wrong RGB values on 100% Green Bar

Manually selected **non-standard 0-255** YUV range & **Rec. 709**:
Correct RGB values on 100% Green Bar

Non-standard **0-255** Bars are also available

Manually selected **0-255** YUV range & **Rec. 601**:
Wrong RGB values on 100% Green Bar

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Color Spaces and Display Issues -6

Examples of color space conversion settings affecting 100/0/75/0 Color Bars.

VideoQ **VQMA4** analyzer "Waveform Scope" Page

Auto-detected **16-235** YUV range & **Rec. 709**:
Correct RGB values on all Bars (perfect balance)

Automatically selected Rec709 (HD) YUV\rightarrowRGB Matrix

Within Selected Line:
R:Max = 235.0 (100.0 %)
Y:Min = 16.0 (6.3 %)
Y:Max = 235.0 (100.0 %)
B:Min = 15.7 (-0.2 %)
B:Max = 235.0 (100.0 %)
G:Min = 15.3 (-0.2 %)
G:Max = 235.0 (100.0 %)
M:Min = 15.1 (-0.4 %)
M:Max = 235.0 (100.0 %)
U:Min = 12.0 (-4.9 %)
U:Max = 235.0 (100.0 %)
V:Min = 44.0 (-37.5 %)
V:Max = 235.0 (100.0 %)
U:Mean = 128.0 (-0.0 %)
V:Mean = 128.0 (-0.0 %)

This is how correct Green color should look

Manually selected **0-255** YUV range & **Rec. 601**:
Wrong RGB values on all Bars (strong misbalance)

Manually selected Rec601 (HD) YUV\rightarrowRGB Matrix

Within Selected Line:
R:Max = 235.4 (92.3 %)
Y:Min = 16.0 (6.3 %)
Y:Max = 235.0 (92.2 %)
B:Min = -12.4 (-4.9 %)
B:Max = 235.0 (92.2 %)
G:Min = 16.0 (6.3 %)
G:Max = 235.0 (92.2 %)
M:Min = 12.0 (-4.9 %)
M:Max = 235.0 (92.2 %)
U:Min = 44.0 (-32.2 %)
U:Max = 235.0 (92.2 %)
V:Min = 128.0 (-0.0 %)
V:Max = 235.0 (92.2 %)
U:Mean = 128.0 (-0.0 %)
V:Mean = 128.0 (-0.0 %)

This Green color is too bright!

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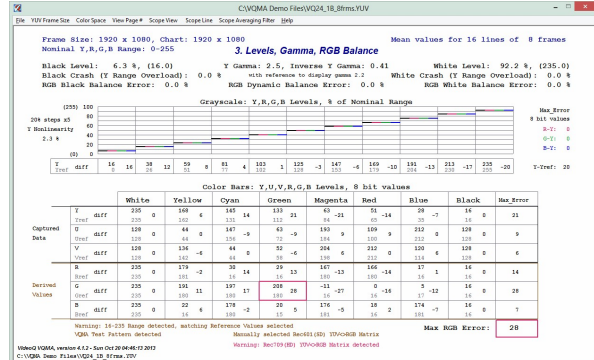
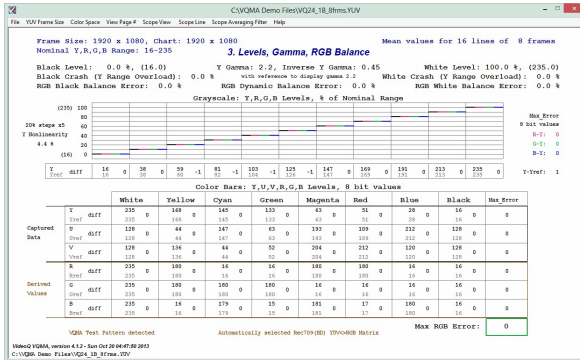
Color Spaces and Display Issues -7

Examples of color space conversion settings affecting 100/0/75/0 Color Bars.

VideoQ VQMA4 analyzer "Levels, Gamma, RGB Balance" Page

Auto-detected 16-235 YUV range & Rec. 709:
Auto-measured Max RGB Error = 0

Manually selected 0-255 YUV range & Rec. 601:
VQMA Page shows two Warnings about this choice.
Auto-measured Max RGB Error = 28d (8 bit levels)



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1. Static Basic Test Patterns

Frame Sizes: 720x480, 720x576, 1280x720, and 1920x1080

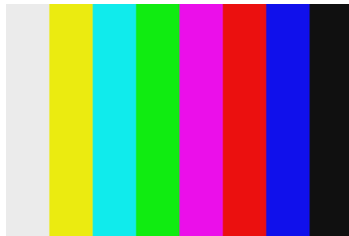
- 1.1. Color Bars 100/0/100/0
- 1.2. Color Bars 100/0/75/0
- 1.3. Grayscale, 10steps with PLUGE
- 1.4. Y Ramp with PLUGE
- 1.5. Pulses and Bars
- 1.6. Y Sweep
- 1.7. Y Multiburst Digital
- 1.8. Blue-Yellow Sweep
- 1.9. UV Sweep
- 1.10. UV Multiburst Digital
- 1.11. Valid Ramps

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Static Basic Test Patterns (1)

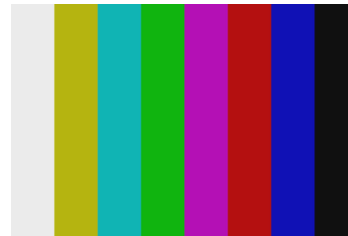
Display Calibration & Color Space Errors Tests

1.1 Color Bars
100/0/100/0



RGB range: 16-235

1.2 Color Bars
100/0/75/0



RGB range: 16-235

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Static Basic Test Patterns (2)

Y Linearity Tests

Pulse Response Test

1.3 Grayscale-10
with PLUGE



Y range: 16-235

1.4 Y Ramp
with PLUGE



Y range: 16-235

1.5 Pulses and Bars



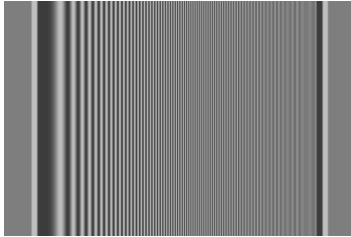
Y range: 16-235

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Static Basic Test Patterns (3)

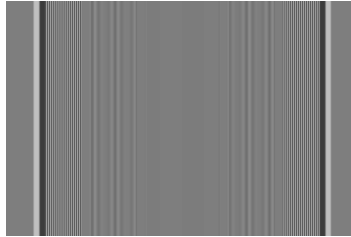
Scaling Artefacts & Frequency Response Tests

1.6 Y Sweep



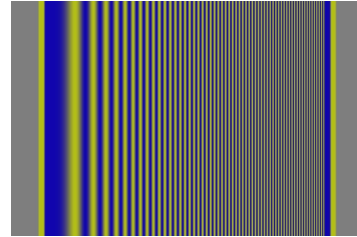
*Min Period: 2.5 Y pixels
(Max Frequency $0.4 \cdot FY$)*

1.7 Y Multiburst Digital



Periods: 2, 2.5, 4 Y pixels

1.8 Blue-Yellow Sweep



*Min Period: 5 Y pixels
(Max Frequency $0.2 \cdot FY$)*

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Static Basic Test Patterns (4)

UV Frequency Response Tests

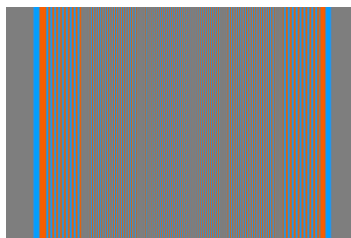
Color Space Test

1.9 UV Sweep



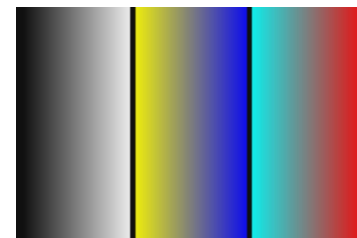
*Min Period: 5 Y pixels
(Max Frequency $0.2 \cdot FY$)*

1.10 UV Multiburst Digital



Periods: 4, 5, 8 Y pixels

1.11 Valid Ramps



RGB range: 16-235

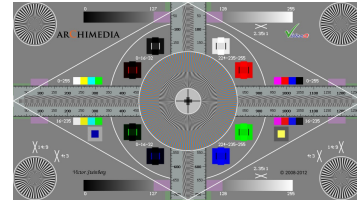
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2. A1: Universal Static Test Chart

Parameters tested:

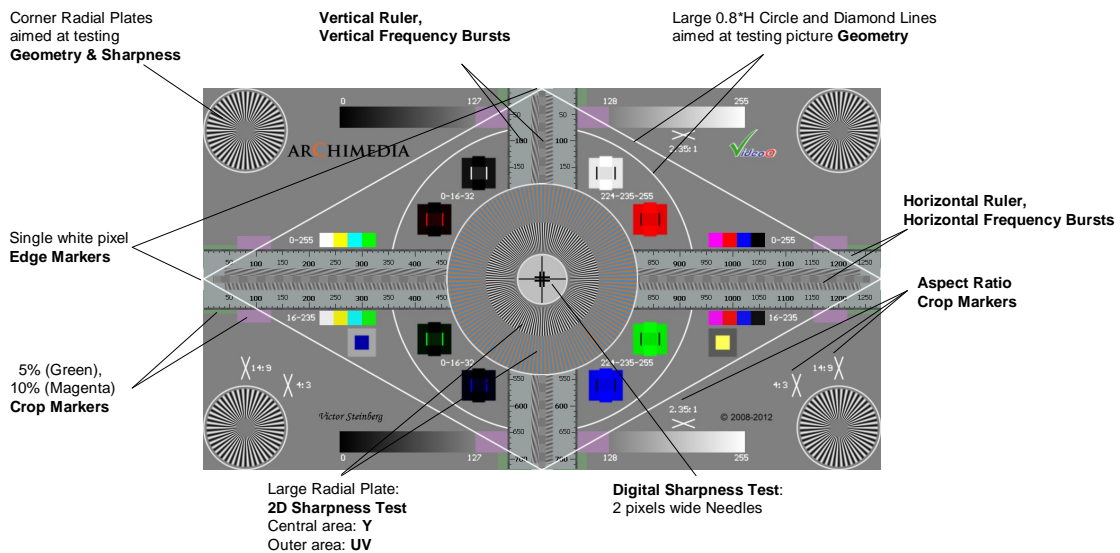
- Geometry:
 - Aspect Ratio,
 - Scaling
 - Cropping
- Y and UV 2D Frequency Responses & Aliasing artefacts
- YUV & RGB levels:
 - Non-linearity (“banding”), Black Crash and White Crash
 - Dynamic Color Balance on Grayscales
 - Color Bars levels vs. Reference levels
 - Monitor Setup: Black and White in R, G an B channels
 - Color Saturation (Y vs. UV Gain)



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A1: Geometry and Scaling Test Components



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A1: Color Test Components

Four Tri-level **Black PLUGE** boxes aimed at testing YRGB min levels

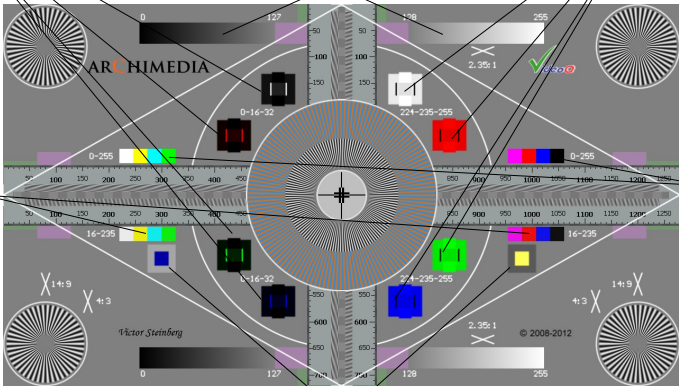
Two full-range **Grayscale Ramps** aimed at testing YRGB linearity

Four Tri-level **White PLUGE** boxes aimed at testing YRGB max levels

16-235 "Low RGB" Split Color Bars

0-255 "High RGB" Split Color Bars

Two **Color Saturation Test** boxes used in "Blue Only" display mode

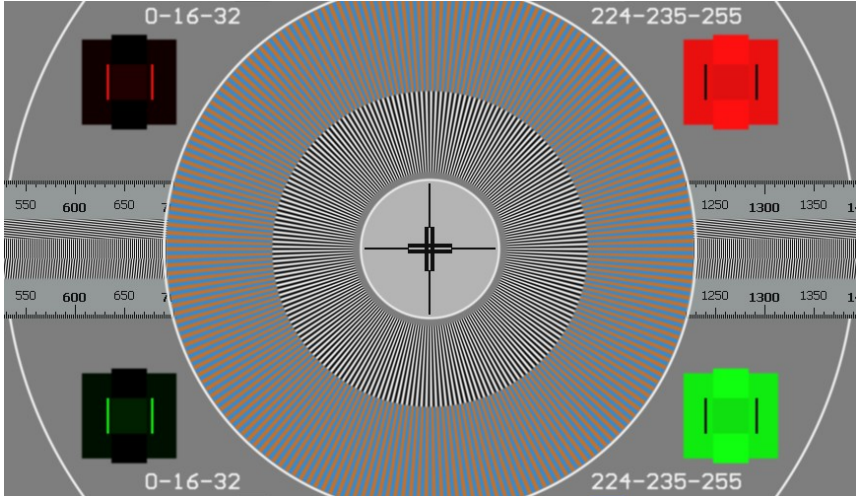


The diagram shows a central test target with various components. At the top and bottom are grayscale ramps labeled '0-255' and '127'. On the left and right are 'Low RGB' and 'High RGB' split color bars. Four PLUGE boxes (black and white) are positioned at the corners. Two color saturation test boxes (red and green) are also present. The target includes a central crosshair and a circular pattern of lines. Text 'ARCHIMEDIA' and 'Victor Steinberg' are visible on the target.

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A1: Central Fragment

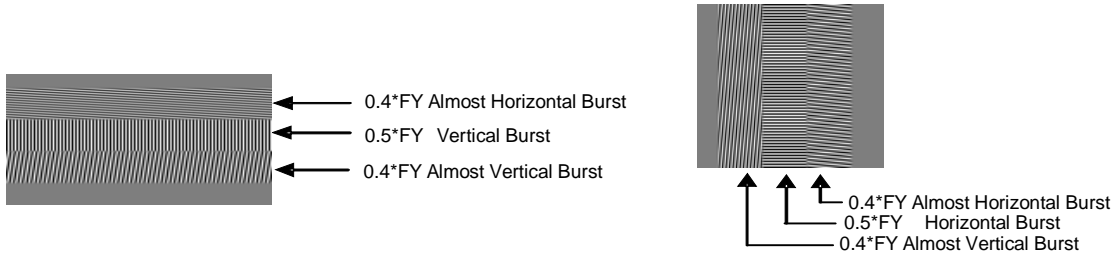


The diagram shows a central fragment of the test target. It features a central crosshair and a circular pattern of lines. Four color saturation test boxes (red, green, blue, and cyan) are positioned around the center. The boxes are labeled '0-16-32' and '224-235-255'. A ruler is visible at the bottom of the fragment.

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Tri-band Combination Burst Patterns



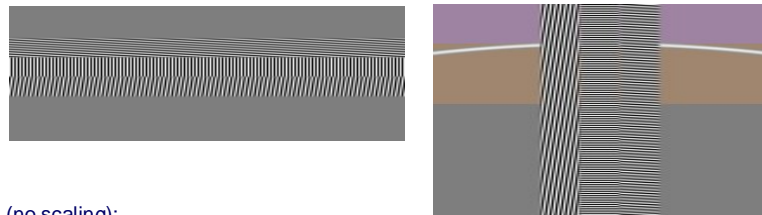
There are two groups of bursts with frequencies proportional to luma pixels rate FY :
full length horizontal bursts band and **full height vertical** bursts band.
 Maximum luminance frequency burst of exactly **0.5 FY** is in the middle of each band.
 Two slightly oblique bands of 0.4 FY surrounds the middle burst.

Two **central 0.5 FY sub-bands** are especially sensitive to any errors in **pixel clock, mapping or scaling**.
 Four other sub-bands allow differentiation between horizontal and vertical distortions thru the whole picture area
 – from left picture edge to the right picture edge and from top to bottom.

Within the burst vertical and almost **vertical lines** test **horizontal frequencies**,
 whilst horizontal and almost **horizontal lines** test **vertical frequencies**.

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Tri-band Combination Burst Pattern Usage



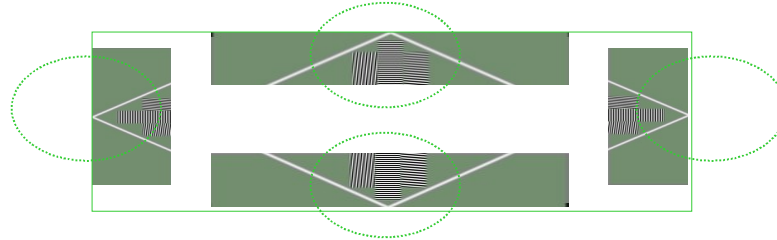
Example of correct settings (no scaling):
 There are no visible beat waves on both horizontal and vertical Tri-band Patterns



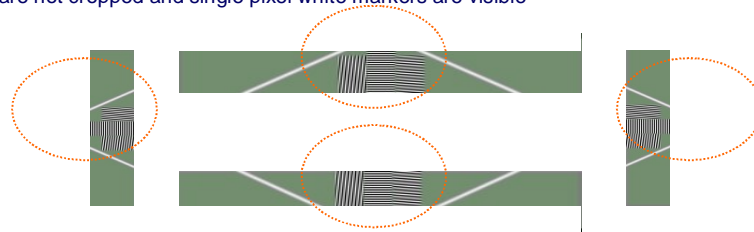
Example of incorrect settings (with scaling):
 Scaling causes beat waves on both horizontal and vertical Tri-band Patterns

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Diamond Pattern and Crop Markers Usage



Example of correct settings (no cropping):
All picture edges are not cropped and single pixel white markers are visible



Example of incorrect settings (with cropping):
Picture edges are cropped

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2.35:1, 4:3, 14:9 Frame Aspect Ratio Markers



A1 pattern is designed for measurement in 16:9 format, as well as in 4:3, 14:9 and 2.35:1 frame formats. Cross-shaped Frame Format Markers indicate precise area for each corresponding frame format.

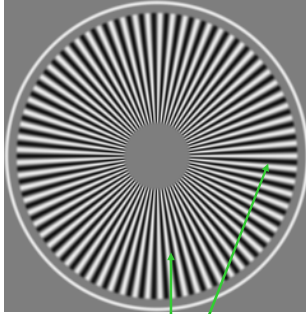
These are several most popular scale and crop modes:

- | 4:3 crop is used to display 16:9 content on legacy standard definition TV sets,
- | 14:9 is a compromise (non-letterboxed) mode used in simulcast broadcasting to present 16:9 content on 4:3 and 16:9 screens,
- | 2.35:1 is used to show letterboxed "cinemascope" movies on 16:9 screens.

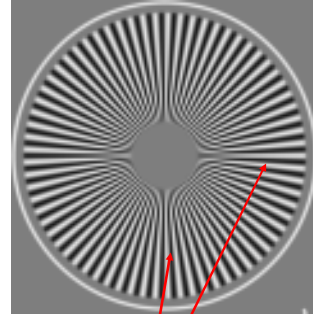
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Radial Plates Usage



Original Size – dot-by-dot:
Full contrast of fine details in all directions

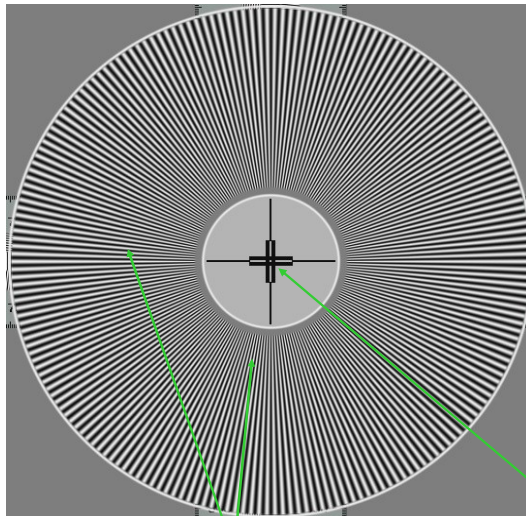


Scaled (Up or Down) Picture:
Loss and/or distortion of fine details

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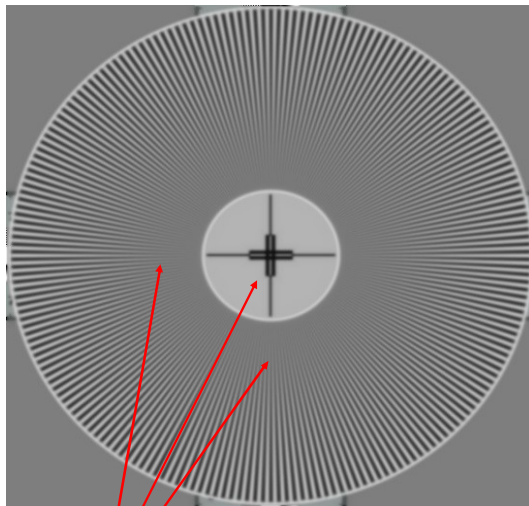
Sharpness Test Usage : Example #1



Optimal Sharpness Control Settings:
Full contrast of fine details in all directions, perfect digital sharpness, no blur, no ghost images

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Sharpness Test Usage: Example #2



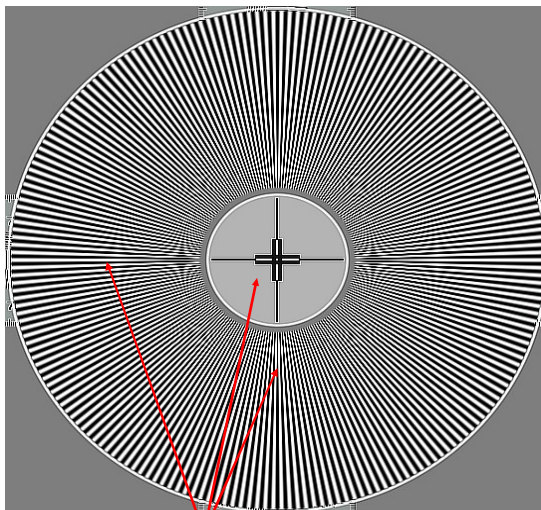
Not enough sharpness:

1. Fine details contrast reduced,
2. Central cross blurred

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Sharpness Test Usage: Example #3



Too much sharpness:

1. Fine details distorted (over-enhanced),
2. Visible ghost images next to central cross

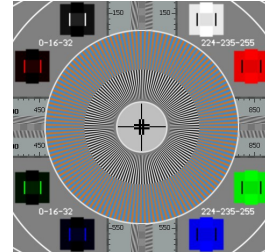
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YRGB PLUGE Boxes and other Color Tests Usage

1. YRGB Range Check:

- I By observing YRGB levels in VideoQ VQV Viewer/Analyzer or similar software tool.
Note that Color Space Conversion, such as 16-235 to 0-255, YUV to RGB and/or 601 (SD) to 709 (HD) matrices, may cause significant YRGB (YUV) level errors
- I By checking the appearance of black and white PLUGE and SPLUGE components: see next slides for details.



2. Color Saturation Check:

- I By observing **Color Bars RGB levels** in VideoQ VQV Viewer/Analyzer or similar software tool: 
 - If color saturation is preserved (correct mode of operation) reconstructed YRGB min and max levels must be **equal on all bars**
- I By checking the appearance of Color Saturation Test boxes in "Blue only mode": 
 - If color saturation is preserved (correct mode of operation) there should be no visible on-screen differences between shades of blue on colored and gray areas

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Black PLUGE & SPLUGE Usage

Fine Tuning (SPLUGE) optional component

Clipped sector (with no shades of gray) is much more than 180 degrees

Clipped sector (with no shades of gray) is much less than 180 degrees

Conical grayscale is clipped exactly half-circle (180 degrees), no shades of gray on the right half

Brightness (Y Offset) is **too low**



Brightness is **too high**



Brightness is **correct**



Coarse Tuning (PLUGE)

Both central super-black vertical band and central small square are almost the same brightness as big black square

Both central super-black vertical band and central small square are clearly visible

The super-black vertical band is almost the same brightness as big black square

Central small square is clearly visible

Note that some versions of A1 Pattern do not contain fine tuning SPLUGE components

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White PLUGE & SPLUGE Usage

Coarse Tuning (PLUGE)

Both central super-white vertical band and central small square are clearly visible

Contrast (Gain) is **too low**



Fine Tuning (SPLUGE)
optional component

Clipped sector (with no shades of gray) is much less than 180 degrees

Both central super-white vertical band and central small square are almost the same brightness as big white square

Contrast is **too high**



Clipped sector (with no shades of gray) is much more than 180 degrees

The super-white vertical band is almost the same brightness as big white square. Central small square is clearly visible

Contrast is **correct**



Conical grayscale is clipped exactly half-circle (180 degrees), no shades of gray on the left half

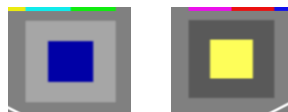
Note that some versions of A1 Pattern do not contain fine tuning SPLUGE components

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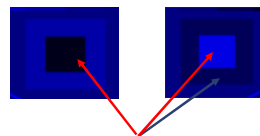
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Color Saturation Test Usage

Normal View
Correct Color Saturation

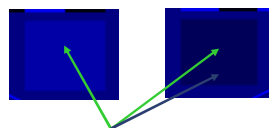


Blue Only Display Mode
Low Color Saturation



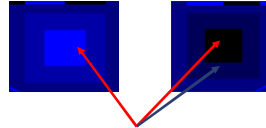
Blue component intensity on **colored** areas **differs** from **gray** areas

Blue Only Display Mode
Correct Color Saturation



Equal **blue** component intensity on **gray** and **colored** areas, inner squares are **not visible**

Blue Only Display Mode
Excessive Color Saturation

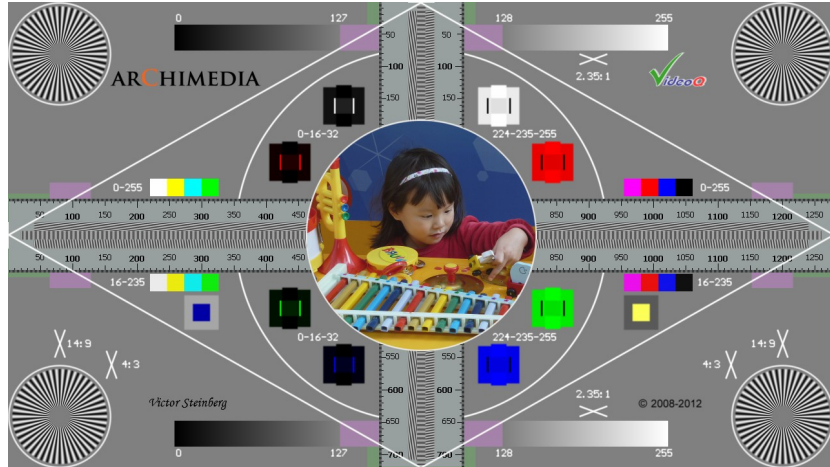


Blue component intensity on **colored** areas **differs** from **gray** areas

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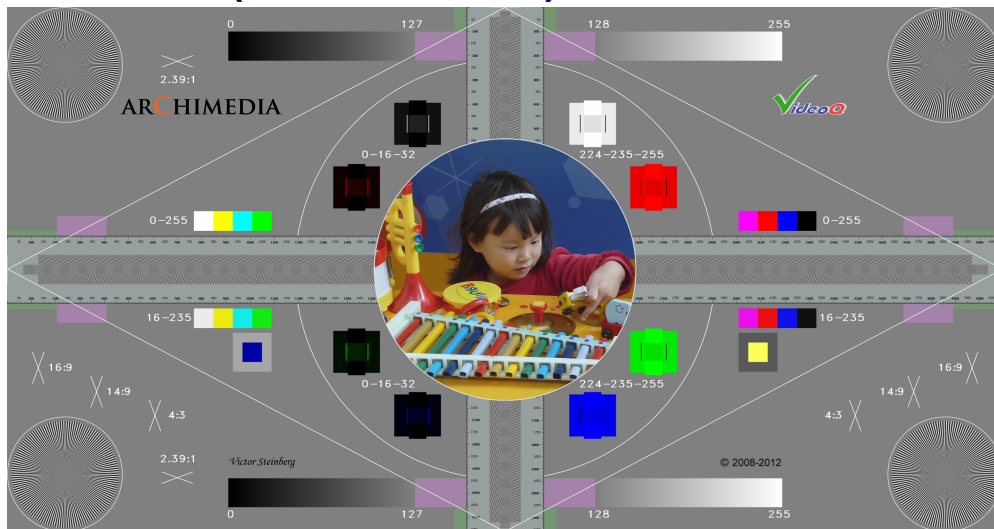
3. A2 – as A1, but with central photo insert



Central photo combines intense colors and flesh tone for overall color rendition quality visual estimation

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A2 - 4K (DCI 4096x2160) frame size version



Slightly different layout because of 1.896:1 aspect ratio; also 16:9 and 2.39:1 Crop Markers added

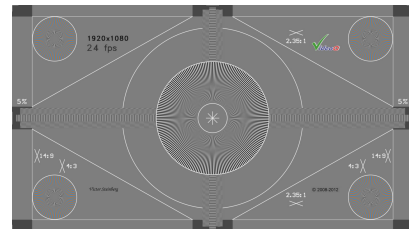
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4. VST – Dynamic Scaling, Cropping, De-interlacing Test

1080p23.976, 1080p24, 1080p25, 1080p29.97, 1080i50, 1080p50, 1080i59.94, 1080p59.94

Family of HD16:9 dynamic patterns suitable for visual picture quality assessment; sub-patterns revealing critical image scaling problems at glance:

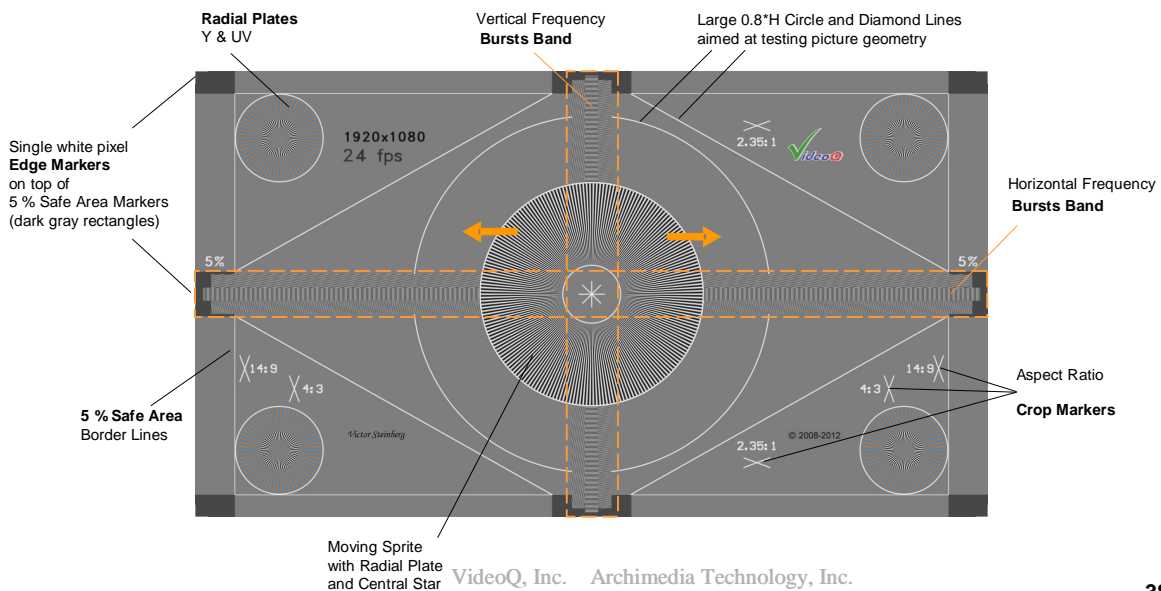
- H & V Pixel Mapping
- Pixel Phase
- Centering & Cropping
- Motion Adaptive De-interlacing artifacts
- Linear and Non-Linear Aspect Ratio Conversion
- Frame Rate Conversion artifacts
- Static and Dynamic Y Sharpness and 2D Frequency Response



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VST Test Pattern Composition



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VST Components Showing Scaling Problems

Missing Edge Markers reveal the slightest Side Cropping

Radial Plates show Y & UV 2D Frequency Response

Highly noticeable Beating Artifacts shows the slightest V Scaling, e.g. 5% overscan

Highly noticeable Beating Artifacts shows the slightest H scaling, e.g. 5% overscan

Full Width and Full Height Tri-band Frequency Bursts allows local scaling non-uniformity detection

Moving Sprite Jerkiness reveals Frame Rate Conversion problems

Dynamic "Trail" behind the Sprite reveals De-interlacing problems

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5. VQMA – Test Pattern for VideoQ SW Analyzer

All-In-One: Single pattern allows automatic measurement of multiple video signal parameters

Radial Plates x4 for visual estimation, camera shading and sharpness measurement

Test Signals:	Parameters:
H Wedges V Wedges	Visual Estimation
Color Bars	YUV/RGB Levels, Color Space Matrix
Grayscales x2, Near-Whites, Near-Blacks	Black & White Levels, RGB Balance, Y Gamma, Y Range Overload
Multi-Burst	Frequency Response, Aliasing Levels
Multi-pulses	Y vs. UV Gain, Needle pulse K-rating

Frames Cadence Test Geometry (Scale/Position/Tilt/Keystone) Markers x4

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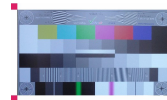
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Parameters Analyzed by VideoQ VQMA

PASS



FAIL



- **Geometry:** Scaling, Aspect Ratio, Position
- **Levels:** Black, White, Color Bars, RGB Balance, Gamma
- **Frequency Response:** in dB vs. scalable tvl, including aliasing levels
- **UV vs. Y Gain** (Color Saturation)
- **K-rating** on needle pulse
- Comprehensive **Noise Analysis**

VQMA checks video data against the target tolerance values contained within customizable VQMA.INI file

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Thank you for attention

Any questions?

