VideoQ - Archimedia
4K Test Patterns Set

Training Presentation

February 2014

www.videoq.com

www.archimediatech.com

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:

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

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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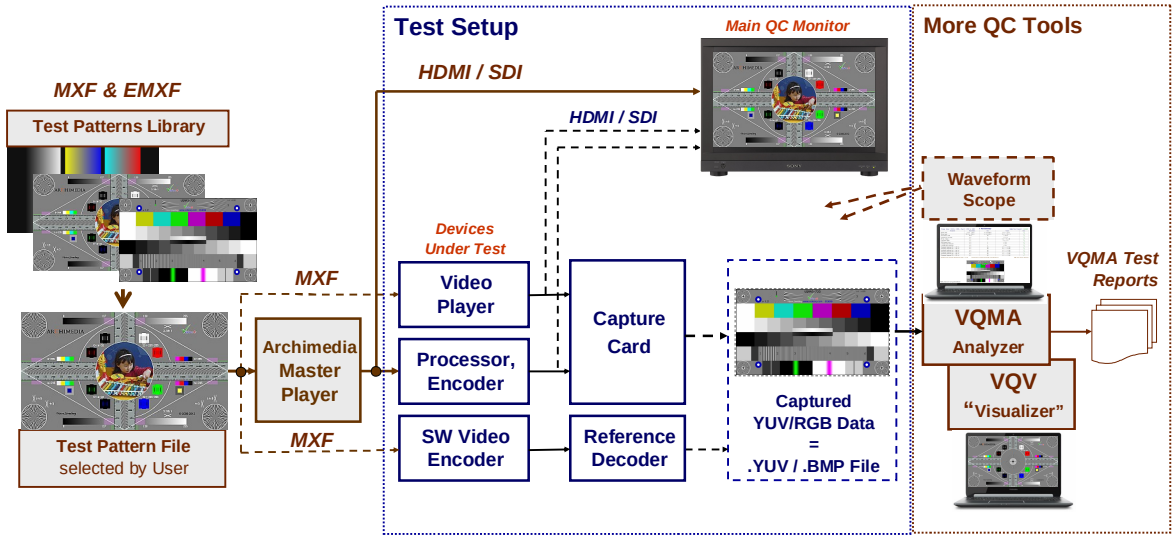
Workflow



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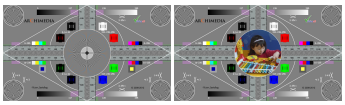
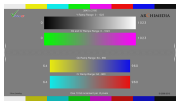
Test Pattern Categories

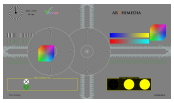
1. **A1/A2** – Universal Static Test Chart
   with optional photo insert



2. **YCbCrLT** – Static Color Components Linearity Test



3. **VST** – Dynamic Scaling & Motion Continuity Test



4. **VQMA** – Matrix Test for VideoQ VQMA Analyzer

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, YCbCrLT and VST files are in **EMXF** format, i.e. encrypted for copy protection, VQMA is not encrypted*

Video data formatted as sequence of **4:4:4 YCbCr 16 bit** samples (interleaved YUV, 48 bpp), 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

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 ó YCbCr (YUV) color space conversion coefficients is 3x3 matrix:

$$\text{RGB2YUVHD} = \begin{pmatrix} 0.2126 & 0.7152 & 0.0722 \\ -0.11457 & -0.38543 & 0.5 \\ 0.5 & -0.45415 & -0.04585 \end{pmatrix} \begin{matrix} Y \\ U \\ V \end{matrix} \text{ Out} \quad \text{In: } R\ G\ B$$

$$\text{RGB2YUVSD} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.16874 & -0.33126 & 0.5 \\ 0.5 & -0.41869 & -0.08131 \end{pmatrix} \begin{matrix} Y \\ U \\ V \end{matrix} \text{ Out} \quad \text{In: } R\ G\ B$$

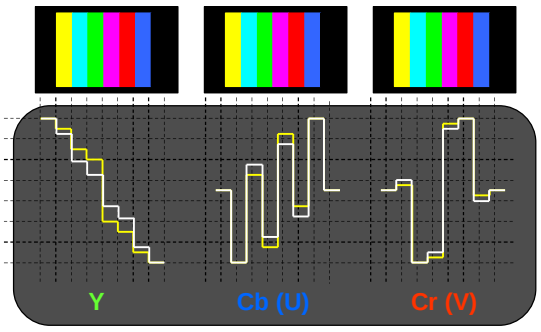
$$\text{YUV2RGBHD} = \begin{pmatrix} 1 & 0 & 1.5748 \\ 1 & -0.18732 & -0.46812 \\ 1 & 1.8556 & 0 \end{pmatrix} \begin{matrix} R \\ G \\ B \end{matrix} \text{ Out} \quad \text{In: } Y\ U\ V$$

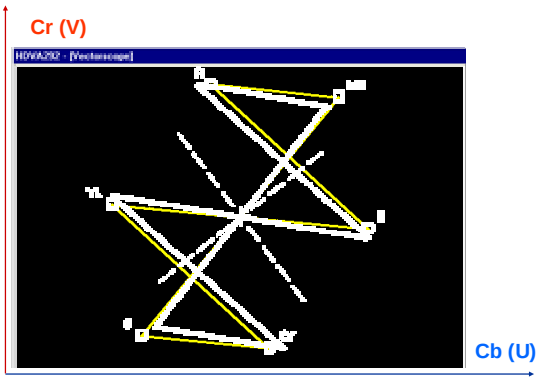
$$\text{YUV2RGBSD} = \begin{pmatrix} 1 & 0 & 1.402 \\ 1 & -0.34414 & -0.71414 \\ 1 & 1.772 & 0 \end{pmatrix} \begin{matrix} R \\ G \\ B \end{matrix} \text{ Out} \quad \text{In: } Y\ U\ V$$

Color Spaces and Display Issues -2

HD and SD YUV levels are significantly different:

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





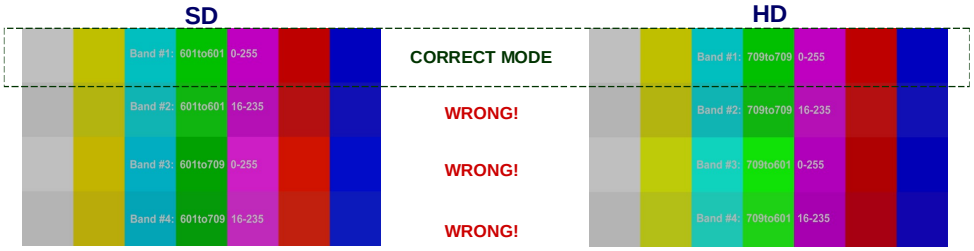
= HD = SD

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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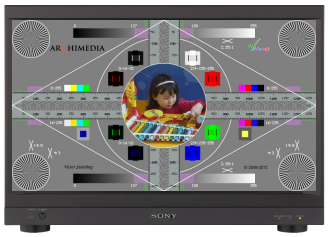
Color Spaces and Display Issues -4

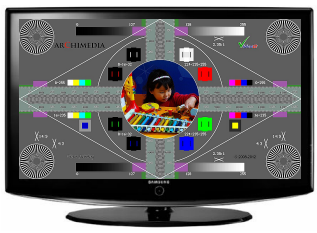
Typically there are two quite different sets of **Display Settings**:

- **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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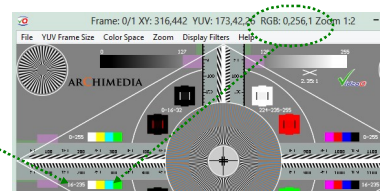
Color Spaces and Display Issues -5

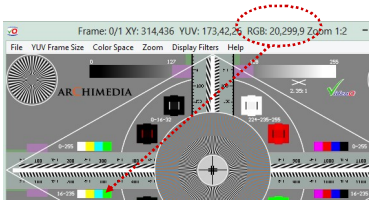
VideoQ **VQV1** viewer displaying the same A2.YUV file in different YUV to RGB conversion modes

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

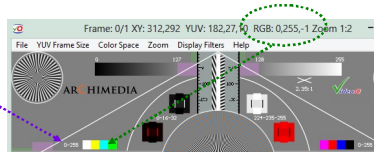


Manually selected **16-235** YUV range & **Rec. 601**:
Wrong RGB values on 100% Green Bar

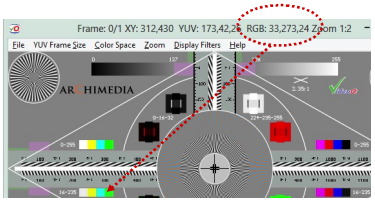


Manually selected ***non-standard*** **0-255** YUV range & **Rec. 709**:
Correct RGB values on 100% Green Bar

Non-standard 0-255 Bars
are also available



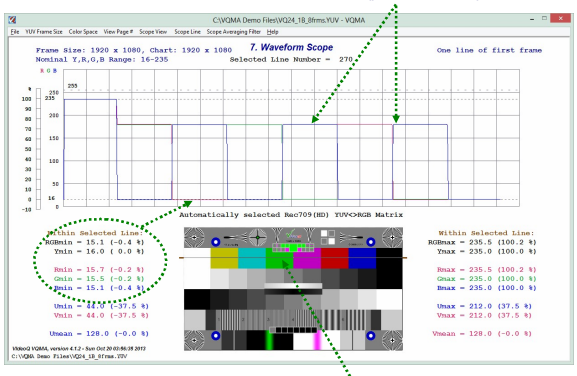
Manually selected **0-255** YUV range & **Rec. 601**:
Wrong RGB values on 100% Green Bar



Color Spaces and Display Issues -6

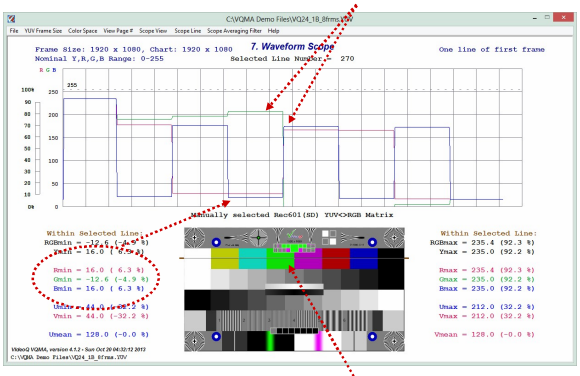
Examples of color space conversion settings affecting 100/0/75/0 Color Bars.
VideoQ **VQMA4** analyzer "Waveform Scope" Page

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



This is how correct Green color should look

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



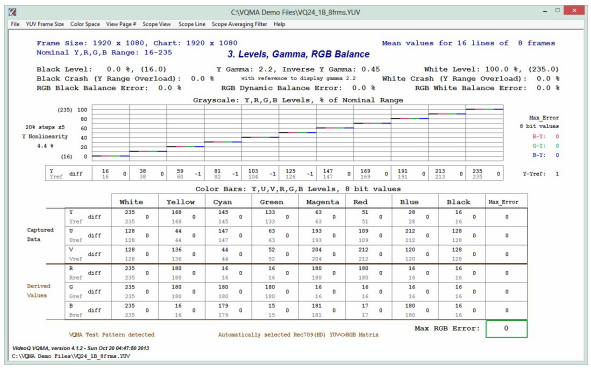
This Green color is too bright!

Color Spaces and Display Issues -7

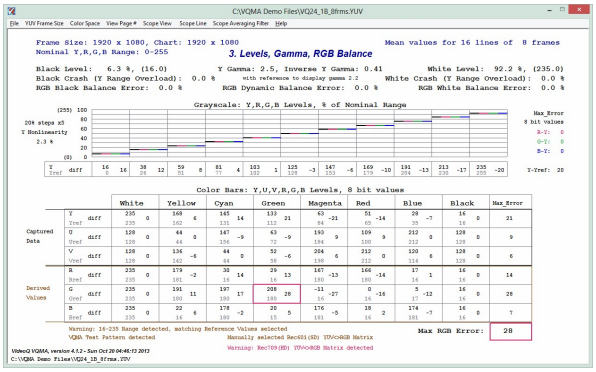
Examples of color space conversion settings affecting 100/0/75/0 Color Bars.

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

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



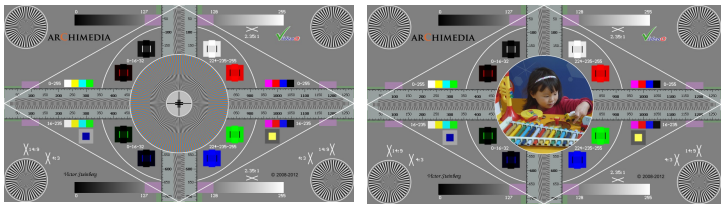
Manually selected **0-255** YUV range & **Rec. 601**:
VQMA Page shows two Warnings about this choice.
Auto-measured **Max RGB Error = 28d (8 bit levels)**



VideoQ - Archimedia Test Patterns

Descriptions & Tutorials

2. A1/A2 – 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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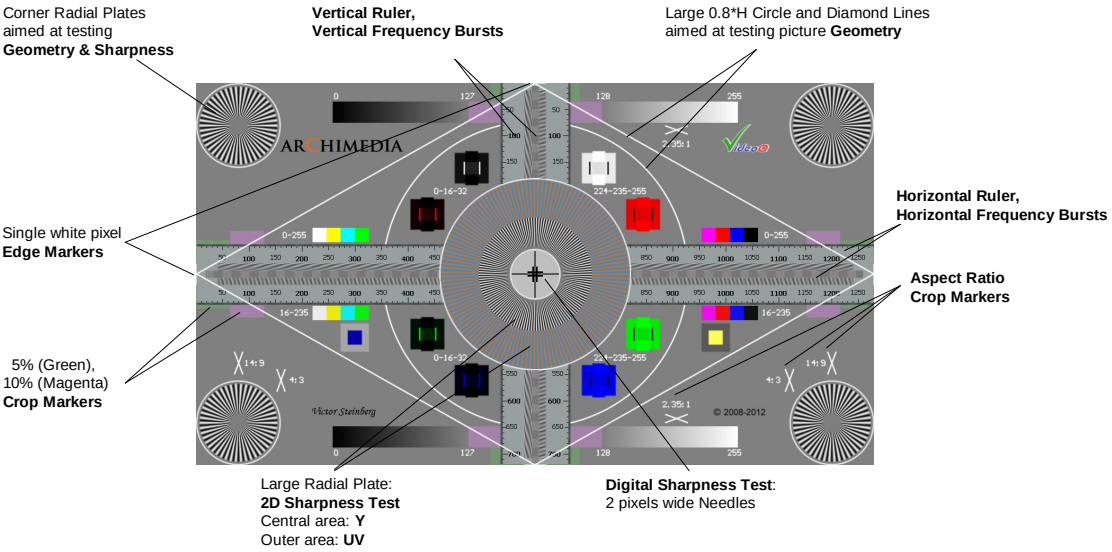
A1: Geometry and Scaling Test Components



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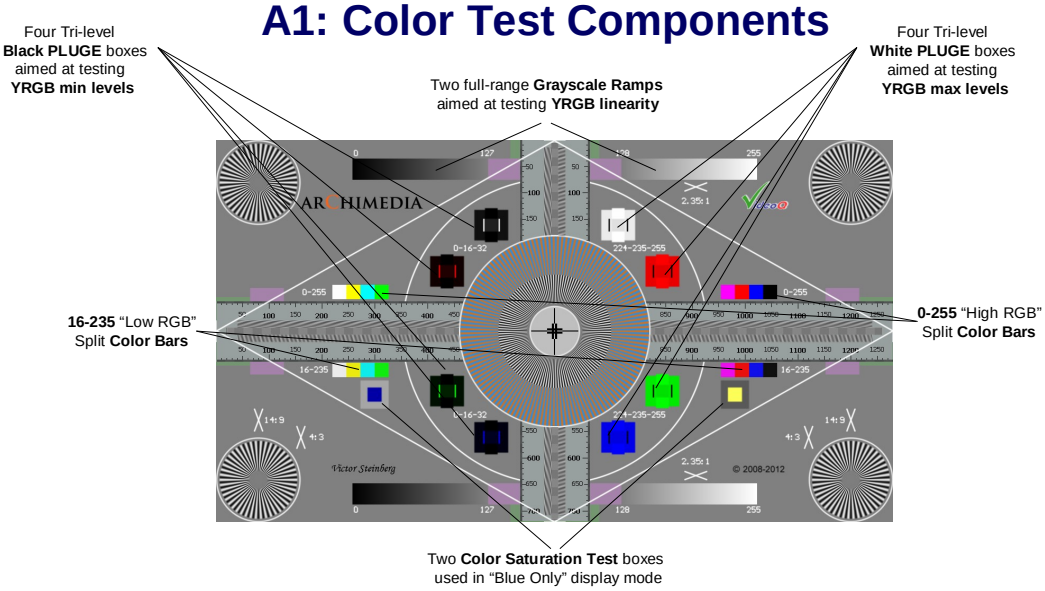
A1: Color Test Components



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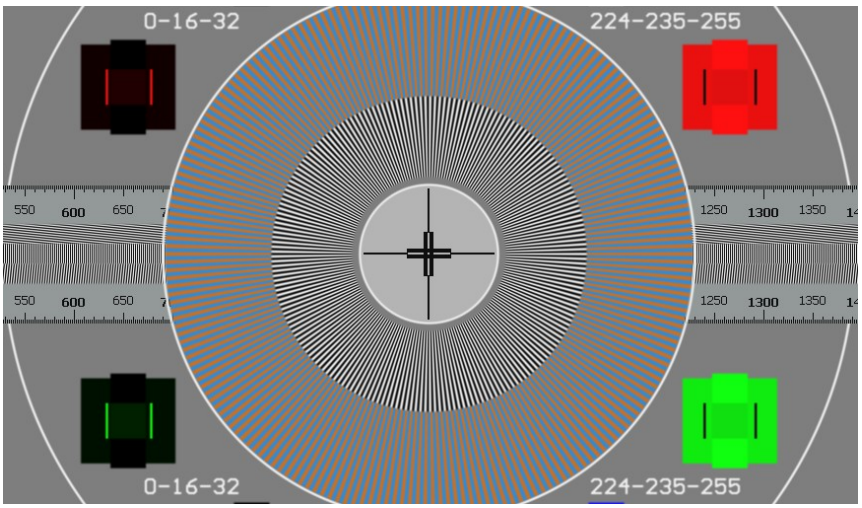
A1: Central Fragment



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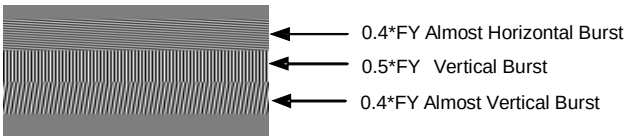
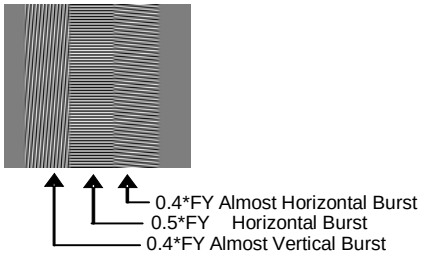
Tri-band Combination Burst Patterns



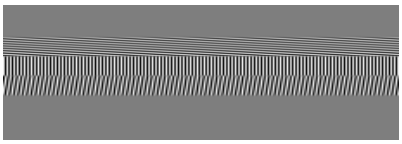


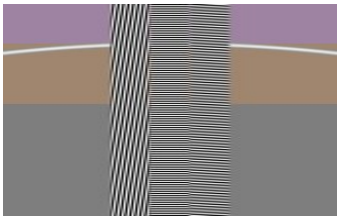
There are two groups of bursts with frequencies proportional to luma pixels rate FY:
full length horizontal bursts band and **full height vertical** bursts band.
Maximum luminance frequency burst of exactly **0.5 FY** is in the middle of each band.
Two slightly oblique bands of 0.4 FY surrounds the middle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

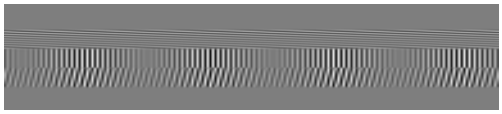
Within the burst vertical and almost **vertical lines** test **horizontal frequencies**,
whilst horizontal and almost **horizontal lines** test **vertical frequencies**.

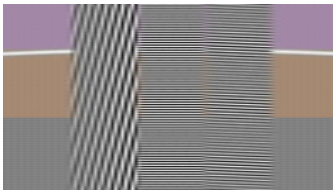
Tri-band Combination Burst Pattern Usage





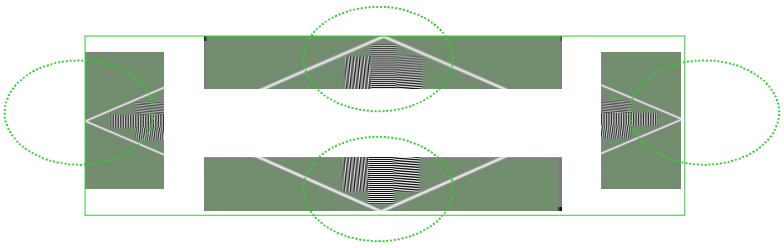
Example of correct settings (no scaling):
There are no visible beat waves on both horizontal and vertical Tri-band Patterns



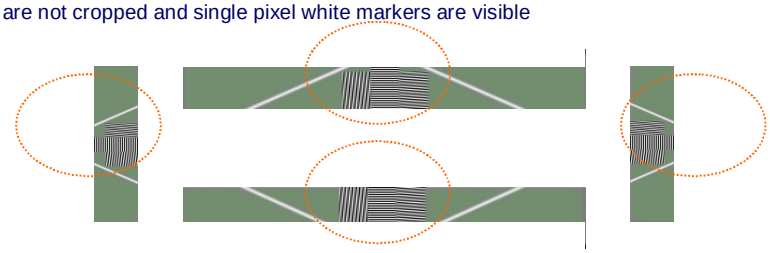


Example of incorrect settings (with scaling):
Scaling causes beat waves on both horizontal and vertical Tri-band Patterns

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

Crop Markers

Correct 4:3 Crop

Wrong 4:3 Crop

A1 pattern is designed for measurement in16:9 format, as well as in 4:3, 14:9 and 2.35:1 frame formats. Cross-shaped Frame Format Markers indicates 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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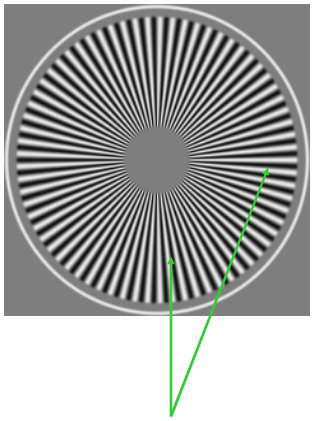
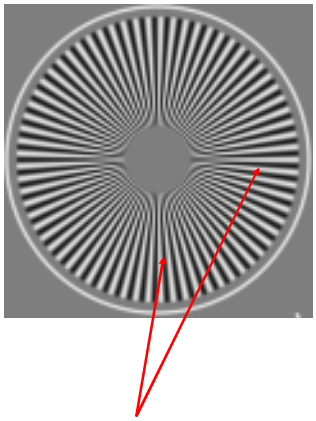
Radial Plates Usage

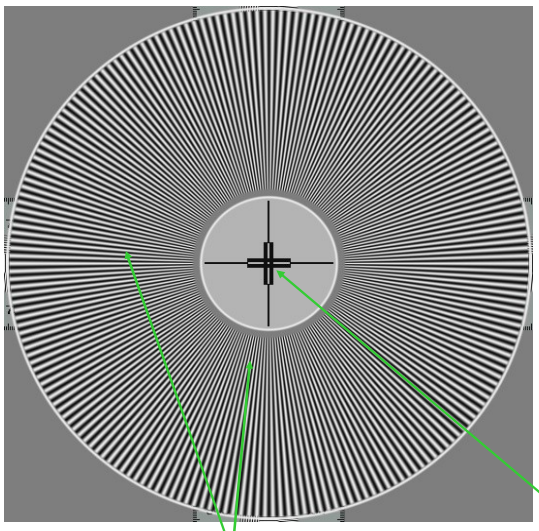


Original Size – dot-by-dot:
Full contrast of **fine details** in all directions



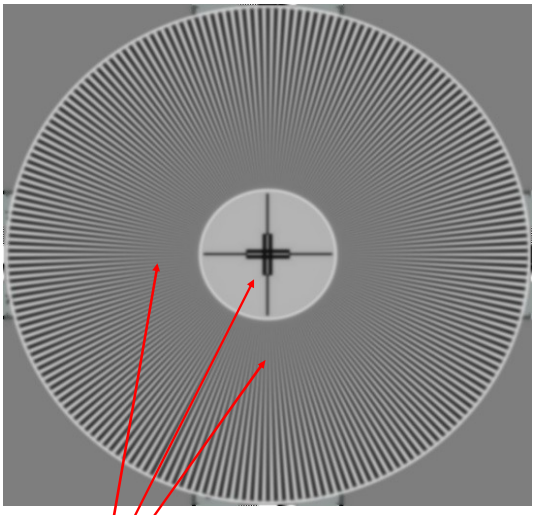
Scaled (Up or Down) Picture:
Loss and/or distortion of **fine details**

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

Sharpness Test Usage: Example #2



Not enough sharpness:
1. Fine details contrast reduced,
2. Central cross blurred

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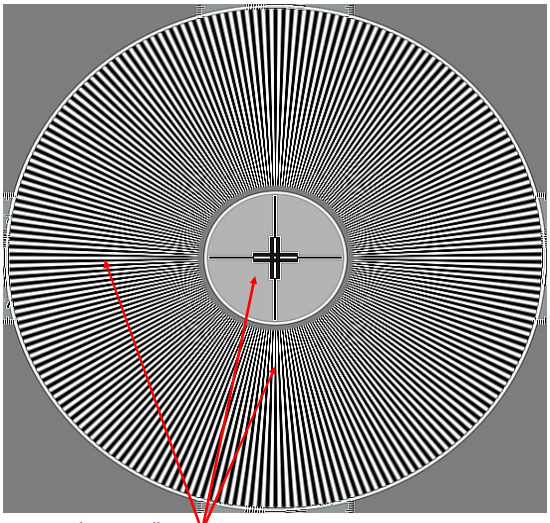
Sharpness Test Usage: Example #3



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

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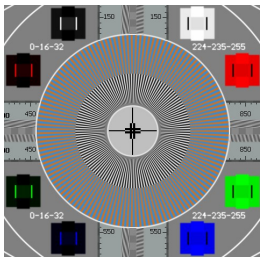
YRGB PLUGE Boxes and other Color Tests Usage

1. YRGB Range Check:

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



2. Color Saturation Check:

- 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**

- 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

Coarse Tuning (PLUGE)

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

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

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

Brightness is **too high**

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

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

Brightness is **correct**

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

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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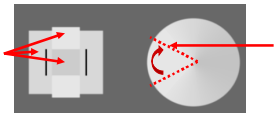
White PLUGE & SPLUGE Usage

Coarse Tuning (PLUGE)

Contrast (Gain) is **too low**

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



Fine Tuning (SPLUGE)
optional component

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

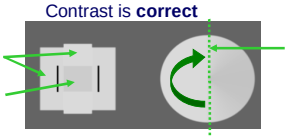
Contrast is **too high**

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

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

Contrast is **correct**

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

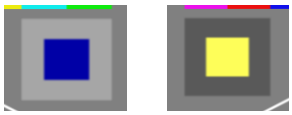


Conical grayscale is clipped exactly half-circle (180 degrees),
no shades of gray on the left half

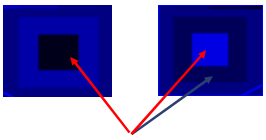
Note that some versions of A1 Pattern do not contain fine tuning SPLUGE components

Color Saturation Test Usage

Normal View
Correct Color Saturation

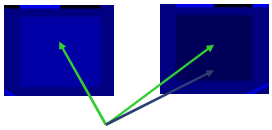


Blue Only Display Mode
Low Color Saturation



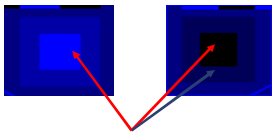
Blue component intensity on **colored** areas **differs** from **gray** areas

Blue Only Display Mode
Correct Color Saturation



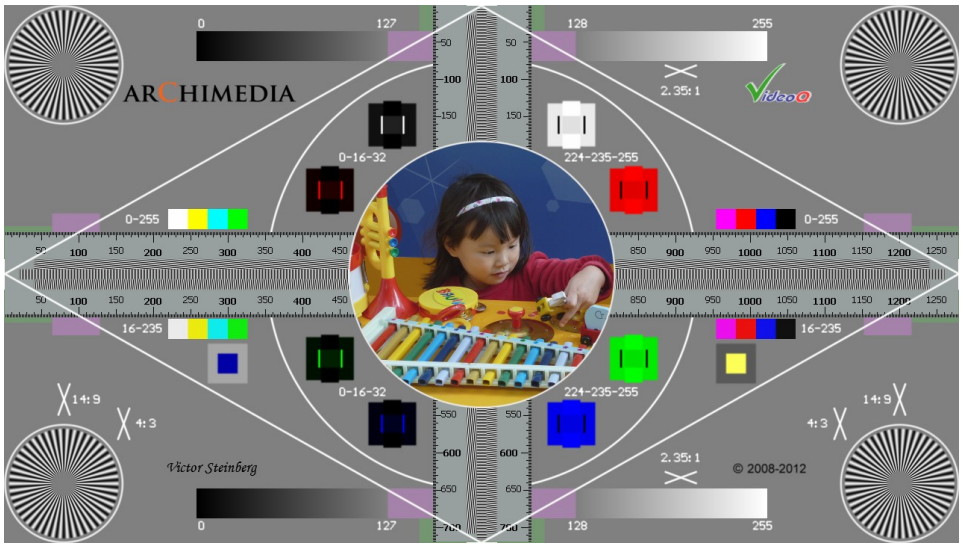
Equal blue component intensity on **gray** and **colored areas**, inner squares **are not visible**

Blue Only Display Mode
Excessive Color Saturation



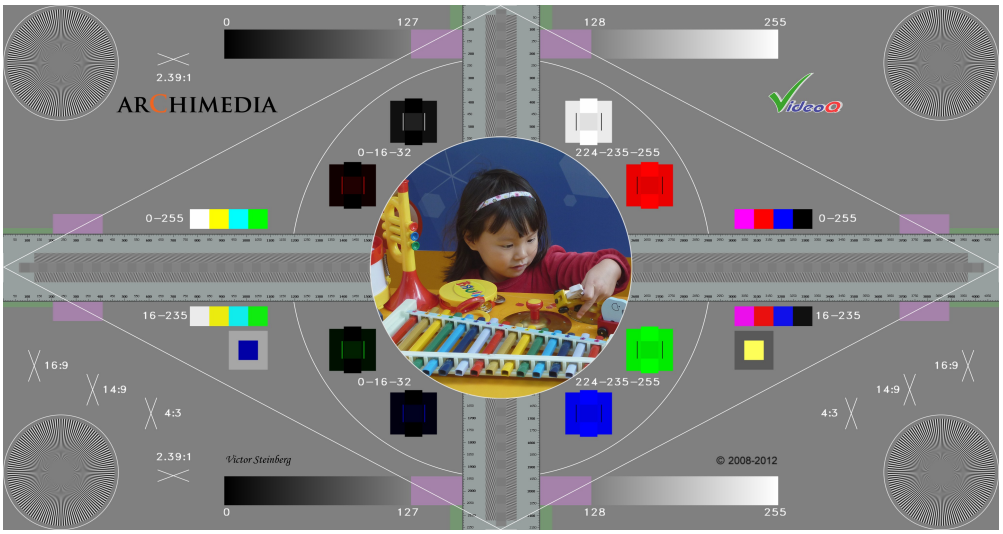
Blue component intensity on **colored** areas **differs** from **gray** areas

A2 – as A1, but with central photo insert



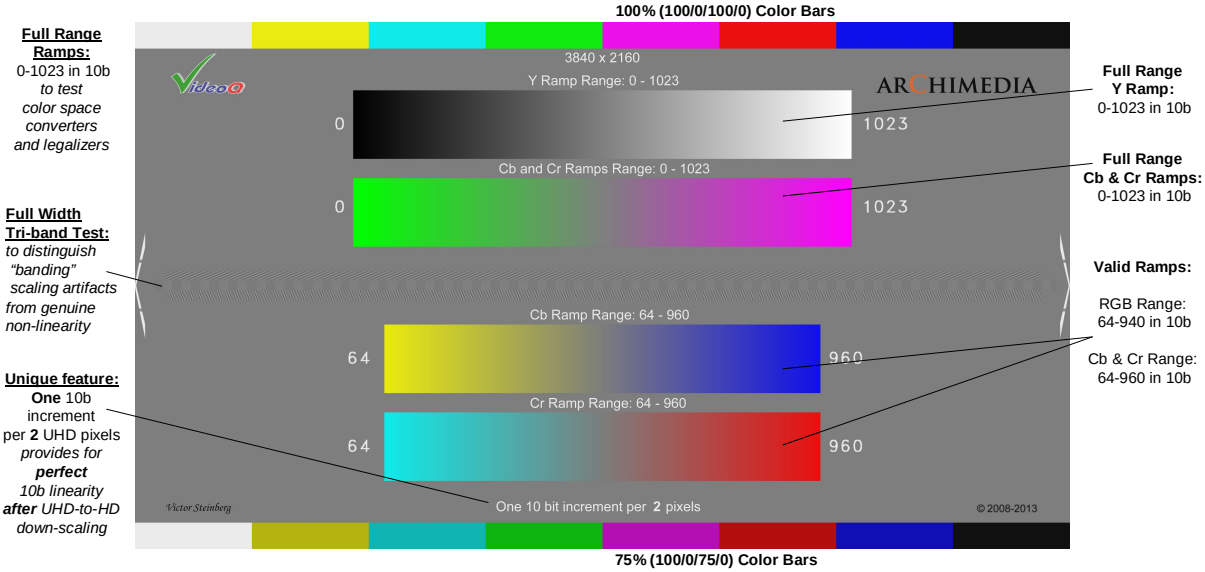
Central photo combines intense colors and flesh tone for overall color rendition quality visual estimation

A2: 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

2. YCbCrLT – Static Color Components Linearity Test



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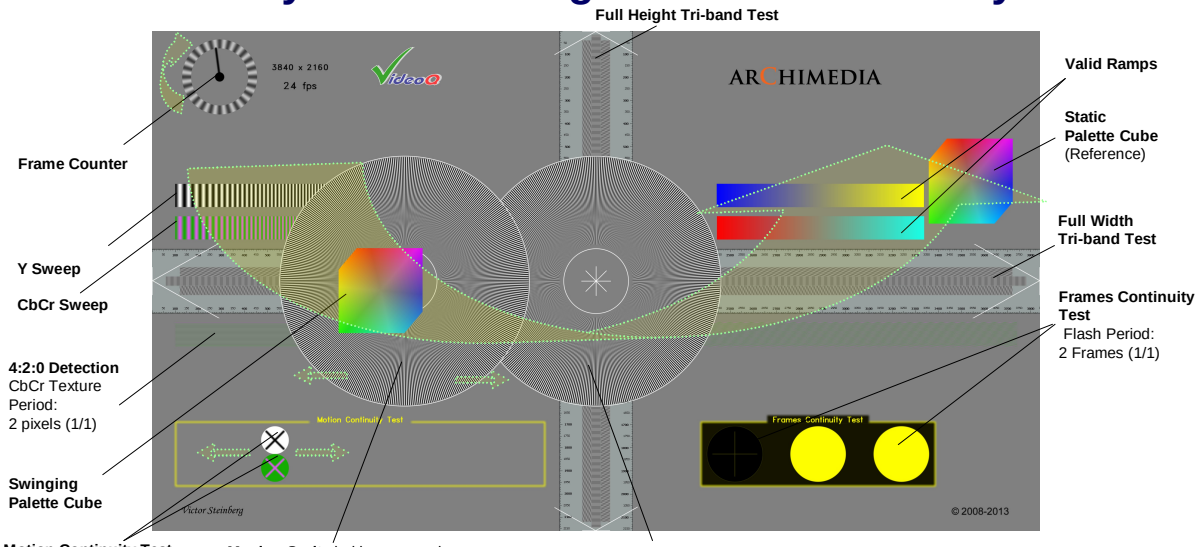
3. VST – Dynamic Scaling & Motion Continuity Test



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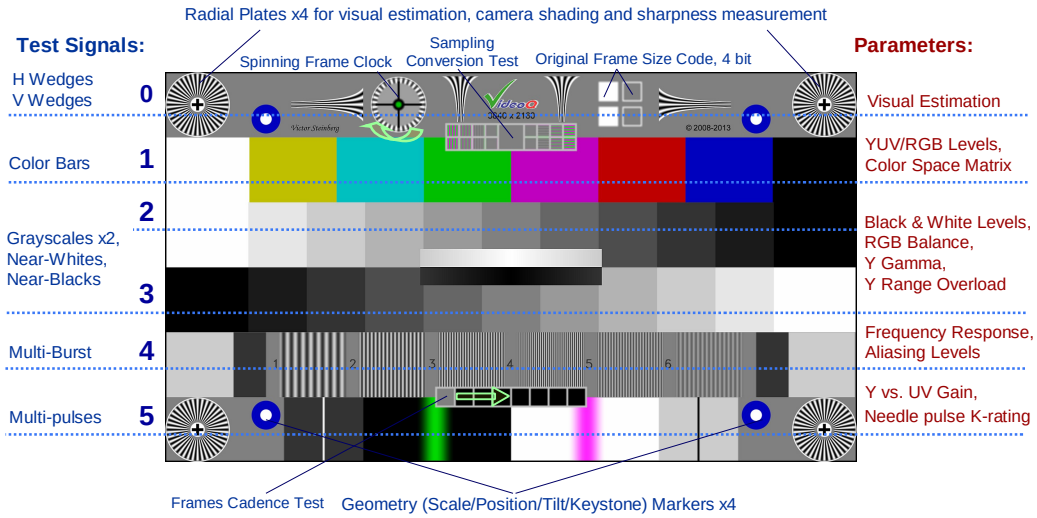
4. VQMA – Test Pattern for VideoQ SW Analyzer

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



Parameters Analyzed by VideoQ VQMA

PASS

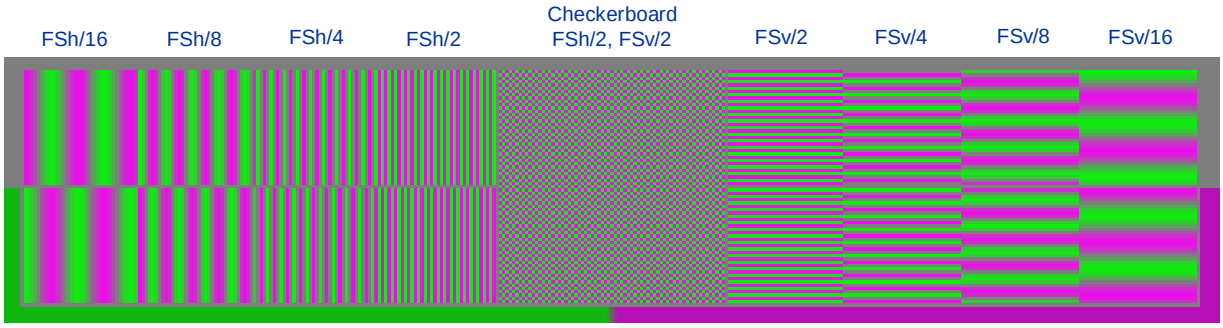
FAIL

- **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

VQMA: Sampling Conversion Test Details

FSh: Original Horizontal Sampling Rate, tvl = Original Frame Width, pixels
FSv: Original Vertical Sampling Rate, tvl = Original Frame Height, pixels



4:2:2 and 4:1:1 (UV H sub-sampling) Detection Area

H & V Scaling Detector
shows any conversion
vs. pristine 4:4:4 YUV/RGB

4:2:0 (UV V sub-sampling) Detection Area

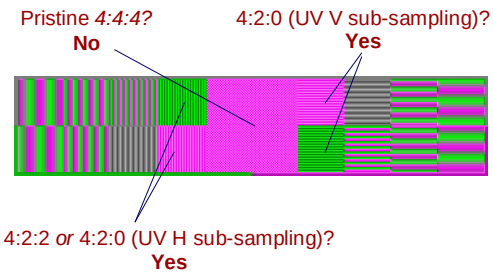
VQMA: Sampling Conversion Test Usage Example

Test appearance after different codecs

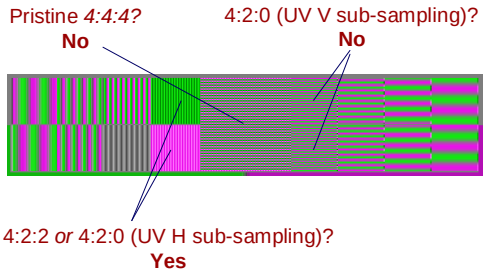
Case #1

Case #2

Dedicated areas indicate different sub-sampling issues:



Sampling Conversion Test Result:
4:2:0 sub-sampling mode detected



Sampling Conversion Test Result:
4:2:2 sub-sampling mode detected

Thank you
for attention

Any questions?

www.videoq.com

www.archimediatech.com