

Measuring Color-Reproduction Quality on TVs and Monitors

Application Note

Products:

R&S® DVSG	Konica Minolta CS-2000
NI LabVIEW	Konica Minolta CS-S10w

This application note presents means to determine the quality of color-reproduction on TVs and monitors using the R&S® DVSG Digital Video Signal Generator in combination with the Konica Minolta CS-2000 spectroradiometer and the accompanying Konica Minolta CS-S10w analysis software.

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1 Overview

1.1 The Task

An important quality criterion of TVs and monitors is the capacity to reproduce images faithfully. Accurate color reproduction is a decisive element of this capacity. To that end, internationally recognized and standardized values are defined by technical standards and recommendations from the relevant committees, such as the EBU (European Broadcasting Union), ITU (International Telecommunication Union) und SMPTE (Society of Motion Picture and Television Engineers). Besides other parameters, these standards prescribe the white point and color temperature, the color coordinates of the primary colors, and therefore also the color gamut.

If, for example, a TV's color temperature is set too high in relation to the common D65 standard, all colors will be displayed with relatively too much blue and too little red – the image will look adulterated and will no longer match the original. Similar is true of the color gamut: If the gamut is too large in comparison to the standard, colors will be distorted. This can leave plants, for example, looking more intense than in the original.

The crux is that almost all manufacturers of consumer TVs consider it sensible, for technical and marketing reasons, to deliver their products in a setting that deviates to a greater or lesser extent from the aforementioned standards and recommendations.

Most modern TVs provide the controls necessary to achieve colors that match the standards, but end consumers lack the relevant specialist skills and measurement devices to set them up properly.

1.2 The Solution

The color-measurement procedure presented in this application note provides information about a display's color reproduction. The test process follows current EBU guidelines (see Chapter 3) and could conceivably be used in a number of areas:

- **Product reviews** in specialist publications, for example, gain objectivity thanks to the measurement procedure presented here, allowing reviewers to make accurate and verifiable statements.
- **TV manufacturers** can increase the color-reproduction quality of their products by providing consistent presets. This could give their products access to new, more-demanding classes of consumer.
- **In the video-production and broadcast industries**, correct color reproduction is an indispensable feature of a display. The monitors in use can be calibrated, allowing manufacturers to eliminate sources of error from the production chain that are responsible for monitors displaying erroneous colors.

Besides the technical operating steps, this document contains notes to bear in mind while carrying out the measurements and on how to interpret the obtained results.

1.3 Advantages Over Other Measurement Setups

- **High precision:** Unlike with test signals from DVD video or Blu-ray, any video codec-specific uncertainties and player inaccuracies can be ruled out. The test patterns and sequences of a digital video signal generator such as the R&S®DVSG are relayed to the tested device in an uncompressed form and with the highest possible accuracy.
- **High versatility:** Test patterns generated by the R&S®DVSG can be edited in a versatile way if necessary. For example, the color-difference level of a video signal can be adjusted in steps of 0.1%.
- **Possibility of automation:** The option of controlling the R&S®DVSG remotely via an external computer and its compatibility with relevant analysis and automation environments, such as National Instruments LabView, allow users to carry out measurements with a high degree of automation.
- **Scalability:** The generator's numerous outputs and seamless integration with system controllers allow users to take similar measurements via a TV's various different inputs. Extending this by adding an external broadcast tester, such as the R&S®SFE or R&S®SFU, even allows laboratories to feed signals to the devices with the integrated tuner.

2 Test Setup

2.1 Schematic Drawing of the Test Setup

The following diagram shows a typical test setup for color measurements on a display according to the current EBU guideline 3325. The peripheral equipment shown here with the R&S®DVSG is a typical setup, but alternative products can be used for color analysis and data evaluation.

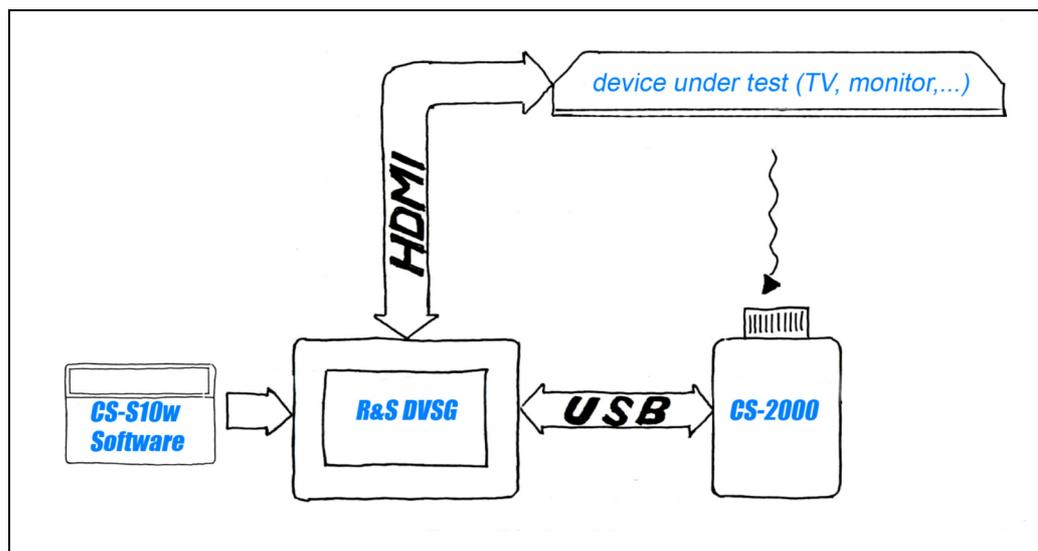


Figure 1: Typical test setup with the R&S®DVSG, Konica Minolta CS-2000 and Konica Minolta CS-S10w software

2.2 Description of the Chosen Components

The following section briefly explains the function of the components that the measurements require.

2.2.1 R&S®DVSG

Function: Digital video signal generator – Generates the reference test signals needed for the measurement process. It inputs these to the tested device (the TV) via HDMI. The generator also has a range of analog video outputs.



Figure 2: R&S®DVSG digital video signal generator

2.2.2 Konica Minolta CS-2000

Function: Colorimeter – the Konica Minolta CS-2000 is a spectroradiometer that's used in the test setup to detect and analyze the light from the tested device according to DIN 5033-4 (Colorimetry; spectrophotometric method). Ideally suited to studying both the luminance and the quality of the light output (color coordinates, spectral analysis), it allows the user to make all optical measurements relevant to displays (contrast ratio, brightness, gamma, uniformity, viewing-angle dependence, color fidelity ...).



Figure 3: Konica Minolta CS-2000 spectroradiometer

2.2.3 Konica Minolta CS-S10w

Function: Data analysis – The optional PC software processes the data arriving from the Konica Minolta CS-2000. It can also be used to trigger measurements and to adjust settings of the device under test. The Konica Minolta CS-2000 and CS-S10w connect to one another via USB. The software can display the obtained measurement data in tabular or graphical form or export them to Microsoft Excel, for example, for further processing. This is considerably more convenient than taking the measurements using the Konica Minolta CS-2000 alone.

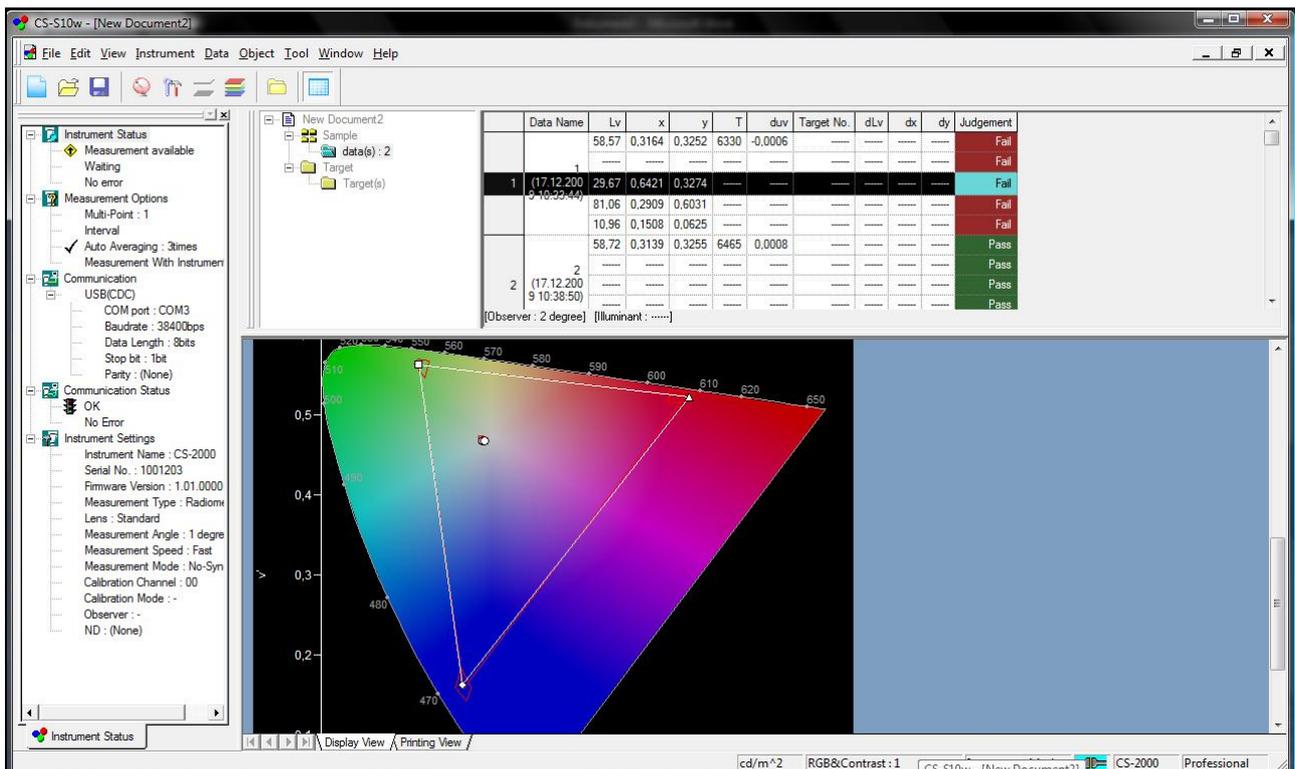


Figure 4: The Konica Minolta CS-S10w data-analysis software

2.2.4 Optional Components

Users can extend the test setup with additional components. Options include, for example, integrating the R&S® DVSG and the Konica Minolta CS-2000 into an NI LabVIEW environment, allowing measurement procedures to be carried out automatically. Other possibilities involve combining the setup with an electronically controlled rotary table in order to carry out angle-specific color measurements.

2.3 Basic Settings

The following section gives the basic settings needed for the color measurements, which are described later. Chapter 3 deals with the practical test procedure.

2.3.1 R&S® DVSG

- To make the measurement procedure as convenient as possible, it is recommended to connect keyboard and mouse via USB to the R&S® DVSG. All operating steps can, of course, also be carried out on the instrument's front panel directly.
- Select the “AV GENERATOR” application – for those operating the device without a mouse, this is accessed by pressing the “APPL” button and selecting “AV GENER.” using the softkeys under the screen.
- The R&S® DVSG contains all of the files necessary for color measurements in various resolutions (480i–1080p), color spaces (YCbCr, RGB), and subsampling varieties (4:4:4, 4:2:2). The test patterns are stored in:

D:\DATA\Lib AV Generator\AV Main\Pattern.

- To make carrying out the measurements easier, it is recommended that the user copies the required test patterns into a new folder. Using the keyboard and mouse, this process is just as easy as on a PC. If, for example, the user is measuring a monitor's gamut, a folder should be created with a name such as “Test Patterns Gamut” and containing the corresponding files (Field Red, Field Green, Field Blue). In our test setup, therefore, we copied the signals for measurements according to the EBU standard into a separate folder on the drive E:\ in order to group the files relevant to the measurement process in a practical way:

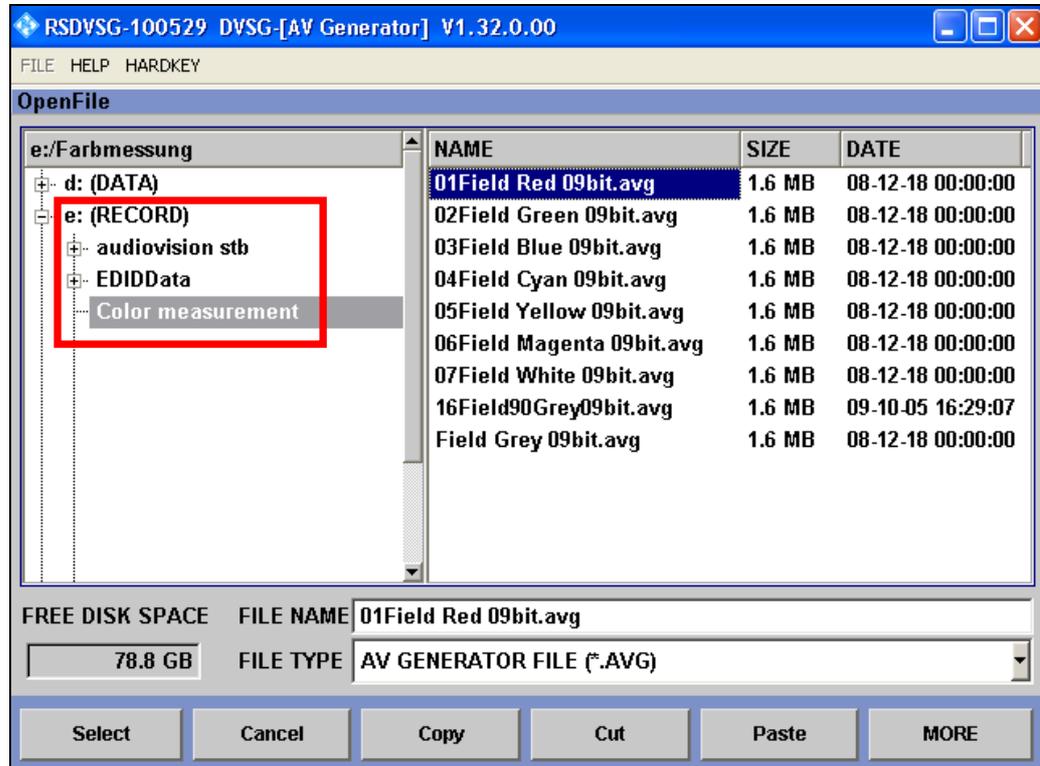


Figure 5: User-created folder containing test patterns in a practical order

- Before every measurement, the user should check that the test pattern's "Adjustment" setting in the "Video" submenu is set to "Calibrated". In the "Variable" setting, all of the levels are subject to change, which can introduce a potential source of error during gamut measurements:

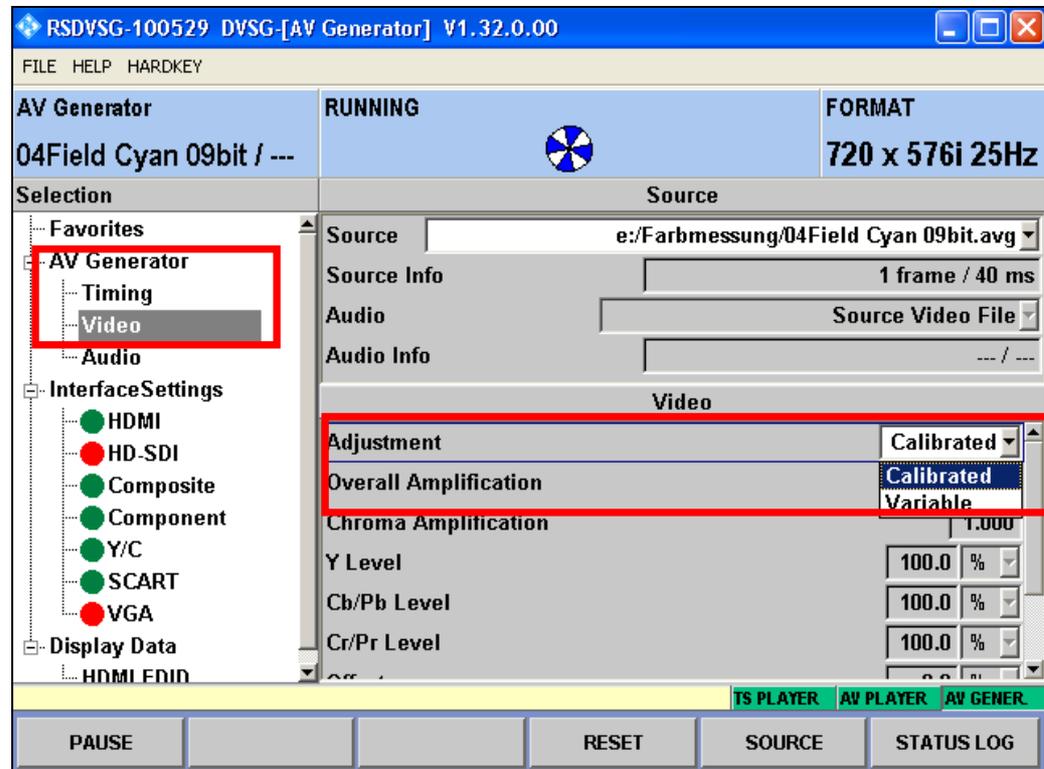


Figure 6: In the "Variable" adjustment mode ("Video" submenu) the test pattern can be edited in a number of ways

2.3.2 Konica Minolta CS-2000

- To make taking measurements as rapid as possible, we recommend setting the largest possible aperture angle of 1°. With smaller angles (either 0.2° or 0.1°) the measurement process takes longer and there is a greater risk that the fine-grained noise of plasma displays will be misinterpreted as color errors. This setting can be adjusted using the dial to the right of the viewfinder.
- For the fastest possible measurements with sufficient precision, we recommend setting the Konica Minolta CS-2000's integration time to the "FAST" mode. This setting is accessed by pressing the "MENU" button on the device and then selecting the "MEAS" submenu. Important: The settings cannot be adjusted in this way if the instrument is in "REMOTE MODE" – in this case, the user should remove the USB cable.

2.3.3 Konica Minolta CS-S10w

- The analysis software is supplied with four different presets, from which it asks users to choose in the “Light-source Color” menu each time the program starts. The “RGB&Contrast” Mode is suitable for color measurements on monitors; in this mode, five successive measurements are interpreted as values for red, green, blue, black, and white.
- The “Connect” command (button F5) in the “Instrument” menu creates a connection between the Konica Minolta CS-2000 and the software. If the connection does not work (“Connection failed”), users should check that the USB cable for remote control is connected and that the hardware copy-protection (USB dongle) is plugged into the PC. In case of connection problems, it can help to unplug and then reattach the cable:

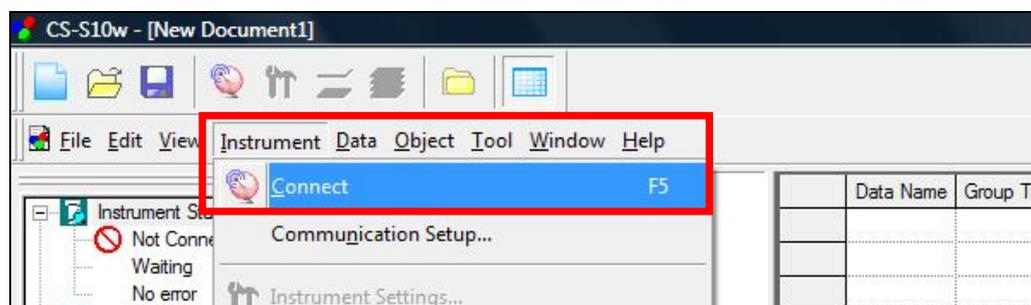


Figure 7: The “Connect” command creates a connection with the Konica Minolta CS-2000

- User-defined “Templates” allow users to adjust the setup optimally for different requirements. Freely adjustable tolerance levels for the various measurement points allow, for example, simple quality control (pass/fail) or automatic repeat measurements for averaging in order to improve the measurement precision:

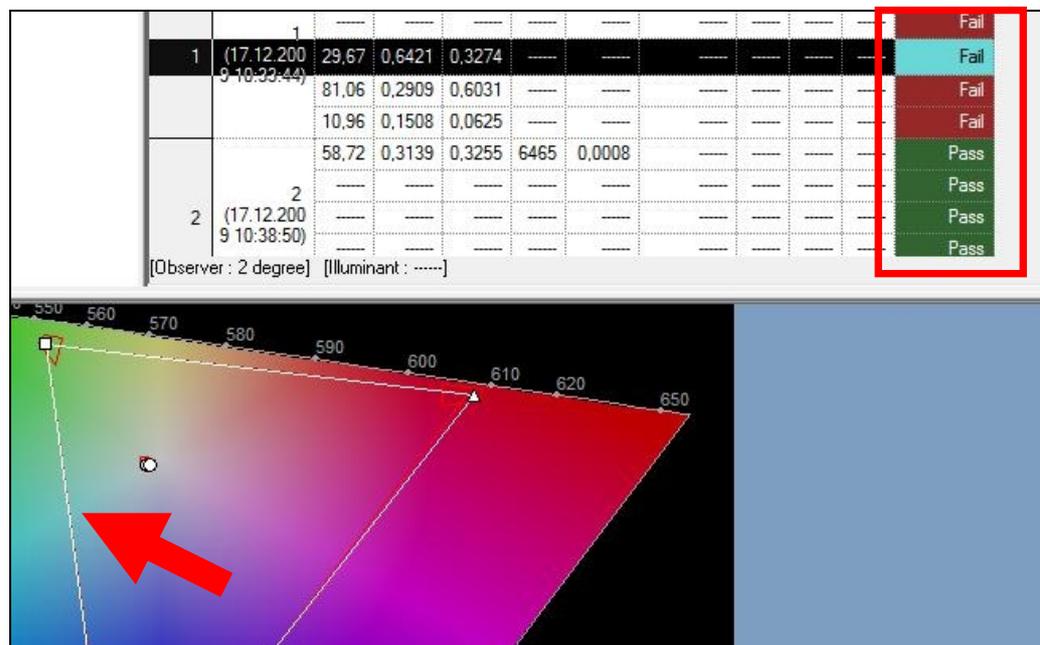


Figure 8: Konica-Minolta CS-S10w software supports easy pass/fail evaluation of measured values by means of tolerance polygons

2.4 Alternative Measurement Equipment

Other light- and color-measuring devices can be used in place of the Konica Minolta CS-2000, including, for example, the Konica Minolta CS-1000 or the cheaper Konica Minolta CS-200. Other sensors can also be used when supported by the relevant measurement software.

When choosing a measuring device for light and colors, however, users should always bear in mind the sensor precision as an important factor.

3 Measurements

The following chapter describes a measurement example which can be used to determine the most important color-reproduction criteria of a display, such as gamut and color temperature. Our account includes tips on how to interpret the obtained values and on what to watch out for when carrying out the color measurements. The same test setup can easily be used to carry out other tasks such as measuring gamma, uniformity, contrast, or viewing-angle dependence.

3.1 Basic Test Sequence

Fundamentally, all of the measurements presented in this application note follow this pattern:

- Test-pattern generation by the R&S®DVSG
- Light analysis by the Konica Minolta CS-2000
- Representation of the measured value using the Konica Minolta CS-S10w analysis software
- Usually the last step is the evaluation and interpretation of the data obtained from individual measurements in an evaluation scheme or measurement report

3.2 Preparatory Measures

Before carrying out the measurements, users should construct the test setup shown in Figure 1. The photo below shows the test setup in practice. Note that, for the purposes of taking this photo, the room is not fully darkened; it should, however, be fully darkened while measurements are being taken:

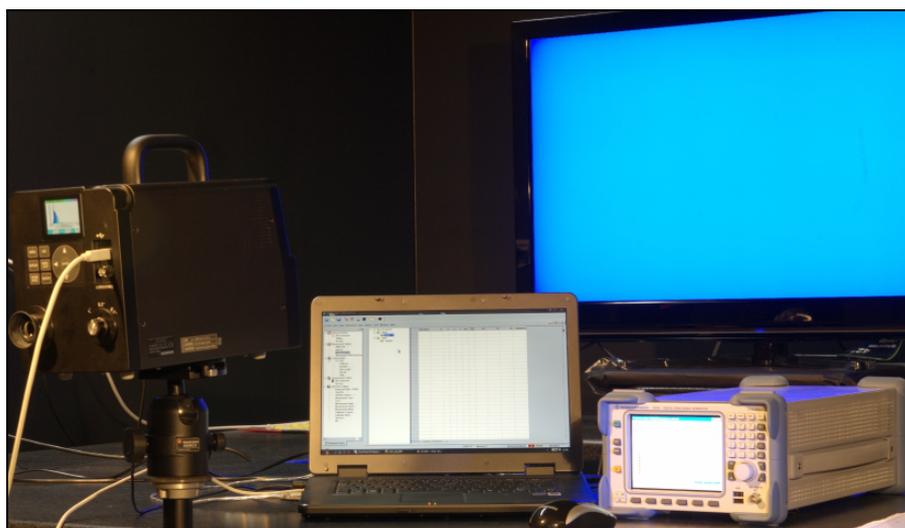


Figure 9: Established test setup in a suitable fully darkened measurement room

3.2.1 Requirements of the Measuring Room

In practice, all measurements should be carried out in a fully darkened – and ideally black – measuring room so that ambient light does not affect the measured values. The guideline VESA FPDM2 (Flat Panel Display Measurements Version 2.0) prescribes a maximum ambient illumination of 1 lx.

Cables should be laid in a way that does not present a tripping hazard. This is easily achieved by using generous cable lengths and by fixing the cables to the floor using sticky tape or similar.

Sports headlamps are ideal for taking notes in the measurement room; unlike handheld flashlights, these offer the advantage that both of the user's hands are free and that the light always points in the user's direction of view.

3.2.2 Positioning of Device Under Test and Spectroradiometer

Correct positioning of both the tested device and the light/color sensor is crucial for obtaining faultless measurements:

- The Konica Minolta CS-2000 should be positioned so that it is free of vibration and cannot wobble. This is easily achieved by mounting it on a sturdy tripod, which can be obtained either from the manufacturer (Konica Minolta Tripod CS-A3) or from a specialist photography supplier. For easy installation, the tripod should allow versatile adjustment (height, horizontal and vertical tilt, rotation angle).
- The Konica Minolta CS-2000 should be positioned so that the integrated sight points toward the center of the tested device's screen at an angle as close as possible to perpendicular (except for special measurements such as viewing-angle dependence). Placing the instrument between three and four times the image height away from the screen has proven effective; for a 50-inch TV, this corresponds to a distance of around two to two and a half meters.
- The Konica Minolta CS-2000's lens should be directed toward and focused on the center of the screen. Focusing is best done using test patterns containing small-scale content such as text; the R&S® DVSG provides numerous such patterns.

3.2.3 Tips on Maintaining Constant Measurement Conditions

To obtain meaningful and reproducible results, we recommend the following measures:

- The tested device should be switched on well in advance of the test, since the brightness and color vary continuously during the warm-up period. Guideline EBU 3273 recommends displaying a gray image with a luminance of 15 cd/m² for three quarters of an hour.

- For future reproducibility, it helps to document all of the tested device's settings and the format of the input signal (e.g., HDMI-576/50i YCbCr 4:2:2 HDCP). The display's playback characteristics can differ dramatically depending on settings and the type of input signal.
- Any automated features that adjust the display's picture in relation to the ambient illumination or similar should be deactivated.

3.3 Measurement of the RGB Primary Colors

The aim of this example measurement is to determine a TV's gamut by measuring the color coordinates of the primary colors red, green, and blue. Of course, the test patterns that the R&S®DVSG provides allow a range of other forms of color analysis – determination of the gamma, grayscale linearity/color temperature, secondary colors, 3D color management, and so on – using similar methods to this.

3.3.1 Procedure

- Initially, a red test pattern (Plain Red.avg) is to be generated. One such pattern is found at "D:\DATA\Lib AV Generator\AV Main\Pattern."
- The test pattern begins when the user double-clicks on the file with the mouse. If no mouse is connected, the user can navigate using the cursor buttons and the combined rotary knob / push button. The R&S®DVSG manual gives further notes on basic operation.
- The test pattern is then captured using the Konica Minolta CS-2000 and CS-S10w: This can be done by pressing F4, by clicking on the four-colored symbol in the top row of icons (third icon from the right), or via the "Instrument/Measure" submenu. A window opens for naming the measurement series and adding comments:

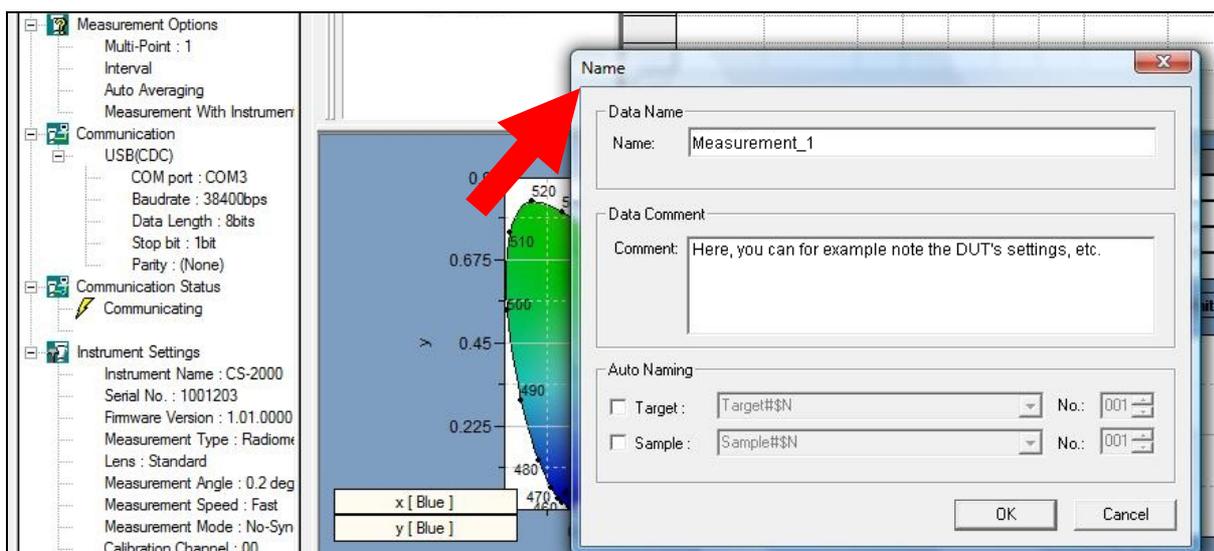


Figure 10: Naming window for the current measurement series

- Clicking “OK” closes the naming window and opens the “RGB&Contrast Measurement” window, from where the measurements are carried out.
- In the “Group Traits” column, the user defines which data each measurement will record. If the tested device’s red color coordinates are to be captured, the user selects “Red”. The screenshot below shows the option set to “Black”. Clicking “Measure” triggers the respective individual measurement.
- Once the data have been captured for red, the user checks the box for green, runs the green test pattern on the R&S® DVSG, and presses “Measure”. The process continues until all five measurements are taken:

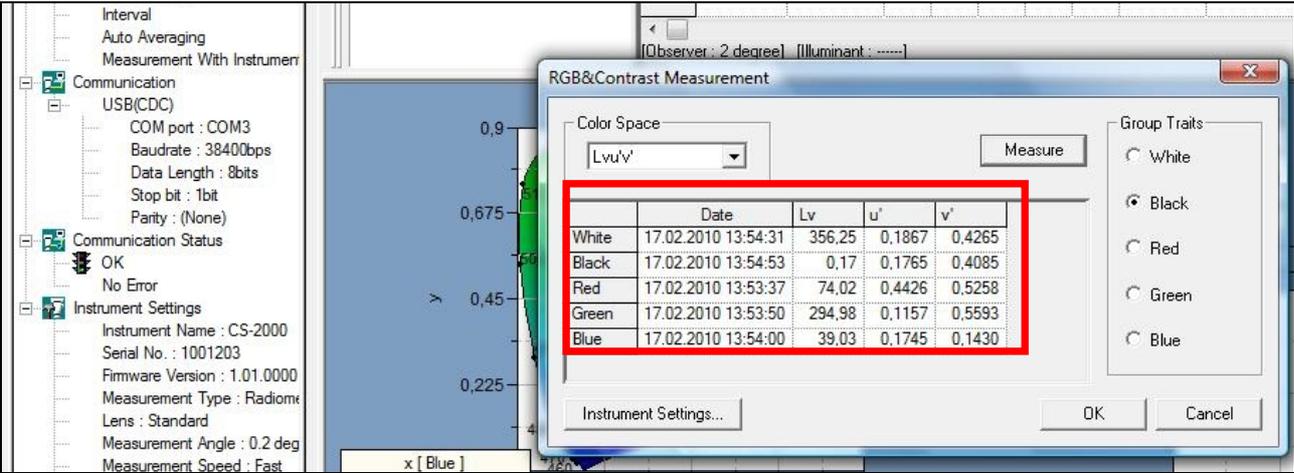


Figure 11: Completed measurement series for red, green, blue, black, and white

- Once all the necessary data are collected, the user presses “OK”. The results now display graphically as a CIE diagram (type 1931) as well as in numerical form, quoting various quality criteria (Lv, x, y, T, duv, contrast):

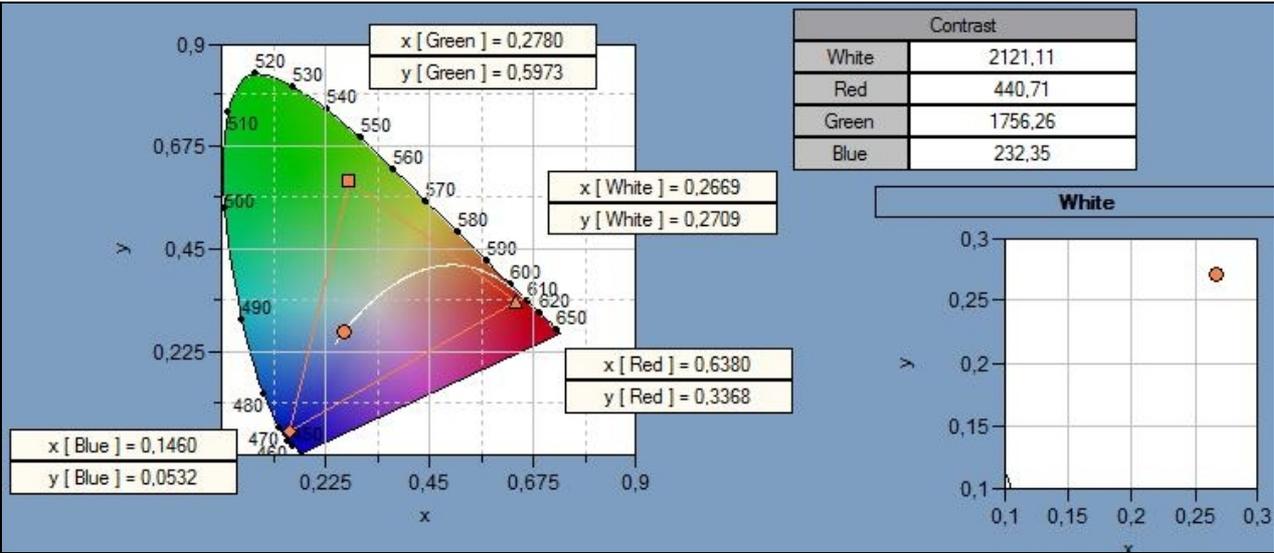


Figure 12: Measurement results display

- In the “Edit” mode, the user can adjust the graph’s properties to meet their requirements (CIE 1976 diagram, enlarge/reduce/position the diagrams).
- Once the measurements are complete, all data series can be stored in a single combined file (*.ces) by clicking “Save As” in the “File” menu:

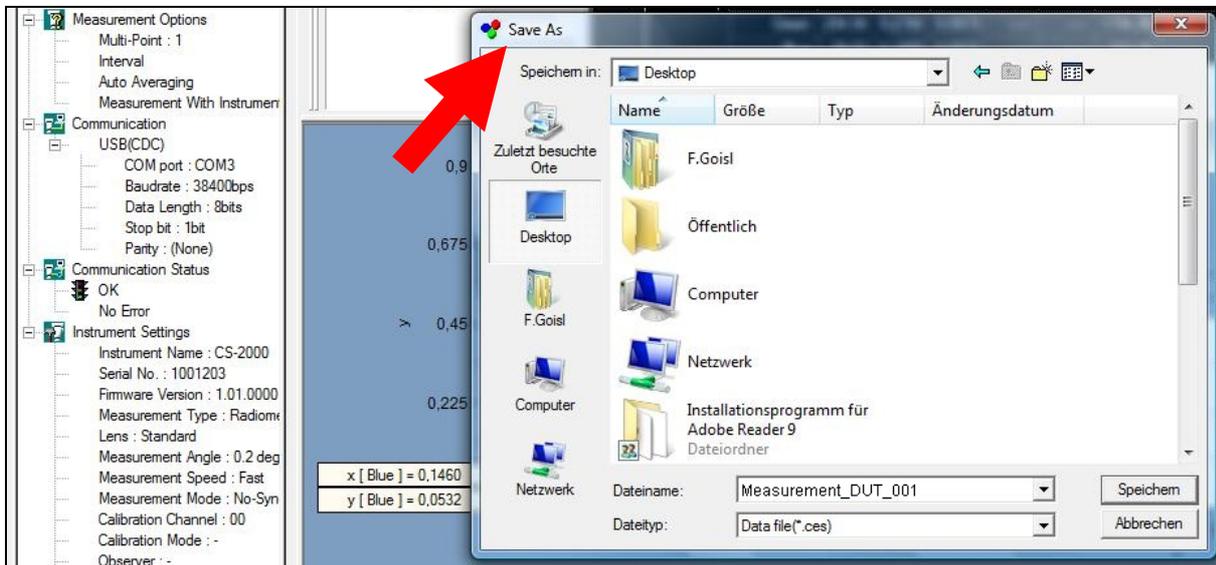


Figure 13: Storing the measurement series in a single file

3.3.2 Interpreting the Measurements

Color reproduction in TVs – except in special models with four or more primary colors – generally involves mixing shades from the primary colors red, green and blue. The color coordinates of these primary colors therefore define the available gamut.

A TV’s gamut should follow the applicable standards. The gamuts relevant to TVs are those defined by EBU (PAL), SMPTE-C (NTSC), and ITU-R BT.709 (Blu-ray, HDTV) – see the table below. EBU Tech 3325 also proposes tolerance regions.

Gamuts of common video standards			
with a D65 white point (x=0.3127; y=0.3291)			
These xy coordinates relate to the CIE 1931 color model.	EBU gamut (PAL, SDTV)	ITU-R BT.709 gamut (HDTV, Blu-ray)	SMPTE-C gamut (NTSC, SDTV)
Primary color Red (E_R')	x=0.64; y=0.33	x=0.64; y=0.33	x=0.64; y=0.34
Primary color Green (E_G')	x=0.29; y=0.60	x=0.30; y=0.60	x=0.31; y=0.595
Primary color Blue (E_B')	x=0.15; y=0.06	x=0.15; y=0.06	x=0.155; y=0.07

Graphical visualization of the gamut typically involves joining the three color coordinates with lines to form a triangle (cf. CIE diagram).

Further measurement series – for example, using grayscales of differing brightness – can give insight into the electro-optical transfer curve (gamma) and gray tracking.

4 Literature

- R&S® DVSG Operating Manual – also see: Quick Start Guide:
http://www2.rohde-schwarz.com/file_10664/Quick_Start_Guide_web_03_00.pdf
- Konica Minolta: CS-2000 Instruction Manual
- Konica Minolta: CS-S10w Instruction Manual
- EBU – Tech 3321: “EBU Guideline for Consumer Flat Panel Displays (FPDs)”,
<http://tech.ebu.ch/docs/tech/tech3321.pdf>
- EBU – Tech 3325: “Methods for the Measurement of the Performance of Studio Monitors”, <http://tech.ebu.ch/docs/tech/tech3325.pdf>
- EBU –Tech 3273-E: “Methods of Measurement of the Colorimetric Performance of Studio Monitors”
- VESA FPDM 2.0: “Flat Panel Display Measurements”

5 Abbreviations

- CCT **Correlated Color Temperature**
The closest matching color temperature quoted in Kelvin.
- cd/m² **Candelas per square meter**
A unit for the luminance on a screen.
- CIE **Commission Internationale d’Eclairage**
Used here to refer specifically to graphical representations of a monitor’s gamut (CIE 1931, CIE 1976).
- D65 **Designation for the white point in common video standards**
CT = 6,504 K; x = 0.313; y = 0.329.
- DCI **Digital Cinema Initiative**
A video standard for digital movie projection in commercial theaters.
- DIN **Deutsches Institut für Normung**
German Institute for standardization.
- duv Degree to which a set of color coordinates deviate from the desired color temperature T, quoted in absolute figures. Positive values indicate a deviation toward green; negative values toward magenta.
- EBU **European Broadcasting Union**

- **HDCP** **High-bandwidth Digital Content Protection**
An encryption technology for HDMI connections.
- **HDMI** **High-Definition Multimedia Interface**
- **HDTV** **High-Definition Television**
- **ITU** **International Telecommunication Union**
- **K** **Kelvin**
A unit of thermodynamic temperature, also used for color temperature.
- **Lv** **Luminance**
Quoted in cd/m^2 .
- **lx** **Lux**
A unit of luminous intensity.
- **SDTV** **Standard-Definition Television**
- **SMPTE** **Society of Motion Picture and Television Engineers**
- **T** **Color temperature**
Quoted in Kelvin.
- **u'** x color coordinate in the CIE 1976 standardized color system.
- **USB** **Universal Serial Bus**
A widespread two-way, high-speed data interface for connecting hardware to a PC.
- **v'** y color coordinate in the CIE 1976 standardized color system.
- **x** x color coordinate in the CIE 1931 standardized color system.
- **y** y color coordinate in the CIE 1931 standardized color system.
- **YCbCr** Color-encoding method in HDMI.

6 Additional Information

Our Application Notes are regularly revised and updated. Check for any changes at <http://www.rohde-schwarz.com>.

Please send any comments and suggestions about this Application Note to Broadcasting-TM-Applications@rohde-schwarz.com.

7 Ordering Information

Designation	Type	Order No.
Base unit		
Digital Video Signal Generator	R&S®DVSG	2113.0008.02
Required options		
AV Signal Generator	R&S®DVSG -K10	2113.0314.02
Recommended options		
AV Signal Generator Extension	R&S®DVSG -B10	2113.0208.02
AV Signal Player	R&S®DVSG -B30	2113.0237.02
TS Player and Recorder	R&S®DVSG -K20	2113.0320.02
Stream libraries		
HDTV sequences	R&S®DV-HDTV	2085.7650.02
H.264 stream Library	R&S®DV-H264	2085.9052.02
DVB-H stream Library	R&S®DV-DVBH	2085.8704.02
Test Card M Sequences	R&S®DV-TCM	2085.7708.02
ISDB-T stream Library	R&S®DV-ISDBT	2085.9146.02
MEDIAFLO streams	R&S®SFU-K222	2110.2968.02
ISDB-T streams	R&S®SFU-K224	2110.4777.02
CMMB streams	R&S®SFU-K225	2112.3649.02
ATSC mobile DTV streams	R&S®SFU-K226	2110.3812.02
TS creation tool		
Advanced Stream Combiner (dongle for USB interface)	R&S®DV-ASC	2085.8804.03

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