Colorimeter DSM-4
Instructions for use

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1 Symbols

The following symbols are used:

WARNING or CAUTION information to avoid personal injury or damage to the product.

ELECTRICAL SHOCK HAZARD. Indicates that an electrical shock could or might occur

Direct current.

Waste Electrical and Electronic Equipment (WEEE). This product complies with the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2012/19/EU.

2 Warnings and instructions for safety

WARNINGS:

- If the unit is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.
- The unit is intended for indoor laboratory use only, at an altitude of less than 3048 m (10,000 feet) above sea level, within a temperature range of 10˚C to 35˚C and a relative humidity range of 10% to 90% non-condensing. If the instrument is stored outside these ranges, it should be left to stand until it equilibrates to within the above limits.
- To avoid unnecessary degradation of the Colorimeter DSM-4 battery, avoid storing the device outside the -20°C to 45°C temperature range.
- Keep the calibrator out of direct sunlight. When not in use, the lid should be on to avoid degradation of the working standards by UV-radiation.
- When measuring on skin where gels, lotions or ointments have been applied, make sure that excess material does not enter the measurement head. Foreign objects that enter the measurement head can be difficult to remove and may impair the performance of the Colorimeter DSM-4.
- Avoid exposure to water. If exposed to smaller amounts such a rain, allow for the device to completely dry and consider contacting Cortex support for aid in assessing if the exposure has affected the integrity of the device.
- Do not disassemble device. There are no user accessible or serviceable parts inside the unit.
- Before using any cleaning or decontamination method except those recommended by the manufacturer, users should check with the manufacturer that the proposed method will not damage the device.
- Do not use chlorine-based disinfectants on the measurement head.

- The device shall only be charged using the charger supplied with the device (Mean Well, GEM12I05-USB, 2.4 A). Do not use the charger if it has been damaged.

3 Radio module information

The Colorimeter DSM-4 contains a Bluetooth® version 2.1 radio module.

Model: RN42

FCC ID: T9J-RN42

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Contains transmitter module IC: 6514A-RN42

This device contains license-exempt transmitter(s)/ receiver(s) that comply with Innovation, Science and Economic Development Canada's license-exempt RSS(s). Operation is subject to the following two conditions: 1. This device may not cause interference; 2. This device must accept any interference, including interference that may cause undesired operation of the device.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: 1. L'appareil ne doit pas produire de brouillage; 2. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

The compliance of the RN42 radio module is listed below:

Category	Country	Standard
Radio	USA	FCC Part 15 Subpart B: 2008 Class B
		FCC CRF Title 47 Part 15 Subpart C
	FCC ID:	T9J-RN42
	Europe	ETSI EN 301 489-1 V1.8.1
		ETSI EN 301 489-17 V2.1.1
		ETSI EN 300 328 V1.7.1
	Canada	IC RSS-210 low power comm. device
	Certification Number:	6514A-RN42
EMC	USA	FCC CFR47 Part 15 subclass B
	Europe	EN 55022 Class B radiated
		EN61000-4-2 ESD immunity
		EN61000-4-3 radiated field
		EN61000-4-6 RF immunity
		EN61000-4-8 power magnetic immunity
Bluetooth	BQB LISTED	B014867- SPP and DUN profiles
Environmental	RoHS	RoHS compliant

4 Introduction

The Colorimeter DSM-4 is a handheld instrument for measurement of color and gloss. Color measurement is based on diffuse reflectance spectroscopy in a 45°/0° configuration while specular gloss is measured in a 60° configuration.

Several skin-related parameters such as erythema index, melanin index, and ITA° score are calculated. The device has an optimized correction matrix for measurement on skin which will provide even higher color accuracy on skin tones. In summary, the instrument measures:

- Color in CIE-L*a*b*, CIE-L*C*h, and CIE-XYZ color spaces
- ITA° score
- Specular gloss (GU)
- Melanin and erythema index

The device measures perceived color and gloss simultaneously at the same location. The individual typology angle (ITA°) is determined by analysis of spectrophotometric data to classify skin phototypes objectively into 6 physiologically relevant groups: very light, light, intermediate, tan, brown, and dark. Melanin and erythema indexes are also calculated automatically. High quality working standards are provided (white, zero, and gloss) in the calibrator to ensure accurate measurements over time (see section 5.6).

The Colorimeter DSM-4 is intended to be used for performing objective color measurements on skin. The device can be used stand-alone to quickly obtain color measurements presented on the display. The device can also be used along-side the Colorimeter DSM-4 pc software providing options for performing and saving multiple measurements. Measurements taken reflect the perceived color of a single spot, the intend of the measurement should be considered when performing the measurement as measurements in only one location does not entirely represent the human body.

A Brief introduction to color theory can be found in Appendix A.

4.1 Color measurement principle

The Colorimeter DSM-4 measures color in the full visible spectrum and converts the data into objective quantifiable tristimulus values that closely matches human visual perception (CIE system). Perceived color is affected by illumination, viewing angle, and field of view. Therefore, it is important to use a measurement configuration that closely correlates with human perception. Color measurement in the Colorimeter DSM-4 is based on diffuse reflectance spectroscopy in a standardized 45°/0° configuration. As illustrated in Figure 1, the test sample is illuminated from an angle of 45° using four circularly arranged D65 light sources. The reflected diffuse light is then detected at 0° using a full visible spectrum color sensor (10° standard observer). This configuration provides a color measurement that closely resembles how color is perceived by the human eye. All specular reflections (gloss) are excluded from the color measurement. However, information about surface gloss can be provided by the integrated 60° gloss meter. Measurements are performed within the 8mm diameter opening in the front of the Colorimeter DSM-4 device. The effective measurement area has a diameter of 4.2 mm when measuring on a plane surface. Chapter 5.2 describes how to correctly perform a measurement.

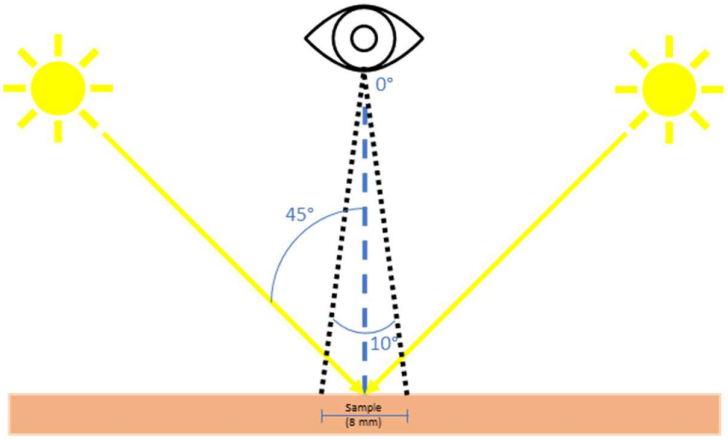


Figure 1: Principle of the 45°/0° configuration. The test sample is illuminated from an angle of 45° using four circularly arranged D65 light sources. The reflected diffuse light is then detected at 0° using a full visible spectrum color sensor (10° standard observer).

4.2 Gloss

The specular reflection (gloss) of a surface is measured in a 60° angle by projecting a light beam onto the surface and measuring the amount of reflected light at an equal but opposite angle. The light source/detector is spectrally adjusted according to the CIE photopic luminous efficiency function *V*(λ) with a D65 light source.

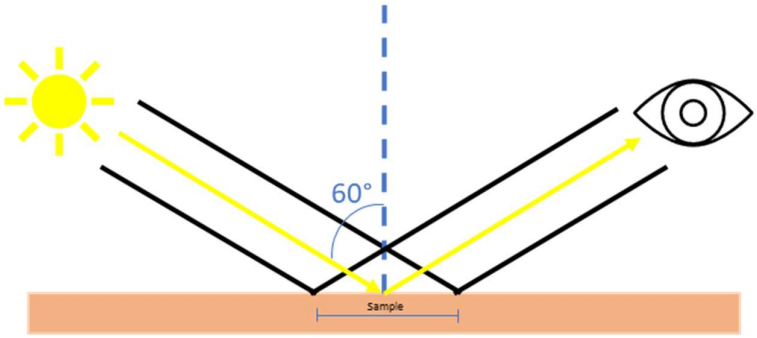


Figure 2: The specular reflection (gloss) of a surface is measured in a 60° angle by projecting a light beam onto the surface and measuring the amount of reflected light at an equal but opposite angle.

The measurement scale is Gloss Units (GU). A polished reference black glass standard with a defined refractive index is used to establish the upper point of calibration (100 GU) while the lower end is defined by no specular reflection. Working standards are provided for gloss calibration ("zero" and "gloss").

4.3 Melanin index (MI)

The melanin index (M) is an objective measure of skin pigmentation. The calculation is based on the diffuse reflectance in the red spectrum centered at 680 nm where melanin is the predominant absorbing chromophore and the interference from hemoglobin is minimal. It is calculated as follows:

$$M = 100 \times log_{10}\left(\frac{1}{R_r}\right)$$

Where M is the melanin index and R_r is the reflectance at 680 nm. The melanin index is calculated in the same way as in all previous generations of the DSM product and is hence included for backwards compatibility. The ITA° score also correlates with the constitutive skin pigmentation and is the recommended alternative to the melanin index.

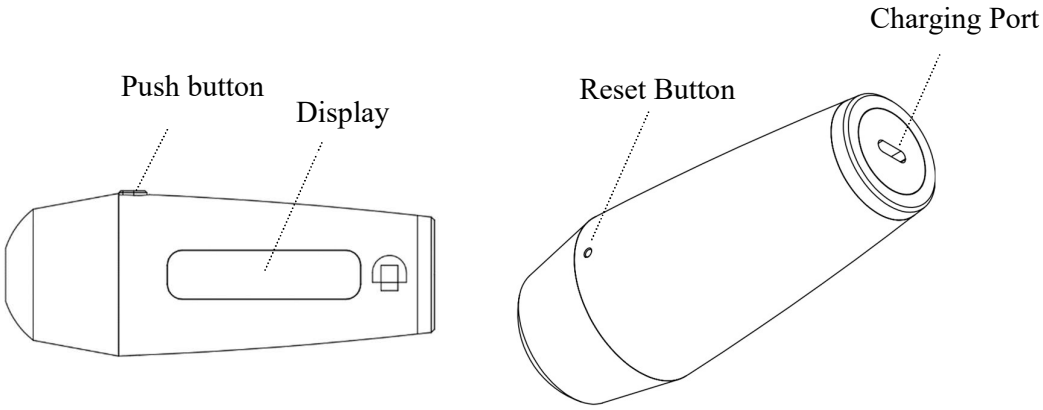
4.4 Erythema index (E)

Erythema can be expressed as an index of hemoglobin relative to melanin.

$$E = 100 \times log_{10}\left(\frac{R_r}{R_g}\right)$$

Where R_r is the reflectance of red light (centered at 680 nm) and R_g is the reflectance of green light (centered at 555 nm). Typical full width half maximum is 52 for red and 39 nm for green. The erythema index is affected by the amount of melanin, and it can therefore be difficult to compare values from measurements on differently pigmented skin. In the CIE-L*a*b* color space, the a* value correlates with erythema and can be used as an alternative to the erythema index. The a* is, however, also affected by the amount of pigmentation.

5 Colorimeter DSM-4 device



5.1 Operation of the push-button

The device has a push button that can be used to power on the device, start a measurement, or start a calibration routine. The button operates as follows:

- If the device is powered off, releasing the button after pressing it down will power on the device.
- When the device is powered on, releasing the button after pressing it down will start a measurement if held down for less than 3 second.
- When the device is powered on, a calibration routine is started by holding the button down for 3 seconds without releasing it.
- While in calibration mode, the device will exit calibration mode if the button is held down for 3 seconds without releasing it.

The device will automatically power off when not used for 60 seconds (default). The time for automatic power-off can be changed in the Colorimeter DSM-4 software.

Input from the push button is ignored during a measurement. An acoustic signal from a buzzer will indicate when the measurement has been completed.

5.2 How to perform a measurement

The measurement head is placed gently on the skin without applying force. If pressure is applied to the skin, the skin color may change because blood is forced away from the capillaries in the area. Depending on the amount of pigment, this may cause the skin to appear pale when compared to the surrounding skin (blanching). Measurements are optimally performed on as plane a surface as possible to avoid any external light from entering the measurement area. Because skin is translucent, measuring in direct sunlight may affect the measurement because light is passed through the skin.

When measuring gloss, it is also important to reduce the amount of force applied to the skin as any skin forced into the head of the probe head will result in non-optimal measuring conditions. Keeping the probe head away from the skin will also result in non-optimal readouts as outside sources of light can interfere with the measurement. The probe shall be held steady and perpendicular to the surface without applying pressure to the skin.

5.3 Color-correction matrix

A Color correction matrix is used on the DSM-4 probe to ensure the most accurate readout based on what range of colors the DSM-4 probe is being used on.

Two different Color correction matrices are available on the Colorimeter DSM-4. Section 6.3.5.1.3 covers how to change the current optimization matrix using the Colorimeter DSM-4 software.

5.3.1 Full Color

The full Color matrix is optimized for the entire color spectrum, attempting to provide the best possible readout no matter what color the measured area has.

5.3.2 Skin optimized

The Skin optimized correction matrix is optimized for skin colors only, resulting in more accurate results when measuring on human skin tones (class I to VI). The average color difference when measuring on skin is generally lower when measuring using this matrix. The average color difference when measuring on non-conventional skin colors (e.g. blue or green), will be higher. Therefore, this matrix should not be used when measuring on anything other than skin.

5.4 Battery and charging

The instrument is powered by an integrated and rechargeable battery that can be re-charged using the included USB-C cable and charger (Mean Well, GEM12I05-USB, 5Vdc at 2.4 A). An indicator on the display indicates battery level as a percentage of full charge. It is not possible to make measurements during charging.

5.5 Measurement mode and time

The Colorimeter DSM-4 has several measurement mode options. Depending on which option is chosen, each measurements may take a different amount of time to complete. Measuring only Color or Gloss will result in a faster measurement. Selecting any option enabling both gloss and color measurement will result in a longer amount of time for each total measurement to complete (from release of push button to buzzer feedback). It is therefore advised that if either color or gloss is not used, it should be disabled in the Colorimeter DSM-4 settings to increase the speed of future measurements.

Measurement modes and how to change them are described in section 6.3.5.1.2. The factory default is that color + gloss is enabled.

Mode	Measurement time
Color	< 1 s
Gloss	< 1 s
Color + gloss	< 2 s

5.6 Calibration

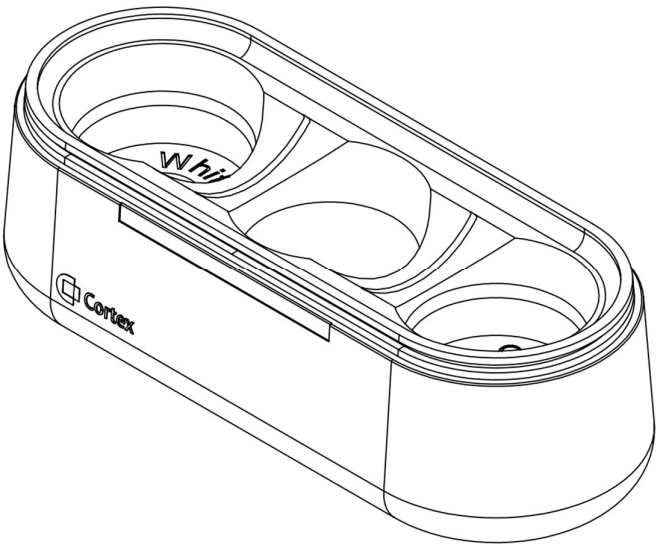
A calibration is performed using the supplied *calibrator that contains working standards for w*hite, zero, and gloss.

It is not necessary to re-calibrate each time the unit is turned on. However, it is recommended to re-calibrate on a regular basis - e.g. daily or after 100 measurements.

Different parts of the calibrator are used based on what measurement mode is currently set for the Colorimeter DSM-4. During a Calibration the DSM-4 probe display will indicate which calibrator slot should be used (if using the Colorimeter DSM-4 software, information will also be displayed on the pc). A beep will be used to indicate if a measurement on a given slot is accepted or rejected. Rejection of calibration can happen either due to dirty working standard or a bad measurement. If a measurement on the calibrator is rejected, the colorimeter DSM-4 probe will display a rejection message and not proceed with the calibration until a proper measurement has been performed.

After each measurement has been accepted, a final press of the push button is required to exit calibration mode.

The Colorimeter DSM-4 can be placed in the calibrator for storage. Keeping the Colorimeter DSM-4 in the calibrator prevents dust from entering the measurement head. Keeping the lid closed will protect the working standards from dust and scratches and prevent that environmental light affects the working standards.



6 Colorimeter DSM-4 Software

This section will cover the Colorimeter DSM-4 Software providing extended features for the Colorimeter DSM-4 device. The Software will provide a user interface for interacting with the Cortex Colorimeter DSM-4. The user interface provides functionality for displaying and saving multiple readouts sent from the Colorimeter as well as several configuration options such as measurement types and screen orientation of the Colorimeter. Additional data is displayed on the user interface including color representation in different color spaces and graphical representations of the color spectrum and ITA scores.

6.1 Requirements

Colorimeter DSM-4 Software version 3.1.0.X is only available for Windows operating systems and will require at least Windows 10 or later.

Connecting to a Colorimeter DSM-4 device requires Bluetooth capabilities on the Windows pc in use.

All PCs running Windows 10 or later with minimum an i3-processor should have no issue running the Colorimeter DSM-4 software. However, the quantity of measurements stored in the software will impact the required amount of RAM. This should not be an issue unless storing 1000+ measurements.

For optimal use, a screen resolution of minimum 1366x768 is required. Unconventional aspect ratios or resolutions may present the user interface poorly.

6.2 Getting Started

Go to https://cortex.dk/downloads and download the newest version of the Colorimeter DSM-4 Software package. The package should include a .msix file for installation of the software on a windows pc.

6.2.1 Installation

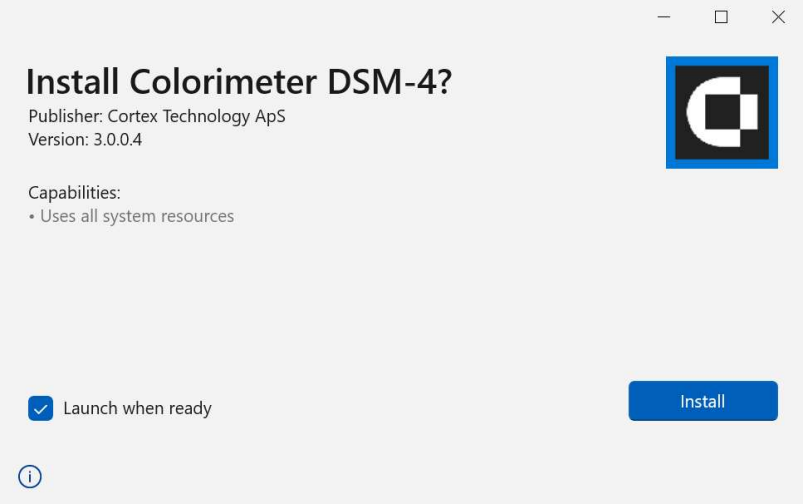


Figure 3 Installation Pop-up for Colorimeter DSM-4 Software

When running the .msix file a popup should appear similar to the one displayed in Figure 3. Note that version number will be different based on the newest version of software released.

Press install and wait for the process to finish.

After installation the program can be found on the system by searching for the software under the name Colorimeter DSM-4. A Desktop shortcut will also be generated for the application, show in **Fejl! Henvisningskilde ikke fundet.**.

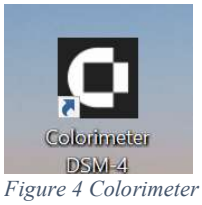


Figure 4 Colorimeter DSM-4 shortcut

If installation fails due to missing “WindowsAppRuntime”, an .exe file can be found on the provided usb called “WindowsAppRuntimeInstall.exe” which will install missing packages.

6.2.2 Pairing a device

For the software to identify Colorimeter probes, an initial pairing will have to take place. This is a required process for every first-time use of the software and will not be required again unless a new probe is used or if the probe has been removed from the Windows Bluetooth device overview. There are two options for pairing a Colorimeter DSM-4 probes.

6.2.2.1 Option 1: Paring using Windows Bluetooth settings

Open Windows settings and enter Bluetooth and other devices menu click on “Add Bluetooth or other devices”.

Make sure the Colorimeter DSM-4 Software is not currently running while pairing, if the device is paired this way, while the software is running the software will need to be restarted to recognize the pairing.

Identify Colorimeter probe in list of Bluetooth devices as shown in Figure 5, Colorimeter name is listed on the probe itself and will either start with “Colori” or “DSM”.

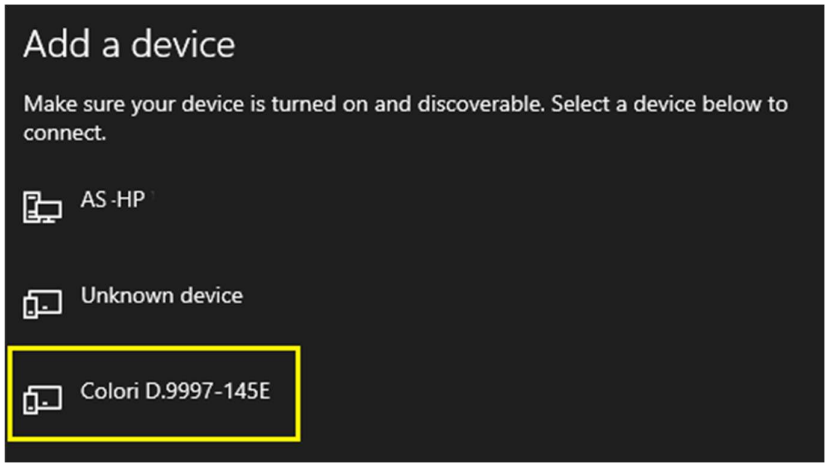


Figure 5 Example of Add device menu, Probe name highlighted in yellow

Select Device and press Connect as shown in Figure 6.

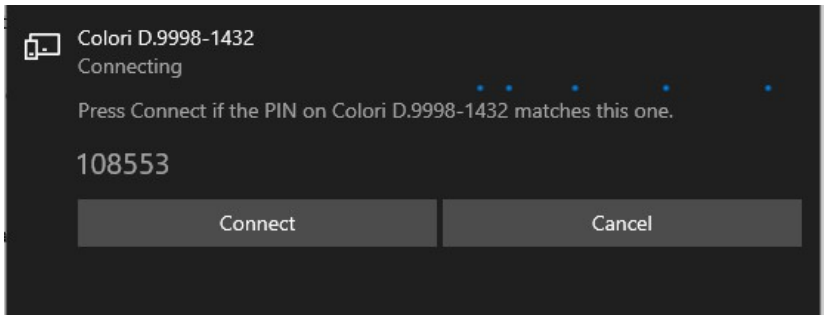


Figure 6 Connection information, PIN is irrelevant and can be ignored in this instance

6.2.2.2 Option 2: Pairing using the Colorimeter DSM-4 Application

Upon launching the Colorimeter DSM-4 software application, if no Bluetooth device is available for connection users will be met with the pop-up message shown in Figure 7.

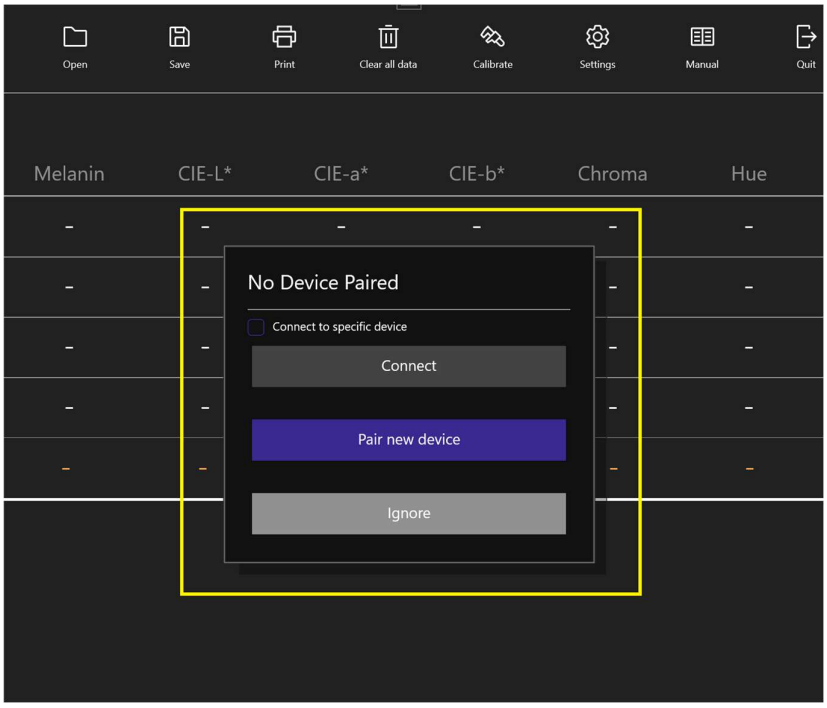


Figure 7 Connection Pop-up

Note: A Colorimeter probe will have to be on during the search for devices as well as the pairing process, Default probes will turn off after 60 seconds of no interaction. Pressing the button on the side of the probe with intervals less than 60 seconds can help reduce any risk of the device turning off while pairing.

If no Colorimeter probes have been previously paired the “Connect” button will be greyed out. Pressing the “Pair new device” button will open up the Bluetooth pairing menu as shown in Figure 8.

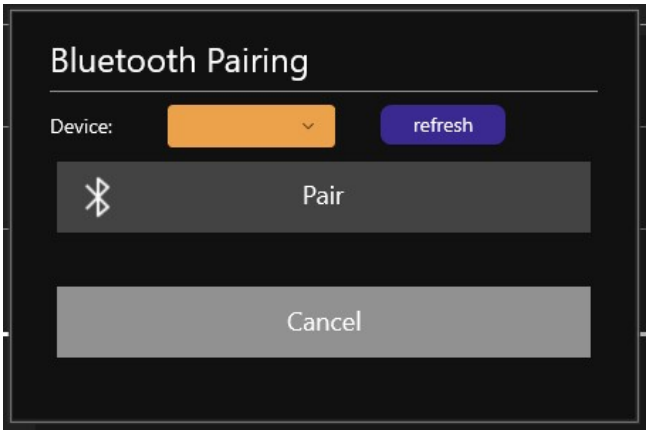


Figure 8 Bluetooth Pairing Menu

If a Colorimeter probe is on previous step, it should be available in the device list shown in Figure 8. If Probe name is not present, Pressing the “Refresh” button, will start a new scan for the device.

When a Colorimeter probe has been identified the “Pair” button will become available as shown in Figure 9. Pressing the “Pair” button will start the Pairing process. When Pairing has completed the menu will be closed and the software will attempt to connect to the newly paired device. If pairing fails a message will be displayed beside the refresh button. If pairing succeeds, but the connection attempt fails, users will be met with the Pop-up message shown in Figure 7.

Figure 9 Device identified in list with pair button enabled

6.2.3 Connecting to a Device

After pairing has completed through either process described in 6.2.2 a connection to the Colorimeter probe can now be established.

6.2.3.1 Connecting to a specific device

If a Colorimeter is to be connected for the first time or several Colorimeters are paired requiring specification of which colorimeter to connect to. An option is available on the connection Pop-up shown in Figure 7 and Figure 10 to specify which paired Colorimeter to connect to.

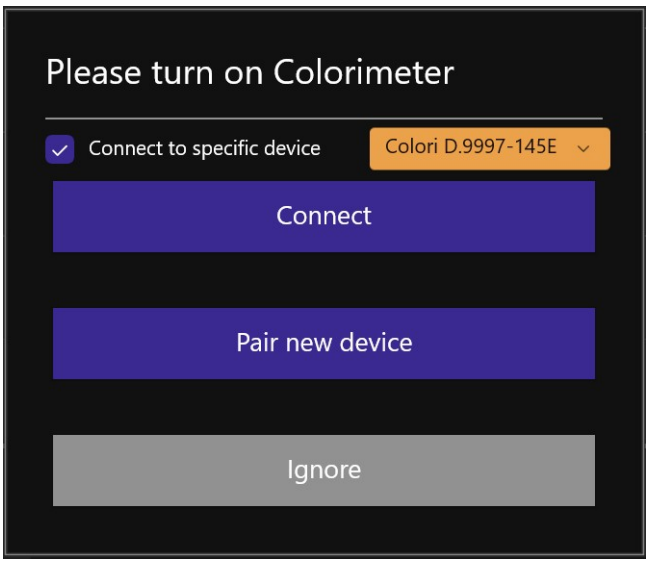


Figure 10 Connection Pop-up with available device

Note: A Colorimeter probe will have to be on during the connection process, Default probes will turn off after 60 seconds of no interaction.

Pressing the “Connect” Button will attempt to establish a connection to the paired Colorimeter probe selected in the device list shown in Figure 10.

If the Connection attempt succeeds the Connection status listed in the lower left corner will update to connected and the software will be properly connected to the Colorimeter probe.

6.2.3.2 Connecting to last used device

If a connection has previously been established to a Colorimeter probe, the Colorimeter DSM-4 software will automatically attempt to connect to the last connected probe during startup (this requires the Probe to be turned on, while the software starts up).

If the initial connection attempt fails, the connection Pop-up will appear. If the “Connect to specific device” checkbox is left unchecked, pressing the “Connect” button will attempt to connect to the last device used.

6.2.3.3 Using Colorimeter DSM-4 software without connecting to a device

If users want to make use of the software without connecting to a Colorimeter probe, pressing the “Ignore” button on the Pop-up shown in Figure 7 and Figure 10, will close the Pop-Up and allow for use of the software with no device connected. If a connection is needed pressing the “connect” button in the lower right corner of the software user interface will attempt to connect to the last available device, and reenable the Connection Pop-up.

6.3 User interface

This section will give a brief description of available features in the Colorimeter DSM-4 software.

6.3.1 General

In Figure 11 the main User-Interface has been divided into three areas for the purpose of this guide. Areas 1, and 2, annotated with orange numbers are general menus available at all times when using the Colorimeter DSM-4 software.

The areas will henceforth be referenced as:

- Area 1 is the “top menu” covered in paragraph 6.3.2.
- Area 2 is the “bottom menu” covered in paragraph 6.3.3.
- Area 3 is the “Data View” covered in paragraph 6.3.4.
- The Settings menu (not displayed in Figure 11) is covered in paragraph 0.
- Documents generated from the software is covered in paragraph 6.3.6.

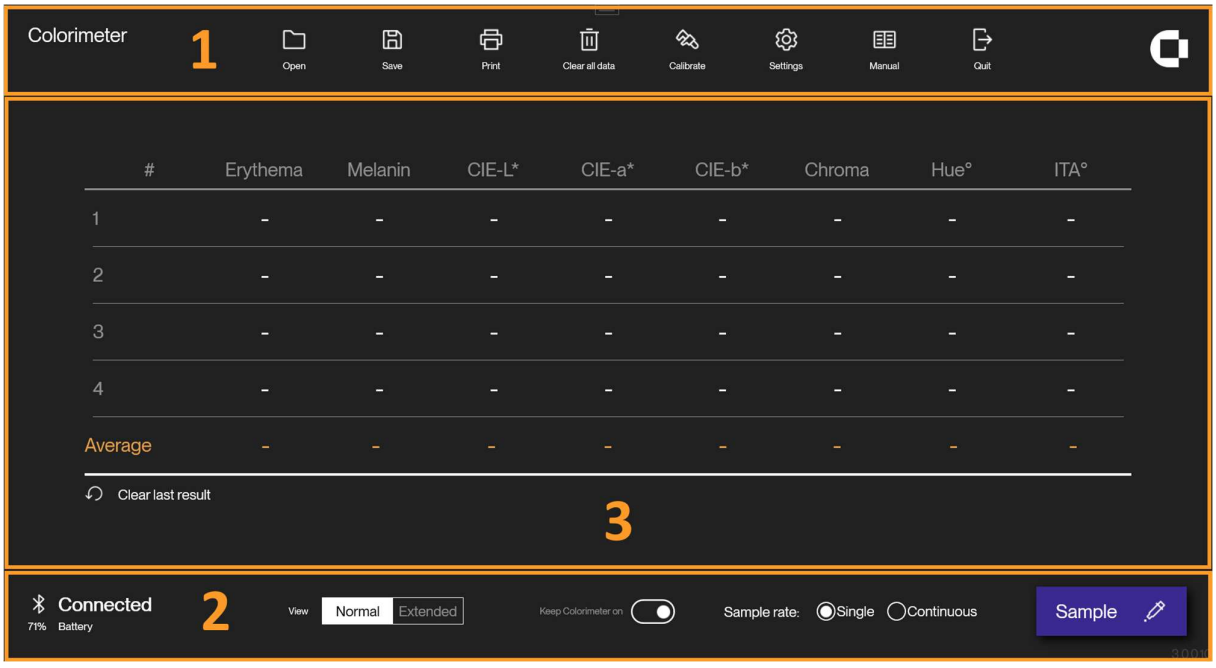


Figure 11 Main User-interface separated into 3 parts in orange

6.3.2 Top Menu

The top menu consists of buttons for general interaction with the software and Colorimeter probes.

6.3.2.1 Open

The Open button allows for importing any previously saved datafiles created using the Colorimeter DSM-4 software or its predecessor DSM-III (see Section 6.4 for further detail). Only files with the .cmf file extension generated by Cortex software can be opened this way.

Any data already open will be lost if not saved before importing new data. A warning will be shown if data will be deleted.

.cmf files will be opened in the currently active data view. Users will be warned if a file containing more than 4 measurements are attempted opened in Normal view.

6.3.2.2 Save

The Save button allows for saving of data collected with the Colorimeter DSM-4 software. Data is saved as a .cmf (Cortex Measurement File) containing all information presented in the user interface along with any metadata required to reopen the file later.

.cmf files can be opened in any text editor and is compatible with excel or similar solutions.

> Manipulation of Data in .cmf files can result in the files becoming unreadable by the Colorimeter DSM-4 software. Therefore, users are encouraged to create copies of saved files if any manipulation of data is needed.

6.3.2.3 Print

The Print button allows for printing of collected data. Pressing the print button will open a pop-up with options for printing. Printing options will be displayed based on currently installed printers on the system including options for printing directly to pdf. A maximum of 75 measurements can be printed this way at a time. A pop-up will warn the user if the number is exceeded. There is no max for how many measurements can be saved to a .cmf file. Examples of generated files can be found in Section 6.3.6.

6.3.2.4 Clear Data

The “Clear all data” button will remove all collected data from both views.

6.3.2.5 Calibrate

The Calibrate button will initiate calibration of the Colorimeter DSM-4 probe. Instructions will be presented, both on the screen of the Colorimeter probe as well as within the software itself. An example of the calibration process can be seen in Figure 12. At any point calibration can be canceled by pressing the Cancel button shown in Figure 12. Pressing cancel will discard any steps preformed during current calibration and revert Colorimeter probe to use calibration values from latest completed calibration. If a Calibration of the Colorimeter probe is due, the user will be informed and the Calibrate icon will change to orange until a calibration has been performed.

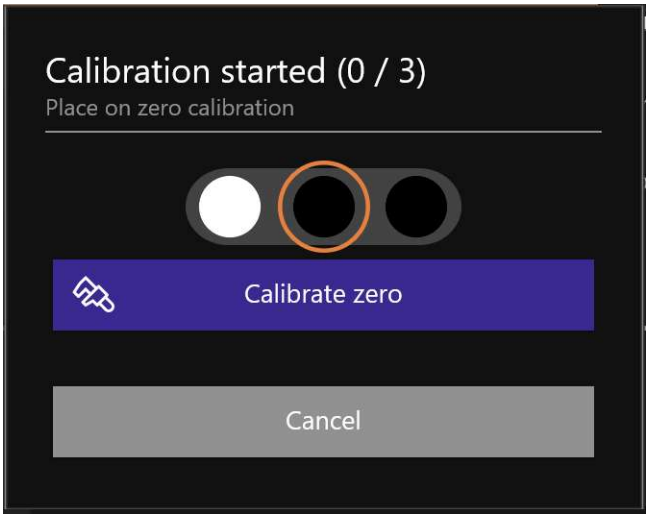


Figure 12 Example of calibration step

6.3.2.6 Settings

The Settings button will open the settings menu on the right side of the user-interface. A full description of the Settings menu can be found in 0.

6.3.2.7 Manual

The Manual button will open this document. This functionality requires a method for displaying pdfs installed on the pc (commonly distributed with Windows itself)

6.3.2.8 Quit

Pressing the Quit button will close the Colorimeter DSM-4 Software.

6.3.3 Bottom Menu

This section will cover the Bottom Menu layout. Items have been numbered in Figure 13.

Figure 13 Bottom Menu numbered for reference

6.3.3.1 Connection status

1: The current connection status to a Colorimeter probe will be displayed here

6.3.3.2 Change view

2: The view type of the “Data View” can be changed here. The current view will be highlighted with a white background. A description of each view can be found in section 6.3.4.

6.3.3.3 Toggle always on

3: While Colorimeter DSM-4 software is running it will by default attempt to keep the Colorimeter probe on, even if it is not in use. This feature can be toggle off allowing the probe to turn off if not in use. The timer for automatic shut-down of the probe can be set in the settings menu described in Section 6.3.5.

6.3.3.4 Change sample rate

4: Default settings require individual measurement to be triggered by either pressing the sample button described in section 6.3.3.5 or by physically pressing the button on the side of the Colorimeter dsm-4 probe. If several measurements need to be made repeatably, sample rate can be set to continuous. Besides the “sample rate” selection is a text box allowing for entry of any number of measurements to be taken during continuous sampling. If the field is left blank, continuous sampling will continue with no maximum count. If a number is entered into the text field (default text is “Max”) continuous sampling will continue until the listed number of measurements have been made. During continuous sampling a new measurement will be taken roughly every 2 seconds. Continuous sampling can be stopped by either pressing the stop button (Figure 13, number 5 changes to “stop” during sampling), or by pressing the button on the side of the Colorimeter device.

6.3.3.5 Sample/connection button

5: The sample button shown in Figure 13 will initiate a measurement if pressed while connected to a Colorimeter probe. If the Ignore button displayed in Figure 7 is pressed, no connection will be made and the Sample button will instead change name and function to attempt a connection if needed. Functionality of the button will revert if a connection is established. While in continuous measurement mode, the sample button will change to instead display “Start” to indicate a sequence of measurements will be started. This button can also be triggered by pressing the keys Alt + M.

6.3.3.6 Software version label

6: The version displayed in the lower left corner of the user-interface is the current software version of the Colorimeter DSM-4 software. On smaller screens the software version may not be visible in the main screen. Software version is also listed in the settings version. If any issues arise with the Colorimeter DSM-4 software, please note the current version listed when contacting Cortex service.

6.3.3.7 Battery Level

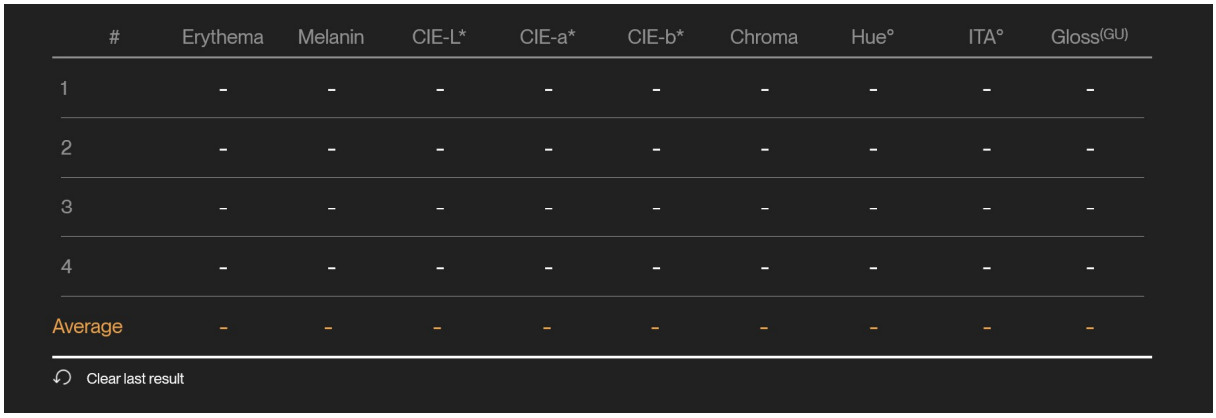
7: While a device is connected, the battery level of the device will be displayed in the lower left corner.

6.3.4 Data View

This section will cover the two types of views for presenting data in the user-interface. Views can be toggled as described in 6.3.3.2. Several data points are presented in the data view independent of what view is enabled.

6.3.4.1 Normal View

Normal view allows for a maximum of 4 measurements to be presented at a time. An average of every measurement currently listed is available as well. Figure 14 shows the normal view without any data, Figure 15 is the same view after 4 measurements have been made. Figure 16 shows the same view change to only display gloss values. The view can also be configured to show everything, but gloss values. These settings will be described in section 6.3.5. Normal view includes the option to clear last result as displayed in Figure 14, Figure 15 and Figure 16 lower left. Pressing this button will delete the last measurement made. If 4 measurements are present in the window, no further measurements will be logged until space has been made by either clicking the clear last result button or clearing all data as described in section 6.3.2.4.



#	Erythema	Melanin	CIE-L*	CIE-a*	CIE-b*	Chroma	Hue°	ITA°	Gloss(GU)
1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
Average	-	-	-	-	-	-	-	-	-

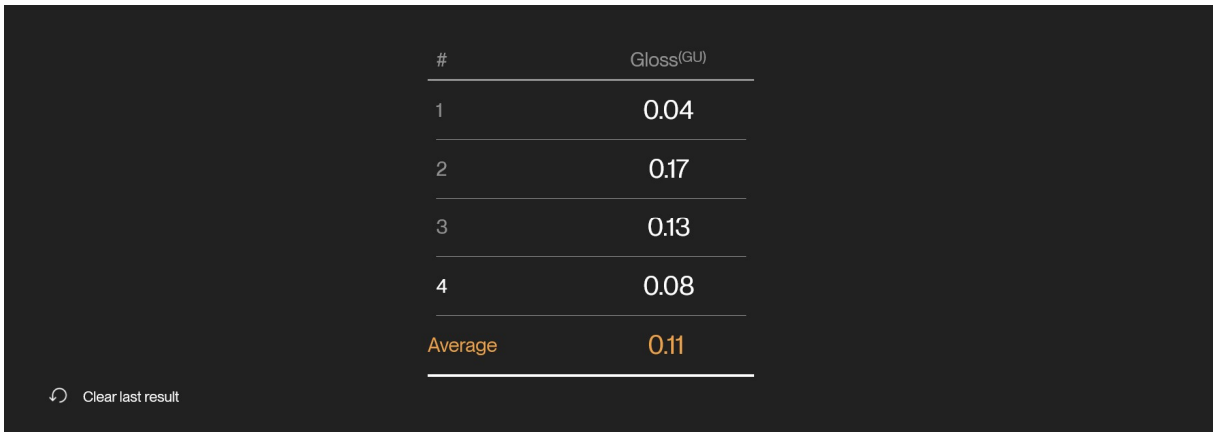
Clear last result

Figure 14 Normal view without any data

#	Erythema	Melanin	CIE-L*	CIE-a*	CIE-b*	Chroma	Hue°	ITA°	Gloss(GU)
1	19.84	33.68	59.86	7.28	15.03	16.70	64.15	33.28 III	0.04
2	17.51	33.96	60.66	6.12	13.90	15.18	66.25	37.50 III	0.17
3	23.77	34.58	57.49	9.19	14.11	16.84	56.92	27.99 IV	0.13
4	24.00	34.35	57.57	9.35	14.24	17.04	56.71	28.01 III	0.08
Average	21.28	34.14	58.90	7.99	14.32	16.44	61.01	31.69 III	0.11

Clear last result

Figure 15 Normal view with data



#	Gloss(GU)
1	0.04
2	0.17
3	0.13
4	0.08
Average	0.11

Clear last result

Figure 16 Normal View changed to only display Gloss values

6.3.4.1.1 Data

Data presented in the normal view consist of the following:

- Erythema
- Melanin
- CIE-L*
- CIE-b*
- CIE-a*
- Chroma
- Hue angle
- ITA-score
    - Besides ITA value, ITA classification is also listed in Roman Numerals (e.g 35.23III indicating the ITA-score of 35.23 equals an ITA classification of “Intermediate” (III))
- Gloss
    - *Listed in Gloss Units’*

6.3.4.2 Extended View

This section will cover the Extended view of the Colorimeter DSM-4 software user-interface. The sections will be covered as follows:

- 1: single measurement info panel
- 2: data presentation panel
- 3: Measurement list

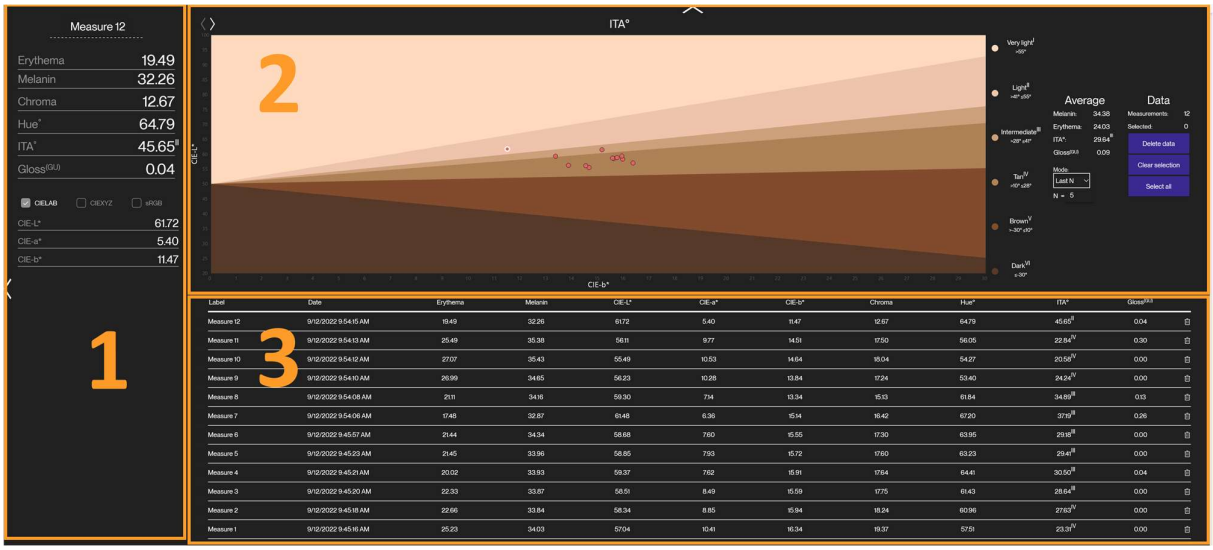


Figure 17 Extended View split into 3 sections for reference

6.3.4.2.1 Single Measurement Info panel

The single measurement info panel covers info regarding a selected measurement as shown in 6.3.4.2.3. When a measurement is made it will automatically appear in the info panel until a new measurement is selected from the measurement list.

The name of the measurement can be edited and will be reflected in the measurement list.

The following data will always be presented in the info panel:

- Erythema
- Melanin
- Chroma
- Hue
- ITA-score along with ITA-classification (e.g 26.55^{IV} indicating the ITA-score of 26.55 equals an ITA classification of “Tan” (IV))

Gloss will be presented if gloss measurements are enabled.

The following data can be toggled on/off:

- CIELAB values
- CIEXYZ values
- sRGB values

Figure 18 Single measurement info panel

Toggling this data off can help make room on smaller screens. If the screen is too small to display all toggled data, the panel will become scrollable by mouse wheel.

If the single measurement panel is not needed, it can be minimized by pressing the arrow on the left side of the panel.

6.3.4.2.2 Data presentation panel

This section will cover the data presentation panel at the top of the Extended view. As several functionalities are present, Figure 19 shows the panel split into 3 sections that will cover the following:

- (1) Graphs covered in section **Fejl! Henvisningskilde ikke fundet.**
- (2) Average Calculator covered in section 0
- (3) Measurement List functions covered in section 0

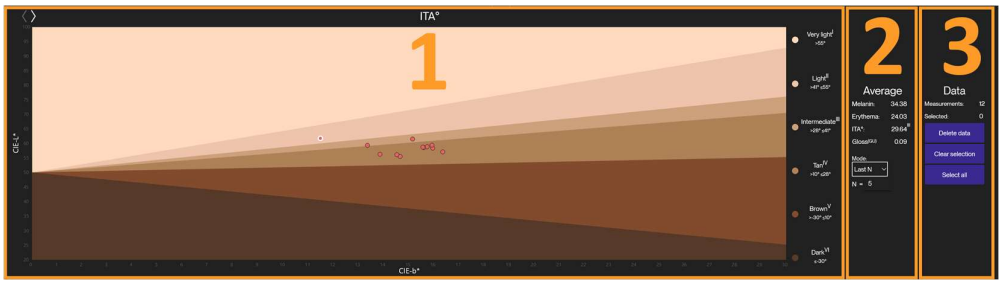


Figure 19 Data presentation panel numbered for reference

a. Graphs

Two graphs are available for displaying measurement data, ITA and color spectrum data. The graphs can be toggled by using the two arrows at the top left shown in Figure 20.

ITA Graph

This is the default graph shown in the Colorimeter DSM-4 Software. All Measurements in the measurement

list will be displayed in the graph if the measurement is within the margin for skin ITA. Any new measurement will be displayed as red circles as shown in Figure 20.

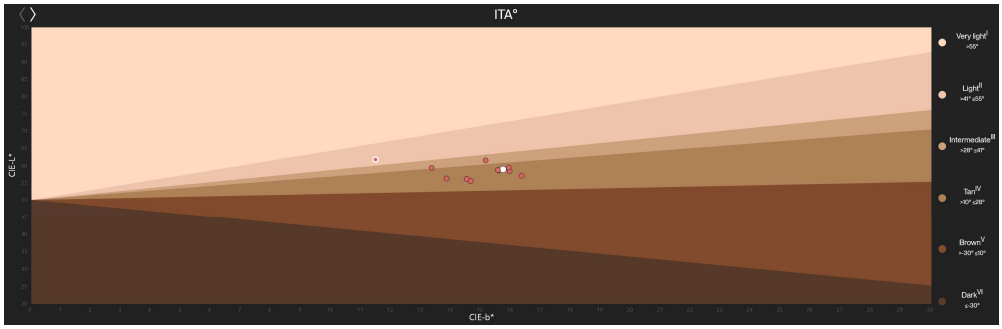


Figure 20 ITA Graph

The Latest measurement performed will be highlighted by a white ring. As shown in Figure 21. Any measurements selected in the measurement list will be highlighted with a white circle instead as shown in Figure 21. Hovering over a measurement in the ITA graph will also display the measurement name, also shown in Figure 21.

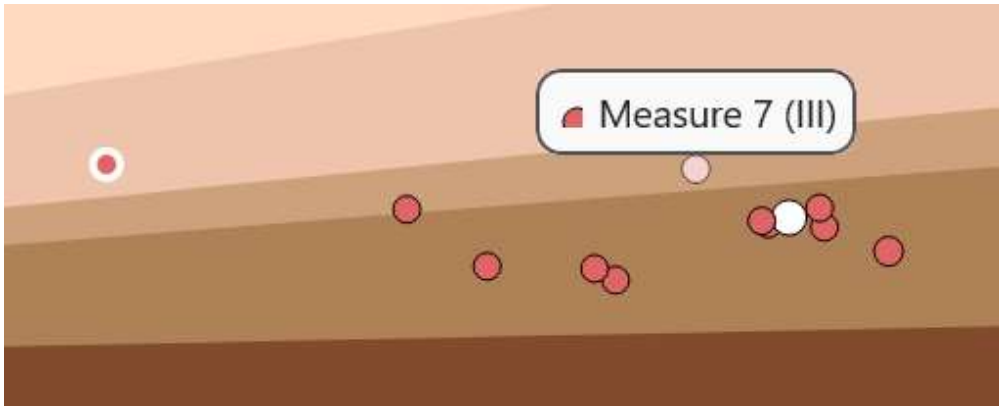


Figure 21 Highlighted measurements and label

Spectrum Graph

The color spectrum graph will display a graph for the last selected measurement displaying the color spectrum, based on raw measurement data as seen in Figure 22.

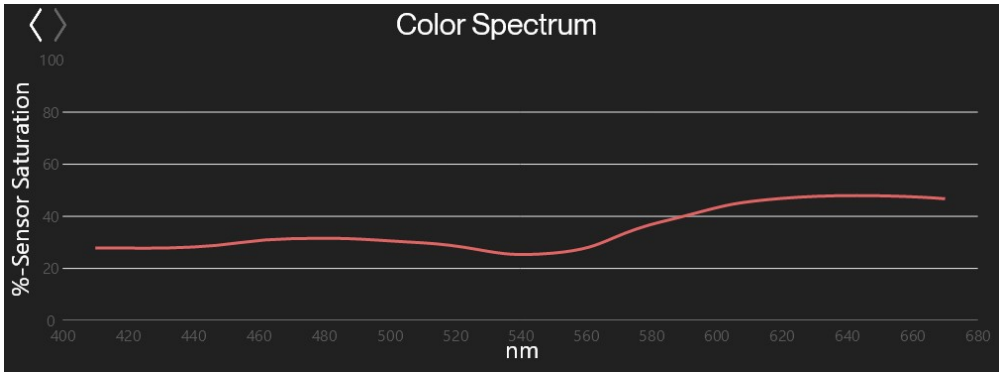


Figure 22 Color spectrum Graph

b. Average Calculator

The average calculator panel allows for different averages to be calculated based on what is selected by the user. The default state of the panel is “None” meaning that no average is calculated. Setting the mode to “Last N” will allow the user to input an N-Value (default value of 5) which will then be used to calculate a running average based on the last N measurement taken.

Setting the average type to be either “All” or “Selected” will calculate a running average of either all measurements or measurement selected respectively. The panel will then display average melanin, erythema, ITA and Gloss for all and selected measurements respectively.

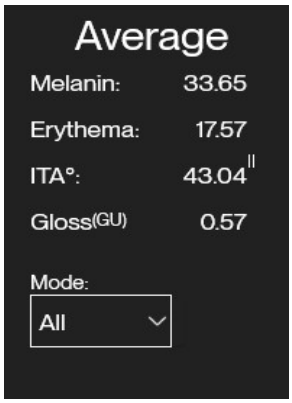


Figure 23 Average calculation panel

c. Measurement list functions

The measurement list function panel includes information regarding the total number of measurements as well as the total number of selected measurements in the measurements list.

By default, all new measurements will be named “Measure X” where X represents the total number of measurements with that naming scheme. However, this can be changed by overwriting the “Measure” listed in the measurement list functions with a new naming scheme. Numbering will reset from 1 when using a new naming scheme but will continue from the highest number if naming scheme matches any measurements in the current list.

Functions in this panel include selecting every measurement in the measurement list, clearing current selection, and deleting measurements.

Pressing the “Delete data” button will prompt the user to select what measurements to delete (everything, only selected measurements, or everything but selected measurements).

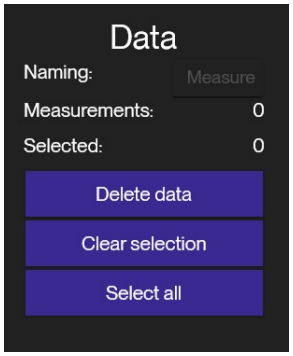


Figure 24 Measurement List functions

6.3.4.2.3 Measurement list

The measurement list panel offers a quick overview of every measurement performed as shown in Figure 25. Much like the information in the single measurement data panel described in 6.3.4.2.1. this view can be changed from settings to only display data currently being measured by a probe. This setting is described in section 6.3.5. Besides measurement data, the date and time of the measurement is also available in this list. On the right side of the list, individual measurements can be removed by pressing the trash can icon.

Label	Date	Erythema	Melanin	CIE-L*	CIE-a*	CIE-b*	Chroma	Hue°	ITA°	Gloss(GU)	
Measure 13	8/31/2022 3:38:12 PM	22.98	31.83	59.72	10.06	9.33	13.72	42.84	46.18II	1.51	
Measure 12	8/31/2022 3:38:10 PM	25.69	33.03	58.60	9.21	6.75	11.42	36.24	51.89II	0.42	
Measure 11	8/31/2022 3:38:08 PM	23.53	33.43	58.85	9.69	8.47	12.87	41.16	46.28II	1.17	
Measure 10	8/31/2022 3:38:06 PM	25.51	34.11	57.21	10.77	9.82	14.57	42.36	36.33III	2.27	
Measure 9	8/31/2022 3:38:00 PM	14.31	36.67	60.59	4.78	12.74	13.61	69.43	39.75III	0.33	
Measure 8	8/31/2022 3:37:53 PM	16.08	36.94	59.79	5.62	12.61	13.81	65.98	37.83III	0.00	
Measure 7	8/31/2022	13.07	32.99	63.47	4.36	13.70	14.38	72.35	44.52II	0.33	

Figure 25 Measurement list

Selected items in the list will be highlighted and a checkmark will appear in the left side of the list for each selected measurement as seen in Figure 26.

	Label	Date	Erythema	Melanin	CIE-L*	CIE-a*	CIE-b*	Chroma	Hue°	ITA°	Gloss(GU)	
	Measure 13	8/31/2022 3:38:12 PM	22.98	31.83	59.72	10.06	9.33	13.72	42.84	46.18 II	1.51	
✓	Measure 12	8/31/2022 3:38:10 PM	25.69	33.03	58.60	9.21	6.75	11.42	36.24	51.89 II	0.42	
✓	Measure 11	8/31/2022 3:38:08 PM	23.53	33.43	58.85	9.69	8.47	12.87	41.16	46.28 II	1.17	
	Measure 10	8/31/2022 3:38:06 PM	25.51	34.11	57.21	10.77	9.82	14.57	42.36	36.33 III	2.27	
	Measure 9	8/31/2022 3:38:00 PM	14.31	36.67	60.59	4.78	12.74	13.61	69.43	39.75 III	0.33	
✓	Measure 8	8/31/2022 3:37:53 PM	16.08	36.94	59.79	5.62	12.61	13.81	65.98	37.83 III	0.00	
	Measure 7	8/31/2022	13.07	32.99	63.47	4.36	13.70	14.38	72.35	44.52 II	0.33	

Figure 26 Measurement list with selected measurements.

6.3.5 Settings Menu

The settings menu can be opened by pressing the settings button described in 6.3.2.6. Note that if no Colorimeter DSM-4 probe is connected, certain features are not shown in the settings menu. The settings menu shown in Figure 27 can be closed by either pressing the “x” in the top right corner of the menu or by pressing the settings button that initially opened the menu.

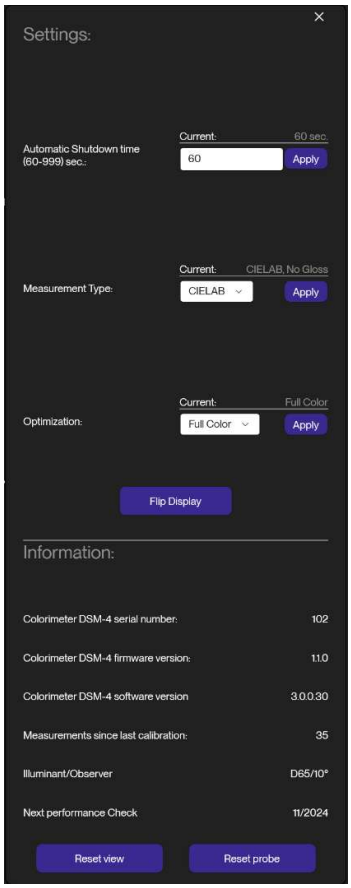


Figure 27 Settings menu

6.3.5.1 Settings

The following settings can be changed in the settings menu:

6.3.5.1.1 Shutdown time:

This is the amount of time a probe is allowed in the on state if it is not interacted with. Default value is 60 seconds. This can be increased up to 999 seconds. Pressing the apply button besides the text field will set the shutdown time to be the current value of the text field.

6.3.5.1.2 Measurement type:

This is the measurement type used on the connected Colorimeter Probe. Values displayed on the Colorimeter probe and software user interface will change based on what is chosen.

The following measurement types are available on Colorimeter DSM-4 probes:

CIELAB:

This will show CIELAB values along with Erythema, Melanin, ITA and Gloss values from measurements.

CIELAB, No Gloss

This type will display the same as “CIELAB” without the Gloss values, This will also decrease the time each measurement takes as the gloss measurement will not be performed.

Gloss

Only Gloss value will be measured and displayed.

CIELCh

Same as “All” but instead of CIELAB values, Chroma, Hue and CIE-L* will be shown on the probe display.

CIELCh, no gloss

Same as LCH without Gloss value.

Note that all measurement settings will effect what is shown on the probe display and user-interface

differently as both CIELAB and LCH values are displayed in the user-interface when available.

If measuring color or gloss only, the column(s) in the displayed list related to the excluded parameter is automatically removed.

This setting can still be changed with no probe connected, which will change what values are displayed. Connecting a probe will reset the display setting to the current measurement setting of the probe.

6.3.5.1.3 Optimization

This option allows the user to change the optimization of the Colorimeter Probe between “Full color” covering all visible colors to “skin optimized” which is more focused on only skin types, sometimes resulting in more precise skin measurements.

6.3.5.1.4 Flip display

For left-handed use, the display on the Colorimeter probe can be flipped by pressing the “flip display” button.

6.3.5.1.5 Reset interface settings

Pressing this button will reset any changes made to the user-interface layout.

6.3.5.1.6 Reset probe settings

Pressing this button will reset settings for connected Colorimeter DSM-4 probe.

6.3.5.2 Information

The following information is presented within the settings menu. Note that when contacting Cortex in any service case regarding the Colorimeter DSM-4 probe or software it can be useful to either include the information listed in the settings menu or provide a screenshot of the entire settings menu.

- Serial number:
  - Serial number of the Colorimeter probe, this will also be present on the probe itself.
- Firmware version
  - Version of firmware currently installed on the Colorimeter probe connected
- Software version
  - Version of user-interface software (same as presented in the bottom right of the bottom menu)
- Measurements since last calibration
  - How many measurements have been performed since the last calibration.
- Illuminant/Observer
  - The Illuminant and observe angle for Colorimeter DSM-4 devices.
- Next performance check
  - Recommended date for performance check of the connected probe.

6.3.6 Generated documents

Time	2022-08-3	Please do not modify original s	00745;001	00000;000	00000;000	Microsoft	3.0.0.10	en-US	E													
Label	Timestamp	Erythema	Melanin	CIE-L*	CIE-a*	CIE-b*	X	Y	Z	Chroma	Hue	ITA	Gloss	sR	sG	sB	CF1	CF2	CF3	CF4	CF5	CF6	CF
Measure 1	8/31/202	22.98	31.83	59.72	10.06	9.33	28.88	27.81	23.89	13.72	42.85	46.18	1.51	179	133	122	1944	4951	6953	7969	7945	11917	
Measure 1	8/31/202	25.69	33.03	58.6	9.21	6.75	27.45	26.6	24.28	11.42	36.24	51.89	0.42	173	131	124	1951	4985	6955	7982	7262	11271	
Measure 1	8/31/202	23.53	33.43	58.85	9.69	8.47	27.84	26.87	23.52	12.87	41.17	46.28	1.17	175	131	122	1893	4866	6828	7808	7562	11473	
Measure 1	8/31/202	25.51	34.11	57.21	10.77	9.82	26.36	25.14	21.16	14.57	42.35	36.33	2.27	173	126	115	1748	4425	6262	7180	7113	10999	
Measure 9	8/31/202	14.31	36.67	60.59	4.78	12.74	28.49	28.78	22.78	13.61	69.42	39.75	0.33	174	139	118	1792	4721	6873	8354	8674	11481	
Measure 8	8/31/202	16.08	36.94	59.79	5.62	12.61	27.83	27.89	22.07	13.81	66	37.83	0	173	136	117	1728	4593	6764	8061	8278	11341	
Measure 7	8/31/202	13.07	32.99	63.47	4.36	13.7	31.66	32.15	25.15	14.38	72.35	44.52	0.33	183	146	124	1937	5238	7660	9321	9714	12751	
Measure 6	8/31/202	14.31	33.04	62.84	4.98	13.85	31.09	31.39	24.4	14.72	70.21	42.83	0.33	182	144	122	1888	5097	7509	9055	9431	12610	
Measure 5	8/31/202	16.32	33.05	61.94	5.83	13.94	30.28	30.33	23.43	15.11	67.3	40.58	0.08	181	142	120	1826	4912	7317	8728	9003	12413	
Measure 4	8/31/202	14.39	33.02	62.91	4.73	13.56	31.11	31.48	24.65	14.37	70.76	43.6	0.08	181	145	123	1903	5139	7569	9145	9417	12608	
Measure 3	8/31/202	13.99	33.3	62.9	4.58	13.62	31.06	31.47	24.61	14.37	71.39	43.47	0.42	181	145	123	1899	5128	7552	9133	9442	12565	
Measure 2	8/31/202	14.24	32.98	62.94	4.81	13.87	31.16	31.51	24.49	14.68	70.88	43.01	0.16	182	145	122	1897	5109	7538	9121	9458	12631	
Measure 1	8/31/202	13.98	33.07	63.01	4.67	13.82	31.21	31.6	24.6	14.59	71.33	43.28	0.25	182	145	122	1904	5129	7553	9158	9494	12630	

Figure 28 .cmf data layout

Data can be exported from the DSM-4 software as a file for printing in pdf format or as a cmf file. A .cmf file is created when the save button is pressed. A .cmf file can be opened in any text editor or excel and similar. The layout is as shown in Figure 28 .cmf data layout.

.cmf files can be modified, but any modification can result in the file becoming unreadable by the Colorimeter DSM-4 software. Therefore, any modification to .cmf files should be made on copies.

Files for printing will be generated as shown in Figure 29 Printing layout. Note that only files printed from normal view includes average values in the printing output.

As .cmf files can be edited and files in general can become corrupted, it may be advantageous to store file in a safe location and potentially create backups if needed.

Colorimeter DSM-4 Skin Color

Label	Timestamp	Erythema	Melanin	CIE-L*	CIE-a*	CIE-b*	Chroma	Hue	ITA	Gloss
1	25/07/2022 15.25.31	14,55	90,12	27,24	26,27	46,11	53,07	60,33	-26,26	4,75
2	25/07/2022 15.25.31	13,47	36,92	61,45	6,36	16,69	17,86	69,14	34,45	1,06
3	25/07/2022 15.25.31	17,54	36,89	59,16	9,50	17,99	20,34	62,16	26,99	0,00
4	25/07/2022 15.25.31	16,42	37,00	59,73	8,75	17,55	19,61	63,50	29,01	0,00
Average	25/07/2022 15.26.02	15,50	50,23	51,90	12,72	24,58	27,72	63,78	16,05	1,45

Figure 29 Printing layout

6.4 DSM-III Compatibility

The Colorimeter DSM-4 Software is also compatible with the DSM-III probe and .cmf files generated by DSM-III probes.

Some features will not be available when using the Colorimeter DSM-4 software with a DSM-III probe as they are not available with the DSM-III probe.

6.4.1 Converting .cmf files from DSM-III software to Colorimeter DSM-4 format

Both the DSM-III and Colorimeter DSM-4 generate .cmf files. The Colorimeter DSM-4 software however includes additional information including LCH-values, sRGB values, ITA-score etc. Converting .cmf files from DSM-III software through the Colorimeter DSM-4 software will also calculate these missing values for later use.

To convert an older .cmf file, simply open it through the Colorimeter DSM-4 software and resave it. This will generate a file containing the newly calculated values missing from the DSM-III file. Original .cmf file can be

chosen for overwrite during save if it is no longer needed, otherwise default save name will reflect the current date and time.

Note that regular RGB values are no longer present in .cmf files generated by the Colorimeter DSM-4 software or present in the user interface. Instead, these values have been replaced with sRGB values, which are not directly comparable to RGB values. sRGB is a standardized absolute color space that is commonly used for monitors, printers, and the web while the RGB values used on the DSMIII is a device-specific color space.

7 Maintenance

For normal cleaning use a dry lint free cloth. For more thorough cleaning the cloth can be soaked in a mild liquid detergent (soap). During cleaning of the probe, be careful to not introduce dirt or liquids into the opening in the probe head as any dirt in the internal parts may adversely affect device performance. Solvents should not be used on the display window as it may become less transparent and crack. When the device is not in use, it should be stored the accompanying calibrator box, or if necessary placed on a clean surface with charging port facing up to avoid any dust settling in the light guide.

Avoid storing device with no charge for extended periods of time (approx. 2 months max).

7.1 Cleaning of the calibrator

For optimum performance, it is important to keep the working standards clean. Dust and other loose particles can be blown off the surface using an inert dusting gas. Do not touch the surface with the fingers or use your mouth to blow on the surface. If blowing off the surface is not enough, a clean cotton wipe or lens tissue soaked in a solvent can be used. Usable solvents are acetone, methylated spirit, and isopropyl alcohol (isopropanol). Read the safety data sheet carefully before using any solvents.

7.2 Cleaning of the measurement head

The measurement head can be cleaned and disinfected on the outer surface using an alcohol swab or cloth soaked in a disinfectant if needed. Do not insert a cotton swab (or any other object) into the measurement head.

8 Technical specifications

8.1 Colorimeter DSM-4 specifications

- 45°/0° colorimeter with full visible spectrum color sensor (10° standard observer)
- Diffuse reflectance spectroscopy color measurement (Specular Component Excluded)
- Light Source: D65 illuminant (CRI > 98).
- Measurement aperture: 8 mm (50 mm^2 area).
- Color space: CIE L*a*b*, L*C*h, XYZ
- Pigmentation (melanin): 0.0 – 99.9.
- Erythema (redness, hemoglobin) 0.0 – 99.9.
- Ceramic (white) and polished black glass (gloss) working standards
- Gloss: 60° specular gloss (GU)
- $\Delta E^*_{ab} \leq 2$ (Average measured on 14 CSSII* ceramic color tiles)
- $\Delta E^*_{00} \leq 1$ (Average measured on 14 CSSII* ceramic color tiles)
- IP class: IP20 (EN60529)
- Environment: Indoor use
- Temperature: 10 to 35 °C

- Relative humidity: 10 to 90 percent relative humidity, non-condensing
- Altitude: 3048 m (10,000 feet) maximum

* The CCSII is a set of standards for checking the consistency of operation and accuracy of color measuring instruments over long periods.

9 Service

Service and repair of the Colorimeter DSM-4 is only to be performed by Cortex Technology.

Please contact your local distributor or Cortex Technology (www.cortex.dk or cortex@cortex.dk) for requests of service and repair.

It is recommended that the Colorimeter DSM-4 is returned to Cortex Technology for a performance check every 2 years to ensure that the device meets specifications. The device should be returned together with the calibrator because the working standards will also be checked.

10 FAQ

Q: Communication is slow between performing a measurement and the data showing up on the pc software

A: Communication between the Colorimeter DSM-4 probe and a pc with the Colorimeter DSM-4 software uses a Bluetooth connection. This connection is vulnerable to noise from outside forces and can be delayed if too many Bluetooth devices are active within the vicinity.

Q: I have paired my probe and pc, but my Colorimeter DSM-4 probe will not connect to my Colorimeter DSM-4 software on the pc.

A: If the Colorimeter DSM-4 probe is on and an attempted connection is failing multiple times, pressing the reset button on the side of the Colorimeter DSM-4 probe (or waiting for the natural shutdown timer on the probe), may help reset the internal Bluetooth component and enable a new connection to be made.

11 Colorimeter DSM-4 parts

Colorimeter DSM-4		Order no. D22200.01
Calibrator		Order no. D22214.01
Power supply		Order no. D22215.01

EU – DECLARATION OF CONFORMITY

We hereby declare that the product mentioned below conforms to the requirements of:

- Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to *electromagnetic compatibility*.
- Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits.
- Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of *radio equipment.*
- Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on *waste electrical and electronic equipment* (WEEE).
- Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)
- Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH). We confirm that, to the best of our knowledge and based on the information provided by our suppliers, the products we supply do not contain any substances listed on the REACH Candidate List of Substances of Very High Concern (SVHC) or release any restricted substances under normal or reasonably foreseeable conditions of use.

Name of product:

Colorimeter DSM-4

Name and address of manufacturer:

Cortex Technology Aps,
Niels Jernes vej 6B
9220 Aalborg Ø,
Denmark.
Tel.: +45 98574100
E-mail: cortex@cortex.dk

Implemented standards:
DS/EN 61000-6-1:2019
DS/EN 61000-6-3:2021
DS/EN 61010-1:2010 + AMD1:2016
DS/EN 61187:1995
DS/EN 50419:2022
DS/EN 62133-2:2017

Place and date: Aalborg 2024/10/02 Signature: Morten Fjorback

Morten Fjorback, Director of R&D and QA/RA

A. Color Theory

Color data can be shown in CIE-L*a*b*, CIE-L*C*h, and XYZ color spaces.

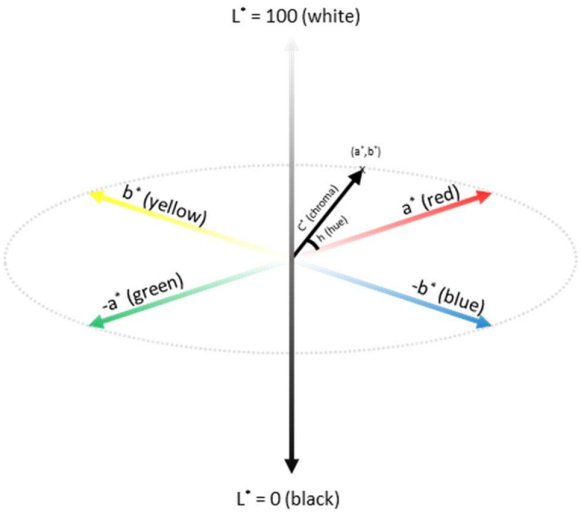


*Figure 30: The three-dimensional CIE-L*a*b* color space where the L* axis represents the lightness from 0 (black) to 100 (white). The L*C*h color space is similar to the L*a*b* color space but uses cylindrical coordinates instead of rectangular coordinates. C* represents chroma and h represents hue angle in the a*b* plane.*

A.1. CIE-L*a*b*

The Colorimeter DSM-4 shows the measured color in the uniform CIE-L*a*b* color space defined by the CIE organization in 1976. The L* axis shows the lightness from 0 (black) to 100 (white). The chromaticity coordinate a* represents the green-red component of a color while the b* component represents the blue-yellow component.

A.2. CIE- L*C*h

Color can also be shown in the L*C*h color space that uses the same diagram as the L*a*b* color space but uses cylindrical coordinates. Lightness L* is the same as L* in the L*a*b* color space. C* is the distance from the center axis and represents color saturation while the hue represents the angle on the chromaticity axes.

A.3. CIE-XYZ

The CIE-XYZ (tristimulus values) is a device-independent representation of color that can be transformed into all modern color spaces. It is a universal color space that encompasses all colors visible to the human eye. The Colorimeter DSM-4 measures color using a D65 light source and a 10° standard observer.

A.4. ITA° score

L* and b* parameters can be used for constitutive pigmentation classification according to the ITA°. The ITA° has been used extensively in dermatological and cosmetic research for objective assessment of skin phototype. The L* value correlates with the level of pigmentation of the skin. The a* value correlates with erythema while the b* value correlates with pigmentation and tanning. The ITA° is calculated as follows:

$$ITA° = \arctan\left(\frac{L^* - 50}{b^*}\right) * \left(\frac{180}{\pi}\right)$$

The ITA° correlates with total melanin content of the skin. The ITA° can be used as an objective classification of skin phototype. The ITA° is classified into 6 categories like the Fitzpatrick Skin Type (FST) that is based on self-reporting and subjective assessment. However, these are two separate methods for skin classification and cannot be used interchangeably. The FST is better suited for subjective assessment of sun reactiveness and not constitutive pigmentation. The table below describes how the different skin phototypes are classified according to the ITA° score.

1) *Del Bino S, Bernerd F: "Variations in skin colour and the biological consequences of ultraviolet radiation exposure." Br J Dermatol 2013;169(Suppl. 3):33-40.*

2) Cole C. Global data of unprotected skin minimal erythema dose relationship to Individual Typology Angle. Photodermatol Photoimmunol Photomed. 2020 Nov;36(6):452-459. doi: 10.1111/phpp.12592. Epub 2020 Aug 6. PMID: 32654351.

3) Osto M, Hamzavi IH, Lim HW, Kohli I. Individual Typology Angle and Fitzpatrick Skin Phototypes are Not Equivalent in Photodermatology. Photochem Photobiol. 2022 Jan;98(1):127-129. doi: 10.1111/php.13562. Epub 2021 Nov 26. PMID: 34796498.

Classification	Skin type	ITA°	Sample color
I	Very light	>55°	
II	Light	55°-41°	
III	Intermediate	41°-28°	
IV	Tan	28°-10°	
V	Brown	10° to -30°	
VI	Dark	<-30°	

A.5. Color difference

While color difference is not displayed in the Colorimeter DSM-4 Software, it is an important aspect of color theory and used in the accompanying calibration certificate for the Colorimeter DSM-4. This section will give a brief introduction to the concept of $\Delta \boldsymbol{E}$.

$\Delta \boldsymbol{E}^*_{\boldsymbol{ab}}$

Delta E 76, CIE76 or $\Delta \boldsymbol{E}^*_{\boldsymbol{ab}}$ is the original version of Delta E. It is used to measure the distance between two points in a 3D space plotted as seen in Figure 30. The calculation for Delta E 76 is a simple calculation of the Euclidean distance using the CIELAB values.

$$\Delta \boldsymbol{E}^*_{\boldsymbol{ab}} = \sqrt{(\boldsymbol{L}^*_{\boldsymbol{2}} - \boldsymbol{L}^*_{\boldsymbol{1}})^2 + (\boldsymbol{a}^*_{\boldsymbol{2}} - \boldsymbol{a}^*_{\boldsymbol{1}})^2 + (\boldsymbol{b}^*_{\boldsymbol{2}} - \boldsymbol{b}^*_{\boldsymbol{1}})^2}$$

A $\Delta \boldsymbol{E}^*_{\boldsymbol{ab}}$ of 2.3 corresponds to a JND (just noticeable difference) for an average observer. As the value of the $\Delta \boldsymbol{E}^*_{\boldsymbol{ab}}$ increases, the more noticeable the color difference becomes.

0 < ΔE < 1 - observer does not notice the difference,

1 < ΔE < 2 - only experienced observer can notice the difference

2 < ΔE < 3.5 - unexperienced observer also notices the difference,

3.5 < ΔE < 5 - clear difference in color is noticed,

5 < ΔE - observer notices two different colors.

Mokrzycki, Wojciech & Tatol, Maciej. (2011). Color difference Delta E - A survey. Machine Graphics and Vision. 20. 383-411.

These classifications are a good starting point for understanding Delta E, however there can be exceptions and the medium on which the colors are displayed also has a factor in the perception of the colors.

Delta E 2000

While Delta E 76 provides an objective Euclidean distance between two colors, it does suffer when working with high saturation colors, and does not take into account the human perception of colors. A newer version of Delta E has later been developed considering not only the CIELAB coordinates but also hue, Chroma, and a scaling factor for the CIELAB a* value.

Delta E 2000 is also referred to as CIEDE2000 or $\Delta \boldsymbol{E}^*_{\boldsymbol{00}}$. Both Delta E 76 and Delta E 2000 are presented in the accompanying calibration certificate to give an indication of both the average Euclidean distance as well as a more precise depiction of the average color difference perception.

As the formula for Delta E 2000 is much more complex than the one for Delta E 76 it will not be listed here but can be found in 4).

$\Delta \boldsymbol{E}^*_{\boldsymbol{00}}$ typically ranges from 0-100 and are usually associated with the following classifications:

$\Delta \boldsymbol{E}^*_{\boldsymbol{00}}$	**Perception**
<=1.0	Not perceptible by human eyes
1-2	Perceptible through close observation
2-10	Perceptible at a glance
11-49	Colors are more similar than opposite
100	Colors are exact opposite

4) *Luo, Ming & Cui, Guihua & Rigg, B.. (2001). The development of the CIE 2000 colour-difference formula: CIEDE2000. Color Research & Application. 26. 340 - 350. 10.1002/col.1049.*