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Coverpage: AS73210-AS89010-C3 SET DK User Guide

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User Guide

AS73210-AS89010-C3 SET DK

Development Kit with USB interface

Content Guide

1 Introduction

The (SET) (DK) AS73210-AS89010-C3 Development Kits includes the AS73210-AS89010-C3 OEM sensor board optional embedded into a metallic casing with optical components and test software.

During this document the AS73210-AS89010-C3 will further on be referred to as "C3".

The main components of the system and its installation and usage are described within this document. The Set DK C3 is delivered without pre-calibration. So it is not specified for an application but was prepared for a user specific calibration as application specific setting and calibration of the system. That can be performed via known XYZ targets or similar within the application or via parallel connected spectrometer, spectral photometer, densitometer or other devices for color measurement and XYZ output The user calibrations can be saved in the sensor within the EEPROM of the C3 for the various applications. Data g and evaluation options can be used for testing and analysis. The C3 SET DK was designed as a test system under laboratory conditions – it is intended to be used for system and application tests in applications for color measurement and control.

Figure 1: Block diagram OEM Sensor board C3
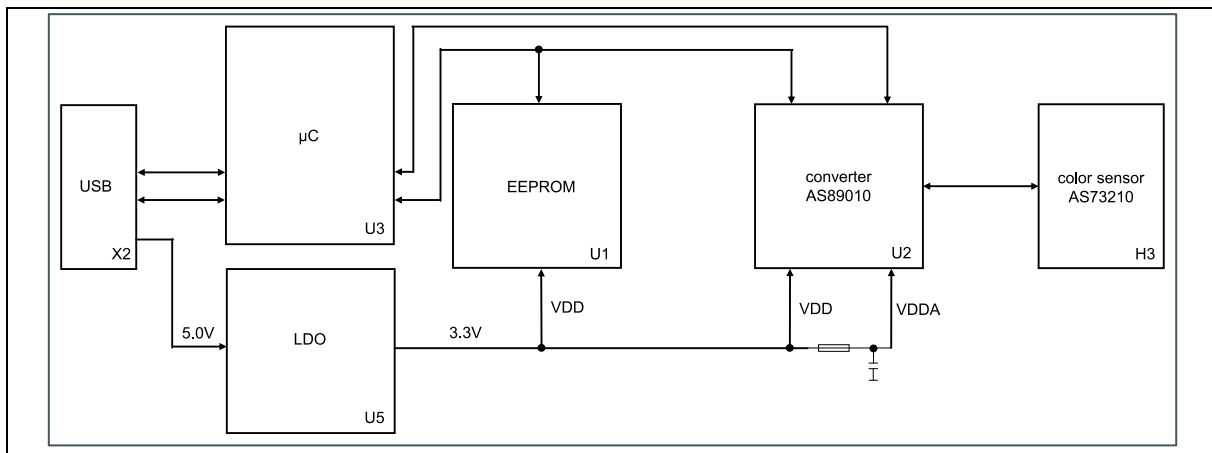
The OEM sensor board C3 [4] is a small PCB for general color measurement and control applications, with a high bandwidth of light y designed for in-line and handheld applications. The sensor board includes the True Color sensor AS73210 [2] (XYZ sensor based on the international CIE 1931 standard (human eye perception), a special analog-to-digital converter AS89010EQ [1] with a high dynamic range (1-to-1,000,000), power supply, a µC with EEPROM for sensor data, an integrated temperature sensor and an USB interface. USB is used for external communication, configuration of the sensor, readout of the sensor data as well as writing and reading of the memory. The standard software is only designed for Windows based systems (Windows 7 and above). For Window based customer test software ams Sensors Germany will offer a JENCOLOR® C3 Library. All links to the reference documents are located at the last section of this document. The following chapters describe the Development Kit and especially the software setup and usage for Windows PCs. Please make sure to install all libraries and the test software before connecting the Development Kit to a computer via USB.

2 Scope of Delivery

The C3 product family includes alternative delivery forms with the following standard elements:

- ▪ One or more sensor board(s) (SET) (DK) C3
- ▪ Documentation: datasheet and more on USB stick
- ▪ Setup for PC test software, driver and MATLAB™ Compiler Runtime on USB stick
- ▪ USB cable (original <3 m)
- ▪ Optional JENCOLOR® C3 Library and optical parts

For the scope of delivery of alternatives see the following table:

Table 1: Scope of delivery for C3 product family

Name	C3 JENCOLOR® Sensor Board with USB-Interface	C3 SET DK Development Kit with USB-Interface
Article	2207900021	220790004
Type of delivery	Plastic cases in carton	Suitcase with inserted components
Sensor-IC AS73210	O	O
Signal converter AS89010EQ	O	O
USB interface	(O)2	O
Firmware µP-programmed	O	O
Bootloader inside	O	O
JENCOLOR® C3 Library	O	O
PC Windows Test software	---2	O
Sensor metallic package with optical aperture	---	O
USB cable	---	O
Suitcase for components	---	O

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[1] Please note, the color sensor is a PCB without package. So sensor handling precautions should be observed to avoid static discharge.

[2] Optional, must be ordered separately.

The housed test system consists from a basic case which will be adapted customized and/or application specific by various parts and optical components (apertures).

The solid basic case was made of anodized aluminum, which protects the sensor board C3 against mechanical stress as well as ESD and EMF. The sensor AS73210 is positioned in the basic case coaxial with a 3/8"-24 UNF internal thread and ready for the application of different optical accessories.

Table 2: Basic case and adapters for the DK

C3JCDK-Basic case	JCDK-Aperture-13.5	JCDK-Aperture-13.5 with IR-cut-off filter	JCDK-1/4"-Adapter	JCDK-SMA-Adapter

There are difference adapters "Aperture" available to adapt for the sensor in the package the angle of incidence and/or to fix the sensor system.

The JCDK-Aperture-13.5 is designed to limit the angle of incidence on the AS73210 to ±10°. It is an optional aperture of the JCDK assortment and characterized with a single groove outside. The outside diameter of 25mm makes it compatible with JCDK-1/4"-Adapter and opto-mechanical system parts (e.g. Linos). In front of the aperture is space for mounting a filter glass with outside diameter up to 22.2 mm and thickness up to mm.

JCDK-1/4"-Adapter is used for mounting the JENCOLOR® DKs on a camera tripod or equivalent holders. On the bottom side there is a centered 1/4"-20 UNC internal thread and 20mm below the optical axis there are two M4 internal threads for mounting the JCDK-1/4"-Adapter on a flat surface. For IR sensible applications order the JCDK aperture 13.5 with inserted IR blocking. For using the adapter with an alternative integrated filter please ask our sales team.

Via the JCDK-SMA-Adapter a fiber optic patch cable with F-SMA 905 plug can be connected to the JENCOLOR® Development Kit. The distance between fiber end and sensor is calculated to achieve an angle of incidence of at most 10° with a fiber core diameter up to 600µm. Minimum NA for illumination of the whole sensor area is 0.22 and to reduce the effect of stray light inside the adapter and the case NA should not exceed 0.39.

3 System Requirements

The minimum system requirements are the following:

- PC Pentium 1 GHz or higher, 512 MB RAM, one free USB (2.0) port
- 1.5 MB free hard drive memory (+ ca. 1.3 GB for MATLAB™ Compiler Runtime)[3]
- .Net Framework 4.5[4] and higher
- Microsoft Windows™ 7 and above
- (optional[5] for import/export functions) Microsoft EXCEL™

4 Specification of C3 SET DK

Table 3: Specification of C3 SET DK

Spectral range	380 nm … 700 nm
Measuring Method	Based on XYZ CIE 1931 standard (user calibration necessary)[6]
Measuring values	ADC digit; ADC current; XYZ; Yxy; Yxy SDCM; Yuv CCT
Gain (reference currents)	Selectable 20nA …5120 nA (5 stages)
Integration time	Selectable 1 ms … 1 sec (infinitely adjustable)
Digital electronic resolution	16 Bit ADC output by using divider for 20 internal bits
LSB min lux	0.00005
FSR min lux	3.31
FSR max lux	13,576.43
Dynamic range	1 – 1,000,000
Power supply	USB powered
PC interface	USB 2.0 full speed
Weight	56g
Operating conditions	Temperature 0 ... 85 °C Humidity 85 % relative humidity at 35 °C

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[3] Alternative software releases requires different MATLAB Compiler Runtime libraries. See the information files on the USB software stick for the required version.

[4] Use the download from Microsoft's websites to install original .NET Framework.

[5] E.g. recommend to use some special program functions like write protocol and others

[6] For more details for sensor response, sensitiveness and other parameters see the AS73210 datasheet

5   Start-up, Installation & Updates

This section of the *document describes* how to install and use the C3 PC software.

It is required to have administration rights and an active internet connection during the installation process. To start the installation of the software just execute the *setupxxxx.exe* file and all required files are installed automatically. Make sure that all files for the installation are in the same directory as the setup.exe. Depending on the PC installation the setup.exe must be started optionally via "run with administrator rights". Normally the setup.exe will install all required libraries, drivers and the test software. You have to accept some conditions or answer questions during the installation process.

After installing the software and drivers connect the sensor board(s) to free USB port(s) of the computer. By using more than one sensor please check that the PC system is able to recognize all sensors. Note, common USB hubs may not be able to connect all sensors.

If no driver has been found or the system cannot find a required DLL and an error message appears; it is required to manually install the driver and libraries on your system. These files for installation are found within the directory of the Setup software.

The sensor board is configured via start-up values but it is necessary to change and adapt them for your application. Select the parameters for amplification and conversion to get a maximum of digits and stable sensor results.

The C3 software is prepared to work with one or more sensor(s) (DK) C3 and in addition (optional) with a special (prepared) spectrometer parallel during the calibration process. Please ask our sales team for information about the supported devices[7] and the installation process of add-on drivers for the spectrometers to use this option.

5.1   Sensor Software Interface & JENCOLOR® C3 Library

The sensor software interface is described in [8]. This description can be used to implement the C3 sensor in customized test systems. Depend on the scope of delivery ams Sensors Germany alternatively offers a JENCOLOR® C3 Library [9] with pre-designed sensor algorithms which can be used to implement the C3 sensor into own test software. This DLL files are stored on the same medium as the install software and documents or must be ordered separately. Please copy the required files from the install medium or alternatives into the own directories. The process which install the test software will not copy any DLL file or documentations. Please note also any *readme.txt* in case of using the JENCOLOR® C3 Library.

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[7] Currently: JETI Specbos 1201/1211 are supported. Ask our sales team for alternatives. The referred driver for the spectrometer must be installed before the C3 software was started.

5.2   Software

All installation software tools can be found in the setup directory of the USB drive. Normally the setup software (*setupxxxx.exe*) will install the test software C3 and necessary driver and DLLs. Execute the Setup file and follows the installation steps.

If the USB drivers cannot be installed automatically then please install them manually. The file "*VCP_V1.3.1_Setup.exe*"[8] is used for 32 bit Windows systems and the file "*VCP_V1.3.1_Setup_x64*" is used for 64 bit systems depending on your computer system. Please check the connection before starting Setup again.

For installation of the test software the MATLAB Compiler Runtime 8.2 version or compatible is required. The setup routines check internally for the required MATLAB DLLs and will install them if necessary[9]. Use the file *"MCR_R2013b_win32_installer.exe"*[9] to install the library manually in case any errors occur.

In case of new software releases ams Sensors Germany will send the update typically as setup.exe. If necessary please use this setup.exe to install the update. More details for the new release will be in a file named readme.txt with comments the update.

5.3   Repair & Remove

The Setup software also allows to repair and uninstall the C3 software as long as the software is installed on the local computer. The Setup Wizard opens and the user needs to select the *Repair* or *Remove* option in the second window.

Please note, the Remove procedure only deletes all files and directories of the test software C3. Drivers and MATLAB DLLs must be deleted manually by using standard Windows procedure ("*System control*", "*Programs and functions*").

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[8] Or newer versions

[9] The install software for MATLAB (*MCR_R2013b_win32_installer.exe or newer versions*) must be/is located in the same directory than the *setup.exe*.

6   Software

6.1   Startup Configuration

Starting the program is possible with/without connecting spectrometer[7] in parallel to the color sensor and with/without writing a logfile. The logfile could be useful for support by sending the file to ams Sensors Germany.

The startup configuration chooses which hardware will be scanned and whether a logfile will be created.

Please note, a spectrometer is required for the sensor calibration however increases the software initialization time. When using a spectrometer the startup configuration must be setup as following (chapter 6.6):

▪   Create/copy a shortcut from the software
▪   right-click to the shortcut and open the properties
▪   within the shortcut tab, add the line: "-*useSpectrometer"* at the end of the target field (e.g.: C:\Program Files (x86)\C3 Testsoftware\C3 Software.exe" -*useSpectrometer*)

**Figure 2: Properties of the shortcut**

To start the software with logfile use the parameter "-writeLog" just as used before for the spectrometer setup.

6.2   Initialization

Immediately after executing the test software *"C3 Testsoftware.exe"* an initialization window appears which starts and scans the system for existing devices. This window indicates the scan progress and reads the current sensor configuration for each connected sensor board. Depending on the used PC hardware, system software and used interfaces this process could take a few moments. Please do not interrupt this process.

Figure 3: Initializing
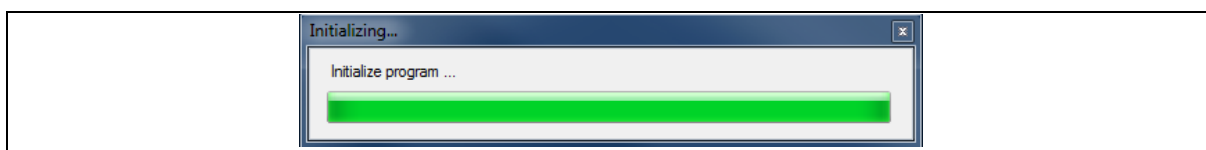
If one or more known devices were found the software opens a window with information about the calibration status. (Start setting – compare Figure 4 - or main user interface – compare Figure 6)

Figure 4: Select sensor start settings
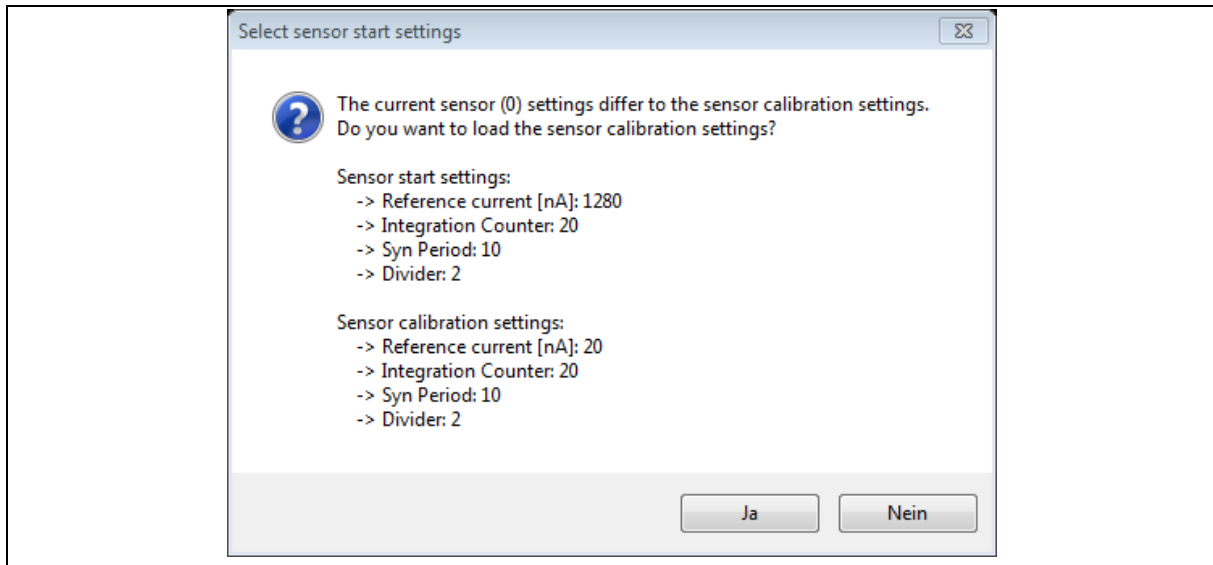
If no devices have been found during the initialization phase, the software shows an error message and switches to demonstration mode. If a sensor device is found but without stored initialized values on EEPROM (offset/dark measurement) then an offset/dark measurement will start automatically. These measured dark values will be used only for this software session (not stored on the sensor hardware) and could be changed in the menu for calibration or during the calibration process.

Note: No real values are measured in demonstration mode – these are simply randomized values.

Figure 5: No sensor found - Demo mode starts
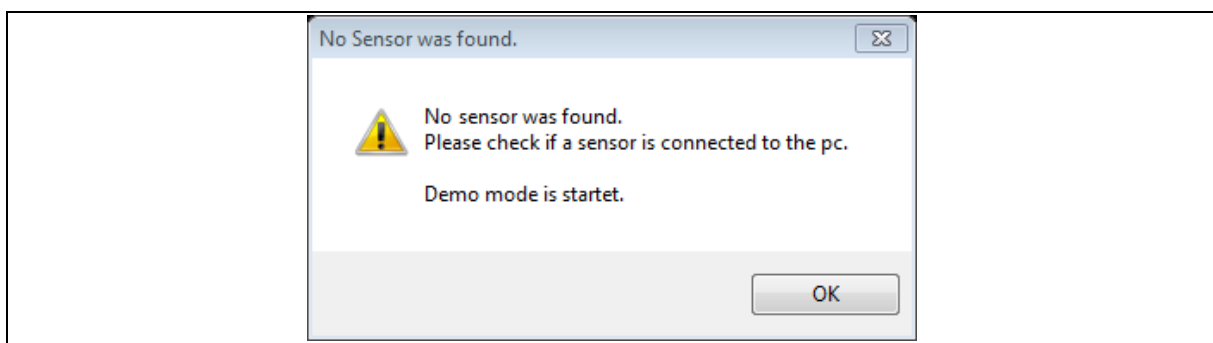
6.3 Main User Interface Elements

After starting the software an user interface opens in the **Scanning Mode** to identify and show the connected hardware and includes different options (button, menu bar, dropdown menu) to change the parameters of the measurement *(Configuration)*[10], to select the output options (**Diagram**) and to control the next program steps (**Measurement, Calibration**).

Configuration (Sensor settings): The most important parameters can be changed directly by the user. It is possible to initialize and control the measurements. After activating via pressing the 'Start' button the test software begins with the measurements. Measurements will be performed sequentially in continuous mode. By selecting parameters such as Integration Time, Divider or Amplification, the sensor system can be directly controlled by the user.

Detect optimal sensor settings: The functions *GET PWM period* and *Detect settings* supports the process of finding parameter settings based on automatically performed measurements.

Get PWM period: is an optional function[11] of the C3 for frequency detection & flicker (frequency not amplitudes shifting) compensation for monitors or displays which operate with specific background PWM frequencies. A Fourier transformation algorithm is utilized to determine these effects and analyzes the measurement frequency in relation to the display-specific PWM. The result is the potential detection of a dominant frequency and compensation recommendation. The analysis is performed at a 2000 Hertz detection frequency. The settings of *IntegrationCounter*, reference current and divider are ignored during this detection procedure.

Detect settings: This function automatically performs measurements to find the specification for *Reference Current* and *Integration Counter* based on the given *SynPeriod.* So the ratio between signal and noise (maximum of digits) can be optimized*.*

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[10] Please note different units of measurements depend on software alternatives and optional functions.

[11] If a grey button for that function is active then this function was not activated. Please contact our sales team if you have an interest to use this function.

Figure 6: Main User interface elements
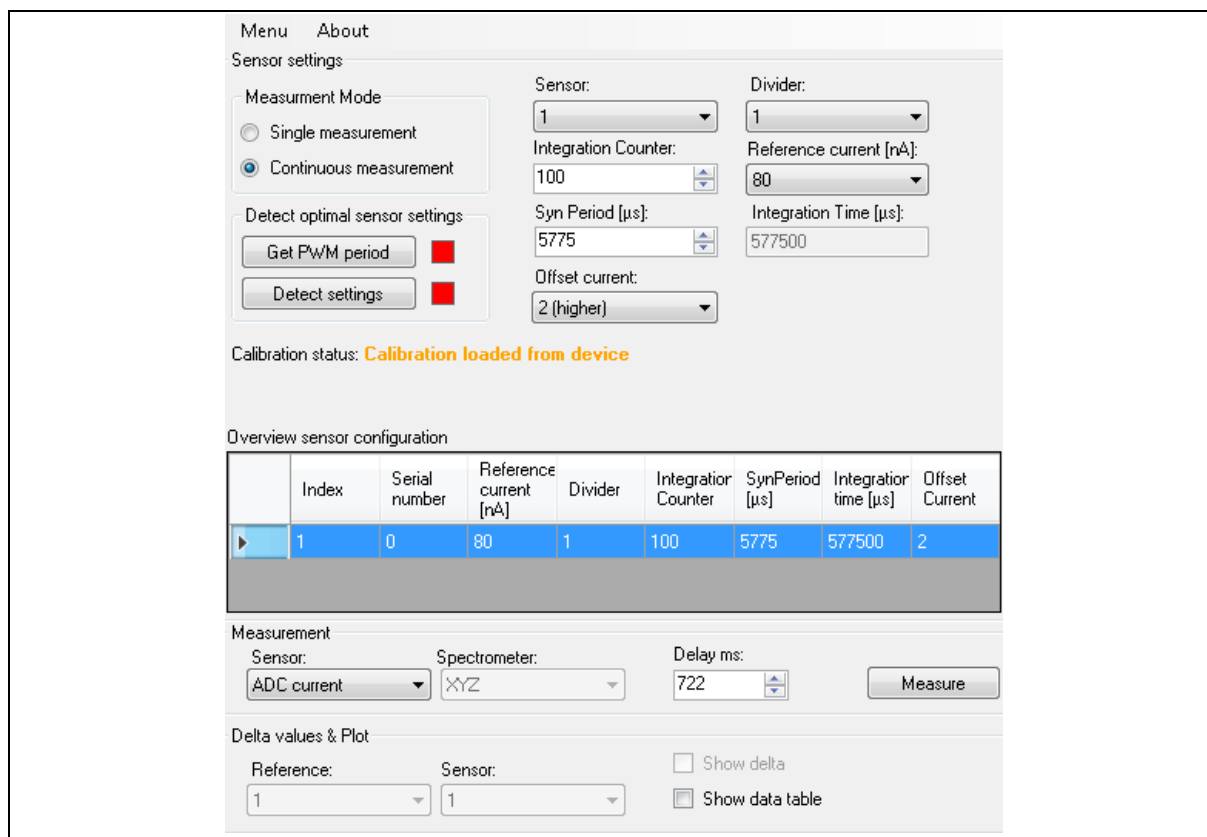
Overview sensor configuration: Print all specified parameters for the connected sensors in a matrix and is the basic window to check or edit the sensor calibration matrix and dark values.

Measurement: Gives the option to modify the behavior during a measurement such as delay or the color space of the connected device. Additionally, the measurement can be started or stopped here (see 6.8).

> *Sensor:* Select the form how the sensor results should be shown and define a *Delay* time between single measurements. Note, *Delay* will be set also automatically by the software based on the specified *Integration Time*. This time cannot be defined smaller.

> *Spectrometer:* Configures an optional spectrometer device for additional measurements by such a device. This one can be used as a reference to compare the measurement results that are taken by the sensor and optimize calibration procedures (see 0).

Delta values & plot: Allows to compare the measurement values to *Reference* values that can be selected. Furthermore, the delta plot can be activated or deactivated. If only one Sensor is connected or more than one device (sensor, spectrometer) with different numbers of measurements is selected, the delta function is disabled or will be stopped by an error.

6.4　Menu Bar

The menu bar includes the functions to start the calibration or save the results to the device, export measurement data, clear measurement values and measure user defined colors via a color patch feature.

Figure 7: Menu bar
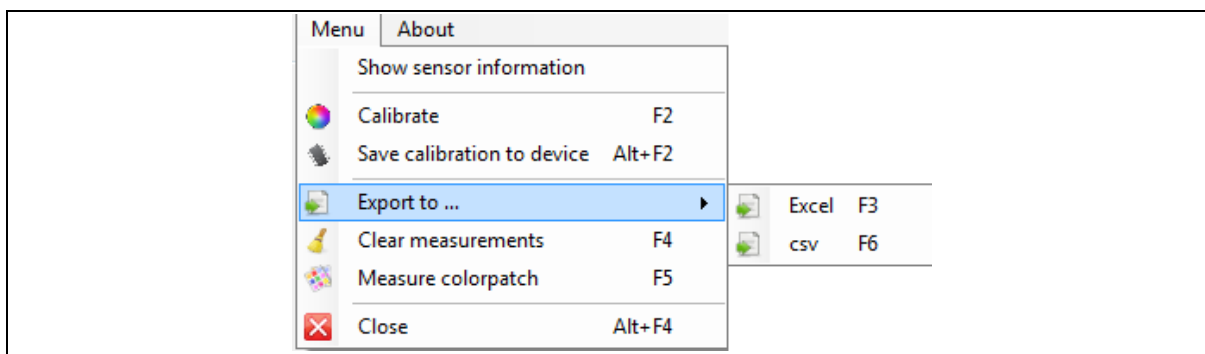
Show sensor information: Use this function to get information about the connected sensors. A table shows the serial number[12] ***of the PCB board inside the package, the number for the packaged sensor and the firmware release of connected sensors.***

Calibrate (F2): Use this option to start a calibration process (also compare chapter 6.10). If no calibration has been performed, the status of calibration is invalid and the button is highlighted in red. After completing a calibration the status is valid and the button is highlighted in green. Changing the amplification values or integration time may require a re-calibration.

Export to Excel (F3): Use this option to save the measurement and calibration data to a file[13].

> ***Excel (F3):*** Saves the data to an .XLSX file of MS Excel.

> ***csv (F6):*** Saves the data to a .CSV file (tab stops as separator). All data and the results of each sensor(s) and spectrometer will be saved to an extra file according to the following pattern:
> "C3_*TIMESTAMP*_sens_*SERIAL*.csv" or "C3_*TIMESTAMP*_spectrometer_*SERIAL*.csv"

> - **TIMESTAMP**: is the time and date of export data: YYYY-MM-DD_hh-mm-ss
> - **SERIAL**: is the serial number of the sensor or the spectrometer
> - Example C3_2014-10-14_11-39-30_sensor_100001

The ***Clear measurements (F4)*** button deletes all measurement values and closes the ***Color space*** window. But it does not delete any register settings[14].

The ***Measure color patch (F5)*** button allows to measure defined colors. The user can insert own colors as RGB values. (For example [255; 0; 0] for red) All inserted RGB colors are shown in a separate window and can be measured via all connected sensors. The user can move the window to any position on the screen (also compare chapter 6.10).

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[12] Depend on delivery form, firmware and board status

[13] Needs an installed MS Excel software on PC.

[14] Please note that register settings only could be changed by new writing or after a hardware reset to default via USB disconnection/connection.

6.5   Sensor Settings

The configuration (sensor setting) can be set to all connected sensors or separately for a specific sensor and table provides an overview about the configuration of each connected sensor in the current system. Use the automatically functions or select a new configuration by changing the gain parameters.

To change the configuration of one sensor just select the specific sensor in the combo box "Sensor" and change the values of the **Integration time**, **Amplification** or **Divider** as needed and to get a maximum of accuracy[15]. Select a sensor and click the right mouse button to see or change its calibration matrix. A change of the calibration matrix must be confirmed separately.

Figure 8: Sensor settings
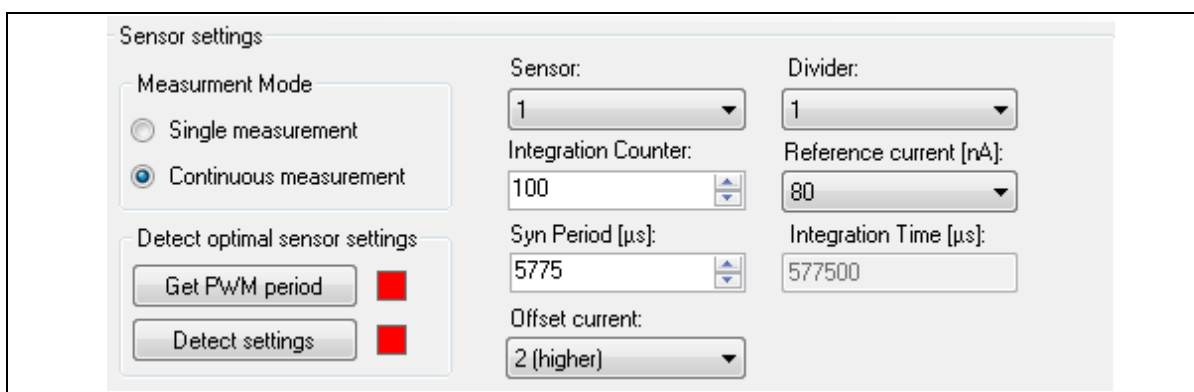
Integration time: Is the product of ***IntegrationCounter*** {1…255} and ***SynPeriod*** {1…50 ms}[16]. So parameters for the Integration time of {1…12,750 ms} are possible.

Example: The integration time of 10 ms is the result of 10 (Counter) * 1 ms (Period).

Reference current [nA]: Configures the amplification of the sensor board by changing the reference currents. Example: The smallest reference current (20 nA) results in the highest gain and increase the accuracy.

Divider: Is used to expand the measurement ranges and to prevent partly saturation. The AS89010EQ uses internal 20 bits for analog-digital-converting and transform 16 bits as sensor result via I²C. An internal implemented digital divider can be used to scale the results from 20 bits to 16 bits. This may be necessary if the resolution of the conversion is set to a value >16 bit (but ≤20 bits). The range is 1 to 16, so dividing by 16 means a bit shift of 4 digits.

Offset current: The test software allows to choose different values for the internal current-offset generation of the signal-amplifier (Offset Current: 3 - low offset, 2 - high offset). The added current enables the device to measure very low input currents even in the presence of a small negative leakage currents. Without an offset current these negative currents would lead to an underflow (see [1] OPTREG Register) and prevent the signal-amplifier from working properly.

The offset current is added to the input current of the sensor and therefore also shows in the conversion result of the amplifier. To eliminate the artificial offset current from the conversion result a theoretical value corresponding to the added offset is subtracted later in the software. In case of

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[15] Specify the parameters to get maximum of digits, adapted for the application specific frequency/time and between noise and saturation - the higher the number of digits the better the accuracy – see also [7].

[16] Please note, the AS89010EQ is working exclusive in SYND-mode and realizes the timing by an internal oscillator - see [1] for more details. Use *SynPeriod* to adapt the measurement on your application. Use *Integration Counter* if possible to increase the digits.

small negative/positive leakage currents on the board this subtraction leads to negative/positive digital values in the software, which show the correct current and current direction at the input pins of the signal amplifier. To quantify these small negative/positive leakage currents it's always recommend to perform a dark measurement before the start of serious measurements (completely cover the sensor). Therefore a dark measurement is always an essential part of the calibration process (see Chapter 6.10).

Figure 9: Calibration status and Overview sensor configuration

Calibration status: shows the status of the calibration of the selected sensor (or all)

- ▪ *Not calibrated*: No calibration data was found on the sensor (standard - if the sensor will be used for first time).
- ▪ *Calibrated*: The sensor has been calibrated since the software was started.
- ▪ *Calibrated manually*: The sensor has been calibrated manually since the software was started
- ▪ *Calibration loaded from device*: The calibration data has been read from the sensor device and loaded into the software calculation process.
- ▪ *Calibrated to different settings*: The parameters for divider and/or reference current have been changed since the last calibration.
- ▪ *The calibration of the devices differ*: There are different calibration states on the sensors. This information is only shown, when more than one sensor with different parameters has been selected.
- ▪ *Please check the calibration of all devices:* There is a calibration error within a device. This information is only shown, when multiple sensors have been selected.

Overview sensor configuration: The table shows the different sensors and their settings AND allows to change the calibration matrix manual. Select a sensor to change the settings.

Show and edit calibration matrix and dark current (click right mouse button): The current calibration matrix and dark current as noise for the selected sensor is shown. The calibration matrix can be edited for each individual sensor. The values can be copy and pasted by right-clicking the mouse button.

Note: When pasting values, these need to be tab stop separated or an XLS array). Otherwise the new values can be edited manually. The window can be closed by standard close button or [x]. In case of changed parameters it must be confirmed to leave the function.

Note: Be careful by using this function because deleted values after stored results cannot be restored. The calibration parameters are temporally until they will be stored at the sensor by using the function *Save calibration to device* in Menu.

Figure 10: Calibration matrix / values for dark current after the process calibration / reading the sensor values from EEPROM
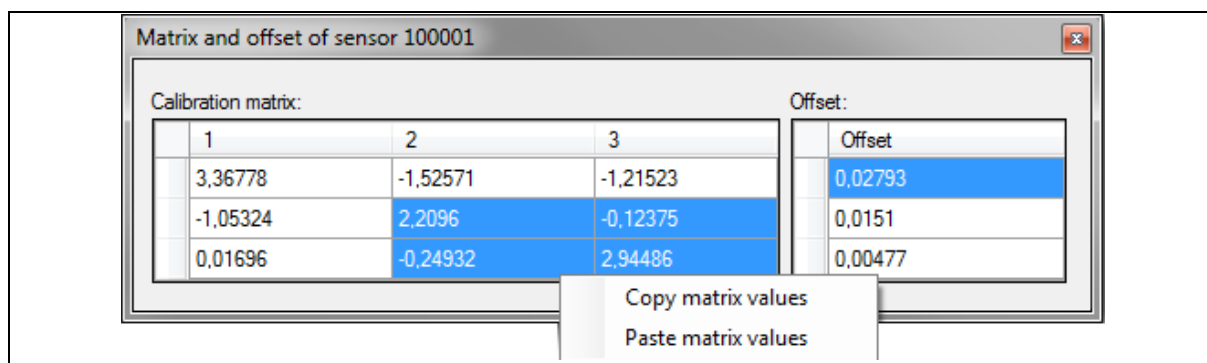
6.6 Get PWM Period

Certain monitors or displays operate with specific background PWM frequencies up to 1000 Hertz (ideal 50~250 Hertz). These frequencies can lead to an overlap of the signal measurement and to oscillating measurement results.

The test software of the C3 utilizes an integrated frequency identification and compensation method (PWM detection) to determine dominant error frequencies.

A Fourier transformation algorithm is utilized to determine these effects and analyzes the measurement frequency in relation to the display-specific PWM.

The result is the potential detection of a dominant frequency and compensation recommendation. The analysis is performed at 2000 Hertz detection frequency.

The settings of IntegrationCounter, reference current and divider are ignored during this detection procedure. For more details please see [6].

Note: This function is optional and must be ordered separately. Please contact our sales team if you want to order it.

6.7   Spectrometer

These features are optional and active if the startup parameter was set (see chapter 6.1) and a sensor C3 and a spectrometer[7] work parallel. In following the functions, parameters and windows used for the spectrometers from JETI Specbos 1201/1211 are described. For further technical details of the spectrometer please check the individual description of the device.

Within the "**Spectrometer** section", specific parameters and options for the parallel usage of the spectrometer and sensors can be set.

Figure 11: Spectrometer settings
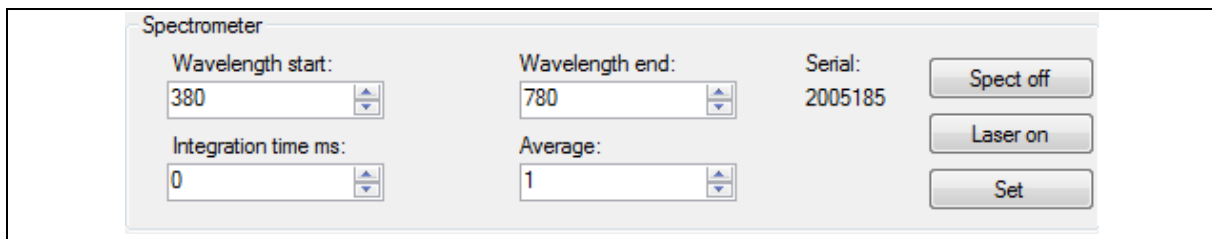
Spect off/on: Turn the spectrometer on/off.

Note: In case of the spectrometer will be switched on, the numbers measurements for sensor devices will be reset.

Laser on/off: Activates the laser spot to focus the spectrometer onto a target. Activated a laser circle indicates the measurement zone.

Set: The configuration will be send to the spectrometer. These values will be used for the next measurement.

Wavelength start/end: Defines the range to detect the spectral data of the source to be measured. The visible spectrum is in range between 380 nm and 780 nm. Other devices with an extended range can also be used.

Integration time: Configures the time to measure an object. The default value is set to 0 and is highly recommended to use.

Average: The amount of measurements that are performed to receive the spectral information about a source or an object.

6.8 Measurement Configuration

Within the "**Measurement** section" the delay between the measurement and the selected color spaces for the specific sensor can be set. Additionally, the measurement procedure can be started and stopped here.

Figure 12: Measurement settings
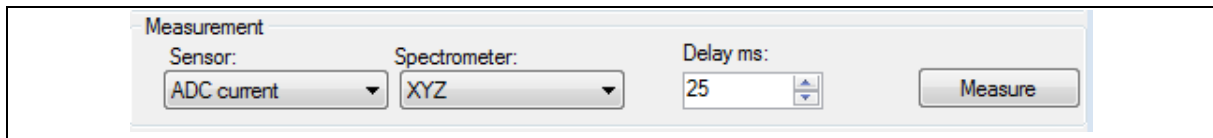
Delay: Sets the waiting period between 2 measurements in milliseconds. The value has an accuracy of ±20 ms depending on the internal Windows scheduler. The minimum delay is equal to the integration time plus a specific time offset.

Sensor & Spectrometer: Configures the color standard to plot for the connected devices. The color standard for the spectrometer is only activated if such a device is connected. Following plots are available.

Note: They can be changed every time before or during measurements

Measurement variable	Measured by C3 sensor	Measured by Spectrometer[17]
$ADC\ digit = OUT - \dfrac{OUTINT}{Offset\ Value}$	O[18]	---
$ADC\ current = \dfrac{OUT * I_{Ref}}{OUTINT} - I_{Dark}$	O[19]	---
XYZ	O[20]	O
Yxy, Yxy (SDCM)	O[20]	O
Yuv	O[20]	O
Correlated Color Temperature	O[20]	O
Spectral values	---	O

Table 4: Measurement values

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[17] Depends on the spectrometer and software implementation; available only for a limited amount of spectrometer.

[18] Raw data's of ADC with consideration of an internal *Offset Value* (see [1] Options Register OPTREG), without correction of dark current. This internal Offset Value will be considered by the software algorithm during the process of following calculations like photo current, XYZ values and others.

[19] Calculated photo current based on Raw data's with consideration of dark current if done.

[20] By using parameters of customer's calibration and standards of CIE1931.

MEASURE(/STOP): Start the measurement procedure all connected devices and their respective configuration or stop the measurements. Additionally, the plot opens to show the measurement values (check Figure 13: Example for active plot

**Figure 13: Example for active plots of the selected sensor by activated data table**
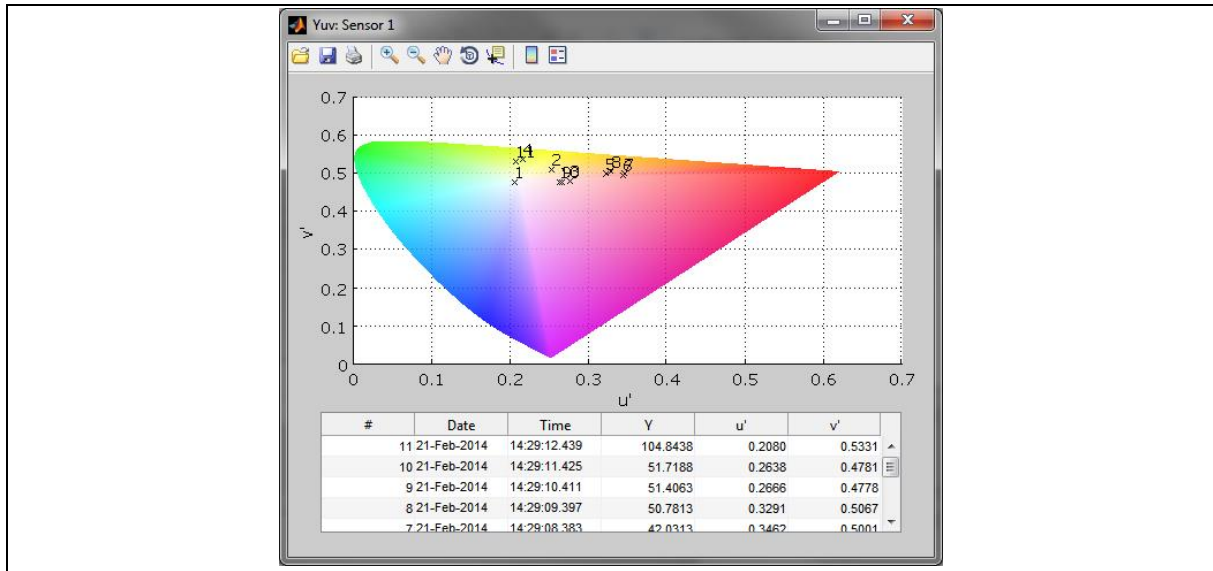
In case of a connected reference device (second sensor or spectrometer) the delta plot continuously shows the difference between a reference and another selected sensor.

Note: The delta plot for different measurements (sensor to sensor or spectrometer to sensor) is only available, if the numbers of measurements for both devices are equal.

Figure 14: Delta values & plot
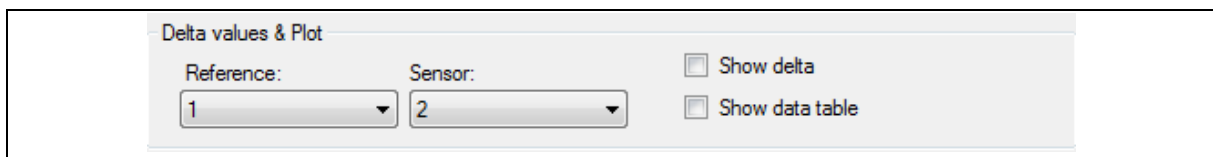
Reference: Is the reference device and can be either a sensor device or a spectrometer.

Sensor: This is the second device for comparison purposes. These values of this sensor are additionally plotted into the color space diagram.

Show delta: Activating the checkbox show the delta plot. To change the reference color diagram or plot just change the value of the sensor dropdown within in the measurement field (see Figure 15).

Show data table: The data table opens in a plot window below the color diagram graph. The data table has influence on the performance of the software processing and could increase the process time for measurements. Therefore the tables are initially deactivated when the program starts. The option can be activated every time by selecting the checkbox.

Figure 15: Reference (delta) measurement
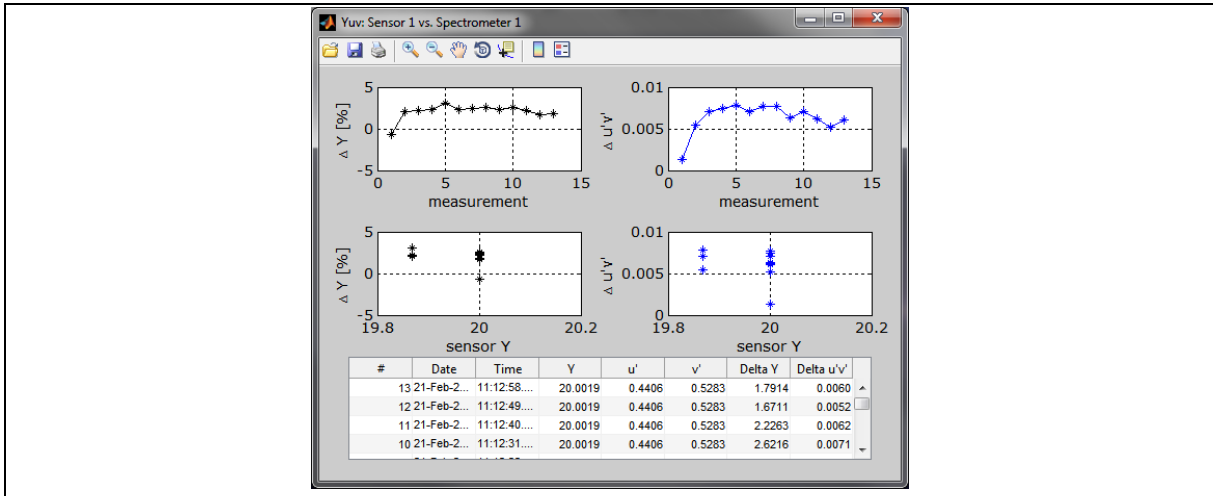
6.9 Color Patch

Color patch (Quick open via F5) or opened in calibration mode - is a window that can be used to generate user defined colors via RGB coordinates, for example (255, 0, 0) for red and (255,255,255) for white. After starting, it is possible to enter or import RGB coordinates for the color patch.

Figure 16: Import window - Color patch for 3 colors (rgb)
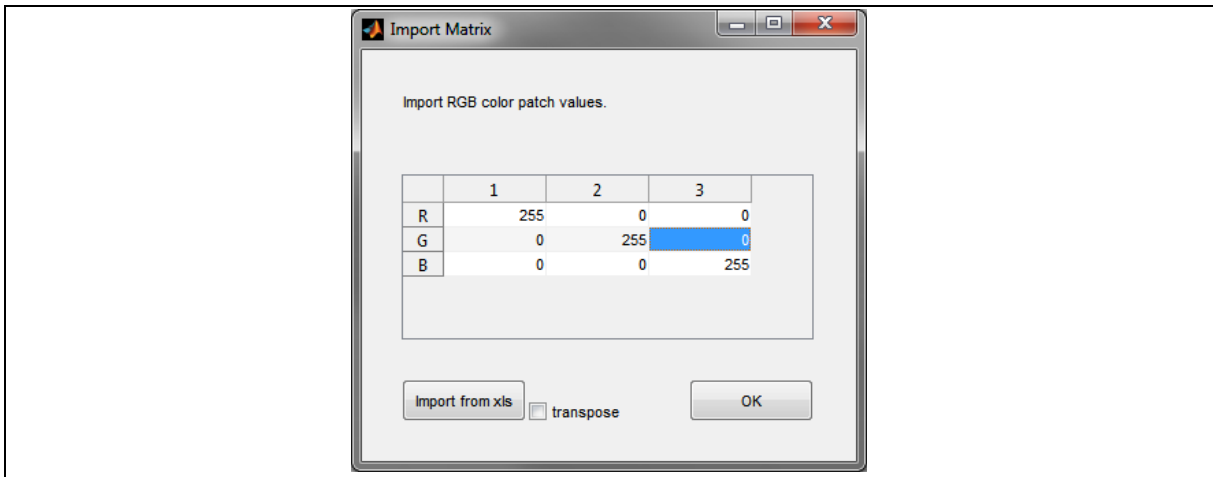
For the standard of three targets the RGB targets values can entered manually into the RGB matrix, like shown in Figure 16. It is also possible to fill the matrix values via 'copy & paste' of (3 x n) values for example from an Excel sheet.

It is also possible to import the data directly from Excel. Simple enter the required vales (ranging from 0 to 255) into an Excel sheet and select them all. Finally, just click '**Import from xls**' and the values are loaded into the table. This is recommenced, when using multiple targets.

Figure 17: Import window – Color patch import via Excel for RGB
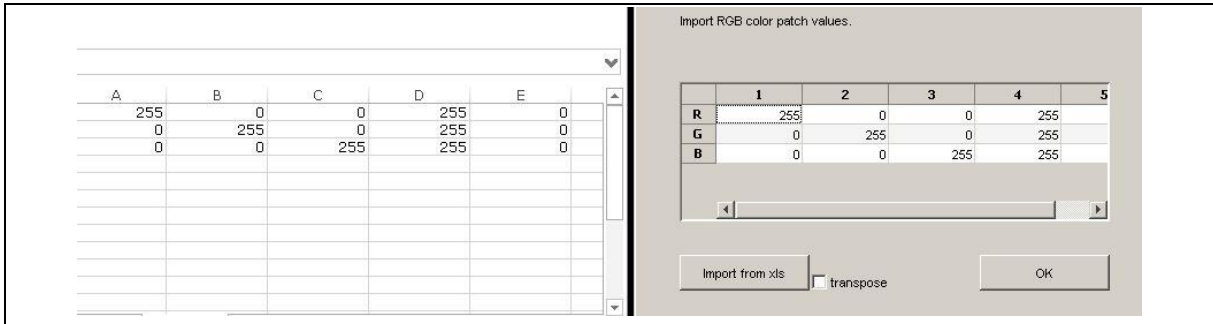
After clicking '**OK**' the Color patch window opens showing the color in the window and the RGB coordinates in its headline. Simply place this window in front of your measurement devices to measure it. The colors will be changed automatically after each device has properly performed the measurement. After all colors have been measured the color patch continues with the first color again, and cycles through.

Figure 18: Color patch window
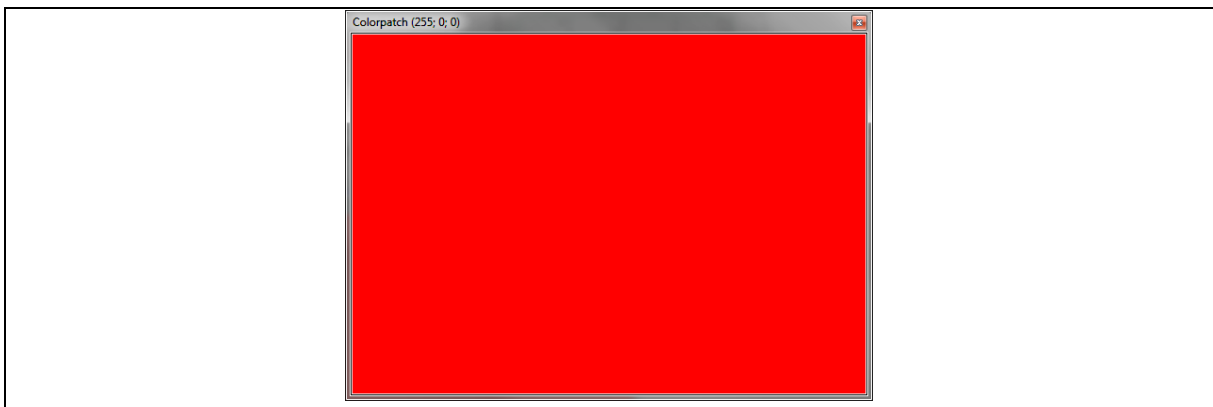
6.10 Calibration

In general a calibration procedure is used to match the target color values with the application specific usage of the C3 system, to obtain a nearly identical behavior of all measuring systems to another (compensate tolerances) and last not least it is essential that defined goals (reference values, operating conditions, light sources, etc.) are used to achieve the highest possible accuracy[21].

---

[21] Normally, after calibration of the measurement system accuracies are possible that surpass the minimum error of the True Color to CIE 1931 (e.g. better than human eye, Delta u'v '<0.003). However, the measurement accuracy depends on many factors such as calibration algorithm, calibration target, faults and external influences as well as from the used reference device.

Note: An absolute and accurate color measurement based on CIE1931 without calibration is not possible!

Traditionally reference values are measured via spectrometer or have to be known prior to the calibration process.

The calibration option is used to create a sensor specific calibration matrix via targets measured by a reference device such as a spectrometer. The standard calibration simply uses an identity matrix which approximates the color space values. Therefore it is recommended to calibrate the sensor in the configuration options for the specific application to get accurate results.

The results of a True Color sensor are XYZ coordinates that can be transformed into all shown color spaces. Please note that a performed calibration is only valid as long as the configuration of this application remains the same.

Note: Changing the amplification level, requires a re-calibration.

This section describes how to calibrate device with C3. For more details, like possible errors during the calibration process, target values for accuracy, variations in calibration, please ask our sales team for application notes or white papers.

Initially it is required to configure set goals for the calibration and to choose the reference values that need to be measured. The main variables are the number of calibration targets and observer (see colorimetric settings of your reference device). The usage of a spectrometer is optional if the XYZ values or the reference targets are known. If a reference device is connected all measurements are performed in parallel with a spectrometer and the sensor boards.

**Figure 19: Configuration of the calibration**
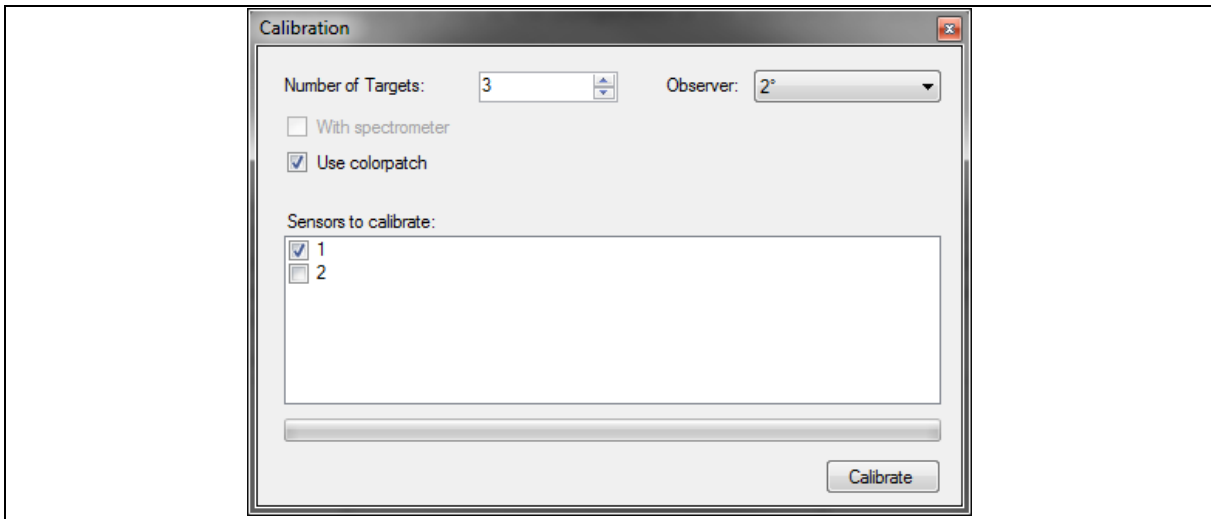
If the color patch is selected a window opens to insert the target values to calibrate directly on your screen. For further information please read chapter 6.9.

**Figure 20: Configuration of the calibration**
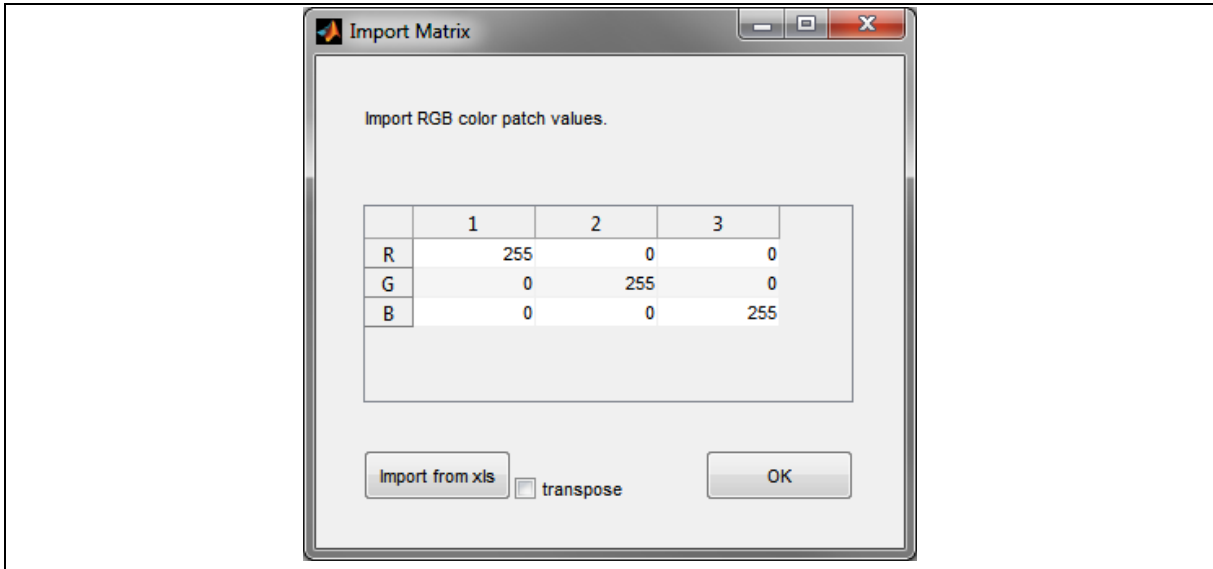
In the next step it is required to detect the dark current values of the sensor. The dark current I_{Dark} will be measured by the capsuled sensor. This step is but highly recommended to compensate the dark current of the photo diodes and will be needed for calculation photo currents for the sensor signals (as sensor response) and for the CIE1931 color points (sensor result).

Figure 21: Calibration – dark current measure request
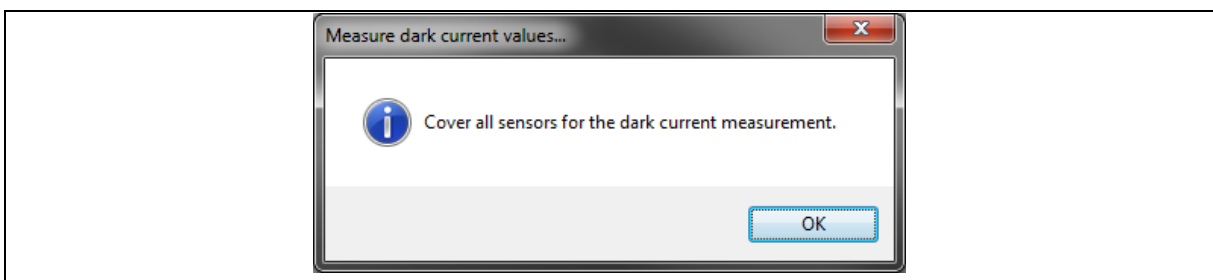
The software now guides the user through the calibration process and requests to setup and place the measurement devices. The following screenshot shows the activated color patch.

Figure 22: Calibration request to measure
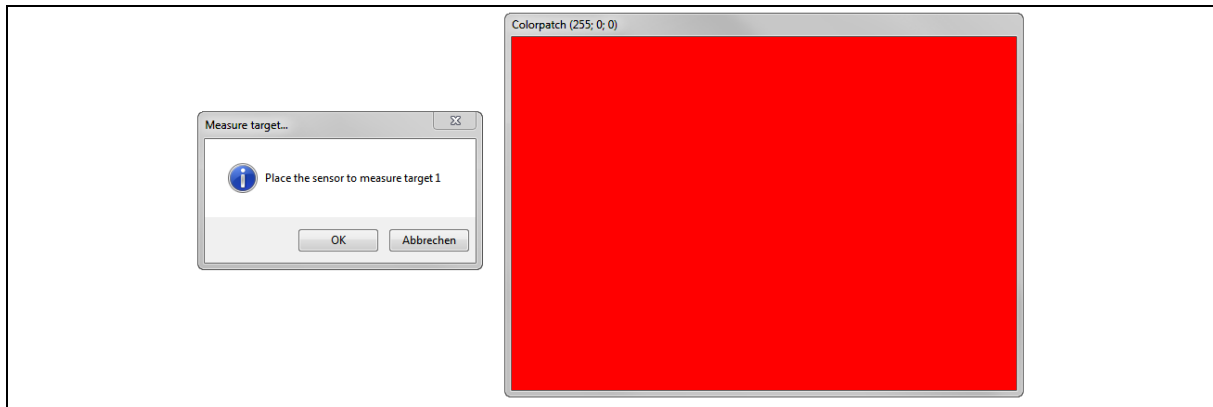
Finally, when all specified colors of the color patch (see chapter 6.9) are measured the next step is to import/insert the XYZ values of the reference device[22]. The reference values can be added directly in the window into the matrix or by importing them for example from Excel.

Note: The reference values need to be measured in parallel and under same operating conditions (room temperature, device position, etc.). Use the color patch on the same reference device otherwise the calibration is invalid and/ or inaccurate.

Note: The usage of a unity matrix (all diagonal "1") in the reference matrix means all sensor values are converted without reference/correction within the color space. These can be used for tests but are only approximate values. By using the diagonal values "1 1 2" the effect of the blue filter is increased.

Figure 23: Import / Insert XYZ reference values[23]

---
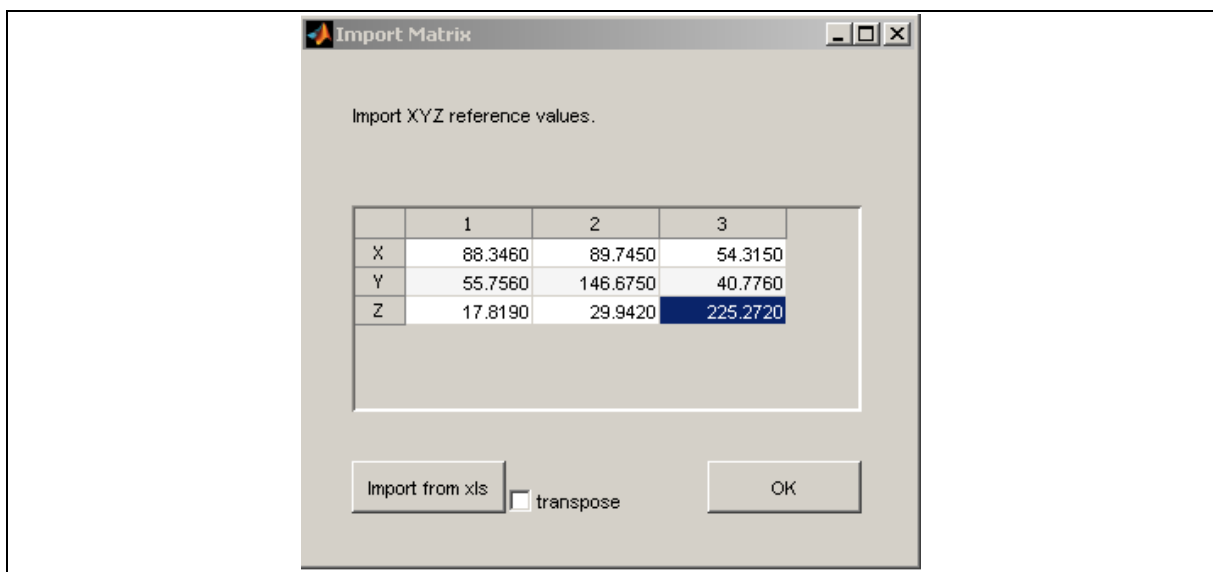
[22] This is not necessary if a supported device was connected during the calibration process.
[23] Please note the notation „." when entering point values.

After confirming the reference input values via '**OK**' button a message box appears and confirms the successful calibration. The calibration values are stored internally on the device and can be checked directly in the test software (see Figure 10) or via Excel export (compare chapter 6.4).

Figure 24: Extract of protocol .XLSX file with XYZ reference values, sensor data's and calibration matrix

Date	10-Mar-2015			
Time	06:41			
Calibration method	JC_MtcsLinRegrCalib			
Observer	2			
XnYnZn		100	100	100
deltaE 94 surface	Graphic arts			
deltaE CMC (lightness	01:01			
Calibration target #		1	2	3
optimized beta				
reference values	X	88,3464819	89,7452054	54,3157693
	Y	55,7656651	146,675995	40,776121
	Z	17,8193923	29,9422076	225,272459
adc values	adc X	0,31378292	0,33022888	0,21663299
	adc Y	0,18670194	0,49936408	0,16549533
	adc Z	0,02741634	0,04738051	0,38277485
adc offset	adc X	7,6587E-05		
	adc Y	0,0001372		
	adc Z	5,6382E-05		
Calibration matrix		288,787885	-9,6063718	-17,387257
		6,04631788	291,919636	-23,1077
		4,97601525	1,1439496	585,21393

Note: A calibration is valid for the used system and defined application. It is not required to re-calibrate until the system configuration or measurement parameters are changed.

For example changing the light source, target and distance to the sensor/object or the reference current require a re-calibration. Under normal usage after calibration the program configuration, e.g. integration time, the calibration remain the same.

7   Quick Start Guide

(Without using *Automatic gain* and *GEtPWM* function)

Step	Action	Basics	Result	Comment / Description
Initializing Test system	• Install software and drivers • Connect sensor boards via USB	Software and hardware are available, all system requirements are fulfilled	Installed software with one or more USB sensor(s) connected	See chapter 5
Setting / control parameters	Set *SynPeriod*	Depending on timing of the application	Found the ideal time management	SynPeriod must be suitable for your application (See chapter 6.1)
	Set *IntegrationCounter*	An ideal ratio between noise (digits) and brightness digits needs to be found (several thousands)	Optimal digits = high accuracy	Specify it as low as possible but so high as necessary(See chapter 6.5
	Set *Reference current* (gain)	Decrease until the digits are in a range with an excellent ratio between noise (digits) and brightness digits (several thousands)	Optimal digits = high accuracy	specify it as low as possible but so high as necessary (see chapter 6.5)
	Set *Divider*	To prevent the risk of saturation increase divider as long as the sensor is not in saturation otherwise decrease gain or IntegrationCounter	Optimal digits = high accuracy	If possible decrease amplification to prevent saturation, consider the divider in the signal calculation (see chapter 6.5)
Sensor calibration	**Dark measurement**	Consider electronically noise – needed to increase accuracy	I_{Dark} which correct sensor result ADC digit	see **Error! Reference source not found.**
	Option #1 Known target values	Use known XYZ values for the calibration target	Possible calibration for the existing target	see chapter 6.10
	Option #2 Spectrometer	Use an existing spectrometer which is supported by the test software of ams Sensors Germany	Possible calibration of any target	see chapter 0
	Option #3 Trial & Error	Use a virtual calibration via simple calibration matrix 1 0 0 0 1 0 0 0 2	No existing reference values and spectrometer	No absolute measurement, estimation values for relative color measurement

8   Example for Measurement

The combination of JENCOLOR® sensors and AS89010EQ converter is ideal to detect and measure colors, color temperatures or brightness of lighting signals. Typical applications are LED control and measurement and/or calibration of video walls and monitors. Below an example of typical accuracies for the latter is shown.

Please note, the results was achieved by a standard and application specific calibrated C3 SET DK (by using spectrometer and an optimized optical coupling sensor and spectrometer to the display). Measurements and calibration were done with a standard 21" display under laboratory conditions.

Figure 25 and Figure 26 show the results and accuracy after calibration. The red line in the figures is the target specification (see Table 5) and limitations for the single brightness regions (in cd/²). The blue points are the achieved measurements results and lie all inside the limitations.

Table 5: Target values for display measurements

Brightness (cd/m²)	0.1 - 1.5	1.5 - 3	3 - 10	10 - 60	> 60
Δu´v´ accuracy	< 0.03	< 0.01	< 0.005	< 0.003	< 0.003
Y accuracy (%)	10	3	2	1.5	1
u´v´ repeatability	< 0.006	< 0.004	< 0.002	< 0.001	< 0.001
Y repeatability (%)	4	0.6	0.4	0.3	0.2
Integration time	1s	1s	1s	0.5s	0.25s

Figure 25: Color accuracy of the example display calibration
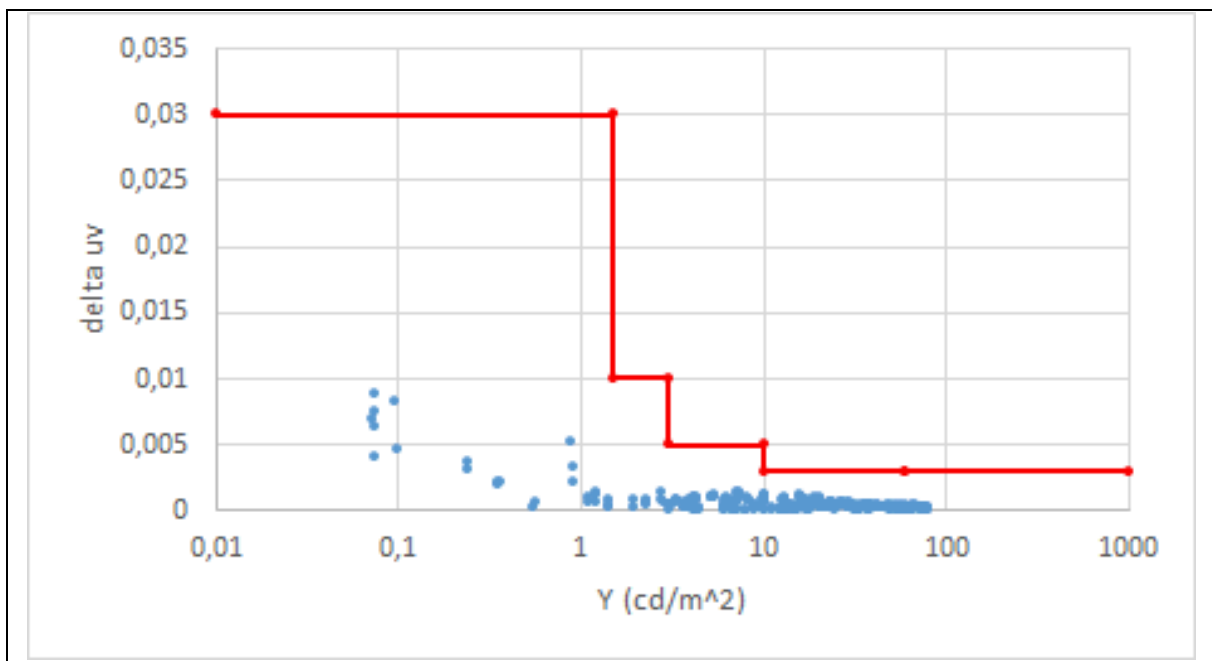
Figure 26: Luminary accuracy of the example display calibration
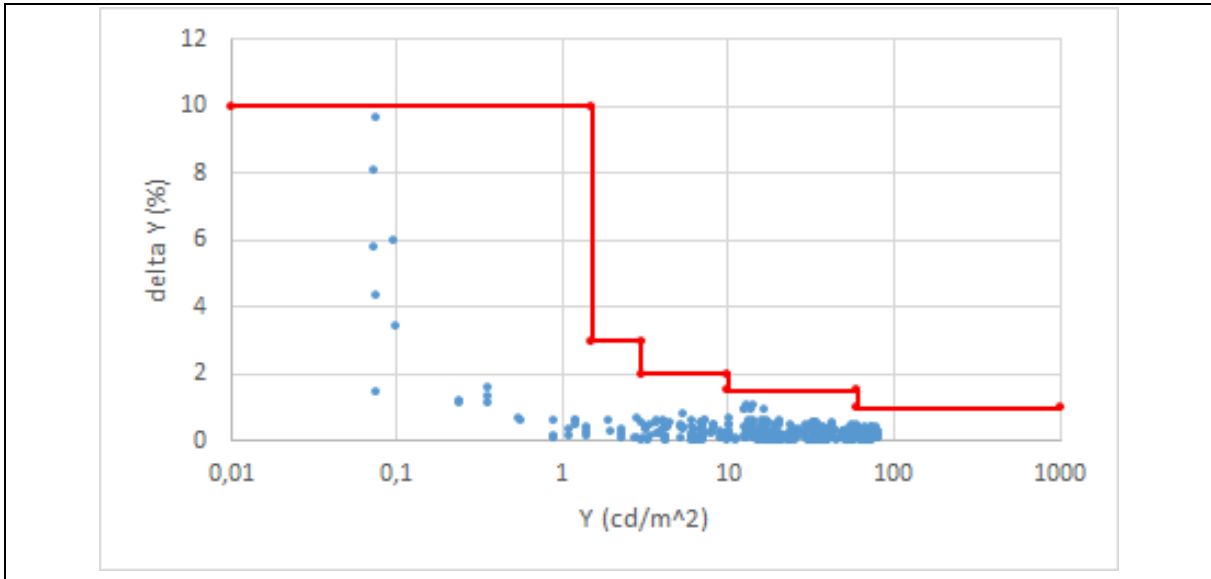
9   Troubleshooting

You have received a tested device that works reliably. Therefore, measurement errors are generally due to the test setup, faults, system incompatibilities or incorrect operation. For example, colorimetric results from a non-calibrated test system are not useful and faulty. The results after calibration depend on the process of calibration itself, the target (color normal) and particularly by the observance of the operating and ambient conditions. So please make sure that there are no drifts or interferences during the measurements. A change or deviation will inevitably lead to errors and may require recalibration.

In case of results, with unexpected sizes, negative[24,25] values or similar errors please check your test system reliability and consider all external influence parameters that take effect on the calibration matrix (see chapter 6.10). After optimization please test again. If you cannot solve the problem, please contact our sales team for further support.

9.1   Out of Range

There are two different out of range errors that can occur during measurements.

- Integration time is to long → decrease the integration time (SynPeriod or IntegrationCounter) or increase the divider
- Amplification is to high → set the reference current to a higher value.

Figure 27: Measurement values out of range
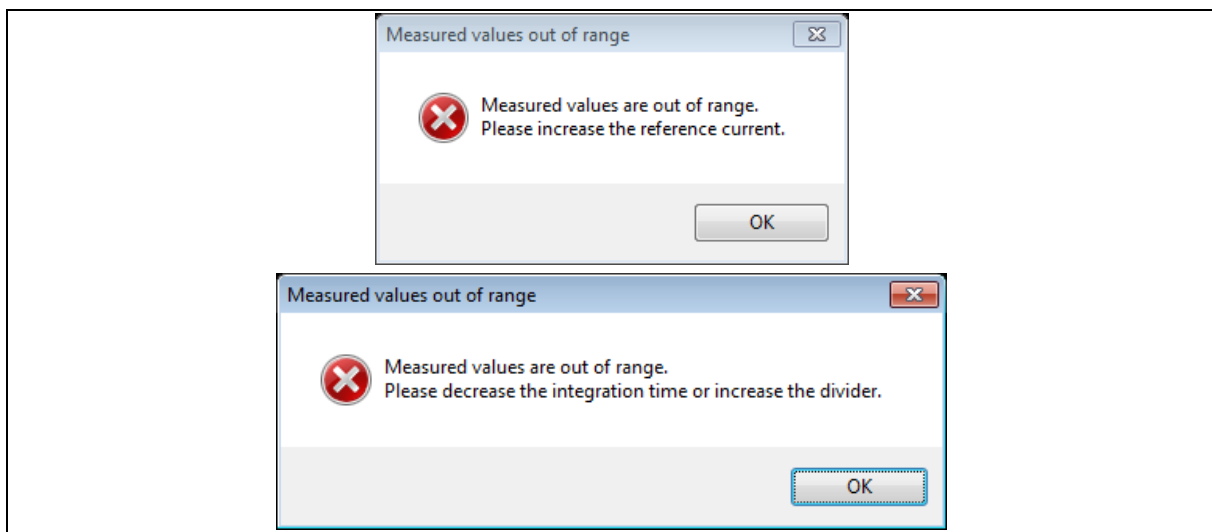
9.2   Measurement Timeout

The measurement is not completed in the specified time. The reason is a communication error to the sensor. Please check if the sensor is correctly connected to the computer. If the error persists, try to reconnect the sensor and restart the software.

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[24] A negative coordinate or a coordinate out of the color space indicates on errors in calibration and/or, interferences or changed conditions or measurement

[25] In exception negative results in photo currents are possible and indicate negative leakage currents (technological reasons) in low-energy measurements. In these cases, please use the method offset correction (see [1] OPTREG Register) and move depend on the Offset Value the workspace about the deficit balance per channel in the positive range.
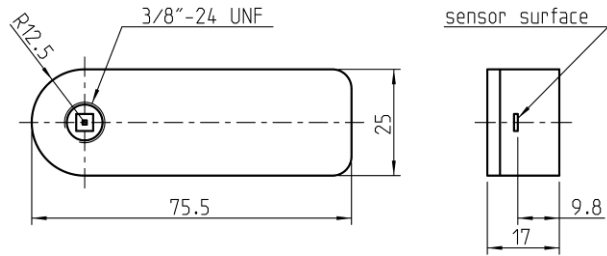
Figure 28: Measurement timeout
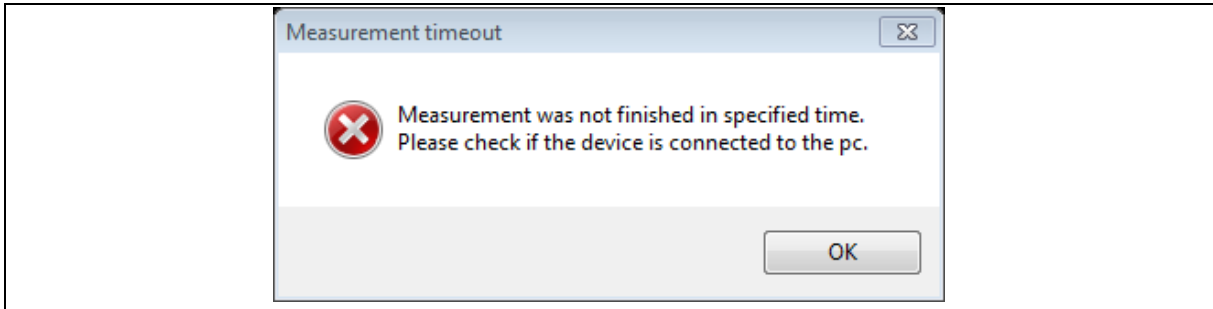
9.3   Known Software Messages & Crashes

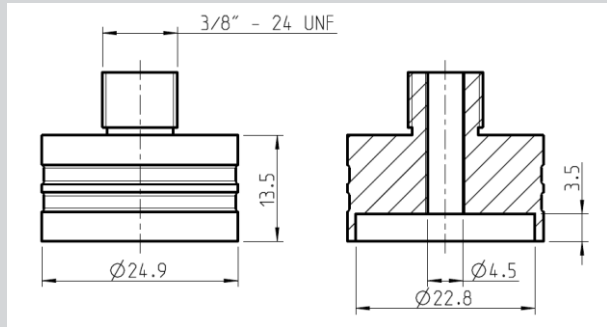| Error	Recommend activity
MWArray assembly failed to be initialized	
Error in mclFreeStackTrace	

10 Mechanical Sizes

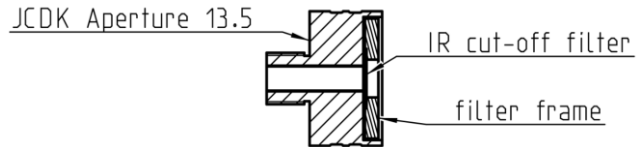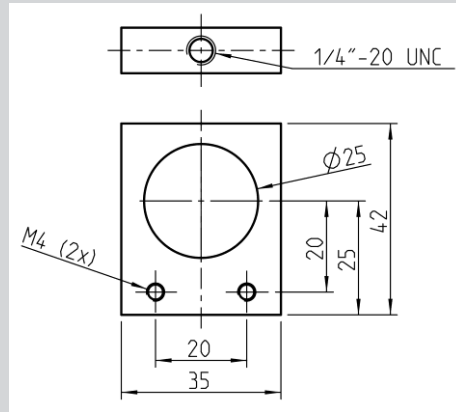**Figure 29: Dimensions of the package and adapters**
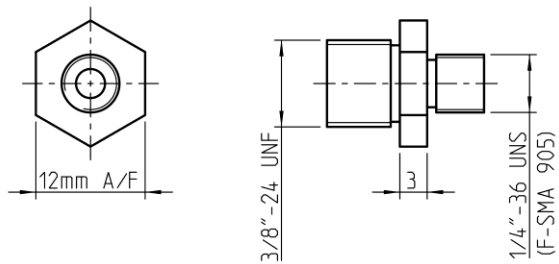
JCDK-Basic-C3

JCDK-Aperture-13.5

with IR-cut-off filter

JCDK-1/4"-Adapter

JCDK-SMA-Adapter

11 Software License Agreement

MATLAB®. © 1984 - 2015 The MathWorks, Inc.

12 Reference Documents

[1] AS89010EQ Converter datasheet
> http://www.mazet.de/en/english-documents/english/data-sheets/AS89010EQ/download

[2] AS73210 Sensor datasheet
> http://www.mazet.de/en/english-documents/english/data-sheets/AS73210/download

[3] EEPROM AT30TSE752 8751D–DTS–8/2012 Atmel datasheet
> http://www.atmel.com/Images/doc8751.pdf

[4] IOW24DG Converter I²C to USB
> http://www.codemercs.com

[5] C3 JENCOLOR® Sensor board with USB interface datasheet

[6] "C3 SET DK flicker" application note

[7] "C3 SET DK Optimized gain" application note

[8] DOC interface MTCS_C3 technical description

[9] C3_DLL_Interface Header of JENCOLOR® C3 Library DLL

13 Ordering Information

NAME	Status	Article
C3 SET DK	Development Kit	220790004
JCDK-Aperture-13.5 with IR-cut-off filter	Accessories	on request
JCDK-1/4"-Adapter	Accessories	on request
JCDK-SMA-Adapter	Accessories	on request

The Development Kits and OEM modules described here are only to be used for compatibility-, qualification tests, and verification procedures or as risks. They are not designed to be used in series products.

Please note, the OEM sensors and kits were designed to be a test system for usage in laboratories only. They are not suitable for outdoor applications or to as series devices for inline measurements. Do not use the device in any process control or in any other series applications!

Before using engineering samples for anything other than system tests, please ask our sales team for status and availability of series or customized system solutions.

14 Contact Information

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16 Revision Information

Changes from previous version to current revision 1-00 (2017-Jul-11)	Page
Initial version 1-00	

Note: Page numbers for the previous version may differ from page numbers in the current revision.

Correction of typographical errors is not explicitly mentioned.