AS73211 XYZ Color Sensor with High Dynamic Range

Evaluation Kit

AS73211-AB5 SET DK Eval Kit

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# Content Guide

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1 Introduction

This document describes the AS73211-AB5 based test systems of ams Sensors Germany, their housing, adapters and further information. The test system includes the OEM AS73211-AB5 sensor board, optional (Development Kit) fitted into a metallic housing with optical interface, a standard PC-to-USB converter as well as Windows PC software. The test software enables to control the converter, calibrate the sensor and allows data logging options including an export out of results. Please note, the Development Kit in any form was designed to be a test system for system and application tests.

The OEM sensor board AS73211-AB5 is a small PCB for general color measurement and control applications, with a high bandwidth for light energy and handheld applications. The sensor board includes the AS73211 XYZ color sensor with a high dynamic range and on-chip temperature sensor, an EEPROM for sensor data and a LDO micro power regulator to manage the analog and digital supply voltage. I²C is used for external communication, configuration of the sensor, readout of the sensor data as well as writing and reading of the memory. A standard I²C-to-USB converter IOW24-DG (see 'IOW24DG Converter I²C to USB', technical details, www.codemercs.com) realizes the PC connection. The PC software is only valid for Windows based systems.

Figure 1:
Block Diagram AS73211-AB5 Development Kit

The following document describes the Development Kit and especially its hardware and software setup and usage for a Windows PC. Before the Development Kit is connected to the PC, make sure that all libraries, driver and the test software are installed on PC. Otherwise, the test software starts in a demonstration mode and does not make real measurements.
1.1 Kit Content

The AS73211-AB5 Evaluation Kit includes alternative delivery forms with the following standard elements:

- Housed sensor board DK AS73211-AB5 (or OEM PCB)
- Setup for PC test software including setup for MATLAB™ Compiler Runtime, not for OEM version
- I²C and/or USB cable with USB converter, not for OEM and/or optional
- Optical cover for realize angle of incidence, not for OEM and/or optional

Alternative IO-Warriors and libraries are available for customers wanting to integrate the kit into own software and system environments.

The following table shows the scope of delivery of alternatives:

**Figure 2:**
**Scope of Delivery**

<table>
<thead>
<tr>
<th>Name</th>
<th>AS73211-AB5 SET DK</th>
<th>AS73211-AB5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article No.</td>
<td>220810004</td>
<td>220810002</td>
</tr>
<tr>
<td>Sensor-IC AS73211</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Interface</td>
<td>I²C / USB via dongle</td>
<td>I²C</td>
</tr>
<tr>
<td>PC Windows Test Software</td>
<td>O</td>
<td>---</td>
</tr>
<tr>
<td>Housing / Adapter</td>
<td>O / O</td>
<td>---</td>
</tr>
<tr>
<td>Aperture</td>
<td>O</td>
<td>Optional</td>
</tr>
<tr>
<td>Optical Cover</td>
<td>O</td>
<td>Optional</td>
</tr>
</tbody>
</table>

O included     --- not available

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 against mechanical stress as well as ESD and EMF. The sensor AS73211 is in the basic case coaxial with a 3/8”-24 UNF internal thread and ready for the application of different optical accessories.
There are difference adapters ‘Aperture’ available to adapt the angle of incidence for the sensor in the package and/or to fix the sensor in the housing.

The JCDK-Mini-Aperture is to limit only the angle of incidence on the AS73211 to ±10°. It is the smallest aperture of the JCDK assortment. The JCDK-Mini-Aperture belongs to the delivery contents of the sensor board.

The JCDK-Aperture-10 is to limit the angle of incidence on the AS73211 to ±10°. It is an optional aperture of the JCDK assortment and characterized with a single groove outside. The outside diameter of 25 mm makes it compatible with JCDK-1/4'-Adapter and opto-mechanical system parts (e.g. Linos opto-mechanical systems). In front of the aperture is space for mounting a filter glass with outside diameter up to 22.2 mm and thickness up to 3.5 mm.

JCDK-1/4'-Adapter is for mounting the DKs on a camera tripod or equivalent holders. On the bottom side there is a centered 1/4'-20 UNC internal thread and 20 mm below the optical axis there are two M4 internal threads for mounting the JCDK-1/4'-Adapter on a flat surface. Order the JCDK aperture 10 with inserted IR blocking for IR sensible applications.

A fiber optic cable with F-SMA 905 plug connects the Development Kit via JCDK-SMA-Adapter. The distance between end of fiber and sensor is calculated to achieve an angle of incidence of 10°. It is recommend to use it with a fiber core diameter up to 600 µm. Minimum numerical aperture (NA) for illumination of the whole sensor area is 0.22. The case numerical aperture should not exceed 0.39 to reduce the effect of stray light inside the adapter.
## 2 Ordering Information

<table>
<thead>
<tr>
<th>Ordering Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS73211-AB5 SET DK</td>
<td>Development Kit; Article 220810004</td>
</tr>
<tr>
<td>AS73211-AB5</td>
<td>Series Article; 22081002</td>
</tr>
<tr>
<td>JCDK-Aperture-10</td>
<td>Accessories Article; 220560004</td>
</tr>
<tr>
<td>JCDK-Aperture-10 with IR-cut-off filter</td>
<td>Accessories Article; 220560001</td>
</tr>
<tr>
<td>JCDK-1/4'-Adapter</td>
<td>Accessories Article; 220560002</td>
</tr>
<tr>
<td>JCDK-SMA-Adapter</td>
<td>Accessories Article; 220560003</td>
</tr>
</tbody>
</table>

This Development Kit and OEM module is only for compatibility-, qualification tests, and verification procedures or demonstrations. It is not designed for use as serial products and/or measuring instruments.
3 System Requirements

For start-up procedures, the following system resources are required:

- PC Pentium 1 GHz or higher
- 512 MB RAM
- 1x free USB (2.0) port
- 80 MB free hard drive memory (+ approx. 1.3 GB for MATLAB™ Compiler Runtime)
- Microsoft Windows™ 7 and above
- (optional for import/export functions) Microsoft EXCEL™
- Internet connection and administration right for runtime and software installation
4 Technical Data

4.1 Working Parameters

Spectral range: 380 nm ... 700 nm
Measuring method: XYZ CIE 1931 standard (user calibration necessary)
Measuring values: ADC digit; ADC current; XYZ; Yxy; Yxy SDCM; Yuv
Gain (reference currents): Selectable 5 nA ... 1024 nA (12 stages)
Integration time: Selectable 1 ms ... 16 s (15 stages)
Digital electronic resolution: 16-bit ADC output by using divider for 24 internal bits
LSB min lux: 0.00043
FSR min lux: 28.17
FSR max lux: 115400.68
Dynamic range: 1 ... 250000000
Power supply: USB powered
PC interface: USB 2.0 full speed
Weight: 58 g plus adapter ca. 5...10 g
Operating conditions: Temperature 0 ... 85 °C
Humidity: 85 % relative humidity at 35 °C

4.2 Maximum Parameters

Figure 4: Maximum Parameters

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment</th>
<th>Unit</th>
<th>Value Min</th>
<th>Value Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS</td>
<td>Storage Temperature</td>
<td>°C</td>
<td>-25</td>
<td>100</td>
</tr>
<tr>
<td>TB (functional)</td>
<td>Operating Temperature</td>
<td>°C</td>
<td>-25</td>
<td>100</td>
</tr>
<tr>
<td>Power Supply</td>
<td></td>
<td>V</td>
<td>3.3 V -5%</td>
<td>5 V +10%</td>
</tr>
</tbody>
</table>
5 Hardware Description

5.1 Overview

Figure 5: Overview of Essential Components and Parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>AS73211-AB5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color sensor</td>
<td>True color XYZ sensor detection comparatively as CIE1931 / DIN5033 for sensitivity and gain</td>
</tr>
<tr>
<td>Temperature sensor</td>
<td>On ASIC - AS73211</td>
</tr>
<tr>
<td>EEPROM</td>
<td>4 kByte, addressable via I²C</td>
</tr>
<tr>
<td>Electronic interface</td>
<td>Fitted standard I²C 400 kHz – for communication</td>
</tr>
<tr>
<td>Optical interface</td>
<td>Plastics aperture (to click on board) to realize angle of incidence</td>
</tr>
</tbody>
</table>

Figure 6: PCB Overview (Front and Rear Panel)
Figure 7:
PCB Dimensions (Front and Rear Panel)

Test points
P9  GND / Pin 2/4/6
P10  RDY / Pin 1
P11  SDA / Pin 7

P12  SCL / Pin 5
P13  SYN / Pin 3
P14  +UB / Pin 8
P15  GND / Pin 6/42
5.2 Schematic

Figure 8: Schematic of Reference Design
5.3 True Color Sensor Function on Chip

The sensor exists from photodiodes with XYZ (comparatively as CIE1931) coated interference filters. The diodes are square segments at the position in the center of the sensor element.

Each of the photodiodes on chip is sensitized with True Color-like (preferably for the color standard\(^1\) CIE 1931 - Commission Internationale de l'Eclairage or International Commission on Illumination) dielectric XYZ spectral filters. The used interference filter technology guarantees high transmission in the band pass range, a very low rest transmission, resistant to aging effects and long-term stable against mechanical and temperature influences during processes. The sensors must be calibrated to get highest color accuracy because small tolerances in manufacturing, non-conformity of CMOS sensitiveness according to the standard observer function and the necessary color matching results deviations from device to device or in lots.

Figure 9:
Typical (relative) Sensitivity (XYZ) of the Color Sensor\(^{(1)}\)

\( S \) (A/W)

350 400 450 500 550 600 650 700 750 800  
\( \lambda \) (nm)

(1) Scanned by Width Broadband Light and Limited Angle of Incidence (<10°)

5.4 Current-to-Digital-Converter

The AS73211 includes a low power and a low noise current-to-capacity-to-digital converter. Three of such channels convert the light signals of photodiodes to a digital result and realize a continuous or

\(^1\) For more details see http://en.wikipedia.org/wiki/CIE_1931_color_space
triggered measurement. The irradiance responsivity can be set in a range of 12 steps by a factor of 2 for each step. The conversion time is internally controlled over a wide range of 15 steps by a factor 2 for each step. Optional, the conversion time can be set externally via input pin SYN to adapt the measurement to the given environment and time base. These features allow the sensor a perfect using in applications of color measurements in a huge range of input light intensity.

With its irradiance responsivity factor and conversion time, sensor board supports a dynamic range of 1-to-250,000,000 and achieves an accuracy of up to 16-bit (internal 24-bit) signal resolution with an irradiance responsivity per count down to 0.0005 pW/cm².

The sensor board solution also includes an inherent ripple rejection of the 50 Hz/60 Hz external disturbances. It is designed to ensure high accuracy at high sensitivity offering high robustness. Automatic Power Down (sleep function) between subsequent measurements offers operation with very low current consumption. Further, it offers a wide range of irradiance responsivity (0.034 counts/(µW/cm²) to 2.1e6 counts/(µW/cm²)), conversion times (125 µs to 16.384 s) and synchronized mode and other control modes adjustable by user programming. The conversion data can be accessed via 16-bit/400 kHz fast mode I²C interface with programmable slave addresses. The measurement of the actual conversion time can be performed for an external triggered measurement.

The supported operating modes of the AS73211 are:

- **CMD Mode** – Single measurement and conversion (controlled via I²C interface),
- **CONT Mode** – Continuous measurement and conversion (periodically recurring measuring cycles) start and stop controlled via I²C interface,
- **SYN[x] modes** - Synchronized measurement and conversion:
  - **[SYNS Mode]** synchronization of start via control signal at pin SYN,
  - **[SYND Mode]** synchronization of start and stop of measuring cycles via control signal at pin SYN.

**Figure 10:**
Block Diagram AS73211
The settings of the irradiance responsivity and conversion time are not affected by the measurement modes but affects directly the sensitivity, numbers of digits, ratio between noise and signals and last not least the accuracy of the sensor system.

The digital values for Setup and all results of the ADC are stored in registers. The communication between sensor and PC User Interface is via I²C (plus USB Serial Com Port). A temperature sensor on chip can be used to read-out the chip-temperature during the color measurements.

An external reference resistor determines the internal reference current for the converter.

For more details, see also the sensor’s data sheet and/or later chapters in this document.

5.5 Power Supply

The sensor board is supplied with voltage via the standard connector. A series regulator on board (type LTC1844ES5-BYP) provides the internal operating voltage of 3.0 V. It is able to move in the range between 3.3 V -5% up to 5 V +10%. Filter supplies the analog and digital components.

5.6 Hardware Interface and Test Points

The connector X1 is used for external power supply and communication. Examples of an adequate connector are 6903 6728 08 67 from Würth Elektronik. The counterpart is 6901 5700 08 72 from Würth Elektronik. A flat cable with grid dimensions of 1.27 mm is used as an interconnector. The maximum length is 0.5 m.

As a contacting option, X2 use a ZIF connector with 0.5mm pitch (e.g. FH12-8S-05.SH from Würth Elektronik) at the end of the backside. A further possibility for connecting is the use of the contact pads P9 to P14 (related test points).

**Figure 11:**

**PIN Assignment X1 and X2 and Test Points**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Label</th>
<th>Type</th>
<th>Function</th>
<th>Related Test Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RDY</td>
<td>out</td>
<td>Ready signal AS89010</td>
<td>P10</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td></td>
<td>Ground</td>
<td>P9</td>
</tr>
<tr>
<td>3</td>
<td>SYN</td>
<td>in</td>
<td>Trigger AS89010</td>
<td>P13</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td></td>
<td>Ground</td>
<td>P9</td>
</tr>
<tr>
<td>5</td>
<td>SCL</td>
<td>in</td>
<td>I²C, serial clock input</td>
<td>P12</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td></td>
<td>Ground</td>
<td>P9</td>
</tr>
<tr>
<td>7</td>
<td>SDA</td>
<td>in/out</td>
<td>I²C, serial data</td>
<td>P11</td>
</tr>
<tr>
<td>8</td>
<td>VDD</td>
<td></td>
<td>Supply voltage</td>
<td>P14</td>
</tr>
</tbody>
</table>
The amplification circuitry and memory consist of a joint I²C interface. The soldering bridges J1 and J2 allow individual addressing, which offer the possibility to have a parallel connection of up to four sensor boards (based on the EEPROM AT30TSE754).

**Figure 12:**
Addressing via Solder Bridge

<table>
<thead>
<tr>
<th>AS73211-AB5 Board</th>
<th>Jumper J3 (A1)</th>
<th>Address A1</th>
<th>Jumper J2 (A0)</th>
<th>Address A0</th>
<th>I²C-Address S73211</th>
<th>I²C-Address EEPROM</th>
<th>Temperature Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (default)</td>
<td>1-2</td>
<td>0</td>
<td>1-2</td>
<td>0</td>
<td>xE8h</td>
<td>xA0h</td>
<td>X90h</td>
</tr>
<tr>
<td>2</td>
<td>1-2</td>
<td>0</td>
<td>2-3</td>
<td>1</td>
<td>xEAh</td>
<td>xA4h</td>
<td>X94h</td>
</tr>
<tr>
<td>3</td>
<td>2-3</td>
<td>1</td>
<td>1-2</td>
<td>0</td>
<td>xECb</td>
<td>xA8b</td>
<td>X98b</td>
</tr>
<tr>
<td>4</td>
<td>2-3</td>
<td>1</td>
<td>2-3</td>
<td>1</td>
<td>xEEh</td>
<td>xACh</td>
<td>X9Ch</td>
</tr>
</tbody>
</table>

### 5.7 Optical Interfaces

The spectral filters of **ams** Sensors Germany’s color sensors are specialized for applications with a broadband source of lighting >10 nm. Therefore, the sensor is only conditionally suitable in combination with narrowband luminous sources.

Based on the packaging, the sensor IC has an aperture angle (beam width) of nearly 90°.

> By nature of physics, interference filters work depending on the angle of incidence. Therefore, a diverted light beam with altered vertical angle up to 10° will not cause a filter shift, which results in deviations. Make sure that the angle of incidence to the sensor device is less than 10° by using lenses, optical holes or casings. For initial operation tests **ams** Sensors Germany offers an aperture cover plate. This simple construction can be attached onto the sensor board.

The section around the color sensor AS73210 is 9 mm wide and was designed especially to fit the mentioned ‘Optical cover’.
This optional optical cover on the circuit board is to limit the angle of aperture / incidence (max. ±10° of vertical beam). A special contact surface connects the optical cover to the circuit board. Therefore, a 2 mm spacing area around the connector and sensor exists. Additionally, two notches are included for equipping a casing.

Another delivery form of the sensor board inserts an alternative optical interface like described here. The following figure shows the mechanical package of the development kit, which includes an alternative optical interface, as well as ESD protected casing.
6 Software Setup

6.1 Setup

Administration permission are needed during process, installation, and work.

The SETUP must be start with the special option ‘run with administration rights’.

The installation process also requires a working internet connection to connect to MATLAB-specific system requirements. Please check your system configuration in Windows System Control for the Internet connection and right settings.

Before you start the SETUP file for the test software check whether the actual MATLAB Compiler Runtime (MCR) 8.2 version (standard installation by MCR_R2013b_win32_installer.exe) is installed on your PC. If MATLAB Compiler Runtime library is not on PC then follow the special instructions in the setup process for MATLAB.

To start the installation test software and GUI, execute the setup.exe file from the USB stick or other memory, which you got. Then all required files are installed automatically. The setup opens a window, which guides the user through the installation systematically.

The setup software checks the installed MCR version. If the version is incorrect the setup attempts to download the correct MCR via internet. If your internet connection requires a proxy server, configure the server using the ‘Connection Settings’ button.

Figure 15:
Setup - Connection Settings

Click ‘Next’ to specify installation options, set the installation path and add a shortcut to the desktop. The installation folder will include the program and data files in several directories.
Figure 16: Setup - Destination Folder

Setup will check the installed MCR version after clicking 'Next'. If the correct version was installed just click 'Next' at the following screen. Otherwise, setup attempts to download the correct version via internet and installs it.

Figure 17: Setup - MATLAB Compiler Runtime Version
Figure 18:  
Download Required Compiler Runtime and Confirm MATLAB License Agreement

In the next screen, there is the option to confirm the MathWorks License Agreement.

Figure 19:  
Setup - Start Installation
The software will be installed into the shown destination folders after confirming via ‘Install’ button.

Figure 20:
Setup - Installing

![Setup - Installing](image)

The installation is ready after confirming via ‘Finish’ button.

Figure 21:
Setup - Installation finished

![Setup - Installation finished](image)

6.2 Remove

Use the windows system setup ‘Add or remove programs’ to uninstall the software.
Figure 22:
Setup - Remove Program

Press 'Uninstall' to delete the complete software package. You may be required to remove manually some files remaining in the installation of the software.

〉 Attention: Create a backup of your own created files (sensor data and measurement results) that are located within the installation folder.
7 Software Description

7.1 Software Start

Use the standard icon to start the software. The ‘Main window’ from the software is opened to set parameters and select the software functions.

Another variant to start the software with specified parameters is to expand the start command in the property menu of the program shortcut by a pre-defined configuration file, which must be added to the software name in the target.

See the following example for a complete text in the target filed of the property dialog to start the software:

‘……. MTCS_INT_AB5.exe’ ‘command example.csv’

Figure 23:
Standard Properties of the Installed AS73211-AB5 Software

In the ‘Main window’ of the test software, the main setup for the measurements e.g. integration time, reference currents and divider must be selected before the measurement process will be started. This
parameter and function can be done via user interface and manually or use alternative the function ‘Load configuration file’ to specify all. Some examples of such predefined specification files are installed automatically during software setup in the directory ‘….Test Software AS73211-AB5\application.

7.2 Main User Interface Elements

After successful installation and running software, the user interface always starts in ‘Expert Mode’ and includes different possibilities (button, menu bar, dropdown menu) to change the parameters for measurements (Configuration), to select form of outputs (Diagram), and to control the next program steps (Measurement, Calibration).

Figure 24:
Main User Interface Elements in Expert Mode

Configuration: User can change direct the most important parameters. It is possible to initialize and control the measurements direct in the main windows or by an initializing file.
Integration Time [ms]: determines the conversion time of the ADC. The higher this time is the better the accuracy (higher number of bits). Set and increase the Integration time based on your application specific timing but avoid saturation. Please note, only the internal clock frequency of 1 MHz is using in the test system although the AS73211 supports as chip alternative and higher frequencies. Therefore, in customized designs the sensor can be adapted on application specific frequencies which results higher integration times and a higher sensitivity.

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

Divider: Is used to expand the measurement ranges and to prevent partly saturation. The AS73211 uses internal 24 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 24 bits to 16 bits. Therefore, use 'Divider' in case of very strong signals to avoid saturation and to get a higher sensitiveness with the compromise of losing lower bits.

After pressing the ‘Measure’ button, the test software starts a measurement with the selected initialization. Based on the selected mode, the measurement will be performed sequentially by command after each click and/or in continuous mode until pressing button ‘Stop’. For realization, the software use only the CMD/CONT modes of the AS73211. User can control directly the sensor system by selecting the parameters of the sensors ADC converter like Integration Time, Reference Current and Divider parts and gain. If an initialization via a *.csv-file was selected then configuration shows the actual selected parameters of *.csv file.

Calibration: Use this button to start the calibration process. As long as no calibration is 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. A change in the configuration parameters changes the status of the calibration back to invalid (red) if the parameters differ from the setting used for the calibration.

Diagram: The representation of the measured data and a table for the data output of the measurements can be enabled / disabled and adjusted.

Measure Reference: A (reference) measurement is started with the selected parameters.

Clear: Deletes all measurement values and closes the Color space window. It does not delete any register settings.

Status: The status window shows important steps performed by the program and I²C status is logged.

In the Menu Bar different functions for the initialization of the program, parameters and/or data input / output are listed.
Load/Save: In ‘Load’, an initialization file for the gain parameters can be read (‘Load Config’). ‘Load Config and measure data’ will restore a saved session file (*.dat) with all gain parameters, calibration and measured data’s of a last session. In ‘Save’ the entry ‘Save Config and measure data’ saves all data of the actual session in a *.dat file and ‘Export…’ writes all configuration data’s and the measured results in a *.xls or *.csv file.

7.2.1 Easy Mode

The ‘Easy Mode’ is designed to be as simple as possible using only limited functions. It can be set manually in menu bar as shown in the following picture in case the expert mode is active.

Figure 25:
Menu Bar - Easy Mode

Figure 26:
Main User Interface Elements in Easy Mode

To configure the device in the ‘Easy Mode’, it is usual to load a predefined configuration *.csv file or a full session file (*.dat) including configuration, calibration and measurements.

After pressing the ‘Measure button’, a color chart appears with the selected diagram, which shows the measured values of the sensors. Using a command based configuration file, clicking generates one new measurement value (in command mode) or continues measurements (in continues mode) until the stop button is pressed. The result(s) of the measurement(s) are shown in the selected form as line diagram, diagram color space window as a figure, or, if activated, in a data table under the figure. The following example shows the color space Yxy.
All results are based on the ADC counts from the output registers MRES1 … MRES3 (ADX or X are the output values from MRES1) and represents either RAW or corrected and/calculated values.

All calculated values are only correct when conditions are meet, as determined by the application (e.g. Lu’V’ results needs a sensor calibration before or are not useful).

After starting the program, this ‘Data table’ is not activated automatically to increase the speed of the measurements. If Data table is activated then the result of the measurement is always displayed in the first line.

The number of measurements is always shown in row one.

**Figure 27:**
Measurement Values – with Selected Yxy Diagram and Selected Data Table

### 7.2.2 Expert Mode

The ‘Expert Mode’ offers further options like a reference measurement, sensor calibration, and a detailed I²C status report. The ‘Expert Mode’ can be activated similar to the Easy Mode via menu button ‘Mode’.
7.3 Basics for Measurements

Each ADC value (Analog-Digital Converted value) is calculated to a photocurrent ('photocurrent_nA') under consideration of a reference current ('refCurrent_nA'), integration time ('nClck') and a digital divider ('divider'). These steps are performed before this value is used for any calibration or colorimetric functions. The following virtual code is used for each sensor channel value - wherein the ADC is the digital 16-bit read out value:

% Correction of bit shift (register CREG2)
% divider = 1 (off), 2, 4 ... 256
Adc = Adc * divider;
% Calculation of the maximum number of clocks nClck
% intTime_ms is the integration time in milliseconds (register CREG1)
% note: the following is only correct for a clock frequency of 1.024MHz (register CREG3)
bit = 10 + log2(intTime_ms);
nClck = 2^bit;

% Check of saturation
sat = nClck - 1;
if sat > 65535
    sat = 65535;
end
if Adc >= sat
    % Error! Sensor channel is saturated!
else
    % Measurement is ok.
end

% Calculation of photo current in nano ampere using the reference currents (register CREG1)
photocurrent_nA = Adc * refCurrent_nA / nClck;

A detailed description of the sensor signal calculation is included in the data sheets of key components, white papers or application notes.

To perform absolute color measurements or for further evaluation of the results in any color space, the sensors system must be calibrated to the specific application or test setup. Please ensure that all continuous processes, measurements and the calibration procedures are performed based on same conditions. Avoid disruptions (e.g. ambient light, NIR, temperature, EMV, mechanical drifts and shocks, fouling, humidity), effects, and drifts and optimize the test system to be stable.

These aspects refer to the DUT (device under test), distances between DUT and sensor as well as all initialization and environment conditions. The sensor, selected illumination and target are used in a closed system for calibration and measurement procedures. A new calibration is required if you change any conditions inside this closed system.

### 7.4 Calibration

The calibration option is used to match the sensor results into an application. The basics for a calibration are a calibration target, a reference device, and algorithms to get the correction values and to correct sensor results. Each calibration will be done under its specific conditions, which must be observed also in time of sensor corrections. Otherwise, calibration and correction cannot be successful.
A standard calibration simply uses an identity matrix, which approximates the color space values based on the CIE1931 Color Standard. This standard is valid under the ‘Luther’ conditions, which are set and described in industrial and scientific standards. This section describes how to calibrate the device by using this GUI.

First, set the observer with which the reference values are measured (see colorimetric settings of your reference device alike a spectrometer or others).

Figure 29:
Calibration - Observer

Then choose whether the calibration matrix should be inserted manually or to measure it.

Figure 30:
Calibration - Targets Measure or Manually

After choosing Import, the calibration matrix and offset values must be inserted e.g. from an Excel sheet like shown in the following figure. Just select the cells for import and press the button Import from xls.
Then, the dark measurement offset values for the sensor must be imported.

When choosing the Measure option, it is required to enter the number of calibration targets to be measured. The minimal amount of targets is the number of sensor channels. Therefore, the sensor board uses at least 3 targets.

Next, the software requests to cover the sensor for an offset measurement. After this following the software performs measurements for each target and guides the user through the process systematically.
In the final step, the software requests to insert XYZ values of the calibration targets measured by a reference device. It is possible to save the results of the calibration process into a special owner configuration file.

If any support during the sensor calibration is needed, please contact our sales team.

A calibration is valid for the used system in its application and under the defined conditions. A new calibration is only required in case relevant system configurations, parameters or conditions for measurement were changed. Such changings can be correctable effects within one calibration like (gain + integration time – use the basic counts as result which is not depending on the ADC parameter setup, temperature – use a look-up-table to correct temperature drifts) or effects without possibility of correction within one calibration. In this case, more than one calibration based on the effects must be used.

After changing the configuration file, the software always tests the specified parameters if a re-calibration is necessary. Then it shows the message ‘No calibration loaded’ or ‘Calibrated with different settings’. In this case, the calibration must be performed again to achieve exact results.
The software tests only known parameters of the test software and cannot check if any external conditions in the test system were changed. Ask our sales team for support during the calibration process or if you do not get the intended results after calibration.

7.5 Load/Save Menu

The ‘Load and Save’ menus provide the option to ‘Load’ and ‘Save’ the configuration, calibration and measurement values in a file with the extension ‘.dat’ (‘Load config and measure data’; ‘Save config and measure data’). To only load a configuration of the sensor, use the Load config menu entry. This allows to load a ‘.csv’ (‘.csv – comma separated values’) configuration file. The ‘Save’ menu also offers an extra feature to export measurement values to ‘.csv’ files or the actual sensor configuration and measurement values to an Excel file (‘.xls’) for further usage. This data can be used for comparison or for statistical calculations.

The export to Excel is only available if Excel is properly installed on your local PC.

Figure 35:
Menu - Load and Save

7.5.1 Configuration Files (*.csv)

The Configuration File (‘.csv – comma separated values) contains all important information about the measurement and configuration behavior. Such files are used for application-specific adjustment of the test board and/or compatible boards. In the installation path of the test software, samples are shown for a configuration file, e.g. ‘command example.csv’.

Processing the *.csv-files is possible with a standard text editor, Open Office Software or MS Excel. However make compliance with the syntax and the extension *.csv when saving. Otherwise, errors will occur during software operation. Figure 36 indicates all relevant syntax, columns and register commands. All grey highlighted columns are comments or user information with no conditions for syntax except for the use of the separation of characters like ‘,’ or ‘;’. In case of using sensors a changing of the line with the keyword ‘ChannelOrder’ is not necessary because the filter set was pre-defined. On the other side, by using alternative sensor boards the channel order must be adapted based on the special configuration. Check the installation or support files like readme.txt or data sheet for more details.
To use a configuration file, select the file and load it by mouse click. Then the parameters inside the files specified will be used.

Figure 36: Command Example.csv

<table>
<thead>
<tr>
<th>STATE</th>
<th>INFO REGISTER</th>
<th>INFO DATA</th>
<th>COMMENT</th>
<th>R/W/X</th>
<th>I²C ADDRESS</th>
<th>REG. DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Init</td>
<td>OSR</td>
<td>Software reset</td>
<td>Reset I²S to clear all registers</td>
<td>W</td>
<td>E8</td>
<td>0</td>
</tr>
<tr>
<td>Init</td>
<td>OSR</td>
<td>Set config mode and no power down</td>
<td>Init configuration and wake up AS89XX (wait 500 µs before measurement)</td>
<td>W</td>
<td>E8</td>
<td>0</td>
</tr>
<tr>
<td>Init</td>
<td>CREG1</td>
<td>R=320/T=64</td>
<td>Set R=reference current [nA] / Tw=integration time [ms]</td>
<td>W</td>
<td>E8</td>
<td>6</td>
</tr>
<tr>
<td>Init</td>
<td>CREG2</td>
<td>Div=1/OUTCONV=enable</td>
<td>Set digital divider and OUTCONV</td>
<td>W</td>
<td>E8</td>
<td>7</td>
</tr>
<tr>
<td>Init</td>
<td>CREG3</td>
<td>Mode=command/Clock=1024/Standby=off/readyPin=push pull</td>
<td>Set mode/standby/readyPin/configuration [kHz]</td>
<td>W</td>
<td>E8</td>
<td>8</td>
</tr>
<tr>
<td>Init</td>
<td>OSR</td>
<td>Set address to register 0</td>
<td>Set address to first configuration register</td>
<td>X</td>
<td>E8</td>
<td>0</td>
</tr>
<tr>
<td>Init</td>
<td>OSR</td>
<td>Read 12 Byte</td>
<td>Read all configuration registers</td>
<td>R</td>
<td>E9</td>
<td>12</td>
</tr>
<tr>
<td>Measure</td>
<td>OSR</td>
<td>Start measure</td>
<td>Begin measurement</td>
<td>W</td>
<td>E8</td>
<td>0</td>
</tr>
<tr>
<td>Measure</td>
<td>OSR</td>
<td>Set address to register 0</td>
<td>Set address to first output register</td>
<td>X</td>
<td>E8</td>
<td>0</td>
</tr>
<tr>
<td>Measure</td>
<td>OSR</td>
<td>Read 10 Byte</td>
<td>Read OSR/STATUS/TEMP/MRES1/MRES2/MRES</td>
<td>R</td>
<td>E9</td>
<td>10</td>
</tr>
</tbody>
</table>

All commands and data’s refer to the I²C communication and register settings of the sensors ADC converter

Description of *.csv columns:

- **State**: All rows containing ‘Init’ are send to the sensor board to initialize the AS73211 after choosing a configuration file. **Important**: Do only use the commands ‘ChannelOrder’, ‘Init’ and ‘Measure’ (case sensitive)! Do not mix ‘Init’ and ‘Measure’ rows!

- **Info Register’/’Info Data’/’Comment**: Columns are not relevant for a functional use.

- **Read/Write**: Insert ‘W’/’X’ for write I²C data with/without I²C-stop (‘X’ is used for ‘repeated start’ functionality) or ‘R’ for read I²C data.

- **I²C Address**: Insert ‘E8’ for write and ‘E9’ for read I²C data.

- **Register**: For write I²C: Insert the register address, which should be written to.

  **Important**: Only insert decimal values 0...255! For read I²C: Leave it empty.
**Data**: For write I²C: Insert the data, which should be written.

**Important**: Only insert decimal values 0...255! For read I²C: Insert the amount of bytes, which should be read.

The Evaluation Software is designed like a simple terminal program. Each write and read command (each row of configuration file) must be written or read via I²C. Check the data sheet of AS73211 for detailed description of all registers. The Evaluation Software can be used only in Command and Continuous mode (compare register CREG3 of AS73211). After software installation in the software directory ‘application’ some samples of *.csv files show several examples to set the system, write/read registers and measure in different modes.
8 Trouble Shooting

An Evaluation Kit works reliably. Therefore, measurement issues are in most cases 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 values or similar errors please check your test system reliability and consider all external influence parameters that take effect on the calibration matrix. After optimization, please test again. If you cannot solve the problem, please contact our sales team for further support.

8.1 Out of Range

There are two different out of range errors (digits ≥65535 or Input Saturation) that can occur during measurements.

- Integration time is too long => Decrease the integration time or increase the divider
- Amplification is too high => Set the reference current to a higher value

8.2 Not Connected Sensor or USB Error

If the software cannot find a sensor at PC then it starts in a demonstration mode and does not make real measurements. Please stop the software, connect the sensor with the PC and start the software again. In case the error still exists, please check the system requirements and start-up or connect your system administration. The same we suggest to do in case of a sudden USB error.

---

A negative coordinate or a coordinate out of the color space indicates on errors in calibration and/or, interferences or changed conditions or measurement. In exception, negative results in photocurrents are possible and indicate negative leakage currents (technological reasons) in low-energy measurements. In these cases, please use the method-offset correction (OPTREG Register) and move depend on the Offset Value the workspace about the deficit balance per channel in the positive range.
Figure 37: USB Connection Error

![USB Connection Error Image]
9 Mechanical Sizes

Figure 38:
Dimensions Package and Adapters
10 Application Notes

10.1 Application-Specific System Configuration

It is advisable to administrate as much light as possible onto the sensor in order to keep the amplification low and therefore improve the signal-noise ratio.

For slow and highly precise measurements using an integrating board, the time basis selected should be as high as possible. In addition, the integration time can be extended by increasing the acquisition counter. When measuring pulsed objects (for example PWM light sources), the integration time must be a multiple of the pulse frequency. Without an EMC casing, the integration time should also be a multiple of the line frequency of 50 Hz in order to avoid overlapping frequency fluctuations (beat effects).

The spectral filters of our color sensors are specialized for applications with a broadband source of lighting >20 nm.

10.2 Calibration

The digitized sensor values must be converted into color coordinates or spectral data depending on the application. Various transformations and algorithms can be used for this purpose. The corresponding parameters are specifically adapted to the application by appropriate sensor calibrations and determined once for each sensor. The basis is formed by application target sets with known colorimetric or spectral data. There are many different known methods for calibration. These, the selected targets and their reference values decide about the accuracy of the sensor system in use. In the following and next chapters, an example will be shown for calibration by using a [3x3] correction matrix by the method of linear progression, which is partly implemented in the GUI.

10.3 Calibration of Emitting Measuring Objects

A requirement for the measurement of emitting objects (self-luminous) is the calibration of the color sensor using a light source setting where the chromatic values are first determined by an appropriate spectrometer or by known XYZ values (based on CIE1931 standard). Use targets for calibration, which represent the full gamut of the application. Please note, not more targets will increase the accuracy for the sensor system but linearity and optimized references are the guaranty for an optimal calibration that results the required True Color quality. Each application and calibration is based on a unique optimized calibration set exists from light source, target (number and specified colors), calibration method and requirements for accuracy. Therefore, it is usual to make simulations to find the optimized specification or contact the ams Sensors Germany team for support this process.
Examples for calibration method:

For determining the chromaticity coordinate, the differing maxima of the spectral sensitivity conditions of the Tri-stimulus value functions are adjusted, with simple scaling or matrixing, to the Tri-stimulus values. The calibration outlay employed is based on one that is accordant with technical feasibility in series manufacture as well as the required measurement and control accuracy.

With simple scaling (compare it with a white balancing), each XYZ(measured) channel has been multiplied by a predetermined simple correction factor K, so that the signal conditions correspond to the Tri-stimulus values XYZ(corrected) for a selected radiating function or combination Color / white point. This method is applicable when the temperature influences are disregarded and with constantly regulated brightness.

Equation 1:

\[
\begin{pmatrix}
 x_{\text{COR}} \\
y_{\text{COR}} \\
z_{\text{COR}}
\end{pmatrix} =
K
\begin{pmatrix}
 x_{\text{MEAS}} \\
y_{\text{MEAS}} \\
z_{\text{MEAS}}
\end{pmatrix}
\]

Scaling of Sensor Results

Another simple method (formal matrixing) without reference values and spectral correction for the sensor is to use a simple matrix \([3:3]\) with diagonal ‘1’. This calibration is not real and valid for measurements but represents only a direct transformation of the measured and not corrected sensor values in the color space CIE1931. The results of this method meet not any absolute accuracies but is logical because the sensor includes alike XYZ filters. The method recommended only for certain relative color measurements or color recognition tasks (it is blue, it is red, it is a green) in the selected color spaces.

Equation 2:

\[
\begin{pmatrix}
 x_{\text{COR}} \\
y_{\text{COR}} \\
z_{\text{COR}}
\end{pmatrix} =
\begin{pmatrix}
 1 & 0 & 0 \\
 0 & 1 & 0 \\
 0 & 0 & 1
\end{pmatrix}
\begin{pmatrix}
 x_{\text{MEAS}} \\
y_{\text{MEAS}} \\
z_{\text{MEAS}}
\end{pmatrix}
\]

Formal Matrixing of Sensor Results

An advanced method, which is also used in the majority of applications, is the use of a transformation matrix for linear transfer of the sensor data into XYZ Tri-stimulus values. Unlike with scaling, matrixing also changes the brightness linearly.

Equation 3:

\[
\begin{pmatrix}
 x_{\text{COR}} \\
y_{\text{COR}} \\
z_{\text{COR}}
\end{pmatrix} =
K
\begin{pmatrix}
 x_{K11} & x_{K12} & x_{K13} \\
x_{K21} & x_{K22} & x_{K23} \\
x_{K31} & x_{K32} & x_{K33}
\end{pmatrix}
\begin{pmatrix}
 x_{\text{MEAS}} \\
y_{\text{MEAS}} \\
z_{\text{MEAS}}
\end{pmatrix}
\]

Matrixing of Sensor Results

It is relatively simple to determine a correction matrix for LED sources and to convert it into series production. This causes the adjustment of at least three (n) full or combination Colors, which are independent from each other, with known Tri-stimulus values XYZ. The n calibrated Colors are adjusted successively to the source. This occurs at the same time as the Tri-stimulus values, with pre-calibrated three-range sensors, are measured and the RGB sensor data is recorded. Consequently, the measurement data constitutes a required matrix XYZ and the sensor data constitutes an actual matrix RGB, each with three rows and n columns. The calculation for the coefficient matrix is shown in the following formula.
Equation 4:

\[
M_{\text{atrix}} = \begin{pmatrix}
x_{K11} & x_{K12} & x_{K13} \\
x_{K21} & x_{K22} & x_{K23} \\
x_{K31} & x_{K32} & x_{K33}
\end{pmatrix} = (XYZ \ast XYZ_{\text{MEA}}) \ast (XYZ \ast XYZ_{\text{MEA}})^{-1}
\]

Calculation of Coefficient Matrix

With this coefficient matrix, all the following sensor data’s \(XYZ_{\text{MEA}}\) are transferred linearly into Tri-stimulus values XYZ and provides the basis for conversion into any Color standards.

In case of any other required details, please ask our sales team for more documents about XYZ calibrations.

10.4 Active Feedback Light Color Control (Color Regulation)

Color measurement tasks can be full filled using a variety of technologies. Three-range RGB color sensors are compact and optimized for rapid color detection. Using RGB filters, these are only suitable for color detection, e.g. measurement of relative color difference.

True Color sensors with XYZ (near) filter have a filter characteristic that makes them suitable for absolute color measurement. With these sensors, it is possible to control the colored light of any number of RGB LEDs with a precision not available using RGB filters. This is possible by the standard spectral value function of the sensor, which replicates the color vision of the human eye.

The result is a system for capturing the LED light that emulates the color perception of human eyes. Therefore, it is possible to control the color of the light to a precision level that any color changes are beyond recognition, therefore invisible to the human eye.

At the same time, the sensor remains solid in its constancy, since it is not disposed to any aging effects or influenced by temperature in respect of the measured color point. It is therefore suitable for use wherever the precision and stability of the colored light are essential - such as in feedback solutions for general lighting solutions, the calibration of the cabin lights of aircrafts, for the background lighting of LCD displays, or as color management system in digital cameras.

True Color sensors allow a generation of natural light sources bases on multi-LEDs and other mixed light sources. This, for example, may be necessary where ambient light is measured and the missing spectral components are added to produce the required light setting.
11 Safety Note

It is essential to keep the sensor surface clean. Dust or scratches will adversely affect the sensor parameters. Sensors should be handled with care, like all optical devices. It is important to perform normal ESD handling and precautions for ESD sensitive devices.
# Revision Information

<table>
<thead>
<tr>
<th>Changes from previous version to current revision v2-00</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actualization ordering codes</td>
<td>6</td>
</tr>
<tr>
<td>Initial version in new template for ams data sheets</td>
<td>all</td>
</tr>
</tbody>
</table>

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.
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