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1. Introduction

Industrial color detection, measurement and monitoring are becoming easier. Notably, where it is claimed that colors are to be detected, measured or compared "like human eyes" in a highly dynamic working environment and with little technical effort, MAZeT's Colorimeter from the JENCOLOR product line provides the optimal solution.

Sensors of this type use the RGB Tri-Stimulus method, imitating the human eye's natural color perception (MCS series), or, alternatively, a method according to DIN 5033, Part 2 – Color Measurement; Standard Colorimetric Systems – CIE 1931 Tri-Stimulus Value Function (MTCS series)¹. JENCOLOR ICs are available in different styles and package versions and can be fitted with a broad range of accessory items (e.g., demonstrator of system testing, testing and function boards, software libraries).



Figure 1: MTCS-C2 Board Colorimeter 2

The MTCS-C2 (Colorimeter 2) kit includes PC software "colorimeter2.exe" under Windows XPTM to handle functions like sensor calibration and anything in connection with measured value representation and output, e.g., in the CIE Lab color space. Furthermore, an API Application Programming Interface (MTCSApi.DLL) with test software can also be supplied (optional).

If required, dedicated drivers and software libraries (tools for calculating the color range and calibration) can be produced and supplied for necessary adjustments to the software. In addition to its IC solutions, MAZeT offers a MTCS-C2 hardware solution based on the MTCS series, which is also referred to as "colorimeter 2." Alongside the color sensor IC, the board integrates all signal processing resources, including interfacing and measuring control and can be adapted within a Design In project.



Figure 2: Operator interface mtcs-Software

Please do not hesitate to contact us for the latest information on available components and scopes of delivery.

2. Starting Up

¹ For data and application sheets, you should contact one of our sales offices.

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2.1 Scope of Delivery

MTCS-C2 (Colorimeter 2) delivery includes²:

- MTCS-C2 (µC Version 2.22) (Colorimeter 2)
- Documentation
- Optional USB cable
- Optional "colorimeter2.exe" PC software (with USB driver of SYS and MTCSApi.dll type)⁴
- Optional macro functions library
- Optional 10° optics consisting of shutter

2.2 System Requirements

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

- PC Pentium 150 MHz or higher
- 8 MB RAM
- 5 MB free hard drive memory
- One free USB (2.0) port
- MS Windows™ XP / 2000

2.3 Components Hook-up



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2.4 Software/Driver Installation

The "colorimeter2.exe" PC software (with USB driver of SYS and MTCSApi.dll type) is installed on your PC by using the setup.exe program.

After a successful installation, the setup procedure should have copied the files "usbcolor2.inf" and "usbio.sys" files to the directories "windows\inf" and the "windows\system32\drivers". Use the USB cable (supplied) to connect the MTCS-C2 to one of your PC's free USB (2.0) ports. The device manager will output a message "found new hardware" on the screen.



Figure 4: Assistant for USB driver installation, page 1

In accordance with Figure 4, select the "Install the software automatically" checkbox and then press "Next."



Figure 5 Assistant for USB driver installation

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In case the software does not install automatically (i.e., Windows cannot find the required files), you should check the directory to which the setup procedure had copied the *.inf and *.sys files. Use this directory for the further driver installation. (The default directory is either \windows\inf or \windows\system32\drivers.)



Figure 6: Assistant for USB driver installation, final page

After pressing "Finish," the USB driver installation is complete.

After a successful driver and software installation, please connect the colorimeter board via USB to the PC and start the MTCS software.

3. Hardware

3.1 MTCS-C2 Board

The following components are integrated on this board⁵:

- MTCSiCS True Color Sensor
- MTI04CQ transimpedance amplifier
- C8051F321 microcontroller with 10 bit AD converter and USB interface
- EEPROM Free memory space for compensation and correction data

The board is supplied with voltage via the USB interface.

The microcontroller has the following functions:

- Controlling and analyzing of the color sensor signals
- Activating the EEPROM for external memory space

⁵ The data sheets for the individual devices can be obtained from the MAZeT sales office.

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Communication via USB



Figure 7: MTCS-C2 principle block diagram

The μ C C8051F321 firmware is designed to support communication via the USB interface, to handle all customized measuring algorithms, simple ADC access operations and averaging of multiple ADC access operation, and to manage customized settings and data for calibrating the sensors.

4. Software

4.1 Software Start

Based on an *.ini file, some functions and parameters are to be defined in the C2 software. Please do not change the details in the *.ini file without support by MAZeT or your distribution partner⁶. The *.ini file includes the following sections and parameters:

*.ini file: conf.ini (standard)		
[section1]		
<pre>// if more than one device is plugged in</pre>		
// wenn mehr als 1 device angeschlossen		
DeviceAnzahl=1		
// automatische Suche		
// AutoSearch		
AutoSearch=0		
// decimal dot for Excel		
// Dezimalpunkt fuer Excel		
Trennzeichen = ","		
// = 1 mit Protokollierung		
// = 1 with protocol		
Protokoll=1		
⁶ Eurthermore, do not change the values in the * ini file under [COLOBIMETER2] :	and [modE]/A]	
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		·		
<pre>// after program start, E // beim Start wird Excel Excel=0 Column=1 //Wait =1 wait for confi //Wait =1 auf Bestaetig Wait=0 // upper Limit fuer Auto AutoGraph=2000 [COLORIMETER2] productid = 8220 vendorid = 152a AnzeigeText=MTCS-C [modEVA] productid = c35d vendorid = 400 AnzeigeText=MTCS_M</pre>	ram start, Excel will be opened t wird Excel geoeffnet rait for confirmation and single measurement uf Bestaetigen warten und Einzelmessung hit fuer AutoGraph =2000 ETER2] = 8220 152a t=MTCS-C2 Colorimeter 2 = c35d 400			
DeviceAnzahl bigger than 1: some c	levices with th	e same IDs can be	connected.	
Trennzeichen: "." or "," are possible. It when saving.		description of the c	lecimal point	
Protokoll=1 The protocol fu		ol function is activated.		
Excel=1 At start be writt function form w	up, Excel® wil ten to the Exce n will write the hen Protokoll i	l be running. All me el-form. If Excel = 0 measurement resu s set to 1.	easurements will , the protocol Its to a *.csv	
form w A user software session can	nen Protokoll i be stari	s set to 1. ted by selecti	ng "mtcs.exe"	

(START/PROGRAM/modEVA_Rev__/modeva__). The window for USB System-Setup will open (Figure 8 or Figure 9). It contains standard entries for "Vendor_ID" and "Product_ID" representing specific Colorimeter conventions. These should not be changed. Please check whether the "BoardType" window includes the right hardware type connected to the PC (colorimeter2) and, if necessary, correct it.



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System Setups			
MTCS - Soft	ware	JENCOLOR	
MTCS-C2 Colorimeter 2 Rev. 4	<u>.XX</u>	111	
Vendor_ID Product_ID x 152A x 8220			
USB Status Result			
the connected hard	ware BoardTyp Col	orimeter 2	

Figure 9: System Setups – Startup window

To check interface communication, click the OK button or press the F8 function key.

When the Colorimeter2 is correctly installed as a USB device, the firmware revision number 0.1x is read and displayed (Figure 10).

🐉 System Setups	
MTCS - Software	JENCOLOR
MTCS-C2 Colorimeter 2 Rev. 4.XX	111
Vendor_ID Product_ID x 152A x 18220	
USB Status Result Initialize USB successful	
open device VendorID 0x152a ProductID 0x8220	
BoardTyp Colorimeter 2	

Figure 10: System setups – USB communication successfully established

After Figure 10, the window is automatically closed and the main window for carrying out measurements (see Section **4.2**) or the window for configuring the measuring environment on the erased memory space (see Section 4.3) is opened.

If "....resetUSB" appears in the "USB Status Result" line, it is recommended to terminate the program, to disconnect and then re-establish the USB connection on the hardware side (Reset hardware) and to restart the PC software.

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4.2 Color Detection and Measurement

MTC5 Mod Eva Kit Rev 4.XX _ 🗆 🗙 Program Copyright! Delay 🖨 0.00 Not Triggered) Clear Monitoring L*a*b* JENCOLOR 150-140-120 100 162.196 X = 80-XYZ 194.354 Y = 60 Z = 31.654 40 20 0.4178 x = CIE Yxy y = 0.5006 0-+1-11 + Y = 194.354 -20 -40 128.762 L* = -60 CIE L*a*b* a* = -26.441 -80 b* = 117.099 100-L* = 128.762 120 u' = 0.205 CIE L*u*v* 140 150- 125.0 100.0 -75.0 -50.0 -25.0 0.0 25.0 50.0 75.0 100.0 125.0 150.0 0.551 v' = 🔽 Auto Max Graph 250 4096= 200 3000-150 2000-100 1000-50 SerialNumber 0- 🖣 0-1.0.0 250

Figure 11 shows the main window for color measurement visualization.

Figure 11: Main window for color measurement

The measured results are represented graphically as XYZ standard Tri-Stimulus values, in a standard chromaticity chart of CIE 1976 L*a*b*and as L*u*v color space.

Please ensure that the color values can only be interpreted more or less in the sense of the color measurement when the board is calibrated to a measurement standard.⁷

A measurement can be triggered and cancelled by clicking the green "Measurement On / Off" or "ENTER" button (if the focus is on the "Measurement On / Off" button). By varying the "delay" time (next to "Measurement On / Off" – input in seconds), the waiting time between two measurements can be changed as desired. The "delay" time also changes the measurement time provided that the other values set in the program (e.g., averaging) and the computing power of the data processor allow this.

⁷ We would be happy to provide you with application guidelines on this subject. Please contact one of our sales offices.

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For graphical display, you may choose between Yxy, L*a*b* or L*u*v* from the list in the top right. A given graphic can be deleted with the "Clear Graph" button or the "DELETE" key.

At the bottom of the window there is an additional area in which the progression of recent values is displayed (Figure 12: Graph of the values

). On the left, the display scale can be adjusted by setting a maximum value for the y-axis. If no progression gauge is displayed for continuous measurement, it may be necessary for the area to be adapted. Selecting "Auto" automatically adjusts the area.

On the left side, you can read the serial number of the current device.

DevNr is used for the selection of the device. It is only visible, if

- The DeviceAnzahl in the conf.ini file is greater than 1
- More than 1 device with the same VendorID and ProductID have been connected



Figure 12. Graph of the variation over time of measured values

4.3 Data Logging

Data logging is divided into two categories. It is possible to store the measurement data in a *.csv file or to write the data directly to Excel®. For data logging in Excel®, it is necessary to install MS Office® 2003. By default, logging to a *.csv file is activated by the conf.ini. The data is stored in the program directory during the measurement process. The settings for data logging can be configured in the conf.ini file. Figure 13 below gives an overview of the logging settings.



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4.4 Menu

A variety of actions ("Program," Figure 15) can be selected by using the menu next to the program information ("Copyright," Figure 14). This is described below.

	🖉 Copyright	×
	Convertent @ MAZeT Control Jene	
	Firmware Revision 2.22	
	MTCS-C2 Colorimeter 2 Kit Revision DLL - Version 4.40	h 4.XX
	Ōk	
L	Figure 14: Copyr	 rright
	Dolorimeter2 Kit Rev 4.303	
	Program Copyright!	
	Colour Patch	F1
	Config File	Eo
	Exit	10
	Figure 15: Mer	ะกม
4.4.4 Color Potob		
4.4.1 Color Patch Solooting "Color Patch" from t	ha manu anablas tha m	magnified colors to be visualized as a
corresponding colored windo cated (Figure 16).	w on the user interfac	e. In addition, RGB values are indi-
A comprehensible matrix for the data is a prerequisite for enable	ne calculation of the R0 ing the correct colors to	GB monitor values from the ADC raw o be displayed (see Section 4.6).
	Colour Patch	
	295 104 87	
	Figure 16: Color Patc	ch display
.		
Attention! Clear differences may occur in	the color reproduction	of the measured targets due to dif-
ferent display types or differen	t settings in the color m	nanagement of the PC and graphics
card.		

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4.4.2 Config File

Selecting "Config File" from the "Program" menu enables application-specific system configuration and calibration data to be loaded and stored (see Section 4.6: Configuration of the application (measuring mode)).

Donfiguration File			×
Load configuration fro	m file or write config	uration to file	
	- 		1
Load from File	Write to File	Cancel	

Figure 17: Accessing the system configuration file

The data is stored in a *.cfg file, organized in the following way:

Line	Contents	Example
1-2	SW Revision / Date / Time	📕 config.cfg - Editor
3	Type of configuration	<u>File Edit Format View H</u> elp
4	0	Colorimeter2 Configuration;
5-7	Offset measurement value	18
8-10	X, Y, Z for type of illumination	45.80
11	0	52.59
12	Max. number of integration inter-	1.00
	vals	0
13	Intensification	361 8
14-22	Matrix raw data => XYZ	0.482549
		0.488187
23-31	Matrix raw data => RGB monitor	-0.468448
		0.499931 1.925709
		-1.369529
		-2.487247
		2.629742
		-0.865567
		<u>U</u>

4.4.3 System Configuration

The sensor system is set to corresponding types of measurement with specific parameters by using System Configuration. There is a detailed description in Section 4.5.

4.4.4 Exit

Selecting "Exit" from the "Program" menu terminates the PC software.

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4.5 Changing the System Configuration

It is only necessary to change the system configurations during initial operation or when changing the measurement type.

The window for changing the system configuration is opened by going to the "Program/ System Configuration" menu or by pressing the F8 key. When the program is run, this user interface is automatically loaded if no configuration data is stored (initial operation).

🖉 Warning	×
eeprom not initialising	
QK	

Figure 18: Reference to empty EEPROM

The following tasks are carried out via the "Application Setups" dialog:

- Application requirement (measurement type)
- Adjustment of measurement conditions (integration time, mean values, etc.)
- Definition of colorimetric ambient conditions (offset, type of standard light, gamma correction)
- Determination of the gain matrix for color range transformation due to target-specific comparison
- Memory allocation on the board

If no configuration is saved ("no saved configuration"), the notification in Figure 18 appears directly after the USB initialization and then the user interface appears, as shown in Figure 19.

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			1		
System Configuration		X			
System Configuration SerialNumber 250.0737.0911 Error 0		JENCOLOR			
ano saved configuration	New Callibratio				
	R Orfsel G Orfsel B Offset	0.000000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.0000 0.00000 0.00000 0.00000 0.0000 0.0000 0.0000 0.00000 0.00000 0.00000 0.00000 0.00000 0.0000 0.000000 0.0000000 0.000000 0.000000 0.0000000 0.000000 0.000000 0.0000000 0.000000 0.000000 0.000000 0.000000 0.0000000 0.0000000 0.0000000 0.00000000			
	BR 1.000 SR 0.000 BA 0.000	1000 RG 0.000000 RB 0.000000 1000 GG 1.000000 GB 0.000000 1000 EG 0.000000 E8 1.000000			
	Matrix RGB RR 1 000 GR 0 0000 8R 0 0000	to Monitor RGB Gamma Corr ① 0.500 866 0.000000 R8 0.000000 866 1.000000 GB 0.000000 866 0.000000 B8 0.000000			
Write default to Sensor) Read From Sensor) Write Io Sensor					

Figure 19: Example of configuration

The choice of application complies with the measurement type used and is selected from the list at the top left.

*	MTCS Colorimeter 2
Γ	no sa∨ed configuration ✔MTCS Colorimeter 2
	MTCS Colorimeter 2 DI

Figure 20: Application configuration (measurement type)

Depending on the application selected, the fields permitted for change are activated.

The configuration data is managed using the "Write default to Sensor," "Read From Sensor," and "Write To Sensor" buttons in the memory on the mainboard.

After the configuration is changed, the "Run Program" button remains inactive until the data is saved, using "Write To Sensor," or is reset, using "Read From Sensor."

Once the system is successfully configured, you can return to measuring mode by pressing the "Run Program" button or F8 key (Main window for color measurement, Figure 11).

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4.5.1 MTCS-C2 Configuration MTCS-C2

In the MTCS-C2 configuration, "Average Counts" determines the number of measurement values by averaging. For example, the MTCS-C2 board can be set to measure light sources, e.g., LEDs or TFT monitors.

An adjustment of the 10 bit ADC value can be entered in the "Shift" field and transmitted via the firmware.

The "Amplification" control dial adjusts the intensification on the MTI. There are 7 intensification levels.

If the intensification=0, the intensification is automatically determined. In order to do this, the tolerance value is required.



Figure 21: Example of configuration for MTCS-C2

In order for the system to be configured, the sensor must be directed at a white surface. With TFT monitors, this can be carried out directly on the screen with an appropriate light background.

Pressing the "Measure" button triggers a measurement and the corresponding measurement values (ADC values with fixed adjustment "Shift") of the three measuring channels are displayed.

After the measuring conditions are adjusted, the system can be calibrated by generating a target-oriented gain matrix. This is explained in more detail in Section 4.6.

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4.5.2 MTCS-C2 DI Configuration

DI stands for Digital Integration, which means that the ADC values (with fixed adjustment "Shift") are added up over a fixed period of time.

The configuration is carried out by means of the active fields, as shown in Figure 22. The integration time is entered into the "Integration Time / ms" field. It can vary between 0 ms and 2,800 ms.

A measurement is carried out in the given integration time. The measurement value ("ADC/Counts") represents the integral deviation of the signal lever divided by the number of integration intervals ("Counts").

System Configuration	
System Configuration SerialNumber 250.0737.0911 Error 0	
ADC / Counts Integration Time / ms Counts 0.000 1500 0000 0000 500 000 0 0 0 0 0 0 0	R Offset 0.000000 G Offset 0.000000 B Offset 0.000000 Matrix RGB to XYZ Matrix RGB to XYZ
	RR 1.000000 RG 0.000000 RB 0.000000 GR 0.000000 GG 1.000000 GB 0.000000 BR 0.000000 BG 0.000000 BB 1.000000 BR 0.000000 BG 0.000000 BB 1.000000 RR 1.000000 RG 0.000000 RB 0.000000 RR 1.000000 RG 0.000000 RB 0.000000 BR 0.000000 RG 0.000000 BB 0.000000 BR 0.000000 BG 0.000000 BB 1.000000
Write default to Sensor) Read From Sensor) Write To Sensor	interrupted measurement (Buat Erogram)

Figure 22: Example configuration for MTCS-C2 DI

The integration time is adjusted using the top control dial. The intensification is adjusted using the bottom control dial.

The intensification on the MTI is adjusted in the "Amplification" field.

A measurement is triggered when the "Measure" button is pressed and the corresponding measurement values (ADC/Counts-Values) are displayed on the three measuring channels.

If "Interrupted Measurement" is selected, no continuous measurements are carried out in the main window, only single measurements. Please note: If Wait=1 in the conf.ini file, "Interrupted Measurement" is automatically selected.

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4.6 Target-oriented Calibration

The system comparison (Figure 23) is carried out on a known target set when the "New Calibration" button is pressed. In the process, the actual system values are calculated to the targets with known XYZ values and, as a result, the offset values and the gain matrix are calculated. The comparison starts with the following window:

🔊 S	ystem Cal	libration	ĺ.					
					Measure	BGBY	aluer,	
	Load St	tandard X1	7 Values		Load I	RGE Yal	.162	JENCOLOR
Nr.	Х	Y	Z	1	R	G	B	
1	000.0	000.0	000.0		00.0	000.0	000.0	Calcutate Manis

Figure 23: Start of System Calibration

The data for a known and measured target set is loaded by pressing the "Load Standard XYZ Values" button. This data set consists of a minimum of 3 (24 recommended) target XYZ and RGB values for the monitor display.

📕 colore	hecker - N	otepad				
<u>F</u> ile <u>E</u> dit	Format <u>V</u> iew	v <u>H</u> elp				
"Standa "Counts 11.540 39.121 18.992 10.621 26.831 32.795 37.419 14.468 29.314 9.311 34.424 46.543 8.843 14.933 20.660 56.336 30.929 15.400 88.291 57.979 35.535 19.425 8.829 3.041	rd Color of colo 10.100 35.800 19.300 24.300 43.100 12.000 19.800 43.100 6.600 44.300 43.100 6.100 23.400 12.000 59.100 19.800 90.000 59.100 36.200 19.800 9.000 3.100	<pre>Value × rs;" 7.210 28.848 38.600 7.595 6.431 42.102 15.596 16.759 11.866 8.757 32.347 10.627 5.670 10.314 34.241 43.370 106.519 69.951 42.825 23.435 10.651 3.669</pre>	YZ C0 24 94 241 97 164 140 7 222 69 255 0 4203 255 207 0 255 249 180 117 53 0	lorchecker; 28 149 119 103 131 253 116 47 29 0 255 142 0 255 142 0 217 3 148 255 249 180 117 53 0	" 13 108 171 39 196 153 21 122 42 68 19 0 142 38 0 142 38 0 142 38 0 124 153 0 124 155 249 0 124 155 249 150 153 0 154 154 155 155 155 155 155 155	
1						🖉 .::

Figure 24: Target data set

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The data set can be calculated using the radiance measurement, for example, from the color range data provided by a ColorChecker from the company GretagMacbeth (Figure 25).

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Figure 25: GretagMacbeth ColorChecker

The use of other targets presumes knowledge of the XYZ values. By monitoring with a spectrometer, an appropriate target file can be created for luminescent objects.

The loaded target file is displayed with the XYZ numerical values and the combination color of the monitor in tabular form (Figure 26).

The actual values are entered automatically during a comparison on a calibrated monitor. To do so, the sensor is positioned in the middle of the colored surface or in the separate color patch field and the comparison is started by clicking "Measure RGB Values." The RGB monitor values stored in the file are successively adjusted and the corresponding actual values are recorded.



Figure 26: System Calibration: Required Values

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When the comparison is carried out on a reflecting target set, the sensors are successively adjusted to measured target colors and the respective actual value is entered when "Measure" is activated (Figure 27).

In the case of incorrect measurements, the last measurement can be deleted and repeated by pressing the "Repeat" button.



Figure 27: System Calibration: Entering the actual values

Use the "Break" button to cancel the calibration and return to the "Application Setups" dialog.

If a continuous calibration (Wait=0 in the conf.ini file) is carried out, this can be canceled using the ESC key.

Once all 24 actual values have been entered, the file is saved and the offset values are calculated. An existing actual value file can be loaded by pressing "Load RGB Values."

	stem Calibration	i i									
	Load Standard XYZ Values			Measure RGB Values		COL	.OR				
Nr. 1 2 3 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	× Y 11.5.4 10.10 93.12 35.4 10.62 13.30 28.83 24.30 32.80 43.10 37.42 30.10 14.47 12.00 9.31 660 9.31 660 9.31 660 9.31 660 9.31 660 9.33 19.80 9.34.2 44.30 46.54 43.10 8.44 610 20.66.34 69.10 30.93 19.80 57.96 59.10 35.54 36.20 19.43 19.80 30.4 3.10	Z 7.21 38.60 49.76 6.43 42.10 16.76 16.76 16.76 16.76 16.76 16.76 10.63 5.67 10.63 10.31 34.24 42.83 23.44 23.44 24.444 24.444 24.44	R 33.88 35.74 35.74 41.95 52.36 59.86 96.28 35.19 39.53 41.34.27 35.29 37.09 40.38 45.30 34.22 36.75 93.65 94.69 36.75 93.85 84.83 48.09	6 40.72 58.31 80.47 41.75 41.06 41.94 43.63 54.06 54.06 54.06 54.06 54.06 54.06 53.77 44.28 84.16 53.77 63.73 164.89	B 13.41 15.78 23.80 59.89 92.56 13.56 13.58 13.56 13.88 14.50 15.64 17.31 13.70 14.61 15.64 17.31 13.70 14.62 15.64 17.31 13.70 14.62 15.23 20.55 51.34 80.19 27.19 83.60 89.31 <i>magental</i>	libratio	Calcule	Late Matrix	tion		
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If the offset-corrected actual values are available, the "Calculate Matrix" button is activated (Figure 28). You can click to calculate the gain matrices, complete the comparison and revert the software back to the "Application Setups" dialog, in which the determined offset values and matrices are displayed.

For the lab values calculated in the measurement, it is still necessary to enter the type of illumination, for which the calibration was carried out ("L*a*b*Light" in Figure 22).

The determined calibration data is stored in the onboard memory when the "Write to Sensor" button is pressed. It becomes available automatically after the system is rebooted, without the need to carry out a new comparison.

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