



Software manual

colorCONTROL LT for
color sensors of series
colorSENSOR
LT-1-ST und LT-2-ST

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1	SOFTWARE „COLORCONTROL LT”	4
1.1	SOFTWARE INSTALLATION	4
1.2	OPERATION	4
1.2.1	<i>Selecting communication interface</i>	4
1.2.2	<i>Sensor configuration</i>	7
1.2.3	<i>Teaching In Colors</i>	18
1.2.4	<i>Color processing</i>	22
1.2.5	<i>Service</i>	25
2	COMMUNICATION PROTOCOL AND COMMAND REFERENCE	28
2.1	PROTOCOL STRUCTURE	28
2.1.1	<i>Burst Mode</i>	29
2.1.2	<i>Fixed point notation</i>	30
2.2	COMMAND REFERENCE	31
2.2.1	<i>System Identification</i>	31
2.2.2	<i>Communication</i>	32
2.2.3	<i>Data Acquisition</i>	33
2.2.4	<i>Sensor Correction</i>	35
2.2.5	<i>Color Transformation</i>	36
2.2.6	<i>Color Table, Color Recognition/Classification</i>	37
2.2.7	<i>Output Encoding</i>	39
2.2.8	<i>Flash Operations and Parameters</i>	40
3	LABVIEW® VIS	42
3.1	STRUCTURE OF COMMAND VIS	42
3.2	OPEN RESOURCE VI AND CLOSE RESOURCE VI	42
3.3	EXAMPLE	43
4	DLL FUNCTION LIBRARY	45
4.1	INTRODUCTION	45
4.2	LIBRARY FUNCTIONS	45
4.2.1	<i>Library</i>	45
4.2.2	<i>USB Library</i>	45
4.2.3	<i>Devices</i>	46
4.3	FILES	48
4.4	REQUIREMENTS	48

1 Software „colorCONTROL LT”

The sensors can be extensively configured by PC software. Therefore software tools are shipped with the sensors for individually adjusting the sensors to any operational environment. The software functions are as follows:

- Sensor parameter configuration (signal gain, scanning frequency, processing mode etc.)
- Color sampling (“Teach In“) procedure
- Color processing (Recognition and classification)
- Displaying of color values

The function is described in detail in the following sections.

1.1 Software installation

The software requires the following minimum system parameters:

- PC with 300 MHz CPU
- 40 MB free hard disc space
- Mouse
- RS232 interface
- USB interface for sensors with USB option
- CD-ROM drive
- VGA graphic with minimum resolution 800x600
- MS Windows® OS (WIN98, WIN ME, WIN2000, WIN XP)

For installation insert the CD-ROM in the CD-ROM drive and follow the installation instruction on the screen. Or, alternatively, start the program “SETUP.EXE“ from the folder [CD drive]:\colorCONTROL the file “SETUP.EXE”

1.2 Operation

1.2.1 Selecting communication interface

The sensor system can be connected via RS232 or USB¹ to the computer. Which interface is going to be used has to be selected right after starting the program (Figure 1).

SERIAL CONNECTION

The configuration of the serial interface is placed on the left hand side. The communication port can be chosen in the field “SELECT COM PORT“ (Figure 1). With “ADDRESS” the corresponding sensor address can be chosen if several sensors are connected to the serial port (refer to “SENSOR ADDRESS” below in section “SERVICE”).

Hint:

The software is limited to the COM ports 1 to 9.

¹ Only available for sensors with USB port.

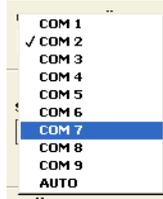


Figure 1: Selecting the RS232 interface port

By default the communication port is configured as follows:

Baud rate: 28800

Data bits: 8

Parity: no

Stop bits: 1

Flow control: no

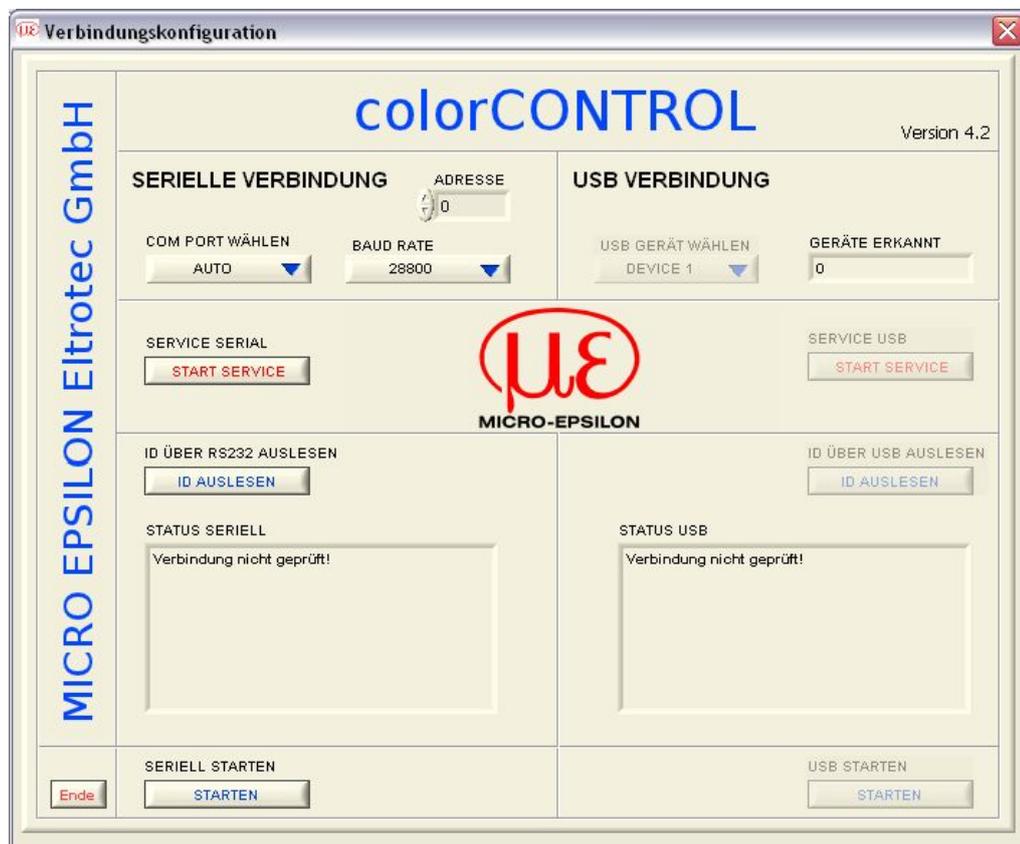


Figure 2: Start window

Status and error information are displayed in the text box “STATUS SERIAL“ below the button “GET ID“.

USB CONNECTION²

The program can be started via USB on the right hand side when a USB interface is available. The number of detected devices is shown in the field “DEVICES DETECTED”. The desired USB device can be chosen with the switch in the field “SELECT USB DEVICES” (Figure 3).



Figure 3: Selecting the desired USB device

SERVICE

With this switch within the field „SERVICE“ a service tool is started, which allows certain special hardware functions and settings. The function are described in Section 1.2.5 (P. 25).

² Only available for sensors with USB port.

1.2.2 Sensor configuration

The parameter window appears (Figure 4) after choosing a connection at the start of the program. The parameter window can always be found under the tab “SENSOR PARAMETERS“ (in the upper area of the program window). The sensor parameters are read out and displayed in the program window.

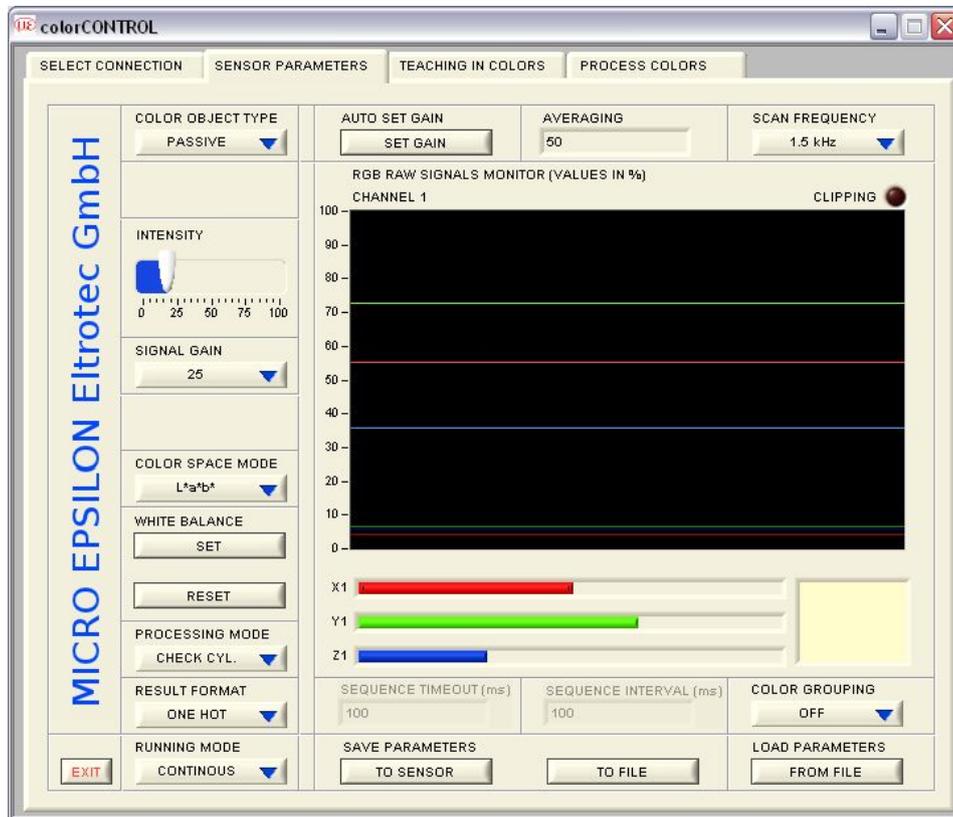


Figure 4: Window for sensor parameter configuration

COLOR OBJECT TYPE

At first the type of object that is going to be measured has to be selected in the field “COLOR OBJECT TYPE“ (Figure 5). The adjustment “ACQUISITION OFF” turns the signal acquisition of the sensor off.

For self shining objects, such as lamps, LEDs etc. choose the “ACTIVE“ mode, for non self-shining objects, also called “Body Colors” choose the “PASSIVE“ Mode”. The latter are so-called body colors and are illuminated by a light source from the sensor system. Otherwise the light source is switched off.

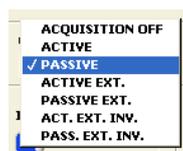


Figure 5: Selecting the object type

There are 4 additional “EXT.” modes, that are intended to be used with an external trigger source to be provided on the “TRG 1” input. With this modes the sensor can be synchronized with an external frequency. The modes with the “INV.” addition invert the TRG 1 signal.

For self-shining objects an ambient light compensation can be realized. For non-self-shining objects a “Master-Slave” operation can be realized in that way that one sensor is switched to the “PASSIVE” mode and all other sensors are adjusted to the “PASSIVE EXT” (or “PASSIVE EXT. INV.”) mode. The master-slave operation is particularly useful for avoiding light interfering effects if several sensor are used in close proximity. Additionally differential a signal processing with to sensors is possible.

INTENSITY³

With the intensity regulator the brightness of the built-in light source can be adjusted.

SIGNAL GAIN³

The amplification gain (out of 4 gains) of the color signals from the primary color sensor can be selected in the field “SIGNAL GAIN“ (Figure 6).

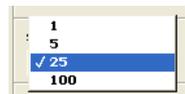


Figure 6: Selecting signal amplification gain

AUTO SET GAIN³

The amplification gain and illumination intensity can be automatically adjusted when the switch in the “AUTO SET GAIN” field is set on. The signal range will be set to approx. 90% of the entire range.

Hint

Before successfully applying the function “AUTO SET GAIN”³ it has to be verified that the sensor system has been put in its operating point and the distance between sensor and objects has been fixed. It is recommended that a white colored object or an object with the highest signal amplitude (brightest object to be measured) is to be used for adjusting the signal amplification gain and further to prevent from overdrive.

COLOR SPACE MODE

The color space which will be used throughout the color measurement is selected in the field “COLOR SPACE MODE“. Depending on the light control setting, one of the following color spaces shown in Table 1 can be selected. Figure 7 shows the selection field in the field “COLOR SPACE MODE“.

³ Only available for sensors with USB port.

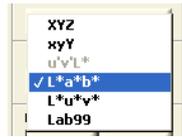


Figure 7: Color space modes

Table 1: Color spaces depending on the two types PASSIVE and ACTIVE

PASSIVE (Body colors)	ACTIVE (Self-shining)
XYZ	XYZ
xyY	xyY
L*a*b*	u'v'L*
L*u*v*	
Lab99	

Hint 1:

Due to the limited hardware accuracy of the sensor and the used non-standard illumination source (white light LED), the obtained color values in the corresponding color spaces are not colorimetrically accurate!

Hint 2:

The ranges of the color values in the parameterization software differ from the common ranges for color values! Table 2 shows the range of the color values for the several color space modes of the software in comparison to the common ranges. The visible range of the color diagrams is pre-defined to a suitable value. To fit the color diagram scales to the desired range, the axes can be adjusted by simply editing the numbers on the corresponding axes.

Table 2: Axis scaling for the parameterization software

Color space	common range	program range	Multiple
XYZ	X: 0...100 Y: 0...100 Z: 0...100	X: 0...100 Y: 0...100 Z: 0...100	1 1 1
xyY	x: 0...1 y: 0...1 Y: 0...100	x: 0...100 y: 0...100 Y: 0...100	100 100 1
L*a*b*	L*: 0...100 a*: -500...+500 b*: -200...+200	L*: 0...100 a*: -500...+500 b*: -200...+200	1 1 1
L*u*v*	L*: 0...100 u*: -1300...+1300 v*: -1300...+1300	L*: 0...100 u*: -1300...+1300 v*: -1300...+1300	1 1 1
u'v'L	L: 0...100 u ² : 0...1 v ² : 0...1	L: 0...100 u ² : 0...100 v ² : 0...100	1 100 100
DIN99	L: 0...100 a: -500...+500 b: -200...+200	L: 0...100 a: -500...+500 b: -200...+200	1 1 1

REFERENCE WHITE

For storing a color value as reference white the actual sensor signals can be sampled in by clicking on the button “SAMPLE” in the field “REFERENCE WHITE”. The signal settings should have set with the GAIN and INTENSITY function before sampling the reference white. It is also recommended to use a white colored object for reference. The function “AUTO SET GAIN“ can simplify adjusting the signal range. The button “DEFAULT“ sets the color values for reference white to 100.

The color values for reference white can also be manually manipulated by clicking on the number and than editing.

Hint 1:

The reference white is crucial for color measurements and displaying and therefore has to be re-sampled at any time when the signal settings, such as gain (AUTO SET GAIN) or light intensity (LIGHT CONTROL - INTENSITY), have changed.

Hint 2:

The reference white is required for proper displaying the color on the monitor and **not needed** for further signal processing in the color spaces XYZ and xyY. On the other hand, the reference white is needed for a correct color transformation into the color spaces $L^*a^*b^*$, $L^*u^*v^*$ and Lab99. Therefore sampling of real sensor values is recommended for the color spaces $L^*a^*b^*$, $L^*u^*v^*$ and Lab99. However the sensor works acceptable even though a reference white has not been sampled as long as the color values do not exceed the pre-defined reference white. In general the sensor works fairly well when using the default (“DEFAULT“) reference white.

PROCESSING MODE

The sensor system provides up to 5 different signal processing modes. The desired mode can be selected in the field “PROCESSING MODE“ by the menu shown in Figure 8.

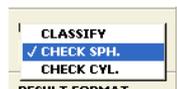


Figure 8: Processing modes

Table 3 shows all processing modes and their description in detail.

Table 3: Processing modes and description

Processing mode	Description
CLASSIFY	The actual measured color value is being classified among pre-sampled color values. A classification is always done independently if the colors match or not. As an example shows, if there is only one color RED stored, all colors will be later classified as RED. Figure 9 shows the classification of the actual color value C_m to the stored color C_3 because the distance between C_m and C_3 is the smallest one.
CHECK SPH.	In the mode CHECK SPH. (spherical) it is to be checked if a measured color is within a spherical tolerance room. If the measured color is within such a spherical room, the check is successful (color recognized), otherwise the check was unsuccessful (color not recognized).

Processing mode	Description
	Figure 10 shows spherical tolerances and a measured color C_m that is within the tolerance C_3 and hence was recognized as the color C_3 .
CHECK CYL.	The mode CHECK CYL. (cylindrical) provides a method for assigning cylindrical tolerance spaces. Tolerance parameters can be configured separately for color and brightness. The measurement principle is shown in Figure 11. Two tolerance parameters (color and brightness tolerance) are necessary. This mode can not be applied in the XYZ color space because there is no coordinate for brightness.

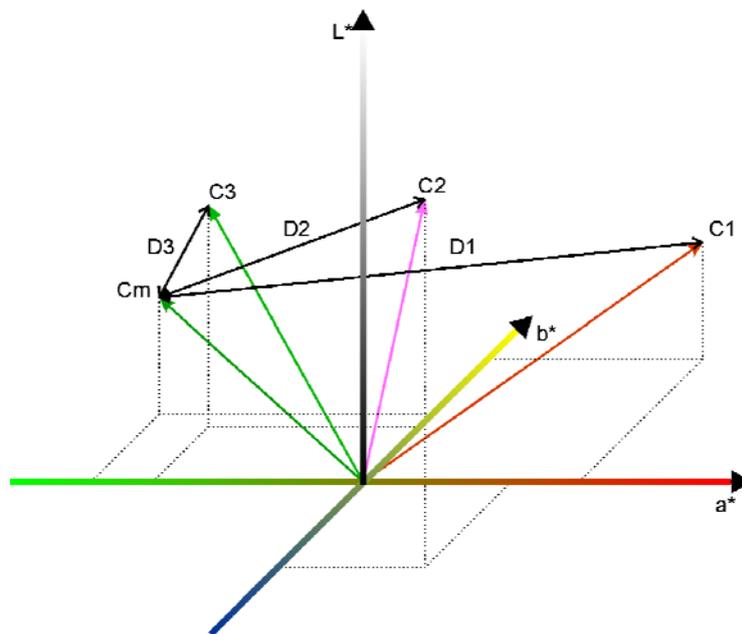


Figure 9: Color classification principle

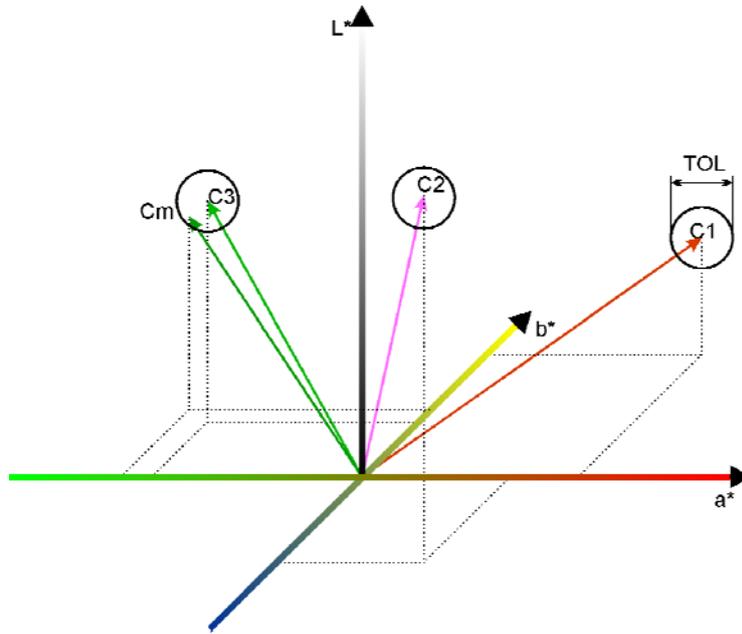


Figure 10: Color space with spherical tolerances

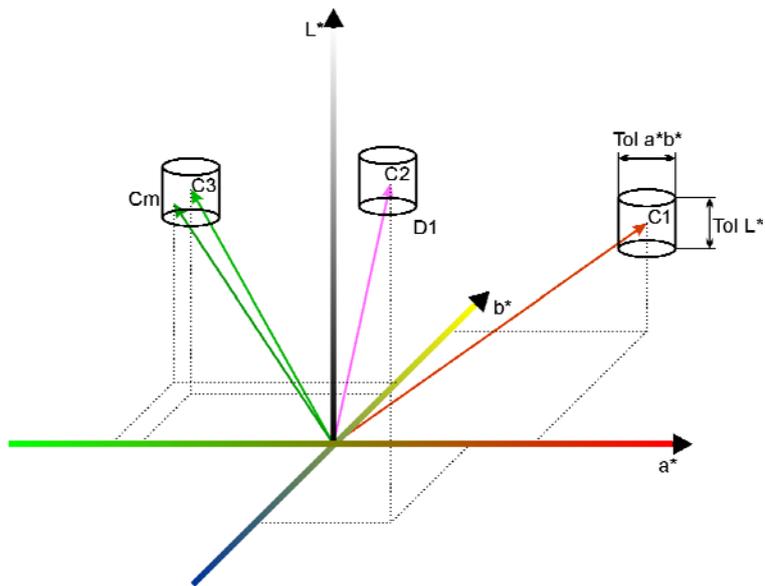


Figure 11: Color space with cylindrical tolerances

RESULT FORMAT

The user defines in the field “RESULT FORMAT“ how the results of the color checking or classification are represented at the outputs of the color sensor. Figure 12 shows the 6 possible output formats and Table 4 shows their descriptions in detail.



Figure 12: Color processing result formats at the sensor outputs

Table 4: Output formats for color checking and classification

Selection	Description
OFF	The outputs keep their last result and are switched off.
ONE HOT	This is a “1-out-of-N” encoding. Each color value in the internal color table (please refer to sect. 1.2.3, subsect. “COLOR TABLE”) is directly assigned to one output signal. Thus there are as many colors possible as sensor outputs are available.
ONE HOT INV.	Refer to “ONE HOT“, but output signals are inverted
BINARY	The result is encoded binary and thus 2^n (n = number of sensor outputs) states are possible. The index 255 is used as “Not recognized” or “Out of tolerance” in the CHECK mode.
BINARY INV.	Refer to “BINARY“, but output signals are inverted
DEVIATION ⁴	If no matching color can be found, this result format indicates the color-deviation from the first entry of the color-table. The meaning of the different output ports is shown in Table 5. This mode is only available with the color-space-modes L*a*b* or LAB99 and processing mode CHECK CYL.

Table 5: Deviation-mode signal assignment

Ausgang	Anzeigensegment
OUT0	1 = color detected, 0 = No color detected
OUT1	Darker
OUT2	Brighter
OUT3	Deviation to red
OUT4	Deviation to green
OUT5	Deviation to yellow
OUT6	Deviation to blue
OUT7	Not used

RUNNING MODE

The **output ports** of the sensor system can be used continuously or triggered (“EXTERN TRG.“ mode). The selection can be made in the field “RUNNING MODE“ (Figure 13).

When continuously used (“CONTINUOUS”), the outputs are always updated as fast as the current adjusted response time.

When the “EXTERN TRG.“ mode was selected, the outputs are updated when a rising edge at the input TRG 0 is detected and remain then in this state until the next rising edge occurs.



Figure 13: Output signals running mode

Additionally the sensor supports two different sequential modes. This makes it possible to detect a color sequence defined by the color table in a trigger based mode or in a time based mode.

⁴ The deviation encoding is only available for sensors with 8 output ports.

The triggered sequence mode („TRG. SEQU.“) compares the actual result with an entry in the color table (please refer to sect. 1.2.3, subsect. “COLOR TABLE”) after each appearing trigger on TRG 0. It starts with entry 0 and goes on after every successful comparison (correct color) to the next entry. If a detected color does not match its table entry, or the time between two trigger events is too long (timeout) the sequence will reset to entry 0. The adjustment of the timeout can be done in the field “SEQUENCE TIMEOUT” (Figure 14)



Figure 14: Timer configuration for triggered color sequence

You can use this mode to recognize a color series of objects with undetermined object distance and appearance time (e.g. to trigger on colored objects on an assembly line that appear in the same order but undetermined in time).

The time based sequence mode („TIMED SEQU.“) works like the triggered sequence mode in principle, but only the beginning of a new sequence has to be indicated by a trigger event on TRG 0. After that the sensor automatically compares the colors after a programmable time (interval). In case a color does not match its corresponding table entry, the sequence will reset to entry 0. The adjustment of the timer interval can be done in the field “SEQUENCE INTERVAL” (Figure 15).



Figure 15: Interval configuration for timed color sequence

Use this mode to recognize a color series of equidistant spaced and timed objects (e.g. a rotating wire with color stripes).

A third sequence mode is chosen by activating “SELF TRIGG SEQ”. For this mode no external trigger is required. The sequence starts by detecting a first color. If every color of the color table is recognized in the right order, the sequence is finished successfully. If the time adjusted in the field „SEQUENCE TIMEOUT“ to detect the next valid color of the color table is exceeded an error signal occurs. The same is for detecting the wrong color sequence order. The coding of the states shows Table 6. **This mode requires the “CHECK SPH” or “CHECK CYL” mode.**

Each state of the sequence detection is treated like an ordinary result of a single color detection and is encoded accordingly. The appearance of the sequence state on the output port can be adjusted by setting the proper “RESULT FORMAT” mode. The following modes are detected:

Table 6: Sequence Encoding

State	Description
OFF	Waiting for start
0	Sequence active
1	Sequence finished successfully
2	Wrong color detected
3	Trigger Timeout (triggered sequence)
4	Trigger too early (timed sequence)

AVERAGING

In the field “AVERAGING” values in the range of 1...65535 for averaging the sensor signals can be adjusted .

Large averaging values are recommended for pure signal quality. Keep in mind that large averaging values reduce the response time of the sensor (Table 7).

SCAN FREQUENCY

The scanning frequency of the sensor system in kHz can be defined in the field “SCAN FREQUENCY“ (Figure 16).

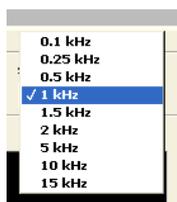


Figure 16: Sensor system scanning frequency

Please notice the following relationship. If the scanning frequency is chosen to be low, the power consumption of the sensor is low too (Illuminant will get darker). But if a high scanning frequency is chosen, the power consumption rises (due to the increasing light intensity).

Hint 1:

The chosen frequency has also influence on the system’s ambient light compensation properties. In the case of artificial ambient light (modulated mainly at 100 Hz) a frequency greater than 1 kHz is recommended in order to achieve good compensation properties.

Hint 2:

Due to hardware limitations higher frequencies for higher signal gain settings (SIGNAL GAIN⁵ > 5) are not available.

Table 7: Examples of dependency of response time on adjusted FREQUENCY and AVERAGING values

FREQUENCY	AVERAGING	Response time
1kHz	1	1ms
10kHz	10	1ms
1kHz	100	100ms
10kHz	10000	1000ms

SIGNAL MONITOR

The current sampled signals from the primary sensor are displayed in the graph “SIGNAL MONITOR“ as raw data. Their description is shown in the following Table 8.

⁵ The SIGNAL GAIN option is only available for colorCONTROL.LT2 sensors.

Table 8: Description of the signals in the sensor signal monitor

Signal color	Description
Light red	Raw data of the red signal (bright phase)
Light green	Raw data of the green signal (bright phase)
Light blue	Raw data of the blue signal (bright phase)
Dark red	Raw data of the red signal (dark phase)
Dark green	Raw data of the green signal (dark phase)
Dark blue	Raw data of the blue signal (dark phase)

The three color bars red, green and blue, displayed underneath the sensor signal monitor show the differential signals of the raw data. In the self-shining mode the signals are identical to the signals in the bright phase. On the right hand side a color sample is displayed that is being continuously calculated from the actual three color signals.

Hint 1:

The signal data from the dark phase are zero in the self-shining mode and thus not visible. If the signal data from the dark phase of body colors (passive mode) are very small, they are also not visible. Moreover the signal amplitudes from the bright and dark phase can possibly overlap and hence only one color is able to be seen at the same time.

Hint 2:

The color sample on the right hand side of the three color bars reproduces a sound color which is similar to the measured object after setting a good reference white. However the color can be incorrect and not 100% identical and shall merely serve as orientation, e.g. during the color sampling process (“Teach-in”) or when displaying tolerance boundaries in color diagrams.

COLOR GROUPING

In the right lower window region a switch is located to activate or deactivate the color grouping function (Figure 17).



Figure 17: Activating and deactivating of color grouping function

With this function arbitrary colors of the color table can be pooled to groups. In this way complex class or tolerance boundaries can be realized. After activating the function in the color table an additional column appears to indicate the group index. Colors with the same group index are mapped to the same sensor output correspondingly to the adjusted „RESULT FORMAT“ mode.

SAVE PARAMETERS

There are two switches in the field “SAVE PARAMETERS“ for saving the current parameter settings.

The switch “TO SENSOR“ stores all parameters into the built-in nonvolatile Flash-memory of the sensor. The parameters will remain in the Flash-memory after power down.

The switch "TO FILE" stores all parameters on a memory drive of a computer that is connected to the sensor system.

LOAD PARAMETERS

The switch "FROM FILE" in the field "LOAD PARAMETERS" loads a parameter set into the sensor system.

Hint:

After starting the software the parameters are automatically loaded from the built-in Flash-memory into the sensor system.

1.2.3 Teaching In Colors

The so-called “Teach-in“ procedure for sampling and storing colors into the color table is done in the tab “TEACHING IN COLORS“ of the program window (Figure 18).

COLOR SPACE MODE

The currently selected color mode is shown in the field “COLOR SPACE MODE“ in the left hand upper area of the program window.

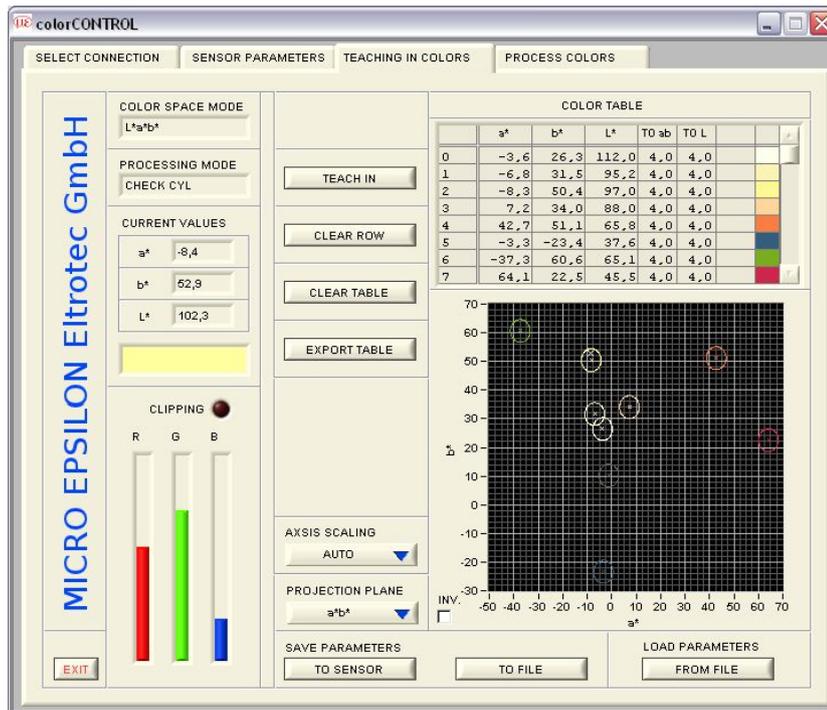


Figure 18: Acquire color sample program window

PROCESSING MODE

The currently selected processing mode is shown in the field “PROCESSING MODE“ below the field “COLOR SPACE MODE“.

CURRENT VALUES

This field shows the current sensor data (color coordinates) as they are transformed within the current selected color space. Beneath these values the current color is shown as a visible color sample (a valid reference white is the basic precondition for proper color representation).

COLOR TABLE

The color table is located on the right hand upper area of the program window. Its function is to store colors for recognition or classification. On the left hand side buttons for sampling and erasing colors are located.

The button "TEACH IN" stores the current color space values into the next free row of the color table. For **overwriting** a row of the color table the PC cursor must be set into the corresponding row. After that the button "TEACH IN" has to be pressed.

The button "CLEAR ROW" clears all color values of one row that has been selected by a mouse click. The then remaining data rows move up.

The button "CLEAR TABLE" clears all entries in the color table.

EXPORT TABLE

The button "EXPORT TABLE" stores the current contents of the color table into a comma separated spreadsheet file (.csv) onto the disk of the PC. The file can easily be processed with common spreadsheet software.

AXIS SCALING

With this selection switch 3 scaling methods can be chosen (Figure 19).



Figure 19: Scaling options

„MANUAL“ allows manually editing of the diagram axes (by marking and editing the numbers on the axes). „DEFAULT“ resets the axes to default values. The setting „AUTO“ activates an auto scaling of the axes.

PROJECTION PLANE

The X and Y axes of the **color diagram** on the right hand side can be selected in field "PROJECTION PLANE" in order to display the desired color plane out of all three possible 2-dimensional planes of the 3-dimensional color space. All colors and tolerances can be completely viewed by this projection plane. **To fit the color diagram scales to the desired range, the axes can be adjusted by editing the numbers on the axes.**



Figure 20: Selecting a 2-dimensional plane out of the 3-dimensional color space

All values stored in the color table (except the row index) can be manually modified. By clicking on a table row the input mode becomes active and numbers can be simply modified by using the keyboard. By entering the RETURN key or clicking on another area within the program window the modified values will be stored into the color table. There is a scroll bar on the right hand side at the table for scrolling the table up and down.

The used table columns depend on the selected processing mode (PROCESSING MODE) and the activated grouping function. Variants are shown in Figure 21, Figure 22, Figure 23 and Figure 24.

COLOR TABLE					
	a*	b*	L*		GRP
0	0,2	0,4	99,9		0
1	-4,3	-22,3	80,6		1
2	-29,0	-17,4	79,8		2
3	-27,5	25,8	70,4		3
4	0,9	57,0	90,0		4
5	8,1	36,5	81,1		5
6	22,4	8,9	60,7		6
7	35,4	-31,2	63,7		7

Figure 21: classify mode

COLOR TABLE						
	a*	b*	L*	TOL		GRP
0	0,2	0,4	99,9	4,0		0
1	-4,3	-22,3	80,6	6,2		1
2	-29,0	-17,4	79,8	7,9		2
3	-27,5	25,8	70,4	3,6		3
4	0,9	57,0	90,0	5,4		4
5	8,1	36,5	81,1	4,5		5
6	22,4	8,9	60,7	3,9		6
7	35,4	-31,2	63,7	4,8		7

Figure 22: recognition with spherical tolerances

COLOR TABLE						
	a*	b*	L*	TO ab	TO L	GRP
0	0,2	0,4	99,9	4,0	5,0	0
1	-4,3	-22,3	80,6	6,2	3,5	1
2	-29,0	-17,4	79,8	7,9	4,0	2
3	-27,5	25,8	70,4	3,6	4,4	3
4	0,9	57,0	90,0	5,4	2,8	4
5	8,1	36,5	81,1	4,5	6,0	5
6	22,4	8,9	60,7	3,9	4,7	6
7	35,4	-31,2	63,7	4,8	7,2	7

Figure 23: recognition with cylindrical tolerances

COLOR TABLE						
	a*	b*	L*			GRP
0	0,2	0,4	99,9			0
1	-4,3	-22,3	80,6			1
2	-29,0	-17,4	79,8			1
3	-27,5	25,8	70,4			2
4	0,9	57,0	90,0			3
5	8,1	36,5	81,1			3
6	22,4	8,9	60,7			3
7	35,4	-31,2	63,7			4

Figure 24: grouping of colors

There are no tolerance target values needed in the classification mode. The recognition mode needs target values: one parameter, spherical radius (column TOL in Figure 22), is required for spherical tolerances and two parameters, color (column TO ab in Figure 23) and brightness (column TO L in Figure 23) tolerance, are required for cylindrical tolerances. The latter is favorable in applications where the color brightness plays a less important role than the actual color. If the TO L tolerance is hereby set to a high value the influence of the color brightness is correspondingly low.

In the right column “GRP” a group index (0...255) can be assigned if the grouping function is activated. The assigned index is encoded according to the adjusted output format (“RESULT FORMAT”). Equal group index numbers activate the same sensor output. In this way different colors can be mapped to the same output.

The color diagram is located in the right lower area of the program window.

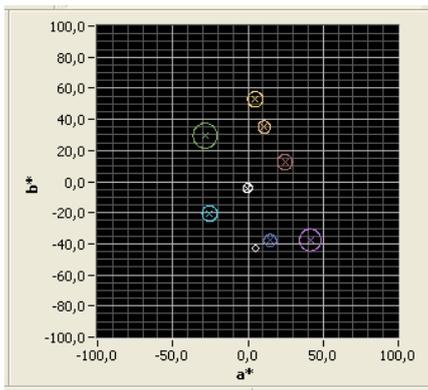


Figure 25: Color diagram with tolerance cylinders in the a*b* plane

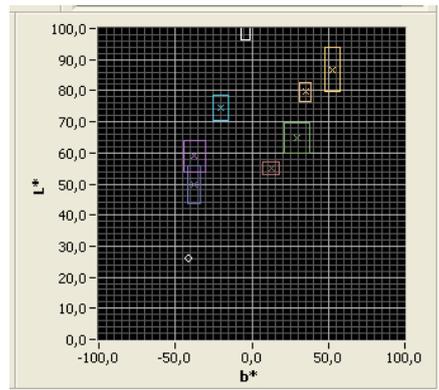


Figure 26: L*b* plane

Figure 25 and Figure 26 show an example color diagram in the L*a*b* color space in the processing mode cylindrical tolerances.

The sample colors in the right column of the color table correspond to the colors resulting from the color values/coordinates in each row. The displayed color complies with the real color only if a valid reference white was successfully sampled before. The visible colors in the color table are also used for displaying the tolerance boundaries in the color diagram and hence support the user at defining the tolerance boundaries in the diagram.

Hint 1:

Despite the tolerance rooms/boundaries may overlap, the color inspection and classification is done always uniquely. The order of colors stored as rows in the color table does not affect in any way the color inspection.

Hint 2:

The tolerance parameters are used as ΔE -like units. Table 9 shows how the human color perception commonly recognizes color variations in the $L^*a^*b^*$ color space. Due to the dependencies of the obtained color values on the used illumination source and the accuracy of the sensor, the table only serves as a clue. Practical tolerance values must be found individually for the sensor.

Table 9: Common values of human perception of color variations

color variation ΔE	human perception
<1	very small color variation that can not be seen by the human eye
1...2	small color variation that can be seen by trained human eye
2...3,5	medium color variation that can be seen by average human eye
3,5...5	considerable color variation
>5	high color variation

Hint 3:

If the spherical tolerances processing mode is selected, the tolerance circles become ellipses in some projection planes due to different scaling of the diagram axes and is, however, merely a displaying effect.

SAVE PARAMETERS

The switch “TO SENSOR“ stores all parameters into the built-in nonvolatile Flash-memory of the sensor. The parameters will remain in the Flash-memory after power down. The switch “TO FILE“ stores all parameters on a memory drive of a computer that is connected to the sensor system.

LOAD PARAMETERS

The switch “FROM FILE“ of the field “LOAD PARAMETERS“ loads a parameter set into the sensor system.

Hint:

The buttons in the fields “SAVE PARAMETERS“ and “LOAD PARAMETERS“ are located in each program tab and perform all the same functionality. An entire parameter set is always stored or loaded. After starting the program all parameters are read out from the built-in Flash-memory and are displayed in the program.

1.2.4 Color processing

Figure 27 shows the program window for color recognition and classification which can be found under the tab “PROCESS COLORS“.

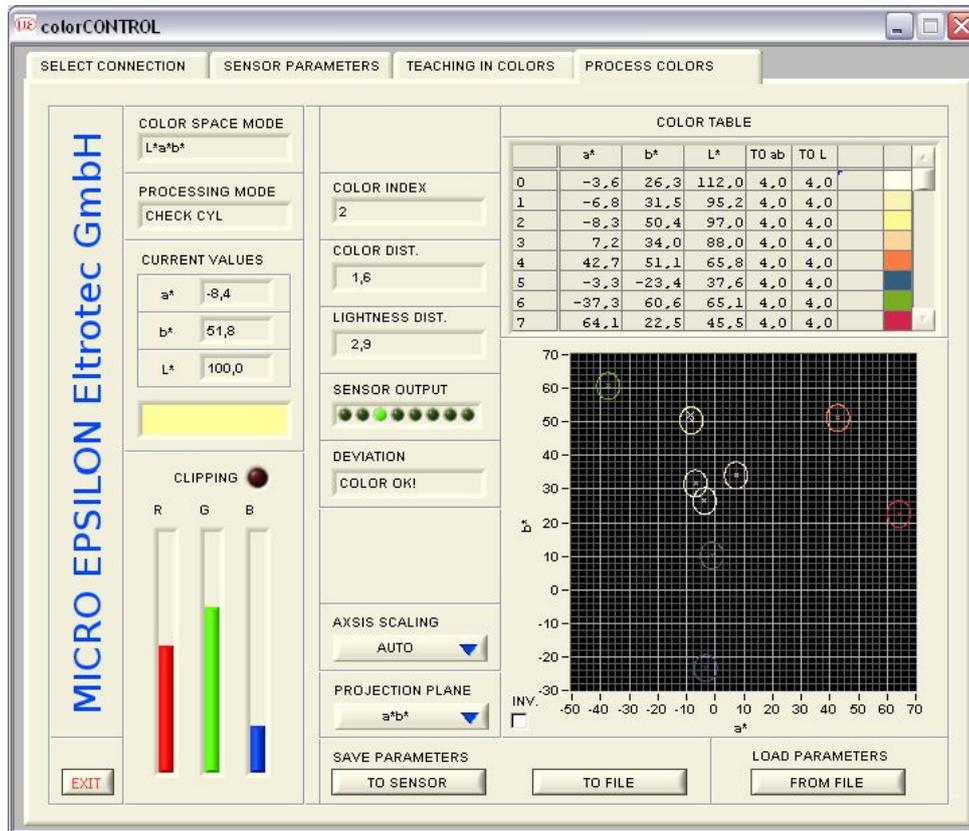


Figure 27: Color recognition and classification program window

The window arrangement and operation is similar to the program window “TEACHING IN COLORS“ except for the three buttons on the left hand side of the color table which are substituted by three number boxes.

COLOR INDEX

The color number of the recognized or classified color is shown in the field ”COLOR INDEX“ and represents the result of the entire sensor system’s signal processing path. This number is the equivalent of the row number in the color table. If in the recognition (checking) processing mode the tolerance boundaries were exceeded, the color number becomes 255. In addition the result is also available at the sensor system’s communication interface.

COLOR DIST

The Euclidean distance between the actual measured color and the recognized or classified (matched) color value is displayed in the field ”COLOR DIST“. If the cylindrical tolerance mode is selected the euclidean distance becomes a 2-dimensional distance vector (2-dimensional color vector). All other processing modes show a 3-dimensional euclidean distance vector.

Hint:

If in the processing modes “CHECK CYL“ and “CHECK SHP“ the tolerance room was exceeded or the color was not recognized (Index 255), the distance to the next closest color is calculated and shown in the field ”COLOR DIST“.

LIGHTNESS DIST

The field "LIGHTNESS DIST" shows the magnitude of the brightness distance in the cylindrical tolerances processing mode (equal to an "altitude difference" in the color space).

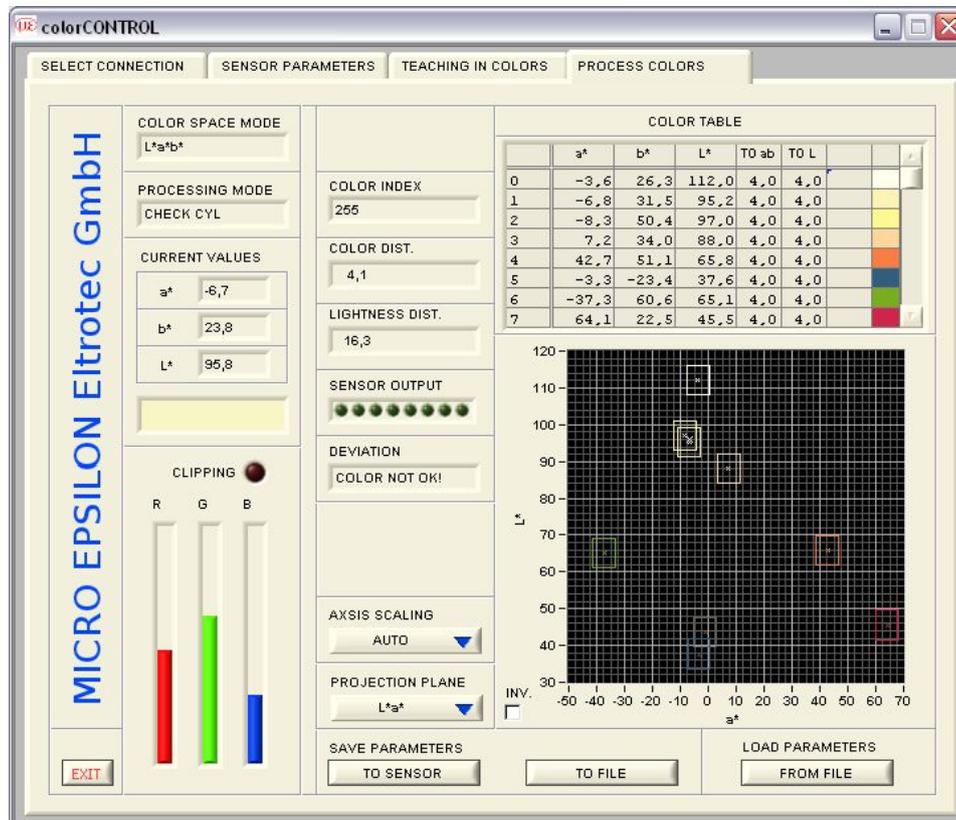


Figure 28: Program window when tolerance was exceeded and color was not recognized

The color distance values can be read out by the RS232 or USB interface.

Hint:

If in the processing mode "CHECK CYL" the tolerance room was exceeded or the color was not recognized, respectively, the brightness distance to the next closest color is calculated and displayed in the field "LIGHTNESS DIST".

SENSOR OUTPUT⁶

This display signals the switching states of the sensor outputs corresponding to the „RESULT FORMAT“ and „COLOR GROUPING“ settings.

⁶ The number of displayed outputs depends on the used sensor type.

DEVIATION⁷

If the result format “DEVIATION” is selected, this display interprets the sensors outputs and displays the color-deviation in plain text. If one of the other result modes is selected, this display just shows whether a color is detected or not.

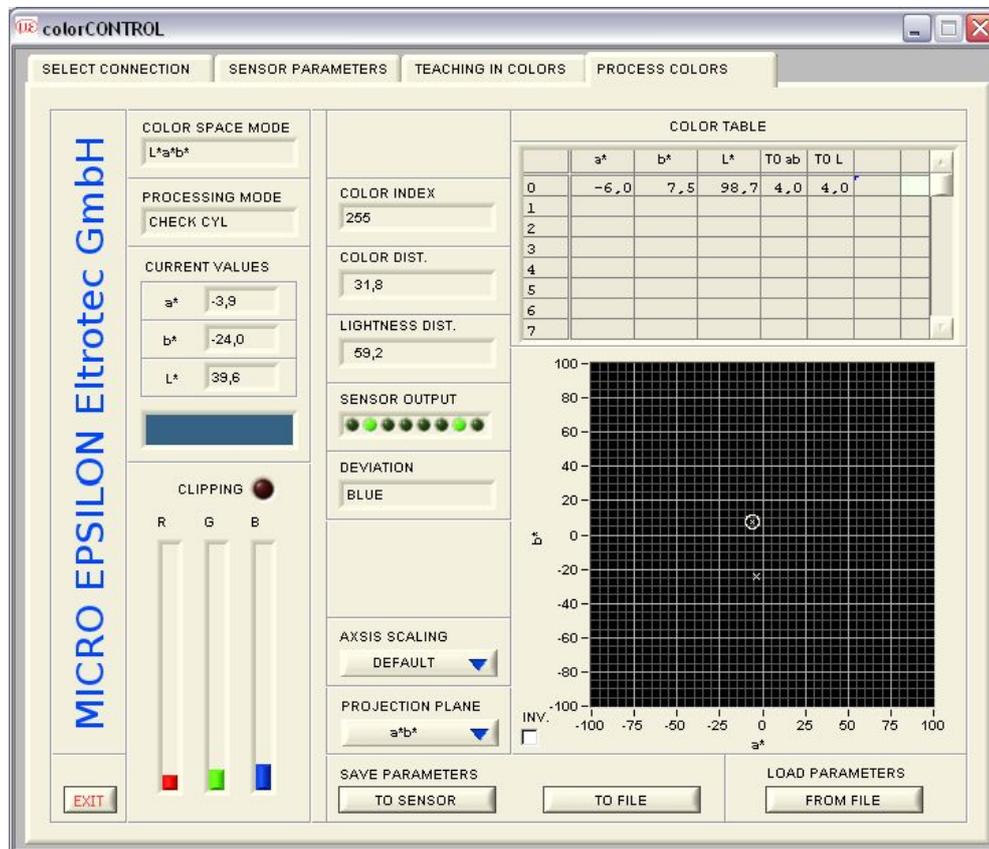


Figure 29: Result format "DEVIATION" - Display of color-deviation

AXIS SCALING

With this selection switch 3 scaling methods can be chosen (ref. to above section).

⁷ Only usable for sensors with 8 outputs.

1.2.5 Service

With the switch within the field „SERVICE“ at the startup-screen a service tool is started, which allows certain special hardware functions and settings. Figure 30 shows the program window.

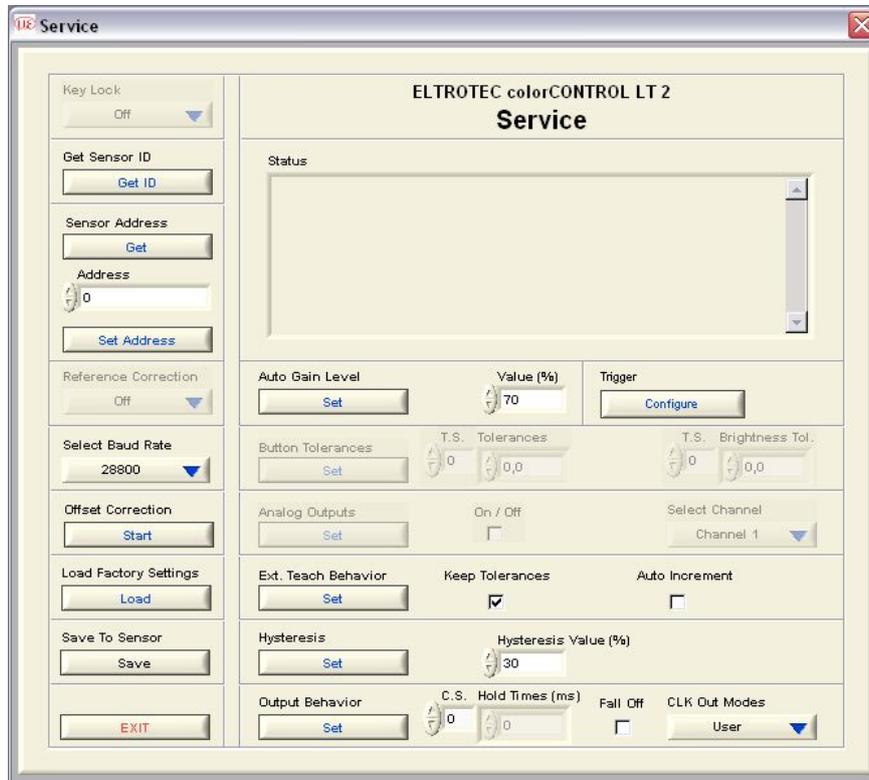


Figure 30: „SERVICE“ program window

KEYLOCK

By this switch the sensor keys are lock or unlocked respectively.

GET SENSOR ID

With „GET ID“ the device serial number and version of the sensor firmware is read from the device and displayed on the right textbox.

SENSOR ADDRESS

With „GET ADDRESS“ in the area of „SENSOR ADDRESS“ the programmed address of the sensor is read out and displayed on the right textbox. Underneath this switch there is a field to set the particular sensor address (scope: 0...255). With „SET ADDRESS“ the sensor is programmed to listen to the chosen address.

BAUD RATE

With the „SELECT BAUD RATE“ switch, the sensor communication is reconfigured to the chosen baudrate.

OFFSET CORRECTION

Press this button to start a routine that ascertains and corrects the sensors offsets. Offsets are the sensors dark signals that are noticeable in the active mode for self-shining objects. For correct operation, the hole of the sensor light input must be darkened.

LOAD FACTORY SETT.

With the „LOAD FACTORY SETT.“ switch the factory settings are loaded into the RAM of the Sensor.

Auto Gain Level

This control is to change the factory preset level of 70%.

Button Tolerances⁸

With this controls the default tolerance values for the 5 possible steps can be changed. The assignment to the 5 blinking impulses is as follows.

Tolerance Step (T.S.)	Blinking impulses	Factory Tolerance Value
0	1	3
1	2	6
2	3	9
3	4	15
4	5	20

The left tolerance values operate in the processing mode “CHECK SPH”. In the operating mode “CHECK CYL.” the right tolerance controls are additionally active. They can be used to change the brightness tolerances.

To adopt the adjusted tolerances the “SET” button must be pushed.

HINWEIS:

In the processing mode “CLASSIFY” the tolerance controls are inactive.

EXT. TEACH BEHAVIOR

There are different ways of using the running mode “EXT. TEACH”. If the checkbox “AUTO INCREMENT” is activated, the new color will be added as new entry of the internal color-table. If it’s disabled, the last valid color-value will be overwritten.

The function “KEEP PREVIOUS TOLERANCES” is only useful with disabled “AUTO INCREMENT”. It overwrites the color-values and keeps the old tolerance-values of the table-entry. If this checkbox is disabled, default tolerances are used.

The button “SET” sends the new properties to the sensor.

SET HYSTERESIS

This function guarantees a stable operation of the sensor system. It is recommended to choose a high hysteresis value if the signal quality is poor in order to prevent the signal processing from instability (“flutter”). The value for hysteresis can be set by pressing “SET HYSTERESIS“. The value adjusted in the field “HYSTERESIS VALUE“ will be set. The value are percentages of the pre-defined tolerances in the color table (refer to sect. 3.2.3).

⁸ Only available for 3-Channel sensors

OUTPUT BEHAVIOR

“Hold Times (ms)”

This function sets a hold time for the sensor outputs. Using the running modes “CONTINUOUS” and “EXT.TEACH” this function holds the output-values for the selected number of milliseconds. The max. adjustable time is 65535 ms. With the Selector C.S. the corresponding color channel can be adjusted.

“Fall Off”

If this function is used with an external triggered mode and the checkbox “Fall off” is enabled, the results fall back after the expiration of the desired number of milliseconds.

“CLK Out Modes”

With this switch the output function of the CLK output (PIN 5 on SB1) can be determined.

Mode	Function
„User“	Can be set with command 0x73
„CLK Out“	Output of Illumination clock
„Color Out“	Additional color channel

SAVE TO SENSOR

With this switch the chosen settings will be stored in flash memory permanently.

Hint

If the program is ended without storing the settings to flash memory permanently, all information are lost after a restart.

2 Communication protocol and command reference

The sensors can be fully controlled via RS232 or USB⁹. All commands are also available as LabVIEW[®] VIs and DLL function library. All software is shipped with the sensor system.

2.1 Protocol structure

There is a uniform protocol for sending and receiving data, respectively. The smallest communication unit is a byte (8 bits), however two bytes are always combined to one word and transferred together.

Protocol structure

ID	LP	AD	RR	DH	DL	...	CH	CL
----	----	----	----	----	----	-----	----	----

The high-order byte is followed by a low-order byte. After sending a command word and receiving by the sensor system, a status response including error codes is sent back after executing the command

Table 10: Protocol Build-Up

Word	Byte	Name	Description
0	0	ID	Command ID, higher 8 Bit of word 0
0	1	LP	Payload Length in Words, lower 8 bit of word 0
1	2	AD	Programmable Sensor Address, higher 8 bit of word 1
1	3	RR	Reserved (always 0), lower 8 bit of word 1
...	...	DH	Data, higher 8 bit
...	...	DL	Data, lower 8 bit
N	...	CH	Frame checksum, higher 8 bit
N	...	CL	Frame checksum, lower 8 bit

The Payload length is limited to 255 words. Bigger frames will lead to unpredictable behavior of the device.

Every sensor can have an 8 bit wide address (AD). The sensor will only respond to commands with this exact address but always to commands with address '0'. This address can be set by command 0x11.

The checksum is a simple addition of all transmitted 16 bit words including the header. After adding all values only the lower 16 Bit will be taken.

⁹ Only available for sensors with USB port.

Table 11: Response Codes

Response	Data Value	Description
0xF0	dep. on com.	Commando executed correctly
0xF1	0x00-0x03	Internal status
	0x04	Frame: wrong checksum
	0x05	Frame: wrong length
	0x06	Frame: receive buffer not ready
	0x07	Frame: unknown error (fatal)
	0x08	Frame: timeout (1s)
0xF2	0x00	Illegal command
0xF3	0x00	Command not enabled
0xF4	0x00	Invalid parameter
0xE0	dep. on com.	Burst mode

If a frame is not transmitted completely within one second the sensor responds with a timeout code (0xF1, Payload: 0x08).

Command sequence example 1:

Setting the light intensity to a value of 0x20: „2401 0000 0020 2421“

System Response to that command: “F000 0000 F000” (no error)

Command sequence example 2:

Reading actual value of the light intensity : „2500 0000 2500“

System Response to that command: “F001 0000 0020 F021” (no error)

2.1.1 Burst Mode

For getting values from the sensor system as fast as possible without querying them, a burst mode has been implemented. When a burst mode is set by the burst mode command (0x12), this initial command is acknowledged as usual. After that, the system will send frames of the following structure continuously, until stopped by another burst mode command, switching the burst mode off again.

Burst Frame Structure

ID	LP	AD	RR	TH	TL	DH	DL	...	CH	CL
----	----	----	----	----	----	----	----	-----	----	----

Table 12: Burst Frame Build-Up

Word	Byte	Name	Description
0	0	ID	Burst Mode response Code, always “0xE0”
0	1	LP	Payload Length in Words, lower 8 bit of word 0
1	2	AD	Programmable Sensor Address, higher 8 bit of word 1
1	3	RR	Reserved (always 0), lower 8 bit of word 1
2	4	TH	Timing information, higher 8 Bit of word 2

2	5	TL	Timing information, lower 8 Bit of word 2
...	...	DH	Begin of burst data. Format according to requested mode.
...	...	DL	Begin of burst data. Format according to requested mode.
N	...	CH	Frame checksum, higher 8 bit
N	...	CL	Frame checksum, lower 8 bit

The burst frame has the same structure like all other frames. Directly after the header a timing counter (TH/TL) is inserted. This counter indicates the time between two successive burst frames in μs . After that, the requested data follows as if it was the payload of the requested burst mode.

Other commands received by the system during a burst will be accepted and acknowledged accordingly.

Burst Mode Sequence example:

Step 1: Enable Burst Mode (2F-Mode):

“1201 0000 0001 1202”. Response: “F000 0000 F000”.

Step 2: Receive Burst Frames

“E00A 0000 22D2 **0112 00F9 0075 0EED 0F06 0F8A 0FFF 0FFF 0FFF** 62D6”.

The system will go on sending frames similar to the above. The delay between this and the last frame is 8.914ms (0x22D2). The bold values represent the payload as if requested by a 0x2F-command.

Step 3: Stop Burst Mode:

“1201 0000 0000 1201”: Response (after the last burst-frame) “F000 0000 F000”

2.1.2 Fixed point notation

In many cases it is necessary to use a more precise numbering system than the 16-bit integer number. For this reason the sensor system uses a 32-bit fixed point format number which has the following structure:

Table 13: Fixed-Point Format (two’s complement)

Bit 31-21	Bit 20-0
Integer part	Fractional part

This format has a range ± 1024 with a resolution of 0.000 000 477. The representation corresponds to the two’s complement. The conversion is described by the following formula:

$$F_{fixed} = F_{real} \cdot 2^{21}$$

Conversion Example 1 : From Float to Fixed Point

a) Number: +1.123

Because the value is positive, the formula can be used directly.

$$1.123 \cdot 2^{21} = 2355101.696 \rightarrow 2355102 = 0x0023EF9E$$

b) Number: -1.123

Because the value is negative, the above result has to be converted to a negative two's complement value by inverting and adding "1":

$$0x0023EF9E \rightarrow 0xFFDC1061 \rightarrow 0xFFDC1062$$

Conversion Example 2: From Fixed Point to Float

a) Number: 0x0023EF9E

Because the most significant bit is "0", this is a positive value. Simple convert by using the above formula.

$$\frac{0x0023EF9E}{2^{21}} = \frac{2355102}{2^{21}} = 1.123000$$

b) Number: 0xFFDC1062

Because the most significant bit is "1", this is a negative value. Before conversion, invert and add "1":

$$0xFFDC1062 \rightarrow 0x0023EF9E = 2355102 \rightarrow -1.123000$$

Important:

Please pay attention to the word order of the low and high word of the 32 bit number. First, the lower part (Bit 15-0) is transmitted, then the higher part (Bit 31-16).

Communication Example:

Setting Reference White to 0.9/0.8/0.75 (Command 0x42)

0.90 → 0x001CCCCC

0.80 → 0x00199999

0.75 → 0x00180000

-> "4206 0000 CCCC 001C 9999 0019 0000 0018 A6B8"

2.2 Command reference

The following section describes all available commands. Data types other than 16 Bit integer (a word) and 32 Bit fixed point are described at the command description directly.

The leading hex-number represents the command id, the rest of the header (for example the length) and the checksum have to be set appropriately to build a complete communication frame.

2.2.1 System Identification

0x01 : ID-String

Response: ASCII-String with 16 Bit Character width

Note: Because the communication is 16-Bit based, only the lower 8 Bit of each word contain ASCII code. The higher 8 Bit are always zero.

0x02 : Device Production Date

Response: 2 words

Word 1: Bit 7-0:	Day
Word 1: Bit 15-8:	Month
Word 2:	Year

Note: To make the date readable the value must be interpreted hexadecimal.

0x03 : Device Feature Index

Response: 1 word

Bit 15-0:	Device Feature Index
-----------	----------------------

0x04 : Device Hardware Revisions

Response: 2 words

Word 1: Bit 15-8:	System Board Revision
Word 1: Bit 7-0:	Communication Board Revision
Word 2: Bit 15-8:	Sensor Board Revision
Word 2: Bit 7-0:	Connector Board Revision

0x05 : Device Software Revision

Response: 1 word

Bit 15-8:	Major Revision
Bit 7-0:	Minor Revision

0x06 : Device Unique Serial Number

Response: 2 words

Word 1:	Device Unique Serial Number (high)
Word 2:	Device Unique Serial Number (low)

2.2.2 Communication

0x10 : Set Baud Rate

Send: 1 word

0:	9.600
1:	14.400
2:	28.800 (default)
3:	38.400
4:	57.600
5:	115.200

Note: As for all commands, the serial baudrate can be set with an USB command.

0x11 : Set Sensor Address

Send: 1 word

Note: Values other than 0-255 are ignored.

0x12: Set Serial Burst Mode

Send: 1 word

- 0: Burst Mode off
- 1: Burst 2F
- 2: Burst 3F
- 3: Burst 4F
- 4: Burst 5F
- 5: Burst 6F

Response:

- Word 0: difference between two burst packages in us
- Word 1: (and following) requested data

Note: For more information about the burst mode feature please refer to chapter 2.1.1.

0x13: Set USB-Burst Mode¹⁰

like 0x12, only for USB

2.2.3 Data Acquisition

0x20 : Set Acquisition Mode

Send: 1 word

- 0: no acquisition
- 1: active light internal triggered
- 2: passive light internal triggered
- 3: active light external triggered
- 4: passive light external triggered
- 5: active light external triggered inverted
- 6: passive light external triggered inverted

0x21 : Read Acquisition Mode

Response: 1 word (like 0x20)

0x22 : Set Transimpedance Amplification¹¹

Send: 1 word

- 0: Amplification factor 1
- 1: Amplification factor 5
- 2: Amplification factor 25
- 3: Amplification factor 100

0x23 : Read Transimpedance Amplification¹¹

Response: 1 word (like 0x22)

¹⁰ Only available for sensors with USB port.

¹¹ This function is only available for colorCONTROL LT2 sensors.

0x24 : Set Illuminating Intensity¹¹

Send: 1 word

Note: Values other than 0-255 are ignored.

0x25 : Read Illuminating Intensity¹²

Response: 1 word (like 0x24)

0x26 : Set Light Compensation Frequency

Send: 1 word

Note: This value represents the time between bright and dark sample phases. The value 0xFFFF represents a frequency of 100Hz, a value of 0x0270 a frequency of 10kHz. Values lower than 0x1D0 (>15kHz) may not give the expected results.

0x27 : Read Light Compensation Frequency

Response: 1 word (like 0x26)

0x28: Auto Gain Setup¹²

Response: 2 words

Word 1: automatically found Gain
 Word 2: automatically found Intensity

0x29: Set Averaging Cycles

Send: 1 word

0x2A: Read Averaging Cycles

Response: 1 word (like 0x29)

0x2D : Read Raw ADC Channels

Response: 7 words

Word 1: [X] Red Value
 Word 2: [Y] Green Value
 Word 3: [Z] Blue Value
 Word 4: Temperature Sensor

Note: Ranges are 0x0000 - 0xFFFF0. The values are 12 Bit, left justified. 0xFFFF0 represents the darkest, 0x0000 the brightest intensity (inverted).

0x2F : Read Compensated ADC Channels

Response: 9 words

Word 1: [X] Comp. Red Value
 Word 2: [Y] Comp. Green Value
 Word 3: [Z] Comp. Blue Value

¹² This function is only available for colorCONTROL LT2 sensors.

Word 4: [X] Red Value (Phase I)
 Word 5: [Y] Green Value (Phase I)
 Word 6: [Z] Blue Value (Phase I)

Word 7: [X] Red Value (Phase II)
 Word 8: [Y] Green Value (Phase II)
 Word 9: [Z] Blue Value (Phase II)

Phase I: Light Phase / no compensation
 Phase II: Dark Phase

Note: Ranges are 0x0000 - 0x0FFF. The values are averaged according to 0x29. 0x0000 represents the darkest, 0x0FFF the brightest value.

2.2.4 Sensor Correction

0x30 : Set Correction Matrix Mode

Send : 1 word

0 : Disabled
 1 : Sensor Level Correction
 2 : Sensor Matrix Correction

0x31 : Read Correction Matrix Mode

Response: 1 word (like 0x30)

0x32 : Set Correction Matrix

Send: 9 x Fixed Point

Matrix formula:
 $X_c = a_{00} * R + a_{01} * G + a_{02} * B$
 $Y_c = a_{10} * R + a_{11} * G + a_{12} * B$
 $Z_c = a_{20} * R + a_{21} * G + a_{22} * B$

Send order:
 a00, a01, a02, a10, a11, a12, a20, a21, a22

Note: The values of the correction matrix are only limited within the range of the fixed point numbers, but to let the system perform reasonable color transformations, the result of each channel should be between 0.0-1.0. The settings can be verified by using command 0x3F.

0x33 : Read Correction Matrix

Response: 9 x Fixed Point (like 0x32)

0x3F : Read Corrected Channels

Response: 3 x Fixed Point

Fixed Point 1: Corrected X Channel
 Fixed Point 2: Corrected Y Channel
 Fixed Point 3: Corrected Z Channel

2.2.5 Color Transformation

0x40 : Set Color Space Mode

Send: 1 word

- 0: XYZ (raw)
- 1: xyY
- 2: L*u'v'
- 3: L*a*b*
- 4: L*u*v*
- 5: Lab99

0x41 : Read Color Space Mode

Response: 1 word (like 0x40)

0x42 : Write Reference White

Send: 3 x Fixed Point

- Fixed Point 1: X reference
- Fixed Point 2: Y reference
- Fixed Point 3: Z reference

Note: The values of the correction matrix are only limited within the range of the fixed point numbers, but to let the system perform reasonable color transformations, the result of each channel should be between 0.0-1.0. A more practical way is to use command 0x44 to set the reference white.

0x43 : Read Reference White

Response: 3 x Fixed Point (like 0x42)

0x44 : Set Reference White

Response: 3 x Fixed Point (like 0x43)

Note: This command takes the actual input light and sets this values as reference white.

0x4F : Read Transformed Channels

Response: 3 x Fixed Point

Tabelle 1: Ranges in different Transformation Modes:

Mode	Read order	Range 1	Range 2	Range 3
0	X, Z, Y	0-1	0-1	0-1
1	x, y, Y	0-1	0-1	0-1
2	u', v', L*	0-1	0-1	0-1
3	a*, b*, L*	+/- 5	+/- 2	0-1
4	u*, v*, L*	+/- 5	+/- 5	0-1
5	a99, b99, L99	+/-5	+/- 2	0-1

2.2.6 Color Table, Color Recognition/Classification

0x50 : Write Color Table Entry

Send: 9 x Fixed Point

Fixed Point 1: Entry number (integer as Fixed Point)

Fixed Point 2: Value 1

Fixed Point 3: Value 2

Fixed Point 4: Value 3

Fixed Point 4: Tolerance 1 (Quadratic value of tolerance in spherical & cylindrical mode)

Fixed Point 5: Tolerance 2 (only cylindrical mode, corresp. to lightness distance)

Fixed Point 7: Raw Value 1 (X)

Fixed Point 8: Raw Value 2 (Y)

Fixed Point 9: Raw Value 3 (Z)

Note: This command writes a complete entry to the 255 entries long color table. The first value is the index of this entry. The next three entries are the transformed color values of the color to be recognized. The two tolerances depend on the classification mode. Please see chapter 1.2.4 for more detailed information. The last three values are the corresponding raw values to the transformed values. A more practical way to create a new entry is to use command 0x56.

0x51 : Read Color Table Entry

Send Entry Number: 1 x Fixed Point

Response:

Fixed Point 1: Value 1

Fixed Point 2: Value 2

Fixed Point 3: Value 3

Fixed Point 4: Tolerance 1 (Quadratic value of tolerance in spherical & cylindrical mode)

Fixed Point 5: Tolerance 2 (only cylindrical mode, corresp. to lightness distance)

Fixed Point 6: Raw Value 1 (X)

Fixed Point 7: Raw Value 2 (Y)
Fixed Point 8: Raw Value 3 (Z)

0x52 : Set Classification Mode

Send: 1 Word

Bit 15-8: Table size (number of valid entries)
Bit 7-0: 0: no classification
1: spherical check (with radius check)
2: cylindrical check (with radius check)
3: spherical classification (without radius check)

Hint:

For the colorSENSOR LT-1-ST the color table size is predefined to at least 3 entries.

0x53 : Read Classification Mode

Response: 1 Word (like 0x52)

0x54 : Set Hysteresis

Send: 1 Word

Note: This command sets a classification hysteresis (in percent) to filter small disturbances within the color recognition. The value enlarges the radius of the actual recognized color and makes it more difficult to leave.

0x55 : Read Hysteresis

Response: 1 Word (like 0x54)

0x56 : Set Color Table Entry

Response: 8 x Fixed Point

Fixed Point 1: Value 1
Fixed Point 2: Value 2
Fixed Point 3: Value 3
Fixed Point 4: Tolerance 1 (Quadratic value of tolerance in spherical & cylindrical mode)
Fixed Point 5: Tolerance 2 (only cylindrical mode, corresp. to lightness distance)
Fixed Point 6: Raw Value 1 (X)
Fixed Point 7: Raw Value 2 (Y)
Fixed Point 8: Raw Value 3 (Z)

Note: This command takes the actual light input as entry and auto-increments the table-size. Tolerances are set default to 4 units.

0x57 : Set Tolerance-Defaults

Send: 2x Fixed Point

Fixed Point 1: Default value for Color-Tolerance = $(\text{Value} / 100)^2$
Fixed Point 2: Default value for Lightness-Distance = $\text{Value} / 100$

0x58 : Read Tolerance-Defaults

Response: 2x Fixed Point

Fixed Point 1: Default value for Color-Tolerance = $(\sqrt{\text{Value}}) * 100$
 Fixed Point 2: Default value for Lightness-Distance = $\text{Value} * 100$

0x5F : Read Classified Value

Response: 3 x Fixed Point

Fixed Point 1: Index of recognized/classified color (closest color)
 Fixed Point 2: Quadratic value of distance 1 (spherical & cylindrical mode)
 Fixed Point 3: Value of Distance 2 (only cylindrical mode, corresp. to lightness distance)

2.2.7 Output Encoding

0x60 : Set Encoding Style

Send: 1 Word

Bit 15-12: Output Mode
 0 = [0000]: continuous
 1 = [0001]: external triggered
 2 = [0010]: trigger controlled sequence
 3 = [0011]: timer controlled sequence
 4 = [0100]: external triggered teach in
 5 = [0101]: self triggered sequence

Bit 11-8: Mapping Mode
 0: no mapping (direct)
 1: mapping enabled (use 0x62 to set entries)

Bit 7: External Teach Mode: Auto increment enable
 0: Auto increment disabled
 1: Auto increment enabled

Bit 6: External Teach Mode: Keep previous tolerance values
 0: Set default tolerances
 1: Keep previous tolerances (only useful in combination with Bit 7)

Bit 5: External Trigger Modes: Automatic fall-off enable
 0: Automatic fall-off disabled
 1: Automatic fall-off enabled

Bit 4: Encoding Polarity
 0: not inverted outputs
 1: inverted outputs

Bit 3-0: Encoding Mode
 0 = [0000]: off (output pins remain unchanged)
 1 = [0001]: direct
 2 = [0010]: 1-hot
 3 = [0011]: 7-segment
 4 = [0100]: Deviation

0x61 : Read Output Mode

Response: 1 Word (like 0x60)

0x62 : Set Encoding Map Entry

Send: 2 Word

Word 1: Table Entry (range 0..255)

Word 2: Table Value (range 0..255)

0x63 : Read Encoding Map Entry

Send: 1 Word (Table Entry 0..255)

Response: 1 Word (Table Value 0..255)

0x64 : Set Sequence Timeout

Send: 1 Word

Note: Sequence Timeout for triggered mode in ms.

0x65 : Read Sequence Timeout

Response: 1 Word (like 0x64)

0x66 : Set Sequence Interval

Send: 1 Word

Note: Time between two automatic samples for timed mode in ms

0x67 : Read Sequence Interval

Response: 1 Word (like 0x66)

0x68 : Set Output hold time

Send: 1 Word

Note: This command sets the time, for which the resulting output signal will be hold constant on the output pins, no matter how short time the detected color was in front of the sensor. The time is given in ms.

0x69 : Read Output hold time

Response: 1 Word (like 0x68)

0x6F: Read Encoded Output

Response: 1 Word (like encoded output pins)

2.2.8 Flash Operations and Parameters

0xA0 : Store Parameter

store all parameter from RAM to Flash

Note: Flash write operations can last up to seconds. The device must not be interrupted and power supply has to be stable during this time. Otherwise the flash may be corrupted and the device may start with an unknown or even a dangerous configuration.

0xA1 : Read Parameter

read stored parameter from Flash into RAM

0xA2 : Read Factory Settings

read factory defaults into RAM

3 LabVIEW® VIs

All commands described in chapter 4 are implemented as LabVIEW VIs and are shipped with this color sensor system. The following VIs are saved as LabVIEW Version 6.1 libraries on CD:

Table 14: LabVIEW libraries

Library	Description
libpcs_cmd.llb	Main library with all commands
libtools.llb	Help library for libpcs_cmd. Internal, shared VIs.
libft.llb	Help library for controlling the USB module.
libpcs_com	general functions for communication

3.1 Structure of command VIs

All command VIs have the same standard structure (Figure 31).

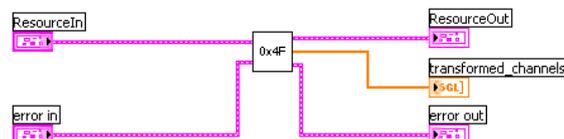


Figure 31: VI entity

Resource Signal

The **Resource** signal is a so-called cluster signal (Figure 32) and contains information and configuration about the communication interface.

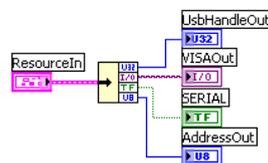


Figure 32: Resource Cluster-Signal

The signal **UsbHandleIn** contains the handle for the USB communication. The **VISAIn** signal stores all information for the serial communication interface. The communication channel is selected by the signal **SERIAL** (TRUE: RS232, FALSE: USB).

error Signal

The error signal is a cluster signal and contains error information (Figure 33).

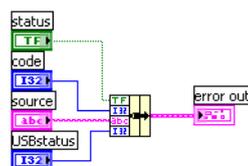


Figure 33: error Cluster-Signal

3.2 Open Resource VI and Close Resource VI

There are VIs for opening and closing the communication channel.

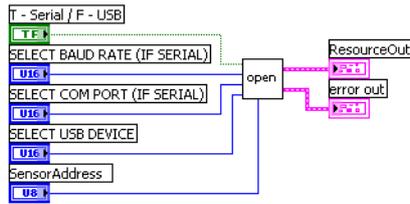


Figure 34: Figure 35: Open Resource VI

The switch **T - Serial / F - USB** selects between RS232 or USB. With the selection switch **SELECT COM PORT (IF SERIAL)** the used COM-Port for the RS232 can be selected. Via the selection switch **SELECT BAUD RATE (IF SERIAL)** the used baud rate can be chosen. With the control “SELECT USB DEVICE” the desired USB device can be chosen.

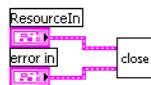


Figure 36: Close Resource VI

For closing the used com port the VI **close resource** is provided.

3.3 Example

Figure 37 shows a block diagram for combination of LabVIEW VIs with the command 0x2F (Read Compensated ADC Channels).

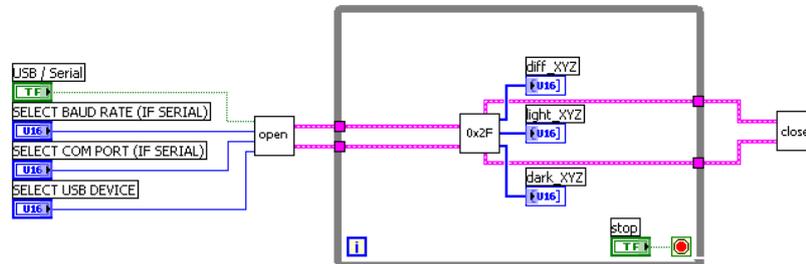


Figure 37: Combination with the command 0x2F (Read Compensated ADC Channels)

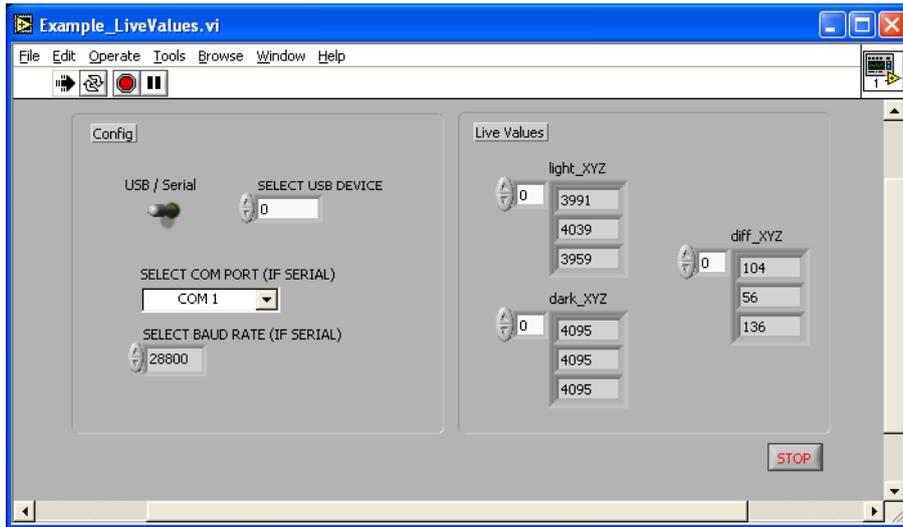


Figure 38: Front Panel of the example VI for the command 0x2F (Read Compensated ADC Channels)

4 DLL Function Library

4.1 Introduction

The function library **PCSLib** contains the functionality to communicate and configure the sensors. For the communication two PC devices are supported: serial interface (COM1, COM2, ...) and the USB interface.

This document describe the library functions its usage and the delivered files.

4.2 Library Functions

Three function layer are supported:

PCS Library:

Information (name, version number) about the PCSLib.

USB Library:

Initializing of the USB-Library.

PCS Devices:

Opening and closing of the interfaces and the communication.

4.2.1 Library

PCS_VersionString

Delivers the **PCSLib** version string in the following format: "PCSLIB 1.3"

```
UCHAR*
PCS_VersionString (void);
```

Parameters:

- none -

Return Value:

string Pointer to the **PCSLib** version string.

4.2.2 USB Library

PCS_initUSBLib

This function loads the USB library and initializes its functions. It is required to call this function, before additional USB functions can be used.

```
ULONG
PCS_initUSBLib (void);
```

Parameters:

- none -

Return Value:

opening status 0 indicates the successful initialisation
 -1 if an error occurs

PCS_closeUSBLib

This function closes the USB library and frees the allocated memory.

```
void PCS_closeUSBLib (void);
```

Parameters:

- none -

Return Value:

- none -

4.2.3 Devices

PCS_getUSBDeviceNum

Detects the number of sensors connected to the USB interface.

```
UCHAR  
PCS_getUSBDeviceNum (ULONG* num);
```

Parameters:

num Pointer that contains the device number.

Return Value:

Communication

error **PCSCS_OK** if command successful, otherwise the return value is an error code.

PCS_openDevice

Opens a communication device (USB or RS232 interface) and initializes the internal device memory structure. Depending on the device type different configuration parameters are used.

```
UCHAR  
PCS_openDevice (struct PCS_Device_def* pcsdev, UCHAR devtype,  
                  UCHAR devnr, ULONG baud);
```

Parameters:

pcsdev Pointer to device structure to be initialized

devtype Device type: **PCSDT_USB**, **PCSDT_RS232**

devnr Device number; depending on device type (USB or RS232 device)

baud RS232 baud rate; default value: 28800 baud

Return Value:

Communication

error **PCSCS_OK** if command successful, otherwise the return value is an error code.

PCS_closeDevice

Closes a previous opened communication device.

```
void  
PCS_closeDevice (struct PCS_Device_def *pcsdev);
```

Parameters:

pcsdev Pointer to the device structure

Return Value:

- none -

PCS_sendCommand

This function sends a command via the opened communication interface to the sensor and delivers the response.

```
UCHAR  
PCS_sendCommand (struct PCS_Device_def* pcsdev,  
                  UCHAR cmd, UCHAR devid,  
                  USHORT* txd, USHORT txd_len,  
                  USHORT* rxd, USHORT* rxd_len,  
                  UCHAR* responsecode);
```

Parameters:

pcsdev Pointer to the device structure
cmd Code of the command to be send
devid Device ID of the sensor for communication.
 0x00 (default) for broadcasting. All sensors connected to the opened
 communication interface are addressed.
txd Pointer to send message
txd_len Length of send message
rxd Pointer to receive message
txd_len Length of receive message
responsecode response code

Return Value:

Communication

error

PCSCS_OK if command successful, otherwise the return value is an error code.

Code Example:

```
#include "libpcs.h"
...

USHORT  x, y, z;
UCHAR   devid = 0x00;           // device id
USHORT  msg_tx[PCS_MAXMESSAGE_SIZE]; // transmit command data
USHORT  msg_rx[PCS_MAXMESSAGE_SIZE]; // received command data
USHORT  msg_tx_len, msg_rx_len;    // data length (rx, tx)
UCHAR   com_status;              // communication status
UCHAR   responsecode;            // protocol response code

msg_tx_len = 0;
com_status = PCS_sendCommand(pcsdev, PCSCC_ReadRawADCChannels, devid,
                             msg_tx, msg_tx_len, msg_rx, &msg_rx_len,
                             &responsecode);

if (com_status != PCSCS_OK || responsecode != PCSRC_OK)
{
    printf("ReadRawADCChannels: communication error: %x, %x\n",
           com_status, responsecode);
} else {
    x = msg_rx[0];                // value x
    y = msg_rx[1];                // value y
    z = msg_rx[2];                // value z
}
```

4.3 Files

File	Description
libpcs.dll libpcs.h	library and header file
Makefile	Makefile to generate the example executables (in this case gcc with cygwin)
acquisition.c acquisition.exe	shows the sensor color values in Lab color space
benchmark.c benchmark.exe	benchmark the USB and serial communication speed
identify.c identify.exe	reads the sensor identify string
PCSLib_en_x.y.pdf	this documentation

4.4 Requirements

- installed FTD2XX.DLL for USB communication
- installed development environment

Revision	Remark
1.8	Chap. 4: commands 0x44 & 0x56 added, command 0x51, 0x60 changed Section 4.1 Description of the fixed point format corrected program screen shots updated, table 7 changed
1.81	Table 10, section 3.2.2 corrected
2.0	Chap. 3: new screenshots of V2.0 implemented, new functions documented
2.01	Section 4.8: Command 0x60 edited Section 3.2.3: Hint 2 and table 12 edited Section 3.2.2, Subsection "COLOR SPACE MODE": Hint added
2.02	Section 3.2.2, Subsection "FREQUENCY": screenshot replaced, Hint 2 added
2.1	Chap. 3: new screenshots of V2.1 implemented Section 3.2.3 new function "EXPORT TABLE" documented
3.01	Chap. 2: edited, Tab. 3 adapted, Sect. 2.2 added Chap. 3: Sect. 3.2.2 Subsect.: "SERVICE" Command "LOAD FACTORY SETT." added, "COLOR OBJECT TYPE" edited, "LIGHT CONTROL" replaced by "INTENSITY", "RUNNING MODE" edited, "HYSTERESIS" replaced by "AVERAGING", "FREQUENCY" edited Chap. 4: Sect. 4.1 Command sequence example added, Command 0x20 edited, commands 0x29 and 0x2A added, commands 0x54 and 0x55 corrected Chap. 6: completely edited, additional specifications added
3.02	Chap. 3: Sect. 3.2.2 Subsect.: "COLOR SPACE MODE": Hint 2 added
3.03	Chap. 2: Subsect.: "SERVICE": „SERVICE“ edited
3.1	Sect. 1.1.4 edited Chap. 2, Sect. 3.2.2, Subsect. "RESULT FORMAT" and Subsect. "RUNNING MODE" edited, Subsect. "FREQUENCY" Table 12 added, Fig. 28 added
3.11	Sect. 2.1.3 Fig. 9 added
3.2	Chap. 3: Sect. 3.2.2 Subsect.: "SERVICE" Commands „OFFSET CORRECTION“, „SET HYSTERESIS“ und „SET OUTPUT HOLD TIME“ added Chap. 2 edited.
3.3	Chap. 3: new screen shots added, new functions "SCALING OPTION" and "SENSOR OUTPUT" added
3.31	Corrected response codes in communication protocol (F1 <> F2)
3.32	specification in tab 25 changed, Sect. 4.2.7 command 0x63 edited
3.33	Screenshots updated, specification adapted
3.4	new screenshots added, Sect. 3.2.1 „SERIAL CONNECTION“ field "ADDRESS" added, Sect. 4.1.9 Command 0x60 „self triggered sequence“ added
4.0	old Chap. 1 "INTRODUCTION AND COLORIMETRIC BASICS", Chap. 2 "SENSOR HARDWARE" and Chap. 6 "SPECIFICATION" removed. New Chap. 4 "DLL Function Library" added.
4.1	New output-modes: Fall off, Deviation, Keep Tolerances, Auto Increment enable
4.2	Screenshots updated; Function "SAMPLE" Sec. 1.2.3 edited
4.3	new screenshots inserted
4.4	New screenshots inserted
4.5	Commands 0x57 and 0x58 inserted, Section 1.2.5 updated (Switch "KEY LOCK" inserted)
4.6	Chap. 2 7-sehm. mode removed
4.7	new screen shots added
4.8	New screenshots, Sec. 1.2.1 edited
4.9	Sect. 2.2.6, Hint for command 0x52 added
5.0	New screenshots in Sec. 1.2.1 "Select Connection" and Sec. 1.2.5 "Service" Sec. 1.2.5 "Service" function "Button Tolerances" introduced
5.1	New screenshots in Sec. 1.2.1 "Select Connection" and Sec. 1.2.5 "Service" Sec. 1.2.5 "Service" function "Button Tolerances" and "Output Behavior" edited



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