admesy
ADVANCED MEASUREMENT SYSTEMS

Arges 45^0 Colorimeter Operating Manual.

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Contents

1 About this manual

The material in this manual is subject to change. No rights can be derived from the content of this manual.

The content of this manual is valid for firmware version higher or equal than 1.01.

In this manual, the following symbols are used to draw your attention.

ⓘ : Practical tip

: Note

2 General introduction

The Arges 45^0 colorimeter is a member of the Admesy Cyclopes series colorimeters. The Arges 45^0 colorimeter offers a unique combination of high speed and accurate colour measurement. Our products are developed with the highest care for usability and robustness of both hardware and software.

2.1 Colorimeter highlights

Colour measurement in XYZ, xy, Luv and CIE L*a*b*.

Other colour spaces available via a supplied colour library.

High speed colour sampling at 10k Samples/s, Luminance at 25K Samples/s.

USB/RS232 communication interfaces.

General purpose I/O (5V TTL) with trigger input and output.

Stand alone usage with Go-NoGo option through GPIO.

2.2 Standards

The colorimeter is compliant to the USBTMC standard and can be used in combination with external provided USBTMC compliant drivers.

Currently it has been tested on Windows, Linux and Apple OSX using NI VISA (http://ww.ni.com/visa)

and using the USBTMC Linux driver since kernel 2.6.28.

For older Linux kernels the open source driver provided by Agilent (http://www.home.agilent.com/upload/cmc_upload/All/usbtmc.html) can be used.

For installation instructions on the Agilent USBTMC driver, refer to the Linux Brontes howto on the Admesy web site (http://www.admesy.nl/products/docs/Admesy_Brontes_Linux_howto.pdf).

3 Electrical interfaces

3.1 USB interface

The USB mini B connector is used to connect the Arges 45^0 Colorimeter to a PC/Laptop. This is the preferred connection method for the Arges 45^0 Colorimeter because of speed.

The Arges 45^0 Colorimeter complies to the USBTMC class protocol and can therefore be used directly with third party provided VISA compliant libraries like NI-VISA .

3.2 RS232 interface

RS232 is provided to connect the Arges 45^0 Colorimeter to any host that doesn't provide USB or for which no USBTMC drivers exist. Using RS232 the high speed options of the colorimeter are still available, only transfer of data to the host is reduced in speed. It is recommended to use USB in case the high speed sampling options are needed.

ⓘ The USB cable should not be connected together with the RS232 cable.

The following table shows the RS232 port configuration.

Baud rate	Data bits	Parity	Stop bits	Flow control	Termination character
115200	8	None	1	None	LF = '\n'

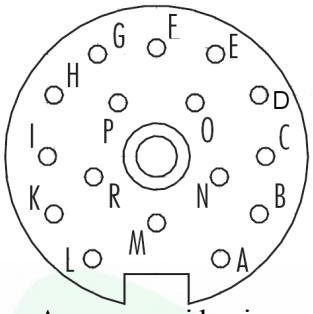
Table 1: RS232 port configuration

3.3 GPIO interface

The general purpose I/O can be used for the following functions :

- Output results to an external source from the Arges 45^0 colorimeter (Go -NoGO operation).
- RS232 communication or USB communication

The GPIO provides one trigger in, eight digital outputs, RS232 and USB communication port.



Arges rear side view

Manufacturer: Binder.

Part number: 09 0337 00 16

GPIO pin layout

Pin	Function
A	9V input
B	Trigger in
C	GND
D	D- (USB)
E	D+ (USB)
F	VBUS (USB)
G	XRX (RS232)
H	XTX (RS232)
I	I/O 0
K	I/O 1
L	I/O 2
M	I/O 3
N	I/O 4
O	I/O 5
P	I/O 6
R	I/O 7

The USB connections on the GPIO are meant for applications where the standard USB-B connector does not provide enough mechanical robustness. They should never be used together with the USB-B connector.

Admesy can provide the needed cable connector or can customize the cable to fit your needs.
The 9V input (pin A) can be used together with GND (pin C) to provide power to the Arges 45^0 colorimeter.
When using this power connection, please refer to the power supply table on the next page.

ⓘ Be careful to not short the 9V supply with any other pins. The I/O pins are only protected up to 5.8V.

3.3.1 Triggering

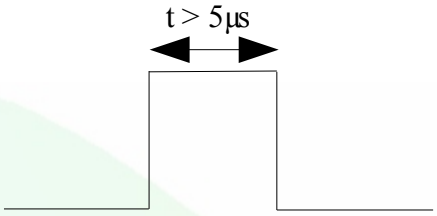
The Arges 45^0 can be triggered when it's operating in USB, RS232 or stand alone mode. In stand alone mode, the configured measurement will be carried out once a trigger arrives and the result will be output via the digital I/O channels on the GPIO connector. When triggering is enabled, the trigger output line will be set to a high level once the measurement has finished and the measurement result is available.

The trigger output will stay at a high value for a minimum of 50µs in stand alone mode. In USB and RS232 it will stay at a high level until the next command is carried out.

In USB, a trigger will carry out the previously send command and send the result to the host via an interrupt endpoint on the USB bus. The colorimeter application allows external triggering in the data logging tab. Supplied code examples show how to use this feature in an application.

In RS232 mode, the trigger output line is used to indicate that the measurement is ready and the data can be read.

The trigger input signal responds to a rising edge and should comply to the following diagram.



Trigger pulses arriving faster than the Arges 45^0 can measure will be ignored, but it may slowdown overall performance. Trigger pulses should not arrive faster than the measurement takes to complete.

The output trigger is made zero before a command starts and made high after the command finishes. The minimum pulse time is 50µs for the trigger output.

Manufacturer: Tyco electronics part number:

<u>solder</u>
Straight Cable Plug, crimp: 1051638-1
Right-Angle Cable Plug, crimp: 1052063-1

<u>clamp</u>
Straight Cable Plug, Crimp: 1050721-1
Right-Angle Cable Plug, Crimp: 1051140-1

3.3.2 I/O

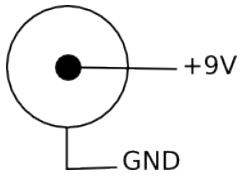
The GPIO can be used in stand alone mode and directly controlled via PC software. When operating in stand alone mode, the I/O is used to output the result of a measurement.

3.4 Power connections

The Arges 45^0 colorimeter should be connected to either powered USB or using a 9V DC power supply.

When using RS232 the colorimeter needs to be powered via the external adapter.

In case a 9V adapter is used, Admesy can only guarantee stable measurement results and CE compliance when using the supplied adapter.



The unit shall be powered by a 9Vdc voltage or via a standard USB PC-port , reinforced separated from Mains, with a limited energy of < 150VA and < 8A.

When stable mounting is needed, the GPIO power input pins (pin A & pin C) can be used to supply power to the Arges 45^0 colorimeter.

For power ratings, please refer to the power supply table on the next page.

	Min voltage	Typical voltage	Max voltage	Consumption
USB powered	4.75V	5.00V	5.25V	Typical 350mA (LED on)
DC-adapter powered	8.50V	9.00V	9.50V	Typical 350mA (LED on)
GPIO powered	8.50V	9.00V	9.50V	Typical 350mA (LED on)

Table 2: Power supply table

4 Communications protocol

4.1 USB

The Arges 45^0 colorimeter can be connected to any USB host that runs Windows, Linux or Apple OSX. The colorimeter is a USBTMC compliant device. This makes the Arges 45^0 colorimeter directly usable in programming languages like NI's Labview and Labwindows or any other language that supports USBTMC.

The Arges 45^0 colorimeter has two interfaces build in, which require a different device driver to be used.

Bootloader	(USB RAW device driver, Vendor ID : 0x1781, Product ID 0x0E92)
Arges 45^0 colorimeter	(USBTMC device driver , Vendor ID : 0x1781, Product ID 0x0E96)

When the Arges 45^0 colorimeter is connected to the host, it will start the Arges 45^0 colorimeter firmware. As soon as the firmware is idle to receive commands, the Power LED goes to the on state.

The firmware updater is a RAW USB device and in order to install this device in Windows, a driver must be installed which is supplied by Admesy. Besides upgrading to new firmware, it is also allowed to downgrade firmware in case this is required. Note that older firmware also may require the use of older software libraries and/or executable versions of software.

The Arges 45^0 colorimeter is USBTMC compliant and can be used with libraries that contain a USBTMC compliant driver like NI-VISA. The Arges 45^0 colorimeter is a USB 2.0 Full speed device.

In case a USB host is detected, it is assumed that the Arges 45^0 colorimeter operates via USB only. This means that RS232 is not functional. Triggering via USB is allowed, but needs to be enabled via software.

4.2 RS232

Arges 45^0 commands are equal for all interfaces. Note that for high speed transfers it is best to use USB.

5 Device drivers

5.1 USB

Since the Arges 45^0 is an USBTMC device, drivers exists for many platforms and processor architectures.

The following table provides an overview of these platforms.

Driver name →	NI-VISA	Libusb	Native kernel driver	Agilent USBTMC
Windows 98	untested	untested	not available	untested
Windows NT	untested	untested	not available	untested
Windows XP	☑	☑	not available	untested
Windows VISTA	☑	☑	not available	untested
Windows CE	untested	untested	not available	untested
Apple OSX PPC	☑	untested	not available	unknown
Apple OSX Intel	☑	untested	not available	unknown
Linux i386 (32bit)	☑	☑	Kernel >= 2.6.28	☑
Linux i386 (64bit)	32bit mode	☑	Kernel >= 2.6.28	☑
Linux ARM	not available	☑	Kernel >= 2.6.28	☑
Linux other	not available	☑	Kernel >= 2.6.28	☑

Untested : Available, but not tested by Admesy.

Native kernel driver : Driver included with the operating system

Admesy supports all tested platforms but does not provide standard applications on all platforms. The above matrix is provided to show the possible platforms for software development.

5.2 RS232

When no USB driver is available or the host system does not provide USB, RS232 can be used as it does not require additional drivers for the Arges 45^0 colorimeter.

6 Command set description

The functions of the colorimeter can be best described via the following categories :

System commands

Configuration commands

Measurement commands

Trigger programming commands

The Arges 45^0 colorimeter uses SCPI like commands for control and measurement. These are ASCII based commands and follow specific rules regarding syntax. Although the Arges 45^0 colorimeter uses SCPI like commands, they deviate from the SCPI standard.

6.1 Command structure

Every command starts with a colon ":", which identifies the root of the command tree. Each further keyword is also separated a colon. In case parameters need to be specified, the last keyword and parameters are separated by a single space character. In case more than one parameter needs to be specified, the parameters need to be separated by a comma.

The command tables show commands in long and short format. The short format is specified by upper case characters. It is allowed to use long and short format or a mixed format. Optional keywords are shown between brackets [...]. Commands are case insensitive, so it is allowed to use both or a mix of upper and lower case.

The command structure is valid for all communication interfaces of the Arges 45^0 colorimeter.

Example commands :

Command table syntax	Valid command syntax examples	Notes
:SENSe:GAIN auto	:sens:gain auto :sense:gain auto :SENS:gain auto :SENSE:GAIN auto	Sets the GAIN function of the Arges 45^0 colorimeter.
:MEASure:XYZ	:measure:XYZ :measure:xyz :meas:XYZ :MEASure:XYZ	The measure commands uses the averaging and gain options.
:SAMPle:XYZ	:sample:XYZ :sample:xyz :samp:XYZ :SAMPle:XYZ	With the SAMPLE command, the Arges 45^0 colorimeter will perform fast sampling to internal memory. Results are read back from memory after the measurement has been performed.

6.2 System commands

The following command can be used to control the Arges 45^0 system or read information about the system.

Table 3: System commands

Command syntax	Parameters	Purpose
:*CLS	none	Clear status
:*IDN?	none	Identification Query
:*RST	none	Reset Command
:*STB?	none	Read Status Byte Query (only USB)
:*TST	none	Self-Test Query
:*FWD?	none	Firmware date Query
:*FWT?	none	Firmware time Query
:SYSTem:VERSion?	none	Get system version information
:SYSTem:ERRor?	none	Retrieve the last occurred error
:SYSTem:ERRor:NEXT?	none	Retrieve previous errors.

Table 4: System commands

The Status byte can be used to retrieve information about the status of a command or the system

Return values of the status command can be seen in the table below :

Code	description
0	System is idle
1	Data is available
2	Command processed
4	Data in buffer (should not occur)
8	An error occurred. Use ":SYSTem:ERRor?" to get the exact error that occurred.

ⓘ The *STB? Command is only available on USB.

6.3 Configuration commands

Configuration commands are used to set parameters of the Arges 45^0 colorimeter that are used by the measurement functions.

The settings are used globally by other measurement functions. The selected white standard is used for CIEL*a*b* and Lu'v' measurements.

The gain setting can be varied over 8 stages. The largest gain factor is “1”. Results from the Arges 45^0 colorimeter include a clip and noise indication which indicate whether the measured light is too bright (clip) or too low (noise). When clipping is detected, the resulting colour will not be correct and a higher gain value should be chosen. When noise is detected, a lower gain value should be chosen. Note that when measuring light from alternating sources, the lowest and highest peaks detected during averaging determine the clip and noise indication levels.

Table 5: Configuration commands

Command syntax	parameters	Range	Purpose
:SENSe:GAIN	Gain	0 – 8 (0 = auto)	Set Gain value
:SENSe:GAIN?	none		Returns the current setting.
:SENSe:AVERage	Averaging (integer)	0 - 4000	Set Averaging value
:SENSe:AVERage?	none		Query Averaging value
:SENSe:GPIO	GPIO	0 – 255	Sets the I/O pins
:SENSe:GPIO?			Query I/O pins
:SENSe:LED	LED	0 - 1	Set LED on / off
:SENSe:LED?	none		Query LED on/off
:SENSe:LIGHT:REG	none		Regulate the LED to the fixed intensity. (Use only in No regulation mode)
:SENSe:LIGHT:STABLE?	none		Retrieves the deviation of the fixed intensity. (usage only in No regulation mode)
:CONFigure:WHITE	string	A, B, C, D40, D42, D50, D55, D65, D75, D90, D95, E, F2, F7, F11 (see table 6 for used values)	Set reference white value for Lab/Luv colour space.
:CONFigure:WHITE?	none		Query white reference
:CONFigure:WHITE:USE	Boolean	0 = no, 1 = yes	Use the stored white value for XYZ, Lab and Luv calculation and stand alone modes. This allows relative measurements
:CONFigure:WHITE:USE?	None	0 – 1	Check if the stored white value is being used.
:CONFigure:MODE	Enum (0,1,2,3,4)	USB,RS232,STANDALONE_LUM,STANDALONE_DE, STANDALONE_COLOUR	Configure the Arges 45^0 mode
:CONFigure:MODE?	none	0 - 4	Returns the current setting.
:CONFigure:LIGHT	Light mode	0-3 Continuous regulation. Delayed, Flash mode (no regulation), No regulation (manual)	Set Light mode Delayed (use ":EEPROM:LIGHT:DELAY") No regulation (use ":SENSe:LIGHT:REG")
:CONFigure:LIGHT?	none		Retrieves the current light mode.
:CONFigure:BAUDRATE	baudrate	0 – 5 (9600 - 230400)	Set RS232 baud rate
:CONFigure:BAUDRATE?	none		Returns the current setting.
:CONFigure:TRIG	Trigger	0 – 1	Set trigger mode
:CONFigure:TRIG?	none		Returns the current setting.

Reference white	X	Y	Z
A	109.8405	100.0000	35.5583
B	99.0899	100.0000	85.3242
C	98.0708	100.0000	118.1847
D40	99.6092	100.0000	60.9432
D42	98.7058	100.0000	65.4253
D50	96.3758	100.0000	82.4087
D55	95.6559	100.0000	92.0311
D65	95.0182	100.0000	108.7485
D75	94.9524	100.0000	122.5079
D90	95.2270	100.0000	138.5514
D95	95.3315	100.0000	142.9635
E	100.0000	100.0000	100.0000
F2	99.1869	100.0000	67.3944
F7	95.0392	100.0000	108.7460
F11	100.9631	100.0000	64.3522

Table 6: White point references

6.4 Measurement commands

Table 5 shows the measurement commands of the Arges 45^0 colorimeter. Regarding colour/luminance measurement there are two kind of commands (MEASure/SAMPle).

The MEASure commands measure the requested values using the set averaging and gain and returns the result in a single structure of three single precision floating point values. Averaging can be set using the :SENSe:AVERage configure command.

The SAMPle commands measure the requested parameters using a sample count and delay time and return an array of data. The array contains single floating point data. Each sample count equals one complete structure, for example one XYZ structure of data.

Command syntax	Parameters	Range	Purpose
:MEASure:XYZ	none		Measure XYZ
:MEASure:Lab	none		Measure CIE L a b colour point (needs reference to be set)
:MEASure:Luv	none		Measure CIE L*u*v* (needs reference to be set)
:SAMPle:XYZ	Samples, delay	0-4000, 0 - 255	Sample XYZ
:SAMPle:Lab	Samples, delay	0-4000, 0 - 255	Sample Lab
:SAMPle:Luv	Samples, delay	0-4000, 0 - 255	Sample Luv
:MEASure:TEMPerature	none		Measure temperature of Sensor head, CPU, LED PCD and Control sensor.

Table 7: Measurement commands

Notes :

1) The delay time is set in sample times, meaning a delay of one will skip one sample.
2) When using high sample amount make sure timeout values in the application software are set accordingly.

6.5 User EEPROM commands

The following commands can be used to store values in the user EEPROM space. Note that they are not stored until a :EEPROM:WRITE command is given. It is advised to reboot the Arges 45^0 after writing new values to the EEPROM.

Command syntax	Parameters	Range	Purpose
:EEPROM:STARTUP:READ	none		Copies startup conditions from EEprom to internal variables. Values can than be read using
:EEPROM:STARTUP:WRITE	Arges 45^0 mode, amp factor	0 – 4 , 0 -8	Copies internal variables to EEprom and sets mode and amp factor.
:EEPROM:LUM:READ	range	1 - 15	Read luminance range of stand alone mode
:EEPROM:LUM:WRITE	Range, value	1 – 15, value(float)	Write luminance values for stand alone mode
:EEPROM:DE:READ	parameter	0 – 15 0 = Lab 1 -15 = dE	Read dE values of stand alone mode
:EEPROM:DE:WRITE	Char, value, (value, value)	0 – 15 for 0, there are 3 float parameters, for 1 -15 there's one parameter	Write dE values for stand alone mode
:EEPROM:COLOUR:READ	colour	0 - 14	Returns L,a,b,dE of the trained colour
:EEPROM:COLOUR:WRITE	L,a,b,dE	0 - 255	Writes L,a,b,dE of the trained colour
:EEPROM:WRITE	none	0-4000, 0 - 255	Write all settings to EEprom. This command fixes the EEprom values.
:EEPROM:SENSe:GAIN	Gain	0 – 8 (0 = auto)	Set the default gain level
:EEPROM:SENSe:GAIN?	None		Retrieves the EEPROM Gain value
:EEPROM:SENSe:AVERage	Average	0 – 4000	Set the default number of samples to average
:EEPROM:SENSe:AVERage?	None		Retrieves the EEPROM average value
:EEPROM:LIGHT:DELAY	Light delay	0 - 65535	Set the number of loop iterations to delay the led regulation.
:EEPROM:LIGHT:DELAY?	None		Retrieves the set light delay.
:EEPROM:CONFigure:WHITE	String	A, B, C, D40, D42, D50, D55, D65, D75, D90, D95, E, F2, F7, F11 (see table 6 for used values)	Set the default white point reference. This is only used for internal colour space conversions
:EEPROM:CONFigure:WHITE?	None		Retrieves the set default white reference
:EEPROM:CONFigure:MODE	Enum (0,1,2,3,4)	USB,RS232,STANDALONE_LUM,STANDALONE_DE,STANDALONE_COLOUR	Configure the Arges 45^0 mode

Command syntax	Parameters	Range	Purpose
:EEPROM:CONFigure:MODE?	None		Retrieves the default operating mode.
:EEPROM:CONFigure:LIGHT	Light mode	0-3 Continuous regulation. Delayed, Flash mode (no regulation), No regulation (manual)	Set Light mode Delayed (use ":EEPROM:LIGHT:DELAY") No regulation (use ":SENSe:LIGHT:REG")
:EEPROM:CONFigure:LIGHT?	None		Retrieves the default light mode.
:EEPROM:CONFigure:BAUDRATE	baudrate	0 – 5 (9600 - 230400)	Set the default RS232 baud rate of the device.
:EEPROM:CONFigure:BAUDRATE?	none		Retrieves the default value for RS232 baud rate
:EEPROM:CONFigure:TRIG	Trigger	0 – 1	Set the external trigger mode (on/off)
:EEPROM:CONFigure:TRIG?	none		Retrieves the set values for the external trigger mode
:EEPROM:STORE:WHITE	White	0 = X, 1 = Y, 2 = Z	Stores the white measurement value for relative measurements
:EEPROM:READ:WHITE?	None		Retrieves the stored white measurement values of the device
:EEPROM:USE:WHITE	Use white	0 = No , 1 = Yes	Use the stored white value at start-up for XYZ, Lab and Luv calculation and standalone modes.
:EEPROM:USE:WHITE?	None		Retrieves if the stored white value is being used at start-up.
:EEPROM:READ:SN	None		Reads the serial number.

6.6 Returned results

:MEASure command return their result in ASCII formatted floating point as shown below :

(X,Y,Z,clip,noise) → %f,%f,%f,%d,%d\n

(X,Y,Z can be substituted for L,a,b or other colour spaces).

Exception to the above is the :MEASure:TEMPerature command.

:MEASure:TEMPerature → (MCU temperature, Sensor temperature, LED PCB temperature, Control sensor temperature) → %f,%f,%f,%f\n

:SAMPle:XYZ, :SAMPLe:Lab and :SAMPLe:Luv commands return their result in “32 bit single precision floating-point” format when operating in USB Mode.

The first three values indicate the delta time between samples and the clip and noise values.

:Sample:XYZ	
dt	%f\n
clip	%f\n
noise	%f\n
Value 1 (X)	%f\n
Value 1 (Y)	%f\n
Value 1 (Z)	%f\n
Value n (n-1) (Y)	%f\n
Value n (n) (Z)	%f\n

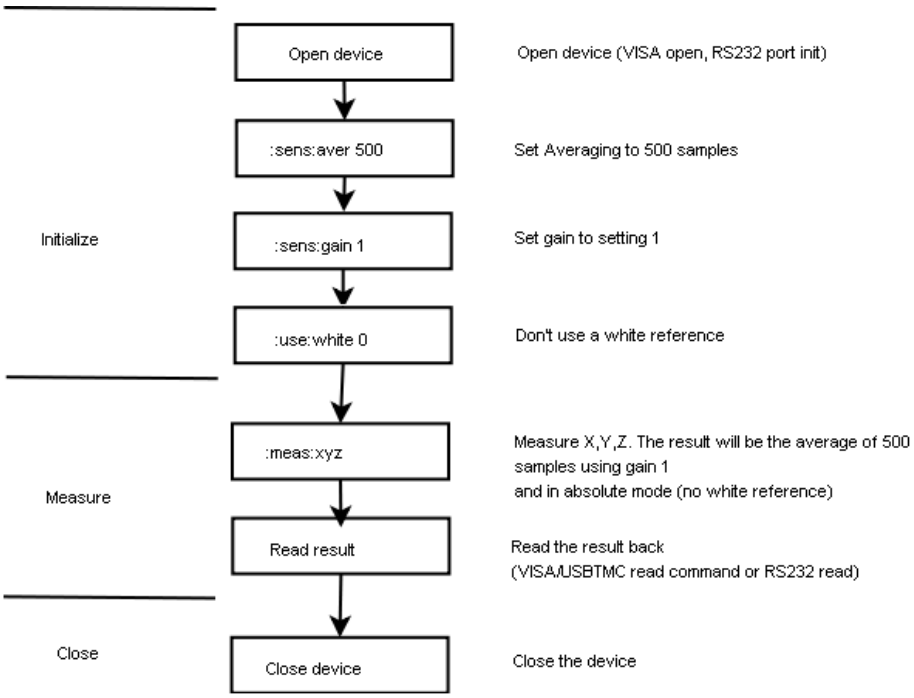
:When operating in RS232 mode the data of the :SAMPLe commands will be returned in ASCII format. All data is separated using a TAB (\t) and the last value is terminated using an end of line constant (\n).

7 Measurement example

The Arges 45^0 uses default settings when the device is started. These can be programmed by the end user so that the device starts with the same settings each time it is connected.

Although it's possible to program all Arges 45^0 devices in a production environment to start with equal settings, it is recommended to set the averaging, gain and SBW values in the initialization routine of the host software.

A typical measurement example to measure XYZ would include the following commands :



8 Arges 45 formulas.

The Arges 45^0 colorimeter uses an XYZ sensor, meaning that other colour spaces are being converted from XYZ. The following sections show the mathematical conversions that are used by the Arges 45^0 colorimeter to perform conversion from XYZ to other colour spaces.

8.1 XYZ to Yxy conversion

$$x = \frac{X}{(X+Y+Z)}$$
$$y = \frac{Y}{(X+Y+Z)}$$
$$z = \frac{Z}{(X+Y+Z)} = 1 - x - y$$

8.2 XYZ to Lab conversion

notes :

1) The Arges 45^0 colorimeter measures in CIEL*a*b* colour space.
2) For Lab measurements a white reference needs to be set. By default the Arges 45^0 is set to D50.

$$e = 216/24389 \, , k = 24389/27$$
$$x_r = X / WhiteRefX \quad , \quad y_r = Y / WhiteRefY \quad , \quad z_r = Z / WhiteRefZ$$
$$f_x = \begin{cases} \sqrt[3]{x_r} & x_r > e \\ \frac{(kx_r + 16)}{116} & x_r \le e \end{cases} \quad f_y = \begin{cases} \sqrt[3]{y_r} & y_r > e \\ \frac{(ky_r + 16)}{116} & y_r \le e \end{cases} \quad f_z = \begin{cases} \sqrt[3]{z_r} & z_r > e \\ \frac{(kz_r + 16)}{116} & z_r \le e \end{cases}$$

$$L = (116 f_x) - 16$$
$$a = 500(f_x - f_y)$$
$$b = 200(f_y - f_z)$$

8.3 XYZ to Luv conversion

Just like Lab, Luv requires a reference to be set. Within the Arges 45^0 colorimeter this is the same variable, set by the :CONFigure:WHITE command.

$$e = 216/24389\,,\, k = 24389/27$$

$$y_r = \frac{Y}{WhiteRefY}\quad ,u = \frac{4\mathrm{X}}{(X + 15\mathrm{Y} + 3\mathrm{Z})}\quad ,v = \frac{9\mathrm{Y}}{(X + 15\mathrm{Y} + 3\mathrm{Z})}$$

$$u_r = \frac{4\mathrm{X}}{(WhiteRefX + 15\mathrm{WhiteRefY} + 3\mathrm{WhiteRefZ})}$$

$$v_r = \frac{9\mathrm{Y}}{(WhiteRefX + 15\mathrm{WhiteRefY} + 3\mathrm{WhiteRefZ})}$$

$$L = \begin{cases} (116\mathrm{y}_r^{1/3} - 16) & y_r > e \\ k y_r & y_r \le e \end{cases}$$

$$u = 13\mathrm{L}(u - u_r)$$

$$v = 13\mathrm{L}(v - v_r)$$

8.4 Delta E calculation

Delta E within the Arges 45^0 is calculated according to the CIE1976 standard. Other formats are available through PC software.

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

Where $L_1a_1b_1$ is the target colour and $L_2a_2b_2$ is the new measured colour to compare to the target.

Note that for Lab measurements a reference white needs to be chosen. Both the target colour and new measured colour should be measured using the same chosen white point.

9 Operating modes

Operation is possible as slave device for a host PC or as stand alone device. In slave mode the Arges 45^0 colorimeter listens to commands send by the host PC as mentioned in the previous paragraphs.

The modes of the Arges 45^0 are :

1) USB mode
2) RS232 mode
1) Stand alone modes :
    - Measure luminance and fit into 15 programmed levels.
    - Measure colour and fit ΔE in 15 programmable levels. Target colour can be set.
    - Measure colour and match the closest of 15 programmed colours (based on ΔE).

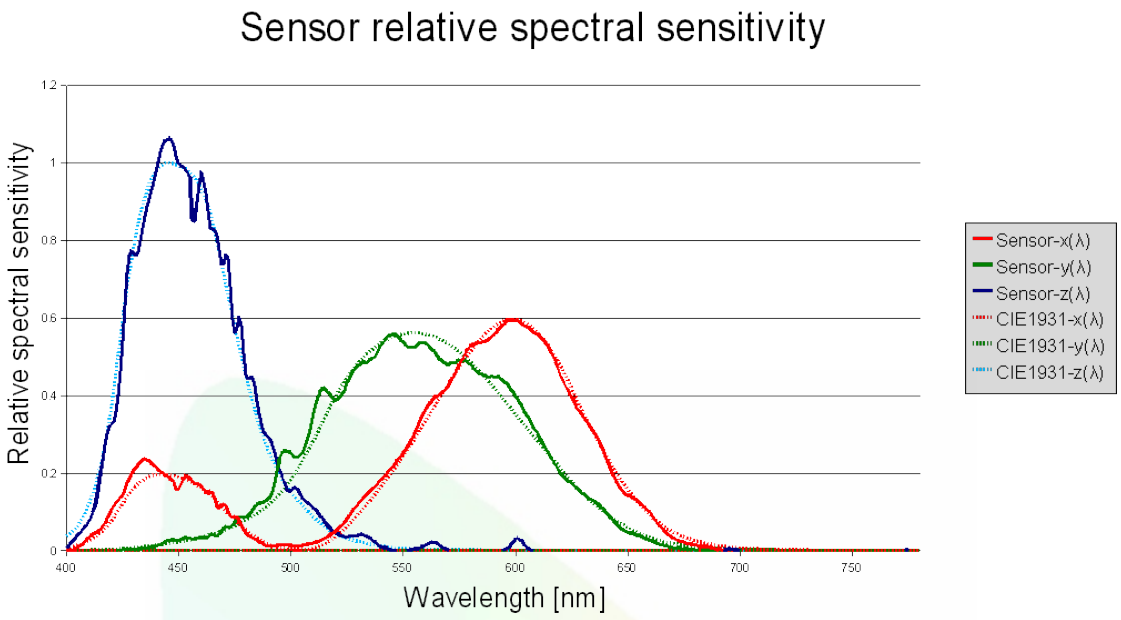
In all modes, USB is still active but when only USB is used, it is recommended to set it to USB mode so that the Arges 45^0 responds in the fastest possible way to commands.

The operating mode must be selected via the Arges 45^0 PC application. All target values can be measured using the configuration utility or input manually.

Once the USB cable is connected, the Arges 45^0 will automatically leave the stand alone mode and listen to USB communication. In stand alone mode, power should be connected via the dedicated 9V power input or via the 9V input of the GPIO connector.

In stand alone mode, trigger in -and output can be enabled to synchronize for the highest possible speed.

10 Typical spectral sensitivity



11 Mechanical drawing (mounting holes)