

Acuity[®]

CCS Prima™ White Light Confocal Displacement Sensor User's Manual



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Acuity
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1. Introduction to the Acuity CCS Prima

The CCS Prima sensor consists of an opto-electronic unit (controller) and one or more interchangeable chromatic objectives (“optical pens”). The optical pen is connected to the controller by a fiber optics cable.

A CD comprising the drivers, the “CCS Manager” program and this User Manual is delivered with each sensor.

1.1 Single-channel CCS Prima Controller

The CCS Prima controller controls signal acquisition, computes the distance data, and provides data transmission functions via the RS232 link or the USB 2.0 link and via the 0-10V analog outputs.

1.1.1 Description

The front panel of the controller features:

- On/Off switch
- Fiber optic sockets for connecting the optical pen and an optional external light source
- RS232 – RS422 connectors and a USB 2.0 connector
- Interface connector for analog outputs and synchronization signals
- Encoder connector
- Power connector
- 3 LED indicators
- A “Dark” button for launching “dark” signal acquisition
- A “Set Zero” button for resetting the analog outputs zero level

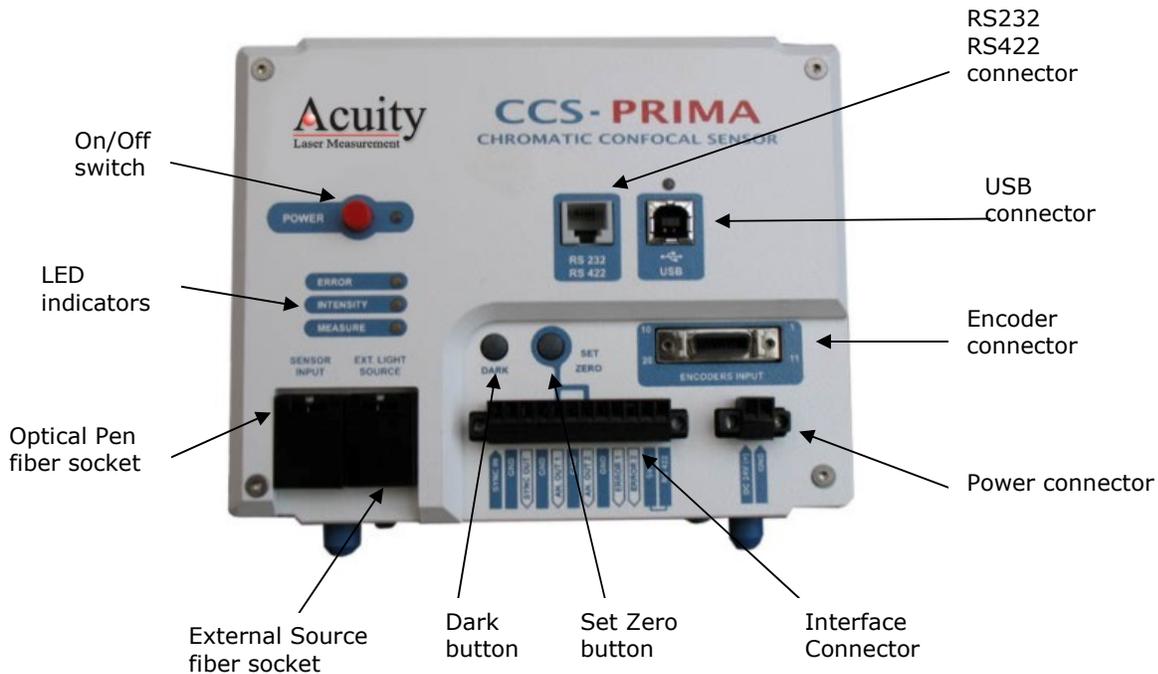


Figure 1 Anatomy of Prima Controller

The rear panel of the controller features a Din Rail Mounting adaptor.

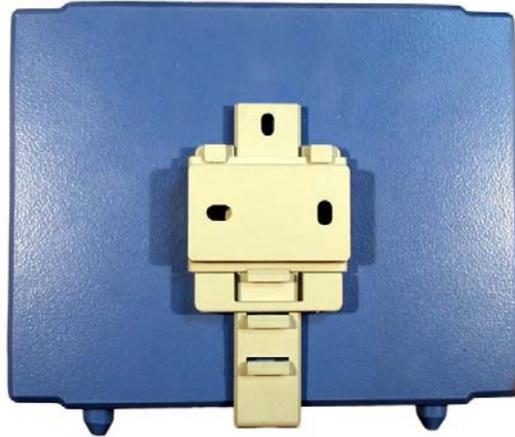


Figure 2 Rear of controller show DIN rail mount

1.1.2 LED indicators

The meanings of the different LED indicators are as follows:

1.1.2.1 "Error" LED indicator

Red: when light source test fails

Orange: on Data-overflow error

Off: no error

1.1.2.2 "Intensity" LED Indicator

Off: if no signal is detected

Red: in case of signal saturation

Green: if signal intensity is comfortable ($> 5\%$ of the maximum level),

Orange: if signal intensity is low ($< 5\%$ of the maximum level)

1.1.2.3 "Measure" LED Indicator

Off: if no object is detected in the measuring range.

Green: at the center of the measuring range (between 15% and 85% of full scale)

Orange: near the limit of measuring range (between 0% and 15% of full scale or between 85% and 100% of full scale)

1.2 Multiplex CCS Prima Controllers

In addition to the standard CCS Prima controller which has a single channel for the measurement from one pen, Acuity can offer multiplexed controllers. The CCS PRIMA2 and CCS PRIMA4 are, respectively, 2-channel and 4-channel multiplexed CCS controllers. They comprise 2 (or 4) fiber connectors on the front panel, so that 2 (or 4) optical pens can be connected permanently. At each moment one of the optical pens is

selected as the “active” channel. In addition to the LED indicators described in section 1.1.2, 2 (or 4) LED indicators, located on the front panel above the fiber connectors, indicate visually the selected channel.

Most of the features of the multiplexed controllers are identical to those of the single-channel controller. The few specific functions of these controllers are described in section 13.

1.3 Optical pen and fiber optics

Optical pens are interchangeable: the same controller can store up to 20 different calibration tables corresponding to different optical pen configurations.

The optical pen is totally passive, since it incorporates no heat sources, electrical sources or moving parts, thus avoiding any thermal expansion which could affect the accuracy of the sensor measuring process.

The fiber optics cable which connects the optical pen to the controller may be ordered with a length up to 10 m. When handling the fiber optics lead take care to avoid bending the fiber to a radius of curvature of less than 20 mm.

Precautions:

When handling the fiber optics lead take care to avoid bending the fiber to a radius of curvature of less than 20 mm.

When no optical fiber is connected, the socket must at all times be fitted with its protection cap to avoid contamination of the fiber tip, which could result in malfunctioning of the sensor.



Figure 3 A modular optical pen with its fiber optic cable

1.4 The light source

The CCS Prima is equipped with an internal light source (white LED). Optionally, it may be ordered with an external light source (Tungsten Halogen lamp or Xenon-arc lamp); in this case the light box should be connected to the “ext. light source” input in the controller front panel using a dedicated fiber optic cable.

The following table resumes the basic properties of the different types of light source:

	White LED	Tungsten Halogen	Xenon arc
Type	Internal	External	External
Brightness	Good	Good	Excellent
Measuring range	Standard	Extended	Standard
Light-level adjustment	Easy (by command)	-	Possible (by hardware)

Contact Acuity or your local distributor for further technical information on the external light sources available for use with your CCS Prima controller.

The sensor features an automatic test of the light source. The "Error" LED-indicator turns RED when the lamp (or the LED) should be replaced. This light source test may be enabled or disabled.

If the light source is an internal white LED, the test is operational only if the LED brightness is set to a level between 80% and 100%.

1.5 Optional accessories

The following accessories may be ordered with the sensor:

AC power supply: provides DC 24V, 3A

USB cable, 2m

RS232 cable, 2m with DB9 connectors

1.5.1 Metrology standards

As optional equipment, Acuity can supply the following metrology standards:

10 μm depth groove

Roughness standard $R_a = 0.8 \mu\text{m}$

Optical flats (diameter 140 mm or 300 mm)

Reference sphere

Metrology standards may be ordered with or without DKD certificate. For more information please contact sales@acuitylaser.com.

2. Safety

The CCS Prima is an opto-electronic instrument. It is safe in normal operating conditions described in this User's Manual. Unlike other Acuity sensors products, the CCS Prima displacement sensor system does not use lasers and is not governed by the same safety considerations.

2.1 Electrical hazards

The CCS Prima controller box should be opened by qualified technicians only. If opened, electrical hazards may exist, especially during an inappropriate tampering of the instrument.

Unplug the instrument from the power outlet before changing accessories, maintenance, cleaning, or changing the lamp.

2.2 Optical hazards

The optical pen emits a beam of visible light with wavelengths ranging from 400 to 750 nm.

The flux contained in this beam is smaller than the MPE (Maximum Permissible Exposure). However it is recommended to avoid looking directly into the optical pen.

2.3 General recommendations

Do not use the instrument if it has been dropped and shows signs of damage or functions improperly, or if the fan does not operate properly. In this case do not open the instrument and contact our helpline: sales@acuitylaser.com.

Repairs should only be carried out by qualified technicians using original replacement parts.

In case of inappropriate use or failure to comply with the instructions, the manufacturer disclaims all liability and the guarantee will not apply. See the Acuity Warranty at the beginning of this document

2.4 Compliance with the EC regulation 89/336/EEC « Electromagnetic Compatibility »

The CCS Prima sensor complies with the generic or specific requirements of the following harmonized standards:

EN 50 081-1	Spurious emission
EN 61000-6-2	Resistance to disturbance

2.5 Compliance with the RoHS Regulation

The CCS Prima is RoHS compliant.

3. Installation and startup

3.1 Electrical Connections

The following paragraphs explain how to:

Connect the sensor to a power supply

Connect the sensor to a host computer using either the RS232/RS422 port or the USB 2.0 port (the two ports may be connected simultaneously),

Connect the analog outputs,

Connect the synchronization signals,

Connect encoders for synchronous reading of position and sensor data

3.1.1 Power

Connect the power connector on the controller front panel to a to a DC 24V, 3A power supply.

(Note: the black connector on the power socket may be screwed off the front panel and connected permanently to the power supply bare cables. Alternatively, a power supply may be ordered from the vendor).

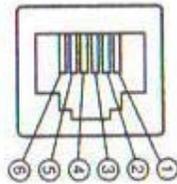
If your sensor is equipped with an external light source, connect the light box to a mains socket following the instructions in its Operating and Maintenance Manual.

3.1.2 RS232 – RS422 connector

The same connector is used for the RS232 or RS422 links. The configuration is done through the interface connector, and more precisely with the last 2 pins (designated, respectively, "5V" and RS422). For RS232 interface these 2 pins should be left floating. For RS422 interface the 2 pins should be connected (RS422 pin connected to 5V pin).

The RS232 RS422 connector is an RJ11 type connector. The pin-out is described below:

Front view:



RS232 pinout:

Pin	Pin Name	Description
3	Rx	Receiver (input)
4	Gnd	Ground
5	Tx	Transceiver (output)

RS422 pinout:

Pin	Pin Name	Description
2	Rx-	Receiver - (Differential Input)
3	Rx+	Receiver + (Differential Input)
4	Gnd	Ground

5	Tx+	Transceiver + (Differential Output)
6	Tx-	Transceiver - (Differential Output)

3.1.3 USB connector

The USB 2.0 connector is a standard B-type connector. An USB 2.0 (High-speed) compliant cable is required. (Note: A USB cable may be ordered from the other vendors).

3.1.4 Analog outputs

The two 0V-10V analog outputs are connected to pins 5 and 7 of the Interface connector, as indicated on the front panel. The "Set zero" button may be used to set the analog output's zero point.

3.1.5 Synchronization signals

The Interface connector on the front panel of CCS Prima includes three pins dedicated to synchronization signals (TTL 0-5V):

Pin n° 1: Sync in

Pin n° 2: Ground

Pin n° 3: Sync out

3.1.6 Encoder connector

The Encoder connector is a 20 points MDR connector (Manufacturer: 3M; Reference 10220-6212PL).

Pinout:

1 : Gnd	5 : b+ (axis 2)
2 : a+ (axis 1)	6 : a+ (axis 3)
3 : b+ (axis 1)	7 : b+ (axis 3)
4 : a+ (axis 2)	20 : 5 Vdc

3.2 Fiber optics connections

Insert the lead of the optical pen fiber optics into the "Sensor Input" fiber socket on the controller front panel, taking care to comply with the correct orientation of the connector.

Connection and disconnection of the fiber optics lead



Figure 4 Connection of the fiber optics lead

To connect the fiber optics, insert the plug into the fiber socket as shown in Figure 4 until a "click" is heard as it locks into position. To remove the fiber optics from its socket, first press on the locking lever, then pull the lead out of the socket.

If your sensor is equipped with an external light source, connect the light box to the "external source" socket located on the controller front panel using the light source fiber optics.

3.3 Installing the USB driver and "CCS Manager" software

3.3.1 Installing the USB driver:

If you wish to communicate with the sensor using the USB port, you should install the dedicated USB driver on the host computer. The driver should be installed for each USB port of the PC to which a CCS sensor is connected.

The driver may be installed from the CD delivered with the sensor. Connect your sensor to the USB 2.0 port and switch it off. Insert the CD, and start the driver installation. **Do not restart the sensor until prompted to do so by the installation program.**

Use a host computer equipped with XP operating system with SP2, or more recent. Insert the "CCS Manager" Utility CD into the CDROM drive.

The Autorun screen appears:

Software and USB driver for CCS and STIL DUO sensors

For Windows XP™ SP2 and Windows VISTA™ operating SYSTEM

- CCS Manager 1.2.7
- USB driver for CCS
- CCS and STIL DUO User's manual
- DLL SDK 2.4.7
- Browse CD
- Website
- Exit





After the driver's installation from the CD, the Windows "Add new Hardware wizard" starts. Select in the first window "Not this time" and in the following one "install automatically". If the Windows wizard starts before or during Acuity driver installation, leave it beside and come back to it when Acuity driver installation is done.

3.3.2 Installing the software

From the Autorun screen, install the "CCS Manager" program. This program is used in the tutorial and the training sections.

If you intend to develop your own program for controlling the sensor, install the DLL SDK (Software Developer's Kit).

3.4 Sensor Startup

If your sensor is equipped with an external light source, switch on the light source first, then the controller, by operating their On/Off switches.

Startup procedure lasts about 10 seconds. The LED indicators on the sensor front panel go on and off, and the startup message indicating the firmware version is sent on the digital output channels, e.g.:

High Speed VART - COM Initiate<

CCS V 1.2.56 CCS © 2006

FPGA : 010175

Booting sequence

At the end of the startup, the sensor starts measuring.

4. Basic System Characteristics

The CCS PRIMA is a high-resolution distance point-sensor. It is based on Chromatic Confocal Imaging (CCI). This chapter gives some basic notions concerning the technology, the applications and the measuring modes of the sensor.

4.1 Chromatic Confocal Imaging (CCI)

Chromatic Confocal Imaging is based on 2 principles:

Confocal imaging

Chromatic coding of the optical axis.

The Confocal setup is an optical setup in which an optical system generates the image S' of a point source S on the surface of the object. The backscattered light is collected by the same optical system, which images the light spot on a pinhole S'' . The pinhole is placed in front of a photodetector. It filters the light rays that can reach the photodetector and for this reason it is also called "spatial filter". Confocal setups are characterized by an exceptional Signal-to-Noise ratio. In the case of CCI, the optical system is the chromatic optical pen and the photodetector is a spectrometer.

Chromatic coding of the optical axis means that the optical system has axial chromatism: each wavelength is focalized at a different point along this axis. Suppose now that a sample is present inside the chromatically-coded range so that the wavelength λ_0 is focalized on its surface. When the reflected (or backscattered) beam reaches the plane of the pinhole, the rays at wavelength are focalized on the pinhole so they can pass through the pinhole and reach the sensitive area of the spectrometer. Other wavelengths are imaged as large spots so they are blocked by the pinhole. The spectrometer "decoding" the sample position by identifying the wavelength λ_0 .

The spectrometer signal corresponds to the spectral repartition of the collected light. It presents a spectral peak. When the object moves inside the measuring range, the spectral peak on the spectrometer shifts.

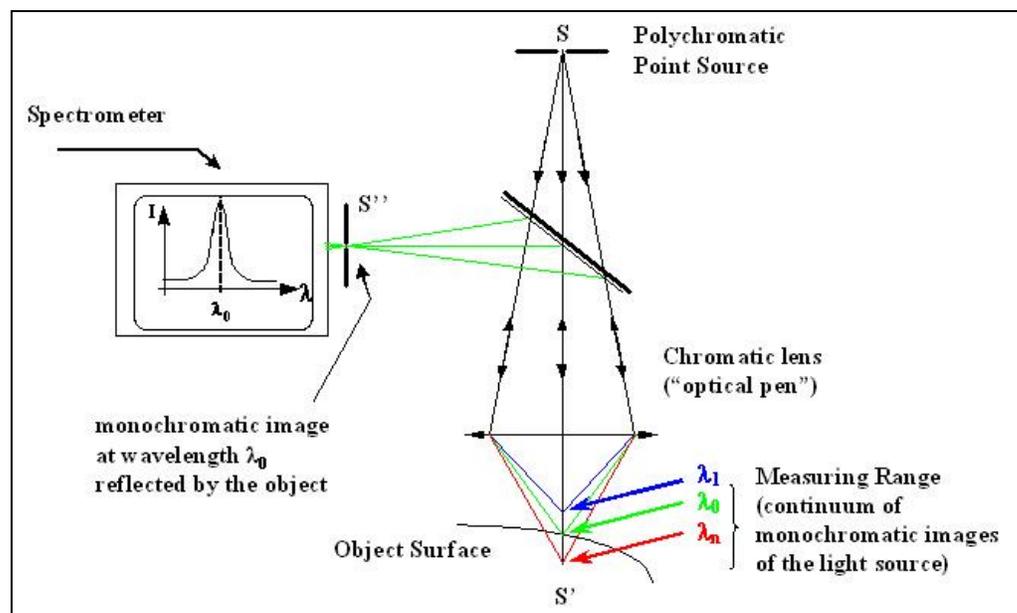
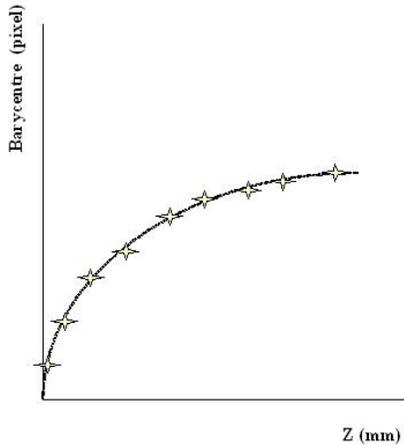


Figure 5 Description of Chromatic Confocal Imaging



The relation between the position of the spectral peak ("barycenter" in pixels) and the axial position of the object ("distance" in μm) is called "calibration lookup table" (LUT).

The calibration LUT, characterizing a specific spectrometer and a specific optical pen, is measured by the fabricant and loaded into the controller.

4.2 Applications

Chromatic confocal sensors are used both in industrial environments for in-line inspection during production process, and in laboratory environments as high precision instruments. Their principal applications are:

Microtopography (measuring the shape of the sample)

Dimensional control (testing whether the size of certain features of manufactured products complies with specifications),

Quality control: (identification and characterization of defects on manufactured products)

Roughness measurement (measuring the statistical characteristics of the sample surface)

Tribology (characterization of mechanical or chemical erosion)

Thickness measurement

Chromatic confocal sensors are fully compatible with the ISO 25178 standard concerning the measurement and analysis of 3D a real surface texture. Moreover, Part 601 of this standard, dedicated to non-contact surface measurement, cites CCI as the first reference technology.

Chromatic confocal sensors can measure samples made of practically any type of material (glass, ceramic, plastic, semiconductor, metal, fabric, paper, leather...). They can measure polished surfaces (mirrors, lenses, wafers) as well as rough ones.

The optical characteristics of the optical pen, and in particular the spot size, the axial resolution and the maximal slope angle, should be suited to the size and slope of the features present on the sample to be measured.

Metallic objects should be measured with the CL1 or the CL2 optical pens, in particular when measuring roughness or in applications requiring high resolution.

When measuring metallic objects with optical pens whose spot size is larger, performances may fall short of specifications. The amount of degradation depends on microstructure of the metallic surface.

4.3 Measuring modes

Chromatic confocal sensors have two measuring modes: "Distance" and "Thickness".

The principal measuring mode of the CCS PRIMA is the “Distance” mode. The sensor is calibrated and tested in this mode. Acuity can furnish a calibration certificate attesting to these test results.

4.3.1 “Distance” measuring mode

The “Distance” measuring mode is dedicated to measuring the altitude of points located on the surface of a sample. The distance data is transmitted with 30-bit digital resolution.

When measuring height profiles on an opaque sample (metal, paper, ceramics...), the use of the “Distance mode” is straightforward.

When measuring thin transparent samples or coated samples, it is possible that the sensor “sees” two signals at the same time: the coating surface reflects one signal and the substrate reflects a second one. By default the sensor selects the strongest signal and ignores all other detected signals, regardless of the relative positions of the spectral peaks. In some applications this behavior is not optimal: in the above example, the substrate reflectivity is often stronger than that of the coating, while one may wish to measure the coating surface. The “First peak” mode, described in the “Advanced Topics” chapter, gives a solution to such applications.

4.3.2 “Thickness” measuring mode

The “Thickness” mode is an additional measuring mode dedicated to measuring the thickness of transparent samples. In this mode the sensor measures simultaneously the positions of the two faces of the transparent sample, and computes the thickness as the difference between these two positions.

Measuring thickness is more difficult than measuring distance and is less precise. It is also subject to some limitations. In order to obtain metrological performances in this mode, a special procedure called “thickness calibration” should be carried out. Thickness calibration is performed by the user. This process requires a thickness standard. The “Thickness” measuring mode is described in section 7.4.

4.4 Measured data

At each point of the sample the sensor measures simultaneously several data.

In the “Distance” measuring mode the measured data are:

- the distance of the measured sample point
- the intensity of the retro-diffused light beam.

In the thickness measuring mode the measured data are:

- the distance and intensity of the first sample face,
- the distance and intensity of the second sample face,
- the thickness.

In addition to measured data the sensor may deliver some additional data (counter, state...). The sensor system may be configured to transmit some or all of these data.

4.5 External scanning

An important characteristic of the CCS PRIMA sensor, is the fact that it is a “point” sensor; in other words, at any given instant the sensor measures a single point located on its optical axis. In order to obtain a profile or measure an entire surface, it is necessary to scan the sample along one or two axes with the aid of some external scanning device. Generally the scanning device is motorized; in some cases it

comprises an encoder for determining the precise position of the sample at any given instant.

For some applications the synchronization between the sensor and the external scanning device is an important issue. The CCS PRIMA may be synchronized both as a "slave" and as a "master". This topic is discussed further in section 12.

5. Communication with the CCS Prima

There are three options for communicating with the CCS Prima sensor: The CCS Manager program, a DLL, direct serial communications via RS232, RS422 or USB.

5.1 Via the CCS Manager

The "CCS Manager" application may be used to configure the sensor very easily and to view, save and print the measured data. It is supplied on a CD with the sensor. It features a "Command Terminal" for low-level communication with the sensor, and allows uploading new firmware versions. The application comprises special procedures for in-situ calibration and for generating refractive index files. In case you have a problem with the sensor, this software can generate with a single mouse click a diagnostics data file with all sensor parameters. Please join the diagnostics file to any technical question addressed to your vendor.

5.2 Via DLL

DLL may be used to interface the sensor with a general-purpose user program.

The « CHR DLL » is intended for user programs in "classic" C or C++ language. The operating manual of the DLL includes a large number of code samples. The "Acuity Sensor DLL" is intended for all .NET compatible languages (Labview, VB, C# C++/CLI, etc.) This DLL features an internal help utility. The DLL for the sensor are provided on a CD.

5.3 Via direct digital I/O

The RS232/RS422 serial link and the USB link enable sensor configuration using a specific control language and acquisition of the measured data. As an example, the Windows™ « Hyper Terminal »™ utility can be used to send the commands and receive the measurements back from the sensor via the RS232 or RS422 link. The Command Terminal of the "CCS Manager" software can be used with either RS or USB link. For communication using the USB port, a dedicated USB driver should be installed on the host device.

The serial link allows baud rates up to 460800. For this link there exist some limitations on the amount of data transmissible simultaneously (see section 9.2). USB allows unlimited data transmission at all rates.

Recommendation: All software applications use the same COM port or USB port to communicate with the sensor. Remember to always free the port by quitting one application before attempting to connect it to another application.

6. Getting started

This chapter is a tutorial intended for new users to familiarize themselves with the main characteristics of the Acuity CCS Prima sensor. For simplification purposes, this tutorial only introduces one measuring mode (« Distance » mode) and one communication option (the « CCS Manager » software and the USB digital output). We recommend that new users follow this tutorial even if they wish subsequently to use a different measuring mode or another communication option.

6.1 Connecting to the CCS Prima

Connect the sensor to a power supply as described in section 3.1.1. Connect it to a free USB 2.0 port of your computer as described in section 3.1.3. Make sure the dedicated USB driver has been previously installed on the computer.

Switch the sensor ON and start the “CCS Manager” program. This program has four access levels.

The “Operator” level requires no password. This level allows configuring the sensor, launching a measurement, viewing and saving the data as time-profiles.

The “User” level requires a password – please contact your vendor to receive it. The “User” level allows, in addition to the above operations, viewing the photodetector signal.

The two other levels are reserved. For this tutorial you can enter either in the “Operator” level or in the “User” level.

The “Connection wizard” window opens.

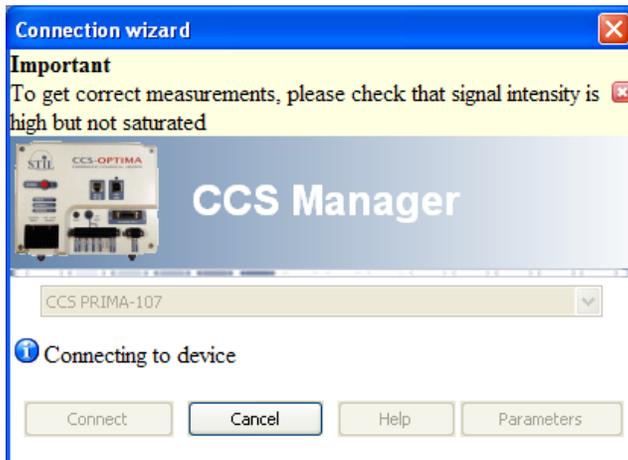
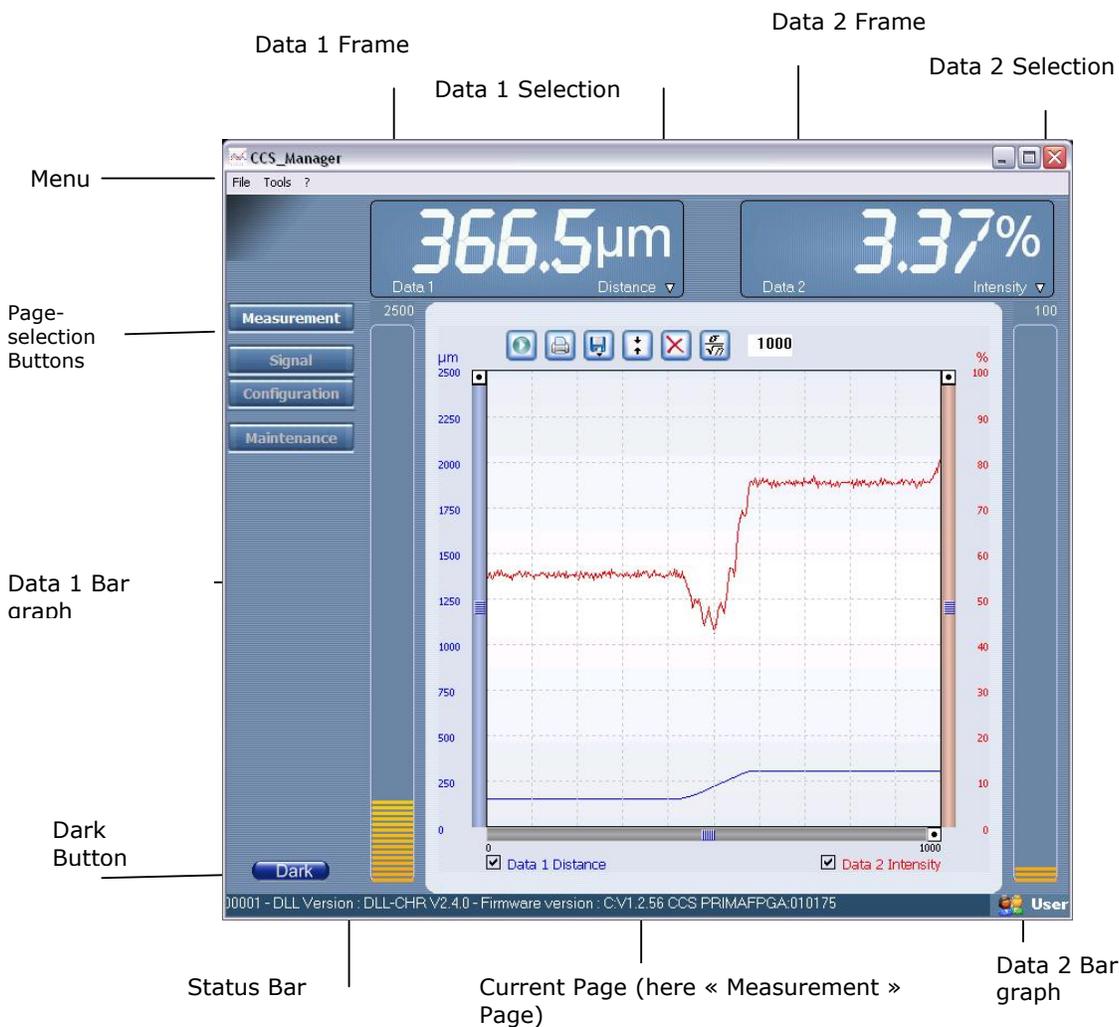


Figure 6 Connection Wizard to CCS Manager Program

The program’s default configuration connects to the CCS device via the USB link. (If you wish to connect to the serial link, click on “Parameters” and check the “Serial link” option, and then click on “Connect”). The program will scan all available USB ports on the host computer until it finds the sensor and will start the connection process, including download of the entire sensor configuration.

The “CCS Manager” Main Window appears: It comprises a menu and two data frames on the top, a status bar at the bottom, page-selection buttons and a “Dark” button on the left, a central zone for displaying the current page, and two data bar graphs.



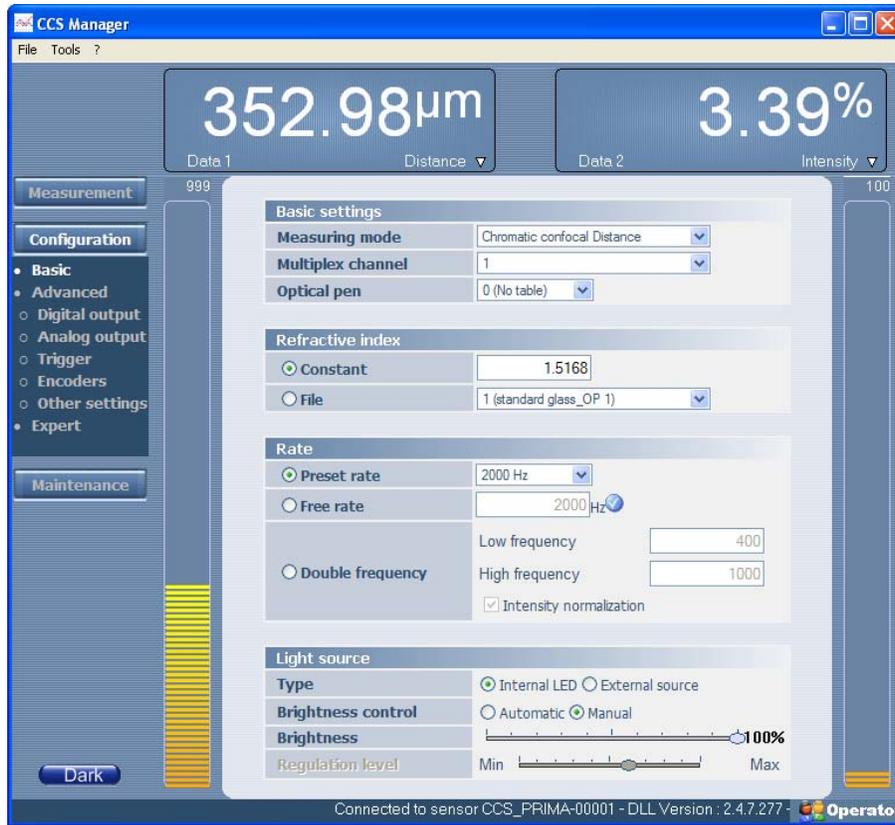
Note: the "Signal" page-selection button does not appear in the "Operator" level.

6.2 Configuring the sensor



Click on the « Configuration » button on the left side of the Main Window to develop the arborescence of configuration pages (1 "Basic" page, 5 "Advanced" pages and 1 "Expert" page)

Select the "Basic" configuration page.



Set the measuring mode to “Distance” and then select a Preset Rate of 100 Hz.

In the list of optical pens select the measuring range corresponding to the optical pen which is physically connected to the controller.

6.3 Saving the configuration

The configuration is the ensemble of settings of all sensor parameters (measuring mode, rate, sensor id, Led brightness level, etc). The sensor has two configurations:

a temporary configuration, kept in the sensor RAM,

a permanent configuration, kept in the non-volatile memory (FLASH memory).

Each time the sensor is switched off, the temporary configuration is lost; on startup the sensor recovers permanent configuration. This allows the user to test different settings, or to adapt the sensor to a particular application, without modifying its permanent configuration. When you wish that the temporary configuration become permanent, you must save it on the FLASH memory. Below are instructions for saving to FLASH memory:

Select a preset rate of 100 Hz

Quit CCS Manger

Switch the sensor off, then restart it.

Connect to “CCS manger” again, open the “Basic” page and observe the rate: the last setting was lost.

Set the rate to 100 Hz again.

Save the configuration to the FLASH memory: in the "File" menu, select "Save the current configuration". The program asks for confirmation: click on "OK".

Quit the "CCS Manager" program; switch the sensor off and on.

Connect to "CCS manager" again, open the "basic" page and observe the rate: the last setting was conserved.

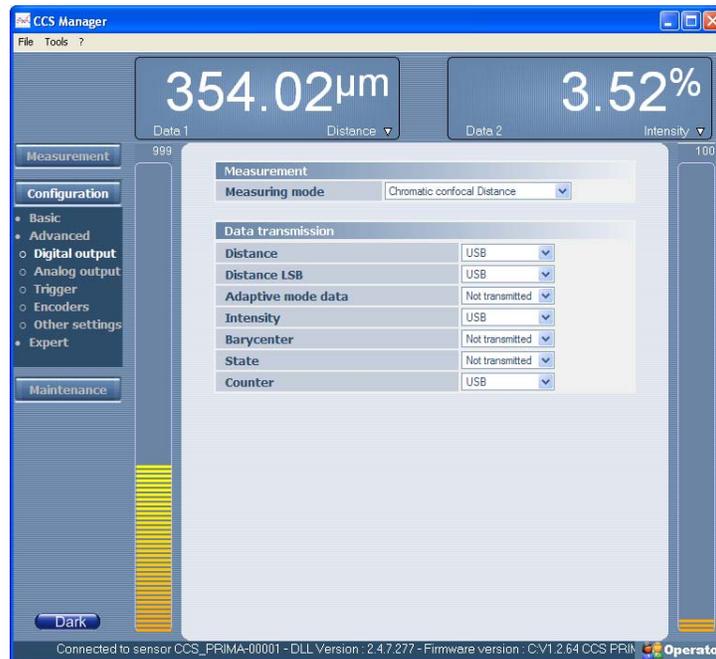
Recommendation:

When you find the optimal settings which suit your application, save the configuration on the sensor FLASH Memory so that the sensor always starts with this "nominal" configuration.

6.4 Selecting the output data

The CCS transmits several data items for each measured point.

Before launching a measurement, you should check that the data item/s you wish to measure are directed to the right output port (the USB port or the Serial port), and that the other data items are not transmitted. On the left side of the Main Window, select the "Digital Output" page.



First, observe the list of available data items in the "Distance" measuring mode. In this mode you can measure the Distance and the Intensity of the reflected signal.

The other data items in the list will be described later so for the moment we shall content ourselves with a brief presentation:

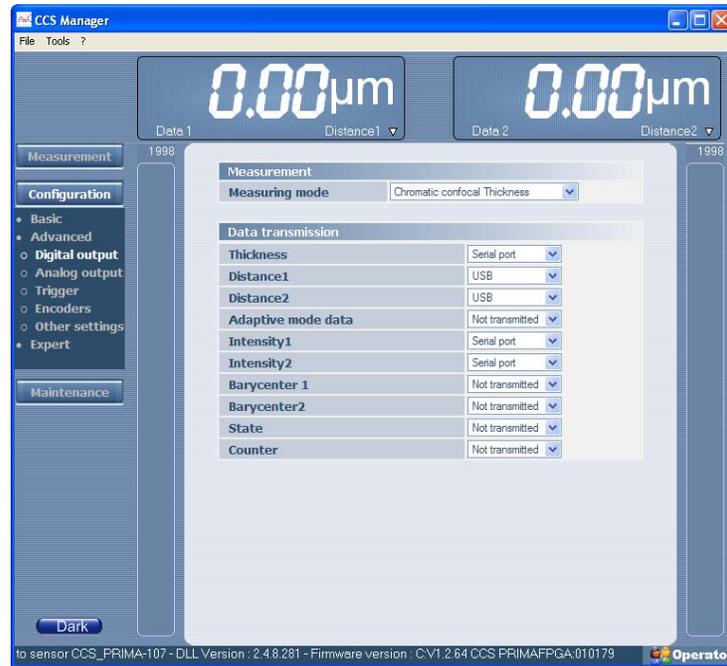
The "Distance LSB" data comprises additional 15-bit resolution to the "Distance" data. This topic is described in §9.1.2. For the moment, each time you select the "Distance" data, select this data as well.

The "Barycenter" data is the position (pixel number) of the spectral peak on the photodetector.

The "Counter" data is a 15-bit cyclic counter incremented at each measured point: this data is supplied as a tool for software developers. This data is particularly useful in the case of "trigger modes".

The "Adaptive mode" data and the "State" data are described in the "Advanced Topics" chapter.

Next, set the measuring mode to "Thickness". In this mode you measure the two faces of a transparent sample, so you have 2 Distances, 2 Intensities and 2 Barycenters:



In the screen copy above, the thickness and the intensities are directed to the RS232, while the 2 distances are directed to USB. In this way one can connect the sensor to two applications simultaneously (e.g. HyperTerminal on the serial port and CCS manager on the USB port).

Note: Encoder data may be transmitted simultaneously with other data regardless of measuring mode. Transmission is enabled and disabled from the "Encoder" page.

To finish, return to the "Distance" measuring mode which is the principal measuring mode of the sensor. Set the "Distance", "Intensity" and "Counter" data to "USB", and the other data to "Not Transmitted". On the left side of the Main Window, select the "Measurement" page.

6.5 Viewing and saving the measured data

Note that each of data1 and data2 is displayed in 3 ways:

Digitally, in the "Data frame"

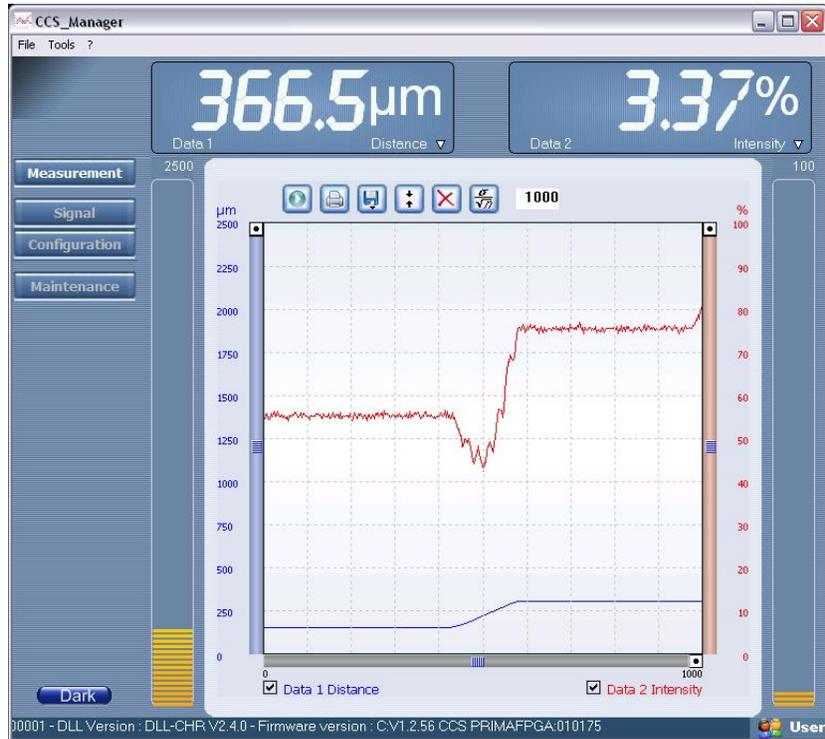
As a barograph (to the left and to the right of the graphic window, respectively)

Graphically, in the graphic window of the Measurement page.

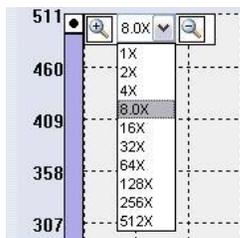
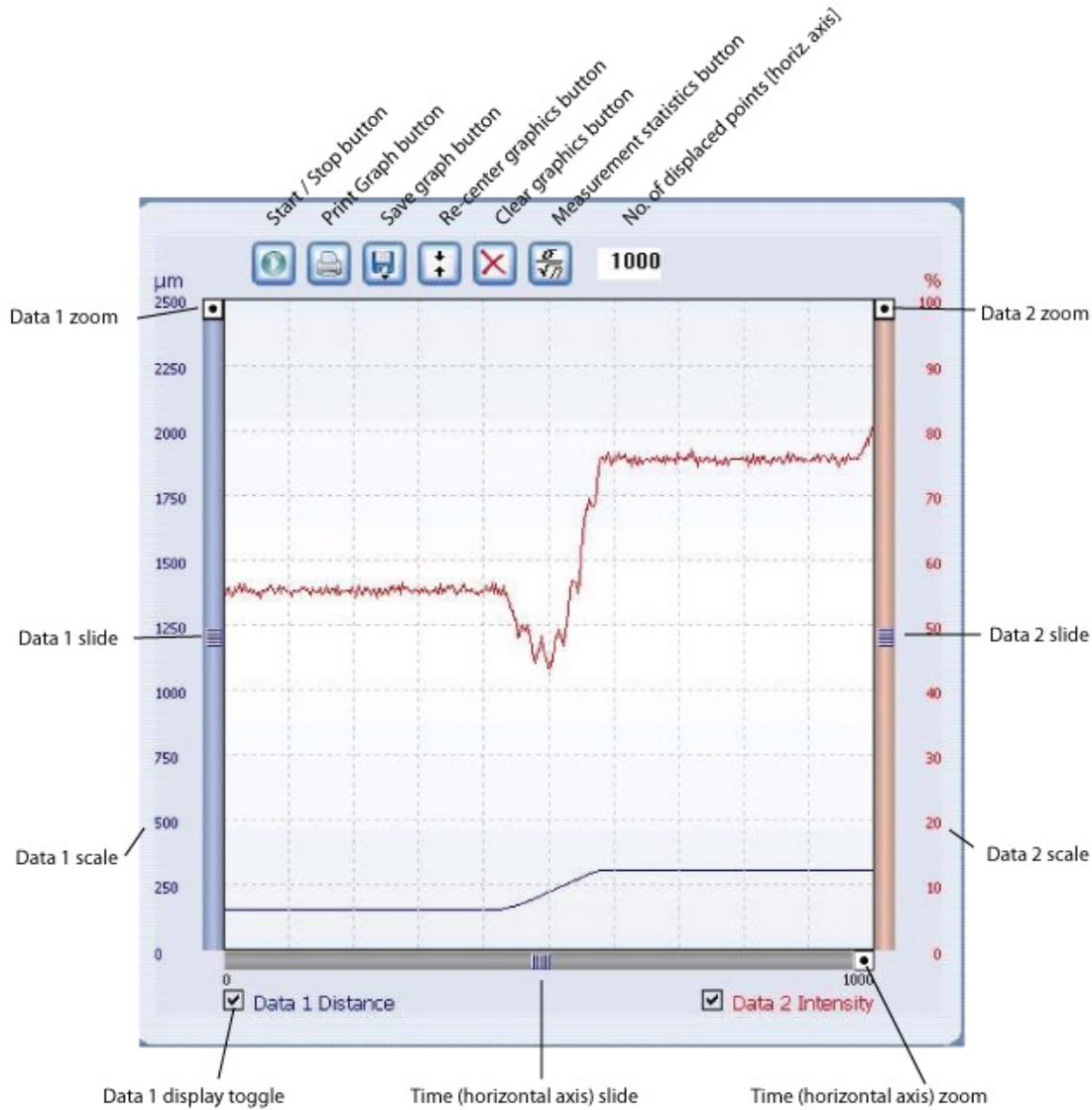
The buttons at the top of the "Measurement" give access to the following functions:

Start and stop the measurement

- Print, Save and Clear the graphics window
- Find the curve at high zoom values
- See the statistics of the last measurement
- Modify the number of displayed points



In the "Data 1 frame" on the top of the Main Window the list shows the transmitted data items (Distance, Intensity, and Counter). Select data1 as "Distance"; In the "Data 2" frame Select "Intensity".



Note that each data has its own scale, zoom factor and slide. To access the zoom, click on the point at the upper end of the scale. You may also zoom with the mouse button.

To save the measured data, use the "save graph" icon. Data may be saved either as a screen-copy (bitmap) or as digital data (text file).

6.6 Acquiring the Dark signal

The dark signal of the sensor is generated by undesirable back-reflections on the optical surfaces inside the sensor. This signal must be measured and saved to the non-volatile memory so that it can be subtracted from the measured signal. The level of the Dark signal depends on the sampling rate and on the LED brightness.

A dark signal acquisition is performed during adjustment by the manufacturer, but must be repeated at regular intervals.

Recommendation: The dark signal acquisition procedure should preferably be performed at least a quarter of an hour after switching on the sensor, in order to ensure that sensor has reached thermal equilibrium.

Dark signal measurement may be launched either by pressing the "Dark" button on the sensor front panel, or by clicking on the "Dark" button on the "CCS Manager" software, or, more generally, by sending the "\$DRK" command to the sensor.

This operation may take a few dozens of seconds, as the sensor measures and saves the "Dark" signal at all pre-set frequencies successively.

In order to perform a dark signal acquisition, it is essential to have no object within the measurement field, or even better, to blank off the light beam by applying a piece of paper over the tip of the optical pen.

Press the "Dark" button on the front panel of the sensor. The "Intensity" and "Measure" Led indicators on the front panel blink on and off in green alternatively, to indicate that the operation is in progress. Keep the optical pen tip blanked off. When measurement is done, the 3 LED indicators blink on and off simultaneously, and their color indicates the result of the operation:

Green: if the level of the acquired dark signal is satisfactory at all rates

Orange: if the dark signal level is too high at low rates, but it is still possible to measure at higher rates

Red: if the dark signal level is too high at all rates.

The piece of paper can now be removed and the sensor can be used in the normal way.

6.6.1 Related topics

High Dark signal - If after completion of the dark acquisition sequence, the color of the blinking LED indicators is orange or red, this means that the acquired dark signal is too high. In this case it is not possible to configure the sensor to the lowest measuring rate (or rates).

If the problem persists, see instructions in the "Maintenance" section 17.2.

Auto adaptive Dark - The CCS features an operation mode ("auto adaptive dark" mode) in which the dark signal is permanently updated. This mode is described in the "Advanced Topics" chapter.

"Fast" Dark – see section 8.2

Measuring the Dark of a Multiplexed sensor – see section 13.2

6.7 Adjusting the LED brightness

Select the light source type corresponding to your model: "Internal LED" or "External source".

If your sensor is equipped with an external light source, please skip this paragraph.

Internal LEDS brightness may be controlled by command. There are two modes for doing this: "Manual" and "Automatic". This section describes the Manual mode. The "Automatic" LED mode is described in the "Advanced Topics" chapter.

The LED emission is modulated at a high rate (100 kHz). The effective brightness is determined by the cycle ratio (percentage of the exposure time for which the LED is on).

Set the level control to "Manual" and move the Brightness slide to the right until the brightness level is 100%.

Place a piece of white paper in front of the optical pen and observe the spot of light emitted by the sensor. Move the paper forward and backward to find the focus plane where the spot brightness is maximal.

Move the brightness slide to the left to get a brightness level of 0%. The light spot disappears.

Try intermediate values

To finish, set the LED to maximal brightness again.

6.7.1 Minimal brightness level

For each frequency there exists a minimal brightness level below which the LED cannot go:

Measuring Rate	Minimal brightness level	Maximal brightness level
Up to 500 Hz	10%	100%
500 Hz – 2000 Hz	25%	100%

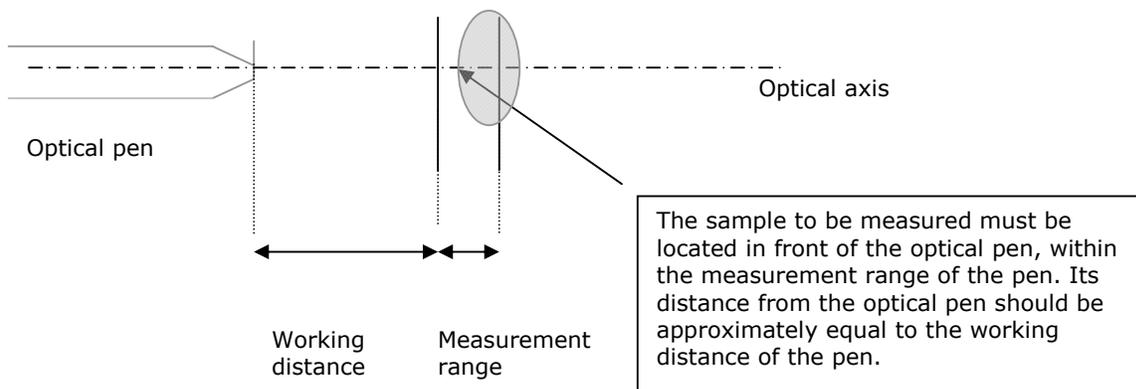
The operator sets the LED to level X	The sensor behavior:
X = 0%	The LED goes off
X ≤ Minimal level	The LED is practically set to the minimal level
X > Minimal level	The LED is set to level X

6.8 Placing the sample within the measurement range of the optical pen

Mount the optical pen on a suitable support (for example, a « V » shape block). Position the sample to be measured in front of the pen, and move it forward or backward until the optical pen working distance is reached.

For pens with a millimetric measurement range, the positioning of the sample within the measurement range of the optical pen is easy to achieve, simply observe on the sample surface or on a piece of white paper the luminous spot emitted by the optical pen: as the measuring range is approached, the spot becomes smaller and smaller and its intensity increases.

For optical pens with a micrometric measurement range, the operation is more difficult: position the sample on a stable support on a small manually translating bed, with a suitable pitch lead screw.



As soon as the sample is located inside the measuring range of the optical pen, the "Measurement" LED indicator on the sensor front panel lights on. Once the sample is

inside the measuring range, use the "Measurement" LED indicator color to adjust its position at the center of the measuring range: This indicator is:

Off - If no object is detected in the measuring range.

Green - At the center of the measuring range (between 15% and 85% of full scale)

Orange - Near the limits of the measuring range (between 0% and 15% of full scale or between 85 and 100% of full scale).

Troubleshooting:

If the "Measurement" LED indicator on the sensor front panel never turns on even though the sample is within the measuring field of the sensor, check the following points:

- The fiber optics cable connector is fully plugged into the socket on the front panel.
- A light beam is emitted from the optical pen and the spot is focused on the sample.
- The distance between the extremity of the optical pen and the surface of the sample is equal to the working distance of the optical pen.
- The sample surface is normal to the optical axis. The local slope must be less than the maximal slope angle of the optical pen.
- The sampling rate selected is the lowest shown in the list (100 Hz), the measuring mode selected is "Distance" mode.
- The displacement pitch of the translation bed carrying the sample is suitable for the measurement (for example, for pen model OP 020, the pitch must be $\leq 5 \mu\text{m}$).
- The Dark signal has been correctly acquired.
- If your sensor's light source is internal, check that the LED brightness is adjusted to the maximum level (100).

6.9 Sample Rate adjustment

There are three options for setting the sampling rate:

The "**Single Frequency**" is the simplest option for adjusting the rate is by selecting one of the preset rates in the list.

A second option consists of selecting a "**free**" rate: this option is described in section 8.3.

The "Double Frequency" option is described in the "Auto-adaptive modes" in section 11 .

In this tutorial we shall use preset rates only.

When the sample is within the central part of the measurement range of the optical pen, select the optimal preset rate in the list: the signal should be strong but not saturated. You can know if the signal is too strong or too weak by watching the "Intensity" LED indicator. This indicator is:

Off - if no signal is detected

Red- in case of signal saturation

Green - if signal intensity is comfortable ($> 5\%$ of the maximum level),

Orange - if signal intensity is low ($< 5\%$ of the maximum level)

If the indicator is red, you should increase the sampling rate or decrease the LED brightness. If it is orange you should lower the sampling rate or increase the LED brightness.

Recommendation: Always set the Rate and the LED Brightness so that the "Intensity" LED Indicator is green. When the signal is low (yellow "Intensity" LED Indicator) or saturated (red "Intensity" LED Indicator) the sensor still measures, but measurement quality may be deteriorated.

6.10 Intensity data

The Intensity data has a dual roles:

it often serves as a quality indicator, for validating that the measurement is performed at optimal conditions

it may be used for generating a "grey level" 2D image of the sample

6.10.1 Intensity as a quality indicator

The « Intensity » data measured by the sensor is an indication of the level of the signal reflected back off the sample, as a percentage of the dynamic response of the sensor. Its value depends on several parameters:

The sampling rate of the sensor

The local slope on the sample (angle between the optical axis and the normal to the surface at the point of impact)

The reflectivity of the sample at the detection wavelength λ_0

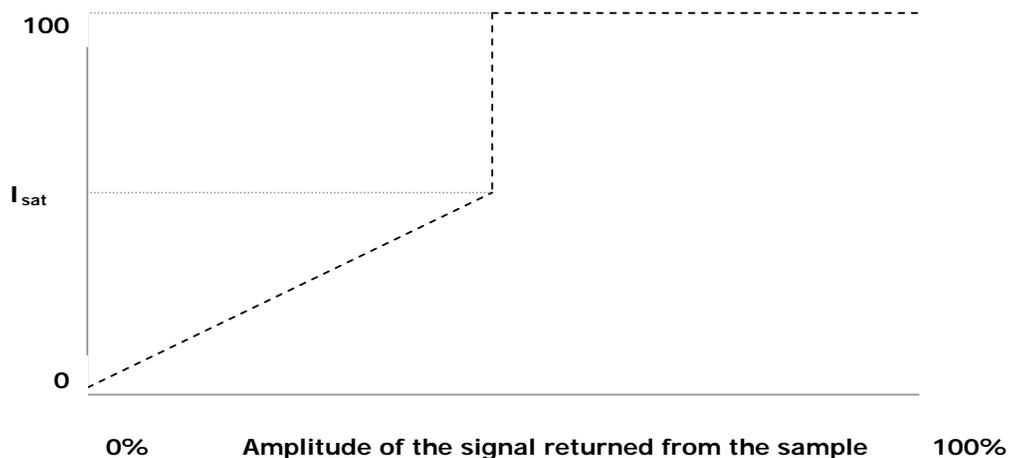
The brightness of the LED at wavelength λ_0

The response of the photodetector at wavelength λ_0

The detection wavelength, λ , varies within the measurement range. Thus it is not surprising that the intensity measured at a given point on the sample varies when the latter is moved within the measurement range of the optical pen.

For each point in the measurement range, the value of the intensity varies between 0% and a maximum value I_{sat} . Beyond that, the sensor is saturated. The state of saturation is indicated by an intensity value of 100% as shown in the graph below, and by the red color of the "Intensity" LED indicator.

Intensity measured by the sensor



The value of I_{sat} depends on the detection wavelength λ_0 , and may vary slowly within the measurement range of the sensor. For some wavelengths I_{sat} equals 99%. For others it is lower.

Example: If I_{sat} is 60% and the sensor is on the limit of saturation, the measured intensity will oscillate between 60% and 100% and the "Intensity" LED indicator will oscillate between GREEN and RED.

Recommendation: Measurement quality is good when the "Intensity" LED-indicator is Green. If the indicator colour is Red, you must increase the rate or lower the LED brightness. If it is Orange, lower the sampling rate or increase the LED brightness.

6.10.2 Intensity images

In many applications it is desirable to obtain, in addition to the 3D measurement, a 2D image of the sample which resembles a microscope image. This can be done by scanning the sample and displaying the Intensity data. In fact the Intensity data gives exactly the same information as one pixel of a camera; by scanning one reconstructs the entire "image".

"Distance" images and "Intensity" images provide complementary information on the sample: the "Distance" image gives information on the altitude of each sample point, while the "Intensity" image gives information on the reflectivity of each sample point. "Distance" images are often displayed in false color or as 3D images, while "Intensity" images are usually displayed in grey-level or as "rendered" images simulating shadow effects. As an example, consider the following pairs of "Distance" and "Intensity" images.

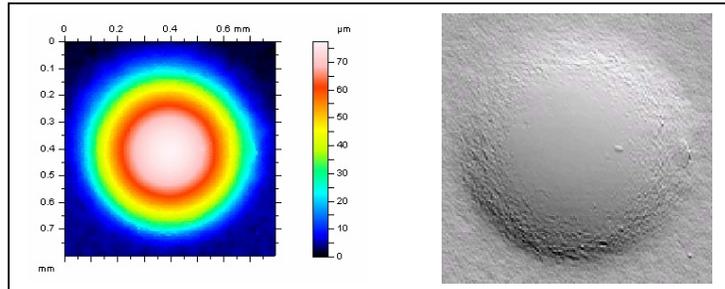


Figure 7 "Distance" image (left) and "Intensity" image (right) of a micro lens

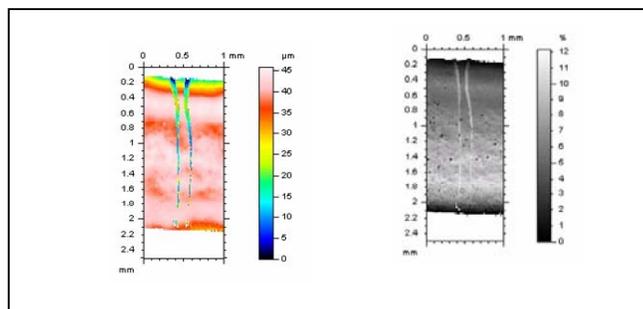


Figure 8 "Distance" Image (left) and "Intensity" image (right) of a scratch on the neck of a glass bottle.

All measured data are available simultaneously, so the "distance" and "intensity" images may be obtained in a single scan.

7. Advanced Configuration

This chapter is a tutorial intended for users having acquired some initial experience with the CCS Prima sensor in the « Distance » measuring mode and using the « CCS Manager » application. This tutorial covers the following topics:

Synchronizing the sensor with external devices:
Synchronizing the sensor with digital encoders
Synchronization signals and « Trigger » modes
More about the "CCS Manager" program
Help Utility
Communication with the sensor via the "CCS Manager" Command Terminal
The "Tools" menu
Communication with the sensor via RS232 serial link using the Windows « Hyper Terminal »™ utility.
The "Thickness" measuring mode

7.1 Synchronizing the sensor with other devices

It is often necessary to synchronize the sensor with an external device, such as an encoder, a motion controller or a photocell indicating the approach of an object traveling on a conveyor belt.

When the external device to be synchronized with the sensor is a digital encoder, this task is particularly easy, as it is performed automatically by the CCS Prima (refer to section 12)

For other types of devices (analog encoders, motion controllers) synchronization may be achieved using synchronization signals and Trigger modes. The CCS Prima may be synchronized with an external device as "master" (using the "Sync out" TTL signals), as a "slave" (using the "Sync in" TTL signals), or in a mixed mode (using both types of signals).

"Trigger modes" specify the way the sensor should respond to rising or falling edges of the "Sync in" signals. The common feature to all trigger modes is that the sensor stops measuring and stands by for an "active" edge on "Sync in" connector. Trigger modes may be enabled and disabled from the "Trigger" page of the "CCS manager" program, by the DLL or by low-level commands. By default, all trigger modes are disabled, and the sensor transmits data without interruption immediately after startup. When no trigger mode is enabled, rising and falling edges of the "Sync in" signal are simply ignored.

7.1.1 The "Start" trigger mode

The simplest trigger mode is the "Start on edge" trigger. It is enabled by sending the "\$TRG" command, either from the Command Terminal or from the "Trigger" page of the "CCS Manager" program.

On receipt of the command, the sensor stands by for the trigger signal. Measurement starts as soon as an "active" edge is detected at the "Sync in" input, with repeatability (jitter) better than 1 μ s.

Once the first "Sync in" pulse is received, the sensor exits the "Start on edge" Trigger mode and resumes normal operation. Additional "Sync in" pulses are simply ignored.

A typical application for this trigger mode is for starting successive scan lines during a 2D scan of a sample: the excellent repeatability ensures that there is no jitter on the beginning of successive scan lines.

Additional trigger modes are described in Section 12.

7.1.2 Training

To train the system to trigger on the desired signal, connect an optical pen to the sensor; configure the sensor to the right optical pen and to « Distance » measuring mode as described in section 6. Launch a « Dark » signal measurement.

Place a sample in the measurement range of the pen and adjust the sampling rate and/or the LED intensity.

Connect the « Sync in » pins on the Interface connector to an adjustable external signal (for example, a TTL 0-5V pulse generator) as described in section 3.1.5. Check that the signal is on 0V.

Select the “Trigger” page of the “CCS Manager” software. Select the “Start” trigger type and rising edge as the “active” edge. Click on the “Enable the selected mode” button to enable the mode.

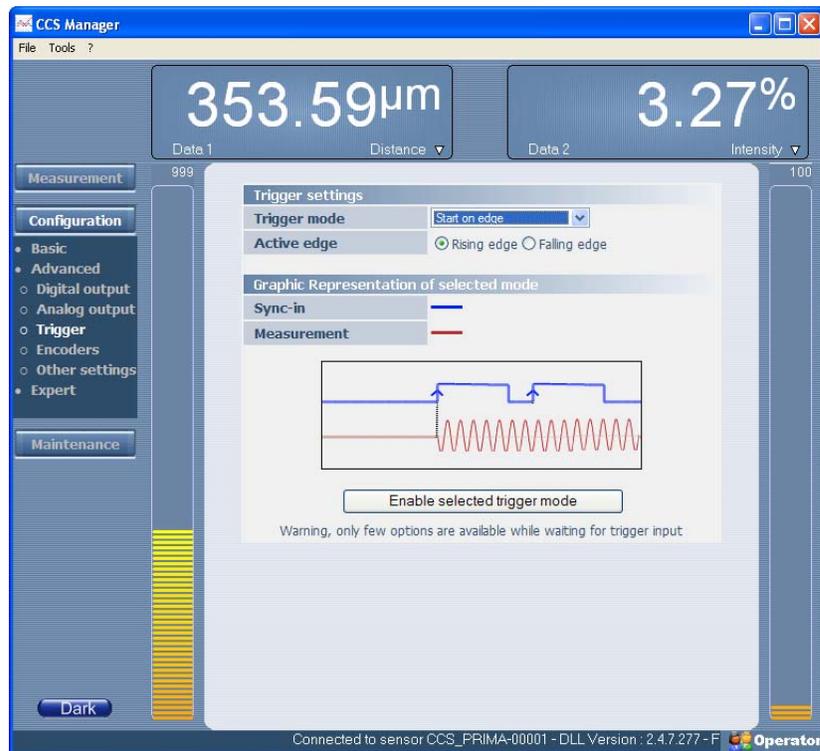


Figure 9 Trigger Settings Dialog Box in CCS Manager

Select the “Measurement” page. Set Data 1 to “Distance” and the number of points to 100, and click several times on the “Start” button.. If previous steps have been carried out correctly, nothing happens: no data is displayed in the Graphic window as the sensor is in standby for a “Sync in” signal. Check that the measurement is not stopped: the “Start/stop” button should look as following:



Send a TTL pulse to the “Sync In” input in order to trigger the measurement: data transmission starts immediately.

7.2 CCS Manager software

7.2.1 Help utility

To learn more about the "CCS Manager" features, click on the "?" icon in the Menu and open the "Help" utility. In particular, we recommend reading the sections concerning the "Maintenance", the Configuration "Other Settings" page and the "Analog Data" page, which are not described in this tutorial.

7.2.2 Command Terminal

Within the CCS Manager is a terminal emulator program with direct, command line communications to the Prima sensor. To access the built-in terminal program, open the "Expert" configuration page.

Type **\$AVR25** (6 characters: \$ sign, 3 upper case letters, and 2 digits) in the "Command" line, and click on the "Send" button. This command sets the temporal averaging to 25. As a result, for each 25 successive points the sensor sends a single value. As a result data transmission is 25 times slower and the signal to noise ratio is improved by a factor of 5 (5 = square root of 25). Watch the sensor reply in the "Sensor response" line.

Type **\$MODO** (\$ sign, 3 upper case letters and 1 digit), and click on the "Send" button. This command selects the "Distance" measuring mode. Watch the sensor reply in the "Sensor response" line.

Type **\$BAU115200** , and click on the "Send" button. This command sets the baud rate to 115200. Watch the sensor reply in the "Sensor response" line.

- Type **\$ASC**, and click on the "Send" button. This command configures the sensor in « ASCII » mode.

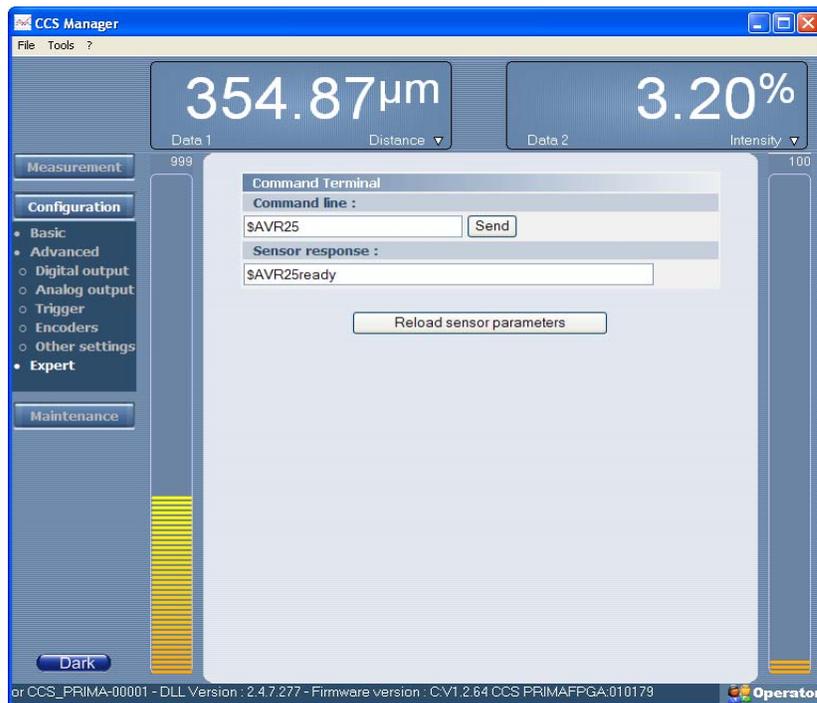


Figure 10 Built-in terminal program in CCS Manager

The Terminal allows communicating with the sensor using the specific CCS command language. Commands are described in detail later on in this manual. For the moment, note that commands begin by a \$ sign, comprise 3 upper case letters, and end with the numerical value of the parameter.

The sensor echoes the command and then sends "ready".

Note the button "Reload sensor parameters" below the command terminal. This button uploads the configuration again, so that the "CCS Manager" program will refresh its parameter list in order to take the modifications following the commands into account. This button has no effect on the sensor, it effects only the "CCS Manger" user interface.

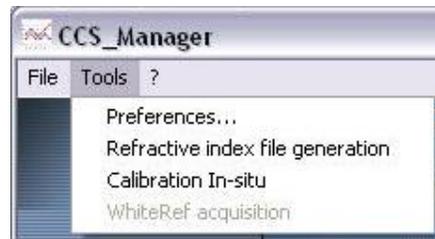
7.2.3 Tools Menu

The « Tools » menu gives access to the « Preferences » page, which allows personalizing the program, and to two additional dedicated calibration procedures:

In-Situ Distance Calibration

Refractive index file generation (Thickness calibration).

Please consult the "Help" pages for more details concerning these features.



7.3 Serial communications

The easiest means to send commands to the CCS Prima is the Command Terminal of the "CCS Manager" software. This Terminal is user friendly, for example it converts lower case characters to upper case and adds missing \$ characters. However if you wish to write your own software using low-level communication, it is useful to get some training in using a standard RS232/RS422 utility such as "HyperTerminal"™ for communicating directly with the sensor.

In the "CCS program", select the "Digital Output" page and Send Data n° 0 (Distance) to the serial port, the other data items to "Not Transmitted".

If the "CCS Manager" application is connected to the sensor RS232 port, you must quit it to release the sensor serial port. If it is connected to the sensor USB port, you may leave it connected as the two channels are independent.

Connect your sensor to a free COM port of the host computer as described in section 3.1.2. Most computers have at least one RS232 port available (COM1). Otherwise, use a USB to RS232 converter and follow the instructions included with that hardware for its installation. Note the assigned serial port.

Be sure that the cable is adapted to the RS port physically connected (RS232 or RS422).

Most PC computer running Microsoft Windows™ has Hyperterminal installed. In the « Start » menu of your PC, select Programs » Accessories » Communication » Hyper Terminal™ utility.

Name your session, and then click on « OK ».

In the « Connect using » field, select the COM port of your computer which is physically connected to the sensor.

In the « Port parameters » window, configure the link as follows :

bits per second : 115200

data bits : 8

parity : none

stop bits : 1

flow control : none

Select the "File/Properties" menu, then, in the window which opens, the "parameters" tab. Click on the "ASCII configuration" button. In the "ASCII Configuration" window, check the first and third boxes of the "ASCII reception" frame. This will add <LF> after each <CR> received. No box should be checked in the "ASCII transmission" frame. Click twice on OK to return to the main window. The utility is now ready for communication with the sensor.

Using the PC's keyboard enter **\$AVR33** then press « Enter ». This command configures the averaging factor at 33. Data output is 3 times faster, as averaging changed from 99 to 33.

Enter **\$AVR?** then press « Enter » to interrogate the sensor on the averaging value. Observe the sensor response (**\$AVR ? 33 ready**) displayed on PC screen.

Enter **\$MOD?** then press « Enter » to interrogate the sensor on the current measuring mode. Observe the response.

Enter **\$SCA** then press « Enter » to interrogate the sensor on the measurement range of the current optical pen. Observe the response.

Enter **\$SRA?** then press « Enter » to interrogate the sensor on the current sampling rate. Observe the response.

Quit the « HyperTerminal »™ utility to release the sensor serial port.

7.4 Measuring thickness

7.4.1 The "Thickness" measuring mode

In the "Thickness" measuring mode the sensor searches for 2 signals, reflected from the 2 faces of a transparent sample. If they are found, it calculates the intensity and distance of face 1 (front face, i.e. the nearest face), the distance and intensity of face 2 (rear face), and the thickness. All these data are available simultaneously.

Important: To obtain a valid measurement in « Thickness » mode, the sensor should be configured to the correct refractive index. Refractive index may be specified either as a constant value or as a file.

7.4.2 Minimum measurable thickness

The thickness of the sample to be measured must be greater or equal to the "Minimum Measured Thickness" of the optical pen. The « Minimum thickness » limit is specified in the data sheet of each optical pen, and may be found on our website www.acuitylaser.com.

If the sample thickness is less than the specified « Minimum thickness » limit, the sensor is unable to resolve the two spectral peaks produced by reflections from the two faces of the sample and considers them as a single peak.

7.4.3 Single surface in "Thickness" mode

Sometimes, a single surface is detected while the sensor is configured to "Thickness" mode. This may occur if one or the other of the sample faces is outside the measuring range, if one of the signals is too weak, or if the thickness is smaller than the "Minimal measurable thickness" of the optical pen. In the latter case the sensor fails to resolve the two surfaces and considers them as a single one.

The "Unmeasured peak handling" (see section 12.5) command determines the behavior of the sensor in such a case. The default behavior is: the data relative to face 2 is set equal to the data of face 1, and the thickness is set to zero.

Recommendation: In « Thickness » mode, place the sample in the center of the measuring range to avoid having either one of the faces close to the limits of the range.

7.4.4 Thickness calibration (refractive index file generation)

Thickness measurement is less precise than Distance measurement, due to several reasons:

By definition, the thickness is computed as a difference so that the noise is doubled,

The refractive index varies with wavelength and as a result, it varies inside the measuring range

The sample itself reduces the quality of the optical beam which passes through its volume

Thickness measurement is more sensitive to errors in angular alignment

The thickness computation is based on paraxial approximation.

For some application relative thickness measurement is sufficient. In this case, the "refractive index" parameter can be set to an approximate value. This is a rapid method but it does not yield precise results.

In order to get metrological precision the sensor should be calibrated in thickness mode. Thickness calibration is a procedure requiring a standard with known thickness. This procedure generates a "refractive index" file which specifies an effective refractive index value for each position in the measuring range. The file is specific to a given sample type (e.g. a 3 mm BK7 glass) and a given sensor. The "CCS manager" software comprises a utility for generating refractive index files (accessible from the "Tools" menu). Please refer to the "Help" utility of this software for a detailed description of this procedure.

The sensor can hold up to 8 refractive index files in its non volatile memory. Existing files may be selected in the "Basic" configuration file of "CCS manager" or by command.

7.4.5 Measuring the Thickness of opaque samples

The "Thickness" mode can only be used for transparent thickness whose thickness is compatible with the min and max measurable thickness of the optical pen.

For measuring the thickness of opaque samples, the most frequently used method consists of using two sensors looking at each other and located on both sides of the sample with collinear optical axes.

Both sensor are configured to "Distance" mode. The Thickness of the sample is given by:

$$\text{Thickness} = K - (D1 + D2)$$

Where D1 and D2 are the distances measured by the two sensors and the constant K is determined using a standard with known thickness.

7.4.6 Teach functions for thickness measurement

In the "Basic" page, set the measuring mode to Thickness. Set the "refractive index" parameter value to the average refractive index of the sample in the visible range. (If you do not know the precise value, leave it at its default value). In the "Digital output" page, select Data n° 0 (Thickness). Set the other data to "Not Transmitted".

Place a thickness sample in the measurement range of the optical pen, such as a glass slide, a piece of cellophane, a transparent plastic film or any other flat transparent sample. If it is a sheet or a film, ensure it is pulled tight. Also check that the axis of the optical pen is normal to the surface of the sample. **The sample thickness must be compatible with the thickness measuring range of the optical pen.**

In the "Measurement" page set the number of points to 3000, and click on "Start".

Move the optical pen slowly backward and forward to bring the two faces of the sample inside the measuring range. As soon as the sample is inside the measuring range, non-zero thickness values appear in the Graphic window.

Note that of the "Measure" LED-indicator depends only on the presence and position of the first peak, it does not tell if a second peak has been detected.

Note that the displayed thickness values are proportional to the refractive index value.

Troubleshooting: If you succeed to obtain a measurement in "Distance" measuring mode, but in "Thickness" measuring mode the measured thickness is zero, check the following points:

- The thickness of the sample must be compatible with the measurement range limits
- The sample must be sufficiently transparent.
- The sample must be pulled tight.
- The optical axis must be normal to the surface of the sample.
- The sampling rate selected must be the lowest in the list
- The two faces of the sample must be inside the measuring range

8. Main functions of the CCS Prima

8.1 Optical pen selection

The CCS Prima sensor may accept up to 20 calibration tables corresponding to 20 different optical pens. The optical pen can be selected in the "Basic" configuration page of CCS Manager, or by sending the 'Select confocal sensor' command.

Note: Multiplexed CCS sensors have different behavior (see section 13.3).

8.1.1 Optical pen selection

The 'Select confocal sensor' command is used to specify or to request the index of the calibration table corresponding to optical pen connected to the CCS.

Select confocal sensor	
Function	Set/request the index of the calibration table
Command	\$SEn or \$SEN ?
Parameter/Value returned	n = index of the table (2 digit integer between 0 and 19)
Example	\$SEN04

8.1.2 Full scale value of the optical pen currently selected

This command is used to get the measurement range of the currently selected optical pen.

Scale	
Function	Request the measurement range of the current optical pen
Command	\$SCA
Value returned	measurement range in microns

8.1.3 List of optical pens

This command is used to get the list of calibration tables and the measuring ranges of the corresponding optical pens.

List	
Function	Request the list of measuring ranges of the 20 calibration ranges
Command	\$LUL
Value returned	List of 20 measuring ranges, in microns

8.2 Dark signal

The Function of the « Dark » signal is explained in the « Getting started » chapter. Dark acquisition may be launched using the "Dark" button on the sensor front panel, from the "CCS Manger" Main Window, or by sending a 'Dark' command.

8.2.1 Acquiring and saving the Dark signal

The 'Dark' command records and saves of the dark signal in the FLASH memory of the CCS Prima for all sampling rates in succession. If the level of the dark signal is too high for low rates, the CCS Prima returns the index of the lowest sampling rate which is usable (see 'Set Sampling rate' command), and lower sampling rates are inhibited.

When done, the sensor returns to the last sampling rate that was before Dark acquisition.

Dark	
Function	Acquire and save the dark signal
Command	\$DRK
Value returned	Index of the lowest sampling rate usable

Note: in case the rate or the LED brightness are modified after a "Dark" command, there is no need to refresh the dark signal.

8.2.2 Minimal rate authorized after Dark acquisition

The 'Minimal rate' command may be used to get to get the minimal sampling rate authorized after last Dark operation:

Minimal rate	
Function	Get the minimal authorized rate (query only)
Command	\$FRM
Value returned	Lowest sampling rate (in Hz).

8.2.3 "Fast" Dark

The « Fast Dark » command only refreshes the dark signal for the current sampling frequency and the current LED brightness. The signal is refreshed in the sensor RAM, without saving the acquisition in the EEPROM.

If the dark signal measured is too high, the CCS Prima returns a « not valid <CRLF> » string and the previous dark signal continues in use.

This command has two optional arguments:

n is an integer indicating the number of successive acquisitions to be averaged in order to obtain the reference dark (default value = 40).

m (default value = 100) indicates the influence of the acquisitions made on the new reference dark according to the formula:

New Dark = (m x Average acquisition + (100 - m) x Old Dark)

Fast Dark	
Function	Acquire the Dark signal for the current sampling rate only without saving in the sensor memory
Command	\$FDK or \$FDKn,m
Parameter/Value returned	n = averaging factor for Dark 1..99 m = weighting factor 1..100 return « Ready » or « Not valid »

Note: in case the rate or the LED brightness are modified after a "Fast Dark" command, the dark signal should be measured again.

8.3 Sampling rate

In the "Single Frequency" mode the sampling rate of the sensor may be managed by two methods:

Selection of a preset sampling rate from a list ("Preset Rate")

Definition of a specific sampling rate ("Free rate" or "Exposure Time")

The first method is recommended for most applications. In this method, the sampling rate is defined by its index. The second method provides greater flexibility in the choice of sampling rate: The "free" sampling rate can be specified in Hz, or the exposure time (inverse of the free rate) can be specified in μs .

This paragraph describes the different methods, followed by some examples.

The "Double Frequency" mode is described in the "Auto-adaptive modes", section 11.

8.3.1 Selecting a preset sampling rate

The CCS Prima has five preset sampling rates:

Index	Sampling rate (HZ)	Exposure time (μs)
00	free rate	Free exposure time
01	100	10000
02	200	5000
03	400	2500
04	1000	1000
05	2000	500

A preset rate may be selected from the "Basic" configuration page of "CCS Manager", or by sending the 'Preset Rate' command.

Preset Rate	
Function	Set/request the index of a preset sampling rate
Command	\$SRAn or \$SRA?
Parameter/Value returned	n = sampling rate index (2 digit integer 0 - 5) Note: limited by the min authorized rate

Note: the command \$SRA0 selects the free rate. The value attributed to the free rate may be set by the "Free rate" command or by the "Exposure time" command described below.

8.3.2 "Free" sampling rate

A free rate may be selected from the "Basic" configuration page of "CCS Manager", or by sending the 'Free Rate' command.

The 'Free Rate' command is used to set the sensor sampling rate to a free value between 100 Hz and 2000 Hz, or to request the value of the free rate.

The index of the free rate in the list of preset rates is 0 (see table above). The last value set to the free rate either by the "Free Rate" command or by the "Exposure time" command may be later activated by sending "\$SRA0".

Note: The Processor may modify slightly the specified value of free rate in order to comply with its internal constraints (the exposure time in μs should be integer), and returns the real value immediately after the echo (see example below).

Free rate	
Function	Set/request the value in Hz of the free rate.
Command	\$FRQn or \$FRQ?
Parameter	n = value of the free sampling rate, in Hz (5 digit integer between 100 and 2000), limited by the min authorized rate
Value returned	m (5 digit integer between 100 and 2000) is the closest rate value $m \geq n$ such that the exposure time in μs is an integer
Example	Command: \$FRQ1995 Response: \$FRQ1995 1996 Note: 1996 Hz corresponds to an integer exposure time (501 μs).

8.3.3 Exposure time

The 'Exposure time' command is used to set/request the free exposure time in μs . The operator can specify any integer exposure time between 00500 and 10000 μs . The free sampling rate is set to 1 000 000/exposure time.

Exposure time	
Function	Set/request the exposure time
Command	\$TEXn or \$TEX?
Parameter	n = value of the free exposure time, in μs (5 digit integer between 00500 and 10000)), limited by the min authorized rate.

8.3.4 Examples

In the following dialog the operator alternates "Preset rate", "Free Rate" and "Exposure Time" commands, and interrogates the sensor to view the results of each command. Read this dialog carefully and make sure you understand the response of the sensor in each case.

Command	Comment	Response from the sensor
\$SRA04	Sets the preset sampling rate index to 4 (1000 Hz)	\$SRA 04<CR> ready
\$SRA?	Interrogates the sensor for the index of the current preset sampling rate	\$SRA?04 ready
\$FRQ?	Interrogates the sensor for the rate in Hz	\$FRQ?01000 ready
\$TEX?	Interrogates the sensor for the exposure time in μs 1000 = 1 000 000/ 1000	\$TEX?01000 ready
\$TEX00530	Sets exposure time to 530 μs (and sets the sampling rate index to 0)	\$TEX00530<CR>0 0530 ready

\$FRQ?	Interrogates the sensor for the rate in Hz 1886 = 1 000 000/ 530	\$FRQ? 1886
\$SRA?	Interrogates the sensor for the index of the current preset sampling rate	SRA? 00 ready
\$FRQ1995	Sets the free rate to 1995 Hz The sensor selects a close value (1996)	\$FRQ1995 <CR> 1996
\$TEX?	Interrogates the sensor for the exposure time in μ s 501 = 1 000 000/ 1996	\$TEX?00501
\$TEX00120	Attempts to set exposure time to a non-authorized value	\$TEX120 not valid ready
\$ SRA01	Sets the preset sampling rate index to 1 (100 Hz) This ends the "free rate" mode	\$SRA01 <CR> ready
\$FRQ?	Interrogates the sensor for the rate in Hz	FRQ?00100 ready
\$SRA00	Sets the preset sampling rate index to 0 ("free rate")	\$SRA00 <CR> ready
\$FRQ?	Interrogates the sensor for the rate in Hz 1996 is the last value attributed to the free rate	\$FRQ? 1996

8.4 Measuring modes

The different measuring modes are described in the 'Going further' chapter.

Index	0	1
Measuring mode	Distance	Thickness

The measuring mode can be selected from the "Basic" configuration page of "CCS manger" or by sending the 'Mode' command.

Measuring Mode	
Function	Set/request the current measuring mode
Command	\$MODn or \$MOD?
Value returned	n = Id of the measuring mode (0-1)

8.5 Refractive index

The sample refractive index is necessary in the "Thickness" measuring mode. Refractive index can be set from the "Basic" configuration page of "CCS manger" or by sending the 'Refractive Index' command.

8.5.1 Setting a constant refractive index

Refractive Index	
Function	Set/request the sample refractive index

Command	\$SRIx or \$SRI?
Value returned	x = sample refractive index (up to 4 decimal digits)
Example	\$SRI1.5120

e

8.5.3 Selecting a Refractive index file

Refractive index file are used to describe the variation of refractive index within the measuring range (see Advanced Topics in section 14).

The "Refractive index file" command is used to load a previously saved refractive index file.

Refractive index file	
Function	Set/request the sample refractive index
Command	\$INFn
Parameter	n = 0 : constant refractive index (determined by last SRI command) n=1..8 : id of an existing refractive index file
Values returned	s: file name x1,x2,x3: the minimal, the maximal and the average refractive index values in the file Command: \$INF3 or \$INF? Response: \$INF3,"BK7", 1.5090, 1.5253, 1.5133
Example	----- Command: \$INF0 Response: \$INF0,"CONSTIND",1.520,1.520,1.520

r
Serial name "CONSTIND" attributed in case the file id is 0.

8.6 Adjustment of the LED brightness

Note: the only type of light source that can be adjusted by command is the LED (internal light source).

LED Brightness can be set from the "Basic" configuration page of "CCS manger" or by sending the 'LED brightness' command.

LED brightness	
Function	Set/request the sample refractive index
Command	\$LEDn or \$LED?
Value returned	n = brightness level (0..100)

For each frequency there exists a minimal brightness level below which the LED cannot go:

Measuring Rate	Minimal brightness level	Maximal brightness level
Up to 500 Hz	10%	100%
500 Hz – 2000 Hz	25%	100%

\$LED0 – puts the LED off

\$LEDX with $X \leq \text{Minimal level}$ sets the LED to the minimal level

\$LEDX with $X > \text{Minimal level}$ sets the LED to level X.

In addition to the LED command, the CCS features an "auto-adaptive LED" mode in which the sensor adapts itself automatically to the reflectivity of the measured sample. This mode is described in the "Auto-adaptive modes" chapter.

8.7 Averaging

The averaging of the measurements by the sensor, improves the signal/noise ratio. When the averaging factor is greater than 1, the sensor transmits the data at the rate f_D

$$F_D = f_s / M,$$

Where : f_D = data transmission rate, f_s = sampling rate = 1/exposure time, M = averaging factor.

Thus, for a sampling rate of 1000 Hz, and an averaging factor of 10, the sensor provides 100 measurement points per second. In order to obtain measurements without averaging, set the averaging to 1.

Averaging is especially useful for difficult samples, for which the signal is low even at the minimum sampling rate. Sometimes averaging is used simply to reduce the data transmission rate.

Recommendation: Do not use high averaging for moving samples, this reduces the transverse resolution and may cause false measurements.

Averaging can be set from the "Other Settings" configuration page of "CCS manger" or by sending the 'Data averaging' command.

Averaging	
Function	Set/request data averaging
Command	\$n or \$AVR ?
Parameter/Value returned	n = averaging (between 1 and 9999)

8.8 Holding the last valid value

The "Hold last value mode" is useful for samples with a great number of non measurable points, due to large local slopes or to a very low reflectivity. When measuring such samples it may be convenient that the value delivered for those positions will not be zero. Instead, the sensor sends the last valid measurement.

Note: if a given data cannot be measured and the last measured value is sent, the "hold last value" bit of the corresponding data item in the "State" data is set (cf. §14.7).

This mode can be configured in the "Other Settings" configuration page of "CCS manger" or by sending the 'Hold last Value' command.

Hold last Value	
Function	Set/request max number of points for "Hold last value mode"
Command	\$HLVn or \$HLV ?
Parameter/Value returned	n = max number of points to hold (between 1 and 999)

8.9 Defining the origin of the encoder measuring range

Encoder reading is relative, so it is necessary to reset them each time they are powered off and on.

The "Rest Encoder" command sets the reading of the desired encoder/s to the "Reset value" 536 870 912, which is the center of the digital range ($536\ 870\ 912 = 2^{30} / 2$).

Reset Encoder	
Function	
Command	\$RCDb1,b2,b3
Parameter/Value returned	bi = 1 if encoder I should be reset.
Example	\$RCD0,1,0 : set the reading of encoder 2 at current position to 536 870 912

Note: Reset value is intentionally is not 0 because encoder data has to be a positive integer.

8.10 Getting the serial number and the firmware version

To know the firmware version of the sensor, you may use either the "About" menu of "CCS Manager", or send the 'Version' command.

Version	
Function	Request the firmware version
Command	\$VER
Value returned	String of characters defining the serial number and the firmware version,

Recommendation: Before contacting the supplier for after-sales service, use the « \$VER » command and record the response from the sensor.

8.11 Saving the current configuration

The « Save setup » command is used to save the current configuration of the CCS Prima sensor on the non-volatile memory. This is essential for the sensor to be able to retrieve the configuration when it is next switched off and on again. If this is not done, the next time the sensor is switched on the sensor will lose all the latest modifications made.

Save Setup	
Function	Save the current configuration in the sensor EEPROM
Command	\$SSU
Parameter/Value returned	none

The configuration can also be saved using the "CCS manager" Menu.

Recommendation: Use the « Save Setup » command to avoid the sensor losing the configuration when the equipment is switched off.

8.12 Resetting the sensor

Resetting the sensor means recovering the factory default values for all parameters. Files saved in the sensor non volatile memory (Calibration lookup tables, dark signal, refractive index files) are not affected by this operation, but current configuration is irreversibly lost.

To reset the sensor proceed as following:

Press **simultaneously** the 2 buttons ("Dark" button and "Set Zero" button) located on the sensor front panel for more than 3 seconds.

When you let off the 2 buttons The 3 LED indicators blink in yellow.

9. Digital Outputs

The CCS Prima features two types of digital I/O:

USB 2.0

RS232 serial link

The USB link is destined both for sending commands and for data acquisition. For this link all measured data may be transmitted at all rates.

The RS232 is destined primarily for sending commands to the sensor. At low measuring rates this link allows data transmission. At medium rates the number of transmissible data is limited, and at 2000 HZ, it is not possible at all. These limitations are described in section 9.2.

The two links may be connected simultaneously to two different applications (be careful in this case to avoid sending conflicting commands).

The present chapter is dedicated to the basic features related to data transmission. The advanced features, such as the details of the command language syntax, the data format or the rules for decoding the data, which are not necessary for most users, are not treated here. Software developers who use low-level commands may find this information in the "Advanced Features" section of this manual.

9.1 Selection of the data to be transmitted

9.1.1 Available data

The sensor measures several data items in parallel at each point of the sample. The table below shows the available data items for both measuring modes:

Data item index	Data items in "Distance" mode	Data items in "Thickness" mode
0	Distance MSB	Thickness
1	Distance LSB	Distance face 1
2	Auto-adaptive mode data	Distance face 2
3	Intensity	Auto-adaptive mode data
4	not used	Intensity face 1
5	not used	Intensity face 2
6	Barycenter	Barycenter face 1
7	not used	Barycenter face 2
8	State	State
9	Counter	Counter
10	Encoder 1 LSB	Encoder 1 LSB
11	Encoder 1 MSB	Encoder 1 MSB
12	Encoder 2 LSB	Encoder 2 LSB
13	Encoder 2 MSB	Encoder 2 MSB
14	Encoder 3 LSB	Encoder 3 LSB
15	Encoder 3 MSB	Encoder 3 MSB

In « Distance» measuring mode, for the sensor to transmit the values of the Distance and Intensity at each measurement via the RS link, the following command must be sent : \$SOD1,1,0,1

In « Distance» measuring mode, for the sensor to transmit the value of the Distance only via the USB link, the following command must be sent : \$SOD 9,9

In “Thickness” measuring mode, for the sensor to transmit the Thickness on USB and the Counter on RS232, the following command must be sent : SOD9,0,0,0,0,0,0,0,0,1

Warning: For the RS link the transmission capacity depends on the sampling rate and the data format (see further in this chapter). Before sending the \$SOD command, check that the number of data items selected is compatible with these parameters in order to avoid data overflow.
There is no limitation on the number of transmitted data items for the USB link.

9.2 Specific features of the RS232 / RS422 link

The RS232 /RS422 connector at the CCS Prima controller front panel should be connected to a free COM Port on the host computer or on the device used for communicating with the sensor, using a direct (non-crossed) serial link wire as described in section 3.1

No specific driver is required.

The baud rate of the sensor RS link should be matched to that of the host computer.

9.2.1 Configuring of the COM port of the host computer

The host computer COM port should be configured as follows:

Data bits : 8

Parity : None

Stop bit : 1

Flow control : None

Transmission baud rate: As high as possible, matched to the sensor baud rate. (*)

(*) The CCS Prima offers baud rates up to 460800 bauds. Note that standard PC COM ports (COM1 and COM2) are limited to 115200 bauds, for higher baud rates a dedicated RS board is required.

The ‘Baud rate’ command sets the baud rate of the CCS Prima RS link.

Baud Rate	
Function	Set/request the sensor RS baud rate
Command	\$BAUn or \$BAU?
Parameter	n= 9600 or 19200 or 38400 or 57600 or 115200 or 230400 or 460800

Note that this command has no effect on the PC baud rate that should be set independently.

9.2.2 Limits of simultaneous data transmissible

The max number of data items transmissible simultaneously per measured point via the RS232/RS422 link depends on the sensor sampling rate and on the RS232/RS422 link baud rate. As far as possible, the highest baud rate available should be used.

Standard RS232 ports on PC mother boards can be configured for baud rates up to 115200 baud. The maximal number of transmissible data items at this baud rates is given by the following tables:

Binary Transmission format –115200 Baud

Measuring rate (Hz)	100	200	400	1000	2000
Max Number of transmitted data	All	All	10	4	1 (*)

Ascii Transmission format –115200 Baud

Measuring rate (Hz)	100	200	400	1000	2000
Max Number of transmitted data	All	8	3	1	-

Commercially available fast RS-Boards may often work at rates up to 460800 bauds. The maximal number of transmissible data items at this baud rates is given by the following tables:

Binary Transmission format – 460800 Baud

Measuring rate (Hz)	100	200	400	1000	2000
Max Number of transmitted data	All	All	All	All	All

Ascii Transmission format - 460800 Baud

Measuring rate (Hz)	100	200	400	1000	2000
Max Number of transmitted data	All	All	All	7	3

When using these tables, please take into consideration the fact that in the "Distance" measuring mode the distance information may be transmitted with 30

bit resolution using 2 data: "Distance MSB" and "Distance LSB". The two data should be enabled for transmission.

In case the user is limited by the capacities of the RS232 link, it is possible to transmit the Distance-MSB data only.

Examples:

Distance measuring RS232 link, 115200 baud, ASCII format:

Up to 400 Hz, distance data may be transmitted at full resolution.

At 1000 Hz, distance data may be transmitted at 15-bit resolution.

At 2000 Hz no data may be transmitted.

If the Binary format is used, the distance may be transmitted at full precision up to 1000 Hz and at 15-bit precision up to 2000 Hz.

Distance measuring RS232 link, 460800 baud, ASCII format:

The RS232 may transmit full-resolution distance (2 data) + Intensity (1 data) up to 2000Hz.

Data overflow

In case the number of transmitted data items specified by the SOD command exceeds the limit, the "Error" led indicated turns to orange and the "data overflow" bit in the "State" data is set.

9.3 Specific features of the USB link

9.3.1 USB driver

Before using the USB channel, a dedicated driver should be installed on the PC. This driver requires XP Operating system with SP2, or more recent (refer to section 3.3)

9.3.2 Using the USB link

The USB connector at the CCS Prima controller front panel should be connected to a free USB Port on the host computer as described in section 3.1.3.

For communicating with the sensor via the USB link it is recommended to use one of the software: described in §5 ("CCS Manager", or "CHR DLL") and not low-level communication.

10. Analog Outputs

The CCS Prima features two identical analog outputs located on the Interface connector on the front panel (cf. §3.1). Both outputs are fully configurable by the operator.

Configuring an analog output consists in specifying the data item to be directed to it (Distance, Thickness, and Intensity) and parameter values corresponding to 0V and to 10V, respectively. This can be done from the "Analog output" configuration page of "CCS manager", or by command.

10.1 Configuring the analog outputs

Analog output	
Function	Set/request the maximum authorized thickness threshold
Command (setting)	\$ANAn,m,p,q
Parameter	n= Id of Analog output to configure (0 or 1) m= Id of data item to be directed to the Analog output (*) p =parameter value corresponding to Vmin (0V) (**) q =parameter value corresponding to Vmax (10V) (**)
Example	\$ANA0,0,0,5000: send data 0(distance) to 1st analog output, 0V corresponds to data0 = 0 µm 10V corresponds to data0 >= 5000 µm
Command (query)	\$ANA?
Value returned	\$ANAm0,p0,q0,m1,p1,q1 n0 is the data item directed to the first analog output (*) p0 is the value corresponding to 0V for the first analog output (**) q0 is the value corresponding to 10V for the first analog output (**) n1 is the data item directed to the second analog output (0..7) p1 is the value corresponding to 0V for the second analog output (**) q1 is the value corresponding to 10V for the second analog output (**)
Example	\$ANA?0,00000,10000,3,00000,00100 ready Data 0 is sent to output 0 , 0V for value 0µm, 10V for value ≥10000µm Data 3 is sent to output 1, 0V for value %, 10V for value 100%

(*) Data item Id for Analog outputs

Data Id	Data Item in "Distance" mode	Data Item in "Thickness" mode
0	Distance	Thickness
1	Not used	Distance face 1
2	Not used	Distance face 2
3	Intensity	Not used
4	Not used	Intensity face 1
5	Not used	Intensity face 2

(**) data scale

In distance mode: Distance data $0 \leq p, q \leq$ measuring range in μm
 Intensity data $0 \leq p, q \leq 100$

In thickness mode: Thickness data $0 \leq p, q \leq 2 \times$ measuring range
 Distance1,2 data $0 \leq p, q \leq 2 \times$ measuring range
 Intensity1,2 data $0 \leq p, q \leq 100$

Notes:

The parameter p (0V value) may be smaller or larger than the parameter q (10V).

If $p < q$ the output voltage increases when data increases, if $p > q$ it is inversed.

A small constant offset ($< 0.2\text{V}$) may be observed ("ADC offset"). To correct for this offset, measure the actual voltage when the data value is 0, and subtract this value from all subsequent measures. The offset is the same for the 2 analog outputs and independent of the selected data.

10.2 Setting the zero values

A simplified method for configuring the Analog outputs is available using the "Set Zero" button on the front panel and/or the SOF command. This method may be used to set the 0V-level of both analog outputs to the current value of the data directed to them.

« Set Analog output Zero »	
Function	Set/reset the analog output 0V value
Command (setting)	SOFn
Parameter	b=0/1 0: set 0V values to current values (equivalent to "Set Zero" button) 1: reset 0V values to 0 (cancels "Set Zero" button operation)
Example	SOF1 (reset 0V values)
Command (query)	Not available

Note:

- The "Set Zero" button has no effect on the 10V values.
- This button does not affect the "ADC offset".

11. Auto-adaptive modes

The CCS Prima features three auto-adaptive modes: the “auto adaptive dark” mode, the “auto adaptive LED” mode and the “double frequency” mode. In these modes the sensor adapts its inner parameters automatically to variations in the ambient temperature (“auto adaptive dark”) or to variations in the intensity of the light beam reflected from the sample (“auto adaptive LED” and the “double frequency”).

The auto-adaptive modes are mutually exclusive: only one of them may be enabled at a time.

11.1 “Auto-adaptive Dark” mode

In this mode the sensor measures automatically the Fast Dark signal (i.e. the Dark signal in the sensor RAM) and adapts it permanently. To do so, the sensor analyses the internal photodetector signal, determines the zone occupied by the signal, and adapts the Fast Dark signal in all other zones.

This mode is particularly useful for compensating slow variation of Dark signal due to temperature change when the sensor configuration (measuring rate, LED brightness) is constant.

Recommendation : To get good results with this mode, wait at least 15 minutes after the sensor and the light source have been powered; Then measure the DARK and enable the “auto adaptive Dark” mode.

Activation of auto-adaptive Dark	
Function	Enable/Disable the auto-adaptive Dark mode
Command	\$ADKb or \$ADK?
Parameter/Value returned	b = 0 or 1

11.2 “Auto-adaptive LED” mode

In this mode the sensor adapts automatically the LED brightness to compensate for variations in the level of the signal returned by the sample.

This mode is very useful for measuring samples with smoothly variable reflectivity or with smoothly variable local slope (e.g. for measuring a lens).

Auto-adaptive LED	
Function	Enable/Disable the auto-adaptive LED mode
Command	\$AALb or \$AAL?
Parameter/Value returned	b = 0/1

The threshold value for this mode is determined by the “Threshold for Auto-adaptive mode” command.

Threshold for Auto-adaptive mode	
Function	Set the threshold value for the auto-adaptive LED mode
Command	\$VTHn or \$VTH?
Parameter/Value returned	n = 0..4095 (higher threshold will result in higher measured intensity) Recommended values: 2500 to 3500.

Notes:

The instantaneous intensity of the LED is coded in the "Auto-adaptive mode" data

Physically, the LED brightness may vary between a minimal level and 100%. When the LED reaches its maximal level, setting the VTH parameter to higher values will not increase the measured intensity.

11.3 "Double Frequency" mode

This mode is useful for samples characterized by strong, rapid point-to-point reflectivity variations, such as samples composed of highly reflective metallic motifs deposited on glass. For such samples it is difficult to select a measuring rate that is well suited to all measured points, as a rate which gives sufficient intensity from the glass surface will generate saturation on the metallic surface. Another example when the "double frequency" mode is useful is that of samples comprising deep holes or sharp slope variations.

In the "double frequency" mode the sensor switches permanently between two frequencies: the low frequency f1 (long exposure time) and the high frequency f2 (short exposure time). It computes the data independently for each frequency, and then selects, for each measured point, the optimal frequency.

The criteria for selecting the optimal frequency are resumed in the following table:

Case	Low frequency	High frequency	Selected frequency
1	Saturated	Saturated	high
2	Saturated	Correct	high
3	Saturated	Null	low
4	Correct	Correct	low
5	Correct	Null	low
6	Null	Null	high

Each couple of acquisitions (one with long exposure and the other with short exposure) is called "a cycle". The sensor delivers one "synchro out" signal per cycle. Measured data is transmitted once per cycle on the digital outputs and updated once per cycle on the analog outputs. The cycle rate f_c is given by the relation:

$$1/f_c = 1/f_1 + 1/f_2$$

11.3.1 Activation

The "double frequency" mode can be activated from the "Basic" configuration page of "CCS manager". Or by the DFA command :

"Double Frequency" Activation	
Function	Enable/Disable the double frequency mode
Command	\$DFAb or \$DFA?
Parameter/Value returned	b = 0/1 (1 to enable)

This command is not authorized when the "auto-adaptive LED" or the "auto-adaptive dark" modes are active (the query form "DFA?" is authorized).

11.3.2 Frequencies

The DFF command sets (or requests) the 2 frequencies for the mode

"Double Frequency" frequencies	
Function	Set/Request the 2 frequencies for the "double frequency" mode
Command	\$DFFf1,f2 or \$DFF?
Parameter/Value returned	f1 = low frequency, f2= high frequency in Hz conditions: $f_{rm} \leq f1 < f2 \leq 1850$ Hz, where f_{rm} is the min authorized rate of the sensor

11.3.3 Intensity

The intensity measured by the sensor depends, on one hand, on the characteristics of the sample (reflectivity, slope) and on the other, on the exposure time. In standard operation mode ("single frequency") the exposure time is constant so that observed intensity variations are directly related to the intensity of reflected from the sample. In the "double frequency" mode both factors vary at the same time so that the interpretation of the Intensity data may be difficult.

For this reason a new parameter, the "normalized intensity" is computed. This is an intensity computed for a fixed frequency (the high frequency), so that it is directly related to the sample characteristics.

Let :

ILF be the intensity measured for the low frequency

IHF be the intensity measured for the high frequency

The following table shows the difference between the "raw" (standard) intensity and the "normalized" intensity.

Available intensities in « Double Frequency » mode

Selected Frequency	« Raw » Intensity	« Normalized » Intensity
Low (f1)	ILF	ILF *f1/f2
High (f2)	IHF	IHF

By default, the transmitted Intensity data is the "Normalized" one. This option may be modified from the "Basic" configuration page of "CCS Manager", or using the "DFI" command.

"Double Frequency" Intensity	
Function	Select the type of transmitted Intensity
Command	\$DFIb or \$DFA?
Parameter/Value returned	b = 0 for "Normalized" intensity, 1 for "Raw" Intensity

11.3.4 Selected frequency bit

The selected frequency for a given cycle is indicated in bit 8 of the "State" data (see section 14.7.2).

Note for users familiar with previous versions of the CCS Sensor firmware:
The "selected frequency" bit replaces the "trigger flip flop" bit of previous versions.

0 indicates that the high frequency was selected, 1 that that low frequency was selected.

11.3.5 Compatibility with other commands/modes

The mode is compatible with most other commands and modes, and in particular: triggering, averaging and manual setting of the LED brightness.

It is not compatible with: auto-adaptive LED mode, auto-adaptive dark mode, fast dark.

Command	Response when the sensor is in "double frequency" mode
AAL, ADK, FDK	Not authorized
DRK	Authorized
TRG, TRE, TRN, TRS, TRF	Authorized
AVR, HLV	Authorized
LED	Authorized
FRQ, TEX, SRA	Authorized (the rate/exposure time is memorized. It is applied when the sensor quits the double frequency mode)

11.3.6 Intensity LED indicator in "Double Frequency" mode

In the "Double Frequency" mode the "Intensity" LED indicator on the front panel is correlated to the High Frequency:

If it is red the signal is saturated at both frequency: you must lower the LED intensity

or increase f_2 .

If it is green, measurement is OK

If it is yellow, it should be ignored.

11.3.7 Synchronization in "double frequency" mode

This paragraph is relevant for applications where the sensor is synchronized with external devices as a "master", using the "Sync out" TTL signals, and the sensor is configured to double-frequency mode.

In single-frequency mode these signals are emitted at the middle of the exposure cycle. As an example, with no averaging the exposure cycle is simple the exposure of a single frame, so that the "sync out" pulses are emitted in the middle of the

exposure time of each individual frame. With averaging of 4, the acquisition cycle consists of the exposure of 4 frames, and the "sync out" pulses are emitted just between the end of exposure of the second frame and the beginning of the exposure of the third frame of the cycle. If the sample is moving, the instant these signals are emitted corresponds to the average position of the sample during the exposure.

In double-frequency mode there are two exposures, one of which is used and the other one abandoned. During the exposure the sensor does not "know" yet which exposure will be selected: the decision is taken only after both images have been read and processed. For this reason the "sync out" pulses are always sent at the middle of the "short" exposure (high rate).

If the short exposure is selected, there is no need for correction. If the long exposure is selected, the "sync out" is shifted by δt relative to the exact instant where they should have been emitted. Suppose now that these pulses are used to latch (read) the position of an encoder and that the sample moves at a velocity V . The temporal shift generates a position shift δx between the position latched from the encoder and the "real" position at the middle of the "long" exposure:

$$\delta t = -0.5 * f_c$$

$$\delta x = V * \delta t$$

Where f_c is the cycle frequency given by the relation: $1/f_c = 1/f_1 + 1/f_2$

In some applications it is desirable to compensate for this shift. As an example consider the application where the depth, width and slope of a scratch on the surface of a flat surface should be measured. Double frequency may be required for this application as the intensity from the slope and/or from the bottom of the scratch is very low, while the intensity from the flat surface is very high. The depth is derived from the difference of the distance values measured on the surface and on the bottom – this data is exact, there is no need for any correction. However the width and the slope involve both sensor data and position data, so that correction should be applied to the position data by post-processing.

The "selected frequency" bit in the "State" data may be used for this purpose:

$$\begin{cases} 0 & \text{if "selected frequency bit"}=0 \end{cases}$$

Correction = {

$$\begin{cases} V * \delta t & \text{if "selected frequency bit"}=1. \end{cases}$$

If the sample is scanned back and forth please note that the sample velocity V is a signed quantity.

12. Synchronization

It is often necessary to synchronize the sensor with an external device, such as an encoder, a motion controller or a photocell indicating the approach of an object traveling on a conveyor belt.

When the external device to be synchronized with the sensor is a digital encoder, this task is particularly easy, as it is performed automatically by the CCS Prima. All you need to do is

Connect the encoders to the "Encoder connector" on the front panel as described in §3.1.6,

Reset each encoder by positioning it at the origin point of the motion range and sending the "Reset Encoder" ("RCD") command,

Configure the sensor to transmit encoder data as well as data measured by the CCS Prima

This may be done either from the "Encoder" page of "CCS Manager" or using the "\$SOD" command (see section 9.1)

For other types of devices (analog encoders, motion controllers) synchronization may be achieved using synchronization signals and Trigger modes. The CCS Prima may be synchronized with an external device as "master" (using the "Sync out" TTL signals), as a "slave" (using the "Sync in" TTL signals), or in a mixed mode (using both types of signals).

"Trigger modes" specify the way the sensor should respond to rising or falling edges of the "Sync in" signals. The common feature to all trigger modes is that the sensor stops measuring and stands by for an "active" edge on "Sync in" connector. Trigger modes may be enabled and disabled from the "Trigger" page of the "CCS manager" program, by the DLL or by low-level commands. By default, all trigger modes are disabled, and the sensor transmits data without interruption immediately after startup. When no trigger mode is enabled, rising and falling edges of the "Sync in" signal are simply ignored.

12.1 "Sync out" signals

Synchronizing the sensor as a "master" means that the "Sync out" TTL signals emitted by the sensor are used to trig (latch) the external device.

The sensor emits one "Sync out" pulse for each measured point at the middle of the Cycle Exposure Time (CET).

$$\text{CET} = \text{EET} * \text{AVR}$$

Where EET = Elementary Exposure Time = 1/measuring rate, AVR = averaging factor.

Example: for a measuring rate of 100 Hz, the Elementary Exposure Time is 10 ms.

By default, the sensor measures with no averaging (AVR=1), so that the Cycle Exposure Time equals the Elementary Exposure Time. If the sensor is configured to an averaging factor of 5, the CET equals 50 ms, as 5 frames are acquired and averaged for each measured point.

In the case of double-frequency rate, please refer to section 11.3.7.

The duration of the "Sync out" pulse (high state) is 10 μ s, irrespective of the CET.

"Sync out" pulses are emitted automatically, with no need for any special configuration.

When the sensor is in stand-by for a trigger, no "sync out" pulses are emitted.

Trouble Shooting:

In firmware versions from 1.2.67 - FPGA 01.01.81 the "Sync out" pulses are sent in the middle of the CET. exposure time. In earlier versions the "Sync out" pulses were emitted at the end of the CET.

If your sensor has been updated to a recent versions but you wish the "Sync out" pulses be to be emitted at the end of the CET, please send the "SYN0" command and save the configuration (cf. §14.8)

YCS)

12.2 "Sync in" signals

Synchronizing the sensor as a "slave" means that the sensor stands by for a trigger signal from an external device. So long as no trigger signal arrives, the sensor is "silent": it does not transmit any data and does not emit any "Sync out" pulse. As soon as it detects a trigger signal on the "Sync in" connector, the sensor starts measuring and emitting "Sync out" pulses.

The "Sync in" signals are 0V-5V TTL signals generated by external devices and intercepted by the sensor. The "active" edge of the « Sync in » signal is the edge which triggers measurement. The active edge (rising edge or falling edge) may be selected by command. The duration of the « Sync in » pulses should be at least 1.2 μ s.

12.3 Trigger modes

The simplest trigger mode is the "Start on edge" trigger. It is enabled by sending the "\$TRG" command, either from the Command Terminal or from the "Trigger" page of the "CCS Manager" program. On receipt of the command, the sensor stands by for the trigger signal. Measurement starts as soon as an "active" edge is detected at the "Sync in" input, with repeatability (jitter) better than 1 μ s. Once the first "Sync in" pulse is received, the sensor exits the "Start on edge" Trigger mode and resumes normal operation. Additional "Sync in" pulses are simply ignored.

Besides the "Start" trigger mode described above, the sensor offers three additional trigger modes:

In the "Start/Stop on State" trigger mode, data transmission starts and stops according to the state of the "Sync in" signal. As an example, data transmission starts when the "Sync in" signal is high (5V) and stops when it is low (0V).

The "Start/Stop on Edge" trigger mode is similar to the "Start/Stop on State", with one difference: data transmission starts and stops by successive "Sync in" pulses and not by changes in signal state.

In the "Burst" trigger mode, the sensor "latches" (transmits) the data of a preset number of points each time it receives a "Sync in" pulse.

Unlike the "Start" trigger mode which is disabled automatically by the first "Sync in" pulse received, the "Start/Stop on State", "Start/Stop on edge" and "Burst" trigger modes should be explicitly disabled by commands. As long as these trigger modes are enabled, successive "Sync in" pulses keep triggering measurements. When all trigger modes are disabled, the sensor resumes normal operation and additional "Sync in" pulses are ignored. The table next page resumes sensor behavior in the different trigger modes.

Active trigger mode	Response to active "Sync in" edges	Response to inactive "Sync in" signal edges
"Start"	1 st active edge starts measurement Next ones are ignored	Ignored
"Start/Stop on State"	Start measurement	Stop measurement
"Start/Stop on Edge"	1 st active edge starts measurement, 2 nd active edge stops measurement, 3 rd active edge starts measurement, And so forth.	ignored
"Burst"	Measure a pre-fixed number of points (N)	Ignored
None	Ignored	Ignored

Notes:

The emission of "Sync out" signals stops and restarts together with data transmission. Each time the sensor starts measuring after a stand-by period, the counter is reset.

12.4 Trigger configuration

12.4.1 "Start" ("TRG") trigger

The « Start Trigger » command puts the sensor on standby for a trigger signal. As soon as an active edge is detected at the "Sync in" input, the sensor starts measuring. Additional "Sync in" signals are ignored.

"Start" trigger	
Function	Enable "Start" trigger mode.
Command	\$TRG
Parameter/Value returned	None

To disable this mode without a hardware trigger, send a "\$" or a "\$CTN" command, and the sensor starts measuring again.

Continue	
Function	Disable « Start Trigger » mode
Command	\$CTN or "\$"
Parameter/Value returned	None

12.4.2 "Start/stop on state" ("TRN") trigger

Data is transmitted when the "Sync in" signal is at the active state. The Active state (high or low) is determined by the "TRF" command.

"Start/stop on state" trigger	
Function	Enable/Disable the "Start/Stop on State" trigger
Command	\$TRNb
Parameter/Value returned	b=1/0

12.4.3 "Start/stop on edge" ("TRS") trigger

Data transmission starts and stops alternatively by successive "Sync in" pulses.

"Start/stop on edge" trigger	
Function	Enable/Disable the "Start/Stop on State" trigger
Command	\$TRsb
Parameter/Value returned	b=1/0

12.4.4 "Burst" ("TRE") trigger

When the "Sync in" signal is received, the sensor transmits the data of a preset number (n) of measured points and stops immediately. Each successive "Sync in" signal triggers the transmission of new group of n measured points, until the mode is disabled.

"Burst" trigger	
Function	Enable/Disable the "Burst" trigger and determine the number of points to latch.
Command	\$TREn (to enable the mode) or \$TRE0 (to disable the mode)
Parameter/Value returned	n = number of points to latch on each "Sync in" pulse (1-9999)

12.4.5 Selecting the active edge/active state

The \$TRF command allows to select the active edge, i.e. the edge which triggers measurement (rising or falling edge). In the case of "Start/Stop on State" trigger mode, this command selects the active state (high or low).

Active edge/active state	
Function	Determines which edge is active for TRG, TRE, TRS Trigger modes Determines which state is active for TRN Trigger mode
Command	\$TRFb
Parameter/Value returned	b = 0 for rising edge and high state, b = 1 for falling edge and for low state.

12.4.6 Software trigger

The "STR" command may be used as software trigger in the "TRE" and "TRS" trigger modes.

Obviously, the software trigger does not have the temporal precision of the hardware trigger.

Software Trigger	
Function	Replace a hardware trigger in the "TRE" or "TRS" modes
Command	\$STR
Parameter/Value returned	None

Trouble shooting:

The Command Terminal of the "CCS Manager" command does not handle the "STR" command correctly.

The software trigger is not available in the "TRN" mode since it simulates a pulse, not a state.

If you wish to use software trigger, use the "TRS" mode instead.

12.5 Identification of the first point measured after trigger

When operating in triggered mode the sensor starts and stops measuring according to the state of the "Sync out" signal. This signal is usually generated by an external device; it arrives to the sensor and not to the user program running on the PC. Except in the case of the "burst" trigger, the user program does not "know" how many points are measured during each time the trigger is "open".

As an example consider a case of a sensor located above a conveyor belt. The sensor is configured to the "Start/Stop on state" mode and the "Sync in" signal, generated by an optical sensor, is high whenever a product is present inside the sensor's field of view. The user program has to process the data profiles and identify the products which do not comply with certain specifications. This program uses one or more large buffers for accumulating the sensor data. The first difficulty that this program has to face is the identification of the limits of each profile, in other words, the identification of the data corresponding to the first point measured after the "sync in" signal goes from low to high.

The solution to this problem resides in the "Counter" data: the counter is reset each time the sensor starts measuring after standby, for all trigger modes. By configuring the sensor to transmit this data together with the "Distance" and the "Intensity" data the user program can easily detect the limits of each profile.

12.6 Maximum rate of "Sync in" pulses

The maximum rate of the "Sync in" pulses is limited by the cycle time required for the exposure, signal reading, data computation and data transmission.

For the "Start/Stop on State" and "Start/Stop on Edge" modes, the cycle time is CYC_{SS}

$CYC_{SS} = 2/M_R + T_e$ is the cycle time with no averaging

$CYC_{SS} = (1+A)/M_R + T_e$ is the cycle time with averaging

M_R is the measuring rate, $T_e \leq 0.2$ ms, $A =$ Averaging factor

For the "Burst" mode, the cycle time is CYC_B

$CYC_B = (1+N) / M_R + T_e$ is the cycle time with no averaging

$CYC_B = (1+N*A) / M_R + T_e$ is the cycle time with averaging

M_R is the measuring rate, $T_e \leq 0.2$ ms, and N is the number of measured points per burst.

Active trigger mode	Maximum "Sync in" pulse rate
"Start"	Not applicable (a single pulse)
"Start/Stop on State"	$1/ CYC_{SS}$
"Start/Stop on Edge"	$1/ CYC_{SS}$
"Burst"	$1/ CYC_B$

Examples for computing the max rate of "Sync in" pulses:

"Start/Stop on State" mode, measuring rate= 100 Hz, $CYC_{SS} = (2*10 + 0.2)$ ms, max rate= 49.5 Hz

"Start/Stop on State" mode, measuring rate=2000 Hz, $CYC_{SS} = (2*0.5+0.2)$ ms, max rate= 833.3 Hz

"Burst" mode with N=5, measuring rate=2000 Hz, $CYC_B = (6*0.5+0.2)$ ms, max rate= 312.5 Hz

13. Multiplex Sensors

This section describes the specific features of the CCS PRIMA2 and CCS PRIMA4 sensors with two and four channels, respectively.

13.1 Channel selection

13.1.1 Setting the selected channel

The "Channel" command allows setting and getting the number of the currently selected channel.

Please note that this function is dedicated to multiplex sensors and will return an error if sent to a single channel CCS Prima.

Channel	
Function	Set/Get the selected multiplex channel
Command	\$CHAN or CHA?
Parameter/Value returned	n :1/2 for a CCS Prima2 1/2/3/4 for a CCS Prima4

13.1.2 Getting the selected channel

The currently selected channel is indicated by 3 methods:

visually, by the LED indicator located on the front panel, just above the optical pen fiber connectors,

in the "Channel" bits of the "state" data (cf. §13.5)

using the interrogative syntax of the "Channel" command.

13.2 Measuring the Dark signal

Each channel has its own "Dark" signal. Each time a different channel is selected, the sensor loads automatically the "Dark" signal corresponding to this channel. The operator should only care about measuring (updating) this signal.

When a multiplexed sensor receives the "Dark" (\$DRK) command described in this manual, or when the "Dark" button on the front panel is pressed, the sensor measures and saves the "Dark" signal of the currently selected channel. The "Dark" button on the User Interface of the "CCS Manager" program has the same effect.

For measuring the "Dark" signals of all channels, the operator may precede in two ways:

Method 1: Measure the Dark of each Channel individually:

Select Channel 1,

Blank the light for the optical pen of channel 1

Measure the "Dark" Signal (using either the "\$DRK" command or the "Dark button")

Select channel 2

Blank the light for the optical pen of channel 1

Measure the "Dark" signal

For CCS Prima 4, repeat for channels 3 and 4

Select the desired channel

Method 2: Measure the Dark of all channels

Blank the light for all optical pens

Send the "Dark all Channels" (\$DKA command)

Please note the execution time of this command is longer than a simple "Dark" command as it is executes the above procedure. The LED indicator shows the progress of the operation.

13.2.1 The "Dark all Channels" commands

As explained above, this command selects the channels successively and measures the Dark for each of them. In case of failure the procedures aborts and does not continue to next channels. When done the sensor returns to the channel that was initially selected.

Dark All Channels	
Function	Measure and save the Dark signal for all Channels
Command	\$DKA
Parameter/Value returned	n1, n2, n3, n4 where ni=minimal authorized rate for channel i

13.3 Lookup Tables

Each channel of a multiplex CCS Prima disposes of 5 locations for the Lookup tables(LUT) corresponding to this channel.

Important :

The LUT of 2 identical optical pens connected to different channels are different.

The parameter n of the "\$SENn" command make take the values 0..4. This parameter is memorized for each channel and is recalled each time that this channel is selected.

As an example, in the following command sequence, the sensor "remembers" the LUT id's for channels 1 & 2.

Command	Response	Signification
\$CHA1	ready	Select channel 1
\$SEN0	ready	Select LUT id 0 pour current channel
\$CHA2	ready	Select channel 2
\$SEN3	ready	Select LUT id 3 for current channel
\$CHA1	ready	Select channel 1
\$SEN?	SEN0ready	Interrogate for current LUT id
\$CHA2	ready	Select channel 2
\$SEN?	SEN3ready	Interrogate for current LUT id

The command "\$SCA?" returns the measuring range of the current LUT of the current channel.

The command "\$LUL" returns the measuring ranges of all tables of all channels in the following order:

LUT 0 channel1, LUT 1 channel 1...LUT 4 channel 1, LUT 0 channel 2, LUT 1 channel 2...etc.

13.4 Trigger

If the sensor is in triggered mode when a new channel is selected it behaves as it does for any other command:

If the sensor is in the "TRG" mode when a new channel is selected, the trigger mode is lost.

If it is in "TRE", "TRS" or "TRN" trigger mode when a new channel is selected, the trigger mode is conserved.

13.5 Channel bits in the "State" data

Bits 11 & 12 (base 0) of the "State" data of Multiplexed sensor indicate the channel number currently selected:

Bits 11 & 12	Channel
00	1
01	2
10	3
11	4

Note: for single channel sensors the bits are set to "00".

13.6 Commutation

Each time a different channel is selected, the sensor performs the following procedure:

Compare the minimal authorized rate of the new channel to the current measuring rate. If the current rate is smaller than the minimal authorized rate the sensor returns "error" and remains at the current channel.

Load the Dark signal of the new channel

Load the sensor id, the LUT and the measuring range value of the new channel,

Reset the "Counter" data

Modify the channel bits of the "State" data.

Commute the selected channel physically

Modify the LED indicator

Commutation time varies according to the configuration of the sensor. It is smaller or equal to 0.4 s.

14. Advanced topics

14.1 Detection threshold

Detection threshold is the minimum Intensity level for a peak to be detected. Smaller peaks are considered as noise.

When measuring a double peak the noise level is often higher. For this reason the CCS controllers feature 3 distinct detection thresholds:

Detection threshold for:	Command
"Distance/strongest peak" measuring mode	MNPx or MNP?
"Distance / 1 st peak" measuring mode	MNPx or MNP?
"Thickness" measuring mode: strongest peak (*)	SPPx or SPP?
"Thickness" measuring mode: weaker peak (*)	SDPx or SDP?
Parameter/Value returned	$0 < x \leq 1$

(*) The value of the SDP parameter should always be set smaller or equal to the value of the SPP parameter.

In most cases the factory-default values of the detection thresholds are optimal. It is recommended that non-expert users do not modify these values without consulting the fabricant.

Experienced users may decrease the thresholds down to 0.005 (for measuring difficult samples in metrological lab conditions) or increase it up to 0.050 when the noise level is particularly high (High temperature, dark signal rarely updated, non optimal measuring rate, etc.). Another case when it may be necessary to increase the detection threshold is when measuring a double peak or a volume-scattering sample.

Detection thresholds should be matched to the noise level and not be used as a means for peak selection.

Troubleshooting:

The physical quantity which is compared to the threshold is the raw signal after dark subtraction (and not the preprocessed signal shown in the "Signal" page of CCS manager software, which is a normalized quantity).

14.2 Light source test

The purpose of the light source test is to indicate when the light source should be replaced. When the light source is the internal white LED this test is not indispensable, as this source has a very long life time. However for external light sources (Tungsten-Halogen lamp or Xenon-arc lamp) is recommended to enable the test, as the life time of these sources is shorter.

14.2.1 Enabling/Disabling the test

Activation of light source test	
Function	Enable/Disable the light source test
Command	\$SLPb or \$SLP?
Parameter/Value returned	b = 0 or 1

Note: when the light source is an internal LED, the test is operational only for LED brightness level 80% to 100%.

14.3 "First peak" mode

"First peak" mode is a feature of the "Distance" measuring mode that is useful for samples comprising one or more transparent layers, e.g. samples whose surface is partially covered with a transparent coating. In this case the sensor "sees" 2 peaks, one from the outer coating surface and one from the substrate. For such samples the reflection of the surface beneath the coating may be stronger than that from the outer coating surface. For the sensor to detect the first peak (instead of the strongest peak, which it does by default), the "First peak" mode should be enabled.

In this mode the sensor selects the first peak that is higher than the detection threshold.

"First peak" mode	
Function	Enable/Disable the "First peak" mode
Command	\$MSPb or \$MSP?
Parameter/Value returned	b = 0 (Strongest peak) or 1 (First Peak).

Notes:

In the "Thickness" measuring mode this command has no effect. The detection threshold in this mode is determined by the MNP command. This mode is very sensitive to noise. In case of false detection of noise peak:

update the dark signal measurement

increase the threshold.

14.4 "Altitude" mode

"Altitude" mode is a feature of the "Distance" measuring mode. When this mode is enabled, the Distance scale is reversed (Altitude instead of Distance):

In Distance mode, Altitude is computed as:

Altitude=Measuring range -Distance

In Thickness mode, the effective measuring range is $n \times$ measuring range in air (n is the refractive index), so that Distance2 may be greater than the measuring range. To avoid negative values, the Altitudes are computed as:

$$\text{Altitude1} = 2 * \text{Measuring Range} - \text{Distance1}$$

$$\text{Altitude1} = 2 * \text{Measuring Range} - \text{Distance2}$$

Note that this means that the Altitude origin is not the same for Distance mode and for Thickness mode.

"Altitude" mode	
Function	Enable/Disable the "Altitude" mode
Command	\$RVSb or \$RVS?
Parameter/Value returned	b = 0 (Distance) or 1 (Altitude).

14.5 Handling of unmeasured peak in Thickness mode

It may happen a single peak is detected while the sensor is configured to "Thickness" mode; this may occur if one of the other of the sample faces is outside the measuring range, or if one of the signals is too weak. The "Unmeasured peak handling" command determines the behavior of the sensor in such a case:

Option 1 (default)

set Distance1, Intensity1 and Barycenter1 to measured values of the single peak

set Distance2, Intensity2 and Barycenter2 equal to Distance1, Intensity1 and Barycenter1, respectively

set the thickness to 0

Option 2:

set Distance1, Intensity1 and Barycenter1 to measured values of the single peak

set Distance2, Intensity2 and Barycenter2 to 0

set the thickness to 0

"Unmeasured peak handling" in Thickness mode	
Function	Determine the values of Distance2, Intensity2 and Barycenter2 data in case a single peak is detected while the sensor is in "Thickness" mode
Command	\$RSPb or \$RSP?
Parameter/Value returned	b = 0 (Option 2 above) or 1 (option 1 above).

14.6 Watchdog

The sensor features software "Watchdog", i.e. a permanent test that validates that the sensor operates normally. In case it does not, the Watchdog resets the sensor after 40 seconds.

This feature is useful for the case the sensor is blocked due to an incomplete command or another reason, in particular for sensors that are not easily accessible. It may be disabled and enabled with the "Watch dog" command.

Watchdog activation

Function	Enable/Disable the watchdog
Command	\$WDEb or \$WDE?
Parameter/Value returned	b = 0 /1

14.7 "Counter", "State" and "Auto-adaptive mode" data

Besides measured data (Distance, Intensity, Barycenter) the sensor also delivers 3 data for controlling the sensor state and for facilitating its integration. These data may be sent on the digital output at the same time as measured data, using the SOD command or any of the software described in section 5.

14.7.1 The "Counter" data

The "Counter" data is an aid for software developers who wish to check that there is no data loss in their acquisition software.

The 15-bit counter is reset each time a Trigger signal is received when the sensor is one of the trigger modes: TRE, TRN, TRS or TRG.

14.7.2 The "State" data

The "State" data is an aggregate of various flags.

bit	flag	bit	flag
0	HLV Barycentre face 2	8	Selected frequency (DF mode) (*)
1	HLV Barycentre face 1	9	Light source test Failure
2	HLV Distance face 2	10	Data overflow for RS transmission
3	HLV Distance face 1	11	
4	HLV Thickness	12	
5	HLV intensity face 2	13	
6	HLV Intensity face 1	14	
7	Saturation flag	15	

The HLV bits are set if the corresponding data is not measured but "held" at last valid value in "Hold last value" mode.

Saturation flag indicates signal saturation. It is set at the same time the "Intensity" LED indicator color turns to red.

The "selected frequency" flag is significant on double-frequency mode only. 0 indicates that the high frequency was selected, 1 that the low frequency was selected.

(*) Note: This bit replaces the "Trigger Flip-flop" bit of previous versions. (The "Trigger Flip Flop" bit was redundant with the "Counter" data).

The "light source test failure" flag indicates lamp should be replaced. Note that this bit is set at the same time as the "Error" LED-indicator turns red. If the light source test is disabled, or if the LED brightness is set to a level lower than 80%, this bit is always zero.

The "data overflow" flag indicates that the number of transmitted data directed to the RS232/RS422 port exceeds the max number of transmissible data (cf. § 9.2). Note that this bit is set at the same time as the "Error" LED-indicator turns Orange.

Note: for multiplexed sensors see section 13.5

14.7.3 The "Auto-adaptive mode" data

In the "Auto-adaptive LED" mode, this data contains the instantaneous LED brightness coded over 8 bits (0..255). This may be useful for analyzing the relative intensity of the signal returned from the sample, as in this mode the "Intensity" data is practically constant.

Relative Intensity = measured Intensity / n.

n = Auto adaptive mode data value

14.8 Synchronization mode

For compatibility with earlier firmware versions, the "Synchronization mode" command allows choosing between two modes:

"Sync out" signals emitted at the end of the acquisition cycle (like in previous versions),

"Sync out" signals emitted at the middle of the acquisition cycle (default)

Synchronization mode	
Function	Select the instant when sync out pulses are emitted
Command	\$SYNb or \$SYN?
Parameter/Value returned	b = 0 /1 (0 : end of the acquisition cycle, 1: middle of the acquisition cycle).

15. Low-level Commands

If you use « CCS Manager » or the DLL for configuring the sensor, you may skip this chapter.

15.1 Command Language

Command language is identical for the two digital I/O channels. The command language syntax and the basic commands are common to all Acuity point sensor controllers (CHR, CCS, INITIAL). However, each controller has some specific commands.

15.1.1 Command syntax

Every command transmitted to the sensor must start by a \$ character.

Every command must end with a <CRLF> (carriage return, line feed) sequence.

Command name consists of 3 higher case letters.

When a command has one or more parameters, the parameters come immediately after the command name.

There should be no comma between the name of the command and the first parameter.

When a command includes several parameters, the parameters are separated by commas.

For query the parameter is replaced by "?"

Note: in USB communication, the entire command should be sent as a single packet.

15.1.2 Sensor response

When powered on, the sensor transmits data according to the last saved configuration. On receipt of character \$, the sensor stops sending data and waits for the remaining command characters. Each received character (including \$) is echoed back.

After processing the command, the sensor responds with one of the following strings, and switches back to normal operation.

echo + optional parameters + "ready<CRLF>": the command has been successfully executed

echo + "invalid cde<CRLF>": the received command is illegal

echo + "not valid<CRLF>": the received command is legal put parameter values are illegal

echo + "error<CRLF>": the command and its parameters are legal but execution has failed.

The table below shows some examples of commands and sensor responses.

Function	Command	Response
----------	---------	----------

Measuring Mode (query)	\$MOD? <CRLF>	\$MOD? 1 ready<CRLF>
Acquire dark signal	\$DRK <CRLF>	\$DRK 3 ready <CRLF>
Set Measuring Mode	\$MOD1<CRLF>	\$MOD1<CR> ready<CRLF>
Select Distance and Intensity data to be transmitted on USB port	\$SOD9,0,0,9<CRLF>	\$SOD9,0,0,9 <CR>ready<CRLF>
Select Output Data (query)	\$SOD? <CRLF>	\$SOD?9,0,0,9,0,0,0,0,0,0,0,0,0,0,0ready<CRLF>
Set ASCII format	\$ASC<CRLF>	\$ASC ready<CRLF>

15.2 Command List for the CCS Prima

Command	Parameter	Action
Basic Settings		
AVR	Averaging value (1-9999)	Data averaging
MOD	Measuring mode Id (0/1)	Measuring mode selection
SEN	Optical pen Id (0 - 19)	Optical pen (calibration table) selection
SCA	Measuring range in μm	Measuring range of selected (Query only)
LUL	List of calibration tables	Measuring ranges of all (Query only)
MNP	0.0-1.0	Detection threshold for Distance mode
SPP	0.0-1.0	Detection threshold for Thick. mode (1 st peak)
SDP	0.0-1.0	Detection threshold for Thick. mode (2 nd peak)
SRA	Preset rate Id (*)	Preset rate selection
FRQ	Rate in Hz (*)	Free rate setting
TEX	Exposure time in μs (*)	Exposure time setting for free rate
FRM	Min Authorized Rate in Hz	Min authorized rate (Query only)
HLV	Max nb of points to hold (0- 999)	« Hold Last value » mode
MSP	0/1	"First Peak" mode enabling
RSP	0/1	"Unmeasured peak handling" in thick. mode
RVS	0/1	"Altitude" Mode enabling
SRI	x.xxxx	Refractive index value
InF	refractive index file id (0/n)	Refractive index file selection

	(*) parameter value are limited by the Min Authorized Rate	
Basic Functions		
DRK	Minimal authorized rate	Acquire and save Dark at all rates (returns Min authorized rate id)
FDKn,m	n= Dark averaging, m=weighting	Acquire Dark at current rate
SSU	-	Save all parameters to non-volatile memory
VER	-	Serial number & firmware version (Query only)
RCD	b1,b2,b3 bi=1:reset encoder i	Reset encoder position
Digital I/O		
SOD	n0,n1..n15 with ni=0/1/9	Select transmission channel for all data items
ASC	-	ASCII mode
BIN	-	Binary mode
BAU	9600..460800	Baud rate (for RS232/RS422)
Analog I/O		
ANA	Output Id, data id, 0V&10 values	Configuration of analog output
SOF	0/1	Set/Reset 0V values
Light Source		
SLP	0/1	Light source test enabling
LED	0..100	LED brightness adjustment
Auto-adaptive modes		
AAL	0/1	"Auto-adaptive LED" mode enabling
VTH	0..4095	Threshold for "Auto-adaptive LED" mode
ADK	0/1	"Auto-adaptive Dark" mode enabling
DFA	0/1	"Double Frequency" mode activation
DFF	f1, f2 in Hz where $f_1 \leq f_2 < 1850$ Hz,	"Double Frequency" mode frequency setting
DFI	0/1	"Double Frequency" mode intensity selection
Trigger		
TRG	-	"Start" Trigger mode enabling "Start" Trigger mode disabling
CTN	0/n, n=1..9999	
TRE	0/1	"Burst" Trigger mode enabling and setting
TRS	0/1	"Start /stop on edge" Trigger mode enabling
TRN	0/1	"Start/stop on state" Trigger mode enabling
TRF		Select active edge
SYN	0/1	Compatibility with previous modes, cf. §14.8
Watch Dog		
WDE	0/1	Watch dog enabling
Multiplex CCS		
CHA	1/2 or 1/2/3/4	Select multiplex channel
DKA	minimal authorized rates	Dark all channels

16. DATA FORMAT AND DATA ENCODING

If you use « CCS Manager » or the DLL for acquiring the data, you may skip this chapter.

16.1 Data transmission formats

The sensor provides 2 data transmission formats: the ASCII format and the binary format.

Data transmission formats are set by commands.

16.1.1 Ascii Format

Ascii	
Function	Configure the sensor to ASCII transmission format
Command	\$ASC
Parameter/Value returned	None

In ASCII format, 5 characters (digits) are transmitted for each data item. The data from the same point are separated by commas, and the successive points are separated by <CRLF> sequence.

Example

Measuring mode = « Thickness »,

Data selected = Thickness, Distance face 1, Distance face 2.

The successive measurement points are identified as A, B, C etc.

The table below shows the first 36 characters transmitted:

ASCII transmission format

X	X	X	X	X	,	X	X	X	X	X	,
Thickness – point A					DSe p	Distance face 1 - point A					DSe p
1	2	3	4	5	6	7	8	9	10	11	12

X	X	X	X	X	CR	LF	X	X	X	X	X
Distance face 2 – point A					PSep		Thickness – point B				
13	14	15	16	17	18	19	20	21	22	23	24

,	X	X	X	X	X	,	X	X	X	X	X
DSe p	Distance face 1 – Point B					DSe p	Distance face 2 – Point B				
25	26	27	28	29	30	31	32	33	34	35	36

X = digit (0-9) DSep = Data separator (comma) PSep= Point separator (CRLF)

Note that in thickness mode the distance information is provided with 15 bits resolution (one data item).

16.1.2 Binary format

In Binary format, 2 bytes are transmitted for each data item with no data separator. Successive points are separated by two consecutive bytes 0xFF (decimal value = 255).

Binary	
Function	Configures the sensor to binary transmission format
Command	\$BIN
Parameter/Value returned	None

Example

Measuring mode = « Distance », Selected data = Distance MSB and Distance LSB

A,B,C = Successive measurement points. The table below shows the first 12 bytes transmitted:

Binary transmission format

X	X	X	X	OxFF	OxFF	X	X	X	X	OxFF	OxFF
Dist - MSB Point A		Dist - LSB Point A		PSep		Dist - MSB Point B		Dist - LSB Point B		PSep	
1	2	3	4	5	6	7	8	9	10	11	12

X= 1 byte of data

PSep = Point separator

16.2 Decoding the data

All data are encoded as integer number. The following rules allow converting them to physical quantities.

16.2.1 Data decoding for the Distance measuring mode

The Distance is encoded over 30 bits (2 data items: MSB and LSB, 15 bits each). To obtain The Distance in μm , use the following relation:

$$\text{Distance} = (\text{Transmitted value of MSB} * 2^{15} + \text{Transmitted value of LSB}) * \text{Measurement range} / 2^{30}$$

The measurement range depends on the optical pen. To get the measuring range of the currently connected confocal optical pen, send the "SCA?" command.

In some cases 15-bit resolution is sufficient. In such cases a simplified relation may be used:

$$\text{Distance} [\mu\text{m}] \sim \text{Transmitted Value of MSB} \times \text{Measurement range} \div 2^{15}$$

Intensity is encoded over 12 bits (0-4095). To obtain the Intensity in % of the sensor dynamics, use the following relation:

$$\text{Intensity} [\%] = \text{Transmitted Value} \times 100\% \div 4095$$

The position of the Barycenter (pixel index of the spectral peak on the photodetector signal) is encoded over 15 bits (0-32767). To obtain the position of the barycenter in pixels, use the following relationship :

$$\text{Barycenter} = (\text{transmitted value} \div \text{Bs}) + \text{Bo}$$

Bs is Barycenter scale, Bo is Barycenter offset. The default values of these parameters for the CCS Prima are:

$$\text{Bs}=32, \quad \text{Bo}= 520$$

Encoder data is coded over 30 bits and transmitted in 2 words of 15 bits each.

The "Reset value" ($536\,870\,912 = 2^{30} / 2$) is attributed to the position where the "\$RCD" command is sent. Each unit equals 1 encoder microstep.

The State data is a word composed of independent bits (cf. § 14.7).

The counter and the Auto-adaptive mode data are described in the "Advanced topics" chapter.

16.2.2 Data decoding in Thickness measuring mode

In Thickness mode Distance1, Distance2 and the Thickness data are encoded over 15 bits (0-32767).

As the refractive index of the sample is generally greater than 1.0, the Thickness and Distance2 may be greater than the measuring range in air. For this reason the scale is twice the measuring range in air.

Note: To get the measuring range of the currently connected confocal optical pen, send the "SCA?" command.

$$\begin{aligned} \text{Thickness} &= \text{Transmitted value} \times \text{Measurement Range} \times \text{Scale factor} \div 32767 \\ \text{Distance face 1} &= \text{Transmitted value} \times \text{Measurement range} \times \text{Scale factor} \div 32767 \\ \text{Distance face 2} &= \text{Transmitted value} \times \text{Measurement range} \times \text{Scale factor} \div 32767 \end{aligned}$$
$$\text{Scale factor} = 2$$

All the other data are encoded in the same way as for the CCI/Distance mode.

17. Maintenance

17.1 Handling the fiber optics

When no fiber optics is connected, the fiber socket located on the controller front panel must at all times be fitted with its protection cap to avoid contamination of the fiber tip, which could result in malfunctioning of the sensor.

Avoid putting anything on the fiber optics or laying it on the floor (not to stamp it).

Avoid wringing or bending it upwards 70 degrees.

The best way to avoid contamination of the fiber optics lead is to keep it permanently connected at both ends, or if it is necessary to disconnect it, to immediately fit a protective cap on the socket at the controller front panel.

17.2 High Dark signals

The first symptom indicating the presence of dust or dirt on the fiber optics tips or inside a fiber connector is an increase in the level of the dark signal. In such a case on completion of the dark acquisition sequence the color of the blinking LED Indicators is orange or red. This means that the acquired dark signal is too high at some sampling rates (orange) or at all sampling rates (red).

Note: For sensors equipped with a custom light source, the dark signal is often higher as these light sources are more intense. For such sensors the warning message should not be interpreted as an indication of a problem.

A high dark signal is not necessarily a problem: If you wish to measure at 2 kHz and the sensor cannot be configured to 100 Hz, there is clearly no reason to be alarmed. However if you wish to measure at 200 Hz and the sensor cannot be configured to 100 Hz, it is recommended to proceed as following:

Step 1: Check that the dark signal was acquired with no object present within the measuring range.

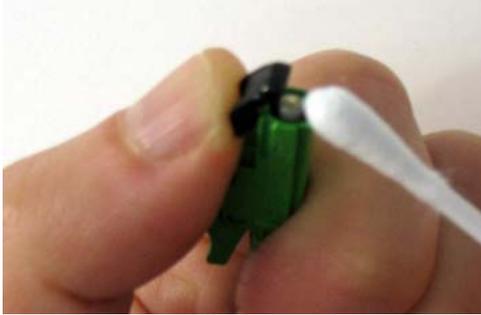
Mask the extremity of the optical pen with a piece of paper, acquire the dark signal again, and watch the color of the blinking LED Indicators at the end of the operation.

If the problem persists:

Step 2: Check if the problem comes from the controller or from the fiber optics connected to the optical pen.

Disconnect the fiber optics from the controller front panel (do not cover the socket with the protecting cap). Acquire the dark signal, and watch the color of the blinking LED Indicators at the end of the operation. If it is orange or red, the problem comes from the fiber optics inside the controller. If it is green, the problem comes from the fiber optics connected to the optical pen.

Step 3: If the problem comes from the optical pen, clean the fiber optics tip:



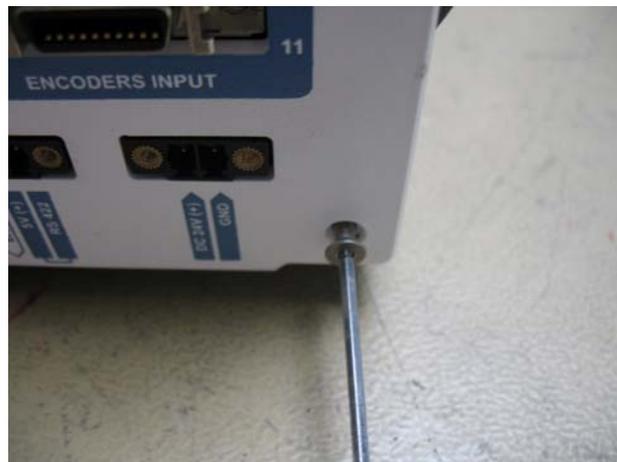
Raise the black protecting cap over the fiber optics plug, and clean the fiber optics tip carefully. Use absorbent cotton, or a paper towel, soaked with alcohol (e.g. Ethanol or Methanol). Perform circular movement so as to push the dust grains away from the fiber tip.

If you have tried cleaning the fiber tip once or twice and the problem persists, it means that the fiber optics is damage. In this case, replace the fiber optics cable by a new one.

Step 4: If the problem comes from the controller clean the fiber coupler inside the controller:

Turn the CCS controller OFF

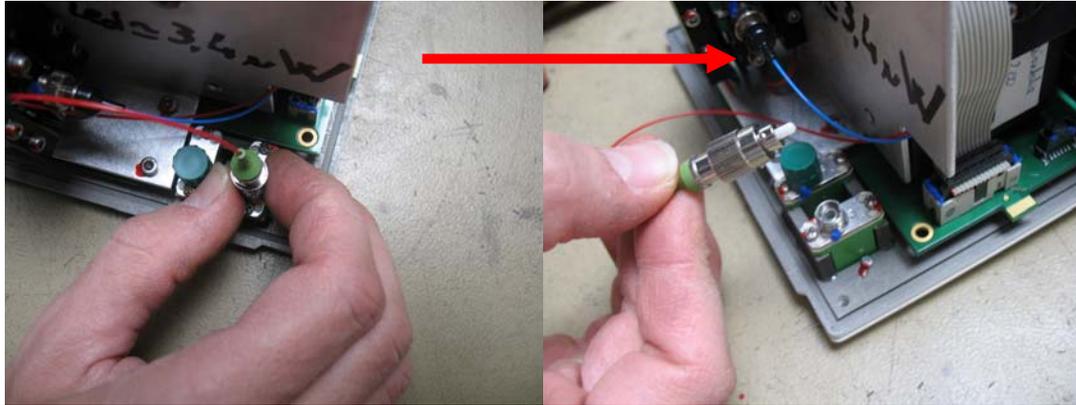
Remove the 4 screws at the corners:



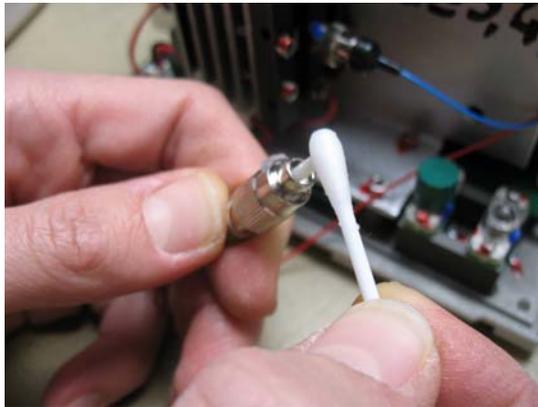
Pull the front panel gently



Unscrew the metallic fiber connector. When it is completely unscrewed pull it out to remove the fiber from the feed-through connector



Clean up the optical fiber extremity carefully with alcohol-soaked cotton :



Replace the optical fiber on the feed - through connector.

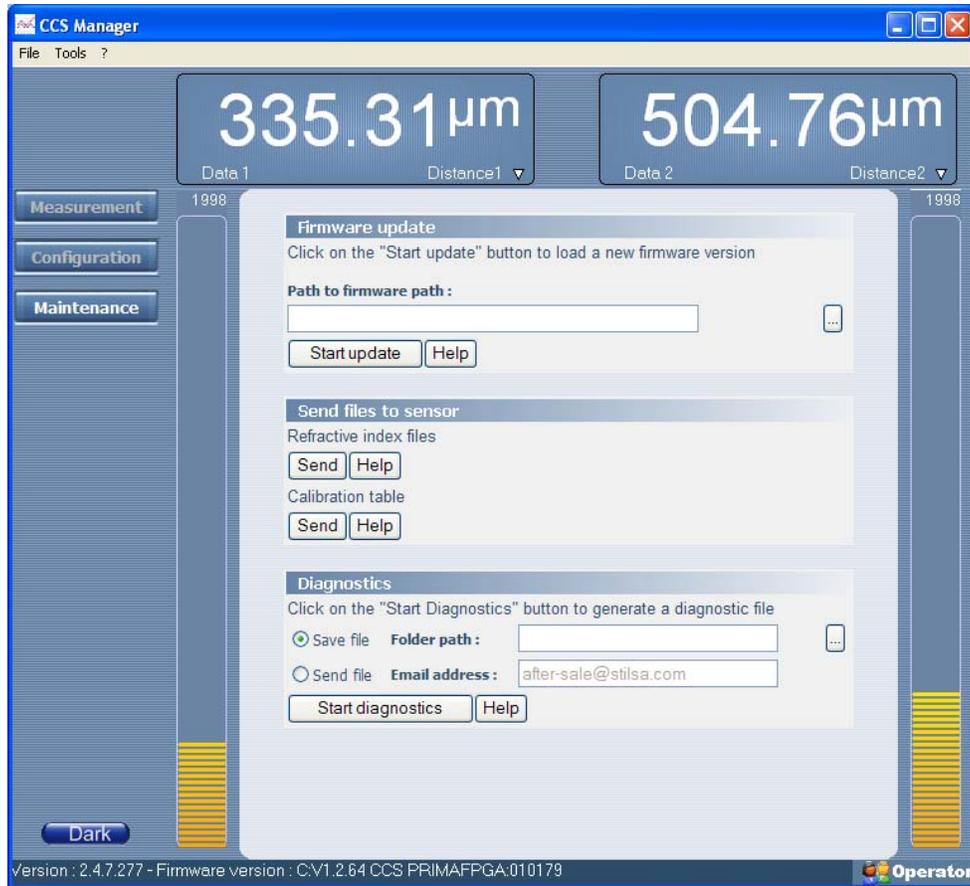
Insert carefully the front panel into the blue box.

Fasten the 4 screws.

Restart the CCS controller and launch a new a dark measurement.

17.3 Diagnostics File

The "CCS Manger" program can collect automatically the sensor configuration and generate a diagnostics file. Diagnostics file can be generated by a simple mouse click, from the "Maintenance" page of this program and saved to the computer hard disk (if your computer is connected to Internet, you may email the file directly). Whenever you contact your vendor for technical support, do not forget to join this file to your query.



17.4 Firmware update

The "Maintenance" page of "CCS Manager" may be also used to upload a new firmware version into the sensor. Please refer to the "Help" page describing this feature (To access help, click on the "?" mark in the menu).

17.5 Technical support

If after reading the manual you have more questions concerning the optimal way to use the sensor, please contact you vendor for technical support.

18. Appendix: Chronograms

The following chronograms describe the temporal behavior of some of the principal tasks performed by the sensor in different configurations.

The chronograms are not required for standard use of the sensor. They are given as an aid to software developers who wish to integrate the sensor in more complex systems.

The following table defines the 4 configurations:

N°	Trigger mode	Data Averaging	Frequency mode
1	None	None	Single frequency
2	"Start" trigger	None	Single frequency
3	None	AVR=3	Single frequency
4	None	None	Double frequency

The tasks shown are:

Task	Duration (typical values)
photodetector exposure	$T_{exp} = 1 / \text{measuring rate}$
photodetector readout	$T_{RO} \sim 0.4 \text{ ms}$
data processing	$T_{PR} \sim 80 \mu\text{s}$
Sync out pulse on the "Sync out" connector	$T_{SO} = 10 \mu\text{s}$
Read the positions of connected digital encoder (if any).	Starts at the same time as the "Sync out"
modification of the analog output voltage	1 cycle time
transmission of the data on the digital outputs	TDT: duration of data transmission is very variable, it depends on the connection type (RS or USB) and of the digital output configuration (SOD command and data format)

Chronogram Description:

1. Frames

For each individual frame, the steps are:

Exposure

Photodetector Readout

Processing

Frames are handled as a pipeline: at the same time that frame i is being exposed, frame $(i-1)$ is read and frame $(i-2)$ is being processed.

2. Cycles

A « cycle » corresponds to one measurement.

With no averaging, the cycle is a single frame (in "Single Frequency" mode) or a couple of frames, one with long exposure and one with short exposure (in "Double Frequency" mode).

For averaging factor N the cycle consists of N frames ("Single Frequency" mode) or N couples of long exposure + short exposure (in "Double Frequency" mode).

For each cycle, the steps are:

Case I: Continuous Acquisition

All the frames of the cycle are exposed successively

One "Sync Out" pulse is emitted.

In "Single Frequency" mode the pulse is emitted in the middle of the exposure of the cycle

In "Double Frequency" mode the pulse is emitted in the middle of the exposure of the N short frames ($N \geq 1$)

At the same time as the "Sync Out" pulse, the sensor reads the position of all connected encoders (if any)

When the processing of the last frame of the cycle is done, the data (and eventually the encoder position) is transmitted on the digital port and the voltage analog outputs is refreshed.

Case II: Triggered acquisition

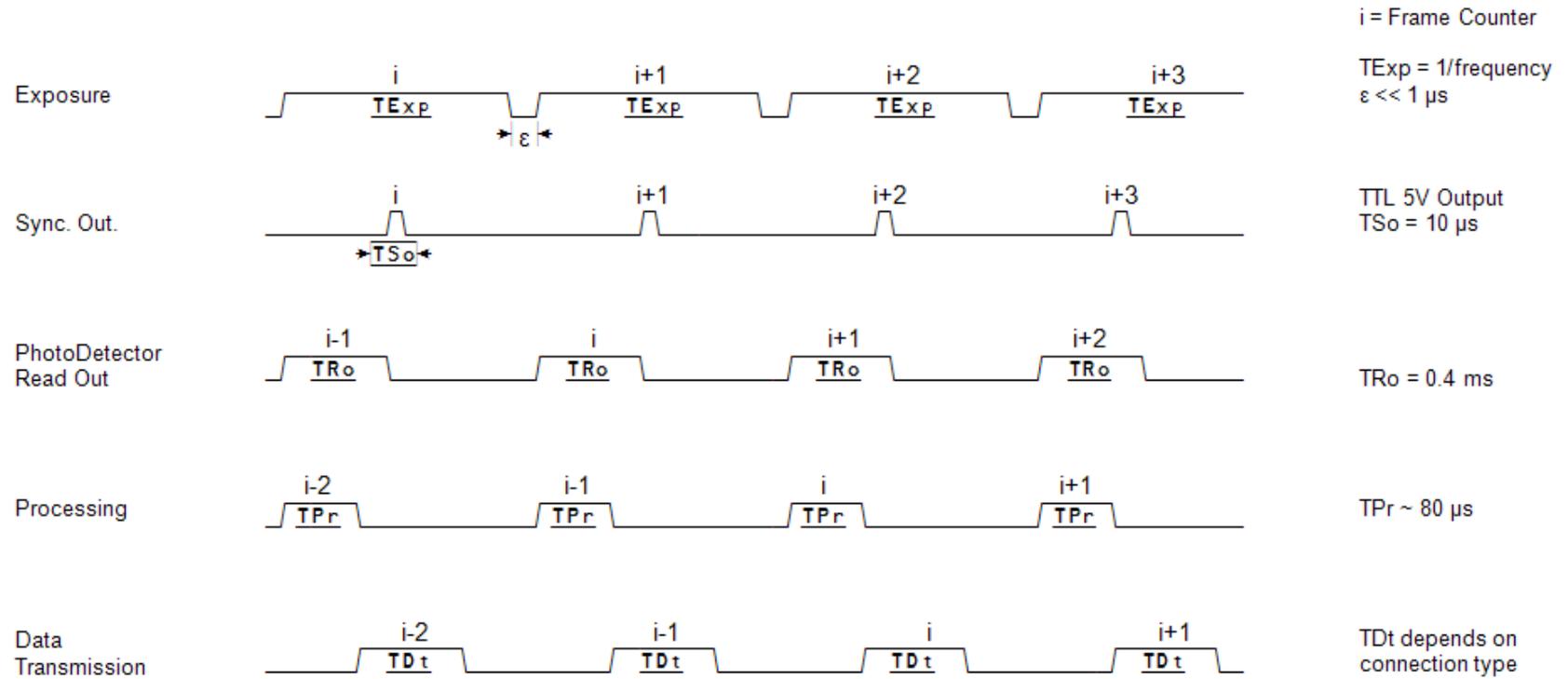
The sensor stands by for Incoming Trigger pulse on the "Sync in" connector.

During stand by nothing comes out of the sensor, but acquisition goes on internally.

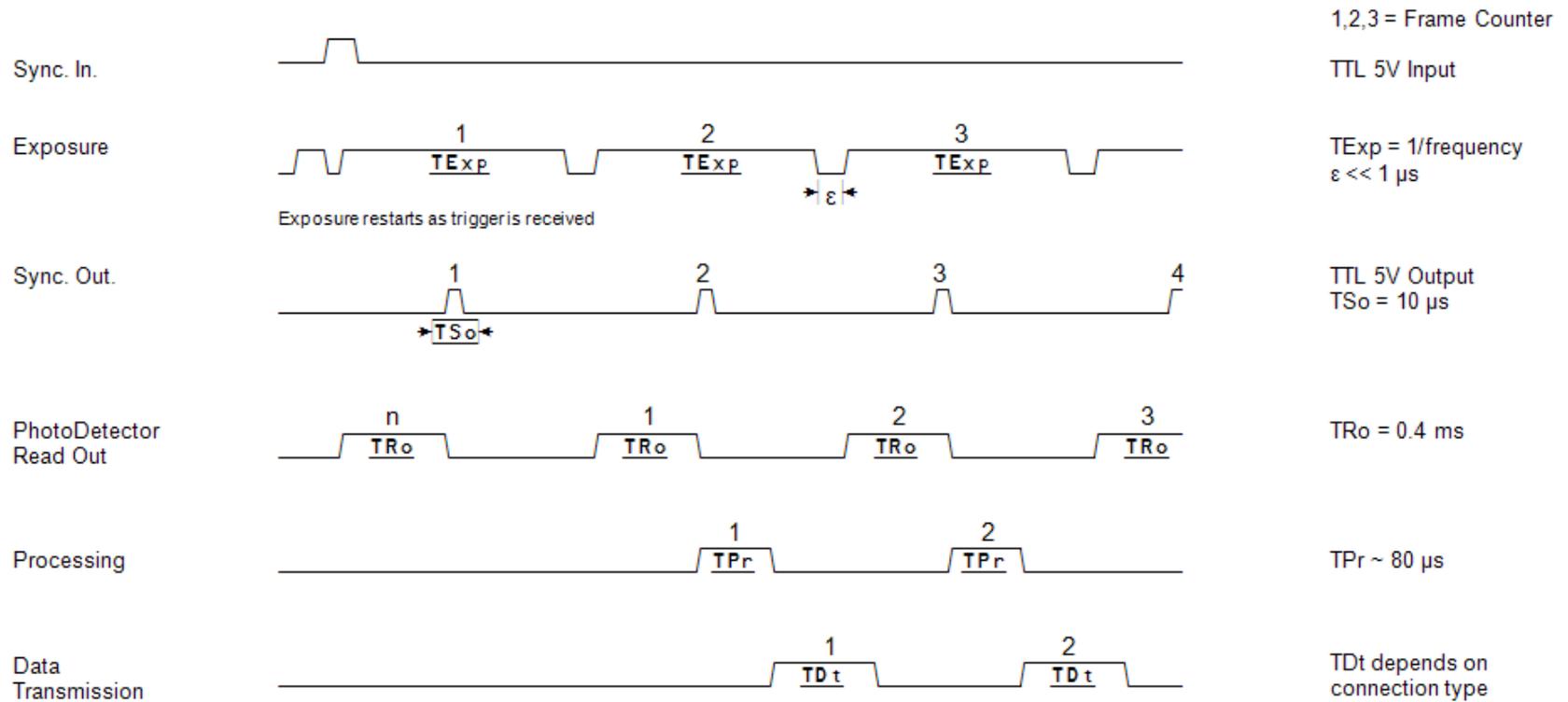
Upon reception of the trigger, the current exposure is aborted and the exposure of a new frame starts immediately (cf. chronogram 2).

The same steps as in case I follow.

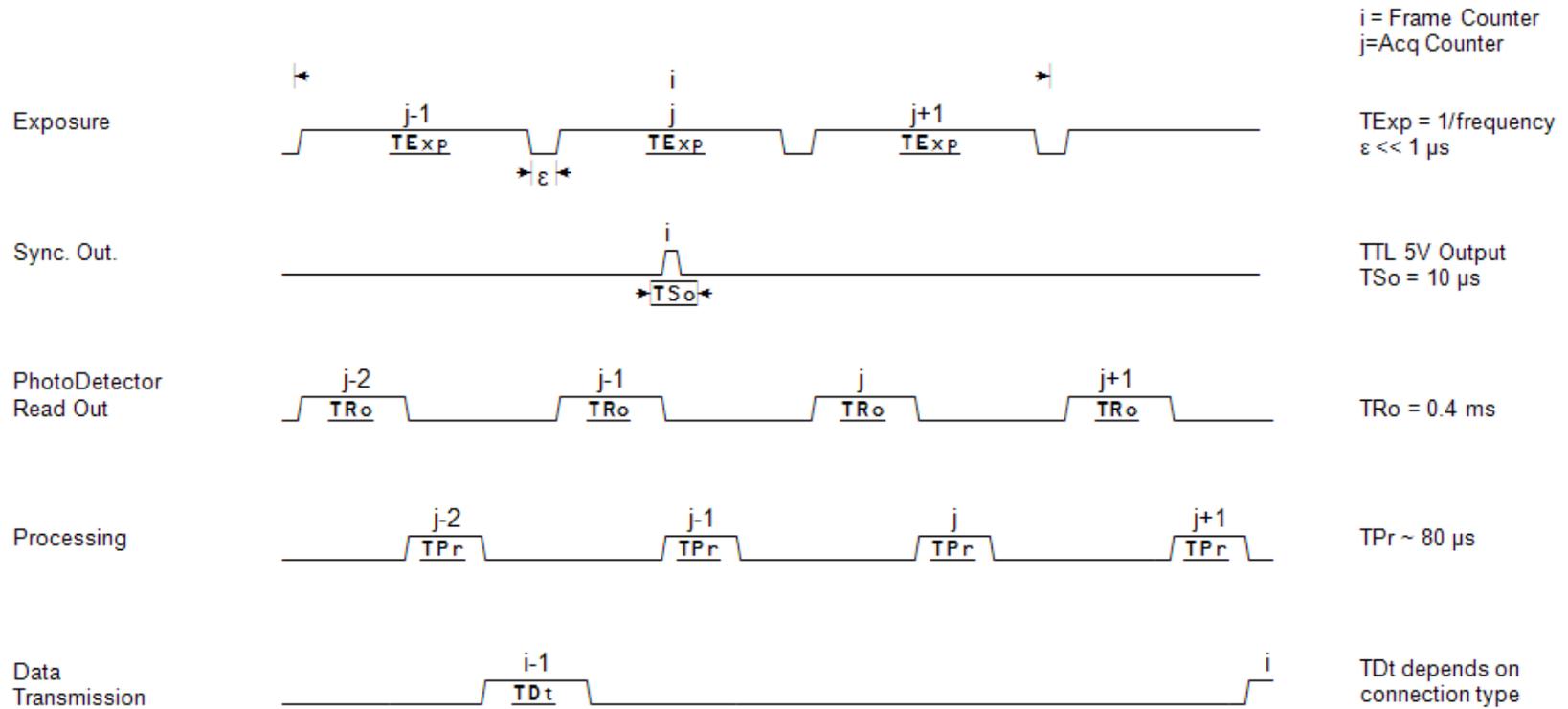
Chronogram 1: Continuous Acquisition, No Averaging, Single Frequency



Chronogram 2 : Start Trigger, Active Edge = Rising, No Averaging, Single Frequency



Chronogram 3 : Continuous Acquisition, Averaging = 3, Single Frequency



Chronogram 4: Continuous Acquisition, No Averaging, Double Frequency

