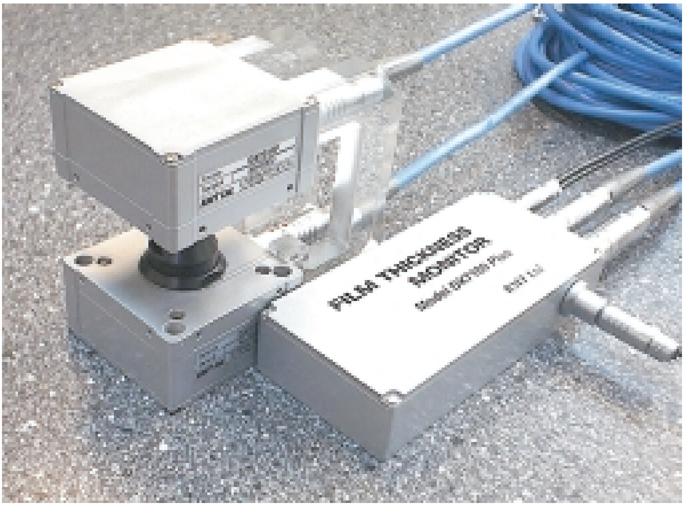
RMT Ltd.

Joint Stock Company

Optical sensor
DX7000 Plus Series

User Guide



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Limited Warranty

RMT Ltd warrants that DX7000 Plus Optical Sensor, if properly used and installed, will be free from defects in material and workmanship and will substantially conform to RMT's publicly available specification for a period of one (1) year after the date of DX7000 Plus Optical Sensor was purchased.

If the DX7000 Plus Optical Sensor which is the subject of this Limited Warranty fails during the warranty period for the reasons covered by this Limited Warranty, RMT, at this option, will :

REPAIR the DX7000 Plus Optical Sensor; **OR**

REPLACE the DX7000 Plus Optical Sensor with another DX7000 Plus Optical Sensor.

Trademark Acknowledgments

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1. Introduction

The company RMT Ltd introduces the new DX7000 series of Optical Sensors for measurement of TOTAL thickness of Polyethylene (PE) and/or Polypropylene (PP) layers or selective measurement of EVOH layer in multilayer plastics.

The principle of operation is based on selective absorption of IR radiation by molecules of the tested media.

The differential double frequency optical scheme provides a high accuracy in wide ranges of humidity and temperature due to the internal thermostabilization.

New types of middle infrared Light Emitters and Photodetectors with built–in thermoelectric cooling are used.

Advantages

- ***high selectivity and stability***
- ***high sensitivity and accuracy***
- ***the long service life***

Features

- ***no moving parts***
- ***minimum dimensions and light weight***
- ***low power consumption***

2. Theory of Operation

Principles of Operation

The NDIR (Non–Dispersive Infra–Red Spectroscopy) measurement method is implemented in the DX7000 Plus sensor.

The DX7000 Plus is based on Non–Dispersive Infra–Red Spectroscopy (NDIR).

The classical double channel scheme (Fig. 2.1) is realized. Intensities of two light beams, passed through measuring film, are compared.

One of the beams (measuring channel) has wavelength which is tuned to optical absorption line of molecules of measured material. The another one (reference

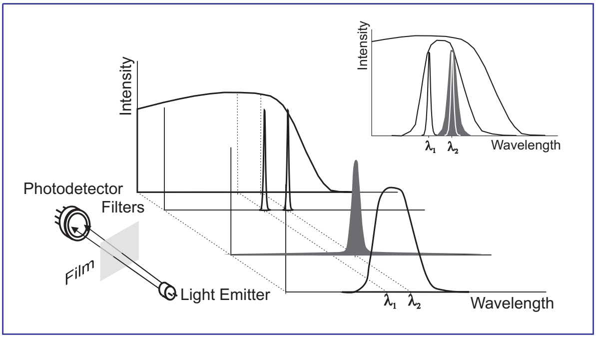


Fig. 2.1. The principle of film thickness measurement realized in DX7000 Plus sensor

channel) serves for control and it's wavelength maximum is placed out from the absorption line.

According to fundamental law, the light absorption in material volume is proportional to concentration of absorbing molecules:

$$I = I_0 \cdot e^{-\alpha C X}$$

where

- I_0 – intensities of light before pass trough material;
- I – intensities of light after pass trough material;
- α – absorption coefficient of the material at the chosen light wavelength;
- C – concentration of absorbing molecules;
- X – film thickness.

At fixed C and known absorption coefficient α, it is possible to calculate the film thickness using measurement of intensity of light (measuring channel) from Light Emitter passed to Photodetector.

Reference channel is used for indirect measuring of initial intensity of light, and allows to eliminate actual ambient conditions (total transparency of material, optics imperfection and so on).

Design Features

The DX7000 Plus Optical Sensor is specially designed for fast response, high sensitivity, low noise and low power consumption.

A number of design features contribute to the performance :

- The infrared source is a special pulsed Light Emitter which operates in microsecond range.
- The light source has long life (> 10000 hours) and assembled with built–in miniature TE coolers for its thermostabilization.
- Radiation from Light Emitter passes through investigating film and is absorbed by dual–element Photodetector.
- Both sensitive elements of the Detector are similar. First one (measuring channel) is covered by miniature narrow band optical filter precisely tuned to absorption line of measured material. Second one also has built–in narrow–band filter, but its wavelength selected out from absorption of the material.
- Both sensitive elements and its filters are placed onto miniature built–in thermoelectric cooler.
- TE coolers of both Light Emitter and Detector are the same. Microcontroller provides temperature regulation with accuracy better than 0.1°C . The

operating temperature is software selectable from ambient down to –15°C.

- All driving functions of Light Emitter and Detector are operated by on–board microcontroller.
- Pre–amplified outputs are processed by the microcontroller. The final result is the digital data of measured film thickness and it is available in real–time through RS–232C port.
- For signal processing the calibrating data of Optical Sensor is used. The data is stored in on–board EEPROM.
- The RS–232C port is also used for remote control from computer.

Operation Overview

The order of measurements with DX7000 Plus device is as follows:

1. Firstly, individual calibration of device is required with using of standard films.

The Photodetectors output signals are non–linear with respect to measuring film thickness. In spite of theoretical formula the intensity of light which passed through material is the integral of various optical rays from Light Emitter. Also sensitivity of Detectors and performance of Light Emitter depend very from its operating temperatures.

Detectors output signals (both measuring U_m and reference U_r channels) are measured to calculate the following D ratio as a function of thickness X of known films from standard set.

Zero ratio $D_0 = f(X=0)$ at zero film thickness is used for polynomial extrapolation of calibration results as:

$$D = \frac{U_m}{U_r}$$

$$Y = \frac{D_0}{D}$$

$$X = A_0 + A_1 \cdot Y + A_2 \cdot Y^2 + A_3 \cdot Y^3 + A_4 \cdot Y^4$$

calculated coefficients $A_0 \ldots A_4$ of polynomial expression and zero ratio D_0 are stored into device internal on–board EEPROM memory.

The first calibration is made by Manufacturer.

The factory standard calibration uses not less than 5 standard films.

Several calibrations as above described are made at different ambient temperatures (in specified operating range) and at corresponding optimal operating temperatures of optocovponents.

Up to 10 such calibrations is possible to store for further application.

Format of calibration data stored in EEPROM memory chip is described below in Chapter 4 “Internal Commands of Sensor”.

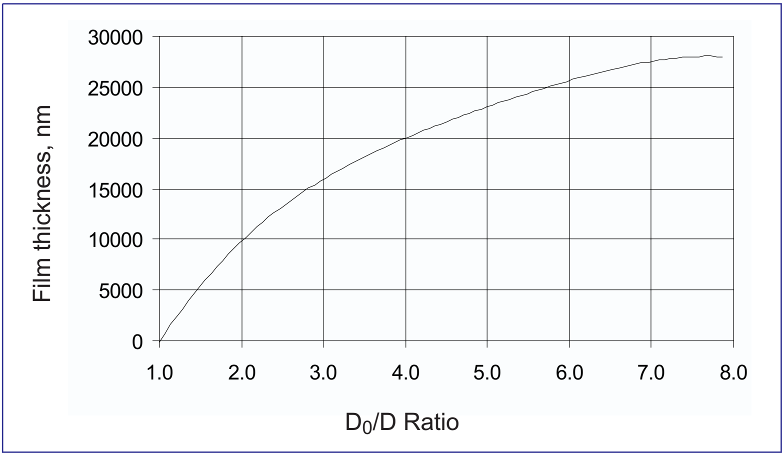
2. During routine operation the detectors output signals are measured to calculate D ratio. Using known “zero” ratio D_0 value Y is calculated.

Finally, using known polynomial coefficients $A_0 \ldots A_4$ the film thickness X is calculated with high accuracy.

Resulted thickness is calculated nm units.

3. To preserve high accuracy of the device it is necessary to do “zero” adjustments periodically as recommended in Chapter 6 of the Manual.

The actual calibration of a typical DX7000 Plus sensor is


30000
25000
20000
15000
10000
5000
0
Film thickness, nm
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
D0/D Ratio

Noise Level

Adjustable noise level is realized due to application of algorithm of digital filtration. The main parameter of a digital filter is a time constant. It is adjustable in a range of 0.05 to 60 s.

If time constant is equal 1, the filtration of a signal is disconnected and instantaneous values of a signal are outputted into telemetry channel. It is the last values, which were measured before issue of telemetry.

Thus it is necessary to remember, that the processes of measurement and of telemetry output are not synchronized, therefore timing is made about accuracy before period of measurements (40…50 μs).

If time constant is equal 0, the algorithm of averaging of measurements on set of values, measured on a time interval equal to period of telemetry output, is used.

Taking into account the note of the previous item, the sample volume at averaging of values can differ on 1 from one period to another.

If time constant it is more 1, the algorithm of the lowpass filter with a pulse transfer function (Z–

$$Y(Z) = \frac{(1 - e^{\frac{-1}{k}}) \cdot Z}{(Z - e^{\frac{-1}{k}})}$$

where k is time constant, is actuated.

An actual characteristics of used signal filtration method is presented at Fig. 2.3.

Effectiveness of the applied algorithm could be described as:

$$N_t = N_0 \cdot t^{-0.65}$$

where

N_t – noise level at applied time constant of filtration,

N_0 – noise level at time constant 1 s,

t – filtering time constant.

The actual effect of noise reduction is presented at Fig. 2.4.

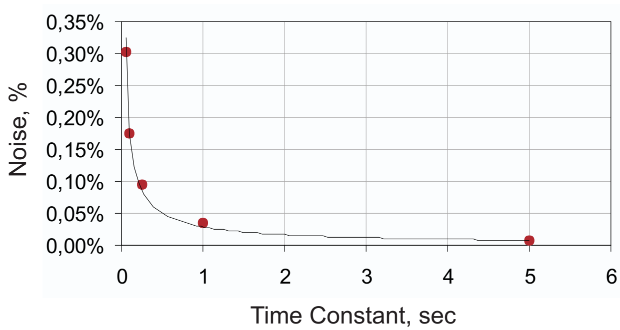


Fig. 2.3. Actual digital filter performance

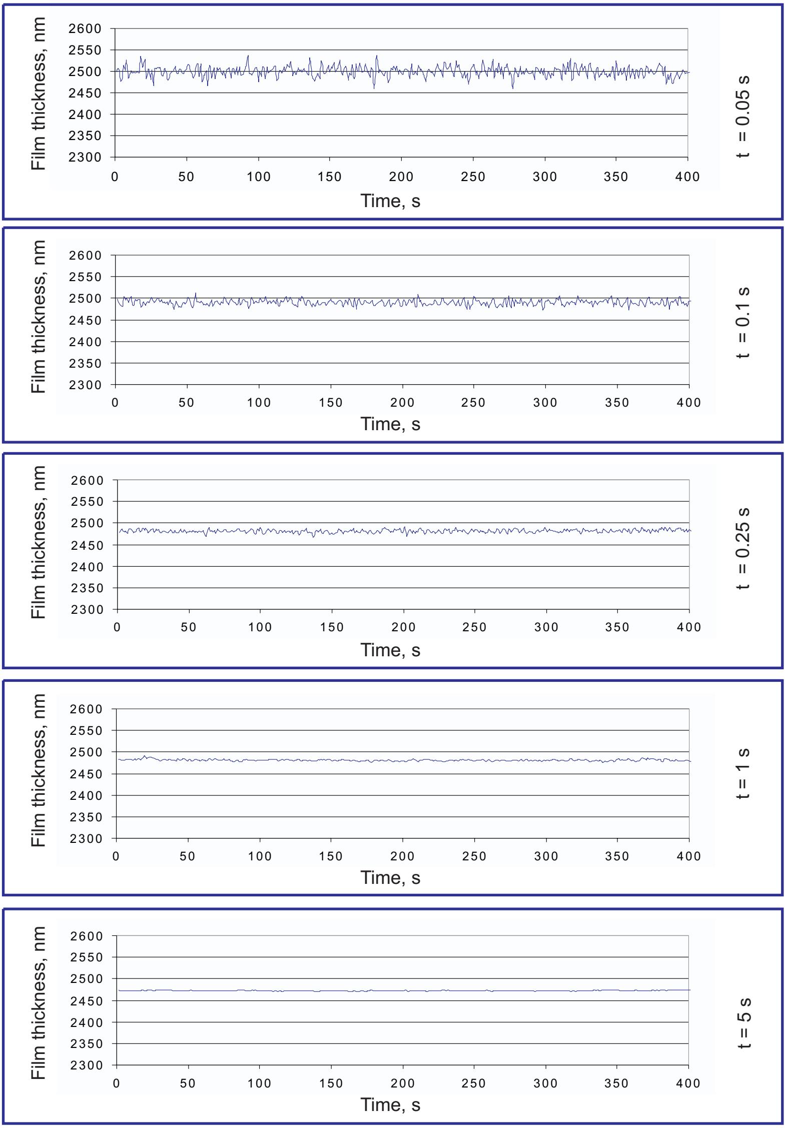


Fig. 2.4. Actual effectiveness of digital filtering algorithm

Speed of Response

The speed of response of Optical Sensor is software selectable from minimal 0.05 second up to 120 second.

Measuring cycle duration is 0.05 seconds.

Depending on speed of response, internal procedure of digital filtering (for noise reduction) with time constant not more than above selected value is available.

At maximal speed of response (0.05 s) the measured data are outputted is without averaging.

3. Hardware

Design Characteristic

The DX7000P Optical Sensor consists of three units:

- DX7010P Detector module (Fig. 3.1),
- DX7011P Emitter module (Fig. 3.2),
- DX7012P Collector module (Fig. 3.3).

The IR detector is mounted onto the DX7010P module and the IR emitter is mounted onto the DX7011P module. The Collector module DX7012P provides a synchronous operation of all parts of Optical Sensor and remote control for PC through the RS−232 port. Apart from it DC/DC converter is placed in a Collector for power supply of all Sensor modules.

All parts are interconnected via four twisted−pair lines of System Interface. Transmission lines of System

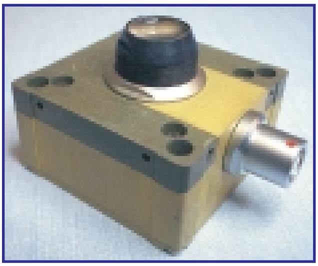


Fig. 3.1. DX7010P Emitter Module exterior

Interface are shown in Fig. 3.4. These lines are the following:

- *RS485+* Noninverting RS−485 interface line,
- *RS485-* Inverting RS−485 interface line,
- *SYNC+* Noninverting synchronization line,
- *SYNC-* Inverting synchronization line,
- *+E* +9 V power supply,
- *GND* Ground,
- *CHASSIS* Chassis of DX7000 Plus equipment.

Fig. 3.2. DX7011P Detector Module exterior

Numbers (Fig. 3.4), placed between connector and signal designators, indicate pin numbers of DHR−15M connectors.

In RS−485 network the DX7012P Collector module is master, while DX7010P and DX7011P are slaves. On the other hand, the master of synchronization line is the DX7010P Detector module. The synchronization frequency corresponds to the repetition rate of the light emitter pulsing.

There is no any difference between the *X1* and *X2* connectors of the DX7012P module. Both the DX7010P and DX7011P modules could be connected to either of them.

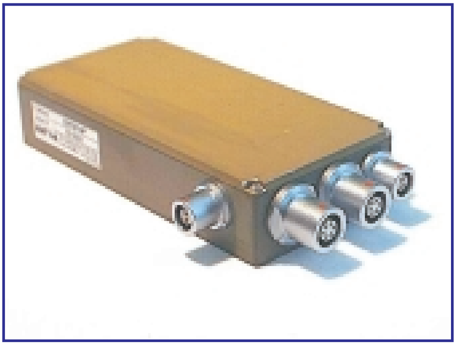


Fig. 3.3. DX7012P module exterior

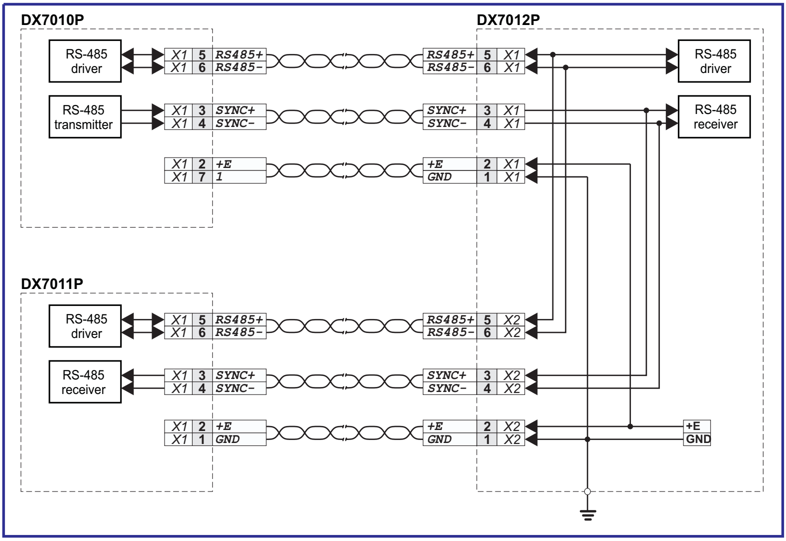


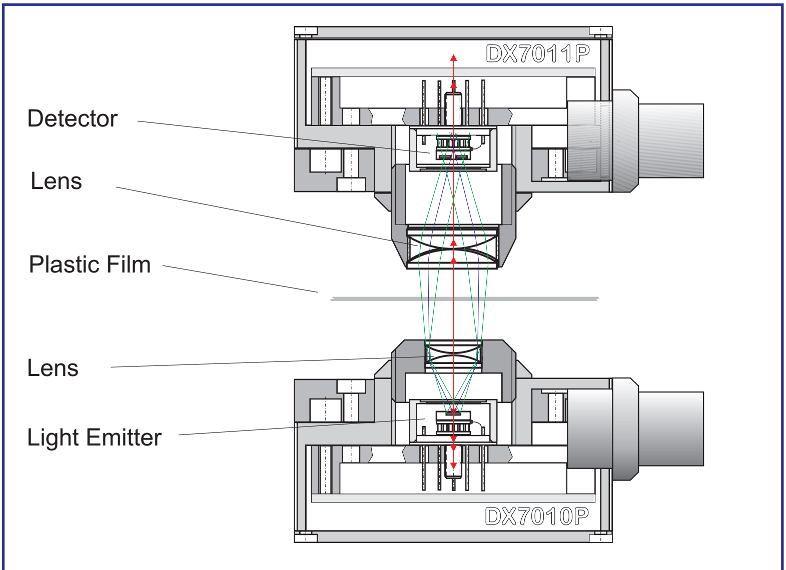
Fig. 3.4. System interface of DX7000 Plus Optical Sensor

Optical–Mechanical Design

Optical schematics of the Sensor is divided into two parts:

Light emitter with lens of Emitter module and dual–element Photodetector with lens system are placed into Detector module.

Light emitter is placed into the focal plane of its lens and Detector is also placed into focal plane of the second lens. So that the optical schematic is insensitive



to slight displacements (± 1 mm) of two modules in XYZ directions (vibrations and so on).

The optical lenses are made of CaF_2. For safety, both lenses may be covered by sapphire windows.

The light emitter and detector are provided by built–in miniature TE coolers. So housings of the both optoelectronic components are mounted onto heat sinks.

Electronics of Optical Sensor

The Optical Sensor consists of Detector Module, Light Emitter Modules and Collector Module.

Structure of the Detector includes 7010–4.0x electronic unit (Fig. 3.6), which provides the following functions:

- thermostabilization of dual–element Detector operation using built–in PID algorithm of regulation of TE coolers with thermosensor,
- power supply of Detector, TE coolers and thermosensor by precise voltage,
- pre–amplification and smoothing of the measuring and reference channels outputs,

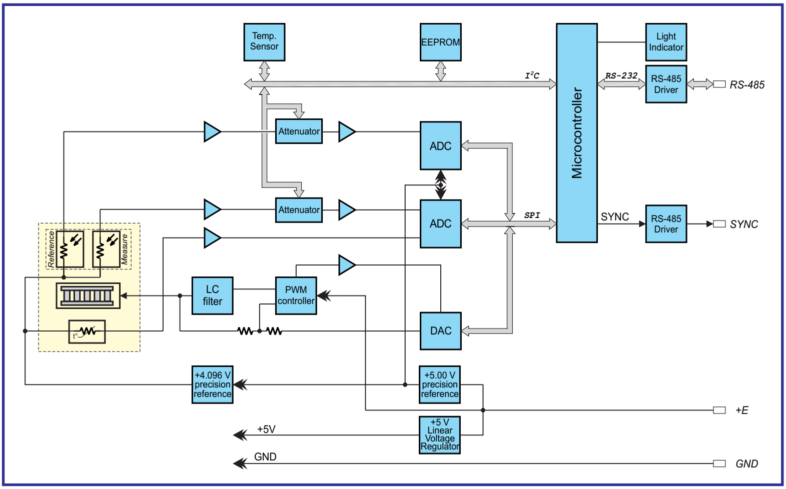


Fig. 3.6. Functional diagram of 7010–4.0x detector unit

- power supply of dual–element Detector and thermistors by precise voltage,
- storage of identifier and individual calibration parameters into on–board EEPROM.

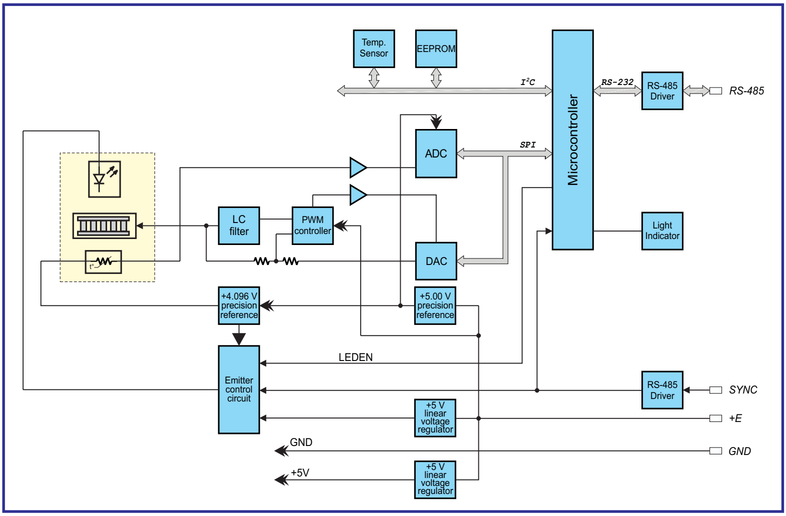


Fig. 3.7. Functional diagram of 7011–4.0x emitter unit

The structure of the Light Emitter includes 7011–4.0x electronic unit (Fig. 3.7), which provides the following functions:

- thermostabilization of light emitter operation using built–in PID algorithm of regulation of TE coolers with the thermosensor,

- power supply of light emitter, TE coolers and thermosensor by precise voltage,
- driving of Light Emitter.

Optoelectronic components (Light Emitter and dual–element Detector) are based on the similar design: similar TO–8 housing; the same built–in miniature thermoelectric (TE) coolers with monitoring thermistors of the equal nominal.

Structure of the Collector Module includes 7014–1.0x electronic unit (Fig. 3.8).

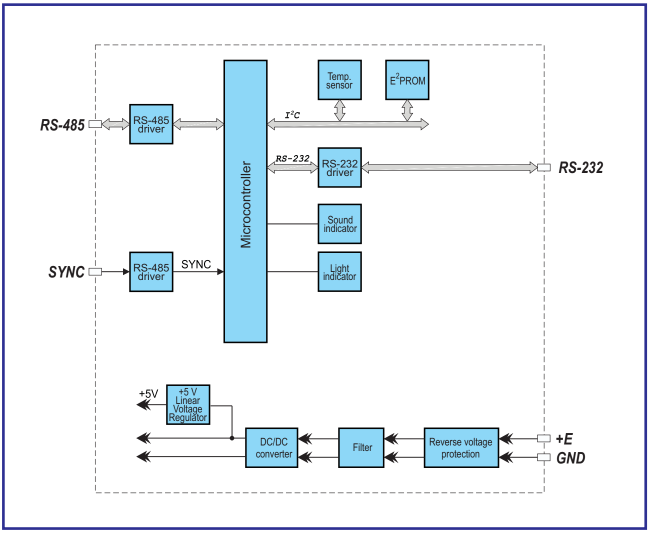


Fig. 3.8. Functional Diagram of 7014–4.0x

The basic functions of 7014−1.0x unit are as follows:

- driving by Emitter and Detector modules through RS−485 interface,
- synchronization of light emitter and detector operation through SYNC lines,
- conversion of amplified output signals values into film thickness with using of the stored calibration data,
- analog output 0...4 V,
- remote control by specialized protocol through RS−232 port,
- light and sound alarms.
- short−circuit protection in the load,
- thermal protection,
- input reverse voltage protection.

Thermistors

For temperature driving by TE coolers, NTC thermistors built into the cold side of TE cooler are used. These thermistors are used in scheme with the serial loading resistor R_L and voltage reference U_{REF}.

Output signal from the thermistor scheme depends on its resistivity, which changes with temperature as :

$$U_{TR} = U_{REF}\left(\frac{R_L}{R_L + R_T}\right)$$

One can see that the accuracy of temperature measurement depends directly on U_{REF}.

In electronic PCBs of Optical Sensor, 4.096 V Precision Voltage Reference is used .

Typical dependence of thermistor's scheme output vs measured temperature is presented in Fig. 3.10.

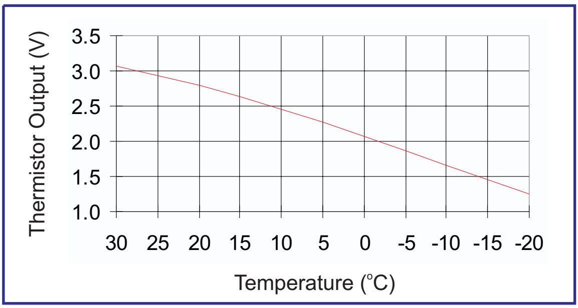


Fig. 3.10. Thermistor's circuit output vs measured temperature

Thermoelectric Coolers

Driving by built–in TE coolers requires particular attention.

First of all, the TE coolers are the components which consume the largest part of power (Fig. 3.11).

Second, the operation of TE coolers directly affect performance parameters of Optical Sensor.

This ratio is approximately 100%/20°C. It is equivalent to temperature drift 1%/0.2°C. It means that if the thermo–stabilization should be with the accuracy of 0.1 deg, then the accuracy of measurements will be 0.5%.

Accuracy of thermostabilization must correspond to the gas concentration measurements sensitivity.

Operating temperature of TE coolers should be selected as optimal: too low temperature stabilization leads to higher power consumption; at higher temperature the output signals (and signal/noise ratio) are lower.

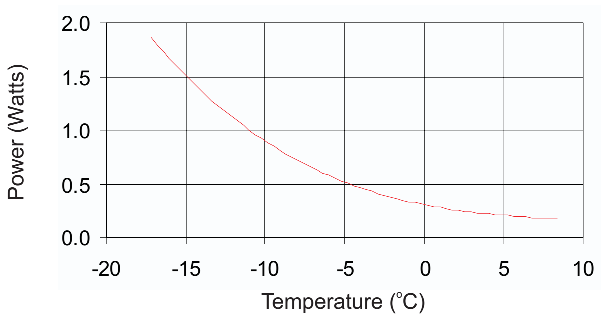


Fig. 3.11. TEC power consumption vs operation temperature

Housing and Dimensions

The electronic modules of the Sensor are encased into the bodies made of a painted aluminum alloy.

The overall dimensions of the DX7000 Plus Sensor parts are shown in Fig. 3.12…3.14.

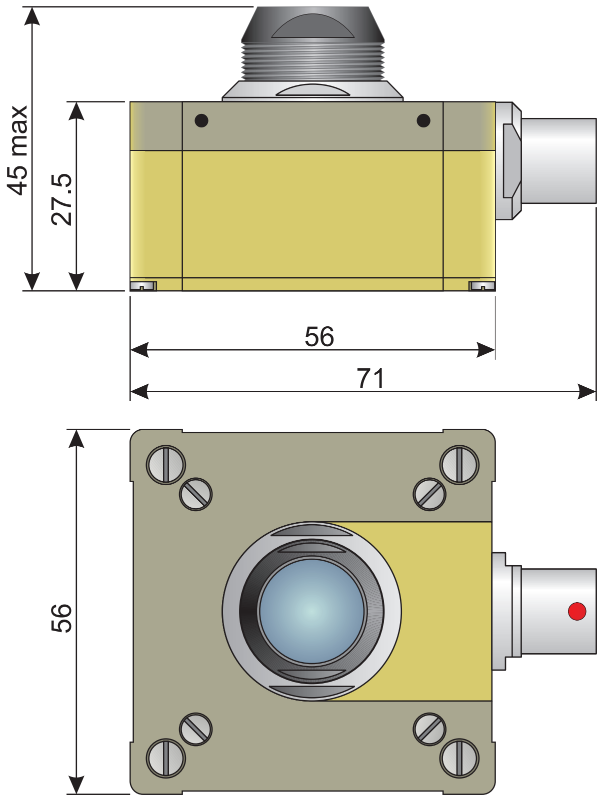


Fig. 3.12. DX7010P Detector module's dimensions (in millimeters)

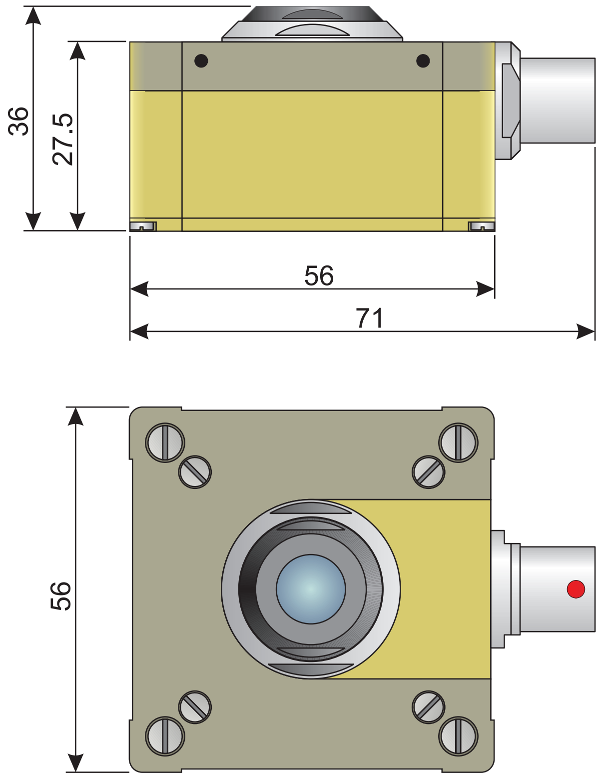


Fig. 3.13. DX7011P Emitter module's dimensions (in millimeters)

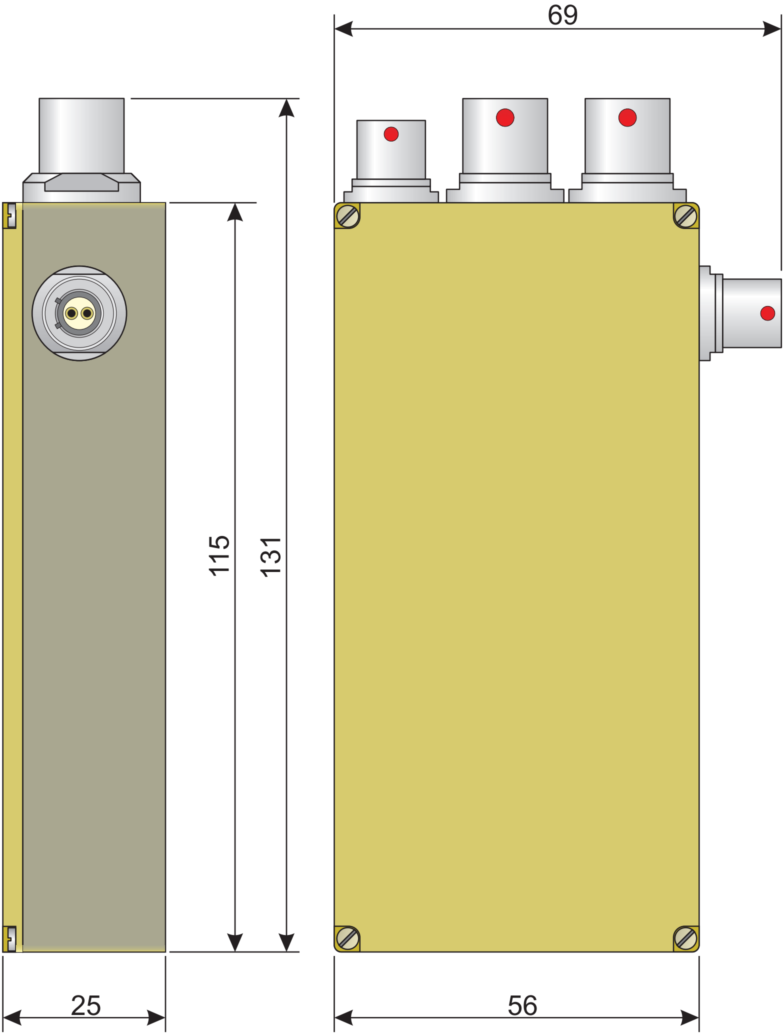


Fig. 3.13. DX7012P Collector module's dimensions (in millimeters)

4. Internal Commands of Sensor

Assignment of Commands

Remote control by Sensor is available using RS–232 port by a set of commands.

They could be divided into two groups:

- driving commands,
- setting commands.

All commands have the same format – the symbol string, which consists of the command name identifier and a list of its parameters. Some commands have no parameters.

The ASCII format is used. All commands must be entered by lower–case letters.

<Space> or <Tab> symbols are used within command string as delimiters.

“Comma” is used to replace a parameter which is not changed during the command execution.

For reduction of parameters or preview of its current status the same commands identifiers are used.

To preview a command preset status only identifier of the command is typed. The command status is returned then.

If the command is typed with a list of parameters, then new parameters substitute preset ones. “Comma” symbol instead of some parameters in the parameter list allows to preserve the earlier preset value.

To transfer any command to Sensor it is necessary to execute the connection protocol. As the result, the Sensor terminates current operation, accepts a new command (or new parameters of the command) and executes the command.

The device which sends the command will be named ***master*** (remote computer, interrogator and so on), Sensor will be named ***slave***.

For simplification of connecting protocol a buffering of input data stream is recommended. The protocol represents the following exchanging order:

master: sends to slave <CR> symbol, and moves into the waiting state;

slave: receives symbol <CR>, returns the string

‘NL' '>',

and holds up current operation and moves to the waiting state – waiting for a command’s input (parameters);

master: if within 5 second it receives any string ending with symbol '>', it sends to the slave the first symbol of the command and moves to the waiting state (waiting for the echo), otherwise it repeats attempts of contact establishing;

slave: receives the next command symbol. If <CR> is received, then transferring of a command is finished, slave executes the received command (during command execution it is possible contacting) and returns the symbol <CR>, (for slave the operation is finished). If the next symbol is received, then slave returns echo and waits for a further command symbol. If during 20 seconds any following command symbol is not received, slave returns the following sequence "error" <CR> and returns to continuation of current command execution (for slave the connection attempt was unsuccessful);

master: receives the echo symbol. If it is <CR>, then it means that the transferred command is received and executed by slave (for master transferring of a command is finished by transferring of <CR>), in input buffer of master the transferred command with list of parameter must be present. If the echo symbol is the earlier transferred command symbol then master transfers the next command symbol and waits for an echo. If during 5 second the echo is not received it means that transferring is unsuccessful.

During operation of Sensor through RS−232 port, the telemetry information is transferring. It could contain both measuring data and any other accompanying information.

Structure and repeating rate of output data could be preset.

The commands can be divided into the following groups:

- the commands for presetting parameters of the Sensor, which allow to do adjustment operations (**hw, sy, em, pr**),
- the commands for preset calibration parameters of Sensor (**fn**),
- the commands for dynamical parameters preset, which establish the volume and repeating rate of telemetry and some parameters of statistic data treatments (**jb**, **di**, **ur**),
- the commands which allow to start and stop measurements (**gc**, **go**, **gt**, **pw**, **rt**, **st**, **ws**, **ze**).

The most commands from the first group being issued with incorrect parameters may occur partial or even full loss of Sensor's working efficiency. Only experienced persons can use these commands for parameters editing.

Therefore, three of four commands from the first group are password protected.

In the Table below the specifications of commands are presented.

Command's mnemonics	Description
`di` <*Outcont*>	Control the structure of output telemetry
`{em, pr}*)` <*T*> <*Kp*> <*Ki*> <*Kd*> <*Devt*>	Change parameters of **em** or **pr** block (parameters of digital thermostabilization)
`fn` <*Num*> <*Tc*> <*Kt*> <*Tenv*> <*Rang*> <d_0> <A_0> <A_1> <A_2> … <A_7>	View/edit calibration tables
`gc` <*Num*>	Start of calibration Mode
`go` <*Num*>	Start of Measuring Mode
`gt`	Start of Test Mode
`hw` <*Km*> <*Kr*> <*Smf*> <*Nz*>	View/edit the table of preset parameters of hardware
`id` <*Uc*> <*Text*>	View/edit identifier of an unit
`jb` <*Trep*> <*Nrep*> <*Kab*> <*Kan*> <*Delay*>	View/edit parameters of measuring cycle)
`rt`	Restart the sensor
`pw` <*password*>	Password entering
`st`	Stop any operation mode
`sy*)` <*Dtl*> <*Dta*> <*Tclk*> <*Cclk*> <*Lclk*> <*Ssum*> <*Fsum*>	View/edit parameters of hardware synchronization
`ur` <*Br*>	Data rate preset for RS-232 channel
`ws` <*Sc*> <*Sp*> <*Se*>	Reading status of the sensor
`ze`	Correction of zero of the sensor

***) password protected**

Commands of the Sensor

The descriptions of the DX7000 Plus sensor commands are given below in alphabetical order.

DI command

<u>Format:</u>

di *<Outcont>*

This command controls the structure of the output telemetry.

The *Outcont* parameter is entered and displayed in a HEX format. The output of each parameter of telemetry is enabled/disabled (1/0) by the appropriate bit of the *Outcont* parameter.

If *Outcont* is omitted, the current value of parameter will be displayed.

<u>Format of *Outcont* parameter</u>

Bit	Bit position	Mnemonic	Description	Format	Units
B_0 0	15 0	Usign	The output signal of measuring channel	word	ADC units
B_0 1	15 0	Uref	The output signal of reference channel	word	ADC units
B_0 2	15 0	Tpr	The temperature of the photodetector	word	ADC units

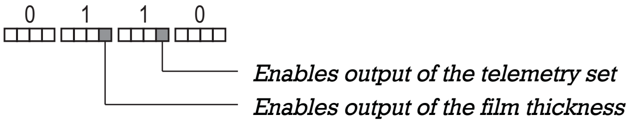
Format of `Outcont` parameter (continued)

Bit	Bit position	Mnemonic	Description	Format	Units
B_{03}		Tem	The temperature of the light emitter	word	ADC units
B_{04}		R	In the **Measurement** mode: the film thickness. In **Calibration** or **Test** modes: the averaged ratio of signals from measuring and reference channels multiplied by factor 10000	float	nm
B_{05}		Tenv	The internal temperature of the	word	°K×10
B_{06}		Num	The measurement number in a current	long	
B_{07}		Cst	The Collector module status (*see* **ws** *command description*)		
B_{08}		Tel	Telemetry output enable (any)		
B_{09}			*Unused*		
B_{10}		Snd	The sound alarm enable		
B_{11}		Dbg	Enables **Debug** mode. If enabled, the telemetry is outputted irrespective of a TECs conditions		
B_{12}		Tipr	The internal temperature of the Detector	word	°K×10
B_{13}		Tiem	The internal temperature of the Emitter	word	°K×10
B_{14}		Upr	The Detector cooler controlling voltage	word	DAC units
B_{15}		Uem	The Emitter cooler controlling voltage	word	DAC units

DI

Example:

> **di** 110<Enter>



EM, PR command
(password protected)

Format:

em *<T> <Kp> <Ki> <Kd> <Devt>*

or

pr *<T> <Kp> <Ki> <Kd> <Devt>*

View/edit parameters of digital temperature regulators.

The **em** and **pr** are identifiers of the Light Emitter and Photodetector TE coolers respectively.

List of parameters

Parameter	Description	Units	Format	Range
T	In the **Calibration** mode:	mV×10	word	[0…40950]
	In the **Test** mode:	DAC units	word	[0…4095]
Kp	Factor of a proportional part of the		float	[10…0]
Ki	Factor of an integral part of the digital		float	[10…0]
Kd	Factor of a differential part of the digital		float	[1000…0]
Devt	Maximum permissible deviation from		byte	[10…50]

EM

Example

```
> pr<Enter>
16000 1.0000E+00 1.0000E-02 0.0000E+00 20
```

16000 – the operating temperature of TE cooler of Photodetector (**pr**),

1.0000E+00 – the factor of a proportional part of the digital temperature regulator,

1.0000E-02 – the factor of an integral part of the digital temperature regulator,

0.0000E+00 – the factor of a differential part of the digital temperature regulator,

20 – the maximum permissible deviation from preassigned temperature.

FN command

Format:

fn *<Num>* *<Tc>* *<Kt>* *<Tenv>* *<Rang>* <d_0>
<A_0> <A > <A_1> … <A > 2 7

View/edit calibration tables.

Each table contains 10 lines. The reference to a particular line is present in each line of temperature ranges table.

Format of calibration table

Parameter	Description	Units	Format	Range
Num	The number of calibration table		byte	[0…9]
Tc	The operating temperature of TE	ADC units×10	word	[0…40950]
Kt	The thermal compensation coefficient			
Tenv	The ambient temperature, at which	°K×10	word	
Rang	The polynomial's order plus 1		byte	[2…7]
d_0	The "zero " Usign/Uref ratio		float	
A_0	The constant term of a polynomial		float	
A_1	Factor at the member of the 1st order		float	
…	…		…	
A_7	Factor at the member of the 7th order		float	

FN

Example

```
> fn0 16000 0.000001 2930 4 1.1<Enter>
> fn0 ,,,,,,0.95,2.1 1 0<Enter>
```

0	– calibrations table line #0
16000	– the opersting temperature of TE coolers
0.000001	– thermal compensation coefficient,
2930	– the ambient temperature is equal to 293°K (+20°C),
4	– the order of the approximating polynomial is equal to 3 (4 – 1),
1.1	– the “zero” ratio is equal to 1.1,
0.95	– the constant term of the polynomial,
2.1	– the factor at the member of the 1st order,
1	– the factor at the member of the 2nd order,
0	– the factor at the member of the 3rd order.

Note

The command is entered by two lines. It is because an available string length is 79 symbols, but parameters of the command require more string length.

GC command

Format:

gc *<Num>*

Start in the **Calibration** mode.

Num designates the calibration table line (temperature range) [0…9], for which the calibration is executed.

Example

> **gc**<Enter>

– start in the **Calibration** mode. The line 0 of temperature ranges table is in use.

GO command

Format:

go <*Num*>

Start in the **Measurement** mode.

Num designates the calibration table line (temperature range) [0...9].

If *Num* is omitted, the sensor automatically determines temperature range.

If the indicated line is filled with incorrect data or if the sensor operates in the automatic mode and can not select suitable range, the *Error* diagnostics is given.

Example

> **go**<Enter>

– start in the **Measurement** mode with automatically selected temperature range.

GT command

Format:

gt

Start in the **Test** mode.

Example

```
> gt<Enter>
```

– start in the Test mode.

HW command

Format:

hw *<Km>* *<Kr>* *<Smf>* *<Nz>*

View/edit the table of preset parameters of hardware.

List of parameters

Parameter	Description	Format	Range
Km	The gain of a channel of a measuring signal	byte	[0…255]
Kr	The gain of a channel of a reference signal	byte	[0…255]
Smf	The smoothing factor of the digital filter for statistical	word	[0…65535]
Nz	Number of a cycles of measurements for statistics accumulation on a **ze** command	word	[0…65535]

Example

```
> hw 200 120 10 100 <Enter>
```

200	– the gain of a channel of a measuring signal processing is equal to 200,
120	– the gain of a channel of a reference signal processing is equal to 120,
10	– the smoothing factor of the digital filter for statistical data processing is equal to 10,
100	– the number of cycles of measurements is equal to 100.

ID command

Format:

id *<Uc> <Text>*

View/edit identifiers of an Optical sensor units.

List of parameters

Parameter	Description	Format	Range
Uc		byte	[0…2]
Text		ASCII	up to 63 char.

Uc values list

Uc	What is displayed
0	The Collector module. The field can be edited
1	The Detector module. The field can be edited
2	The Emitter module. The field can be edited
omitted	The software revision #. Fixed field, cannot be edited

Example

```
> id<Enter>
> DX7X00 Ver. 4.00
```

– software version DX7x00 – 4.00.

JB command

Format:

jb *<Trep> <Nrep> <Kab> <Kan> <Delay>*

View/edit parameters of **JB** block.

List of parameters

Parameter	Description	Units	Format	Range
Trep		[sec·0.01]	word	[0…65535]
Nrep	Total number of measurement cycles. If "0" is set, then default continues operation is realized.		word	[5…65535]
Kab	Factor of the correction on concentration		float	[0.01…100]
Kan	Factor of normalization of an analog signal. If *Kan* = 0, analog output is disabled		float	
Delay	Delay time before auto-start. If *Delay* = 0, then auto-start is disabled	[sec·0.01]	word	[0…65535]

Example

```
> jb 100 1000 0.5 0.1 0<Enter>
```

100	– the repeating rate of telemetry data output is equal to 1 sec (0.01×100),
1000	– the total number of measurement cycles is equal to 1000,
0.5	– the factor of the correction on concentration of an absorbent in a material is equal to 0.5,
0.1	– the factor of normalization of an analog signal is equal to 0.1,
0	– auto−start is disabled.

PW command

Format:

pw *<password>*

Password entering.

Permits access to the following set of hardware tuning commands:

em, pr
hw
sy

Example

```
> pw abCDefgH<Enter> OK
```

– the hardware presetting commands are available now. (If abCDefgH is a valid password).

```
> pw abCDeFGH<Enter> Error
```

– the invalid password is entered.

RT command

Format:

rt

Restart the sensor.

The command initiates the same sequence of actions as during the startup procedure after sensor's power up.

Example

```
> rt<Enter>
```

– the sensor operation is terminated and the startup procedure is initiated.

ST command

Format:

st

The command stops any operation mode.

Example

> **st**<Enter>

– the sensor is stopped

SY command
(password protected)

Format:

```
sy <Dtl> <Dta> <Tclk> <Cclk> <Lclk>
  <Ssum> <Fsum>
```

View/edit parameters.

List of parameters

Parameter	Description	Units	Range
Dtl	Pulse duration of light emitter	μs	[1…100]
Dta	Delay between light emitter pulse fall and output	μs	[0…100]
Tclk	The main synchronization clock period	μs	[3000…5000]
Cclk	Divider of the main synchronization clock period for LED indicator of Detector module. Recommended value is 1,000,000/*Tclk*		[1…20]
Lclk	Divider of the main synchronization clock period for		[1…4]
Ssum	Sample size for the first level averaging digital filter when using averaging digital filter at the second level of filtration		[1…50]
Fsum	Sample size for the first level averaging digital filter when using low pass digital filter at the second level of filtration		[1…50]

SY

Example

sy 50 5 5000 2 10 20

50	– the pulse duration of light emitter is equal to 50 μs
5	– the delay between light emitter pulse fall and output signals sampling start is equal to 5 μs
5000	– the main synchronization clock period is equal to 5000 μs
2	– clock period for LED indicator is equal to 0.5 sec (2 Hz)
10	– the sample size for the first level averaging digital filter when using averaging digital filter at the second level of filtration is equal to 10 readouts
20	– the sample size for the first level averaging digital filter when using low pass digital filter at the second level of filtration is equal to 20 readouts

UR command

Format:

ur *
*

View/edit preset for RS—232 channel transmission baud rate.

List of parameters

Parameter	Baud rate	Value
Br	0	9600 Baud
	1	19200 Baud
	2	38400 Baud
	3	57600 Baud

The new parameters inure only after sensor's power ON or after* RT *command.

Example

> **ur**0<Enter>

0 – the baud rate is equal to 9600.

WS command

Format:

ws *<Sc>* *<Sp>* *<Se>*

Reading status of the sensor.

The command returns three bytes of current status. The first byte is Collector status, the second and the third are Photodetector and Emitter statuses, respectively.

List of parameters

<table>
<tr><th>Parameter</th><th>Description</th></tr>
<tr><td>Sc</td><td>
<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="2">The system status</td><td colspan="2">Unused</td><td colspan="4">The number of the temperature range</td></tr>
</table>

<u>The system status</u> <u>field format:</u>
Bits
7 6
□□ The system is OFF
□■ TE coolers are out of normal operation
■□ The system is stable, but TE coolers are near its maximum operating current
■■ Everything is OK
</td></tr>
</table>

List of parameters (continued)

Parameter	Description
Sp *Se*	see below

7	6	5	4	3	2	1	0
Summary status	TEC status			*Unused*		The operating mode	

The opereting mode field format:

Bits 1 0	
□□	The module is OFF
□■	The module is in **Test** mode
■□	The module is in **Measuring** mode
■■	*Unused*

TEC status field format:

Bits 6 4	
□□□	The TEC is OFF
□□■	The TEC is out normal operation
□■□	The TEC is OK
□■■	*Unused*
■□□	It is too hot, the TEC is out of normal operation
■□■	It is too cold, the TEC is out of normal operation
■■□	It is hot, TEC's temperature is stable, but TE cooler is near its maximum operating currentt
■■■	It is cold, TEC's temperature is stable, but TE cooler is near its minimum operating current

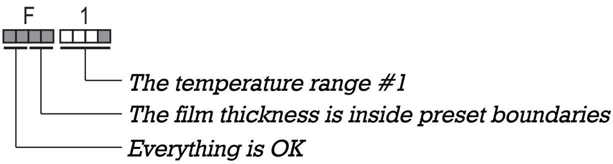
The summary status field format:

Bits 7	
□	The module is not ready
■	The module is OK

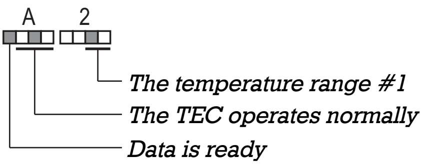
Example:

```
> ws<Enter>
> F1  A2  A2
```

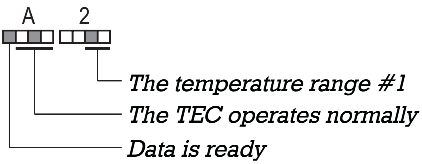
F1 – the Collector status:



A2 – the Photodetector status:



A2 – the Emitter status:



F1 A2 A2 – the Sensor is in normal

ZE command

Format:

ze

Correction of zero of the sensor.

The command will be accepted, if the sensor is in a **Measurement** mode. Otherwise the command will be rejected and the message ERROR given.

After obtaining a command the sensor terminates a telemetry output on time necessary for the statistics collecting for an evaluation of value of parameter D_0. After completion of accumulation of statistics the measured value of D_0 is recorded into the appropriate line of calibration table according to the selected operational temperature range. The statistics accumulation is made by summation *Nz* of smoothed measurements.

Example

`> ze<Enter>`

– correction of zero of the sensor.

Format of Output Telemetry

The telemetry information is outputted as a sequence of numbers, separated by the <Space> symbol. The numbers are in ASCII format.

The sequence is enclosed by curly brackets (“{” and “}”), begins from the <CR> symbol and is closed by the <LF> symbol.

Format of numbers and measurement units are indicated in the table on the next page.

The structure of the outputted telemetry information is determined by DI command.

The order of parameters’ arrangement in a line of the telemetry information is the following:

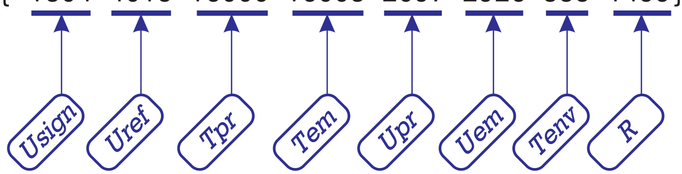
{ <Num> <Usign> <Uref> <Tpr> <Tem> <Upr> <Uem> <Tenv> <Tipr> <Tiem> <Sc> <R> }

Any of the parameters is present at a line only in the event that its output is allowed by the appropriate bit of parameters of **`di`** command.

Mnemonic	Description	Format	Units
Num	The measurement number in a current session	long	
Usign	The output signal of measuring channel	word	ADC units
Uref	The output signal of reference channel	word	ADC units
Tpr	The temperature of the photodetector	word	ADC units
Tem	The temperature of the light emitter	word	ADC units
Upr	The Detector cooler controlling voltage	word	DAC units
Uem	The Emitter cooler controlling voltage	word	DAC units
Tenv	The internal temperature of the Collector module	word	°K×10
Tipr	The internal temperature of the Detector module	word	°K×10
Tiem	The internal temperature of the Emitter module	word	°K×10
Sc	The Collector status	byte	
R	The measuring film thickness	word	nm

Example:

```
>di CB3F
>go
{ 1702 3899 16000 16001 2098 2930 335 1540}
{ 1682 3866 16000 16001 2097 2929 335 1545}
{ 1700 3898 16000 16001 2097 2929 335 1541}
{ 1784 3990 16000 15999 2097 2928 335 1506}
{ 1804 4015 16000 16003 2097 2926 335 1499}
```



EEPROM Data Format

Various operating parameters are stored in on–board EEPROM circuit:

- calibration data,
- synchronization parameters,
- measuring mode presets,
- TE cooling algorithm presets,
- Optical Unit identification.

The EEPROM usage structure is placed in Table 4.1.

The formats of the First Calibration Data Block is given in Table 4.2.

Formats of another reserved (if applied) Calibration Data Blocks are the same as the first one.

Table 4.1. EEPROM Data Structure

Item	Address (hex)	Content	Command
1	0x0040	Block of synchronization parameters	sy
2	0x0080	Block of hardware preset parameters	hw
3	0x00C0	Parameters of thermostabilization of Detector	em
4	0x0100	Parameters of thermostabilization of Light Emitter	pr
5	0x0140	Optical Unit Identifier	id
6	0x0180	Block of parameters of measuring cycle	jb
7	0x01C0	Block of transmission baud rate parameters	ur
8	0x0200	Telemetry structure control block	di
9	0x0240	Calibration data block (first calibration data)	fn 0
10	0x0280	Calibration data block	fn 1
11	0x02C0	Calibration data block	fn 2
	...	...	...

Table 4.2. Format of the First Calibration Data Block

Item	Address (hex)	Content	Name	Format
1	0000	TE coolers Operating Temperature	*Tc*	int16
2	0002	Thermal compensation coefficient	*Kt*	float
3	0006	Ambient Temperature of Calibration	*Tenv*	int16
4	0008	Polynomial's order	*Rang*	int8
5	0009	"Zero" Value	d_0	float
6	0013	Polynomial Coefficient A_0	A_0	float
7	0017	Polynomial Coefficient A_1	A_1	float
8	001B	Polynomial Coefficient A_2	A_2	float
		...		

Errors handling

After power up, during the startup procedure, the Collector module verifies the check sums of every data block located in the modules' EEPROMs.

Also the collector checks the presence of Detector and Emitter modules on the interface line.

If some EEPROM data block contains corrupted data or any module does not responses to the Collectors request, the Collector sends an error message to the RS−232 line and stops the Sensor.

The error number is represented by 24 bits code combination where each position corresponds to Table 4.3.

The error message is displayed by 6 digits in HEX format preceded by the "Error" prefix.

Example

```
>Error000005
```

– check sum error in **sy** parameters block,

– there is no response from the Detector module.

```
>Error100000
```

– attempt to change password−protected data.

Table 4.3. Error codes list

Bit	Bit position	Description
0	23 15 7 0	No connection with Detector Module
1	23 15 7 0	No connection with Emitter Module
2	23 15 7 0	Check sum error in **sy** parameters block
3	23 15 7 0	Check sum error in **hw** parameters block
4	23 15 7 0	Check sum error in **em** parameters block
5	23 15 7 0	Check sum error in **pr** parameters block
6	23 15 7 0	Check sum error in **id0** parameters block
7	23 15 7 0	Check sum error in **jb** parameters block
8	23 15 7 0	Check sum error in **ur** parameters block
9	23 15 7 0	Check sum error in **di** parameters block
10	23 15 7 0	Check sum error in **fn0** parameters block
11	23 15 7 0	Check sum error in **fn1** parameters block
12	23 15 7 0	Check sum error in **fn2** parameters block
13	23 15 7 0	Check sum error in **fn3** parameters block
14	23 15 7 0	Check sum error in **fn4** parameters block
15	23 15 7 0	Check sum error in **fn5** parameters block
16	23 15 7 0	Check sum error in **fn6** parameters block
17	23 15 7 0	Check sum error in **fn7** parameters block
18	23 15 7 0	Check sum error in **fn8** parameters block
19	23 15 7 0	Check sum error in **fn9** parameters block
20	23 15 7 0	Attempt to change password protected data
21	23 15 7 0	*Reserved*
22	23 15 7 0	*Reserved*
23	23 15 7 0	*Reserved*

5. Working with DX7000 Plus Sensor

The Sensor is controlled with an Intel class computer. It can be done by two ways.

The first way is based on the use of any communication program. Thus the analyzer is controlled with the help of special commands entered manually via the keyboard.

The second way is based on using the **DX7000 Vision** software. The **DX7000 Vision** software provides all possible operational modes of the DX7000 Plus Sensor. The **DX7000 Vision** has a simple interface and does not demand a User's special knowledge.

The **DX7000 Vision** software is delivered with the DX7000 Plus Sensor.

The following consideration involves Sensor control based on using the **DX7000 Vision** software.

To run the **DX7000 Vision** software, your system must meet or exceed the following hardware and software requirements:

- Intel Pentium class computer with Windows 95/98/2000 operating system
- Free COM port
- 16 MB of RAM (32 MB recommended)

- 6 MB free hard drive space
- CD ROM drive
- Mouse or compatible pointing device

The use of **DX7000 Vision** software does not demand a user's wide experience. And on the contrary, the manual method of sensor operating control requires a careful study of sensor's commands set.

This way can be recommended only for experienced users.

But if nevertheless you want to use this way of sensor controlling you must be acquainted with some standard communication programs, such as the Hyper Terminal for Windows OS (for example). You must also be able to perform some simple tunings of communication program.

Be guided by Chapter 4 of this Manual when controlling the sensor manually.

Irrespective of a method of sensor control it is necessary at first to do some hardware preparations.

Hardware Preparation

Three modules (DX7010P, DX7011P, DX7014P) must be connected one with another (Fig. 5.1).

The side surfaces of the modules are presented in Fig. 5.2…5.4.

At the side surface of the Collector module there are the following items:

- connector of RS–232 interface,
- system interface connector #1,
- system interface connector #2,
- power source connector (24V DC).

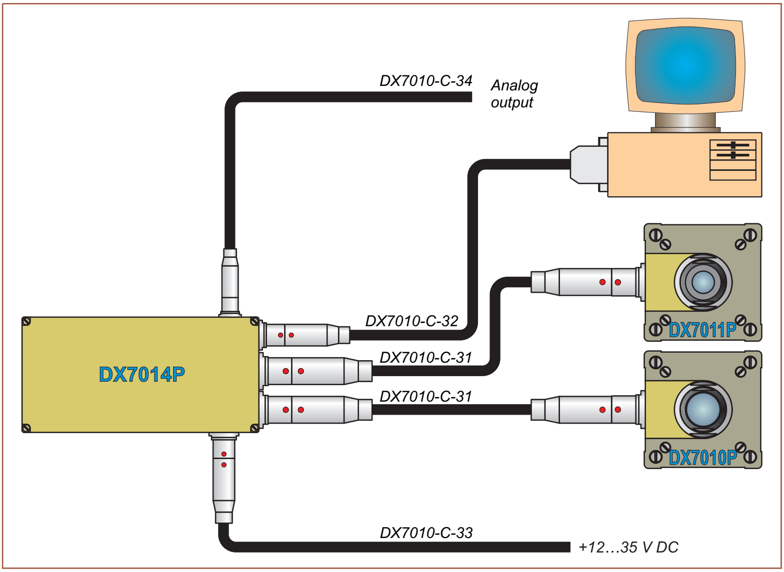


Fig. 5.1. DX7000 Plus system components interconnections.

On–board driver of RS–232 interface forms signals of standard levels, in accordance with specifications of IA/TIA–232E and V.28. The Interface is used for connecting with a remote computer or interrogator module.

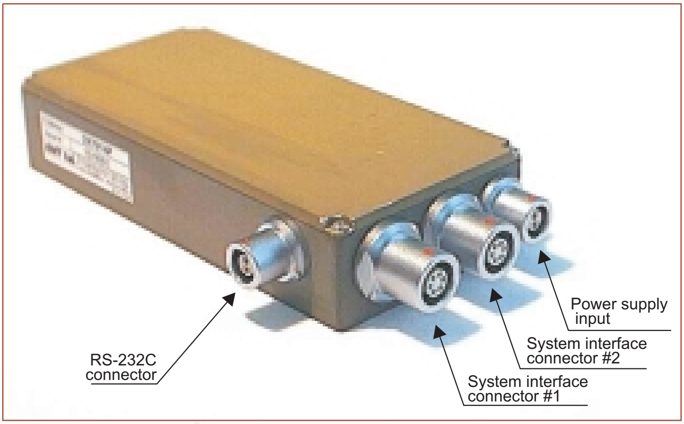


Fig. 5.2. Side view of DX7014P module.

At the side surfaces of the Detector and Emitter modules there are similar system interface connectors.

For measurements of thin TOTAL films the Detector and Emitter modules must be placed face to face (Fig. 5.5).

The optimal distance between lens systems of both modules is 10 mm. Displacement between axises ±1 mm (max).

There is no difference between System interfaces connectors #1 and #2 of DX7014P module. Both

DX7010P and DX7011P modules may be connected to anyone.

Any external DC Power Supply is suitable: voltage range is +12...+35 V (+24 V nominal), min current is 300 mA. There are no special requirements for the DC current stability.

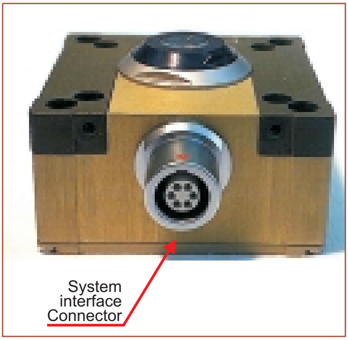


Fig. 5.3. Side view of DX7010P module.

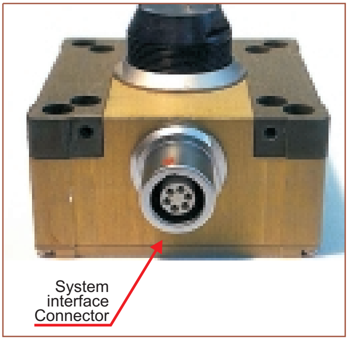


Fig. 5.4. Side view of DX7011P module.

In case of the reverse polarity of power supply the sensor is provided with a built–in protection.

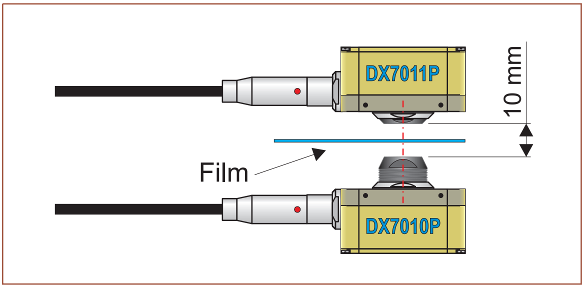


Fig. 5.5. Detector and Emitter modules mounting

Program Installation

The **DX7000 Vision** software is supplied on CD.

Insert a CD into the appropriate drive and start the Setup program.

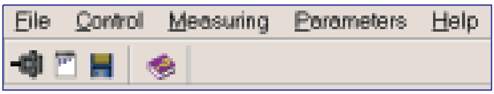
Pass all steps of the installation procedure sequentially according to the directions of the installer.

When selecting the logic disk you must keep in mind that the program requires not less than 6 Mb of hard disk space.

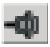
Connecting to Device

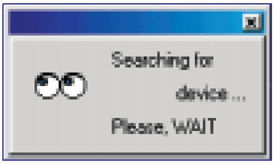
Run the DX7000.exe program by clicking on the program name in Microsoft Explorer window, for example, or on the appropriate icon created on the desktop by DX7000 Installer program.

The program menu and the tool bar of DX7000 program window have the following view originally:



The status bar placed at the bottom of **DX7000 Vision** window indicates the "Disconnected" condition:

Select «Control >> Connect» from the program menu or click on the  button on the tool bar. The next window will be displayed while the program searching for connected device:



There are two situations at the end of auto–detecting procedure:

- The sensor was found. The next message appears:

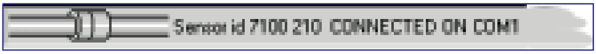
- The sensor was not found. The next warning message appears:

Please, check the device attached to the communi–cation port. Perhaps when **DX7000 Vision** is started but another program from DX7000 Software Group (such as

Calibration or Zero Adjustments) is already running. Close that program and try connecting again.

If the device was found successfully by the program the tool bar extended as shown

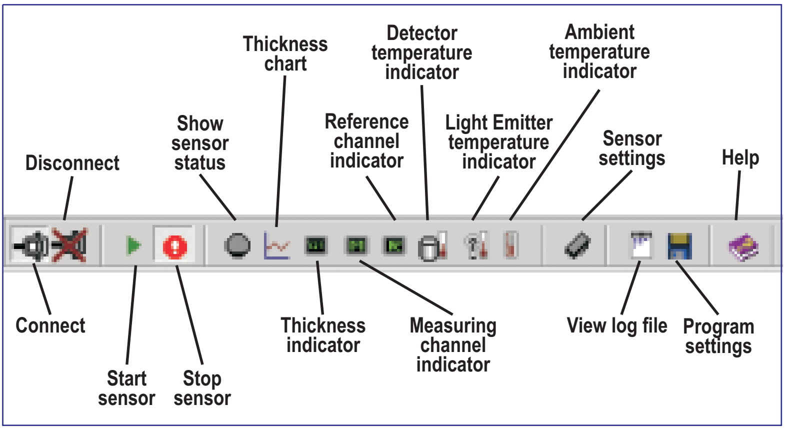
and the status bar changed to



after successful establishing of the connection.

Tool Bar Description

The assignment of all tool bar buttons is shown in the following figure:

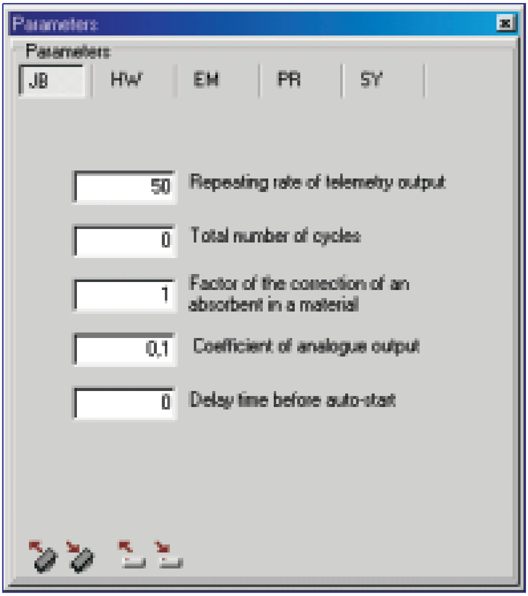


All tool bar buttons duplicate the menu commands. (This means you can select «Control >> Connect» or simply click on the  button of the tool bar).

Sensor Settings

The sensor hardware parameters can be configured with the **DX7000 Vision**. Please, read this Manual carefully before deciding to do a new parameters adjustment. Click on the  button on the program tool bar or select «Parameters >> Edit» to open the Parameters window. It contains five pages:

- **<JB>** page. Parameters for Measuring Cycle
- **<HW>** page. Parameters for Measuring Channel Synchronization.
- **<EM>** page. Parameters of digital temperature regulators for Light Emitter.
- **<PR>** page. Parameters of digital temperature regulators for Detector.
- **<SY>** page. Parameters of synchronization of



Select parameters page you want to edit by clicking on its name from the page switcher. Every time you switching the parameters page sensor parameters are loaded from the sensor. You can read parameters in every sensor mode.

There are four buttons at the bottom of parameters window:

 Read parameters from the sensor.

 Write new parameters to the sensor.

 Read backup parameters from the file.

 Write parameters into the backup file.

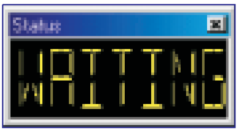
Parameters can be saved in a special file of ***.ini** type for backup later if needed.

To write new parameters into the sensor you shold stop it. Then fill in parameters fields you need and click on the button. Warning message will be shown if the sensor is NOT stopped.

Sensor Control

The sensor is ***stopped*** after the connection has been established. To set **Measuring** mode click on the tool bar button or select «Control >> Start sensor» from the program menu.

Device status indicator will be changed to



while the sensor preparing for measurements and changed again to

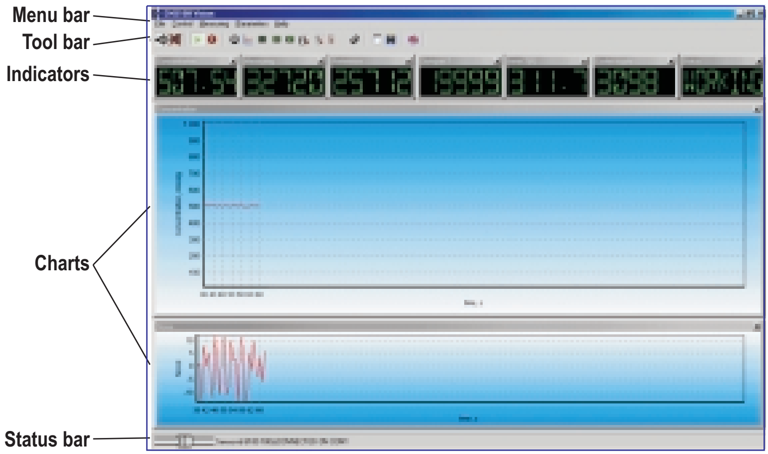
when the measuring cycle begins.

The preparation procedure consists of the following:

- according to the ambient temperature the optimal calibration data block is retrieved.
- the thermostabilization algorithm is started; time required for cooling down and transient process of stabilization is approximately 60 s.
- after that the measuring cycle is turned on and the results outputting is started through RS−232 port.

Status *WAITING* will be shown all the time while the preparation procedure is being carried out..

DX7000 Vision Window



There are the following items within the Main window of **DX7000 Vision**:

- Menu bar
- Tool bar
- Indication windows
- Charts
- Status bar

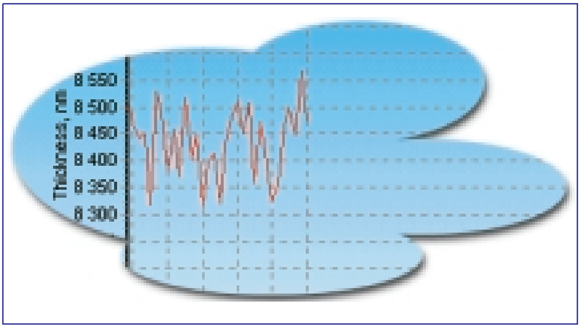
Charts

Four charts in **DX7000 Vision** are available:

- The main chart (thickness measurement)
- Noise chart
- Total chart
- Logging chart

Main Chart (Thickness Output)

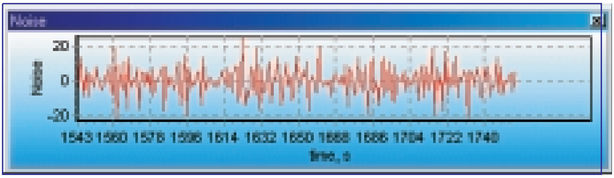
Click on  on the toolbar or select «Measuring >> Thickness >> Chart» from the program menu to open the main chart window.



The main chart shows a film thickness value in real time. It can contain up to 250 thickness readouts. After that the main chart will be cleared and will start from the beginning.

Noise Chart

Click the right mouse button on the main chart (thickness output) and select «View Noise» from the popup menu to open the **Noise Chart** window.



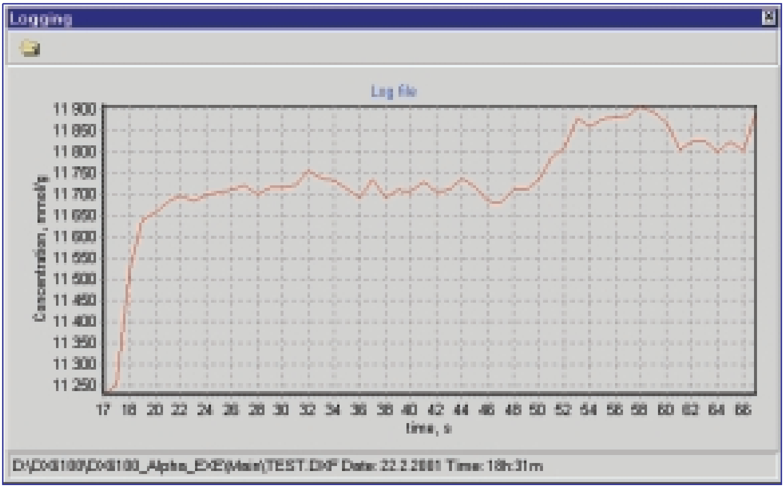
Total Chart

Click right the mouse button on the Main chart (thickness output) and select «View Total» from the popup menu to open the **Total Chart** window.

The **Total Chart** shows film thickness in real time. It can contain up to 5000 points of thickness readouts. After that **Total Chart** will be cleared and started from the beginning.

Logging Chart

Click on the button on the toolbar or select «File >> Open log» from the program menu to open the logging chart window. The logging chart window will be opened.



Click on the button in the top left corner of Logging window. The «Select file» dialog will be started. The chosen DX7000 Vision log file (***.dxf** file extension) will be represented in the graphic form in the Logging window.

Charts Settings

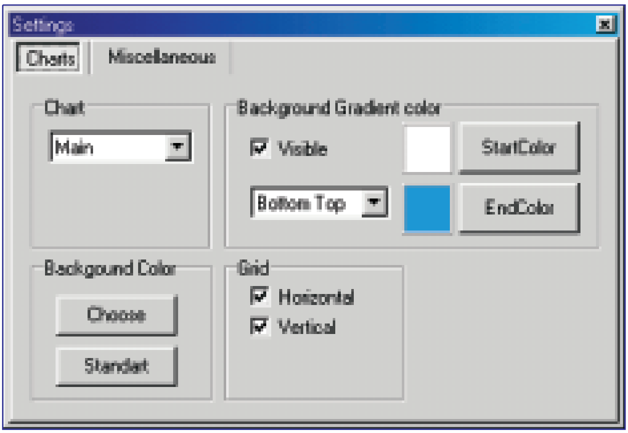
Select «File >> Settings» from the program menu to open settings window. It consists of two pages: Chart and Miscellaneous. The program chart parameters can be adjusted on the Chart page. The Miscellaneous page is used for reserving log filename setting and floating panels alignment.

Chart Page

Select a chart you want to make settings by pressing on the chart dropdown list 

. The main chart is selected default. The following parameters can be adjusted:

- Chart background color.
- Chart background gradient colors and direction
- Chart grids (vertical and horizontal)



Setting Background Color

Click on the Choose button. The color selecting dialog will be opened. Select a color you like and press «OK» to set a new chart background color. The selected color will be automatically saved and loaded every time you start the **DX7000 Vision**. The standard Windows color (light–gray usually) can be easily adjusted by clicking on the Standart button.

Setting Gradient Background Colors

Specify gradient start and end colors using StartColor and EndColor buttons. Every time you press one of those buttons the color selecting dialog will be opened. Select a color you like and press «OK». Now specify gradient direction by clicking on the gradient direction dropdown list From Center . Click on the Visible to enable (or disable) gradient background for selected chart. Gradient preferences will be automatically saved and loaded every time you start the **DX7000 Vision**.

Setting Grid Preferences

Set vertical and horizontal grid enabling/disabling by clicking on 

check boxes. Selected preferences will be automatically saved and loaded every time you start the **DX7000 Vision**.

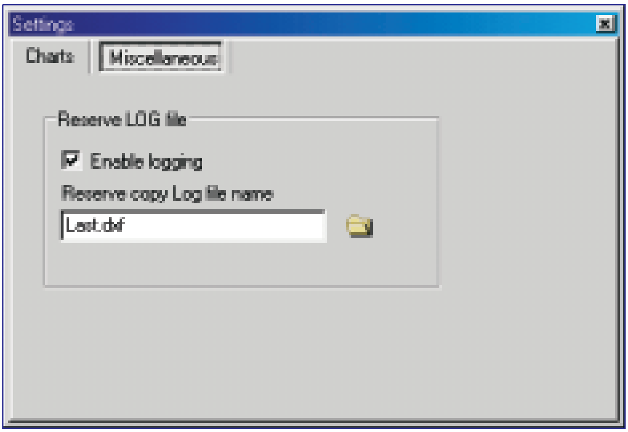
> ***Warning!***
>
> ***All chart preferences saved in *.INI files are placed in the program install directory. Do not delete or edit them manually.***

Miscellaneous Page

Set logging enable/disable by clicking on the 

check box of Miscellaneous page. Specify the name of the reserve log file in the Name field 

.



Please, enter a name manually or automatically using the  button. The reserve log file is created every time (if logging enabled) the sensor operates in **Measuring** mode. The «Save log file» dialog will be opened when the sensor is stopped or the program is closed. Save the current log with another name choosing «Save» in the «Save file» dialog. Or select «Cancel». In this case the reserve log file will be held until next time the sensor is set to measuring mode in the **DX7000 Vision**.

Floating Windows

The **DX7000 Vision** is based on the floating panels interface. Feel free while moving, resizing and opening/closing program panels (charts, indicators and etc). All you preferences (panels sizes, position, state on/off) will be automatically saved and loaded every time you start the **DX7000 Vision**. Alignment to invisible grid is available in the program for each panel to make moving more accurately. Click on the 

check box to enable/disable alignment. Of course it will be saved and loaded every time you start the **DX7000 Vision**.

Warning!

All panel preferences saved in *.INI files are placed in the program installation directory. Do not delete or edit them manually.

Indicators

There are seven indication windows used for the measured data and main sensor operating parameters representation in digital form:

- Thickness
- Measuring channel signal
- Reference channel signal
- Temperature of Light Emitter
- Temperature of Detector
- Inner temperature
- Sensor status

Thickness Indicator

Click on the button on the program tool bar or select «Measuring >> Thickness >> Indicator» to open the thickness indicator.

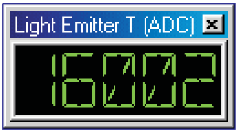
Measuring Channel Signal Indicator

Click on the button on the program tool bar or select «Measuring >> Detector signals>> Measuring channel» from the program menu to open the measuring channel signal indicator. It shows a measuring channel signal value in ADC units.

Reference Channel Signal Indicator

Click on the button on the program tool bar or select «Measuring >> Detector signals>> Reference channel» from the program menu to open the reference channel signal indicator. It shows a reference channel signal value in ADC units.

Light Emitter Temperature Indicator



Click on the button on the program tool bar or select «Measuring >> Temperature >> Light Emitter» from the program menu to open the Light Emitter temperature indicator. It shows the Light Emitter temperature in ADC units.

Detector Temperature Indicator

Click on the button on the program tool bar or select «Measuring >> Temperature >> Detector» from the program menu to open the Detector temperature indicator. It shows the Detector temperature in ADC units.

Inner Temperature Indicator

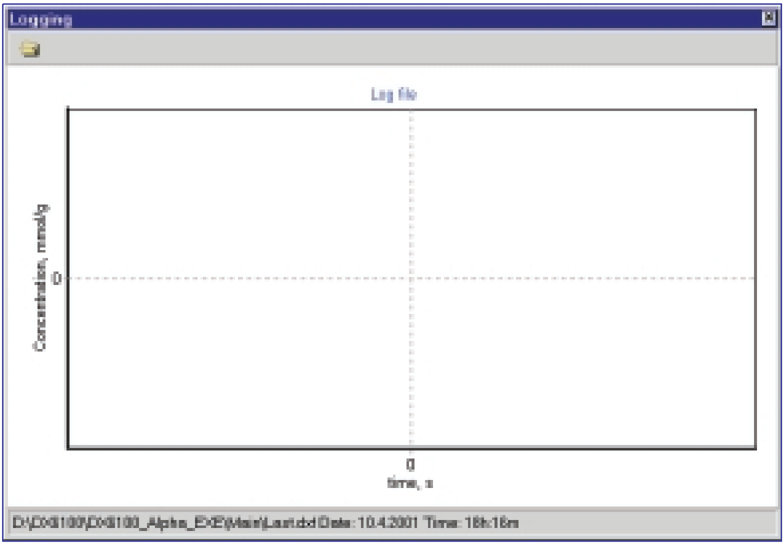
Click on the button on the program tool bar or select «Measuring >> Misc >> Inner» from the program menu to open the inner temperature indicator. It shows the inner temperature in °C.

Sensor Status Indicator

Click on the button on the program tool bar to open the sensor status indicator. It indicates one of three states: *STOPPED*, *WAITING* and *WORKING* depending on the device status.

Log File Viewing

Select «File >> Open log» from the program menu or click on the button on the tool bar. Log file viewing window will be opened.



Click on the button and select a log file. Click on the «Open» button. The selected log file will be loaded into the chart. Each log file contains a header with useful information and film thickness telemetry. File information is placed at the bottom of the logging window.

6. Calibration

Preparation

First of all a User must prepare the set of calibration films of known thickness.

The number of calibration films should be at least two more than the desirable polynomial order (See Chapter 2). In turn the order of a polynomial determines the accuracy of approximation, and hence the measurement accuracy.

The following close to optimum set of calibration films can be recommended (in percentages to upper thickness of measurement range):

Extended Kit	Standard Kit
0	0
1	1
5	5
10	10
15	–
30	–
50	50
65	–
100	100

Any other sets of standard samples a User can apply according to one's reasons. But be sure that the samples are within specified measurement range and the customer standard films provide an accurate calibration.

Now the Analyzer and appropriate software should be prepared:

1. Connect the DX7000 Plus sensor to a computer using the RS−232 cable.
2. Connect Power supply to the Sensor.
3. Run the DX7000 Vision program.
4. Run the Calibration routine.

All the other steps of the calibration procedure must be performed under the guidance of Calibration routine from the **DX7000 Vision** software programs set.

DX7000 Calibration Window

The DX7000 Calibration window looks as shown in Fig. 6.1.

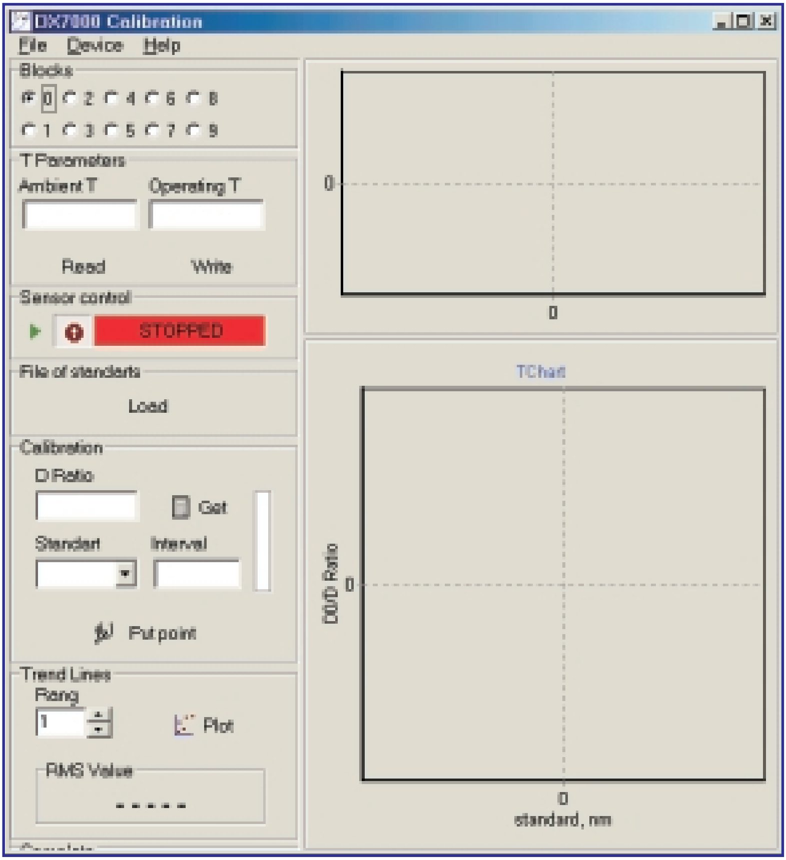


Fig. 6.1. The DX7000 Calibration window

Sequence of Actions

1. Connect to the sensor.
2. Select the calibration block.
3. Select temperature parameters.
4. Set the sensor to the **Calibration** mode.
5. Choose the file of standards.
6. Add points to the calibration chart.
7. Plot the trend line.
8. Write the result to the sensor.

Connection

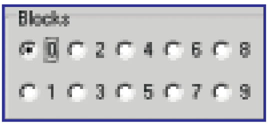
Connection to the sensor is established automatically after starting zero adjustments program. Be sure that no other program fromthe **DX7000 Vision** group is opened (there can be a conflict about using one communication port by multiple programs). The following message will be displayed after the successful connection:

If an error occurred while connecting to device, the following message will be shown:

In this case check if the sensor is connected to the communication port and turned on. Select "Device >> Connect" from the program menu. If all preparations are correct connection will be established.

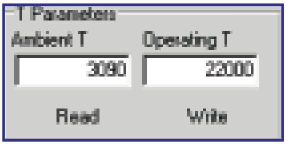
Selecting Block

Select the calibration block to set a new zero by clicking on the blocks group. The calibration block with number 0 is selected by default and temperature parameters of the selected block are displayed in the T Parameters section.



Temperature Parameters

Ambient and Operating temperatures are displayed in T Parameters section. These are temperature parameters of the selected calibration block. Click on the Read button to read parameters and the Write button to send new temperature parameters to the sensor. The sensor must be stopped for writing parameters.



File of Standards

The file of standards contains the standard values of film thickness. It's a simple text file including thickness values placed in a column with ETF extension. Use the standard Windows notepad to create it. The file of standards is useful for entering thickness values for a new point.

Select "File >> Standards >> Load" or press

the button from File of Standards section to load file. Standards combobox will be filled with values after loading.

Adding New Point

Put the calibration film into the measuring gap of the sensor. Click on the  button to start the sensor in the **Calibration** mode. Please, wait until the 

status displayed on the sensor status panel. The new status 

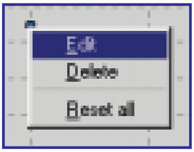
will be displayed when sensor begins to measure. The top Chart area will start to fill with measured values. Wait until the top chart values become stable and click on the  button to calculate a current signal value. Wait until the current signal is calculated and placed into the D Ratio Editbox.

Now set a standard thickness value (or simply select it from the Standard combobox if the file of standards loaded) and enter confidence interval in the Interval editbox (1% of the standard thickness value is set automatically after standard thickness input). Click on the 

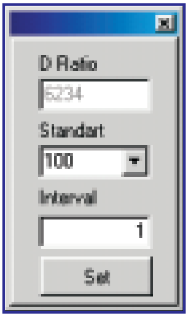
button to add a new point in the calibration chart.

Editing Points

Click the right mouse button on the entered point in the calibration chart. The popup menu will be displayed:



Choose Edit from the menu items to edit the selected point. The following window will be displayed:



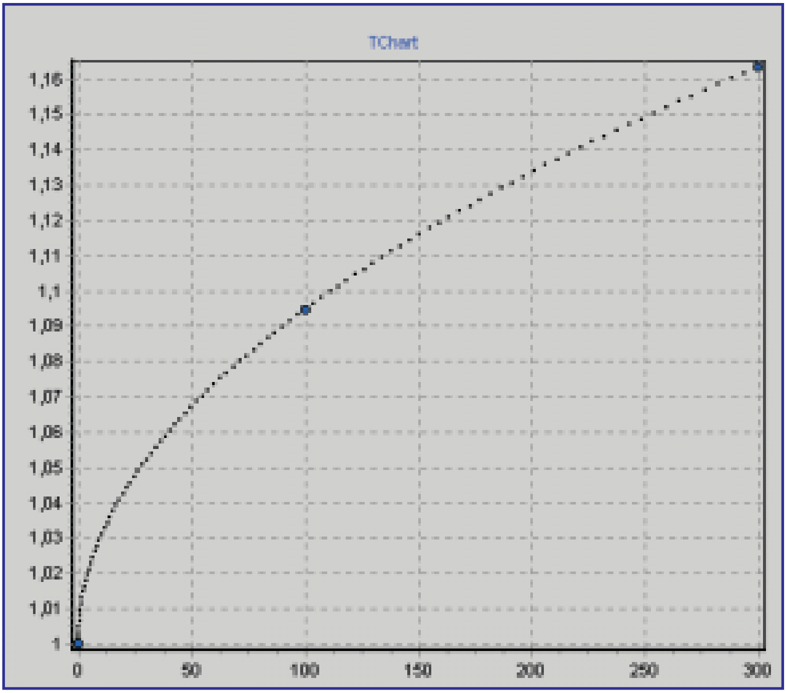
D Ratio is not changeable. Only the standard thickness value and confidence interval can be changed. Also there Delete and Reset all items in the popup menu. Choose Delete to delete the selected point and Reset all to delete all points on the calibration chart.

Plotting Trend Lines

Select a polynomial rank from the Rang editbox 

using up/down arrows. Then click on the 

button to plot a trend line on the calibration chart.



The RMS value will be displayed in Trend Line section

Writing Result

Sensor must be stopped to write the calculated result. Click on the  button to send the result to the sensor.

Zero Adjustments

To ensure a high accuracy, a simple adjustment can be made to adjust “zero” ratio D_0.

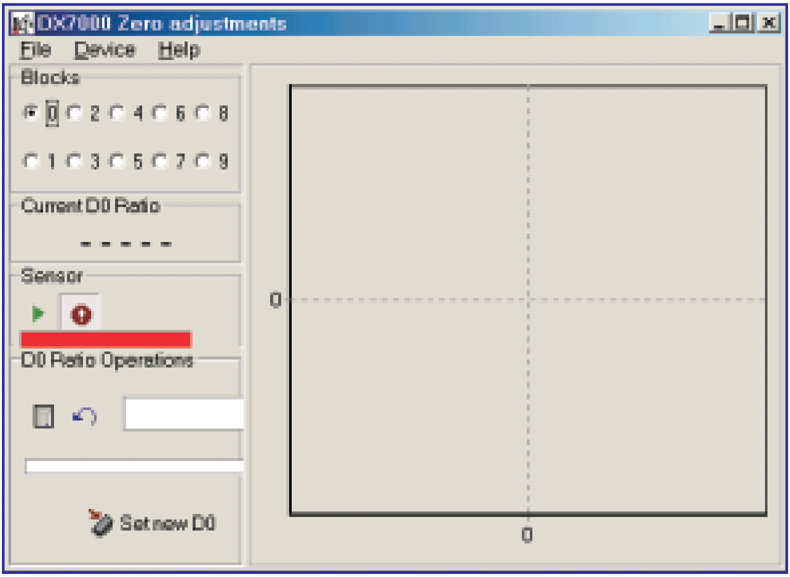
The zero parameter D_0 should be periodically set. The procedure requires to start the Sensor in the **Calibration** mode with no film in the measuring gap.

After the telemetry data output (D_0) will be started and the value of D_0 becomes stable, the D_0 data can be fixed.

A new D_0 coefficient will be stored in E^2PROM instead of old one.

DX7000 Plus Zero Adjustments

To adjust the Sensor zero one should use the `zeroadj.exe` program from the DX7000 Vision program set.



Connection

Connection to the sensor is established automatically after starting the zero adjustments program. Be sure that no other program from the **DX7000 Vision** group is opened. (There can be a conflict about using one communication port by multiple programs). The following message will be displayed after the successful connection:

If an error occurred while connecting to the device, the following message will be shown:

In this case check if the Sensor is connected to the communication port and turned on, and select "Device >> Connect" from the program menu. If all preparations are correct, the connection will be established.

Selecting block

Select the calibration block to set a new zero by clicking on the blocks group. The calibration block with number 0 is selected by default and temperature parameters of the selected block are displayed in the T Parameters section.

Click on the button to start the sensor in the **Calibration** mode. Please, wait until the WAITING status is displayed on the sensor status panel. A new status will be displayed when the Sensor begins to measure MEASURING . The chart area will start to fill with measured values. Wait until the chart value becomes stable and click on the button to calculate a current zero value. Wait until the zero parameter is calculated. A new zero parameter will be displayed in the edit box. The last zero parameter can be backuped by pressing button.

Click on the Set new D0 button to send a new zero parameter to the Ssensor.

Re–Calibration

In the standard option, the DX7000 Plus Sensor is delivered with one calibration data set. The calibration is made at optimal operating temperature.

A User can make re–calibration at any time. It is possible to do this at other operation temperatures, with larger set of reference films higher order polynomial) and to replace the stored data set by a new one.

According to customer’s demands the re–calibration could be done by a manufacturer at request.

On–board memory has additionally 9 data blocks for more calibrations – totally up to 10 different calibrations.

The polynomial coefficients A_j depend on the design of the Sensor’s optical scheme. It is not necessary to make re–calibration often.

Recommended re–calibration period is 1 year.

7. Standard Kit

#	Item	Code	Quan.
1	Detector module	DX7010P	1
2	Emitter module	DX7011P	1
3	Collector module	DX7012P	1
4	System interface cable	DX7010-C-31	2
5	RS-232 cable	DX7010-C-33/9	1
6	Power supply cable	DX7010-C-32	1
7	DX7000 Plus User Manual		1
8	DX7000 Vision software CD		1

8. Specifications

Type	NDIR sensor with open path
Detector	Lead selenide with TE cooler
Measured Material	TOTAL or EVOH film thickness

Detector

	TOTAL	EVOH
Measured channel	3.60 μm	2.85 μm
Reference channel	4.00 μm	2.63 μm

Parameters

	TOTAL	EVOH
Film thickness	0 ... 50 μm	0 ... 40 μm
Repeatability	0.5 %	0.25 %
Accuracy [1)]	0.5 μm	0.5 %

Sampling distance

10 mm

Timing	
Speed of response [2)]	0.01 s
Alarms	
Light	Two color LED
Sound	> 85 dB
Supply requirements	
Supply voltage	+12 to +35 V DC
Maximum supply power	4.0 W
Nominal supply power	2.5 W
Interfaces	
Digital	RS−232C
Analog	0…4.095 V
Operation conditions	
Temperature range	0° to 50°C
Relative humidity	0 to 95%

Mechanical

Emitter module dimensions	56 × 71 × 45 mm
Detector module dimensions	56 × 71 × 36 mm
Collector module dimensions	131 × 69 × 25 mm
Emitter module weight	220 g
Detector module weight	210 g
Collector module weight	250 g

1) *At Averaging Time Constant = 0.2 second. Features of signal processing – see Chapter "Noise Level".*

2) *Software Adjustable*

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