LMI Selcom
MEASUREMENT & CONTROL

finger kg

User's Manual

SLS 5000

SLS 6000

SLS 2400

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1 INTRODUCTION

This manual is a description of the Selcom Laser Sensor (SLS) family, SLS 5000 and SLS 6000. **The sensors have laser classification 2 or 3B**. Read chapter 3 Safety Requirements before connecting the sensor. For specific sensor configurations such as wide spot, see Appendix I.

This sensor is intended for use in applications where distance, thickness or level is to be measured. The ambient temperature surrounding the sensor should be 0°C to 50°C but the temperature of the measured object may vary from deep frozen to +1600°C. The sensor is equipped with a temperature guard that shuts the laser off should the surrounding temperature exceed the limits. The sensor is not intended for measurement on objects hotter than +1600°C.

No changes or modifications may be made to the sensor or its cable unless you have a written permission from LMI Selcom. If the sensor is opened or modified without permission, warranty is voided.

For your own safety, follow the instructions in this manual.

If you get problems when using the SLS sensor, contact your local LMI Selcom office or your local distributor.

The delivery of a SLS 5000 sensor contains:

- SLS 5000 sensor
- Isolation washers 8 pcs
- Users manual 1 pcs

The delivery of a SLS 6000 sensor contains:

- SLS 6000 sensor
- Isolation washers 4 pcs
- Users manual 1 pcs

2 TECHNICAL DESCRIPTION

2.1 Identification of parts SLS 5000

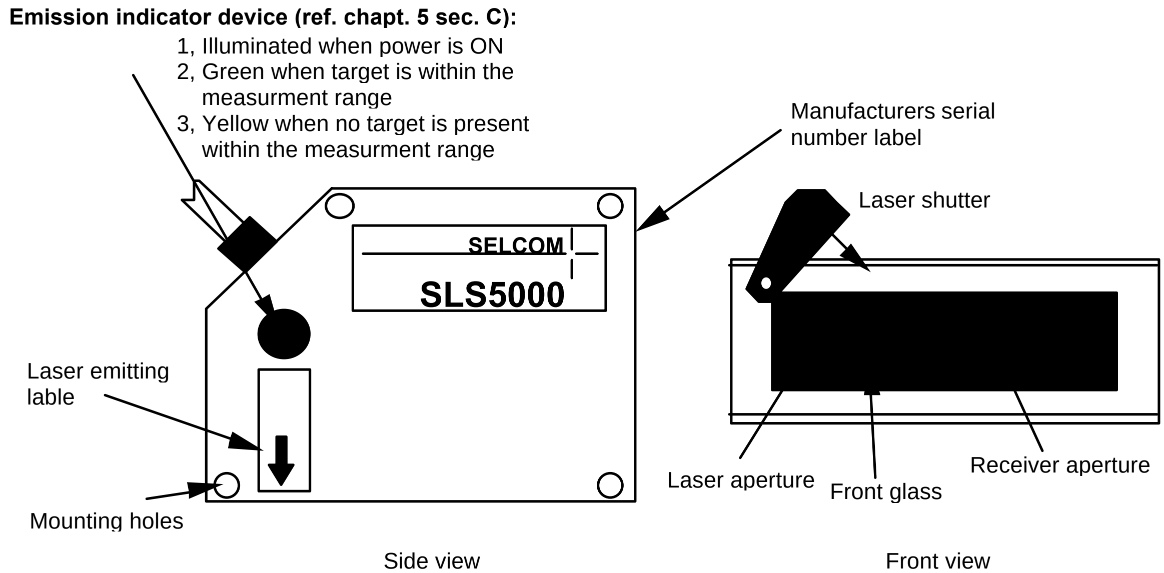


Figure 1: Identification of parts SLS 5000

2.2 Identification of parts SLS 6000

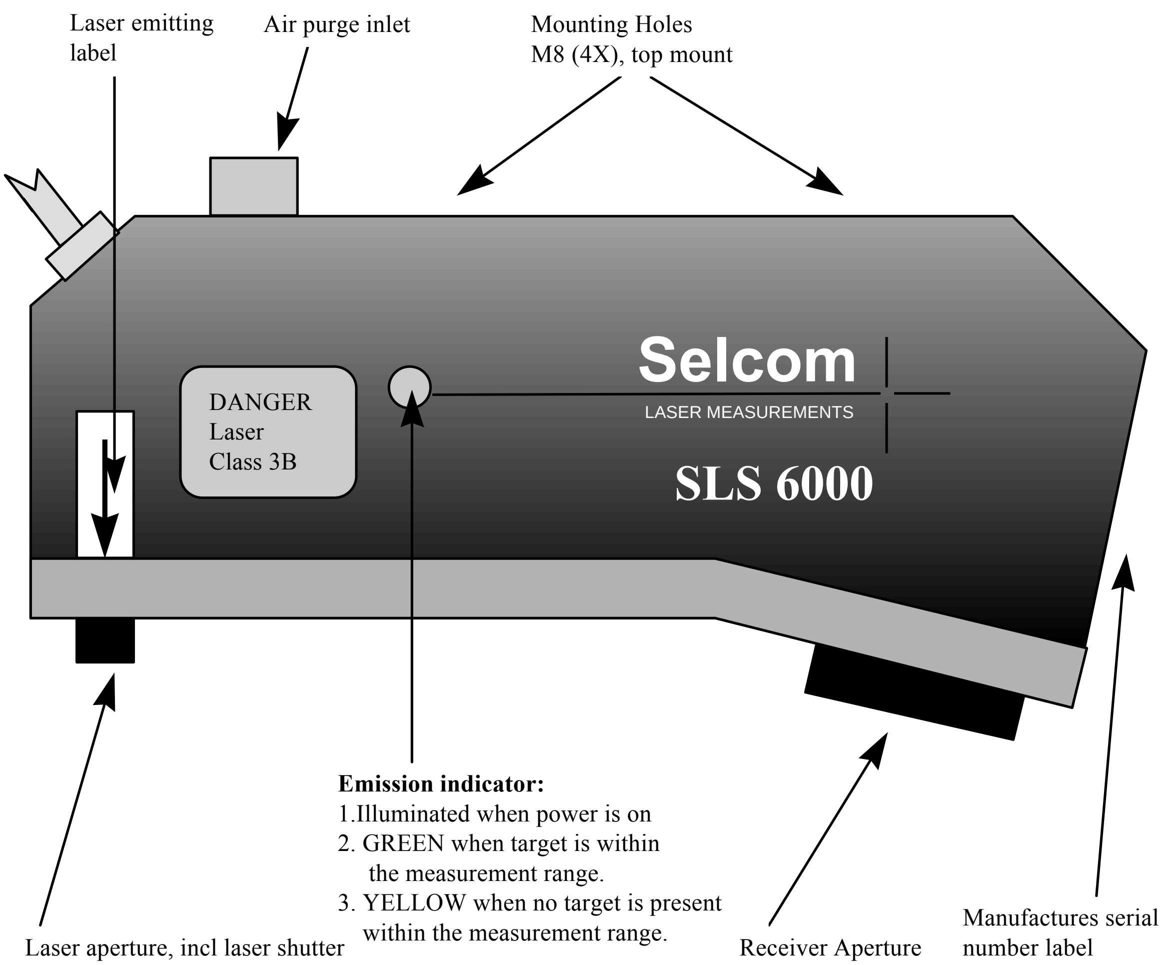


Figure 2:SLS 6000

2.3 Manufacturers serial number label

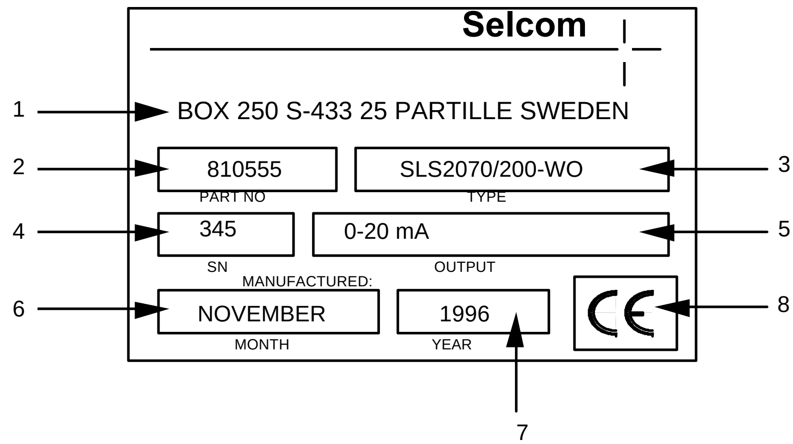


Figure 3: Manufacturers serial number label

The serial number label contains the following information:

1. The address of LMI Selcom AB in Sweden.
2. The part number of the product. Refer to this part number when contacting LMI Selcom.
3. Type description of the sensor. SLS5070/200-BM means:

   SLS5000

   Measurement Range = 70 mm

   Stand Off = 200 mm

   Optimized for Building Material (BM)

   Other applications are:

   MM = Molten metal

   RO = Road

   RU = Rubber

   SW = Saw mill

   Other letter combinations may occur.

4. Serial number of the sensor. Refer to this serial number when contacting LMI Selcom.

5. Available outputs, one analog and one digital. The outputs are selected when ordering the sensor. Possible combinations are:

   mA / Selcom

   mA / Selcom

   mA / RS422

   mA / RS422

   RS232 is always available, ref to appendix E for details.

6. Month of manufacture.

7. Year of manufacturer

8. CE-mark. Indicates that the product fulfills the emc-directive according to EN 89/336/EEC

The SLS sensors consist of a light source and a detector integrated with optics and electronics. The light source is a near infrared semi conductor laser diode. This laser diode illuminates a spot on the surface of the object to be measured, (log, car body, gypsum board etc.).

”An electronic eye that detects a light spot”

The spot is only detectable to the human eye but clearly visible to the detector of the SLS SENSOR. The detector is situated at the back of the receiver part, similar to the retina of the human eye.

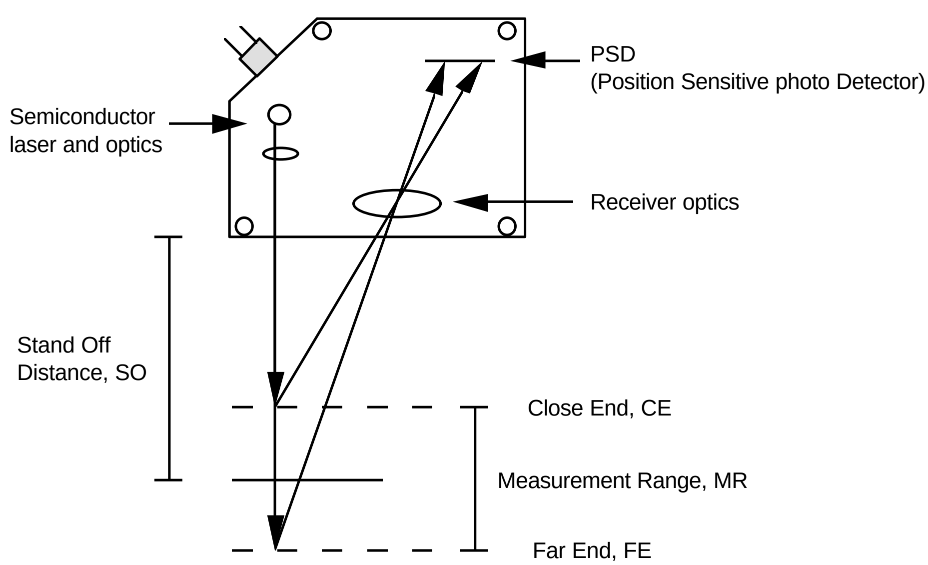


Figure 4: Measurement principle and definitions

Depending of the distance between the SLS sensor and the light spot, the Stand Off distance, the image of the light spot will be focused on a certain spot on the detector. The detector is a high resolution, position sensitive detector. It converts the light spot to electrical signals from which the electronics can calculate the actual distance to the object.

”Moving objects, no problem”

The measurement is very rapid. The SLS sensor repeats the measurement sequence 16000 times per second. This makes it possible to measure moving and vibrating objects.

By using several SLS sensors you can measure thickness, profiles, diameter, etc. The accuracy is high; the error is normally less than 0.2% of the measurement range.

2.4 The analog position sensitive detector

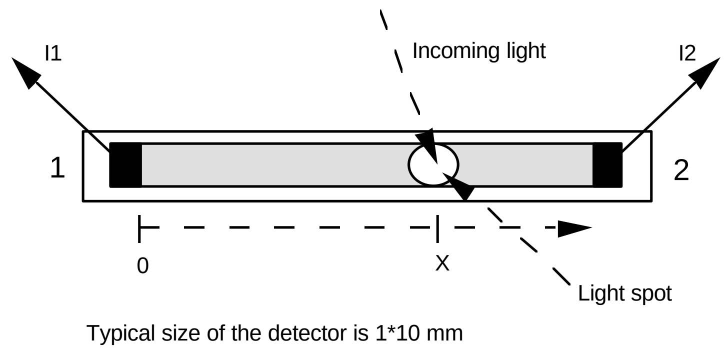


Figure 5: The analog position sensitive detector

The detector current, generated by the light spot is divided into two parts: I1 and I2.

The distances between the light spot and the electrodes 1 and 2 give the ratio between the currents.

2.4.1 Advantages

Advantages:

Fast. Rise time 10-90 % (typical) = 0.2 µsec.

High suppression of ambient light.

Very high resolution. Limited only by the following Analogue-to-Digital converter.

The technique also enables fast regulation of the output laser power. This fast regulation makes measurement of almost any material or surface possible and allows for fast and big variations of measured surfaces color and reflectiveness.

2.4.2 Linearization

Linearization:

The function between the raw output from the detector and the actual distance between the SLS sensor and the measured object is non-linear. This non-linearity is mainly due to the geometry of this type of measurements and to the analog portion of the data processing. Therefore each sensor is factory calibrated to compensate for any non-linearity or other built-in error.

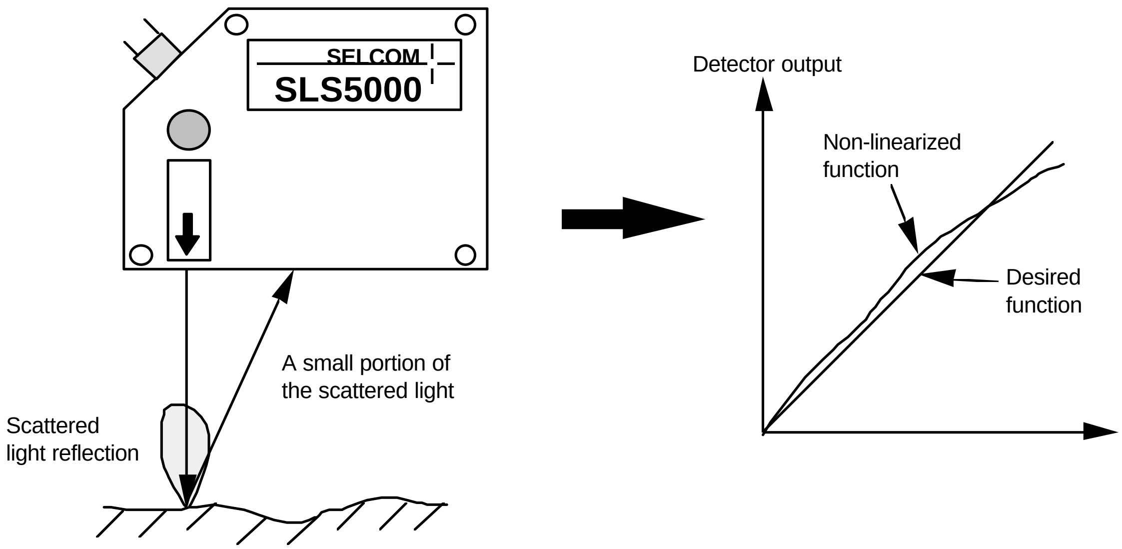


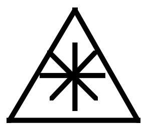
Figure 6: Illustration of linearization

Linearization is performed for each sensor by means of a correction table, which is calculated and stored in the sensor.

3 SAFETY REQUIREMENT

3.1 Symbols

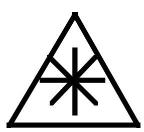
The following symbol appears in the manual:



The symbol identifies conditions or practices that are hazardous

3.2 Safety precautions

The light source of the SLS is a semiconductor laser emitting visible or invisible light. The SLS has a 2 or 3B classification. The classification for each sensor is stated on the laser warning labels on the sensor. Make sure that you take the proper precautions for the laser class of the sensor you are using. If you are uncertain of the laser class or if you have questions regarding precautions or laser safety standards, please contact your nearest LMI office. The following safety precautions must be observed when working with the equipment:



The emitted light can damage the eye if directly exposed, or if the laser light is reflected by a mirror or any mirror like surface directly into the eye.

Follow all warnings and instructions in the manual. Personnel working with or near the SLS must be informed about safety distance, hazardous area and other installation specific hazards.

Ensure that the voltage from the power supply matches the specifications for the equipment.

If otherwise is not explicitly stated, always disconnect the power supply unit during installation, service and maintenance of the SLS. The power supply unit delivered from LMI Selcom is provided with a key control. Remove this key to prevent that the laser is turned on unintentionally.

It is recommended to use safety goggles during installation, service and maintenance.

If possible seal off the hazardous area defined in fig. 8 below to prevent unauthorized personnel from getting exposed to laser light.

3.3 Safety distance

SLS with laser class 2:

Precautions are only required to prevent continuous viewing of the direct beam; a momentary (t < 0.25s) exposure as would occur in accidental viewing situations is not considered hazardous. However, the laser beam should not be intentionally aimed at people.

SLS with laser class 3B:

The safety distance is depending on Stand Off and working power and can be found in the Quality record that comes with each sensor delivered. **See appendix G- Quality Record for the actual safety distance of your sensor.**

In appendix B and I you can find examples of calculation. The Stand Off distance valid for your equipment can be read from the manufacturers serial number label on the SLS sensor, in accordance with the figure below:

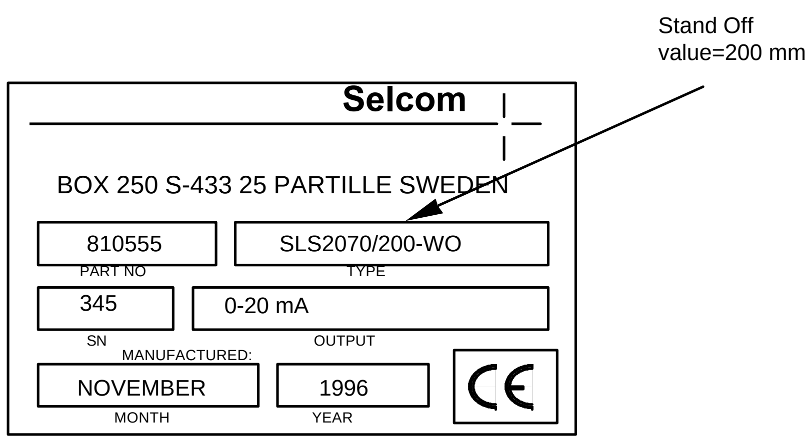


Figure 7: Label

Definition of safety distance and hazardous area:

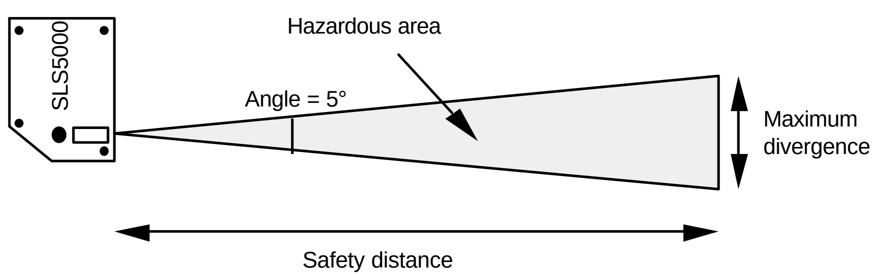


Figure 8: Definition of safety distance and hazardous area

Maximum divergence = TAN(5°) * (Safety distance)

Actual divergence for each Stand Off configuration is stated in section 7, Technical data.

3.4 Safety precautions

The safety precautions below are mainly for class 3B laser sensors. The recommendation for Beam path termination is valid for both class 2 and 3B laser sensors. It is always recommended to follow as many of the precautions as possible irrespective of laser class.

Summary of use precautions for products with a laser safety class 2 or 3B (see text of standard for complete precautions):

	Class **3B**	Class **2**	
Remote interlock,	X		Connect to room or door circuits. Pin no 14 (LASER ON) of the SLS connector can be used for this purpose.
Key control	X		Remove key when not in use. Key control is provided when power supply is delivered by LMI Selcom. To conform to safety requirements a key control must be installed. Pin no 14 (LASER ON) or pin no 15 (+24 VDC) of the SLS connector can be used for this purpose.
Laser shutter	X		When in use prevents inadvertent exposure. Provided by LMI Selcom and permanently mounted on the front of the sensor. See chapter 2, figure 1.
Emission indicator device	X		Indicates that the laser is energized. See chapter 2, figure 1. Provided by LMI Selcom and permanently mounted on the side of the sensor. One of the LEDs is always lit. • The yellow LED is lit when the sensor signals Invalid, e.g. no object inside the measurement range, too little light scattered back to the detector, to much light scattered back to the detector. • The green LED is lit when the measurement is Valid
Warning signs	X		Follow precautions on warning signs. Warning labels are attached to the sensor. See section 3.5.
Beam path (valid for both laser class 2 and 3B)	X	X	Terminate beam at the end of its useful path by a diffusely reflecting material or an absorber.

	Class **3B**	Class **2**	
Specula reflection	X		Prevent unintentional reflections
Eye protection	X		Required if engineering and administrative procedures not practicable.
Protective clothing	X		Not required
Training	X		Required for all operator and maintenance personnel. Personnel working with or near the SLS5000 must be informed about safety distance, hazardous area and other installation specific hazards.

3.5 Warning labels, class 3B

The following labels are attached to the sensor:

All languages:

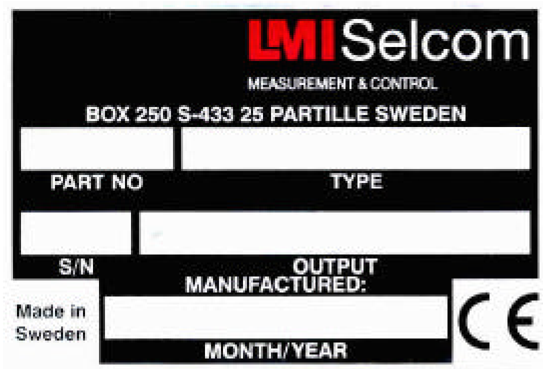


Figure 9: Manufacturers serial number label

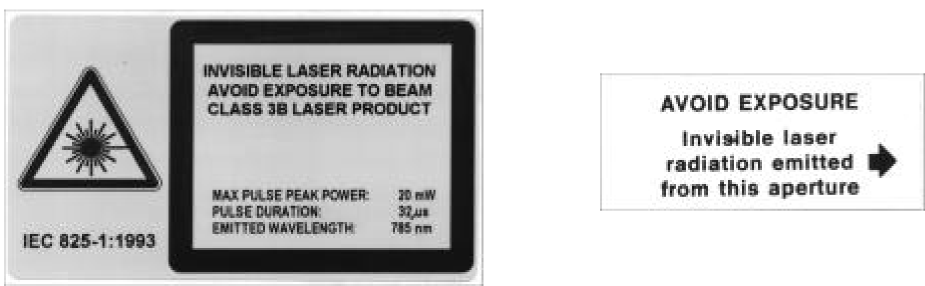
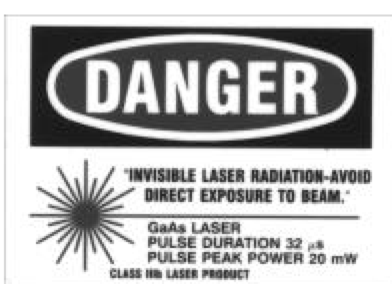
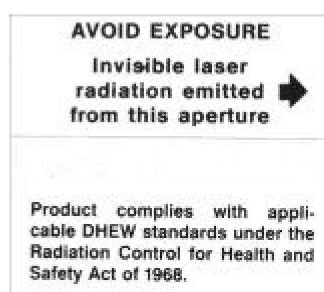


Figure 10: IEC - 825 (example English)





ANSI: Figure 11 a: Explanatory label **Figure 11 b: Aperture label**

3.6 Warning labels, class 2

The following labels are attached to the sensor:

All languages:

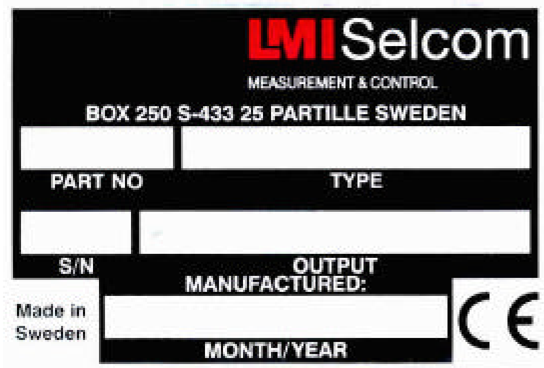
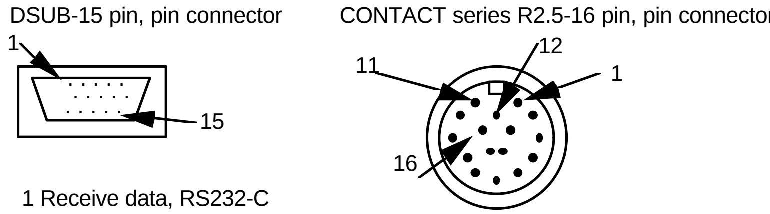


Figure 12: Manufacturers serial number label

Figure 13: IEC - 825 (example English) **Aperture Label**

4 INSTALLATION

4.1 Pin configuration



1 Receive data, RS232-C
9 Transmit data, RS232-C

3 CLOCK, SELCOM interface or RS422 Rx+
4 CLOCK-inv, SELCOM interface or RS422 Rx-
5 DATA, SELCOM interface or RS422 Tx+
6 DATA-inv, SELCOM interface or RS422 Tx-

8 Invalid out-, (when analog interface is used)
12 Invalid out+, (when analog interface is used)
13 Analog out

11 Ground
14 Laser ON, (+24 VDC)
15 Power, (+24 VDC)

Figure 14: 15 pin DSUB miniature, pin connector (3 rows) and 16 pin CONTACT series R2.5, pin connector, front views.

Note: The DSUBmin connector meets IP50 (NEMA 1). The connector may require extra protection if mounted in a humid environment, although dust alone will not require any added precautions.

The CONTACT connector meets IP65 (NEMA 4) when connected with mating connector.

The SLS data can only be accessed through the interface that was specified at the time of ordering (see serial number label ”Output”).

4.2 Cable requirements

4.2.1 Cable length

Interface	Pin number	Max cable length
RS 232	1, 9, 11	15m
RS 422 or Selcom serial	3, 4, 5, 6	100 m
Analog	11, 13	100 m (<7.5 Ω/signal lead)
Invalid	8, 12	100 m

4.2.2 Signal leads with demand for twisted pairs

Interface	Pin number
RxD - GND (RS232)	1, 11
TxD - GND (RS232)	9, 11
CLOCK - CLOCK-inverse	3, 4
DATA - DATA-inverse	5, 6
Rx+ - Rx- (RS422)	3, 4
Tx+ - Tx- (RS422)	5, 6

4.2.3 Signal leads without demand for twisted pairs

Signal lead	Pin number
Analog out (Current source)	13
Laser ON +24VDC (+5 - +32 VDC)	14
Invalid out+ (optocoupled)	12
Invalid out- (optocoupled)	8

4.2.4 Power supply leads

Main power. The power supply leads should be dimensioned so that the voltage between pin 15 (+24VDC) and pin 11 (GND) never falls below 18 VDC. For a 24 VDC power source this means that the total resistance in the power and ground leads must not exceed 15 ohms.

Laser ON (control input). Pin 14 must be held at +24 VDC (+5 - +32 VDC) to enable the laser.

4.2.5 Cable screening

The cable shall include a screen connected to GND at the ”sensor end” of the cable.

4.3 Analog output

4.3.1 General considerations

The analog current output of the SLS5/6000 sensors is derived from the same high performance and accuracy digital distance data as available over the Selcom Serial, RS232 and RS422 interfaces.

The digital information has passed through a high performance digital to analog current converter supplying an easy to acquire signal form for many industrial users and processes.

As a complement to the analog output, an ”Invalid out” signal is available. The sensors are available in two versions (factory set, not to be changed by the user!) regarding the state of the analog output when data is considered ”invalid”:

”Hold latest valid” i.e. the analog output current is held at the latest valid D/A converted data value.

”Zero out on invalid” is only available with 4-20 mA output i.e. the analog current output is set to 0 mA as long as data is considered invalid.

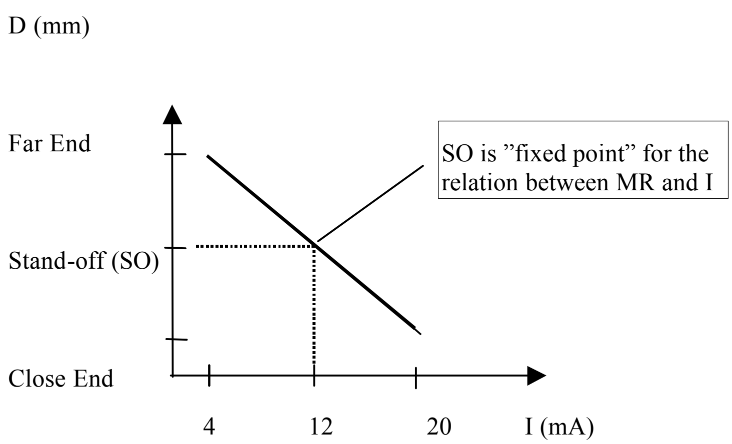
IMPORTANT: The transformation of the current output to engineering units (i.e. mm, inches etc.) in a control computer, PLC etc. requires the use of a ”scale factor (SF_I)” that defines the relation between current output and engineering unit. For a given sensor measurement range the only valid scale factor figure is given in the table on page 19.

It is NOT CORRECT and will lead to erroneous results if the measurement range is simply divided by the current range!!

If an absolute distance between the target and the sensor (or some other ref. Point) is to be computed, it is necessary to be aware of the fact that the fixed calibration point between the sensor and the current output is defined at the Stand-Off distance as being 10 mA for a 0-20 mA sensor and 12 mA for a 4-20 mA sensor.

4.3.2 Referencing of analog current output to sensor - target distance

4 - 20 mA case



Compute distance D (sensor - target): D **= (12 - I) * SF_I + SO**

Where: SO = Stand-Off distance i.e. distance from sensor front to MR midpoint

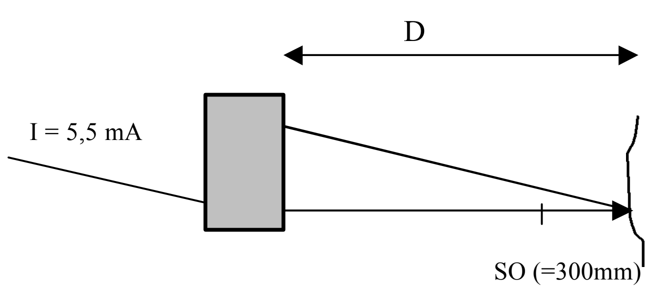
SF_I = Analog current output scale factor. Expressed as ”mm/mA”.

I = Analog current output in mA.

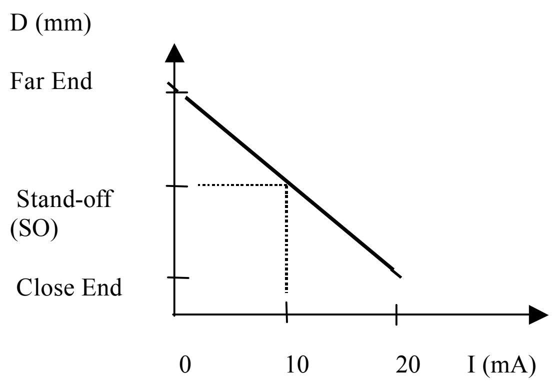
D = Measured distance from sensor front to target in mm.

Example: Sensor is SLS5200/300 => SF_I = 12,8 mm/mA SO = 300 mm

D = (12 - 5,5) * 12,8 + 300 = 383,2 mm



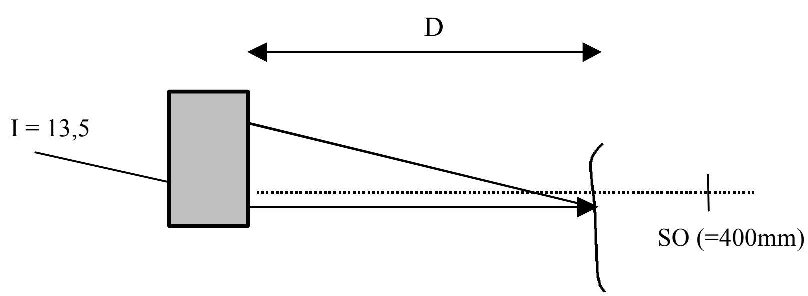
0 - 20 mA case



Compute distance D (sensor - target): D **= (10 - I) * SF_I + SO**

Example: Sensor is SLS5325/400 => SF_I = 16,64 mm/mA, SO = 400 mm

D = (10 - 13,5) * 16,64 + 400 = 341,76 mm



Analog current scale factors (SF_I) for SLS5/6000 sensors:

MR (mm)	0-20 mA SF_I (mm/mA)	4-20 mA SF_I (mm/mA)
6	0,3072	0,3840
10	0,512	0.64
16	0,8192	1,024
20	1,024	1,28
35	1,792	2,24
50	2,56	3,2
70	3,584	4,48
100	5,12	6,4
150	7,68	9,6
175	8,96	11,2
200	10,24	12,8
225	11,52	14,4
250	12,8	16,0
300	15,36	19,2
325	16,64	20,8
375	19,2	24,0
525	26,88	33,6
550	28,16	35,2
575	29,44	36,8
725	37,12	46,4
850	43,52	54,4
1000	51,2	64,0

4.4 Load conditions for analog output

The current output load resistance should not exceed 500 ohms. A return path to ground should be provided via pin 11 (GND). The total resistance in the analog out lead and the ground lead must not exceed 15 ohms.

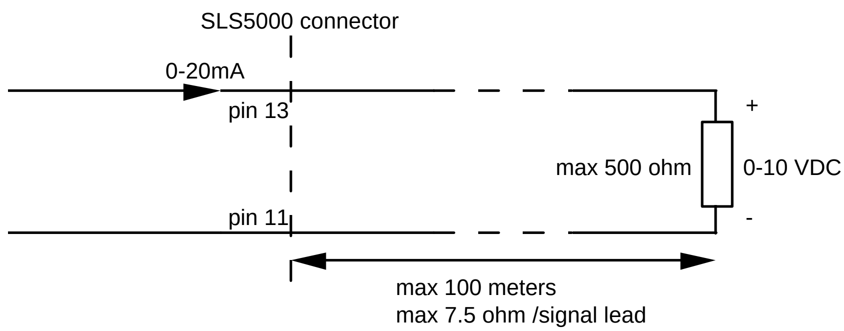


Figure 15: Example of connection:

Note:

We recommend the use of temperature stable resistors to reduce the effects of voltage variations due to resistance changes.

Always turn the power off before connecting or disconnecting the analog output load.

4.4.1 Alternative connections for valid output

The output transistor conducts as long as the measurement is valid.

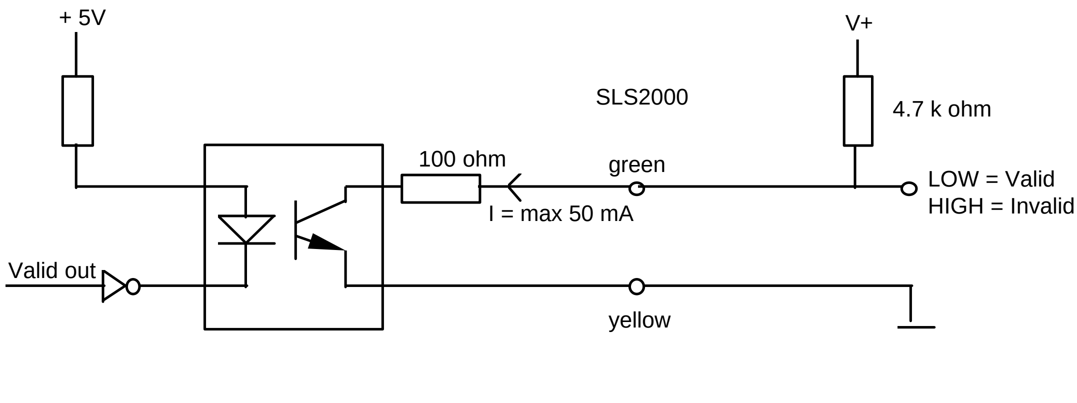


Figure 16: Example of connection (current sink):

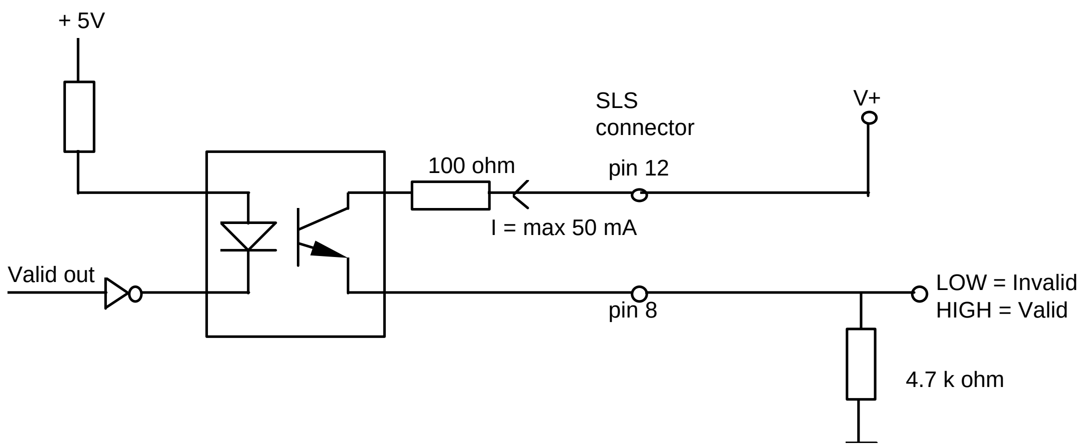


Figure 17: Example of connection (current source):

Due to cable crosstalk the spectral characteristics of the analog current output, as measured over a 100 Ohm resistor, may have the following principal appearance:

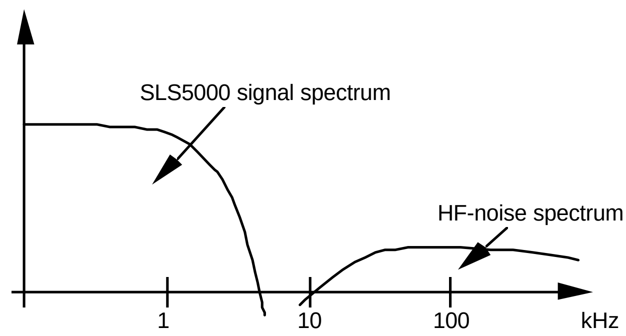


Figure 18: Illustration of spectrum

The analog output of the SLS sensor mainly finds its use in low bandwidth, industrial measurement and control applications. The signal conversion equipment in such applications is normally band limited to low frequencies making the system insensitive or high frequency noise.

For some wide band applications like vibration analysis or when the signal is to be manually studied with an oscilloscope, the high frequency noise may be a problem. In these casesan anti-aliasing filter may be added between the load resistor and the registration equipment.

A simple but in most cases sufficient filter is shown below. The components as chosen will give an upper frequency limitation of 1.6 kHz. It is important that the filter and the registration equipment is connected with as short cabling as possible to avoid additional noise pick-up.

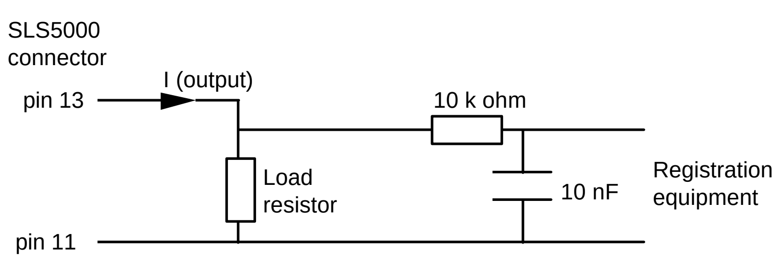


Figure 19: Example of filter

4.5 Electrical installations, examples

Below are four examples of electrical connections using the available interfaces provided by the SLS sensor:

4.5.1 Analog output, 0-20 mA

Analog output with filtering, see Appendix C

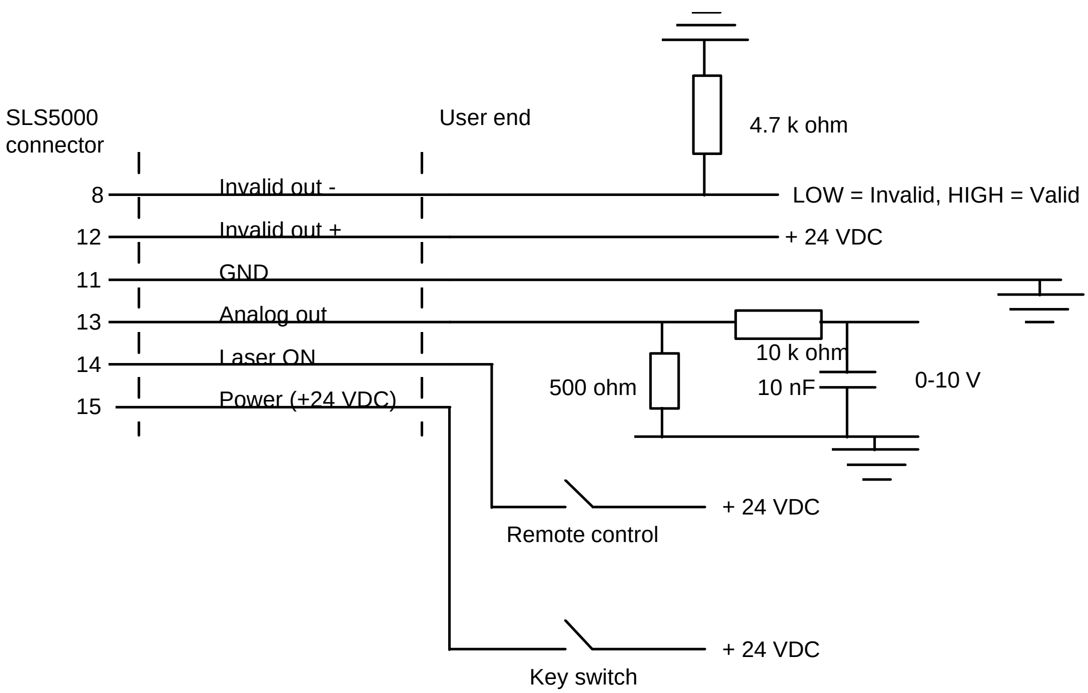


Figure 20: Analog output with filtering

4.5.2 Selcom synchronous serial interface

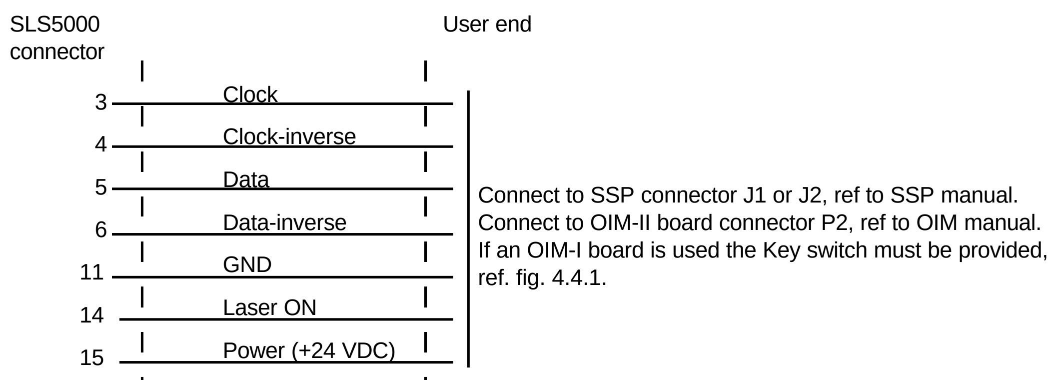


Figure 21: Selcom synchronous serial interfaceRS422 interface

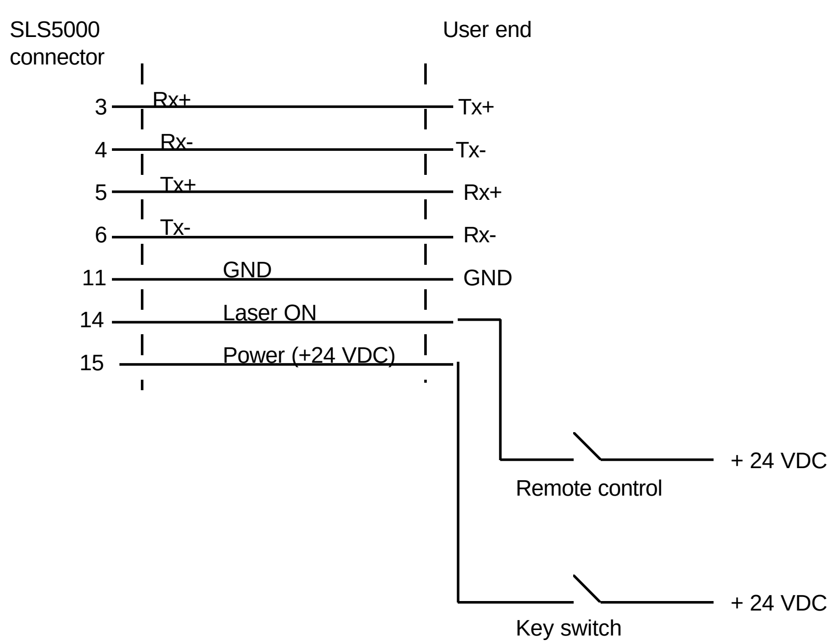


Figure 22: RS422 interface

4.5.3 RS232 interface

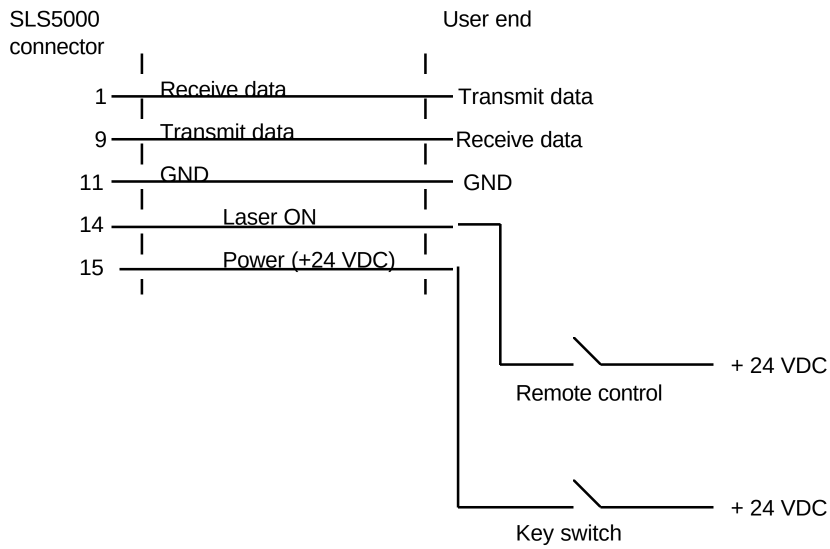
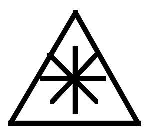


Figure 23: RS232 interface

4.6 Mechanical installation.

The SLS sensor must be mounted rigidly in such a way that neither thermal expansion of the fixture nor external forces may influence its position. Otherwise the accuracy of the system will be affected and frequent re calibrations of the system may be necessary. Calibrate the system as often as possible to avoid influence of mechanical fixture drift due to time and temperature.

Make sure that the optical path is not obstructed.



It is possible during installation that unintentional exposure to laser light may occur take extra care not to look into the laser aperture of the SLS sensor unless you are certain that the laser beam is turned off. Tools that are used during installation may give mirror like reflections.

If possible wear protective goggles.

The laser beam of the SLS sensor cannot burn skin.

Eight plastic mounting washers are enclosed in the delivery. These washers may be used to electrically isolate the sensor from its mounting surface, see figure below.

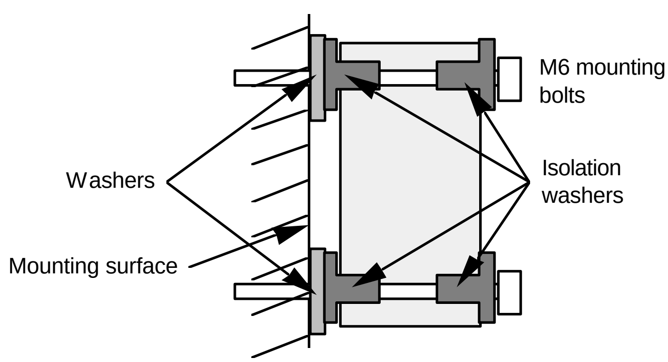


Figure 24: Illustration of how to mount the plastic-mounting washers

Mounting Surface

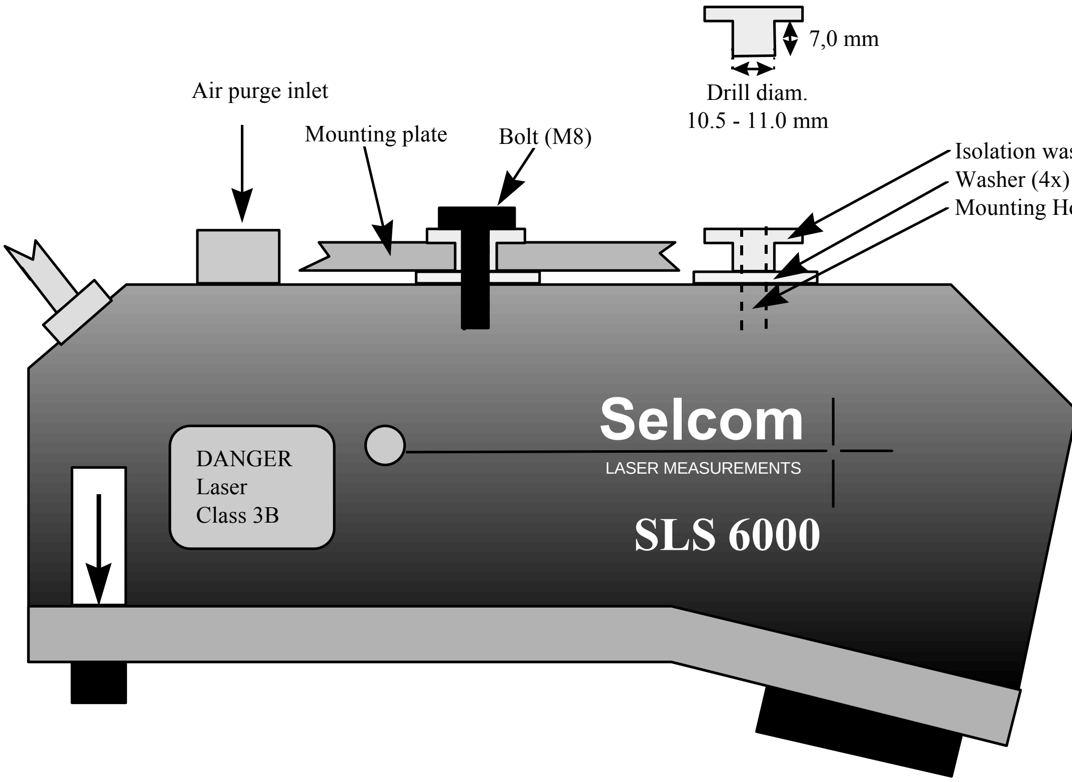


Figure 25: SLS 6000

4.6.1 For a single SLS sensor system

The distance between the SLS sensor and the reference plane must not be changed.

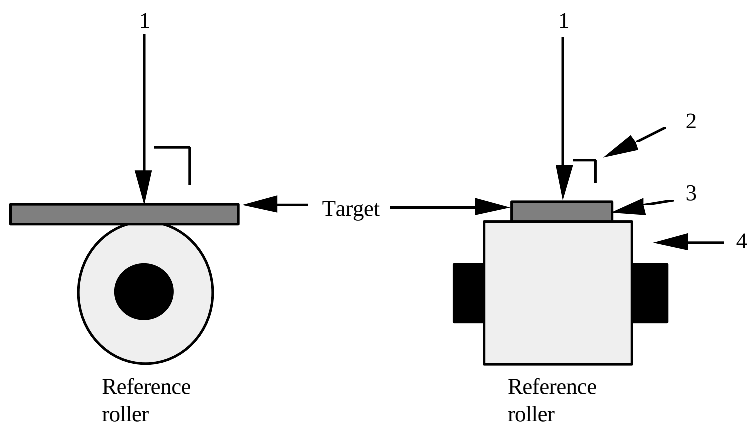


Figure 26: Measurement against the reference plane

1. Laser beam
2. If the incoming laser beam is not perpendicular to the measured surface, compensation for the angle may be necessary.
3. Good contact between the reference surface and the measured material is important.
4. Eccentricity of a reference roll may cause variation in the thickness value. Keeping track of the roll while performing multiple calibrations may solve this problem.

4.6.2 For a dual SLS sensor system

The distance between the two SLS sensors must not be changed, between calibration and measurement.

The accuracy of a dual SLS sensor system for thickness measurement is highly dependent on laser beam adjustment of the two sensors. It is necessary to have the two laser beams concentric through the entire measurement range. In the left figure below, the thickness will decrease when the measured object is tilted as in the figure and increase (more than correct) when tilted the other way. In the right figure the thickness of the measured object will increase for any tilt angle.

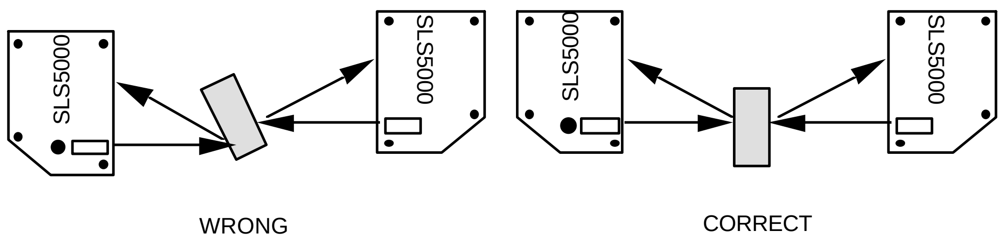


Figure 27: Installation example, dual sensor thickness measurement

- Useful equipment:
- IR-viewer.
- Piece of cardboard paper (about 0.5 x 100 x 100 mm, preferably blue).
- Piece of non-transparent material (about 5 x 100 x 100 mm, with even thickness).
- Horizontal spirit level.

1. Sensor 1 is mounted in its fixed position. Use the horizontal sprit level. Make sure that the mechanical flap in front of the laser aperture is in the closed position.

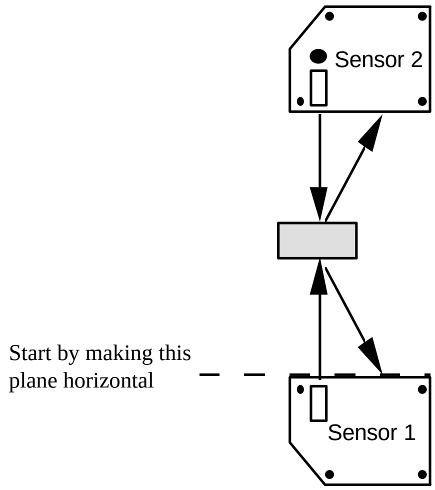


Figure 28: Illustration of how to mount the sensor

2. Sensor 2 should be loosely mounted, not fixed. The sensor should be turned off with the mechanical flap open.

3. Turn sensor 1 on. Cover the receiver aperture of sensor 1 to make the sensor output maximum laser intensity. Open the mechanical flap.

4. Adjust sensor 2. The light spot from sensor 1 must fall on the laser aperture of sensor 2 as concentricity as possible.

5. Turn sensor 1 off and leave the mechanical flap open.

6. Secure the position of sensor 2 (not finally).

7. Cover the receiver aperture of sensor 2 to make the sensor output maximum laser intensity.

8. Turn sensor 2 on. Adjust sensor 2 by tilting it only. The light spot from sensor 2 must fall on the laser aperture of sensor 1 as concentricity as possible. Sensor 2 can be tilted by carefully loosening some bolts and placing thin shims between the SLS sensor and the mounting surface.

9. Turn sensor 2 off. Fix its position finally.

10. Remove the covers for the receiver apertures.

The sensors should now be correctly mounted. A control procedure is described on the next page.

The following control procedure can be used to verify that an installation is correctly made or to check for mechanical changes in the mounting structure:

1. Cover the receiver apertures of sensor 1 and 2 to make the sensor output maximum laser intensity.

2. Turn sensor 1 and 2 on.

3. Put the piece of cardboard paper in the measurement range. Make sure by moving the paper along the laser beams that they coincide everywhere between the sensors. If an infrared (820 nm) laser is used, the IR-viewer is necessary to see the light spots. A near infrared (780 nm) laser can be seen without the help of an IR-viewer (especially on a blue color).

Since the cardboard paper is semi transparent for infrared light, the light control circuits of the two SLS sensors will interfere. This is noted as a variation in the light intensity of the spot on the paper. This phenomenon will not occur when using special designed sensors for semi transparent materials.

4. Remove the cover over the receiver opening. Put the piece of non-transparent material in the measurement range. Try to keep it as perpendicular to the laser beams as possible. If the sensors are correctly aligned you will note an increase of the thickness when you tilt the plate. A decrease of the thickness value is an indication that the sensors are misaligned.

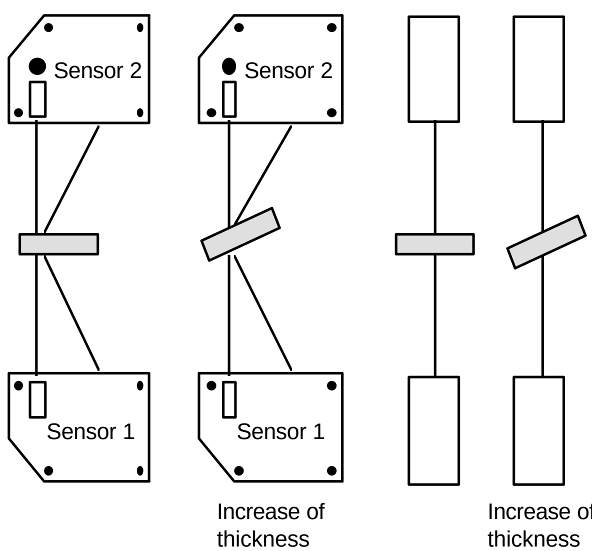


Figure 29: Illustration of item 4 above.

Avoid set-ups where the two sensors can see each other when they are supposed to measure. A set-up as described in the left figure will produce a variation in the output value at approximately 1 Hz. See also section 4.3.1.

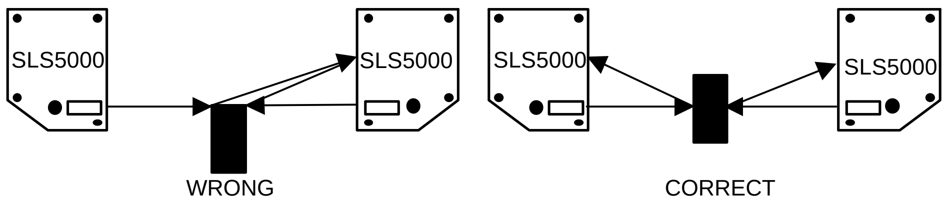


Figure 30: Dual sensor thickness measurement

4.7 Hints for measurements

The SLS sensor is designed to give a true and dependable measurement for a vast range of materials, surfaces and speed of target/surface.

Sensor features:

All sensors:

High speed of light power control.

Dynamic range of light power output extremely wide,

from nanowatts to 5 mW.

Selected before production:

Bandwidth of position data from up to **2 kHz.**

Sampling rate **16 000** times per second.

Small laser spot.

Some materials or surfaces requires some considerations and advises to get the best possible performance.

The target characteristics can be structured into:

1. Material.
2. Surface texture.
3. Temperature of the material.
4. The geometry of the material.

4.8 Material

4.8.1 General group. Mat surfaces.

There is a bulk of different materials that falls into the general group, i.e. easily measured on for the SLS sensor. Generally these materials have a mat type of surface.

Examples from this group are paper, hot rolled steel, concrete, gypsum etc.

4.8.2 Fibrous material

The obvious example in this group is any kind of wood: logs, sawn boards, parquet blocks, etc. When the laser light meets this type of surface it is spread somewhat along the fibers. The center of gravity of the spot can then move out of the expected position and the result will be an error in the output data. This will occur if the optical triangle is oriented parallel to the direction of the fibers.

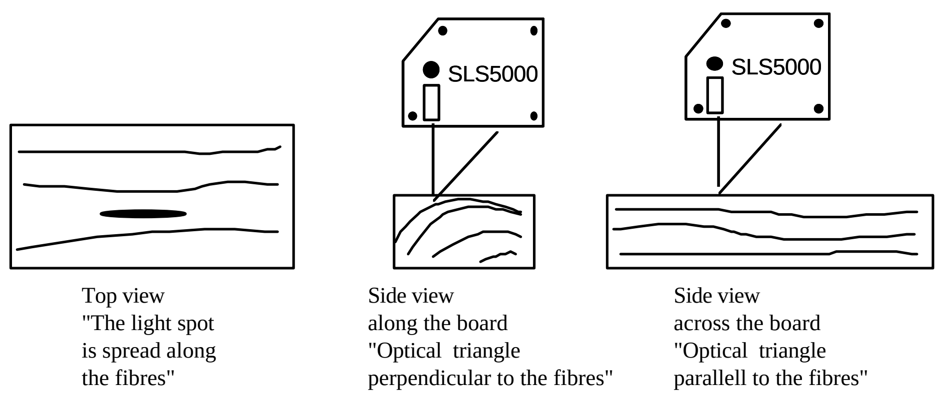


Figure 31: Fibrous material

4.8.2.1 Advise:

Mount the sensor with the optical triangle perpendicular to the direction of the fibers.

4.8.3 Shiny materials. Black and shiny materials.

Stainless steel, molten metal and other mirror like surfaces. They scatter very little light back to the detector due to the fact that most of the light is reflected according to optical law of reflections. The amount of light scattered in the direction of the receiving lens can vary rapidly over time and with a wide range of magnitude.

Black materials scatter only a small part of the incident light. Black materials in combination with a shiny appearance, like fresh extruded rubber or wet asphalt, require a very powerful light control.

It is important to use an SLS sensor specially designed for measurement on this type of surface.

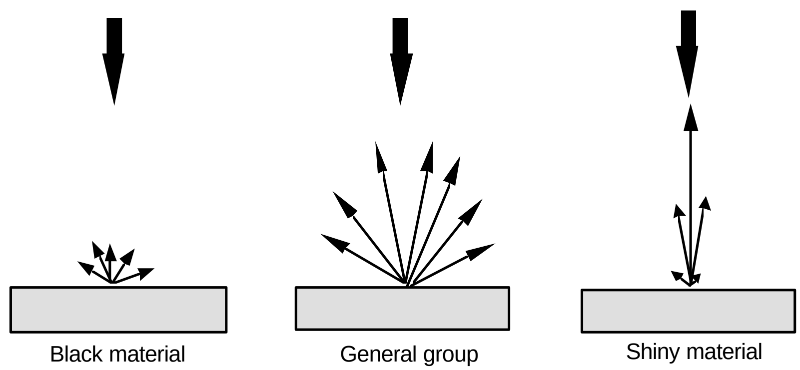


Figure 32: Illustration of reflection

4.8.3.1 Advise

For extremely shiny materials like molten metal (magnesium with protection gas or coated zinc plates very close to the bath) without any skin or oxide on the surface it may be necessary to tilt the SLS sensor somewhat to get enough light in the direction of the receiving optics consult LMI Selcom.

Note that some material ages optically, e.g. car paint or uncured rubber. Compare an absolutely fresh sample from the extruder measured immediately and after 15 minutes a great difference will be noticeable.

4.8.4 Transparent materials

Transparent materials cannot be measured since no light is scattered on the surface (e.g. glass). Transparent materials like **coolant oil or water** on a surface will add roughly half the thickness of the oil or water layer (given by the refraction index) to the thickness or position data.

4.8.4.1 Advise

The compensation for the layer thickness is roughly 50% of the actual transparent layer thickness. (For oil and water layers).

4.8.5 Semitransparent materials

The semitransparent material will scatter enough light to produce a stable measurement, but there will also be a penetration of light into the material and a contribution from internal reflections (as well as background reflections). The result is a position reading that is below the actual surface. The ”offset” value depends on the degree of transparency. In many situations the offset is small and constant and can be calibrated for.

A method to measure this offset is to stick a thin strip of adhesive paper to the surface and scan the material (the thickness of a paper is approximately 0.1 mm).

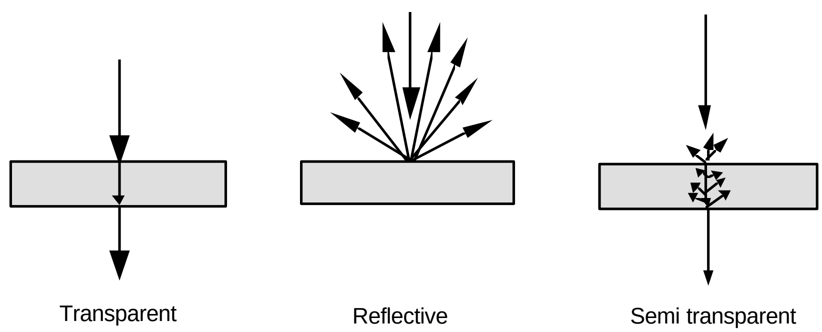


Figure 33: Light behaviour on transmission material

4.8.6 Unstable thickness reading

In the case of a dual sensor system, the sensors will receive not only reflected light but also the transmitted light from ”the opposite” SLS sensor. Since they are working at nearly the same frequency, they will interfere with each other. The output from the system will contain a low frequency component (~1 Hz) even if the set up is in steady state. This is an important phenomenon that has to be considered in all dual applications. Note that special designed SLS sensors can be ordered to avoid this phenomenon.

4.8.6.1 Advise

Single sensor thickness measurement using a mechanical reference:

Offset compensation for penetration can be useful if the material is homogeneous.

Dual sensor thickness measurement on semitransparent materials:

Use SLS sensors designed for semitransparent materials.

4.8.7 Surface texture. Static texture error

A basic statement to take care of is that the light spot produced on the target covers a certain area and the SLS sensor will respond to the center of gravity of the image of that spot on the detector. If the spot covers an area that gives an irregular amount of scattered light in the direction of the receiving optics, the SLS sensor reads a position of the surface below or above the true surface.

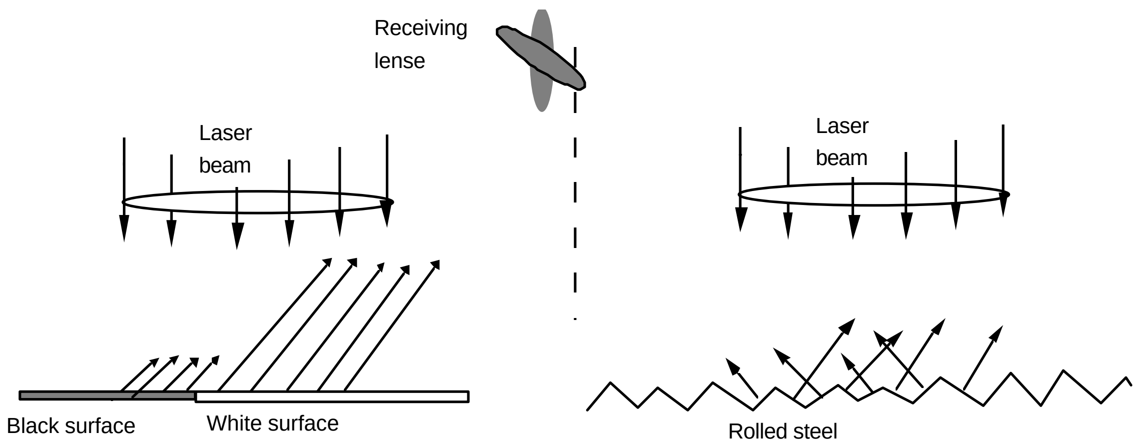


Figure 34: Reflection depending on target material

The change in the position output depends on the orientation of the sensor. The magnitude and the duration in length depend on the size of the laser spot. As a general rule the spot must be as small as possible. An example of output from the SLS sensor is shown in the figure below.

Note that if the SLS sensor is rotated 90 degrees to the orientation indicated, **no error spikes occurs.**

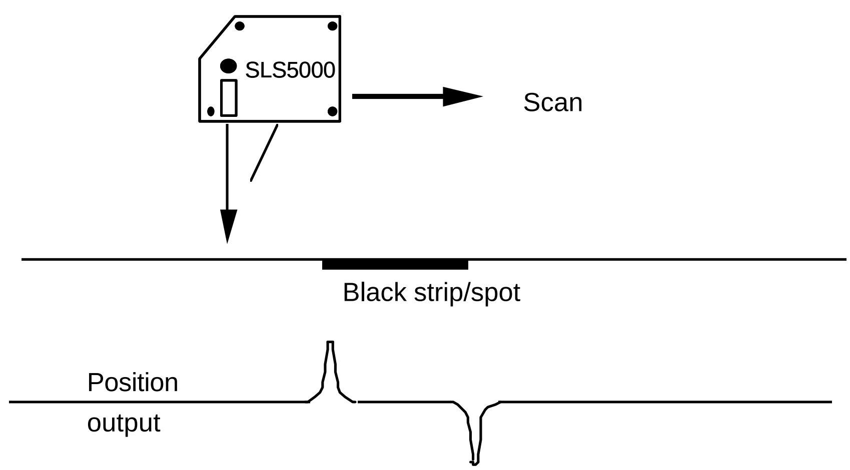


Figure 35: Example of output from the SLS sensor

Surfaces with a regular pattern from machining (e.g. rolling marks or from grinding) will cause a uniform scattered reflection. This will result as a static error that varies depending on where on the machining marks the center of gravity of the light spot is located. Scanning across the marks and averaging the measured data can eliminate this error.

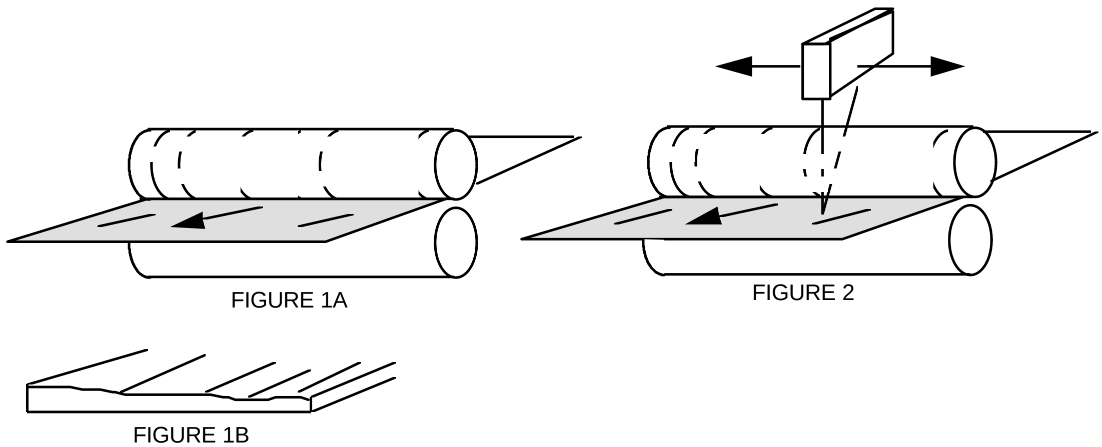


Figure 36:

Fig. 1 A — The regular surface is often produced in a rolling mill and looks like a rib mark structure along the strip.

Fig. 1 B — In other words regular thickness variations across the strip.

Fig. 2 — The SLS sensor should be mounted parallel to the ”ribs” and with a scanning direction across the direction of travel.

4.8.7.1 Advise

If possible orient the optical triangle parallel to surface irregularities.

If possible try to calibrate by letting the laser spot scan over a distance

(e.g. 10 mm) of the surface, to eliminate static texture error.

Calculate an average over distance when measuring.

4.8.8 Temperature of the material

Due to the given specification of the SLS sensor it has a maximum temperature coefficient of 200 ppm. That is for the SLS sensor housing temperature. The temperature of the object does not affect the accuracy at all within the given specifications.

4.8.8.1 Advise

The SLS sensor system will measure the actual thickness of the hot material. Be sure to take into account the temperature expansion effect when comparing with other measurements.

4.8.9 Geometry of the material. Secondary reflections

The SLS sensor position data is given by the center of gravity of laser light on the detector. The laser light must origin from the laser spot on the surface. If laser light scattered from the spot reaches the detector via a secondary reflection that may affect the reading.

In most cases the phenomena can be avoided by orienting the SLS sensor according to the figure below.

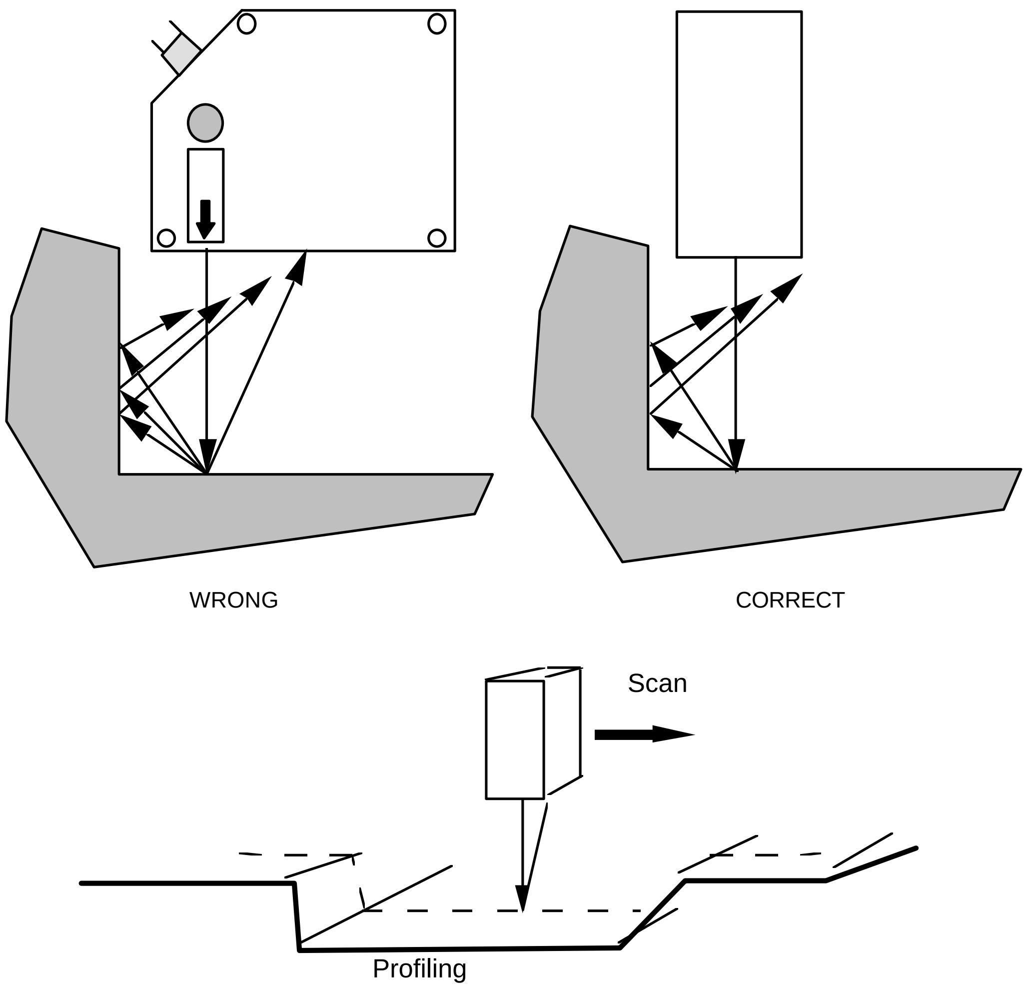
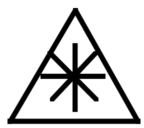


Figure 37: Sensor orienteering

5 SERVICE AND MAINTENANCE



It is possible during service and maintenance that unintentional exposure to laser light may occur takes extra care not to look into the laser aperture of the SLS sensor unless you are certain that the laser beam is turned off. Tools that are used during installation may give mirror like reflections. If possible wear protective goggles.

The laser beam of the SLS sensor cannot burn skin.

No changes or modifications may be made to the sensor or its cable unless you have a written permission from LMI Selcom. If the sensor is opened or modified without permission, warranty is voided.

For service, contact the LMI Selcom office closest to your location or your local distributor.

It is recommended that the following be performed on a regular basis depending on environmental conditions.

Keeping the front glass clean

1.Turn the power OFF.

- If LMI Selcom provides the power supply: remove the key.
- Other wise: make sure that the power cannot be unintentionally turned on.

2. Wipe the front glass clean using a soft, lint free cloth, if necessary moisten with mild cleaning fluid (e.g. cleaning alcohol).

3. Check the front glass for adherent particles or damage. If damaged, contact your LMI Selcom representative.

4. Turn the power ON.

Visual check for damage

1 Turn the power OFF

If the power supply is provided by LMI Selcom: remove the key.

Other wise: make sure that the power cannot be unintentionally turned on.

1 Check the sensor for mechanical damage.

2 Check the cable for damage.

3 Check that mounting screws/bolts are tightened.

4 Check that any extra accessories are working.

5 Check filters and hoses for air purge.

6 Check calibration block.

7 Turn the power ON.

LED-indicators (Yellow and Green)

1 Both LED-OFF

Main power to the SLS is OFF, Check the +24 VDC supply.

2 Both LED-ON

- Power up and initialization sequence (approximately 10 sec.)
- The sensor set-up menu is active (SLS5000 and SLS6000 only, see Appendix E Parameter Setup.)

3 Green LED-ON

Laser is ON

Object in measurement range (or in a false measurement range, check distance

between sensor and object!)

Laser spot invisible to the naked human eye

4. Yellow LED-ON

- Laser is OFF or
- Laser is ON but no object in the measurement range or
- Laser is ON with an object in the measurement range

Indication that the Laser is faulty, contact LMI Selcom!

5. Yellow and Green LED is blinking

Faulty sensor condition, contact LMI Selcom!

6 BLOCK DIAGRAM

Principal diagram:

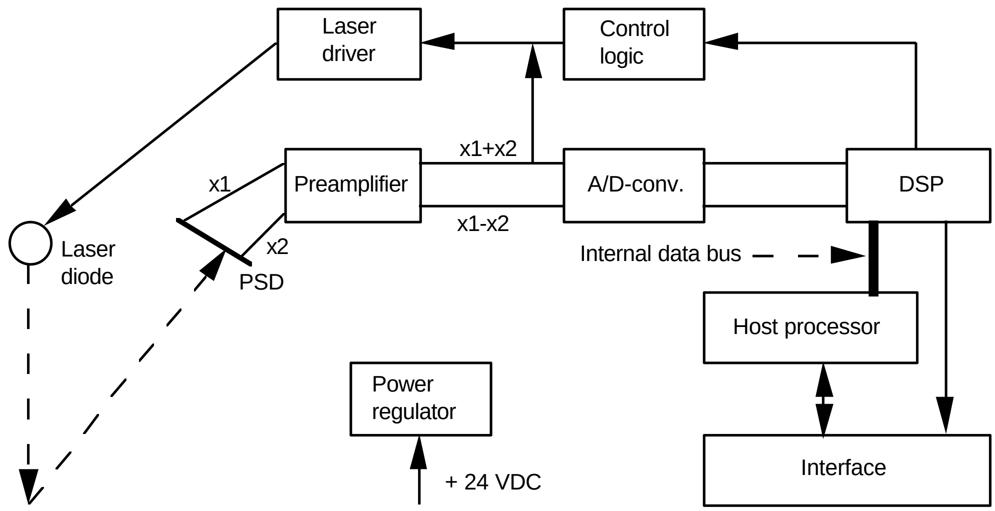


Figure 38: Principal diagram

7 TECHNICAL DATA

7.1 Dimensions SLS 5000

Length:	135 mm	(5.3 inches)
Height:	105 mm	(4.1 inches)
Width:	51 mm	(2.0 inches)
Weight:	1.1 kg	(2.2 lbs)

7.2 Dimensions SLS 6000

Length:	376 mm	(14.8 inches)
Height:	169 mm	(6.6 inches)
Width:	70 mm	(2.7 inches)
Weight:	4.4 kg	(9.9 lbs)

Environmental conditions:

Temperature:

- Operating: 0-50 °C (32-120 °F)
- Storage: -30-70 °C (-20-160 °F)

Protection class :IP65 (NEMA 4)

(excluding connector)

Power requirements:

- Input voltage :+24 VDC (18-32 VDC)
- Input current: 250 mA (350-200 mA)
- Start-up current :> 500 mA

Resolution :0.025 % of Measurement Range

Inaccuracy :0.2 % of Measurement Range

(Includes non-linearity and error)

Sampling frequency: 16 kHz

Bandwidth: up to 2 kHz

7.3 Sensor configurations SLS 5000

MR (mm)	SO (mm)	Spot size at SO (mm)	Irradiance angle A (degree)	Resolution 1 LSB = (µm)
6	50	0,1	2,69	1,5
20	50	0,1	2,69	5
50	65	0,1	2,07	12,5
10	100	0,3	1,29	2,5
20	100	0,3	1,29	5
35	100	0,3	1,29	8,75
35	200	0,4	0,63	8,75
70	200	0,4	0,63	17,5
100	200	0,4	0,63	25
70	300	0,6	0,4	17,5
150	300	0,6	0,4	37,5
200	300	0,6	0,4	50
325	400	0,4	0,32	81,25

7.4 Sensor configurations SLS 6000

MR (mm)	SO (mm)	Spot size at SO (mm)	Irradiance angle A (degree)	Resolution 1 LSB = (µm)
100	500	0,5	0,25	25
175	500	0,5	0,25	43,75
250	500	0,5	0,25	62,5
225	750	0,5	0,16	56,25
375	750	0,5	0,16	93,75
525	750	0,5	0,16	131,25
375	1000	0,5	0,12	93,75
575	1000	0,5	0,12	143,75
725	1000	0,5	0,12	181,25
550	1250	0,5	0,1	137,5
850	1250	0,5	0,1	212,5
1000	1250	0,5	0,1	250

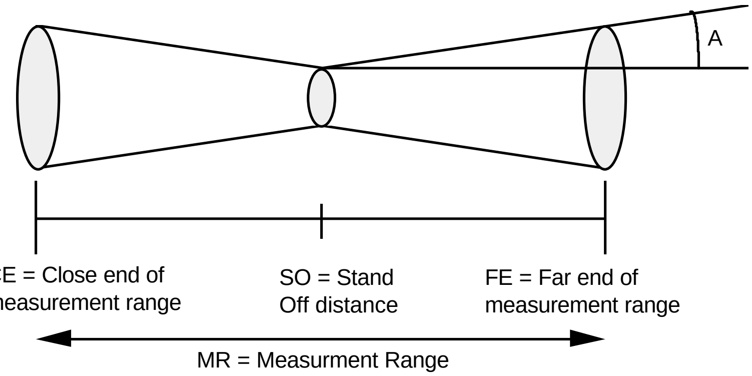


Figure 39: Illustration of laser beam

Output signal interface:	Analog
current source	
external impedance:	max 500 Ω
max cable length:	100 m
selectable at delivery (see manufacturers serial number label):	0-20 mA
Far end value:	0 mA
Close end value:	20 mA
Resolution:	4.88 microA/LSB
	or 4-20 mA
Far end value:	4 mA
Close end value:	20 mA
Resolution:	3.90 microA/LSB

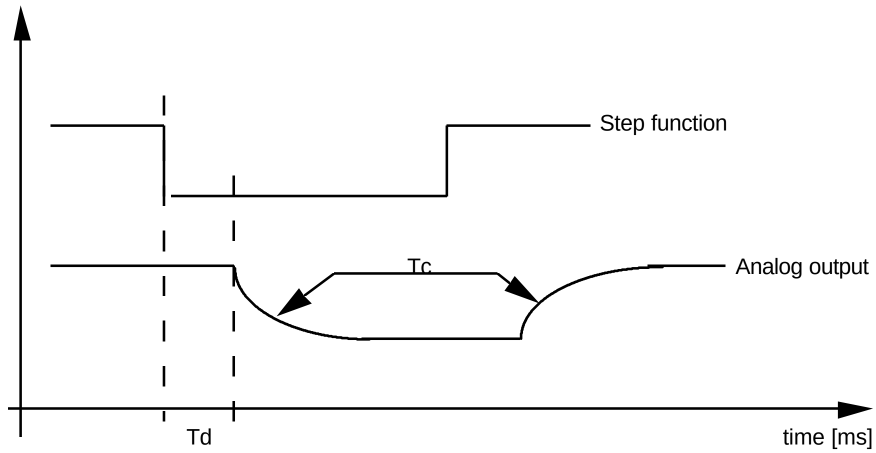


Figure 40: The step response

Td = delay time, Tc = time constant

Time	Error (% of step)
Tc	36 %
2Tc	13 %
3Tc	5 %
4 Tc	2 %

External impedance = 500 ΩTd = 200 µs.

Tc = 80 µs. (at 2 kHz bandwidth)

External impedance = 500 Ω + filter according to appendix C.

Td = 300 µs.

Tc = 100 µs. (at 1.6 kHz bandwidth)

Digital : RS232-C

No hardware handshaking

Protocol: SLS-ASYNCH-1

Ref: Appendix E

Optional digital:

7.5 Selcom serial synchronous interface

Selcom standard input: C+C-inv, D+D-inv

Logical "1": C > 0.6 V + C-inv

D > 0.6 V + D-inv

Logical "0": C-inv > 0.6 V + C

inv > 0.6 V + D

or

RS422

Full duplex

Protocol: SLS-ASYNCH-1

Ref: Appendix E

Invalid output:

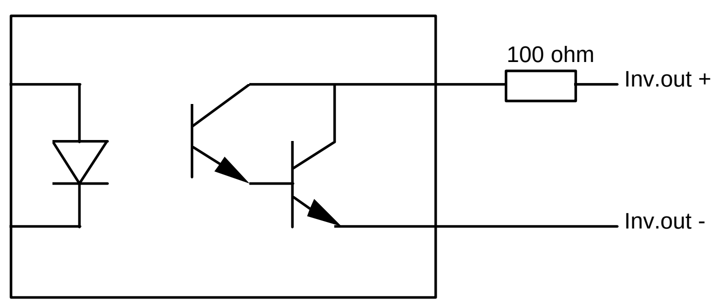


Figure 41: Optocoupled

Max ratings: V_{CE} 35 V

I_C 50 mA

Rise time (typical): 60 µs

Fall time (typical): 53 µs

APPENDIX A, Revision page

Revision	Date	Page	Description
P6.0	971216	All	ÄB7-130.Chapter 4.3 Analog output, revised
P7.0	980326	All	ÄB8-19.Update the SLS manual with safety calculations for wide spot
P8.0	980915	All	The lay out is changed. ÄB8-44. Chapter 4.3.1 General considerations is revised
P8.1	99-08-31	28	Fig 23: SLS 6000 is changed.
		Front	The text in the front is changed. SLS2401 is added.
P9.0	00-01-25	All	Laser safety: Class 2 added and Class IIIb changed to Class 3B, Selcom changed to LMI Selcom
P9.1	00-04-19	Chapter 3 Laser safety,	Safety distance table and calculation revised.
		Appendix A	Old revision information deleted from this list.
		Appendix G	Quality record sheet added.

APPENDIX B, Safety distance calculations

Assumptions and equations are in accordance with European standard EN60825: 1991 and American standard IEC 825. The following is an example of a calculation.

Laser safety class	3B	
Wave length	L	785 nm
Pulse frequency	f	16 kHz
Duty cycle		50 %
Pulse length	T	31.2microsec.
Laser diode power	P_{max}	35 mW
Max sensor power	P_{smax}	17.5 mW
(50% loss in optics and mechanics)		
Normal pulse power	P_{pmax}	≤10 mW
Normal average working power (50% duty cycle)	P_{nave}	≤5 mW
Aperture	a	4.8 mm

The calculations are made as follows:

1. Calculate by using tables in the standards, the maximum permissible exposure (MPE) during a specified period of time.
2. Calculate the maximum energy in each pulse sent out by the sensor.
3. This energy must be distributed over an area to satisfy the MPE value.
4. The results stated in section 3.3 are adjusted upwards compared to the calculations below.

5. Maximum Permissible Exposure for a single pulse (MPE_S) at the cornea for direct exposure to laser radiation during T= $31.2*10^{-6}$ seconds is given by the equation (EN 60825:1991, table VI page 42):

MPE_S ={t=T=$31.2*10^{-6}$ s}= $18*C_4*t^{0.75}$ [$J*m^{-2}$]

where $C_4 = 10^{((L-700)/500)}$

MPE_S = 0.011 $J*m^{-2}$

During 1000 seconds $16*10^{+6}$ pulses are produced. The Maximum Permissible Exposure for the pulse train (MPE_t) must be reduced by a factor given by the equation (EN60825: 1991, §13.3.1):

$MPE_t=MPE_S*N^{-0.25}$where N= number of pulses expected in an exposure = $16*10^{+6}$ pulses MPE_t= 0.000174 $J*m^{-2}$

Energy in each pulse: H = P*T = $1.09*10^{-6}$ J

where **P** is:

P_{smax} for calculations according to standards (power losses due to mechanical constraints and optical transmission is estimated conservatively to 50 %)

P_{pmax} for calculations during normal working conditions.

This energy must be distributed over an area A to satisfy the MPE_t value:

$H/A=MPE_t$ => $A=H/MPE_t$

A= 0.0063 square meters

$A=\pi*r^2$ => 2*r=d= diameter of this area A

d=0.089 meter

Geometry gives:

Aperture/ASO = d/s s = distance from focus to area A

ASO = Aperture Stand Off = SO + 22 mm for SLS 5000

ASO = Aperture Stand Off = SO + 53 mm for SLS 6000

s = d*ASO/a

The safety distance, or the Nominal Ocular Hazard Distance (NOHD):

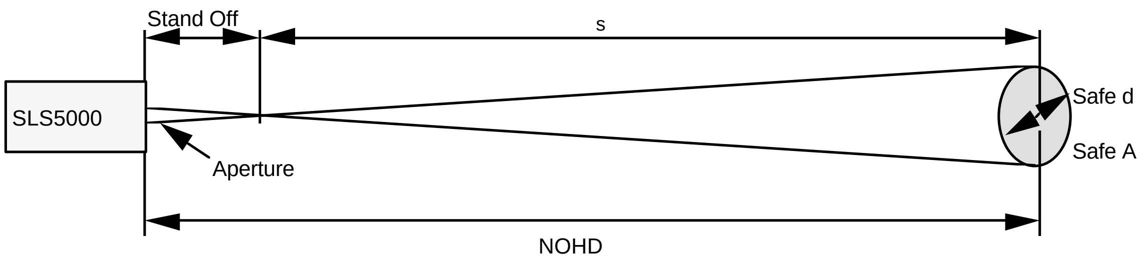


Figure 42: The safety distance, or the NOHD

NOHD = s+SO

APPENDIX D, Accessories

LMI Selcom can supply the following accessories:

- Additional cables
- Heat protected cables
- Air purge adapter
- Power supply
- Heat shield (temperatures < 750 °C)

APPENDIX E, SLS-asynch-1, protocol

General information

Baud rate	9600 baud	(RS-232)
	38400 baud	(RS-422)
Character length	8 LSBs	
Parity	None	
Start LSBs	1 LSB	
Stop LSBs	1 LSB	
HW handshake	None	
SW handshake	XON/XOFF	(RS-232, ASCII reply mode only)
Max update rate	50 Hz	(RS-232, ASCII reply mode)
	100 Hz	(RS-232, binary reply mode)
	1000 Hz	(RS-422)

The SLS sensor always operates as a slave, i.e. it never initiates a data transfer itself. All data transfers must be requested by an external device, referred to in the rest of this document as the *master*. The master can communicate with the SLS sensor either via RS-232 or RS-422. The RS-422 command set is a subset of the full RS-232 command set. RS-232 commands are always ASCII, whereas RS-422 commands are binary. The output from the SLS may be either ASCII or binary over RS-232 but is always binary over RS-422.

Definitions

Distance Value	The reply differs with the measurement unit that is used. The actual number of fractional digits (in the case of millimeters or inches) depends on the sensors scale factor.
Measurement Validity	The reply gives the validity of the signal as a percentage of the last 100 samples
Laser Intensity	The reply gives the laser intensity as a percentage of the maximum. The maximum is calibrated when the sensor is manufactured. A command for reading the actual laser power in milliwatts exists in RS232, ASCII reply mode (see section Laser Intensity).
Sensor Temperature	The reply gives the temperature in degrees Celsius. It is measured inside the sensor.

Conventions

The following conventions are used in this document:

nnnnn Groups of the letter **n** stand for integer numbers written with ASCII characters. The number of **n**'s indicate the maximum permitted number of characters. Fewer characters may be used.

Rrr.rrr Groups of the letter **r** stand for real numbers (i.e. numbers with an integer part and a fractional part) written with ASCII characters. The number of **r**'s to the left of the decimal point indicate the maximum permitted number of characters for the integer part, and the number of **r**'s to the right of the decimal point indicate the maximum number of characters for the fractional part. Fewer characters may be used, and the decimal point may be omitted if it is not needed.

0xXX The notation **0xXX** indicates a binary byte value. The two following characters are in hexadecimal notation. **NOTE:** This is *not* an ASCII representation. For example, if a byte value is given as 0x41, only one character (one byte) will be sent, in this case the character 'A', and *not* the four characters '0', 'x', '4', '1'. Where successive bytes refer to different types of data, they are distinguished by the notation **0xXX**, **0xYY** etc.

0xXXXX The notation **0xXXXX** indicates a binary word value. It is transmitted as two characters (bytes) with the most significant byte first. Where successive words refer to different types of data, they are distinguished by using the notation **0xXXXX**, **0xYYYY** etc.

ASCII Commands and Replies (RS-232)

Command and Reply Structure

RS-232 commands and replies are structured as follows:

Every command sent from the master must be preceded by a ”dollar” character ($).

Every command sent from the master must be terminated by a ”greater than” character (>). This terminating character will be referred to as the *prompter* in the rest of this document.

There will be no output from the SLS sensor until the prompter has been received.

Between the leading ”dollar” character and the prompter comes the actual command. It consists of a command character (always an uppercase letter) and possibly a numerical parameter, depending on the command. The commands belonging to the batch class described in section Batch Commands may be concatenated in a single command, so that there may be up to four command characters at the same time.

The SLS sensor outputs a prompter as soon as it is ready to process commands after power on. No commands may be issued by the master until it has received this initial prompter.

Replies from the SLS sensor always start with the command character and end with the prompter. In between there may be data, depending on the command. There is no initial ”dollar” character in the reply.

The master may not output a new command until it has received a prompter back from the SLS sensor in response to the previous command.

Illegal commands, commands whose parameters are outside the legal range, and commands which contain more characters than the maximum (12 characters) will be rejected by the SLS sensor.

Batch Commands

The ”Distance Value”, ”Measurement Validity”, ”Laser Intensity” and ”Probe Temperature” commands all take a parameter **nnnnn**, which determines how many values the SLS sensor should transmit. The data transmitted as a result of such a command is referred to as a *batch* in the rest of this document. These four commands may also be concatenated into a single command. In this case they may appear in any order, but they must precede the **nnnnn** parameter. The parameter applies equally to all the data types in the command (i.e. it is not possible to ask for one number of distance values and another number of temperature values).

Distance Value:

Command: **$Dnnnnn>** (msm unit = LSBs)

Reply: **Dnnnn>**

Drrr.rrr> (msm unit = millimeters)

Drr.rrrrr> (msm unit = inches)

This command causes the SLS sensor to transmit a number of distance values. The number of values is determined by the parameter **nnnnn**. The maximum value that can be used is 65535. A parameter value of 0 causes the SLS sensor to transmit distance values continuously until it receives another batch command.

The reply to this command differs with the measurement unit that is used. The actual number of fractional digits (in the case of millimeters or inches) depends on the probe's scale factor. The numbers shown here represent the maximum.

Measurement Validity (%)

Command: **$Vnnnnn>**

Reply: **Vnnn>**

The parameter **nnnnn** works the same as for the "Distance Value" command.

Laser Intensity (percent of maximum)

Command: **$Innnnn>**

Reply: **Innn>**

The parameter **nnnnn** works the same as for the "Distance Value" command.

Sensor Temperature (°C)

Command: **$Tnnnnn>**

Reply: **T+nn** / **T-nn**

The parameter **nnnnn** works the same as for the "Distance Value" command.

Examples

Command: **$DITV200>**

Reply: **DnnnnVnnnInnnT+nn>DnnnnVnnnInnnT+nn>** (200 repetitions)

This command causes the SLS sensor to send 200 groups of values, where each group contains one distance value, one validity value, one intensity value and one temperature value. The example shows LSBs as measurement unit.

Note:

Although the command letters were given in the order D, I, T, V in this example, the SLS sensor always replies with the values ordered D, V, I, T.

Command: **$D0>**

Reply: **Dr.rr>Dr.rr>** .... (Repeated continuously)

This command causes the SLS sensor to send distance values continuously, until a new command is received. The example shows millimeters or inches as measurement unit.

Single commands

All commands except the four described in section Batch Commands will only cause a single reply from the SLS sensor. They cannot be concatenated but must be given individually.

Laser Intensity (milliwatts)

Command: **$W>**

Reply: **Wr.rr>**

Laser On / Off

Command: **$L1>** (laser on)

$L0> (laser off)

Reply: **L1>**

L0>

Set Averaging Factor / Filter Cutoff Frequency

Command: **$Annnn>**

Reply: **Annnn>** (**nnnn** same as in command)

The current SLS sensor software employs an averaging filter. In this case the parameter **nnnn** determines how many samples should be included in every average. Any number between 1 and 1024 may be given.

Set Output Rate For Batch Data

Command: **$Bnnn>**

Reply: **Bnnn>** (**nnn** same as in command)

This command makes it possible to control the rate at which output is produced by the SLS sensor in response to a batch command. The parameter nnn is a divisor which is applied to the basic 100 Hz frequency used by the RS-232 communication routines. In ASCII reply mode the highest possible output rate is 50 Hz, so **nnn** may not be lower than 2. The limitation to three characters means that the highest legal value is 999, giving an output rate of about 0.1 Hz, or one value every 10 seconds.

Synchronize (reset filter)

Command: **$S>**

Reply: **S>**

This command causes the SLS sensor to restart its filtering cycle from scratch. It may be used to ensure that several probes are in sync with each other.

Set Nominal Value (for calibration)

Command:	**$Nnnnn>**	(measurement unit = LSBs)
	$Nrrr.rrr>	(measurement unit = millimeters)
	$Nrr.rrrrr>	(measurement unit = inches)
Reply:	**Nnnnn>**	(**nnnn** same as in command)
	Nrrr.rrr>	(**rrr.rrr** same as in command)
	Nrr.rrrrr>	(**rr.rrrrr** same as in command)

This command is used to set a nominal value to be used at a subsequent calibration (see section Calibrate).

Calibrate

Command:	**$C>**	
Reply:	**C1>**	(calibration was OK) (calibration failed)
	C0>	

The SLS sensor can be calibrated against a reference if, for example, it is desired to measure thickness of an object. The reference object should be in place and its thickness should have been given to the probe with the ”Nominal Value” command before the calibration is started.

Example:

An SLS sensor is set up to measure the thickness of steel plates (in millimeters). The plates rest on a flat surface while they are measured. A calibration piece with the known thickness of 50 mm is used. First, the Nominal Value command is given:

$N50.0>

The SLS sensor replies:

N50.0>

Then the calibration piece is put in place, and the Calibration command is given:

$C>

The SLS sensor replies:

C1> (presuming that the calibration was OK)

After this, the SLS sensor will present the actual thickness in mm of every plate that passes.

Reset Calibration

Command: **$R>**

Reply: **R>**

This command resets the offsets calculated by a calibration to zero.

Parameter Setup

Command: **$P>**

Reply: **PWD>**

This command is used to enter a setup menu, where some of the SLS sensor's internal parameters can be modified. This is an interactive menu, which demands the use of an ANSI terminal (or a PC running an ANSI terminal emulation program). Before the setup menu is shown, the user must enter the password after the **PWD>** reply from the probe.

Command: **$SELCAT>**

Parameter:	**Options:**	**Keyb:**
Measurement Units:	LSBs/Millimeters/Inches	Tab-key
Protocol Type:	ASCII/Binary	Tab-key
Interface:	Selcom/RS-422	Tab-key
Samples Per Average:	1 - 1024	Num. Keys + Enter
Valid threshold (%)	10 - 90	Num. Keys + Enter
Analog Output On Invalid:	Hold Latest Valid/Output Zero	Tab-key
F1 = Save And Exit		F1
F2 = Save Do Not Exit		F2
F3 = Exit Do Not Save		F3

Illegal commands

Command: **$Q>** (as an *example* of an illegal command)

Reply:

All commands, which are illegal, have parameters with values outside the legal range, or contain too many characters (more than 12) will be rejected by the SLS sensor and cause the reply shown above.

Binary replies (RS-232)

The SLS sensor can be set up to give binary replies over RS-232. The primary reason for using this mode would be to speed up the data transfers and to make the master's job easier in decoding the SLS sensor's output. Only a subset of the commands described in section Conventions can be used with binary replies. For instance, it would be impossible or at least rather complicated to transmit a fractional value in binary mode.

Note:

Only the replies are binary. The commands sent by the master to the SLS sensors are the same as in ASCII reply mode.

Reply structure

In binary mode the reply to each command has a leading identifier, which consists of one byte, but there is no trailing prompter. In the replies to batch commands only one identifier is output for the whole batch, i.e. no identifying byte is prefixed to each data item. This means that the master must keep a correct count of received bytes in order to decode data properly and to know when the next command can be sent. This is especially important in the batch commands where large amounts of data, with different types of data intermixed, may occur.

Batch Commands

The batch commands can be used in binary mode. If two or more commands are concatenated, the identifier bytes are ORed together in the reply to allow the master to check that the SLS sensor understood the command correctly.

Distance Value

Command **$Dnnnnn>**

Reply: **0xE1 0xXXXX 0xYYYY 0xYYYY** ... (repeated nnnnn times)

This command can be used *only* if the measurement unit is LSBs. The first binary word after the identifier **0xE1** is the parameter **nnnnn** in binary form.

Measurement Validity (%)

Command: **$Vnnnnn>**

Reply: **0xE2 0xXXXX 0xYY 0xYY** ... (repeated nnnnn times)

The first binary word after the identifier **0xE2** is the parameter **nnnnn** in binary form.

Laser Intensity (percent of maximum)

Command: **$Innnnn>**

Reply: **0xE4 0xXXXX 0xYY 0xYY** ... (repeated nnnnn times)

The first binary word after the identifier **0xE4** is the parameter **nnnnn** in binary form.

Sensor Temperature (°C)

Command: **$Tnnnnn>**

Reply: **0xE8 0xXXXX 0xYY 0xYY** ... (repeated nnnnn times)

The first binary word after the identifier **0xE8** is the parameter **nnnnn** in binary form.

Examples

Command: **$DI100>**

Reply: **0xE5 0x0064 0xXXXX 0xYY 0xXXXX 0xYY**

(repeated 100 times)

This command requests 100 groups consisting of a distance and an intensity value. The identifier **0xE5** is the inclusive OR of **0xE1** (Distance) and **0xE4** (Intensity) and allows the master to check that the command was properly understood. **0x0064** is the data count, being the binary word equivalent to 100. After these items there will come 100 groups consisting of one 2-byte distance value (**0xXXXX**) and one 1-byte intensity value (**0xYY**).

Command: **$DVIT1>**

Reply: **0xEF 0x0001 0xXXXX 0xYY 0xZZ 0xTT**

This command requests one group of data containing all four possible items. The identifier **0xEF** is the inclusive OR of **0xE1** (Distance), **0xE2** (Validity), **0xE4** (Intensity) and **0xE8** (Temperature). **0x0001** is of course the data count (1), **0xXXXX** is the distance value, **0xYY** is the validity, **0xZZ** the intensity and **0xTT** the temperature.

Single Commands

Laser On / Off

Command: **$L1>** (laser on)

$L0> (laser off)

Reply: **0x71** (laser on)

0x70 (laser off)

Averaging Factor / Filter Cutoff Frequency

Command: **$Annnn>**

Reply: **0xA0 0xXXXX**

The first binary word after the identifier **0xA0** is the parameter **nnnn** in binary form.

Set Output Rate For Batch Data

Command: **$Bnnn>**

Reply: **0xB0 0xXX**

The first binary byte after the identifier **0xB0** is the parameter **nnn** in binary form. The parameter may be as low as 1 in binary reply mode, giving an output rate of 100 Hz.

Synchronize (reset filter)

Command: **$S>**

Reply: **0x90**

Set Nominal Value (for calibration)

Command: **$Nnnnn>** (measurement unit = LSBs)

Reply: **0x80 0xXXXX**

This command can be used *only* if the measurement unit is LSBs. The first binary word after the identifier **0x80** is the parameter **nnnn** in binary form.

Calibrate

Command: **$C>**

Reply: **0xC1** (calibration was OK)

0xC0 (calibration failed)

Reset Calibration

Command: **$R>**

Reply: **0xD0**

Illegal commands

Command: **$Q>** (as an *example* of an illegal command)

Reply: **0xFF**

Binary commands and replies (RS-422)

Both commands and replies sent over RS-422 are binary. The command set is basically a subset of the RS-232 ASCII command set, but there is also a special command for requesting a batch of distance values with single laser intensity and probe temperature values added at the end of the batch. This command has no counterpart in the RS-232 command set and is included for backward compatibility with a specific software version.

Command and Reply Structure

The RS-422 commands and replies are not structured in any special way. It is in the nature of binary communication that any byte value may occur as data, and therefore it is not possible to set aside certain values for exclusive use as prompters, command indicators etc. Instead, it is of *vital importance* that both the master and the SLS sensor keeps a correct byte count in order to interpret commands and replies correctly.

The SLS sensor will not output anything over the RS-422 lines on power up.

Batch Commands

If more two or more commands are concatenated, the identifier bytes are ORed together in the reply to allow the master to check that the SLS sensor understood the command correctly.

Distance Value

Command: **0xE1 0xXXXX**

Reply: **0xE1 0xXXXX 0xYYYY 0xYYYY** ... (repeated 0xXXXX times)

This command will report measurement values in LSBs, and without any calibration offset applied. The command works even if a measurement unit other than LSBs has been entered in the setup. The first binary word after the command identifier **0xE1** is the number of data items to be transmitted in the batch. The maximum is 0xFFFF (65535 values) and the minimum is 0x0001 (1 value). If the parameter is 0x0000, data will be transmitted continuously until the next batch command is received.

Measurement Validity (%)

Command: **0xE2 0xXXXX**

Reply: **0xE2 0xXXXX 0xYY 0xYY** ... (repeated 0xXXXX times)

The parameter 0xXXXX works the same as for the ”Distance Value” command.

Laser Intensity (percent of maximum)

Command: **0xE4 0xXXXX**

Reply: **0xE4 0xXXXX 0xYY 0xYY** ... (repeated 0xXXXX times)

The parameter 0xXXXX works the same as for the ”Distance Value” command.

Sensor Temperature (°C)

Command: **0xE8 0xXXXX**

Reply: **0xE8 0xXXXX 0xYY 0xYY** ... (repeated 0xXXXX times)

The parameter 0xXXXX works the same as for the ”Distance Value” command.

Special Batch

Command: **0xF0 0xXXXX**

Reply: **0xF1 0xYYYY** .. (repeated 0xXXXX times) **0xZZ 0xTT**

This command requests a batch of 0xXXXX distance values followed by one laser intensity and one temperature value. Note that the reply identifier in this case is not identical to the command identifier. This is for backward compatibility reasons. A parameter value of 0x0000 cannot be used with this command and would in any case be useless (this would in effect be equivalent to the command 0xE1 0x0000).

Note : For compatibility, the count parameter is NOT included in the reply of this command.

Examples

Command: **0xE3 0x0100**

Reply: **0xE3 0x0100 0xXXXX 0xYY 0xXXXX 0xYY**

(repeated 256 times)

This command requests 256 groups consisting of a distance and a validity value. The identifier **0xE3** is the inclusive OR of **0xE1** (Distance) and **0xE2** (Validity) and allows the master to check that the command was properly understood. **0x0100** is the data count, being the binary word equivalent to 256. After these items there will come 256 groups consisting of one 2-byte distance value (**0xXXXX**) and one 1-byte validity value (**0xYY**).

Command: **0xF0 0x2710**

Reply: **0xF1 0xXXXX** (repeated 10000 times) **0xYY 0xTT**

This command requests a batch of 10000 (0x2710) distance values followed by one laser intensity and one temperature value.

Single Commands

Laser On / Off

Command: **0x71** (laser on)

0x70 (laser off)

Reply: **0x71** (laser on)

0x70 (laser off)

Averaging Factor / Filter Cutoff Frequency

Command: **0xA0 0xXXXX**

Reply: **0xA0 0xXXXX**

Set Output Rate For Batch Data

Command: **0xB0 0xXXXX**

Reply: **0xB0 0xXXXX**

The first binary word after the command identifier **0xB0** is a divisor which is applied to the 16 kHz sampling frequency. It may take on any value between 0x0010 (16) and 0xFFFF (65535), inclusive. This gives output rates from 1000 Hz to 0.244 Hz (one value every 4 seconds).

Synchronize (reset filter)

Command: **0x90**

Reply: **0x90**

Illegal Commands

Command: **0x33** (as an *example* of an illegal command)

Reply: **0xFF**

APPENDIX F, SLS power unit 24

The SLS Power unit 24 can supply one or two SLS sensor sensors.

The customer must provide a power cable of suitable length, fitting the power receptacle.

Demands on additional cables to the sensor(s) or to registration equipment according to chapter 4.2, Cable requirements.

Front panel:

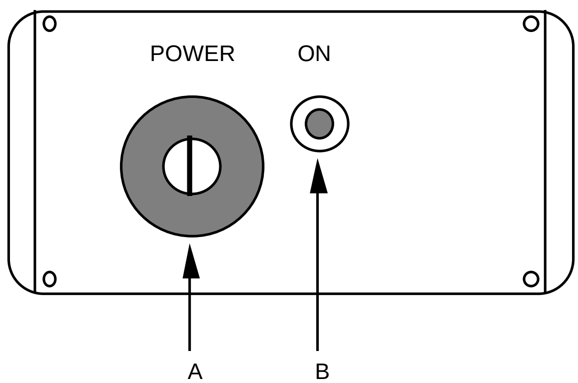


Figure 43: Front panel

A Key switch. The key is removable when power is off

B Power ON LED. Illuminated when power is turned on. Color: Green.

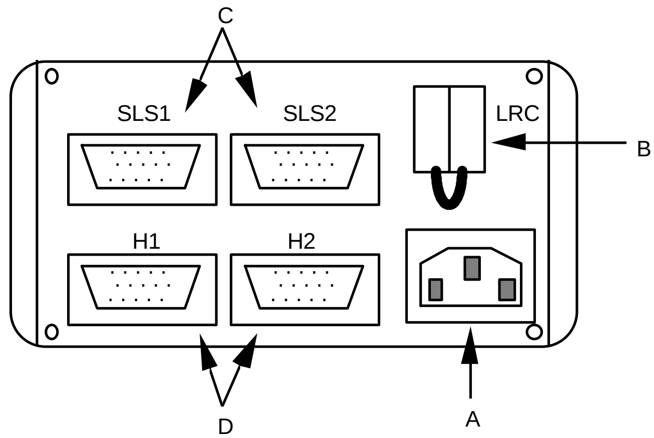


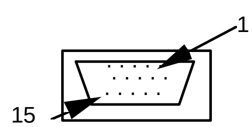
Figure 44: Rear panel

A Power receptacle

B Laser Remote Control, LRC connector Screw terminal with a jumper controlling the LASER ON signal to both SLS1 and SLS2.The lasers are on if power is on AND the jumper or a remote switch is closed.

C Two SLS sensors connectors, SLS1 and SLS2. Socket connectors for easy connection of one or two SLS sensors with DSUBmin connectors.

Front view, DSUB-15 pin, socket connector
SLS Powerbox 24
connectors SLS1 and SLS2



1 Receive data, RS232-C
9 Transmit data, RS232-C

3 CLOCK, SELCOM interface or RS422 Rx+
4 CLOCK-inv, SELCOM interface or RS422 Rx-
5 DATA, SELCOM interface or RS422 Tx+
6 DATA-inv, SELCOM interface or RS422 Tx-

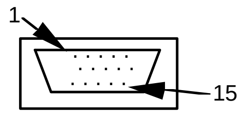
8 Invalid out-, (when analog interface is used)
12 Invalid out + , (when analog interface is used)
13 Analog out

11 Ground
14 Laser ON, (+24 VDC)
15 Power, (+24 VDC)

Figure 45: SLS1 and SLS2 connector pin configuration

D Two output connectors, H1 and H2.Pin connectors with capacity to output all signals available from the SLS sensor.

Front view, DSUB-15 pin, pin connector SLS Powerbox 24
connectors H1 and H2



1 Receive data, RS232-C
9 Transmit data, RS232-C

3 CLOCK, SELCOM interface or RS422 Rx+
4 CLOCK-inv, SELCOM interface or RS422 Rx-
5 DATA, SELCOM interface or RS422 Tx+
6 DATA-inv, SELCOM interface or RS422 Tx-

8 Invalid out-, (when analog interface is used)
12 Invalid out + , (when analog interface is used)
13 Analog out

11 Ground

Figure 46: H1 and H2 connector pin configuration

Technical specification:
Dimensions:

Length:	218.6 mm	(8.5 inches)
Height:	62.8 mm	(2.5 inches)
Width:	143.7 mm	(5.6 inches)
Weight:	1.4 kg	(3.1 lbs)

Environmental conditions:
Protection class: IP50 NEMA 1
Temperature:

Operating:	0-50 °C	(32-120°F)
Storage:	-30-70 °C	(-20-160°F)

Power requirements:
Input voltage: 110/230 VAC (± 10 %)
Line frequency: 50/60 Hz
Power consumption: 40 W (50 W peak at startup)

APPENDIX G, Quality Record

The Quality Record is delivered together with every sensor from LMI Selcom. Its purpose is to present the most important data about the sensor in a compact way. More information about different aspects of the Quality Record information, such as laser safety, specifications etc. are available in the relevant manual sections. This appendix is just intended as a quick reference.

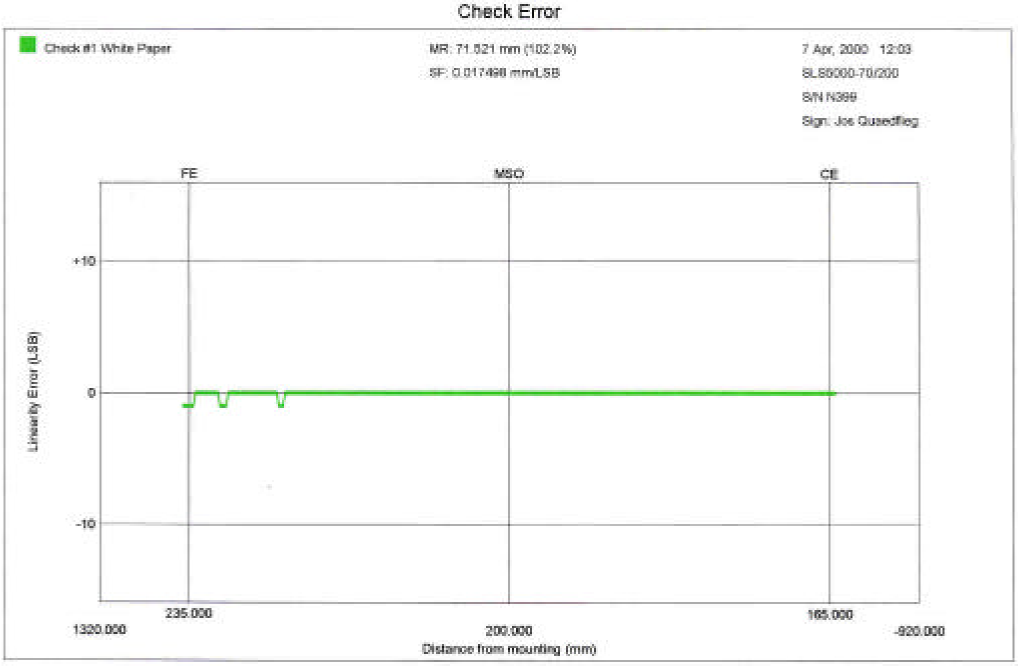
LMI Selcom
MEASUREMENT & CONTROL

QUALITY RECORD

NOTE: A general description of the Quality Record, as well as explanations for terms and abbreviations, can be found in the Optocator/SLS5000 User's Manual, appendix G.

Sensor Info	Sensor type:	SLS5000-70/200-SW	Date:	7 Apr, 2000
	Part number:	808617	Operator:	Jos Quaedflieg
	Serial number:	N399	Signature:	
Parameters	Measurement Range:	70.0 mm (-0% / +2.4%)	Sampling frequency:	16 kHz
	Mounting Stand-Off:	200.0 mm (± 4.0 mm)	Bandwidth:	2 kHz
	Scale Factor:	0.017500 mm/LSB (± 1‰)		
	Output(s):	Selcom / 0 - 20 mA / RS-232		
	Special tests:	☒ Not required	☐ Required; have been carried out	
Laser Safety	Max average power:	4 mW		
	Wavelength:	675 nm (Visible Red)		
	Safety distance:	4.5 m (according to EN60825 and IEC825)		
	Emission delay:	Power ON		

Check Error



Top part

The top part of the Quality Record page is devoted to text information. It is subdivided into sections which group related parameters together. The following list explains what each parameter means.

Section ”Sensor Info”

Sensor type:	The sensor’s official type designation.
Part number:	LMI Selcom’s internal part number.
Serial number:	The serial number of this particular sensor.
Date:	The date when the Quality Record was printed.
Operator:	The name of the person who was responsible for preparing this sensor for delivery.
Signature:	The operator’s personal signature.

Section ”Parameters”

Measurement Range:	The ***nominal*** Measurement Range for the sensor type. The actual Measurement Range for each individual sensor may be different from the nominal value by as much as shown by the tolerance indication in parenthesis.
Mounting Standoff:	The ***nominal*** Mounting Stand-Off for the sensor type. The actual Mounting Stand-Off for each individual sensor may be different from the nominal value by as much as shown by the tolerance indication in parenthesis.
Scale Factor:	The ***nominal*** Scale Factor for the sensor type. The actual Scale Factor for each individual sensor may be different from the nominal value by as much as shown by the tolerance indication in parenthesis.
Outputs:	The output interfaces available in this sensor. Optocators always have just one output (the ”Selcom” output). SLS sensors have multiple outputs: RS-232, one out of two different analog outputs, and one out of either the ”Selcom” or RS-422. See section **Explanations** below for

	information about these different interfaces.

Sampling Frequency:	The basic rate of raw data collection in this sensor (see **Explanations** section below).
Bandwidth:	The analog bandwidth of this sensor.
Special tests:	Some sensor types for specific applications must be put through special tests, which are not compulsory for all sensors. The operator must check one of these two boxes to indicate whether such tests are required, and if so that they have been carried out.

Section ”Laser Safety”

Max average power:	The laser in LMI Selcom’s sensors is a pulsed type, i.e. it emits pulses of very brief duration and is shut off in between. This number indicates the maximum power if the pulses are averaged over time.
Wavelength:	The laser emits light of a single wavelength, given in nanometers. There is an indication in parenthesis, which tells whether light at this particular wavelength is visible (see **Explanations** section below).
Safety distance:	The laser light always has a certain divergence, which makes the energy density decrease as the distance from the laser increases. At a certain distance, the energy density falls below the level where a direct exposure can cause damage to the human eye. How this distance is defined and how it should be calculated is specified in international standards EN60825 and IEC825. The number here is calculated according to these standards. Control logic inside the sensor will prevent output of more than normal working power. A faulty or damaged sensor may however exceed this level of output power. The safety distance for a faulty sensor will never exceed the safety distance calculated.

Emission delay:	Selcom's sensors can be equipped with two different types of emission delay. One (called **Laser ON** delay) will always cause a short delay every time the laser control signal is turned on, before the laser actually starts emitting laser light. The other type (called **Power ON** delay) will only cause a delay when the sensor is first powered up. All subsequent cycling of the laser control signal will control the laser without any delays.

Explanations:

The **"Selcom" output** is a proprietary synchronous serial output. It uses a clock and a data signal; with the clock only running while data is being transmitted. Each data item is 16 bits.

RS-232 and **RS-422** are standard asynchronous serial interfaces.

The **analog output** from the SLS sensors can be configured either for 4 - 20 mA or 0-20 mA operation.

Sampling frequency and **bandwidth** are related but not identical quantities. The sampling frequency tells how often the sensor evaluates the raw analog signal by performing an A/D conversion. The bandwidth value tells how that analog signal is conditioned before the A/D conversion. In order to avoid certain signal processing problems, the bandwidth has to be lower than the sampling frequency (it may not exceed 50% of the sampling frequency), and for that reason the signal is put through an analog filter stage before the A/D conversion. Although it is not a theoretically correct way to express it, one might say that the bandwidth determines how fast a measurement signal may change, and have the change detected by the sensor.

The **wavelength** of a laser is important for two reasons:

You need to know if you want to purchase protective equipment (goggles).

It determines if the light spot can be detected by human eyesight. This is an important safety factor, because invisible radiation obviously constitutes a danger to people who are not aware of its presence.

The lasers used by LMI Selcom are classed as ***visible***, ***near-visible IR*** (infra-red) or ***invisible IR***. The near-visible IR class needs some further explanation. At these wavelengths, the laser light spot is visible under favorable circumstances, i.e. output near the laser's maximum, low ambient light, and a suitable surface, e.g. a piece of blue paper.

Bottom Part

The bottom part of the Quality Record shows a diagram, which is generated during the linearization procedure. Every sensor goes through the linearization process, because the raw signal from the detector is non-linear due to optical geometry and reproduction errors. In the linearization process, a translation table is constructed and stored in non-volatile memory inside the sensor. When the sensor measures, the raw data values are used as addresses into the table, and the output consists of the data from those addresses.

Using a moving target, and simultaneously reading data from the sensor and a reference scale, which gives the target’s position with great accuracy, makes the linearization. The target material is white paper, which is a ”neutral” material in terms of light reflection and dispersal.

The diagram shows the result from a check (on the same white paper target), which is made after the translation table, has been installed in the sensor. The ideal result is a perfectly flat graph on the zero line. In practice there are always a few small deviations, because of noise from the sensor. The important thing is that the general ”trend” of the line is horizontal, i.e. that the scale factor is correct.

The linearization as well as the linearity check is both made with the ”Selcom” interface.

The target’s distance (in millimeters) from the sensor’s mounting surface is shown in the diagram’s horizontal axis. On the vertical axis you can see the deviation from linearity in sensor LSBs. The size of one LSB (least significant bit) in millimeters is given by the sensor’s scale factor.

The scale factor that results from the check measurement is printed out explicitly in the upper part of the diagram. In the line above that one, you can see the Measurement Range that has been achieved, both in millimeters and as a percentage of the nominal Measurement Range.

The upper right corner of the diagram contains the date and time when the check was performed, the sensor type and serial number, and the name of the operator.

Service report

Please fill in the header and a description of the problem and send the form to LMI SELCOM together with your equipment

Customer : ______________________ **Date :** ______________________

Reported by : ______________________ Telephone : ______________________

Address : ______________________ Telefax : ______________________

______________________ Attention : LMI SELCOM Service Dep.

Equipment **Type** **S/N** **Description of the problem or symptoms**

☐ Repair and return

☐ Send us an estimate of the cost of repair and wait for our confirmation

Filled in by LMI SELCOM

Checked by :
....

Service check

Action

Action performed by :
....

Germany
finger GmbH & CO KG
Sapelloh 84
Sapelloh 84
Telephone : +49 (0) 5767 9602 0
Main:+49 (0) 5767 9602 0
email:info@finger-kg.de

USA
LMI SELCOM, INC
21666 Melrose
SOUTHFIELD MI 48075, USA
Telephone : +1 248 355 5900
Telefax : +1 248 355 3283

APPENDIX H, Dimensional drawings

APPENDIX I, Wide Spot Safety distance calculation

Assumptions and equations are in accordance with European standard EN60825: 1991 and American standard IEC 825. The following is an example of a calculation.

Laser safety class	3B	
Wave length	L	675 nm
Pulse frequency	f	16 kHz
Duty cycle		50 %
Pulse length	T	31.2 microsec
Laser diode power	P_{max}	30 mW
Max peak sensor power	P_{pmax}	20 mW
Max average sensor power	P_{smax}	10 mW
Aperture	a	5.4

The calculations are made as follows:

1. Calculate by using tables in the standards, the maximum permissible exposure (MPE) during a specified period of time.
2. Calculate the maximum energy in each pulse sent out by the sensor.
3. This energy must be distributed over an area to satisfy the MPE value.
4. The result stated is adjusted upwards compared to the calculations below.
5. The results

Maximum Permissible Exposure for a single pulse (MPE_S) at the cornea for direct exposure to laser radiation during $T= 31.2*10^{-6}$seconds is given by the equation (EN 60825:1991, table VI page 42):

$$MPE_S = \{t=T=31.2*10^{-6}\ s\}= 18 * t^{0.75}\ [J*m^{-2}]$$

$$MPE_S = 0.0075\ J*m^{-2}$$

During 1000 seconds $16*10^{+6}$ pulses are produced. The Maximum Permissible Exposure for the pulse train (MPE_t) must be reduced by a factor given by the equation (EN60825: 1991, §13.3.1):

$MPE_t=MPE_s*N^{-0.25}$

where N= number of pulses expected in an exposure = $16*10^{+6}$ pulses

MPE_t= 0.00012 $J*m^{-2}$

Energy in each pulse: H = P*T = $3.1*10^{-7}$ J

where **P** is:

P_{smax} for calculations according to standards (power losses due to mechanical constraints and optical transmission is estimated conservatively to 50 %)

This energy must be distributed over an area A to satisfy the MPE_t value:

$H/A=MPE_t$ => $A=H/MPE_t$

A= 0.0026 square meters

The laser spot has a rectangular form.

This results in a second-degree equation expressing the area as a function of the distance x in front of the sensor. At x = NOHD the MPE constraint is satisfied.

For details, please contact the laser safety officer at LMI Selcom.

As a consequence of some inaccuracy in numbers and sensor individuals, 20% is added on the hazard distance.

Part no	L mm	F kHz	Duty cycle	T µs	P_{max} mW	P_{pmax} mW	P_{smax} mW	A mm	SO mm	NOH m
812059	675	16	50%	31.2	30	20	10	5.4	300	2.0