KEYENCE

Laser Displacement Meter

LC series

Technical Manual

KEYENCE

LC SERIES
TECHNICAL MANUAL

CONTENTS

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1 SPECIFICATIONS

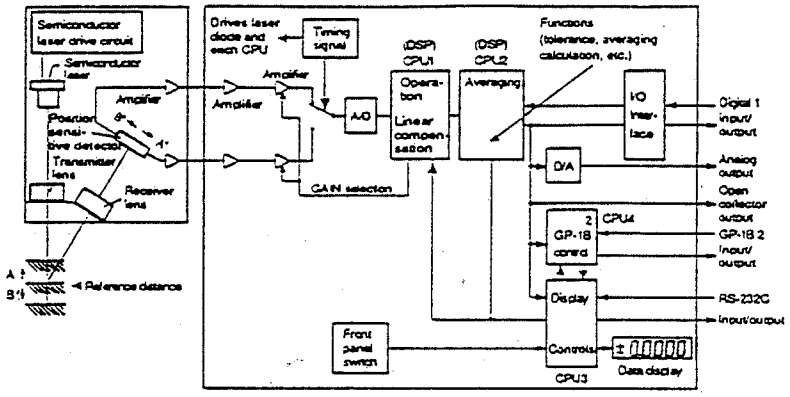
SPECIFICATIONS

Type			Standard		Long range	
Model		Sensor head	LC-2210	LC-2220	LC-2310	LC-2320
		Controller	LC-2100			
Measuring range			±3 mm		±8 mm	
Operating distance			30 mm		50 mm	
Reference distance			31 mm		51 mm	
Laser			Semiconductor laser			
		Wavelength	780 nm	670 nm (red)	780 nm	670 nm (red)
		Output	Max.: 3 mW Avg.: 1.5 mW	Max.: 1.9 mW Avg.: 950 μW	Max.: 3 mW Avg.: 1.5 mW	Max.: 1.9 mW Avg.: 950 μW
		Class	IIIb	II	IIIb	II
		Pulse duration (width)	12.5 μs			
Min./max. spot diameter			70 to 90 μm	110 to 140 μm	80 to 140 μm	140 to 230 μm
Resolution[1]			0.2 μm		0.5 μm	
Linearity[2]			±0.1% of F.S.			
Sampling frequency			40 kHz			
Response frequency			16 kHz (-3 dB; number of measurements for averaging: 1)			
Response time			100 μs			
Number of measurements for averaging			1 to 2.048 (12 levels switch-selectable)			
OFFSET range			±2.9998 mm		±7.9995 mm	
GAIN adjustment			AUTO/MANUAL (3 levels switch-selectable)			
Input		Digital displacement[3]	16-bit parallel/TTL level			
			1 LSB = 0.2 μm		1 LSB = 0.5 μm	
	Control	HOLD timing	Non-voltage input (contact, solid-state)			
		AUTO ZERO setting				
		LASER EMISSION CONTROL REMOTE				
Output		Digital displacement[4]	16-bit parallel, TTL level, NPN open-collector			
			1 LSB = 0.2 μm		1 LSB = 0.5 μm	
		Analog displacement[6]	±3 V/±3 mm (output impedance:0Ω)		±4 V/±8 mm (output impedance:0Ω)	
	Control	Upper/lower limit	NPN open-collector: 100 mA max. (30 V max.) Residual voltage: 1 V max.			
	Alarm	LIGHT INTENSITY				
		OVER AREA				
Interface		RS-232C	Displacement data output and external control input (baud rate: 75 to 19.200 bps selectable)			
		GP-IB	Displacement data output and external control input[6]			
Temperature fluctuation		Sensor head	±1.5 μm/°C			
		Controller	±0.1 μm/°C			
Power supply			85 to 264 VAC, 50/60 Hz			
Power consumption			45 VA max.			
Operating illumination			2,000 lux max.		1,000 lux max.	
Operating temperature			0 to +50°C	0 to +35°C	0 to +50°C	0 to +35°C
Operating humidity			35 to 85%RH (no condensation)			
Weight			Sensor head: 170 g Controller: 3,200 g			

1, 2: When using a white diffuse-reflective object as the target and the number of measurements for averaging set at 2,048.
3, 4, 6: Available as an option.
5. When OFFSET is set to '0'. (Output of ±6 V (LC-2210/2220) of ±8 V (LC-2310/2320), depending on OFFSET value.)
7. Incandescent or fluorescent lamp.

2. OPERATING PRINCIPLE

Operating principle



When a target moves (A or B in the figure above), the semiconductor laser beam spot (A' or B') moves accordingly on the position-sensitive detector in the sensor head. This spot displacement is then converted into a digital signal. After data processing, including linear compensation and averaging, the system displays and outputs the results.

1. Digital I/O board (optional) mounted.
2. GP-IB I/O board (optional) mounted.

3. RESOLUTION

a) Definition

- When the LC measures a target, there is a minute fluctuation in the displayed measurement value. This fluctuation occurs even if the target is motionless, and the range of the fluctuation is called the "resolution".
- In the case of the LC, the resolution is principally determined by the resolution of the position-sensitive detector (PSD) itself and level of noise occurring in the LC's internal circuit.
- The resolution specified in our catalog is the data obtained by measuring a white target 2048 times for averaging (optimal conditions for measurement). In the case of the LC-2100 controller, this resolution is designed to correspond to the display resolution (minimum unit of indication).

b) Factors that affect resolution

- The resolution also varies with different targets.
  Change in the intensity of light received or in the number of measurements for averaging affects the resolution.
- The resolution is degraded when the intensity of light received decreases, or when the number of measurements for averaging is decreased.
- For a better understanding of how much the resolution is affected by these factors, see Fig. 1 "Resolution vs. intensity of light received/number of measurement for averaging".

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LC2-TM-04

DATA SHEET

"Resolution vs. intensity of light received/ number of measurements for averaging" (typical)

Measuring conditions:

Target positioned at reference distance
Measurement mode: P-P mode

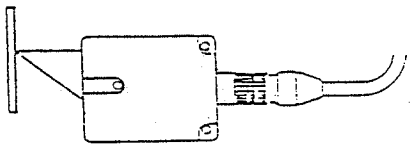
Controller : LC-2100

Sensor head: LC-2210/2220

Target Materials

No. 1	White paper	No. 5	Acrylic card (Orange)
No. 2	Acrylic card (white)	No. 6	Acrylic card (Opaline)
No. 3	Acrylic card (Ivory)	No. 7	Acrylic card (Brown)
No. 4	Acrylic card (Opaline)	No. 7	Acrylic card (Chocolate brown)

Schematic



LC

2210

Unit: μm

Work-piece No.	INTENSITY	Number of measurements for averaging											
		2048	1024	512	256	128	64	32	16	8	4	2	1
1	3690	0.2	0.2	0.4	0.6	0.6	0.8	1.0	1.4	2.0	2.8	4.0	5.6
2	2500	0.2	0.4	0.4	0.6	1.0	1.2	1.4	2.0	2.8	4.2	5.6	8.2
3	2090	0.2	0.4	0.6	0.6	1.0	1.2	1.6	2.4	3.4	5.0	7.0	9.6
4	1185	0.4	0.6	0.6	1.2	1.4	2.4	3.0	4.4	6.2	9.0	12.0	18.0
5	750	0.6	0.8	1.2	1.6	2.2	3.4	4.4	7.6	10.2	14.4	20.0	27.4
6	515	1.2	1.6	2.0	2.8	3.6	5.2	7.0	10.2	14.8	20.6	29.8	40.0
7	250	1.0	1.6	2.0	3.4	4.8	6.8	10.2	15.0	22.0	31.0	45.0	65.0
8	145	1.6	2.4	3.6	5.2	7.6	12.0	18.0	25.0	35.0	55.0	75.0	120.0

2220

Unit: μm

Work-piece No.	INTENSITY	Number of measurements for averaging											
		2048	1024	512	256	128	64	32	16	8	4	2	1
1	4770	0.2	0.2	0.4	0.4	0.6	0.8	1.0	1.4	2.0	3.0	4.4	5.6
2	3220	0.2	0.4	0.4	0.4	0.6	1.0	1.4	2.2	3.2	4.4	6.4	9.0
3	2720	0.2	0.4	0.6	0.6	0.8	1.2	1.6	2.4	3.6	5.2	7.4	10.4
4	1510	0.4	0.8	1.0	1.2	1.6	2.4	3.2	4.6	6.6	9.6	13.2	20.0
5	910	0.8	1.2	1.6	2.0	3.2	4.2	5.2	8.2	11.0	17.0	22.0	32.0
6	730	1.0	2.0	2.4	2.8	3.4	4.8	7.0	9.8	14.0	20.0	28.0	40.0
7	350	1.2	2.0	2.8	4.0	5.6	8.6	13.0	17.0	26.0	37.0	50.0	80.0
8	190	2.0	3.0	5.0	7.0	10.0	15.0	20.0	30.0	45.0	65.0	90.0	140.0

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LC2-TM-05

DATA SHEET

"Resolution vs. intensity of light received/ number of measurements for averaging" (typical)

Measuring conditions:

Target positioned at reference distance
Measurement mode: P-P mode

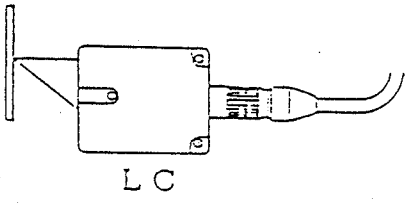
Controller : LC-2100

Sensor head: LC-2310/2320

Target Materials

No. 1 White paper
No. 2 Acrylic card (white)
No. 3 Acrylic card (Ivory)
No. 4 Acrylic card (Opaline)
No. 5 Acrylic card (Orange)
No. 6 Acrylic card (Opaline)
No. 7 Acrylic card (Brown)
No. 7 Acrylic card (Chocolate brown)

Schematic



2 3 1 0

Unit: μm

Work-piece No.	INTENSITY	Number of measurements for averaging											
		2048	1024	512	256	128	64	32	16	8	4	2	1
1	3550	0.5	0.5	1.0	1.0	1.5	2.5	3.5	5.0	7.5	10.0	15.0	20.0
2	2635	0.5	1.0	1.0	1.5	2.0	3.0	5.0	6.5	9.0	14.0	19.0	25.0
3	2230	1.0	1.0	1.5	2.0	2.5	4.0	6.0	8.0	12.0	16.0	24.0	30.0
4	1535	1.0	1.5	2.0	2.5	4.0	6.0	8.0	11.5	17.5	25.0	32.0	42.0
5	970	1.5	2.5	3.0	4.5	6.5	9.5	13.0	20.0	33.0	40.0	52.0	70.0
6	765	2.0	3.0	4.5	5.5	8.0	11.0	15.0	25.0	35.0	46.0	60.0	85.0
7	230	4.0	6.0	9.0	15.0	20.0	31.5	47.5	67.5	90.0	140.0	180.0	250.0
8	135	7.0	10.0	15.0	20.0	35.0	50.0	75.0	100.0	150.0	250.0	300.0	400.0

2 3 2 0

Unit: μm

Work-piece No.	INTENSITY	Number of measurements for averaging											
		2048	1024	512	256	128	64	32	16	8	4	2	1
1	4155	0.5	0.5	1.0	1.0	1.5	2.5	3.0	4.0	6.0	8.0	11.0	17.5
2	3305	0.5	1.0	1.0	1.5	1.5	2.5	3.5	5.0	7.0	10.0	15.0	20.0
3	2790	0.5	1.0	1.0	1.5	2.0	3.0	4.0	6.0	8.5	13.0	18.0	25.0
4	1860	1.0	1.5	1.5	2.0	3.0	4.5	6.5	9.0	13.0	19.5	26.0	38.0
5	1255	1.0	1.5	2.0	3.0	4.0	6.0	9.0	13.0	20.0	28.0	40.0	55.0
6	1190	1.5	2.0	2.5	3.0	4.5	7.0	11.0	15.0	21.5	31.5	42.0	60.0
7	290	3.0	5.0	7.0	11.0	15.5	23.0	35.0	50.0	75.0	110.0	160.0	230.0
8	170	5.0	8.0	13.0	20.0	25.0	40.0	60.0	90.0	130.0	190.0	250.0	400.0

c) Resolution when measuring moving target

- Resolution attained when measuring a moving target, as in the case of measuring unevenness on a metal surface, is different from that attained by measuring a stationary target. This is true when scanning a target by moving a sensor head.
- When measuring a moving target (or moving the sensor head), resolution will deteriorate due to factors affecting the intensity of light received, such as target color variation and unevenness or scratches in target surface. It is therefore recommended to perform a verification test for a specific job and to make relevant arrangements.

d) How to check resolution

- Securely position a target so that it is not affected by vibration. Set the number of measurements for averaging to the same number for the actual measurement.
- Press the MODE key once to set the mode to the P-P (peak to peak) MODE.
- Initiate measurement in the P-P MODE and, after a few seconds, a certain value appears on the LC-2100's display. This is the resolution.
- Press the HOLD key twice to reset the display. Repeat this procedure to confirm the resolution.

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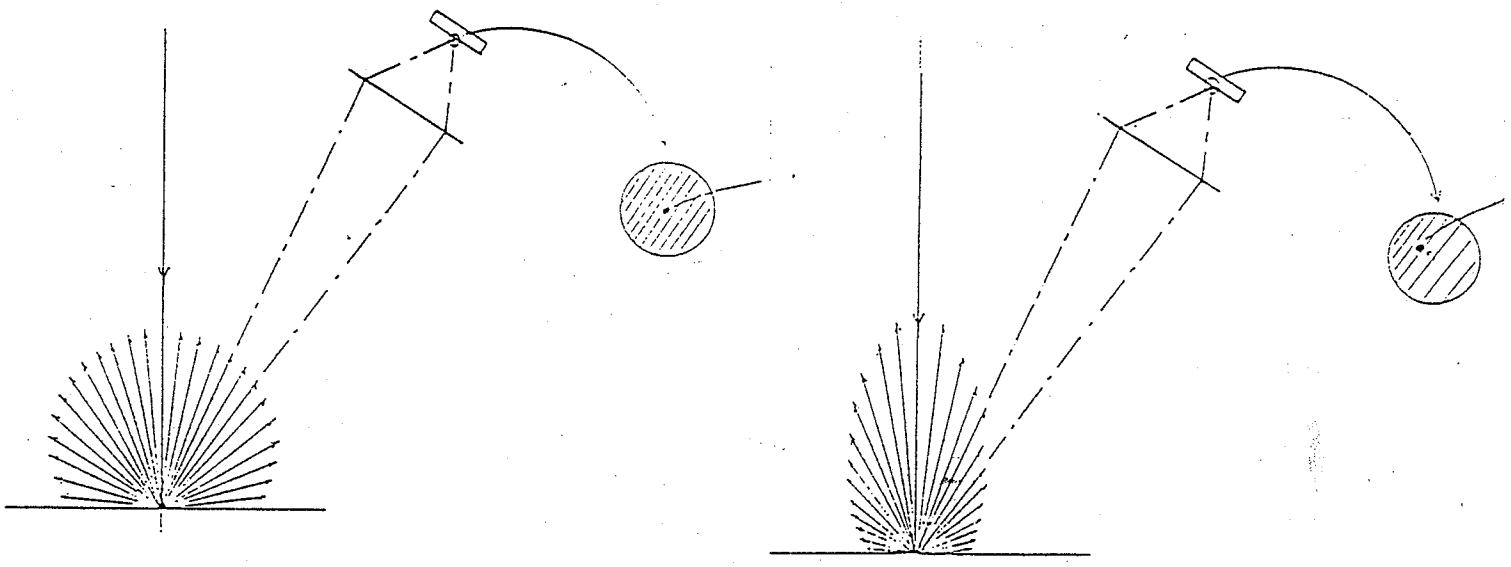
4 LINEARITY

a) Meaning of "±0.1% of F.S."

- The F.S. (full scale) represents an overall measurement range, which is 6 mm on the LC-2210/2220, and 16 mm on the LC-2310/2320.
- Accordingly, the linearity of the LC-2210/2220 and LC-2310/2320 is ±6 μm and ±16 μm, respectively.
- As in the case of resolution, these values are those obtained by measuring a white target 2048 times for averaging.

b) Factors that affect linearity

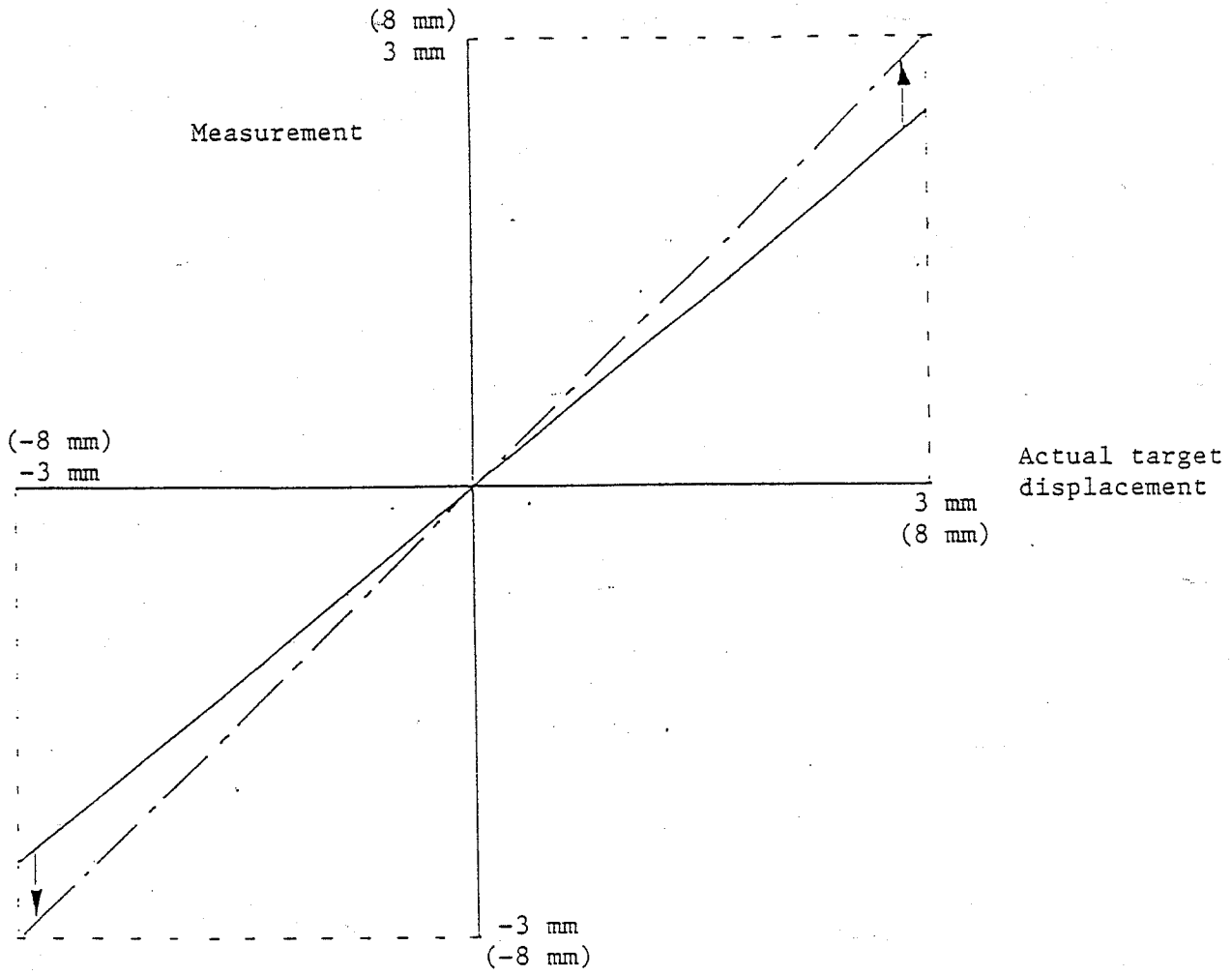
- The linearity varies with different targets.
- This is because not only the intensity of received light varies, but also high- and low-intensity areas occur on an individual beam spot on the PSD with different targets.
- The PSD outputs a current in proportion to the distance from the beam spot center to both ends of the PSD. Non-uniform light intensity in a beam spot focused on the PSD causes the PSD to output an inappropriate current level as if the beam spot is in a different position, since the weighted center of the beam spot is shifted.



5. CALIBRATION

a) Objective of calibration

- A different target will reflect a laser beam differently, and the sensor may fail to attain the measuring accuracy that was achieved with the standard target.
- The purpose of calibration is to obtain the same measuring accuracy as with the standard target by correcting the sensor using an actual target.



b) Purpose of entering numeral for calibration

- When measuring the displacement of a standard target with the factory-calibrated LC2 sensor, the LC-2210/2220 will output "+3.000" for a target displacement of 3 mm, and the LC-2310/2320 will output "+8.000" for a target displacement of 8 mm to the display of the controller. This means, with a standard target, the actual displacement corresponds to the measurement at a ratio of 1:1.
- If, for example, the LC-2210/2220 displays "+2.9000" relative to an actual displacement of +3 mm, the sensor must be calibrated by entering "+3.1034" as a calibration set value. This value can be determined using the following formula:

$$\text{Calibration set value} = \frac{\text{actual displacement} \times 3\ \text{mm}}{\text{displayed measurement value}}$$

Thus,

$$\frac{3\ \text{mm}}{2.9\ \text{mm}} \times 3\ \text{mm} = 3.1034$$

9 GAIN

a) Meaning of GAIN

- The electric signal outputted from the PSD is weak, and cannot be directly processed by the CPU.
- Therefore, an amplified signal is fed into the CPU.
- The intensity of the signal varies according to the intensity of the light received. Accordingly, the system uses a larger amplification factor for a weaker signal (smaller intensity of light received), and uses a smaller factor for a stronger signal (larger intensity of light received).
- The GAIN selection means the change in the amplification factor.

b) Selection between AUTO GAIN and MANUAL GAIN

- Usually, the LC series sensor is used in the AUTO GAIN mode. In this mode, the sensor automatically selects an appropriate gain, thus optimizing the amplification. However, measurements may vary by 1 to 2 μm, when the GAIN is switched from one to the other.
- When measuring a target whose reflection corresponds to the border between two adjacent GAIN ranges, specify the GAIN range setting in the MANUAL mode.
- When setting the GAIN range in the MANUAL mode, select one range for higher light intensity.

Note: The GAIN range used for measuring a white object is GAIN2.

10. AUTO ZERO INPUT/RESET

a) AUTO ZERO INPUT/RESET and time required

- The pulse duration for enabling the cancelling of the AUTO ZERO mode is 6.4 msec. or longer.
- If the AUTO ZERO INPUT (or RESET) signal is inputted immediately after the AUTO ZERO RESET (or AUTO ZERO INPUT) signal, the time interval between the two input signals must be 380 msec. or longer.
- Also, after the entry of the AUTO ZERO RESET signal, a minimum of 319.6 msec. is required before the indication on the LC-2100 controller turns to zero.

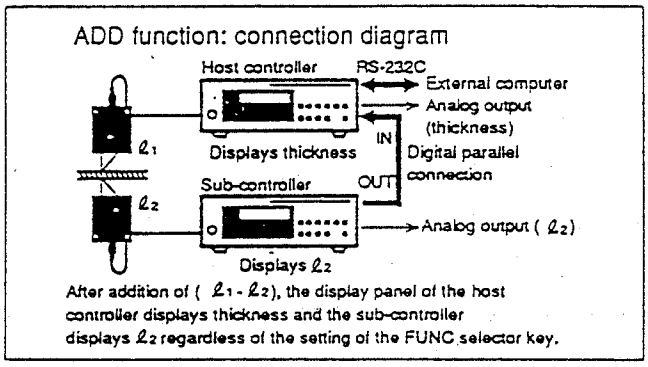
b) AUTO ZERO and moving target

- While the sensor is measuring a moving target, the AUTO ZERO INPUT should not be entered. This is because the LC-2100's internal circuit processes the AUTO ZERO INPUT based on a measurement obtained through a period that starts 160 msec. ahead of the entry, and, therefore, change of the measurement caused by the movement of the target results in incorrect zero setting.

11. THICKNESS MEASUREMENT WITH ADD FUNCTION

a) Measurement procedure

1. Prepare a measurement sample whose thickness is known. The sample (hereinafter, referred to as the master) must be the same as those actually processed.
2. Position the two sensor heads so that the top and bottom surfaces of the master are in the operation range of the upper and lower sensor heads, respectively.



Note: Be sure that both sensor heads can be micro-adjusted by, for example, attaching each sensor head to a spindle of a micrometer, so that they can be repositioned for calibration or product changeover.

3. Calibrate the sensor with the master.
   Note: Do not yet use the ADD function.
4. Adjust the position of the sensor heads so that both displays on the host controller and sub-controller turn to "0.0000" (±10 μm).
5. Select the ADD function by pressing the FUNC selector key.
6. Press the ZERO key on the sub-controller, and then press the ZERO key on the host controller. This will turn the indication on the host controller to "0.0000".

Note: At this point, the display of the sub-controller indicates the displacement of the target surface measured by the sub-sensor head (bottom surface of the target in the previous diagram). The host controller displays the difference of thickness between the master and the current target.
For measuring the thickness difference only relative to the master, the adjustment is completed.

7. For displaying the absolute thickness of the target, enter the thickness of the master using the OFFSET function on the host controller.
Note: Since the maximum offset value is 2.9998 mm with the LC-2210/2220, and 7.9995 mm with the LC-2310/2320, the sensor cannot measure an absolute thickness greater than that. For measuring a thickness exceeding the above, contact KEYENCE.

b) Important notes

- While measuring, the effect of vibration to the target should be minimized. Also, the target should not be tilted.
- Align the optical axes (beam spots) of the two sensor heads.
Set the same number of measurements for averaging on the host controller and sub-controller.

Note: The appropriate number of measurements for averaging varies depending on the output to be used: analog output, open collector output, RS-232C output, digital output or GP-IB output. For correct setting, contact KEYENCE.

c) Resolution and linearity in ADD function

- This section discusses the resolution and linearity when two LC sensor systems are used in ADD function.
- The resolution and linearity of the sub-controller are the same as when the controller is used independently.
- Regarding the host controller, both the resolution and linearity are the sum total of that of the two controllers. This is because the host controller processes (adds) the two measurement values.

12 NOTES FOR EXTENDING LC SENSOR CABLE

1. The LC2100 controller requires readjustment when used with a long cable. For this purpose, send the controller and sensor head to KEYENCE.
2. For the LC-2220/2320, a special sensor head optional is available for use with a 10 m long cable.
   Note that the standard sensor head is not compatible with this cable. Again, send the controller to KEYENCE for readjustment.
3. For more details, contact KEYENCE.

CONTROLLER

Type	Model
For 5m-cable sensor Head	LC-2100 SO(8102)
For 10m-cable sensor Head	LC-2100 SO(8108)

Note: When using an optional interface (GP-1B or Digital I/O interface), contact KEYENCE for cable extention.

SENSOR HEAD

Type	Model
5 m cable	LC-2210
	LC-2220
	LC-2310
	LC-2320
10 m cable	LC-2220 SO (8109)
	LC-2320 SO (8110)
	LC-2210 SO (8111)
	LC-2310 SO (8112)

CONNECTION CABLE

Type	Model
5 m	OP-90648
10 m	OP-91865

Note: For further information including adjustment fee, contact KEYENCE.