Calibration of an Optical Sensor

Jimmy H. Daruwalla
Sidwell Friends School

Advanced Adventures in Science

Under the Supervision of
Dr. Nicholas G. Dagalakis
Intelligent Systems Division
National Institute of Standards and Technology

March 9th, 2001

Abstract

An inexpensive optical reflective sensor was evaluated for possible use as a precision proximity sensor. The output signal of the sensor was measured as a function of the distance of a flat reflecting surface from the front glass window of the sensor. The experimental data support the hypothesis that the sensor may be used as a precision proximity sensor.

Key words: proximity sensor, precision sensor, inexpensive sensor, optical sensor

Introduction

Proximity sensors have been used to determine distances between two objects. During everyday technological experiments in precision engineering, a need for an inexpensive but accurate proximity sensor has arisen. I have tested to see if an inexpensive sensor currently used for scanning barcodes will be able to stand up to the needs of precision engineers today.

This idea was first proposed by Dr. Lowell Howard, when he was still working for the Precision Engineering Division (PED) of the National Institute of Standards and Technology (NIST). Dr. Howard also built the sensor signal conditioning electronics used in my experiment.

Hypothesis

The 655 nm Precision Optical Reflective Sensor manufactured by Agilent Technologies [1] under the trade name HEDS-1500[1] can be used for precision proximity sensing.

---

[1] HEDS-1500 is a trademark of Agilent Technologies. This and certain commercial products are identified in this paper to specify experimental procedures adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the products identified are necessarily the best available for the purpose.

Background

Non-contact distance measurement is very important for precision manufacturing operations. The most commonly used sensors for this type of operations are laser interferometers and capacitance gages. Both of these sensors are expensive and bulky. For example, a good capacitance sensor can cost from $2,000 and up. Opto-electronic reflective sensors are inexpensive and are built in very small sizes. For example, the HEDS-1500 with its signal conditioning electronics is estimated to cost around $200, for small quantity purchases. This is an order of magnitude decrease in cost.

Experimental Setup

Figure 1 shows a picture of the basic experimental setup. It consists of a differential micrometer bolted on a vibration isolation table (on the left side in the picture) and the optical sensor that is being calibrated (on the right side in the picture). Not shown in this picture is a digital oscilloscope that was used to measure the output voltage from the signal conditioning unit of the optical sensor. The Excel program was used to tabulate and plot the data.

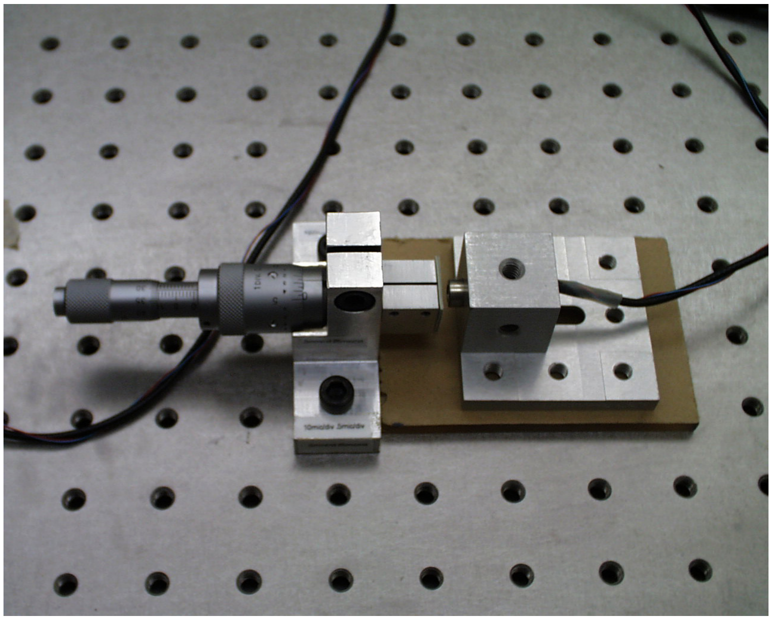

Figure 1. Basic experimental setup

Optical Sensor

The optical sensor I have used for this test is manufactured by Agilent Technologies. It is used for many things like bar code scanning, pattern recognition, paper edge locating, etc. The sensor works by emitting a red light from its built in LED. The light reflects off a surface and is read by a photo-detector. Figure 2 shows a schematic cross section of the HEDS-1500 reflective sensor. The module contains a visible LED emitter and a matched photo-detector diode. A bifurcated aspheric lens is used to image the emitted light to a spot 4.27 mm in front of the package. A glass window covers the front of the module and constitutes the reference plane for the measurement of the proximity distance to the reflecting surface. The output signal of the photo-diode is a current, which is amplified and filtered by the signal conditioning electronics to generate the output signal used during the calibration tests.

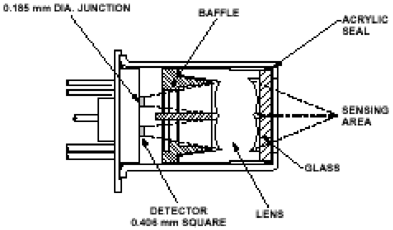

Figure 2. HEDS-1500 reflective sensor

Micrometer

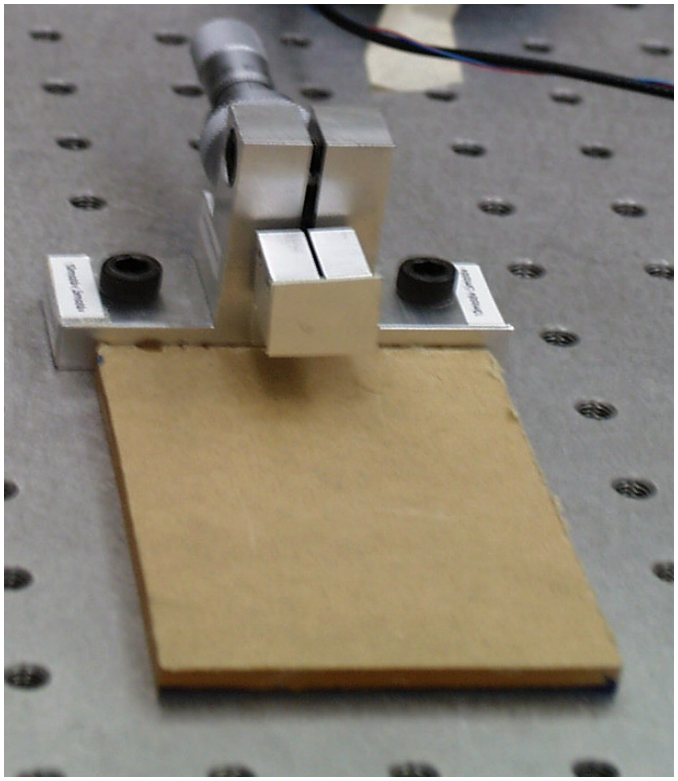

Figure 3. The differential micro-meter with the target cube

Because very minute displacements are being used in this experiment, moving surfaces to and from the sensor by hand would be extremely inaccurate. So a micrometer is used to move the surface, a target metal cube, away from the sensor. Figure 3 shows a picture of the micro-meter with the target cube mounted at the tip of its stem. This micrometer has the capability to move the cube at fine and coarse increments. The fine increment resolution is 0.5 μm/division and the coarse increment resolution is 10 μm/division. A specially designed mount holds the micro-meter firmly ancored on the surface of a vibration isolation table. The target cube moving surface is covered by aluminum adhesive tape. The optical sensor with its mount are positioned on a plastic spacing plate, which is free to move on the surface of the table.

Oscilloscope

A Nicolet Oscilloscope is a basic scope that reads the output from the signal conditioning unit of the sensor and projects it onto the screen, telling us the exact output level, in terms of millivolts.

Test Procedure

1. First, I set up the instruments and positioned them as shown before in the Experiment setup.
2. Then, with the cube and optical sensor touching, I began to move the cube away from the sensor using first the fine controls on the micrometer at .5 μm increments. After I had reached a distance of 25 μm I switched to the micro-meter coarse control thumb-screw and moved at larger increments of 500 μm.
3. Then I recorded the voltage output displayed on the Nicolet Scope. This is the voltage output of the sensor at that particular distance from the cube.
4. I repeated steps 2-3 until I reached the micrometer's limit of retraction at 11,000 μm.
5. I then plotted the results on a graph as shown next.

6. After the first plot of the data the test was repeated, but this time I concentrated on the segment from 3000 μm to 3500 μm distance and I used smaller increments of 100 μm in order to obtain a finer resolution plot.

Test Results

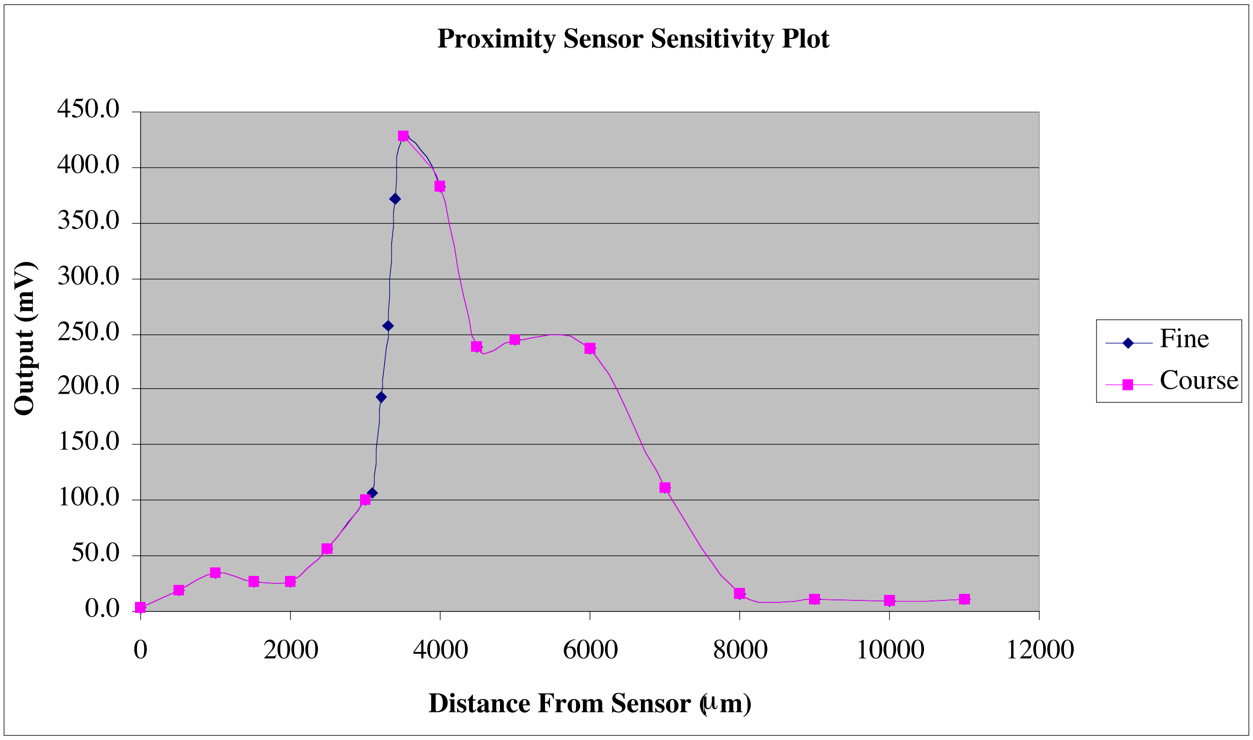

Figure 4. Test results plot

The results are plotted on the graph shown here. Coarse is the graph that we first plotted. On this graph we noted the point of interest, a linear segment in the graph. This is a point of interest because a linear output is needed for the sensor to be an affective proximity sensor. We then preformed more tests focused on that particular segment and plotted the results as shown in Fine. The test data are provided in the Appendix. The sensitivity of the sensor in the fine test segment is also given in the Appendix.

Conclusions

Because of time limitations only the data given in the Appendix could be collected. Although this is a very limited set of data they do suggest that, as shown in the sensitivity plot, there is one section of the graph, between 3000 μm and 3500 μm, where the plot is approximately linear. This shows that, between those two distances, the optical sensor may be used as a proximity sensor. At other distances, the optical sensor can also be used as a proximity sensor, but the ouput will have to be matched with the distance at every point using a look up table.

References

1. Agilent Technologies, <**www.semiconductor.agilent.com**>.

Appendix

Coarse Displacement Test Results:

Micrometer Displacement in µm	Output Voltage in mV
0	3.4
500	19.0
1000	35.0
1500	27.0
2000	26.0
2500	56.5
3000	100.0
3500	427.5
4000	382.0
4500	238.0
5000	244.0
6000	236.0
7000	112.0
8000	15.0
9000	10.5
10000	10.0
11000	11.0

Fine Displacement Test Results:

Micrometer Displacement in µm	Output Voltage in mV	Sensitivity in mV/ µm
3100	107	
3200	193.5	0.865
3300	257	0.635
3400	371	1.140
	Average	0.880