LABORATORY STAND FOR INVESTIGATION OF OPTOELECTRONIC MEASUREMET DEVICES WITH CMOS IMAGE SENSORS AND PROGRAMMABLE LOGIC

Todor Djamiykov, Nikolay Nenov

Department of Electronics, Technical university, 8 Kliment Ohridski, 1756 Sofia, Bulgaria, phone: +359 2 965 32 69, e-mail: tsd@vmei.acad.bg nenov@mail.bg

Abstract

The proposed paper presents features of laboratory stand for investigation of optoelectronic measurement devices. Various methods for measurement of different parameters with high accuracy in real time are described. CMOS image sensor is used. For calculations in each measurement programmable logic is used. PLDs have great advantages in fast parallel processes. In the paper are described special features in realization of the stand. Other useful feature of the stand is visualization of the frames from image sensor directly on a monitor. The results of the calculations can be visualized on the same monitor, on separate display or sent to the computer. All image processing algorithms are implemented in XC3S400 FPGA.

Keywords: Measurement system, CMOS image sensor, Image processing, VHDL, Real-time applications,

1. Introduction

Laboratory stand for investigation of optoelectronic measurement devices was developed as a part of a project for assistance of the education in the university. The aim was to develop a flexible multifunctional stand with simple manipulation. To be useful in practice all calculations in the stand must be executed in real time. This condition put high requirements to the electronic components used in it. Programmable logic devices fit best to these requirements.

All measurements will be performed in the laboratory. This fact put some restrictions in realization of the stand. This also defines conditions during the measurements.

Base requirements to the stand are:

- work in a laboratory
- work in real time
- output the results on a monitor and display
- communications with a computer
- possibility for management of additional functional blocks according to the measurement task

2. Hardware description

Work in real time and complication of used algorithms put very strict requirements to the hardware. FPGA was used, because of its speed and advantages in parallel processes. FPGA XC3S400 by Xilinx is used. The firmware of the stand is written in VHDL with WebPack 6. Used sensor is CMOS image sensor. It is on separate module and this allows it to be changed. There is capability to be used three different sensors counted in Table 1:

Signature	Type	Resolution	Size	Manufacturer
OV7610	CMOS	640 x 480	1/3"	OmniVision
KAC-1648	CMOS	1200 x 1024	1/2"	Kodak
OV2610	CMOS	1600 x 1200	1/2"	OmniVision

Table 1 – List of supported sensors

The data for the frame in the image sensor is generated pixel by pixel and line by line. If it is necessary entire frame to be kept there is video RAM for one frame.

The structure of the stand is divided onto separate modules. This allows bigger flexibility and possibility for upgrade.

3. Description of the measurement tasks

Measurement tasks which our time realized are:

- measurement of plane coordinates of light spot
- measurement of distance
- measurement of dimensions (diameter, width, length)
- measurement of surface of object

The type of measurement task and settings are performed with a keyboard on the stand.

Short description of the measurement task is follow.

3.1. Measurement of plane coordinates of light spot

The block diagram of the system for measurement of plane coordinates is shown on Figure 1. The measured object is laser spot. The laser beam falls over the screen and optoelectronic system is orientated perpendicular to the screen. The aim is to equalize absolute object coordinates X, Y to relative coordinates X', Y' of the measurement system. The essence of the method is segmentation over the frame is obtained from the image sensor. After that COM (centre of mass) is calculated according to equations 1.

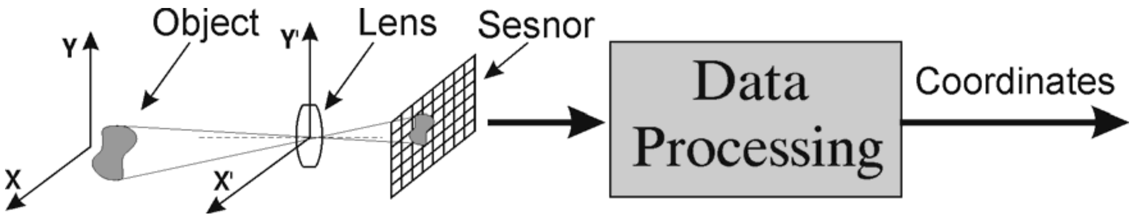

Figure 1: Block diagram of the system for object's coordinates measurement

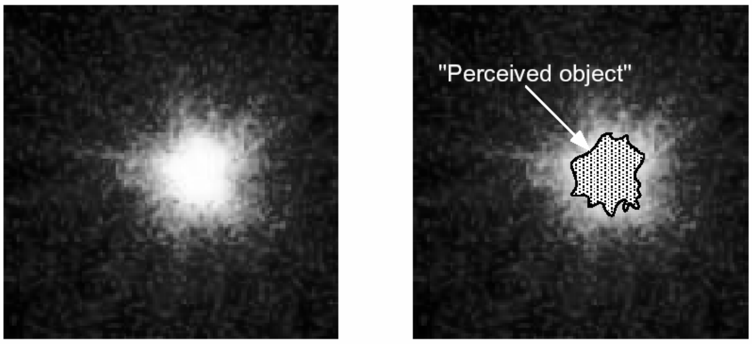

Figure 2: Segmentation over the frame from the image sensor

(1) $$Xc = \frac{\sum_{i=1}^{p} XiEi}{\sum_{i=1}^{p} Ei} \qquad Yc = \frac{\sum_{i=1}^{p} YiEi}{\sum_{i=1}^{p} Ei} \qquad Ec = \frac{\sum_{i=1}^{p} Ei}{p}$$

- Xc, Yc – |Coordinates of COM
- Ec – Average intensity of the object
- Xi, Yi, Ei – Coordinates and intensity of the current pixel
- p – Number of the pixels belong to the object

3.2. Measurement of distance

Common method for measurement of distance is triangular method. This method also uses projection of laser spot over surface. Laser beam is not perpendicular to the surface. If the distance is changed – position of the laser spot also changes i.e. the position of the laser spot is changed according to the distance between the screen and optoelectronic system. This is shown on Figure 3. According to the size of laboratory we consider that limitations for the measured distance are L

= 0,5÷5 m. Used method requires a screen for projection of the laser beam. Instead of screen some of the walls in the laboratory can be used.

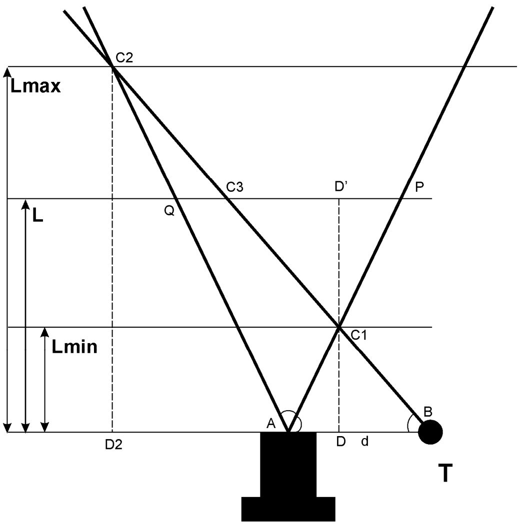

Figure 3: Triangular method for measurement of distance

The gap between the sensor and laser source is called base.

(2) $\angle C_1AC_3 = \xi$ - angle of view

(3) $\angle ABC_1 = \alpha$ - angle between the surface of the image sensor and laser beam

(4) $$\angle BAC_1 = \angle D_2AC_2 = \frac{180-\zeta}{2} = \beta$$

(5) $$L\min = d\frac{tg\alpha.tg\beta}{tg\alpha + tg\beta}$$ - minimum measured distance

(6) $$L\max = d\frac{\sin\alpha.\sin\beta}{\sin(180-\alpha-\beta)}$$ - maximum measured distance

(7) $$L = d\frac{QP.(L\max - L)tg\beta}{2.QC_3.L\max}$$ - distance between the image sensor and laser spot

3.3. Measurement of dimensions

The size of the object can be measured with the stand shown on Figure 4.

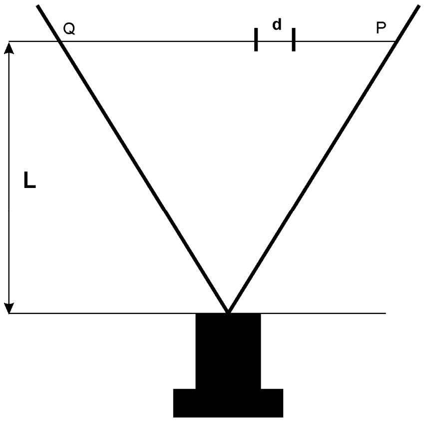

Figure 4: Measurement of the sizes

There is diffusion screen with backlight. It is situated on distance L away from the image sensor. Measured object makes shadow which falls over the image sensor. The size d is measured after segmentation over the image.

(8) $$d = QP.\frac{n_1}{n}$$

- n – resolution of the image sensor
- n_1 – number of overshadowed pixels
- QP – size of the viewed area

3.4. Measurement of surface of the object

This measurement also uses diffusion screen situated on the definite distance away from the image sensor – Figure 5.

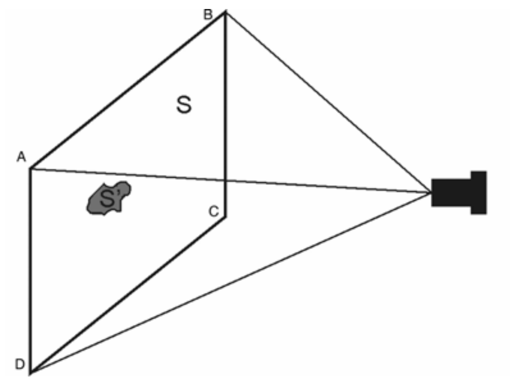

Figure 5: Measurement of surface of the object

Number of the pixels overshadowed by the object is:

(9) $q = \int_{x=n1}^{n2} \int_{y=p1}^{p2} dxdy$ - number of the pixels belong to the object

(10) S = AB.BC – size of the viewed area

(11) $S_1 = S \frac{q}{n.p}$, object' surface

- q – number of the overshadowed pixels in the image sensor
- n,p – resolution of the image sensor array
- S – size of the viewed area

4. Conclusion

This paper presented laboratory stand for investigation of optoelectronic measurements devices. It can be used in education of the students. It can be also used in the industry to perform specific tasks. In the stand are used contemporary electronic elements and technologies. This is precondition for high quality and accuracy in the measurements.

5. References

1. Hamblen J.O, *Rapid Prototyping of digital systems*, Kluwer Academic Publishers, Boston / Dordrecht / London, 2001.
2. OV7620 Product specifications – REV0.9 (10/19/99) Omnivision Technologies INC.
3. Roth C. H., *Digital system design using VHDL*, PWS Publishing Company 1997.
4. Smith S. W., *The scientist and engineer's guide to Digital Signal Processing*, California Technical Publishing / San Diego, 1999.