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# Design an Economic Portable Data Acquisition for Optical Tomography System using Embedded System

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***Abstract*— *This paper presents the development of a low cost, simple and accurate portable data acquisition for optical tomography system. To get precise outputs in data acquisition for optical tomography system, the basic required unit is Data Acquisition System (DAS). However, the finite of available equipment's that implement (DAS) for optical tomography makes it to be costly. In order to overcome this case, a low cost embedded system design can be used instead. Data acquisition of 128 x 64 pixels from Complementary Metal Oxide Semiconductor (CMOS) optical image sensor is controlled by the developed embedded system and then sent to Visual Basic Application display unit.*

***Keywords*— *Optical Tomography system, Data Acquisition, laser light, image sensor.*

## I. INTRODUCTION

Tomography technique has been used for system diagnosis in medical industries and then it get attention by another fields such as (agriculture and aerospace, petroleum, food) industry. The variety of Tomography system is related to both sensor type and the system determination purpose [1]. The chosen of sensor type is commonly depends on the feature of the analysed flow material. Furthermore, there are several factors like (the need of high speed processing, the availability of the overall system development resources, the digitizer accuracy and the cost), that help in the selection of the processing system. Regarding to the high necessity of sensor technology at any measurement system, therefore; it is important to select the sensor according to the measured properties. For instance, impedance sensor needs that the flow material to be electrically conducting, whereas capacitance sensor is convenient for non-conducting fluid flow. Generally, Tomography System consists of the following basic units as shown in Figure 1:

- sensor unit
- data acquisition system
- image reconstruction system
- display unit

The whole system is totally controlled by controller unit.

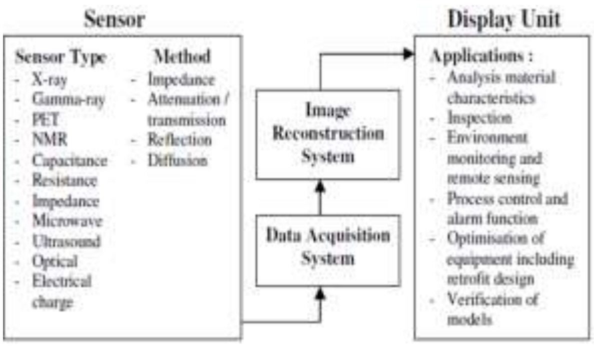


Fig. 1. Tomography Systems

Sensor unit is a component of light source and image sensor. Usually, laser or white light are used as light source. The proposed design has been used laser light source because of its features such as (monochromatic, less error, minimal deviation, and produces a collimated light about 1 mm in diameter as shown in Figure 2) [2].

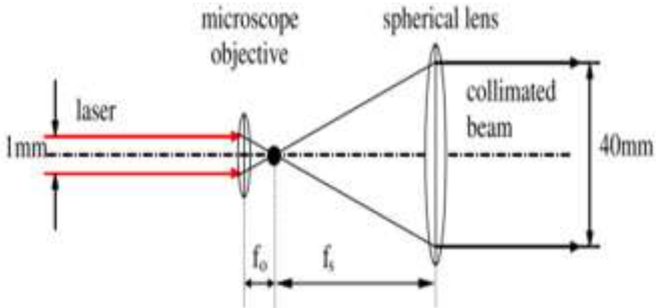


Fig. 2. Laser light

Complementary Metal Oxide Semiconductor (CMOS) or Charge-coupled Device (CCD) are used as image sensors. CMOS has many features that's made it more desirable in design like (low cost, less complexity, low power consumption) [5].

## II. DATA ACQUISITION

The most significant unit in tomography system is Data Acquisition System (DAS). The function of DAS is to analyze the signal that received from image sensor and convert it to data information to be sent to image reconstruction system. Comparing with the traditional single light projection, it was confirmed that fiber optic sensors can be used to fulfill the higher data acquisition rate [3]. The high cost of DAS related to two main reasons, the first one is the finite number of available equipment's that can implement efficient DAS optical tomography system and the second one is the growing demand of DAS. Most researchers, usually uses the available costly DAS and based on this condition, its necessary to find

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solution to overcome this situation by introduce a simple low cost design of DAS with aid of embedded system

## III. Controller Unit

The main function of controller unit is to program the majority of the system including: DAS, image reconstruction in addition to display unit system.

Moreover, the compilation of the whole optical tomography system is done by controller unit. Therefore; the controller unit considered as the core of the system and impacts on its feature regarding to the solution that offered to embedded system design. Previous work, have been used Field-Programmable Gate Array (FPGA) based system as controller unit that improves the whole system performance especially the speed of the system [4], but at the same time it increases the system cost significantly and for this purpose the need for simple and low cost was required. Embedded – based controller is a multifunctional and high flexible controller with several ready-use standard peripherals.

Among the high stability and inexpensive types of microprocessor is ARM design architecture which is vastly used in mobile phone processor. An LPC2103 ARM7 family has 8 KB on-chip static RAM with 32 KB on-chip flash program is convenient to be used in this work regarding to many reasons such as (mobility, flexibility, low cost, ability to be justified by several supporting peripherals which comes together in the chip and it considered as a compact system comparing with FPGA and computers).

## IV. Design Overview

This work has two implementation phases, hardware and software. System design consists of light laser, optical CMOS image sensor, ARM7microprocessor LPC2103, visual basic application and communication peripherals.

The whole system block diagram is shown in Figure 3

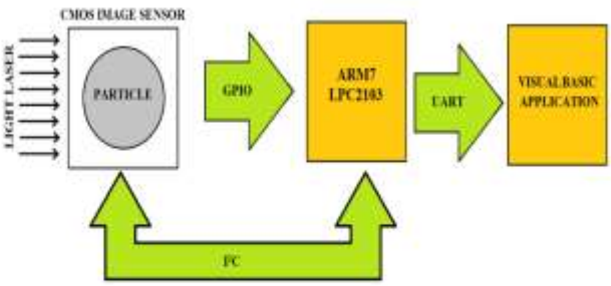


Fig. 3. System Block Diagram

### A. Hardware Implementation

Hardware design consist of (sensor, controller and display unit). In sensor unit, light laser will generate monochrome signal output signal to be detected by CMOS image sensor and converts it to 10 bits parallel digitize data. The selected CMOS image sensor is type MT9V034C12STM Aptina Corp and figure 4 shows its pin-out

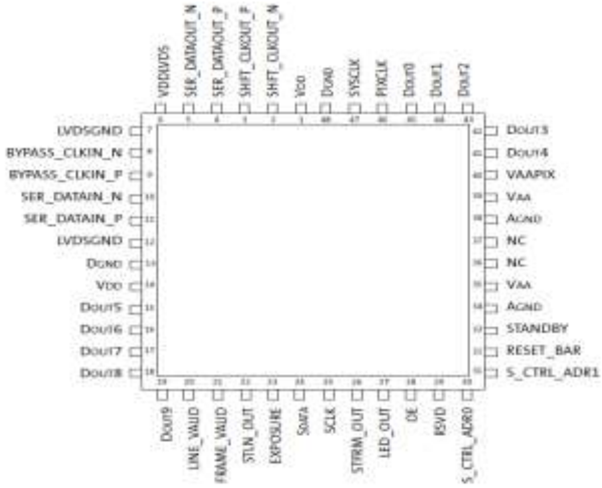


Fig. 4. CMOS (MT9V034C12STM) pin-out

Controller unit is responsible of system compilation including data sampling and processing in addition to interfacing and results display. An advanced microprocessor type LPC2103 ARM7 has been used as a controller and its operates with 5 volts DC and gets speed 8MHz of main clock which is suitable to interact with the selected CMOS image sensor type MT9V034C12STM. LPC2103 controller includes several peripherals such as Universal Asynchronous Receiver/ Transmitter (UART) and Inter-Integrated circuit $I^2C$ peripheral which are used for interfacing through pins (P0.0, P0.1) and (P0.2, P0.3) pins respectively. The connection with CMOS image sensor is through (P0.24, P0.25) pins. Figure 5 illustrates input-output pins for LPC2103 UNO32 controller.

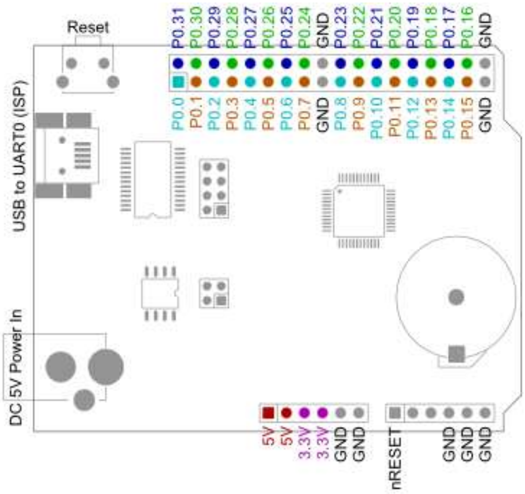


Fig. 5. Input-output pin for LPC2103

Display unit, represented by computer is connected to controller through UART, but adding chip FT232R to LPC2103 UNO32 board to support UART with USB converter and this technology will perform high security through saving unique number in each device through data assembling.

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### B. Software Implementation

The required communication peripherals are I2C, GPIO (General Purpose Input/output) and UART. I2C is used for MT9V034 image sensor setting by changing its register value. Enabling row and column binning features needs 2-wired serial interface bus using 16-bits sequences. When data transmission starts, a signal is sent to image sensor, then getting response through acknowledgment (AKC) signal from image sensor and then the controller will send the required amended register address for both column and row binning. After getting another (AKC), the controller will sent a set of 16-bits data to setup column and row binning features. At the end of this process, the controller will end the communication by sending STOP signal. MT9V034 image sensor produces 4 types of outputs signals such as (PIXCLK, LINE_VALID (LV), FRAME_VALID (FV) and DOUT) which are connected to the controller as shown in figure 6.

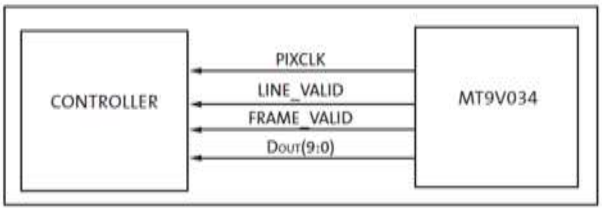

Fig. 6. Output signals of image sensor

PIXCLK is an invert of sensor master clock. LINE_VALID (LV) is an indicator for row pixel, so a single row of output data pixel (DOUT) with completed cycle of (LV) will be generated when MT9V034 image sensor is take an image. FRAME_VALID (FV) is an indicator for complete image capturing. When LV is 1, then a 10- bit of valid pixel of DOUT is confirmed in each PIXCLK duration as illustrated in figure 7.

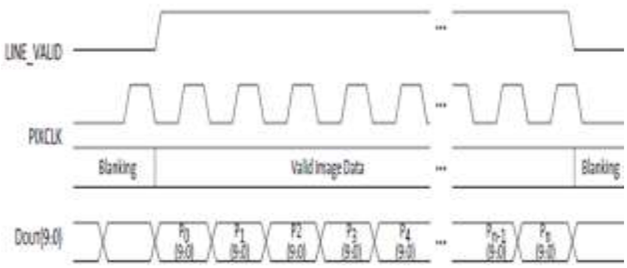

Fig. 7. Output signals timing diagram

The process of data sampling is started by initializing controller, image sensor MT9V034C12STM register and UART peripheral. LPC2103 controller will be in waiting state for (U) character that send from visual basic application and after starting, LPC2103 will start sampling output pixel then data output sampling to 128 x 64 resolution will start after confirming new FV. The sampled data will be saved into memory. Figure 8 shows the flowchart of this algorithm.

Regarding to monochrome color chart, the received data from image sensor will be performed within range (0-225) as shown in figure 9.

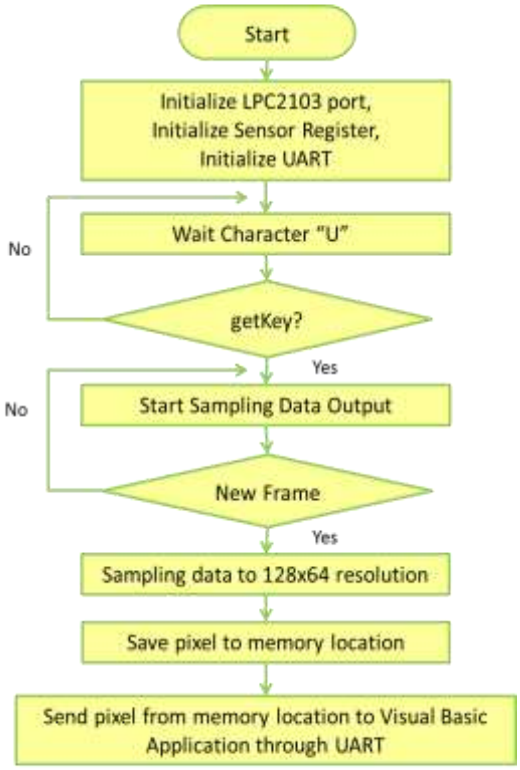

Fig. 8. Data sampling flowchart

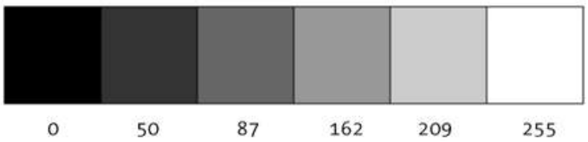

Fig. 9. Essential monochrome color chart

Graphic User Interface (GUI) is used to display the completed image frame. GUI application has been developed by visual basic programing so that it can integrate computer with controller. GUI output window allows to choose CMOS ports and taken time in addition to many other options such as calculating packets and pixels number that have been received from CMOS sensor. Row output pixel value can be exported into excel file by clicking on export bottom as shown in figure 10.

Fig. 10. GUI application window

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## V. Results and Discussion

The main objective of this work is to design an economical and simple Data Acquisition System (DAS) which is consist of sensor, controller and display unit. The basic function of DAS is sampling row data that received from optical image sensor and display them by GUI application. Various states of sensor were tested (uncovered, fully covered, right covered, top covered and cross covered) by covering CMOS with dark paperboard and each state was done under two lightening conditions, the first one in normal light environment and the second one using light laser. Figure 11 indicates the uncovered state and it was noticed that output displayed image using light laser was pure white while in normal light was close to gray and that's because of shadow detection by image sensor where as in fully covered state, the image was same because the sensor was totally covered with black paper. The right covered state is to show row pixel sampling and as indicated in figure 12, while top covered state to show column pixel sampling as shown in figure 13. It is clearly noticed that the object's shape that has been displayed in visual basic application in not clear due to shadow detection. Cross covered state handles row and column pixel sampling as shown in figure 14.

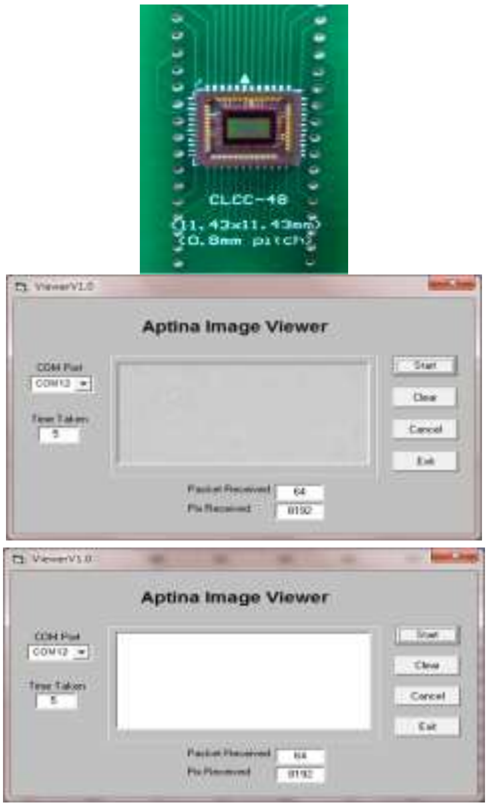

Fig. 11. Uncovered state

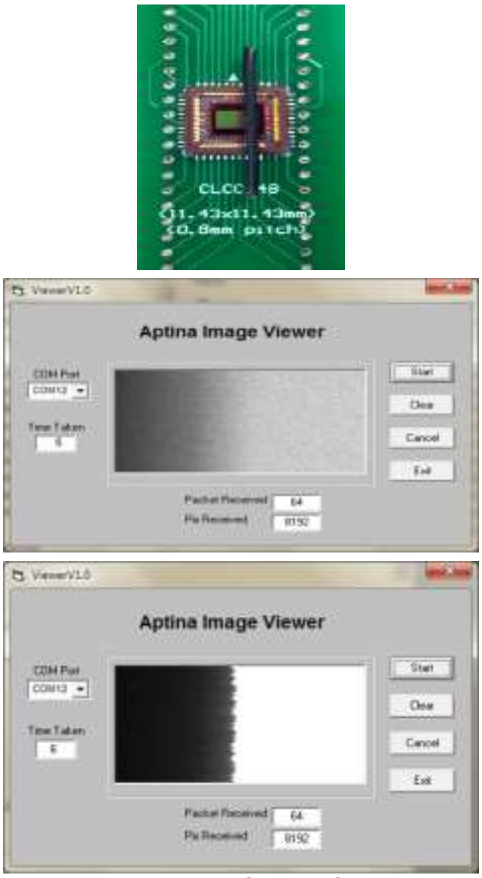

Fig. 12. Right Covered state

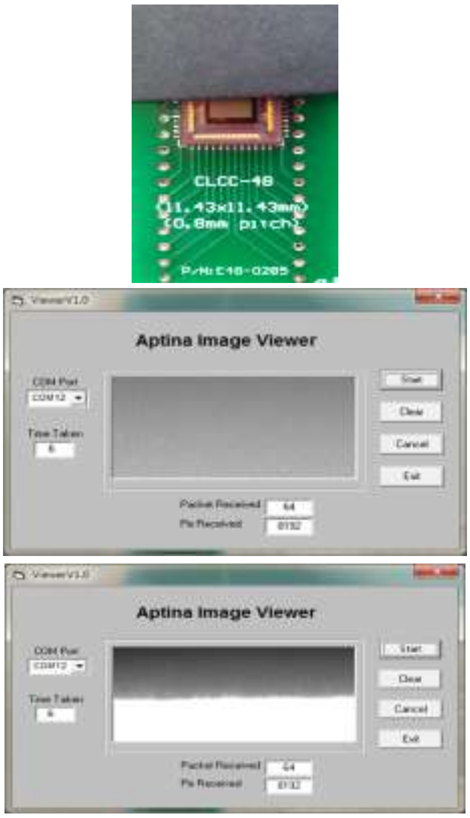

Fig. 13. Top Covered state

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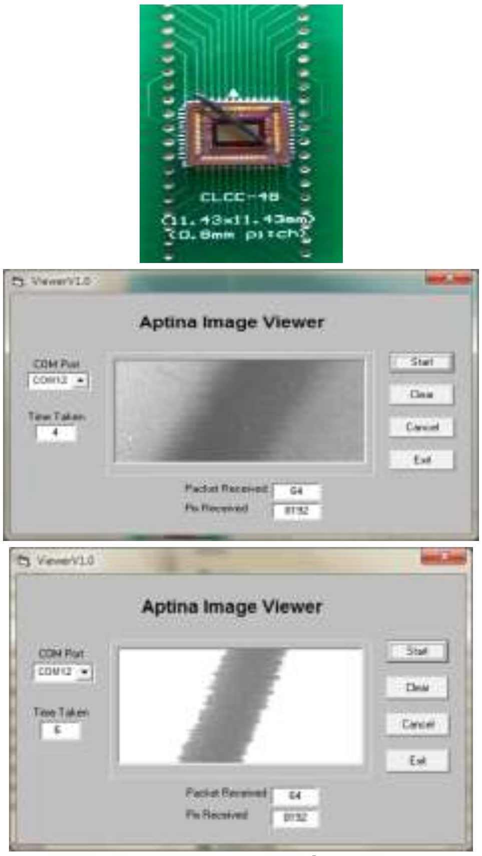


Fig. 14. Cross Covered state

## VI. CONCLUSION

The objective of this work have been reached through introducing a developed low cost and simple Data Acquisition System (DAS) for optical tomography system. Data acquisition of 128 x 64 pixels with Complementary Metal Oxide Semiconductor (CMOS) optical image sensor is controlled by the developed embedded system and then sent to Visual Basic Application display unit using Graphic User Interface (GUI). Several tests have been done under various condition of CMOS image sensors under two lightening conditions and it was found that the images were more accurate using light laser and the overall system cost didn't exceed 85 USD comparing with the available DAS in the markets that starts from 299 USD to 850 USD based on eBay website.

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