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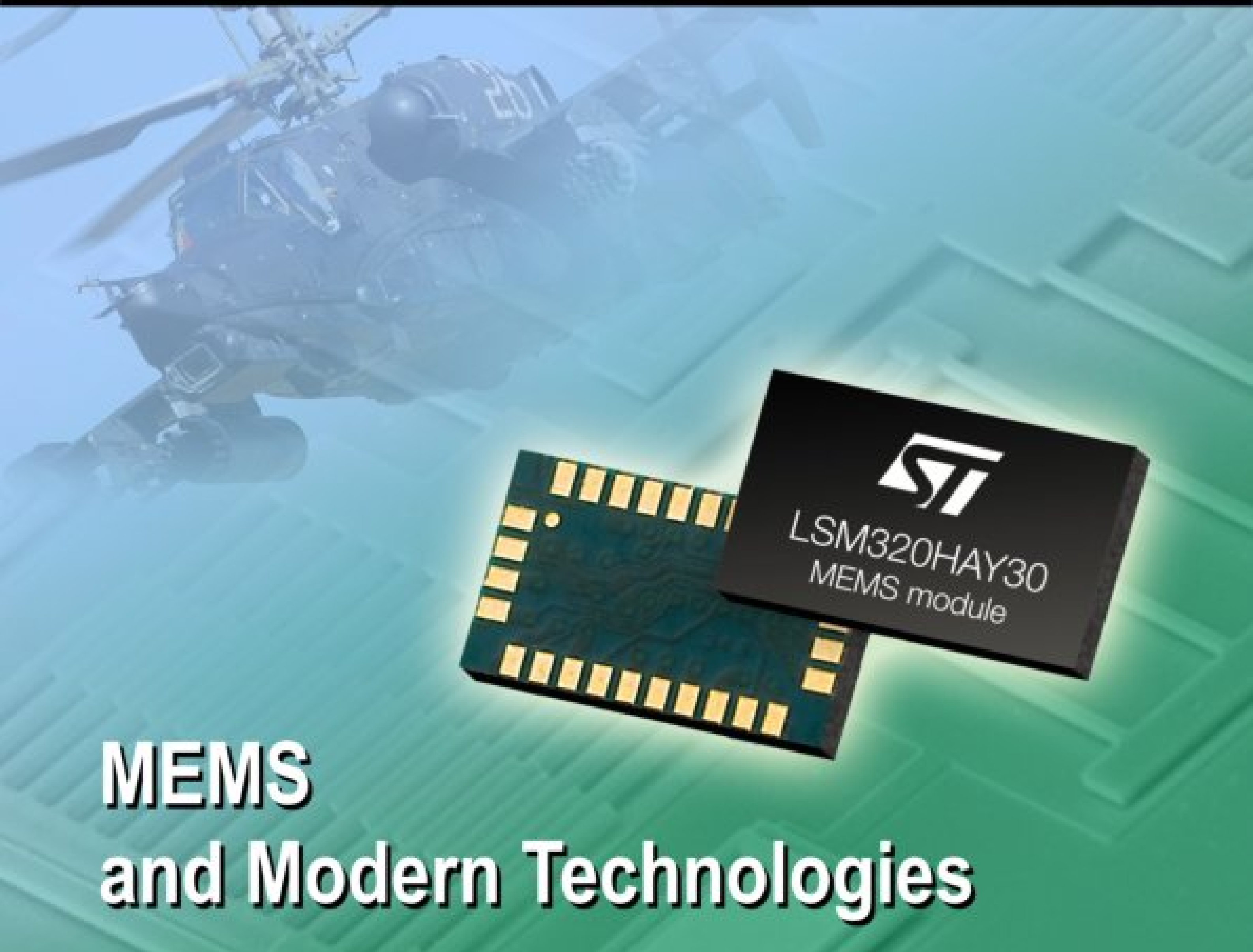

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Initial Study on Optical Tomographic Instrumentation System Based on CMOS Area Image Sensors

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Abstract: This research investigates the use of complementary metal-oxide semiconductor (abbreviated as CMOS) area image sensors in optical tomography system. The system consists of a lighting system, a measurement section and a data acquisition system. Two area image sensors are configured around a square shaped measurement section for a two projections system. Each area image sensors consists of 1600 × 1400 pixels with a pixel size of 2.8 × 2.8 micron, hence producing a high resolution system. This paper explains the initial study on activating the CMOS area image sensor model MT9D1C12STC manufactured by Micron Technology. *Copyright © 2012 IFSA.*

Keywords: CMOS, Area image sensor, Optical tomography.

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1. Introduction

With higher expectations in food industries from the customers' awareness to have high quality and safe standard, the need for accurate, fast and precise process in measuring the physical properties of food is continue to grow [1, 2]. Sometimes, human perception could be easily fooled. Hence an embedded tomography system will provide an alternative to solve that problem. The tomography system will make the inspection more accurate and precise, due to its non-destructive and non-intrusive characteristics.

Tomography imaging system is a method of viewing and analyzing a cross sectional image, where users are capable to observe and to characterize an object from the reconstructed image [3-7]. Process tomography is an investigation of a process flow happened in a conveyor by visualizing the internal behaviour of the process through different boundaries of components [2, 8, 9]. There are different types of tomography system that have been designed for process tomography such as electrical (impedance, capacitance and inductance), radiation (optical, ultrasonic, x-ray, positron electromagnetic tomography (PET) and magnetic resonance) and resonance (ultrasonic). Since the research is based on food inspection, the radiation based tomography such as X-Ray, PET and magnetic resonance is avoided because specific procedures are needed to handle it.

In optical tomography, light is projected through different medium of an object and the output signal is detected through the amount of light received by the optical sensor [3]. This type of tomography is based on non intrusive characteristic and safe to be applied in food industry since its transducer does not required a direct contact with the measurand [10]. Moreover, it can also provide high resolution images which is about 1 % of diameter of cross section [8].It has the advantages of a simple and inexpensive method [11]. Generally, an optical tomography system contains sensor fixture, optical sensors, signal measurement circuitry, data acquisition system and computer as a medium of processing and displaying the image.

The market for image sensors has experienced growth in recent years due to the increasing demands of mobile imaging, internet-based video conference, security and biometrics. A charge-coupled device (CCD) had been the dominant in image sensor area. However, some improvement has been made in the design of image sensors to be implemented in Complementary Metal-Oxide Semiconductor (CMOS) technologies. It has been used in several high-volume products such as optical mouse, personal computer cameras, mobile phone and others.

Both devices have their own advantages. The CCD consumes several watts (1-5 W) and it cannot be monolithically integrated with analog readout and digital electronics makes the embedded system becomes complicated. Other disadvantages of CCD are it suffers from high power dissipation due to its high capacitance devices and limited readout rate. Therefore, a CMOS image sensor is chosen as it is more suitable to be used as an image sensor in the optical tomography system.

2. Experimental Setup

The optical tomography system is based on two projections system and consists of the lighting system, measurement system, microcontroller module, and image reconstruction system. The two projections system has two pairs of illumination system and CMOS area image sensors. Fig. 1 illustrates the layout of the overall system. Fig. 2 shows the communication signals between the CMOS area images sensor, microcontroller and the Personal Computer (PC) to display an image.

The lighting system used a red laser diode with a wavelength of 600 nanometers. Low power laser diode is chosen due to the sensitivity of the CMOS area image sensor. The minimum output diameter of the laser beam is 4.48 mm but in order to get a collimated light across the CMOS area image sensor, the beam is magnified to 10 mm. Focal length for the objective lens and the spherical lens are 4 mm and 40 mm, respectively. In this case, the light will traverse through the objective lens and the spherical lens in order to produce collimated light for the image sensor.

The CMOS area image sensor is the sensing component in the optical tomography. The image sensor used is MT9D1C12STC CMOS area image sensor manufactured by Micron Technology. It has 1600 × 400 pixels with 2.8 micron × 2.8 micron pixel size. The output from the CMOS area image sensor will be transferred into microcontroller module.

Microcontroller module contains data acquisition system and microcontroller. ATMEL ATMEGA32 microcontroller is used as synchronization and clocking input of the CMOS area image sensor. Any image that is captured by the CMOS area image sensor will be sent to the microcontroller and to the personal computer directly after being processed by the data acquisition system.

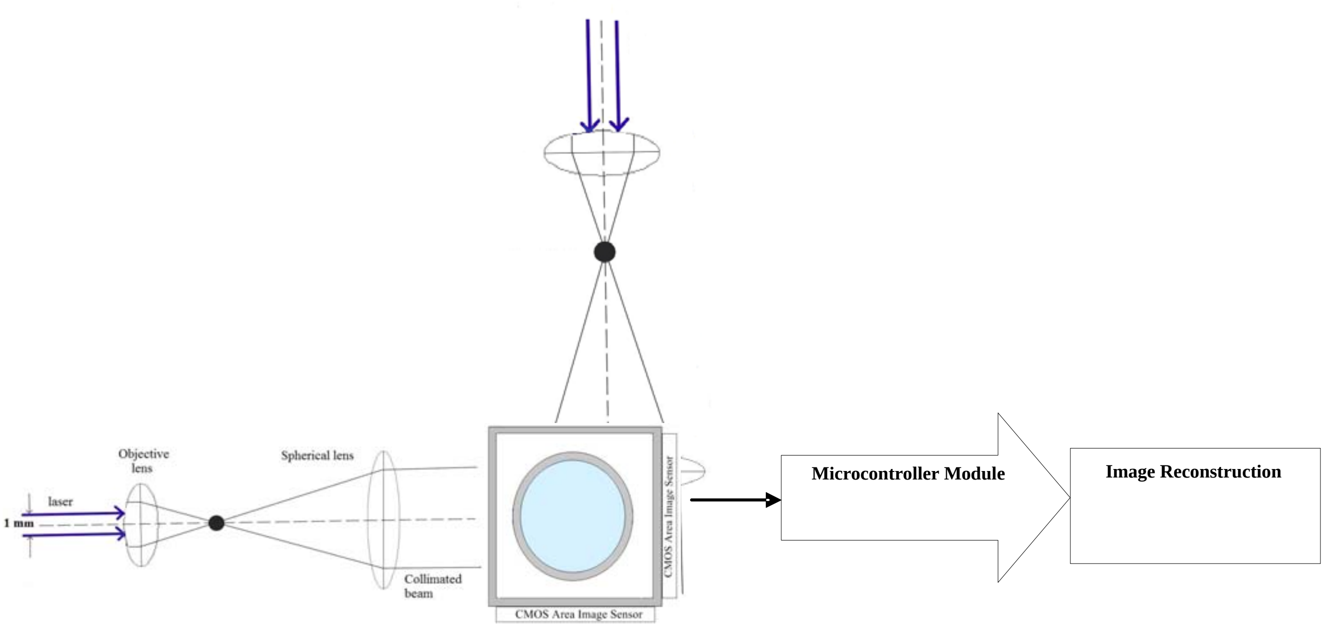


Fig. 1. Overall system.

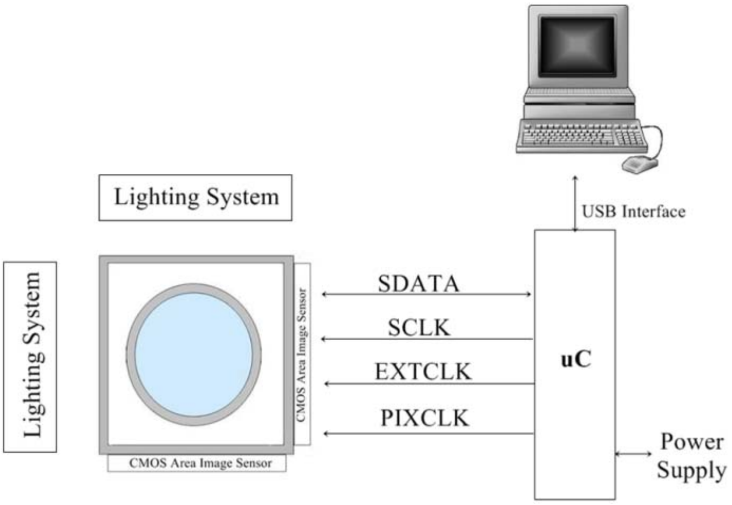


Fig. 2. CMOS area image sensor and microcontroller communication.

2.1. The Lighting System

The elements in the lighting system will be placed in a box to avoid any light disturbance from surrounding. The lighting system consists of a low power laser (0.5 Watts), an objective lens and a spherical lens. There will be two identical boxes for the overall system due to the two projections used in the system.

2.2. The Measurement Section

The CMOS area sensor used is based on the model MT9D131C12STC manufactured by Micron Technology, Inc which has 1600 × 1200 active pixels. The size of the sensor is 14.22 mm × 14.22 mm. The CMOS area sensor must be fully illuminated by light. Therefore, a pipe with a diameter of 15 mm is chosen which is slightly bigger than the size of the CMOS area sensor.

Fig. 3 shows the front view of the overall pipe system. A square-shaped measurement section is designed for a two projection system with a size of 43 mm × 43 mm. There will be 10 mm gap between the perspex and the outer pipe to ensure the pipe is well suited inside the pipe.

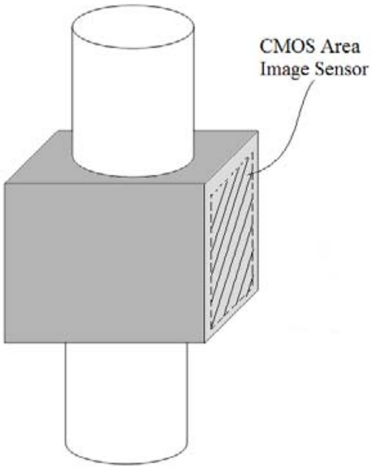


Fig. 3. Front view of the pipe.

2.3. CMOS Area Image Sensor

Fig. 4 shows the MT9D1C12STC CMOS area image sensor. Rather than soldering directly to the board, 48 pins Ceramic Leaded Chip Carrier (CLCC) to Dual Inline Package (DIP) Programming and Test Integrated Circuit (IC) adapter is used to simplify the board and for sensor replacement.

Fig. 4. CMOS area image sensor.

2.4. The Microcontroller Module

For an embedded system, ATMEL ATMEGA32 is chosen as the microcontroller. For initial study on the system, driver clockings for the CMOS image sensor are generated using this microcontroller. Fig. 5 shows the schematic diagram for the CMOS area image sensor connection whilst Fig. 6 shows the experimental circuit for driving the image sensor. Driving the CMOS area image sensor is simpler compared to CCD image sensor. For the CMOS area image sensor, once the supply is stable, the hard reset sequence needs to be followed. Other than that, all the supply should be turned at the same time to minimize the leakage current.

After the power supplies are stable, an input clock EXTCLK is supplied the sensor. The frequency requirement for EXTCLK is 6 MHz until 40 MHz. After that, RESET must be asserted (active low) for at least 1 µs. While input clock is still running, RESET will be de-asserted (active high). Fig. 7 shows detail of the power up timing.

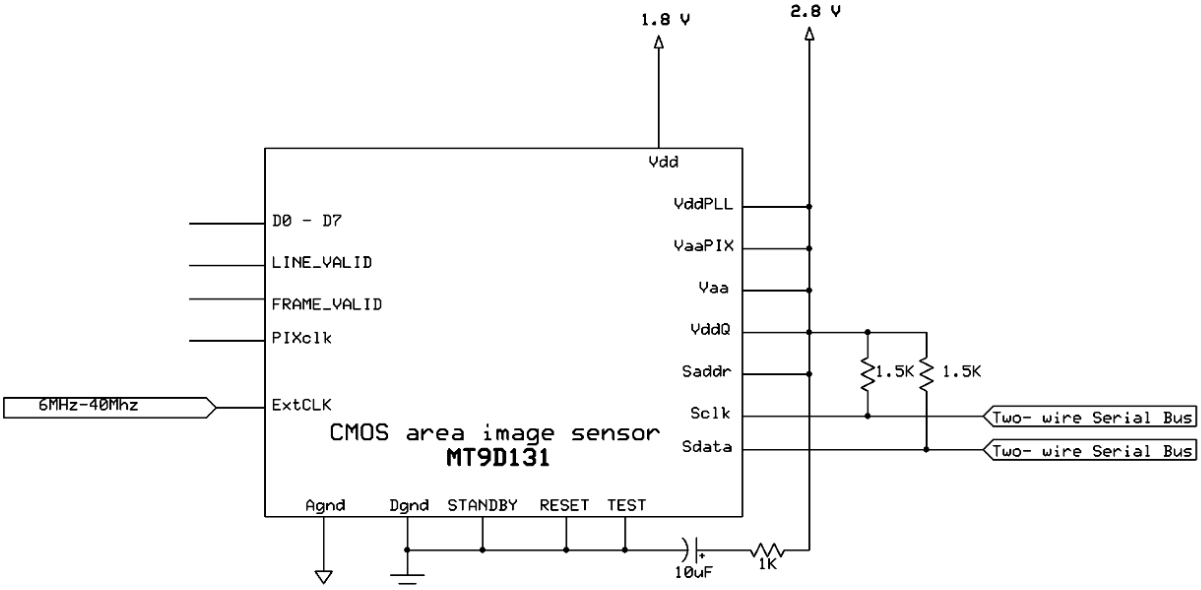


Fig. 5. Schematic diagram for driving CMOS area image sensor.

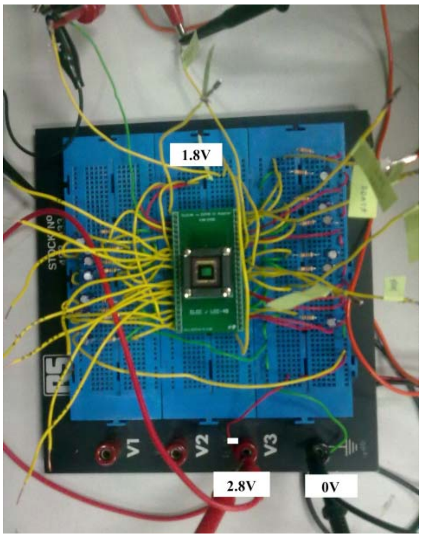


Fig. 6. Experimental set up for power up a CMOS area image sensor.

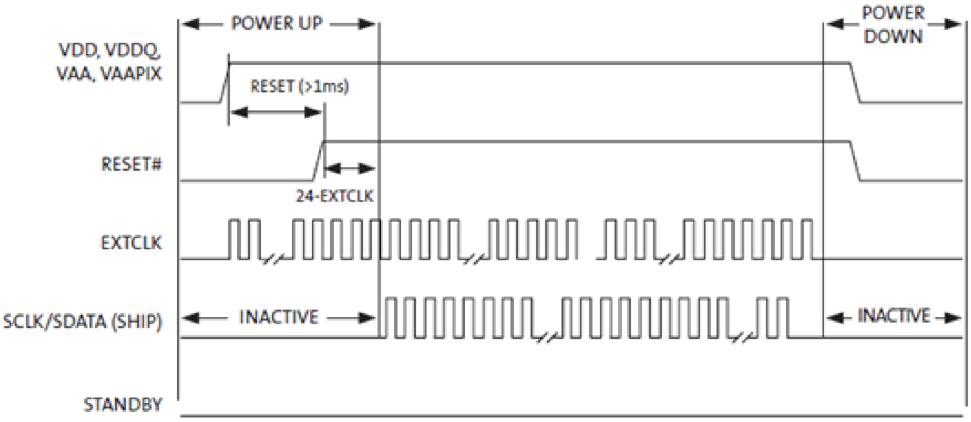
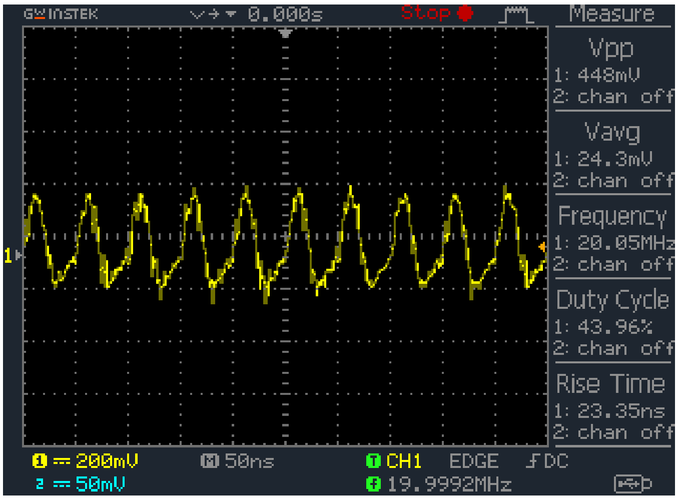


Fig. 7. Power up timing diagram.

3. Results and Discussion

3.1. Initial Study on Driving the CMOS Area Image Sensor

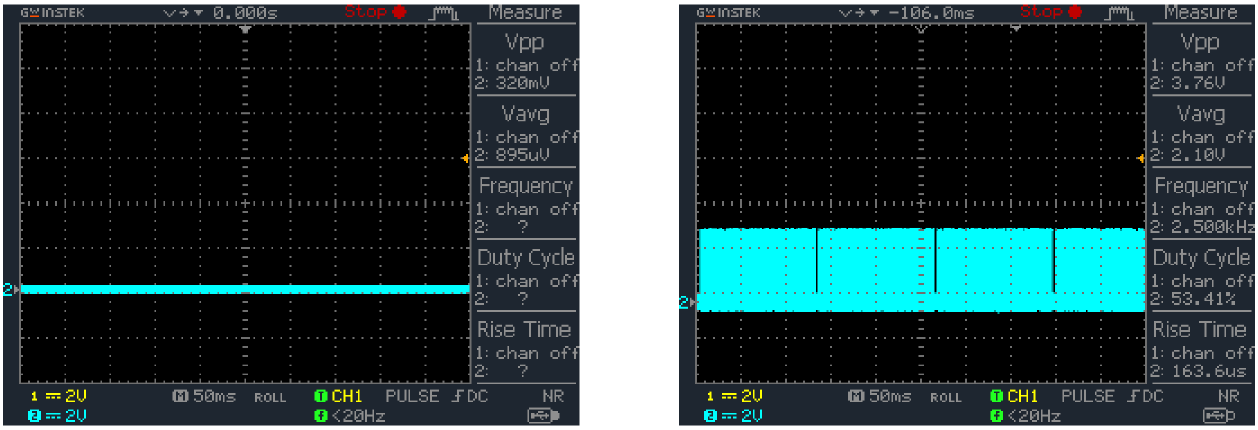
Four conditions were carried out during the experiment where the CMOS sensor is fully exposed to light or blocked from light or only part of the sensor is blocked (right and left of the sensor). The EXTCLK input signal is clocked at 20 MHz and the signal is shown in Fig. 8.



```
Vpp
1: 448mV
2: chan off
Vavg
1: 24.3mV
2: chan off
Frequency
1: 20.05MHz
2: chan off
Duty Cycle
1: 43.96%
2: chan off
Rise Time
1: 23.35ns
2: chan off
1 == 200mV    M 50ns    T CH1   EDGE   DC
2 == 50mV               T 19.9992MHz
```

Fig. 8. EXTCLK input signal.

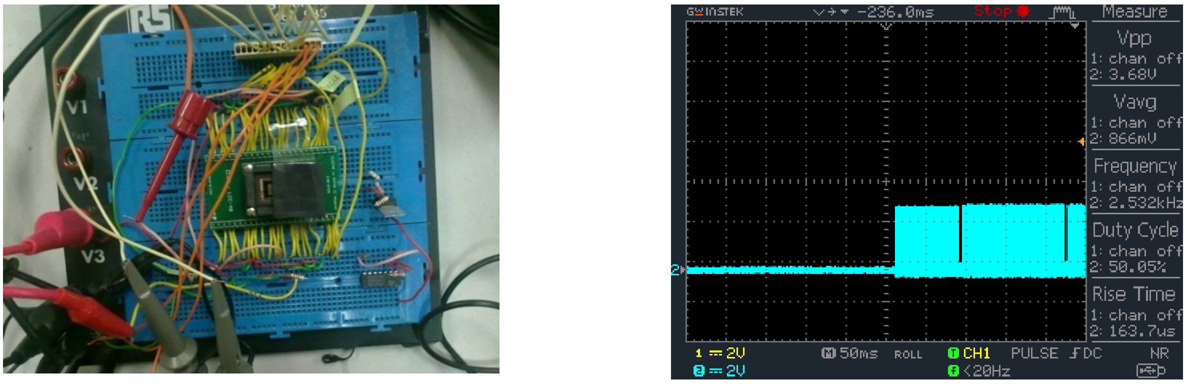
For the first condition, the CMOS sensor was totally exposed to the light. The value of output signal was approximately 0.2 V as shown in Fig. 9. In contrast, for the second condition where the CMOS sensor was totally blocked from the light, the output signal was approximately 3.8 V, as shown in Fig. 10. It can be concluded that the output signal is HIGH when the CMOS sensor detects shadow i.e. total darkness. On the other hand, the output signal is LOW when the sensor is exposed to light.



(a) (b)

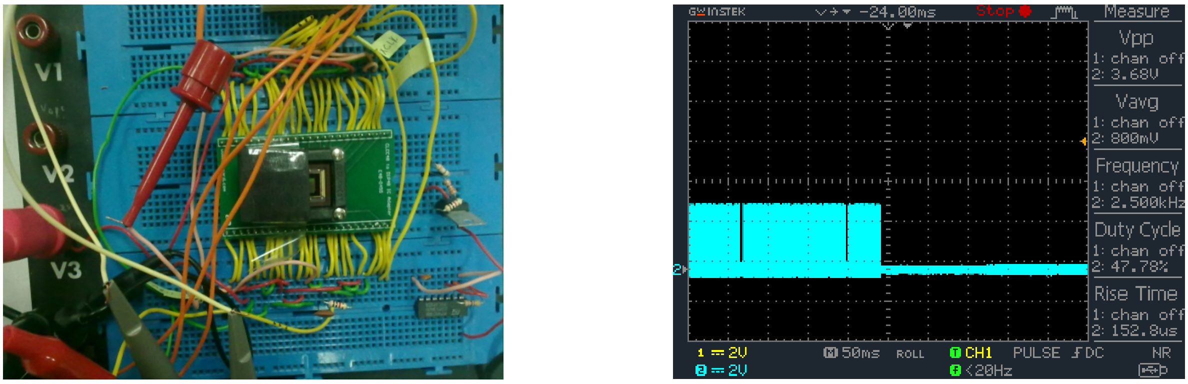
Fig. 9. Output signals for (a) fully exposed to light, and (b) total darkness.

Fig. 10 and Fig. 11 show the conditions when part of the CMOS sensor are blocked from light, either on right or left of the sensors. The output signals show a combination of HIGH and LOW signals, depending on whether the CMOS sensor detects light or shadow, respectively.



(a) (b)

Fig. 10. Output signals when a part of the CMOS sensor is blocked (on the right) from light.



(a) (b)

Fig. 11. Output signals when a part of the CMOS sensor is blocked (on the left) from light.

It can be concluded that the CMOS area image sensor is capable of detecting shadow of any objects. This initial study on the operation of CMOS area image sensor proved that the sensor can characterize any particles between the light source and the sensor. By using the CMOS area image sensor in the optical tomography system, visualization of internal process flow is possible.

4. Conclusion

Food inspection can be done accurately and precisely using non instrusive and non destructive methods. High resolution image can be reconstructed using a CMOS area image sensor which is being used as an optical sensor applied in optical tomography system. This research will be useful to the food industries to upgrade their quality control (QC) and quality assurance (QA).

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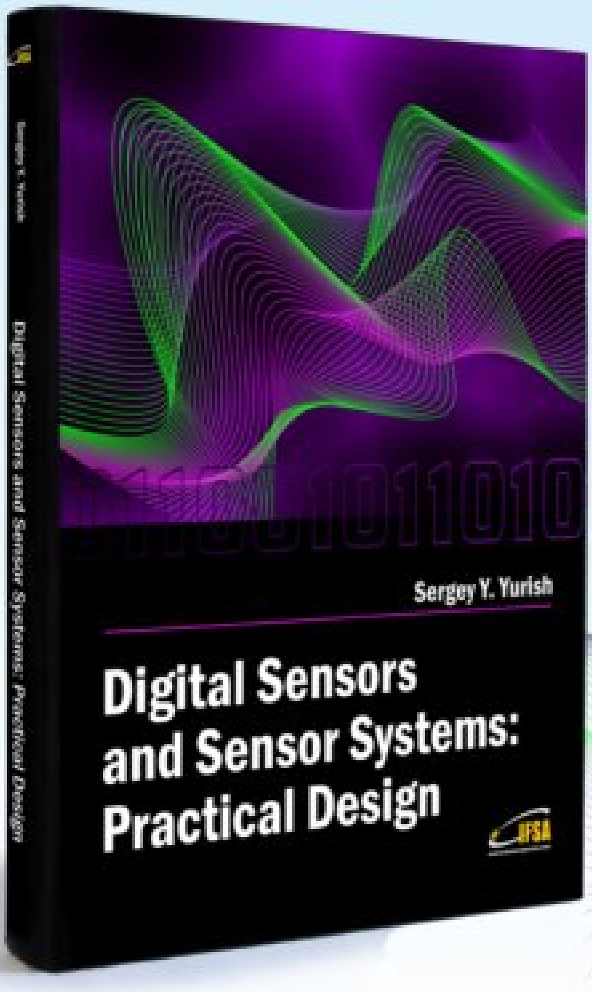

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