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LABVIEW BASED DRIVER FOR CHARGE-COUPLED DEVICE LINEAR IMAGE SENSOR

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Abstract. This paper describes the development of LabVIEW based driver for charge-coupled device (CCD) linear image sensor in optical tomography system. The Sony ILX551A CCD linear image sensor contains 2048 effective pixels, each pixel approximately 14 microns in size. The sensor requires suitable clocking signals (ϕROG and ϕCLK) before the pixel values that represent the attenuated optical intensity can be serially read. The output from the CCD is the optical intensity measured in voltage or shadow of the object intercepting the optical beam, pathlength between light source and the CCD linear image sensor. When solid particles blocking certain area of the optical path length, the shadow of the object will be casted on several affected pixels of the linear image sensor, and value on the output signal will be obtained. The exact location of objects on output signal produced for various conditions is important in order to verify the proper clocking signals generated for Sony ILX551A. The results demonstrate that the clocking signal at 1MHz frequency for the CCD Sony ILX551A is successfully generated and capable of acquiring tomographic data.

Keywords. CCD linear image sensor; LabVIEW; projection; optical tomography

Abstrak. Kertas kerja ini menerangkan tentang pembangunan sistem pemacu untuk sensor imej lelurus peranti pengecas gandingan (CCD) dalam system tomografi optik berasaskan perisian LabVIEW. Sensor imej lelurus CCD jenis SONY ILX551A yang mempunyai 2048 piksel yang efektif dengan setiap pixel bersaiz 14 mikron telah digunakan. Sensor ini memerlukan isyarat-isyarat jam (ϕROG dan ϕCLK) yang sesuai sebelum nilai-nilai piksel yang mewakili keamatan optik yang diukur dalam voltan dapat dibaca secara sesiri. Keluaran dari CCD adalah keamatan optik yang diukur dalam unit voltan atau bayangan objek yang memotong alur cahaya iaitu panjang laluan di antara punca cahaya dan sensor CCD. Apabila pepejal menghalang sebahagian laluan optik, bayangan objek akan terpancar ke atas beberapa piksel sensor CCD yang terlibat, dan nilai keluaran didapati. Lokasi objek yang tepat dari isyarat keluaran untuk beberapa keadaan adalah penting untuk mengesahkan isyarat jam adalah sesuai untuk sensor Sony ILX551A. Hasil keputusan menunjukkan isyarat jam pada frekuensi 1MHz yang dikenakan

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dikenakan kepada sensor CCD Sony ILX551A berjaya dijanakan dan data tomografi mampu diperolehi.

Kata kunci: Tomografi optik; LabVIEW; sensor imej linar CCD; unjuran

1.0 INTRODUCTION

A charge-coupled device (CCD) [1, 2] was initially conceived of as a new type of computer memory circuit. It soon became apparent that the CCD had found in many other potential applications. They are found in digital cameras, scanners, medical devices, satellite surveillance and in instrumentation for astronomy and astrophysics. There are many scientific publications that mention the use of CCDs and many millions of digital cameras that used CCD sensors [3, 4]. Astronomy with astrophysics has become a significant application area for CCDs. The CCD's early promise as a memory element has since disappeared but its superb ability to detect light has turned it into the industry-standard image sensor technology. Its light sensitive property was quickly exploited for imaging applications and it produced a major revolution especially in Astronomy field [5, 6]. A CCD image sensor is a device for the movement of electrical charge, usually from within the device to an area where the charge can be manipulated. This is achieved by shifting the signals between stages within the device one at a time. The CCD can also be used as a form of memory or for delaying samples of analog signals. Today, they are most widely used in arrays of photoelectric light sensors to serialize parallel analog signals [7, 8]. One particular CCD linear image sensor, Sony ILX551A has 2048 pixels to capture and store the data of a one dimensional (1-D) image. However, it requires suitable clocking system to enable the 2048 analog voltages to be serially read, transferred and converted to digital data. A suitable driver and interface card are needed to generate the clocking system, to configure the CCD linear image sensor and to serially convert and record the data.

In this paper, the work is focused on how to generate a suitable clocking signal for Sony ILX551A CCD linear image sensor, so that the image of a particle can be captured and stored digitally for subsequent image reconstruction process. Besides that, the work is also concentrated on how to program a USB 6251 card to enable the analog output from ILX551A CCD linear image sensor being transferred and converted to digital output for image data storage.

The Sony ILX551A CCD linear image sensor requires suitable clocking signal to be generated so that the sensor could capture the image of a particle. LabVIEW 8.2 software [9] was implemented in order to generate the clocking signal and also to display the output signal from the CCD sensor. The LabVIEW software was chosen as the data acquisition system because it contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to troubleshoot a written code. The interface card used in this work is USB 6251, for communication between LabVIEW software and CCD sensor. A number of experiments were carried out to verify the generated clocking signal suitable for the Sony ILX551A CCD linear image sensor. LabVIEW has the advantage of better graphical user interface (GUI) through its front panel features that can visualize the actual instruments for friendly usage.

2.0 METHODOLOGY AND IMPLEMENTATION

The tomography system consists of an array of sensors, a signal conditioning and data acquisition system as well as a reconstruction and display system where the collected data are processed using a reconstruction algorithm to provide an image. Figure 1 shows the basic CCD based optical tomography system. As illustrated in Figure 1, the scope of this work is concentrated more on the study of the system within the dotted box in the diagram, which is the configuration needed by Sony ILX551A CCD linear image sensor, by generating suitable clocking signals to enable the CCD sensor to capture image, transfer and store the output for image data storage.

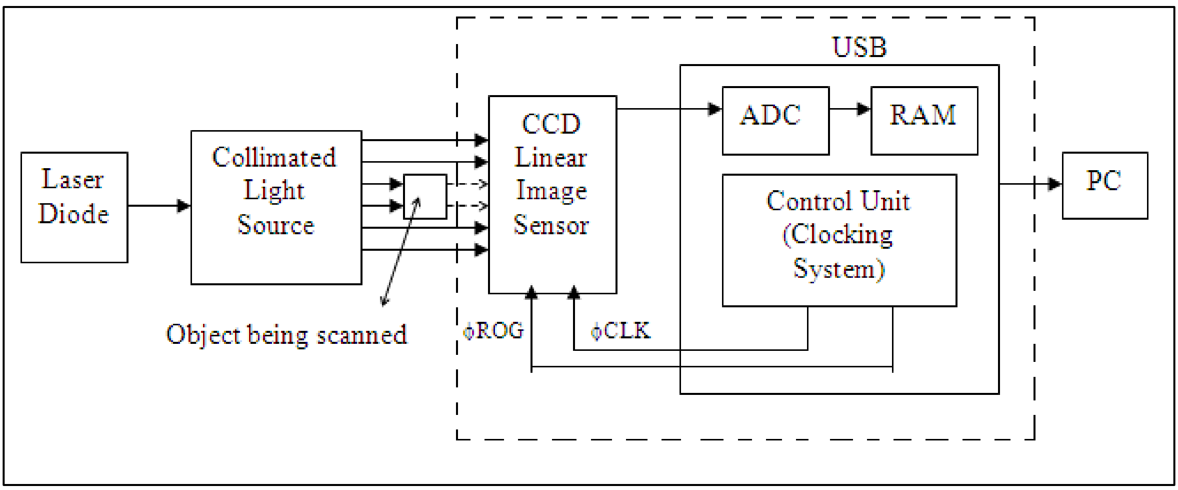


Figure 1 Basic CCD based optical tomography system

2.1 CCD Configuration

The configuration needed by Sony ILX551A is studied. The clocking signals required for Sony ILX551A are ϕROG and ϕCLK, as shown in Figure 2. By using LabVIEW software, the clocking signals (ϕROG signal and ϕCLK signal) can be generated by designing a block diagram. The next step is to test the block diagram with the CCD sensor. For an initial step, a digital oscilloscope was used to ensure the correct clocking signals as in figure 2 were generated. If the clocking signal was not compatible with the CCD sensor operation, the block diagram had to be adjusted and modified. Once the suitable clocking signals are obtained, a series of experiments were then conducted and the output signals were displayed on the front panel of the LabVIEW software.

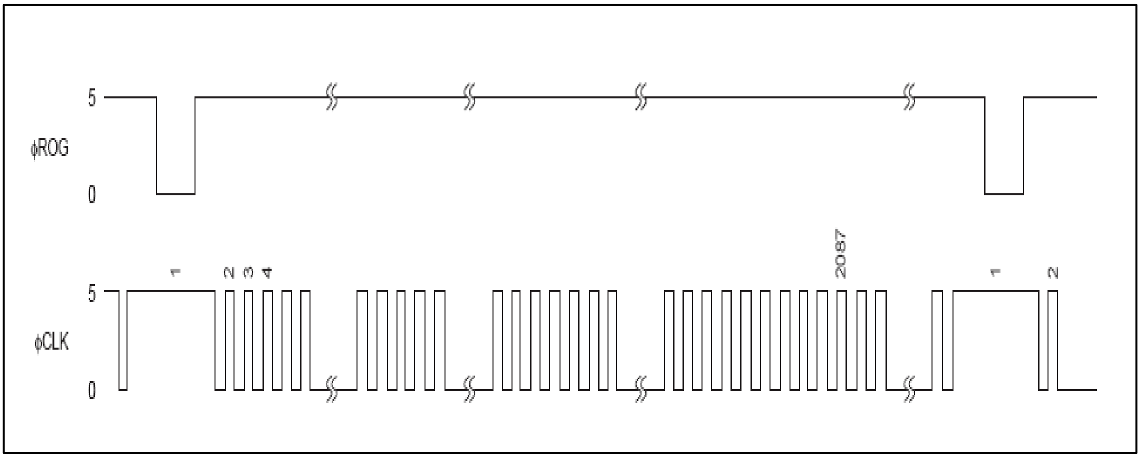


Figure 2 Clocking system required by Sony ILX551A CCD linear image sensor

2.2 LabVIEW 8.2 Software (Block Diagram) Implementation

In order to generate the clocking signals for the CCD sensor, LabVIEW window's block diagram is used. It also used to display the output signal. In this work, two types of sequence structure as illustrated in Figure 3 were used to execute more frames or sub-diagrams sequentially. **Stacked Sequence Structure** as shown in Figure 3(a) was used to conserve space on the window's block diagram. The first frame is used to generate ϕROG signal together with first and second pulse of ϕCLK signal, while the second frame is used to generate continuous 2085 pulses of ϕCLK signal as well as displaying the output signal. **Flat Sequence Structure** as shown in Figure 3(b) was used to execute more tasks sequentially from left to right of sequences.

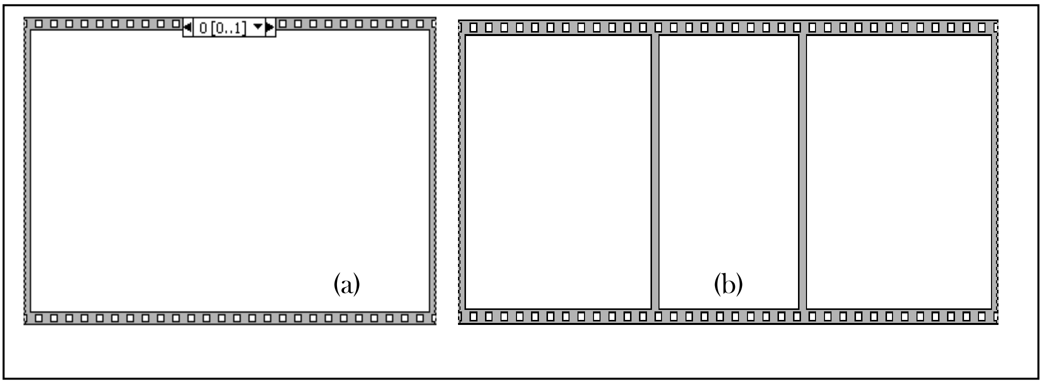


Figure 3 Sequence structures. (a) stacked (b) flat

Figure 4 shows the block diagram used to generate ɸROG together with first and second pulse of ɸCLK signal. In Figure 4(a), **DAQmx Create Channel VIs** was used to create ɸROG signal and ɸCLK signals respectively. In Figure 4(b), **DAQmx Write VIs** was used to generate both pulse signals sequentially from left to right of flat sequence structure. The *wristwatch* icon indicates that the task has to wait for 2 ms before it was executed to obtain clocking signal. Finally, in Figure 4(c), **DAQmx Stop VI** and **Clear VI** were used to stop and clear the task after both signals were generated.

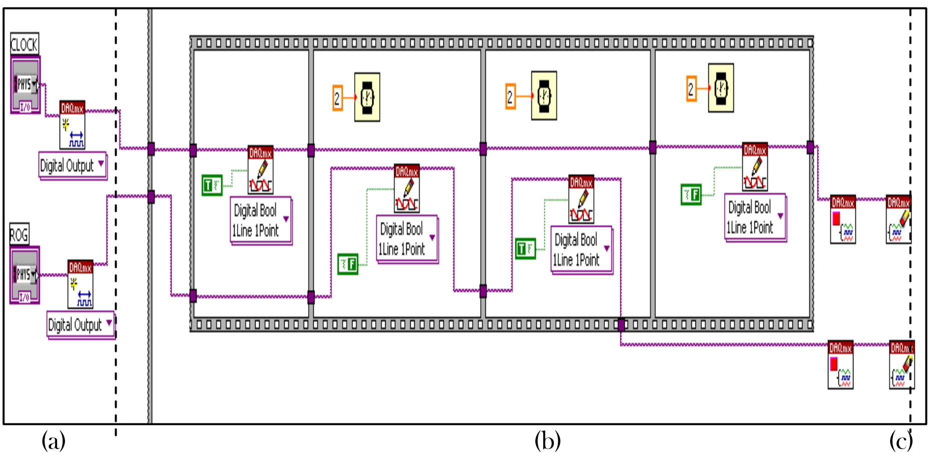


Figure 4 Block diagram used for ɸROG signal and first and second pulse of ɸCLK signal generation

The block diagram that was used to display the output signal from CCD sensor and recorded the image data is shown in Figure 5. In Figure 5 (a), **DAQmx Create Channel VI** was used to create the analog input signal. Since the output signal from CCD is operated as input signal for the system, **AI (Analog Input) Voltage** was selected. The minimum and maximum values can be set by user as the range for displayed signal. A *Physical Channel* is a terminal at which analog signal can be measured or generated. For Figure 5 (b), **DAQmx Read VI** was used to read a waveform from a task that contains a single analog input channel. The output signal is displayed in Waveform Chart. The data of image can be saved in file of interest through *Path* provided. In this case, data is stored in an *Excel file* (.csv).

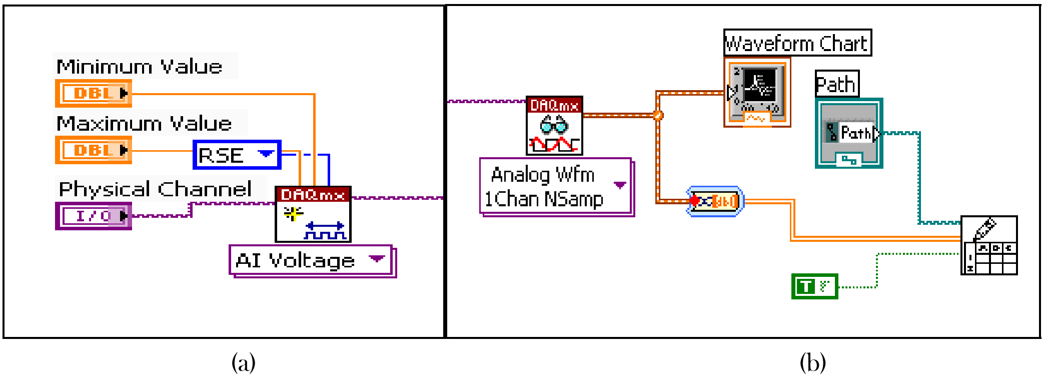


Figure 5 Display and record the output signal from CCD sensor. (a) DAQmx Create Channel VI (b) DAQmx Read VI

The continuous digital pulse train generation for ϕCLK signal used one of the built-in LabVIEW examples. The corresponding block diagram is shown in Figure 6 which is used to generate 2085 pulses for ϕCLK signal. In Figure 6(a), **Counter Output Channel** is created to produce a pulse signal in terms of *Frequency*. The *rate* terminal used to set a required frequency and 50% *duty cycle* is selected. *Idle State* of the pulse was set to high. In Figure 6(b), **DAQmx Timing VI (Implicit)** is used to configure the duration of the pulse generation. *Finite Sample* was chosen so that number of pulse signal required can be set. **DAQmx Start VI** is used to begin the pulse train generation. For Figure 6(c), **While Loop** is used to generate pulses signal continuously until all 2085 pulses have completely generated or when the **Stop** button is pressed. **DAQmx Is**

Task Done? VI is used to check for errors every 100ms. Finally in Figure 6(d), **DAQmx Clear Task VI** is used to clear the task, and a message would display after the task is stopped or completed.

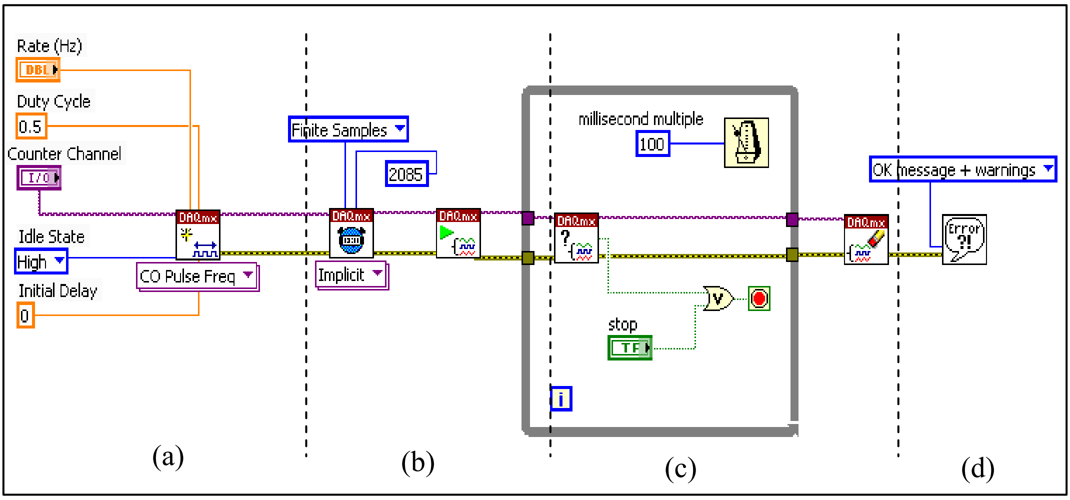


Figure 6 Continuous digital pulse train for ϕCLK signal generation

2.3 Experimental Setup

A number of experiments were conducted for various conditions of CCD sensor. The experiment was set up as illustrated in Figure 7. The whole experiment was done under a controlled ambient light. The experiment was carried out in the dim light where the lamps in the laboratory were switched off. It is important to control the ambient light since the CCD sensor is very sensitive to the light. The main reason in controlling the ambient light is to avoid the pixels of sensor being saturated. If the pixels are saturated, the sensor is not able to detect the shadow of the object. Under this condition, the sensor is said to have low sensitivity to the light.

A simple protection circuit using diode was connected to the CCD sensor since operation of Sony ILX551A CCD linear image sensor requires two external power supply voltages with 9V for V_{DD1} (pin 20) and 5V for V_{DD2} (pin 8, 9, 21, 22). During the experiment, LabVIEW generate the clocking signal and displayed the digital output signal from the CCD sensor on the front panel. USB6251 is the interface card between the CCD sensor and LabVIEW software. NI-DAQmx driver and measurement services software are used for programming interfaces between LabVIEW software and USB 6251. Besides, Bayonet Neill-Concelman

(BNC) connector is also used in this work for simplifying connections between USB 6251 and CCD sensor.

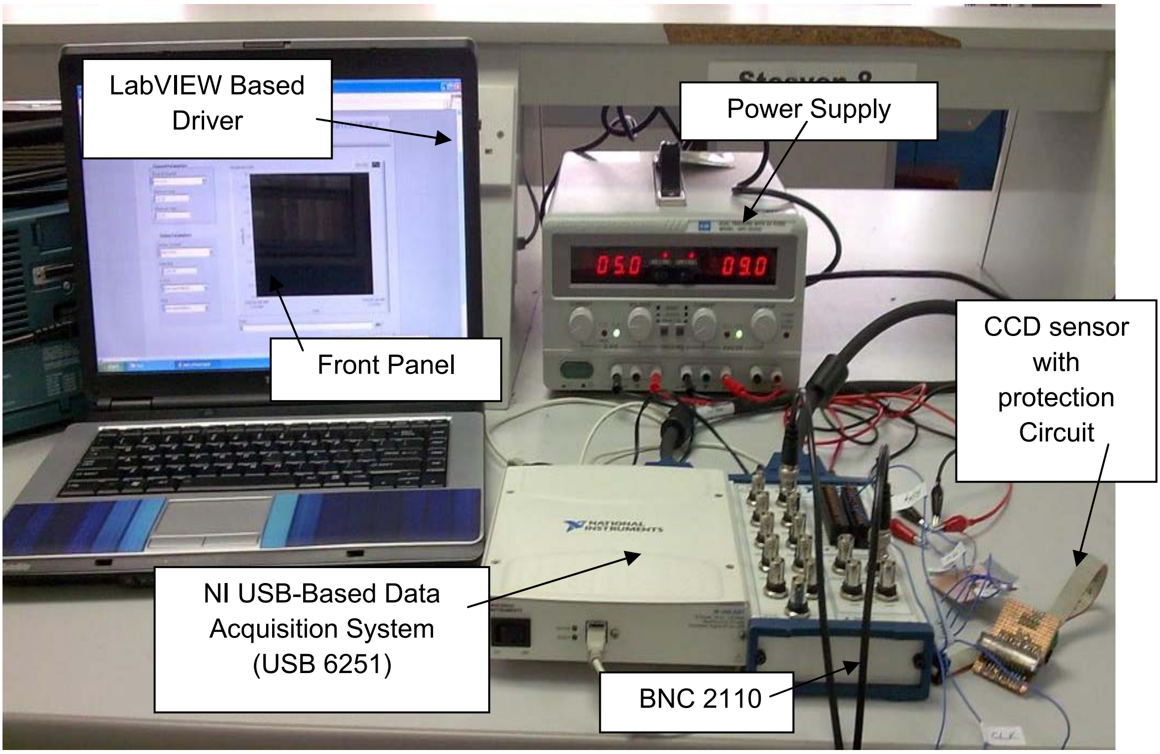
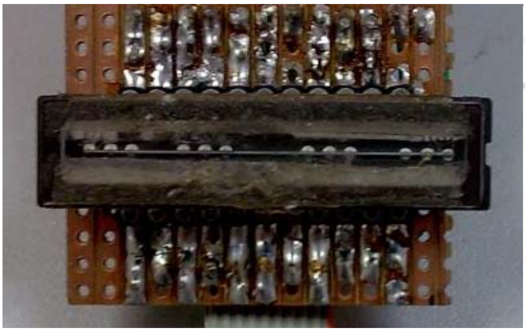


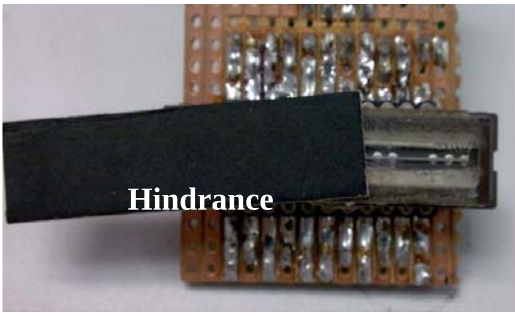
Figure 7 Experimental setup

In order to demonstrate the results, four conditions of CCD sensor that had been carried out during the experiment, as shown in Figure 8. These conditions consists of condition where full part of CCD sensor is exposed (Figure 8a) or blocked (Figure 8b) from ambient light and part of CCD sensor is blocked (Figure 8c and 8d) from ambient light.

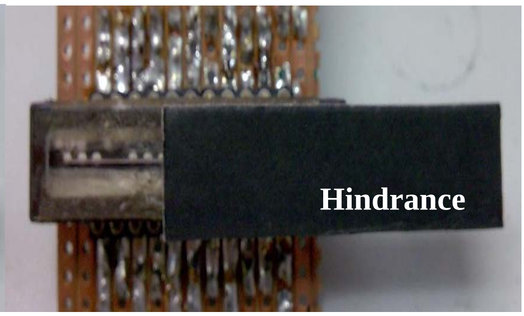


(a)

(b)



(c)



(d)

Figure 8 Four conditions of CCD sensor for experiments

3.0 RESULTS AND DISCUSSIONS

Figure 9 and Figure 10 show the ϕROG signal and ϕCLK signal generated for the Sony ILX551A, as displayed on oscilloscope respectively. The grid on oscilloscope was set to 5V per division (5V/div) for y-axis. In Figure 9, the generated ϕCLK signal is represented by pulse signal while the constant 5V signal was for the ϕROG signal. There are 2087 pulses signal generated for ϕCLK signal when the ϕROG signal is 5V. Meanwhile in Figure 10, the ϕROG signal acted as a switch for ϕCLK signal. Once the ϕROG signal was HIGH, the ϕCLK signal started to count as the first pulse signal. The ϕROG signal was decreased to 0V when the total 2087 pulses signal was generated. One cycle of ϕROG signal consists of 2087 pulses of ϕCLK signal.

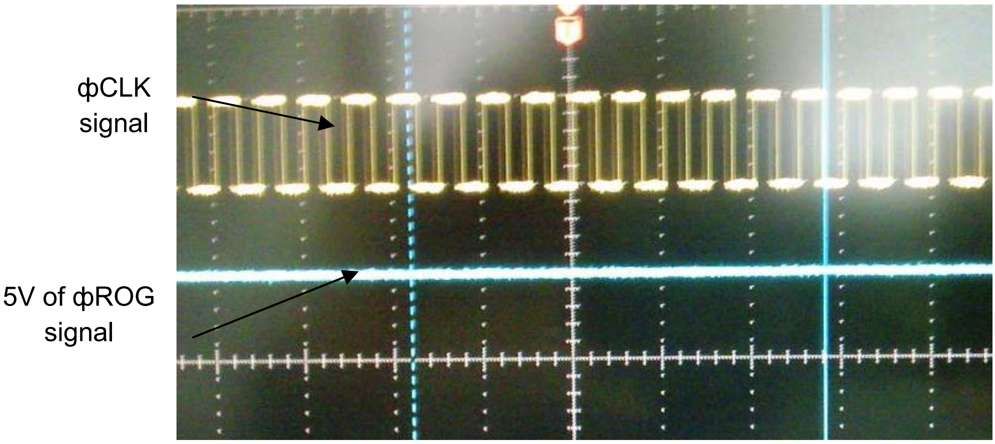


Figure 9 Signal generated for ΦCLK and ϕROG

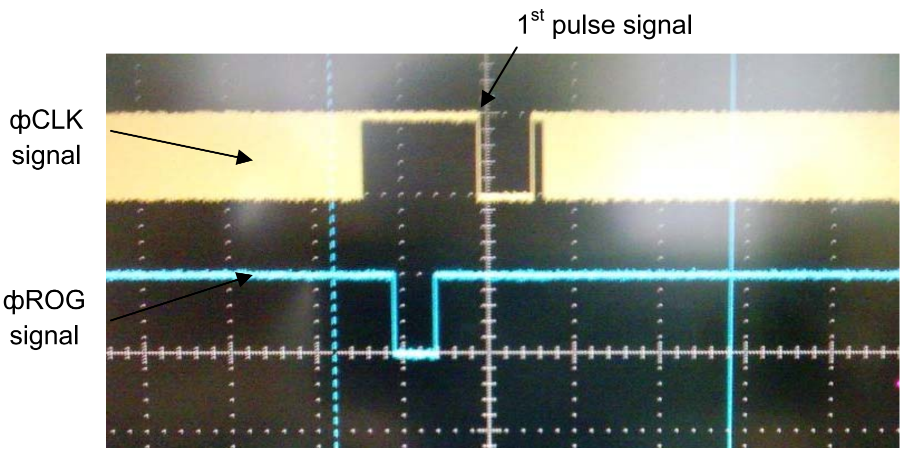


Figure 10 ϕROG signal acted as a switch for the ϕCLK signal

Four conditions of CCD sensor as previously described had been studied in understanding the operation of CCD linear image sensorl. The output signals for four different conditions of CCD sensor are shown in Figure 11 (a-d).

For the first condition, the CCD sensor was totally exposed to the controlled ambient light. The value of output signal was approximately 1V as shown in Figure 11(a). In contrast, for the second condition where the CCD sensor was totally blocked from the controlled ambient light, the output signal was approximately 4.5V, as shown in Figure 11(b).

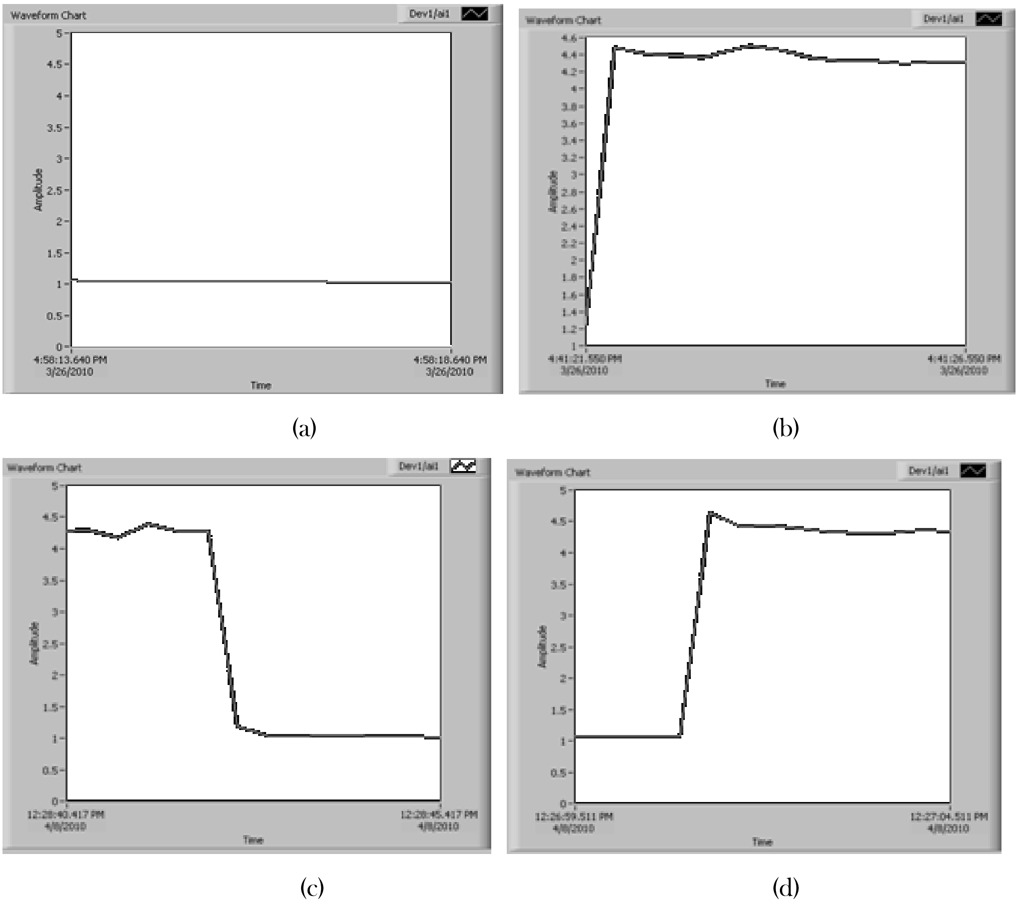


Figure 11 Output signals displayed on a front panel

For the third condition, first part of the CCD sensor was blocked from ambient light. Since the CCD sensor detected the shadow of hindrance, the output signal for first half part gave approximately 4.5V reading. Then, it decreased to approximately 1V, corresponding the part of CCD sensor that exposed to the ambient light as shown in Figure 11(c). On the other hand, for fourth condition, second part of the CCD sensor was blocked from ambient light. As a result, the output signal produced for first half part gave approximately 1V reading. Then, it increased to approximately 4.5V as shown in Figure 11(d).

The results showed that the output signal of CCD Sony ILX551A is within the range of 1V to 4.5V. 1V indicates the minimum value when the CCD sensor is exposed to the controlled ambient light. On the other hand, 4.5V indicates the maximum value when the CCD sensor is fully covered by solid, opaque object from the controlled ambient light. The LabVIEW program was run continuously during the experiment which means the 2087 pulses of clock signal run repeatedly. This was because the output signal displayed on front panel was not exactly same as the signal displayed on real oscilloscope. Through observation, the signal displayed on the front panel was slower than that on oscilloscope. Although the output signal was successfully converted and digitally displayed on the LabVIEW front panel, further works on data recording and storing process of the corresponding pixel values are yet to be implemented for tomographic image reconstruction work.

4.0 CONCLUSIONS

The work has been successfully implemented the LabVIEW 8.2 as a driver for Sony ILX551A CCD linear image sensor. The clocking signal at 1MHz frequency for CCD Sony ILX551A is successfully generated. The LabVIEW based driver provides more advantages such that it has less wiring and better graphical user interface (GUI) through its front panel features that can visualize the actual instruments for friendly usage. The output signal from CCD Sony ILX551A is successfully converted and digitally displayed on a computer screen. From the experiment, Sony ILX551A provides output voltage ranging from 1V to 4.5V for minimum and maximum value under the controlled ambient light.

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