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Electrical and Computer Engineering

Low Cost High Speed Data Acquisition Board for laboratory laser system

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Master Thesis

Supervisor

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LOW COST HIGH SPEED DATA ACQUISITION BOARD FOR LABORATORY LASER SYSTEM

by

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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DEDICATION

To my family, My supervisor Prof. Dr. Osman Nuri Ucan, the jury's members of the thesis and to Altinbas University.

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ABSTRACT

LOW COST HIGH SPEED DATA ACQUISITION BOARD FOR LABORATORY LASER SYSTEM

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Data acquisition (DAQ) is the devises that can collect and processing of data in order to uses in automated control. The DAQ systems is available as an integral part that used with many systems. These systems are designed to measure specific factors by used a transducer or a sensor (an instrument that can converts the measurable physical quantity to an electrical signal. Then store these measurements and analyzes it then display it. Due to the large application of DAQ and its usage there is a challenge to design low cost DAQ system that will Analog input channels can vary in number from one to several hundred or thousands. Building low cost DAQ system with multi functionality is one of the most challenge that can reduce cost of systems and make it available for everyone. Microcontroller is low cost, convenient and flexible device, it has been developed rapidly and the application of it become widely in recent years, which can be utilized in DAQ system prototype. In this work we have designed a PC based DAQ system that can be used to control laser system and accruing the effect on laser signal when changes the parameters which is display in scope within user interface program in real time. The proposed system composed from three main types sensor, where LDR sensor has been used to detect the laser signal. The processing unit, we have used Arduino UNO a microcontroller to control the operation and gathering information from sensor. The third part is PC, in which, we have designed a DAQ and controls program under LabVIEW software. This program offers a user-friendly graphic user interface (GUI) that allowing the operator to control the DAQ with ability to change some laser parameters such as increase or decrease the laser beam power, convert continues laser to pulses laser with ability to determine the pulses time by controls the switching function. Furthermore, the LDR will record any change in laser signal and send it to microcontroller and then to PC where the program will show the signal. The test result show that the proposed DAQ system operate smoothly and effectivity and can gathering data with accuracy and the result has been closed to traditional oscilloscope system. The system is low in cost as it dependent on relatively low-cost component. The proposed system can serve to add a DAQ and controller for oldest laser devise or fabricated lasers.

Keywords: Data Acquisition, DAQ, Laser system controller, Microcontroller, Arduino.

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LIST OF ABBREVIATIONS

V_{LSB}	:	Voltage of the least significant bit
V_n	:	Voltage at the current step
V_{n+1}	:	Voltage at the next step
AC	:	Spontaneous Recombination Lifetime
A/D	:	DC to Ac convertor
ADC	:	Analog to digital converter
CPU	:	Central processing unit
D/A	:	DC to Ac convertor
DAQ	:	The Group Velocity Dispersion
DAQ	:	Data acquisition
DAS	:	Data acquisition system
DC	:	Direct Current
DMA	:	Direct Memory Access
DMM	:	Digital Multi-Meter
DNL	:	Nonlinearity
DSP	:	Digital signal processing
EISA	:	European Imaging and Sound Association
FPGA	:	Field Programmable Gate Array
GHz	:	Giga Hertz

GUI	:	Graphic user interface
Hz	:	Hertz
I/O	:	Input/output
I2C	:	Inter-integrated circuit
IBM	:	International business machines corporation
ICSP	:	In circuit serial programming
ISA	:	Industry standard architecture
LabVIEW	:	Laboratory virtual instrument engineering workbench
LDR	:	Light dependence resistance
LSB	:	Least significant bit
MCU	:	Microcontroller Unit
MXI	:	Multisystem Extension Interface
OS	:	Operating system
PC	:	Personal computer
PCI	:	Peripheral component interconnect
PCU	:	Processing control unit
PIC	:	Peripheral interface controller
PWM	:	Pulse width modulation
PXI	:	PCI extensions for instrumentation
RS232	:	Computer serial interface

SDA	:	Serial data line
SPI	:	Serial peripheral interface
UART	:	Universal asynchronous receiver-transmitter
UI	:	User interface
USB	:	Universal serial bus
VME	:	Virtual machine environment
VXI	:	VME bus extensions for instrumentation

1. INTRODUCTION

1.1 OVERVIEW

Data acquisition (which also called DAS or DAQ) is the process of measure a physical or electrical phenomenon like for example pressure, current, voltage, sound or temperature with a computer. A typical DAQ system involves DAQ measuring hardware, sensors, and a computer equipped with programmable software. The DAQ used to convert analog waveforms taken from sensors to a digital value that can be processing in computer. DAQ systems has been developed over the years from the outdated model which is an electromechanical recorder including often one to four channels to almost all-electronic systems able to measure a large number of variables together. Early systems utilized paper chart and magnetic tape or rolls to permanently record the signals, however, as development of computers, especially personal computers (PC), the speed and quantity of data with which they can be gathered raised dramatically. Even so, several of the classic data-collection systems yet exist and are used regularly [1].

Generally, DAQ plugin boards are typical-function data acquisition devices that are suitable for calibrating signals. The function of DAQ is to measure electrical a or physical phenomenon like sound, pressure, temperature, voltage, current, etc. computing-based data acquisition has used a grouping of hardware, software, and a computing system to get measurements. As each DAQ system is identified by its application specifications, each system offers a typical purpose of analyzing, acquiring, and providing information. DAQ systems include sensors, signals, actuators, DAQ devices, signal conditioning, and application software [2].

The area of DAQ includes a variety of activities. At it is simplest level, it includes reads the electrical signals right into a computer making use of Several type of sensor. Such signals will possibly represent the physical process state such as shape and size of a manufactured component, orientation and position of machine tools, heating system temperature, etc. The acquired data will possibly have displayed, printed or stored. often the data must be processed or analysed in several ways so as to make additional signals for managing external devices or for interfacing to many Some other computers. This would possibly include manipulating the static indication, however it's also often important to deal at time-varying signals likewise. Several systems will possibly involve data to be collected over time spans of several weeks or days. Some other will require short breaks of extremely high-speed data acquisition possibly at rates of nearly thousands of indications per second. The most main reason for making use of the PC for data acquisition and controls now days is that there's a large and increasing pool of scientists, programmers and engineers that are familiarized with the PC [3, 4].

1.2 THE PURPOSE AND MOTIVATION OF DAQ SYSTEM

Every DAQ task has its own unique issues. DAQ measurement and test can be fixed or mobile, can be utilized on a test cell or under serious environmental conditions and in for academic purposes or laboratory research. These systems can be utilized not just for electric signals but is also to measure pressure, temperature, force, acceleration, light, sound, displacement and position, with sensors is needed at the input of the DAQs channels. Gaining appropriate results from a DAQ is depend on the conditioning of the signal, the DAQ components, the PC and the software [5].

Signal conditioning ensures that the signal about being measured aren't going to damage the system, guarding to prevent overvoltage and overcurrent which adjusting the input ranges to the input range of ADC. The most important component composing the DAQ hardware is the ADC that digitizes the conditioned signal with a certain sampling frequency and resolution. It's also constructed by a processing unit to send the acquired data to the PC to be analyzed and processed [6].

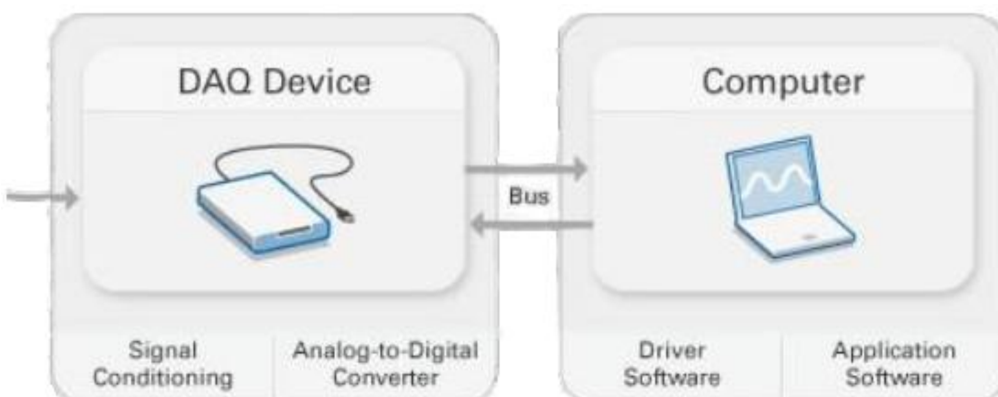


Figure 1.1: Parts of a DAQ System [7]

The main specifications to take into consideration in cases where selecting a DAQ system are the ADC resolution, input ranges, maximum sampling frequency, the possibility of simultaneous acquisition and the number of channels. The device cost will also be an important factor because the goal is to develop a DAQ system identical to the presented systems in the market with low cost. The costs of the presently available devices differ depending on the criteria above and another certain characteristic of each device. This work is aimed to to implement, develop and characterize a small-sized DAQ device controlled and powered by USB. The communication bus of computer-DAQ can significantly affect the maximum speeds of continually acquire data. [7]. Table 1.1 illustrated a comparison between some of the DAQs available in the market is shown.

Table 1.1 a number of DAQ systems that available on the market and its Features and prices

Manufacturer	Model	Acquisition	Maximum Sampling Frequency	Resolution	Number of channels	Range	Price
National Instruments	NI USB-6008 [2]	Non Simultaneous	10 kS/s[1]	12 bit	12	± 1 V up to ± 10 V	160 €
	NI USB-6009 [2]	Non Simultaneous	48 kS/s	14 bit	12	± 1 V up to ± 10 V	220 €
	NI USB-9215 [3]	Simultaneous	100 kS/s/ch	16 bit	4	± 10 V	519 €
Data Translation	DT9816 [4]	Simultaneous	50 kS/s/ch	16 bit	6	± 5 V or ± 10 V	315 €
	DT9816 A [4]	Simultaneous	150 kS/s/ch	16 bit	6	± 5 V or ± 10 V	385 €
	DT9816 S [4]	Simultaneous	750 kS/s/ch	16 bit	6	± 5 V or ± 10 V	460 €
ADLINK Technology	USB-1901 [5]	Simultaneous	250[2] kS/s	16 bit	16	$\pm 0,2$ V up to ± 10 V	455 €
	USB-1902 [5]	Simultaneous	250[2] kS/s	16 bit	16	$\pm 0,2$ V up to ± 10 V	560 €
	USB-1903 [5]	Simultaneous	250[2] kS/s	16 bit	16	$\pm 0,2$ V up to ± 10 V	565 €
Keithley	KUSB-3100 [6]	Simultaneous	50 kS/s	12 bit	8	$\pm 1,25$ V up to ± 10 V	380 €
	KUSB-3102 [6]	Simultaneous	100 kS/s	12 bit	8	$\pm 1,25$ V up to ± 10 V	1050 €
	KUSB-3108 [6]	Simultaneous	50 kS/s	16 bit	8	$\pm 0,02$ V up to ± 10 V	1110 €
Agilent	U2300A [7]	Simultaneous	3 MS/s[3]	16 bit	16	$\pm 1,25$ V up to ± 10 V	1235 €
	U2500A [8]	Simultaneous	2 MS/s/ch	16 bit	16	$\pm 1,25$ V up to ± 10 V	1365 €

1.3 RELATED WORKS

Camargo et al (2015) [8] made a DAQ System making use of Arduino for the integrating of sensors to the computer. The system had been qualified for poultry coops environment external and internal conditions (humidity and temperature) measurement.

Kashyap (2015) [9], has Designed a Lower Cost Multi-Channel DAQ System concerning Meteorological Application. The proposed DAQ had been designed to acquiring barometric pressure, temperature, light intensity, altitude and humidity direct from the environment and save the data in a computer concerning future use. The sensors have been interfaced with microcontroller based ATmega328 that performs the acquiring purpose and data logging.

Simões and Souza (2016) [10], has developed a cheap computerized DAQ system for urban sites humidity and temperature monitoring based on IoT (internet of things). They developed a computerized DAQ system that communicates the interoperability and interaction of the humidity and temperature sensors via the internet. The excremental results showed that the use of IoT enhanced the effectivity of automatic decision making for the system.

Misiruk et al (2016) [11] established a DAQ System depending on Arduino Platform for Measurements of Langmuir Probe Plasma. Arduino Nano has-been employed to design this simple DAQ system and Bluetooth has-been employed for data transmitting. An Android program has-been established for data analysis and visualization. The system has-been successfully implemented to obtain Langmuir probe using a hollow anode measurements data.

1.4 AIM OF THE WORK

The main goal of this project is aiming to design and constructed a DAQ system that able to process and measure several parameters by using the Arduino platform and PC based program for GUI monitoring, with the related tests. It is expected that the proposed DAQ system allows user to control the microcontroller in a very easy way by utilising a computer, without need of having a deep knowledge relating to Arduino programming. The user should be able to control the system and read the information by using user interface (UI), which is user-friendly and suitable to use. The method on how the system controls and measures the parameters is themain goals. The system should be not receive any incorrect data, or poor precision data , since that means the system is failure in its application.

1.5 THESIS LAYOUT

This thesis is organized in four chapters besides this chapter and ends with references, each chapter is described as follows:

- **Chapter Two:** reviews the DAQ techniques besides the explained the main component of DAQ system. Also, explained some types of DAQ systems and its features and explained the software that can be used to develop these systems.
- **Chapter Three:** describes the design of the DAQ system with all component and techniques used in it.
- **Chapter Four**: details the results and summarizes the most significant conclusions of the proposed system presented in this work.
- **Chapter Five:** presents the conclusions, and suggestions for future work.

2. THEORETICAL CONCEPT OF DAQ SYSTEMS

2.1 INTRODUCTION

This chapter presents an overview of technologies and methods relevant to inertial measurement, data acquisition and their application.

2.2 DAQ SYSTEMS CONCEPTS

DAQ systems are equipment that measure physical quantities and translate them into a digital data format to be processing and storage by computers. The standard constituents of a data acquisition platform are (i) sensors that convert the measurement into a signal, (ii) Acquisition Board or Processing Control Unit (PCU), which is the unit that receive signal from sensors then convert it to digital signal then transmit it to computer (iii) Computer or (PC) it is the final part when signal received and processed. [12]. Figure 2.1 sows the general acquisition system. This system is structured thorough hardware elements.

Figure 2.1 A typical structure of DAQ system [12]

As shown from figure 2.1, each one of these elements provides certain function. The first part (sensor) is sense the certain information that has designed for it (for example, temperature sensor measure the environmental temperature) and then send it readings which is analog signal to acquisition board. The processing control unit (PCU) is the second element included in the acquisition system. It is including some significant operation such as signal processors and analog to digital converter (ADC). The signal processors module is executing the mathematical operations on sensor signals, while the ADC is converting the analog signal to digital. The PCU can receive the information from the sensor or another external device and output it to computer. The computer is the final element of DAQ system, which is processes the data coming from the acquisition board that connected to a computer via communication port such as serial communication such as (RS232) or parallel communication such as USB. The input signal in acquisition system can be digital or analog. Referring to the analog signal from the sensor should be converted to digital signal using the ADC [12].

2.2.1 Sensors

The first component in an acquisition system is known as sensor or transducer. The sensors are at the simplest measurement devices, basically a detector that measures a amount in the physical world and changes it to a signal that can be read by an observer. A fundamental example is the mercury thermometer that measures the temperature value and transforms it into a visual signal; in such a case, a distance that can be interpreted visually by the user. Current sensors are available in a range of sizes, shapes and operating principles. There're generally found in everyday activities as equipment which we interact with: switches, buttons or the monitoring devices foundes in medical apparatus, machinery, automobiles and so on. The sensors can function in an analog way such as a voltmeter or thermometer or they can function in a native digital state, for example, a two-way switch [13].

Important principles of sensors, no matter of function or measured quantity, are those of precision and accuracy. Accuracy is a check of how close the measurement is to the real value and the precision is a check of how unchanged the measurement is under unchanged conditions. The large majority of sensors are generally calibrated by comparing measurements against established standards. An additional important concept is that of resolution that is the minimum, amount of change in measurement quantity that the sensor can detect [14].

There are several parameters to consider in the functionality of the acquisition system. Some of these parameters are the following [15]:

- **Measurement range:** This range is specified for the minimum and maximum value which it can be measured for the sensor, and this get an appropriate behavior.

- **Sensibility:** It is the relationship concerning the magnitude of input and output in absence of errors. In cases where the relation is continuous in the measurement range, the sensor is then being linear.
- **Resolution:** This parameter is the minimal change in the input variable which can be determined on the output.
- **Precision:** It defines the concordance degree between the result and the measurement magnitude value.

2.2.2 The Processing Control Unit (PCU)

In a DAQ system, the PCU controls the conditioning of analog signal (attenuation or amplification chain along with digitally programmable gains). Also, it is responsible for control the sampling frequency and gathering up the data from the ADC. The PCU can communicate with another devices through variety of protocols. The most typically used protocols are USB, I2C, UART and SPI. An additional protocol is parallel communication which usually used to communicate the processing unit with the other components. Most of these protocols could be implemented in software. Even so, the presence of dedicated hardware modules inside control unit used in implementation of the DAQ system can permits more control flexibility of any module [16].

As processing the data might need a high computing power amount, the data need to be transferred to an alternative peripheral like a computer. The data transfer between the DAQ system and the PC can be achieved by an auxiliary component or by the microcontroller itself. Depending on the communication type, transmission rates needed and the portability of the DAQ, several protocols are more practical than others. With respect to higher transmission rates, the PCI and PCI-Express are best. For higher portability, the protocols such as USB, ethernetor or 802.11x will be more suited. In Table 2.1, some key features to select the communication protocol are shown [17].

Table 2.1: Communication protocols used on DAQ systems [17]

Specification	Communication Method				
	USB	PCI	PCI Express	Ethernet	802.11x
Communication type	Series	Parallel	Parallel	Series	Wireless
Speed	60MB/s	132MB/s	250MB/s	125MB/s	6.75MB/s
Portability	Yes	No	No	Yes	Yes

2.2.2.1 Signal Processors

Signal processors are parts of a DAQ system that execute mathematical operations upon sensor signals. There're a range of possible objectives for such processors, involves but not limited to: conversion, filtering, amplification and smoothing. The signal processors nature can vary from electronic, electrical, mechanical or software [13].

2.2.2.2 Analog to Digital Converters

The ADC or analog to digital converter, is an element that converts a continuous analog measure to the digital discrete amount. The ADC reads an analog quantity as measured by a sensor and transforms it into a digital comparative that can be processed by a computer. The ADC is the last important link in a DAQ system that permits the computer to interface with the analog real world. The sensor measured the physical quantity, then transforms it into an analog signal like for example a voltage that can then in turn be transformed into a digital value [17].

The conversion in ADC is divided in three stages, sampling, quantification and codification as shown in Figure 2.2.

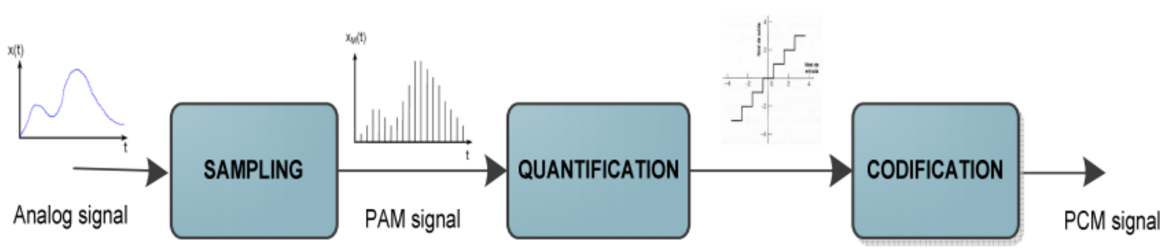


Figure 2.2 Sampling, quantification and codification in an acquisition system [12]

A. **Sampling:** The sampling process is the conversion process from the continuous signals to discrete signals. Thus, the signal is measured in certain periods of time. The sampling frequency is calculated by the Nyquist criterion, that says it should be at minimum twice the signal bandwidth.

B. **Quantification:** In this part, it presents the amplitude signal utilising a finite number in a specific time. If the converter has n bit, generally there are 2 n values or states which can be represented.

C. **Codification**: At last, the last stage describes the assigned value representation for the signal thorough a symbol combination, 0 and 1 binary codification.

After that, the signal is available to be processed by a software code that will determine an output signal depending on a specific requirement.

There are many types of ADCs that all accomplish the corresponding function but just employ several methods to attain this task. Some common types are [17]:

- Integrating
- Direct-conversion
- Successive-approximation
- Counter-ramp
- Ramp-comparison

Many ADCs have a linear response for their input signals, which is usually their output is proportionate to their input. The ADC choice is depending upon the input signal type of and its estimated characteristics for example, rate of change, frequency, speed and so on [18].

Quantifying ADC efficiency is achieved by the following parameters [19, 20]:

- **Resolution:** the ADC resolution is measure amount of digital values appear as the output through a given range of input signal. Mainly, it is defined as a binary number for an ADC, as the output is digital. For example, an 8bit ADC could have a resolution corresponding to 28 or 256.

- **Offset and full-scale error:** The offset error is due to the requirement for the input signal to reach the primary threshold just before triggering a change in the ADC output. In other hand, the full-scale error is comparable to offset error but is at the other end of the scale: if the input signal attains the upper limit of the ADC measurable scale. The information on offset error are shown in figure 2.3 while full-scale error is shown in Figure 2.4.

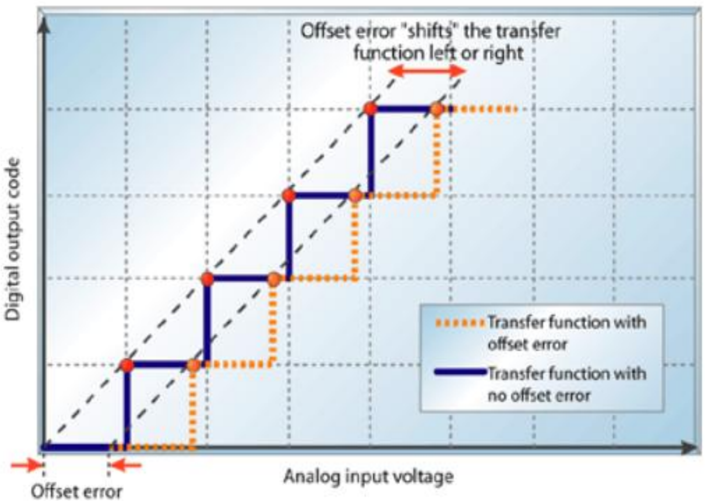


Figure 2.3 Offset Error

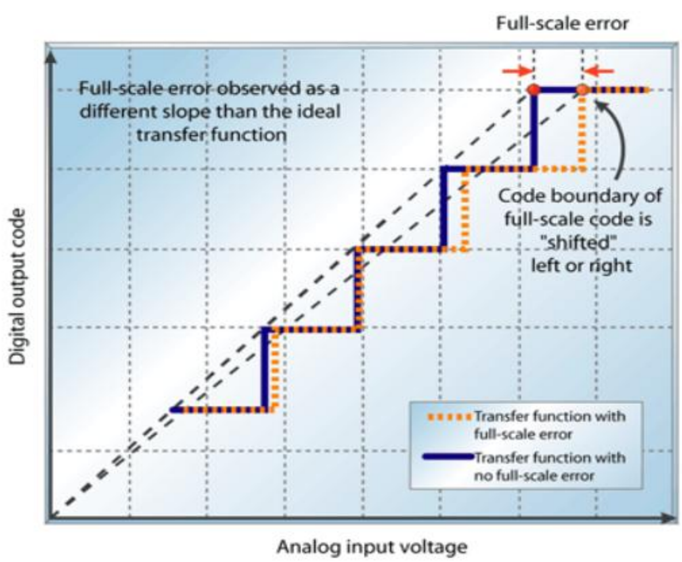


Figure 2.4 Full-Scale Error

- **Nonlinearity:** As mentioned before, an ideal ADC could have a linear output with considered to the input signal. Nonlinearity is a measure how the real output symbol deviates via this ideal linear relationship. A method to evaluate nonlinearity is by differential nonlinearity, that is defined in equation (2.1) as [13]:

$$DNL = \frac{V_{n+1} - V_n}{V_{LSB}} \tag{2.1}$$

Where, V_n is the voltage at the current step, V_{n+1} is the voltage at the next step, and V_{LSB} is the smallest detectable change in voltage called the voltage of the least significant bit (LSB).

- **Quantization error:** The quantization error is the last significant error source inherent to ADC. This special error can be calculated as the different between the input signal and output signal of ADC. Due to the fact that the output signal is digital in nature (that is looks as ‘steps’), it is not able to absolutely represent an analog signal completely. Figure 2.5 shows the concept of quantization error: As shown in figure, the dotted line symbolizes a smooth analog ramp signal; and the blue line refers to the ADC step-like digital output.

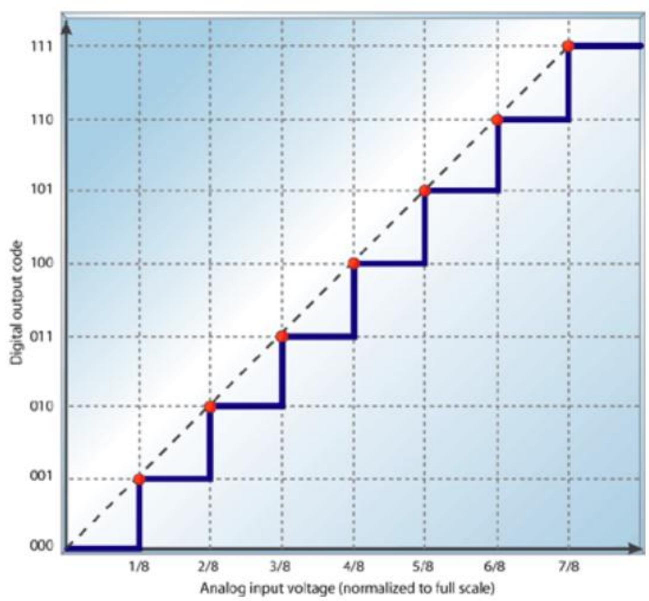


Figure 2.5: ADC Quantisation Error [19]

2.3 DAQ TYPES

The DAQ and the control hardware is commercially available in a different form. It is amiable in different levels of accuracy, speed, channel count, functionality, resolution, and price. This part is summarizing the benefits and features that generally involved in the several categories, according to products [20].

2.3.1 Plugin DAQ Boards

Like modems, display adapters and another expansion board type, the plugin DAQ boards has been designed for installing in motherboard slots within the computer. In the present day, most DAQ boards are designed for the earlier ISA buses or current PCI. DAQ plugin boards and interfaces are designed for other buses (Micro Channel®, IBM, EISA and several Apple buses), however, these plugins are no longer considered market products. As a category, plugin boards provide a range of adequate sensitivity, high speed, high channel counts and test functions to measure relatively low signal levels, and it in lower cost [21].

The features of plugin DAQ boards are [22]:

- Most cost-effective method of control and computerized measurement.
- High-speed method that available in range from 100kHz up to 1GHz and higher.
- The range of input voltage is limited to around ±10V.
- Existing in multi-functional versions that may combine timing, D/A, A/D, counting, digital I/O and specific functions.
- Changing or making connections to I/O terminals of board can be undesirable.
- Great for tasks that from low to medium channel counts.
- Use of PC internal resources and expansion slots may consume PC resources and limit expansion potential.
- Performance sufficient to excellent for the majority of tasks, however, electrical noise within the PC may limit the ability to do sensitive measurements.

2.3.2 External DAQ Systems

The external data-acquisition devices are the dedicated devices that can connect to computers via Ethernet, USB, RS232, or other connection techniques. In all of these bus-based cases, the software posts register commands through the bus to the PC in order to transfer data and control the device. These DAQ are able to integration with common PC technologies and it enables for related hardware and software architectures throughout a range of devices. These systems are often provided more I/O channels, a noise-free electrical environment, and higher versatility and speed in adapting for several applications. Now a day, external DAQ systems typically take the form of a stand-alone measurement solution and test focused toward industrial applications. The range of applications for that external DAQ has been used is commonly demand much more than the DAQ system that based on a PC with plugin boards can provide or this architecture type is basically inappropriate for the application.

They're many architectures for external industrial DAQ systems, such as Compact PCI, PXI, VME, MXI, and VXI. These systems make use of standardized board racks, mechanically robust, and plugin instrument modules which usually offer a full functions range for measurement and test [22].

The features of external DAQ system are:

- Multiple board slots enable matching and mixing boards to services higher channel counts and specialized control and acquisition tasks.
- Chassis provides an electrically noise-free environment rather than the computer, which permitting for more sensitive measurements.
- Make use of standard interfaces (Ethernet, USB, FireWire, IEEE-488, RS-232) can assist in long distance acquisition, networking, daisy chaining and can be use with different types of computers.
- Dedicated memory and processor can support essential stand-alone acquisition independent of a computer or “real-time” control applications.

- The architectures of standardized modular are easy to configure, mechanically robust and are able to provide for a wide range of control functions and measurement.
- Required accessories, modules and chassis are affordable for high channel counts.
- A lot of architectures have low vendor support, and it is limiting the sources of accessories and equipment available.

2.3.3 Discrete Instruments

These systems are an electronic test instruments that consisted mainly of singlechannel meters, related instrumentation, and sources designed for multi-purpose applications. Throughout the years, the increases of communication interfaces and improvements in instrument manufacturing, design, and measurement technology is extended the functionality and range of these instruments. New equipment such as counter/timers, micro-ohmmeters, scanners, SourceMeter® instruments, multiplexers, nanovoltmeters and various other specialized instrumentation made it conceivable to make measurement systems and computer-controlled test that offer excellent resolution and sensitivity [26].

The features of discrete (Bench/Rack) instruments are [26]:

- Support sensitivities and measurement ranges commonly over and above the limits of standard plugin DAQ boards and eternal DAQ systems.
- Use standard interfaces such as (RS-232, USB, IEEE-488 FireWire) that have compatibility with non-IBM-compatible PC, support long-distance acquisition, or can be uses with computers that have no available expansion slots.
- Most ideal for measurement of temperature, resistance, inductance, capacitance, current, voltage, etc. Might not be good solutions for signal conditioning requirements and some types of specific sensors.
- In general, it is slower than plugin DAQ boards or external DAQ systems.
- More costly than standard DAQ systems on a per-channel basis.

2.3.4 Hybrid DAQ Systems

Hybrid DAQ are a basically recent advancement in external DAQ systems. A standard hybrid DAQ combined a DMM (digit multimeter) type UI with many standard DAQ functions and expansion functions in a compact, instrument such as package. Standard functions involve triggering, event counting, timing, process control, DC and AC current and voltage measurements, and frequency and temperature measurements, [27].

The features of hybrid DAQ system are:

- Provides sensitivity, accuracy, and measurement range regular of bench DMMs, and excellent to standard DAQ equipment.
- The front end of digit multimeter with digital display and the front side panel controls offer resolution equal to a digit multimeter (18bit to 22bit A/D or greater).
- Built-in program and data storage memory for process control and stand-alone data logging.
- Make use of standard interfaces (IEEE488) which usually support acquisition for long-distance and give compatibility with non-PC computers.
- low cost.
- The expansion capacity is Limited (less important because the capability of base test is currently complete).
- Commonly, more slowly than plugin DAQ boards or external DAQ systems.

2.4 DAQ PLATFORM

DAQ can be generally classified to about three different categories: computer based DAQ, DAQ based upon separate acquisition devices, and Modular DAQ. Figure 2 shows the about three types of DAQ system [9].

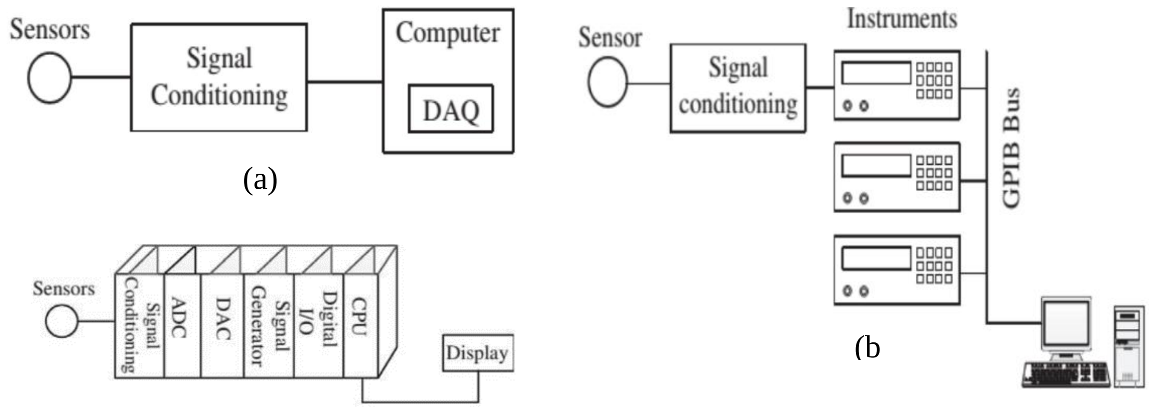


Figure 2.6: Block diagram of different type of DAQ systems, (a) PC Type (b) Type based Separated acquisition instruments and (c) Modular Type [9].

In this thesis we have focused on DAQ based PC. This system is consisted from three main parts with microcontroller selection requisites and proceeds with a short explanation of the selected MCU and designed DAQ hardware.

2.5 HARDWARE REQUIREMENT FOR COMPUTER BASED DAQ

2.5.1 Personal Computer (PC)

The Personal Computer (which also terms PC) is represent any typical-purpose computer whose original sales price, capabilities and size makes it valuable for people and that is intended to be functioned directly by an end-user without the need of intervening computer operator. The PC could be utilized for DAQ system that can significantly affect the maximum speeds where is able to constantly attain data. The current technology offers PowerPC and Pentium and class processors including the higher performance architecture of PCI bus along with the traditional USB and ISA bus. With the development of PCMCIA, portable DAQ is fast becoming a much flexible replacement for desktop computer based DAQ systems. In remote DAQ applications which make use of RS232 or RS485 serial communication. The capabilities of data transfer of the PC used can considerably affect the DAQ system performance. To obtain the DMA benefits or interrupt transfers, the DAQ board that been choose should also be able of making these transfers types. The factor that limits the acquiring large quantities of data is generally the hard drive. The hard drive fragmentation and disk access time can considerably decrease the maximum rate at which will data can be streamed and acquired to disk. Applications that requesting a real-time processing to deal with higher frequency will needs a high-speed, 32bit processor or 64bit with its associated coprocessor, or a dedicated plugin processor including a DSP board (digital signal processing). When the application just scales and acquires a reading once or double a second, even so, a low-end computer can be sufficient [28, 29].

2.5.2 Processing Control Unit (PCU)

As described in section 2.2.2, the processing control unit is accountable on various operations involve doing the analog to digital converter, receiving signal from sensors, etc. This controller could be the FPGA (Field Programmable Gate Array), PIC (Peripheral Interface Controller) or a DSP (Digital Signal Processor). In present years, there are an increase of developing and manufacturing the control units and there is a wide range of microcontroller units that be available to everyone because of its low cost and simple in programming.

Microcontroller is a one chip microcomputer for embedded control uses. It has a many same main component as in a full-sized PC except for minimized in memory and computing capabilities. This hardware involve memory, CPU, and I/O capability. The microcontrollers are designed for use on embedded tasks for a great many modern devices including machine control systems, mobile electronics, etc. [30].

Many microcontrollers packed on development or “header” boards as one shown in figure 2., by this way it can allow for easy connection with different sensors and electronic storage units, performing a good choice as the basis of a DAQ platform.

Figure 2.7: AT90CAN128 AVR Microcontroller and Header Board [31].

The name "Header boards" is named simply since they enlarge the tiny connector format utilized by the integrated circuit to the larger, furthermore user-friendly format. Most of microcontrollers manufactured by this way make it possible for easy connectivity with separate electronic storage units and sensors, which makes them a best choice as the basis of a DAQ platform. The interfacing of sensors with microcontrollers could be easily accomplished by using built-in ADC. Specific higher or mid-range microcontrollers services other communication protocols including the following [32]:

- **I2C (Inter-Integrated Circuit):** It is a multi-master serial sole ended bus which includes an SDA and SCL.
- **UART (Universal Asynchronous Receive Transmit):** This protocol is permitting the communication of parallel signals in a serial format. Physically, it consists of a receive and transmit input.
- **SPI (Serial-Parallel Interface) Bus:** It is the synchronous serial data link that includes, the MOSI (master output/slave input) connection, the SCLK (serial clock output) and the MISO (master input/slave output).

The significant advantage of microcontrollers it is cost effective relatively low in cost). One famous type of microcontroller utilized for experimental or research purposes is the Arduino family [33]. Table 4 shows a comparison of some common boards of the Arduino family includes its price.

Table 2.2: Communication protocols used on DAQ systems [33]

Arduino Model	Clock Speed (MHz)	Flash Memory (kilobyte)	Number of Analog Inputs	Number of Digital I/O pins	Number of UART ports	Typical Price in $US
Mega2560	16	256	54	16	4	58.42
Due milanove	16	32	14	14	1	22.47
Leonardo	16	32	12	25	1	23.97
Uno	16	32	6	14	1	29.96
Fio	8	32	8	14	1	24.95

2.5.3 Software

The software converts the DAQ hardware and PC to a complete DAQ system. The DAQ hardware not including software is unusable and the DAQ hardware with insufficient software is practically useless. The most of DAQ applications work with driver software, which is the layer of program that straight programs the DAQ hardware registers, controlling its operation and its integrating with the computer resources, including memory, DMA and processor interrupt. The driver software covers the low-level, complicated features of hardware programming, offer easy-to-figure out interface. When selecting driver software, they're many factors should be taken in consideration. The driver functions for managing DAQ hardware could be arranged into timing, digital and analog I/O, and Typically almost all drivers should have this basic functionality, it needs to make sure that the driver perform more than just get data off and, on the board,, but it should make some further functionality which includes [34]:

- Stream data from and to disk.
- Acquire data at selected sampling rates.
- Integrate much more than one DAQ board
- Use programmed DMA, interrupts and I/O to transfer data.
- It can have acquired data in background and in same time can processing in the foreground.
- Carry out several functions at the same time

There are many specialist DAQ software packages are available that are geared mainly for use with PCs. One example of such a product is "LabVIEW" from National Instruments™, which specified as a graphical programming environment used from large numbers of scientists and engineers to develop advanced control, test and measurement and systems. This software type permits the user to interface and connect with several sensors while enabling the ability to test and design an interface for a DAQ system [35].

3. THE PROPOSED SYSTEM DESIGNS

3.1 THE PROPOSED DAQ SYSTEM STRUCTURE

In this work we have proposed DAQ system that can control the laser device in order to perform some operation such as controls the laser beam power, convert the continues signal laser to pulses and controls the number of pulses as well as makes pulses as a function of time.

The proposed DAQ is consisted from three main components: Sensors, Digital-Analog input/output (DA-IO), Controller and graphic user interface (GUI). Figure 3 shows the scheme of proposed DAQ system.

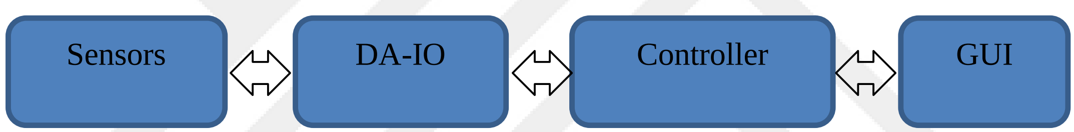


Figure 3.1 Proposed DAQ system scheme

The proposed DAQ unit is consisted from: main parts: Microcontroller, Light Sensor, light emitted diode, communication ports, Figure 3.2 illustrated the proposed system structure.

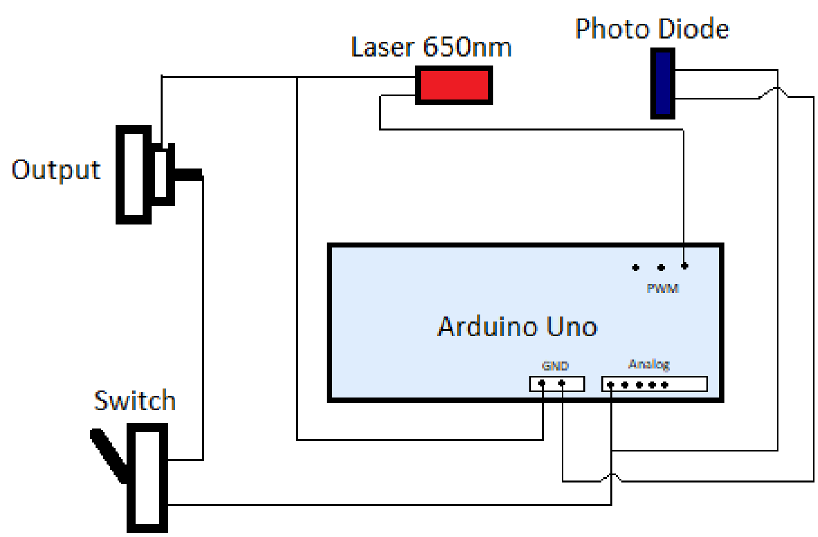


Figure 3.2 The proposed DAQ system structure

3.2 SENSORS

Sensors are the first input element used in checking out physical quantities (for example position, force or temperature) towards a DAQ system. They're commonly used to determine analogue signals. In this work we have used photocell sensor in order to receive laser signal and show the signal in GUI.

The photocell sensor or light dependence resistance (LDR) component is the part responsible of measuring the value of the lights falling over photo resistor element. The LDR has been connected to microcontroller via connection wires.

3.3 MICRO CONTROLLER

The controller can be used as the communicator between the PC and real world. Based on the sensors calibration factor, the signal will be converted and gain the actual output. This work implements a low cost DAQ by used low cost microcontroller. In this work we have used Arduino MCU which is commonly used microcontroller unit because it efficient and low cost. Arduino is the open source device for developing PC that can control and sense wide range of the physical world than the PC. It is an open-source platform for physical computing depending on a small microcontroller board, in addition to the development environment used to writing software to programing the board. The software of Arduino is written in either C/C++ programming language.

This Ardunio board has a microprocessor that comes from a organization called Atmel. The chip is called an AVR, which is running at only 16MHz with an 8bit core, and includes a very small amount of existing memory, with 32kB of storage and 2 KB of RAM.

In this work we have used Arduino UNO as a control unit. This MUC is based on the ATmega328P processor. It has 6 analog inputs, fourteen digital I/O pins (where six pins can be utilized as PWM outputs), an ICSP header, a 16MHz quartz crystal, a power port, a USB and a reset button. It has almost everything required to support the microcontroller; Arduino can be supplied with electrical power by either connected it to a computer via a USB or can use AC-to DC transformer and connect it to power jack or it can use the battery. The programing code is very much simplistic for this Arduino microcontroller. As a result, it has multiple benefits, easy to use methodology, less expensive solution with appropriate results. Figure 3.3 shows the Arduino UNO Microcontroller board and the Table 3.1 shows the Arduino UNO MCU specification.

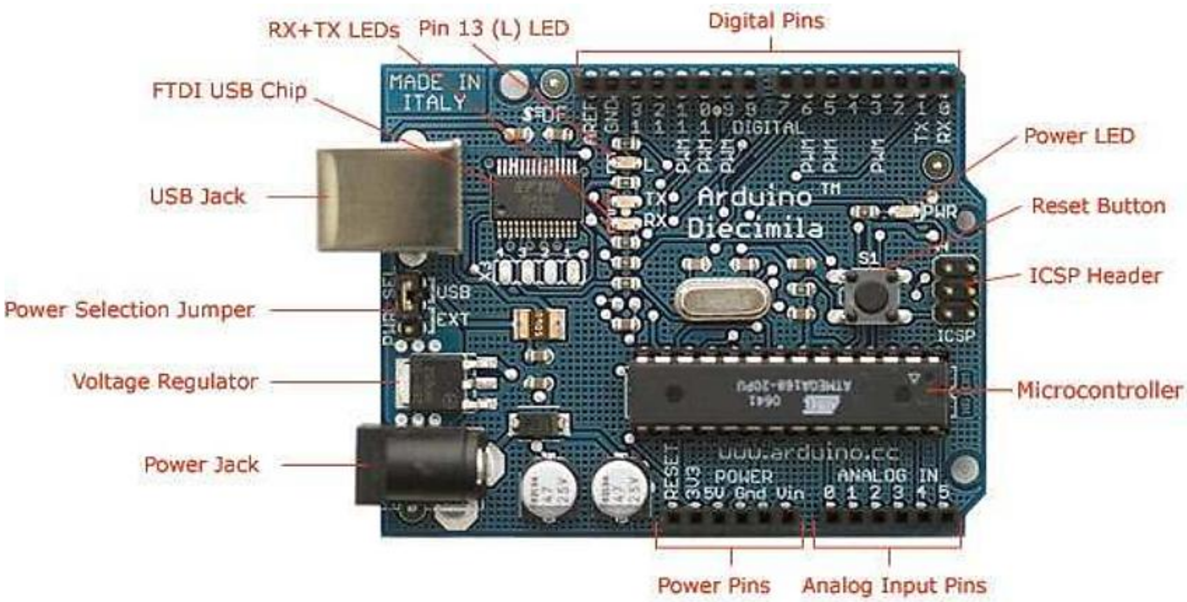


Figure 3.3 Details of Arduino UNO MCU

Table 3.1: Arduino UNO Specification

CPU	ATmega328
Clock Speed	16 MHz
Flash Memory	32 KB
SRAM	2 KB
Digital I/O pins	14
Analog Input Pins	6
Input Voltage	7 V to 12 V
Input Voltage (Limits)	6 V to 20 V
Operating Voltage	5 V
DC Current for 3.3V Pin	50 mA
DC Current per I/O Pin	40 mA
Analog Input Current	6

3.4 GRAPHICAL USER INTERFACE (GUI)

The GUI is showing the calibrated signals on the computer software or on display. In this work the GUI is designed by used LABVIEW, which is the product of National Instruments, which is powerful software system that fits the requirement for instrument control, data presentation, data acquisition, and data processing. It is a high-level programming language that follows the internal structures of C language. It uses the G language (the graphical programming language) departing from the classic high-level languages like: Basic, Pascal or C language. However, it offers extra simplicity and features regarding producing signal processing calculations. It can run on PC under many operation systems such as windows, Linux, Apple Mac OSX, etc.

The graphical programs of LabVIEW known as Virtual Instruments or basically VIs, consists of Block Diagram and Front Panel. LabVIEW manages DAQ, analysis and display into one system. In order to controlling instruments and acquiring data, the LabVIEW operates over RS-232, USB, and IEEE-488 (GPIB) protocols in addition to other A/D, D/A and digital I/O interface boards. LabVIEW analysis Library provides the user a wide-ranging of resources for linear algebra, statistical analysis, filtering, signal processing and many more. The LabVIEW from version 5 and up can supports Active X Control making it possible for user to control the object in Web Browser.

The LabVIEW toolkit assists to perfectly interface the Arduino microcontroller with LabVIEW software. by used LabVIEW, we are able to acquire data or control the Arduino. Figure 3.4 shows the block diagram of program structure in LabVIEW. In this work we have designed a program that mange the laser operation such as laser intensity and pulses duration via controlled the Arduino microcontroller, figure 3.5 shows the program scheme in LabVIEW.

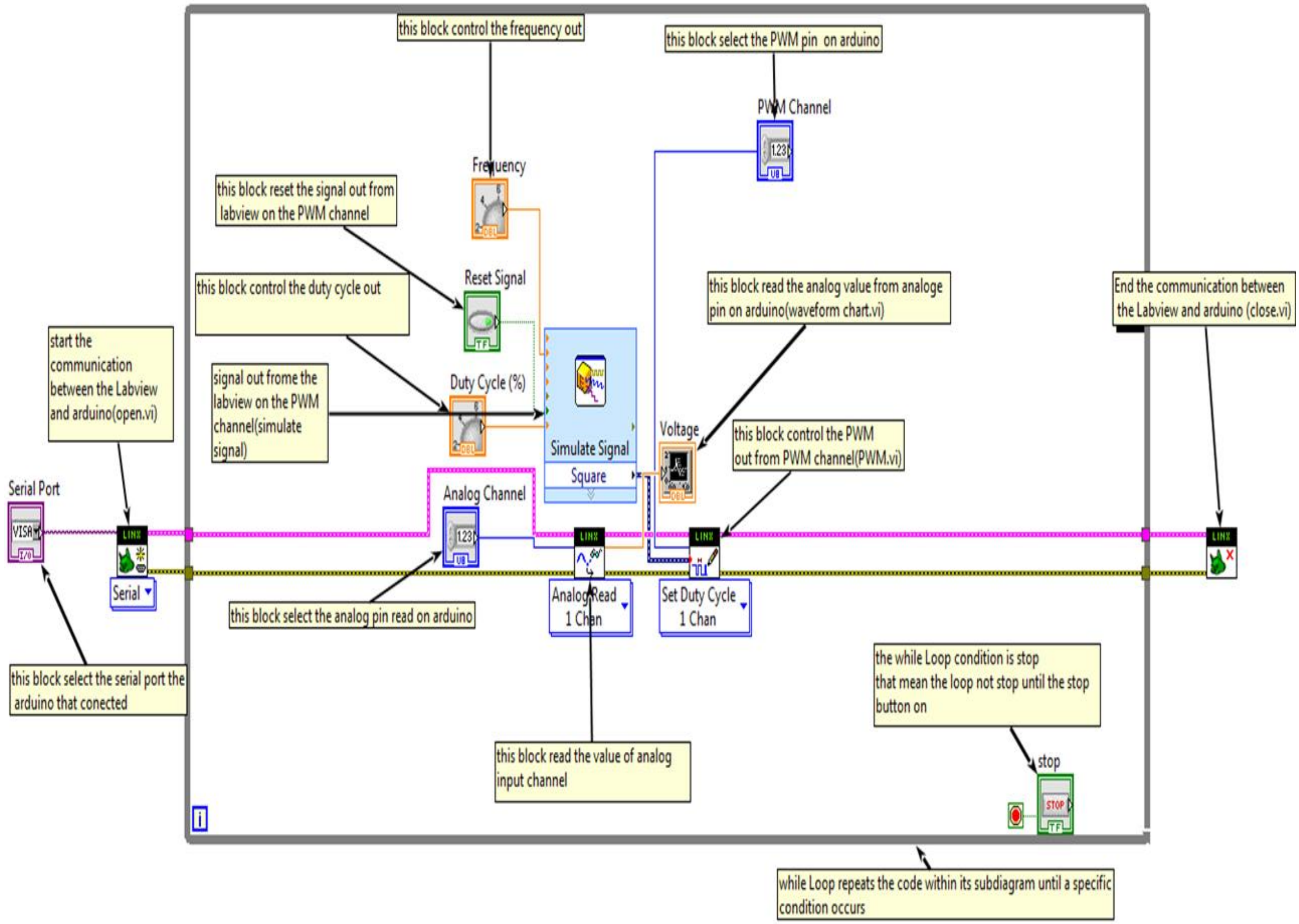


Figure 3.4: The block diagram of program structure in LabVIEW

The GUI has been designed to be simple and it includes the adjusting tuner to make desired function, and it contain display in order to show the laser signal result in real time. Figure 3.4 shows the GUI that can be controlled by users.

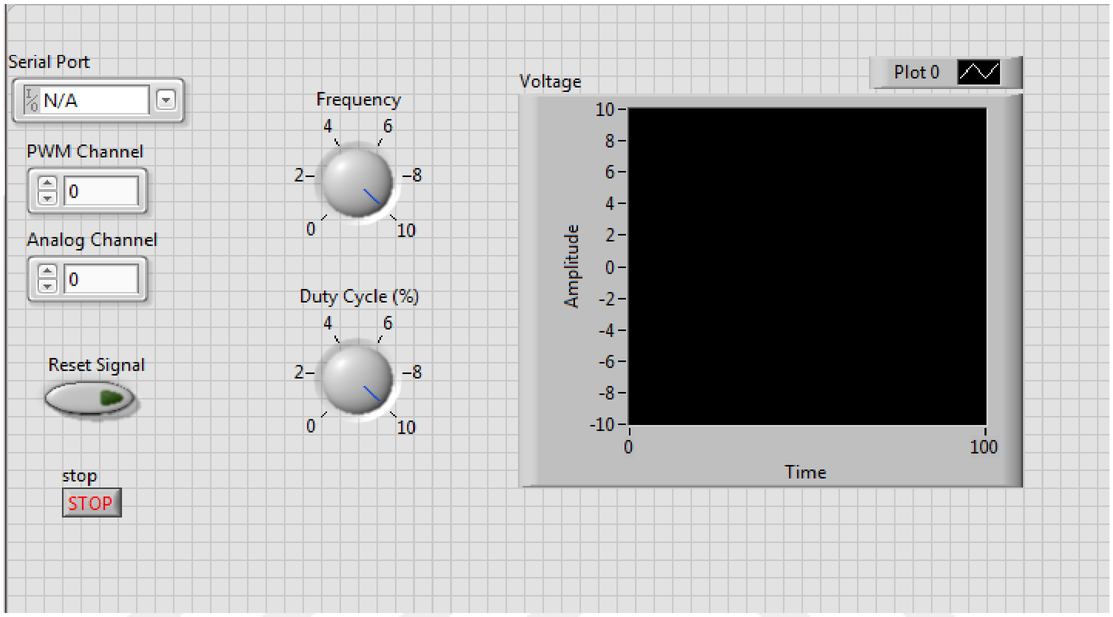


Figure 3.5: The GUI program in LabVIEW

The GUI includes

1. **Serial Port:** to select the serial port on Arduino.
2. **PWM Channel:** it is the pulse width modulation channel, used to select the PWM pin on Arduino
3. **Analog Channel:** determine the analog channel
4. **Frequency:** to control the frequency out
5. **Duty Cycle:** Control the pulse
6. **Reset Signal:** Reset signal out from LabVIEW to PWM channel.
7. **Stop:** To stop the operation
8. **Plot:** is the signal scope that user can view the function and operation in real time. The user can adjust the parameters and he can see the result directly on plot.

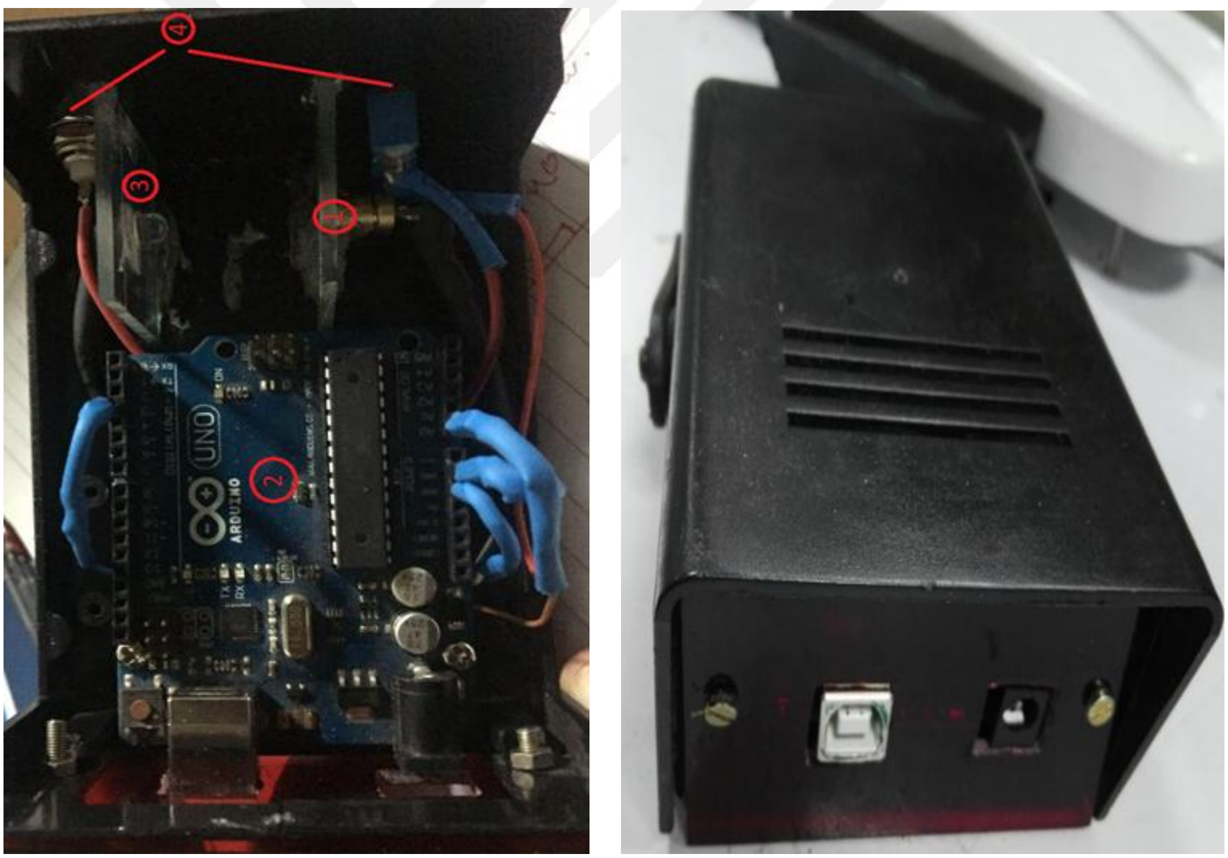
The operation of proposed system that the user can control the intensity of laser by converted the frequency tuner in GUI and can also controlled make laser shot as pulses with selected pulse duration via used Duty Cycle tuner in GUI. The microcontroller controlled the laser function. In other side, the photo diode can receive the laser signal and then transmitted electric signal to microcontroller which stores that value in its ROM. Then the microcontroller will transfer data to LabVIEW by using VISA tool.

4. RESULTS

This chapter presents the experiments results that leads to measure the operation of DAQ system and determine the accuracy of system in operating the laser source and gathering data.

4.1 SYSTEM SETUP

The proposed DAQ system (figure 4.1) has been tested in order to test the accuracy of operation controlled and gathering signals, and ease of use.



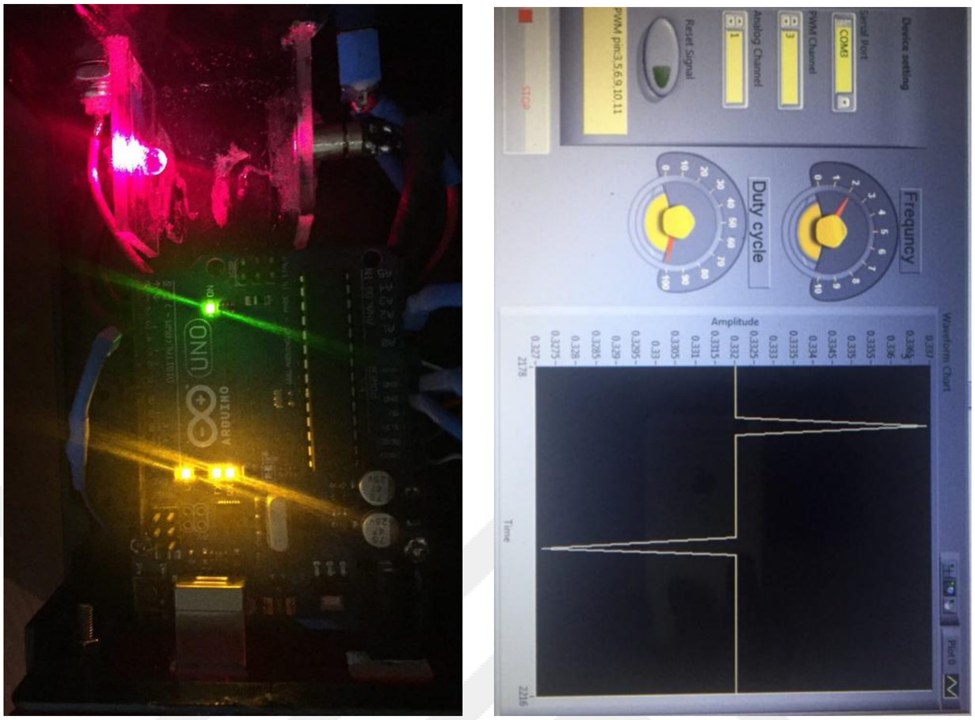
(a) (b)

Figure 4.1: The proposed DAQ system, (a) internal component, (b) outer structure

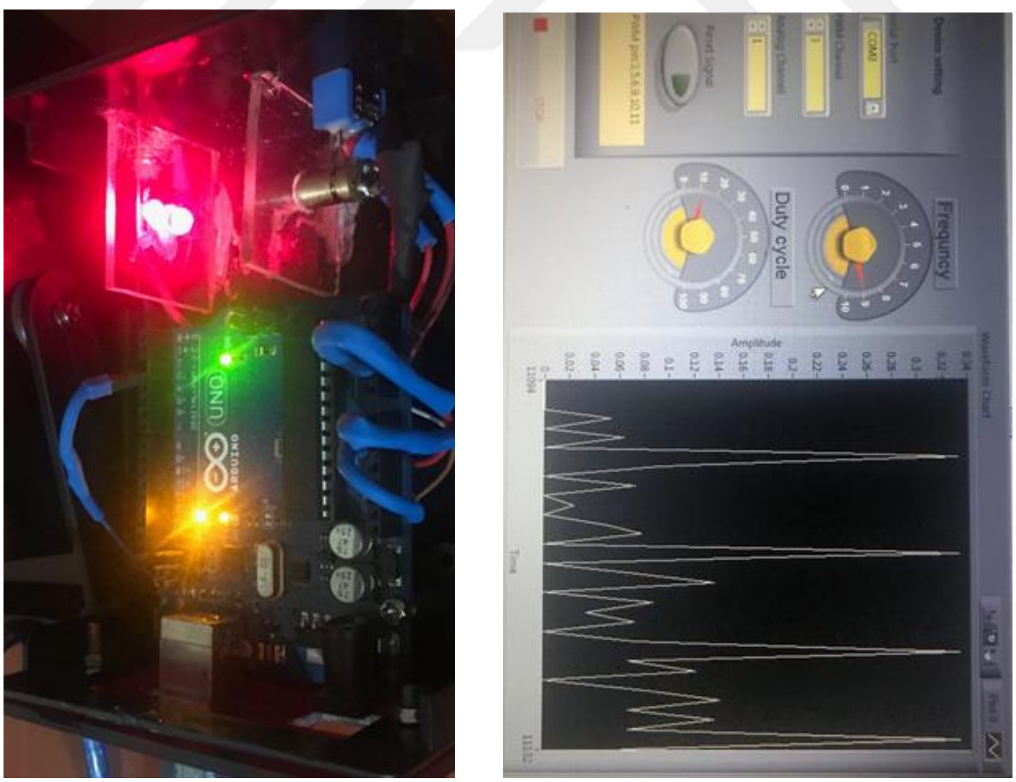
As show from figure 4.1(a), the DAQ unit is consisted from 4 parts, (1) is the LDR sensor that used to receive light signal (Laser) then transfer it to microcontroller, the LDR take its power from Arduino power pin and send recoded data to analog pins in Arduino board. (2) is the Arduino UNO microcontroller that control all operation. It connected to computer via USB port which is also supplies power to controller. (3) The light source, we have used 650nm laser in order to test the proposed DAQ system operation. (4) connection ports, these ports used to connect DAQ system with practical laser device in order to control specific operation and gathering information. There are two connectors in proposed system, one near LDR this to connect external LDR or any light detector to display the received signal on GUI scope of system and see the result in real time when change parameter, and second near laser source which can be connected to light source or its power supply system in order to controls some functions such as make laser be pulses and

4.2 OPERATION TEST

In this test, we have test the operation of proposed system in both controlling and acquisition data. At first increased the frequency tuner to identify the effect on laser source. The effect of frequency tuner is to adjust the voltage of laser source which effect on laser power, as increase the frequency value the voltage feed the laser source increase, and it can be notice the intensity of laser beam has been increases as a result of this increases. In other hand, as decrease the frequency the voltage will be decreases and the intensity decreases too. Figure 4.2 show the effect on laser intensity as frequency increases or decreases.



(a)



(b)

Figure 4.2: The proposed DAQ system at operation, (a) the laser signal when the frequency at 2 degree, (b) the laser signal when the frequency at 9 degrees

As shown from figure 5.2, the laser intensity when put frequency value to 2 is less than the intensity when the frequency value put to 9.

Also, we have tested the operation of laser pulse generation. As the laser source connected to system is continues beam we can generate pulses laser by controls the switching function. This done by adjust the Duty Cycle tuner. This function can control the time interval between switching the on off value which is (0) for off and (1) for on. As the value of duration increase the time of pulse increases too. Figure 4.3 shows the signal shape in oscilloscope as changed of duration value.

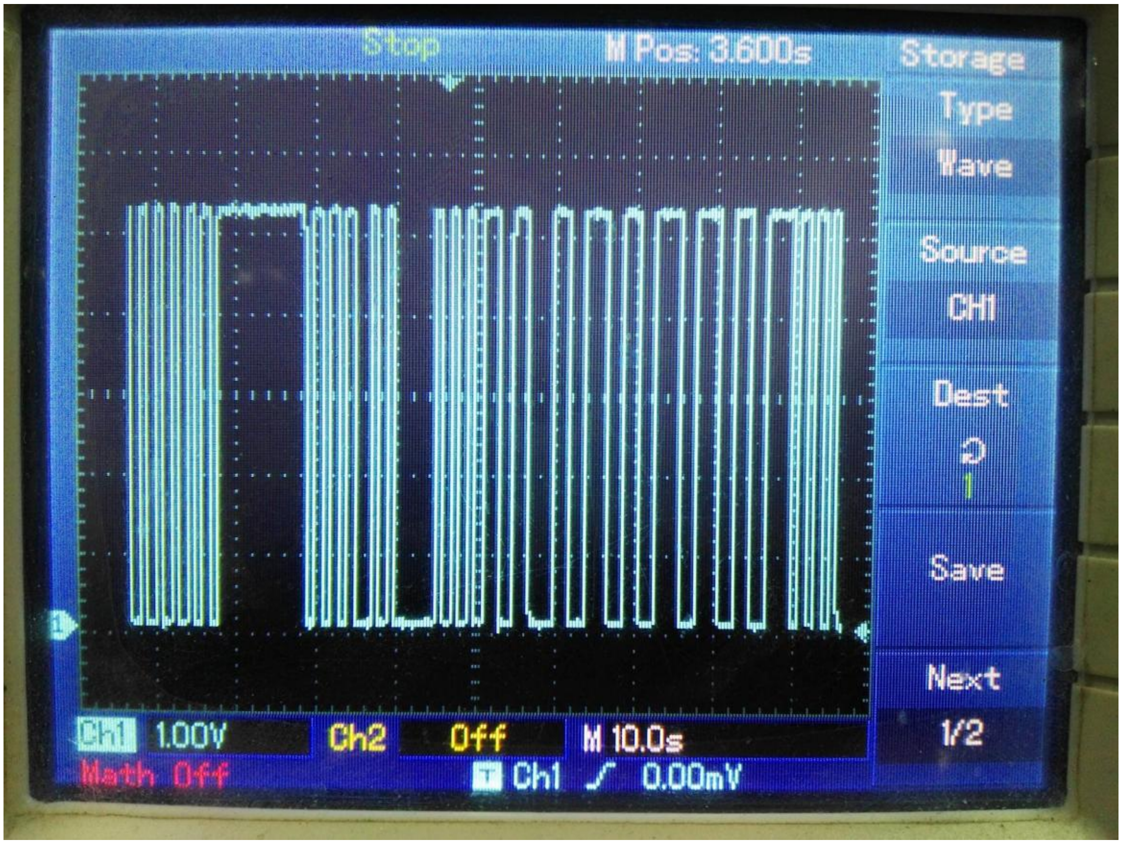
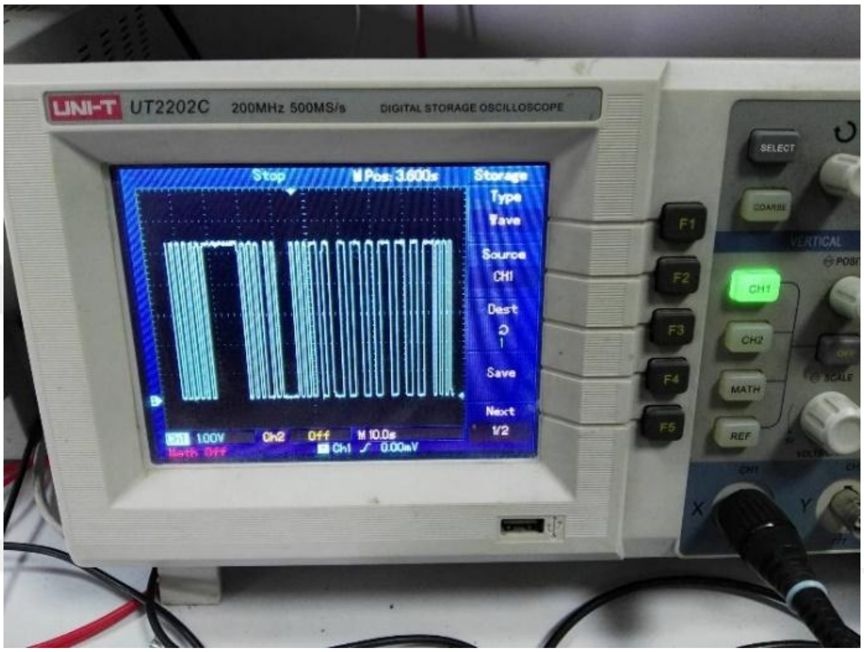


Figure 4.3: The laser signal received by LDR as changes the duration value.

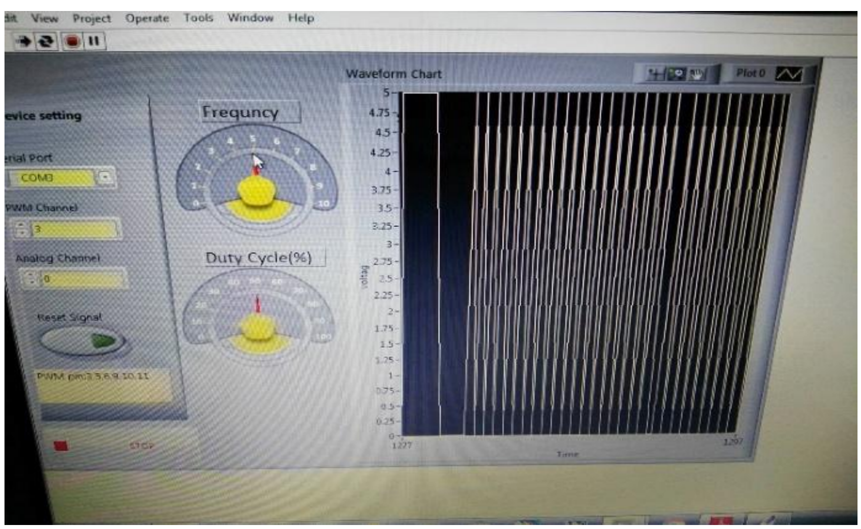
The operation test shows that the system run smoothly, and the controlling orders run fast without any problem. The GUI is simple and easy to use and any one with little information can learn how to use it.

4.3 GATHERING DATA TEST

The DAQ gathering laser signals by used photo diode, we have compared it with an authorized 200MHz digital oscilloscope type (UNI-T) model (UT2202C). Figure 4.4 (a) and 7(b) shows the laser signal in oscilloscope and GUI of DAQ respectively that recorded for same laser pulses.



(a)



(b)

Figure 4.4 the laser signal recorded from (a) digital oscilloscope, (b)proposed system GUI.

As shown from figure 4.4 (a) and (b), the laser signal recorded by the proposed system is relatively identical to laser signal recorded by the professional digital oscilloscope. This provide that the DAQ have high accuracy with some advantage that it can recorded the signal continuously in addition to controlling device and see the results instantly.

5. CONCLUSIONS

In this work, we have proposed a PC based DAQ system that utilized for control and gathering signals form laboratory laser systems. The proposed DAQ has been designed with low cost component where Arduino Uno used as a microcontroller. The experimental results show that the proposed DAQ system run smoothly and it easy to use. The laser signal recorded by DAQ is relatively same as the signal recorded by professional digital oscilloscope, in addition to the signal display in real time without any delay so the user can modify the setting and view result Instantaneously. The system was successfully implemented as proposed and results were obtained as expected. The application of proposed system can be utilized in make a DAQ system for old devices or for new fabricated laser devices.

Compared with to related work [8], the proposed system has some key point of advantage can be pointed in follows:

1- The proposed system is designed as dual operator DAQ and controller that control the laser to generated a desired laser signal such as control the number of pulses, pulse width, generate sequence of pulses and see the effect of modification in real time monitor that is useful in laser application, while the system proposed by [8] has been designed to gathering environmental measurement such as temperature, humidity and the optical sensor detect the light intensity with no controlling function.
2- The proposed system has been designing to work as oscilloscope that detect an optical signal and preview the signal and the effect of any change in laser beam in real time.
3- The Arduino MCU in proposed system used as external computer based “LabVIEW” DAQ that integrated with LabVIEW program (which is professional program used to design a GUI for practical equipment) to be as interfacing board while in [8] they used “Scilab” software which is opensource limited and DIY software that not give acquire and certified result compared with LabVIEW.

For future works, we suggest to investigating the use of different types of MCU that based on different processing technique such as MCU based ARM Cortex processor. And compered between them with take in consecration the operation and data gathering accuracy. In addition, we also suggest to investigating the ability of system to employee in different application rather than laser device.

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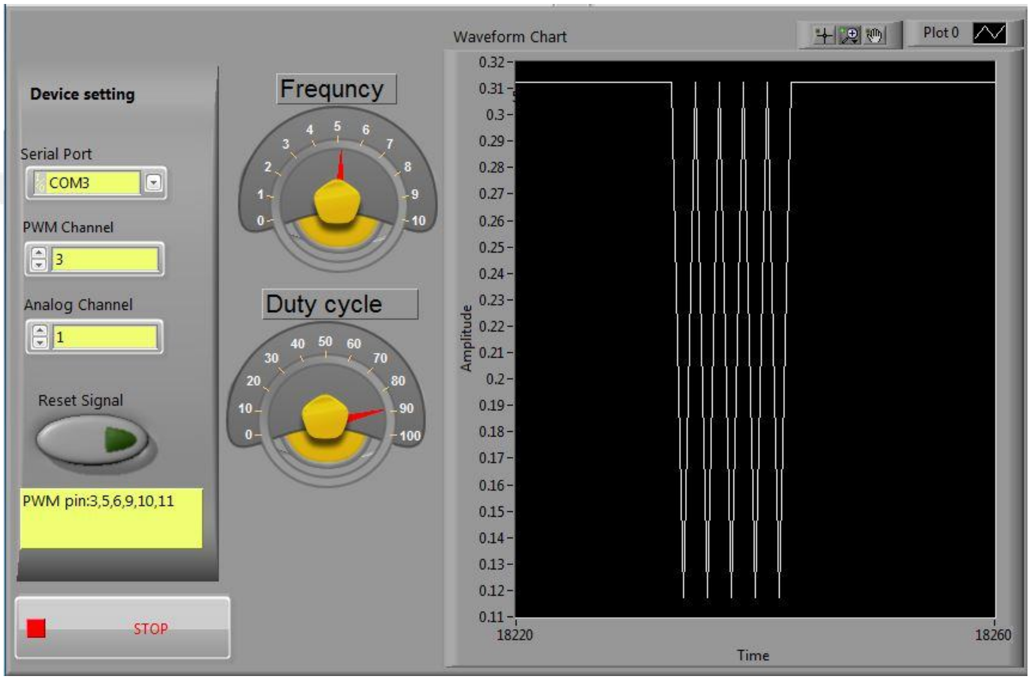
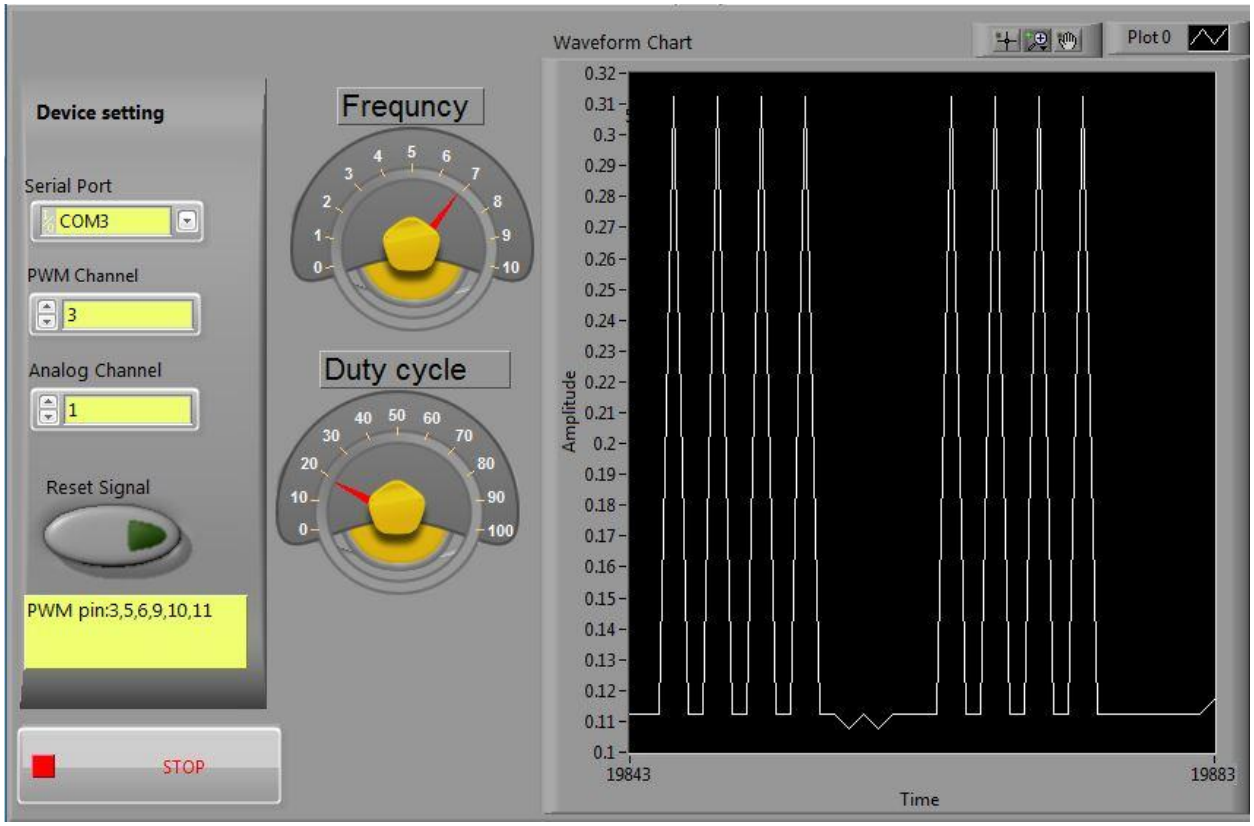
APPENDİX A

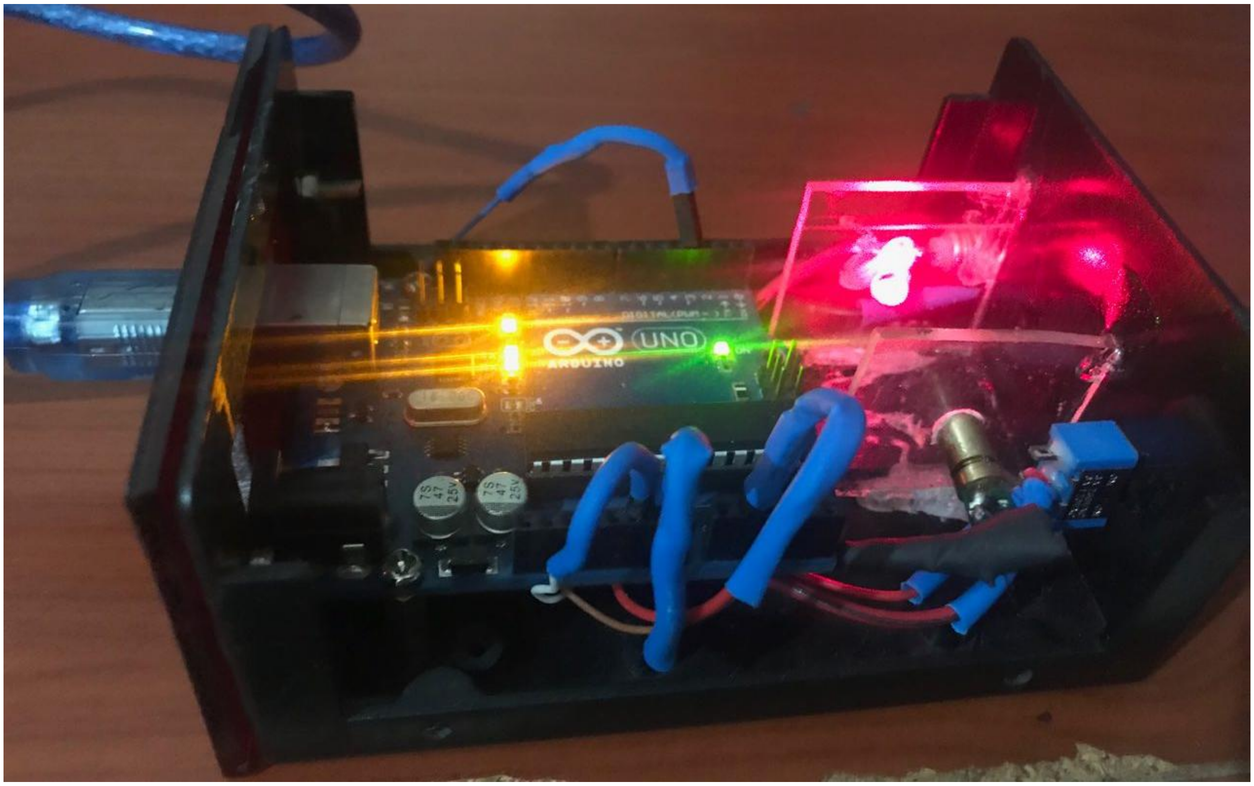
A.1 DAQ SCOPE RESULTS

A.1.1 Results for pulse duration 5 and 90% Intensity

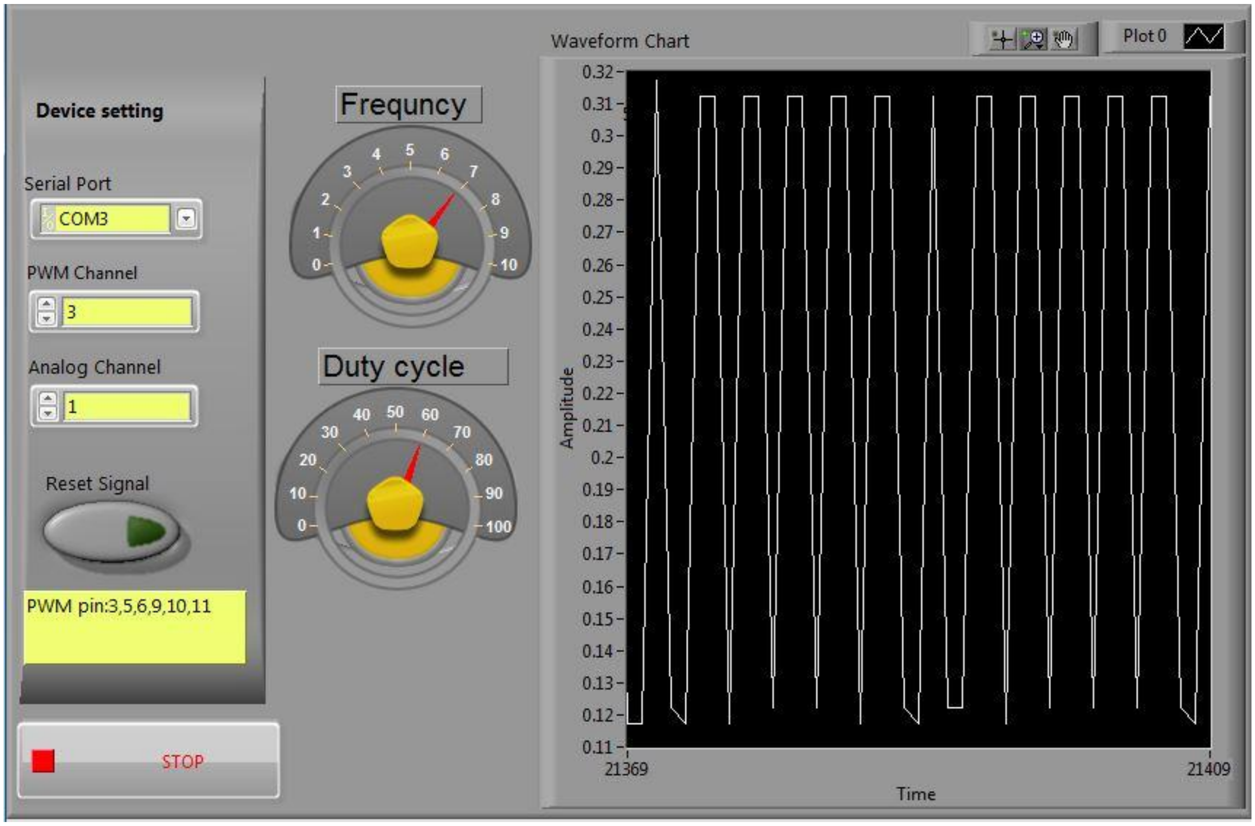


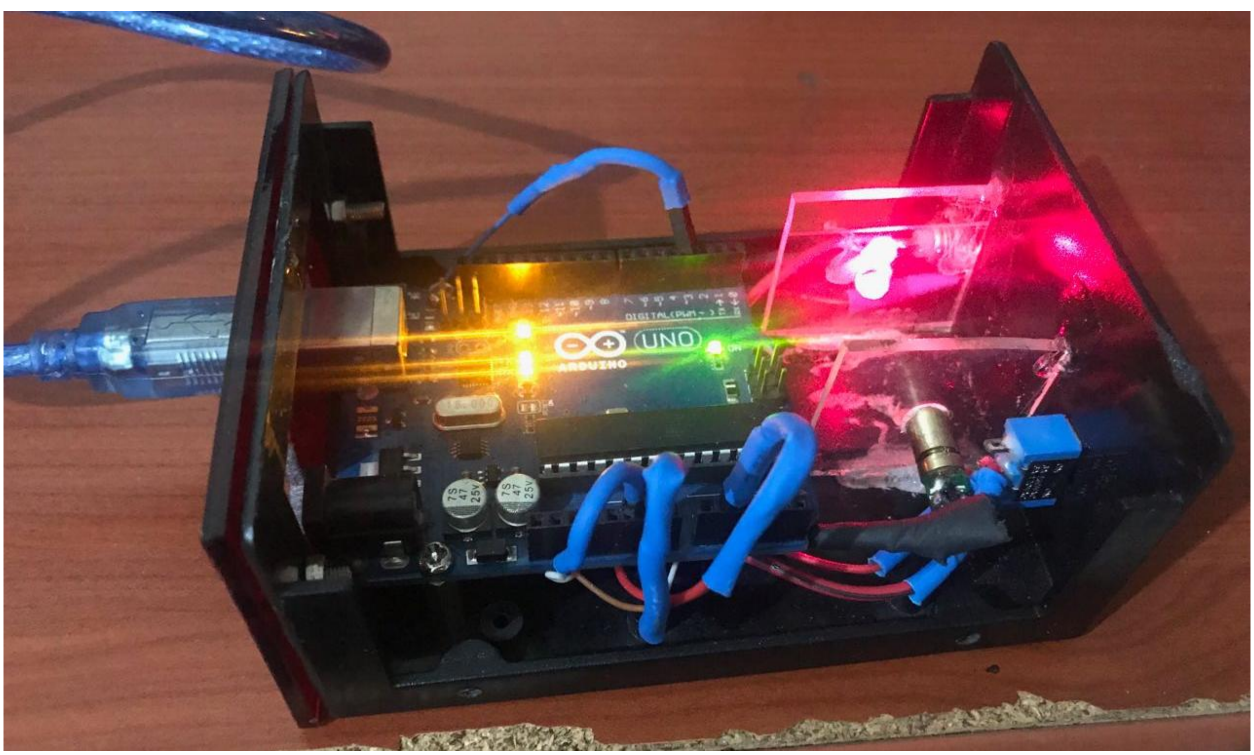
A.1.2 Results for pulse duration 7 and 20% Intensity



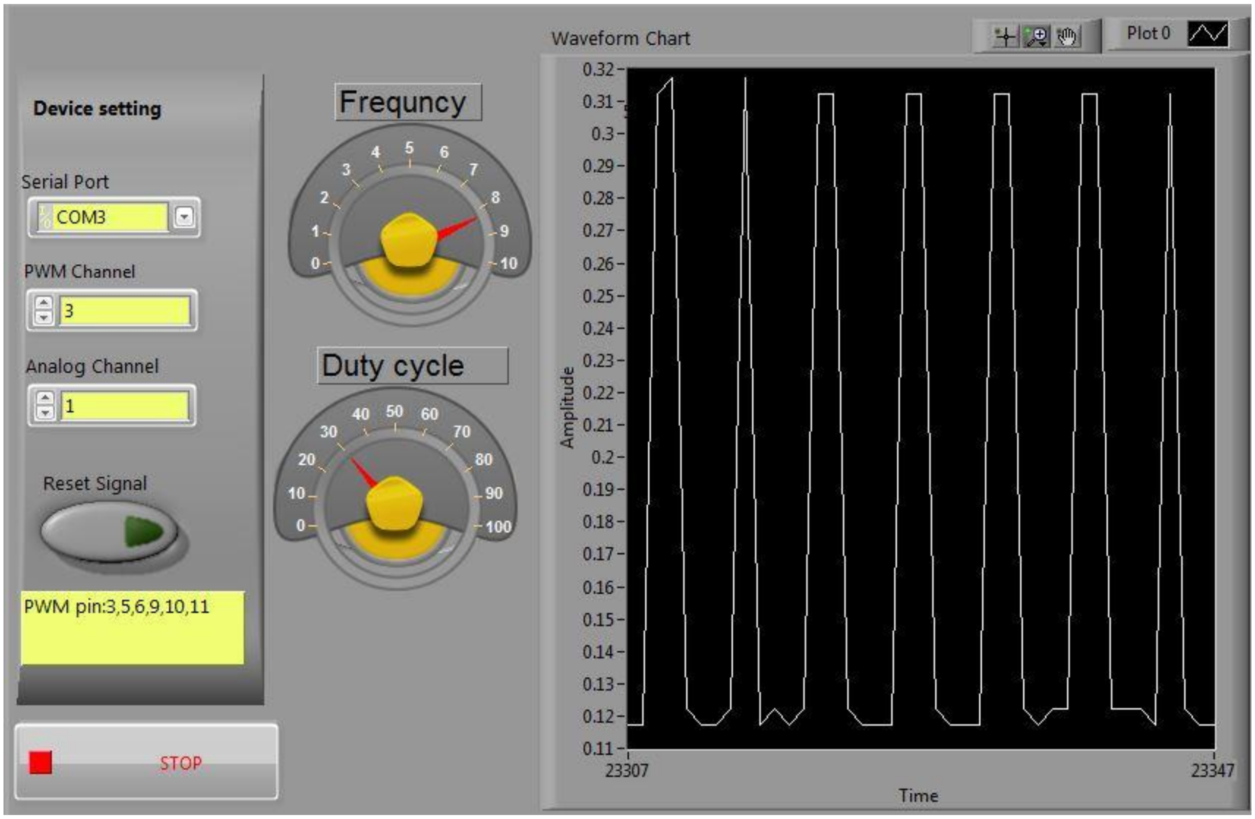


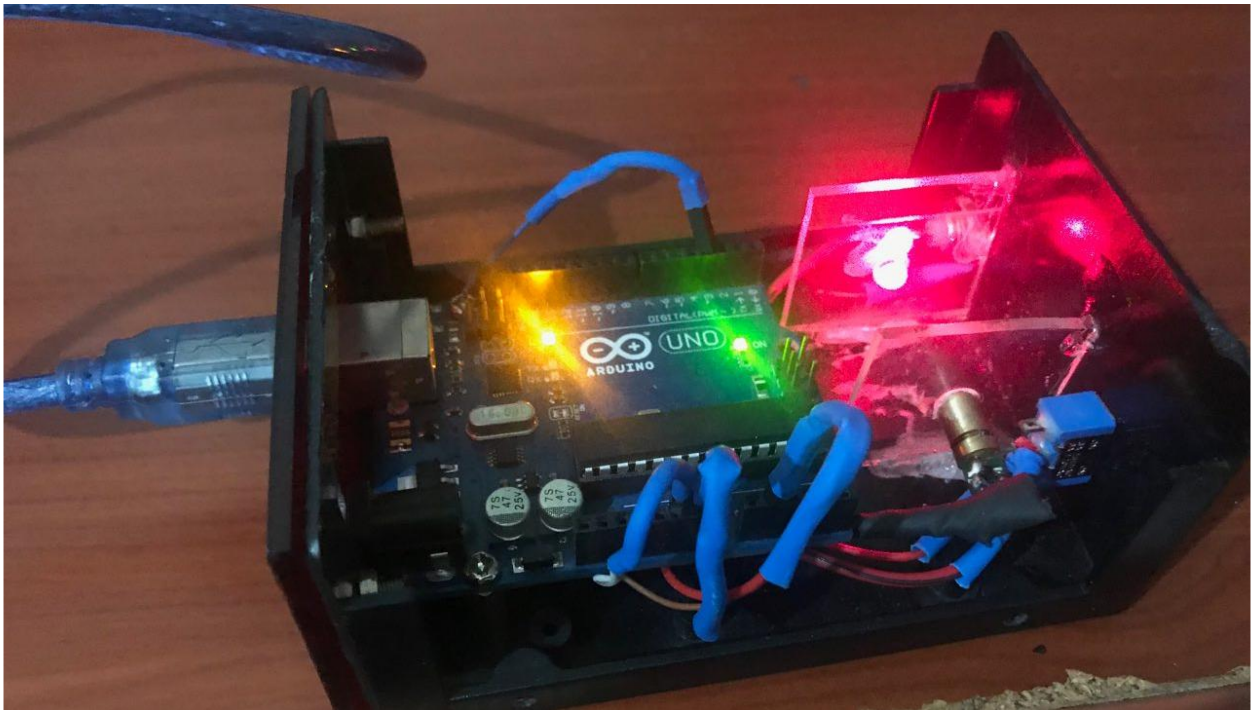
A.1.3 Results for pulse duration 5 and 60% Intensity



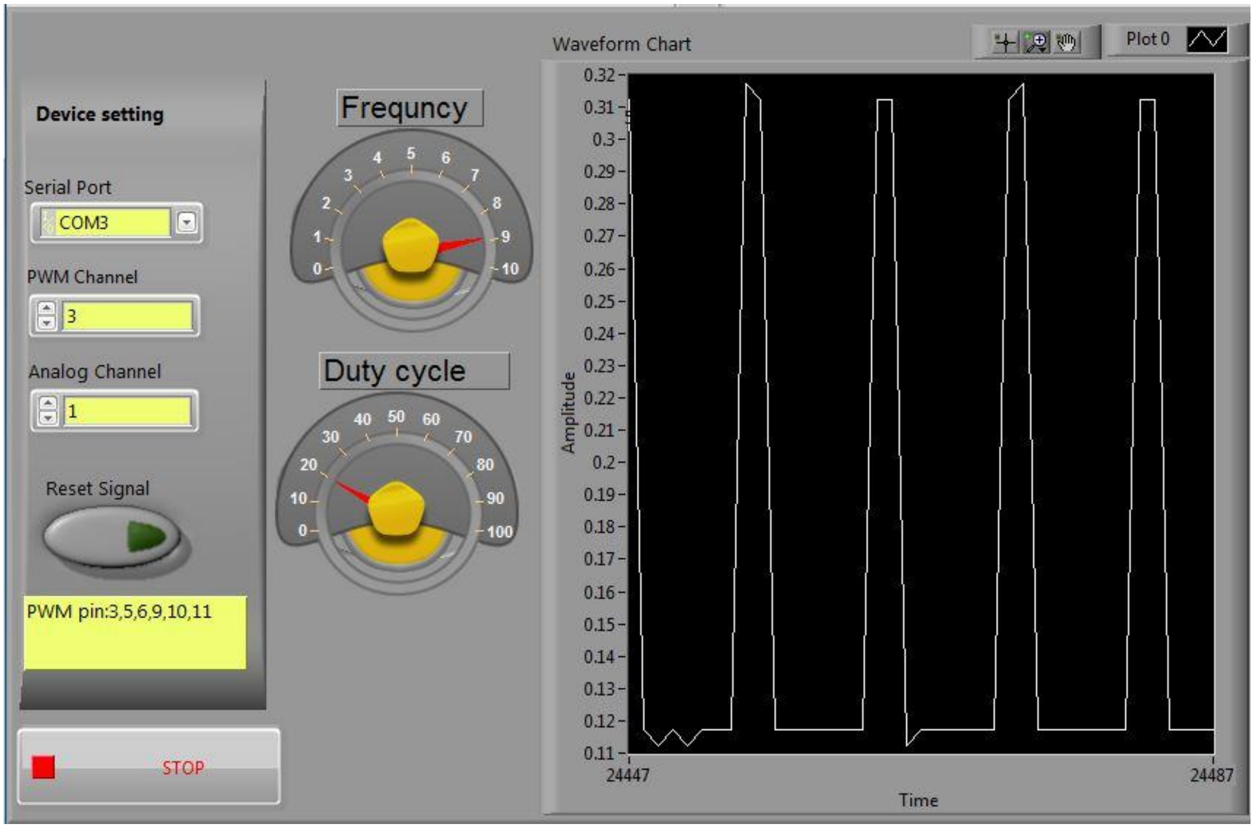


A.1.4 Results for pulse duration 8 and 30% Intensity

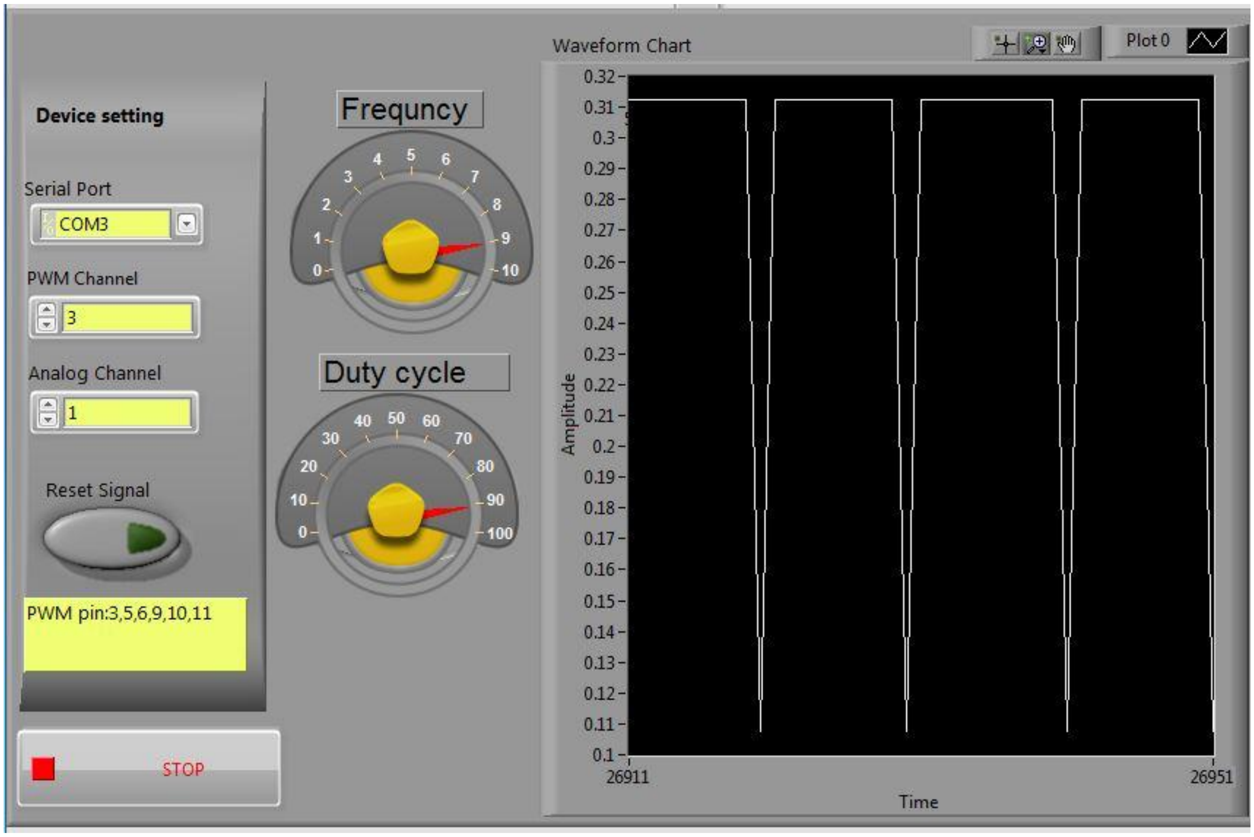




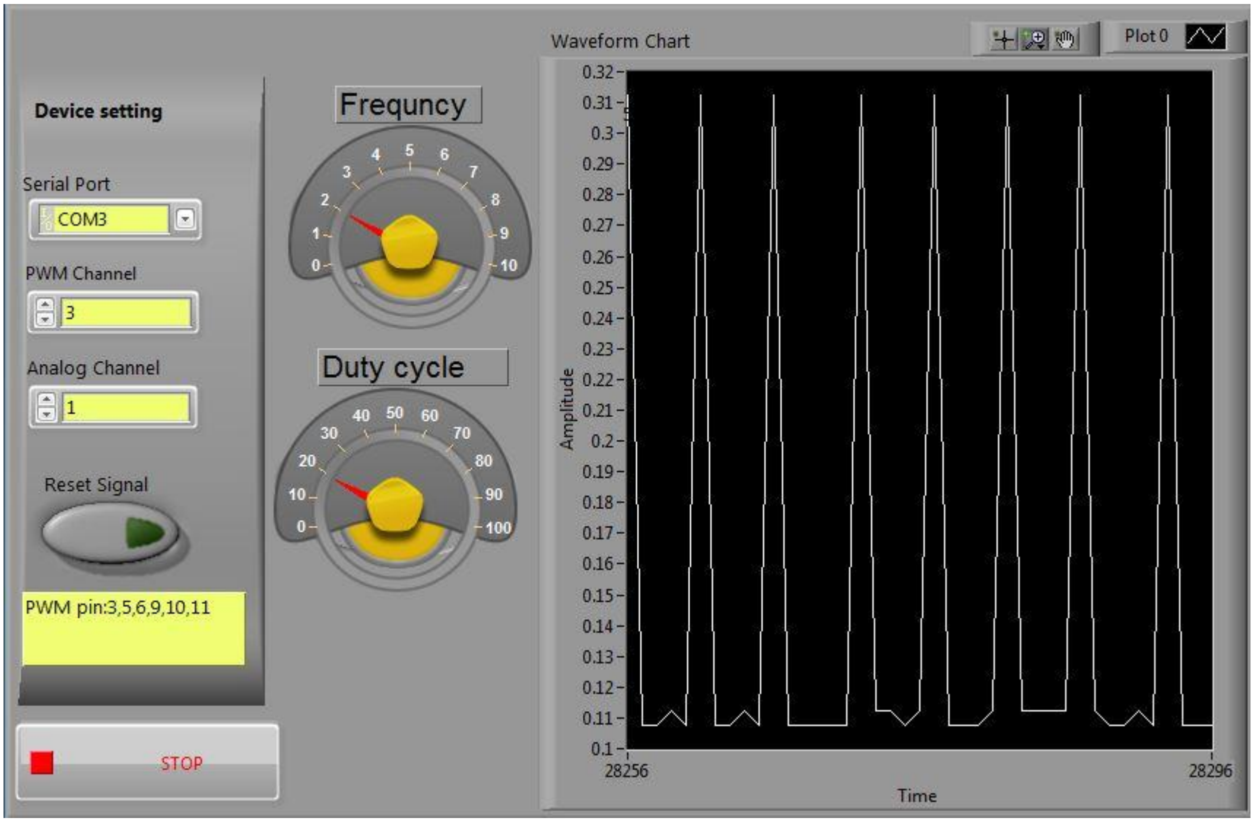
A.1.5 Results for pulse duration 9 and 20% Intensity



A.1.6 Results for pulse duration 9 and 90% Intensity



A.1.7 Results for pulse duration 2 and 20% Intensity



A.1.8 Results for pulse duration 2 and 50% Intensity