DESIGN AND CONSTRUCTION OF FREQUENCY, INDUCTANCE LOGICAL CONDITION, CIRCUIT CONTINUITY AND CURRENT DATA ACQUISITION SYSTEM

Aung Zaw Myint[1],Win Kyaw[2], San Ngwe Oo[3]

Abstract

In the present work, data acquisition system is designed to measure frequency, inductance, current, digital logic condition and circuit continuity. The system is constructed using an Arduino mega 2560 development board, resistors, capacitors, comparator, and various sensors. The respective sensors sensed physical phenomenon and sent electrical signal to Arduino ATmega2560 microcontroller. The measuring results data are displayed on the LCD, stored in micro SD card and logged in excel sheet directly using the parallax data acquisition (PLX-DAQ) as the same time. The system is innovatively designed to measure five different types of physical quantities.

Keywords: Data acquisition, Arduino ATmega2560, sensors, micro SD card, parallax data acquisition (PLX-DAQ).

Introduction

A process of gathering and measuring electrical data information in a specific method is known as data acquisition. In the study of electronics, data acquisition system is essential to acquire the various parameters of electrical and physical properties to process a control system or to drive a prototype design [Simon, (2010)]. Data acquisition system is very important to develop analyses an electronic circuit, material science, thin film technology, developing solar cells and study of semiconductor researches. Data acquisition applications are usually controlled by software programs developed using various general-purpose programming languages such as Assembly, BASIC, C, C++, Fortran, Java, Lab VIEW, Pascal, etc. Data acquisition system is the process of sampling signals into digital numeric values to measure real world physical conditions. Data acquisition system convert analog waveforms into digital values for processing [Floyd, (2006)]. Data acquisition begins with the physical phenomenon using a sensor such as the temperature of a room, the intensity of a light source, or the force applied to an object [Karvinen, (2014)].

Materials and Method

Arduino Mega Microcontroller

An Arduino microcontroller is a microcontroller built onto a single printed circuit board. This board provides all of the circuitry necessary for a useful control task: microprocessor, I/O circuits, clock generator, RAM, stored program memory and any support ICs necessary. The microcontroller utilized in the circuit is chosen Arduino Mega 2560 has large numbers of digital and analog I/O pins, larger program memory in Arduino development boards, easy to upload the program code. This code can be created with higher level programming language. Arduino mega is the heart of the circuit in which a program code to operate the data acquisition system [John, (2013)]. The Arduino mega consists of 54 digital I/O pins and 16 analog input pins. The Arduino mega board is operated with 16MHz crystal oscillator. The component of Arduino mega microcontroller is shown in Figure 1.

[1] Dr, Lecturer, Department of Physics, Dagon University
[2] Dr, Professor, Department of Physics, Loikaw University
[3] Dr, Associate Professor, Department of Physics, University of Computer Studies (Dawei)

Rotary Encoder Module

A rotary encoder-based menu is created to choose different measuring quantities by rotating the rotary encoder. Component of rotary encoder module is shown in Figure 2. A rotary encoder is a type of position sensor which is used for determining the angular position of a rotating shaft. It generates an electrical signal, either analog or digital, according to the rotational movement. Turning the rotor will change the menu and pressing the rotor will enter the selected menu and pressing again will return to start of the menu selection. Selections are made the menu in following order,

1. Logic Probe
2. Continuity Tester
3. Frequency Meter
4. Inductance Meter
5. Current Meter

Micro SD Card Module

In some data acquisition, micro-SD card is required to log the measuring results [Jack, (2015)]. Logging data to the micro SD card and exporting data to excel worksheet are at the time for measuring physical quantities. The terms SD card stands for "Secure Digital" Card, there are many types of SD cards. The SD cards can work in two operating modes, one is using the SD mode commands and the other is serial peripheral interface (SPI) mode. The SPI module consists of six pins and they are four SPI pins and two power pins. The component of micro SD card module is as shown in Figure 3. The data logging on SD memory card can be stored measuring data. While the data is logging on the micro SD card, the data can be exported to the excel worksheet by connecting the circuit using USB cable [Harold, (2011)]. The Parallax Data Acquisitions (PLX-DAQ) tool software is an add-in tool for Microsoft Excel.

LM311 Comparator IC

The LM311 device is single high-speed voltage comparator. This device is designed to operate from a wide range of power supply ±15 V voltages for operational amplifiers and 5 V supplies for logic systems. The output levels are compatible with TTL circuits. The LM311 device is an 8-pin chip which has 2 power inputs which are VCC and VEE. The pin7 is an open collector pin of the output transistor. All inputs and outputs can be isolated from system ground. The LM311 of output go high or low depending on the difference voltage between its two inputs (+, -). Component of LM311 comparator and pin out diagram are shown Figure 4.

Current Sensor Module

The current sensor module includes the famous ACS712 IC to measure current using the Hall Effect principle. This module can measure current AC or DC current up to 5 A. The device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. [Bhattacharya, (2015)]. The module is connected in series with the load and be extra cautious to avoid shorts. On the other side, it has three pins. The Vcc is connected to +5 V to power the module and the ground is connected to the ground. Then the analog voltage given out by the ACS712 module is read using any analog pin on the Microcontroller. Component of current sensor module and pin out diagram are shown in Figure 5.

Figure 1 The component of Arduino mega microcontroller

Figure 2 Component of rotary encoder module

Figure 3 Component of micro SD card module

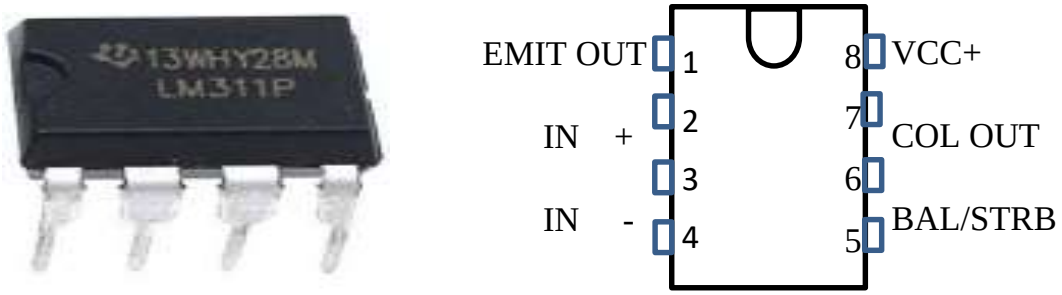

Figure 4 Component of LM311 comparator and pin out diagram

Figure 5 Component of current sensor module

Hardware Development and Operation

The main board consisted of Arduino Mega 2560 board, rotary encoder, alphanumeric liquid crystal display (LCD 20×4), a micro SD card module, comparator, current sensors and two lithium ion batteries. The block diagram of data acquisition system is shown in Figure 6. The flow chart of data acquisition system is shown in Figure 7. Data acquisition system is controlled by

software programs developed using Arduino C programming language. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE employed the program to convert executable code into a text file in hexadecimal encoding [Eide, (2008)].

The results of data acquisition system are illustrated with alphanumerical liquid crystal display LCD and sent to micro SD card. While the data is logging on the micro SD card, the data could be exported to the excel worksheet by connecting the circuit with computer using USB cable. PLX-DAQ is a simple add-on software to log Microsoft excel sheets for laboratory purpose. Parallax data acquisition tool (PLX-DAQ) software acquires up to 26 channels of data from any Parallax microcontrollers and drops the numbers into columns. PLX-DAQ provided easy spreadsheet analysis of data collected in the field that laboratory analysis of sensors and real-time equipment monitoring. Circuit diagram of data acquisition system is shown in Figure 8. The photograph of data acquisition system is shown in Figure 9.

For logic probe tester circuit, the Arduino mega board of an analog input pin A7 and a ground pin are applied. The logic conditions of a digital circuit board can be differentiated. Rotary encoder can be selected the condition of logic probe. Arduino microcontroller regarded input signal voltage level specifications as 0 to 0.8 V for logic LOW and 2 to 5 V as logic HIGH. The range can be converted by using 10 bits analog to digital conversion. The resolution is 4.88mV for each ten-bit digital values 1024. For 0.8 V, the digital value is 164(800 mV/4.88 mV). The analog reading on analog input A7 pin between 0 and 164 can be concluded as logic LOW level. For 2 V, the digital value is 409(2000 mV/ 4.88 mV). The analog reading on analog input A7 pin between 409 and 1023 can be concluded as logic HIGH level. But the voltage is detected between 0.8 to 2 V (the digital number between 164 and 409). The reading can be concluded neither logic LOW nor logic HIGH. In this condition, the logic probe will display FLOAT on the LCD display.

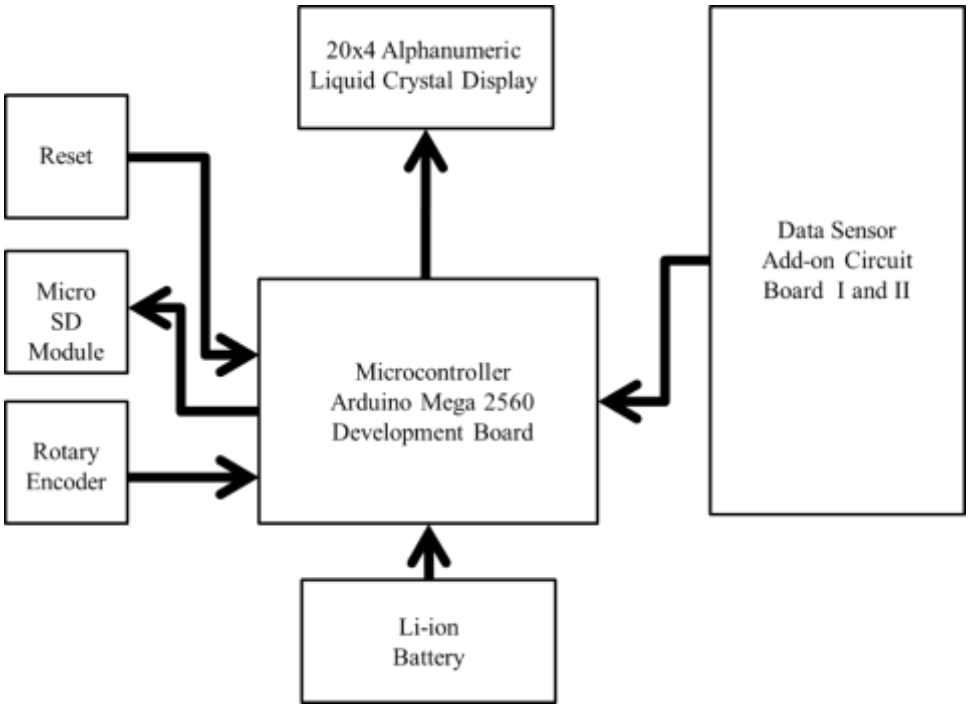

Figure 6 The block diagram of data acquisition system

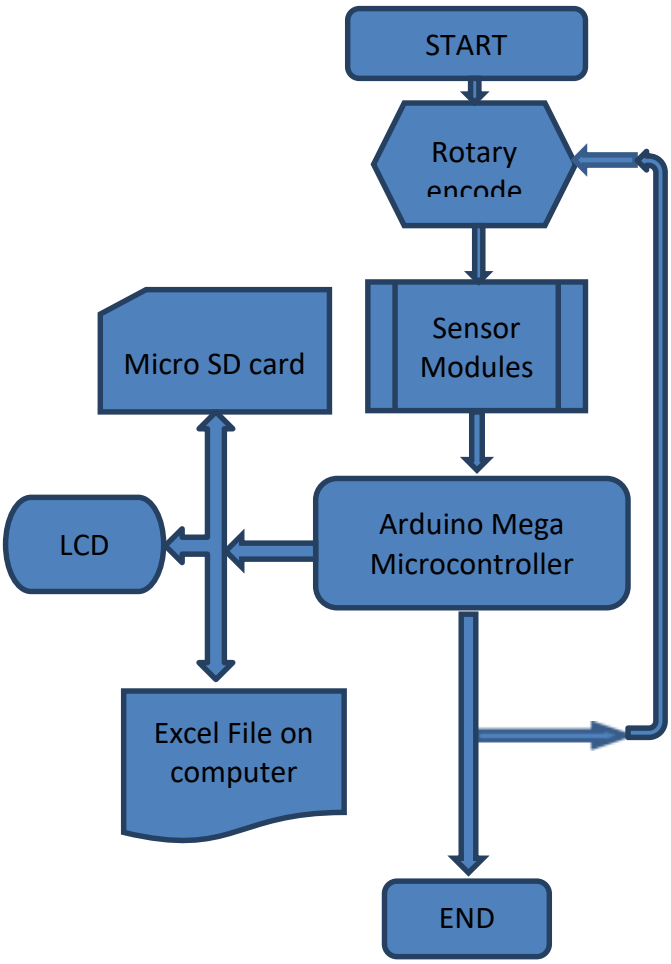

Figure 7 The flow chart of data acquisition system

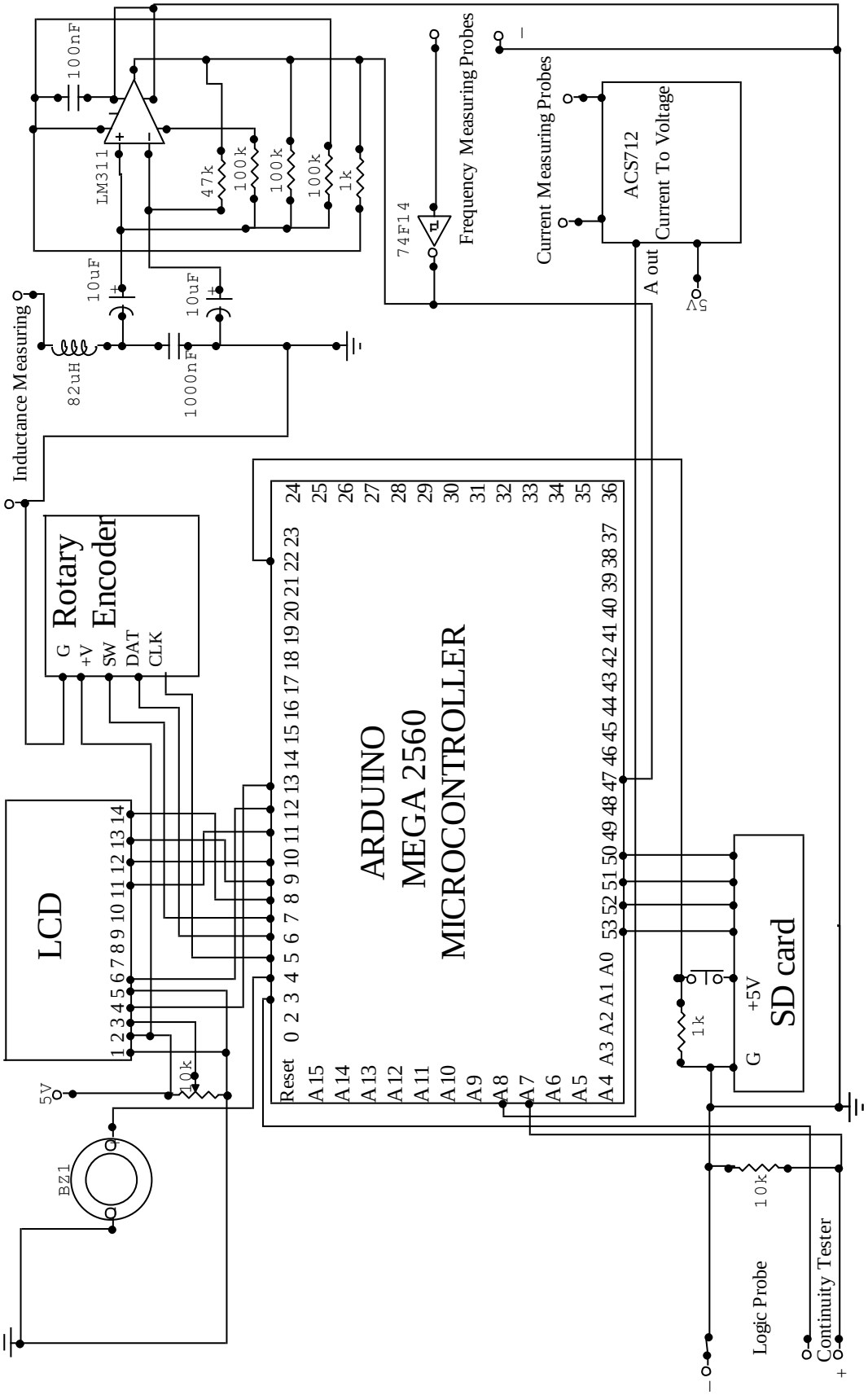

Figure 8 The schematic circuit diagram of data acquisition system

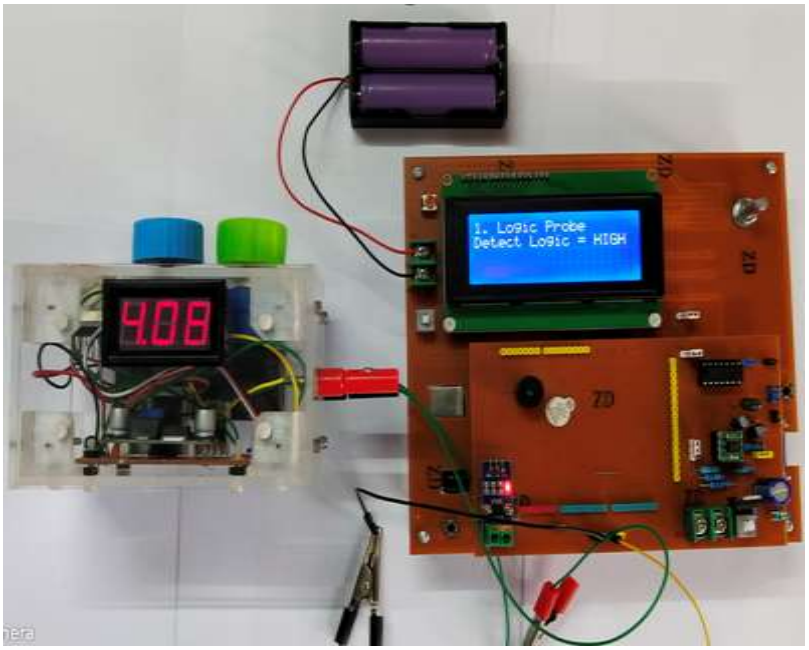

Figure 9 The photograph of data acquisition system

For continuity tester circuit, Arduino microcontroller of digital pin 3 and an analog pin A7 are applied. The continuity tester read the analog value under a specific condition. The buzzer is used to generate a sound under 50 Ω between two probes for continuity. The digital value is 1024 for 10-bit resolution. If the digital value is greater than 41(0.2 V), the buzzer would generate to continue. The connection between two points is successful. If the digital value is less than the 41, the connection of continuity testing is failed and buzzer would generate short tone.

The circuit is capable to measure both alternating current AC and direct current DC. The current sensor ACS712 is used to convert the current under measuring into relative voltage. The DC or AC current can be calculated from that voltage through the Arduino analog to digital converter. In this design, measurement of the current does not exceed 5Amp. The reading results are displayed on the LCD screen.

The frequency measuring circuit utilized an inverter IC 7414, two test probes and Arduino mega microcontroller of pin 47. The input frequency is feed to the input pin 47 through an inverter gate. The input pin 47 is available to read TTL logic level input. Pin 47 was specific for frequency counting library in programming. In this case, the counting begin is followed by a parameter called gate interval in milliseconds. The millisecond or micro second functions are limited to measure the periods of high frequencies. But Arduino programming in the frequency library file is capable of measuring high frequency values without error. Then the value of input frequency is counted and displayed on the LCD.

Measuring inductance values cannot be achieved only with microcontroller. Arduino mega microcontroller of pin 47 can be used to read the frequency value of inductor-capacitor (LC) circuit in frequency library for Arduino programming. Inductor-capacitor LC circuit is frequency resonator used as oscillator in series inductor and capacitor to oscillate. LC series circuit is one of the most important circuits used electrical and electronic circuits.

The LC meter is used a LM311 IC that functions as a frequency generator. The unknown inductance value can be obtained the relation of inductance and frequency $L = 1/(4\pi^2 C f^2)$. where L is the inductance in Henry (H), C was the oscillator capacitance in Farad (F) and f is the oscillation frequency in Hertz (Hz). Then an unknown inductance value is fed into the non-

inverting input pin of LM311 comparator. The output pin of LM311 comparator is fed into a specific input 47 pin of Arduino mega microcontroller.

Results and Discussion

The logic probe circuit can be differentiated three different logic levels for TTL input logic states. They are logic HIGH, FLOAT and logic LOW functions. The voltage between 0 to 0.8 V is logic LOW and 0.8 to 2 V is FLOATE. The voltage greater than 2 V and up to 5 V is logic HIGH. The continuity testing circuit is selected by using rotary encoder. If the two probes are disconnecting condition in testing circuit, LCD would display as "Fail" and the buzzer would generate a short beeping tone on every second. If the two probes are connecting condition in testing circuit, LCD will display as "Connected" and the buzzer would generate a continuous high frequency short beeping tone on every second.

The current sensor ACS712 is used as the current to voltage converter circuit. In this data collection, nichrome wire of load resistance that 7 ohms, 5 ohms, 2.7 ohms, 2.5 ohms and 2 ohms are tested with 3volts dc power supply. Comparison results of DAQ and digital multi-meter for measuring DC current using supply 3 V are shown in Table 1.

The pin 47 of Arduino mega microcontroller is connected with both inductance measuring circuit and frequency measuring circuit. In this measurement, an inverter gate (TTL7414) is added to achieve digital level on the frequency reading. Measuring Frequency is obtained from a portable digital signal generator. Other frequency data generated by an astable oscillator 555circuit is collected and compared with the portable digital oscilloscope. The data results are illustrated in Table 2. The most important part of inductance measuring circuit is the operational amplifier LM311N and LC circuit. The various inductors can be measured in this circuit. Comparison results of DAQ and color code values for measuring various inductors are illustrated in Table 3.

Table 1 Comparison results of DAQ and multi-meter for measuring current using supply 3V

No	Load Resistance(Ω)	Digital Multimeter current(A)	DAQ measuring current(A)	Deviation (A)
1	2	1.509	1.50	0.009
2	2.5	1.201	1.21	0.009
3	2.7	1.131	1.13	0.001
4	5	0.601	0.59	0.11
5	7	0.426	0.42	0.006

Table 2 Comparison results of DAQ and astable oscillator circuit for measuring frequency

No	Astable circuit (Hz)	DAQ measuring Frequency(Hz)	Deviation (Hz)
1	25.58	25.55	0.03
2	255.79	255.73	0.06
3	544.24	542.22	0.02
4	2.55E3	2.54E3	0.01
5	25.58E3	25.56E3	0.02

Table 3 Comparison results of DAQ and color code values for measuring various inductors

No	Marking color code (H)	Inductors values (μH)	DAQ measuring Inductance (μH)	Deviation (μH)
1	(Blue,gray,brown,gold)	680 ± 05%	675	05
2	2×(Blue,gray,brown,gold)	1360 ±05%	1358	02
3	470 μH	470 ±20%	471	01
4	820 H	820 ±20%	818	02

Conclusion

The data acquisition system for five different quantities is successfully constructed. For measuring current system, large loading is required the current through. If the loads are very small, the reading cannot illustrate stable and correct reading. The reading is exactly for measuring the current between 400 mA and 5 A. In the frequency measurement, the range from 0.01 Hz to 100 GHz can be measured. Comparison results of DAQ and astable oscillator circuit for measuring frequency are shown in Table 2.

The inductance measuring system can measure larger than 10nH vales with acceptable results. But for the inductors in very small 0.01 nH range cannot be measure in stable. Comparison results of DAQ and color code values for measuring various inductors are shown in Table 3. The results are acceptable and most of data comparison approach to theoretical calculations. Finally, data acquisition is a process that begins with systematic data collection from various sources to achieve a beneficial decision.

Future Extension

In some of recent work, the innovative design of data acquisition system has been constructed for five different quantities to measure frequency, inductance, current, digital logic condition and circuit continuity. Especially for current measuring, ACS712 current sensor range from 400mA to 5A is used for large current. Current measuring for small amount of current range μA to nA will be designed and developed.

Acknowledgement

The authors would like to acknowledge Professor Dr Khin Khin Win, Head of Department of Physics, University of Yangon, for her valuable suggestion and comments for this work.

References

Bhattacharya, S. K. (2015). Electrical measurement and control, kindle ed, INDIA VIKAS.

Eide, A. R., Jenison, R. D., Northup, L. L. and Mickelson, S. (2008). Introduction to Engineering Problem Solving, 5th ed, New York: McGraw-Hill.

Floyd, T. L (2006). Digital Fundamental, 9th ed, New Jersey: Prentice Hall.

Harold, T. (2011). Practical Arduino Engineering, Paul Manning ed, (SBN-13: 978-1-4302-3886-7).

Jack, J, Purdum. (2015). Beginning C for Arduino: learn C programming for the Arduino, 2nd ed, New York: (ISBN 9781484209400).

John, B. (2013). Arduino Workshop, William Pollock (ISBN-13: 978-1-59327-448-1).

Karvinen, T. and Karvinen, K. (2014). Getting Started with Sensors: Measure the World with Electronics, Arduino, and Raspberry Pi, Maker Media, Inc.

Simon, M. (2010). 30 Arduino Projects for the Evil Genius, New York: McGraw Hill.