Journal of the Nigerian Association of Mathematical Physics
Volume 30, **(May,** ***2015*****), pp343 – 348**

Design and Construction of a Temperature and Pressure Data Acquisition System

Okosun O., Osa E, Okokhere O.V and Omashor

Electrical/Electronic Engineering Department, University of Benin, Benin City, Nigeria.

Abstract

It is sometimes necessary for physical parameters such as temperature and pressure to be monitored especially in systems where performance relies on the values of these parameters. Hence it is necessary to design systems that can monitor these physical parameters. In this work, a temperature and pressure monitor is designed. The system takes in temperature and pressure readings from the temperature sensor (LM35) and the pressure sensor (MPX4115A) respectively. The temperature and pressure readings are processed by a microcontroller (PIC16F877A) and displayed on an LCD. The readings are also sent through RS232 serial communication protocol to a graphical user interface (GUI) on a computer which displays the temperature and pressure readings in graphical form. The system was designed, tested and found to work properly.

Keywords: Graphical User Interface, LM35,MPX4115A, RS-232 Communication protocol, PIC16f877A.

1.0 Introduction

A very important achievement in the evolution of science was man's ability to measure real world physical quantities. Over time, the methods of measurements advanced and also the need to not only measure these quantities but perform other manipulations on these parameters arose. The implication of this was that systems that could accurately measure these real life parameters and transform them into a form in which the processes to be carried out on them could be done easily became necessary. Thus this formed the birth of data acquisition systems.

In simple terms, a data acquisition system also known as DAQ forms an interface between the real world of physical parameters which are analog in nature and the artificial world of digital communication and control .In other words, the system captures data about an actual system and stores that information in a format that can be easily retrievable for purposes of engineering or scientific review and analysis. Data acquisition is widely used in many areas of industry. There are many different components to a data acquisition system including sensors, communication links, signal processors, computers, databases, data acquisition software, etc. All these items have to operate together to make a successful data acquisition system.

A key feature to mention here concerning DAQs is that they should be able to capture information programmatically or automatically that is without hands on human intervention or guidance. Due to the increasing need for data acquisition systems, it has become necessary for research to be carried out on the subject matter and the discovery and design of ways to make the systems easier and more convenient for man to use.

Various forms of data acquisition systems exist. We have standalone DAQs that don't have to be connected to a computer system (although some of them may have a computer connection option in them). We also have computer plug-in DAQs. The method of communication between the DAQ and the computer could either be a hard-wired connection or it could be wireless communication. This work looks at the design and construction a hard-wired computer plug-in DAQ which can also have the option of being a standalone device.

While researching on past works relating to this project topic, several related works were discovered. These works will be discussed in this sub-section.

A design and implementation of a microcontroller based embedded system for data logging and remote monitoring of environmental parameters with simplicity to users was carried out [1]. The parameters that were measured were temperature and relative humidity. The transmission of the measured information is done by short message service (sms) to the mobile phones of users. Also the system had data-logging capabilities and the logged data could be transferred to a personal computer. An improvement that the project topic discussed in this technical report gives to the above mentioned data

Corresponding author: Okosun O., E-mail: oduware.aghama@uniben.edu, Tel.: +23408132979652

acquisition system example is that the measurement of pressure has been incorporated in this project through the use of the MPX4115A pressure sensor.
In the design of a humidor, the techniques of data acquisition apply too [2]. A humidor is a special box where cigarettes are kept and which is equipped with a humidification device (to be filled with water at regular intervals). The goal is to maintain a relative humidity of 70%. The sensor used to detect the humidity in the humidor is an SHT75. The sensor is connected to the microcontroller by a thin ribbon cable. The output display is an LED display. An improvement to this mentioned project that the DAQ to be constructed gives is that the information that is being monitored can be monitored from a computer through a graphical user interface. Although the LM35 temperature sensor that is being used in this project design has a lower accuracy of ±0.5˚C than the SHT75 (whose accuracy is ±0.3˚C), its cost is smaller than the SHT75 sensor hence the use of LM35 in this project more affordable.
A design of a low cost microcontroller based weather monitoring system was carried out [3]. The system measured temperature, atmospheric pressure and relative humidity with the aid of LM35, MPX4115A and HSP15A sensors respectively. The measured data could be displayed on a LCD display as well as on a graphical user interface in a PC through a USB link. This design has similarities to this project topic as the same sensors are used as well as the same means of communication which the graphical user interface is chosen.
A design was made on a wireless weather monitoring system that monitored temperature with the use of LM35 sensor and displayed the readings on an LCD [4]. The readings were also transmitted through a GSM module to a phone. The system to be designed in this project work incorporates the monitoring of pressure as well as the design of a graphical user interface.
The development of a wireless hurricane wind and pressure monitoring system was done [5]. Temperature, pressure and wind pressure was measured with the aid of LM34, MPX4115A and a young anemometer respectively. The data gotten from the sensor was also transmitted to a computer interface through a transceiver. This project also bears a resemblance to the project topic being done here. The LM34 temperature sensor used in the above mentioned design is basically the same as the LM35 temperature sensor to be used in this project work. The only difference between LM34 and LM35 is that LM34 gives temperature reading in degrees Fahrenheit while LM35 gives temperature reading in degrees Celsius. Also the project work to be done here will incorporate a graphical user interface to plot a graph of the measured parameters. This work differ from other previous works as it employs serial data communication for retrieving data unto the GUI and also the circuit realization was done on printed circuit board, PCB and as an improvement, the circuit uses MPX4115A that gives a linear voltage-pressure variation hence eliminating the need for further signal conditioning with differential amplifiers.

1. Principles of Operations of the Data Acquisition System

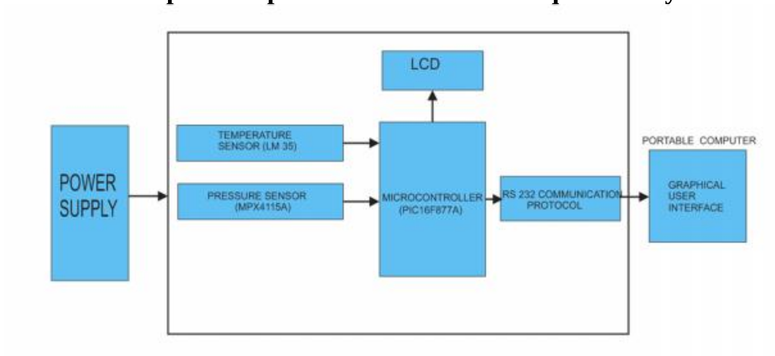

Figure 1: Block diagram of the data acquisition system

Figure one shows the block diagram of the entire system. The power supply block supplies the require power requirement for the whole system. The pressure sensor and the temperature sensor output a voltage proportional to the pressure and temperature being measured. The voltage output from the sensors is fed into the microcontroller which is the brain box of the whole system. The microcontroller outputs the sensor reading to the LCD as well as to the graphical user interface through RS-232 serial communication protocol.

2.1 RS-232 Communication Protocol.

RS-232 stands for **Recommended Standard 232.** It is a standard communication protocol for linking computer and its peripheral devices to allow serial data exchange. In simple terms RS232 defines the voltage paths used for data exchange between devices. It specifies common voltage and signal level, common pin configuration and minimum amount of control signals. RS-232 is designed to handle communications between two devices with a distance limit of around 80 to 130 ft, depending on the bit rate and cable type. RS-232 is an asynchronous serial communication protocol. In serial communication, the whole information say a byte is transmitted one bit at a time. The protocol is asynchronous because there is no separate clock signal as here are in other like protocols like SPI and I^2C. It is protocol that makes very easy for a microcontroller circuit to be linked to a standard PC [6].

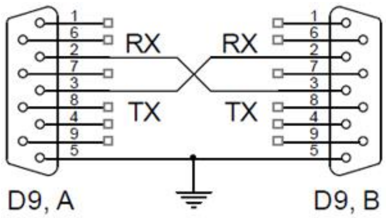

Figure 2: Wiring diagram for RS-232

The voltage level for RS-232 differs from that of the microcontroller it will work with. RS-232 operates with the following voltage levels:

- **Logic 0 or ON output:** +5V to +15V
- **Logic 1 or Off output:** -5V to -15V
- **Logic 0 or On input:** +3V to +15V
- **Logic 1 of Off input:** -3V to -15V

A microcontroller on the other works with a voltage level of +5V for logic level 1 and 0V for a logic level 0. Because of this incompatibility in voltage levels between the RS-232 protocol and the microcontroller a level converter chip is need. An example of such a chip is the **MAX232** [6].

3.0 The Design of the Data Acquisition System

3.1 The Power Supply Circuit

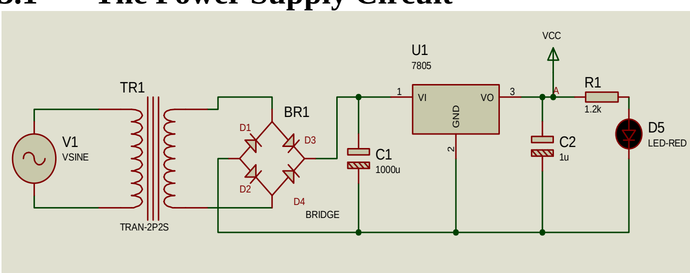

Figure 3: The power supply circuit

The voltage requirement for the data acquisition system is +5V. Vsine in Figure 3 represents the alternating current (A.C) voltage in which the device will be plugged to. Transformer T1 is a 220/240V to 12V step down transformer which converts the A.C voltage from 220V to 12V.The current rating of the transformer is 300mA. The bridge rectifier arrangement (BR1) is made up of four 1N4001 diodes D1, D2, D3, and D4. The bridge rectifier converts the alternating current which periodically reverses direction to direct current which flows in one direction. Capacitor C1 acts as a filter to smoothen the ripples from the bridge output. The voltage regulator (7805) gives the stabilized required 5V from the approximate 12V output gotten from the bridge rectifier- filter arrangement. The capacitor C2 also acts as a filter to filter out any ripple that may exist at the output of the voltage regulator. The 5v (VCC) needed is tapped at node A above. The red LED D5 serves as an indicator to show when power is available.

3.2 The Sensor and LCD Circuit

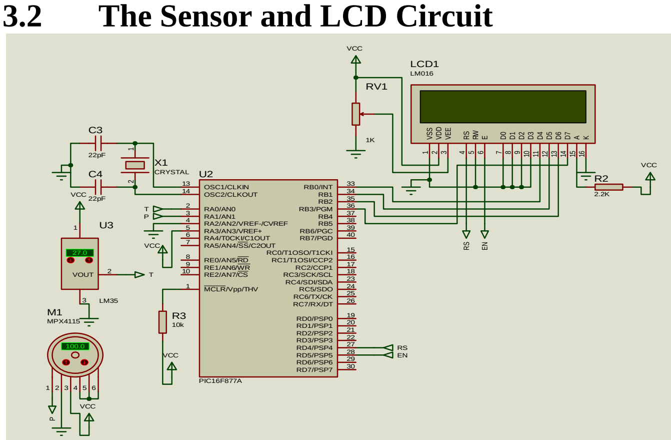

Figure 4: Sensor and LCD circuit.

3.2.1 The Pressure Sensor Circuit

From Figure 4, the pin one of the MPX4115A sensor which outputs a voltage proportional to the pressure measurement is connected to pin 3 of the microcontroller. Pin 3 is one of the analogue channels of the microcontroller through which analogue inputs to be converted to digital form by the microcontroller's in-built analogue to digital converter (ADC) are placed. Pin 2 and 3 of the sensor are connected to Ground and VCC respectively. Pins 4, 5 and 6 are no connects. These pins have internal device connections.

From the data sheet of MPX4115A, the relationship between the output voltage (V_{out}) and the measured pressure(P) is given as:

$V_{out} = V_S$ (P x 0.009 - 0.095) ± (Pressure Error x Temp. Factor x 0.009 x V_S) ---------------- (1)

V_S = 5.1 V ± 0.25 V

Where:

V_S = Supply voltage

The pressure error for a pressure range of 15 to 115(kPa) is ±1.5 (kPa)

The temperature factor differs for different temperature range as shown in Table 1:

Table 1: Temperature factor of MPX4115A sensor

Temperature(˚C)	**Temperature Factor**
-40	3
0 to 85	1
+125	3

From equation (1), by making measured pressure (P) the subject of the formula the following equation is gotten:

P = (V_{out}± (Pressure Error × Temp. Factor × 0.009V_S) + 0.095V_S) / 0.009V_S -- - - - - - - - - - - - - - (2)

Equation (2) will be used to write an expression for pressure in the microcontroller C code so that the microcontroller can then output this measured pressure value to the LCD. It must be noted that for V_{out} to be used by the microcontroller for manipulations and other operations it must have been converted to a digital form by the microcontroller's ADC.

The ADC of the PIC16F877A microcontroller is a 10 bit ADC. The resolution of an ADC is given as:

Resolution = analogue full scale output/ (2^n – 1) - - - - - - - - - - - - - - -- - - - - - - - - - - - - (3)

Where n is the number of bits of the ADC

For the 10 bit ADC of PIC16F877A, n = 10 and the Analogue full scale output is 5V, hence

Resolution = 5/ (2^{10} – 1) = 5/1023= 4.887mV- - - - - - - - - - - - - - -- - - - - - - - - - - - - - - - - (4)

The above calculation shows that the step size of the ADC is 4.887mV. the 10 bit ADC has 1023 steps. With the resolution as 4.877mV is means that to get the real voltage equivalent entering of the input entering the ADC, the ADC output needs to be multiplied by the resolution of the ADC

3.2.2 The Temperature Sensor Circuit

From Figure 4, pin 2 of the temperature sensor is connected to pin 2 of the microcontroller which is an analogue input channel pin. Also pins 1 and 3 of the sensor are connected Vcc and ground.

From the data sheet of LM35, temperature increases by 1˚C for every 10mV rise in voltage

Let V_{out} be the output from the sensor, then

Temperature reading = V_{out}/10mV- - - - - - - - - - - - - -- - - - - - - - - - - - - - - - - - - -- - - - - - - - (5)

3.2.3 LCD Circuit

The LCD has sixteen pins as shown in figure 4. Pin 1(VSS) and 2(VDD) are connected to Vcc and Ground respectively. Pin 3(VEE) which is a contrast setting pin is connected to a 1k potentiometer to control contrast. Contrast is the difference in luminance and colour that make an image distinguishable. As the resistance of the potentiometer is varied, contrast varies. The register select (pin4) and enable (pin5) are connected to pins 27 and 28 of the microcontroller. D0 to D7 (pins 7 to 14) of the LCD are the data pins of the LCD.

In the circuit in Figure 4, the LCD is being operated in 4-bit mode. The 4-bit mode helps save valuable I/O pins of the microcontroller. Hence since 4-bit mode is used here, pins D0 to D3 are grounded while pins D4 to D7 are connected to pins 36 to 39. The read/write pin (pin5) is also grounded. Pins A and K are used to activate the LCD backlight circuit. The back light of the LCD is an LED hence resistor R2 serves as a current limiting resistor to the LED to prevent damage due to excessive current flow. Pin K which is connected to ground completes the backlight circuit. We shall assume that the microcontroller is operating at a frequency of 4MHz.

3.3RS-232 Serial Communication Circuit

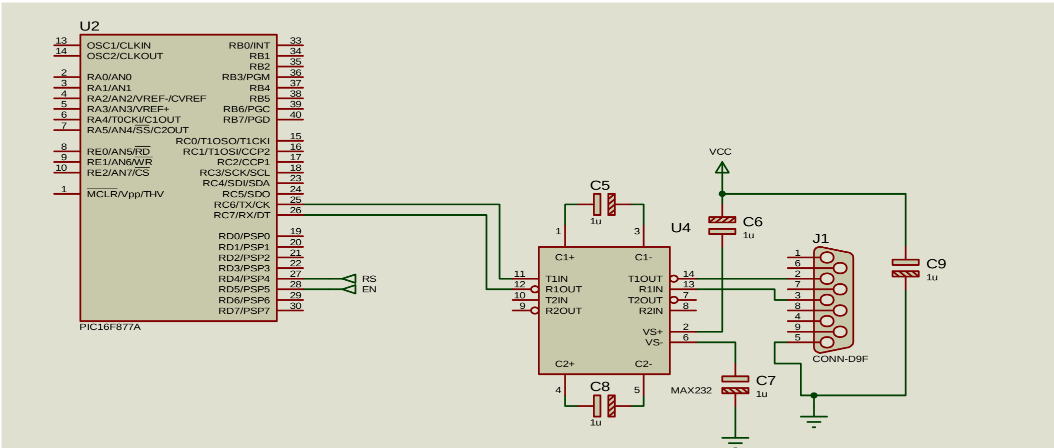

Figure 5: RS-232 serial communication circuit

Pins 25 and 26 of the microcontroller are the transmit pin (TXD) and the receive pin (RXD) respectively. The TXD pin of the microcontroller is connected to pin 11(T1IN) of the max232 IC which changes the voltage level of the signal to the required level (i.e from 0V to +15V or 5V to -15V). This signal then comes out through pin 14(T1OUT) of max232 and enters pin 2 of the D9 connector. Pin 2 of the 9 pin D-sub connector represents RXD pin which takes the transmitted signal to the computer.
The TXD pin of the D-sub connector (pin 3) receives signals from the computer and sends it to pin 13 (R1IN) of max232 which converts the signal voltage before sending it to pin 12(R1OUT) of max232 which is connected to the RXD pin of the microcontroller.
The capacitors C5 and C8 connected between pin 1 and 3, and pin 4 and 5 of max232 are needed for the charge pump in the max232 IC which does the voltage level change. Capacitor C6 connected between pin 2 and VCC, capacitor C7 connected between pin 6 and Capacitor C9 connected between VCC and ground serves as decoupling capacitors to filter undesired noise from the power supply.

3.4 The Design of The Graphical User Interface

The graphical user interfaced was design with visual basic language. Visual studio 2010 integrated development environment (IDE) was used to do the GUI design. The design was in two stages:

- The design of the outlook of the GUI
- The writing of the programming codes to make the designed outlook of the GUI function in the intended way.

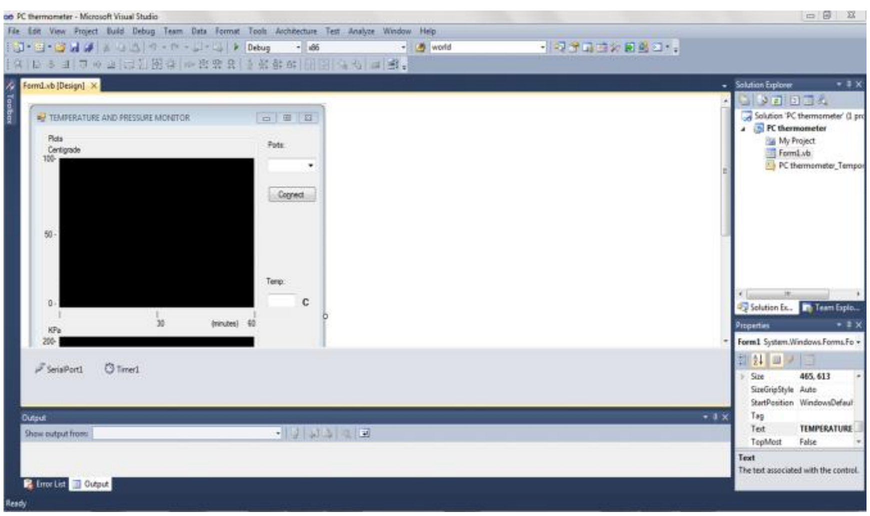

Figure 6: Form design for the GUI

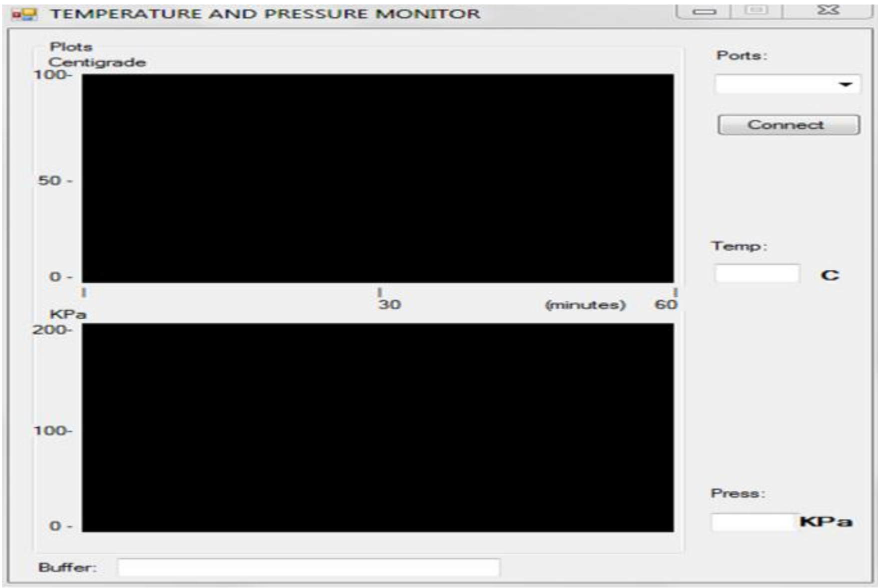

Figure 7: The completed GUI form design

The Figure 7 above shows a Graphical User Interface that holds the plot of Temperature and Pressure variations with time.

4.0 Conclusion

The aim of this work was to design a data acquisition system that could sense temperature and pressure and display the values of these parameters on both an LCD and a graphical user interface. The system was designed for monitoring and analysis of the parameters (temperature and pressure).With the purpose of this work in mind, the various stages in design involved were thoroughly and carefully implemented starting from the power supply unit to the programs written for the microcontroller and the graphical user interface and finally to the whole setup.

After necessary precautions were taken, the stages combination gave rise to the data acquisition system that could monitor and analyze the temperature and pressure of a given environment as required.

At this point, after the system had worked satisfactorily, it was concluded that the aim of this work had been realized.

5.0 References

[1.] Nhivekar G.S, Mudholker R., (2011) "Data Logger and Remote Monitoring System for Multiple Parameter Measurement Applications", e-journal of science and technology, Volume 3, pg 55-62.

[2.] MarcusGunnarsson (2006). Precision Hygrometer. Retrieved from http://marcusgun.awardspace.com/humidor.html (Accessed on: September 20th, 2014).

[3.] Kamarul A.N., Chow C.O., Mohamad F.I., (2006) "A Low Cost Microcontroller-Based Weather Monitoring System", CMU. Journal, Volume 5(1), pg 33-40.

[4.] Keshav K.S, Styline C., (2013) "Design of Wireless Weather Monitoring System", Department of Electronics And Communication Engineering National Institute of Technology, pg 1-45.

[5.] Chelakara S., Jean-Paul P., Ivica K., Larry B., Bartel V., Antonio V., Federic K., Carlos O., (2009) "Development And Testing Of A Second Generation Wireless Hurricane Wind And Pressure Monitoring System", Americas Conference On Wind Engineering, 11th edition, pg 1-15.

[6.] Axelson J.L., (2007) "Serial Port Complete", Lakeview Research LLC, second edition, Madison, Wiscousin, U.S.A, pg 43-58

[7.] Freescale Semiconductor, (2006) "MPX4115 Series Data Sheet". Retrieved from:www.datasheetcatalog.com/datasheets_pdf/M/P/X/4/MPX4115.shtml (Accessed on: February 2nd , 2015).

[8.] Texas Instrument, (2004) "MAX232 Data Sheet". Retrieved from: www.ti.com/lit/ds/symlink/max232.pdf (Accessed on: February 2nd, 2015).

[9.] Tocci R.J., Widmer N.S., (2001) "Digital Systems Principles And Applications", Prentice-Hall, eight edition.