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Design and Development of PC Based Integrated Data Acquisition System for pH and Temperature measurement

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Abstract

A PC based integrated data acquisition system for pH and Temperature is designed and developed to improve the performance and flexibility of the data acquisition system compared with traditional approaches. For this acquisition system, an analog signal conditioning circuit board is designed to extract the signals from the sensors of pH and temperature. This board is interfaced to PC through a data acquisition board that is installed in the PCI slot. Graphical programming software LabVIEW is used to design programs that provide the instrumental control and acquisition for the experimental data. This developed virtual instrument has the facilities of calibration for accurate measurements and also has the data logging system to store, analyze data for future use. pH of various materials has been measured with temperature and compared them to the reference values which show the accuracy of the system. A comparative study of pH vs. temperature has been done for 3 familiar materials that show the pH value increases with temperature. The system is cost-effective and user friendly and can be used for medical, industrial, chemical or home applications.

1. Introduction

Data acquisition is the process by which electrical or physical phenomena such as voltage, current, temperature, pressure, or sound from the real world are measured and converted into a digital format for processing, analysis, and storage by a computer. PC-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements. [6]. The components to be considered when building a computer based basic DAQ system are transducers and sensors, signal conditioning circuits, DAQ hardware and driver, application software with PC. A transducer is a device that converts a physical phenomenon into a measurable electrical signal, such as voltage or current. Sometimes transducers generate signals too difficult or too dangerous to measure directly with a DAQ device. For instance, when dealing with high voltages, noisy environments, and extreme high and low signals, or simultaneous signal measurement, signal conditioning is essential for an effective DAQ system. Signal conditioning maximizes the accuracy of a system, allows sensors to operate properly, and guarantees safety. DAQ hardware acts as the interface between the computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the computer can interpret them. Driver software transforms the PC and the DAQ hardware into a complete data acquisition, analysis, and presentation tool. Without software the DAQ device will not work properly. Driver software is the layer of software for easily communicating with the

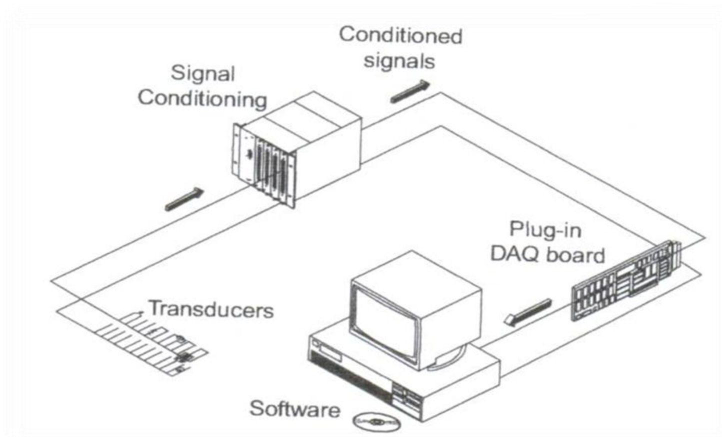


Fig. 1: PC-Based Data Acquisition

hardware. It forms the middle layer between the application software and the hardware. The application layer can be either a development environment in which we build a custom application that meets specific criteria, or it can be a configuration-based program with preset functionality. Application software adds analysis and presentation capabilities to driver software.

2. pH fundamentals

pH is a logarithmic measure of hydrogen ion concentration, originally defined by Danish biochemist Søren Peter Lauritz Sørensen in 1909 .

$$pH = -\log[H^+]$$

Where log is a base-10 logarithm and $[H^+]$ is the concentration of hydrogen ions in moles per liter of solution [43]. A pH *(*potential of *Hydrogen)* measurement reveals if a solution is acidic or alkaline (also base or basic*).* If the solution has an equal amount of acidic and alkaline molecules, the pH is considered neutral. The pH scale is logarithmic and runs from 0.0 to 14.0 with 7.0 being neutral. Readings less than 7.0 indicate acidic solutions, while higher readings indicate alkaline or base solutions.

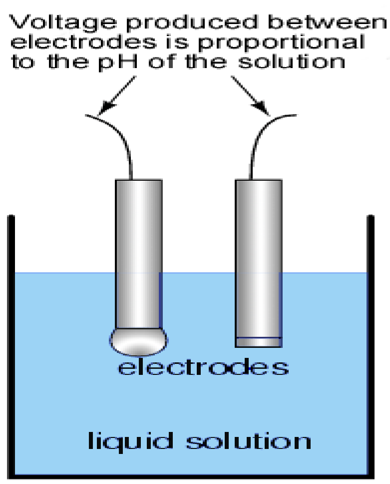


Fig. 2: pH Electrode

A pH measurement loop is made up of three components, the pH sensor, which includes a measuring electrode, a reference electrode, and a temperature sensor; a preamplifier; and an analyzer or transmitter. A pH measurement loop is essentially a battery where the positive terminal is the measuring electrode and the negative terminal is the reference electrode. The measuring electrode, which is sensitive to the hydrogen ion, develops a potential (voltage) directly related to the hydrogen ion concentration of the solution. The reference electrode provides a stable potential against which the measuring electrode can be compared. When immersed in the solution, the reference electrode potential does not change with the changing hydrogen ion concentration. A solution in the reference electrode also makes contact with the sample solution and the measuring electrode through a junction, completing the circuit. The output of the measuring electrode changes with temperature (even though the process remains at a constant pH), so a temperature sensor is necessary to correct for this change in output. Temperature compensation is contained within the instrument, because pH electrodes and measurements are temperature sensitive. The temperature compensation may be either manual or automatic. With manual compensation, a separate temperature measurement is required, and the pH meter manual compensation control can be set with the approximate temperature value. With automatic temperature compensation (ATC), the signal from a separate temperature probe is fed into the pH meter, so that it can accurately determine pH value of the sample at that temperature. [8], [9]

3. Designs and Implementation:

3.1 Design scenario

The Block diagram of a typical Data Acquisition system for pH is given below. For this acquisition system, an analog signal conditioning board is designed to get the signals from the sensors of pH. This board is interfaced to PC through a connecting cable and a data acquisition board is installed in the PCI slot. At the far end, there is pH sensor, which is connected to low pass filter through co-axial cable. Low pass filter is again connected to buffer circuit via bus. The buffer circuit is wired to DAQ card.

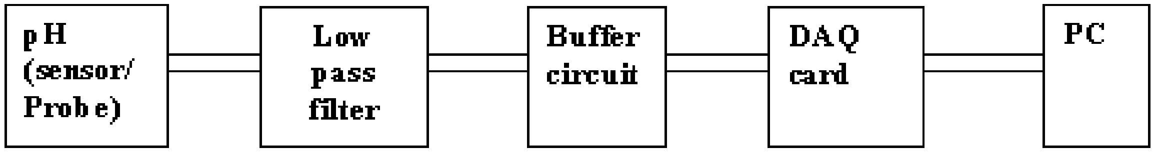


Fig 3: Block diagram of a typical Data Acquisition system for pH

3.2 Analog signal conditioning circuit board

The pH probe with model number RS425-819 (Spear probe pH electrode w/BNC plug.1m L) is used to get the corresponding voltage from the solutions. A low-pass filter is used to reduce the noise of the signal that comes from the pH probe. The cutoff frequency of the filter is $f_{cut\text{-}off} = 1/2\pi RC = 338.799$ Hz. A buffer amplifier (sometimes simply called a buffer) is one that provides electrical impedance transformation from one circuit to another. The CA3140A BiMOS operational amplifiers feature gate protected MOSFET (PMOS) transistors in the input circuit to provide very high input impedance, very low input current, and high-speed performance.

3.3 Temperature sensing circuit

pH electrodes and measurements are temperature sensitive. So a temperature sensor LM35 that is available and low cost is used to measure the temperature of the solutions and attached to pH probe. The output of the LM35 is voltage in mV range that is interface to the analog channel 1 (ACH1) of the DAQ card and using LabVIEW programming software that output voltage is converted to temperature in degree Celsius.

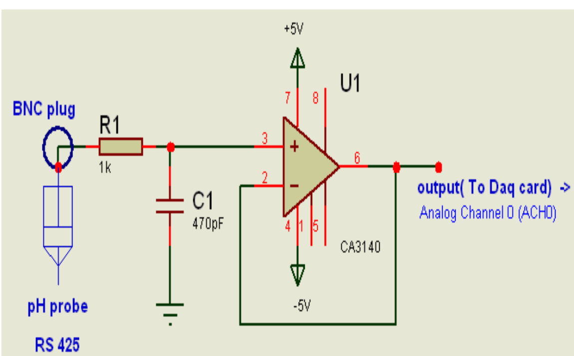


Fig 4: Schematic diagram of signal Conditioning circuit

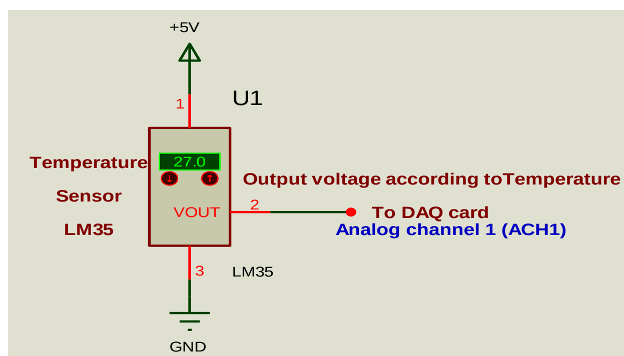


Fig 5: Schematic diagram of Temperature sensor

3.4 DAQ card installation

The NI-DAQ driver software nidaq861 is installed before installing the DAQ board (NI-6024E). For installing DAQ card, the expansion slot cover on the back panel of the computer is removed and the board is inserted into a 5 V PCI slot. The mounting bracket of the board is screwed to the back panel rail of the computer and the board is connected to the signal conditioning circuit board through a cable (NI-R6868).

3.5 Software Development

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a platform and development environment for a visual programming language from National Instruments. Basically LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. A user interface is built for pH and temperature by using a set of tools and objects that is known as the front panel. Then code is added using graphical representations of functions to control the front panel objects. The block diagram contains this code and resembles a flowchart.

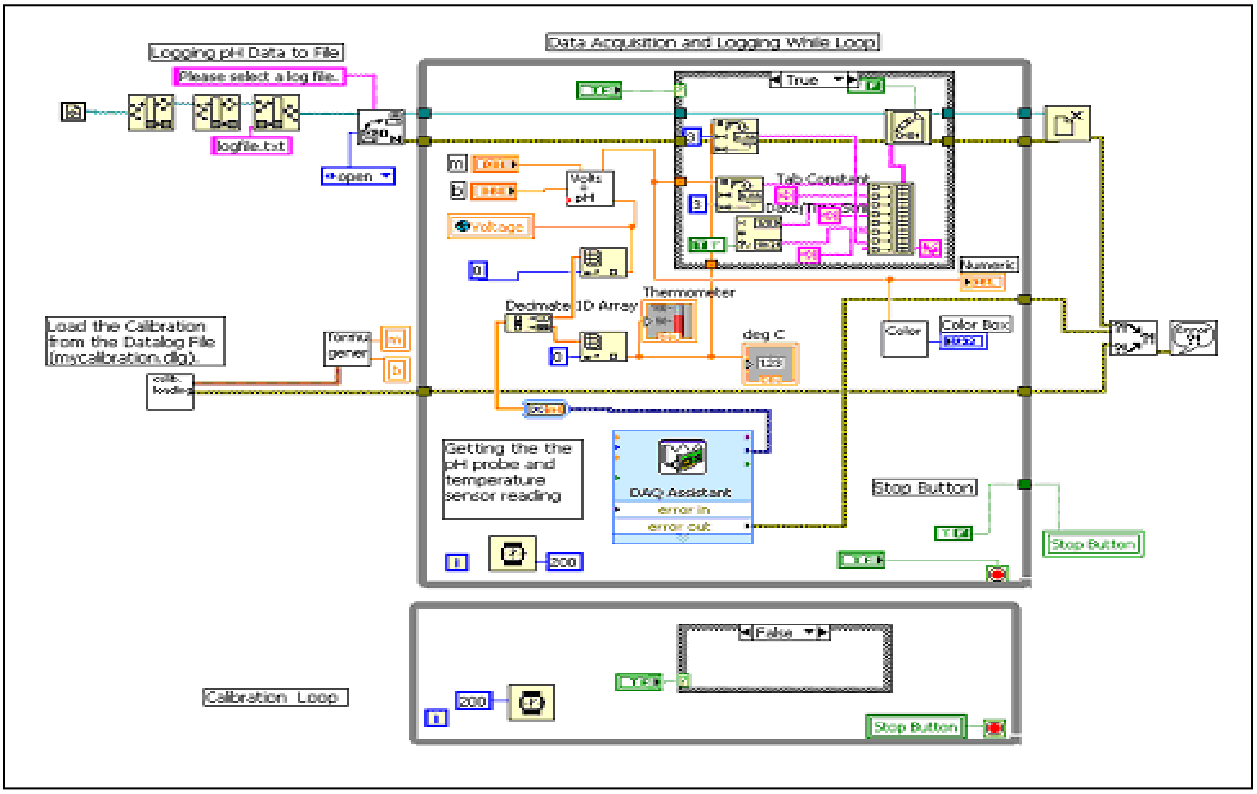


Fig. 6: Block diagram of the data acquisition system for pH and Temperature

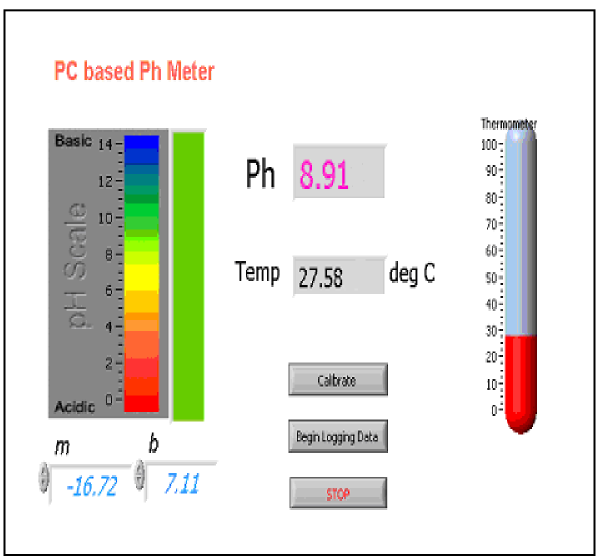


Fig. 7: User interface of the DAQ system

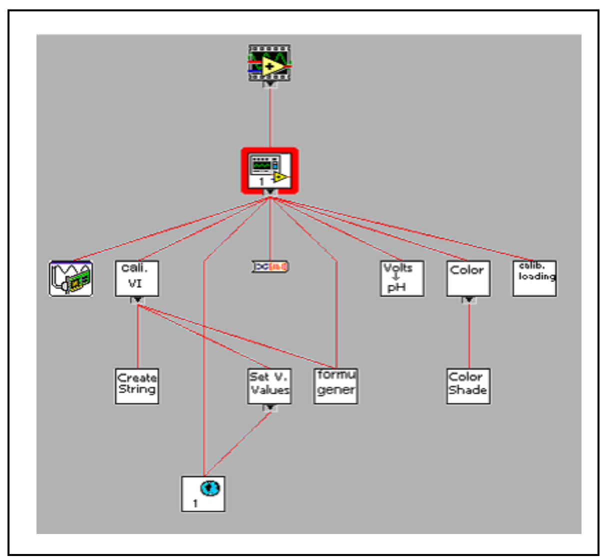


Fig. 8: VI hierarchy of the DAQ system

4. Measurements and Observations

4.1 pH measurement of different materials at room temperature

A comparison of measured pH values by the developed DAQ system of different materials at room temperature with the pH meter readings that are used in laborites has been made in the following table. The measured pH values of various materials at room temperatures show a good agreement with their reference values. The discrepancy between measured and meter values is very negligible; this difference is down to instrumental error as it is very difficult to maintain instrumental accuracy when pH and temperature is measured simultaneously or probably this could be due to the problem lying with pH probe.

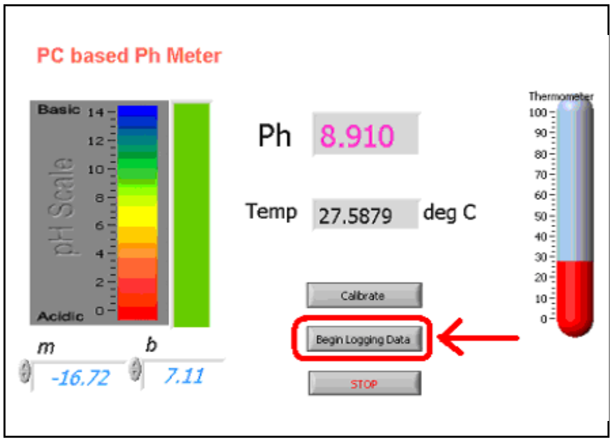
Sl.	Name of Materials	Measured pH values	pH meter reading	Temperature At Room ^{0}C	Comments
1	Lemon	2.27	2	25.39	Strongly Acidic
2	Antiseptic solution (Savlon)	5.52	5.5	25.88	Weakly Acidic
3	Tea	5.97	6	26.36	Weakly Acidic
4	Milk	6.38	6.3	25.64	Acidic
5	Black Coffee	5.01	5	25.63	Acidic
6		6.12	6.1	26.12	Acidic
7	Sugar	4.98	5	26.12	Acidic
8	“Pure Water”	7.00	7	26.85	neutral
9	Soya bean Oil	7.22	7.25	26.12	Basic
10	Water	7.44	7.4	26.85	Basic
11	Gum	8.27	8.22	25.63	Basic
12	Soap (Lux)	9.32	9.3	26.12	Weakly Basic
13	Vim	9.98	10	25.88	Weakly Basic
14	Wheel Detergent	10.1	10.2	26.37	Weakly Basic
15	Detergent powder (Surf Excel)	10.51	10.5	26.37	Weakly basic

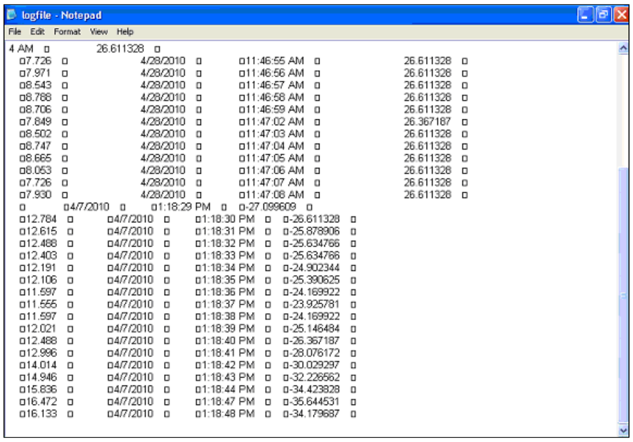
4.2 Measurement of pH Values with changing Temperature of 3 Different Materials

Material	Time	pH	Temperature ^{0}C
Sugar	2 mins.	9.15	47.36
		8.74	44.18
		8.72	41.74
		8.69	41.50
		8.24	40.28
		8.12	36.38
Milk	2 mins.	8.87	49.04
		8.50	43.70
		8.12	39.79
		7.81	39.03
		7.02	37.84
		7	37.59
		6.950	36.13
Detergent powder (Vim)	2 mins	11.07	41.75
		10.58	41.50
		10.47	41.02
		9.97	39.31
		9.93	37.59
		9.89	35.64
		9.64	34.91

It is worthwhile to note that in all the cases pH increases with the increase of temperature that follows the conventional law of pH and temperature.

4.3 Developed DAQ system as a data logger



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4 AM 26.611328
7.726 4/28/2010 11:46:55 AM 26.611328
7.971 4/28/2010 11:46:56 AM 26.611328
8.543 4/28/2010 11:46:57 AM 26.611328
8.788 4/28/2010 11:46:58 AM 26.611328
8.706 4/28/2010 11:46:59 AM 26.611328
7.849 4/28/2010 11:47:02 AM 26.367187
8.502 4/28/2010 11:47:03 AM 26.611328
8.747 4/28/2010 11:47:04 AM 26.611328
8.665 4/28/2010 11:47:05 AM 26.611328
8.053 4/28/2010 11:47:06 AM 26.611328
7.726 4/28/2010 11:47:07 AM 26.611328
7.930 4/28/2010 11:47:08 AM 26.611328
4/7/2010 1:18:29 PM -27.099609
12.784 4/7/2010 1:18:30 PM -26.611328
12.615 4/7/2010 1:18:31 PM -25.878906
12.488 4/7/2010 1:18:32 PM -25.634766
12.403 4/7/2010 1:18:33 PM -25.634766
12.191 4/7/2010 1:18:34 PM -24.902344
12.106 4/7/2010 1:18:35 PM -25.390625
11.597 4/7/2010 1:18:36 PM -24.169922
11.555 4/7/2010 1:18:37 PM -23.925781
11.597 4/7/2010 1:18:38 PM -24.169922
12.021 4/7/2010 1:18:39 PM -25.146484
12.488 4/7/2010 1:18:40 PM -26.367187
12.996 4/7/2010 1:18:41 PM -28.076172
14.014 4/7/2010 1:18:42 PM -30.029297
14.946 4/7/2010 1:18:43 PM -32.226562
15.836 4/7/2010 1:18:44 PM -34.423828
16.472 4/7/2010 1:18:47 PM -35.644531
16.133 4/7/2010 1:18:48 PM -34.179687
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Using the front panel one can store data (pH and Temperature) and use it various purposes in future. By pressing, “begin logging data” icon one can save data as a log-file in text format on the specific location of hard drive of the PC.

Conclusion

An integrated PC based system for Data Acquisition system has been developed and it is used for analysis of observed results for pH and temperature employing LabVIEW, DAQ and other necessary equipments. Study in this field is the first of its kind in our country, to the best my knowledge. Results that are found are very impressive as they show a pretty good agreement with the meter values and follow conventional rules. The major advantage of the system is that it can store data continuously, which are not available in conventional meters. This system can be very useful to meteorological and agricultural research as it saves money, manpower and energy. The developed system can be used for other remote sensor applications to transfer measurement information and configuration commands. It can be easily extended for controlling the renewable energy systems like photovoltaic system.

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