Development of Virtual pH Analyzer

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Abstract- **This paper presents the development of the virtual pH analyzer that can be used for continuous process applications. The development of virtual pH analyzer is divided into two parts: virtual pH measurement and virtual pH control system. The G-programming language potentialities of LabVIEW^{TM} version 2011 running on a Dell Core 2 Duo 2.0GHz, 3GB RAM computer with Windows 7 Ultimate operating system was utilized for data acquisition and control. The front panel has been designed to mimic the actual pH analyzer and the ON/OFF control strategy is applied for pH control system. Developed virtual instrument shows accuracy , flexibility and power compared to the conventional pH instruments.**

Keywords: virtual instrument, LabVIEW, data acquisition and control, pH analyzer, ON/OFF control

I. Introduction

The trends in measurement and instrumentation field these days apply the computer-based system to control and monitor the process elements and devices either in the laboratory or in the field. This application ranges from standalone computerized instrumentation systems to networked computerized instrumentation systems such as the distributed control system [1]. The developments in the instrumentation and measurement systems have passed through different advancement stages till they are in the forms we have today.

Despite the great development and the progress in the measurement and instrumentation field, there are some limitations accompany them such as the fact the real instruments are costly and space consuming. In addition, the processing capabilities are limited which unable to cope with new processing techniques because the instrument is manufacturing orientation. Due to that, the scenario in measurement and instrumentation field had changed to the development of new instrumentation generation known as Virtual Instrument (VI) [2].

The difference between a virtual and conventional instrumentation is that it is a software-based instruments [3] that mimic the appearance and the jobs of the real instrument using personal computer for all user interaction and control. The functions performed by each instrument are software implemented and thus can easily be reconfigured to cope with various applications.

This work is primarily to devise virtual pH analyzer to replace the conventional real instrument used in continuous process applications. The development was divided into two parts namely pH meter and pH controller. The main philosophy behind the development of virtual pH analyzer was to develop a powerful, accurate and flexible instrument using standard personal computer and affordable software.

II. pH Analyzer

Essentially, a pH meter is a microprocessor-based electronic instrument with high input impedance used for measuring the voltage of an electrode sensitive to the hydrogen ion concentration, relative to another electrode which exhibits a constant voltage [4].

The example of the traditional real pH meter is shown in Fig. 1. The meter ranges from simple to complex and expensive laboratory instruments with memory storage of only 100 measurements [5].

Fig. 1: Traditional pH meter

Conventionally, the pH measurement of any solutions involves the use of several instruments such as pH electrode and pH analyzer connected to a strip chart recorder and some other data acquisition devices. Each of these instruments handles each function and to expand the tasks handled requires buying another instrument and hardware that might be costly.

Therefore, the efficient and flexible instrument with an easy way to monitor and control the pH measurement without increasing its cost is required.

III. THE THEORY OF pH MEASUREMENT

The pH of the solution can be measured using electrode. The electrode behavior can be described by Nernst equation [4] in which the electrode develops a potential that gives the voltage output proportional to pH value. The voltage output of the pH electrode is temperature dependent as described by Eq. (1).

$$v = v_0 + (1.98 \times 10^{-4}) T_k pH \quad \text{...Eq. (1)}$$

where v is the total measured voltage in milivolt, v_0 is the intersect point value and T_k is the measured temperature in unit of Kelvin.

Temperature has a significant effect on pH measurement. Mainly, the temperature effects on electrode slope [6]. In addition to that, the temperature coefficient variation effects on material being measured by the sensor. Table I shows the Nernst slope variation with temperature effects on pH electrode.

TABLE I: Nernst Slope Variation to the temperature [6]

Temperature °C	Nernst slope (mV/pH)	Temperature °C	Nernst slope (mV/pH)
0	54.20	40	62.14
10	56.18	50	64.12
20	58.17	60	66.10
25	59.16	70	68.09
30	60.15	80	70.07

The intersection point of calibration lines plotted for different temperatures is called the isothermal point for pH electrode. Generally, the isothermal point for ideal pH electrode is 0mV at 7pH with a Nernst slope of -59.16mV/pH at 25^{0}C. In practice, a Nernst slope in the range of -55mV/pH to -60mV/pH and an asymmetry potential of ±15mV are acceptable [5,7].

The error due to temperature is the function of both temperature and the pH being measured. The errors will increase as the temperature change is increased. Normally in this case, the correction factor based on 0.003pH/^{0}C/pH unit away from pH7 is applied to the final reading of the pH analyzer.

IV. pH CONTROL SYSTEM

pH control system can be defined as a system that measures the pH of an input solution and controls the addition of a neutralizing agent (on demand) to maintain the output solution at the pH of 7, or within certain acceptable limits. It is in effect of a continuous titration [8].

In general, the ON/OFF control method is best suited for only continuous process applications. The example of a continuous process with ON/OFF control method is shown in Fig. 2. In this system, pH of the solution in the reaction tank is measured using pH sensor. Then, this measured signal is compared to the desired value via pH analyzer. An analyser provides ON/OFF control system so that the signal to the actuator controlling the reagent addition is always set in one of two positions, either fully open (ON) or fully closed (OFF). However, this result to rapid cycling and it could damage the final control element [9].

In this case, the ON/OFF controller with upper and lower hysteresis limits is required. These limits will hold the final control element “ON” for a longer time which results in smooth operation without rapid cycling [9].

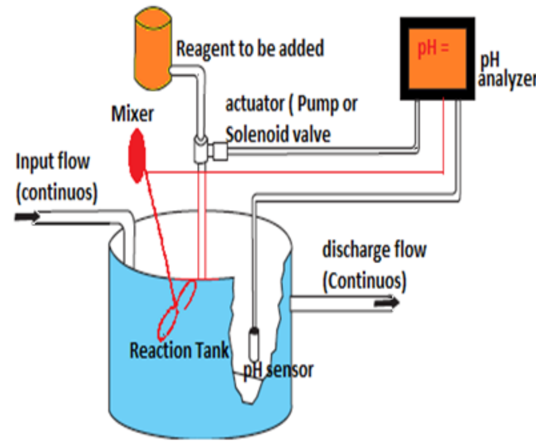


Fig. 2: Continuous process with ON/OFF control[9]

V. METHODOLOGY

The development of the virtual pH analyzer can be divided into two phases: pH measurement and control system. The pH measurement phase consists of two components namely data acquisition and data display whereas the pH control system phase comprises of data processing and control signal generation components.

The program is written in LabVIEW version 2011 running on a Dell Core 2 Duo 2.0GHz, 3GB RAM computer with Windows 7 Ultimate operating system. All the components of virtual pH analyzer are performed in a loop structure that runs until the user decides to stop the operation of the instrument. Each of the components of the instrument is elaborated in the following paragraphs.

Data acquisition: In this component, a man-machine interface is programmed for conFiguring the outputs from a pH electrode (in this case, voltage and temperature). It is then displaying the current pH measurement thru virtual meter display and color scale. The program also exhibits the amount of hydrogen concentration that corresponds to the voltage and temperature reading. Besides, the slope variation to the temperature is also displayed. This will help the user to visualize the accuracy of the instrument. However, the slope is dependent on the pH electrode in use. On top of that, the collected data were stored to hard disk, allowing the user to select a data file. Thus, the stored data can be retrieved for further calculation and also can be exported to other software application.

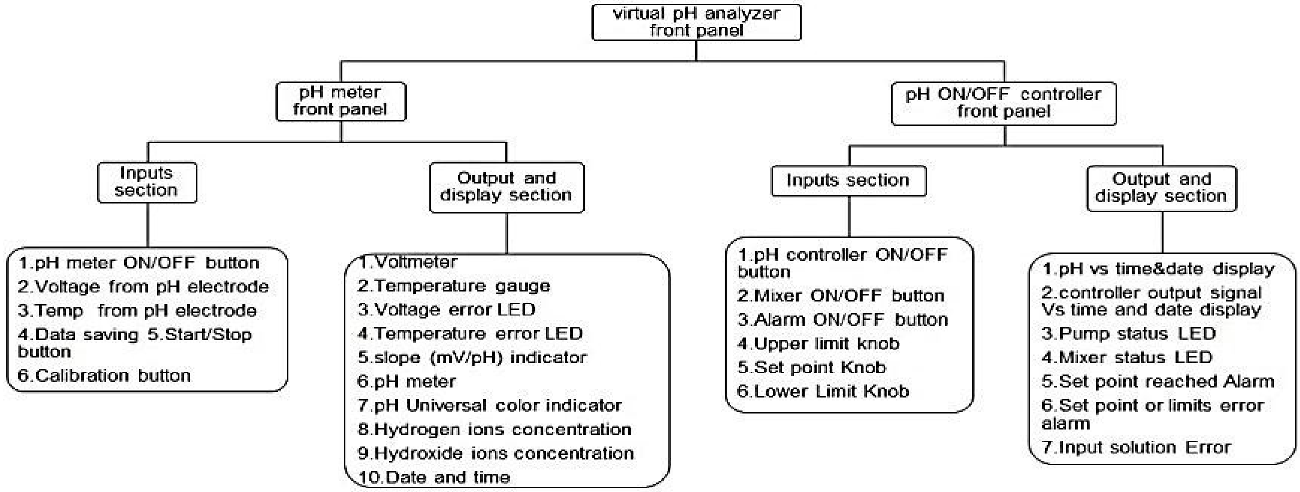


Fig. 3: Indicators and controls on the virtual pH analyzer front panel

Data display: The front panel of the instrument is created in the economic and simple way for monitoring and controlling purposes with the formation of knobs, buttons, meters, color scale and graph. Fig. 3 shows all the controls and indicators used in the front panel according to their respective function.

Data processing: In this work, the output voltage and temperature signals from pH transducer are undergoing the data processing component in which these signals are converted into pH using Nernst equation principle shown in Eq.1. In this component, a pH measurement was programmed in such that at 25^{o}C, the voltage for a unit pH is -59 mV. In order to automatic compensate the errors from changes in electrode sensitivity due to changes in temperature, a correction factor based on 0.003 pH/^{o}C/pH unit away from pH 7 was applied to the final reading[10].

In addition, the Hydrogen and Hydroxyl concentrations of the solution are calculated based on the fact that at any aqueous solution, the concentration of hydrogen ions multiplied by the concentration of hydroxide ions is constant.

Besides, there are three types of alarm have been created: *error set point*, *input* and *set point reached* alarms. The *error set point* alarm is to ensure that the set point is lies between hysteresis lower and upper limits. In this instance, if condition was not met the LED activates and producing alarm sound. Similarly, the *error input* alarm is created to indicate whether the measurement and control can be executed in which the measured pH value should be less than the hysteresis upper limit. Likewise, the *set point reached* alarm is activated when the set point is reached and it is also to inform the user to turn OFF the mixer.

Control signal generation: The control system component is developed in which it compares the measured pH with the desired value and if necessary, an ON/OFF control signals is used to activate the pump. In this work, the control of pH is done automatically in which the program is written in such that the pump is used to ON until the set point is reached.

The mixer is used to allow the solution well mixed and to stable a pH reading. In this case, the mixer is manually activated by the user in which the mixer should be turn OFF when the set point is reached. Fig. 4 shows the flow chart for pH ON/OFF control system.

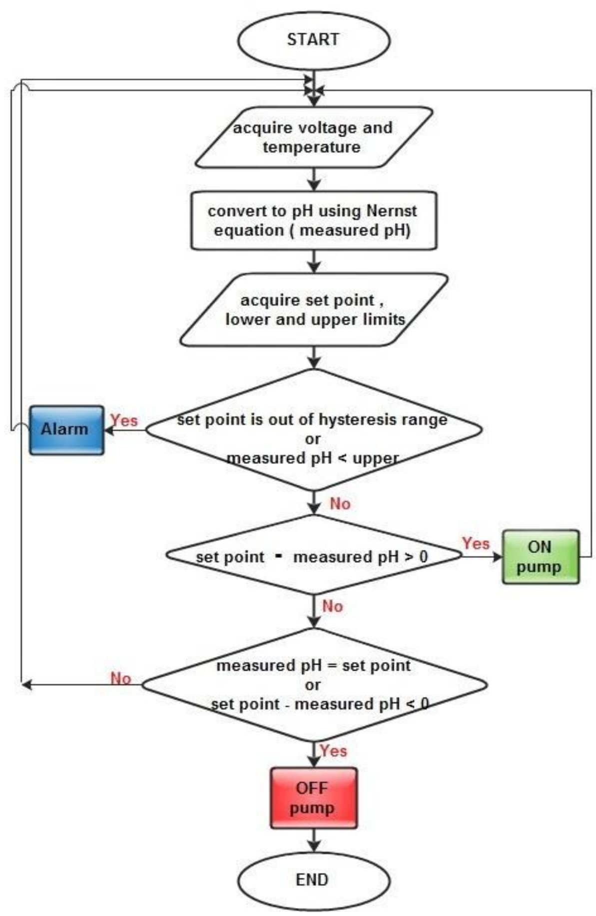


Fig. 4: pH ON/OFF control system flow chart

The accuracy [11] of the developed virtual pH analyzer is tested by comparing the reading from the conventional instrument. In this case, the standard experiment procedure [12] is taken and the closeness of the measured value to the standard value is compared. For instance, the readings from three different buffers are taken by the conventional pH meter (sesensION3 pH meter manufactured by Hach shown in Fig.1) and developed virtual pH analyzer in which then these readings are compared.

VI. Results And Discussion

Fig. 5 shows the front panel of the developed pH analyzer that mimic the actual instrument for continuous process applications whereas Fig. 6 shows the programming module for the pH meter. The controls and data displays for the system are designed so that the observation and control of the system can be done via software environment. These programming modules can be modified at any time by the user according to specific needs.

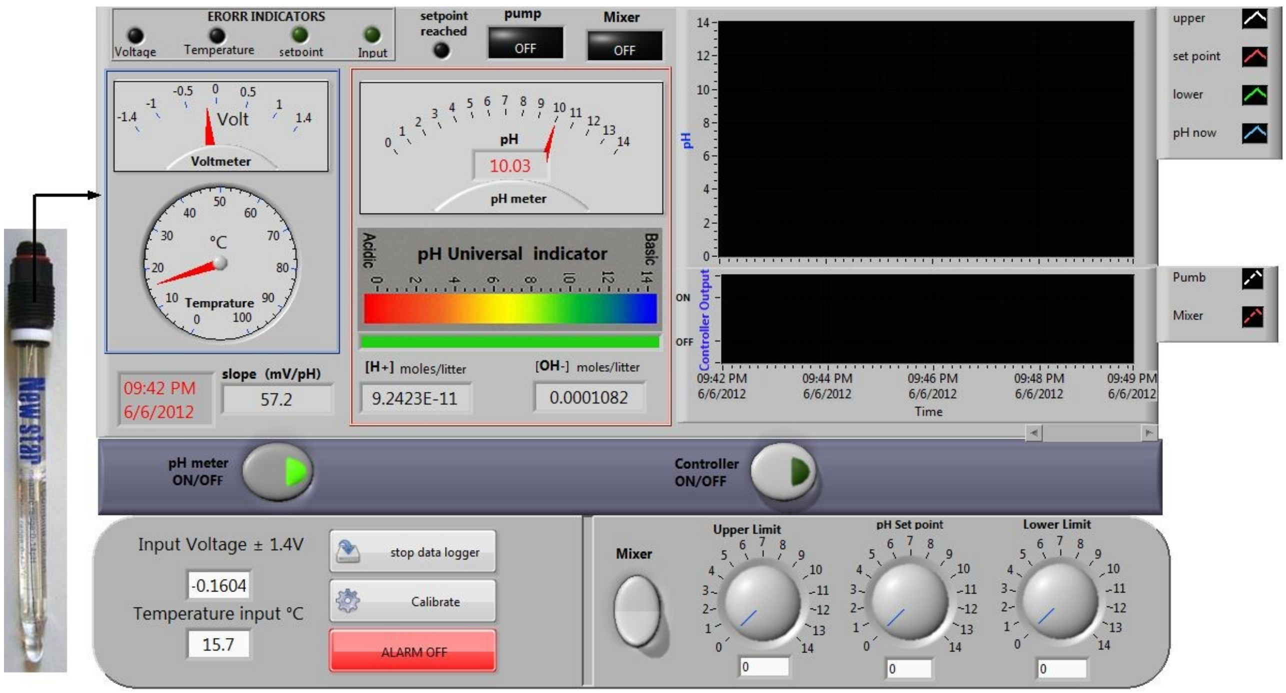


Fig. 5: Front panel of virtual pH analyzer

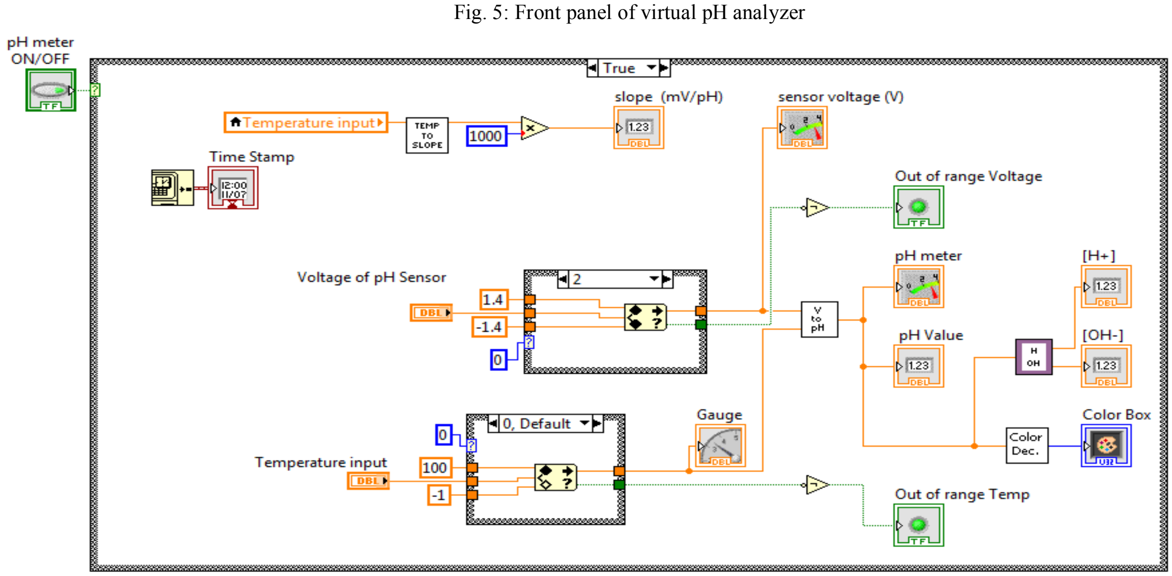


Fig. 6: programming module of virtual pH meter

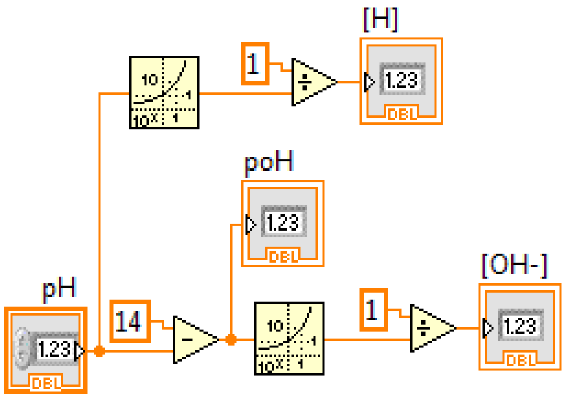


Fig. 7: programming module for data conversion.

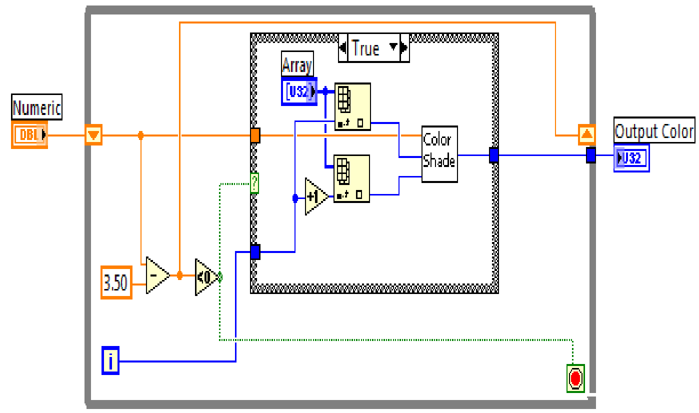


Fig. 8: color control programming module.

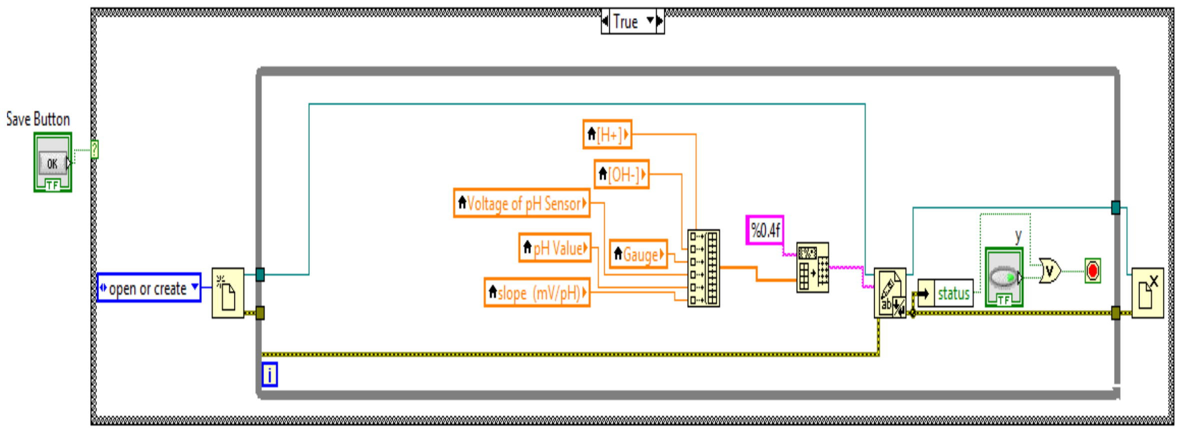
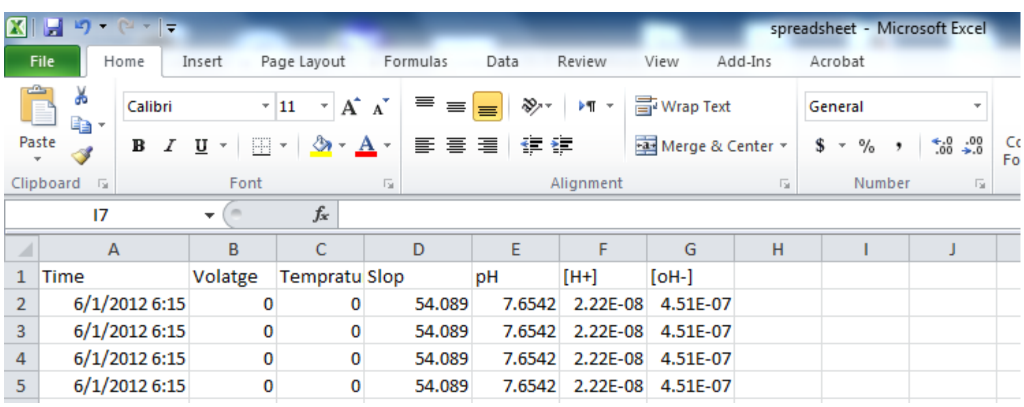


Fig. 9a: Data saving programming module.



	A	B	C	D	E	F	G
1	Time	Volatge	Tempratu	Slop	pH	[H+]	[oH-]
2	6/1/2012 6:15	0	0	54.089	7.6542	2.22E-08	4.51E-07
3	6/1/2012 6:15	0	0	54.089	7.6542	2.22E-08	4.51E-07
4	6/1/2012 6:15	0	0	54.089	7.6542	2.22E-08	4.51E-07
5	6/1/2012 6:15	0	0	54.089	7.6542	2.22E-08	4.51E-07

Fig. 9b: Microsoft excel file containing pH meter data.

The programming module that describes the functionality of the virtual pH analyzer is shown in Fig. 7 to Fig. 11. For instance, Fig. 7 shows the code that calculates and displays the concentration of the Hydrogen and Hydroxyl ions in moles/l units on pH meter front panel. Whereas Color control programming module that generates five colors in different gradients (red, orange, yellow, green and dark blue) which represent the pH value is shown in Fig. 8. On the other hand the G-programming for data saving which resulted data are saved into Excel Worksheet file are shown in Fig 9a and Fig 9b respectively.

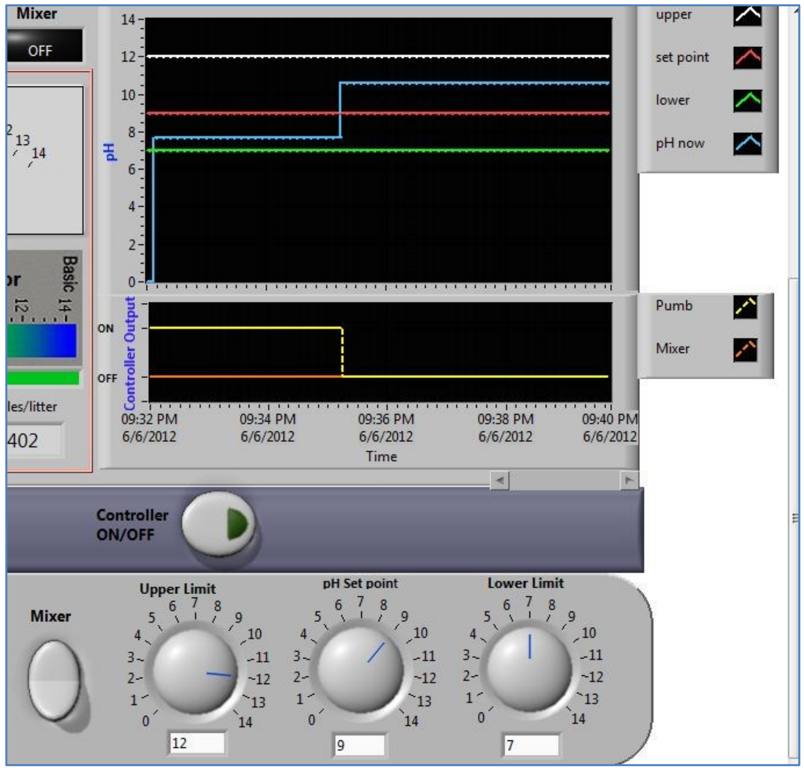


Fig. 10a: controller front panel.

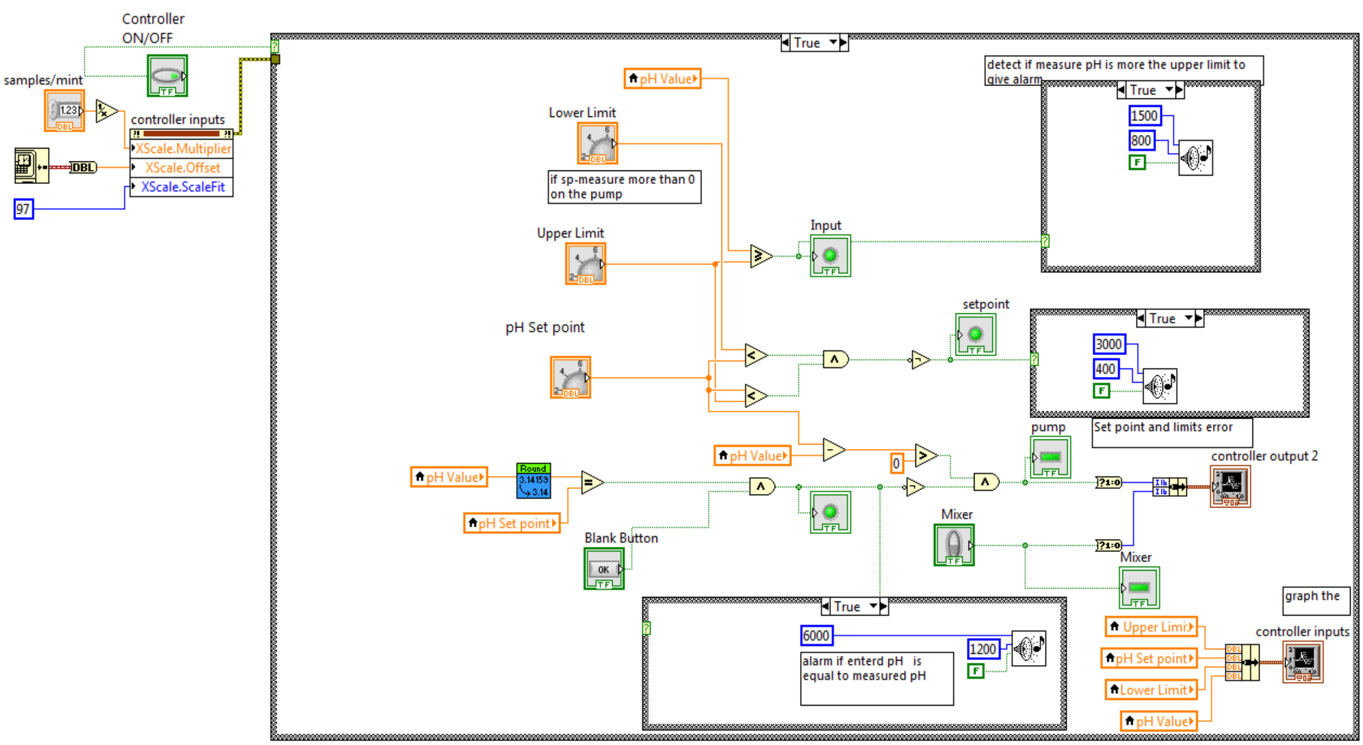


Fig. 10b: Controller programming module.

Fig.10a display the front panel of the developed pH controller and its corresponding programming module is shown in Fig. 10b. The graph on the front panel shows step by step record of the pH ON/OFF controller activities. As shown in Fig. 10a, the controller sending ON pump signal (yellow line) in order to start injecting the reagent when the measured pH (blue line) was less than the set point (red line) and simultaneously the controller sent OFF pump signal to avoid excess reagent adding when the measured pH was above set point value. Fig. 10b describes programming module which executes control algorithm as illustrated in Fig.4.

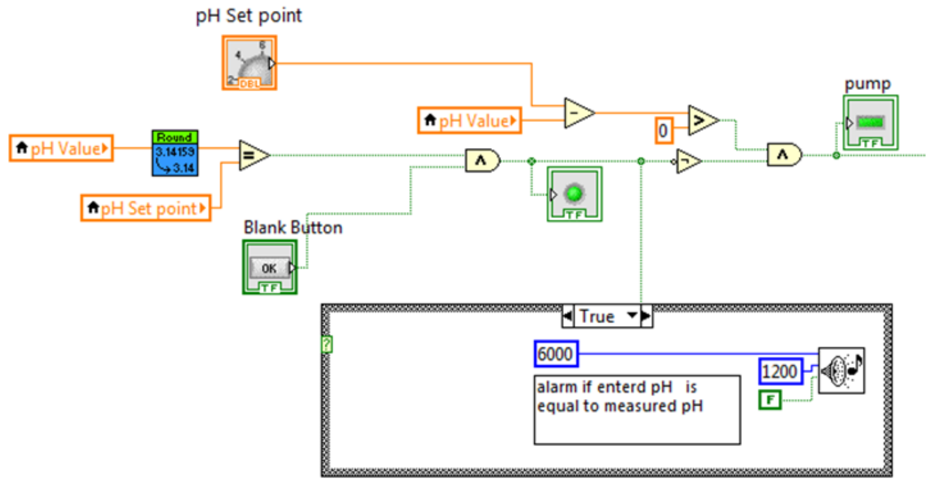


Fig. 11: set point alarm programming module.

The resulted code reported in Fig. 11 activates blue LED indicator and a unique peep alarm when the set is reached.

Table II shows the readings from the conventional pH meter and developed virtual pH analyzer. The results show that the developed virtual pH analyzer gives accurate readings as compared to the conventional pH meter. The pH values from the virtual pH analyzer are closer to the buffer pH values than readings acquired by the conventional pH meter.

TABLE II : comparison of virtual pH meter results, conventional pH meter readings with buffer values

Buffer pH value	Electrode Voltage (mv)	Electrode Temperature (°C)	conventional pH Reading	VI pH reading
4.01	176.2	15.3	3.69	4.072
7	100.2	17.4	6.89	7.019
10.01	-160.4	15.7	9.76	10.030

VII. Conclusion

A virtual pH analyzer for continuous process application is successfully developed and tested. The developed user interface, gives the flexibility to observe the variation of input and output of the process in real-time mode.

This virtual pH analyzer proves a relatively high accuracy compared to conventional pH meter.

The power of this developed pH analyzer that it's utilizing the computer power compared to the conventional meters that utilizes the limited power of microprocessor.

The application of a virtual instrument has the advantage that all the engineering units can be converted on a software basis and the system is monitored and controlled by a personal computer operating in a specific software environment.

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