Design of Virtual Instrumentation for pH Measurements

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ABSTRACT

Virtual instrumentation is a modern concept in the field of instrumentation design technology. In the present work, simple and inexpensive signal processing circuit is designed in our laboratory, using off-the-shelf components, to amplify signal received from glass electrode. The designed prototype consists of an USB based data acquisition card 4711, procured from Advantech, interfaced to the IBM compatible PC, operated under windows 7 operating system. User friendly data acquisition software is developed in VB.NET at the back end as well as at the front end to accomplish data acquisition, parameter setting, file manipulation, control and synchronization of the other functions involved in the measurements. The GUI control panel directly displays the pH value of the liquid under test at a given temperature. The designed pH measurement system has been tested in our laboratory and found to be much easy to operate, reliable, powerful and effective as compared to that of the conventional pH measurement instruments.

1. INTRODUCTION

Virtual instrumentation [1, 2] is the modern, powerful and effective concept in electronics instrumentation. It is the software representation of traditional and exciting new measurement instruments on a computer. In recent years, computers have virtually replaced almost all the measuring devices and control systems, due to the advancement in semi-conductor technology, increased processing power of PC, ergonomic window based software and growing list of available interfaces and drivers of the personal computers. Software has taken the complete control over the hardware. Such a software control of the instruments has given rise to entirely new field of instrumentation called the virtual instrumentation (V. I.).

The pH [3-6] meter measures the concentration of hydrogen ions (H^+) in an aqueous solution that are responsible for its acidic and alkaline nature.

A **pH meter** is an electronic instrument used for measuring the pH (acidity or alkalinity) of a liquid (though special probes are sometimes used to measure the pH of semi-solid substances). A typical pH meter consist of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading.

2. THEORY

The first commercial pH meter is reported around 1936 by Radiometer in Denmark and by Arnold Orville Beckman in the United States. While Beckman was an assistant professor of chemistry at the California Institute of Technology, he was asked to devise a quick and accurate method for measuring the acidity of lemon juice for the California Fruit Growers Exchange (Sunkist). Beckman's invention helped him to launch the Beckman Instruments Company (now Beckman Coulter). In 2004 the Beckman pH meter was designated an ACS National Historic Chemical Landmark in recognition of its significance as the first commercially successful electronic pH meter.

The characteristics of a pH measurement depend on the individual properties of the measuring electrodes [7, 8]. Most of the electrodes used today in measurement of pH are combination electrodes.

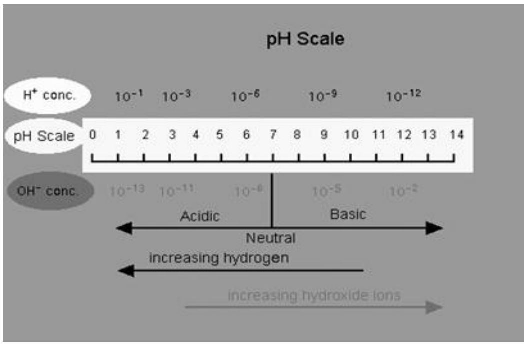

Fig 1. pH Scale

In the simplest and most used versions, a glass electrode, a tube made by a special semi-porous glass containing an HCl solution with a known concentration (better termed as activity) of H^+ and a silver (Ag) probe covered by AgCl (silver chloride) immersed in it. Outside this glass tube, there is other Ag probe, equally immersed in the solution to be measured for its H^+ activity and linked with the other Ag/AgCl glass electrode that is the reference, with a constant electric potential. The porous glass of the electrode prevents the H^+ ions to diffuse from both sides, but allows the exchange of Na^+ ions (contained in the silicates of the glass) with the external solution, for keeping the continuity to this electrical system. The H^+ activity difference between the solution inside the electrode and the external one is measured as electric potential difference, then, converted in pH units (0-14) by the instrument (Fig 1.). This electrode is small, also few centimetre long, easy and fast to use and sensitive (± 0.001 pH units) and the relation between the potential measured and the H^+ activity (a) is expressed by the Nernst equation,

$$E = E^0 - 0.059 \log [a0(H+) / a1(H)]$$

Where

E is the electric potential

E^0 is constant depending on metal

a0(H+) is the activity of H+ inside the electrode, constant =1,

a1(H+) is the unknown activity of the solution to be measured.

So, the formula becomes:

$E = E^0 - 0.059\ [1 / a1(H+)]$
but, following the definition of pH
($pH = \log 1 / a(H+)$),

This formula is simplified as,

$E = E^0 - 0.059\ pH$ then,

$pH = (E0 - E) / 0.059$

In other word, the voltage produced is about 0.059 volt per pH unit.

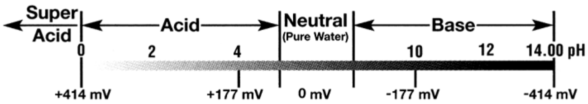

Fig 2. pH Scale with emf values.

For accomplishing precision in the measurement, the pH meter is to be calibrated before the actual measurements are to be performed (Fig 2.), since the glass electrode may not show a reproducible e.m.f. over longer periods of time. Calibration should be performed with at least two standard buffer solutions that span the range of pH values to be measured. For general purpose measurements, buffers at pH 4 and pH 10 are acceptable.

In the present work, we have made use of the modern concept of virtual instrumentation for the estimation of pH of the liquid under test. A locally available electrode is used in the present setup. The other required circuit and data acquisition card, USB 4711A, interfaced with a computer and the necessary software is written in VB.NET [9, 10] to display pH at given temperature on the user screen.

3. EXPERIMENTAL

Fig. 3 shows the block diagram of the system designed in our laboratory. Glass electrode is immersed in the liquid/solution under investigation for pH measurement. A temperature sensor is also dipped in the liquid for temperature measurement. Output voltage is proportional to the pH of the solution under test. This signal is amplified by an amplifier. A data acquisition card, USB 4711A is used to acquire this amplified signal. Data acquisition software at the back end as well as front end is written in VB.NET and the interactive and friendly GUI control panel screen is designed to accomplish data acquisition, parameter setting, file manipulation, control and synchronization of the other functions involved in the measurements. The GUI control panel directly displays the pH and temperature of the liquid under test. User friendly program allows the user to store the data in a data base file which can be used for further processing.

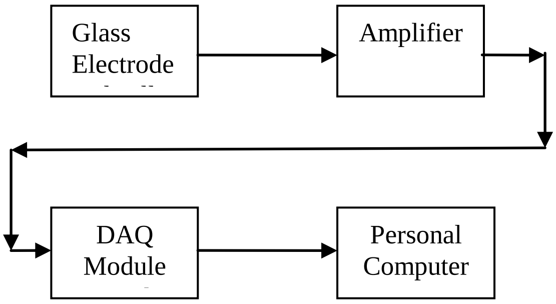

Fig 3: Block diagram of System

4. CALIBRATION

Table 1. pH Verses mV

(For calibration)

pH	mV	pH	mV
0	413	7.87	-59
0.07	410	8.71	-107
0.11	408	9.08	-131
0.16	404	9.7	-183
0.21	401	9.81	-195
2.45	270	10.3	-204
4.55	175	10.45	-208
5.64	105	10.94	-220
5.74	94	11	-236
6.3	58	12	-295
6.7	26	13	-355
7	0	14	-413

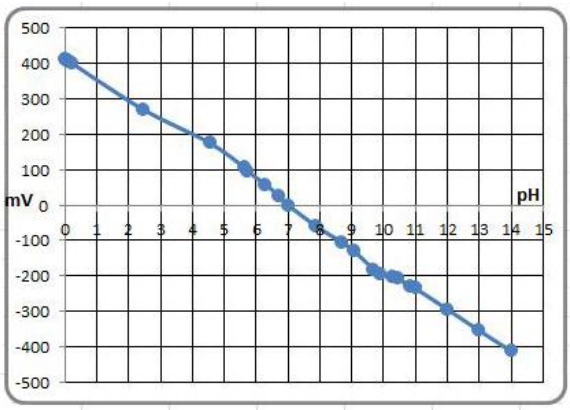

Fig 4. pH verses millivolt graph for calibration.

Glass electrode is calibrated initially using standard solutions of known pH values in our laboratory as shown in Fig. 4. By carrying out regression analysis [11] equation (1) is obtained:

E = 0.413 - 0.059 * pH (1)

pH = (0.413 - E) / 0.059 (2)

where

E = Electric potential

pH = pH of the solutions.

A graphical user interface (GUI) control panel is designed in VB for data processing of the measurement parameters such as temperature and potential developed across electrode for the liquid under test. pH value is estimated from the above measured parameters and displayed on the control panel screen. The screen shot of pH measurement along with the actual setup is shown in Fig. 5.

Fig 5. Photograph of the Experimental Setup

5. RESULT

The facilities of the designed virtual instrumentation used to measure the pH and temperature of the given solution. Initially the calibration of the glass electrode is carried out. The total setup is then used to find the pH of the solution under test, at a given temperature. With the help of virtual instrumentation, not only pH measurements but also temperature estimations have become an easy, faster and much reliable. Moreover, it is possible to extend the measurements at the desired temperature using a refrigerating-heating circulating thermostat. Table 2 shows the pH of some solutions measured for different liquids at room temperature.

Table 2: pH of some standard liquids

Liquid	**Temp (^oC)**	**Voltage produced (mV)**	**pH**
Acetic Acid	**29.5**	**270**	**2.45**
Acetone	**29.5**	**95**	**5.60**
Ethyl Acetate	**29.5**	**72**	**5.74**
Aniline	**29.5**	**53**	**6.38**
Chloroform	**29.5**	**-59**	**7.87**

6. DISCUSSION

Virtual Instrumentation designed for pH measurement of a liquid at a particular temperature using a glass electrode amplifier and a data acquisition card (USB 4711A), is simple in design, faster, reliable, cheaper and accurate with online/offline storage (for database) and processing capabilities. This virtual instrumentation finds extensive use in modern analytical chemistry lab.

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