Development of pH-meter Monitoring System Using Arduino

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***Abstract*-This paperwork presents the complete circuit used to interface a pH-meter using Arduino. The objective of study is to investigate the accuracy of the pH-meter using Arduino as a microcontroller. The study focused on the accuracy of ph-meter when tested to specified ph buffer. The pH-meter is tested to 4 difference pH buffer to determine the accuracy of this pH –meter. The result shows that this pH-meter has an accuracy of 97% compare to an average pH meter that is about 99% of error. As a conclusion, this pH-meter is very good because the error is below 10%.**

Keywords: pH measurement, pH-meter, pH Glass electrodes, Arduino Uno, Acid, Alkaline, Neutral

I. INTRODUCTION

A pH-meter is an electronic device used for measuring and displays the pH solution of alkaline, acid or neutral though pH probes. pH-meter also can be used to measure the pH of semisolid substances such as cream, an ointment, a gel or a lotion. Basically, pH-meter is an electronic meter that measures the potential difference connected to special measuring probe [5] .There are 3 major type of measuring probes that are glass electrode, metallic electrode and ISFET sensor. Usually, glass electrode are the common probe that been used. Nowadays, millions of pH-meters are used under operation worldwide, in applications ranging from agriculture, pharmaceutical, chemical, food industries and also biological process monitoring [2]. Basically, pH is given by Eq. (1).

$$pH = - \log [H+] \quad (1)$$

Where;

H+ = hydrogen ions' molar concentration. .

Many type of commercialize pH-meter are fixed with limited function and cannot be controlled using computer via USB port. It will make user impossible to add any extra function to the pH-meter. The usual pH-meter can only view pH value but we can't include any extra additional function such as recording, monitoring, controlling and communications with a supervisory system. Therefore this pH-meter is as an alternative to overcome this problem because Arduino can be interfaced by lot kind of sensors and other shield that capability with Arduino.

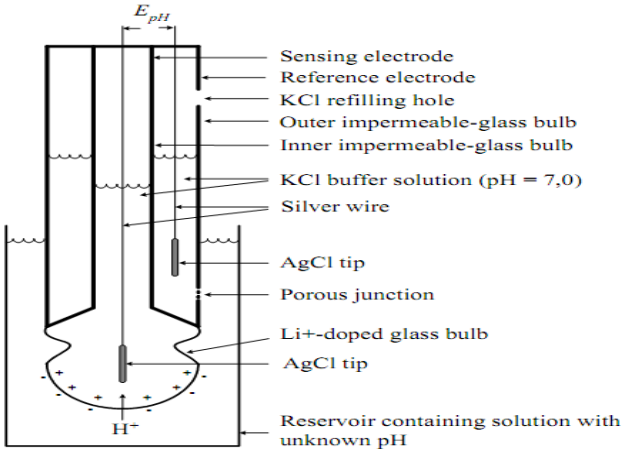


Fig.1. Cross sectional of pH glass electrode [4]

The cross sectional of glass electrode is shown in Fig.1. Glass membrane, reference junction and reference electrolyte are 3 main part of this pH probe.

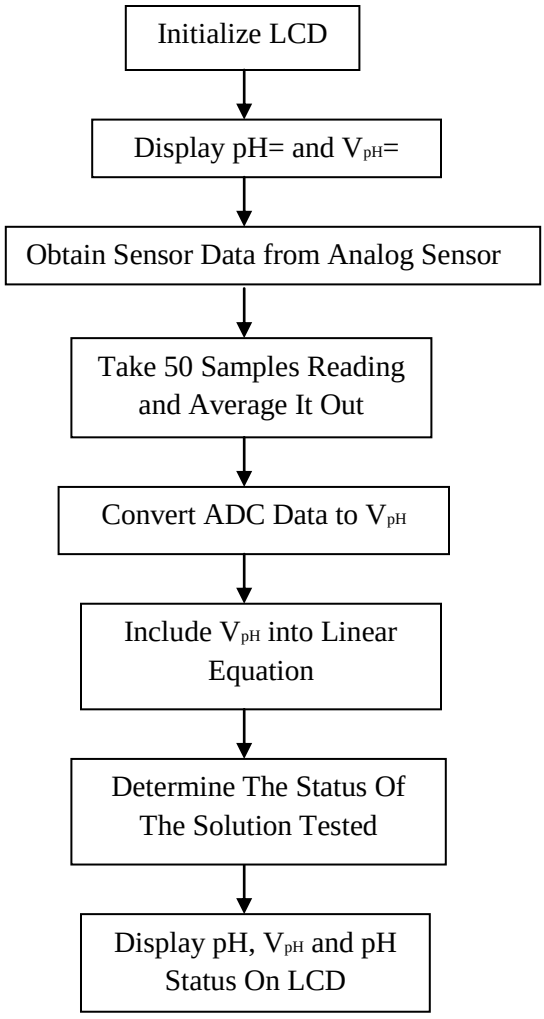
II. METHODOLOGY

This project consists of two parts which is software design and hardware design. The hardware part consists of four separate parts which is ph probe, pH amplifier, Arduino Uno and LCD. The pH amplifier circuit used to amplify the small voltage signal from the pH glass electrode[7]. This circuit also is used to adjust the offset and gain of the input signal to control the slope and y-intercept of the ph linear equation. Within the 0-14 pH range, glass pH electrodes generate a signal that ranges approximately from +200 mV to -200 mV that depend on the ion concentration of different solution[5] and [6]. The pH amplifier translates the pH signal to 0-5V input range of ADC[3]. This gives 1024 steps on 5V. pH amplifier circuit will give 0 -14 pH in range of 0-1.8V (V_{pH}) and about 369 steps is used. The V_{pH} then included to linear equation because the pH must be assumed that the actual value of pH is directly proportional to the value of V_{pH}. The experiment is then conducted to measure V_{pH} using 4 different buffers which are pH 1.68, pH 9.18, pH 10.01 and pH 12.42. During experiment, both offset and gain trimmer is fixed in halfway resistance values which are 5KΩ and 500KΩ respectively. The software part cover all the converting the VpH value that came from pH amplifier. This is including the linear equation from the experiment that has been done.

2.1 Software Design

```
#include <LiquidCrystal.h>

// select the input pin for ph amplifier
int sensorPin = A0;
// variable to store the value coming from the sensor
float sensorValue = 0;
float VpH = 1;
float straightline = 2;
int reading;
int i;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup() {
  Serial.begin(9600);
 // set up the LCD's number of columns and rows:
 lcd.begin(16, 2);

 // Print a message to the LCD.

 lcd.print("pH=");
 lcd.setCursor(8,0);
 lcd.print("VpH=");
}

void loop() {

 reading = 0;
 for(i = 1; i < 50; i++){
  reading += analogRead(sensorPin);
  delay(10);
 }
 //average it out
 reading /= i;
 // read the value from the sensor:
 sensorValue = analogRead(sensorPin);
 //voltage from amplifier
 VpH = ((sensorValue/1024)*4.8);
 //straightline equation for the vph vs ph buffer graph
 straightline = (8.098*VpH-1.085);
 delay(sensorValue);

lcd.setCursor(3,0);
lcd.print(straightline);
delay(1000);
lcd.setCursor(12,0);
lcd.print(VpH);
delay(1000);

// for hyper terminal

Serial.print("pH=");
Serial.print(straightline);
Serial.print("  VpH=");
Serial.print(VpH);

//if else statement for pH status

if (straightline >= 1.0 && straightline < 7.0) {
   lcd.setCursor(0,1);
   lcd.print("<Acid Solution>");
   Serial.println("  <Acid Solution>");

   delay (1000);
   }

if (straightline >= 7.0 && straightline < 14.0) {
      lcd.setCursor(0,1);
     lcd.print(" <Base Solution>");
     Serial.println("  <Base Solution>");
     delay (1000);
     }

if (straightline == 7.0) {
       lcd.setCursor(0,1);
       lcd.print("Neutral");
       Serial.println("  <Neutral>");
       delay (1000);
}
```

2.2 Code Block Diagram



The code above work to convert the pH voltage (V_{pH}) from amplifier circuit to pH value using linear line equation and displayed to LCD. First, to use LCD function, liquid crystal library must be uploaded to the code. Next, the analog sensor (V_{pH}) translated by A/D converter by reading an analog sensor on analog pin 0.Then, the system continue by take a sample of 50 readings and average it out to get an accurate reading. After that, the averaged input converted back to view voltage (V_{pH}) and then the voltage included in the linear line equation to view the pH value and V_{pH} on LCD. The display also will display the status of the solution whether it acid solution, base solution or natural solution depend on the pH solution tested.

2.3 Hardware Design

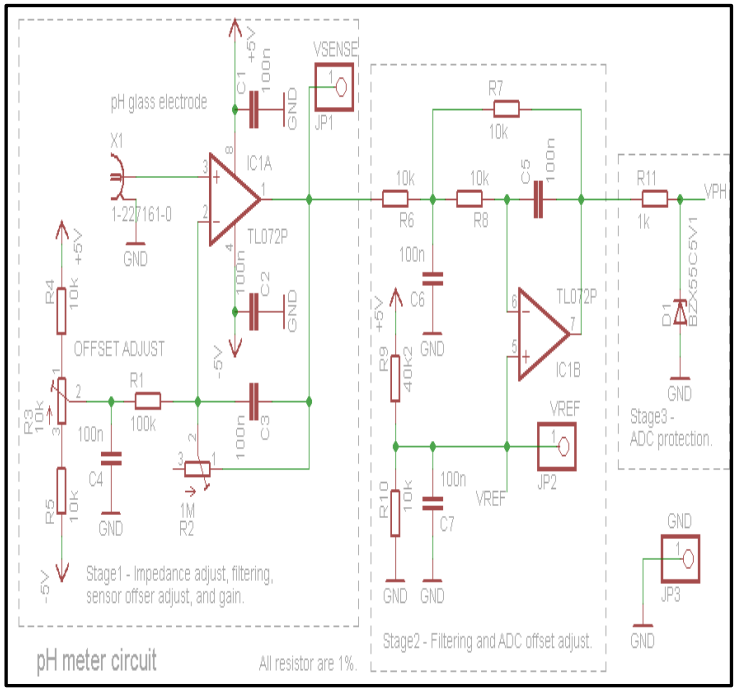


Fig. 2: pH Amplifier Circuit

The pH amplifier circuit shown in figure 2 consists of two stages amplifier. The amplifier used in this circuit is low noise J-FET dual operational amplifier. The first stage of this amplifier is to control the impedance adjusts, filtering, sensor offset adjusts and gain adjust. Two trimpot R4 and R5 in this stage used to adjust the offset and the gain of the amplifier. The second stage is to filtering and ADC offset adjust. To make sure this circuit runs properly, potential difference at pin5 at this amplifier should be remain about 1V. At the end of the circuit, zener diode BZX55C5V1 is used for ADC protection. This zener diode is very importance because we don't want high voltage flow through Arduino.

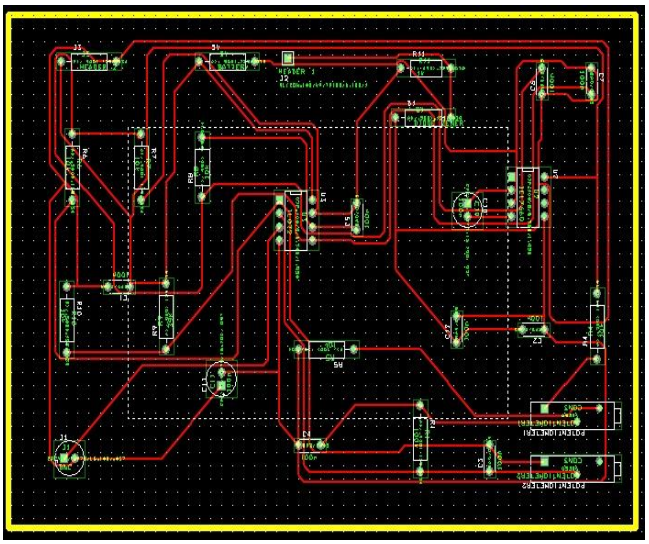


Fig. 3 Layout for Amplifier Circuit

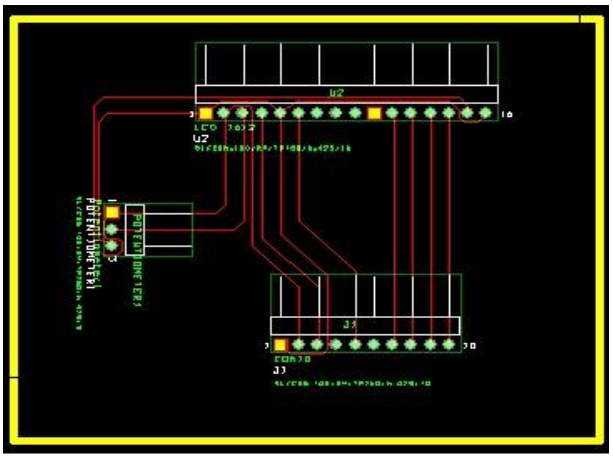


Fig. 4 Layout for LCD

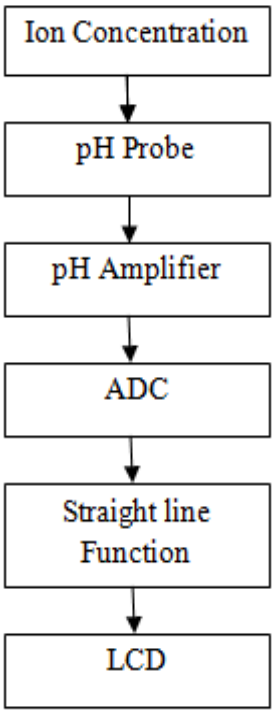
Fig.5 Arduino Uno

Fig. 6 BNC pH Glass Electrode

Figure 3 and 4 shows the amplifier and LCD circuit layout designed using Orcad software. Orcad is one of software that use to design circuit. In this designing, single layer type of PCB has been choose. First, Orcad Capture is used to create the circuit schematic. After that, the schematic is transfer to Orcad layout for designing the both layout. Finally, Gerb Tool has been used to print out the complete circuit. After finish designing this layout, it continues to PCB making.

Figure 5 is Arduino Uno.Arduino Uno is microcontroller board based on the ATmega328.This microcontroller uses to control all the code in this pH–meter. It has 6 analog input pins. Only one analog input use in this pH-meter. Figure 6 is BNC glass electrode. This glass probe use BNC connection to connect with pH amplifier circuit. BNC connection is used to get an accurate reading because this connector has low impedance that is about 75Ω compare to other connector.

2.4 pH-meter block diagram



pH-meter block diagram

The pH-meter block diagram shows the overall flow system in this pH-meter. It starts with glass electrode sense the ion concentration in the solution. The probe than convert it into small voltage in range of -200mV until +200mV and transfer it to pH amplifier circuit. The pH amplifier circuit than amplify the small signal into V_{pH} in range of 0-1.8V.After that, it will go to ADC and included in linear line equation. Finally, the value of pH will be displayed on LCD.

III.RESULT AND DISCUSSION

The pH electrode has been immersed into four buffer solutions whose pH is 1.68, 9.18, 10.01 and 12.42 respectively at room temperature and the resulting V_{pH} have been recorded with a precision multimeter to read the V_{pH} for every buffer used. A plot of V_{pH} as a linear function of the buffers solution pH is shown in Fig.2. As the plot shows, pH glass electrode behaves as expected but the value has a slightly different with actual function line equation (2). The function of the linear line equation is;

$$f(V_{pH}) = 8.098\ V_{pH} - 1.085 \qquad (2)$$

From the equation (2), the actual pH value can be obtained by insert the value of V_{pH}. These values appear in Table II as actual pH, whereas those measured by the pH-meter are named measured pH. In general, the results are quite good, with relative errors is about 3.06% where the highest error is recorded 5.35% at pH 1.68 solution and the lowest error is 1.63% at pH 9.18. The 5.35% error obtained when tests with pH 1.68 solution were done might be due to buffer solution contamination. When testing been running, every solution is tasted 3 times to get the accurate reading as possible. After finish, the result of the pH-meter experiment has appeared quite good and as expected.

Fig. 7 Experiment setup using four different buffers

Figure 7 show the experiment setup using four different buffers. All connection must be connect perfectly to avoid any error occur during running this experiment. Otherwise, the will be an error during measurement.

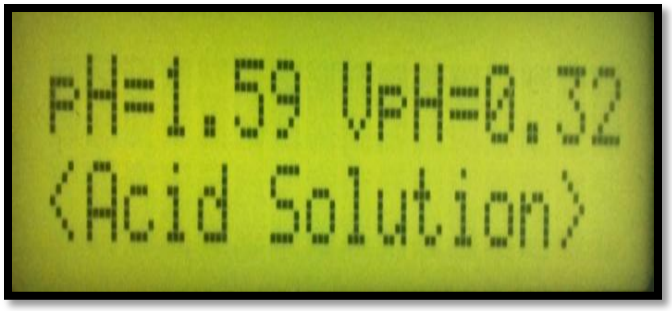


Fig. 8 LCD view from pH 1.68 buffer

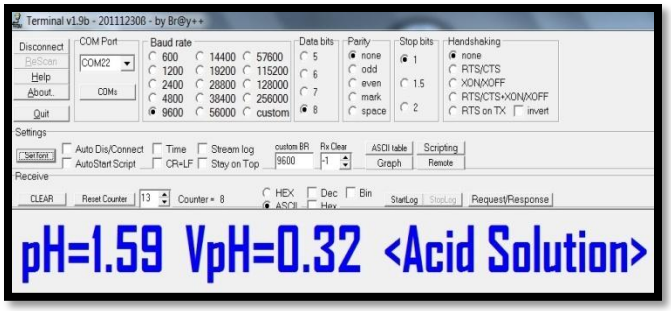


Fig.11 pH monitoring via PC for buffer pH 1.68

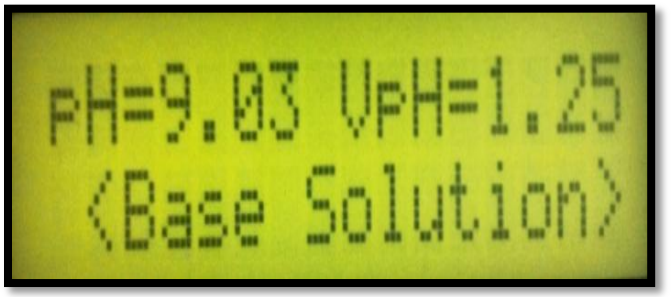


Fig. 9 LCD view from pH 9.18 buffer

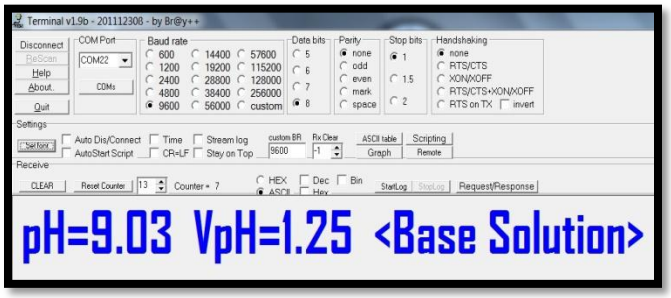


Fig.12 pH monitoring via PC for buffer pH 9.18

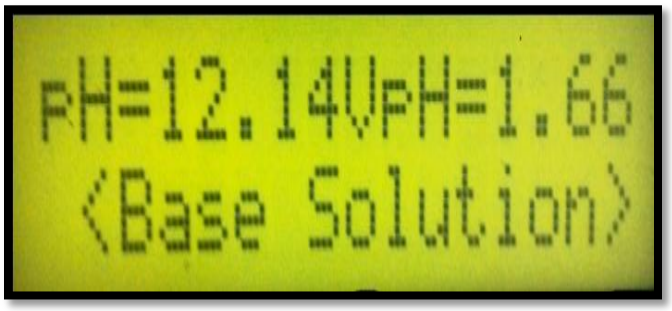


Fig.10 LCD view from pH 12.46 buffer

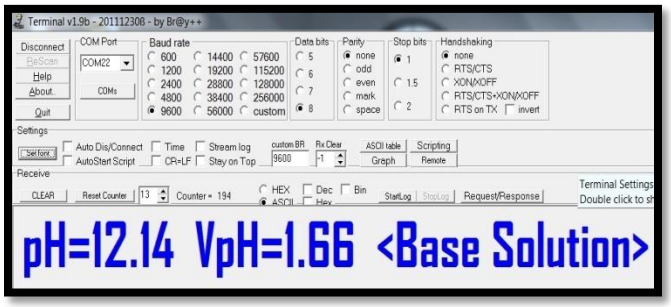


Fig.13 pH monitoring via PC for buffer pH 12.42

Figure 8, 9 and 10 show the display on LCD during experiment been conduct. The info that LCD display is the value of pH, V_{pH} and pH status.

Figure 11, 12 and 13 show the display on PC via hyper terminal. Like LCD, it will display the same value of pH, V_{pH} and pH status. This function will make user easier to monitor the ph value.

TABLE I. EXPERIMENT RESULT FOR MEASURING FOUR DIFFRENCE BUFFER

pH Buffer (pH)	V_{pH} (V)
1.68	0.32
9.18	1.25
10.01	1.46
12.42	1.66

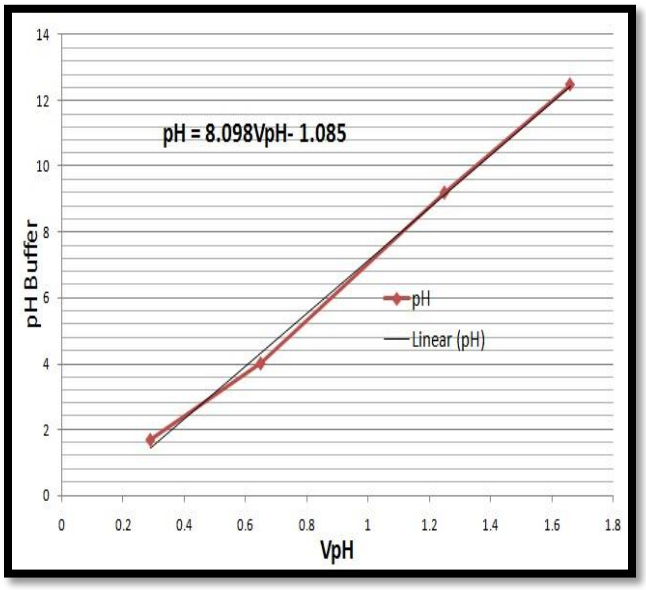


Fig.14 VpH versus pH

Graph above shows the comparison between linear line of the pH buffer and V_{pH}. The line equation that get from experiment is $pH=8.098V_{pH}-1.085$. Although some of the linear line and the line of pH has a difference, but still the pH line has a linear line.

TABLE II. ERROR GRAPH

Measured pH (pH)	Actual pH (pH)	Error (%)
1.59	1.68	5.35
9.03	9.18	1.63
10.32	10.01	3.01
12.14	12.42	2.25

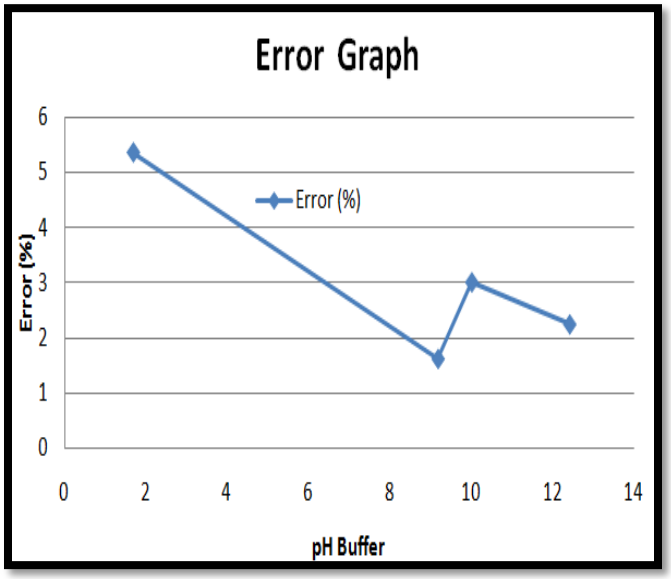


Fig. 15 Error Graph

Graph above shows the error versus pH buffer .The highest error recorded at pH buffer between pH 2 until pH 4. The rest of pH buffer show that the error is low. Overall, the error of this pH meter is very good with relative error of about 3.05%.

IV. SUMMARY

This paper has thoroughly presented the circuit for a digital pH-meter capable of realizing pH measurements within 3.06 % error or 0.03pH. This pH-meter is quite good because the error is below 10%.pH glass electrode has also been tested and shows that it works as expected. This pH-meter can be further improved to increase its accuracy and reliability by enhancing the software and hardware and yet can carry out a number of useful and more complex functions such as recording, monitoring, communicating and controlling with a supervisory system.

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