Design of Real Time Calibrated Digital Voltmeter Based on Arduino UNO

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ABSTRACT

In this paper, the design and implementation of a low cost calibrated digital voltmeter based on Arduino UNO is presented. The proposed design uses the internal 10-bit Analog to Digital converter of Arduino UNO. Simple linear regression model is applied for the calibration of voltmeter. However, voltage divider circuitry is being used for the enhancement of input voltage range. This technique can be implemented to any other system where calibrated voltage measurement is required through Arduino UNO interface.

Keywords: *Arduino, ADC, Linear Regression, Voltage Measurement*

1. INTRODUCTION

In today's fast world automation is required in order to save our time and whenever we automate some process, we need sensors. Sensors usually generate output in the form of current or voltage. If we can observe correct value of voltage in Arduino UNO than automation through Arduino UNO will become very easy [1].

In Arduino UNO, there is a built-in 10-bit resolution Analog to Digital converter (ADC) that is able to convert continuous input voltage range (i.e., 0V to 5V) to 1024 discrete levels. This ADC can be used to sense the analog voltage level and generate the corresponding digital value [2]. The digital value that Arduino will generate requires some calibration because these results are not accurate. In order to minimize the error of Arduino generated values, implementation of the linear regression model is proposed.

The linear regression is used to predict the value of output variable based on one or more input variables. The aim is to develop a linear relationship to estimate the value of output variable.

The rest of the paper is organized as follows: Section 2 discusses the simple linear regression for reducing error in measured voltage by Arduino UNO. The proposed hardware design

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including Arduino UNO, LCD and voltage divider circuit are presented in Section 3 and 4. Discussion on the experimental results is carried out in Section 5. Finally, conclusions are drawn.

2. LINEAR REGRESSION

Regression is a way to determine the statistical relationship between two or more variables. It utilizes the given information about the dependent and independent variables and predicts the corresponding change in the dependent variable for a certain change in the independent variable. Linear regression is common form of regression. It develops a linear model using the given value of variables for the prediction of values of dependent variable. Let x is independent and y is dependent variable. A linear regression model can be applied on the given values of variables, x and y, in order to predict the values of y for corresponding values of x [3].

The equation of a linear regression line has the form shown in Eq. (1). The constants, a and b, indicate the intercept and the slope of the line, respectively, as shown in Eq. (2) and Eq. (3) [4].

$$y = a + bx \tag{1}$$

$$a = \frac{(\sum_{i=1}^{n} y)(\sum_{i=1}^{n} x^2) - (\sum_{i=1}^{n} x)(\sum_{i=1}^{n} xy)}{n(\sum_{i=1}^{n} x^2) - (\sum_{i=1}^{n} x)^2} \tag{2}$$

$$b = \frac{n(\sum_{i=1}^{n} xy) - (\sum_{i=1}^{n} x)(\sum_{i=1}^{n} y)}{n(\sum_{i=1}^{n} x^2) - (\sum_{i=1}^{n} x)^2} \tag{3}$$

3. HARDWARE

Hardware of the proposed calibrated digital voltmeter consist of three hardware portions.

A. Arduino UNO

It is a microcontroller-based board on ATmega328p. It contains 14 digital input and output pins and six pins can be used as Pulse Width Modulation outputs. It also has six analog inputs and it can work on 16MHz quartz crystal frequency. A USB connection, power jack and in-circuit system programming header, reset button and two LEDs are included with it [5].

Analog to Digital Converter (ADC) is the concerned part of Arduino UNO for the measurement of voltage. There are different specification of ADC in different microcontrollers. However, Arduino UNO has 10-bit ADC. It has 10-bit resolution which means it can assign the input sensed voltage in the range 0V-5V any value in the range 0-

1023. In other word, It has 1024 different levels to assign to the sensed continuous voltage value. There are specific six pins on the microcontroller for reading analog voltages and these pins are labeled as A0 to A5 on the board.

As the ADC has 10-bit resolution, it assigns the maximum measured voltage to its maximum level. For instance, if the analog voltage value is 5 volts, the ADC maps this analog value to 1023. A multiple of ratio 1023/5 is assigned to any other analog values less than 5 volts as shown in Eq. (4) [6].

$$Measured\ Analog\ Voltage = \frac{ADC\ Value * 5}{Resolution\ of\ ADC} \tag{4}$$

B. Voltage Divider Circuit

Voltage divider circuit is used with Arduino UNO in order to increase the sensing range of ADC because Arduino UNO ADC works with 0V to 5V but we intend to sense the voltage higher than 5V [7]. Fig. 1 shows the schematic of a voltage divider.

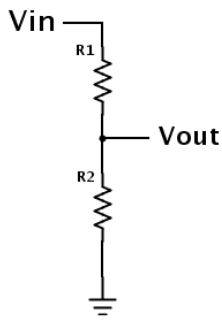

Fig. 1. Schematic of Voltage Divider

$$V_{out} = V_{in} * \frac{R_2}{R_1 + R_2} \tag{5}$$

In order to measure voltage, test voltage is applied at V_{in} and the corresponding voltage will appear at V_{out}. By the selection of suitable values of R_1 and R_2 required range of voltages can be sensed. By rearranging the equation, we can have

$$V_{in} = V_{out} * \frac{(R_1 + R_2)}{R_2} \tag{6}$$

C. Lquid Crystal Display

The 16×2 Liquid Crystal Display (LCD) is a mostly used basic display device. It has two rows and 16 characters can viewed on each row. Fig. 2 shows the schematic for the LCD [8]. Although, the LCD shown in Fig. 2 supports ASCII characters, eight custom characters can be displayed on its screen.

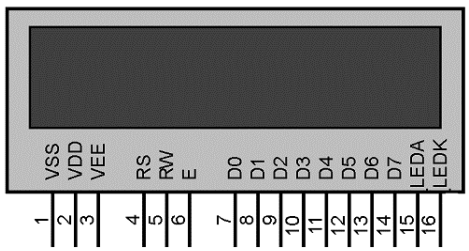

Fig. 2. Pins configuration of LCD 16×2

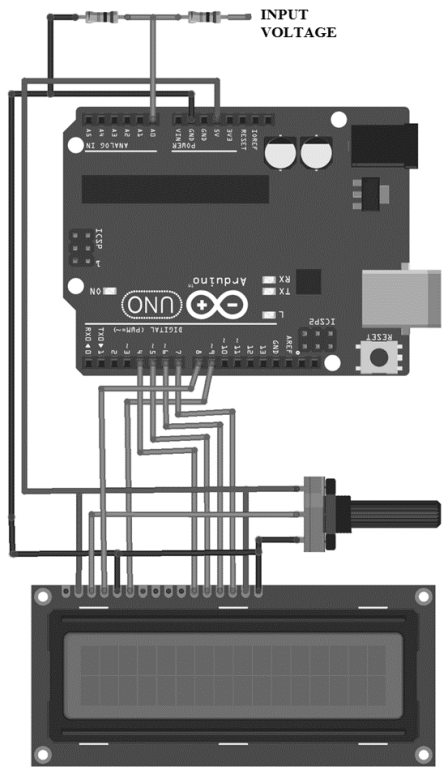

Fig. 3. Schematic of Arduino based digital voltmeter

4. HARDWARE SCHEMATIC

In Fig. 3, Arduino UNO is interfaced with voltage divider circuit in order to measure the voltage range of 0V to 30V and LCD is connected to display the voltage value. To set the contrast of LCD, Potentiometer is used.

Fig. 4 shows the flow chart of the proposed system design that takes the average of thousand samples for one reading. This is because the output of ADC of Arduino UNO changes very rapidly. After that simple linear regression model (shown in Fig. 5) is applied to the existing values for the generation of accurate voltage values. Finally, the output is displayed on the LCD.

5. EXPERIMENTAL RESULTS

In this section, experimental results are present. Table 1 and 2 show the comparison between voltages measured using Arduino, multimeter, and corrected Arduino.

Table 1. Voltage Comparison (First 15 Readings)

Reading No.	Arduino Measured Voltage	Multimeter Measured Voltage	Corrected Arduino Voltage
1	0.91	0.96	1
2	2.1	2.05	2.1
3	3.15	3.04	3.07
4	4.22	4.03	4.05
5	5.31	5.05	5.06
6	6.4	6.05	6.06
7	7.47	7.05	7.05
8	8.54	8.03	8.04
9	9.61	9.04	9.03
10	10.68	10.02	10.01
11	11.74	11.01	10.99
12	12.87	12.05	12.03
13	13.89	13.01	12.97
14	14.99	14.02	13.99
15	16.06	15.01	14.98

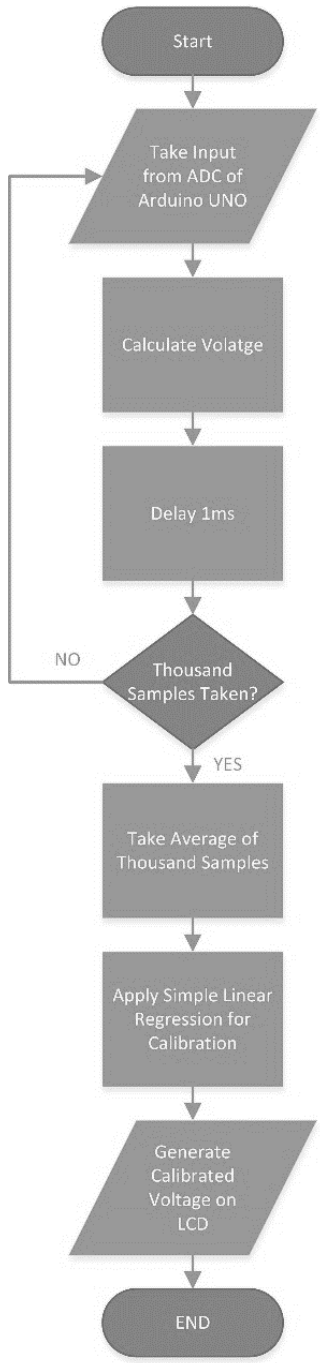

Fig. 4. Flow Chart

Table 1. Voltage Comparison (Next 15 Readings)

Reading No.	Arduino Measured Voltages	Multimeter Measured Voltages	Corrected Arduino Voltages
16	17.14	16.01	15.97
17	18.21	17.01	16.96
18	19.3	18.01	17.97
19	20.37	19.01	18.95
20	21.6	20.1	20.09
21	22.63	21	21.04
22	23.69	22	22.02
23	24.72	23	22.97
24	25.85	24	24.01
25	26.96	25	25.03
26	28.02	26	26.01
27	29.12	27	27.03
28	30.19	28	28.01
29	31.38	29	29.11
30	32.31	30	29.97

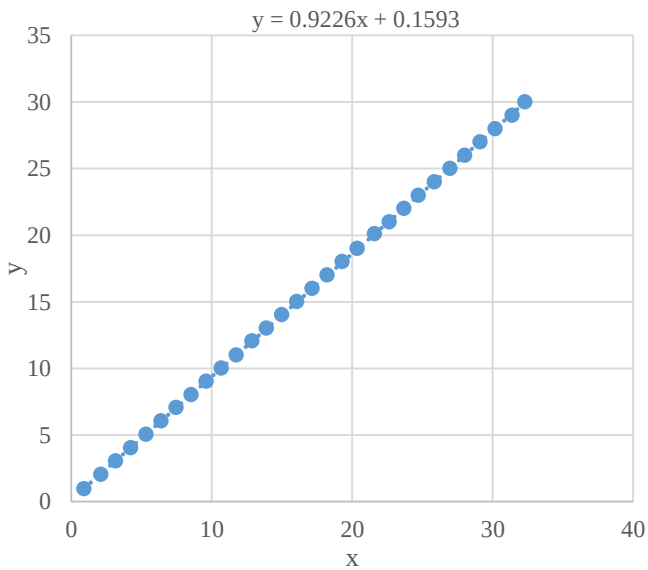

Fig. 5. Simple Linear Regression Implementation

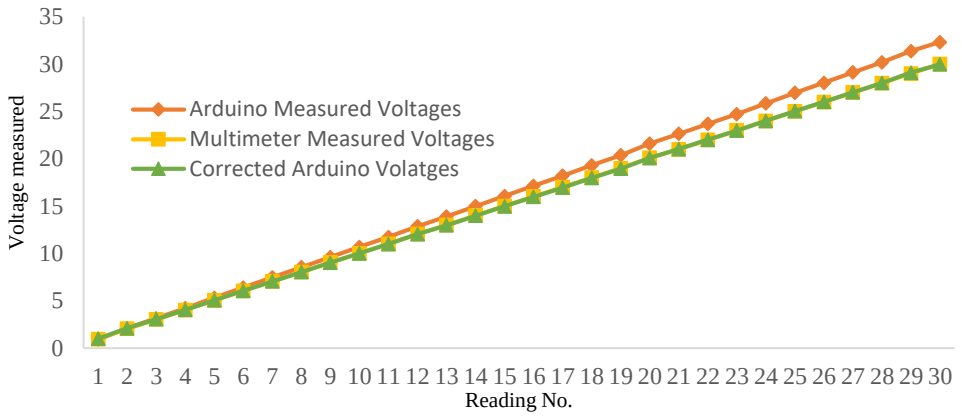

Fig. 6. Comparision of output voltages

It is evident from Fig. 6 that the overlapping of Multimeter measured voltages and the corrected Arduino voltages. The error in voltage readings is reduced. But there is still some error because resistors are used in voltage divider circuit and the resistance value vary with the change of temperature. The tolerance value of resistance must be considered in order to get precise voltage readings.

6. CONCLUSIONS

In this paper, an idea to develop Arduino UNO based voltmeter is presented. It is observed from the results that the voltages generated by Arduino UNO are not precise. In order to overcome this shortcoming, a model is designed and implemented. In the proposed model, simple linear regression is utilized for obtaining reading with less error. It is evident from the results that the proposed method reduces the error in voltage readings. The proposed methods can be used with any Arduino UNO based application which requires accurate voltage without using any external module with it.

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