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Design, Construction and Evaluation of a Power Digital Meter for Laboratory Use

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Measurement provides a standard for everyday things and processes. Without the ability to measure, it would be difficult for scientists to conduct experiments or form theories. It is essential in farming, engineering, construction, manufacturing, commerce, and numerous other occupations and activities, hence plays a very important role in our lives. While conducting experiment(s) on electrical or electronics it is essential to measure voltage and current using an ammeter, voltmeter or multimeter. This measurement was used in computing the power drowns in the circuit. In this regard a direct current (DC) digital meter is designed, constructed and evaluated to measure voltage, current and the power being expended in a circuit directly. The materials chosen based on their simplicity and availability within the locality. Micro controller integrated circuit (IC) ATMEGA32A was programmed for the operations while the TC1602A (IC) alphanumeric liquid crystal display (LCD) was chosen as the human-machine interface (HMI) between the human user and the digital control system. After the construction, it was tested and compared with the standard and found to be working satisfactory.

Keywords: Direct Current, Liquid Crystal display, Human-Machine Interface and Analogue to Digital Converter

1. Introduction

Power engineering is the oldest and most traditional of the various areas within electrical engineering, yet no other facet of modern technology is currently experiencing a greater transformation or seeing more attention and interest from the public and government. In [5] Measurement techniques have been reported to have immense importance ever since the start of human civilization, when measurements were first needed to regulate the transfer of goods in barter trade to ensure that exchanges was fair. The industrial revolution during the nineteenth century brought about a rapid development of new instruments and measurement techniques to satisfy the needs of industrialized production techniques. Since that time, there has been a large and rapid growth in new industrial technology. This has been particularly evident during the last part of the twentieth century, encouraged by developments in electronics in general and computers in particular. This, in turn, has required a parallel growth in new instruments and measurement techniques [1]. Microcontroller integrated circuits are classified based on their architecture. The most common types architecture are; AVR, PIC and 8051. Others include; ARM processors, Programmable System-on-Chip (PSoC) and many others, some of which are used in very narrow range of applications or are more like applications processors than microcontrollers [4].

Essentially, an analogue to digital converter (ADC) takes an instantaneous snapshot, or sample of an analogue input and converts the observed voltage into a string of binary digits—a number. A DAC performs the reverse operation of converting a discrete number into analogue output voltage. When an analogue signal is applied to an ADC, the ADC evaluates the instantaneous sample of that signal against predefined high and low voltage extremes that define an allowable input range for that ADC [8]. The ATmega32 features a 10-bit successive approximation ADC. The ADC is connected to an 8-channel Analog Multiplexer which allows 8 single-ended voltage inputs constructed from the pins of Port A. The single-ended voltage inputs refer to 0V (GND) [2]. Most often while conducting experiments, measurement becomes necessary. The current drown in the circuit and potential difference across need to be measured using at least two measuring instruments. In this regard a single measuring instrument is being design and constructed to measure both potential difference, current and power consumed within the circuit at the same time. There is no need to compute for the power expanded in the circuit neither the calculator.

The design can be use independently or attach to a power supply output. The performance of the system was analyzed with standard meters.

2. Materials and Methods

2.1 Design Procedure

The system was designed by considering various functional units that follows in an orderly manner as flow chart shown in Figure 1. On reset the system initializes the hardware, LCD, ADC, and the timer after the initialization, which follows by accumulating of voltage and current values. If time is not greater than one second the signal is send back, but if greater than one second the system continue to format the values of the current, voltage and the power. It is then sent to display both the voltage, current and power on the screen.

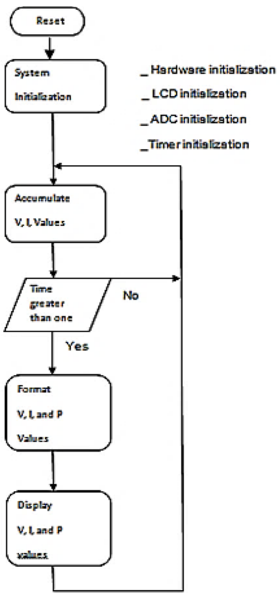

Figure 1. Voltmeter, Ammeter and power Flow Chart.

2.1.1 Voltage Measuring Circuit Design

Since the laboratory measurements is mostly DC of potential difference (PD) between 0 to 25 volt, the meter was target slightly above for safety reason. Microcontroller ATMEGE32A is programmed to measure varying voltage (0 – 30 V) and current drawn from the power supply (I_{max} =10A). It is chosen due to its so many applications and can empower a system-designer to optimize the device for power consumption versus processing speed. Moreover a stable DC voltage is required to power the microcontroller and the liquid crystal display (LCD) circuits. 5 V, 30 mA is required for its operation [2]. Since the system is low-voltage by design, the direct interfacing of the regulated power supply to the microcontroller is employed using resistors. The resistors were scaled to give a maximum output voltage of 5 volts when connected to a 30 volt DC supply. The resistors were chosen based on the potential divider as shown in Figure 2.

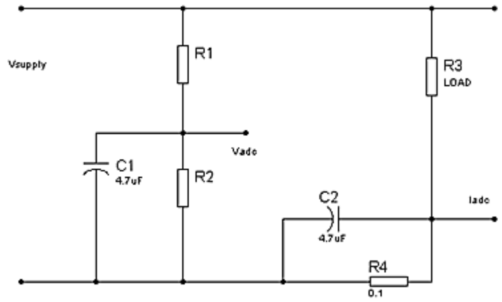

Figure 2. Voltage Divider Attenuator Circuit

The PD on ADC (V_{ADC}) is given by

$$V_{ADC} = V_{power\ supply}\left(\frac{R_2}{R_1+R_2}\right) \qquad 1$$

Where; V_{ADC} is on the ADC input, R_1 is upper resistance of the potential divider, R_2 is lower resistance of the potential divider and $V_{power\ supply}$ is output voltage of the power supply

The upper resistance (R_1) of the potential divider was assumed to be 47 KΩ. The PD into the ADC should not be more than 5 volt while the maximum PD to be measured is 30 volt. After substitution R_2 was evaluated to be 1 kΩ.

2.1.2 Current Measurement Meter Design

The current was measured using current-to-voltage converter; a resistor was placed in series with the output of the power supply. Being in series to the supply there is also a voltage drop across it, which is directly proportional to the magnitude of the product of the resistance and the current

$$V_{sense} = I_{supply}\ X\ R_{sense} \qquad 2$$

Where; V_{sense} is voltage developed across the resistor, I_{supply} is current flowing from the power supply and R_{sense} is current-sensing resistance.

The Ammeter was designed to measure current up to 10 A. A resistor of 10 watt, 0.1 ohm was chosen in the design. The maximum power dissipated on the resistor is therefore equal to 10 watt.

$$P=I^2R \qquad 3$$

$$I^2 = \frac{10}{0.1} = 100\ or\ I = 10\ A$$

The Power is obtained by multiplying current and potential difference. The percentage error was computed as $\frac{X_{standard}-X_{constructed}}{X_{standard}} * 100$ 4

2.1.3 System User Interface (LCD) Circuit Design

An alphanumeric liquid crystal display (LCD) was used as the human-machine interface (HMI) between the human user and the digital control system. The display type (TC1602A) was chosen due to its Portability, easy compatibility with the microcontroller and excellent display of information. The display size of 16 columns by 2 rows alphanumeric LCD module was selected, due to its compact size and ability to be connected in 4-bit mode to save microcontroller I/O ports availability. Data transferred between the microcontroller and the LCD module using 4-bit interface mode only requires the upper four data lines (Ports); that is D4 to D7 are used and the data is transferred as two 4-bit nibbles.
A variable resistor is connected to the V_{EE} terminal of the LCD to control the voltage across its terminals, hence the contrast of the LCD backlight (Figure 3). Based on the datasheet, a resistor is selected which allows a current range of 0.09 – 0.15 mA to be inputted to the V_{EE} terminal. The resistor value was calculated using ohms law. Since the operating supply voltage is 5 volts, and a minimum specified contrast current is 0.09 mA. The resistance value was calculated to be 5.0/0.09 mA = 56 kΩ. The resistance for this operation should be a variable one; therefore a standard value that is closer to it is 50 kΩ and is used [7]

Since the microcontroller and LCD circuits operate on 5 Volt only, LM2576 switching regulator is used. The main purpose is that it has a bit higher input voltage up to 40 Volt [6]. The microcontroller ATMEGA32A was programmed to measure both the current and voltage in addition to that of power by simply multiplying the two values. Materials used in the system construction were shown in Table 1. The circuit diagram prepared with "Proteus Intelligent Schematic Input system (ISIS) ", is presented in Figures 4.

Table 1. Material Used for Construction

S/N	Component	Description	Quantity
1	Integrated Circuit	LM2576	1
2	Capacitor	1000 µF, 50 V	1
3	Capacitor	1000 µF, 16 V	1
4	Capacitor	10 µF	1
5	Capacitor	4.7 µF	3
6	Capacitor	0.1 µF	2
7	Resistor	56 kΩ	1
8	Resistor	1 kΩ	2
9	Resistor	0.1 Ω (10W)	1
10	Resistor	47 Ω	2
11	Resistor	500 Ω	1
12	Potentiometer	10 kΩ	1
13	Potentiometer	50 kΩ	1
14	LCD	16 x 2	1
15	Diode	14002	3

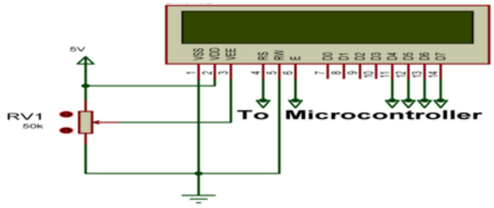

Figure 3. Liquid Crystal Display Circuit Diagram source: [7]

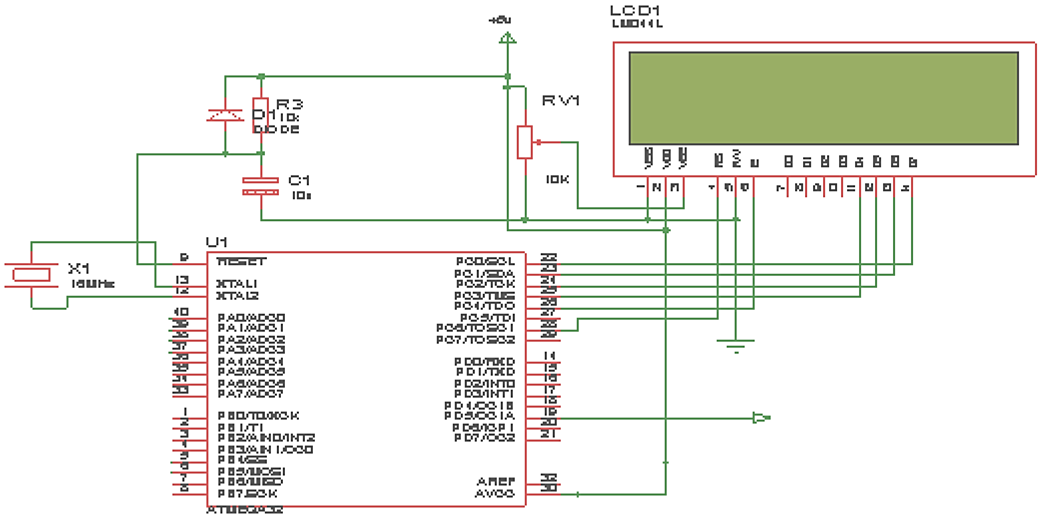

Figure 4. The Designed Circuit Showing PIC and LCD Connections

2.2 System Construction Procedure

After the circuit design, construction was done on a separate breadboard later transferred to the Vero-board. Moreover, a multimeter was used to conduct test on the components being used. The values of the resistors were also found to be within their tolerance value. To minimize the chance of damage due to overheating on ICs, IC sockets were soldered on their positions. The ICs were plugged in after soldering. This was done in case the ICs needed replacing after a malfunction

2.2.1 Program Writing

In [3], it was stated that the CPU microcontroller can only recognize certain groups of bits as valid instructions in the machine language. It is difficult to program directly in this binary machine language even for the simplest microcontrollers. Instead, several languages have been developed to “talk” with the microcontroller, e.g., the assembly language. Assembly language is very close to machine language. It allows users to write programs using easily remembered mnemonics for the instructions, and symbolic names for memory locations and variables. It can produce the most efficient codes and allows users to set flags and registers that are inaccessible in high-level languages.

Every microcontroller has its own special assembly language, and no standard for assembly language exists. Usually the program, or source code, is written in Microsoft Notepad or Word, and then translated by an assembler program to produce the output as an object code that the microcontroller can execute. The microcontroller cannot execute assembly language instructions directly; instead, it can recognize object code that has been converted into machine language [3]. The microcontroller was programmed using ICC AVR C compiler and development studio. The compiler was chosen as it supports standard C libraries with optimized code footprint and reasonable execution speed, even on an 8-bit machine. The written program on the microcontroller is shown in appendix, while the photograph of the construction is shown in Plate 1.

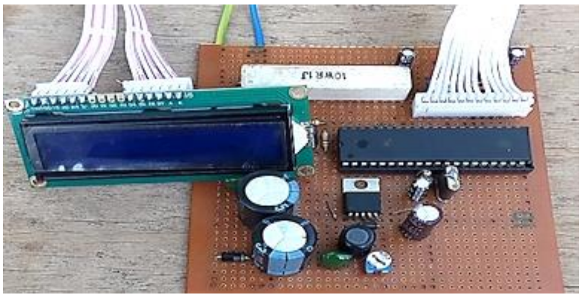

Plate 1. Photograph of the Constructed Circuit

2.3 Accuracy Test of the Measuring Meters

The meter is to measure the current drawn from power supply, and the level of the voltage from the regulated power supply. Both the ammeter and voltmeter readings were displayed on the LCD. The measurements were done by connecting a resistor load R_L across power supply output as shown in Figure 5.

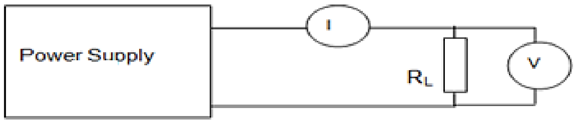

Figure 5. Voltmeter Ammeter Accuracy Test

3. Results and Discussion

3.1 Accuracy Test of Measuring Meters

Accuracy test was conducted by comparing the observed readings of the constructed meter (Y) with that of the standard one (X) while the letters C and S represents the constructed and standard respectively as shown on Table 2.

Table 2. Result of Ammeter/Voltmeter Percentage Errors

S/Ns	Voltage (V_S)	Current (A_S)	Voltage (V_C)	Current (A_C)	% Error(v)	% Error(i)
1	17	0.81	17.04	0.83	-0.2353	-2.4691
2	15	0.7	15.05	0.72	-0.3333	-2.8571
3	13	0.6	12.95	0.68	0.3846	-13.3333
4	11	0.51	11.06	0.53	-0.5455	-3.9216
5	9	0.42	9.06	0.4	-0.6667	4.7619
6	7	0.33	7.07	0.34	-1.0000	-3.0303
7	5	0.23	5.04	0.29	-0.8000	-26.0870
8	3	0.14	3.05	0.18	-1.6667	-28.5714

The percentage error was found to be insignificant in most cases except on some low current measurements, which might be due to human error. The observations obtained were also interpreted using statistical software as shown in Figures 6 and 7.

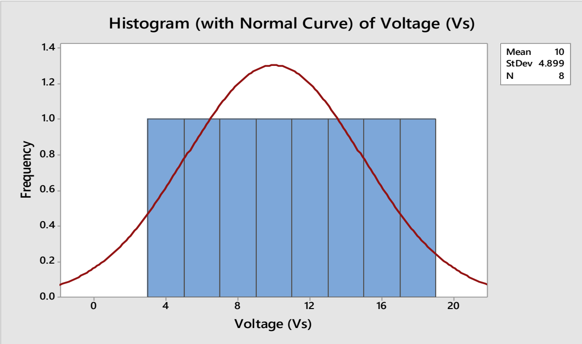

Figure 6 (a). Histogram of Voltage V_S

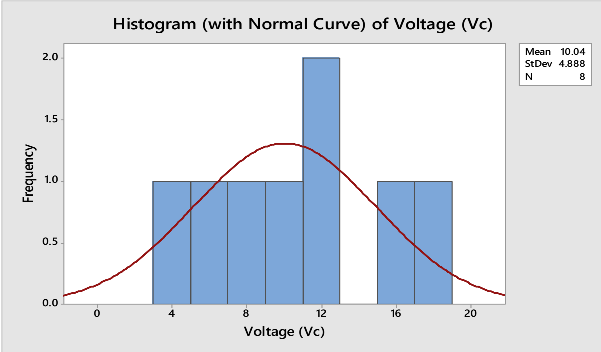

Figure 6 (b). Histogram of Voltage V_C

Descriptive Statistics: Voltage (Vs), Voltage (Vc)

Variable	N	N*	Percent	CumPct	Mean	SE Mean	StDev	Variance	CoefVar	Minimum
Voltage (Vs)	8	0	100	100	10.00	1.73	4.90	24.00	48.99	3.00
Voltage (Vc)	8	0	100	100	10.04	1.73	4.89	23.89	48.69	3.05

Variable	Maximum
Voltage (Vs)	17.00
Voltage (Vc)	17.04

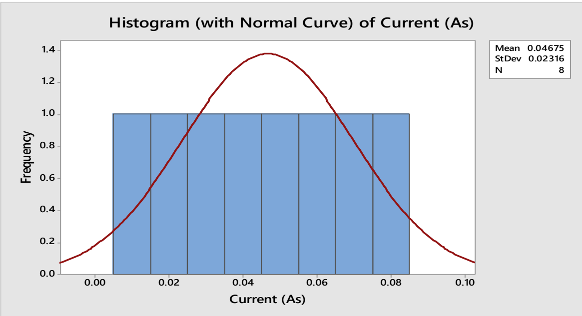

Figure 7(a). Histogram of Current A_S

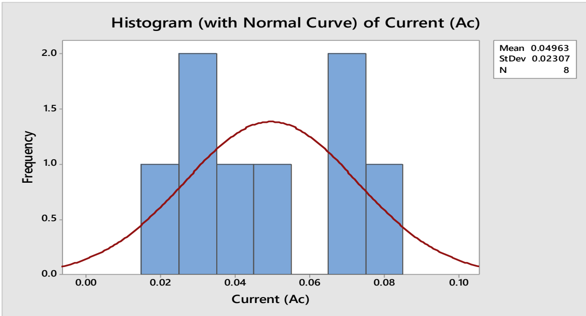

Figure 7(b). Histogram of Current A_C

Descriptive Statistics: Current (As), Current (Ac)

Variable	N	N*	Percent	CumPct	Mean	SE Mean	StDev	Variance	Minimum	Maximum
Current (As)	8	0	100	100	0.04675	0.00819	0.02316	0.00054	0.01400	0.08100
Current (Ac)	8	0	100	100	0.04963	0.00816	0.02307	0.00053	0.01800	0.08300

Interpretation of the Voltmeters Results

The means shown from the result in Figure 6 indicates that standard voltmeter (V_S) readings are approximately 0.04 volt lower than constructed voltmeter (V_C) readings, and the spread of the data is about the same.

In Figure 7, the means shown from the results indicates that standard ammeter (A_S) readings are approximately 0.00288 ampere less than constructed ammeter (A_C) readings, and the spread of the data is about the same

4. Conclusion

The current, voltage and power measuring meter was successfully designed and constructed using locally available electrical and electronics components. The constructed meter was experimentally tested and statistically compared with the standard meter. Results from the statistical analyses, it was found that the error difference between it and the standard is very small, or in another word the spread of the readings is about the same. Therefore the meter is said to be working satisfactory.

Conflict of interest

The authors declare no conflict of interest.

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