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DESIGN AND IMPLEMENTATION OF MICROCONTROLLER – BASED DIGITAL DEVICE FOR DIRECT DISTANCE MEASUREMENT

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Abstract

Distance measurement plays a vital role in engineering, science and business, however, available direct distance measuring instruments have limitations. Although direct distance measuring devices like tapes could measure short distances with good degree of accuracy, this technique require two persons thereby wasting time and manpower. Incorrect readings due to failure to record previous reading, not leveling the instrument and error due to parallax hamper its efficiency in long distance measurements. A simple digital distance measuring device designed with AT89S53 microcontroller, thick but flexible metal wire and seven segment display among other components is presented. Values of distance measurement made with the device agree very well with that made by tape with a maximum percentage error of .53% . Since the measurement was carried out by one person, error due to poor alignment and sagging of tape was eliminated. Display of number of revolutions on seven segment display also ruled out error due to parallax. A maximum of 660 seconds (11minutes) was gained when a distance of 268m was measured. The device can be used for long distance measurement, saves time, man power and cost. It can find application in land surveying, building and construction of roads. It is recommended that improvement of the efficiency of this device be made by employing a software that can directly convert number of revolutions to distance

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***Keywords*:** Distance measurement, microcontroller, signal conditioning, Digital device.

1.0 INTRODUCTION

Measurement has been necessary since human beings first began trading with their neighbors. In addition to trading, early societies also needed to be able to measure to perform many other tasks. When people turned from leading a nomadic life to settling in one place, other measurements such as measurement of land for building and agriculture as well as building materials became important [1]. Distance measurement plays vital role in engineering, science and business. Distance is always measured between the two points. Generally it is possible only by making contact with target whose distance is to be measured [2]. As our societies became increasingly technologically oriented, the need for higher measurement accuracy, speed of measurement and lower cost in many fields also increased.

Distance measurement can be done directly or indirectly. Electronic distance measurewment (EDM) and optical distance measurement (ODM) are two techniques for indirect, also known as non – contact, distance measurement. EDM and ODM techniques can be fast and automated. They encourage online operations, direct transfer of data and also eliminate errors due to data recording and storage [3, 4]. However, they become hard to use when there is large amount of inconsistency or existence of large obstructions in the terrain. Presently, the detection techniques of laser, radar, and infrared ray have been widely applied in the aspect of obstruction detection and distance measurement [5, 6, 7]. Nevertheless, atmospheric variation in temperature, pressure and humidity adversely affect the result of measurements [4, 7]. Hence, they are not widely used due to their high cost, and increase in measurement errors due to change in atmospheric parameters.

On the other hand, taping is the commonest method of direct distance measurement which could also be achieved by the use of Pacing, Passometer, Pedometer, Speedometer, Chain, and Perambulator [8, 9]. The use of tape for distance

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measurement though cheap to implement is not time effective and cannot be employed in non – linear terrain. Moreover, measurement of long distance with this method is tedious. Besides, it does not have a perfect accuracy due to parallax and errors due to tension, sagging, poor alignment and other personal limitations [4, 10]. Hence, the need to develop simple and cost effective designs for accurate direct distance measurement.

2.0 DIRECT DISTANCE MEASUREMENT WITH TAPE

Distance is the amount of space between two points. Distance measurement considered in this research is horizontal; hence it is such that is carried out on the earth surface. Tape is commonly used for short and long direct distance measurement. It could be linen, metric steel, invar or synthetic type [7]. Distance measurement with tape usually involves two people. Also, it is prone to several errors such as [7, 10]

i. Error due to temperature variation corrected thus;

$$C_T = k(T_1 - T_2)L \tag{1}$$

Where $k = 0000065$ is the coefficient of thermal expansion of steel per 1°F, T_1 is the observed temperature during measurement in °F, T_2 is the standard temperature of tape in 1°F (usually 68°F) and L is the measured length(distance) in feet.

ii. Error due to tape being shorter than the standard length which can be corrected as follows:

$$C_l = L\frac{(l_1 - l)}{l} \tag{2}$$

Where C_l is the correction applied to recorded measurement, L is the recorded measurement, l_1 and l are the nominal and actual tape length respectively.

iii. Error due to sag. This can be corrected based on equation (3)

$$C_{sag} = \frac{W^2L}{24P_0^2} \tag{3}$$

Where W is the total weight of the tape, L is the unsupported length of tape and P_o applied pull during measurement.

iv. Error due to tension which is corrected as follows

$$C_P = \frac{(P_o - P_s)L}{AE} \tag{4}$$

Where P_o is the applied pull during measurement, P_s is the standard pull, L is the nominal length of the rule or the total distance measured, A is the cross sectional area of the tape and E is the modulus of elasticity of the tape.

v. Other sources of errors include; poor alignment and human sources such as parallax, misreading of tapes and so on.

It is noteworthy to state that though the correction of these errors can enhance accuracy of measured distance, it will equally make taping more laborious and time consuming.

3.0 MATERIALS AND METHOD

A basic measurement system consists mainly of the four blocks: sensing element, signal conditioning element and signal processing element and presentation element as shown in fig.1. The sensing element converts the non-electrical signal into electrical signals (e.g. voltage, current, resistance, capacitance etc.) while the signal conditioning element converts and manipulates this electrical signal into an undistorted voltage level suitable for further processing [11]. The signal processing element takes the output of the signal conditioning element and converts into a form more suitable for presentation and other uses (display, recording, feedback control etc.). Analog-to-digital converters, linearization circuits etc. fall under the category of signal processing circuits. For many detectors the power supply is low direct current (dc) voltage.

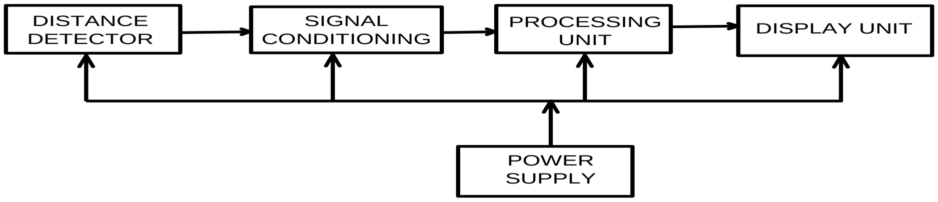

Fig.1 Block Diagram of the Designed System

The materials employed in this design include:

1. Power (dc battery)
2. Distance detector which include fixed resistor and push button and circular object (wheel)
3. Signal conditioning unit with transistor as the active component.
4. AT89S52 microcontroller signal processing unit
5. Seven segment display

The actualization of this project was done using two processes, this includes; software and hardware implementation. The software implementation involves the development of the source code for the microcontroller and uploading it into the microcontroller. On the other hand, the hardware part involved the physical construction of the system. Each of the units in figure1 was designed, tested and coupled together. The coupled system is constructed and used to carry out some distance measurement alongside a tape rule.

Distance Detector Unit

The simplest distance sensor is a mechanical switch that returns one bit of information which is touching or not touching [12].The distance detector comprises of a circular object of about one meter in circumference, a push button switch S_1, and a resistor. The push button and the resistor are connected in parallel. The pull – up resistor which sources power from the 5V power supply provides a default state of high as output. The push button is depressed when the circular object had gone one complete rotation to provide an output pulse which is the required signal of about one meter. The typical switch configuration is shown in figure 2. If I is the input current and V_{in} and V_{out} are input and output voltage respectively, then, from ohms law [1],

$$V_{in} = IR_{eff} \quad (5)$$

$$= I(R_1 + R_2) \quad (6)$$

Where $R_{eff} = R_1 + R_2$ is the effective resistance of R_1 and R_2. R_1 is the resistance of the switch S_1.

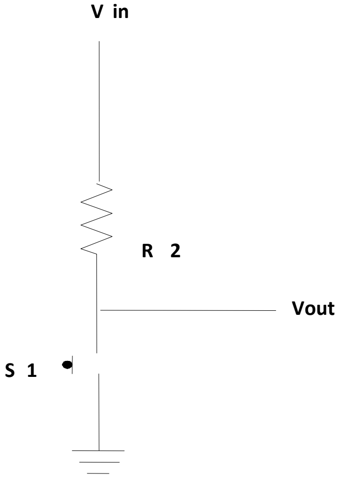

Fig. 2 Switch Configuration

From equation (2),

$$I = \frac{V_{in}}{R_1 + R_2} \quad (7)$$

$$V_{out} = IR_2 \quad (8)$$

Combine equations (7) and (8) to eliminate I

$$V_{out} = \frac{V_{in}R_2}{R_1+R_2} \quad (9)$$

Considering S_1 to be R_1 such that R_2 and R_1 form a voltage divider network.

$$\frac{V_o}{R_2} = \frac{V_{in}}{R_1+R_2}$$

When S_1 is closed (pressed) R_1 is zero (0)

If $V_{in} = 5V, R_1 = 0,$ Let $R_2 = 10K\Omega$ then from equation (9),

$$V_o = 5V$$

Thus

When S_1 is open (not pressed) R_1 has infinite value

$$R_1 = \infty$$

$$V_o = \frac{V_{in}R_2}{R_1+R_2} = 0$$

Signal conditioning circuit

Signal conditioning circuit was used to process the output of the sensor (detector) in the measurement device in such a way as to make it suitable for further processing in the next stage. This involves filtering and amplification. In Filtering stage, a capacitor was used to eliminate the undesired noise from the signal. Amplifying stage helps to increase the resolution of the input signal and increase the Signal-to-Noise Ratio (SNR) [13, 14]. Three – stage NPN bipolar transistors were employed in this design.

Processing unit.

AT89S52 microcontroller was used to provide the signal data and command signal that controls the display unit with the help of the written program which is burnt into the chip. Figure 3 shows the schematic diagram of AT89S52 microcontroller.

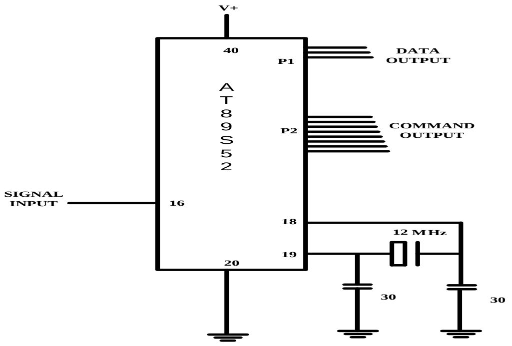

Fig. 3: Schematic Diagram of AT89S52 Microcontroller.

The Atmel AT89S52 was used for the design because it is a powerful low power, quick programming microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications [1, 15]. The electrical characteristics of AT89S52 microcontroller include $T_A = -40\ to\ 85°C$ and $V_{CC} = 4.0\ to\ 5.5V$ [15]. The standard features of this integrated circuit can also be found in Data sheet for AT89S52.

Display Unit

Seven segment display shown in figure 4 was used to display the number of revolutions. This is preferred to liquid crystal display because it contain no liquid inside hence, it is reliable at all temperature. More so, it is efficient because it is made of diodes it requires low power, low cost and can also be driven directly [16, 17].

Fig. 4 Seven Segment Display

The individual units were coupled on a Vero board and the complete circuit is shown in figure 5.

The construction was done in such a way as to make maintenance and repairs easy and

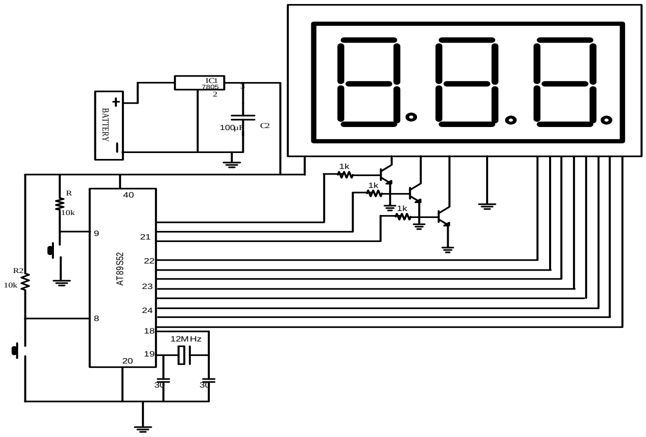

Fig. 5 Circuit Diagram of the Designed Digital Device affordable for the user, should there be any system breakdown. The constructed work placed in a case is shown in figure 6.

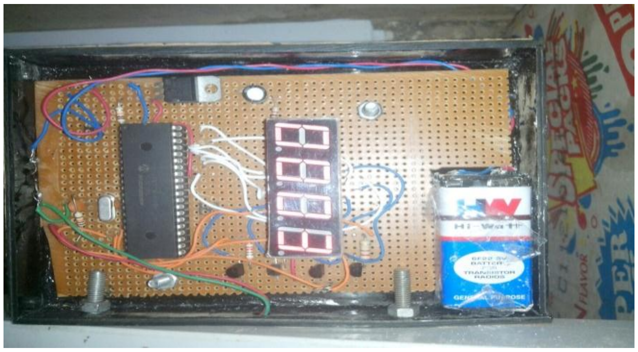

Fig. 6 Picture of the Constructed Digital Measurement Device in a Case.

4.0 RESULT

To validate the accuracy of the device, linear distance of different locations were measured in the vicinity of Federal University Dutsinma, Katsina State, Nigeria using designed digital device and tape. Since tape rule has high degree of accuracy at short distances only short distances were considered. As the wheel makes contact with the area of interest, it generates output pulse which is reflected in the seven segment display. The seven segments will display the number of rotation of the wheel.

The wheel diameter is the measurement of a straight line across the its center. The circumference of a circle is the total distance around a circle [18]. Mathematically,

$$Circumference = diameter\ of\ the\ circle\ (\ d)\ \times \pi(pi)$$

The diameter (d) of the wheel is $28.0cm$

$$Distance = number\ of\ revolution\ of\ the\ wheel \times\ circumference\ of\ the\ wheel$$

$$circumference\ of\ the\ wheel = 3.14 \times 28cm = 87.92cm$$

The result of linear distance of different locations measured using tape rule as well as digital measuring device is presented in table 1.

Table 1: Result of Distance Measurement with Digital Instrument and Measuring tape

Location	**Measurement with Digital Instrument**			**Measurement with tape**	
	Number of revolution	Distance (m)	Time (minute)	Distance (m)	Time (minute)
Old chemistry lab	19.20	16.87	1.0	16.90	2.0
Old biochemistry lab	19.10	16.79	1.0	16.80	2.0
Old biology lab	19.20	16.87	1.0	16.90	2.0
Old physics lab	21.10	18.60	1.0	18.70	2.0
Large lecture hall 1	27.10	24.70	1.0	24.70	3.0
L Large lecture hall 2	27.10	24.70	1.0	24.70	3.0
From VC lodge to Clinic	304.50	267.7	7.0	268.00	18.0
From works Dept. to Auditorium	113.30	99.61	5.0	100.0	7.0
From Clinic to 2nd gate	145.00	127.5	5.0	128.0	8.0
From block E to English Lab	99.00	87.00	3.0	87.0	5.0
From Senate to Main gate	225.00	197.82	6.0	198.0	12.0

The results of table 1 is rearranged in ascending order of locations with longer distances. Serial number is assigned to each location; then the percentage error of the measured values with designed digital device relative to measured values with tape was calculated. Time gained by using the designed digital device were also obtained from table 1 and the result is presented in table 2.

Table 2: Measured Distances Showing Percentage Error and Time Gained with the Use of the Device Relative to Tape

S/N	Location	Measured Distance Values (m)		Percentage Error (%)	Time Gained by using the device (s)
		Device	Tape		
1	Old biochemistry lab	16.79	16.80	0.06	60.0
2	Old biochemistry lab	16.87	16.90	0.18	60.0
3	Old biology lab	16.87	16.90	0.18	60.0
4	Old physics lab	18.60	18.70	0.53	60.0
5	Large Lecture Hall1	24.70	24.70	0.00	120.0
6	Large Lecture Hall 2	24.70	24.70	0.00	120.0
7	Block E to English Lab	87.00	87.00	0.00	120.0
8	Works Building to Auditorium	99.61	100.00	0.39	120.0
9	Clinic to 2nd Gate	127.50	128.00	0.39	180.0
10	Senate to Main gate	197.82	198.00	0.09	360.0
11	Vice Chancellor’s lodge to Clinic	267.70	268.00	0.11	660.0

5.0 DISCUSSION

The number of revolutions covered in each location was read from the seven segment display hence eliminating reading error due to parallax. The measured distance values from the designed digital device and the tape presented in table 1has good correlation. Table 2 shows that the percentage error recorded by using the designed digital device relative to the use of tape is minimal. It was observed that higher accuracy (0.00%) was recorded in locations without corners hence, the accuracy is independent of size of the measured location but on the nature of the terrain.

The results presented in tables 1 and 2 show that the constructed digital measuring device can measure a distance at shorter time than tape. The constructed digital distance measuring instrument can measure a linear distance up to several kilometers as far as the user can go. Only one of the researcher used the device to make measurement per time and for each location, thereby eliminating the error due to poor alignment and sagging of taping. Moreover, time of measurement was shorter than that spent using tape. A maximum of 660 seconds were gained in the measurement of 268m distance. The longer the distance, the more the time gained as revealed by times of measurements made at locations numbers 8,9,10 and 11 in table 2. The speed of measurement may be attributed to the fact that only one person was involved and the measurement technique is simple and easy. This device can be used for direct distance measurement in both flat and hilly/rocky terrain. Hence it can find application in land surveying, building and construction of roads.

6.0 CONCLUSION

The design and construction of a digital distance measuring device was done considering some factors such as economy, availability of components, efficiency, portability and durability. The performance of the project after test met the research objectives. This digital distance measuring device eliminates sagging, faulty marking and poor alignment problem in tape based distance measurement and takes care of the human error due to parallax. It is also cost and time effective as it requires only one person to carry out the measurement. Therefore, a design that can enhance speedy and accurate measurement of distance at low cost was achieved.

However, like every aspect of engineering there is still room for improvement and further research. Further work will be done to enhance the performance of the system by adding a circuit at the output that will directly convert the number of revolutions to distance in meters.

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