IMPLEMENTATION OF ELECTRONIC WALKING STICK FOR THE BLIND USING A MICROCONTROLLER AND ULTRASONIC SENSOR

Dr. S.D. Yusuf, Dr. I. Umar and Ghali S.R

ABSTRACT

The difficulties encountered by visually impaired people has been a major problem in our society. How to carter for their mobility, reduce the danger and difficulties of finding obstacle in their ways and make movement so fast and safer for them. In this study, an electronic walking stick for the blind was implemented using a microcontroller Atmega328 and an ultrasonic sensor. The electronic circuit was simulated in stages using Proteus 8.0 design suit. Stages includes the RF module unit, moisture sensor unit, Light sensor unit, ultrasonic module unit, voltage regulator unit, and the buzzer unit. The simulated circuit was constructed on a printed circuit board and tested for continuity and power ON. Also an evaluation performance test was carried out with 40 volunteers who were blindfolded and walked through a path with the stick for straight obstacles detection, water detection, and the remote control detection. The true positive, false positive, true negative and false negative were recorded. Results shows that the constructed walking stick performed very well according to the specification of the design with sensitivity of 98% and specificity of 96%. Implying that the constructed device can correctly identify 98% presence of obstacles and 96% of No obstacle along the path with 97% accuracy. However, it may also fail to identify 2% presence of obstacles and 4% of obstacles when there are no obstacles. The walking stick with an alarm system is a welcoming solution for the visually impaired people since the device can serve to them like an artificial vision. It is affordable, light weight and suitable for the blind people to aid in their navigation.

Index Terms *walking stick, ultrasonic module, microcontroller, Proteus design suit, visually impaired, implementation.*

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I. INTRODUCTION

Vision is the most important part of human physiology as 83% of the information being gotten from the environment is via sight. There is a significant increase in cases of blindness in the world in general. The statistics by the World Health Organization (WHO) estimated that there are 285 billion people in world with visual impairment, 39 billion of which are blind and 246 with low vision [1]. The majority of people with poor vision are in the developing world and are over the age of 50 years and about 90% of the world's visually impaired live in developing countries [2]. Iraq is a particular case of this problem and this cases occur due to terrorist operations and birth defects in newborns because of water and food contamination. Since advancement in science and technology always try to make human life easier, there is a great need to develop a device that can help the visually impaired people to live without problems related to walking in homes, public roads or any other place [3]. Even for the non-visually impaired, the congestion of obstacles is sometimes problematic, it is even worse for the visually impaired. People with visual disabilities or blindness often depend on external assistance like trained dogs, humans, or special electronic devices as support systems for decision-making [4].

Existing devices are able to detect and recognize objects that emerge on the floor, but a considerable risk also includes the objects that are at a certain depth, or obstacles above waist level or stairs [5]. The most widely used stick is the long cane because it can feel the nature of the path and detect obstacles in the path for the blind person [6]. The long cane has several limitations such as range; limited to the length of the cane, typically one pace ahead of the user, difficulties detecting overhanging obstacles, and safe storage in public places [7]. Due to its inherent limitations, the long cane does not provide protection for the body above the waist elevation. Consequently, there is no guarantee that the presence of obstacles such as low slung signposts, utility boxes, tree branches, overhanging wires, can be detected by the blind person in time to avoid a collision. Generally, in place of the white cane a guidance person can be used as their mobility aid. Human aid has a lot of disadvantages as the person can get fatigue or fall sick.

With the advance in modern technologies many different types of devices are available to support the mobility of the blind or visually impaired persons. These mobility aids are generally known as Electronic Travel Aids (ETAs) [8]. The most important function of ETA for the blind persons is to get information on the nature of the road and the position of obstacles when they are in unknown places. With this information, they need to arrive at their destinations, avoiding unexpected obstacles [9]. However, Mohammed [10] observed some problems with currently available devices. First, the rangefinder technology is unreliable in its detection of step-downs or step-ups, such as curbs. Secondly, blind users find the sounds of various pitches or tactile vibrations being used to code the spatial information to be esoteric and difficult to understand. Thirdly, most blind users do not find the slight improvement in mobility performance to be worth the extra cost which can be many thousands of dollars, and the additional worry of maintaining a complex, expensive battery operated system that must be carried around and kept track of. Therefore, a more robust device that takes care of these limitations needs to be implemented for better aiding and mobility of the blind persons. In view of the above, the objective of this study is to implement an electronic walking stick for the blind using a microcontroller and an ultrasonic sensor.

2. MATERIALS

The materials and their specification that were used for the implementation of an electronic walking stick for the blind includes microcontroller ATmega328, voltage regulator LM7805, HTI2E and HTI2D encoder and decoder IC for RF module.

3. METHOD

The methods for implementation of the electronics walking stick for the blind was carried out in three (3) parts to include software design method, hardware construction method and circuit analysis (testing) method. The method was carried out in stages according to the block diagram presented in figure 1. The various stages include the RF module circuit, moisture detector, light detector, ultrasonic module, and voltage regulator circuit.

3.1 SOFTWARE DESIGN METHOD

The software design for the system includes circuit simulation, algorithm, flow chart, and choice of programming language.

A. Circuit Simulation Method

The simulation of the electronics working stick for the blind was carried out in stages according to the block diagram presented in figure 1. The circuit was simulated using Proteus ver8.0 software.

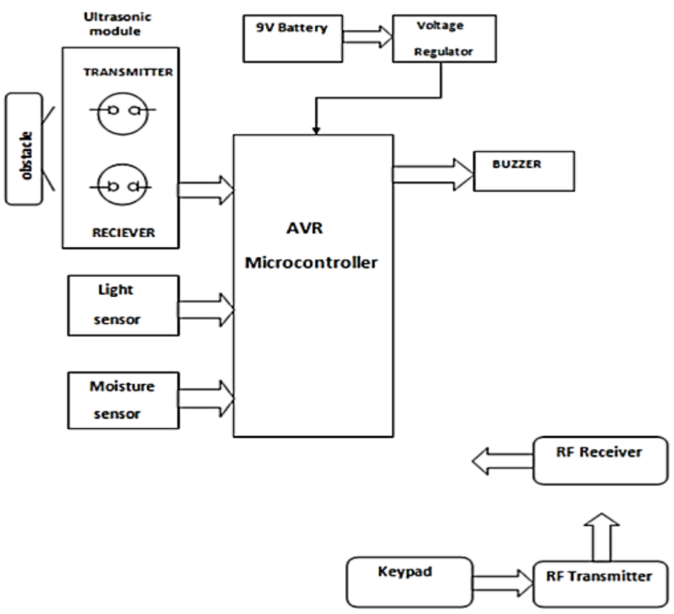


Fig. 1. Block diagram of the proposed electronics walking stick.

A. AVR Microcontroller Circuit

Microcontroller is the advanced version of microprocessors. It contain chip central processing unit (CPU), Read Only Memory (ROM), Random Access Memory (RAM), input/output unit, interrupts controller etc. [11]. Therefore a microcontroller is used for high speed signal processing operation inside an embedded system. The ATMega328 pinout diagram is as shown in figure 2.

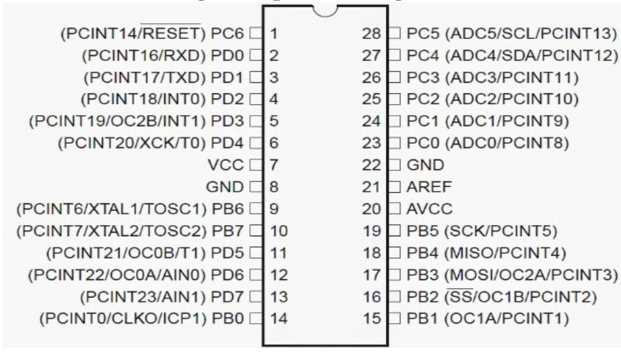


Fig. 2. ATMega328 pin out diagram [11].

B. Buzzer Unit

This is an audio signaling devices, which may be mechanical, electromechanical or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, confirmation of user input such as a mouse click or keystroke. The buzzer circuit is shown in figure 3.

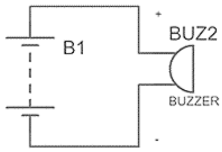


Fig. 3. Buzzer circuit.

C. RF Module

An RF module (radio-frequency module) is a small electronic device used to transmit and/or receive radio signals between two devices. In an embedded system it is often desirable to communicate with another device wirelessly. This wireless communication maybe accomplished through optical communication or through radio frequency (RF) communication [11]. The RF module is shown in figure 4.

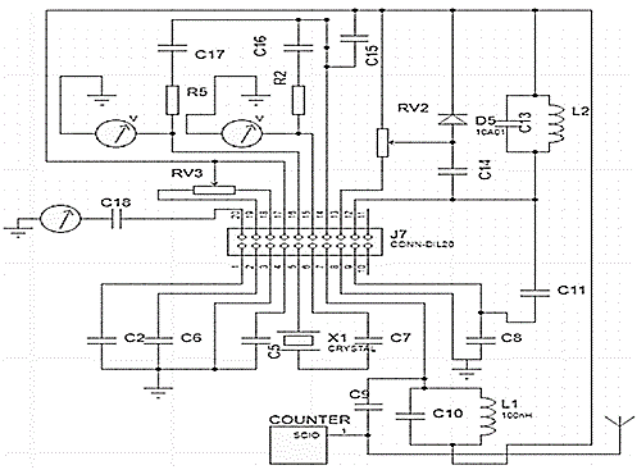


Fig. 4. The RF module [11].

D. Moisture Sensors Unit

The Soil Moisture Sensor is used to measure the volumetric water content in soil. Soil moisture sensor uses capacitance to soil, where the dielectric permittivity is a function of the water medium content. The sensor creates a voltage proportional to the dielectric permittivity, and therefore the water content of the soil. This makes it ideal for performing experiments in courses such as soil science, agricultural science, environmental science, horticulture, botany, and biology [12]. The moisture sensor unit is shown in figure 5.

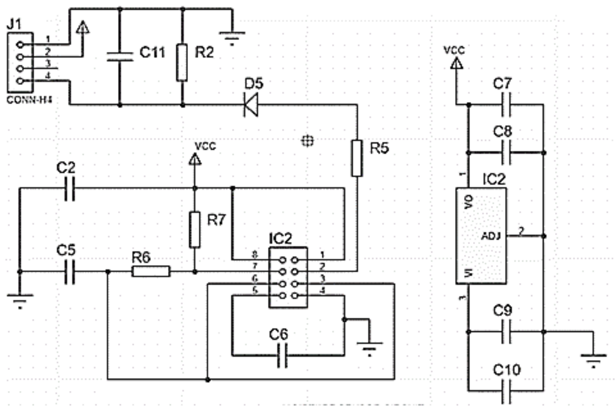


Fig. 5. The moisture sensor unit [12].

E. Light Sensor Unit

The light sensor is an electronic device used to detect light. It is a passive devices that convert this “light energy” whether visible or in the infra-red parts of the spectrum into an electrical signal output. Light sensors are more commonly known as “Photoelectric Devices” or “Photo Sensors” because they convert light energy (photons) into electricity (electrons). There are several types of light sensors. A photo cell or photo resistor is a small sensor which changes its resistance when light shine on it. Photomultipliers detect light and multiply it [12]. The light sensor unit is shown in figure 6.

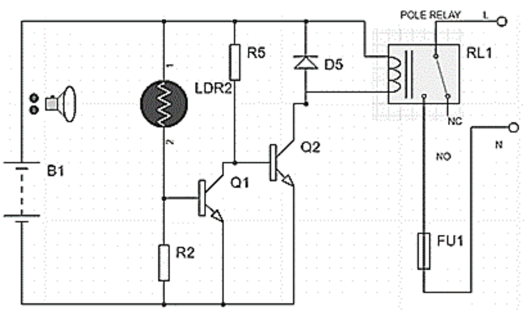


Fig. 6. The light sensor unit [12].

F. Ultrasonic Module Unit

An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves. It works on the principle of SONAR and RADAR system which is used to determine the distance to an object. An ultrasonic sensor generates the high-frequency sound (ultrasound) waves and when this waves hits the object, it reflects as echo which is sensed by the receiver [13]. By measuring the time required for the echo to reach to the receiver, the ultrasonic module can calculate and measure the distance. Ultrasonic ranging module HC-SR04 was used as it provides 2cm - 400cm non-contact measurement function, with ranging accuracy that can reach 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The ultrasonic module is shown in figure 7.

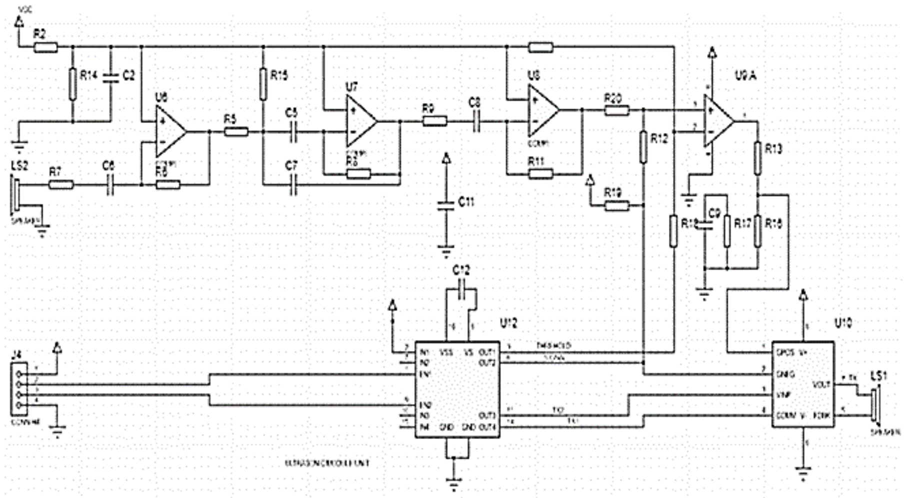


Fig. 7. The ultrasonic module [12].

G. Voltage Regulator Circuit

The voltage regulator automatically maintain a content voltage level. A voltage regulator may use a simple feed-forward design or may include negative feedback. The LM78XX/ LM78XXA series of three-terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a Wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection or thermal overload protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output Current [13]. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents with output voltages of 5, 6, 8, 9, 10, 12, 15, 18, and 24V. The LM7805 voltage regulator was used for this study. The regulator circuit is shown in figure 8.

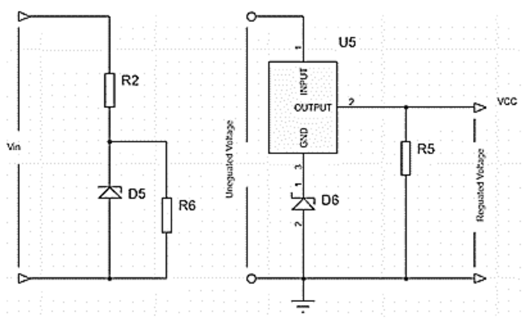


Fig. 8. The regulator circuit [13].

H. Nine-Volt Battery Unit

This is a common size of battery that was introduced for the early transistor radios. It has a rectangular prism shape with rounded edges and a polarized snap connector at the top. This type is commonly used in Walkie-Talkies, Clock and Smoke detectors.

B. Flowchart

The flow chart for the electronic walk stick for the blind is presented as shown in figure 9.

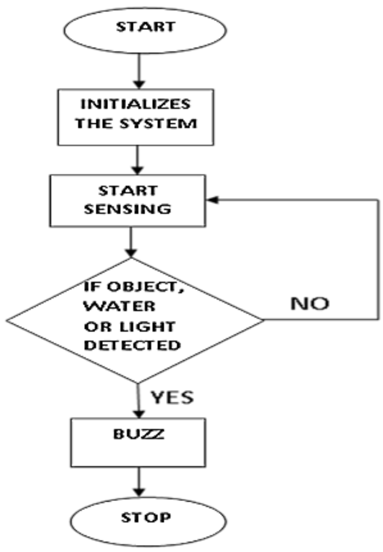


Fig. 9. Flowchart for the proposed electronic walking stick.

C. Algorithm

The algorithm that explains the flow chart for the electronic walk stick for the blind is presented as follows:

1. Start
2. Sensor Detection
3. If Obstacle/Moisture/Light detected then start alarm/buzz
4. If not, continue sensing
5. Stop.

D. Choice of Programming Language

The programming language used in the implementation of this work is Embedded C and for implementation of portions of the code with high timing accuracy and size efficiency.

3.2 HARDWARE CONSTRUCTION METHOD

The circuit construction was carried out in stages according to the block diagram shown in figure 1. The component were assembled on electronics breadboard first to be sure of terminal connections and later fixed on a printable circuit board (PCB) and soldered using the soldering iron and MBO 1mm wire lead solder, +183°C melting point. The microprocessor holder was first mounted, followed by water sensor and holder of Ultrasonic sensor. After fixing the main components the passive components were assembled.

3.3 CIRCUIT TESTING AND ANALYSIS METHOD

Components testing was carried out prior to fixing them on the Printed Circuit Board. Also Continuity test and Power ON test were carried out during construction to ensure proper functioning of the circuit and to ensure that no components in the circuit undergo heating when the device is on use and also to avoid overloading and impedance mismatch from the various stages. Finally the constructed prototype was tested and the performance evaluation test was carried out for specificity, sensitivity and accuracy tests.

A. Continuity Test Method

The continuity test was carried out to make sure no cable or line jammed and all lines are having free flow of electrons. In electronics, a continuity test is carried out to check and see if current flows in an electric circuit (that it is in fact a complete circuit). This will be achieved by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open". Devices that can be used to perform continuity tests include multi meters which measure current and specialized continuity testers which are cheaper and more basic devices, or generally with a simple light bulb that lights up when current flows.

This test is performed just after the hardware soldering and configuration has been completed. The test is aimed at finding any electrical open paths in the circuit after the soldering. Many times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, improper usage of the soldering iron, component failures and presence of bugs in the circuit diagram. We use a multi meter to perform this test in this study.

B. Power ON Test Method

This test is performed to check whether the voltage at different terminals is according to the requirement or not. The multi meter was put in voltage mode and the test is performed without the microcontroller. Test-run test was also carried out when the system was ON and the respond of the input components like ultrasonic sensor, water sensor and remote control functions were observed. At this point almost all the expected results was achieved but remote control failed until when the receiver and transmitter were changed to directional ones for easy location of the electronics walking stick for the blind when misplaced. The unidirectional ones cannot serve the purpose of finding the missing stick, it only communicates with the RF Receiver and transmitter as far as you are within the range. But directional ones can only communicate while directed to the receiver and transmitter facing each other for easy locating.

C. Performance Evaluation Test Method

This was done to evaluate the prototype circuit functionality to access how successful is the device performance. The response of the system should be in line with the design. Evaluation test was achieved using the following measurements:

True Positive (TP): Number of obstacle detection that are correctly detected by the system.

False Negative (FN): Number of obstacle detection that are wrongly undetected by the system.

True Negative (TN): Number of obstacle undetected that are correctly undetected by the system.

False Positive (FP): Number of obstacle undetected that are wrongly detected by the system.

The values obtained from the outcome of the test was used to calculate the specificity, sensitivity and accuracy of the device.

Specificity ($\boldsymbol{S_p}$): This is the ability of the system to correctly identify NO obstacles on the path. This was calculated as follows:

$$S_p = \frac{\text{TN}}{\text{TN+FP}} \text{ x } 100 \quad (1)$$

Sensitivity ($\boldsymbol{S_e}$): This is the ability of the system to correctly detect obstacles in its path and can be calculated as follows:

$$S_e = \frac{\text{TP}}{\text{TP+FN}} \text{ x } 100 \quad (2)$$

Accuracy ($\boldsymbol{A_{cc}}$): This is the degree to which the result of our measurement, calculation, or specifications conforms to the correct value or the standard value.

$$A_{cc} = \frac{\text{TP+TN}}{\text{TP+ FN+TN+FP}} \text{ x } 100 \quad (3)$$

4. RESULTS

4.1 SIMULATION RESULTS

The simulation was carried out in stages according to the block diagram in figure 1 and the results are presented in figures 10, 11, 12 and 13. Fig. 10 presents the general simulated circuit of the electronic working stick for the blind, while Fig. 11, 12 and 13 presents the pre-simulations first carried out with Ref Volt (Non holding) and LDR (Holding) Volt before the power supply, then, with Ref Voltage of 2V and LDR Voltage of 4.76V, as LED remains OFF, and finally with LDR Volt drastically decreased to 1.67V following increase of light intensity and LED ON.

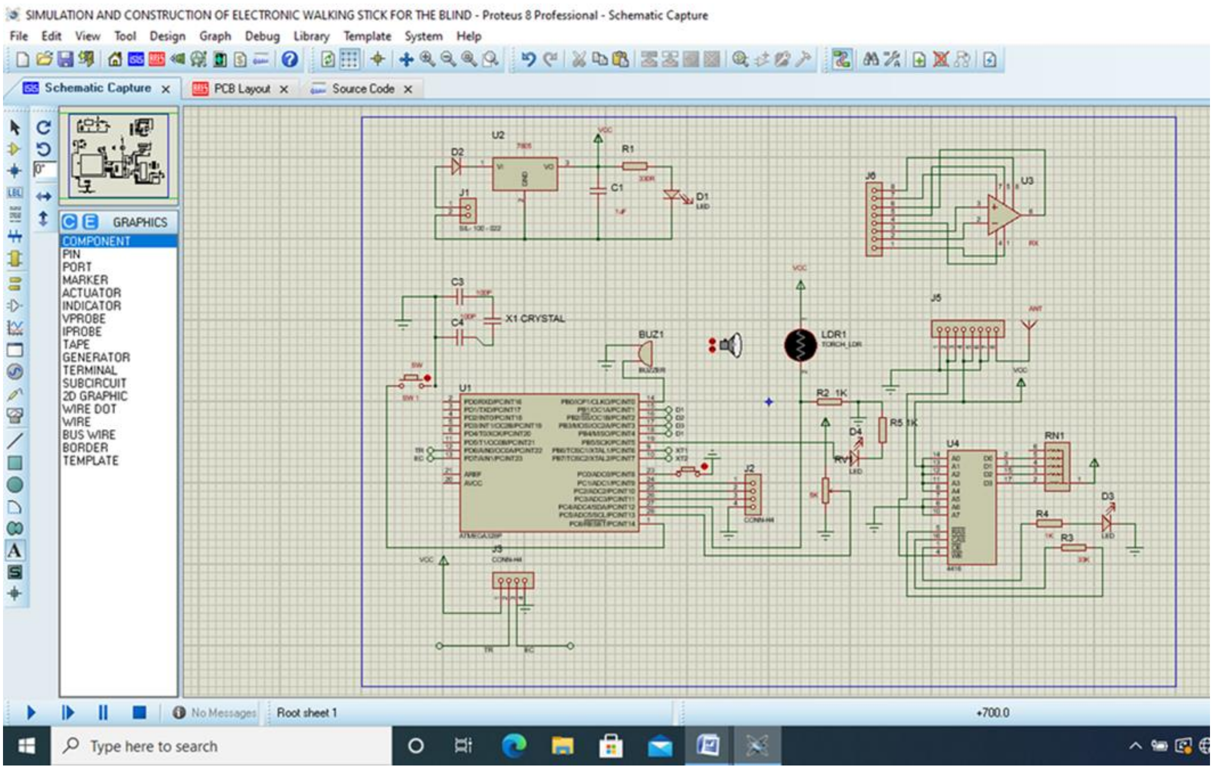


Fig. 10. Simulated general circuit of electronic working stick for the blind.

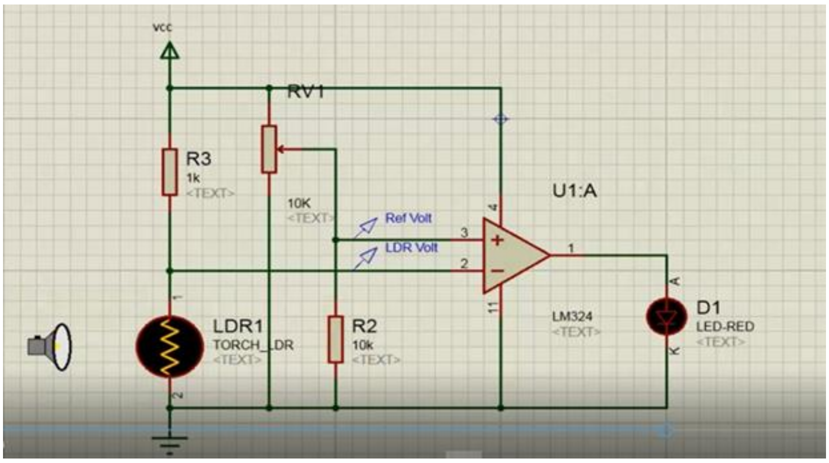


Fig. 11. Pre- simulating showing Ref Volt (Non holding) and LDR (Holding) Volt before the power supply.

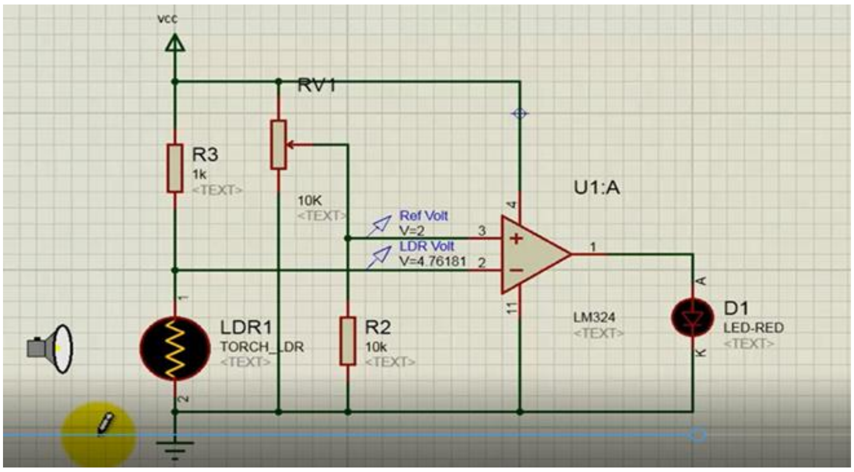


Fig. 12. Simulation with Ref Voltage 2V and LDR Voltage 4.76V, LED remains OFF.

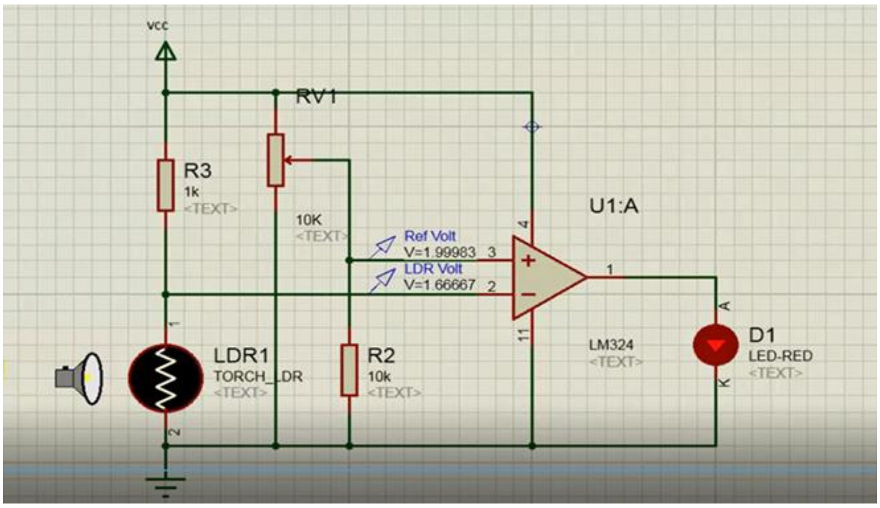


Fig. 13. Simulation with LDR Volt 1.67V due to increase of light intensity and LED ON.

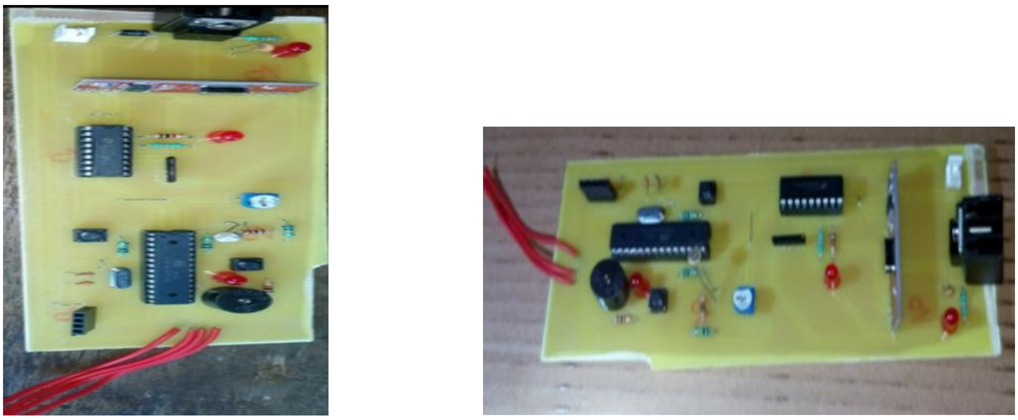
Figs. 11 to 13 are the simulated circuits for the blind stick integrated with ultrasonic sensor along with light and water sensing. Ultrasonic sensor detects obstacles ahead using ultrasonic waves. On sensing obstacles it alerts the blind man. When the system is powered by 9Vdc supply the voltage will be regulated by the regulator and the 5V output will enter the circuit while LED1 indicator glows, both Ref and LDR voltage is zero. Pressing switch SW1 makes the power enter the microcontroller and other parts of the circuit for action, Ref voltage reads 2V and LDR Voltage reads higher volt of 4.76V. Switch SW2 can be press to trigger the buzzer to make sound in order to test system effectiveness.

The range of detection can be varied with the help of potentiometer mounted on the blind stick. When LDR starts sensing light intensity, as the intensity increases the LDR voltage will start decreasing until it reaches 1.67V then the LED2 comes ON and trigger the buzzer to buzz. The same thing if ultrasonic sensor starts sensing obstacles the sensor passes this data to the microcontroller which processes this data and calculate if the obstacle is close enough, the microcontroller sends a signal to sound a different buzzer. If the obstacle is not that close the circuit does nothing. It also detects and sounds a different buzzer if it detects water. Apart from the stick unit a wireless RF based remote is provided such that the blind person can detect if there is light or darkness in the room. The blind also can find the stick if forgotten where it is kept by simply pressing the remote button to sound a buzzer.

4.2 HARDWARE CONSTRUCTION

A. Circuit Construction

The construction was carried out first on a bread board to ensure that the circuit is working as required, then transferred to the PC board for permanent soldering. The power section was completed by mounting the power regulator where the operation voltage and control voltage were determined by using 5V battery. Then mounting of the ICs was carefully carried out, followed by the input components including ultrasound sensor, RF receiver and water detector. The shunt and limiting resistors were also connected to limit and control the flow of current to the input terminals. The constructed circuit showing the top and side views of the device is as shown in figure 14 while the remote control for the electronics walking stick at the point of testing after assembling is presented in figure 15.



a) Top view **b) Side view**

Fig. 14. Constructed circuit (top and side views).

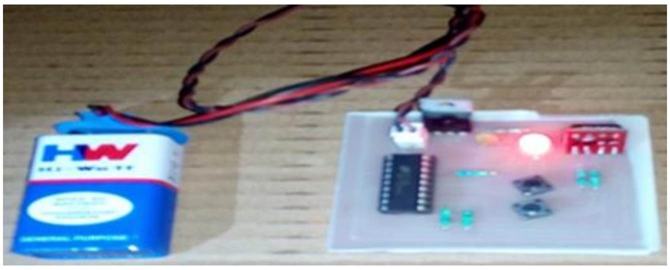


Fig. 15. Constructed remote control circuit tested with battery.

B. Casing and Packaging

The casing of the Electronic Walking Stick, was made of PVC materials. The stick measuring 100cm x 2.5cm attached with 15cm x 6cm x 7cm box was provided to the system for mechanical protection. The orthographic projection has shown its two side views (Side and Top) in figure 14. It is provided with two numbers of 0.5cm diameter hole for the push bottom switches (On and Reset), four numbers of 0.25cm diameter hole within 0.5cm diameter groove at the edges of its top side for screw lock, one number of 0.5cm diameter hole for the power switch tighten by 1.5cm diameter nut. Others include two numbers of 1.5cm diameter hole spaced apart 1.0cm for Ultrasonic Sensor, two numbers of 0.5cm diameter hole for Light and Moisture sensors accordingly. It has three numbers of LED indicators (Red for power, yellow sensing starting and blue for buzzer). Provision for system's ventilation was also provided. The complete isometric diagram of the casing showing the various dimensions is as shown in figure 16, while the complete packaged constructed walking stick with full casing is shown in figure 17.

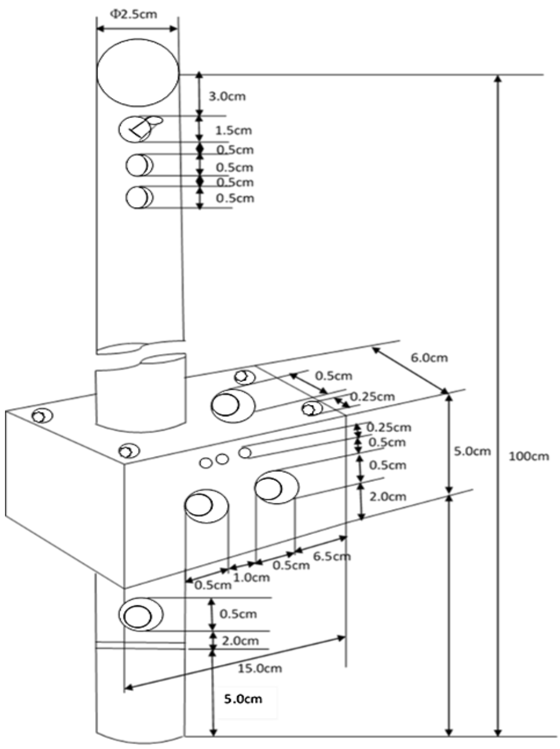


Fig. 16. The isometric diagram of the casing.

Fig. 17. Complete packaged electronic walking stick.

4.3 OUTPUT TEST ANALYSIS

A. Continuity Test

In this study, the multi meter was used to perform this test. We keep the multi meter in buzzer mode and connect the ground terminal of the multi meter to the ground. We connect both the terminals across the path that needs to be checked. If there is continuation then you will hear the beep sound.

B. Power ON Test

In this test, we take a multi meter and put it in voltage mode. Firstly, we check the output of the transformer, whether we get the required 12V AC voltage. Then we apply this voltage to the power supply circuit. Note that we do this test without microcontroller because if there is any excessive voltage, this may lead to damaging the controller. We check for the input to the voltage regulator i.e. are we getting an input of 12V and an output of 5V. This 5V output is given to the microcontrollers' 40th pin. Hence we check for the voltage level at 40th pin. Similarly, we check for the other terminals for the required voltage. In this way we can assure that the voltage at all the terminals were as per the requirement, as specified in the proposed circuit.

C. Performance Evaluation Test

The performance evaluation was carried out to ascertain the functionality of the constructed device. The device was tested about 40 trials each for the straight obstacles detection, water detection, and the remote control detection with different people who volunteered to be blindfolded and walked through a path using the constructed walking stick for the blind. However, the number of times the device detected different objects, the number of times it gives a false alarm, and the number of times it didn't detect an object was recorded and tabulated. The results for the performance analysis are presented in Table 1.

Table 1: Performance evaluation result

S/N	Obstacle Detection	No. of Trials	True Positive (TP)	False Negative (FN)	True Negative (TN)	False Positive (FP)
1	**Straight Detection**	40	40	0	38	2
2	**Water Detection**	40	39	1	37	3
3	**Remote Detection**	40	38	2	40	0
	Total	120	117	3	115	5

Table 1 is the analysis result for the test carried out on the constructed device. The output test results revealed some vital information that was useful in the analysis. A total of 120 trials was carried out of which the number of true positive was about 117, false negative was 3, true negative was about 115, and false positive was 5. The result was used to calculate specificity, sensitivity and accuracy of the constructed automatic walking stick for the blind.

The specificity ($\boldsymbol{S_p}$) of the constructed device was calculated using equation (1) as:

$$S_p = \frac{115}{115+5} \text{ x } 100 = 95.83\%$$

The Sensitivity ($\boldsymbol{S_e}$) of the constructed device was calculated using Equation (2) as:

$$S_e = \frac{117}{117+3} \text{ x } 100 = 97.5\%$$

The Accuracy ($\boldsymbol{A_{cc}}$) of the constructed device was calculated using Equation (3) as:

$$A_{cc} = \frac{117+115}{117+3+115+5} \text{ x } 100 = 96.67\%$$

The parameters evaluated, gives the device performance in terms of differentiating real detection and other activities. The results obtained validate the hybrid obstacle detection algorithm used in this work. This give reasonable and expected results, showing the effectiveness of the algorithm used and the rating of the device overall performance.

5. DISCUSSION

The constructed electronic walking stick when subjected to various test have revealed vital information that ascertain its functionality. The continuity test revealed that the circuit was continues with no short circuits along the paths, or broken conductors, or damaged components, or excessive resistance along the circuit. While the power ON test shows that, the voltage at the different terminals was according to the requirement and specification of the simulated circuit. This is similar to that of [14], [15], [16], and [17]. For the performance analysis on the device, Findings from this study has revealed that the sensitivity is 98% and the specificity is 96%. This implies that the electronic walking stick will correctly identify 98% of the obstacles in its path, but it will also fail to identify 2% of them. The walking stick will also correctly identify 96% of No obstacle along the path, but it will also identify 4% of obstacles when there are no obstacles. Findings has also revealed that the accuracy was about 97%, which implies that the design conforms to the correct value specifications of the circuit and that object detection using the constructed device is close to that of a standard walking stick and we are 97% sure. However, of all the previous work reviewed, none of the similar works were able to calculate specificity, sensitivity and accuracy such as [2], [3], [11], [14], [16], [18], [19], [20], [21], and [22]. This reveals the additional contribution of this work to the existing literature.

The prototype was able to identify different obstacle on the path accurately. The major weaknesses of the device is it inability to detect obstacle little bit above the waist and after introducing a switch on the Electronics walking stick to a distance of handle which was not in original design, it made the water detector not to be as active as it was before installation of the switch. With calculated accuracy of 97%, means the device is highly reliable, safer to use and above all can be named as intelligent walking stick for the blind. In line with this, the electronic walking stick can serve as an aid, safer way to improve the walking speed, avoidance of accidents and reduce the need of human guide/ helper to the blind so that they can go for their own business without solidly depending on another person.

6. CONCLUSION

Electronics Travel Aids (ETA) is a device which alerts its user when obstacles are detected on the paths. Most detection measure acceleration, frequency and body posture. The aim is to minimize risk and hazard to the user. Electronics walking stick is user friendly and can be used both indoor and outdoor. It provides high quality protection and reduce accident. Electronics walking stick was designed to automatically generate alarm whenever detection of obstacle occurred. If there is any misplacement of the device, a Remote control has been incorporate to transmit RF signal with help of RF receiver from the ETA to respond with alarm at the direction of the Remote that is why the directional RF Transmitter and receiver are used. With this Electronics walking stick the performance was evaluated base on the accuracy of obstacle detection with satisfactory result. The electronic walking stick circuit being cost effective is thus expected to be used by majority of the visually impaired section of the society. However, additional sensors and actuators for detection of fire or smoke and GPS system to ease navigation in an unfamiliar pathway via central monitoring system can be added to improve on the circuit for future design.

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