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DEVELOPMENT OF INFRARED-BASED LOW COST BIDIRECTIONAL COUNTER

Amusa K. A., Adewusi A. and Olanipekun A. J.

Electrical and Electronics Engineering Department, Federal University of Agriculture, Abeokuta

**Corresponding Email:amusaakinwale@gmail.com*

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ABSTRACT

The aim of this research was the development of low cost infrared-based bidirectional counting system that could be deployed to take the count of people entering/exiting a given space. People counting system in crowded places is a practical application that can be approached via varieties of ways, which vary in the level of complexity. The control circuit of the developed device was built around AT89C52 microcontroller, JK flip-flop and operational amplifier as comparator. The sensor network is made of two pairs of infrared transmitter and receiver circuit. Light emitting diode was used as the transmitter while a phototransistor is utilized as the receiver. Provision was made for visual display of the count through the use of seven-segment display module. As counting is not usually limited to the entry/exit point of a place, the developed bidirectional counter could as well be deployed in a wide range of applications that provide information for management of the volume and flow into a location. This paper describes the relevance of this design in meeting the expectations for safety and security in the society.

Keywords:*Infrared,counting system, bidirectional, counter*

INTRODUCTION

Counting is as old as the world itself. Varieties of method have evolved to achieve accurate and effective counting of items/objecst of interest. In recent years, different systems for counting people have been developed and used. Counting of people is vital for operational, safety and security reasons. Devices and systems with capability of offering these functions constitute highly effective tools for awareness creation and intelligence development (Ryan *et al.,* 2014; Al-Zaydi *et al.,* 2016). Information about the number of people present in a given space is a veritable tool that can be used to develop business intelligence as well as crowd management (Al-Zaydi *et al.,* 2016).

Different approaches are in existence for counting people, which include tally counter (Zhu *et al.,* 2009), infrared beams (Amin *et al.,* 2008), ultrasonic sensor networks (Chen *et al.,* 2008), thermal imaging (Li *et al.,* 2011; Tu *et al*., 2013; Tanaka, 2010), computer vision (Lin et al., 2011; Gandhi *et al.,* 2012; Hou and Pang, 2011), mobile phones service set identifier (Ma & Chan, 2013; Shbib *et al.,* 2013), wireless sensor networks (Yuan *et al*., 2013; Nakatsuka *et al.,* 2008) and wireless fidelity based counting systems (Xi *et al.,* 2014).

What informs the choice of a particular technology is a function of needs and priorities which include the degree of accuracy, cost, flexibility and the complexity of the required information. In general, detection methods for counting of people are broadly grouped into two: the obstructive and non-obstructive methods (Prabakaran *et al.,* 2011). In the first group, detection of the number of people requires personal contact, which obstructs the path. Examples include turnstiles and mat-type foot switches (Kutschera *et al*., 2011). The latter group is non-contact and non-obstruct sensor, of which the camera is chiefly employed.

This paper describes the bidirectional counter that is based on application of infrared beams developed for detection and counting of people entering or exiting a given area. The developed system is low cost and can be deployed in a number of places where there is need to count the people passing in/or out of the area.

MATERIALS AND METHODS

DESIGN CONSIDERATIONS

The Infra-Red (IR) -based bidirectional counter developed counts either way (IN or OUT) depending on the interrupt received from the sensors and displays the count on the display unit. On the whole, the device has four building blocks as depicted in Figure 1. They are power supply unit, sensor unit control unit and the display unit. Each of these building blocks entails a number of discrete electronic components or module for its realization.

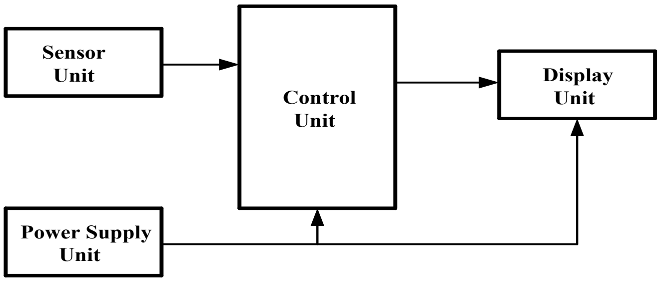


Figure 1: Block diagram of IR-based bidirectional counter

Power Supply Unit

The power supply unit is designed around a 220V/9V, 500mA step down transformer. A bridge rectifier is used for rectification of 9V ac from the secondary terminal of the transformer. In order to have 5V dc that is required by microcontroller, which occupies the heart of the system, an LM7805 voltage regulator is utilized to regulate 9V dc to 5V dc supply. An electrolytic capacitor of capacitance value $1000\mu F, 25V$ is used to filter out pulse that might still be present after rectification before regulation while another capacitor having value of $10\mu F$ is employed as loading capacitor for LM7805. Figure 2 shows the circuit of the designed power supply unit.

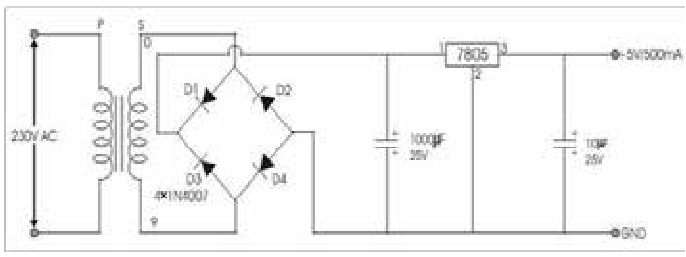


Figure 2: Circuit diagram of power supply unit

Control Unit

The control unit is built around microcontroller AT89C52 with operational amplifier LM324 configured as comparator and JK flip-flop 74LS76 as main components. The microcontroller AT89C52 is a forty pins integrated circuit having operating voltage in the range 4.0-5.5V dc. Its choice is informed by features such as 8-kilobyte in-system reprogrammable flash memory, three-level program memory lock, 256 by 8-bit internal RAM, 8 interrupt sources among others. The output current of each pin is at 5V dc, 15mA while the clock signal is 12MHz. To ensure steady clock pulse, a crystal oscillator connected to pins XTAL1 and XTAL2 of AT89C52 is employed to provide the clock signal. Two capacitors, C_3 and C_4 are used for loading and smoothening of the clock signals. Values of C_3 and C_4 are obtained via:

$$C_L = C_s + \frac{C_3 \times C_4}{C_3 + C_4} \quad ....(1)$$

where C_L is the optimum load capacitance of the crystal given as $22pF$ (ATMEL AT89C52 manual), C_s is the stray capacitance of the printed circuit board. It typically has a value of $5.5pF$. For this design, the values of $C_3 = C_4$, which reduces (1) to

$$C_L = C_s + 0.5C_3 \quad .... (2)$$

from which C_3 is determined to be $33pF$.

A typical comparator compares two voltage or current levels and switches its output in favour of the larger one. LM324 when configured without a negative feedback functions as a comparator. When its non-inverting input $(V+)$ is at a higher voltage than the inverting input $(V-)$, the high gain of LM324 causes it to output the most positive voltage it can. In the case when the non-inverting input is of lower voltage than the voltage at the inverting input, LM324 output the most negative voltage it can. These features of LM324 are exploited in this design and informed its choice as the comparator.

Flip-flop is a bi-stable multi-vibrator which is capable of holding a one-bit data in its memory. The control of a typical flip-flop is often realized via the use of one or two control signals and/or clock signal. JK flip-flop is utilized in this work because it can be configured to work as different variants of flip-flop such as SR flip-flop and D flip-flop, depending on the setting and logic values of J and K. Specifically, combination of $J = 1$ and $K = 0$ set the flip-flop while those of $J = 0$ and $K = 1$, reset the flip-flop. When $J = K = 1$, the flip-flop is toggled, causing its output to change to the logical complement of its current value state. Setting $J = K = 0$ causes the flip-flop to hold its current state. Because of this versatility of JK flip-flop, it is employed in this work to aid logic state manipulation that is required.

Sensor Unit

Two pairs of IR transmitter and receiver circuits formed the sensor unit in this research work. IR Light Emitting Diodes (LED) (IR TX1 and IR TX2) were used as the transmitters while phototransistors (L14F1) were used as receivers. In addition, NPN (2N3904) transistor was employed as amplifier in the design.

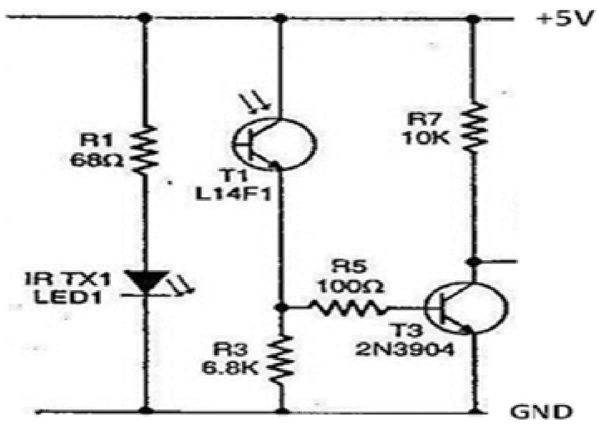


Figure 3: Sensor unit

It is required that IR LED emits radiation in the window between $920nm$ and $960nm$ so that the current flowing through the LED will be $50mA$. Consequently, there is need for introduction of limiting resistor in series with the LED. With the supply voltage of 5V, voltage drop across LED is 1.6V and current flowing of 50mA; application of Ohm's law yields the value of limiting resistor to be 68Ω. Based on the information available in the datasheet of the phototransistor (L14F1), other resistances value are obtained and applied as specified. The circuit diagram of the IR LED transmitter-L14F1 phototransistor with other components forming the sensor unit is shown in Figure 3.

Display Unit

In order to give visual information about the count, the developed device has a display unit incorporated. LTS543 CC, seven-segment display module was employed. The output voltage of each pin of AT89C52 microcontroller is at 5V dc, 15mA. Based on available information in the datasheet of LTS543 CC display module, the LED in the module has a forward voltage of 1.7V; there is need for the introduction of limiting resistor for the interface between the output pin of AT89C52 and the input of the seven-segment display module. Again, application of the Ohm's law and above information concerning the supply voltage and voltage drop across LED forming the seven-segment display module gives the value of the limiting resistor to be connected in the interface between AT89C52 and LTS543 CC display module to be 220Ω. Figure 4 illustrates connections between AT89C52 and LTS543 CC display module.

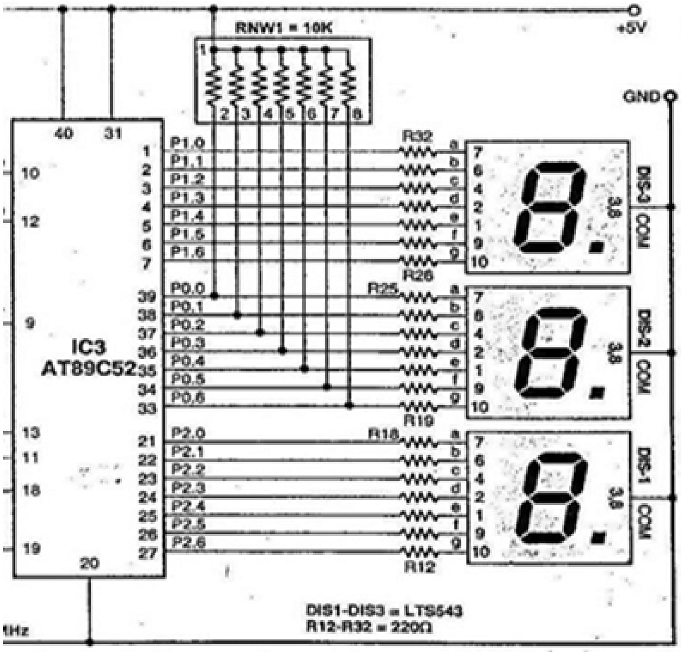


Figure 4: Connection between AT89C52 pins and LTS543 CC display module

Firmware of AT89C52 microcontroller

After completion of the circuit design, the AT89C52 microcontroller to be used has to be programmed. The instruction for AT89C52 is written in assembly language and compiled using C51 Keilmicrovision software to generate hexadecimal codes.This hexadecimal file is then transferred to AT89C52 through the USBPICPROG software. The following lines of algorithm are used for the design of the firmware of AT89C52:

Step 1: Start the process;

Step 2: Select ports 0, 1, and 2 of AT89C52 as the output ports for displaying the count value in the seven-segment display;

Step 3: Select port 3 of AT89C52 as the output port for providing set pulse to JK flip-flop;

Step 4: When external interrupt INT0 occurred in AT89C52, increase the count by 1;

Step 5: When external interrupt INT1 occurred in AT89C52, decrease the count by 1.

Step 6: Continue the process in step 4 or step 5, depending on the interrupt that occurs.

RESULTS AND DISCUSSION

IMPLEMENTATION

Figure 5 shows the complete circuit design for the IR-based bidirectional counter. First the design is simulated using Proteus software, to ensure there is no error in the design process and that the circuit will work when implemented. Thereafter, components are sourced locally and assembled in line with Figure 5. Figure 6 shows the assembled components with labels.

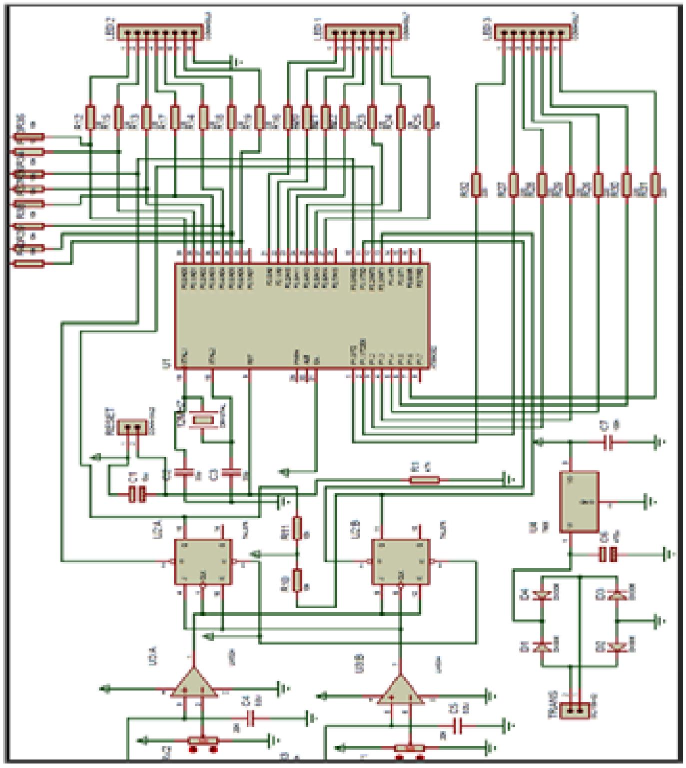


Figure 5: Circuit diagram of IR-based bidirectional counter

WORKING PRINCIPLE OF THE IR-BASED BIDIRECTIONAL COUNTER

Two pairs of IR transmitter-receiver setup are used as sensors at the entrance/exit of the passage as shown in Figure 7. The pairs detect interruption of the IR beam and generate clock pulse for the AT89C52 microcontroller to work on. AT89C52 controls the count and LTS543 CC module displays the count accordingly based on the clock pulse received by AT89C52. When there is no interrupt, the IR beams continuously from the transmitter (LED) on the phototransistor T1 (L14F1), causing it to conduct and drives transistor T3 into saturation (see Figure 3) due to high emitter voltage of T1. At this instance, the pin 3 which is the input pin of the comparator (U3: A) goes low while its output pin 1 goes high.

When there is interrupt, say IR beam from IR TX1 is interrupted, the phototransistor T1 (RXV 1) and transistor T3 are cut-off. This causes the input pin 3 of U3: A (operational amplifier) to go high and the output pin 1 low. This low output pin 1 of U3: A provides negative trigger pulse to pin 1 of U2: A (JK flip-flop) to toggle its output to low. As the IR TX2 beam is interrupted next, there is no change in the output of U2: B (JK flip-flop) because the low input at J and k pins of U2: B are connected to clock pin 1 of U2: A, which sends negative-going pulse to clock pin 6 of U2:B. This combination triggers the external interrupt INT0 at pin 12 of AT89C52 microcontroller which causes the count to be increased by 1. The count is reflected in display unit instantly.

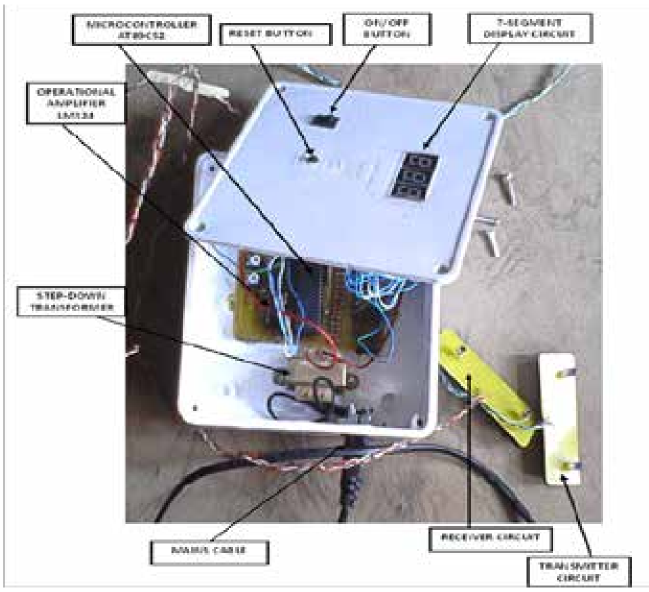


Figure 6: Picture of the assembled units with labels

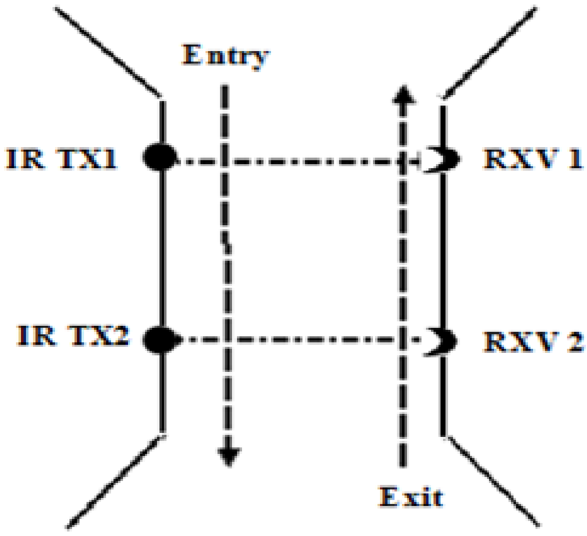


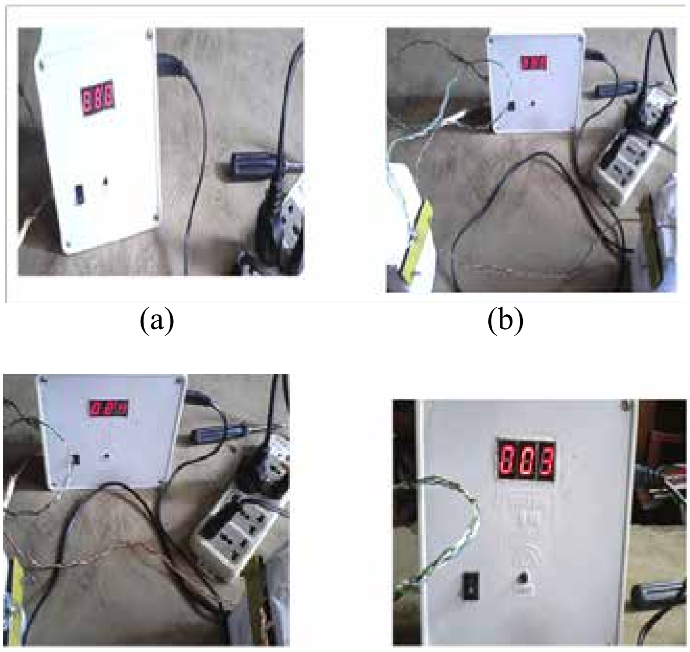
Figure 7: Sensors arrangement at an entrance

On the other hand, when the interrupt comes first from IR TX2 before that of the IR beam from IR TX1, it signals exit. The output pin 7 of U3: B goes low and provides clock pulse to pin 6 of JK flop-flop U2: B to toggle its high input to output low. Due to link between pin 6 of U2: B with J and K pins of U2: A, the low input at those pins of U2: A trigger the external interrupt INT1 at pin 13 of AT89C52 microcontroller. This leads to decrease in the count by 1 and the display unit changes its entry accordingly.

Provision is made in the design for power-on reset pulse to initiated to the AT89C52 microcontroller via the use of an electrolytic capacitor specified as $10\mu F, 16V$. A push-to-on switch $S1$ is employed to trigger the capacitor for reset pulse. When AT89C52 is reset, the flip-flops are brought into set state through the microcontroller during the software run time.

PERFORMANCE TESTS

After the construction, tests were carried out from the input stage to the final output stage of the developed device to ascertain its conformity with the design specifications. Each of the individual circuits making up the totality of the IR-based bidirectional counter is tested one after the other after the construction and they were found to be working as expected before being assembled. Figure 8 presents pictorial illustrations of the results of tests carried out on the constructed device.



(a) (b)

(c) (d)

Figure 8: Results of performance tests carried out on the constructed IR-based bidirectional counter (a) power ON, counter displays 000 (b) maximum possible count, counter displays 999 (c) Response after 24 interrupts of INT0, counter displays 024 (d) Response after 21 interrupts of INT1 using (c) as takeoff, counter displays 003

CONCLUSION

The IR-based bidirectional counter developed here employed a microcontroller, display unit and control circuit in its design and construction. It can count up or down depending on the interrupt of the IR link received by the control unit. The developed device has the potential of reducing human effort in counting the number of persons entering/exiting and occupying an enclosed area in a time. The cost of implementing it is reasonable and all the components are readily available in the market.

Counting is not limited to the entry/exit point of a place but it has a wide range of applications that provide information for management of the volume and flow into a location. Consequently, the developed IR-based bidirectional counter can be used in places such as court rooms, offices, colleges and schools, seminar halls, stadia, parks, movie theaters, churches or mosques and libraries, to effectively manage the number of the occupants at any moment. It reduces human effort, saves valuable time in tally or manual counting and possibility of human errors.

Though, the developed device works satisfactorily in the present design, it may however, be enhanced for a wider counting range of above three digits through the use of liquid crystal display and of course modification of the firmware of the microcontroller. In addition, the sensing range of the device could also be improved upon through the replacement of IR sensors by a laser torch arrangement. Thus, the circuit can be used to monitor visitor flow in effective manner, where the visitors have tobe counted and controlled.

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