A Microcontroller Based Football Stadium Capacity Counter

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***Abstract*— In this work, a microcontroller based football stadium population counter was designed and implemented hands on using two active infrared sensor systems and the microcontroller system. The active infrared sensor systems consisted of an active sensing section whose task was to detect persons separately one after another using different entrance and exit points of the football stadium but also in robotics applications. From the sensing system a signal conditioning circuit was used in order to get a suitable and desirable output signal that the microcontroller could recognize and process. The microcontroller system, whose task was to determine the number of persons inside the stadium, consisted of one AT89C51 microcontroller outputting to the seven segment displays. By recognizing both the number of entering and leaving persons, the microcontroller executed a simple high level language program to determine the real number of spectators inside the stadium, and then displayed the obtained result on the seven segment displays. The counter system was designed with a capacity of 9999, although this could be improved through cascaded systems or by using more advanced embedded systems or robotics techniques.**

***Index Term*— Microcontroller AT89C51, infrared transmitter, infrared receiver, signal conditioner, population counter, football stadium.**

I. Introduction

IT is difficult for venue organizers to know the precise number of persons present in the stadium and determine game-day attendance so as to avoid exceeding the spectator capacity, and in some cases robotics alternatives are required [1-4]. In professional football matches, it is very important to tell the number of people attending the football game [5]. This number is used for many applications including demand studies [6], team quality, ticket price effects, weather effects, knowing how well the football team and the professional football club in general, is perceived by its supporters, and team traditional rivalry as well as loyalty of its fans [7, 8]. It also helps in determining revenue generation for the club per game, and the effects of national television broadcasts [9]. Additionally for health and safety reasons, the attendance should not exceed the capacity of the stadium, and a precise system that can display the number of spectators in the stadium at a given instance would prevent crowd disturbances, ensure safety and order within the confines and vicinity of the stadium thus greatly simplifying the job of the stadium's hazards and risks management team [10-14]. In this work, a system was designed and implemented based on a microcontroller that determines the attendance of a football stadium at a given instance during the match but can also be applied to modern venues that house large crowds [15, 16].

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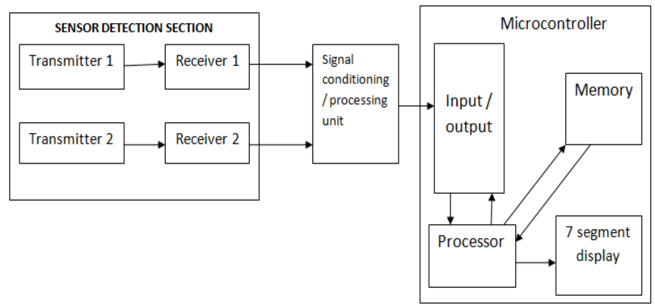
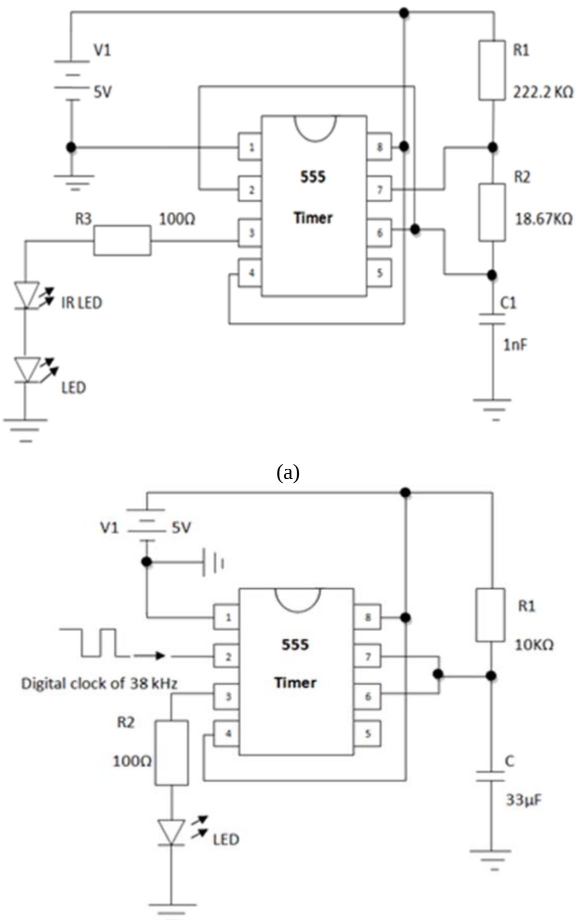


Fig. 1. Block diagram of a microcontroller based football stadium population counter

Previously a population counter was hands on implemented using wave pipelining [17], and combinational threshold logic was used to implement a parallel counter [18], however both techniques do not use any transducer systems. Others used microprocessors as the controlling components in the system. This was done in the counting of photon pulses [19], while monitoring the status of bees and counting the colony activity 20], and in counting the number of set bits in an input vector using logic components [21].

However, such systems result in the need to have separate peripherals in including external memory and output displays. Microcontrollers have also been used as controlling devices in a thermal neutron detector to monitor radiation [22], in a phase locked loop [23], and in a lab on chip [24], but mainly with passive infrared sensors whose accuracy can be degraded by heavy rain or snow, and cannot distinguish individuals in a group and changes in a background [25]. As such, most of these systems cannot be implemented in situations where the variable takes long during the sensing stages of the system, and in different weather conditions.

In this work, active infrared sensors were used in the sensing section with one at the entrance, and the other at the exit.



(a)

(b)

Fig. 2. Circuit design of (a) infrared transmitter, and (b) receiver.

Active infrared sensors are not influenced by external temperature and light conditions as they have their own radiation source, they are unobtrusive, easy to install, and can cover a field of view [26].The other parts of the system were the signal conditioning circuit, and a microcontroller used as an up and down counter, as shown in a block diagram in Fig. 1.

II. Materials and Methods

The design methodology employed in the implementation of the microcontroller based football stadium population counter involved block by block design of the sensing section and the microcontroller interface.

A. Sensing system

There were two systems in the development of the active infrared motion detection of the entering and leaving spectators at the entrance and exit points respectively. The active infrared sensing system employed in this work, included a radiation emitting source, also known as an infrared transmitter and a detector also known as infrared receiver. The receiver was sensitive to interruptions in the radiation sensed from the source. The output of the infrared receiver was connected to the microcontroller via a signal conditioning circuit. The purpose of the microcontroller was to count up or down using a high level language program, and display the final count on the seven segment displays. The microcontroller AT89C51 was used in this work as an up and down counter that could change its state in either direction under control of an up–down selector input. The active infrared sensors at the entrance and exit points were designed in a similar way.

1) Infrared transmitter

The infrared transmitter circuit was designed to generate a carrier frequency of 38 kHz to drive the emitted infrared radiations from the emitter to an infrared receiver module TSOP1738 using the 555 timer chip as an astable multivibrator [27, 28]. The 555 timer chip is a bipolar eight-pin mini dual-in-line package (DIP) device consisting of transistors, resistors, and diodes arranged to form two comparators, a flip-flop, and a high current output stage. Pin 1 is ground, pin 2 is the trigger input, pin 3 is the output, pin 4 is the reset, pin 5 is the control voltage, pin 6 is the threshold input, pin 7 is the discharge, and pin 8 is for the power supply [29]. For the design of the astable multivibrator, pin 1 was grounded, pin 2 and pin 6 were connected together to allow the circuit to re-trigger itself on each and every timing cycle, pin 3 was connected to the infrared emitter through resistor R3, pin 4 was connected to the 5V power supply to avoid any unwanted resetting of the timer, pin 5 was not used, pin 7 was connected to the timing resistors R1 and R2, and pin 8 was also connected to power supply. This is shown in Fig. 2 (a).

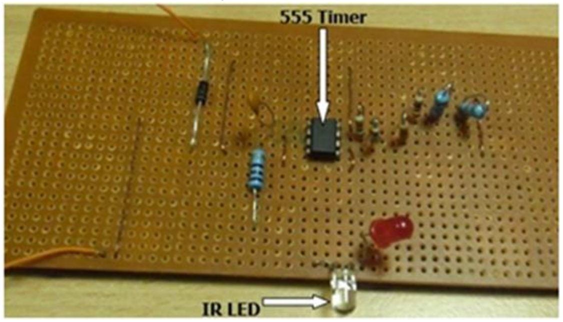
The external components on the circuit were resistors R1 and R2, capacitor C1, and a light emitting diode (LED), that were designed basing on the carrier frequency f, as determined from Equation 1. For the chosen frequency of 38 kHz, R1 was calculated as 222.2 kΩ, R2 as 18.67 kΩ, and C1 as 1 nF and the generated pulse had a duty cycle of 50.2%. The implementation of the circuit is shown in Fig. 3 (a).

2) Infrared receiver

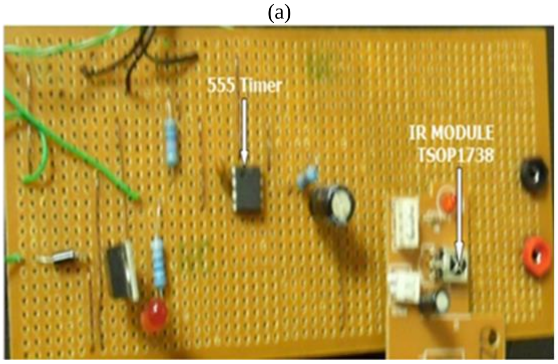
In the design of this block, a 555 timer was used working as a monostable multivibrator with its trigger (pin 2) connected to the output of the infrared receiver module in order to generate a negative trigger to the multivibrator [30]. All other pins were connected as shown in Fig. 2 (b) and the implementation on a circuit board in Fig. 3 (b). The negative going trigger pulse was designed to be shorter than the output pulse width so as to allow the timing capacitor to charge and ;discharge fully. Once triggered the timer stayed high and the time it spent in this state was controlled by the resistor and capacitor values given in Equation 2. The output pulse signal was either ON or OFF depending on the presence or absence of an obstacle between the transmitter and the receiver. The circuit comprised of resistors R3 and R4, capacitor C2, and a light emitting diode LED. R3 and C2 were designed using Equation 2 below such that R3 = 10 kΩ and C2 = 33 μF allowing for a pulse from the receiver to be on for a duration τ of 363 μs. R4 was designed to be 100 Ω.

B. Signal conditioning block

To avoid noise signals from the infrared sensor systems that would prevent the microcontroller unit from giving exact results, a passive filter was designed whose output was fed into the microcontroller system for each of the two sensors.



(a)



(b)

Fig. 3. Circuit board implementation of (a) infrared transmitter, and (b) receiver.

This signal conditioning circuit consisted of a smoothing capacitor and a resistor that helped in removing unwanted signals that would result in multiple counts by the microcontroller for a single detection. The circuit designed for this purpose is shown in Fig. 4 as part of the microcontroller circuit.

C. Microcontroller and display section

The microcontroller AT89C51, a low-power but high-performance CMOS 8-bit microcomputer that was used in this control section, was programmed using the high level language C, and Keil as the compiler [31]. The program was burned into the microcontroller via the USB8051 programmer device [32]. Fig. 4 shows the circuit connection to the display as well as sensing and conditioning sections. The important pins in the circuit connection included: pins 1 to 4 which are bidirectional ports of port 1 that were used as outputs to the seven segment displays, pin 9 used for resetting the microcontroller; pins 14 and 15 which were external inputs from the two infrared sensors systems through the signal conditioning circuit; pins 18 and 19 which were connected to an on-chip oscillator of 16MHz frequency; pin 20 was grounded, pins 21 to 27 which corresponded to some ports in port 2 connected to the displays through resistors; pin 31 which was for external access was connected to the power supply to enable the chip to execute internal programs [33]. Transistors in the circuit were used to switch on the displays so that the microcontroller did not sink or source all the current passing through the light emitting diodes.

III. Results and Discussion

The implementation of the microcontroller, conditioning and display sections is shown in Fig. 5.

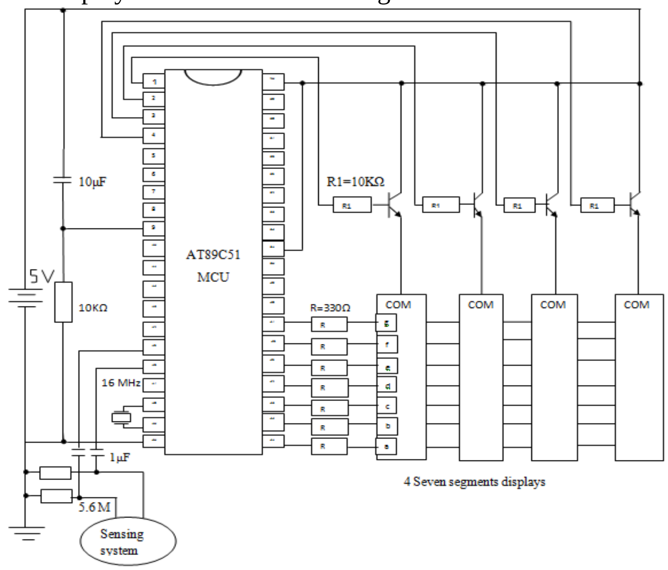


Fig. 4. Circuit of Microcontroller with 4 seven segment displays

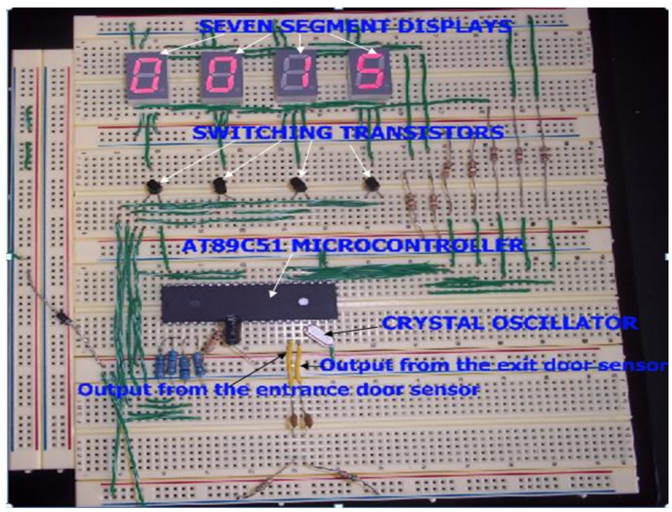


Fig. 5. Circuit of Microcontroller with 4 seven segment displays

The implementation of the sensing systems was shown in Fig. 3. The microcontroller was observed to count up and down depending on the detection at the entry and exit points, and displaying the count at any instance on the seven segment display. When the active infrared sensors at both exit and entry points detected the motion of a spectator they sent high level input signals to the microcontroller inputs, which processed them according to the embedded program, resulting into an increase or decrease of the count that was displayed on the seven segment display.

From the embedded program into the AT89C51 microcontroller, when powering the system displayed 0000 then the microcontroller counted up to 9999 as spectators were detected by the infrared sensor at the entry point of the stadium. The microcontroller counted down to 0000 following the detection of spectators at the exit point. If the sensor system detected a spectator for the first time at the exit door of the stadium without being detected at the entry, the initial value 0000 was shown on the seven segment displays. If at the same time both sensors at the entry and exit points detected spectators at the same time, the seven segment displays retained their value, meaning that there had been no change in the state of the counter. If the microcontroller counted up to 9999 then a spectator was detected at the entry while the maximum count had been reached, that person was not be counted and the displays retain maximum count. This means was interpreted that the stadium had reached its full capacity. In such a situation, cascading additional displays would result into increasing the count or resetting the microcontroller by switching off the power, would allow recounting to occur. The former option was recommended.

IV. Conclusions

A microcontroller was programmed and used in the implementation of a counter that can be used to monitor and display the attendance of a football match by counting up and down spectators as they move in and out of the stadium. This was demonstrated by using active infrared sensors, a signal conditioning circuit, and a microcontroller connected to seven segment displays. By using active infrared sensors it has been demonstrated that detection of human motion is possible and this was made more efficient by making the infrared transmitters and their corresponding receiver modules as close as possible to one another, with a good line of sight, to avoid noise. From these observations, installing the infrared sensors at the entry and exit points of the stadium would result in efficient detection of the entering and leaving spectators, so that the sensed signals can be used to count up and down by the microcontroller with the help of the embedded code, and displaying the result. A maximum count of 9999 was observed although this could be increased through cascading or resetting the microcontroller. Employing other micro-controlling systems including robotics techniques, and then integrating the system onto a microchip, plus improving the display system using liquid crystal displays (LCD) with more output capacity, are some of the areas of further research in this work.

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