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Camera-less Sensing of Human Movements for Eldercare and Security

Anton G Pereira, Liyanage C De Silva, Amal Punchihewa
Institute of Information Sciences and Technology,
Massey University, Palmerston North, New Zealand

Abstract

This paper presents the necessity and possibility of a camera-less human movement detector for elder care environments or home security applications. A simple low cost solution for such an implementation is presented. Main reason for eliminating the usage of a camera is due to the fact that cameras can violate privacy. They also tend to consume a lot of power and processing capacity. In this paper we present a solution to these problems using a simple low power consumption sensor based detection circuitry with the use of a photodiode acting as the 'eye' for the circuit. The paper reports results from the preliminary prototype testing.

Keywords: sensor based detection, detector system, camera-less, human movements

1 Introduction

The necessity for the development of human detection methods in the field of modern health care and security systems has become very popular and essential in our world today. There are many techniques currently being used for human detection. It is necessary to detect the presence of the human in advance before processing the human activities such as falling, standing or walking etc[1].

There are generally two techniques that have currently been researched for human detection namely sensor and camera based detection. Sensor based detection are such as [2], [3] and [4]where infrared sensors and carbon dioxide sensors are used to detect motion and magnetic sensors utilized to detect the opening and closing of doors. An illumination sensor is a type of sensor where once the subject is present, the sensor relies on changes in the environment caused by the subject to trigger a chain of events in the circuit. A more fascinating approach is a system called Cenwits [5] Connection-less Sensor-Based Tracking Using Witnesses. This is a mobile system that emits a signal from time to time using RF communication. When two of these mobile sensors are close to each other, information is gathered such as time and location at that time of the subject carrying the sensor and finally all information is dumped at an excess point. This system would be useful for application in a large area where it being necessary to keep track of individuals.

The second technique is camera based detection and can be seen in [7] where it involves a single camera tracking a number of people. The system works by extracting points and identifying feature points from an image, creates a path and clusters them and finally each of these clusters corresponds to a person. The W^4: Who? When? Where? What? [8] technique relies on the system to solely identify a combination of shapes and sizes from the image segmentation of the monochromatic imagery to identify a subject's presence and its interaction and time. The system in [9] uses multiple cameras to detect human motion by selecting the best viewpoints of the images to extract a maximum amount of information on the individual or multiple amounts of individuals. The results of the system are reconstructions of the human position, normal axis and body size.

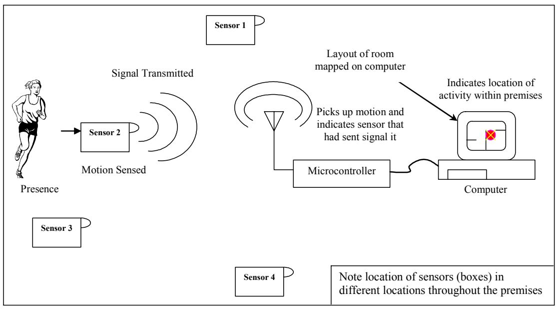

Figure 1: System Overview

2 Approach

In this paper we are aiming at a system which can detect movements in multiple remote locations and communicate the location information into a central controller. A simple system block diagram is shown in the Figure 1. We have developed a system that detects changes in illumination caused in the environment that the system has been placed in. There are all sorts of causes of illumination. The sort of illumination change that we are after is caused by human motion. The system is prone to the effects of slow variations in environment such as the drifting by of clouds and rapid variations such as the light being switched off suddenly hence the necessity for the system to have proper filtering. The block diagram shown in Figure 2 below summarizes the operation of the system.

When changes are initially detected it causes oscillation in the circuit. This is done by the use of a photodiode that picks up the changes and acting as a current source leads to oscillation with the use of an

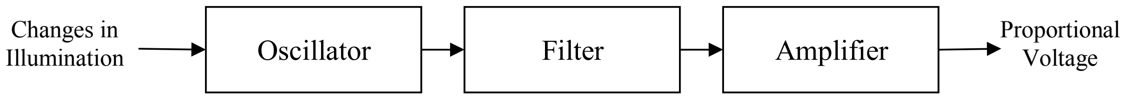

Figure 2: Sensor System Block Diagram

LM 358 operational amplifier (op amp), capacitor and BC584C NPN transistor. Basically this block acts as a controlled oscillator imitating the situation experienced by the photodiode. The output of the oscillation block will be a square wave oscillating at varying frequency.

The next section is an essential part of the system to ensure that the desired frequencies of a certain motion are sensed. Since we had initially designed the system for an eldercare environment, we decided a frequency between 0.1Hz to 20Hz to be sufficient for an elderly subject's detection. Hence all other changes related to the slow and rapid variations will be attenuated by the system. This block essentially consists of a band pass filter passing the frequencies mentioned above.

Finally the amplifier block that consists of an inverting-amplifier configuration which, inverts and amplifies the incoming signal producing a significant enough voltage if a human subject had passed by.

3 Implementation

We had used the circuit simulator, Protel, to perform an in-depth analysis on the system based on ideal conditions. In the circuit simulator, we replaced the phototransistor with a current source setting it to operate on a piecewise linear operation hence we could key in a whole set of current values and the corresponding value of current at that time. The simulated sensor system is shown in Figure 3.

Prior to performing the task mentioned above, we used a phototransistor exposing it to different degrees of lighting and from that we were able to record the resulting current from the different sorts of exposures. These current values were the necessary values to be keyed into our piecewise linear operation table for our simulated current source. Based on that, we attained the input waveform as shown in Figure 4 at the input of the non-inverting op amp A, which is proportional to the current from the phototransistor. There were three sorts of lighting that the system was tested under, excluding the condition when the system was deactivated. This is shown in Table 1 and its corresponding current value at the emitter of the phototransistor.

The method we had used to cause the system to experience motion was by simply walking in front of the photodiode slowly and even at times, for a more significant effect, by intentionally waving our hand in front of the photodiode.

Table 1: Exposed Conditions of Lighting

Lighting Condition		**Estimated Current value, μA**
Darkened room		0.5, 0.51
Natural & Artificial lighting	No motion	Random variation between 45.3 to 45.5
	Motion	Random variation between 17.1 to 45.0

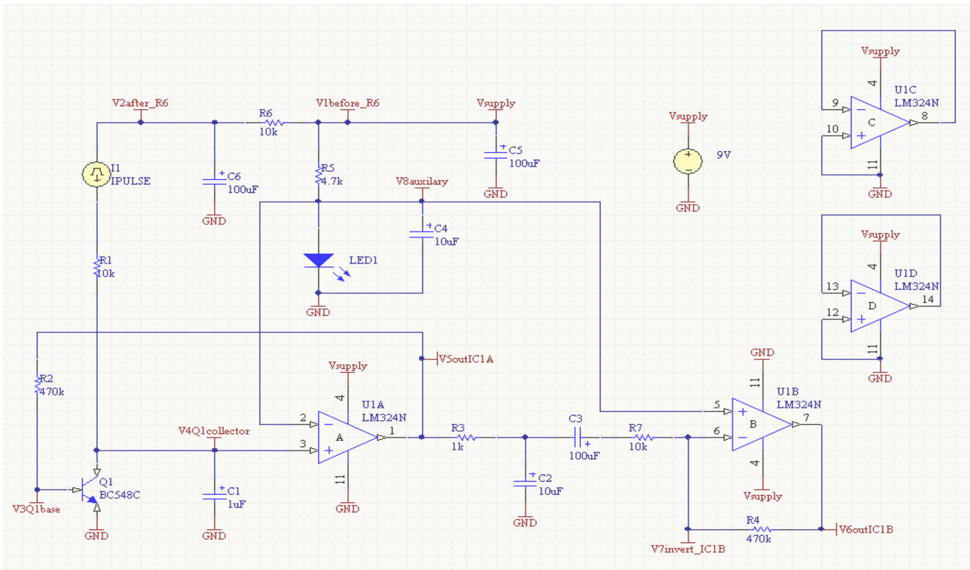

Figure 3: Simulated circuit of proposed system

Now we explain the situation experienced by the phototransistor based Figure 4. Initially at time 0 to about 5ms shows the circuit in a deactivated state. Beyond 5ms is when the circuit is switched on. Up to time 120ms is when the circuit is exposed to a rapid chain of events based on Table 1. Then we had exposed the phototransistor to no motion and all of a sudden, to a darkened room and then back to no motion and the rest of the conditions are quite self-explanatory in the figure itself.

Once the circuit had been through the simulation, we proceeded to construct the circuit on a breadboard to ensure our circuit behaved as predicted in the software simulations and to test all possible problems that the circuit could face when exposed to real world conditions. From the breadboard we proceeded to design the final PCB for the circuit and it was placed in a proper black box to encompass the entire system. There were two LEDs utilized, a green and a red type.

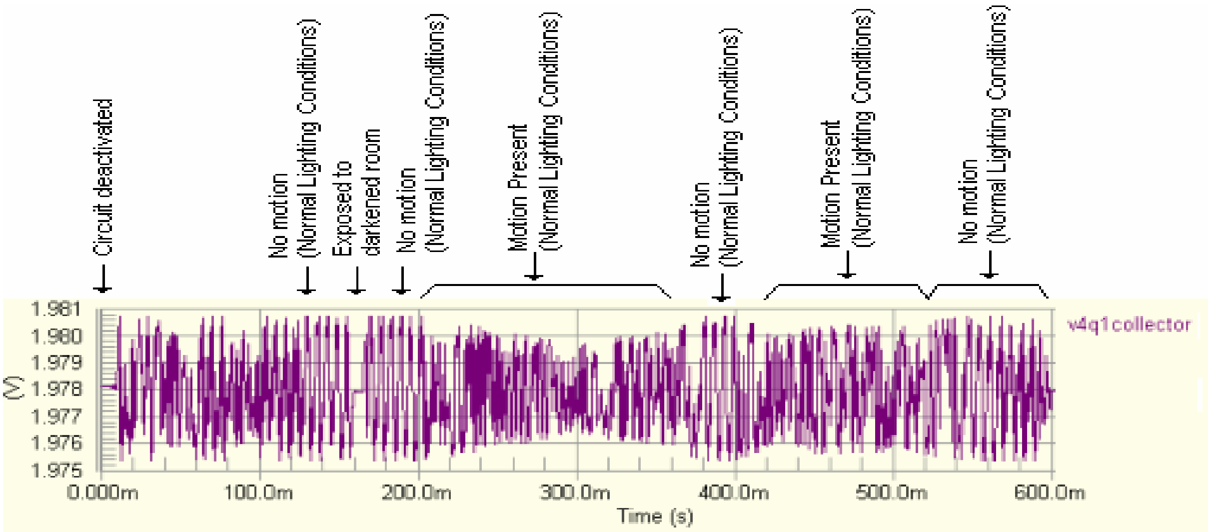

Figure 4: Resulting waveform based on piecewise linear operation of the current source

The former to indicate the circuit was active and the latter to indicate the circuit had picked up human motion. A buzzer was also connected to the circuit for testing that practically turned on when red LED was activated. Two switches were hard-wired to the circuit, one to turn the system ON or OFF and the other to simply enable or disable the buzzer. All these were installed for the convenience of the user when the system was to be demonstrated.

4 Results

Based on the simulated system discussed we had manage to attain valuable information. From the input waveform of Figure 4, the system generates an output as shown in Figure 5 with the input signal once again printed for convenient comparison for the reader. As notice, when motion is present a significant high is also output by the system. Throughout the rapid changes initially till 120ms, there are slight highs but being rather insignificant at that point in time as it is expected to be unable to activate the LED or buzzer. At time 130ms to 200ms is the only discrepancy the system has produced. At a closer look it is noticed a constant voltage value is maintained for a small amount of time. This is likely to have caused the system to output a high. After this time the results are satisfactory as it has manage to indicate when human motion had been detected and under no motion condition remains at zero output value. The amplification section can be adjusted further to raise the gain of the system if needed.

When the system is initially powered the buzzer sounded with the red LED being active briefly for approximately one second. The green LED stayed on as expected indicating the system is in operation. The system was tested under normal lighting conditions mostly during the mornings and afternoons. Once we had moved the circuit about, it made a soft 'tweet' sound every time. With a light source placed in front of the photodiode, not necessary directly in front of it, the buzzer sounded louder than before once we had briefly moved one of our hands in front of the photodiode slowly.

It would be apparent that the system delivers constant results when exposed to a dedicated light source to detect motion. With its own dedicated light source present, the output signal could measure to as high as 7.55V.

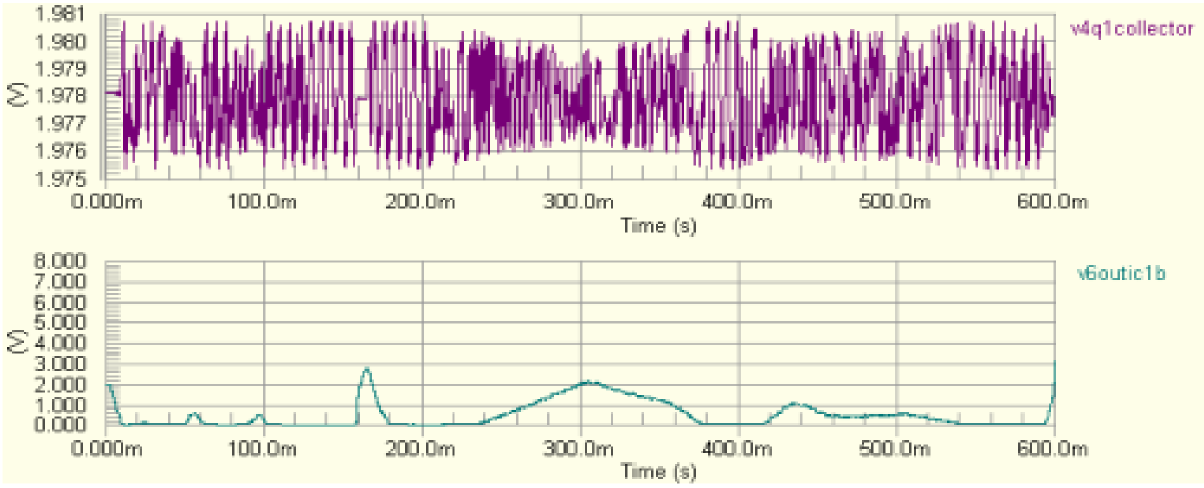

Figure 5: Comparison of input and output signal of the system

Figure 6 is the comparison of voltage waveforms at the input and the output of the detector system. The channel 1 is the input (the upper waveform) which represents the voltage at the emitter (emitter of the current source, I_1, of Figure 3) of the phototransistor of the oscillation block. The channel 2 (the lower waveform) represents the output voltage of the inverting amplifier (pin 7 of op amp B, of Figure 3) of the amplification block, in reference to Figure 2.

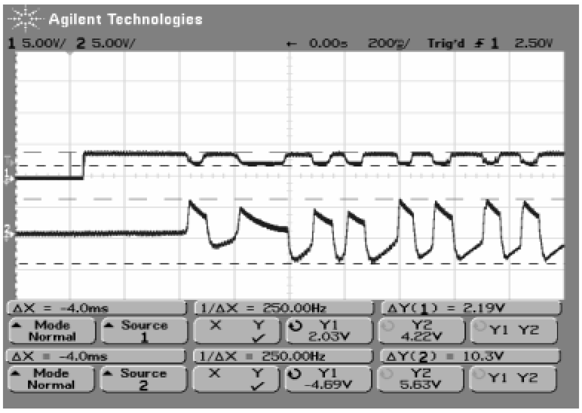

Figure 6: Input and output signal waveforms of hardware implementation

Our presented measurements were from the hardware, measured using an oscilloscope. It basically shows the situation experienced by the circuit when there is motion present with the whole group of spikes corresponding to beeping sounds. The results of Figure 6 were generated by moving ones hand quickly in front of the photodiode.

In Figure 7 we see a pulse caused by the motion of an individual moving in a particular direction. This pulse is the output of a non-inverting Schmitt trigger comparator configuration with hysteresis and the other wave seen in the image originates from channel 1 of the oscilloscope and is the output of the detector system. We had set the reference voltage to vary between two to three volts depending on the light intensity at the time as sensed by an LDR configured circuit.

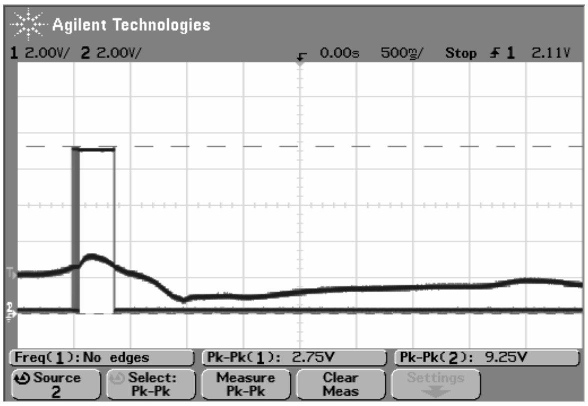

Figure 7: Pulse caused by human motion

In Figure 8 on channel 1 is the output waveform of the of the detector system and on channel 2 is the corresponding pulses to be sent to the microcontroller which is approximately 1V. The waveform shown here was generated by the hand motion in front of the photodiode by waving left to right. It indicates that the hand was moved right twice and left twice being in the order of left to right, right to left, left to right and right to left again.

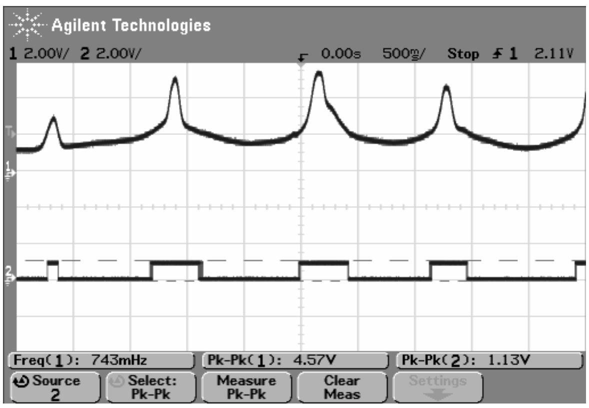

Figure 8: Pulses caused by direct movement of the hand in front of the photodiode

In Figure 9 and Figure 10 shows the final product consisting of the system's PCB encompassed within the black box that was taken care to ensure generated similar results to that of the hardware implementation on breadboard. The PCB was placed inside and held in place by a slot to ensure that no movement of the PCB was possible while the circuit was in transit. It would be undesirable for the PCB to move because as noticed in Figure 9 on the bottom right corner is a small hole for the photodiode to protrude out to receive signals and this photodiode need be held steady at all times.

Figure 9: Exterior of the designed detector black box

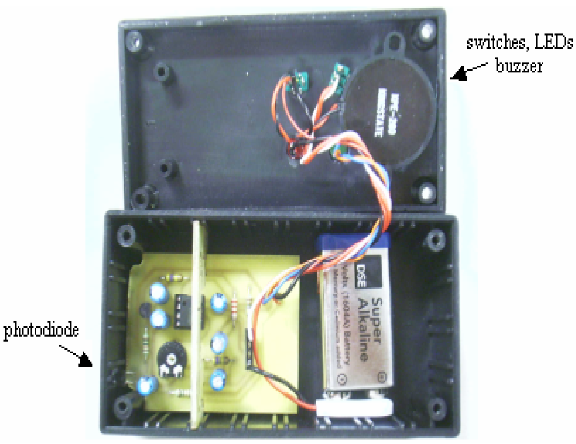

Figure 10: Interior of the designed detector black box encompassing PCB

5 Discussions

The sole dependency for this system to work is depicted by law of physics, where if a body passes a lighted surface, the light would tend to reflect off the body in small amounts causing changes in illumination about the environment, so reflection and refraction would play a major role in this system.
The current system design enables us to keep several detectors in the home of an elderly person and track his/her movements remotely without intruding his/her privacy extensively, compared to the installation of cameras inside the house.

As this research is a new area of human-tracking without camera, we were unable to make a significant comparison of our results with any other similar research work.

For future work, we envisaged extending our detector to be both audio and light sensitive enabling the system to trigger an alarm in a central monitoring station if there were occurrences of unusual behaviours. One of the expected unusual behaviours is elder person's sudden collapse (without having any time to activate his manual alarm). Further we can expect to monitor their health conditions by detecting coughing patterns of the elderly by using an audio sensor.

6 Acknowledgements

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