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Motion Detector Using IR sensors and ARM7 LPC2148

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Abstract - The present work describes the design and development of a reliable and simple automated motion detectordesigned to study motion of an object along linear path by implementation of smart logic and control system based on embedded systems using a microcontroller and IR sensors.The Motion Detector, designed and developed in the laboratory, is built around an advanced 32 bit, low power microcontroller LPC2148 and TSOP sensors and interfaced with computer. The software is developed in C and Visual Basic. The aim of the design is to measure displacement, velocity and acceleration of body moving along straight line and show the graphical representations instantaneously. This will help explain linear motion qualitatively as well as quantitatively. The accuracy of the method was established through its ability to correctly plot the graphs of linear motion.

Keywords - LPC2148 Microcontroller, Receiver, Transmitter, Sensor, Motion Detector.

I. Introduction

Sensors have become a very versatile and integral part of most of our day to day equipment. Sensors are the devices which detect and measure the non-electrical parameters such as position, temperature, pressure, speed, distance, weight, sound etc from the surrounding. They do this by converting the physical parameters into electrical signals which can be measured directly.

An accurate measurement of physical variables is very important in many applications [2]. In modern physics, chemistry, biology and engineering laboratories sensors have more prominence than manual measurements. This paper presents the design of a system which can be used by the laboratories to overcome these problems and provide a better, reliable, accurate and cost effective solution. This system is designed by interfacing object detection sensor with the help of a microcontroller (LPC2148) to the computer. Since, the outputs of the sensors are analog in nature, so, after signal conditioning, they are connected to the A/D converter pins of the microcontroller. The result is displayed on the LCD which is interfaced with the microcontroller. The heart of the circuit is NPX LPC2148 microcontroller. This microcontroller is designed with high performance 32-bit ARM7TDMI-S CPU which has instantaneous emulation and it is embedded on-chip static 40 KB RAM and high speed 512 KB flash memory [98]. It is appropriate for developing applications which require high speed data communication and real time clock for data checking.

The ARM7TDMI-S is a 32-bit high-performance, general purpose microprocessor having less silicon die area and very low power consumption because it uses three stage pipelines to execute instructions [6, 8]. This three stage pipeline technique has independent fetch, execute and decode stages. An exclusive accelerator architecture and memory interface of 128-bit wide and facilitate code execution of 32-bit at the highest clock rate enables high speed 60 MHz operation. It uses Reduced Instruction Set Computing (RISC) principles in its architecture which is much more powerful, faster and simple than the Complex Instruction Set Computing (CISC). The code is reduced by more than thirty percent by optional 16-bit thumb mode with least performance consequence for significant code size applications.

Because it has very minimal power consumption, the LPC2148 micro-processors are ideal for those applications where size of equipment is critical as in access control systems. Since it has on-chip boot loader software, In-System Programming (ISP) and In-Application Programming (IAP) are supported by this system Programming of 256 bytes is possible in 1 ms single flash sector or full chip erase is possible in 400 ms in this microcontroller. These devices are very suitable for communication gateways and protocol converters due to features like serial communications interfaces ranging from a USB 2.0 full-speed device, multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kB to 40 kB. Soft modems, voice recognition and low end imaging, provides both large buffer size and high processing power [4].

These microcontrollers are appropriate for applications in industrial control systems and medical systems due to various 32-bit timers, single/dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO cables with level sensitive external interrupt pins present on it. It also has a low powered real time clock with 32 kHz clock input. On the top of all it has 50 pin expansion header which provides for up to 45 of general purpose I/O pins (0V-5V). Besides all these features this board also provides devices such as LEDs, Buzzer, IR receiver, user switches and a 16*2 LCD for display [4].

II. Design of Microcontroller Based Motion Detector

The motion detector circuit is built with 32-bit microcontroller LPC2148 (Phillips), A stable multi-vibrator, Infrared (IR) transmitter- receiver array, 16 × 2 character LCD, DIP switch, Zener diode, DC power supply. Combination of all above components as per the circuit diagram makes the fully functional system. The circuit is interfaced to computer with serial port (or USB to serial convertor). The block diagram of the motion detector is given in Figure 1.

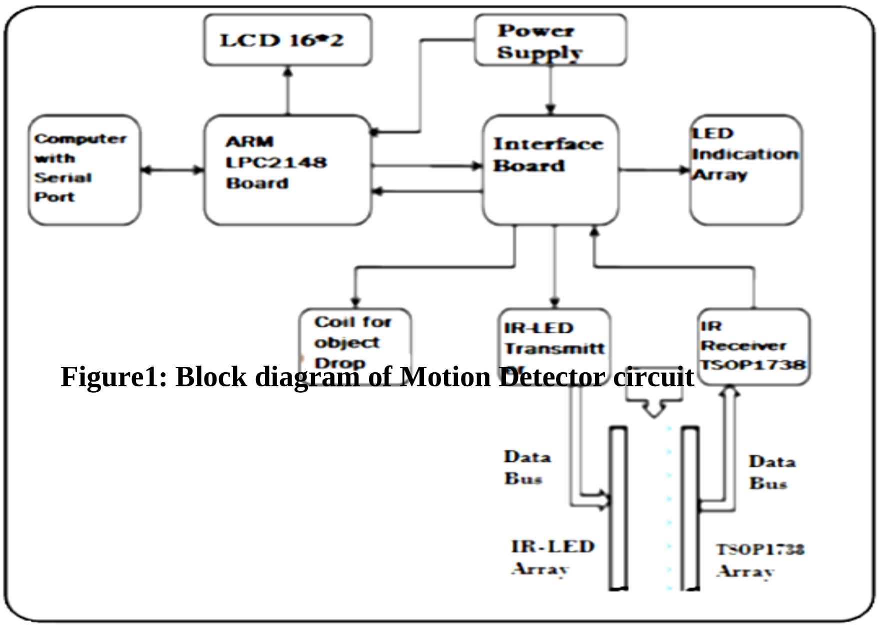

Figure1: Block diagram of Motion Detector circuit

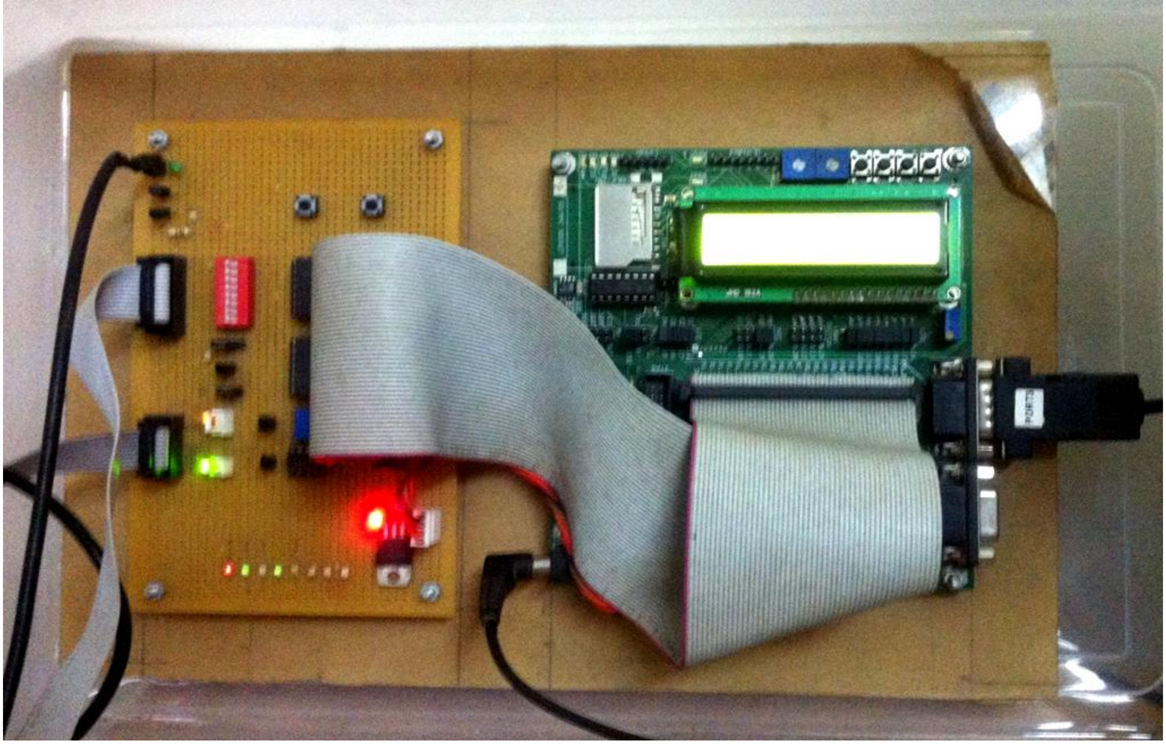

Figure 2: Motion Detector board

In LPC-2148 Microcontroller units most of the pins can be configured to provide different functions, they are multiplexed. All pins of the ports on LPC-2148 microcontroller can be accessed with the help of the 50 pin main expansion header [6]. The expansion header enables the user to interface external peripherals/devices to LPC-2148 microcontroller. It also has a 3.3V supply which can be utilized to power external devices.

The outside physical 'analog' world and the 'digital' world of microcontrollers are connected by ADCs. They are unidirectional that is reading analog data from outside, converting it to digital format and sending it 'into' the microcontroller. The resolution of an ADC is the measure of its accuracy.LPC-2148 has two built-in, 10 bit successive approximation ADCs with input multiplexing among 6 or 8 pins. With the reference voltage V_{ref} of 3.3V on LPC2148 and the ADC set to give the output between 0 and 1023, the maximum 10-bit data the 0V would give output 0, 3.3V (or higher) would give output 1023. A 10-bit ADC of LPC2148 will break the 0-5V range analog voltage in 5/1023 = 4.8mV

It also has power-down mode. The range of the ADCs present in the board is 0V to typically 3V. The 10-bit ADCs with conversion time of 2.44 μs per channel give a total of 6/14 analog inputs, for single or multiple inputs ADCs also supports burst conversion mode.

The LPC-2148 has a 4-bit HD44780 based LCD interface. LPC-2148 has a 2*16 LCD which can display the two lines of16 characters each.

III. The IR Transmitter andReceiverTSOP1738

The TSOP1738 is one of the members of IR remote control receiver series and are the IR filters supporting all major transmission codes. TSOP1738 sensors are miniaturized receivers, used in PCM remote control system and also for detection of object when object approaching within the range of the sensor or is moving between the IR pair sensors.TSOP 1738 sensor module has inbuilt control circuits which amplify the coded pulses which it receives from the IR transmitter. After the signal is received from PIN photodiode a voltage signal is generated. AGC the automatic gain control receives this input signal. The output is again fed back to AGC in order to adjust the gain to a particular level within a given range of input signals. To filter undesired frequencies the final signal from AGC is passed to a band pass filter. From the band pass filter the signal goes to a demodulator and this demodulated output is used to drive an NPN transistor. The output signal from the collector of NPN transistor is obtained at pin 3 of TSOP1738. TSOP1738 is sensitive to 38 kHz frequency of the IR spectrum [3].

The TSOP1738 sensor forms the main constituent of this circuit. The transmitter circuit is designed to sense IR signals of the range of 38 KHz from the transmitter. The Vs is connected to 5V power supply, the GND to ground. The output was taken from the OUT pin of TSOP1738 which is a high signal in the absence IR signals and low output whenever IR signal is incident on TSOP1738.This logic is used in the design of above receiver circuit to detect the IR signals [7].

IR transmitter and receiver circuit is designed using 555 timer IC as an a stable multi-vibrator. As the IC 555 was used as mono-stable multivibrator, the negative trigger to the input pin no. 2 of the 555 IC will result in a high output at the 3rd pin of the IC 555 thus indicating detection of IR signals. To reduce ripples in the power supply a 100µF capacitor C_1 is used. Pins number 1 and 8 of timer 555 are connected to Vcc and GND respectively and are used to give power. Pin number 4 is connected to $V_{cc..}$ It is the reset pin and is active low input. Pin 5 is not used in this transmitter circuit it is grounded through a capacitor to avoid high frequency disturbances through it. It is the control voltage pin. The capacitor C_2 charged to V_{cc} using R_1 and R_2 resistors. It discharges via R_2 and number 7 pin of the IC 555. Resistors R_1, R_2 and Capacitor C_2 determines the time period of oscillation. The voltage across capacitor C_2 is connected to the internal comparators using pins 2 and 6 of IC 555. Output is taken from the pin number 3 of the IC 555.so the a stable multi-vibrator of 38 kHz made using IC 555 timer is appropriate for this [3].Charging time constant of the capacitor is calculated using the expression $0.693*(R_1+R_2)C_2$ and discharging time constant is calculated using the formula $0.693*R_2C_2$. They are almost same in magnitude. The RESET pin of 555 can be used for transferring the binary data [7].

TSOP1738 receives the signals sent by the IR transmitter. The Vs terminal is given +5V signal and ground is connected to GND pin of TSOP1738. The output of TSOP1738 sensor will be active low. The output of TSOP1738 becomes HIGH when no infrared rays fall on it and the output will become LOW when 38 KHz infrared rays fall on it [3].

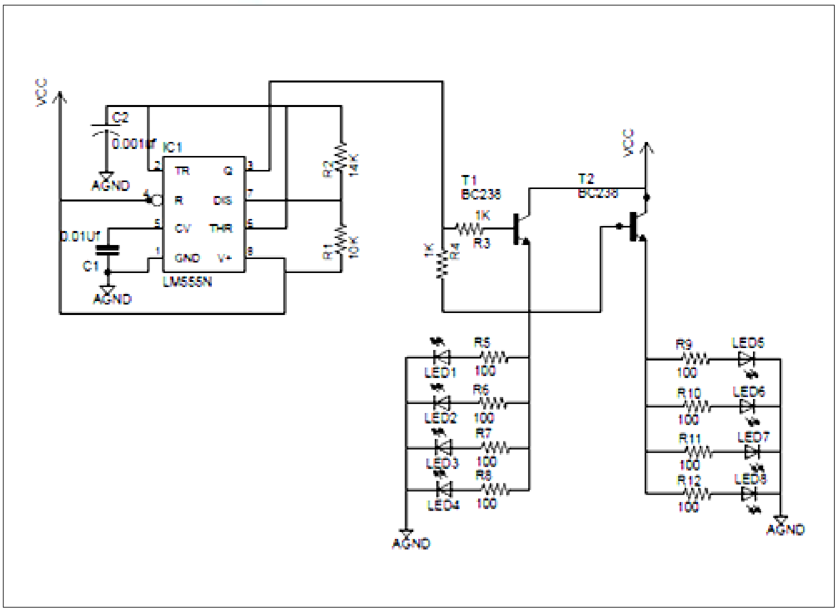

Figure 3: IR Transmitter 38 KHz

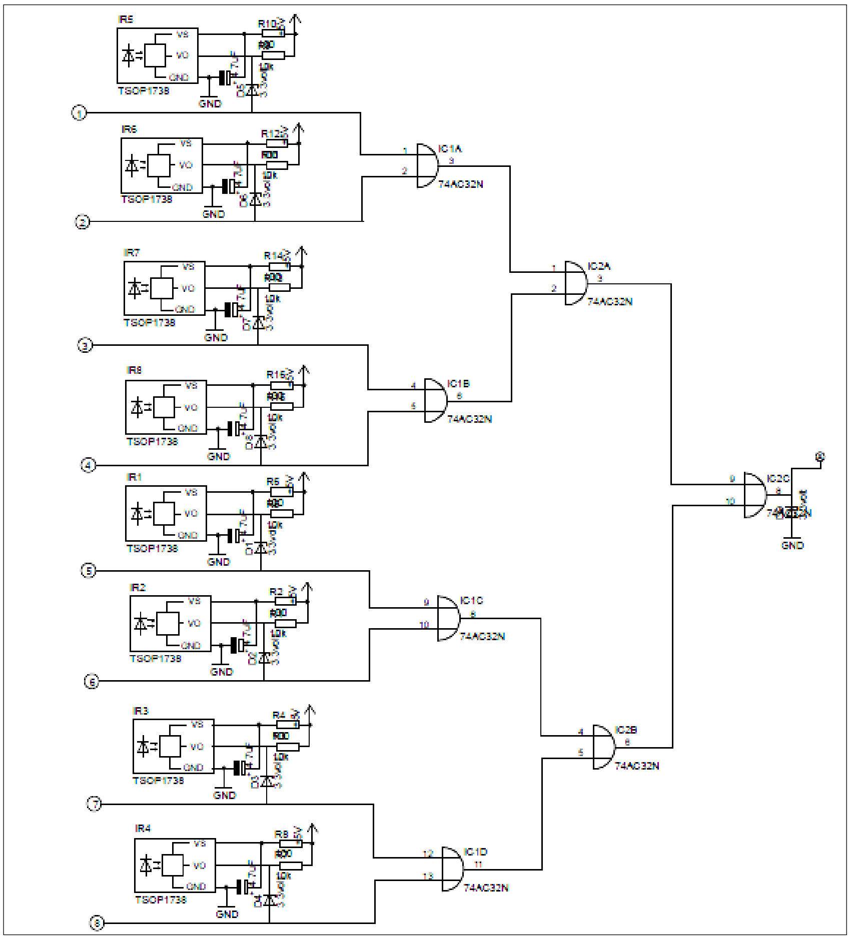

Figure 4: TSOP1738 IR receiver

IV. Working

For detection of moving object we have used standard IR transmitters and IR receivers. In this circuit TSOP1738 IR receiver module is used. For this module the incident light must have data format which is square wave with frequency 38 KHz [3]. IR transmitter with 38 KHz frequency has been designed using 555 Timer IC in a stable multi-vibrator mode as shown in Figure 3.7. The output of a stable multi-vibrator is square wave with ~63.20% duty cycle [5]. The output of the a stable multi-vibrator is directly connected to the eight numbers of 3mm Infrared LED's in parallel to create eight different IR sources. All IR transmitters could be fixed on board along the trajectory of motion with separation as desired. On the other side, eight numbers of IR receivers are arranged exactly in front of the IR transmitter pair wise. An array of IR transmitter-receiver pair is arranged in such way that emitted light from IR LED should fall on the IR receiver. The output of TSOP1738 sensor is interfaced with ARM LPC2148 microcontroller by using two resisters (10KΩ and 300Ω) and one capacitor (4.7µf) in parallel with output and ground. One more 3.3 volt Zener diode connected in parallel with capacitor to regulate output voltage up to 3.3v Volt which protects microcontroller from unwanted voltage spice. Eight outputs from all receivers are connected to the microcontroller directly. All sensor's output are 'OR' by using OR logic gate IC7432. Using combination seven 2-input OR gates we made one OR gate with, 8-input and one output.

When IR light fall on the TSOP, it gives '0' output. But, when light is blocked by object, receiver changes the output state from '0' to '1'. The output state of receiver changes with respect to object position. When object cut the IR ray then output of 8-input 'OR' gate is 'HIGH' and serves as interrupt for

LPC2148.This sequence happens every time when object cut the IR ray. To monitor and record every output change and generate an interrupt we need one ‘OR’ gate having eight inputs - One output. Cascading of eight inputs - one output OR gate is done with 8 number of two input - one output OR gate IC 7432. The high priority external interrupt initialize the 16 bit timers to calculate time between two successive receivers. When this occurs, current counter value in the timer variable is sent through serial port to PC/Laptop with corresponding sensor number. The time measurement accuracy is around 10μSec and it can be improved by using high frequency (40MHz) crystal in PLL mode.

The software is designed using C and Visual Basic to collect sensor data to compute speed and acceleration using distance between the sensors and plots them on the screen as the function of time. The sensor alignment should be perfect and all sensors need to be checked for sending data. The software checks these conditions as well.

When IR sensor array and IR LED array properly mounted and distance between successive sensors is measured, we can switch on the ‘system’. There is an indicator LED in the system which confirms if the IR sensors and receivers are aligned perfectly by giving welcome message on the LCD screen. An indicator LED array is provided on board, where each LED represents unique sensor pair, to check if selected number of sensors is working or not using. When the pair is not working, the corresponding LED does not glow. The distance between successive sensors is entered in the software allows and software takes that distances when we click on “Set Distance” button. Once the sensor alignment is perfect we can select the sensor as per requirement using “Up” and “Down” buttons on the screen. When number of sensors is fixed then reset the system using reset switch and press “Set” button. Then circuit will check if selected number of sensors are working or not using LED array where each LED represent unique sensor pair. One by one all LED ON and again OFF in reverse order. If all sensors are properly aligned, the LCD shows the message ‘Ready to Use’.
Observations are recorded when an object passes in between the array of sensor pairs. The system stores the counter’s count as the object passes the second sensor pair and calculates the time between first and second sensor pair. This time with the distance between the first and second sensor pair generates second data point. In this manner time taken by the object to pass through each consecutive sensor pairs is stored in the system as it passes through the aligned sensors and with distance between corresponding sensors pairs stored in the system generates eight data points for displacement-time graph. Using these data points the software generates three graphs viz. Displacement v/s time, Velocity v/s time, and Acceleration v/s time.The average velocity between two consecutive sensors pairs is calculated using the relation $V_{avg} = \Delta S/\Delta t$. The object can be moved either in forward or backward direction across the sensors. The time between two sensors is measured with an accuracy of 0.00001 seconds (10 μs) which ensures the final result is accurate to three significant figures [1].

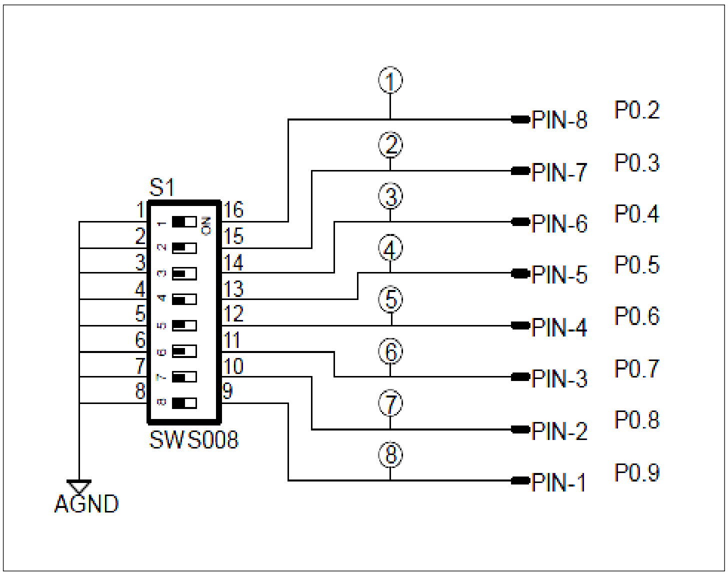

Figure 5: Sensor selection circuit

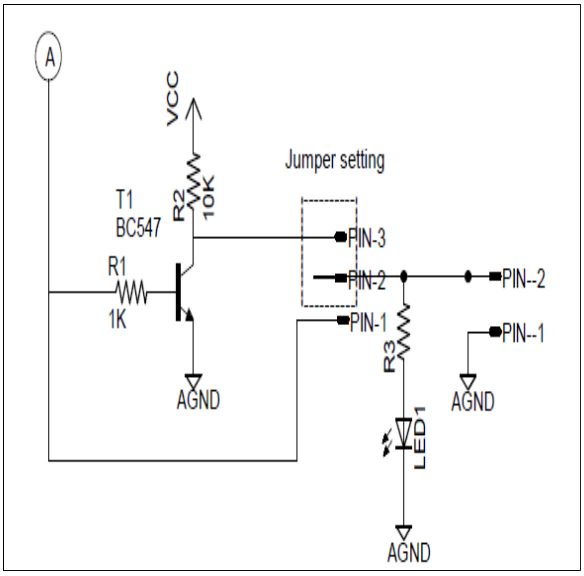

Figure 6: Voltage Regulator 5Volt

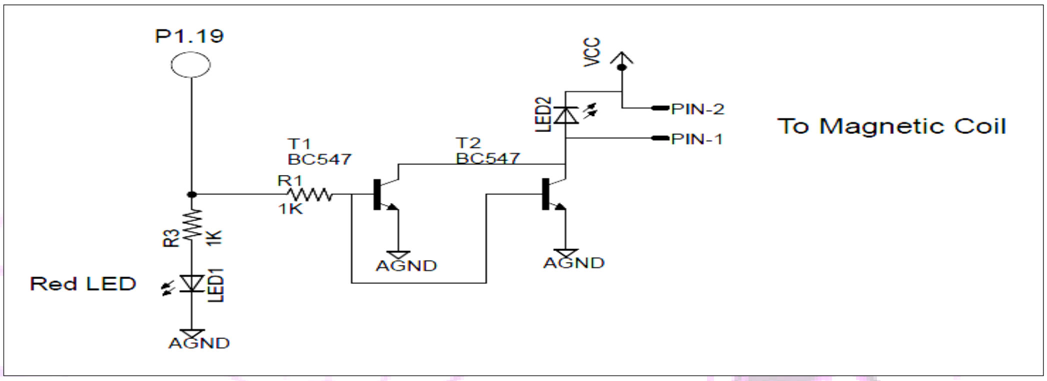

Figure 7: Interrupt Circuit

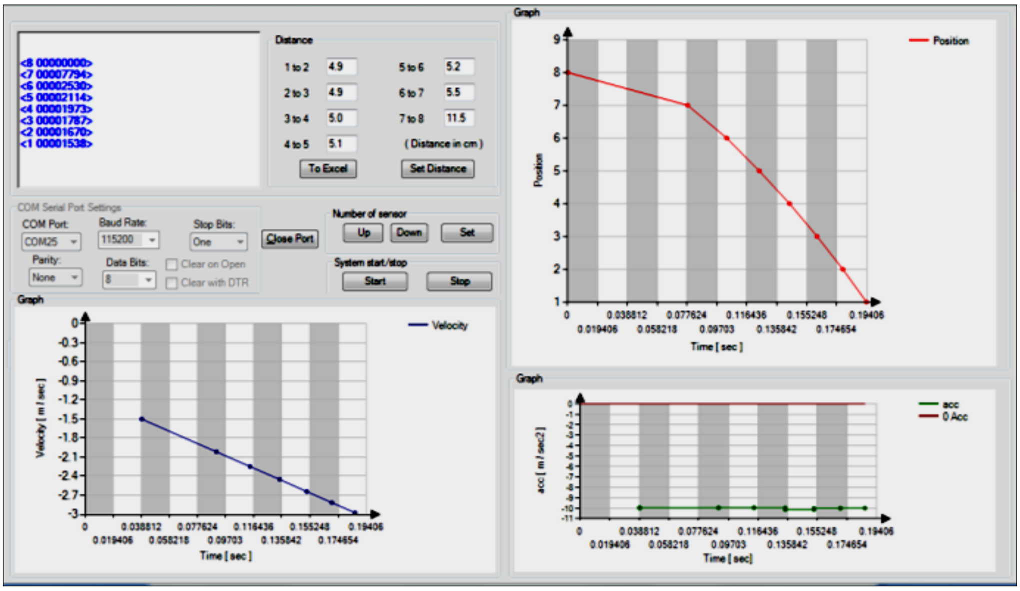

Figure8:Screenshot of the software window

V. Conclusion

The system designed accurately sense motion and show graphs of motion instantaneously. The experimental errors are very minimal and the apparatus enables multiple readings in a very short time. The advantage of graphically visualizing the displacement, velocity and acceleration graphs instantaneously was found to be extremely helpful by students to understand motion of the object.

The accurate performance and validity of the experimental setup is proven by the ease of experimentation, availability of simultaneous charting of results and ability to take multiple readings on very short duration. We believe that such a setup will be very helpful to the students.

The major disadvantage, of this design, is that only one 'function' of the pin can be used at a time and the pin need to carefully chosen in order to avoid losing some required functionality, because the particular pin we need is also being used for some other function. On the LPC2148 64 pins are available, along with the various functions that are physically connected to or are associated with each pin.

VI. References

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