

School of Computing, Engineering
and Physical Sciences

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Infrared Curtain
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I declare that all material contained in this
report, including ideas described in the text,
computer programs and drawings, is my
own work except where explicitly and
individually acknowledged.

Signed

Date

Abstract

This project will explain principles and the construction of an infrared curtain.

An infrared curtain is a safety device usually consisting in two columns with infrared emitters on one and infrared receivers on the other. Lining these columns one in front the other and controlling the electronic components' behaviour it is possible to form an invisible barrier and determine when something has gone through it.

Determining the requirements and the limitations for both the project and the human body is the first step. Then taking into account this requirements different ideas on how to determine when the curtain is crossed with advantages and disadvantages will be shown. Also, some hardware solutions to achieve the result are analysed. Once all the hardware parts are chosen the software is programmed according to it. The program will be explained and commented.

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I would like to thank my family and Sandra for supporting me during the whole year and taking good care of me during the holidays while remembering that I have to work hard.

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1 Introduction

Workplace accidents have been present since the man began manufacturing things, from smashing a finger while cutting a stone axe to die at work while hunting wild animals. It is instinct to protect yourself from injuries, and probably from this instinct was later born the industrial safety.

Since year 400 b.C. Hippocrates suggested the miners to wash after work to avoid lead intoxication, also Plato and Aristotle studied some deformities suffered by some workers with similar activities and how to prevent them.

With the industrial revolution (S. XVIII-XIV), motorized machines and steam power, the number of workplace accidents increased, but the safety devices took some more time to appear. It was in 1877, when Massachusetts ordered to guard the dangerous machinery. From this first guard of hazardous machines to infrared curtains has been a long way, but always towards safety. Infrared curtains are electronic devices that forms an invisible barrier of infrared light. They have different uses, for example they can count people or/and objects crossing them or, placed before a space or object to protect it or people near them. They are common in factories to protect workers from dangerous machines by shutting down these if they detect something going through them.



Illustration 1: Infrared curtain in a factory.

In this project infrared LED's will be used as it is a requirement. The Infrared LED's are LED's made with a chemical compound that emits infrared light. The infrared photo diodes or infrared receivers on the contrary detects the infrared light.



Illustration 2: IR LED and IR Photodiode

To control everything a microcontroller will be used, a microcontroller is a small computer embedded in a single circuit. In this case a Microchip PIC microcontroller is used.

2 Requirements analysis

This project objective is to build a infrared curtain able to detect any object bigger than a 50 pence coin. The measures of this coin is 27.3 mm. To be able to detect that the resolution of the curtain has to be bigger than that.

The use of infrared LEDs is a rigid requirement, they have to be able of radiate over a distance of 1 meter so the photodiode detect the infrared light and be capable to determine if something has crossed the curtain. Depending on the set up of the emitters and the receivers a wider or narrower dispersion angle.

Also the length and height of the curtain are fixed values, those are 1000 mm by 300 mm. This decide the size of the model, with the only chance to make it bigger to allocate any element needed.

The time response of the system has to be enough to detect a human hand movement.

3 Model design

The first and most decisive step was to decide how LEDs and photodiodes would be placed and how to control them, as the rest of the project depends on this decision. Here are shown some of the ideas.

3.1 IR LEDs and IR photodiodes

LED stands for light-emitting diode. LEDs are formed by a semiconductor material doped to create a P-N junction. When this junction is crossed by an electrical current the electrons in the N side find a hole from the P side, falls into a lower orbital around its atom's nucleus, releasing energy in the process. This energy is released in the form of a photon. Depending on the material forming the P-N junction the amount of energy varies, and with this also does the frequency of the wave generated. In the infrared light case, this material is either Gallium Arsenide (GaAs) or Aluminium Gallium Arsenide (AlGaAs). These compounds generate a radiation with a wavelength of 760 nm which correspond to the infrared spectrum.

On the contrary infrared photodiodes generates a current when they receive this kind wavelength.

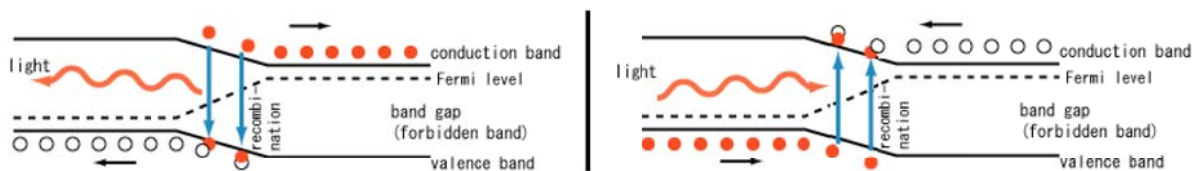


Illustration 3: LED / Photodiode working principle

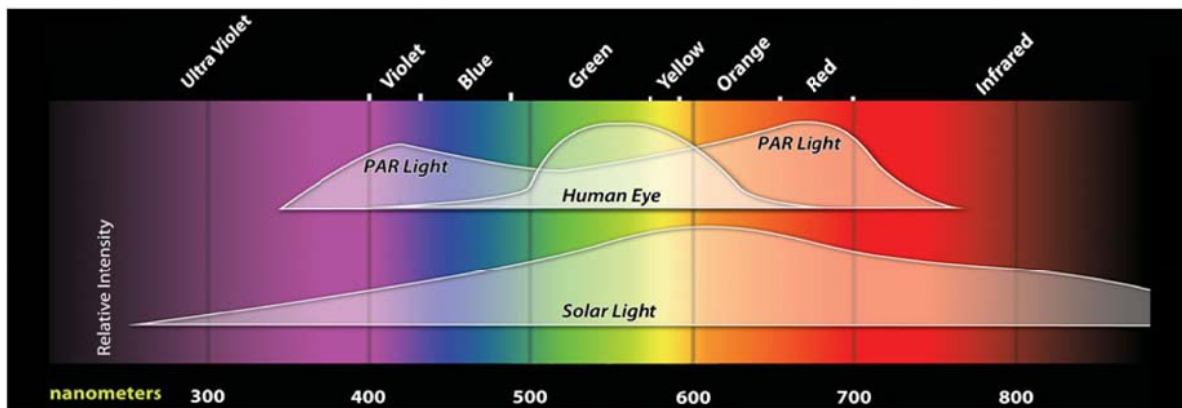


Illustration 4: Electromagnetic spectrum

3.2 Ideas for LEDs' placement and control.

3.2.1 IRLEDs always on.

The first idea is to put a row of IR LED in one side of the frame and power them. On the other side of the frame there should be all the sensors receiving the IR light. This will not work since the sensors will always detect some level of IR coming from different LEDs. In the image below this problem can be observed, when something broke some of the beams could still be detected by the sensors.

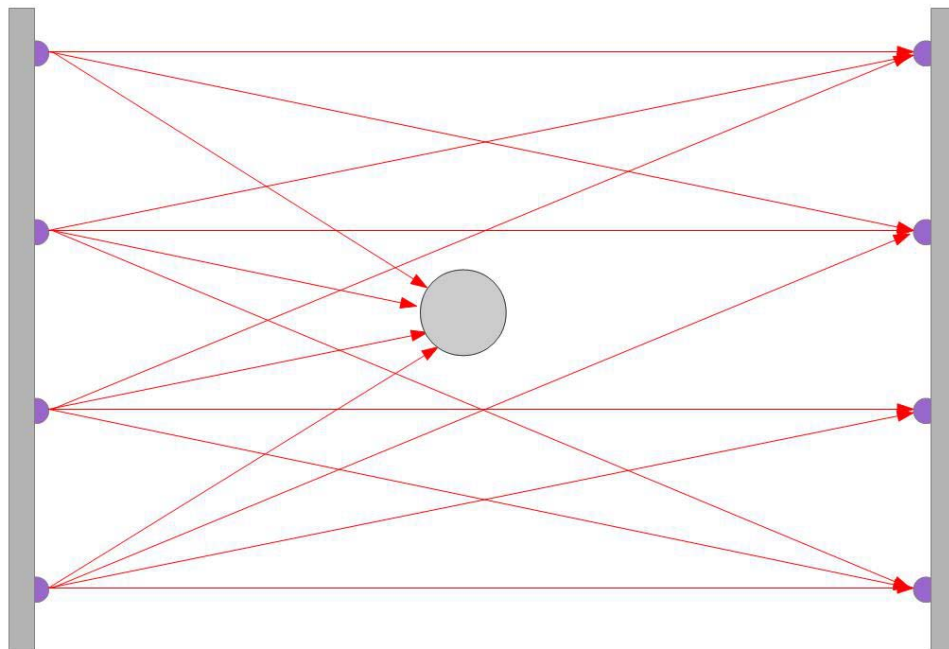


Illustration 5: Problems of always ON IRLEDs

3.2.2 One IRLED with wide angle.

Using only one LED has a simpler control, but has two main disadvantages. They can be appreciated in the following picture:

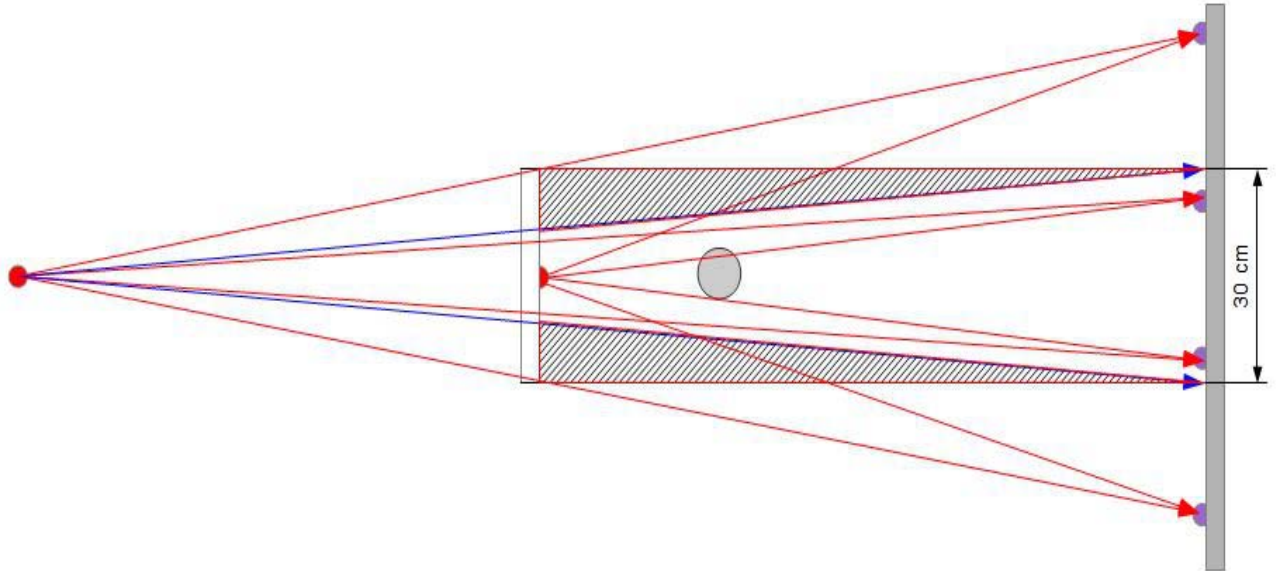


Illustration 6: Problems of one single IRLED.

To know how far the LED must be it is possible to approximate the length of the arc in a circle to a straight line. This is the formula used:

$$L = 2 \cdot \pi \cdot r \cdot \frac{\alpha}{360} \quad (1)^*$$

If the frame of the curtain is strictly 300 mm high, only up to the blue line can be detected, leaving the hatched area free for any object to enter without being detected. Supposing a dispersion angle of 30° ($\pi/6$) for the LED and also re-arranging (1) the LED must be:

$$L = 2 \cdot \pi \cdot r \cdot \left(\frac{\alpha}{360}\right); r = \frac{L \cdot 360}{2 \cdot \pi \cdot \alpha} = \frac{300}{\frac{\pi}{6}} = 570 \text{ mm}$$

That means it is 430 mm after the frame. If the LED is placed in the frame it will spread up to 520 mm at the end of the frame.

* α is the dispersion angle of the IRLED.

If the frame can be bigger than 300 mm, the previous undetected area can be covered with beams. For that the opposite side of the frame should be bigger. To cover the 300 mm at the beginning of the frame the LED must be, rearranging (1), 570 mm away from that edge. The other side must be:

$$L = 2 \cdot \pi \cdot (100 + 57) \cdot \frac{300}{360} = 820 \text{ mm}$$

That is 520 mm bigger than the frame.

These disadvantages make this option infeasible.

3.2.3 Opposite IRLEDs (ON/OFF)

In this set up an IRLED and a sensor alternates in both columns as shown in the picture.

The dispersion angle of the IRLEDs must not be bigger than:

$$\frac{150}{\left(1000 \cdot 2 \cdot \frac{\pi}{360}\right)} = 8,59^\circ$$

This angle can be achieved placing a visor on the LEDs.

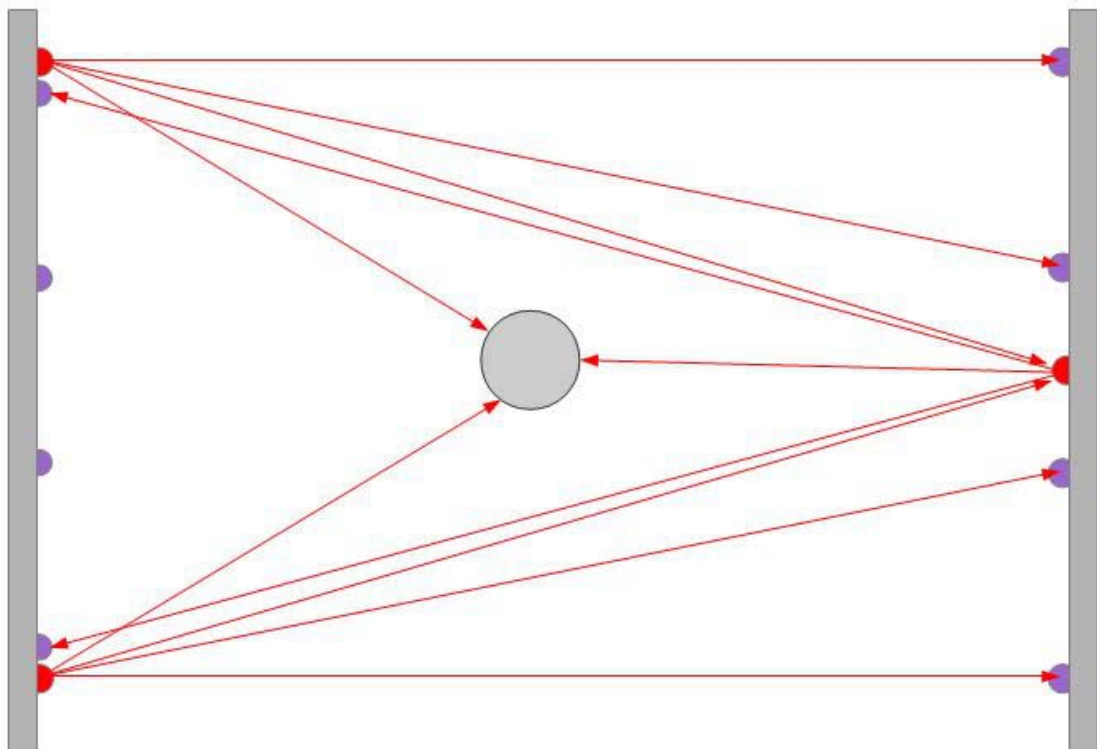


Illustration 7: Opposite LEDs and photodiodes

This set-up requires a more complex wiring than the rest, but it is possible to do a cycle faster.

In this particular case there is no critical need of speed, so this solutions is discarded.

3.2.4 Cycle power on IRLEDs.

In this solution the IRLEDs are powered, one after the other. The IR LED's are all in the same column and the sensor on the other one. In this example even with the same LED positions once one of the sensor does not detect the infrared light the stop signal can be sent to the machine.

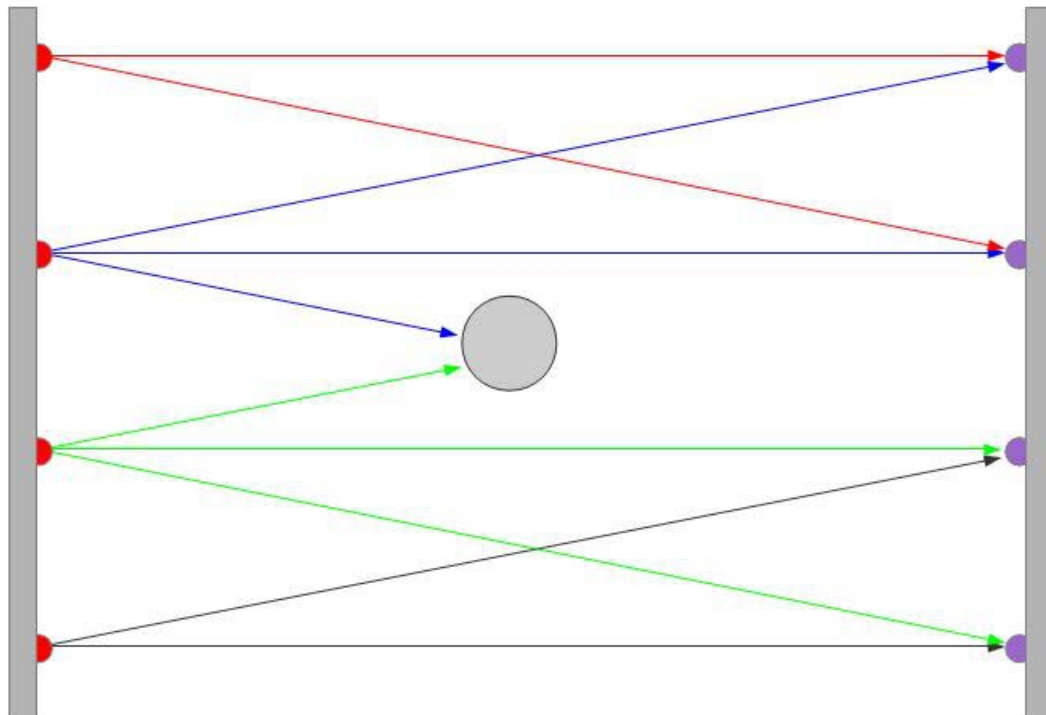


Illustration 8: Cycling LEDs' power

This set up is the chosen since this solutions offers a full coverage of the window and is easier to implement.

3.3 Number of Infrared LED.

The dimensions of the infrared curtain are 1000 mm long and 300 mm high. As it has to detect a 50p coin that has a 27.3 mm diameter, IRLEDs should be positioned at some closer distance.

25 mm is the chosen distance in this project. If the first LED is placed 25 mm from the edge as shown in the next image a total of eleven LEDs will be needed.

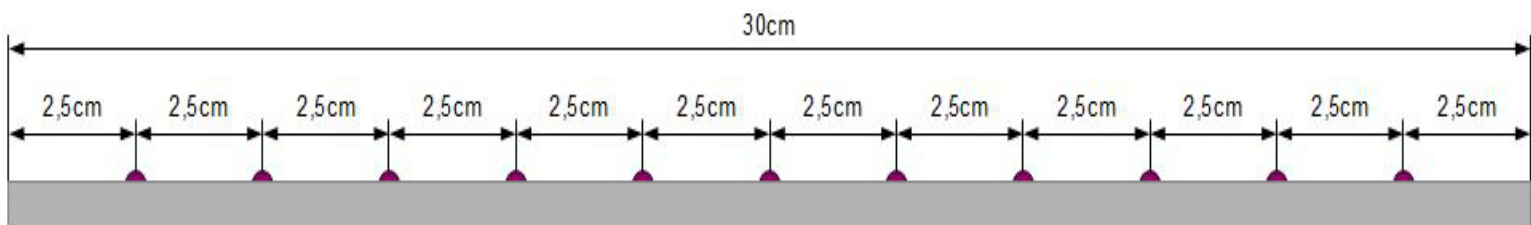


Illustration 9: LED Placement

3.4 Sampling frequency.

This project's objective is to detect anything bigger than a 50p coin moving as fast a human hand. As recorded by the Guinness World Records the fastest hand movement was performed by John Ozuna, achieving a speed of 69.6 km/h (19.333 m/s) with a left hand jab (a jab is made by throwing a fist straight ahead fully extending the arm).

As the infrared curtain frame is about 5 cm (0.05m) it would take to Ozuma's hand a bit more than 2.5 ms to go through it. Therefore the refresh rate of the curtain should be $1 / (2.5 \text{ ms}) = 400 \text{ Hz}$ for each IRLED, that is $400 * 11 = 4400 \text{ Hz}$ for the micro controller to be able to check all the LEDs on time.

3.5 Flowchart:

The program running in the micro-controller has the following flowchart.

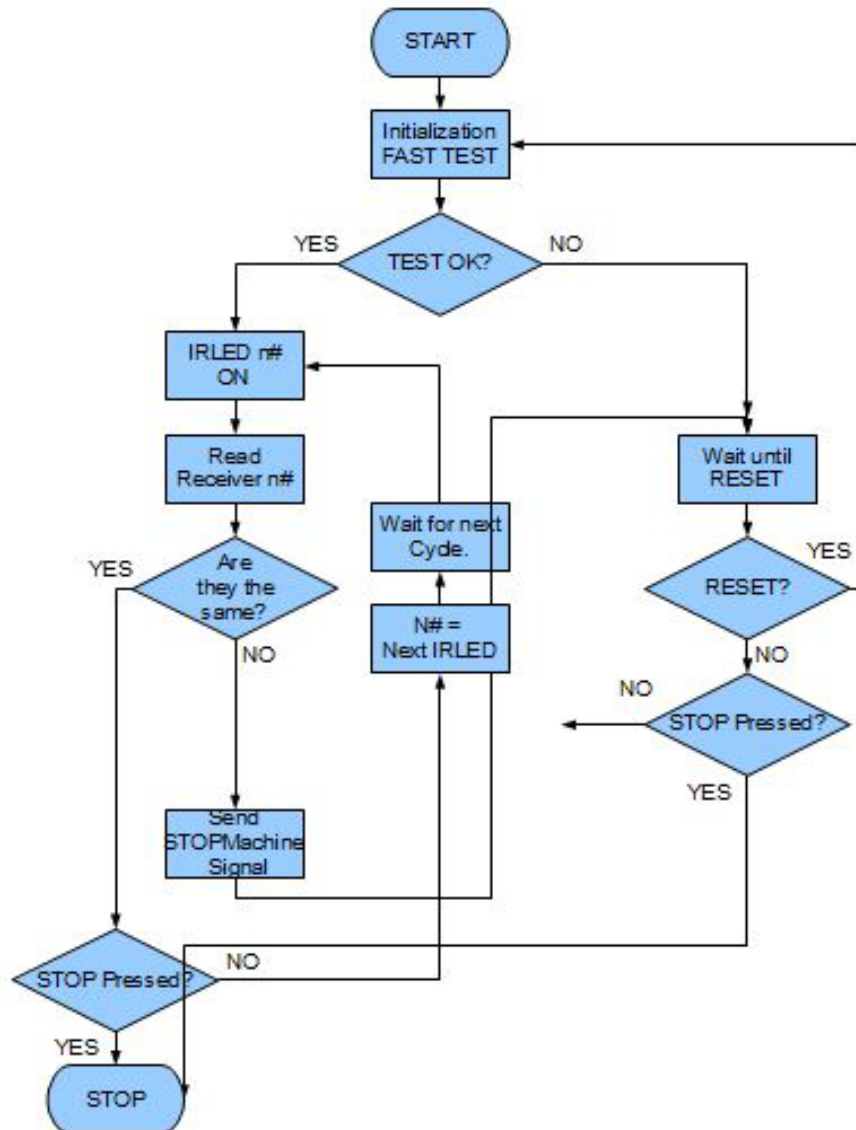


Illustration 10: Program flowchart

During the Initialization a fast test was performed to check that all the LEDs and receivers are working and/or the frame does not contain anything blocking the IR beams. To achieve this every LED will be turned ON one by one and then checked if any receiver has detected it, after that, the maximum number of LED allowed by the micro-controller will be turned ON and the output of the receivers will be read by the micro-controller.

·If this test fails the program will go to the “RESET?” loop explained bellow.

If this test is successful the main program will start, cycling through every couple of LED-receiver in order, until one of the beams is cut. That will mean that something has gone through the curtain and a STOP signal will be sent to the machinery behind or bellow the curtain.

The system will remain in this state until the RESET button is pressed. When this happen the program will return to the initialization part, the test will determine if there is something still breaking the beams or a LED/receiver has broke during the run time of the program. If there is it wont start and go back to the “RESET?” loop.

LEDs will rotate in one direction UP -> DOWN to maintain the time between without checking that time to a minimum.

3.6 Circuit Design.

There was another choice to do at this point of the project:

- Digital circuit:

This method was discarded very fast due to the resulting design was too complex, is would made use of a high number of logical gates cluttering the PCB, and the final circuit would be hardly expandable.

- FPGA:

A FPGA can be programmed as if it was the digital circuit from the previous point, also they are re-programmable, so the code can be changed in the future. Due to the lacking knowledge on this matter this solution was also discarded.

- Micro controller:

This last option usually can be programmed in Assembly language and in C language, allowing greater flexibility in a future expansion or improvement. Previous work with different micro-controllers tipped the scale in favour of this solution.

3.6.1 Main Board.

The central part of the circuit for this project is the PIC microcontroller. Around it are placed the rest of the components. The main board will allocate this PIC and any other components required to make it work.

On a first visit to Stores CM 107 the PICDEM 2 DEMO BOARD was chosen over the PICSTART PLUS due to the fact that this last one only has serial connectivity and the laptop used on this project lacks this interface.

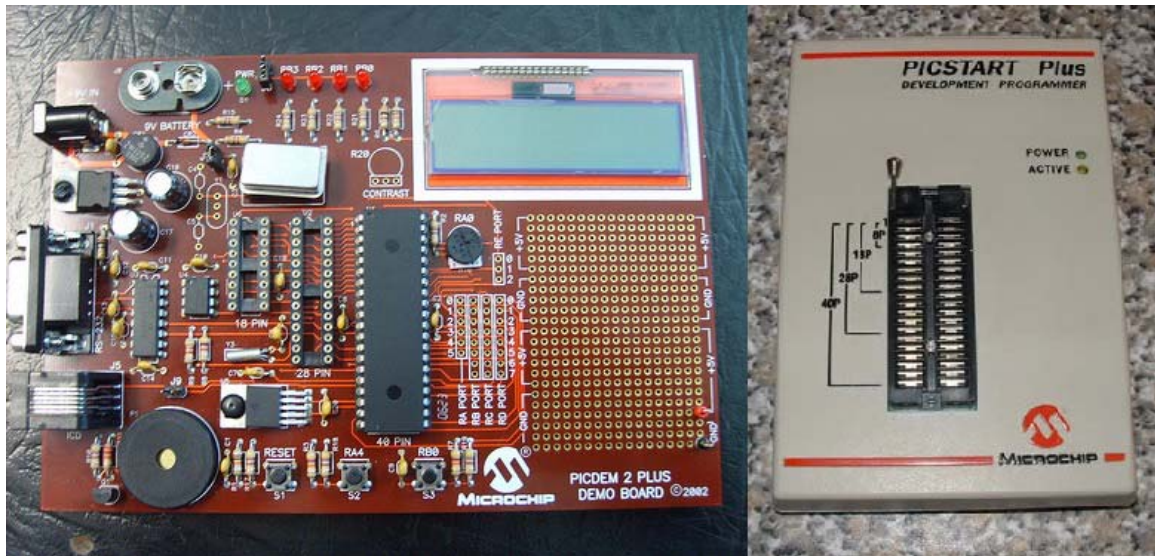


Illustration 11: PICDEM 2 PLUS and PICSTART PLUS

After a couple of days testing and searching over the internet information about an error occurring when trying to establish a connection between the device and laptop it is discarded. This specific version of the PICDEM 2 PLUS does not support 64 bit operating systems, which is the operating system version on the laptop and also on the computers in the C&T building laboratories.

After this hitch with the development board the decision to buy a model known to work on Windows 7 64bits edition. The model is the PICKit 3 Starter Kit with PIC16F1829 and PIC18F14K22. The reasons to buy this model are:

- Works on Windows 7 64bits Ed.
- Low price and student discount available if bought directly from Microchip.
- Supports a wide range of PIC microcontrollers.
- Can order extra PIC16F1829 in case one get damaged.
- Recommendation from a colleague.



Illustration 12: PICKit3 Starter Kit

The PIC used in the project was the PIC16F1829, it is an 8 bit micro-controller manufactured by Microchip and included in the Starter Kit purchased. This μ Controller has 20 pins in a DIP package and since 11 IRLEDS and 11 IR are needed, exceeding the numbers of pins. To reduce the use of a multiplexer and a demultiplexer is required.

A demultiplexer is a device that can forward a single input signal into different output line depending on the binary number on its selector inputs.

A multiplexer on the contrary can forward different inputs into a single output line, also depending on the selector lines value.

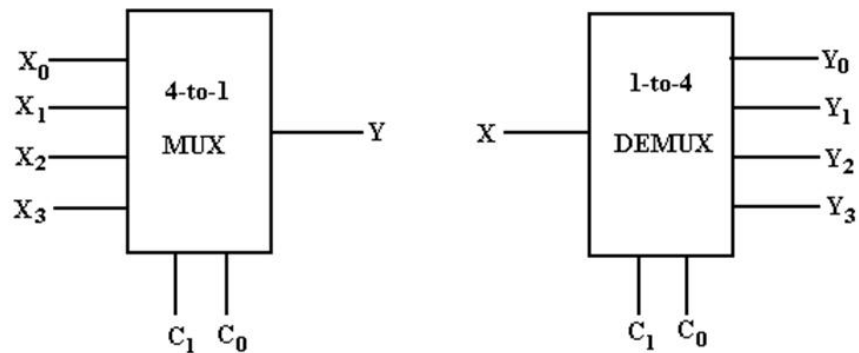


Illustration 13: Multiplexer and demultiplexer

On a later visit to Stores, the multiplexer / demultiplexer 74cd4067 was acquired. This dual usage of the same integrated circuit makes easier the implementation in the project as only one datasheet has to be studied. Next step was determine the selector line combination used to control eleven outputs/inputs. For that the next table was made.

Binary code	Decimal number	LED number
0000	0	1
0001	1	2
0010	2	3
0011	3	4
0100	4	5
0101	5	6
0110	6	7
0111	7	8
1000	8	9
1001	9	10
1010	10	11
1011	11	-
1100	12	-
1101	13	-
1110	14	-
1111	15	-

Table 1: Binary to Decimal

With this the number of I/O pins have been reduced from 22 to only 10, 4 to control the multiplexer, 4 for the demultiplexer and one for each with the data. As the IRLED and the IR receiver that will be ON have to be in the same height the multiplexer and the demultiplexer can share the selection lines, reducing even more the pins needed down to 6. It is still possible eliminate another cable coming out from the micro-controller since the demultiplexer input line will be always set as ON, it can be connected to Vcc, and with this the current demand from the μC is reduced. This number of free pins can be used to expand the capacity of the system, for example it is possible to add five more LEDs to get a bigger curtain by just typing a few lines of code in the program, and if a new version of the main board includes a bigger multiplexer (6 control lines to 64 outputs) or it can manage more curtains (11 total free pins, can manage up to 5 more curtains with individual STOP signal.)

Some other components had to be included in this printed circuit board or PCB to complete the requirements or to add functionality. These elements are a Stop signal, a Reset button, coupling capacitors for each IC and one connector header for both multiplexer and demultiplexer.

To simulate the Stop signal a red LED was wired to the PIC, the Reset button was also wired to a free PIC's pin. The $0.1\ \mu\text{F}$ coupling capacitors were included to ensure a constant voltage on the PIC and the multiplexer.

The circuit was designed using Proteus ISIS v7.7.

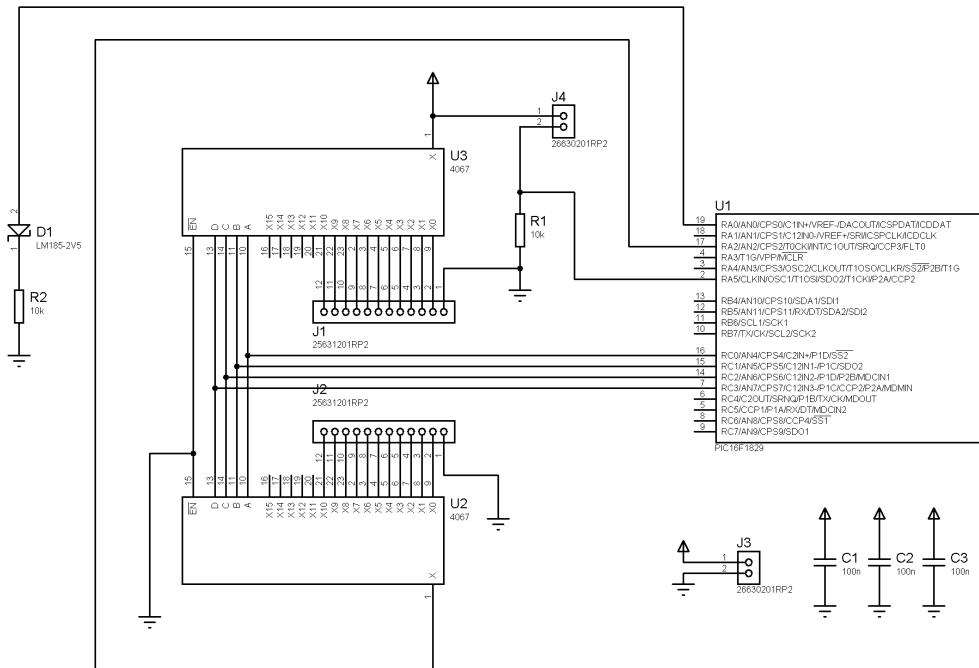


Illustration 14: Main board schematic

Once the schematic was done, the circuit design had to be transferred to ARES, the PCB design program of Proteus. Once every component was located and connected it was shown to the staff in Stores to confirm it was OK according to their requisites. It was not fully compatible with the manufacturing process used, so a minor changes had to be done in order to the PCB be made.

This changes were:

- Increase the width of the tracks.
- Increase the copper area in the pads.
- Minimise the number of tracks on the TOP side of the board.

After these modifications the layout was send to fabrication.

With the PCB retrieved from Stores, it passed a fast check out, and two holes were missed. Also a flaw in this design was noticed, the red LED that simulates the STOP signal was also missed. Later on that day a second version of the PCB with even bigger pads was sent back to Stores.

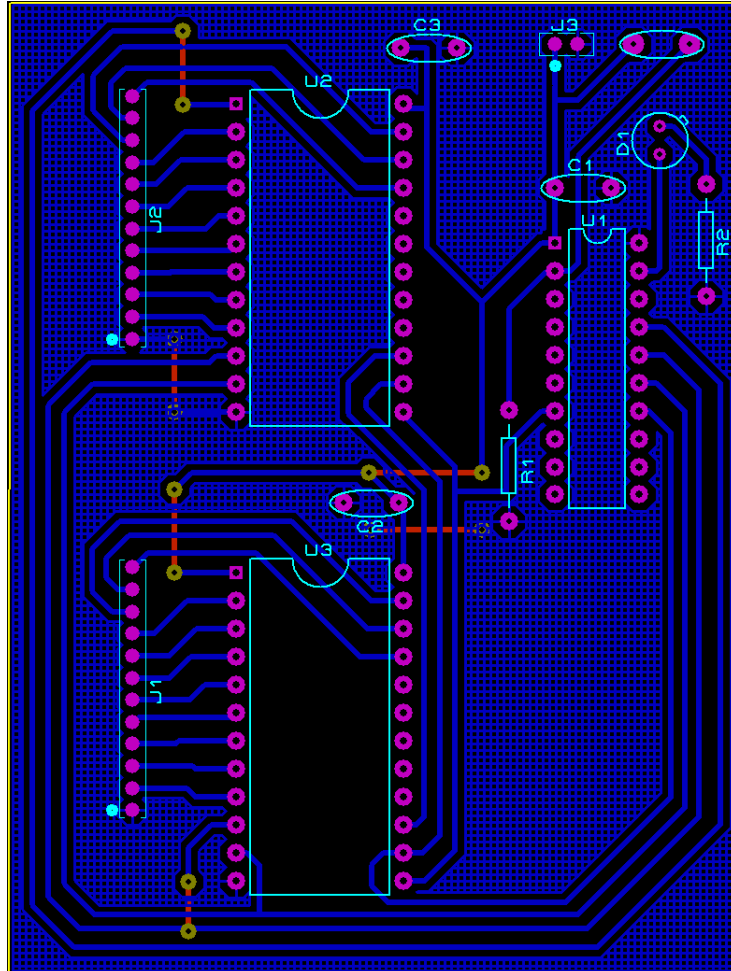


Illustration 15: Main board PCB Layout

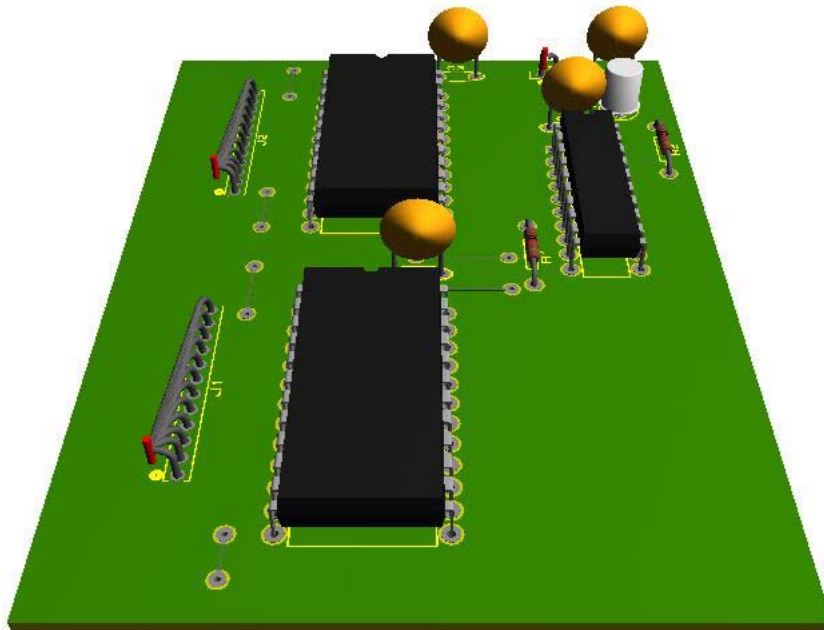


Illustration 16: Preview of the main board

3.6.2 IR Photodiodes Boards.

The reverse current of the IR photodiodes is extremely low as shown in the next illustration.

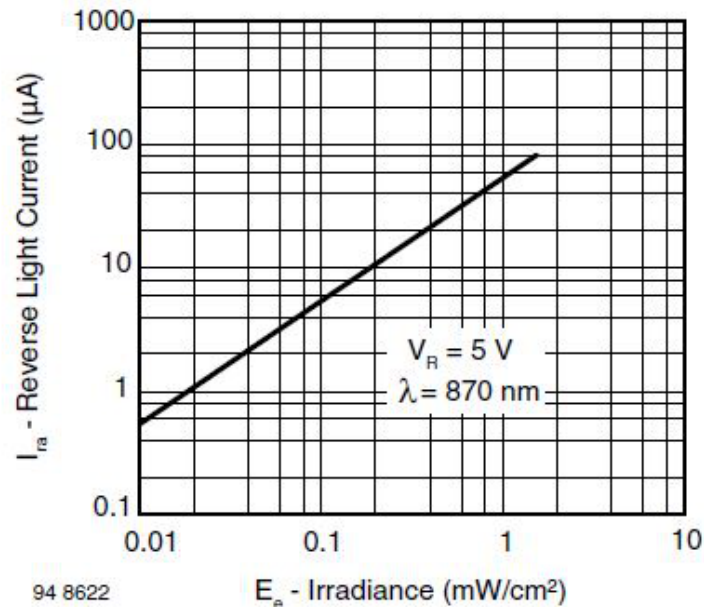


Illustration 17: Current vs. Irradiance on a photodiode

To solve that a simple circuit was designed on ISIS to be connected with every IR photodiode. This circuit amplifies the low current generated by the photodiode when lit with IR light. The value of the resistor R_{BE} was calculated according to this formulas to suppress the dark current influence.

$$R_{BE} < \frac{V_{BE}}{I_d} ; R_{BE} > \frac{V_{BE}}{I_p - \frac{V_{CC}}{R_L \cdot h_{FE}}}$$

According to datasheets the average dark current I_d is 1 nA, reverse light current I_p typical value is 55 μ A, h_{FE} standard value for the S8050 transistor is 50 while the V_{BE} is 1.4 V and the voltage supply V_{CC} was 5 V. Fixing R_L to 10 k Ω the value for R_{BE} had to be bigger than 31.11 k Ω , and smaller than 1.4 M Ω . The value chosen finally was 33 k Ω .

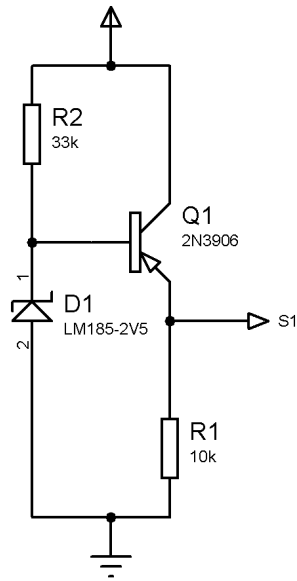


Illustration 18: Current amplifier schematic

In order to fit the size of the board within the Store limits the eleven photodiodes were split in three PCBs, two containing four photodiodes each and the other with three.

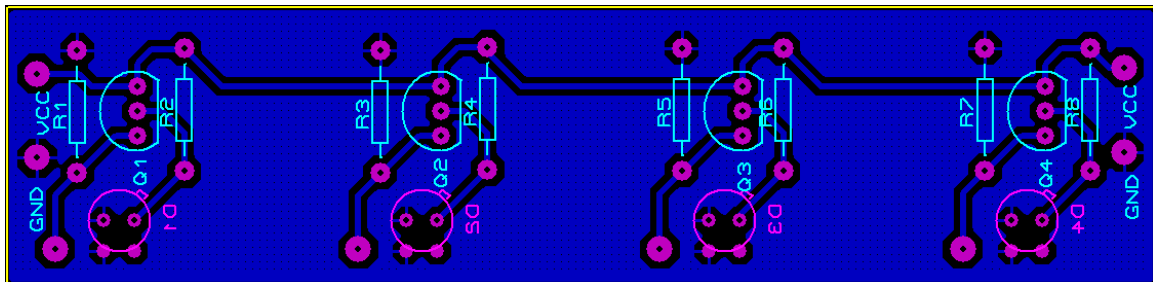


Illustration 19: 4 photodiodes PCB Layout

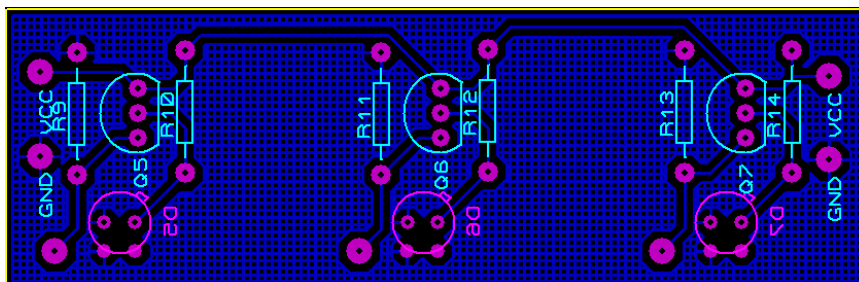


Illustration 20: 3 photodiodes PCB Layout

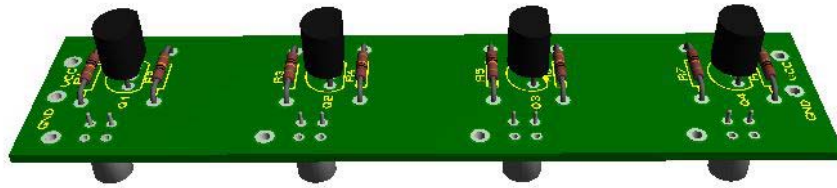


Illustration 21: Preview for 4 photodiodes PCB

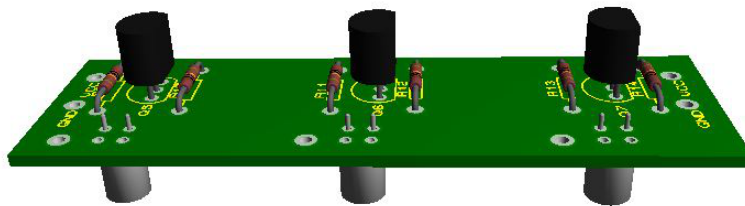


Illustration 22: Preview for 3 photodiodes PCB

Note the photodiodes were located on the BOTTOM side of the PCB, the reason for this will be explained in a later point.

3.7 Program Design.

The PIC microcontroller was programmed using the integrated development environment provided by Microchip, MPLAB X IDE V1.70. This IDE allowed the use of C programming language, which made a lot easier the work required to program the PIC than what it would had if programmed in assembler code for PIC. The program was build according to the flow chart in chapter 4.3.

The first part of the program is the PIC set up. This part was executed once by the MPLAB and it configured the I/O ports.

```
void main(void)
{
    bit TESTOK;
    OSCCON = 0b00111000;           //500KHz clock speed

    //PORT A configuration
    TRISAbits.TRISA2 = 1;         //switch as input
    TRISAbits.TRISA5 = 1;         //switch as input
    TRISAbits.TRISA0 = 0;         //switch as output
    ANSELA = 0;                   //PORT A digital switch

    //PORT C configuration
    TRISC = 0;                     //all LED pins are outputs
    LATC = 0;                       //sequence start on "0"
```

Text 1: Initialization code

The next part of the program was designed as a test to make sure all the LEDs and the photodiodes work properly. This section of the program is executed as it is connected to a power supply.

It goes through the first while loop powering one LED after the other and check if it is received by their own photodiode. until until all the LEDs have been tested. If any LED fails it is not detected by the μC and it makes the red LED blink at 2 Hz as many times as the number of the LED that had failed and then it stay in the last while loop on line 19 until the reset button is pressed and the test runs again.

```
1  TESTOK=0;
2  LATC = 0b00000000;
3  while (!TESTOK) {
4      __delay_ms(5);
5      while (LATC > 0b00001011) {
6          if (inPIN == 1) {
7              LATC = LATC + 1;
8              __delay_ms(5);
9          }
10         if (inPIN == 0) {
11             LATC = LATC + 1;
12             while (LATC <> 0) {
13                 LATC = LATC - 1;
14                 LATA0 = 1;
15                 __delay_ms(500);
16                 LATA0 = 0;
17                 __delay_ms(500);
18             }
19             while (!Reset) { }
20         }
21     }
22     TESTOK = 1;
23 }
```

Text 2: Test LEDs code

If the initial test is successful the program continues onto the next loop where it keeps checking in the same way the test does if the curtain is broken.

```
1   while (TESTOK) {
2       __delay_us(1);           //delay for AT LEAST 1 us
3       if (inPIN) {
4           LATC = LATC +1;       //decrement 1 the value of PORT C
5           if (LATC == 0b00001011) { //when 11 are off, restart.
6               LATC = 0;
7           }
8       }
9       if (!inPIN) {
10          TESTOK = 0;
11      }
12  }
```

Text 3: Main loop code

Once the program were loaded into the microcontroller's ROM, when it is powered it will boot up and start running the program that can be resumed like this:

```
1   While (1) {
2       Initial Test
3       Main Loop
4   }
```

Text 4: Program structure

The μ controller is running at 500 kHz, and one instruction is executed in 4 clock cycles, so one instruction equals to 0,8 μ s. The main loop consist of 5 instructions maximum, it will take 4 μ s to light a LED and read the photodiode. 44 μ s to perform a full cycle, that meas it check the curtain at 22 kHz, more than 5 times faster than the requirement of 4400 Hz.

3.8 Frame Design

The frame of the curtain is the structure where the LEDs and the photodiodes are secured, so it had to be built in a robust material. Observing last year student's frame structure for this project was a big help on the design of this frame. On that model the devices were placed in a metal covered PVC strip installed vertically in a slot carved in a piece of wood. This assembly looked unstable and with a high percentage to not line-up properly.

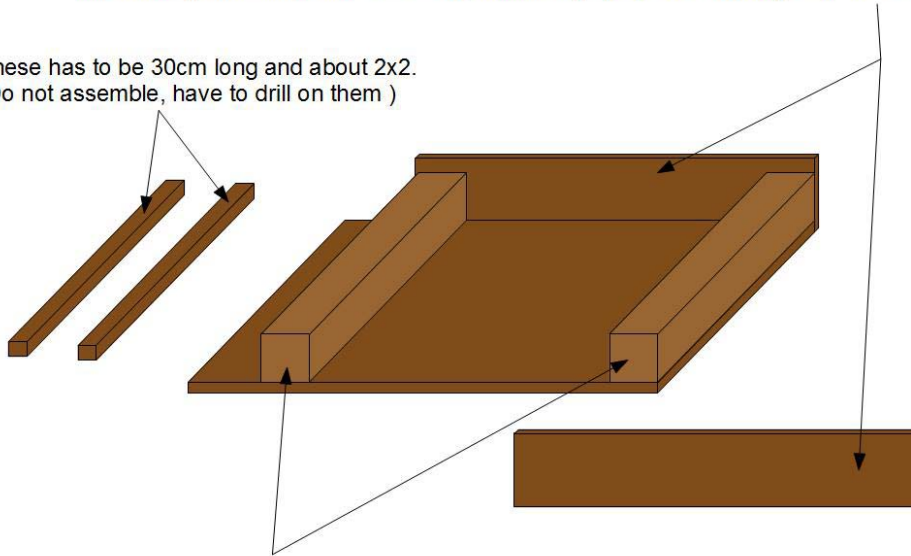


Illustration 23: Frame from other student.

Before of seeing this material the idea of a full solid frame was considered, and the next model was sketched. This model was sent by email to the responsible for the wood workshop on Victoria Building, but after a little conversation with him and my project supervisor was decided that it would be easier and faster to made it myself. This events occurred near Christmas, so taking advantage of the free time and the tools available at home a new and lighter version of the frame was built and carried back to UCLan.

The lateral pieces don't have to be very thick, they are just for making a closed box.

These has to be 30cm long and about 2x2.
(Do not assemble, have to drill on them)



This pieces can be 2 solid rectangular blocks(30x5x5),
or 4 smaller cubes one for each corner(5x5x5)

Illustration 24: First model sketch

The frame was designed to stand in a horizontal position, to minimise any possible shaking.
Two small wooden strips were attached to the main piece to add stability.



Illustration 25: Model's frame

The frame was designed at the same time it was the PCB and that offered the chance to make them fit perfectly. That was the reason to place the photodiodes on the solder side of the PCB, so the can be assemble and keep in place with out any fastening system.

4 Model's assembly.

Once all the designs were chosen and the separate pieces were made the only thing it remained to do was putting everything together. First the program had to be loaded into the PIC16F1829, the four PCBs had to be soldered and then install the programmed PIC in its socket and the wooden pieces of the frame glued and painted (as shown the previous picture).

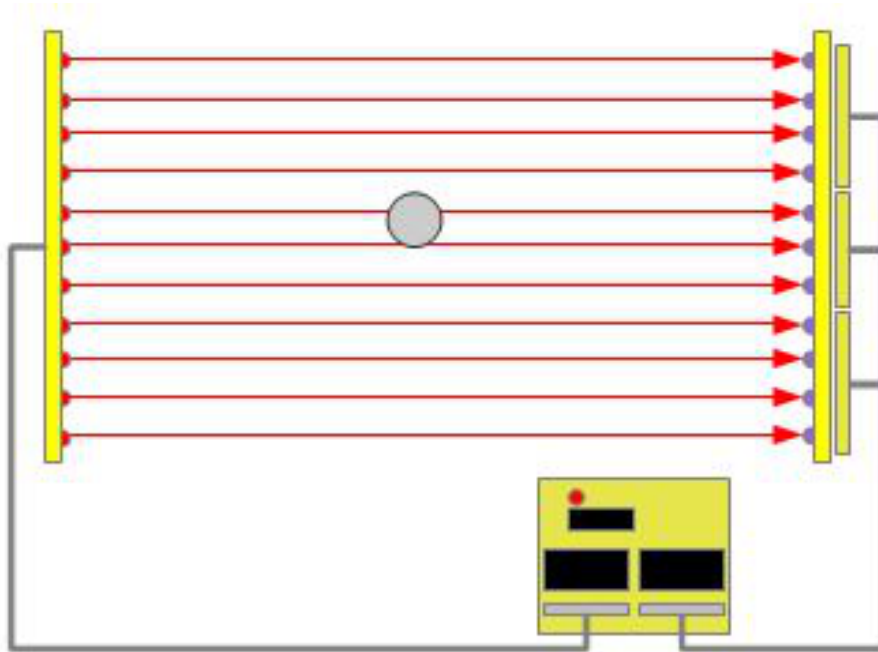


Illustration 26: Model sketch up

4.1 Soldering the PCBs.

4.1.1 Main board

The PCB was soldered on the CM130 on different sessions following different guides and tips on how to solder. During the solder process there was not setback that could delayed the remaining work. The soldering order was from the flattest component like the linking wires to the highest ones. The PIC was installed on a socket so it can be uninstalled without problem to update the program, upgrade the PIC or replace it if damaged somehow. Special care was taken when soldering the 74cd4067's (multiplexer/demultiplexer), limiting the time the soldering iron was in contact with them and lowering the temperature to avoid any internal damage and making sure the orientation was the correct one.

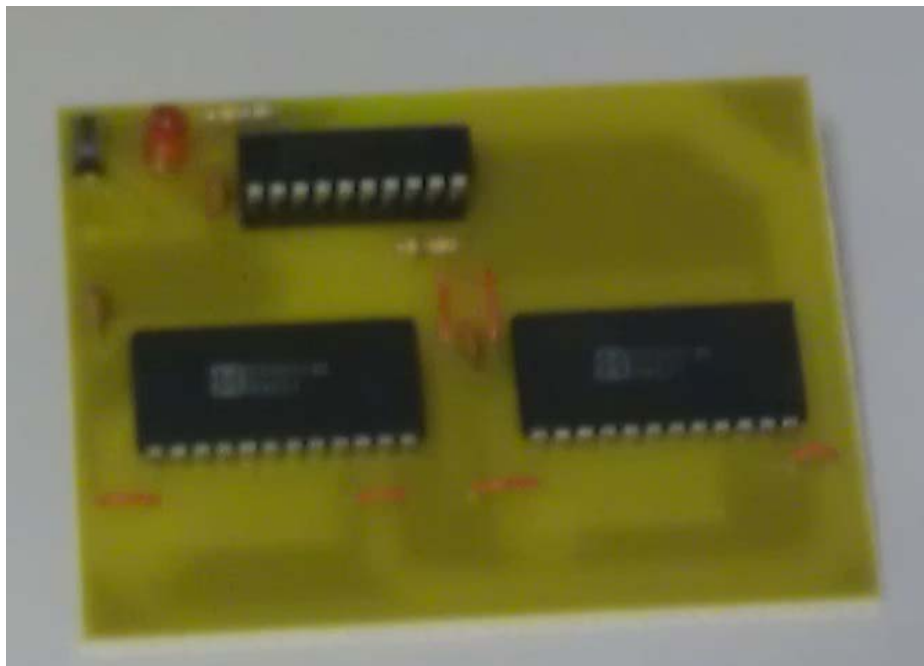


Illustration 27: Finished PCB

4.1.2 Sensor boards

The three PCBs with the IR photodiodes were connected together by the ground and power supply wires, and with the main board by eleven output wires one for each photodiode. The IR LEDs were soldered by wires to the main board with no PCB. For both LED and photodiodes the polarity was check before soldering.

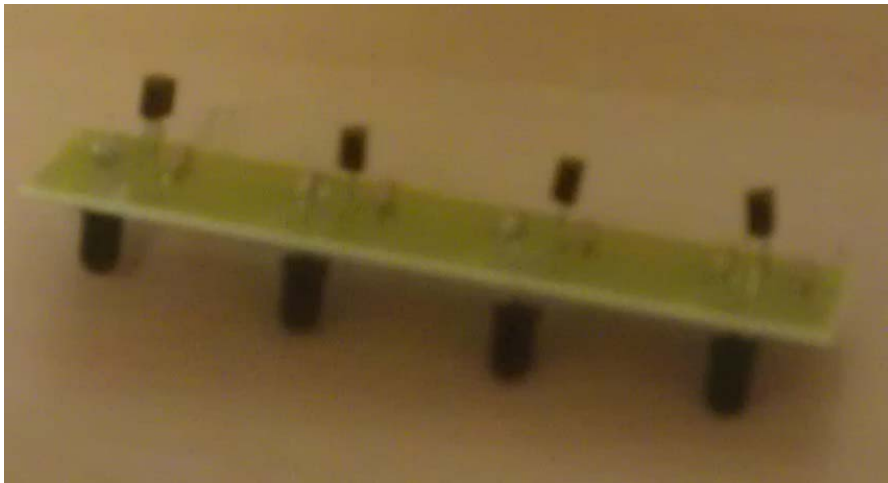


Illustration 28: Photodiodes mounted on board

4.2 Final assembly

Last thing to do was placing the IR LEDs in one side of the frame and the PCBs with the IR photodiodes on the other. Some test were performed and the coin was detected as it crosses the curtain but sadly it was not all the time. This could be caused by the different sun light level when the test were done, for not being completely straightened or because the coin was not perpendicular to the infrared light. Solve this will be noted as the main objective in a future work.

5 Conclusions

The work made during the whole year was well worth when you can see your model finished and nearly functional. Having worked in an assembly line for sometime I understand the importance of safety systems in this environments. It has been interesting using a new micro-controller and with this project I could buy a development kit for myself, allowing me to make future projects with it.

Doing this project has thought me more things than just how to program a PIC in C language or design a PCB with all the calculations it requires. Things about myself and how a project had to be managed and the importance of planning with or without a Gantt chart.

6 Future works

The main objective for a future work should be to increase as much as possible the percentage of successful test runs.

Further development on this project may include increasing the number of LEDs / photodiodes giving a better resolution or a wider area covered with the same resolution. Other possibility is to control more than one curtain with the same μ controller, as it is at the moment and with the current PIC model it would be possible to control a total of six curtains with 16 LEDs each. The PIC needs 2 pins for power supply, one for a reset button, and in this project it uses 4 as line selector for the multiplexer/demultiplexer, this lets 13 free pins, every curtain needs its own STOP signal and an input signal, making 6 pairs for 6 curtains, and the extra pin can be used as a line selector turning the system in six “32 IRLEDs curtains” enough to cover a small manufacturing platform.

7 Appendices

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Abbreviations

- AlGaAs: Aluminium Gallium Arsenide.
DIP: Dual In-line Package
GaAs: Gallium Arsenide
IDE: Integrated Development Environment.
i.e.: id est (that is)
IR: Infra-Red.
IC: Integrated Circuit.
I/O: Input / Output.
LED: Light Emitting Diode.
Op Amp: Operational Amplifier.
PCB: Printed Circuit Board.
PIC: Peripheral Interface Controller
Programmable Interface Controller
Programmable Intelligent Computer
ROM: Read Only Memory.

Bill of materials

Bill Of Materials For Infrared curtains

24 Resistors

Quantity:	References	Value
11	R1, R3, R5, R7, R9, R11, R13,R15, R17,R19, R21	10k
11	R2, R4, R6, R8, R10, R12, R14, R16, R18, R20,R22	33k
1	R23	470
1	R24	180

11 Transistors

Quantity:	References	Value
11	Q1-Q11	2N3906

12 Diodes

Quantity:	References	Value	1
11	D1-D11	TSHF5210	
1	D2	L-7113HD	

3 Capacitors

Quantity:	References	Value
3	C1-C3	100n

3 Integrated Circuits

Quantity:	References	Value
1	U1	PIC16F1829
2	U2, U3	4067

1 Miscellaneous

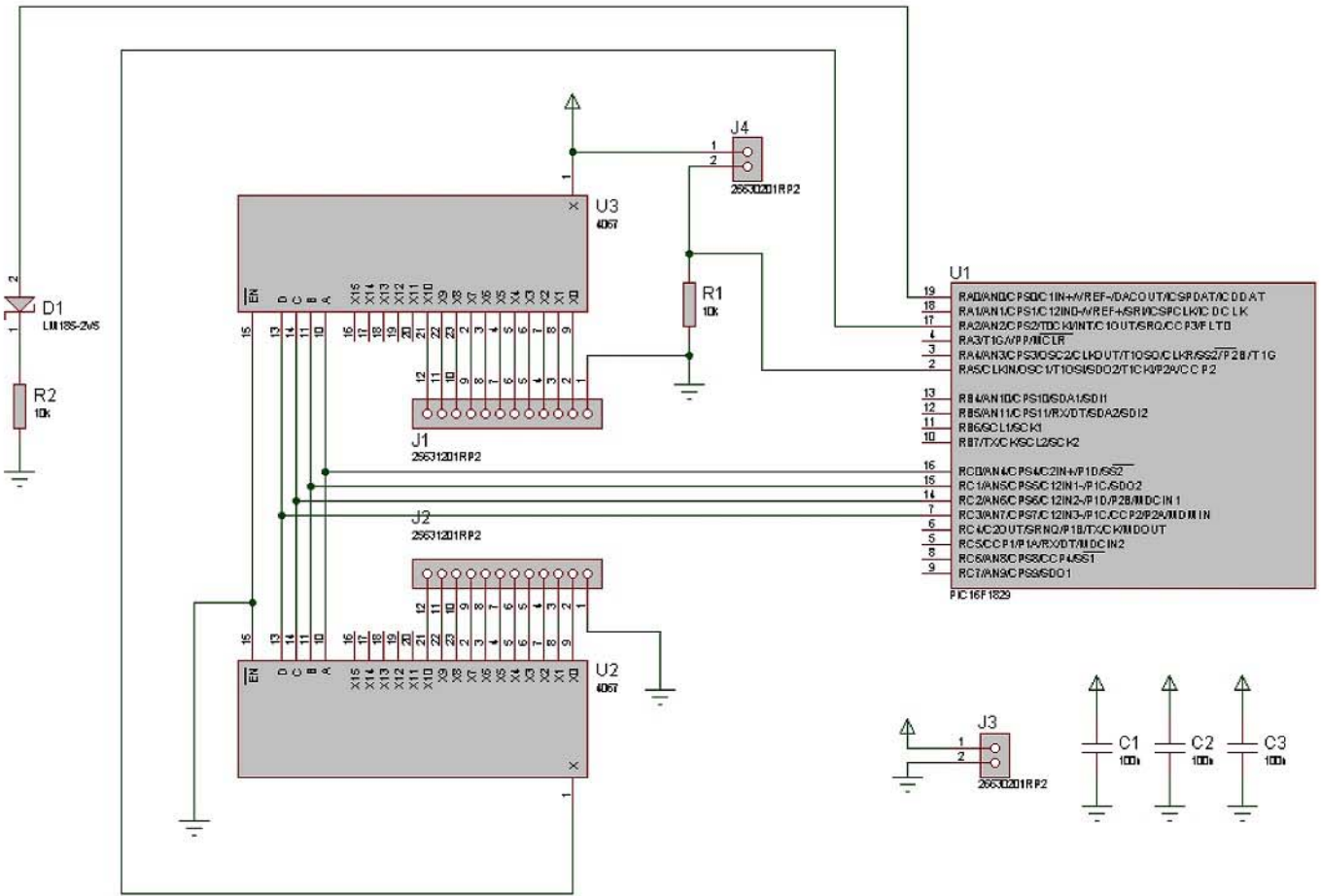
Quantity:	References	Value
1	Button	2WK559

PCB Plans:

- Main board schematic
- Main board bottom copper
- Main board Drill plot
- Main board solder resist

- 4LEDs board schematics
- 4LEDs board bottom copper
- 4LEDs board Drill plot
- 4LEDs board solder resist

- 3LEDs board schematics
- 3LEDs board bottom copper
- 3LEDs board Drill plot
- 3LEDs board solder resist




U1

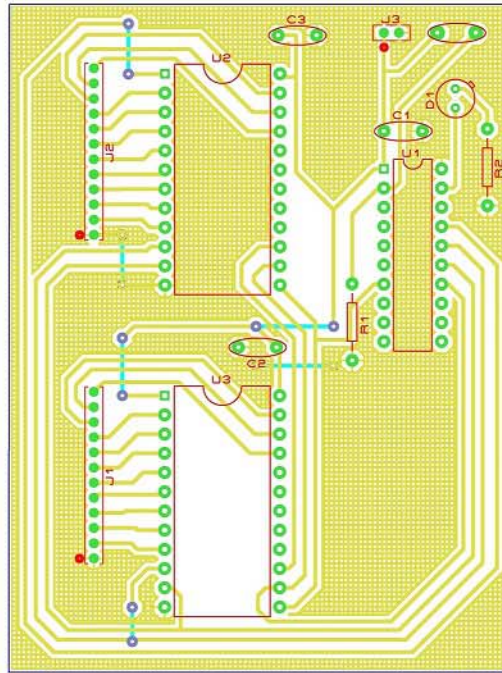
19	RADIAN/C PSDC 1IN+/REF-/DAC0 UT/IC SP DATA/ D D A T
18	RA1AN1/C PS1C 12IN0-/VREF+/SRVCS/CLKIC D C L K
17	RADIAN/C PS2TDC K/INTC IO/UTS/RQ/CC P3V L T D
4	RA3T1G/V P/INCLIF
3	RAAR/N3C PS3QSC2C LMO UT/T10SD/C L/R/SS2/P2B/T1G
2	RASC L/K/OSC V/T10SVSD02/T1C/K/P2V/C C P2
13	RB4AN1/C PS10SDA1/SD11
12	RB5AN11/C PS11/RX/D/SDA2/SD12
11	RB6GCL16C K1
10	RB7/TXC KSC L26C K2
15	RC0V/N/C PS4C2IN+/P1D/SS2
15	RC1V/N/C PS6C 12IN1-/P1C/SD02
14	RC2V/N/C PS6C 12IN2-/P1D/P2B/M DC IN 1
7	RC3V/N/C PS7C 12IN3-/P1C/CC P2P2V/M D M IN
6	RC4C 2D UT/SR/NO/P1B/TXC K/M D OUT
5	RC5C C1/P1/RX/D17/M DC IN2
8	RC6V/N/C PS3CC P4/SS1
9	RC7V/N/C PS3GDD1
	PIC 16F1829


-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil
-	-	-	-	Date Drawn	23/04/2013
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A	-	-	SG	Clients Ref	
Issue	Date	Description of Modification	By		

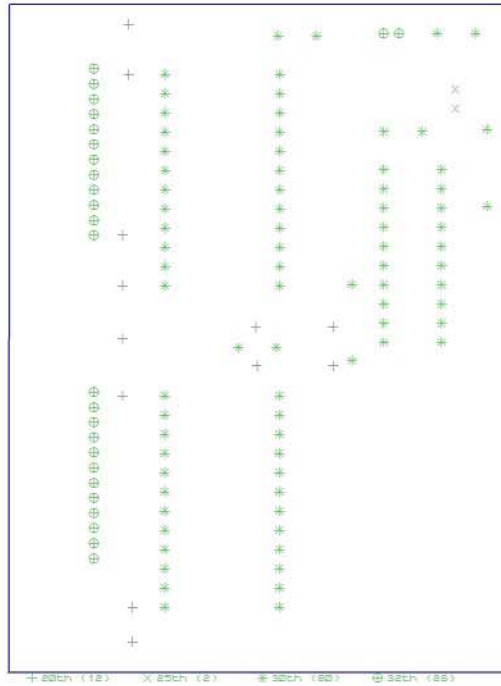
PCB Schematic




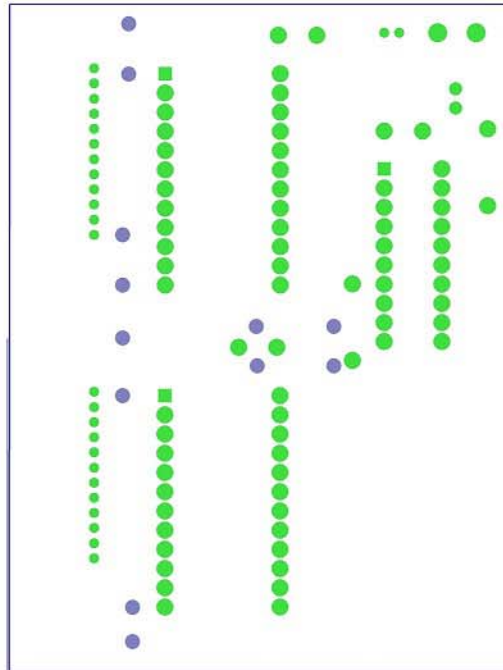
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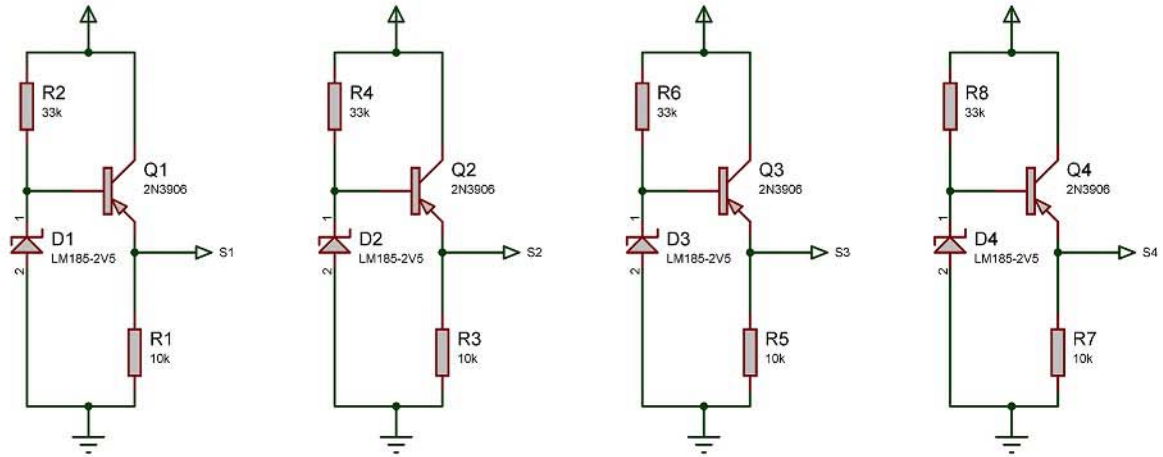
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-	-	-	-	Scale	1:1	
-	-	-	-	Client	UCLAN	
A	-	-	SG	Client's Ref		 Issue 2
Issue	Date	Description of Modification	By	Client's Ref		




-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	PCB Drill Plot
-	-	-	-	Date Drawn	23/04/2013	
-	-	-	-	Scale	1:1	
-	-	-	-	Client	UCLAN	
A	-	-	SG	Client's Ref		
Issue	Date	Description of Modification	By			
						Issue 3




-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	<p style="text-align: center;">PCB Solder resist</p>
-	-	-	-	Date Drawn	23/04/2013	
-	-	-	-	Scale	1:1	
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A	-	-	SG	Clients Ref		
Issue	Date	Description of Modification	By			
						Issue 4




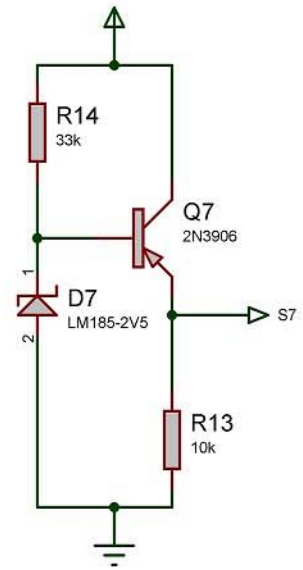
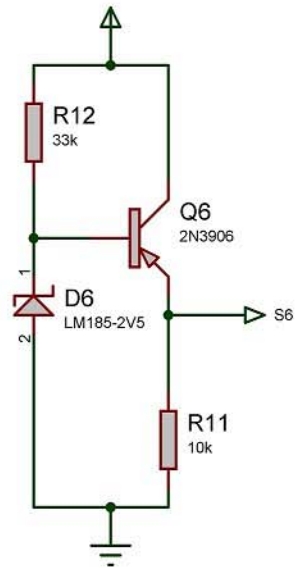
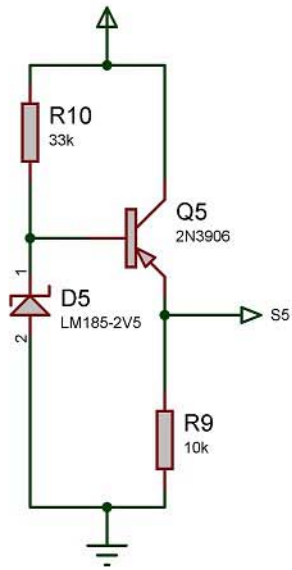
-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	<p style="text-align: center;">PCB 4 Led Schematic</p> 
-	-	-	-	Date Drawn	23/04/2013	
-	-	-	-	Scale	1:1	
-	-	-	-	Client	UCLAN	
A	-	-	SG	Client's Ref		
Issue	Date	Description of Modification	By			<p style="text-align: center;">Issue 5</p>



-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	<p style="text-align: center;">PCB 4 Led Bottom copper</p>
-	-	-	-	Date Drawn	23/04/2013	
-	-	-	-	Scale	1:1	
-	-	-	-	Client	UCLAN	
A	-	-	SG	Clients Ref		
Issue	Date	Description of Modification	By			
						Issue 6



-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	<p style="text-align: center;">PCB 4 Led Drill Plot</p> 	<p style="text-align: center;">Issue 7</p>
-	-	-	-	Date Drawn	23/04/2013		
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A	-	-	SG	Clients Ref			
Issue	Date	Description of Modification	By				

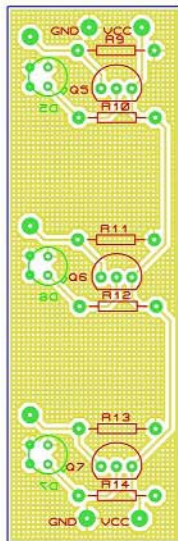



-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil
-	-	-	-	Date Drawn	23/04/2013
-	-	-	-	Scale	1:1
-	-	-	-	Client	UCLAN
A	-	-	SG	Clients Ref	
Issue	Date	Description of Modification	By		

PCB
3 LED Schematic




Issue
9



-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	<p style="text-align: center;">PCB 3 LED Bottom Copper</p>
-	-	-	-	Date Drawn	23/04/2013	
-	-	-	-	Scale	1:1	
-	-	-	-	Client	UCLAN	
A	-	-	SG	Clients Ref		
Issue	Date	Description of Modification	By			
						Issue 10



-	-	-	-	Drawn By	Miguel Angel Lazaro-Civil	PCB 3 LED Drill Plot
-	-	-	-	Date Drawn	23/04/2013	
-	-	-	-	Scale	1:1	
-	-	-	-	Client	UCLAN	
A	-	-	SG	Client's Ref		 Issue 11
Issue	Date	Description of Modification	By			

Source Code

```
/*
 * File: main.c
 * Author: Mick
 *
 * Created on 16/02/13, 16:54
 */

#include <htc.h> //PIC hardware mapping
#include <pic16f1829.h>
#include <xc.h>
#define _XTAL_FREQ 500000 //Used by the XC8 delay_ms(x) macro
#define inPIN RA2
#define Reset RA5

//config bits that are part-specific for the PIC16F1829
#pragma config FOSC=INTOSC , WDTE=OFF , PWRTE=OFF , MCLRE=OFF , CP=OFF
#pragma config CPD=OFF , BOREN=ON , CLKOUTEN=OFF , IESO=OFF , FCMEN=OFF
#pragma config WRT=OFF , PLLEN=OFF , STVREN=OFF , LVP=OFF

/* -----PORTA-----
 * Bit#: -7---6---5---4---3---2---1---0---
 * LED: -----|RST|-----|inP|--|outP|-
 * -----
 * -----PORTC-----
 * Bit#: -7---6---5---4---3---2---1---0---
 * LED: -----|DS4|DS3|DS2|DS1|-
 * -----*/
```

```
//unsigned char adc(void);

bit TESTOK;
void main(void)
{

    OSCCON = 0b00111000;          //500KHz clock speed
                                //PORT A configuration
    TRISAbits.TRISA2 = 1;        //switch as input
    TRISAbits.TRISA5 = 1;        //switch as input
    TRISAbits.TRISA0 = 0;        //switch as output
    ANSELA = 0;                  //PORT A digital switch

                                //PORT C configuration
    TRISC = 0;                   //all LED pins are outputs
    LATC = 0;                    //sequence start on "0"

                                //
/*  TRISAbits.TRISA4 = 1;        //
    ANSELAbits.ANSA4 = 1;        //
    ADCON0 = 0b00001101;        //
    ADCON1 = 0b00010000;        /**/
    while (1)
    {

//Initial TEST

    TESTOK=0;                    //this make the test run once
    LATC = 0b00000000;
    while (!TESTOK)
    {
```

```
_delay(10);
while (LATC > 0b00001011)
{
    if (inPIN == 1)
    {
        LATC = LATC + 1;           //decrement 1 the value of PORT C
        __delay_ms(5);
    }
    if (inPIN == 0)
    {
        LATC = LATC + 1;
        while (LATC != 0)         //Control signal to MUX/DEMUX = 15
        {
            LATC = LATC - 1;
            LATA0 = 1;
            __delay_ms(500);      //f<25 Hz so blinking is perceived
            LATA0 = 0;
            __delay_ms(500);      //f=2 Hz
        }
        while (!Reset)
        {
            //Keep the program here until the reset button
            //is pressed, and then the
        }
    }
}
TESTOK = 1;
}
```

```
//Main Loop
while (TESTOK)
{
    __delay_us(1);          //delay for AT LEAST 1 us
    if (inPIN)
    {
        LATC = LATC +1;    //decrement 1 the value of PORT C
        if (LATC == 0b00001011) //when 11 are off, restart.
        {
            LATC = 0;
        }
    }
    if (!inPIN)
    {
        TESTOK = 0;
    }
}
}
```


Datasheets



Data sheet acquired from Harris Semiconductor
SCHS052B – Revised June 2003

CD4067B, CD4097B Types

CMOS Analog Multiplexers/Demultiplexers

High-Voltage Types (20-Volt Rating)

- CD4067B – Single 16-Channel Multiplexer/Demultiplexer
- CD4097B – Differential 8-Channel Multiplexer/Demultiplexer

■ CD4067B and CD4097B CMOS analog multiplexers/demultiplexers* are digitally controlled analog switches having low ON impedance, low OFF leakage current, and internal address decoding. In addition, the ON resistance is relatively constant over the full input-signal range.

The CD4067B is a 16-channel multiplexer with four binary control inputs, A, B, C, D, and an inhibit input, arranged so that any combination of the inputs selects one switch.

The CD4097B is a differential 8-channel multiplexer having three binary control inputs A, B, C, and an inhibit input. The inputs permit selection of one of eight pairs of switches.

A logic "1" present at the inhibit input turns all channels off.

The CD4067B and CD4097B types are supplied in 24-lead hermetic dual-in-line ceramic packages (F3A suffix), 24-lead dual-in-line plastic packages (E suffix), 24-lead small-outline packages (M, M96, and NSR suffixes), and 24-lead thin shrink small-outline packages (P and PWR suffixes).

*When these devices are used as demultiplexers, the channel in/out terminals are the outputs and the common out/in terminals are the inputs.

Recommended Operating Conditions at T_A = 25°C (Unless Otherwise Specified)

For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges. Values shown apply to all types except as noted.

Characteristic	Min.	Max.	Units
Supply-Voltage Range (T _A =Full Package-Temp. Range)	3	18	V
Multiplexer Switch Input Current Capability	—	25	mA
Output Load Resistance	100	—	Ω

NOTE:

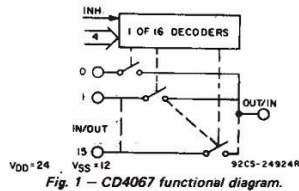
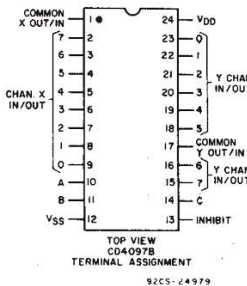
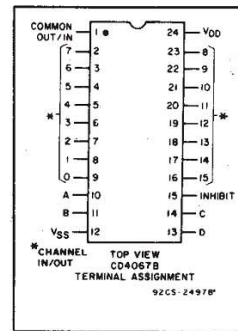
In certain applications, the external load-resistor current may include both V_{DD} and signal-line components. To avoid drawing V_{DD} current when switch current flows into the transmission gate inputs, the voltage drop across the bidirectional switch must not exceed 0.8 volt (calculated from R_{ON} values shown in ELECTRICAL CHARACTERISTICS CHART). No V_{DD} current will flow through R_L if the switch current flows into terminal 1 on the CD4067; terminals 1 and 17 on the CD4097.

Features:

- Low ON resistance: 125 Ω (typ.) over 15 V_{p-p} signal-input range for V_{DD}-V_{SS}=15 V
- High OFF resistance: channel leakage of ±10 pA (typ.) @ V_{DD}-V_{SS}=10 V
- Matched switch characteristics: R_{ON}=5 Ω (typ.) for V_{DD}-V_{SS}=15 V
- Very low quiescent power dissipation under all digital-control input and supply conditions: 0.2 μW (typ.) @ V_{DD}-V_{SS}=10 V
- Binary address decoding on chip
- 5-V, 10-V, and 15-V parametric ratings
- 100% tested for quiescent current at 20 V
- Standardized symmetrical output characteristics
- Maximum input current of 1 μA at 18 V over full package temperature range; 100 nA at 18 V and 25°C
- Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"

Applications:

- Analog and digital multiplexing and demultiplexing
- A/D and D/A conversion
- Signal gating



CD4067 TRUTH TABLE

A	B	C	D	Inh	Selected Channel
X	X	X	X	1	None
0	0	0	0	0	0
1	0	0	0	0	1
0	1	0	0	0	2
1	1	0	0	0	3
0	0	1	0	0	4
1	0	1	0	0	5
0	1	1	0	0	6
1	1	1	0	0	7
0	0	0	1	0	8
1	0	0	1	0	9
0	1	0	1	0	10
1	1	0	1	0	11
0	0	1	1	0	12
1	0	1	1	0	13
0	1	1	1	0	14
1	1	1	1	0	15

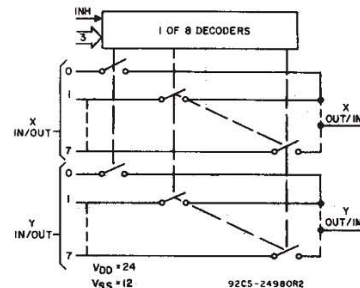


Fig. 2—CD4097 functional diagram.

CD4097 TRUTH TABLE

A	B	C	Inh	Selected Channel
X	X	X	1	None
0	0	0	0	0X, 0Y
1	0	0	0	1X, 1Y
0	1	0	0	2X, 2Y
1	1	0	0	3X, 3Y
0	0	1	0	4X, 4Y
1	0	1	0	5X, 5Y
0	1	1	0	6X, 6Y
1	1	1	0	7X, 7Y

3
COMMERCIAL CMOS
HIGH VOLTAGE ICs

CD4067B, CD4097B Types

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)						Units		
	V _{IS} (V)	V _{SS} (V)	V _{DD} (V)	-55	-40	+85	+125	+25				
SIGNAL INPUTS (V _{IS}) AND OUTPUTS (V _{OS})												
Quiescent Device Current, I _{DD} Max.			5	5	5	150	150	—	0.04	5	μA	
			10	10	10	300	300	—	0.04	10		
			15	20	20	600	600	—	0.04	20		
ON-state Resistance V _{SS} ≤ V _{IS} ≤ V _{DD} I _{on} Max.			20	100	100	3000	3000	—	0.08	100	Ω	
		0	5	800	850	1200	1300	—	470	1050		
		0	10	310	330	520	550	—	180	400		
Change in on-state Resistance (Between Any Two Channels) Δ _{on}			0	15	200	210	300	320	—	125	240	Ω
		0	5	—	—	—	—	—	15	—		
		0	10	—	—	—	—	—	10	—		
OFF Channel Leakage Current: Any Channel OFF Max. or All Channels OFF (Common OUT/IN) Max.		0	18	±100*		±1000*		—	+0.1	±100*	nA	
Capacitance: Input, C _{IS}									5		pF	
Output, C _{OS}									55			
CD4067									35			
CD4097		-5	5						0.2			
Feed-through, C _{IOS}												
Propagation Delay Time (Signal Input to Output)	V _{DD}	R _L = 200 KΩ C _L = 50 pF t _r , t _f = 20 ns	5	—	—	—	—	—	30	60	ns	
			10	—	—	—	—	—	15	30		
			15	—	—	—	—	—	10	20		
CONTROL (ADDRESS or INHIBIT) V _C												
Input Low Voltage, V _{IL} Max.	V _{DD} thru 1 KΩ	R _L = 1 KΩ to V _{SS} I _S < 2 μA on all OFF Channels	5	1.5		—		—	1.5		V	
			10	3		—		—	3			
			15	4		—		—	4			
Input High Voltage, V _{IH} Min.	1 KΩ		5	3.5		3.5		—	—			
			10	7		7		—	—			
			15	11		11		—	—			

* Determined by minimum feasible leakage measurement for automatic testing.

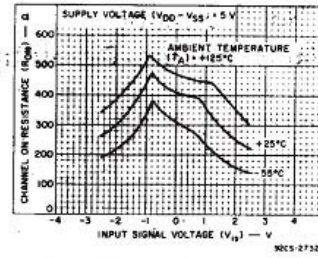


Fig. 3—Typical ON resistance vs. input signal voltage (all types).

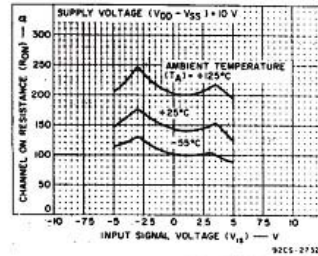


Fig. 4—Typical ON resistance vs. input signal voltage (all types).

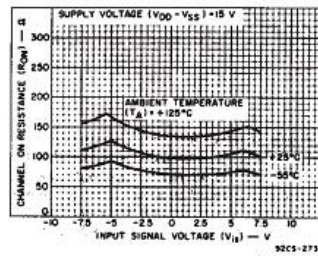


Fig. 5—Typical ON resistance vs. input signal voltage (all types).

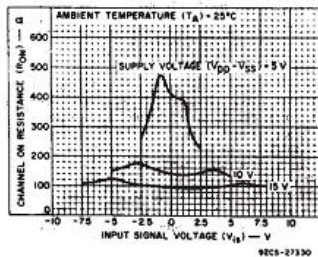


Fig. 6—Typical ON resistance vs. input signal voltage (all types).



PIC16(L)F1825/1829

14/20-Pin Flash Microcontrollers with XLP Technology

High-Performance RISC CPU:

- Only 49 Instructions to Learn:
 - All single-cycle instructions except branches
- Operating Speed:
 - DC – 32 MHz oscillator/clock input
 - DC – 125 ns instruction cycle
- Up to 16 Kbytes Linear Program Memory Addressing
- Up to 1024 bytes Linear Data Memory Addressing
- Interrupt Capability with Automatic Context Saving
- 16-Level Deep Hardware Stack with Optional Overflow/Underflow Reset
- Direct, Indirect and Relative Addressing modes:
 - Two full 16-bit File Select Registers (FSRs)
 - FSRs can read program and data memory

Flexible Oscillator Structure:

- Precision 32 MHz Internal Oscillator Block:
 - Factory calibrated to $\pm 1\%$, typical
 - Software selectable frequencies range of 31 kHz to 32 MHz
- 31 kHz Low-Power Internal Oscillator
- Four Crystal modes up to 32 MHz
- Three External Clock modes up to 32 MHz
- 4x Phase Lock Loop (PLL)
- Fail-Safe Clock Monitor:
 - Allows for safe shutdown if peripheral clock stops
- Two-Speed Oscillator Start-Up
- Reference Clock Module:
 - Programmable clock output frequency and duty cycle

Special Microcontroller Features:

- 1.8V-5.5V Operation – PIC16F1825/1829
- 1.8V-3.6V Operation – PIC16LF1825/1829
- Self-Programmable under Software Control
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Programmable Brown-out Reset (BOR)
- Extended Watchdog Timer (WDT)
- In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via Two Pins
- Enhanced Low-Voltage Programming (LVP)
- Programmable Code Protection
- Power-Saving Sleep mode

Extreme Low-Power Management

PIC16LF1825/1829 with XLP:

- Sleep mode: 20 nA @ 1.8V, typical
- Watchdog Timer: 300 nA @ 1.8V, typical
- Timer1 Oscillator: 650 nA @ 32 kHz, 1.8V, typical
- Operating Current: 48 μ A/MHz @ 1.8V, typical

Analog Features:

- Analog-to-Digital Converter (ADC) Module:
 - 10-bit resolution, up to 12 channels
 - Auto acquisition capability
 - Conversion available during Sleep
- Analog Comparator Module:
 - Two rail-to-rail analog comparators
 - Power mode control
 - Software controllable hysteresis
- Voltage Reference Module:
 - Fixed Voltage Reference (FVR) with 1.024V, 2.048V and 4.096V output levels
 - 5-bit rail-to-rail resistive DAC with positive and negative reference selection

Peripheral Highlights:

- Up to 17 I/O Pins and 1 Input Only Pin:
 - High current sink/source 25 mA/25 mA
 - Programmable weak pull-ups
 - Programmable interrupt-on-change pins
- Timer0: 8-Bit Timer/Counter with 8-Bit Prescaler
- Enhanced Timer1:
 - 16-bit timer/counter with prescaler
 - External Gate Input mode
 - Dedicated, low-power 32 kHz oscillator driver
- Three Timer2-types: 8-Bit Timer/Counter with 8-Bit Period Register, Prescaler and Postscaler
- Two Capture, Compare, PWM (CCP) Modules
- Two Enhanced CCP (ECCP) Modules:
 - Software selectable time bases
 - Auto-shutdown and auto-restart
 - PWM steering
- Up to Two Master Synchronous Serial Port (MSSP) with SPI and I²C™ with:
 - 7-bit address masking
 - SMBus/PMBus™ compatibility
- Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) Module
- mTouch™ Sensing Oscillator Module:
 - Up to 12 input channels

PIC16(L)F1825/1829

FIGURE 3: 20-PIN DIAGRAM FOR PIC16(L)F1829

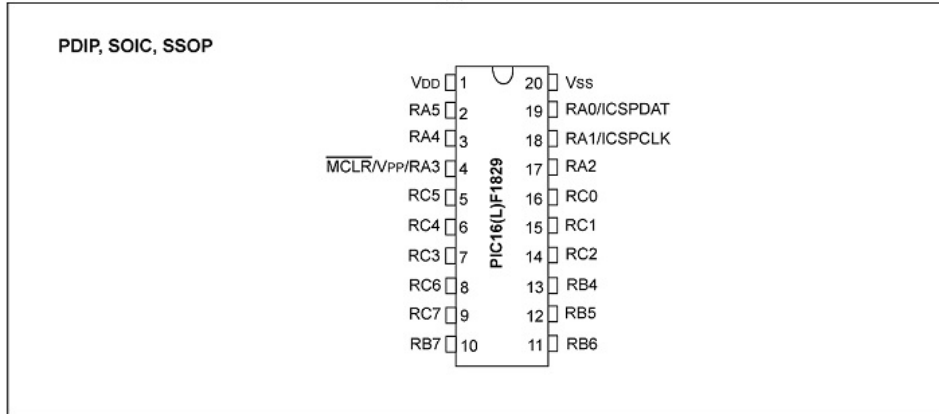
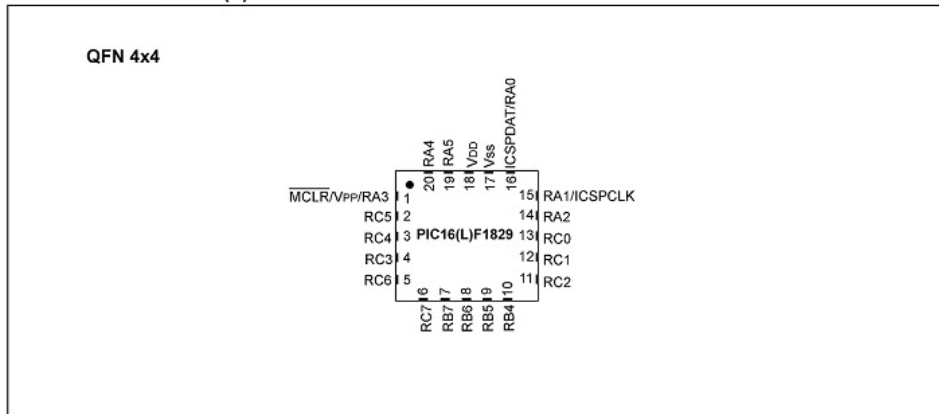


FIGURE 4: PIC16(L)F1829 20-PIN QFN



PIC16(L)F1825/1829

TABLE 2: 20-PIN ALLOCATION TABLE (PIC16(L)F1829)

I/O	20-Pin PDIP/SSOP		A/D	Reference	Cap Sense	Comparator	SR Latch	Timers	CCP	EUSART	SSP	Interrupt	Modulator	Pull-up	Basic
	20-Pin QFN	20-Pin QFN													
RA0	19	16	AN0	VREF-DACOUT	CPS0	C1IN+	—	—	—	—	—	IOE	—	Y	ICSPDAT/ICDDAT
RA1	18	15	AN1	VREF+	CPS1	C12IN0-	SRI	—	—	—	—	IOE	—	Y	ICSPCLK/ICDCLK
RA2	17	14	AN2	—	CPS2	C1OUT	SRQ	T0CKI	CCP3FLT0	—	—	INT/IOE	—	Y	—
RA3	4	1	—	—	—	—	—	T1G ⁽¹⁾	—	—	—	IOE	—	Y ⁽⁴⁾	MCLR VPP
RA4	3	20	AN3	—	CPS3	—	—	T1G ⁽¹⁾ T1OSO	P2B ⁽¹⁾	—	SS2 ⁽¹⁾	IOE	—	Y	OSC2 CLKOUT CLKR
RA5	2	19	—	—	—	—	—	T1CKI T1OSI	CCP2 ⁽¹⁾ P2A ⁽¹⁾	—	SDO2 ⁽¹⁾	IOE	—	Y	OSC1 CLKIN
RB4	13	10	AN10	—	CPS10	—	—	—	—	—	SDA1 SDI1	IOE	—	Y	—
RB5	12	9	AN11	—	CPS11	—	—	—	—	RX ⁽¹⁾ DT ⁽¹⁾	SDA2 SDI2	IOE	—	Y	—
RB6	11	8	—	—	—	—	—	—	—	—	SCL1 SCK1	IOE	—	Y	—
RB7	10	7	—	—	—	—	—	—	—	TX ⁽¹⁾ CK ⁽¹⁾	SCL2 SCK2	IOE	—	Y	—
RC0	16	13	AN4	—	CPS4	C2IN+	—	—	P1D ⁽¹⁾	—	SS2 ⁽¹⁾	—	—	Y	—
RC1	15	12	AN5	—	CPS5	C12IN1-	—	—	P1C ⁽¹⁾	—	SDO2 ⁽¹⁾	—	—	Y	—
RC2	14	11	AN6	—	CPS6	C12IN2-	—	—	P1D ⁽¹⁾ P2B ⁽¹⁾	—	—	—	MDCIN1	Y	—
RC3	7	4	AN7	—	CPS7	C12IN3-	—	—	P1C ⁽¹⁾ CCP2 ⁽¹⁾ P2A ⁽¹⁾	—	—	—	MDCIN2	Y	—
RC4	6	3	—	—	—	C2OUT	SRNQ	—	P1B	TX ⁽¹⁾ CK ⁽¹⁾	—	—	MDOUT	Y	—
RC5	5	2	—	—	—	—	—	—	CCP1 P1A	RX ⁽¹⁾ DT ⁽¹⁾	—	—	MDCIN2	Y	—
RC6	8	5	AN8	—	CPS8	—	—	—	CCP4	—	SS1	—	—	Y	—
RC7	9	6	AN9	—	CPS9	—	—	—	—	—	SDO1	—	—	Y	—
VDD	1	18	—	—	—	—	—	—	—	—	—	—	—	—	VDD
VSS	20	17	—	—	—	—	—	—	—	—	—	—	—	—	VSS

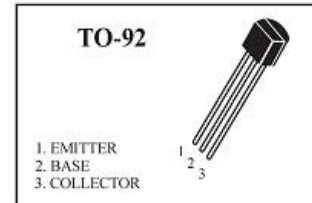
Note 1: Pin function is selectable via the APFC0N0 or APFC0N1 register.



S8050

NPN General Purpose Transistors

Lead(Pb)-Free



ABSOLUTE MAXIMUM RATINGS (Ta=25 °C)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V _{CEO}	25	Vdc
Collector-Base Voltage	V _{CBO}	40	Vdc
Emitter-Base Voltage	V _{EBO}	5.0	Vdc
Collector Current	I _C	500	mAdc
Total Device Dissipation Ta=25 °C	P _D	0.625	W
Junction Temperature	T _j	150	°C
Storage, Temperature	T _{stg}	-55 to +150	°C

ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage (I _C = 0.1 mAdc, I _B =0)	V _{(BR)CEO}	25	-	Vdc
Collector-Base Breakdown Voltage (I _C = 100 µAdc, I _E =0)	V _{(BR)CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I _E = 100 µAdc, I _C =0)	V _{(BR)EBO}	5.0	-	Vdc
Collector Cutoff Current (V _{CE} = 20 Vdc, I _B =0)	I _{CE0}	-	0.1	uAdc
Collector Cutoff Current (V _{CB} = 40 Vdc, I _E =0)	I _{CBO}	-	0.1	uAdc
Emitter Cutoff Current (V _{EB} = 3.0Vdc, I _C =0)	I _{EBO}	-	0.1	uAdc

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S8050



ELECTRICAL CHARACTERISTICS ($T_A=25^\circ\text{C}$ unless otherwise noted) (Continued)

Characteristics	Symbol	Min	TYP	Max	Unit
-----------------	--------	-----	-----	-----	------

ON CHARACTERISTICS

DC Current Gain ($I_C=50\text{ Adc}, V_{CE}=1.0\text{ Vdc}$)	$h_{FE}(1)$	85	-	300	-
DC Current Gain ($I_C=500\text{ mAdc}, V_{CE}=1.0\text{ Vdc}$)	$h_{FE}(2)$	50	-	-	-
Collector-Emitter Saturation Voltage ($I_C=500\text{ Adc}, I_B=50\text{ mAdc}$)	$V_{CE(sat)}$	-	-	0.6	Vdc
Base-Emitter Saturation Voltage ($I_C=500\text{ mAdc}, I_B=50\text{ mAdc}$)	$V_{BE(sat)}$	-	-	1.2	Vdc
Current-Gain-Bandwidth Product ($I_C=20\text{ mAdc}, V_{CE}=6.0\text{ Vdc}, f=30\text{ MHz}$)	f_T	150	-	-	MHz

Classification of $h_{FE}(1)$

Rank	B	C	D
Range	85-160	120-200	160-300

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Statement of Work

University of Central Lancashire Department of Technology

**EL3990 Statement of Work
Infrared Curtain
B.Eng (Hons.) Electronic Engineering**

Issue 1, 09 November 2012

M. A. Lazaro-Civil

1 Aim

This project will build a 30×100cm infra-red curtain able to detect any object bigger than a 50p coin.

2 Background

Infra-red curtains or light barriers are electronic devices used to detect the presence of objects going through them. They are used as a safety equipment, when the beams forming the curtains are broken a signal is send, usually to stop the machine behind them.

They are based in optoelectronic devices, IR-Leds and IR-photodiodes, activated in a sequential order and sending a coded beam.

3 Activities

3.1 Work breakdown structure

1. Background Study
 - 1.1. Background research
2. Prototype construction
 - 2.1. Requirement analysis
 - 2.2. PCB Design
 - 2.3. Program μ Controller
3. Model testing
 - 3.1. Debug program
 - 3.2. Correct model errors
4. Reporting
 - 4.1. Interim report preparation
 - 4.2. Final report preparation

3.2 Task descriptions

During background research (WBS 1.1) information about different infrared curtain manufacturers, basic operation of infrared diodes and infrared receivers and the programming of a micro controller on C/assembler will be gatherer.

The project has to meet some needs that will be studied in the requirement analysis stage (WBS 2.1). Once studied, a PCB will be designed using a micro controller as a main component (WBS 2.2). The result of this will be a prototype.

If everything is correct during (WBS 2.2) the next stage will not be necessary, but if something goes wrong it will be reconsidered, repaired or reprogrammed at this moment (WBS 3.1 & 3.2). This will grant a functional model.

All the progress will be written down in a report, forming the progress report (WBS 4.1) and a final report at the end of April (WBS 4.2).

Infrared curtain Statement of Work
Issue 1, 09 November 2012

3.3 Programme

A Gantt chart is attached.

4 Dependencies

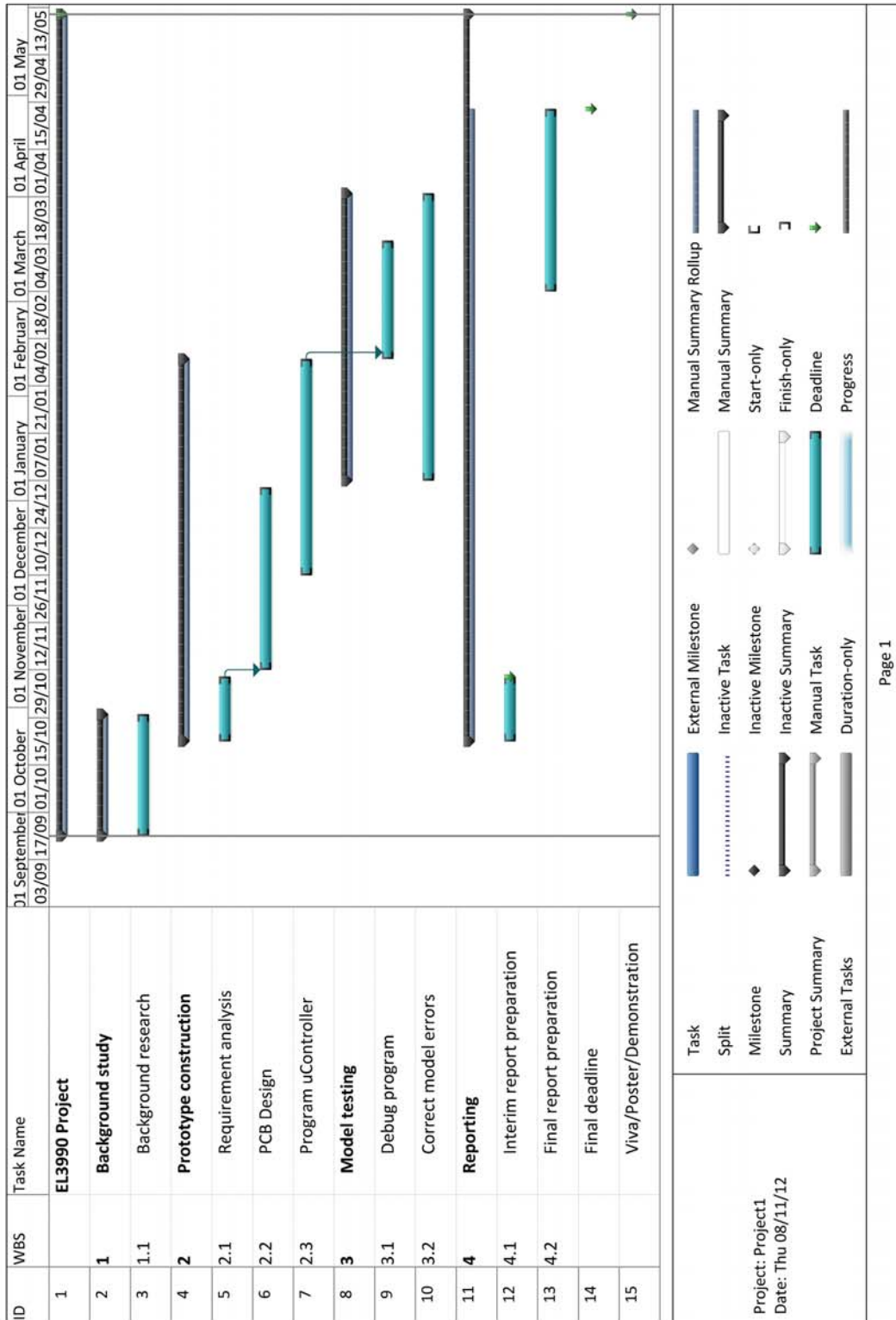
The project will need the use of some laboratories and equipment in order to build the prototype.

5 Risk management

1. Lost or failure of the laptop, causing delay at some point of the project. To prevent this all work is saved in a cloud storage system such as Dropbox also keeping a local copy of everything.
2. Procrastination of work due to other modules assignments or illness causing a mark penalty. In order to avoid this there is a Gantt chart attached with all the dead lines.
3. Delay on component delivery or PCB manufacturing, making a delay in the whole project. To avoid this, the PCB design is scheduled just after the requirement analysis, giving some leeway if that occurs.

6 Deliverables

Item	Due date
1. Interim report	09 Nov 2012
2. Infrared curtain	02 Apr 2012
3. Final report (2 copies)	26 Apr 2012



University of Central Lancashire Department of Technology
School of Computing, Engineering and Physical Sciences

M.A. LAZARO-CIVIL

INFRARED CURTAIN

(EL3990)

Submitted in partial satisfaction
of the requirements for the degree of
Bachelor of Engineering (with Honours)
in
Electronic Engineering

April 2013

I declare that all material contained in this report, including ideas described in the text, computer programs and drawings, is in my own work except where explicitly and individually acknowledged.

Signed

Date

Infrared curtain Progress Report
Issue 1, 09 November 2012

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1 Introduction.

Infrared curtains are mostly used as a safety measure in industrial environments, in order to avoid possible damages, injuries or even deaths due to the proximity of active machinery. They can be used instead of physical barriers, increasing the available space while reducing the time to access or manipulate the machine.



Fig 1.a: Infrared Light Curtain (Light Curtain and Machine Guard Solutions, 2009)

Similar technology has been used outside the industry, for example the VirtualWall of Roomba also uses infrared light to create a barrier that the robot can not go through.



Fig 1.b: Roomba VirtualWall (iRobot)

Infrared curtain Progress Report
Issue 1, 09 November 2012

The use of infrared light on these devices is due to the fact of being invisible to the human eye. This is because the wavelength of the light that the IRLED emits is between 750nm and 1mm approximately while the human eye can see from 390nm up to 750nm.



Fig 1.c: Infrared Light wavelength (NASA, 2011)

2 Background research

“**Light Curtain** – An active optoelectronic device which contains one or more transmitting elements and one or more receiving elements which form a sensing field with a specified minimum object resolution. A light curtain is also called a “presence sensing device””. (OMRON, 2006-2011)

IRLED is the acronym of Infra Red Light Emitting Diode. They are made of GaAs (gallium arsenide) with a wave length of 950 nm making it invisible to the human eye.

3 Requirement analysis

The system has to detect any object bigger than a 50p coin, moving as fast as a human hand can, in a 30cm X 100cm area.

4 Specifications:

4.1 Hardware:

To achieve the requirements the IRLED's have to be 25mm one from each other, since the 50p coin is 27.3mm. This makes a total of 11 IRLED in the frame of the model.

To maintain the number of output from the μ Controller low, a multiplexer and a demultiplexer, reducing the number from 11 to just 4 wires for control and 2 for the data I/O.

4.2 Software:

Knowing that the IRLED's project a cone of IR light instead of straight line of IR light, different IR receivers can detect the same source. To solve that it is needed to activate them alternatively in a fast sequence.

4.3 Block diagram

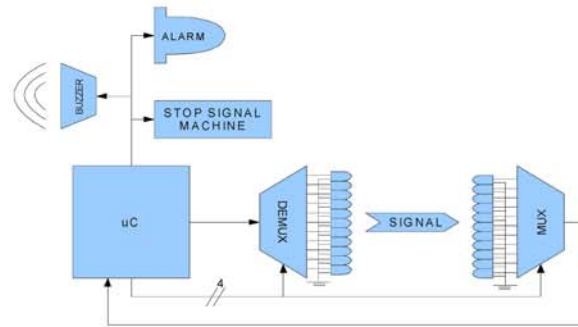


Fig.1 Block diagram of the system.

4.4 Flow chart

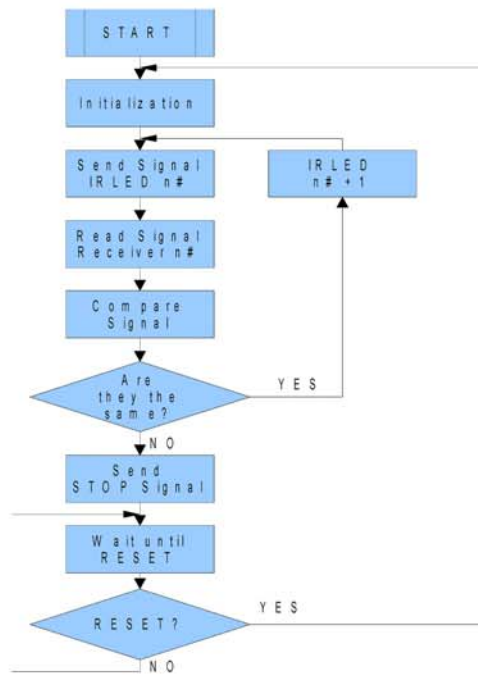


Fig. 2 Flow chart of the program.

Infrared curtain Progress Report
Issue 1, 09 November 2012

5 PCB Design

A PCB design program, such as PROTEUS available in CM129, will be used to make the PCB layout according to the block diagram from above.

6 Testing

The testing must be done every time something in the code or in the hardware part has changed. This can be made on the labs or at home depending of the testing subject and the possible solution

7 Future work

For the next weeks the main objective is to decide which μ Controller will be used in the project as well as determining the range of the available IRLEDs in the electronic store (CM107).

8 Bibliography

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