Smarter Smart Lights

Design Report

IC The Light Group

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22nd February 2007

1. Contents

2. Executive Summary

Lighting utilisation in office buildings in the UK and European Union in general is an important issue in energy efficiency as well as a massive market nowadays. Our project is concerned with the development of an automatic system for lighting control.

A presence detection system was developed for the following main reasons:

- Existing systems for intelligent lighting using infrared motion sensors are insufficient and troublesome during extracurricular work sessions.
- There is a modern trend towards energy efficiency as ecological awareness becomes an important issue in the business sector.

Aiming to improve these specific areas of interest, the development of an intelligent lighting system (ICALS) was approached. ICALS targets three key aspects of the behaviour of individuals inside offices in order to achieve effective presence detection: movement, computer use, and mobile phone use. For the technical part of this project the ICALS team worked on developing circuits for sensing human behaviour, as well as an effective control system to ensure the best configuration is applied to each specific office environment; using resources at Imperial College London including internet service, technical reports and books, surveys, and individual and collective knowledge of team integrants in the areas of analogue electronics, digital electronics, programming and electronic engineering PC applications.

ICALS is composed of 4 circuits connected through the appropriate interfaces. These include a mobile phone detector, an infrared movement sensor and software for obtaining information about PC use, all managed by a user-friendly control system.

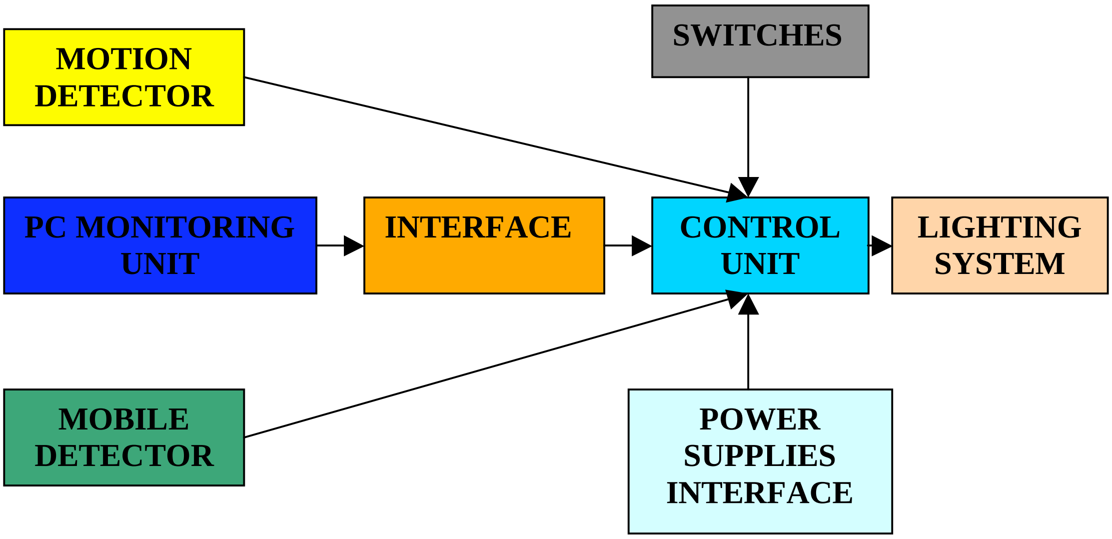
The system operation is as follows:
The mobile phone detector is a hybrid (analogue/digital) system composed of antennas, active filters and monostable timers. The circuit detects mobile phone signals in the GSM 1.7GHZ-1.9GHz range, and outputs pulses of 0-12V whenever a mobile phone is present. These are used as logic inputs to the control system.
The PC unit is a software based system for Windows XP, programmed on C++. It consists of two programs codenamed “user detector” and “office detector”. These will be installed in the workstations and the main server respectively. User Detector collects log-in, mouse and keyboard use information and Office Detector is in charge of keeping record of this information and making the decision of “in use” or “not in use”.
The infrared motion detector is an analogue circuit with two Pyroelectric sensing elements that detect heat infrared radiation from moving people as they affect one sensor at a time. It has a Fresnel lens mounted that yields 90° sensing angle and a depth of 90 feet. 4 of these will be installed in the office for a 360° angle.
The control system consists of a logic network including oscillators, logic gates, multiplexers, counters, switches, amplifiers, resistors and other external components. It ensures the synchronous operation of all three systems and acts as an interface between the detecting system and the mains supply to the office lights as well as providing the user with seven different options of operation which combine the three detectors.

We believe that this approach to automatic lighting will be an effective means of providing efficient energy utilisation, with important business, technological and ecological implications.

3. Top level design

3.1 Block diagram

It was decided that the top level design should be more general and hence we decided to create a new one and downgrade the previously produced top level design to be a medium level design. Appendix A includes the block diagram of the previous Top level design.



4. Medium level design
4.1 Block diagram
Figure 4.1 – 1(next page) shows the Medium level design of the system.

4.2 Changes from 1st Stage
In the first stage of the project, there were some differences from this diagram. First of all, the PIR system had its blocks renamed. These new names reflect the low level design with more accuracy. The PIR block will output a voltage of either 0V or 5V.

The PC Monitoring Unit has its block also remained. It will output from the serial port of the computer a voltage in the range of -25V and 25V and an interface will take of that voltage and convert to 5V and 0V respectively (interchanges the voltages – more on this on the PC Monitoring Unit analysis).

The Mobile Signal Detector will also output 0V or 5V.

The Control Unit had one more input added. The Control Switches will allow the buyer to choose which of the modes of the system he will use.

Another block was added which models the Power supplies. The system will be plugged to the mains and a transformer will be required to drop this voltage to 12V.

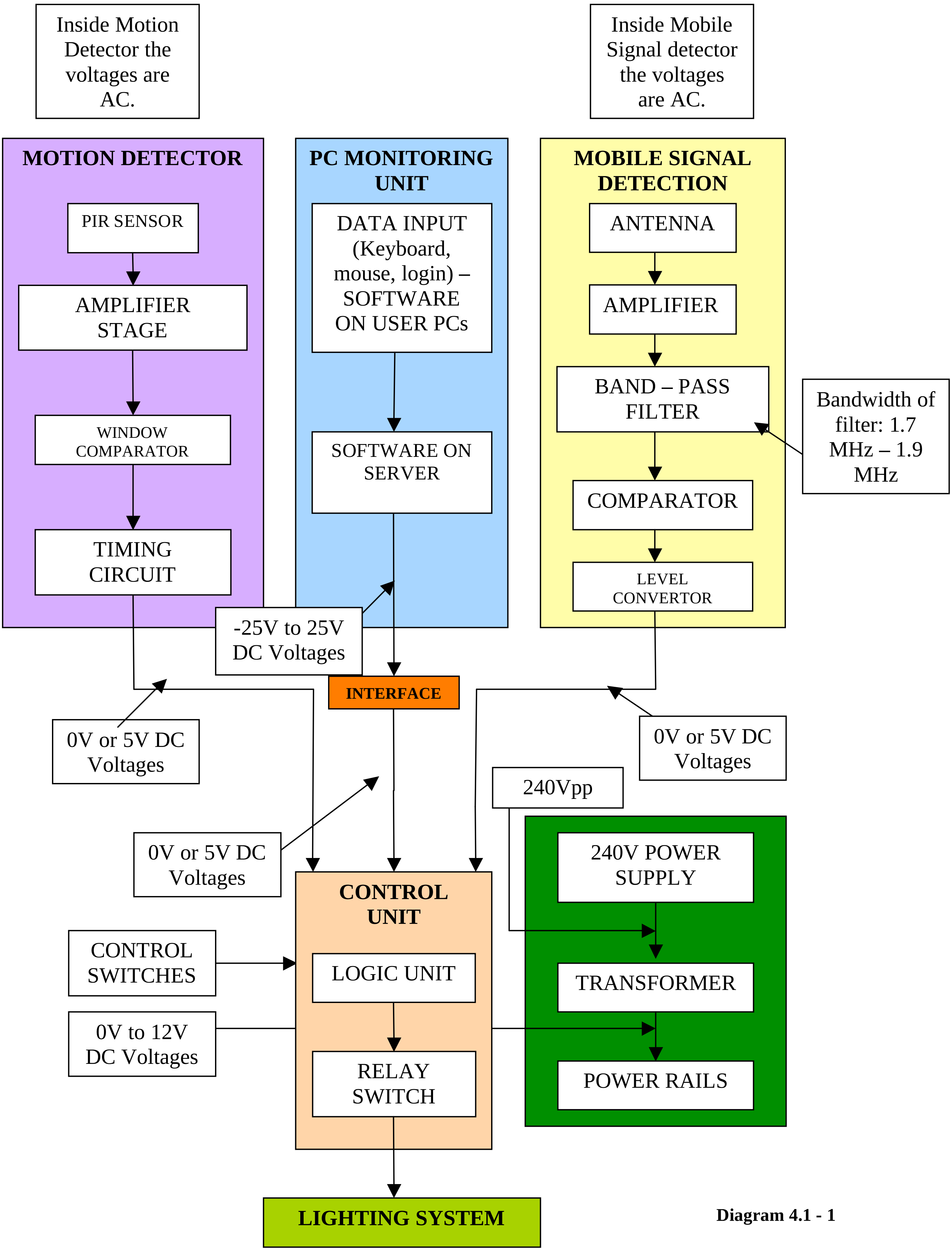


Diagram 4.1 - 1

5. Low Level Design

In order to accurately design a low level for our system we designed the parts separately.

6. Motion detector

6.1 Overview

Most “presence detectors” are based on motion detectors. One of the most used technical methods implementing a motion detector is a PIR. This is because any object that generates heat can be detected by an infrared sensor. These objects include a human being. Infrared radiation has a longer wavelength than visible light and cannot be seen. This doesn’t mean though that it cannot be detected. Human beings emit radiation which is strongest at a wavelength of 9.4 μm[1].

6.2 Pyroelectric Sensor

Pyroelectric sensors have a crystalline material, which generates a surface electric charge when exposed to heat in the form of infrared radiation. A change in the amount of radiation reaching this material can be measured by a sensitive FET, contained in the sensor. Since the sensor is sensitive over a wide range in the spectrum, a filter is used to filter out all radiation except that coming from a band between 8 and 14μm.

Note also that electrical signals from a PIR sensor have a very low frequency and have a range between 0.1 and 10 Hz.

The next two sections present two circuit proposals.

6.3 Circuit Solution No.1

In Appendix B you can find Solution No.1.

Circuit Solution No.1 is based on the KC778B circuit requires 12V DC supply and costs $2.45 on orders of 1000+ components. It also has a RE200B PIR sensor. It requires a warm up period of 90 seconds to take effect.

6.4 Circuit Solution No.2

In Appendix C the circuit solution No.2 is shown.

Glolab Corporation has designed this circuit and our aim was to analyze and adapt it to our requirements. The heart of the electronic circuit is the CD4538 IC which costs $0.44 so it is much cheaper than the IC used in the previous solution.

6.5 PIR 325 Sensor

Analysis on the PIR 325 Sensor is shown in Appendix G

6.6 Analysis of Circuit

When motion is detected the sensor will output a very small voltage transition at pin 2. This is needed to be amplified. There are two IC in this electronic circuit. The first one is a LM324 which contains 4 operational amplifiers. Two of them are used as an amplifier while the other two are used as a comparator.

The second integrated circuit is the CD4538. IC1C and IC1D are those used as a window comparator and respond to signals of about 200 millivolts above and below Vcc/2. The purpose of the window comparator is to provide a small voltage window or dead zone that

[1] http://www.glolab.com./pirparts/pirmanual.PDF

will not respond to small voltage transitions caused by noise or minor fluctuations from the sensor.

R10 and C6 form a time constant and determine the amount of time that RY1 remains closed after motion is detected. All components can operate between 5 V and 12 V.

6.7 Detailed Analysis and Calculations

The FET device (built in the PIR) had a pulldown resistor (value 100k) connected to its terminal pin 2 and this resistor is grounded. Connected to the FET a 2 stage amplifier gives a gain of 10, 000. Since the electrical signals have a bandwidth between 0.1 Hz and 10 Hz, the amplifier is bandlimited to below 10 Hz in order to reject the frequency noise.

When motion is detected a very small voltage of about 20 mVpp will flow through transistor pin 2. This is fed into the first stage of the amplifier. This is at a high impedance level and hence doesn't load the sensor. C3 and R4 act as a high pass filter and as a feedback network. R3 and C2 act also as a high pass filter and as bias and connect pin 2 to ground. This network forms a band – pass filter (since the capacitors introduce low and high frequency poles) and also set the operating point. Hence it filters out noise outside the frequency band (0.1 Hz to 10 Hz) and makes the amplifier more stable.
The gain of the first op- amp is:

$$H_1 = 1 + \frac{R_4}{R_3} = 1 + \frac{1\text{M}\Omega}{10K\Omega} = 101$$

The low and high cut – off frequency can be calculated by the following equations:

$$f_{oL} = \frac{1}{2\pi R3C2} = 1.59Hz$$

$$f_{oH} = \frac{1}{2\pi R4C3} = \frac{1}{2\pi \times 1M\Omega \times 0.1\mu F} = 1.59Hz$$

Although the low cut – off frequency is suitable the value found for the high cut – off frequency is not. So C3 will be changed to 0.015 µF so that:

$$f_{oH} = \frac{1}{2\pi R4C3} = \frac{1}{2\pi \times 1M\Omega \times 0.015\mu F} = 10.6Hz$$

So the first change is that C3 = 0.015 µF.

The output of the first stage is fed into another band – pass filter which inverting gain shown in the following equation:

$$H_2 = -\frac{R_8}{R_5} = -\frac{1\text{M}\Omega}{10K\Omega} = -100$$

The cut – off frequencies will be the same as above and hence **C5 needs to be changed to 0.015 µF as well**.
C4 blocks DC voltage flow.
As mentioned above IC1C and IC1D form a window comparator that responds to signals about 200 millivolts above and below Vcc/2. This window is set by the low current voltage drops across D1 and D2. Comparator outputs feed through D3 and D4 that pass only the positive transitions into CD4538. IC1C will not turn on until pin 10 becomes more positive than pin 9. IC1D will not turn on until pin 13 becomes more negative than 12. The window comparator provides a 400 mV dead zone that it will not respond so that it can ignore any noise errors.

The CD4538 performs two functions. One is that it provides an adjustable delay between the load activation and when motion events are sensed. The other is that it provides an adjustable dwell time to keep the load active even after motion stops.

It also performs three optional functions. It can re–trigger the delay so that it will extend the delay, it can re – trigger the dwell time so that repeating motion will extend the time the load remains active and a day / night function which inhibits motion sensing during day.

The connecting circuitry is documented in the CD4538 datasheet.
At the output of CD4538 a RY1 coil is present. One end is connected to the power supplies. Since the motion detector will control the switch RY1 can be removed. D5 can also be removed, because it was present only to protect from back EMF when the coil produced a spike.
Hence the resulting circuit is shown in figure 6.7 - 1.

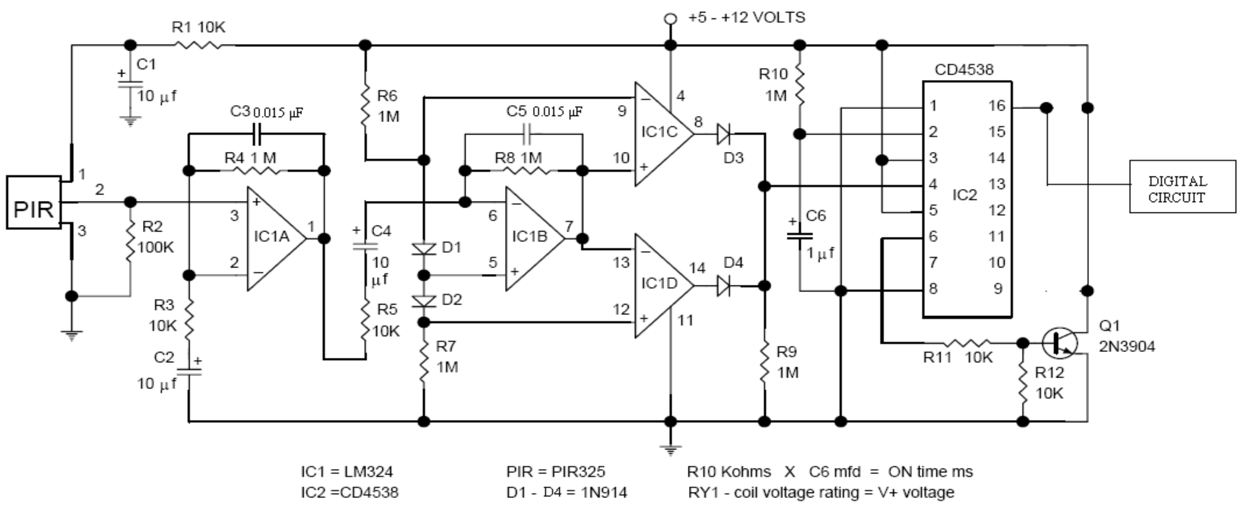


Figure 6.7 - 1: Motion Detector Circuit

The supply voltage to be used was decided to be 12V. Note that a 100pF capacitor may be needed to be added in parallel to R2 so that it will shunt any RF energy that might be picked up from radio transmitters or cell phones.

6.8 PSpice Simulation

For PSpice analysis read in Appendix H.

6.9 Installation Instructions

Two solutions were thought on how to actually install the motion detector sensor. The first method that was thought was to put the sensors on the ceiling. The problem with that is if the sensor is used without a Fresnel lens to have a wider view angle, the range would only be 3 feet. Therefore a Fresnel lens is required which limits the angle to 90 degrees which means that it can cover (for a room with height 3.5m) only around 0.5m. Figure 6.9 - 1 illustrates the idea.

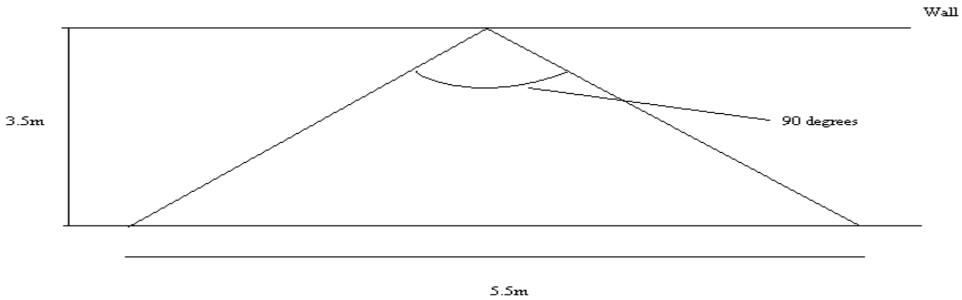


Figure 6.9 - 1: Installation Solution No.1

The other solution is to put sensors on the four edges of the room. This means that some zones will be uncovered depending on office geometry. Extra sensors can be used to cover the whole office.

We decided to go on with solution no.1 and use 4 sensors to cover the whole 360 degrees space. It may also require its own power supply unit if it is not physically close to the control unit.

6.10 Motion Detector Circuit Specifications

The motion detector circuit has some specifications. These are summarized in the following table:

Supply Voltage	5V
Load Current	3A

The above table is for typical operation.

The component list for this section of the system is shown in Appendix D.

7. Test Specification of Motion Detector circuit

7.1 Overview

The circuit will be built and tested in 3 stages. In the first stage contains the PIR sensor and the amplifier. The second stage contains the window comparator and the third stage contains the CD4538 IC. Appendix C (figure C – 2) shows how the circuit is split into 3 stages.

Before using the PIR sensor, an AC voltage source can be used with 20mVpp. For the power supplies a 12V DC source can be used.
Note that it is always better to first add IC, then transistors, capacitors, diodes and then resistors.

7.2 Stage 1 and Stage 2

For this stage the two amplifiers should be checked to see if they give the gain required (i.e. 100 each). The nodes leading to pins 9, 10, 13 and 12 provide inputs for the window comparator and should be checked. For IC1C to turn on pin 9 needs to be more negative than pin 10 and for IC1D to turn on pin 12 needs to be more positive than pin 13.

PIR sensor can be tested separately. The sensor should provide a 20mVpp signal which should be measured by an oscilloscope. If RF energy is present a 100pF capacitor must be added in parallel with R2 so that it is shunted.

7.3 Stage 3

The CD4538 should output from pin 16 either 0V or 5V and this should be tested. The rest of the connections are trivial. CD4538 is an IC and should work with no real problems. Its input comes from the IC1C or IC1D.

8. PC Monitoring Unit

8.1 Overview of system

The PC Monitoring Unit will be responsible in detecting if anyone in the office uses a computer. In an office there are several computers which are used by the employees (workstations) and these are usually connected to a computer which acts as a server. It was decided that computer software should be developed which will be installed on all the computers in an office. Any decisions the software takes, will be sent to the office server. In most of the cases, each office has its own server and therefore we can assume that the data received from computers by a server through our software will be from computers in the same office. The case described above is summarised in figure 8.1 -1.

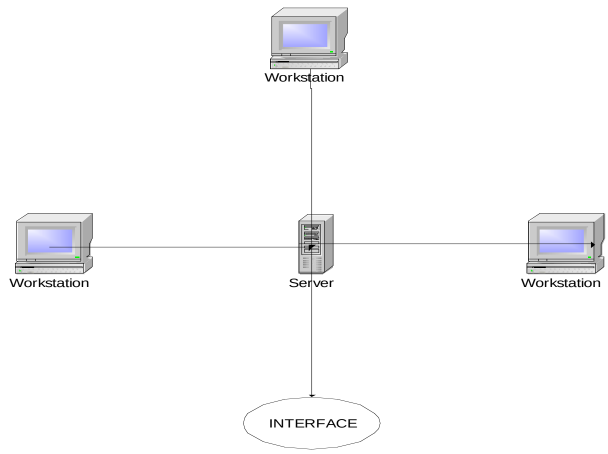


Figure 8.1 - 1: Connection of workstations with server

It was decided that since the most widely used operating system in offices is Windows XP, the computer software should be developed for this platform. This was a critical decision because Windows XP runs on an NT platform. The server has to communicate with a digital circuit and this should be done through an interface. The output of the server has to be sent therefore to the outside world through a port. Since NT platforms do not allow direct access of ports, the solution needs to come around this obstacle. High level languages allow accessing ports through various libraries so this shouldn't be a big problem.

Two different software programs were decided to be developed. One of the two will be installed on the workstations and was decided to be given a code name called "User Detector" and the other on the main server called "Office Detector" (although the code names may change on final product).

The software will be developed on Borland Builder C++ 6.0. A graphical user interface (GUI) will also be developed for both of the programs so that it will make it more user friendly. The next sections will analyse in more depth the operation of the software.

8.2 User Detector

8.2.1 User Detector Overview

The software installed on workstations will run continuously. For simplicity we will consider just one workstation and then generalise. To detect if a computer is used, the most basic check that can be done is if the user is logged in. If the user is not logged in, the software is not ran and hence the workstation will not send any information to the server. Hence this operation is beyond the scope of the software since it cannot determine if a workstation is logged in or not (read more on this later when the Office Detector will be considered).

When the user is logged in, the software will be ran automatically (since by default it will start when Windows open). Once the software is ran a message to the server will be sent letting it know that the user is logged in. Any use of the computer will inform the software that the computer is used. Mouse clicks, mouse movements or keys of keyboard pressed are all considered to be evidence that the computer is used. It is important to note that all these events should be identified by the software even when the software is minimized in the system tray (as it will be in all cases). Therefore all global events (as opposed to local events happening in the program) should be considered.

Each time an event occurs it will initialise a timer which will count up to 10 minutes. If during this time another event occurs then the timer will be reset. If nothing happens, a message will be displayed on the screen which will ask the user if he is present. If the user doesn't answer within a time of 5 minutes then the software will send a message to the server letting it know that the user stopped working on the computer. If within the 5 minutes the user responds to the message, another timer will be set which will count up to 30 minutes. Within this time if any movement occurs will reset the timer. Once the timer reaches 30 minutes then a message will be displayed, asking again the user if he uses the computer. The same procedure follows until the user doesn't respond to the message for 5 minutes. Once this happens, a message will be sent to the server saying that the user stopped working on the workstation. The flow chart summarizing the operation of the "User Detector" is shown in figure 8.2 – 1.

8.2.2 Software Design

8.2.2.1 Architectural Design and abstract specification

The purpose of the architectural design of the software is to identify the sub – systems. The software will be divided into various files. These files will contain the various sub – systems of the software. The "User Detector" software will have a GUI and hence one of the files called GUI.cpp will be responsible of handling all the user interfaces. Another file called DecisionMaking.cpp will be created which will contain all the functions that have to do with the correct operation of the software. The error handling and the exception catcher will be handled by the ErrorHandler.cpp file. Another file which will take and handle the inputs called Input.cpp will also be written.

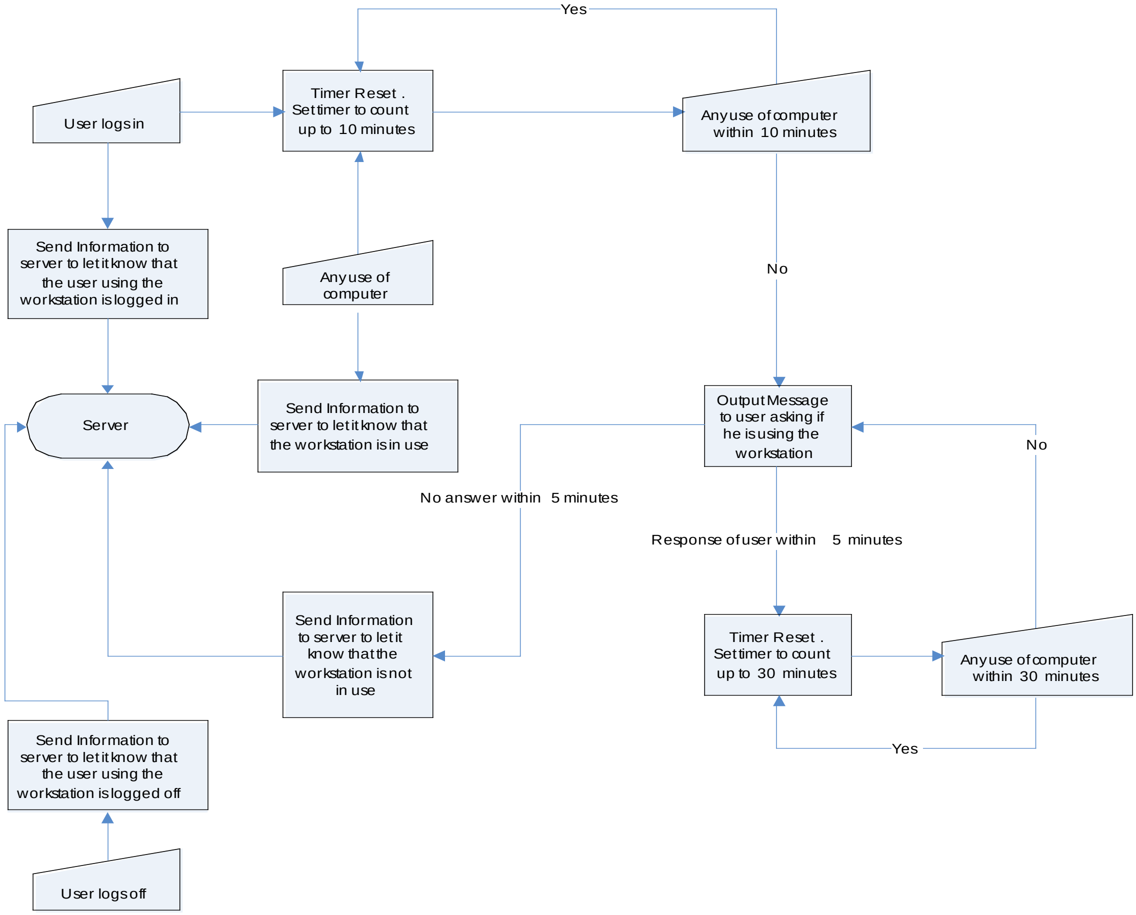


Figure 8.2 - 1: Flowchart summarizing the operation of the User Detector

8.2.2.2 Component Design

The first sub – system, GUI.cpp which handles the GUI of the software will be designed in the Borland Builder version 6.0. A menu bar will be present at the upper side of the program, and the timers will be shown in the main part, just for reference. Functions controlling the buttons will also be made.

The DecisionMaking.cpp will have a function that will set up the counters, a function to output messages on the screen, a function that will send information to the server and a function that will interrupt the timers.

The Input.cpp will have a function to take input from mouse clicks, a function to take inputs from mouse movement and a function to take input from keys pressed on keyboard. A log in function will also be written.
The ErrorHandler.cpp will handle all errors and catch all exceptions. Design of this file can better be done after all other files are actually written.

8.2.2.3 Data structure Design

The software doesn’t need any kind of linked lists or tress because it doesn’t require having any memory. There will be some classes to handle mouse clicks and movements as well as key operations and some GUI button functions. As far as the decision making file, it will only require simple functions with variables instead of classes.

8.2.2.4 Algorithm Design

The algorithms for most parts of the software are easy. The important functions are those in the DecisionMaking.cpp file which is the core of the software.

DecisionMaking.cpp Algorithm

Function SetTimer(Inputs: DurationOfTimer)
    Reset timer
    Start timer count up to DurationOfTimer

Function Interrupt(Inputs: MouseMovement, MouseClicks, KeysPressed)
    If any of the inputs occur
        If message already outputted
            Call SetTimer(Input: 30 minutes)
            Call MsgToUser
        Else
            Set MsgOutputtedAgain = Yes
            Call SetTimer(Input:10 minutes)
            Call MsgToUser
        End
    End

Function MsgToUser(ComputerUsed)
    Ask user if he is using the computer
    Call SetTimer(Input: 5 minutes)
    If user answers within 5 minutes then
            Call SetTimer(Input: 30 minutes)
    else
            Call InformServer(Input: No)
    End

Function InformServer(Input: ComputerUsed)   Send information to server that ComputerUsed status is updated.

Input.cpp Algorithm

Function Mouse()
    On mouse.click call function Interrupt
    On mouse.movement call function Interrupt

Function Keyboard()   On key.pressed call function Interrupt
Function LogIn()   Call InformServer(Yes)

The GUI.cpp is trivial whereas the ErrorHandler.cpp will be designed later.

8.3 Office Detector

8.3.1 Office Detector Overview

The “Office Detector” software will be installed on the computer acting as a server for the office. It will have the responsibility of keeping a record of which computers are being in used and making the final decision of whether there is any computer used or not. Note that the program will run continuously

First it will check which computers are logged in and which are not and update its record. Then its record will be updated on real time as data are received from the computers. Once all computers are assumed to be not used it will output to the outside, physical, world a signal that no user action is detected. Figure 8.3.1 - 1 shows the flowchart that summarizes the operation of the “Office Detector”.

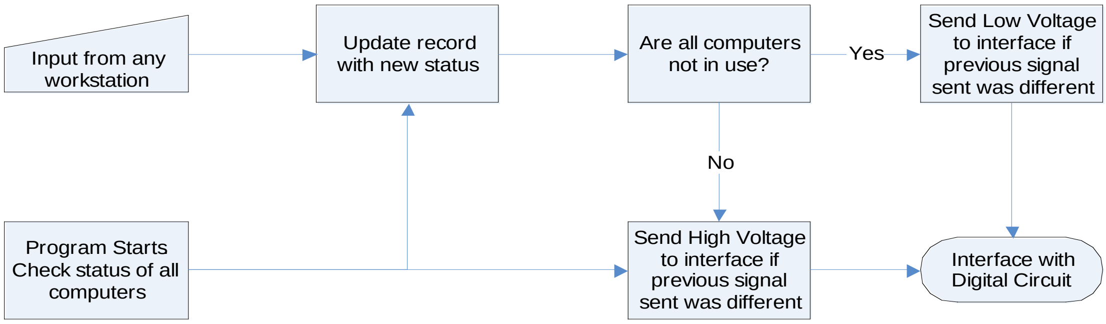


Figure 8.3.1 – 1: Flowchart summarizing Office Detector’s operation

8.3.2 Software Design

8.3.2.1 Architectural Design and abstract specification

The “Office Detector software” will be divided into various files to enhance the modularity of the program. One of the files called Inputs.cpp will handle the inputs of the program and one file called Output.cpp will handle the output of the program to the physical world. The GUI.cpp file will handle the GUI functions of the program whereas the Record.cpp will hold all record operations. Again there will be an ErrorHandler.cpp file which will hold all the exception handling procedures of the software.

8.3.2.2 Component Design

The various files will contain different functions. The GUI.cpp will have a standard format analogous to the “User detector” program and hence there is no need to elaborate on it. The Inputs.cpp file will have a function which it will receive inputs from the workstations and a function which will pass information to the record functions. Record.cpp will hold a function for keeping a record of the status of the workstations, a function which will update the records and a function that will keep track of the previous status of the record as a whole. Outputs.cpp will send information to the physical world.

8.3.2.3 Data structure Design

The data structure for this software will be a bit more complicated. An array or linked list will be used to keep track of the record of the status of the workstations.

8.3.2.4 Algorithm Design

The most important file is that of Records.cpp.

Records.cpp Algorithm
Function UpdateStatus(Input: WorkStationNo, Status)   Update Status of Workstation with no. WorkStationNo
Function CreateRecord(Input WorkStations, Status)   Create the array with Status of all workstations

Function OfficeStatus
        OfficeStatus = Low
        For x = 1 to WorkStationNumbers
            Check Status
            If at least one WorkStation has Status as Being Used
                    Set OfficeStatus = High
                    Set X = WorkStationNumbers
            End
        End

Inputs.cpp Algorithm
Function InputFromWorkstations (Input: InfoWorkStation) Call UpdateStatus(InfoWorkstation)

Output.cpp Algorithm
Function SendInfo(Input: OfficeStatus) GetCommState() SetCommState(OfficeStatus) Send OfficeStatus to port
Function GetCommState(Input: OfficeStatus) Communicate with serial port to get state
Function SetCommState() Defines the state of the serial port

8.4 Minimum Specifications for PC Monitoring Unit

- Network connection. Computer acting as a main server
- Microsoft Windows 2000 (or XP)
- Serial Port with RS232 protocol

9. Test Specification of PC Monitoring Unit

The software will be tested in three steps. The first step is to input data to the "User Detector" and check its outputs. The second step is to test the output data of "Office Detector" with specific inputs. The third step is to test if the two programs work well together.

Each function of the software will be tested once it is written before moving to the next function. The modularity of the program helps to identify easily errors. An exception handler will also be used to eliminate any bugs.

All kinds of combinations will be examined. The response of the program, the speed which it will communicate and the efficiency will be tested. The part that communicates with the outside world will also need to be tested along with the interface and the digital circuit.

10. Interface of PC Monitoring Unit with Control Unit

10.1 Overview

The PC Monitoring Unit is a software package which checks whether computers in an office are used. Its decision must be outputted to the Control Unit which will use the inputs from three input sources to control the lighting of the room. In order to communicate with the Control Unit, the software must output its decision through a port. It was decided that the port to be used for the communication should be the serial port. In order to connect the serial port to the Control Unit, an interface has to be used in between the two, in order to make them compatible. Figure 10.1 – 1 summarizes the connection between the server and the Digital Circuit

Figure 10.1-1: Connection between Server and Digital Circuit

The system was designed so that the digital circuit doesn't need to output anything back to the server. If there is any need to do so, the interface was decided to be able to be easily upgradeable to this case.

10.2 Serial Port Theory

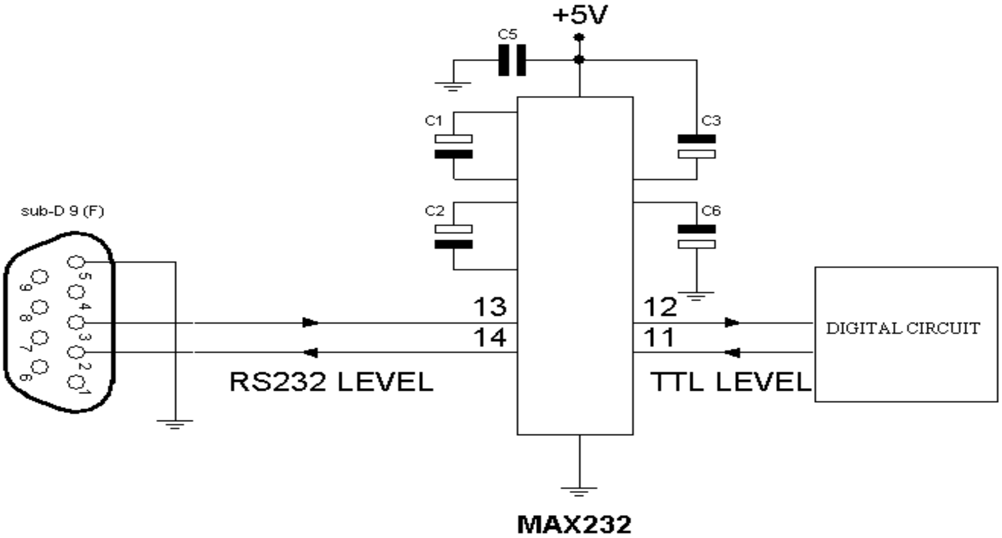
The serial port theory can be found in Appendix I.

10.3 Circuit Solution No.1

The circuit in Appendix E uses two transistors. Its advantage is that it doesn't use any IC, but it shouldn't be used if serial data has to be transmitted for long distances.

10.4 Circuit Solution No.2

This circuit uses a MAX232 IC. The circuit is very stable and is used in many professional designs. The IC is cheap and it also protects the inputs and outputs from electrostatic discharge. It operates from a Single +5 Power Supply.



[3]

Figure 10.4 - 1: Circuit Solution No.2

According to the MAX232 Datasheet, C1 – C6 are electrolytic and should have values of 1µF. The MAX232 schematic is shown in figure 10.4 - 2.

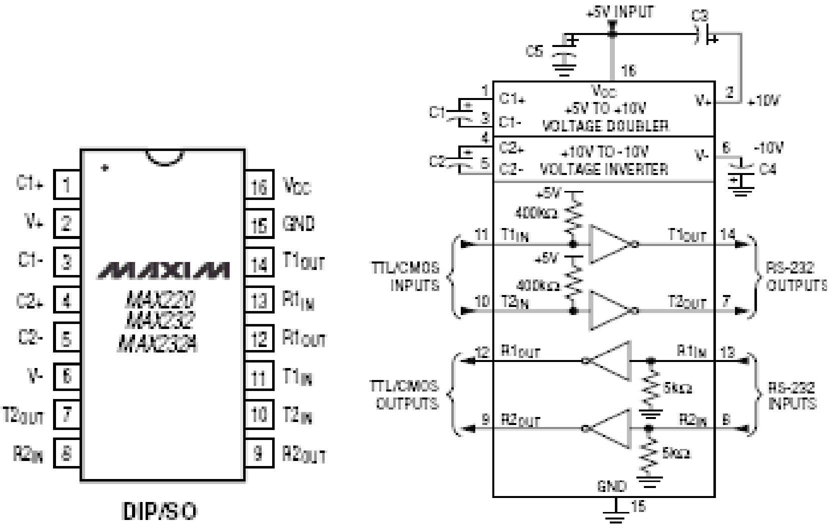


Figure 10.4 - 2: MAX232 schematic

10.5 Decision

Since the circuit based on the MAX232 IC is more stable and at the same time the cost is low, it was decided that this circuit should be used.

10.6 Interface Circuit Specification

The interface circuit specification is basically determined by the MAX232 IC specifications. The most important points are:

- Power supply of +5V is required
- Rin is between +/- 30V
- Tout is between +/- 15V

More detailed specification of the MAX232 IC can be found in its datasheet. This can be found on MAXIM's website.

10.7 Component list

Name	Value	Quantity
Electrolytic Capacitor	1 µF	5
MAX232 IC	-	1

11. Test Specification of Interface Circuit of PC Monitoring Unit with Control Unit

The interface circuit is a simple circuit and can be easily tested independently. Since the input from the serial port is between -25V to -3V or 3V to 25V, DC voltages in that range can be applied to port 13. The voltage at port 12 should be checked which should be 0V for any input voltage between 3V and 25V and 5V for any input voltage between -25V and -3V. This is because the serial port is active low.

12. Mobile Signal Detector

12.1 Overview

As discussed in the previous section, mobile phone detection will be one of the sensors used to detect the presence of an individual in a room. The circuit will have the following block diagram:

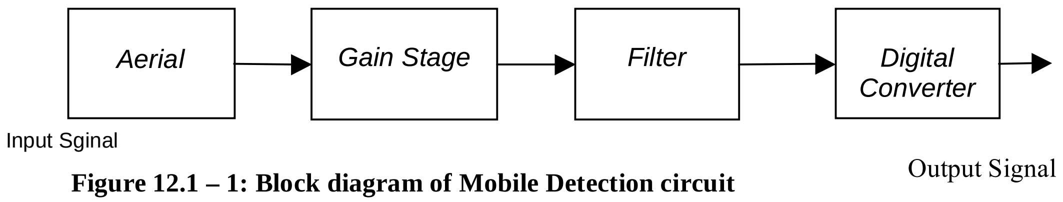


Figure 12.1 – 1: Block diagram of Mobile Detection circuit

The initial stage which picks up the signal is the aerial. A simple aerial could be devised by using a piece of wire which is one quarter of the wavelength of the desired signal. In our case, this would be:

$$\frac{\lambda}{4} = \frac{c}{f} = \frac{3\times10^{8}}{4\times1.8\times10^{9}} = 4cm$$

However, our group came to the decision that the best solution would be to purchase an antenna from the internet, which has already been tuned to the desired frequency and also provides a gain of 2.5 dB.

When dealing with mobile phone frequencies which are in the order of 1.8GHz, several complications arise. Due to the extremely high frequency of the signal, op – amp filter circuits cannot be used as they contain a fixed bandwidth × gain product. Also all cables in this frequency will act as transmission lines, meaning that without correct termination impedances, reflections could occur, meaning that a portion of the signal would be lost.

A possible solution would be to initially to demodulate the signal using a germanium diode and therefore reduce the frequency significantly. It is difficult to guess the frequency of the output of the diode. When building the circuit, a spectrum analyzer will be used to determine the frequency components of the outputs. Hence a change in the original design is likely to be made. Our estimate for the output of the demodulator will be 100 KHz. Also, as we do not know the exact amplitude of the signal, therefore, it is difficult to specify the required gain. However, a reasonable estimate that the demodulated signal will be ≈10μV, and that the output voltage of 1V is required for realistic operation, a gain of $\frac{1}{10\times10^{6}}=100{,}000$ will be needed.
A possible solution for the detection, rectification and amplification of a mobile signal at a frequency of 1800MHz is shown in figure 12.1 – 2. The signal is picked up by an aerial, length $\frac{\lambda}{4}$ and rectified by a Schottky diode. It is then just amplified by an inverting op – amp, where the 100nF decoupling capacitor also performs low frequency attenuation. The gain of the op – amp is set to 820 and the output is then fed into an earphone, where the 220 Ω resistor performs impedance matching for maximum power transmission. In the design in figure 12.1 - 2, there is a mirror image of the amplifier in the bottom half of the circuit. This is used to trace the location of the signal. The second aerial will induce a different voltage if the device is moved and therefore point the user in the general direction of the signal. For our design, as we are only interested in the presence of the mobile phone and not its location, we will only use the top half of the circuit.
We can improve this circuit by separating the 820 gain of the circuit into several stages in order to improve stability and add extra filtering to the signal to attenuate noise.

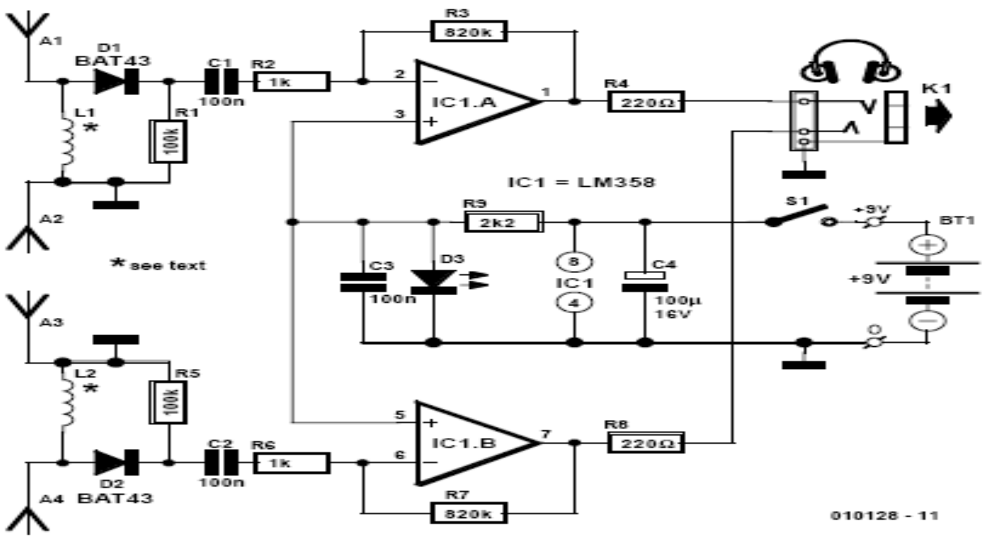


Figure 12.1 – 2: Circuit to be used[2]

12.2 Aerial and Signal Amplification

After the signal is received and demodulated via the diode, it will be amplified via the three op – amps, each having a gain of -10. To achieve this gain, the ratio of the input and feedback resistors have to be 1:10. Therefore, in first three amplifying stages, the values will be 1KΩ and 10KΩ for the input and feedback resistors respectively. The 100nF A.C coupling

[2] http://www.elektor-electronics.co.uk/Default.aspx?tabid=28&year=2002&month=5&art=50661&group=Microcontrollers

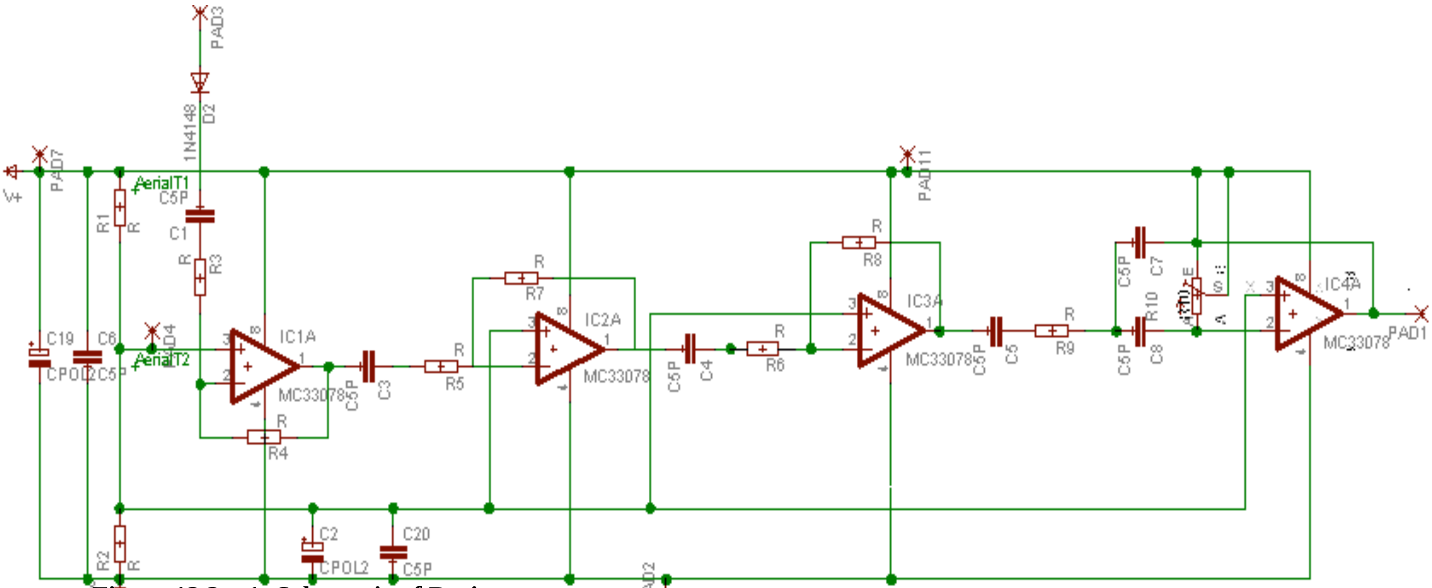


Figure 12.2 – 1: Schematic of Design

capacitor between each stage will also provide high pass filtering at a break frequency:

$$f = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 1\times 10^{3} \times 100 \times 10^{-9}} = 1.6KHz$$

This break frequency will attenuate any 50Hz transmission line frequencies and allow the mobile signal to pass through.

Although at this stage it is difficult to specify the frequency of the demodulated signal at the aerial, an estimate can be made. The demodulated signal will be approximately equal to the frequency of the pulses emitted from the mobile. This can approximated to 2 KHz. The Delyiannnis Friend circuit can be used to provide a gain and filter the signal at the same time.

Transfer function of the filter is given by equation:

$$H(j\omega) = \frac{-j\omega R_6 C_3}{1-\omega^2 R_6 R_5 C_3 C_4 + j\omega R_5 (C_3 + C_4)}$$

If condition is made $C_3 = C_4$
The Quality factor of this stage will hence be:

$$\therefore \omega_0 = \frac{1}{\sqrt{R_6 R_5} C}$$

$$Q = 0.5\sqrt{\frac{R_6}{R_5}}$$

$$H_{0BP} = -2Q^2$$

From the above equation it can be seen that a higher gain will give a higher Q. However, the value of resistors should not be very big because the currents in this part of the circuit are quite small. Therefore a good compromise would be to have a gain of -32.

$$-32 = -2Q^2$$

$$Q = 4$$

$$\therefore \sqrt{\frac{R_6}{R_5}} = 8$$

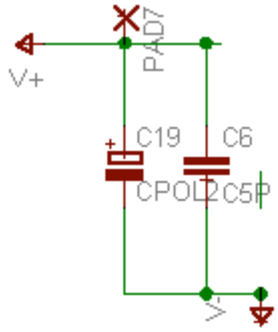
$\therefore \omega_0 = \dfrac{1}{8R_5C}$, If R_5 is set to 500Ω. The value for the capacitor can be worked out:

$\therefore C = \dfrac{1}{2\pi \times f \times 8R_5} = 20nF$, $\therefore R_6 = 32K\Omega$

These values will be subject to change depending on the frequency and the amplitude of the received signal.

12.3 Power Supply of Motion Detector Circuit

In the circuit there will be a 12VDC power supply which needs to be decoupled to ensure circuit stability. This is done by connecting two capacitors, one ceramic and one electrolytic in parallel with the supply. The impedance (including ESR) of the capacitors need to be <10Ω. All different supplies will need separate decoupling.



A value of 100µF can be used for C19 and 100nF for C6. Because the electrolytic capacitor has a very low ESR and low impedance at 2 KHz. Therefore, the overall parallel impedance will be<<10Ω.

Fig12.3 -1: Power Supply Decoupling

12.4 Virtual Earth

A virtual earth is required for circuits which require a negative voltage. For example the op – amp chips need a ±6V supply. This is achieved by connecting 12 V to +Vcc and then using a potential divider with equivalent values to have 6V as virtual earth.

One of the requirements of the control unit is that the output voltage has to be a digital signal with 12V and 0V is needed to represent the presence of a mobile signal and no mobile phone respectively. The output of the signal after amplification will be a very small pulse with an approximate duration of 600µs.

To satisfy the requirements, a 555 monostable circuit will be triggered by the mobile signal to produce a short pulse of certain duration. However, a monostable circuit needs to be triggered by a falling edge (0V), which means the output of the gain stage will need to be inverted. This will be done by a 555 timer, as shown in the picture below.

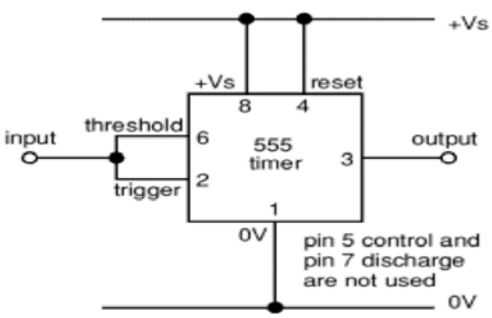


Figure 12.4 – 1: 555 Timer
[3]

[3] http://www.kpsec.freeuk.com/555timer.htm#edgetrigger

In this circuit, if the input >2/3 Vs, the output will be zero. Otherwise the output will be high. Therefore, signal inversion is performed.

The mono stable circuit will be used to output a pulse of certain duration after a falling edge on pin 2:

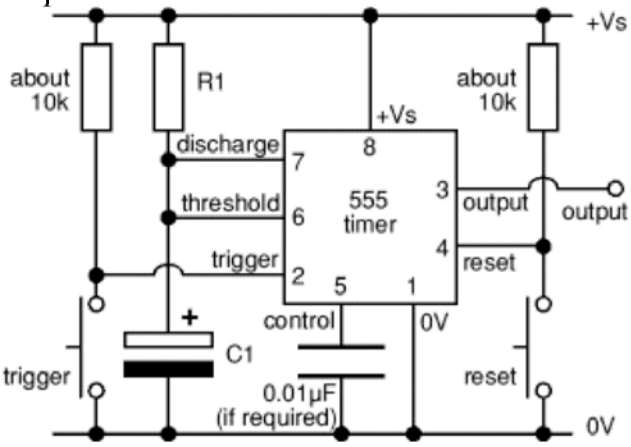


Figure 12.4 – 2: 555 timer circuit
[4]

The output of the previous 555 will be connected to the trigger of the timer shown in the above diagram. Therefore while there is no mobile phone present in the room, the trigger input will be high. However, when a mobile phone has been detected, the trigger of the monostable will go momentarily low, causing there to be a pulse at the output of the timer.

The duration of the output of the pulse will be is determined by the R1 and C1, components given by equation:

$T = 1.1 \times R1 \times C1$

If the duration of the needed pulse, is approximated to be 5 seconds, and R1 = 100KΩ
C1 = 45 uF.

The component list of the circuit is shown in Appendix L.

12.5 Another solution for the Mobile signal detector

You can find another solution for the mobile signal detector in Appendix K. This is our contingency plan for this part.

13. Test Specification of Mobile Signal Detector

13.1 Overview

While building the circuit board, it will be necessary to test each stage of the mobile detection circuit and repair any encountered problems.

After soldering the components of the IC1 chip (Op – amp), before the chip is placed into its terminal, the power supply rails will be tested. By connecting 12 V and 0V to V+ and V- respectively, it will be possible to test that Pin 3 of IC 1 (Op – amp) is biased to 6V with respect to earth. Also, Pin 8 should be connected to 12V and Pin 4 to 0V.

[4] http://www.kpsec.freeuk.com/555timer.htm

After the chip is placed into its terminals, the chip will be tested for the same conditions, to make sure there is no short circuit. Also, the outputs of both op – amps will tested to check that they are at virtual earth (6V)

13.2 Testing Operation of Op – Amps

When all bias conditions of the op- amp have been satisfied, its operation will be tested. I.e. Is the gain of the op – amp the same as specified?
A signal generator will be used to produce a 2 KHz sine wave with an amplitude of 0.1 V. The input will be connected to the C1 (capacitor) and the output on pin 1 of the op- amp will be measured. If the output is a 1V sine wave with the same frequency, the op – amp will be assumed to be working correctly.
While testing the circuit, if one of the inputs from the generator is connected to C1, the other pin should be connected to V- (0V) and not the virtual earth (6V). This is because the signal generator is itself connected to earth and if the 0V lead will be connected to virtual earth (6V), a short circuit will be made between earth and 6V, meaning the op – amps will not function correctly.

The same testing procedure will be applied to both IC1 and 2 which contain the op – amps.
After building all the gain stages and connecting them together, it will be possible to test if the signal from the mobile phone can be detected by our sensor. By connecting the output of gain stage to the oscilloscope, and placing an operating mobile phone near the aerial, short bursts of pulses should be seen on the oscilloscope indicating the presence of a mobile phone.

13.3 Testing 555 timers:

To test the 555 timer, as in the previous case, the bias conditions will need to be initially tested. On both timers, pins 4, 8 should be connected to 12 V, and pin 1 to 0V.
The first timer, which just performs inversion, can be tested by checking the output while the input is connected to either +12V or 0V. If the output is inverted, the timer is working as expected.
The second timer should produce a square wave with duration of 5 seconds on a falling edge to the input. Therefore, if the output (pin 3) is connected to the oscilloscope and pin 2 is connected momentarily to zero volts, a square wave should be seen on for 5 seconds.
If both timers are connected together, the output (pin 3) should only produce a square on the rising edge to the first 555 circuit.

To test the complete system, the operation of a mobile phone near the antenna should produce a square wave for 5 seconds at the output of the 555 timer.

14. Power Supply Interface

The PIR, MP and Control unit blocks will all operate at 12 V. To supply the power rails of the PCBs, an AC to DC adaptor will be used. This will convert the 240V from the mains supply to 12V, 0.4A. The circuit will have the suitable jack input for the power supply. Alternatively, a 12V AC/DC converter PCB circuit can be integrated in the device, and feed it directly from the mains. Further, as it can be seen figure 14 - 1, the power rails will be decoupled, using two capacitors in parallel, one electrolytic (100µF) and one ceramic (100nF). Any parts in any block that need less than 12V will be supplied after a potential divider.

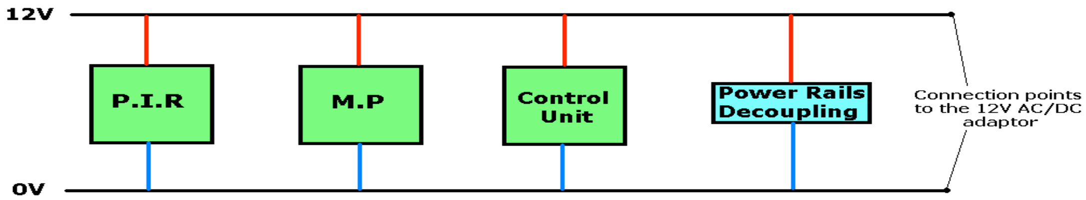


Figure 14 - 1: Power supply for PCBs

Figure 14 – 2 shows the adapter to be used.

Figure 14 - 2: 12V AC/DC adapter to be used (left) and alternative 12V AC/DC PCB circuit.

15. Control Unit

15.1 Overview

The purpose of the control unit is for the user to be able to select a combination of inputs and to choose in what way the inputs to be processed to control the lighting system of an office. The control unit will be implemented with logic gates, multiplexers, counters, switches, amplifiers, resistors and other external components.

The control unit has 4 inputs, 3 of the inputs are the outputs from the 3 previous stages i.e. Motion Detector (PIR), Mobile Signal Detector (MOB) and the Computer Monitoring Unit *[Interface]* (PC). The fourth input is from an external switch to decide which path to be followed in the control unit (This will be discussed later on). There is also a clock input but this is generated within the unit and it will be used for synchronizing the digital circuits. The four inputs will be either Logic 0 (low) or Logic 1 (high) i.e. 0 and 5 Volts respectively.

The 3 inputs from the previous stages are combined in 7 different ways. This gives the user a vast variety of choices to select for the most appropriate and best setting for their office. The seven combinations are shown in figure 15.1 – 1.

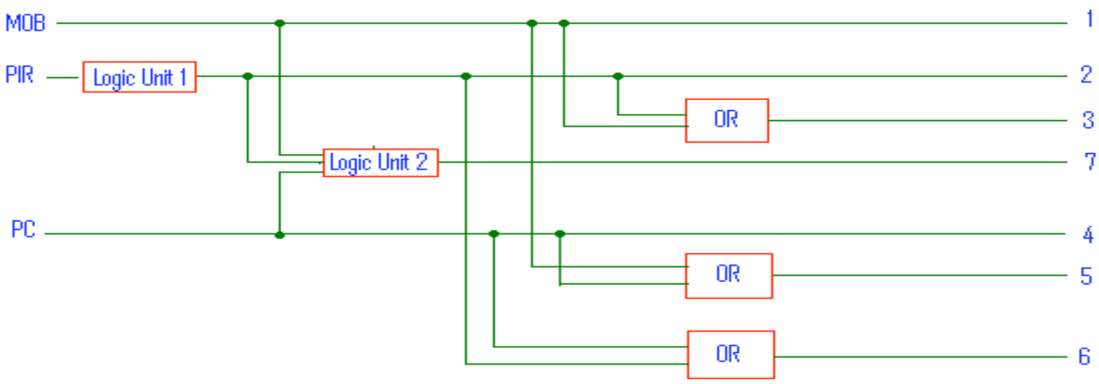


Figure 15.1 – 1: Seven different possible combinations

15.2 Logic Unit 1

The output of the PIR will follow 2 paths as shown in figure 15.2 – 1. The first path is when its logic is high thus making the path go directly to the next stage of the circuitry. If however the PIR logic is low, then a synchronous 4-bit counter is enabled that has a clock input of 1 minute period. This means that the counter will increment its value by 1 every minute. Since it is a 4-bit counter, it will count from 0000 to 1111 (i.e. 0-15). This will give a 16 minute delay to the PIR output. As a result, when the PIR is low it will take 16 minutes to go the next stage.

The next stage of circuitry is a 2-input Multiplexer which is used to select which path to be taken. The select input of the multiplexer is the PIR output.

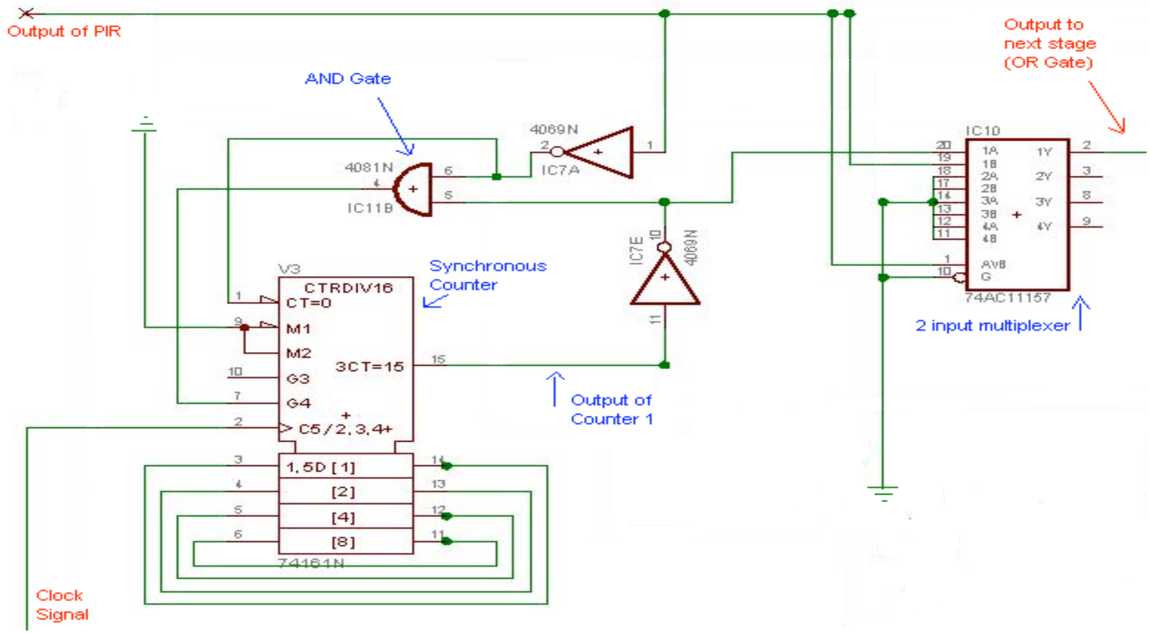


Figure 15.2 – 1: Two paths for PIR with 2-input Multiplexer

It is important to note that the synchronous counter will reset only when the PIR is high again. If the counter counts to 15 and the PIR is low then the chip will be disabled and thus the output will remain constant (i.e. output 1) until it resets. A NOT gate is used to invert the output.

The output of the multiplexer is now the PIR output that will be used for the remaining control unit. So now for the first 6 cases, the implementation is done with simple logic gates. We require one OR gate chip. This chip has 4, 2-input OR gates and its power supplies are 0 and 5 Volts.

15.3 Logic unit 2

The 7th case is more complex, but more interesting and useful at the same time. In this case all 3 inputs are used. The Logic unit 2 will determine how the MOB will affect the final output. That is, when the PIR is Logic 0 for a long time, then the MOB input will be neglected. The PIR has to be low for 32 minutes for the MOB to be neglected. A second synchronous counter will count another 16 minutes (16+16 = 32). However the counter will reset as soon as the PIR becomes high, so the MOB is taken into consideration again. At the end of this logic unit there is a three input OR gate as shown in figure 15.3 - 1.

Also in figure 15.3 – 2 shows the output for logic unit 1 and 2.

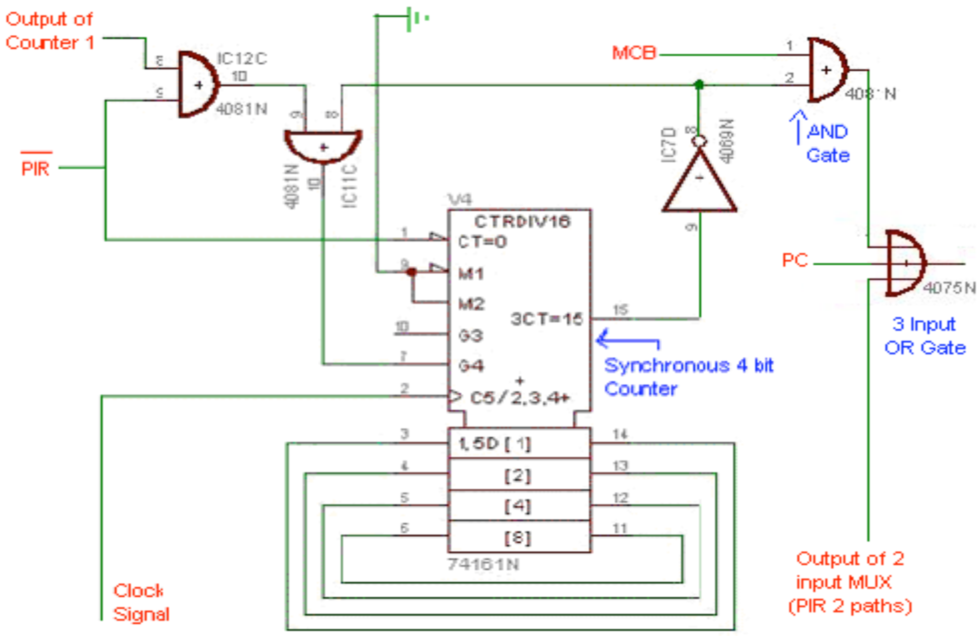


Figure 15.3 - 1: All three inputs taken into consideration, MOB neglected after 32 minutes

A crystal oscillator will be used to create a clock signal which will be used in the synchronous counters. However, this clock signal has a frequency of 10 Hz; therefore we will have to add some ripple counters to reduce the frequency so that the period of the clock signal will be 1 minute (more details in the test specification of the control unit).

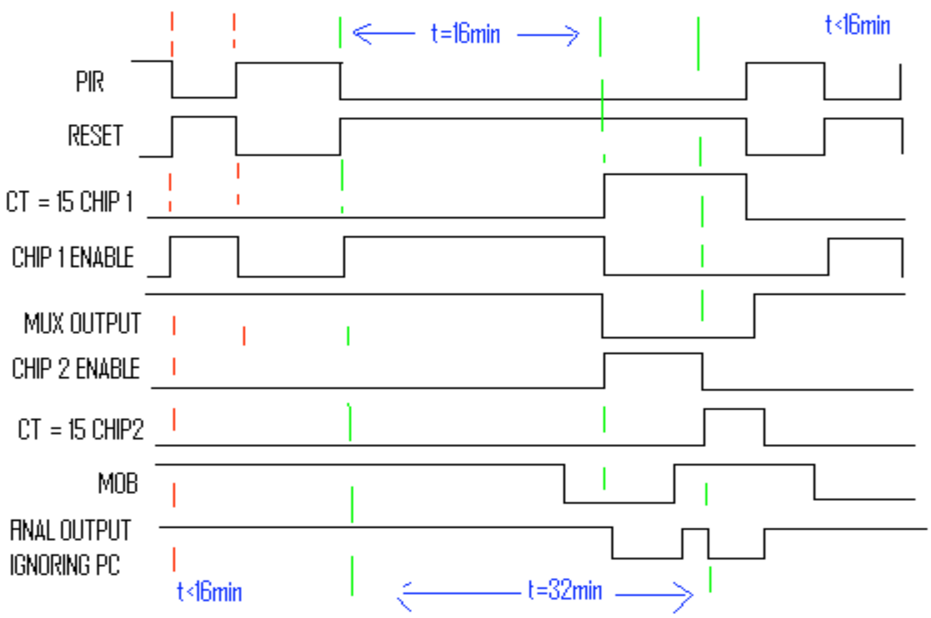


Figure 15.3 - 2: OUTPUT for LOGIC UNIT 1 AND 2

15.4 Select inputs for multiplexer that chooses the data input that will be processed

Now that we have seven different outputs, we need to use and 8-input Multiplexer (MUX) with 3-select inputs. The 8th input is grounded so when it is selected the lights are turned off.

The select inputs of the MUX will be determined by either an external switch or a knob. By using a knob which controls a variable resistor in a potential divider, we can output 8 different voltages (0, 1, 2, 3, 4, 5, 6 and 7 Volts). These outputs will be fed into 8 comparators as shown in figure 15.4 – 1.

The circuit will compare the output of the potential divider with 8 predetermined reference values. The reference values are 0, 1, 2, 3, 4, 5, 6 and 7 Volts. The output of the comparator will either be 0 or 5 Volts (Logic 0 or 1 respectively), and will be fed into a priority encoder. The priority encoder will convert the output of the potential divider into 3-bit binary number. The 3 bits can then be used as select inputs for the 8-input MUX.

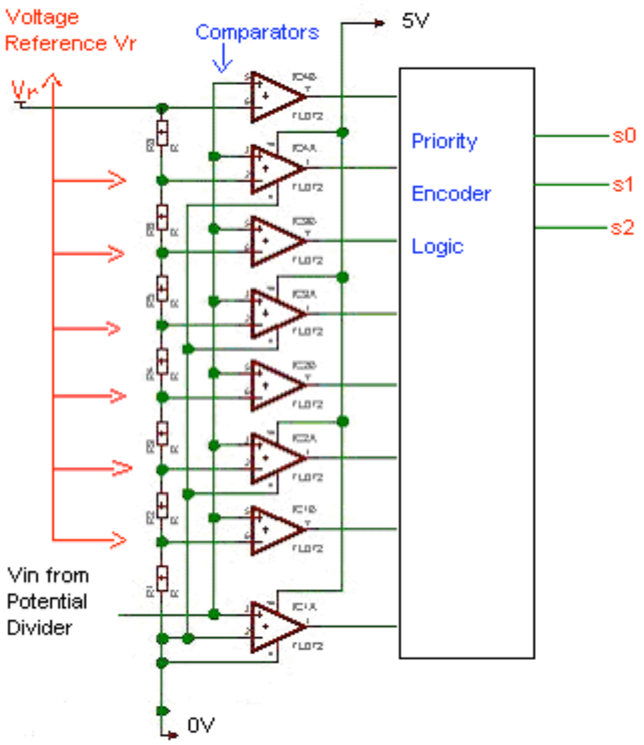
Another method to generate the select inputs for the multiplexer is to use a 4 way SIL Switch[5]. The switch has 4 select buttons but we will only use 3. The chip will either let 5V or 0V pass through and go to the select inputs of the MUX. By pressing buttons 1, 2, 3 in different combinations we can select any of the 8 data inputs of the MUX.

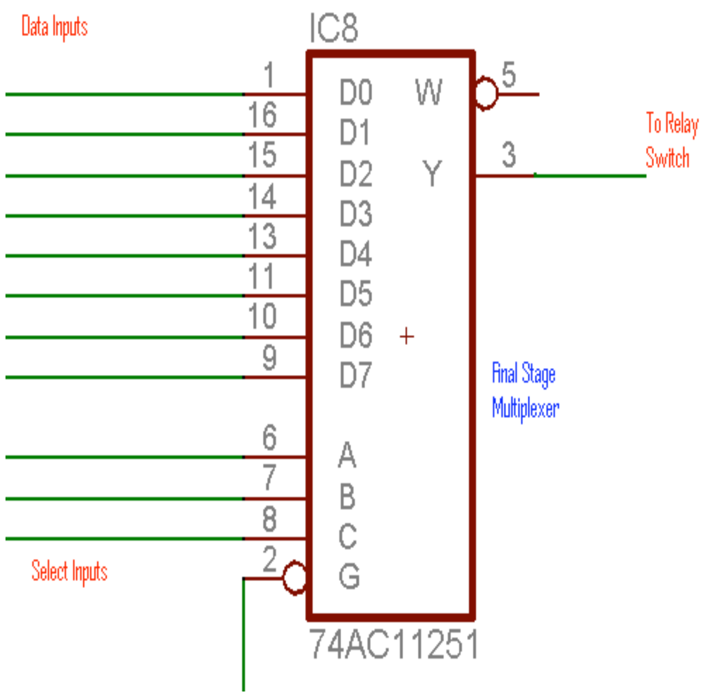
Name	Quantity	Value/Code
R	7	1K
Potentiometer	1	0 – 6K
Op-Amp	4	TL072
Priority Encoder	1	4532

OR

4 – way switch	1	SIL Switch

Table 15.4 – 1: Comparison between Variable resistor and 4 – way switch select inputs





[5] http://www.jprelec.co.uk/docs/PImages/pdfcopies/800-655D.PDF

Figure 15.4 – 1: Flash A/D Converter[6] with Priority encoder (left). Final Stage Multiplexer with Select inputs (right)

The second method is more convenient therefore this is what we will use for the select inputs of our 8-input multiplexer.

The output of the multiplexer will either be 0 or 5 Volts (logic 0 or 1). This voltage will control a relay switch which will switch ON or OFF the lighting system. However a current amplifier is required because the current from chips are very small to control the relay switch. We need currents of about 200mA. Relay coils produce brief high voltage 'spikes' when they are switched off and this can destroy transistors and ICs in the circuit. To prevent damage we must connect a protection diode across the relay. The component list is shown in Appendix F.

Contingency plan for clock signal

Another way to generate a clock signal is to use a 555-timer[7]. The figure below shows how the connections must be done, while the equations show us how to calculate the component values.

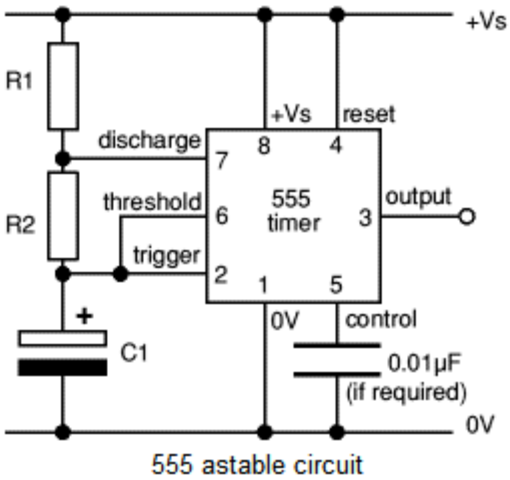


Figure 16 – 5 : Clock Signal Generator

f= 1.44/((R1+2R2)*C1)
The time period can be split into two parts: T = Tm + Ts .
High time (output high): Tm = 0.7 × (R1 + R2) × C1
Low time (output low): Ts = 0.7 × R2 × C1

We want a 50% duty-cycle so Tm = Ts = 0.5s and T = 1s. Therefore we have two equations with two unknowns. Solving the equations simultaneously we can find values of R1, R2 and C1 for any clock frequency.

16. Control Unit Test Specification

The control unit will be on a separate board for experimental reasons, therefore it can be tested on its own. We can apply the input signals PIR, MOB and PC, but if we want we can replace these by test signals from signal generators. All we need is, to replace the input signal with 0 or 5 Volts signals. The circuitry for the control unit involves mostly digital logic i.e. IC chips. It would be good to check every chip we use for its functionality.

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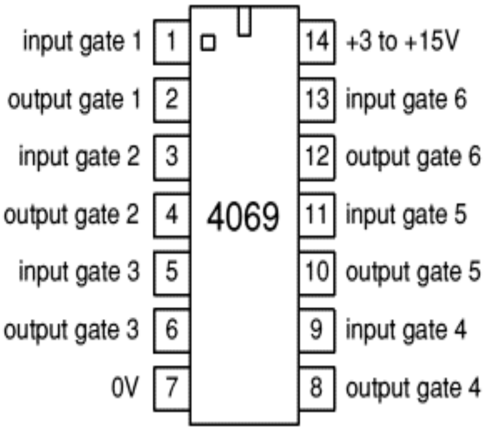
[6] http://www.ee.ic.ac.uk/hp/staff/dmb/courses/dig2/4_Analog.pdf
[7] http://www.doctronics.co.uk/555.htm#astable

Starting with the hex NOT (inverting buffer) gate-4069[8], we need to connect pin 14 to +5V and pin 7 to ground (0V). We can test if the NOT gates work by applying a test signal of 5V. The output must be 0V and vice versa.
The next chips to be tested are the Quad 2-input gates (AND – 4081, OR – 4071)[9]. Again we connect pins 14 and 7 to +5V and ground respectively. We apply the test signals to the gates and check each corresponding OR/AND gate.



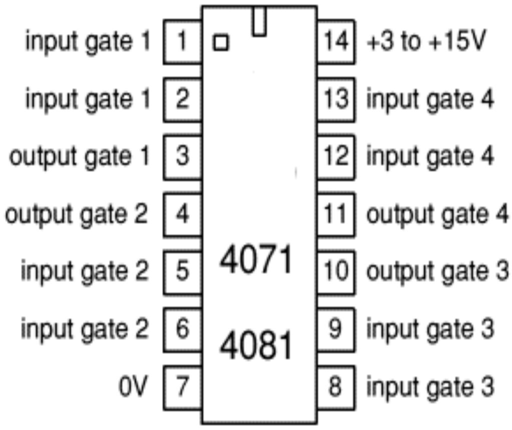
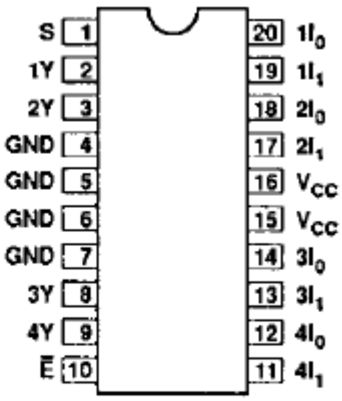
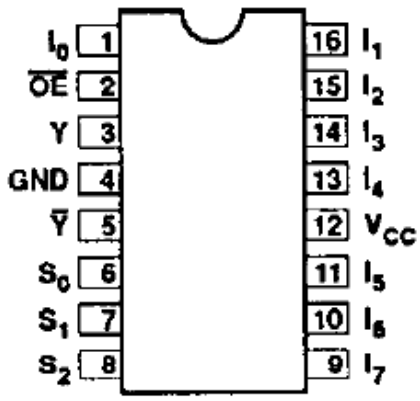


Figure 16 -1: Hex NOT gate (left), Quad 2-input AND/OR gate (right)

Exactly same procedure is performed for the Triple 3-input OR gate-4075.
Moving away from the simple logic gates, the next IC chip to be tested is the Quad 2-input multiplexer-74AC11157[10]. Now we connect pins 4, 5, 6, 7 and 10 to ground while pins 15 and 16 to +5V. Notice that pin 10 (has an inverted output) is connected to 0V so that it enables the chip. Pin 1 is the select input and is connected to the same test signal as pin 20, whereas pin 19 is connected to a different test signal. The rest of the inputs are connected to ground and their outputs are left free because we don't need them.
The other multiplexer we use in our control unit is an 8-input. Its code is 74AC11251. We connect pin 12 to +5V, pins 2 and 4 to ground. Pins 6, 7 and 8 are the select inputs and pin 3 is the output. The rest are data inputs. By applying test signals to the select inputs we choose which data input to pass through and go to the output. Hence we can check the chips functionality by changing the combination of the select inputs and observing the corresponding data input and final output.

Figure 16 – 2: Quad 2-input Multiplexer (left), 8-input Multiplexer[11] (right)





[8] http://www.kpsec.freeuk.com/components/cmos.htm
[9] http://www.kpsec.freeuk.com/components/cmos.htm
[10] http://www.kpsec.freeuk.com/components/74series.htm
[11] http://www.kpsec.freeuk.com/components/74series.htm

The counters we use to delay some of the inputs are Synchronous 4-bit counters-74161. This device counts from 0 to 15 (0000 – 1111 binary). For normal operation (counting), pins 1, 7, 9, 10 and 16 must be logic high (5V), while pins 8 and 10 must be logic low (0V). By inserting a clock signal of 1 Hz we have to wait 16 seconds for the output to be high.

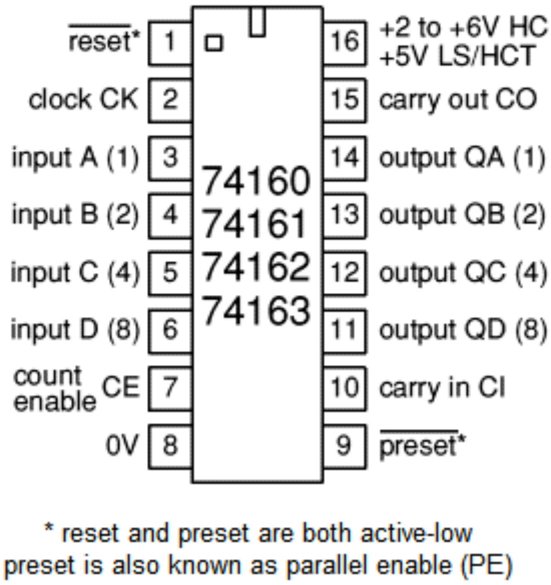


Figure 16 -3: 4-bit Synchronous Counter

A 4-way SIL switch is also used. We can check if the switches work by applying a test signal to the inputs and looking at the output of each path with its corresponding switch selection.

Relay [12]Switch 808-472. We connect a test signal to pin 5 and connect a pin 1 to the ground. We can check the position of the switch. To test it we can just measure the voltage across a test resistor which is placed in the two paths available. Then we invert the test signal and the position of the switch must also invert. Note that a separate current/voltage must be entered in the 2 paths of the switch.

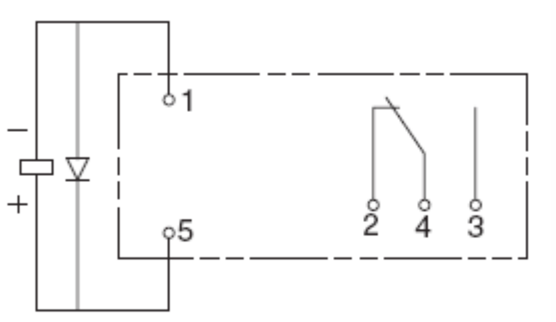


Figure 16 – 4: Relay Switch

The Crystal Oscillator outputs a clock signal of 10Hz. We will use a ripple counter (Div by 10) to output a clock signal with frequency of 1Hz. This clock will be used for testing only. However, in the actual case we will make the clock signal to oscillate with 1 minute period.

[12] http://docs-europe.origin.electrocomponents.com/webdocs/002b/0900766b8002b911.pdf

This can be done by adding 2 more ripple counters that divide together the frequency by 60. Therefore 1 ripple counter will be Div by 10 and the other Div by 6.

Now that we tested all the parts separately, it is time to test the circuit when we connect the components together. We will divide the entire control unit into 2 parts. 1st part is to test *Logic Unit 1* and 2nd part is the *Logic Unit 2*. After testing these 2 circuits we will interconnect them and finalize circuit with all the components. (Note logic units 1 and 2 were discussed previously about their operations).

Logic Unit 1

To this part of the circuit only 1 input is connected, the "PIR". Logic unit 1 is composed by several ICs, these are the 4-bit synchronous counter, the 2 input multiplexer, AND gates, NOT gates and Clock signal.

So we use the pin connections discussed above and we replace the test signals to all the stages except that for the 1st NOT gate, with the corresponding output of its previous stage.

Logic Unit 2

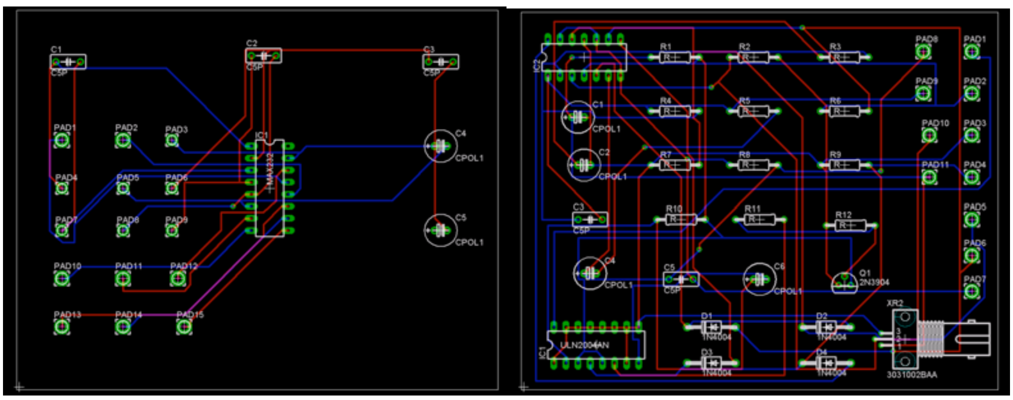
All 3 inputs are used in Logic Unit 2. This part is composed by a 4 bit counter, AND gates, NOT gates, a 3- input OR and a Clock signal. The procedure of testing this circuitry is similar to the one used in Logic Unit 1. (Diagrams and outputs of different stages of the Logic Units are shown previously)

Now that we tested the logic units we can connect all the components of the control unit and test the output for all 7 cases with every possible test signal combinations of the three original inputs.

The complete circuit of the Control Unit is shown in Appendix J

17. PCB boards

Appendix J includes the PCB boards for the circuits. Note that in the final product, all the circuits will be on the same PCB. Here below, in figure 17.1 – 1 the PCB board layouts are shown in small figures just for completeness (For bigger figures look in the Appendix J).



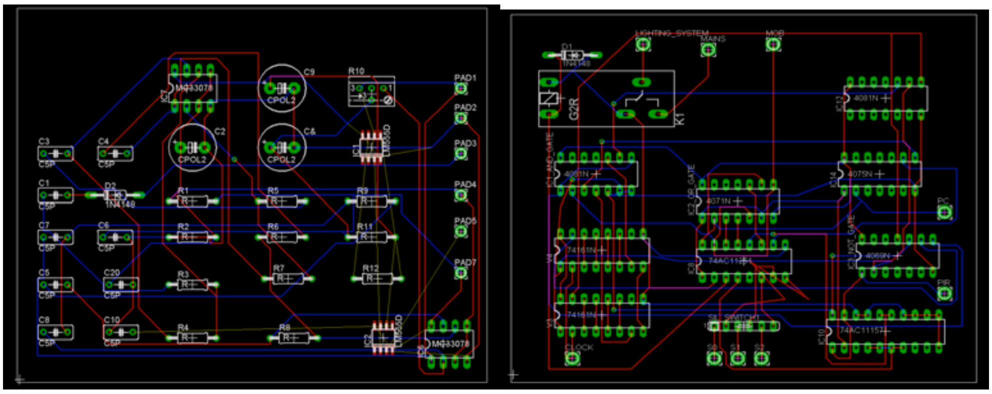


Figure 17.1 – 1: PCB layouts of Interface Unit, Motion Detector circuit above and below the Motion detector circuit and the Control Unit are shown

18. Test specification of the whole system

Before testing the whole system, the various parts should be connected together. For easier and more efficient testing, the system should first be tested in labs. The motion detector circuit output and the mobile signal detector output should be connected to the Control Unit. The PC Monitoring Unit should be connected to the interface, which in turn should be connected to the Control Unit. The Control Unit will be connected to a relay switch. Once this part of the system works, the adapter should also be connected to the systems so that correct power up of the system is done as predicted.

To ensure that testing is correct, the output of the system, from the switch should either be 0V or 5V and this should measured. During testing, measurements at the inputs and outputs of the blocks should be done, although they are supposed to be working since extensive testing was done at an earlier stage.

19. Conclusion

The design report tries to identify the system and from a high level design, step by step, block by block, move to a detail low level design which will allow us to implement the system in the 3rd stage of the project.

It was important to split the system into parts so that parallel work could be done which utilised the time allocated better. It is also important to comment that all parts have a contingency plan associated with it so that if anything goes wrong, an alternative solution can be adapted.

Designing the system was a challenging task which gave us the opportunity to handle complicated circuits and analyse them. Designing the control unit from scratch was one of the most rewarding parts of the project.

20. References

[1] http://www.glolab.com./pirparts/pirmanual.PDF *(accessed 9 Feb 2007)*

[2] http://www.elektorelectronics.co.uk/Default.aspx?tabid=28&year=2002&month=5&art=50661&group=Microcontrollers *(accessed 22 Jan 2007)*

[3] http://www.kpsec.freeuk.com/555timer.htm#edgetrigger *(accessed 25 Jan 2007)*

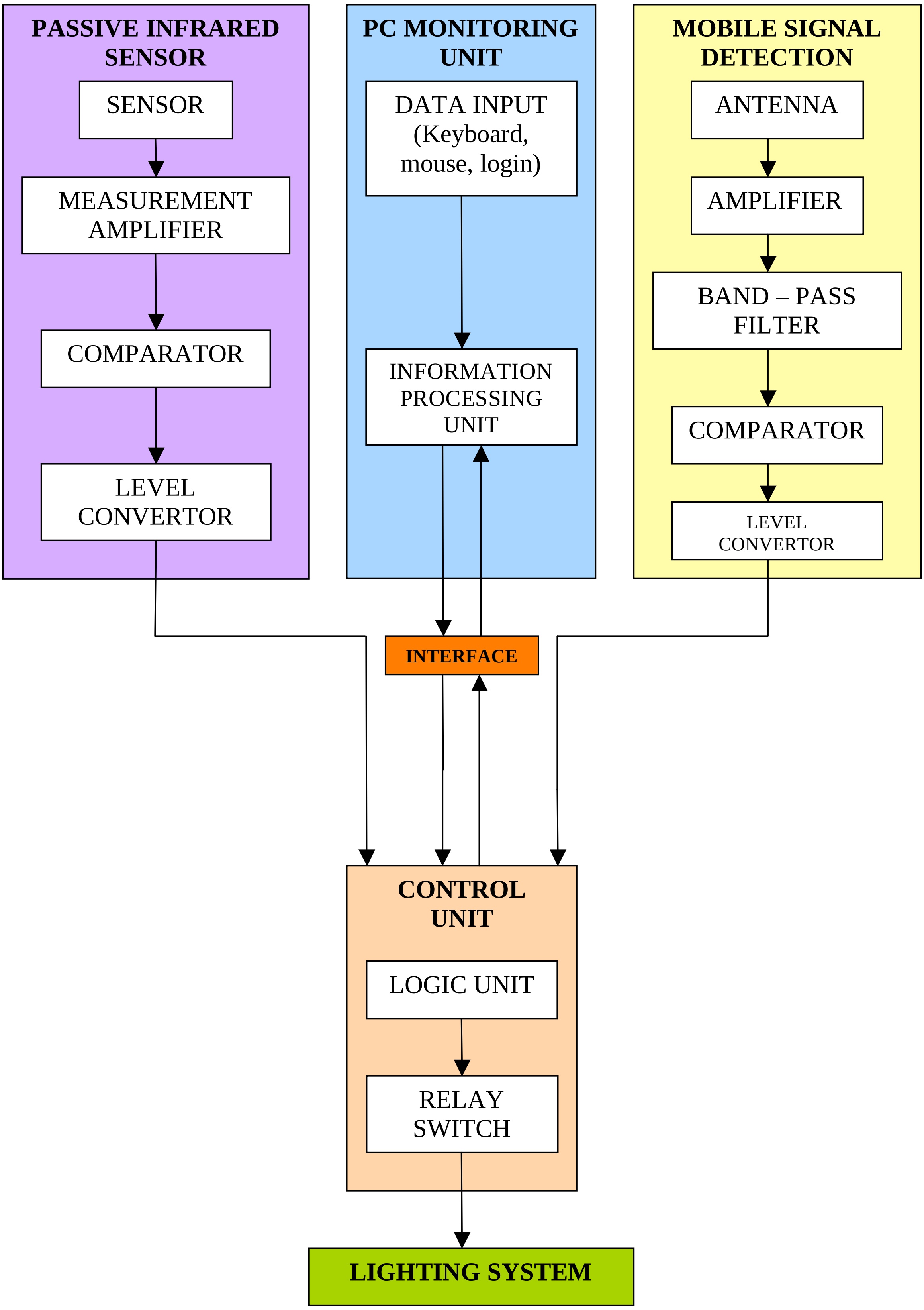
[4] http://www.kpsec.freeuk.com/555timer.htm *(accessed 15 Jan 2007)*

[5] http://www.jprelec.co.uk/docs/PImages/pdfcopies/800-655D.PDF *(accessed 18 Jan 2007)*
[6] http://www.ee.ic.ac.uk/hp/staff/dmb/courses/dig2/4_Analog.pdf *(accessed 27 Jan 2007)*
[7] http://www.kpsec.freeuk.com/components/cmos.htm *(accessed 24 Jan 2007)*
[8] http://www.kpsec.freeuk.com/components/cmos.htm *(accessed 24 Jan 2007)*
[9] http://www.kpsec.freeuk.com/components/74series.htm *(accessed 24 Jan 2007)*
[10] http://www.kpsec.freeuk.com/components/74series.htm *(accessed 24 Jan 2007)*
[11] http://docs-europe.origin.electrocomponents.com/webdocs/002b/0900766b8002b911.pdf *(accessed 15 Feb 2007)*
[12] http://www.electronic-kits-and-projects.com/kit-files/3000/3030.pdf *(accessed 15 Feb 2007)*
[13] http://www.glolab.com./pirparts/pirmanual.PDF *(accessed 9 Feb 2007)*
[14] http://www.coolcircuit.com/circuit/rs232_driver/index.html *(accessed 24 Jan 2007)*
[15] http://www.kpsec.freeuk.com/components/74series.htm *(accessed 24 Jan 2007)*
[16] http://www.electronic-kits-and-projects.com/kit-files/3000/3030.pdf *(accessed 15 Feb 2007)*
[1]7 http://www.roundsolutions.com/gsm-antenna/ANT-CAB.pdf *(accessed 13 Feb 2007)*
[18] http://www.minicircuits.com/pdfs/GVA-84+.pdf *(accessed 17 Feb 2007)*

Appendix A – Top Level design of system as thought in the 1st term

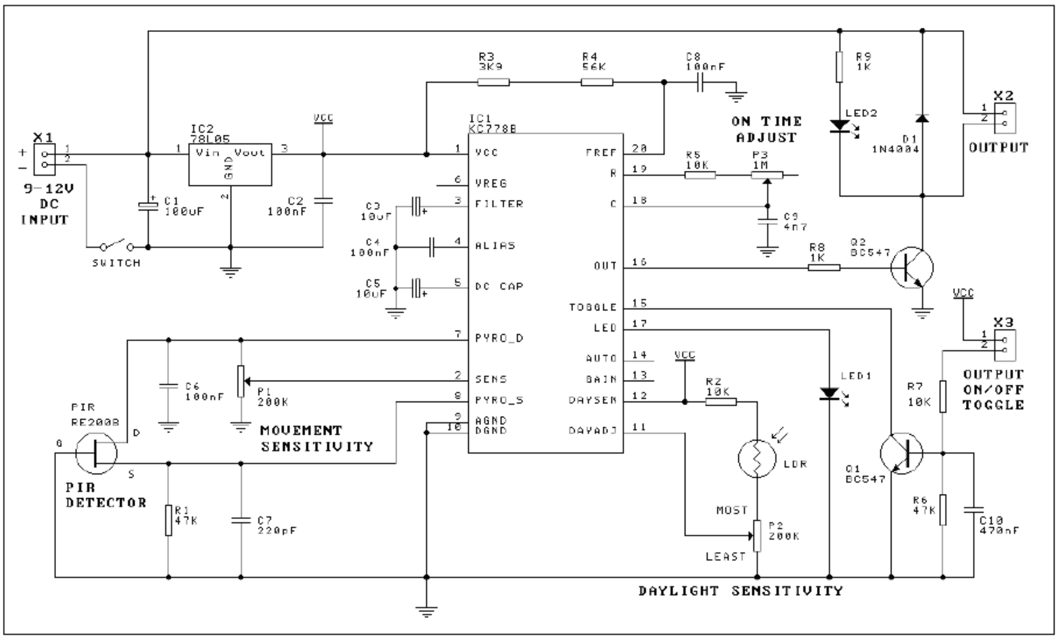
Appendix A.1 Block Diagram

The top level design block diagram (diagram A.1 - 1) which is shown below contains all the main parts of the system proposed in solution 1 in the first term.



Appendix B – Motion Detector Circuit solution No.1

Figure B – 1 shows the circuit solution No.1

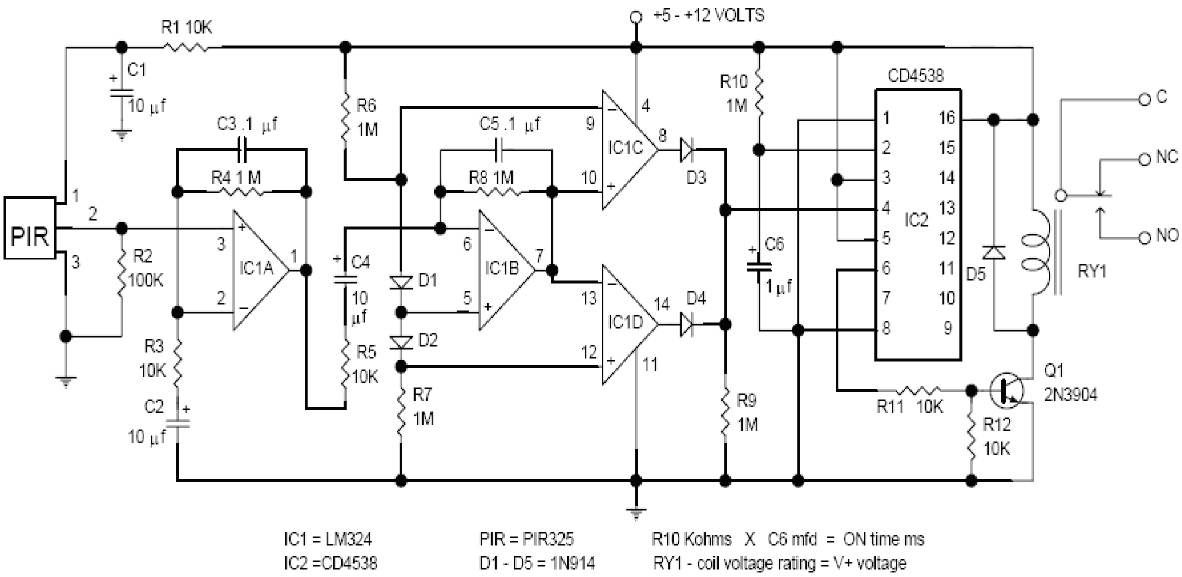


[13]

Figure B – 1: Circuit Solution No.1

Appendix C – Motion Detector Circuit Solution No.2

Figure C – 1 shows circuit solution No.2



[14]

Figure C - 1: Circuit Solution No.2

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[12] http://www.electronic-kits-and-projects.com/kit-files/3000/3030.pdf
[13] http://www.glolab.com./pirparts/pirmanual.PDF

Circuit Solution No.2 was finally modified to this:

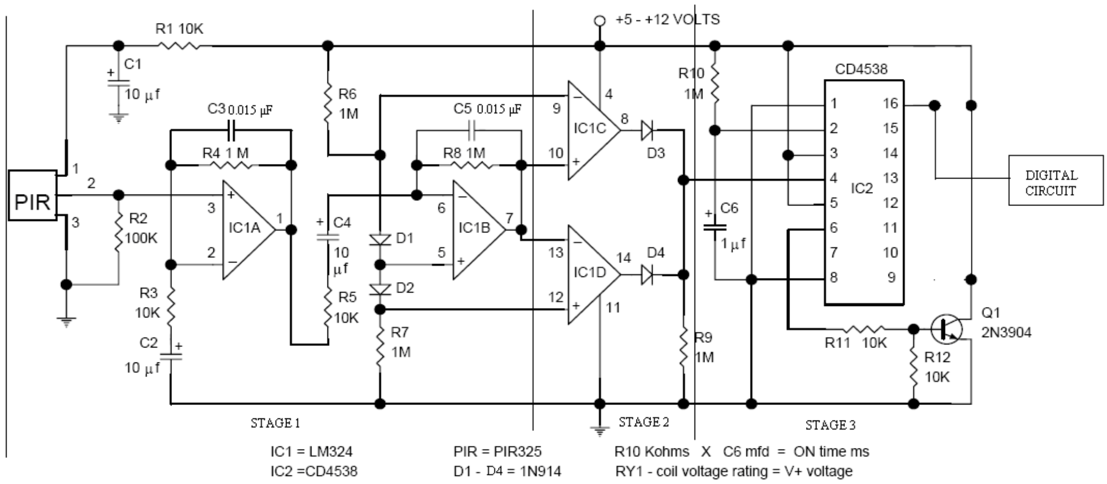


Figure C – 2: Circuit Solution No.2 modified

Note that this circuit is split into the three build stages.

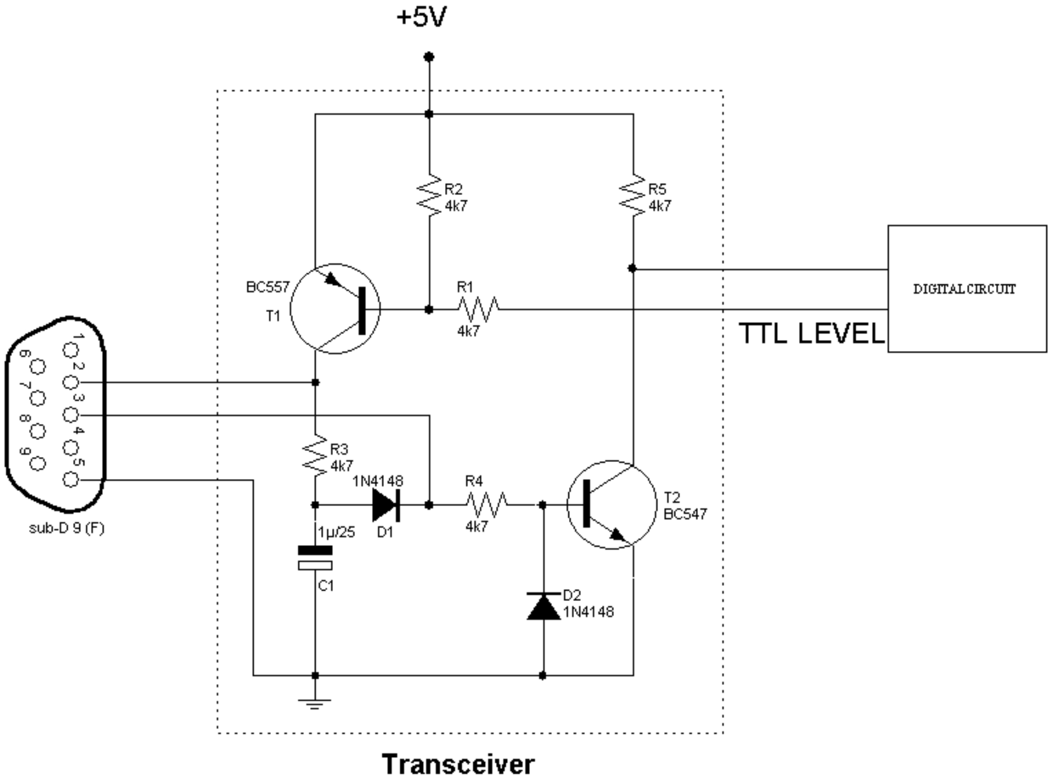
Appendix D – Component list for Motion Detector Circuit

Here is the component list:

Name	Value
PIR	-
Fresnel lens	-
R1	10k
R2	100k
R3	10k
R4	1M
R5	10K
R6	1M
R7	1M
R8	1M
R9	1M
R10	1M
R11	10K
R12	10K
C1	10µF
C2	10µF
C3	0.015µF
C4	10µF
C5	0.015µF
C6	1µF
LM324	-
CD4538	-
D1 – 1N914	-
D2 – 1N914	-
D3 – 1N914	-
D4 – 1N914	-
Q1 – 2N3904	-

Appendix E – Interface Circuit Solution No.1

Below is Circuit Solution No.1



[15]

Figure E - 1: Circuit Solution No.1

Appendix F: Component list for Control Unit

Here is the component list for the Control Unit

Name	Quantity	Value/Code
4 – way switch	1	SIL Switch
8 input MUX	1	74AC11251
Quad 2 input MUX	1	74AC11157
Synchronous 4 bit Counter[16]	2	74161
Hex Inverter	1	4069
4, 2 input AND gate	1	4081
4, 2 input OR gate	1	4071
3, 3 input OR gate	1	4075
Relay Switch	1	
Crystal Oscillator	1	

Table E - 1: Final component list for the control unit

[15] http://www.coolcircuit.com/circuit/rs232_driver/index.html
[16] http://www.kpsec.freeuk.com/components/74series.htm

Appendix G: PIR 325 sensor

The PIR325 sensor to be used has two sensing elements. Vibration, temperature changes and sunlight affect both elements at the same time and cancel each other out. In the case of a body moving in front of the sensor, it will activate first the one element and then the other. So in order to activate the sensor, the radiating source must pass across the sensor horizontally when pins 1 and 2 are on a horizontal plane. Figure G - 1 summarizes this concept.

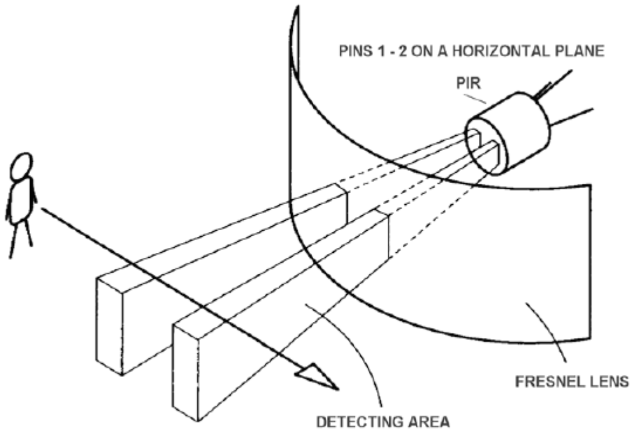


Figure G - 1: Activating the PIR325 sensor

The signal that is produced after a body is detected is shown in figure G - 2. It is about 20mVpp.

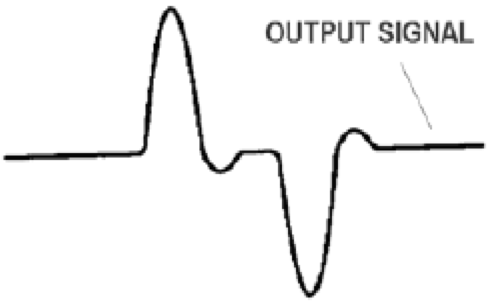


Figure 6.5 - 2: Electrical signal produced

[17]Table G -1 shows the PIR325 specifications.

PIR325 Specifications	
Element Size	2x1, 2 elements
Spectral Response (1)	5 – 14 µm
Noise	20 µVpp
Output (2)	3900 mVpp
Offset Voltage (3)	1.0 V
Supply Voltage (4)	2.5 – 15 V
Operating Temperature	-30 – 70 C

Table G - 1: PIR 325 specifications

Notes:

[17] http://www.electronic-kits-and-projects.com/kit-files/3000/3030.pdf

1. With built – in filter
2. After 72dB amplifier gain
3. At source pin 2 with 5 Volts and 100k load
4. Well filtered power supply

The viewing angle of the PIR325 sensor is shown in figure G-3.

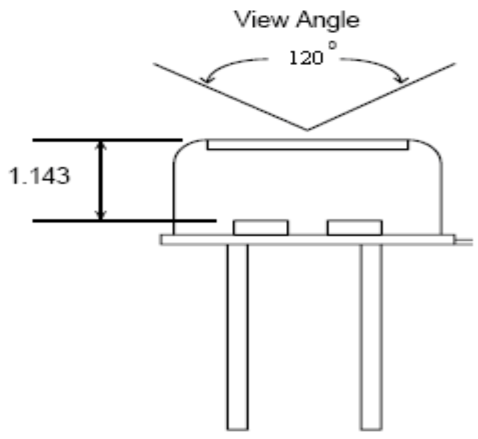


Figure G- 3: Viewing angle of PIR325 sensor

Together with the PIR sensor a Fresnel lens will be used. A Fresnel lens is a Plano convex lens that is collapsed on itself thus minimizing absorption losses. The FL65 lens has a focal length of 1.65 cm. When used along with a PIR325 it has a view field of 90 degrees. The range of the PIR sensor without a Fresnel lens is 3 feet. Using a Fresnel lens it increases to 90 feet.

Appendix H - PSpice Simulation of Motion Detector Circuit

Figure H-1 shows the voltages DC wise:

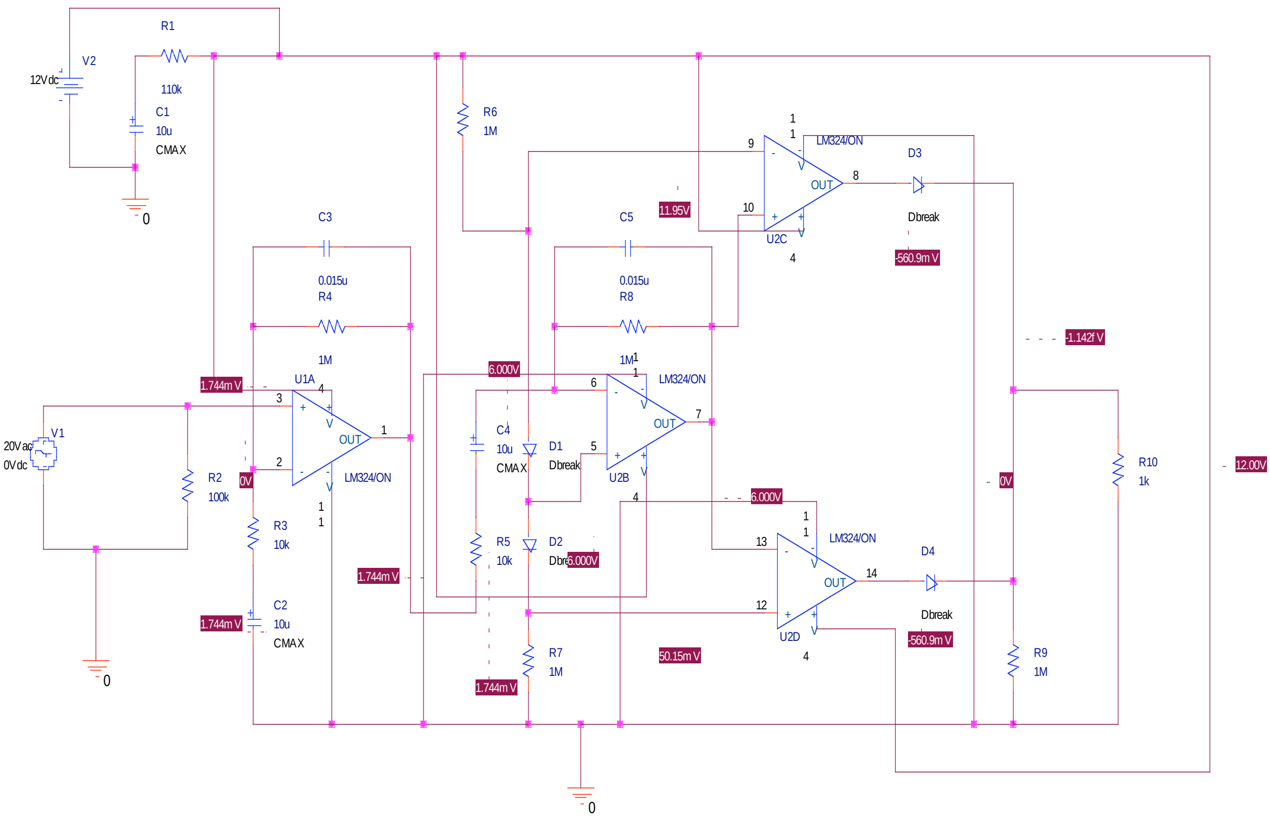


Figure H - 1: DC voltages of the circuit

Appendix I: Serial Port Theory

Before designing the interface circuit, it is important to discuss a few features of the serial port. The serial port's electrical specifications are defined by the RS232C standard. The logic 0 outputted to the serial port is between +3 and +25 V, whereas the logic 1 is between -3 and -25V. The region between -3V to +3V is undefined. The open circuit voltage should always be below 25V and the short circuit current should not exceed 500mA.

There are two sizes of serial ports. The D – Type 25 pin connector and the D – Type 9 pin connector. In our circuit a D – Type 9 pin connector was decided to be used (shown in Figure H - 1).

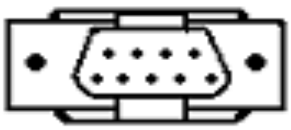


Figure I - 1: D – Type 9 pin connector

Table I– 1 summarizes the operation of the 9 pins.

D-Type-9 Pin No.	Abbreviation	Full Name
Pin 1	CD	Carrier Detect
Pin 2	RD	Receive Data

Pin 3	TD	Transmit Data
Pin 4	DTR	Data Terminal Ready
Pin 5	SG	Signal Ground
Pin 6	DSR	Data Set Ready
Pin 7	RTS	Request To Send
Pin 8	CTS	Clear To Send
Pin 9	RI	Ring Indicator

Table I – 1: Operation of the pins

From this table, it is obvious that we need Pin 3, Pin 2 (for upgradeable reasons) and Pin 5 (which is the signal ground). Now, it is important to note that to use these pins we need to convert the voltages they output to a standard voltage. So, since the digital circuit to be connected to, will accept inputs between levels of 0V and 5V, it is required to use a level converter to do that.

In the next two sections, two circuit proposals are shown. The first solution converts the voltage using transistors. The second circuit is based on an Integrated Circuit (IC) called MAX232.

Appendix J – PCB boards

The software EAGLE was used to create the PCB boards. Figure J – 1 shows the schematic of the motion detector circuit as designed in EAGLE.

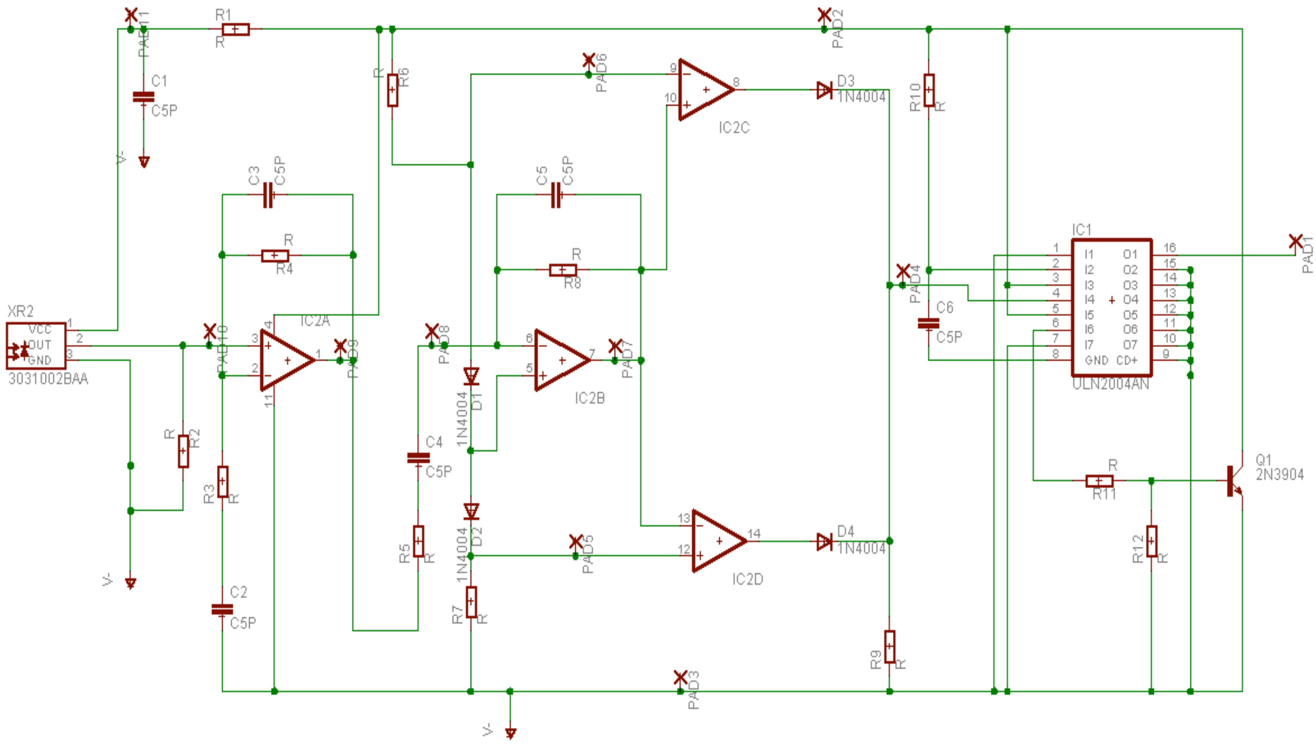


Figure J – 1: Motion Detector circuit in EAGLE

The PCB layout of the motion detector is shown in Figure J – 2.

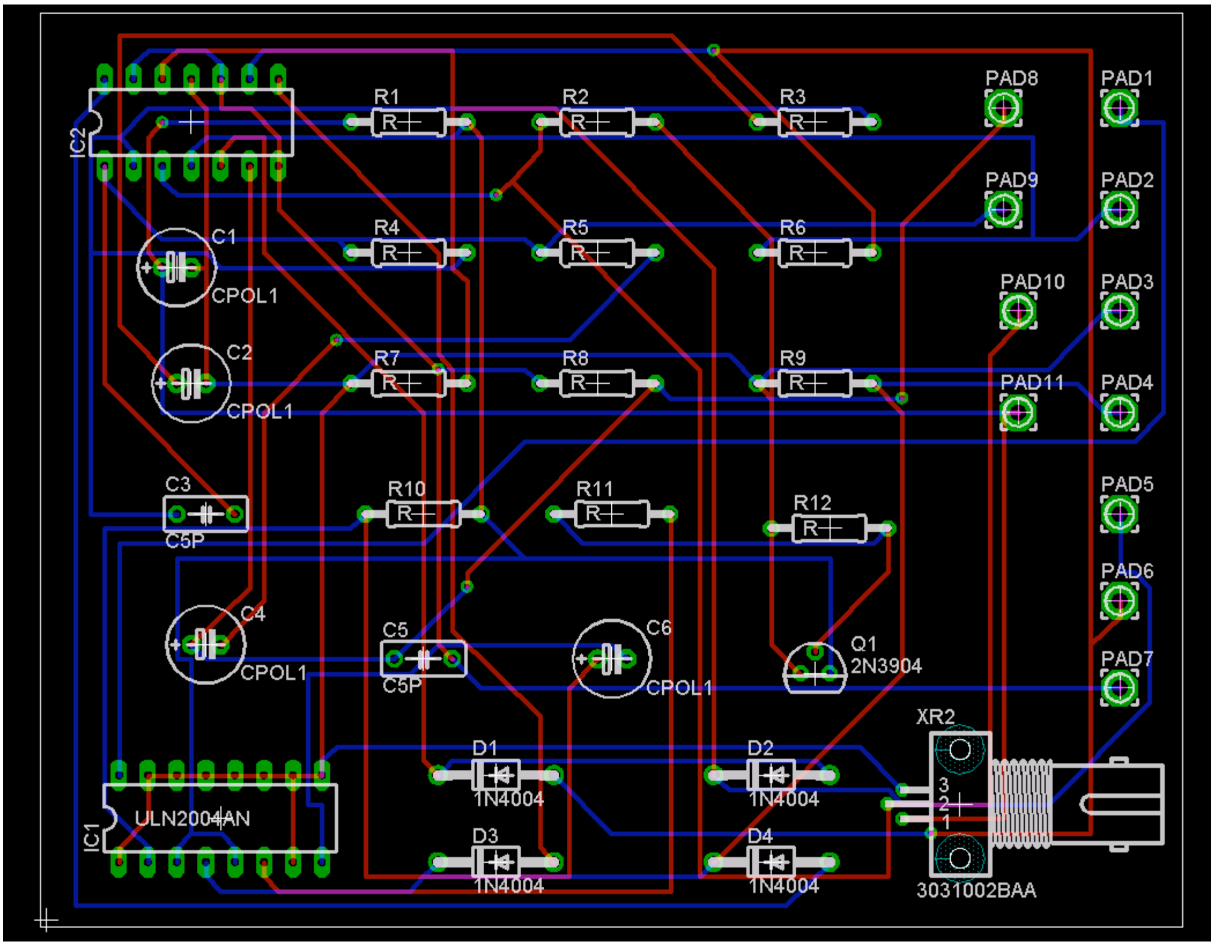


Figure J – 2: PCB layout of motion detector circuit

The schematic in EAGLE for the Interface circuit between the PC Monitoring Unit and the Control Unit is shown in Figure J - 3:

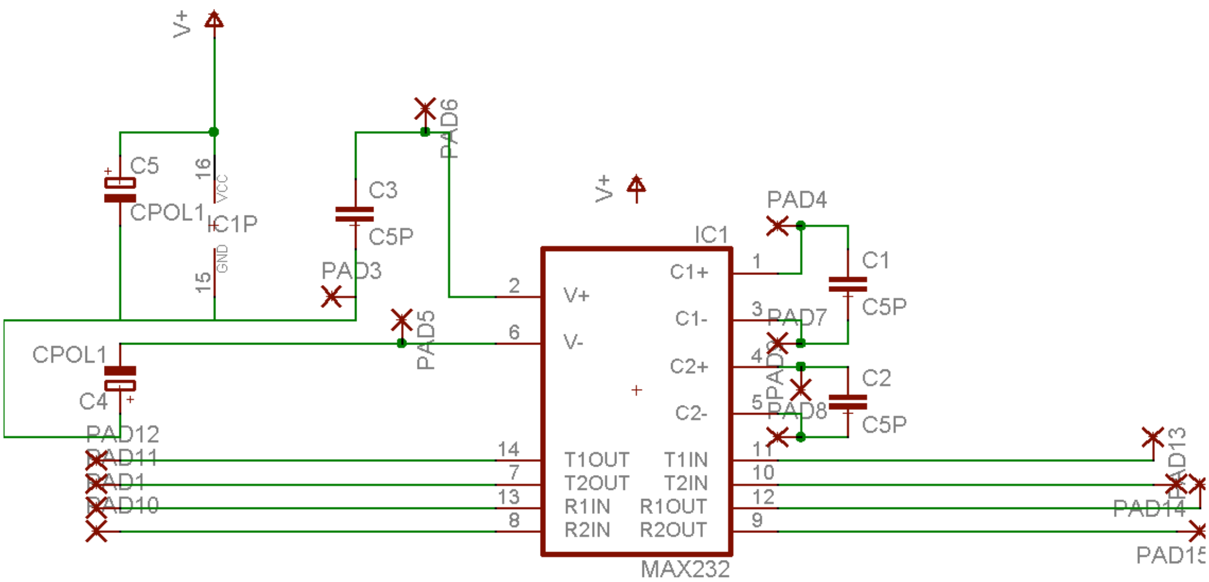


Figure J – 3: Schematic in EAGLE for the Interface circuit between the PC Monitoring Unit and the Control Unit

Figure J – 4 shows the PCB layout of the Interface circuit.

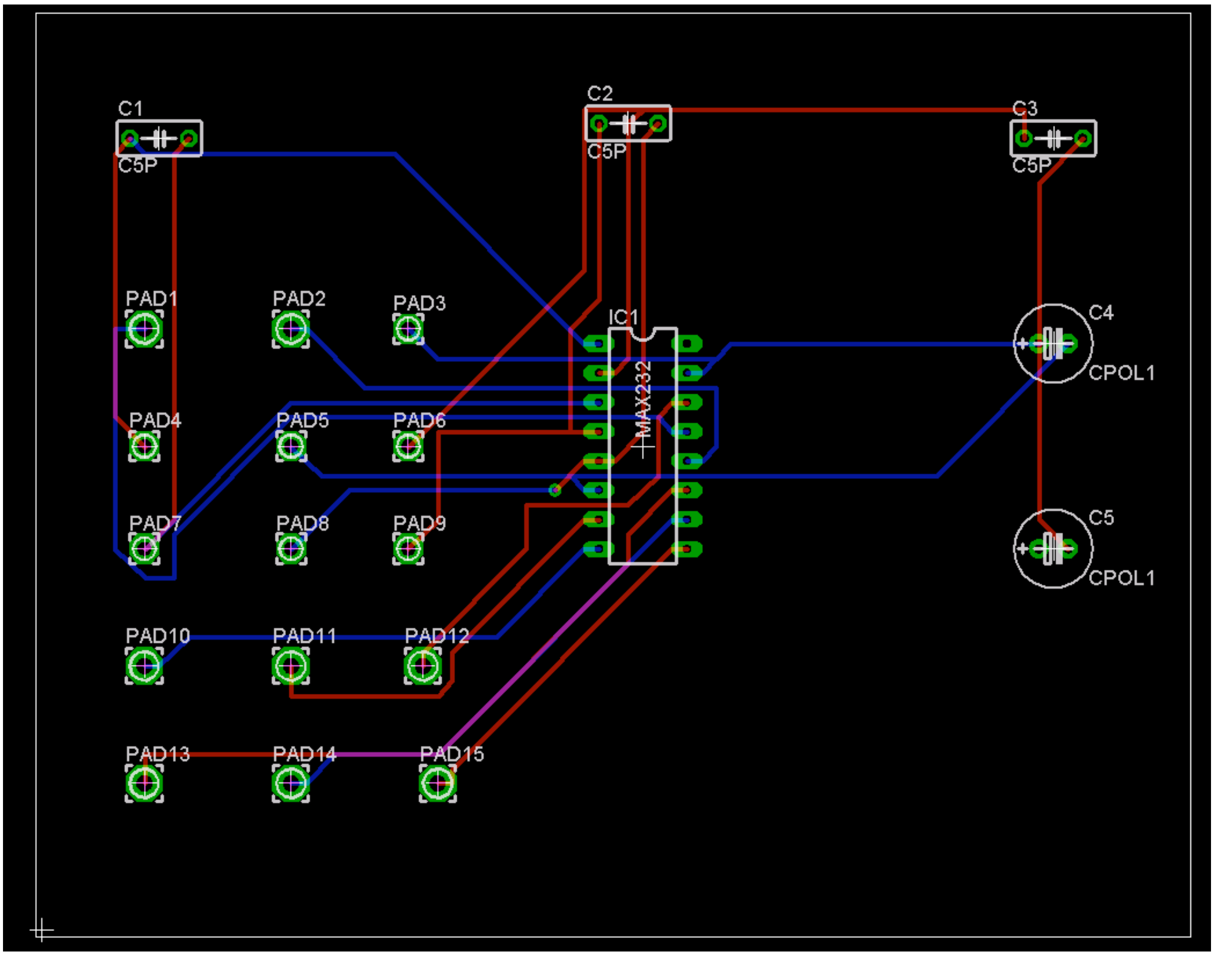


Figure J – 4: PCB layout of the Interface circuit

Figure J – 5 shows the Mobile signal detector schematic and figure J – 6 shows its PCB layout

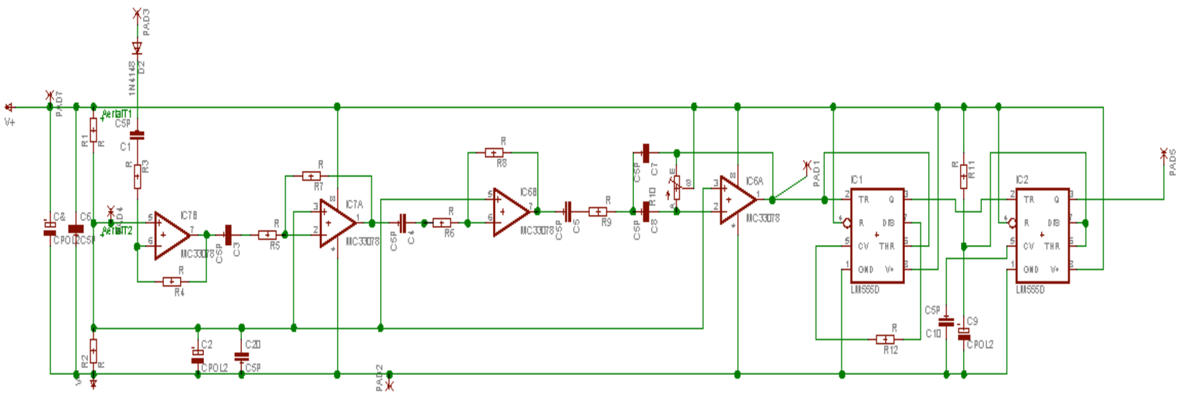


Figure J – 5: Schematic of the Mobile Signal Detector circuit

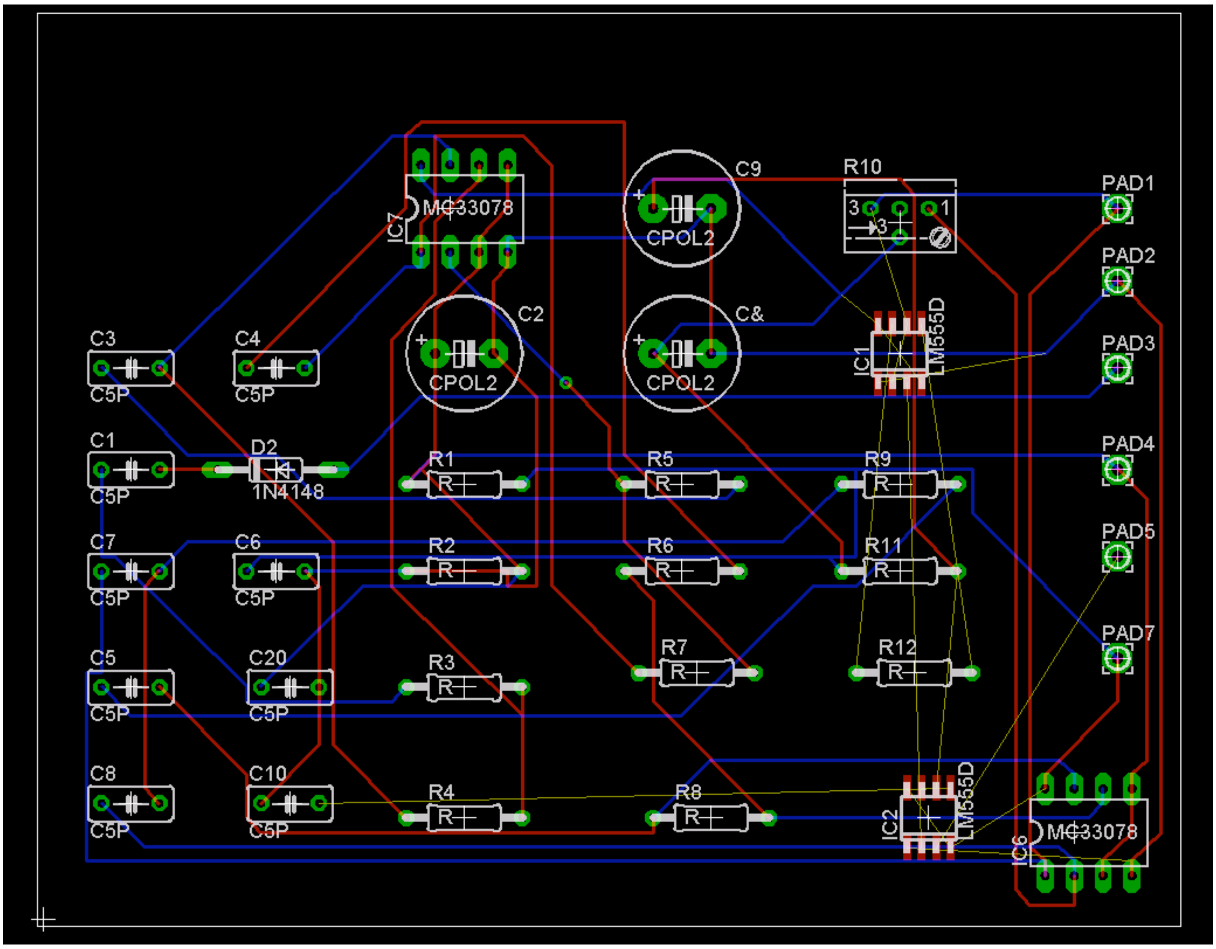


Figure J -6: PCB layout of the Motion Detector Circuit

Finally figure J – 7 show the schematic of the Control Unit circuit and figure J – 8 shows the PCB layout of the Control Unit.

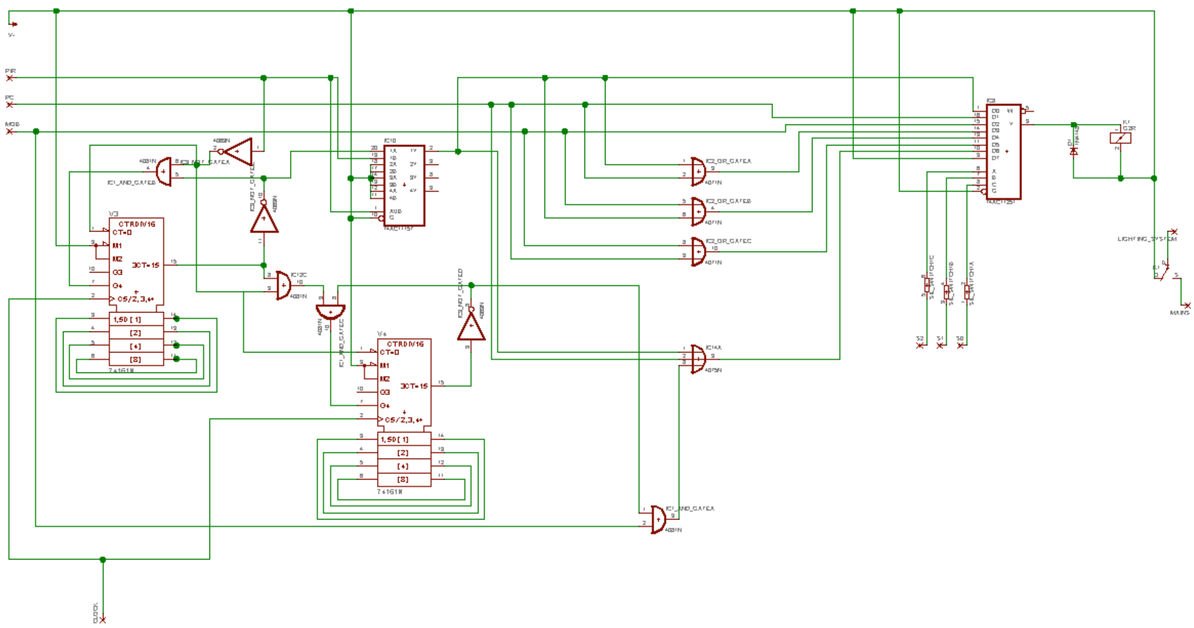


Figure J – 7: Schematic of the Control Unit circuit

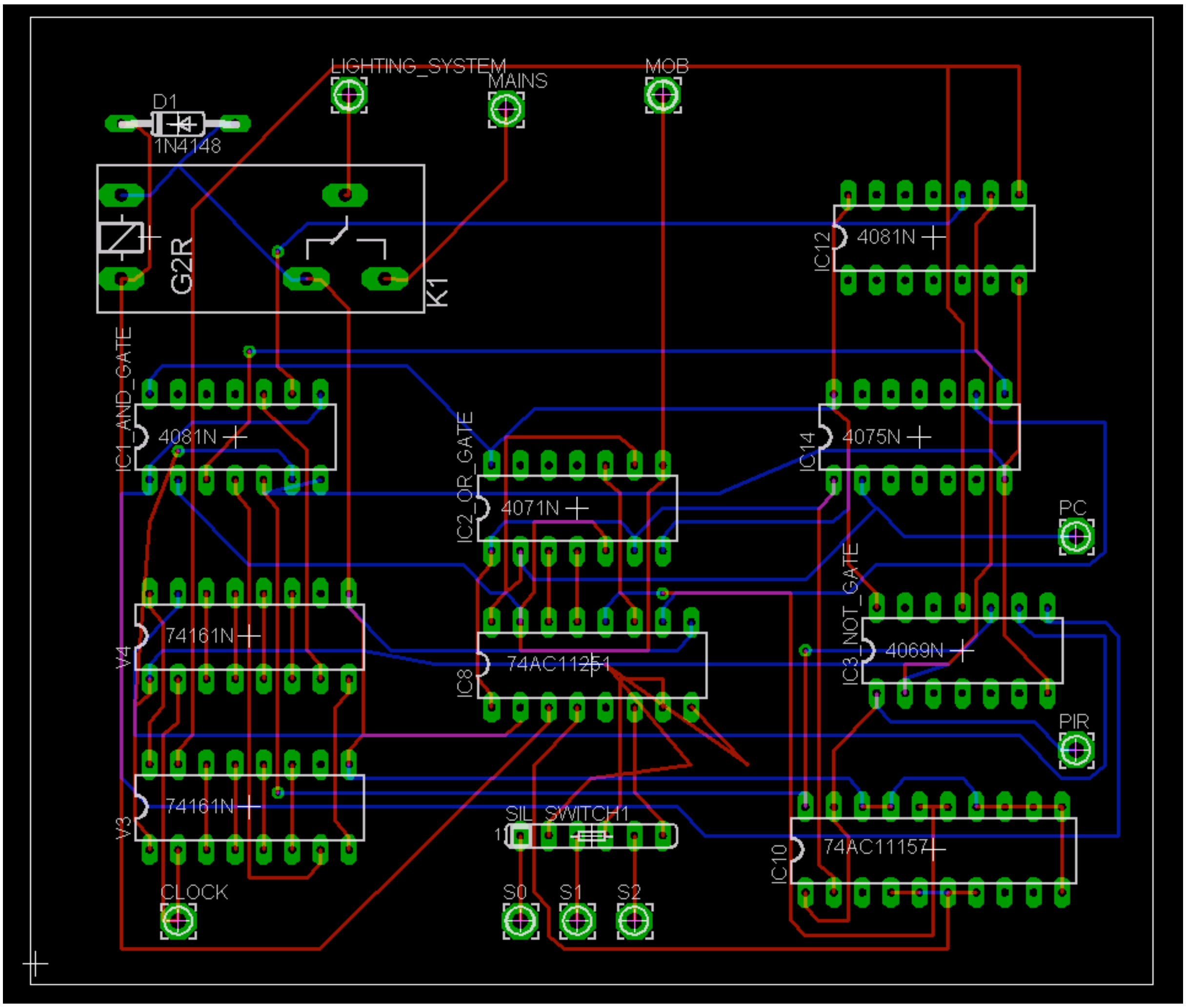


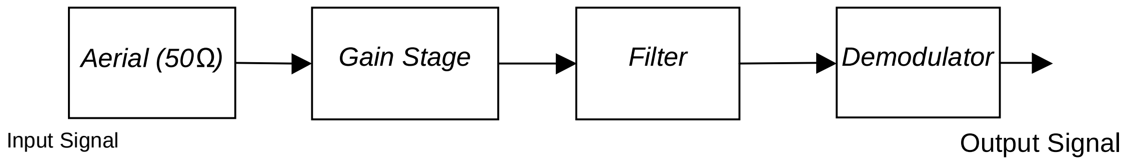
Figure J – 8: PCB layout of the Control Unit circuit

Appendix K – Contingency Plan for Mobile Signal Detector

Due to the fact that we are picking up a signal with a frequency of 1800 MHz and demodulating it without amplification, there is a possibility that the circuit will not work.
In this case our group has come up with a contingency plan.

Special RF components exist, such as amplifiers and filters which are used to enhance signals at such high frequency.
However, if this method is used other problems such as wave reflections need to be considered. If there is a slight impedance mismatch between two wires, due to transmission line theory, part of the wave will be reflected. Therefore, micro strip transmission lines and coaxial cables (both can be made to have a resistance of 50Ω) need to be used to connect components together.

A block diagram of the circuit is drawn below:



K -1: Block diagram of Mobile Detection circuit – Contingency Plan

In this circuit, to avoid reflections, all arrow represent either a coax cable or micro-strip transmission lines at 50Ω

Antenna
Used to pick up mobile signal in the range 1710 – 1880 MHz. Omni – directional.[18]

Gain Stage
An amplification stage which gives a gain of 24dB, would be used in this stage. It can be used up to a frequency of 6GHz. Therefore, suitable for amplification of our signal.[19]
Three of these stages would need to be connected in series to achieve the required gain.

Filter
A filter with a pass band of 1000 – 2200MHz could be used to attenuate any low frequency noise. This filter provides an attenuation of >40dB for frequencies below 500MHz.

Demodulation
A simple Schottky diode can be used for the demodulation stage.

Appendix L – Component List of Mobile Signal Detector

Name	**Value**
Magnetic – Antenna Quad band	ANT – GXM102 – FME/F- SMA/M
R1	10K
R2	10K
R3	1K
R4	10K
R5	1K
R6	1K
R7	10K
R8	10K
R9	500
R10	32K – TRIMMER
C5	100nF
C9	100uF
C6	100nF
C1	100nF
C2	100uF

[18] http://www.roundsolutions.com/gsm-antenna/ANT-CAB.pdf
[19] http://www.minicircuits.com/pdfs/GVA-84+.pdf

C20	100nF
C3	100nF
C4	100nF
C7	20nF
C8	20nF
C9	45uF
R11	100K
R12	10K
C11	0.01uF
R13	10K
MC33078 $\times$2	Op – amp circuit
NE555$\times$2	555 Timer