

Rory DelaCourt Major Project

by Rory Delacourt

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Wireless Footfall Counter: Developing Devices for Public Venues

By

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Project submitted as part of the requirements for the award of
BEng (Hons) Computer Systems and Electronics

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Declaration

I, Rory William DelaCourt, declare that I am the sole author of this project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

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Form of Consent

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Abstract

The project that is being represented in this report is an investigation into the current standards within the security sector at chosen venues and how they operate in regards to crowd control and management of individuals when a high number of occupants are travelling in and out of a premises. The implementation of an electronic device in this given field has been shown to be extremely advantageous for matters of reliability and monitoring the movements of visitors within the premises. Maintaining efficiency and ensuring the device remains cost-effective is an important factor to consider. Through a deep analysis into the desired field, logical and reasonable options can be obtained which aid the progress of the project and provide a way of comparing the various different paths which can be taken. This is important to a project's development as problems possibly occur and alterations will be required. Along with building on new ideas, the use of already existing technologies within this field have been considered as possible options, for example, people sensing and counting systems which already exist in buildings will be the main focus areas. When regarding the engineering development of the project this is one of the most useful sources to aid the development of the device as it shortens an already tight timeline to complete goals which are being set throughout the development cycle and changed constantly.

The intended device utilises the use of wireless Bluetooth connectivity, the sharing of data to a linked network of devices and a central computer can ensure the effective monitoring of occupants within a venue which allows for ease of maintenance when obeying to guidelines and laws. Simple signals can be sent through a microcontroller by the user which can then send that data onwards to Bluetooth TTL module which in turn sends the data to another device and computer which can store the overall information so it can be displayed or retrieved at a data date for review purposes, extra features such as an alert function have been added to further improve the development and adds an extra security addition to people who work in a place of work which can prove hostile.

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Chapter 1:

1. Introduction

Personal devices which have the function of recording data can be seen as an evolution of technology. They are a useful and positive progression from the mechanical devices and methods that are predominantly used and are useful when used in relation to verbal communication or the manual logging of data. Physical recording of data will always be required, the use of technical devices to record data, however often remove human error and decrease workloads.

This project aims to carryout thorough research in environments where customer flow is at a high level and communication between employees is regarded difficult. Places such as nightclub, pubs and concerts can be considered in this bracket, extreme numbers of visitors enter and leave these venues or premises in large numbers and at a fast pace. The overall aim of this project is to address whether the modern market has a pre-existing device which could be applied to these particular requirements and to what effectiveness it could be implemented. In particularly, whether this existing device could work with the specific requirements and data required by the discussed establishments.

The revenue of bars, taverns and the nightclub industry in the United States is estimated to exceed 24 billion U.S. dollars in 2015 according to a report by 'IBISWORLD' [1]. This information raises the question of why more funding has not been given to the security sectors of these industries. This report aims to research what the current standards and methods that these employees are working under and also what is potential available to them on the market. With the overall goal of developing a cost efficient device which improves on those current standards it is believe that this will relieve the stress load of work on security employees in the high traffic customer environments.

All reports and investigations regarding the subject field will provide an insight into how the project can be developed and even improved, research on areas where technological methods have and are being used to capture and record the incoming and outgoing flow of people in all areas and environments will be researched deeply and analysed for their potential implementation in this project. Once the device is in development it will require sufficient and relevant data, with solid testing and the possibility of future advancements being outlined.

1.1. Background Introduction

1.1.1. Intended area of implementation

A major aspect that had to be considered in the development of this project was the area or environment that it was intended to be implemented within. The device itself must be taking into consideration, particularly any limitations which could be placed on it by the desired location and also whether it will be helpful for employees, decreasing their work load as opposed to becoming a hindrance.

The desired location for this device is, predominately, areas that will be crowded – venues and entertainment establishments where there is a consistently high volume of incoming and outgoing individuals. A prime example of this would be a city centre nightclub during its peak business hours, during which huge numbers of patrons are entering and exiting at once. Statistics collected in **Fig. 11.2 to 11.9** show the flow of customers in and out of these establishments with all corresponding data. These numbers are incredibly high and even with the security staff that are employed it can be a difficult task to record and maintain a record of these numbers, for example, **Fig. 11.4, Fig. 11.6 and 11.8** display the time constraints which staff are already operating under. In these instances, no data has been logged due to the existence of other responsibilities.

This is a major factor to consider when deciding on the benefits of implementing such a device, as during busy hours of service, employees have to balance their workload. The employees who are usually left responsible for this are, predominantly, bouncers. A bouncer is “a person employed by a nightclub or similar establishment to prevent troublemakers and other unwanted people entering or to eject them from the premises” [2]. So regarding this they have to control the flow of customers to ensure that the building abides by the “Code of Good Practice for Licensed Premises” [3] labelled under PS6 shown in **Fig. 1.1** and recording it appropriately to also abide to the policy PS7 labelled in **Fig. 1.1**, but to also have to efficiently deal with rowdy and violent customers on a regular occasion. These nightclubs, pubs or bars very often get extremely crowded at weekend events when alcohol consumption is very high and a report [4] investigates the key issues in alcohol-related violence while another report written [5] states that “In the combined datasets of the 2012/13 and 2013/14 CSEW, 70% of violent incidents occurring at the weekend, and 70% of violent incidents occurring in the evening or night, were alcohol related”.

Code of Good Practice for Licensed Premises	
Policy PS6	A documented capacity should be set by an organisation for the building as an overall and also individuals rooms within that premises, this can be completely with a professional risk assessment completed by an authorised person or persons with consultation of the fire safety authority. When this capacity is set there are multiple factors which should be considered such as floor space, number of toilets, available fire exits with the width of entrance to those exits and also space that will be taken up by queuing by specific areas
Policy PS7	States the need of the business to adopt a method of managing and maintaining the capacity to prevent overcrowding and localised overcrowding, the use of electronic systems, ticket sales, clickers or head counts are considered appropriate for the counting of numbers

Figure 1.1: Policies PS6 & PS7 for the Code of Good Practice for Licensed Premises, obtained from [3]

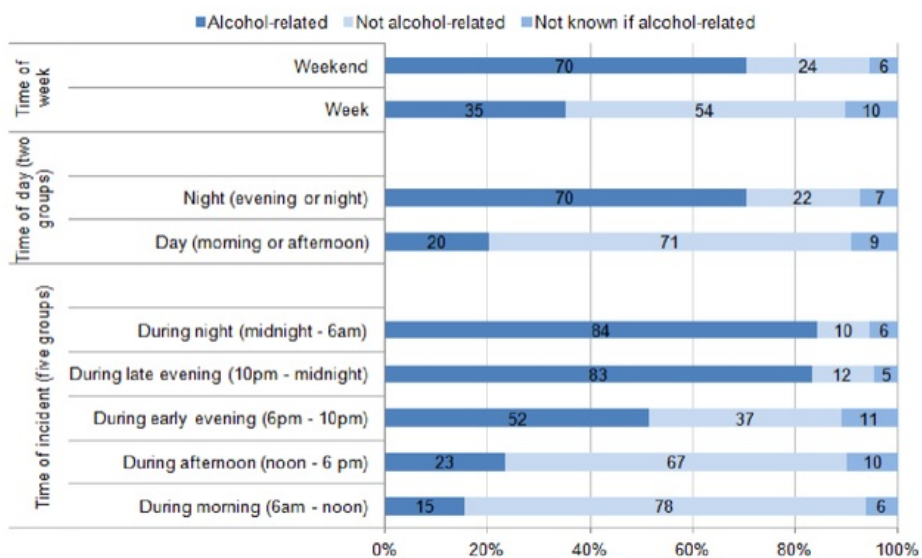


Figure 1.2: Chart showing timing of violent incidents and whether the victim perceived the offender(s) so be under the influence of alcohol, combined data from 2012/12 and 2013/14, obtained from [5]

1.1.2. Project Timeline

Time management is an essential factor to consider in the development of any project in any field of work, so one that is based around Engineering means that the jobs and sections need to be categorised and given time constraints with working deadlines so that they can be completed to a high detailed level with good background research and within the time limit that has been set. Due to the fact that the project was being undertaken whilst under university timetables it meant that time was always one of the major concerns in how far it can be developed and documented, for a brief outlay of what was expected an issue had to be researched in-depth to identify what parameters are in place so a solution could be thought up, time is then needed to look over and clarify the possible success of this solution before moving towards the engineering development of a prototype. After this tests can be undertaken to obtain data which is used in this report to reference and prove previously stated theory in hard copy form, time for this report had to be accounted for also as it was one of the most time consuming jobs of this project, all the information and data that had been collected had to be organised and documented accordingly in a manner that would represent the stages that were undertaken to get to the final stage of the project. For a more detailed view of the timeline for the project the personal Gantt chart can be seen in **Fig. 7.1**.

1.1.3. Potential Market Attraction

The technology required for this proposal, in itself, already exists. The aim, however, to develop a device which can aid security personnel at these venues, can be regarded as a new product. There is, therefore, a strong potential for this device to be attractive in the market if it well designed and build in a cost-efficient way. The major factor here is convincing personnel and employees that paying for the product would optimise procedures and ease workloads.

Chapter 2:

2. Research Methodology

“Methodology” is more than how a person intends to use methods to obtain data throughout the research period, it is often considered necessary to account for the concepts and theories which are used within those methods. For instance, in this project it can be regarded as the process which is used to collect the information and data which will advantageous and useful in terms of developing the project idea. The methodology can consist of the research of publications, surveys and other various techniques, throughout this chapter detail on what, why and how each procedure was used in regards to generating the solution to the issue is being discussed.

2.1. Research Onion

The research onion is a research strategy which was developed in 2007 by Saunders et al [6], this overview which is focused on the way a researcher should collect data to essentially answer an overall research question [6]. The ‘onion’ is broken down into layers whereas you would start off understanding and choosing a philosophy which ties in appropriately with the work you intend to research, to then how the research will be executed and analysed. The research onion is made up of 6 layers, these are [7]:

- Philosophical Stances
- Approaches
- Strategies
- Choices
- Time Horizons
- Techniques and Procedures

Philosophical Stances

Within each layer there are a number of different paths which prove helpful depending on the research that is being done. The first philosophical layer concentrates on the philosophies which provide choices to the way the research is generated, the stance which suits this project the most would be positivism; this is a stance which allows for research questions to be generated and realistic questions can be collected and compared to what exists in the real world, e.g. data which already exists [7].

Approaches

The second layer is one which focuses on the approaches that can be taken by the individual and is split between the deductive and inductive approach style. With these approaches they are more closely tied to this project and what it intends to do, although there is little work which has been published attempting to achieve what this project outlines, which is a focus behind the inductive approach the main focus and approach towards the development of this project is generating an overall question and the research which follow is to attempt to answer it. Through this statement it means that the deductive approach would be the suited approach for this project.

Strategies

The strategies layer is one that refers to the style of research that will be used to collect and analyse the relevant data for the report. Each method has its own benefits and limitations associated with it, through this association it is closely tied in with the philosophies layer of the onion and it also allows for more than one strategy to be chosen as long as the decision and work that it reveals can be justified [7]. Firstly, the experiment section is applicable to this project as is the action research; these allow for the researcher to be involved in the strategy as it generates data which can then be statistically analysed [7]. Experiment is applicable by allowing for experiments to be done and from those experiments produce data can be collected and further the development of the project, the action research is then focused around collecting data with the purpose of aiding and progressing the development of the project through influencing the decisions and paths.

Choices

The next layer is choices; this is focused on defining whether qualitative or quantitative methods will be used in the research [7]. This is then sub-divided in three sections, the mono method is based on only using qualitative or quantitative, you then have mixed methods which focuses on using both qualitative and quantitative research methods in the collection of data and analysis and the last

method is called multi-method; this is when the researcher uses both methods but is restricted to only using one from each which results in the data only be analysed from one point of view [7]. The method which is best suited to the research in this project is the mixed method, this is so the limitation which can be found from using the other two methods can be offset and by combining both qualitative and quantitative there will be less data missed and will result in a greater level of analysis.

Time horizon

Coming to the fifth layer, time horizon segments the choices between two, cross-sectional which is regarded as a short-term study and then longitudinal which is the opposite and focuses on the research which is taken over a longer period of time [7]. With this given project data will be recorded over a longer time span giving varying results which can then be analysed.

Techniques and procedures

The final layer in the research onion is one called techniques and procedures, this when the design moves further on down its timescale as data collection is its priority [7]. All data thus far must be analysed and through this a direction will be set for the further development of the project.

As this project is based around experiments and the analysing of the data that is produced through those experiments there is requirement for hardware and software.

Hardware Required

- Soldering iron
- Ammeter/Multimeter
- Source of power (power supply and/or battery pack)
- PicKit3
- Various Components (Capacitor, resistors etc.)
- Breadboard

There is also a need for software in this project, it allows for the design to be built and tested to fault find before the physical prototype is made.

Software Required

- Proteus (8 Professional)
- Easy-PC
- CCSC
- MPLAB IBE
- Solidworks
- Circuit Diagram (Circuit Designing Software)
- Yed Graph Editor
- UWTSD Online Library

Chapter 3:

3. Research & Review of Literature

A project of this nature covers an extensive range of possible research criteria. There already exists a market for this particular type of technology, albeit not used in this particular context, and therefore, this research will include existing work from the field and any potential developments that could be utilised in the progression of this particular project.

For the effective implementation of a communication device in this project, the intended scenario in which this device is intended to be used must be thoroughly researched and analysed. The major questions that this research intends to answer is what methods and devices are being used by individuals at this current time and what their advantages and disadvantages may be. Another aspect that needs to be looked at is theoretical research which has already been done. Other groups or individuals may have focused on the issue or field previously and their findings and published documents may prove to be advantageous to providing extra insight into the area. If they clearly state a methodology with respective results displaying what went wrong in their attempts, then using these findings will save time, ensuring similar mistakes are not made.

The first section of the literature review will consist of an in-depth view of the collected research and comparisons that relate to the chosen field and the environment where the device is intended to be implemented. This will also review the current standards and techniques which are being used in the industry to record and manage footfall numbers within a premise, for example, whether that be manual, mechanical or electronic means of tracking and consolidating data.

Market Research

This section of the report is focused on researching and evaluating the target areas where the device in development is intended to be implemented. By doing this an understanding of the current standards that take place can be used to justify the reasoning of an electronic handheld device, the identification of limitations and hindrances in the current field help the progression of the project. After this has been identified an insight into existing developments in useful fields is given and also a showing of available technologies and methods are shown and evaluated in their potential use for the project.

3.1.1. Initial Research

Current Standards

The current standards and tools that employees are using at this time is an important factor which needed to be looked into. Such information will provide knowledge on what the limitations may be and, more importantly, what electronic or advanced engineering developments could be made.

After research into the topic, it was found that security employees are using and have been for a number of years' manual counter clickers as shown in **Fig. 3.1**. This mechanical device is simple clicker, you press the button down a single time and the overall count gets incremented, simple in its logic and also its use, however thus brings us to the limitations which this project attempts to focus on.

With the current system that venues and clubs use the employed staff manually record people as they come in one by one and then at timed interval they are required to collaborate and record the overall count. This is method which is unnecessary and time consuming, as shown in **Section 10.4** of this report; the collected data which shows this relevant data shows that at times there are only three doormen working at a single time. For this number of employees to be expected to balance this work load whilst dealing with unexpected situations such as intoxicated individuals or people who are acting in a disturbing manner can sometimes mean that areas in the job do not get completed to a respectful level or even at all. A survey was taken focused on obtaining the opinions of individuals who are currently in security line of work and can be seen in the appendix of this report in **section 10.3**.

There has been recent addition into the market of a digital tally counter as shown in **Fig. 3.2**, this is a small device which is very similar to the mechanical version in the terms of that the user simply presses a button for an addition to the overall count and minus for a subtraction. In terms of reliability it could an improvement on the mechanical models, however after researching these digital models are no commonly found in use by these security personnel. This raises the question of and in terms of realism there is a high possibility that employees in this line of work will not want to spend ten GBP for something which does not offer more than the cheaper model.

Manual Counter Clicker

	Mechanical Device
	Max Count: 9999
	Material: Metal & Plastic
	Item Weight: 59g
	Price: £1.40

Figure 3.1: Manual Counter clicker [8]

Digital Tally Counter

	Digital Device
	Max Count: 9999
	Material: Plastic & Rubber
	Reset Button
	Price: £10.00

Figure 3.2: Digital Tally Counter [9]

Acknowledging the current standards researched, it can now be seen that the current methods and lack of devices to aid these employees is an issue which needs to be addressed. The next step of the research in its current state is now to look to what devices and technology already exists on the market, could they potentially either be implemented directly into the intended area of work or be used in the development of a device for the intended purpose.

3.1.2. Obtained Research Information

For a research project of this size and nature, information and real-time data can provide an excellent insight into what goals may be obtainable. In short, real life data can demonstrate the difficulty which security personnel currently face during their work shifts, and therefore, can act as justification for proposing the implementation of a counting device similar to the one suggested in this project. This can be shown in the inconsistent data which is captured in these places of work or even simply opinions collected from individuals who work in these professions, within the environment or have witnessed the procedures within such establishments.

This section is intended to display the evidence collected through the means of emails, enquiries and questionnaires.

Questionnaire

A questionnaire was submitted containing five easily completed questions. The questionnaire featured questions concerning the current standards and what thoughts were on the implementation of an Electronic device in the workplace. The questionnaire was created and posted using “**SurveyMonkey**”. The questions followed by the answers can be seen the appendix of this report under **section 10.3**.

The only issue that came from collecting this data was the lack of people available to collect data from, it was not a questionnaire which could be posted to the general public due to the specific line of work it is aimed at.

Doorman logs

The most interesting and educational researched that was collected throughout this section was the doorman logs. This is information that was obtained from the Griffin Pub located in Swansea city centre; through the hours of the day this venue acts as local pub which serves drink and food whilst showing sports. However, at late hours of this location it is used as a nightclub venue where a large number of people go to drink, socialise and enjoy the atmosphere.

This is perfect example of the target area which this report focuses on, it is also the intended work environment that the ‘**Electronic Tally Counter**’ will be potentially used in. The information that was received was valuable logs of existing data which is recorded at the end of shift cycles, as discussed in **section 1.1** of this report. The logs consist of recorded data; visitor count in the premises is written down at intervals of thirty minutes, times of the fire checks through the night, an

approximate number of ID's that were checked, how many doorstaff were on duty and also how many individuals were either refused entry or ejected from the premises for the stated reason. These separate logs can be seen in detail in the appendix of this report, **10.2**.

3.1.3. Existing Projects & Reports

As discussed before, with the research of existing projects that can be related to this project an opinion and data can be retrieved which saves time and effort which was essential. The major issue that was found when researching for these projects and reports was the lack of reliable content. The project was initially chosen due to such a device and system not existing in the market and even after throughout research that fact still remained true.

This section in the report is therefore a focus on reports which utilise or use technologies and methods which can be related and potentially implemented into the project.

Bluetooth Location Networks

Written by F.J. Gonzalez-Castano, J. Garcia-Reinoso [10]

This following report is BLN focused around an m-commerce network, discussions around the use of PDAs or mobile devices being used inside a store to transmit and receive information. It states that, "customers walk around a large commercial area or mall carrying wireless PDAs. A PDA client allows its user not only to purchase items, make reservations or request information, but also to receive" [10]. The area which is reliable to this project is focused around the utilisation of the Bluetooth technology, with the potential use of Bluetooth in the devices the required information could be sent and retrieved over a network.

A Kinect-Based People-Flow Counting System

Written by [11]

This is a paper for a proposed bi-directional people counting system; the system is to be setup above a doorway so the flow of pedestrians can be recorded. The system will utilise a depth image information from a Kinect system and this allows for the morphological processing of the object to determine the region of interest (ROI).

The proposed flow chart taken from the report shown below in **Fig. 3.3**:

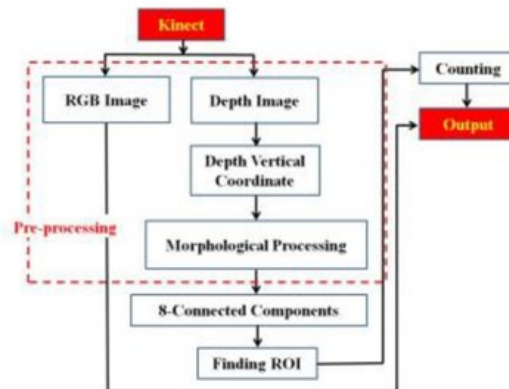


Figure 3.3: Proposed flowchart from report [11]

The results of the report state that under normal circumstances the system provides reliable results, this is interesting for a counting method. However, it does not provide results concerning extreme traffic which is the main concern over the project.

Development of an Automatic People-Counting and Environment Monitoring System Based on Wireless Sensor Network in Real Time

Written by [12]

The researched report is a description and analysis of a people counting system which is designed for tracking in a mountain area. Although it is a system for an entirely different area than the one proposed in this report the method of collaborating and presenting the data can be regarded as a goal of this project.

The system in the taken report uses a developed interface board and RF board for communicating the data to a server and then a client. A photo-beam sensor is their method of capturing movement and their results vary from the sensors ability to capture movement from further distances of over 2 metres.

3.1.4. People Counting Devices

The initial research that was conducted as part of this project showed that there is no device which is being marketed right now which aims to do which this project does. The next step of the research was to look at relevant devices and technologies which already exist to see if and how they could be implemented into our design.

This next section is a breakdown of that technology, where they are currently being used and also how they work. The major question this section reveals is why hasn't a counting system been implemented into a busy nightclub environment, from that point what are possibilities of using any discovered technologies to aid a device or system.

Note: All counting device and products in this section utilise specifically designed software which enables the collected data to be saved to a database or computer.

Turnstiles

The first example that is frequency used in venues and is an effective and manageable method, is the use of turnstile units at concerts; here people enter in a moderately organised fashion through these turnstiles units and in turn a count is added to an overall number which would have been set up through a counting system database on a computer. So when individuals leave the premises through other designated units a count is taken away reducing the overall count. This is an effective method which is in place today and companies such as “edsuk” [13] supply these units for hire or sale with counting systems available to match, a prime example of the use of these turnstiles is that the O2 arena located in London. The website states [14] the use of 18 turnstiles in the North entrance alone with the only other entrances being for disabled persons.

The major issue with using these turnstiles units in places like nightclubs or busy pubs is the extreme volume that enters at a single time, in the manner that these people enter is also an issue. For most clubs the entrances are designed to be narrow, these entrances are highly populated areas and are used as the only exit from the premises also. Along with the impractical issue that would arise from the installation of a turnstile unit, this means that use of a device such as this would not ideal for capturing the required data in this project.

Infra-red Sensors

Beam counters or infra-red counters are regarded as a cost effective method of collecting footfall trends; the unit must be installed on a flat surface such as a wall or door frame and an infra-

red beam is emitted and reflected on a reflector placed directly opposite [15]. Its functionality is based upon the when the beam is broken by a person passing, it registers a count. Through communication with “**PeopleCounting**” [15] a list of counters was obtained, the units offer around a five-meter range for the beam and five separate units are sold. The cheapest in the range is **£230** and the most expensive is **£519** with both requiring an installation fee if done under the same company.

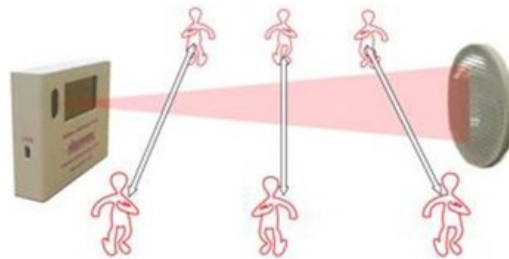


Figure 3.4: Infra-red beam counter [15]

The decision was not to use infra-red technology in the design; the disadvantages that would be encountered would result in unreliable and inefficient data. The sensors are unable to recognise if visitors are entering or exiting the premises, also the high traffic in nightclubs and venues is high so entrances will be crossed in groups again meaning that only a count of one will be added to an overall. For the price point and these major disadvantages, it means that this method can be completely disregarded in its addition to the development of the project.

Controller Units

A controller unit is the only manual input unit used in this section as a comparison, the unit as seen below in **Fig. 3.5** is a large unit which is installed around an entrance. Its function is dependent on the user, as a person enters they would use a card to either enter or exit; this in turn would adjust an overall count which is displayed on a **LCD** screen. The useful aspect that this method offers is that the unit is accurate and also allows for limits to be set up prior, if these limits are met then an alert is sounded allowing staff to know.

The disadvantage of using this unit consists of the impracticality that it would pose with the expectation of customers entering themselves in a counting system. In realistic terms visitors are going to do this and the unit itself is far too large for it to be discretely placed in an entrance.



Figure 3.5: Controller Counting unit [16]

Brickstream Steroscopic Counters

This counter is a unit which is installed on a ceiling around an entrance, it utilises video based detection software to detect when people enter or exit. It is regarded as the newest generation of video analytics [15], It is the newest technology in the market which offers customer tracking data analysis. The device offers its beneficial perks in with the promise of accurate readings whilst being able to filter out objects like trolleys, is ability to work in low ambient lighting and being able to store data to flash memory for 10 days.

Again however there are major issues with this device if it were to be introduced into an environment such as a nightclub, the extreme traffic flow that has been stating here mean that the video based technology would not be able to differentiate an individual person when groups of around five to ten are entering at a single time. Through personnel communication with the company **“PeopleCounting”** [15], a product enquiry was received and shows that a single one of these unit packages costs **£1,968** and only becomes slightly lower if 25+ sites are ordered at a time. With the addition costs of **£250** if an outdoor unit is required and installation costs of **£325** per day plus travel expenses for all units this device package becomes very expensive.

Evaluating these issues mean that it would be impossible to implement a video based detection system into the intended environment is not currently plausible.



Figure 3.6: Brickstream Steroscopic Counter [17]

Irisys Gazelle Thermal Counters

There are numerous thermal counters for sale on the market from various distributors, this Gazelle thermal counter has been chosen as an example with the underlying principle that the majority of similar sensors on the market rely on the same technology. A thermal counter functions under the principle of detecting body heat, a person body is detected and contrasted against the temperature of a background; this results in the reading.

Then brings the disadvantages of using this technology, especially in the intended environment where multiple persons will be passing through a single time. Articles [18] and [19] do extensive research on thermal basic technologies and both discuss the issues it has with multiple heat signatures affecting readings. From pricing information obtained through personnel communication [15], “**PeopleCounting**” sell a single one of these units for **£1,858** with an additional **£325** installation charge as discussed for the video counter.

Considering the results produced with this technology, it would appear that the data which is produced is often times unreliable. In addition to this, the price point is quite high, which therefore, renders it inappropriate for this particular project and its initial principals and requirements.



Figure 3.7: Irisys Thermal Counter [20]

Cognimatics TrueView People Counter

A counter which is marketed by Cognimatics [21] describes its produce as “a leading application in foot traffic”. A camera is installed on a ceiling as shown in **Fig. 3.8**, once this is done it is linked to a software module; where then traffic of customers flowing underneath are captured and recorded. However, this is a product which is specifically aimed at stores, in the manual provided by Cognimatics [22] it clearly states the parameters which the camera needs to be able to function. Some of these are no near doorways where moving objects can interfere with readings, plenty of lighting installed as it will not function well in the dark and reflective surfaces and light will also affect readings. These requirements alone mean that it would not a suitable method to be implemented into this project. The Cognimatics people counting system was retailing for **£659.43** [23] which is a price range that this project is also attempting to avoid.



Figure 3.8: Cognimatics Counter Setup [22]

3.2. Communication Method

The method of **communication** is an important factor for how the device will function, it is how the input and output data from the device will be **transmitted** and collected in an effective and efficient way. Therefore, through this section a list of the communications methods that were considered for the use in this project have been specified and evaluated accordingly.

3.2.1. Radio wave

The first method that was considered for its use in the device was radio wave communication, it is part of a larger group of waves called “**Electromagnetic radiation**”; radio waves are part of this group [24]. For its relation to the transmission of data there are two common ways that information can be put into radio waves, **A.M** and **F.M**. These are commonly referred to as known on a radio, now radio waves have generally large patterns with the amplitude and frequency staying the similar all the time [24] and the ability to receive the signal is dependent on tuning a receiving module to match the same frequency as the transmitter.

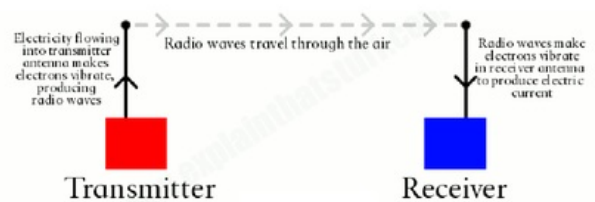


Figure 3.9: Radiowave example [25]

A useful and simplistic example of radio wave communication being used is in a remote control car, reference [26] details the construction of a project involving a small RC car in which the use of radio communication is detailed and explained.

Below are examples of radio modules, these modules are bought as “**out of the box**” wireless RF serial communicators:

XRF Wireless Data Module [27]	USB RSF Radio Module [28]
Operating Voltage: 2-3.6V	Pre-built USB stick
ISM Band: 315 to 900MHz	ISM band: 868 to 915
Power Consumption: Tx = 32mA, Rx = 20mA	Power Consumption: Tx = 36mA, Rx = 24mA
Range: 500m	Transfer Rate: 250kbps
Baud rates: 1200 – 115200	N/A
Price: £14.40	Price: 24.00

Figure 3.10: Radio module specifications, [27], [28]

Note: Modules shown above in **Fig. 3.10** are transmitting and receiving modules, both are needed in a design build for the transmission of data.

Radio wave communication is a reliable method which offers superior range, it is widely used and the prebuilt modules shown in **Fig. 3.10** mean that their implementation into a device would be simplistic. There are, however, limitations and factors which need to be considered. Bars and clubs situated within city centres provide doormen with radio devices on a pub watch scheme, which allows information to be transmitted between establishments [29]. For this to be effective a number of different frequencies are used, for the Swansea, Wales area it is **453.1500 to 460.0000** as of the current 2016 frequencies [30]. This varies for areas spanning around the UK and although there is low chance of interference from a radio wave based device, it is not impossible. A major issue is legal limitation when a prototype is being tested, the **frequency allocation table (2013)** [31] show the allocations of radio frequencies within the UK. If that is considered along with the high price for the modules and the higher power consumption when compared to other methods a realistic comparison needs to be made.

3.2.2. Infrared

Infrared transmission is in reference to energy in the region of electromagnetic radiation spectrum, it sends frequencies which are higher than microwaves but lower than those of visible light [32]. This technology is used in a number of wireless communications, monitoring and control applications; some of these consist of:

- Home entertainment control boxes
- Wireless networks

- Intrusion Detection
- Motion Detectors
- Links between laptops and desktop computers

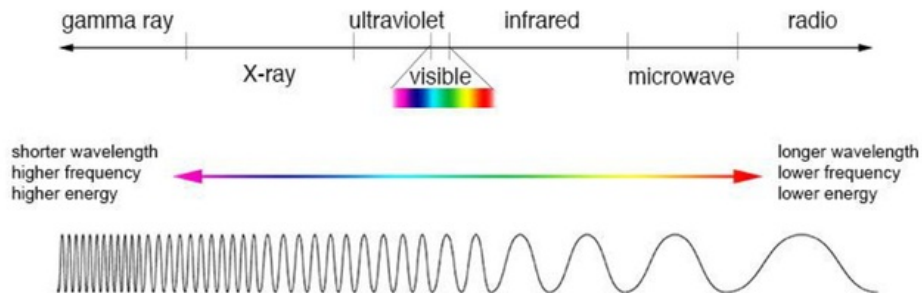


Figure 3.11: Electromagnetic Spectrum

This method of communication is in wide use in today's technology, mostly commonly known in remote controls for devices such as RC cars or to control a television. The signal from the transmitter is sent through a light emitting diode (**LED**) which is then received by the another LED on the receiver box which then decodes the signal which contains the message or command. Infrared is capable of transferring files and data **bidirectionally**.

The communication method is capable of transferring the data from device to device and then onto a computer, however, infrared has a number of constraints that need to be considered. The **wireless communication** is restricted to line of sight, and therefore, the transmitter and receiver have to be in the same room with no objects blocking the view. The range is also produces a poor performance when compared to **radio** and **Bluetooth**, the device has to be within an estimated 10 meters of the receiver and with the collective evaluation of the disadvantages stated the use of this technology in the device would not be considered the most practical.

3.2.3. Bluetooth

Bluetooth is wireless communication standard (**IEEE 802.15.1**), it is designed to be a short ranged method of communication which has low power consumption. Bluetooth defines a protocol stack of several layers, **Fig. 3.12** shows a simplified version of this [33]. It operates on a **ISM band**

frequency of **2.4GHz** while supporting a bit rate of **1 Mbps**, through these specifications this technology has reduced interference when compared to other wireless technologies [33]. For further detailed information regarding Bluetooth see reference [33].

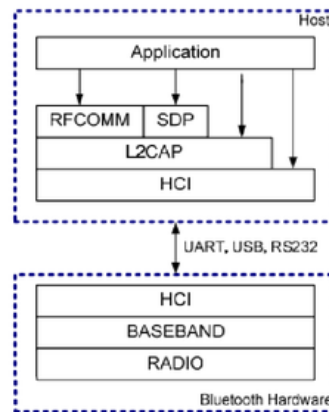


Figure 3.12: Bluetooth Stack, Master and Slave Bluetooth Modules [33]

With the Bluetooth modules the options are the **HC-05** or **HC-06**, these modules are the same; the only difference being the software/firmware that is loaded on it. This firmware is designed to use the pins on the modules differently, the HC-05 module has the full firmware on it and can be both a master and slave device; whereas, the HC-06 module can only be slave device. In short, the HC-06 module suffices enough for the needs of this project, the slave mode allows for wireless serial communication which will allow for data to be bidirectionally transmitted to a host computer.

Specification	Bluetooth Module		
	RS232 TTL Transceiver Module [34]	HT Bluetooth Module V2 [35]	HT Bluetooth Master/Slave [36]
Operating Voltage(V)	3.3	3.3-5	3.3-5
Current Usage(mA)	20-30 (pairing), 8 (after)	40 Max	40 Max
Range(ft.)	30	60	60
Flash Memory	External 8Mbit	External 8Mbit	External 8Mbit
Bluetooth Version	2.0	2.0	2.0
Voltage regulation	No	Yes	Yes
Module	HC-06	HC-06	HC-05
Price (£)	2.90	12.00	14.40

Figure 3.13: Comparison Table of Bluetooth modules

Note: All Bluetooth module shown in the above comparison table utilise a **RS232 HC-05** or **HC-06** Bluetooth transceiver module. The differences consist of addition breakout boards offering additional features.

As an evaluation of the communication method Bluetooth is a cheap and reliable method which can implemented in an electronic device. The power requirements once the module is paired are extremely low as shown above in **Fig 3.13**, consuming a current of only 8mA which is extremely beneficial when the battery life of the device is considered.

The modules are easy to use, automatically sense and detect other matched devices which are connected. The security of having a passcode to have access means that devices in use within a venue will only be controlled by security personnel, other Bluetooth device will such as phones will now be able to pair with these devices.

Bluetooth Adapter (Dongle)

With the use of a Bluetooth module inside the handheld device there needs to be method for a computer to receive the sent data. This is achieved with the utilization of a **Bluetooth dongle**; this is a small USB adapter which allows computers to communicate with other Bluetooth devices, such as the counting device.

Using this dongle is a fairly simple process, the **USB** is plugged into the required computer and after the relevant drivers have been installed; if it is required at all it will then begin sending signals out searching for Bluetooth devices in the area. From this stage the option to communicate with them is complete by the user of the computer.



Avantree Bluetooth 4.0 USB Dongle
Bluetooth Low Energy (BLE)
Data Transfer Rate: Up to 3Mbps
ISM Band: 2.402-2.480GHz
Price: £7.99

Figure 3.14: Bluetooth Adapter Specifications [37]

3.3. Microcontroller Selection

The selection of a microcontroller in any embedded system design is an important stage which requires a breakdown of the intended functions of the device, what will the device fundamentally do? It is important at this stage of the selection to choose a microcontroller which not only allows for your inputs, outputs and other requirements but also not to choose one which is unnecessary and designed for more complex tasks.

So a device is being developed which will allow for user inputs to control an overall count, this count needs to be transmitted through the method of communication discussed in **section 3.2** of this report. The device also needs to be portable for it to be practical in a busy environment so needs to be battery operated and with the addition of a small motor a method of alerting the user can be had. The final function of the device is to be capable of sending an alert or alarm to all other devices connected, this would utilise the motor in the design. All together meaning that the device would require a microcontroller which allows for three inputs which are the buttons and then three outputs one for the motor and two for the communication module (TX & RX). The 'Art of Electronics' [38] discusses the important features microcontrollers offer in detail, it goes on to also discusses how one should be chosen depending upon a gadgets demands.

Specifications	Microcontroller		
	PIC12F1501	PIC12F609	PIC16F887
Program Memory Type	Flash	Flash	Flash
Program Memory (KB)	1.75	1.75	14
RAM (Bytes)	64	64	368
Max CPU Speed	20 MHz	20 MHz	20 MHz
Pin Count	8	8	40
Total A/D Channels	4	0	14
Internal Oscillator	16 MHz, 32 KHz	4 MHz, 8MHz	8 MHz, 32 MHz
Operating Voltage(V)	1.8-5.5	2-15	2-5.5
Price (£)	0.31	0.37	1.27

Figure 3.15: Microcontroller comparison table [39]

The comparisons that were done to evaluate the potential microcontrollers are shown **above**; the table breaks down each one so specifications can be seen and evaluated efficiently. For this project the **PIC12F1501** was selected, after the discussion on the inputs and outputs of the device it was clarified

that an eight pin microcontroller would suffice. It allows for serial data communication, the **64 bytes** of linear data memory addressing is sufficient enough as the programming for the **PIC** will not be of a large size and the internal oscillator offers more than enough speed for the desired task. The other feature such as the on-board comparator and **ADC** are extras which will not be used but for the **£0.31** the microcontroller is the cheapest on the list and saves space on the final build size.

3.4. Motor Selection

The function and practical application of a motor in the design, is to allow for a method of alerting the user when they are in a loud and noisy environment. It is a known fact that music at these clubs play at extreme volumes which make hearing a difficult task. Noises in these clubs as a matter of fact can reach **110 decibels**; this is the equivalent of a jet engine during take-off [40]. Therefore, the addition of a speaker or noise function into the device would be seen as waste. Instead the use of a small motor inside the device will be the method which is used to notify the user when an alert is sent out or given.

This section is a focus on the types of motors which could have been used in the design with a brief analysis given of each. The chosen motor will be specified and the reasons for its choice are justified, explaining how it will be effectively implemented into the design with considerations for other aspects and components given.

3.4.1. Standard DC Motor

A **standard** direct current motor is a simple electric motor; electricity is run through it so a magnetic field is produced. This electrical energy is converted into mechanical which is then used to move the shaft of the motor. Its relation for the project is can it be used to notify the user of a device when an alert or alarm is sent, realistic not to a degree whereas the user would instantly be notified.

3.4.2. ERM Vibration Motor

A **vibration** motor is very small standard **DC motor** which has an off-centre load attached to the shaft, so in basic terms when this motor is powered it rotates and the unbalanced mass attached creates a centripetal force. With the application of one of these motors to an object, such as a small handheld device; then that centripetal force acts upon the object causing it to **displace (vibrate)**. Essentially the force that the motor produces is dependent upon the size of the mass attached to the motor, the distance between the mass centre of gravity and the motor shaft and also the speed of the motor (rpm).

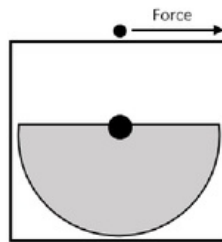


Figure 3.16: Vibration Motor

There are two aspects of which the vibration is commonly quoted, the Vibration Amplitude and the Vibration Frequency [41], a specific and technical analysis of these aspects has been given in [41]. Below in the figure these have been simplified and shown:

Frequency	Amplitude
RPM = Revolutions Per Minute	$F = mr\omega^2$
Hz = Cycles Per Second	m = Mass of Eccentric Mass(kg)
Vibration Frequency (Hz) = $\frac{\text{RPM}}{60}$	r = "Eccentricity" of Eccentric Mass (m)
	ω = Angular Velocity (rads^{-1})

Figure 3.17: Aspects of Vibration [41]

The amount of vibration amplitude the motor will produce, however, is highly dependent on the size of the object the motor is attached to. As an example the shown vibration motor in **Fig.3.16** which is designed for use in a device such as a small mobile phone would be ineffective and would not cause much displacement if it were attached to a larger object.

Available Vibration Motors

4mm – 11mm [42]	4mm – 9mm Type [43]	5mm – 20mm [44]
		
Rated Operating V: 0.9-1.8V	Rated Operating V: 1.1-1.8V	Rated Operating V: 1.5-3.6V
Body Diameter: 4mm	Body Diameter: 4mm	Body Diameter: 5.3mm
Body Length: 11.4mm	Body Length: 9.3mm	Body Length: 20mm
Counterweight Radius: 4mm	Counterweight Radius: 2.5mm	Counterweight Radius: N/A
Rated Vibration Speed: 14,000 rpm [$\pm 4,600$]	Rated Vibration Speed: 8,500 rpm [$\pm 2,100$]	Rated Vibration Speed: 15,000 rpm [$\pm 3,000$]
Typical Current: 65mA	Typical Current: 90mA	Typical Current: 44mA
Max Current: 78-140mA	Max Current: 110-140mA	Max Current: 65-95mA
Normalised Amplitude: 1.2G	Normalised Amplitude: 0.7G	Normalised Amplitude: 0.95G
Terminal Resistance: 14 Ω	Terminal Resistance: 12 Ω	Terminal Resistance: 45 Ω
Price: £4.20	Price: £4.20	Price: £4.91

Figure 3.18: Vibration Motor Comparison Table

All above motors are acceptable examples of vibration motors, with the device in development all that is required is a small motor for a method of alerting the user. For the purpose of the experimental approach of this project the **4mm – 11mm** and **4mm – 9mm** motors were purchased. These two motors have very similar characteristics and specifications so would not affect testing and results to a serious degree whilst software based designs are produced. In the design section of this report it can be seen how these tests were undertaken and how the motors were best utilised by the **microcontroller** as an output.

3.4.3. Back EMF

Back EMF or **back electromagnetic force** is a voltage that appears in the opposite direction to the current flow of a motor. This voltage occurs due to the motors coils moving in a relative direction to that of a magnetic field, as a result this back **EMF** can have an effect to the speed of a motor. With any motor it can be broken down into an equivalent circuit as shown below in **Fig. 3.19**, a motor essentially consists of a typical current than it draws from the power supply; the greatest being at the beginning of the process. A typical terminal resistance and then the backward acting voltage or **back EMF**.

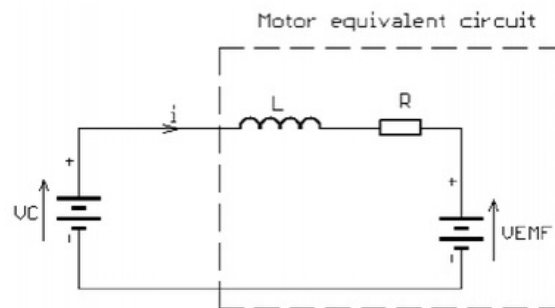


Figure 3.19: Motor equivalent Circuit [45]

As an example the **4mm – 9mm** vibration motor from previous section has been selected for the calculation of the **back EMF**:

4mm - 9mm Motor [43]
Rated Voltage: 1.5V
Typical Current: 30mA
Rated RPM: 8,5000 rpm
Terminal Resistance: 12 Ω

Figure 3.20: Required specifications for back EMF calculation

If a motor is stalled and is being power by the rated voltage, the current through the motor is being limited by a resistance:

$$I_{Stall} = \frac{V_{supply}}{R}$$
$$I_{Stall} = \frac{1.5}{12\Omega} = 125mA$$

When the motor is rotating, therefore, the back EMF that is produced will work against the supply voltage and in turn reducing the current of the circuit, in this case the typical current for the motor is **90mA**. This means that the amount of back EMF produced is equal to the reduction in the current times the terminal resistance [45]:

$$VBEMF = (I_{Stall} - I).R$$
$$VBEMF = (125mA - 90mA).12\Omega$$
$$VBEMF = 0.42V$$

OR

Substitute I_{Stall} from above:

$$VBEMF = \left(\frac{V_{supply}}{R} - I \right).R$$
$$VBEMF = V_{supply} - (I.R)$$
$$VBEMF = 1.5 - (90mA.12)$$
$$VBEMF = 0.42V$$

3.5. Battery Selection

Selecting an appropriate battery for the design is an important factor which will affect how long the device will operate for. The calculation of the estimated consumption of the circuit and the resulting **mA Hour** requirements are shown and discussed in **section 4.2.1**.

This short section is an analysis of a number of the batteries that could potentially be used in the final design to power the device. Only a small selection of the batteries are shown in this section due to high variety of options available on the market. For a detailed and analytical review of the different battery types available references [46] [47] provide a detailed breakdown.

The common batteries that are available can be divided into two categories:

- Primary Type
- Secondary Type

3.5.1. Primary Type

The primary type of battery stated is a common disposable group which cannot be recharged. The most common from this list being **alkaline** batteries, these are the most commonly used batteries as they provide a high energy density and long lasting performance. The second listed primary battery is a **Zinc-Carbon** type, these are also known as dry cells and have a typical voltage of **1.5V**. They typically have a long lifespan but do not function well at lower temperatures.

3.5.1. Secondary Type

Secondary batteries are the second type discussed; these are more commonly known as rechargeable types. **Alkaline** batteries also come in rechargeable types, these have the longest life shelf of any chargeable battery listed and every time the battery is charged the over capacity drops making it less efficient. The last battery shown is the rechargeable **NiMH (Nickel-Metal Hydride)**, these have a very large capacity when compared to other batteries but are also slightly larger than regular **AA** batteries.

Overall, any of the batteries discussed could be implemented into the design as the voltage source. As the requirements of the circuit are low and as is the current consumption; discussed in **section 4.2.1**.

Chapter 4:

4. Design and Implementation

The design of a device or system is a process which goes through different layers, the **ADDIE model** [48] is a process which is adopted by designers and developers. It consists of five layers shown below in **Fig. 4.1**, these represent a flexible guideline as there are multiple variations of the model. In this project it helps layout the stages for development of the design, it has us analyse the design in segments as simple diagrams are created to show the design on a fundamental level. After each stage an evaluation is undertaken before that outcome feeds into the subsequent step [48].

This section as whole will see the development of all the segments that have been researched as they are build up, tested and evaluated. After this they can be grouped together creating the important parts which ultimately form the device with relevant data, issues encountered are discussed and how they were overcome. This section is divided into the sub sections that they were completed in, through this reliable and analytical reviews of the data can be made as it progresses.

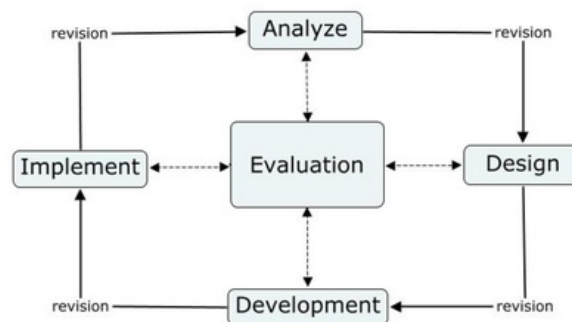


Figure 4.1: ADDIE Design Layer Framework [49]

4.1. Initial Designs

The beginning of the design development for any project requires the segmentation of the individual components which the device and system will consist of. At the most fundamental level block diagrams are created to give a simplistic view of how the device will function, as shown in below in **Fig. 4.2**. For these designs the fundamental components of the device need to be identified

so they can be placed correctly, by doing this it aids the developer as they can be analysed before progressing.

- Microcontroller (PIC12F1501)
- Vibration Motor (4mm – 9mm type)
- Communication Method (TTL Bluetooth Module)
- Device Inputs (Push Button Switches)

The microcontroller as in the majority of most electronic designs acts the middle core component, all other modules and components in the system will have an interaction with PIC which ultimately control how the device behaves.

As shown below in a simple diagram of the device, the inputs will activate designated pins of the microcontroller which in turn will adjust the overall count and send a message or in the case of an alarm situation the vibration motor will simultaneously be turned as a message is produced through the Bluetooth module.

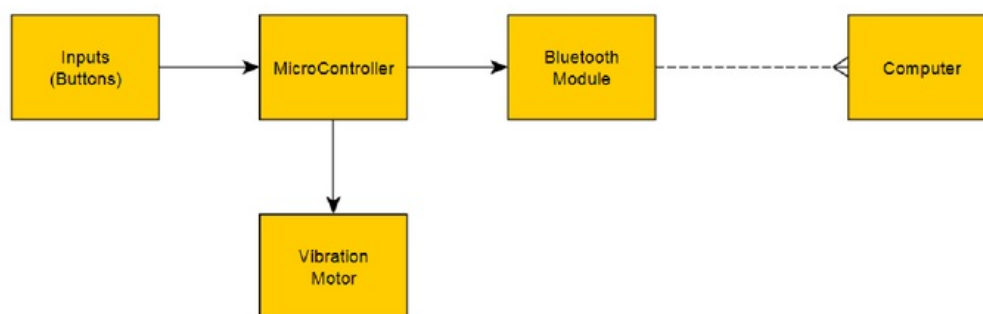


Figure 4.2: Initial Block Diagram

As the project develops further improvements and adjustments can be made to designs, this can be seen through unexpected issues or improvements that progress the device and system further. Once this greater knowledge of these components is obtained these adjustments can be made accordingly to the device and ultimately produce what can be consider a refined design which has gone through multiple stages of progression.

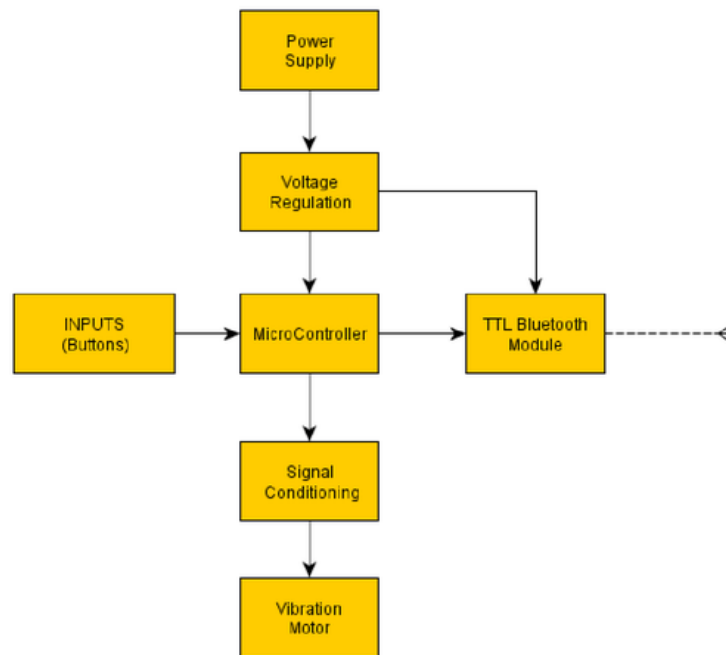


Figure 4.3: Further Block Diagram

The above diagram is simple progression from the diagram shown previously in **Fig. 4.2**, as specifications for the components were researched it was clear that the power for the system would require a form of regulation. The microcontroller will require regulation if the battery supply exceeded **5V**, the Bluetooth module and the vibration motor in the circuit will also need a form of regulation or conditioning so they are not damaged. These tests and results are shown in the implementation section of this report.

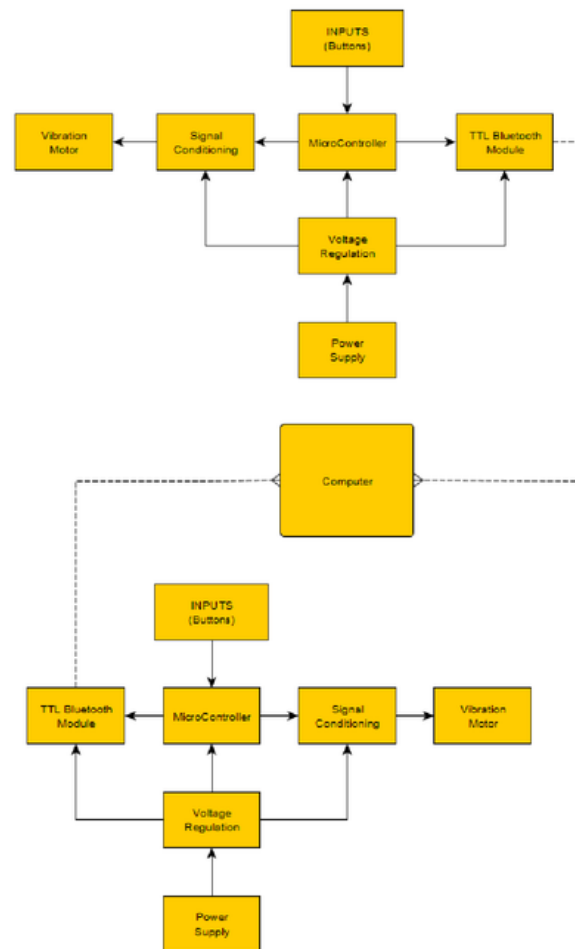


Figure 4.4: Expanded Block Diagram

The ultimate goal if the device were implemented within a premises or venue would be to have a number of the same devices which would be synced to a host computer. This computer would act as the server for the customer flow count to be sent directly from the devices where the data from all device would be collaborated giving an overall count or separate depending on the owner's preferences. The above diagram **Fig. 4.4** shows this in an expanded version of the block diagram where more than one device is in use, ultimately a much larger number of the same devices could all be connected and send data simultaneously.

Proposed Setup

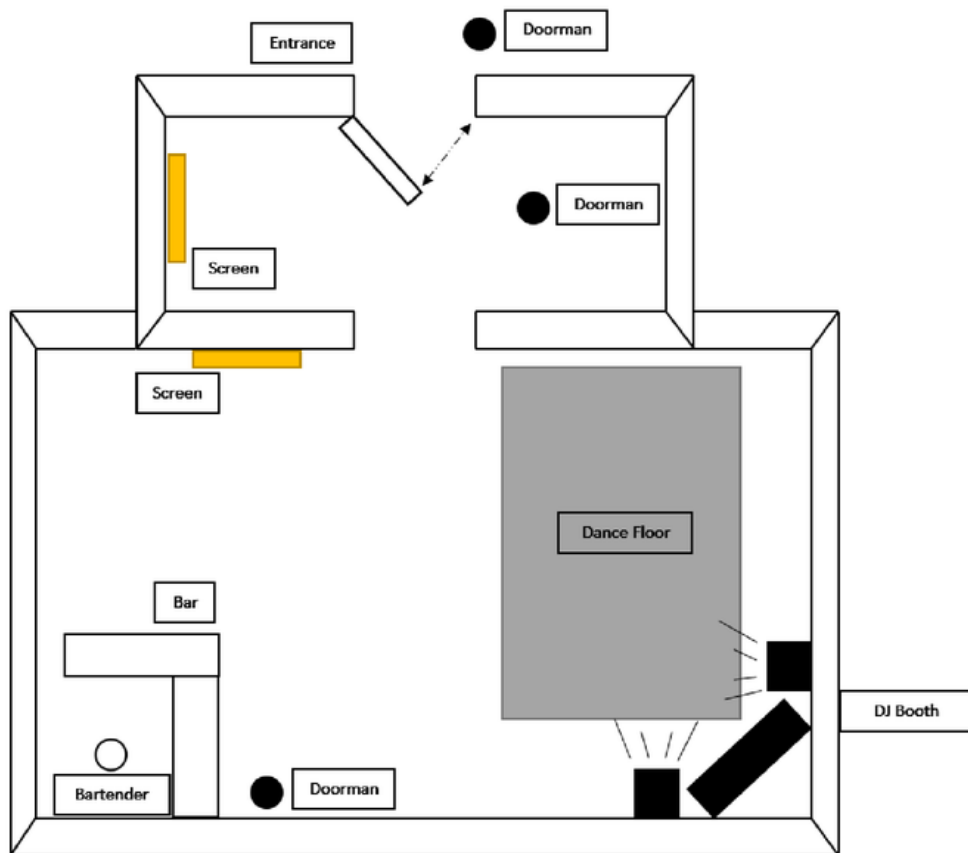


Figure 4.5: Proposed Setup in Nightclub

The proposed setup shown a downscaled nightclub, it suggests that with the utilisation of the devices doormen can be placed a number of different spots over the premises and still have a view of a screen. The purpose of this is so when the visitor count is sent to the main computer which needs to be within the range that the Bluetooth modules require, the overall count can be displayed on these screens allowing simple and easy method of maintaining that flow.

4.1.1. Software Flowchart

When the device is at a level where it can function according to design requirements it should follow a procedure, through this it allows for an evaluation of the software and hardware to be made as it is compared to the software flowcharts created. **Fig. 4.6** shows a detailed process that the software should follow, if the device is to function as intended it needs to have strict decision making where from the appropriate output can be selected.

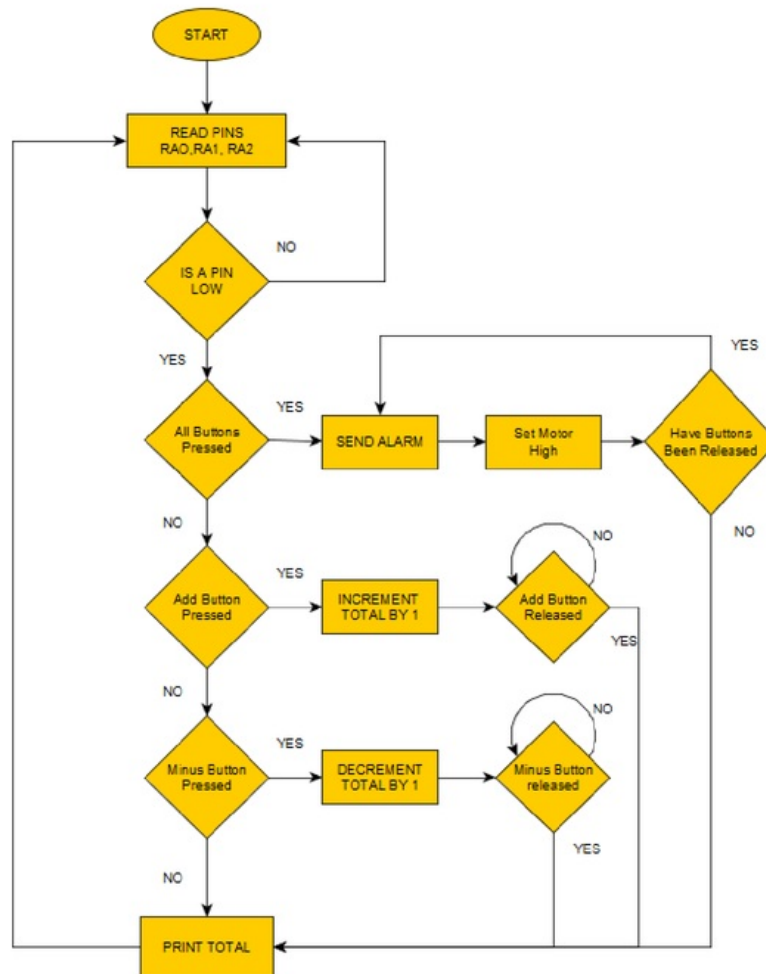


Figure 4.6: Device Options Software Flowchart

The diagram when broken is a representation of the device running through its general cycle. Pins **RA0, RA1 and RA2** are the input pins for device and are controlled by push buttons, when the user wants to alter the total button 1 (**RA1**) will increment the total by one, button 2 (**RA2**) is then the minus option; this will decrement the total. This leaves the final function of the device which is the alarm, this is activated when the user of the device holds all three buttons down simultaneously activating the motor which is connected to pin **RA3** as seen in **Fig. 4.31**, the alarm message is also sent when these are held down through the Bluetooth module relaying the message to all other device users and printing a message on the display screen.

For all situations there is an added decision layer, this is when the user must release the pressed buttons if the process is to proceed. Through this function it ensures that firstly only an addition or subtraction of one can be made by a single button pressed per cycle and then it keeps the device in alert mode until the user has let go of all buttons resuming its main function.

Bluetooth Software Flowchart

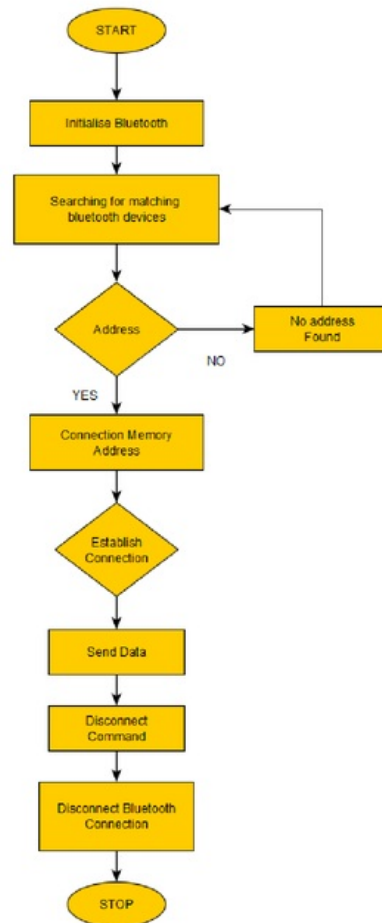


Figure 4.7: Basic Bluetooth Software Flowchart

The process of initialising the Bluetooth module and pairing with other devices is shown broken in the above diagram. It shows how after the Bluetooth module has been activated it automatically begins revealing that it is available to be connected to. After a passcode and confirmation of the address a connection is then established, from here the devices remember that they are paired; even after a disconnection. From this point onwards data can be simply sent between devices, in terms of the handheld counting device numbers or messages.

4.2. Microcontroller

The device and system requires a method of input so the microcontroller can communicate with the Bluetooth module, simple push button complete this function to an acceptable level. Therefore, the buttons labelled will act as the user inputs and will require three input pins from the PIC.

The microcontroller that was chosen for the design was the **PIC12F1501**; the specifications of the PIC are shown in **Fig.3.15**. By choosing a microcontroller this small it minimises board requirements and also cost, as will be discussed later the programming for the task required is not extensive so the memory available from the PIC suffices. The process where the PIC is tested in the design is when the HEX code is successfully transferred from software to hardware; this process is done at a later stage in the design in the software development.



Figure 4.8: PIC12F1501 Pinout Diagram [50]

PIN	FUNCTION
1- VDD	Power (+3.3V from LE33)
2- RA5	Tx (Output)
3- RA4	Rx (Output)
4- RA3	Vibration Motor (Output)
5- RA2	Button 1- Minus (Input)
6- RA1	Button 2- Add (Input)
7- RA0	Button 3- Alarm (Input)
8- VSS	GND

Figure 4.9: Microcontroller Pin Layout

Proteus designs and simulations allow for the circuit to be built quickly so tests can be done. Before this can be done the PIC12F1501 needs to be setup on CCS, this is the C compiler which allows for the PIC to be setup. The outputs and inputs for the PIC are designated as the code libraries, internal oscillator clock speed is chosen, the PIC12F1501 features a 16MHz oscillator as previously discussed.

4.2.1. Configuration Words

For the PIC12F1501 in this design the configuration word 1 and 2 was adjusted for software and hardware purposes, this is a series of configurable settings which was arranged in Proteus outside of the program code [51]. They are special derivatives which include low level parameters which include selecting which pins are used for programming, the relevant PIC12F1501 datasheet [52] was used to obtain and then decide which bits are cleared '0' and which are set '1'.

Configuration Word 1

13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	1	1	0	0	0	0	1	0	0
3		F				8				4			

Figure 4.10: Configuration Word 1 Table Hex Values

Configuration Word 2

13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	1	1	1	1	1	1	1	1	1	1	1
3		7				F				F			

Figure 4.11: Configuration Word 2 Table Hex Values

The tables above in **Figs 4.10, 4.11** shows how the information was collected, the data then needs to be added to the microcontroller file '**0x3F84 & 0x37FF**'. From the relevant PIC datasheet, the functions were decided according to the designs requirements and setup.

Beginning from bit 13-12 unimplemented reads as 1, bit 11 which is the clock out enable bit; this is set to 1 as the CLKOUT pin is using an I/O function, bits 10-9 are both 1 as the brownout reset is enabled for its use in the circuit. Bit 8 is the same as 13-12 therefore is set to 1, bit 7 is set to 0 as the memory code protection is required and the LVP bit=1 so bit 6 is ignored. Moving onto but 5 and the power up timer is enable so is assigned to 0, for the design the watchdog timer is not required so bits 4-3 are both set to 0, bit 2 once again is unimplemented so reads as 1 and finally bits 1-0 are the oscillator selection bits and is set to 10 so the external clock of the microcontroller is set to a medium power mode on the CLK pin. From the resulting bit numbers as they formed into the table shown in **Fig. 4.10** it can be seen how the hex numbers are collected so they can be transferred and as configuration word 2 follows a similar process as 1 of designating the bits the data from **Fig. 4.11** can be directly linked to the datasheet [52].

4.3. TTL Bluetooth Transceiver Module

The Bluetooth module is the chosen method of communication for the device; this was chosen after an analysed comparison of the methods previously in the report. Ultimately Bluetooth was chosen for the following reasons:

- Quick easy setup and connectivity
- Very small module (W: 27mm x H: 13mm)
- Cheap to buy (£2.90)
- Secure connection (need passcode)
- Easy to simulate and test

The software and hardware setup and implementation are relatively simple, making it ideal for this particular project. All research based reports and work that was evaluated showed that Bluetooth would be a good addition to the project and device.

For simulation purposes the **PIC12F1501** which had been setup in the microcontroller section to a virtual terminal would serve as the testing method and would be used to represent the module. By connecting the two designated transmitting (**Tx=RA4**) and Receiving (**Rx=RA5**) pins of the PIC to the opposing inputs of the terminal a software version of the module can be made. From this point onwards it can be quickly tested to ensure it working correctly, the simple addition of a few lines of code involving 'printf ("Press button to alter total");' this allows for output shown in **Fig. 4.13**.

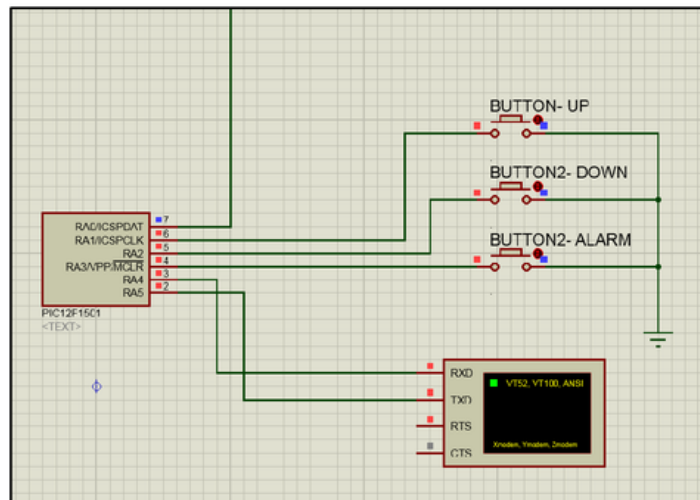


Figure 4.12: Virtual Terminal Proteus Setup

Above the setup of the **PIC12F1501** along with the three inputs buttons and virtual terminal is shown; the virtual terminal here is used as a representation of the **TTL Bluetooth module** as it can both send and receive data to and from the PIC.

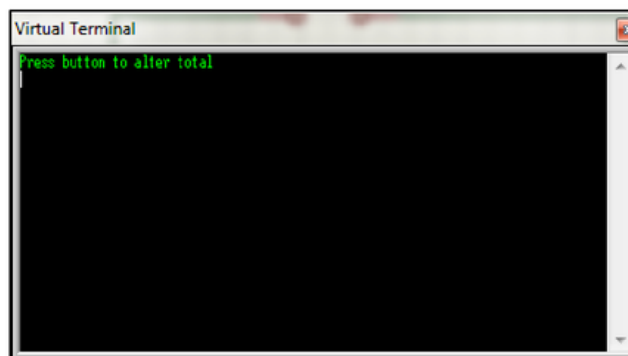


Figure 4.13: Virtual Terminal Test

A screenshot is shown of the resulting Proteus virtual terminal test which produces a simple message.

Implementation

As the simulation for the Bluetooth communication module did not have a component to use on the Proteus software there was no data relating to the pinout and prototype setup. The module itself very small as stated before, giving only 1.5mm spacing between each of the 34 pins. However, serial communication is being used and the module itself has been designed to offer other methods of data transfer including SPI. This means that only six pins are directly needed for the purpose of completing the required task, the **UART Tx and Rx, +3.3V power supply** which will be taken from the circuits voltage regulator as discussed later and the ground and LED pins. The LED is connected to pin 24 of the module and a **470 Ohm** resistor is used as shown in **Fig. 4.14**; this LEDs purpose in the design is a status indicator. When the module is set up correctly the LED will consistently flash as it makes itself available as a communication module, this continues until it is paired and then the LED will flash solid stating a successful connection has been made.

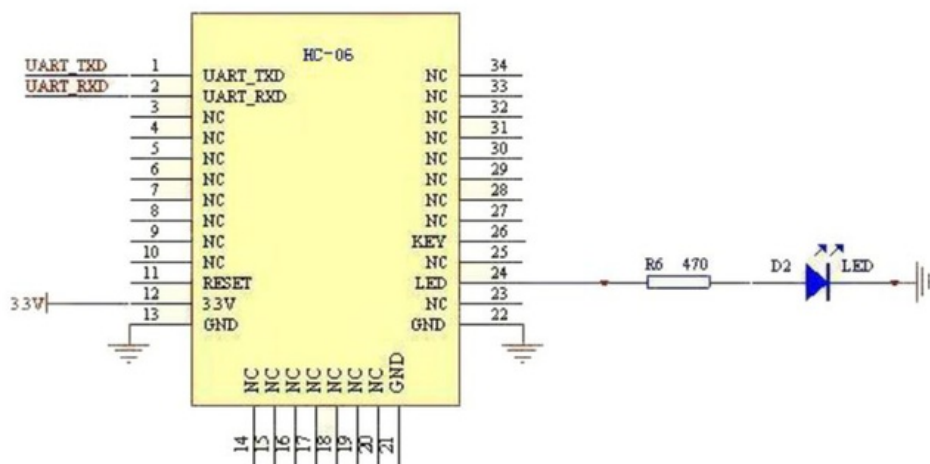


Figure 4.14: Bluetooth Module Pinout Diagram [53]

Pin Number	Function
Pin 1	Transmit (Tx)
Pin 2	Receive (Rx)
Pin 12	Power - 3.3V
Pin 13	Ground (GND)
Pin 22	Ground (GND)
Pin 24	LED (Status Indicator)
Pin 25	NC (Used for stability)
Pin 26	PI0(3)/KEY (Used for stability)

Figure 4.15: Bluetooth Pins used in design

The table above shows the pins that were soldered in the prototype build, pins 25 and 26 are not need but were soldered for stability purposes and as they not used they do not interfere with the wiring.

After the diagrams and research was complete the prototype build was made according to the specification listened above. When there is power supplied to the HC-06 Bluetooth module the green LED in **Fig. 4.16** begins to flash and awaits a connection to be established.

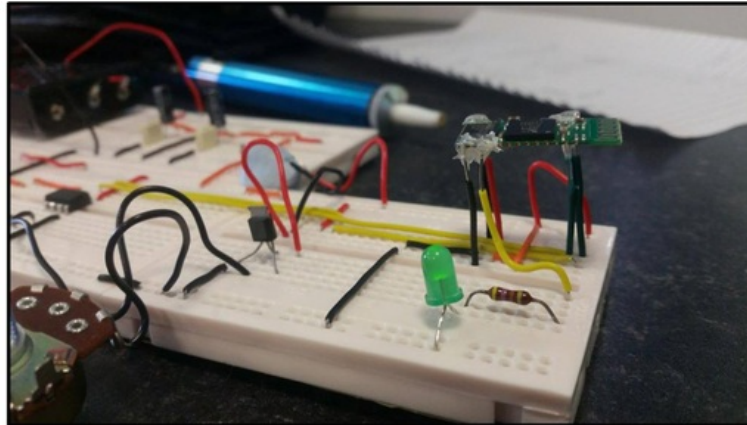


Figure 4.16: Bluetooth module with LED Indicator Prototype

Pairing the Bluetooth Module

In order for the Bluetooth module to be capable of paring with a computer for the testing of the finished prototype build, a Bluetooth dongle such as the one discussed in **section 3.2.3** will be required. This module is a simple '**plug & play**' unit and once it is connected to a computer it allows for the user to view all Bluetooth devices that are transmitting within moderate distance. With the option to connect to the devices also, the HC-06 module can be paired to the computer. An authorisation passkey will be required at this stage and by default this is '**1234**' [34], the module as shown below in **Fig. 4.17** is now connected and allows for an expansion of its status and properties through the '**device manager**' on windows.

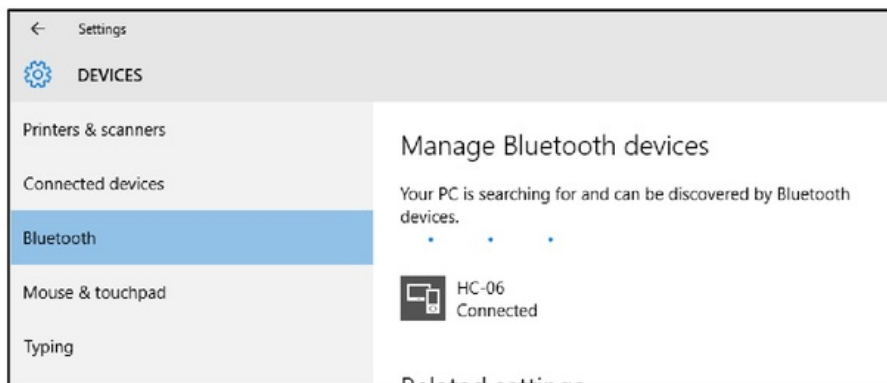


Figure 4.17: Computer Search Revealing HC-06

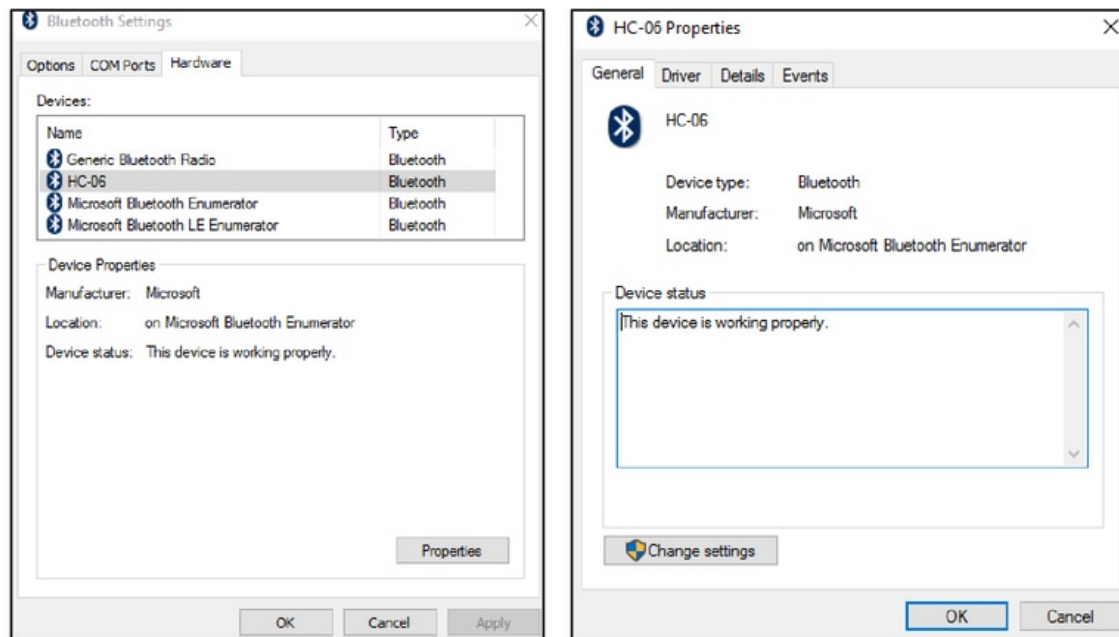


Figure 4.18: HC-06 Connection Status & Properties

The setup and pairing of the TTL HC-06 Bluetooth Module proves to be successful, which allows the project development to be taken further. The next development and testing that now involves the Bluetooth module prototype is in the final design when the software code has been transferred onto the PIC12F1501 and the input buttons can be used to alter the count system. The involved communication methods will then be responsible for sending that data to a computer through wireless serial RS232 so it can be read.

4.4. ERM Vibration Motor

4mm – 9mm Type

As discussed in **section 3.4** of this report, all compared vibration motors are considered acceptable for a small handheld device. For the design the stockier 4mm – 9mm type motor was chosen. This was a decision that was based on how the testing would be undertaken; it is considered to be the more solid and least fragile motor. On the prototype board it will not be attached to a casing at first so will be moving around freely which could damage wiring.

This section shows how the motor was set up and how it was effectively implemented into the design. Its main function in the design is to act as an output for the PIC12F1501 when an alarm has been sent, for this to be possible its function has to be reliant upon the assigned output pin of the microcontroller sending the correct signal. Therefore, a circuit must be designed which allows for the motor to be operated when needed.

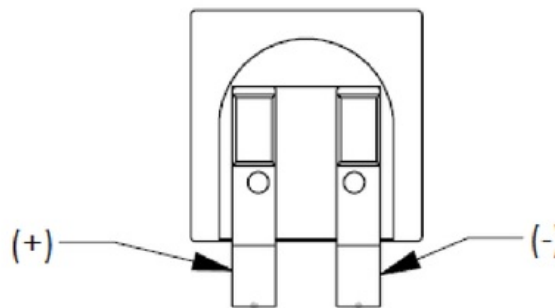
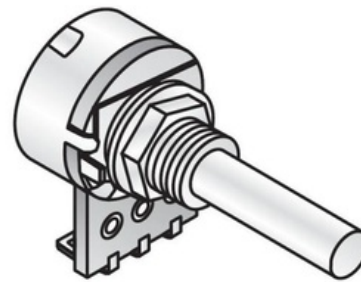
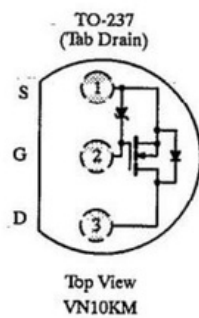


Figure 4.19: Vibration Motor Pinout

The motor chosen has a functioning voltage range of **1.1 to 1.8V**, so a form of voltage regulation or signal would be required for the design. After designs were considered and tested the addition of a **FET** into the circuit was chosen, with this setup in series with a **100K** potentiometer and a three point **SPDT** switch a small test circuit was created.

The example shown below in **Fig. 4.21** shows how this simulation design was setup and tested. The motor is powered by **+3.3V** which represents the output from the **LE33** regulator in the main build, this motor is then also connected to the source pin of the **VN10KM** as the gate pin leads to the potentiometer and the switch. The final third pin of the FET is the drain pin; its purpose being to drain all the voltage on the source pin to ground so the motor is not powered. The switch shown in

the simulation acts as a substitution for the microcontroller, this way a high or low output can be simulate. This functions accordingly when the output pin of the microcontroller is high it supplies another voltage to the gate pin of the VN10KM, this restricts the current going through to the drain and allows for the motor to be powered. This level of restriction or allowance is then controlled by the potentiometer in the circuit, this ensures that the motor will not receive all of the +3.3V across it from the supply.



100K POT

Figure 4.20: VN10KM [54] & 100K Potentiometer [55]

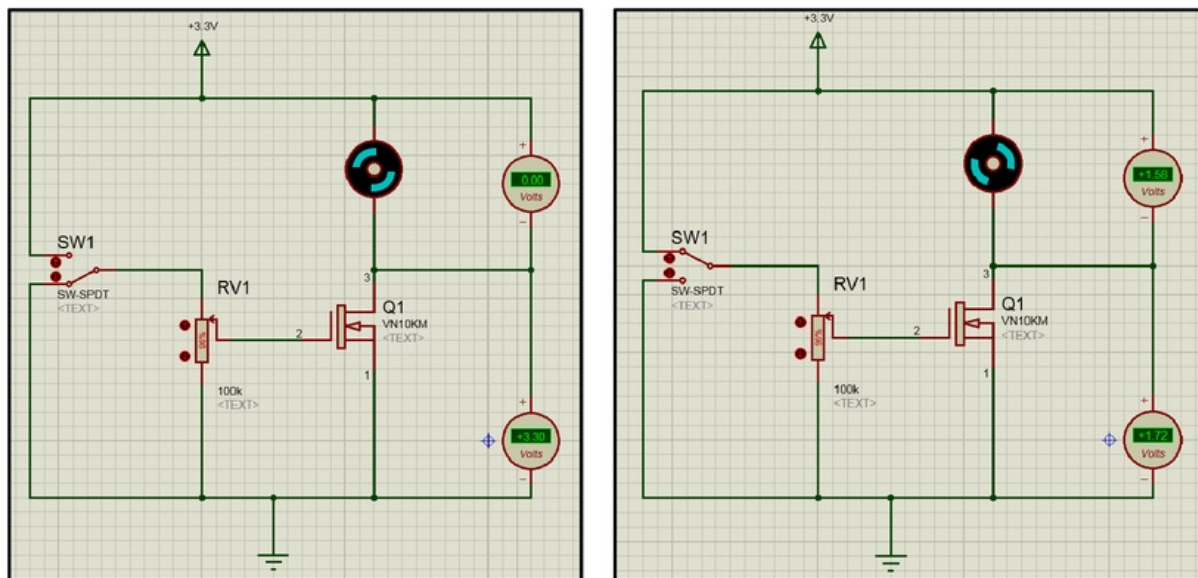


Figure 4.21: Proteus Motor Circuit Tests

An example of the theory and simulation built on Proteus is given above, displaying two scenarios from the test. On the left the switch links the potentiometer to the gate pin of the VN10KM which mean all voltage into the source pin is drained to ground. The second example on the right then shows the situation where the pin connected the power supply to the gate pin; creating a voltage to the FET and allowing the motor to function.

Following this successful simulation of the design, the vibration motor and its associated components could now potentially be built, essentially allowing a prototype circuit to be created. The creation of this prototype then allows more progress to be made, as errors and discrepancies can be eradicated and adjustments and refinements made. The circuit built on breadboard is shown in **Fig. 4.22** and the motor and FET is identified as they connected to the pot and PIC12F1501.

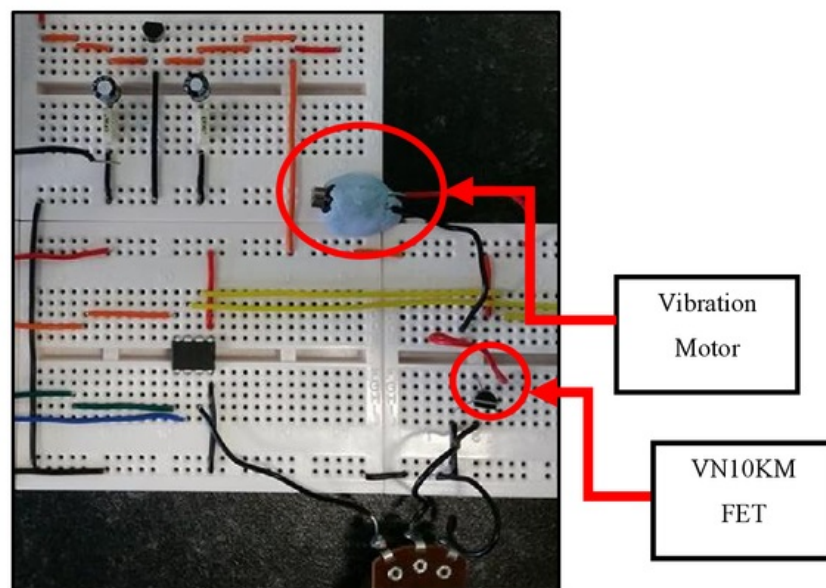


Figure 4.22: Motor Circuit Prototype Setup

Note: The small vibration motor in the design was moving around excessively as was expected, therefore, it was secured with blue tack to breadboard to minimise damage to the wiring of the motor.

4.5. LE33 Voltage Regulator

A consistent and stable power supply is an important part of any circuit design, for this a voltage regulator offers a consistent supply for components and parts for the circuit. The voltage requirement in the circuit is at a low level which means a small power supply has been chosen, three AA batteries giving **1.5V** each with an overall of **4.5V**. Therefore, the only regulation which is required is for the TTL Bluetooth module discussed in **section 4.2** of the report, the module functions on **3.3V** of power so a **LE33** voltage regulator was chosen. The layout with its respective pinouts are shown below in **Fig. 4.1:**

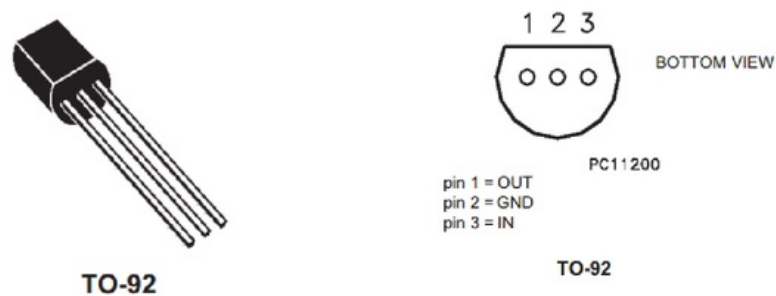


Figure 4.23: LE33 Voltage Regulator Pin Layout [56]

The **LE33** regulator is part of the LE00 series which are low drop off with very low quiescent current [56]. Its b drop means that the device will function even if the battery pack in the circuit drops from **4.5V to 3.5V** which is efficient and extends the battery life of the device. The regulators datasheet [56] states that it only needs a single **2.2 μ F capacitor** for stability which allows for room and cost saving.

For the purpose of experiments and testing the **LE33** is setup first on Proteus with **two .1k63** capacitors and **two 47 μ F** electrolytic capacitors. The setup is shown below:

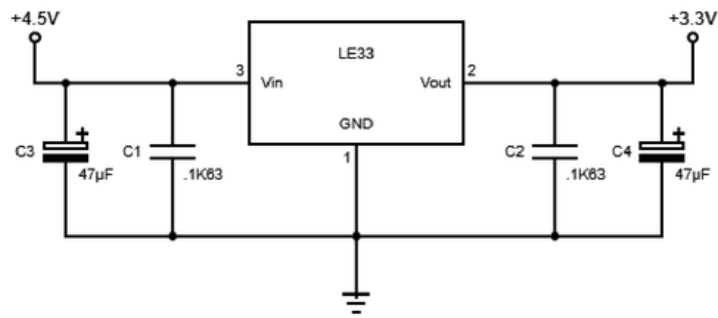


Figure 4.24: LE33 Voltage Regulator Circuit Diagram, created using Circuit-Diagram Software

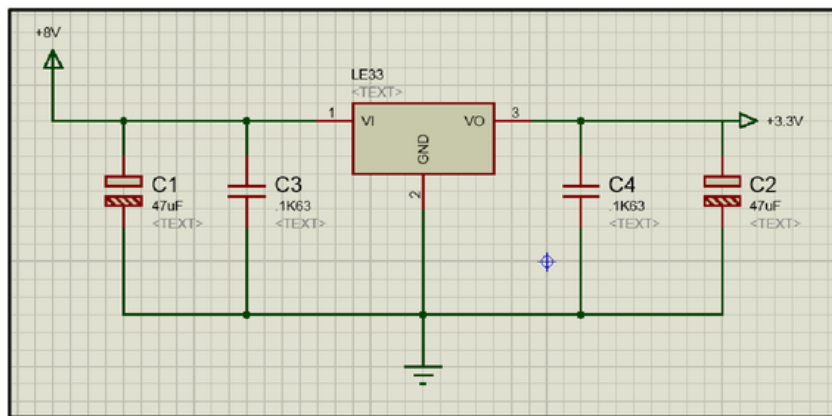


Figure 4.25: LE33 Proteus Design

The design created on the Proteus simulation software shows the successful regulation of the input voltage to the required **+3.3V**. Doing this ensures that the specific components such as the microcontroller, Bluetooth module and motor receive the correct voltage that they need to function and also so they are not damaged by unexpected voltage surges.

Implementation

The simple design and simulation of the regulator on Proteus it can be transferred to a breadboard for use within the design. **The LE33** regulator is relatively simple component to implement into the design, its importance is however regarded very high; this is the protection for the

valuable areas and components of the design as all functioning areas will require the +3.3V regulated output.

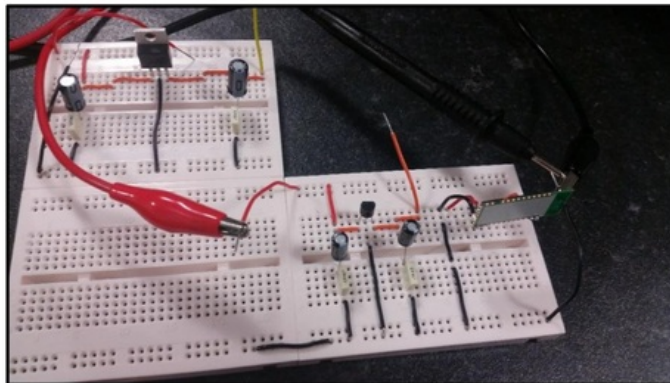


Figure 4.26: LE33 with HC-06 BT Module

Above in **Fig. 4.26** the setup of the **LE33** regulator is shown on breadboard, +4.3V was supplied to the input of the regulator as a matching supply that the 3 x 1.5V batteries would provide. The regulator has a rated drop off of only 0.2V which is very low, this mean that any voltage above 3.5V will be regulated.

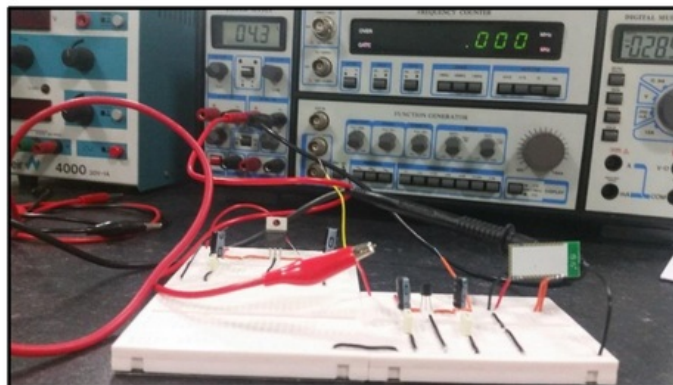


Figure 4.27: LE33 Regulator Test

The resulting voltage readings using a multimeter from the **LE33** circuit are shown in **Fig. 4.28**. The successful and correct reading of 3.3V is shown on the output of the regulator, this allows for its implementation into the final prototype desing.



Figure 4.28: LE33 Multimeter Readings

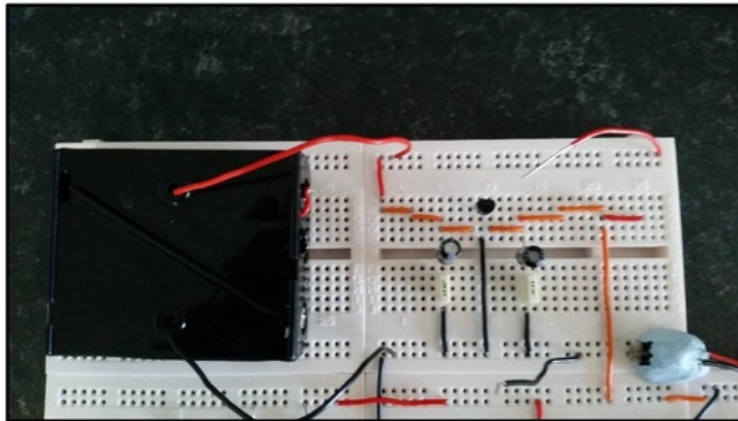


Figure 4.29: Battery and LE33 Setup

Fig. 4.29 show how the regulator and power supply was organised on the breadboard so the wiring would not interfere with other areas of the build.

4.1. Software Development

The software development of the mentioned project is an essential and important area which needed its own development cycle; as the physical design did. The required coding for the microcontroller is done on the Proteus simulation software that has been used throughout his project, this way the **C coding** language could be utilised making the task significantly easier to accomplish when compared to the assembly language alternative.

The programming of the **PIC** in the design could essentially be regarded as one of the most significant aspects as this is where the commands, situations, inputs and outputs for the design are located. Through this section the development of the coding is shown, it is broken down as the code is explained for its introduction and the advantages that it provides.

4.1.1. Coding

The code that was used can be seen in appendix of the report, **section 10.5** with the relevant commenting to explain the individual commands it has been extracted directly from the Proteus simulation. The coding involved for the development of the device from start to end is not of a high complexity but still has a major role in the functionality of how the device operates. The utilisation of the flags in the coding means that it ensures reliable readings when the buttons are pressed, for example when the addition button is pressed on the device it enters the flag state incrementing the overall total by **1**; the program is not allowed to leave this flag state until the button is released. This method of altering the total means that the very high oscillator speeds of the microcontroller will not add more than **1** to the total per button press.

The next stage with the completion of the software is to apply that the code to the main Proteus design and evaluate the findings. If successful results are provided, then further progression can be made and the software code can be transferred onto the **PIC12F1501** so it can be tested on the prototype design. This process is shown in next section of the report.

4.2. Final Circuit Design

The final design section of the report is a focus on collecting all the previously design sections of the design and grouping them into a single functioning design. The given grouped design can then onwards from the point be tested, evaluated and developed; this is a trial and error stage where the design is tweaked and refined.

The first step is to import and test the simulation design; **Fig. 4.31** shows how the **Proteus** circuit has been made and how all aspects of the designs are connected to the microcontroller. The regulator in the design is being represented by the power supply and the **HC-06** Bluetooth module is replaced by the virtual terminal.

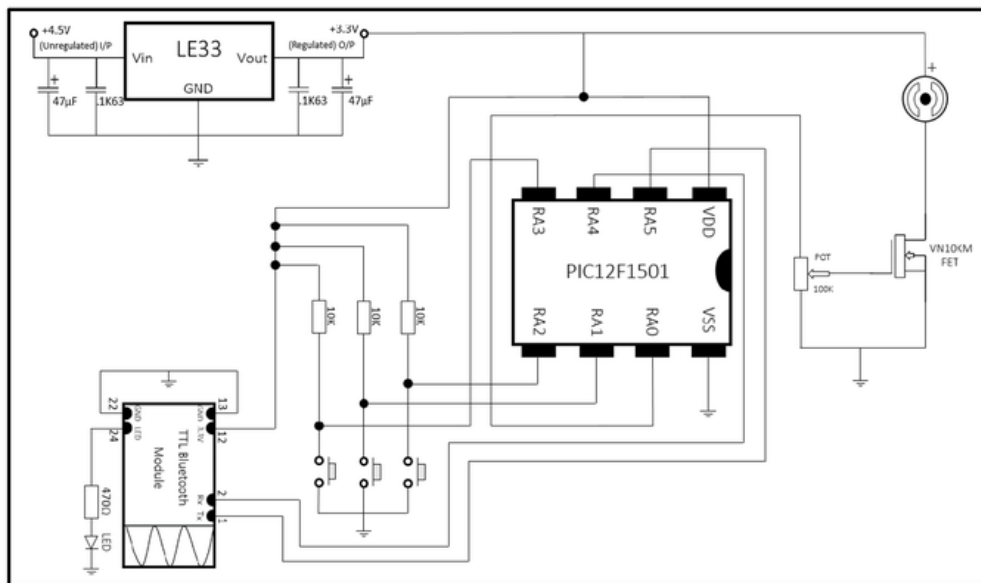


Figure 4.30: Final Circuit Diagram

The Proteus design is shown below, the simulation is running and **no** buttons are pressed therefore the simulation is not showing any function.

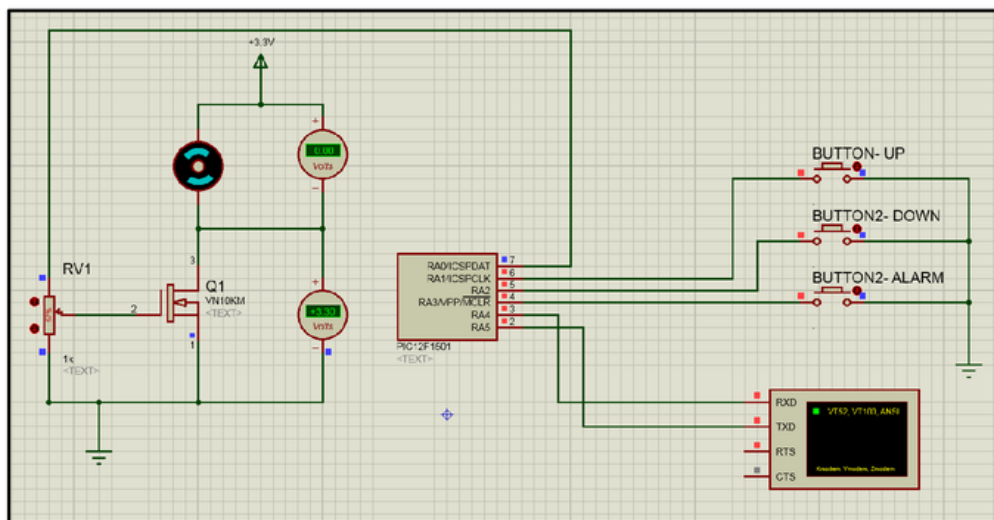


Figure 4.31: Full Proteus Design

Add Test

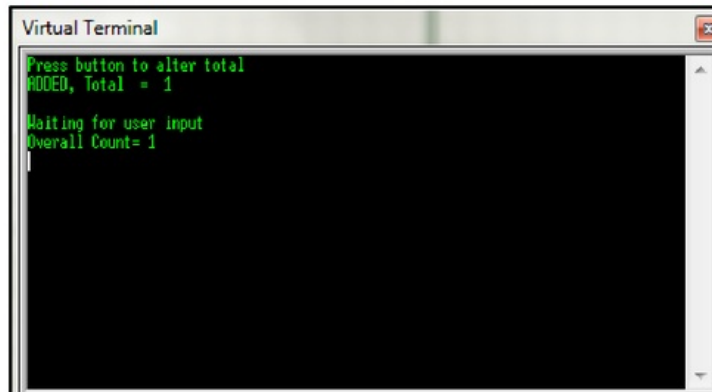


Figure 4.32: Virtual Terminal Add Test

For the first simulation test of the full circuit the 'UP' button is pressed, this produces the resulting message on the virtual terminal shown above in **Fig. 3.32**. The result is what is expected and increments the total by **1** per button press.

Minus Test

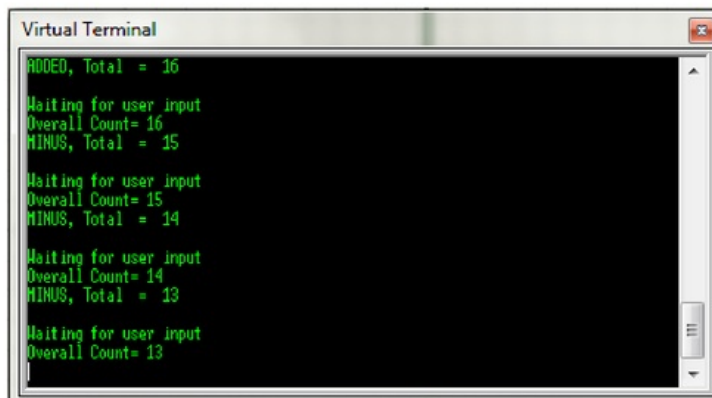


Figure 4.33: Virtual Terminal Minus Test

The second test of the simulation was to take away one from the total, this represents the user of the device pressing the **minus** button when an individual leaves the premises or establishment. The

button labelled down on **Fig 3.31** is pressed, the resulting message and change to the overall count is shown above in **Fig. 4.33**. The results again are successful and decrement the total once per hit.

Alarm Test

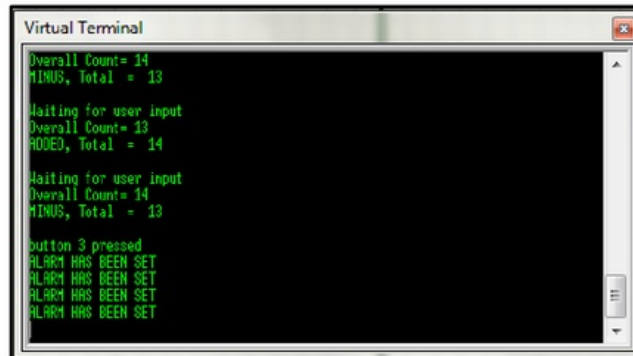


Figure 4.34: Virtual Terminal Alarm Test

The final message and button test was to set the alarm function on the device; this is again a representation of a real life situation of when a security member needs assistance so presses all buttons down at once to send the **alarm**. The **Fig 4.34** shows this being done, once all three buttons are set to down on the simulation the alarm message is produced continuously, the resulting motor response from the alarm function is shown below in **Fig 4.35** and shows how when the buttons are down **PIN RA0** is set to **high** and the **motor** begins to move (+1.51V across the motor).

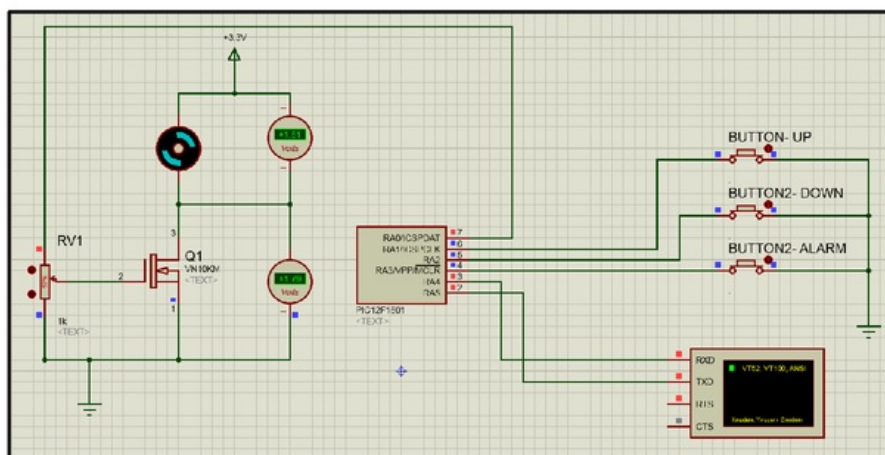


Figure 4.35: Proteus Alarm with Motor Test

Implementation

Following the successful design and testing of the simulation for the device, the full prototype circuit can be assembled knowing it can be replicated from software to hardware. The functioning C code that has been generated is to now be transferred onto the **PIC12F1501** by using a **PICKIT 3** and **MPLAB IBE**. These allow for the **Proteus HEX file** of the design to be uploaded and downloaded to the PIC after it has been correctly connected to the **PICKIT3** following the pinout shown in **Fig. 4.36**.

From this point onwards the microcontroller will contain the generated code and the full circuit prototype can be tested. This next subsection of the report is a showing of that testing as the steps are documented and evaluated accordingly.

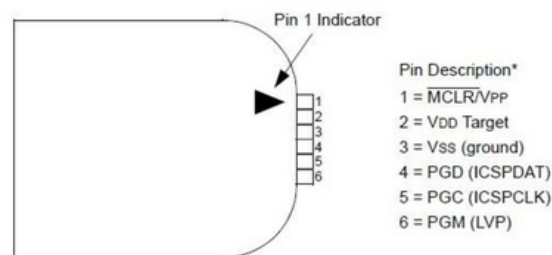


Figure 4.36: PICKIT 3 Pinout [57]

The finished design on breadboard can be seen in **Fig. 4.37** and is has been sectioned according the designs functions, by directly referencing the design to the block layout shown in **Fig. 4.38** it can be seen how the inputs are kept to the left side of the board, the microcontroller is in the centre of the design, power associated parts are at the top with the battery pack and regulator and finally the outputs of the design are on the right board and contain the Bluetooth module and vibration motor circuit.

The full prototype circuit is shown below:

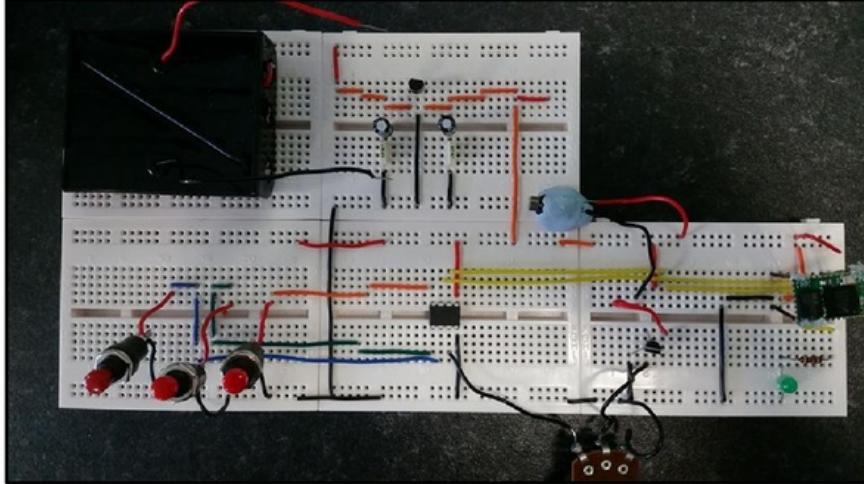


Figure 4.37: Full Prototype Circuit Design

The block diagram below is to show a simple layout of the design; this allows for easy identification of key components:

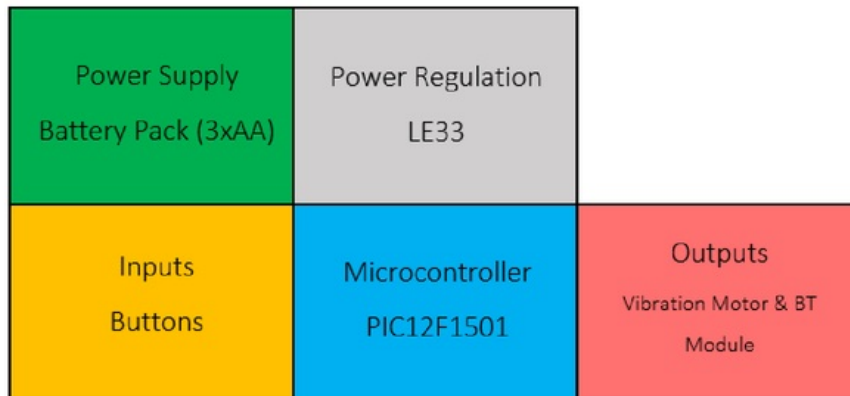


Figure 4.38: Breadboard Section Layout

With the board now setup and functioning on the expected basic levels the testing of the design as whole needs to be begin. As shown and discussed previously in **section 4.3** of the report the Bluetooth module is transmitting correctly, the next stage is show the inputs of the device affecting the output that is sent to a computer via **RS232**. For this the virtual terminal software ‘Termite’ was used, this allows for information to be read off the serial port of a computer and with the addition of the Bluetooth Dongle from **section 3.2.3** the device and computer are almost ready to exchange information.

The first step in pairing the device with ‘Termite’ is to configure the port settings on the software to receive incoming data on **COM3** and at a baud rate of **9600**, this means that the serial port is capable of transmitting 9600 bits of data per second. The final step required from this point is to match the device by clicking ‘**connect**’, the example below **Fig. 4.39** shows these settings being applied to the software so the connection could be made.



Figure 4.39: Port & Baud Rate Selection

The design and Bluetooth module is now successfully connected and the flashing LED on the circuit board goes from a flashing state to solid stating a connection has been made. The terminal on the computer now beings to print the message which has been programming into the PIC and being transmitted from the HC-06 module to the computer.

The testing of the devices functionality is next; the **addition** button successfully **increments** the count value by one with an instant response time. The example below shows this addition:

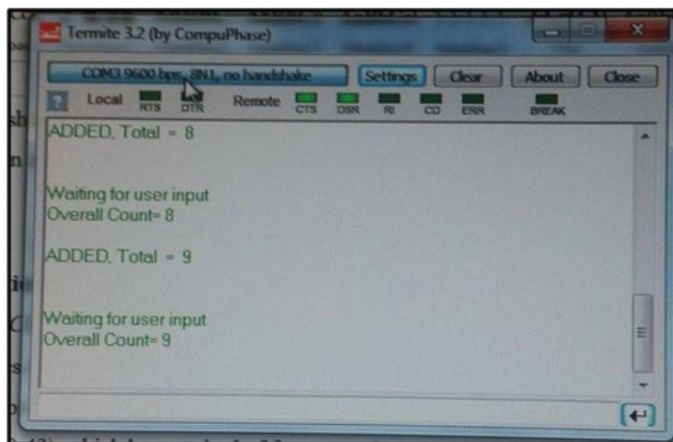


Figure 4.40: Final Design Add Test

Just as the addition button was tested, the **minus** is tested also; this provides positive results also resulting in the successful decrement of the total count by just **1** per press and is shown below:

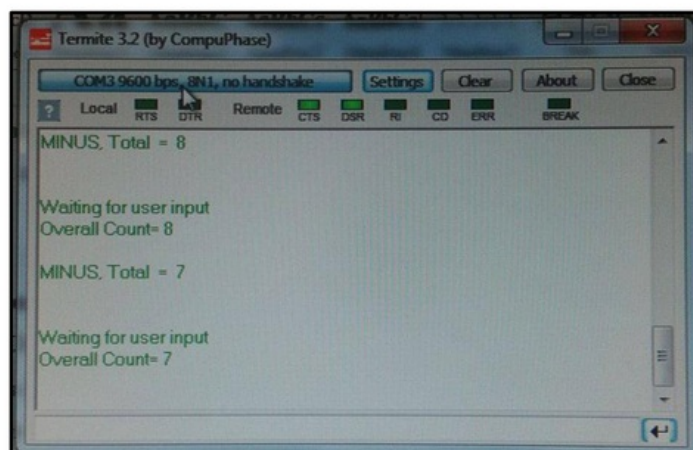


Figure 4.41: Final Design Minus Test

The final test of the device was to set the alarm function, all three buttons on the device are pressed simultaneously. This results in the vibration motor going off for a second per press and also the alarm message is printed on the Termitte terminal. This is shown below in **Fig. 4.42**:

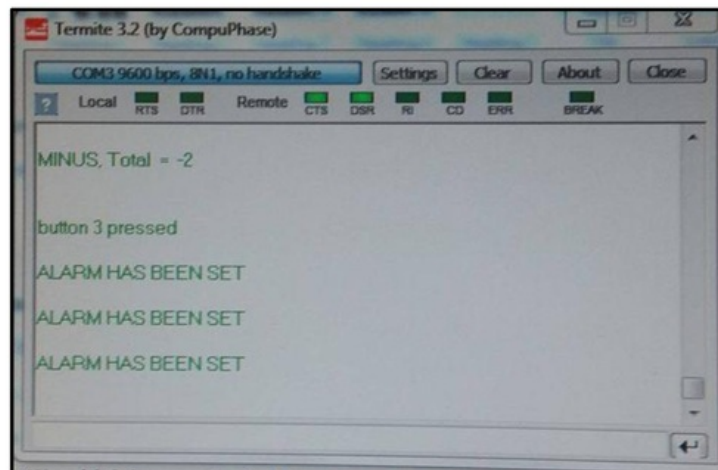


Figure 4.42: Final Design Alarm Test

As a quick analysis of the finding regarding the prototype design, it can be considered a success when compared to goals and aims which the device was designed for. The prototype design is transmitting the individual message and altering the data over serial **RS232** successfully, the vibration motor is working as intended also as it only functioning when the alarm state is recognised.

The device and project could be improved and developed massively, for it to be market and field ready numerous additions need to be made. This is discussed later in the report in the evaluation section.

4.2.1. Device Lifespan

As previously discussed in the report, once the components and their specifications for the device have been decided upon an estimation of real time performance can be calculated. As the device has been tested with AA batteries producing **4.5V** which then is regulated to **3.3V** by the on-board **LE33** regulator, it has produced reliable data and their implementation in a real time environment would be regarded feasible. As the AA battery source has been decided there are multiple choices as shown in **section 2.5** of the report, these are interchangeable so can be changed depending on the preference of the user at any time.

For an estimate calculation for to be made the current consumption for the circuit is shown:

	Current Consumption (Secs Per Hour)
Microcontroller	4mA for 3600s
Vibration Motor	90mA for 15s
Bluetooth Module	8mA for 3600s

Figure 4.43: Typical Current Consumption for device

Note: 3600 seconds in an hour, vibration motors usage is estimated (usage is situational)

Average Current Consumption:

$$\begin{aligned}
 &90 \cdot 10^{-3} \cdot \left(\frac{15}{3600}\right) + 12 \cdot 10^{-3} \cdot \left(\frac{3600}{3600}\right) \\
 &= 0.0012375 \\
 &I_{\text{draw}} = 12.375\text{mA}
 \end{aligned}$$

Current draw for device:

Current Draw for device is I_{draw} , T is hours device is expected to operate for:

$$\begin{aligned}
 \text{AmpHours} &= I_{\text{draw}} \cdot T \\
 \text{AmpHours} &= 12.375\text{mA} \cdot 5 \\
 \text{AmpHours} &= 61.875\text{mA}
 \end{aligned}$$

This states that the typical current draw from the device is **12.375mA**, with an average expected use of roughly **five hours** a day the device draws **61.875mA Hour**.

Life Cycle Consideration:

$$\frac{61.875\text{mA}}{0.8} = 77.344\text{mA Hour}$$

The above calculation is in consideration to the life expectancy of the battery, batteries especially rechargeable are not expected to be run down below **80%**. By doing this it extends the number of cycles for the battery and also lets the battery degrade while it is charged or changed before the design does not have enough time.

Rate of Discharge Consideration:

$$\frac{77.344mA}{0.5} = 154.688mA \text{ Hour}$$

With considerations for when the devices current draw is higher and also for when some batteries discharge at a faster rate meaning that fewer amp hours are produced. This is called **the “Peukart Effect”** [58], this is common in alkaline and other batteries. The calculation above is a consideration for this and the results state that for the device to function for the estimated five hours a **154.69mA** Hour battery would be required if there is an average of **12.375mA** current is drawn from the power supply.

4.3. Product Design

The visual aspect of the device is another aspect which is considered in this report, the device has been follow requirements. The device has to a correct size to hold the designed PCB of the device, the Bluetooth module, the vibration motor and battery pack have to put into consideration also. The input buttons which are the main function points of the device from the outside need to be area where they are accessible but also so all are not pressed accidentally at a single time (would set the alarm). These factors with the aim to make the device aesthetically pleasing for market and personal reasons mean that cycle of developing and refining the design is required.

The following section demonstrates the stages of development that the device goes through from simple sketched designs, to software built one and finally a physical printed model.

4.3.1. Initial Design

At its most fundamental level the initial concept design of the device is shown below:

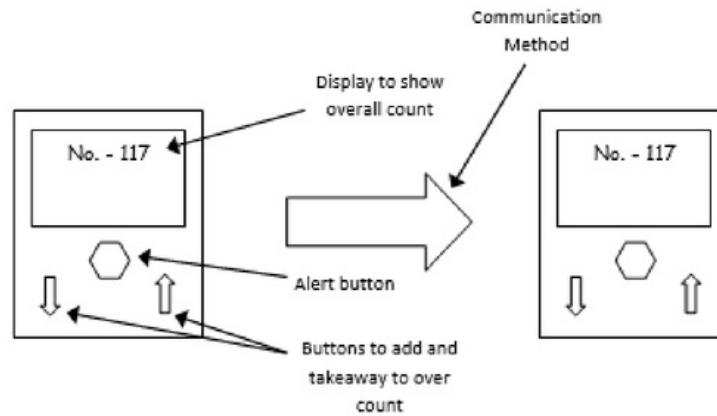


Figure 4.44: Initial Design

4.3.2. Solidworks Development

Once a product design was conceptually agreed upon the advancement of a further design could be completed. For this the software package Solidworks [59] was used, Solidworks is a solid modelling computer aided design (CAD) and computer aided engineering (CAE) program which allows for the creation of realistic 3D designs which can be transferred to CAD creating hardware; in this instance a 3D printer.

The advantages of using software such as this is that it allows for the professional and precise design of the device that was so basically shown earlier in the development. With the dimensions and requirements obtained from components and the PCB in an Easy-PC design, the handheld device can be moulded around those requirements producing a well-structured design that has a pleasing composition.

Below the designs are shown of the device as it was developed in Solidworks:

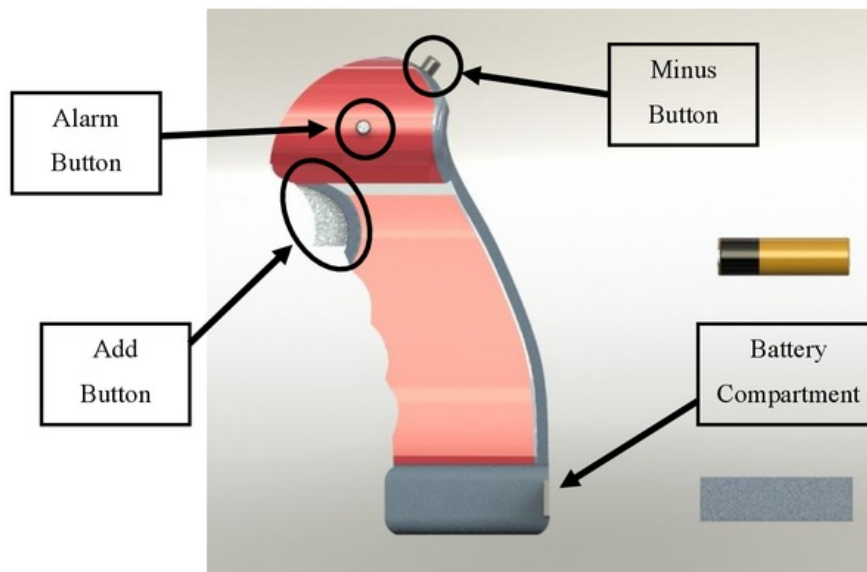


Figure 4.45: Solidworks Design, Side View

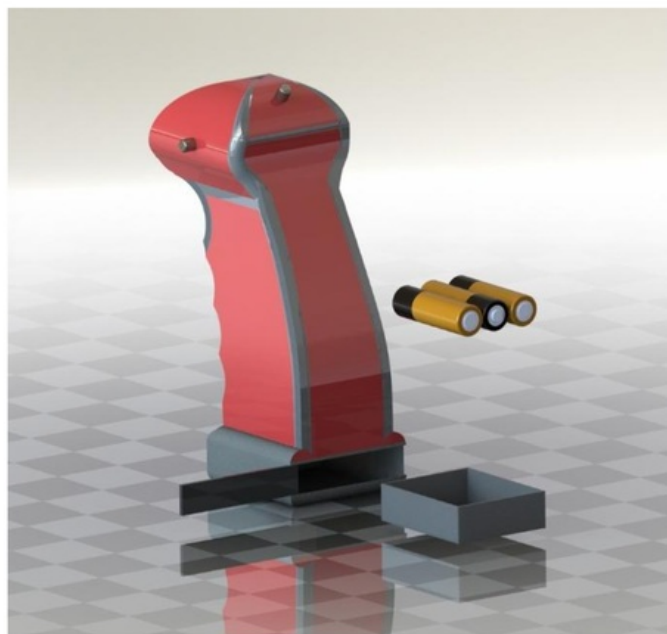


Figure 4.46: Solidworks Design, Back View

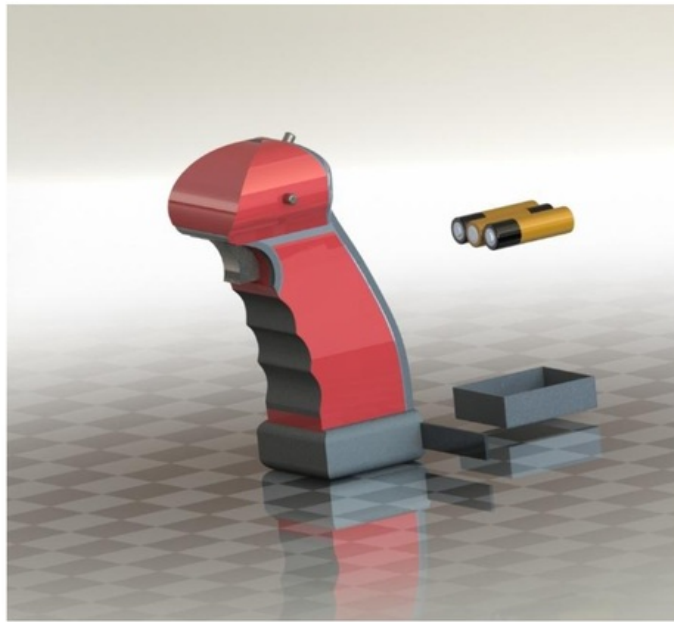


Figure 4.47: Solidworks Design, Front Side View

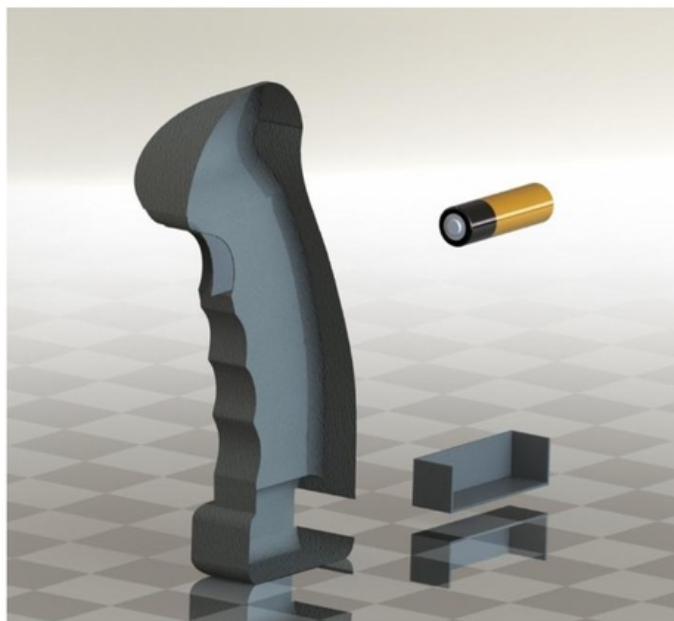


Figure 4.48: Solidworks Design, Inside View

Chapter 5:

5. Testing and Evaluation

The prototype device is now functioning to a level which can be considered acceptable, meaning that a series of tests can now be done to see how different aspects of the design will work. This section will display the tests that were done in order to see what the limits and reliability of the design are.

5.1. Range Test

The first test was to test the device communication range, once the device has established a connection to the computer and virtual terminal the distance between the device and receiving computer was increased three metres at a time where the buttons were pressed five times. This was done with a wall in-between and so the reliability and range could be tested, the resulting table below shows the test findings:

Distance (Metres)	Signals Received
3	5
6	5
9	5
12	5
15	5
18	6
21	5
24	0
27	0 (Device lost Connection)

Figure 5.1: Range Test Results

When comparing the range results to the **HC-06** datasheet [60], it states that the module has a range of up to **10 metres** (30 feet), therefore, the results obtained from the range tests show that the module is successful at ranges of more than **20 metres**. These result are both surprising and positive, the only issue that was recorded was the extra count received at **18 metres**; the reasons for this are unknown and if the project had a longer timeline this could have been documented.

5.2. Initial Connection Test

The initial connection tests were done to see the distance that the device needed to be away from the host computer to first connect and initialise. The tests were done under the same circumstances as the previous test; one wall was in the way as the distance was increased one metre at a time. The results were recorded and are shown below:

Distance (Metres)	Connection Established
1	YES
2	YES
3	YES
4	YES
5	YES
6	YES
7	NO (Connection Lost)

Figure 5.2: Device Initial Connection Results

The results for the initialisation tests show that the distance that the device is allowed to be from the computer and still connect is **6 metres**. These results show that the distance is considerably lower than the devices data transmission range capabilities.

5.3. Parts Listing

Component	Price (£)
PIC12F1501 [39]	0.31
HC-06 Bluetooth Module [61]	2.90
Bluetooth Dongle [37]	7.99
Vibration Motor (4mm - 9mm) [43]	4.20
VN10KM FET	N/A
100K Potentiometer [62]	0.48
LE33 Regulator [63]	0.34
Capacitors x 2 [64]	0.16 x 1
Electrolytic Capacitors x 2 [65]	0.11 x 1
Resistors x 3 [66]	0.008 x 1
Push Buttons x 3 [67]	1.81 x 1
TOTAL	22.21 Approx.

Figure 5.3: Part & Price Listing

Note: The **VN10KM FET** is difficult to buy, a **VN2222LL** is a close equivalent [68]. The **LE33** regulator only requires a single **2.2µF capacitor (£0.14)** to function.

The price listing for the device build in shown above in **Fig. 5.3**, this price specification is based upon the current build of the device which means that in the future the device could be refined and simplified. As stated the **LE33** only needs one capacitor and in a real time scenario multiple of these devices would be in play and would all use only one Bluetooth dongle between them; this would make the device **£13.82** instead which is considerable lower.

Chapter 6:

6. Evaluation

To outline the project as a whole, the initial aims and goals must be answered, the objective was to research and then from that relevant research develop a device which should be handheld that can improve communication between security personnel at venues and other places of work. To analyse and see if this was achieved to a level where it can be considered a success the sections throughout this design need to be evaluated.

The research of the environments that these security personnel operate in gave an understanding of what has to be dealt with on an average shift, the corresponding log data in **section 10.2** proves very advantageous in confirming this. The current standards were acknowledged as methods and devices were established, this was previously known as it was a major reason behind the development beginning.

6.1. Questionnaire

The questionnaire results that were obtained after publishing it specifically to individuals who are working in the security sector resulted in 10 survey forms being filled out; results can be seen in section 10.3. The results predominately showed that the current standards need improving, although the manual clickers in use at the moment don't seem to cause much concern, the methods of recording that data when it is busy does.

Therefore, a major aspect which the device proposed offers is the automatic logging of data over a network of devices. This question (**Q4**) when asked was always answered with either 'yes' or 'maybe', this is a reassuring response and if the project were to be taken further would be one of the main focus points.

6.2. Refining the Project

If the project process were to begin again there are a number of areas and aspects which would have been approached differently; these consist of:

- A better management of time as this was the major issue towards the development and project end.

- A better understanding of the C coding language would be learnt as it was the most difficult area to develop within the project. This hindered the further progression of the device as no method of receiving commands from the computer was established.
- The possibility of adding data storage or USB data transfer into the device would prove an advantageous addition.
- Another device would be made so more than one set of information could be sent to a host computer at a time. This would allow the program to be tested in its ability to deal with multiple streams of data.

Overall, these extra features and aspects would improve the project and device. The major constraints were the timescale of the project and also the lack of coding knowledge.

Chapter 7:

7. Project Conclusion

To conclude and summarise the project that is represented in this report the project start end need to be assessed and compared. The goal was to create a handheld device which would potentially improve on current standards within the security secure. Throughout the report a high amount of research and literature has been collected and reviewed so a greater knowledge surrounding the subject field could be obtained. This information has been directly used to both decide paths and also aid current ones, the communication methods have been compared and Bluetooth has been chosen as a result; this is now considered the correct choice after its implementation and testing.

The design and implementation of the individual sections of the device have been simulated and constructed successfully and although time played a major factor in further development a functioning device which can produce relevant and comparable data. This is one of the main goals for a project of this scope and through that assessment it can be regarded a success.

7.1. Future Advancements

If the project were to be taken further with it being in its current state, the communication back and forth between the computer would be developed. It is a feeling that this was a goal which was not far away towards the end of the project and time was the major factor. The construction of another device would mean that multiple streams of data can be sent to the computer simultaneously to see if any issue would arise. The design of an Easy-PC design would give an estimate of what the PCB for the device would look like, it can be designed around a handheld model to ensure that it is small enough to fit. The final addition that could be made in the possible reducing in components such as the capacitors in the regulator, this would make the design smaller, lighter and cheaper.

Chapter 8:

8. Project Reflection

It has been the goal in Electronics based studies to research and design a device which consists of both hardware and software. Through this an interest in what is required to make an engineering device or product market worthy has been the motivation for further research, the relatable security and venue based environments means that a moderate level of understanding was taking into account before the project start.

Through the projects entirety skills and base knowledge surrounding the technology, techniques and methods have been improved and through a reflection the following can be said:

- The project was approached with a low base knowledge of what would be required to develop a handheld device which is capable of sending a user generated count through RS232
- The importance of time-management in a project such as this one has been realised, with a short time scale the following of a pre-planned Gantt chart or schedule is invaluable.
- Research and comparison skills have been developed through the search for required components and modules for the design of the device.
- The understanding and knowledge to be able to write C programming for microcontroller has been gained, this was previously unknown and is now regarded as an invaluable understanding for Electronics & Computer Systems
- The knowledge of how to transfer the written C code onto the PIC12F1501 was learnt also using MPLAB IBE
- A much greater knowledge of what Bluetooth is and how it functions was gained through the research and implementation section of the report, the experience of setting up and documenting a module up in a prototype has further base knowledge.
- Finally, the importance of making the design, prototype and report understandable and presentable is major factor in a large report

As an overall evaluation of the project, it is a process which increases knowledge surrounding the subject incredibility, new techniques and skills are obtained which can be applied to other projects in the future. A feeling of accomplishment was gained although the project could have improved greatly and developed further.

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10. Appendix

10.1. Gantt Chart

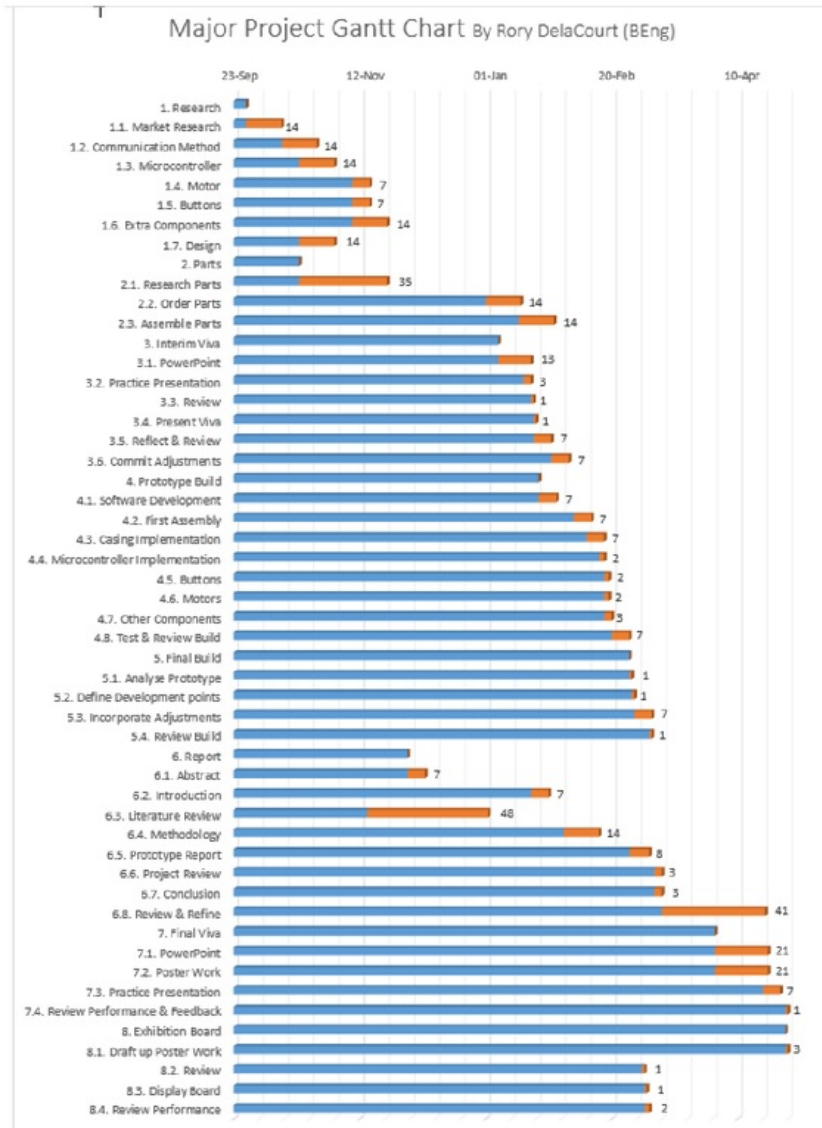


Figure 10.1: Personal Gantt Chart

10.2.Security Doorman Log Data

All data was obtained through personal communication with Griffin Swansea [69] part of Stonegate Pub Company [70] management personnel, all data is recorded by security employees who are under employment of Elite Security Group [71] and then passed onto Griffin management for data management.

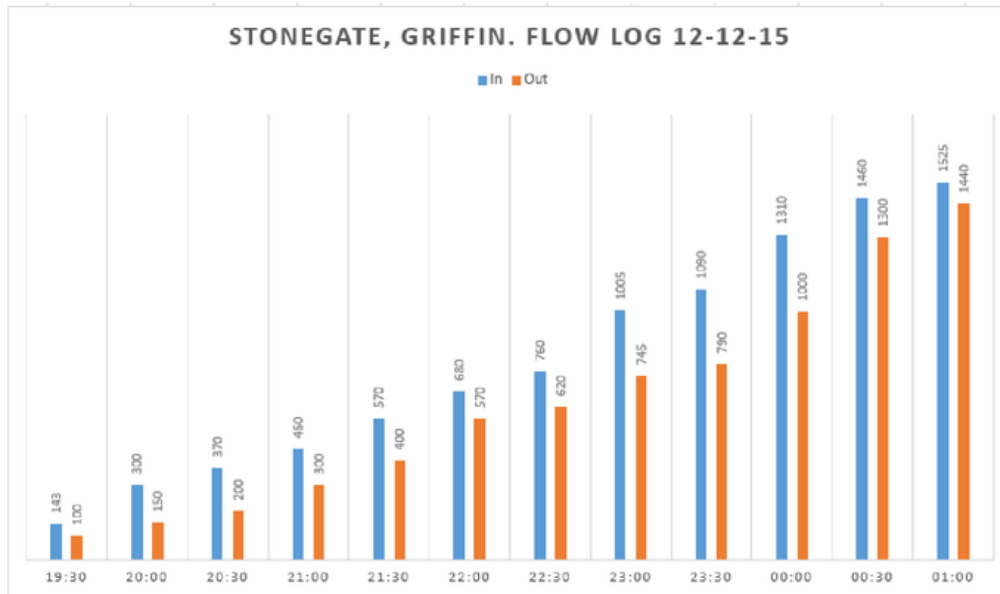


Figure 10.2: Customer Flow chart from Griffin Pub on 12th December 2015, Recorded by Elite Security Group staff and data obtained on 20th February 2016 [72]

ID's Checked (Approx.)	1000	
Doormen Employed	4	
Refusals	Drunk- 4	No .ID- 1
Ejections	5	
Fire Checks	Every Half Hour (30 Minutes)	

Figure 1010.3: Logged Security Information for the Griffin Pub on 12th December 2015, Recorded by Elite Security [72]

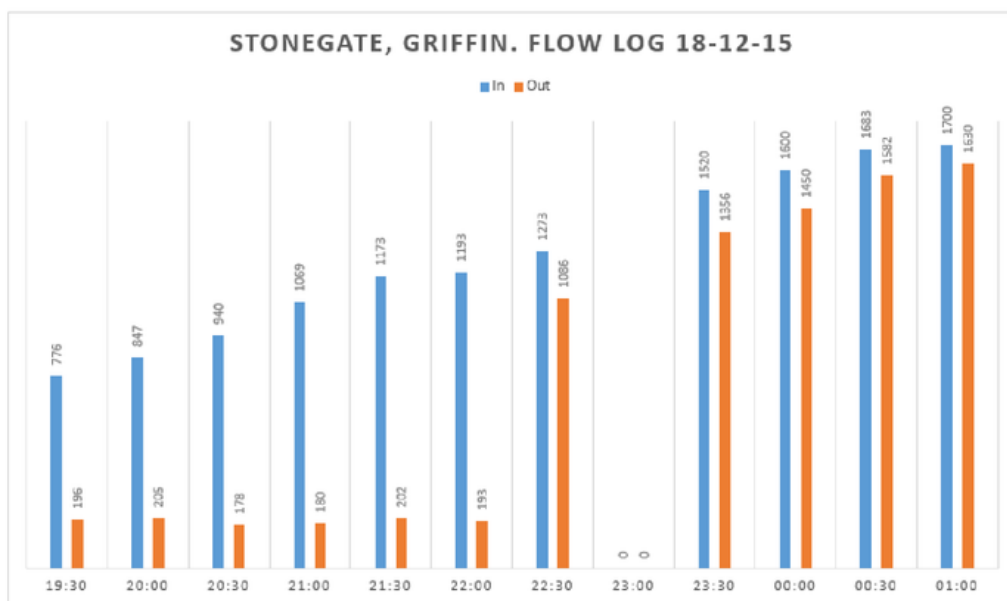


Figure 1010.4: Customer Flow chart from Griffin Pub on 18th December 2015, Recorded by Elite Security Group staff and data obtained on 20th February [72]

ID's Checked (Approx.)	1500	
Doormen Employed	3	
Refusals	Drunk- 10	No .ID- 5
Ejections	10	
Fire Checks	Every Half Hour (30 Minutes)	

Figure 10.5: Logged Security Information for the Griffin Pub on 18th December 2015, Recorded by Elite Security [72]

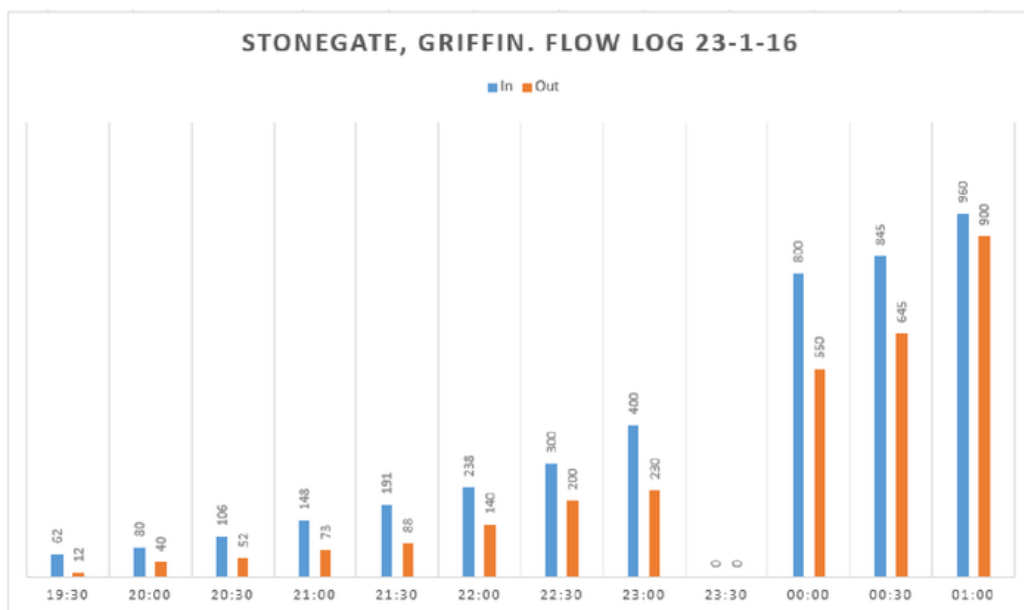


Figure 100.6: Customer Flow chart from Griffin Pub on 23rd January 2016, Recorded by Elite Security Group staff and data obtained on 20th February [72]

ID's Checked (Approx.)	900	
Doormen Employed	3	
Refusals	Drunk- 4	No .ID- 8
Ejections	2	
Fire Checks	Every Half Hour (30 Minutes)	

Figure 10.7: Logged Security Information for the Griffin Pub on 23rd January 2016, Recorded by Elite Security [72]

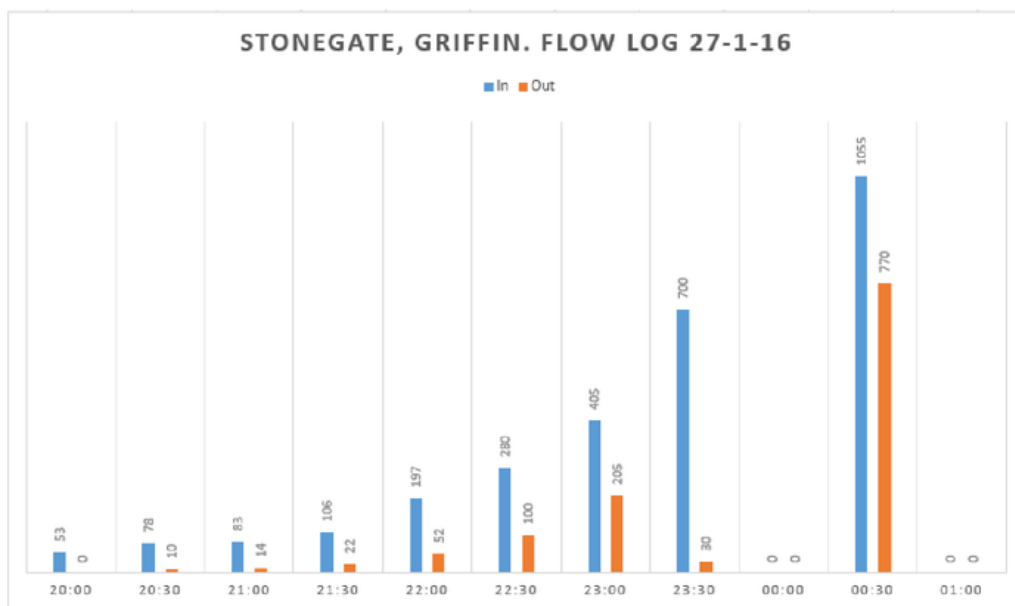


Figure 10.8: Customer Flow chart from Griffin Pub on 27th January 2016, Recorded by Elite Security Group staff and data obtained on 20th February [72]

ID's Checked (Approx.)	110	
Doormen Employed	4	
Refusals	Drunk- 6	No .ID- 5
Ejections	5	
Fire Checks	Every Half Hour (30 Minutes)	

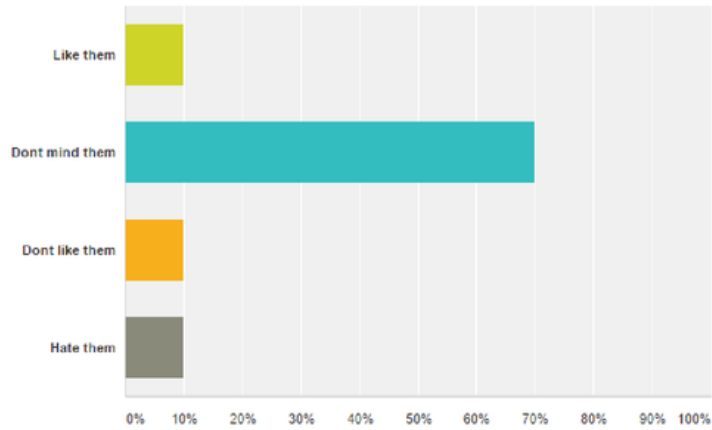
Figure 10.9: Logged Security Information for the Griffin Pub on 27th January 2016, Recorded by Elite Security [72]

10.3.Questionnaire

Question 1

What do you think of the manual clickers
you use right now?

Answered: 10 Skipped: 0

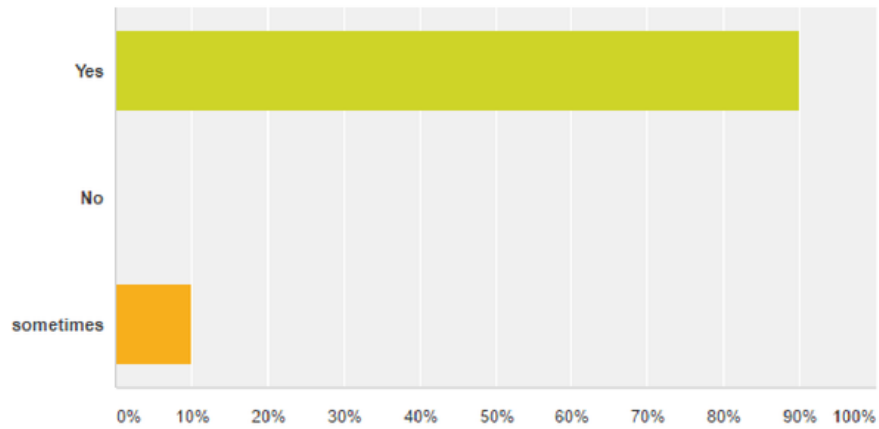


Answer Choices	Responses
Like them	10.00% 1
Dont mind them	70.00% 7
Dont like them	10.00% 1
Hate them	10.00% 1
Total	10

Question 2

Do you find yourself understaffed on busy day/nights?

Answered: 10 Skipped: 0

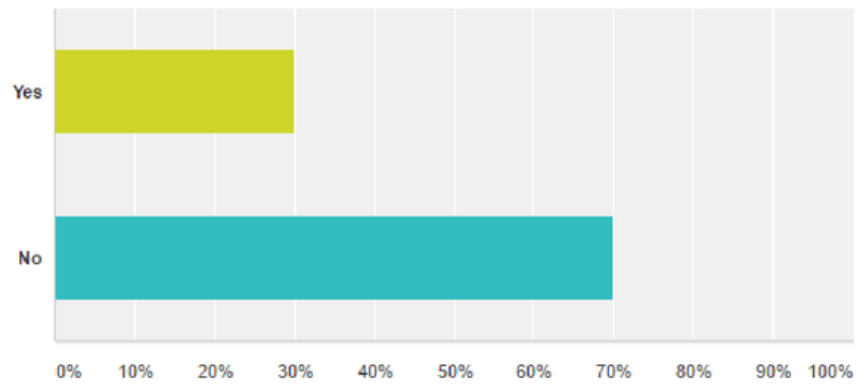


Answer Choices	Responses	
Yes	90.00%	9
No	0.00%	0
sometimes	10.00%	1
Total		10

Question 3

Have you heard of an electronic counter clicker before?

Answered: 10 Skipped: 0

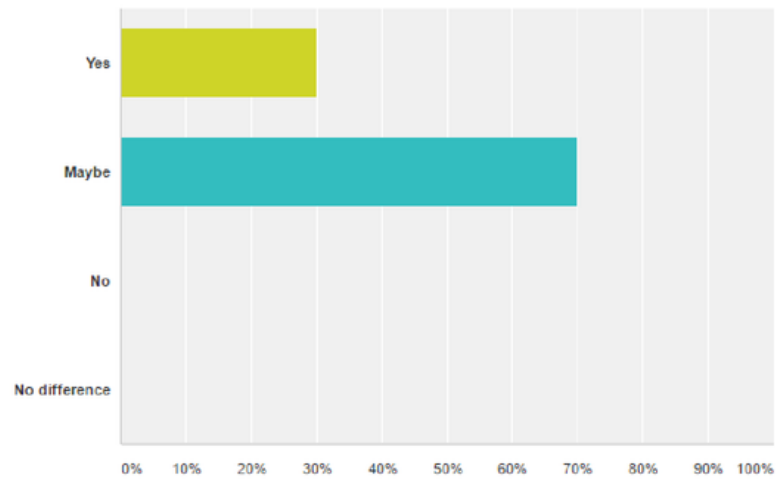


Answer Choices	Responses	
Yes	30.00%	3
No	70.00%	7
Total Respondents: 10		

Question 4

Do you think using an overall automated counting system would help?

Answered: 10 Skipped: 0

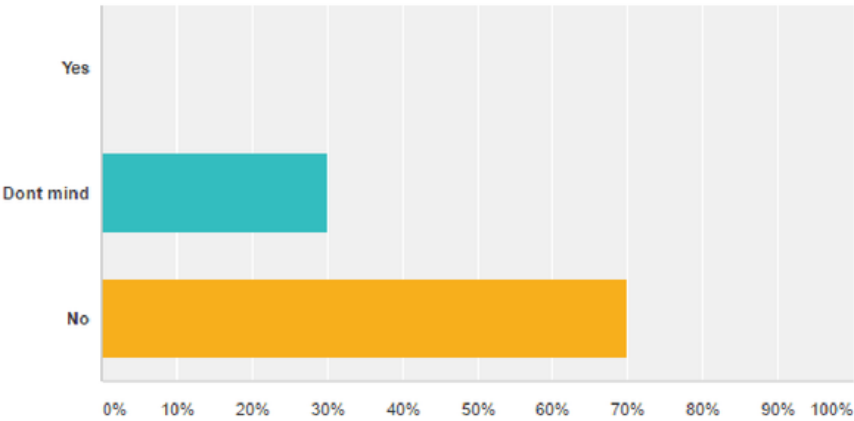


Answer Choices	Responses	
Yes	30.00%	3
Maybe	70.00%	7
No	0.00%	0
No difference	0.00%	0
Total		10

Question 5

Do you like filling out data logs
for customer flow? (people in and out)

Answered: 10 Skipped: 0



Answer Choices	Responses	
Yes	0.00%	0
Dont mind	30.00%	3
No	70.00%	7
Total		10

10.4. People Counting Solutions & Pricing

The following information was obtained during email correspondence from People “Counting Axiomatic Technology LTD”. These emails were received from a company representative and contain product information and pricing. Below are segments of the relevant products that are sold with their pricing options:

10.4.1. Beam Counters

Standard Q-Scan Counters	Single Unit	Additional Units	5 + Units	25+ Units	50+ Units
Q-Scan Unicomm V2.0	£230	£225	£215	£205	£195
Q-Scan Twincomm V2.0	£285	£280	£270	£260	£245
Q-Scan Unicomm with SD Card	£270	£265	£255	£245	£235
Q-Scan Twincomm with SD Card	£325	£320	£310	£300	£285
Q-Scan Twincomm with Ethernet Connection	£409	£405	£395	£385	£360
Twincomm with Ethernet connection central server with automated Excel Reporting*	£519	£499	£480	£460	£440
*Where Excel reporting or Web-based reporting is required a broadband / network connection must be provided. Web-based reporting will cost extra and requires an annual license (see <i>page 6</i> for more information) Mounting Posts are now available at £90 each + delivery					

Figure 10.10: Beam Counters units and pricing [15]

10.4.2. Irisys Gazelle Thermal Counter

Thermal Counter Price (typical package)					
1 Indoor Gazelle Thermal Image Counter Connection equipment RECAP Base Software installed on your server, with automated Excel reporting Remote counter connection & configuration with accuracy validation 12 Months system support and warranty					
Single Site	Additional Sites	5+ Sites	25+ Sites	50+ Sites	150+ Sites
£1,858	£1,785	£1,672	£1,567	£1,446	£1,296
N.B. Based on a single entrance at each location – additional counters or entrances cost £995 per entrance/counter including remote configuration. High Mount counter for ceilings above 4.5 metres high will cost an additional £75. Configuration of additional count lines will cost extra.					

Figure 10.11: Thermal Counter unit with pricing [15]

10.4.3. Brickstream 2300™ Video Counter

Brickstream 2300 (typical package)					
1 Standard Indoor 2300™ Video Counter Connection equipment RECAP Base Software with automated Excel reporting Remote counter connection & configuration, and accuracy validation 12 months system support and warranty					
Single Site	Additional Sites	5+ Sites	25+ Sites	50+ Sites	150+ Sites
£1,968	£1,895	£1,782	£1,667	£1,546	£1,394
N.B. Based on a single standard entrance at each location – additional entrances £1,095 per counter including remote configuration. Software prices for multiple zones on a single site will depend on the scale of the project. ** Advanced units for group, multi-zone or queue counting will cost an additional £100 per unit plus configuration costs based on the nature of the metrics required. Please contact the Axiomatic sales team for a tailored quotation. Higher mount units will cost an extra £300 per unit (Above 4.5 metres). For outdoor IP65 cases, please at £225 to the standard price.					

Figure 10.12: Video Counter Unit with pricing [15]

10.4.4. Support and Maintenance Information with prices

Support & Maintenance

Equipment and software is under warranty for the first 12 months from the date of installation. Axiomatic offer optional on-going system monitoring and support. To discuss the different levels of system monitoring or support, please refer to our standard terms and conditions or speak with our sales advisers. Where applicable; continued support and maintenance covers your annual RECAP SQL web-reporting license. Standard annual support prices per site are as follows:

Number of Sites	Single	Additional Sites	10+	25+	50+
Q-Scan Twincomm with RECAP	£155	£145	£135	£130	£125
Irisys Thermal Counter	£480	£435	£405	£365	£320
Brickstream Video Counter	£500	£465	£430	£389	£340
<i>The above support prices are based upon 1 counter per site. Support prices are calculated based upon the complexity and scope of your system. For multisite, or multiple counter deployments, your support costs will be calculated in a quotation tailored to your needs.</i>					

Figure 10.13: Support and Maintenance information with prices [15]

10.5. Project Coding (C#)

```
#include <main.h>
#ZERO_RAM

int a = 0;
state;
int flags[4];

void main ()
{
port_a_pullups(0xFF);
printf ("\nPress button to alter total\n\r");

    while(TRUE)
    {
        if(!input(PIN_A1))
        {
            if(!flags[0])
            {
                flags[0]=1;
                a++;
                printf("ADDED, Total = %d\n\r",a);
            }
        }
        else
        {
            flags[0]=0;
        }

        if(!input(PIN_A2))
        {
            if(!flags[1])
            {
                flags[1]=1;
                a--;
                printf("MINUS, Total = %d\n\r",a);
            }
        }
    }
    Else
```

```

{
flags[1]=0;
}

if(!input(PIN_A3))
{
if(!flags[2])
{
flags[2]=1;
printf("\n\rbutton 3 pressed\n\r");
}
}
Else
{
flags[2]=0;
}

if( (flags[0]) && (flags[1]) && (flags[2]) )
{
printf("ALARM HAS BEEN SET\n\r");
output_high(PIN_A0);
delay_ms(1000);
output_low(PIN_A0);
}
else
{
flags[4]=0;
}

if((flags[0]+flags[1]+flags[2]))
{
if(!flags[3])
{
flags[3]=1;
printf("\n\rWaiting for user input \r\n");
printf("Overall Count= %d\n\r",a);
}
}
else
{
flags[3]=0;
}
}

```

}