University of Canterbury

Velocity Determination of Rifle and Pistol Ammunition

Chronograph

Matt Kokshoorn
4-SH

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Report Marking Sheet

Students Name:

Item	Out of	Mark
Presentation/Layout	25	
Technical quality of the design	25	
Completeness with regard to the specifications	20	
Feasibility of the system	20	
Sustainability	10	
Comments:		
Marker	Overall Mark: /100	

Executive Summary

This report details the engineering design process undertaken to develop a chronograph used to determine the velocity of firearm ammunition. The design procedure used in this project can be seen below in Figure 1. Due to the nature of this assignment the core steps will involve; problem identification, research, requirements specification, concept generation and design. Sustainability elements are also considered to ensure the proposed product has no adverse effects on stakeholders.

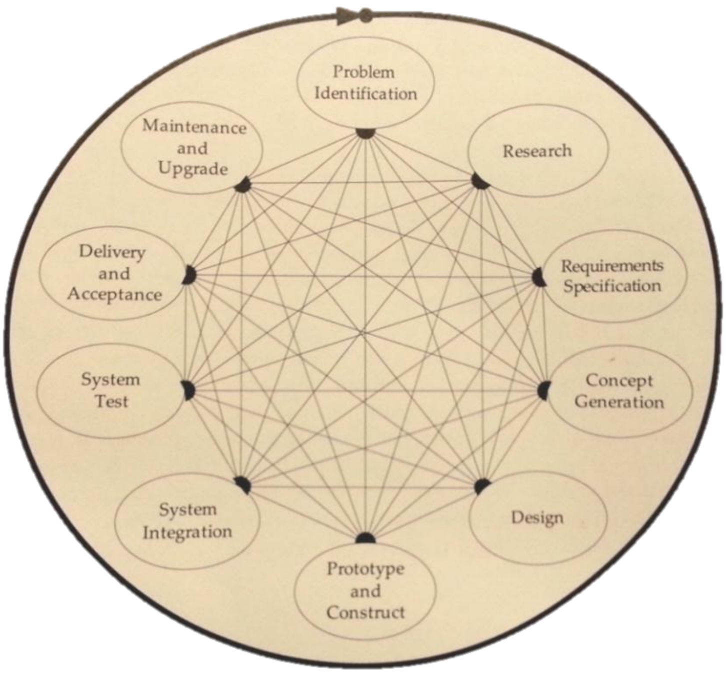

Figure 1 - The Engineering Design Process [1]

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1) Problem Identification

In the field and at shooting ranges, it is important for firearm owners to know the velocity of the ammunition they are firing for a number of reasons.

- Velocity data can lead to the early fault detection within a gun or ammunition, preventing further damage to the firearm and saving the owner a significant amount of money. Furthermore repeated use of a damaged firearm could pose as a major safety hazard.

- Firearm owners that reload their own ammunition use velocity statistics to move towards greater quality ammunition refills.

- Airgun users require velocity data for performance optimisation as many CO2 and Gas operated firearms produce peak velocities at particular pressures. Conversely some airgun competitions require firearm velocities to be limited due to safety concerns. Many regions also have legal obligations regarding ammunition velocities and hunting.

There exists a need for firearm owners to record and observe ammunition velocity data while in the field. This need can be identified for variety of users, ammunitions and gun classes.

2) Research

In order to successfully conceive a solution to the problems previously discussed, research must be undertaken into the concepts surrounding existing chronographs. This research should provide adequate material to generate an appropriate set of requirement specifications leading to informed conceptualisations.

2.1) Ammunition Behaviour and Properties

Velocity

The velocity of ammunition as it leaves the barrel of a firearm is known as the muzzle velocity. From this point onwards the velocity of the projectile will quickly diminish due to the drag of air. The muzzle velocity can be measured in a number of ways but should be done so as close to the muzzle as possible as to obtain a reliable results. Typical ranges of velocities that can be expected of three different forms of firearms can be seen be seen below in

Table 1.

Table 1 - Typical Ammunition Velocities and Calibres for a Range of Firearms [2]

Firearm Type:	Muzzle Velocities (FPS)	Muzzle Velocities (m/s)	Caliber (Inches)	Caliber (mm)
Paintballs	200-300	50-91	0.68 in	17.3 mm
Pistols	750 - 1300	228 -396	0.22 in - 0.45 in	5.6 mm - 11.4 mm

Rifle	1900 - 4000	580-1200	0.17 in - 0.45 in	4.3 mm – 11.4 mm

Dimensions and Materials

The caliber of a gun refers to the inside diameter of the firearm's barrel and therefore maximum diameter of ammunition being fired. A list of caliber ranges can be seen on the previous page in

Table 1. Both rifle and pistol ammunition is typically metallic whereas paintball and airgun rounds usually comprise of dye filled gelatine.

2.2) Firearm Layout and Dimensions

Firearm layout is an important consideration for designing a general use chronograph. Of particular interest is the placement of scopes and moving components. If a chronograph were to be mounted on the end of such a fire arm it is important both for safety and practical reasons to investigate the various designs it could be mounted upon.

Scope/Sight Positioning

Rifles, pistols and paintball guns share the common sighting method of lining up two points running along the upper portion of a barrel. A mounted chronograph must avoid interfering with these sightings. Additionally riffles often feature an attachable scope above the trigger portion of the barrel. This is a larger piece of equipment and lies above the default sighting system of the rifle. Avoiding interference with the sights will also ensure there is no interference with the scope.

Barrel Clearance

The mounting of a chronograph would require a safe and firm point of contact to the firearm. Both rifles and paintball guns maintain a circular barrel at the bullet exit point with no moving components. The reloading mechanism and barrel of many pistols should be considered due to the rectangular exterior and moving parts.

2.3) Existing Methods of Velocity Determination

Ballistic Pendulum

The ballistic pendulum is the oldest method of velocity determination. It involves a projectile being shot into a mass at the bottom of a pendulum. From the displacement of the pendulum from equilibrium, the momentum and therefore the velocity of the bullet can be determined. This method has been outdated by more modern chronographs and any attempt to modernise would still require knowledge of the projectile mass. Additionally there are clear safety concerns surrounding such a collision.

Optical Detection

Optical detection of a projectile is a relatively simple concept. It consists of a series of light emitting sources each being directed towards photosensitive devices [3]. When a mass passes between source and sensor, the state of the photosensitive device will change. By using two or more of these in in succession, the time delay between each state change can be recorded and the velocity of the projectile determined. This method could easily be applied to a barrel mounted chronograph at little expense and complexity. Optical methods do however have the drawback of not reliably operating in all lighting conditions.

Electromagnetic

This method of velocity determination uses electromagnetic sensors to detect a passing mass leaving the muzzle of a firearm. Since the sensors utilise the effects of a mass disrupting a magnetic field, the ammunition is not required to be metallic. Electromagnetic chronographs have been found to not be as accurate as optical sensors but still boast a 1% margin of error [4].

Acoustic

Acoustic methods of velocity determination involve measuring the difference in time between the sounds of the bullet leaving the barrel and hitting a set target at a known distance [5]. The velocity of the projectile can then be calculated. This method has the advantage that it could be used for both metallic and non-metallic ammunition and could easily be integrated into a mountable device using microphone(s). The clear drawback of this method is that it requires knowledge of target distance.

Doppler Detection

Methods previously discussed rely on distance over time or momentum calculations. Instead this method uses a Doppler radar placed in near proximity to the firearm. The radar typically beams a microwave signal towards a moving object and then analyses the frequency shift of the reflected signal due to the ammunitions velocity. While this method is very accurate it involves high precision equipment that can be quite costly [6].

2.4) Required Data and User Interface

The velocities obtained from the chronograph need to be processed and displayed to the user. Many firearm owners not only require a data log of velocities but also an assortment of statistical measurements such as; high/low velocities, extreme spreads, velocity averages and standard deviations [7]. Users have commented to like simple interfaces and large display fonts.

Users would like to be able to upload there chronograph data to a PDA or computer. According to an IDC press release, the smartphone market has increased by 42.5% year over year for the first quarter of 2012 [8]. This increase is expected to continue with Androids and IOS based phones as the fore runners.

2.5) Existing Market

There are currently a range of chronographs available for purchase. The most commonly used methods of velocity determination are optical, electromagnetic and Doppler radar however many of these products are limited to non-barrel mounted designs. To effectively develop a competitive product the retail prices and designs of some of the current leading products must be investigated.

The MagnetoSpeed V1 Ballistic Chronograph

The MagnetoSpeed chronograph is the leading product for electromagnetic based sensors. It retails at $250US ($308.26NZ as of 27/8/2012) and claims to be within 1% accuracy. It is able to be mounted to both pistols and rifles and offers a backlit LCD display connected to sensor via a 3.5mm data and micro SD card uploading. It is stated to work with barrels up to 1 inch (25.4mm) in diameter [9]. The LCD display shows statistical velocity measurements of maximum, minimum average and standard deviation. It also allows bad shots to be deleted and bullet types to be changed. The only apparent drawback of the MagnetoSpeed is the trend increasing error with decreasing ammunition velocity. The MagnetoSpeed chronograph is relatively new product and has been receiving a number of good reviews.

The ProChrono Pal Chronograph

The ProChrono Pal Chronograph is a popular product among New Zealand fire arms store such as Gun City and NZ Hunter. It uses optical velocity determination techniques with an operational velocity range form 21 - 7,000 fps (6.4 ms^{-1} – 2133ms^{-1}). It retails at $299 NZ and is supplied by a single 9V alkaline battery using approximately 15mA lasting approximately 37 hours. Its display is simply and shows a single velocity with no statistical information.

Despite the clear disadvantage of not being able to be mounted to a barrel and taken into the field, the ProChrono Pal Chronograph memory capacity is limited to 99 shots and has clear limitations regarding user interfacing. Interestingly enough the ProChrono series and similar non mountable products seem to be the only Chronograph being sold in majority of New Zealand's firearm stores.

X Cortech X3200 Shooting Chronograph

The X Cortech X3200 Shooting chronograph is designed for smaller ammunitions (10-365ms^{-1}) however uses optical techniques that could be applied to a range of firearms [10]. Its interface consists of just three buttons and sensor uses optical detection to determine the ammunition velocity. The chronograph, while although portable, cannot be mounted and runs off a 4 AAA battery supply. The X Cortech X3200 retails at $95

Figure 2 - The MagnetoSpeed V1 (Left), ProChrono Pal (Centre) and X Cortech X3200 (Right)

3) Requirements Specification

Functionality and Performance

The chronograph must be able to determine the velocity of the ammunition to an equal or higher precision to that of other chronograph products. The chronograph must be able to be accurately used with a large range of firearms including; airguns, rifles and pistols. The chronographs performance must not be affected by external conditions such as lighting.

Interface

The chronograph must have a display unit for data to be shown. This data should include a range of statistical information determined from the velocities. The data from the chronograph must also be able to be relayed, in real-time, to a PDA or Smartphone device and resultantly allow graphing functionality. The user interface should be easy to operate and allow for deletion of 'bad shots' along with distinctions between different ammunition data series.

Electrical

The chronograph must be supplied by a light, rechargeable power source capable of powering the chronograph for at least one day in the field without requiring recharging. The chronograph display should incorporate a light source so that the screen can be seen.

Mechanical

The chronograph must be light and portable and easy to mount onto a variety of barrels. It must support appropriate ammunition. The mounted component(s) of the chronograph must safely secure to the barrel so that it does not interfere with shots and sightings. The mounted component(s) must also be designed in such a way as to minimise the effects of any disturbances from environmental conditions. The design must be robust and visually appealing.

Economic

The cost of the chronograph must be minimised so that the product can be sold at a competitive price. The chronograph should appeal to the market and stand out as an attractive product.

Sustainability

The production of the chronograph must be done in a way that it supports adequate working conditions for employees. The electrical components should be designed to ensure electrical power efficiency and should incorporate the use of rechargeable sources of power. The chronograph must be designed to maximise product lifetime and ensure user worth. Additionally components and materials that are selected should be cause any negative effects to the environment to the environment.

4) Concept Generation

By evaluating the range of different options available in accordance with the requirements specification, a clearer picture of a product design can be established. The key design options relate to the; method of velocity determination, electrical design, mechanical design and software design.

4.1) Method of Velocity Determination

Methods of velocity determination as indicated by 'section 2.3)' include; ballistic pendulum, optical detection, electromagnetic, acoustic and Doppler radar detection. The ballistic pendulum and acoustic detection methods are not practical due to their mechanical nature and required knowledge distance to target respectively.

As result, there remain three feasible sensor methods that could be used; electromagnetic, optical and Doppler radar. Each method is vastly different with advantages and disadvantages that go beyond the requirement specifications. Therefore the concepts must be evaluated using an analytical hierarchal process incorporating a decision matrix as outlined by "Design for Electrical and Computer Engineers" [1]. The selected design criteria reflect both the requirement specifications and additional elements that will lead to a successful product. The pairwise comparison matrix to determine the weighting can be seen in Appendix 1. The resulting evaluation matrix can be seen below in Table 2.

Table 2 - Decision Evaluation Matrix used for Method of Velocity Determination.

Criteria	Weighting	Electromagnetic	Optical Detection	Doppler Radar
Accuracy	0.13	4	7	9
Uniqueness	0.06	5	8	8
Mount ability	0.28	6	4	4
Simplicity	0.19	3	8	1
Cost Effectiveness	0.10	4	7	2
Safety	0.24	5	4	7
Score		4.66	5.69	4.83
Normalised Score		0.45	0.55	0.47

Due to the feasible design, low cost and uniqueness of a mounted product version, optical detection has been selected as the optimal method of velocity determination.

4.2) Electrical Conceptualization

Sensors

Optical velocity determination will require two or more photo coupled devices in succession located at the end of the firearm muzzle. The photo electric devices must be capable of quickly reacting to the break in coupling. For this reason photodiodes should be used over photoconductive devices as they can react within a few nanoseconds versus the photoconductor response time of around 50ms [11].

The sensor also requires a light emitting device that corresponds to the required wavelength and frequency of the photodiodes. The light source should be selected to minimise power consumption so to keep the chronograph to high level of sustainability and maximise life as per the requirement specifications. This could be done either using a directional LED or a laser diode. Both the sensor and the light source should be implemented to minimise any interference from natural light.

The photosensitive devices should then be wired as a voltage divider network and be fed into the logical inputs of the microcontroller.

User Interface

A display should be chosen to minimise power consumption. This could be done using an organic light emitting diode (OLED) display. An OLED display also generates its own light so will require no additional backlight to be seeing the display in low light environments. The biodegradable nature of the display will also reduce environmental impact at the end of the chronographs lifetime.

In order for the user to interact with the chronograph, a number of buttons will need to be used. The number of buttons will depend on the complexity of the software. Electrically the buttons will need to be configured in voltage divider network and fed into a logical input of the microcontroller. Buttons will be required both for navigation on the display, to turn the chronograph/display off and put it into standby mode.

Power Supply

In order to increase overall sustainability and meet the specifications requirements, the chronograph should incorporate a means of power supply that is rechargeable. This would most easily be implemented by use of a low voltage lithium ion battery.

4.3) Mechanical Conceptualization

In order for the design to meet the requirements specification, the sensor must be mounted near the end of the barrel in a safe manner that does not impede aiming mechanisms. This means that the surrounding casing and mechanical structure of the sensor should extend from the barrel in a circular fashion, allowing more than enough room for the largest ammunition to pass through. The largest ammunition has been determined in section 2.1) to be the paintballs with a typical diameter of 17.3mm. For this to be done without interfering with the sights, the mechanical components of the sensor should not extend above the barrel as this would impair vision.

The mechanism for securing the chronograph the barrel of the gun needs to be secure to ensure the chronograph is safe from moving into the path of the bullet. This will need to be done either by means of an adjustable strap of screw clamp. The mechanical structure should also be designed so that the distance between the sensors is not subject to change. This will increase accuracy by ensuring that the chronograph accuracy will not deviate with wear.

4.4) Microcontroller Conceptualization

Processor

using optical detection will require a microcontroller with a processing speed great enough to detect change in states of both photoelectric devices. As a measure of redundancy the microcontroller CPU clock cycle should actually be several times greater than the minimum described by Equation 1.

$$f_{CPU} > \frac{V_{maximum\ bullet\ velocity}}{d_{between\ sensors}} = \frac{1{,}200}{d_{between\ sensors}} \qquad \text{(Equation 1)}$$

Communications

For the product to meet the requirements specification, the microcontroller should be able to relay information to a PDA/smart device for graphing functionality via supporting communications hardware. Judging by current trends seen in *'section 2.4'* it is clear that the number smartphone users are rapidly increasing. This suggests that the most popular technique to achieve this functionality may be to upload the data to a smartphone. This could be done via a smartphone/device system such as Bluetooth, near field communications or WIFI. Since Bluetooth is a more commonly used form of real time communication and easily interfaced with microcontrollers it is the preferred method of data transfer.

I/O Considerations

Another important consideration influencing microcontroller selection is the number of I/O ports. Inputs include at least 2 sensors, and the buttons. The outputs will include the number of ports required to interface with the display and communications peripherals.

Software

The microcontroller will need to be programmed to detect the change in state from each of the photo sensitive devices. This could be done either by polling or more accurately by use of interrupts. The microcontroller will then have to use a timer mechanism to measure the time between each sensor and use this along with knowledge of the fixed distance between the sensors to calculate the muzzle velocity. The data will then need to be stored in non-volatile memory such as EEPROM or Flash memory followed by the statistical calculations and smartphone upload.

The software will also need to support the laser being put into standby mode by push of a button. This should turn the laser diode off to conserve battery life. The software also needs to allow for the changing of bullet types so that different ammunitions can be recorded and compared separately at any one time. Functionality should be included to allow the removal of any bad shots from the data tables.

App

In order for the microcontroller to upload data to a PDA or Smartphone, software must be implemented to receive and process the information in real time. The software will involve the receiving of velocity data, statistical calculations and multiple display functions. The app needs to design to cater for a large number of devices.

5) Design

Using the previously discussed concepts a complete proposal of the planned chronograph can be designed to meet the requirements specifications.

5.1) Sensor Design

The final sensor design schematic can be seen above in Figure 3. The sensor uses two ZD1955 laser diode [12] each directed towards a DD-660 narrow band photo diode with spectral response shown in Figure 3 [13]. When the lasers are enabled by the MCU, they each emit light of wave length 655nm. While there is not object present the photo diode, sensitive to wavelengths between 600nm and 700nm, will be conducting. This will cause the sensor 1 and 2 outputs to be logic high. As passing ammunition blocks a lasers path each photo diode will become non-conducting and dropping the voltage at sensor one and two to logic low as shown in Appendix 4. Using the micro controller to detect this change in states and timing the delays between them, the velocity of the ammunition can be determined.

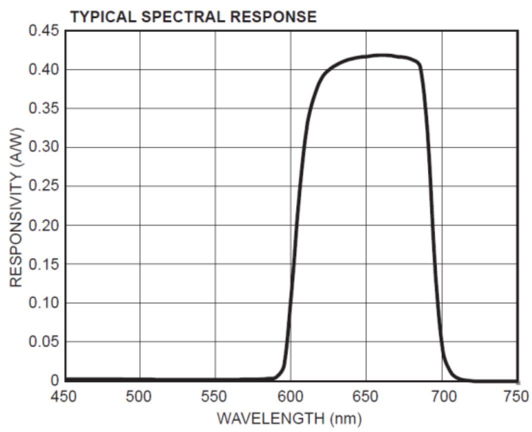

Figure 3 – Spectral Response of Narrowband Wavelength Detector Component [13]

5.2) Electrical Design

A list of components used in the final design can be seen in Appendix 2 along with a brief overview of each set of major component groups below. Complete circuit schematics can be seen in Appendix 3 and Appendix 4.

Laser

The selected laser operates at 2.4V and 40mA. Two of these are used in the final design each with a 65 ohm current limiting resistor. Each laser and photodiode cost $8.10 NZD and $13.20 NZD respectively.

Display and Connection

The final design uses a '*NHD-0420DZW-AG5'* OLED display [14] driven by a HDD44780 controller ($39.28NZD). The display and driver together require a 43mA, 5V supply and have dimensions of

98mm by 60mm. The screen and sensor are to be connected via a specialised data jack for this system. This is estimated to cost approximately $1.20NZD and is not shown in circuit schematics.

Bluetooth Module

The final design uses a GP-GC021 Bluetooth module [15] ($22.68 NZD) that can be seen in Appendix 4. It requires a 3.3V, 10 mA supply and operates at 9.6Kbps. It is connected to the RX and TX ports of the Atmega8 Microcontroller and has an operating frequency band of 2.4 GHz-2.48 GHz.

Microcontroller Unit (MCU) and UI

The selected MCU is an Atmel ATmega8 [16] and draws approximately 3.6mA at 5V. The MCU is to be embedded on a PCB and interfaced with the other modules as shown in Appendix 3. The six user interface buttons are connected to digital inputs on the ATmega8 along with the two sensor inputs. In a similar manner, the laser enabled LED driving circuit is connected to one of the digital outputs.

Supply and Power Usage

The final design uses two polymer lithium ions at 3.7V, 2 Ah [17] battery cells ($16.27 NZD) in series to achieve a 7.4V portable power supply as can be seen in Appendix 3. Each cell weighs only 36g adhering to the lightweight requirements specified. Additionally the cells are rechargeable, eliminating the need for disposable batteries and therefore enhancing sustainability. An LM7512C [18] voltage regulator ($1.26 NZD) is used to produce a stable 5V voltage for the micro controller and other components. A Decoupling capacitor are used as close to the supply as possible to increase stability. Additionally a slide switch is used to turn the supply on and off ($1.00 NZD) and is located on the sensor component. A battery charging cable is to be supplied with the chronograph unit and costs approximately $2.00 NZD.

It is estimated that the entire system should draw approximately 136 mA while the lasers and screen are active and 70mA while in an idle state. Assuming average current of 96mA the system will last approximately 20.7 hours in the field. This time should be more than adequate for the chronographs required application.

Positioning

The bulk of the electrical components are to be housed within the sensor casing shown in Figure 4 with the exception of the OLED display and driver which are housed in the barrel mounted sensor casing seen in Figure 5 on the following page. This is so that the sensor can operate without having the display connected and instead data is relayed to a smartphone device.

5.3) Mechanical Design

Mechanical structure diagrams of the proposed chronograph can be seen on the following page in Figure 4 and Figure 5. Figure 4 shows the barrel mounted sensor structure with an exaggerated laser beam to emphasise sensor operation. The sensor component has been designed in a way to allow a clearance for ammunition caliber sizes up to that of a paintball gun (17.3mm). The clamping mechanism is designed so that the sensor can be safely secured to a range of firearm barrel sizes by fastening the circular clamps.

Due to the nature of the parts touching the barrel the chronograph sensor will also be able to be securely fastened to the lower (stationary) portion of pistol barrels. Additionally the design minimises the effects of ambient light via a sun shield over hanging the top portion of the sensor without disturbing the firearms sighting path as per the requirement specifications. Each laser and photo diode are 10cm apart.

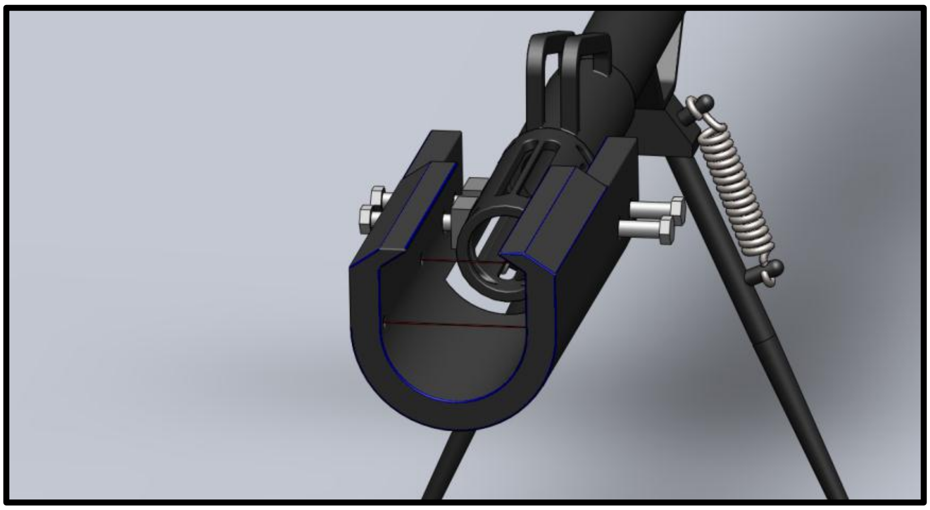

Figure 4 - Mechanical Structure Diagram of Mounted Sensor Component [19].

Figure 5 shows the proposed casing for the OLED display and driver. It is designed so it can be mounted across the upper portion of the firearm in a similar clamping method to that previously described. The display clamp can also be retracted so that the Interface can be handheld and rotated in to face the firearm when not being used.

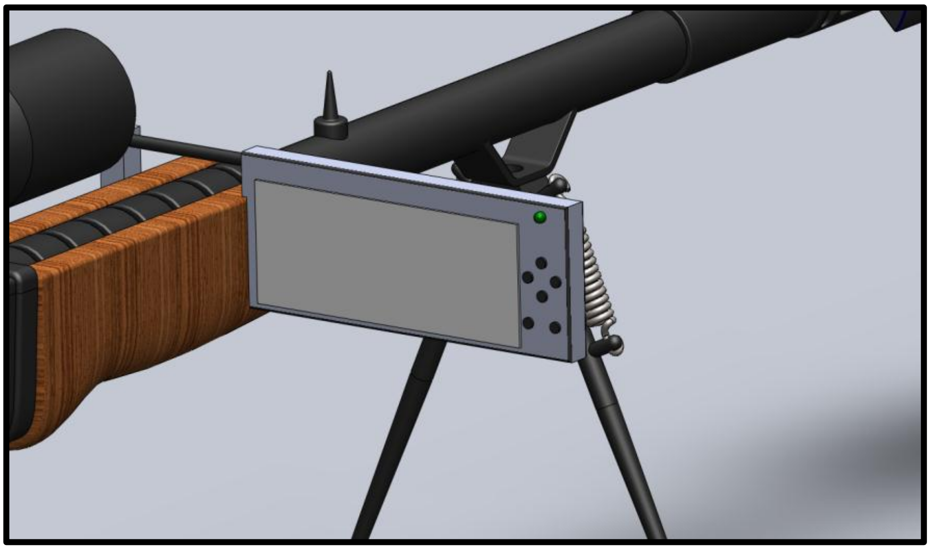

Figure 5 - Mechanical Structure Diagram of Mounted Display Component [19].

Both components will be constructed from a robust plastic such as polycarbonate and estimated to cost approximately $3.20 excluding labour and initial manufacturing costs [20].

5.4) Microcontroller/Software Design

The Microcontroller unit selected for the chronograph system is an Atmel Atmega8. This has been selected due to its low cost ($3.51NZD), appropriate I/O requirement and detailed documentation. The 8MHz processor far exceeds the 12 KHz requirement specified by Equation 3 and comes with appropriate UART communication peripherals that operate with the GP-GC021 Bluetooth module. A flow diagram outlining the proposed software modules can be seen Appendix 6 and Appendix 5.

The microcontroller software can be divided into two task groups, foreground interrupt driven processes and background non-time critical processes. The background tasks involve interactions with the user such as pushing on of the buttons on the UI or toggling the laser. The foreground tasks consist of time critical duties such as Bluetooth uploading and timing of the laser interruptions to calculate ammunition velocities. A model of the User Interface can be seen below in.

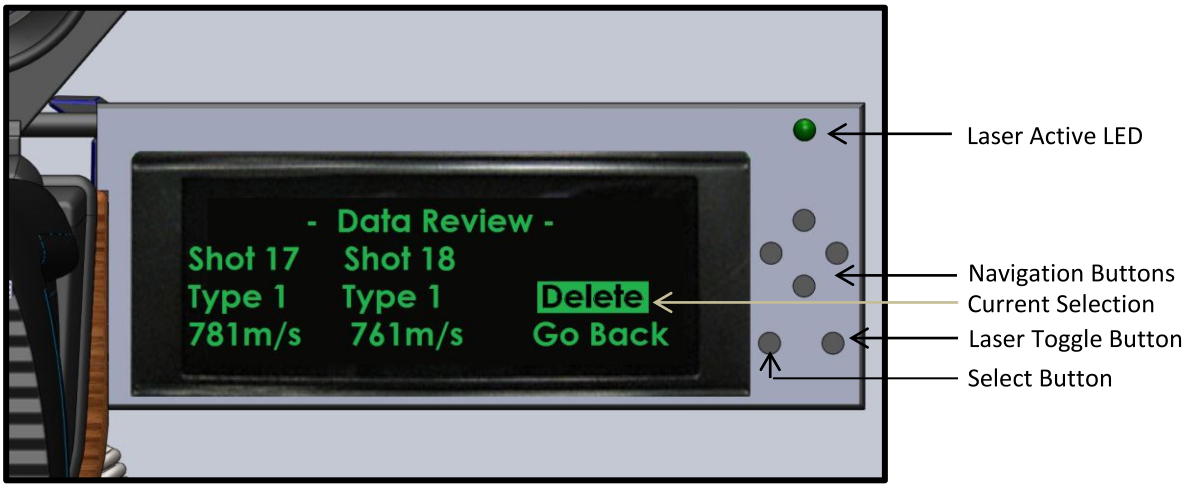

Figure 6 - Proposed User Interface Layout [14] .

Calculations and Storage

The software design requires interrupts to be set up corresponding to the logical inputs for sensor one and sensor two. Upon each interrupt the time should be recorded using one of the ATmega8's 16 bit timers**.** After the second interrupt has been received the time the difference should be calculated and then converted to time. The velocity is then calculated as 0.1m divided by this time difference (Using d as the 10cm=0.1m laser displacement). The software will then write this value along with its data series type (1, 2, 3 …) to the EEPROM so that data will not be lost at power down. Due to the high processing speed of the ATMega8 statistical data can be calculated upon entry to the statistical data display screen.

OLED Interface

Figure 6 above shows the proposed user interface for the system. The display system can be traversed using the navigation buttons. The current selection can be seen by the green surrounded option. The current screen shown is the data review display. By selecting back and then selecting statistical data the MCU will be prompted to calculate and display statistical quantities. These quantities include; averages, standard deviations, data ranges, minimums and maximums of each data set and will be displayed in a similar way to those shown above.

Mobile App – Bluetooth Interfacing

The final design utilises the Bluetooth module to allow data transfer to a mobile smartphone device running Android OS or IOS. This is to make the most of the growing number smartphone users worldwide. As a result the final chronograph design requires an app to be written for both Android OS and IOS. A screen shot of the proposed graphical display can be seen below in Figure 7. The app will receive velocity data from the ATmega8, calculate statistical data and show it in a meaning full and attractive way. Furthermore as the velocities are uploaded in real time, time and GPS location data can be recorded for future reference.

Figure 7 - Screenshots of how data could be displayed on a Samsung Galaxy S3 [21] (Left) and an Apple IPhone 3G [22] (Right).

5.5) Costs

The costs of each section can be seen below in Table 3. The full system cost has come to $116.39. The next similar mountable chronograph, MagnetoSpeed, retails around $309NZD. This means the chronograph can be sold at competitive price.

Section	Estimated Cost
Sensor	$42.6
Electrical (Modules)	$62.39
Electrical (Standard Components)	$4.69
Mechanical	$3.20
Microcontroller	$3.51
Total	$116.39

Table 3- Costs of System

6) Sustainability of Design

The proposed chronograph must meet the issues of sustainability stated in the requirements specification. These criterions have been developed to ensure that the quality of the product is preserved and there are little negative effects to social, economic and environmental stakeholders as a consequence.

Stakeholder Identification

Stakeholders in the product can be anyone involved with its production, sales, and use. These groups include; investors, assembly line workers, retailers, hunters, paintball players and marksmen.

Social - Manufacturing

Mass production of the product needs to conduct in a way that supports adequate working conditions. For this to be achieved the manufacturing could be done in New Zealand as opposed to outsourcing production to countries that do not support fair workers' rights. Although this would increase the production costs, it would lead to economic benefits regarding employment in the area chosen for production. The rise in cost resulting from production in New Zealand is acceptable due to the chronograph's low design cost. This would inevitably lead to economic disadvantages to stakeholders that have invested in the product however the social benefits received would increase company public relations. Additionally by not exploiting underpaid workers in countries such as China and Taiwan, further awareness into the social welfare of these groups can be promoted.

Environment -Components

To be considered sustainable the final product must have a long product life cycle and be constructed from materials that are not damaging to environment. The design incorporates two major components that reduce environmental impact. The first of these is the use of Lithium Ion cells as the power source of the chronograph system. Since these cells are rechargeable it eliminates the need to constantly replace lead-acid based batteries. When incorrectly disposed these batteries can leak into surrounding ecosystems and lead to long lasting negative effects on the environment. The second major sustainable component included in the design is the OLED display. Since this structure is biodegradable it is easily disposed of.

Another environmental benefit from the chronograph is the encouragement for hunters and marksmen to reload their center fire cartridges as discussed in the problem identification.

Economic – Product Life

The product is to be designed in a way to maximize product lifetime. By doing this, economic benefits will be received by investors from good product reputation and the resulting sales. This also removes any economic affects for the customers who would be at a loss if the product life time were low. Product lifetime could be extended by using higher quality materials and offering longer warranties. Additionally this aspect reinforces the need for a quality manufacturer supporting the decision to produce the Chronographs in country like New Zealand.

7) Conclusion

The proposed chronograph has met all the criteria described in the requirements specifications. It uses optical methods of velocity determination that have been proven to give a high level of accuracy. The mechanical design of the sensor should ensure that sensor operation is not affected by external lighting conditions. The design also includes many safety conscious decisions such as clearances for larger ammunitions and secure methods of mounting components to the firearm. The chronograph uses a user friendly interface and excellent graphing functionality when linked to a smartphone device.

The cost of the chronograph has been estimated to come to $116.39 NZD. As a result the chronograph is feasible by design and cost and can be sold at a competitive price.

The next step of the design process would be to begin prototyping the design. This process would lead back to design process should any problems occur or improvements be made

In conclusion, the designed chronograph more than adequately meet the needs of the social groups initially identified. It will greatly benefit all fire arm users whether they are refilling their cartridges, monitoring their competitive performance or simply firearm users interested in their ammunitions characteristics.

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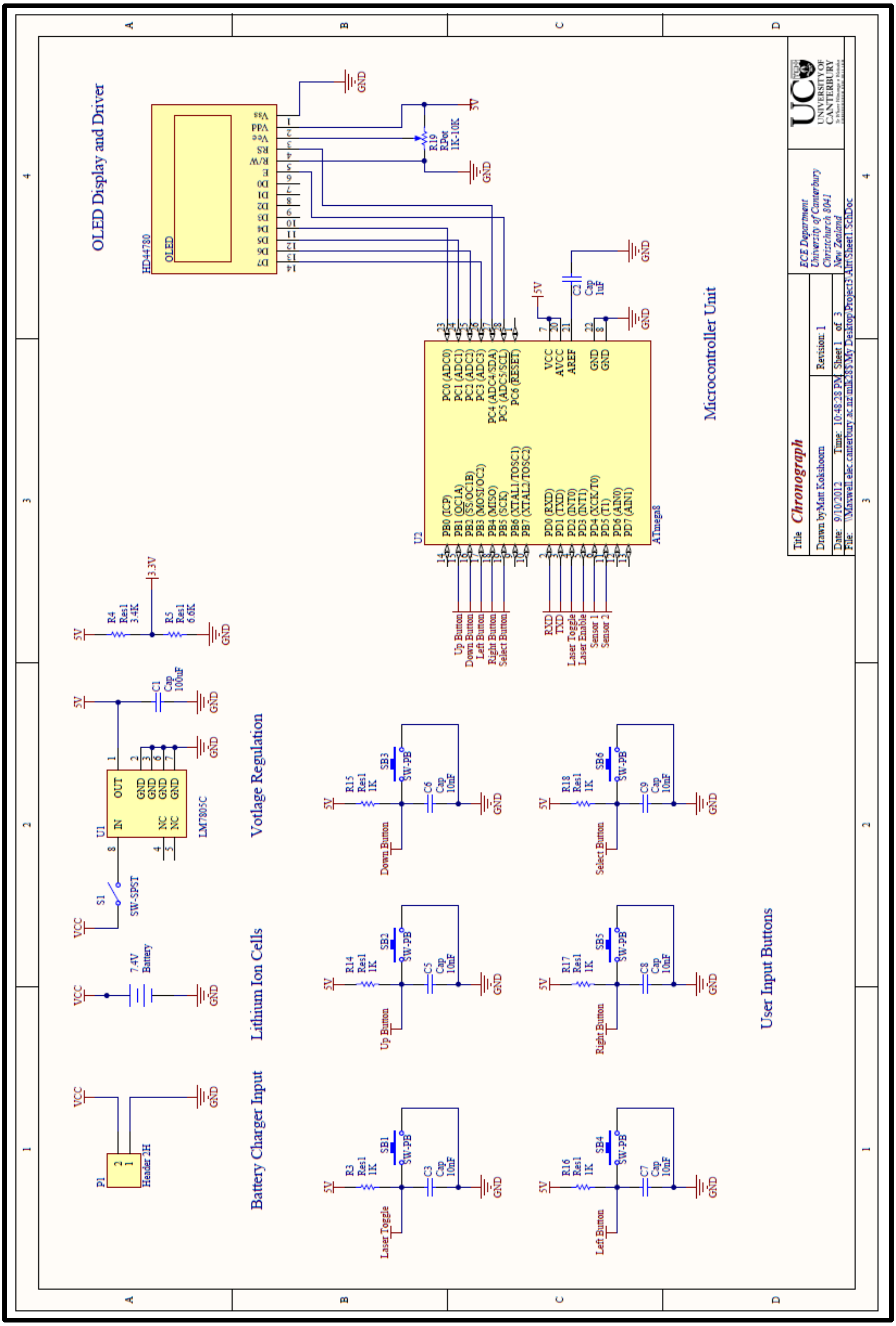
9) Appendix

	Accuracy	Uniqueness	Mount ability	Simplicity	Cost Effectiveness	Safety	Geometric Mean	Weighting
Accuracy	1	2	0.5	0.5	2	0.5	0.87	0.13
Uniqueness	0.5	1	0.25	0.5	0.5	0.33	0.40	0.06
Mount ability	2	3	1	2	2	1	1.89	0.28
Simplicity	2	2	0.5	1	1	2	1.32	0.19
Cost Effectiveness	0.5	2	0.5	1	1	0.25	0.66	0.10
Safety	2	3	1	0.5	4	1	1.64	0.24

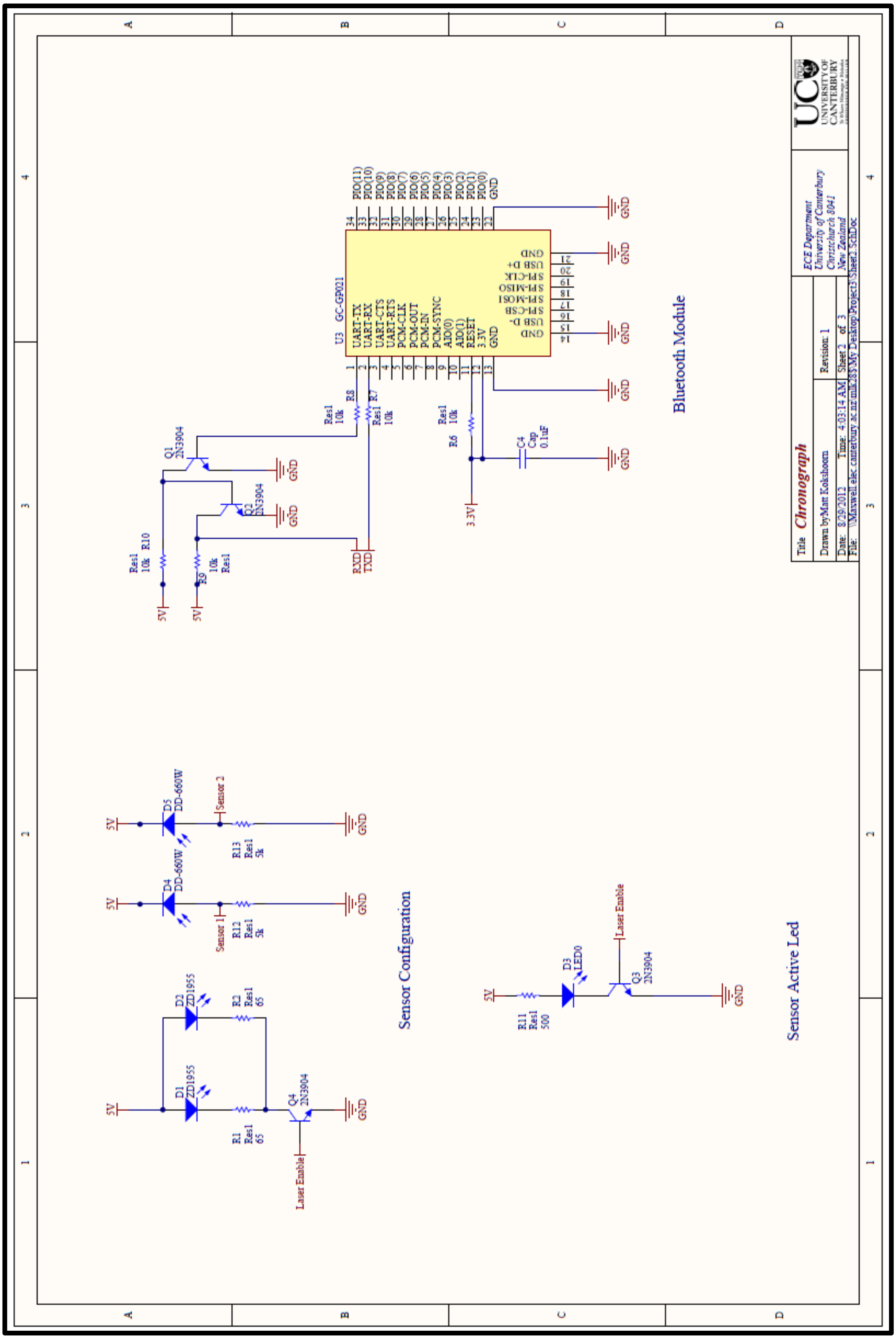
Appendix 1 - Pairwise Comparison of Selection Criteria for Velocity Determination Method

Comment	Description	Designator	Footprint	LibRef	Quantity
Battery	Multicell Battery	7.4V	BAT-2	Battery	1
Cap	Capacitor	C1, C2, C3, C4, C5, C6, C7, C8, C9	RAD-0.3	Cap	9
ZD1955	Subminiature High Performance AlInGaP Red LED Lamp	D1, D2	2.2X2.1X2.2Z	HLMA-PF00-N0031	2
LED0	Typical INFRARED GaAs LED	D3	LED-0	LED0	1
DD-660W	Photosensitive Diode	D4, D5	PIN2	Photo Sen	2
HD44780		LCD		HD44780	1
Header 2H	Header, 2-Pin, Right Angle	P1	HDR1X2H	Header 2H	1
2N3904	NPN General Purpose Amplifier	Q1, Q2, Q3, Q4	BCY-W3/E4	2N3904	4
Res1	Resistor	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18	AXIAL-0.3	Res1	18
RPot	Potentiometer	R19	VR5	RPot	1
SW-SPST	Single-Pole, Single-Throw Switch	S1	SPST-2	SW-SPST	1
SW-PB	Switch	SB1, SB2, SB3, SB4, SB5, SB6	SPST-2	SW-PB	6
LM7805C	3-Terminal Positive Regulators	U1	M08A_N	LM78L05ACM	1
ATmega8	8-Bit AVR Microcontroller with 8K Bytes of In-System Programmable Flash Memory	U2	28P3	ATmega8-16PC	1
GC-GP021		U3		GP-GC021	1

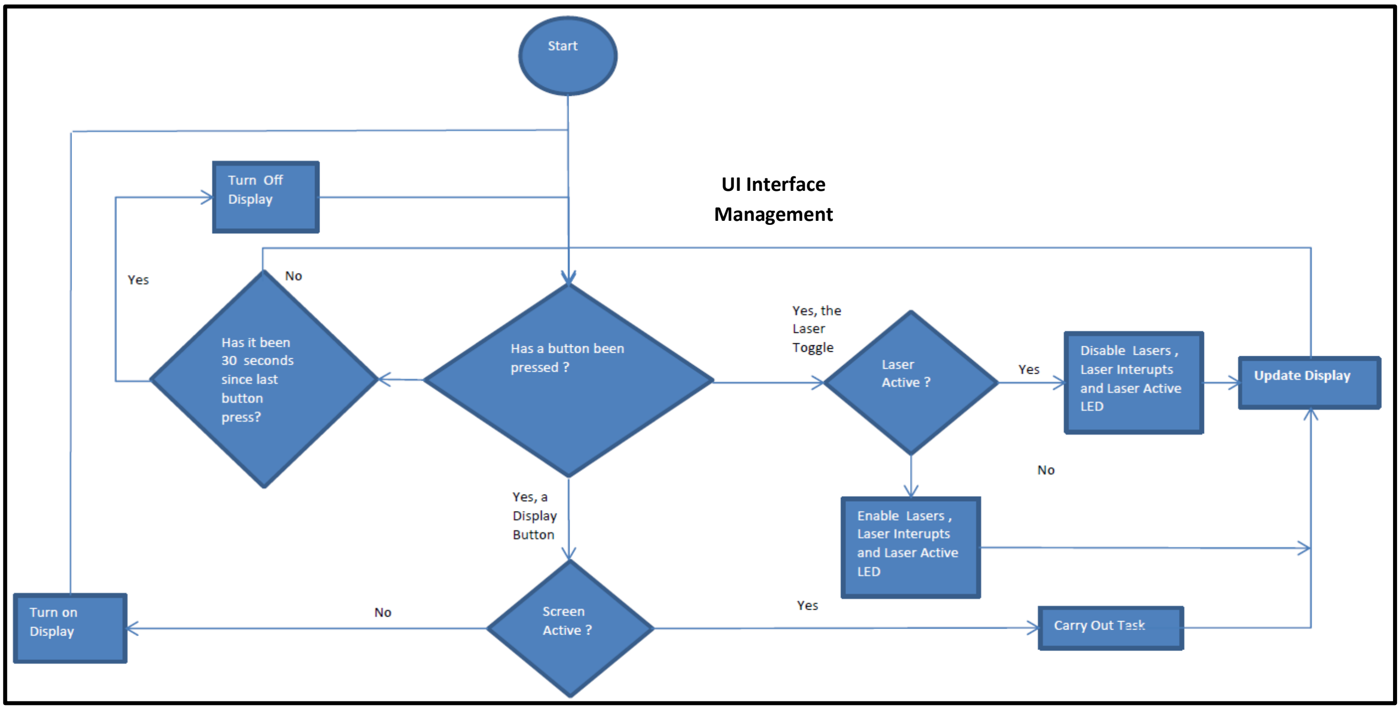
Appendix 2- Bill of Electrical Materials (Altium Summer Edition 09)



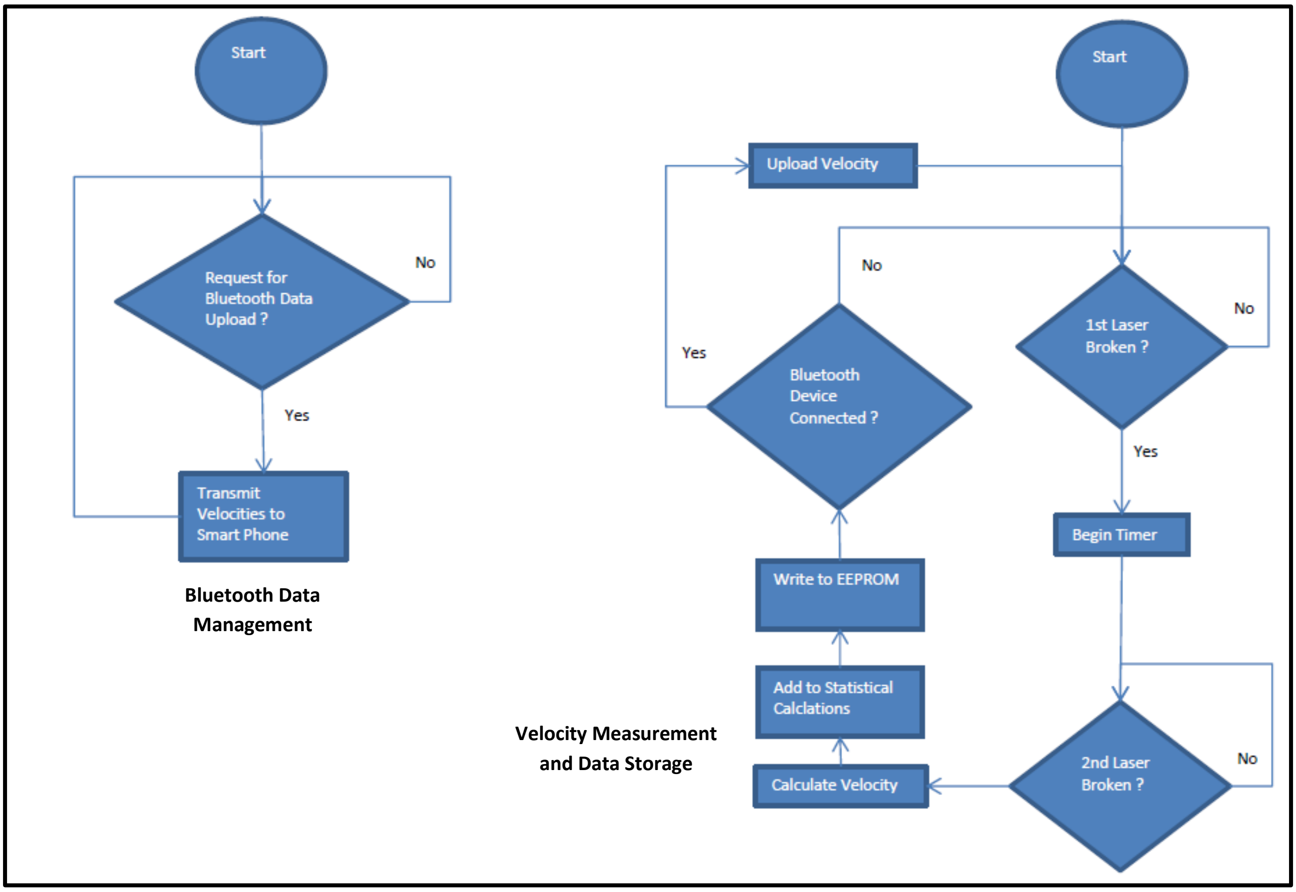
Appendix 3 - Electrical Schematic Sheet One



Appendix 4 - Electrical Schematic Sheet Two



Appendix 6 - Software State Flow Diagram Showing Normal Background Operation



Appendix 5 - Software State Flow Diagram Showing Interrupt Driven Foreground Operation