

ECE 480

Final Proposal

2/20/2014

Ballistic Chronograph

Sponsor: Brian Wright

Facilitator: Dr. Nihar Mahapatra

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Executive Summary:

Ballistic Chronographs are used to measure the velocity of projectiles. The most common application is a downrange implementation to measure the velocity of bullets mid-flight on a shooting range. Commercial Chronographs exist, but are expensive and have many drawbacks that make them unreliable. The commercial Chronographs use infrared sensors to detect projectiles, and screens come in different shapes, most commonly a triangle. Our prototype will have a 14 inch x 14 inch square screen, making it easier to aim the projectile and gather data. While infrared sensors are a working option, they are unreliable due to changing light conditions. Our prototype will use line lasers to detect projectiles passing through each screen, rather than IR sensors to increase reliability. Additionally, most commercial Chronographs have no wireless transmission of data back to the user. For convenience, all data from our prototype will be reported back over Bluetooth, targeting and Android phone, where they can control and save Chronograph data.

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Introduction:

The idea behind this project was developed by ECE shop representative Brian Wright. The main goal was to develop a low cost ballistic chronograph that will have more features than more expensive commercial competitors. As commercial units usually cost \$150-200 or more, which may also lack features and reliability outside of determining projectile velocity, it is reasonable to develop a low-cost solution with more features for the public.

The main purpose of a ballistic chronograph is to measure the velocity of a projectile in flight. It can be any projectile such as bullets or arrows, or rocks fired from a slingshot - as long as they pass ballistic chronograph sensors, their velocity will be calculated and outputted for the end-user. Moreover, the chronograph should be able to output various specifications that will be based on its own sensors such as humidity, temperature, altitude and pressure that can also influence the velocity of a projectile. Therefore, this data should be helpful for the user with its intended target audience, specifically shooting professionals.

The sponsor wants to receive a ballistic chronograph that will be able to handle the above tasks, in addition to storing data and sending it to an Android smartphone via Bluetooth, or optionally store data on a microSD card that can be used to see data on a computer. It is expected that this project will cost less and outperform comparable commercial units available on the market.

Background:

A chronograph is an instrument that measures the velocity of a project mid-flight. One such type can be attached to the end of a gun's barrel which would give the muzzle velocity. In most cases, this would be trivial because this value could be calculated by hand. The important information for the user would not necessarily be what the velocity of the projectile is as it leaves the barrel, but the velocity of the projectile at a distance. Chronographs that are mounted on the gun's barrel are limited in their capabilities.

Chronographs also have to have a way in which they are able to accurately track the projectile's velocity. This can be attained by using infrared sensors. A flaw with using infrared sensors is that they tend to have low accuracy because of changing light conditions. Being able to detect the velocity of a projectile with a high degree of accuracy is very important for a shooter, especially one who is shooting at a distance. The chronograph should be able to detect a wide range of velocities and report the conditions of the environment so the user will gain an understanding on how his projectile was affected.

Design Specification:

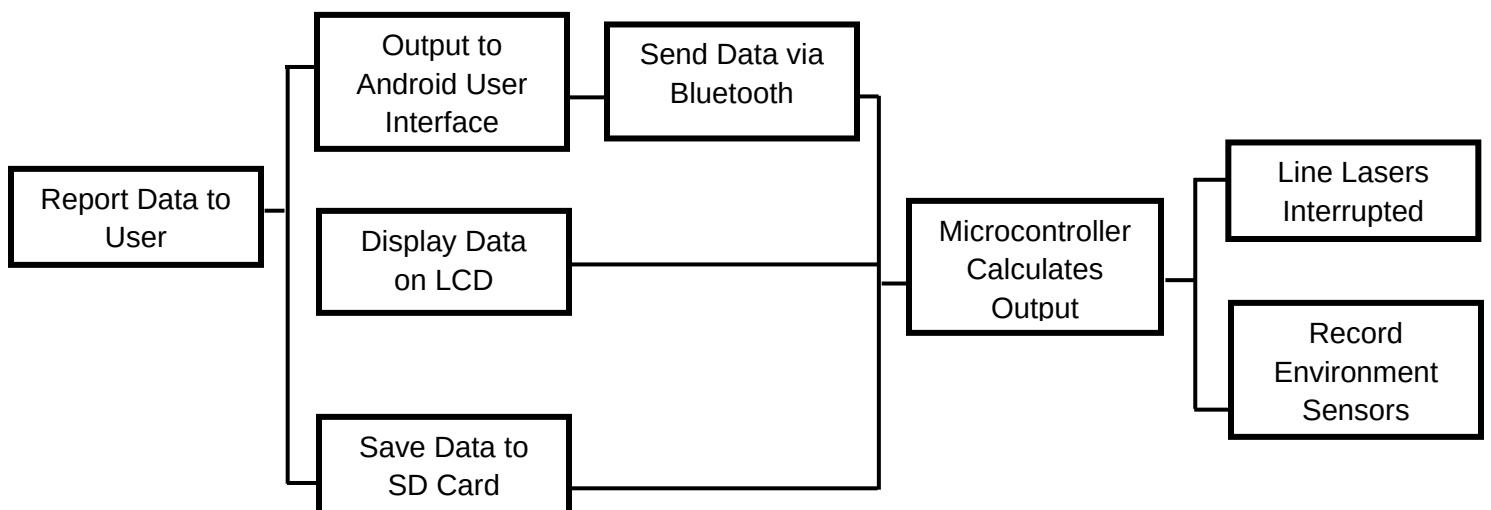
The Chronograph is expected to be able to record data about the environment, including temperature, humidity, altitude, wind speed, and air pressure. Additionally, it must provide the primary features of measuring and storing projectile velocities, and reporting all recorded data to the user. It is expected to be far away from the source of the projectile, gathering data mid-flight. This is called a downrange Chronograph.

One of the primary apertures of a Chronograph is a screen. A screen is a two dimensional plane defined by a group a sensors. When the plane has been breached by a projectile, a timestamp is saved. The Chronograph will have two screens, each 14 square inches, placed in a line with identical orientation, separated by 14 inches. The speed of the projectile will be determined in feet per second, as it is clocked at both ends of the known distance.

In order to represent the above criteria, a microcontroller will be setup between the two screens, whose inputs are a series of sensors. Line lasers powering LEDs will be used to define the Screens, with peripheral sensors to gather the other necessary information around the screens. An LCD will be used to report basic information, such as projectile velocity, but will not have advanced features like past velocities and multiple sensor outputs.

Reporting the complete set of data, as well as saving past data sets will be achieved through a wireless Bluetooth package. By broadcasting all of the data to a waiting Android phone, via a custom application, the user will be able to easily get the data from the Chronograph from a distance. This design specification highly prioritizes data acquisition and storage, and reliable reporting to the user. Such priorities were reflected in each of our conceptual designs.

Fast Diagram:



Conceptual Design Descriptions:

The design should be comprised of a two screen system, with the screens coming from line lasers which will be used to create power from a series of light emitting diodes. Interrupting the line laser at any point in the screen will result in an LED losing power, which will cut off the current from the LEDs. The LEDs will be connected as an input to a microcontroller. The changes in input to the microcontroller will trigger an interrupt that will be used to calculate the time between the events when each respective laser screen is broken by the projectile. This method is believed to be more effective than methods commercially being produced, which use IR sensors in a similar fashion. The major drawback to IR sensors is that they are very easily affected by ambient lighting in a negative manner, causing the ballistic chronographs to not work properly in certain lighting conditions. The line laser method should be similar in cost to the IR method as well.

The main advantage to using IR sensors instead of a line laser would make the design closer to the commercial products, which have been proven to work.^[1] This design could be improved in other areas, to give the user of the device greater feedback of surrounding conditions, such as temperature, humidity, barometric pressure, as well as ballistic information. This information could then be stored to a smartphone via Bluetooth for future reference. These concepts could also be applied to the line laser scheme.

A third potential design scheme could use ultrasonic sensors spread out over a large area to track the projectiles via the Doppler Effect. With this method a radar signal at a certain frequency would be transmitted over an area and reflected off the projectile. The returned signal would then be examined to determine the change in frequency of the returned signal, compared to the original signal. Knowing the change in frequencies would allow for the calculation of the projectile velocity. The advantage to this design is that the projectile would not need to be fired through such a small area as in the previously discussed designs. The disadvantage is that this design would be much harder to implement since it would exist on a much larger scale. It would also require more parts to implement and be much more complex, which would drive up the cost. Prototyping this third idea would be a much larger challenge, and much greater investment than the previous two.

Ranking of Conceptual Designs:

Design	Cost	Complexity	Experimental Time	Workability	Overall Rank
Line Laser- Diode	1	1	1	1	1
IR Sensor	1	1	1	2	2
Doppler Effect	2	2	2	3	3

The three design ideas have been ranked from one to three, with one being the idea thought to be most able to be implemented and three being the hardest to implement.

The designs of the Line Laser and IR Sensor chronographs could be implemented for very similar cost to build each. The required components for each are priced similarly. The Doppler Effect chronograph concept would be much harder to stay on budget with, as it would require many more resources to implement.

The complexity of the Line Laser and IR Sensor methods would be very similar. They would use the same principles with different components. The Doppler effect system would require many more components and much more planning to be integrated successfully.

Again, the Line Laser and IR Sensor methods would require similar experimental time to get functioning. Because of the large scale of the Doppler Effect system experimental time would be much greater and perhaps longer than the time allotted for this project. The ultrasonic implementation would also require a much larger testing area, and much more research.

The design that is believed would work best is the line laser chronograph. It could potentially make up for some of the shortfalls of the IR sensor based product. The Doppler Effect concept would be difficult test and implement, therefore it is not a highly desired design.

Overall, the designs are ranked: 1) Line laser chronograph, because it can possibly improve on a working concept. 2) IR Sensor chronograph, because it is a working design that has some drawbacks, and some improvements from the line laser design, such as the user interface, could be migrated to this solution. 3) Doppler effect chronograph, since the design is more complex than the previous two concepts and would likely be hard to implement given the time and budget constraints of the project.

Proposed Design Solutions:

The best solution would be the Line Laser solution. This solution can provide an increase in accuracy over the infrared solution that is already seen in industry. Lasers will be able to detect if a projectile has intersected with a chronograph screen. The projectile will cross two sets of screens to calculate the velocity. After calculating the velocity, it will take a snapshot of the other values its sensors are monitoring and will report this back to the user. The user will either have Bluetooth connectivity and the appropriate Android application or will be able to obtain the information from the LCD. Figure 1 illustrates this dataflow.

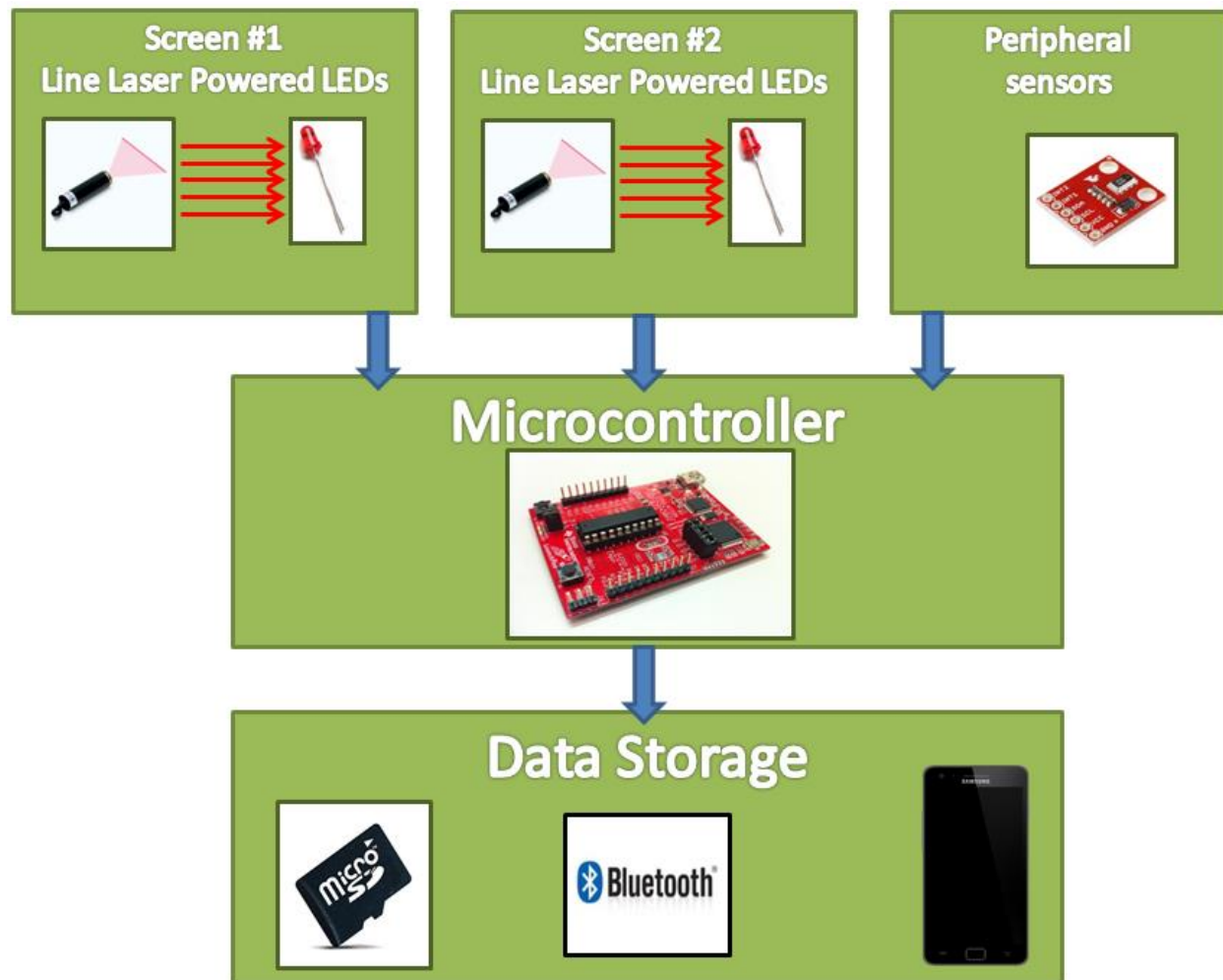


Figure 1. Chronograph Design Concept

If prototyping experiments show this solution is not feasible, it will be easy to switch over to infrared sensors because the industry has already proven they are acceptable. Although there are already chronographs that use infrared sensors, they can be improved by including other sensors and providing a better user interface with more information available to the individual. In this scheme, the infrared sensors will be used to determine the velocity of the projectile instead of using a line laser.

Risks Analysis:

Since the commercial products are using an infrared sensor, the idea of our project is using a line laser. After installing the line laser setup, the prototype will be tested, and adjust current or voltage of the setup. Using the line laser, the prototype that will be built will increase the reliability and accuracy.

Since the project is using a chronograph to measure the speed of bullet or other high speed objects, the components have to be covered by hard metal case to make sure it would not easily get damaged from use. The hard metal cover also can sink the heat from the components which can provide the prototype a stable environment. Furthermore, all the sensors need a stable environment that can keep them working properly. Due to the requirement of sensitivity in this project, a case made from aluminum would be the ideal material.

The power of the line laser will be using as 5 mW, however, if the detector cannot be sensitive enough to output the signal, the power of the line laser should be increased. A high power laser might start fires and could injure the user. All students have to wear safety goggles, and keep watching the power difference during the experiment. [2]

All the data will be measured and sent to a microcontroller which will do the calculations and send the user the data. The ideal way for the system to communicate with the user will be to send its data using Bluetooth to an Android device. The risk from this idea will be the creating of the applications for the Android system. Time and lack of experience will be the main issues. Starting to create the application earlier will give more time to refine the whole prototype, even if it failed at the beginning because team members will still have time to fix or seek other solutions.

In the prototype testing, high speed movement of the object may cause injury so a safe place to test has to be carefully considered.

Project Management Plan:

- Xuming Zhang - Presentation Prep -

Primarily responsible for the organization of the oral report and peer editing of the presentation report. Other responsibilities includes creating powerpoint file to represent our project, and sketching the outline of the presentation. Setting up the practices before the presentation and controlling the direction of the poster at the end of the project.

- Nicholas Mancuso - Manager -

Primarily responsible for communicating with the Sponsor and Facilitators, and ensuring that the prototype evolves along with the design specifications. Responsible for plotting out the overview of work time and setting up weekly meetings.

- Madi Kassymbekov - Webmaster -

Primarily responsible for the organization, update and maintenance of the team's webpage, setting up team's email. Responsible for preparing Team's project CD, videos and images.

- James Cracchiolo - Document Prep -

Responsible for the handling of the team's documents. This includes any schematics, proposals, or any other document can be distributed to the team and that it is easily accessible.

- Steven Kanitz - Lab Coordinator -

Responsible for coordinating lab times for prototyping, ordering necessary parts, and ensuring the design remains possible throughout the experimental prototyping stages.

- Important Deadlines:

- Pre-Proposal Due : Friday, 1/31/2014
- Final Proposal Due : Friday, 2/28/2014
- Progress Report #1 Due : Friday, 3/14/2014
- First Prototype Demo : Week of 3/24/2014
- Progress Report #2 Due : Friday 4/11/2014
- Final Prototype Demo : Week of 4/14/2014
- Final Report Due : Wednesday 4/23/2014
- Final Presentation : Wednesday 4/23/2014
- Design Day : Thursday 4/24/2014

Budget:

The total allocated budget for this project is \$500, however the current design scheme should not exceed \$200. The rough breakdown of projected cost is as follows.

- Current estimate:

Item	Quantity	Price
Line Laser	2	\$20
Sensors*	x	\$30
SD card	1	\$10
LCD Screen for microcontroller	1	\$10
Projectiles for Testing	x	\$20
Screen Frames	x	\$30
LEDS	x	\$5
Additional Unknown Expenses	x	\$50
Estimated Total		\$175

* includes Temperature, Air pressure, Humidity, Altitude

References:

[1] "Who Needs a Chronograph?" *Who Needs a Chronograph?* Pyramid Air, n.d. Web. 28 Jan. 2014.

<http://www.pyramidair.com/article/Who_needs_a_chronograph_August_2006/31>.

[2] "Stanford University Laser Safety Manual." *Stanford University Laser Safety Manual*. Stanford University, n.d. Web. 27 Jan. 2014.

<<http://www.stanford.edu/dept/EHS/prod/researchlab/radlaser/laser/procedures/classes.html>>.