

Small, Lightweight Speed and Distance Sensor for Skiers/Snowboarders

Air Force Research Laboratory

Design Team 5

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Executive Summary

Performance analysis devices are an essential component of training methodologies in modern athletics. Current trends have seen professional level equipment becoming more readily available to amateur athletes in recent years. In snow sports like skiing this top down migration of technologies for training has been slow making a huge gap in the market for portable devices targeted at ski enthusiasts. For skiers the primary information necessary to compare the performance of individuals is speed; a device that would allow users to measure their speed in order to record progress would be a welcome entry to this consumer sector.

This document outlines a design for an inexpensive speed and distance sensor that can be used by snow sports enthusiasts of all skill levels. By using low cost materials, maintaining minimal power consumption of on-board electrical devices and harnessing the size benefits of high frequency Doppler detection the proposed design will allow for the production of a useful and robust product for all skiers and snowboarders. The project is sponsored by the Air Force Research Laboratory and is the third iteration of a speed/distance recorded for skiers.

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Introduction

When training for any sport, some sort of performance measurement is required in order to see improvement in technique and expertise. In skiing and snowboarding, the most important measurement is speed. Speed is critical in all aspects of snowboarding and skiing. In freestyle competitions, achieving the correct speed is necessary in order to safely hit a jump. For racing, the fastest competitor wins, so knowing one's speed is extremely vital.

The device that Design Team 6 proposes to make is a light weight temperature resistant speed sensor. The device will use Doppler radar technology in order to calculate the speed of the user, and to measure the distance traveled. The device will be intuitive and simple to use. For safety's sake, the device will not be viewable when motion is detected. Due to the standard environment of the system, some special needs must be met. The device must function in cold temperatures, down to -10°F. This device must also last on internal battery power for at least two hours.

Lastly, the method of operation for the device will be simple. In chunks of one minute each, the device will store peak and average speed. The device will also turn off by user input or after a default time period. Finally, the data will be able to be saved or deleted on the device, and be transferrable to another computer.

Background

There have been two attempts to design project with similar specifications before. The first attempt was during the spring of 2008. The design team implemented GPS as its basis of measurement, and paired it with a Blue device. The biggest problem encountered was the large error when turns were involved in the route. Other problems with the device include lack of waterproofing and large size¹.

The second attempt, during autumn of 2009, used system which relied on GPS and an Inertial Navigation System. Inertial Navigation System (INS) uses multi-axis accelerometer and multi-axis gyroscopes to measure the speed. It is good for short term measurements, but accuracy decreases over time. The combined system uses GPS as a long-term reliable source of input, and INS as a local short term error checking. This combined system offers accurate results. Unfortunately, this design attempt failed due to the complexity and time limitations².

The current marketplace device Tech 4 O SI- Ski 1 Speedometer uses Doppler radar technology to measure the speed of the user³. The Tech 4 Speedometer also has a simple and safe display to the user. The Speedometer comes in two portions, the Wireless radar module, and the display stopwatch. The radar module attaches to the belt or leg, and the display can be clipped to any available loops on the user. One drawback of the system is,

Doppler radar devices use the principles of the Doppler Effect to calculate the speed of targeted objects. The Doppler Effect is a change in frequency of a wave based on the relative speed of an object⁴. For example, a train sounds its horn at a given pitch. As the train approaches a listener, the pitch of the horn sounds higher, because the wave has shifted to a higher frequency. As the train passes and moves away from the listener, the pitch decreases because the frequency decreases.

A Doppler radar device uses this effect to calculate the speed of nearby objects or the speed of itself. The device emits multiple pulses, and receives a reflection of the wave. Due to the velocity of the object, the reflection of the wave has a different frequency. The difference in the frequency is used to calculate the velocity of the target. This can also be used to calculate the velocity of the emitting device.

Design Specification

Our device design is currently outlined by the following feature set:

- **Measurements** (minimum one minute intervals)
 - Average speed
 - Max Speed
 - Distance Travelled
- **Safety**
 - Lightweight (< 2 lbs.)
 - Disabled display during recording
 - Weather resistance
 - Low temperature operation (-10F)
- **Power and Efficiency**
 - Auto-off after 10 minutes of operation
 - At least 2 hours of battery life
- **Operation**
 - Data storage requirement for at least 10 minutes of run data
 - Data report on LCD or data export to external device

Conceptual Design

Our design for the speed and distance sensor will utilize a Doppler radar system. The device will have a user interface that allows users to access previously stored data or begin the speed and distance tracking process. Our device will have three main components: the radar device, the control system, and the user interface.

Radar Device

The radar device is a Doppler noise radar. The radar works by transmitting electromagnetic waves towards the ground and receiving the reflected waves. The reflected waves are then mixed with the transmitted waveform to determine the frequency shift. From the frequency shift, the instantaneous speed can be determined. From the speed the distance can be derived by the control system.

Control System

The device will be controlled by a microprocessor. The microprocessor will receive input from the user through the user interface, receive, process, and store data from the radar device, and finally store data for future viewing or uploading.

User Interface

The user interface will consist of a LCD or OLED screen that displays the menu options. The display must be able to be manipulated while wearing winter clothes and operate in below zero temperatures. At the users command, the device will be able to retrieve previously stored data, or begin the tracking process. The user will be able to navigate the options through the use of pushbuttons for easy manipulation.

Project Management Plan

Tasks for the project have been divided based on individual team member's interests and area of expertise. The team is divided into two sub-teams: microcontroller programming and Doppler sensor design. Contingent upon the successful operation of a Doppler module (prefabricated or custom) the two teams will focus solely on device operation and integration.

1. Design and Simulation

The design team will decide on device operation process flow and perform feasibility tests in the laboratory to determine whether certain components or techniques will be useful for the project. Through laboratory tests the team will learn what issues need to be focused on, what will and will not work for the project. Simulations for component interface will be carried out as necessary. Simple programming will be performed by all team members to become comfortable with programming a PIC. Choosing and purchasing components will be ongoing during the design process.

2. Prototyping

Once design and component acquisition has been completed the team will prototype the device for testing. Breadboard prototyping responsibilities will be evenly distributed to all design team members. During this time power design and measurement will be performed to ensure proper efficiency and ensure all power requirements are met. The objective of this is to produce an operating proof-of-concept for testing and analysis.

3. Testing

Testing will be performed in order to calibrate the device for real world operation. Plans for testing will include a skateboard test to model flat surface behavior of the device and (weather permitting) a down slope snowboard/ski test. The team will take time during this phase to adapt the design to any flaws or lack or features that may be encountered in a live action scenario. Development of a build and testing procedure for the final build phase will be performed to prevent mistakes during construction.

4. Final Product Build and Testing

Once we've integrated new design additions from the testing stage we will design a PCB layout for the final device and custom housing to contain the PCB, batteries and modules. We will construct the final device using the building guideline and prepare the final device for demonstration.

Distribution of Labor

Members of the design team have each been given unique roles during the duration of project development as well as their sub-team designation. The roles can be seen in table below.

<i>Doppler Sensor Module and Analog Design</i>	Kunal Verma	Project Manager
	Justin Erskine	Web Master
<i>Microcontroller Programming and Interface Design</i>	Tim Ross	Documentation Prep
	Temika Cage	Presentation Prep
	Ben Guild	Lab Coordinator

Budget

The LCD display will be the main interface between the user and the device. Information taken during the ski run will be shown on the LCD screen when the user requests it. Most LCD screens are listed in the price range above. They are relatively cheap and effective.

The Motion sensor is the most important part related to the project. All the measurement data will be taken from it and processed to develop the information that will eventually be outputted for the user to understand.

Cost Breakdown	
Item	Cost
Microcontroller	\$4.00
LCD Display	\$20.00
Motion Sensor	\$15.00
EPROM	\$5.00
Battery	\$10.00
Project Box	\$10.00
Total Cost	\$64.00

EPROM will store all the long term data and information for future use. The cost of this item is low for the many different types available.

Rechargeable batteries are very affordable and reliable. The battery we will use can provide more than enough power to fit the design specifications. The higher cost buy-in of rechargeable batteries will be recouped through the multiple reuses of the rechargeable battery.

The project box is very practical since this device is supposed to be mobile. The components of the device need to be contained for the purpose of mobility. For the prototype we will use a pre-manufacture standard case but in the future a container could be designed for optimal performance.

References

¹ "Information Links." *ECE Design Team 10*. Web. 07 Feb. 2010.

<<http://www.egr.msu.edu/classes/ece480/goodman/spring08/group10/documents/documents.htm>>.

² "ECE480: Design Team 6." *ECE Design Team 6*. Web. 07 Feb. 2010.

<<http://www.egr.msu.edu/classes/ece480/goodman/fall09/group06/>>.

³ "Amazon.com: Tech 4 O SI- Ski 1 Speedometer: Sports & Outdoors." *Amazon.com: Online Shopping for Electronics, Apparel, Computers, Books, DVDs & more*. Web. 08 Feb. 2010. <http://www.amazon.com/Tech-2831000-SI-Ski-Speedometer/dp/B000EQ82IM/ref=pd_sxp_f_r/191-3981142-2188238>.

⁴ CopRadar.com -- subsidiary of Sawicki Enterprises (1999-2000). "Doppler Principles (Police Traffic Radar Handbook)". CopRadar.com -- subsidiary of Sawicki Enterprises. <http://www.copradar.com/preview/chapt2/ch2d1.html>. Retrieved July 17, 2009.