The Skiidometer

Senior Project Description
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**Functional Description**

**Introduction**

I have been skiing since I’ve been able to walk. As my skills have improved, and as ski technology has progressed over the last couple decades, I have been overcome with a need for speed. However, there does not seem to be a device for measuring velocity for the avid skier and snowboarder. The project I propose to build over the course of the next several months is what I call the Skiidometer. It will be a simple device which will serve as a digital companion on the ski slopes. By using a Global Positioning System (GPS) receiver, the user can see their current position, velocity, altitude, and distance traveled. These useful measurements can be found on a convenient handheld portable device with an easy to read Liquid Crystal Display.

**Hardware and Applications**

The final design for the Skiidometer will be lightweight, portable, waterproof, and shockproof (Figure 1). Encompassed in a relatively small enclosure, it may be easily carried in a coat pocket or backpack. This unit is the brains of the operation because it contains the GPS receiver, antenna and the microcontroller. Designed for use on the mountain, a portable power supply will be used. This supply will consist of four AA NiMh batteries. Mounted within the main unit will be a 4 x 20 Liquid Crystal Display (LCD1), backlight button, and power button.

![Figure 1 – System Hardware](image-url)
The main function of the Skiidometer will be the “quick glance” digital speedometer. It will exist separately from the rest of the portable unit for instant viewing while hurling down the mountain at heroic velocities. The current velocity will be displayed on a large character 4 x 20 display, (LCD2). The display will be mounted on the user’s wrist, or some other convenient place for an easy view. Incorporated onto this digital speedometer will be a set/reset button. The set/reset button will serve as the user control for recording data such as average velocity, distance traveled, and change in altitude. The external unit (Figure 2) will be connected to the main unit by a serial connection along with two other wires for button communication with the microcontroller.

Figure 2 – Sketch of Assembled Hardware
Final product dimensions for the main unit are to stay within 5.0” high, 5.0” wide, 1.0” deep, while the maximum dimensions for the external display are 2.5” high, 4.5” wide, and 0.5” deep.

A detailed block diagram of the Skiidometer hardware is illustrated in Figure 3. As shown, the main components of the hardware system revolve around the Motorola microcontroller -- M68HC12B32. This is the controller that handles the tasks of the user interface between the displays and the push buttons and manipulating the received GPS data. The main components include the Motorola Hawk antenna, Motorola M12+ GPS receiver, two LCD displays, four push buttons (power, set/reset, (2) LCD backlight), and the portable power supply. The GPS receiver is an essential component to the hardware system. It transmits all the necessary data for the Skiidometer to properly function.

**Figure 3 – Functional Hardware Diagram**

**M12+ GPS Receiver**

The M12+ is the GPS receiver module device manufactured by Motorola. The GPS receiver obtains data such as position, velocity, and time by continuously tracking the NAVSTAR satellites. The NAVigation Satellite Timing and Ranging (NAVSTAR) GPS is an all weather radio based satellite navigation system that enables users to accurately determine their 3-dimensional position, velocity, and time worldwide. The
The overall system consists of three major segments: the space segment, the ground (control) segment, and the user segment. Figure 4 illustrates this concept.

The space segment is a constellation of satellites. The constellation is composed of twenty-four satellites, twelve of which the M12+ uses for global positioning. The satellites operate in circular 20,200 km (10,900 nm) orbits at an inclination angle of 55 degrees and with a 12-hour period. The satellites transmit on two L-band frequencies: \( L_1 = 1575.42 \text{ MHz} \) and \( L_2 = 1227.6 \text{ MH} \). The ground control segment consists of a master control center and a number of widely separated monitoring stations. The ground network tracks the satellites, precisely determines their orbits, and periodically uploads this information and other system data to all satellites for retransmission to the user. The user segment is the collection of all GPS user receivers, like the Motorola Oncore M12+ GPS Receiver that I’ll be implementing. The GPS Receiver’s position is determined by the geometric intersection of several simultaneously observed satellites, to receiver distances from satellites with known coordinates in space. In the case of the M12+, it uses 12 of the 24 satellites. The 12 satellites send their signals to earth which are received all in parallel to determine worldly position. The M12+ GPS receives the data and measures the transmission time required for a satellite signal to reach the receiver. The receiver manipulates all 12 of these times to establish the user’s three-dimensional position.

**Hawk Antenna**

The Skiidometer uses an antenna that receives the data at 1575.42 MHz and transmits the data to the GPS. The 3Vdc version of the Hawk GPS Antenna is designed to operate with Motorola’s M12+ Oncore GPS receiver, as well as many other 3Vdc GPS receivers from other manufacturers. Once the antenna receives the coded GPS
satellite signals they are digitally processed by the M12+ receiver. This information is a full range of navigation data consisting of position, velocity, time, and heading. This data is then sent to the Motorola HC12 microcontroller by serial link for further manipulation.

**M68HC912B32**

As previously stated, I will be using Motorola’s M68HC912B32 microcontroller (HC12). The HC12 resources used are shown in Figure 3. The HC12 receives the navigation data in serial TTL form through its SCI port (PS0-1). This data is then manipulated to output the appropriate statistics onto the LCD1 display. Port A (PA0-7) and Port B (PB0-2) connect the 11 I/O lines which the LCD1 needs to function. The other serial connection on the HC12 is the SPI. This will be used to operate the second display (LCD2) on the (PS5) pin. The connection must first be run through a SCI to SPI converter (MAX3100). The four push buttons, Power and Set/Reset, and the two LCD light buttons use Port B on the pins (PB4-7).

There is memory available on the HC12 to store data from the GPS receiver. The main program written to operate the unit will be stored in the 32k bytes of Flash EEPROM/ROM. The 1k byte of RAM will be used to store the navigation variables from the GPS receiver for further examination. The 768 bytes of EEPROM is non-volatile memory. All the data over the course of the day on the slope will be stored here. This data will be the navigation data like average velocity, total distance traveled, and changes in altitude.

Two other major components of the Skiidometer will be the two backlit LCD displays. LCD1 will display the current altitude, time, heading, and position (Latitude & Longitude). LCD2 will display the current velocity in MPH.

The power supply used will be 4 AA batteries (Table 1). The input voltage will be 6 VDC. This input voltage will be regulated by two DC to DC converters. One output will be 5.0 VDC to supply power to the LCDs and the HC12. The other output will be regulated at 3.0 VDC to supply power to the M12+ GPS and its Hawk antenna.

<table>
<thead>
<tr>
<th><strong>5.0 VDC Supply</strong></th>
<th>Max. Current</th>
<th>Max. Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCU</td>
<td>45 mA</td>
<td>225 mW</td>
</tr>
<tr>
<td>LCD1 (backlit)</td>
<td>100 mA</td>
<td>500 mW</td>
</tr>
<tr>
<td>LCD2 (backlit)</td>
<td>100 mA</td>
<td>500 mW</td>
</tr>
</tbody>
</table>

Total 5V Source power dissipation: 245 mA 1225mW

<table>
<thead>
<tr>
<th><strong>3.0 VDC Supply</strong></th>
<th>Max. Current</th>
<th>Max. Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawk Antenna</td>
<td>20 mA</td>
<td>60 mW</td>
</tr>
<tr>
<td>M12+ GPS</td>
<td>45 mA</td>
<td>225 mW</td>
</tr>
</tbody>
</table>

Total 3V Source power dissipation: 65mA 285 mW

Table 1 -- Maximum Power Dissipation
**Software Description**

The software requirements will be met for the Skiidometer by writing in the C programming language. The written program will consist of six different modules. Each different module will contain its own set of tasks and functions. These software modules will be KERNEL, BUTTON, LCD_1, LCD_2, NAV_DATA, and MAIN. The following is a list of each module and the description of what it will do:

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KERNEL</td>
<td>MicroC/OS-II will be used for the timing, as a preemptive kernel and will handle task switching, scheduling, and event services.</td>
</tr>
<tr>
<td>BUTTON</td>
<td>This will serve as a monitor for button activation and debouncing.</td>
</tr>
<tr>
<td>LCD_1</td>
<td>This module will have functions necessary to keep the display on the main unit working properly. Its functions will include the initialization and the backlight operation.</td>
</tr>
<tr>
<td>LCD_2</td>
<td>This module is the same as LCD_1, but will be applied to the LCD2 and will include the configuration for the SPI to SCI conversion.</td>
</tr>
<tr>
<td>NAV_DATA</td>
<td>This module will read the navigation data which the M12+ receives. It will organize the data and store them as variables.</td>
</tr>
<tr>
<td>MAIN</td>
<td>The MAIN module will continuously keep the LCDs updated with current navigation data.</td>
</tr>
</tbody>
</table>

**User Interface Description**

The user interface will be quite simple to operate. It will consist of two LCDs and four push buttons. Figure 2 shows where one can find these items on the Skiidometer. Both LCDs will be a 4 row by 20 column display with a backlight. When the power button is held in for 2 seconds the Skiidometer is turned on. At this moment both LCDs are initiated and turned on also. Both the LCD’s backlights are turned on for five seconds to signify the powering up process. Figure 5 shows what the user will see when the system is powered up.
When the M12+ receiver is online with the navigation satellites the letter “O” will appear in the bottom right corner of LCD 1. LCD 2 is a 4 by 20 display, however it allows for a big character mode. This mode is perfect for the user to quickly glance down to read the current speed. LCD 2 simply serves as the speedometer and it always display the current velocity. The navigation data, including velocity is continuously updated at a chosen rate between 1-255Hz.

The power button is activated when pressed for 2 seconds. Whether the Skiidometer is on or off, it will switch. There will be a second button on the main unit called Light. When in a dim situation, and pressed, this button simply turns on the LCD 1 backlight. LCD 2 has this button also (please refer to Figure 2). This apparatus will also have a set/reset button. This button will be pressed by the user at the top of the ski run. This sets the recorders in motion. The recorders keep track of the velocity, change in altitude, and distance traveled. When the user arrives at the bottom of the ski run then they press the button again to stop the recording process.

**Development Plan**

During this first Fall quarter my development has consisted of a large amount of web surfing. I have done copious amounts of research on the HC12 and the M12+ GPS receiver. The last few weeks have been filled up with writing my project proposal and this project description, and finding/ordering parts. I plan to have all of the necessary components to the Skiidometer by the beginning of the Winter quarter. During the Winter break, I would like to obtain all these necessary parts as well as familiarize myself with the M12+ GPS. I would also like to begin reading Prof. Morton’s text “Embedded Microcontrollers” to get my foot in the door with the C programming language. I took a C++ class several years ago so I must be reacquainted with it. I will write all of my software in “C”. It is necessary for manipulating the GPS navigation data as well as having the user interface operate. The following is a weekly schedule I will try to follow in order to create the Skiidometer.

**Winter Quarter 2003**

Jan. 5 – 11
Connect the hardware together. Test the LCD screens and the M12+.

Jan 12 – 18
Begin work on software. Outline program modules and tasks.

Jan 19 – 25
Setup power supply and voltage regulators.

Jan 26 – Feb 1
Modify existing code for 4 x 20 LCD screens for my application.

Feb 2 – 8
Work on integration of LCDs to the HC12.
Feb 9 – 15
   Work on rough draft for LCD code
Feb 16 – 22
   Work on rough draft for Button interface code.
Feb 23 – Mar 1
   Work on rough draft for initialization code.
Mar 2 – 8
   Writing code…..
Mar 9 – 15
   Dead week, study for finals. Time allowing, write code.
Mar 16 – 22
   Finals

Spring Quarter 2003
Mar 30 – Apr 5
   Work on finalizing code.
Apr 6 – 12
   Work on finalizing code.
Apr 13 – 19
   Work on finalizing code.
Apr 20 – 26
   Week open for unexpected delays.
Apr 27 – May 3
   Review the project prototype design.
May 4 – 10
   Final software integration in prototype.
May 11 – 17
   Prototype testing
May 18 – 24
   Prototype testing
May 25 – 31
   Review software code
Jun 1 – 7
   Dead week, Demonstrate project
Jun 8 – 13
   Finals week,
Jun 14
   DONE.

Development Hardware/Software
The development of the Skiidometer will occur in the Et 340 lab here at WWU. This lab has all the necessary testing equipment and tools for my project development.
The equipment used will include the digital oscilloscope, digital multimeter, programmable power supply, computers, Noral debugger pod, and a soldering iron. The system development hardware I plan to use will include the evaluation boards for both the HC12 and the M12+ along with their software. The software needed to accomplish all this will include the Motorola Winoncore12, as well as the software on the Et 340 computers. These programs include Introl compiler, CodeWright 6.0, and Flex High Level Debugger.

Prototype Demonstration
My demonstration prototype of the Skiidometer will be a standalone system. Construction of the prototype will include mounting the LCD1 and the two main unit buttons in an enclosure which will not exceed 5” by 5” by 1”. The external LCD screen will be mounted on a wrist strap and the two buttons will be mounted on this display as well. A wire wrap will be used to keep the three wires together. Once the prototype is fully functional, I will solder all the components together.

To fully demonstrate the Skiidometer will be a challenge, for the GPS receiver will not function indoors. I will use a poster to help depict how the unit functions, especially the GPS. I may take a digital video recording of the Skiidometer in action. This recording may be played back on a computer in the Et 340 lab for proof of functionality.

Electrical Specifications

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Position: 100 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Altitude: 156 m</td>
</tr>
<tr>
<td></td>
<td>Velocity: .02 m/s</td>
</tr>
<tr>
<td></td>
<td>Time: + - 500 ns</td>
</tr>
</tbody>
</table>

Startup Time (TTFF):  
Hot: 15 s  
Warm: 45 s  
Cold: 70 s

Reacquisition Time:  
After 60 sec. Obstruction: 3.5 s

Data Rate: 1 - 255 Hz Variable Navigation Solution Update Rate

Power Requirements:  
4 -- AA NiMh  
Est. Batt. Life: ~5.5 hours  
Worst case Pwr Diss.: <350 mA (see Table 1)

Special Environmental Req.:  
Outdoor Operation  
Shockproof \ Waterproof enclosure  
Operating Temp. Range: -40° to 85° C
## Preliminary Parts List

<table>
<thead>
<tr>
<th>Description</th>
<th>Part #</th>
<th>Sources</th>
<th>Cost ($)</th>
<th>Current (max)</th>
<th>Lead Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna</td>
<td>01R43913L01</td>
<td>Synergy incl. w/ GPS</td>
<td>20 mA</td>
<td>Have</td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>M12+</td>
<td>Synergy</td>
<td>149</td>
<td>45 mA</td>
<td>Have</td>
</tr>
<tr>
<td>4 x 20 LCD</td>
<td>HC20401</td>
<td>HyeLCD</td>
<td>49</td>
<td>100 mA</td>
<td>Have</td>
</tr>
<tr>
<td>4X 20 LCD</td>
<td>BPP-420L</td>
<td>Scott Edwards Elec.</td>
<td>59</td>
<td>100 mA</td>
<td>2 weeks</td>
</tr>
<tr>
<td>MCU</td>
<td>B32ASSM</td>
<td>Seattle Robotics</td>
<td>19.26</td>
<td>45 mA</td>
<td>2 weeks</td>
</tr>
<tr>
<td>16 MHZ crystal</td>
<td>73-XT49U1600-20</td>
<td>Mouser</td>
<td>0.41</td>
<td>n/a</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Push Buttons</td>
<td>275-1556</td>
<td>Radio Shack</td>
<td>1.25 * 2</td>
<td>n/a</td>
<td>Have</td>
</tr>
<tr>
<td>Push Buttons</td>
<td>275-646</td>
<td>Radio Shack</td>
<td>2.29 * 2</td>
<td>n/a</td>
<td>Have</td>
</tr>
<tr>
<td>Batteries</td>
<td>P107-ND</td>
<td>Digi-Key</td>
<td>.57 *4</td>
<td>n/a</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Battery holder</td>
<td>270-383</td>
<td>Radio Shack</td>
<td>1.59</td>
<td>n/a</td>
<td>Have</td>
</tr>
<tr>
<td>DC/DC conv.</td>
<td>MAX710, MAX711</td>
<td>Maxim</td>
<td>2.95 *2</td>
<td>0.2 mA</td>
<td>1 week</td>
</tr>
<tr>
<td>Reset IC</td>
<td>MAX6314</td>
<td>Maxim</td>
<td>0.99</td>
<td>12 uA</td>
<td>1 week</td>
</tr>
<tr>
<td>PCB</td>
<td>400-964</td>
<td>Mouser</td>
<td>15</td>
<td>n/a</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Case</td>
<td>1599EBKBAT</td>
<td>Allied Electronics</td>
<td>10.66</td>
<td>n/a</td>
<td>2 weeks</td>
</tr>
<tr>
<td>SCI to SPI conv.</td>
<td>MAX3100</td>
<td>Maxim</td>
<td>2.79</td>
<td>0.27 mA</td>
<td>1 week</td>
</tr>
<tr>
<td>Totals:</td>
<td></td>
<td></td>
<td>$322.96</td>
<td>310.47 mA</td>
<td></td>
</tr>
</tbody>
</table>