Component Analysis

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Assignment Evaluation:

Item	Score (0-5)	Weight	Points	Notes
Assignment-Specific Items				
Analysis of Component 1		x2		
Analysis of Component 2		x2		
Analysis of Component 3		x2		
Bill of Materials		x6		
Writing-Specific Items				
Spelling and Grammar		x2		
Formatting and Citations		x1		
Figures and Graphs		x2		
Technical Writing Style		x3		
Total Score				

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

General Comments:
Relevant overall comments about the paper will be included here

IMPORTANT NOTE: The Bill of Materials is a separate document and should be downloaded and filled out for another assignment. The Bill of Materials is to be submitted separately, per the course calendar (possibly on a different week), and will graded collectively with this assignment.

1.0 Component Analysis:

The Snow-weAR Goggles require 6 major components: an OLED display, a GPS receiver, a LoRa Radio transceiver, an Inertial Measurement Unit, an ADC Power Monitor, and a Microcontroller. The OLED display is the primary user interface of the device and relays all relevant information to the user. The GPS receiver collects coordinate information for use in partner tracking. The LoRa Radio transceiver allows the user to locate another user relative to their location. The Inertial Measurement Unit provides acceleration and incline information for speed calculations. The ADC Power Monitor records the current battery levels for the device. The Microcontroller serves as the central computing power for the design and controls all computations and interfacing between components.

1.1 Analysis of Component 1: OLED Display

The Transparent OLED Display is the main form of communication with the user. The display will be placed over the lens of the Snow-weAR goggles so that information can be viewed during use. To minimize view obstruction, the OLED display must have a large transparent active area with little to no opaque sections. The display must also be small enough to aesthetically fit within the user's line of sight through the goggles, which limits the height of the display to not exceed 2.5 inches, the approximate height of snow sport goggles [1].

The Snow-weAR goggles provide the user with various metrics and device information; however, too much visual distraction can be a safety hazard for the user, so the goggles will allow for the user to toggle the currently displayed information to minimize the amount of information provided at any one time while providing clear, concise visuals. The OLED display must therefore be able to update the display quickly, ideally having the option to only update certain subsections of the display at a time. Additionally, having a fully customizable display will provide freedom of display style to improve user experience.

Three Transparent OLED displays were compared for use in the Snow-weAR goggles project: Crystalfontz 128x56 Transparent OLED Display (Crystalfontz) [2], SparkFun Transparent Graphical OLED Breakout (Qwiic) (SparkFun Graphical) [3], and SparkFun Transparent OLED HUD Breakout (Qwiic) (SparkFun HUD) [4]. These displays were chosen based on the size limitations inherent to the design. All three options support I2C and have a large transparent active area relative to the size of the display.




Attribute	TOLED		
	Crystalfontz	SparkFun Graphical	SparkFun HUD
Size	1.38in x 0.603in	1.4in x 0.71in	4.17in x 1.49in
Pixels	128x56	128x56	230 segments
Cost (Single)	$26.08	$39.95	$99.95
Required Components	ZIF Connector $0.84 (5 part min) OLED Breakout Board $11.22 Dev Kit $51.02	None	None
Logic Voltage	3.3v	3.3v	3.3v
Power Voltage	12v	12v	12v
Supported Interfaces	I2C and SPI	I2C and SPI	I2C
Operating Temp	-40-158 F	-40-158 F	-40-158 F
Storage Temp	-40-176 F	-40-185 F	-40-185 F
Demo Code	Available	Available	Available
Weight	0.11 ounces	Unknown	Unknown
Operating Lifetime	Min 5,000 hours	Min 5,000 hours	Min 5,000 hours
Orientation	Wide	Wide	Wide
Display	Customizable	Customizable	Fixed (varying colors)

The SparkFun Transparent Graphical OLED Breakout display was chosen due to its customizable display, large operating and storage temperature ranges, I2C and SPI support, and compact size. The SparkFun Transparent Graphical OLED Breakout display was chosen over the Crystalfontz display, which has many similar features, because of the ease of integration, with no additional required components making the SparkFun Transparent Graphical OLED Breakout display the more cost effective option [5] [6] [7].

1.2 Analysis of Component 2: GPS Receiver

The GPS module needs to be capable of accurately receiving coordinate data and altitude. It must also operate with relatively low power consumption to conserve battery power. Physical size of the component was an important consideration so that it is able to fit within the space constraints of the goggles alongside the other components.

Three GPS modules were looked at as possible solutions for the project. Each module has resources and support available and meets all of the required criteria of the component. They are similar in accuracy and cost but vary in overall size and power consumption.

Device	**BN-880Q [8]**	**SIM808 [9]**	**MTK3339 [10]**
Manufacturer	Beitian	SIMCom	Adafruit
Operating Temperature (C)	-40 to 85	-40 to 85	-40 to 85
Size (mm)	28 x 28 x 8	24 x 24 x 3	16 x 16 x 5
Positional Accuracy (m)	2	2.5	3
Acquisition Sensitivity (dBm)	-160	-147	-145
Power Consumption (mA)	75	44	20 to 25
Supply Voltage (V)	3.0 to 5.5	3.4 to 4.4	3.0 to 4.3
Cost	$35	$30	$30

The MTK3339 was chosen. It is the smallest of the three options and consumes much less power than other options. The MTK3339 also has a sleep mode that can be activated when the GPS is not in use to further reduce power draw.

1.3 Analysis of Component 3: LoRa Transceiver

The purpose of the transceiver chip on each Snow-weAR device is to transmit and receive GPS locations from partner devices across the ski slopes. To achieve this, a low power, high range communication protocol was selected. The physical layer of this protocol is called LoRa (Long Range), and the LoRaWAN communication protocol will be used. Besides low power consumption and rural ranges of up to 10 km, LoRa has the added benefit of operating within unlicensed frequencies over a frequency band of 12 MHz and the option to expand the network into a mesh capable of extending range and capabilities with more users [11].

Two chip candidates were investigated. They were selected because of the availability of support and a development kit for each chip. Newer chip options were considered but ruled out before the research phase due to lack of documentation, development options, and limited supply.

The two primary constraints on the chip were power consumption and cost. Ultimately, the system needed to cost less than similar athletic feedback technology on the market. The budget allocated $60 for the transceiver and antenna, but this budget approached the cost of more expensive solutions on the market, and so lower cost methods were prioritized. Power was also a significant factor across all components, because many high consumption components such as GPS, radio, and the OLED display have to be powered.

Below is a comparison of both chips considered:

Device	**RFM95W [12]**	**SX1276 [13]**
Manufacturer	Hope RF	Semtech
Frequency Range (MHz)	868/915	868/915
Bandwidth (kHz)	7.8 to 500	7.8 to 500
Operating Temperature (C)	-20 to 70	-40 to 85
Power consumption (Idle) (uA)	1.5	1.5
Power consumption (RX) (mA)	10.8	10.8
Power consumption (TX) (mA)	20 to 120	20 to 120
Supply Voltage (V)	1.8 to 3.7	1.8 to 3.7
Cost	$20	$9

The SX1276 was chosen. For development purposes, a module by Seeed Studio will be used. This chip was selected, because it is lower cost and also has more support and datasheets available from Semtech and other 3rd party providers.

1.4 Analysis of Component 4: Inertial Measurement Unit

The Inertial Measurement Unit will be responsible for supplying accurate data of the following metrics: degree of tilt in the YZ plane, cardinal direction, and acceleration. To accomplish this, the chosen IMU requires a gyroscope, an accelerometer, and a magnetometer. Preliminary research was conducted on the Adafruit LSM6DSOX 6 [14] and the SEN-12756 [15], but neither was equipped with a magnetometer and so were removed from consideration. The SEN-12756 is included in the below chart to gauge whether losing a magnetometer would be made up for with superior performance in other areas. The remaining two IMU chips compared are the SparkFun OpenLog Artemis [16] and the Adafruit BNO055 Absolute Orientation Sensor [17].

Device	**OpenLog Artemis**	**BNO055**	**SEN-12756**
Manufacturer	Adafruit	Adafruit	Sparkfun
Supply Voltage (V)	3.3 to 6.5	3.3	1.95 to 3.6
Frequency	250Hz	100Hz	Unknown
Interface	SPI	12C	12C
Cost	$49.95	$19.95	$9.95

While the OpenLog Artemis has a dedicated battery and flash, the BNO055 was chosen as it supports nine degrees of freedom, gravity vectors, and has an ambient temperature sensor rated for -40 degrees celsius.

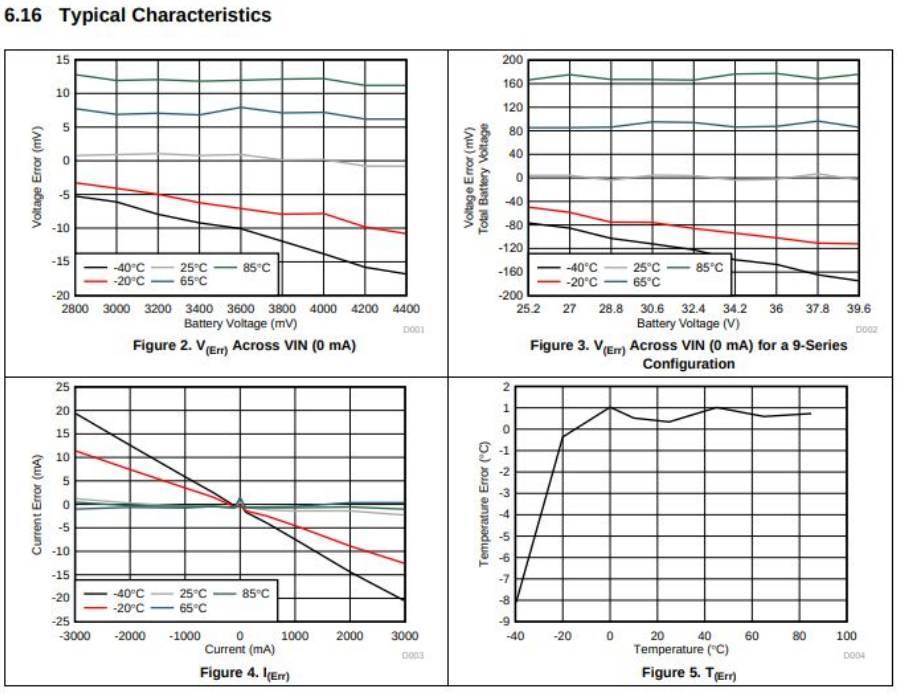
1.5 Analysis of Component 5: Coulomb Counter

The coulomb counter is included in the system to assess power usage and other statistics while the device is in use. This is an important feature, as battery levels are a particular concern with certain high power components such as GPS, radio, and an OLED display. Monitoring power consumption will allow the user to assess battery life and make decisions accordingly.

The coulomb counter has to be able to relay digital data that contains enough information for the main processor to estimate charge remaining within 10%. It does this by integrating current over time. The device chosen communicates with the microcontroller via an I2C interface.

The main priority for this feature is to require as little overhead as possible from the main microcontroller to free up RAM and flash for more product-relevant processes. Measuring power and energy consumption requires significant processing power, so a chip with an embedded ADC and an internal power accumulator that relays the already processed information to the main microcontroller was favored.

The BQ34110PW by Texas Instruments was selected [18]. It uses I2C communication to relay state of charge, time to empty, and state of health data, and was the only integrated circuit examined that processed data to that extent to minimize processing load on the main microcontroller. It also has low error across target temperatures of 0 degrees Celsuis.



Analysis of error across temperature ranges for the BQ34110PW

1.6 Analysis of Component 6: Microcontroller

Based on the chosen components for the Transparent OLED Display, LoRa Radio Transceiver, IMU, GPS, and ADC, the microcontroller used for the Snow-weAR Goggles must meet the following criteria:

Device	OLED	LoRa	IMU	GPS	Coulomb Counter	Micro Requirements
Interface	SPI/I2C	SPI	I2C	SPI/I2C	I2C	3 SPI, 2 I2C
RAM	1kB	N/A	N/A	N/A	N/A	5kB
Flash	10kB	1.2 kB	N/A	N/A	1 kB	20kB
Data Rate	400kbps	18 bps	100bps	9.6kbps	200 kbps	400kbps
Voltage	3.3 V	1.8 V	3.3V	3.3V	2.7 V	3.3 V

The microcontroller is the integrating component of the Snow-weAR goggles which must interface with all secondary components. Three candidate Microcontrollers were compared: the STM32L4 [19], the Teensy 4.0 [20], and the ESP32 Feather Board [21]. The microcontrollers were chosen based on the team members previous and current experiences with the microcontroller family hardware both in Purdue courses including ECE 362 and ECE 40862 as well as outside projects. The specific microcontroller within each family was chosen based on the peripheral and memory requirements stated above.

Attribute	Microcontroller		
	STM32L452CEU6	Teensy 4.0	ESP32 Feather Board
Size	7mmx7mm	6.26 x 5.12 x 0.31 in	50mm x 23.5mm x 19.0mm
Cost (Single)	$7.72	$19.95	$19.95
Power Supply	1.71V - 3.6V	3.3V	3.3v
Temperature Range	-40-85C	0-70C	-40-125C
RAM	160KB	1024KB	520KB
Flash	512KB	2048KB	4MB
Analog Peripherals	ADC, DAC, OpAmp, comparators, reference	2ADC, 14 pins	12ADC, 2DAC
I2C	4	3	2
SPI	3 (plus 1 Quad SPI)	3	3
Temp Sensor	Yes	No	No
Availability	Available Now from US vendor	Available now from SparkFun	Unknown

The STM32L4 microcontroller was selected based on its versatility, with a greater number of I2C and SPI peripherals, built-in temperature sensor, adequate memory, and familiarity/support resources from the team members and teaching staff. The STM32L Series has many variations of microcontrollers within the family, so implementations could be transferred to a similar microcontroller in the family if required.

2.0 Sources Cited:

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