DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Design document for

Ison

Submitted to:

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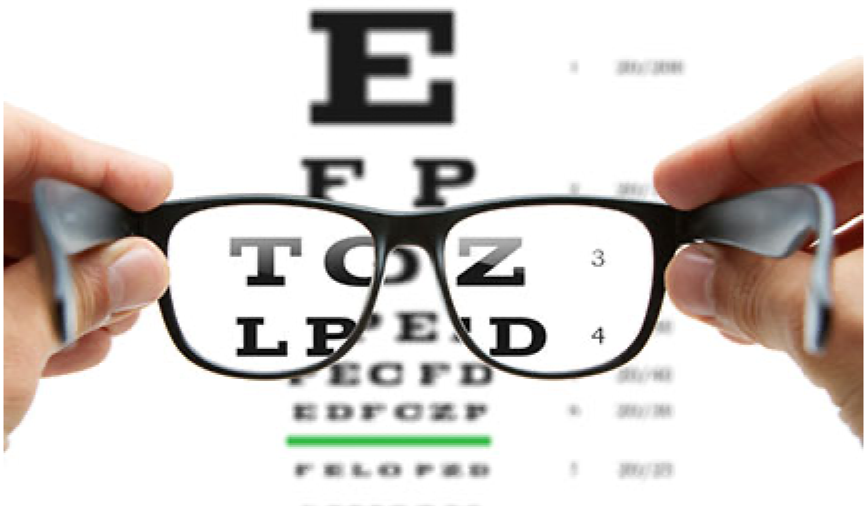

[Image source: https://www.morningside-eye.co.za/treatments-poor-vision]

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LIST OF ABBREVIATIONS

AI - Artificial Intelligence
BLE - Bluetooth® Low Energy
CNN - Convolutional Neural Network
CRNN - Convolutional-Recurrent Neural Network
GPS - Global Positioning System
IEEE - Institute of Electrical and Electronics Engineers
LSTM - Long Short-Term Memory
mAh - milliampere-hours
mm - millimeters
OCR - Optical Character Recognition
PCB - Printed circuit board
RNN - Recurrent Neural Network
V - Volts

EXECUTIVE SUMMARY

Many people with visual impairments struggle to read physical text that they encounter in their day-to-day life, like restaurant menus and billboards. This struggle affects their quality of life. Ison helps people with visual impairments by providing them with more independence. Ison is a pair of smart reading glasses that converts printed text to speech for the user to hear. Similar products are already on the market, but they are much larger and attract attention. Unlike the competitors, Ison offers discreet reading assistance with other convenient features, like translation and extended battery life. Figure 1 shows an overview of Ison's design.

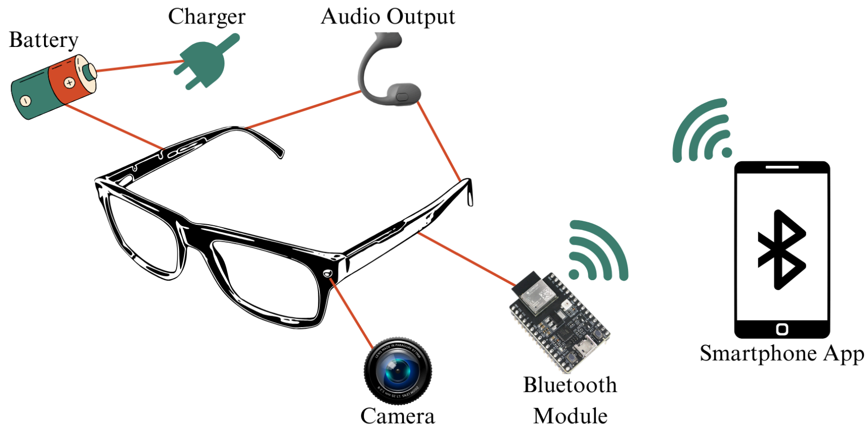

Figure 1: Ison Overview

It is critical that Ison meets the user's needs, so the team followed several constraints and requirements. To ensure Ison users' comfort, the glasses weigh less than 100 grams. The companion app takes less than 5 minutes to set up and uses a screen reader to guide users through the set-up process. To guarantee accurate text recognition, Ison's camera captures images in 1920 x 1080 resolution. Optical character recognition (OCR) software then detects text in these images with 95% accuracy. The audio output has adjustable volume, ranging from 60 to 90 decibels, to provide safe listening. To ensure reliability, the glasses can withstand a 5'8" drop and operate for at least 7 hours on one charge.

Ison's design approach comprises various choices to optimize each subsystem. To enable Ison's functionality, a small Bluetooth module attaches to the glasses to connect them with the user's smartphone. The Ison glasses run on a 3.7-V battery that powers the electronic modules, including the audio transducers, camera, and Bluetooth module. A charging module is connected to the battery which recharges when plugged into a power source. Ison utilizes a built-in OCR model that uses machine learning to recognize text in images. Similar to how humans improve their reading skills through practice, the accuracy of Ison's OCR process improves through machine learning training methods and usage over time.

Ison offers a wearable solution for those who have difficulties with reading. Ison also offers translation capabilities with support for three languages, but the language selection will be expanded upon in the future to accommodate more languages. The companion application has an easily traversable user interface with options to change language, setup Bluetooth, and adjust volume. Furthermore, Ison will offer a variety of frame sizes and styles to accommodate the user's preferences. Ultimately, Ison aims to increase user independence, and the design team plans to add more frame customization and built-in features, such as a smart assistant, GPS navigator, and more.

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1. DESIGN REQUIREMENT/ CONSTRAINTS

Ison is designed to improve the lives of users with visual impairments. Ison glasses integrate into the user's life by providing comfort and utility for everyday use while maintaining a discreet appearance. This product features a camera that detects text and speakers that read this text to the user. The camera image data is sent to a connected smartphone which performs the text to speech conversion, and then the audio data is sent to the speakers to be read aloud. This document is divided into three major sections explaining the design requirements, constraints, and standards of the Ison glasses.

1.1. Design Requirements

The product adheres to specific marketing and engineering design requirements. These requirements set guidelines for the functionality of the product and its integration within society. The marketing requirements explain the project's goals from the perspective of the user. In contrast, the engineering requirements are the descriptions of the technical specifications needed to implement these marketing requirements.

1.1.1. Marketing Requirements

Ison's marketing requirements outline the project's objectives from the user's standpoint. The list below describes the specific marketing requirements in order from most general to most specific. Figure 2-1 shows a more detailed visual layout of the marketing requirements.

1. Ison is comfortable and discreet.
2. Ison is easy to use.
3. Ison is rechargeable and works for at least eight hours.
4. Ison detects physical text in different fonts and languages.
5. Ison converts text to audio.
6. Ison's companion app allows the user to change the output volume and language.
7. Ison accurately reads text to the user within five seconds.

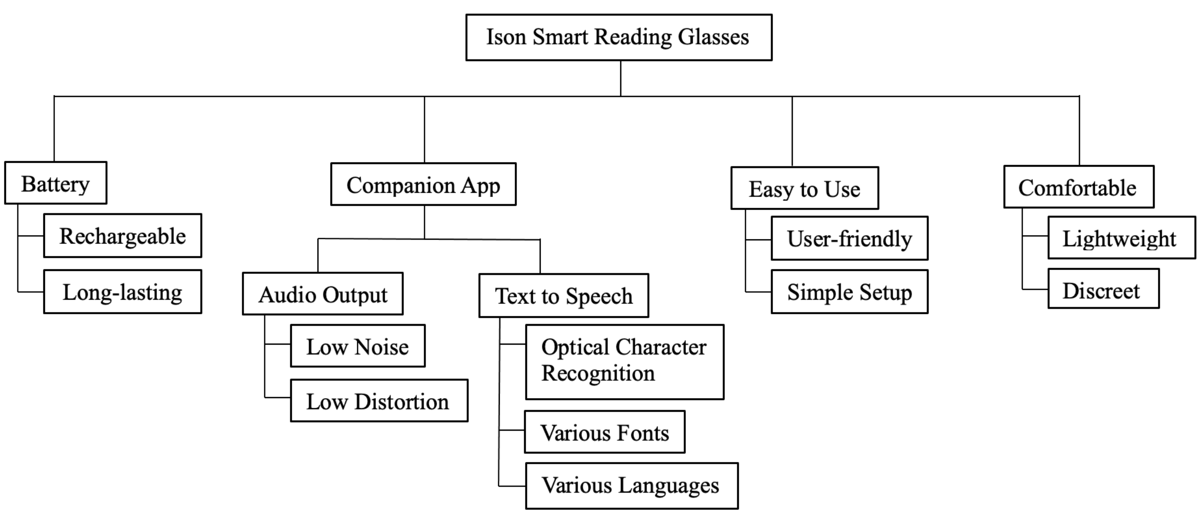

Figure 1-1: Objective Tree for Ison Glasses

Figure 1-1 displays Ison's marketing requirements in more detail. These marketing requirements reflect the user's needs which influences the technical design and requirements of Ison.

1.1.2. Engineering Requirements

Ison's engineering requirements satisfy the user's needs through the implementation of technical specifications. Table 1-1 shows the engineering design requirements and the marketing requirements that they fulfill as well as justification for each engineering requirement.

Table 1-1: Engineering Design Requirements

Marketing Requirements	Engineering Requirements	Justification
1	Ison weighs less than 100 grams.	Typical glasses weigh approximately 25-50 grams [1], Ison glasses will weigh slightly more to account for the additional technology.
2	The average set-up time for the companion app is no more than 5 minutes and uses audio to instruct the user through the set-up process.	The companion app must be easy to set up for people with visual impairments.
3	Ison has a USB-C charging system and a rechargeable battery capable of continuous operation for up to 8 hours.	An 8-hour battery life allows operation for a standard work day. USB-C supports fast charging and shares a cable type with other devices, such as cell phones and wireless headphones.
4, 5	Ison's camera captures grayscale images in 1920 x 1080 resolution.	Mono cameras are easier to operate, and grayscale images are less complex and easier to process [2].
5, 7	Ison recognizes text in various fonts through the smartphone application with at least 95% accuracy.	Artificial intelligence is used in the smartphone application for image processing. It detects text in different fonts and at various angles [3].
6	Ison converts text to speech audio to output through the smartphone application to the user within a range of 60 - 90 dB [4].	Since users with visual disabilities can not read text, Ison reads to users.
Marketing Requirements: 1. Ison is comfortable and discreet. 2. Ison is easy to use. 3. Ison is rechargeable and works for at least eight hours. 4. Ison detects physical text in different fonts and languages. 5. Ison converts text to audio. 6. Ison's companion app allows users to change the output volume and language. 7. Ison accurately reads text to the user within five seconds.		

Ison glasses capture images through the camera built into the glasses, and a Bluetooth module sends these images to the smartphone application. The pairing of the bluetooth module and the smartphone is simple and efficient to avoid frustration for the user. The application uses artificial intelligence to extract text from the images, as it can be trained to detect text similar to how humans read. The application then converts the text to audio and uses the Bluetooth module to send the audio data to the built-in speakers on the glasses. The glasses require a built-in rechargeable battery to operate, and USB-C charging systems are becoming more common in electronics [5]. To increase accessibility, USB-C is used as the charging system since many electronics use them today.

1.2. Constraints

Ison is designed to assist people who are visually handicapped in their everyday lives, but various factors influence the path to achieving this goal. Ison's design is affected by constraints that are both self-imposed and imposed by others. Self-imposed constraints are put in place by the design team to ensure the final product functions as efficiently as it can. Constraints imposed by others are limitations set by stakeholders, like economic factors that affect the time and cost it takes to design Ison. Table 1-2 shows these constraints in more detail.

Table 1-2: Constraints

Type	Name	Description
Reliability	Durability	Ison glasses can withstand normal wear and tear over time and drops from 5'8" – the average height in the USA [6].
Reliability	Battery life	Ison holds a charge for at least eight hours.
Manufacturability	Weight / Size	Ison glasses have an internal frame width under 125 mm, a temple length of 125 to 130 mm, and weigh less than 100 grams.
Economic	Cost	The design team has a budget of $1,000 to build Ison.
Economic	Time	The design team has nine months to design and build Ison, with complete subsystems done by April 2024 and a fully integrated system by November 2024.
Usability	Wireless Communication	Ison transfers data via Bluetooth to a mobile device.
Usability	Application	Ison's companion smartphone application is supported on Android mobile devices.

One constraint is durability, as the glasses should be able to withstand small drops and normal wear and tear without breaking and requiring replacement. Another constraint is weight and size; the glasses should be light enough and small enough that the user can wear them all day without becoming uncomfortable. A major constraint is battery life. Users likely want to wear the glasses almost all day, so the glasses need to have a battery life that allows them to operate for the majority of the day. An economic constraint is cost, as the total project cost can not exceed one thousand dollars. Another economic constraint is time, as the project must be completed within the designated time frame. Finally, the project utilizes Bluetooth to send data to an application on an Android device. The data processing is done on the app. This allows the glasses to avoid having processors on them, which means they weigh less. Android devices are used because Android is an open-source operating system, which allows more customization [7].

1.3. Standards

Ison adheres to the following Institute of Electrical and Electronics Engineers (IEEE) and Bluetooth® Special Interest Group (SIG) standards to ensure safe and optimal operation for consumer use and to maintain interoperability and extensibility.

Table 1-3: Engineering Standards

Specific Standard	Standard Document	Specification / Application
IEEE 1621-2004 [8]	The device follows the IEEE standard for consumer electronics.	Ison manages the user interface of the power status control to ensure a common interface between different devices.
Bluetooth® Core Specification v5.3 [9]	The device follows the protocols outlined for Bluetooth communication by the Bluetooth® SIG.	Ison properly implements Bluetooth® to transmit data to a mobile device for processing and to receive audio data from this device.
IEEE 360-2022 [10]	The device follows the IEEE standard for the architecture of wearable devices.	Ison follows safety standards for wearables regarding temperatures, materials, electromagnetic radiation, and environmental factors.

These standards influence the design methodology for Ison. By adhering to them, the Ison design team ensures interoperability for wireless communication between devices as well as upholding the safest and most reliable practices for handling power in consumer electronic devices.

2. DESIGN APPROACH

This section provides an overview of the design process of Ison and a comparative analysis of two design alternatives. Each choice made in the design process aligns with the previously determined requirements, constraints, and standards. The Design Options section outlines the pros and cons of two design options. The next section provides a comprehensive overview of the system that includes the interconnectionality between subsystems, followed by a section detailing individual subsystem operations. The final section involves a high-level system diagram and an examination of the intended approach to reach a finished prototype.

2.1. Design Options

Design Option 1 involves a modular attachment for glasses that clips directly onto the glasses frame of the user. This design would allow the user to attach the device to an already existing pair of glasses, eliminating the need to buy a new pair of glasses. However, since this design option is not built into the frame like Option 2, the project would have to be compatible with a variety of frames. The variety of existing frame types and sizes makes it difficult to design an attachment that can be adjusted to fit any. This design might also be slightly uncomfortable for the user, as one side of the glasses is weighed down by the attached device. The design that the team settled on involves a built-in camera, speakers, and a Bluetooth® module. Having components that are built into the glasses frame allows the device to maintain a more discreet appearance. Both of the design options rely on the user's smartphone for image processing and text-to-speech tasks. Therefore, both the smartphone and the glasses themselves must be charged for the product to work, which is a minor drawback.

2.1.1. Design Option 1

The original design considered was to house all the electrical components in a container that could be attached to any pair of glasses. Figure 3-1 illustrates what this option would look like and where it would be located on a pair of glasses. The advantage of this option is its versatility. However, this option would stand out from normal glasses and would not be comfortable or easily usable. Since Ison's main target audience consists of people with visual impairments, making a product that requires physical manipulation was not as feasible as the alternative. Moreover, this option would be attached to only one side of a pair of glasses, which is easily noticeable by people around the user and has an uneven weight distribution. The uneven weight distribution on the glasses would be uncomfortable for the user as the glasses would feel lopsided, and this imbalance could lead to the glasses falling off of the user's face. The design team decided not to pursue Option 1 in favor of Option 2.

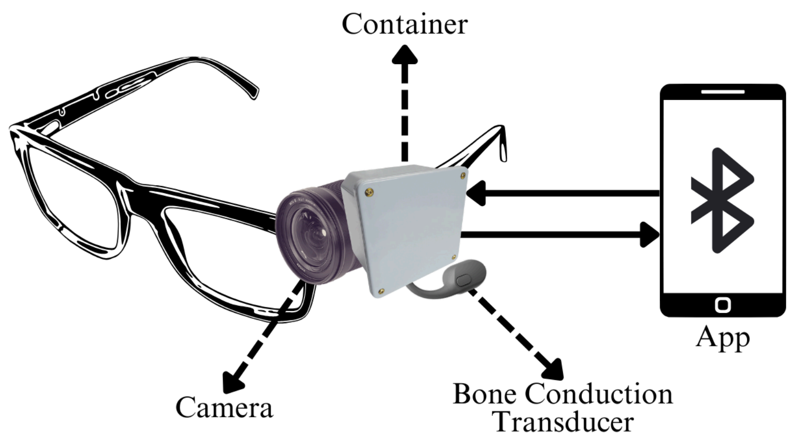

Fig. 2-1: Add-On Functionality Schematic

Figure 2-1 shows the main components of the system, as well as the system's location relative to the glasses frame. A Bluetooth® module within the container sends the visual data captured by the camera to the smartphone application for processing, and the application sends back audio data. This option was not selected because it lacks comfort and covertness.

2.1.2. Design Option 2

The Ison team opted for a 3D-printed pair of glasses with subsystems that are built into the frame. One of the goals of Ison is to make life easier for people with visual impairments, and the built-in design does not require the user to clip an attachment onto the frame themselves, as this task may be difficult for a person with visual impairments. It also lowers the risk of the user losing or damaging the device as a one-piece design is more rigid and withstands drops better than a modular design. This design option also uses a Bluetooth module to send camera images to the companion smartphone application for processing, and the OCR software within the application sends audio files back to the Bluetooth® module. These audio files are played back to the user through the bone conduction transducers. The built-in components allow

Ison to be smaller and more discreet. This design option was selected because it more closely aligns with Ison's goals of comfort and covertness.

While this design option allows the design team to achieve some of the goals, it also makes other goals more challenging. The additional weight from a full pair of glasses with two speakers as opposed to one challenges the goal of keeping Ison's weight below 100 grams. It would also be less versatile than Option 1, as the Ison hardware does not attach to the user's pre-existing glasses. This design requires the hardware to be used with the glasses frame provided. Despite the presented disadvantages of this design option, the design team chose it because it best suits Ison's vision. Figure 2-2 shows where the core components are placed inside of the glasses frame, as well as a basic functionality overview.

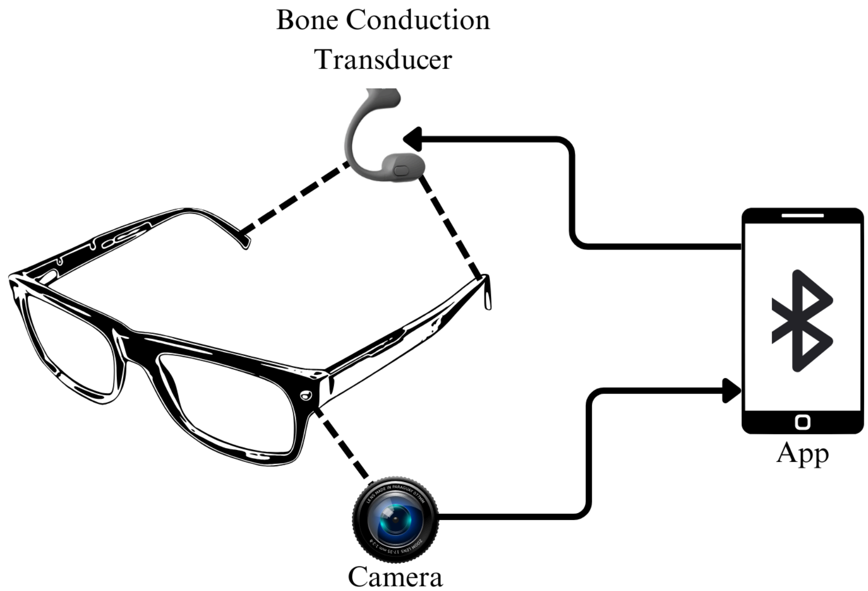

Fig. 2-2: Built-In Functionality Schematic

Figure 2-2 shows the design option that the team selected. The figure visually demonstrates how the information is transmitted and received throughout the system as well as the locations of the components that interact with the software and the user.

2.2. System Overview

Ison is designed to use optical character recognition software to convert visual data from the camera into audio output. Ison's functionality is depicted at a basic level in Figure 2-3. The only inputs that allow the system to function are the visual data recorded by the camera and the battery to power the components. The system seamlessly generates an audio output corresponding to the visual data provided by the camera input.

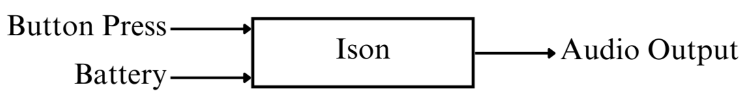

Fig. 2-3: Ison Functionality Overview (Level 0)

Figure 2-4 provides a more in-depth overview of the Ison system functionality, including physical and Bluetooth® connections between the modules.

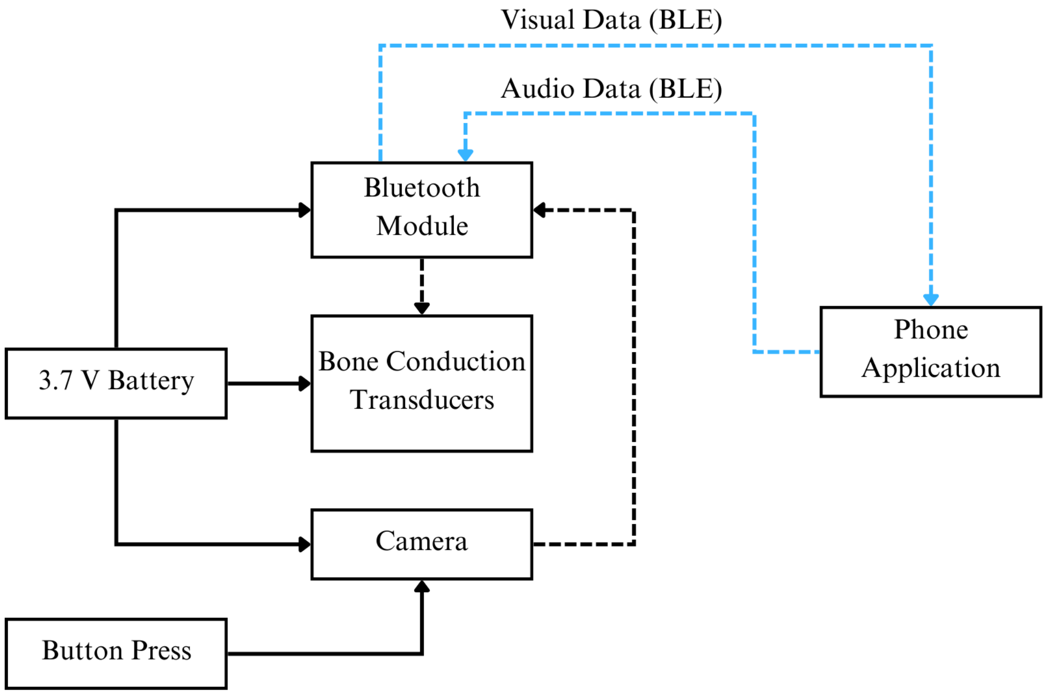

Fig. 2-4: Ison Functionality Overview (Level 1)

All the components within the frames are powered by a 3.7-V lithium polymer, or LiPo, battery. The camera collects visual data, which is then transmitted via Bluetooth to the companion smartphone application. This information is processed into audio data within the app. This audio data is then sent from the app back to the bone conduction transducer subsystem via Bluetooth. The bone conduction transducers convert the audio signals into mechanical vibrations, which audibly read the text recorded by the camera to the user.

2.3. Subsystems

The Ison design consists of five distinct subsystems. Subsystem 1 is communication, which utilizes a Bluetooth® module to transmit information between the camera, the bone conduction transducers, and the user's smartphone. Subsystem 2 is text-to-speech, which uses artificial intelligence to extract text from images taken by the camera built into the glasses and converts it to an audio file. Subsystem 3 is the audio output, which includes the bone conduction modules to play the text-to-speech audio file. Subsystem 4 is power, which is where the device's battery is recharged for the next usage. Finally, Subsystem 5 is the companion app, which houses the text-to-speech AI and manages user preferences.

2.3.1. Subsystem 1: Communication

This subsystem consists of the project's Bluetooth® capabilities. It transmits the picture data and receives the audio output file from the user's smartphone. To avoid the use of unnecessary wires and cords, the communication between the smartphone and the glasses should be wireless. Therefore, Bluetooth® was the simple and logical choice. To maintain a low weight and small size, the selected Bluetooth® module is lightweight and compact. Table 2-1 compares the Bluetooth® options considered.

Table 2-1: Bluetooth® Options

Bluetooth® Module	TX/RX	Data Rate (Mbps)	Size (mm)	Weight (g)	Price
Requirements	**Can Both Transmit and Receive Data**	**50**	**Max. 50 x 40**	**Max. < 30**	**Max. $20**
Sparkfun ESP32-C3 Mini Development Board [11]	Yes	150	46 x 26	~25	$8.95
DigiKey ESP32-C3FH4 [12]	Yes	54	5 x 5	~1	$1.30
Electronic Spices Bluetooth® Stereo Audio Receiver [13]	No	N/A	~15 x 10	~10	Unavailable

The Ison design team decided that the Sparkfun ESP-32 best suits the project requirement because it is capable of its size and transmit/receive capabilities. The ESP32-C3FH4 from DigiKey was the first choice because of its small size. However, the Sparkfun board has a much higher data rate, which is better for sending image and video data. Although it is slightly larger than desired, the ESP32-C3 from Sparkfun was selected because it meets all the necessary criteria and is capable of transmitting images very quickly.

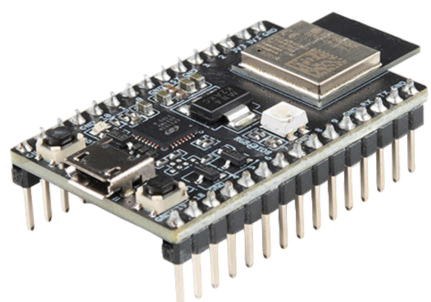

Fig. 2-5: Bluetooth® Module

Figure 2-5 shows the Bluetooth® module: the Sparkfun ESP32-C3 Mini Development Board. The Ison team chose to use this board for its size, weight, and data rate.

2.3.2. Subsystem 2: Text-to-Speech

This subsystem consists of hardware and software to accomplish the text-to-speech conversion task. The hardware component in this subsystem is the camera, which captures images at the push of a button and sends these images to the companion app through the Bluetooth® subsystem. For the camera, the team chose the Waveshare IMX219 because this camera module meets the desired technical specifications set by the team, such as size, weight, and resolution. Table 2-2 compares the camera options considered. In the “Resolution” column, a “p” indicates a progressive scan, and the number preceding it specifies the number of vertical pixels with a horizontal-to-vertical pixel ratio of 16:9 [14].

Table 2-2: Camera Options

Product	Resolution	Field of View	Dimensions (mm)	Weight (g)	Price
Desired Specs:	**Min. 1080p**	**Min. 90º**	**Max. 20 x 20 x 20**	**Max. 30**	**Max. $100**
Waveshare IMX219 [15]	≥1080p	160º	~20 x 13.5 x 15.3	10	$15.99
Vernier WiFi Security Surveillance Camera [16]	720p – 1080p	140º	<30 x 30 x 38	N/A	$34.99
MER2-630-60U3M [17]	3088 x 2064	N/A	29 x 29 x 29	65	$235

The software components of this subsystem are the AI model for optical character recognition (OCR) and the text-to-speech algorithm. OCR is the process of detecting and extracting text from an input image. The Ison team chose to build an AI model and train it from scratch for this task instead of using a pre-trained model. The text-to-speech algorithms take in the OCR text output and convert it to an audio file of an artificial voice reading the text. The audio file is then transmitted back to the Bluetooth® module to be played to the wearer. This process is illustrated in figure 2-6. The text-to-speech algorithms use the pyTTSx3 package [18]. Another text-to-speech Python package, Google Text-to-Speech (gTTS), was considered because it can interface with Google Translate and save speech audio as an mp3 [19]. However, gTTS requires an internet connection, which does not suit Ison's vision. The pyTTSx3 package was selected because it is open-source, supports multiple operating systems, saves speech conversion as an audio file, and works offline. Figure 3-6 shows an overview of how the text-to-speech system works.

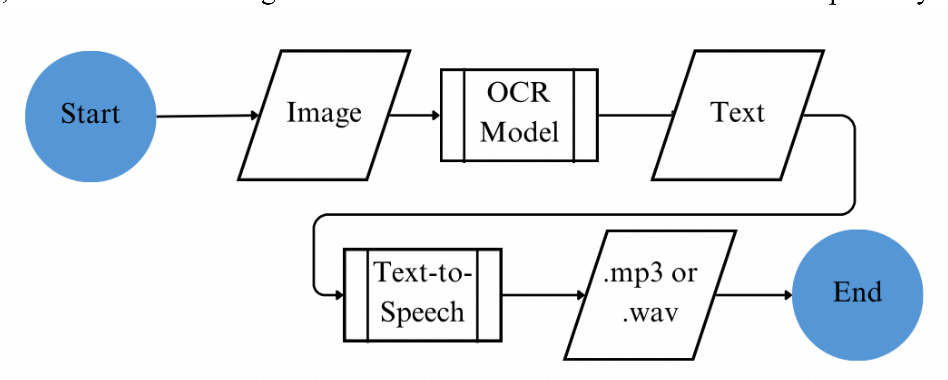

Fig. 2-6: Text-to-Speech Flowchart

Figure 2-6 provides a visual representation of the flow of data through the Ison software, from raw image data to speech audio data.

2.3.3. Subsystem 3: Audio Output

To output audio for the users of Ison glasses, the team chose bone conduction transducers. The audio output subsystem could be implemented with either speakers or bone conduction transducer. The main dilemma with incorporating speakers is the isolation from the user's surroundings and others hearing the audio output. Since bone conduction does not transmit audio through the air but via mechanical vibrations through the skull, the user can still hear their surroundings and discreetly listen to Ison's audio output.

Listed in Table 2-3 are possible bone conduction transducer options, and the selected transducer is shown in Figure 2-7.

Table 2-3: Bone Conduction Transducer Comparison

Audio Output Component	Product Size (mm)	Sound Pressure Level (dB)	Weight (g)	Price
Requirements	**Max. 25.4 x 25.4**	**60 - 90**	**Max. 20**	**Max. $20 (each)**
Adafruit Bone Conductor Transducer with Wires [20]	15.2 x 20.3	90	9.6	$8.95 (each)
Sardfxul Mini Speaker Bone Conduction Loudspeaker For Audio [21]	16.0 x 16.0	95	None Specified	$8.92
Alibaba Bone Conductor Transducer [22]	10.2 x 10.2 x 5.1	None Specified	10	$3.00

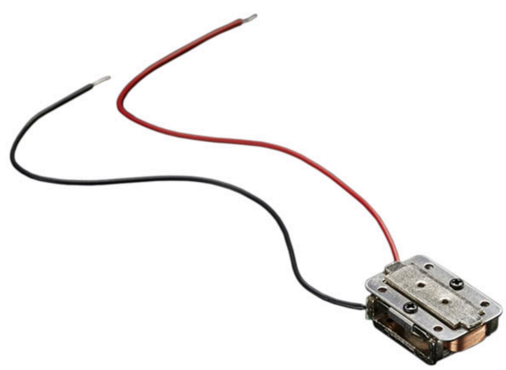

Fig. 2-7: Bone Conductor Transducer [23]

Figure 2-7 shows the Adafruit bone conductor transducer that the Ison team chose to implement because it outputs at an acceptable volume and weighs less than 10 grams.

2.3.4. Subsystem 4: Power

The power supply setup of Ison glasses is pivotal to its functionality. A rechargeable LiPo battery powers Ison's chosen modules. The Ison glasses operate within a voltage range of 3 to 4 volts (V), which is the minimum voltage required to power all the components on the Ison glasses. The AKZYTUE Rechargeable Lithium Battery with a capacity of 1200 milliampere-hours (mAh) supplies the hardware on the glasses with 3.7 V. The battery choice, as detailed in Table 3-4, was driven by multiple factors. While a larger and more powerful battery would be preferable, there are multiple modules housed inside the Ison glasses, so dimensions are important for the battery. Based on this constraint, the Ison team compromised on capacity in favor of smaller dimensions. Initial research and calculations suggest that a 3.7 V/1200 mAh battery provides roughly 11 hours of uninterrupted operation, but additional testing is required.

Table 2-4: Lithium Battery Pack Comparison

Battery Pack	Product Size (mm)	Voltage (V)	Capacity (mAh)	Weight (g)	Price
Requirements	**Max. 50.8 x 50.8 x 25.4**	**3.7**	**Max. 2000**	**Max. 30**	**Max. $50 (each)**
AKZYTUE Rechargeable Lithium Battery [24]	50.0 x 45.9 x 8.9	3.7	1200	28	$11.99 (each)
KP Lithium Battery [25]	39.8 x 35.1 x 11.9	3.7	300	25	$3.50 (each)
AKZYTUE LiPo Battery [26]	53.1 x 35.1 x 7.9	3.7	1500	28	$11.80 (each)

Based on Ison's calculations, the product is expected to get approximately 7 to 11 hours of uninterrupted use, which is a standard workday. By assumption, the glasses operate under a minimum of 25 mA and 1000 mA to reach the time frame. As shown in (1) and (2) below, Ison glasses operate for a maximum time of 11 hours before requiring a recharge.

$$\frac{11}{12}(25\,mA) + \frac{1}{12}(1000\,mA) = 106.25\,mA \tag{1}$$

$$\frac{1200\,mAh}{106.25\,mA} = 11.30\,h \tag{2}$$

The AKZYTUE battery is the best option because of the capacity, product size, and duration, even though the pricing is high and the weight is 28 g. The chosen battery is shown in Figure 3-8.

Fig. 2-8: Lithium Polymer Battery [21]

Charging a 3.7-V lithium battery to 5 V typically involves utilizing a charging module specifically designed for this purpose. Table 3-5 shows the charging module picked for Ison based on the output voltage, weight, and size. The chosen charger module includes protection features such as overcharge protection, overcurrent protection, and charge cut-off to safeguard both the battery and the charging circuitry, as the low voltages Ison operates with do not require any of them. Considering the functionality of Ison, the charging module effectively facilitates the transformation of the input voltage to the appropriate level, enabling the battery to be charged quickly and efficiently.

Table 2-5: Lithium Battery Charger Module Comparison

Charging Module	**Product Size (mm)**	**Output Voltage (V)**	**Capacity (mAh)**	**Weight (g)**	**Price**
Requirements	**Max. 101.6 x 76.2 x 25.4**	**5**	**Max. 1500**	**Max. 5**	**Max. $25 (each)**
HiLetgo Lithium Battery Charger Module [25]	101.6 x 63.5 x 12.7	5	1000	5	3 pcs for $5.99
Adafruit PowerBoost 500 Charger [26]	22.8 x 38.0 x 2.03	5	1000	4	$14.95 (each)
ICSTORE DC Charging Boost [27]	24.9 x 20.1 x 54.9	5	1000	10	2 pcs for $1.99

The chosen charger module is shown in Figure 2-9.

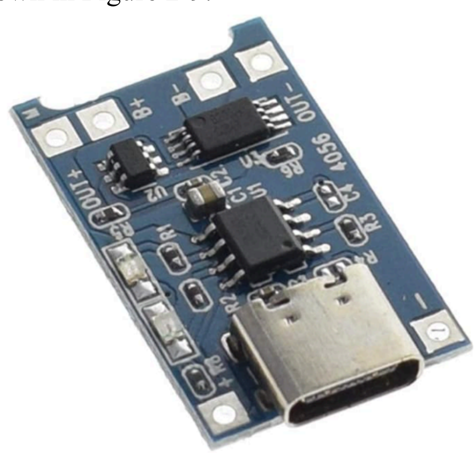

Fig. 2-9: HiLetgo Lithium Battery Charging Module [25]

This module was selected because it holds a charge longer than the other options. Although it is slightly larger than the other options, the 3D-printed glasses frame allows enough room for the charging module as well as the other components.

2.3.5. Subsystem 5: Smartphone Application

Ison has a companion app that works as a processor while featuring language selection and volume settings options. Moreover, the app also has a Bluetooth® setup selection that allows the user to connect the app to the glasses. This connection audibly communicates to the user to allow for a smooth and easy connection. The Bluetooth® feature on the glasses transmit and receive the sensor data with the app. The app functions can be viewed in Figure 2-10.

Fig. 2-10: Smartphone Application User Interface Mockup

Figure 2-10 shows a mockup of the companion application's user interface. This interface consists of a language selection, Bluetooth® setup, and volume settings. All three of these options use large graphics to help users with visual impairments, and text is inserted above these graphics so that screen readers can read the text in each block to the user and they can click the corresponding block.

2.4. Level 2 Prototype Design

The Ison product consists of five seamlessly integrated subsystems. The product has a fast and accurate return rate while also maintaining visual appeal. The Ison app interface is user-friendly with language selection and volume adjustment. The Ison glasses can detect and transmit text from a multitude of languages and document types in different settings. Moreover, the glasses are able to maintain a charge for up to 11 hours.

2.4.1. Level 2 Diagram

The Ison system starts at the foundation of power, which is the 3.7-V LiPo battery. This battery can maintain an 11-hour charge that can then be recharged using the lithium battery charger. The battery is used to charge the Bluetooth® board, bone conduction transducers, and Waveshare camera. The Bluetooth® board can receive and transmit image and audio data to the user's smartphone. The app is where the processing of sensor data takes place by utilizing the text-to-speech subsystem. Furthermore, the text-to-speech subsystem uses OCR software to detect text from the visual data and then converts that output into audio data. This detection can change depending on the users' alterations within the app. The app then sends this audio data back to the Bluetooth® module. Moreover, the app allows the user to change the volume of the audio output and the language being detected and transmitted. An overview of how these subsystems interact is shown in Figure 2-11.

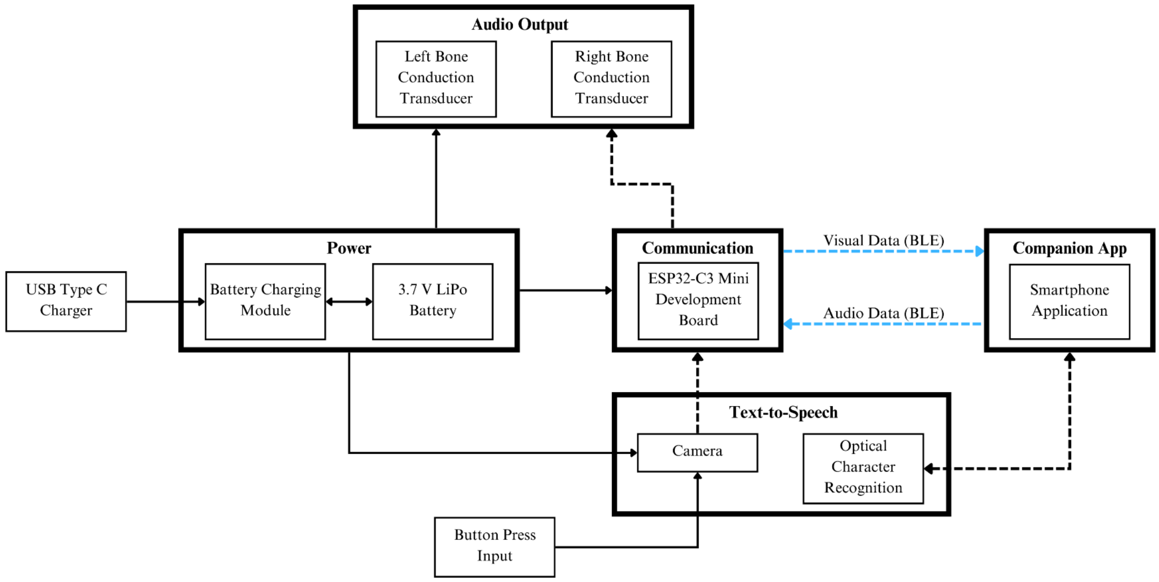

Fig. 2-11: Ison Functionality Overview (Level 2)

Ison is designed to allow individuals with a visual impairment to input visual text. Reading aid is accomplished by the intricate integration of the project's subsystems: power, communication, companion app, text-to-speech, and audio output.

3. EVALUATION

The Ison glasses contain five key subsystems: the power supply, the Bluetooth® system, the companion application, the text-to-speech system, and the audio output. Testing must be performed on each of these subsystems to ensure they work as intended before system integration can begin.

3.1. Test Certification: Power Supply

Testing the power supply involves a full evaluation of both the power source and other electronic modules. This subsystem includes the rechargeable LiPo battery, power circuitry, and the charging module. The first test is verifying the battery's capacity and performance under various conditions to ensure it meets the required energy outputs. This testing will showcase its ability to deliver a consistent voltage and current to the Bluetooth® module, camera, and bone conduction transducers for the glasses. The next test is the power management circuitry where it will be examined for effective power distribution, the prevention of overcharging, and necessary protections against short circuits or overheating. The other test is the charging module whose durability and functionality are tested while maintaining a secure connection and supporting efficient charging. Throughout these testing processes, the power supply subsystem's performance is monitored for any issues or inefficiencies that could affect the user's experience such as reduced battery life or power failures. An additional test is the weight of the power supply on the glasses to ensure that it is comfortable for users.

3.2. Test Certification: Bluetooth® System

Three tests will be performed on the Bluetooth® module to verify proper functionality. Two of the tests require a connection between the module and a smartphone, so the first test verifies that the Bluetooth® module can properly connect to a smartphone. Five different phones will be paired with the module one at a time to ensure the module can connect to any phone that an Ison user may have. The Ison glasses must be able to transmit and receive data from the user's smartphone. Visual data from the camera on the glasses is transmitted from the Bluetooth® module to the smartphone, where text-to-speech processing is performed in the companion application. Audio data is then sent back to the Bluetooth® module, where it is played through the audio output on the glasses.

The second Bluetooth® system test verifies that data can be transmitted to a smartphone. While the Bluetooth® module is connected to a computer, the Arduino IDE can be used to input numbers or letters that are then sent to the smartphone through the Bluetooth® module. To verify that the numbers were transmitted to the smartphone, a serial Bluetooth® terminal application can be downloaded, where any symbols transmitted will appear in their hexadecimal ASCII form. For example, a "1" transmitted through the Bluetooth® module using the Arduino IDE will appear on the smartphone terminal application as "0x31".

The third and final Bluetooth® system test verifies that data can be transmitted from the smartphone back to the Bluetooth® module. The setup for this test is identical to the second test, but a number or letter inputted in hexadecimal form through the smartphone will appear in the Arduino IDE terminal in ASCII form. When "0x31" is put in the smartphone Bluetooth® terminal, the number "1" will appear in the Arduino® IDE terminal. These three tests verify that the Bluetooth® module can connect to a smartphone and data can be transmitted to and from a smartphone, which are required features of the Ison glasses.

3.3. Test Certification: Companion Application

For the companion app to be fully functional it needs to be downloadable on all types of Android phones and work properly across all its capabilities, including language selection, Bluetooth® connection, and volume control. To ensure these functionalities, we need to test the app under various conditions. Firstly, we will verify that the app can be downloaded on multiple Android phones and that it functions as expected. The testing process consists of three trials. The first test will evaluate the app's ability to connect to the Bluetooth® module via bluetooth selection. We need to validate the app's connection to the Bluetooth® module on the glasses. To test this, the app will display a loading screen, and when it successfully connects to the module, it will indicate success by displaying the word connected. The second test will check the app's ability to change the language of the relayed speech, whether it be English, Spanish, or French. We will select all three languages and ensure that the language relayed back to the user matches the selected option. The third test will assess the app's ability to adjust the volume of the bone transducers based on the audio bar selections. This will be done by changing the volume on the app while listening to the bone transducers' output. These three tests will determine whether the app's functions are working correctly or if further action is needed. We will repeat these tests on multiple Android phones to ensure multi-device compatibility.

3.4. Test Certification: Text-to-Speech System

The main high-risk component of the text-to-speech subsystem is the AI which is trained for optical character recognition. Testing for the subsystem will determine if the image quality, image processing, and detection accuracy are all satisfactory for the final product. Image quality passes or fails based on the team members' assessment of the clarity of test images containing text from the camera under test. Image processing tests will be judged similarly, but the images under test will be post processing. This will help the team determine the size to readjust all input images since the neural network input size is based on the pixel height and width of images. The final test will determine the detection accuracy by running the OCR program on images containing. Accuracy will be measured as a percentage of the individual characters (letters & numbers) that were correctly detected. Results of this testing will determine if more training is needed and the specific cases that the AI struggles with.

3.5. Test Certification: Audio Output

For the audio output, two tests will be performed. One for ensuring the decibel intensity does not exceed 90 dB for the user and is preferably within a comfortable range, and also another for durability. To test the audio output decibel range, a decibel meter will be used. Several measurements will be performed and Ison's software will be adjusted as needed to ensure safe listening for Ison users. The audio output must remain functional after taking off and putting on the glasses as loose connections were an issue in the past prototype. The audio output must also remain functional when dropped from a max height of 5'8", which will be performed on a hard, tiled floor.

4. SUMMARY AND FUTURE WORK

The design team encountered many challenges throughout the development process. The team was able to address many issues and implement solutions in a manner that had little effect on the overall timeline of the project. Some of the major issues faced involved reliability of components, machine learning, and circuitry design and housing.

Some of our components needed replacing in Capstone Design II for various reasons. First off, the original 3D printed frames melted and were uncomfortable due to the frame's shape and rigidity. This led the team to consider different materials for the frames as well as new designs. Another component-related issue was the wiring and connectors for the bone conduction module. While the selected transducers met many of the requirements for function and size, the connection points had been difficult to solder, and the wires break easily even when soldered. The team opted to look into better wiring solutions following these difficulties.

The OCR software consists of a machine learning (ML) model and text-to-speech script. The team struggled with the ML and data mining; many online datasets lacked sufficient variety and using multiple datasets overcomplicated the data processing steps of the code. Thus, the team opted to create a dataset by pooling images either taken or found online by the team members. The other issue related to ML was fine-tuning the CRNN architecture to learn effectively on the given data, which came down to trial-and-error once the general architecture had been laid out.

The final hurdle was designing the housing/frames for Ison. The team struggled to design a frame sufficient to fit all of the electronic components while being a reasonable size. In addition, the placement and layout planning of the circuit within the glasses was difficult as many components are connected in ways that cause overlapping wires and boards. A better wiring solution will be the temporary fix. However, in the future, the team will move towards printed circuit boards (PCBs) once confident with the reliability and performance of selected parts.

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