3. 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.

3.1. 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.

3.1.1. 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.

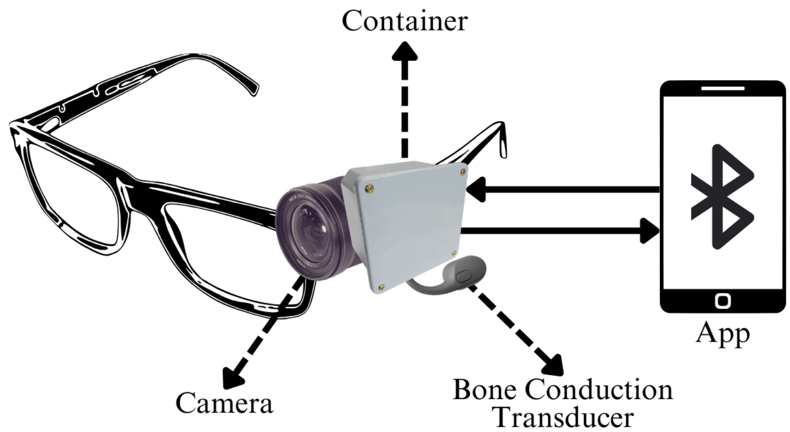

Fig. 3-1: Add-On Functionality Schematic

Figure 3-1 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.

3.1.2. 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 optical character recognition 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 3-2 shows where the core components are placed inside of the glasses frame, as well as a basic functionality overview.

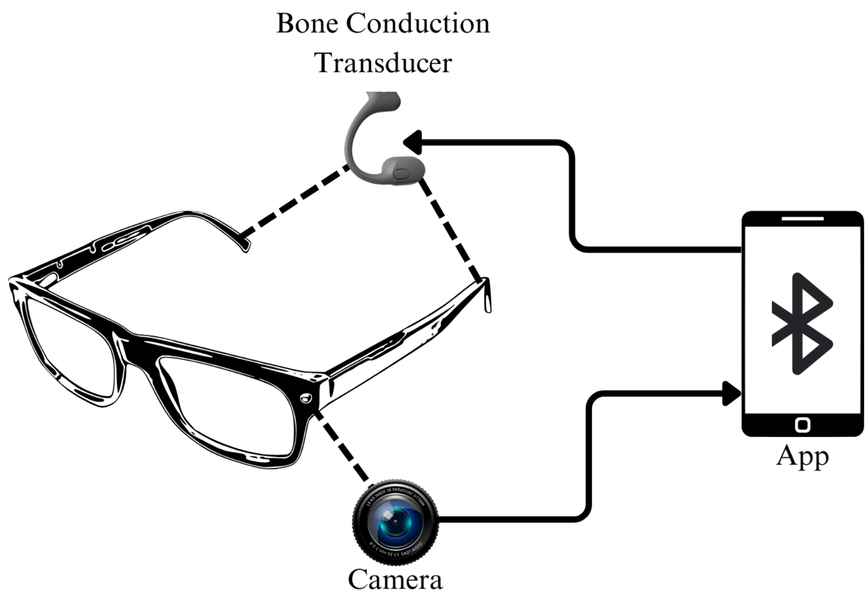

Fig. 3-2: Built-In Functionality Schematic

Figure 3-2 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.

3.2. 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 3-3. 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.

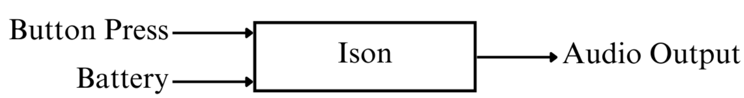

Fig. 3-3: Ison Functionality Overview (Level 0)

Figure 3-4 provides a more in-depth overview of the Ison system functionality, including physical and over-the-air connections between the modules.

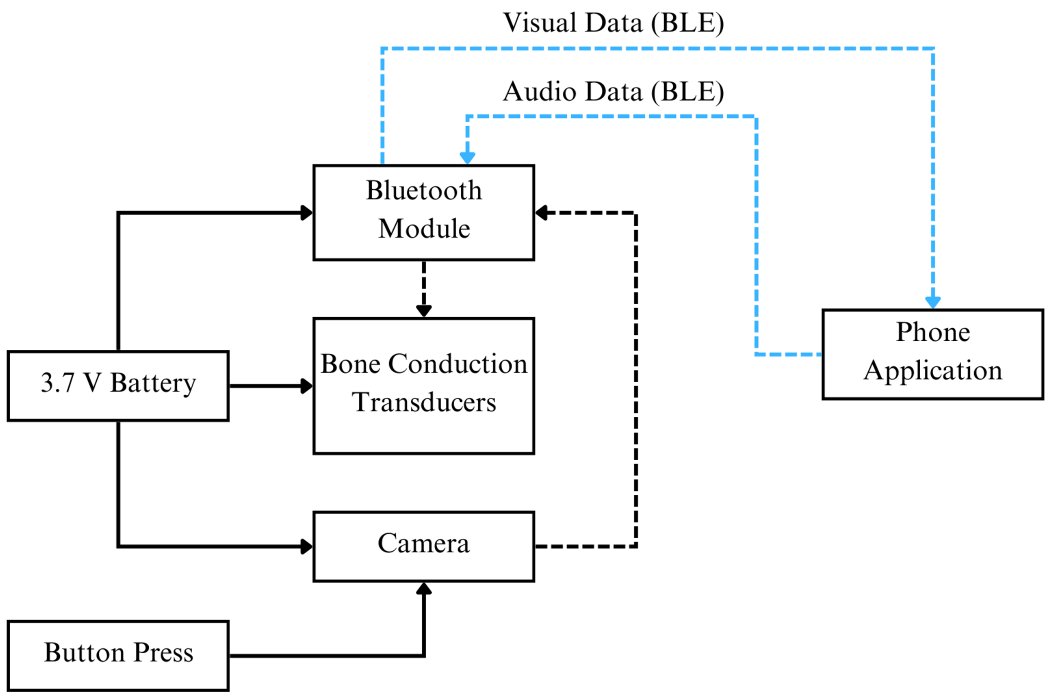

Fig. 3-4: Ison Functionality Overview (Level 1)

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.

3.3. 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.

3.3.1. 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 3-1 compares the Bluetooth options considered.

Table 3-1: 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 [1]	Yes	150	46 x 26	~25	$8.95
DigiKey ESP32-C3FH4 [2]	Yes	54	5 x 5	~1	$1.30
Electronic Spices Bluetooth Stereo Audio Receiver [3]	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.

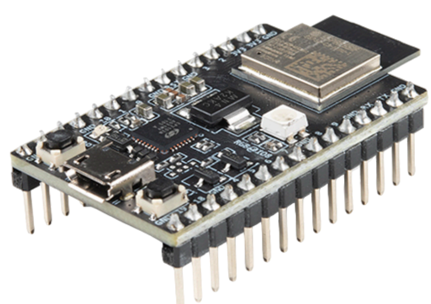

Fig. 3-5: Bluetooth Module

Figure 3-5 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.

3.3.2. 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 3-2 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 [4].

Table 3-2: 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 [5]	≥1080p	160º	~20 x 13.5 x 15.3	10	$15.99
Vernier WiFi Security Surveillance Camera [6]	720p – 1080p	140º	<30 x 30 x 38	N/A	$34.99
MER2-630-60U3 M [7]	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 3-6. The text-to-speech algorithms use the pyTTSx3 package [8]. 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 [9]. 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.

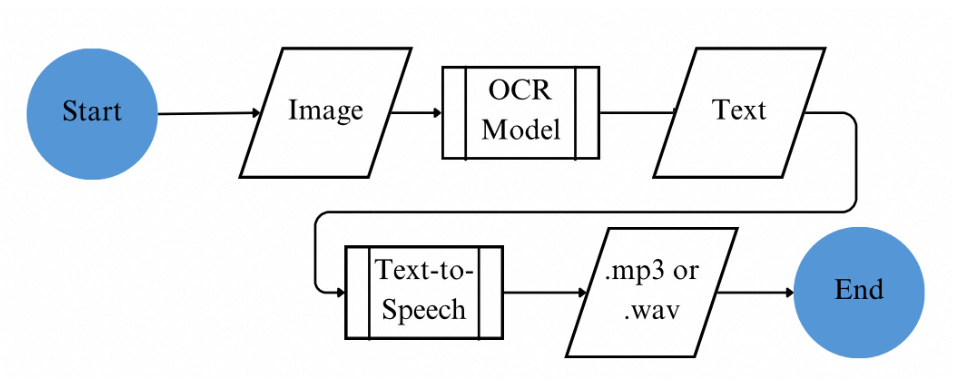

Fig. 3-6: Text-to-Speech Flowchart

Figure 3-6 provides a visual representation of the flow of data through the Ison software, from raw image data to speech audio data.

3.3.3. 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 3-3 are possible bone conduction transducer options, and the selected transducer is shown in Figure 3-7.

Table 3-3: 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 [10]	15.2 x 20.3	90	9.6	$8.95 (each)
Sardfxul Mini Speaker Bone Conduction Loudspeaker For Audio [11]	16.0 x 16.0	95	None Specified	$8.92
Alibaba Bone Conductor Transducer [12]	10.2 x 10.2 x 5.1	None Specified	10	$3.00

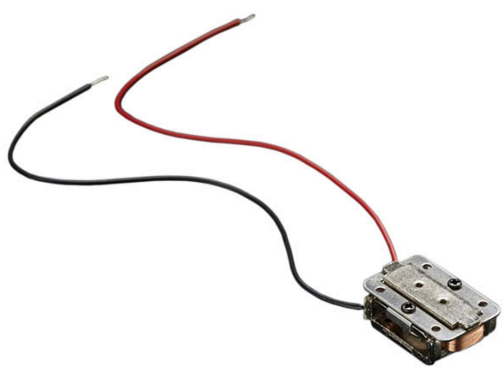

Fig. 3-7: Bone Conductor Transducer [13]

Figure 3-7 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.

3.3.4. 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 3-4: 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 [14]	50.0 x 45.9 x 8.9	3.7	1200	28	$11.99 (each)
KP Lithium Battery [15]	39.8 x 35.1 x 11.9	3.7	300	25	$3.50 (each)
AKZYTUE LiPo Battery [16]	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. 3-8: Lithium Polymer Battery [11]

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 3-5: 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 [15]	101.6 x 63.5 x 12.7	5	1000	5	3 pcs for $5.99
Adafruit PowerBoost 500 Charger [16]	22.8 x 38.0 x 2.03	5	1000	4	$14.95 (each)
ICSTORE DC Charging Boost [17]	24.9 x 20.1 x 54.9	5	1000	10	2 pcs for $1.99

The chosen charger module is shown in Figure 3-9.

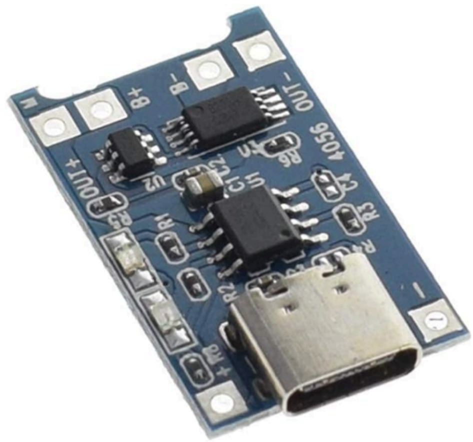

Fig. 3-9: HiLetgo Lithium Battery Charging Module [15]

This module was selected because it holds a charge longer compared to 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.

3.3.5. 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 3-10.

Fig. 3-10: Smartphone Application User Interface Mockup

Figure 3-10 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.

3.4. 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.

3.4.1. 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 3-11.

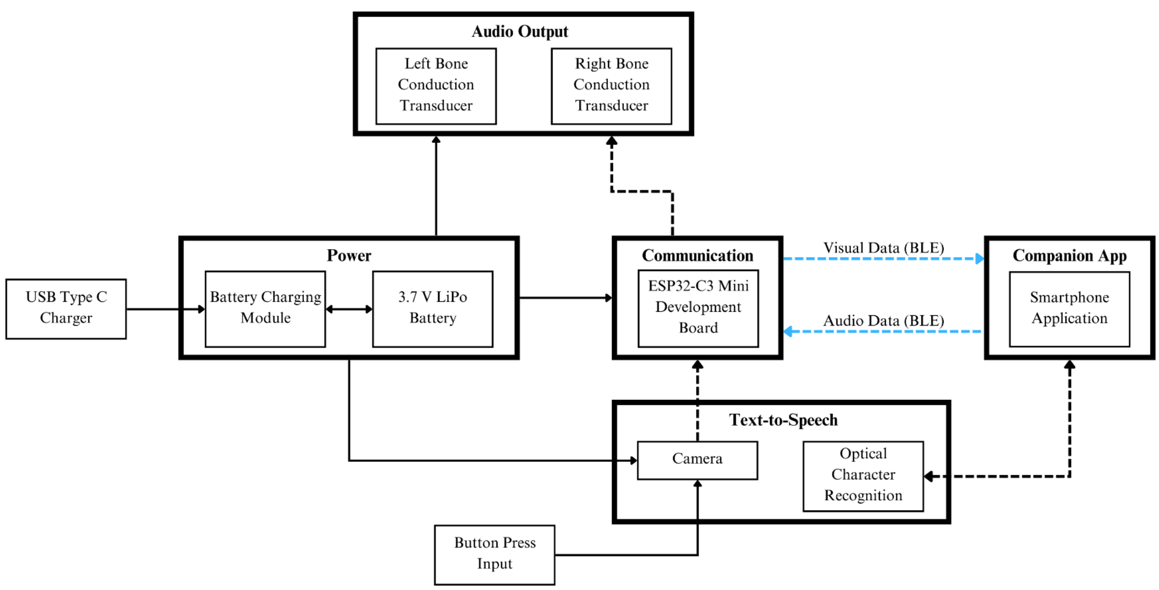

Fig. 3-11: Ison Functionality Overview (Level 2)

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.

References

[1] M. #655393, “ESP32-C3 mini development board,” WRL-18036 - SparkFun Electronics, https://www.sparkfun.com/products/18036 (accessed Apr. 23, 2024).

[2] Espressif Systems, “ESP32-C3FH4,” DigiKey, https://www.digikey.com/en/products/detail/espressif-systems/ESP32-C3FH4/14115592 (accessed Apr. 12, 2024).

[3] “Electronic spices bluetooth stereo audio receiver wireless hi-fi transmitter version - 2.0 USB MP3,” Amazon.in: Electronics, https://www.amazon.in/Electronic-Spices-Bluetooth-Receiver-Transmitter/dp/B07V3WS9XN/ref=pd_sbs_1?pd_rd_w=5GcN8&pf_rd_p=615bd5a5-1a50-4edd-8e1a-d43e80e83d87&pf_rd_r=3G24X5AH8VTV7K104V27&pd_rd_r=a2acf19e-4ad7-4d74-95ac-fb6f18099051&pd_rd_wg=1qNiY&pd_rd_i=B07V3WS9XN&psc=1 (accessed Apr. 15, 2024).

[4] Adobe, “A beginner’s guide to video resolution,” *www.adobe.com*. https://www.adobe.com/creativecloud/video/discover/video-resolution.html

[5] “Waveshare IMX219 Camera Module, Compatible with Raspberry Pi 5, 160 Degree FoV, with 8-megapixel IMX219 Sensor and Features 160 Degree Field of View,” Amazon, https://www.amazon.com/Waveshare-IMX219-Camera-Official-Raspberry/dp/B07H2D4WYR/ref=asc_df_B07H2D4WYR/ (accessed Apr. 15, 2024).

[6] “Small WiFi Security Camera Night Vision Security Surveillance Cam,” Vernier, https://verniershop.com/products/small-wifi-security-camera-night-vision-security-cam?currency=USD&variant=40807170539590&utm_medium=cpc&utm_source=google&utm_campaign=Google%20Shopping&stkn=247f16242035&gad_source=1&gclid=CjwKCAjw7-SvBhB6EiwAwYdCAR--LqmOSj6jPV1ogBQh7SMqcpSHVTWG__luHxn2JmwB3q0yD3IJqhoCzzIQAvD_BwE (accessed Apr. 15, 2024).

[7] “Industrial USB 3.0 Vision camera,” industrial-cameras.com, https://industrial-cameras.com/collections/usb3-vision-camera/products/usb-camera-3-0-6-3mp-monochrome-sony-imx178-mer2-630-60u3m (accessed Apr. 14, 2024).

[8] N. Bhat, “Offline Text To Speech (TTS) converter for Python,” GitHub, Jun. 25, 2021. https://github.com/nateshmbhat/pyttsx3 (accessed Apr. 15, 2024).

[9] “Convert Text to Speech in Python,” *GeeksforGeeks*, May 24, 2017. https://www.geeksforgeeks.org/convert-text-speech-python/

[10] Adafruit Industries LLC, "Bone Conductor Transducer with Wires - 8 Ohm 1 Watt," Adafruit, https://www.adafruit.com/product/1674?gad_source=1&gclid=EAIaIQobChMI26-pgZH-hAMVmgytBh1_iwt8EAQYASABEgLDBPD_BwE (accessed Apr. 15, 2024).

[11] “Sardfxul 10Pcs 16mm Mini Speaker Bone Conduction Loudspeaker 8 Ohm 1W For Audio,” Walmart, https://www.walmart.com/ip/Sardfxul-10Pcs-16mm-Mini-Speaker-Bone-Conduction-Loudspeaker-8-Ohm-1W-For-Audio/1654561025?wmlspartner=wlpa&selectedSellerId=101260945&adid=22

2222222281654561025_101260945_14069003552_202077872&wl0=&wl1=g&wl2=m&wl3=42423897272&wl4=pla-295289030566&wl5=1020785&wl6=&wl7=&wl8=&wl9=pla&wl10=671366292&wl11=online&wl12=1654561025_101260945&veh=sem&gad_source=1&gbraid=0AAAAADmfBIo7flUP1BBI8Fkrn0Vj0o8Iw&gclid=EAIaIQobChMI26-pgZH-hAMVmgytBh1_iwt8EAQYDSABEgIRqPD_BwE (accessed Apr. 15, 2024).

[12] "1.5w 4.5 Ohm Bone Conductor Transducer With Wires Hearing Aid Headset Speaker Bt Module Oscillator 14mmx21.5mm - Buy Bone Conductor Transducer With Wires,Bone Conductor,1.5w Bone Conductor Product on Alibaba.com," www.alibaba.com, https://www.alibaba.com/product-detail/1-5W-4-5-ohm-BONE_62419392274.html?spm=a2700.pccps_detail.0.0.13f913a0Oime4N.

[13] Adafruit Industries LLC. "1674 Adafruit Industries LLC | Audio Products | DigiKey," DigiKey, https://www.digikey.com/en/products/detail/adafruit-industries-llc/1674/6827067 (accessed Apr. 15, 2024).

[14] "AKZYTUE Lipo Battery Rechargeable," Amazon, https://www.amazon.com/AKZYTUE-1200mAh-Battery-Rechargeable-Connector/dp/B07TWHHCNK (accessed Apr. 12, 2024).

[15] "KP Rechargeable Battery for Tone," Amazon, https://www.amazon.in/KP401230-3-7V-Rechargeable-Battery-Bluetooth/dp/B08PSKZZXM (accessed Apr. 12, 2024).

[16] "AKZYTUE Lipo Battery Rechargeable," Amazon, https://www.amazon.com/1500mAh-battery-Rechargeable-Lithium-Connector/dp/B07BTN9TYN (accessed Apr. 15, 2024).

[17] HiLetgo, "Lithium Battery Charger Module with Protection Functions," Amazon, https://www.amazon.com/HiLetgo-Lithium-Charging-Protection-Functions/dp/B07PKND8KG (accessed Apr. 15, 2024).

[18] Adafruit Industries, "PowerBoost 500 Charger - Rechargeable 5V Lipo USB Boost @ 500MA+," https://www.adafruit.com/product/1944 (accessed Apr. 12, 2024).

[19] ICSTORE, "TP4056 lithium battery charging module," Amazon, https://www.amazon.in/ICSTORE-TP4056-lithium-battery-charging/dp/B082YVLP35 (accessed Apr. 12, 2024).