BUDDYCARE MATE

Prepared for: Dr. Gary Zientara, United States Army Research Institute of Environmental Medicine

Shrika Eddula and Alexa Plotkin

June, 2023 – August, 2023

Background

Shrika Eddula and Alexa Plotkin were X-Force Fellows during the summer 2023 cycle. The X-Force program is within the National Security and Innovation Network and provides undergraduate, graduate, and recent graduates the opportunity to act as consultants for the United States Department of Defense. For this project, Shrika and Alexa were contracted with the United States Army Research Institute of Environmental Medicine under the advisory of Dr. Gary Zientara. All work presented in this document was completed during a teen week period from June, 2023 through August, 2023.

Shrika Eddula is an incoming second year at Massachusetts Institute of Technology majoring in Computer Science and Neuroscience. Alexa Plotkin is an incoming third year at The Ohio State University majoring in Mechanical Engineering on a pre-med track. Shrika focused on developing the code and Alexa focused on choosing the hardware components, but the final design is a combined effort between fellows. In future communications, the fellows can be contacted at: Plotkin.18@osu.edu (Alexa) and shrika@mit.edu (Shrika).

Purpose

The purpose of this project is to research and design a smartphone sized (160 x 80 x 10 millimeters [mm]) drone attachment that can remotely assess a wounded Warfighter's state of consciousness on the battlefield as per the Glasgow Coma Scale (GCS). Through a combination of computer vision and natural language processing, the approach integrates both AI and functional hardware components, such as optical, audio, and laser, in a semi-autonomous system as a tool for future Army Medics that can give vital insight into a wounded Warfighter's neurological state. Looking towards the future, this device will be part of a system of drone attachments used for remote triage that assists military medics during dangerous situations. This system will allow medics to view necessary vital signs and strategize an optimal method to assist of wounded Warfighters without entering the field.

Proposal

The Proposal includes *Section I,* Section *II, Section III,* and *Section IV*. *Section I* explains the Glasgow Coma scale. *Section II* explains the process of assessing the patient using the device. *Section III* examines the hardware recommendations. All proposed hardware is sold by a U.S.A. based company. *Section IV* examines the software.

Section I: Glasgow Coma Scale

The scale chosen for the BuddyCare Mate to determine a wounded Warfighter's state of consciousness is the Glasgow Coma Scale (GCS). GCS was chosen because of its use in the United States Army Standard Medical Operating Guidelines. Additionally, since its creation in 1974, it has been rated as “substantially reliable” in over 85% of studies. The scale has a holistic approach to addressing a patient's consciousness by evaluating eye, verbal, and motor response. Eye response scores include: 1 – no eye opening, 2 – eye opening to pain, 3 – eye opening to command, 4 – eyes open spontaneously. Verbal response scores include: 1 – no verbal response, 2 – incomprehensible, 3 – inappropriate words, 4 – confused, 5 - orientated. Motor response scores include: 1 – no motor response, 2 – abnormal extension to pain, 3 – abnormal flexion to pain, 4 – withdrawal from pain, 5 – localizing pain, 6 – obeys commands. The total from all three assessments is the patient's GCS score, ranging from 3 to 15. The classification of GCS' scores relationship to traumatic brain injury is: severe 3 – 8, moderate 9 – 12, mild 13 – 15 [3].

Section II: Assessment

The BuddyCare Mate device is designed to assess the three components of GCS from a minimum of 1 meter (m) away from a patient. For each response tested, the pain stimulation is provided through a laser attached to the BuddyCare Mate. Reassuring dialogue and answers to basic questions asked by the patient are provided through a speaker, microphone, and Natural Language Processing (NLP) software. The eye response is assessed using a camera and blink detection software. The verbal response utilizes the speaker, microphone, and NLP software. The motor response utilizes the camera and pose detection software. The control flow sequence was chosen to minimize the number of times the pain stimulation was applied to the patient and the amount of computation needed to be performed on any given patient. The results will be sent and presented in a comprehensive Graphical User Interface (GUI) that gives a remote medic context into both the patient's GCS score and any further relevant information such as dialogue exchanged, battlefield conditions, etc. A diagram of the GUI can be found in Appendix A. The control flow sequence depicting the timeline of processing software can be found in Figure B 1. The control flow sequence depicting the GCS scoring outcome can be found in Figure B 2.

Section III: Hardware Recommendations

A 3D Solidworks model depicting all hardware component can be found in Appendix C.

<u>Camera:</u>

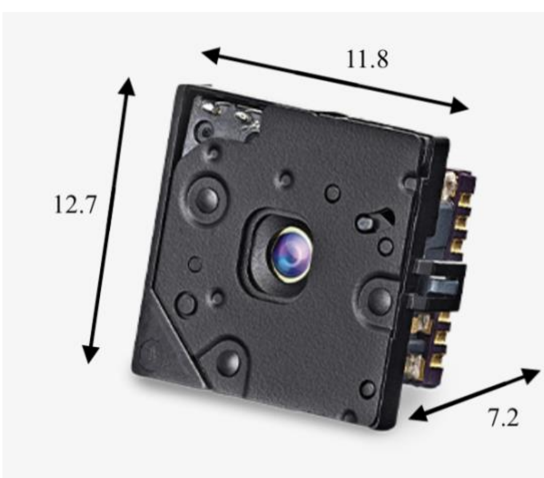

Figure 2: Teledyne FLIR Lepton 3.5

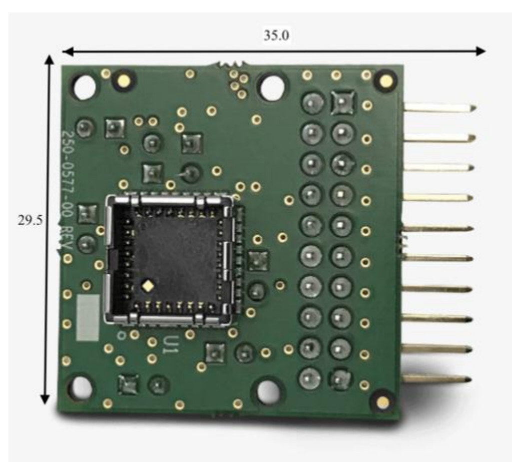

Figure 3: Teledyne FLIR Lepton Breakout Board 2.0

The camera chosen for this project is the Teledyne FLIR Lepton 3.5. This is because of the size and environmental operating conditions of the camera. The camera is 11.8 x 12.7 x 7.2 mm in dimension, is resistant to 1500 G shock for .4 milliseconds, and can operate from -40 ºC to +80 ºC. The camera operates at 8.7 frames per second with a 160 x 120-pixel display. This low resolution has been integrated into the computer software to follow. The camera module is powered by 2.5 – 3.1 volts (V), 0.15 watts (W) and .03 - .06 amps (A). More details concerning the Teledyne FLIR Lepton 3.5 can be found in Figure C 1. The camera is suggested to be used with the FLIR Lepton Breakout Board v2.0 for easier integration. Utilizing the breakout board, voltage runs at 3.3 – 5.0 V. More details concerning the FLIR Lepton Breakout Board, such as the pin-out, can be found in Figure C 2.

Speaker:

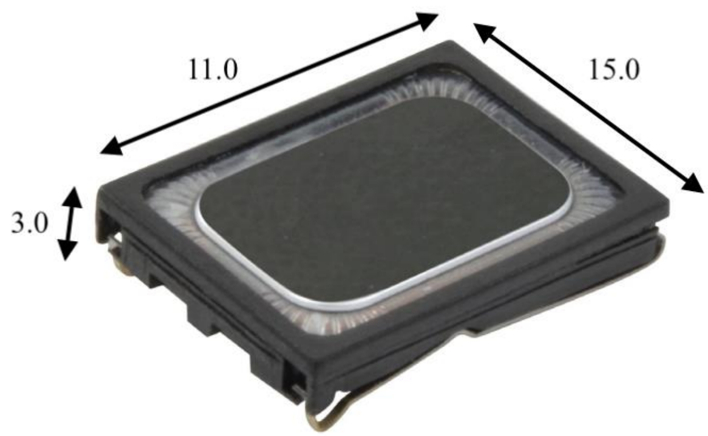

Figure 4: CUIDevices CMS-15113-078X-67

The speaker chosen for this project is the CUIDevices CMS-15113-078X-67. A drone typically operates around 80 decibels (dB) which can be decreased by manipulating portions of the drone itself. Options include sanding down propellers, having slower propellers, and utilizing several smaller motors rather than one larger option. Without knowing the decibel level of the drone this device will be placed on, research was done into speakers operating at 80 dB or higher. The speaker chosen for this project was because of its decibel level, size, Ingress Protection Rating, and termination options. The CUIDevices CMS model is 15 x 11 x 3 mm in dimension, operates at a maximum of 94 dB, and has an Ingress Protection Rating of IP67. Termination options include spring contacts, solder pads, wire leads, Molex housing, and JST housing. Although Molex and JST housing are not standard on the microcomputer chosen for this project, the five options allow for ease of integration when choosing the final design. The speaker operates at 1.0 W, 9.2 ohms, 0.1 A, and 2.73 V of direct current. More details concerning the CUIDevices CMS-15113-078X-67 can be found in Figure C 3. The computer that will be used for this project does not include a direct audio input/output port. Because of this, a digital-to-analog converter (DAC) would be recommended. A typical DAC operates between 3.3 – 5.0 V and 0.1 A.

Microphone:

There is not a microphone chosen for the project at this time. Because this device is part of a network of remote triage systems, most of which require a microphone, the microphone utilized in this device does not need to be a part of the cell-phone-sized design. Initial research done into microphone attachments for drones yielded only one company with a functional product at this time: Dotterel, an Australian based company. Through a meeting with the CEO of Dotterel, it was explained that because of the noise of the propellers, the only functional way to attach a microphone to a drone is by extending the microphone in front of the drone and utilizing noise reduction software that can differentiate noise from in front versus behind the microphone. More information concerning Dotterel's aerial audio can be found on the Dotterel website [2].

Laser:

There is not a laser chosen for the project at this time. There is preliminary research that can be used to design a successful pain stimulating laser. Research has been done on pain stimulation through Carbon Dioxide [1], Yttrium Aluminum Garnet (YAG) [8], and diode lasers [10]. Due to the nature of the size and difficulty to replace parts of the Carbon Dioxide and Yttrium Aluminum Garnet lasers, the fellows suggest that BuddyCare Mate project use a diode laser. Requirements of the laser be that it has a focal length of 1 m and has a fluence (J/cm^2) high enough to stimulate a painful sensation but below the maximum permissible exposure limit (MPE) for skin. Classifications for MPE ratings are visible, near infrared (IR), and IR which are determined by wavelength in nanometers (nm) [11]. Within these three classifications, research was done into the pain stimulation fluency. Findings are summarized in Table 1.

Potential solution	IR Laser	Near IR Laser	Visible Light Laser
Wavelength (nm)	1550	980	525
Pain Stimulation Fluence (J/cm^2)	0.3	varied	0.02
MPE for 1µs-10s exposure length to skin (J/cm^2)	0.5	1.0	1.0

Table 1: Laser pain stimulation fluence compared to MPE

A conclusion drawn from the table is that both an IR and visible light laser can stimulate nerves with a fluency below the MPE for skin. It is easier to commercially purchase an IR laser in smaller dimensions than a visible light laser, so the recommendation would be to purchase an IR laser. Note that although the IR experiment was performed on rats, the MPE threshold for rats and humans on the IR spectra is similar, so comparisons between these conclusions and humans can reasonably be made [12]. There is conflicting data concerning pulse duration, and irradiance diameter that induces pain. Helpful information concerning these aspects can be found in a current United States patent that outlines a 980 nm laser used for pain stimulation with data on the resultant pain perception given varied number of pulses, length of pulse, and irradiated diameter [6]. Additional information can be found in a similar experiment using the visible light spectra [5]. Because of the potential danger of the laser, the fellows and the sponsor have chosen to leave the design of the laser to a specialized engineer. The suggestion moving forward would be to purchase an IR laser with specifications focal length of 1 m, fluency of 0.3 – 0.5 J/cm^2, and has pulsing functionality.

Microcomputer:

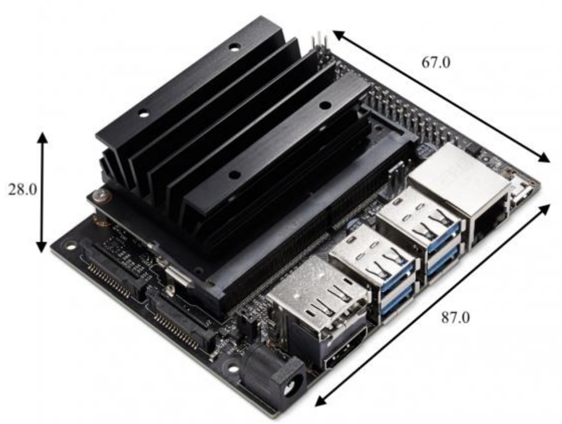

Figure 5: Nvidia Jetson Nano Developer Kit

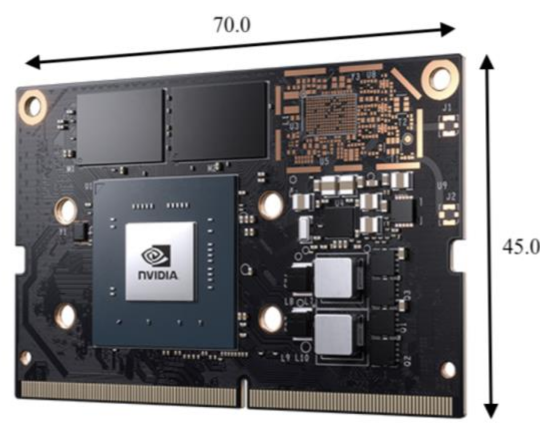

Figure 6: Nvidia Jetson Nano Module

The microcomputer chosen for this project is the Nvidia Jetson Nano. This is because these computers are often used on drones due to their size and processing power. The two versions of this micro-computer are the Nvidia Jetson Nano Developer Kit and the Nvidia Jetson Nano Module. For pre-production purposes, the Nvidia Jetson Nano Developer Kit is suggested. This is because it has basic, non-customizable functionality with no designated operating lifetime. The developer kit is 87 x 67 x 28 mm in dimension, including a 9.2 mm high heatsink. For production purposes, it is recommended to use the Nvidia Jetson Nano Module. This is because the module has a guaranteed operating lifetime of 5 years and can be customized depending on the carrier board [7]. The module is 70 x 45 mm in dimension, but the height of the module largely depends on the size of the carrier board and enclosure. Both options run on a minimum of

4.75 V and operate with 5.0 – 10.0 W of power. More details concerning the Nvidia Jetson Nano Developer Kit and Module can be found on the respective datasheets (not included in appendices due to the size of documents).

Power Source:

Figure 7: MAXAMPS 2000 1S LiPo battery

The power source chosen for this project is MAXAMPS 2000 1S LiPo battery. This is because of the material, size, current, and voltage that the battery supplies. Lithium polymer batteries are often chosen for drone usage because of their durability, weight, and capacity. MAXAMPS 2000 1S LiPo Battery is 68 x 45 x 8 mm in dimension, supplies 2 A at 2 Ah, and provides 3.7 V. Although the Nvidia Jetson typically runs on 5.0 V, 2.0 A source, a 2S battery (7.4 V) is typically 15 mm or higher in dimension. Because the Nvidia Jetson requires at least 4.75 V of continuous power, a step-up converted is required to use this battery. Using the step-up converter permits the battery to supply a smaller voltage, reducing the size. More details concerning the MAXAMPS 2000 1S LiPo battery can be found in Figure C 4.

The Teledyne FLIR Lepton camera and breakout board chosen for this project requires around .06 A and between 3.3 – 5 V. The CUIDevices speaker and generalized DAC chosen for this project requires around .01A and between 3.3 – 5.0 V. The microphone likely will not draw more than .05 A and will be chosen to require between 3.3 – 5.0 V.

Circuit:

The Developer Kit has micro-USB, Ethernet, USB type A, HDMI, and Power Jack ports as well as a 40-pin expansion header, Camera Connector, Button Header, Serial Port Header, M.2 Key E Slot, and Fan Header. The expansion header includes I2S, Audio Clock, I2C (x2), SPI (x2), UARTS, and GPIO interfaces. All signals on the header use 3.3 V levels. The laser can be attached through the expansion header. The camera and breakout board can be connected through the MIPI CSI-2 Camera Connector or through the expansion header. The Nvidia Jetson Nano does not come with a direct audio input or output option. The digital to analog converter will connect through the 40-pin expansion header. Each stack of the USB type A connectors is limited to 1 A each. The capacity of the chosen power source will determine through which port the power is connected through. If the capacity for the power source is below 2 A, the power source can be plugged into the micro-USB outlet. It is important to note that if the capacity of the power source is above 2 A, it is recommended that the power source be plugged into the Power Jack instead of the micro-USB.

The Module's carrier board is customizable. The number of ports, connectors, size, and materials can be customized. Depending on the soldering and pin-outs of the board, it is possible that the only required ports would be an expansion header with similar connectivity to the 40-pin expansion header on the Developer Kit, ethernet connection, and a connection for the power supply. Optimally, the device would be 80 x 80 x 10 mm or smaller and have an Ingress Protection rating of 6 for solids. The Nvidia website provides suggested manufacturers for the carrier board, development kit, or full system [4].

Section IV: Software

The software designed for this project can be broken down into three parts: eye response, verbal response, and motor response. All components were coded using the Python programming language and deployed for testing on a mobile phone. The authors have provided all the code used in the project in the following GitHub repository in Appendix E.

Eye Response

In accordance with the Glasgow Coma Scale, the eye response assessment must consider patient blinking patterns in response to various stimuli. Thus, an eye blink detection application was developed using facial landmarks and computer vision (OpenCV). The detector was built based off computations for the eye aspect ratio (EAR), a metric introduced by Soukupová and Čech in 2016 [9]. The EAR ratio is calculated based on the distances between eye related facial landmarks and will dramatically drop when the eye closes, indicating that a blink has happened. There are 6 facial landmarks associated with each eye, as seen in the Figure 8.

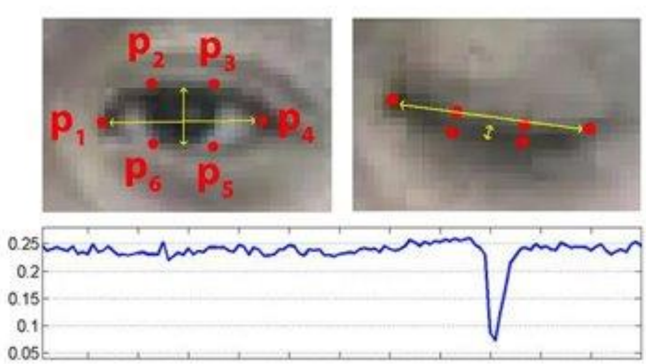

Figure 8: Eye blink detection software

The code itself is provided in the detect_blink.py file in the provided Github Repo and starts by defining a function called eye_aspect_ratio(eye) to calculate the EAR for a given eye using the six facial landmarks seen in the image. Then, the video stream starts from the input file or live camera and frame processing begins. In each frame, detect faces using the dlib face detector and calculate the EAR for each eye. The program checks if the EAR is below the blink threshold. If so, we increment the blink frame counter; otherwise, if the eyes were closed for a sufficient number of frames, increment the total number of blinks.

Verbal Response

Along with the assessment metric needed for the Glasgow Coma Scale, our Verbal Response software humanizes the drone and also includes natural language capabilities in which the patient is able to converse with our device. Our pipeline includes a 3-step process that starts off by converting text to speech using the Google Text-to-Speech (gTTS) API and then plays the generated speech as an audio file using the Python playsound library. Next, the Python speech recognition module, PyAudio, and the Google Speech Recognition API are utilized for transcribing patient responses. The transcribe_speech() function uses the microphone to listen for 10 seconds, captures the audio, and transcribes it using the Google Speech Recognition API. If the API cannot understand the audio or if there is a request error, predefined messages are returned accordingly. Lastly, the ask_question(prompt) function uses the OpenAI GPT-3.5 Turbo API to allow for natural language processing of the transcribed patient response and either answer their questions, store relevant information, or give an appropriate verbal response score.

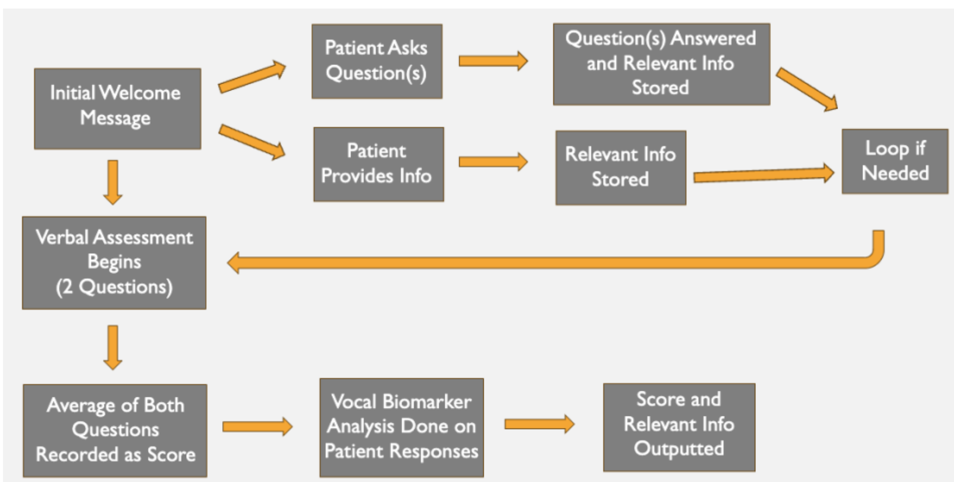

Figure 9: Verbal processing sequence

In regard to our process flow, the diagram above provides a visual depiction. The program will start off with a reassuring message to the patient as well as provide some background information on the device and its purpose. A conversation loop in which we detect whether the patient is asking a question, providing us with background information on their condition, or indicating that they are ready for the verbal assessment takes place. The verbal assessment itself consists of averaging the score over 2 questions, the first prompting the patient for the current year and the second for the current president of the United States. Lastly, although not implemented yet, a vocal biomarker analysis software will be run on all patient responses to assess cognitive fatigue and other signs of stress beyond just the GCS.

Motor Response

Lastly, the Motor Response software was built as a Pose Detector system that utilizes the Python Mediapipe library to detect and analyze human body poses through the webcam in real-time. The PoseDetector class is responsible for processing and detecting poses using the Mediapipe pose estimation model. The findPose() method finds the body pose in an input image, while the getPosition() method extracts the key points of the detected pose.

The code also includes an evaluate_motor_response() function, which evaluates a patient's motor response based on the detected key points and the pose descriptions detailed by the GCS. It calculates the distance between shoulder and wrist keypoints and assigns a motor response score accordingly. The main() function initializes the webcam capture, detects poses, extracts keypoints, and evaluates the motor response score for each frame. The results are displayed in real-time, including the frames per second (FPS) and the motor response score. The system uses circles to highlight the wrist keypoints in the video feed, making it easier to visualize the detected pose. Lastly, although not implemented yet, laser functionality will need to be added as a means for pain stimulation and navigation/aim functionalities will need to be developed such that the pain can be invoked in accordance with the motor response algorithm.

References

[1] *A laser stimulator for the study of cutaneous thermal and pain sensations*. (1976, January 1). IEEE Journals & Magazine | IEEE Xplore. https://ieeexplore.ieee.org/document/4121001

[2] *Aerial Audio*. (n.d.). https://www.dotterel.com/technology/aerial-audio

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[4] *Jetson Partner Hardware Products*. (2023, July 13). NVIDIA Developer. https://developer.nvidia.com/embedded/jetson-partner-products

[5] Jun, J., Park, J., Kim, S., Bae, Y. M., Park, J., Kim, H., Choi, S., Jung, S. J., Park, S. H., Yeom, D., Jung, G., Kim, J., & Chung, S. (2015). Laser-induced thermoelastic effects can evoke tactile sensations. *Scientific Reports*, *5*(1). https://doi.org/10.1038/srep11016

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[7] *NVIDIA Jetson FAQ*. (2023, July 13). NVIDIA Developer. https://developer.nvidia.com/embedded/faq#:~:text=The%20developer%20kit%20is%20used,environment%20throughout%20their%20operating%20lifetime

[8] Ohara, S., Crone, N. E., Weiss, N., Treede, R., & Lenz, F. A. (2004). Cutaneous painful laser stimuli evoke responses recorded directly from primary somatosensory cortex in

awake humans. *Journal of Neurophysiology*, *91*(6), 2734–2746. https://doi.org/10.1152/jn.00912.2003

[9] Soukupová, T., & Čech, J. (2016). Real-Time Eye Blink Detection using Facial Landmarks [Article]. *21st Computer Vision Winter Workshop*.

[10] Tzabazis, A., Klukinov, M., Crottaz-Herbette, S., Nemenov, M. I., Angst, M. S., & Yeomans, D. C. (2011). Selective nociceptor activation in volunteers by infrared diode laser. *Molecular Pain*, *7*, 1744–18. https://doi.org/10.1186/1744-8069-7-18

[11] *UCSB Laser Safety Manual*. (2000). University of California Santa Barbara, Environmental Health and Safety.

[12] Welch, A. J., & Van Gemert, M. J. (2011). *Optical-Thermal response of Laser-Irradiated tissue*. Springer Science & Business Media.

APPENDIX A

Graphical User Interface

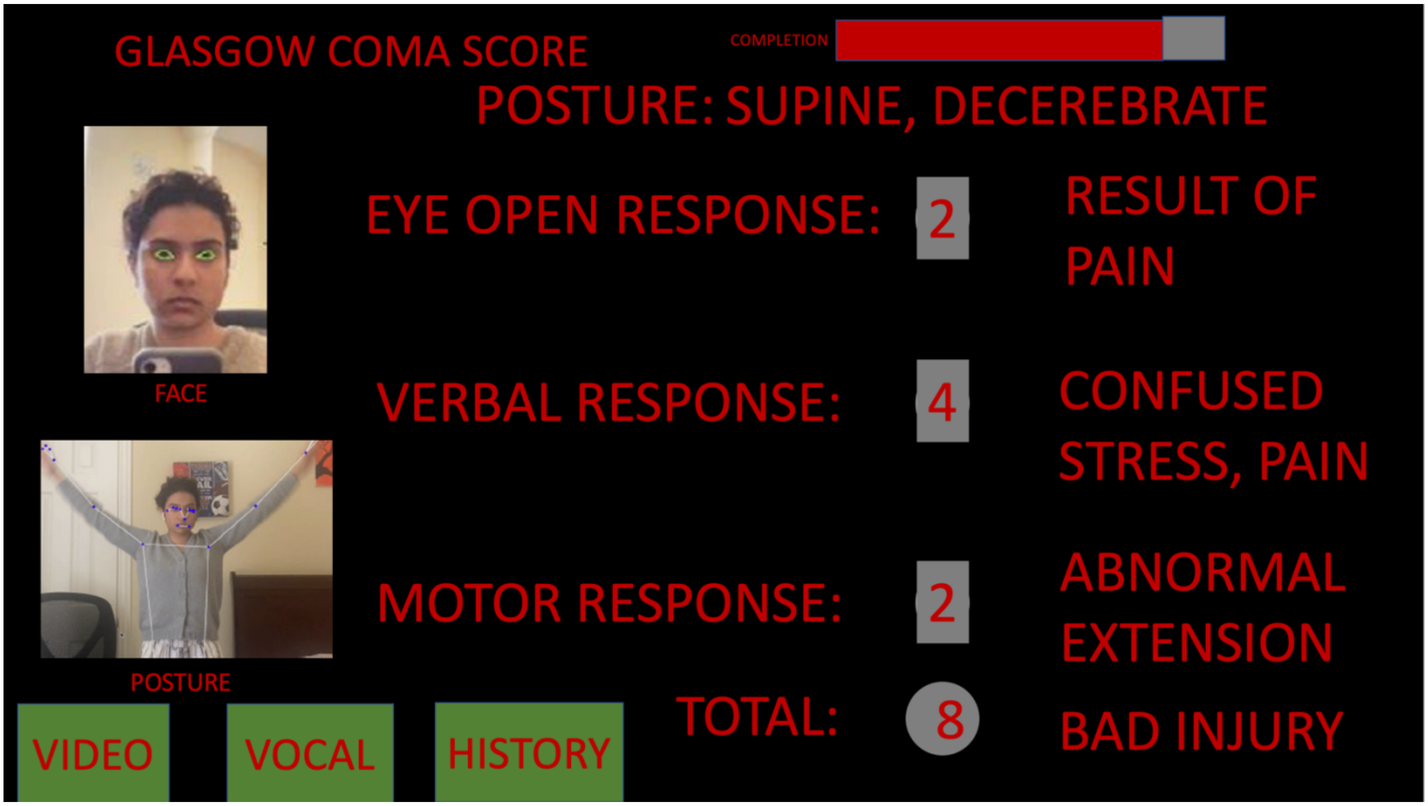


Figure A 1: Graphical user interface during assessment.

Figure A 2: Graphical user interface post assessment [cont.].

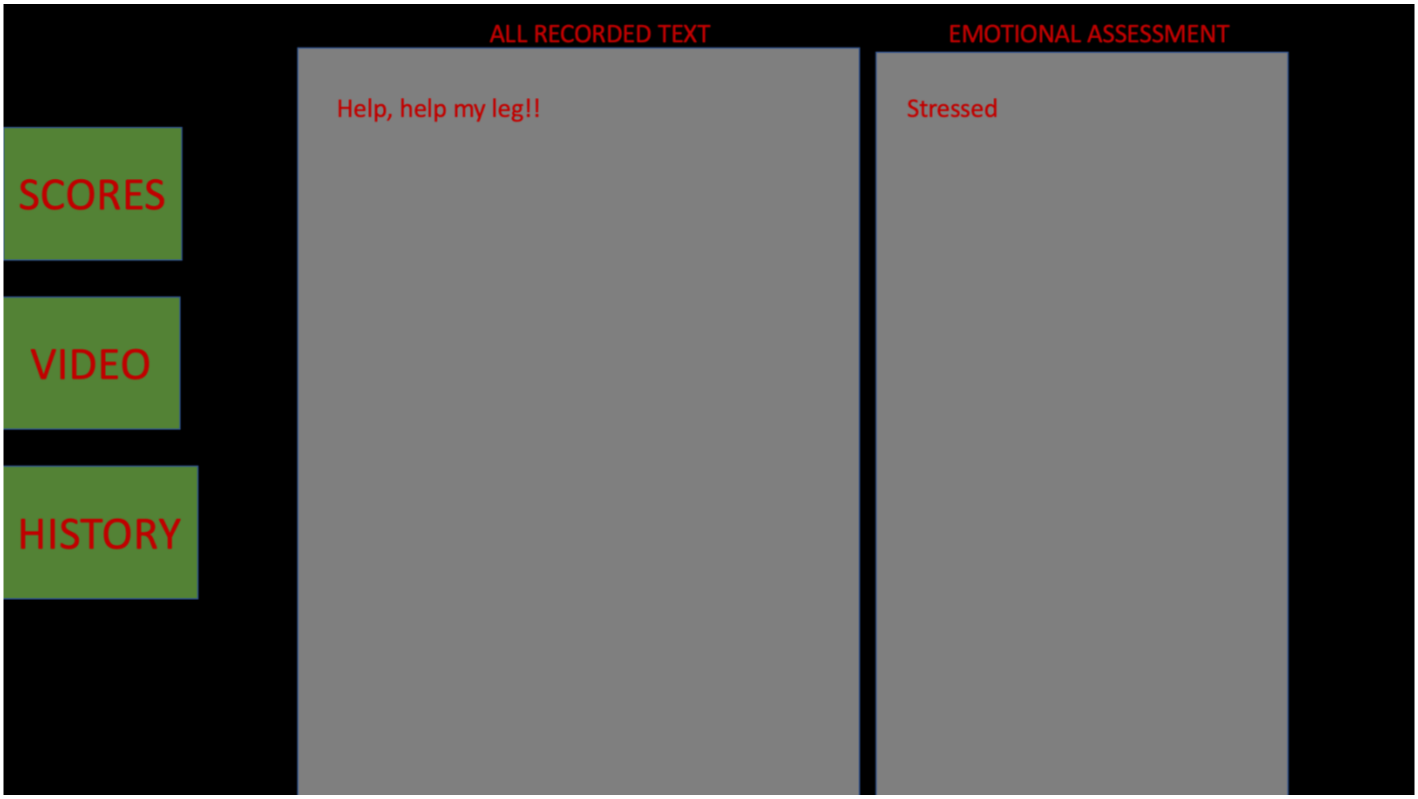


Figure A 3: Graphical user interface post assessment [cont.].

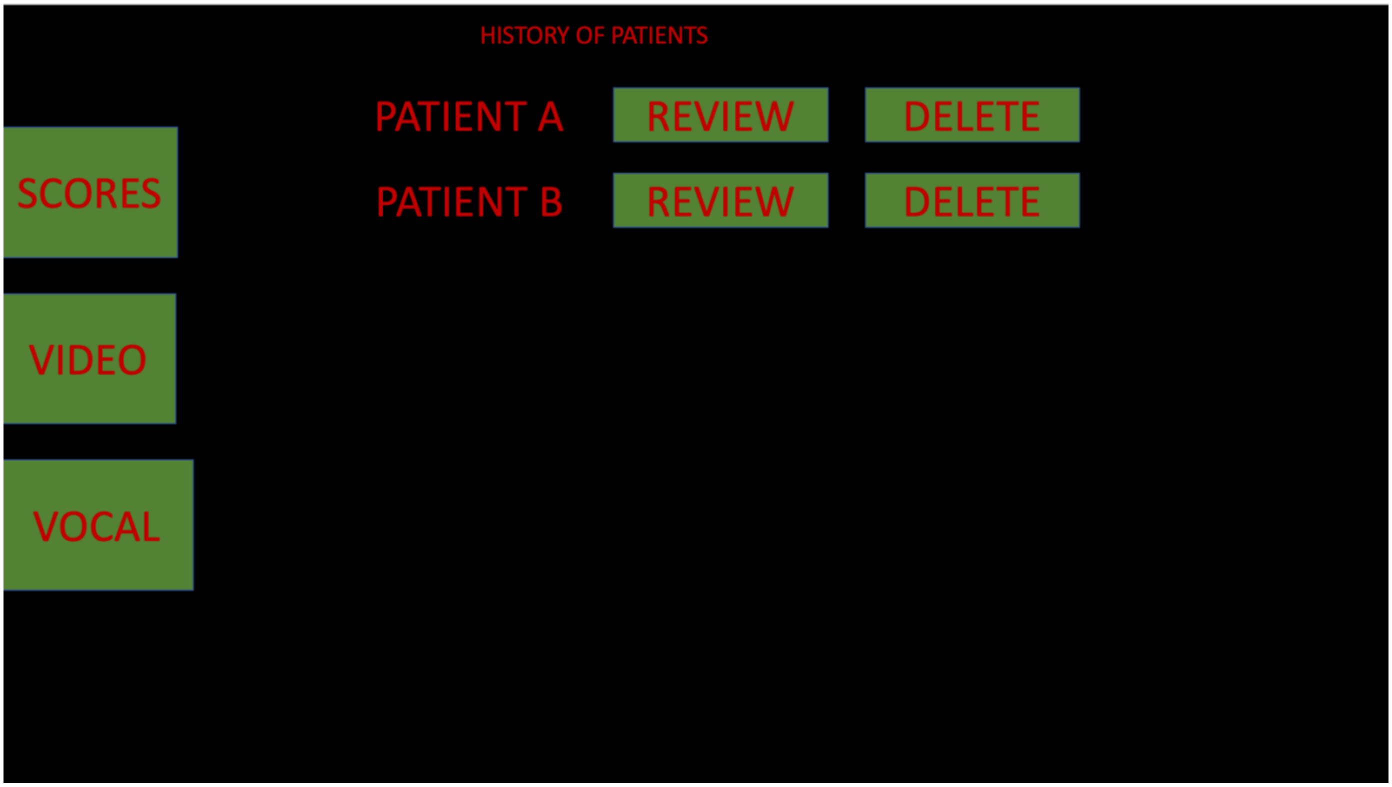


Figure A 4: Graphical user interface post assessment [cont.].

APPENDIX B

Control Flow Sequences

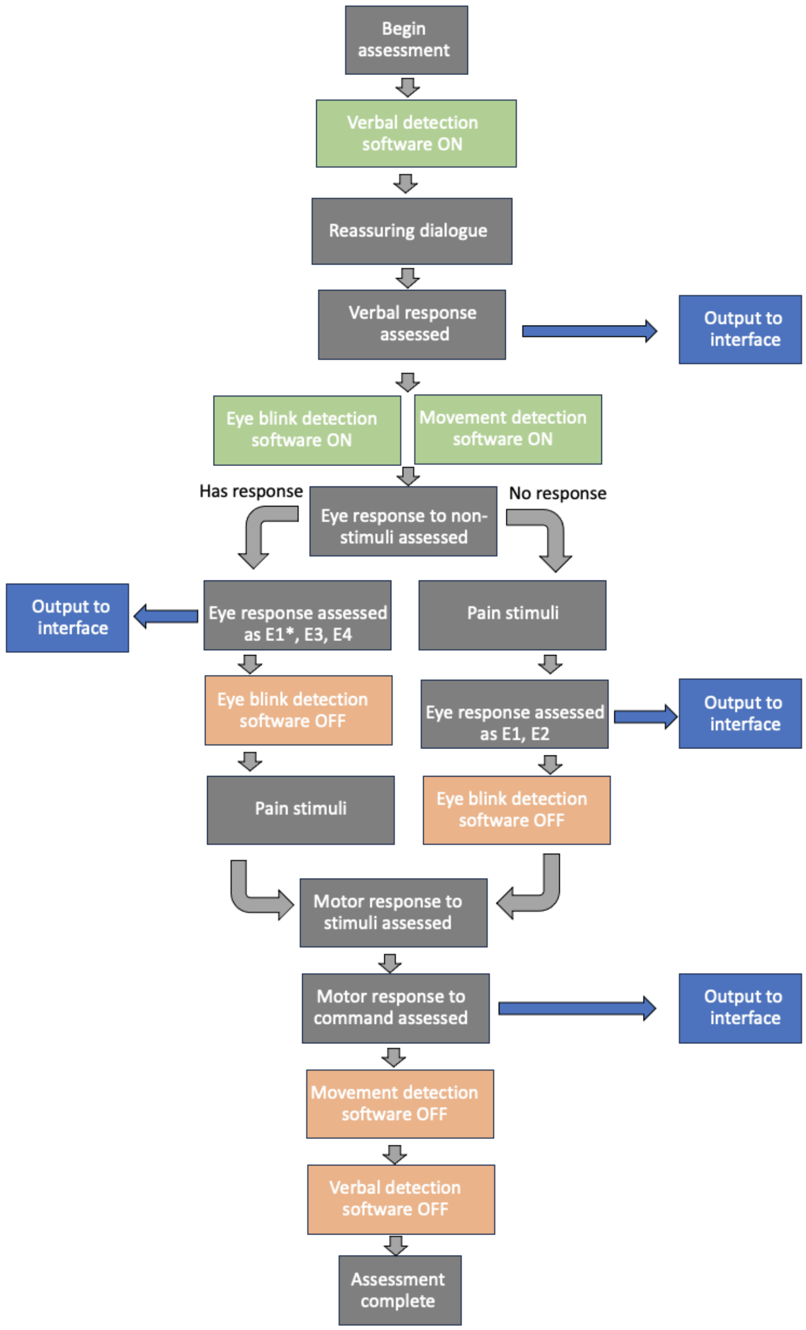


Figure B 1: Control flow sequence depicting timeline of processing software.

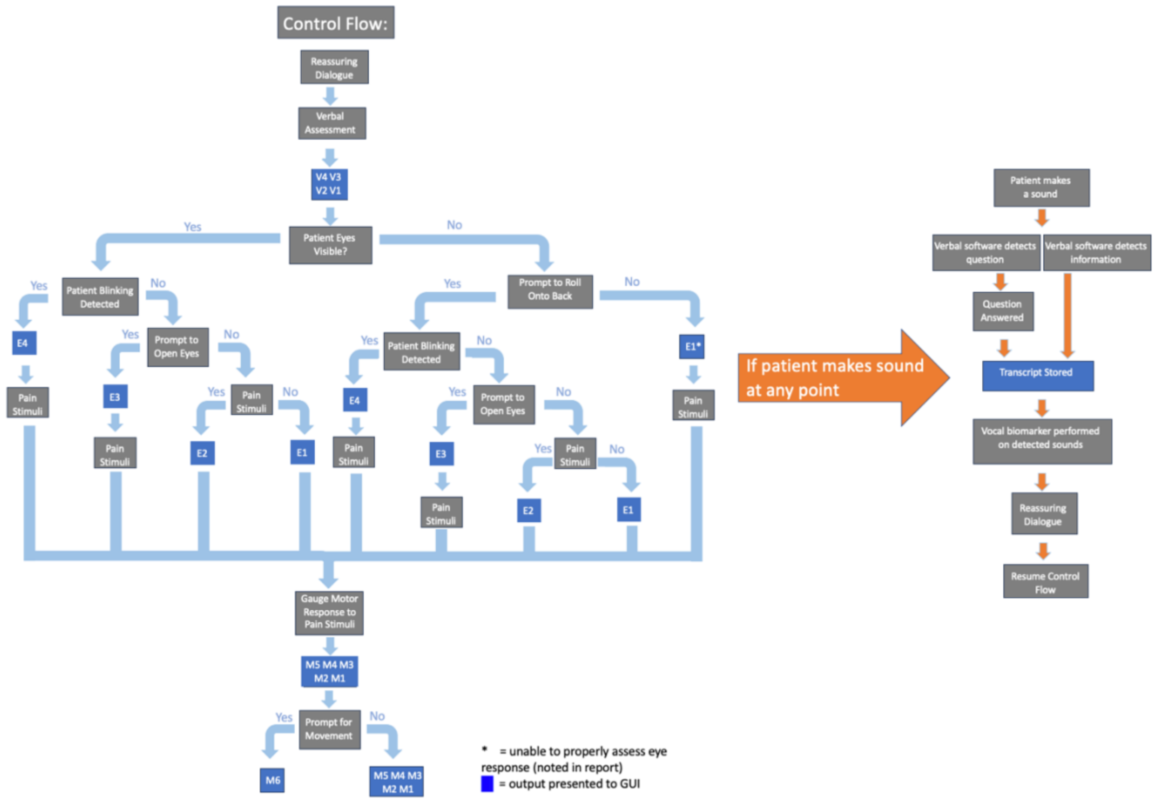


Figure B 2: Control flow sequence depicting GCS scoring outcome.

APPENDIX C

3D model and drawing

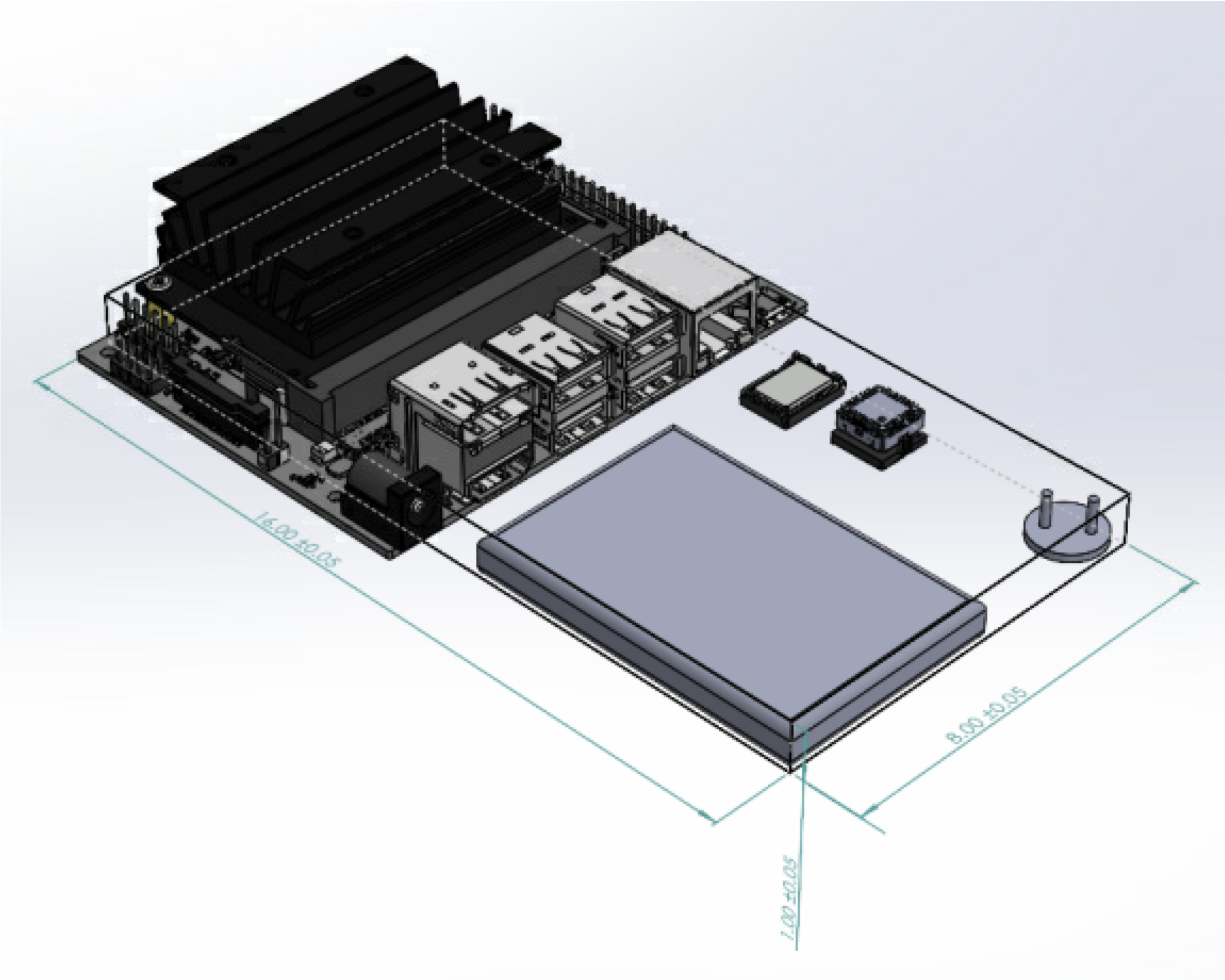


Figure C 1: Solidworks 3D model (isometric) placing computer, battery, speaker, camera, and laser.

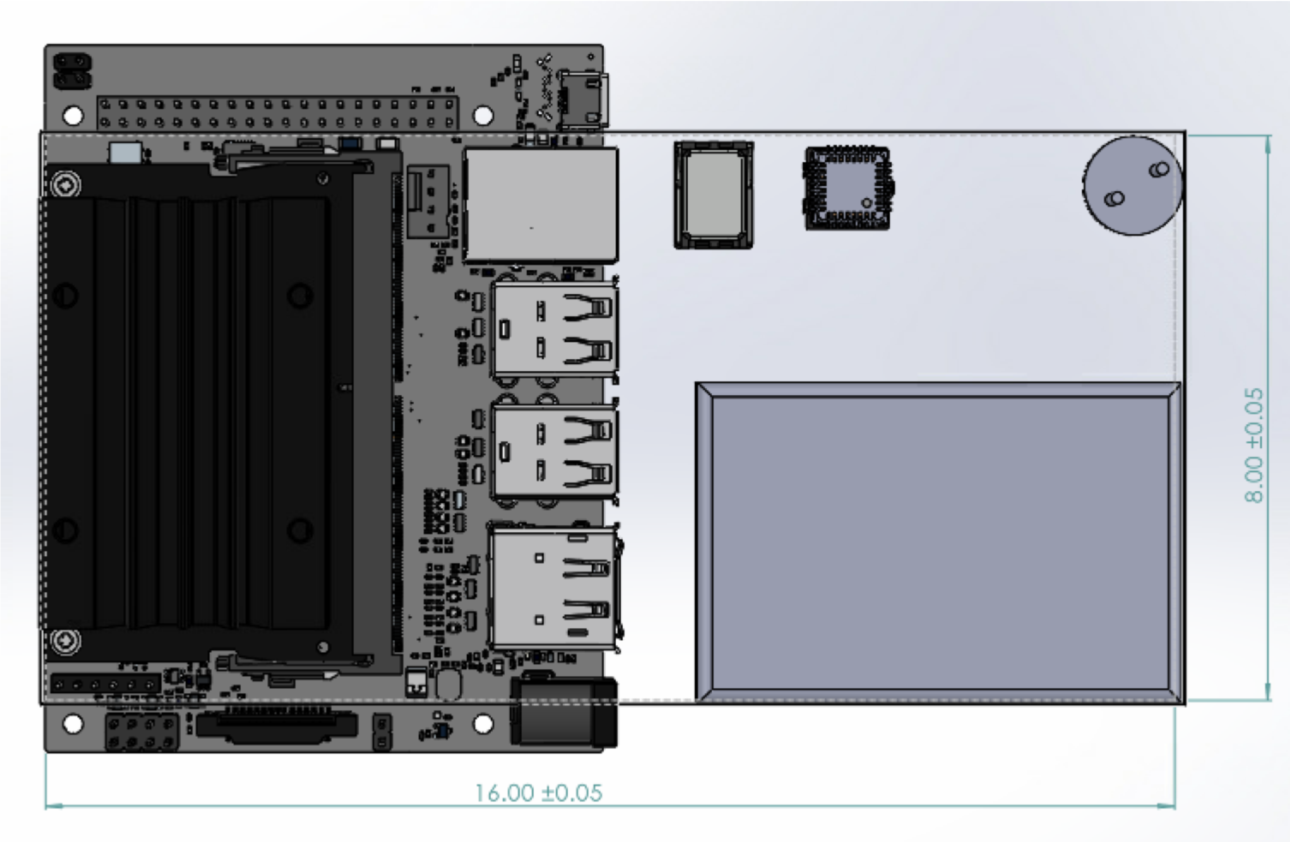


Figure C 2: Solidworks 3D model placing (top) computer, battery, speaker, camera, and laser.

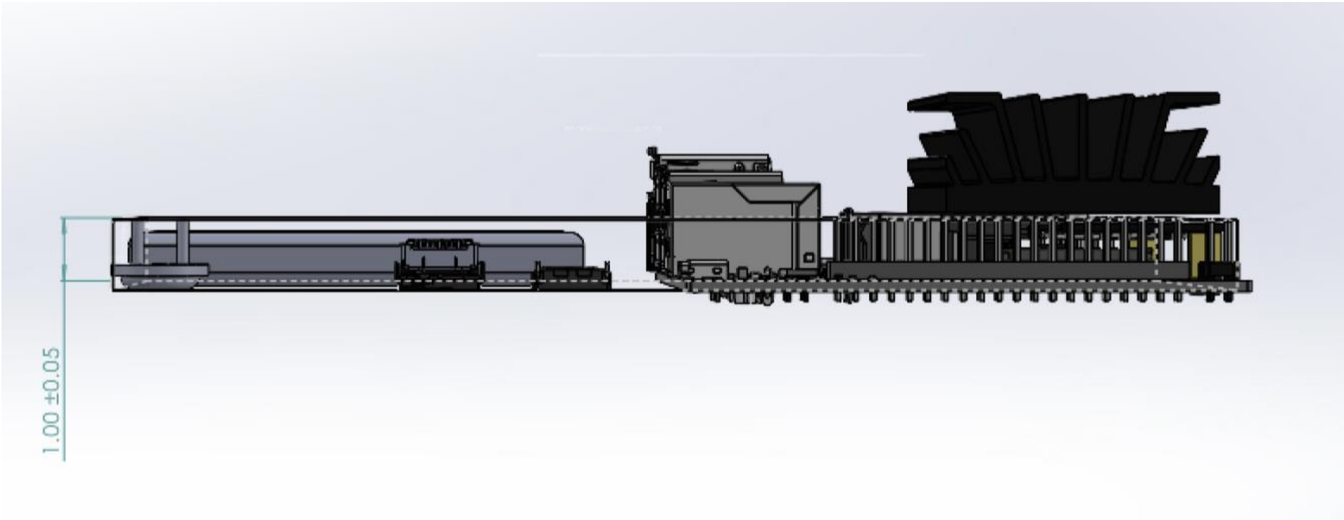


Figure C 3: Solidworks 3D model (side) placing computer, battery, speaker, camera, and laser.

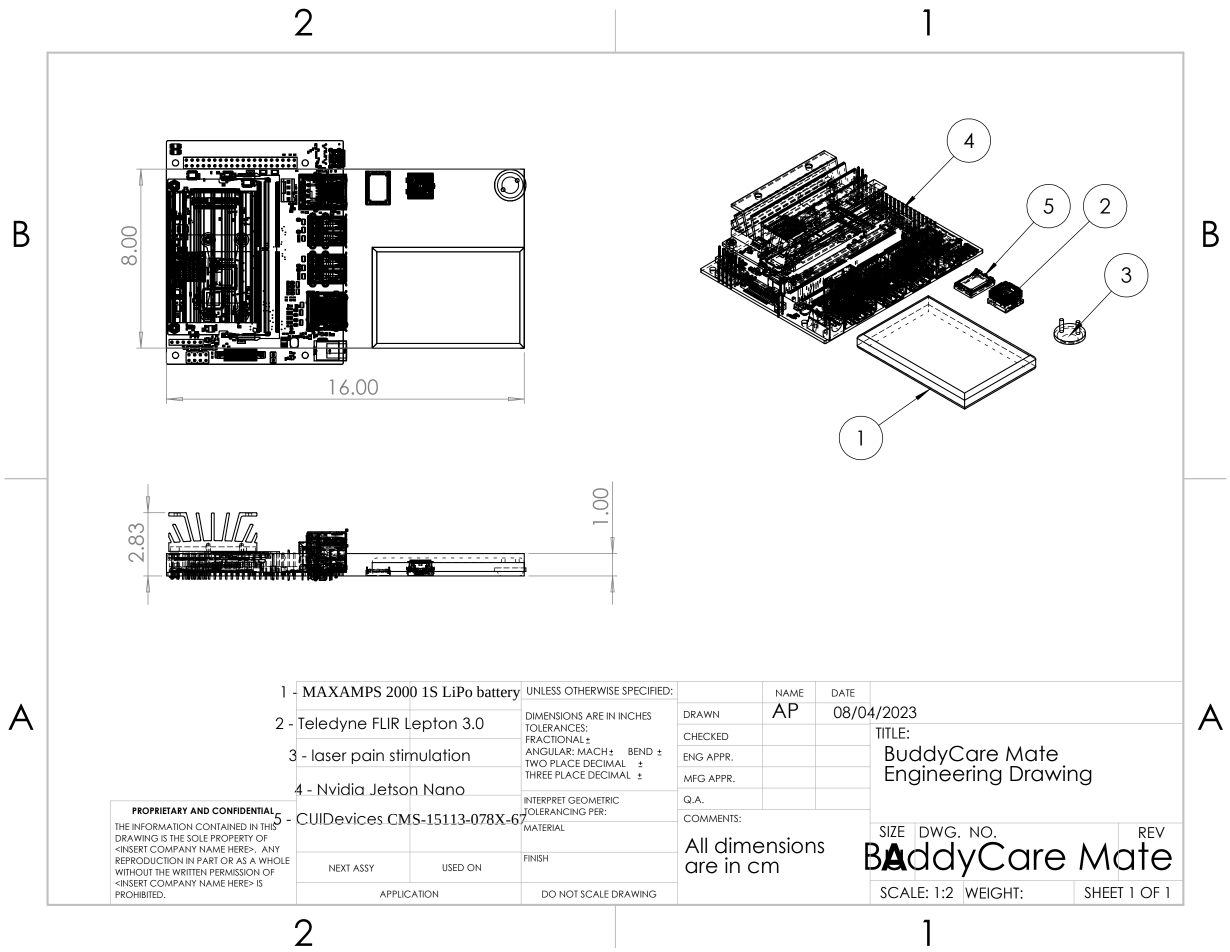


Figure C 4: Solidworks technical drawing depicting computer, battery, speaker, camera, and laser.

APPENDIX D

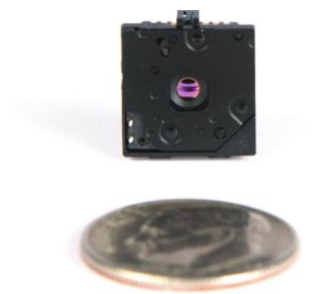
Datasheets

NSIN

TELEDYNE FLIR

160 x 120 HIGH RESOLUTION
MICRO THERMAL CAMERA

LEPTON® 3 SERIES



FLIR's highest resolution LWIR micro thermal imaging module now includes LEPTON 3.5. LEPTON 3.5 offers the same 160x120, 12 micron, uncooled FPA found in the Lepton 3.0 but now provides calibrated radiometric output across the entire 19,200 pixel array. Lepton 3.5 also increases the scene dynamic range to +400 degrees C providing even greater flexibility for demanding applications. Incorporating the same form and fit as the other most popular Lepton products, the Lepton 3.5 allows for a fast and easy upgrade path with little effort. The revolutionary Lepton was the first complete longwave infrared sensor small enough to be used in smartphones and other mobile platforms. The new radiometric Lepton 3.5 offers users more advanced capability where temperature values and high temperature scenes are required. Smaller than a dime, low power consumption, unmatched image quality, and simple integration coupled with the lowest cost of any FPA based thermal sensor on the market today provides users the tool for innovative product development efforts.

ENHANCED IR SENSOR
Greater resolution & sensitivity than common thermopile arrays

- 160 x 120 active pixels
- Thermal sensitivity <50 mK
- Low operating power – 140 mW typical, 650 mW during shutter event
- Low power standby mode

MICRO THERMAL IMAGER
Uncooled thermal imaging for small electronics

- 57° lens
- Integrated digital thermal image processing
- Integrated shutter
- Fast time to image (<0.5 seconds)
- Radiometry for temperature values of every pixel
- Increased scene dynamic range: +400° C (450° C typical)

EASE OF INTEGRATION
Simplifies development & manufacturing of thermal-enabled devices

- Small 11.8 x 12.7 x 7.2 mm package
- SPI video interfaces
- Uses standard cell phone-compatible power supplies
- Two-wire serial control interface
- 32-pin socket interface to connector

For More Information Visit:
https://www.flir.com/leptonintegration

www.teledyneflir.com

06/30/2022 REV1

Figure D 1: Teledyne FLIR Lepton 3.5 Series datasheet.

NSIN

TELEDYNE FLIR

SPECIFICATIONS

Overview	Lepton 3.5
Sensor technology	Uncooled VOx microbolometer
Spectral range	Longwave infrared, 8 μm to 14 μm
Array format	160 x 120, progressive scan
Pixel size	12 μm
Effective frame rate	8.7 Hz (commercial application exportable)
Thermal sensitivity	<50 mK (0.050° C)
Temperature compensation	Automatic. Output image independent of camera temperature.
Radiometric Accuracy	High gain Mode: Greater of +/- 5° C or 5% (typical) Low Gain Mode: Greater of +/- 10° C or 10% (typical)
Non-uniformity corrections	Integral Shutter
Scene dynamic range	High Gain Mode: -10° to +140° C Low Gain Mode: -10° to +400° C (at room temperature) -10° to +450° C (typical)
Image optimization	Factory configured and fully automated
FOV - horizontal	57°
FOV - diagonal	71°
Lens Type	f/1.1
Output format	User-selectable 14-bit, 8-bit (AGC applied), or 24-bit RGB (AGC and colorization applied)
Solar protection	Integral
Electrical	
Input clock	25-MHz nominal, CMOS IO Voltage Levels
Video data interface	Video over SPI
Control port	CCI (I2C-like), CMOS IO Voltage Levels
Input supply voltage (nominal)	2.8 V, 1.2 V, 2.5 V to 3.1 V IO
Power dissipation (Typical, room temp)	Nominally 150 mW (operating), 650 mW (during shutter event), 5 mW (standby)
Mechanical	
Package dimensions – socket version (w x l x h)	10.50 x 12.70 x 7.14 mm
Weight	0.9 grams
Environmental	
Optimum operating temperature range	-10°C to +80°C
Non-operating temperature range	-40 °C to +80 °C
Shock	1500 G @ 0.4 ms
Ordering	
Part Numbers	500-0771-01

Specifications are subject to change without notice.
For the most up-to-date specs, go to https://www.flir.com/leptonintegration

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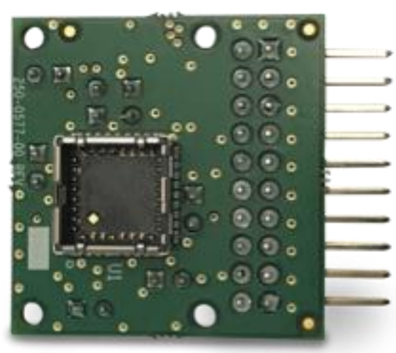
For More Information Visit:
https://www.flir.com/leptonintegration

www.teledyneflir.com

Figure D 1: Teledyne FLIR Lepton 3.5 Series datasheet [cont.].

FLIR



PN: 250-0577-00

EASY-TO-INTERFACE EVALUATION BOARD

FLIR Lepton® Camera Breakout Board v2.0

The FLIR Lepton® Thermal Camera Breakout Board is an easy-to-interface evaluation board to quickly connect all versions of the FLIR Lepton camera module to common platforms like Raspberry Pi* or custom hardware such as mobile development kits. It provides on-board power supplies, generated from 3 – 5.5V, and a master clock. Local power supplies, the master clock and the power-up sequence components can all be by-passed using a jumper.

Lepton sold separately or in a kit through major electronic component distributors worldwide.

www.flir.com/lepton-bob

SIZE, WEIGHT AND POWER (SWAP)

Enhanced Features

- Operating temperature 0°C to 55°C
- Input Voltage: 3 V to 5.5 V
- Space-Saving, (29.5 mm × 29.0 mm)
- Works with all FLIR Lepton® modules

EASE OF INTEGRATION

Faster time to market

- Access to SPI and I2C camera module interfaces
- Provides 25-MHz reference clock (can be by-passed)
- Power Efficient 1.2 V core voltage (can be by-passed)
- Dual Low Noise LDO for 2.8 V voltage (can be by-passed)
- 32-pin Molex camera socket for Lepton® Module
- 100 Mil Header

APPLICATIONS

Designed for applications where SWaP, cost, and quality are critical

- Rugged and Mobile Devices
- Smart Buildings and Smart Cities
- Motion Sensor
- Gesture Recognition

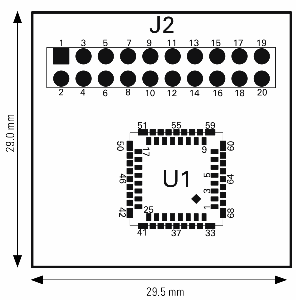
*Raspberry Pi is a trademark of the Raspberry Pi Foundation. This product is not designed or qualified for production use.

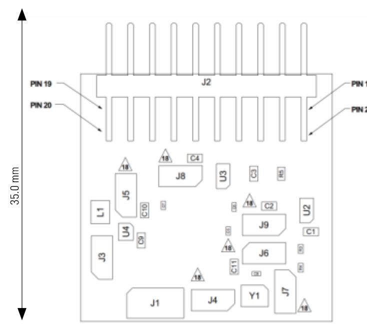
Figure D 2: Teledyne FLIR Lepton Breakout Board v2.0 datasheet.

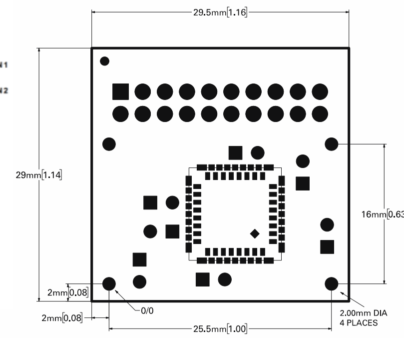
NSIN

SPECIFICATIONS

Mechanical







Thickness including Molex socket and jumper pins but excluding the Lepton: 15mm.

Figure 1. Mounting hole locations.

Electrical

Schematic: 250-0577-24_R200
Assembly drawing: 250-0577-25_R200
The Lepton breakout board comes with jumpers on J5 – J9 installed. With all jumpers installed Lepton can be operated from J2 with 3-5V on J3 pin 2*. Jumpers J5 – J9 can be removed to provide control individual voltage, master clock or power up sequence externally.

*The diode D1 on version R120 of the Lepton Breakout Board 250-0577-00 is installed with the wrong orientation which prevents powering the Lepton from J2 pin 2. However, the Lepton can be powered with 3 – 5V on J3 pin 2.

Pin-Out

Pin #	Function	Pin #	Function
Pin 1	GND	Pin 2	Power in 3 – 5.5V
Pin 3	VPROG	Pin 4	VCC28
Pin 5	SDA	Pin 6	VCC28_IO
Pin 7	SPI_CLK	Pin 8	SCL
Pin 9	SPI_MOSI	Pin 10	SPI_CS
Pin 11	GPIO0	Pin 12	SPI_MISO
Pin 13	GPIO2	Pin 14	GPIO1
Pin 15	GPIO3 / VSYNC	Pin 16	VCC12
Pin 17	RESET_L	Pin 18	MASTER_CLK
Pin 19	GND	Pin 20	PW_DWN_L

Specifications are subject to change without notice. For the most up-to-date specs, go to www.flir.com

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NASDAQ: FLIR

21-0085-OEM

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Figure D 2: Teledyne FLIR Lepton Breakout Board v2.0 datasheet [cont.].

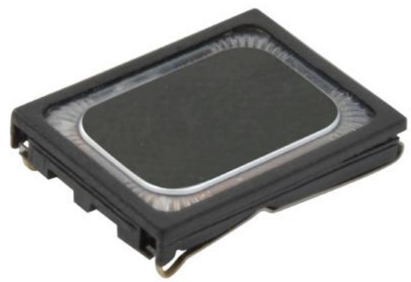
Additional Resources: Product Page | 3D Model | PCB Footprint

CUIDEVICES

date 08/05/2022
page 1 of 6

SERIES: CMS-15113-078X-67 | DESCRIPTION: SPEAKER

FEATURES
- IP67 rated face
- protection against dust and water ingression
- micro-speaker
- 3 mm height
- 5 available termination options



RoHS IP67

SPECIFICATIONS

parameter	conditions/description	min	typ	max	units
input power	max power: as per IEC-268-5, in 1 cc box		0.7	1.0	W
impedance	at 2.0 kHz, 2.37 Vrms	6.8	8	9.2	Ω
coil resistance		6.48	7.2	7.92	Ω
resonant frequency (Fo)	at 1.0 Vrms in free air, 10 cm at 2.37 Vrms in 1 cc box, 10 cm	560 800	700 1,000	840 1,200	Hz Hz
frequency response		100		20,000	Hz
sound pressure level	at 0.7 W, 10 cm, avg 0.8, 1.0, 1.5, 2.0 kHz, 1 cc box	88	91	94	dB
distortion	at 800~1,200 Hz, 2.37 Vrms, 10 cm at 1,201~5,000 Hz, 2.37 Vrms, 10 cm			15 10	% %
buzz, rattle, etc.	must be normal at sine wave, 0.2~2 kHz, 1 cc box			2.37	Vrms
polarity	cone moves forward w/ positive dc current to "+" terminal				
dimensions	15 x 11 x 3				mm
magnet	Nd-Fe-B				
cone material	PEEK				
weight			1.5		g
operating temperature		-20		70	°C
storage temperature		-40		85	°C
hand soldering	for maximum 3 seconds (N/A for spring contacts)			380	°C
RoHS	yes				
IP level	IP67 (front side)				

Notes: 1. All specifications measured at 15~35°C, humidity at 25~75%, under 86~106 kPa pressure, unless otherwise noted.

PART NUMBER KEY

CMS-15113-078 XX - 67

Base Number

Termination Options:
S = spring contacts
SP = solder pads
L100 = wire leads, no connector
L100A = wire leads with Molex housing 51021-0200
L100B = wire leads with JST housing SHR-02V-S-B

cuidevices.com

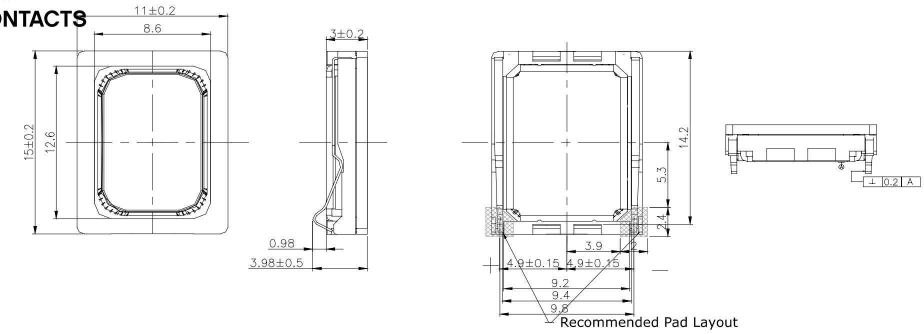
Figure D 3: CUIDevices CMS-15113-078X-67 Datasheet.

Additional Resources: Product Page | 3D Model | PCB Footprint

MECHANICAL DRAWINGS

units: mm
tolerance: ±0.2 mm

SPRING CONTACTS



SOLDER PADS

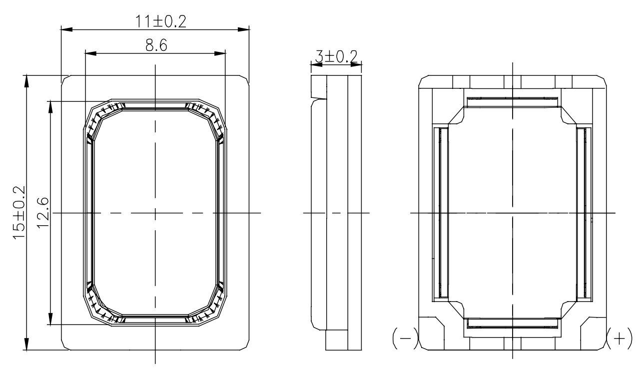


Figure D 3: CUIDevices CMS-15113-078X-67 Datasheet [cont.].

Additional Resources: Product Page | 3D Model | PCB Footprint

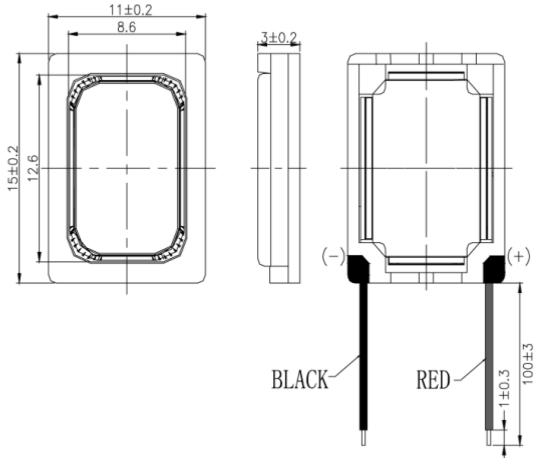
CUI DEVICES | **SERIES:** CMS-15113-078X-67 | **DESCRIPTION:** SPEAKER **date** 08/05/2022 | **page** 3 of 6

MECHANICAL DRAWINGS (CONTINUED)

units: mm
tolerance: ±0.2 mm

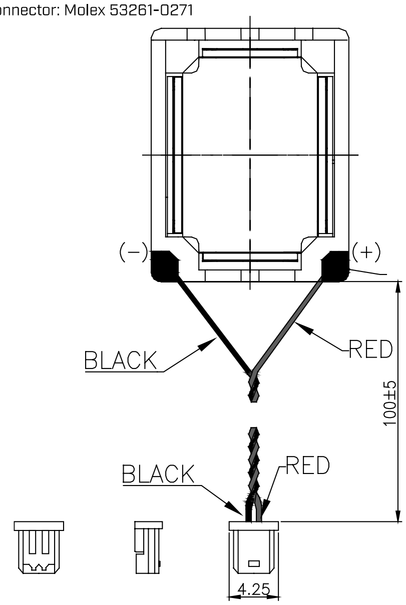
WIRE LEADS, NO CONNECTOR

wire: UL 1571 32 AWG



WIRE LEADS WITH MOLEX CONNECTOR

wire: UL 1571 30 AWG
connector: Molex 51021-0200
mating connector: Molex 53261-0271



WIRE LEADS WITH JST CONNECTOR

wire: UL 1571 30 AWG
connector: JST SHR-02V-S-B
mating connector: JST BM02B-SRSS-TB

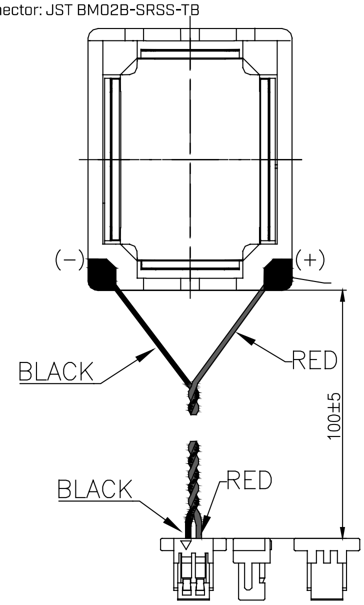


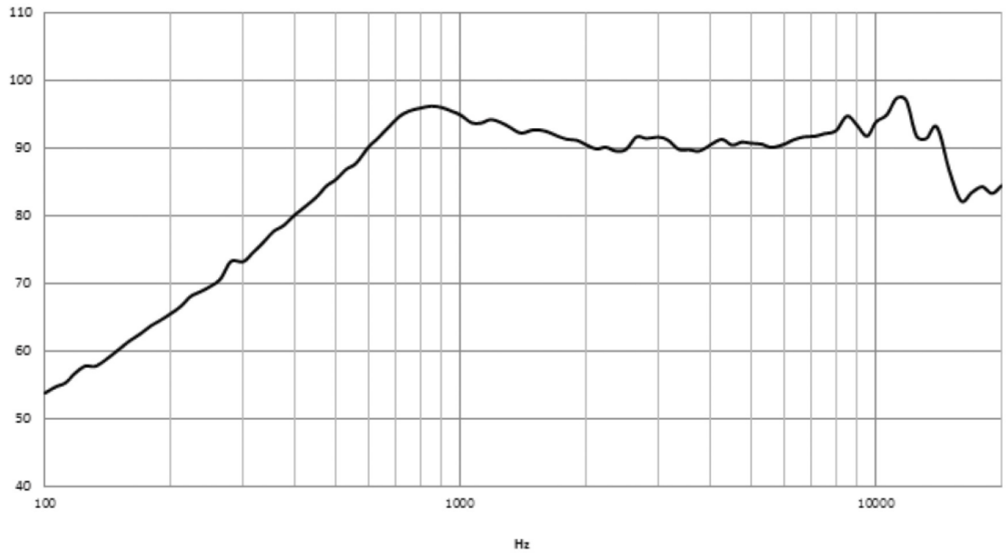
Figure D 3: CUIDevices CMS-15113-078X-67 Datasheet [cont.].

Additional Resources: Product Page | 3D Model | PCB Footprint

RESPONSE CURVES

Frequency Response Curve

Test Conditions: 2.37 Vrms / 10 cm in 1 cc box



Total Harmonic Distortion Curve

Test Conditions: 2.37 Vrms / 10 cm in 1 cc box

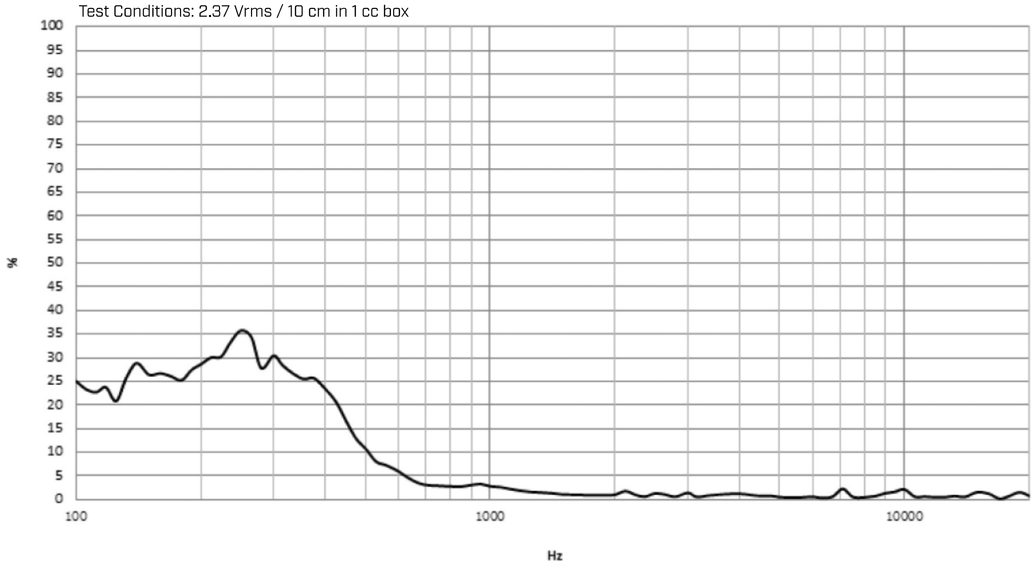


Figure D 3: CUIDevices CMS-15113-078X-67 Datasheet [cont.].

Additional Resources: Product Page | 3D Model | PCB Footprint

PACKAGING

units: mm

Tray Size: 290 x 215 mm
Tray QTY: 100 pcs per tray
Carton Size: 470 x 300 x 310 mm
Carton QTY: 5,000 pcs per carton

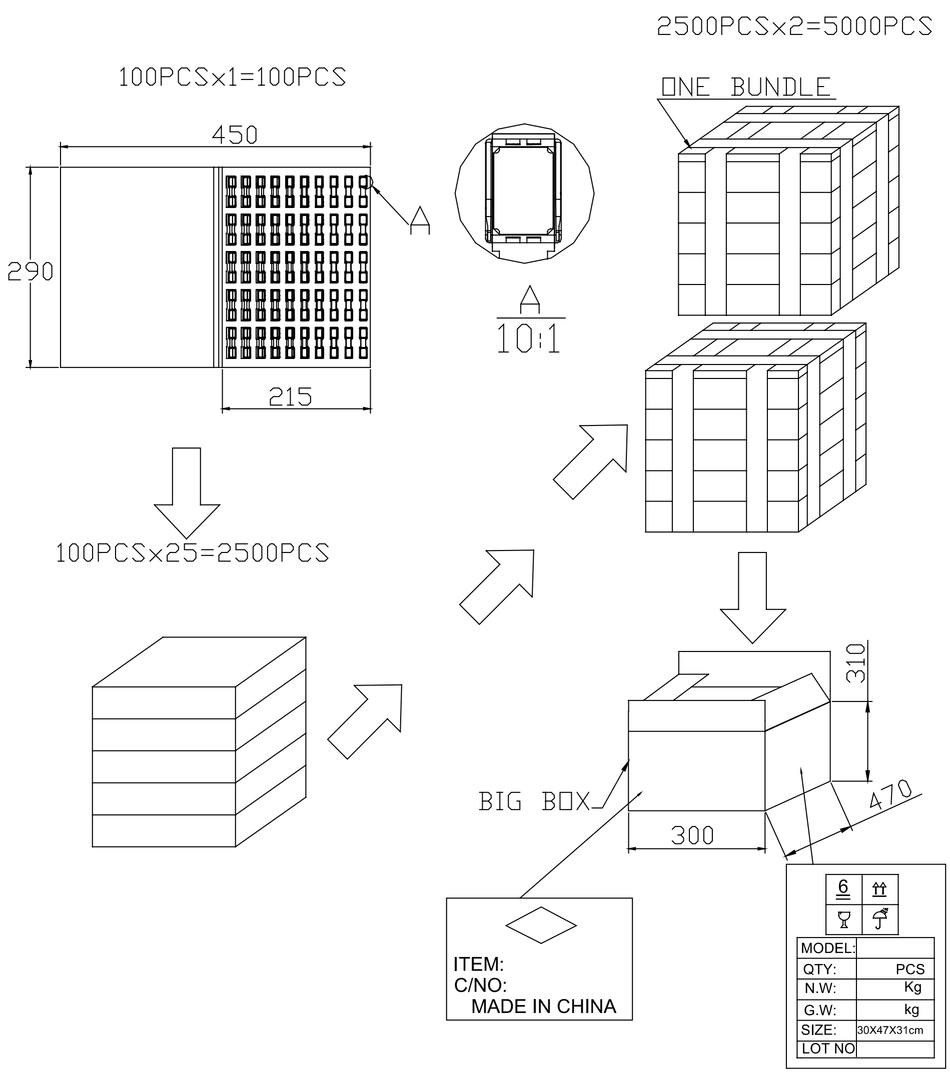


Figure D 3: CUIDevices CMS-15113-078X-67 Datasheet [cont.].

REVISION HISTORY

rev.	description	date
1.0	initial release	07/23/2018
1.01	brand update	01/24/2020
1.02	added Molex and JST connector options, updated packaging	10/23/2020
1.03	logo, datasheet style update	08/05/2022

The revision history provided is for informational purposes only and is believed to be accurate.

Figure D 3: CUIDevices CMS-15113-078X-67 Datasheet [cont.].

MAXAMPS LITHIUM ION POLYMER(LiPo) BATTERY

MODEL NO: MA-2000-1s-Lipo-Pack

CONSUMER APPLICATIONS

- Robotics
- Unmanned Aerial Systems (UAS) –Drones
- RC vehicles

COMMERCIAL & GOVERNMENT APPLICATIONS

- Unmanned Aerial Systems (UAS) –Drones
- Unmanned Ground Vehicles (UGV)
- Robotics
- Mobile Energy Storage
- Vehicles

TECHNICAL DATA

- BATTERY DIMENSIONS –68 x 45 x 8mm
- BATTERY WEIGHT –55g
- BATTERY CAPACITY @0.5C RATE - 2Ah (2000mAh)
- VOLTAGE - 3.7v (NOMINAL/STORAGE) ; 3v (MIN) ; 4.2v (MAX)
- WATT HOURS - 7.4Wh
- ENERGY DENSITY @Nominal Voltage - 135Wh/kg
- INTERNAL IMPEDANCE (1KHZ AC TYPICAL) –3mΩ
- STANDARD CHARGE RATE - 2A (1C MAX)
- BALANCE CHARGE RATE - 10A (5C MAX)
- MAXIMUM CONTINUOUS DISCHARGE - 50A (25C)
- MAXIMUM PEAK DISCHARGE - 200A (100C)
- CYCLE LIFE –Varies per application/usage/care
- OPERATING TEMPERATURE – 0°C to 60°C
- STORAGE TEMPERATURE – 0°C to 23°C

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Figure D 4: MAXAMPS 2000 LiPo battery datasheet.

APPENDIX E

Code

Code: